11 Vessel in same condition as in question 10, transfers some HFO from No. 1 DBT to No 2 P such that No 2 P becomes full, while No 1 remains partly full. Find the resultant GM fluid if the final KG is 8.950 m.

Note 1: It is not necessary to rework the entire problem. Just make the necessary changes to the final part of the working of the answer to question 10, thus:

FSM obtained finally in question 10	2087.4 tm
No 2 DBT is now not slack	-684 tm
Final FSM for this question	1403.4 tm

Note 2: Where a tank was originally slack but has now become full or empty, its FSM has to be subtracted from the final FSM obtained in question 10.

Note 3: When a tank was originally empty or full but has now become slack, its FSM must be added to the final FSM obtained in question 10.

The final fluid GM can now be computed in the usual manner.

12 Vessel in same condition as in question 10, transfers SW ballast from FP into No 3S and into AP, such that No 3S becomes full while FP and AP remain partly full. Find the GM fluid if final KG is 8.880 m.

13 Vessel in same condition as in question 10, consumes the following while on passage:

All the HFO (200 t) from No 1 DB.
Half the HFO (i.e. 100 t) from No 3 C.

All the FW from No 4 P & S (Total 200 t).
Find the fluid GM on arrival at the next port.

Note 4: Find KG on arrival by taking moments about keel, as explained in chapter 7, and add an extra column for changes in FSM, as shown below. Bear in mind notes 1, 2 & 3, under question 11.

Remarks	Weight (t) L	Weight (t) D	KG (m)	Moment about keel (tm) L	Moment about keel (tm) D	FSM (tm)
Ship in Q 10	10,000	-	8.954	89540	-	2087.4
No.1 DB	-	200	1.15	-	230	(-)399

and so on.

Note 5: When dealing with several tanks, as in a ship's calculation such as this, the change of KG of a tank due to change in its sounding may be ignored. This is the actual practice at sea.

For example: When half of the HFO (i.e. 100 t) from No 3 C is pumped out, the moment of the discharged weight about keel would be 100 x 0.6 = 60 tm.

14 Vessel in same condition as in question 10, consumes the following on a passage:

All HFO (i.e. 150 t) from No 2 Port.

Part HFO (i.e. 50 t) from No 3 C.

All FW (i.e. 100 t) from No 4 S.

Find the GM fluid on arrival port.

15 Vessel in same condition as in question 10, loads 1000 t cargo in No 2 LH KG 4 m; 2000 t cargo in No 4 LH KG 5 m. Find the final GM fluid, given that the final KM is 10.0 m.

16 A ship of 5000 t displacement has a DB tank 18 m long and 12 m wide, partly full of SW. Find the FSC in the following cases:

(a) If the tank is undivided.
(b) If the tank is divided into identical P & S watertight divisions and

(i) both sides are slack
(ii) only one side is slack.

(c) If the tank is divided into P, S & C identical watertight divisions and

(i) all three of these are slack.
(ii) Only two of these are slack.
(iii) Only one of these is slack.

(d) If the tank is divided into four identical watertight divisions — Port inner, Port outer, Stbd inner, Stbd outer — and

(i) All four of these are slack.
(ii) Any three of these are slack.
(iii) Any two of these are slack.
(iv) Any one of these is slack.

Note: The use of $1/n^2$ would be a very quick method of solving this question.

17 A ship of 10000 t displacement has a fresh water DB tank which is 20 m long and divided into P, S and C watertight divisions. The P & S divisions are each 4 m wide, while the C division is 12 m wide. Calculate the FSC in the following cases:-

(a) Only the port side tank is slack.
(b) Both port and stbd tanks are slack.
(c) Only the centre tank is slack.
(d) All three tanks — PS&C — are slack.
(e) If all the three divisions were not separate but formed one undivided tank 20 m broad.

Note: $1/n^2$ cannot be used here as the watertight divisions are not identical.

18 A ship has a very small GM. It is decided to fill up SW ballast, one tank at a time, in six tanks whose particularts are:-

Tank	'i' about tank's centre line
No 1 DB	280 m^4
No 2 P or S	600
No 3 P or S	350
No 3 C	650

State the order in which the tanks must be filled so as to keep FSC at a minimum at all times.

19 An unstable vessel is at her angle of loll. The following tanks are available for SW ballast:-

Tank	'i' about tank's centre line
No 1 DB	400 m^4
No 2 P	700
No 2 S	700
No 4 P	250
No 4 S	250
No 4 C	800

If it is decided to ballast three tanks with SW, one at a time, state what order should be followed so as to keep FSE to a minimum.

20 A vessel of W 8000 t, KM 7.9 m, KG 7.0 m, has a tank 15 m long and 12 m wide, partly full of HFO of RD 0.95.

(a) Find her moment of statical stability at 6° heel.

(b) If her BM is 4.9 m, find her moment of statical stability at 20° heel assuming that she is wall-sided.

13

List

List is the transverse inclination caused when the COG of the ship is off the centre line.

For a ship to be in static equilibrium, the forces of buoyancy and gravity must cancel each other out. In other words, for a ship to be in static equilibrium,

(i) the force of buoyancy must equal the force of gravity and

(ii) the COB and COG of the ship must be in a vertical line, as illustrated in following figure A.

If the COG is moved out of the centre line of the ship, due to asymmetrical loading or discharging or due to transverse shift of weights aboard as shown in figure B,

(i) the ship will sink or rise as necessary until the force of buoyancy equals the force of gravity and

(ii) the forces of buoyancy and gravity will form a couple which will cause the ship to incline until the COB comes vertically below the COG as illustrated in figure C.

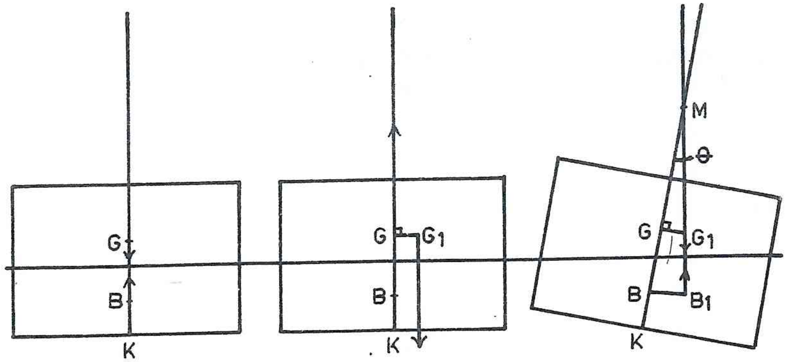


FIG. A FIG. B FIG. C

In the foregoing figures, GG_1 is the transverse shift of COG. The couple formed by the forces of gravity and buoyancy causes the ship to incline. As the ship inclines, the COB shifts to the lower side, as explained in chapter 9, and when it comes vertically under G_1, the ship would be in static equilibrium. The angle of inclination at which this happens is the list — θ in foregoing figure C.

<u>In right-angled triangle MGG_1,</u>

$\text{Tan}\ \theta = \frac{GG_1}{GM}$ where

- θ is the angle of list.
- GG_1 is the transverse shift of COG.
- GM is the final fluid GM before listing.

Since $GG_1 = \frac{\overleftrightarrow{dw}}{W}$, the formula becomes

$\text{Tan}\ \theta = \frac{\overleftrightarrow{dw}}{W.GM}$ where

- θ is the angle of list.
- dw is the final listing moment in tonne metres.
- W is the final displacement in tonnes.
- GM is the final fluid GM in metres.

In order to calculate the angle of list systematically, the following order of work is suggested:

(i) Find the final listing moment ($\overleftrightarrow{dw}$).
(ii) Find the final displacement (W).
(iii) Find the final fluid GM.
(iv) Apply the list formula $\text{Tan}\ \theta = \frac{dw}{W.GM}$

<u>Example 1</u>

On a ship of W 5000 t, GM 0.8m, 40 t of cargo is shifted transversely by 10 m. Find the list.

Final listing moment = $\overleftrightarrow{dw}$ = 10 x 40 = 400 tm.
W remains unchanged.
GM remains unchanged.

$$\text{Tan}\ \theta = \frac{\overleftrightarrow{dw}}{W.GM} = \frac{400}{5000 \times 0.8} = 0.1$$

Hence, θ = 5.71° or 5° 43'.

<u>Example 2</u>

On a ship of W 8000 t, KG 7.0 m, KM 7.5 m, 100 t of cargo is loaded on the upper deck (KG 9.2 m) 2 m to port of the centre line. Find the list.

Final listing moment = $\overleftarrow{dw}$ = 2 x 100 = 200 tm to port

Final W = 8000 + 100 = 8100 t.

$GG_1\uparrow = \frac{wd}{W} = \frac{100 \times 2.2}{8100} = 0.027$ m

	KG	=	7.000 m
	$GG_1\uparrow$	=	<u>0.027</u> m
Final	KG	=	7.027 m
	KM	=	<u>7.500</u> m

$$\text{Final GM} = 0.473 \text{ m}$$

$$\tan\theta = \frac{\overleftarrow{dw}}{W.GM} = \frac{200}{8100 \times 0.473} = 0.05220$$

Hence θ = 2.99° or 2°59' to port.

Example 3

A ship of W 10000 t, KM 7.0 m, KG 6.0 m works cargo as follows:

Loads 800 t in No 2 LH (KG 3.75) 4 m to port of the centre line.

Loads 600 t in No 4 LH (KG 6.0 m) 8 m to starboard of the centre line.

Discharges 400 t from upper deck (KG 10.0 m) 2 m to port of the centre line.

If her free surface moment is 4400 tm, find the final list.

To find the FLM

Remarks	Weight (t) Loaded	Weight (t) Disch	dist off CL (m)	Listing mom(tm) Port	Listing mom(tm) Stbd
Cargo No 2 LH	800	-	4 m to P	3200	-
Cargo No 4 LH	600	-	8 m to S	-	4800
Cargo UD	-	400	2 m to P	-	800
			Total	3200	5600
					- 3200
			FLM =		2400 tm

The next step is to find the final fluid GM.

Remarks	Weight Loaded	Weight Disch	KG	Moment by keel Loaded	Moment by keel Disch
Ship	10,000	-	6.0	60,000	-
Cargo 2 LH	800	-	3.75	3,000	-
Cargo 4 LH	600	-	6.0	3,600	-
Cargo UD	-	400	10.0	-	4,000
Total	11,400	400		66,600	4,000
	- 400			-4,000	
Final	11,000 t		Final	62,600 tm	

$$\text{Final KG} = \frac{62,600}{11,000} = 5.691 \text{ m}$$

$$FSC = \frac{FSM}{W} = \frac{4400}{11000} = 0.4 \text{ m}$$

	KM	=	7.000 m
Final	KG	=	5.691 m
Solid	GM	=	1.309 m
	FSC	=	0.400 m
Fluid	GM	=	0.909 m

To find the list

$$\tan\theta = \frac{FLM}{W.GM} = \frac{2400}{11000 \times 0.909} = 0.24002$$

Hence, θ = 13.5° or 13°30' to stbd.

Example 4

A ship of W 8000 t, GM 0.6 m, is listed 5° to starboard. How many tonnes of HFO must be transferred from No 2 S to No 2 P to upright the vessel, if the centres of the tanks are 7 m apart?

$\text{Tan } \theta = \frac{\overleftrightarrow{dw}}{W.GM}$ or $\overleftrightarrow{dw} = W.GM.\text{Tan } \theta$

Hence, dw = 8000 x 0.6 x Tan 5° = 420 tm

7w = 420 or w = 60 t

Example 5

A ship of 15000 t W, KM 9.0 m, KG 8.7 m is listed 10° to port. She now loads 150 t of cargo 7 m above the keel and 4 m to starboard of the centre line. Find the final list.

To find the initial listing moment

$\text{Tan } \theta = \frac{\overleftarrow{dw}}{W.GM}$ or dw = W . GM . Tan θ

Hence, $\overleftarrow{dw}$ = 15000 x 0.3 x Tan 10° = 793.5 tm

Hence, initial listing moment or ILM = 793.5 tm to port.

To find final listing moment

LM caused now = 150 x 4 = 600.0 tm to stbd.
ILM = 793.5 tm to port.
FLM = 193.5 tm to port.

To find final W & fluid GM

Final W = 15000 + 150 = 15150 t

$GG_1\downarrow = \frac{dw}{W} = \frac{1.7 \times 150}{15150} = 0.017$ m

Original KG = 8.700 m
$GG_1\downarrow$ = 0.017 m
Final KG = 8.683 m

Final KG = 8.683 m
KM = 9.000 m
Solid GM = 0.317 m
FSC = 0.000 m
Fluid GM = 0.317 m

To find the list

$\text{Tan } \theta = \frac{FLM}{W.GM} = \frac{193.5}{15150 \times 0.317} = 0.04029$

Hence, θ = 2.31° or 2°18' to port.

Example 6

A ship of W 16000 t, KM 9.0 m, KG 8.0 m is listed 7° to starboard. She then works cargo as follows:

Loads 1600 t cargo KG 4.5 m, 5.0 m to port.

Loads 1400 t cargo KG 8.0 m, 4.5 m to stbd.

Discharges 1000 t KG 6.5 m, 1.0 from stbd.

Find how many tonnes of ballast must be transferred transversely to upright the vessel, if the P & S tank-centres are 10 m apart.

Note: The vessel is required to be upright. Hence FLM must be zero. Since final KG is not asked here, it need not be calculated.

To find the FLM

ILM = W . GM . Tan θ = 16000 x 1.0 x Tan 7°
= 1964.6 tm to stbd.

Remarks	Weight(t) Loaded	Disch	Dist from CL (m)	Listing mom(tm) Port	Stbd
ILM	-	-	-	-	1964.6
Cargo	1600	-	5m to port	8000	-
Cargo	1400	-	4.5m to stbd	-	6300
Cargo	-	1000	1m from stbd	1000	-
				9000	8264.6
				- 8264.6	
			FLM	735.4	to port.

To upright vessel, required to cause a LM of 735.4 to starboard, by shifting ballast — tank-centres 10 m apart.

Hence, dw = 735.4

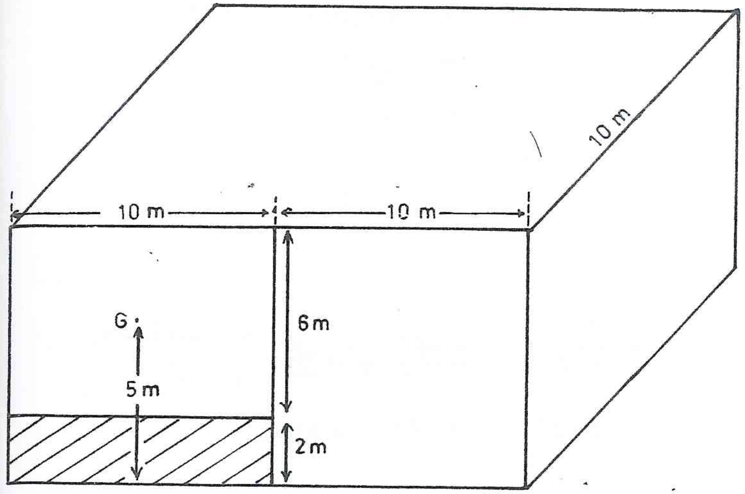
10w = 735.4

w = 73.54 t

Required to shift 73.5 t from port tank to starboard tank.

Example 7

A ship displacing 9000 t has KM 8.7 m, KG 7.2 m. She is now listed 8° to port. She has port and starboard deep tanks, each 10 m long, 10 m wide and 8 m deep. The port side deep tank, which was full of SW, is pumped out until its sounding is 2 m. Assuming that no other tanks on the ship are slack, find the final list.



To find the FLM

ILM = W . GM . Tan θ = 9000 x 1.5 x Tan 8°

= 1897.3 tm to port

Weight of SW pumped out = 10 x 10 x 6 x 1.025

= 615 t

LM caused = 615 x 5 = 3075.0 tm to stbd

ILM = 1897.3 tm to port

FLM = 1177.7 tm to stbd

To find the final fluid GM

(9000 x 7.2) - (615 x 5) = 8385 x Final KG

Final KG = 7.361 m

$$FSC = \frac{i\ di}{W} = \frac{lb^3 \times di}{12\ W} = \frac{10 \times 10^3 \times 1.025}{12 \times 8385}$$

= 0.102 m

$$\text{KM} = 8.700 \text{ m}$$
$$\text{Final KG} = \underline{7.361} \text{ m}$$
$$\text{Solid GM} = 1.339 \text{ m}$$
$$\text{FSC} = \underline{0.102} \text{ m}$$
$$\text{Fluid GM} = 1.237 \text{ m}$$

To find the list

$$\text{Tan } \theta = \frac{\text{FLM}}{\text{W . GM}} = \frac{1177.7}{8385 \times 1.237} = 0.11354$$

Hence, θ = 6.48° or 6°29' to stbd.

Example 8

A ship of 15000 t displacement, KM 8.6 m, KG 7.0 m, is to discharge a 100 t heavy lift from the centre line of No 2 LH (KG 2 m) by her jumbo derrick whose head is 20 m above the keel. The FSM (free surface moment) is 1000 tm. Find the list caused when the derrick swings the weight 14 m away from the centre line of the ship.

To find the FLM

$$\text{FLM} = dw = 14 \times 100 = 1400 \text{ tm.}$$

To find the final fluid GM

(When weight is hanging from derrick head)

$$GG_1 \uparrow = \frac{dw}{W} = \frac{18 \times 100}{15000} = 0.120 \text{ m}$$

$$\text{FSC} = \frac{\text{FSM}}{W} = \frac{1000}{15000} = 0.067 \text{ m}$$

$$\text{Original KG} = 7.000 \text{ m}$$
$$GG_1 \uparrow = \underline{0.120} \text{ m}$$
$$\text{New KG} = 7.120 \text{ m}$$

$$\text{New KG} = 7.120 \text{ m}$$
$$\text{KM} = \underline{8.600} \text{ m}$$
$$\text{Solid GM} = 1.480 \text{ m}$$
$$\text{FSC} = \underline{0.067} \text{ m}$$
$$\text{Fluid GM} = 1.413 \text{ m}$$

To find the list

$$\text{Tan } \theta = \frac{\text{FLM}}{\text{W . GM}} = \frac{1400}{15000 \times 1.413} = 0.06605$$

Hence θ = 3.78° or 3°47'.

When the weight is hanging from the derrick with an outreach of 14 m, the list would be 3.78° or 3°47'.

Example 9

A ship of 8000 t displacement has a mean draft of 7.8 m and is to be loaded to a mean draft of 8.0 m. Her GM is 0.8 m and TPC is 20. She is listed 4° to starboard at present. How much cargo should be loaded into the port and starboard 'tween decks (centres 5 m & 6 m off the centre line respectively) for the ship to complete loading and finish upright.

$$\text{Sinkage} = 8.0 - 7.8 = 0.2 \text{ m} = 20 \text{ cm}$$

$$\text{Can load} = s \times \text{TPC} = 20 \times 20 = 400 \text{ t}$$

$$\text{ILM} = \text{W . GM . tan } \theta = 8000 \times 0.8 \times \tan 4°$$
$$= 447.5 \text{ tm to stbd.}$$

Let the cargo to be loaded on the port side be x tonnes. Hence, the cargo to be loaded on the starboard side would be (400 - x) tonnes.

	Port	Stbd
ILM	-	447.5
Cargo on port side	5 x	-
Cargo on stbd side	-	6(400 – x)
Total	5 x	447.5 + 6(400 – x)

To finish upright, port LM = stbd LM.

Hence, 5 x = 447.5 + 6(400 – x)
Hence, x = 259 t (port side)
& (400 - x) = 141 t (stbd side).

Example 10

A ship of W 11000 t, KM 7.4 m, and KG 6.0 m is listed 4° to port. A heavy lift weighting 150 t is to be discharged from No 3 LH using the ship's jumbo derrick whose head is 23 m above the keel and whose heel is on the centre line. While in No 3 LH, the COG of the weight is 3 m above the keel and 5 m to port of the centre line. Find the list at each of the following stages:

i) As soon as the derrick picks up the load from the LH.

ii) When the derrick has swung the load 15 m to starboard of the centrte line.

iii) After discharging the weight.

$$\text{Tan } \theta = \frac{dw}{W \cdot GM} \quad \text{or} \quad dw = W \cdot GM \cdot \tan \theta$$

Hence, ILM = 11000 x 1.4 x tan 4° = 1076.9 tm to port

Stage (i)

As soon as the derrick picks up the load, the COG of the weight shifts from LH (KG 3 m) to the derrick head (KG 23 m) i.e., d = 20 m upwards. Since the GM changes, the list would change.

$$GG_1\uparrow = \frac{dw}{W} = \frac{20 \times 150}{11000} = 0.273 \text{ m}$$

Original GM = 1.400 m
$GG_1\uparrow$ = 0.273 m
GM at stage (i) = 1.127 m

$$\text{Tan } \theta = \frac{LM}{W \cdot GM} = \frac{1076.9}{11000 \times 1.127} = 0.08687$$

Hence, θ at stage (i) = 4.96° or 4°58' to port.

Stage (ii)

When the derrick has swung out 15 m to starboard of the centre line, the weight has actually travelled 20 m to starboard because it was originally lying 5 m to port of the centre line.

LM caused = 20 x 150 = 3000.0 tm to stbd
ILM = 1076.9 tm to port
FLM = 1923.1 tm to stbd

$$\text{Tan } \theta = \frac{FLM}{W \cdot GM} = \frac{1923.1}{11000 \times 1.127} = 0.15513$$

Hence, θ at stage (ii) = 8.82° or 8°49' to stbd.

Stage (iii)

As soon as the weight is discharged, the LM, GM and W change, causing the list to change.

Final W = 11000 - 150 = 10850 t

LM caused now	= 15 x 150	= 2250.0 tm	to port.
LM during stage (ii)		= 1923.1 tm	to stbd.
	FLM	= 326.9 tm	to port.

KG of ship at stages (i) & (ii)	=	6.273	m
Height of derrick head above keel	=	23.000	m
	d =	16.727	m

$$GG_1 \downarrow = \frac{dw}{W} = \frac{16.727 \times 150}{10850} = 0.231 \text{ m}$$

GM during stages (i) & (ii)	=	1.127	m
GM during stage (iii)		1.358	m

$$\text{Tan } \theta = \frac{FLM}{W \cdot GM} = \frac{326.9}{10850 \times 1.358} = 0.02219$$

Hence, Final θ = 1.27° or 1°16' to port.

Exercise 11

List

1) On a ship of W 5000 t, GM 0.3 m, 20 t was shifted transversely by 5 m. Find the list.

2) On a ship of W 8000 t, GM 2.0 m, if the following transverse shiftings were done, find the list:

200 t cargo shifted 4 m to stbd
100 t cargo shifted 2 m to port
100 t cargo shifted 4 m to port
50 t stores shifted 20 m to stbd

3) If 200 t of cargo was shifted downwards by 10 m and to starboard by 5 m on a ship of W 10000 t, KG 7.0 m, KM 7.4 m, find the list.

4) A quantity of grain estimated to be 100 t shifts transversely by 12 m and upwards by 1.5 m, on a ship of W 12000 t, GM 1.2 m. Find the list caused.

5) A ship displaces 4950 t and has KG 4.85 m, KM 5.79 m. Cargo weighing 50 t is loaded 1.25 m above the keel and 4 m to port of the centre line. Find the list.

6) A weight of 100 t is discharged from a position 2.45 m above the keel and 6 m to port of the centre line of a ship of W 10000 t, KM 8.25 m, KG 7.45 m. Find the list.

7) A ship of 10000 t displacement, KG 8.3 m carries out the following cargo operations:

Qty. (t)	Loaded or discharged	KG (m)	Distance off centre line
200	D	10.0	5 m port
800	D	2.3	4 m stbd
500	D	5.2	3 m port
250	L	8.0	nil
250	L	12.0	nil

If the final KM is 9.6 m, find the list.

8) A ship of W 9000 t, KG 8.3 m loads 600 t of cargo (KG 4.0 m, 3 m to port of the centre line) and discharges 400 t of cargo (KG 9.0 m, from 5 m to port of the centre line). 200 t of cargo is then shifted upwards by 5 m and to starboard by 8 m. 300 t of cargo is then is then shifted 1 m downwards and 4 m port. Find the list if the final KM is 8.95 m.

9) A ship of W 18000 t, KG 7.75 m, discharges 1500 t (6.0 m above the keel and 3 m port of the centre line) and loads 500 t (10 m above the keel and 4 m port of the centre line). Cargo was then shifted as follows:

500 t upwards 2 m and to starboard 4 m

800 t downwards 2 m and to port 3 m.

If the final KM is 8.935 m, find the list.

10) A ship listed 8° to port, displaces 12000 t and has KM 7.54 m and KG 6.8 m. Find how many tonnes of SW ballast must be transferred from No 2 port DB tank to No 2 stbd DB tank, to upright in vessel, if the tank-centres are 10 m apart.

11) A ship displacing 4000 t has GM 1.0 m (KM 10.0 m & KG 9.0 m) and is listed 10° to port. If 16000 t of cargo is now loaded on the centre line and the final GM is 1.0 m (KM 9.0 m & KG 8.0 m), state whether the list would change. If yes, find the new list.

12) A ship of W 10000 t, GM 1.5 m , is listed 5° to stbd. If cargo is shifted vertically until her final GM is 0.5 m, state whether the list would change. If yes, find the new list.

13) A ship of W 8500 t, KM 9.0 m, KG 8.3 m, is listed $8\frac{1}{2}$° to stbd. The following cargo operations were carried out:

200 t discharged KG 4 m from 5 m stbd of CL.

300 t discharged KG 5 m from 2 m port of CL.

100 t loaded KG 2 m, 4 m to stbd of CL.

200 t shifted up by 2 m and port by 3 m.

If the final KM is 9.3 m, find the final list.

14) A ship of 15000 t displacement, KG 8.7 m, KM 9.5 m, is listed 10° to port. The following cargo work was carried out:

500 t loaded, KG 8.0 m, 5 m stbd of CL.

300 t discharged, KG 4.0 m, 4 port of CL.

Find the quantity of SW ballast that must be transferred transversely to bring the vessel upright, the tank centres being 12 m apart.

(Note: Since vessel is required upright, it is not necessary to calculate the final KG or GM unless specifically asked).

15) A bulk carrier presently of 12250 t, KM 9.8 m, KG 9.0 m has a list of $6\frac{1}{2}$° to starboard. She then loads 1250 t of ore (KG 8 m, 2 m to stbd of centre line) and discharges 250 t of ore (KG 2 m, 5 m from starboard of centre line). 160 t of SW ballast is then transferred from the stbd shoulder tank to the port DB tank (vertically downwards by 9 m and transversely by 10 m). Find the final list, assuming that there are no slack tanks, given that the final KM is 9.6 m.

16) From a ship of W 8000 t, KM 8.6 m, KG 8.0 m, some deck cargo was washed overboard (KG 10 m, 8 m from the centre line). If the resultant list is 3°, find the quantity of cargo lost.

17) A ship of W 16000 t, KM 7.5 m, KG 6.0 m, TPC 25, is listed 3° to port. Her present mean draft is 8.6 m and she is to finish loading at 8.8 m mean draft. Space is available 5 m off the centre line, on either

side. State how much cargo must be stowed on either side to finish upright.

18) A ship displacing 12000 t has KM 9.0 m, KG 7.25 m. A 200 t heavy-lift is to be loaded by ship's jumbo whose head is 24 m above the keel.

Find (i) The list as soon as the derrick picks up the weight from the wharf on the stbd side with an outreach of 15 m.

(ii) The list when the weight is placed on the upper deck KG 10 m, 7 m to stbd of the centre line.

19) A ship of W 10000 t, KM 7.3 m, KG 6.8 m, is listed 5° to port. A heavy-lift weighing 100 t, lying 6 m to port of the centre line and KG 10.0 m, is to be shifted to the lower hold KG 2.0 m on the centre line of the ship, by the ship's jumbo derrick whose head is 28 m above the keel.

Find (i) The list as soon as the derrick takes the load.

(ii) The list when the derrick swings the load to the centre line.

(iii) The list after the shifting is over.

20) A ship of W 13000 t, KM 8.75 m, KG 8.0 m, has a list of 6° to starboard. A heavy-lift weighing 150 t, lying on the upper deck 9 m above the keel and 5 m to stbd of the centre line, is to be discharged using the ship's jumbo derrick whose head is 22 m above the keel. Calculate

(i) The list as soon as the load is taken by the derrick.

(ii) When the load is hanging over the port side of the ship with an outreach of 10 m from the centre line.

(iii) After discharging the heavy-lift.

21) A ship of 10000 t displacement is floating in SW and has KM of 10.8 m and KG of 9.0 m. She is listing 10° to stbd. She has two rectangular deep tanks, one on either side, each 12 m long, 12 m wide and 9 m deep. The stbd tank is full of FW while the port one is empty. If FW is to be transferred from the stbd tank to the port one, find

(i) the quantity of FW to transfer to bring the ship upright.

(ii) the list if one third of the original FW in the stbd tank is transferred to the port tank.

Note: Fluid GM should be used here.

22) On a ship 8000 t displacement, 50 t is shifted transversely by 4 m. Find the list if the total FSM is 1216 tm, KM 7.0 m, KG 6.4 m.

23) A ship has W 10000 t, KM 7.8 m, KG 7.075 m, and is upright. No 3 port and stbd DB tanks are full of HFO RD 0.95. Each tank is rectangular, 15 m long, 12 m wide and 2 m deep. Calculate the list when HFO is consumed from No 3 stbd until the sounding is 1.2 m.

24) A vessel displacing 9000 t has KM 8.02 m, KG 7.5 m, and is upright. She loads 250 t KG 12 m, 3 m to stbd of the centre line; loads 1000 t KG 3 m, 1 m to port of the centre line; discharges 250 t KG 8 m, 2 m to stbd of the centre line. 100 t of cargo is then shifted

transversely 3 m to stbd. If the total FSM is 1200 tm, calculate the final list.

25) A ship of 14000 t displacement, KM 9.0 m, KG 7.8 m, has a total FSM of 2100 tm and is listed 8° to port. How many tonnes must be shifted transversely by 10 m to upright the ship?

14

Stiff And Tender Vessels

	STIFF VESSEL	TENDER VESSEL
1	A stiff vessel is one with an unduly large GM for her type, size and nature.	A tender vessel is one with a small GM for her type, size and nature.

Note: Type refers to general cargo, bulker, tanker, etc., while nature refers to peculiarities of the vessel.

2	Angle and period of roll is small.	Angle and period of roll is large.
3	Rolling is violent and irregular.	Rolling is smooth and regular.
4	Uncomfortable for people on board because of jerky movements.	Less uncomfortable for people on board as movements are regular.
5	Severe stresses set up on hull.	Less severe stresses set up on hull.
6	General cargo likely to break loose due to jerky movements.	General cargo, once secured properly, is less likely to break loose.

7	Bulk cargo less likely to shift as angle of roll is small.	Bulk cargo more likely to shift as angle of roll is large.
8	No likelihood of vessel becoming unstable during passage owing to consumption of fuel and fresh water from DB tanks and also due to FSE of tanks in use.	Likelihood of vessel becoming unstable during passage owing to consumption of fuel and fresh water from DB tanks and also due to FSE of tanks in use.
9	Greater ability to withstand loss of GM, if any, caused by bilging.	Less ability to withstand such loss of GM.

Note: Bilging is the flooding of a compartment, as a result of damage, whereby water has free access to come in and go out.

10	Greater ability to withstand transverse shift of cargo — list caused by such shift is small.	Less ability to withstand transverse shift or cargo — list caused by such shift is large.

Note: As explained in the previous chapter,

$$\text{Tan } \theta = \frac{dw}{W \cdot GM}$$

It is obvious from the foregoing formula that the list caused varies inversely as the GM fluid. Considering identical circumstances, the list resulting from transverse shift of cargo will be less if the vessel is stiff and much more if the vessel is tender.

15

STABILITY OF VESSELS WITH DECK CARGO OF TIMBER

A vessel with a considerable quantity of timber as deck cargo is likely to be tender at the commencement of the voyage itself, owing to such weight loaded so high up on the ship.

On passage, the GM will decrease further owing to the following reasons:-

1) Consumption of fuel oil and fresh water from double bottom tanks.
2) Free surface effect of tanks in use.
3) Absorption of water by the timber on deck. This depends on:
   a) Type of wood — teak, oak, pine, etc.
   b) Nature of timber — logs, blocks, planks, boards etc., — the greater the surface area exposed, the greater the absorption.
   c) Age of timber — new timber would contain sap and hence not absorb much water whereas old timber would be dry and can absorb more.
   d) The amount of precipitation and spray experienced. In the case of spray, the absorption may be asymmetrical — more on windward side than on leeward side.

In view of the foregoing points, the amount of water absorbed is variable and though it can be as high as thirty percent of the weight of timber, it is generally around ten to fifteen percent or so. This is equivalent to adding weight on deck, thereby causing a rise of the centre of gravity of the ship.

A vessel with a deck cargo of timber, therefore, becomes less and less stable, possibly unstable, during the passage. It may not be possible to increase the metacentric height before departure from the port, owing to lack of deadweight available — the vessel may already be down to her loadline.

In order to keep the vessel stable at all times, the following precautions should be taken:-

i) Plan cargo stowage in lower holds and tween decks in such a manner as to have as large a metacentric height as possible.

ii) Ensure that the number of slack tanks is kept to minimum and also restricted to those tanks with minimum moment of inerta about the tank's centreline.

iii) During the passage, use fuel oil and fresh water first from the slack tanks until they are completely empty.

iv) During the passage, fill up adequate ballast tanks, one at a time, those with smallest 'i' first, as and when the fuel oil and fresh water tanks get empty, ensuring that the vessel does not get overloaded at any time.

16

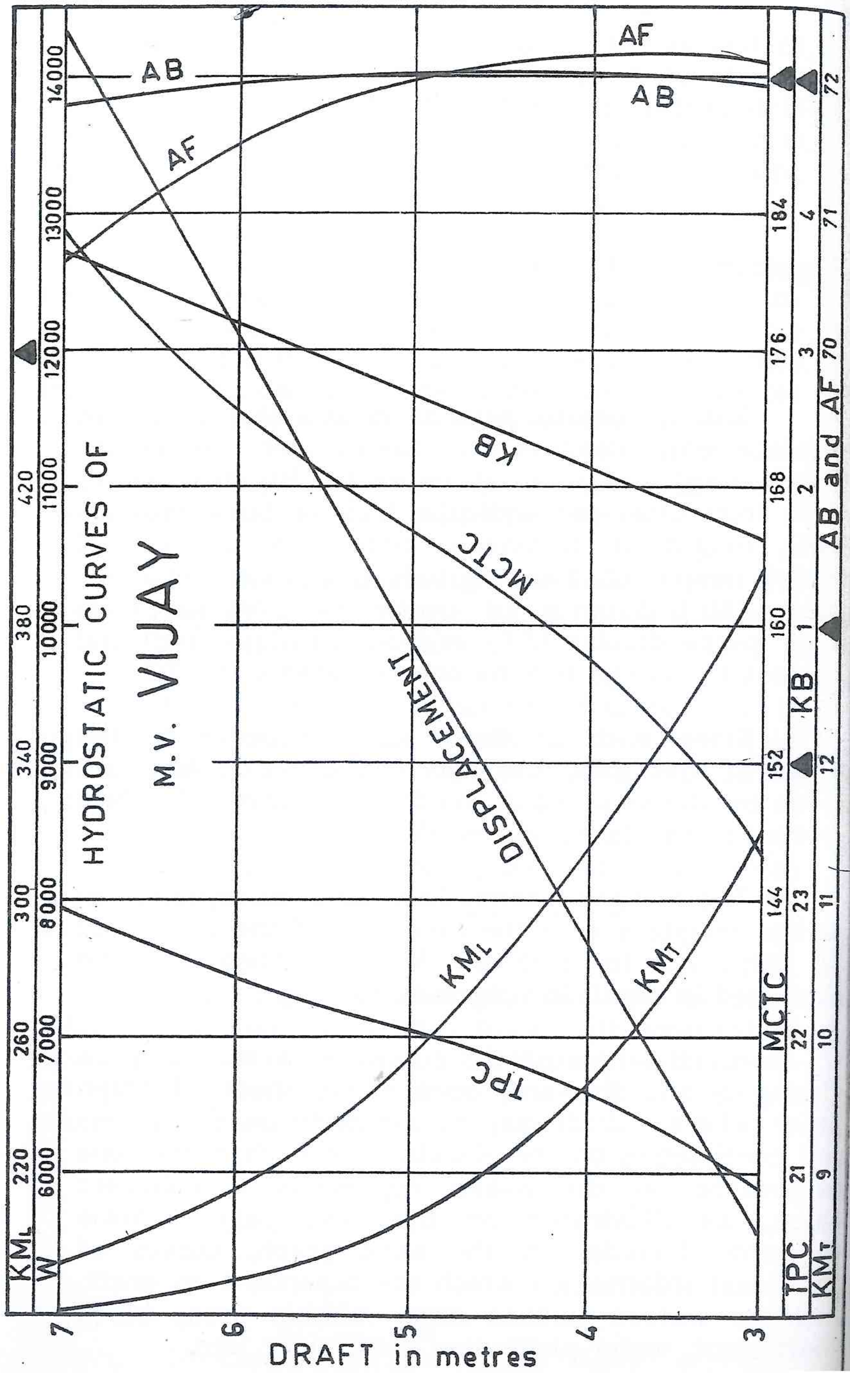
Hydrostatic Curves

The hydrostatic particulars of a ship consist of displacement, deadweight, tonnes per centimetre (TPC), height of COB above keel (KB), distance of COB from after perpendicular (AB) or from midships (HB), height of transverse metacentre above keel (KM_T), height of the longitudinal metacentre above keel (KM_L), distance of centre of flotation from after perpendicular (AF) or from midships (HF) and moment to change trim by one centimetre (MCTC).

Since each of these values depends on the draft of the ship, the hydrostatic particulars are given by the shipyard in the form of curves of tables plotted or tabulated against draft.

The foregoing terms have all been explained in earlier chapters with the exception of the last three — KM_L, AF (or HF) and MCTC. These will be explained in detail in volume II.

All the hydrostatic curves of a ship may be given, by the shipyard, on a single sheet of graph paper wherein draft may be indicated on the Y-axis and centimetres on the X-axis. For each curve, one centimetre on the X-axis represents a different value, as illustrated on the next page. Some shipyards include, on the same graph, curves of additional information which are dependant on draft, such as wetted surface area, midship area, block coefficient, water-plane area coefficient, etc.



In this chapter, the working will be confined to the construction of one curve at a time. Problems based on the hydrostatic particulars as a whole are included in the next chapter.

When constructing graphs, the following notes may be borne in mind:-

i) The scale used should be the largest that will fit on the paper used.

ii) The scale chosen on each axis should be clearly indicated.

iii) The curves may be drawn to scale on ordinary paper. It is not necessary to use graph paper.

iv) The graphs need to be drawn only within the given limits, for example: if the drafts are given between 2 m and 8 m, it is not normally necessary to show drafts less than 2 m or more than 8 m on the graph.

Example 1

Given the following information, construct a displacement curve:

Draft (m)	2	3	4	5	6
Displ (t)	1400	3200	5050	7000	9000

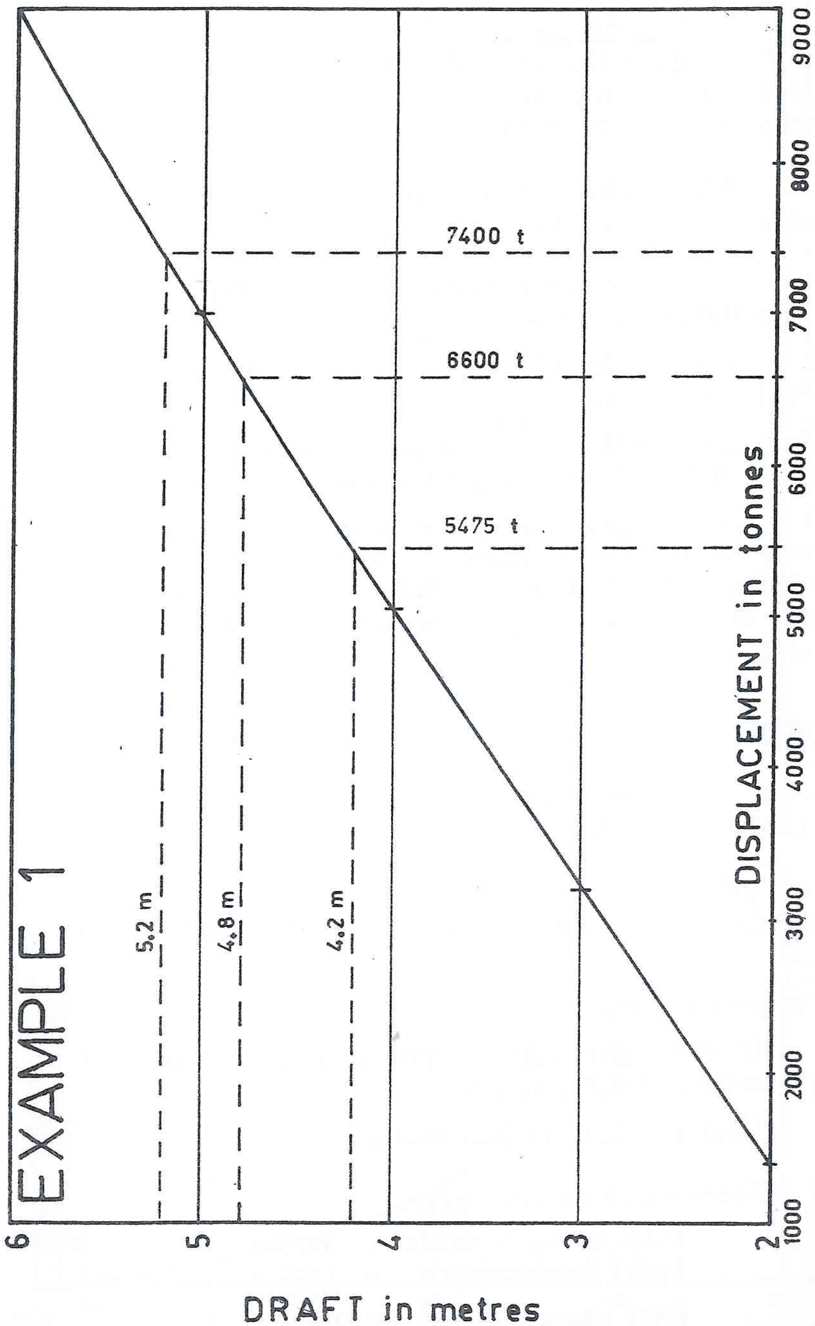
From your curve,

i) If the light displacement is 1300 t, find the DWT aboard at 4.2 m draft.

ii) Find the TPC at 5 m draft.

i) From curve on next page,

Disp. at 4.2 m draft = 5475 t
Light displacement = 1300 t
DWT aboard = 4175 t



ii) Disp. at 5.2 m draft = 7400 t
Disp. at 4.8 m draft = 6600 t

40 cm draft corresponds to 800 t

1 cm draft would mean $\frac{800}{40} = 20$ t

Hence, TPC at 5 m draft = 20

Example 2

Construct a TPC curve from the following information:

Draft	1	2	3	4	5
TPC	3.44	5.81	7.00	7.62	8.00

From your curve, find the area of the water plane at 3.6 m draft in SW.

From graph (next page) TPC at 3.6 m draft = 7.4

$\frac{1.025A}{100} = 7.4$ or $A = \frac{7.4 \times 100}{1.025} = 722 \text{ m}^2$

Hence, area of WP at 3.6 m draft = 722 m^2

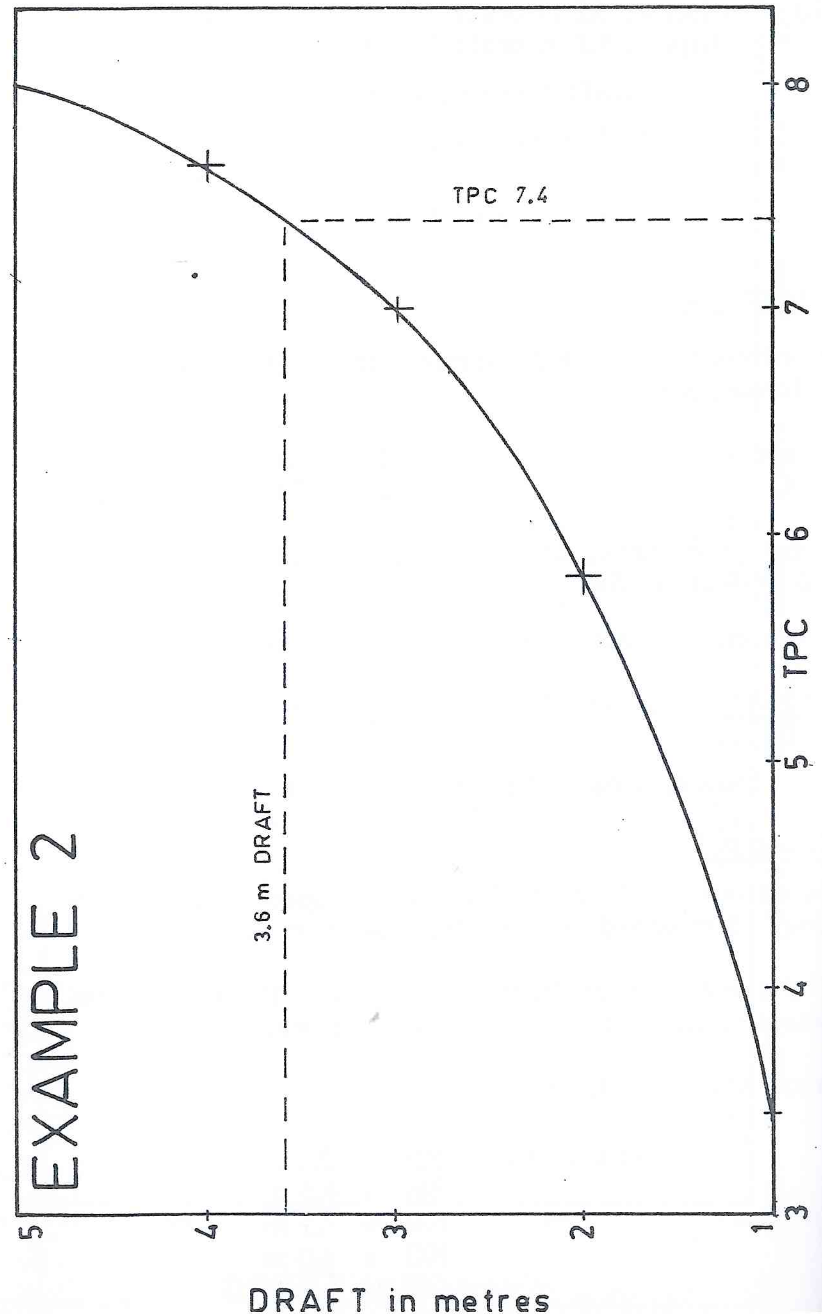
Example 3

Construct a KB curve for a box-shaped vessel 150 m long, 18 m broad between 4 m and 9 m draft.

If the BM at 6 m draft is 4.5 m, and the KG of the vessel is 6.0 m, find the GM at that draft.

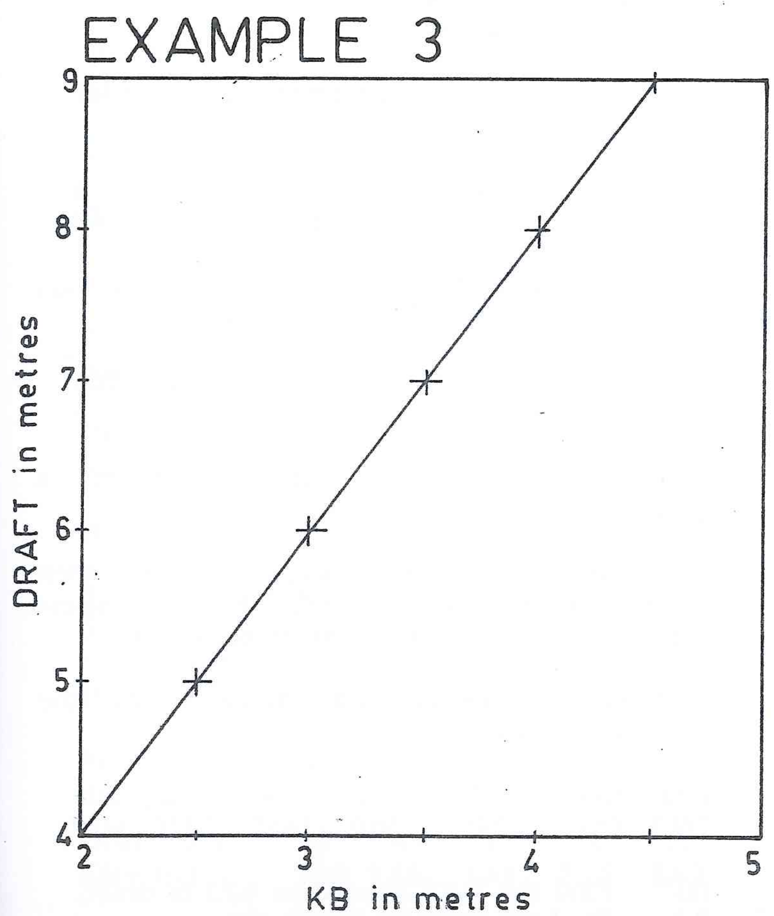
Since KB = $\frac{1}{2}$ draft,

At 6 m draft KB = 3.0 m
BM = 4.5 m
KM = 7.5 m
KG = 6.0 m
GM = 1.5 m



To construct graph

Draft	KB
4 m	2.0 m
5	2.5
6	3.0
7	3.5
8	4.0
9	4.5



Exercise 12

Hydrostatic curves

1 Construct a displacement curve from the following information:-

Draft (m)	1	1.5	2	2.5	3
Disp (t)	330	1020	1950	2930	3850

From your graph, find:

(a) TPC at 2 m draft.
(b) The draft when disp is 3000 t.

2 Given the following information, construct a displacement curve:-

Draft (m)	4	5	6	7	8
Disp (t)	7600	9800	12000	14300	16600

If the present draft is 5.4 m, and the load draft is 7.8 m, find the DWT available.

3

Disp (t)	770	1270	1800	2400	3100
Draft (m)	1	2	3	4	5

Using the foregoing data, construct a displacement curve.

If on arrival, the draft was 1.8 m and then 2000 t of cargo was loaded, 200 t of ballast was pumped out, find the draft on sailing.

4 Construct a deadweight curve, from the following data:-

Draft (m)	2	3	4	5	6
DWT (t)	360	980	1680	2770	4080

(a) Find the DWT aboard at 4.75 m draft.
(b) Find the TPC at 4 m draft.

(c) If the light displacement is 376 t, find the displacement at 5.4 m draft.

5 Construct a TPC curve from the following:-

Draft (m)	2	3	4	5	6	7
TPC	20.90	21.62	22.08	22.47	22.95	23.54

From your curve, find the TPC at 6.6 m draft and at 3.3 m draft.

6 The following is taken from a ship's hydrostatic particulars:-

Draft (m)	1	2	3	4	5	6
TPC	58.90	62.30	63.0	64.60	65.32	65.86

(a) Find the area of the waterplane at 4.2 m draft.
(b) At 4 m draft, the vessel loads 325 t of cargo. Find the new draft.

7 From the following information, construct a KB curve:-

Draft (m)	1	2	3	4
KB (m)	0.667	1.333	2.0	2.667

If at 2.4 m draft the BM is 2.5 m, find the KM.

8 Construct a KB curve for a box-shaped vessel 50 m long and 12 m wide between the drafts of 1 m and 5 m.
If at 4 m draft the BM is 3 m, find the KM.

9 From the following information, construct a KM_T curve:-

Draft (m)	2	4	6	8	10
KM_T (m)	16.0	9.86	8.44	8.25	8.62

From your graph,

(a) Find the minimum value of KM_T and the draft at which it occurs.

(b) If the KG is 6.3 m, find the GM at 5.6 m draft.

10 The following is taken from the hydrostatic particulars of a ship:-

Draft (m)	2	3	4	5	6	8	10
KM_L (m)	560	391	303	248	211	174	156

If the KG is 8 m, find the GM_L at 7 m draft.

17

HYDROSTATIC TABLES

As mentioned in the previous chapter, the hydrostatic particulars of a ship may be given in the form of curves or tables plotted or tabulated against draft. Appendix I at the end of the book is the hydrostatic table of an imaginary general cargo ship m.v. 'VIJAY'. The use of the hydrostatic table can be understood properly by going through the following worked examples:

Example 1

Find the hydrostatic particulars of m.v. 'VIJAY' at a draft of 5.1 m in SW.

This is obtained by direct linear interpolation between the tabulated values against the drafts of 5.0 m and 5.2 m.

Required draft	5.100 m
Next below as per table	5.000 m
Difference from next below	.100 m
Tabulated interval	.200 m
Interpolation ratio	$\frac{.1}{.2} = 0.5$

	Draft	W	TPC	MCTC
Next below	5.0	9891	22.06	165.7
Next above	5.2	10333	22.14	167.1

	Draft	W	TPC	MCTC
Tabular difference	.2	442	.08	1.4
Interpolation ratio	x.5	x.5	x.5	x.5
Diff. from top line	.1	221	.04	.7
Top line	5.0	9891	22.06	165.7
Required values	5.1	10112	22.10	166.4

	Draft	AB	AF	KB	KM_T	KM_L
Next below	5.0	72.014	71.913	2.685	8.686	254.3
Next above	5.2	72.011	71.842	2.789	8.566	245.4
Tab. diff.	.2	.003	.071	.104	.120	8.9
Int. ratio	x.5	x.5	x.5	x.5	x.5	x.5
Difference	.1	.002	.036	.052	.060	4.5
Top line	5.0	72.014	71.913	2.685	8.686	254.3
Reqd. values	5.1	72.012	71.877	2.737	8.626	249.8

Note 1: W and KM_L may be worked to one decimal place and the others to three decimal places.

Note 2: In actual practice, the interpolation need not be shown so elaborately. Such interpolation may be done mentally, or in rough, or by a calculator and only the results shown.

Example 2

Find the hydrostatic particulars of m.v. 'VIJAY' at a displacement of 11762 t in SW.

This is obtained by direct linear interpolation between the tabulated values against the SW displacements just below and just abcve the given SW displacement.

Required displacement	11762 t
Next below as per table	11672 t
Difference from next below	90 t
Tabulated interval	450 t

Interpolation ratio = $\frac{90}{450}$ = 0.2

	W	Draft	TPC	MCTC
Next below	11672	5.8	22.37	171.3
Next above	12122	6.0	22.45	172.9
Tabular difference	450	0.2	.08	1.6
Interpolation ratio	x.2	x.2	x.2	x.2
Diff. from top line	90	.04	.016	.32
Top line	11672	5.80	22.370	171.3
Required values	11762	5.84	22.386	171.6

	W	AB	AF	KB	KM_T	KM_L
Next below	11672	71.977	71.586	3.102	8.298	223.0
Next above	12122	71.960	71.472	3.205	8.234	217.2
Tab. diff.	450	.017	.114	.103	.064	5.8
Int. ratio	x.2	x.2	x.2	x.2	x.2	x.2
Difference	90	.003	.023	.021	.013	1.2
Top line	11672	71.977	71.586	3.102	8.298	223.0
Reqd.values	11762	71.974	71.563	3.123	8.285	221.8

See notes at the end of example 1.

Example 3

Find the displacement of m.v. 'VIJAY' when floating at a draft of 6.4 m in DW of RD 1.015.

At 6.4 m draft in SW, W = 13030 t.

(This was obtained from the hydrostatic tables).

At 6.4 m draft in SW, u/w volume = $\frac{13030}{1.025}$ m^3

Hence, u/w volume of ship at 6.4 m draft in any water $= \dfrac{13030}{1.025}$ m^3

At 6.4 m draft in DW RD 1.015,

$$W = \frac{13030}{1.025} \times 1.015 = 12902.9 \text{ t}$$

Example 4

Find the draft of m.v. 'VIJAY' in DW of RD 1.010, at a displacement of 10650 tonnes.

Three methods of working this out are shown. The first one is more tedious but is very easy to understand. The second method is quicker to do, once the reasoning is understood. The third method is applicable only in this case, where displacement is given, and is hence not recommended for general use.

Alternative 1

Draft m	W in SW t	u/w vol m^3	W in DW of RD 1.010 t
5.2	10333	$\frac{10333}{1.025}$	$\frac{10333}{1.025} \times 1.010 = 10181.8$
5.4	10777	$\frac{10777}{1.025}$	$\frac{10777}{1.025} \times 1.010 = 10619.3$
5.6	11223	$\frac{11223}{1.025}$	$\frac{11223}{1.025} \times 1.010 = 11058.8$

The first two columns are taken from the hydrostatic table, while the next two are computed.

Interpolation is done between the first and last columns for the desired W of 10650 t in DW as shown on the next page:

W in DW t	Draft m	
10619.3	5.4	
11058.8	5.6	
10650	5.414	answer

Alternative 2

The underwater volume of a ship for a given draft is constant.

So at any draft,

$$\frac{W \text{ in SW}}{1.025} \times \text{density of DW} = W \text{ in DW (at same draft)}$$

OR

$$W \text{ in SW} = \frac{W \text{ in DW} \times 1.025}{\text{density of DW}} \quad \text{(at same draft)}$$

In this case,

$$W \text{ at same draft in SW} = \frac{10650 \times 1.025}{1.010} = 10808.2 \text{ t}$$

Using the first two columns of the hydrostatic table, interpolate for W of 10808.2 t, as shown below:

W in SW t	Draft m	
10777	5.4	
11223	5.6	
10808.8	5.414	answer

Alternative 3

Entering the hydrostatic table with W of 10650 t, the draft and TPC, both for SW, can be obtained:

W	Draft (SW)	TPC (SW)
10333	5.2	22.14
10777	5.4	22.22
10650	5.343	22.197

FWA at 5.343 m SW draft $= \frac{W}{40\,TPC}$

$= \frac{10650}{40 \times 22.197}$

$=$ 12 cm

DWA at 5.343 m SW draft $= \frac{(1.025 - 1.010)}{.025} \times 12$

$=$ 7.2 cm $=$ .072 m

SW draft for W 10650 t $=$ 5.343 m

DWA $=$ .072 m

DW draft for W 10650 t $=$ 5.415 m

Note: This method can be used only where W is given and draft in DW or FW is to be calculated. It cannot be used to find W accurately, given draft in DW or FW. This method is, therefore, not recommended for general use.

Example 5

Find the hydrostatic particulars of m.v. 'VIJAY' at 6.8 m draft in DW of RD 1.015.

From the hydrostatic table,

Draft	W in SW	TPC	MCTC	AB	AF	KB	KM_T	KM_L

AB, AF, KB, KM_T and KM_L are functions of the ship's underwater volume and shape and are hence dependant on the draft only, not on the density of water displaced. Their values tabulated against draft hold good in any water, whether SW, FW or DW, for that draft.

However, W, TPC, and MCTC are functions of the draft and the density of water displaced. A correction would have to be applied, for the density of DW, to the tabulated values which are for SW.

Note: A simple thumb rule for quick thinking would be that, among all the hydrostatic particulars tabulated against draft, those given in metres hold good for that draft in water of any density whereas those given in other units (t, t cm^{-1}, tm cm^{-1}) are for SW and need correction for DW or FW.

As explained in detail in example 4, at any draft,

W in DW $= \frac{\text{W in SW} \times \text{density of DW}}{1025}$ (at same draft)

At 6.8 m draft in DW, W $= \frac{13943 \times 1.015}{1.025} =$ 13807 t

The same correction for DW density must be applied to the tabulated TPC and MCTC.

At 6.8 m draft in DW, TPC $= \frac{22.83 \times 1.015}{1.025}$

$=$ 22.607 t cm^{-1}

At 6.8 m draft in DW, MCTC $= \frac{180.3 \times 1.015}{1.025}$

$=$ 178.541 tm cm^{-1}

Example 6

Find the hydrostatic particulars of m.v. 'VIJAY' at 12122 t displacement in FW.

As explained in detail in example 4,

$$W \text{ in SW} = \frac{W \text{ in DW} \times 1.025}{\text{density of DW}} \quad \text{(at same draft)}$$

$$= \frac{12122 \times 1.025}{1} = 12425 \text{ t}$$

Whereas she is displacing 12122 t of FW, she would displace 12425 t of SW at the same draft. The draft and the hydrostatic particulars may be interpolated for 12425 t of W in SW and the results obtained in two lots — the first lot requiring correction for density; the second lot being correct as it is.

$$\text{At any draft, W in FW} = \frac{\text{W in SW} \times 1}{1.025}$$

Hence, to convert SW W, TPC and MCTC to FW divide each by 1.025.

From hydrostatic table

	W	Draft	TPC	MCTC
In SW	12122	6.0	22.45	172.9
In SW	12575	6.2	22.54	174.6
In SW	12425	6.134	22.510	174.03
Corrn.	÷ 1.025		÷ 1.025	÷ 1.025
In FW	12122	6.134	21.961	169.79

From hydrostatic table,

Draft	AB	AF	KB	KM_T	KM_L
6.0	71.960	71.472	3.205	8.234	217.2
6.2	71.939	71.329	3.309	8.180	211.6
6.134	71.946	71.376	3.275	8.198	213.4

These particulars, AB, AF, KB, KM_T and KM_L, hold good at 6.134 m draft in water of any density.

Example 7

M.V. 'VIJAY', floating at 3.8 m draft in SW, loads 3640 t of cargo and pumps out 810 t of ballast. Find her new draft.

From hydrostatic table, at 3.8 m draft W	=	7277t
Cargo loaded	=	3640t
		10917t
Ballast out	=	810t
New W	=	10107t

Interpolating from hydrostatic table for W 10107t,

W	Draft
9891	5.0
10333	5.2
10107	5.098 m

Example 8

Initial SW draft of m.v. 'VIJAY' was 5.4 m and the final SW draft was 4.7 m. Meanwhile 2000 t of ballast was pumped out. Find the amount of cargo worked.

From hydrostatic table, W at 5.4 m draft	=	10777 t
Ballast out	=	2000 t
W before cargo work	=	8777 t
From hydrostatic table, W at 4.7 m draft	=	9232 t
Hence, cargo loaded	=	455 t

Note Though cargo work and deballasting may have been done simultaneously, it is easier to work it out as if the known quantity was handled first.

Example 9

M.V. 'VIJAY' arrives with a draft of 6.2 m in DW of RD 1.012. She is expected to load 2800 t of cargo and discharge 1098 t. Compute her departure draft in (i) DW (ii) SW.

At 6 .2 m draft, W in DW $= \dfrac{\text{W in SW} \times 1.012}{1.025}$

$= \dfrac{12575 \times 1.012}{1.025}$

$= 12415.5$ t

Hence arrival W	=	12415.5 t +
Cargo loaded	=	2800.0 t
		15215.5 t −
Cargo discharged	=	1098.0 t
Departure W.	=	14117.5 t

From hydrostatic table,

W	Draft in SW
13943 t	6.8 m
14402 t	7.0 m
14117.5 t	6.876 m

Hence, SW draft on departure = 6.876 m = answer (ii)

To find the DW draft on departure, using hydrostatic table meant for SW, work as shown in example 4.

If draft is constant, u/w vol of a ship is also constant.

$$\frac{\text{W in SW}}{1.025} = \frac{\text{W in DW}}{\text{DW density}}$$

Hence, at same draft, W in SW $= \dfrac{14117.5 \times 1.025}{1.012}$

$= 14298.9$ t

If ship is displacing 14117.5 t of DW, she would displace 14298.9 t of SW, at same draft. So entering the hydrostatic table with 14298.9 t, the draft can be obtained. This is the draft in DW at 14117.5 t W.

W	Draft
13943 t	6.8 m
14402 t	7.0 m
14298.9 t	6.955 m

Hence departure draft in DW = 6.955 m answer (i)
in SW = 6.876 m answer (ii)

Example 10

On arrival port, m.v. 'VIJAY' had a draft of 6.6 m when RD was 1.010. On departure the draft and RD were 5.4 m and 1.020. Find the amount of cargo worked.

Arrival W $= \dfrac{13486 \times 1.010}{1.025} = 13288.6$ t

Departure W $= \dfrac{10777 \times 1.020}{1.025} = 10724.4$ t

Hence, cargo worked in port: discharged 2564.2 t

Exercise 13
Hydrostatic table

1. Find the hydrostatic particulars of m.v. 'VIJAY' at 4.72 m draft in SW.

2. Find the hydrostatic particulars of m.v. 'VIJAY' at a displacement of 7990 t in SW.

3. If the draft of m.v. 'VIJAY' is 5.0 m in DW of RD 1.005, find the displacement.

4 Find the displacement when m.v. 'VIJAY' is at 5.63 m draft in water of RD 1.017.

5 Find the DW draft of m.v. 'VIJAY' when her displacement is 12650 t, if RD of DW is 1.009.

6 At 10,000 t displacement, find the draft of m.v. 'VIJAY' in DW of RD 1.020.

7 Find the hydrostatic particulars of m.v. 'VIJAY' at 5.0 m draft in DW of RD 1.015.

8 State the hydrostatic particulars of m.v. 'VIJAY' in FW at a draft of 6.1 m.

9 Calculate the hydrostatic particulars of m.v. 'VIJAY' at 4.7 m draft in DW of RD 1.013.

10 Find the hydrostatic particulars of m.v. 'VIJAY' at 10,000 t displacement in FW.

11 If m.v. 'VIJAY' has a displacement of 8576 t, find her hydrostatic particulars in DW of RD 1.018.

12 M.V. 'VIJAY' has a draft of 5.1 m in SW. She then loads 1800 t of cargo and takes on 400 t of bunkers and FW. Find her new draft.

13 The arrival and departure drafts of m.v. 'VIJAY' were 4.6 m and 5.0 m in SW. In port, 1500 t of bunkers, FW and stores were received. Find the amount of cargo worked. State whether the cargo was loaded or discharged.

14 M.V.'VIJAY' at 4.0 m draft in SW loads 5000 t of cargo and pumps out 800 t of ballast. Find her final draft.

15 Initial draft of m.v. 'VIJAY' in DW of RD 1.010

is 5.3 m. She then loads 2500 t of cargo. Find her final draft (i) in the same dock. (ii) in SW.

16 M.V. 'VIJAY' is floating in DW of RD 1.017 at a draft of 5.6 m. How much cargo can be loaded so that her draft will be 6.4 m in SW?

17 M.V. 'VIJAY' arrives outside a river port at a SW draft of 6.0 m. She is to cross a 5.4 m deep bar in the river RD 1.015. Find the minimum cargo to discharge into lighters, so that she may cross the bar with an under-keel clearance of 0.4 m.

18 M.V. 'VIJAY' arrives at the port of Cochin (India) at 4.9 m draft in RD 1.006. On departure the draft was found to be 6.0 m — hydrometer reading 1.018. While in port, 2 heavy lifts weighting 200 t each were discharged. Find the amount of general cargo worked.

19 M.V. 'VIJAY' leaves the port of Bombay at 6.8 m draft in SW, bound for Calcutta. The owners want to know what would be the FW draft on arrival at the Calcutta pilot station. Can you help them out? Steaming time six days, consuming 20 t of fuel and 15 t of FW per day. State also the SW draft on arrival.

20 M.V.'VIJAY' is expected to arrive at a river port at a FW draft not exceeding 6.3 m. She is at present in DW of RD 1.020 at 5.4 m draft. Find the maximum amount of cargo that may be loaded at present, if the steaming time to the river port is eight days, daily consumption of fuel being 14 t and FW 16 t.

HYDROSTATIC DRAFT

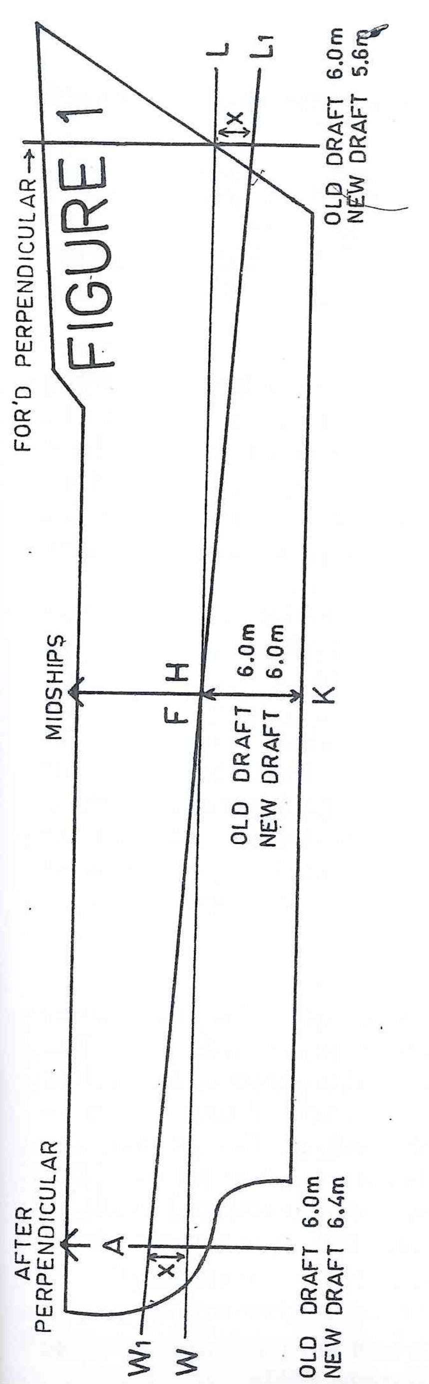
The hydrostatic particulars of a ship are indicated against hydrostatic draft which is the true draft of the ship. Hydrostatic draft may be a little different from the midship's draft (which is the arithmetical mean of the drafts for'd and aft) when the ship is not on an even keel.

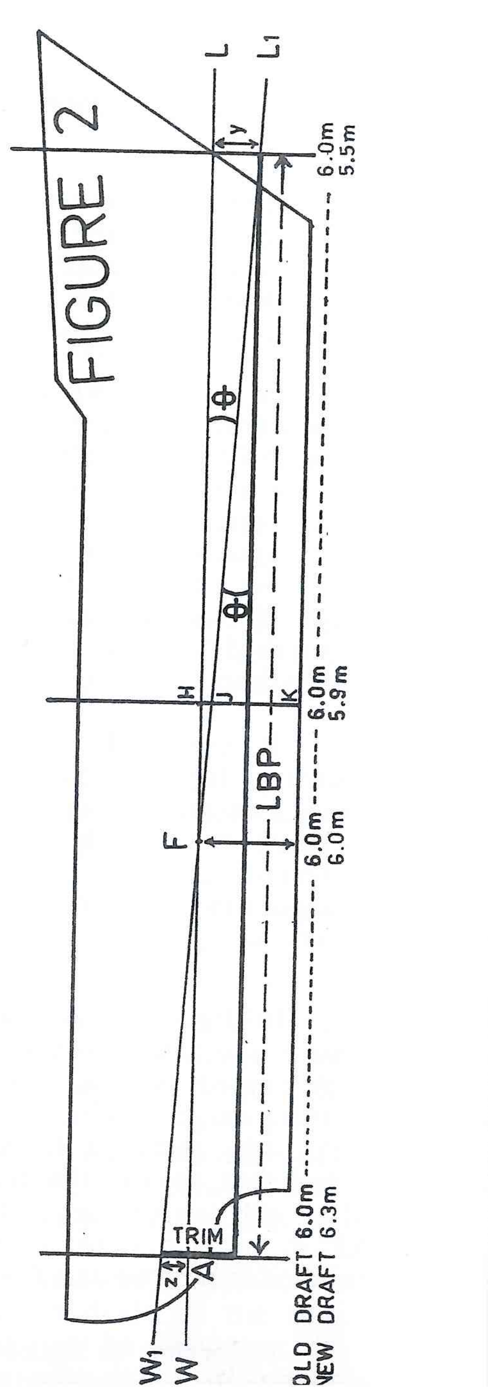
The hydrostatic draft of a ship is the draft measured at the centre of flotation (COF).

COF is the geometric centre of the waterplane area of the ship and it is the point about which she would pivot, when her trim is changed. The position of COF is indicated by its distance forward of the after perpendicular of the ship (AF) or by its distance forward or abaft midships (HF). AF (or HF, as the case maybe) depends on the hydrostatic draft of the ship and its values are indicated against it in the hydrostatic particulars.

The meaning of hydrostatic draft is further explained as follows:

Imagine a ship floating at an even keel draft of 6.0 m. This means that her draft at the forward perpendicular is 6.0 m and at the after perpendicular is 6.0 m. Her mean draft (or draft amidships) also it is 6.0 m. If some cargo is now shifted aft, the ship's after draft would increase and her forward draft would decrease — she would trim by the stern.





Trim is the difference between the drafts forward and aft.

If the COF is situated amidships i.e., if F and H were coincident, the ship would pivot about F and the change of drafts at the forward and after perpendiculars would be the same in value but opposite in sign, as shown in figure 1.

In figure 1, WL is the waterline before, & W_1L_1 the waterline after, the shifting of cargo towards aft. Because COF is amidships, the decrease in draft for'd and the increase in draft aft are equal, indicated by x in figure 1. The trim caused would then be 2x. The drafts before and after shifting of cargo are also indicated at the bottom of the figure at the for'd perpendicular, the after perpendicular and amidships (mean draft). When the COF is amidships, mean draft and hydrostatic draft are the same.

If the COF is situated abaft amidships, as shown in figure 2, the change of drafts for'd and aft would not only be opposite in sign (decrease for'd & increase aft in this case) but would also be of different values — greater change for'd and smaller change aft — indicated by y & z respectively in figure 2.

In figure 2, WL & W_1L_1 are the waterlines before and after shifting of cargo towards aft. The trim caused is y+z. The drafts before and after shifting cargo are indicated at each of four points — for'd, aft, midships (mean) and at F. It may be noted that before, the drafts were 6.0 m all over but after shifting of cargo, the mean (midships) draft in 5.9 m in this case whereas the hydrostatic draft remains unaltered at 6.0 m.

Referring to figure 2 and omitting any specific
...le, in right angled triangle FHJ

$$\frac{HJ}{HF} = \text{Tan } \theta$$

But Tan θ also $= \frac{Trim}{LBP}$

So $\frac{HJ}{HF} = \frac{Trim}{LBP}$ or $HJ = \frac{HF \times Trim}{LBP}$

Hence, correction to apply to mean draft to obtain hydrostatic draft $= \frac{HF \times Trim}{LBP}$

This correction is positive when COF is abaft midships and the vessel is trimmed by the stern.

If the vessel was now trimmed by the head, by shifting cargo forward, the correction to apply to mean draft to obtain hydrostatic draft would be negative as illustrated by figure 3.

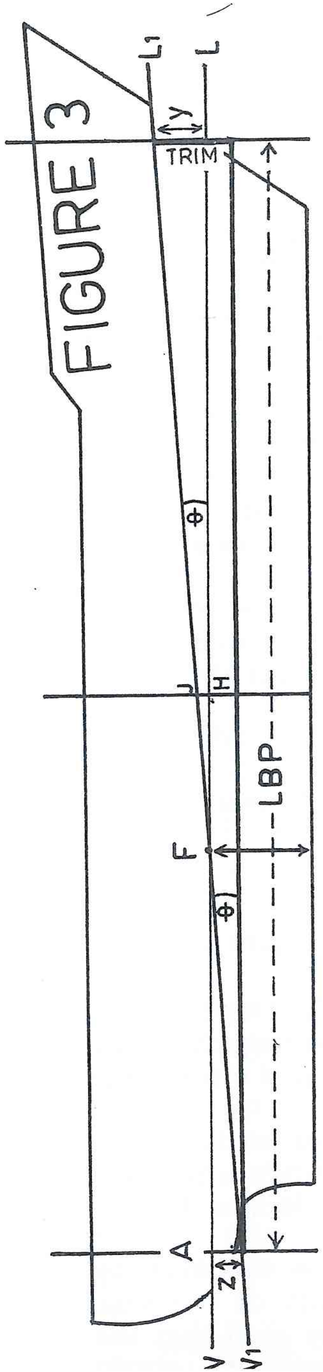
Similar simple illustrations can be made, where F is forward of midships, to show that:

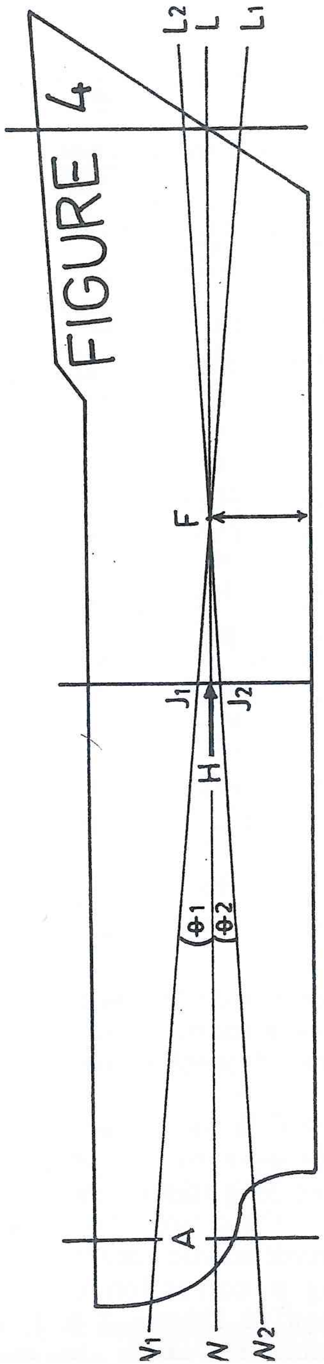
Correction to apply to mean draft to obtain hydrostatic draft $= \frac{HF \times trim}{LBP}$ (See figure 4)

This correction is positive when HF and trim are of same name (both aft or both for'd) and negative when they are of contrary names (one for'd and other aft).

Note: HF is the distance of COF from amidships and is convenient to use if the ship's hydrostatic table indicates longitudinal distances from midships (H).

Hydrostatic draft may also be obtained by applying a correction to the aft draft of the ship. Referring to figures 2 & 3, it may be seen that the correction to apply to the aft draft to obtain





hydrostatic draft is z, to be subtracted when the ship is trimmed by the stern and added when trimmed by the head.

$$\frac{z}{AF} = \frac{Trim}{LBP} \quad \text{(Since both = Tan } \theta\text{)}$$

$$\text{Hence, } z = \frac{AF \times Trim}{LBP}$$

Hence, correction to apply to after draft to obtain hydrostatic draft $= \dfrac{AF \times Trim}{LBP}$

This correction is negative when the vessel is trimmed by the stern and positive when trimmed by the head.

<u>Note</u> AF is the distance of the COF from the after perpendicular of the ship and is convenient to use when the ship's hydrostatic table indicates longitudinal distances from the after perpendicular (A).

<u>Example 1</u>

A ship is floating at a draft of 4.9 m for'd & 6.3 m aft. Her LBP is 120 m. If her COF is 2 m abaft midships (HF 2 m aft or AF 58 m), calculate the hydrostatic draft.

For'd	4.9 m	For'd	4.9 m
Aft	6.3 m	Aft	6.3 m
Mean	5.6 m	Trim	1.4 m by stern

Correction to mean draft $= \dfrac{HF \times Trim}{LBP}$

$= \dfrac{2 \times 1.4}{120}$

$= 0.023$ m

Since HF and trim are of same name (both aft), this correction is positive.

Mean draft	5.600 m
Correction	+0.023 m
Hydrostatic draft	5.623 m answer.

OR

Correction to aft draft $= \frac{AF \times Trim}{LBP}$

$= \frac{58 \times 1.4}{120} = 0.677$ m

Since trim is by stern, this correction is negative.

Aft draft	6.300 m
Correction	-0.677 m
Hydrostatic draft	5.623 m answer.

Example 2

Find the hydrostatic draft given the following particulars: Draft for'd 6.8 m, aft 5.0 m, COF 3 m aft of midships (i.e., HF 3 m aft or AF 60 m), LBP 126 m.

For'd	6.8 m	For'd	6.8 m
Aft	5.0 m	Aft	5.0 m
Mean	5.9 m	Trim	1.8 m by head

Correction to mean draft $= \frac{HF \times Trim}{LBP}$

$= \frac{3 \times 1.8}{126} = 0.043$ m

Since HF and trim are of contrary names, this correction is negative.

Mean draft	5.900 m
Correction	-0.043 m
Hydrostatic draft	5.857 m answer.

OR

Correction to aft draft $= \frac{AF \times Trim}{LBP}$

$= \frac{60 \times 1.8}{126} = 0.857$ m

Since trim is by head, this correction is positive.

Aft draft	5.000 m
Correction	+0.857 m
Hydrostatic draft	5.857 m answer.

Example 3

M.V. 'VIJAY' is floating in SW at 5.0 m for'd and 7.0 m aft. Find her hydrostatic draft, using the hydrostatic table given in Appendix I.

For'd	5.0 m	For'd	5.0 m
Aft	7.0 m	Aft	7.0 m
Mean	6.0 m	Trim	2.0 m by stern

For mean draft of 6.0 m, AF = 71.472 m

Correction to aft draft $= \frac{AF \times Trim}{LBP}$

$= \frac{71.472 \times 2}{140} = 1.021$ m

Since trim is by stern, this correction is negative.

Aft draft	7.000 m
Correction	-1.021 m
Hydrostatic draft	5.979 m answer.

OR

HF in this case is 1.472 m for'd

Correction to mean draft $= \frac{\text{HF x Trim}}{\text{LBP}}$

$= \frac{1.472 \times 2}{140} = 0.021$ m

Since the trim and HF are of contrary names, this correction is negative.

Mean draft	6.000 m
Correction	-0.021 m
Hydrostatic draft	5.979 m answer.

Example 4

Find the hydrostatic draft of m.v. 'VIJAY' when at 4.9 m for'd draft and 5.5 m aft draft in DW of RD 1.010.

For'd	4.9 m	For'd	4.9 m	
Aft	5.5 m	Aft	5.5 m	
Mean	5.2 m	Trim	0.6 m	by stern

From the hydrostatic table, AF is 71.842 m at 5.2 m draft in water of any density.

Corrn to aft draft $= \frac{\text{AF x Trim}}{\text{LBP}}$

$= \frac{71.842 \times 0.6}{140} = 0.308$ m

Since trim is by stern, this correction is negative.

Aft draft	5.500 m
Correction	-0.308 m
Hydrostatic draft	5.192 m answer.

Note : This may also be worked using HF as illustrated in earlier examples.

Exercise 14

Hydrostatic draft

1. Drafts for'd 6.6 m, aft 8.6 m; COF 2 m for'd of midships; LBP 100 m. Find hydrostatic draft.

2. Given the following particulars, find the hydrostatic draft in DW of RD 1.016 : Drafts for'd 4.9 m, aft 4.3 m; HF 3.0 m for'd; LBP 120 m.

3. A vessel is floating in FW at drafts of 8.0 m for'd and 12.0 m aft. If her HF is 2.5 aft and LBP is 200 m, calculate her hydrostatic draft.

4. Drafts for'd 9.6 m, aft 8.2 in SW; COF 1.8 m abaft midships; LBP 180 m. Find hydrostatic draft.

5. A ship is floating in water of RD 1.012 at drafts of 7.2 m for'd and 8.8 m aft. Find her hydrostatic draft if the COF is amidships.

6. A ship of LBP 176 m is floating in FW at a draft of 12.6 m for'd and 12.6 m aft. If her COF is 3 m for'd of midships, find her hydrostatic draft.

7. Drafts in FW, for'd 6.6 m, aft 8.4 m, LBP 200 m; AF 96 m. Find hydrostatic draft.

8. M.V. 'VIJAY' is floating in DW of RD 1.020 at drafts of 4.2 m for'd and 6.0 m aft. Find her hydrostatic draft.

9. M.V. 'VIJAY' is floating in DW of RD 1.015 at drafts of 5.0 m for'd and 7.0 m aft. Find her hydrostatic draft in SW.

NOTE: Find hydrostatic draft in DW and then compute hydrostatic draft in SW.

10 M.V. 'VIJAY' is floating at drafts of 6.2 m for'd and 7.8 m aft in FW. Find her present displacement. If the departure draft in SW is not to exceed 7.0 m state how much cargo she may load.

ANSWERS

Exercise 1

1 1123.2 t **2** 1.158 m **3** 1646.4 t, 0.24 m
4 423.6 t, 0.291 m **5** 1537.5 t **6** 3.398 m, 5136.8 t
7 1.5 m **8** 0.333 m **9** 6428.8 t, 0.41 m
10 8956.3 t, 1.097 m

Exercise 2

1 164 t **2** 47470 t (two sides 15150 t, two ends 2020 t and keel 30300 t) **3** 2000 m **4** 440.4 t towards shallower side. **5** 15.804 m **6** 738 t **7** 145.3 t **8** 6.864 t **9** 50.02 t **10** 8200 t, 4100 t outwards.

Exercise 3

1 25.6 t, 0.8 **2** 0.732 m, 0.75 **3** 1.386 m
4 7.92 t **5** 328 t **6** 0.689 t **7** 102.5 t
8 1.749 t **9** 6 m **10** 2025 t

Exercise 4

1 7380 t, 18081 t, 10701 t **2** 10906 t, 5740 t, 1291.5 t
3 32.8 tcm^{-1}, 32.0 tcm^{-1}, 32.48 tcm^{-1}
4 163.59 t **5** 9092.16 t, 2907.84 t **6** 0.7
7 30% **8** 42.857% **9** 29.268 tcm^{-1}, 29.795 tcm^{-1}
10 788.3 t

Exercise 5

1 8.2 m **2** 12.2 cm rise. **3** 6.4 cm sinkage.
4 8.4 cm rise. **5** 5.0 cm **6** 1.063 m **7** 31.71%
8 2979.5 t **9** 4590 t **10** 320 t **11** 212.2 t
12 152.2 t **13** 397.7 t **14** 620.8 t **15** 427.8 t
16 307.9 t **17** 906 t **18** 640 t **19** 567.2 t
20 309.7 t

Exercise 6

1 6.1 m   2 5.75 m   3 4.11 m   4 6.45 m
5 Decreases by 0.75 m   6 10.8 m   7 450.45 t
8 (a) 7.9 m   (b) 7.45 m   9 (a) 9.358 m   (b) 9.188 m
10 (a) 8.057 m   (b) 8.010 m

Exercise 7

1 3.380 m   2 4.100 m   3 6.109 m   4 4.183 m
5 4.865 m   6 1272.7 t   7 225.8 m
8 (a) 8.475 m   9 (a) 8.191 m   10 (a) 7.120 m
(b) 8.266 m   (b) 7.954 m   (b) 7.053 m

Exercise 8

1 1.6 m   2 3.048 m   3 3.558 m   4 1328.4 t
5 0.082 m   6 0.053 m   7 0.497 m   8 2.487 m
9 KB 2.5 m, AB 28.107 m   10 KB 3.667 m, AB 22.5 m

Exercise 9

1 348.6 tm   2 1200 tm, 7.243 m   3 7.505 m
4 GZ 0.239 m, RM 1912 tm   5 GZ 0.300 m, RM 1200 tm

Exercise 10

1 0.043 m   2 0.050 m   3 0.600 m   4 0.974 m
5 0.054 m   6 0.456 m   7 0.785 m   8 0.386 m
9 0.574 m   10 0.737 m   11 0.810 m
12 0.833 m   13 0.285 m   14 0.458 m   15 1.874 m
16 (a) 0.531 m   (b) (i) 0.133 m   (b) (ii) 0.066 m
(c) (i) 0.059 m   (c) (ii) 0.039 m   (c) (iii) 0.020 m
(d) (i) 0.033 m   (d) (ii) 0.025 m   (d) (iii) 0.017 m
(d) (iv) 0.008 m   17 (a) 0.0107 m   (b) 0.021 m

17 (c) 0.288 m   (d) 0.309 m.   (e) 1.333 m
18 No. 1, No. 3 any one side, No. 3 other side, No. 2 any one side, No. 2 other side, No. 3 centre.
19 No. 4 wing tank on lower side, No. 4 wing tank on higher side, No. 1 DB tank.
20 (a) 537.7 tm   (b) GZ 0.331 m, RM 2648 tm

Exercise 11

1 3.81° or 3° 49′   2 4.29° or 4° 17′ to stbd.
3 9.46° or 9°28′ to stbd.   4 4.81° or 4° 49′
5 2.35° or 2° 21′ to port.   6 4.63° or 4° 38′ to stbd.
7 8.23° or 8° 14′ to port.   8 4.21° or 4° 13′ to stbd.
9 7.04° or 7° 03′ to stbd.   10 124.8 t
11 2.02° or 2°01′ to port.   12 14.71° or 14°42′ to stbd.
13 2.56° or 2°33′ to stbd.   14 132 t from stbd. to port.
15 4.93° or 4°56′ to stbd.   16 31.7 t
17 124.2 t on port side, 375.8 t on stbd side.
18 (i) 9.46° or 9°28′ to stbd.   (ii) 3.85° or 3°51′ to stbd
19 (i) 7.78° or 7°47′ to port.   (ii) 2.91°or 2°55′ to stbd.
(iii) 1.61° or 1°36′ to stbd.
20 (i) 7.48° or 7°29′ to stbd.   (ii) 8.93° or 8°56′ to port.
(iii) 1.61° or 1°36′ to stbd.
21 (i) 264.5 t   (ii) 6.69° or 6°42′ to port.
22 3.19° or 3°12′   23 10.69° or 10°41′ to port.
24 3.43° or 3°26′ to port.   25 206.6 t to stbd.

Exercise 12

1 (a) 19.5 tcm^{-1} (b) 2.55 m   2 5425 t   3 4.85 m
4 (a) 2450 t   (b) 8.75 tcm^{-1} (c) 3616 t
5 23.26 tcm^{-1}, 21.78 tcm^{-1} 6 (a) 6317.1m^2 (b) 4.054 m
7 4.100 m   8 5.000 m   9 (a) 8.2 m at 7.5 m draft.
(b) 2.25 m   10 179 m

Exercise 13

1

Draft	RD	W	TPC	MCTC
4.72	1.025	9275.8	21.938	163.66
AB	AF	KB	KMT	KML
72.016	71.987	2.535	8.894	268.0

2

W	RD	Draft	TPC	MCTC
7990	1.025	4.130	21.665	158.972
AB	AF	KB	KMT	KML
72.011	72.109	2.218	9.495	301.3

3 9698.0 t 4 11202.2 t 5 6.321 m 6 5.071 m

7

Draft	RD	W	TPC	MCTC
5.0	1.015	9794.5	21.845	164.083
AB	AF	KB	KMT	KML
72.014	71.913	2.685	8.686	254.3

8

Draft	RD	W	TPC	MCTC
6.1	1.000	12047.3	21.946	169.512
AB	AF	KB	KMT	KML
71.950	71.401	3.257	8.207	214.4

9

Draft	RD	W	TPC	MCTC
4.7	1.013	9123.9	21.673	161.586
AB	AF	KB	KMT	KML
72.017	71.992	2.525	8.910	269.0

10

W	RD	Draft	TPC	MCTC
10000	1.000	5.162	21.585	162.765
AB	AF	KB	KMT	KML
72.012	71.855	2.769	8.589	247.1

11

W	RD	Draft	TPC	MCTC
8576	1.018	4.427	21.663	160.386
AB	AF	KB	KMT	KML
72.015	72.050	2.381	9.156	283.5

12 6.084 m 13 622 t discharged. 14 5.905 m
15 (i) 6.427 m (ii) 6.343 m 16 1894.6 t
17 2327.5 t 18 Loaded 2947.5 t
19 6.858 m, 6.708 m 20 2005.8 t

Exercise 14

1 7.560 m 2 4.615 m 3 10.050 m
4 8.886 m 5 8.000 m 6 12.600 m
7 7.536 m 8 5.076 m 9 5.927 m
10 14035.0 t, 367.0 t

Appendix I

HYDROSTATIC TABLE OF M.V. 'VIJAY'

DRAFT	W t in SW	TPC t cm-1	MCTC tm cm-1	AB m	AF m	KB m	KM_T m	KM_L m
3.0	5580	20.88	146.9	71.956	72.127	1.605	11.470	397.9
3.2	6000	21.07	149.6	71.968	72.141	1.710	11.030	375.8
3.4	6423	21.22	152.1	71.979	72.141	1.823	10.630	356.1
3.6	6849	21.36	154.1	71.990	72.141	1.931	10.274	339.1
3.8	7277	21.48	156.0	71.998	72.141	2.039	9.950	323.6
4.0	7708	21.60	157.8	72.008	72.127	2.147	9.660	309.9
4.2	8141	21.70	159.6	72.012	72.099	2.256	9.406	296.7
4.4	8576	21.80	161.3	72.015	72.056	2.367	9.182	285.0
4.6	9013	21.89	162.7	72.017	72.013	2.473	8.992	274.1
4.8	9451	21.97	164.3	72.016	71.970	2.576	8.828	263.9
5.0	9891	22.06	165.7	72.014	71.913	2.685	8.686	254.3
5.2	10333	22.14	167.1	72.011	71.842	2.789	8.566	245.4
5.4	10777	22.22	168.5	72.003	71.757	2.892	8.460	237.5
5.6	11223	22.30	169.9	71.990	71.671	2 998	8.374	229.9
5.8	11672	22.37	171.3	71.977	71.586	3.102	8.298	223.0
6.0	12122	22.45	172.9	71.960	71.472	3.205	8.234	217.2
6.2	12575	22.54	174.6	71.939	71.329	3.309	8.180	211.6
6.4	13030	22.64	176.4	71.914	71.172	3.413	8.136	206.6
6.6	13486	22.73	178.2	71.887	71.001	3.516	8.100	202.4
6.8	13943	22.83	180.3	71.856	70.802	3.620	8.076	198.4
7.0	14402	22.93	182.7	71.819	70.602	3.725	8.054	194.6

W displacement
A after perpendicular
K keel
SW salt water of RD 1.025

Load W 19943 t
Light W 6000 t
DWT 13943 t

LOA 150.00 m
LBP 140.00 m
GRT 10,000 Tons
NRT 5576 Tons