# TEAM 18 – PENETROMETER

*Operational Manual*

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Due Friday, April 3rd, 2014

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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 a CpE 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 designing 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

The 2014-2015 Penetrometer group would like to thank the following people for contributing their knowledge, expertise and support to the project:

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 operation and troubleshooting processes for the penetrometer. The penetrometer that Team 18 designed is lightweight, portable, and easy to use. The penetrometer will be used to identify different types of soil and locate midden, if present. Midden is soil that contains any archaeological remains or organic matter from past groups of people who lived on that land. The penetrometer weighs less than 50 pounds, and is easier to transport than the previous design from last year. The data gathered from the load cells will be sent to the DAQ, and will be displayed on the handheld tablet using Bluetooth capabilities. The use of the penetrometer in the field is simple. The user will need to ensure the DAQ is paired with the tablet before testing. Once the DAQ is paired with the tablet, the user may start forcing the penetrometer into the ground using the drop weight mechanism. The data can be viewed on the tablet during or after testing. There should not be many issues while testing in the field, but if there are any minor issues, they will be easy to correct. The penetrometer does not require much regular maintenance. The user will need to remove any debris from the device at the end of the day. After extensive testing, the cone tip and sealants may need to be replaced, but these are inexpensive and simple to change. This penetrometer meets the objectives and constraints provided by the sponsor, and is a significant improvement from last year.

# 1. Introduction

The objective of this project is to design and build a penetrometer that can identify midden in remote locations and differentiate soil types at various depths. The prototype must be relatively lightweight, have strength in compression, and be portable. The penetrometer was originally used as an agricultural tool to determine the soil compaction, which helped farmers decide if the soil could be used for crop production. Due to varied results from site to site, a standard design of the penetrometer was developed. Archaeologists use penetrometers to locate soil midden levels as well as determine how deep it runs below the ground. The method that they currently use is somewhat unreliable, as it takes experience to use a penetrometer to simply "feel" for midden as it penetrates through the soil. This information can assists archaeologists in verifying if there is organic material present at the test site. Team 18 will develop a prototype of a penetrometer that is portable, wireless, and easy to use in the field. This penetrometer prototype will determine the type of soil by calculating the friction coefficient of the soil. The prototype should produce reliable data that can be transmitted to a handheld device.

# 2. Functional Analysis

The functional analysis section of this report will cover the overall project function and how the penetrometer will work in the field.

## *2.1. Project Function*

As an extension of the 2013-2014 senior design project, it is the object 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. The original goal of the project was to "design an instrument that can identify midden and differentiate soil types at various depths." 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. Currently, this year's project has been to redesign last year's design project. Team 18 has taken the prototype out into the field at the National Park Services' testing site. However, upon the first day of field testing, the epoxy failed and the tip of the penetrometer no longer took input readings. With the failed prototype as an example, Team 18 has gathered much information as what not to do with this year's design. The main objectives the Team 18 has been focusing on throughout the year are designing a penetrometer that is lightweight (under 50 pounds), portable, and able to identify midden levels. The data should also be displayed wirelessly on a handheld device.

## *2.2. Penetrometer Operation*

The penetrometer will be used to determine the friction coefficient of the soil present in order to identify different types of soil and midden. The penetrometer will have two load cells integrated into the top housing of the device, which will read the two forces from the ground. One force will be felt on the friction cone tip, due to the impact of the ground; the second force will be felt on the side walls of the shaft, due to the friction between the penetrometer and the soil. Two inner hollow shafts will transmit these forces to the corresponding load cells in order to achieve maximum accuracy and minimum interference.

The penetrometer will have a drop-weight mechanism on top of the housing, which will be used to force the penetrometer through the ground. This method was chosen over the T-bar handle method because the repetitive force applied to the device needs to be constant and precise. All of the electrical components will be housed in a separate carrying case.

The results found while using the penetrometer will be sent to a handheld tablet using a data acquisition module with Bluetooth capabilities. The app created for use with this device will allow the results to be displayed graphically, and the data can either be saved or sent to another computer.

## 3. Project & Product Specifications

The following section of the report will explain the dimensions of the crucial parts of the penetrometer as well as some important characteristics of different components.

### *3.1. Important Components*

The most important component dimensions necessary in designing the penetrometer were the friction sleeve length and the cone tip size. The friction sleeve is of the utmost importance in relation with the reliability of the data found from penetrometer testing. If the sleeve is too long, it will measure the friction of several different layers of soil which could skew the readings too much to be able to identify the correct soil type. If it is too short in length, then the friction reading will be too small to analyse. Seen in Figure 1 is the close up friction sleeve with dimensions. The length was chosen as 2.5 inches. After consulting with the archaeologists it was found that the midden depths can greatly vary based on how many years there were deposits. If the level is measured to be 3 cm then the midden is not important enough to document so the only midden being probed for is midden with depths greater than an inch. Two and a half inches was chosen in order to guarantee a friction measurement could be made and it is not too long to be skewed by the layers previously measured about it.

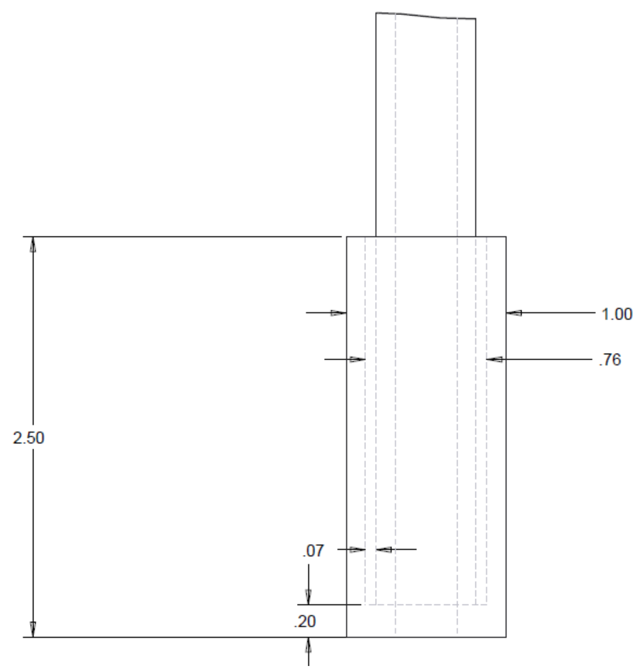

Figure 1. Friction Sleeve

The cone tip design is based off of penetrometer standards found in the Geology National Engineering Handbook by NRCS[4].This caused for a 30 degree angle cone tip combined with our diameter of 1 inch. The cone has a depth of 0.289 inches. This can be seen in Figure 2.

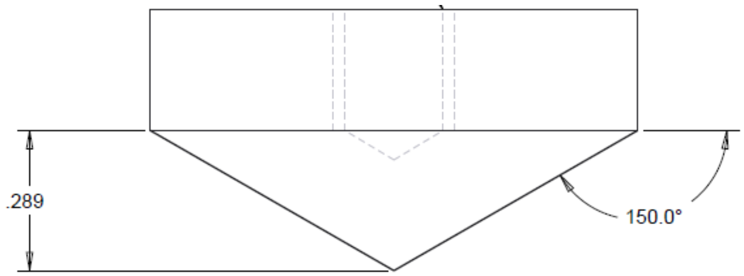


Figure 2. Cone Tip

Other than the dimension tolerances that were important, the load cells sensitivity was very important to take into consideration due to the low force read from the friction sleeve and the high force read from the cone tip. The design allowed us to choose more on the capacity of the load cells instead of the size of each load cell. From each load cell, the voltage measurement will be transferred through an amplifier that will allow for a strong signal that will be easily readable by the data acquisition module that was purchased. The housing discs that were machined for each load cell must be created with a tight enough tolerance as for the load cells not to shift while receiving the impact force from the respective rods.


Figure 3. Futek Button Load Cell


Figure 4. Futek Donut Load Cell

**BTH-1208LS Wireless Multifunctional Data Acquisition (DAQ)**

The DAQ shown in Figure 5 acquires data over Bluetooth or USB connection. The device will record the output voltage from the load cells and relay the data, through Bluetooth, to an Android device running an application. The specifications can be seen in Figure 6.


Figure 5. DAQ BTH-1208LS

| | |
|---|---|
| **Analog Input** | |
| Sample Rate: | 47 kS/s |
| Number of Channels: | 8 SE/ 4 DI |
| Range, Bipolar: | -20 to 20V, -10 to 10, -5 to 5, -4 to 4V, -2.5 to 2.5, -2 to 2, -1.25 to 1.25, -1 to 1 |
| Resolution: | 12 bit |
| **Analog Output** | |
| Resolution: | 12 bit |
| Number of Channels: | 2 |
| Range, Unipolar: | 0 to 2.5V |
| **Digital I/O** | |
| Number of Channels: | 8 |
| **Counter Timer** | |
| Counter Inputs: | 1 |
| Counter Resolution: | 32 bit |
| **Measurement Type** | |
| Measurement Type: | Voltage Output , Counter , Digital I/O , Multifunction |
| **Interface List** | |
| Interface: | Wireless |

Figure 6. DAQ Specifications

**Laser Range Finder**

The laser range finder shown in Figure 7 is a device from last year's design. This device uses a laser and a reference point on the penetrometer. As the penetrometer travels into the soil, the reference point will move closer to the laser and measure the displacement. This displacement is the distance the tip of the penetrometer has travelled. This device measures and records the depth and sends the information to an app developed by the team.

**Texas Instruments UA7810 15V Voltage Regulator**

A Texas Instruments 15V voltage regulator shown in Figure 8 will be used to ensure that a constant 15V is provided to the load cells. The voltage regulator has a maximum input voltage of 30V and a minimum input voltage of 17.5V. A 22.2V rechargeable battery will supply the input voltage for this project.

**Futek CSG110 Amplifier**

The same manufacturer of the load cells makes amplifiers as well. This amplifier, pictured in Figure 9, is used so that the analog output of the load cells will be in the +/- 5V range. The Futek amplifier will filter noise much more effectively than an amplifier designed by the team because Futek has the resources and technology to get the best out of their products. Designing an amplifier on our own will create too much noise, and the signal may be lost. The Futek amplifier has adjustable gain DIP switches to achieve your specified output.

Figure 7. Laser Range Finder

Figure 8. Voltage Regulator


Figure 9. Futek Amplifier

*3.2. Characteristics of Different Components*

Stainless steel was chosen as the material of choice for the penetrometer. This is due to the high yield stress and the ductility of the material. The entire penetrometer is repeatedly under the stress of a 15 lb drop weight and needs to be able to handle this force elastically. Stainless steel was the most monetarily efficient and suitable material.

The drop weight itself was chosen as 15 lb because it will allow for several readings in a shorter distance. It will allow enough force for the penetrometer to move through the ground, but not so much that there are not enough readings to gather accurate data. 15 lbs is also a simple amount of weight to lift so the user does not get overly strained throughout the day.

## 4. Project Assembly

The project assembly portion of this report will show the 3D model of the project and crucial components and their assemblies.

*4.1. 3D Model Overview*

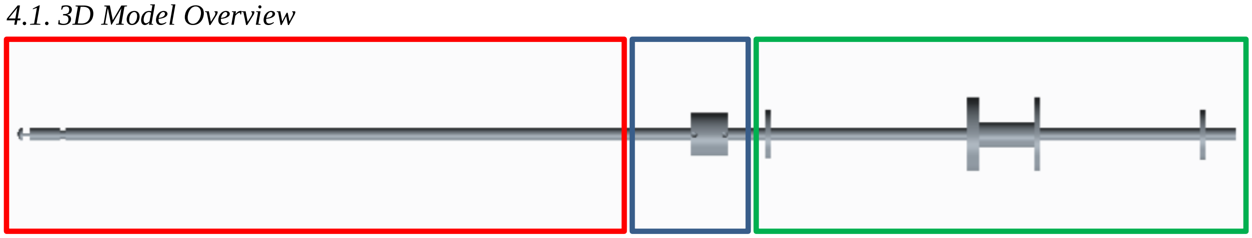

Figure 10. 3D Model of Penetrometer

*4.2. Close-Up Assemblies*

As shown in the following figures, the completed penetrometer is composed of three sections (Figure 10): a housing design (Figure 11a), a shaft design (Figure 11b), and a drop weight design (Figure 11c). Each section is composed of several pieces that can be found in the Appendix D 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.

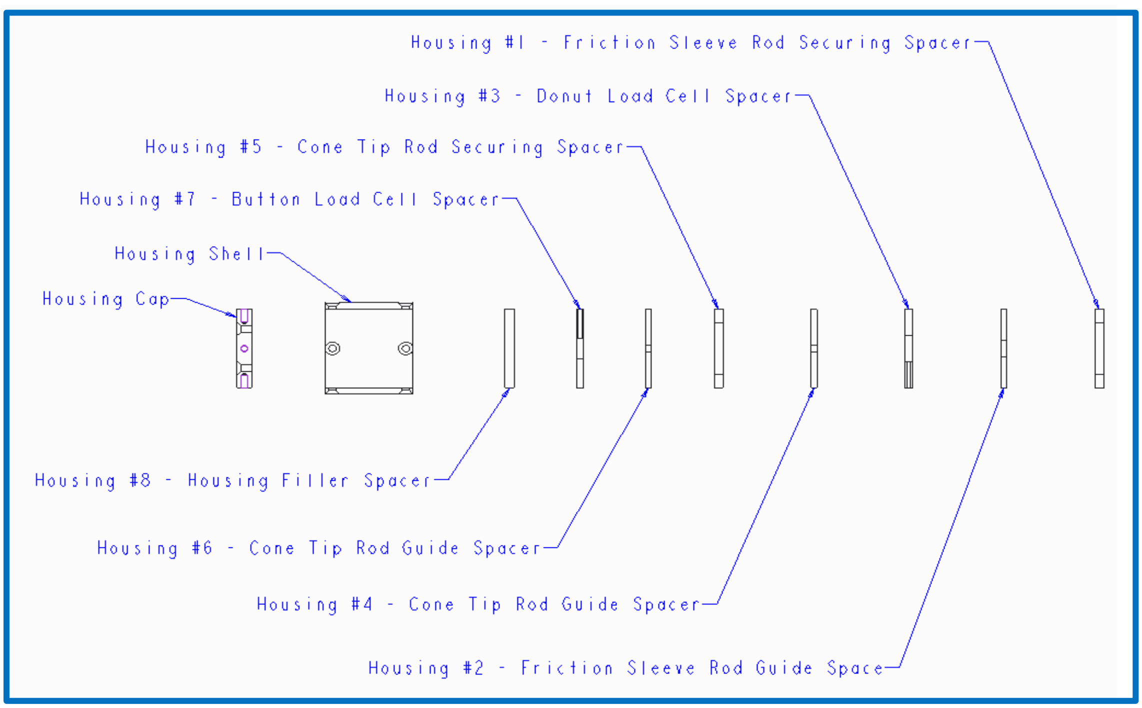




Figure 11a. Exploded View of Housing

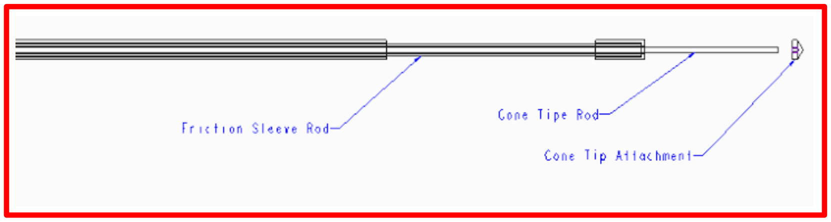


Figure 11b. Exploded View of Shaft

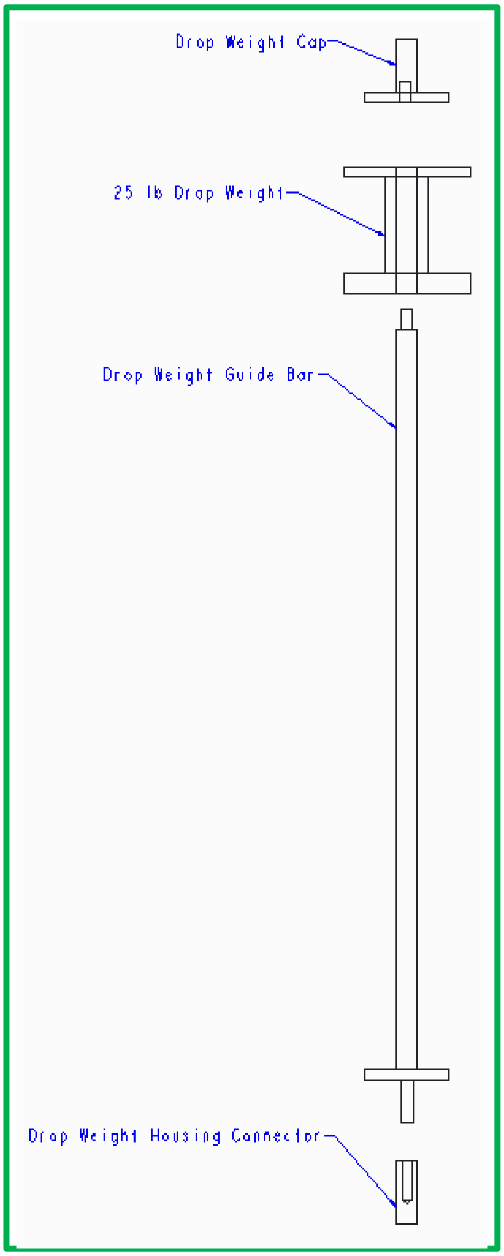


Figure 11c. Exploded View of Drop Weight

*4.3 Mechanical Assembly Process*

1. Screw the cone tip on to the smallest rod, the cone tip rod.

Figure 12. Cone Tip Rod

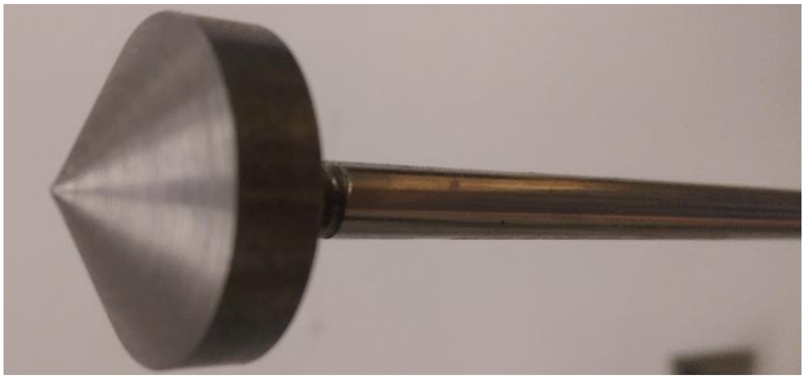

Figure 13. Cone Tip Rod with Cone Tip

2. The second layer is the friction sleeve rod which the cone tip assembly will be slide through with the cone tip at the bottom of the rod near the friction sleeve itself.

Figure 14. Friction Sleeve Rod

Figure 15. Friction Sleeve Rod and Cone Tip Rod

Figure 16. Friction Sleeve Rod and Cone Tip Rod Assembly

Figure 17. Shaft Assembly

3. The outer shell shaft will be slid over the combined friction sleeve and cone tip rods all the way to the friction sleeve at the bottom of the rod. The two rods, friction sleeve rod and cone tip rod, ends will be protruding from the housing base connected to the out shell shaft.

Figure 18. Outer Shell Shaft

Figure 19. Outer Shell Shaft and Shaft Assembly

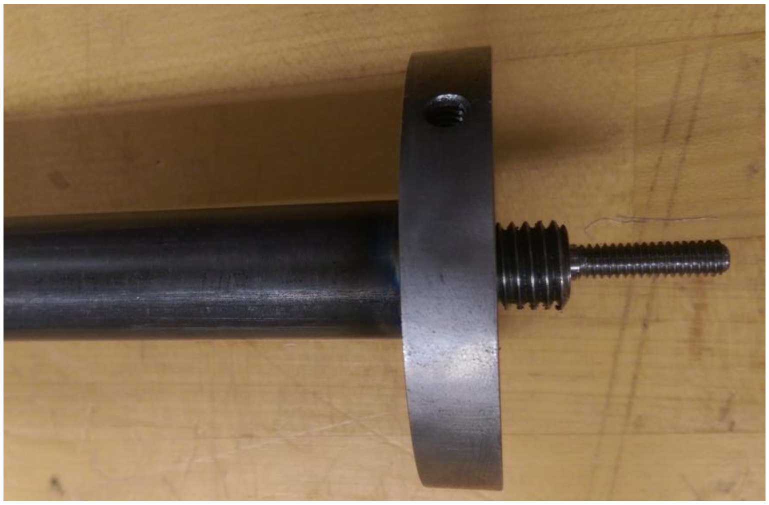

Figure 20. Housing Base Assembly

4. The friction sleeve rod and cone tip will have a corresponding restraining disc matched with the rod. The restraining disc of the friction sleeve will be screwed on only and the cone tip restraining disc will be screwed on later in the assembly.

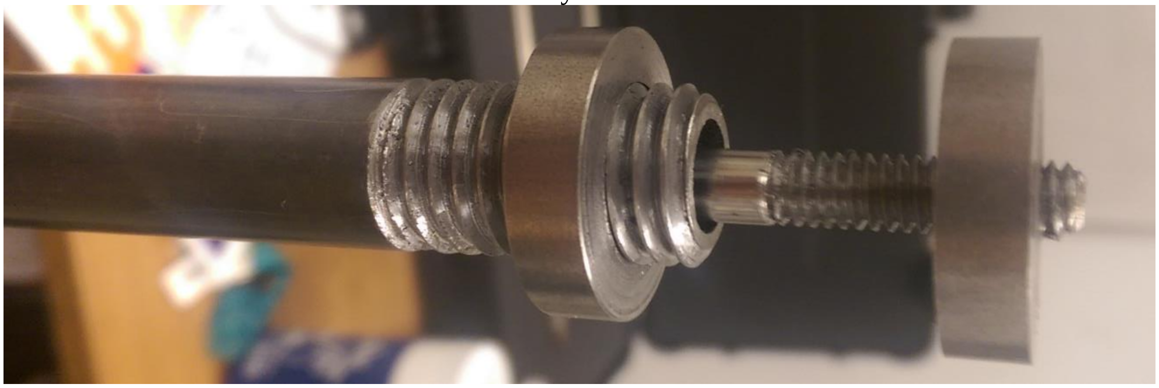

Figure 21. Restraining Discs

Figure 22. Cone Tip Rod Restraining Disc

5. The housing is comprised of a base, shell, eight inner discs and a top disc for sealing. The discs will have a specific geometry and placement within the housing. Refer to the appendix for numbering and geometry of each disc.

Figure 23. Housing Shell

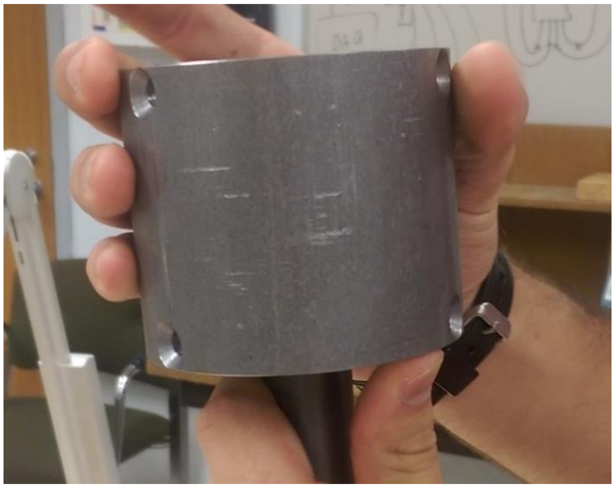

Figure 24. Housing and Base Assembly

The ordering for the discs within the housing are as follows: disc 1, disc 2, disc 3, disc 4, disc 1, disc 4, disc 7 and disc 8. Disc 1 and disc 4 have multiple discs of the same geometry that will be used in the overall housing. Please refer to Appendix D for specific discs.

Figure 25. Donut Load Cell Assembly


Figure 26. Disc Assembly 3


Figure 27. Disc Assembly 4

Figure 28. Button Load Cell Disc

Figure 29. Button Load Cell Assembly

6. After all of the disks are installed, the top disk can be secured into place with screws. Then the drop weight rod can be screwed onto the housing followed by the drop weight and the top lock cylinder as well. This completes the construction of the mechanical side of construction.

Figure 30. Drop Weight Guide Bar

Figure 31. Drop Weight

Figure 32. Securing Drop Weight

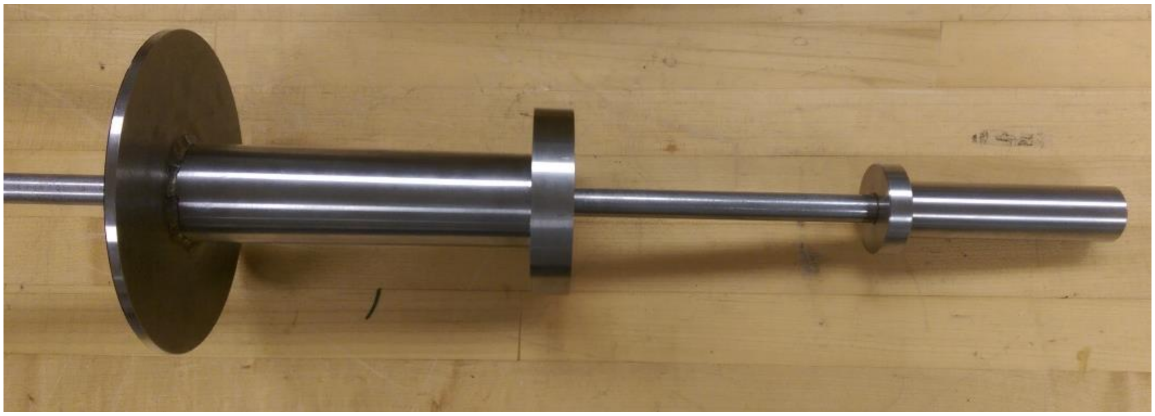

Figure 33. Drop Weight Assembly

*4.4 Electrical 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 34. Notice that the PC board pictured 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 35, 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).

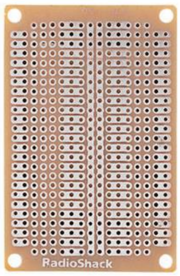


Figure 34. PC Board

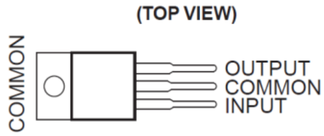


Figure 35. Voltage Regulator with Pins

Figure 36. 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 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 10kHz 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 37) 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

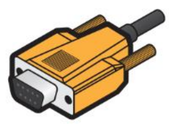

Figure 37. Power Side DB9 Cable

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.

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 38. 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 in Figure 39, 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

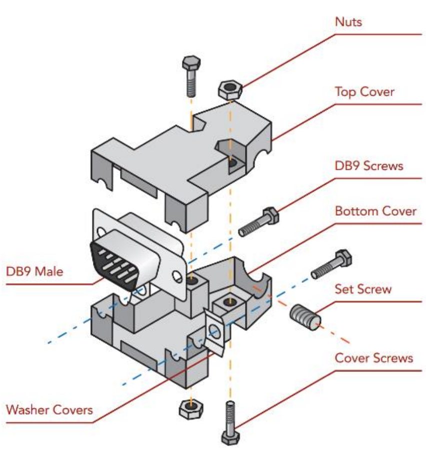


Figure 38. DB9 Connector

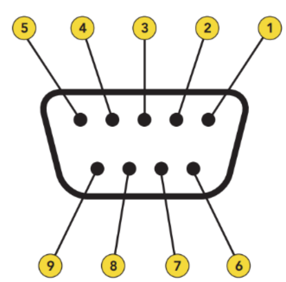


Figure 39. Female Connection of the DB9 Connector

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.

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. 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.

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 40 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 40.

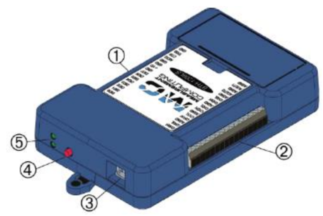


Figure 40. DAQ Components

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 41. 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.

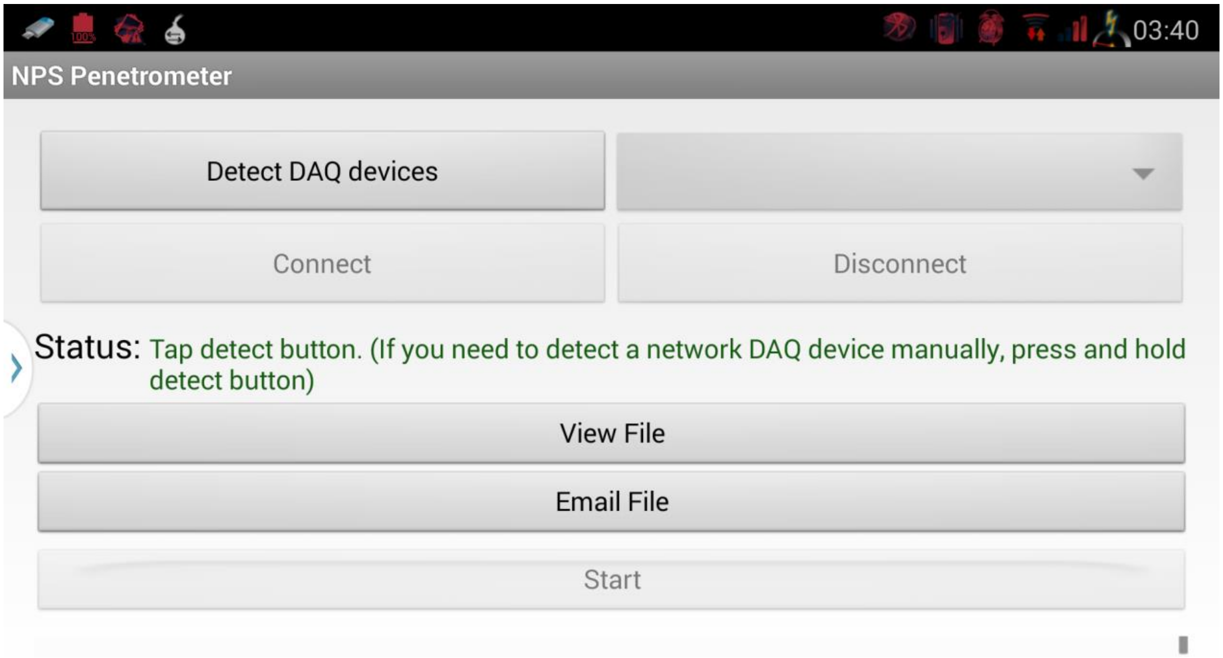


Figure 41. Home Screen of NPS App

## 5. Operation Instruction

The operation instruction portion of the report will explain what procedure to follow when operating the penetrometer and what notifications to look for while testing.

*5.1. Procedure to Operate*

1. Turn on the power switch on the circuit board.
2. Turn on the DAQ by pressing the small black button on the side of the DAQ.
3. Hold the button for approximately 3 seconds until you see a flashing green light. This will confirm that the DAQ is ready to pair through Bluetooth with the tablet.
4. Open the "NPS Penetrometer" app on the tablet, and click "Connect" to connect to the DAQ.
5. Place the penetrometer vertically in the desired position to take measurements.
6. When ready, press "Start" within the app to start taking measurements.
7. While holding the penetrometer as perpendicular with the ground, and as steady as possible, raise the weight on the penetrometer to its maximum height and release the weight to allow it to fall. This will drive the penetrometer into the soil.
8. Repeat step 7 until the penetrometer cannot travel any further into the soil. Be sure to raise the weight to its maximum height before each drop.

9. Press “Stop” on the app to stop the recording.
10. The data will then be saved to the tablet in an excel file for further analysis.
11. Repeat steps 5-10 to take more measurements at different locations.

*5.2. Notification During the Operation*

- If the app will not connect to the DAQ, inspect the DAQ to make sure that there are flashing green lights to indicate that a connection is ready to be made. If the lights are not flashing, hold the button for approximately 3 seconds.
- Make sure the penetrometer is held steady and perpendicular to the ground throughout the time of testing. This will ensure maximum reliability and provide the best results.
- While the app is gathering results, the graph can be expanded to a full screen view by tapping twice, and returned to its original size by tapping twice again.

## 6. Troubleshooting

The troubleshooting portion of this report will reveal potential problems with the penetrometer and how to solve these problems when they occur.

### *6.1. Potential Electrical Problems and Solutions*

Table 1. Troubleshooting for Electrical Problems

| Problem | Cause | Solution |
|---|---|---|
| **Unable to connect to the DAQ** | DAQ may not be in Bluetooth mode. | 1. Ensure the DAQ is in Bluetooth mode.<br>2. Ensure device is paired with mobile device.<br>    a. The security code is 0000.<br>3. Ensure Bluetooth is on in the mobile device. |
| **Unable to turn on the DAQ** | The batteries may be dead or not connected. | 1. Ensure the batteries have sufficient power.<br>2. Ensure the batteries are properly connected to the DAQ.<br>3. If all else fails, contact Measurement Computing Corporation.<br>    a. Tel: (508) 946-5100 |
| **Unable to connect to the mobile device** | The mobile device may be dead or not in Bluetooth mode. | 1. Ensure the mobile device has sufficient power.<br>2. Ensure Bluetooth on the mobile device is on.<br>3. Ensure device is paired with the DAQ.<br>    a. The security code is 0000.<br>4. Ensure the device battery is properly connected.<br>5. If all else fails contact device manufacturer. |
| **Unable to launch the application** | The application or mobile device may be malfunctioning. | 1. Close all applications.<br>    a. Restart the app.<br>2. Restart the mobile device.<br>    a. Restart the app.<br>3. Uninstall the app.<br>    a. Reinstall the app. |
| **Application fails to launch** | The application is malfunctioning. | 1. Restart the mobile device.<br>    a. Restart the app.<br>2. Delete all log files.<br>    a. Restart the app. |

*6.2 Potential Mechanical Problems and Solutions*

Table 2. Troubleshooting for Mechanical Problems

| Problem | Cause | Solution |
|---|---|---|
| **No output reading from the load cells** | The wires may not be properly connected, or the battery may need to be charged. | 1. Ensure that the load wires are connected properly to the input power supply regulator.<br>2. Ensure the battery has enough power to power the regulator and load cells.<br>3. Disconnect the load cell wiring from the regulator.<br>a. Plug the corresponding wires back into the regulator to check if connection is correct. |
| **High output reading** | The amplifier may not be in the correct range, or the wiring may be incorrect. | 1. Check and verify that the amplifier of the load cells is locked in the ±5 V range.<br>2. Ensure that the regulator is working properly and not allowing too much voltage to pass through to the amplifier.<br>3. Ensure the load cell wiring is connected properly to the corresponding amplifier connections.<br>4. Ensure that the corresponding shaft rod is not locked in an upward forced position. |
| **Low output reading** | The components may not be powered sufficiently. | 1. Check and verify that the amplifier is receiving adequate power from the regulator.<br>2. Ensure the battery has enough power left to sustain the amplifier regulator.<br>3. Check to make sure the connection between the load cells and amplifiers is secure.<br>4. Ensure that the corresponding shaft rod is screwed securely in place and not loose on the secure disc. |
| **Constant (non-changing) output reading** | There may be debris inside the sealing. | 1. Check to make sure there are no tears in the sealing of the friction sleeve for clogging of the shaft.<br>2. Test each load cell by moving the corresponding shaft rod with adequate force. |

## 7. Regular Maintenance

The regular maintenance portion of this report will detail how to clean out and take care of the penetrometer and its corresponding equipment. It will also explain what parts need to be replaced routinely.

### *7.1. Routine Maintenance*

The mechanical shaft of the penetrometer will require routine maintenance after every day in the field. To begin, the outside of the shaft must be wiped clean with a cloth. All debris must be cleaned off of the shaft to ensure future reliability of the device. Every time the penetrometer is taken into and out of the field, the electronics wiring must be disconnected from the clip to ensure it does not tear the wire from the load cells while being transported. When taking the drop weight off of the penetrometer to put the device away, all of the upper shaft screws should be wiped free of debris.

At the end of soil testing the 22.2V Li-ion battery pack should be replaced by a spare battery pack. The battery pack that was just recently removed should be charged X hours in order to provide full charge. The battery pack should not be charged longer than eight hours in order to prevent overcharge. However, the battery pack does contain overcharge protection but should still not be overcharged often. The DAQ's AA battery should be recharged once the batteries reach half capacity. This capacity can be determined by using the battery fuel gauge that comes with an Energizer Smart Charger for AA NiMH batteries. After the rechargeable NiMH AA batteries have been recharged a few hundred times it is best to replace them with new NiMH AA batteries to improve performance and reliability.

### *7.2. Key Component Replacement*

The main two components that will need replacement over extended use are going to be the cone tip and the seals for the friction sleeve. To replace the cone tip it is a simple matter of unscrewing the current cone tip and replacing it with a new one. When the seals are replaced, the current seals must be cut off the device carefully and the inside of the device must be cleaned out while it is open. To install new seals see the assembly portion of this report.

Both of these components are very cheap and easy to machine. The cone tip model specifications can be seen in Appendix A, and the sealant material is already provided in excess for the sponsor to reuse.

Each 22.2V Li-ion battery pack will have to be replaced after X lifecycles. Each voltage regulator will have to be replaced after X hours of use.

## 8. Spare Parts

This section states what spare parts are good to have for extended operation in order to avoid operation interruption.

### *8.1. Spare Parts List*

- 2 Extra cone tips
- Extra Sealant material
- Total of 4 22.2V Li-ion battery packs
- Total of 5 TL780-15C Voltage Regulators
- Total of 2 Chargers for the 22.2V Li-ion batteries

- Total of 2 chargers for the NiMH AA batteries used for DAQ

## 9. 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, and the number of wires has been minimized. The wires are not exposed, and the data gathered from the load cells is transmitted from the DAQ to the tablet using Bluetooth capabilities. When using the penetrometer in the field, the user first needs to turn on and enable the DAQ, to ensure that it will connect to the tablet over Bluetooth. Once the DAQ is prepared to send the gathered data to the app running on the tablet, the user may start taking measurements. While holding the penetrometer perpendicular to the ground, the user will lift the drop weigh mechanism at the top of the device, and release it to force the penetrometer into the ground. This will be repeated until the penetrometer cannot go any deeper. The penetrometer will then be removed from the ground, the user will stop the DAQ from collecting data, and the user can now test at another site using the same process. The results gathered by the DAQ can be viewed on the app running on the tablet at any time during or after testing. There may be a few problems that arise before or during testing, but most can be avoided or corrected by: ensuring all devices and wires are properly connected, making sure the DAQ is Bluetooth enabled, and ensuring the batteries and the tablet have sufficient charge. If there is an issue with the app on the tablet, the app may either need to be closed out or reinstalled, or the tablet may need to be restarted. There is not much regular maintenance for the penetrometer. The device needs to be wiped down at the end of each day in the field, including the drop weight and screws, to remove any debris. The cone tip and sealants are the only components that may need to be replaced after extensive use, but both components are inexpensive and easy to reinstall. Overall, the penetrometer is a lightweight, portable device that is simple to use in the field, provides reliable data transmitted wirelessly, and requires little routine maintenance.

## 10. References

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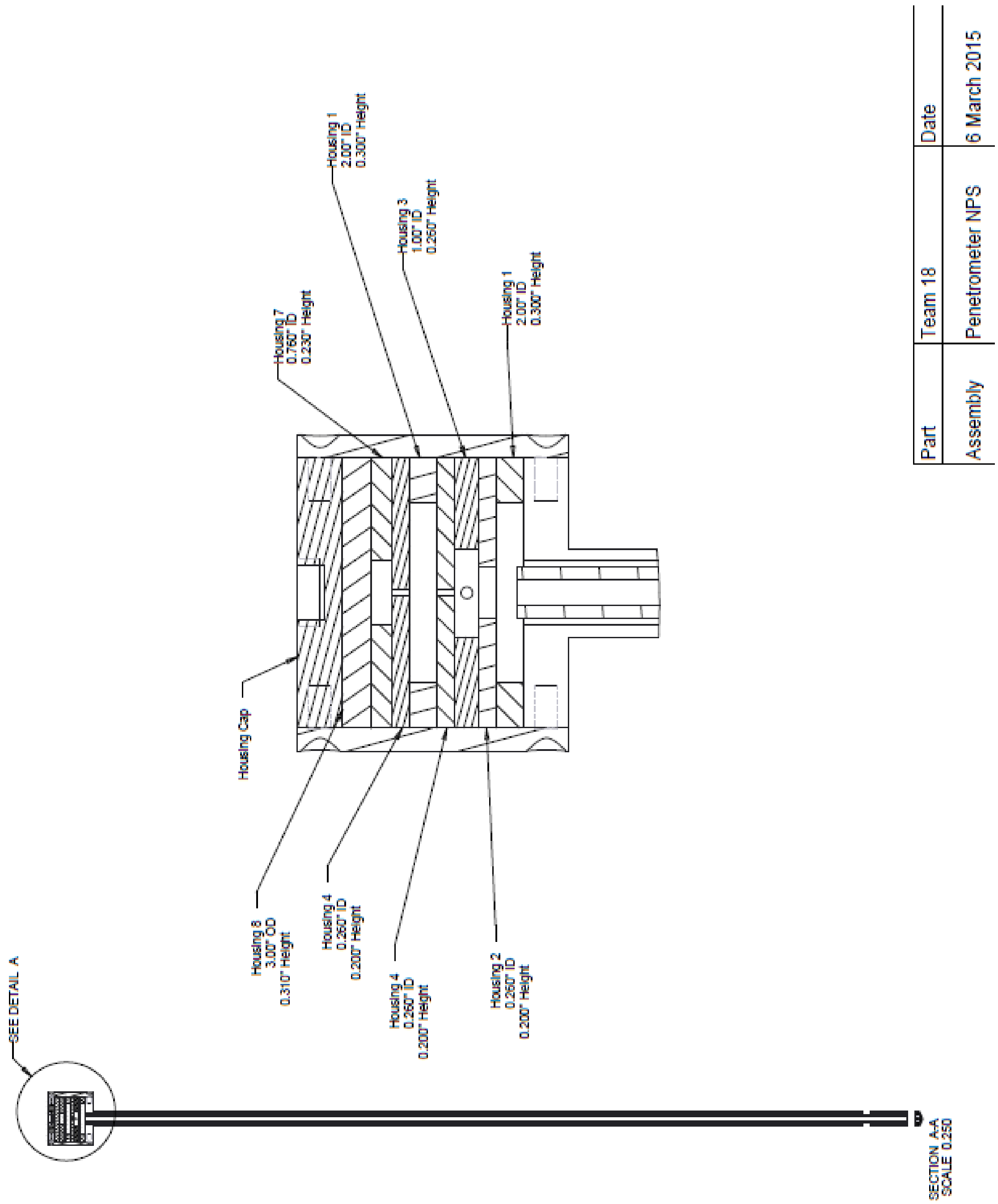
4 NRCS. "Cone Penetrometer." Soil and Water Management. United States Department of Agriculture, 1 Jan. 2012. Web. 1 April. 2015. <http://directives.sc.egov.usda.gov/OpenNonWebContent.aspx?content=31850.wba>.

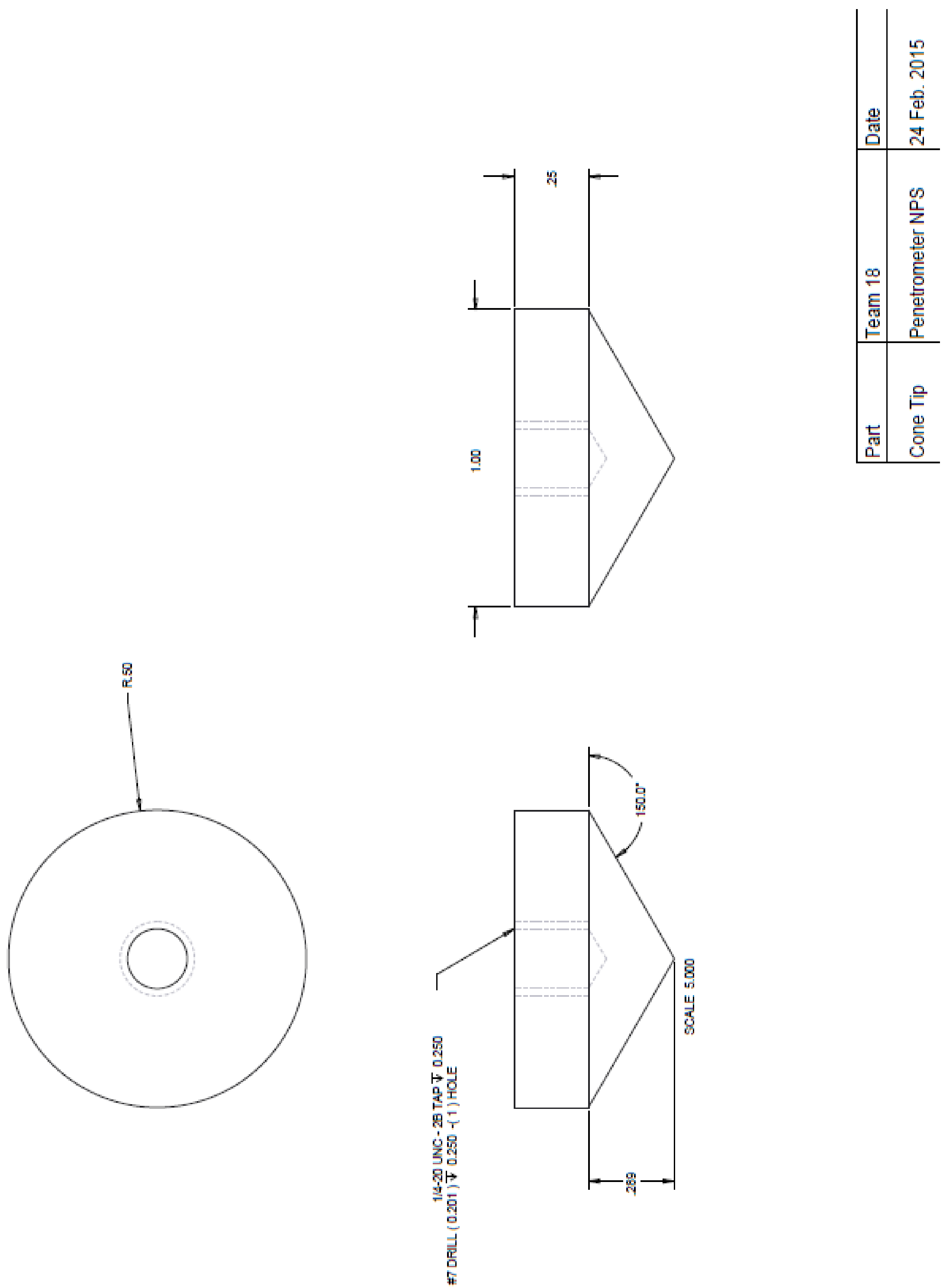
## 11. Appendix A

Pro E Drawings

A – Pro E Drawings



A – Pro E Drawings



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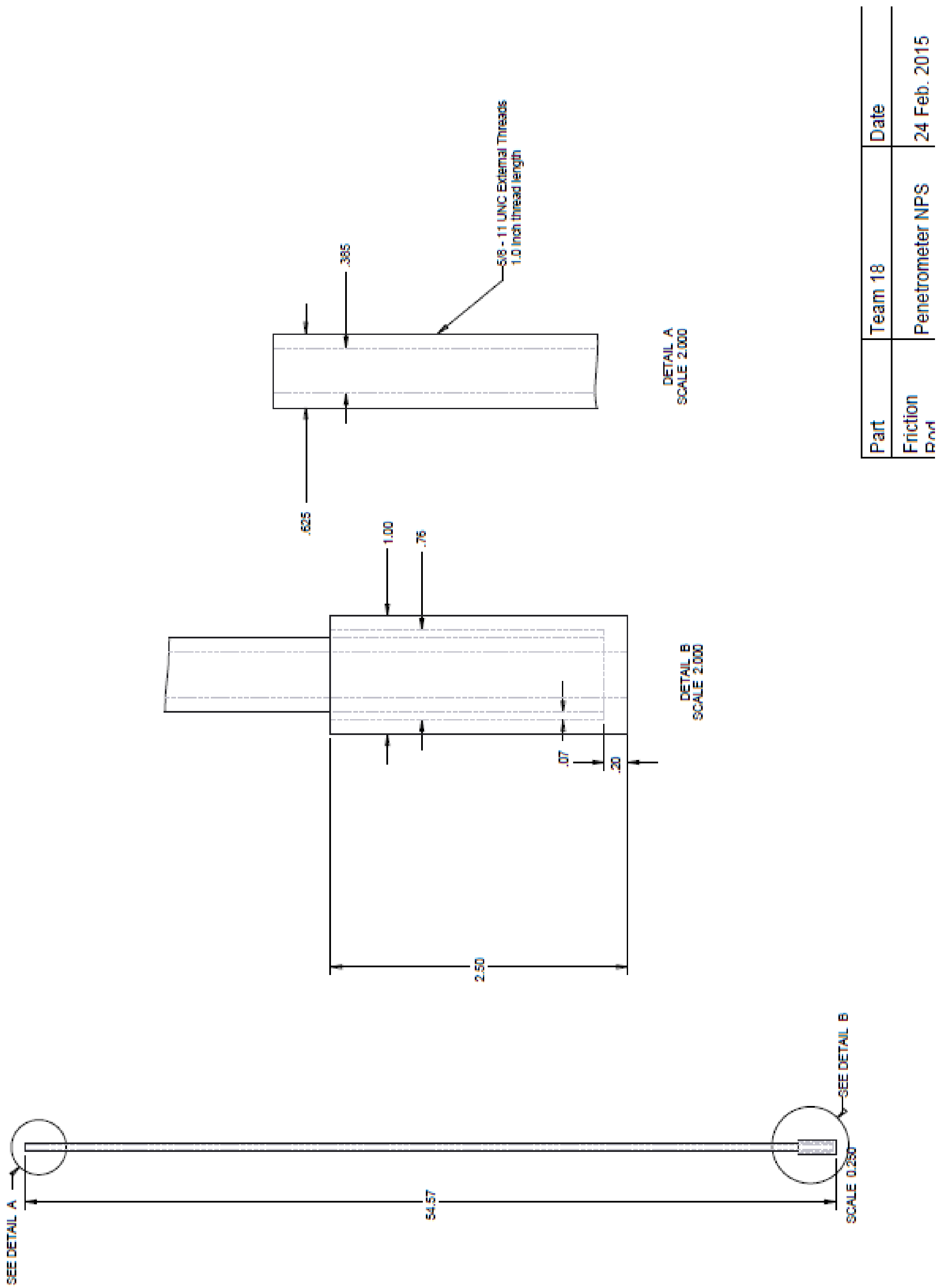

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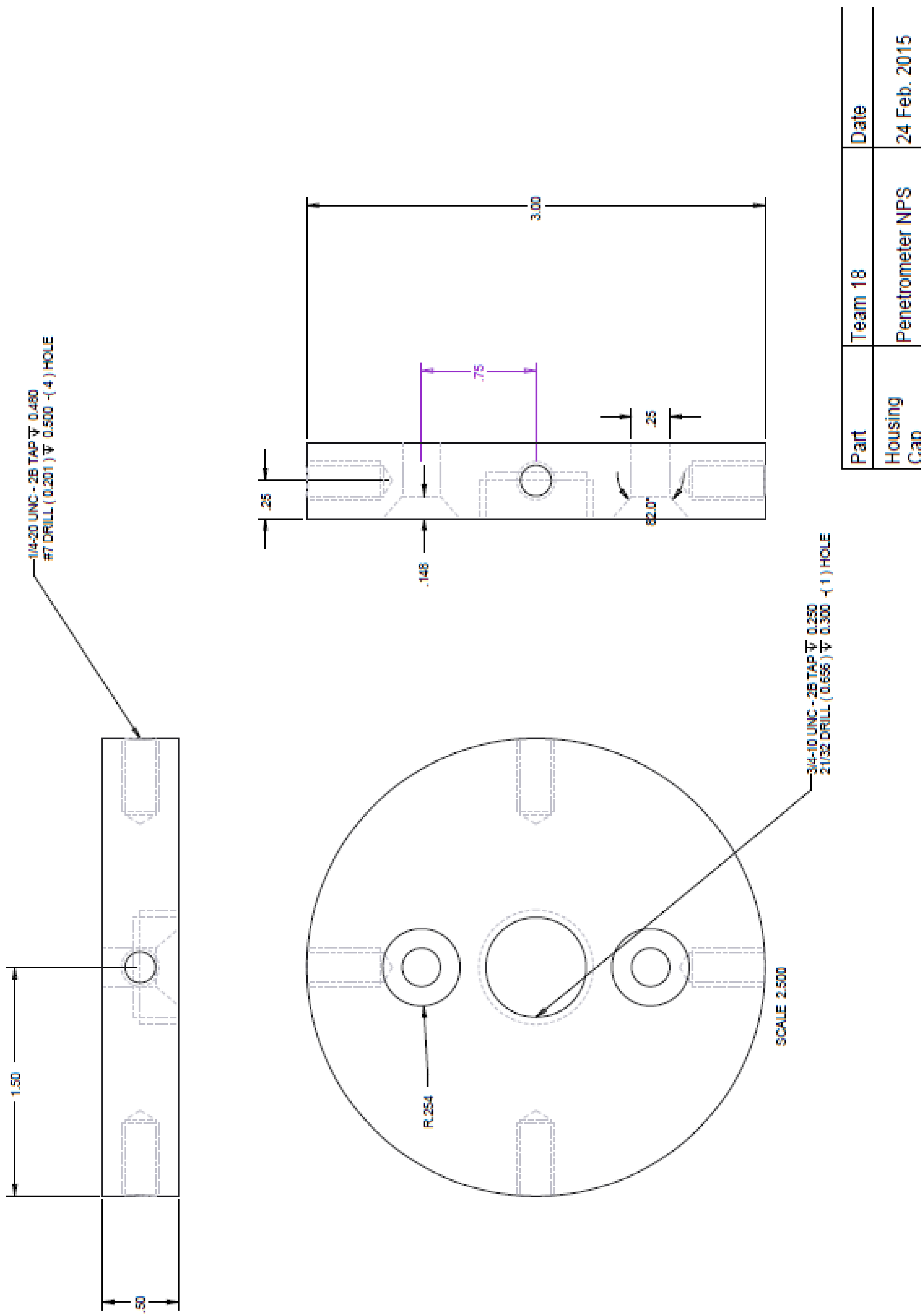

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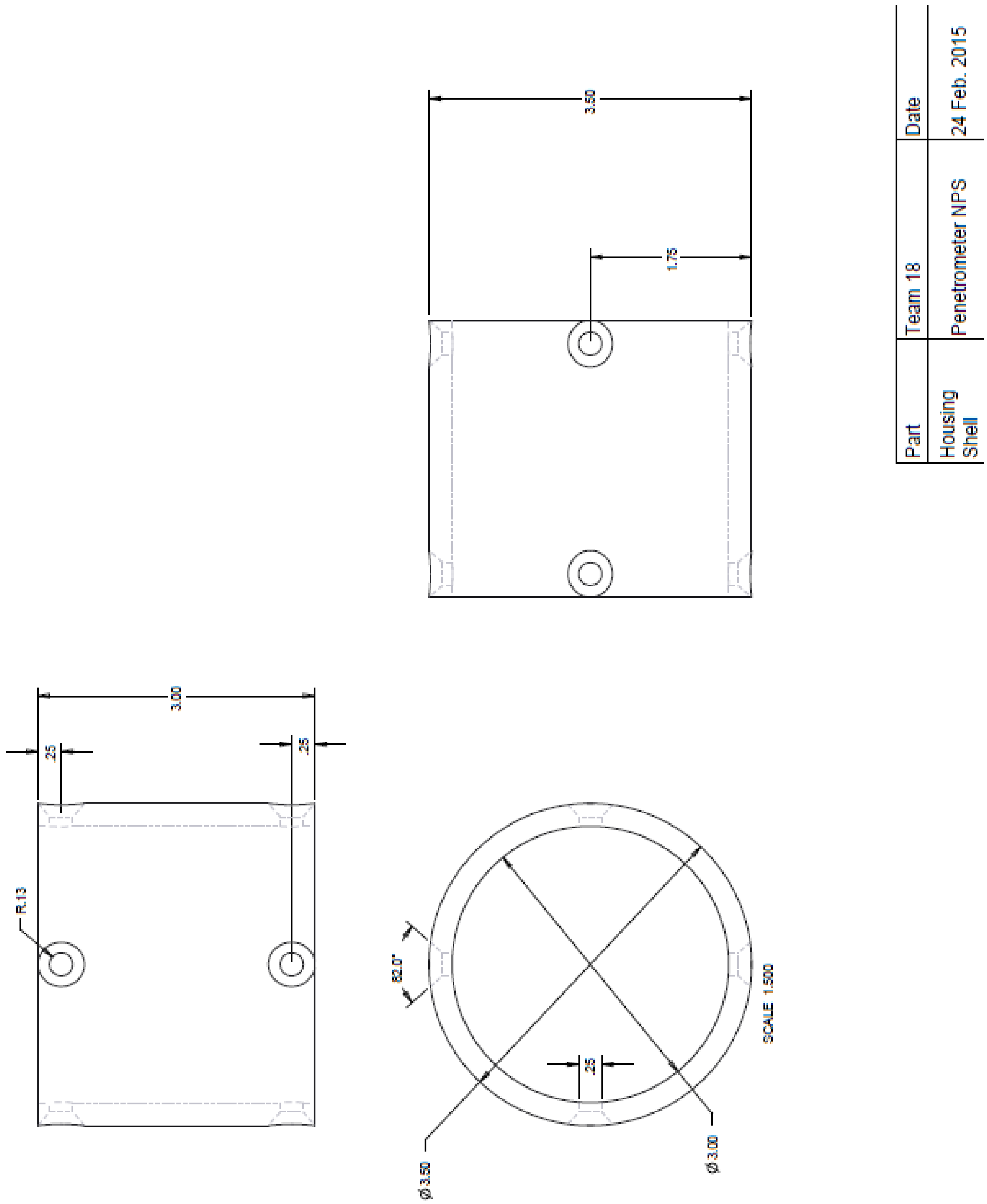
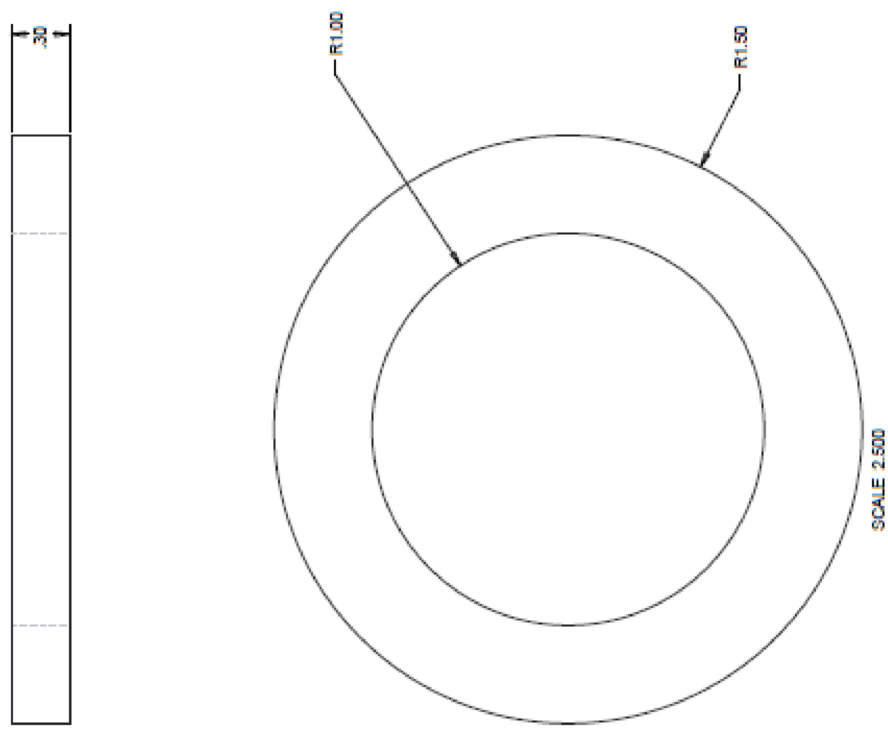


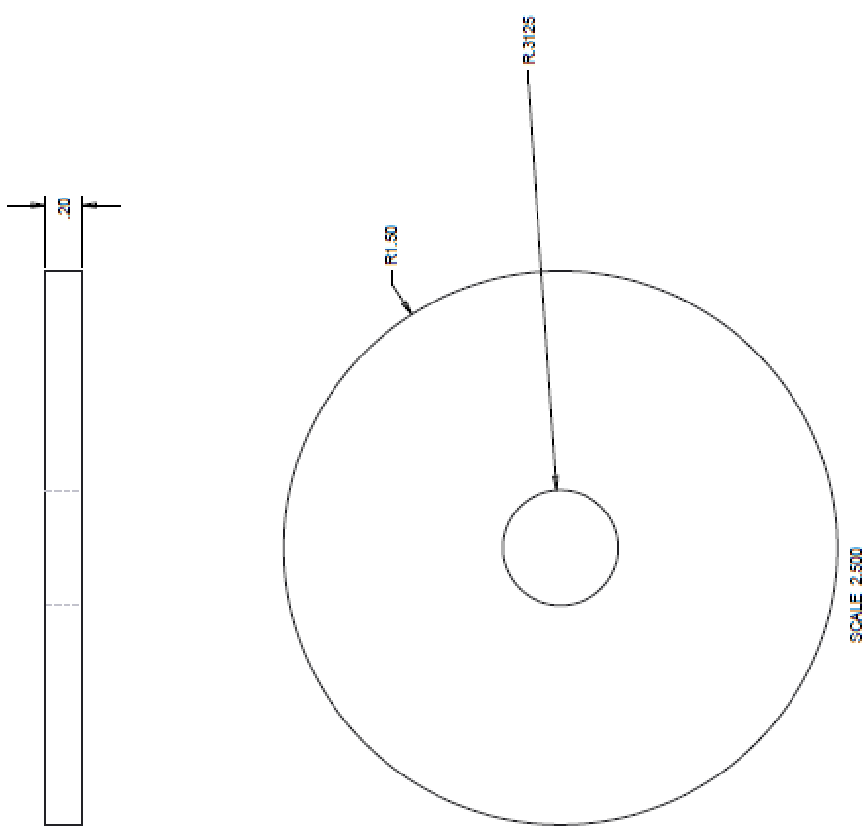
A – Pro E Drawings

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



A – Pro E Drawings

| Part | Team 18 | Date |
| --- | --- | --- |
| Housing 2 | Penetrometer NPS | 24 Feb. 2015 |



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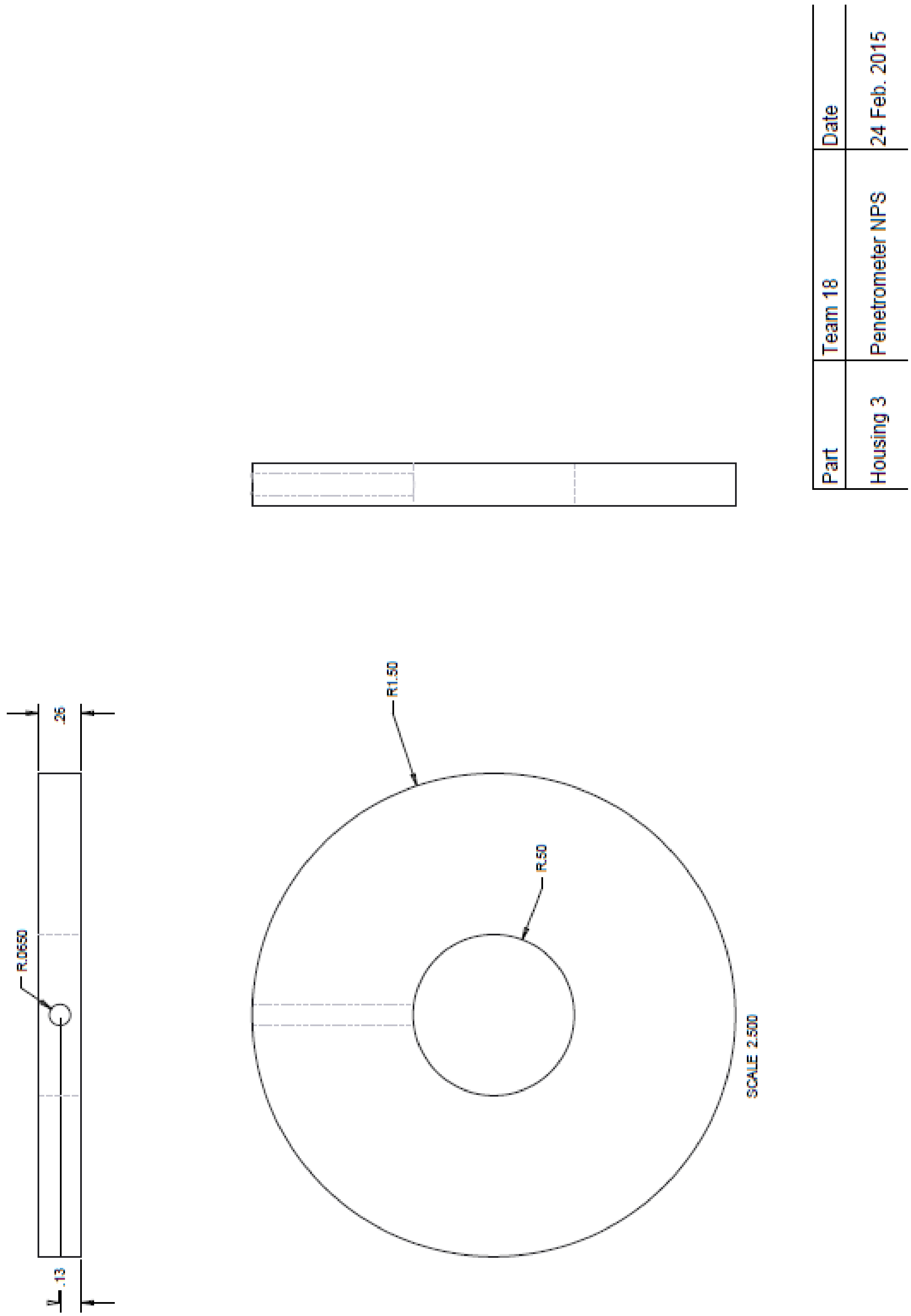

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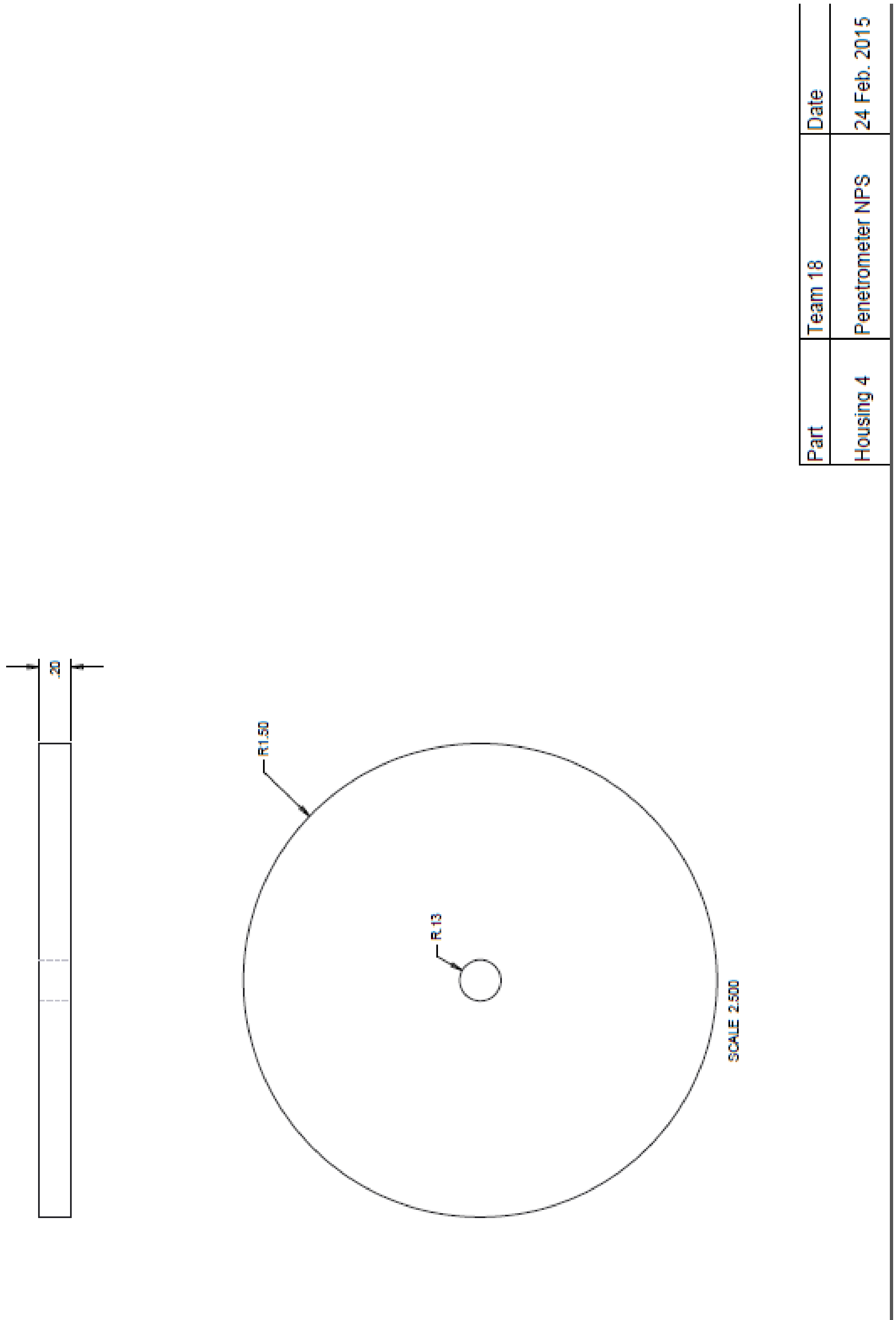

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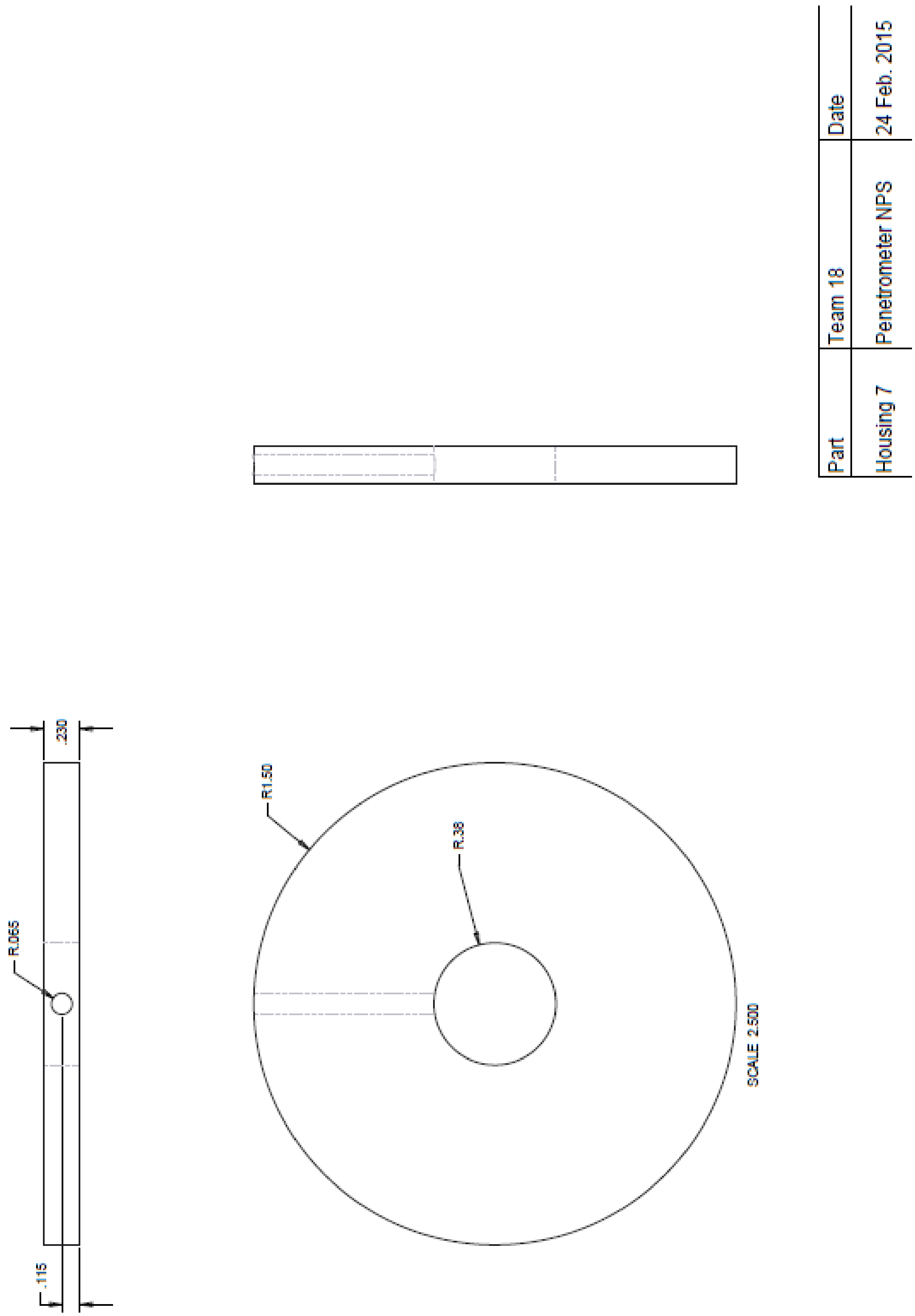

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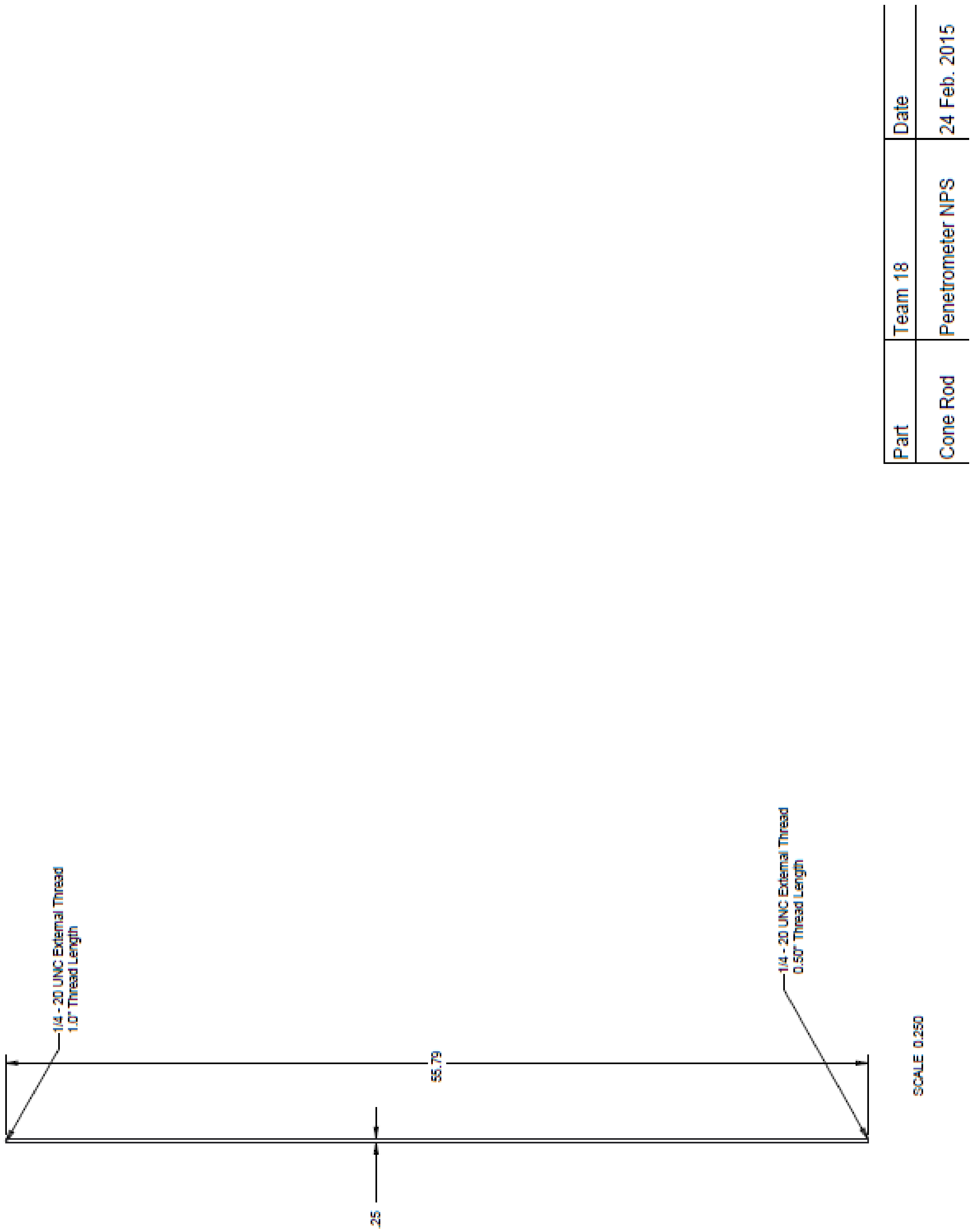

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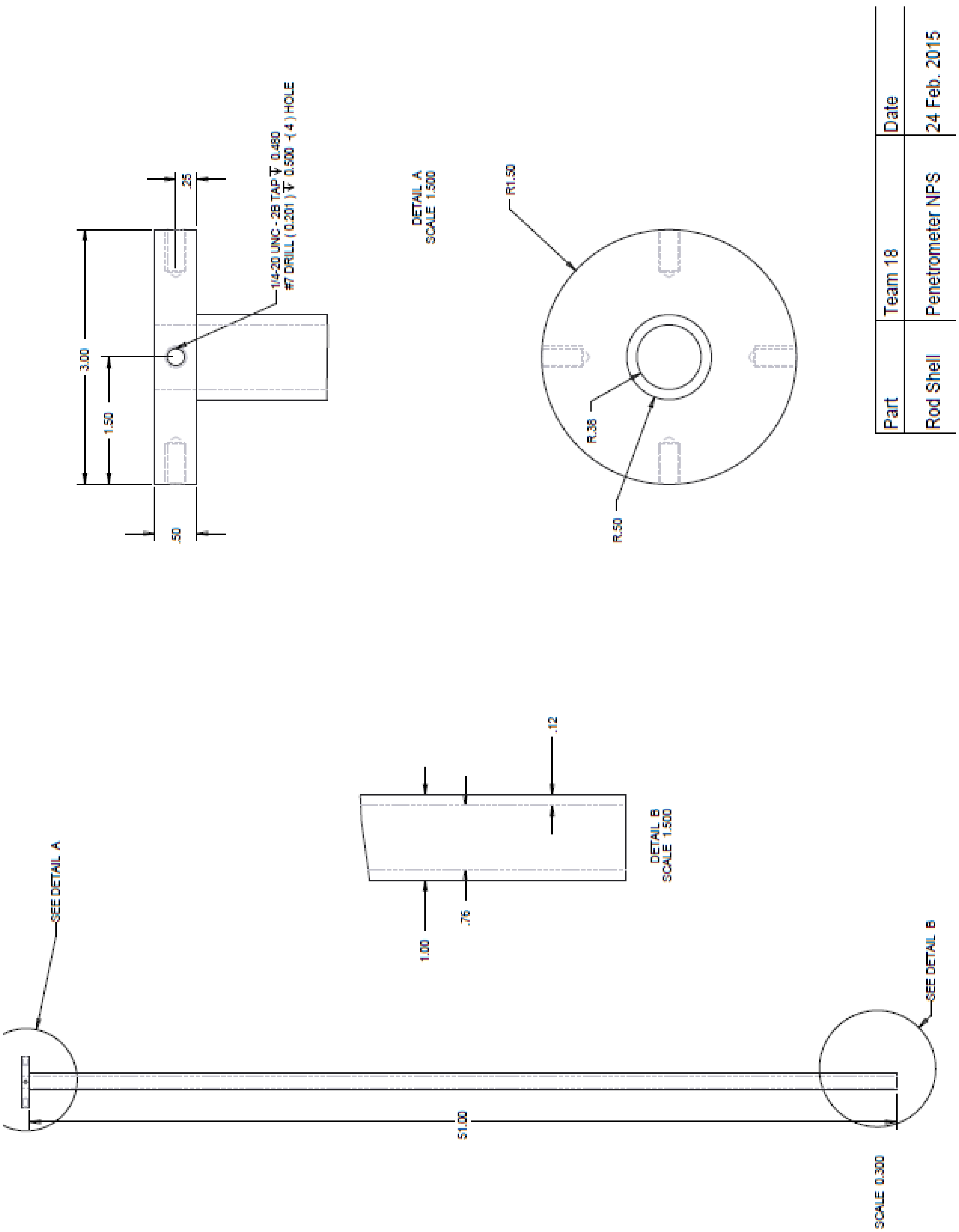

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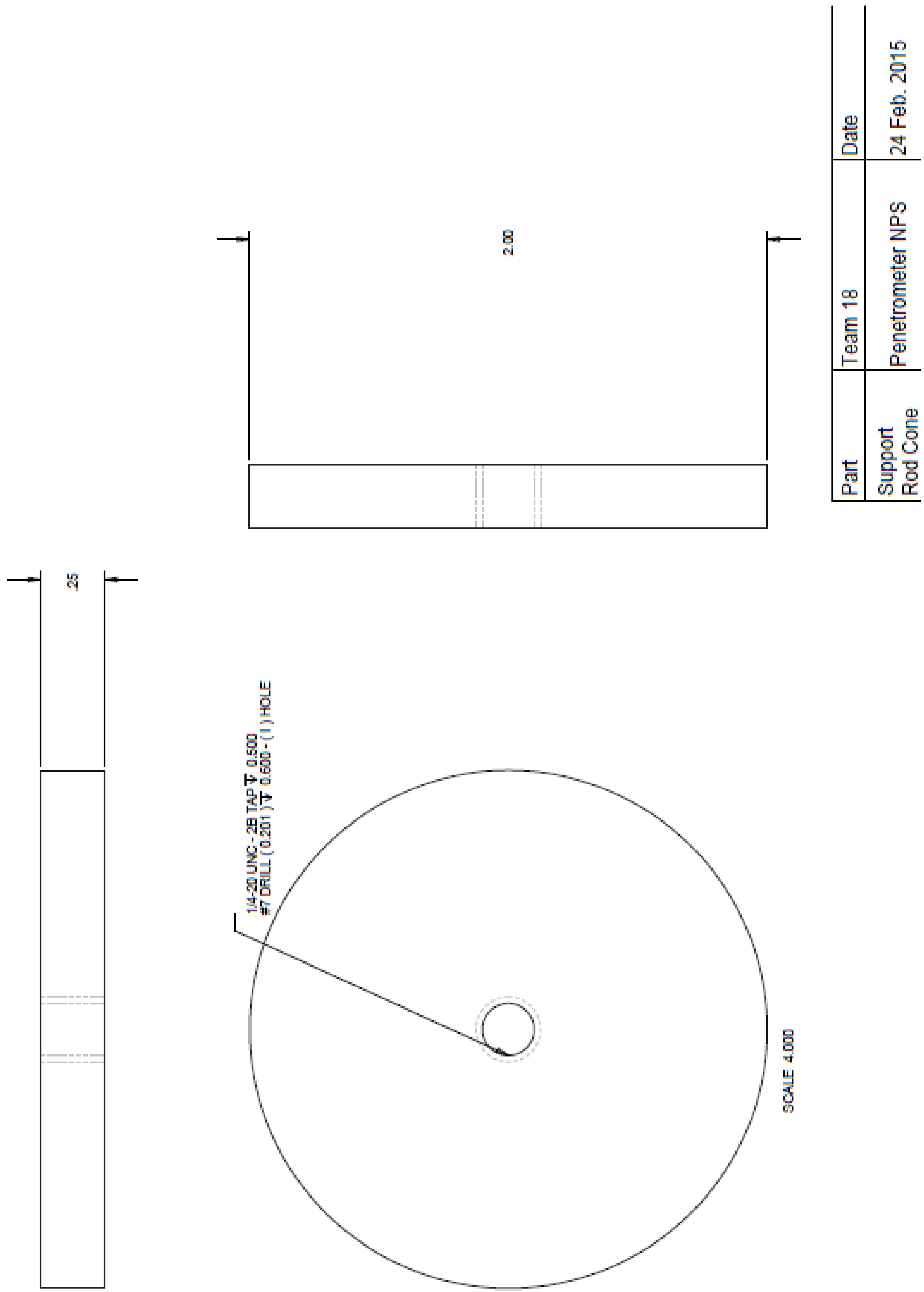

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