Squatting ships distort tonnage truth

When a ship loads at one port and discharges at another a draft survey is carried out at the arrival port, to check that the cargo deadweight (dwt) remains constant and that this is satisfactory for the ship-owner at the port of arrival.

The cargo deadweight constant is a check that the amount of cargo that left the first port arrived at the second port, it is then effectively a check on whether pilferage has taken place between the two ports. A master, a chief engineer or a naval architect may carry out this draft survey with anchors in the housed position.

Deadweight (dwt) for a merchant ship can consist of cargo, oil, fresh water, water ballast, lubricating oil, stores, boilers up to working level, crew and effects and passengers. In this article, it is the cargo deadweight on which I am focusing my attention. As an 'attachment' I include comments on ship squat.

A well-conducted draft survey is capable of achieving an absolute accuracy of within plus or minus 0.50% of the cargo deadweight. In a perfect world the cargo deadweight arriving at the arrival port will be the same as that which left the departure port. In other words it will be constant, though this is very hard to achieve.

Modifications have to be made for hog and sag, longitudinal centre of floatation (LCF), density of water in which the vessel floats, the contents used, water ballast added or deducted etc. However, sometimes one correction is overlooked. If the vessel has been in an ebb tide situation in the departure port and is then moored in the arrival port with zero current, there will appear to be a discrepancy in the vessel's Weight. What has caused this to be so?

If the tidal ebb speed is not the same for both ports, then there will be a change in the displacement, known as the cargo deadweight constant. With an Ebb Tide present, there are false drafts, ford and aft, from which the vessel's displacement is derived.

Ship squat is generally the decrease in underkeel clearance usually caused by the forward speed of the vessel. It is the algebraic sum of the mean bodily sinkage and a trimming effect forward and aft. Ship squat

Col 1	2	3	4	5	Column 6	7	Column 8	Column 9	10	11	12	13	14	15	16	Col 17
L	b	T	H	W	water density	Cb	gangplank width	width of influence	B	BxH	S	Kc	Kmbs	TPC	Vtide	W error
m	m	m	m	tonnes	t/cu.m		m	m	m	sq.m				tonnes	kts	tonnes
1. MOLASSES TANKER - LADEN CONDITION																
109.6	19.00	5.60	8.00	9179	1.000	0.760	10.00	169	104	832	0.133	1.24	0.928	17.71	1.5	35
2. MOLASSES TANKER - LIGHT CONDITION																
109.6	19.00	4.84	8.00	7508	1.000	0.745	10.00	172	105	843	0.109	1.07	0.960	17.30	2.0	53
3. RO-RO VESSEL																
131.4	26.00	6.12	7.50	12540	1.026	0.685	10.00	289	167	1255	0.127	1.19	0.735	27.60	3.0	128
4. 100,000 TONNES VLCC																
254.5	42.42	13.50	16.20	122500	1.026	0.820	10.00	354	208	3369	0.170	1.49	0.712	95.84	4.0	1336

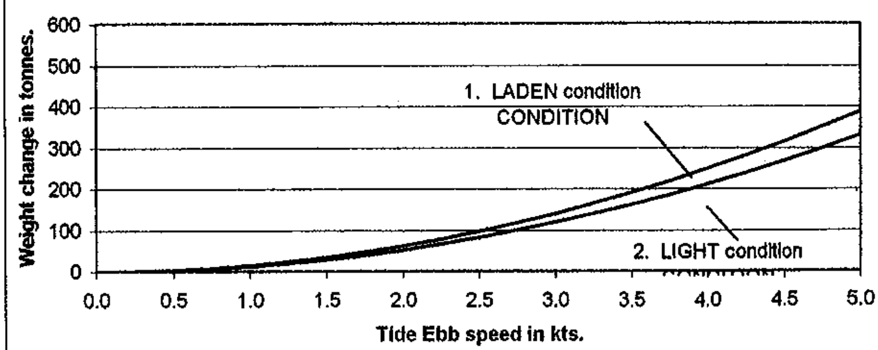
TABLE 1

SHIP	1	2	3	4
Vt	error	error	error	error
0.0	0	0	0	0
0.5	4	3	4	21
1.0	16	13	14	84
1.5	35	30	32	188
2.0	62	53	57	334
2.5	97	83	89	522
3.0	140	119	128	752
3.5	191	162	174	1023
4.0	249	212	228	1336
4.5	315	268	288	1691
5.0	389	331	356	2088

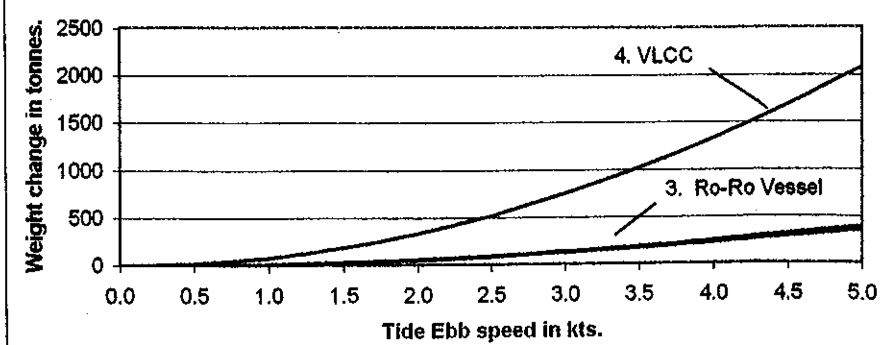
TABLE 2

L = LBP.
b = Breadth Mld.
T = mean draft at LCF.
LCF = Long'l Centre of Flotation.
H = water depth.
Cb = block coefficient of ship.
Gangplank width = gap from shore to shipside.
width of influence = artificial water width in open water conditions.
bxT = Cross sectional area amidships.
B = width of infuence, (or if less), is actual width of river.
BxH = Cross sectional area of river
S = Blockage Factor = (Bxt)/(BxH)
Kc = confined channel or open water coefficient.
Kmbs = mean bodily sinkage oefficient.
TPC = Tonnes Per Centimetre immersion.
Vtide = speed of Tide Ebb in knots.
W error = Weight change re Tidal Ebb speed

Weight changes against tidal ebb speed for various conditions of loading. See notes page 34



Molasses Tanker - Weight change re tidal ebb speed.



VLCC & Ro-Ro Vessel - Weight change re tidal ebb speed.

also occurs on a moored ship adjacent to a berth, when an ebb tide is flowing.

Whether the vessel is moving ahead at speed or is a static ship in an ebb tide, it can be observed that draft changes take place compared to the vessel that is stationary floating in water of zero current speed.

When an ebb tide is present there are changes in the constant for each positive value of the ebb tide speed. Average values for an ebb tide is 4knots. In some cases it can be up to 6knots, after heavy rain or when snows thaw.

It means that a person undertaking a draft survey will overestimate the mean bodily sinkage leading to a discrepancy in the constant prediction. Over the period of one year, for a ship-owner anxious not to overload his vessel, this could amount to an important and significant loss of earnings.

The plimsoll line could be submerged simply due to the effects of an ebb tide, and not because of overloading a vessel.

Three vessels have been chose to illustrate the change in cargo deadweight constant and maximum ship squats relating to ebb tide speeds. They are:

1. Molasses tanker in laden condition.
   See Table 1.
2. Molasses tanker in light condition.
   See Table 1.
3. 2090dwt ro-ro vessel.
   See Table 1.
4. 100,000dwt very large crude Carrier (VLCC).
   See Table 1.

There are 13 variables, as outlined in Table 1, connected with the estimation of Cargo deadweight Constant in an Ebb Tide. They are:

Notes regarding Table 1.

The first 6 out of 17 columns give General Particulars relating to each of the selected vessels.

In Column 7, the Cb = (W/density)/ (L x b x T)

In Column 9, the width of influence = $\{7.04/(Cb)^{0.85}\}$ x b metres.

In Column 10, B = (gangplank gap, shore to shipside) + (0.50 x b) + (0.50 x width of influence).

If the width of river water is less than this B, use actual width of river for predicting the blockage factor.

In Column 12, S = the blockage Factor.

In Column 13, the Kc = $5.74 \times S^{0.76}$

In Column 14, the Kmbs = $1 - 20(0.700 - \text{ship's actual Cb})^2$

In Column 17, 'W error' is the change in displacement due to Ebb Tide speed being positive. It is the cargo deadweight constant modified only for ebb tide speed.

Tables and Graphs.

Table 2 gives the Cargo deadweight constants or changes in displacement for the four ship conditions. Range of tide speeds are from 0 to 5knots. Figures 2a and 2b graphically show the data contained in Table 2.

Table 3 gives the maximum squats for the four ship conditions. Range off Tide speeds are from 0 to 5knots. Figures 3 graphically show the data contained in Table 3.

Formulae.

The Global formula for change in displacement is:

Kc x Kmbs x (max squat in open water in cms @ H/T of 1.10) x TPC tonnes.

The change in Displacement for each ship condition reduces to:

Ship 1..........displacement change = 15.56 x $(V_T)^2$.....tonnes.......see Figure 2a.
Ship 2..........displacement change = 13.25 x $(V_T)^2$.....tonnes.........see Figure 2a.
Ship 3..........displacement changer = 14.22 x $(V_T)^2$.....tonnes.......see Figure 2b.
Ship 4..........displacement change = 83.50 x $(V_T)^2$.....tonnes.........see Figure 2b.

The Global formula for maximum squat is:

Kc x (maximum squat in open water @ H/T of 1.10) metres.

The maximum squat for each ship condition reduces to:

Ship 1..........max squat = 0.0094 x $(V_T)^2$......metres.................see Figure 3.
Ship 2..........max squat = 0.0081 x $(V_T)^2$.......metres..................see Figure 3.
Ship 3..........max squat = 0.0069 x $(V_T)^2$.....metres..................see Figure 3.
Ship 4..........max squat = 0.0122 x $(V_T)^2$.....metres..................see Figure 3.

When moored, if a vessel is on even keel and the Ebb Tide is approaching the vessel's Bow, then:

When Cb > 0.700, Max squat will occur at the bow. ship trims by the bow.

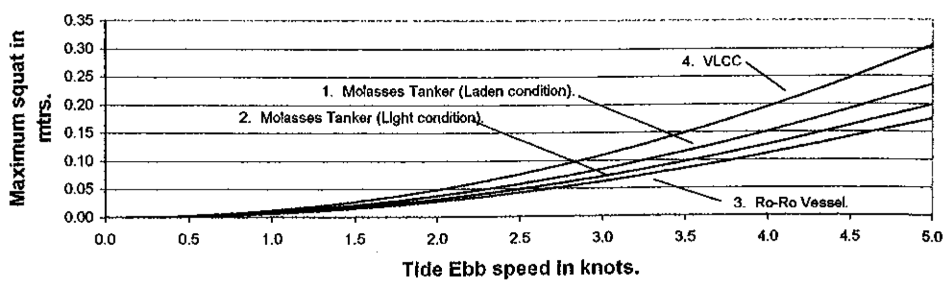
When Cb < 0.700, Max squat will occur at the stern. ship trims by the stern.

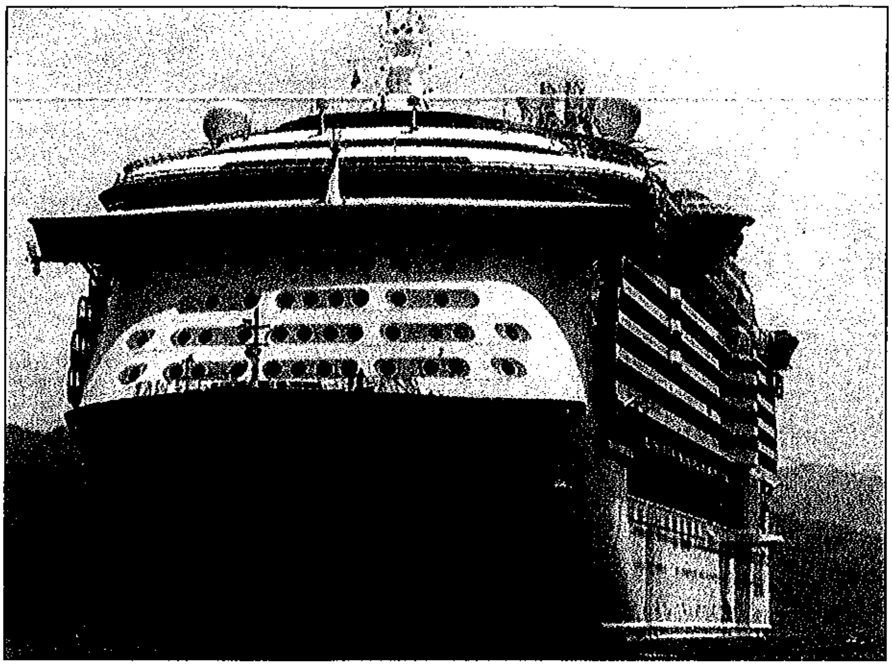
When Cb is very close to 0.700, max squat will occur at the bow, amidships and the stern. There will be no trim component in the squat value.

When moored, if a vessel is on an even keel and the ebb tide is approaching the vessel's Stern, then:

Maximum squats against tidal ebb speed.

TABLE 3				
Vt knots	max squat	max squat	max squat	max squat
0.0	0.00	0.00	0.00	0.00
0.5	0.00	0.00	0.00	0.00
1.0	0.01	0.01	0.01	0.01
1.5	0.02	0.02	0.02	0.03
2.0	0.04	0.03	0.03	0.05
2.5	0.06	0.05	0.04	0.08
3.0	0.08	0.07	0.06	0.11
3.5	0.12	0.10	0.09	0.15
4.0	0.15	0.13	0.11	0.20
4.5	0.19	0.16	0.14	0.25
5.0	0.24	0.20	0.17	0.31
SHIP	1	2	3	4





The Freedom of the Seas, the world's largest cruise liner at 154,000gt, the size of the vessel and its squat can increase the possibility of grounding.

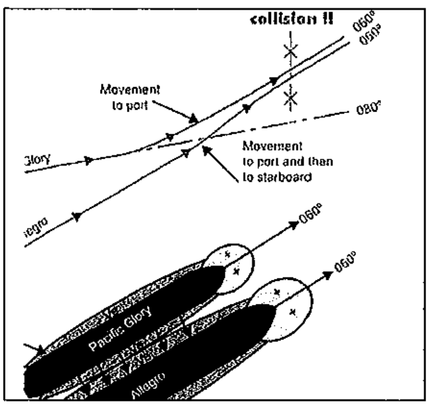
A replenishment at sea manoeuvre in the Persian Gulf, in February 2006

When Cb > 0.700, Max squat will occur at the Stern. Ship trims by the Stern.

When Cb < 0.700, Max squat will occur at the bow. Ship trims by the bow.

When Cb is very close to 0.700, Max squat will occur at the Bow, amidships and the Stern. There will be no trim component in the squat value.

A collision between the *Pacific Glory* and the *Allegro* on 27 October 1970 the vessels were drawn together after the ships came too close.



When moored, if a vessel is trimming by the Bow or by the Stern, and an Ebb Tide is present, then maximum squat will occur under the larger static end draft. The Dynamic trim will always be added to the static trim. This is why it is advisable to have the moored ship on even keel when ebb tide is zero.

Conclusions:

- With an ebb tide present, there are false drafts forward and aft. These false drafts give an over-estimation of ship displacement.
- The cargo deadweight constant can be quite appreciable, especially for the higher ebb tide speeds of 5knots in shallow water conditions. Note for the VLCC for a tidal speed of 3knots it was 752tonnes and at 5knots it was 2088tonnes.
- Of all the variables, the width of the gangplank (shore to shipside) makes negligible difference in the preceding calculations.
- As H/T becomes less, the ship is more and more in shallow conditions. This leads to greater values for the cargo deadweight constant. It also leads to greater squats. Perhaps even causing the moored vessel to go aground in the silt and mud adjacent to a jetty!!
- Effects of mooring lines, side fenders and gangplanks etc will have some bearing on the final magnitudes derived. Nevertheless, this mathematical treatise has shown that there is a strong case for including tidal speed within a draft survey. *NA*

References.

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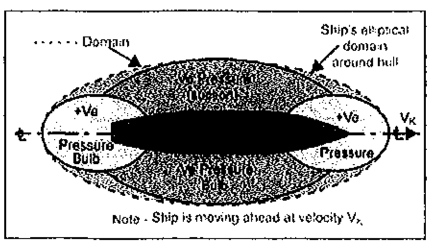
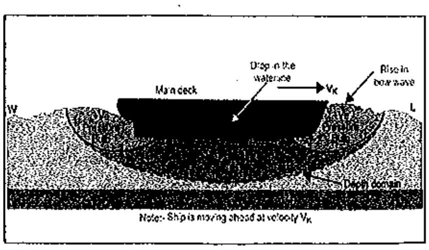
www.ship-squat.com

Pressure bulbs around a moving vessel.





Excessive squat causing grounding of a fine form vessel.