TEAM 18 – PENETROMETER

Design for Manufacturing, Reliability, and Economics Report

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Group Member Information

Carren Brown is the Team Ambassador. She is an ME student at FAMU, expecting to graduate with a specialty in Mechanics and Materials. She has completed two summer internships at Florida Power & Light and Colgate-Palmolive. She plans to earn a Master's degree in Engineering Management, and then begin a career in manufacturing.

Deneuve Brutus is an EE student at FSU, expecting to graduate in May of 2015. He is currently a .NET intern at Marquis Software, Inc. in Tallahassee, FL. He plans on working as a Software Engineer, while pursuing a Master's of Science in Engineering Management. He is an active Reservist in the United States Navy.

Peter Hettmann is the team's Treasurer. He is an ME student at FSU, expecting to graduate with a specialty in Dynamics and Mechatronic Design. He has completed two summer internships at Siemens Energy and at Senninger Irrigation. After graduation, he plans to pursue higher education in Computer Science/Engineering with a career in robotics.

Sean Kane is the team's Lead EE. He is an EE student at FSU. He currently holds a part time internship with RCC Consultants, Inc., who is contracted with the Florida Department of Transportation (FDOT) to work on the public safety communication system. He plans to stay in Tallahassee, FL after he graduates to continue work with the FDOT.

Natalie Marini is the Team Leader. She is an ME student at FSU, expecting to graduate with a specialty in Thermal Fluid Sciences. She has previously completed three summer internships at Siemens Energy, and plans on continuing work in the power industry when she graduates.

Mitchell Robinson is an EE student at FSU, expecting to graduate in May of 2015. He plans on using his degree to work in the power industry and is specializing in power generation. Mitchell intends on being part of the collaborative effort in design the smart grid in order to meet higher energy efficiency.

Maritza Whittaker is the Team Secretary and Webmaster. She is an ME student at FSU. She has previously completed two summer internships at exp, Inc. and at Oceaneering Entertainment Systems in Orlando, FL. She hopes to pursue a career in the entertainment industry after graduation.

Acknowledgement

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To Dr. Frank for sharing his knowledge and expertise with the electrical aspect of the design. To Dr. Shih for frequently providing important assessment of the overall design of the project. To Dr. Gupta for providing expertise to ensure the compatibility between the electrical and mechanical aspects of the design. And finally to Dr. Russo for providing support and feedback to the group to ensure the design of the project meets the needs of the National Park Service.

Abstract

The following report will discuss the summation of Team 18's design for manufacturing, reliability, and economics for a friction cone penetrometer. The team was given the task to design and prototype a penetrometer for the National Park Services (NPS). The penetrometer will be used to assist archaeologists in identifying different soil types and in locating midden within their dig sites. Midden is soil that contains domestic waste and artifacts of past human life, specifically their past waste. The penetrometer must be easy to use, portable, weigh less than 50 pounds, as well as be reliable for the user. The penetrometer will also have the ability to wirelessly transmit the data to a handheld Android device. This prototype will utilize a drop weight similar to last year's design, two load cells housed above the shaft to obtain the friction coefficient of each soil type, and a personalized app and DAQ system to obtain the experimental data. The following report will discuss in detail any and all adversities the team has faced during design as well as discuss the assembly process, the testing process and the procurement process during both semesters of design and build. Constant communication has also been kept between the team and their advisor, instructors, and sponsor, in order to seek guidance and have a clear indication of what is expected for this project.

1. Introduction

The purpose of this project is to design and construct a device that can properly differentiate soil types and identify any midden that is present. Current handheld penetrometers are only used to determine the compaction of the soil. This method is not an exact science, and requires a person with much experience to determine the results. Penetrometers that are able to detect different soil types and midden are far too large to be used efficiently in the field. The goal of Team 18 was to combine these two ideas and develop a handheld penetrometer that has the ability to identify midden by determining the soil's friction coefficient. The team has created a prototype that is lightweight and easy to use in the field. The device is also portable and has the ability to transfer the force from the bottom portion of the shaft to the top housing where the load cells are located. The readings from the load cells will be transmitted wirelessly to a handheld tablet, using the data acquisition module. These readings will allow the team to calculate the friction coefficient of the soil, and therefore determine the type of soil present and if there is any midden in the area.

A penetrometer is a basic force instrument in design and simple in use. However, it cannot be effectively used by a novice for precise results. Originally, a penetrometer was used by agricultural personnel for penetration of the ground soil on several acres of land to determine the soil compaction and how viable the soil will be for crop production. Before a standardized penetrometer, results could vary from farm to farm and with different surveying teams. Depending on the varying level of experience by the surveying team, these results can either be interpreted as good or bad soil results.

As an extension of the 2013-2014 senior design project, it is the objective of Team 18 to redesign a penetrometer which will detect midden levels in the soil present at the Southeast Archaeological Center & National Park Services' field testing site. This penetrometer will have portable and wireless capabilities in order to properly distinguish the type of soil present below the ground. It has been established that the sponsor is looking for a more reliable and easier-to-use system than the prototype designed by the previous senior design project.

The goal statement of Team 18 is as follows: "Design an instrument that can identify midden and differentiate soil types at various depths."

The following objectives were provided to the Team from discussion with the National Park Services and Dr. Russo, the Team's sponsor. It must be able to identify midden levels in remote locations and weigh less than 50 lbs. The penetrometer should wirelessly display results to a handheld device and be very portable to use out in the field.

There have been a multitude of constraints placed on the design. These constraints are as follows: the prototype design must be easy to use by only one person in the field, without assistance, the diameter of the prototype must be small enough for the device to penetrate the ground easily, the material of the prototype must be strong enough for the device to penetrate the ground without fracturing, the prototype design must wirelessly relay reliable data out in the field, making it be portable for the user, and finally the total cost must not exceed $2,000.

However, the sponsor is able to expand the budget if it is deemed necessary by the team and the advisor.

2. Design for Manufacturing

The design for manufacturing section of this report will cover how the penetrometer was assembled from start to finish, how much time it took to construct, and a discussion on the complexity of the overall project. An exploded view will be shown to further clarify the final design.

2.1. Assembly Process

The first step for assembly is to apply the acetyl to the center shaft and friction transmission rod to add support and minimize friction. The acetyl is machined in shorter pieces and needs to be stacked all the way up the rods for full support. After this is finished the rods can be combined. Starting with the center load shaft, the cone tip can be screwed onto the shaft that already contains the acetyl. Then, the friction transmission shaft can be slid down over the center load shaft. The friction shaft must be aligned correctly and measured out to have a gap below the shaft and the cone tip to allow for a seal. At this point, the bottom seal should be applied by use of a heat gun and steady hands. After the seal cools and is tested to be sturdy, the outside shaft can be slid on over the friction transmission shaft with another gap left in between for a seal. At this point, the second seal is applied by means of the heat gun, and then it is cooled. Once the entire lower section of the shaft is assembled, the load cells and upper housing will need to be constructed. The outer shaft is to be screwed onto the bottom housing disk. Then, the walls of the housing will be screwed on. At this point, the load cells can be installed. Taking the two sides of the housing insulation, each load cell should be placed in their respective location. Both housing shelves are then inserted at the same time into the housing cylinder. The top housing disk is then screwed on.

The bulk of construction should now be complete with the exception of the bar used for the penetrometer's drop weight. Another cushion disk should be screwed onto the upper housing disk. The drop weight rod is then attached to this disk. The drop weight should at this point slide onto this rod. A top disk is screwed onto the drop weight rod, and the mechanical assembly should be finished.

After the load cells have been installed in the penetrometer the electrical system is ready for installation. Now the voltage regulator must be connected to the electrical system. First the voltage regulator must be connected to a PC board like the one seen in Figure 1. Notice that the PC board pictured in Figure 1 has two vertical strips in the middle. Taking the left strip as the positive node and the right strip as the negative node place the input pin, as seen in Figure 2, into the positive strip and the common pin into the negative strip. Then place the output pin into the nearest node to the left or right of the center strips (whichever is easier). Now solder the pins to their respective nodes. The battery is now ready to be connected to the voltage regulator. Take the positive terminal of the battery (red wire) and connect it to the positive strip of the PC board. Now place the negative terminal of the battery (black wire) into the common node of the PC board. Solder the two terminal of the battery to the PC board. The output node and common node will now serve as the "new" power nodes with fixed voltage (15V).

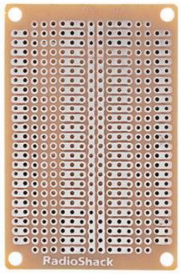


Figure 1. PC Board

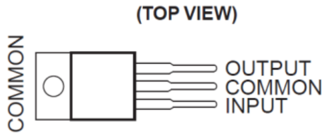


Figure 2. Voltage Regulator with Pins

Figure 3. Voltage Regulator

Take the casing off both op amps by inserting a flat edge between the upper and bottom cover casings and prying them loose from each other. In order to set the desired gain use the switches denoted by "SW3" of the op amp, as seen in Figure 6, and place pins 6 and 8 in the up (on) position (all others in down/off position). Now flip SW1 to up so that the excitation is set to 5V. To set the polarity to straight (for compression) set SW2 to the down position. To set the bandwidth of the op amp to 10 kHz put SW4 in the up position. After all switches are correctly placed, put the casing back on both op amps.

Now take one power side DB9 cable (pictured in Figure 4) and place its red wire into the output node of the PC board. Then place the black wire of the power DB9 cable and place it into the common node of the PC board. Now solder both the red and black wires to the PC board. The remaining connections of the DB9 power cable are the blue, orange, white and green wires. The white and blue wires are for current output and will not be used in this application. The green and orange wires will later be connected to the DAQ. Now the female DB9 of the power side DB9 cable is ready to be plugged into the male DB9 of the op amp. For the next power side DB9 cable repeat the same process that was just described. At this point the PC board is ready to be housed for protection. Before placing the housing around the PC board make sure all connections to the board are secure. Place the housing around the PC board.

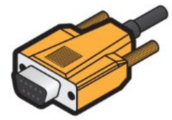


Figure 4. Power Side DB9 Cable

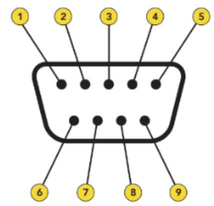


Figure 5. Male DB9 of Op Amp

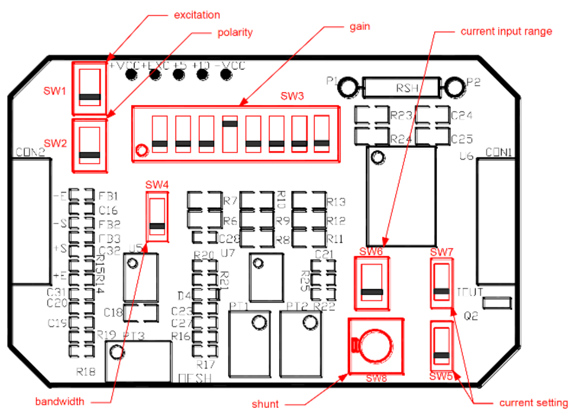


Figure 6 – Inside of Op amp

Now it is time to connect each load cell to an op amp. First take apart the casing of the DB9 connector by removing the nuts and screws that are pictured in Figure 7. Now the female side of the DB9 connector is free for the load cell wires to be soldered to. Before continuing it is imperative to connect the wires of each load cell to the female DB9 connector as described ahead and NOT to the female DB9 that is attached to the op amp! Using the pin configuration of the female DB9, seen below in Figure 8, solder the red wire of the LLB 300 load cell into pin location 1. Next, take the green wire from the LLB 300 load cell and solder to pin 2 of the female DB9. Take the white wire from the LLB 300 and solder it to pin 3 of the female DB9 connector. Then take the black wire of the LLB 300 and solder it to pin 4 of the female DB9 connector. Next place the casing around the DB9 connector and connect the male end into the female end of one of the op amps. For the LTH 300 load cell follow the same procedure and same color code. Now both load cells are connected to an op amp.

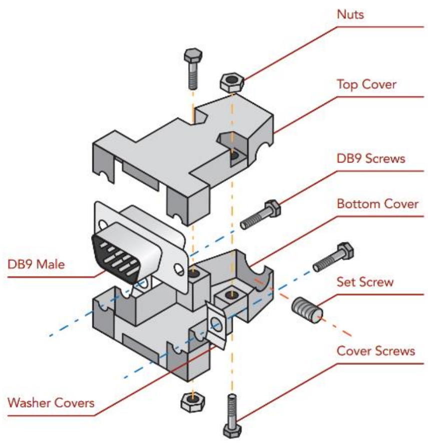


Figure 7. DB9 Connector

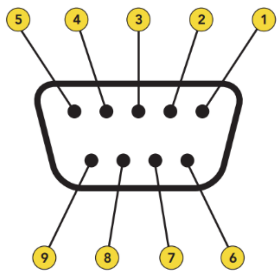


Figure 8. Female Connection of the DB9 Connector

Next connect one op amp to the DAQ by connecting the green wire of the power side DB9 of the selected op amp to the analog input 0, as pictured in Figure 9. Then take the orange cable of the selected power DB9 cable and connect it to analog input 1. Repeat the same process for the other op amp however connect it to analog input 2 and 3, respectively.

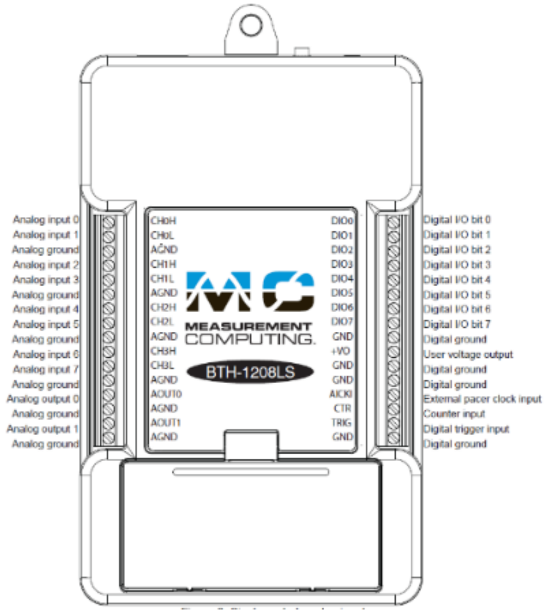


Figure 9. DAQ Pin Connections

The Android device is now ready to be connected to the DAQ. First make sure the android device is configured to host a Bluetooth device. See the respective android device's manual to turn on its Bluetooth pairing capability. Next press and hold the red button that is located at position 4 of Figure 10 for at least 5 seconds in order to power on the device and put it into pairing mode. Once the power and statues LEDs are flashing alternately the device is in pairing mode and is ready to be paired with the host device. These LEDs are located at location 5 of Figure 10.

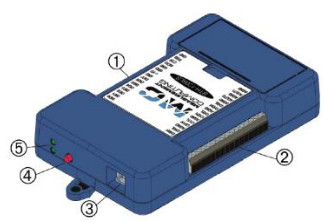


Figure 10. DAQ Components

Now open up the custom NPS app of the android device. Once opened the home screen of the NPS app should be pictured as seen in Figure 11. Press the button that says "detect DAQ devices". Once the DAQ is detected press the button that says "Connect to DAQ". The entire electrical system of the NPS penetrometer is now ready for use.

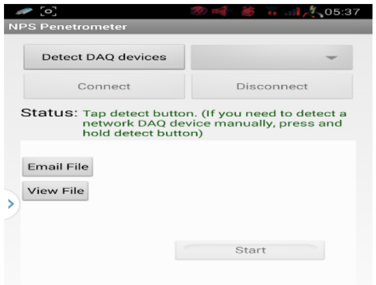


Figure 11. Home Screen of NPS App

2.2. Assembly Analysis (Time and Efficiency)

The build was originally estimated to take a total of two hours. As of the original due date of this report, Team 18 has yet to receive parts back from the machine shop. It is still anticipated that the actual build of the prototype will take no longer than five hours, conservatively. The biggest problem the team believes to run into will be properly aligning the seals around the friction sleeve and properly cleaning all of the components for first time use.

2.3. Manufacturing Analysis

There were around 20 components in the final design of the penetrometer. This included all of the rods, housing disks, cone tip, and housing support components. The complexity of the design was due to the attempt to minimize the shaft diameter to allow for easier penetration in the ground. To do this, the team had to transmit the load to the upper shaft instead of having the load cells near the cone tip. This called for multiple transmission shafts and a more complex design. Last year had a much simpler design, but the shaft diameter was too large to efficiently get through the soil. By changing the design to have the load cells at the top, the design had to be much more complex and since this has never been done before, the team had a lot of confusion as to dimensioning the shaft diameters. The goal was to make the device user friendly and easy to use which meant minimizing the rod diameter, requiring a complex design. As far as making it the design simpler, more research would have to go into safely housing and installing strain gauges in the base of the penetrometer. Considering the diameter of the shaft had to be minimized as a main constraint of the project, the complexity of the project and the components used were necessary to successfully meet the scope of the project.

2.4. Exploded View of Assembly

As shown in the figures below, the completed penetrometer is composed of three sections (figure 4A): a housing design (indicated in green, figure 4B), a drop weight design (indicated in red, figure 4C), and a shaft design (indicated in blue, figure 4D). Each section is composed of several pieces that can be found in the appendix A-2 of this report. The drop weight design is composed of four separate pieces which were ordered pre-modelling of the penetrometer and do not have to be machined for the completion of the penetrometer. The section that connects the drop weight design and the housing design is a connector piece that will have to be machined and welded in place that will be taking a large majority of the impact from the 25 lb weight that will be dropped to apply the load through the penetrometer.

The second piece of the penetrometer is the housing design, the housing design has the most amount of pieces incorporated into the design and must have the highest level of precision when machining. This precision is needed due to the housing having to securely place both the button and donut load cells that will be receiving the force from the friction sleeve rod and the cone tip rod. The load cells that are secured into the housing must not move from the repetitive force from each respective rod and must not shift and off center the location of the force on each load cell. The other discs located in the housing each have their respective duties as supporting each rod to not fall through the penetrometer, and guiding each rod to their respective load cells. The housing will also be sealed by two plates at the bottom and top of the housing shell and this will allow for easy extraction of the discs for maintenance and repair when necessary.

The final section of the penetrometer is the shaft section which is comprised of the outer shell, friction sleeve rod, cone tip rod, and cone tip. The outer shell rod is used as protective layer as dirt, moisture and damage cannot be done to the friction sleeve and inner most cone tip rod. The friction sleeve is the second most layer of the rod design and is connected to the friction sleeve itself which will “feel” the force of the different soil as it slides through the soil. The inner most layer is the cone tip rod, this rod is connected directly to a detachable cone tip located at the bottom of the penetrometer and used as the striking point as the penetrometer enters the ground. The cone tip rod will transmit the force applied to the cone tip through the center of the penetrometer to its respective load cell located in the housing.

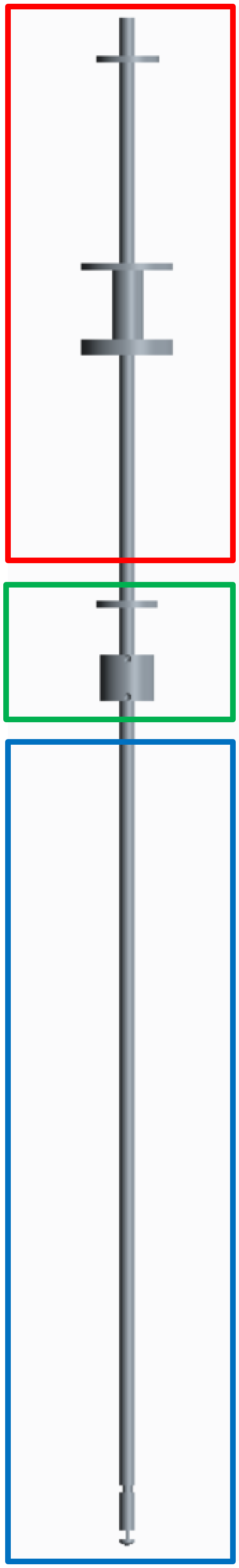


Figure 12. Full Assembly View

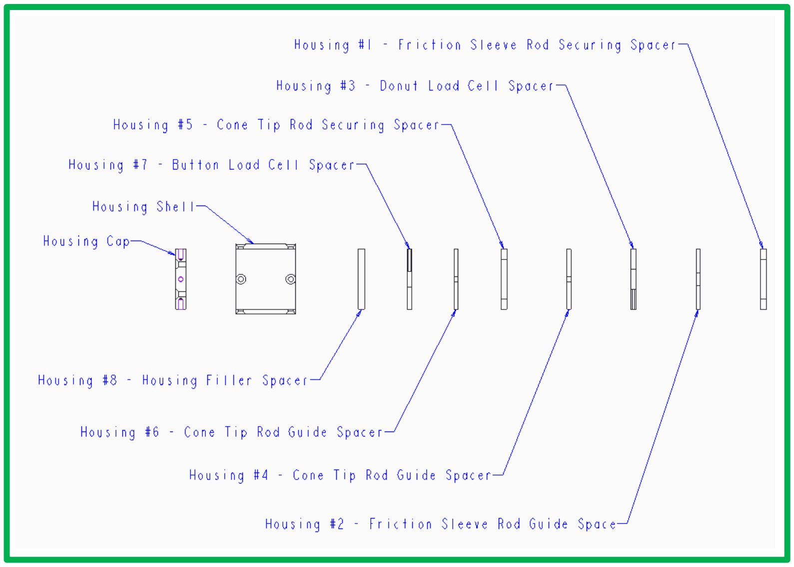


Figure 13a. Housing Exploded View

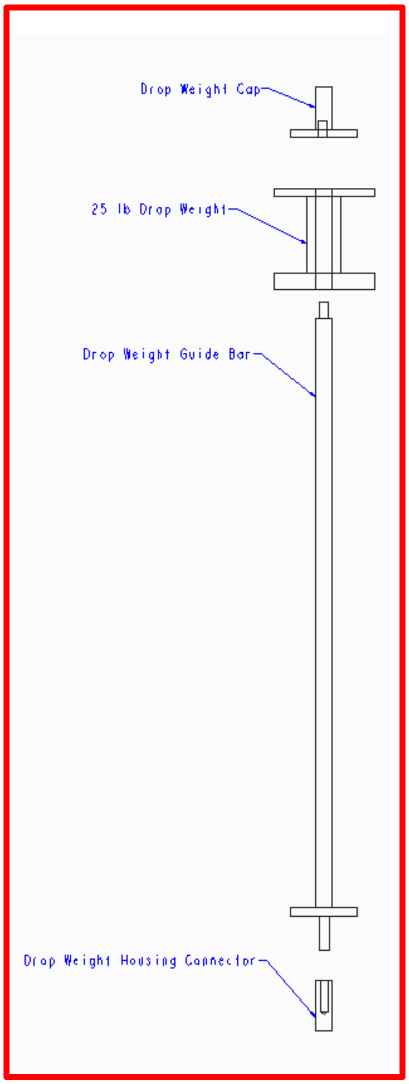


Figure 13b. Drop Weight Exploded View

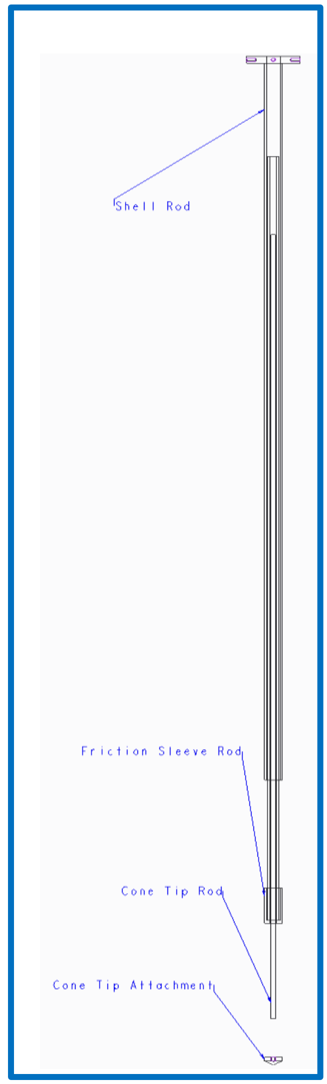


Figure 13c. Cone Tip Exploded View

3. Design for Reliability

The following section of the report will reveal how well the prototype performs when used once and when used of a longer period of time. It will discuss the main reliability concerns in the project and how they are being addressed. An FMEA will be found to quantify the failure modes and effects of the project.

3.1. Performance Results

In figure 14 the graph for the cone tip impact force is shown over an increasing depth in a bucket test. Each peak seen on the graph is when the drop weight was dropped and the penetrometer was forced further into the ground. This graph in particular is what was being read by the button load cell in the upper housing. The peaks seen are pretty consistent throughout the entire test done.

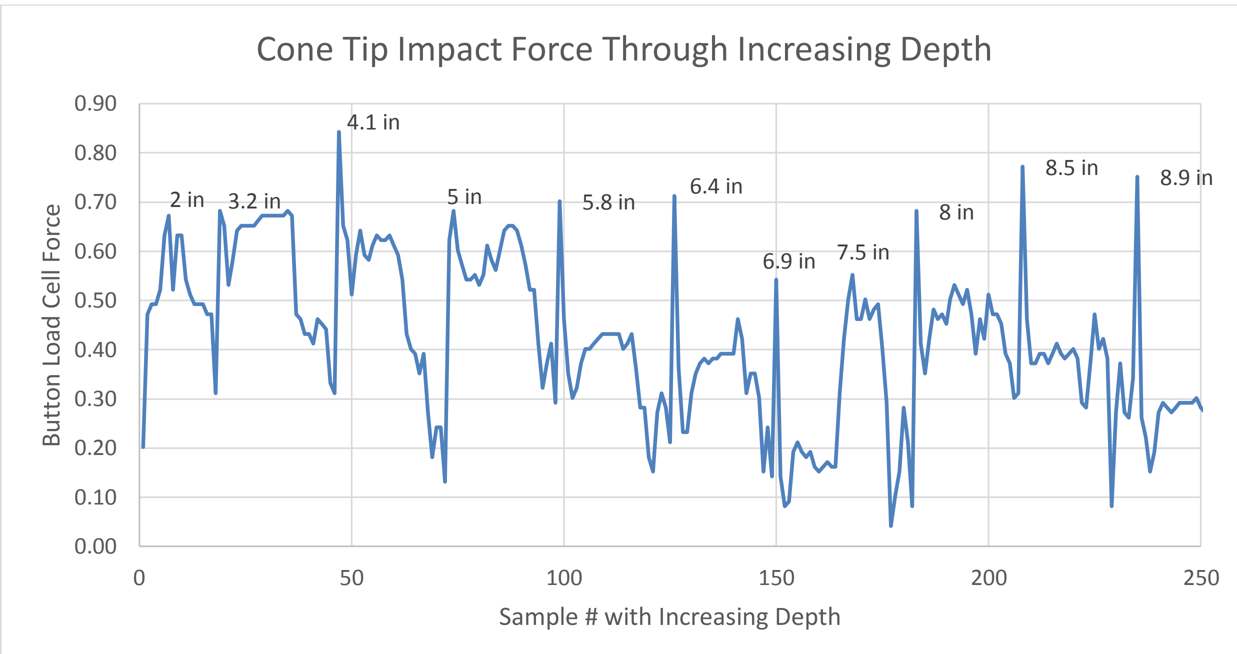


Figure 14. Cone Tip Impact Force through Increasing Depth

In figure 15, the graph for the friction sleeve force is shown over an increasing depth in a bucket test. This is what was read by the thru-hole load cell in the lower part of the housing. The friction sleeve is connected to a transmission shaft so whenever the shaft is moved by traveling further into the soil, the transmission shaft activates the load cell and you get the peaks seen.

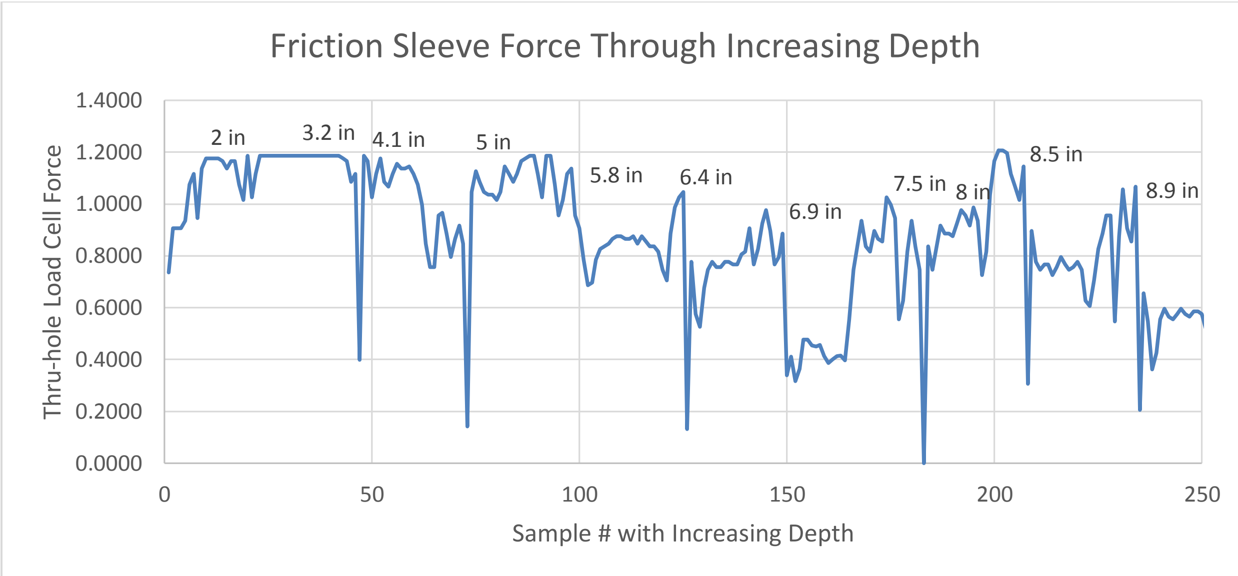


Figure 15. Friction Sleeve Force through Increasing Depth

Using these two figures, a friction coefficient can be found to identify the soil. Each peak has a force value given by the calibrated load cells. Using the average value for the peaks in the cone tip impact force diagram and the average value for the peaks in the friction sleeve force diagram the following equation can be used to calculate the friction coefficient.

$$Friction\ Coefficient = \frac{Top\ Load\ Cell - Bottom\ Load\ Cell}{Bottom\ Load\ Cell}$$

For this test, it was found that the friction coefficient was 0.3966. Using a given table for materials and their friction coefficients, it is found that the "Clean fine sand, silty or clayey fine to medium sand" friction factor is in the range of 0.35 to 0.45. This agrees with our data's finding with our value directly in the middle of this range confirming the test was accurate. When tested again a friction coefficient of 0.39906 was found. This is a difference of 0.00246. Both tests were very close in their results found further proving the accuracy of the probe.

3.2. Failure Modes and Effects Analysis

The above FMEA in the A-1 appendix (Table 1) shows the potential failure modes that could occur with the penetrometer operation along with what effects these failures will cause in relation to the reliability and further use of the penetrometer. The RPN is calculated by multiplying the severity ranking by the occurrence and the ability to detect if the problem is going to happen. The higher the number, the more of a problem the failure mode is. Looking at the table it is seen that the two worst failure modes are if the seals that hold the friction sleeve buckle and break, and if the alignment of the rods is off it can also pose a potential problem. To prevent this, extra sealant material was purchased to have on hand at all times for a quick fix, and the seals are being tested repeatedly in the lab. By design, the alignment problems were minimized, but testing is being done to ensure calibration in case there is slight bending. The material choice of stainless steel also ensures that there will not be any fracture in the penetrometer rods themselves.

4. Design for Economics

The Design for Economics portion of this report will cover the budget breakdown. It will go over how much the whole product costs as well as each component, and it will compare our product with similar ones on the market.

4.1. Procurement

Our procurement is broken down into three sections of products: electrical components, mechanical components and electrical mechanical components. The mechanical components, mostly steel, was purchased due to convenience and pricing because of the large amount of different sizes that are necessary for our project. The batteries that were bought comprised a large majority of the budget and these batteries were calculated to be within the needed voltage and amp per hour for all day use with the electronics of the project. There were additional batteries bought for quick exchanges in the field because there will not be a power supply in the field of work with the penetrometer. The data acquisition module is a more unique purchase as it was researched and compared to several other modules such as microprocessors, like the Arduino. The built-in Bluetooth feature of the module and the sampling data rate made the data acquisition module a more suitable choice. The electrical mechanical components were bought together from Futek. The load cells did not have to be special ordered but instead were in stock and standard makes from Futek. This availability for a mid-range force reading in such a small size made these load cells optimal for purchasing. Futek also had their own model of a 5V and 10V amplifiers that could be purchased alongside these load cells to minimize the amount of noise and zero offset from the signal and allowed the team to move forward without the necessity to build an op amp not standard to the load cells.

4.2. Budget Analysis

Below is the mechanical and electrical breakdown of the budget where the team was allotted a $2,000.00 budget. Team 18 has exceeded this amount; however, there has been a $20,000.00 budget from the National Park Services and they were able to purchase the entirety of the project with this new budget. A total of $2,711.40 has been used.

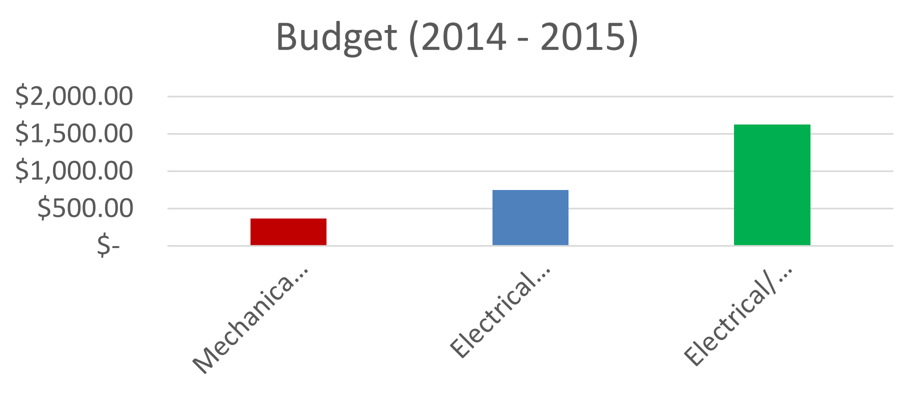


Figure 16. Overall budget analysis

For the mechanical breakdown of the budget, the bulk of the money was spent on both the donut and button load cells: $500.00 was spent on the button load cell and $425.00 was spent on the donut load cell, both load cells were purchased from Futek. The remaining breakdown comes from the materials necessary to complete the project the purchased from McMaster-Carr, totalling in $340.21, its breakdown can be seen below in figure 17.

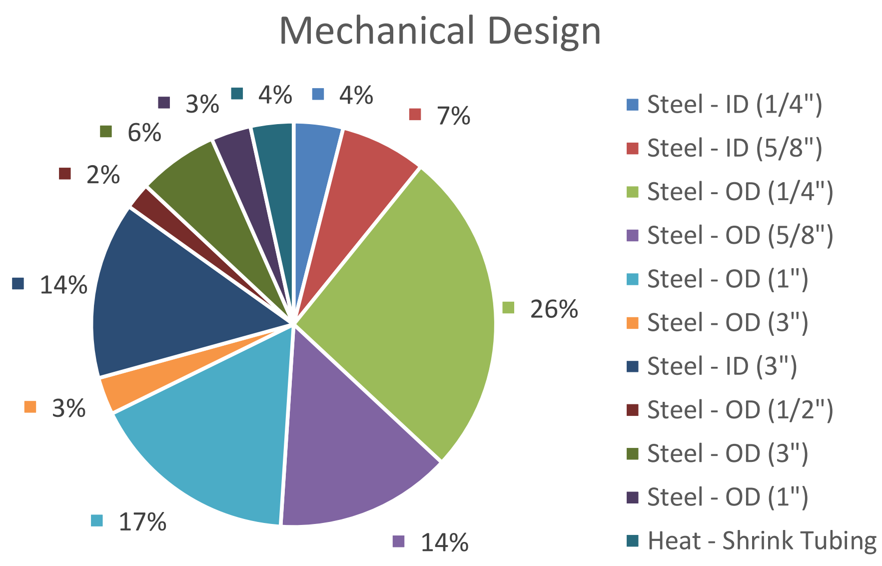


Figure 17. Mechanical Design Budget Analysis

For the electrical and mechanical breakdown of the budget, as seen below in figure 17, the bulk of the money was spent on the two load cells, totalling to 57% of the budget at a cost of $925.00 and 43% of the budget was spent on the load cell amplifier totalling to $700.00 which was also purchased directly from Futek.

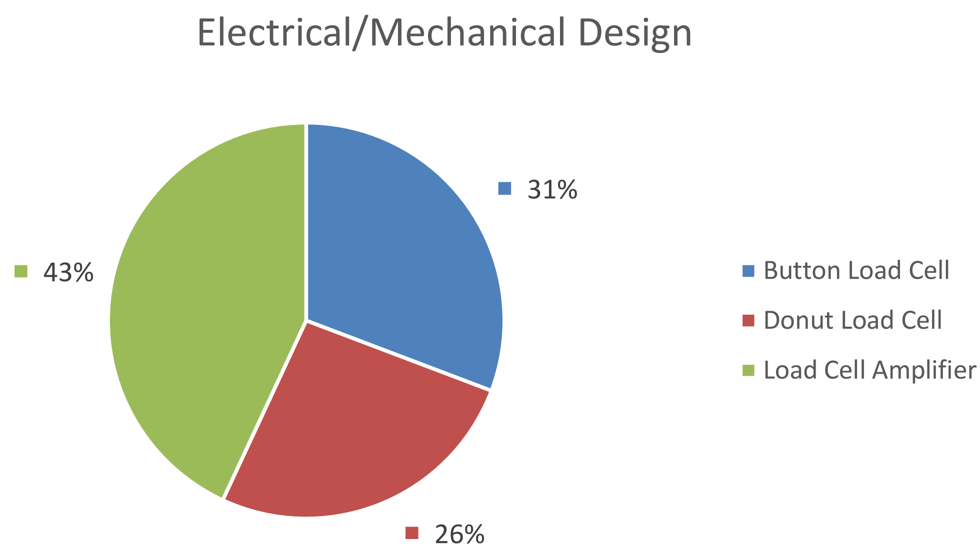


Figure 18. Electrical/Mechanical Design Budget Analysis

For the electrical breakdown of the budget, the bulk of the money was spent on the batteries, totalling to 73% of the electrical budget at a cost of $700.00 which was also purchased directly from Futek. $542.36 was spent on four batteries and $199.99 was spent on the DAQ. A total of only $3.85 was spent on the voltage regulator purchased from Texas Instruments. This total breakdown can be seen below in figure 19.

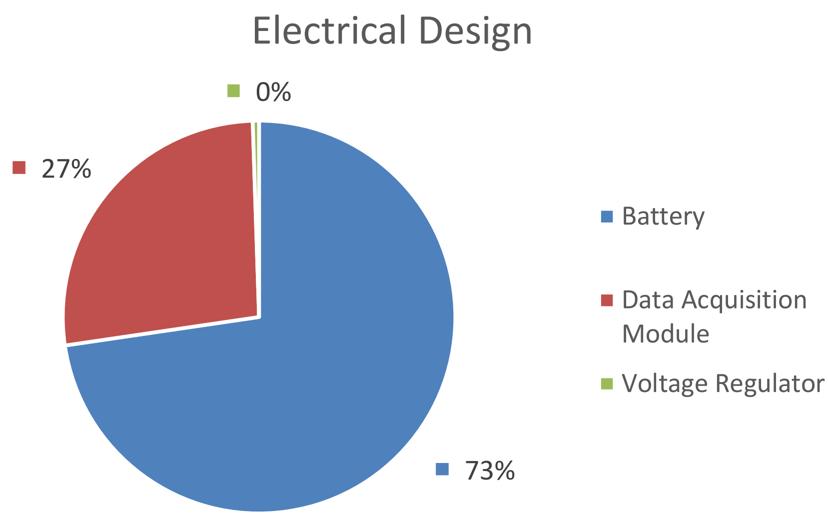


Figure 19. Electrical Design Budget Analysis

5. Conclusion

The objective of this project was to design and build a prototype of a functioning penetrometer that has the ability to differentiate between different types of soil and locate midden based upon the calculated friction coefficient. The penetrometer is portable and weighs less than 50 pounds. It is also user friendly, meaning the operation is not cumbersome. The penetrometer will be forced into the ground, perpendicularly, by means of a drop weight mechanism. As it penetrates the ground, forces will be read by two load cells, a doughnut and button load cell housed above the shafts that will provide readings to determine the friction coefficient of the soil present. The assembly process of this design has created many problems with Team 18, but has been finalized. Every part needed to operate the penetrometer can be seen in Appendix A-2. Currently, the team is still waiting for parts to be returned by the machine shop, which has inhibited their abilities to conduct the tests necessary to complete the project. Financially, the team has had some issues, as they have gone over budget. However, with approval by both the sponsor and team advisor, the team has been able to purchase every part necessary for the project.

6. Appendix A-1

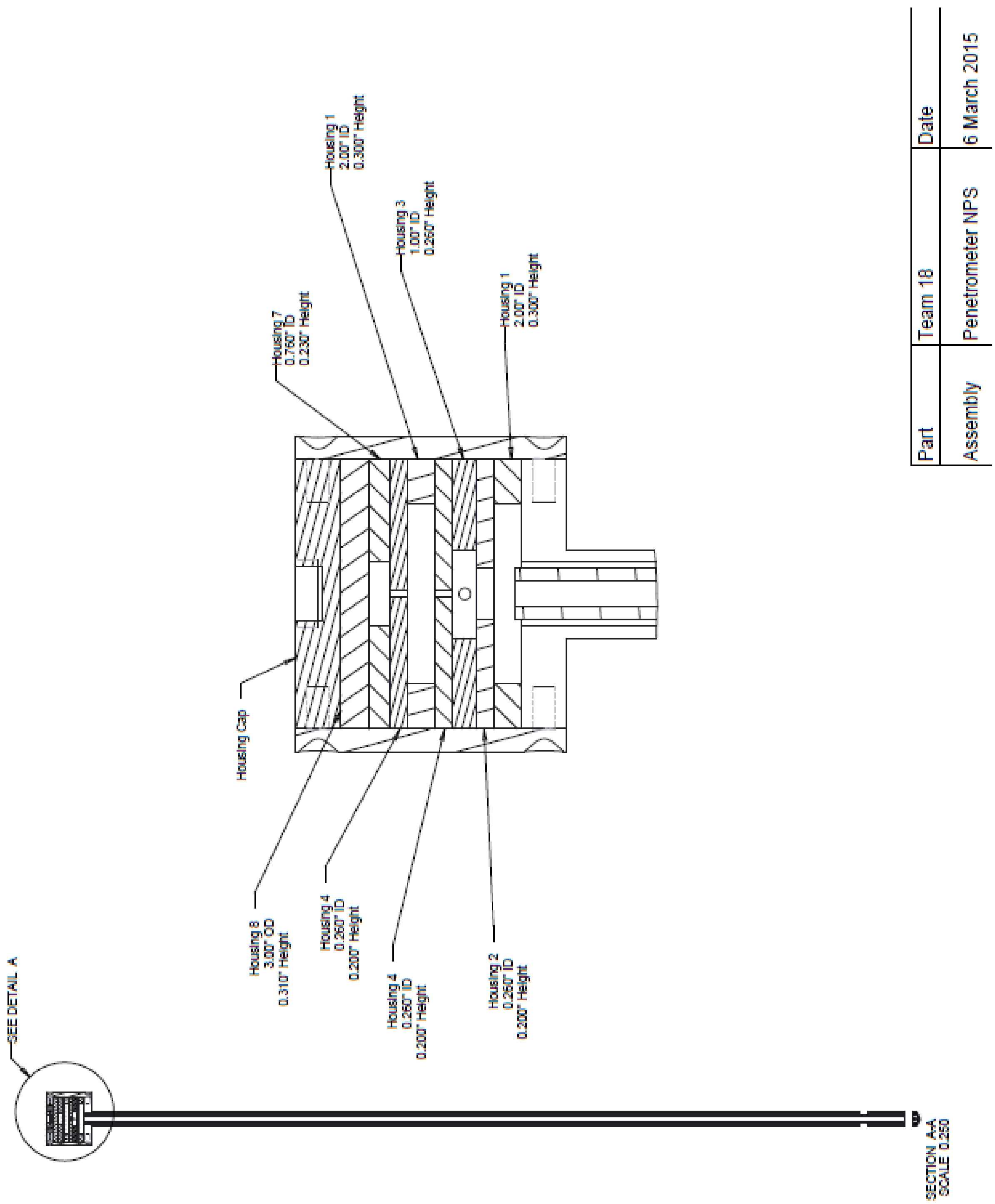
A-1 – FMEA Analysis

Table 1. Failure Modes Effects Analysis

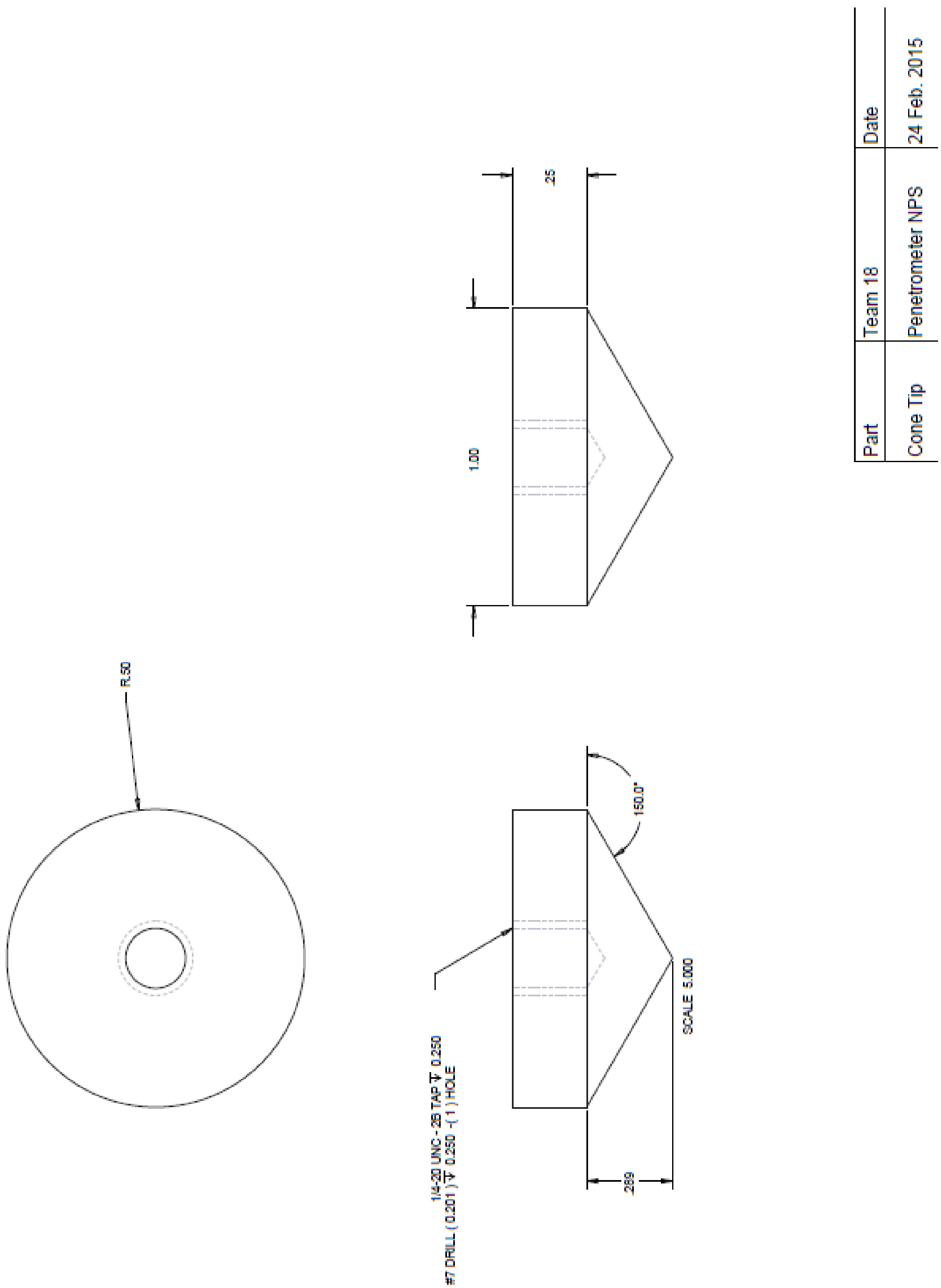
Process Function	Potential Failure Mode	Potential Failure Effects	SEV	Potential Causes	OCC	Current Controls	DET	RPN	Recommended Action	Action Taken
Cone tip impacts with soil	Cone tip breaks	False readings, debris into the system, seals brake	9	Assembled incorrectly, weak material, shreaded screw	1	Use strong material and ensure proper installation	2	18	Have an extra cone tip in case of damage	Visually check cone tip before each test
Penetrometer impacts with soil	Seals buckle and break	False readings, debris in the system, linear alignment is bent throughout the rods	7	Assembled incorrectly, not enough sealant used, material not strong enough	4	Use a strong sealant and give it proper time to set when installed	3	84	Test seals in the lab before ground testing them, have extra sealing material around to ensure the correct amount is used	Visually check seals before each test
Friction sleeve slides through soil	Seals are not elastic enough to move with friction	No friction readings from the upper load cell	7	Poor choice in sealing material	2	Test seals in the lab to ensure they are elastic enough	1	14	Test seals in the lab for elasticity	Check readings in lab before field testing
Penetrometer impacts with soil	Alignment of rods is bent	False readings, no readings, too much friction between shafts	6	Not enough support between rods, seals aren't straight, housing is unaligned	4	Very carefully construct device, tight clearnaces	3	72	Check at each step of assembly for alignment and test results for accuracy	Careful installation
Penetrometer impacts with soil	Housing unaligned	False readings, no readings	6	Housing disks don't have tight enough clearances, installed wrong	1	Machine properly, check clearances during assembly	1	6	Machine properly, check clearances during assembly	Machine properly, check clearances during assembly
App setup	DAQ is not in Bluetooth pairing mode	No readings	1	DAQ not in Bluetooth pairing mode	2	App indicates if there is a connection with the DAQ or not	1	2	Hold the button on the DAQ for 3 seconds until green flashing lights are seen	Hold the button on the DAQ for 3 seconds until green flashing lights are seen
DAQ setup	Low DAQ battery	No readings	3	AA batteries in the DAQ are low, not charged	3	Charge the bateries when not in use	1	9	Charge the batteries when not in use, carry spare AA batteries	Replace the AA batteries with the spare ones, and charge the dead batteries
Power source	22.2V battery is low	False readings, no readings	3	Battery pack is low, not charged	4	Charge the bateries when not in use	1	12	Charge the batteries when not in use, carry spare battery pack	Replace the battery pack with the spare one, and charge the dead battery

7. Appendix A-2

A-2 – Pro E Drawings



A-2 – Pro E Drawings



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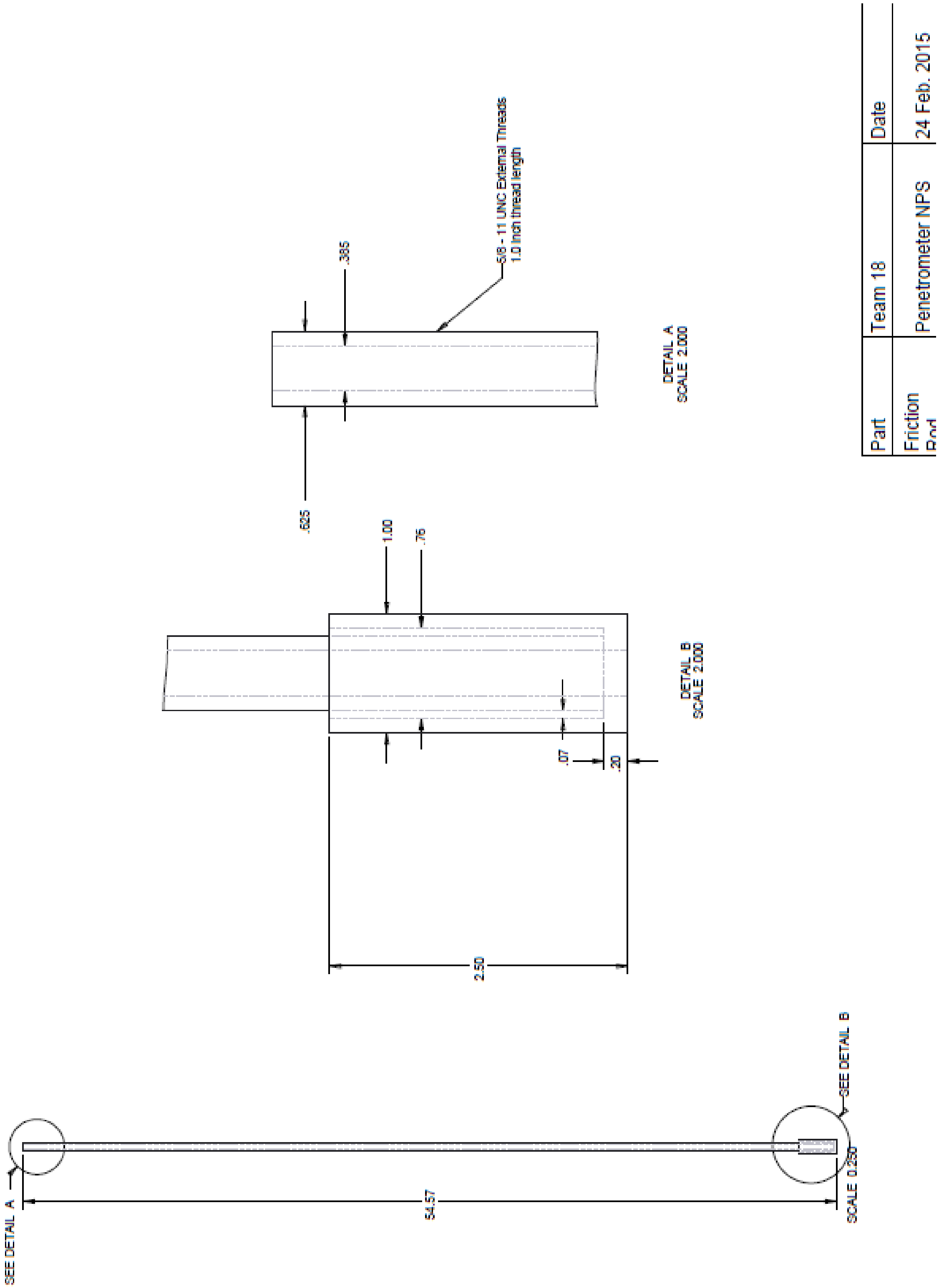

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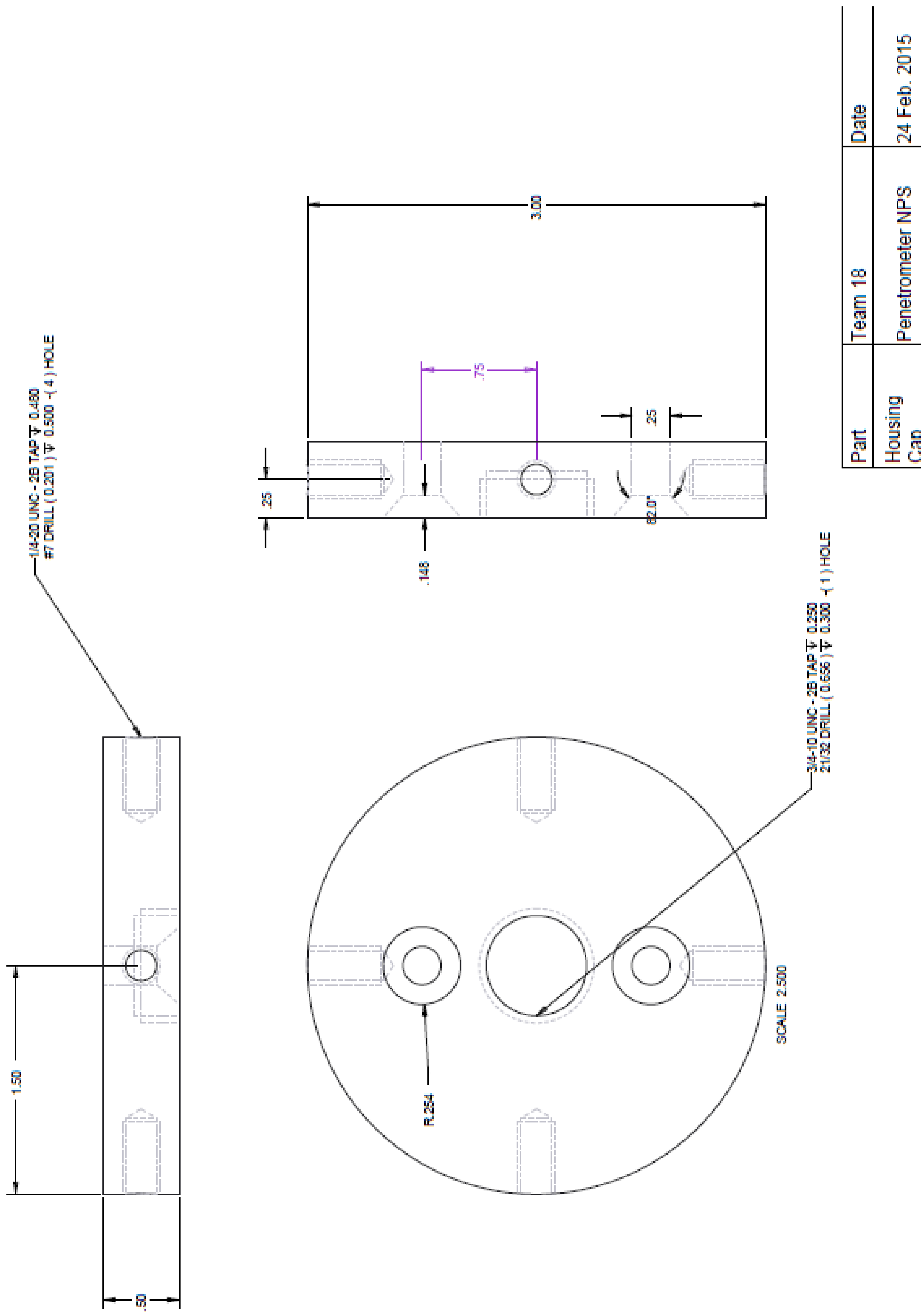

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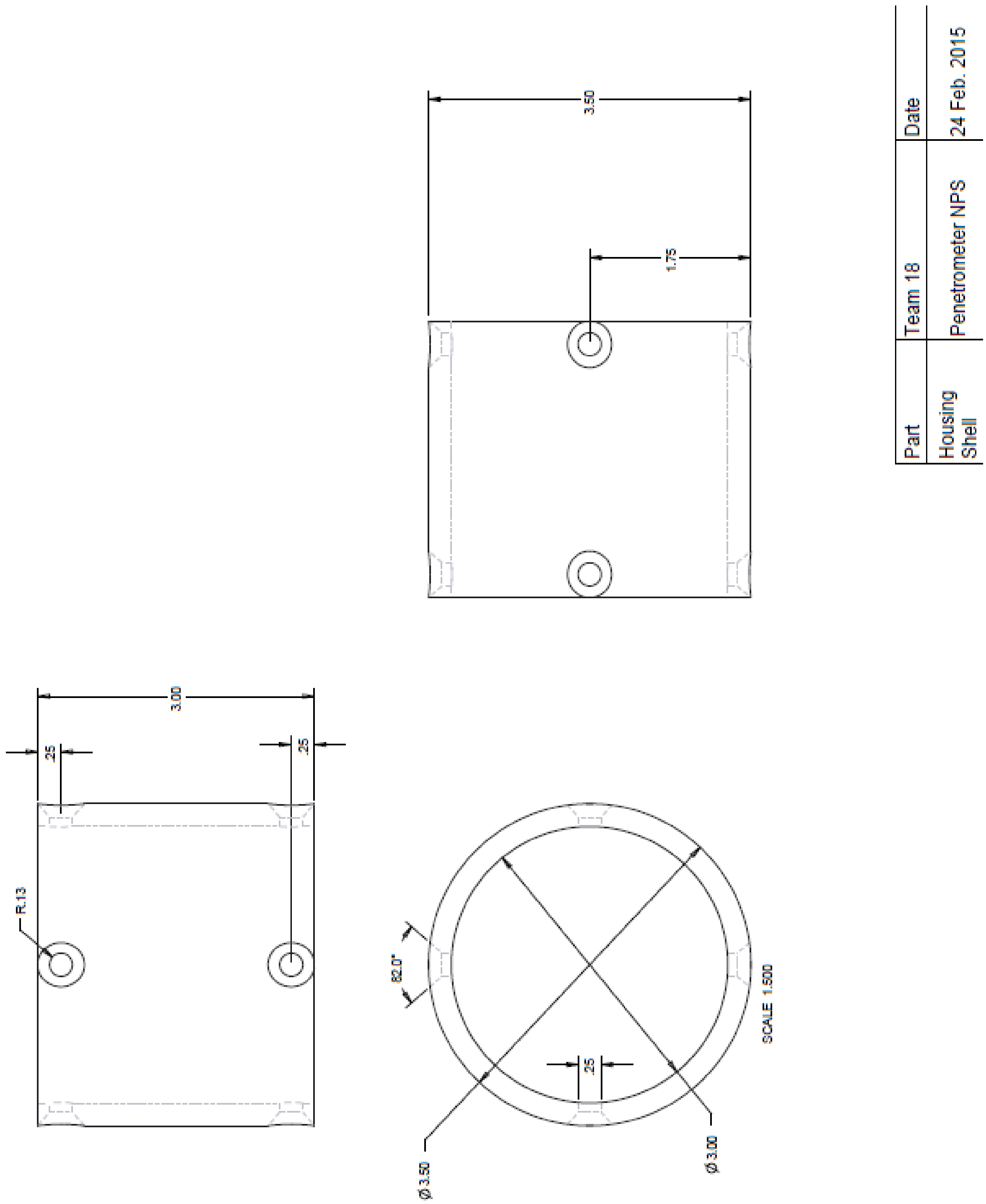
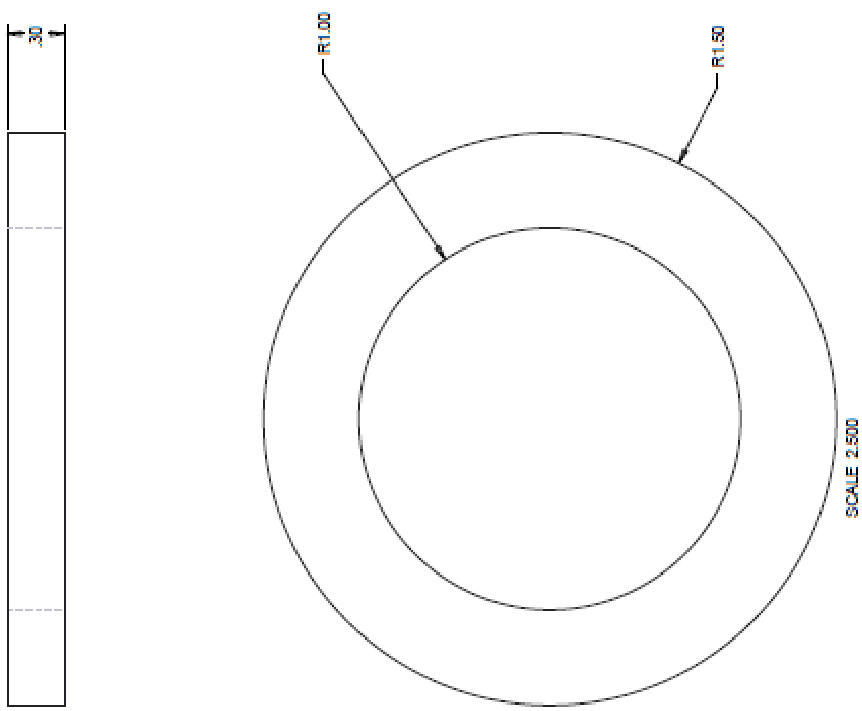


A-2 – Pro E Drawings

Part	Team 18	Date
Housing 1	Penetrometer NPS	24 Feb. 2015



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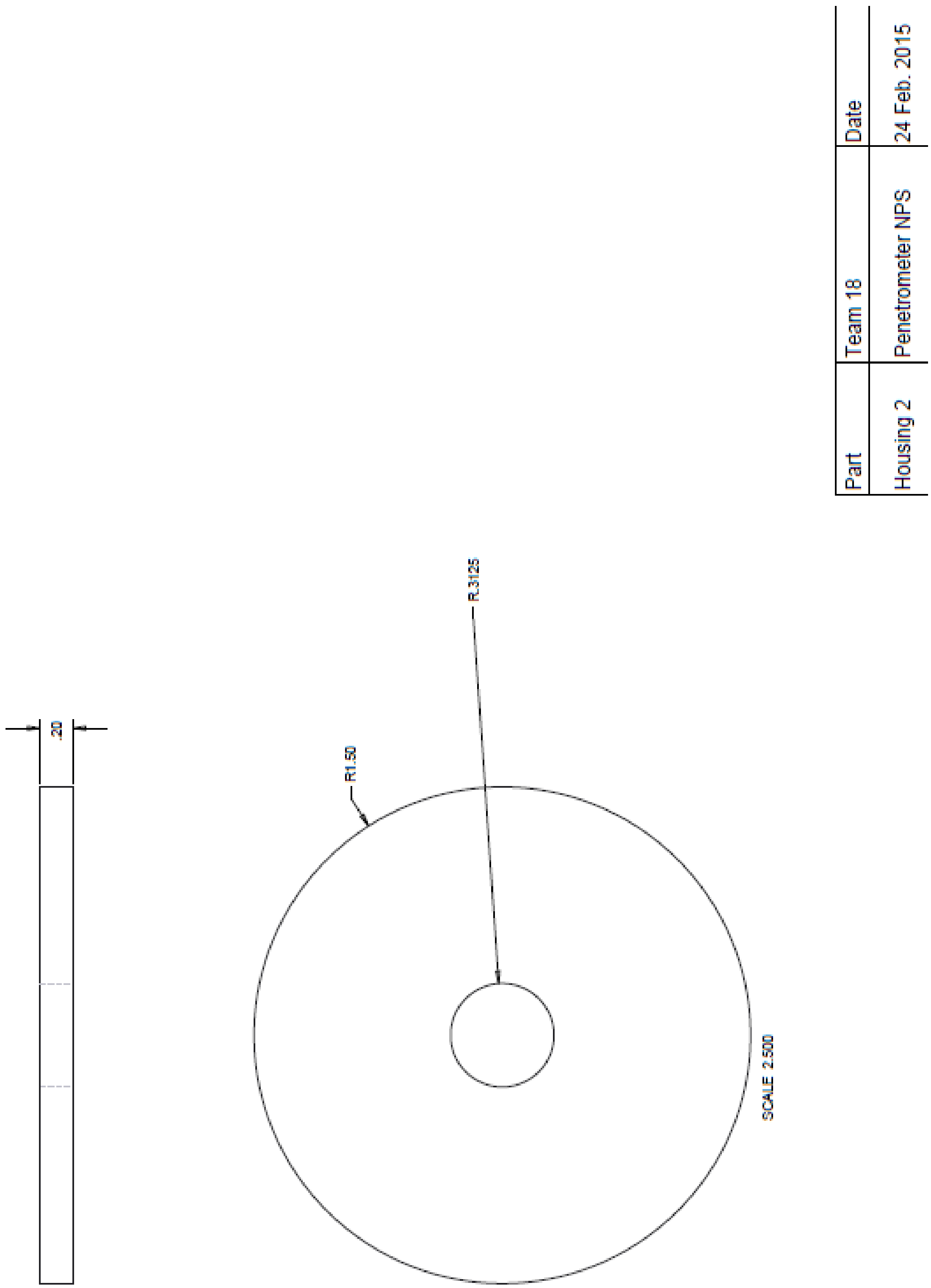

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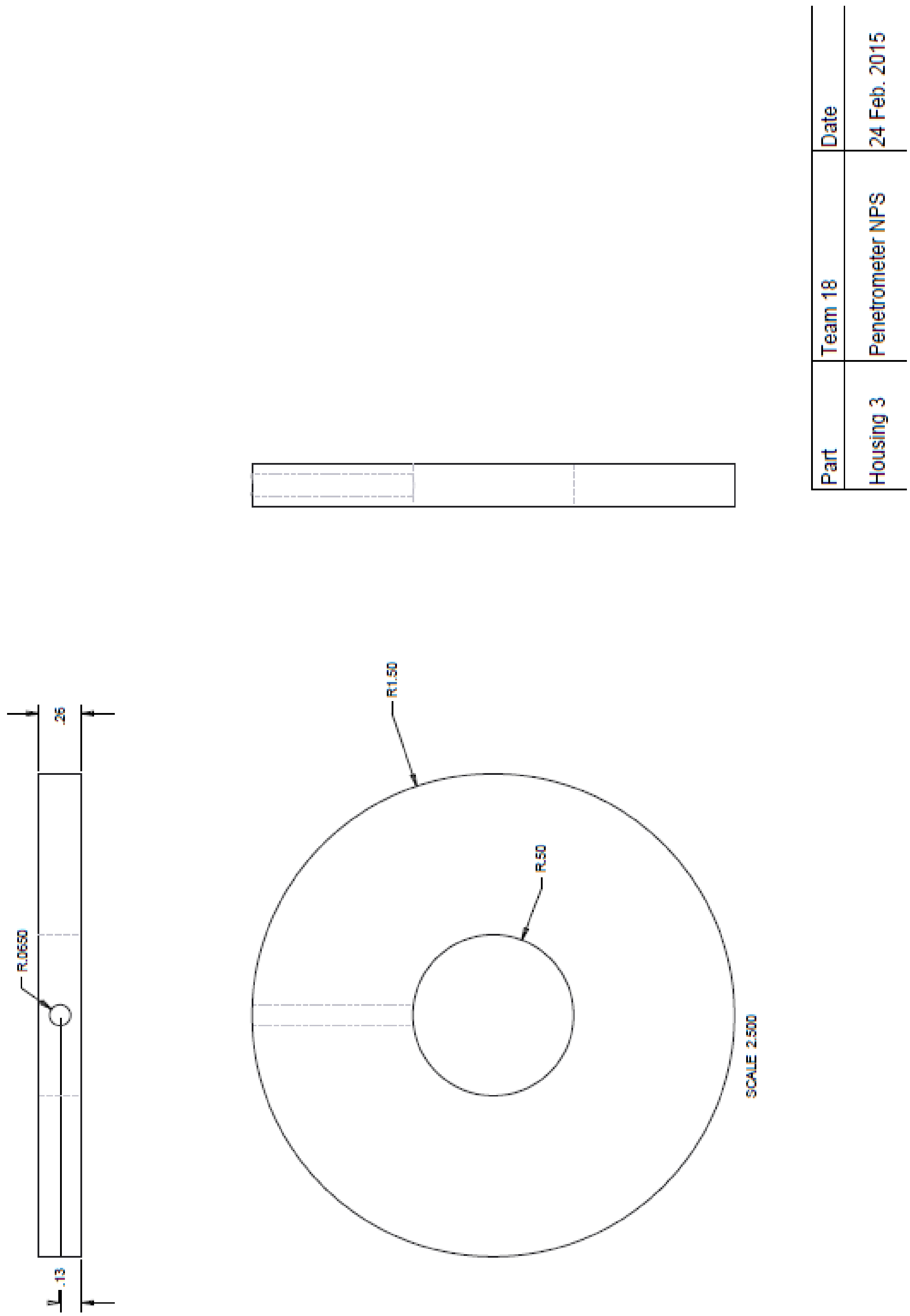

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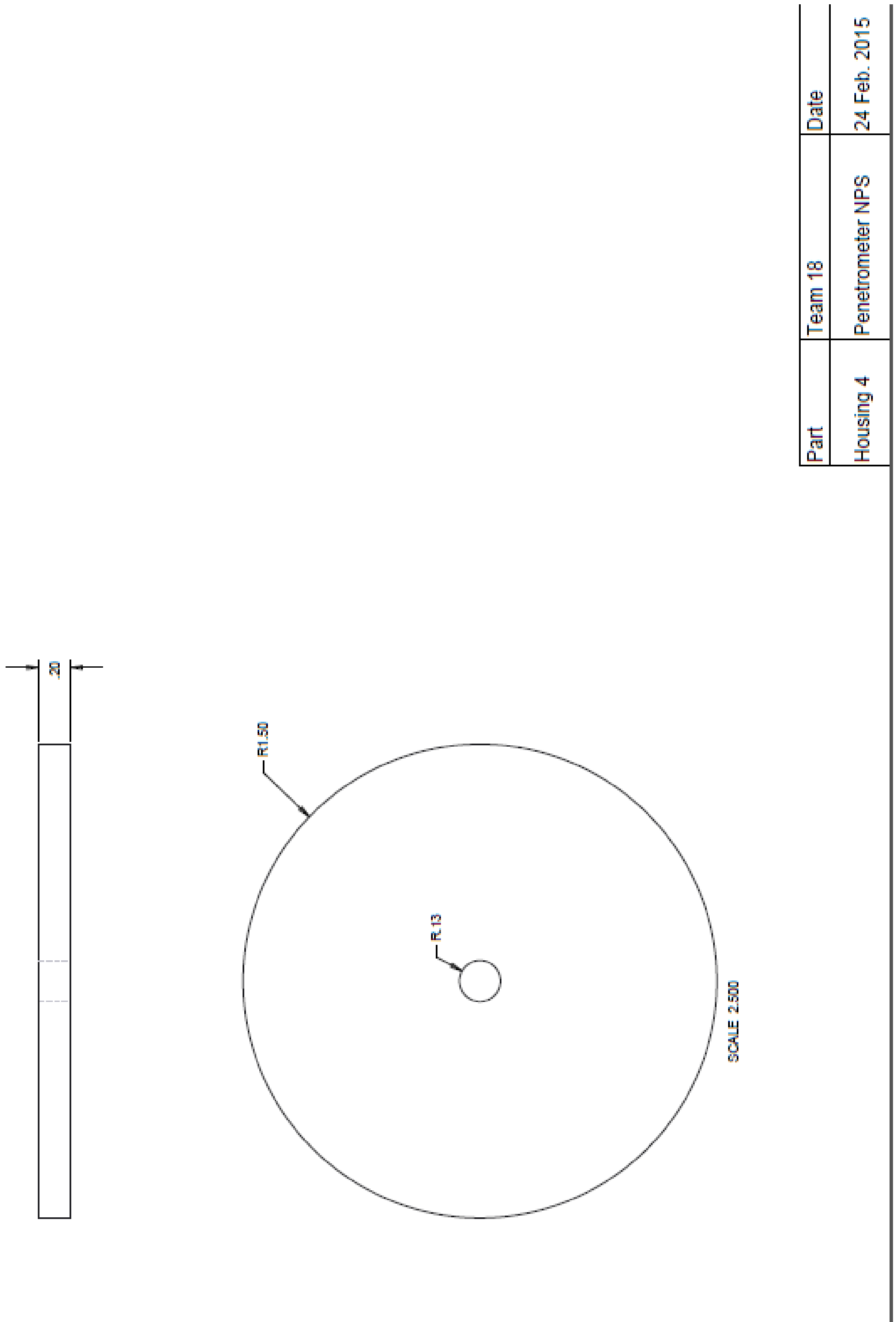

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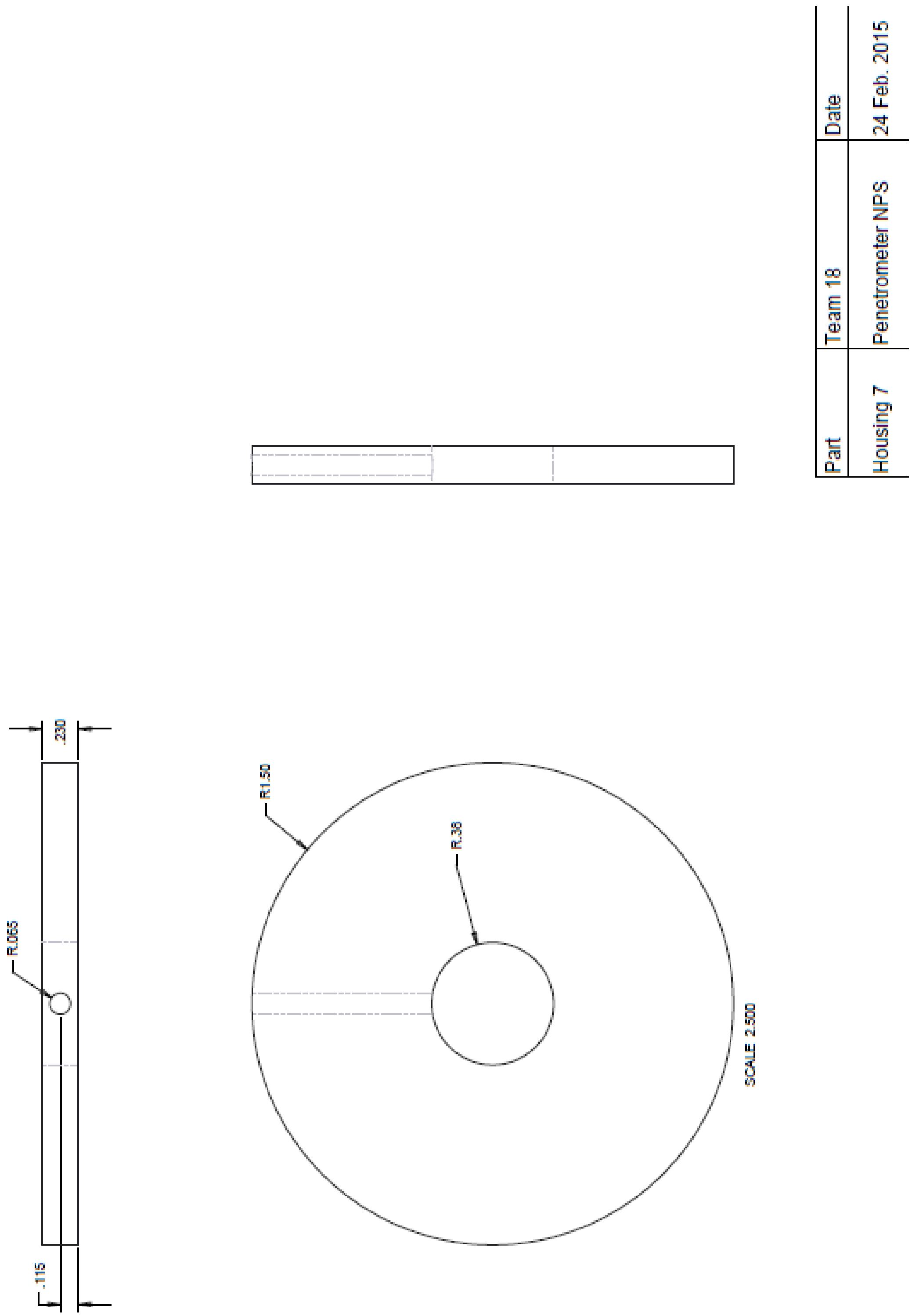

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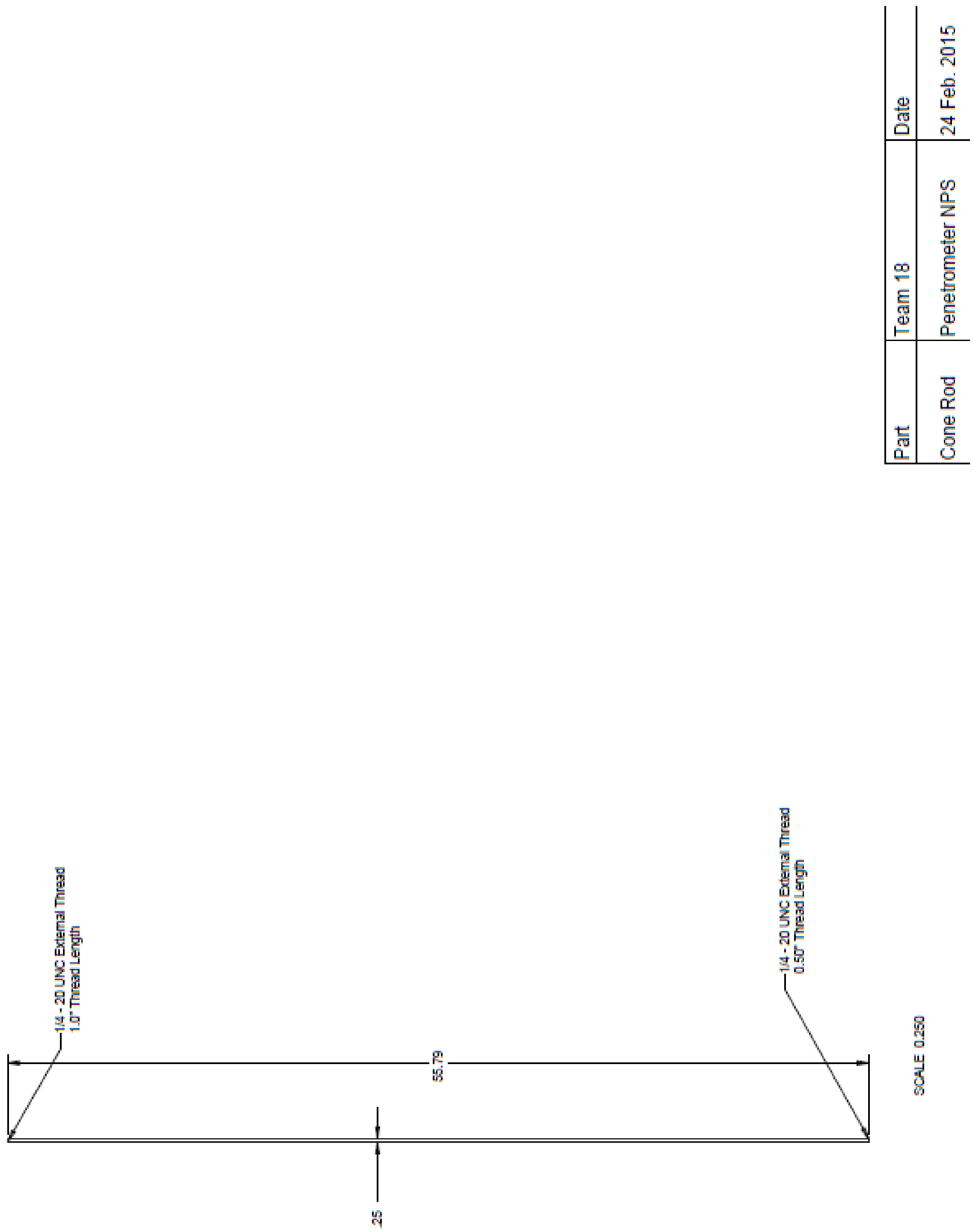

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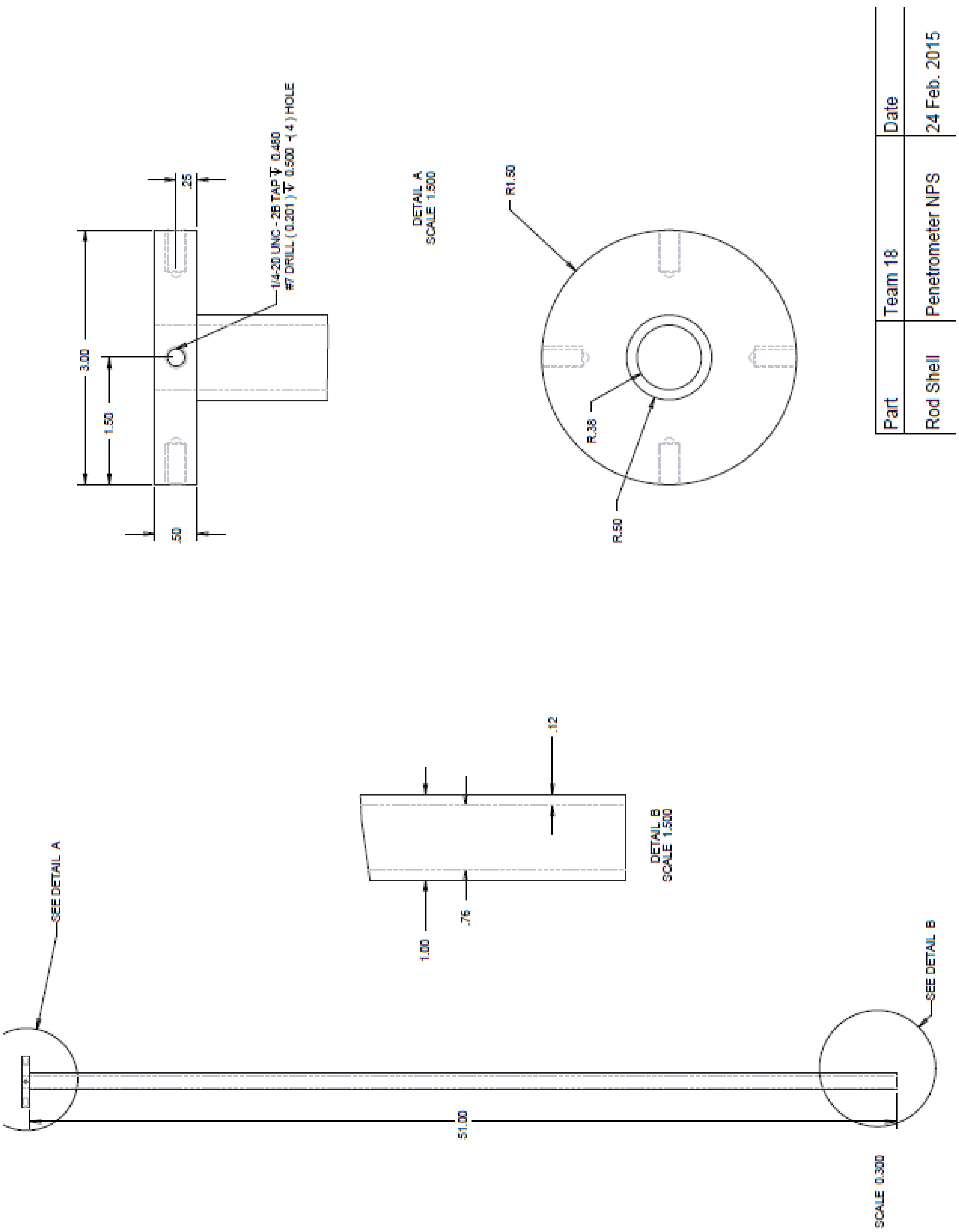

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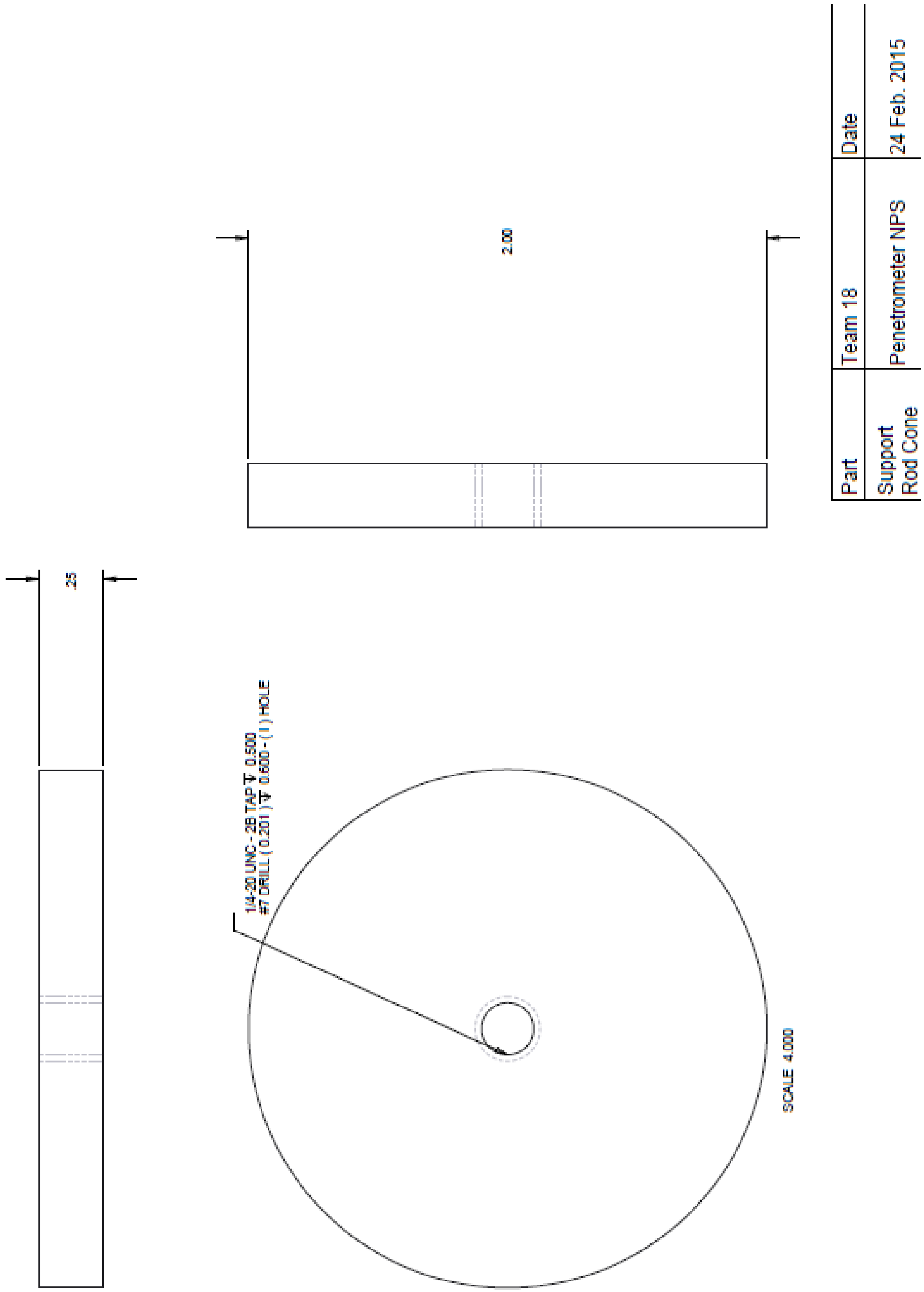

A-2 – Pro E Drawings