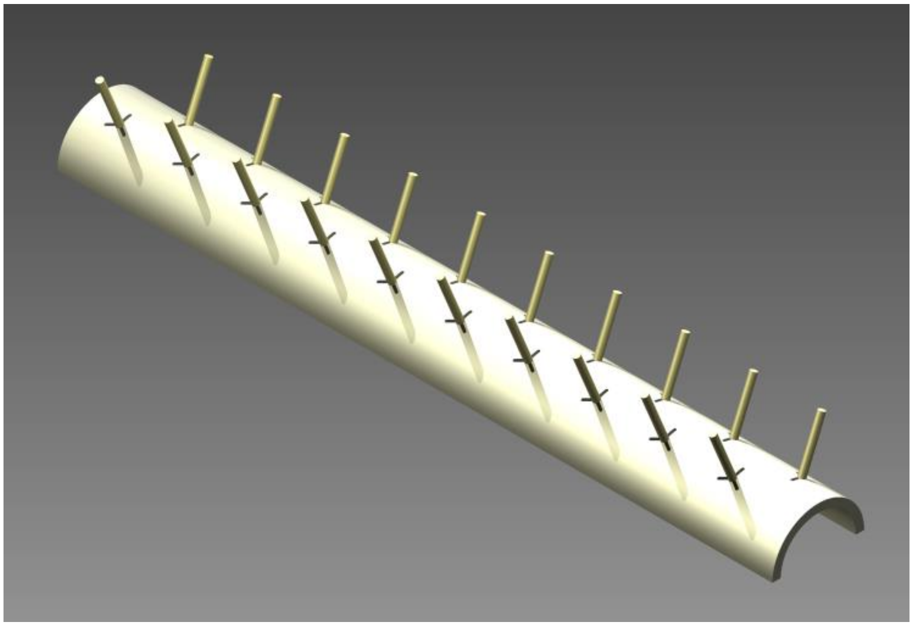
2015



Fixture for Corrosion Testing

JODY TAYLOR, JOSHUA MILLS, PHIL SHEETS, TRAVIS WEIGOLD

Introduction

Our team has developed an engineered fixture to hold parts during a fog corrosion test. The fixture is designed to fit and optimize the space inside a Q-fog Cycle Corrosion Tester 600 while conforming to ASTM B117 standards.

The design is a revision of a current fixture used by Eaton Corporation. We addressed design flaws that have compromised test results as well as optimized the fixture for the new test bench.

Objective

Eaton Corporation recently decommissioned an old corrosion test chamber and a new Q-fog Cycle Corrosion Tester 600 has been acquired to replace it. The fixturing used in the old tester will not fit the new one. The objective of this project was to improve on the original design and create a new fixture specifically for the new chamber. The features that were improved on are:

- Minimize fixture on part contact to eliminate puddling which can cause a false corrosion initiation point (Figure 1.)
- Create a replaceable pin system.
- Ensure fixture can hold the weight of a variety of parts

Figure 1

Specifications

The fixtures were designed so that the test will follow ASTM B117 standards. The following specifications were required to ensure the test would comply:

- Made from corrosion resistant material
- Should not warp or bow (creep) over time
- Cannot tip over when parts are loaded with a total weight per Eaton’s desire
- The parts cannot touch/drip on each other

Design

We selected materials, developed multiple designs and then narrowed them down to a final production design. The design was modeled with AutoDesk Inventor. From the model, production drawings were developed and delivered to the fabrication shop.

Research on what materials would be suitable for the working conditions of the test and what calculations would be required to assure that the selected material would be adequate (see bibliography for full list of references).

During the design and material selection we calculated the deflection and deformation of the materials under possible different conditions (see appendix A). The result of the calculations proved that the selected materials would be suitable for the application.

One calculation that was used was to see how a weight would deflect the fixture pins. The bending of the fixture pins with a load of 2lb would deflect them at most 5 degrees. This would make the final angle of the pin 28 degrees which is with in the 15-30 degree allowable range.

The total load the fixture could handle without failing was also calculated. The result showed the chosen material could handle a load of almost 3,000 lb an inch. The max required for the testing scenario would be 75 lb an inch. This is well within the calculated range.

The final design was reviewed and modified until we were satisfied with it. This design was modeled and cad drawings for production were developed from the model.

Components

The fixture is being produced in two different models to be able accommodate multiple sizes of fittings. Each model will consist of two different parts:

1. Body
2. Inserts

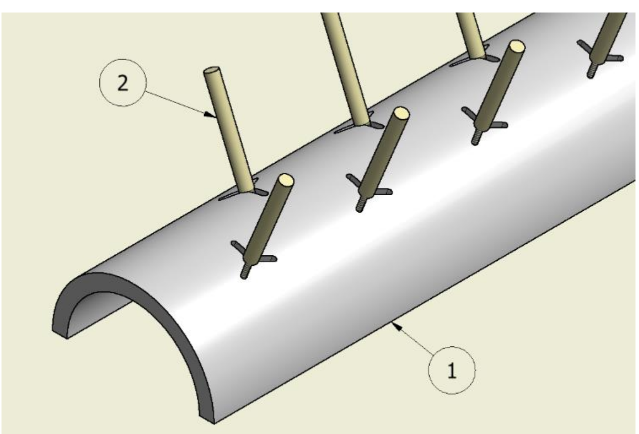


Figure 2

The body will be made from 3” schedule 80 PVC and will have 20 insert drains / threads milled into at even intervals. The inserts are cut from Chemical Resistant PVC Rod stock with the ends threaded to fit into the insert drains. These materials were chosen to withstand the harsh environment of the corrosion test chamber. The materials have more than 10x the strength required to support the material.

BODY			
Part	A	B	MATERIAL
#1	1/4-28 UNF-2B	R 1.75"	3" SCHD 80 PVC
#2	3/8-24 UNF-2B	R 1.75"	3" SCHD 80 PVC

Table 1

Table 1 defines the parameters of the two different body parts. The dimensions correspond with the labeled parts in figure 3 and 4. These different insert sizes allow for the different inserts to fit into the body. Insert part 1 has ¼-28 UNF-2B size threads and part 2 has 3/8-24 UNF-2B size threads. These are standard size threads and will be easily milled by most shops. The overall length of the fixture is 27.5” which is the same width as the corrosion test chamber and will fit tight against the walls.

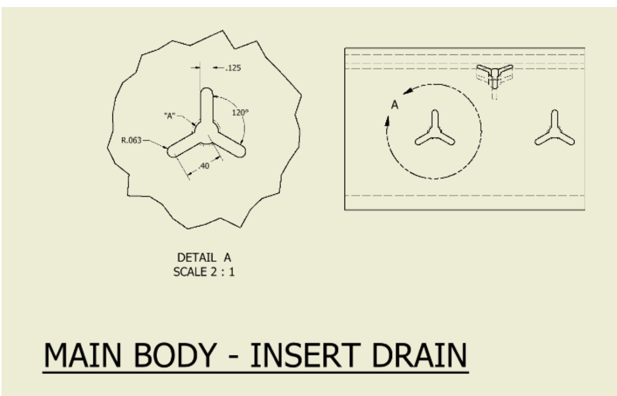


Figure 3

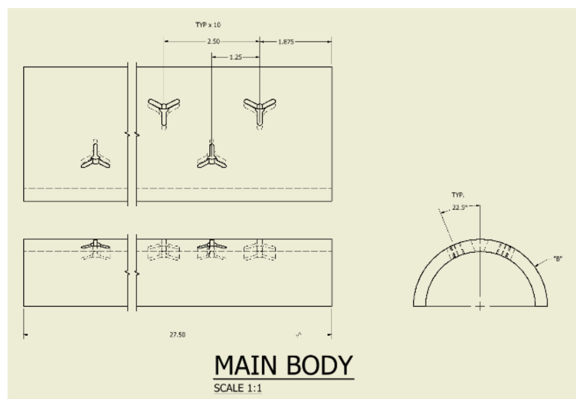


Figure 4

Table 2 defines the parameters of the 2 different insert parts.

INSERT			
Part	D	MATERIAL	C
#3	1/4"	1/4" CHEMICAL RESITANT PVC ROD	1/4-28 UNF-2A
#4	3/8"	3/8" CHEMICAL RESITANT PVC ROD	3/8-24 UNF-2A

Table 2

The dimensions correspond with the labels in figure 5.

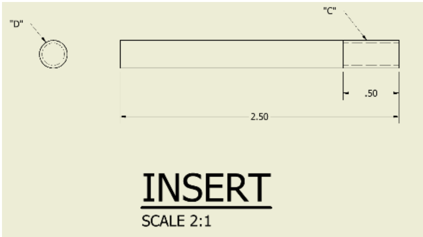


Figure 5

The inserts are 2.5” long with a 0.5” thread that will fit into the corresponding insert drain. The inserts will either have a ¼-28 UNF-2A (part #3) or a ¾-28 UNF-2A (part #4) thread. The diameter of the rod that will be milled is ¼” diameter (part #3) and ¾” diameter (part #4).

(see appendix B for complete production drawings)

Fabrication

Once the designs had been finalized and the production drawings finished, they were turned over to the fabrication shop at Eaton. The shop developed and executed a fabrication procedure. Figure 6 shows one of the bases being fabricated.

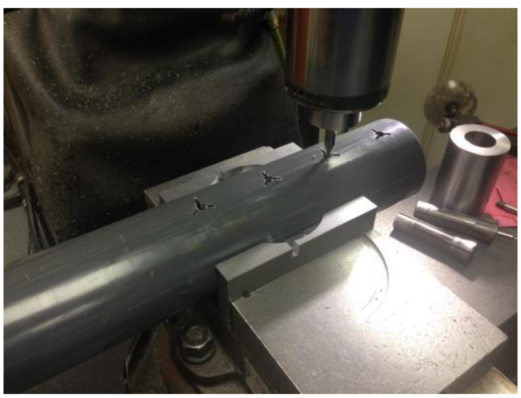


Figure 6

Figure 7 shows inserts after being milled.

Figure 7

Impressions left from the chuck of the lath can be seen. This was not expected, however, it resulted in a useful feature and were determined by Eaton to have no adverse effects on the fit and function of the fixtures.

The impressions left were able to be used as a means for installing the inserts into the body (figure 8). A box wrench fit perfectly around the flat areas left will being fabricated. This allowed for a much quicker assembly time.

Figure 8

Testing

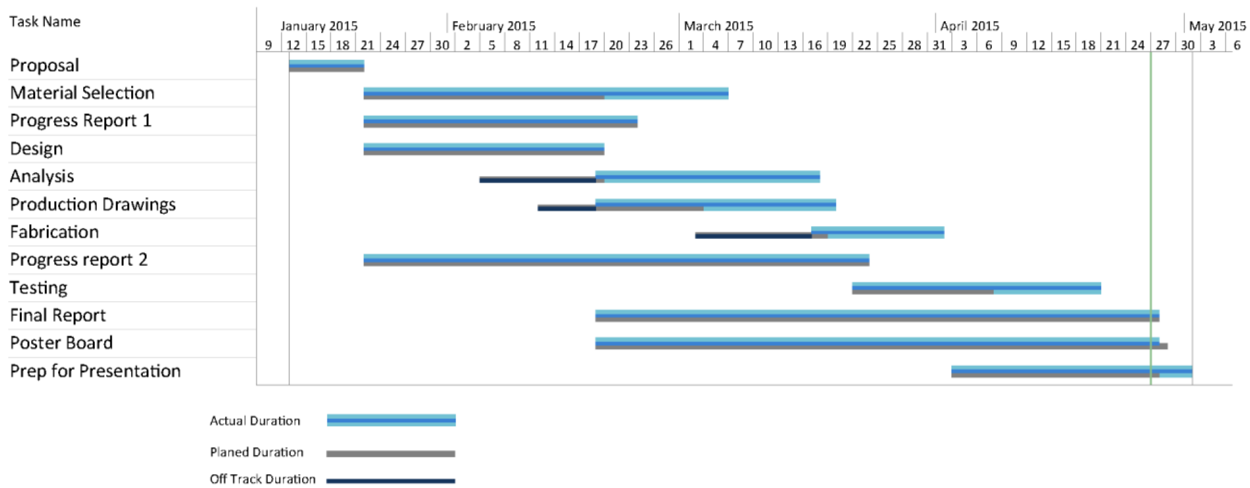
Testing was done per a procedure developed to determine if the fixture will allow the parts to be tested to ASTM B117 standards. At the time of this test, the fixtures have been tested in the fog tester for over 250 hours. The following specifications were tested for compliance:

- Made from corrosion resistant material
    - According to the specifications, the materials are suitable for the test environment. Visual inspect after use shows no signs of corrosion.
- Fit securely in the fog machine (approx. 27 inches long)
    - The fixture was placed into the Q-fog cycle corrosion tester and verified to fit securely.
- Hold several varieties of manufactured parts
    - A variety of parts were placed on the fixtures and were verified to meet the rest of the test specifications while installed.
- Prevent buildup of condensate fog
    - After a 250+ hours test cycle, the drainage cuts near at the base of the inserts have provided the designed drainage required to alleviate the condensate build up.
- Easily removable for cleaning
    - The fixtures were easily removed by a one person. The threaded inserts were able to be removed easily and replaced.
- Withstand 98^{o}F
    - 98^{o}F is within the operable temperature range of the PVC that was chose. Visual inspection after test verified that there was not any deformation due to heat.

- Cannot tip over when parts are loaded
    - A variety of parts were loaded on to the fixture in varying patterns to verify the stability of the fixture. No tip overs were encountered.
- The parts cannot touch/drip on each other
    - The parts were visually inspected and verified during a test cycle not to drip on each other.

Conclusion

The development and creation of the corrosion test fixture was a success. All required and planed specifications were met and verified by testing. The design time line goals were met or compensated (see table 3) for so that the fixtures was able to be field tested and implemented.



The fixtures came in over 75% under budget while meeting all requirements. Table 3 shows the total cost brake down of the production.

The fixtures are currently being used in operation by Eaton and they are pleased with the outcome. The production drawings provided along with the fixtures will allow for replacements to be produced quickly if need in the future.

Description	Material	Quantity	Cost
Main Body	**3” SCHD 80 PVC**	**15 feet**	**$ 103.10**
Pin – ¼ inch	**PVC (Type I) PVC**	**25 feet**	**$ 38.28**
Pin – 3/8 inch	**PVC (Type I) PVC**	**25 feet**	**$ 50.34**
Machining		**12 fixtures**	**$ 1934.00**
		Total Cost	**$ 2144.72**
		Fixtures Required	**12**
		Final cost per fixture	**$ 178.73**

Table 3

APPENDIX A: CALCULATIONS AND FIGURES

I. Deflection considered due to the weight of the main body.

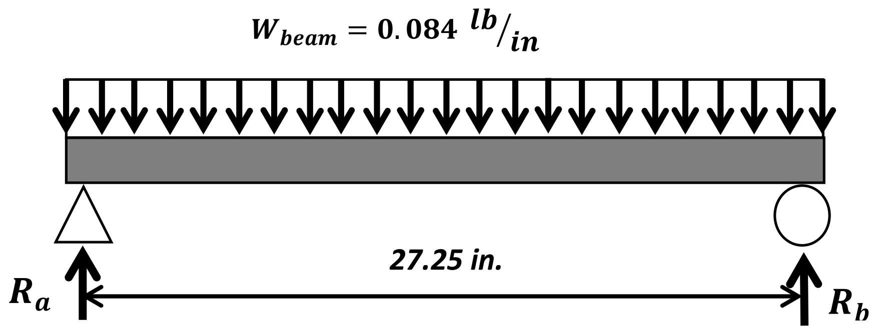


Figure 1b: Main Body Uniform Load

Material Dimensions - Schedule 80 PVC Pipe (George Fischer Harvel)

Nom Size	O.D.	I.D.	Min Wall	wt/ft
3.000 in	3.500 in	2.864 in	0.300 in	2.010 lb/ft

Weight of main body (W_b)

- Main Body is half section of pipe

$$W_b = \frac{2.010\ lb * ft}{ft * 2 * 12\ in} = 0.084\ {}^{lb}/_{in}$$

Equations used to calculate deflection due to the weight of the beam (Barry, Dupen)

$$R_a = R_b = \frac{W_b L}{2} = \frac{0.084\ lb * 27.25\ in}{in * 2} = 1.145\ lb$$

$$M_{max} = \frac{W_b L^2}{8}\ at\ the\ midspan = \frac{0.084\ lb * (27.25\ in)^2}{in * 8} = 7.797\ lb * in$$

$$\Delta_{max} = \frac{5wL^4}{384EI}\ at\ the\ midspan$$

Tensile Modulus of Elasticity @ 73°F (George Fischer Harvel)

- E = 420,000 psi

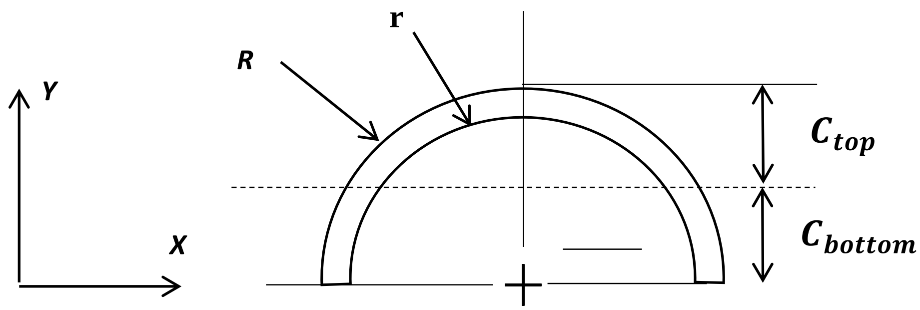


Figure 2b: Half Shell Diagram

Area moment of inertia Section properties (engineersedge.com)

$$I_y = 0.1098\,(R^4 - r^4) - \left(\frac{0.283R^2r^2(R-r)}{R+r}\right)$$

$$R_{O.D.} = 3.500\ in$$

$$r_{I.D.} = 2.864\ in$$

$$I_y = 0.1098\,(3.50\ in^4 - 2.864\ in^4) - \left(\frac{0.283(3.500\ in^2)(2.864\ in^2)(3.500\ in - 2.864\ in)}{3.500\ in - 2.864\ in}\right)$$

$$I_y = 6.2476\ in^4$$

Determine the deflection due to the weight of the beam

$$\Delta_{max} = \frac{5wL^4}{384EI} = \frac{5 * 0.084\ lb * (27.25\ in)^4 * \ in^2}{in * 384 * 420{,}000\ lb * 6.2476\ in^4}$$

$$Deflection\ of\ main\ body = \Delta_{max} = 2.30\ x\ 10^{-4}\ in$$

II. Reaction forces determined under average and maximum loaded conditions.

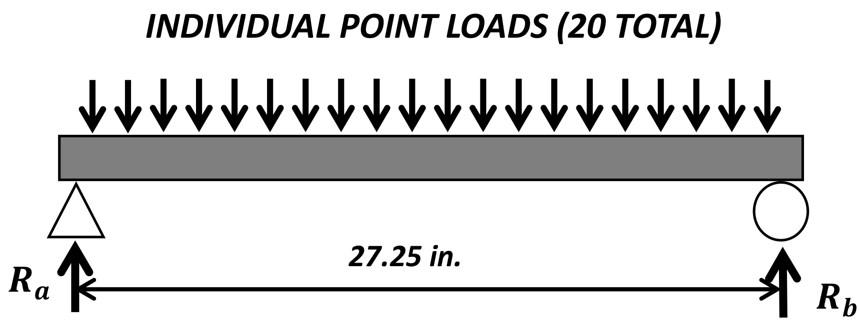


Figure 3b: Diagram of Point Load Symmetric Load Pattern

Load scenario 1:

- 20 Test Specimens.
- Distance between each specimen 1.286 inch.
- Weight of each specimen is 30 grams or 0.0661 lbs.
- Load is considered symmetrical

Load scenario 2:

- 20 Test Specimens.
- Distance between each specimen 1.286 inch.
- Weight of each specimen is 2.0 lbs.
- Load is considered symmetrical.

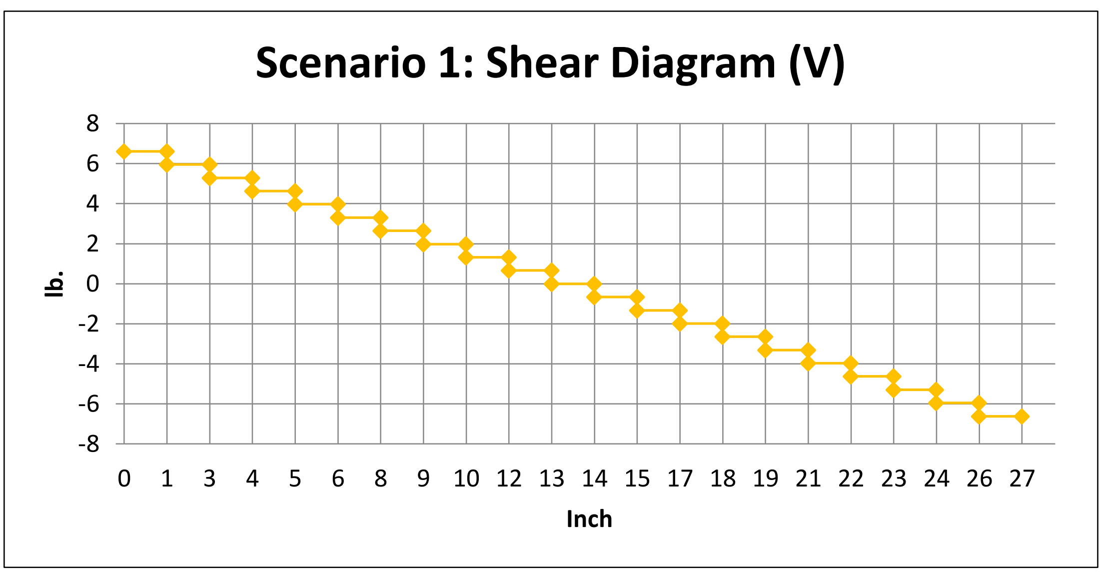
$$+^{\curvearrowleft}\Sigma M_a = Ra = Rb = \frac{W}{2} = \frac{WL}{2}$$

$$V_1 = R_a\,;\ V_2 = V_1 - P_2\,;\ V_3 = V_2 - P_3\,;\ \dots\dots\dots$$

$$M_{max} = \frac{Pbx}{L}$$

Table 2b: Results from calculations considering scenario 1.

Point Loads	Location from R_a (inch)	Point Load (lbs.)	ΣMa (Inch*lb)	Shear Points	Shear Loads (lbs.)	Moment Points	Moment (lb*in)
Ra	0	0	0	VRa	6.614	MRa	0
P1	1.286	0.0661	0.085	V1	6.614	M1	8.50
P2	2.571	0.0661	0.170	V2	5.9526	M2	16.16
P3	3.857	0.0661	0.255	V3	5.2912	M3	22.96
P4	5.143	0.0661	0.340	V4	4.6298	M4	28.92
P5	6.429	0.0661	0.425	V5	3.9684	M5	34.02
P6	7.714	0.0661	0.510	V6	3.307	M6	38.27
P7	9.000	0.0661	0.595	V7	2.6456	M7	41.68
P8	10.286	0.0661	0.680	V8	1.9842	M8	44.23
P9	11.571	0.0661	0.765	V9	1.3228	M9	45.93
P10	12.857	0.0661	0.850	V10	0.6614	M10	46.78
P11	14.143	0.0661	0.935	V11	0	M11	46.78
P12	15.429	0.0661	1.020	V12	-0.6614	M12	45.93
P13	16.714	0.0661	1.105	V13	-1.3228	M13	44.23
P14	18.000	0.0661	1.190	V14	-1.9842	M14	41.68
P15	19.286	0.0661	1.276	V15	-2.6456	M15	38.27
P16	20.571	0.0661	1.361	V16	-3.307	M16	34.02
P17	21.857	0.0661	1.446	V17	-3.9684	M17	28.92
P18	23.143	0.0661	1.531	V18	-4.6298	M18	22.96
P19	24.429	0.0661	1.616	V19	-5.2912	M19	16.16
P20	25.714	0.0661	1.701	V20	-5.9526	M20	8.50
Rb	0	0	0	VRb	-6.614	MRb	0.00



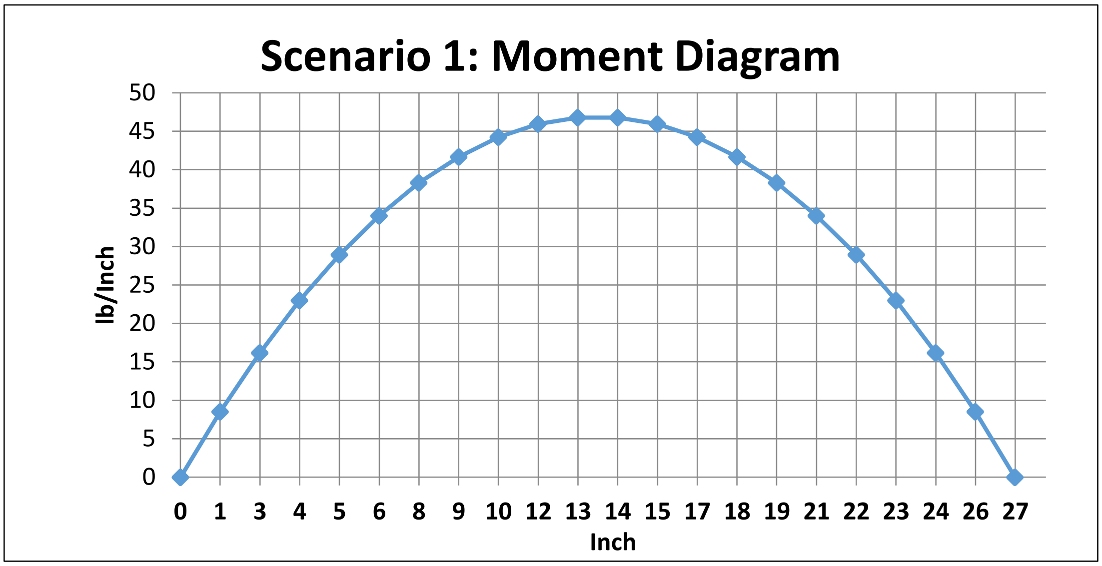


Figure 5b: Moment Diagram for Load Scenario 1

Table 3b: Results from calculations considering scenario 2.

Point Loads	Location from R_a (inch)	Point Load (lbs.)	ΣMa (Inch*lb)	Shear Points	Shear Loads (lbs.)	Moment Points	Moment (lb*in)
Ra	0.000	0.0	0.0	VRa	20.0	MRa	0
1	1.286	2.0	2.571	V1	20.0	M1	25.71
2	2.571	2.0	5.143	V2	18.0	M2	48.86
3	3.857	2.0	7.714	V3	16.0	M3	69.44
4	5.143	2.0	10.286	V4	14.0	M4	87.44
5	6.429	2.0	12.857	V5	12.0	M5	102.87
6	7.714	2.0	15.429	V6	10.0	M6	115.73
7	9.000	2.0	18.000	V7	8.0	M7	126.02
8	10.286	2.0	20.571	V8	6.0	M8	133.74
9	11.571	2.0	23.143	V9	4.0	M9	138.88
10	12.857	2.0	25.714	V10	2.0	M10	141.45
11	14.143	2.0	28.286	V11	0.0	M11	141.45
12	15.429	2.0	30.857	V12	-2.0	M12	138.88
13	16.714	2.0	33.429	V13	-4.0	M13	133.74
14	18.000	2.0	36.000	V14	-6.0	M14	126.02
15	19.286	2.0	38.571	V15	-8.0	M15	115.73
16	20.571	2.0	41.143	V16	-10.0	M16	102.87
17	21.857	2.0	43.714	V17	-12.0	M17	87.44
18	23.143	2.0	46.286	V18	-14.0	M18	69.44
19	24.429	2.0	48.857	V19	-16.0	M19	48.86
20	25.714	2.0	51.429	V20	-18.0	M20	25.71
Rb	27.000	0.0	0.0	V_{Rb}	-20.0	M_{Rb}	0.0

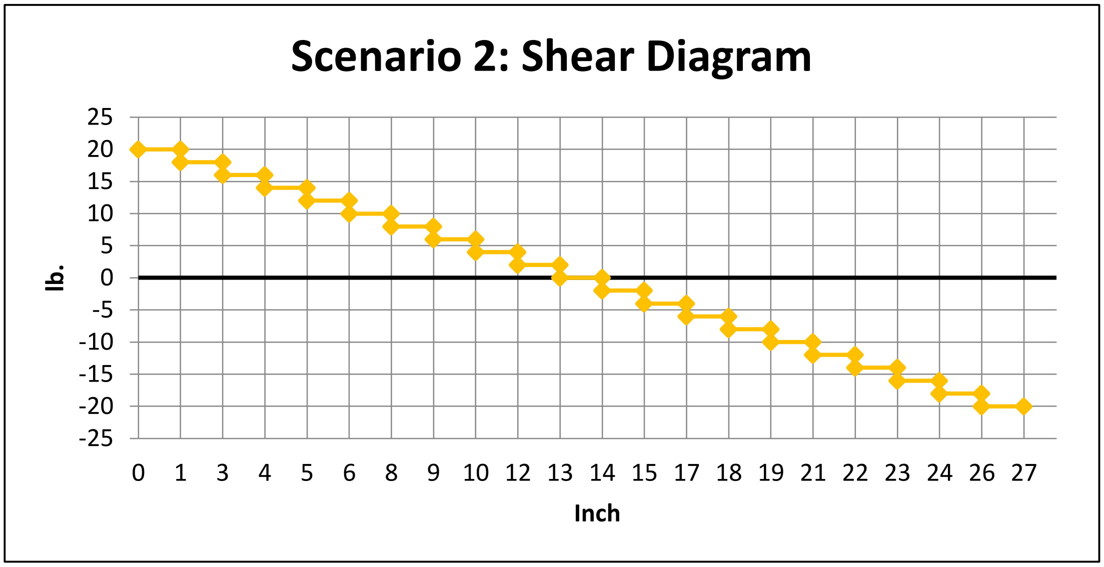


Figure 6b: Shear Force Diagram for Load Scenario 2

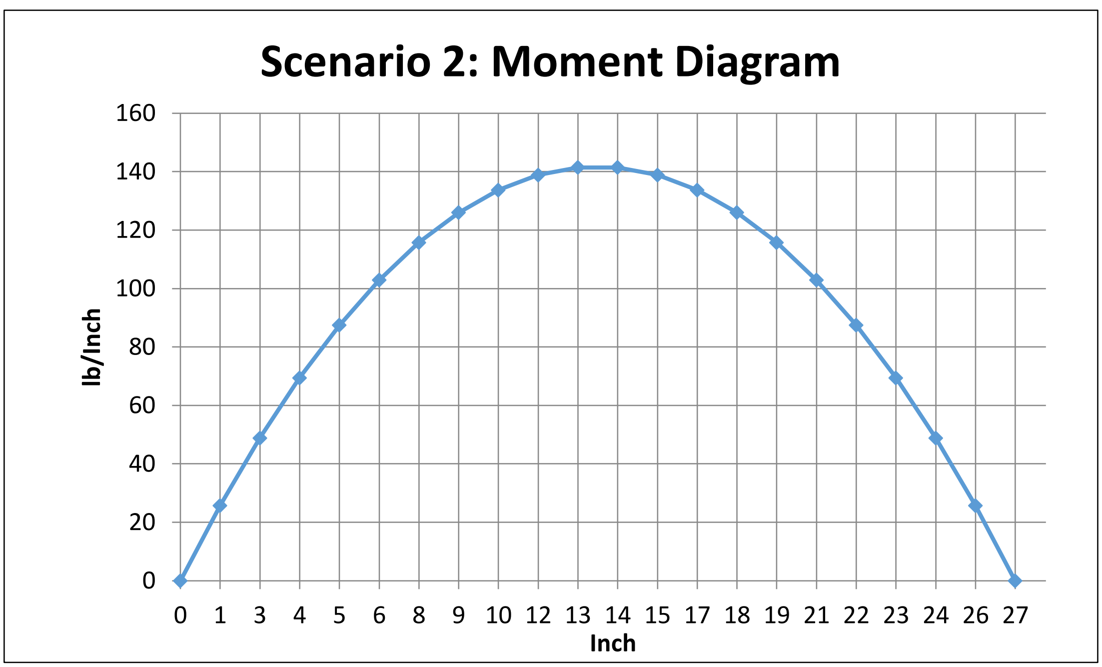


Figure 7b: Moment Diagram for Load Scenario 1

III. Maximum Deflection:

Maximum deflection at the mid-span was calculated considering the identical point loads, symmetrically placed on the main body.

$$\Delta_{max} = \frac{Pa}{24EI}(3L^2 - 4a^2)\ at\ the\ midspan$$

Table 4b: Results from calculations of maximum deflection at the mid-span.

Point Loads	Location from R_a (inch)	Point Load (lbs.)	Δ_{max} @ mid-span (inch)
1	1.286	2.0	8.90E-05
2	2.571	2.0	1.76E-04
3	3.857	2.0	2.61E-04
4	5.143	2.0	3.40E-04
5	6.429	2.0	4.13E-04
6	7.714	2.0	4.77E-04
7	9.000	2.0	5.32E-04
8	10.286	2.0	5.76E-04
9	11.571	2.0	6.07E-04
10	12.857	2.0	6.21E-04
		Total Deflection	4.09E-03

Total Deflection at the mid-span due to the weight of the main body and maximum load condition.

$$Deflection\ due\ to\ weight\ of\ the\ beam = \Delta_{max} = 2.30\ x\ 10^{-4}\ in$$

$$Deflection\ due\ to\ maximum\ load\ condition = \Delta_{max} = 4.09\ x\ 10^{-3}\ in$$

$$Total\ Deflect\ at\ the\ midspan\ \Delta_{max} = 2.30\ x\ 10^{-4}\ in + 4.09\ x\ 10^{-3}\ in\ = 4.32\ x\ 10^{-3}\ in$$

IV. Bending Stress about the main body:

Bending stress calculated under maximum loading condition. Compound shapes like the half-pipe are not symmetrical about the x-x neutral axis, so there are two centroid values (C_{top} and C_{bottom}) to consider. The largest bending stress occurs on the surface with the largest centroid value. (Barry, Dupen)

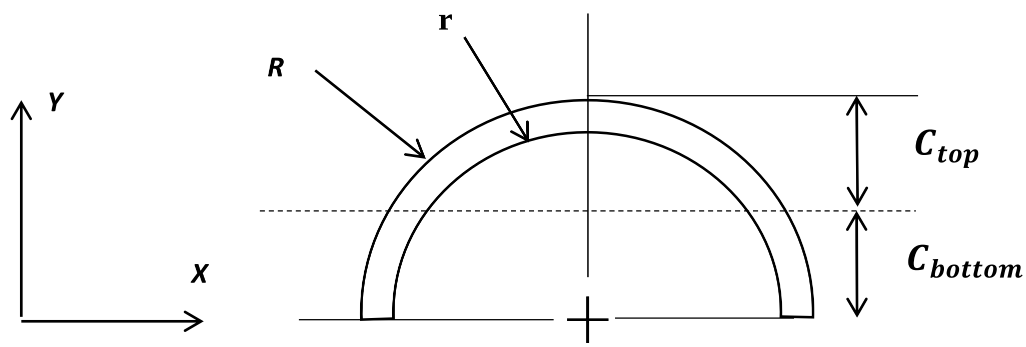


Figure 8b: Half-Shell Diagram

$$C_{top} = R\left(1 - \frac{2}{\pi}\right) = 1.75\ in\ \left(1 - \frac{2}{\pi}\right) = 0.636\ in$$

$$C_{bottom} = \frac{2R}{\pi} = \frac{2(1.75\ in)}{\pi} = 1.114\ in$$

The largest stress is the tensile stress along the bottom surface of the half-pipe.

$$\sigma = \frac{MC_{bottom}}{I_y} = \frac{141.45\ lb * in\ (1.114\ in)}{6.2476\ in^4} = 25.223\ psi$$

V. Pin Calculations (reaction force and deflection).

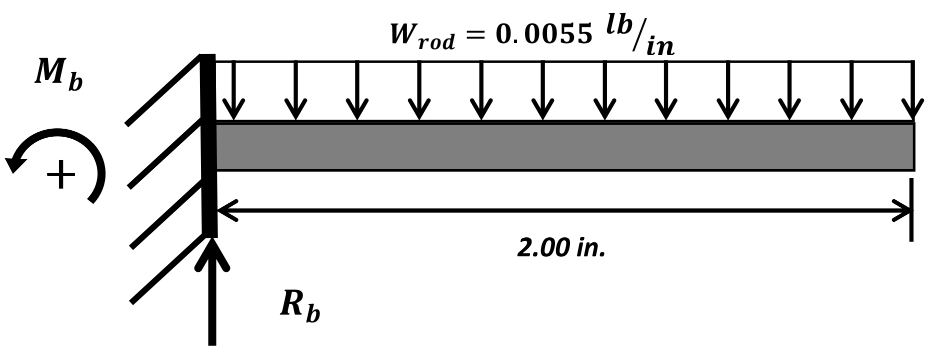


Figure 9b: Uniform distributed load along the pin.

Deflection due to the weight of the pin

$$\Delta_{max} = \frac{wL^4}{8EI}$$

$$R_b = V_{max} = wL$$

$$M_b = M_{max} = \frac{xL^2}{2}$$

Table 5b: Results of calculations uniform load.

DEFLECTION DUE TO WEIGHT OF PIN		
PIN SIZE	0.250 in.	0.375 in.
R_b	0.0048 lb.	0.011 lb.
M_b	0.0048 lb. * in.	0.011 lb.*in.
Δ_{max}	$5.854\ x\ 10^{-4}\ in$	$2.654\ x\ 10^{-5}\ in$

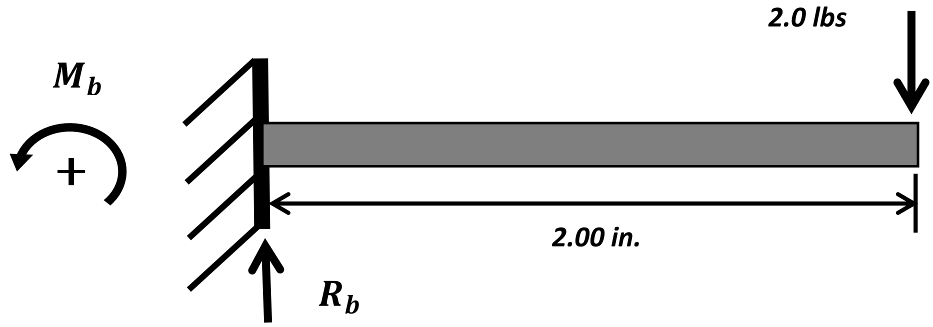


Figure 10b: Pin diagram under maximum loaded condition.

Maximum load condition considered as 2.0 lb. point load at the end of the pin.

$$R_b = V_{max} = P$$

$$M_b = M_{max} = PL$$

$$\Delta_{max} = \frac{PL^3}{3EI}$$

Table 6b: Calculation results from maximum load condition.

DEFLECTION DUE TO POINT LOAD AT END OF PIN		
PIN SIZE	0.250 in.	0.375 in.
$\boldsymbol{R_b}$	2.00 lb.	2.00 lb.
$\boldsymbol{M_b}$	4.00 lb. * in.	4.00 lb. * in.
$\Delta_{\boldsymbol{max}}$	0.065 in.	0.0128 in.
$\Delta_{\boldsymbol{max,TOTAL}}$	0.066 in.	0.0129 in.

VI. Bending stress about the pin.

Maximum bending stress due to 2.0 lb point load at the end of the pin.

$$Section\ modulus = S_x = \frac{\pi D^3}{32}$$

$$Bending\ stress = \sigma = \frac{M}{S}$$

<u>0.25 inch pin</u>

$$M = 4.00\ lb * in$$

$$S = 0.0015\ in^3$$

$$\sigma = 2666.7\ psi$$

<u>0.375 inch pin</u>

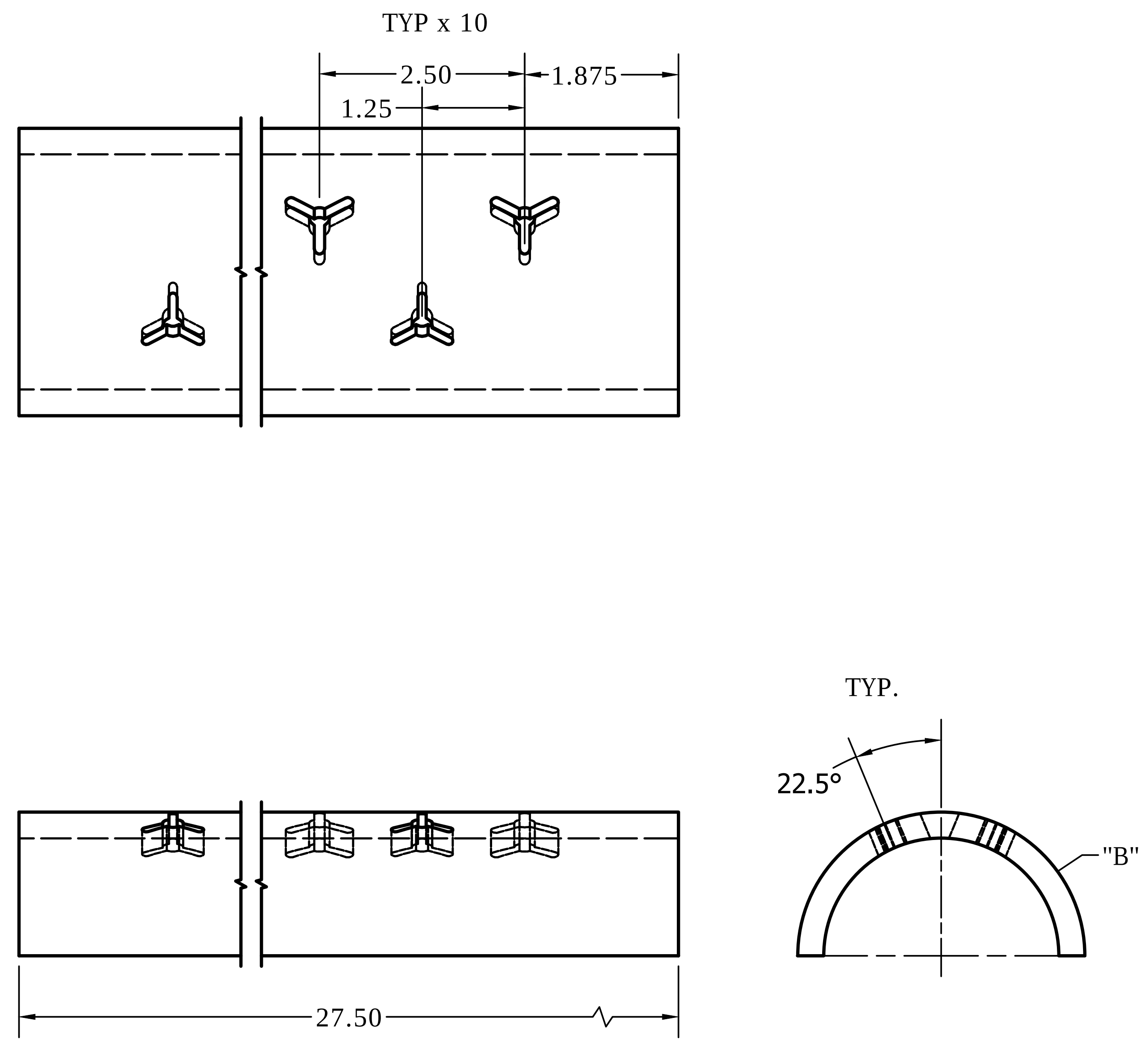
$$M = 4.00\ lb * in$$

$$S = 0.0052\ in^3$$

$$\sigma = 769.20\ psi$$

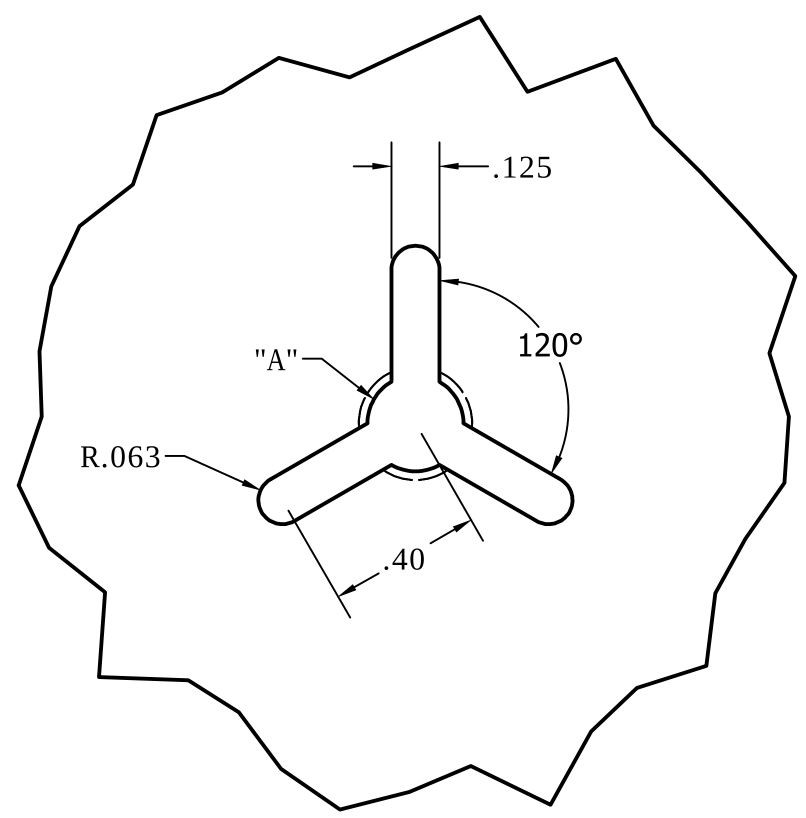
Appendix B: Production Drawing

SEE FOLLOWING PAGE FOR FULL SIZE DRAWING

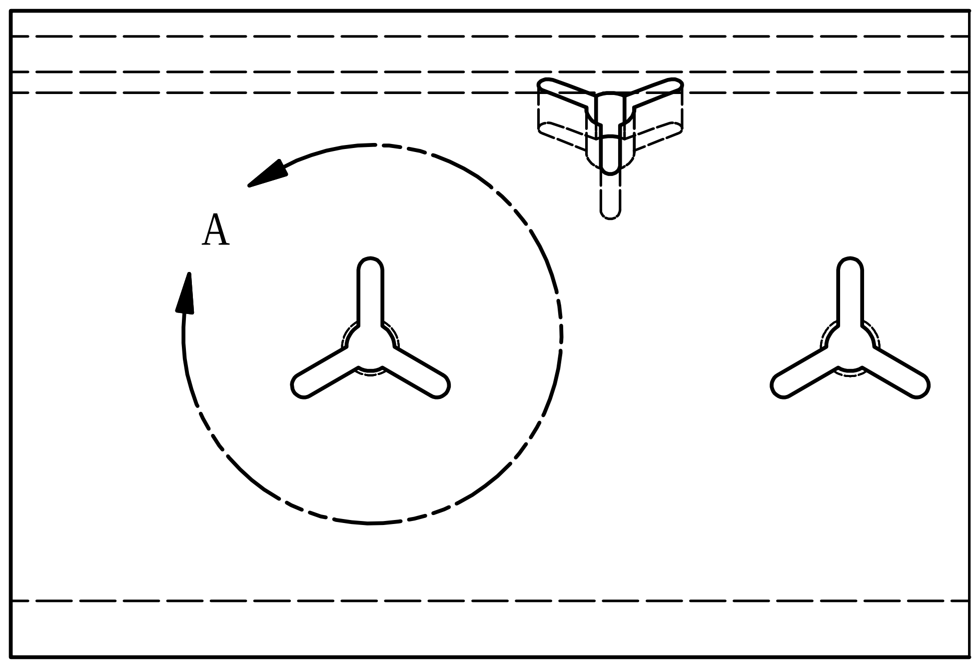


MAIN BODY

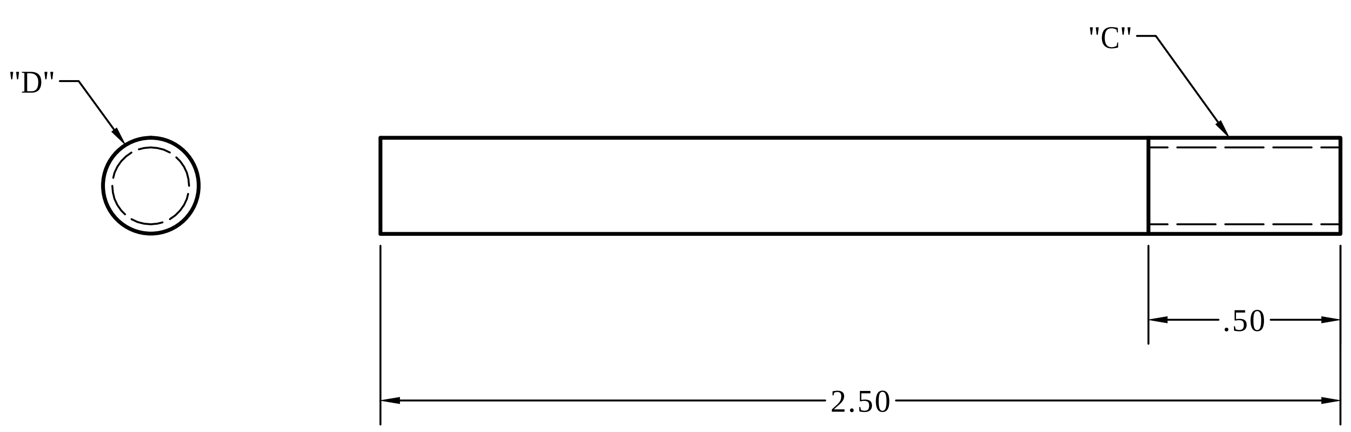
SCALE 1:2



DETAIL A
SCALE 2 : 1

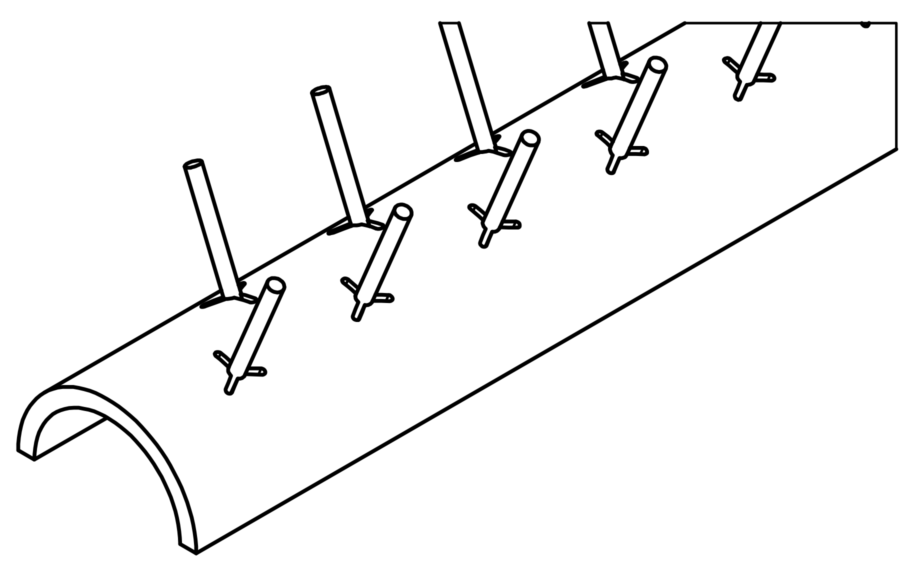


MAIN BODY - INSERT DRAIN



INSERT

SCALE 2:1



ASSEMBLY

BODY			
Part	A	B	MATERIAL
#1	1/4-28 UNF-2B	R 1.75"	3" SCHD 80 PVC
#2	3/8-24 UNF-2B	R 1.75"	3" SCHD 80 PVC

INSERT			
Part	D	MATERIAL	C
#3	1/4"	1/4" CHEMICAL RESITANT PVC ROD	1/4-28 UNF-2A
#4	3/8"	3/8" CHEMICAL RESITANT PVC ROD	3/8-24 UNF-2A

*	
FOR PART No.	

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
DIMENSIONS ARE AFTER PLATING
TOLERANCE ON:
.XX ±.02 | .XXX ±.005 | ANGLES ± 1/4°
125 FINISH PER ANSI Y14.36
REMOVE ALL BURRS
ALL CORNERS .010/.005 R. OR BREAK
ALL DIAMETERS MUST BE CONCENTRIC WITHIN .005 T.I.R.
DIMENSIONING PER ANSI Y14.5
WORK TO DIMENSIONS
DO NOT SCALE

DRAWN J TAYLOR	DATE *
CHECKED J TAYLOR	DATE *
APPROVED J TAYLOR	DATE *
TCN NUMBER *	DATE *
PROJECT NO.	APC NO.
DESIGN APPROVED	
APPROVED	

EATON Aeroquip PRODUCTS
Van Wert, Ohio, U.S.A.

DRAWING TITLE: TEST FIXTURE

SIZE	(CAGE) CODE NO.	DRAWING NUMBER
C	09479	1
SCALE N/A	R	CAD	SHEET 1 OF 1

REV.
SH. *
DWG. NO. *

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