LONGITUDUNAL TRIM
USING (LCB ~ LCG) METHOD

NOTE :
As of 2005 and the new MCA syllabus Longitudinal Trim questions will have to be done by the LCB~LCG method. The old method of solving trim questions using LCF will not be allowed. One has to remember that taking moments about the LCF is only correct when the LCF has not changed. As a ship rises due to discharged weight or sinks further due to added weight, the LCF changes. Unless the change is very small the LCB~LCG method must be used. Now what is small will vary from ship to ship.
If the hydrostatic data has been provided, then LCB~LCG method must be used. Otherwise LCF method will have to be used.

Longitudinal centre of gravity (LCG represented by G_L)

Is the position of the ship's centre of gravity relative to the length (longitudinally) of the ship taken from the A.P. Symbol G_L in diagrams. It is the point where all W_f can said to be acting downward through.

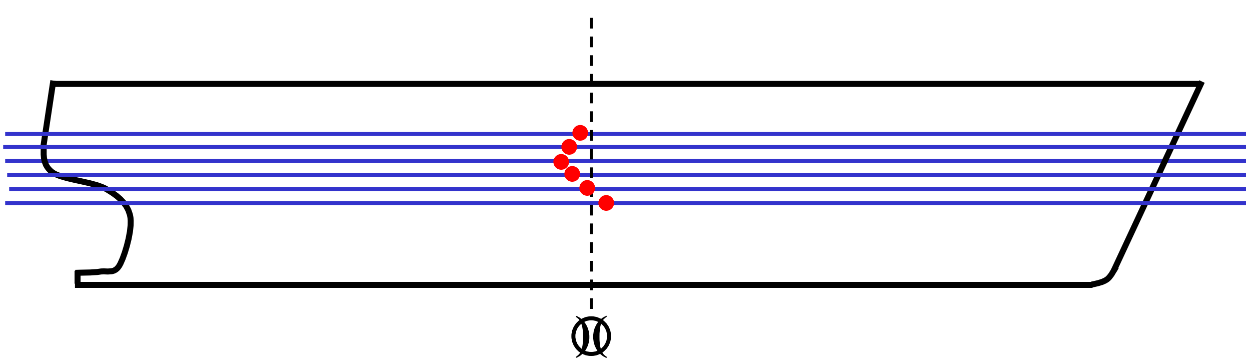
Longitudinal centre of buoyancy (LCB represented by BL)

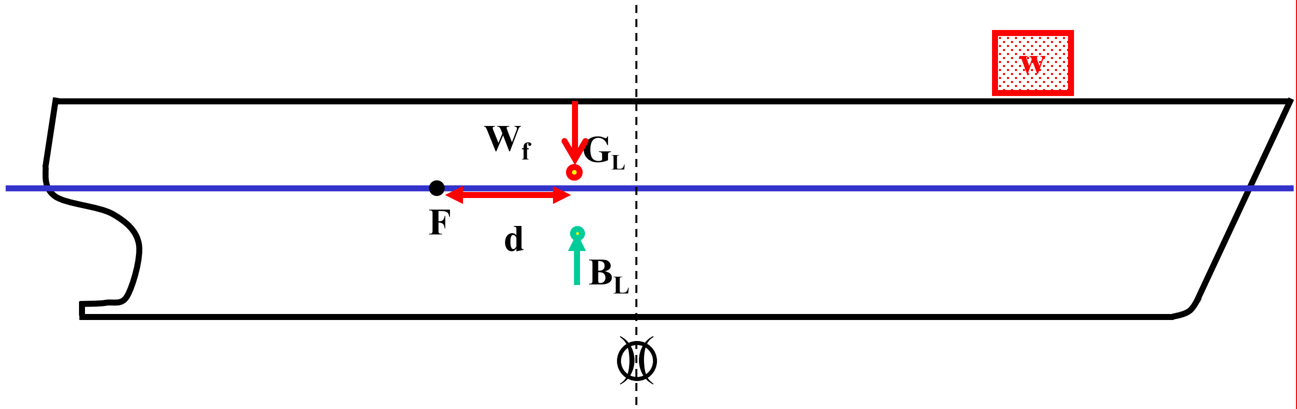
Is the volumetric centre, (or point) of the ship's under water volume where all the buoyancy force, Bf can be said to act upwards through and is expressed relative to the A.P. of the ship. Symbol BL in diagrams

Longitudinal centre of Flotation (LCF represented by F)

It is the point about which the ship pivots. Is the geometric centre of the ship's water-plane area at a particular draught and is ***the point about which the ship will trim***. It's position will change with draught.

It is the point through which a line drawn transversely bisects the water plane into two equal halves. It is expressed relative to distance from A.P.





Consider the ship shown.
By laws of Flotation Wf = Bf

In the above diagram ;
Since F is the pivot point, if we take moments about F, then

*Clockwise moments = Wf * d (distance Wf is acting from F).*
*Counter Clockwise moments = Bf * d (distance Bf is acting from F).*

Since Wf =Bf by laws of flotation and ‘d’ ,
the distance where Wf & Bf are acting are vertically above each other, i.e. same distance from ‘F’ (also from A.P.)

so ***Counter clockwise moments = Clockwise moments.***

In this case the resultant moments about centre of flotation, ‘F’ is zero. So the vessel will be at Even Keel.

Similarly it can also be inferred if Wf & Bf are vertically above each other at any other draft then the vessel must be on Even Keel as there are no trimming moments. The “B” referred to is the Even Keel centre of Buoyancy “B”.

Now let us take the same vessel again, on even keel i.e.

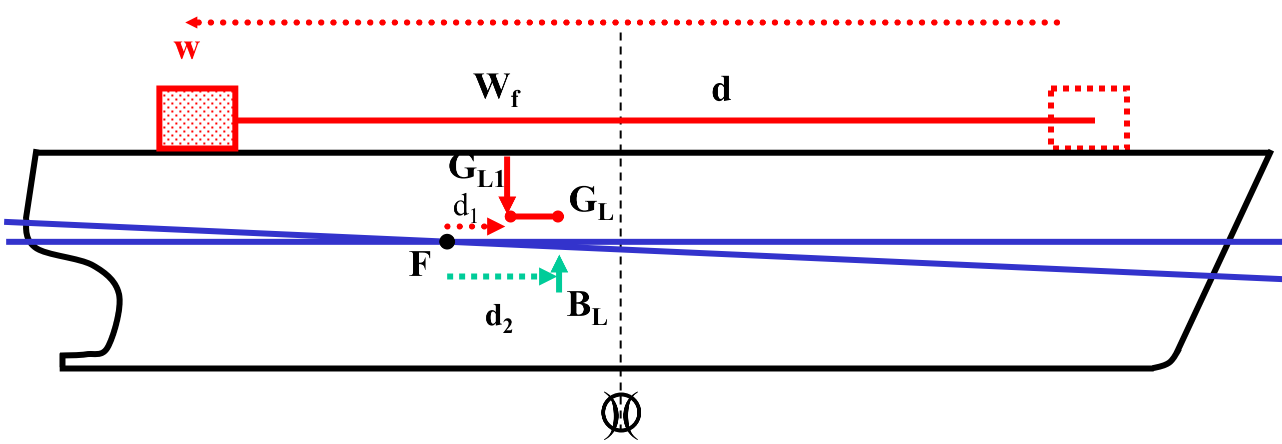
W_f is vertically inline with B_f. A weight 'w' which is already on board is shifted aft through a distance, 'd'. The moment caused by this shift is = w x d

However we know from previous that, when a weight is shifted, GG_H = w x d/W so can say G_LG_{L1} x W = w x d

Since the vessel was on even keel i.e. G_L was above $B_{L.}$ Now because G_L has moved to $G_{L1,}$ moments about 'F' due to W_f and B_f are not the same.

Clockwise moments about F = $W_f * d_1$

Counter Clockwise Moments about F = $B_f * d_2$



Since Wf = Bf,

Trimming moments about F, = $W_f * d_1 - B_f * d_2 = (W_f * d_1) - (W_f * d_2)$

= Wf ($d_1 \sim d_2$) but distance d1~d2 = distance (LCG~LCB)

Thus we can say C.O.T. = <u>W x (LCG~LCB)</u>

MCTC

We know Trimming moment = w × d (only shift of weight)

∴ **Trimming moment = (LCB~LCG)× Wf**

The ship trims until both LCB and LCG are in the same vertical line again.

$$\text{C.O.T.} = \frac{W * (LCb \sim LCg)}{MCTC}$$

Change of trim (C.O.T.)
Is the difference in ***cms*** between the trim in the initial condition and the trim in the final condition.

SAQ

A ship has the following initial draughts:

	F 6.00 m	***A 5.86 m***
and final draughts:	***F 5.66 m***	***A 6.20 m***

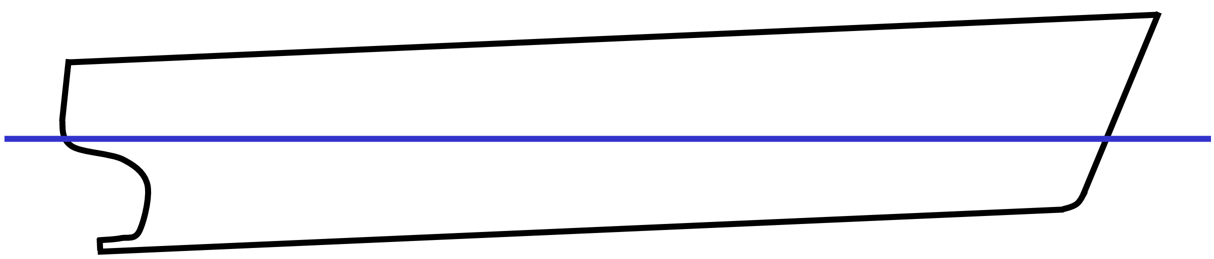
after cargo on board is shifted.
Calculate the change of trim that has occurred.

See next page for solution.

LONGITUDINAL STABILITY (1)

Trim

Is the difference (in ***cms)*** between the forward and aft draughts, as measured at the ***forward*** and ***aft perpendiculars*** respectively.



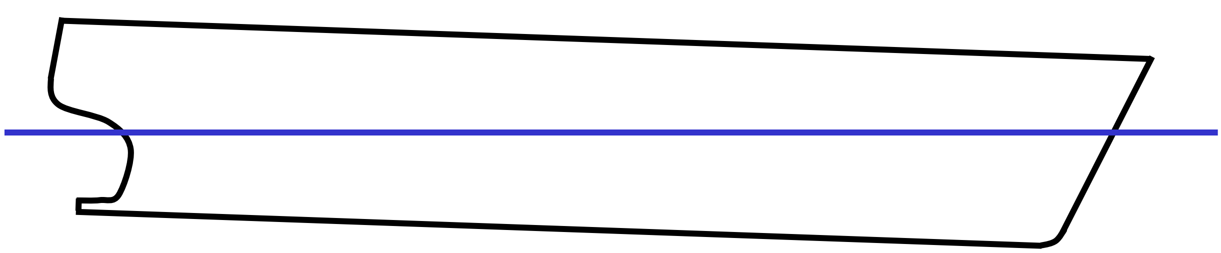
The ship above has draughts F 2.20 m A 2.68 m.

The trim of the ship is: 2.68

- 2.20

0.48 m by the ***stern***;

48 cms by the stern.



The ship above has draughts F 2.70 m A 2.32 m.

The trim of the ship is: 2.70

- 2.32

0.38 m by the ***head***;

38 cms by the head.

Answer

Initial draughts:
F 6.00 m A 5.86 m: Trim = 0.14 m by HEAD
Final draughts:
F 5.66 m A 6.20 m: Trim = 0.54 m by STERN
Therefore: Change of trim = 0.68 m by STERN

= 68 cms by STERN

Assuming no weights loaded or discharged.

Moment to change trim by one centimetre (MCTC)

This is the trimming moment (w × d) required to change the ship's trim by exactly 1 cm. It is tabulated in the ship's hydrostatic particulars and used to determine the change in trim without change of draft.

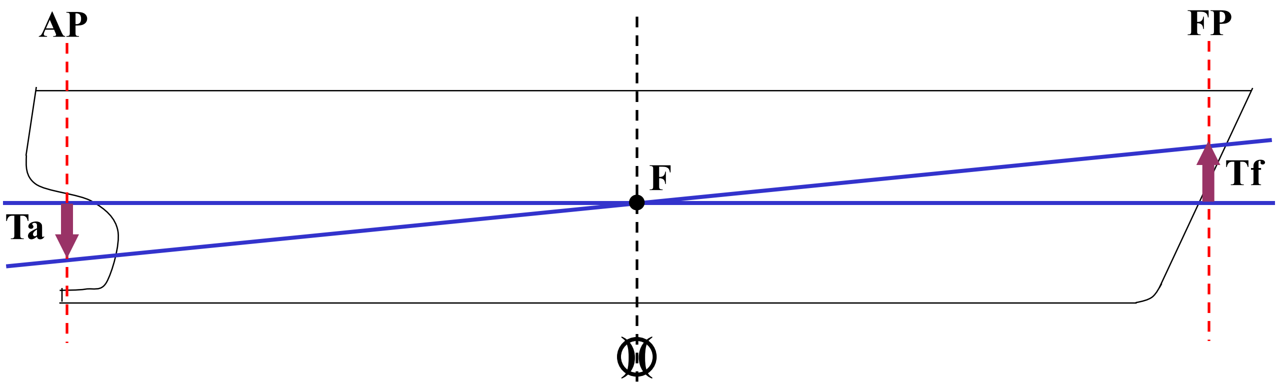
$$\text{COT (cms)} = \frac{w \times d}{\text{MCTC}} = \frac{\text{Trimming moment}}{\text{MCTC}}$$

$$= \frac{W \times GG'}{\text{MCTC}}$$

$$= \frac{W \times (LCB \sim LCG)}{\text{MCTC}}$$

The position of the LCF determines how the change of trim (COT) will be apportioned between the forward and aft draughts.

Ship with LCF amidships



If LCF amidships then: $\boxed{\mathbf{Ta = Tf = \frac{COT}{2}}}$

where: Ta = change of draught aft due to trim; and
Tf = change of draught forward due to trim.

SAQ

A ship floats at draughts F 6.50 m and A 6.80 m. Determine the final draughts if 25 tonnes is moved 45 m forward given that MCTC is 112.5 t-m and the LCF is amidships.

Answer

$$COT = \frac{w \times d}{MCTC} = \frac{25 \times 45}{112.5} = 10 \text{ cms} = 0.100 \text{ m}$$

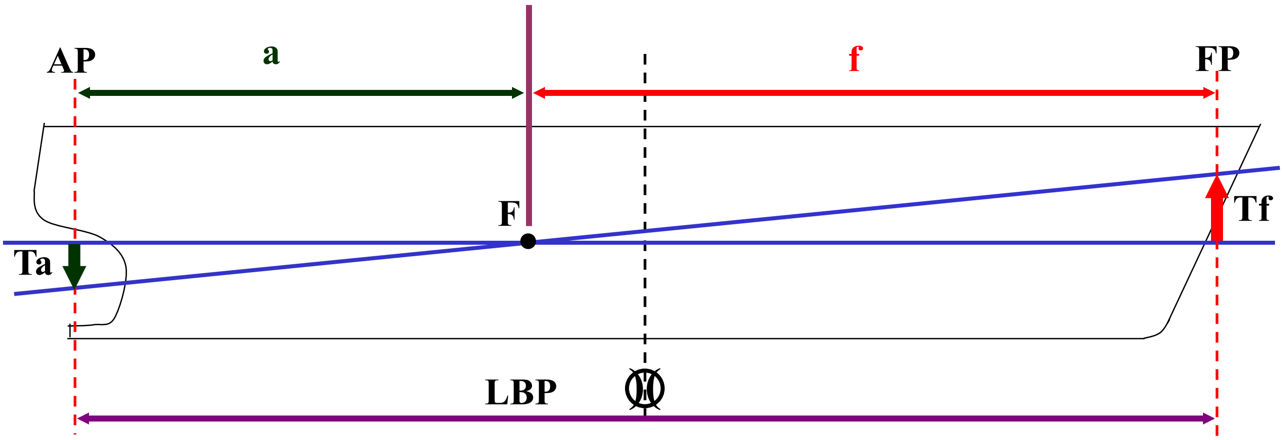
$$Ta = Tf = \frac{0.100}{2} = +/- \ 0.050 \text{ m}$$

Weight is moved forward so the ship will trim by the HEAD.

Initial draughts	***F 6.500***	***A 6.800***
Trim	***+ 0.050***	***- 0.050***
FINAL	***F 6.550 m***	***A 6.750 m***

Ship with LCF not amidships

In this case the change of trim (COT) will have to be ***apportioned*** to the forward and aft draughts according to the position of the LCF within the ship's length.



If the sketch above triangles are similar thus :

$$\frac{a}{Ta} = \frac{f}{Tf} \quad \text{and } Ta + Tf = COT$$

Therefore: $$\boxed{\mathbf{Ta = \frac{a}{LBP} \times COT}}$$ and $$\boxed{\mathbf{Tf = \frac{f}{LBP} \times COT}}$$

Where a = distance of CF (LCF) from A.P.
f = distance of CF from F.P. (L.B.P. – LCF)

SAQ

A ship has initial draughts F 10.25 m and A 10.15 m. A weight of 95 tonnes is moved aft through a distance of 42 m. Calculate the final draughts given that LBP is 100 m, LCF is 48 m foap and MCTC is 285 t-m.

See next page for solution.

Answer

$$COT = \frac{w \times d}{MCTC} = \frac{95 \times 42}{285} = 14 \text{ cms}$$

$$Ta = \frac{48}{100} \times 14 = 6.7 \text{ cms} = 0.067 \text{ m}$$

$$Tf = \frac{52}{100} \times 14 = 7.3 \text{ cms} = 0.073 \text{ m}$$

Weight is moved aft so the ship will trim by the STERN.

Initial draughts	***F 10.250***	***A 10.150***
Trim	***- 0. 073***	***+ 0.067***
FINAL	***F 10.177 m***	***A 10.217 m***

Calculating Final Draught by LCG~LCB method

The following procedure should be followed:

1. Calculate the A.M.D.
2. Using AMD enter hydrostatics, find LCF.
3. Using LCF, apply correction to Draught Aft and obtain T.M.D.
4. Using TMD note Displacement, LCB, MCTC, LCF interpolating if necessary.
5. Using C.O.T. = W x (LCB~LCG)/MCTC
   calculate position of Initial LCG.
6. Using LCG obtained from above, calculate moments about A.P. similar to calculating KG but taking moments about A.P.
7. Calculate final LCG,
   LCG = Sum of Longitudinal Moments/Final Displacement
8. Enter Hydrostatic tables with final displacement and find T.M.D., LCB, LCF & MCTC.
9. Using Formula COT = W x (LCB~LCG)/MCTC obtain total COT
10. Apply trim correction using LCF to T.M.D. to obtain final draughts forward and aft.

NOTE : In this method there is no need to apply sinkage or rise.

TIP : Always draw a sketch to help you picture what is happening!

Loading/discharging single weight LCG~LCB method

Vessel on even keel find LCG and subsequent draft & trim

Consider the following example:

A ship 140 m in length floats at draughts F 5.60 m & A 5.60 m
A weight of 220 tonnes is loaded 50 m FOAP.
Calculate the final draft and trim?

Note : Solve this question using the hydrostatic sheet provided on next slide.

HYDROSTATIC PARTICULARS EXTRACTS

DRAFT m	DISPL. t SW RD 1.025	DISPL. t FW RD 1.000	TPC t SW RD 1.025	TPC t FW RD 1.000	MCTC t-m SW RD 1.025	MCTC t-m FW RD 1.000	KMt m	KB m	LCB foap m	LCF foap m
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

THESE HYDROSTATIC PARTICULARS HAVE BEEN DEVELOPED WITH THE VESSEL FLOATING ON EVEN KEEL.

TRIM - SINGLE WEIGHT (LCB ~ LCG) METHOD)

	TMD = 5.6 m	Since V/L on E/K	Enter data
W =	11402	m	
LCB =	70.57	m foap	
LCG =	70.57 m		
MCTC	165	t-m	

	Weight (t)	Dist from LCF	
	11402	70.57	804639.14
	220	50	11000
NET	11622	70.181	815639.14

COT = $\dfrac{\textbf{W * (LCB\sim LCG)}}{\textbf{MCTC}}$

COT = $\dfrac{11622\ (70.53 - 70.181)}{166.1}$

COT = 24.4

TMD	**5.70 m**	Using:
LCF	**68.65 m FOAP**	
MCTC	**166.1 m**	

COT = 24.4 cms

Apportion the COT using:

Ta = $\dfrac{\textbf{LCf}}{\textbf{LBP}}$ **x COT**

Tf = $\dfrac{\textbf{(L - LCf)}}{\textbf{LBP}}$ **x COT**

Ta =	**12.4**	**cms**	**= 0.124**	**m**
Tf =	**12.0**	**cms**	**= 0.120**	**m**

Find final draughts

	Fwd	Aft
Initial	5.700	5.700
Trim	-0.120	0.124
FINAL DRAUGHTS	5.580	5.824

Loading/discharging multiple weights using (LCB~LCG)

A tabular approach needs to be adopted where moments are taken about the A.P..

Consider the following example:

A ship 140 m in length floats at drafts F 6.24 m and A 6.36 m.

The following cargo is worked:

Load	***120 t***	***lcg 10.0 m foap;***
Load	***73 t***	***lcg 86 m foap;***
Discharge	***36 t***	***lcg 22 m foap;***
Discharge	***48 t***	***lcg 60 m foap.***

Calculate the final draughts.

Use hydrostatic tables on previous page for this question.

TRIM	MULTIPLE	WEIGHTS	LCB~LCG	METHOD

COT = W x (LCB~LCG)/MCTC

12 = 12979 x (70.32- LCG) = / 173.9   70.159 m

ITEM	Weight (t)	LCG/Dist from AP	Mom abt A.P.
Ship	12979	70.159	910593.7
Load	120	10	1200
Load	73	86	6278
Disch.	-36	22	-792
Disch.	-48	60	-2880
NET	13088	69.865	914399.7

New Displacement TMD = 6.35 m

LCB = 70.30 m

LCF = 68.05

MCTC = 170.3 T-m

Using: COT = W x (LCB~LCG) / MCTC

COT = 13088 x (70.30-69.865) / 170.3

COT = 33.4 cms

Apportion the COT using:

Ta = a / LBP x COT

Tf = f / LBP x COT

Ta =	16.2	cms	=	0.162	m
Tf =	17.2	cms	=	0.172	m

	Fwd	Aft
Final TMD	6.350	6.350
Trim	-0.172	0.162
FINAL DRAFTS	6.178	6.512

Most trim problems are straight forward provided that you understand the information that is being given and can recognise the formula to which it belongs.

$$\textbf{COT cms} = \frac{\textbf{W x (LCB\~{}LCG)}}{\textbf{MCTC}}$$

Apportion COT to forward and aft draughts using:

$$\textbf{Ta} = \frac{\textbf{a}}{\textbf{LBP}} \times \textbf{COT} \quad \text{and} \quad \textbf{Tf} = \frac{\textbf{f}}{\textbf{LBP}} \times \textbf{COT}$$

NOTE

In the (LCB~LCG) method the T.M.D. for the appropriate Displacement is calculated and all other relevant factors such as LCF, MCTC, LCB are obtained for the calculated T.M.D. interpolating as necessary. If a '*hydrostatic particulars'* table is not given, then it has to be assumed that the values of TPC, MCTC and LCF position do not significantly change i.e. they remain constant for the range of draughts concerned.