Design of the IOT wave suppressor

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SUMMARY

The Institute for Ocean Technology specializes in researching and testing models of ships. The Department of National Defence has contracted IOT to develop a stern appendage that will reduce hydrodynamic resistance on the Halifax Class frigate. This appendage will also improve speed and propeller cavitation performance, and reduce the stern wave. The model used for testing contains sensitive electrical equipment which is vulnerable to forces induced by the stern wave impacting the model at the end of high-speed runs. There is also a risk of the stern wave washing over the transom and causing further damage to equipment. Researchers at the Institute have proposed a method to solve these problems through the development of a device called the Wave Suppressor. This device would be used to dissipate the wave energy, and thereby reduce the impact force of the wave on the stern of the model and prevent the stern wave from washing over the transom.

This report details the design considerations used in the development of the proposed mechanism and describes its various components. It covers the design criteria that the Wave Suppressor must meet, and how the Wave Suppressor fulfills these requirements. The report first sets the design criteria and then proceeds to describe the Suppressor's connection to the tow tank carriage, the design factors involved in ensuring the wave will be fully suppressed, and the control of the suppressor. It also includes calculations that were used in the design process and provides assembly drawings of the wave suppressor.

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SR-2005-23

Jeswin Jeyasurya

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1.0 INTRODUCTION

The Institute for Ocean Technology - National Research Council has been contracted by the Department of National Defence to carry out research in the development of a stern appendage for the Halifax Class frigate. This research has been driven by a concern regarding escalating fuel prices. Once it is developed, the stern appendage will reduce hydrodynamic resistance on the vessel, which will increase the fuel efficiency and reduce operating costs. The institute will perform tests in the towing tank facility to determine which stern flap arrangement will provide the least amount of hydrodynamic resistance. At the end of high velocity runs (maximum test speed is 4.4 m/s), the wave following the model will slam into its stern with a large amount of force. This force can cause damage to sensitive electrical equipment. There is also a possibility that the stern wave will wash over the transom and cause further damage to equipment. In order to solve these problems, a device has been developed to dissipate the energy of the wave before it reaches the stern of the model. This device, called the Wave Suppressor, is a hinged two-piece frame with expanded metal mesh on the bottom half. Near the end of each high-speed run, the suppressor is manually deployed into the water with the expanded metal on the bottom half dissipating the energy of the wave before it reaches the stern. This report details the design of the Wave Suppressor and describes its various components.

2.0 FACILITY DESCRIPTION

The testing facility for the Halifax Class frigate is the IOT Clearwater Towing Tank. The vessel will be attached to a carriage that will run down the tank at various speeds, up to a maximum of 4.4 m/s. The experiments will be performed in calm water, without the use of the wave-making device. The model used for testing is 9 m in length with a flat transom stern.

Figure 1. Tow Tank and Carriage

The diagrams below show a side view of the testing configuration. The model is attached to the carriage using a Tow Post. When the model reaches the end of the run, the following wave keeps travelling until it hits the stern. The suppressor will reduce the impact force and ensure that the wave will not wash over the stern.

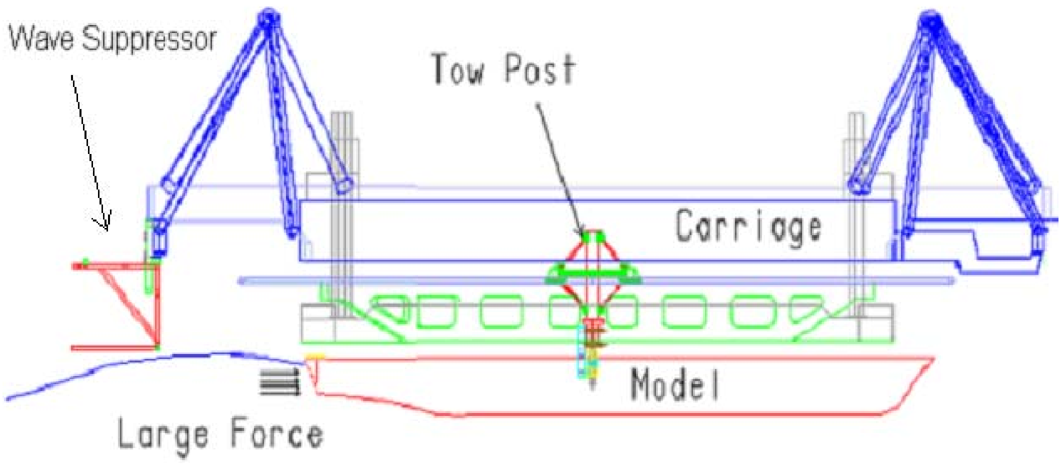


Figure 2: Illustration of Model and Carriage with raised Wave Suppressor

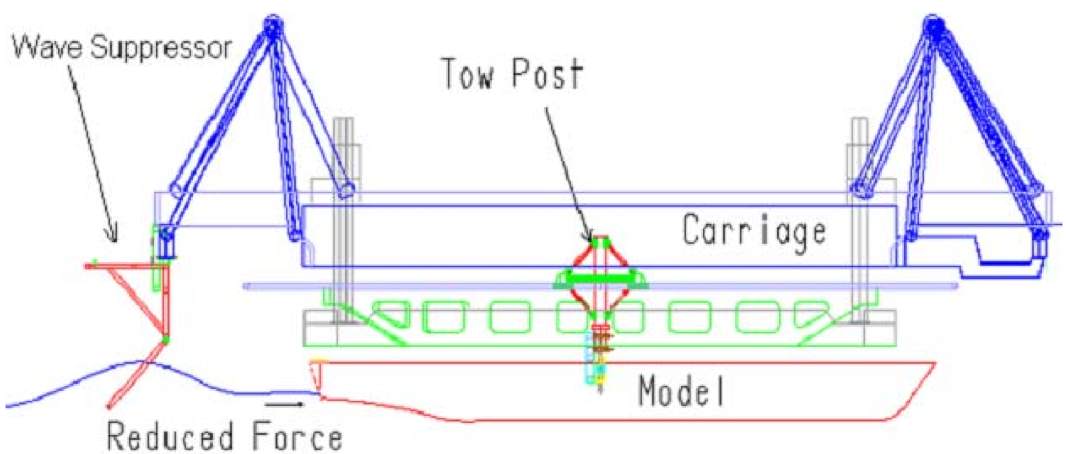


Figure 3: Illustration of Model and Carriage with lowered Wave Suppressor

3.0 SUPPRESSOR COMPONENTS

The wave suppressor consists of the following components:

- Hollow Structural Steel Frame. 2”x 2” and 3”x 2” cross section
- Expanded Metal Sheets, 45 Percent Porosity
- Angle Steel, 5”x 3” and 2”x 2” cross section
- Fabricated Steel Clamps
- Fabricated Steel Support Bracket
- Steel Chain

4.0 DESIGN CRITERIA

The underlying principle of the wave suppressor was to design a steel hinged frame covered with expanded metal mesh. The frame would be dropped at the end of the run and held at an angle to dissipate the wave energy before it reached the stern of the model. In designing this frame, the following design criteria had to be met.

- Suppressor attachment and compatibility
  - The suppressor must be able to attach to both the east and west ends of the carriage.
  - The suppressor must be centered on the west end of the carriage.

- The suppressor must be designed to accommodate an existing Pull Point Apparatus, which will create an obstruction, since it is also centered on the west end of the carriage.

- Suppressor Design
    - The suppressor must have hinges that are able to withstand the force of the wave.
    - The suppressor must be able to dissipate the energy of the stern wave
    - The suppressor must be designed to handle a max wave height of 12”
    - When the suppressor is fully deployed it must form a 45° angle to the water surface and the end of the frame should be at a depth of 15.75”.
    - The suppressor must be 80” in width.

- The suppressor must be designed for rapid manual deployment.

5.0 SUPPRESSOR DESIGN

5.1 Design Overview

The wave suppressor was designed as a two-piece frame, hinged in the middle. The top piece will be clamped to the carriage and the bottom piece free to drop into the water. The frame consists of 2 “x 2” steel box tube with support gussets to prevent bending from forces that arise when the frame is deployed. There are two beams on either end of the frame. Chains attached to the ends of these beams and the ends of the bottom frame are used to stop the suppressor when it is deployed. Ropes attached to the bottom frame are used to raise the suppressor. The bottom frame also has multiple layers of expanded metal sheets bolted onto it.

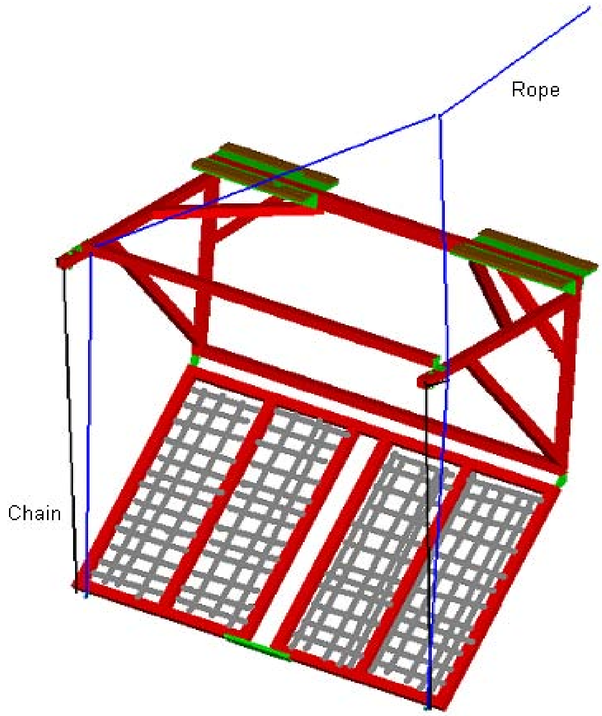


Figure 4. Illustration of Wave Suppressor

5.2 Suppressor and Carriage Interface

5.2.1 Location, Compatibility, and Attachment

It was determined that the best location for attaching the suppressor to the carriage is to clamp it to the underside of an I-Beam running beneath the west end of the carriage. A special clamp has been fabricated to clamp the steel angle on the Suppressor to the I-Beam. Another I-Beam runs beneath the east end of the carriage, hence this method of attachment is compatible with the east end of the carriage as well. Bolts connecting the clamp and steel angle together will provide the clamping force when the bolts are tightened. Calculations were performed to ensure that the clamping force of the bolt is large enough to hold the suppressor to the carriage without any chance of failure. These calculations can be seen in Appendix A.

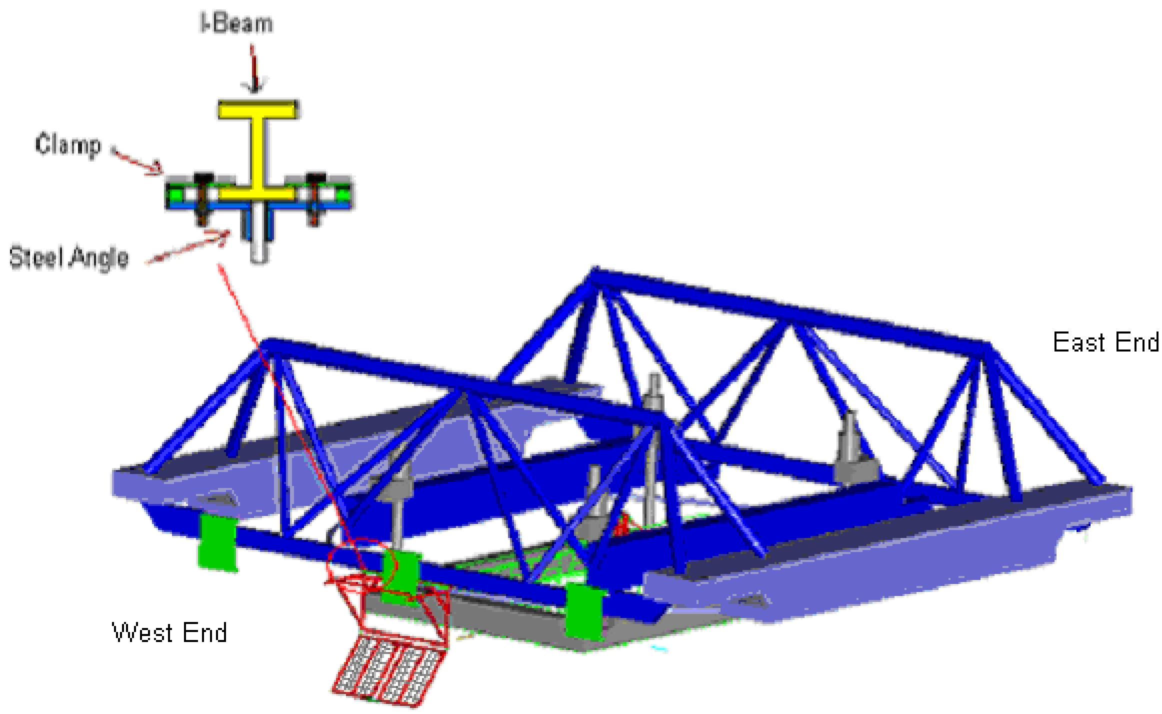


Figure 5. Illustration of Suppressor and Carriage interface

5.2.2 Pull Point Compatibility

The suppressor was designed to avoid interference with the existing pull point apparatus. The pull point apparatus is 3″ wide at its widest point and extends vertically, centered on the west end of the carriage. It moves up and down, extending as far as the water surface.

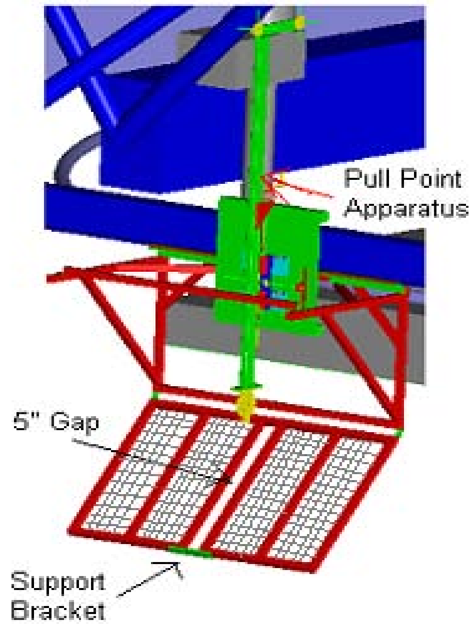


Figure 6. Illustration of mounted Suppressor with Pull Point Apparatus in place

To prevent interference with the Pull Point Apparatus, the bottom half of the suppressor was designed as a two-piece frame with a 5″ gap in the middle. Because the Pull Point Apparatus is 3″ wide at its widest point, the five-inch gap will leave an inch of clearance on either side. This gap is along the whole length of the frame but can be made smaller by closing the gap using expanded metal sheets. This option will only be utilized if it is determined that a significant amount of wave energy is passing through the gap. In addition a support bracket has been fabricated to connect the bottom of the two pieces together (see figure 6). This will reduce the effects of any twisting moments on the bottom frame.

5.3 Wave Suppression Design Factors

5.3.1 Hinge Design

The hinge was designed to be a simple pin connection connecting the top and bottom frames together. It was necessary to ensure that the steel bolts used in the hinge will have enough strength to resist the various shearing forces acting on it. These include forces caused by the weight of the suppressor, the force of the wave impact, and hydrostatic pressure forces. The weight of the suppressor was determined by summing the weights of the individual components. The force of the wave impact was found using the momentum equation.

$$Ft = mV$$

Where: F = Force (N)
t = time (s)
m = mass (kg)
V = velocity (m/s)

The hydrostatic force was found using the hydrostatic pressure equation

$$F = PA$$

Where: F = Force (N)
P = Pressure (kPa)
A = Cross-sectional area (m^2)

As a prerequisite to performing these calculations, the maximum height and volume of the wave over the suppressor had to be determined. Detailed calculations can be found in Appendix A.

5.3.2 Frame Design

The lengths of both the top and bottom pieces of the frame were determined using two design requirements. The first requirement was that the suppressor should handle a maximum wave height of 12″. This means that before it is deployed (bottom frame parallel to water surface), the suppressor should allow up to a 12” high wave to pass beneath it. The second requirement was that the depth of the suppressor should be at least 15.75″ below the water surface when fully deployed (at a 45° angle to water surface). To satisfy the first requirement, the top piece had a designed length of 41.75″. Since the I-beam is at a fixed height of 61.75″ above the water, when the suppressor is attached there will be a gap larger than the minimum 12″ of clearance required, ensuring there is no wave interference. The bottom piece has a length of 48.5″. This length satisfies the second design requirement by ensuring that when fully deployed, the suppressor will have a depth greater than the required 15.75″ below the water surface. The frame width is 80” as initially specified. This width is sufficient as the model is 37″ in width**.** Two to four layers of expanded metal mesh will be bolted onto the edge of the frame, depending on how many layers are needed to adequately dissipate the wave energy. This will be decided after the Wave Suppressor is tested in the towing tank. Each layer of expanded metal consists of two 48″ by 37.5″ sheets, as this will leave 5″ of clearance space for the Pull Point Device. See Figure 7, Illustration of Suppressor Cross-section for a dimensioned cross-section of the suppressor.

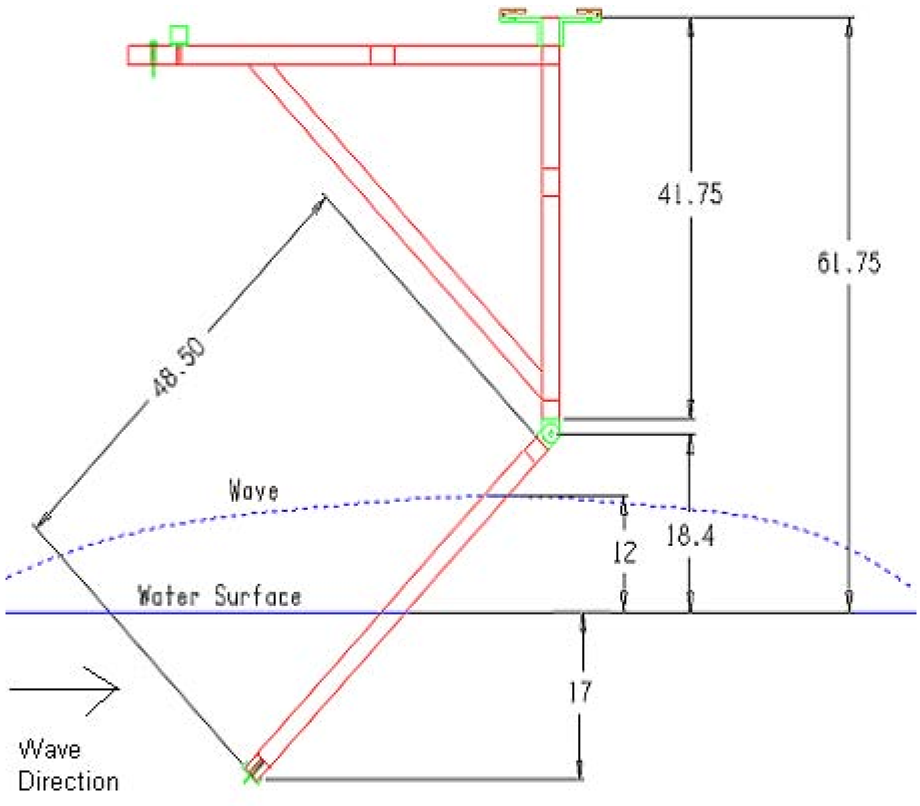


Figure 7. Illustration of Suppressor Cross-section

5.4 Suppressor Control

5.4.1 Suppressor Deployment:

The suppressor was designed to be deployed using a block and tackle system. Ropes will be connected from the ends of the bottom frame to a block and tackle system on the carriage. The purpose of this system is to reduce the amount of force required to raise the suppressor. A jam cleat will be used to hold and release the rope when it is ready to be deployed.

5.4.2 Suppressor Stopping

The design criteria of the wave suppressor specified that when fully deployed, it should be at a 45 degree angle to the water surface. This is so that the wave will ride up the suppressor rather than directly impact it. To satisfy this criterion, two beams were place on the top corners of the suppressor that extend out in front of it. Chains have been attached to each of these beams with the other ends of the chains attaching to the ends of the bottom frame. The length of the chain has been predetermined so that when the suppressor is released, it will stop at a 45° angle to the water surface. The metal links in the chain are strong enough to withstand the impact, and gussets have been placed underneath each beam to prevent bending from the impact force. In addition a crossbeam has been added to provide support in the transverse direction (see figure 8).

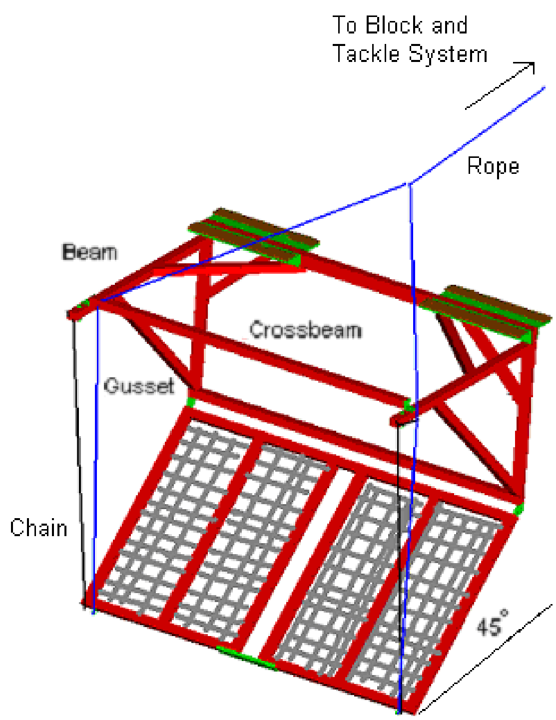


Figure 8. Illustration of deployed Wave Suppressor

6.0 Suppressor As-Built Modifications

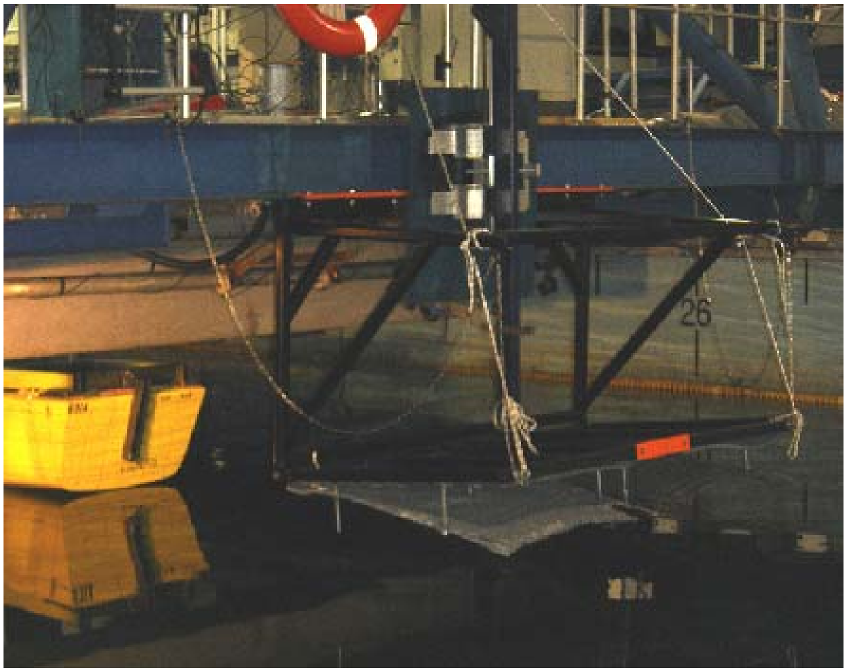


Figure 9. Picture of Installed Suppressor and Model Stern

During the installation of the suppressor a number of small modifications were made to the original design. A section had to be cut out of the center of the top of the frame, between the pieces of steel angle. This modification was made to avoid interference with a gusset on the I-beam that was creating an obstruction. In addition, the chain was attached to I-bolts on the carriage rather to the ends of the corner beams as originally planned. This was done so that the carriage rather than the suppressor would absorb the impact force. The suppressor was too heavy to raise manually so an electric winch was used to raise it. The suppressor can still be quickly released using the jam cleat. Finally, the suppressor was tested using two sheets of expanded metal. The two sheets were able to adequately dissipate the wave energy and reduce the force and height of the wave impacting the model.

7.0 REFERENCES

Shigley, J.E., Mischke, C.R. (1989). Mechanical Engineering Design 5th edition . United States of America: McGraw-Hill, Inc.

ASME/ANSI B18.3-1986, Socket Cap, Shoulder, and Set Screws (Inch Series). New York: The American Society of Mechanical Engineers.

APPENDIX A

Design Calculations

Design Calculations

All Calculations were performed in metric except for calculations involving loads on bolts, which are performed in British Standard.

-Wave Volume over suppressor calculations

General wave profile equation

Z = H/2*sin (kx - wt)

Z & x – wave profile coordinates
H – Amplitude of wave
k – wave number
w – frequency (radians)
t – time

GEDAP Program WAVE (Version 1.20) generated a table of values of wave parameters for 7 m deep water (towing tank is 7 m deep)

Parameters were selected based on which set of values matched closest the following criteria

- Max wave speed is 4.4 m/s
- Wave length is greater than 9 m
- Max Amplitude (H) is 0.6 m

The set of values that matched closest to the initial criteria include these other values.

w = 2.0942 rad/s
k = .22897 m^-1
Period = 3 s
Phase Velocity = 4.6649 m/s
Wave Length = 13.995 m

Wave Profile Equation (with values substituted)

Z = 0.3*sin (0.44897x – 2.0942t)

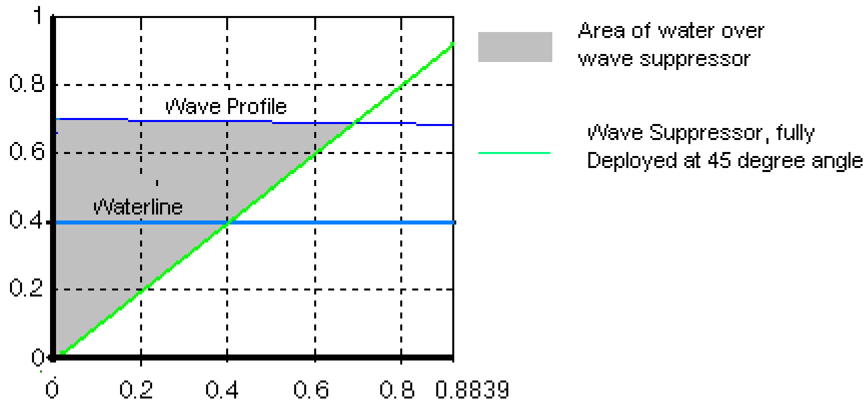
The wave profile and the wave suppresser profile view were graphed in Matlab using the following equations

Deployed Wave Suppressor

Z = x
Wave Profile

$Z = 0.3*\sin(0.44897x - 2.0942t) + 0.4$

t = 2.35 was substituted into the above equation. Using Matlab it was determined that this was the time at which the maximum amount of water was over the suppressor.



Graph of Wave Profile and Wave suppressor

Integrating in the grey shaded area, it was determined that the area of water over the suppressor was 0.2438 m^2

In addition the graph shows that the length of suppressor underwater is 0.81384 m, and the depth to which it extends is 0.6925 m.

The Mass of water was found using the width of the suppressor (2 m), the calculated area (0.2438 m^2), and the density of water (1000 kg/m^3).

m = Width*Area*Density
m = 2*.2438*1000
m = 487.6 kg

Wave Impact Equation:

F = mV/t

M = Mass of wave
V = Phase velocity of wave
t = ½ wave period
F = 487.6*4.6649/1.5
F = 1516 N

The wave impact force is 1516 N

Hydrostatic Pressure Calculations

For these calculations it is assumed that the wave suppressor is a solid plate. This will result in the absolute maximum pressure being calculated

P = density*gravity*height

Density = 1000 kg/m^3
Gravity = 9.8m/s^2
Height = 0.6925/2

The height (distance to center of gravity of plate) is half of the depth to which the wave suppressor extends.

P = 1000*9.8*0.3463
P = 3393.25 Pa

P = F/A
F = P*A

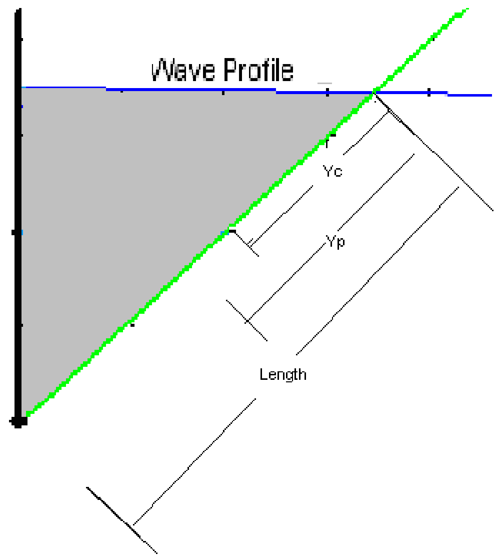
A = Area of suppressor under water

F = 3395.25*(2*0.81384)
= 5523.2 N

The hydrostatic force is 5523.2 N

Both these forces act at the center of pressure of the Wave Suppressor

Center of Pressure Calculations



Ixx = 1/12*base*length
Ixx = 1/12*2*0.81384
Ixx = 0.089839

Yc = Length/2 (center of gravity of plate under water)
= 0.81384/2
= 0.40692 m

Yp = Center of pressure of suppressor
Yp = Yc + Ixx/ (Area*Yc)
= 0.40692 + 0.089839/(1.62768*0.40692)

Yp = 0.54256 m

Gravitational Force Calculations

Weight of bottom frame.

Expanded Metal, 45 % porosity, 16.5 kg/ layer.
4 Layers, 66 kg

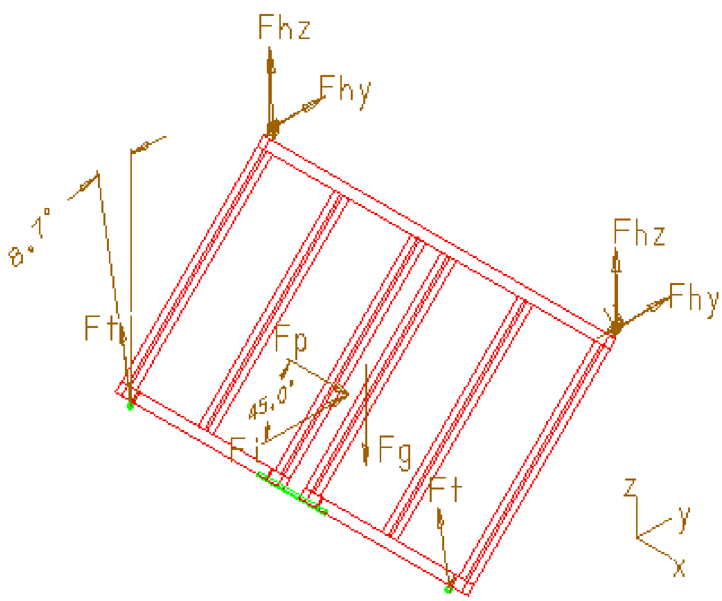
Hollow Structural Steel,
34 kg

Total 100 kg

Gravitational force = 100*9.81
= 981 kg

Using this information, that is the wave impact force, the hydrostatic pressure force, the gravitational force and location of these forces, the forces on the hinges and the stopping chain can be determined.

Hinge and Chain Forces



Known:
Fi = 1516 N
Fp= 5523.2 N
Fg ~1000 N

Unknown:
Ft - Tension force on chain
Fhy, Fhz - y and z components of hinge force

$\sum Fy = 0$
$-2Ft*\sin(8.7) + Fi + Fp*\cos(45) + 2Fhy = 0$ (1)

$\sum Fz = 0$
2Fhz – Fg – Fp*sin(45) + 2*Ft*cos(8.7) = 0 (2)

$\sum Mx = 0$
-(2*Ft*cos(8.7))*0.88 – (2*Ft*sin(8.7))*0.88 +Fg*cos(45)*0.625
+ Fi*0.575 + Fp*0.813 = 0 (3)

Ft = 2901 N

Substitute in to Equation (1) and (2)

Fhy = -3013 N

Fhz = -416 N

Total hinge force = Sqrt(Fhy^2 +Fhz^2)

Fh = 3041N
Fh = 684 lb

Minimum tensile strength - 7/16" coarse thread bolt = 19 100 lb (ASME/ANSI B18.3-1986, p. 146)

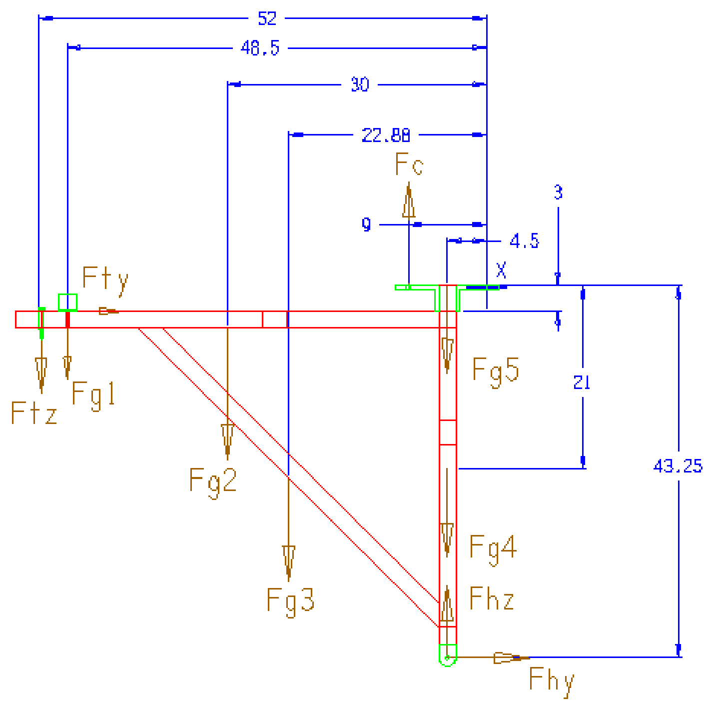
Max shear load on bolt is 0.4*min tensile strength (Shigley, Mischke, 1989, p.12)

For 7/16" bolt, max shear = 19100* 0.4 = 7640 lb

Shear force on hinge bolt = 684 lb << 7640 lb

A 7/16" bolt will be strong enough to hold the suppressor without failure.

Vertical Clamping Force Calculations



Forces on half of the frame

Fc = clamping force of bolt

Ftz = Ft*cos(8.7) = 2901*cos(8.7) = 2867.6 N
Fty = Ft*sin(8.7) = 2901*sin(8.7) = 438.8 N

Fhz = 416 N
Fhy = 3013 N

Fg_1 = (3.77kg)*9.81 = 37 N
Fg_2 = (7.65kg)*9.81 = 75 N
Fg_3 = (7.14kg)*9.81 = 70 N
Fg_4 = (11.72 kg)*9.81 = 115 N
Fg_5 = (11.72 kg)*9.81 = 115 N

$\sum Mx = 0$

$Fc*9 = Ftz*52 + Fty*3 + Fg_1*48.5 + Fg_2*30 + Fg_3*23 + Fg_4*4.5 + Fg_5*4.5 + Fhy*43.25 – Fhz*4.5$

Fc = 31595 N
Fc = 7102.8 lb

The clamping force of the bolts must be greater than 7102.8 lb. This force is distributed over three bolts.

Clamping force (force) required per bolt:

7102.8/3 = 2367.6 lb

This force can also be seen as the tensile load on the bolt

Max tensile load on bolt is the proof load

½" bolt proof load = 19800 lb (ASME/ANSI B18.3-1986, p. 146)

2367.6 lb << 19800 lb

A ½" bolt will be strong enough to clamp the suppressor onto the I-beam.

APPENDIX B

Fabrication Drawings

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NO.	ZONE	DESCRIPTION	DATE	APPROVED

Part File
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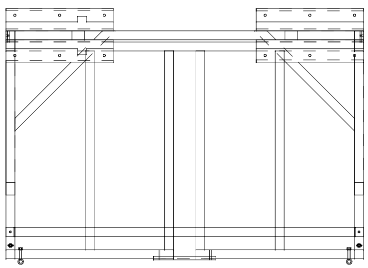

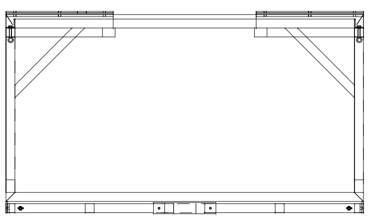

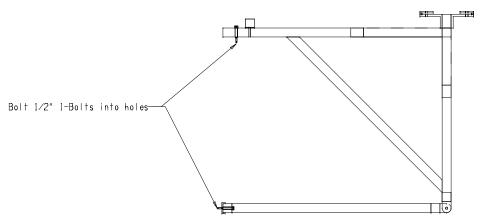

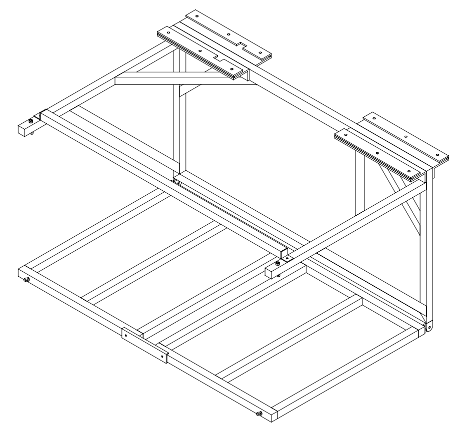

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TOLERANCES
(unless specified)
0.X ± 0.03
0.XX ± 0.015
0.XXX ± 0.005
Angle +/- .5 deg.
Fabrication +/- .04
Fraction < 6 inch +/- 1/64
> 6 inch +/- 1/32

Material

Heat Treatment

FINISH

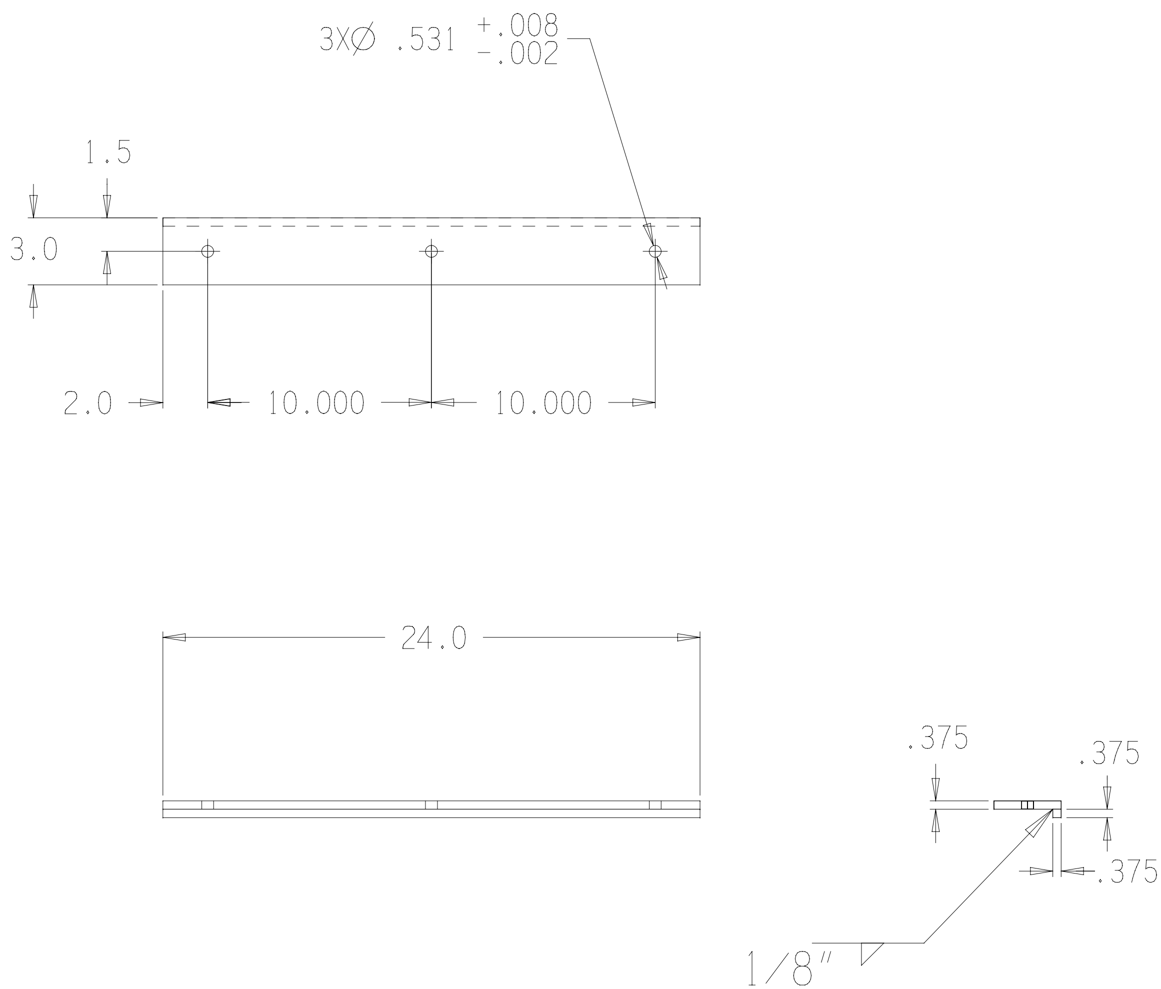
DIMENSIONS IN: INCHES ☒ MILLIMETERS ☐

THIRD ANGLE

Institute for Marine Dynamics
Kerwin Place, P.O. Box 12093, Postal Station A
St. John's, Newfoundland A1B 3T5

TRAX 2104
TITLE CPF Stern Wedges Assembly Drawing
DRAWN J Jeyasurya
APPROVED
Quantity
A3
NUMBER 2104Z01
REV
SCALE NTS
DATE
SHEET 1 OF 1

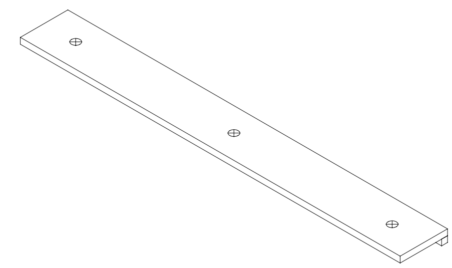
NUMBER



REVISIONS				
NO.	ZONE	DESCRIPTION	DATE	APPROVED

Part File
CAD_User\Projects\42_2104_16 CPF Stern Flaps\Student\CADKEY\Wave Suppressor.ckd

Notes:
Holes should line up with holes on steel angle
Deburr - Remove All Sharp Edges



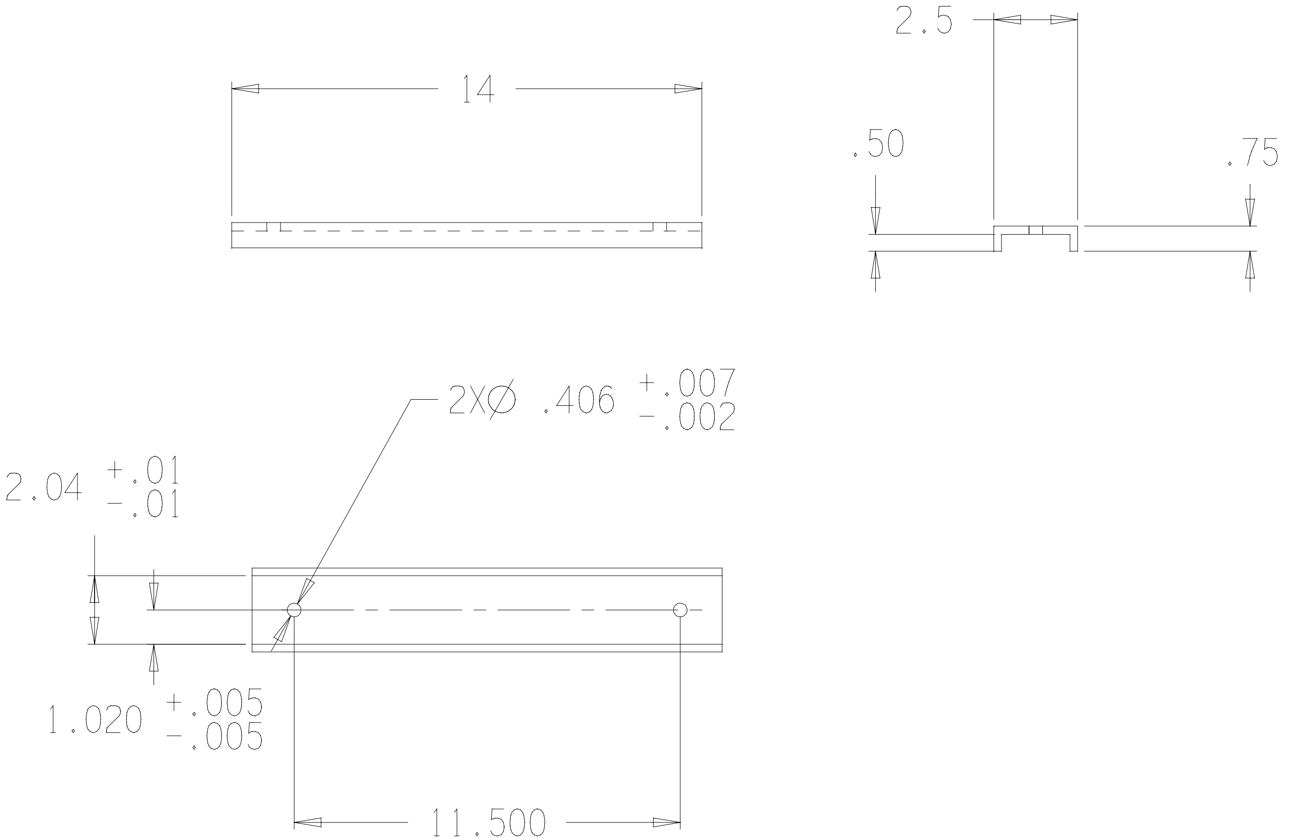
National Research Council Canada — Conseil national de recherches Canada — NRC-CNRC

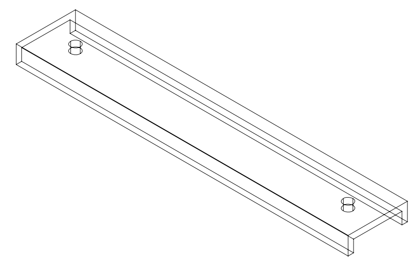
TOLERANCES (unless specified) 0.X ± 0.03 0.XX ± 0.015 0.XXX ± 0.005 Angle +/- .5 deg. Fabrication +/- .04 Fraction < 6 inch +/- 1/64 > 6 inch +/- 1/32	Material Steel Heat Treatment FINISH DIMENSIONS IN: INCHES ☒ MILLIMETERS ☐ THIRD ANGLE	Institute for Marine Dynamics Kerwin Place, P.O. Box 12093, Postal Station A St. John's, Newfoundland A1B 3T5	
		TRAX 2104 DRAWN J Jeyasurya APPROVED Quantity 2	TITLE CPF Stern Wedges Suppressor Clamp A3 — NUMBER 2104Z02 — REV SCALE NTS — DATE 2005-Oct-4 — SHEET 1 OF 1

REVISIONS				
NO.	ZONE	DESCRIPTION	DATE	APPROVED

Part File
CAD_User\Projects\42_2104_16 CPF Stern Flaps\Student\CADKEY\Wave Suppressor.ckd

Notes:
Holes should line up with 3/8" holes on bottom frame
Deburr - Remove All Sharp Edges





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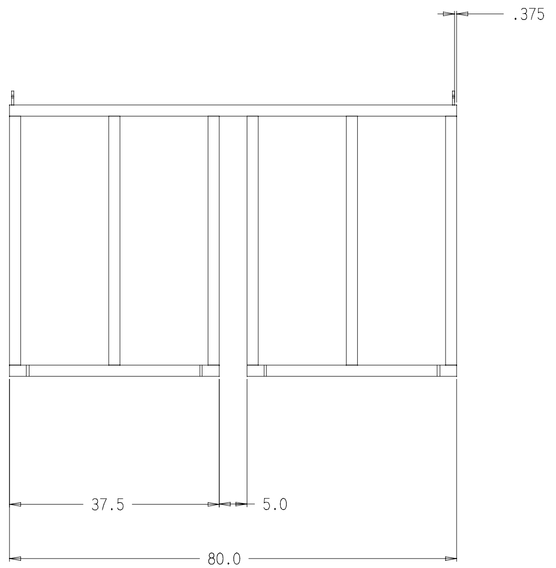
Institute for Marine Dynamics
Kerwin Place, P.O. Box 12093, Postal Station A
St. John's, Newfoundland A1B 3T5

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	
FINISH	
DIMENSIONS IN:	INCHES ☒ MILLIMETERS ☐
THIRD ANGLE	
TRAX	2104
DRAWN	J Jeyasurya
APPROVED	
Quantity	1
TITLE	CPF Stern Wedges Suppressor Support Bracket
SIZE	A3
NUMBER	2104Z03
REV	
SCALE	NTS
DATE	
SHEET	1 OF 1

REVISIONS				
NO.	ZONE	DESCRIPTION	DATE	APPROVED



Part File
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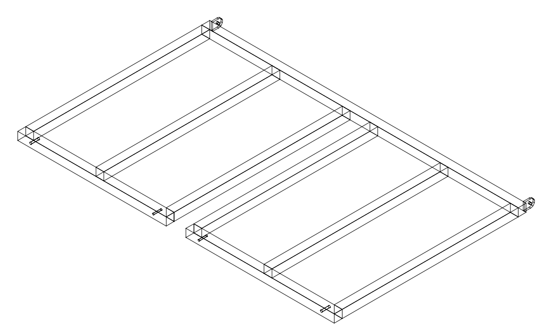
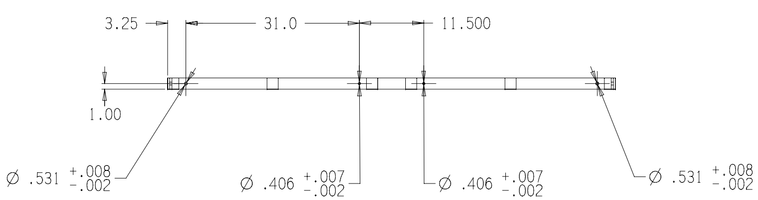
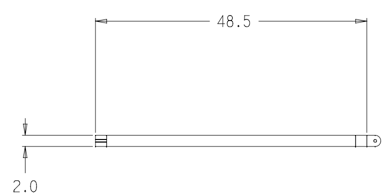
Notes:
Close all ends of box tube
Use 7/16" bolts for hinges
Welding:
1/8" fillet weld all around joints







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TOLERANCES (unless specified)	Material 2x2x3/16 HSS	Institute for Marine Dynamics
0.X ± 0.03	Heat Treatment	Kerwin Place, P.O. Box 12093, Postal Station A St. John's, Newfoundland A1B 3T5
0.XX ± 0.015	FINISH	TRAX 2104
0.XXX ± 0.005	DIMENSIONS IN: INCHES ☒ MILLIMETERS ☐	DRAWN J Jeyasurya
Angle +/- .5 deg.	THIRD ANGLE	APPROVED
Fabrication +/- .04		Quantity 1
Fraction < 6 inch +/- 1/64; > 6 inch +/- 1/32		

TITLE CPF Stern Wedges Suppressor Bottom Frame

SIZE	NUMBER	REV
A3	2104Z04	

SCALE NTS | DATE | SHEET 1 OF 1

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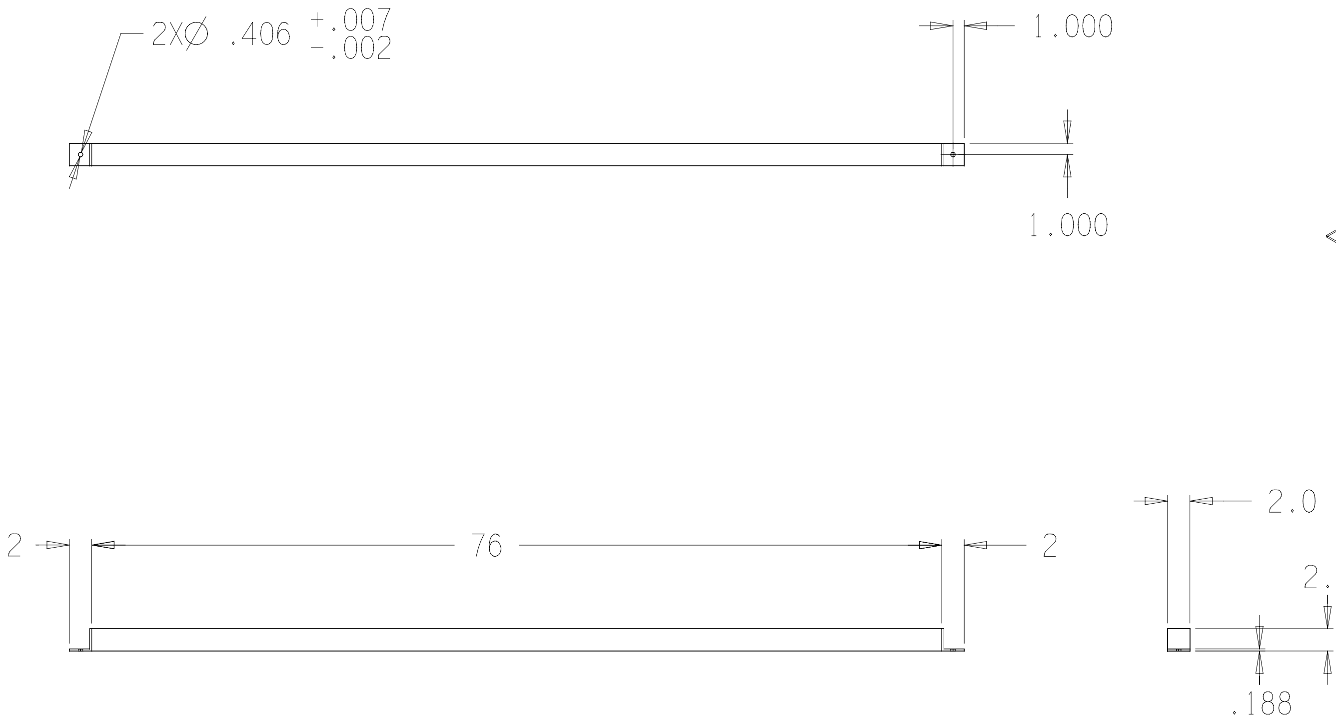
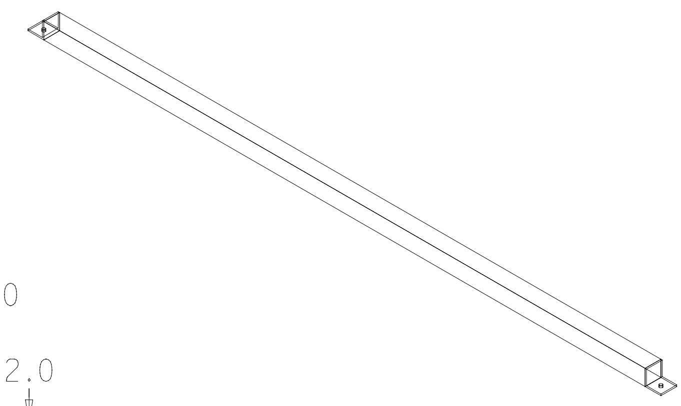
REVISIONS				
NO.	ZONE	DESCRIPTION	DATE	APPROVED

Part File
CAD_User\Projects\42_2104_16 CPF Stern Flaps\Student\CADKEY\Wave Suppressor.ckd

Notes:
Holes should line up with 3/8" holes on top frame
Deburr - Remove All Sharp Edges
Welding:
1/8" fillet welds joining angle to box tube





National Research Council Canada
Conseil national de recherches Canada
NRC-CNRC

TOLERANCES (unless specified)	Material
0.X ± 0.03	2x2x3/16 HSS
0.XX ± 0.015	2x2x3/16 steel angle
0.XXX ± 0.005	Heat Treatment
Angle +/- .5 deg.	FINISH
Fabrication +/- .04	DIMENSIONS IN: INCHES ☒ MILLIMETERS ☐
Fraction < 6 inch +/- 1/64; > 6 inch +/- 1/32	THIRD ANGLE

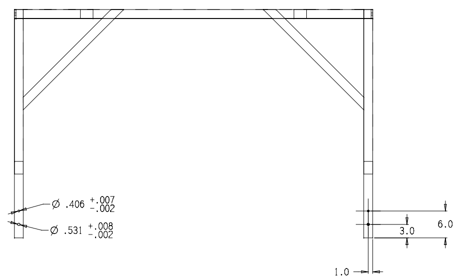
Institute for Marine Dynamics
Kerwin Place, P.O. Box 12093, Postal Station A
St. John's, Newfoundland A1B 3T5

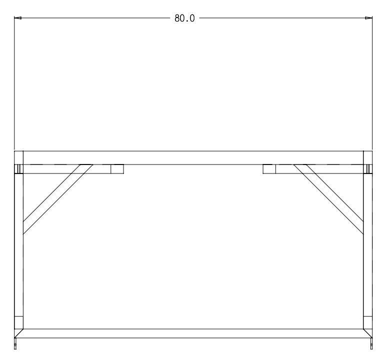
TRAX	2104	TITLE	CPF Stern Wedges Suppressor Cross-Brace
DRAWN	J Jeyasurya		
APPROVED		A3	NUMBER 2104Z05 REV
Quantity	1	SCALE NTS	DATE SHEET 1 OF 1

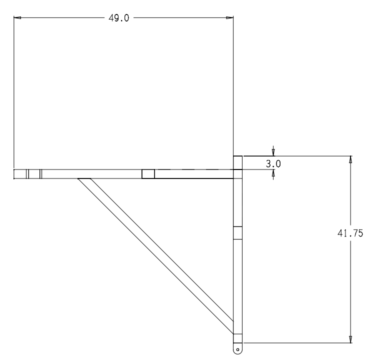
REVISIONS				
NO.	ZONE	DESCRIPTION	DATE	APPROVED

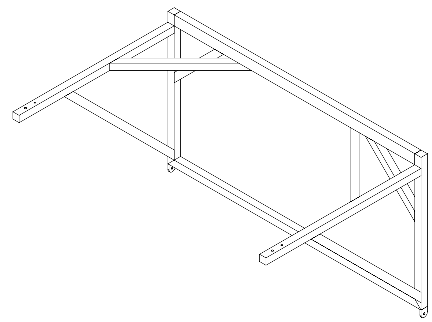
Part File
CAD_User\Projects\42_2104_16 CPF Stern Flaps\Student\CADKEY\Wave Suppressor.ckd

Notes:
Close all ends of box tube
3/8" holes must line up with cross-brace holes
Use 7/16" bolts for hinges
Welding: 1/8" fillet welds all around joints









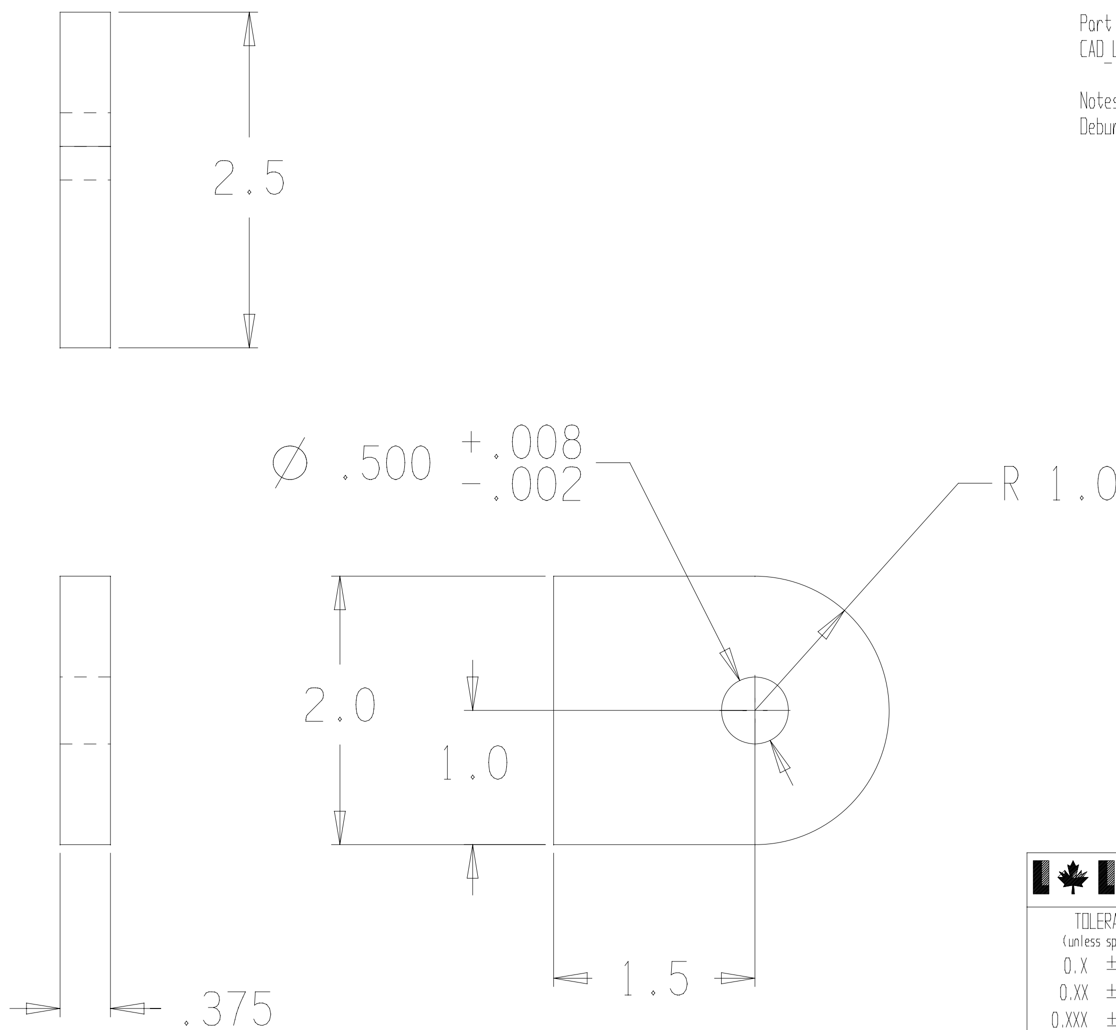
National Research Council Canada
Conseil national de recherches Canada
NRC-CNRC

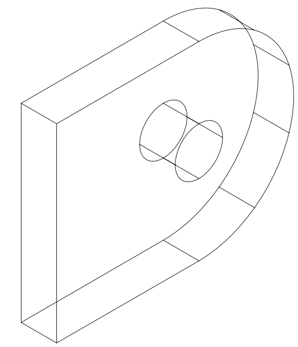
TOLERANCES (unless specified)	Material 2x2x3/16 HSS 3x2x3/16 HSS Heat Treatment	Institute for Marine Dynamics Kerwin Place, P.O. Box 12093, Postal Station A St. John's, Newfoundland A1B 3T5	
0.X ± 0.03 0.XX ± 0.015 0.XXX ± 0.005 Angle +/- .5 deg. Fabrication +/- .04 Fraction < 6 inch +/- 1/64 > 6 inch +/- 1/32	FINISH	TRAX 2104	TITLE CPF Stern Wedges Suppressor Top Frame
	DIMENSIONS IN: INCHES ☒ MILLIMETERS ☐	DRAWN J Jeyasurya	
	THIRD ANGLE	APPROVED	A3 — NUMBER 2104Z06 — REV 1
		Quantity 1	SCALE NTS — DATE — SHEET 1 OF 1

REVISIONS				
NO.	ZONE	DESCRIPTION	DATE	APPROVED

Part File
CAD_User\Projects\42_2104_16 CPF Stern Flaps\Student\CADKEY\Wave Suppressor.ckd

Notes:
Deburr - Remove All Sharp Edges





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Institute for Marine Dynamics
Kerwin Place, P.O. Box 12093, Postal Station A
St. John's, Newfoundland A1B 3T5

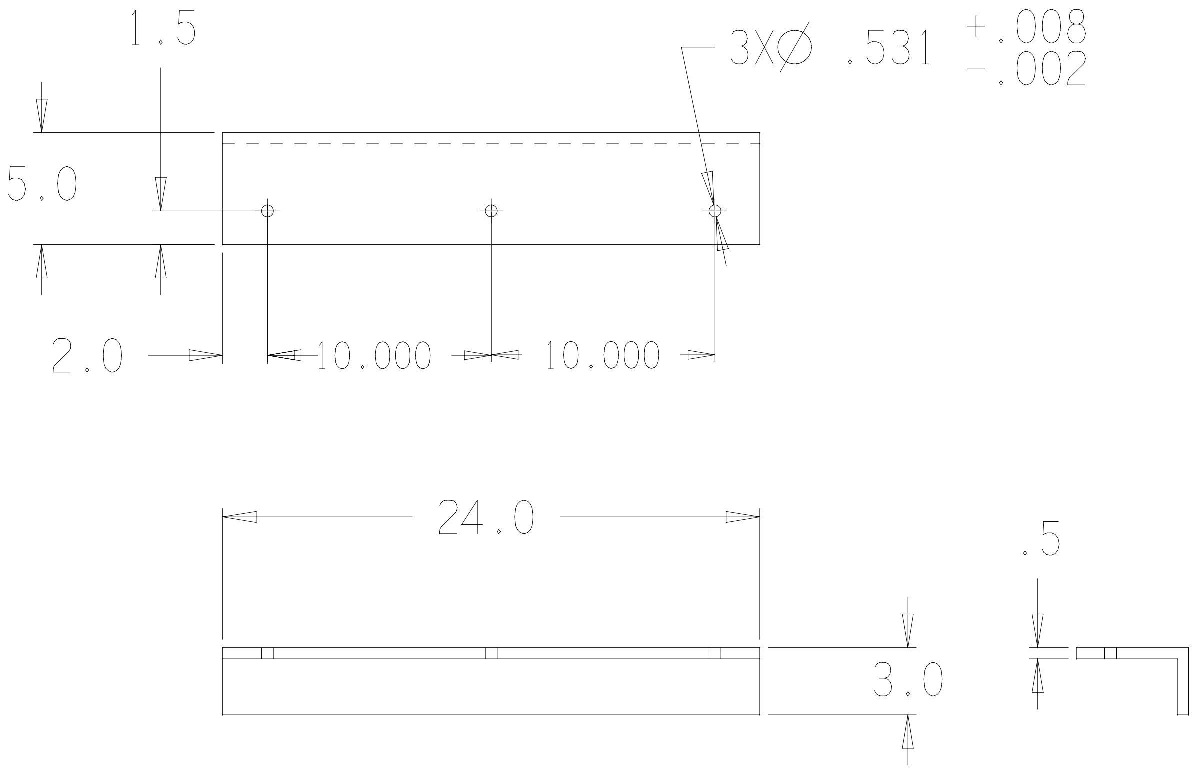
TOLERANCES
(unless specified)
0.X ± 0.03
0.XX ± 0.015
0.XXX ± 0.005
Angle +/- .5 deg.
Fabrication +/- .04
Fraction < 6 inch +/- 1/64
> 6 inch +/- 1/32

Material: Steel
Heat Treatment
FINISH
DIMENSIONS IN: INCHES ☒ MILLIMETERS ☐
THIRD ANGLE

TRAX: 2104
DRAWN: J Jeyasurya
APPROVED
Quantity: 4
TITLE: CPF Stern Wedges Suppressor Hinge
A3
NUMBER: 2104Z07
REV
SCALE: NTS
DATE
SHEET 1 OF 1

REVISIONS

NO.	ZONE	DESCRIPTION	DATE	APPROVED



Part File
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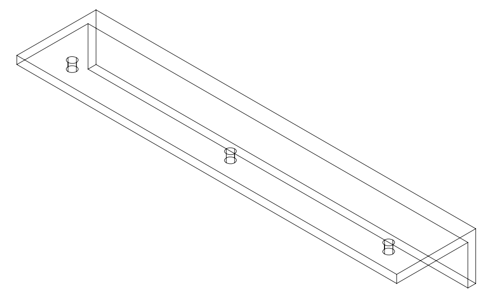
Note:
Holes should line up with holes on clamp



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Conseil national de recherches Canada
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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 5x3x1/2 steel angle Heat Treatment	Institute for Marine Dynamics Kerwin Place, P.O. Box 12093, Postal Station A St. John's, Newfoundland A1B 3T5
	FINISH	TRAX 2104
	DIMENSIONS IN: INCHES ☒ MILLIMETERS ☐	DRAWN J Jeyasurya
	THIRD ANGLE	APPROVED
		Quantity 4

TITLE CPF Stern Wedges Suppressor Steel Angle

	NUMBER	REV
A3	2104Z08	

SCALE NTS | DATE | SHEET 1 OF 1

REVISIONS

NO.	ZONE	DESCRIPTION	DATE	APPROVED

Part File
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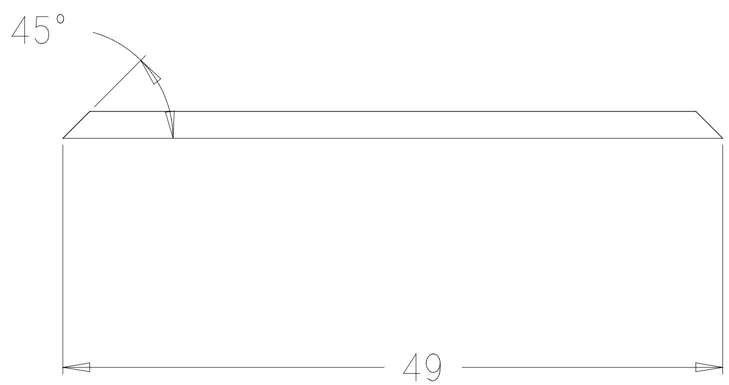

National Research Council Canada
Conseil national de recherches Canada
NRC-CNRC

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: 2x2x3/16 HSS
Heat Treatment
FINISH
DIMENSIONS IN: INCHES ☒ MILLIMETERS ☐
THIRD ANGLE

Institute for Marine Dynamics
Kerwin Place, P.O. Box 12093, Postal Station A
St. John's, Newfoundland A1B 3T5

TRAX: 2104
DRAWN: J Jeyasurya
APPROVED
Quantity: 2
TITLE: CPF Stern Wedges Suppressor Gusset1
A3
NUMBER: 2104Z09
REV
SCALE: NTS
DATE
SHEET 1 OF 1

REVISIONS				
NO.	ZONE	DESCRIPTION	DATE	APPROVED

Notes:

Deburr - Remove All Sharp Edges

Part File
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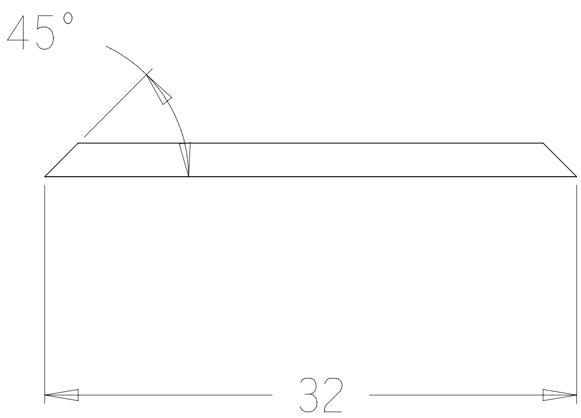

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TOLERANCES (unless specified) 0.X ± 0.03 0.XX ± 0.015 0.XXX ± 0.005 Angle +/- .5 deg. Fabrication +/- .04 Fraction < 6 inch +/- 1/64 > 6 inch +/- 1/32	Material 2x2x3/16 HSS Heat Treatment FINISH DIMENSIONS IN: INCHES ☒ MILLIMETERS ☐ THIRD ANGLE	Institute for Marine Dynamics Kerwin Place, P.O. Box 12093, Postal Station A St. John's, Newfoundland A1B 3T5	
		TRAX 2104 DRAWN J Jeyasurya APPROVED Quantity 2	TITLE CPF Stern Wedges Suppressor Gusset2 A3 NUMBER 2104Z10 REV SCALE NTS DATE SHEET 1 OF 1

REVISIONS

NO.	ZONE	DESCRIPTION	DATE	APPROVED

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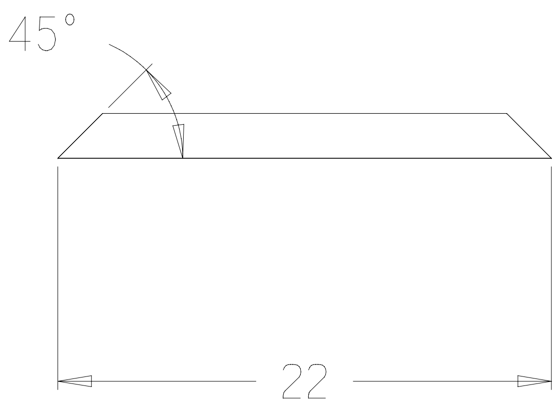

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Conseil national de recherches Canada
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Institute for Marine Dynamics
Kerwin Place, P.O. Box 12093, Postal Station A
St. John's, Newfoundland A1B 3T5

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
2x2x3/16 HSS
Heat Treatment
FINISH
DIMENSIONS IN: INCHES ☒ MILLIMETERS ☐
THIRD ANGLE

TRAX 2104
DRAWN J Jeyasurya
APPROVED
Quantity 2

TITLE CPF Stern Wedges Suppressor Gusset3
A3
NUMBER 2120Z11
REV
SCALE NTS
DATE
SHEET 1 OF 1

REVISIONS

NO.	ZONE	DESCRIPTION	DATE	APPROVED

Part File
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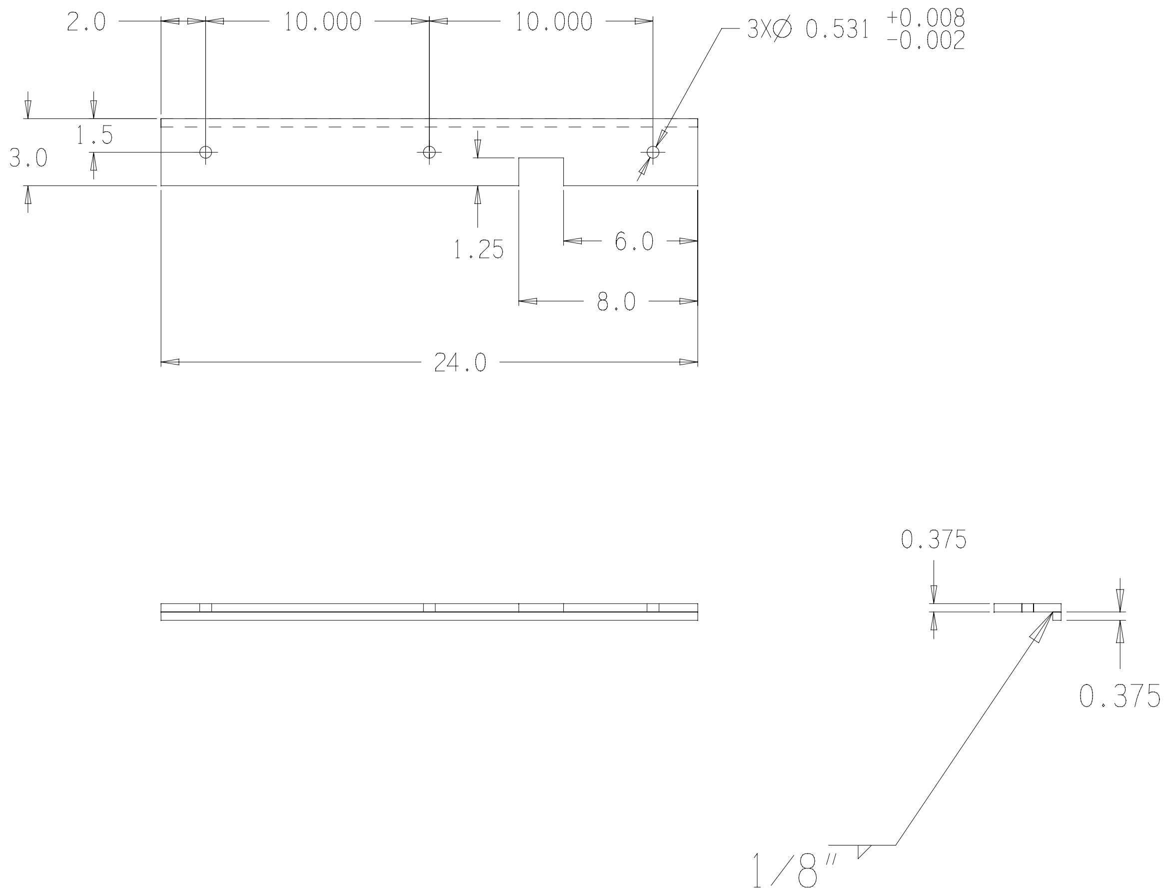
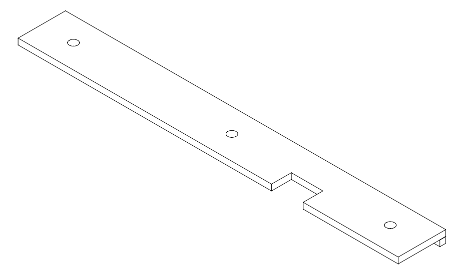
Notes:
Holes should line up with holes on steel angle
Deburr - Remove All Sharp Edges





National Research Council Canada	Conseil national de recherches Canada	NRC-CNRC

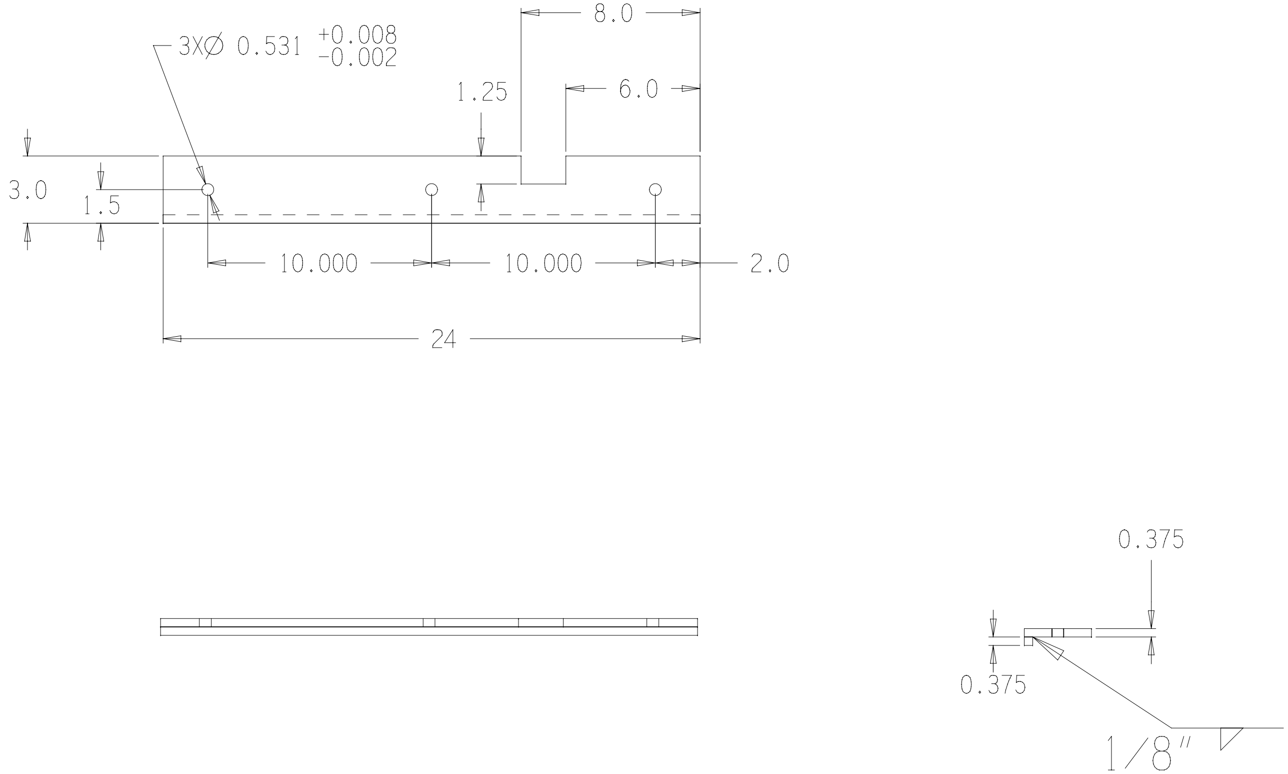
TOLERANCES (unless specified)	
0.X	± 0.03
0.XX	± 0.015
0.XXX	± 0.005
Angle	+/- .5 deg.
Fabrication	+/- .04
Fraction < 6 inch	+/- 1/64
Fraction > 6 inch	+/- 1/32

Material: Steel
Heat Treatment:
FINISH:
DIMENSIONS IN: INCHES ☒ MILLIMETERS ☐
THIRD ANGLE

Institute for Marine Dynamics
Kerwin Place, P.O. Box 12093, Postal Station A
St. John's, Newfoundland A1B 3T5

TRAX	2104
DRAWN	J Jeyasurya
APPROVED	
Quantity	1
TITLE	CPF Stern Wedges Suppressor Clamp
SIZE	A3
NUMBER	2104Z12
REV	
SCALE	NTS
DATE	2005-Oct-4
SHEET	1 OF 1

REVISIONS				
NO.	ZONE	DESCRIPTION	DATE	APPROVED



Part File
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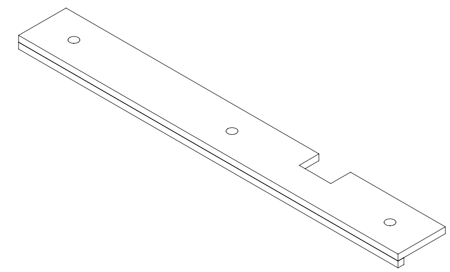
Notes:
Holes should line up with holes on steel angle
Deburr - Remove All Sharp Edges



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TOLERANCES (unless specified)	Material	Institute for Marine Dynamics
0.X ± 0.03	Steel	Kerwin Place, P.O. Box 12093, Postal Station A
0.XX ± 0.015	Heat Treatment	St. John's, Newfoundland A1B 3T5
0.XXX ± 0.005	FINISH	TRAX 2104 — TITLE CPF Stern Wedges Suppressor Clamp
Angle +/- .5 deg.	DIMENSIONS IN: INCHES ☒ MILLIMETERS ☐	DRAWN J Jeyasurya
Fabrication +/- .04		APPROVED — A3 — NUMBER 2104Z13 — REV
Fraction < 6 inch +/- 1/64; > 6 inch +/- 1/32	THIRD ANGLE	Quantity 1 — SCALE NTS — DATE 2005-Oct-4 — SHEET 1 OF 1