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Draft Survey: The Question of Accuracy

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Abstract
Presented paper relates to the influence of the accuracy of calculations on the results of the Draft Survey method. This method is designed for determine the total weight of cargo a ship is actually loaded, in tons.

Keywords: Cargo Capacity, Draft Survey Method, Poland

1. Introduction

The actual cargo loaded depends on the ship's maximum allowable immersion (deadweight) at the relevant season, which will include the capacity of fuel, lubricating oil, provisions, fresh water, crew, ballast water, and the ship-constant.

Cargo capacity (ton) = deadweight (ton) – balast, fuel, provisions, etc. (ton)

However, in practice sometimes the discharging report occurs, which shows a shortage of the cargo discharged in port of destination. Such claim seemed rather doubtful and has to be refused when the amount of cargo loaded was verified by Draft Survey, as the carrier is under an obligation to verify the amount of cargo and to verify its condition at the time the cargo comes into his custody and care.

2. The Accurate Calculations of Cargo Capacity

Draft has a direct correlation to the displacement of the ship and to the deadweight at the same time.

Deadweight (ton) = displacement Δ (ton) – light ship weight (ton)

It is important that the draft is accurately determined since each incorrect centimeter in draft can mean a displacement difference of several tons. Below, in Table 1 are presented the Hydrostatic data of the semi-container ship which has been used for the further calculations. The main particulars of the ship are as follows:

Gross Capacity GT	11 573
Maximum Displacement	20 767 (ton)
Deadweight	13 593 (ton)
Length Overal	l149.15 m
Breadth	22.00 m
High to the main deck	12.00 m
Maximum draught	9.14 m

Table 1: The selected Hydrostatic data of the semi-container ship

T [m]	V [m³]	Δ [ton]	TPC [ton/cm]	M_J [tonm/m]	LCB [m]	LCF [m]
5.24	10719	11020	23.4	16686	0.52	0.68
5.28	10810	11113	23.4	16717	0.52	0.66
5.30	10856	11161	23.4	16732	0.52	0.66
5.32	10901	11207	23.4	16747	0.52	0.65

The density of water ρ, in which the ship floats must be determined accurately.
The mean draft T (m) is measured at the half distance mark of the ship's length between perpendiculars (1/2 L_{PP}). This mean draft is the same as the sum of the draft in the fore and aft perpendiculars, divided by two.
In practice the draft marks are not located on the perpendiculars nor on the centerline, as it has been presented in Fig 1.

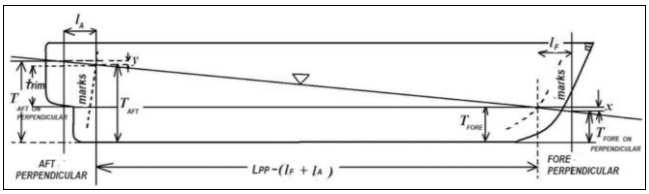

Fig 1: The corrections ***x*** and ***y*** for drafts marks to place them on perpendiculars

The value reading from the fore and aft marks has to be corrected in order to find the value at the perpendiculars.
It mens, that the corrections ***x*** and ***y*** are necessary to have the drafts information on perpendiculars, and to determine the proper value of the displacement from the hydrostatic data. The above corrections are available to be used from ship's hydrostatic documentation.
However the drafts can be calculated directly as the perpendiculars data, by formulas (2) and (3), as shown in Fig 2.

The ship's trim (t) describes the following formula (1):

$$t = \frac{\Delta \cdot (LCG - LCB)}{M_J}$$

Where: LCG - logitudinal center of gravity,
LCB – longitudinal center of buoyancy
M_J - moment to change the trim per unit

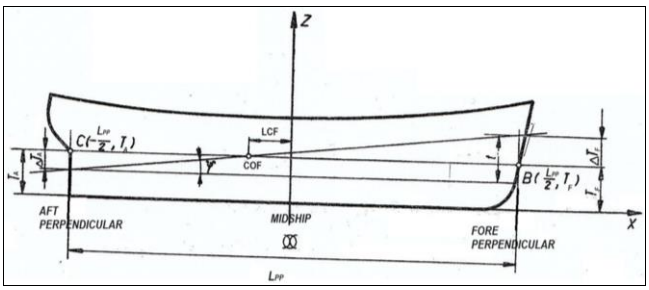

Fig 2: The corrections ΔT_A and ΔT_F to get a proper mean draft T

The longitudinal form data: LCB, LCF and Moment to change trim per unit M_J are used to determine:

- The correct displacement at an accepted draft,
- The draft before and after loading.

The correct draft is the vertical distance from the base line to the waterline at the Center of Flotation - COF. However the COF in practice does not correlate to $L_{PP}/2$ and the above does it means that the ship has a trim, and special „trim correction" to be adjusted for the correct displacement determination.
Trim adjustment is determined by formulas (4 – 6). It should be added that trim adjustment only be applied if a hydrostatic table with a trim of nil is used.
In practice an additional, the different one correction should be taken into consideration. It means the correction of deflection of the ship's hull for hogging or sagging. But in this case the ship is not deflected and the said correction is not to be calculated.
The initial data for draft survey calculation has been presented in Table 2. The conditions are as follows: As the ship floats in the sea water: ρ = 1.025 t/m², it is not necessary to calculate the correction for the density of water.

For the ship Displacement (Δ) of 11 128.34 t, the folowing hydrostatic data has to be read:

1. The mean draft T = 5.29 m,
2. The Longitudinal Center of Buoyancy LCB = 0.52 m,
3. The Longitudinal Center of Flotation LCF = 0.66 m,
4. The Moment to change the trim per unit M_J =16 724 tm/m,
5. The length of the ship between the Perpendiculars: L_{pp}=140 m.

Calculated trim as per formula (1) equals: t = - 0.2129 m.

Table 2: The initial data for draft survey calculations

	mass [t]	**LCG [m]**	**VCG [m]**	**M_{LCG} [tm]**	**M_{VCG} [tm]**	**Δmh [tm]**
Light ship	9773.00	66.94	8.65	654204.62	84536.45	2439.00
Ship-constant	300.00	60.00	10.00	18000.00	3000.00	00.00
Cargo in hold No. 2	1055.34	103.30	3.01	109016.62	3176.57	12430.07
Displacement	11128.34	70.20	8.15	781221.24	90713.02	14869.07

The drafts fore and aft are, correspondingly:

$$T_{fore} = T + (L_{pp}/2 - LCF) \cdot (t/L_{pp}) = 5.19 \text{ m.} \quad (2)$$

$$T_{aft} = T + (- L_{pp}/2 - LCF) \cdot (t/L_{pp}) = 5.40 \text{ m.} \quad (3)$$

3. The Influece of Draft Accuracy on a Ship-Constant Determination

The more accurate calculations of fore and aft drafts are giving the new value of the mean draft

T = (5.19 m + 5.40 m)/2 = 5.295 m,
and the trim t = - 0.21 m.

The hydrostatics data for the more correctly calculated value of the mean draft are as follows:

The Immersion: TPC = 23.4 t/cm; LCF = 0.66 m; M_J = 16 728 tm/m;

$M_{J\ (T+\ 0.5m)}$ = 17 127 tm/m; $M_{J\ (T-\ 0.5\ m)}$ = 16 364 tm/m

The new value of the Displacement_1 (Δ_1) = 11149 t

The corrections for the Displacement Δ_1 due to the ship's trim are as follows:

$$CORR\ 1 = 100 \cdot LCF \cdot TPC \cdot (t/L_{PP}) = -2.32\ t \quad (4)$$

$$CORR\ 2 = 0{,}5 \cdot (t^2 / L_{PP}) \cdot [M_{J\ (T + 0.5m)} - M_{J\ (T - 0{,}5\ m)}] = 0.12\ t \quad (5)$$

The corrected Displacement is:

$$\Delta_{1\ CORRECTED} = \Delta_1 + CORR\ 1 + CORR\ 2 = 11\ 146.80\ t. \quad (6)$$

The calculations of the Ship-constant value for the corrected hydrostatic data has been presented in Table 2.

Table 2: The corrected results of Ship-constant calculations

	mass [t]	LCG [m]	VCG [m]	M_{LCG} [tm]	M_{VCG} [tm]
Ship's Displacement	11146.80	70.20	8.15	782505.36	90846.42
Light ship	- 9773.00	66.94	8.65	- 654204.62	- 84536.45
Cargo in hold No.2	- 1055.00	103.30	3.01	- 108981.50	- 3175.55
Ship-constant	318.80	60.60	9.83	19319.24	3134.42

The Ship-constant value from Table 2 is not the same as the initial. The difference between the initial and obtained value of the Ship - constant equals +18.80 t.
The drafts fore and aft, which has been used for calculations, were defined with the accuracy of 1cm. It is clear that it is not a satisfactory degree.
When improved the accuracy of the draft determination to 0.1 cm, the obtained results are as follows:
T_{FORE} = 5.181 m, T_{AFT} = 5.394 m, trim t = - 0.213 m, the mean draft T = 5.287 m, and the new value of the Displacement Δ_2 = 11 1330 t.
The corrections Corr 1 and Corr 2 due to the trim of the ship are giving the value

$$Corr\ \Delta_2 = Corr1 + Corr2 = -2.20\ t.$$

The results of ship-constant calculations has been presented in Table 3. These results are very close to the initial.
The value of corrected Displacement equals:

$$\Delta_{2\ CORRECTED} = 11\ 127.80\ t.$$

Table 3: The more accurate results of Ship-constant calculations

	mass [t]	LCG [m]	VCG [m]	M_{LCG} [tm]	M_{VCG}[tm]
Ship's Displacement	11127.80	70.20	8.15	78117.56	90691.57
Light Ship	- 9773.00	66.94	8.65	- 654204.62	- 84536.45
Cargo in Hold No. 2	- 1055.00	103.30	3.01	- 108981.50	- 3175.55
Ship-constant	299.80	59.99	9.94	17985.44	2979.57

When again improved the accuracy of the draft determination to 0.01 cm, the results of the draft survey calculations are as follows:

T_{FORE} = 5.1810 m; T_{AFT} = 5.3939 m; trim t = - 0.231 m; the mean draft T = 5.2875 m,

Displacement Δ_3 = 11 130 t.

The hydrostatic data for the above parametrs are presented below:

Immersion TPC = 23.4 t/cm; LCF = 0.66m; the Moment to change trim per unit

M_J = 16 722.626 tm/m;

The corrections to the Displacement due to the trim of the ship has been calculated as:

CORR 1 = - 2.3486 t; CORR 2 = 0.1234 t.

The fiinal results of corrected Displacement is:

$$\Delta_{3\ CORRECTED} = \Delta_3 + CORR1 + CORR2 = 11\ 130\ t - 2.2\ t = 11\ 127.80\ t$$

The results of the Ship–constant determination for the accuracy of 0.01 cm in draft calculations, has been presented in Table 4.
The obtained parameters of the Ship-constant are very close to the initial value.

Table 4: The results of high accuracy of Ship-constant determination

	mass [t]	LCG[m]	VCG [m]	M_{LCG} [tm]	M_{VCG} [tm]
Ship's Displacement	11127.80	70.2011	8.1515	781171.56	90708.26
Light Ship	- 9773.00	66.94	8.65	- 654204.62	- 84536.45
Cargo in Hold No. 2	-1055.00	103.30	3.01	- 108981.50	-3175.55
Ship- constant	299.80	59.99	9.99	17985.44	2996.26

4. Conclusions

In a general, the amount of cargo loaded on the ship depends on, among other things:

- The capacity of space reserved for cargo,
- The maximum cargo capacity (tonnage) of the trade route,
- The duration of voyage relative to the amount of fuel which reduces the cargo capacity,
- The maximal permissable draft during the voyage.

Table 5: The comparison of obtained results of Draft Survey calculations

	Ship-constant [t]	LCG (X) [m]	VCG (Z) [m]
Initial Data	300.00	60.00	10.00
Accuracy of draft calculations 1 cm	318.80	60.95	9.83
Accuracy of draft calculations 0.1 cm	299.80	59.99	9.94
Accuracy of draft calculations 0.01 cm	299.80	59.99	9.99

However, on the begining of the voyage the captain should be familiar with the actual weight of cargo loaded. The total weight of cargo is calculating by Draft Survey method. How accurate the result can be obtained - it has been presented in the above analyse and compared in Table 5.

5. References

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