FLORIDA DEPARTMENT OF TRANSPORTATION
State Materials Office
5007 NE 39th Avenue
Gainesville, Florida 32609

January 5, 2021

Florida Method of Test
for
Determination of Mean Permeability in the Field Using the Vertical In situ Permeameter (VIP)

Designation: FM 5-614

1. SCOPE

1.1 This method describes the procedure to determine the mean coefficient of permeability in the field using the Vertical In situ Permeameter (VIP) probe.

2. APPARATUS

2.1 Vertical In situ Permeameter (VIP) Probe.

2.2 SPT Drill Rig: AWJ Connections.

2.3 Falling Head Vessel (Water Tank / Piezometer) with Hose Attachment.

2.4 AWJ Hose Adaptor.

2.5 Air Compressor with Tank (optional).

2.6 Miscellaneous Equipment: tape measure, stopwatch, copper grease sealant, PTFE tape, dry erase marker, chalk, temperature gun or thermometer.

3. PROBE MECHANICS

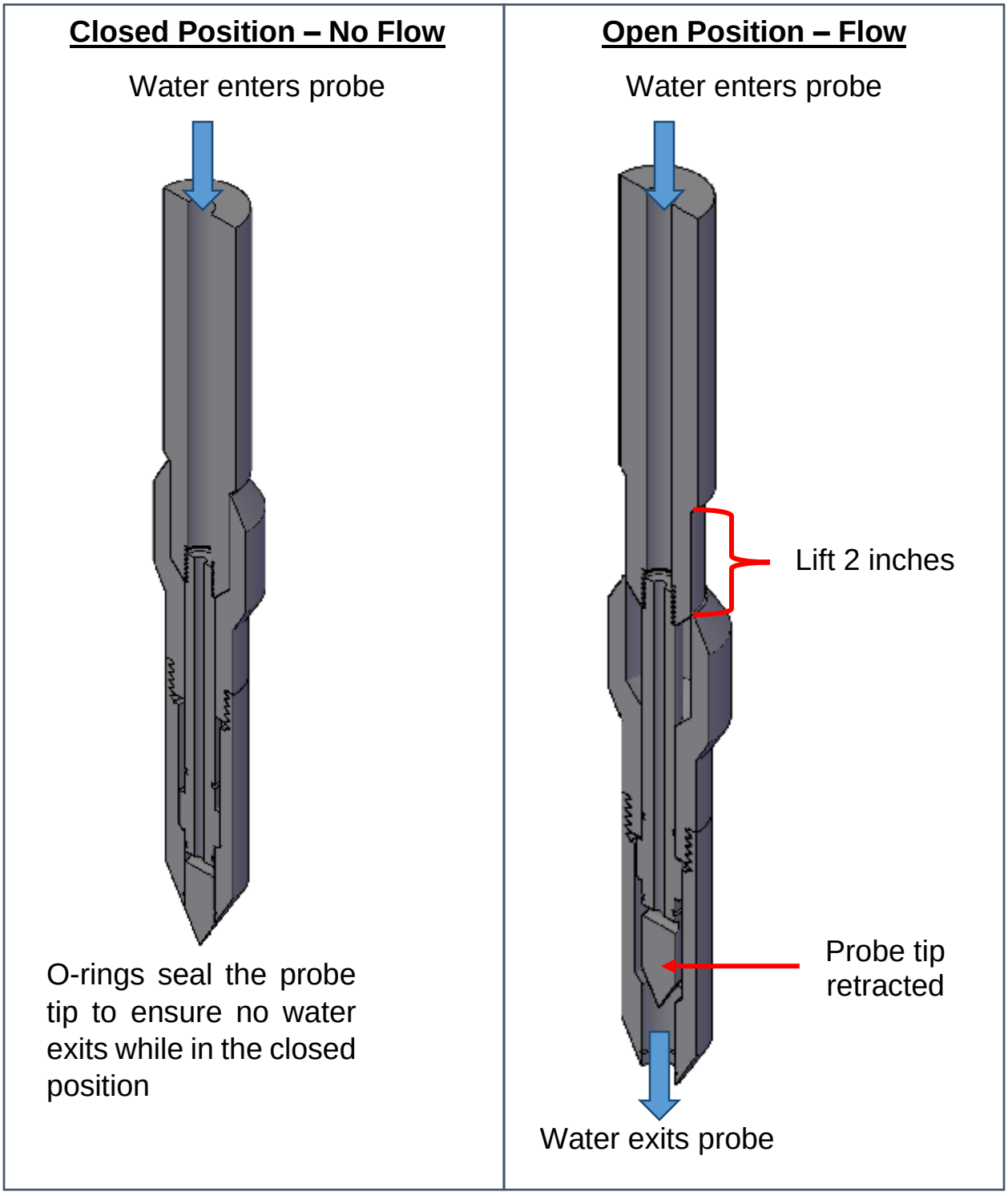

Figure 1: VIP Probe Mechanics

4. PROCEDURE

4.1 Place PTFE (Plumbers) tape on threaded probe connections. Follow assembly steps covered in Sections 4.1.1 to 4.1.4 to assemble probe.

Note: The smaller threaded connection (interior) requires 3 layers of PTFE tape and the larger threaded connection (exterior) requires 4 layers of PTFE tape to ensure leakage does not occur.

4.1.1 Arrange probe parts A through D.

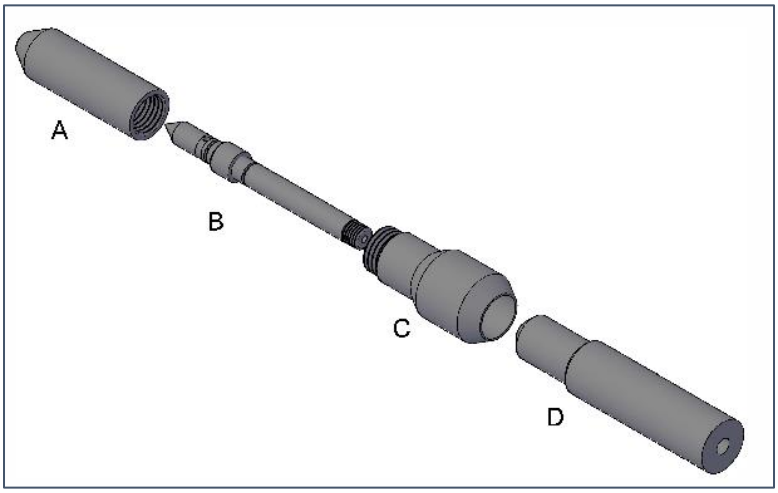

Figure 2: Step 1 of Probe Assembly

4.1.2 Slide part C onto part B.

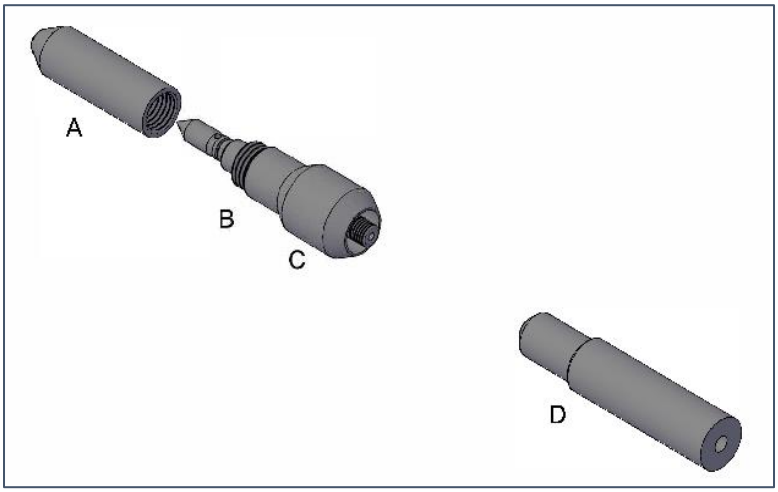

Figure 3: Step 2 of Probe Assembly

4.1.3 Slide part D into part C and thread onto part B using clockwise rotation.

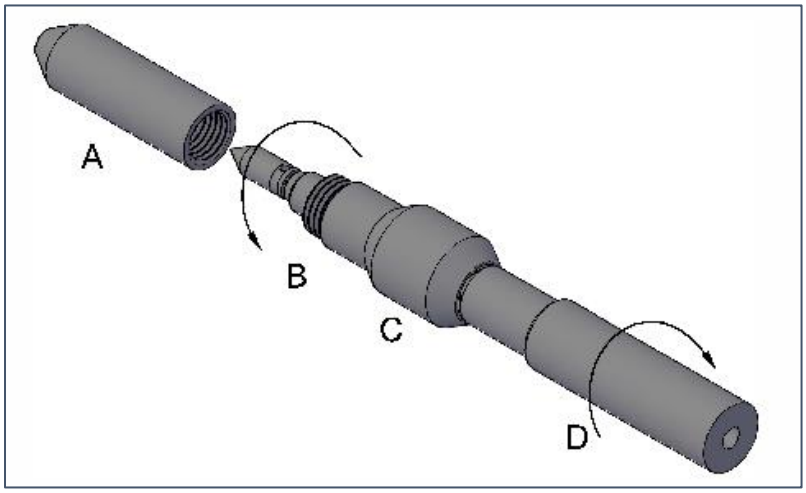

Figure 4: Step 3 of Probe Assembly

4.1.4 Thread part A onto part C using counterclockwise rotation.

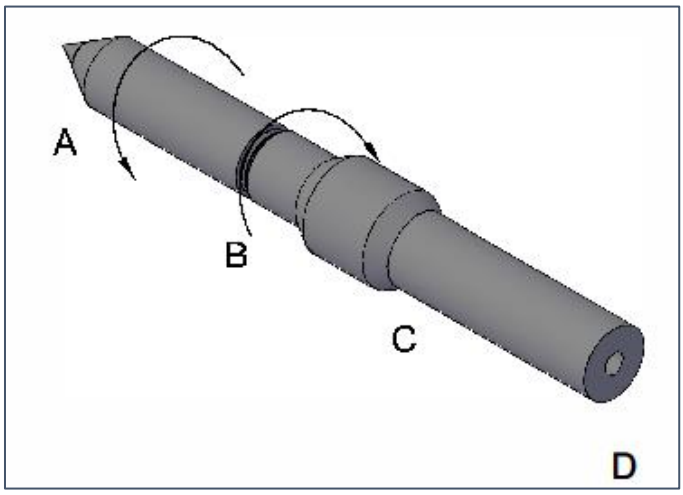

Figure 5: Step 4 of Probe Assembly

Note: When threading part A onto part C, it is recommended to retract the inner rod as depicted in Figure 4 to reduce O-ring resistance during rotation.

4.2 Thread probe onto the first AWJ rod that is attached to the drill rig. It is recommended to place thicker PTFE tape (gas line tape – typically yellow) on this threaded connection. A grease sealant, such as copper grease, can be used as an alternative to the PTFE tape.

4.3 Advance probe to desired test depth using the SPT rig's direct push technique.

4.3.1 Place grease sealant between threaded AWJ rod connections.

4.3.2 During probe advancement, several AWJ rods may be required to achieve the desired test depth. The length of the probe and AWJ rods used should be measured to ensure the probe tip is advanced to the desired test depth. The final AWJ rod should be marked with chalk in two locations. The first chalked location provides a reference between the ground surface elevation (GSE) and the total rod length (probe and AWJ rods) required to reach the desired test depth. The second chalk mark is placed 2 inches below the ground surface chalk mark and is used to track vertical movement of the probe when transitioning between the open and closed positions.

Note: When direct push is not viable, pre-drilling might be necessary. Stop drill minimum of 1 foot prior to final testing depth. Ensure probe is closed before advancement.

4.4 Once the desired test depth has been achieved, fill the AWJ rods with water and remove any air voids prior to attaching the falling head vessel hose connection. Once the AWJ rods have been filled, the water level inside the rods should stabilize. If stabilization does not occur, either air voids are still present, the probe is not fully closed off, or water is leaking from an AWJ rod threaded connection. Stabilization should be achieved prior to running a test. Failure to achieve stabilization prior to testing may result in erroneous measures of hydraulic conductivity.

4.5 Attach AWJ hose adapter to the top of the AWJ rods, fill with water, and remove any air voids.

4.6 Fill the falling head vessel with water. Allow water to freely drain from the attached hose to ensure all air voids are removed prior to AWJ hose adaptor attachment.

4.6.1 Attach the hose from falling head vessel to the AWJ hose adaptor.

4.6.2 Ensure the water hose is not kinked or restricting flow.

4.6.3 Allow water to flow into the AWJ rods and ensure the water level in the falling head vessel has stabilized. Add additional water, as necessary.

4.7 Attach SPT rig cable hook to the AWJ rod above ground surface.

4.8 Slowly lift the AWJ rod at ground surface 2 inches using the attached SPT cable hook to open the probe for testing. Use the chalk marks (4.3.2) to track the 2-inch vertical movement. The cable hook should remain in place throughout testing to ensure the probe remains stationary in the fully open position.

4.9 Let water drain for 15 minutes to ensure soil is saturated. Add additional water to the falling head vessel, as necessary. When testing soils with higher permeability, attaching a continuous supply of water to the falling head vessel may be necessary. Measure water temperature with thermometer and record on data sheet. After 15 minutes of saturation, the testing can begin.

Note: The total test time and recording increments to be used during the actual VIP test should be estimated based on the flow observed during the 15-minute saturation period. The initial water temperature should be compared to the final water temperature recorded at the end of testing.

4.10 Begin test. Start stopwatch when water level is at readable mark. **See Figure 9** (Page 13) for recording time and total length of test. Use a dry erase marker to mark the water level on the tank for each reading at the predetermined recording increments.

4.11 Once the testing has been completed, ensure that a sufficient supply of water is available in the falling head vessel to continuously flush the probe while transitioning to the closed position. This may require a continuous water supply to be attached to the falling head vessel for probe flushing. Measure water temperature with thermometer and record on data sheet.

4.12 While system is flushing, remove SPT cable hook and push down 2 inches to close the probe. The ground surface chalk mark (4.3.2) should now be at ground level again. Check the falling head vessel water level for stabilization. Stabilization ensures the probe has been returned to the closed position.

Note: Compressed air can be used to assist flushing the probe for certain soil types. This may be required if fat clays or low plasticity cohesive soils in a liquid state are continuously encountered. In most cases the water head from the falling head vessel is sufficient to properly flush the probe.

4.13 Disconnect water hose from AWJ hose adapter.

4.14 Remove AWJ hose adaptor from top of AWJ rods.

4.15 The probe is now ready to be pushed to next test depth.

5. CALCULATIONS

$$k_m = \frac{\pi d^2}{4F(t_f - t_i)} ln \frac{H_i}{H_f}$$

Where: k_m = mean permeability (L/T)

d = piezometer (water tank) inner diameter (L)

D = vertical flow port diameter (L) = 0.75-in = 1.905-cm

F = Hvorslev (Case C) shape factor = 3D (L) = 5.715-cm

t_i, t_f = initial and final time of test, respectively (T)

H_i, H_f = initial and final water head, respectively (L)

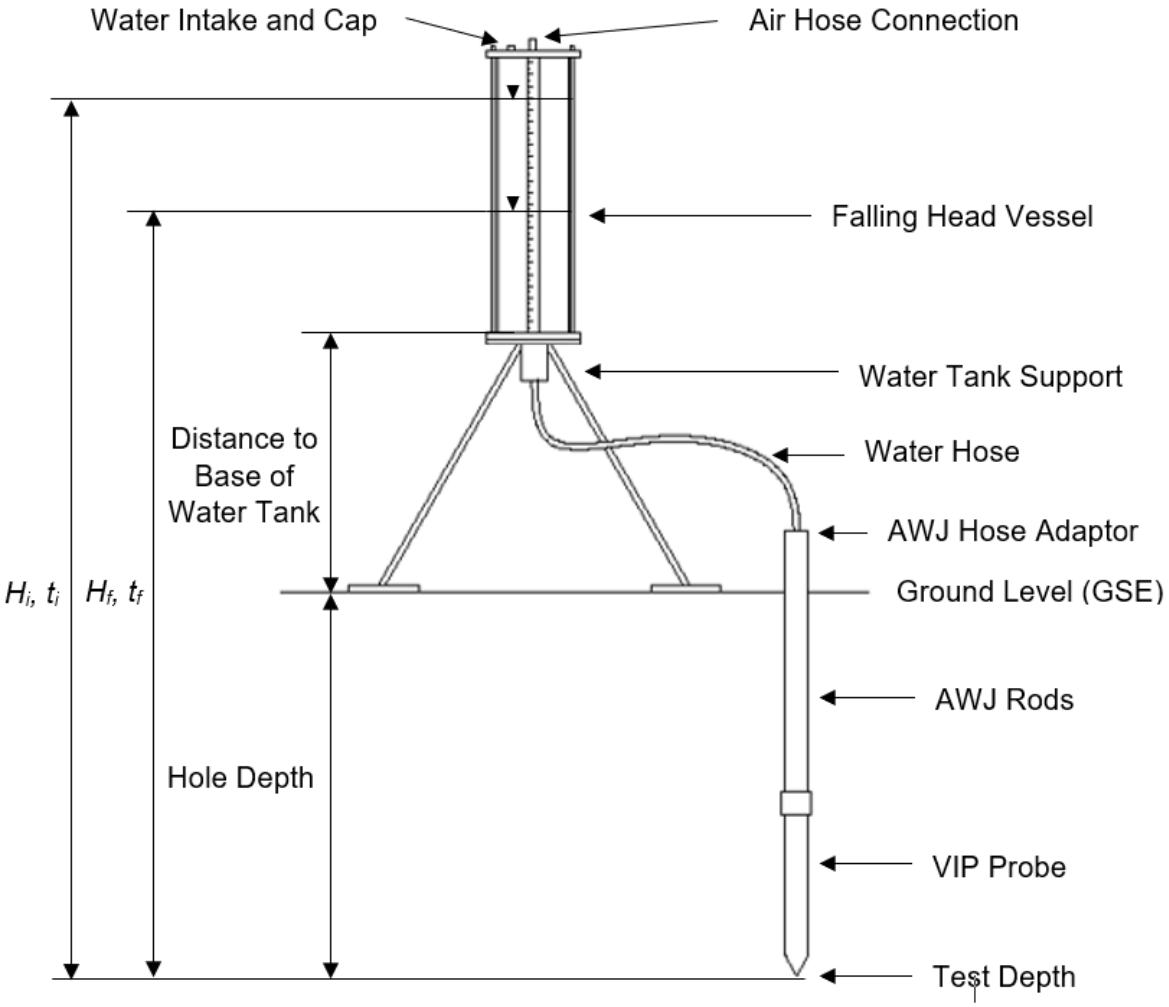

Figure 6: VIP Test Setup and Measurements for Mean Permeability Calculations

Note: When the ground water table (GWT) is above the test depth, the ground water head above the test depth should be subtracted from the initial and final head used to calculate the mean permeability.

5.1 Upper Permeability Limit

Tests were performed in which the probe was left to drain freely into the air to estimate the limiting flow rate and upper permeability limit of the VIP probe. Drainage of the water tank (14.38-cm inner diameter) from 200.7-cm to 171.9-cm above the injection port of the probe took 47.2 seconds on average. Thus, an average injection head of 186.3-cm corresponds to an injection flow rate of 99.1 cm^3/s. From this and knowing F = 3D = 5.715 cm (D = 1.905 cm, injection port diameter), a maximum conductivity k_{max} = 99.1 / (186.3 * 5.715) = 0.0931 cm/s is recommended. Above this value, the hydraulic resistance of the probe and hose would be larger than the hydraulic resistance of the aquifer, affecting the accuracy of the aquifer's permeability value.

6. REPORT

The test results should be reported as shown in Appendix A (**See Figure 10)** and contain the following information:

6.1 Site Information

6.1.1 Date, project location, tested by, and weather/notes

6.2 Borehole Information

6.2.1 Hole number, station – offset, test number, hole depth (ft)[a], water table depth (ft) [a], drill depth (ft) [a], hole diameter (in) [a], water temperature (°C or °F) [b], and distance to base of water tank (in) [a]

6.2.2 Grain size analysis, soil classification, maximum particle size, and percentage of oversized material

6.3 Test Information

6.3.1 Reading number, time – t_i and t_f (seconds or minutes) [a], and height in water tank – H_i and H_f (in) [c]

6.4 Calculation

6.4.1 k_m = mean permeability (L/T)

6.4.2 d = piezometer (water tank) inner diameter (L)

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[a]Report values to the nearest tenth

[b]Report temperature to ±1 degree

[c]Report values to the nearest $^1/_{32}$ of an inch

APPENDIX A: SUPPLEMENTAL SHEETS

Equipment Checklist

VIP ASSEMBLY:

Item	Inspection	In	Out
Probe	- Clean with wire brush - Threading - O-ring		
Probe Maintenance Set	- Wire brush - Extra O-rings		
VIP Probe AWJ Connection	- Soil and/or organic debris - Loose PTFE tape / Excess grease		
AWJ Hose Connection	- Loose PTFE tape / Excess grease		
Water Vessel with Cap	- Cap (top of water tank) - Nuts to secure to stand - Leaking at connections		
Support Stand	- Loose connection components		
Water Hose – Probe/Tank Connection	- Connection leaks		
Portable Air Compressor with Tank	- Pressure		
Air Hose	- Quick connections		
Tank Tape Measure	- Alignment and bonding - Old markings from test readings		
Stopwatch	- Proper functionality		
Temperature Gun / Thermometer	- Measure temperature of test water		
Clipboard			
Data Sheet with Pen	- Extra - Thin dry eraser marker for water tank		

SPT RIG:

Item	Inspection	In	Out
AWJ Rods	- Multiple lengths - Leaks at connections		
Grease Sealant	- Properly seals connections		
Water Source	- 3-gallon water tank * # of tests		
Water Hose	- Connects drill rig / external water supply to falling head vessel		
Air Compressor	- Pressure - Instead of portable		
Electrical Source (for rig without compressed air)	- 450 W		
Chalk	- Visibility on AWJ		
Water Level Indicator and Hand Auger	- If pre-drilling is not required (no hole)		

Figure 7: Equipment Checklist

SETUP:

Task	Description
Probe	▪ Assemble probe - Add PTFE tape and ensure threaded connections are tight ▪ Attach probe to SPT rig, use grease sealant between the AWJ connections
Water Supply	▪ Setup support stand and secure water tank – Place on level ground where it will not interfere with testing – Ensure water hose for probe will reach – Ensure water hose to fill tank will reach ▪ Attach water hose to base of water tank – Place end of hose on top of water tank to prevent flow if a shut-off valve is not present ▪ Fill water tank
Air Supply	▪ If using air compressor on SPT rig ➔ adjust air pressure to proper level (Figure 9) – Attach air hose and place near water tank ▪ If using portable air compressor ➔ attach to electrical source and fill air tank – Adjust air pressure to proper level (Figure 9) – Attach air hose and place near water tank
Misc.	▪ Have data sheets and pen attached to clipboard – Multiples – Thin dry erase marker for water tank ▪ Check stopwatch ▪ Have tape measure and chalk ready

BREAKDOWN:

Task	Description
Probe	▪ Remove AWJ connection from top of drill string ▪ Remove probe from soil – Disconnect AWJ rods ▪ Clean probe with water and compressed air if necessary – Open/close probe to ensure smooth transitions
Water Supply	▪ Drain water tank away from pathways – Ensure cap is tight ▪ Disconnect water hose from base of water tank – Coil ▪ Remove water tank from support stand ▪ Breakdown support stand
Air Supply	▪ Disconnect air hose from air compressor – Coil ▪ Turn off air compressor
Misc.	▪ Make sure all data sheets/pen are together and attached to clipboard – Ensure data sheet is filled out completely ○ Date, time, weather conditions, etc. ▪ Collect stopwatch, tape measure, and chalk ▪ Use checklist to ensure all equipment is packed for next location

Figure 8: Setup and Breakdown Tables

Supplemental Information

Testing Times Based on Soil Type and Flushing Recommendations*.

Testing Recommendations (Estimate during saturation)			**Flushing Recommendations** (If needed, typically not required)	
Soil Type	**Recording Increment**	**Total Length of Test**	**Air Pressure**	**Flush Time**
Coarse Sand	15 – 30 sec	3 – 5 min	10 – 20 psi	10 sec
Fine Sand	30 sec – 1 min	5 – 10 min	15 – 25 psi	10 – 30 sec
Silty Sand	30 sec – 1 min	5 – 10 min	20 – 30 psi	10 – 30 sec
Sandy Silt	1 – 5 min	10 – 50 min	25 – 35 psi	10 – 30 sec
Clay	5 – 15 min	45 - 60 min	30 – 45 psi	30 sec – 1 min

*Numbers in this table are general approximations and will vary based on actual soil type and field conditions. Proper discretion should be used when selecting values. Initial saturation can be used to estimate appropriate values for recording increments and the total length of the test. The air pressures and flushing times are estimates based on flushing trials completed during development. Typically, pressurized flushing is not necessary. Water tank is rated for 90-psi but it is not recommended to pressurize the tank to this pressure.

Figure 9: Supplemental Information

Reporting Data Sheet

Site/Project Information:			
Date		**Testing Company**	
Contract/Project #		**Tested By**	
Project Location			
Weather/Notes			

Borehole Information:			
Hole No.		**Drill Depth (ft) for pre-drilled hole**	
Station – Offset			
Test No.		**Hole Diameter (in)**	
Hole Depth (ft)		**Water Temperature (°C or °F) – circle**	
Water Table (ft)			
Distance to Base of Water Tank (in) – measured from ground surface			

Test Information:			
Vessel Tank (Piezometer) inner diameter (cm)		**Hvorslev (Case C) shape factor, F = 3D (cm)**	5.715

Reading No.	**Time (sec or min)**		**Height in Water Tank (in)**	**Change in Time Δt (sec)**	**H_i (in)**	**H_f (in)**	**k_m**
Start	0	sec		-	-	-	-
1							
2							
3							
4							
5							
6							
7							
8							
19							
10							
11							
12							
13							
14							
15							
Other:					**Average k_m (cm/sec)**		
					Average k_m (in/sec)		
					Average k_m (ft/day)		

Figure 10: Data Sheet Template

APPENDIX B: SHOP DRAWINGS

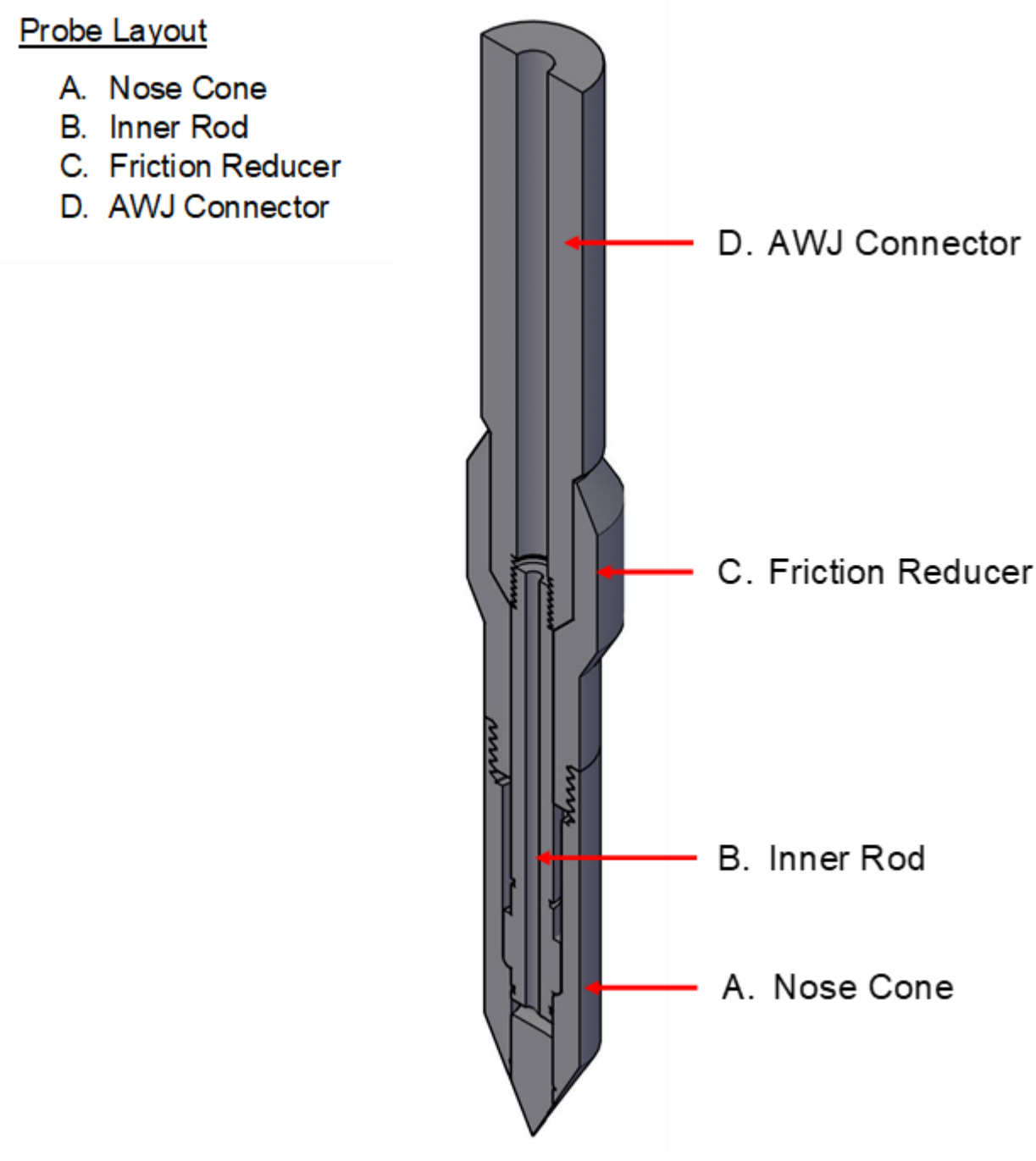

Figure 11: Probe Layout

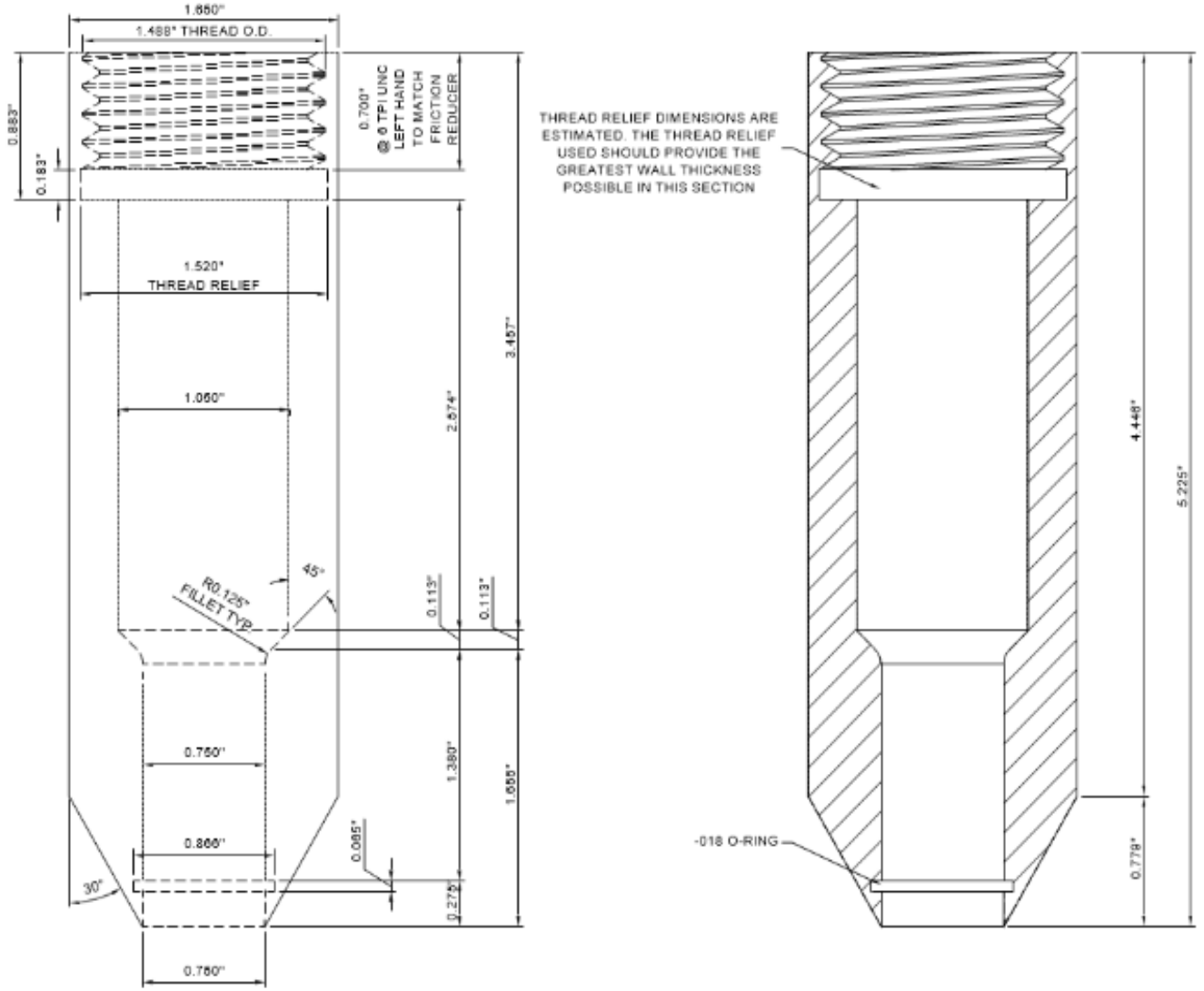

Figure 12: Nose Cone

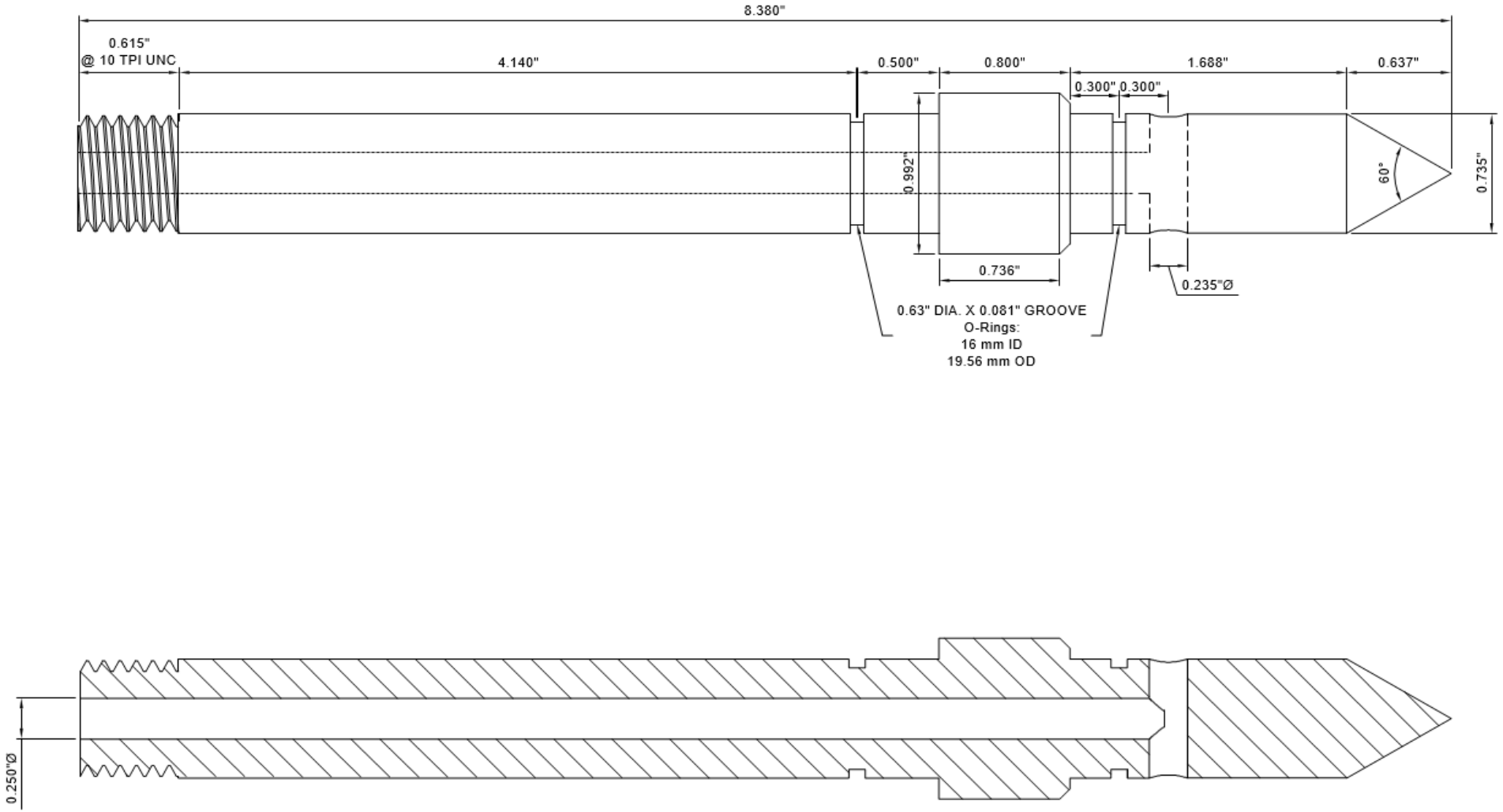

Figure 13: Inner Rod

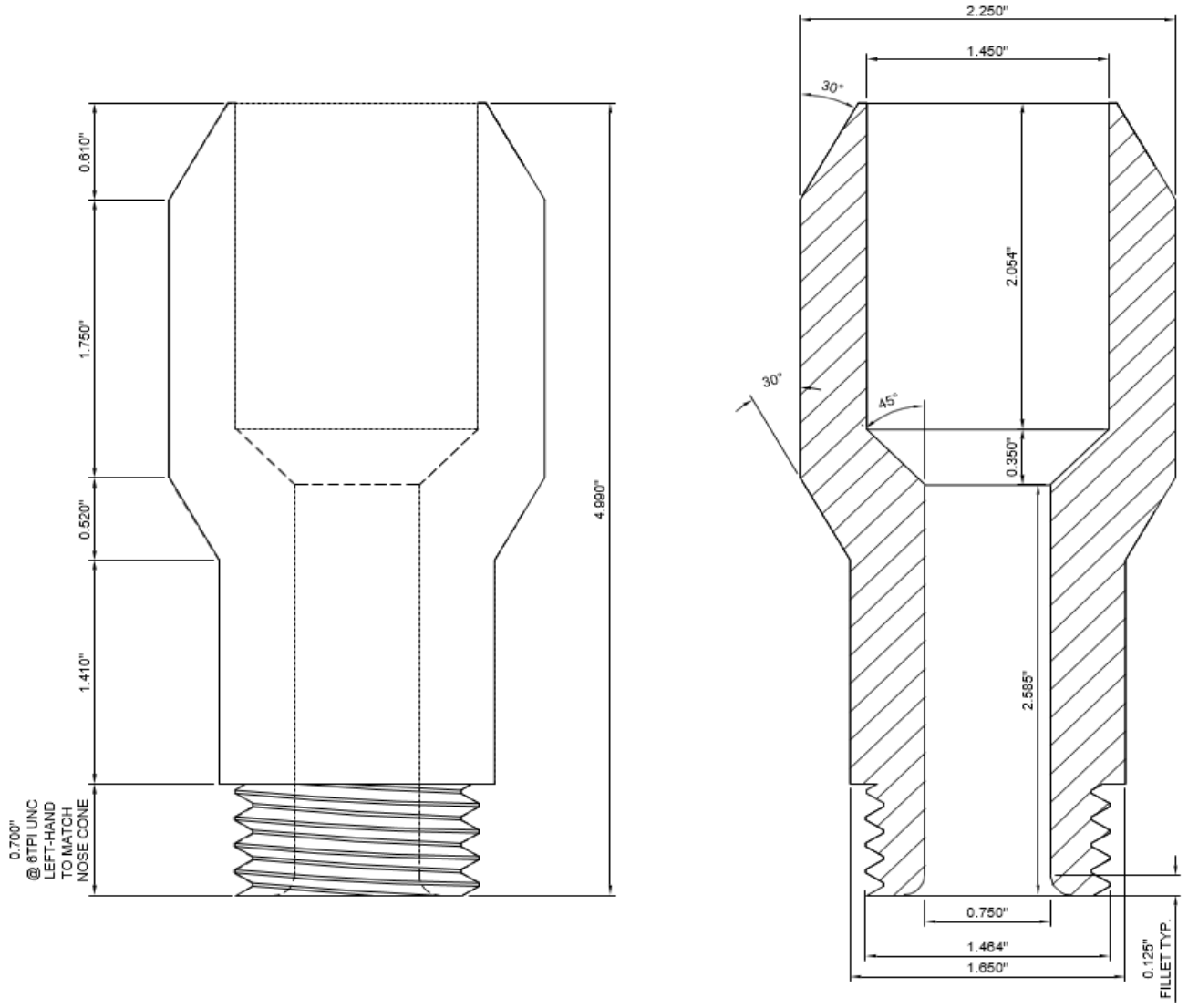

Figure 14: Friction Reducer

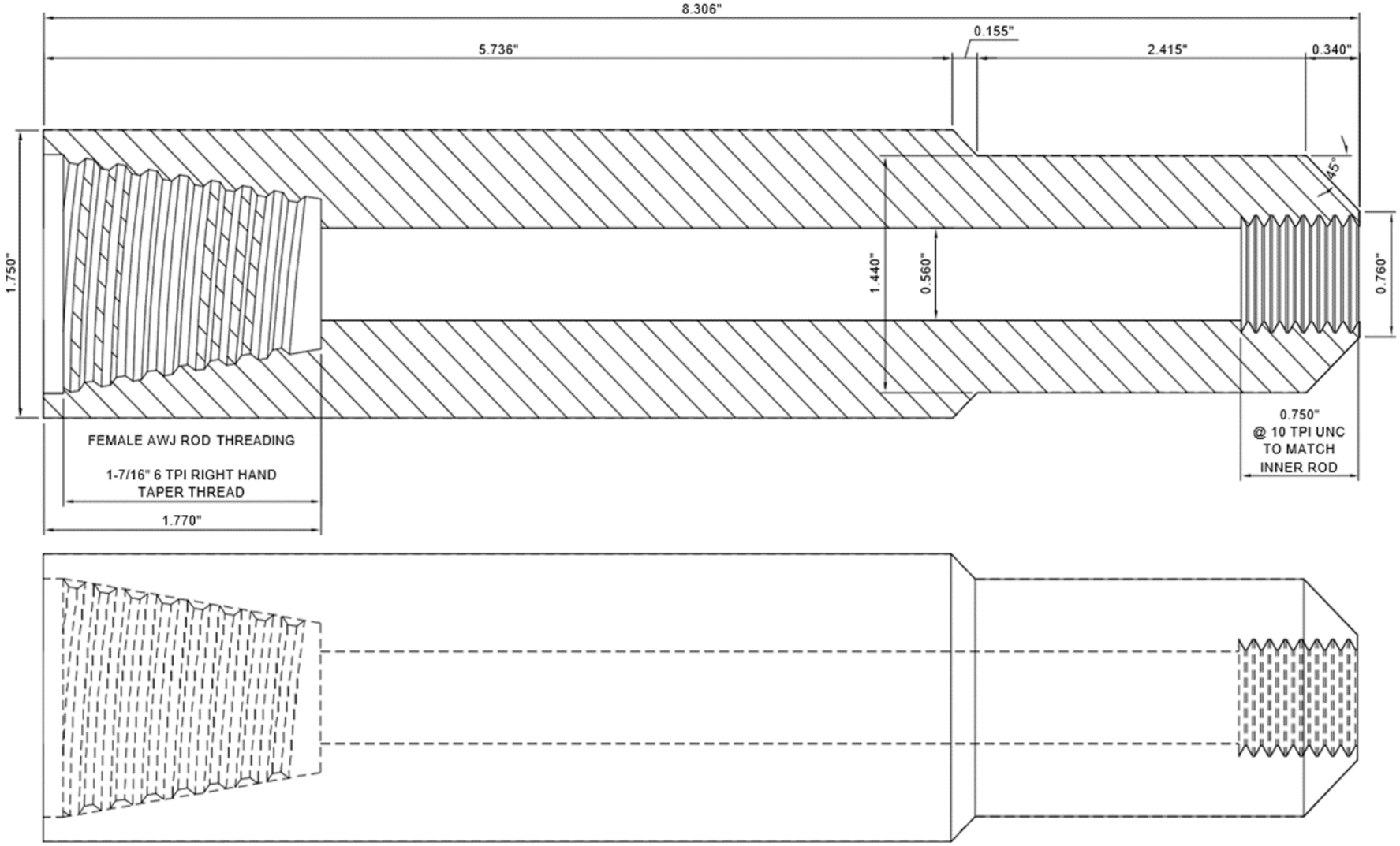

Figure 15: AWJ Connector

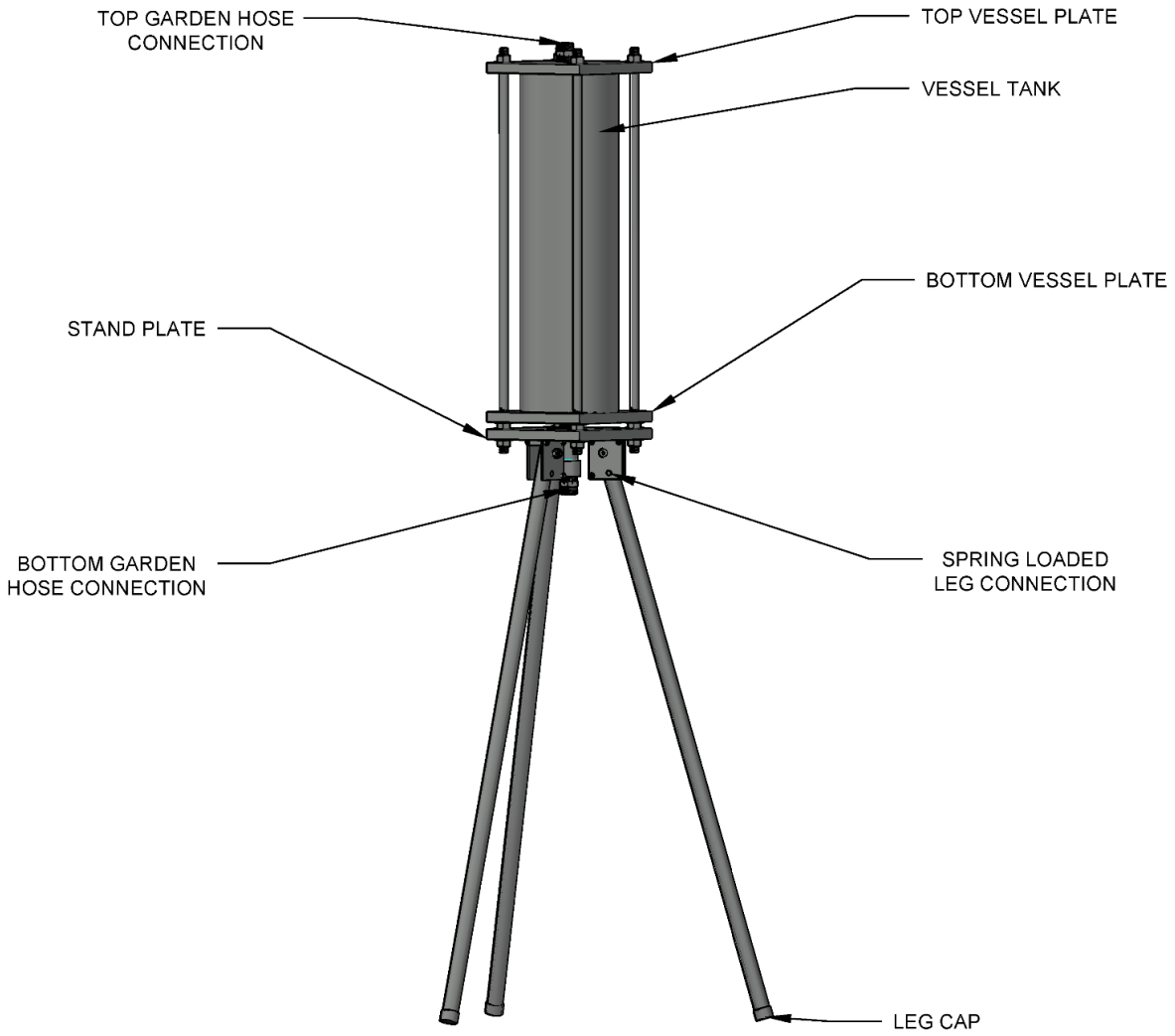

Figure 16: Falling Head Vessel Overview

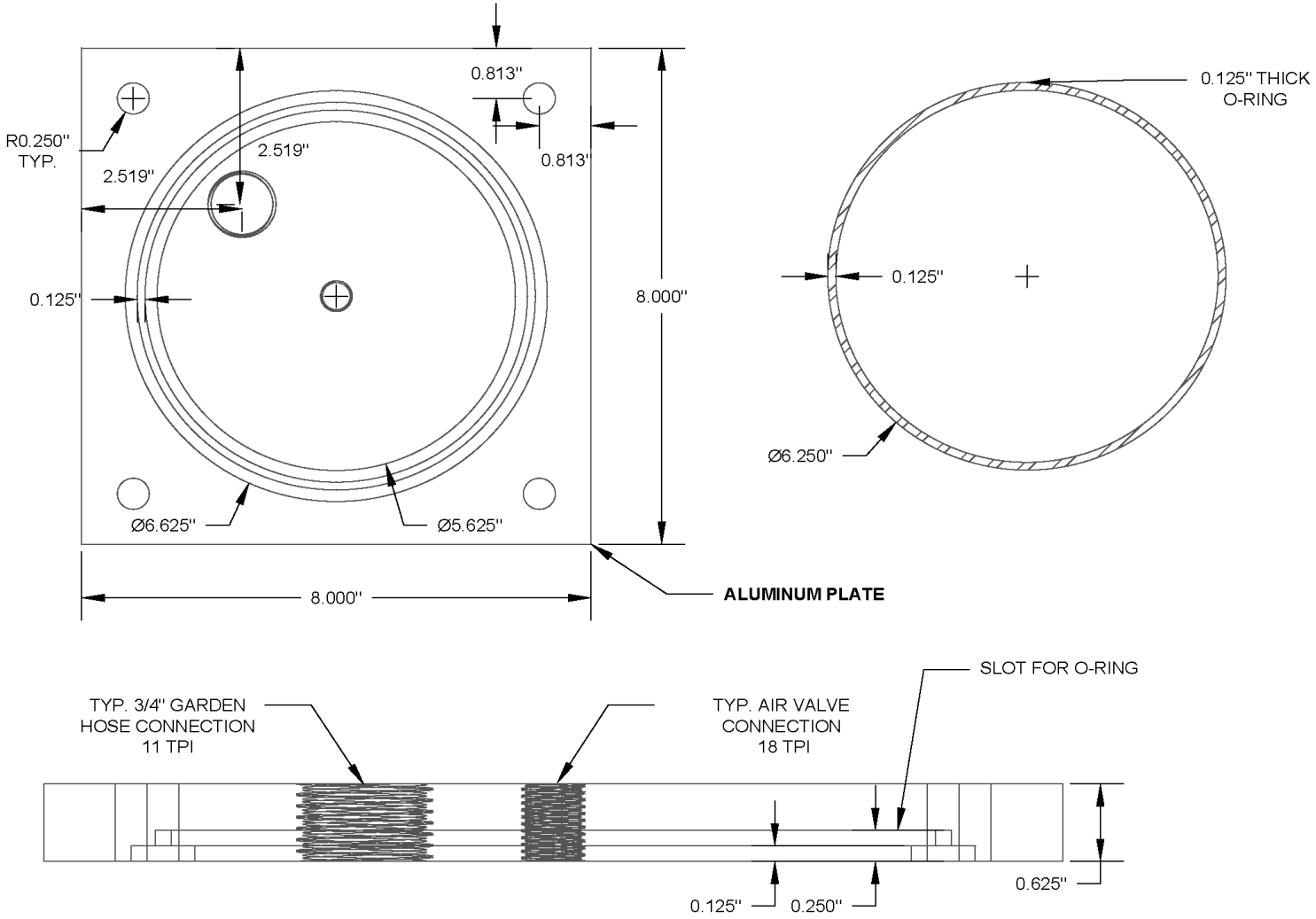

Figure 17: Top Vessel Plate

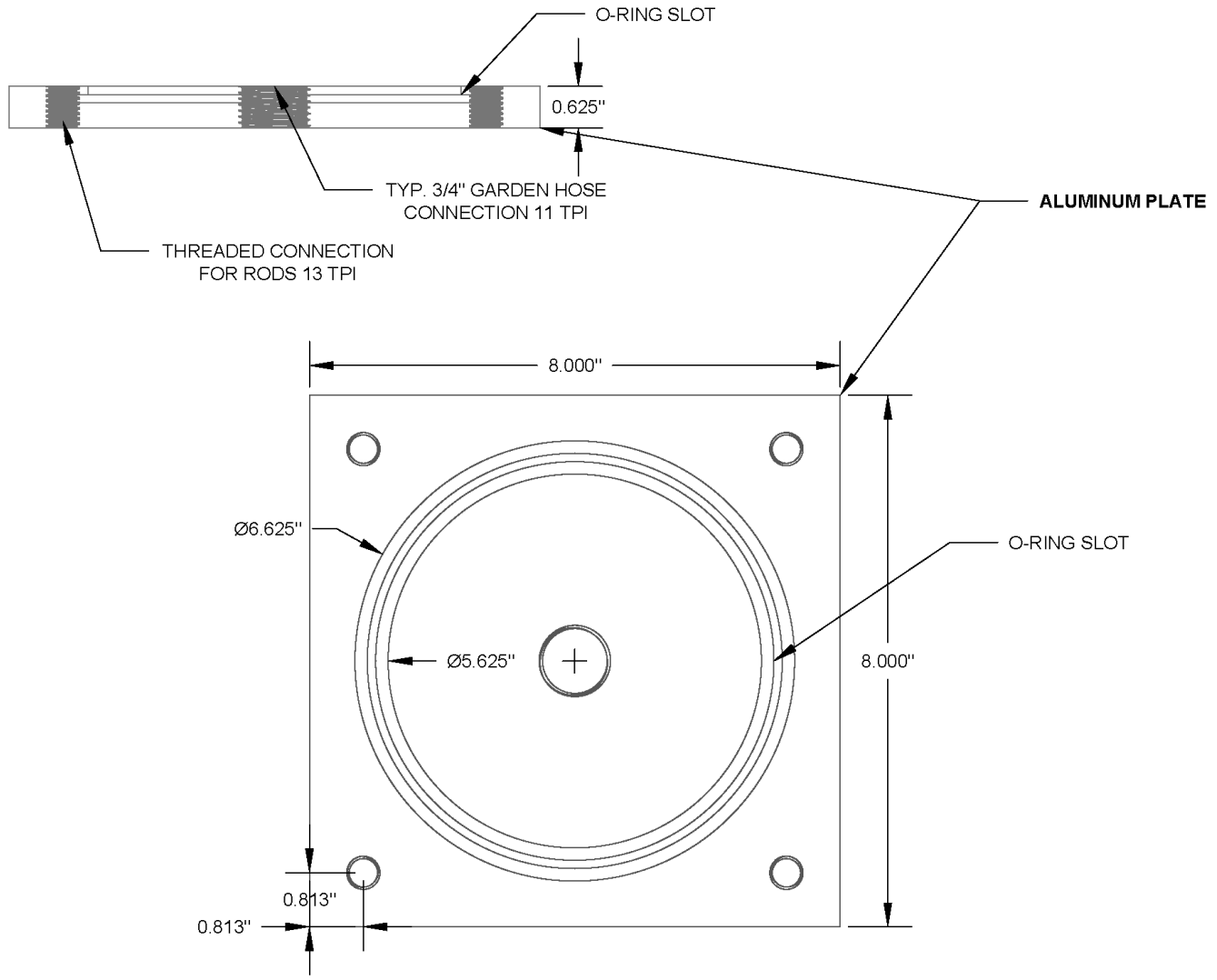

Figure 18: Bottom Vessel Plate

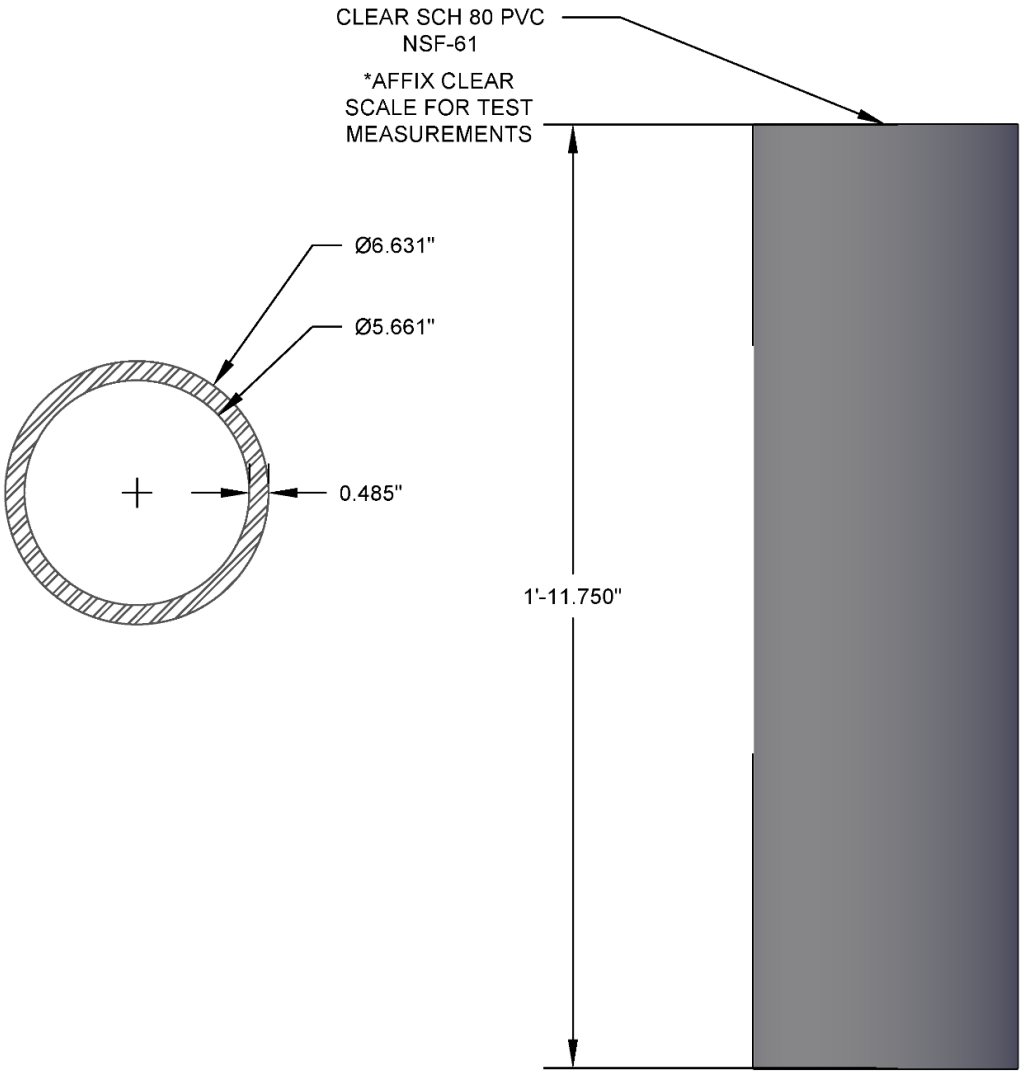

Figure 19: Falling Head Vessel Tank (Piezometer)

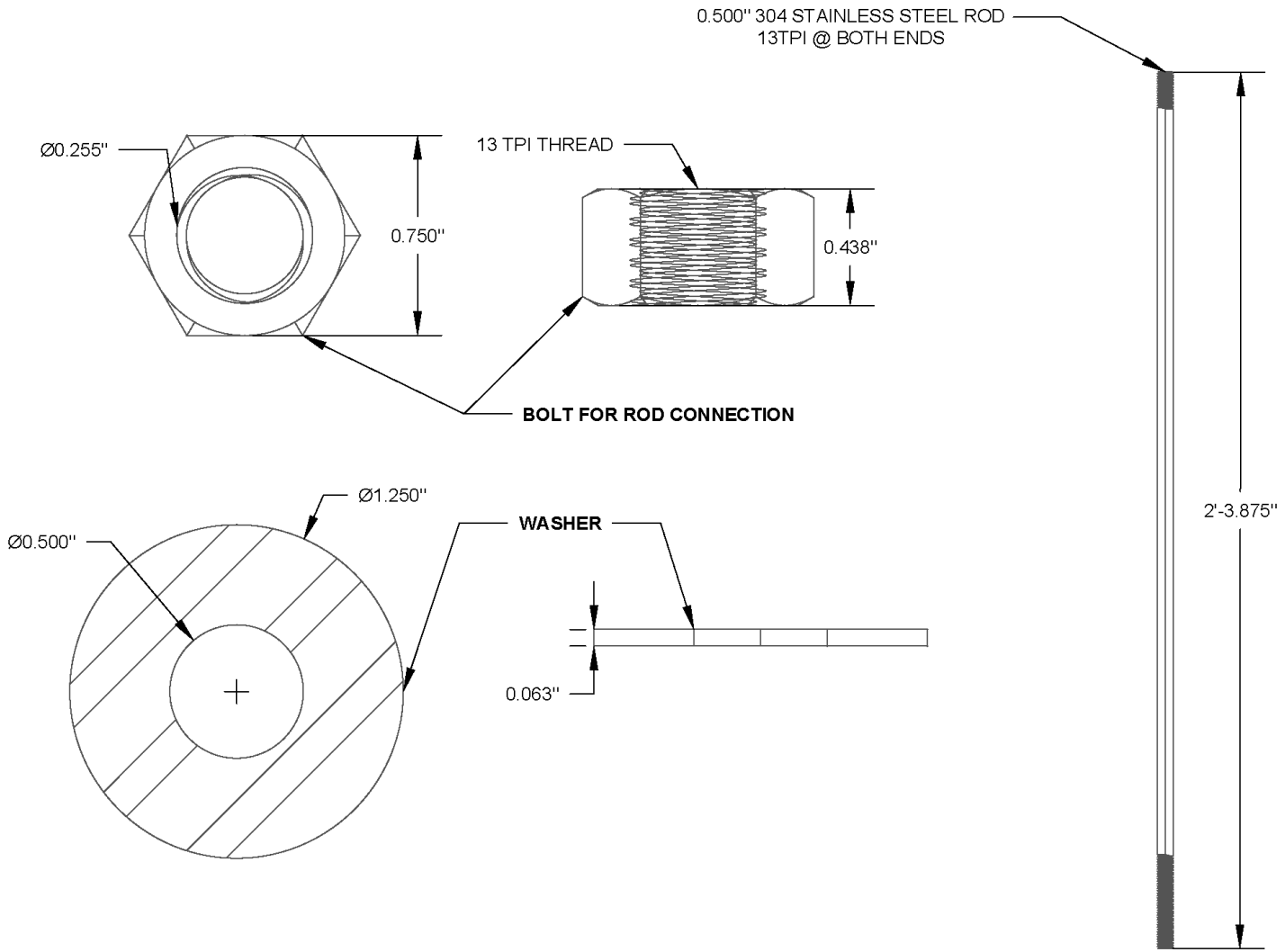

Figure 20: Threaded Rods, Bolts, and Washers

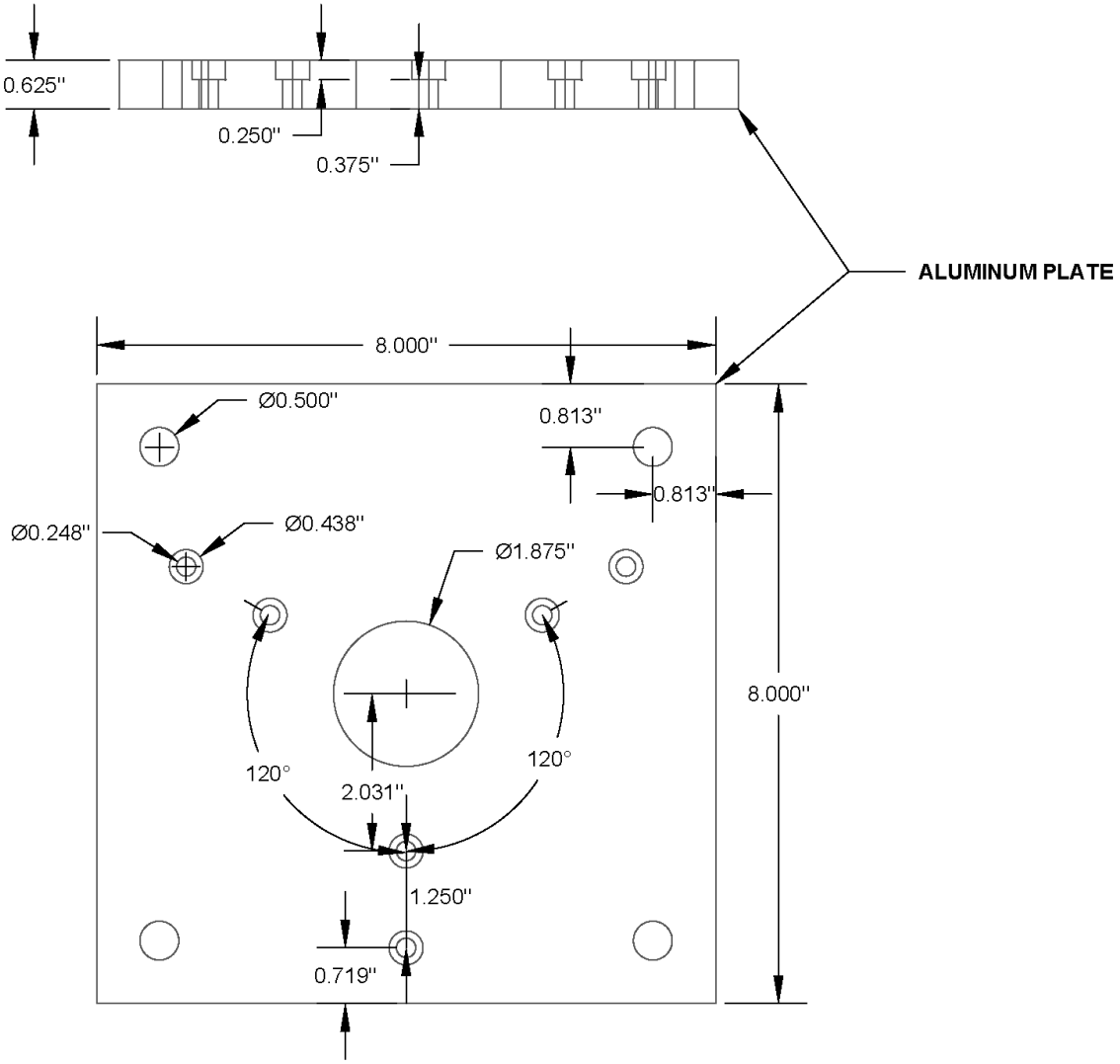

Figure 21: Stand Plate

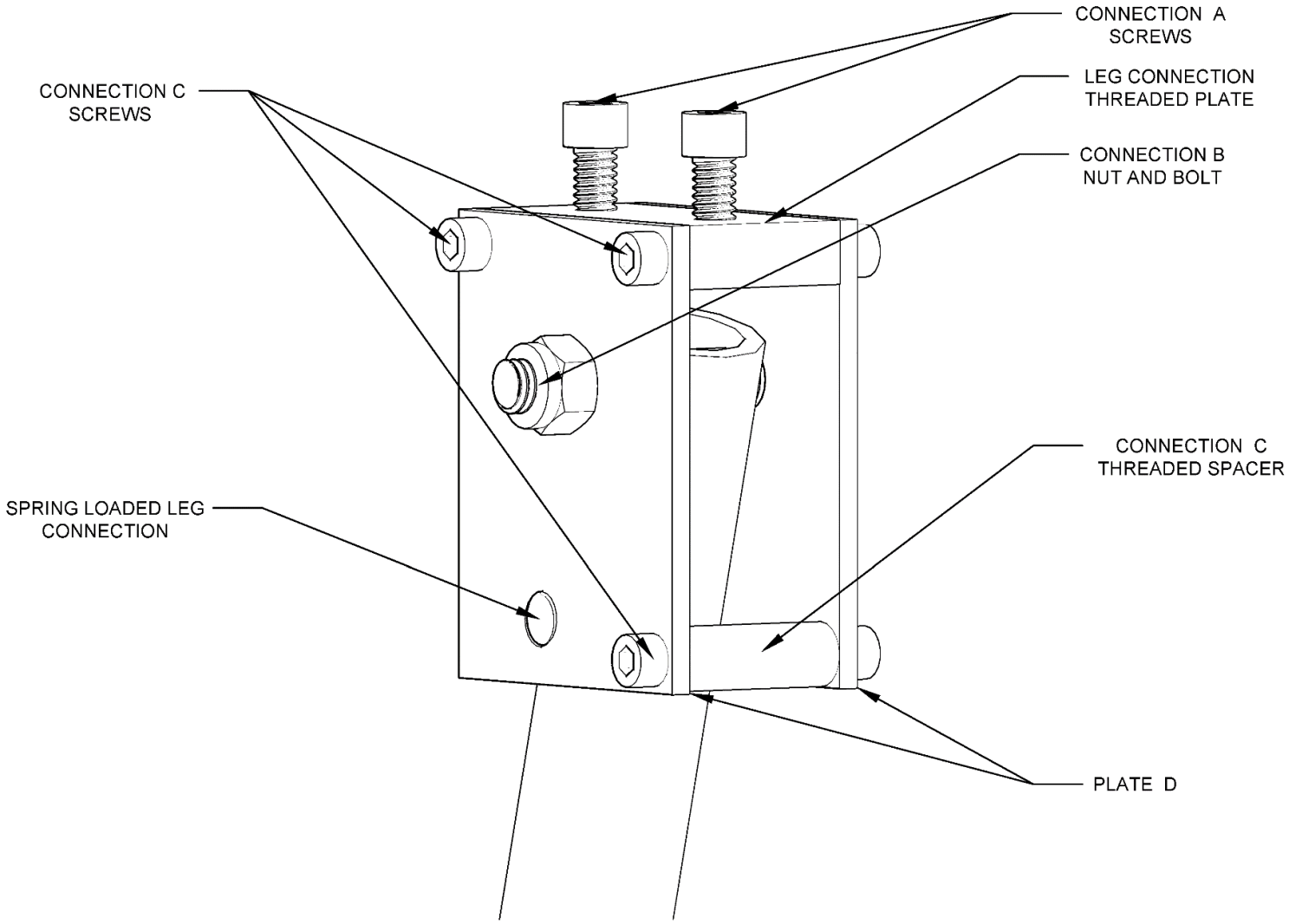

Figure 22: Leg Connection Overview

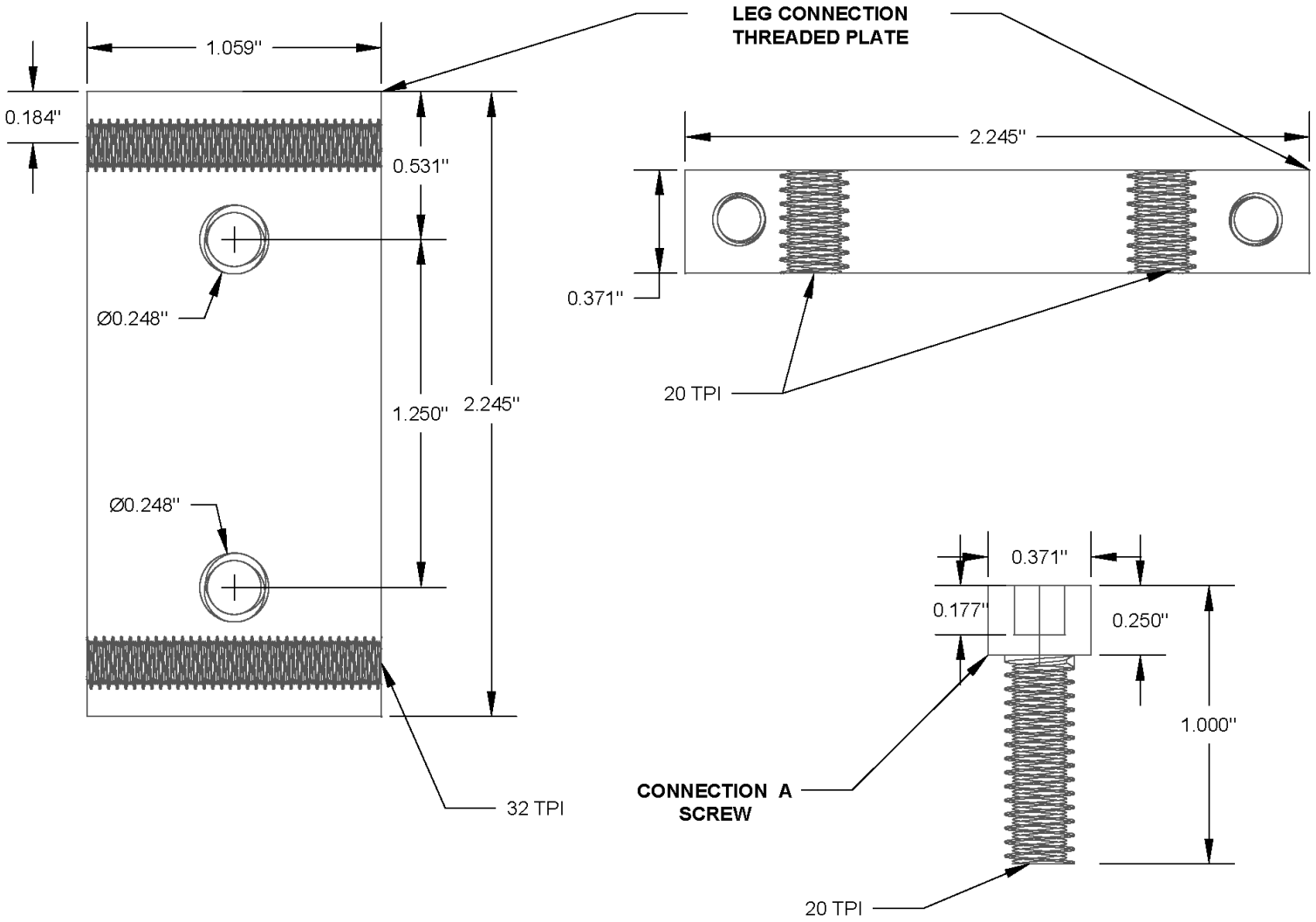

Figure 23: Leg Connection Threaded Plate and Connection-A Screws

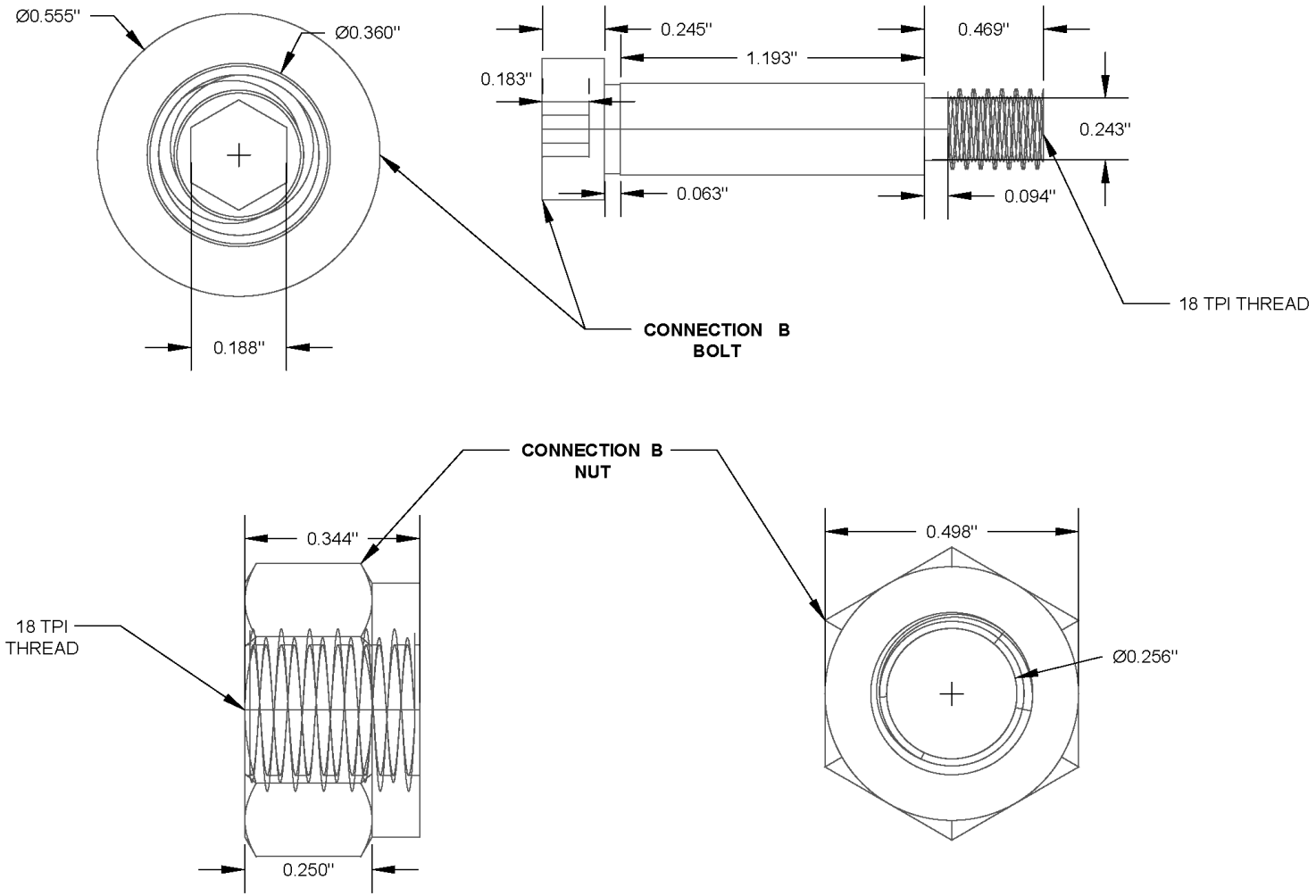

Figure 24: Leg Connection-B Nut and Bolt

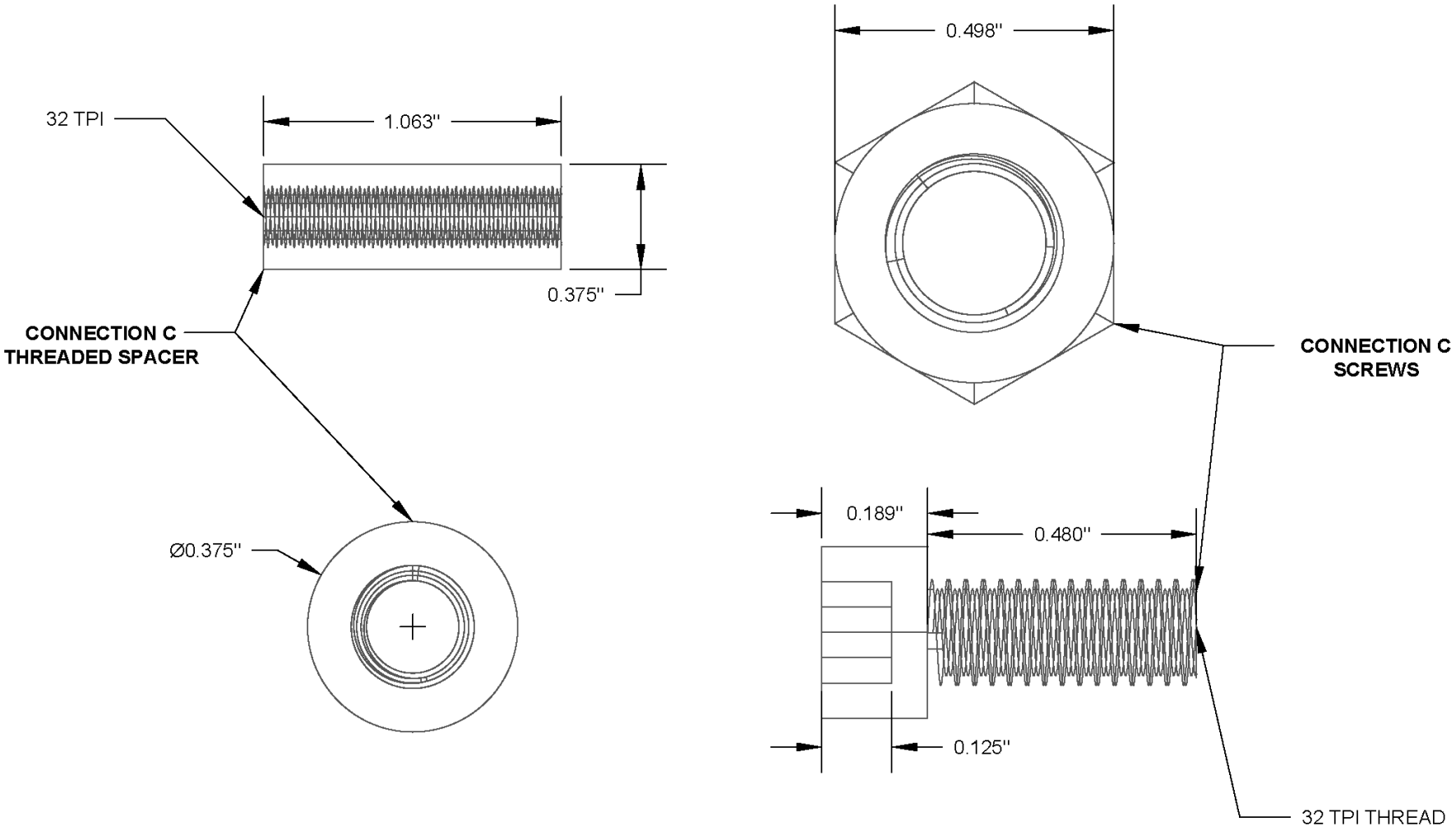

Figure 25: Leg Connection-C Screws and Threaded Spacer

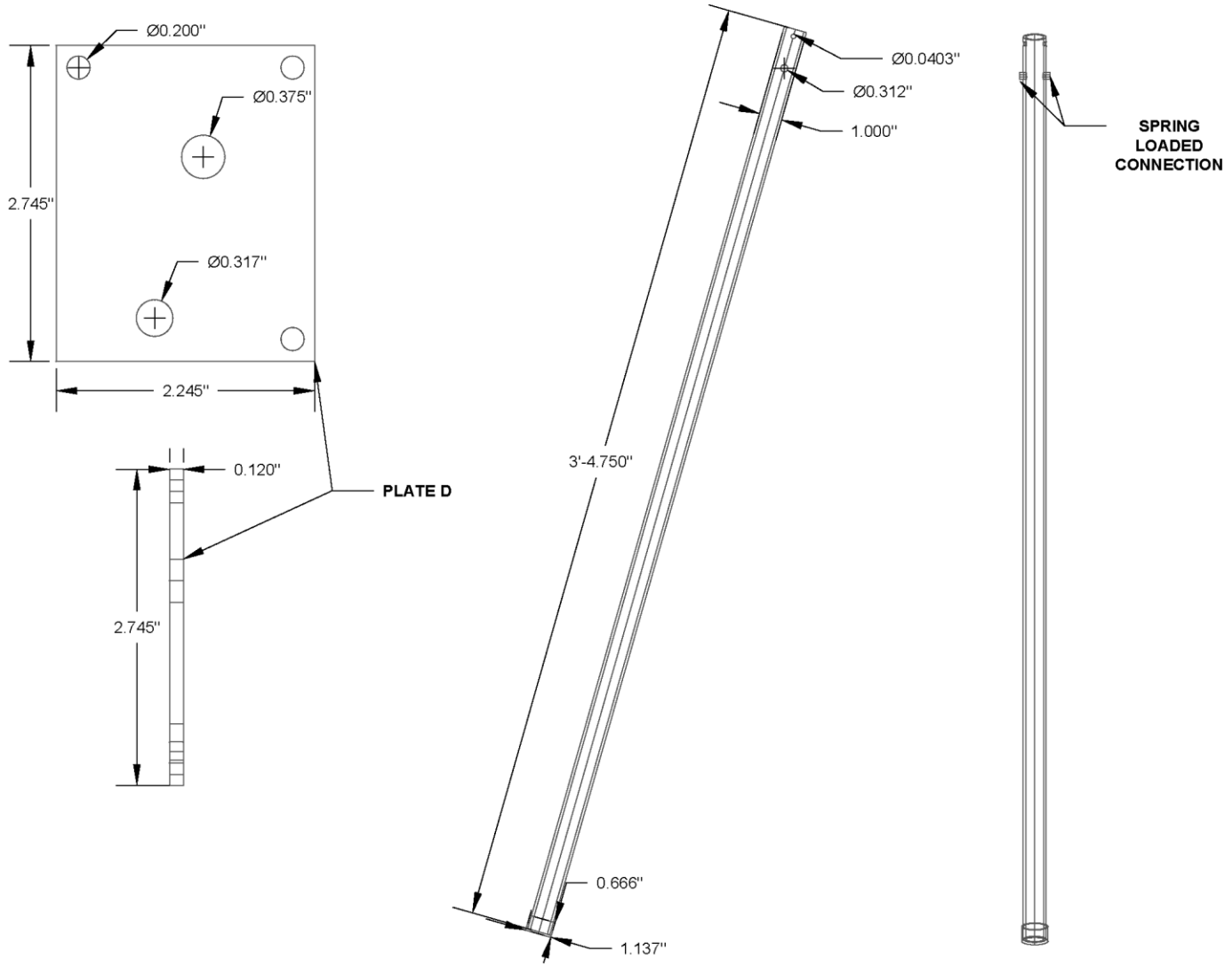

Figure 26: Stand Legs and Connection-D Plates

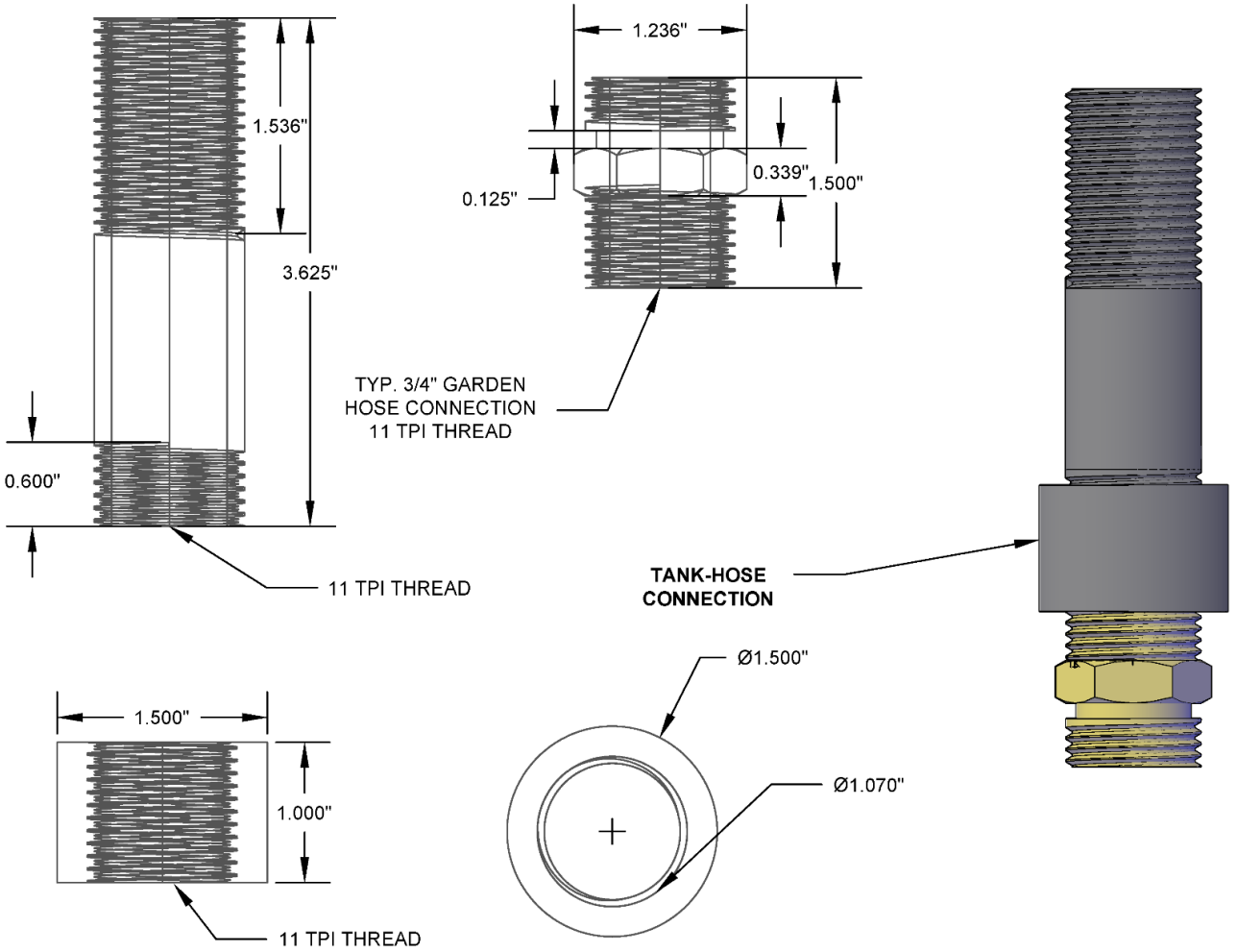

Figure 27: Tank Hose Connection Pieces