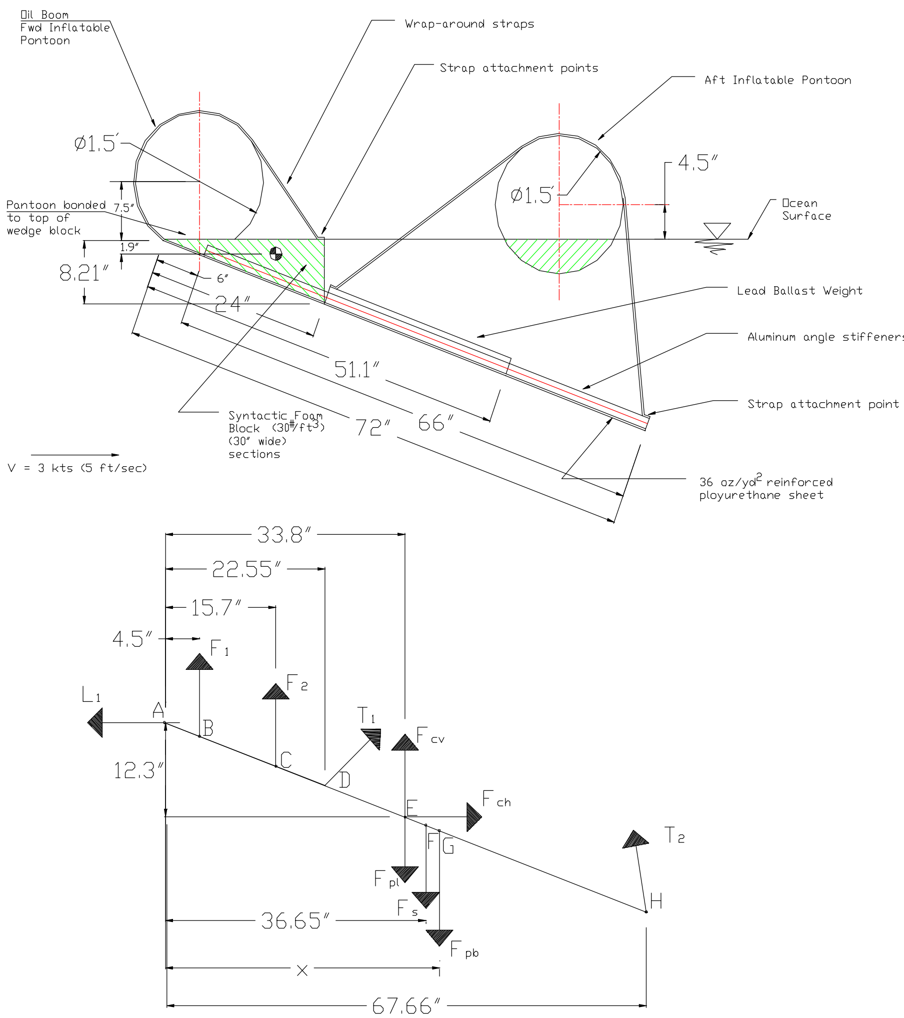

Figure 1

Legend

F_1 = Buoyant Force of Forward Pontoon
F_2 = Buoyancy of Syntactic Foam Block
F_3 = Buoyant Force of After Pontoon
F_{cv} = Vertical Lift Component due to Current
F_{ch} = Horizontal Lift Component due to Current
F_{pl} = Weight of Ramp Boom Sheet
F_s = In-water Weight of Aluminum Stiffener
F_{pb} = In-water Weight of Lead Ballast
L_1 = Tensile Force Required to Restrain the Boom
T_1 ,T_2 = Tensile Forces Required to Restrain Aft Pontoon

<u>Force Analysis on the Ramp Boom Surface</u>

Assumptions, Design Highlights

1. The Ramp Boom will be treated as a rigid plate in the fore and aft dimensions due to the reinforcement provided by the 66” long aluminum angle stiffeners and the triangular shaped syntactic foam fwd. flotation wedges.

2. The forward and aft pontoons are to be inflated during deployment and deflated upon recovery. Their weight is insignificant with respect to the other Ramp Boom components.

3. The syntactic foam fwd. flotation wedge is to be installed in 30” wide sections with a 12” wide wedge-shaped gap between each section. A free-flooding covered space is to be contained in the 12” wide gap between the 30” wide syntactic foam wedges. This will permit the Ramp Boom to be folded for storage. The free flooding covered-spaces will not be open at the forward edge of the Ramp Boom so that no oil can pass through the fwd. pontoon.

4. For convenience, the inflation points for both pontoons are to be sited at the same end of the Ramp Boom. This end will be on the in-boat end (i.e. the last part of the Ramp Boom to be deployed and the first part to be recovered).

5. The Ramp Boom surface will be fabricated from Poly-fabric reinforced Polyurethane sheet with a density of 36 $oz/yd^2 = 0.25\ ^{\#}/ft^2$.

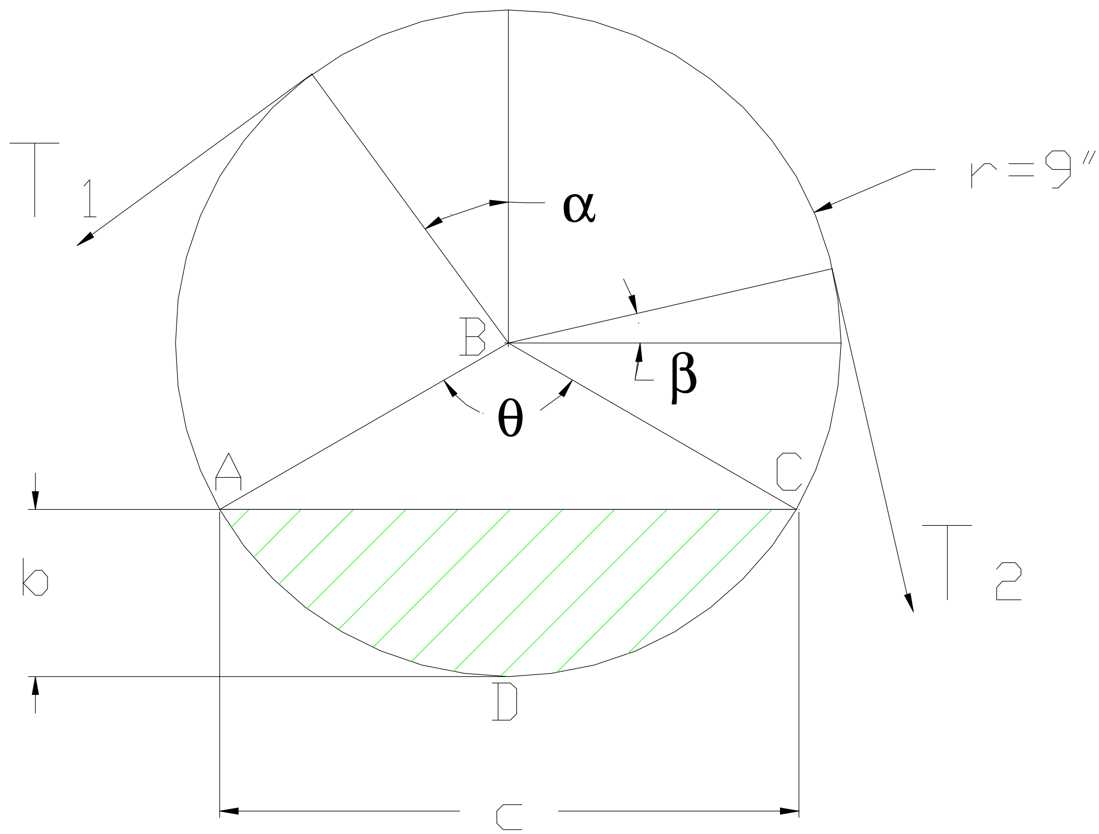

Figure 2

Calculation of F_2

First we will calculate the buoyancy force of the syntactic foam block in an assumed condition of total submersion in sea water for a unit width of 1 ft.

$F_{(\text{Block only})}$ = (Volume of Block) – (Volume of Seawater Displaced)

$$F_{(\text{Block only})} = \left[\frac{1}{2}(22.55'')(8.21'')(1\,ft)\left(\frac{1\,ft^2}{144in^2}\right)(64^{\#}/ft^3)\right] - \left[\frac{1}{2}(22.55'')(8.21'')(1\,ft)\left(\frac{1\,ft^2}{144in^2}\right)(30^{\#}/ft^3)\right]$$

$$F_{(\text{Block only})} = \left[(64-30)^{\#}/ft^3\right]\left[\frac{1}{2}(22.55'')(8.21'')(1\,ft)\left(\frac{1\,ft^2}{144in^2}\right)\right]$$

$$F_{(\text{Block only})} = 21.96^{\#}$$

Averaging this buoyant force over a 42” overall width to account for a 30” wide block section and a 12” wide free-flooded section.

$$F_2 = \frac{F_{(\text{Block only})} + F_{(12\text{" wide free flooded section})}}{42\text{"}} \qquad \text{where } F_{(12\text{" wide free flooded section})} = 0$$

$$F_2 = \frac{(21.96^{\#})(30\text{"}) + 0}{42\text{"}}$$

$$F_2 = 15.7^{\#}$$

Calculation of F_s

The aluminum reinforcing angles used to stiffen the Polyurethane sheet used for the construction of the Ramp Boom are to be placed on the top of the sheet and will be held in place with rivets. The angle size chosen for this design is 1”x1”x1/4”. The alloy with the best strength and corrosion resistance for this application is 6061-T6. The length of each stiffener is 66” and they are spaced 6” apart. To further aid in stiffening the Ramp Boom in the fore and aft directions, these reinforcing angles will be placed starting at the aftmost end and running 66” forward. This will place them under the syntactic foam block, which will reinforce the area of the Ramp Boom just aft of the block.

$F_{s'}$ = The in-air weight of the pair of stiffeners used in each unit (12”) width of the Ramp Boom
$F_{s'} = (2)(0.51^{\#}/\text{linear ft})[(66\text{"})/(12\text{"}/\text{ft})] = 5.6^{\#}$

The volume of the 2 aluminum stiffeners ;
$= (5.6^{\#}) / (0.0966^{\#}/\text{in}^3)(1728\text{in}^3/\text{ft}^3) = 0.034\ \text{ft}^3$

The volume of the saltwater displaced by the aluminum stiffeners ;
$= (64^{\#}/\text{ft}^3)(0.034\text{ft}^3) = 2.2^{\#}$

F_s = The actual in-water weight of the aluminum stiffeners, and;
$F_s = F_{s'} - 2.2^{\#} = 5.6^{\#} - 2.2^{\#} = 3.4^{\#}$

Note : This weight is for a *pair* of aluminum stiffeners.

Calculation of F_{cv}

The equation for the normal lift on a fixed inclined plate submerged in a fluid, moving with a velocity of 3 knots is :

$F_c = (1/2).\rho.\ V^2\ .\ C_L\ .\ A$ where $\rho = (64^{\#}/ft^3) / (32.2ft/sec^2) = 1.99$ slugs/ft

$V = 3$ kts $= 5$ ft/sec

$C_L = 0.7$ for a 20^0 angle

$A = 1' \times 6' = 6\ ft^2$

$F_c = (1/2)[(64^{\#}/ft^3)/(32.2ft/sec^2)](5ft/sec)^2(0.7)(6ft^2)$

$F_c = 104.35^{\#}$ Normal to the plane of the Ramp Boom

Breaking this normal force into its vertical and horizontal components for a unit Ramp Boom width of 1 ft yields :

$F_{cv} = 104.35^{\#} (\cos 20^0) = 98^{\#} =$ Vertical lift component

$F_{ch} = 104.35^{\#} (\sin 20^0) = 35.7^{\#} =$ Horizontal lift component

Summing the horizontal forces from the Ramp Boom free-body diagram;

L_1 = Tensile force required to restrain the boom / unit length

$L_1 = F_{ch} = 35.7^{\#}/ft$

Therefore to restrain a 16′-6” wide prototype section of the Ramp Boom at a 3 kts current ;

Force Required $= (L_1)(16.5ft) = 589^{\#}$

<u>Calculation of F_{pl}</u>

The density of the Polyurethane sheet to be used is 36 oz/yd^2 .

= (36 oz)(0.0625$^{\#}$/oz) / (yd^2)(9ft^2/yd^2) = 0.25$^{\#}$/ft^2

F_{pl} = (0.25$^{\#}$/ft^2)(6ft^2) = 1.5$^{\#}$ per unit width in air.

Note : It will be assumed that the in-water weight will be equal to the in-air weight for the Polyurethane sheet.

<u>Calculation of F_{pb}</u>

The submersion depth of the after pontoon will be set to the assumed value of 4.5" which is a good starting point and provides a large amount of reserve buoyancy to be maintained. (b=4.5" , refer to fig. 2)
Also the inclination angle β (refer to fig. 2) will be set to 5 degrees, since the Ramp Boom is desired to be at 25 degrees while there is no lift current.

$$c = 2\sqrt{18b - b^2} = 15.6"$$

$$q = 2\sin^{-1}\left(\frac{c}{18}\right) = 120^{\circ}$$

$$F_b = \left[81p\left(\frac{120}{360}\right) - \left(\frac{1}{2}\right)(15.6)(9-4.5)\right]\left(\frac{64}{144}\right) = 22.1^{\#}$$

where F_b = buoyancy of aft pontoon

Geometric constraint;

$$\frac{12.71 + 9\cos a}{\tan a} + 9(\sin a + \cos 5) + (29.13 + 9\sin 5)\tan 5 = 45.105$$

$$a = 35.3^{\circ}$$

For aft pontoon equilibrium;

$$T_1 \cos a = T_2 \sin 5$$

$$T_1 \sin a + T_2 \cos 5 = F_b$$

Solve for T_1 and T_2 ; $T_1 = 2.231^{\#}$ $T_2 = 20.89^{\#}$

F_{pb} can be found by solving the sum of the vertical force equation as it is the only unknown in the equation.

$F_1 + F_2 + T_1 \sin(35.3) + T_2 \cos(5) + F_{cv} - F_{pl} - F_s = F_{pb}$

$F_{pb} = 0 + 15.7^{\#} + 22.1^{\#} + 98^{\#} - 1.5^{\#} - 3.4^{\#}$

$F_{pb} = 130.9^{\#}$

Note : This force is to be equally shared among two stiffeners therefore each stiffener will require a ballast weight of $130.9^{\#}/2 = 65.45^{\#}$. The distribution and placement of the lead weight will be determined in the following summation of moments (Refer to the free-body diagram shown on page 1) :

$$\sum M_A = 0 = F_1(4.5'') + F_2(15.7'') + T_1(\sin 35.3)(22.55'') + T_1(\cos 35.3)(8.21'') \\ + F_{cv}(33.8'') - F_{pl}(33.8'') - F_s(36.7'') - F_{pb}(x) + F_{ch}(12.3'') \\ + T_2(\cos 5)(67.66'') - T_2(\sin 5)(24.63'')$$

solving for x;

$x = 39.97''$

Note that this dimension is a direct horizontal dimension. In order to place it on the inclined Ramp Boom it must be divided by cos 20^0.
$x_{\text{on the boom itself}} = 39.97” / \cos(20^0) = 42.54”$

Therefore $65.45^{\#}$ of lead ballast will be attached to each reinforcing angle in such a way that the centroid of the lead weight will be 42.5” after of the forward edge of the Ramp Boom. To achieve this weight placement, each $65.45^{\#}$ ballast weight will be cast over an angle stiffener to create a composite stiffener / ballast weight.

Calculation / Optimization of the Composite Stiffener / Ballast Weight

Notes :

1. As lead is more noble in saltwater than aluminum, measures must be taken to eliminate or at least reduce the galvanic action between the two metals. A recommended approach for this protection would be to completely coat the entire composite stiffener assembly with a vinyl coating (much like that used for coating tool handles). This would isolate both metals from electrolyte (i.e. saltwater) and inhibit galvanic action.
2. The above vinyl coating would also provide the additional benefit of chafe protection.
3. The composite stiffener / ballast weight assembly will be riveted to the Ramp Boom Polyurethane sheet on the side and will extend from the aftermost end fore by 66”.
4. The lead ballast weights will be cast at 20” in length with the center placed 30.9” forward of the after end.

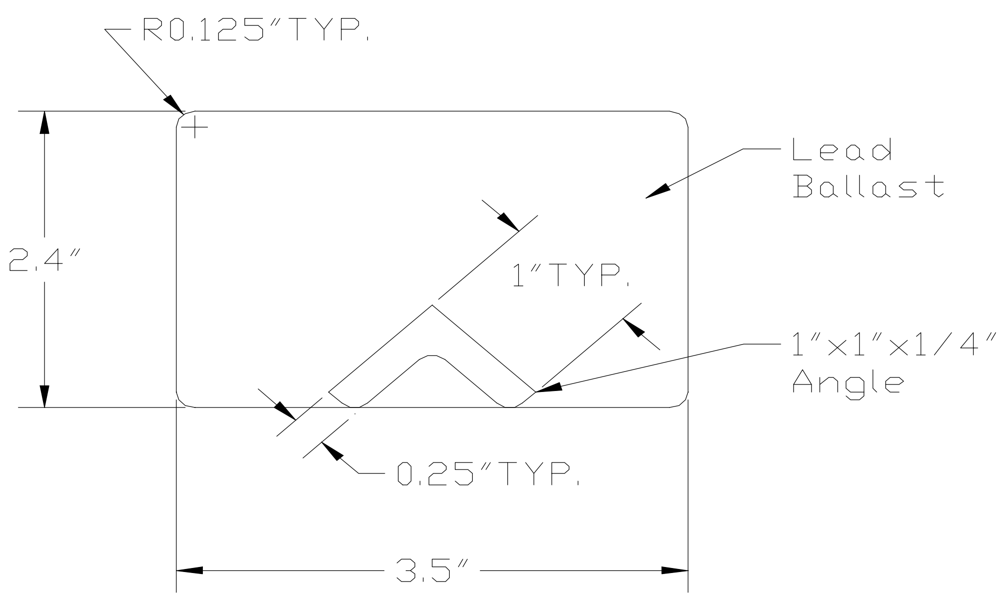

Figure 3

The wt/ft for this 1” angle = $0.51^{\#}$/linear ft

The volume in a 1 ft section = $(0.51^{\#}) / (0.0966^{\#}/in^3) = 5.28\ in^3$

The area of a typical cross section of this angle = $(5.28\ in^3)/(12\ in) = 0.44\ in^2$

For a 20” long lead ballast weight section the weight per foot ; $= (65.45^{\#}) / (20in)(1ft/12in) = 39.27^{\#}/\text{linear ft}$

Now calculating the volume of lead in a $39.27^{\#}$ section 1 ft length ; $= (39.27^{\#}) / (0.411^{\#}/in^3) = 95.55\ in^3$

The typical cross section of lead without the aluminum angle would then be ; $= (95.55\ in^3) / (12\ in) = 7.96\ in^2$

By using a nominal cross section of the lead with a 3.5” assumed width, the height of the lead can be determined by adding the area of the aluminum angle and then calculating the increment in height required to compensate for the angle which yields;

The cross sectional area of the lead alone $= 7.96\ in^2$

The cross sectional area of the angle alone $= 0.44\ in^2$

The sum of the areas of both lead and angle $= 8.4\ in^2$

The height of the lead $= (8.4\ in^2) / (3.5\ in) = 2.4\ in$

SUMMARY

The Ramp Boom, built to the above particulars, will be in equilibrium with a 20 angle of inclination when restrained on each end in a 3 knot current. In conditions of less than 3 knots the Ramp Boom will remain in an angle of inclination of approximately 25 , due to the large amount of reserve buoyancy provided by the aft pontoon.

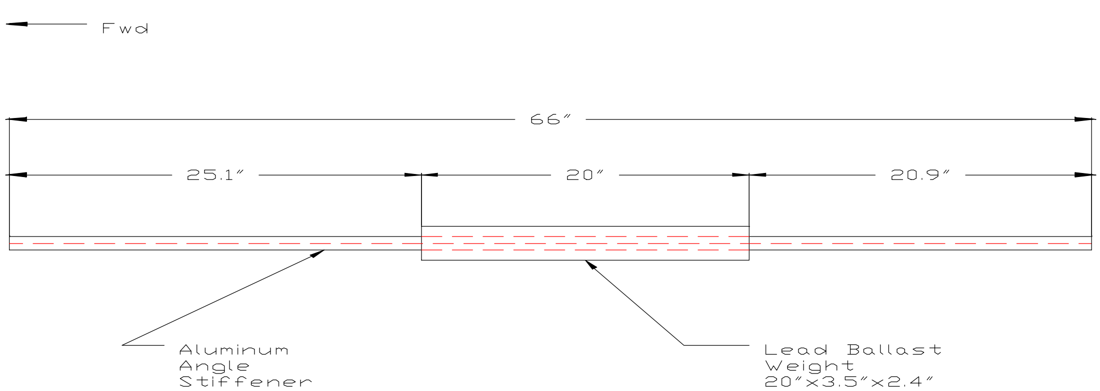

Figure 4