Team 24: Magnetically Coupled Pump System for Cryogenic Propellant Tank Destratification

FAMU/FSU College of Engineering
Department of Mechanical Engineering

Operation Manual

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Team Member Biography's

Matthew Boebinger (Team Leader): Matthew is a senior mechanical engineering student that is specializing in mechanics and materials engineering at Florida State University. After graduating in Spring 2015 with his Bachelors of Science in Mechanical Engineering, he plans on pursuing a Master's degree and then a Doctoral degree in materials engineering.

Kahasim Brown: Kahasim is a senior mechanical engineering student specializing in thermal fluid and aerospace sciences with a minor in Business Administration. After graduating he plans on receiving his professional engineering degree while sharpening his mechanical tools development and starting a business hosted in his hometown.

Anthony Ciciarelli: Anthony is a senior mechanical engineering student with a focus in thermal fluids at Florida State University. He will graduate in the spring 2015 with a Bachelor of Science in Mechanical Engineering. After graduation he plans on pursuing a full time job in the industry, obtaining his MBA, and obtaining a professional engineering license.

Janet Massengale: Janet is a senior mechanical engineering student specializing in thermal fluid sciences at Florida State University. This is her second year as the treasurer of ASME. She is also the webmaster for both the SWE and AIAA. Upon graduation she plans to work in the pulp and paper industry and obtain a professional engineering license.

Acknowledgement

The team would like to acknowledge faculty advisor Dr. Wei Guo, as well as our engineering liaisons Jim Martin and James Smith for their knowledge and assistance in making the project successful. Additional acknowledgements to Dr. Gupta and Dr. Shih for their constructive feedback on the teams project throughout the semester.

Abstract

National Aeronautical and Space Administration has proposed a project to mix cryogenic fluids by way of magnetic coupling the rotational motion from the motor to the impeller in the cryostat through a flange. The prototype consists of several crucial parts. These crucial parts can be split into the mechanical components and electrical components. The mechanical components consist of the outer magnet coupler, the inner magnet coupler and its pump attachment, as well as the pump housing and the pump impeller. The crucial electrical components consist of the 24V DC motor and the motor controller. In this report the procedure for manufacturing the prototype system is discussed in length as well as discussing the procedure for operation of the system. Also discussed in this report in the troubleshooting section are the possible sources for improper operation. As well as the sources for error, the solutions and regular maintenance procedure are discussed.

1. Functional Analysis

The magnetically coupled pump is being used to continuously pump cryogens to keep them at a homogenous temperature as long as possible. Cryogens such as liquid hydrogen and liquid oxygen that are used as propellants for rocket fuel need to be stored for long periods of time. During this time, these cryogens begin to boil from the stratified layers inside the tank. This pump system will destratify these layers allowing a longer period of time before the tank vents from a pressure rise due to the liquid becoming vapor. The fully assembled pump system can be seen in Figure 1

By using magnetic coupling technology, the use of the electric motor inside the tank is removed and can be operated outside the cryostat. This eliminates all of the waste heat that the motor gives off into the tank.

A block diagram is used to simplify the pump system and can be seen in Figure 2. A power supply will power a DC motor that is control by means of a motor driver. This will vary the voltage to the motor thus varying the speed. Four magnets within a magnet housing are mounted to the motor shaft that will spin when the motor is turned on. Within the tank there is another set of 4 magnets within a housing that are coupled to the four magnets on the outside of the tank by alternating poles. Between the two couplers there is a 6" ConFlat flange. Attached to the inner coupler is the rest of the pump system that will circulate the cryogen producing successful destratification.

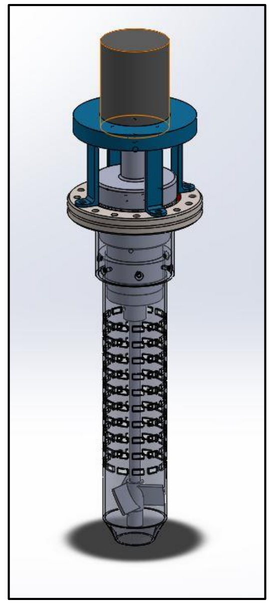


Figure 1: Fully assembled pump system

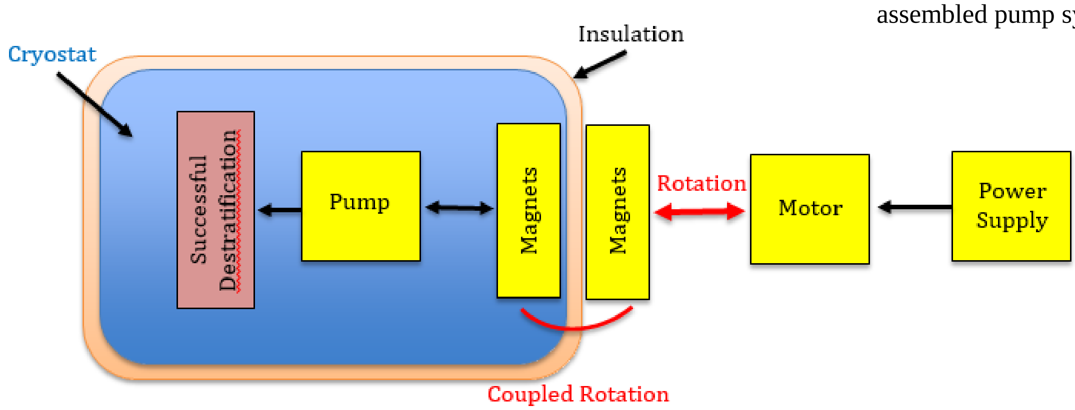


Figure 2: Block diagram of the magnetically couple pump system

2. Project Specification and Assembly

In the following section the overall system of the prototype will be examined. Below can be seen the cross section of the coupling region of the prototype as well as the prototype installed into testing cryostat provided to us from NASA Marshall Space Flight Center. Our prototype consists of several key sub-assemblies that revolve around key components that are necessary to the project. Most of these are mechanical in nature and consist of the outer magnet coupler, inner magnet coupler, and the pump components. However there are several key electrical components such as the micro controller and motor used in the project. These components are labeled below in the exploded view of the total design.

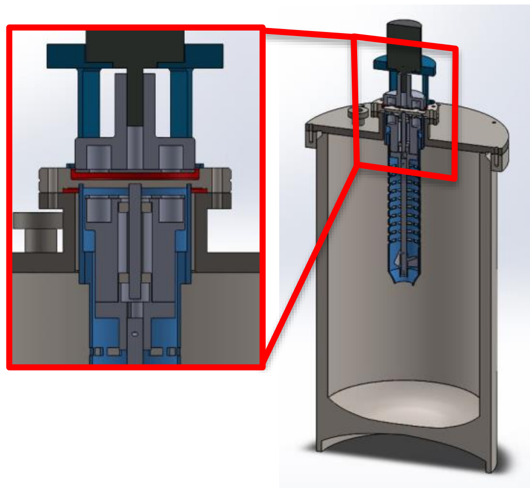
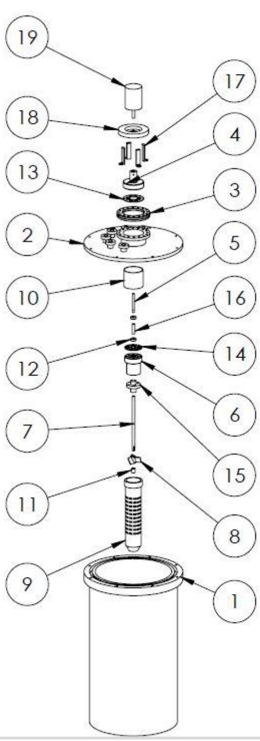


Figure 3: Cross section of the prototype in the testing cryostat with a close up of the coupling region



ITEM NO.	PART NUMBER	QTY.
1	CF-1424 Cryostat	1
2	Cryostat Lid	1
3	6inch ConFlat Flange - Milled	1
4	Outer Magnet Coupler	1
5	Static Shaft	1
6	Inner Magnet Coupler	1
7	Axial Pump Shaft	1
8	Sample Propeller	1
9	Pump Housing	1
10	Housing Anchors	1
11	Shaft Cap	1
12	Bearings	2
13	Outer Magnet Coupler Faceplate	1
14	Inner Magnet Coupler Faceplate	1
15	Inner Magnet Coupler Pump Attachment	1
16	Bushing	1
17	Motor Mount Leg	4
18	Motor Mount	1
19	Sample Motor	1

Figure 4: Prototype System Assembly

2.1. Mechanical Design

2.1.1. Outer Magnet Coupler

The outer magnet coupler is the one of the two essential components of the total design of the system (Fig 5). This coupler is directly attached to the motor used in our project and holds the four 1 T magnets used for the magnet coupling in place. The essential dimensions of the outer magnet coupler are the large diameter must be 3.75” diameter and coupler itself must be 3.0” tall. Dimensions crucial to the function of the system are the diameter of the magnet circle and the female hole for the motor shaft. The magnets must be on a 2.25 inch diameter circle with alternating poles to ensure coupling. The female hole for the motor shaft is 0.5” in diameter with a 1/8”keyway. The outer coupler is attached to the motor shaft using a set screw with an offset of 3/16” from the motor to ensure that the coupler does not scrap against the flange.

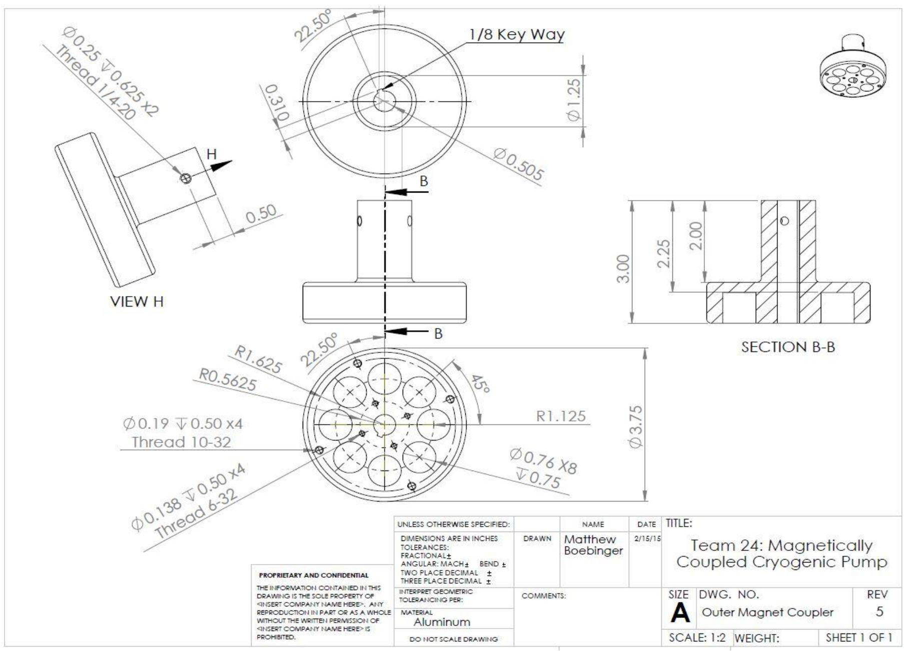


Figure 5: Outer Magnet Coupler Engineering Drawing

2.1.2. Inner Magnet Coupler and Pump Attachment

The inner coupler is the opposite part to the outer coupler and will couple with it through the four opposite 1 T magnets on the same diameter (Fig 6). The large diameter is 3.125” and the secondary diameter is 2.50”. The system also has a height of 3.25” and a central hole that is 28mm in diameter with a lip that has a diameter of 22.5mm on the magnet face. This coupler will rotate around a static shaft that is 3.5” long using a bearing system that consists of two bearings with an outer diameter of 28 mm and inner diameter of 10mm. The bearings system is then suspended by attaching the inner coupler pump attachment. This part has an extended cylinder that goes into the central hole and braces against the second bearing, thereby suspending the system with about a 1/10” separation from the flange. The inner coupler pump attachment also has the female hole for the pump that is 0.5” in diameter and will hold the shaft in place using a pin.

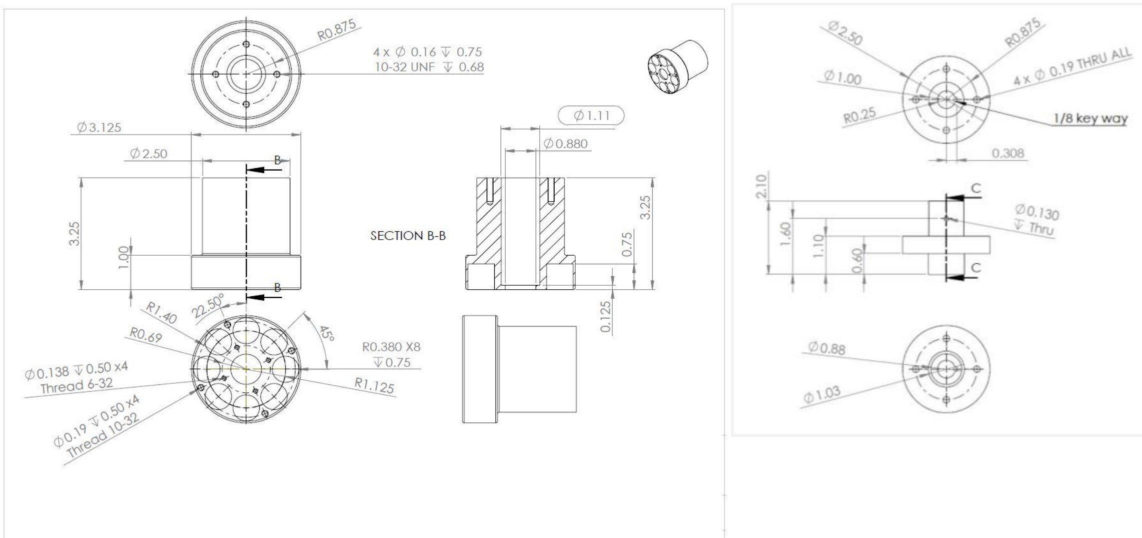


Figure 6: Inner Magnet Coupler and Pump Attachment Engineering Drawing

2.1.3. Pump Housing, Anchor, and Impeller

The key components in the pump design are the pump housing and the impeller provided to us by NASA Marshall Space Flight Center and these can be seen in Figure 7. The pump housing was made to be able to go over the impeller provided and be able to attach to the pump housing anchor. The impeller is shown with an outer diameter of a little less than 2.65”. Therefore the inner diameter of the pump housing was made to be 2.65” to ensure the pumping of fluid through the housing. The pump housing was made to be 13.5” long making it the largest part of the prototype design. The pump housing has an outlet of 1.55” in diameter as was designed for in earlier calculations and inlets throughout the length of the pump housing to allow fluid flow.

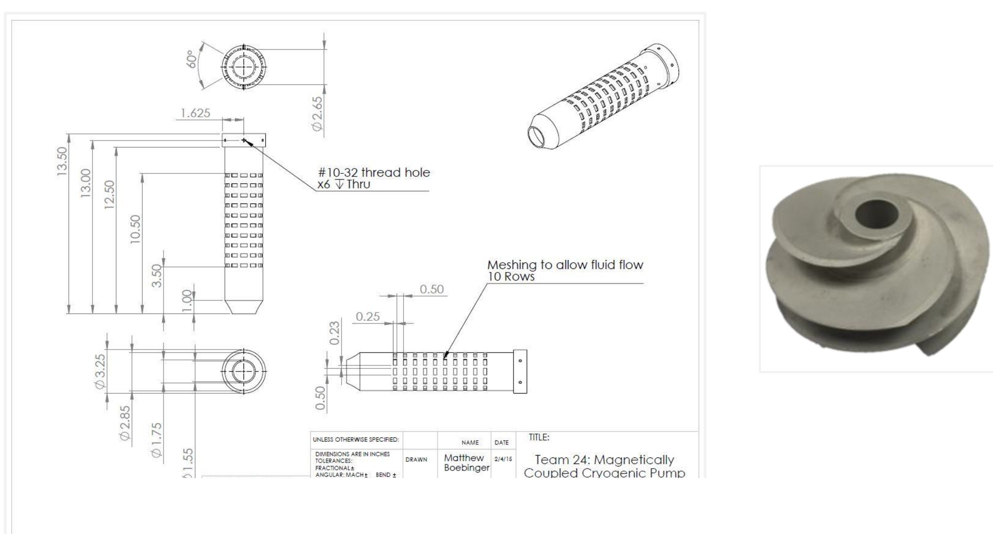


Figure 7: Pump Housing Engineering Drawing and the provided Impeller

2.2. Electrical Design

The electrical design of the project is very simple in nature. It consists of a 24V DC motor, a motor controller for the motor, and a battery. The system is design to be used for an extended period of time so a large 24V 20 Ah battery will be used to test the prototype. The battery is then wired to the RioRand RRCCM9NSPC DC motor controller which consists of two PWM frequency switches and a potentiometer knob. The PWM frequency switches can be adjusted to reduce noise for motors. Since our motor will be running at relatively low speeds both switches should be flipped to the on position. The potentiometer can be used to change the speed of the motor to ensure the best pumping conditions. The motor that is being used in our prototype is the AmpFlow E30-150. It is a 24 V DC motor that has a peak HP of 1.0 and a maximum RPM of 5600. More specifications of the selected motor can be seen in Table 1. The geometry of the motor consists of a diameter of 3.1", a length of 4.0" and a shaft diameter of 0.5" and shaft length of 2.0", and a more detailed look at the dimensions of the motor can be seen in the Appendix A. The motor controller and motor can be seen in Figure 8.

Table 1: E30-150 Motor Specifications

Diameter (inches)	3.1	**Shaft Dia. (inches)**	0.5
Length (inches)	4.0	**Shaft Length (inches)**	2.0
Peak HP	1.0	**Keyway (inches)**	0.125
Stall Torque (oz-in)	710	**Capacitors**	No
Efficiency	76%	**No Load Amps**	2.1
Voltage	24 V	**Resistance (Ohms)**	0.190
RPM @ 24V	5600	**Kt (oz-in/Amp)**	5.70
Weight (pounds)	3.6	**Kv (RPM/Volt)**	237

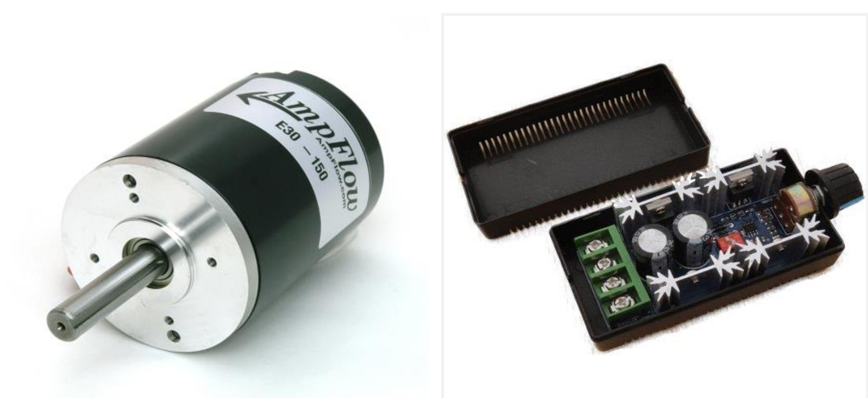


Figure 8: Electrical Components that consist of the AmpFlow 24 V DC motor and the RioRand motor controller

3. Operation Instructions

The assembly drawing can be seen back in Figure 4. The total assembly time after the welding certain components and epoxying the motor mount legs to the motor mount can be done in less than 4 hours. The assembly is done in a series of steps with five different sections.

1. Pre Assembly

Before any assembly of the pump system can begin certain components of the pump need to be prepared.

a. The motor mount consist of five parts. The motor mount plate and the four legs. These components are made out of PVC and need to be epoxied together before assembly. Once epoxied, the motor mount needs to sit for at least twelve hours so the epoxy can cure.
b. The static shaft that will mount the inner coupler needs to be welded to the flange.
c. Once the static shaft is welded to the flange, the pump anchor will also need to be welded to the same side of the flange as the static shaft.
d. Lastly, the rotating shaft will need to be welded to the inner coupler attachment, making sure the rotating shaft remains straight.

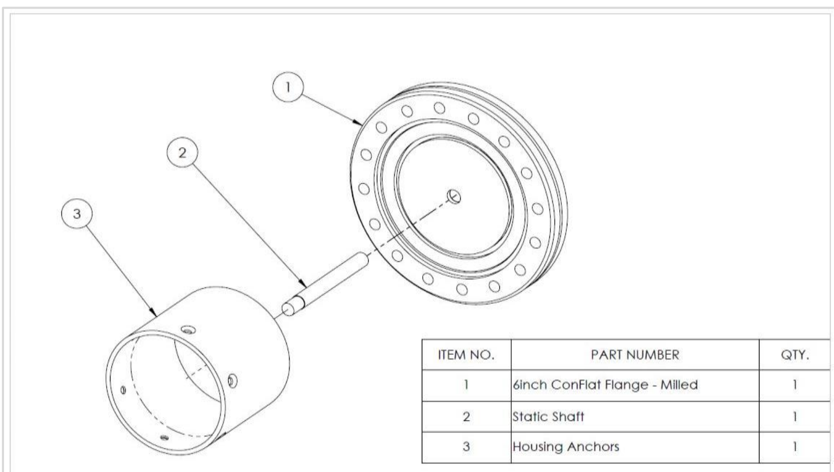


Figure 9: Welding Sub-Assembly with the pump housing anchor and static

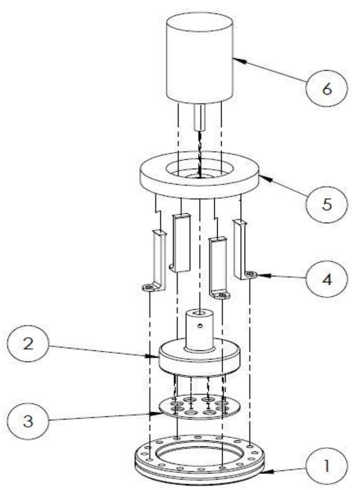
2. Magnet Insertion and Coupler Assembly

When inserting the magnets into both couplers, make sure they are alternating poles using the faceplate as a guide and to keep the magnets in place.

a. Attach the outer coupler faceplate with one of the outer 10-32 x 0.5"screws.
b. Insert one magnet into its appropriate hole.
c. Rotate the faceplate so that it holds the inserted magnet in place.
d. Insert the next magnet with the opposite poles facing outwards.
e. Rotate the faceplate so that it now holds both magnets in place.
f. Repeat steps 4 and 5 until all the magnets are in place and the faceplate lines up with its screw holes.
g. Screw the faceplate in securely

3. Outer Coupler and Motor Sub-Assembly

a. Secure the motor to the motor mount using for 8/32 ½" screws
b. Attach the outer coupler to the motor shaft and securing it with two ¼-20 set screws
c. Do NOT attach the motor mount to the flange

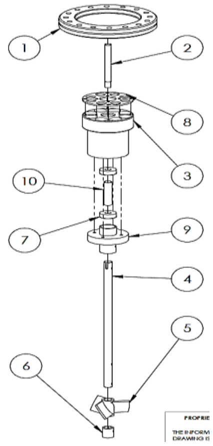


ITEM NO.	PART NUMBER	QTY.
1	6inch ConFlat Flange - Milled	1
2	Outer Magnet Coupler	1
3	Outer Magnet Coupler Faceplate	1
4	Motor Mount Leg	4
5	Motor Mount	1
6	Sample Motor	1

Figure 10: Outer Coupler and Motor Sub-Assembly

4. Inner Coupler Sub-Assembly

a. Make sure the flange is on a flat surface with the static shaft and pump anchor facing up.
b. Place one roller bear into the inner coupler and place on the static shaft. Once on the static shaft, insert the bushing and the second ball bearing securing it with a washer and 10-32 locking nut.
c. After the bearings and bushing is secure, attach the impeller and shaft cap to the rotating shaft using the appropriate length 3/16" pins. Once secured, attach the inner coupler pump attachment to the inner magnet coupler using the four 10-32 x 1.25" screws with the impeller facing up
d. After the inner coupler pump attachment is secured to the inner coupler, attach the pump housing to the pump anchor using the six 10-32 x 3/8" countersink screws.



ITEM NO.	PART NUMBER	QTY.
1	6inch ConFlat Flange - Milled	1
2	Static Shaft	1
3	Inner Magnet Coupler	1
4	Axial Pump Shaft	1
5	Sample Propeller	1
6	Shaft Cap	1
7	Bearings	2
8	Inner Magnet Coupler Faceplate	1
9	Inner Magnet Coupler Pump Attachment	1
10	Bushing	1

Figure 11: Inner Coupler Sub-Assembly and the impeller that was provided by NASA

5. Final Assembly

a. Once the inner coupler sub-assembly is complete, place the inner coupler assembly inside the 3.75” port on top of the cryostat lid with the copper gasket.
b. Mount the outer coupler and motor sub-assembly to the flange using the four 5/16 bolts provided and continuing to seal the flange with the remaining twelve bolts

3.1 Operating Instructions

a. Using the wiring diagram below (Fig 12) correctly wire the motor to the driver. Before wiring the battery or other power source to the driver make sure the driver is in the OFF position.
b. Wire the battery or power sourced to the driver, double checking the voltage and the ground are in the right ports
c. Wire battery to the motor driver and rotate the motor driver knob clockwise slowly. As the knob continues to turn clockwise, the speed increases causing the pump to produce higher flow rates.
d. To turn off the motor, rotate the knob on the driver counter clockwise until it makes a “clicking” noise. Remove the system after the motor has completely stopped.

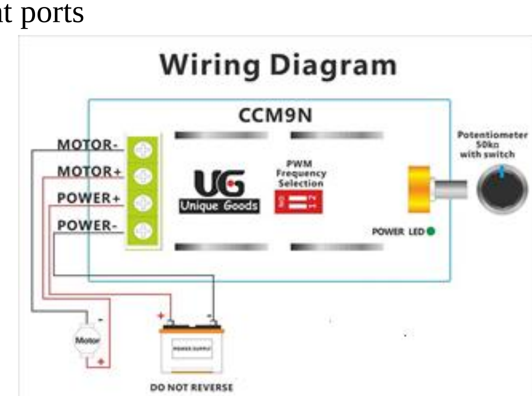


Figure 12: Wiring diagram for motor driver

4. Troubleshooting

Sources of improper operation

1. Electrical – After an extended period of time of operation running at the maximum setting could cause the motor to burnout and requires a new motor to be installed to continue operation. Additionally, batteries should be checked for proper voltage and electric current rates to ensure that the motor controller and motor function properly.
2. Magnetic Error – The slippage of the magnets improperly rotates the pump shaft and creates improper mixing of the cryogenic fluid. In order to ensure the best coupling strength four magnets with alternating poles must be used in each coupler. Also to ensure greatest coupling strength ensure that the design is properly installed to minimize distance between the couplers
3. Excessive Vibration and Collisions – Excessive vibration and collisions will alter the path of the rotating components of the system and cause failure eventually due to un-alignment of these components. If any components scrape against the pump housing or flange, the parts have been improperly installed. All forms of vibration and collision with other objects should be avoided to prevent failures and ensure operation.
4. Improper Sealing – Improper sealing allows evaporated cryogenic fluid to leak out. Make sure the tank is sealed correctly and the pressure check value is operating to regulate the amount of evaporated fluid within the tank. This allows the tank to store the cryogenic fluid properly without unwanted discharge which alters the enclosure of the tank.
5. Pressure Check Value – The pressure check value needs to be operating correctly to monitor the pressure within the tank. This eliminates uncontrollable discharge of vapor from the surroundings of the tank.

5. Regular Maintenance

Although this is a continuous operating system, sporadic maintenance is required to ensure proper operation and a high level of performance. This alleviates the risk of malfunctions with long term use of this product and increases the life span of the product significantly. With proper maintenance, the possibilities of malfunctions can be eliminated or significantly reduced to make this product perfect for any application and the optimal level of performance can be maintained to produce excellent results.

The maintenance procedure should include all the functions/sub-functions listed below and should be performed after each long continuous projects. For shorter projects, the maintenance procedure should be performed discretionary with a recommended monthly period of time. This allows smooth and safe operation of the product. Immediate maintenance should be performed after extremely hazardous environments such as storm conditions or significant changes in the environment.

1. Electrical Components
    a. Observe motor and electric controller conditions
    b. Charge battery after depleted 20 Ah
    c. Replace the battery after lifetime
2. Electrical Wires
    a. Check the wires for improper connections, damages in the wire, and more.
    b. Check harnesses, connectors, solders, and all other connection points for security
3. Mechanical Components for Wear
    a. Rust and corrosion of metal components creates potential area of leak and material failure. Replace any mechanical components if necessary.
    b. Search for dents in pump housing
    c. Replace bearings after they have reached the rated lifetime of 8000 hours
    d. Check bushings, keys, and pins
    e. Evaluate welds and pressed components
4. Magnets
    a. Check the condition of the magnets to ensure no chipping
5. Fasteners are Tighten
    a. Check for loosen screws that holds components together within the system
    b. Tighten bolts, nuts, and all fasteners as well
6. Complete Overall System
    a. Perform analysis of the complete working system
    b. Relate data from previous analysis
    c. Relate to theoretical results

6. Spare Parts

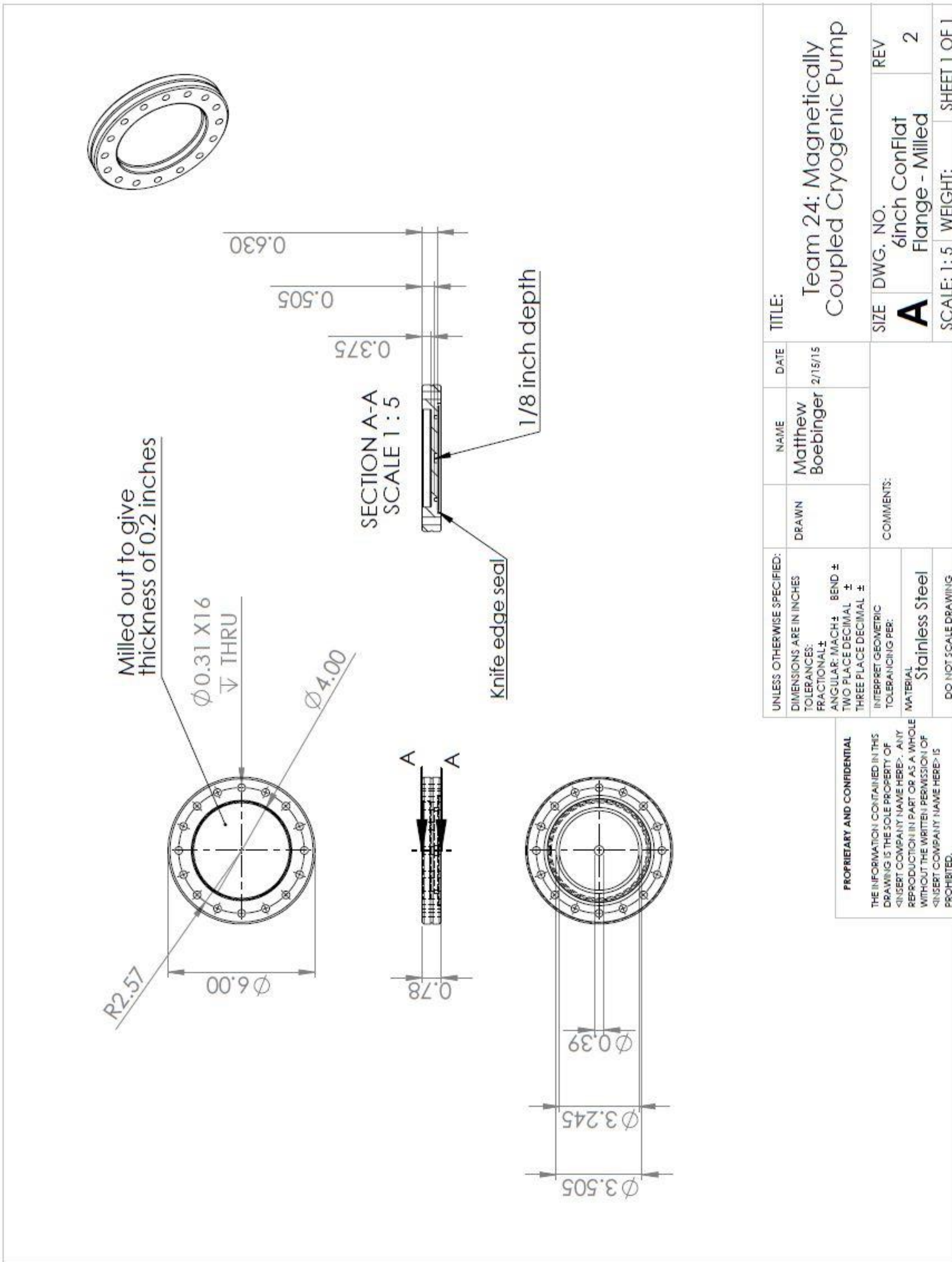
All the mechanical parts should have spare parts included with the assembly. This includes pins, bearings, keys, screws, bolts, nuts, and all the mechanical parts within the assembly. Spare parts for the electrical components of the assembly will not be provided but a replacement battery will be needed after extended periods of use. Any replacements or repairs shall be achievable with all the spare parts available/easy to obtain.

7. References

[1] Senior Design Project Definition Group 24. PDF.

[2] W., Van Sciver Steven. Helium Cryogenics. New York: Plenum, 1986. Print.

Appendix A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R2.57
Ø6.00
0.78
A
A
Ø0.39
Ø3.245
Ø3.505
SECTION A-A
SCALE 1 : 5
1/8 inch depth
Knife edge seal
0.375
0.505
0.630
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
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MATERIAL
Stainless Steel
DO NOT SCALE DRAWING
PROPRIETARY AND CONFIDENTIAL
THE INFORMATION CONTAINED IN THIS DRAWING IS THE SOLE PROPERTY OF <INSERT COMPANY NAME HERE>. ANY REPRODUCTION IN PART OR AS A WHOLE WITHOUT THE WRITTEN PERMISSION OF <INSERT COMPANY NAME HERE> IS PROHIBITED.
DRAWN
NAME
Matthew Boebinger
DATE
2/15/15
COMMENTS:
TITLE:
Team 24: Magnetically Coupled Cryogenic Pump
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A
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REV
2
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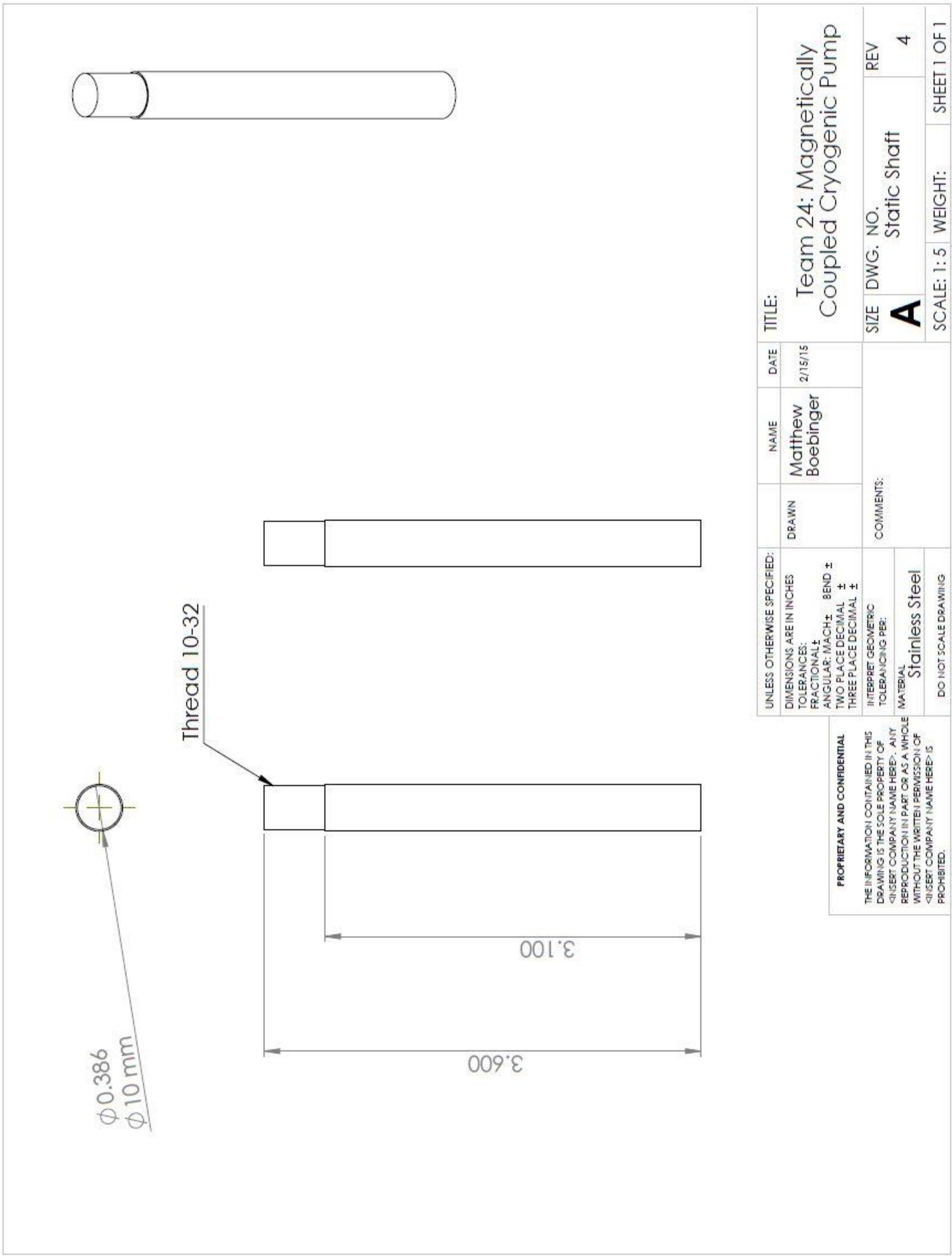
WEIGHT:
SHEET 1 OF 1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3.600
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ANGULAR: MACH± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
Stainless Steel
DO NOT SCALE DRAWING
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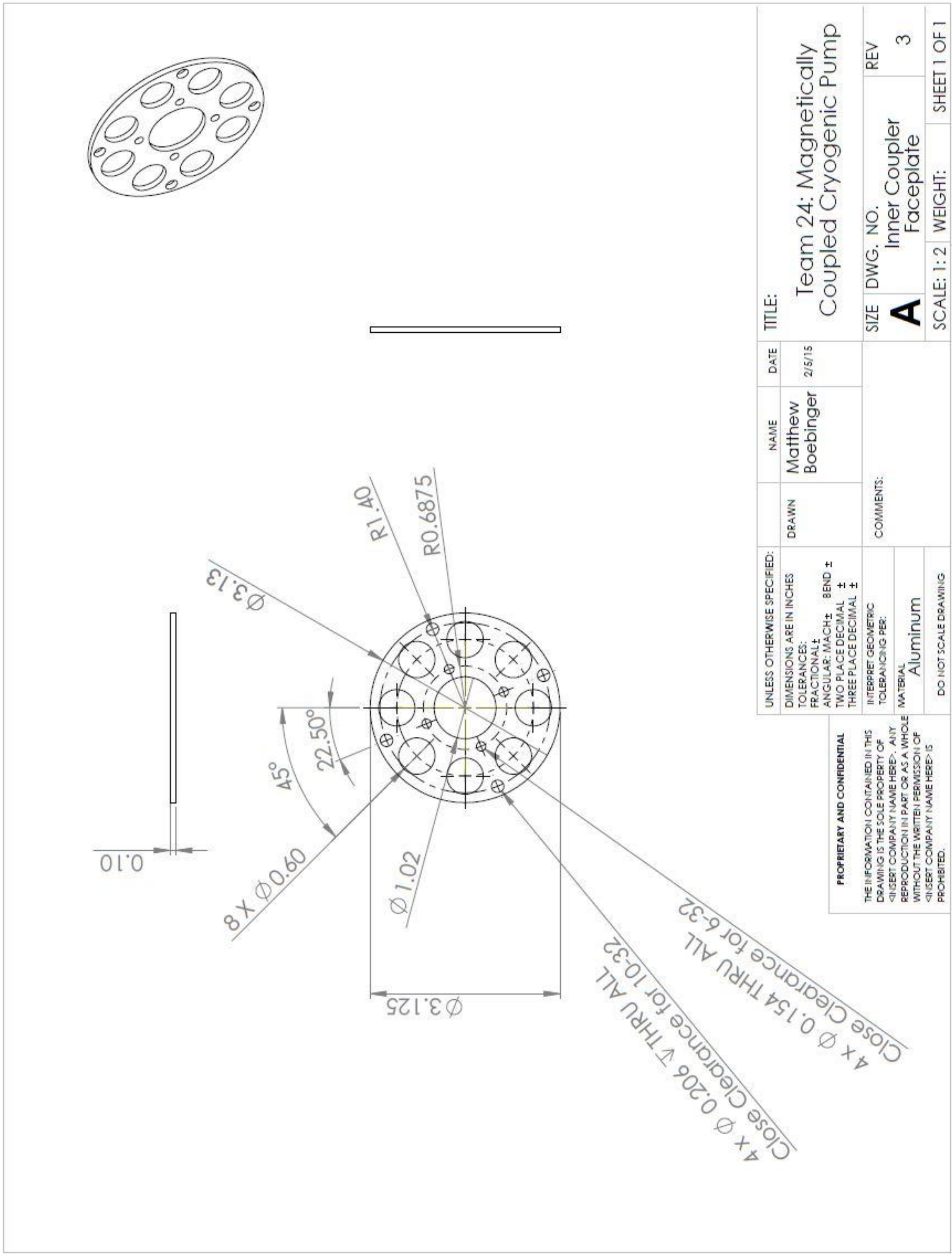
DRAWN
NAME
Matthew Boebinger
DATE
2/15/15
COMMENTS:
TITLE:
Team 24: Magnetically Coupled Cryogenic Pump
SIZE
A
DWG. NO.
Static Shaft
REV
4
SCALE: 1:5
WEIGHT:
SHEET 1 OF 1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SHEET 1 OF 1
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NAME
Matthew Boebinger
DATE
2/5/15
COMMENTS:
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MATERIAL
Aluminum
DO NOT SCALE DRAWING
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R1.40
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45°
8 X Ø0.60
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Ø3.125
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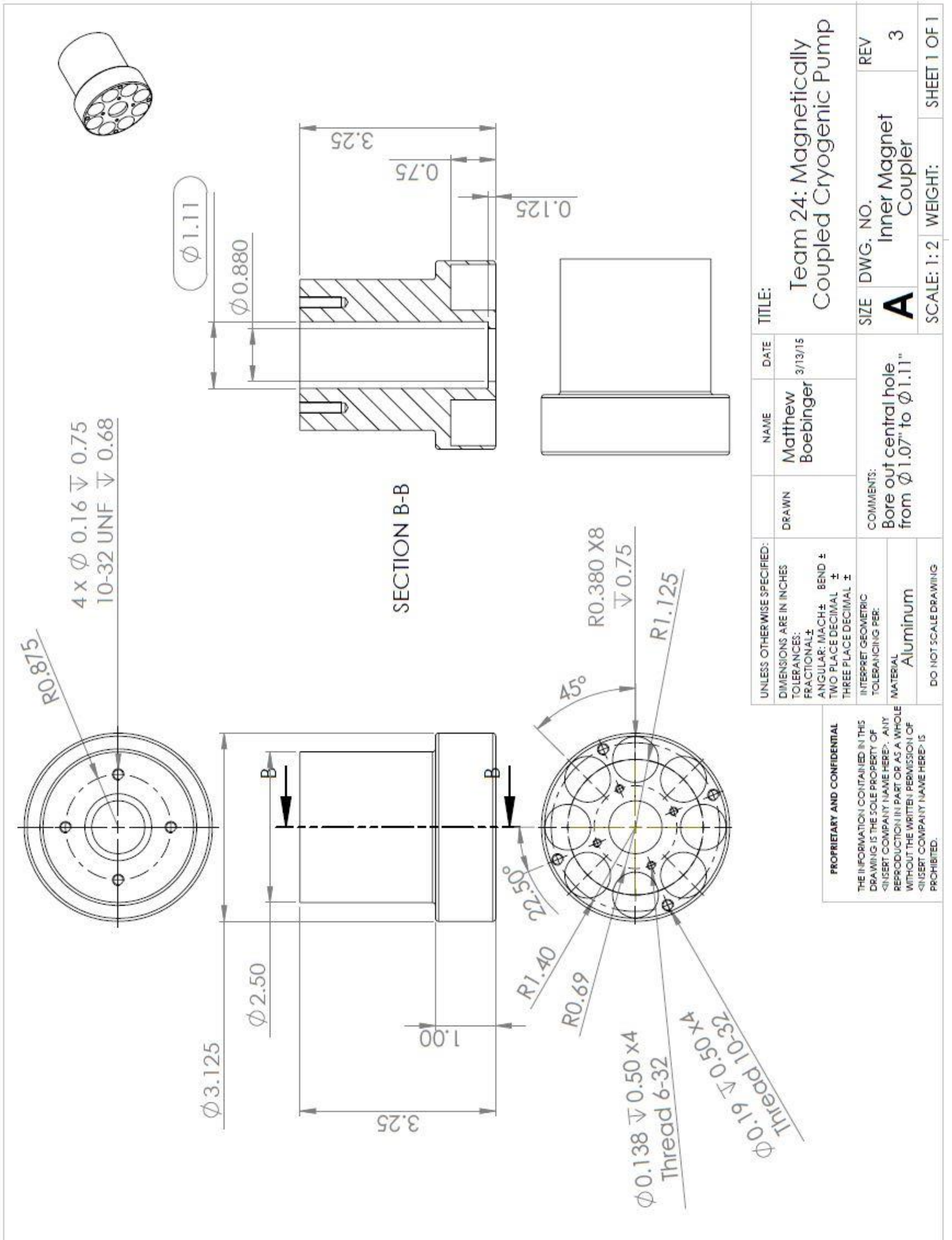
4 x Ø 0.206 THRU ALL
Close Clearance for 10-32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10-32 UNF ↧ 0.68
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↧0.75
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45°
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Ø2.50
1.00
3.25
Ø0.138 ↧ 0.50 x4
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Ø0.19 ↧ 0.50 x4
Thread 10-32
B
B
PROPRIETARY AND CONFIDENTIAL
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DIMENSIONS ARE IN INCHES
MATERIAL
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DO NOT SCALE DRAWING
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NAME
Matthew Boebinger
DATE
3/13/15
COMMENTS:
Bore out central hole from Ø1.07" to Ø1.11"
TITLE:
Team 24: Magnetically Coupled Cryogenic Pump
SIZE
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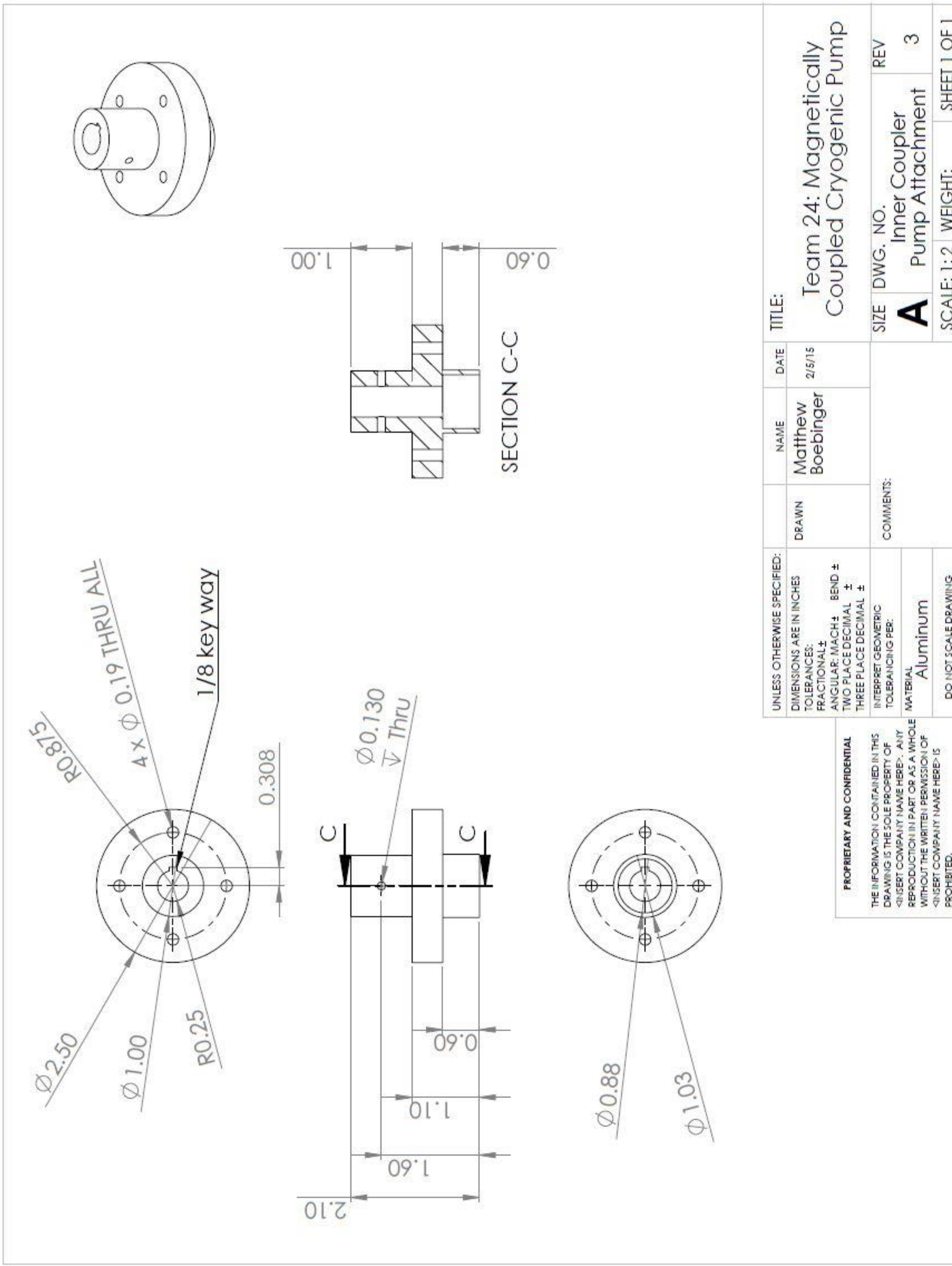
DWG. NO.
Inner Magnet Coupler
REV
3
SCALE: 1:2
WEIGHT:
SHEET 1 OF 1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NAME
Matthew Boebinger
DATE
2/5/15
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TOLERANCES:
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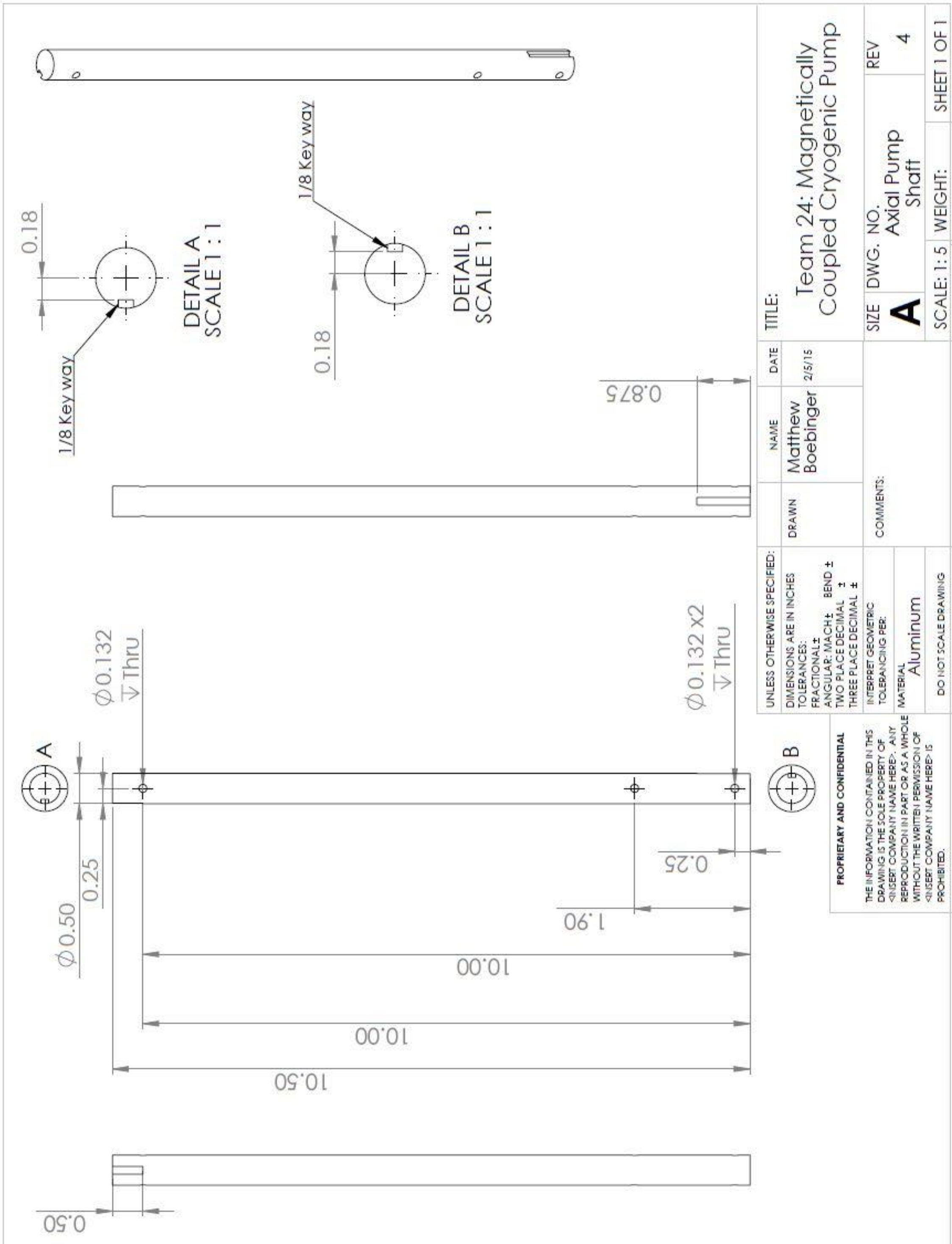
ANGULAR: MACH± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
Aluminum
DO NOT SCALE DRAWING
PROPRIETARY AND CONFIDENTIAL
SECTION C-C
1/8 key way
4 X Ø 0.19 THRU ALL
R0.875
0.308
Ø0.130 Thru
Ø2.50
Ø1.00
R0.25
Ø0.88
Ø1.03
0.60
1.10
1.60
2.10
1.00
C



1/8 Key way
0.18
DETAIL A
SCALE 1 : 1
1/8 Key way
0.18
DETAIL B
SCALE 1 : 1
0.875
A
Ø0.50
0.25
Ø0.132
Thru
Ø0.132 X2
Thru
B
0.25
1.90
10.00
10.00
10.50
0.50
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL±
ANGULAR: MACH± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
Aluminum
DO NOT SCALE DRAWING
DRAWN
NAME
Matthew Boebinger
DATE
2/5/15
COMMENTS:
TITLE:
Team 24: Magnetically Coupled Cryogenic Pump
SIZE
A
DWG. NO.
Axial Pump Shaft
REV
4
SCALE: 1:5
WEIGHT:
SHEET 1 OF 1
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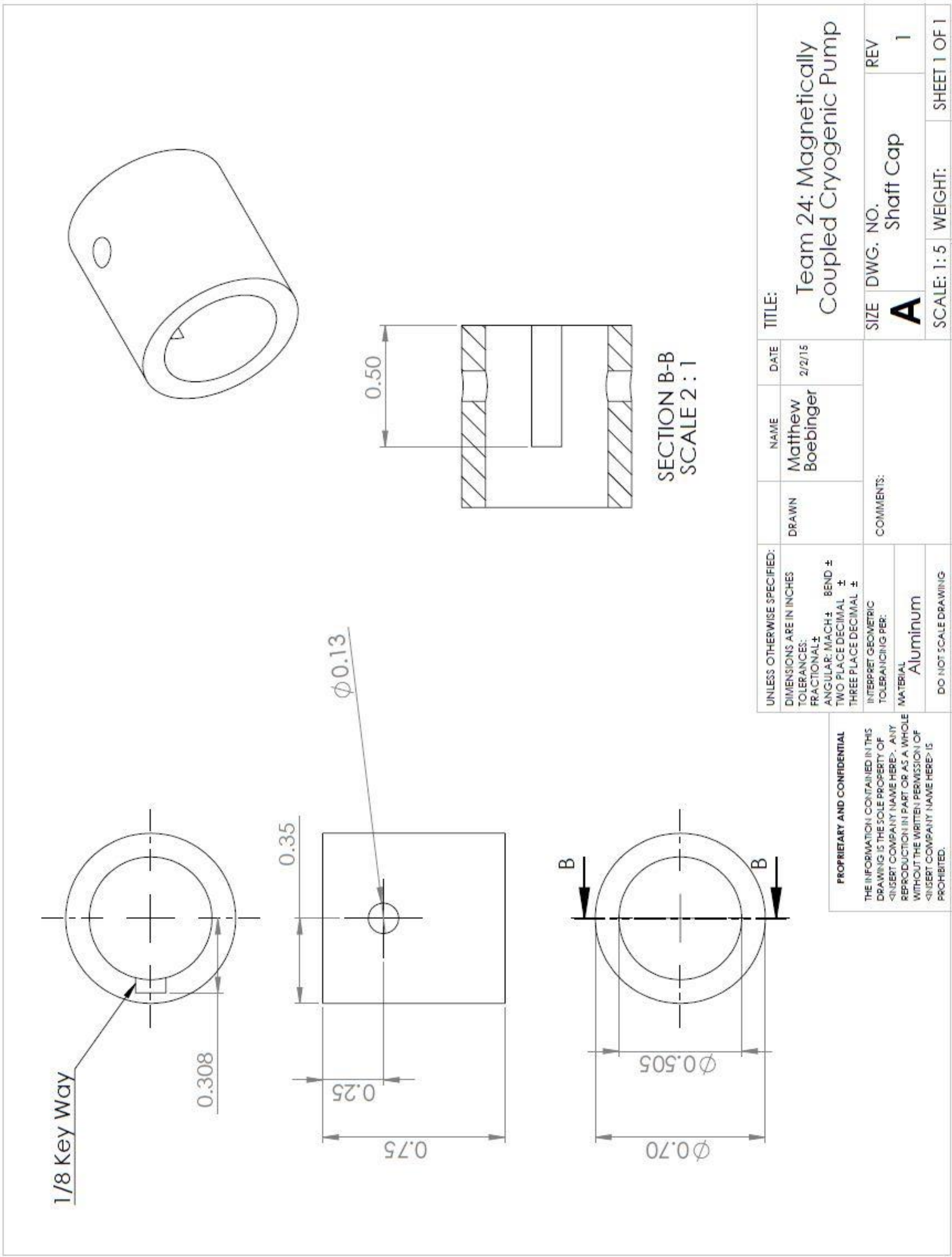

1/8 Key Way
0.308
0.35
Ø0.13
0.25
0.75
B
B
Ø0.505
Ø0.70
0.50
SECTION B-B
SCALE 2 : 1
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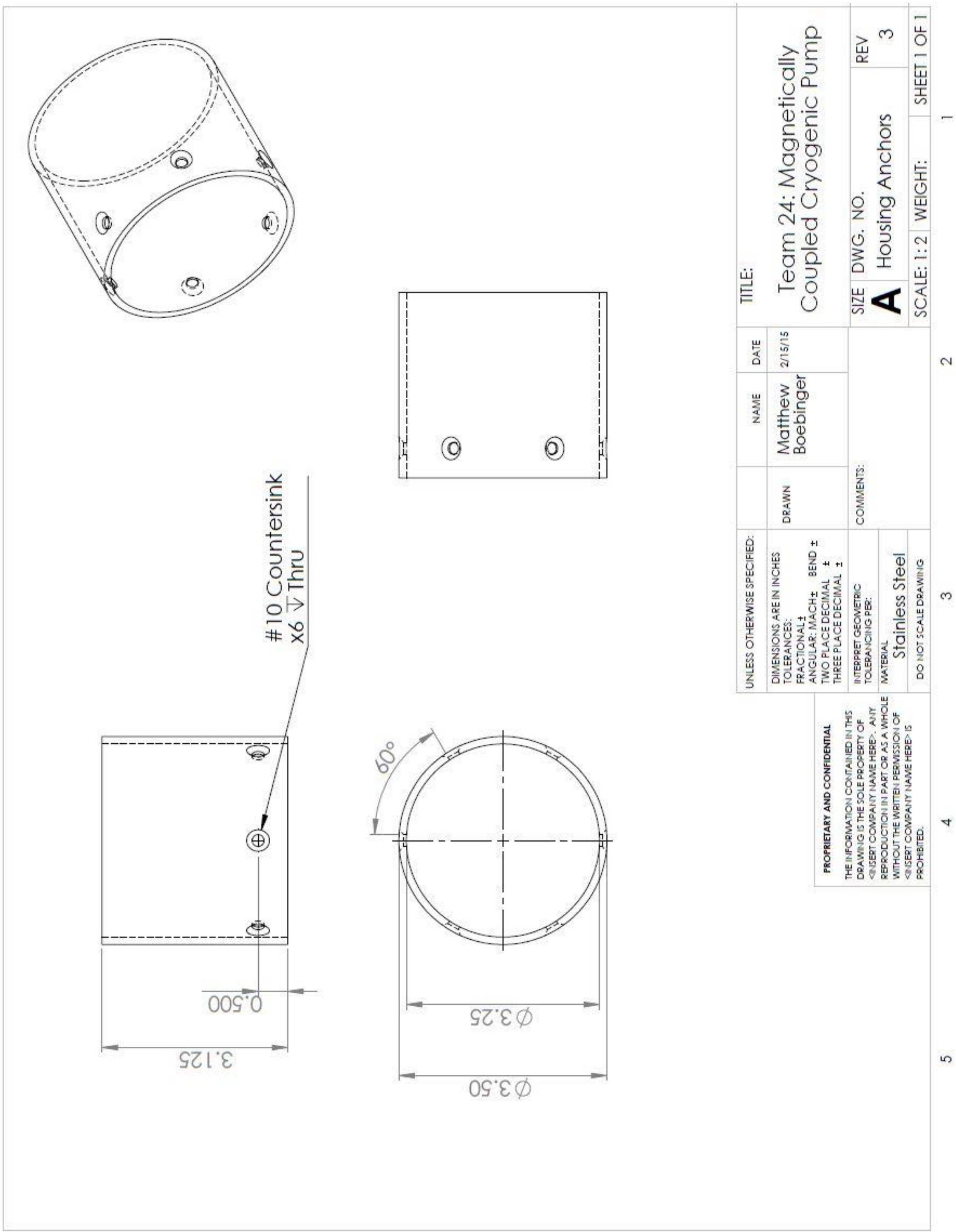
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
Aluminum
DO NOT SCALE DRAWING
DRAWN
NAME
Matthew Boebinger
DATE
2/2/15
COMMENTS:
TITLE:
Team 24: Magnetically Coupled Cryogenic Pump
SIZE
A
DWG. NO.
Shaft Cap
REV
1
SCALE: 1:5
WEIGHT:
SHEET 1 OF 1


#10 Countersink
x6 ⊽ Thru
60°
0.500
3.125
∅3.25
∅3.50
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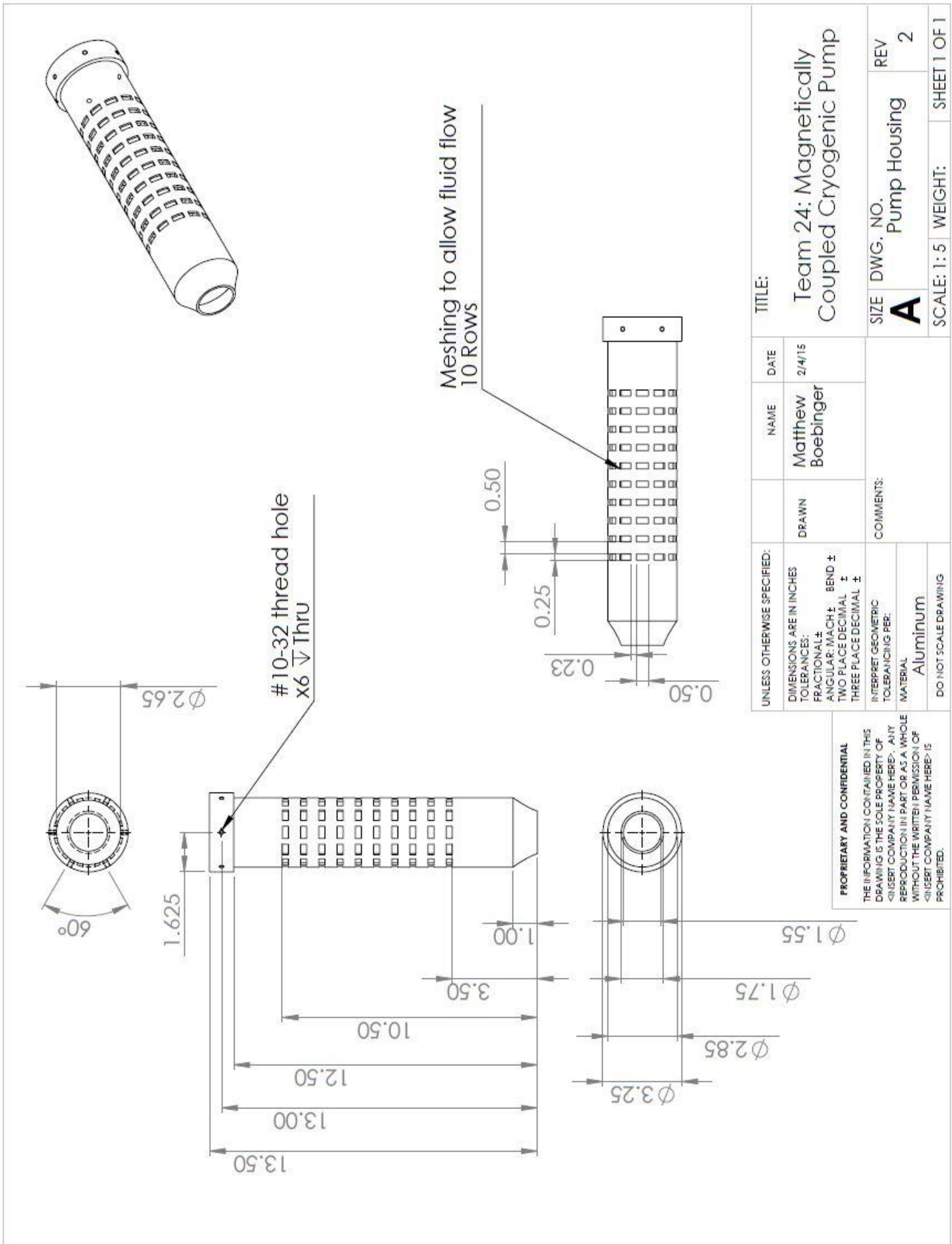
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL±
ANGULAR: MACH± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
Stainless Steel
DO NOT SCALE DRAWING
DRAWN
NAME
Matthew Boebinger
DATE
2/15/15
COMMENTS:
TITLE:
Team 24: Magnetically Coupled Cryogenic Pump
SIZE
A
DWG. NO.
Housing Anchors
REV
3
SCALE: 1:2
WEIGHT:
SHEET 1 OF 1


Meshing to allow fluid flow
10 Rows
#10-32 thread hole
x6 ⊽ Thru
Ø2.65
60°
1.625
0.50
0.25
0.23
0.50
1.00
3.50
10.50
12.50
13.00
13.50
Ø1.55
Ø1.75
Ø2.85
Ø3.25
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
Aluminum
DO NOT SCALE DRAWING
DRAWN
NAME
DATE
Matthew Boebinger
2/4/15
COMMENTS:
TITLE:
Team 24: Magnetically Coupled Cryogenic Pump
SIZE
A
DWG. NO.
Pump Housing
REV
2
SCALE: 1:5
WEIGHT:
SHEET 1 OF 1
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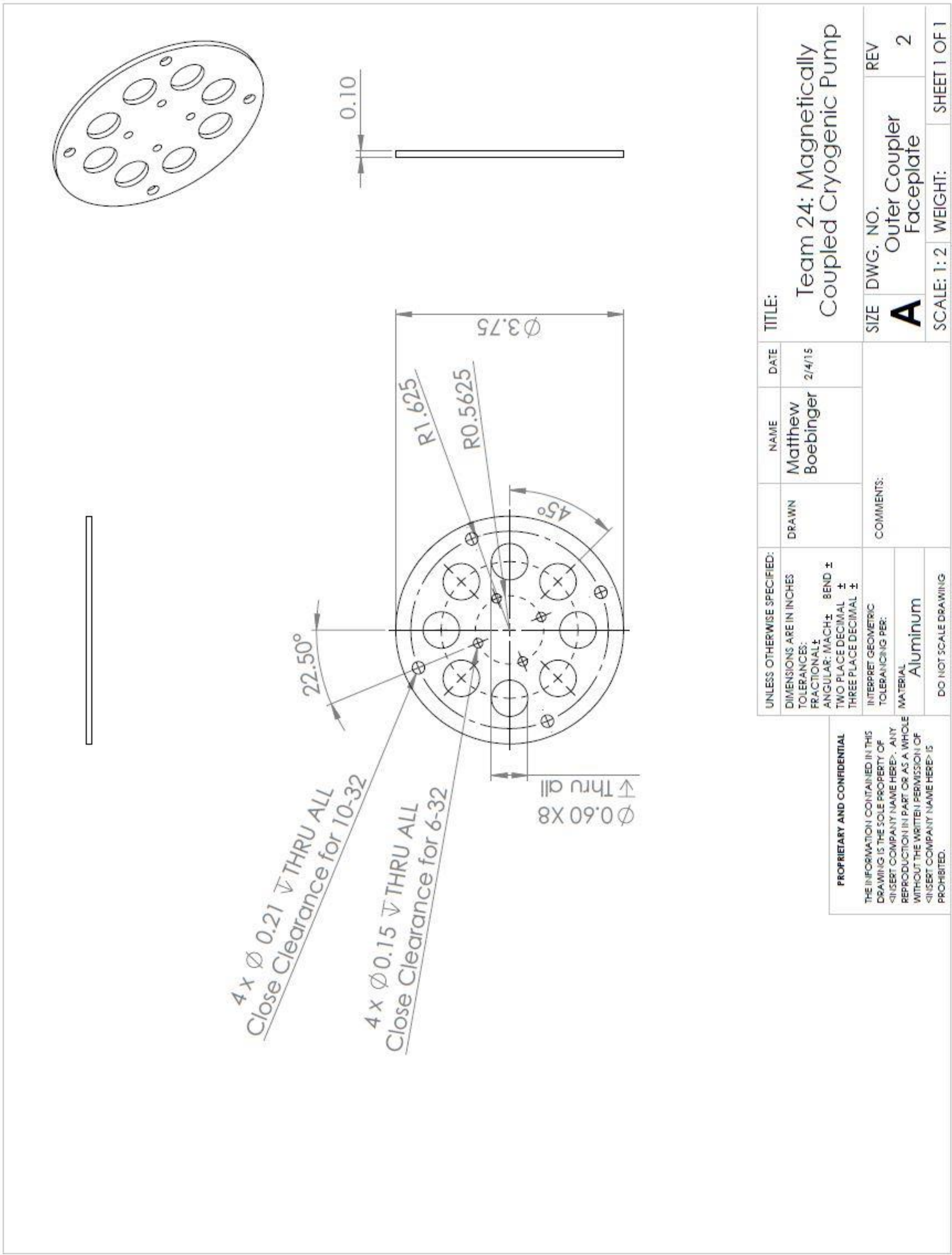

0.10
Ø3.75
R1.625
R0.5625
45°
22.50°
Ø0.60 X8
Thru all
4 x Ø 0.21 THRU ALL
Close Clearance for 10-32
4 x Ø0.15 THRU ALL
Close Clearance for 6-32
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL±
ANGULAR: MACH± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
Aluminum
DO NOT SCALE DRAWING
DRAWN
NAME
Matthew Boebinger
DATE
2/4/15
COMMENTS:
TITLE:
Team 24: Magnetically Coupled Cryogenic Pump
SIZE
A
DWG. NO.
Outer Coupler Faceplate
REV
2
SCALE: 1:2
WEIGHT:
SHEET 1 OF 1
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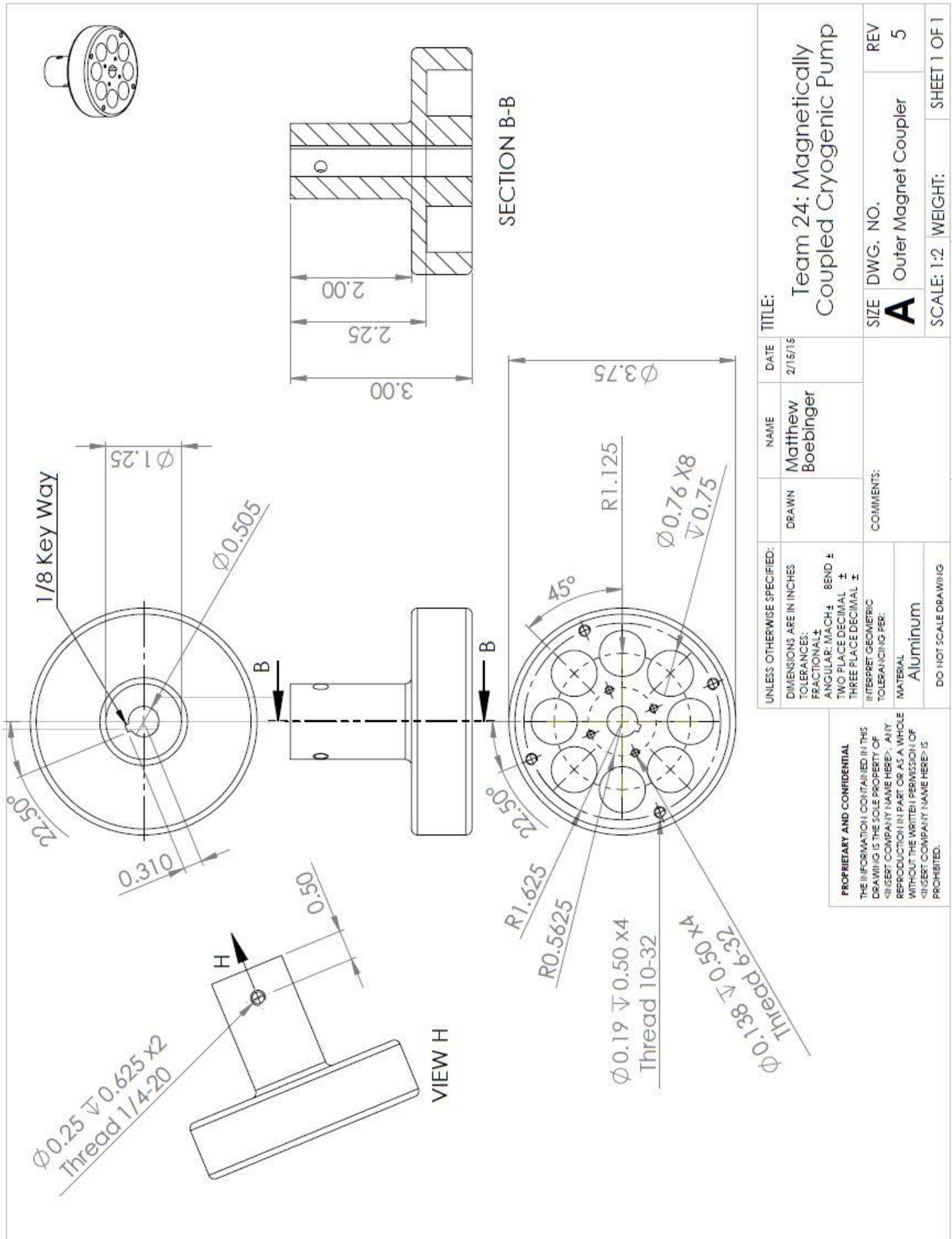
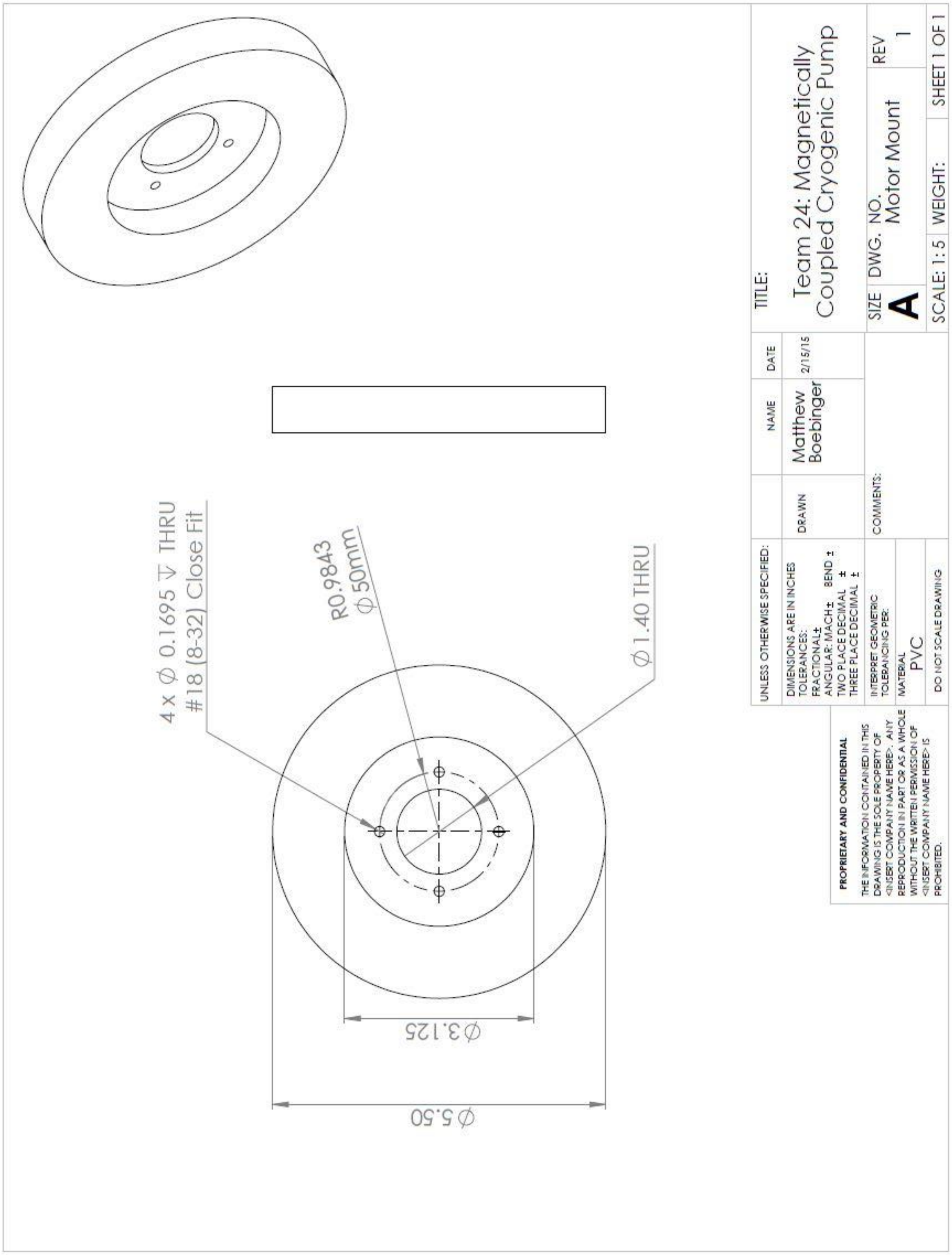

SECTION B-B
2.00
2.25
3.00
Ø3.75
Ø1.25
1/8 Key Way
Ø0.505
R1.125
Ø0.76 X8
↧0.75
45°
B
B
22.50°
0.310
22.50°
0.50
H
R1.625
R0.5625
Ø0.19 ↧0.50 x4
Thread 10-32
Ø0.138 ↧0.50 x4
Thread 6-32
VIEW H
Ø0.25 ↧0.625 x2
Thread 1/4-20
TITLE:
Team 24: Magnetically Coupled Cryogenic Pump
NAME
DATE
DRAWN
Matthew Boebinger
2/15/15
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
COMMENTS:
MATERIAL
Aluminum
DO NOT SCALE DRAWING
PROPRIETARY AND CONFIDENTIAL
SIZE
A
DWG. NO.
Outer Magnet Coupler
REV
5
SCALE: 1:2
WEIGHT:
SHEET 1 OF 1


4 X ∅ 0.1695 ↧ THRU
#18 (8-32) Close Fit
R0.9843
∅ 50mm
∅1.40 THRU
∅3.125
∅5.50
TITLE:
Team 24: Magnetically Coupled Cryogenic Pump
NAME
DATE
DRAWN
Matthew Boebinger
2/15/15
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL±
ANGULAR: MACH± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
PVC
DO NOT SCALE DRAWING
COMMENTS:
SIZE
A
DWG. NO.
Motor Mount
REV
1
SCALE: 1:5
WEIGHT:
SHEET 1 OF 1
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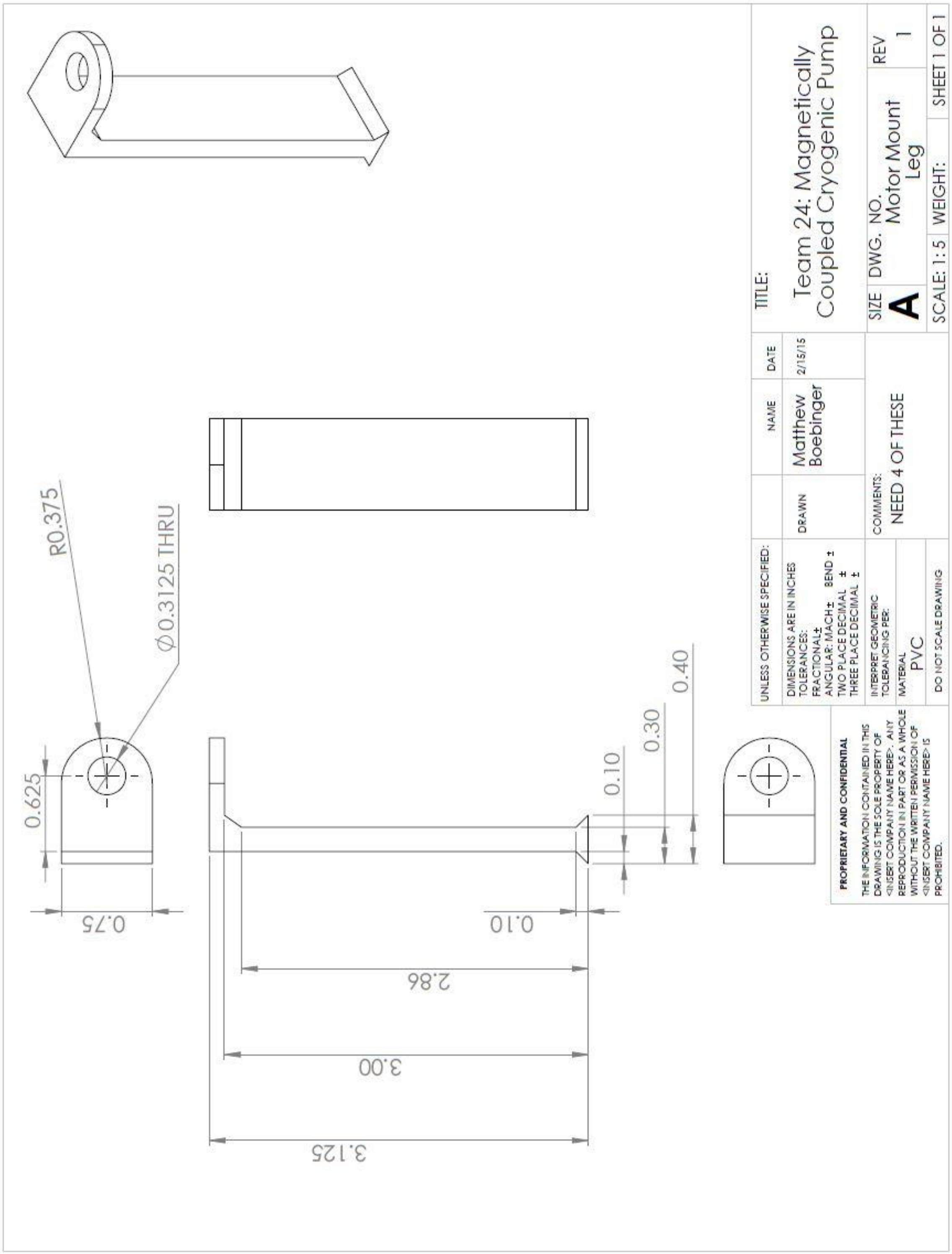
R0.375
Ø0.3125 THRU
0.625
0.75
0.10
0.30
0.40
0.10
2.86
3.00
3.125
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL±
ANGULAR: MACH± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
PVC
DO NOT SCALE DRAWING
NAME
DATE
DRAWN
Matthew Boebinger
2/15/15
COMMENTS:
NEED 4 OF THESE
TITLE:
Team 24: Magnetically Coupled Cryogenic Pump
SIZE
A
DWG. NO.
Motor Mount Leg
REV
1
SCALE: 1:5
WEIGHT:
SHEET 1 OF 1
PROPRIETARY AND CONFIDENTIAL
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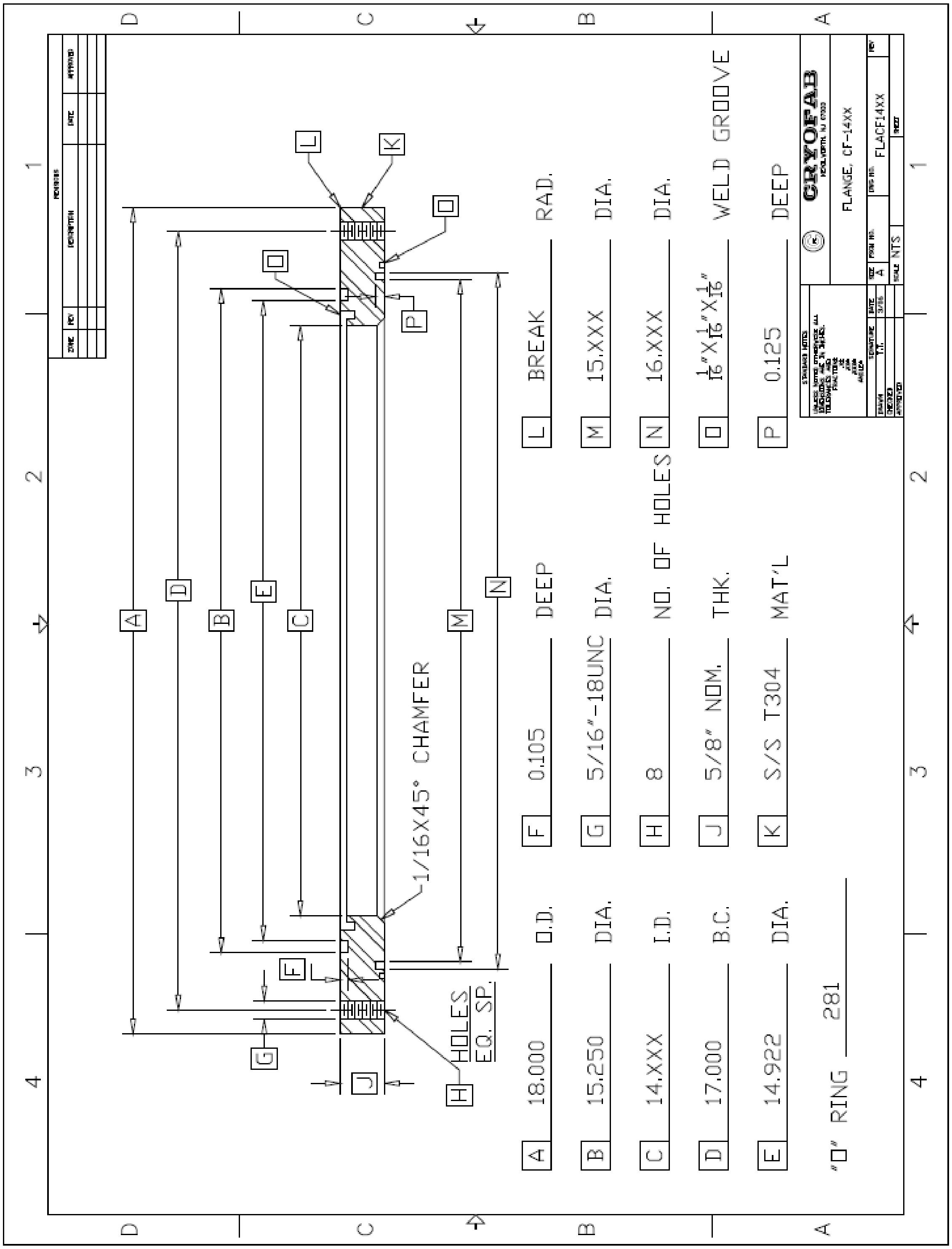
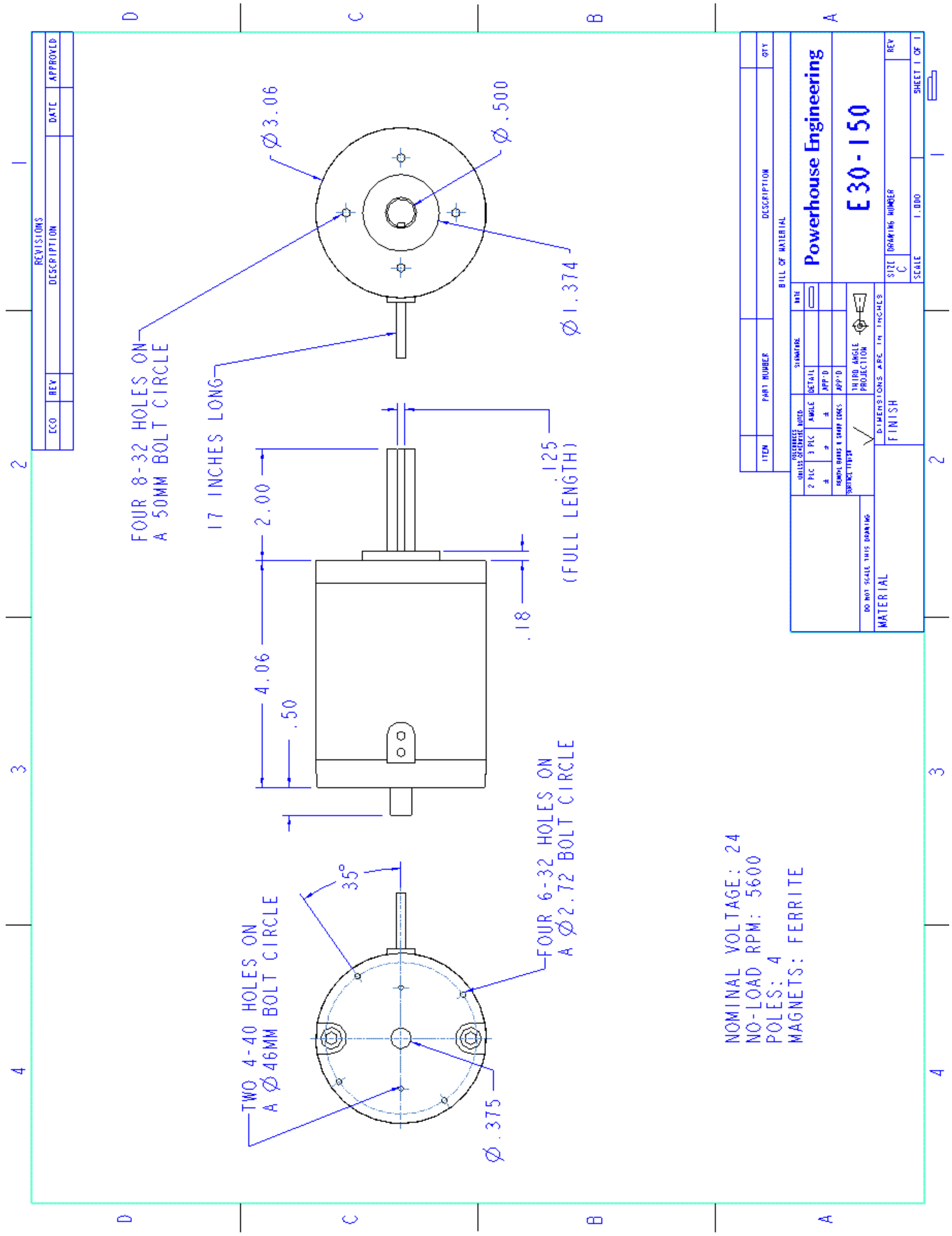

A 18.000 O.D.
B 15.250 DIA.
C 14.XXX I.D.
D 17.000 B.C.
E 14.922 DIA.
F 0.105 DEEP
G 5/16"-18UNC DIA.
H 8 NO. OF HOLES
J 5/8" NOM. THK.
K S/S T304 MAT'L
L BREAK RAD.
M 15.XXX DIA.
N 16.XXX DIA.
O 1/16"X1/16"X1/16" WELD GROOVE
P 0.125 DEEP
"O" RING 281
1/16X45° CHAMFER
HOLES EQ. SP.
CRYOFAB
FLANGE, CF-14XX
FLACF14XX
NTS


FOUR 8-32 HOLES ON
A 50MM BOLT CIRCLE
17 INCHES LONG
Ø3.06
Ø.500
Ø1.374
2.00
4.06
.50
.125
(FULL LENGTH)
.18
FOUR 6-32 HOLES ON
A Ø2.72 BOLT CIRCLE
TWO 4-40 HOLES ON
A Ø46MM BOLT CIRCLE
35°
Ø.375
NOMINAL VOLTAGE: 24
NO-LOAD RPM: 5600
POLES: 4
MAGNETS: FERRITE
Powerhouse Engineering
E30-150
REVISIONS
BILL OF MATERIAL
DIMENSIONS ARE IN INCHES
FINISH
MATERIAL
SCALE 1.000
SHEET 1 OF 1