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.

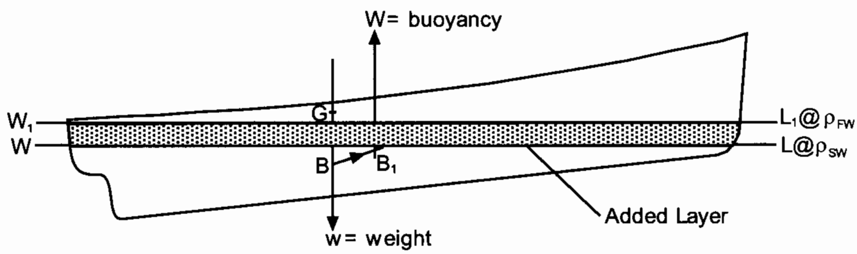

Fig. 37.1

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

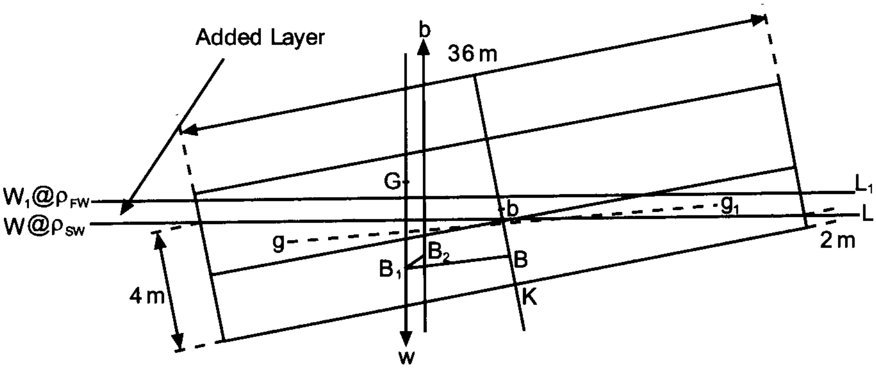

Fig. 37.2

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

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

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

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

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

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

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

$$\text{Original mean draft} = 3.000\,\text{m}$$

$$\text{New mean draft} = 3.075\,\text{m say draft } d_2$$

(c) Find the Change of Trim

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

$$B_1B_2 = \frac{v \times d}{V} \qquad W = LBd_{SW} \times \rho_{SW}$$

$$= \frac{10.8 \times 2}{442.8} \qquad = 36 \times 4 \times 3 \times 1.025$$

$$\therefore B_1B_2 = 0.0487\,\text{m} \qquad \therefore W = 442.8 \text{ tonnes}$$

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

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

$$BM_{L(2)} = \frac{L^2}{12d_{(2)}}$$

$$= \frac{36^2}{12 \times 3.075}$$

$$= \frac{36}{1.025}\,\text{m} = 35.12\,\text{m}$$

$$\text{MCTC} \simeq \frac{W \times BM_L}{100 \times L}$$

$$= \frac{442.8 \times 35.12}{100 \times 36}$$

$$= 4.32 \text{ tonnes metres}$$

$$\text{Change of Trim} = \frac{\text{Trimming Moment}}{\text{MCTC}}$$

$$= \frac{21.56}{4.32} = 5\,\text{cm}$$

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.