Outcome 1
LESSON 2
Tonnes per Centimetre Immersion (TPC)

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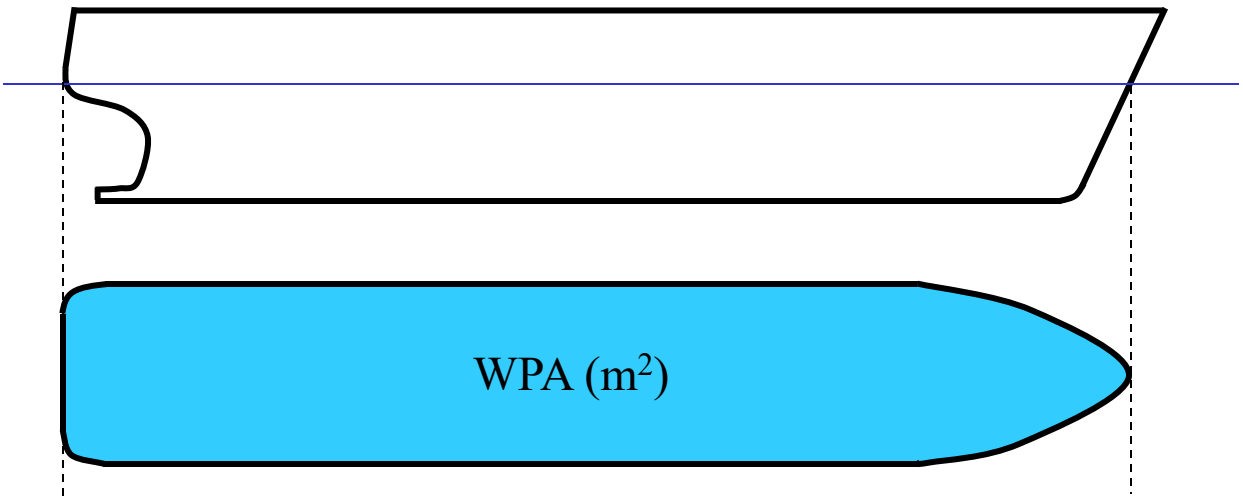
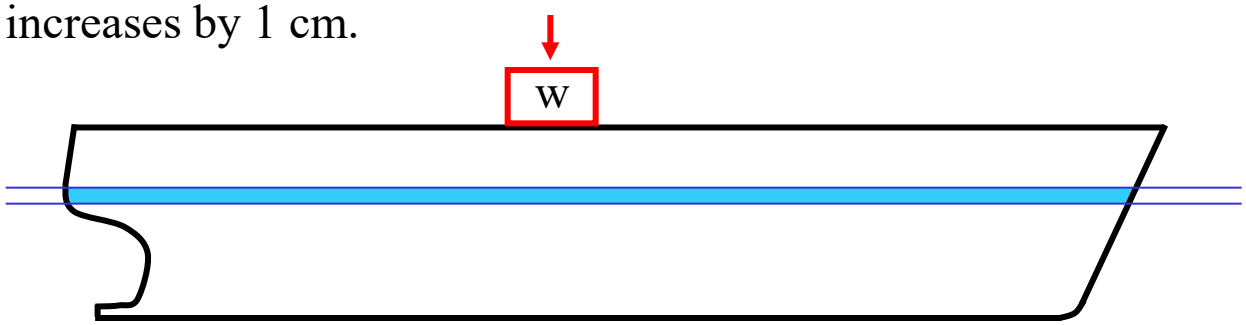
TONNES PER CENTIMETRE IMMERSION (TPC)

The ***TPC*** for any given draught is the weight which must be loaded or discharged to change the ship's mean draught by ***one centimetre***.

Consider the ship shown floating in salt water (RD 1.025) with a waterplane area (WPA) at the waterline as shown.



A weight 'w' tonnes is loaded on deck so that the mean draught increases by 1 cm.



SAQ

What is the mass of the additional 'slice' of displaced water equal to?

Answer

The mass of the additional slice of displaced water is the same as the added weight 'w'.

Since: Mass = Volume × Density

then: Added displacement = Vol. of slice × density.

If the WPA is assumed to not significantly change between the two waterlines, then:

Added displacement = (WPA(m^2) × 1 cm) × density;

Added displacement = WPA(m^2) × $\frac{1}{100}$ (m) × density;

Thus, the formula for TPC is given by:

$$\textbf{TPC} = \frac{\textbf{WPA}}{\textbf{100}} \times \rho$$

SAQ

Calculate the TPC for ship with a waterplane area of 1500 m^2 when it is floating in:

(a) salt water; (b) fresh water; (c) dock water of RD 1.005.

Answer

$$TPC = \frac{WPA}{100} \times \rho$$

a) $TPC = \frac{1500}{100} \times 1.025 = 15.375$

b) $TPC = \frac{1500}{100} \times 1.000 = 15.000$

c) $TPC = \frac{1500}{100} \times 1.005 = 15.075$

Consideration of the TPC formula indicates that:

* ***TPC increases with WPA and for a normal ship-shape the WPA will increase with draught.***
* ***TPC increases with density. Two values of TPC are often quoted in ship's hydrostatic data, TPC_{SW} and TPC_{FW}.***

TPC values for the draught range of a ship allow us to calculate how much cargo/ballast etc. to load or discharge to achieve a required draught.

$$\textbf{Sinkage/Rise (cms)} = \frac{w}{TPC}$$

where 'w' represents the total weight that is loaded or discharged to change the draught of the ship.

DRAUGHT	DISPL.	DISPL.	TPC	TPC	MCTC	MCTC	KMt	KB	LCB	LCF
m	t	t	t	t	t-m	t-m	m	m	foap	foap
	SW	FW	SW	FW	SW	FW			m	m
	RD 1.025	RD 1.000	RD 1.025	RD 1.000	RD 1.025	RD 1.000				
7.00	14576	14220	23.13	22.57	184.6	180.1	8.34	3.64	70.03	67.35
6.90	14345	13996	23.06	22.50	183.0	178.5	8.35	3.58	70.08	67.46
6.80	14115	13771	22.99	22.43	181.4	177.0	8.36	3.53	70.12	67.57
6.70	13886	13548	22.92	22.36	179.9	175.5	8.37	3.48	70.16	67.68
6.60	13657	13324	22.85	22.29	178.3	174.0	8.38	3.43	70.20	67.79
6.50	13429	13102	22.78	22.23	176.8	172.5	8.39	3.38	70.24	67.90
6.40	13201	12879	22.72	22.17	175.3	171.0	8.41	3.33	70.28	68.00
6.30	12975	12658	22.66	22.11	173.9	169.6	8.43	3.28	70.32	68.10
6.20	12748	12437	22.60	22.05	172.5	168.3	8.46	3.22	70.35	68.20
6.10	12523	12217	22.54	21.99	171.1	167.0	8.49	3.17	70.38	68.30
6.00	12297	11997	22.48	21.93	169.8	165.7	8.52	3.11	70.42	68.39
5.90	12073	11778	22.43	21.87	168.5	164.4	8.55	3.06	70.46	68.43
5.80	11848	11559	22.37	21.82	167.3	163.2	8.59	3.01	70.50	68.57
5.70	11625	11342	22.32	21.77	166.1	162.1	8.63	2.95	70.53	68.65
5.60	11402	11124	22.26	21.72	165.0	161.0	8.67	2.90	70.57	68.73
5.50	11180	10908	22.21	21.66	163.9	160.0	8.71	2.85	70.60	68.80
5.40	10958	10691	22.15	21.61	162.9	158.9	8.76	2.80	70.64	68.88
5.30	10737	10476	22.10	21.56	161.8	157.9	8.81	2.74	70.68	68.95
5.20	10516	10260	22.05	21.51	160.8	156.9	8.86	2.69	70.72	69.02
5.10	10296	10045	22.00	21.46	159.8	155.9	8.92	2.63	70.75	69.09
5.00	10076	9830	21.95	21.41	158.8	154.9	8.98	2.58	70.79	69.16
4.90	9857	9616	21.90	21.36	157.9	154.0	9.06	2.53	70.82	69.23
4.80	9638	9403	21.85	21.32	156.9	153.1	9.13	2.48	70.86	69.29
4.70	9420	9190	21.80	21.27	156.0	152.2	9.22	2.43	70.90	69.35
4.60	9202	8978	21.75	21.22	155.1	151.3	9.30	2.38	70.93	69.42
4.50	8985	8766	21.70	21.17	154.2	150.5	9.40	2.32	70.96	69.48
4.40	8768	8554	21.65	21.12	153.3	149.6	9.49	2.27	71.00	69.55
4.30	8552	8344	21.60	21.07	152.4	148.7	9.60	2.22	71.04	69.62
4.20	8336	8133	21.55	21.02	151.5	147.8	9.71	2.17	71.08	69.68
4.10	8121	7923	21.50	20.97	150.6	146.9	9.83	2.12	71.12	69.74
4.00	7906	7713	21.45	20.93	149.7	146.0	9.96	2.07	71.15	69.81
3.90	7692	7505	21.40	20.88	148.7	145.1	10.11	2.01	71.18	69.88
3.80	7478	7296	21.35	20.83	147.8	144.2	10.25	1.96	71.22	69.94
3.70	7265	7088	21.30	20.78	146.8	143.3	10.41	1.91	71.25	70.00
3.60	7052	6880	21.24	20.72	145.9	142.3	10.57	1.86	71.29	70.07
3.50	6840	6673	21.19	20.67	144.9	141.3	10.76	1.81	71.33	70.14
THESE HYDROSTATIC PARTICULARS HAVE BEEN DEVELOPED WITH THE VESSEL FLOATING ON EVEN KEEL.										

SAQ

A ship has an initial mean draught of 5.10 m in salt water and is required to complete loading with a draught of 6.40 m. Using the hydrostatic particulars calculate the amount of cargo that must be loaded.

The answer may be calculated in two ways:

Method 1

1. Read off the displacements (SW) for both the initial and required final draughts.
2. Subtract the smaller from the larger.
3. Result equals the amount to load.

Method 2

1. Read off the TPC $_{SW}$ values for both the initial and required final draughts.
2. Calculate the mean TPC_{SW} value.
3. Calculate the required change in draught; in this case sinkage.
4. Use the formula:

$$\textbf{Sinkage/Rise (cms)} = \frac{w}{TPC}$$

to find 'w', the amount to load.

Answer

Method 1

Initial draught 5.10 m $\Delta_{SW} = 10296$ ***t***

Required draught 6.40 m $\Delta_{SW} = 13201$ ***t***

Cargo to load $= 2905$ ***t***

Method 2

Initial draught 5.10 m $TPC_{SW} = 22.00$

Required draught 6.40 m $TPC_{SW} = 22.72$

$$\text{Mean } TPC_{SW} = \frac{22.00 + 22.72}{2} = 22.36$$

Sinkage (cms) = 6.40 m - 5.10 m = 1.30 m = 130 cms

$$\text{Sinkage (cms)} = \frac{w}{TPC_{SW}}$$

$$\text{Cargo to load } (w) = \text{Sinkage} \times \text{Mean } TPC_{SW}$$

$$= 130 \times 22.36 = 2906.80 \text{ t}$$

The answers may differ slightly because in using the mean value of TPC it is assumed that the TPC value will change linearly between the range of draughts concerned.

SAQ

Had the ship been floating in fresh water (FW), would the amount of cargo to load be the same to achieve the required draught of 6.40 m in fresh water.

Answer

Method 1

Initial draught 5.10 m Δ_{FW} ***= 10045 t***

Required draught 6.40 m Δ_{FW} ***= 12879 t***

CARGO TO LOAD = 2834 t

Method 2

Initial draught 5.10 m TPC_{FW} ***= 21.46***

Required draught 6.40 m TPC_{FW} ***= 22.17***

$$\text{Mean } TPC_{FW} = \frac{21.46 + 22.17}{2} = 21.815$$

Sinkage (cms) = 6.40 m - 5.10 m = 1.30 m = 130 cms

$$\text{Sinkage (cms)} = \frac{w}{TPC_{FW}}$$

$$\text{Cargo to load } (w) = \text{Sinkage} \times \text{Mean } TPC_{FW}$$

$$= 130 \times 21.815 = 2835.95 \text{ t}$$

* The displacement for the correct density must be used in all calculations.

* The TPC for the density in which the ship is loading in should be used in calculations.

* It is usual to calculate the amount to load on the basis of the required ***salt water draught***.