A BRIEF REPORT ON DRAUGHT SURVEYS FOR BULK CARGO QUANTITY ASSESSMENTS

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In most of the bulk cargo trades, it is not possible to establish the weight of the cargo by direct measurement. Therefore, the only possible method of finding the amount of cargo on board a ship is by means of a draught survey, which entails taking the draught of a ship before and after handling the cargo and calculating the displacements. The difference between the initial and loaded displacement represents the cargo on board.

2) WHAT IS A DRAUGHT SURVEY :

The very first principle of floatation is that the "WEIGHT OF A FLOATING BODY IS EQUAL TO THE WEIGHT OF THE LIQUID DISPLACED BY IT". Based on this fundamental principle, if one is able to establish the total weight of the liquid displaced by a floating ship, we would be able to establish the total weight of the ship itself including whatever it has on board at that time.

2.1) TOTAL WEIGHT OF A SHIP :

The total weight of any ship at anytime is the mathematical sum of the following five elements.

a) *Its own lightweight.*
b) *The total cargo on board.*
c) *The total quantity of bunkers on board*
d) *The total quantity of freshwater on board as well as the ballast water, if any.*
e) *Plus the total constant of the vessel.*

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2.2) HOW TO ARRIVE AT THE WEIGHT OF THE CARGO ON BOARD :

Since the total weight of the ship is a combination of all the above described five components, we can identify and quantify each of them by different methods.

2.2.1.) The Ship's own lightweight is provided in the main ship's data book compiled and provided by the original builders of the vessel on delivering the ship to the ship owners which is termed as the lightweight. That weight is ascertained by the builders by calculating the total quantity of steel and other materials utilised for building the ship and by taking into account the weight of all the additional fittings in place on the vessel and also by taking into account of the total weight of her propulsion machineries, auxiliary engines, pumps and fittings and all the other essential implements required by a seagoing vessel such as her anchors, anchor chains, mooring ropes, essential minimum stores etc. The overall sum of all the above items are clubbed together and declared under the heading of "LIGHT WEIGHT" of the ship. Every ship's document contains this information.

2.2.2) The total quantity of bunkers available on board any vessel can be ascertained by taking the soundings (measurements) of all the Fuel Oil, Diesel Oil and Lubricating Oil tanks and arriving at their respective individual weights (volume obtained X density).

2.2.3) Similarly, the total quantity of freshwater and ballast water if any can also be ascertained by sounding the different tanks containing them and by arriving at their respective collective weights. It must be mentioned here that all ships are provided with adequate number of segregated tanks in which bunkers, freshwater and ballast water can be stored and all such tanks have separate tank calibration tables.

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2.2.4) Once we establish the overall weight of the three important factors ie., the lightweight of the ship, total quantity of bunkers and total quantities of freshwater and ballast water remaining on board, the residual factor contributing towards the overall displacement of the ship can be isolated which is termed as the Cargo + Constant factor.

2.2.5) This is precisely what is done at the time of an initial draught survey on a loaded vessel when the attending surveyor arrives at the residual "Cargo + Constant" factor out of the total calculated displacement of the vessel.

2.2.6) With the above findings in hand, if the same surveyor attends to the same vessel for the final draught survey which is carried out soon after the last sling-load of cargo is out of the vessel, he can easily arrive at one of the hitherto unknown factor ie., the CONSTANT — of the vessel.

2.2.7) Assuming that the particular vessel's on board conditions remain unchanged during the brief period of the vessel's stay at a port discharging her cargo, the 'constant' she had on board on her arrival, per force, would remain very much the same on completion of discharge of cargo, as well. Therefore, if the established quantum of "constant" is removed from the original 'CARGO + CONSTANT' factor, one can easily arrive at the total quantity of the cargo the vessel could have had on board on her arrival at the port and subsequently got discharged later.

3) The above manner of carrying out an initial & final draught survey on a loaded ship will reveal the total cargo the vessel had discharged at a port. This approach of course is applicable only to a loaded ship arriving at a port and for finding out the total quantity of cargo she carried on board.

Contd 4

3.1) On the reverse side, if however, where one has to establish the total quantity of bulk cargo a vessel is likely to load at a port, the same also can be attained by means of similar draught surveys only. In this case, if an initial draught survey prior to the commencement of cargo loading is carried out/the vessel's 'constant' can be arrived at straightaway. The only perceptible difference one comes across in this case is that unlike in the case of a loaded vessel's draught survey, where one has to wait until the very last for arriving at the 'CONSTANT' factor, the same is established here at the time of the initial draught survey itself. When the constant is arrived at prior to the commencement of cargo loading itself, the total quantity of cargo loaded can straightaway be established by carrying out a final draught survey at which time the rest of the variable items available on board besides the constant, such as the bunkers freshwater, ballast water etc., can be sounded, ascertained and eliminated one by one along with the 'CONSTANT' and the lightweight of the vessel from the full displacement of the vessel in the loaded condition. The remaining factor is the total quantity of cargo loaded on board.

3.2) In short, if one has to establish the total quantity of bulk cargo a vessel loads / discharges a minimum two draught surveys - one initial prior to cargo loading / discharging and another one on completion of cargo completion has to carried out as accurately as possible.

3.3) At this stage, a brief look back on how a ship's displacement itself is arrived at is of paramount importance.

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3.3.1) Every ship has numerical markings on her both sides at three different locations — a) at the forward end b) at the mid-ship region and c) at the after end of the vessel, markings mostly in meters and centimeters or sometimes in feet and inches. These markings which are known as draught marks are indicative of vessel's immersion in Dockwater at those points and they are marked from the bottom of the ship (keel) upwards throughout. A general accurate reading of the water level at these six draught markings will give an indication as to what extent the vessel is immersed in the Dockwater at that time. For the purpose of draught surveys, from the above six readings an overall general mean immersion of the vessel is arrived at through a formula

$$\textbf{Mean average draught} = \frac{\textbf{Forward Draught + After Draught + (6 x mean midship draught)}}{\textbf{8}}$$

3.3.2) All ships are provided by the builders with a deadweight scale drawing from which the vessel's displacement in Metric Tonnes vis-à-vis her mean draught at anytime can be read off easily. However, since the builders have compiled the deadweight scale assuming that the vessel will be floating generally in normal seawater with a density of 1.025, any draught readings of a vessel obtained in water of density different to the original assumed density of 1.025, necessarily will have to undergo a corresponding density correction to arrive at the appropriate displacement in saltwater. Needless to add that the vessel will draw deeper draught in dockwater of density less than 1.025 and vice-verse.

The general formula for correcting the displacement of the vessel for density variation is

$$\textbf{True displacement} \quad \frac{\textbf{Scale displacement x Density of Dockwater}}{\textbf{Density used for the displacement scale}}$$

Contd...6

3.3.3) As mentioned earlier, for each different bunker, ballast or freshwater tank of a vessel, a certified calibration table will be available on board from which the respective volumes / weights of the contents of each tank can be ascertained. The calibration usually is in centimeter and the corresponding volumes are generally in cubic meters. The actual weight of the contents can be arrived at by the formula

Weight volume x density.

Normally for freshwater, the density is taken as 1.000 while for ballast seawater it is 1.025. For bunkers and lubricants the densities are provided by the respective suppliers and they are always less than 1.000.

4) CONCLUSION :

A commonly held view is that draught surveys do not guarantee sufficiently accurate results most of the times. This notion probably came about because there is no universally recognised procedure laid out for carrying out a draught survey and each surveyor has his own way of attending to it, although covering all the above mentioned functions.

In the absence of any other more reliable cargo weight assessment method of availability, as far as a shipload of cargo is concerned, draught surveys continue to remain as the best available method for calculating the quantity of cargo. If the draught readings are obtained carefully and accurately and if all different calculations are carried out in a thorough manner, a substantially reliable result can be achieved through a draught survey. It is difficult to quantify the extent of errors likely to occur in a draught survey, the reliability of which depends entirely upon the care, skill and devotion exercised by an attending surveyor.

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With advancing age of a vessel, her original deadweight scale and other tank calibration data themselves may not reflect the true upto-date results they are designed to provide. Similarly the constant factor of a vessel seldom remains any bit constant but remains liable to change each voyage. Hence, it is of utmost importance to establish correctly the most upto-date 'constant' factor of a vessel at each cargo operation time because no other weight element on a ship is as unpredictable as this one is.

O L I O **T H E E N D** ❑ ❑ ❑

GLOSSARY OF SOME IMPORTANT NAUTICAL TERMS USED IN A DRAUGHT SURVEY

1)	*Draught (Draft) marks of a vessel -*	*The depth of the ship below waterline shown on shipsides.*
2)	*Forward (For'd) part of a vessel -*	*The front portion of a ship.*
3)	*After (Aft.) part of a vessel*	*The rear end of a vessel.*
4)	*Mid-ship part of the vessel*	*The mid-length area of a ship. The*
5)	*GROSS Tons*	*total overall internal enclosed volume of the ship ascertained in Cubic feet and divided by 100.*
0)	*NETT Tons*	*Total Gross tons less all the unearning spaces such as the Navigating, machinery, bunker, ballast and designated store spaces, reckoned in tons.*
1)	*Displacement of a vessel*	*The total weight of the ship plus all other weights available on board in tons.*
2)	*Deadweight of the vessel*	*The maximum operational cargo carrying capacity of the ship, in tons.*
3)	*Bunkers*	*Fuel Oil, Diesel Oil and Lubricating Oil used on board a ship.*
4)	*Ballast water*	*Extra water weight added on a vessel intentionally for obtaining deeper draught for better Navigational advantages of the ship, reckoned in tons.*
5)	*Constant of a vessel*	*The total accumulated unaccounted weights on a ship, other than fresh, ballast waters and bunkers, reckoned in tons.*

FACTORS AFFECTING DRAFT SURVEYS

IT IS DIFFICULT to determine very accurately the mass of' a ship under normal operating conditions. The traditional procedures employed by ship's officers are usually considered adequate; but there are many sources from which errors may arise. This note draws attention to some of these possible errors and in some cases suggests ways of eliminating or reducing them.

Determination of the equivalent level keel condition

delciminc the ship's mass using the hydrostatic data normally available on a ship requires corrections to be made to determine the equivalent even keel draft. For accuracy this requires not only a trim correction but also a correction for list. When a ship of normal form heels it rises bodily in the water and its mean draft decreases. At the ends of the ship, where it is not wall sided in way of the waterline, the wedge emerging from the water is smaller than the wedge being immersed. To correct this difference, the ship naturally lifts out of the water until the emerging volume is equal to the newly immersed volume. For a small ship the difference in draft will not be large and the effect on displacement could probably be neglected provided the list is not more than a couple of degrees. (Fig 1.) However, for a large ship the error in the calculated ship mass when this effect is ignored may be significant. It would be a simple matter at the design stage when the hydrostatics are produced, using a computer program to include a sub-routine providing a correction table to account for the effect of list at any operational draft. With the data currently supplied to ships it would be difficult to make an accurate correction.

However, the following expression will give some idea of the error involved in the calculated ship mass if no correction is made: Error = 6 (TPC — TPC $_2$) x (D $_z$ — D tonne's, where D_i and D_2 are the drafts in metres at amidships on each side of the vessel and TPC, and TN $_2$ are the tonnes per centimetre immersion corresponding to these drafts.

When corrections are made for trim the longitudinal centre of flotation (LFC) used is usually that which corresponds to the mean draft. But with large trims this may not be the axis about which the ship should be considered to rotate. The actual position of the axis will vary with the amount of trim and the hull form of the vessel. The trim correction tables produced for ships by some shipyards take this into account and it is unfortunate that such tables are not universally provided. Empirical IM-mulfte do exist to correct fur the shift in I ,CF but these are unlikely to he accurate fur all types of hull form. The calculation of the volume of displacement could be made directly from the Bonjean curves but this would be time-consuming and possibly inaccurate unless the curves were reproduced accurately and on a large scale.

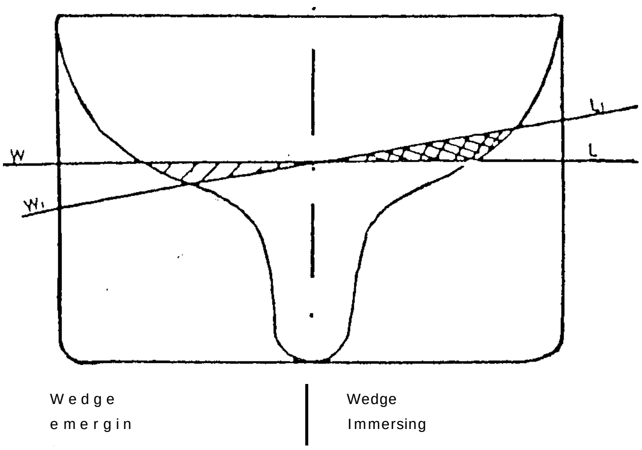
Most calculations of displacement assume that the draft i.t the fore and aft perpendiculars of the design waterline are known. However, in many cases the draft read from the marks on the ends of a ship do not give these values. It is a simple matter to produce curves to enable the measured drafts to be corrected to equivalent FP and AP values. If no correction is made the calculated ship mass may be in error, in some cases, to the extent of several hundred tonnes.

Determination of density

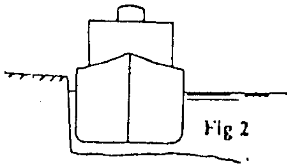
Traditionally a bucket is thrown over the ship's side and the specific gravity of the water collected, as measured by a hydrometer, is used in the displacement calculation. However, in many rivers the density will change with water depth as different current layers are encountered. Therefore the density of a bucket of surface water will not necessarily be representative of all the water surrounding the ship and a displacement calculated using this one figure may be inaccurate. The mean of a series of samples taken over a range of water depths, extending to the ship's draft and at various points around the vessel, should give reasonable average density on which to base calculations, provided the variation in density is not too large. Simple devices exist for taking water samples from any depth alongside a vessel.

The hydrometers used to measure the density sometimes have scales which do not extend below 'I', where '1' usually corresponds to the specific gravity of fresh water at 15°C. So when the hydrometer is placed in fresh water warmer than 15°C it is off the bottom of the scale. In tropical regions and close to warm water outfalls, the water temperature is often above 15°C and a 'guestimate' has to be made of the

I Fig I

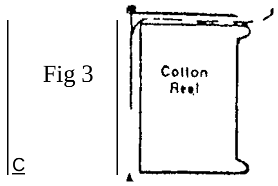


Piece of Card with
pin through centre

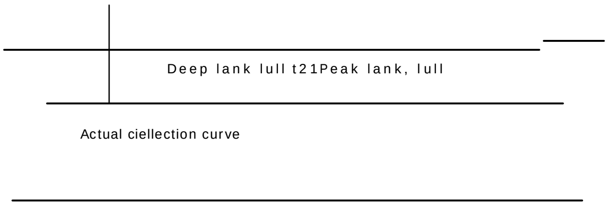


Restricted section of
vessel alongside

Fig 3



Air current



Assumed deflection cur.,
(parabolic)

Fig 4

specific gravity by ,visually extrapolating the scale on the hydrometer downwards. It would help if the scale on all such instruments were extended down to, say, 0.995 which-would cover the warmest fresh water likely to be encountered.

Another point worth noting is that the hydrometer measures specific gravity which, for the hydrometers commonly used, is defined as the sample water density divided by the density of fresh water at I 5"C. Then the specific gravity of fresh water at 15°C, is `1,000'. However, the mass density of fresh water at 15°C is 0.9990 tonnes per cubic metre. For ship mass calculations it is the mass density that is required not the specific gravity. Assuming that the specific gravity and the mass density have the same numerical value involves a slight error (100 tonnes in the displacement calculation of 100,000 tonnes). Recalibrating an hydrometer to read density directly would be a simple job and a correction, which is often forgotten, would be avoided.

Sinkage and trim caused by currents and tidal streams

Most seafarers are well aware of the effect known as `squat' which causes ships to increase their draft when travelling at speed in shallow water. What they may not be aware of is that a ship moored or anchored in shallow water experiences the same effect when there is a tidal stream or current running. The cause of both effects is similar.

Consider a ship moored in a river. (Fig 2.) When a current is running the ship constricts the flow. The water must then increase its speed in orde'r that the same quantity passes through the restricted space as does through the unrestricted space, in any given period of time. The water flowing at higher speed under the bottom of the vessel causes a reduction in pressure on the bottom (this occurs by virtue of' the Bernoulli effect) and the ship sinks deeper in the water.

The Bernoulli effect can be demonstrated by trying to blow a piece of card off the end of a cotton reel. (Fig 3.) It is impossible to blow the card off. The high air velocity on the inner face of the card causes a local drop in pressure relative to the outer face of the card, thus keeping it firmly pressed on the end of the reel. Bernoulli's equation, which governs this effect, is

$P + p—^{v2} + pgh =$ constant, where P is the pressure,

p the water density, v is the velocity and Ii the depth of water. Clearly as v increases, at a given water depth, P must decrease for the equation to remain constant.

The amount of sinkage caused by this effect will depend, therefore, on the water velocity. It will also depend on the depth of water beneath the keel and the ship's length. The sinkage in some cases will be considerable. For example, a 1,600-tonne coaster moored in a river where the current is running at 4 knots will experience a sinkage of at least 5 cm where there is about 0.35 m of water under the keel. It is therefore desirable to wait until the depth of water under the keel is as large as possible before measuring drafts if there is any current.

Clearly in a tidal stream it would he better to measure the draft at slack water thus avoiding this sinkage effect if at all possible. With data currently available it would not be possible for the sinkage likely to be experienced to be estimated in all CIASCS. An approximate theoretical estimate can be made but the procedure involved is relatively complicated (see Dand & Ferguson *The Squat of Full Form Ships in Shallow Water T .1t1* NA Vol 115, 1973).

Further errors can occur when the drafts are read due to the wave pattern around the ship produced by the current. These waves are additional to those produced by the wind which also make an accurate reading of the draft marks difficult. Measuring draft with the help of a long transparent plastic tube, with its lower end well below the water surface with the opening pointing downwards, will largely eliminate the effect of these waves. The tube is held alongside the vessel and the water level in the tube read against the ship's draft marks.

Correction for hog and sag

When the mean of the Ibrward and after draft marks is different from the mean draft amidships, a correction is sometimes made for hog or sag. For hog, two thirds of this difference is usually added to the mean of the draft at the ends, and for sag, two thirds of this difference is subtracted. The correction is based on the assumption that ships bend into smooth parabolic curves. This is quite reasonable in some cases, but not in all. (Fig 4.)

Consider a ship with engines aft, a large full deep tank amidships and with the forward peak tank full. The deflected shape will not follow a parabolic curve but a broken line. It should be possible for design offices to supply information concerning the form of the deflection curve for certain critical conditions allowing a more accurate correction for hog or sag to be made in cases where the deflection is significant.

Conclusion

There are many possible sources of error in the calculation of ship displacement, and this chapter touches on a few of them. The errors outlined here may not be significant in all cases, However, it is possible that one or more of these sources of error can result in considerable inaccuracy in the displacement calculation if appropriate steps are not taken.r]