Chapter 37
Effect of change of density on draft and trim

When a ship passes from water of one density to water of another density the mean draft is changed and if the ship is heavily trimmed, the change in the position of the centre of buoyancy will cause the trim to change.

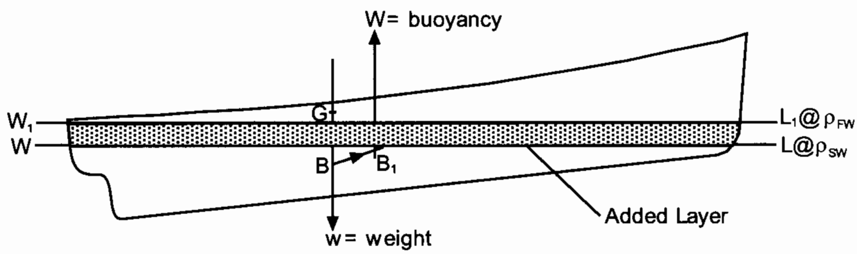

Fig. 37.1

Let the ship in Figure 37.1 float in salt water at the waterline WL. B represents the position of the centre of buoyancy and G the centre of gravity. For equilibrium, B and G must lie in the same vertical line.

If the ship now passes into fresh water, the mean draft will increase. Let W_1L_1 represent the new waterline and b the centre of gravity of the extra volume of the water displaced. The centre of buoyancy of the ship, being the centre of gravity of the displaced water, will move from B to B_1 in a direction directly towards b. The force of buoyancy now acts vertically upwards through B_1 and the ship's weight acts vertically downwards through G, giving a trimming moment equal to the product of the displacement and the longitudinal distance between the centres of gravity and buoyancy. The ship will then change trim to bring the centres of gravity and buoyancy back in to the same vertical line.

Example

A box-shaped pontoon is 36 m long, 4 m wide and floats in salt water at drafts F 2.00 m. A 4.00 m. Find the new drafts if the pontoon now passes into fresh

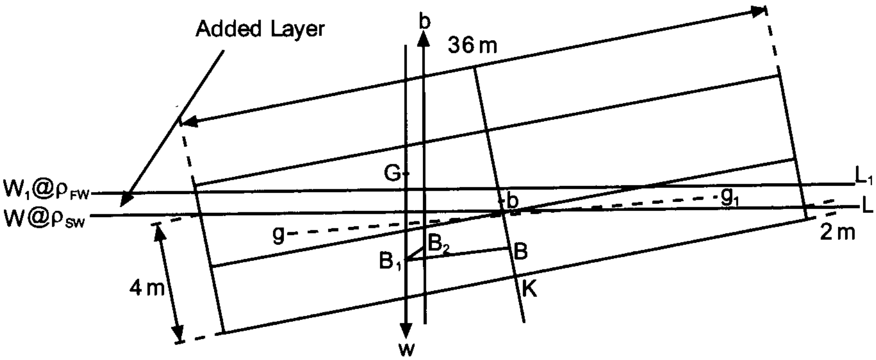

Fig. 37.2

water. Assume salt water density is $1.025\,t/m^3$. Assume fresh water density $= 1.000\,t/m^3$.

(a) To Find the Position of B_1

$$BB_1 = \frac{v \times gg_1}{V}$$

$$v = \frac{1}{2} \times 1 \times \frac{36}{2} \times 4 \qquad gg_1 = \frac{2}{3} \times 36 \qquad V = 36 \times 4 \times 3$$

$$= 36\,\text{cu. m} \qquad gg_1 = 24\ \text{m} \qquad = 432\,\text{cu. m}$$

$$\therefore\ BB_1 = \frac{36 \times 24}{432}$$

$$= 2\,\text{m}$$

Because the angle of trim is small, BB_1 is considered to be the horizontal component of the shift of the centre of buoyancy.

Now let the pontoon enter fresh water, i.e. from ρ_{SW} into ρ_{FW}. Pontoon will develop mean bodily sinkage.

(b) To Find the New Draft

In Salt Water

$$\text{Mass} = \text{Volume} \times \text{Density}$$

$$= 36 \times 4 \times 3 \times 1.025$$

In Fresh Water.

$$\text{Mass} = \text{Volume} \times \text{Density}$$

$$\therefore\ \text{Volume} = \frac{\text{Mass}}{\text{Density}}$$

$$= \frac{36 \times 4 \times 3 \times 1.025}{1.000}\ \text{cu. m}$$

(Mass in Salt water = Mass in Fresh Water)

Let

$$\text{MBS} = \text{Mean Bodily Sinkage} \qquad \rho_{SW} = \text{higher density}, \rho_{FW} = \text{lower density}$$

$$\text{MBS} = \frac{W}{\text{TPC}_{SW}} \times \frac{(\rho_{SW} - \rho_{FW})}{\rho_{FW}}$$

$$\text{MBS} = \frac{\cancel{L}\cancel{B}\,d\cancel{\rho_{SW}}}{\frac{\cancel{L} \times \cancel{B}}{100} \times \cancel{\rho_{SW}}} \left\{\frac{\rho_{SW} - \rho_{FW}}{\rho_{FW}}\right\}$$

$$\therefore \text{MBS} = \frac{d(\rho_{SW} - \rho_{FW})}{\rho_{FW}} \times 100$$

$$\text{MBS} = \frac{3 \times 0.025}{1.000} \times 100 = \underline{0.075\text{ m}}$$

$$\therefore \text{MBS} = 0.075\text{ m}$$

Original mean draft $= 3.000$ m

New mean draft $= 3.075$ m say draft d_2

(c) Find the Change of Trim

Let B_1B_2 be the horizontal component of the shift of the centre of buoyancy. Then

$$B_1B_2 = \frac{v \times d}{V} = \frac{10.8 \times 2}{442.8}$$

$$\therefore B_1B_2 = 0.0487\text{ m}$$

$$W = LBd_{SW} \times \rho_{SW} = 36 \times 4 \times 3 \times 1.025$$

$$\therefore W = 442.8\text{ tonnes}$$

$$\text{Trimming Moment} = W \times B_1B_2$$

$$= 36 \times 4 \times 3 \times \frac{1.025}{1.000}\text{ t} \times 0.0487\text{ m} = 21.56\text{ t m}$$

$$BM_{L(2)} = \frac{L^2}{12d_{(2)}} = \frac{36^2}{12 \times 3.075} = \frac{36}{1.025}\text{ m} = 35.12\text{ m}$$

$$\text{MCTC} \simeq \frac{W \times BM_L}{100 \times L} = \frac{442.8 \times 35.12}{100 \times 36} = 4.32\text{ tonnes metres}$$

$$\text{Change of Trim} = \frac{\text{Trimming Moment}}{\text{MCTC}} = \frac{21.56}{4.32} = 5\text{ cm}$$

Change of Trim = 5 cm by the stern

= 0.05 m by the stern

Drafts before Trimming	A	4.075 m	F	2.075 m
Change due to trim		+0.025 m		−0.025 m
New Drafts	A	4.100 m	F	2.050 m

In practice the trimming effects are so small that they are often ignored by shipboard personnel. Note in the above example the trim ratio forward and aft was only $2\frac{1}{2}$ cm.

However, for D.Tp. examinations, they must be studied and fully understood.

Exercise 37

1 A box-shaped vessel is 72 m long, 8 m wide and floats in salt water at drafts F 4.00 m. A 8.00 m. Find the new drafts if the vessel now passes into fresh water.

2 A box-shaped vessel is 36 m long, 5 m wide and floats in fresh water at drafts F 2.50 m. A 4.50 m. Find the new drafts if the vessel now passes into salt water.

3 A ship has a displacement of 9100 tonnes, LBP of 120 m, even-keel draft of 7 m in fresh water of density of 1.000 t/m^3.

From her Hydrostatic Curves it was found that:

$MCTC_{SW}$ is 130 t m/cm
TPC_{SW} is 17.3 t
LCB is 2 m forward ⦶ and
LCF is 1.0 aft ⦶.

Calculate the new end drafts when this vessel moves into water having a density of 1.02 t/m^3 without any change in the ship's displacement of 9100 tonnes.

Chapter 38
List with zero metacentric height

When a weight is shifted transversely in a ship with zero initial metacentric height, the resulting list can be found using the 'Wall sided' formula.

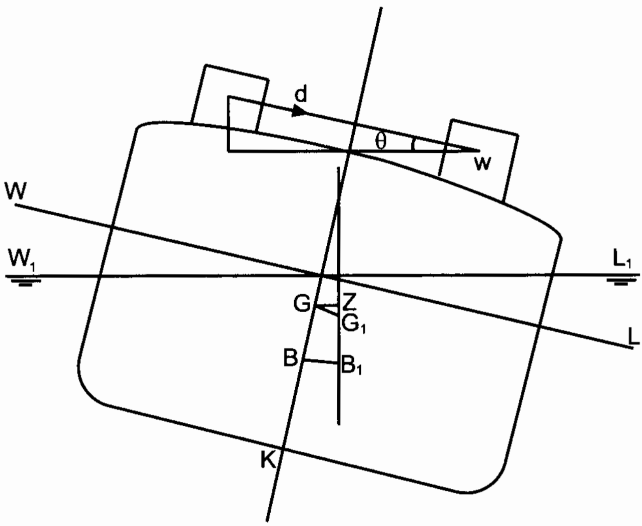

Fig. 38.1

The ship shown in Figure 38.1 has zero initial metacentric height. When a weight of mass 'w' is shifted transversely through a distance 'd', the ship's centre of gravity shifts from G to G_1 where the direction GG_1 is parallel to the shift of the centre of gravity of the weight shifted. The ship will then incline to bring the centres of gravity and buoyancy in the same vertical line.

The horizontal component of the shift of the ship's centre of gravity is equal to GZ and the horizontal component of the shift of the centre of gravity of the weight is equal to $d\cos\theta$.

$$\therefore\ w \times d\cdot\cos\theta = W \times GZ$$

The length GZ, although not a righting lever in this case can be found using the 'Wall-sided' formula.

i.e.

$$GZ = (GM + \tfrac{1}{2}\cdot BM\cdot\tan^2\theta)\sin\theta$$

$$\therefore\ w \times d\cdot\cos\theta = W\cdot\sin\theta\,(GM + \tfrac{1}{2}\cdot BM\cdot\tan^2\theta)$$

If

$$GM = 0$$

Then

$$w \times d\cdot\cos\theta = W\cdot\sin\theta\cdot\tfrac{1}{2}\,BM\cdot\tan^2\theta$$

$$\frac{w \times d}{W} = \frac{\sin\theta}{\cos\theta}\cdot\tfrac{1}{2}\cdot BM\cdot\tan^2\theta$$

$$\frac{2\cdot w\cdot d}{BM\cdot W} = \tan^3\theta$$

or

$$\tan\theta = \sqrt[3]{\frac{2\cdot w\cdot d}{BM\cdot W}}$$

Example

A ship of 12 250 tonnes displacement, has KM = 8 m, KB = 3.8 m, KG = 8 m and is floating upright. Find the list if a weight of 2 tonnes, already on board, is shifted transversely through a horizontal distance of 12 m, assuming that the ship is wall-sided.

KM =	8.0 m
	−
KB =	3.8 m
BM =	4.2 m

The ship has zero GM

$$\therefore\ \tan \text{list} = \sqrt[3]{\frac{2\cdot w\cdot d}{W\cdot BM}}$$

$$\tan \text{list} = \sqrt[3]{\frac{2\cdot 2\cdot 12}{12\,250 \times 4.2}} = 0.0977$$

Ans. List = 5° 34′

Exercise 38

1 Find the list when a mass of 10 tonnes is shifted transversely through a horizontal distance of 14 m in a ship of 8000 tonnes displacement which has zero initial metacentric height. BM = 2 m.

2 A ship of 8000 tonnes displacement has zero initial metacentric height. BM = 4 m. Find the list if a weight of 20 tonnes is shifted transversely across the deck through a horizontal distance of 10 m.

3 A ship of 10 000 tonnes displacement is floating in water of density 1.025 kg/cu. m and has a zero initial metacentric height. Calculate the list when a mass of 15 tonnes is moved transversely across the deck through a horizontal distance of 18 m. The second moment of the waterplane area about the centre line is 10^5 m^4.

4 A ship of 12 250 tonnes displacement is floating upright. KB = 3.8 m, KM = 8 m and KG = 8 m. Assuming that the ship is wall-sided, find the list if a mass of 2 tonnes, already on board, is shifted transversely through a horizontal distance of 12 m.

Chapter 39
The Trim and Stability book

When a new ship is nearing completion, a Trim and Stability book is produced by the shipbuilder and presented to the shipowner. Shipboard officers will use this for the day to day operation of the vessel. In the Trim and Stability book is the following technical data:

1 General particulars of the ship.
2 Inclining experiment report and its results.
3 Capacity, VCG, LCG particulars for all holds, compartments, tanks etc.
4 Cross curves of stability. These may be GZ curves or KN curves.
5 Deadweight scale data. May be in diagram form or in tabular form.
6 Hydrostatic curves. May be in graphical form or in tabular form.
7 Example conditions of loading such as:

    Lightweight (empty vessel) condition.
    Full-loaded Departure and Arrival conditions.
    Heavy-ballast Departure and Arrival conditions.
    Medium-ballast Departure and Arrival conditions.
    Light-ballast Departure and Arrival conditions.

    On each condition of loading there is a profile and plan view (at upper deck level usually). A colour scheme is adopted for each item of deadweight. Examples could be red for cargo, blue for fresh water, green for water ballast, brown for oil. Hatched lines for this Dwt distribution signify wing tanks P and S.

    For each loaded condition, in the interests of safety, it is necessary to show:

    Deadweight.
    End draughts, thereby signifying a satisfactory and safe trim situation.
    KG with no Free Surface Effects (FSE), and KG with FSE taken into account.

Final transverse metacentric height (GM). This informs the officer if the ship is in stable, unstable or neutral equilibrium. It can also indicate if the ship's stability is approaching a dangerous state.
Total Free Surface Effects of all slack tanks in this condition of loading.

A statical stability curve relevant to the actual loaded condition with the important characteristics clearly indicated. For each S/S curve it is important to observe the following:

Maximum GZ and the angle of heel at which it occurs.
Range of stability.
Area enclosed from zero degrees to thirty degrees (A1) and the area enclosed from thirty degrees to forty degrees (A2) as shown in Figure 39.1.
Shear force and bending moment curves, with upper limit lines clearly superimposed as shown in Figure 39.2.

8 Metric equivalents. For example, TPI″ to TPC, MCTI″ to MCTC, or tons to tonnes.

All of this information is sent to a D.Tp. surveyor for appraisal. On many ships today this data is part of a computer package. The deadweight items are keyed in by the officer prior to any weights actually being moved. The computer screen will then indicate if the prescribed condition of loading is indeed safe from the point of view of stability and strength.

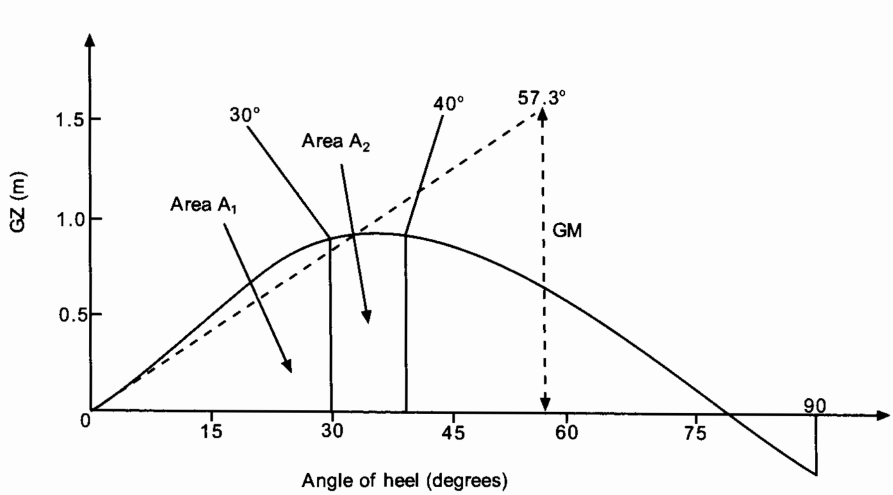

Fig. 39.1. Enclosed areas on a statical stability curve.

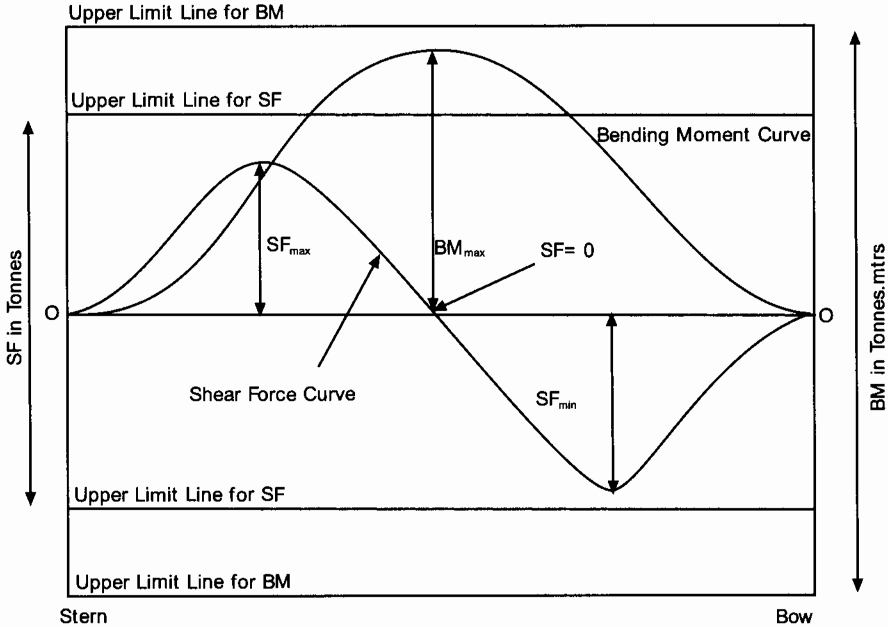

Fig. 39.2. SF and BM curves with upper limit lines.