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Student Report (National Research Council of Canada. Institute for Ocean Technology); no. SR-2007-06, 2007

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DOCUMENTATION PAGE

REPORT NUMBER SR-2007-06	NRC REPORT NUMBER	DATE April 2007		
REPORT SECURITY CLASSIFICATION Unclassified		DISTRIBUTION Unlimited		
TITLE Pipe-in-Pipe Mount Design				
AUTHOR(S) B. Guy				
CORPORATE AUTHOR(S)/PERFORMING AGENCY(S) National Research Council – Institute for Ocean Technology				
PUBLICATION				
SPONSORING AGENCY(S) NRC-IOT				
IMD PROJECT NUMBER 42_2193_16		NRC FILE NUMBER		
KEY WORDS Pipe in pipe, 42_2193_16, Riser, MDTF		PAGES 26	FIGS. 22	TABLES 0
SUMMARY This project concerns the design of a mounting system for an experimental riser model. Two concepts, a structure and an adapter joint, have been conceived, and the results are shown.				
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PIPE-IN-PIPE MOUNT DESIGN

SR-2007-06

Brent Guy

April 2007

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1.0 INTRODUCTION

This project is related to the Pipe-in-Pipe (PIP) Riser Systems project being completed by Dr. Ahmed Derradji. Briefly, the project pertains to the attempt to find a suitable mounting system for the experimental pipe being tested in water. Two main concepts have been conceived, one using a structure with a mounted actuator frame, and the other using the Marine Dynamic Test Facility (MDTF) struts attached to the existing tow post adapter, which would oscillate the pipe back and forth. Specifically, the second concept refers to a bolt pattern adapter joint connecting the load cell of the riser to the bottom of the tow post adapter. Both concepts have been considered, modelled, and simulated. The results are shown.

2.0 PIPE-IN-PIPE RISER SYSTEMS

2.1 Project Overview

Project Name: “Performance of pipe-in-pipe riser systems”

Project Number: 42_2193_16

The project concerns the experimental testing of riser systems for use offshore in coastal Newfoundland and Labrador. It is an attempt to measure the effect of such harsh environmental conditions on PIP systems. The tests will be carried out in both air and water, with air setting the standard for all tests thereafter. The pipe system consists of inner and outer pipes, with specifically placed spacers in between. This design should provide superior strength and structural integrity compared to simple, single-pipe designs. The experimental riser system has been both designed and fabricated internally at the Institute for Ocean Technology (IOT), and the experiment is to be performed there as well.

2.1.1 Purpose

The purpose of the experiment is:

- A) To determine the fatigue life span and performance of PIP riser systems;
- B) To compare such performance to that of a single-pipe design.

2.1.2 Collaborators

The collaborators on the project are A. Derradji, I. Konuk, and R. Beresford.

2.1.3 Environmental Considerations

As shown in Figure 1, offshore Newfoundland and Labrador consists of the Grand Banks, Felmish Cap, and Orphan Basin. The existing oil fields in this region are Hibernia, Terra Nova, and White Rose. The ocean environment is known to be typically harsh and rugged. It is characterized by high winds and waves, icebergs, and continuous currents. The presence of high winds makes the region especially harsh and tumultuous. The offshore structures present in these areas must be precisely engineered to be able to withstand such environmental damage. In what is considered one of the most severe ocean locations in the world, it is difficult to design any form of large structures. It is only through simulation and experimentation can one accurately gain a degree of certainty.

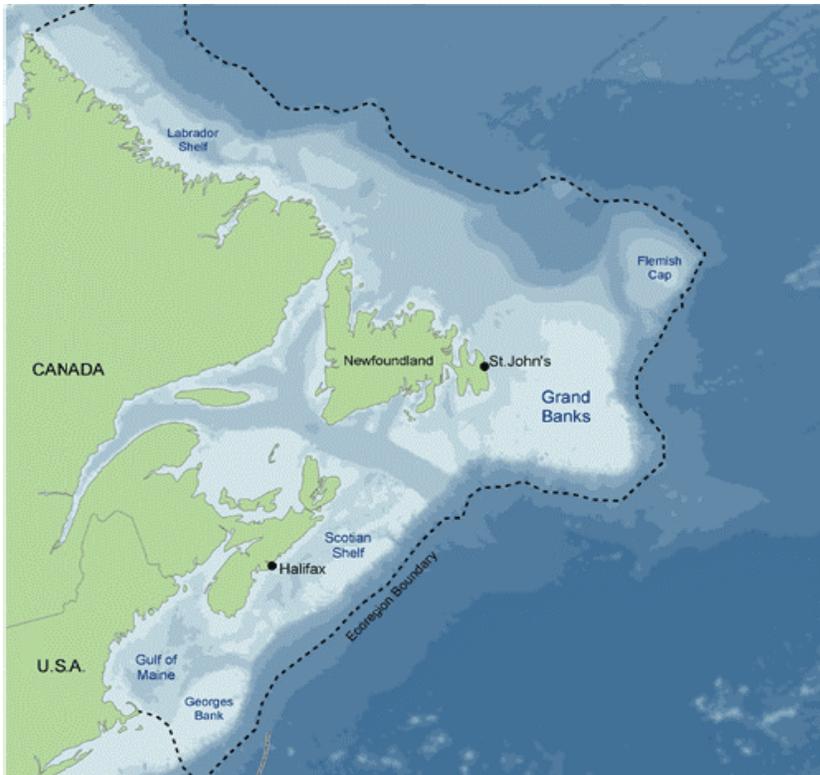


Figure 1 – Coastal Newfoundland and Labrador

2.2 Riser Systems Configuration

There are many different types of riser configurations available. The one that has been selected for experimentation is the “Catenary (Free Hanging) Configuration”, shown in Figure 2. It is favourable for its simplicity and low cost, but in some instances can be considered an unrealistic model for extreme weather conditions.



Figure 2 – Free Hanging Configuration

2.3 Experiment

2.3.1 Set-Up

For the tests completed in air, the pipe was to be oscillated back and forth by a hydraulic actuator mounted to a frame. The frame was designed by Trent Slade, and can be seen in Figure 6. The riser model itself is made of standard aluminum, and is shown in Figure 3. Each pipe has a wall thickness of 3.175 mm. The diameter of the outer pipe is 101.6 mm, and the inner diameter is 95.25 mm. The outer pipe has a length of 5.0 m, and the inner pipe measures slightly shorter, at 4.88 m. The spacers, as shown in Figure 5, are located between the two pipes and are made of rubber. Rubber was selected to reduce vibrations caused by metal striking metal. The spacers are located every 0.5 m along the length of the model.

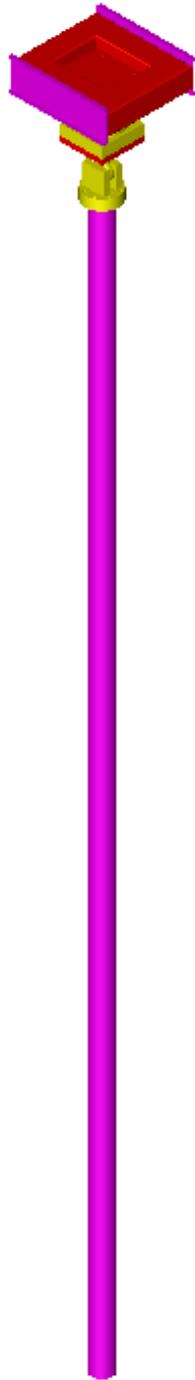


Figure 3 – Pipe-in-Pipe Riser Model

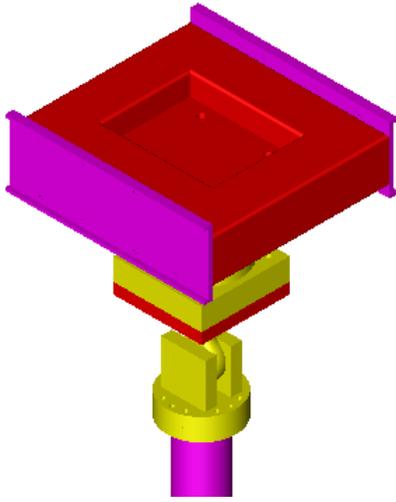


Figure 4 – Load Cell Mount



Figure 5 – Spacer Assembly

2.3.2 Instrumentation

The experiment makes use of the following:

- yo-yo potentiometer
- load cell
- motion sensors
- motion pack
- Peak Motus motion tracking software

2.3.3 *Test Frame Concepts*

For the experiments in water, a new test frame had to be designed. The two concepts are presented in Sections 3.0 and 4.0.

3.0 STRUCTURAL CONCEPT

3.1 Overview

In the early stages of the experimental phase of the project, there arose a need to develop some form of tower structure for the test frame. A structure that would be made of 6 in. x 6 in. box steel tubing was a viable option. The structure would be mounted to bolt holes in the floor of the Ocean Engineering Basin (OEB). Upon further investigation, it was noted that the existing holes in the floor would not be suitable, as some were previously filled with a silicon substance, and some were not suitably straight. The structure had to be tall enough to allow the pipe to hang freely, and could not be filled with internal cross bracings that would interfere with pipe activity. The top platform of the structure would mount to the bottom footprint of the actuator frame, to be discussed later.

3.2 Test Frame

The test frame supports the hydraulic actuator used to oscillate the riser system, and was designed primarily by Trent Slade. It is shown in Figures 6, 7, 8 and 9. It is simply a box-style hollow frame with four legs. On the bottom of each of the legs is a mounting pattern.

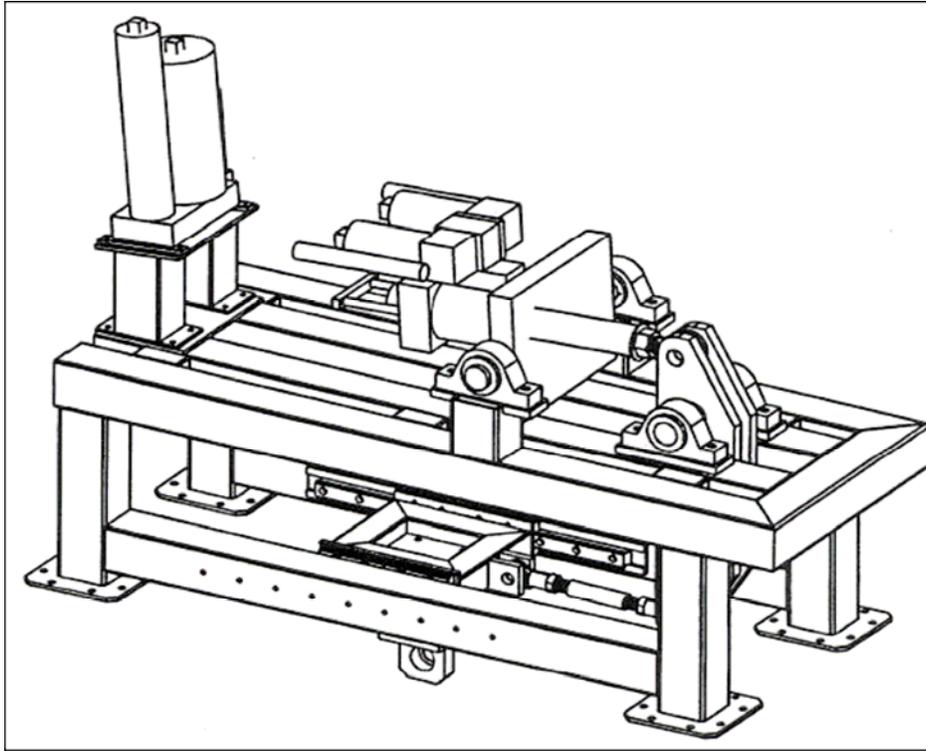


Figure 6 – Actuator Frame Assembly

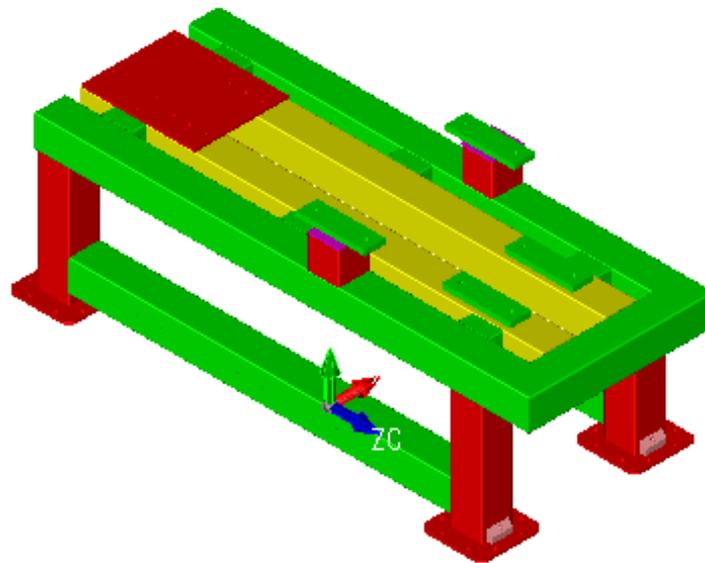


Figure 7 – Actuator Frame Isometric

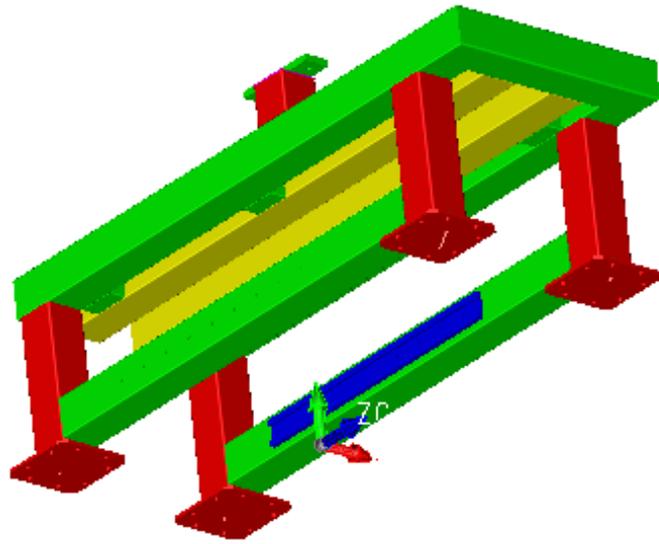


Figure 8 – Actuator Frame Bottom

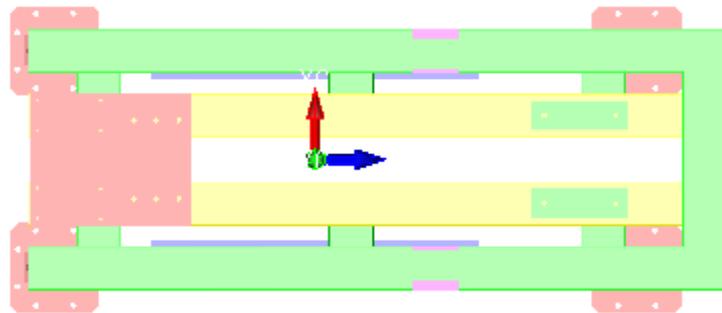


Figure 9 – Actuator Frame Top

3.3 Design Concepts

Two concepts were proposed. Shown in Figure 10, the first concept consisted of a webbed front and back, with hollow interior and side sections, and bracings running across the top and bottom. The second design was a four-legged structure with bracings in the vertices. It provided a lot of room for pipe activity and camera visibility, as well as strength in the direction perpendicular to pipe motion. Notice, in Figure 11, that the square bracing on the bottom of the structure is elevated slightly.

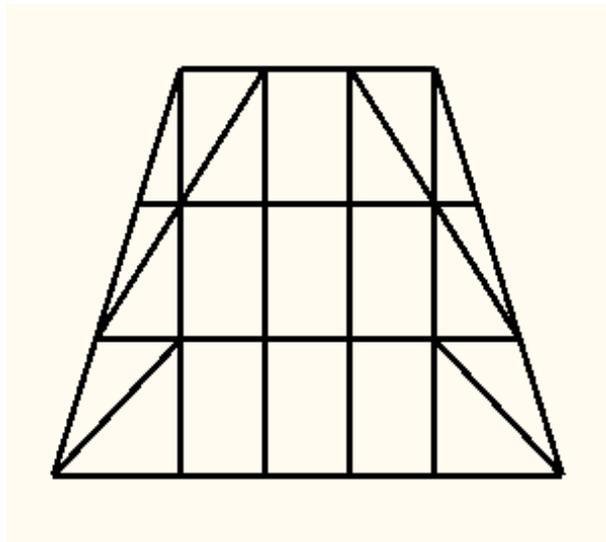


Figure 10 – Structural Concept #1

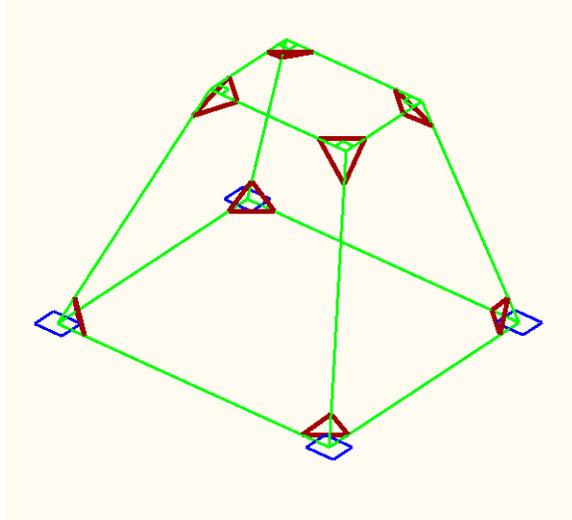


Figure 11 – Structural Concept #2 Profile

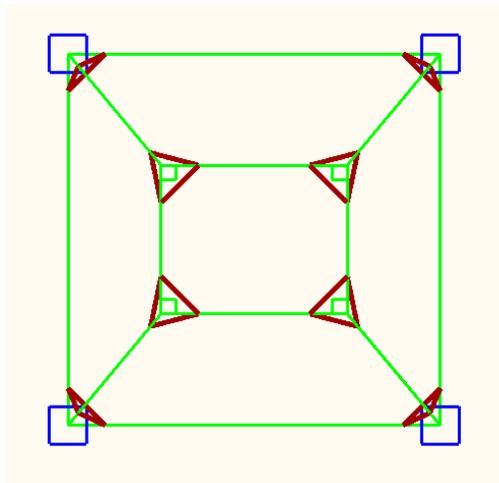


Figure 12 – Structural Concept #2 Top

In the end it was decided that the first concept would be most suitable, as the deflection values (see Section 3.4 ANSYS Analysis) in the second concept were too large. After some additional bracings were added, the final concept was to be rendered in a CAD environment. Only after viewing the design on a more realistic scale, would it be selected for production.

3.4 ANSYS Analysis

ANSYS is a finite element analysis (FEA) software package. FEA is a numerical method of deconstructing a complex system into smaller pieces. It is best known for its applications in mechanical design. It can determine stress, strain, and deflection modes, determine buckling loads and mode shapes, and even analyse thermal or electromagnetic behaviour. To keep the discussion succinct, the following two diagrams address the simulation adequately. In Figure 13, the red arrows are the applied horizontal loads, which simulate the oscillation of the hydraulic actuator. The bottom of the structure is fixed, as though it were mounted to the floor. The simulation is started, and in Figure 14 one can see the mode shape, of how the structure bends and deflects under the load condition applied. These deflections are exaggerated in the current image, and the exaggeration scale is user-determined. For the ANSYS code used for the simulation, see Appendices.

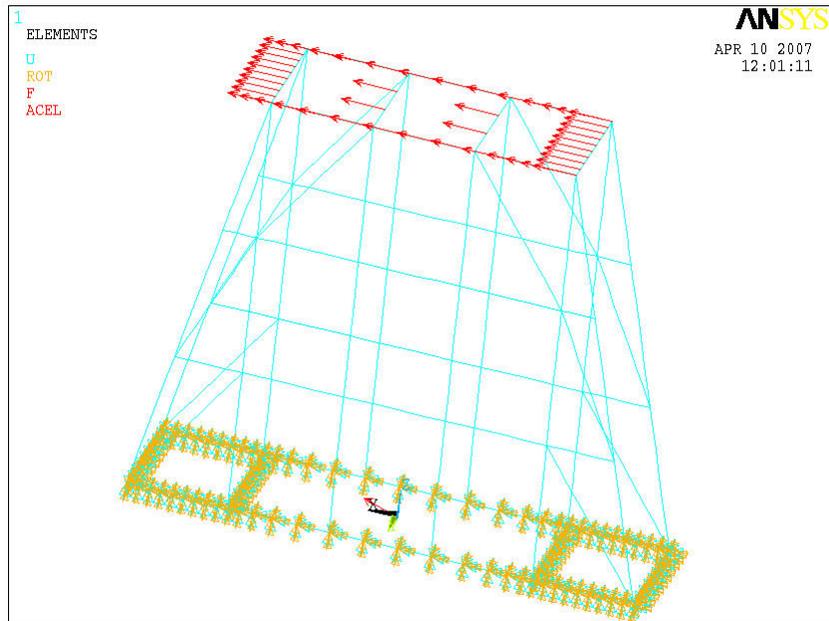


Figure 13 – Applying Loads to Model

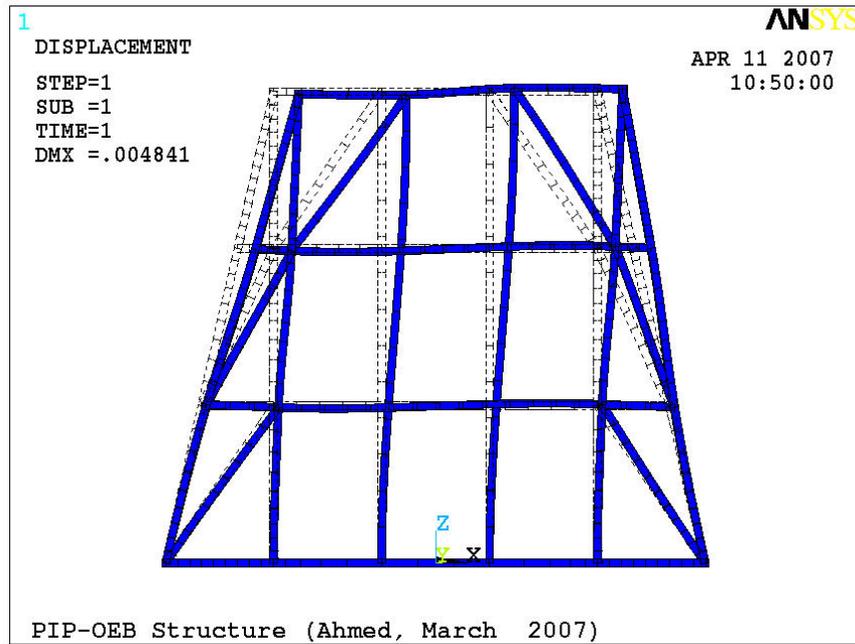


Figure 14 – Mode Shape

3.5 CAD Model

The following images are the rendered model of the structure proposed:

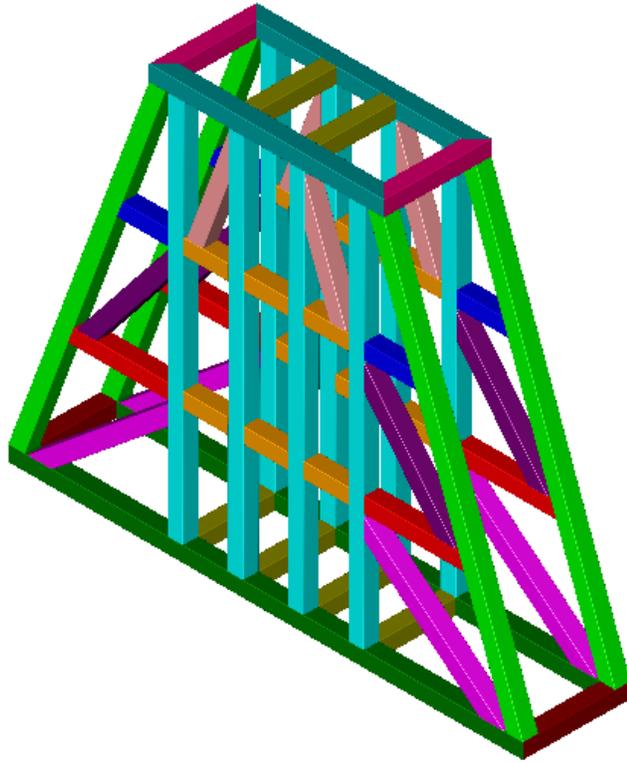


Figure 15 – Structural Design Isometric

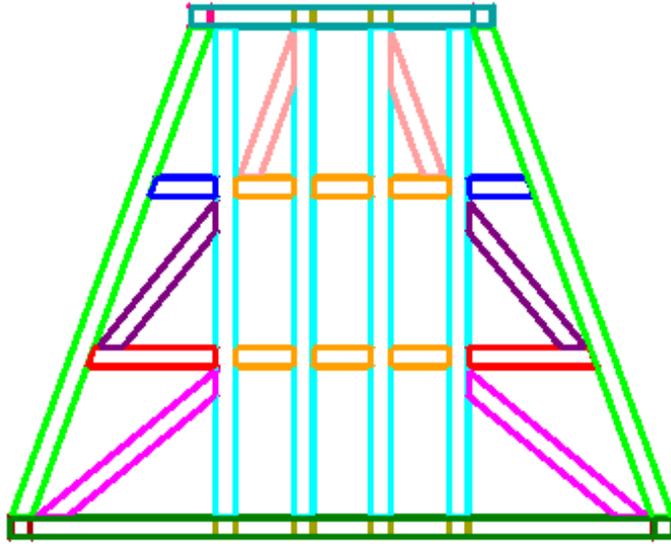


Figure 16 – Structural Design Front

The faults in using a structure appeared after rendering. Due to the sheer size of the structure, and the dimensions of the tubing, it was obvious that the structure would be quite heavy, hard to manufacture, and would have extremely decreased visibility throughout. Such conditions certainly did not seem ideal for the project at hand.

4.0 TOW POST ADAPTER CONCEPT

4.1 Overview

During the analysis of the fabrication drawings for the structural concept, Dr. Derradji became aware of a second option for an experimental set-up. By making use of the Marine Dynamic Test Facility in the Clearwater Tow Tank (CWTT), a set-up could be devised such that the struts of the MDTF (see Figure 17) would oscillate the pipe. The pipe would be attached to the tow post adapter (see Figure 18), and allowed to hang down into the tank. The approximate depth of the tank is 7.0 m, a suitable height, so all that was required was a way to connect the pipe to the tow post adapter. In Figure 19, the existing circular bolt pattern located on the bottom of the tow post adapter is shown. A joint was to be designed which would connect this circular pattern to the square pattern on the top of the pipe's load cell.

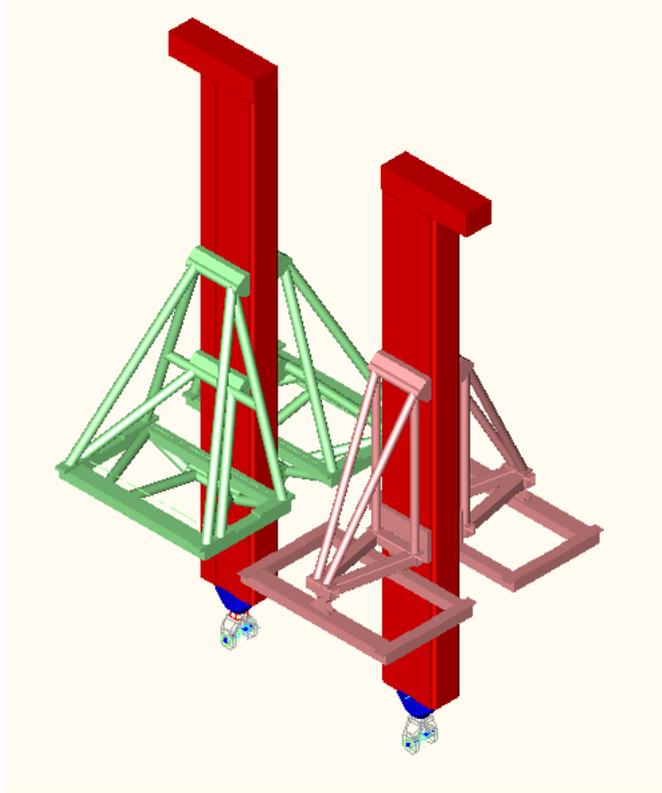


Figure 17 – MDTF

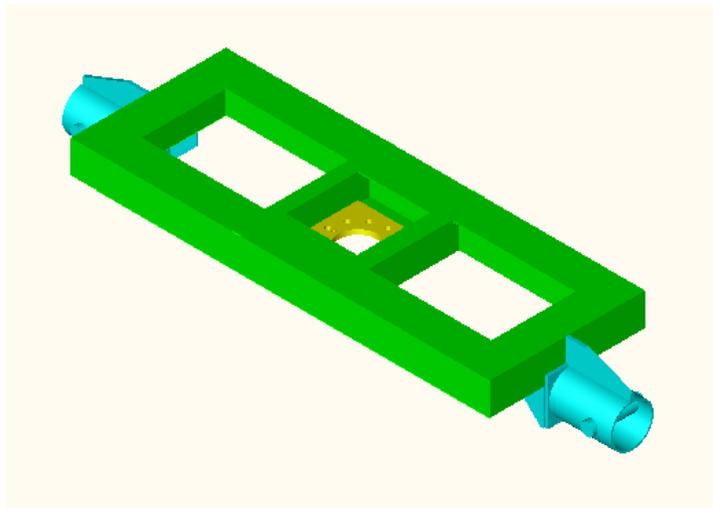


Figure 18 – Tow Post Adapter Above

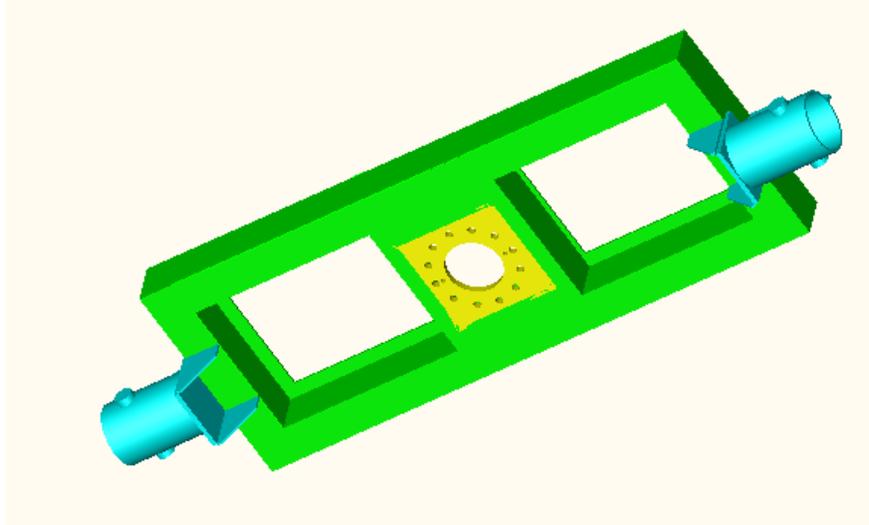


Figure 19 – Tow Post Adapter Below

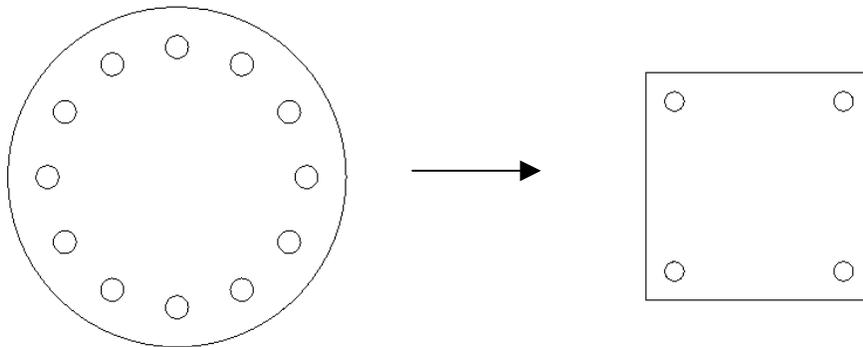


Figure 20 – Bolt Pattern Conversion

4.2 Design Concepts

The conception of this design was straightforward. At first glance, perhaps a simple plate with both patterns drilled in it would be suitable. But installation becomes a problem. Hence, the concept followed that consisted of a circular plate, a square plate, and a midsection pipe. The top and bottom plates had the coordinated bolt patterns on them, with the circular pattern threaded, and the bottom drilled. The length of the midsection pipe was determined by ease of installation, and the thickness of each plate

was approximately determined by inquiries directed to the manufacturer of the load cell. After such dimensions were reiterated with ANSYS analysis. Figure 21 shows the design. For accurate dimensions and tolerances, see Appendices.

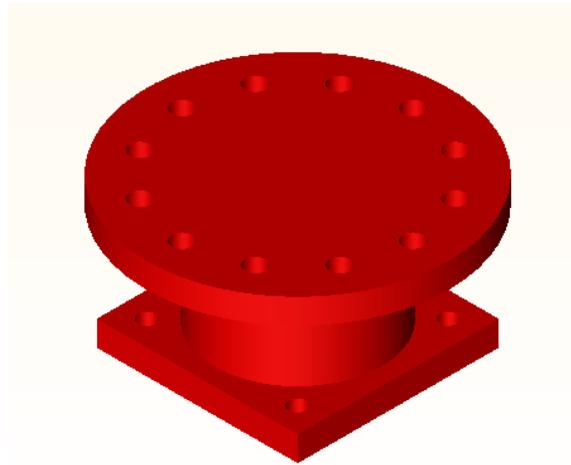


Figure 21 – Tow Post Adapter Joint

When bolted to the adapter, it appears as shown in Figure 22. Braces have also been added to the tow post adapter itself, to provide more strength. The dimensions and tolerance of the tow post adapter have been included in Appendix B – Detailed Fabrication Drawings.

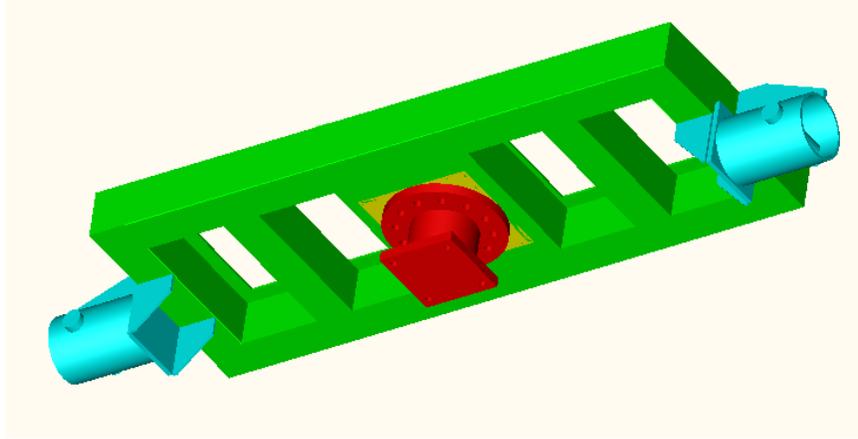


Figure 22 – Tow Post Adapter Assembly

4.3 Design Criteria

The joint was required to join the circular bolt pattern on the tow post adapter with the square bolt pattern on top of the AMTI MC8 Series load cell, which is connected to the top of the testing pipe.

The accuracy of the hole locations for the bolt patterns had to be precise, especially due to the uncertainty attributed to the fact that the circular pattern was already existing. Upon measurement of the pattern, it was noticed that some of the holes were off by a small fraction, so any deviance in the top flange of the joint could prove to be a problem. The load cell's square pattern was easier to design for, considering the locations of the holes are extremely precise, and the dimensions can be found on the AMTI website. The height of the joint was not required to be as accurate, as long as it was noted in the final design specs.

The dimensions of the flanges are oversized from the bolt locations at convenient values. The midsection pipe was already in stock at IOT, and was cut to a reasonable height to allow for bolt installation. The thickness of the two flanges was selected to be

1.0 inch. After consulting a member of the AMTI support staff, they replied that a 1.0 inch thick plate would suffice provided it was built to dimensions of the top of the cell. For ease of manufacturing, the same thickness of plate was repeated for the top flange, with adequate strength considerations.

There has been room accounted for in the general design of the joint for installation. The top will be bolted down through a hollow section in the middle of the top post adapter, and the load cell will be bolted on in the four corners of the bottom flange. For the top flange 3/4-10 UNC bolts will be used, and 5/8-11 UNC bolts for the bottom flange.

The joint will be made out of steel, and two 1/8 fillet welds will be made around the outer circumference of the midsection pipe, joining both flanges to it.

5.0 FEASIBILITY STUDY

In order to determine which concept was more appropriate for selection for manufacturing, a feasibility study had to be invoked. Topics range from cost to performance, and in the end it allows the designer to select the concept that will best fit the need.

Concept # 1: Structure

Hard Cash: \$ 7,500

Fabrication Time: 1,000 hrs

\$50,000

No option to increase riser length

Test Location: OEB

Availability: Fair

Risk Factor: HIGH

Problems:

- Weight of structure
- Footprint location
- Pump on platform
- Oil contamination
- Heating of pump at high power

Concept # 2: Tow Post Adapter

Hard Cash: \$ 1,000

Fabrication Time: 75 hrs

\$4,000

Option to double length of riser

Test Location: CWTT

Availability: Poor

Risk Factor: Moderate to Low

Problems:

- Strut strength
- MDTF performance
- Installation cost
- Cost of repeating experiment

5.1 Recommendations

- 1) Select the Tow Post Adapter concept for production.
- 2) Keep the Structural concept open until it is determined how the MDTF will perform.

6.0 CONCLUSION

This project has been a perfect example of how a design can evolve, and end up becoming almost unrecognizable upon conclusion. For example, it was presumed that the test frame supporting the hydraulic actuator was necessary for usage. Therefore, initially only reasonable concept appeared to be a structural one. Shortly thereafter, the notion of using the MDTF in conjunction with the tow post adapter became a viable option, and the structure actually became a concept that was vastly over-engineered and costly. In the end, the design was very simple, and cost a considerable amount less than the prior one. This is an indication that when designing a project, one should truly spend the most time conceiving rather than designing and plugging resources into materials and manufacturing. It is the planning that truly results in optimal designs, and when one has the most ideal conception of how to approach the problem, the design process itself becomes a rather quick and confident procedure. In the case of this project, the problem of determining the proper way to support the experimental pipe was solved in what I believe is the most efficient and simple manner.

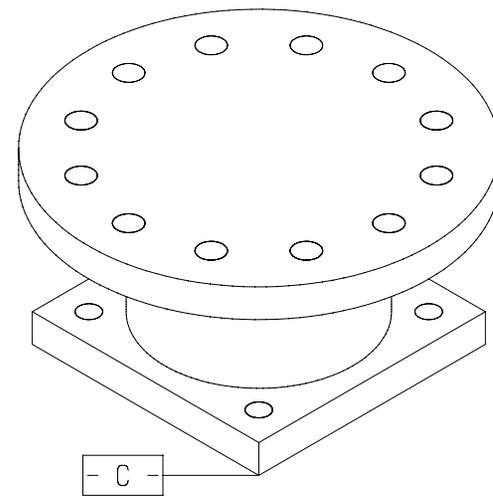
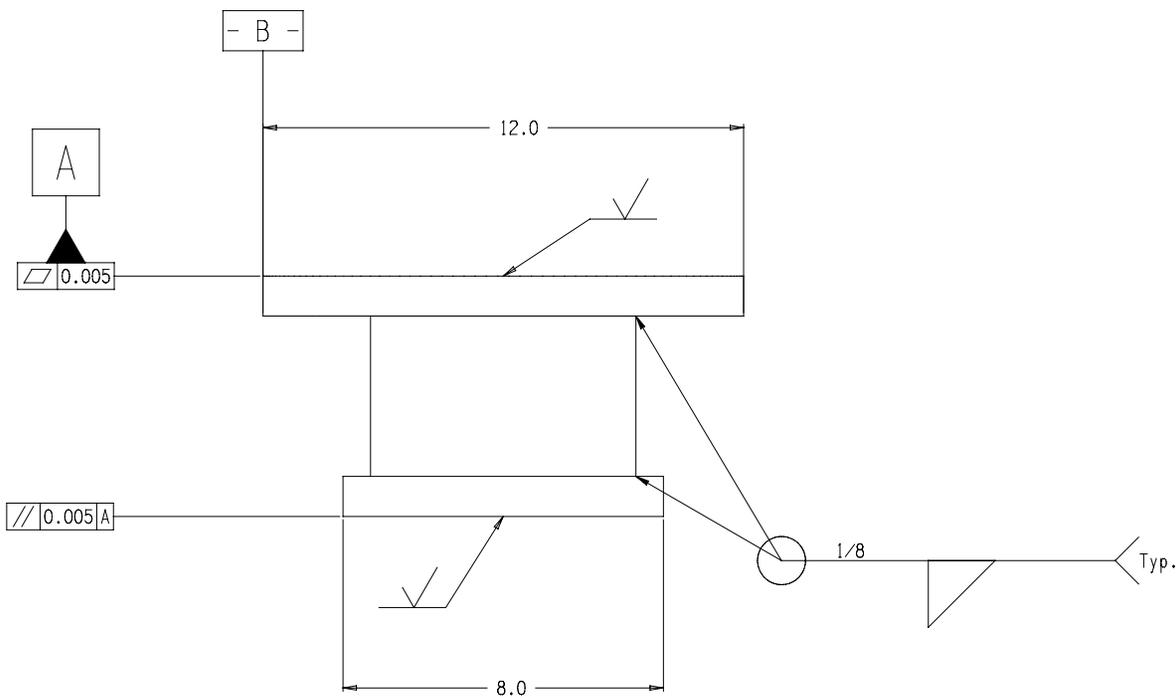
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Notes: Height of joint will be slightly below 6 inches. It may be skewed due to machining on top and bottom surfaces.

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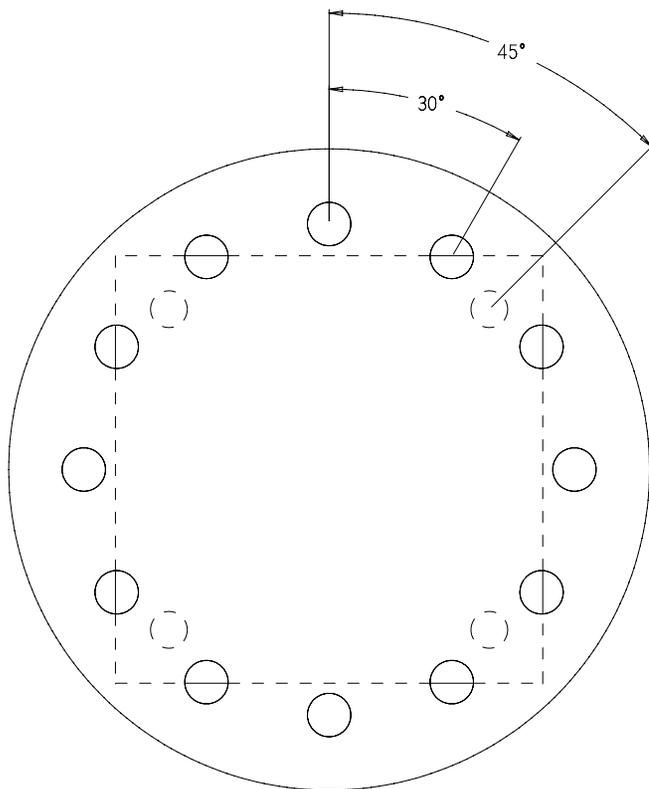


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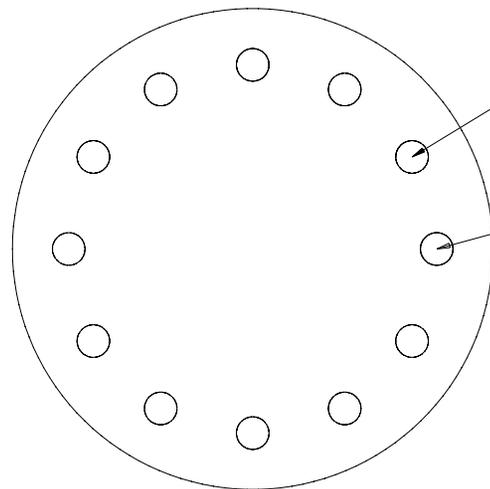


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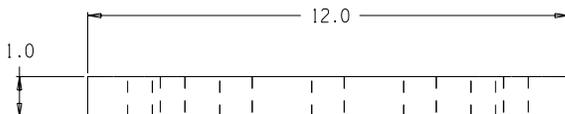
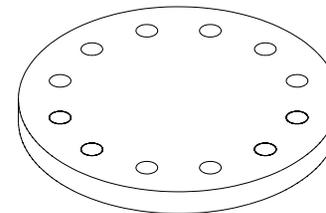
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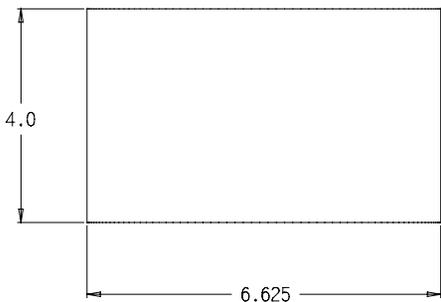
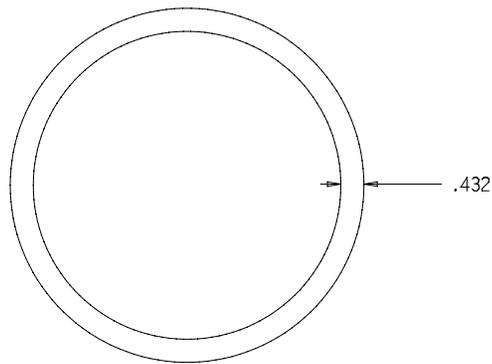


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TOLERANCES (unless specified) 0.X ± 0.03 0.XX ± 0.015 0.XXX ± 0.005 Angle +/- .5 deg. Fabrication +/- .04 Fraction < 6 inch +/- 1/64 > 6 inch +/- 1/32		Material Steel Heat Treatment		Institute for Marine Dynamics Kerwin Place, P.O. Box 12093, Postal Station A St. John's, Newfoundland A1B 3T5	
FINISH		TRAX 858		TITLE Pipe-in-pipe Adapter Joint Top Circular Mount	
DIMENSIONING IN: INCHES <input checked="" type="checkbox"/> MILLIMETERS <input type="checkbox"/>		DRAWN B. Guy		APPROVED	
		APPROVED		NUMBER 42 2193 16	
QUANTITY 1		SCALE 1 : 1		DATE 07-Mar-2007 SHEET 1 OF 1	

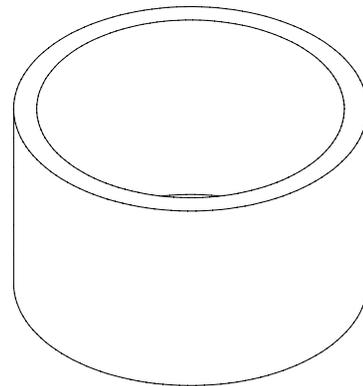
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REVISIONS				
NO.	DATE	DESCRIPTION	DATE	APPROVED

Notes:
 Deburr - Remove All Sharp Edges



Existing Pipe
 Schedule 80

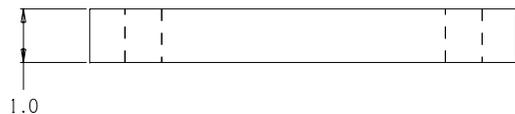
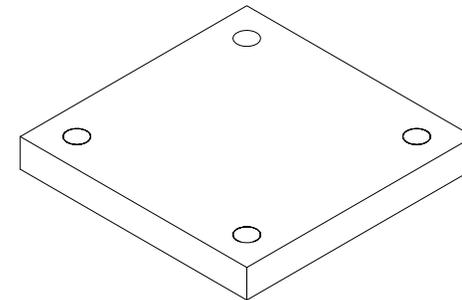
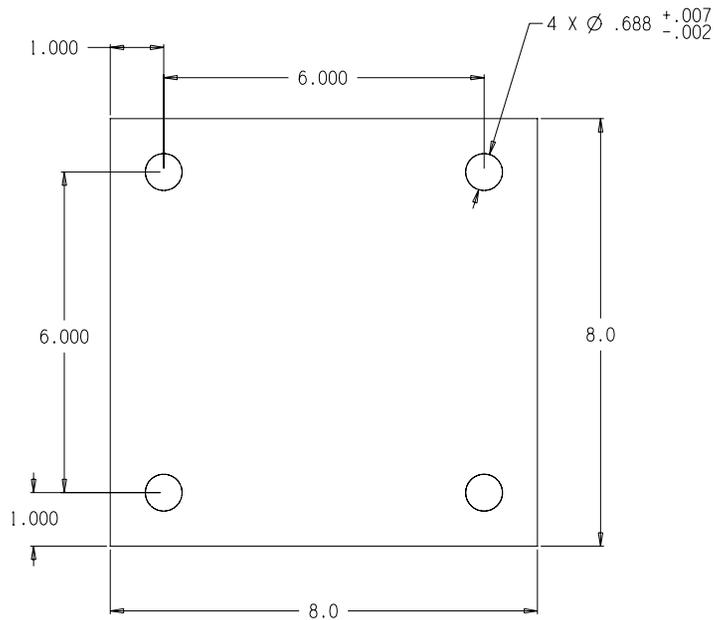


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TOLERANCES (unless specified) 0.X ± 0.03 0.XX ± 0.015 0.XXX ± 0.005 Angle +/- .5 deg. Fabrication +/- .04 Fraction < 6 inch +/- 1/64 > 6 inch +/- 1/32		Material Steel Heat Treatment		<i>Institute for Marine Dynamics</i> Kerwin Place, P.O. Box 12093, Postal Station A St. John's, Newfoundland A1B 3T5	
FINISH		TRAX 858		TITLE Pipe-in-pipe Adapter Joint Midsection Pipe	
DIMENSIONING IN: <input checked="" type="checkbox"/> INCHES <input type="checkbox"/> MILLIMETERS		DRAWN B. Guy		APPROVED	
THIRD ANGLE		QUANTITY 1		A3 NUMBER 42 2193 16 SCALE 1 : 1 DATE 07-Mar-2007 SHEET 1 OF 1	

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REVISIONS				
NO.	ZONE	DESCRIPTION	DATE	APPROVED

Notes:
Deburr - Remove All Sharp Edges



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TOLERANCES (unless specified) 0.X ± 0.03 0.XX ± 0.015 0.XXX ± 0.005 Angle +/- .5 deg. Fabrication +/- .04 Fraction < 6 inch +/- 1/64 > 6 inch +/- 1/32		Material Steel Heat Treatment	Institute for Marine Dynamics Kerwin Place, P.O. Box 12093, Postal Station A St. John's, Newfoundland A1B 3T5		
FINISH	TRAX 858	TITLE Pipe-in-pipe Adapter Joint Botton Square Mount		A3	NUMBER 42 2193 16
DIMENSIONING IN: <input checked="" type="checkbox"/> INCHES <input type="checkbox"/> MILLIMETERS	DRAWN B. Guy	APPROVED	SCALE 1 : 1	DATE 07-Mar-2007	SHEET 1 OF 1
THIRD ANGLE	QUANTITY 1				

APPENDIX B

ANSYS CODE

```

!
FINISH
/CLEAR, START
!
/PREP7
!
K,1,-1.2,-0.45,0 $k,2,1.2,-
0.45,0 $k,3,1.2,0.45,0
$K,4,-1.2,0.45,0
1,1,2 $l,2,3
$l,3,4
$l,4,1

K,11,-1.2,-0.45,3.5
$K,12,1.2,-0.45,3.5
$K,13,1.2,0.45,3.5 $K,14,-
1.2,0.45,3.5
1,11,12 $l,12,13
$l,13,14
$l,14,11

1,1,11 $l,2,12
$l,3,13 $l,4,14

K,21,-2,-0.45,0 $K,22,2,-0.45,0
$K,23,2,0.45,0 $K,24,-2,0.45,0

1,1,21 $l,2,22
$l,3,23
$l,4,24
1,11,21 $l,12,22
$l,13,23 $l,14,24

$l,21,24 $l,22,23

ldiv,all,,,3
1,46,29 $l,29,31, $l,31,48
1,52,35 $l,35,33, $l,33,50

1,45,30 $l,30,32, $l,32,47
1,51,36 $l,36,34, $l,34,49

1,23,33 $l,34,50 $l,24,35
$l,52,36
1,22,31 $l,32,48 $l,21,29
$l,46,30
1,17,30 $l,25,34
1,18,32 $l,26,36

1,17,5 $l,25,9

```

```

1,18,6 $l,26,10
1,18,25
1,17,26
NUMMRG,ALL, , , ,LOW

ex,1,0.2e+12
dens,1,7600.
NXY,1,.3
!
r,1,.003,1.0E-5,1.0E-5,.007,.007
!
et,1,4
lmesh,all

NSEL,S,LOC,Z,-.01,.01
enode
d,all,all
allsel

/sol
ANTYPE,0
NSEL,S,LOC,Z,3.51,3.495
f,all,fx,10000.
allsel
ACEL,10,10,10
solve
finish

```