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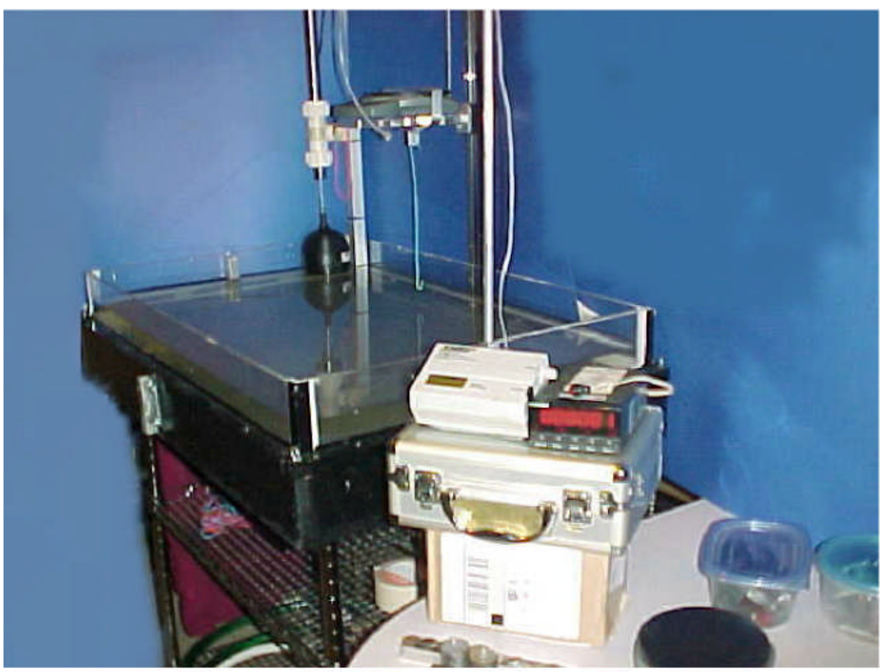
REPORT ON TESTING OF INCLINE METHODS

FOR

WEIGHT MOVEMENTS and LOADCELL MOVEMENTS

BY

TESTING IN A CONTROLED ENVIORMENT & TEST TANK



CONTEXT

Testing Overview

The testing was devised to create a controlled environment and testing of different shaped hull styles. Its mission was to ascertain the true properties of the heeling action against the hull in both traditional weight movement incline and the loadcell movement incline. By carefully recording the rise or fall of the water line, in the test tank, it could be ascertained if a change in the volume of displacement was occurring and to what amount along with if it was a gain or loss, still keeping in mind that the actual weight of the vessel did not change. There were three types of hull configurations tested,

1st was a cylindrical (tube) shape vessel that corresponds with our "Theories of incline page" later in this presentation,

2nd was a Bakers Pan that the side walls were set to such an angle that there would be no change in the water line plane of the vessel at any angle,

3rd was a true replica model of a liftboat.

The goal of the testing was to prove out what method of inclining a vessel would produce the most accurate results by eliminating false assumptions, human error, pre-loading of the water plane and/or volume displacement and ease of implementation.

The result of the testing follows with some very interesting data obtained. The test was run for the results of the incline itself as per the method used, it was felt that lightship values were not necessary since that is a function of calculation only. The setup of the test comparison was to first incline the vessel with weights as per normal ASTM procedures to obtain the degree of heel at the given moment. All data was recorded on an Excel spread sheet set up for computation of said data to give results on the gain or loss of volume, weight of water contained in that volume, moment and degree. The spreadsheet also contains a section to record the hydrostatics results produced by said raw data.

The next step was to re-set the vessel for the loadcell method of incline; all test instruments remained the same. The incline weights were removed for the test and the vessel was then placed into the test tank for volume displacement measurement then zeroed for the test. The vessel was then inclined with the loadcell method matching the degree of heel produced by the weight method as close a possible. All results were recorded as per the weight method for a comparison of results.

Note: the surface level measurement shown in the results that have a(-) in front of it is showing an INCREASE in water line level thus showing the vessel to deepen its draft. Also note that all calculations for moment are in LB & FT. as well as all results in FT due to our Hydrostatics program.

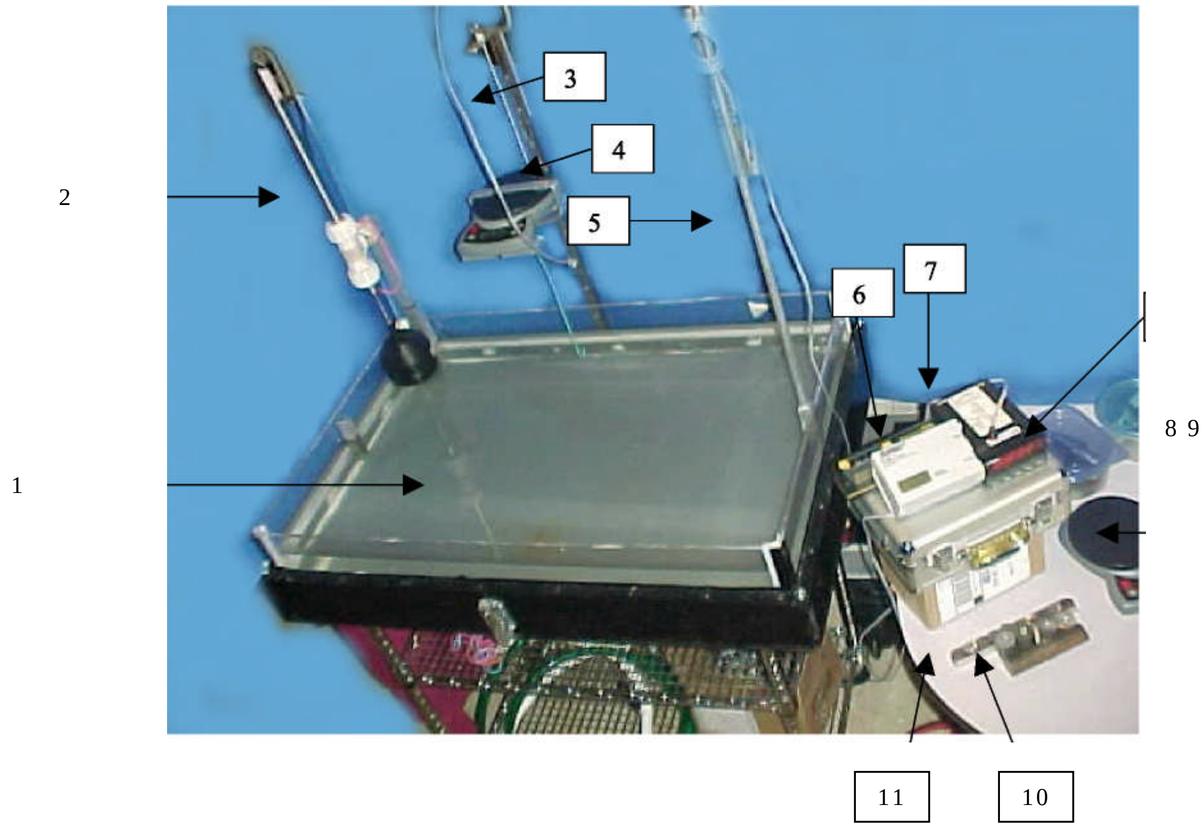
Theory of Weight Procedure

Customarily the incline experiment is conducted by the introduction of weight to the vessel. Weights are placed at predetermined stations and the angle of heel is recorded. Once this is done, the heeling moment is compared to the angle of heel and a vertical center of gravity is calculated. This is a proven method and has been in use for several hundred years. It is, however, subject to any number of inaccuracies as well as hazards to personnel and equipment.

Theory of Loadcell Procedure

The procedure for the use of a loadcell in lieu of weights is quite simple in principle. A loadcell is attached to the vessel at the sheer and a small crane or other device is used to produce a heeling action, in this method the precise angle desired could be obtained. The resulting Righting Moment produced by the Vessel is measured by the loadcell and recorded just as the movement of the weights in the conventional incline experiment. Since the distance of the loadcell from centerline remains constant, the heeling moment is easy to calculate to an accuracy that could never be achieved with the movement of weights on the deck.

TEST TANK & EQUIPMENT:



1: Test Tank; 33 ¾" x 22" x 7", Water surface area as shown for testing is 741.125 square inches. Water SG is 1 with a density of 62.42.

2: Linear displacement transducer; calibrated at one inch of total travel (+0.5"/-0.5"). Linearity of unit is .23% as NIST testing, accuracy calibration then from "0" is then 0.00115" in total travel. Float is standard plastic toilet ball.

3: Scale Slide Mechanism; Unit is constructed to act as a crane for the scale unit. It travels on a ball bearing "Vee" grooved slider; the slider is raised and lowered by rotating a screw of 8– 32 inch thread to increase or decrease the load and angle of degree of heel.

4: Scale; Model CS 200 OHAUS, Capacity 200g x 0.1g or readout to 0.00 oz. Calibrated by Alabama Scale Company and certified accurate. The scale is used to measure the load applied to the test vessel at the degree of incline indicated.

5: Holder Arm & Cable for the degree indicator # 6

6: Angle Star Protractor System; NIST certified angle finder, reading in 0.00 degree, adjustable to “0”, Readout unit connected to AccuStar Electronic Clinometer (not pictured) by cable (#5), the AEC is firmly attached to the vessel being tested.

7: Readout & controller for # 2, readout set to 0.00000 of an inch.

8: Lead test weights.

9: Scale; Model CS 2000 OHAUS, Capacity 2000g x 1g or readout to 0 lb 0.00 oz. Calibrated by Alabama Scale Company and certified accurate. The scale is used to measure the load applied to the test vessel at the degree of incline indicated.

10: Steel test weights.

11: Steel incline weights. **TANK**

SETUP & TEST START

A: Tank is filled to the appropriate level and allowed to reach room temperature.

B: After “A” is accomplished a SG and temperature reading is taken and recorded.

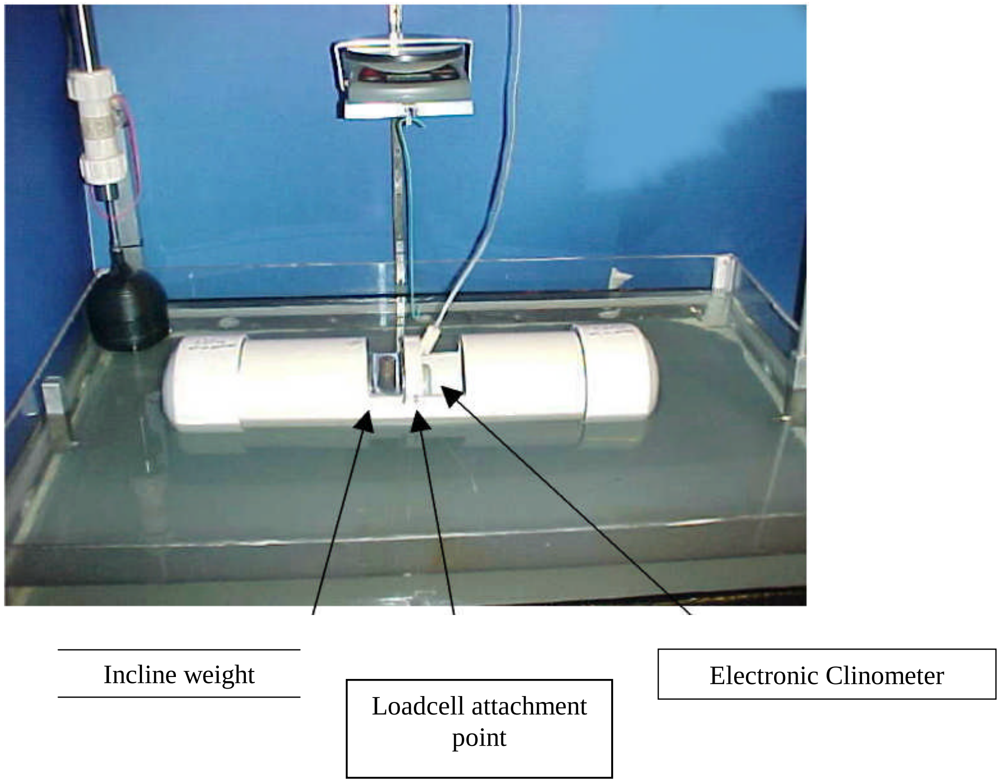
C: Next the Linear (#2 & 7) system is “0” to the water level for indication of rise or fall.

D: The vessel being tested is then lowered into the tank, the Linear is allowed to settle and a reading is taken. This reading will interpolate the volume of displacement of the vessel as sitting in the water. Reading x Surface area will give additional volume created. Once this is done then the Linear is rezeroed for the testing.

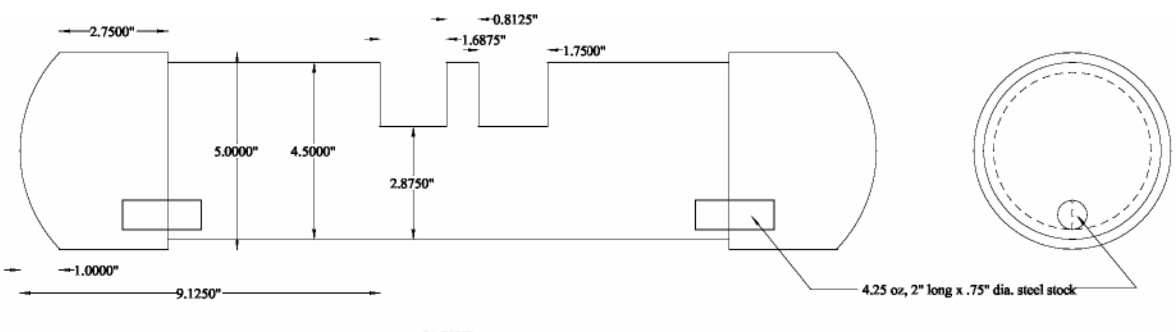
E: Incline testing by both methods then proceeds with recording the rise or fall of the water level at each incline movement along with the degree of heel and the moment taken to produce it.

INCLINE OF TUBE

Picture of TUBE & Setup;



Drawing of TUBE;



TUBE setup;

The tube was made to the specifications as per the drawing above and chosen because of its shape, the shape adds no resistance to rotation about the axes. The two 4.25 oz weights were added to the tube to give it a VCG for the purpose of inclining. The 1.6875” notch was created to give a level surface on which to move the incline weight. The other notch was created as an opening that the Electronic Clinometer could be installed through. The location of the centerline of the Electronic Clinometer was mounted as close as possible to the physical centerline of the tube. The tube was then weigh by scale for a true weight and a set point for comparison by volume calculations.

The tube was then set into the tank for volume measurement and to run the incline test by using the weight method. The weight used is #4 at 1.34 oz, it was moved outboard from centerline at 0.25" intervals for a total of five movements. All data was recorded and shown below.

Incline by Weight Method;

The chart below shows the overall results as recorded:

Incline test in tank										
VESSEL:	TUBE		Input Cell	Test tank area =		741.125	sq.in.	Water condition		1 Inch to FT.
scale wt =	88	Oz	Input Cell	Wt of Water per cu.in =		0.576969	Oz	SG =	1	0.0833
Item Wt .=	88	Oz	Size = 21.75" loa x 5" Dia. Oa					water dens:	62.42	
Surface. Ch = change in tank depth as measured with liner transducer: (-)= increase in height									CID = Cu. In. Disp.	
CALCULATIONS by Calculated Displacement										
Start surface	0.20652	CID =153.057135		Wt. Oz =88.30922212		Wt Lb = 5 . 5 1 9 3 2 6		with incline wts on deck		
USING WEIGHTS METHOD TO INCLINE								CALCULATIONS		
Movement	**Deg. Heel**	**surface ch.**	**CID**	**Wt. Ch oz**	**% of total**	**wt ch lb**	**cu. Ft.**	**Wt. Oz**	**Lb.**	**moment**
1~ 4	0.57	-0.00051	-0.377974	-0.218079137	-0.002469	-0.013629946	-0.000218735	1.34	0.08375	0.001742
2~ 4	1.48	-0.00172	-1.274735	-0.735482578	-0.008328	-0.045967661	-0.000737694	1.34	0.08375	0.003492375
3~ 4	2.56	0.00036	0.266805	0.153938214	0.001743	0.009621138	0.000154401	1.34	0.08375	0.005234375
4~ 4	3.49	0.00034	0.251983	0.145386091	0.001646	0.009086631	0.000145823	1.34	0.08375	0.006976375
5~ 4	4.89	0.00063	0.466909	0.269391875	0.003051	0.016836992	0.000270202	1.34	0.08375	0.008718375
6~4	0.00	0.00000	0.000000	0	0.000000	0	0	0.00	0.00000	0
1" moves	Wt. # 4	1.34	in Oz.			in Oz.		Moment = Ft. x LB		

Shown above are the five movements of the tube using a weight to produce the moments and degrees of heel. You will note in the "surface ch." Column in movements # 1 & 2 there is an increase in the water line which translates into an increase in displacement volume, with movements #3 to 5 there is a decrease in waterline which translates into a decrease in displacement volume. The "CID" column is showing the calculated volume of increase or decrease of the vessel as calculated by the surface area of the tank verses the amount of the surface change. The "AS Incline TEST 1" results are as calculated by our hydrostatics program and are shown in feet. The average VCG is shown in feet and converted into inches at right to give some assimilation to the vessel.

In reading the results the following interpolations will be obtained for all movements;
Movement 1~ using weight #4, degree of heel is 0.57, surface change of test tank is –0.00051" which means there was an increase (rise) of the water level in the tank, the CID of –0.377974 means that there was an increase in volume of the tube (deeper draft) of that amount and is expressed as Cubic Inch Displacement (CID) or expressed as the TUBE increased its volume displacement by 0.377974 to carry the same weight load as applied by a short leverage arm acting against the axes, the vessel is still carrying the same load weight as in the neutral position.

Incline by Loadcell Method;

The chart below shows the overall results as recorded:

Start surface	0.20543	CID =	152.2493088 Wt. Oz =		87.84313142 Wt Lb =		5.490195714	INCHES		FEET
USING LOADCELL METHOD TO INCLINE								2.4375	distance	0.203125
Movement	**Deg. Heel**	**surface ch.**	**CID**	**Wt. Ch oz**	**% of total**	**wt ch lb**	**cu. Ft.**	reading oz	lb	moment
1	0.59	0.00028	0.207515	0.119729722	0.001361	0.007483108	0.00012009	0.24	0.0150	0.003046875
2	1.50	0.00056	0.415030	0.239459444	0.002721	0.014966215	0.000240179	0.32	0.0200	0.0040625
3	2.53	0.00058	0.429853	0.248011567	0.002818	0.015500723	0.000248757	0.51	0.0319	0.006474609
4	3.49	0.00113	0.837471	0.48319495	0.005491	0.030199684	0.000484648	0.65	0.0406	0.008251953
5	4.89	0.00295	2.186319	1.261438143	0.014335	0.078839884	0.001265231	0.85	0.0531	0.010791016
6	0.00	0.00000	0.000000	0	0.000000	0	0	0.00	0.0000	0

Note the Surface ch. Column; there was no gain in displacement volume.

Comparison of both methods;

HEEL DEGREES:

The heeling degrees was kept as close as possible to allow for interpolations. The columns of data in the title cell are named "wtm" for weight method and "lcm" for loadcell method.

Movement	Wtm Deg. Heel	Lcm Deg. Heel
1	0.57	0.59
2	1.48	1.50
3	2.56	2.53
4	3.49	3.49
5	4.89	4.89
6	0.00	0.00

As shown the degree of heel difference was kept to a minimum, with M4 & M5 matching.

SURFACE CHANGE:

The surface of the tank directly corresponds to a change in volume displacement or draft of the object within the tank. By measuring the change in the level of the tank, the volume gain or loss can be calculated and applied to the objects gain or loss.

Movement	Wtm surface ch.	Lcm surface ch.
1: 0.57 – 0.59	-0.00051	0.00028
2: 1.48 – 1.50	-0.00172	0.00056
3: 2.56 – 2.53	0.00036	0.00058
4: 3.49 – 3.49	0.00034	0.00113
5: 4.89 – 4.89	0.00063	0.00295
6	0.00000	0.00000

Note the surface change for the Weight Method; the first two movements had a gain in surface, which means that the TUBE displaced more volume (deeper draft). The remaining three movements there was a loss in the height of the surface this would be a loss in volume displacement.

The surface change for the Loadcell Method stayed with a constant loss of surface height, then a constant loss of volume displacement.

VOLUME DISPLACEMENT CHANGE:

From the table above the displacement volume of change of the object can be calculated. This change does not reflect a change in the objects weight but a change in the axis of buoyancy of which the leverage is applied.

Movement	Wtm CID	Lcm CID
1: 0.57 – 0.59	-0.377974	0.207515
2: 1.48 – 1.50	-1.274735	0.415030
3: 2.56 – 2.53	0.266805	0.429853
4: 3.49 – 3.49	0.251983	0.837471
5: 4.89 – 4.89	0.466909	2.186319
6	0.000000	0.000000

In the Wtm column you will note the cubic inch displacement gain or loss. As stated above there was a gain in movements 1& 2, the gain in #2 was very significant as compared to any loss in the following movements.

THE FOLLOWING CHARTS SHOW THE COMPARESON BETWEEN BOTH METHODS.

The data shown was obtained from our hydrostatics program and compiled for easy reference.

CALCULATIONS FOR WATERPLANE AREA CHANGE:

Movement	Wtm WPA	Lcm WPA
1: 0.57 – 0.59	1.1896	1.1881
2: 1.48 – 1.50	1.1894	1.1879
3: 2.56 – 2.53	1.1896	1.1880
4: 3.49 – 3.49	1.1895	1.1880
5: 4.89 – 4.89	1.1895	1.1880
6	0.000000	0.000000

Note in both methods that the waterplane area had changed overall by 0.0002.

CALCULATIONS FOR VCG, TCB, TCF, TKM:

Movement	Wtm VCG'	Lcm VCG'	Wtm TCB'	Lcm TCB'	Wtm TCF'	Lcm TCF'	Wtm TKM'	Lcm TKM'
1: 0.57 – 0.59	0.1780	0.1550	0.0013	0.0014	0.0009	0.0009	0.2082	0.2082
2: 1.48 – 1.50	0.1840	0.1805	0.0034	0.0035	0.0023	0.0023	0.2082	0.2082
3: 2.56 – 2.53	0.1873	0.1820	0.0059	0.0058	0.0039	0.0039	0.2083	0.2083
4: 3.49 – 3.49	0.1877	0.1839	0.0080	0.0080	0.0054	0.0054	0.2084	0.2084
5: 4.89 – 4.89	0.1899	0.1855	0.0112	0.0112	0.0075	0.0075	0.2086	0.2086
6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

CALCULATIONS FOR VCB, VCF, DRAFT, VOLUME FT^3:

Deg. Heel	Wtm VCB'	Lcm VCB'	Wtm VCF'	Lcm VCF'	Wtm Draft'	Lcm Draft	Wtm Vol. Ft^3	Lcm Vol. Ft^3
0.57 - 0.59	0.0766	0.0764	0.1199	0.1195	0.1190	0.1195	0.0884	0.0880
1.48 - 1.50	0.0767	0.0764	0.1199	0.1195	0.1199	0.1195	0.0884	0.0880
2.56 - 2.53	0.0768	0.0765	0.1200	0.1196	0.1199	0.1195	0.0884	0.0880
3.49 - 3.49	0.0769	0.0766	0.1201	0.1197	0.1199	0.1195	0.0884	0.0880
4.89 - 4.89	0.0771	0.0769	0.1202	0.1198	0.1199	0.1195	0.0884	0.0880
0.00	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

The above charts show that when the calculations for the various properties of the TUBE were made that there is no difference in the linearity of the properties results of each method. There is a difference between the two methods in the VCG. The VCG of the Weight Movement is higher due to the weight of 1.34 oz used to incline the TUBE, this weight would be backed off in normal calculations but it has already corrupted the data by artificially changing the properties of the volume displacement verses the axis of rotation.

It should also be noted that using the Loadcell method to incline, the TUBE was inclined in its TRUE lightship configuration thus allowing for the true movement of the TUBE without any falsely imposed properties of rotation to be introduced.

Calculation of the average VCG for the two findings are;

Weight Method as Inclined:	0.1853’	or	2.2245”
Loadcell Method:	0.1773’	or	2.1285”

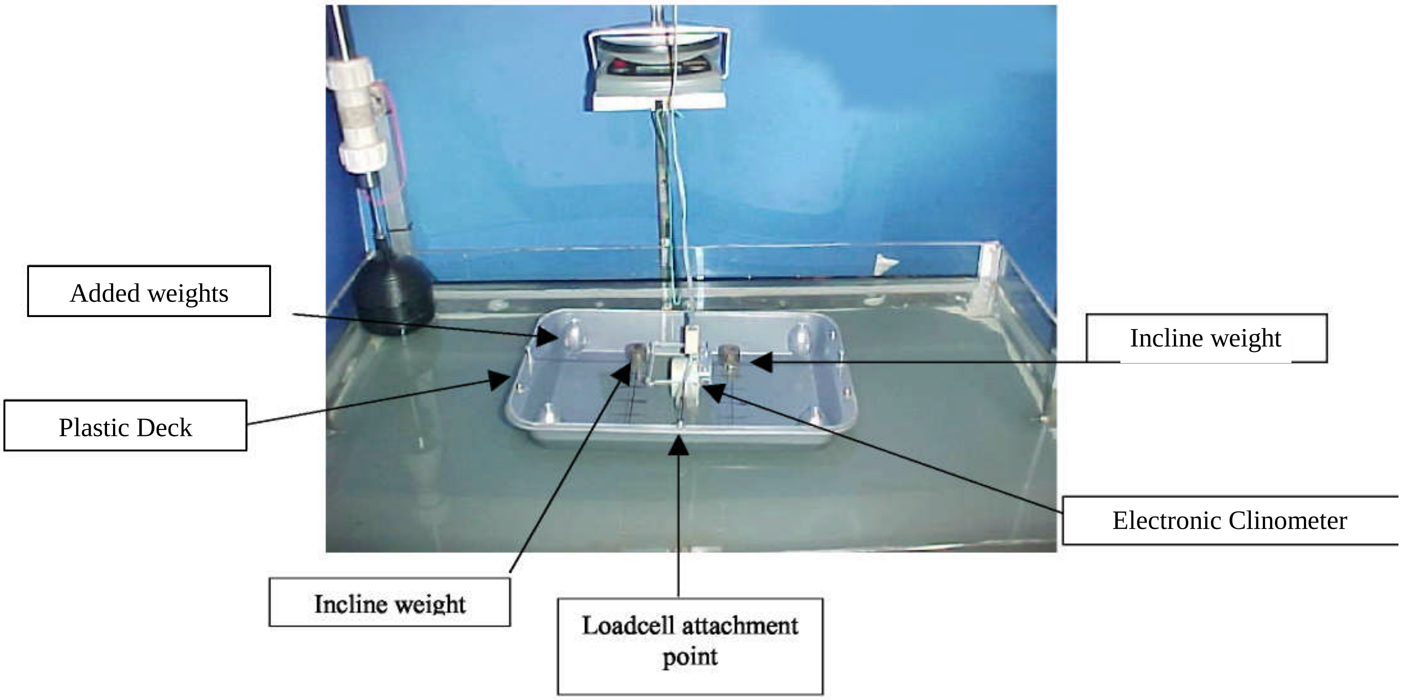
Using the Weight Method the TUBE had to work to over come the imposed extra weight that is not normal to its true form and properties of buoyancies. The weight caused the TUBE to seek a deeper draft in movements 1 & 2 to compensate for the added leverage to its natural center of buoyancy. The TCB did not have enough volume of displacement under it to support the weight causing this action. Once the volume of displacement became sufficient enough in the rest of the movements the properties of the TUBE returned to its natural state but except for movements 1& 2 at a deeper draft.

Using the Loadcell Method the TUBE is rotated about its axis in its natural state. This provided for a more accurate VCG of the TUBE. In comparing the calculated results between the two methods you will find that the TCB, TCF, TKM match (some with interpolation) but the VCG is different for all movements. This is due to the TUBE not working to overcome the introduced weight and rotating about its natural lightship axis.

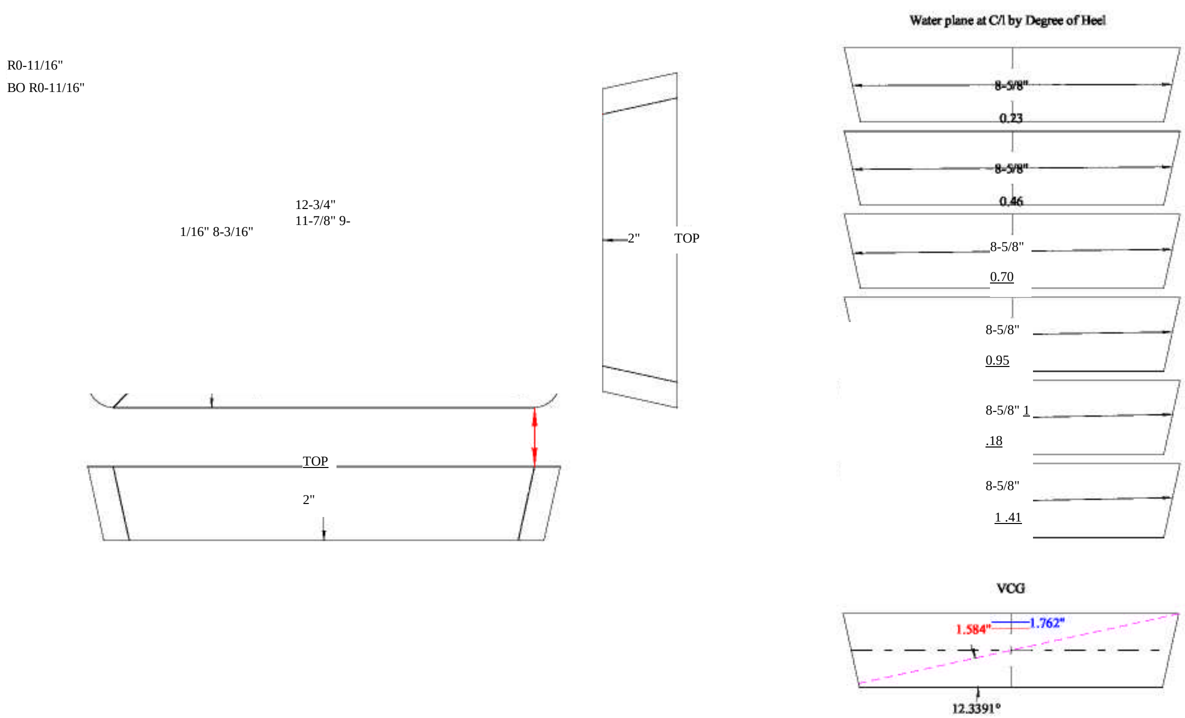
In choosing the TUBE in this experiment to set a base line for comparison there was no artificially introduced properties of form to contend with or back calculate out, only the introduced weigh of the incline weight and the actions caused thereby.

INCLINE OF Baker's Pan

Picture of BAKER'S PAN & Setup;



Drawing of Baker's Pan;



VESSEL: Baker's Secret

Baker’s Pan setup;

The pan was made to the specifications as per the drawing above and chosen because of its shape, the shape adds no resistance to rotation about the axis. The four 8 oz weights were added to the pan to give it a VCG for the purpose of inclining. The plastic deck was added to give a level surface on which to move the incline weight. The opening in the deck was created so as the Electronic Clinometer could be installed. The location of the centerline of the Electronic Clinometer was mounted as close as possible to the physical centerline of the pan. The pan was then weigh by scale for a true weight and a set point for comparison by volume calculations.

The pan was then set into the tank for volume measurement and to run the incline test by using the weight method. The weights used is #4 at 1.34 oz and #2 at 1.28 oz, it was moved outboard from centerline at 1” intervals for a total of six movements. All data was recorded and shown below.

The right section of the drawing shows the water plane throughout the movements. This was generated to show that with rotation about the axis, the water plane did not change at each heeling movement.

Incline by Weight Method;

The chart below shows the overall results as recorded:

Incline test in tank										
VESSEL:	Baker's Secret		Input Cell	Test tank area =		741.125	sq.in.	Water condition		1 Inch to FT.
scale wt =	68.7	Oz	Input Cell	Wt of Water per cu.in =		0.576969	Oz	SG =	1	0.0833
Item Wt .=	68.7	Oz		Size = 11.875" loa x 9.125" beam x 2" Molded depth				water dens:	62.42	
Surface. Ch = change in tank depth as measured with liner transducer: (-)= increase in height									CID = Cu. In. Disp.	
CALCULATIONS by Calculated Displacement										
Start surface	0.16841	CID =124.8128613		Wt. Oz =72.01315174		Wt Lb = 4 . 5 0 0 8 2 2		with incline wts on deck		
USING WEIGHTS METHOD TO INCLINE								CALCULATIONS		
Movement	**Deg. Heel**	**surface ch.**	**CID**	**Wt. Ch oz**	**% of total**	**wt ch lb**	**cu. Ft.**	**Wt. Oz**	**Lb.**	**moment**
1~ 4	0.23	0.00000	0.000000	0	0.000000	0	0	1.34	0.08375	0.006976375
2~ 2	0.46	0.00000	0.000000	0	0.000000	0	0	1.28	0.08000	0.013640375
3~ 4	0.70	-0.00177	-1.311791	-0.756862886	-0.011017	-0.04730393	-0.000759138	1.34	0.08375	0.02061675
4~ 2	0.95	-0.00188	-1.393315	-0.803899562	-0.011702	-0.050243723	-0.000806317	1.28	0.08000	0.02731675
5~ 4	1.18	-0.00185	-1.371081	-0.791071378	-0.011515	-0.049441961	-0.00079345	1.34	0.08375	0.034293125
6~ 2	1.41	-0.00187	-1.385904	-0.799623501	-0.011639	-0.049976469	-0.000802028	1.28	0.08000	0.040957125
1" moves	Wt. # 4	1.34	in Oz.	Wt # 2	1.28	in Oz.		Moment = Ft. x LB		

Shown above are the six movements of the pan using two weights to produce the moments and degree of heel.

Incline by Loadcell Method;

The chart below shows the overall results as recorded:

Start surface	0.16572	CID =	122.819235	Wt. Oz =	70.8628912	Wt Lb =	4.4289307	INCHES		FEET
USING LOADCELL METHOD TO INCLINE								4.625	distance	0.385416667
Movement	**Deg. Heel**	**surface ch.**	**CID**	**Wt. Ch oz**	**% of total**	**wt ch lb**	**cu. Ft.**	reading oz	lb	moment
1	0.22	0.00007	0.051879	0.029932431	0.000436	0.001870777	3.00224E-05	0.23	0.0144	0.005540365
2	0.46	0.00192	1.422960	0.821003808	0.011951	0.051312738	0.000823472	0.52	0.0325	0.012526042
3	0.70	0.00191	1.415549	0.816727747	0.011888	0.051045484	0.000819183	0.80	0.0500	0.019270833
4	0.95	0.00185	1.371081	0.791071378	0.011515	0.049441961	0.00079345	1.12	0.0700	0.026979167
5	1.17	0.00186	1.378493	0.795347439	0.011577	0.049709215	0.000797739	1.41	0.0881	0.033964844
6	1.42	0.00284	2.104795	1.214401466	0.017677	0.075900092	0.001218053	1.71	0.1069	0.041191406

Shown above are the six movements of the pan using the Loadcell to produce the moments and degree of heel.

Comparison of both methods;

HEEL DEGREES:

The heeling degrees was kept as close as possible to allow for interpolations. The columns of data in the title cell are named “Wtm” for weight method and “Lcm” for loadcell method.

Movement & weight #	Wtm Deg. Heel	Lcm Deg. Heel
1 ~ 4	0.23	0.22
2 ~ 2	0.46	0.46
3 ~ 4	0.70	0.70
4 ~ 2	0.95	0.95
5 ~ 4	1.18	1.17
6 ~ 2	1.41	1.42

As shown the degree of heel difference was kept to a minimum, with M2, M3 & M4 matching.

SURFACE CHANGE:

The surface of the tank directly corresponds to a change in volume displacement or draft of the object within the tank. By measuring the change in the level of the tank, the volume gain or loss can be calculated and applied to the objects gain or loss.

Movement & Degree	Wtm surface ch.	Lcm surface ch.
1: 0.23 – 0.22	0.00000	0.00007
2: 0.46 – 0.46	0.00000	0.00192
3: 0.70 – 0.70	-0.00177	0.00191
4: 0.95 – 0.95	-0.00188	0.00185
5: 1.18 – 1.17	-0.00185	0.00186
6: 1.41– 1.42	-0.00187	0.00284

Note the surface change for the Weight Method; the first two movements had a no gain or loss in surface. The remaining four movements there was a gain in the height of the surface this would be a gain in volume displacement.

The surface change for the Loadcell Method stayed with a constant loss of surface height, then a constant loss of volume displacement.

VOLUME DISPLACEMENT CHANGE:

From the table above the displacement volume of change of the object can be calculated. This change does not reflect a change in the objects weight but a change in the axis of buoyancy of which the leverage is applied.

Movement & Degree	Movement & weight #	Wtm CID	Lcm CID
1: 0.23 – 0.22	1~ 4	0.000000	0.051879
2: 0.46 – 0.46	2~ 2	0.000000	1.422960
3: 0.70 – 0.70	3~ 4	-1.311791	1.415549
4: 0.95 – 0.95	4~ 2	-1.393315	1.371081
5: 1.18 – 1.17	5~ 4	-1.371081	1.378493
6: 1.41 – 1.42	6~ 2	-1.385904	2.104795

In the Wtm column you will note that the cubic inch displacement was neutral for the first 2 movements then a gain occurred for movements 3 to 6.

The Lcm column shows a loss in volume displacement, which is constant with the changing TCB, TCF as inclined in the lightship condition.

THE FOLLOWING CHARTS SHOW THE COMPARESON BETWEEN BOTH METHODS.

The data shown was obtained from our hydrostatics program and compiled for easy reference.

CALCULATIONS FOR WATERPLANE AREA CHANGE:

Movement	Wtm WPA	Lcm WPA
1: 0.23 – 0.22	0.7439	0.7430
2: 0.46 – 0.46	0.7440	0.7431
3: 0.70 – 0.70	0.7441	0.7433
4: 0.95 – 0.95	0.7443	0.7434
5: 1.18 – 1.17	0.7444	0.7435
6: 1.41 – 1.42	0.7446	0.7437

Note in both methods that the changes in waterline area are both constant and linear.

CALCULATIONS FOR VCG, TCB, TCF, TKM:

Movement& Degree	Wtm VCG'	WtmLt.Ship VCG'	Lcm VCG'	Wtm TCB'	Wtm Lt.Ship TCB'	Lcm TCB'	Wtm TCF'	Wtm Lt.Ship TCF'	Lcm TCF'	Wtm TKM'	Wtm Lt.Ship TKM'	Lcm TKM'
1: 0.23 – 0.22	0.1200	0.1235	0.1800	0.0018	0.0019	0.0017	0.0003	0.0003	0.0003	0.5010	0.5128	0.5060
2: 0.46 – 0.46	0.1250	0.1287	0.1560	0.0036	0.0037	0.0037	0.0007	0.0007	0.0007	0.5011	0.5129	0.5062
3: 0.70 – 0.70	0.1260	0.1297	0.1520	0.0055	0.0057	0.0056	0.0011	0.0011	0.0011	0.5012	0.5130	0.5063
4: 0.95 – 0.95	0.1350	0.1391	0.1400	0.0075	0.0077	0.0075	0.0014	0.0014	0.0014	0.5014	0.5131	0.5064
5: 1.18 – 1.17	0.1310	0.1349	0.1320	0.0093	0.0095	0.0093	0.0018	0.0018	0.0018	0.5016	0.5133	0.5066
6: 1.41 – 1.42	0.1320	0.1359	0.1320	0.0112	0.0114	0.0113	0.0021	0.0021	0.0022	0.5018	0.5135	0.5068

CALCULATIONS FOR VCB, VCF, DRAFT, VOLUME FT^3:

Deg. Heel	Wtm VCB'	Lcm VCB'	Wtm VCF'	Lcm VCF'	Wtm Draft'	Lcm Draft	Wtm Vol. Ft^3	Lcm Vol. Ft^3
1: 0.23 – 0.22	0.0519	0.0511	0.1022	0.1006	0.1022	0.1006	0.0721	0.0710
2: 0.46 – 0.46	0.0519	0.0511	0.1022	0.1006	0.1022	0.1006	0.0721	0.0710
3: 0.70 – 0.70	0.0519	0.0511	0.1022	0.1006	0.1022	0.1006	0.0721	0.0710
4: 0.95 – 0.95	0.0519	0.0511	0.1022	0.1006	0.1022	0.1006	0.0721	0.0710
5: 1.18 – 1.17	0.0519	0.0511	0.1022	0.1007	0.1022	0.1006	0.0721	0.0710
6: 1.41 – 1.42	0.0520	0.0512	0.1022	0.1007	0.1022	0.1006	0.0721	0.0710

The above chart is a comparison between the Weight Method "AS INCLINED" and the Loadcell Method.

The chart shows that when the calculations for the various properties of the Baker's Pan were made that there is slight difference in the TCB, no difference TCF and a difference TKM result of each method. There is a difference between the two methods & lightship calculations in the VCG. The VCG of the Weight Movement is lower due to the weight of incline weights used to incline the Pan giving a larger volume of displacement and water plane area then the loadcell method at lightship, this weight was backed off in the lightship calculations but it has already corrupted the data by artificially changing the properties of the volume displacement verses the axis of rotation.

It should also be noted that using the Loadcell method to incline, the Baker's Pan was inclined in its TRUE lightship configuration thus allowing for the true movement of the Baker's Pan without any falsely imposed properties of rotation to be introduced.

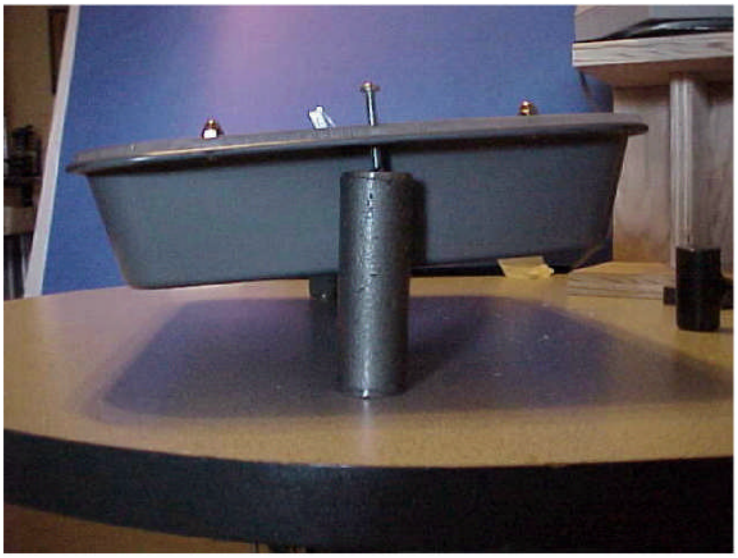
Calculation of the average VCG for the three findings are;

Weight Method as Inclined:	0.1281'	or	1.5372"
Weight Method Lt. Ship:	0.1319'	or	1.5828"
Loadcell Method:	0.1486'	or	1.7840"

Note that the VCG of the Loadcell Method is higher than both the Weight Method Incline and the calculated lightship results of that incline. In the TUBE experiment the results were opposite with the Weight Method having a higher VCG than the Loadcell Method.

In proving out which VCG was correct the following pictured experiment was conducted on the Baker's Pan. The pan was installed with a set of "pivots" at each end of its longitudinal centerline. The pivot screws were honed to a point at their end for a balance point. The screws were then threaded in to the height of the corresponding VCG's of the Lightship and Loadcell results.

Baker's Pan with pivot point set to 1.582" VCG as per Weight results



Note that the pan is balancing at an angle thus showing that the VCG is set lower then the actual VCG of the pan. When rocked the pan would almost immediately return to this position.

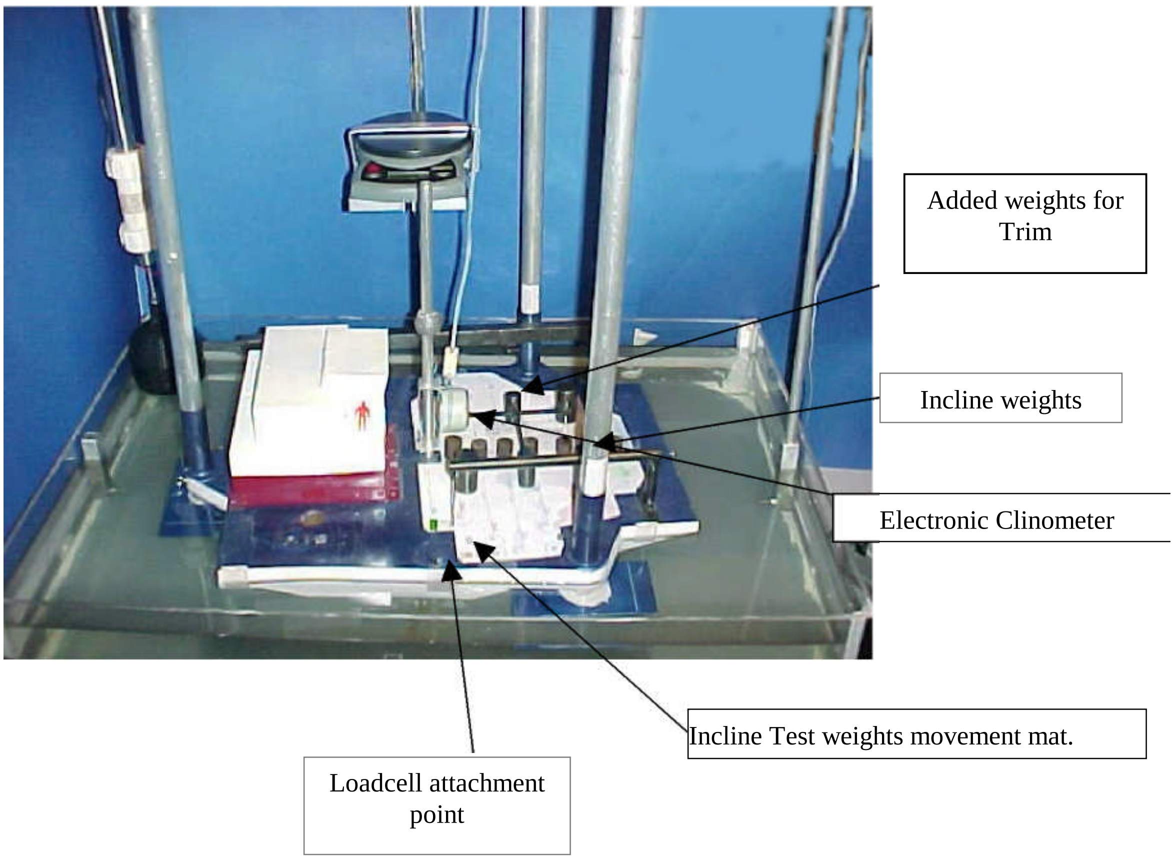
Baker's Pan with pivot point set to 1.784" as per Loadcell results.

Note that the pan is balancing at level thus showing that the VCG is set at the actual VCG of the pan. It should be also noted that when the pan was rocked it took quite some time for it to settle out with always returning to the same level plane.

INCLINE OF Liftboat Replica Model

The liftboat model pictured and used in this experiment was made for a court case, the model is to the dimensions and weigh of the original vessels as built when in question, and exhibits the same properties as said vessels at that time, they are in service today in their modified condition.

Picture of Liftboat & Setup;



Drawing of Liftboat;
The liftboat was made to the specifications as per the original vessel drawings and incline reports to scale. A copy of the "Model Builders Report" is on file and available. The models dimensions are as follows.

LOA: 20" Beam M/S: 14.45" Molded Depth: 2.21" Leg length: 43.77"
Weight as certified of hull & super structure: 5.4545 Lb. Weight of total model as shown: 13.8666 Lb

Liftboat setup;
The liftboat was set into the tank for volume measurement and to run the incline test by using the weight method. The weights used for the incline are the duplicates to model scale weights as used in the original vessels incline with the same movements re-enacted. A deck load had to be added to correct Trim and to avoid the possibility of breaking water plane. All data was recorded and shown below.

Incline by Weight Method;

The chart below shows the overall results as recorded:

Incline test in tank

VESSEL:	Liftboat w/legs,pads, consum		Input Cell	Test tank area =		741.125	sq.in.	Water condition		1 Inch to FT.
scale wt =	212.943	Oz	Input Cell	Wt of Water per cu.in =		0.576969	Oz	SG =	1	0.0833
Item Wt .=	221.863	Oz		Size = 20" loa x 14.45" beam x 2.21" Molded depth			w/ deck wt of 18.8 oz	water dens:	62.42	
Surface. Ch = change in tank depth as measured with liner transducer: (-)= increase in height									CID = Cu. In. Disp.	

CALCULATIONS by Calculated Displacement

Start surface	0.54127		CID =401.1487288		Wt. Oz =231.4503809		Wt Lb = 14.4656649	with incline wts on deck		
USING WEIGHTS METHOD TO INCLINE								CALCULATIONS		
Movement	**Deg. Heel**	**surface ch.**	**CID**	**Wt. Ch oz**	**% of total**	**wt ch lb**	**cu. Ft.**	**Wt. Oz**	**Lb.**	**moment**
1~ 2&3	0.62	-0.00319	-2.364189	-1.364063619	-0.006148	-0.085253976	-0.001368165	2.58	0.16100	0.0805
2~ 1&4	1.12	-0.00220	-1.630475	-0.94073353	-0.004240	-0.058795846	-0.000943562	2.56	0.16006	0.1499021
3~ 7a &8	1.52	-0.00179	-1.326614	-0.765415009	-0.003450	-0.047838438	-0.000767716	2.19	0.13694	0.20303773
4~ 7&5	1.76	-0.00333	-2.467946	-1.42392848	-0.006418	-0.08899553	-0.00142821	1.59	0.09966	0.234958872
5~ 0	0.00	0.00000	0.000000	0	0.000000	0	0		0.00000	0.234958872
6~ 0	0.00	0.00000	0.000000	0	0.000000	0	0		0.00000	0.234958872
as p er sheet	Wt. # 2& 3	2.58	Wt # 4& 1	2.56	Wt. # 7a & 8	2.191	Wt. # 7& 5	1.5945		

RESULTS ofINCLINE

	As Inclined TEST 1						Corrected ; Incline Wts removed TEST 2			
VCG'	TCB'	TCF'	TKM'		**Deg. Heel**		VCG'	TCB'	TCF'	TKM'
1.5070	0.0098	0.0000	0.9924		0.62		1.5570	0.0101	0.0028	1.0168
1.5216	0.0177	0.0018	0.9868		1.12		1.5701	0.0183	0.0040	1.0141
1.5188	0.0239	0.0030	0.9839		1.52		1.5675	0.0247	0.0045	1.0138
1.5176	0.0277	0.0035	0.9831		1.76		1.5666	0.0286	0.0047	1.0139
0.0000	0.0000	0.0000	0.0000		0.00		0.0000	0.0000	0.0000	0.0000
0.0000	0.0000	0.0000	0.0000		0.00		0.0000	0.0000	0.0000	0.0000
1.0108	AVG	INCHES =	12.1300				1.0435	AVG	INCHES =	12.5224

Shown above are the four movements of the liftboat using eight weights to produce the moments and degree of heel. You will note in the “surface ch.” Column in movements # 1 to 4 there is an increase in the water line, which translates into an increase in displacement volume, or deeper draft. The “CID” column is showing the calculated volume of increase of the vessel as calculated by the surface area of the tank verses the amount of the surface change. The “AS Incline TEST 1” results are as calculated by our hydrostatics program and are shown in feet. The average VCG is shown in feet and converted into inches at right to give some assimilation to the vessel. The “Corrected” calculations were done for this incline, due to hull form and to produce comparison data, the Corrected data shows the vessel in the fully loaded condition with the incline weights removed. In doing the “Traditionally accepted Calculations” for lightship it should be noted that no compensation is made for what would be a “reduced moment” of the heel if the vessel was heeled without the weights. This “backing off” of the incline weights should also include the “backing off” of the moment that it took to produce said angle. This is not done thus a FALSE assumption is made for the moment and thus a FALSE VCG at lightship is calculated and assumed.

Incline by Loadcell Method;

The chart below shows the overall results as recorded:

Start surface	0.52326	CID =	387.8010675 Wt. Oz =		223.7491941 Wt Lb =		13.98432463	INCHES		FEET
USING LOADCELL METHOD TO INCLINE								7.25	distance	0.604166667
Movement	**Deg. Heel**	**surface ch.**	**CID**	**Wt. Ch oz**	**% of total**	**wt ch lb**	**cu. Ft.**	reading oz	lb	moment
1	0.62	0.00512	3.794560	2.189343489	0.009868	0.136833968	0.002195926	2.06	0.1288	0.077786458
2	1.12	0.00656	4.861780	2.805096345	0.012643	0.175318522	0.00281353	3.91	0.2444	0.147643229
3	1.52	0.00669	4.958126	2.860685144	0.012894	0.178792822	0.002869286	5.27	0.3294	0.198997396
4	1.76	0.00784	5.810420	3.352432217	0.015110	0.209527014	0.003362512	6.04	0.3775	0.228072917
5	0.00	0.00000	0.000000	0	0.000000	0	0	0.00	0.0000	0
6	0.00	0.00000	0.000000	0	0.000000	0	0	0.00	0.0000	0

RESULTS of INCLINE				
	As Inclined	TEST 3		
VCG'	TCB'	TCF'	TKM'	**Deg. Heel**
1.5325	0.0101	0.0023	1.0135	0.62
1.5553	0.0182	0.0038	1.0099	1.12
1.5498	0.0246	0.0044	1.0094	1.52
1.5439	0.0285	0.0046	1.0095	1.76
0.0000	0.0000	0.0000	0.0000	0
0.0000	0.0000	0.0000	0.0000	0
1.0303	AVG	INCHES =	12.363	

Note there are no "Corrected Lightship" calculations since the liftboat was inclined in Full load condition using the Loadcell Method with the incline weights removed.

Comparison of both methods;

HEEL DEGREES:

The heeling degrees were kept as close as possible to allow for interpolations. The columns of data in the title cell are named "Wtm" for weight method and "Lcm" for loadcell method.

Movement & WTS	Wtm Deg. Heel	Lcm Deg. Heel
1~ 2& 3	0.62	0.62
2~ 1& 4	1.12	1.12
3~ 7a & 8	1.52	1.52
4~ 7&5	1.76	1.76

As shown the degree of heel was matched in every movement.

SURFACE CHANGE:

The surface of the tank directly corresponds to a change in volume displacement or draft of the object within the tank. By measuring the change in the level of the tank, the volume gain or loss can be calculated and applied to the objects gain or loss.

Movement & Degrees	Wtm surface ch.	Lcm surface ch.
1: 0.62 – 0.62	-0.00319	0.00512
2: 1.12 – 1.12	-0.00220	0.00656
3: 1.52 – 1.52	-0.00179	0.00669
4: 1.76 – 1.76	-0.00333	0.00784

Note the surface change for the Weight Method; all four movements had a gain in surface height this would be a gain in volume displacement.

The surface change for the Loadcell Method stayed with a constant loss of surface height, then a constant loss of volume displacement.

VOLUME DISPLACEMENT CHANGE:

From the table above the displacement volume of change of the object can be calculated. This change does not reflect a change in the objects weight but a change in the axis of buoyancy of which the leverage is applied.

Movement & Degrees	Wtm CID	Lcm CID
1: 0.62 – 0.62	-2.364189	3.794560
2: 1.12 – 1.12	-1.630475	4.861780
3: 1.52 – 1.52	-1.326614	4.958126
4: 1.76 – 1.76	-2.467946	5.810420

In the Wtm column you will note that the cubic inch displacement gain occurred for all movements.

The Lcm column shows a loss in volume displacement, which is constant with the changing TCB, TCF as inclined in the lightship or full load condition.

THE FOLLOWING CHARTS SHOW THE COMPARESON BETWEEN BOTH METHODS.

The data shown was obtained from our hydrostatics program and compiled for easy reference.

CALCULATIONS FOR WATERPLANE AREA CHANGE:

Movement & Degrees	Wtm WPA	Wtm F/load WPA	Lcm WPA
1: 0.62 – 0.62	1.9197	1.9059	1.9086
2: 1.12 – 1.12	1.9120	1.8978	1.8997
3: 1.52 – 1.52	1.9056	1.8941	1.8957
4: 1.76 – 1.76	1.9029	1.8925	1.8939

Note in both methods and back calculation, that the changes in waterline area are both constant and liner.

CALCULATIONS FOR VCB, VCF, DRAFT, VOLUME FT^3:

Movement & Degrees	Wtm VCB'	Wtm F/load VCB'	Lcm VCB'	Wtm VCF'	Wtm F/load VCF'	Lcm VCF'	Wtm Draft'	Wtm F/load Draft'	Lcm Draft'	Wtm Vol. Ft^3	Wtm F/load Vol. Ft^3	Lcm Vol. Ft^3
1: 0.62 – 0.62	0.0871	0.0845	0.0848	0.1536	0.1489	0.1496	0.1536	0.1489	0.1496	0.2317	0.2228	0.2240
2: 1.12 – 1.12	0.0872	0.0846	0.0850	0.1536	0.1490	0.1496	0.1536	0.1489	0.1496	0.2317	0.2228	0.2240
3: 1.52 – 1.52	0.0873	0.0847	0.0851	0.1536	0.1490	0.1496	0.1536	0.1489	0.1496	0.2317	0.2228	0.2240
4: 1.76 – 1.76	0.0874	0.0849	0.0852	0.1536	0.1490	0.1496	0.1536	0.1489	0.1496	0.2317	0.2228	0.2240

CALCULATIONS FOR VCG, TCB, TCF, TKM:

The chart bellow is a comparison of the calculations of both methods including corrected for Wtm.

Movement & Degrees	Wtm VCG'	Wtm corrected VCG'	Lcm VCG'	Wtm TCB'	Wtm corrected TCB'	Lcm TCB'	Wtm TCF'	Wtm corrected TCF'	Lcm TCF'	Wtm TKM'	Wtm corrected TKM'	Lcm TKM'
1: 0.62 – 0.62	1.5070	1.5570	1.5325	0.0098	0.0101	0.0101	0.0000	0.0028	0.0023	0.9924	1.0168	1.0135
2: 1.12 – 1.12	1.5216	1.5701	1.5553	0.0177	0.0183	0.0182	0.0018	0.0040	0.0038	0.9868	1.0141	1.0099
3: 1.52 – 1.52	1.5188	1.5675	1.5498	0.0239	0.0247	0.0246	0.0030	0.0045	0.0044	0.9839	1.0138	1.0094
4: 1.76 – 1.76	1.5176	1.5666	1.5439	0.0277	0.0286	0.0285	0.0035	0.0047	0.0046	0.9831	1.0139	1.0095

The chart shows that when the calculations for the various properties of the Liftboat were made that there is difference in the TCB, TCF and TKM result of each method. There is a slight difference between the loadcell method and the corrected calculations in the results. The VCG of the Weight Movement is lower due to the weight of incline weights used to incline the Liftboat giving a larger volume of displacement and water plane area than the loadcell method at this condition, this weight was backed off in the corrected calculations but it has already corrupted the data by artificially changing the properties of the volume displacement verses the axis of rotation.

It should also be noted that using the Loadcell method to incline, the Baker’s Pan was inclined in its TRUE lightship configuration thus allowing for the true movement of the Baker’s Pan without any falsely imposed properties of rotation to be introduced.

Calculation of the average VCG for the three findings are;

Weight Method as Inclined:	1.5163’	or	18.1956”
Weight Method corrected:	1.5653’	or	18.7836”
Loadcell Method:	1.5454’	or	18.5448”

Note that the VCG of the Loadcell Method is higher than the Weight Method Incline, the calculated corrected results are higher than the Loadcell Method. In the TUBE experiment the results were opposite with the Weight Method having a higher VCG than the Loadcell Method.

There was another incline experiment preformed on the model using both methods and calculated as if it was preformed on the original vessel using the real world weight of the vessel, incline weights, consumables and deck load. The results obtained from that test are as follows:

Incline using weights

VESSEL CALCULATIONS Review as per USCG form CG-993-8				
Vessel at time of Stability Test - Condition 0 as Calculated				
Corrected Displacement	898.72L	tons	Midship = 44.70835Ft.	aft of "0"
Mean virtual metacentric height obtained from plot of inclining moments verses tangents of angles of heel	30.29Feet	From Mean of Incline sheet		
		Corrected SG as Inclined		0.97832
Correction for Free Surface	0Feet	Density	lb/ft^3 =	61.0667344
Mean Metacentric Height	GM			

From Hydrostatics Page from X=0 station (bow, main deck to stem intersection):							
LCB =	48.312	LKM Ft .=	0	Moment to Trim	1 Inch	0	Ft. ton
LCF =	49.17	LGM Ft .=	0		MT 1 Ft. =	0	calculated
VCB =	0	TKM Ft .=	60.77		Trim Ft. =	0.00	
TCG =	0	TGM Ft. =	0		T Lever =	0	
LWL =	0			V.C.G.	^ base line	30.48	calculated
BWL =	0				L.C.G. =	-3.60	Neg. = AFT of Midship
LCB =	-3.60365	Neg. = AFT					
	LCF =-	Neg. = AFT		See Hydrostatics Pages 8, 8a, for all other data			

Vessel Lightship - Condition 1 as Calculated

ITEMS	Displ. & Weight	V. C. G. Above Base Lever	Vertical Moment	L. C. G. From Feet AFT	AFT Moment	Midship Feet FWD	FWD Moment	List of Major Equip. etc. included in condition
Ship Condition "0"	898.72	30.478184	27391.353	3.60365	3238.67233			See Above
Weights to ADD		0#DIV/0!		0#DIV/0!	0	#DIV/0!	0	page 15 Stow & Equip. list
Weights to Subtract	167.0815	5.6269333	940.15643	9.83	139.150452	22.79	4566.6791	page 15 Stow & Equip. list
Weights to Subtract	78.18	4.9297928	385.4112	#DIV/0!	0	11.25	879.525	page 13 Tankage
Weights to Subtract	38.419643	11.237465	431.73938	2.96	16.3414286	19.25	557.36134	page 18 Test Weights
Weights to Subtract		0#DIV/0!		0#DIV/0!	0	#DIV/0!	0	page 18 Trim Weights
Weights to Relocate			712.24607		0		0	page 12 Relocate list
Ship Condition "I"	615.03886	42.836793	26346.292	5.0129848	3083.18045	9.76127815	6003.5654	
				Calculated LCG =	4.74829338	2920.38496	Total Moment	
				Hydrostatics LCG =	0 f r	hydrostatics page 9a at Trim° = 0		
Molded draft at LCF at Lightship Displacement in Salt Water					644.385102	Lton		

Incline using Loadcell:

VESSEL CALCULATIONS	Review as per USCG form CG-993-8		
Vessel at time of Stability Test - Condition 0 as Calculated			
Corrected Displacement	860.3L tons	Midship =	44.70835Ft. aft of "0"
Mean virtual metacentric height obtained from plot of inclining moments verses tangents of angles of heel	32.41Feet	From Mean of Incline sheet	
	Corrected SG as Inclined		0.97832
Correction for Free Surface	0 Feet	Density lb/ft^3 =	61.0667344
Mean Metacentric Height	GM = 3 2 . 4 1 Feet		

From Hydrostatics Page from X=0 station (bow, main deck to stem intersection):						
LCB =	48.312	LKM Ft .=	0	Moment to Trim 1 Inch	0	Ft. ton
LCF =	49.17	LGM Ft .=	0	MT 1 Ft. =	0	calculated
VCB =	0	TKM Ft .=	63.15	Trim Ft. =	0.00	
TCG =	0	TGM Ft. =	0	T Lever =	0	
LWL =	0			V.C.G. ^ base line	30.74	calculated
BWL =	0			L.C.G. =	-3.60	Neg. = AFT of Midship
LCB =	-3.60365	Neg. = AFT				
	LCF = -	Neg. = AFT		See Hydrostatics Pages 8, 8a, for all other data		

Vessel Lightship - Condition 1 as Calculated								
ITEMS	Displ. & Weight	V. C. G. Above Base Lever	Vertical Moment	L. C. G. From Midship Feet AFT	AFT Moment	Feet FWD	FWD Moment	List of Major Equip. etc. included in condition
Ship Condition "0"	860.3	30.744687	26449.654	3.60365	3100.2201			See Above
Weights to ADD		0#DIV/0!		0#DIV/0!	0	#DIV/0!	0	page 15 Stow & Equip. list
Weights to Subtract	167.0815	5.6269333	940.15643	9.83	139.150452	22.79	4566.6791	page 15 Stow & Equip. list
Weights to Subtract	78.18	4.9297928	385.4112	#DIV/0!	0	11.25	879.525	page 13 Tankage
Weights to Subtract		0#DIV/0!	0	2.96	0	19.25	0	page 18 Test Weights
Weights to Subtract		0#DIV/0!		0#DIV/0!	0	#DIV/0!	0	page 18 Trim Weights
Weights to Relocate			712.24607		0		0	page 12 Relocate list
Ship Condition "I"	615.0385	42.007667	25836.333	4.814446	2961.06964	8.85506196	5446.2041	
				Calculated LCG =	4.040616	2485.13442	Total Moment	
				Hydrostatics LCG =	0	from hydrostatics page 9a at Trim° = 0		
Molded draft at LCF at Lightship Displacement in Salt				@1.025	644.384728	Lton		

The above results of the two different methods of heeling the vessel demonstrate in real world weights and measurements what the differences between the two methods produce.

The “As Inclined” results show the Weight Method to produce a VCG of 30.48’ and the Loadcell Method produces a 30.74’ VCG, slightly more conservative. Once all the weight of consumables, test weights and deck weight were removed and accounted for by calculation in the “Condition 1” section the Weight Method produced a lightship VCG of 42.84’ and the Loadcell Method produced a lightship VCG of 42.00’. The results of VCG of the above testing are comparable to the results obtained on the last incline of the original vessel under USCG witness.

ARGUMENT;

“Weight Incline rotates the vessel on its axis without changing its water plane properties: FALSE

“Loadcell Incline is lifting the vessel and changing the water plane properties: FALSE

“The Loadcell method raises the TKM giving a false VCG.” FALSE

SUMMATION;

The weight incline changes the properties of a vessel by introducing a weight to leverage action that acts against the axis of the vessel both in the negative and positive for volume displacement as well as the leverage point. It cannot be predicted as to which effect it has on a hull form without timely and costly measurements and calculations. The weight method does both aspects of an argument, it increases the volume displacement or pushes the hull down and it also decreases the volume displacement or lifts the hull up. Both events can happen in a single incline of a vessel and without vigilance and correct measurements at each movement it can give an incorrect VCG.

The weight incline on a perfect cylindrical hull form has been shown to increase volume displacement at low degrees of angles while decreasing volume displacement on higher angles of heeling within the same incline. It has also shown on a different hull type, a barge style hull with sides shaped as to not change water plans cross section, it goes from no change at lower angles to increase volume displacement at the higher angles. This same hull was put to a “balance test” to confirm the results of the VCG, it was found that the incline resulting VCG was low and incorrect.

This effect could be described as the “volume buoyancy to axis ratio” below the axis of rotation of the form. When increased volume displacement occurs it is the reaction of the hull form not being able to support the leverage applied by the rotation about the axis at that point. The reverse happens when there is a decrease in volume displacement, the distance between the axis and vertical bottom of the hull form is increased thus the larger leverage arm occurs. This then causes the TCG of the axis to rotate about the hull forms volume instead of rotating about the axis. This is the most favorable method since the VCG of the hull form is changing uniformly with the change in the volume to axis ratio.

TKM is directly related to the draft/displacement of the vessel. The lightship TKM is the initial TKM used by the loadcell method of incline. The TKM of the vessel, when inclined with the weight method, is lowered by the introduction of the weights. If the TKM were being raised by the loadcell method then the resulting VCG would be excessively higher than the VCG arrived at by the weight method in all conditions and hull forms, assuming that the TGM remains constant.

Although, when using the Incline Weights, there are certain effects to point out about the effects of the weights on the results of the incline. First the weights are artificially changing the true VCG of the vessel by introducing their own VCG to the vessel. This would have to be back calculated out for every movement by reducing the moment by the weights moment verses weights VCG verses weights TCG. The simple calculation of removing the weigh of the weights and using the same moment obtained with the weights on (calculation used now) does not show the true VCG of the vessel, the moment shows the VCG of the vessel with the weights on and only that moment. Although you have seemingly brought the vessel back to the perceive “lightship characteristics” by back calculating the weigh reduction you have not back calculated the moment, thus the resulting VCG is incorrect due to the fact that you are showing a higher moment to true hull form then it would have taken if the weights were not on the vessel. This false moment is showing a VCG other than what the vessel actually has.

You will note below that in the first experiment using the TUBE the VCG of the Weight Method as inclined is higher then the Loadcell Method.

Calculation of the average VCG for the two findings are:

Weight Method as Inclined:	0.1853’	or	2.2245”
Loadcell Method:	0.1773’	or	2.1285”

In the second experiment of the Baker’s Pan, the VCG’s obtained show the “as inclined” VCG to be lower than the “calculated lightship” VCG, this calculation was obtained by the traditional method of backing off the weight values without correcting the weight moment values.

Note that by lowering the water plane and increasing the hull volume, the VCG obtained by the weight movement was based on a greater “volume to axis ratio” than the Loadcell Method, which rotated the hull form about its axis in the lightship condition. This incline did not have any other influences on the results such as weight above the deck with a high VCG contributing to the takeover of the hull forms VCG. As shown above (page 16) the true VCG was not concluded in either the “as inclined” or “calculated lightship” VCG of the vessel since the true moment was not obtained to rotate the hull form about its axis.

Calculation of the average VCG for the three findings are;

Weight Method as Inclined:	0.1281’	or	1.5372”
Weight Method Lt. Ship:	0.1319’	or	1.5828”
Loadcell Method:	0.1486’	or	1.7840”

In the third experiment of a typical hull form of a liftboat the results were altered by a high VCG of the legs and other structures. When obtaining the “as inclined” VCG the vessels hull form had a greater Volume displacement thus greater resistance to heel than would be in a lighter condition along with the falsely imposed incline weights moment. When back calculating the findings to get the lightship values, again the false moment carried into the calculation compounding the other interactions of the legs and superstructure to give an incorrect VCG. The Loadcell Method rotated the hull form on its axis allowing the superstructure and legs to act upon the hull form in its natural state in that condition. The moments and VCG obtained by the Loadcell are the exact values that it took to produce the heeling action and thus the correct VCG.

Calculation of the average VCG for the three findings are;

Weight Method as Inclined:	1.5163’	or	18.1956”
Weight Method corrected:	1.5653’	or	18.7836”
Loadcell Method:	1.5454’	or	18.5448”

Conclusion;

The use of the Weight Method is flawed by the falsely imposed moment verses the VCG of the weights; this is due to the lack of back calculating the falsely imposed moment of the weight itself. It has been shown above that the weights have had an erratic effect on the hull form within a single incline by increasing and then decreasing the volume of the hull thus giving a non-liner result. The result was dependent on the “volume to axis ratio” as shown; any standard calculations used today do not take this into account. The Loadcell on the other hand gave the same consistent data without the “added leverage” effect of the “volume to axis ratio” shown in the weight movements. This data produced a more accurate VCG as demonstrated in the “Balancing Test” of the pan. It also demonstrates that the Loadcell method is rotating the hull form about its axis verses the volume of displacement thus the “volume to axis ratio” is remaining constant to the hull form and weight thus allowing the VCG of the mass about the axis to act in a true and consistent manner. When employing the Loadcell to generate the heeling moment the vessel can be tested in its “true” lightship condition such as a recently built vessel just launched. The loadcell is also unlimited in its use, degrees of heel can be matched to the testers wishes and the resistance values of the hull can be read, example of this is the tester wishes to test the vessel at 0.5°, the elevation of the loadcell can be raised to make the vessel heeling angle match the 0.5° and the resistance reading can be taken in pounds or tons, this can be repeated as many times as the tester wants. Additionally, some vessels can not be inclined to the full 4° as stated in the ASTM specifications due to the weight needed to produce the moment, in the case of the newer liftboats it can be as much or more then 75,000 lbs of weights, with a loadcell it would be simply be the case of using a calibrated loadcell of 100k lb. As seen above, we recreated the heel of the original Weight Inclines degree of heeling with the Loadcell. This also could be an invaluable tool for recreating previous inclines to see what went wrong or to verify the VCG in a timely efficient manner.

In our testing on Real World vessels, such as Fishing Vessels we found that the time taken to fully incline a vessel in this manner, using our electronic data collection equipment in conjunction, was less than thirty (30) minutes to perform the test on both sides for the full incline. This allows for less environmental intrusion into the results of the incline.

Authored and Testing by;

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Mays