Hydrostatic Pressure

By John Fuller

Fluid Mechanics Lab

Wednesday(1-345pm)

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Abstract

The objective of this lab is to determine the hydrostatic thrust acting on a plane surface immersed in water when the surface is partially submerged or fully submerged. Also to determine the experimental center of pressure, and the theoretical center of pressure for each of the trials performed.

Introduction

Hydrostatic pressure is, the pressure exerted by a fluid at equilibrium due to the force of gravity. A fluid in this condition is known as a hydrostatic fluid. So our Hydrostatic pressure lab was to determine the hydrostatic pressure of water on a flat surface. Adding weight and then filling the tank with water to the point where the apparatus was in equilibrium. so we can calculate the force on the flat surface using the given equations.

Physical Setting

All procedures for the orifice and free jet flow lab were performed at UAA in the ANSEP building in room 102. the room is equipped with the testing apparatus for this lab. The building is at room temperature and is at standard atmospheric pressure.

Experimental Procedures

Equipment
The equipment required for the testing of this lab is:
- The F1-12 Hydrostatic Pressure Apparatus
- F1-10 Hydraulics Bench (water source)
- Graduated Cylinder
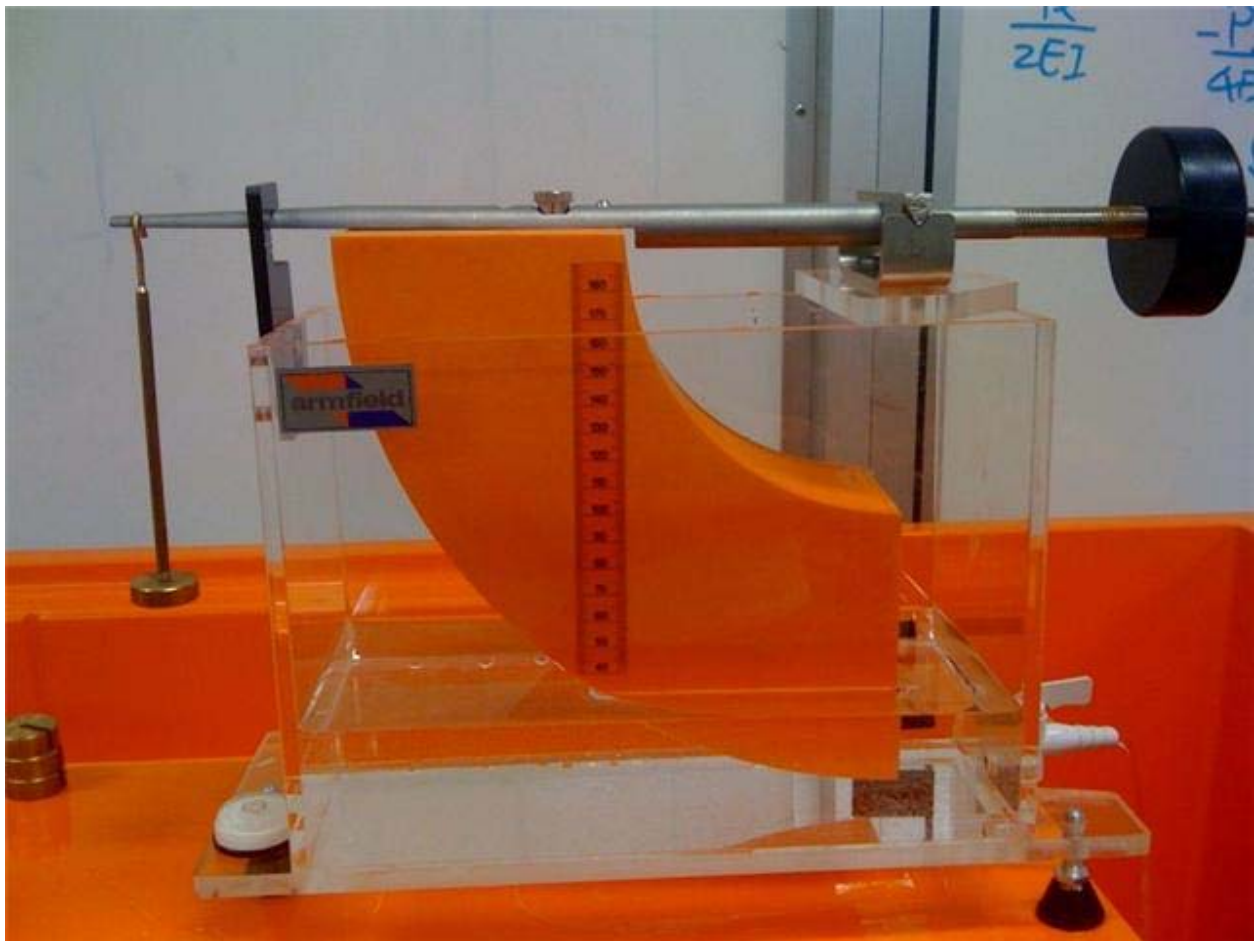
Procedure - Equipment set-up
Position the empty F1-12 flotation tank on the Hydraulics Bench, then adjust the screwed feet until the built-in circular spirit level indicates that the tank is level in both planes. Position the balance arm on the knife edges and check that the arm is free to swing. Then find the empty weight hanger in the groove at the end of the balance arm. Move the counter-balance weight until the balance arm is horizontal by the checking that the central index mark on the beam level indicator.

**Procedure - Taking a Set of Results**
The first part of this lab test was completed by adding mass to the balancing arm with the mass hanger in 50 gram increments until the tank is full. Water was then added to the tank to level the balancing arm by increasing the force on the plane surface. The height of the water measurements were recorded along with the added mass.

The second part of this lab was completed by starting with a full tank and removing mass. The height of the water and added mass were recorded as in the first part of the lab.
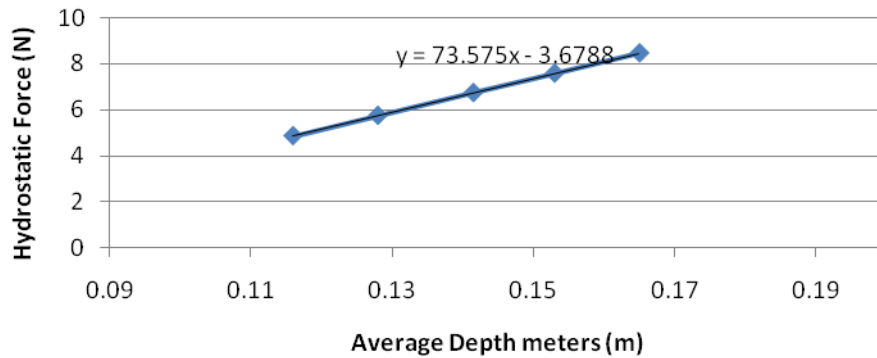
Results
From the data collected the hydrostatic pressure and distance to the centre of pressure can be calculated for both the partially submerged and fully submerged plane surface. Once this is done the theoretical hydrostatic pressure and distance to the centre of pressure can be calculated. From this one could compare the theoretical values to the actual values measured. The percent difference is then determined. The percent difference between the measured and theoretical forces was almost nearly zero for all increments. We did have some discrepancy between the measured and theoretical depths to the center of pressure. The percent error of depth to the center of pressure ranged from 1.79% to 50.42%. Following is the graphs for the hydrostatic pressure and the distance to the centre of pressure for both partially and fully submerged.

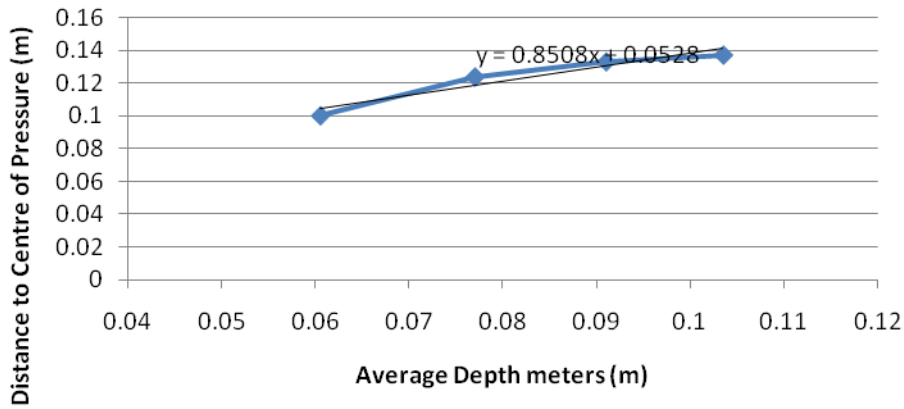# Hydrostatic Force vs. Average Depth (Partially Submerged)
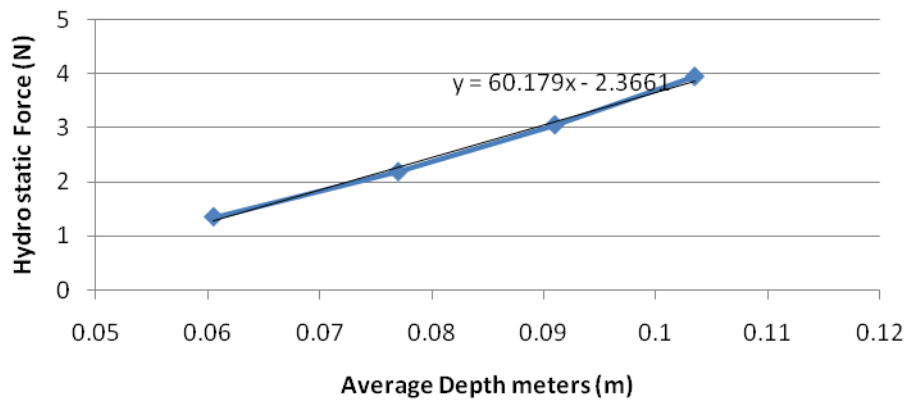
$y = 60.179x - 2.3661$

Hydrostatic Force (N) vs. Average Depth meters (m)

Hydrostatic Force vs. Average Depth (Fully Submerged)

$y = 73.575x - 3.6788$

Hydrostatic Force (N) vs. Average Depth meters (m)

Distance to Centre of Pressure vs. Average Depth (Partially Submerged)

Distance to Centre of Pressure (m)

y = 0.8508x + 0.0528

Average Depth meters (m)

Distance to Centre of Pressure vs. Average Depth (Fully Submerged)

Distance to Centre of Pressure (m)

y = 0.085x + 0.1293

Average Depth meters (m)

Measured Distance to Centre of Pressure vs. Theoretical Distance to Centre of Pressure (Partially Submerged)
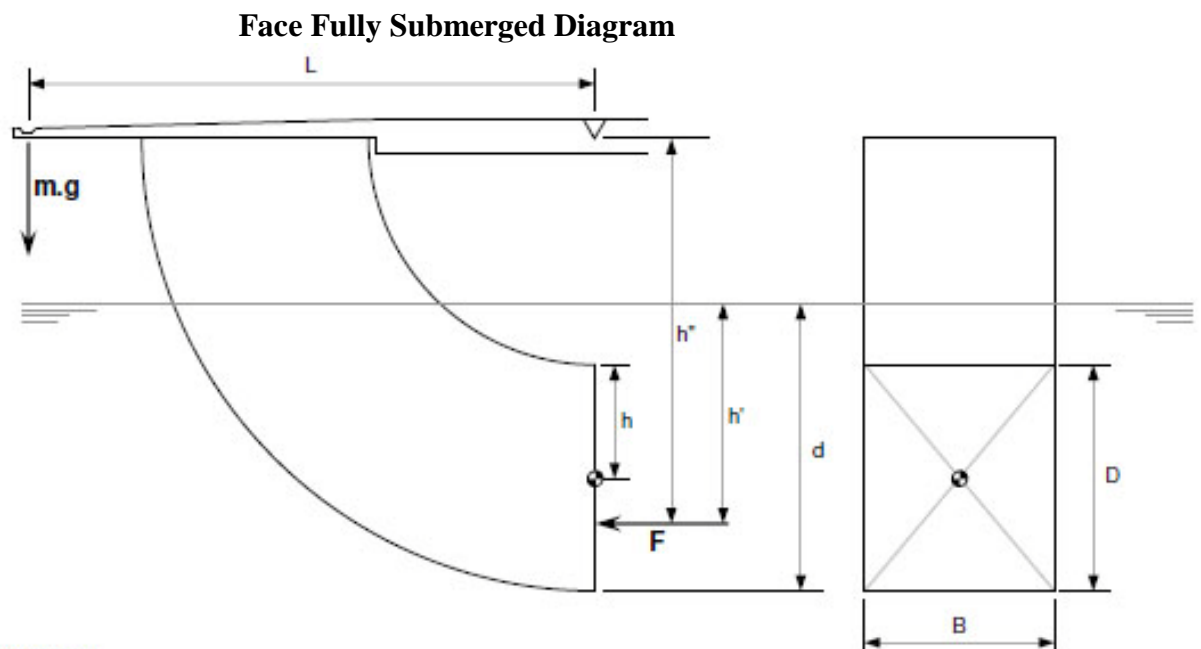

Measured Distance to Centre of Pressure vs. Theoretical Distance to Centre of Pressure (Fully Submerged)
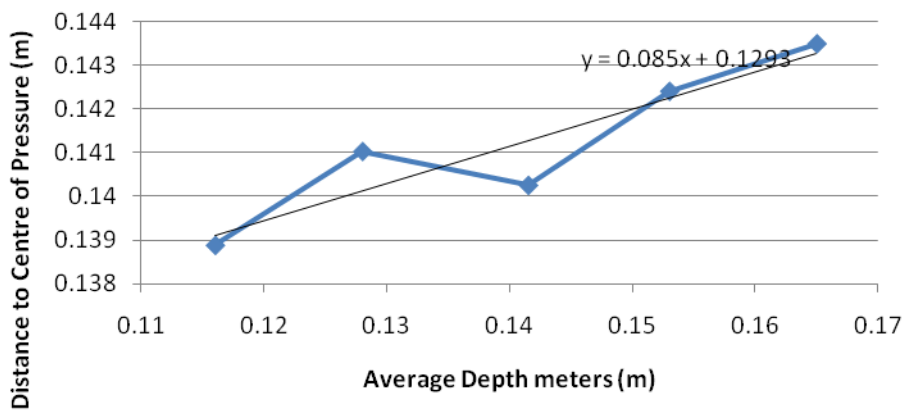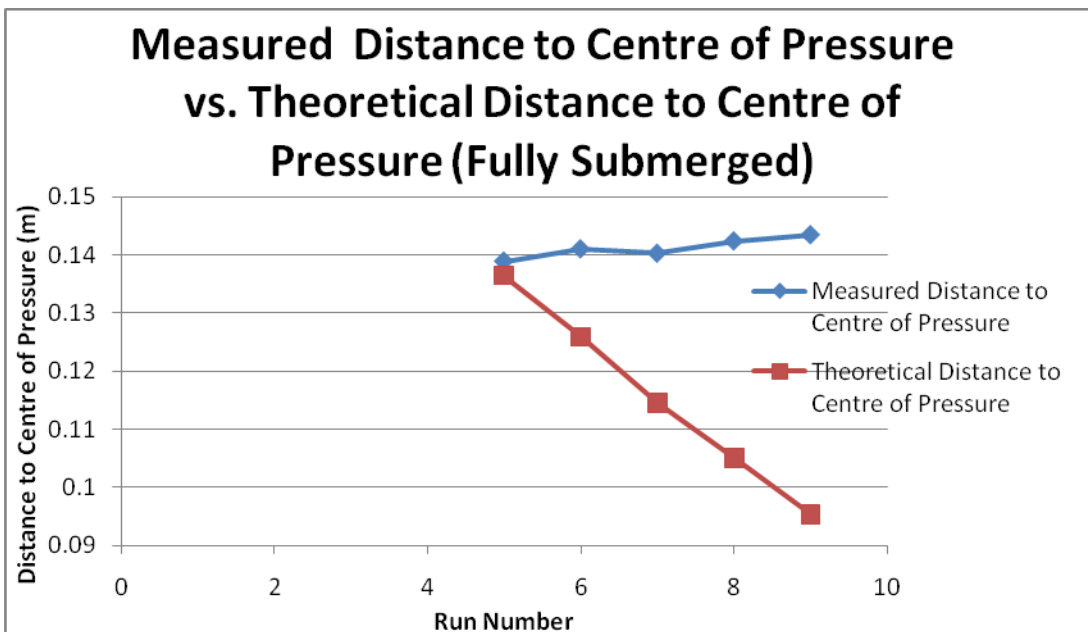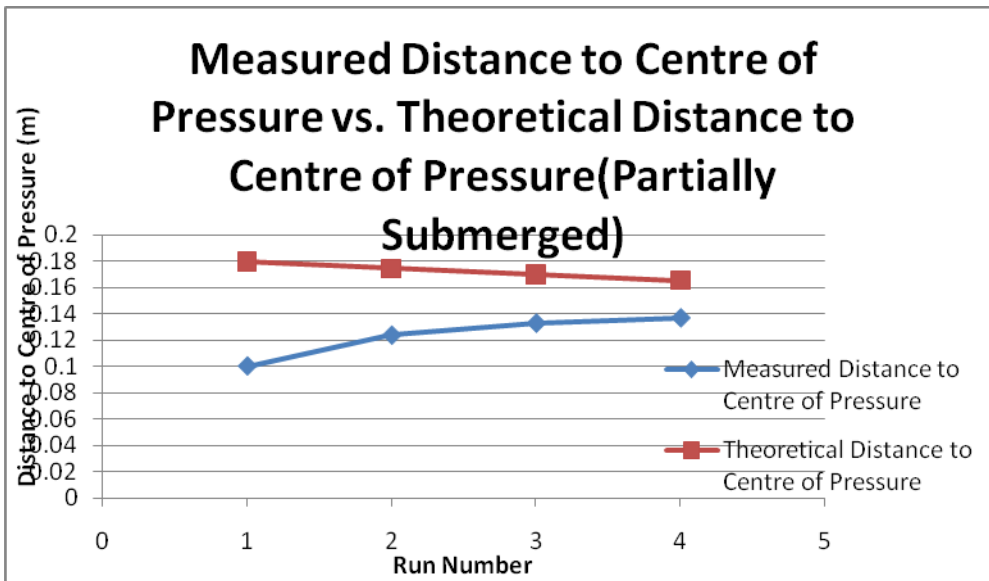
Sample Calculations
Experimental equations used for face fully submerged:

Face Fully Submerged Diagram

Where:
    d is the depth of submersion,
    F is the hydrostatic thrust exerted on the quadrant,
    h' is the depth of the centre of pressure,
    h" is the distance of centre of pressure below the pivot,
    B is the width of the surface, and
    D is the depth of the surface
    W is the weight on the hanger (=mg)

M = Fh"

Fh" = WL = mgL

    Sample: $F = \left[\frac{mgL}{h"}\right] = (0.050)(9.81)(0.275)/(0.100175 = 1.346\frac{(kg\times m)}{s^2}$ =>
1.35 N
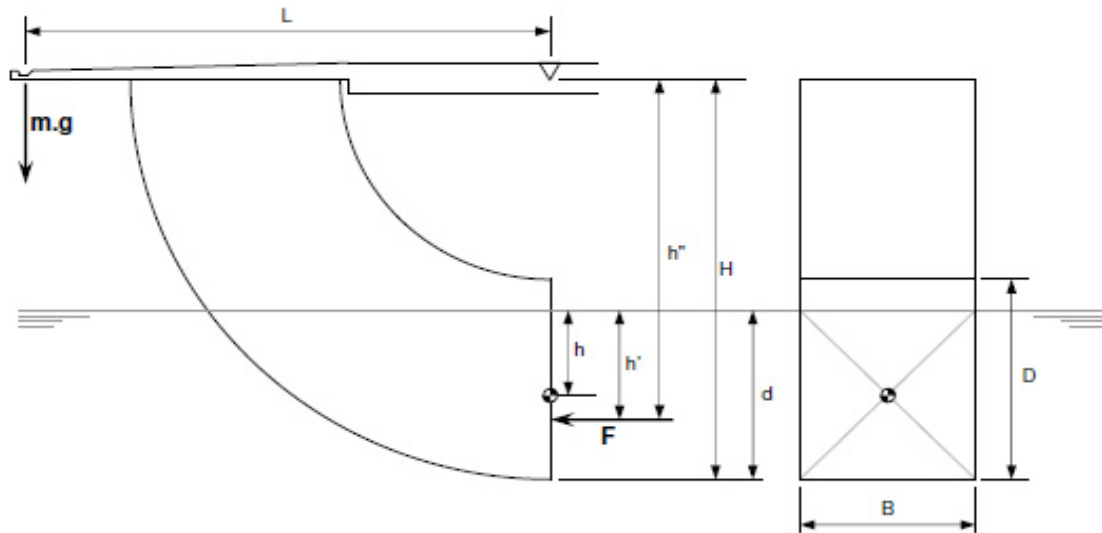
$h" = \left[\frac{mL}{\rho BD\left[d-\left(\frac{D}{2}\right)\right]}\right]$

    Sample: $(0.05)(0.275)/(1000)(0.75)(0.1)[0.0605-(0.1^2)]=$ **0.100175 m**

Experimental equations used for face partially submerged:

Partially Submerged Face Diagram

Where:
L is the horizontal distance between the pivot point and the weight hanger,
H is the vertical distance between the pivot and the base of the quadrant,
D is the height of the quadrant face, B is the width of the quadrant face,
d is the depth of water from the base of the quadrant, and
h' is the vertical distance between the surface and the centre of pressure.

The forces shown are F, the hydrostatic thrust, and m.g, the weight.

M = Fh"

Fh" = WL = mgL

$$h" = \left[\frac{mgL}{F}\right] = \left[\frac{2mL}{\rho Bd^2}\right]$$

Sample: $h" = 2(0.05)(0.275)/(1000)(0.75)(0.1\char`\^2) = 0.179m$

Discussion

 The force applied in the system vertical face of buoyant material counter acts the mass added to the hanging arm. so we know that if we move away from the sea level, the pressure will change either with air or water. So in our experiment also change in pressure because of the weight of the water above and buoyant forces clearly show the properties of water. The water pressure was so high that we add the mass 50 g to 450g even still quadrant was able to support it in static equilibrium. So the idea let us to believe that the curved area allows for a larger surface with which the water can act upon for less change in depth. This would explain such a large jump in force applied after breaking the upper plane of the vertical face.

Conclusion

The graphical analysis of our lab shows that a linear relationship between Hydrostatic force and Average Depth for the Partially Submerged and the graph of Hydrostatic Force and Average Depth for Fully Submerged is also linear. Our Theoretical force compared to the measured force were nearly identical with a percent errors of 2.04e^-14%. The error in the distance to the centre of pressure compared to the theoretical was outrageously high with a percent error of 50.42%.   The graphical analysis showed a linear relationship between Hydrostatic Force and Average Depth for only fully submerged. The graph of Hydrostatic Force and Average Depth for partially submerged is not perfectly linear.

References

Armfield Limited, *2002*, Instruction Manual F1-16,; Ringwood, Hampshire.   BH24 1DY England

Appendices

		Measured						Theoretical		Percent Difference	
Run #	Mass Added (kg)	Depth Working (Up) (m)	Depth Working (Down) (m)	Average Depth ((Up+Down)/2) (m)	Hydrostatic Thrust=F (N)	Distance to Centre of Pressure= h (m)	Measured Turning Moment (Nm)	Theoretical Distance to Center of Pressure (m)	Theoretical Hydrostatic Force=F (N)	Percent Difference Force (%)	Percent Difference Center of Pressure (%)
1	0.05	0.06	0.061	0.0605	1.346514	0.100175	13.44158	0.179833	1.346514469	0.00E+00	44.30
2	0.1	0.077	0.077	0.077	2.181131	0.123686	17.63444	0.174333	2.1811	-2.04E-14	29.05
3	0.15	0.091	0.091	0.091	3.046373	0.132834	22.93365	0.169667	3.046372875	-2.92E-14	21.71
4	0.2	0.103	0.104	0.1035	3.940769	0.136915	28.78262	0.1655	3.940768969	1.13E-14	17.27
5	0.25	0.116	0.116	0.116	4.85595	0.138889	0.674438	0.136445	4.85595	-1.83E-14	-1.79
6	0.3	0.128	0.128	0.128	5.73885	0.141026	0.809325	0.125889	5.73885	1.55E-14	-12.02
7	0.35	0.142	0.141	0.1415	6.732113	0.140255	0.944213	0.114502	6.7321125	-1.32E-14	-22.49
8	0.4	0.153	0.153	0.153	7.578225	0.142395	1.0791	0.105063	7.578225	0.00E+00	-35.53
9	0.45	0.165	0.165	0.165	8.461125	0.143478	1.213988	0.095386	8.461125	0.00E+00	-50.42

Demensions	
Height of verical face (m)	0.1
Vertical Distance from base to	0.2
Lenth of Moment Arm (m)	0.275
Width of face (m)	0.075
Gravity (m/S²)	9.81
Density of Water (kg/m^3)	1000

Added Mass (g)	Measured turning moment	Depth	Hydrostatic thrust	Distance to center of pressure	Turning Moment	
50		60				
100		77				
150		91				
200		103				
250		116				
300		128				
350		142				
400		153				
450		165				
400		153				
350		141				
300		128				
250		116				
200		104				
150		91				
100		77				
50		61				

9-29-10

Taylor Rawlins