STABILITY, TRIM AND CARGO CALCULATIONS ON M.V 'HINDSHIP' AND OIL TANKERS

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PREFACE

Till recently, there was some disparity between the stability and trim calculation which a ship's officer faced on bard ships, in practice, and those presented him in text books. The problem set in the examinations now, involve the use of the trim and stability particulars of a ship.

In this book therefore we have endeavoured to provide practical problems based on the trim and stability particulars of M.V. 'Hindship'. The aim of this book is to help ship's officers in preparing for their certificates of competency examinations. It should also provide a guide for their practical stability work on ships.

Fair proficiency in the theory of stability for the respective grades is assumed. Brief notes and comments have been included in the text wherever thought necessary for clear understanding.

Each problem has been carefully designed so that it teaches something new which illustrates and amplifies the theory and brings into sharp focus, the fine points without which the student may find himself unsure.

We have been able to restrict the total number of problems in this book by avoiding repetition of identical problems. This should enable the students, who are hard pressed for time to learn the subject matter in the shortest possible period.

To promote step-by-step learning, and to ensure that, at each step, the student grasps the principles and processes used in the solutions, the problems have been graded with care. The special feature of this book is that every problem has been worked out. This book is in no way a condensation of ordinary text material. It is intended to be a comprehensive book of stability and trim calculations.

For the purpose of revision, particularly so before the examination, the student is advised to work out the problems from the section titled 'Test Yourself'. The problems in that section have been arranged in random order to test the student's proficiency in solving the various types of problems.

We have exercised care to eliminate any arithmetical or printing errors. If however, any errors are detected, we would be thankful if they are communicated to us.

We are very grateful to all our colleagues in the profession for their encouragement which has helped us in this endeavour. We are particularly indebted to our students both past and present whose searching questions and quest for knowledge have helped us in producing this book.

T. K. Joseph, S. S. S. Rewari

PREFACE TO SECOND EDITION

The book has been revised to increase its usefulness to the merchant navy officers, both when studying for their certificate of Competency examinations and for their practical work on board ships. To highlight the important aspects of safety, further theory, illustrations and problems have been added.

T. K. J., S. S. S. R

PREFACE TO THIRD EDITION

It gives us great satisfaction to publish the New Edition of this book coinciding with the full implementation of the Convention on Standards of Training Certification and Watch keeping (STCW' 78), as amended in 1995.

The book has been extensively revised to meet the requirements of the latest syllabi of Masters & Mates examination and international regulations.

Additional topics ***(SHIP SQUAT, DRAFT SURVEY, LOAD LINE/DEAD WEIGHT CALCULATIONS, HEEL DUE TO TURN, ROLLING PERIOD, WEATHER CRITERIA, STABILITY REQUIREMENTS FOR SHIPS LOADED WITH GRAIN IN BULK, INTACT STABILITY CRITERIA FOR CARGO AND PASSENGER SHIPS. CARGO CALCULATIONS ON OIL TANKERS AND PRACTICAL USE OF ULLAGE TABLES)*** have been added to make it a comprehensive text book both for examination and ship operation purposes. A special feature of this new edition is the inclusion of ***Practical Cargo Calculations*** for various types of ships including ***Oil Tankers***. Care has been taken to ensure that all category of students benefit; ranging from the pre-sea level to the Masters & Mates level. The book covers the entire syllabus of B.Sc. (Nautical Sciences) degree course, of various Indian Universities. In our considered opinion the Marine Engineering students will also find it extremely useful in understanding the practical aspects of ship's stability as contained in their syllabus.

We would particularly like to thank Chief Officer **Shri Vijay Kumar** B.Sc. (Nautical Sciences) one of our ex-student who has taken great pains in checking the text, reworking the calculations and formatting the text. His contribution in Chapters on Oil Tanker and Use of Ullage Tables is specially acknowledged. We wish him all the best in his career.

A special mention has to be made of **Miss Renu Kanda,** who took up the challenge of deciphering and reading our hand written technical scribbles and converted them into readable and presentable material. Without her efforts, our latest publications would not have been possible. We sincerely acknowledge her herculean efforts.

We are indeed grateful to our students, who besides using this book for their examinations have also carried the same to their respective ships and

acknowledged its usefulness on board. They also sent us their valuable suggestions, all of which, we have attempted to include in this latest edition.

Capt. T.K. Joseph **Capt. S.S.S Rewari**

Contents

STABILITY INFORMATION TO BE PROVIDED

As per the code of intact stability, the stability information to be supplied to ships has been standardised and made more comprehensive. Present-day ships are therefore provided with this information in a format basically similar to the **Booklet of Trim and Stability Particulars of M.V. 'Hindship'**. The information relating to the stability of the vessel to be provided for the master may be briefly summarised as follows:-

1) General particulars of the ship, including dimensions, tonnages, summer draft, displacement, dead weight etc.

2) Instructions on the use of the booklet.

3) General arrangement plans showing watertight compartments, closures, vents, downflooding angles, permanent ballast if any, allowable deck loadings, and free board diagrams.

4) Hydrostatic curves or tables and cross curves of stability on a free trimming basis for a range of displacements between light and load draft and for a range of trim anticipated in normal operating conditions.

5) Capacity plan or tables showing capacities and centres of gravity (both longitudinally and vertically) for each cargo space.

6) Tank sounding tables showing capacities, centres of gravity (both longitudinally and vertically) and free surface data for each tank.

7) Information on loading restrictions such as maximum KG or minimum GM curve or table that can be used to determine compliance with the applicable stability criteria.

8) Standard operating conditions and examples for developing other acceptable loading conditions using the information contained in stability booklet.

9) A brief description of the stability calculations done, including any assumptions.

10) General precautions for preventing unintentional flooding.

11) Information concerning the use of any special cross-flooding fittings, if provided, with descriptions of damage which may be require cross flooding.

12) Any other guidance for the safe operation of the ship under normal and emergency conditions.

13) A table of contents and index for the booklet.

14) Inclining test report for the ship.

OR, where the stability data is based on a sister ship, the inclining test report of the sister ship along with the light ship measurement report for the ship in question.

OR, where the light ship particulars are determined by other methods than the inclining of the ship or her sister, a summary of the method used to determine those particulars.

15) Recommendation for the determination of the ship's stability by means of an in-service inclining test.

The format of the booklet and the information included will vary depending on the type of ship and her operation.

DEFINITION PERTAINING TO HYDROSTATIC PARTICULARS

Density of a substance is its mass per unit volume, normally expressed as tonnes per cubic metre in ship calculations.

Relative Density of a substance is the ratio between the density of that substance and the density of fresh water.

Displacement of the ship is the weight of the ship and its contents or the weight of water displaced by the ship in that condition.

Displacement = Underwater volume of the ship x the density of the water in which she is floating.

It should be noted that the volume of displacement is the underwater volume of the ship. When a ship proceeds from water of one density to water of another density, the volume of displacement changes, whereas the displacement remains unchanged.

Hydrostatic Draft Or True Mean Draft is the draft at the centre of floatation. When the ship is on an even keel, the drafts forward and aft, the mean draft and the hydrostatic draft are all the same.

TPC (Tonnes per centimetre Immersion) at any draft is the weight in tonnes which should be loaded or discharged to change the vessel's mean draft by one centimetre, in saltwater.

$$TPC = \frac{1.025 \times \text{Area of ship's water plane}}{100}$$

MCTC or MCT 1 cm (Moment To Change Trim By One Centimetre) is the moment required to change the total trim of the vessel by one centimetre.

$$MCTC = \frac{W \times GM_L}{100 \times L}$$

CB (Centre of Buoyancy) is the geometric centre of the underwater volume of the ship. The entire buoyancy provided by the displaced water may be considered to act vertically upwards through this point.

LCB (Longitudinal Centre of Buoyancy) is the longitudinal separation between the After Perpendicular and the centre of buoyancy.

VCB (Vertical Centre of Buoyancy) is the vertical separation between the keel and the centre of buoyancy.

CF (Centre of Floatation) is the centroid of the ship's water plane area.

LCF (Longitudinal Centre of Floatation) is the longitudinal separation between the After Perpendicular and the Centre of Floatation.

M (Transverse Metacentre) is the point of intersection of the vertical lines through the Centres of Buoyancy in the upright condition and the vertical line through the centre of Buoyancy in slightly inclined condition.

KM is the vertical separation between the keel and the transverse metacentre.

M_L (Longitudinal Metacentre) is the point of intersection of the vertical line through the Centre of Buoyancy in the even keel condition and the vertical line through the Centre of Buoyancy in a slightly trimmed condition.

KM_L is the vertical separation between the keel and the longitudinal metacentre.

GM (Metacentric Height) is the vertical separation between the centre of gravity and the transverse metacentre.

NOTE: In stability calculations in various text books, the different hydrostatic particulars like TPC, MCTC, LCF, KM etc. are assumed constant despite change in displacement/draft, to facilitate easier solution. This assumption is incorrect and **cannot** be used while practically calculating stability/trim on board ships. It must therefore, be borne in mind that all the hydrostatic particulars of the ship change with draft/displacement. The calculations in this book have taken this important fact into account.

It should also be noted that though the displacement remains unchanged, yet some of the hydrostatic particulars change with density of water in which the ship is floating. Even when the density and the displacement are constant, some of them like KM also change with HEEL and TRIM, as the shape of waterplane alters when these parameters change. This fact has been taken into consideration in problems on LIST/HEEL, where the value of KM is assumed constant only for very small angles of heel.

GENERAL INSTRUCTIONS

When using the Trim and Stability data for M.V. 'Hindship,' the following should be taken into account **unless** otherwise stated:-

1. Relative densities of liquids shall be taken as follows:-

Salt Water	1.025	Fresh Water	1.00
Heavy Fuel Oil	0.95	Diesel Oil	0.88
Lub. Oil	0.90	Cylinder Oil	0.92

2. GZ curves, hydrostatic curves and displacement scale are for inspection only. For actual calculations, the KN tables on pages 20 - 21 and 7 - 8 respectively should be used. Interpolated values shall be considered correct for in between displacements/drafts.

3. Draft marks are to be assumed as being at the fore and aft perpendiculars.

4. KG means the KG without allowing for free surface correction.

5. GM (Solid) means GM without allowing for free surface correction.

6. GM (Fluid) means GM (Solid) - FSC.

7. FSC is to be applied to the GM and not to the KG, except when determining GZ values from KN.

8. When determining GZ from KN, corrected KG means KG + FSC.

9. Kg of liquid in any tank is to be presumed as for full tank.

10. Moment of inertia for calculations of FSC is to be obtained from page 18 and the FSC is to be worked out as indicated on page 19.

11. Hydrostatic draft means the draft at the centre of floatation.

12. All information taken from pages 7 and 8 relates to hydrostatic draft. However, when the trim of the ship is not given, the mean draft may be considered to be the same as the hydrostatic draft.

13. A tank shall be considered full when filled to its 100% capacity.

14. When a change of displacement is involved, the hydrostatic data is to be obtained corresponding to the final draft/displacement.

15. Trim is to be calculated as indicated at the commencement of the chapter on trim in this book.

16. On page 20 and 21, where righting arm (KN) values are given under columns 'A' and 'B' the values given under column 'B' alone should be used.

17. Weights added or removed from any compartment are to be assumed at, or from the respective centres of gravity of the compartment (both vertical and longitudinal), unless stated otherwise.

18. For calculations involving capacities of cargo compartments, the grain capacities are to be used.

FAMILIARIZATION WITH THE BOOKLET OF TRIM & STABILITY PARTICULARS OF M.V. 'HINDSHIP'

Prior to proceeding to the **actual calculations**, the student should familiarize himself with the **content** and **layout** of the M.V. 'Hindship' trim and stability booklet. For this, the following exercises will be useful.

1. Find the LBP and Moulded Breadth of M.V. 'Hindship'.

2. Locate the criteria of minimum stability requirements as per the CODE OF 'INTACT STABILITY'.

3. Find the Displacement, TPC, MCTC, LCB, LCF, VCB, KM and KM_L at a draft of 4.2m.

4. Find the capacity of No. 2TD.

5. Find the Lcg and Kg of No. 3 Hold.

6. Find the Capacity, Kg and Lcg of No. 4 DB tank (C)

7. Find the weight of ballast in the Aft Peak tank, when full

8. Find the moment of inertia of No. 12 DB tank (S).

9. Find the KN value at a displacement of 13,500 t, when heeled 40^0.

10. Find the draft, freeboard, displacement and deadweight at the Winter load line.

11. Find the FWA of the ship.

12. In condition No. 5, find the following:-

    (i) Weight of cargo in No. 5 TD.

    (ii) Longitudinal moment of No. 5 DB tank (S).

    (iii) Total free surface moment of the ship.

    (iv) Displacement of the ship.

    (v) Vertical Moment of the ship.

    (vi) Kg of oil in Storage & Settling tanks.

    (vii) Weight of the mail cargo.

    (viii) LCB of the ship.

(ix) Hydrostatic draft

(x) Total trim

(xi) KG

(xii) FSC

(xiii) Righting Lever at 10^0 heel.

(xiv) Area under GZ curve upto 40^0.

(xv) Maximum GZ and the angle of heel at which it occurs.

(xvi) LCF of ship.

ANSWERS

1.	(a)	143.16 m	(b)	20.00 m			Page 3 'Hindship' Booklet
2.							Page 5 'Hindship' Booklet
3.	(a)	8038 t	(b)	21.72 t	(c)	160.7 mt	
	(d)	73.014 m	(e)	73.103 m	(f)	2.256 m	
	(g)	9.610 m	(h)	290.1 m			Page 7. 'Hindship' Booklet
4.	1854.9 cu. metres						Page 9 'Hindship' Booklet
5.	(a)	80.63 m	(b)	5.0 m			Page 9 'Hindship' Booklet
6.	(a)	2574cu.m	(b)	0.63 m	(c)	57.58 m	Page 13 'Hindship' Booklet
7.	117.8 x 1.025 = 120.745 t						Page 15 'Hindship' Booklet
8.	17 m^4						Page 18 'Hindship' Booklet
9.	5.845 m						Page 21 'Hindship' Booklet
10.	(a)	9.041 m	(b)	2.81 m	(c)	19151 t	
	(d)	13651 t					Page 24. 'Hindship' Booklet
11.	202 mm						Page 24. 'Hindship' Booklet
12.	(i)	715.8 t	(ii)	1510 mt	(iii)	1552 mt	
	(iv)	18529.3 t	(v)	139700 mt	(vi)	6.46 m	
	(vii)	5.1 t	(viii)	72.356 m			Pages 46 & 47
	(ix)	8.785 m	(x)	0.201 m	(xi)	7.539 m	
	(xii)	(-) 0.084 m	(xiii)	0.191 m	(xiv)	0.237 mrad	
	(xv)	0.650 m at 41.5°			(xvi)	143.16 x 49.07/100 = 70.249 m	

Note

When utilizing data given for condition 1 to 11, the values as given for the **condition** are to be used though calculations may not agree exactly with them, e.g.

(i) Condition No. 11, the vertical moment of 235 t of refrigerated cargo, at a Kg of 10.36 is indicated as 2435 mt instead of (235 x 10.36) = 2434.6 mt. The value 2435 is to be used.

(ii) In the same condition, No. 3 DB tank (P) (C) & (S) is said to contain 442.5 t of WB. Calculations ($431.7m^3$ x 1.025 = 442.5t) show that the tanks are full to 100% capacity. Yet a FS moment of 120 mt has been indicated against these tanks. The tank is to be considered slack with a FS moment of 120 mt.

(iii) In the same condition, the L. Moment is indicated as 1108044 mt, while displacement of 15460.2 x LCG, 71.671 gives 1108048 mt. The value 1108044 mt is to be used.

DETERMINATION OF HYDROSTATIC PARTICULARS

1. *Find the Hydrostatic particulars (Hydrostatic draft, TPC, MCTC, LCB, LCF, VCB, KM and KM_L) of M.V. 'Hindship' at a displacement of 9540 tonnes.*

Displacement	Hydrostatic Draft	TPC	MCTC	LCB	LCF	VCB	KM	KM_L
9348	4.80	21.99	165.4	73.018	72.974	2.576	9.032	257.3
9540 ?								
9788	5.00	22.08	166.8	73.016	72.917	2.684	8.890	247.7
440	0.2	0.09	1.4	0.002	0.057	0.108	0.142	9.6

For diff. in displacement of 440 t diff. in hydrostatic draft = 0.2 m

For diff. in displacement of (9540 - 9348) = 192 t diff. in hydrostatic draft.

Interpolating as above, we have:-

diff. in Hydrostatic draft $= \dfrac{0.2 \times 192}{440} = 0.087$ Hyd. draft = 4.80 + 0.087 = ***4.887 m***

diff. in TPC $= \dfrac{0.09 \times 192}{440} = 0.039$ TPC $= 21.99 + 0.039 =$ ***22.029 t***

diff. in MCTC $= \dfrac{1.4 \times 192}{440} = 0.611$ MCTC $= 165.4 + 0.611 =$ ***166.011 mt***

diff. in LCB $= \dfrac{0.002 \times 192}{440} = 0.001$ LCB $= 73.018 - 0.001 =$ ***73.017 m***

diff. in LCF $= \dfrac{0.057 \times 192}{440} = 0.025$ LCF $= 72.947 - 0.025 =$ ***72.949 m***

diff. in VCB $= \dfrac{0.108 \times 192}{440} = 0.047$ VCB $= 2.576 + 0.047 =$ ***2.623 m***

$$\text{diff. in KM} = \frac{0.142 \times 192}{440} = 0.062 \quad KM = 9.032 - 0.062 = \mathbf{\textit{8.970 m}}$$

$$\text{diff. in } KM_L = \frac{9.6 \times 192}{440} = 4.189 \quad KM_L = 257.3 - 4.189 = \mathbf{\textit{253.111 m}}$$

2. *Find the Hydrostatic particulars of M.V. 'Hindship' floating at the hydrostatic draft of 7.66m.*

Hydrostatic Draft	Displacement	TPC	MCTC	LCB	LCF	VCB	KM	KM_L
7.60	15693	23.29	191.8	72.690	70.979	4.040	8.238	178.9
7.66?								
7.80	16161	23.41	194.6	72.641	70.780	4.144	8.240	176.6
0.20	468	0.12	2.8	0.049	0.199	0.104	0.002	2.3

Interpolating between the above values:-

$$\text{Diff. in disp.} = \frac{468 \times 0.06}{0.20} = 140.4 \quad \text{Disp.} = 15693 + 140.4 = \mathbf{\textit{15833.4 t}}$$

$$\text{Diff. in TPC} = \frac{0.12 \times 0.06}{0.20} = 0.036 \quad TPC = 23.29 + 0.036 = \mathbf{\textit{23.326 t}}$$

$$\text{Diff. in MCTC} = \frac{2.8 \times 0.06}{0.20} = 0.84 \quad MCTC = 191.8 + 0.84 = \mathbf{\textit{192.64 mt}}$$

$$\text{Diff. in LCB} = \frac{0.049 \times 0.06}{0.20} = 0.015 \quad LCB = 72.690 - 0.015 = \mathbf{\textit{72.675 m}}$$

$$\text{Diff. in LCF} = \frac{0.199 \times 0.06}{0.20} = 0.060 \quad LCF = 70.979 - 0.060 = \mathbf{\textit{70.919 m}}$$

$$\text{Diff. in VCB} = \frac{0.104 \times 0.06}{0.20} = 0.031 \quad VCB = 4.040 + 0.031 = \mathbf{\textit{4.071 m}}$$

$$\text{Diff. in KM} = \frac{0.002 \times 0.06}{0.20} = 0.001 \quad \text{KM} = 8.238 + 0.001 = \mathbf{\textit{8.239 m}}$$

$$\text{Diff. in KM}_L = \frac{2.3 \times 0.06}{0.20} = 0.690 \quad \text{KM}_L = 178.9 - 0.690 = \mathbf{\textit{178.210 m}}$$

DETERMINATION OF HYDROSTATIC PARTICULARS IN WATER OF DENSITIES OTHER THAN SALT WATER.

3. *Find the hydrostatic particulars of M.V. 'Hindship' at a hydrostatic draft of 5.60 m. in water R.D. 1.015.*

It should be noted that the hydrostatic particulars supplied are for the vessel floating in salt water. When the vessel is floating in water of any other density, some of the tabulated particulars will alter as shown below.

DISPLACEMENT

The displacement at a particular draft i.e. a particular underwater volume obviously **varies directly** as the density of the water. THUS DISPLACEMENT IS DIRECTLY PROPORTIONAL TO DENSITY OF WATER. At a draft of 5.6 m in SW, the displ. (from the tables) = 11120 t, therefore

$$\text{Disp. in RD 1.015} = 11120 \times \frac{1.015}{1.025} = \mathbf{11011.5}\ t$$

TPC

For an immersion of 1 cm, at a particular draft, the volume of water displaced remains the same therefore the TPC (the weight of water displacement for 1 cm immersion) WOULD VARY DIRECTLY AS THE DENSITY OF THE WATER.

$$\text{TPC} = 22.32 \times \frac{1.015}{1.025} = \mathbf{22.10}\ t$$

MCTC

Though the density of water has altered, since the KM_L which is equal to KB + BM_L depends on the underwater shape and volume of the vessel as well as the shape of the waterplane, the KM_L for a particular draft remains unchanged irrespective of the change in the density of water. Therefore, if the KG is unaltered, the GM_L would remain the same. The length of the vessel at that water line also remains unchanged. Therefore, in the

$$\text{expression, MCTC} = \frac{W \times GM_L}{100\ L}$$

the only parameter that changes when the density is altered, is the displacement W, which varies directly as the density of water. Thus MCTC at a particular draft VARIES DIRECTLY AS DISPLACEMENT i.e. DIRECTLY AS THE DENSITY.

$$\text{MCTC} = 171.0 \times \frac{1.015}{1.025} = \mathit{169.33\ \ mt}$$

LCB

LCB depends on the underwater volume and its shape, which are unaltered.

LCB = *72.992 m* (UNCHANGED)

LCF

LCF depends on the shape of the water plane which remains unchanged.

LCF = *72.675 m* (UNCHANGED)

VCB

VCB depends on the shape of the underwater volume, which remains unchanged.

VCB = *2.998 m* (UNCHANGED)

KM

KM = KB + BM, depends on the underwater volume and shape as well as the shape of the vessel's waterplane. Since these have not altered,

KM = *8.578 m* (UNCHANGED)

KM_L

As stated for MCTC, the KM_L will remain unaltered.

KM_L = *223.3 m* (UNCHANGED)

4. *Find the hydrostatic particulars of M.V. 'Hindship' at a displacement of 12,200 tonnes in water of RD 1.010.*

HYDROSTATIC DRAFT

Since the hydrostatic particulars supplied are for SW, the displacement of 12,200 t. in water of RD 1.010 should be converted to its corresponding under water volume and thence to the displacement in SW for that underwater volume, to obtain the hydrostatic particulars from the tables which are provided for the ship being in SW.

For a displ. of 12,200 t in water RD 1.010, underwater volume

$$V = \frac{W}{\delta} = \frac{12200}{1.010}$$

Displacement in SW for that underwater volume

$$= V \times \delta_1 = \frac{12200}{1.010} \times 1.025 = 12381.2 \text{ t}$$

Hydrostatic draft for displacement 12381.2 t in SW.

$$= 6.00 + \frac{0.2 \times 362.2}{453}$$

Hydrostatic draft = 6.00 + 0.16 = ***6.16 m***

NOTE: It should be clearly understood that the actual displacement of the ship i.e. its weight remains 12,200t as given in the question. Her displacement at that draft in SW was found only to facilitate obtaining the data from the table which is tabulated for the vessel in SW.

TPC

$$\text{TPC (in SW)} = \frac{1.025\text{ A}}{100}$$ where A is the waterplane area at that draft.

The TPC required is for a waterplane area corresponding to the draft in SW for a displacement of 12381.2 t.

TPC for displ. 12381.2 t in SW $= 22.47 + 0.09 \times \frac{362.2}{453}$

$= 22.47 + 0.07$

$= 22.54$ t

As in Qn. 3, TPC at that draft in water δ 1.010.

$22.54 \times \frac{1.010}{1.025} = \mathit{22.21\ t}$

MCTC

As explained in Qn. 3, the MCTC at a particular draft varies directly as the displacement at that draft, that is directly as the density, MCTC for a draft corresponding to a SW.

disp. of 12381.2 t $= 174.0 + 1.7 \times \frac{362.2}{453}$

$= 174.0 + 1.36$

$= \mathit{175.36\ mt}$

∴ MCTC at that draft, in water of RD 1.010

$= 175.36 \times \frac{1.010}{1.025} = \mathit{172.79\ mt}$

LCB

The LCB depends on the underwater volume and it's shape. It will therefore correspond to a draft in SW for a displacement of 12381.2 t.

$\text{LCB} = 72.962 - \frac{0.21 \times 362.2}{453} = 72.962 - 0.017 = \mathit{72.945\ m}$

LCF

LCF depends on the shape of the waterplane. It will therefore correspond to a draft in SW for a displacement of 12381.2t

$$LCF = 72.476 - \frac{0.143 \times 362.2}{453} = 72.476 - 0.114 = \textit{72.362 m}$$

VCB

VCB depends on the shape of the underwater volume. It will therefore correspond to a draft in SW for a displacement of 12381.2t.

$$VCB = 3.204 + \frac{0.104 \times 362.2}{453} = 3.204 + 0.083 = \textit{3.287 m}$$

KM

KM depends on the underwater volume and the shape of the waterplane. It will therefore correspond to a draft in SW for a displacement of 12381.2 t.

$$KM = 8.438 - \frac{0.054 \times 362.2}{453} = 8.438 - 0.043 = \textit{8.395 m}$$

KM_L

KM_L also depends on the underwater volume and shape of the waterplane. It will therefore correspond to a draft in SW for a displacement of 12381.2 t.

$$KM_L = 210.6 - \frac{5.6 \times 362.2}{453} = 210.6 - 4.48 = \textit{206.12 m}$$

Alternatively, once the hydrostatic draft of 6.16 m was obtained, the remaining hydrostatic particulars could have been interpolated for the hydrostatic draft of 6.16 m, instead of interpolating for the SW displ. of 12381.2 t. This method would also give the same results.

Note: In general, hydrostatic data supplied to ships provide the various values at 10 cm intervals, thereby reducing the interpolation required.

5. *M.V. 'Hindship' floating at a hydrostatic draft of 7.12 m loads 900 tonnes of cargo in 3 TD. Calculate her final hydrostatic draft and state whether this loading will trim her by the head or by the stern.*

For draft 7.12 m	displacement	=	14576.2 t
Initial displacement		=	14576.2 t
Cargo loaded		=	900.0 t
Final displacement		=	15476.2 t
For displacement 15476.2 t	= draft	=	7.507 m

Final hydrostatic draft = 7.507 m

For the hydrostatic draft of 7.507 m, LCF from AP = 71.08 m, (from Hydrostatic particulars table).

From table of CAPACITIES & Cgs of DRY CARGO SPACES, Lcg of 3 TD = 80.79 m from AP.

Since the weight has been loaded forward of CF, she will **trim by the HEAD.**

6. *At 8 A.M., on 27th January, M.V. 'Hindship' was at a hydrostatic draft of 7.30 m. At 8 A.M the next day, she was at a hydrostatic draft of 7.975 m. Find the amount of cargo loaded during the day, if No. 2 DB tanks (P & S), which were full with water ballast were pumped out and the Port Tween Deck Drinking Water tank was filled with fresh water, during the interval.*

Initial displ. for draft 7.30 m	=	14993.5 t
Ballast pumped out from No. 2 (P & S)	=	capacity x density
= 404.8 x 1.025	=	(-) 414.9 t
	=	14578.6 t
FW recd. in Port TD Drinking water tank	=	capacity x density
= 49.7 x 1.0	=	(+) 49.7 t
		14628.3 t
Displ. after above operations	=	14628.3 t
Final displ. at 7.975 m draft	=	16575.8 t
		1947.5 t

Cargo loaded during the day = 1947.5 t

CALCULATION OF HYDROSTATIC DRAFT FROM DRAFTS FORD AND AFT

1. For a vessel with no trim, the drafts ford and aft is the mean draft as well as the hydrostatic draft.

2. For a vessel which is trimmed, obtain the arithmetical mean draft. Determine the position of LCF for this mean draft.

3. Calculate the Hydrostatic draft as below:

   Hydrostatic draft = draft aft ($\pm$) correction, where

   $$\text{Correction} = \frac{\text{trim} \times \text{LCF}}{\text{LBP}}$$

Note: (i) Correction is -ve when trimmed by the stern,

+ve when trimmed by the head,

(ii) Correction is unaffected by density of water, in which ship is floating.

4. From the hydrostatic tables, any required hydrostatic particulars can be determined against the hydrostatic draft.

7. *M.V. 'Hindship' is floating at a draft of F 5..65 m, A 7.45 m. Calculate (i) her hydrostatic draft (ii) her displacement.*

Initial Drafts F 5.65 m } trim 1.80 by stern
A 7.45 m }
M 6.55 m

For mean draft 6.55 m LCF = 72.048 m. ford of AP

$$\text{Corrn. to After draft} = \frac{1.80 \times 72.048}{143.16} = 0.906 \text{ m}$$

Hydrostatic draft = After draft $\pm$ corn. to A. draft.

Hydrostatic draft = 7.45 - 0.906 = 6.544 m (-ve, since V/L is trimmed stern)

Displacement for hydrostatic draft 6.544 m. = 13255.3 t

8. *M.V. 'Hindship' is floating at a draft of F 7.40 m, A 6.60 m, in dock water of RD 1.016. Calculate her*

(i) hydrostatic draft, (ii) displacement, (iii) deadweight.

(i) Original drafts F 7.40 m, A 6.60 m } trim 0.80 m by head

M 7.00 m

LCF for mean draft 7.00 m = 71.606 m

Corrn. to After draft = $\frac{0.8 \times 71.606}{143.16}$ = 0.40 m (+ve as she is trimmed by the head)

After draft = 6.60 m

Hydrostatic draft = 7.00 m

(ii) For hydrostatic draft 7.00 m, displacement in SW = 14299 t

Displacement at that draft in water of RD 1.016 = $\frac{14299 \times 1.016}{1.025}$

Displacement in RD 1.016 = 14173.4 t

(iii) Light displacement (from condition No. 1) = 5499.8 t

Deadweight = 14173.4 - 5499.8 = 8673.6 t

Deadweight = 8673.6 t

9. *M.V. 'Hindship' arrives at a port, where the density of water is 1.014 t/m^{-3} at an even keel draft of 6.72 m. She sails at a draft of F 7.2 m, A 7.3 m. 120 t of FW was received and 40 t of fuel and FW were consumed in port. Calculate the weight of cargo loaded at that port*

Sailing drafts F 7.20 m, A 7.30 m } trim 0.10 m by stern
M 7.25 m

LCF for mean draft 7.25 m = 71.343 m

After draft = 7.300 m

Corrn. to After draft $= \dfrac{0.1 \times 71.343}{143.16} = 0.050$ m

Sailing hydrostatic draft = 7.250 m

SW displ. for arrival hydro = 13657.2 t

Displ. at that draft in δ 1.014 $= 13657.2 \times \dfrac{1.014}{1.025} = 13510.6$ t

SW displ. for sailing hydro draft 7.250 m = 14877.3 t

Displ at that craft in δ 1.014 $= 14877.3 \times \dfrac{1.014}{1.025} = 14717.6$ t

Arrival displacement	=	13510.6 t
FW received	= (+)	120.0 t
Fuel & FW consumed	= (-)	40.0 t
Displ. after above operations	=	13590.6 t
Sailing displacement	=	14717.6 t
Cargo loaded in port	=	***1127.0 t***

10. *M.V. 'Hindship' arrives at a port in water of RD 1.012 with drafts F 6.15 m, A 7.22 m. Her sailing draft in water of RD 1.025 was F 5.33 m, A 5.98 m. Calculate the weight of cargo discharged at that port, if 85 tonnes of fuel and fresh water were consumed in the port.*

LCF for mean draft 6.685 m = 71.92 m

After draft = 7.22 m

Corrn. to Aft draft $= \dfrac{1.07 \times 71.92}{143.16} = 0.537$ m

Arr. hydro draft = 7.22 - 0.537 = 6.683 m

Displ. in SW for hydro. draft 6.683 m = 13572.7 t

Displ. at that draft in δ 1.012 $= 13572.7 \times \dfrac{1.012}{1.025}$

= 13400.6 t

Dep. draft F 5.33 m, A 5.98 m } trim 0.65 m by stern

M 5.655 m

LCF for mean draft 5.655 m = 72.652 m

After draft = 5.98 m

Corrn. to After draft $= \dfrac{0.65 \times 72.652}{143.16} = 0.33$ m

Dep. hydro draft = 5.65 m

Displ in SW for hydro draft 5.65 m = 11232.3 t

Arrival Displacement = 13400.6 t

Departure Displacement = 11232.3 t

Reduction in displacement = 2168.3 t

Fuel and water consumed = 85.0 t

Weight of cargo discharged = 2083.3 t

KG BY MOMENTS AND FINAL GM

In considering a ship's stability, the GM is an important criterion. GM is the vertical separation between the centre of gravity and the transverse metacentre of the ship, that is KM - KG.

As indicated in the earlier problems, the KM for any displacement is available from the hydrostatic tables.

The KG of the vessel is usually obtained by the principle of moments. The moments are taken about the keel of the vessel. The vertical moment of the ship's displacement is obtained as the product of the displacement and the KG (not the KG corrected for free surface effect). Thereafter, such calculations may involve three operations, i.e. loading, discharging and shifting.

Moments of weights loaded are added and those of weights discharged, subtracted. When a weight is shifted, the change in the moment about the keel is obtained as the product of the weight shifted and the vertical distance through which it is shifted. This quantity is **added** when weights are shifted **upwards** and **subtracted** when weights are shifted **downwards**.

$$\text{Final KG} = \frac{\text{Final Moment}}{\text{Final Displacement}}$$

Free surface of liquid in any compartment causes a virtual rise in the centre of gravity and, therefore, a corresponding virtual loss in the GM of the vessel. Therefore, this correction (FSC) is subtracted from GM (Solid) to obtain GM (Fluid). Conversely GM (Solid) can be obtained by adding the FSC to GM (Fluid). The FSC is customarily applied to the GM and not to the KG.

11. *M.V. 'Hindship' arrives port in Condition No. 11. She then loads and discharges as follows:-*

Compartment	*Disch.*	*Load*	*Kg.*	*V.Moments*
Locomotives on Deck	*760 t*		*13.83 m*	*10510 mt*
2 TD	*400 t*		*10.70 m*	*4280 mt*
4 TD	*200 t*		*10.40 m*	*2080 mt*
2 TD		*300 t*	*10.70 m*	*3210 mt*
4 TD		*150 t*	*10.40 m*	*1560 mt*

Assuming the FS correction in the final condition was 0.107 m and bunker consumption was negligible, calculate the GM (Fluid), after the above operations.

	Weights (t)		Kg (m)	V. Moments (mt)	
	Disch.	Load		Disch.	Load
Ship in condition 11		15460.2	7.726		119451
Locomotives	760		13.83	10510	
2 TD	400		10.72	4288	
4 TD	200		10.42	2084	
2 TD		300.0	10.72		3216
4 TD		150.0	10.42		1563
	1360	15910.2		16882	124230

Final V. Moments = 124230 - 16882 = 107348 mt

Final Weight = 15910.2 - 1360 = 14550.2

$$\text{Final KG} = \frac{\text{Final Moment}}{\text{Final Wt.}} = \frac{107348}{14550.2} = 7.378 \text{ m}$$

KM for displacement of 14550.2 t	=	8.250 m
Final KG	=	7.378 m
GM (Solid)	=	0.872 m
FSC	=	(-) 0.107 m
GM (Fluid)	=	***0.765 m***

When weights are shifted and the KG of the ship is to be calculated by moments, the moment of shift is obtained as the product of the weight shifted and the vertical distance through which it is shifted. The moment is **ADDED** if the shift is **UPWARDS** and **SUBTRACTED** if the shift is **DOWNWARDS, REMEMBER THAT SHIFTING A WEIGHT DOES NOT ALTER THE DISPLACEMENT OF THE VESSEL.**

12. *M. V. 'Hindship' is at Bombay in Condition No. 4. A consignment of cargo weighing 500 tonnes is shifted from 3 Hold to the Upper Deck, Kg 13.28 m. Find the final GM (Solid and Fluid).*

Upper deck Kg = 13.28 m

3 Hold Kg = 5.00 m

Distance shifted 'd' = 8.28 m (upwards)

			KG (m)	V moments (mt)
Initial displacement	=	19617.0 t	7.272	142648
Wt. shifted	=	500.0 t	8.280	(+) 4140
Final displacement	=	19617.0 t		
Final V. moment	=			146788

$$\text{Final KG} = \text{Final KG} = \frac{\text{Final Moment}}{\text{Final Displacement}} = \frac{146788}{19617} = 7.483 \text{ m}$$

Alternative method to find KG

$$GG_1 = \frac{w \times d}{W} = \frac{500 \times 8.28}{19617}$$

$$= 0.211 \text{ m}$$

Original KG = 7.272 m

GG_1 (+) = 0.211 m

Final KG = 7.483 m

KM for condition No. 4 = 8.435 m

Final KG = 7.483 m

GM (Solid) = 0.952 m

FSC for cond. No. 4 = (-) 0.070 m

GM (Fluid) = 0.882 m

13. *M. V. 'Hindship' floating in Condition No. 2 loads 400 tonnes of cargo in No. 1 TD and on the voyage consumes the entire oil in No. 2 DB tanks P & S. Calculate GM (Solid & Fluid). As change of displacement is negligible, assume FSC constant.*

		Wt. (t)	KG (m)	V. Moment (mt)
Initial displacement		7799.0	6.942	54137
Cargo loaded	(+)	400.0	11.170	(+) 4468
		8199.0		58605
Oil consumed	(-)	384.6	0.65	(-) 250
Final Wt.		7814.4	Final V. Moment	58355

Final KG = $\frac{58355}{7814.4}$ = 7.468 m

KM = 9.745 m (The KM changes with change of displacement. In this case however, since displacement has hardly changed, KM given for the condition has been used.)

KG = 7.468 m

GM (Solid) = 2.277 m

FSC = (-) 0.233 m (obtained from particulars of Condition No. 2.)

GM (Fluid) = 2.044 m

14. *M.V. 'Hindship' floating in condition No. 5, discharges the entire cargo from No. 1 TD, No. 5 Poop Deck and refrigerated cargo spaces. No. 4 DB tank (C) is filled with water ballast. FSC in final condition is 0.0895 m. Calculate her GM (Fluid).*

		Weights (t)	KG (m)	V. Moment (mt)
Condition No. 5		18529.3	7.539	139700
No. 1 TD	(-)	681.7	11.17	(-) 7615
No. 5 Poop Deck	(-)	542.6	13.76	(-) 7466
Ref. Cargo	(-)	235.0	10.36	(-) 2435
No. 4 (C) (257.4 x 1.025)	(+)	263.8	0.63	(+) 166.2
Final displacement		17333.8	Final moment	122350.2

$$\text{Final KG} = \frac{122350.2}{17333.8} = 7.058 \text{ m}$$

KM for displacement of 17333.8 t	=	8.280 m
KG	=	7.058 m
GM (Solid)	=	*1.222 m*
FSC in Final condition	=	(-) 0.0895 m
GM (Fluid)	=	*1.132 m*

15. *M. V. 'Hindship' floating in Condition No. 7, discharges the entire cargo in No. 2 TD and fills in the Bulbous Bow with 186.6 tonnes of water ballast, Kg. 3.52 m. Assuming theoretically that the deck cargo of locomotives was shifted to No. 2 TD and also No. 4 (P & S) DB tanks were slackened, increasing the FSC by 0.035 m, calculate the final GM (Fluid) of the ship.*

		Weights (t)	KG (m)	V.Moments (mt)
Cond. No. 7		18529.3	7.807	144653
2 TD	(-)	1058.4	10.720	(-) 11346
B. Bow	(+)	186.6	3.520	(+) 656.8
Shift of locos		760.0	*3.110	(-) 2363.6
(Does not alter displ.)				

Final Wt. = 17657.5 Final Moment = 131600.2

*Kg of locos = 13.83 m

Kg of No: 2 TD = 10.72 m

Shift of wt. Downwards = 3.11 m

$$\text{Final KG} = \frac{\text{Final Moment}}{\text{Final Wt.}} = \frac{131600.2}{17657.5} = 7.453 \text{ m}$$

KM for displacement of 17657.5 t	=	8.295 m
KG	=	7.453 m

GM (Solid) = 0.842 m

Final FSC = 0.084 + 0.035 = (-) 0.119 m

GM (Fluid) = 0.723 m

16. *M. V. 'Hindship' is in condition No. 2. Find her GM (Fluid) after the following operations are carried out:-*

Loads	*1 TD*	*601 tonnes*
Loads	*3 Hold*	*1520 tonnes Kg1.70 m*
Loads	*5 Hold*	*420 tonnes*

Pumps out F. Pk Tank

Pumps out No. 4 DB Tanks (P & S)

FSC in the final condition, is 0.155 m,

		Weight (t)	KG (m)		V.Moments (mt)
Cond. No. 2		7799.0	6.942		54137
Loads 1TD	(+)	601	11.17	(+)	6713.2
Loads 3 Hold	(+)	1520	1.70	(+)	2584.0
Loads 5 Hold	(+)	420	6.91	(+)	2902.2
		10,340.0			66,336.4
Pumped out F. Pk.	(-)	106.1	6.31	(-)	669
Pumped out 4 (P&S)	(-)	261.2	0.68	(-)	178
Final Wt.	=	9972.7	Final moments	=	65,489.4

Final KG $= \frac{65489.3}{9972.7} = 6.567$ m

KM for displacement of 9972.7 t = 8.840 m

KG = 6.567 m

GM (Solid) = 2.273 m

FSC for final condition = (-) 0.155 m

GM (Fluid) = 2.118 m

FREE SURFACE CORRECTION

As stated earlier, a virtual rise in the CG and a consequent virtual loss of GM occurs whenever there is a free surface of liquid in any compartment in the ship. This loss is not present if the tank is either completely full or completely empty, as there is no free surface of liquid in either of the conditions. The virtual loss in GM is obtained by the expression

$$\frac{i}{V} \times \frac{\delta t}{\delta s}$$

Where i = moment of inertia of the free surface area

V = underwater volume of the ship

δt = density of liquid in the tank.

δs = density of water in which the ship is floating.

The numerator ($i \times \delta t$) is referred to as the Free Surface Moment and the denominator ($V \times \delta s$) is the displacement of the ship. The denominator being the ship's displacement, is independent of the density of water in which the ship is floating. The moments of inertia for the various tanks are available on page 18 of the Booklet of Trim and Stability particulars of M.V. 'Hindship'.

The moment of inertia of each slack tank is multiplied by the density of liquid in that tank to obtain the free surface moment. The total free surface moment divided by the displacement, as shown on page 19 of the above booklet gives the virtual loss in GM or FSC. For a particular displacement, FSC is independent of the density of water in which the ship floats.

17. *M.V. 'Hindship' at a displacement of 18420 tonnes, has a free surface moment of 1972 mt.*

(a) Calculate the free surface correction.

(b) If at the same displacement, the FS moment was 1104 mt, calculate the FSC.

a) $\text{FSC} = \dfrac{\text{FS Moment}}{\text{Displacement}} = \dfrac{1972}{18420} = $ ***0.107 m***

b) $\text{FSC} = \dfrac{\text{FS Moment}}{\text{Displacement}} = \dfrac{1104}{18420} = $ ***0.060 m***

18. *M. V. 'Hindship' at a displacement of 14240 tonnes, had a FSC of 0.087 m. Find the FSC after having discharge 3210 tonnes of cargo, assuming the tank soundings remained unchanged.*

Since FSC	=	$\frac{\text{FSM}}{\text{Displacement}}$		
Free Surface moment	=	FSC x displacement		
	=	0.087 x 14240	=	1238.88 mt
Final displacement	=	14240 - 3210	=	11030 t
FSC after discharge	=	$\frac{\text{FSM}}{\text{Displacement}}$	=	$\frac{1238.88}{11030}$
	=	0.112 m		
Final FSC	=	***0.112 m***		

19. *M.V. 'Hindship' floating at a displacement of 8420 tonnes, has a free surface moment of 1542 mt. Find her GM (Fluid) if KG = 7.651 m.*

FSC	=	$\frac{\text{Free surface moment}}{\text{Displacement}}$	=	$\frac{1542}{8420}$
			=	0.183 m
KM for displacement 8420 t			=	9.413 m
KG			=	7.651 m
GM (Solid)			=	1.762 m
FSC			=	0.183 m
GM (Fluid)			=	***1.579 m***

20. *M.V. 'Hindship' floating at a mean draft of 7.50m, KG 7.726 m has the following tanks slack.*

No. 3 D B tanks P, C & S	*containing Water Ballast*
No. 5 D B tank Port	*containing D O*
No. 5 D B tank Stbd.	*containing H F O*

'Tween deck F W tank Stbd. containing F W

(a) Find her GM (Fluid)

(b) If the displacement of the ship is 10,280 t with the same tanks slack, calculate the FSC.

(a) For draft 7.5 m,

Displacement = 15459.5 t

KM = 8.238 m

		Moments of Inertia (m^4)		Density		FS Moment (mt)
No. 3 P & S 2 x 227 (SW)	=	454	x	1.025	=	465.35
No. 3 Centre (SW)	=	1181	x	1.025	=	1210.53
No. 5 Port (D.O.)	=	172	x	0.88	=	151.36
No. 5 Stbd. (H.F.O.)	=	95	x	0.95	=	90.25
TD FW tank	=	42	x	1.0	=	42.00
Total FS Moment					=	1959.49

$$FSC = \frac{FSM}{Displacement} = \frac{1959.49}{15459.5}$$

$$= 0.127 \text{ m}$$

KM	=	8.238 m
KG	=	7.726 m
GM (Solid)	=	0.512 m
FSC	=	0.127 m
GM (Fluid)	=	*0.385 m*

b) $FSC = \frac{FSM}{Displacement} = \frac{1959.49}{10,280}$

FSC = 0.191 m

DETERMINATION OF GM (FLUID)

21. *M.V. 'Hindship' in Condition No. 4, discharges the entire cargo from 1 TD and No. 3 TD. The entire HFO from the settling and service tanks P & S is shifted to No. 4 DB tank centre. Find the final KG and GM (Fluid).*

	Weights (t)	KG (m)	V. Moments (mt)
Condition No. 4 displ.	19617	7.272	142648
No. 1 TD (-)	681.7	11.170	(-) 7615
No. 3 TD (-)	887.7	10.370	(-) 9205
Shift of HFO	$131 \left\{ \begin{matrix} 6.09 - 0.63 \\ = 5.46 \end{matrix} \right\} \downarrow 5.46$		(-) 715

Final Wt = 18047.6 Final Moment = 125113

Final KG = $\frac{125113}{18047.6}$ = 6.932 m

Original FS Moment	=	1372 mt
FS Moment of settling & Service tanks	= (-)	15 mt
FS Moments of No. 4 centre = 1408 x 0.95	= (+)	1337.6 mt
Final FS Moment	=	2694.6 mt
Final FSC = $\frac{2694.6}{18047.6}$	=	0.149 m
KM for displacement 18047.6	=	8.316 m
KG	=	6.932 m
GM (Solid)	=	1.384 m
FSC	=	0.149 m
GM (Fluid)	=	***1.235 m***

22. *M.V. 'Hindship' at a draft of F 5.38 m, A 6.17 m, GM (Fluid) 0.83 m. FSC 0.092 m discharges 430 t from No. 3 TD, Vcg 10.2 m, and loads 250 t in No. 5 LTD. 300 t of fuel oil was received equally distributed in No. 2 DB tanks (P & S). Calculate her GM (Fluid).*

Original drafts F 5.38 m, A 6.17 m } trim 0.79 m by stern

M 5.775 m

LCF for mean draft 5.775 m	=		72.601 m
After draft	=		6.17 m
Corrn. $= \dfrac{0.79 \times 72.601}{143.16}$	=	(-)	0.40 m
Original hydrostatic draft	=		5.77 m
Original displacement	=		11501.7 t
KM	=		8.513 m
Original GM (Fluid)	=		0.830 m
FSC	=		0.092 m
GM (Solid)	=		0.922 m
KM	=		8.513 m
Original KG	=		7.591 m

		Weights (t)	KG (m)		V. Moments (mt)
Original displ.		11501.7	7.591		87309.4
Disch. from 3 TD	(-)	430	10.2	(-)	4386.0
Loaded in No. 5 LTD	(+)	250	10.69	(+)	2672.5
Fuel oil in 2 DB tank	(+)	300	0.65	(+)	195.0
Final Weight	=	11621.7	Final V. Moments =		85790.9

Final KG = $\frac{85790.9}{11621.7}$ = 7.382 m

Original FSM = 0.092 x 11501.7 = 1058.2 mt

FSM in 2(P&S) = 1436 x 0.95 = (+) 1364.2 mt

Final FSM = 2422.4 mt

Final FSC = $\frac{2422.4}{11621.7}$ = 0.208 m

KM for displacement 11621.7 t = 8.495 m

Final KG = 7.382 m

Final GM (Solid) = 1.113 m

FSC = 0.208 m

Final GM (Fluid) = 0.905 m

23. *M.V. 'Hindship' at a river port in water of RD 1.014 has a displacement of 10,230 t. GM (Fluid) 0.82 m. FSC 0.077 m. She loads 470 t of cargo Kg 9.8 m. 150 t of water ballast is run into No. 1 DB tank. Find her final GM (Fluid).*

For displacement 10,230 t in density 1,014

equivalent weight in salt water = $\frac{10,230 \times 1.025}{1.014}$

= 10340.9 t

(her displacement in SW when floating at the same draft).

GM (Fluid) = 0.820 m

FSC = 0.077 m

GM (Solid) = 0.897 m

We obtain the KM for 10340.9 t from the tables as explained in question 4.

KM for displacement 10340.9 t in SW = 8.744 m

KG = KM - GM (Solid) = 8.744 - 0.897 = 7.847 m

		Weight (t)	KG (m)		V. Moments (mt)
Original displ.		10230	7.847		80274.8
Loaded	(+)	470	9.8	(+)	4606.0
Ballast in 1 DB	(+)	150	1.14	(+)	171.0
Final Weight	=	10850	Final V. Moments	=	85051.8

$$\text{Final KG} = \frac{850051.8}{10850} = 7.839 \text{ m}$$

Initial FSM = 0.077 x 10230 = 787.7 mt.

FSM in 1 DB tank = 419 x 1.014 = 424.9 mt.

Final FSM = 1212.6 mt.

$$\text{Final FSC} = \frac{1212.6}{10850} = 0.112 \text{ m}$$

For displacement 10850 t in density 1.014 equivalent weight in SW

$$= \frac{10850 \times 1.025}{1.014} = 10967.7 \text{ t}$$

KM for displacement 10967.7 t in SW = 8.607 m

Final KG = 7.839 m

Final GM (Solid) = 0.768 m

FSC = 0.112 m

Final GM (Fluid) = 0.656 m

24. *M.V. 'Hindship' in condition No. 7 pumps out 60 tonnes of ballast each from No. 4 DB tanks P and S. The entire diesel oil in No. 5 tank P is consumed in shifting to the dock. Calculate her GM (Fluid) on arriving the dock where the RD of water is 1.007.*

		Weights (t)	KG (m)		V. Moments (mt)
Initial displ.		18529.3	7.807		144653
No. 4 DB Tk P&S	(-)	120.0	0.68	(-)	82
No. 5 DB Tk P	(-)	17.7	0.21	(-)	4
Final Weight	=	18391.6	Final V. Moment	=	144567

Final KG $= \frac{144567}{18391.6} = 7.861$ m

Initial FSM = 1552 mt

FSM of No. 4 P & S = 542 x 1.025 = (+) 556 mt

FSM of No. 5 P = (-) 152 mt

Final FSM = 1956 mt

Final FSC $= \frac{\text{Final FSM}}{\text{Final Displ.}} = \frac{1956}{18391.6} = 0.106$ m

For displacement 18391.6 t in δ 1.007, equivalent weight in SW

$= 18391.6 \times \frac{1.025}{1.007} = 18720.3$ t

From tables, KM for displ. 18720.3 t = 8.364 m

Final KG = 7.861 m

Final GM (Solid) = 0.503 m

Final FSC = 0.106 m

Final GM (Fluid) = 0.397 m

25. *M. V. 'Hindship' displacing 12,400 t in water of RD 1.010, has a GM (Fluid) of 0.58 m. FSM 1530 mt. She loads 620 t in No. 2 Hold, Kg 5.02 m. No. 2 DB tanks P & S which contained 50 t each SW ballast was pumped out. A 150 t parcel of cargo was shifted from No.2 Hold to No.3 TD. Calculate her final GM (Fluid).*

For displ. 12,400 t in δ 1.010, equivalent weight in SW.

$$= \quad 12400 \times \frac{1.025}{1.010} \quad = \quad 12584 \text{ t}$$

From tables, KM for displ. 12584 t = 8.373 m

Initial GM (Fluid) = 0.580 m

$$\text{FSC} = \frac{1530}{12400} = 0.123 \text{ m}$$

Initial GM (Solid) = 0.703 m

Initial KG = 7.670 m

		Weights (t)	KG (m)		V. Moments (mt)
Initial displ.		12400	7.67		95108
No. 2 LH	(+)	620	5.02	(+)	3112.4
No. 2 DB Tk, P&S	(-)	100	0.65	(-)	65.0
Shifted		150	↑ 5.39	(+)	808.5
Final Weight	=	12920	Final V. Moment	=	98964

$$\text{Final KG} = \frac{98964}{12920}$$

Initial FSM = 1530 mt

No. 2 DB tank P&S = 1436 x 1.025 = - 1472 mt

Final FSM = 58 mt

$$\text{Final FSC} = \frac{58}{12920} = 0.004 \text{ m}$$

For displ. 12920 t in RD 1.010, equivalent weight in SW

$$= 12920 \times \frac{1.025}{1.010} = 13112 \text{ t}$$

From tables, KM for displ. 13112 t = 8.325 m

Final KG = 7.660 m

Final GM (Solid) = 0.665 m

FSC = 0.004 m

Final GM (Fluid) = 0.661 m

26. *M. V. 'Hindship' berthed in dock where RD of the Water is 1.007 at a draft of F 7.87 m, A 8.32 m, KG 7.45 m, FSM 970 mt. She discharges 410 t of cargo from 2 TD. A 60 t case is shifted from deck Kg 14.7 m to No. 2 Hold. 110 t of water was received in No. 8 P and S tanks Kg. 2.77 m filling them completely. Calculate her GM (Fluid), if additional FSE was created in No. 3 DB tank (C) containing HFO.*

Initial draft F 7.87 m, A 8.32 m } trim 0.45 m by stern

M 8.095m

LCF for mean draft 8.095 m = 70.507 m

After draft = 8.320 m

$$\text{Corrn. to Aft draft} = \frac{0.45 \times 70.507}{143.16} = 0.222 \text{ m}$$

Hydrostatic draft = 8.098 m

Displacement at 8.098 m draft in density 1.007

$$= \frac{16870.7 \times 1.007}{1.025} = 16574.4 \text{ t}$$

		Weights (t)	Kg. (m)		V.Moments (mt)
Initial displ.		16574.4	7.45		123479.3
Discharged from 2 TD	(-)	410	10.72	(-)	4395.2
Shifted		60	↓ 9.72	(-)	583.2
Water received in No. 8 (P&S)		110	2.77	(+)	304.7

Final Wt. = 16274.4 Final V.Moment = 118805.6

Final KG = $\frac{118805.6}{16274.4}$ = 7.300 m

Original FSM = 970 mt

No. 8 (P&S) 23 x 1.0 = (-) 23 mt

No. 3 (C) 1181 x 0.95 = (+) 1122 mt

Final FSM = 2069 mt

Final FSC = $\frac{2069}{16274.4}$ = 0.127 m

For displacement 16274.4 t in density 1.007, equivalent

Weight in SW = $\frac{16274.4 \times 1.025}{1.007}$

KM for above displacement = 8.249 m

KG = 7.300 m

GM (Solid) = 0.949 m

FSC = 0.127 m

Final GM (Fluid) = 0.822 m

27. *M. V. 'Hindship' at a displacement of 7087.3 t, KG 7.45 m, FSC 0.103 m, is in water of density 1.012 t/m³. No. 2 Hold and No. 5 Hold which were empty are fully loaded with cargo stowing at 0.75 m³/t and 1.08 m³/t respectively. The After Peak tank which was empty, is filled with water of density 1.005 t/m³. Calculate her GM (Fluid) in the final condition.*

Cargo loaded in 2 Hold $= \dfrac{3586.7}{0.75} = 4782.3$ t

Cargo loaded in 5 Hold $= \dfrac{684.0}{1.08} = 633.3$ t

Ballast in A. PK. tank = 117.8 x 1.005 = 118.4 t

	Weights (t)	KG (m)	V. Moments (mt)
Original displ.	7087.3	7.45	52800
Loaded in No. 2 Hold	(+) 4782.3	4.98	(+) 23816
Loaded in No. 5 Hold	(+) 633.3	6.91	(+) 4376
Ballast in A. Pk.	(+) 118.4	8.81	(+) 1043
Final Wt.	= 12621.3	Final V. Moment	= 82035

Final KG $= \dfrac{82033}{12621.3} = 6.500$ m

Original FSM = 0.103 x 7087.3 = 730 mt

For displacement 12621.3 t in density 1.012,

Equivalent weight in SW $= \dfrac{12621.3 \times 1.025}{1.012} = 12783.4$ t

KM for above displacement = 8.354 m

Final KG = 6.500 m

GM (Solid) = 1.854 m

Final FSC $= \dfrac{730}{12621.3} = 0.058$ m

GM (Fluid) = 1.796 m

28. *M. V. 'Hindship' loading in FW is at a hydrostatic draft of 7.30 m KG 7.90 m. 1300 tonnes of cargo is to be loaded. What should be the KG of the cargo to be loaded so that her final GM is 0.5m, i) in SW (ii) in FW.*

(i) Displ. for hydrostatic draft 7.30 m in SW = 14993.5 t

Displ. at that draft in FW $= \dfrac{14993.5 \times 1.0}{1.025} = 14627.8$ t

Cargo to be loaded = 1300 t

Final Displacement = 15927.8 t

KM in SW for displ. 15927.8 t = 8.239 m

GM reqd. = 0.500 m

Final KG reqd. = 7.739 m

		Weight (t)	KG (m)	V. Moments (mt)
Initial displ.		14627.8	7.9	115559.6
Loaded	(+)	1300	x	(+) 1300x
Final Wt.	=	15927.8	Final V. Moments	= 115559.6 + 1300x

$$\text{Final KG} = \frac{115559.6 + 1300x}{15927.8} = 7.739 \text{ m}$$

$$x = \frac{(7.739 \times 15927.8) - 115559.6}{1300} = 5.927 \text{ m}$$

Kg of weight to be loaded = 5.927 m

(ii) For displacement 15927.8 t in FW, equivalent weight in

$$\text{SW} = \frac{15927.8 \times 1.025}{1.000} = 16326 \text{ t}$$

KM for displacement 16326 t in SW	= 8.243 m
GM required	= 0.500 m
Final KG required	= 7.743 m

	Weights (t)	KG (m)	V. Moments (mt)
Initial displ.	14627.8	7.9	115559.6
Loaded	(+) 1300	x	(+) 1300x

Final Wt. = 15927.8 Final V. Moments = 115559.6 + 1300x

$$\text{Final KG} = \frac{115559.6 + 1300\,x}{15927.8} = 7.743 \text{ m}$$

$$x = \frac{(7.743 \times 15927.8) - 115559.6}{1300} = 5.976 \text{ m}$$

Kg of weight to be loaded = 5.976 m

29. *M. V. 'Hindship' floating at a mean draft of 5.5 m. KG 7.53 m, FSC in the final condition 0.104 m, has to load 1200 tonnes of cargo in No. 2 Hold and No. 2 TD. Find the amount of cargo to be loaded in each space to complete the ship with a GM (Fluid) of 1 m.*

Since the trim of the vessel is not given, the mean draft may be considered as the hydrostatic draft.

Displacement for hydrostatic draft 5.5 m	= 10897 t
To load	= 1200 t
Final Displacement	= 12097 t
GM (Fluid) required	= 1.000 m
FSC	= 0.104 m
GM (Solid) required	= 1.104 m

KM for displacement of 12097 t = 8.429 m

KG required = 7.325 m

Let 'x' tonnes be loaded in No. 2 Hold (Kg = 4.98 m)

Then cargo loaded in No. 2 TD = (1200 - x), (Kg 10.72 m)

	Weights (t)	KG (m)	V. Moment (mt)
Initial displ.	10,897	7.53	82054.4
No. 2 Hold	x	4.98	4.98x
No. 2 TD	(1200 - x)	10.72	12864 - 10.72x

Final Weights = 12097 Final Moments = 94918.4 - 5.74x

Final KG = $7.325 = \frac{94918.4 - 5.74x}{12097}$

12097 x 7.325 = 94918.4 - 5.74x

5.74x = 94918.4 - 88610.5 = 6307.9

x = $\frac{6307.9}{5.74}$ = 1098.9 t

Cargo to load in No. 2 Hold = 1098.9 t

Cargo to load in No. 2 TD = 1200 - 1098.9

= 101.1 t

Cargo to load No. 2 Hold = *1098.9 t*

Cargo to load No. 2 TD = *101.1 t*

30. ***M.V. 'Hindship' arrives port in condition No. 7. One of the locomotives, weighing 76 tonnes is to be discharged, using the ship's jumbo derrick; the head of which is 25 metres above the keel. Find her GM (Fluid).***

(i) ***When the locomotive is hanging on the derrick, 0.5 metre above the deck.***

(ii) ***When the locomotive has been discharged.***

			Weights (t)	K.G. (m)	V. Moments (mt)
(i)	Condition No. 7		18529.3	7.807	144653
	* Shifted		76.0	11.17	(+) 849
	Final Wt.	=	18529.3	Final Moment	= 145502

(* When a wt. is lifted by the derrick the virtual Cg of the wt. is the derrick head, irrespective of the ht. through which the wt has been lifted).

Final KG = $\frac{145502}{18529.3}$ = 7.852 m

KM (unchanged) = 8.349 m

GM (Solid) = 0.497 m

FSC (unchanged) (-) = 0.084 m

GM (Fluid) = ***0.413 m***

(ii)			Weights (t)	KG. (m)		V. Moments (mt)
	Condition No. 7		18529.3	7.807		144653
	discharged	(-)	76	13.83	(-)	1051
	Final Wt.	=	18453.3	Final Moment	=	143602

Final KG = $\frac{143602}{18453.3}$ = 7.782 m

KM for Final displacement = 8.344 m

Final KG = 7.782 m

GM (Solid) = 0.562 m

Original FSM = 1552 mt

Final FSC = $\frac{1552}{18453.3}$ = (-) 0.084 m

GM (Fluid) = ***0.478 m***

FORE & AFT SHIFT OF G

When finding moments about AP, moments of weights LOADED are ADDED and those of weights DISCHARGED are SUBTRACTED.

When weights are shifted in the fore & aft direction, the moment of the shift is obtained as the product of the wt. shifted and the horizontal distance through which it is shifted. The moment is ADDED if the wt is shifted FOR'D and SUBTRACTED if the wt is shifted AFT, on the same principle as for moments of weights shifted vertically, when considering moments about the keel.

31. *M. V. 'Hindship', when floating in Condition No. 2, transfers the water ballast in the Fore Peak tank to the After Peak tank. Find the horizontal shift of the ship's centre of gravity.*

LCG of ship in Condition No. 2 = 65.344 m

Lcg of Fore Peak Tank = 137.18 m

Lcg of Aft. Peak Tank = 3.58 m

∴ Distance ballast was shifted aft = 137.18 - 3.58 = 133.60 m

	Weights (t)	LCG (m)	L. Moments (mt)
Initial Displ.	7799	65.344	509617
Shifted	106.1	133.6	(-) 14175
Final Weight	7799	Final Moments	495442

Final LCG = $\frac{\text{Final L. Moments}}{\text{Final Wt.}}$

= $\frac{495442}{7799}$ = 63.526 m

Final LCG = 63.526 m ford of AP

Initial LCG = 65.344 m ford of AP

Horizontal Shift of G = 1.818 m

Shift of G = ***1.818 m towards Stern***

32. *M.V. 'Hindship' is floating at a draft of F 8.68 m, A 8.88 m in water of density 1.010 tonnes/m³. LCG 72.129 m. It is desired to obtain an LCG of 71.9 m by discharging 400 t of cargo. Calculate the position from where the weight should be discharged.*

Original Draft F 8.68 m, A 8.88 m } trim 0.2 m by stern

M 8.78 m

Aft. Draft	=	8.880 m
Corrn. to Aft draft $= \frac{0.2 \times 69.927}{143.16}$	=	0.098 m
Hydro draft	=	8.782 m
Displ in SW for hydrostatic draft 8.782 m	=	18521.4 t
Hence displ. at that draft in density 1.010	=	$\frac{18521.4 \times 1.010}{1.025}$
	=	18250.4 t

	Weight (t)	LCG (m)	L. Moments (mt)
Original displ.	18250.4	72.129	1316383
Disch.	(-) 400	x	(-) 400x
Final displ.	17850.4	Final L. Moments	1316383 - 400x

$$\text{Final LCG} = 71.9 = \frac{1316383 - 400x}{17850.4}$$

$$x = \frac{(71.9 \times 17850.4) - 1316383}{400} = 82.348 \text{ m}$$

400 t to be discharged from 82.348 m. ford of AP

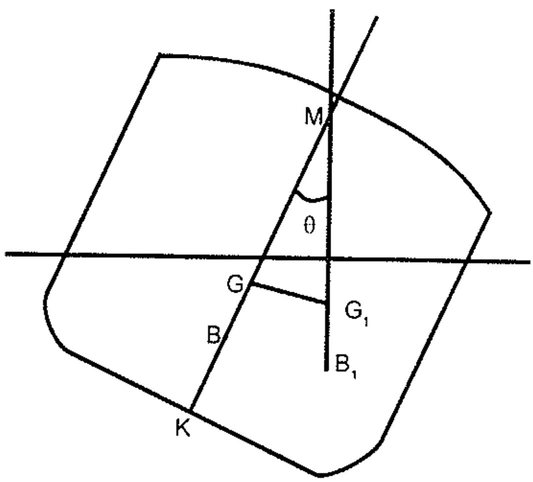
ATHWARTSHIP SHIFT OF 'G' AND LIST

When only one weight is loaded, discharged or shifted, the shift of G, i.e. GG_1 may be calculated by the expressions

$GG_1 = \frac{w \times d}{W + w}, \frac{w \times d}{W - w}$ or $\frac{w \times d}{W}$ respectively, where W is the original displacement and w the weight loaded discharged or shifted. For loading and discharging 'd' is the athwartship distance between g of the weight and G of the ship. In the case of shifting, 'd' is the athwartship distance through which the weight is shifted. For an upright ship, G is on the centre line.

When more than one weight is involved, it would be more convenient to calculate GG_1 by moments about the centre line.

The resultant moment about the centre line obtained as the algebraic sum of moments to port and moments to starboard, divided by the final displacement gives the athwartship GG_1.



From the figure it can be seen that the list may be calculated by the expression

$$\tan \theta = \frac{GG_1}{GM\ (Fluid)}$$

The above formula can be used without appreciable loss of accuracy for very small angles of list only because, as she lists, her water plane area changes causing a change in her KM and consequently her GM. Lists of larger angles can be correctly determined by plotting her heeling arm curve over her curve of statical stability, as shown, later.

33. *M. V. 'Hindship', displacing 7720 tonnes KG 8.42 m, no FSC, loads 330 tonnes, Kg 10.52 m and cg 2 m off the centre line to starboard. Calculate the resultant list.*

		Weights (t)	KG (m)		V. Moment (mt)
Initial displ.		7720	8.42		65002.4
Loaded	(+)	130	10.52	(+)	1367.6
Final Wt.	=	7850	Final Moment	=	66370

$$\text{Final KG} = \frac{66370}{7850} = 8.455 \text{ m}$$

KM for displacement of 7850 t = 9.720 m

GM (Solid) = 1.265 m

FSC = NIL

GM (Fluid) = 1.265 m

$$\text{Horizontal Athwartship shift of G} = \frac{w \times d}{W + w}$$

$$= \frac{2 \times 130}{7850}$$

$$= 0.03312$$

$$\tan \theta = \frac{GG_1}{GM\ (Fluid)}$$

$$= \frac{0.03312}{1.265}$$

θ = Angle of List = 1^0 30′ to Stbd

34. ***M. V. 'Hindship' is in Condition No. 2. Find the shift of her CG if 100 tonnes of cargo is shifted transversely over a distance of 10 m. Also find the resulting list.***

$$\text{Transfer } GG_1 = \frac{w \times d}{W} = \frac{100 \times 10}{7799} = 0.128 \text{ m}$$

$$GG_1 = 0.128 \text{ m}$$

GM (Fluid) for Condition No. 2 = 2.57 m

$$\tan\theta = \frac{GG_1}{GM\ (Fluid)} = \frac{0.128}{2.57}$$

$$\theta = \textit{Angle of List} = 2^0\ 51'$$

35. ***M. V. 'Hindship' floating at a draft of F 5.70 m, A 7.60 m, KG 6.12 m, loads 400 t of cargo in 3 TD, 2 m off the centre line to port. Calculate her angle of list No. FSC.***

Original drafts F 5.70 m, A 7.60 m } trim 1.90 m by stern
M 6.65 m

LCF for mean draft 6.65 m		=	71.955 m
After draft		=	7.600 m
Corrn. to After draft	= $\frac{1.90 \times 71.955}{143.16}$	=	(-) 0.955 m
Hydrostatic draft		=	6.645 m
For Hydrostatic draft 6.645 m, displacement		=	13486 t

	Weights (t)	KG (m)	V. Moments (mt)
Initial displacement	13486	6.12	82534
Loaded	(+) 400	10.37	(+) 4148
Final Wt.	= 13886	Final V. Moments	= 86682

Final KG $= \frac{86682}{13886}$ = 6.242 m

KM for displacement of 13886 t = 8.278 m

GM (Solid) = 2.036 m

FSC = NIL

GM (Fluid) = 2.036 m

Transverse $GG_1 = \frac{w \times d}{W + w} = \frac{400 \times 2}{13886} = 0.0576$ m

$$\tan \theta = \frac{GG_1}{GM\ (Fluid)} = \frac{0.0576}{2.036}$$

θ = Angle of List = 1°37′ to Port

36. *M. V. 'Hindship' in condition No. 5, receives 100 tonnes of D.O. in No.7 Port DB tank, Cg 5 metres off the centre line. Calculate the resulting list.*

	Weights (t)	KG (m)	V. Moments (mt)
Condition No. 5 displ.	18529.3	7.539	139700
No. 7 Port	(+) 100.0	2.620	(+) 262
Final Wt.	= 18629.3	Final V. Moments =	139962

Final KG $= \frac{\text{Final Moment}}{\text{Final Wt.}} = \frac{139962}{18629.3} = 7.513$ m

Volume of D.O. in No. 7 Port $= \frac{\text{wt.}}{\text{density}} = \frac{100}{0.88} = 113.63 \text{ m}^3$

Since the total capacity of No. 7 Port is 114.6 m^3, the tank is SLACK.

Original Free Surface Moment = 1552 mt

FSM of No. 7 Port = (50 x 0.88) = 44 mt

Final FSM = 1596 mt

Final FSC $= \frac{1596}{18629.3} = 0.086 \text{ m}$

KM for displ. 18629.3 t = 8.357 m

KG = 7.513 m

GM (Solid) = 0.844 m

FSC = 0.086 m

GM (Fluid) = 0.758 m

Transverse $GG_1 = \frac{w \times d}{W + w} = \frac{100 \times 5}{18629.3} = 0.02684 \text{ m}$

$\tan\theta = \frac{GG_1}{GM\ (Fluid)} = \frac{0.02684}{0.758}$

θ = Angle of List = 2^0 2' to Port

37. *M. V.'Hindship', displacing 13530 t in water of density 1.015 t/m³, KG 7.344 m, FSC 0.076 m, shifts a weight of 30 tonnes from 3 m off the centre line on the port side to 4.5 m off the centre line on the stbd. Calculate the resultant list.*

Underwater volume in δ 1.015 $= \frac{\text{Displ.}}{\delta} = \frac{13530}{1.015} = 13330 \text{ m}^3$

Displacement in SW for underwater volume 13330 m^3

= Equivalent weight in SW = V x δ_1 = 13330 x 1.025 = 13663.3 t

KM for displacement 13663.3 t	=	8.289 m
KG	=	7.344 m
GM (Solid)	=	0.945 m
FSC	=	0.076 m
GM (Fluid)	=	0.869 m

$$\text{Transverse } GG_1 = \frac{w \times d}{W} = \frac{30 \times 7.5}{13530} = 0.01662 \text{ m}$$

$$\tan \theta = \frac{GG_1}{GM\ (Fluid)} = \frac{0.01662}{13530} = 0.01912$$

θ = Angle of List = $1^0 06'$ to stbd.

38. ***M. V. 'Hindship' in Condition No. 8, consumes the entire H.F.O. from No. 5 DB tank (S), cg 4 metres from the centre line. Find the resultant list.***

		Weights (t)	KG (m)		V. Moments (mt)
Condition No.		16133	7.263		117177
No. 5 (S)	(-)	46.4	0.870	(-)	40
Final Wt.	=	16086.6	Final V. Momts	=	117137

FS Moment in Condition No. 8	=	1372 mt
Change in FS Moment	=	nil
Final FS Moment	=	1372 mt

$$\text{FSC in final condition} = \frac{1372}{16086.6} = 0.085 \text{ m}$$

$$\text{Final KG} = \frac{\text{Final Moment}}{\text{Final Wt.}} = \frac{117137}{16086.6} = 7.282 \text{ m}$$

KM for displacement 16086.6 t	=	8.238 m
GM (Solid)	=	0.956 m
FSC	=	0.085 m
GM (Fluid)	=	0.871 m

$$\text{Transfer } GG_1 = \frac{w \times d}{W - w} = \frac{4 \times 46.4}{16086.6} = 0.01153 \text{ m}$$

$$\tan\theta = \frac{GG_1}{GM\text{ (Fluid)}} = \frac{0.01153}{0.871} = 0.0132 \text{ m}$$

$$\theta = \textit{Angle of List} = 0^0 45' \textit{ to Port}$$

39. ***M.V.'Hindship' floating at a hydrostatic draft of 6.10 m is listed $2\frac{1}{4}^0$ to port, GM (Fluid) 0.491 m. To bring her upright, where with respect to the centre line, should 100 tonnes be***

(a) loaded,

(b) discharged

(c) if the list was to be corrected by shifting 100 tonnes transversely, through what distance should the weights, be moved.

Displacement for hydrostatic draft of 6.10 m = 12245.5 t

$$\tan\theta = \frac{GG_1}{GM(\text{Fluid})}$$

$\therefore$ GG_1 causing list = GM (Fluid) x $\tan\theta$

= 0.491 x $\tan 2\frac{1}{4}^0$ = 0.019292

Moment to port causing list = GG_1 x W

= 0.019292 x 12245.5 = 236.24 mt

To correct the list, an equal moment should be caused to starboard.

Since Moment = weight x distance

(a) distance from CL., at which weight should be loaded

$$= \frac{\text{Moment}}{\text{wt.}} = \frac{236.24}{100} = 2.362 \ m \ to \ starbd$$

(b) Similarly, the dist. from CL at which the wt. should be discharged

$$= \frac{\text{Moment}}{\text{wt.}} = \frac{236.24}{100} = 2.362 \ m \ to \ port$$

(c) Distance through which the wt. should be shifted transversely

$$= \frac{\text{Moment}}{\text{wt.}} = \frac{236.24}{100} = 2.362 \ m \ towards \ starbd$$

Note: The GM (Fluid) would change when weights are loaded or discharged, as KM and FSC would alter. However, that does not figure in the calculation because, when the transverse moments to port and stbd are equal, the ship's G is on her centreline. When the G is on her centreline, she will be upright, whatever her GM, provided it is positive.

40. *A Wt. of 20 tonnes, when moved transversely through a distance of 18 metres, causes M. V. 'Hindship' floating at a mean draft of 5.92 m, to list 2.6°. Calculate her GM (Solid), given FSC, 0.082 m.*

For draft 5.92 m. displacement = 11839 t

For draft 5.92 m displacement KM = 8.464 m

$$\text{Transverse } GG_1 = \frac{w \times d}{W} = \frac{20 \times 18}{11839} = 0.0304 \text{ m}$$

$$\text{GM (Fluid)} = \frac{GG_1}{\tan \theta} = \frac{0.0304}{\tan 2.6^0} = 0.670 \text{ m}$$

FSC = 0.082 m

GM (Solid) = *0.752 m*

41. *M. V. 'Hindship' displacing 16398 t. KG 7.15 m, FSC 0.08m discharged 280 t, Kg 6.20 m, Cg 1.4 m off the CL to stbd and loaded 280 t, Kg 6.2 m, Cg 3.5 m to stbd of CL. A 70 t parcel of cargo was shifted horizontally from 3.6 m port of CL to 1.2 m port of CL. Calculate the resultant list.*

Since 280 t were discharged and 280 t loaded at the same Kg and the third parcel of cargo was shifted horizontally only, the ship's KG will remain unchanged.

The FSC also remains unchanged as the displacement and FSM have not altered.

To find the transverse GG_1

	Weights (t)	Dist. from CL (m)	Transverse moments (mt)
Disch	280	1.4 (S)	392 (P)
Loaded	280	3.5 (S)	980 (S)
Shifted	70	2.4 to (S)	168 (S)
Resultant Moment		=	756 (S)

Transverse $GG_1 = \frac{756}{1639} = 0.0461$ m

KM for displ 16398 t	=	8.245 m
KG	=	7.15 m
GM (Solid)	=	1.095 m
FSC	=	0.080 m
GM (Fluid)	=	1.015 m

$$\tan\theta = \frac{GG_1}{GM(Fluid)} = \frac{0.0461}{0.015} = 0.0454 \text{ m}$$

θ = **Angle of List = 2°36' to stbd**

42. *M. V. 'Hindship' floating at a mean draft of 7.12 m in water of RD 1.008 KG 6.12 m loads 900 t of cargo in 3TD, 2 m off CL to port and 200 t in No. 4 TD, 2.5 m to stbd of CL. An 80 t, lift is discharged from deck kg 14.1 m, cg 4 m to port of CL. Calculate her final mean draft and angle of list if the FSC in the final condition was 0.12 m.*

Displ. in SW for M. draft 7.12 m = 14576.2 t

Displ. at that draft in δ 1.008 $= 14576.2 \times \frac{1.008}{1.025} = 14334.4$ t

	Weights (t)	KG (m)	V. Moments (mt)	Dist from CL (m)	Trans. Moments (mt)
Ship	14334.4	6.12	87726.5	0.0	-
Loads No. 3 TD	(+) 900	10.37	(+) 9333.0	2.0 (P)	1800 (P)
Loads No. 4 TD	(+) 200	10.76	(+) 2152.0	2.5 (S)	500 (S)
Disch. from Dk	(-) 80	14.10	(-) 1128.0	4.0 (P)	320 (S)
Final Displ.	= 15354.4	Final V.M =	98083.5	Final Trans. M	980 (P)

Equivalent displ in SW for displ 15354.4 t in δ 1.008

$$= 15354.4 \times \frac{1.025}{1.008} = 15613.4 \text{ t}$$

KM for displ. 15613.4 t = 8.238 m

$$\text{Final KG} = \frac{98083.5}{15354.4} = 6.388 \text{ m}$$

GM (Solid) = 1.850 m

FSC = 0.120 m

GM (Fluid) = 1.730 m

$$\text{Transverse } GG_1 = \frac{980}{15354.4} = 0.06383 \text{ m}$$

$$\tan\theta = \frac{GG_1}{GM\ (Fluid)} = \frac{0.0638}{1.73}$$

θ = Angle of List = 2°07' to Port

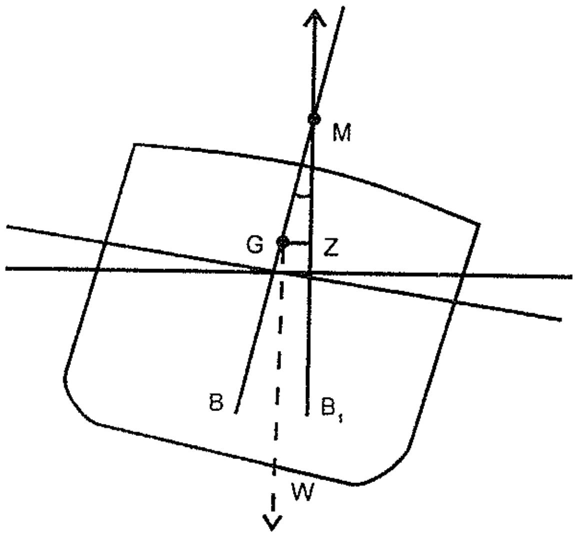
For displ 15613.4 t in SW, hydrostatic draft from tables = 7.566 m

Final Mean Draft = 7.566 m

RIGHTING MOMENT

The Righting Lever GZ is the perpendicular distance between the ship's Centre of Gravity and the vertical line through the Centre of Buoyancy in an inclined condition.

The Righting Moment or Moment of Statical Stability of a vessel at any angle of heel is the moment with which she tends to return to the original upright condition, when heeled to that angle by an external force.



For very small angles of heel, GZ = GM x sin θ

At larger angles of heel, GZ must be obtained as

KN - (corrected KG x sin θ)

Righting Moment = W x GZ

43. *Calculate the Righting Moment of M. V. 'Hindship' at an angle of heel of 10^0 in Condition No. 4.*

Righting Moment	=	W x GZ
GZ for 10^0 heel in condition No. 4	=	0.262 m
Therefore Righting Moment	=	19617 x 0.262
Righting Moment	=	*5139.65 mt*

RELATIONSHIP BETWEEN DENSITY, DRAFT & DISPLACEMENT

The Student is advised to refer to definition of Displacement, Volume of Displacement, Density and Relative Density, given earlier in this book.

LAW OF FLOATATION: Every body floating in a fluid, displaces a volume of that fluid equal in mass to the mass of that body.

Therefore, in the case of a ship, her Displacement = Weight of water displaced.

The weight of any substance = It's volume x it's density. Thus the Weight of the ship = Volume of water displaced by the ship x Density of that water.

$$W = V \times \delta$$

When a ship proceeds from water of one density to water of another density, her displacement does not alter. Therefore from the above expression, it can be seen that W remaining constant, V, the underwater volume and therefore the draft must increase if the density of water decreases, and conversely the underwater volume and the draft must decrease if the density increases.

It should also be noted that the displacement of a ship floating at the **same draft** in water of **different densities**, will not be the same as the underwater volumes would be the same, but the densities are different.

The Freshwater Allowance of a ship is the number of millimetres by which the mean draft of the ship changes when she proceeds from Salt Water to Fresh Water or from Fresh Water to Salt Water, when floating at the Load water line.

$$\text{FWA (in mm)} = \frac{W}{4TPC}$$

The FWA given in the Load Line Certificate is valid only for drafts corresponding to waterlines between W & TF marks. For drafts less than winter draft the FWA for the concerned draft may be calculated by the above expression using W and TPC, both in salt water at that draft.

Dock Water Allowance for densities between those of FW and SW may be obtained by simple proportion.

$$\text{Thus, Dock Water Allowance} = \frac{\text{FWA} \times \text{(Difference in densities)}}{(1.025 - 1.000)}$$

Calculations in this section may also be done using first principles of volume, density and weight.

44. *M. V. 'Hindship' floating at her summer draft, in salt water, proceeds to water of density 1.007 tonnes/m3. Calculate her freeboard.*

FWA = 202 mm

Dock water allowance $= \dfrac{202 \times (1.025 - 1.007)}{(1.025 - 1.000)}$

$= \dfrac{202 \times 0.018}{0.025} = 145 \text{ mm} = 0.145 \text{ m}$

Summer freeboard = 2.626 m

Dockwater allowance = 0.145 m

∴ ***Freeboard in water of density 1.007 = 2.481 m***

45. *M. V. 'Hindship', is floating in water of SG 1.012, with a freeboard of 4.42 m. Calculate her displacement.*

Summer draft = 9.233 m

Summer freeboard = 2.626 m

Distance between keel & deck line = 11.859 m

Present freeboard = 4.420 m

∴ Present draft in dockwater = 7.439 m

Displacement in salt water for 7.439 m, draft = 15317 t

∴ Under water volume, V, at that draft $= \dfrac{15317}{1.025} \text{ m}^3$

∴ Displacement at the same draft in dockwater (RD 1.012)

$= V \times \delta_1 = \dfrac{15317}{1.025} \times 1.012$

$=$ ***15122.7 t***

46. *M. V. 'Hindship' is floating in water of RD 1.025, at an even keel draft of 3.9 m. Calculate the hydrostatic draft at which she will float, in water of RD 1.011 at the same displacement.*

(i) using FWA, calculated for the draft in question.

(ii) without the use of FWA.

(i) Displacement at 3.9 m = 7389.5 t

TPC at 3.9 m draft = 21.56 t

$$\text{FWA (in mm)} = \frac{W}{4\ \text{TPC}} = \frac{7389.5}{4 \times 21.56}$$

$$= 85.7 \text{ mm}$$

$$\text{Dockwater allowance} = \frac{\text{FWA} \times \text{diff .in densities}}{1.025 - 1.000}$$

$$= \frac{85.7 \times 0.014}{0.025}$$

$$= 48 \text{ mm} = 0.048 \text{ m}$$

Original draft = 3.900 m

Dockwater allowance = 0.048 m

∴ ***Hydrostatic draft in dock water = 3.948 m***

(ii) Displacement at 3.9 m draft = 7389.5 t

Underwater volume, for the above displacement,

$$\text{in water of RD 1.011} = \frac{W}{\delta} = \frac{7389.5}{1.011} = 7309.09 \text{ m}^3$$

If drafts could be read off from hydrostatic tables, against underwater volumes, we could obtain the required mean draft, directly. Since however, the hydrostatic tables are tabulated for SW displacements against drafts, we have to convert the underwater volume to its corresponding displacement in SW.

Displ. in SW for vol. 7309.09 m^3 = $V \times \delta_1$ = 7309.09 x 1.025

= 7491.82 t

From hydrostatic tables, hydrostatic draft for the above displ.

= 3.948 m

∴ ***Hydrostatic draft in dock water = 3.948 m***

47. *M. V. 'Hindship' floating in water RD 1.025 at a draft of F 7.23 m, A 7.93 m, loads 940 t and sails to another port consuming 130 t of fuel and FW. Find her arrival hydrostatic draft at the second port in water RD 1.009.*

Original drafts F 7.23 m, A 7.93 m } trim 0.7 m by stern

M 7.58 m

LCF for mean draft 7.58		=		71.000 m
After draft		=		7.930 m
Corrn. to After draft =	$\frac{0.7 \times 71.0}{143.16}$	=	(-)	0.348 m
Original hydrostatic draft		=		7.582 m
Original Displacement (for draft 7.582)		=		15651 t
Cargo loaded		=	(+)	940 t
Fuel & FW consumed		=	(-)	130 t
Final displacement		=		16461 t

Underwater Volume for displacement of 16461 in density 1.009

$$= \frac{16461}{1.009} = 16314.1 \text{ m}^3$$

Displacement in salt water for the above underwater volume

= 16314.1 x 1.025 = 16722 t

Hydrostatic draft for SW displacement of 16722 t = 8.036 m

Final Hydrostatic draft = 8.036 m

48. *M. V. 'Hindship' loading in dock water of RD 1.010, is floating at a mean draft of 8.9 m. Calculate the amount of cargo she can load prior to sailing into a Winter Zone, if 120 tonnes of bunkers is yet to be received and 45 tonnes of FW and fuel is expected to be consumed before sailing.*

Since the draft of the vessel is now less that the winter draft, the SW draft will be still lesser. The FWA of the ship is therefore not applicable. The problem is therefore worked from first principles.

Displ. SW at the draft of 8.9 m = 18808 t

Underwater volume at that draft $= \frac{W}{\delta} = \frac{18808}{1.025} = 18349.2\ m^3$

$\therefore$ Displ. for the above under water volume in water of RD 1.010.

= V x d = 18349.2 x 1.010 = 18532.7 t

Winter displacement = 19151.0 t

Increase in displacement allowable = 618.3 t

Net wt. to be received = 120 - 45 = 75.0 t

$\therefore$ ***Wt. of cargo that can be loaded = 543.3 t***

49. *M. V. 'Hindship' loading in dockwater of density 1008 Kg/m³ is to sail into a Summer Zone. She is floating with her starboard plimsol 2 cms above water line and port plimsol 6 cms below water line. Calculate the amount of cargo that can be loaded before she commences her voyage.*

Starboard Plimsol	2 cms above WL
Port Plimsol	6 cms below WL
	4 cms below WL

Mean level of Plimsol $= \frac{4}{2}$ = 2 cms below WL

= 0.020 m

Dockwater allowance $= \frac{202 \times 17}{25} = 137.4$ mm

= 0.137 m

Summer draft	= 9.233 m
Immersion of Plimsol (+)	= 0.020 m
Present draft in dockwater	= 9.253 m
Dockwater allowance (-)	= 0.137 m
Present S. W. draft	= 9.116 m
Displacement for draft 9.116 m	= 19332.88 t
Summer displacement	= 19617.00 t
∴ ***Cargo that can be loaded***	= ***284.12 t***

50. *M. V. 'Hindship' floating on an even keel in dock water of RD 1.017 with her starboard plimsol 15 cms above water and port plimsol 11.6 cms above water is to sail from the dock with a maximum even keel draft of 9.2 m. Calculate:*

(i) The maximum amount of cargo that can be loaded.
(ii) her draft on reaching the sea.

Starboard Plimsol	15 cms above WL
Port Plimsol	11.6 cms above WL
	26.6 cms above WL

Mean Level of Plimsol $= \frac{26.6}{2}$ = 13.3 cms above WL

Summer draft	= 9.233 m
Mean level of Plimsol (-)	= 0.133 m above WL
∴ Present hydrostatic draft	= 9.100 m

(i) Salt water displ. for 9.1 m draft = 19294 t

Dock water displacement for that draft $= \frac{19294 \times 1.017}{1.025} = 19143.4$ t

Salt water displacement for maximum permissible draft (9.20 m)

= 19537 t

Dock water displacement for that draft $= \frac{19537 \times 1.017}{1.025} = 19384.5$ t

Maximum amount of cargo that can be loaded = 19384.5 - 19143.4
= 241.1 t

Maximum amount of cargo that can be loaded = 241.1 t

(ii) Saltwater Draft for final displacement of 19384.5 t = 9.137 m

SW draft in the final condition = 9.137 m

51. *M .V. 'Hindship' loading in dockwater of RD 1.008 has a freeboard of 2.43 m on the port side and 2.28 m on the starboard side. Calculate the amount of cargo she may load or must discharge prior to sailing at the tropical draft in SW.*

Starbd. freeboard = 2.28 m

Port freeboard = <u>2.43 m</u>

= 4.71 m

Mean freeboard $= \frac{4.71}{2} = 2.355$ m

To find the distance between keel & deck line.

Add the draft and its corresponding freeboard

Summer draft = 9.233 m

Summer freeboard = 2.626 m

Dist. between keel & dk line = 11.859 m

Present freeboard = 2.355 m

Present draft in water RD 1.008 = 9.504 m

Dockwater Allowance $= \dfrac{\text{F. W. A} \times \text{diff. in densities}}{25}$

$= \dfrac{202 \times 17}{25} = 137.4$ mm

= 0.137 m

Present draft in S. W = 9.504 - 0.137

= 9.367 m

Displacement for draft 9.367 m = 19943.6 t

Tropical displacement = 20085 t

∴ ***Cargo that can be loaded = 141.4 t***

52. *M. V. 'Hindship' loads to her Summer mark, in Fresh Water and proceeds down river to another port consuming 30 tonnes of bunkers and water. At this port, she loads some cargo and is again at her Summer draft in water of RD 1.016. Find the number of tonnes of cargo loaded at the second port.*

Under water vol. at Summer draft $= \dfrac{\text{Displacement}}{\text{Density}}$

$= \dfrac{19617}{1.025} = 13138.5\ m^3$

Displ. at summer draft in FW = Volume x δ

= 19138.5 x 1.000

= 19138.5 t

Displ. at Summer draft in water of density 1.016

= 19138.5 x 1.016

= 19444.7 t

∴ Weight added on ship = 19444.7 - 19138.5

= 306.2 t

Bunkers and water consumed = 30.0 t

∴ ***Cargo loaded at 2nd Port = 336.2 t***

BLOCK COEFFICIENT (C_b) & WATER PLANE COEFFICIENT (C_w)

53. *Calculate the block coefficient and water plane coefficient of M. V. 'Hindship' at her summer draft, assuming the maximum breadth of water plane at that draft to be the moulded breadth. Compare your answers with those obtained from the Hydrostatic Curves.*

Length of the water plane at Summer draft is the LBP

(a) Block Coeff. Cb $= \dfrac{\text{Volume of displacement}}{L \times B \times \text{draft.}}$

Volume of disp. $= \dfrac{19617}{1.025} = 19138.5 \text{ m}^3$

$\therefore$ Cb $= \dfrac{19138.5}{143.16 \times 20 \times 9.233} = 0.72395$

***Cb* = 0.724**

***From Hydrostatic Curves, Cb* = 0.723**

(b) Water plane Coeff. Cw $= \dfrac{\text{Area of water plane}}{L \times B}$

Area of W. P. $= \dfrac{TPC \times 100}{1.025}$

$= \dfrac{24.28 \times 100}{1.025} = 2368.7 \text{ m}^3$

Cw $= \dfrac{2368.7}{143.16 \times 20} = 0.82731$

***Cw* = 0.827**

***From Hydrostatic Curves, Cw* = 0.830**

54. *M.V. 'Hindship' floating at a displacement of 13750 tonnes, KG 6.2 m, FSC 0.12 m, is listed $1\frac{1}{2}^0$ to starbd. Find the amount of cargo to be loaded in No. 4 TD, 6 m off the centre line to bring the vessel upright.*

KM for displ. 13750 t	= 8.285 m
KG	= 6.200 m
GM (Solid)	= 2.085 m
FSC	= 0.120 m
GM (Fluid)	= 1.965 m

GG_1 causing $1\frac{1}{2}^0$ list = GM (Fluid) x tan θ = 1.965 x tan $1\frac{1}{2}^0$

= 0.0515 m

Moment causing list to (S) = 0.0515 x 13750 = 707.5 mt

$\therefore$ Equating moments P & S to bring her upright

$$\chi \times 6 = 707.5$$

$$\chi = \frac{707.5}{6} = 117.9 \text{ t}$$

Amount of cargo to be loaded = 117.9 t

Note: A doubt may arise, as to why the final KG has not figured in the working. The student should understand that the final KG is immaterial in this type of problem, because when the moment to port equals the moment to starbd, the ship must be upright provided the GM is positive, as explained under question 39.

If however, the final list is to be calculated after various operations, the final GM (Fluid) and therefore her final KG would be required.

55. *M. V. 'Hindship' in Condition No. 5 loads and discharges as follows:-*

Discharges 150 tonnes from No. 1 TD cg 6 m, to stbd of CL.

Discharges 50 tonnes from No. 3 TD Kg. 11.15 m, cg 1.3 m to port of CL.

Fills up No. 8 DB tank (S) cg. 2.4 m from CL with FW. A parcel of cargo weighing 40 tonnes is shifted 6.2 metres vertically downwards and 1.8 m transversely to starboard. Calculate the resultant list.

	Weights (t)	KG (m)		V. Moments (mt)	Dist. from CL (m)	Transverse Moments (mt)
Condition No. 5 displ	18529.3	7.539		139700	0	0
Disch. from No. 1 TD (-)	150.0	11.17	(-)	1675.5	6	900 (P)
Disch. from No. 3 TD (-)	50	11.15	(-)	557.5	1.3	65 (S)
Receives FW No. 8 (S) (+)	63.4	2.77	(+)	175.6	2.4	152.2 (S)
Shifted 40 t	40	↓ 6.2	(-)	248.0	1.8	72.0 (S)

Final Wt. = 18392.7 Final V.M. = 137394.6 Final T. M. = 610.8 (P)

$$\text{Final KG} = \frac{137394.6}{18392.7} = 7.470 \text{ m}$$

KM for displ. 18392.7 t = 8.340 m

Final GM (Solid) = 0.870 m

$$\text{FSC} = \frac{1552}{18392.7} = 0.084 \text{ m}$$

Final GM (Fluid) = 0.786 m

$$\text{Transverse } GG_1 = \frac{610.8}{18392.7} = 0.03321 \text{ m}$$

$$\tan\theta = \frac{GG_1}{GM(\text{Fluid})} = \frac{0.03321}{0.786}$$

θ = *Angle of List* = *2°25' to port*

56. *M. V. 'Hindship' at a displacement of 13750 t KG 7.32 m, FS Moment 1146 mt. is listed* $2\frac{1}{2}^0$ *to starbd and has yet to load 380 tonnes of cargo. Space is available in No. 3 TD, 1.5 metre to starbd of centre line, and in No. 5 U TD, 6.2 metres to port of CL. Find the amount of cargo to be loaded in each space, so that the ship will be upright on completion.*

$$FSC = \frac{\text{FS Moment}}{\text{Displacement}} = \frac{1146}{13750} = 0.083 \text{ m}$$

KM for displacement of 13750 t = 8.285 m

KG = 7.320 m

GM (Solid) = 0.965 m

FSC = 0.083 m

GM (Fluid) = 0.882 m

GG_1 causing list of $2\frac{1}{2}^0$ to starbd = GM (Fluid) x tan θ

= 0.882 x tan $2\frac{1}{2}^0$

= 0.03851 mt

Moment causing list to starbd. = GG_1 x W

= 0.03851 x 13750

= 529.51 mt

Let 'x' tonnes be loaded on the port side and

(380 - x) tonnes be loaded on the starbd side

Equating moment to port & starbd, to bring the vessel upright.

x x 6.2 = (380 - x) x 1.5 + 529.51

6.2 x + 1.5x = 570 + 529.51

7.7x = 1099.51

$$x = \frac{1099.51}{7.7} = 142.79 \text{ t}$$

Cargo to be loaded on port side = *142.79 t*

Cargo to be loaded on stabd side = *380 - 142.79 = 237.21 t*

57. *M. V. 'Hindship' in Condition No. 7 is listed 3^0 to port No. 7 DB tank starbd is than filled with DO, cg 3.8 m from CL. Calculate the final list.*

GG_1 causing list of 3^0 to port = GM (Fluid) x tan θ

= 0.458 x tan 3^0 = 0.024 m

Moment causing that list = GG_1 x W

= 0.024 x 18529.3 = 444.7 mt

Wt. of DO added in No. 7 (S) = (101.9 x 0.88) = 89.672 t

Moment to stabd caused by DO added (w x d)

= 89.672 x 3.8

= 340.75 mt

Resultant Moment to Port = 444.7 - 340.75

= 103.95 mt

	Weights (t)	KG (m)	V. Moments (mt)
Condition No. 7 displacement	18529.3	7.807	144653
DO added	89.672	2.59	232.25
Final Wt.	18618.972	Final Moment	144885.25

$$\text{Final KG} = \frac{144885.25}{18618.672} = 7.782 \text{ m}$$

$$\text{Final FSC} = \frac{\text{FS Moment}}{\text{Final displ.}} = \frac{1552}{18618.672} = 0.083 \text{ m}$$

KM for displ. 18618.972 t = 8.356 m

KG	=	7.782 m
GM (Solid)	=	0.574 m
FSC	=	0.083 m
GM (Fluid)	=	0.491 m

$$\text{Transverse } GG_1 \text{ in final condition} = \frac{\text{Resultant Moment}}{\text{Displacement}}$$

$$= \frac{103.95}{18618.972}$$

$$\tan\theta = \frac{GG_1}{GM(\text{Fluid})} = \frac{0.0056}{0.491}$$

θ = Angle of List = 0°39.3' to Port

58. *M. V. 'Hindship' at a hydrostatic draft of 5.76 m in FW is listed 0°50' to port. KG 7.68 m, FSC 0.09 m. A parcel of cargo weighing 80 t is shifted from 1 m to port of CL to 4.5 m off the CL to port. Calculate the final list.*

Displacement in SW for hydrostatic draft 5.76 m = 11479.2 t

$$\text{Displ. at that draft in FW} = 11479.2 \times \frac{1.000}{1.025} = 11199.2 \text{ t}$$

KM for draft 5.76 m	=	8.517 m
KG	=	7.680 m
GM (Solid)	=	0.837 m
FSC	=	0.090 m
GM (Fluid)	=	0.747 m

Initial transverse GG_1 = GM (Fl) x tan θ = 0.747 x tan $0^0 50'$

Initial listing moment = GG_1 x W = 0.747 x 0.0146 x 11199.2

= 122 mt (P)

Listing moment due to shift of cargo = 80 x 3.5 = 280 mt (P)

Final listing moment = 122 (P) + 280 (P)
= 402 mt (P)

$$\text{Transverse } GG_1 = \frac{402}{11199.2} = 0.0359 \text{ m}$$

$$\tan\theta = \frac{GG_1}{GM(\text{Fluid})} = \frac{0.0359}{0.747}$$

θ = Angle of List = $2^0 45'$ to Port

59. *M. V. 'Hindship' floating at a displacement of 19150 tonnes, KG 6.65 m, FSC 0.042 m, has yet to load 2 locomotives weighing 76 tonnes each, with her own gear. The first locomotive is placed on deck (quay side), Cg 13.83 m above the base and 6 metres from CL. The derrick then plumbs the quay with it's head 21.5 m above the base and 13 m from CL and lifts the second locomotive to be placed on deck, on the other side. Calculate the maximum list during the operation.*

The maximum list will occur when one locomotive has been loaded on deck on the quay side and the second locomotive has been lifted by the derrick swung over the quay.

To find KG and transverse GG_1 in the above condition.

	Weights (t)	KG (m)	V. Moments (mt)	Dist. From CL (m)	Trans. Momt (mt)
Ship	19150	6.65	127347.5	0	-
1st Loco	76	13.83	1051.1	6.0	456.0
2nd Loco.	76	21.50	1634.0	13.0	988.0
Final Wt.	19302	Final V. Mmt.	130032.6	F. Trans Mmt.	1444.0

Final KG $= \frac{130032.6}{19302} = 6.737$ m

Final Transverse GG_1 $= \frac{1444}{19302} = 0.0748$ m

Original FSM = FSC x Original Displacement

= 0.042 x 19150 = 804.3mt

FSC in Final condition $= \frac{\text{FSM}}{\text{Final Displ.}} = \frac{804.3}{19302} = 0.042$ m

KM for displ 19302 t = 8.409 m

KG = 6.737 m

GM (Solid) = 1.672 m

FSC = 0.042 m

GM (Fluid) = 1.630 m

$\tan\theta = \frac{GG_1}{GM(\text{Fluid})} = \frac{0.0748}{1.630}$

θ = Angle of list = $2^0 38'$

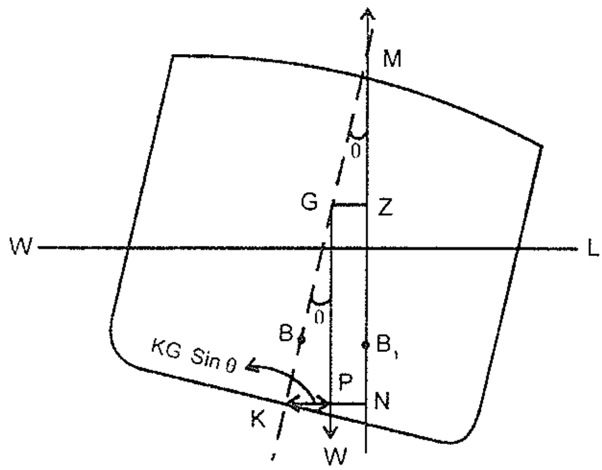
Maximum List during the operation = $2^0 38'$

RIGHTING MOMENT USING KN VALUES

The student should recall that at very small angles of heel, GZ may be obtained as GM x sin θ.

At larger angles of heel, GZ must be obtained as

KN - (Corrected KG x sin θ)



As can be seen from the figure, GZ = PN = KN - KP

= KN - (KG sin θ)

From the figure, it appears that GZ could be obtained as GM sin θ for any angle of heel. It cannot be done in practice, as the GM changes with the angle of heel. The change in GM is caused, due to change in the position of M with heel. Since this change is negligible for small angles of heel, GM may be considered constant at such angles of heel.

The hydrostatic table provides the KM for the upright condition only and not for different angles of heel, but the KN is available for various angles of heel. Therefore GZ can be obtained very correctly from the expression KN - (KG sin θ), for any angle of heel.

The stability particulars provided on ships give KN values at different displacements at convenient intervals of heel. For intermediate values of displacement and heel, KN values may be interpolated linearly without appreciable loss of accuracy.

60. *Find the Moment of statical stability of M. V. 'Hindship' at an angle of heel of 7°, when displacing 16133 t, KG 7.57 m, FSC 0.085 m.*

KG	=	7.570 m
FSC	=	0.085 m
Corrected KG	=	7.655 m
GZ = KN - Corrected KG sin θ		
KN at 7° heel for displ. 16133 t		
(interpolating between 5° & 10°)	=	1.055 m
Corrected KG sin θ = 7.655 x sin 7°	=	0.933 m
∴ GZ	=	0.122 m
Moments of Statical Stability	=	W x GZ
	=	16133 x 0.122
	=	*1968.23 mt*

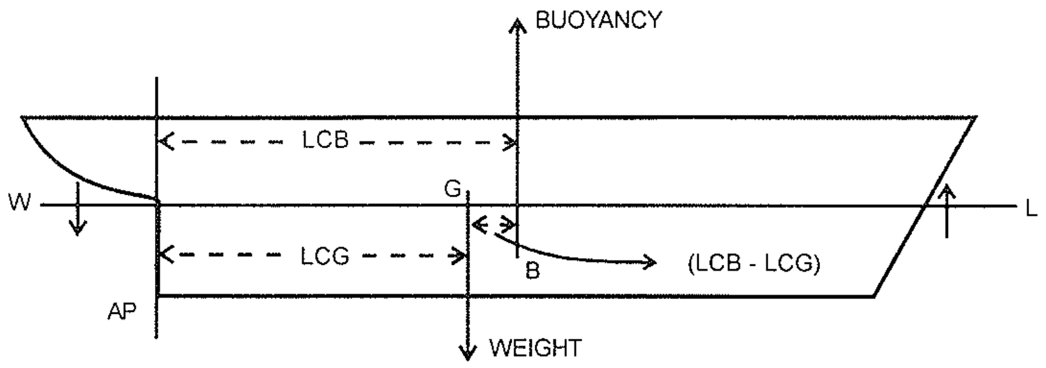
TRIM

TRIM - is the difference between the ford draft and the after draft.

CENTRE OF FLOATATION: (CF) is the centroid of the ship's water plane area. The ship trims about this point.

CALCULATION OF TRIM: Since the hydrostatic particulars of the vessel are available, the trim of the vessel can be calculated accurately by the method explained below.

When a ship is in static equilibrium, the buoyancy provided by the displaced water is exactly equal to the ship's weight. When the Centre of Buoyancy and the Centre of Gravity are in the same vertical line, these forces produce no couple and therefore the ship is in static equilibrium at her present trim.

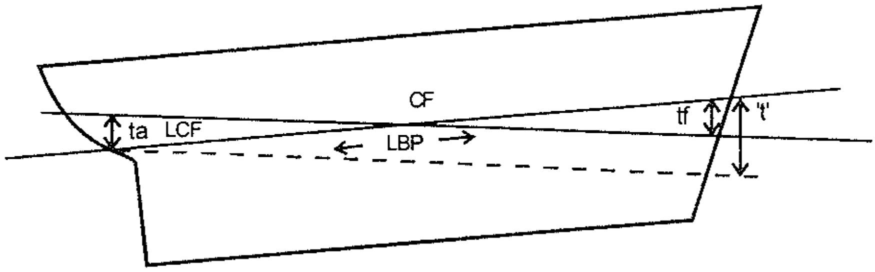


When the centre of buoyancy and the centre of gravity are not in the same vertical line, as shown in the figure, these two equal and opposite forces set up a couple tending to trim the vessel. The moment of this couple i.e. Trimming Moment, is obtained by the product of one of the forces and the lever between the forces i.e. (LCB - LCG) x displacement. The Trimming Moment divided by the MCTC gives the total trim of the ship in centimetres which is then divided by 100 to give the trim in metres.

Thus Total trim 't' metres = $\dfrac{(LCB - LCG)}{MCTC \times 100} \times$ displacement

As can be seen from the figure the trim obtained would be **by the stern.**

If the LCB was less than LCG the above formula would result in a negative trim indicating trim **by the head.**



As shown in the above figure, the after trim would bear a ratio to the LCF as the total trim bears to the length of the ship, i.e. $\frac{t_a}{LCF} = \frac{t}{LBP}$

$$t_a = \frac{t \times LCF}{LBP}$$

Similarly $t_f = \frac{t \times (LBP - LCF)}{LBP}$

Also $t_f = t - t_a$ and vice versa,

$t_a = t - t_f$

NOTES TO CALCULATE TRIM OF VESSEL AFTER LOADING/DISCHARGING/SHIFTING

1. For a vessel with no trim, the arithmetical mean draft is the same as the hydrostatic draft.

   For a vessel which is trimmed, obtain the arithmetical mean draft. Determine the position of LCF from AP, for this mean draft.

2. Calculate the hydrostatic draft as below:

   Hydrostatic draft = draft Aft $\pm$ correction, where the correction

$$= \frac{\text{Trim} \times \text{LCF}}{\text{LBP}}$$

   Note: Correction is -ve when trimmed by stern

   +ve when trimmed by head

3. From the hydrostatic tables, determine against the hydrostatic draft; the corresponding displacement (if not given).

4. List the various weights involved in arriving at the final displacement, viz, original displacement, weights loaded, discharged or shifted, together with their Lcg. Calculate the final longitudinal moment and final displacement.

5. Find the LCG from AP as follows:

$$\text{LCG from AP} = \frac{\text{Final Long. moments}}{\text{Final displacement}}$$

6. Determine against final displacement, the values of Hydrostatic draft, MCTC, LCB and LCF.

7. Total trim 't' (metre) $= \dfrac{\text{LCB} - \text{LCG}}{\text{MCTC} \times 100} \times \text{Displacement}$

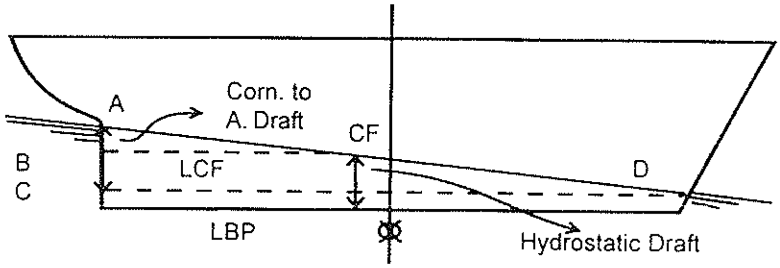
8. Trim aft 't_a' (metre) $= \dfrac{\text{'t'} \times \text{LCF}}{\text{LBP}}$

9. Trim forward 't_f' (metre) = 't' - 't_a'

   Draft aft = Hydrostatic draft + 't_a'

   Draft fwd = Hydrostatic draft - 't_f'

The hydrostatic draft of a ship is her true mean draft, that is, the draft at the Centre of Floatation.



In the case illustrated above, the vessel is trimmed by the stern. Her hydrostatic draft is after draft - the correction AB. It can also be seen from the similar triangles ACD and ABF, that $\dfrac{\text{AB (corrn.)}}{\text{BCF (LCF)}} = \dfrac{\text{AC (trim)}}{\text{CD (LBP)}}$

$$\text{Corrn.} \times \text{LBP} = \text{trim} \times \text{LCF}$$

$$\therefore \text{Corrn. to A draft} = \frac{\text{Trim} \times \text{LCF}}{\text{LBP}}$$

Since, Length of the ship is constant, the corrn. will vary directly as LCF and also directly as the trim.

The student should be able to visualise that when the vessel is trimmed by the head, the hydrostatic draft will be After Draft + the correction.

As can be seen from the above expression, the correction to the after draft is independent of the density of water in which the vessel may be floating.

EFFECT ON DRAFT FORE & AFT DUE TO LOADING/DISCHARGING/SHIFTING

61. *M. V. 'Hindship' floating at a draft of F 5.65 m, and A 7.45 m, LCG 70.47 m, ford of AP, loads 500 tonnes of cargo, 100.5 m ford of AP. Calculate (i) her final displacement (ii) final hydrostatic draft and (iii) final drafts F & A.*

Initial drafts F 5.65 m, A 7.45 m } trim = 1.80 m by stern

M 6.55 m LCF = 72.048 m ford of AP

Corrn. to After draft $= \dfrac{1.80 \times 72.048}{143.16} = 0.906$ m

Hydrostatic draft = After draft ± Corrn. from table 'A'

= 7.45 - 0.906 = 6.544 m

(-ve since V/L is trimmed by stern)

Displacement for Hydrostatic draft: 6.544 = 13255.3 t

Cargo loaded = 500.0 t

Final displacement = 13755.3 t

Final Hydrostatic draft = 6.763 m

For displacement 13755.3 t MCTC = 181.0 mt

LCB = 72.864 m ford of AP

LCF = 71.843 m ford of AP

	Weights (t)	LCG (m)	L. Moments (mt)
Original displ.	13255.3	70.47	934101
Cargo loaded	500	100.50	50250
Final Wt	13755.3	Final L. Moments	984351

Final LCG $= \dfrac{\text{Final L. Moment}}{\text{Final Wt}} = \dfrac{984351}{13755.3} = 71.562$ m ford of AP

$$\text{Total trim 't'} = \frac{\text{LCB} - \text{LCG}}{\text{MCTC} \times 100} \times \text{Displacement}$$

$$= \frac{72.864 - 71.562}{181 \times 100} \times 13755.3$$

$$= 0.989 \text{ m by stern}$$

Note: The Couple produced by the weight acting downwards through G, and the buoyancy acting upwards through B will trim the vessel by the stern in this case as her LCG is abaft her LCB.

$$\text{trim aft 't}_a\text{'} = \frac{\text{total trim} \times \text{LCF}}{\text{LBP}} = \frac{0.989 \times 71.843}{143.16}$$

$$t_a = 0.496 \text{ m}$$

$$\text{trim ford 't}_f\text{'} = \text{total trim - trim aft} = 0.989 - 0.496$$

$$t_f = 0.493 \text{ m}$$

		F		A
Hydrostatic draft		6.763 m		6.763 m
Trim	(-)	0.493 m	(+)	0.496 m

Final drafts = F 6.270 m A 7.259 m

Note: 1) The total trim calculated is the entire trim and not the change of trim caused by loading 500 tonnes.

2) Since the Hydrostatic particulars of M. V. 'Hindship' are given for the even keel condition, the Hydrostatic draft obtained from the tables for the final displacement is that for the even keel condition. Therefore t_a and t_f are applied to the Hydrostatic draft to obtain the drafts F & A.

62. *M. V. 'Hindship' is at a draft of F 8.778 m, A 8.792 m, LCG, 72.34 m ford of AP. She discharges 206 tonnes of cargo from No. 5 LTD. Calculate the drafts F and A.*

Initial drafts F 8.778 m, A 8.792 m } trim 0.014 m by stern

M 8.785 m   LCF 69.923 m of AP

Corrn. to After draft $= \dfrac{0.014 \times 69.923}{143.16} = 0.007$ m

Hydrostatic draft = After draft ± Corrn. from table 'A'

= 8.792 - 0.007 = 8.785 m

Displacement for hydrostatic drafts 8.785 m	=	18529 t
Cargo discharged	=	206 t
Final displacement	=	18323 t
For displacement 18323 t, Hydrostatic draft	=	8.70 m
MCTC	=	207.50 mt
LCB	=	72.382 m
LCF	=	69.989 m

	Weights (t)	LCG (m)	L. Moments (mt)
Original displ.	18529	72.34	1340388
Cargo disch.	(-) 206	17.24	(-) 3551
Final Wt.	18323	Final Moment	1336837

Final LCG $= \dfrac{\text{Final Moments}}{\text{Final Wt}} = \dfrac{1336387}{18323} = 72.96$ m

$$\text{Total trim 't'} = \frac{LCB - LCG}{MCTC \times 100} \times \text{Displacement}$$

$$= \frac{(72.382 - 72.960)}{207.5 \times 100} \times 18323$$

$$t = -\ 0.510 \text{ m}$$

The negative trim indicates that the vessel is trimmed by the Head, which is also substantiated by the fact that LCG is ford of LCB.

$$t_a = \frac{t \times LCF}{LBP} = \frac{0.510 \times 69.989}{143.16}$$

$$t_a = 0.249 \text{ m}$$

$$t_f = t - t_a = 0.510 - 0.249 = 0.261 \text{ m}$$

		F		A
Hydrostatic draft		8.700 m		8.700 m
trim	(+)	0.261 m	(-)	0.249 m
Final drafts	*F*	*8.961 m*	*A*	*8.451 m*

63. *M. V. 'Hindship' arrives port in Condition No. 5 and discharges the entire cargo from No. 1 TD, No. 5 Poop Deck and Refrigerated Cargo Spaces. No. 4 DB tank (centre) is filled with water ballast. Calculate her GM (Fluid) and drafts F & A.*

	Weights (t)	KG (m)	V. Moments (mt)	LCG (m)	L. Moments (mt)
Displ. in Condition No.	18529.3	7.539	139700	72.129	1336498
No. 1 TD	(-) 681.7	11.17	(-) 7615	124.67	(-) 84988
No. 5 Poop Dk	(-) 542.6	13.76	(-) 7466	14.78	(-) 8020
Ref. cargo	(-) 235.0	10.36	(-) 2435	60.17	(-) 14140
No. 4 (C) (257.4 x 1.025)	(+) 263.8	0.63	(+) 166	57.58	(+) 15189
Final Wt.	= 17333.8	Final V. Mt.	= 122350	Final L. Mt.	= 1244539

Final KG $= \dfrac{122350}{17333.8} = 7.058$ m

Final FSC $= \dfrac{1552}{17333.8} = 0.089$ m

KM for displ. 17333.8 t = 8.280 m

KG = 7.058 m

GM (Solid) = 1.2215 m

FSC = 0.089 m

GM (Fluid) = 1.133 m

Final LCG $= \dfrac{1244539}{17333.8} = 71.798$ m

For displ. 17333.8 t

Hydrostatic draft = 8.290 m

MCTC = 201.5 mt

LCB = 72.505 m

LCF = 70.332 m

Total trim 't' $= \dfrac{LCB - LCG}{MCTC \times 100} \times$ Displacement

$= \dfrac{72.505 - 71.798}{201.5 \times 100} \times 17333.8$

Total trim 't' = 0.608 m by stern

$t_a = \dfrac{t \times LCF}{LBP} = \dfrac{0.608 \times 70.332}{143.16} = 0.299$ m

$t_f = t - t_a = 0.608 - 0.299 = 0.309$ m

		F		A
Final Hydrostatic draft		8.290		8.290
Trim	(-)	0.309	(+)	0.299
Final drafts	*F*	*7.981 m*	*A*	*8.589 m*

64. *M. V. 'Hindship' in Condition No. 7, discharges the entire cargo in No. 2 TD, and fills in the bulbous bow with 186.6 tonnes of water ballast, Kg 3.52 m, Lcg 139.6 m ford of AP. Assume theoretically that the deck cargo of locomotives was shifted to No. 2 TD. A negligible quantity of water was inadvertently pumped out from No. 4 P & S, DB tanks, causing them to become slack. Calculate her GM (Fluid) and drafts F & A in the final condition.*

	Weights (t)	KG (m)	V. Moments (mt)	LCG (m)	L. Moments (mt)
Displ. in Condition No. 7	18529.3	7.807	144653	72.340	1340415
No. 2 TD	(-)1058.4	10.72	(-) 11346	103.91	(-) 109978
Bulbous Bow	(+) 186.6	3.52	(+) 657	139.60	(+) 26049
Shift of locos	760.0	*3.11	(-) **2364	19.87	(+) 15101

*(13.83 - 10.72 = 3.11) **(103.91 - 84.04 = 19.87 F)

Final Wt. = 17657.5 F.V. Momt = 131600 F.L. Momt = 1271587

Final KG $= \dfrac{131600}{17657.5} = 7.453$ m

Final LCG $= \dfrac{1271587}{17657.5} = 72.014$ m

To find final FSC

Original FS Moment = 1552 mt

FSM of No. 4 (P & S)

(542 x 1.025) = 556 mt

Final FS Moments = 2108 mt

Final FSC $= \dfrac{\text{FS Moment}}{\text{Displacement}} = \dfrac{2108}{17657.5} = 0.119$ m

KM for displ. 17657.5 = 8.295 m

KG	=	7.453 m
GM (Solid)	=	0.842 m
FSC	=	0.119 m
GM (Fluid)	=	0.723 m

For displacement of 17657.5 t

Hydrostatic draft	=	8.425 m
MCTC	=	203.5 mt
LCB	=	72.466 m
LCF	=	70.217 m
Final LCG	=	72.014 m

$$\text{Total trim 't'} = \frac{LCB - LCG}{MCTC \times 100} \times \text{Displacement}$$

$$= \frac{72.466 - 72.014}{203.5 \times 100} \times 17657.5 = 0.392 \text{ m}$$

$$t_a = \frac{t \times LCF}{LBP} = \frac{0.392 \times 70.217}{143.16} = 0.192 \text{ m}$$

$$t_f = t - t_a = 0.392 - 0.192 = 0.200 \text{ m}$$

		F		A
Hydrostatic draft		8.425		8.425
trim	(-)	0.200	(+)	0.192
Final drafts	***F***	***8.225 m***	***A***	***8.617 m***

65. *M. V. 'Hindship' is floating at a draft of F 5.62 m, A 6.78 m, A wt. of 220 tonnes is then shifted from No. 3 TD to a position 112.5 metres ford of AP. Calculate the final drafts F & A.*

Original drafts F 5.62 m, A 6.78 m } trim 1.16 m by stern
M 6.20 m

LCF for mean draft 6.20 m = 72.333 m

After draft = 6.780 m

Corn. to After draft = $\frac{1.16 \times 72.333}{143.16}$ = (-) 0.586 m

Hydrostatic draft = 6.194 m

For Hydrostatic draft 6.194 m

LCF = 72.338 m

MCTC = 175.600 mt

Lcg of No. 3 TD = 80.79 m ford of AP

Cargo shifted to = 112.50 m ford of AP

Distance cargo shifted = 112.50 - 80.79 = 31.71 m ford

Moment of shift = 220 x 31.71 = 6976 mt ford

Total trim caused by shift = $\frac{\text{Moment}}{\text{MCTC} \times 100}$ = $\frac{6976}{175.6 \times 100}$

= 0.397 m by Head

After trim = $\frac{\text{Total trim} \times \text{LCF}}{\text{LBP}}$ = $\frac{0.397 \times 72.338}{143.16}$

= 0.201 m

Ford trim = Total trim - After trim - 0.397 - 0.201 = 0.196 m

		F		A
Original drafts		5.620		6.780
trim due to shift	(+)	0.196	(-)	0.201
Final drafts	*F*	*5.816 m*	*A*	*6.579 m*

NB 1) It should be noted that the trim calculated is the change in trim due to shift of cargo and not the total trim of the vessel, as is done in earlier trim problems. Change in trim is therefore applied to the original drafts F & A and **not** to the Hydrostatic drafts. This was possible as the displacement, hydrostatic draft and therefore the hydrostatic particulars remain unchanged before and after the operation.

2) This question can also be worked by finding the initial LCG of the ship as shown in the next problem. Since however the displacement remains unchanged in this problem, the Hydrostatic particulars also remain unchanged and therefore the method shown above is simpler.

66. *M. V. 'Hindship' floating at a draft of F 5.70 m, A 7.60 m, discharges the entire cargo from No. 4 TD which was full. The stowage factor of the cargo in No. 4 TD was 2/3 cubic metre per tonne. Calculate the drafts F & A, after discharge.*

Original drafts F 5.70 m, A 7.60 m } trim 1.90 m by stern

M 6.65 m

LCF for mean draft 6.65 m = 71.955 m

After draft = 7.600 m

Corn. to After draft = $\frac{1.90 \times 71.955}{143.16}$ = (-) 0.955 m

Hydrostatic draft = 6.645 m

For Hydrostatic draft 6.645 m, displacement = 13486 t

LCB = 72.882 m

MCTC = 179.77 mt

Original Total trim 't' = $\dfrac{LCB - LCG}{MCTC \times 100} \times$ Displacement

$$1.90 = \frac{72.882 - LCG}{179.77 \times 100} \times 13486$$

$$1.90 \times 179.77 \times 100 = (72.882 - LCG) \times 13486$$

$$= 72.882 \times 13486 - 13486 \times LCG$$

$$13486 \times LCG = (72.882 \times 13486) - (1.90 \times 179.77 \times 100)$$

$$\therefore \text{ Original LCG} = \frac{(72.882 \times 13486) - (1.90 \times 179.77 \times 100)}{13486}$$

$$= 70.349 \text{ m}$$

Wt. of cargo discharged = $\dfrac{\text{Volume}}{\text{S.F.}}$

$$= \frac{507.7}{2/3} = \frac{507.7 \times 3}{2} = 761.6 \text{ t}$$

		Weights (t)	LCG (m)	L. Moments (mt)
Original displ.		134862	70.349	948726.6
No. 4 TD	(-)	761.6	57.44	(-) 43746.3

Final Wt. = 12724.4 Final L.Moment = 904980.3

$$\text{Final LCG} = \frac{904980.3}{12724.4} = 71.121 \text{ m}$$

For final displ. 12724.4 t

LCB = 72.927 m

Hydrostatic draft = 6.3110 m

MCTC = 176.70 mt

LCF = 72.246 m

$$\text{Total trim } t = \frac{LCB - LCG}{MCTC \times 100} \times \text{Displacement}$$

$$= \frac{72.927 - 71.121}{176.7 \times 100} \times 12724.4$$

Total trim t = 1.301 m

$$t_a = \frac{t \times LCF}{LBP} = \frac{1.301 \times 72.246}{143.16} = 0.657 \text{ m}$$

$$t_f = t - t_a = 1.301 - 0.657 = 0.644 \text{ m}$$

		F		A
Hydrostatic draft		6.311 m		6.311 m
trim	(-)	0.644 m	(+)	0.657 m
Final Drafts	*F*	*5.667 m*	*A*	*6.968 m*

67. *M. V. 'Hindship' at a draft of F 7.66 m, A 7.82 m, loads 220 t in No. 2 TD and consumes 30 t of FW from the TD drinking water tank (P). Calculate the final drafts F & A.*

Original drafts F 7.66 m, A 7.82 m } trim 0.16 m by stern
M 7.74 m

LCF for mean draft 7.74 m = 70.840 m

$$\text{Corrn. to After draft} = \frac{0.16 \times 70.84}{143.16} = 0.079 \text{ m}$$

After draft = 7.820 m

Hydrostatic draft = 7.741 m

For hydrostatic draft 7.741 m,

Displacement = 16023 t

MCTC = 193.774 mt

LCB = 72.655 m

$$\text{Total trim } t = \frac{LCB - LCG}{MCTC \times 100} \times \text{Displacement}$$

$$(LCB - LCG) = \frac{t \times MCTC \times 100}{\text{displacement}} = \frac{0.16 \times 193.774 \times 100}{16023}$$

$$= 0.193 \text{ m}$$

LCB = 72.655 m

Original LCG = 72.462 m

	Weights (t)	LCG (m)	L. Moments (mt)
Original displ.	16023	72.462	1161058.6
Loaded 2 TD (+)	220	103.91	(+) 22860.2
FW consumed (-)	30	5.86	(-) 175.8
Final displ. =	16213	Final L. Moments =	1183743

$$\text{Final LCG} = \frac{1183743}{16213} = 73.012 \text{ m}$$

For displacement 16213 t

Hydrostatic draft = 7.822 m

MCTC = 194.907 mt

LCB = 72.635 m

LCF = 70.760 m

$$\text{Total Trim } t = \frac{LCB - LCG}{MCTC \times 100} \times \text{Displacement}$$

$$= \frac{(72.635 - 73.012)}{194.907 \times 100} \times 16213$$

= (-) 0.314 m (Note -ve sign indicates trim by the head).

$t_a = \frac{t \times LCF}{LBP} = \frac{0.314 \times 70.76}{143.16} = (-)\ 0.155$ m

$t_f = t - t_a = -0.314 - (-0.155) = (-)\ 0.159$ m

Draft (Frd) = Hydrostatic draft - t_f

= 7.822 (-) - 0.159 m = 7.981 m

Draft (Aft) = Hydrostatic draft + t_a

= 7.822 (+) - 0.155 m = 7.667 m

Final drafts F 7.981 m, A 7.667 m

EFFECT OF DRAFT FORE & AFT DUE TO LOADING/DISCHARGING/ SHIFTING IN DIFFERENT DENSITIES

(Before attempting problems on this topic, the student is advised to carefully recapitulate Qns. 3 and 4.)

68. *M. V. 'Hindship' in a river port of water of RD 1.014 is at a displacement of 10230 t, GM (Fluid) 0.82 m, FSC 0.077 m, LCG 71.62 m. She loads 470 t, Lcg 60.20 m Kg 9.8 m. 150 t of water ballast is run into No. 1 DB tank. Find her final drafts F & A and GM (Fluid).*

Initial displacement		=	10230 t
Equivalent weight in SW	= $\frac{10230 \times 1.025}{1.014}$	=	10340.9 t
GM (Fluid)		=	0.820 m
FSC		=	0.077 m
GM (Solid)		=	0.897 m
KM for displ. 10340.9 t		=	8.744 m
KG		=	7.847 m
Initial FSM	= 0.077 x 10230	=	787.7 mt
FSM in 1 DB tank	= 419 x 1.014	=	424.9 mt
Final FSM		=	1212.6 mt

	Weights (t)	KG (m)	V. Moments (mt)	LCG (m)	L. Moments (mt)
Original displ.	10230	7.847	80274.8	71.62	32672.6
Loads	(+) 470	9.80	(+) 4606.0	60.20	(+) 28294.0
No. 1 DB tank	(+) 150	1.14	(+) 171.0	124.63	(+) 18694.5
Final Wt	= 10850	F. V. M	= 5051.8	F.L.M.	= 779661.1

$$\text{Final KG} = \frac{85051.8}{10850} = 7.839 \text{ m}$$

Final LCG $= \dfrac{779661.1}{10850} = 71.858$ m

Final FSC $= \dfrac{1212.6}{10850} = 0.112$ m

For displacement 10850 t in density 1.014, equivalent Weight in SW

$$= \frac{10850 \times 1.025}{1.014} = 10967.7 \text{ t}$$

Hydrostatic draft = 5.532 m (From hydrostatic tables for displ. 10967.7 t)

MCTC in SW = for displ. 10967.7 = 170.522

MCTC in DW $= \dfrac{170.522 \times 1.014}{1.025} = 168.692$

LCB = 72.996 m (From hydrostatic tables for displ. 10967.7 t)

LCF = 72.704 m (From hydrostatic tables for displ. 10967.7 t)

KM = 8.607 m (From hydrostatic tables for displ. 10967.7 t)

Total trim 't' $= \dfrac{(LCB - LCG)}{MCTC \times 100} \times$ Displacement

$$= \frac{(72.996 - 71.858)}{168.692 \times 100} \times 10850 = 0.732 \text{ m}$$

$$t_a = \frac{t \times LCF}{LBP} = \frac{0.732 \times 72.704}{143.16} = 0.372 \text{ m}$$

$$t_f = t - t_a = 0.732 - 0.372 = 0.360 \text{ m}$$

		F		A
Final Hydrostatic draft		5.532 m		5.532 m
trim	(-)	0.360 m	(+)	0.372 m
Final draft		*5.172 m*		*5.904 m*

Final KM	=	8.607 m
Final KG	=	7.839 m
Final GM (Solid)	=	0.768 m
FSC	=	0.112 m
Final GM (Fluid)	=	***0.656 m***

69. *M. V. 'Hindship' at a draft of F 5.38 m, A 6.17 m, has GM (Fluid) 0.83 m and FSC 0.092 m. She discharges 430 t from No. 3 TD, VCg 10.2, LCg 78.5 m and loads 250 t in No. 5 LTD. 300 t of fuel oil was received equally distributed in No. 2 DB tanks P & S. Calculate her final drafts F & A and GM (Fluid).*

Original draft F 5.38 m, A 6.17 m } trim 0.79 m by stern; M 5.775 m

LCF for mean draft 5.775 m	=	72.601 m
After draft	=	6.170 m
Corrn. = $\frac{0.79 \times 72.601}{143.16}$	=	0.400 m
Original hydro draft	=	5.770 m
Original displ.	=	11501.7 t
LCB	=	72.981 m
MCTC	=	172.19 mt
KM	=	8.513 m
Original GM (Fluid)	=	0.830 m
FSC	=	0.092 m
Original GM (Solid)	=	0.922 m
Original KM	=	8.513 m
Original KG	=	7.591 m

$$t = \frac{(LCB - LCG)}{MCTC \times 100} \times Displ.$$

$$0.79 = \frac{(LCB - LCG)}{172.19 \times 100} \times 11501.7$$

$$(LCB - LCG) = \frac{0.79 \times 172.19 \times 100}{11501.7} = 1.183 \text{ m}$$

LCB = 72.981 m

Original LCG = 71.798 m

		Weight (t)	KG (m)	V. Moments (mt)	LCG (m)	L. Moments (mt)
Original displ.		11501.7	7.591	87309.4	71.798	825799.1
Disch No. 3 TD	(-)	430	10.20	(-) 4386.0	78.500	(-) 33755.0
Loads No. 5 LTD	(+)	250	10.69	(+) 2672.5	17.240	(+) 4310.0
Fuel oil						
No. 2 DB Tk	(+)	300	0.65	(+) 195.0	102.20	(+) 30660.0
Final Wt.		11621.7	Final V.Mmts	85790.9	Final L.Mmts	827014.1

$$\text{Final KG} = \frac{85790.9}{11621.7} = 7.382 \text{ m}$$

$$\text{Final LCG} = \frac{827014.1}{11621.7} = 71.161 \text{ m}$$

Original FSM = 0.092 x 11501.7 = 1058.2 mt

FSM in No.2 (P&S) = 1436 x 0.95 = 1364.2 mt

Final FSM = 2422.4 mt

$$\text{Final FSC} = \frac{2422.4}{11621.7} = 0.208 \text{ m}$$

For final displ. 11621.7 t

Hydrostatic draft = 5.823 m

MCTC	=	172.587 mt
LCB	=	72.977 m
LCF	=	72.577 m
KM	=	8.495 m
Final KG	=	7.382 m
Final GM (Solid)	=	1.113 m
FSC	=	0.208 m
Final GM (Fluid)	=	0.905 m

$$\text{Total trim 't'} = \frac{(\text{LCB} - \text{LCG})}{\text{MCTC} \times 100} \times \text{Displ.}$$

$$= \frac{(72.977 - 71.161)}{172.587 \times 100} \times 11621.7 \quad = \quad 1.223 \text{ m}$$

$$\text{After trim, } t_a = \frac{t \times \text{LCF}}{\text{LBP}} = \frac{1.223 \times 72.577}{143.16} \quad = \quad 0.620 \text{ m}$$

$$t_f = t - t_a = 1.223 - 0.620 \quad = \quad 0.603 \text{ m}$$

Hydro. draft		5.823 m		5.823 m
trim	(-)	0.603 m	(+)	0.620 m
Final draft	***F*** =	***5.220m***	***A*** =	***6.443 m***

70. *M. V. 'Hindship' berthed in a dock where RD of water is 1.007, at a draft of F 7.87 m, A 8.32 m, KG 7.45 m, FSM 970 mt. She discharged 410 t of cargo from 2 TD. A 60 t case is shifted from deck, Kg 14.7 m, Lcg 58.6 m, to No. 2 Hold. 110 t of water Kg 2.77, Lcg 16.23 m was received in No. 8 (P & S) tanks, filling them completely. Calculate the draft F & A at which she would sail from the dock. Also calculate her sailing GM (Fluid) if additional FSE was created in No. 3 DB tank (centre) which contained HFO.*

F 7.870 m
A 8.320 m } trim = 0.45 m by stern

M 8.095 m   LCF = 70.507 m

Corrn. to A. draft $= \dfrac{0.45 \times 70.507}{143.16} = 0.222$ m

A. draft $= 8.320$ m

Hydro draft $= 8.098$ m

For hydro. draft 8.098 m SW, displ. $= 16870.7$ t

Displ in δ 1.007 $= \dfrac{16870.7 \times 1.007}{1.025} = 16574.4$ t

MCTC in (SW) $= 198.772$ mt

MCTC in δ 1.007 $= \dfrac{198.772 \times 1.007}{1.025} = 195.281$ mt

LCB $= 72.561$ m

trim $= \dfrac{(LCB - LCG)}{MCTC \times 100} \times$ Displ.

(LCB - LCG) $= \dfrac{t \times MCTC \times 100}{Displ.} = \dfrac{0.45 \times 195.281 \times 100}{16574.4}$

$= 0.530$ m

LCB $= 72.561$ m

LCG $= 72.561 - 0.530 = 72.031$ m

	Weights (t)	KG (m)	V. Moments (mt)	LCG (m)	L. Moments (mt)
Initial displ.	16574.4	7.45	123479.3	72.031	1193870.6
Disch 2 TD (-)	410	10.72	(-) 4395.2	103.91	(-) 42603.1
Shifted	60	↓ 9.72	(-) 583.2	44.54	(+) 2672.4
No. 8 (P&S) (+)	110	2.77	(+) 304.7	16.23	(+) 1785.3

Final wt. = 16274.4 Final V. Mmt. = 118805.6 Final L. Mmt = 1155725.2

Original FSM $= 970$ mt

No. 8 (P & S) $= 23 \times 1.0 = (-)\ 23$ mt

No. 3 (C)	=	1181 x 0.95	= (+)	1122 mt
Final FSM			=	2069 mt

$$\text{Final FSC} = \frac{2069}{16274.4} = 0.127 \text{ m}$$

$$\text{Final KG} = \frac{118805.6}{16274.4} = 7.300 \text{ m}$$

$$\text{Final LCG} = \frac{1155725.2}{16274.4} = 71.015 \text{ m}$$

For displ. 16274.4 in δ 1.007, equivalent wt. in SW

= 16565.3 t

Hydrostatic draft	=	7.971 m

$$\text{MCTC} = \frac{196.988 \times 1.007}{1.025} = 193.528 \text{ m}$$

LCB	=	72.596 m
LCF	=	70.622 m
KM	=	8.249 m
Final KG	=	7.300 m
Final GM (Solid)	=	0.949 m
Final FSC	=	0.127 m
Final GM (Fluid)	=	0.822 m

$$\text{Total trim 't'} = \frac{(\text{LCB} - \text{LCG})}{\text{MCTC} \times 100} \times \text{Displ.}$$

$$= \frac{(72.597 - 71.015)}{193.528 \times 100} \times 16274.4$$

$$= 1.330 \text{ m}$$

$$t_a = \frac{t \times \text{LCF}}{\text{LBP}} = \frac{1.33 \times 70.622}{143.16} = 0.656 \text{ m}$$

$t_f = t - t_a = 1.330 - 0.656 = 0.674$ m

		F		A
Final hydrostatic draft		7.971 m		7.971 m
trim	(-)	0.674 m	(+)	0.656 m
Final draft	*F*	*7.297 m*	*A*	*8.627 m*

N.B. It should be noted that the Hydrostatic Particulars of M. V. 'Hindship' are given for the EVEN KEEL condition. Thus, if the CB and the CG are brought in the same vertical line at any particular Hydrostatic draft, there will be no trimming moment and the ship will be on an even keel. This argument is used in solving the problems on this topic.

71. *M. V. 'Hindship' is floating at a draft of F 7.2 m., A 7.8 m.*

(a) *Find, where with respect to AP 200 tonnes of cargo is to be loaded to bring her on an even keel.*

(b) *If instead of loading as in (a), the even keel condition was to be achieved by shifting cargo from No. 5 Hold to No. 3 Hold, find the amount of cargo to be shifted.*

a) Initial draft F 7.2m, A 7.8m } trim = 0.6 m by stern

M 7.5m

LCF for mean draft 7.5 m	=	71.086 m
Aft draft	=	7.800 m
Corrn. to Aft. draft = $\frac{0.6 \times 71.086}{143.16}$	= (-)	0.298 m
Hydrostatic draft	=	7.502 m
For hydrostatic draft 7.502 m		
LCB	=	72.714 m
MCTC	=	190.4 mt
Displacement	=	15464 t

$$\text{Total trim} = \frac{(\text{LCB} - \text{LCG})}{\text{MCTC} \times 100} \times \text{Displ.}$$

Let 'x' be the original LCG of the ship.

Then $0.6 = \frac{72.714 - x}{190.4 \times 100} \times 15464$

$\therefore \quad 0.6 \times 19040 = 15464 \times 72.714 - 15464x$

$= 1124449.3 - 15464x$

$x = \frac{1113025.3}{15464} = 71.975$ m

Original LCG = 71.975 m

Original displacement = 15464 t

To load = 200 t

Final displacement = 15664 t

LCB for final displacement = 72.693 m

To be on an even keel, LCB = LCG

Let y be the Lcg of the weight to be loaded

	Weight (t)	LCG (m)	L. Moments (mt)
Original displacement	15464	71.975	1113025.3
Loaded	200	y	200 y
Final displacement	15664	Final L. Moment	1113025.3 + 200 y

Final LCG $= \frac{1113025.3 + 200\,y}{15664} = 72.693$ (LCG = LCB)

$200\,y = 15664 \times 72.693 - 1113025.3$

$y = \frac{25637.852}{200} = 128.19$ m

Cargo is to be loaded 128.19 m ford of AP.

(b) Lcg of No. 3 Hold = 80.63 m

Lcg of No. 5 Hold = 17.31 m

Distance through which cargo is to be shifted = 63.32 m

As in (a) above, Original displacement	=	15464 t
Original LCB	=	72.714 m
Original LCG	=	71.975 m
For even keel condition, LCG should equal LCB	=	72.714 m
GG_1 reqd. in the ford direction = 72.714 - 71.975	=	0.739 m

$$GG_1 = \frac{w \times d}{W} = \frac{w \times 63.32}{15464} = 0.739$$

w = 180.478 t

Cargo to be shifted = 180.5 tonnes

72. *M. V. 'Hindship' in Condition No. 10, has to load 800 tonnes of cargo. Space is available in No. 1 TD, 125 metres ford of AP and in No. 3 TD, 80 metres ford of AP. Find the amount of cargo to load in each space to finish the ship on an even keel. State also the final drafts F & A.*

Displacement in Condition No. 10	=	16133 t
Cargo to be loaded	=	800 t
Final displacement	=	16933 t
LCB for displacement 16933 t	=	72.553 m

To achieve even keel condition, LCG should also be 72.553 m, ford of AP. Let 'x' tonnes be loaded in No. 1 and (800 - x) tonnes in No. 3.

		Weights (t)	LCG (m)		L.Moments (mt)
Displacement in Condition No.10		16133	70.289		1133972
No. 1 TD	(+)	x	125	(+)	125x
No. 3 TD	(+)	(800 - x)	80	(+)	64000 - 80x
	=	16933	Final L.Mmts.	=	1197972 + 45x

$$\text{Final LCG} = \frac{1197972 + 45x}{16933} = 72.553$$

$$45x = (16933 \times 72.553) - 1197972$$

$$x = \frac{30568}{45} = 679.3 \text{ t}$$

Cargo to be loaded in No. 1 TD = 679.3 t

Cargo to be loaded in No. 3 TD = 800 - 679.3 = 120.7 t

Hydrostatic draft for displacement 16933 t = 8.124 m

Since the V/L is on an even keel

The drafts F & A = 8.124 m

75. *M.V. 'Hindship' sails in condition No. 6. On the voyage, she is expected to consume 230 tonnes of fuel from No. 3 DB tank No. 7 DB tanks. Find the amount to be consumed from each tank to arrive on an even keel.*

Displacement in condition No. 6 = 19617 t

Fuel consumed = 230 t

Displacement on arrival = 19387 t

LCB for displacement 19387 t = 72.243 m

Let x tonnes be consumed from No. 7 DB tanks and (230 -x) tonnes from No. 3 DB tank.

		Weights (t)	LCG (m)		L. Moments (mt)
Displacement in condition No. 6		19617	71.813		1408746
No. 7 DB tank	(-)	x	22.97	(-)	22.97x
No. 3 DB tank	(-)	(230 - x)	80.63	(-)	(18544.9 - 80.63x)
Final Weight	=	19387	Final L.Mmts	=	1390201.1 + 57.66x

$$\text{Final LCG} = \frac{1390201.1 + 57.66x}{19387}$$

$$57.66x = (19387 \times 72.243) - 1390201.1$$

$$x = \frac{10373.9}{57.66} = 179.92 \text{ t}$$

Fuel to be consumed from No. 7 DB tanks = 179.92 t

Fuel to be consumed from No. 3 DB tanks = 230 - 179.92 = 50.08t

74. *M.V. 'Hindship' arrives in Condition No. 7 and discharges the entire cargo from No. 4 TD. Given, change in LCB due to ballasting is negligible, find the amount of ballast to be run into the Aft Peak tank to bring her on an even keel. Also calculate the drafts F & A after ballasting.*

		Weights (t)	LCG (m)	L.Moments (mt)
Displacement in Condition No. 7		18529.3	72.340	1340415
No. 4 TD	(-)	296.2	57.680	(-) 17085

Final wt. = 18233.1 Final L.Mmts. = 1323330

$$\text{LCG} = \frac{1323330}{18233.1} = 72.578 \text{ m}$$

LCB for displacement 18233.1 = 72.394 m

Let 'x' tonnes of ballast be run into Aft Peak

	Weights (t)	LCG (m)	L. Moments (mt)
Displacement	18233.1	72.578	1323330
Ballast in A Pk (+)	x	3.58	(+) 3.58x

Final Wt. = 18233.1 + x Final L. Moment 1323330 + 3.58x

$$\text{Final LCG} = \frac{1323330 + 3.58x}{18233.1 + x} = 72.394 \text{ m}$$

$1323330 + 3.58x = (18233.1 \times 72.394) + 72.394x$

$68.814x = 3363$

$x = \frac{3363}{68.814} = 48.87 \text{ t}$

Ballast to be run into Aft Pk = 48.87 t (approx.)

Though the change in LCB is stated to be negligible, there will in fact be some small change. Therefore the above figure of 48.87 tonnes is approximate.

Displacement after ballasting = 18233.1 + 48.87

= 18281.97 t

Hydrostatic draft for 18281.97 = 8.684 m

Drafts F & A = 8.684 m

75. *M. V. 'Hindship' loading in dock water, RD 1.018 is on an even keel draft of 8.4 m, with a GM (Solid) of 0.45 m. She is to sail on an even keel at her summer draft in SW. Space has been allocated for the following parcels:-*

400 t in No. 2	*Kg 11 m*	*LCg 107 m*
350 t in No. 4	*Kg 9.8 m*	*LCg 53 m*
650 t in No. 5 TD	*Kg 10 m*	*LCg 18 m*

The remaining cargo is to be loaded in No. 1, Kg 5.5 m, LCg 122 m and No. 5 Hold Kg 6 m, LCg 15 m. Calculate the amount to be loaded in each of these spaces and the final GM (Fluid) of the vessel, if her FSM was 2500 mt.

KM for draft 8.4 m = 8.292 m

Initial GM (Solid) = 0.450 m

Initial KG = 7.842 m

Displ. in SW at draft 8.4 m = 17598 t

Displ. at that draft in water RD 1.018 = $\frac{17598 \times 1.018}{1.025}$ = 17477.8 t

Displ. at summer draft in SW = 19617.0 t

Total cargo to load = 2139.2 t

Weight of cargo for which space has been allotted = 1400 t

Wt. of cargo to be loaded in No. 1 and 5 Holds = 739.2 t

Let x tonnes to be loaded in No. 1 and (739.2 -x) t in No. 5 Hold.

As she is on an even keel, Initial LCG = LCB for draft 8.4 m, i.e. 72.473m

As she should finish on an even keel,

Final LCG = LCB for draft 9.233 m = 72.212

	Weights (t)	LCG (m)	L. Moments (mt)
Initial displ.	17477.8	72.473	1266668.5
No. 2	400.0	107.0	42800.0
No. 4	350.0	53.0	18550.0
No. 5 TD	650.0	18.0	11700.0
No. 1	x	122.0	122x
No. 5H	739.2 - x	15.0	11088 - 15x
Final Wt.	19617.0	Final L. Mmts	1350806.5 + 107x

$$\text{Final LCG} = 72.212 = \frac{1350806.5 + 107x}{19617}$$

$$x = \frac{(19617 \times 72.212) - 1350806.5}{107} = 614.7 \text{ t}$$

Cargo to be loaded in No. 1 = 614.7 t

Cargo to be loaded in No. 5 H = 739.2 - 614.7 = 124.5 t

	Weights (t)	KG (m)	V. Moments (mt)
Initial displ.	17477.8	7.842	137060.9
No. 2	400.0	11.0	4400.0
No. 4	350.0	9.8	3430.0
No. 5 TD	650.0	10.0	6500.0
No. 1	14.7	5.5	3380.9
No. 5H	124.5	6.0	747.0
Final Wt.	19617.0	Final V. Moment	155518.8

Final KM = 8.435 m

$$\text{Final KG} = \frac{155518.8}{19617} = 7.928 \text{ m}$$

GM (Solid) = 0.507 m

$$\text{FSC} = \frac{2500}{19617} = 0.127 \text{ m}$$

Final GM (Fluid) = 0.380 m

TO KEEP THE DRAFT AT ONE END CONSTANT

76. *M. V. 'Hindship' in Condition No. 2, has to load 220 tonnes of cargo. Where should this be loaded to keep her after draft unchanged?*

Displacement in condition No. 2	=	7799 t
Cargo to load	=	220 t
Final displacement	=	8019 t
For displ. 8019 t. Hydrostatic draft	=	4.191 m
MCTC	=	160.621 m
LCB	=	73.014 m
LCF	=	73.104 m
Hydrostatic draft	=	4.191 m
After draft reqd. (Same as in condition No. 2)	=	6.012 m
∴ After trim reqd.	=	1.821 m

$$\text{Total trim reqd.} = \frac{LBP \times t_a}{LCF} = \frac{143.16 \times 1.821}{73.104} = 3.566 \text{ m}$$

Since the trim reqd. is by the stern, LCB is > LCG.

$$\text{Total trim t} = \frac{(LCB - LCG) \times \text{Displacement}}{MCTC \times 100}$$

$$3.566 = \frac{(LCB - LCG) \times 8019}{160.621 \times 100}$$

$$(LCB - LCG) = \frac{3.566 \times 160.621 \times 100}{8019}$$

$$(LCB - LCG) = 7.143 \text{ m}$$

$$LCG = 73.014 - 7.143 = 65.871 \text{ m}$$

This is the final LCG reqd. to provide the above trim.

	Weight (t)	LCG (m)		L. Moments (mt)
Original displ.	7799	65.344		509617
Cargo loaded (+)	220	x	(+)	220x

Final Wt. = 8019 Final Moment = 509617 + 220x

$$\text{Final LCG} = \frac{509617 + 220x}{8019} = 65.871 \text{ m}$$

$$220x = (8019 \times 65.871) - 509617$$

$$= 18602.54$$

$$= \frac{18602.54}{220} = 84.557 \text{ m}$$

Cargo to be loaded 84.557 m ford of AP.

77. *M. V. 'Hindship' in SW at a draft of 7.25 m ford and 8.10 m aft, has to load 170 t of cargo. Where with respect to AP should this cargo be loaded so that her ford draft would remain the same in water of RD 1.015.*

Initial draft F 7.250 m, A 8.100 m } trim = 0.85 m by stern

M 7.675 m LCF = 70.904 m

$$\text{Corrn. to Aft draft} = \frac{0.85 \times 70.904}{143.16} = 0.421 \text{ m}$$

Aft draft = 8.100 m

Initial Hydrostatic draft = 7.679 m

For hydrostatic draft 7.679 m,

Displacement = 15877.9 t

MCTC = 192.91 mt

LCB = 72.671 m

LCF = 70.900 m

$$\text{Initial trim 't'} = \frac{(LCB - LCG) \times \text{Displacement}}{MCTC \times 100}$$

$$\therefore (LCB - LCG) = \frac{t \times MCTC \times 100}{\text{Displ.}} = \frac{0.85 \times 192.91 \times 100}{15877.9}$$

= 1.033 m

LCB = 72.671 m

Initial LCG = 71.638 m

Initial Displ. = 15877.9 t

To be loaded = 170.0 t

Final displ. = 16047.9 t

For displ. 16047.9 t in δ 1.015, equivalent weight in SW.

$$= 16047.9 \times \frac{1.025}{1.015} = 16206 \text{ t}$$

For displ. 16206 t Hydro draft = 7.819 m

$$MCTC = \frac{194.866 \times 1.015}{1.025} = 192.965 \text{ mt}$$

LCB = 72.636 m

LCF = 70.762 m

Ford draft reqd. = 7.250 m

Final hydro draft = 7.819 m

F. trim reqd. = 0.569 m

$$\text{F. Trim} = \frac{\text{T. Trim} \times \text{Ford Length}}{\text{Total Length}}$$

$$\therefore \text{Total Trim} = \frac{\text{F. Trim} \times \text{T. Length}}{\text{Ford Length}}$$

Ford length = LBP - LCF = 143.16 - 70.762 = 72.398 m

$$\therefore \text{ T. Trim 't'} = \frac{0.569 \times 143.16}{72.398} = 1.125 \text{ m}$$

$$\text{'t'} = \frac{(LCB - LCG)}{MCTC \times 100} \times \text{Displacement}$$

$$\therefore LCB - LCG = \frac{t \times MCTC \times 100}{Displ.}$$

$$= \frac{1.125 \times 192.965 \times 100}{16047.9} = 1.353 \text{ m}$$

Final LCB = 72.636 m

∴ Final LCG reqd. = 71.283 m

	Weights (t)	LCG (m)	L. Moments (mt)
Initial displ.	15877.9	71.638	1137461
Loaded (+)	170.0	x	(+) 170x
Final displ.	16047.9	Final L. Moment	= 1137461 + 170x

$$\text{Final LCG} = 71.283 = \frac{1137461 + 170x}{16047.9}$$

$$\therefore x = \frac{71.283 \times 16047.9 - 1137461}{170}$$

Cargo to be loaded 38.126 m ford of AP

TO ACHIEVE A DESIRED TRIM

78. *M.V. 'Hindship' in Condition No. 8 has to discharge 300 tonnes, prior to sailing. Calculate the position with respect to AP, from where, this weight is to be discharged to enable her so sail trimmed 1.5 metres by the stern. Also find the sailing drafts F & A.*

Displacement in Condition No. 8	= 16133 t
To discharge	= 300 t
Final displacement	= 15833 t
For displacement 15833 t	
Hydrostatic draft	= 7.660 m
MCTC	= 192.638 m
LCB	= 72.675 m
LCF	= 70.919 m

Total trim $= \dfrac{(LCB - LCG)}{MCTC \times 100} \times \text{Displ.}$

Desired total trim = 1.5 m

$\therefore \quad 1.5 = \dfrac{(LCB - LCG)}{192.638 \times 100} \times 15833$

$1.5 \times 192.638 \times 100 = (LCB - LCG) \times 15833$

$(LCB - LCG) = \dfrac{1.5 \times 192.638 \times 100}{15833}$

$= 1.825 \text{ m}$

Final LCG reqd. to produce the above trim = 72.675 - 1.825

= 70.850 m

	Weights (t)	LCG (m)	L. Moments (mt)
Original displ.	16133	70.045	1130041
Wt. discharged (-)	300	x	(-) 300x

Final Wt. = 15833 Final L. Moment = 1130041 - 300x

$$\text{Final LCG} = \frac{1130041 - 300x}{15833} = 70.850 \text{ m}$$

$$300x = 1130041 - (15833 \times 70.85)$$

$$300x = 8273$$

$$x = \frac{8273}{300} = 27.577 \text{ m ford of AP}$$

Position from where 300 t is to be disch. = 27.577 m ford of AP

To find Sailing drafts F & A

$$\text{After } 't_a' = \frac{t \times LCF}{LBP} = \frac{1.5 \times 70.919}{143.16}$$

$$'t_a' = 0.743 \text{ m}$$

$$'t_f' = t - ta$$

$$= 1.5 - 0.743 = 0.757 \text{ m}$$

		F		A
Final Hydrostatic draft		7.660 m		7.660 m
trim	(-)	0.757 m	(+)	0.743 m
Final drafts	*F*	*6.903 m*	*A*	*8.403 m*

79. *M.V. 'Hindship' in dock water of density 1.007 t/m^3 is at a draft of F 7.62 m, A 7.94 m. She has to load 450 t of cargo. Calculate the position with respect of AP, where this weight should be loaded so that she would be trimmed 1 m by the stern on completion.*

Initial drafts F 7.62 m, A 7.94 m } trim 0.32 m by stern

M 7.78 m

LCF for mean draft 7.78 m = 70.800 m

Corrn. to after draft $= \dfrac{0.32 \times 70.8}{143.16} = 0.158$ m

After draft = 7.940 m

Hydrostatic draft = 7.782 m

For hydrostatic draft 7.782 m, displacement in density 1.007

$$= \frac{16118.9 \times 1.007}{1.025} = 15835.8 \text{ t}$$

MCTC $= \dfrac{194.347 \times 1.007}{1.025} = 190.935$ mt

LCB = 72.645 m

Total trim = 0.32 $= \dfrac{(LCB - LCG)}{190.935 \times 100} \times 15835.8$

$\therefore$ (LCB - LCG) $= \dfrac{0.32 \times 190.935 \times 100}{15835.8} = 0.386$ m

Original LCB = 72.645 m

$\therefore$ Original LCG = 72.259 m

Original displacement = 15835.8 t

To load = 450.0 t

Final displacement = 16285.8 t

Equivalent weight in SW = $\frac{16285.8 \times 1.025}{1.007}$ = 16576.9 t

For displacement of 16576.9 t

LCB = 72.594 m

MCTC = 193.596 mt $\left(\text{MCTC in SW} \times \frac{1.007}{1.025}\right)$

Required trim = 1.0 = $\frac{(\text{LCB} - \text{LCG})}{193.596 \times 100} \times 16285.8$

$\therefore$ (LCB - LCG) = $\frac{1.0 \times 193.596 \times 100}{16285.8}$ = 1.189 m

LCB = 72.594 m

$\therefore$ Final LCG reqd. = 71.405 m

	Weight (t)	LCG (m)		L. Moments (mt)
Initial displ.	15835.8	72.259		1144279
To load (+)	450.0	x	(+)	450x

Final Wt. = 16285.8 Final L. Moments = 1144279 + 450x

Final LCG = 71.405 = $\frac{1144279 + 450x}{16285.8}$

$$x = \frac{(71.405 \times 16285.8) - 1144279}{450}$$

= 41.352 m

The Wt. should be loaded 41.352 m ford of AP.

TO ACHIEVE A DESIRED DRAFT AT ONE END

80. *M.V. 'Hindship' in Condition No. 3, sustained damage aft. To effect repairs, it is required to reduce the after draft to. 4.5 m by loading 518 tonnes in the fore part of the vessel. Find how far abaft the fore perpendicular, this weight should be loaded?*

Displacement in Condition No. 3	= 7087.3 t
To load	= 518.0 t
Final displacement	= 7605.3 t
For displacement of 7605.3 t Hydrostatic draft	= 4.00 m
MCTC	= 158.9 mt
LCB	= 73.010 m
LCF	= 73.131 m
After draft required	= 4.50 m
Hydrostatic draft	= 4.00 m
After trim reqd.	= 0.50 m

Total trim reqd. $\dfrac{t_a \times \text{LBP}}{\text{LCF}} = \dfrac{0.5 \times 143.16}{73.131} = 0.979$ m (by stern)

Total trim 't' $= \dfrac{\text{LCB} - \text{LCG}}{\text{MCTC} \times 100} \times \text{Displacement}$

LCB - LCG $= \dfrac{\text{total trim} \times \text{MCTC} \times 100}{\text{Displacement}}$

$= \dfrac{0.979 \times 158.9 \times 100}{7605.3} = 2.045$ m

LCB in final condition	= 73.010 m
LCB - LCG	= 2.045 m
Final LCG reqd.	= 70.965 m

	Weight (t)	LCG (m)	L. Moments (mt)
Original displ.	7087.3	67.679	479662
To load	518.0	x	518x
Final Wt.	7605.3	Final moments	479662 + 518x

$$\text{Final LCG} = 70.965 = \frac{479662 + 518x}{7605.3}$$

$$518x = (7605.3 \times 70.965) - 479662$$

$$= 60132$$

$$x = \frac{60132}{518} = 115.923 \text{ m from AP}$$

LBP of ship = 143.16 m

Distance from FP = 143.16 - 115.923 = 27.237 m

81. *M.V. 'Hindship' in Fresh Water is at a draft of F 6.32 m, A 7.18 m. Calculate the position with respect to AP, from where 140 t should be discharged to reduce her ford draft by 32 cms.*

Initial drafts F 6.32 m, A 7.18 m } trim 0.86 m by stern
M 6.75 m

LCF for mean draft 6.75 m = 71.856 m

$$\text{Corrn. to After draft} = \frac{0.86 \times 71.856}{143.16} = 0.431 \text{ m}$$

After draft = 7.180 m

Hydrostatic draft in FW = 6.749 m

For draft 6.749 m, displacement in FW $= \dfrac{13723.5 \times 1.000}{1.025}$

$= 13388.8$ t

MCTC $= \dfrac{180.865 \times 1.000}{1.025} = 176.454$ mt

LCB $= 72.866$ m

Present trim $= 0.86 = \dfrac{(LCB - LCG)}{176.454 \times 100} \times 13388.8$

$\therefore$ (LCB - LCG) $= \dfrac{0.86 \times 176.454 \times 100}{13388.8} = 1.133$ m

LCB $= 72.866$ m

$\therefore$ Initial LCG $= 71.733$ m

Initial displacement $= 13388.8$ t

To discharge $= 140.0$ t

Final displacement $= 13248.8$ t

Equivalent wt. in SW $= \dfrac{13248.8 \times 1.025}{1.000} = 13580.0$ t

For displacement of 13580 t Hydrostatic draft $= 6.686$ m

MCTC $= \dfrac{180.205 \times 1.0}{1.025} = 175.810$ mt

LCB $= 72.876$ m

LCF $= 71.919$ m

For'd draft required $= 6.000$ m

Hydrostatic draft $= 6.686$ m

$\therefore$ Ford trim reqd. $= 0.686$ m

Ford length = LBP - LCF = 143.16 - 71.919 $= 71.241$ m

$$\text{Ford trim} = \frac{\text{Total trim} \times \text{Ford length}}{\text{Total length}}$$

$$\therefore \text{Total trim} = \frac{\text{Ford trim} \times \text{Total length}}{\text{Ford length}}$$

$$= \frac{0.686 \times 143.16}{71.241} = 1.379 \text{ m}$$

$$1.379 = \frac{\text{LCB} - \text{LCG}}{\text{MCTC} \times 100} \times \text{Displacement}$$

$$\therefore (\text{LCB} - \text{LCG}) = \frac{t \times \text{MCTC} \times 100}{\text{Displ.}} = \frac{1.379 \times 175.81 \times 100}{13248.8}$$

$$= 1.830 \text{ m}$$

$$\text{LCB} = 72.876 \text{ m}$$

$$\therefore \text{Final LCG reqd.} = 71.046 \text{ m}$$

		Weight (t)	LCG (m)		L. Moments (mt)
Original displ.		13388.8	71.733		960418.8
To discharge	(-)	140.0	x	(-)	140x

Final Wt. = 13248.8 Final L. Moment = 960418.8 - 140x

$$\text{Final LCG} = 71.046 = \frac{960418.8 - 140x}{13248.8}$$

$$\therefore x = \frac{(71.046 \times 13248.8)}{140} = 136.747 \text{ m}$$

Weight to be discharged from 136.747 m ford of AP.

CHANGE OF TRIM DUE TO CHANGE OF DENSITY

The student is already aware that the hydrostatic draft of the vessel changes when she proceeds from water of one density to water of another density. He should further note that the trim of the vessel also alters with the change of density. As can be seen from the following problem the change in trim is caused due to the change in the value of LCB, as the hydrostatic draft changes with change of density. Since the value of LCB changes, the total trim obtained by the formula, 't' = $\frac{(LCB - LCG)}{MCTC \times 100} \times W$ also changes.

82. *M.V. 'Hindship' is at an even keel draft of 9.35 m in dock water of RD 1.004. Calculate her drafts F & A on reaching the sea. Assume fuel and fresh water consumption negligible.*

Displ. in SW at a draft 9.35 m = 19902.25 t

Displ. at that draft in δ 1.004 = $\frac{19902.25 \times 1.004}{1.025}$ = 19494.5 t

Initial LCG = LCB. (As she is on an even keel) = 72.175 m

For displacement 19494.5 t in SW,

Hydrostatic draft = 9.183 m

MCTC = 214.264 mt

LCB = 72.229 m

LCF = 69.625 m

Final trim 't' $= \frac{(LCB - LCG)}{MCTC \times 100} \times \text{Displ.}$

$= \frac{(72.229 - 72.175)}{214.264 \times 100} \times 19494.5$

$= 0.049$ m

$'t_a' = \frac{t \times LCF}{LBP} = \frac{0.049 \times 69.625}{143.16} = 0.024$ m

$t_f = t - t_a = 0.049 - 0.024 = 0.025$ m

			F		A
Hydro draft in SW	=		9.183 m		9.183 m
Trim	=	(-)	0.025 m	(+)	0.024 m

Final drafts F & A, F 9.158 m A 9.207 m

Trim tables are provided indicating change in draft Forward and Aft at different mean drafts, when tanks are filled to their capacity and also for addition of 100 t weight, at different positions with respect to midships.

These tables may be used for determination of approximate drafts after loading or discharging weights which are not large. The tables can be used for weights shifted also, as it can be considered as the weight discharged from one position and then loaded at the other position.

It should be noted that more accurate results are obtained by calculations as indicated in the earlier problems. When large changes in displacement are involved, this method should not be used, as the position of CF and the value of MCTC may change considerably.

83. *M.V. 'Hindship' floating at a draft of F 5.45 m, A 6.53 m, fills up No. 1 DB tank with water ballast, discharges 120 t of cargo from No. 2 TD, 99.5 m ford of AP and shifts a 70 t parcel of cargo from No. 2 TD to No. 4 TD. Using the trim tables, determine the final drafts F & A.*

	F (m)	A (m)	M (m)
Original drafts	5.450	6.530	5.990
Interpolating for mean draft 5.99 m from tank's trim tables for 161.50 t WB in No. 1 DB tank.			
Change in draft.	(+) 0.310	(-) 0.174	
	5.760	6.356	
Cg of No. 2 TD = 99.5 m fwd of AP			
Midships = 71.58 m ford of AP.			
∴ Cargo discharged from 27.92 m ford of midships.			
Change in draft due to discharging 120 t from 27.92 m ford of midships	(-) 0.144	(+) 0.041	
Note: Signs are reversed as weights was discharged, and values obtained for 100 t are multiplied by 120/100			

	5.616	6.397
Shifts of cargo from	5.616	6.397
No. 2 TD to No. 4 TD is equivalent to discharging that cargo from No. 2 TD and then loading it at No.4 TD		
The change in drafts due to this operation is therefore determined in two stages as indicated below.		
Change in draft due to discharging 70 t. from No. 2 TD, 32.33 m ford of midships.	(-) 0.093	(+) 0.032
Change in draft due to loading 70 t in No. 4 TD, 14.140 m aft of midships.	(+) 0.001	(+) 0.062
Final drafts	*F. 5.524 m*	*A 6.491 m*

84. *M.V. 'Hindship' in Condition No. 3 is listed 3^0 to starbd. It is desired to increase her trim to 3 metres by the stern and to bring her upright by transferring water ballast from No. 2 DB tanks to No. 4 DB tanks P and S only. Calculate the final distribution of water ballast in No. 2 and No. 4 DB tanks to achieve this, with No. 4 Port filled to capacity. Assume Cgs of No. 2 and No. 4 (P & S) tanks are 6.7 metres from the centre line.*

Displacement in Condition No. 3 = 7087.3 t

MCTC = 156.7 mt

GM (Fluid) = 2.586 m

Present trim = 2.406 m by stern

Reqd. trim = 3.000 m by stern

Change of trim reqd. = 0.594 m by stern

Let x tonnes be transferred from No. 2 to No. 4 tanks in order to increase her trim by 0.594 m.

Trimming Moment reqd. = 0.594 x 100 x 156.7 mt

Distance between Lcg of No. 2 and No. 4 tanks.

= 102.20 - 58.14 = 44.06 m

Trimming Moment required = wt. x distance shifted

∴ 0.594 x 100 x 156.7 = x x 44.06

$$x = \frac{.594 \times 100 \times 156.7}{44.06} = 211.26 \text{ t}$$

WB to be transferred from No.2 to No.4 = 211.26 t

GG_1 causing present list of 3^0 = GM tan θ

= 2.586 x tan 3^0

= 0.1355 m

Moment causing 3^0 list to starbd = GG_1 x W

$= 0.1355 \times 7087.3$

$= 960.329$ mt

To bring her upright, an equal moment should be caused to port by transferring ballast from starbd to port through a distance (6.7 + 6.7) = 13.4 m.

Let 'y' tonnes be transferred from S to P.

Then $960.329 = y \times 13.4$

$$y = \frac{960.329}{13.4} = 71.68 \text{ t}$$

Water ballast to be transferred from S to P = 71.68 t

Ballast to transfer from No. 2 to No. 4 to increase her trim to 3 metres = 211.26 t

Ballast to transfer from No. 2 S to No. 4 P to bring her upright = 71.68 t

Further quantity to transfer from No. 2 to No. 4 (P to P or S to S) = 139.58 t

Full capacity of No. 4 Port = 127.4 x 1.025

= 130.59 t

Ballast to be transferred from No. 2 S to No. 4 P

= 71.68 t

Ballast to be transferred from No. 2. P to No. 4 P, to fill it to its capacity = 58.91 t

Ballast to transferred from No. 2 S to No. 4 S = 139.58 - 58.91

= 80.67 t

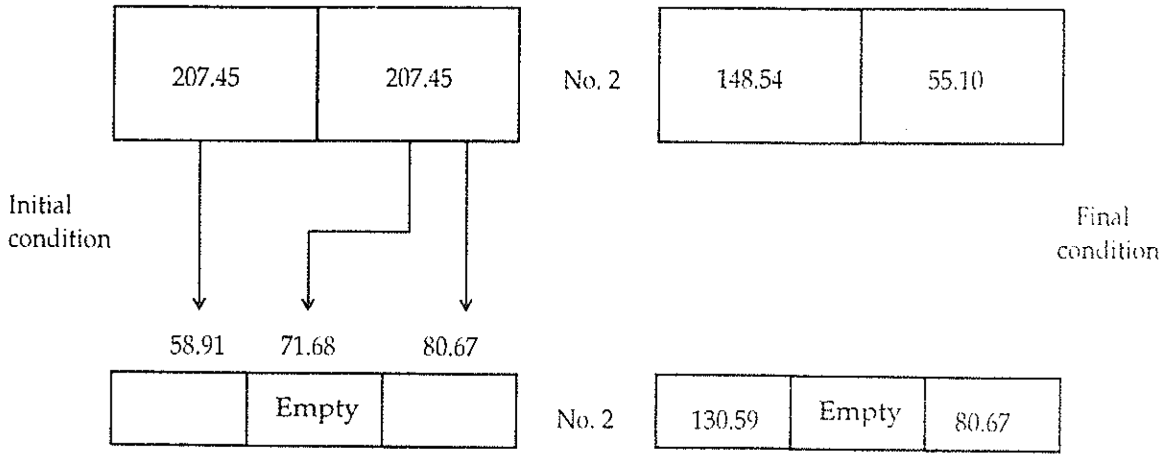
Total ballast removed from No. 2 S = 0.67 + 71.68

= 152.35 t

Ballast remaining in No. 2 S = 207.45 - 152.35

= 55.10 t

Ballast remaining in No. 2 P = 207.45 - 58.91 = 148.54 t



Note: When ballast is transferred, the FSC will change, causing a reduction in her GM, but this does not feature in the calculation above, because we know that when port moment equals starbd moment, the ship will be upright, regardless of the amount of +ve GM.

85. *M.V. 'Hindship' loading in river water of RD 1.012 is at a draft of F 5.16 m A 6.02 m. She then pumps out the entire ballast in No. 1 and 4 (P, C & S) DB tanks, which were filled in earlier at the same berth. No. 3 (P & S) and No. 5 DB tank(s) which were empty are filled with H.F.O. Calculate to the nearest tonnes the maximum quantity of cargo that can be loaded, so that the vessel will be at her Summer draft on reaching the open sea. Allow fuel and water consumption as follows, 50 tonnes in port and 70 tonnes for river passage.*

Also calculate to the nearest 0.01 m, the even keel sailing draft at the loading berth, in the river water.

Initial drafts F 5.16 m, A 6.02 m } trim 0.86 m by stern

M 5.59 m LCF = 72.679 m

After draft = 6.020 m

Corrn. to After draft $= \dfrac{0.86 \times 72.679}{143.16} = (-)\ 0.436$ m

Hydrostatic draft = 5.584 m

Displacement in SW at Hydrostatic draft of 5.584 m

= 11084.32 t

$\therefore$ Present under water volume $= \dfrac{W}{\delta} = \dfrac{11084.32}{1.025} = 10813.97\ m^3$

$\therefore$ Present displ. in water of RD 1.012 = 10813.97 x 1.012
= 10943.74t

Total ballast pumped out = v x δ_1

No. 1 = 157.6 m^3

No. 4 (P & S) = 254.8 m^3

No. 4 (C) = 257.4 m^3

669.8×1.012

$= \dfrac{(-)\ 677.84\ t}{10265.90\ t}$

Total H.F.O. received = v x δ		
No. 3 (P & S) = 221 m^3		
No. 5 = 48.8 m^3		
269.8 m^3 x 0.95	= (+)	256.31
		10522.21 t
Fuel and water to be consumed (70 + 50)	= (-)	120.00 t
Displacement after above operations		10402.21 t
Summer displacement	=	19617.00 t
Cargo that can be loaded	=	9214.79 t

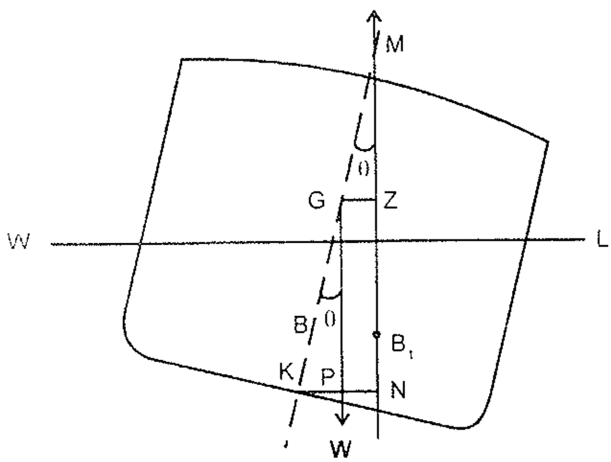
Maximum cargo that can be loaded = 9215 t

Summer displacement	=	19617 t
Fuel & water for river passage	= (+)	70 t
Displacement on sailing		19687 t
Hydro. draft in SW for displ. 19687 t	=	9.262 m
River water allowance = $\frac{202 \times 13}{25}$	=	0.105 m
Sailing draft in river water	=	9.367 m

Even keel sailing draft = 9.370 m

CURVES OF STABILITY

CROSS CURVES OF STABILITY (KN CURVES)



GZ = PN = KN - KP
KP = KG sin θ
∴ GZ = KN - (KG. sin θ)

The student is already familiar with the Righting Lever GZ, which is measured from the centre of gravity. It can be seen from the above figure that KN is the righting lever as measured from the keel. The values of KN will vary with heel and displacement.

Cross Curves of Stability are a set of curves of KN values plotted against a scale of displacements for various angles of heel. These curves facilitate obtaining of KN values, at any displacement, for the particular angles of heel for which the curves are drawn. The student should verify this for himself by inspecting the Cross Curves available in the Trim & Stability particulars of M.V. 'Hindship' or any other ship.

Very often, KN values are also given in a tabular form in addition to the curves, as in the case of M.V. 'Hindship'. The main use of KN values is to obtain GZ for any KG, at any displacement, for different angle of heel. From the above figure it can be seen that the GZ at any angle of heel may be obtained by the expression GZ = KN - (KG sin θ). From the GZ values obtained at the different angles of heel, it is possible to construct the curve of statical stability for that condition.

Curve of Statical Stability

This is a curve of GZ values plotted against a scale of heel for a particular displacement and a particular KG. Such curves are available in the Trim & Stability particulars of all ships for the various conditions. From a curve of statical stability, it is possible to ascertain the following:

a) The Initial metacentric height, (GM fluid).

Note: This should not be done in practice - as the GM found is likely to be very inaccurate.

b) The angle of contraflexure (i.e. the angle of heel upto which the rate of increase of GZ with heel is increasing. (Though the GZ may increase further, the rate of increase of GZ begins to decrease at this angle). The angle of contraflexure occurs at about the angle of heel at which the deck edge immerses.

c) The maximum GZ value of the vessel and the angle of heel at which it occurs.

d) The angle of vanishing stability and the range of stability.

e) The dynamical stability of the vessel at any angle of heel i.e. the work done in inclining the vessel upto that angle. (This can be found as the product of the displacement of the vessel and the area under the curve of statical stability upto that angle, in meter-radians).

f) Whether the ship fulfills the various stability criteria specified in the code of intact stability for various types of ships.

g) Accurate determination of List produced due to transverse shift of the ship's centre of Gravity, or due to a heeling moment applied.

h) The angle of loll in a vessel with an initial negative metacentric height.

Note: Though theoretically the ships GM (fluid) can be found from her curve of statical stability as stated under a) above and shown in Qn. 86, this method of finding the ship's GM should never be adopted in practice as large errors can occur in the GM obtained. This is so because the angle at which the tangent to the curve is drawn at its origin is likely to be inaccurate.

INTACT STABILITY CRITERIA FOR ALL PASSENGER AND CARGO SHIPS

1. The area under the GZ curve should not be less than 0.055 meter radians upto an angle of heel of 30^0.

2. The area under the curve upto an angle of 40^0 or the angle of flooding (whichever is least) shall not be less than 0.09 meter radians.

3. The area under the curve between 30^0 and 40^0 or the angle of flooding (whichever is least) shall not be less than 0.03 meter-radians.

4. The righting lever GZ shall be at least 0.20 m at an angle of heel equal to or greater than 30^0.

5. The maximum righting lever should occur at an angle of heel preferably exceeding 30^0 but not less than 25^0.

6. The initial metacentric height should not be less than 0.15 m.

Provision shall be made for a safe margin of stability at all stages of the voyage, regard being given to addition of weight, such as these due to absorption of water and icing and to loss of weight, such as those due to consumption of fuel and stores.

Ships carrying oil-based pollutants in bulk, should be able to satisfy the above criteria during all loading and ballasting operations.

In addition, for passenger ships

(i) the angle of heel on account of crowding of passengers to one side should not exceed 10^0, and

(ii) the angle of heel on account of turning should not exceed 10^0 when calculated using the formula:

$$M_R = 0.02 \frac{V_0^2}{L} \times W \left(KG - \frac{d}{2} \right)$$

where M_R = heeling moment (mt)

V_0 = service speed (m/s)

L = length of ship at water line (m)

W = displacement (t)

d = draft (m)

KG = that of ship (m)

All passenger and cargo ships should also satisfy the Severe Wind and Rolling criterion (weather criterion). This criterion indicates the ability of the ship to withstand the combined effect of wind and rolling.

SHIPS CARRYING TIMBER DECK CARGO AND USING TIMBER LOAD LINES

For ships carrying timber deck cargoes and using timber load lines, provided that the cargo extends longitudinally between superstructures (if there is no superstructure at the after end, the timber deck cargo should extend to the after end of the after most hatchway) and transversely for the full beam of the ship, the Administration may apply the following criteria in lieu of those mentioned above for cargo ships.

1. The area under the GZ curve should not be less than 0.08 meter radians upto an angle of 40^0 or the angle of flooding (whichever is least).

2. The maximum righting lever should be at least 0.25 m.

3. In the departure condition, the metacentric height should not be less than 0.10 m and at all times during the voyage the metacentric height should be positive after correction for F.S.E., absorption of water by the deck cargo and accretion of ice on exposed surfaces.

SHIPS CARRYING GRAIN IN BULK

(As Per Grain Code)

Ships carrying grain in bulk should satisfy the following criteria, throughout the voyage.

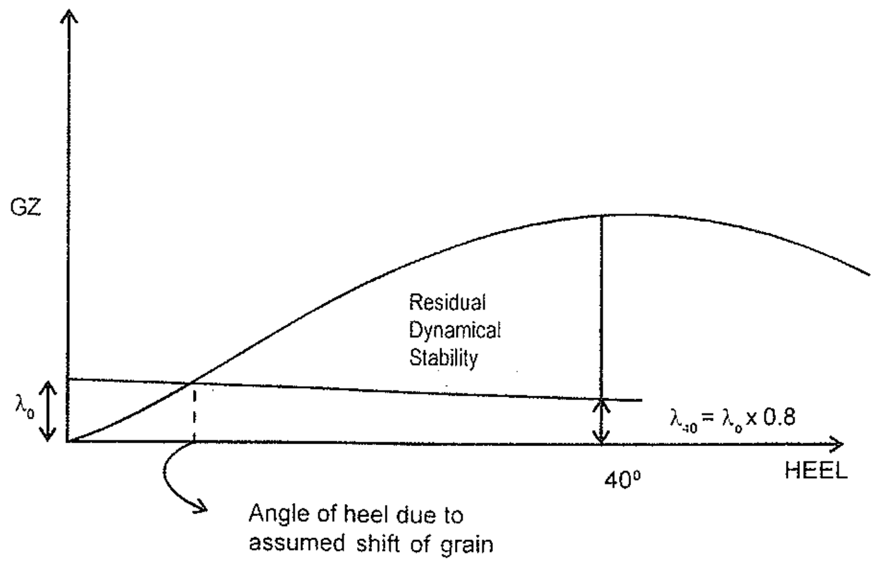
1. The angle of heel due to the assumed shift of grain, obtained by plotting the heeling arm curve over her curve of statical stability shall not be greater than 12^0. In ships constructed on or after 1st January, 1994, the angle of heel shall not be greater than 12^0 or the angle of heel at which the deck edge immerses, whichever is least.

2. The residual positive area between the heeling arm curve and the curve of GZ upto an angle of heel of 40^0 or the angle of flooding or the angle of maximum separation between the heeling arm curve and the GZ curve (whichever is least) shall not be less than 0.075 meter radians.

3. The initial GM (Fluid) shall not be less than 0.3 m.

4. The ship shall be upright on proceeding to sea.

If required, before loading grain, the master shall demonstrate that in the proposed loading condition, the ship will meet the above criteria at all stages of the voyage.



$$\lambda_0 = \frac{\text{Assumed volumetric heeling moment}}{\text{Stowage factor} \times \text{displacement}}$$

$$\lambda_{40} = \lambda_0 \times 0.8$$

OFF-SHORE SUPPLY VESSELS

For offshore supply vessels of not more than 100 m in length, where the vessels characteristics render compliance with the criteria prescribed for cargo ships impracticable, the Administration may apply the following criteria.

1. The maximum righting lever should occur at an angle of heel not less than 15^0.

2. The area under the GZ curve should not be less than 0.070 meter-radians upto an angle of 15^0 when the maximum righting lever occurs at 15^0.

It should not be less than 0.055 meter radian upto an angle of 30^0 when the maximum righting lever occurs at 30^0 or above. Where the maximum righting lever occurs at angles between 15^0 and 30^0, the corresponding area under the righting lever curve should be at least.

$0.055 + 0.001 (30^0 - \theta_{max})$ meter-radians.

3. The area under the GZ curve between the angles of 30^0 and 40^0 or the angle of flooding whichever is least should not be less than 0.03 meter radians.

4. The righting lever (GZ) should be at least 0.20 m at an angle of heel equal to or greater than 30^0.

5. The initial transverse metacentric height should not be less than 0.15 m at an angle of heel equal to or greater than 30^0.

Compliance with the stability criteria does not ensure immunity against capsizing regardless of the circumstances. Prudence and good seamanship should be exercised having regard to the season, weather and the navigational zone and appropriate action should be taken as to course and speed warranted by prevailing circumstances.

The students's attention is drawn to items 7 and 8 of the General Instructions. When determining GZ values from KN, the corrected KG (KG - FSC) is to be used.

86. *M. V. 'Hindship' in Condition No. 5 shifted some weight vertically upwards, so that her KG increased by 0.22 m.*

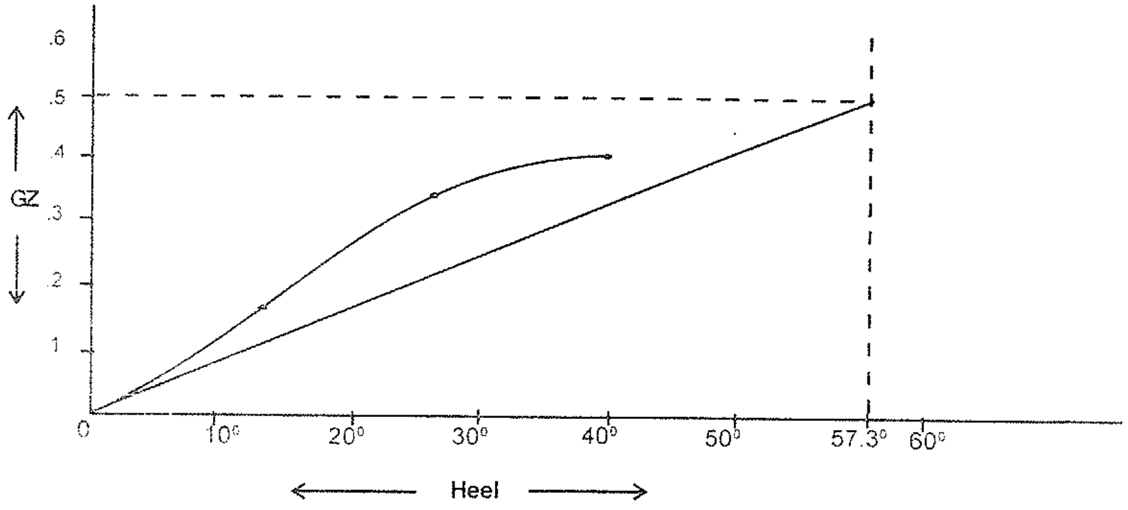
 (i) Using GZ ordinates at 10^0 intervals, draw her statical stability curve, upto a heel of 30^0.

 (ii) From the curve drawn, estimate her initial metacentric height.

 (iii) Calculate the dynamical stability of the vessel, at an angle of heel of 30^0.

(i)

Heel	Original GZ	Upward GG_1	sin θ	Corn to GZ $= GG_1 \sin\theta$	Corrected GZ = Original GZ - Corn.	SM	Product for Area
0^0	0.000	0.22	0.0	0.0	0.0	1	0.000
10^0	0.191	0.22	0.174	0.038	0.153	3	0.459
20^0	0.383	0.22	0.342	0.075	0.308	3	0.924
30^0	0.500	0.22	0.500	0.110	0.390	1	0.390
						SUM	1.773



(ii) To estimate the vessel's initial metacentric height, draw a tangent to the curve of statical stability, at its origin. Erect a perpendicular at one radian (57.3^0). From their point of intersection, return to the GZ scale to read off the GM (Fluid)

Note: In practice, this will not give an accurate value of GM as the tangent drawn may not be at the very correct angle.

Estimated Initial GM = 0.50 m

(iii) Area under the curve of statical stability upto 30^0 heel

$$= 1.773 \times \frac{3}{8} \times \frac{10}{57.3}$$

$$= 0.116 \text{ m radians}$$

Dynamical stability = Area x W = 0.116 x 18,529.3

= 2150 tm

Dynamical Stability at 30^0 heel = 2150 tm

87. *M.V. 'Hindship' displacing 18,529 tonnes, KG 7.539 m, FSC 0.084 m.*

(i) Find her GM (Fluid)

(ii) Draw the statical stability curve for this condition.

(iii) From the curve find

(a) The maximum GZ and the angle of heel at which it occurs.

(b) The angle of vanishing stability.

(c) The change in the range of stability, when a constant upsetting moment of 4500 tonnes metre is applied to the ship.

(d) The list produced by the above upsetting moment.

(iv) State whether the ship fulfills criterion regarding the area upto 30° of the Minimum Stability Requirements of the Code of Intact Stability.

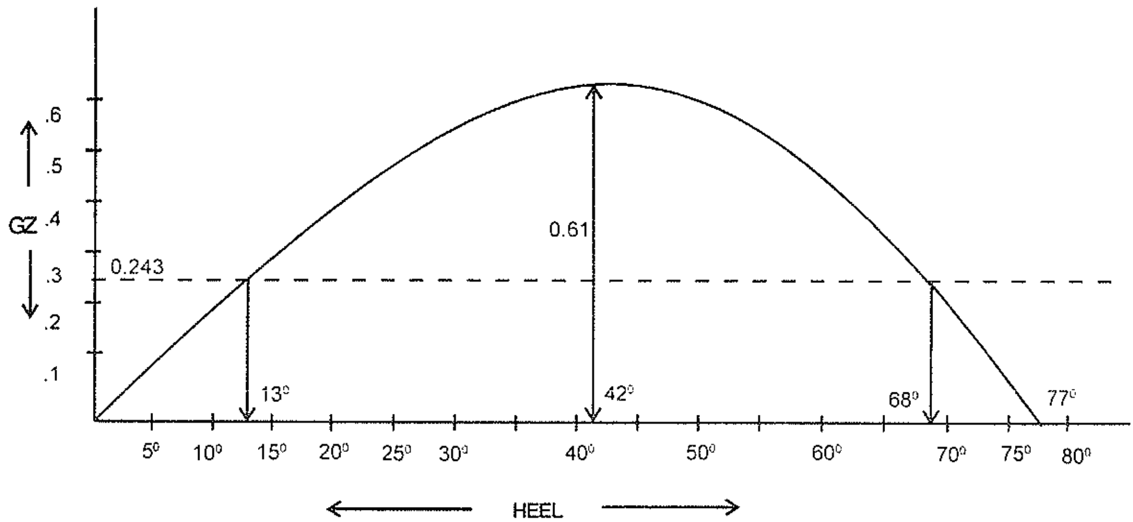
(i)

KM for displ. of 18529 t	=	8.349 m
KG	=	7.539 m
GM (Solid)	=	0.810 m
FSC	=	0.084 m
GM (Fluid)	=	***0.726 m***

(ii) To find corrected KG in order to determine GZ values from KN values.

KG	=	7.539 m
FSC	=	(+) 0.084 m
Corrected KG	=	7.623 m
GZ	=	KN - (Corrected KG x sin θ)

θ	0°	5°	10°	15°	20°	25°	30°	40°	45°	60°	75°
sin θ	0	0.087	0.174	0.259	0.342	0.423	0.500	0.643	0.707	0.866	0.966
KN	0	0.760	1.517	2.252	2.990	3.629	4.312	5.498	5.978	7.027	7.416
-KG sin θ	0	0.663	1.326	1.974	2.607	3.225	3.812	4.902	5.389	6.602	7.364
GZ	0	0.097	0.191	0.278	0.383	0.404	0.500	0.596	0.589	0.425	0.052
S.M.	1	4	2	4	2	4	1	SUM			
PRODUCT	0.0	0.388	0.382	1.112	0.766	1.616	0.500	4.764			



(iii) (a) **Maximum GZ = 0.61 m at 42^0 angle of heel**

(b) **Angle of Vanishing Stability = 77^0**

(c) Upsetting lever = $\dfrac{\text{upsetting moment}}{\text{Displacement}} = \dfrac{4500}{18529} = 0.243$ m

New range of stability = 13^0 to 68^0 = 55^0

Reduction in the range of stability = 77^0 - 55^0 = 22^0

(d) **List produced by the upsetting moment = 13^0**

(iv) Area under the Curve upto 30^0 $= 4.764 \times \dfrac{1}{3} \times \dfrac{5}{57.3}$

= 0.139 metre radians.

Since the area is greater than 0.055 metre radians, the ship satisfies the criterion regarding the area upto 30^0 of the Code of Intact Stability.

88. *M.V. 'Hindship' in Condition No. 9, pumps out, 100 tonnes of ballast each from No. 2 (P) and No. 2 (S), DB tanks,*

(i) Calculate her righting levers at 10^0 intervals upto an angle of heel of 40^0.

(ii) Calculate her dynamical stability at an angle of heel of 40^0.

(iii) Also state, whether the ship fulfills the criteria regarding areas

upto 30°, upto 40° or the angle of flooding, and between 30° and 40° or the angle of flooding; given angle of flooding as 42°.

		Weight (t)	KG (m)	V. Moments (mt)
Displacement Condition No. 9		15727.8	7.334	115352
Ballast pumped out	(-)	200	0.65	(-) 130
Final Weight	=	15527.8	Final Moment	115222

Final KG $= \dfrac{115222}{15527.8} = 7.420$ m

Original FS Moment = 1552 mt

FS moment of No. 2 (P&S) (1436 x 1.025) = 1472 mt

Final FS moment = 3024 mt

Final FSC $= \dfrac{3024}{15527.8} = 0.195$ m

To find corrected KG to determine GZ values from KN.

KG = 7.420 m

FSC = (+) 0.195 m

Corrected KG = 7.615 m

θ	0°	10°	20°	30°	40°	
Sin θ	0.0	0.174	0.342	0.500	0.643	
KN	0.0	1.500	2.965	4.414	5.723	
- KG Sin θ	0.0	1.325	2.604	3.808	4.896	
GZ	0.0	0.175	0.361	0.606	0.827	
S.M.	1	4	2	4	1	SUM
PRODUCT FOR AREA	0.0	0.700	0.722	2.424	0.827	4.673
* S.M.			- 1	8	5	SUM
PRODUCT FOR AREA			-0.361	4.848	4.135	8.622

(ii) Area under the Curve upto 40^0 = $4.673 \times \frac{1}{3} \quad \frac{10}{57.3}$

= 0.27184 m radians.

Dynamical Stability at 40^0 heel = 0.27184 x 15527.8

= 4221.07 mt

Dynamical Stability at 40^0 heel = 4221.1 tm

* Common interval, 10^0 and the ordinates being the GZ values.

(iii) Area under the Curve between 30^0 & 40^0 heel.

$$= \quad 8.622 \times \frac{1}{12} \times \frac{10}{57.3} \quad = 0.12539 \text{ mrad}$$

Area under the Curve upto 30^0 = 0.27184 - 0.12539

= 0.14645 mrad

Area under the Curve upto 30^0 = 0.14645 mrad, which is greater than 0.055

Criterion for area upto 30^0 is satisfied.

Area under the curve upto 40^0 = 0.27184 mrad, which is greater than 0.09

Criterion for area upto 40^0 or angle of flooding is satisfied.

Area under the Curve between 30^0 & 40^0 = 0.12539 mrad which is greater than 0.03.

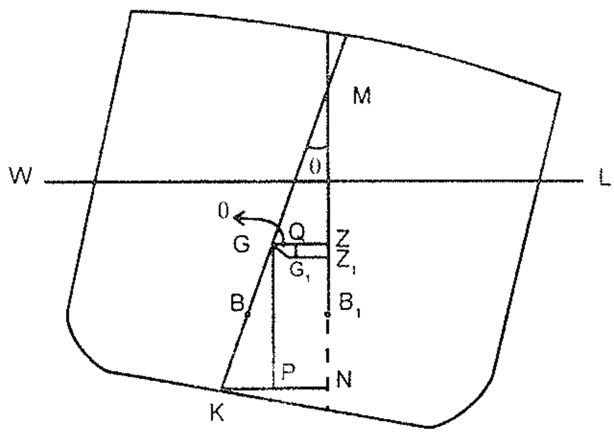
Criterion for area between 30^0 and 40^0 or the angle of flooding is also satisfied.

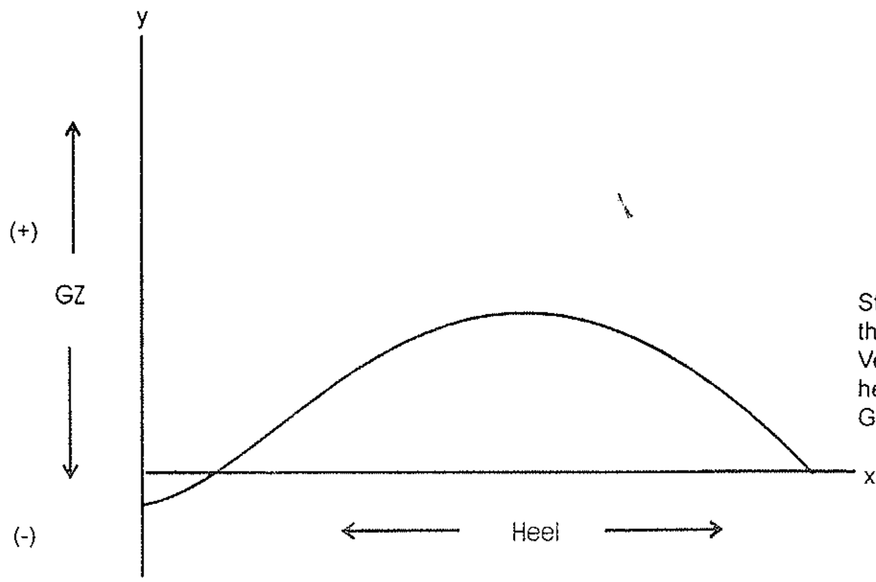
DETERMINATION OF LIST DUE TO TRANSVERSE SHIFT OF 'G' FROM CURVE OF STATICAL STABILITY.

The student is already aware that the list produced by a transverse shift of 'G' can be obtained by the expression

$$\tan \theta = \frac{GG_1}{GM},$$

provided the list is small. The reason why this expression is not applicable at large angles of heel is that as the list becomes larger, the value of KM and, therefore, GM changes considerably (as her water plane area changes with heel) and thus the initial GM used in the above expression is no more applicable. The list may, however, be determined accurately from a curve of statical stability as explained below.





Statical stability curve for the side on which the Vessel is heeled, with heel on the X axis and GZ on the Y axis.

Any loading, discharging or shifting operation may produce both a vertical shift and a transverse shift of G. As done in the previous problems on curves of statical stability, the GZ's at various angles of heel were obtained, by the expression GZ = KN - (KG sin θ). The KG used in this expression is the final corrected KG obtained after allowing for any vertical shift of G and also the FSC.

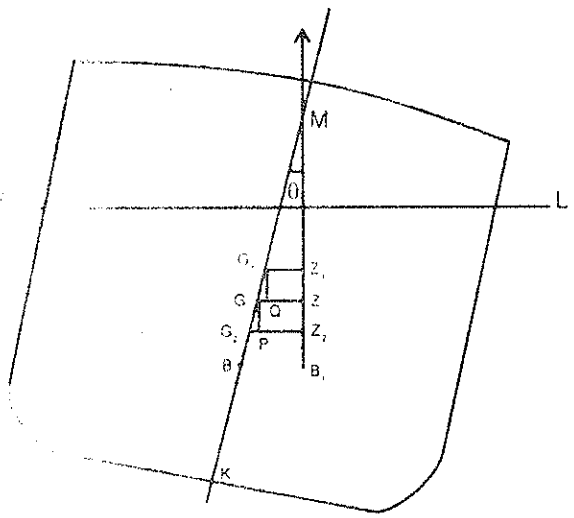
Where a transverse shift of G is also involved, it can be seen from the figure on the previous page that the GZ at any angle of heel, on the side to which she is heeled, reduces by an amount GG_1 cos θ.

To obtain the list from a curve of statical stability the final KG (corrected KG) is first obtained, and the GZ values at the various angles of heel are determined by the expression GZ = KN - KG sin θ. The reduction in GZ due to transverse shift of G, equal to GG_1 cos θ is then subtracted from the GZ values as obtained above. The corrected GZ values so obtained are plotted as a curve of statical stability.

The list is then read off, where the curve attains zero value, as at earlier angles the vessel has a -ve GZ (heeling lever) while at larger angles, she has +ve GZ values (Righting levers), as can be seen from the curves in the following problems.

It should be noted that the curve drawn is only for the side to which she is listed. Though the GZ values are negative initially, it is important to note that this is not due to a -ve GM. As the G shifts transversely, the vessel lists till the new Centre of Buoyancy once again comes in the same vertical line as the centre of Gravity. At this list, she attains static equilibrium.

DETERMINATION OF LIST WHEN GZ VALUES ARE GIVEN.



For upward shift of G
$GQ = GG_1 \times \sin\theta$
$G_1Z_1 = GZ - GQ = GZ - GG1 \sin\theta$
For downward shift of G
$G_2Z_2 = GZ + GG_2 \sin\theta$

In a theoretical problem where only GZ values at different angles of heel are given, whereafter some vertical and transverse shift of G has occurred, the GZ values for the new condition may be obtained as follows:

1. Add or subtract vertical $GG_1 \sin\theta$ (+) for downward shift of G.
   (-) for upward shift of G.

2. Subtract transverse $GG_1 \cos\theta$.

   The statical stability curve may now be plotted and the list determined, as indicated earlier.

   This method is resorted to as KN and KG values are not available to use the method indicated earlier.

89. *M.V. 'Hindship' is at a draft of F 6.38 m, A 7.24 m, KG 8.06 m, FSM 1172 mt, 100 t of ballast is run into No. 3 (P) DB tank, Cg 8.0 m from CL. Draw the curve of statical stability and from it, determine the angle of list.*

Initial drafts	F	6.38 m	trim 0.86 m by stern
	A	7.24 m	
	M	6.81 m	

LCF for draft 6.81 m = 71.796 m

Correction to Aft draft = $\frac{0.86 \times 71.796}{143.16}$ = 0.431 m

After draft = 7.240 m

Hydrostatic draft = 6.809 m

Displacement for draft 6.809 m = 13860.7 t

		Weights (t)	KG (m)	V. Moments (mt)
Displacement		13860.7	8.06	111717.2
No. 3 DB tank (P)	(+)	100.0	0.67	(+) 67.0
Final Weight	=	13960.7	Final V. Moment	= 111784.2

Final KG = $\frac{111784.2}{13960.7}$ = 8.007 m

Original FSM = 1172 mt

No. 3 P = 227 x 1.025 = 232.68 mt

Final FSM = 1404.68 mt

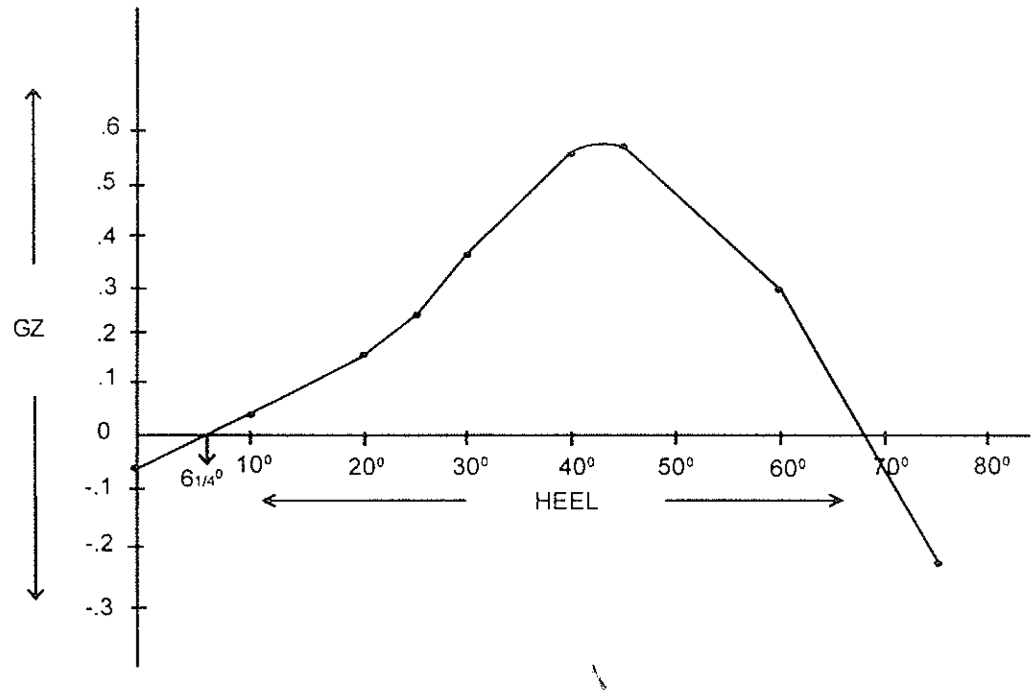
Final FSC = $\frac{1404.68}{13960.7}$ = (+) 0.101 m

Corrected KG = 8.108 m

Transverse GG_1 = $\frac{100 \times 8}{13960.7}$ = 0.0573 m

θ	0°	5°	10°	15°	20°	25°	30°	40°	45°	60°	75°
sin θ	0.000	0.087	0.174	0.259	0.342	0.423	0.500	0.643	0.707	0.866	0.966
cos θ	1.000	0.996	0.985	0.966	0.940	0.906	0.866	0.766	0.707	0.500	0.259
KN	0.000	0.755	1.506	2.232	2.982	3.723	4.471	5.819	6.350	7.353	7.619
- KG sin θ	0.000	0.705	1.411	2.100	2.773	3.430	4.054	5.213	5.732	7.022	7.832
Uncorrected GZ	0.000	0.050	0.095	0.132	0.209	0.293	0.417	0.606	0.618	0.331	(-) 0.213
Transverse $GG_1 \cos\theta$	0.057	0.057	0.056	0.055	0.054	0.052	0.050	0.044	0.041	0.029	0.015
Corrected GZ	(-) 0.057	(-) 0.007	0.039	0.077	0.155	0.241	0.367	0.562	0.577	0.302	(-) 0.229

STATICAL STABILITY CURVE FOR PORT HEEL



Angle of list as indicated by the curve = $6\frac{1}{4}°$ *to Port.*

The curve indicates that the GZ values are negative upto a heel of $6\frac{1}{4}°$, and positive thereafter. In other words, heeling levers operate upto a heel of $6\frac{1}{4}°$ and righting levers are present thereafter. The ship will attain static equilibrium at the angle of heel at which neither heeling nor righting levers are present, which in this case occurs at $6\frac{1}{4}^{0}$.

Note: In practice, on board a ship, when the accurate list is required to be determined, it is not necessary to draw the entire curve of statical stability. A part of the curve till GZ values become positive would suffice.

90. *M.V. 'Hindship' in Condition No. 5 loads and discharges as follows: Discharges 250 t from No. 1 TD, cg 6 m to starbd of CL. Discharges 50 t from No. 3 TD, Kg 11.15 m cg 1.3 m to port of CL. Fills up No. 8 DB tank (S) cg 1.8 m from CL, with FW. A parcel of cargo weighing 40 t is shifted 6.2 m vertically downwards and 16 m transversely to port. Draw the curve of statical stability for this condition and determine the resultant list.*

	Weights (t)	KG (m)	V. Moments (mt)	Dist from CL (m)	T.Moments (mt)	
Condition No. 5	18529.3	7.539	139700	0	0	
Disch. No. 1 TD (-)	250.0	11.17	(-) 2792.5	6	1500	(P)
Disch. No. 3 TD (-)	50.0	11.15	(-) 557.5	1.3	65	(S)
FW in No. 8 (S) (+)	63.4	2.77	(+) 175.6	1.8	114.1	(S)
Shifted 40 t.	40.0	6.2	(-) 248.0	16	640.0	(P)
Final Wt. =	18292.7	Final V.Mmts =	136277.6	Final T.Mmts.	1960.9	(P)

$$\text{Final KG} = \frac{136277.6}{18292.7} = 7.450 \text{ m}$$

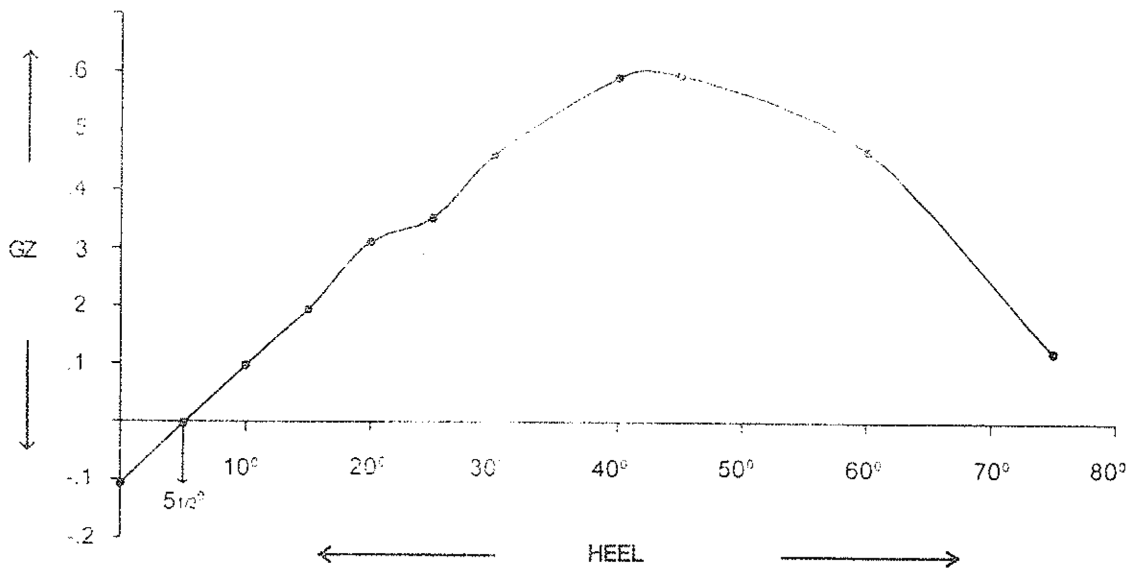
$$\text{FSC} = \frac{1552}{18292.7} = (+)\ 0.085 \text{ m}$$

$$\text{Corrected KG} = 7.535 \text{ m}$$

$$\text{Transverse } GG_1 = \frac{1960.9}{18292.7} = 0.1072 \text{ m}$$

θ	0^0	5^0	10^0	15^0	20^0	25^0	30^0	40^0	45^0	60^0	75^0
sin θ	0.000	0.087	0.174	0.259	0.342	0.423	0.500	0.643	0.707	0.866	0.966
cos θ	1.000	0.996	0.985	0.966	0.940	0.906	0.866	0.766	0.707	0.500	0.259
KN	0.000	0.759	1.513	2.249	2.990	3.636	4.320	5.517	5.997	7.044	7.426
- KG sin θ	0.000	0.656	1.311	1.952	2.577	3.187	3.768	4.845	5.327	6.525	7.279
Uncorrected GZ	0.000	0.103	0.202	0.297	0.413	0.449	0.552	0.672	0.670	0.519	0.147
Transverse $GG_1 \cos\theta$	0.107	0.107	0.106	0.104	0.101	0.097	0.093	0.082	0.076	0.054	0.028
Corrected GZ	(-) 0.107	(-) 0.004	0.096	0.193	0.312	0.352	0.459	0.590	0.594	0.465	0.119

STATICAL STABILITY CURVE FOR PORT HEEL



Angle of List obtained from curve = $5\frac{1}{2}^0$ (P)

91. *M.V. 'Hindship' floating at a hydrostatic draft of 8.785 m, KG 7.807 m, FS Moment 1552 mt has homogeneous cargo stowing at 1.78 cubic metres per tonne in No. 3 Hold. Consider No. 3 Hold to be cuboidal, (length and breadth of the hold remains constant over the entire height) of length 21 m and breadth 20 m. The cargo in this compartment shifts, raising the surface on the starboard side by 1.5 m and lowering the surface on the port side by same amount. Draw the curve of statical stability and hence determine her list.*

Discuss briefly the effect of this shift of cargo on the stability of the vessel.

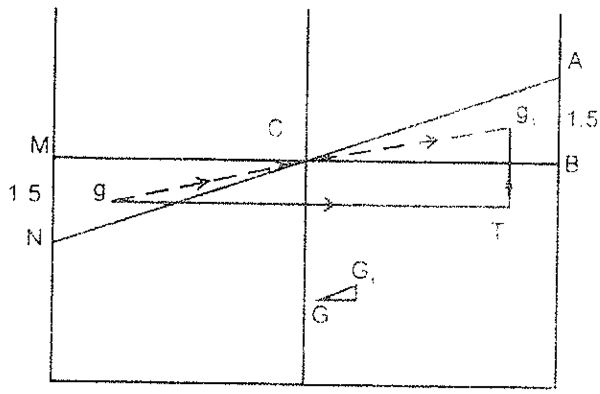


Fig (i)

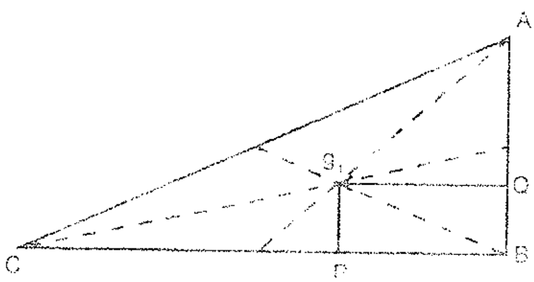


Fig (ii)

The wedge shaped volume of cargo CMN, has shifted to the other wedge shaped volume CAB. The centre of gravity of the cargo which shifted, has moved from g to g_1 (horizontal shift gT and vertical shift Tg_1)

By similar triangles, CP $= \frac{2}{3}$ CB and $g_1P = \frac{1}{3}$ AB

∴ Horizontal shift of g $=$ gT $= 2 \times$ CP

$= \frac{4}{3}$ CB $= \frac{2}{3}$ MB $= \frac{2 \times 20}{3} = \frac{4}{3}$ m

Vertical shift of g $= Tg_1 = 2g_1P = \frac{2}{3} \times 1.5 = 1.0$ m

For hydrostatic draft 8.785 m Displacement $=$ 18528.7 t

Volume of cargo shifted $= \frac{10}{2} \times 1.5 \times 21 = 157.5$ m^3

$$\text{Wt. of cargo shifted} = \frac{157.5}{1.78} = 88.5 \text{ t}$$

$$\text{Transverse } GG_1 = \frac{w \times d}{W} = \frac{88.5 \times 40}{18528.7 \times 3} = 0.0637 \text{ m}$$

$$\text{Vertical } GG_1 = \frac{88.5 \times 1}{18528.7} = 0.00477 = 0.005 \text{ m}$$

Original KG = 7.807 m

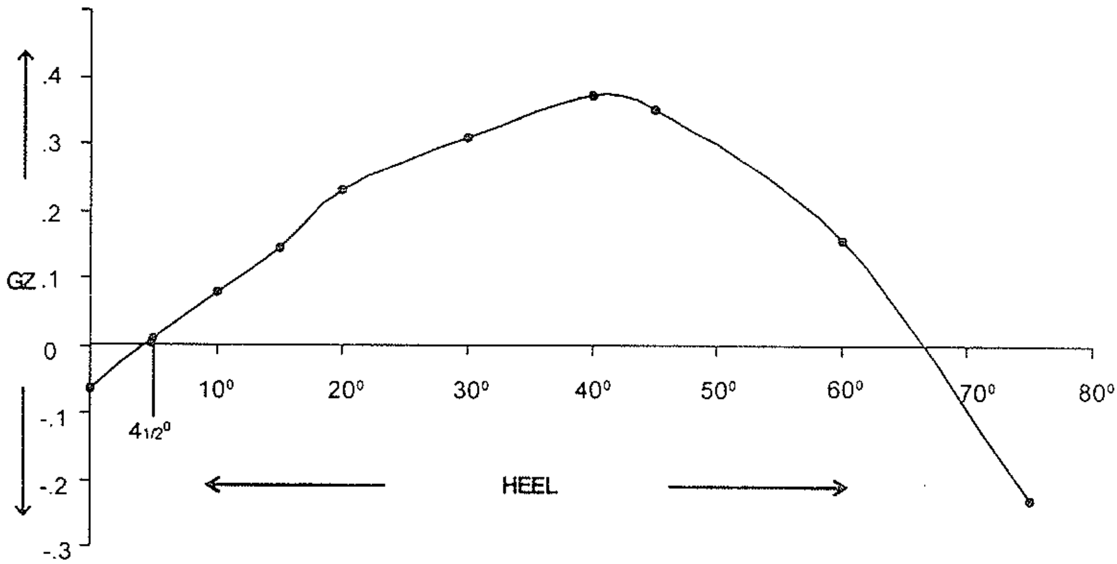
Vertical GG_1 = (+) 0.005 m

$$\text{FSC} = \frac{1552}{18528.7} = (+)0.084 \text{ m}$$

Corrected Kg = 7.896 m

θ	0^0	5^0	10^0	15^0	20^0	25^0	30^0	40^0	45^0	60^0	75^0
$\sin\theta$	0.000	0.087	0.174	0.259	0.342	0.423	0.500	0.643	0.707	0.866	0.966
$\cos\theta$	1.000	0.996	0.985	0.966	0.940	0.906	0.866	0.766	0.707	0.500	0.259
KN	0.000	0.760	1.517	2.252	2.990	3.629	4.312	5.498	5.978	7.027	7.416
$- KG \sin\theta$	0.000	0.687	1.374	2.045	2.700	3.340	3.948	5.077	5.582	6.838	7.628
Uncorrected GZ	0.000	0.073	0.143	0.207	0.290	0.289	0.364	0.421	0.396	0.189	(-) 0.212
Transverse $GG_1 \cos\theta$	0.064	0.063	0.063	0.062	0.060	0.058	0.055	0.049	0.045	0.032	0.016
Corrected GZ	(-) 0.064	0.010	0.080	0.145	0.230	0.231	0.309	0.372	0.351	0.157	(-) 0.228

STATICAL STABILITY CURVE FOR STARBD HEEL



Angle of list = $4\frac{1}{2}^0$ to starbd

Effect of shift of cargo on Stability

(i) A permanent list of $4{1/2}^0$ to starbd is caused.

(ii) The righting levers at all angles of heel are reduced.

(iii) As a result of (ii) above, the maximum righting lever becomes smaller.

(iv) Also because of (ii) above, the angle of vanishing stability and the range of stability are both reduced.

92. *M.V. 'Hindship' is in Condition No. 7 in water of RD 1.025. Rough weather causes 400 tonnes of cargo to shift horizontally through a distance of 8.5 metres and vertically downwards through a distance of 3 meters. Draw the Curve of Statical Stability upto a heel of 40^0, after the shift of cargo has taken place. From the Curve estimate the resulting angle of list.*

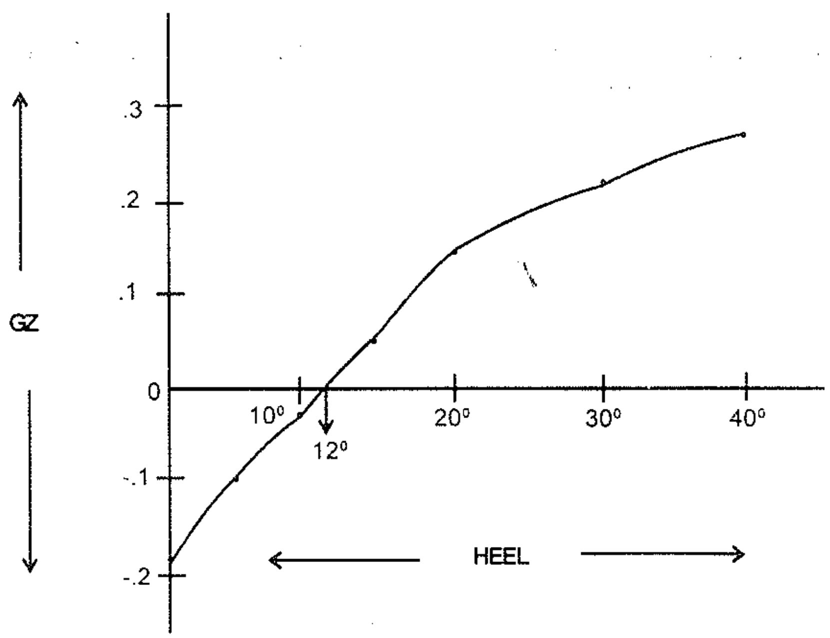
$$\text{Transverse } GG_1 = \frac{w \times d}{W} = \frac{400 \times 8.5}{18529.3} = 0.1835 \text{ m}$$

$$\text{Vertical } GG_1 = \frac{w \times d}{W} = \frac{400 \times 3}{18529.3} = 0.0648 \text{ m}$$

As explained earlier, due to the HORIZONTAL shift of the cargo, all GZ values will decrease by an amount equal to transverse $GG_1 \cos\theta$, and because the G has shifted downwards it will increase by an amount equal to vertical $GG_1 \sin\theta$, for each value of θ.

θ	0^0	5^0	10^0	15^0	20^0	25^0	30^0	35^0	40^0
sin θ	0.000	0.087	0.174	0.259	0.342	0.423	0.500	0.574	0.643
cos θ	1.000	0.996	0.985	0.966	0.940	0.906	0.866	0.819	0.766
Original GZ (Cond.No.7)	0.000	0.073	0.144	0.208	0.291	0.291	0.366	0.371	0.374
(-) Transverse $GG_1 \cos\theta$	0.184	0.183	0.181	0.177	0.172	0.166	0.159	0.150	0.140
GZ Corrected for transverse shift of G	(-) 0.184	(-) 0.110	(-) 0.037	0.031	0.119	0.125	0.207	0.221	0.234
(+) Vertical $GG_1 \sin\theta$	0.000	0.006	0.011	0.017	0.022	0.027	0.032	0.037	0.042
Final GZ	(-) 0.184	(-) 0.104	(-) 0.026	0.048	0.141	0.152	0.239	0.258	0.276

STATICAL STABILITY CURVE FOR THE HEELED SIDE



Resulting Angle of list 12^0

93. *M.V. 'Hindship' is at a draft of F 7.98 m, A 8.59 m, KG 7.059 m, FSC 0.089 m. Using the table of Cross Curves of Stability Particulars, calculate her righting levers upto 75⁰ heel. Assuming the angle of heel at which flooding occurs is 44⁰, state whether she satisfies each intact stability criteria of the code on intact stability for cargo ships.*

Original draft	F	7.98 m	trim 0.61 m
	A	8.59 m	
	M	8.285 m	

LCF for M. draft 8.285 m = 70.336 m

After draft = 8.590 m

Correction to A draft = $\frac{0.61 \times 70.336}{143.16}$ = 0.300 m

Hydrostatic draft = 8.290 m

KM for Hydrostatic draft 8.29 m = 8.280 m

KG = 7.059 m

GM (Solid) = 1.221 m

FSC = 0.089 m

GM (Fluid) = 1.132 m

Criterion regarding initial GM is satisfied as it is greater than 0.15 m

To find corrected KG

KG = 7.059 m

FSC = (+) 0.089 m

Corrected KG = 7.148 m

θ	0^0	5^0	10^0	15^0	20^0	25^0	30^0	40^0	45^0	60^0	75^0
sin θ	0.0	0.087	0.174	0.259	0.342	0.423	0.50	0.643	0.707	0.866	0.966
KN	0.0	0.755	1.504	2.234	2.982	3.663	4.351	5.593	6.075	7.114	7.466
- KG sin θ	0.0	0.622	1.244	1.851	2.445	3.024	3.574	4.596	5.054	6.190	6.905
GZ	0.0	0.133	0.260	0.383	0.537	0.639	0.777	0.997	1.021	0.924	0.561
S.M.	1	4	2	4	2	4	1		SUM		
Product	0.0	0.532	0.520	1.532	1.074	2.556	0.777		6.991		
* S.M.	1		4		2		4	1	SUM		
Product	0.0		1.040		1.074		3.108	.0.997	6.219		

* Common interval, 10^0 and the ordinates being the GZ values.

Area under the curve upto 30^0 $= 6.991 \times \frac{1}{3} \times \frac{5}{57.3}$

= 0.2034 mrad, which is greater than 0.055

This criterion is satisfied.

Area under the Curve upto 40^0 $= 6.219 \times \frac{1}{3} \times \frac{10}{57.3}$

= 0.3618 mrad, which is greater than 0.09

This criterion therefore is satisfied.

Area under the Curve between 30^0 & 40^0.

= 0.3618 - 0.2034 = 0.1584 mrad, which is greater than 0.03

This criterion therefore is satisfied.

The maximum GZ occurs at an angle of heel > 25^0

This criterion therefore is satisfied.

The righting lever is > 0.2 m at an angle of heel greater than 30^0. Therefore this criterion is also satisfied.

Each requirement of the Code on intact stability is therefore satisfied.

Note: Though accurate results are obtained by using 5^0 intervals upto 30^0, sufficiently reliable results would be obtained by using 10^0 intervals.

CURVES SHOWING MINIMUM INITIAL 'GM' REQUIRED (OR MAXIMUM KG ALLOWABLE) TO COMPLY WITH THE MINIMUM STABILITY REQUIREMENTS OF THE CODE ON INTACT STABILITY

Such curves are provided as a part of the Trim & Stability Particulars of ships. From the last problem, the student will appreciate that the calculations involved in ensuring that the vessel satisfies the minimum stability requirements, is rather time consuming Separate curves indicating the minimum GM or maximum KG which would satisfy each of the minimum stability criteria are developed in the shipyard and plotted with draft/displacement on one axis and the minimum GM, or maximum KG on the other axis as shown in the diagram at the end of this text.

As can be seen from the set of curves, if the ship's GM is greater than the values represented by each curve, the ship would satisfy all the minimum stability requirements. Therefore, it is evident that, all the requirements are satisfied provided the GM value at any particular draft/displacement is greater than the values represented by the dotted enveloping line. This information is provided as curves or tables of minimum GM, or maximum KG or maximum deadweight moment related to displacement or draft in saltwater. If using the deadweight moment, the free surface moment of the ship should be added to the ship's deadweight moment before comparison with her maximum permissible deadweight moment for that displacement.

Though it would appear from the above, that GM is the only parameter to be considered regarding the ship's stability, the student should realize that GM values required to satisfy each stability requirement, have been developed using the minimum criteria as regards statical stability curves. The fundamental importance of the statical stability curve for any condition should not therefore be ever underrated. As a criterion of her stability and survival capability in a seaway, her curve of statical stability, the areas under it and her GZ values at various angles of heel are of utmost importance. This is so because the areas under her statical stability curve, which are functions of her dynamical stability at those angles of heel should be large enough to overcome any heeling moment applied to the ship by waves, wind etc. under even the worst weather and state of sea she is likely to experience during the voyage.

Ships required to meet stability criteria prescribed for her class of vessels when in a damaged condition are provided with curves of tables of minimum GM or maximum KG to be maintained in the intact condition, so that, despite the assumed damage for her class of vessels, she will meet the damage stability criteria for her class of vessels.

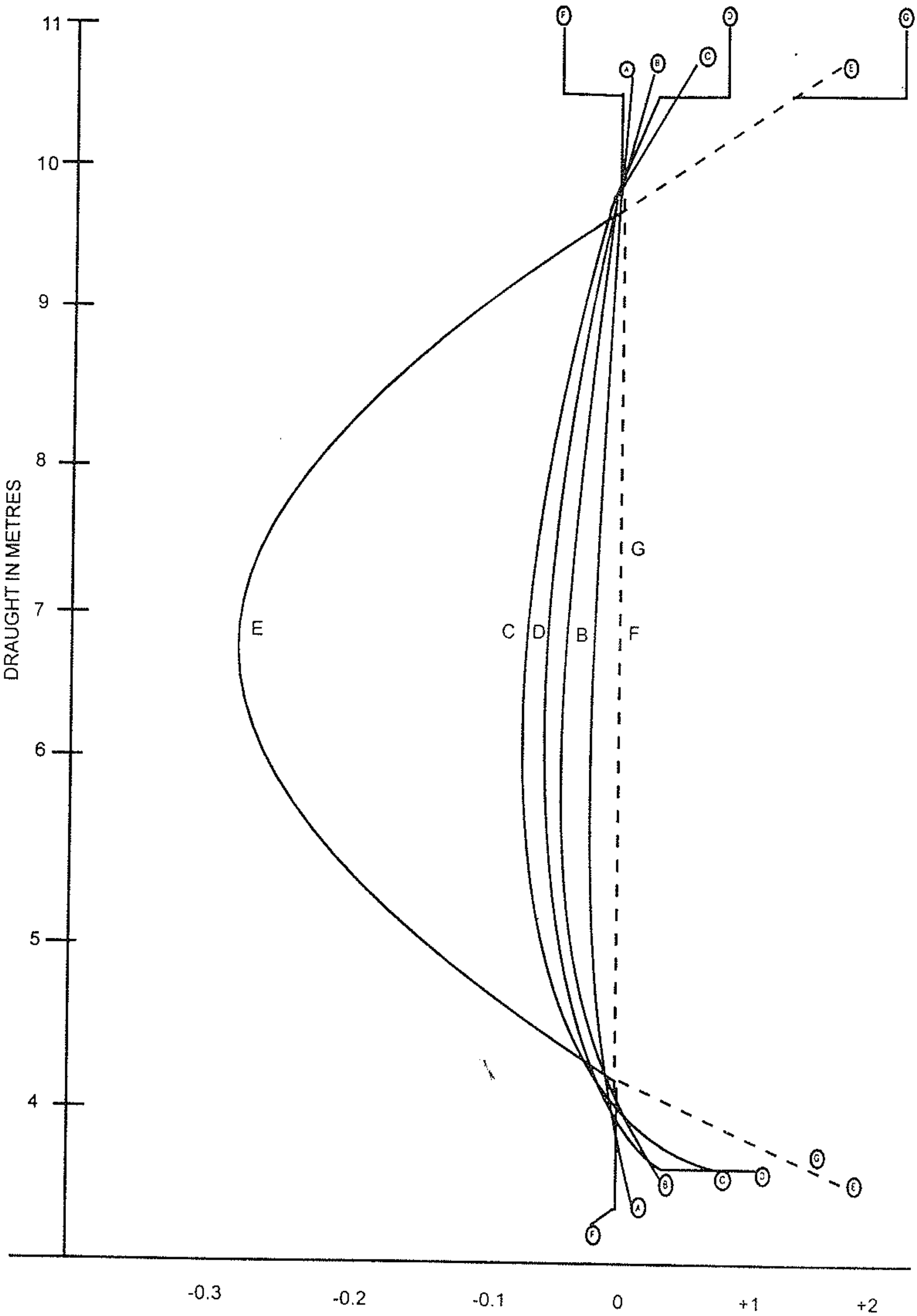
The ship's officer should be aware that the KM available to him in the

"Hydrostatic particulars" of the ship, is for the UPRIGHT CONDITION. In most ships, as in the case of M.V. 'Hindship', the KM provided, is for the EVEN KEEL CONDITION. Should the vessel be trimmed, the shape of her waterplane will change causing a corresponding change in the KM, and therefore in the GM. This effect will be very pronounced, in case of ships with fine lines. As the after water plane is considerably fuller than the forward one at certain drafts, the GM is likely to reduce considerably, when trimmed by the head.

Some ships may be provided with important hydrostatic particulars for different trims. Where such particulars are available, the ship's officer should utilize the data for the actual trim the ship is in, as this will provide him with more realistic results. However, if the hydrostatic particulars of his ship are available only for the Even keel condition, he would do well, to ensure that the calculated GM, of the vessel is large enough, to allow for any change in the KM, caused due to the trim.

When the ship is at sea, and pitching heavily, the change in KM will be very pronounced, particularly in ships with fine lines. In such ships, if the GM is not adequate, it may be noticed, that when pitched heavily, the GM may become very small, or even negative, thereby causing the ship, to roll to large angles.

Similarly, when a vessel is rolling, her LCB changes as her angle of roll changes. When the LCB changes, her trim alters. This is known as free trimming. This effect is very prominent in small ships like offshore supply vessels and to a lesser extant in larger ships. The Cross Curves of stability are therefore now required to be provided to ships on a free trimming basis for a range of displacements between light and load drafts and a range of trims anticipated in normal operating conditions. (Refer to stability information to be provided to ships on page 1.)



MINIMUM GM REQUIRED TO COMPLY WITH CODE ON INTACT STABILITY FOR CARGO SHIPS.

CURVES SHOWING THE MINIMUM INITIAL GM REQUIRED TO COMPLY WITH THE STABILITY CRITERIA AS PER CODE OF INTACT STABILITY FOR CARGO SHIPS

The curves A to F on the previous page show the minimum GM required at different drafts to comply with each of the Intact Stability Code requirements as indicated below.

A) Area under GZ curve upto 30^0 shall not be less than 0.055 meter-radians.

B) Area under GZ curve upto 40^0 or the angle of flooding (whichever is least) shall not be less than 0.090 meter-radians.

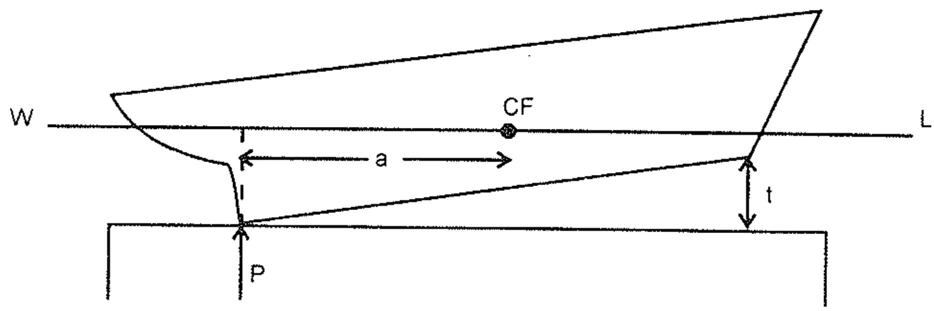
C) Area under GZ curve between 30^0 & 40^0 or angle of flooding (whichever is least) shall not be less than 0.030 meter-radians.

D) That the Righting Lever (GZ) shall not be less than 0.2 m at an angle of heel or equal to or greater than 30^0.

E) The Maximum Righting Lever shall occur at an angle heel of not less than 25^0.

F) The Initial Metacentric Height (GM) shall not be less than 0.150 m.

G) The dotted enveloping line indicates the GM required to comply with the entire stability Criteria (A) to (F).



When a ship is floating, the weight of the ship is balanced by the buoyancy provided by the underwater volume. This would be so, even at the instant when one end of the ship just touches the blocks. If the water level falls thereafter, a part of the weight of the ship rests on the blocks, while the remainder is supported by the buoyancy provided by the reduced underwater volume. Thus, at any instant the total weight is balanced by (i) the upward reaction from the block on the keel (which is equal to weight of the ship resting on the blocks) and (ii) the buoyancy being provided by the reduced underwater volume.

The reaction provided by the blocks acting upwards on the keel may be considered as a negative weight, or a weight discharged from that point. The student is already aware that when a weight is discharged, the vertical $GG_1 = \dfrac{w \times d}{W - w}$ where 'd' is the vertical distance between G of the ship and g of the weight discharged.

Thus if the reaction provided by the blocks is 'P' tonnes, the virtual rise in the ships centre of gravity (GG_1) or in other words, the virtual loss in the GM, can be obtained by the expression, $\dfrac{P \times KG}{W - P}$, where P the upthrust provided by the blocks may considered as the weight discharged, and KG the vertical distance between the ship's G and the g of weight discharged is equivalent to 'd', as in this case, the weight has been considered discharged from the keel level. The KG to be used in this expression is the KG (not the KG corrected for FSC). This virtual loss in the GM may also be found by the expression $GG_1 = \dfrac{P \times KM}{W}$, where the KM to be used is the KM for the virtual displacement of the vessel at that instant i.e. KM for a displacement of (W - P).

The FSC, when a part of the ship's weight is taken on the blocks is

$$\frac{FSM}{W - P}$$

Though the loss in GM and therefore the residual GM calculated separately using the two expression would give slightly different results, it should not be inferred that the slight difference is due to one expression being more accurate than the other. This is due to the fact that the criterion of the ship's stability is the Righting Moment she has at any angle of heel and not just the initial GM. The Righting Moment obtained for any small angle of heel by the expression W x GM sin θ utilizing the GM obtained by either of the expressions would be nearly the same. This is so, because in one case the virtual displacement of the vessel is (W - P), while in the other case, it is W itself.

It is essential that the ship is stable at all stages between the first end of the ship taking blocks and the entire keel resting on the blocks. Once the entire keel takes the blocks, the stability of the ship, is not a matter of great concern. However, when only one end of the vessel is resting on the blocks, should she become unstable, she will heel over, damaging her bottom and the blocks. To ensure that she is stable throughout the period between one end touching the blocks and the entire keel resting on the blocks, it is sufficient to ensure that she is stable at the instant before the second end of the ship takes the blocks. It is obvious that, if she is stable at that instant when the second end of the ship takes the blocks, she must have been stable at all prior occasions for the reason that as the level of water falls the force P increase and therefore the virtual GM of the vessel decreases throughout this period.

To calculate the loss of GM at the instant, she takes the blocks all over, it is necessary to know the value of the force P at that instant. This can be easily obtained as the total trim she had on entering the dock is nullified when her entire keel rests on level blocks. The trimming moment that she had on entering the dock is equal to trim in cms 't' x MCTC. To reduce that trim to zero, an equal and opposite trimming moment was provided by the upward force P acting at the end of the ship which first took the blocks. The trimming moment provided by any force = The force x it's fore and aft distance from the CF.

Since the trim has been reduced to zero, the initial trimming moment and the trimming moment provided by the force 'P' would be equal i.e. P x a = t x MCTC where 'a' is the fore and aft distance between the CF and the end of the ship which took the block first. In the above expression, P is the only unknown, which can be determined and then used in the expressions mentioned earlier, to ascertain the virtual loss of GM at that instant.

After she takes the blocks all over, the force P can be obtained as the difference between her displacement at her hydrostatic draft when afloat and that at her present hydrostatic draft. If the blocks are level and the vessel has taken blocks all over, the present draft F, A and hydrostatic draft would all be the same.

Note: During drydocking, the virtual displacement, KM, MCTC, LCF and FSC of the vessel would change with the fall in water level. For a small change in the draft, the change in the above parameters is not significant and therefore may be disregarded.
For a large change in draft, the change in these parameters can not be ignored. Also, the FSC then is $\frac{FSM}{W - P}$

94. *M.V. 'Hindship' at a draft of F 3.82 m, A 5.46 m in water of density 1.015 is being drydocked. KG, 8.38 m, FSC 0.12 m. Assuming the KM, MCTC, LCF and FSC remain unchanged over the range of drafts involved, calculate (i) the virtual GM of the vessel on taking blocks all over (ii) her righting moment at a heel of 2°, at the critical instant (iii) the fore and after drafts at which her virtual GM becomes nil.*

$$\left.\begin{array}{ll} F & 3.82\text{ m} \\ A & 5.46\text{ m} \end{array}\right\}\text{ trim 1.64 m by stern}$$

M 4.64 m

LCF for mean draft of 4.64 m = 73.008 m

$$\text{Corrn. to A draft} = \frac{t \times LCF}{LBP} = \frac{1.64 \times 73.008}{143.16} = 0.836\text{ m}$$

After draft = 5.460 m

Hydrostatic draft = 4.624 m

Hydrostatic particulars in water of density 1.015

$$\text{Displacement} = \frac{8962.56 \times 1.015}{1.025} = 8875.1\text{ t}$$

$$MCTC = \frac{163.992 \times 1.015}{1.025} = 162.392 \text{ m}$$

LCF = 73.012 m

KM = 9.176 m

KG = 8.380 m

GM (Solid) = 0.796 m

FSC = 0.120 m

GM (Fluid) = 0.676 m

Virtual loss of GM on taking the blocks all over

$P \times a = t \times MCTC$

$$P = \frac{t \times MCTC}{a}$$

$$= \frac{162.392 \times 164}{73.012} = 364.766 \text{ t}$$

Method I

(i) Virtual loss of GM $= \frac{P \times KG}{W - P}$

$$= \frac{364.8 \times 8.38}{(8875.1 - 364.8)}$$

Virtual loss of GM = 0.359 m

Original GM = 0.676 m

Virtual GM on taking blocks all over = 0.317 m

Method II

Virtual Loss of GM $= \frac{P \times KM}{W}$

$$= \frac{364.8 \times 9.176}{8875.1}$$

Virtual loss of GM = 0.377 m

Original GM = 0.676 m

Virtual GM on taking blocks all over = 0.299 m

(ii) Righting moment	Righting moment
$= GM \sin\theta \times (W - P)$	$= GM \sin\theta \times W$
$= 0.317 \sin 2^0 \times 8510.3$	$= 0.299 \sin 2^0 \times 8875.1$
$=$ ***94.1 tm***	$=$ ***92.6 tm***

(iii) For virtual GM to become zero, virtual loss of GM must equal the original GM.

Virtual loss of GM $= \dfrac{P \times KG}{W - P}$	Virtual Loss of GM $= \dfrac{P \times KM}{W}$
$0.676 = \dfrac{P \times 8.38}{W - P}$	$0.676 = \dfrac{P \times 9.176}{8875.1}$
$0.676\ W - 0.676\ P = 8.38\ P$	
$8.38\ P + 0.676\ P = 0.676 \times 8875.1$	
$P = \dfrac{0.676 \times 8875.1}{9.056}$	
$P = 662.5$ t	$P = 653.8$ t
Virtual displ. when GM becomes zero	Virtual displ. when GM becomes zero
$= 8875.1 - 662.5$	$= 8875.1 - 653.8$
$= 8212.6$ t	$= 8221.3$ t
Equivalent weight in SW	Equivalent weight in SW
$\dfrac{8212.6 \times 1.025}{1.015} = 8293.5$ t	$\dfrac{8221.3 \times 1.025}{1.015} = 8302.3$ t
Hydrostatic draft = 4.317 m	Hydrostatic draft = 4.321 m
Since she is already on level blocks	Since she is already on level blocks,
Hydrostatic draft = draft F & A	Hydrostatic draft = draft F & A
F & A draft = 4.317 m	***F & A draft = 4.321 m***

95. *M.V. 'Hindship' displacing 9540 tonnes and trimmed 0.78 m by the stern is to be drydocked for bottom inspection. KG 7.826 m, FSC 0.164 m. Calculate:-*

(i) *The GM (Fluid) of the vessel before entering dry dock.*

(ii) *The virtual GM of the vessel when her keel takes the blocks all along the length the vessel.*

(iii) *The ford and after draft, at which the virtual GM of the vessel becomes zero.*

(iv) *The fall in water level, between the vessel taking blocks all over and her virtual GM becoming zero.*

(i)	At a displacement of 9540 t, KM	= 8.970 m
	KG	= 7.826 m
	GM (Solid)	= 1.144 m
	FSC	= 0.164 m
	GM (Fluid)	= 0.980 m
	GM (Fluid) before entering dry dock	***= 0.980 m***

(ii)	At a displ. of 9540 t, MCTC	= 166.00 mt
	LCF	= 72.949 m

Calculation of virtual loss of GM on taking blocks all over

$P \times a = t \times MCTC$ (where t = trim in cms)

$P = \frac{t \times MCTC}{a}$ and a = dist. between CF & AP

$P = \frac{78 \times 166}{72.949}$

$= 177.5$ t

Note: Alternative methods have been shown for working sections (ii), (iii) & (iv). When sufficient information is available in the question, either method may be used, but the student should follow any one method, throughout the problem. It is however advisable for the students to learn both the methods, as sometimes, the information given in the question is sufficient for one of the methods only.

Virtual displacement on taking blocks all over = W - P

= 9540 - 177.5 = 9362.5 t

For displacement 9362.5,

KM = 9.027 m

FSM = FSC x W = 1564.56 mt

FSC on taking blocks all over = $\frac{FSM}{W - P}$ = $\frac{1564.56}{9362.5}$

= 0.167 m

Method 1

Virtual loss of GM = $\frac{P \times KG}{W - P}$

= $\frac{177.5 \times 7.826}{9362.5}$ = 0.148 m

KM for displ. 9362.5 t	= 9.027 m
KG	= 7.826 m
GM (Solid)	= 1.201 m
FSC	= - 0.167 m
GM (Fluid)	= 1.034 m
Virtual loss of GM	= - 0.148 m
Residual GM on taking blocks all over	*= 0.886 m*

Method 2

Virtual loss of GM = $\frac{P \times KM}{W}$

= $\frac{177.5 \times 9.027}{9540}$ = 0.168 m

KM for displ. 9362.5 t	= 9.027 m
KG	= 7.826 m
GM (Solid)	= 1.201 m
FSC	= - 0.167 m
GM (Fluid)	= 1.034 m
Virtual loss of GM	= - 0.168 m
Residual GM on taking blocks all over	*= 0.866 m*

(iii) For the virtual GM to become zero, the virtual loss of GM should be exactly equal to her GM, at that instant, without considering the virtual loss. However, to find her GM (Fluid) at that instant, we need the force P at that instant to obtain her virtual displacement, KM and FSC then. As the virtual displacement then is (W - P) and as P is unknown, we first do an approximate calculation of force P, using the initial values of KM and FSC. Using the force P thus obtained, we find a near accurate value of her virtual displacement, KM and FSC for the instant she becomes unstable. Using these values, we obtain her GM (fluid) which is the virtual loss of GM that should occur to cause her to become unstable. We now do a more accurate calculation of force P and hence her virtual displacement and drafts F and A, when she becomes unstable.

Approximate calculation of force P

For Virtual GM to become nil, virtual loss of GM = Initial GM (fluid)

Method 1

$$0.980 = \frac{P \times KG}{W - P} = \frac{P \times 7.826}{9540 - P}$$

$$7.826\ P = 0.980\ (9540 - P)$$

$$8.806\ P = 9349.2$$

$$P = 1061.7\ t$$

Method 2

$$0.980 = \frac{P \times KM}{W} = \frac{P \times 8.970}{9540}$$

$$P = \frac{0.980 \times 9540}{8.97}$$

$$P = 1042.3\ t$$

Accurate calculation of force P

Method 1:

Virtual displ. = 9540 - 1061.7

= 8478.3 t

KM for displ. 8478.3 t	=	9.384 m
KG	=	7.826 m
GM (Solid)	=	1.558 m
FSC = $\frac{1564.56}{8478.3}$	=	0.185 m
GM (Fluid) then	=	1.373 m

Method 2:

Virtual displ. = 9540 - 1042.3

= 8497.7 t

KM for displ. 8497.7 t	=	9.376 m
KG	=	7.826 m
GM (Solid)	=	1.550 m
FSC = $\frac{1564.56}{8497.7}$	=	0.184 m
GM (Fluid) then	=	1.366 m

V. loss of GM $= \dfrac{P \times KG}{W - P}$

$1.373 = \dfrac{P \times 7.82}{9540 - P}$

$13098.42 - 1.373\ P = 7.826\ P$

$P = \dfrac{13098.42}{9.199} = 1423.9\ t$

V. displ. then = 9540 - 1423.9

= 8116.1 t

Hydrostatic draft for displ. of 8116.1 t = 4.236 m

Since she is already on level blocks the F and A drafts = the hydrostatic draft = 4.236 m

V. loss of GM $= \dfrac{P \times KM}{W}$

$1.366 = \dfrac{P \times 9.376}{9540}$

$P = \dfrac{1.366 \times 9540}{9.376} = 1389.9\ t$

V. displ. then = 9540 - 1389.9

= 8150.1 t

Hydrostatic draft for displ. of 8150.1 t = 4.252 m

Since she is already on level blocks the F and A drafts = the hydrostatic draft = 4.252 m

(iv) Virtual displacement on taking blocks all over = 9540 - 177.5

= 9362.5 t

Hydrostatic draft for displ. of 9362.5 t = 4.806 m

Hydrostatic draft for displ. of 9362.5 t = 4.806 m

Fall in W.L. between vessel taking blocks all over and her virtual GM becoming zero

= 4.806 m - 4.236 m = 0.570 m

Fall in W. L. = 0.570 m

Fall in W.L. between vessel taking blocks all over and her virtual GM becoming zero

= 4.806 m - 4.252 m = 0.554 m

Fall in W. L. = 0.554 m

96. *M.V. 'Hindship' floating at a displacement of 18,820 tonnes, KG 7.728 m, FSC 0.092 m, is to be drydocked.*

a) Calculate the maximum trim by the stern allowable to ensure a virtual GM of at least 0.3 m on taking the blocks fore and aft.

b) At the maximum permissible trim, find

(i) Her drafts F & A, on entering dry dock.

(ii) The draft Forward, at which the head would take the blocks.

(iii) The fall in water level between taking blocks Aft and taking blocks For'd.

(a) For displacement of 18820 t

MCTC	=	210.47 mt
LCF	=	69.836 m
KM	=	8.371 m
Hydrostatic Draft	=	8.905 m
KM	=	8.371 m
KG	=	7.728 m
GM (Solid)	=	0.643 m
FSC	=	0.092 m
GM (Fluid)	=	0.551 m
Residual GM reqd.	=	0.300 m
Loss of GM permissible	=	0.251 m

Method I

$$\text{Virtual loss of GM} = \frac{P \times KM}{W}$$

Method II

$$\text{Virtual loss of GM} = \frac{P \times KG}{W - P}$$

$$\therefore \quad 0.251 = \frac{P \times 8.371}{18820}$$

$$P = \frac{0.251 \times 18820}{8.371}$$

$$P = 564.3 \text{ t}$$

$$\therefore \quad 0.251 = \frac{P \times 7.728}{(18820 - P)}$$

$$18820 \times 0.251 = P\,(7.728 + 0.251)$$

$$P = \frac{18820 \times 0.251}{(7.728 + 0.251)} = \frac{4723.82}{7.979}$$

$$P = 592 \text{ t}$$

Since the force P is fairly large, we do a more accurate calculation again, using the hydrostatic particulars for the virtual displacement then.

V. displ. on taking blocks all over = 18820 - 564.3 = 18255.7 t

For displacement of 18255.7 t,

MCTC = 207.083 mt

LCF = 70.011 m

KM = 8.330 m

KG = 7.728 m

GM (Solid) = 0.602 m

$$FSC = \frac{FSM}{W-P} = \frac{0.092 \times 18820}{18255.7}$$

= 0.095 m

GM (Fluid) = 0.507 m

Residual GM required

= 0.300 m

V. loss of GM permissible

= 0.207 m

V. displ. on taking blocks all over = 18820 - 592 = 18228 t

For displacement of 18228 t

MCTC = 206.911 mt

LCF = 70.020 m

KM = 8.328 m

KG = 7.728 m

GM (Solid) = 0.600 m

$$FSC = \frac{FSM}{W-P} = \frac{0.092 \times 18820}{18228}$$

= 0.095 m

GM (Fluid) = 0.505 m

Residual GM required

= 0.300 m

V. loss of GM permissible

= 0.205 m

$$V.\ loss\ of\ GM = \frac{P \times KM}{W}$$

$$\therefore \quad 0.207 = \frac{P \times 8.333}{18820}$$

$$P = 467.7\ t$$

$$P \times a = t \times MCTC$$

$$t = \frac{P \times a}{MCTC} = \frac{467.7 \times 70.011}{207.083}$$

Max. trim allowable = 1.581 m

$$V.\ loss\ of\ GM = \frac{P \times KG}{W - P}$$

$$\therefore \quad 0.205 = \frac{P \times 7.728}{18820 - P}$$

$$3858.1 - 0.205\ P = 7.728\ P$$

$$P = \frac{3858.1}{7.933} = 486.3\ t$$

$$P \times a = t \times MCTC$$

$$t = \frac{P \times a}{MCTC} = \frac{486.3 \times 70.020}{206.911}$$

Max. trim allowable = 1.646 m

(b) (i)

$$t_a = \frac{t \times LCF}{LBP}$$

$$= \frac{1.581 \times 69.836}{143.16}$$

$$t_a = 0.771\ m$$

$$t_f = t - t_a$$

$$= 1.581 - 0.771$$

$$t_f = 0.810\ m$$

Original hydrostatic draft

	F	A
	8.905 m	8.905 m
trim	(-) 0.810 m	(+) 0.771 m

Drafts on entering dry dock

F 8.095 m A 9.676 m

(i)

$$t_a = \frac{t \times LCF}{LBP}$$

$$= \frac{1.646 \times 69.836}{143.16}$$

$$t_a = 0.803\ m$$

$$t_f = t - t_a$$

$$= 1.646 - 0.803$$

$$t_f = 0.843\ m$$

Original hydrostatic draft

	F	A
	8.905 m	8.905 m
trim	(-) 0.843 m	(+) 0.803 m

Drafts on entering dry dock

F 8.062 m A 9.708 m

(b)(ii) Original displ. = 18820 t	Original displ. = 18820.0 t
Upthrust 'P' on taking blocks F & A = 467.7 t	Upthrust 'P' on taking blocks F & A = 486.3 t
∴ Virtual disp. on taking block For'd = 18352.3 t	∴ Virtual disp. on taking block For'd = 18333.7 t
Hydrostatic draft for displ. 18352.3 t = 8.712 m	Hydrostatic draft for displ. 18333.7 t = 8.704 m

Since the vessel will be on an even keel, on taking the blocks F & A, the For'd and the After draft, will be equal to the Hydrostatic draft.

Draft Ford, at which the head will touch the blocks = 8.712 m	***Draft Ford, at which the head will touch the blocks = 8.704 m***

(b)(iii) Stern will take the blocks, when the depth of water over the blocks equals the original draft Aft.

The head will take the blocks, when the depth of water over the blocks equals the draft at which the head touches the block, as calculated above.

Original draft Aft, as per b (i) = 9.676 m	Original draft Aft, as per b (i) = 9.708 m
Draft at which head takes the blocks, as per b (ii) = 8.712 m	Draft at which head takes the blocks, as per b (ii) = 8.704 m
Fall in water level = 0.964 m	***Fall in water level = 1.004 m***

97. *M.V. Hindship sailed from port in condition No. 8 soon after departure she grounded on an isolated rock, without damage to her hull. The drafts then were observed to be F 5.90 m A 9.30 m. Calculate the following:-*

i) The upthrust provided by the rock.

ii) The position with respect to AP, where the grounding occured.

iii) The virtual GM of the ship then.

iv) The angle of heel, if she grounded 2 m to starboard of centre line.

v) The rise of tide required for the ship to refloat.

After grounding

F 5.90 m } trim 3.40 m
A 9.30 m }
M 7.60 m LCF 70.979 m

Corrn. to A draft $= \frac{3.4 \times 70.979}{143.16}$ = 1.686 m

Aft draft on grounding = 9.300 m
Hydrostatic draft on grounding = 7.614 m

For draft 7.614 m

Displacement	= 15725.8 t
MCTC	= 191.996 mt
LCB	= 72.687 m
LCF	= 70.965 m
KM	= 8.238 m

1) Displacement in condition on No. 8 = 16133 t
Displacement after grounding = 15725.8 t

∴ *upthrust provided by rock* = *407.2 t*

2) Total trim t $= 3.4 = \frac{(LCB - LCG)}{MCTC \times 100} \times W$

$\therefore$ (LCB - LCG) $= \frac{3.4 \times 191.996 \times 100}{15725.8}$

$= 4.151$ m

LCB $= \underline{72.687}$ m

LCG $= 68.536$ m

Let the rock be x m for'd of AP.

Then, LCG $= \frac{\text{Long . Moments}}{W} = \frac{1130041 - 407.2x}{15725.8}$

$= 68.536\text{ m}$

407.2 x $= 1130041 - (15725.8 \times 68.536)$

x $= \frac{52257.6}{407.2} = 128.334$ m

She has grounded 128.334 m ford of AP

3) V. loss of GM $= \frac{P \times KM}{W} = \frac{407.2 \times 8.238}{16133} = 0.208$ m

New FSC $= \frac{FSM}{W - P} = \frac{1372}{15725.8} = 0.087$ m

KM	=	8.238	m
KG	=	<u>7.263</u>	m
GM (Solid)	=	0.975	m
V. loss	=	<u>0.208</u>	m
V. GM (Solid)	=	0.767	m
FSC	=	<u>0.087</u>	m
V. GM (Fluid)	=	***0.680***	***m***

4) $\tan\theta = \frac{GG_1}{GM\,(Fluid)} = \frac{d \times w}{(W - w)\,.\,GM} = \frac{2 \times 407.2}{15725.8 \times 0.680}$

θ = Angle of heel = 4.36°

5) For the vessel to re-float, as the tide rises, the draft at the position she grounded should become the same as the draft at that position before the grounding occured.

To find the original draft at the position she grounded

$$\text{corn. to Aft draft} = \frac{t \times \text{dist from AP}}{\text{LBP}} = \frac{2.157 \times 128.334}{143.16}$$

$$= 1.934 \text{ m}$$

Original Aft draft $= \underline{8.860}$ m
Original draft at position she grounded $= 6.926$ m

To find present draft at position she grounded

$$\text{Corn. to Aft draft} = \frac{3.4 \times 128.334}{143.16} = 3.048 \text{ m}$$

Present Aft draft $= \underline{9.300}$ m
Present draft at position she grounded $= 6.252$ m

$\therefore$ Rise of tide reqd. to refloat = 6.926 - 6.252 = 0.674 m

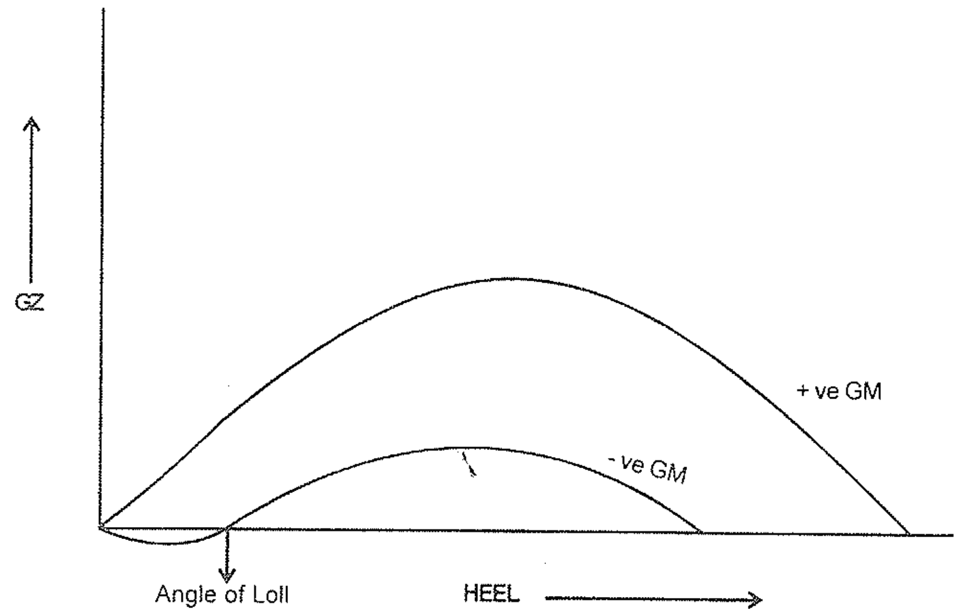
Rise of tide required = ***0.674 m***

ANGLE OF LOLL

A vessel with an initial negative metacentric height is unstable in the upright condition and therefore heels over as she has a capsizing lever when inclined slightly. On heeling, the centre of buoyancy moves out from the centre line till, at a particular angle of heel the centre of buoyancy and the centre of gravity are in the same vertical line. At this angle of heel, her G and M are coincident. The angle of heel at which this occurs is called the angle of loll. In still water, the vessel will remain heeled to that angle. It should be realised that no righting levers are present upto the angle of loll on either Port or starboard sides. Thus she may incline to her angle of loll either to port side or to starboard side.

Though she attains positive stability and therefore righting levers at larger angles of heel, when rolling in a seaway, it should be realized that the righting levers would be fairly small as her statical stability curve is shallow. Even a small heeling moment will therefore cause the vessel to heel over to dangerously large angles, because her dynamical stability (which is a function of the area under the positive part of the curve) is very small.

The following sketch illustrates the statical curve of a vessel with a +ve GM and of the same vessel with initial -ve GM.



As can be seen from the sketch, the vessel with an initial -ve metacentric height has capsizing levers till her angle of loll. The maximum GZ value, the angle of vanishing stability, the range of +ve stability and the dynamical stability at any angle of heel are all very much less than those for the same vessel with +ve GM.

Should a vessel develop a -ve GM, at sea, due to unforeseen circumstances, it should be realised that she will roll to very large angles of heel and not just between the angle of loll on either side. This is so because, as she rolls from one side to the other, since there are no righting levers operating between the angles of loll on either side to oppose the roll, she builds up a large amount of rotational energy. Since her statical stability curve is shallow, the area under that curve and, therefore, the dynamical stability upto any angle of heel is very small. The rotational energy cannot therefore be overcome till very large angles of heel are reached. This can result in shift of cargo causing further deterioration in the situation, possibly leading to capsizing.

To correct such a condition, it is necessary to remedy the basic cause i.e. G being too high. The G may be lowered by reducing free surface effect in various tanks or by trimming down weights or by ballasting at a low level.

When ballasting, care should be taken to ballast a centre tank of small width (to reduce FSC during ballasting), and if that is not available, a divided tank, commencing with the low side. When that tank is full, the high side tank should be filled to even out the weight distribution. If on the contrary the high side tank was ballasted initially, as would have been done to correct a list due to excess weight on the lowside, it would lead to dangerous consequences including capsizing. This could happen because, on adding weight on the high side, she would flop over to that side and heel further to dangerously large angles on that side, or even capsize.

The student is already familiar with the drawing of the curves of statical stability for any condition. The angle of loll can be accurately determined by drawing the statical Stability Curve for the condition she is in and then reading off the angle of loll from the curve at the point at which the righting lever becomes +ve.

An approximate value of the angle of loll may be obtained quickly, provided the angle of loll is not large, assuming the ship to be wallsided, by the use of the expression:

$$\tan\theta = \sqrt{\frac{2.\,GM}{BM}}$$

At the angle of loll, she develops positive stability. The positive GM at the angle of loll may be obtained by the expression:

2 x initial GM x sec. angle of loll.

98. *M.V. 'Hindship' is floating at a displacement of 16875.5 tonnes, KG 8.158 m, FS Moment 1798 mt. Assuming her to be wall sided, calculate her angle of loll. Also calculate her GM at the angle of loll.*

FSC = $\frac{1798}{16875.5}$ = 0.107 m

For displ. 16875.5 t

KB = 4.304 m

KM = 8.260 m

∴ BM = 3.956 m

KG = 8.158 m

GM (Solid) = 8.260 - 8.158 = 0.102 m

FSC = 0.107 m

GM (Fluid) = 0.005 m (negative)

tan angle of loll = $\sqrt{\frac{2.GM}{BM}}$ = $\sqrt{\frac{2 \times 0.005}{3.956}}$

θ = ***Angle of Loll = 2^0 53'***

GM at the Angle of Loll = 2 x Initial GM x sec angle of loll

= 2 x 0.005 x sec 2^0 53'

= 0.010 m

GM at the Angle of Loll = 0.010 m

99. *M.V. 'Hindship' floating at a draft of F 5.73 m, A 6.42 m, is at an angle of loll of 4^0, FS moment 1563 mt. Assuming the ship to be wallsided, calculate her KG.*

Draft F 5.73 m, A 6.42 m } trim 0.69 m by stern

M 6.075 m LCF 72.422 m

After draft = 6.420 m

Corn. to A draft $= \dfrac{0.69 \times 72.422}{143.16}$ = (-) 0.349 m

Hydrostatic draft = 6.071 m

For Hydrostatic draft 6.071 m,

Displacement = 12179.8 t

KM = 8.419 m

KB = 3.241 m

BM = 5.178 m

$$\tan \text{ Angle of Loll} = \sqrt{\frac{2\,GM}{BM}}$$

$$\tan^2 \text{ Angle of Loll} = \frac{2\,GM}{BM}$$

$$\text{Initial GM} = \frac{BM \times \tan^2 \text{angle of Loll}}{2}$$

$$= \frac{5.178 \times \tan^2 4^0}{2}$$

= 0.013 m (negative)

$$FSC = \frac{1563}{12179.8} = 0.128 \text{ m}$$

GM (Solid) = 0.115 m (positive)

KM = 8.419 m

KG = 8.304 m

INCLINING TEST

The ship's KG for any loading condition can be calculated, provided its value is known accurately for the light condition. Light ship means the ship complete in all respects but without stores, consumables, cargo, crew and effects and without any liquids except that machinery and piping fluids such as lubricants and hydraulics are at operating levels.

Regulations II - I/22 of SOLAS requires every passenger ship regardless of size and every cargo ship of length 24 m and over to be inclined to determine the elements of her stability. Where any structural alterations are made to the ship thereafter, which would affect her stability elements, the ship shall be re-inclined.

At intervals not exceeding five years, a light weight survey shall be carried out on all passenger ships to verify any change in light ship displacement and LCG. If there is a deviation of light ship displacement exceeding 2% or a deviation in the LCG exceeding 1% of L, she shall be re-inclined.

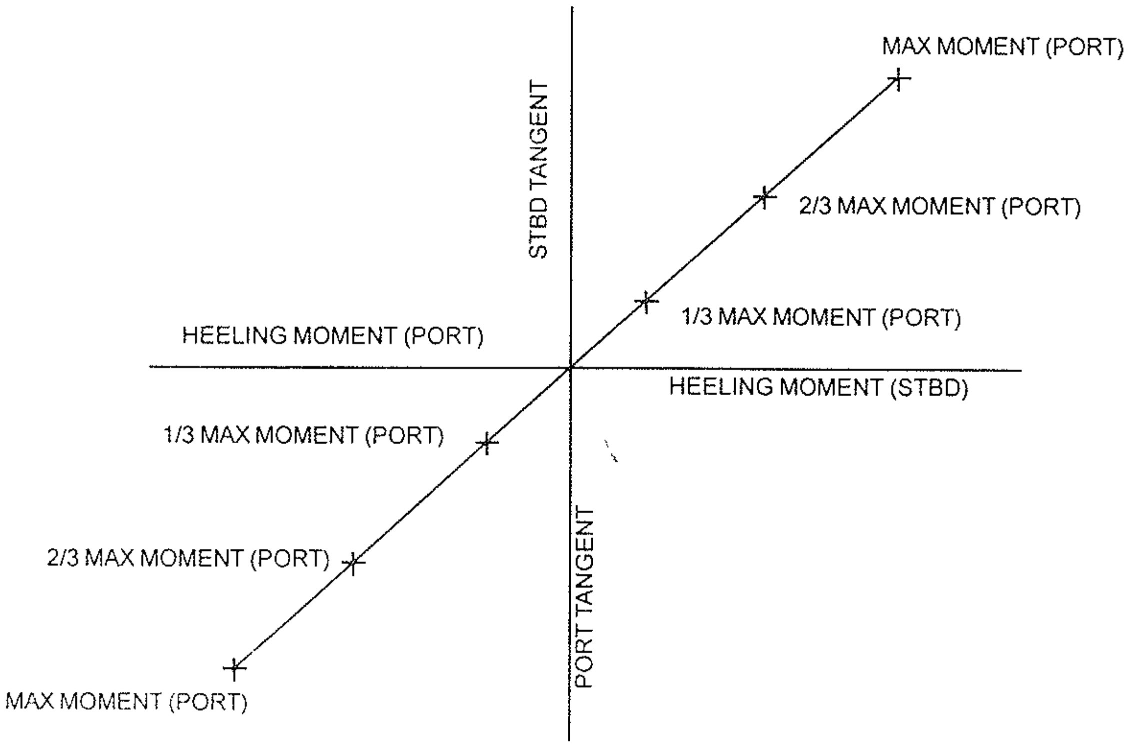
The administration may allow the inclining test to be dispensed with for an individual ship provided basic stability data are available from the inclining test of a sister ship. The Administration may also allow the inclining test to be dispensed with for an individual ship or class of ships specially designed for the carriage of liquids or ore in bulk, if by reference to existing data for similar ships, it clearly indicates that due to the ships proportions and arrangements, more than sufficient metacentric height will be available in all probable loading conditions.

The inclining test is carried out in the ship yard, when the ship is as near completion as possible.

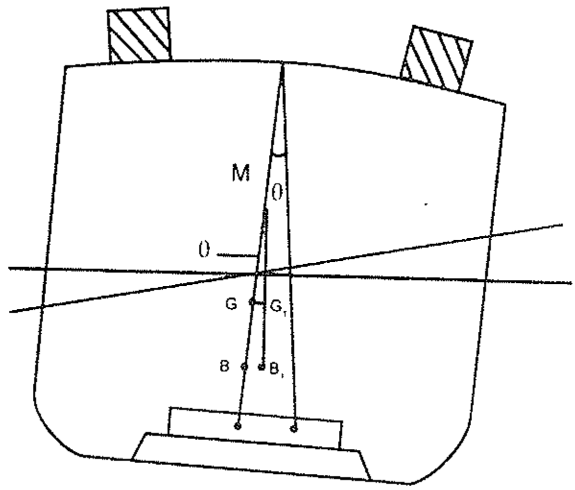
Two or three long pendulums are generally rigged, one forward, one midships and one aft. The pendulums are of pianowire, and their bobs are immersed in troughs of oil to damp their oscillation. The pendulums should be about 4 to 6 m in length and should give a deflection of at least 15 cms, when the ship inclines. The use of three pendulums are recommended but a minimum of two should be used. They should be located as far apart as practicable and should be protected from wind. The use of an inclinometer or U tube may be considered. There should however be at least one pendulum. Graduated battens are set up beneath each pendulum to measure the deflections of the pendulum when the vessel heels.

Ideally, six equal weights are placed on deck, three on each side, at measured equal distances off the centre line. The weights used for inclining the vessel should be such that when they are shifted transversely, they will produce an inclination between 2 degree and 4 degrees. In large ships a minimum inclination of 1 degree may be accepted. If the inclination produced is too large, her water plane area and therefore her KM will change significantly and the inclination produced will not be proportional to the inclining moment provided. On the other hand, if the inclination is very small, any small error in reading the deflection on the plumb line would introduce significant errors in the calculation of her GM.

The initial position of the plumbline is noted against each batten. Using a dock side crane, one weight is shifted port to starboard and the deflection noted on each plumbline. A second weight is shifted port to starboard and the deflection on the plumblines noted again. The third weight is also then shifted port to starboard and the deflection of each plumbline noted. All the three shifted weights are then returned to their original position on the port side and the deflection, if any, on the plumblines noted. This entire procedure is then repeated with the three weights from the starboard side. A plot is then made with the heeling moment (w x d) on the X axis and tan θ (deflection / length of plumbline) on the Y axis. The plot of all readings on each pendulum should lie on a straight line. Deviations of any plot from the straight line indicates there were other moments acting on the ship during that inclining. These moments should be identified and removed and those weight movements repeated until a straight line of all the plots is achieved.



$$\text{TAN } \theta = \frac{\text{DEFLECTION OF PLUMBLINE LINE}}{\text{LENGTH OF PLUMB LINE}}$$



When a weight of 'w' tonnes is shifted transversely through a distance 'd' metres, the listing moment = d x w tm and the transverse $GG_1 = \frac{d \times w}{W}$ m

$$\text{Or } GM = GG_1 = \frac{d \times w}{W \cdot \tan\theta}$$

$$= \frac{d \times w}{W \dfrac{\text{deflection}}{\text{length of plumbline}}}$$

It should be noted that 'W' used in the calculation is the displacement of the ship at the time of the inclining test, including the inclining weights and any other weights on board. The GM obtained will be the GM (Fluid) of the ship in that condition.

The KM for displacement 'W' t is obtained from the vessels hydrostatic data. By subtracting the calculated GM (Fluid) from the KM, we obtain the corrected KG in that condition. The FSC if any is subtracted from the corrected KG to obtain her KG in that condition. By taking moments about the keel, allowance is then made for any weights on board, including the inclining weights, which do not form part of the light ship, to obtain her 'light KG'.

Precautions necessary when conducting the Inclining Test.

1. The ship must be upright at the commencement of the test.
2. The ship's trim should be such that the deviation from her designed trim does not exceed 1% of L.

3. Her draft should be such that abrupt changes will not occur in her water plane, when inclined.

4. An accurate list is to be made of any items of weight yet to be placed on board, and those to be removed from the ship, together with their KGs and LCGs so that correct allowance can be made for them in the calculation of the ship's light KG and LCG.

5. Temporary material, tool boxes, staging, sand, debris etc. on board should be removed and all personnel not involved in the inclining test should also be sent ashore.

6. Decks should be free of water and snow or ice should be removed.

7. Preferably, all tanks should be empty and clean or completely full. Slack tanks should be kept to a minimum, their exact soundings noted and their FSC accurately determined, to allow for the weight of liquid in them and their FSCs in the calculation of light ship parameters.

8. The ship should be moored in a quiet, sheltered area, free from external forces such as propeller wash from passing ships or discharge from shore side pumps.

9. Ideally, there should be no wind, current or tide running.

10. The depth of water should be sufficient to ensure that she will not contact the bottom at any location, when inclined.

11. The ship should be so moored as to allow unrestricted heeling. Access ramps should be removed and power lines hoses etc. connected to shore should be minimized.

12. All derricks, boats etc. should be housed and secured in their seagoing condition.

13. The drafts, F, A and midships should be accurately read on each side of the ship to establish her water line to determine her displacement accurately, at that time. The specific gravity of the water should be obtained accurately by taking water samples forward, midships and aft, at a sufficient depth.

14. The test weights used should be compact such that their VCGs can be accurately determined. Their weights should be accurately recorded.

15. Water ballast transfer is generally not acceptable, for inclining the ship.

100. M.V. 'Hindship' was floating with all compartments empty except as follows:-

No. 2 (P & S) DB tanks full with water ballast.

No. 1 DB tank contained 100 tonnes of H.F.O.

An Inclining Experiment was conducted in this condition. A weight of 10 tonnes Kg. 10.2 m, shifted transversely through a distance of 17.6 m, caused a deflection of 8.3 cms in a plumb line 8.5 m in length. Calculate the GM (solid) and the KG of the light ship.

Light Displacement of M.V. 'Hindship' = 5499.8 t

Water ballast in No. 2 (P & S) = 404.8 x 1.025

= 414.92 t

H.F.O. in No. 1 DB tank = 100.00 t

Inclining weight = 10.00 t

Displacement at the time of Inclining Experiment

= 6024.72 t

KM for displacement of 6024.72 t = 11.113 m

$$\text{GM (Fluid)} = \frac{w \times d}{W \times \tan\theta} = \frac{w \times d}{W \times \frac{\text{deflection}}{\text{length}}}$$

$$= \frac{10 \times 17.6}{6024.72 \times \frac{0.083}{8.5}} = 2.992 \text{ m}$$

Corrected KG, when heeled = 11.113 - 2.992 = 8.121 m

$$\text{FSC for No. 1 tank} = \frac{419 \times 0.95}{6024.72} = 0.066 \text{ m}$$

KG when heeled = 8.055 m

		Weights (t)	KG (m)		Moments (mt)
Total Displacement		6024.72	8.055		48529.1
No. 2 DB tanks	(-)	414.92	0.65	(-)	269.7
No. 1 DB tank	(-)	100.0	1.14	(-)	114.0
Inclining Wt	(-)	10.0	10.2	(-)	102.0
Light Wt		5499.8	Lt. Moment		48043.4

$$\textit{Light KG} = \frac{48043.4}{5499.8} = 8.735 \text{ m}$$

KM for light displacement = 11.651 m

Light GM (Solid) = 2.916 m

101. *M.V. 'Hindship' in Condition No. 7 struck a rock piercing her outer bottom in way of No. 4 P, C & S and No. 5 P & S DB tanks. Calculate the drafts F & A at which she will float and her GM (Fluid) after bilging.*

Since No. 4 (P & S) DB tanks already contain S.W to their full capacity, no further amount of water is added in these tanks on bilging. Thus they do not enter into the calculations.

Wt of water entering No. 4 (C) DB tank = 257.4 x 1.025

= 263.8t

Capacity of No. 5 (P) = 83.5 m^3

Vol. of D.O. oil in it = $\frac{17.7}{0.88}$ = 20.1 m^3

Wt of water entering No. 5 (P) = 63.4 x 1.025 = 65 t

Capacity of No. 5 (S) = 48.8 m^3

Vol of H.F.O in it = $\frac{38.0}{0.95}$ = 40.0 m^3

Wt of water entering No. 5 (S) = 8.8 x 1.025 = 9t

	Weights (t)	KG (m)	V. Moments (mt)	LCG (m)	L.Moments (mt)
Cond. No. 7	18529.3	7.807	144653	72.340	1340415
No. 4 (C)	263.8	0.63	166.2	57.58	15189.6
No. 5 (P)	65.0	0.85	55.3	38.24	2485.6
No. 5 (S)	9.0	0.87	7.8	39.73	357.6

Final Wt 18867.1 F.V. Moment 144882.3 F.L. Mmts. 1358447.8

LCG = $\frac{1358447.8}{18867.1}$ = 72.001 m

$$KG = \frac{144882.3}{18867.1} = 7.679 \text{ m}$$

To find FSC after bilging,

Original F. S. Moment = 1552 mt

FSM of No. 5 (P & S) = (-) 242 mt

Final F S Moment = 1310 mt

$$\text{Final FSC} = \frac{1310}{18867.1} = 0.069 \text{ m}$$

KM for displ. 18867.1 = 8.374 m

KG = 7.679 m

GM (Solid) = 0.695 m

FSC = 0.069 m

GM (Fluid) = 0.626 m

For displacement 18867.1

Hydrostatic draft = 8.924 m

MCTC = 210.74 m

LCB = 72.312 m

LCF = 69.822 m

$$\text{Total trim } t = \frac{LCB - LCG}{MCTC \times 100} \times W$$

$$= \frac{72.312 - 72.001}{210.74 \times 100} \times 18867.1 = 0.278 \text{ m}$$

$$t_a = \frac{t \times LCF}{LBP} = \frac{0.278 \times 69.822}{143.16}$$

$$= 0.136 \text{ m}$$

$$t_f = t - t_a = 0.278 - 0.136 = 0.142$$

	F		A	
Hydrostatic Draft		8.924 m		8.924 m
trim	(-)	0.142 m	(+)	0.136 m
Final Draft	*F*	*8.782 m*	*A*	*9.060 m*

Note: 1. The problem has been solved by the added weight method.

2. The vessel will have the above drafts and GM immediately after bilging, if the oil in No. 5 (P & S) DB tanks is not displaced by water. Over some period of time, water is likely to replace the oil, when, theoretically, these values will change. However, since the amount of oil involved is very small, the change will be negligible.

102. *M.V. 'Hindship' at a draft F 5.80 m, A 6.36 m, KG 7.2 m, FSM 1190 mt. bilged her No.2 hold with permeability 60%.The No. 2 DB tank, 1.3 m deep, beneath the hold remained intact. The hold is of length 26 m, and of mean width 19 m. Calculate her GM (Fluid) and drafts F & A after the bilging.*

$$\left.\begin{matrix} F\ 5.80\ m \\ A\ 6.36\ m \end{matrix}\right\} \text{trim } 0.56 \text{ m by stern}$$

M 6.08 m LCF 72.419 m

$$\text{Correction to Aft draft} = \frac{0.56 \times 72.419}{143.16}$$

$$\therefore \text{ Hydrostatic draft} = 6.360 - 0.283 = 6.077 \text{ m}$$

For draft of 6.077 m

Displ. = 12193.4 t		TPC = 22.505	
MCTC = 174.655 mt		LCF = 72.421 m	
LCB = 72.954 m		KB = 3.244 m	

$$\therefore \text{ Vol. of displ.} = \frac{12193.4}{1.025} = 11896.3 \text{ m}^3$$

$\therefore$ Area of water plane

$$= \frac{22.505 \times 100}{1.025}$$

$$= 2195.6 \quad m^3$$

$$\text{trim} = \frac{(LCB - LCG)}{MCTC \times 100} \times W$$

$$\therefore (LCB - LCG) = \frac{t \times MCTC \times 100}{W} = \frac{0.56 \times 174.655 \times 100}{12193.4}$$

$$= 0.802 \quad m$$

$\therefore$ LCG = 72.954 - 0.802 = 72.152 m

Corrn. to Aft draft to obtain draft at mid length of No. 2 hold

$$(LCG = 103.14) = \frac{0.56 \times 103.14}{143.16} = 0.403 \quad m$$

$\therefore$ draft at mid length of No. 2 hold = 6.36 - 0.403 = 5.957 m

Vol. of lost buoyancy = 26 x 19 (5.957 - 1.3) 0.6 = 1380.3 m^3

Total water plane area = 2195.6 m^2

Water plane area lost = 26 x 19 x .6 = <u>296.4</u> m^2

$\therefore$ Intact water plane area = 1899.2 m^2

$$\text{Mean sinkage} = \frac{\text{Vol. of lost buoyancy}}{\text{Intact w.p. area}} = \frac{1380.3}{1899.2} = 0.727 \quad m$$

Bilged hydrostatic draft 6.077 + 0.727 = 6.804 m

For draft of 6.804 KB = 3.622 m
(in intact condition)

TPC = 22.852 t

$$\therefore \text{w.p.area} = \frac{22.852 \times 100}{1.025} = 2229.5 \quad m^2$$

LCF = 71.802 m

Displacement = 13849.2 t

$\therefore$ Vol. of displacement $= \dfrac{13849.2}{1.025} = 13511.4 \ m^3$

KB at draft of 6.804 m in bilged condition.

$$= \frac{\text{Total under water vol.} \times \text{its KB} - \text{vol. not intact} \times \text{its KB}}{\text{intact under water vol.}}$$

$$= \frac{(13511.4 \times 3.622) - 26 \times 19\ (5.957 - 1.3 + 0.727) \times 0.6x}{11896.3}$$

$$= \frac{48938 - 26 \times 19 \times 5.384 \times 0.6 \times 3.922}{11896.3} = \frac{48938.3 - 6258.8}{11896.3} = 3.588 \ m$$

For draft 6.804 m

intact KM	=	8.280 m	intact KML	=	191.528 m
intact KB	=	3.622 m	intact KB	=	3.622 m
$\therefore$ intact BM	=	4.658 m	$\therefore$ intact BML	=	87.906 m

Since $BM = \dfrac{I_{CL}}{V}$, intact $I_{CL} = BM \times V$

$\therefore$ intact I_{CL} at draft 6.804 m $= 4.658 \times 13511.4 = 62936.0 \ m^4$

I_{CL} of lost water plane $= \dfrac{26 \times 19^3}{12} \times 0.6 = \underline{8917.0 \ m^4}$

I_{CL} of intact water plane $= 54019 \ m^4$

$\therefore$ Bilged BM $= \dfrac{54019}{11896} = 4.541$ m

Bilged KB = $\underline{3.588}$ m

Bilged KM = 8.129 m

Bilged KG = $\underline{7.200}$ m

GM = 0.929 m

FSC $= \dfrac{1190}{12193.4} = \underline{0.098}$ m

GM (Fluid) = 0.831 m

$$\text{Bilged LCF} = \frac{\text{Total area} \times \text{its CF} - \text{lost area} \times \text{its CF}}{\text{intact area}}$$

$$= \frac{2229.5 \times 71.802 - 19 \times 26 \times 0.6 \times 103.14}{2229.5 - 19 \times 26 \times 0.6}$$

$$= \frac{160082.6 - 30570.7}{1933.1} = 66.997 \text{ m}$$

Intact I_{CF} = $BM_L \times V$ = 187.906 x 13511.4 = 2538873 m^4

∴ Intact I(new CF) = 2538873 + 2229.5 $(75.802 - 66.997)^2$

= 2590347.8 m^4

I(new CF) of lost w.p. area $= \frac{19 \times 26^3}{12} \times 0.6 + 19 \times 26 \times 0.6\ (103.14 - 66.997)^2$

= 16697 + 387192 = 403889.2 m^4

∴ I(new CF) of intact w.p = 2590347.8 - 403889.2 = 2186458.6 m^4

Bilged BM_L $= \frac{2186458.5}{11896} = 183.798$ m

Bilged KB = 3.588 m

Bilged KM_L = 187.386 m

KG = 7.200 m

Bilged GM_L = 180.186 m

∴ Bilged MCTC $= \frac{W \times GM_L}{100\,L} = \frac{12193.4 \times 180.186}{100 \times 143.16} = 153.470$ tm

LCB at a displacement of 13849.2 t = 72.857 m

$$\text{New LCB} = \frac{\text{total vol} \times \text{its LCB} - \text{vol not intact} \times \text{its LCB}}{\text{intact under water vol.}}$$

$$= \frac{13511.4 \times 72.857 - 26 \times 19 \times [(5.957 - 1.3 + 0.707) \times 0.6]\,103.14}{11896}$$

$$= \frac{13511.4 \times 72.857 - 1595.8 \times 103.14}{11896} = 68.915 \text{ m}$$

$$t = \frac{(LCB - LCG)}{MCTC \times 100} W = \frac{(68.915 - 72.152)}{153.470 \times 100} \times 12193.4 = 2.572 \text{ m (by head)}$$

$$t_a = \frac{t \times LCF}{LBP} = \frac{2.572 \times 66.997}{143.16} = 1.204 \text{ m}$$

$$t_f = t - t_a = 2.572 - 1.204 = 1.368 \text{ m}$$

	F	A
Hydro. draft	6.804 m	6.804 m
trim	+ 1.368 m	- 1.204 m
Final drafts	*F 8.172 m*	*A 5.600 m*

103. *M. V. 'Hindship' floating at a Hydrostatic draft of 8.8 m has, zero GM. Calculate the list produced if a weight of 2 tonnes already on board is shifted transversely through a horizontal distance of 2.45 metres. Assume the ship to be wall sided at the water line.*

For hydrostatic draft of 8.8 m,

Displacement = 18565 t

KM = 8.352 m

KB = 4.674 m

BM = 3.678 m

$$\tan \text{ list} = \sqrt[3]{\frac{2 \times w \times d}{W \times BM}} = \sqrt[3]{\frac{2 \times 2 \times 2.45}{18565 \times 3.678}}$$

tan list = 0.0523

Angle of list = 3^0

104. *Calculate the Moment of Inertia of the water plane (a) about the centre line and (b) about the transverse axis through CF of M.V. 'Hindship' at an even keel draft of 7.70 m.*

a)

$$BM = I_{CL}/V$$

$$I_{CL} = BM \times V$$

$$= BM \times \frac{\text{Displacement}}{1.025}$$

For even keel draft of 7.70 m

Displacement = 15927 t

KM = 8.239 m

KB = 4.092 m

BM = 4.147 m

$$I_{CL} = \frac{4.147 \times 15927}{1.025} = 64437 \ m^4$$

Moment of I_{CL} = *64437* m^4

b)

$$BM_L = \frac{I_{CF}}{V}$$

$$I_{CF} = BM_L \times V$$

$$= BM_L \times \frac{\text{Displacement}}{1.025}$$

For even keel draft of 7.70 m

KM_L = 177.75 m

KB = 4.092 m

BM_L = 173.658 m

$$\therefore I_{CF} = \frac{173.658 \times 15927}{1.025} = 2698391.1 \ m^4$$

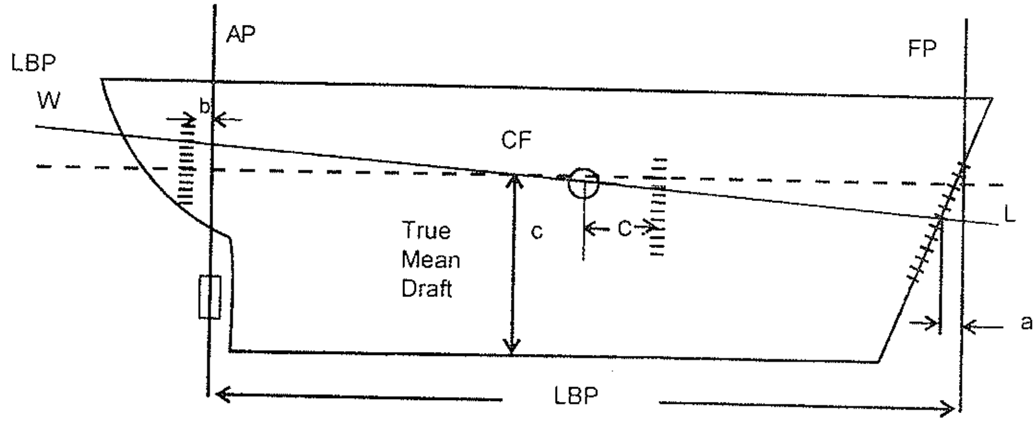
If the vessel's loaded displacement is obtained and the sum of the light displacement, 'constant' and weight of other non cargo items on board are subtracted from the load displacement, the weight of cargo on board should theoretically result. However, this method is subject to errors due to the unknown quantities such as weight of bottom fouling, and the exact weight of the constant etc.

Alternatively, the quantity of cargo loaded may be estimated as the difference in displacement before and after loading, after making allowance for known non-cargo items on board such as fuel, stores, fresh water, any ballast etc. at both instances. Similarly, the quantity of cargo discharged can be estimated by comparing the displacements before and after discharge after making allowance for the weight of non-cargo items on board at both instances. This method would be preferable as unknown quantities such as weight of the ship's constant the weight of bottom fouling etc. is automatically allowed for in this method as they would add to the displacement equally at both instances. By using the same procedure at the loading and discharging ports, the results can be compared and any error will show up.

When conducting a draft survey, the drafts F, A and midships should be read accurately, on both sides of the ship, to obtain the mean of P&S drafts F, A and amidships.

Correction for Position of Draft Marks

The ships hydrostatic data, including her displacement scale are provided for drafts measured at the fore and after perpendiculars, at her designed trim, with no hog or sag. Since the F & A draft marks may not be at the perpendiculars and similarly the amidship draft marks not exactly at the mid point of the length between perpendicular (where the plimsol marks are exactly located), the observed drafts should be corrected to obtain the drafts at the F and A perpendiculars and at the mid point of the length between perpendiculars.



For the case illustrated above, the length between end draft marks = (LBP - a + b), for which the trim (observed draft A ~ observed draft F) is say 't'm. Then by proportion, $\frac{t}{(LBP - a + b)} = \frac{corrn.F}{a} = \frac{corrn. ⊗}{c} = \frac{corrn.A}{b}$

The correction to the observed drafts are thus obtained and when these are applied to the observed drafts, we obtain the drafts at the F&A perpendiculars and at mid length. An inspection of the plan would indicate whether the corrections are to be added to or subtracted from the observed drafts. In the case illustrated, the corrections are to be subtracted from the observed drafts F and A and added to the observed draft amidships.

Correction for Hull Deformation

If the draft at mid length is not equal to the mean of the drafts at the F & A perpendicular it indicates that the ship is hogging or sagging. The mean draft is the mean of the drafts at the F & A perpendiculars. When sagging, the displacement obtained for the mean draft would be less and when hogging, it would be more than the actual displacement of the ship in that condition. The hog/sag correction to the displacement is generally effected by obtaining the "mean of means", which is

$$\left(\frac{F.draft + A\ draft + 6 \times Amidships\ draft}{8}\right)$$

or as 1/4 mean draft +3/4 Amidship's draft.

First Trim Correction (Layer Correction)

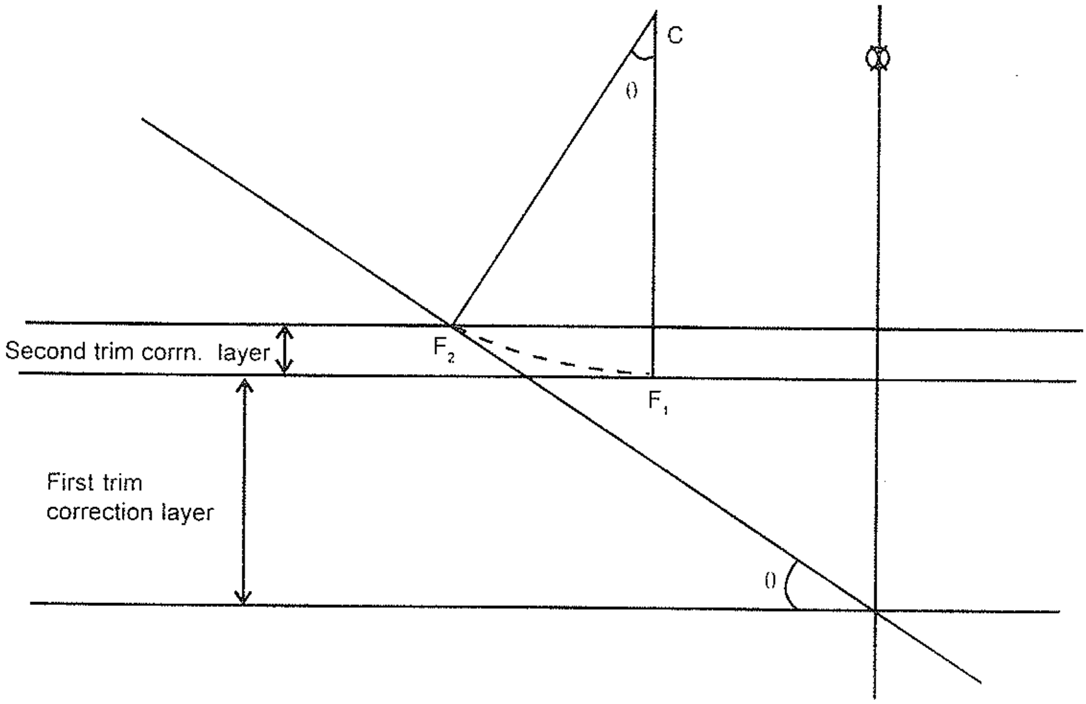
This is the normal correction to obtain the true mean draft of the vessel the draft at the CF) and is obtained as

$$\frac{trim \times dist\ of\ CF\ from\ mid\ point\ between\ perpendiculars}{LBP}$$

where trim is the difference between the drafts at the F&A perpendiculars. This correction will obviously be positive if the CF is closer to the end to which she is trimmed, than the midship point. If not, the correction is negative. This correction applied to the 'mean of means' gives the true mean draft. The displacement of the vessel is obtained for the true mean draft of the vessel from her displacement scale.

Second Trim Correction (Nemoto's formula)

The first trim correction is based on the assumption that, when a ship trims, she trims about a fixed point i.e. the CF at that waterline. But the CF itself changes when a ship trims. The CF rotates in the arc of a circle such that the waterline is always tangential to the arc at the CF.



As the CF moves in the arc of a circle when the trim differs from that for which the ship's displacement scale is provided (almost invariably for the even keel condition), a further correction becomes necessary. The correction in tonnes to the displacement caused by this is obtained as

$$\frac{50 \times (\text{trim in m})^2 \times (MCTC_1 \sim MCTC_2)}{LBP}$$

where $(MCTC_1 \sim MCTC_2)$ is the difference between the MCTCs for drafts 50 cms greater and 50 cms. lesser than the mean of mean drafts of the vessel. The correction in tonnes may also be obtained as

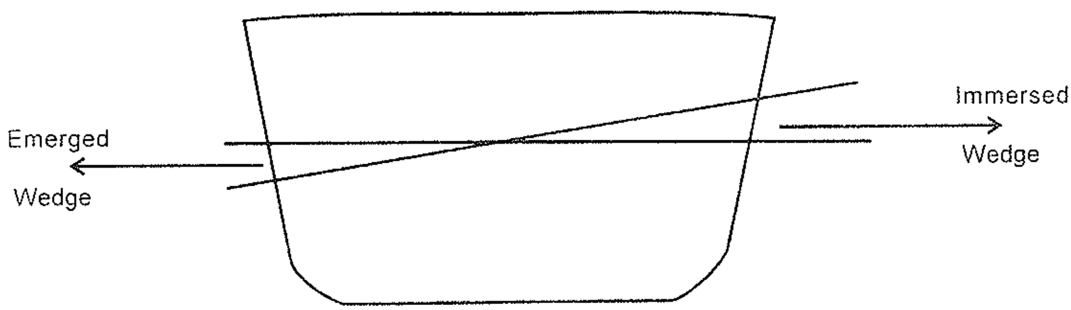
$$\frac{50 \times (\text{trim in m})^2}{LBP} \times \frac{7.2}{B}(TPC^2{}_1 \sim TPC^2{}_2)$$

where (TPC_1 and TPC_2) are the TPCs at drafts 50 cms. greater and 50 cms lesser than the mean of mean drafts. This correction in tonnes is always additive to the displacement because, when the CF moves in the arc of a circle an additional layer is immersed. This correction is significant if the ship's trim differs from the trim for which the displacement scale is provided by more than 0.01 L.

Correction for List

The ship should preferably be upright when conducting a draft survey. If the vessel has a list she rises bodily as the immersed wedge is larger than the emerged wedge, particularly on ships with a large flare. This reduces the draft of the vessel. Therefore the following correction which is always positive is applied to the displacement.

Corn. in tonnes = 6 (d_1 - d_2) (TPC_1 - TPC_2) when d_1 and d_2 are the drafts amidships on the immersed and emerged sides respectively and TPC_1 and TPC_2 the TPCs for those respective drafts.



Density Correction

The ship's displacement scale is provided for a standard density of water, usually 1.025 t/m³ since other standards are also used, it is important to check the value used for the displacement scale provided. The ship's displacement is then obtained as

$$\frac{\text{scale displacement} \times \text{density of water}}{\text{density used for displacement scale}}$$

Constant

If a draft survey is conducted when the ship has no cargo on board, the difference between her actual displacement obtained from the displacement scale and displacement obtained as the sum of her light displacement and all other, known weights on board then, would give the ship's 'constant', i.e. the weights of spare propeller, cylinder liners, stores etc. onboard (which do not form part of the ship's, light weight). An abnormally small or large constant points to an error in computation. The results should then be re-checked. The 'constant' would alter over a period of time as a result of additional equipment, accretion of stores, effect of corrosion etc. This increase in 'constant' with time would obviously vary from ship to ship. As a rule of thumb, it has been suggested that after 'n' years of her life the 'constant' may be estimated as **(0.5 + 0.05n) % of the ship's deadweight**. The 0.5% is for the rapid increase which occurs in the first year of her life. Other estimates suggested are 0.25% of the ship's light displacement for every year of service or 2.5 x TPC for every 5 years of service. However none of the above are likely to provide exact values.

Factors Influencing Accuracy

The drafts must be observed accurately, preferably using a boat to obtain the best accuracy possible. Ideally there should be no waves or current/ tide running when the drafts are observed. Any wave disturbance of the water surface will influence the accuracy of the observed drafts even if draft gauges are used. A tide or current running would produce a build up of water against the loading edge and also a squat, which would affect the drafts observed.

The density of water in which the ship floats used to calculate the ship's displacement must be based on a representative sample of the water, taken from at least three positions along the ship's length, away from discharges from the ship, at various depths, on the side away from the quay to avoid any discharge from the shore and to avoid any stagnant water trapped between the ship and the jetty. A weighted container with a perforated lid lowered to the deepest draft and raised at a constant speed would ensure a fairly representative sample. However, even this may not ensure accuracy where stratification of water layers exists. When the under keel clearance is small and the sea bed is of soft mud, the density of the lower layer of water can be as high as 2.00 due to the mud in suspension. It is impracticable to allow for this effect which tends to reduce the loaded draft i.e. underestimate the loaded displacement.

The density and temperature of the water samples should be measured at the time the drafts are observed as the density varies with the state of tide. To measure density, a glass hydrometer designed for water, not oil, should be used as the surface tension of water and oil differs. Brass instruments are not accurate enough for this purpose. When reading the hydrometer any parallax error should be avoided and it should be ensured that no air bubbles adhere to the submerged position of the instrument. As is often the case if the hydrometer is calibrated for water in vacuum 0.001 should be subtracted from the hydrometer reading to allow for the weight/volume relationship in air as compared to that in vacuum. If the water is not at the calibration temperature of the instrument (usually 60^0 F), a further correction supplied with the instrument must be applied.

The exact weight of liquids in the tanks must be obtained by obtaining their accurate ullages and making due allowance for the ship's trim and any list, using the correction tables provided with the tank calibration tables. The correction tables should take into account the effect of the liquid surface touching the top or bottom of the tank. The density of any ballast in the tanks should be measured as it may differ considerably from that of the water in which the ship floats.

When the anchors and cables are down, the displacement would obviously be lesser than when they are housed.

It should therefore be obvious that accurate calculation of the quantity of cargo onboard would depend largely on the skill and care exercised by the individual-which is difficult to quantify. If carried out carefully, it should be possible to produce fairly accurate results.

Every efforts should be made to ensure that the bill of lading does not overstate the quantity cargo loaded. Should short delivery claims arise, it is possible for the owners to contest such claims by showing that the bill of loading quantity is incorrect. In this, the ship's determination of the quantity at the load port and discharge port is of considerable importance, not necessarily in terms of absolute accuracy but in terms of consistency i.e. a common yard stick (the ship itself) having been used for both measurements. If it is also shown that no cargo has been lost during the voyage (by reference to log books) and that all cargo loaded has been delivered, it goes a long way in overturning the bill of lading figure.

105. *M.V. 'Hindship' arrived port with the following drafts F 8.65 m, A 8.89m, Mid 8.81 m. Density of dockwater 1.018 weights on board: H.O. 250 t, D.O. 85 t, FW 112 t, L.O 18 t, and unpumpable ballast 45 t. If the constant and stores as determined on completion of discharge was 150 t. Calculate the quantity of cargo discharged. Draft marks are located 2m aft of FP, 4m ford of AP and 1m ford of midship.*

Observed drafts F 8.65 m, A 8.89 m } trim = 0.24 m by stern

M 8.71 m

Length between marks = 143.16 - 2 - 4 = 137.16m

Corn. to observed drafts F $= \dfrac{0.24 \times 2}{137.16} = 0.003$ m

$\therefore$ draft at FP = 8.650 - 0.003 = 8.647 m

Corn. to observed draft A $= \dfrac{0.24 \times 4}{137.16} = 0.007$ m

$\therefore$ drafts at AP $= 8.890 + 0.007 = 8.897$ m

Corrn. to observed mid draft $= \dfrac{0.24 \times 1}{137.16} = 0.02$ m

$\therefore$ draft at $= 8.810 + 0.002 = 8.812$ m

Mean of Means $= \dfrac{8.647 + 8.897 + 6 \times 8.812}{8}$

$= 8.802$ m

Mid length of LBP $= \dfrac{143.16}{2}$ m

$= 71.580$ m ford of AP

LCF for 8.802 draft $= 69.910$ ford of AP

CF is abaft by $= 1.670$ m

1st trim corrn. $= \dfrac{\text{trim} \times \text{dist. of CF from midlength}}{\text{LBP}}$

Where trim between perpendiculars $= 8.897 - 8.647 = 0.250$ m

Corrn. $= \dfrac{0.25 \times 1.670}{143.16}$

$= 0.003$ m (+ve as CF is towards the trimmed end)

$\therefore$ True Mean draft $= 8.802 + 0.003 = 8.805$ m

displ. for 8.805 m $= 18577.2$ t

2nd trim corrn. $= \dfrac{50 \times (\text{trim in m})^2\ (MCTC_1 \sim MCTC_2)}{\text{LBP}}$

$= \dfrac{50 \times (0.25)^2 \times 14.3}{143.16} = 0.3$ t

$\therefore$ Displ. in SW $= 18577.2 + 0.3 = 18577.5$ t

Displ. in DW $= \dfrac{18577.5 \times 1.018}{1.025} = 18450.6$ t

Total non-cargo wts. on board $= 250 + 85 + 112 + 18 + 45 + 150$

$=$ <u>660.0</u> t

$= 17790.6$ t

Light displacement $=$ <u>5499.8</u> t

$\therefore$ *cargo discharged* $=$ *12290.8 t*

106. *M.V. 'Hindship' arrives at the discharge port with the following drafts in SW. F port 6.69 m, stbd. 6.65m, A port 8.86m, stbd. 8.75m, mid port 7.91 m, stbd. 7.75 m. The for'd draft marks are 5m abaft the FP, the mid marks are 2m abaft the midships and the after marks are at the AP. On arrival she has 125.5 t of fuel oil, 22.4 t of D.O., 43.3 t of FW, 23.0 t of ballast and 101.5 t crew, personnel effects, provisions and stores on board. Calculate the amount of cargo on board assuming constant for her age of 16 years as (0.5 + 0.05n)% of her deadweight.*

	P	S	M	
F	6.69 m	6.65 m	6.67 m	trim = 2.135 m
A	8.86 m	8.75 m	8.805 m	
Mid	7.91 m	7.75 m	7.83 m	

Dist between end draft marks = 143.16 - 5.0 = 138.16

Corn. to observed draft F $= \dfrac{2.135 \times 5}{138.16} = 0.077$

$\therefore$ draft at FP = 6.67 - 0.077 = 6.593 m

Corn. to mid draft $= \dfrac{2.135 \times 2}{138.16} = 0.031$

$\therefore$ draft at ⊗ = 7.83 - 0.031 = 7.799 m

draft at AP = 8.805 m

Trim between perpendiculars = 8.805 - 6.593 = 2.212 m

Mean of means $= \dfrac{6.593 + 8.805 + 6 \times 7.799}{8} = 7.774$ m

LCF for 7.774 m = 70.806 m ford of AP

Mid pt. between perpendicular = 71.58 m ford of AP

CF is abaft mid point by = 0.774 m

1st trim corn. $= \dfrac{\text{trim} \times \text{dist of CF from mid point}}{\text{LBP}} = \dfrac{2.212 \times 0.774}{143.16}$

= 0.012(+ve)

$\therefore$ True mean draft = 7.774 + 0.012 = 7.786 m

displacement for 7.786 m = 16128.2 t

2^{nd} trim corn.	=	$\frac{50 \times (\text{trim in m})^2 \times (MCTC_1 \sim MCTC_2)}{LBP}$	
MCTC for 8.274	=	201.273 and MCTC for 7.274	= 187.362
($MCTC_1$ ~ $MCTC_2$)	=	201.273 - 187.362	= 13.911
Corn.	=	$\frac{50 \times (2.212)^2 \times 13.911}{143.16}$	= 23.8 t (+ve)
displacement	=	16128.2 + 23.8	= 16152 t
Corn. for list	=	$6(d_1 - d_2)\ (TPC_1 - TPC_2)$	
	=	6(7.91 - 7.75) (23.96 - 23.5)	= 0.4 t
Actual displ. in SW	=	16152 + 0.4	= 16152.4 t
Constant	=	(0.5 + 16 x 0.05)% of 14117	= 183.5 t

Total non-cargo = 183.5 + 125.5 + 22.4 + 43.3 + 23.0 + 101.5
= 499.2 t

∴ ***Cargo on board* = *16152.4 - 499.2 - 5499.8* = *10153.4 t***

107. *M.V. 'Hindship' arrived port for part discharge at the following drafts F (P) 8.88 m, (S) 8.92 m, Mid (P) 8.96 m, (S) 9.16 m, A (P) 9.24 m, (S) 9.36 m respectively. Density of DW = 1.016 t/m³. During her port stay she consumed 25t of FW and 5 t of D.O. She received 600 t of H.O. She sailed from the port with drafts 6.00 m, F and A and 6.04 m mid draft. Calculate the quantity of cargo discharged at the port, if the for'd draft marks are 2 m for'd of FP, after marks 3 m aft of AP and mid marks are 1 m for'd of midships.*

To calculate arrival displacement

	P	S	M	
F	8.88 m	8.92 m	8.90 m	trim = 0.40 m by stern
A	9.24 m	9.36 m	9.30 m	
Mid	8.96 m	9.16 m	9.06 m	

Distance between end marks = 143.16 + 2.0 + 3.0 = 148.16 m

Corn. to F draft = $\frac{0.4 \times 2}{148.16}$ = 0.005 m (+ve)

Corn. to A draft = $\frac{0.4 \times 3}{148.16}$ = 0.008 m (-ve)

Corn. to mid draft = $\frac{0.4 \times 1}{148.16}$ = 0.003 m (+ve)

draft at FP = 8.90 + 0.005 = 8.905 m

draft at AP = 9.30 - 0.008 = 9.292 m

draft at midship = 9.06 + 0.003 = 9.063 m

Mean of means = $\frac{8.905 + 9.292 + 6 \times 9.603}{8}$

= 9.072 m

LCF for 9.072 m = 69.711 m

1/2 LBP = 71.580 m

dist. between CF & mid ship = 1.869 m

1st trim corn. = $\frac{1.869 \times 0.387}{143.16}$ = 0.005 m (+ve)

∴ True mean draft = 9.072 + 0.005 = 9.077 m

displacement for 9.077 m = 19238.1 t

2nd trim corn. = $\frac{50 \times (\text{trim in m})^2 \times (MCTC_1 \sim MCTC_2)}{LBP}$

2nd trim corn. = $\frac{50 \times (0.387)^2 \times 14.04}{143.16}$ = 0.7 t

True displacement in SW = 19313.1 t

Corn. for list is negligible

∴ Arrival displacement = $\frac{19313.1 \times 1.016}{1.025}$ = 19143.5t

To calculate sailing displacement

Since she is on an even keel, no correction is necessary for displacement of draft marks from perpendiculars or midship.

$\therefore$ Mean of means $= \dfrac{6.0 + 6.0 + 6.04 \times 6}{8} = 6.030$ m

Since vessel is on even keel no 1st or 2nd trim corrections are necessary.

$\therefore$ True Mean draft = Mean of Means = 6.030 m

displacement for 6.030 m in SW = 12087.0 t

$\therefore$ displacement in DW $= \dfrac{12087 \times 1.016}{1.025} = 11980.9$ t

Difference between arrival and sailing displacements

= 19143.5 - 11980.9 = 7162.6 t

water and oil consumed = - 30.0 t

7132.6 t

H. oil received +600.0 t

$\therefore$ *cargo discharged* = *7732.6 t*

108. *M.V. 'Hindship' is at a draft of F 9.20 m, A 9.30 m, mid 9.30 m, in water of RD 1.005. The draft marks are 3 m aft of FP, 1.5 m aft of midships and 5 m ford of AP. She is to shift to a berth where the maximum permissible draft is 6.00 m. Calculate the amount of cargo to discharge if after discharging that cargo she is expected to hog by 10 cms.*

To calculate initial displacement

Draft F 9.20 m
A 9.30 m } Trim = 0.1 m by stern

mid 9.30 m

Length between marks = 143.16 - 3.0 - 5.0 = 135.16 m

Corn. to For'd draft $= \dfrac{0.10 \times 3}{135.16} = 0.002$ m (-ve)

Corn. to Aft draft = $\dfrac{0.10 \times 5}{135.16}$ = 0.004 m (+ve)

Corn. to mid draft = $\dfrac{0.10 \times 1.5}{135.16}$ = 0.001 m (-ve)

Corrected drafts F = 9.20 - 0.002 = 9.198 m } Trim = 0.106 m by stern

A = 9.30 + 0.004 = 9.304 m

mid = 9.30 - 0.001 = 9.299 m

Mean of Means = $\dfrac{9.198 + 9.304 + 6 \times (9.299)}{8}$ = 9.287 m

LCF for 9.287m = 69.557 m f'ord of AP

mid length = $\dfrac{143.16}{2}$ = 71.550 m for'd of AP

CF = 1.993 m aft of mid length

$\therefore$ 1st trim corn. = $\dfrac{0.106 \times 1.993}{143.16}$ = 0.0015 m (+ve)

T. Mean draft = 9.287 + 0.002 = 9.289 m

displacement for 9.289 m in SW = 19753.7 t

2nd trim corn. is negligible

$\therefore$ Initial displacement in DW = $\dfrac{19753.7 \times 1.005}{1.025}$ = 19368.3 t

To calculate displacement at F&A draft of 6.00 m

Draft F&A = 6.00 m - trim is nil

mid draft with hog = 5.90 m

Mean of Means = $\dfrac{2 \times 6.00 + 6 \times 5.90}{8}$ = 5.925 m

Displacement in SW for 5.925 m = 11850.25 t

$\therefore$ Displacement in DW $= \dfrac{11850.25 \times 1.005}{1.025} = 11619$ t

$\therefore$ ***Cargo to discharge*** $= \mathbf{\mathit{19368.3 - 11619 = 7749.3\ t}}$

109. *M.V. 'Hindship' arrived port in a partly loaded condition with drafts F 6.65 m, A 6.95 m and mid 6.76 m in water of density 1.010 t/m³. Calculate the quantity of cargo she can load if she is to sail into a summer zone on an even keel in SW, with an expected sag of 8 cms. 56 t of fuel and FW is expected to be consumed in port and 20 t during the down river passage. The draft marks are 2 m for'd of FP, 2 m abaft midship, and 3 m abaft AP.*

Also find the sailing draft F & A in DW.

To calculate arrival displacement.

F 6.65 m
A 6.95 m
mid 6.76 m — Trim = 0.30 m by stern

Length between marks = 143.16 + 2 + 3 = 148.16 m

Corrn. to F. draft $= \dfrac{0.3 \times 2}{148.16} = 0.004$ m (+ve)

Corrn. to A draft $= \dfrac{0.3 \times 2}{148.16} = 0.004$ m (-ve)

Corrn. to mid draft $= \dfrac{0.3 \times 3}{148.16} = 0.006$ m (-ve)

Corrected drafts F = 6.65 + 0.004 = 6.654 m

A = 6.95 - 0.004 = 6.946 m

mid = 6.76 - 0.006 = 6.754 m

Trim = 0.292 m by stern

Mean of Means $= \dfrac{6.654 + 6.946 + 6 \times 6.754}{8} = 6.766$ m

LCF for draft 6.766 = 71.840 m for'd of AP mid length = $\frac{143.16}{2}$ = 71.580 m for'd of AP

CF = 0.26 m ford of mid length

1st trim corn. = $\frac{0.26 \times 0.292}{143.16}$ = 0.001 m (-ve)

True Mean draft = 6.766 - 0.001 = 6.765 m

Displacement for 6.765 m = 13760.0 t

2nd trim corn. = $\frac{50 \times (0.292)^2 \times 10.96}{143.16}$ = 0.3 t

Displacement in SW = 13760.3 t

∴ Displacement in DW = $\frac{13761.1 \times 1.010}{1.025}$ = 13558.9 t

To calculate sailing displacement

Under the international load line convention, the minimum freeboard to be maintained is at mid length where the load lines are exactly located. In this calculation therefore, the draft amidships in SW should be the ship's summer draft i.e. 9.233 m. Since a sag of 8 cms is expected the drafts at the F&A perpendiculars should be 9.233 - 0.080 = 9.153 m as she is to be on an even keel.

∴ Mean of Means = $\frac{2\,(9.153) + 6\ (9.233)}{8}$ = 9.213 m

Since the vessel is on even keel, the 1st and 2nd trim correction are nil.

∴ True Mean draft = Mean of means = 9.213 m

Displacement in SW for 9.213 m = 19568.7 t

Sailing displacement = 19568.7 + 20 = 19588.7 t

Arrival displacement = 13558.9 t

difference = 6029.8 t

Fuel & FW to be consumed = 56.0 t

∴ cargo to load = 6085.8 t

To calculate sailing drafts in DW

Sailing displacement in SW = 19588.7 t

equivalent weight $= \dfrac{19588.7 \times 1.025}{1.010}$ = 19879.6 t

True Mean draft for 19879.6 = 9.341 m

Since V/L is to be even keel, true mean draft

= Mean of means = 9.341 m

$\therefore \quad 9.341 = \dfrac{dF + dA + 6\,dM}{8}$

If draft F&A is x,

$\dfrac{2x + 6 \times (x + 0.08)}{8} = x + 0.06 = 9.341$ t

x = draft F&A = 9.341 - 0.06 = 9.281 m

$\therefore$ Draft at F&A perpendiculars = 9.281 m

mid draft = 9.281 + 0.08 = 9.361 m

Since V/L is to be on an even keel on arrival in SW,

the LCB for her displacement then (19568.7 t) = LCG

$\therefore$ LCB = LCG = 72.216 m

LCB for 19879.6 t = 72.178 m

On sailing from DW (LCB - LCG) = - 0.038 m

LCF for displacement 19879.6 t = 69.521 m

MCTC for displacement 19879.6 t = 216.54 tm

$\therefore$ MCTC in DW $= 216.54 \times \dfrac{1.010}{1.025}$ = 213.37 tm

$\therefore$ trim 't' $= \dfrac{-0.038 \times 19588.7}{213.37 \times 100}$ = 0.0349 m

by hd

$\therefore$ trim between draft marks $= \dfrac{0.0349 \times 148.316}{143.16} = 0.036$ m

$'t_a' = \dfrac{0.036 \times (69.521 + 3)}{148.16} = 0.018$ m

$'t_f' = 0.036 - 0.018 = 0.018$ m

$\therefore$ ***Sailing draft in DW*** $= \mathit{9.281 + 0.018} = \mathit{9.299}$ *m F*

$= \mathit{9.281 - 0.018} = \mathit{9.263}$ *m A*

Note: When sailing in the hogged condition, the F&A drafts would be greater than the mid draft. As per the international load line convention the minimum freeboard is to be maintained at the loadline marks. If loaded to her marks, her mean of mean draft would be greater than the allowable draft for the applicable load line without the hog. The port state control would normally not allow such overloading. The maximum displacement that would be allowed would be the displacement for the applicable load line without any hull deflection.

110. *M.V. 'Hindship' is loading in tropical zone in water of R.D. 1.010. She is to enter a port in summer zone after 5 days steaming, where she is to receive 300 t of fuel and 100 t of FW. She is expected to enter winter zone after a further 7 days steaming. Calculate the maximum amount of cargo she can load if she has 230 t of fuel, 150 t of FW, 100 t of stores and 20 t of unpumpable ballast. Her constant is 120 t and daily consumption is 36 t of fuel and 15 t of FW.*

Tropical deadweight		= 14585 t	
5 days consumption	= (36 + 15) 5	= - 255 t	
Deadweight on arrival port (S. Zone)		= 14330 t	
Fuel & FW recd.	= (300 + 100)	= 400 t	
Deadweight on dep into S. Zone		= 14730 t	Excess 613 t
Summer deadweight		= 14117 t	
7 days consumption	= (36 + 15) 7	= - 357 t	
Deadweight on entering W. Zone		= 13760 t	Excess 109 t
Winter deadweight		= 13651 t	
Total Excess		= 722 t	

∴ Max permissible deadweight at load port

= 14585 - 722 = 13863 t

Non Cargo items on board

= 230 + 150 + 100 + 20 + 120 = - 620 t

∴ ***Maximum cargo to load = 13243 t***

111. *M.V. Hindship arrived at a load port in tropical zone with 480 t of bunkers, 290 t of FW, 80 t of stores and a constant of 110 t. She is to sail with maximum cargo after 5 days port stay. She will enter summer zone 3 1/2 days after departure and after a further 5 1/2 days she will re-enter tropical zone. Two days thereafter she is to call at a port for 12 hours to receive 120t of FW and the maximum amount of bunkers. 5 days after departure from the bunkering port, she will re-enter summer zone. Calculate the maximum amount of cargo she can load at the load port and thereafter, the maximum amount of bunkers she can receive at the bunkering port. Fuel and FW consumption are 35t and 16t respectively at sea and 5t and 16t respectively in port.*

5 days fuel cons. in port = 5 x 5 = 25 t

5 days FW cons. in port = 16 x 5 = 80 t

Fuel on board on dep. load port = 480 - 25 = 455 t

FW on board on dep. load port = 290 - 80 = 210 t

Tropical deadweight = 14585 t

3 1/2 days sea cons. = (35 + 16) 3.5 = - 178.5 t

Deadweight on dep into S. Zone = 14406.5 t } Excess cargo
Summer deadweight = 14117.0 t } = 289.5 t

5 1/2 days sea cons. = (35+16) 5.5 = - 280.5 t

Deadweight on entering T. zone = 13836.5 t (Allowable 14585t)

2 days sea cons. = (35+16) 2 = 102.0 t

Deadweight on arr. bunkering port = 13734.5 t

1/2 day port cons. = (16+5) 0.5 = - 10.5 t

= 13724.0 t

FW to be received = + 120.0 t

= 13844.0 t

Tropical dead weight = 14585.0 t

Bunkers to receive = 741.0 t

5 days sea cons. = (35 + 16) 5 = - 255.0 t

Deadweight on entering into S. Zone	= 14330 t	}	Excess bunkers = 213 t
Summer deadweight	= 14117 t	}	

Max. deadweight allowable at load port = 14585 - 289.5

= 14295.5 t

Non cargo items: 455 + 210 + 80 +110 = 855.0 t

∴ ***Max. cargo to load at load port = 13440.5 t***

Max. bunkers to receive = 741 - 213 = 528.0 t

112. *M.V. 'Hindship' arrives at a load port in summer zone with 110 t of fuel, 80 t of FW, 90 t of stores and a constant of 110 t as determined by a draft survey. The load port stay is 4 days. The daily consumption of fuel and FW are 6 t and 16 t respectively in port and 36 t and 16 t respectively at sea. She will enter winter zone 5 days after sailing, and a further 2 days later she is to call at a port for half a day for bunkers and FW. From there, to the port of discharge is 3 days steaming. If she is to have 2 days reserve fuel and FW at all times when at sea. Calculate the maximum amount of cargo she can load and the fuel and FW to be at the intermediate port.*

Fuel consumed at load port = 6 x 4 = 24 t

FW consumed at load port = 16 x 4 = 64 t

∴ Fuel remaining on board = 110 - 24 = 86 t

FW remaining on board = 80 - 64 = 16 t

Fuel reqd. on sailing = (7+2 days reserve) x 36 = 324 t

∴ Fuel to be received at load port = 324 - 86 = 238 t

FW reqd. on sailing = (7+2 days reserve) x 16 = 144 t

∴ FW to be received at load port = 144 - 16 = 128 t

Summer deadweight = 14117 t

Fuel & FW consumption for 5 days (36+16) 5 = - 260 t

Deadweight on entering into W. Zone	= 13857 t	}	Excess cargo = 206 t
Winter deadweight	= 13651 t	}	

2 days consumption at sea = (36 + 16) 2 = - 104 t

= 13547 t

1/2 day port consumption = (6 + 16) 0.5 = - 11 t
= 13536 t

Fuel on board = 324 - (36 x 7 x 6 x 0.5) = 69 t

Fuel reqd. on sailing = (3 + 2 days reserve) x 36 = 180 t

Fuel to receive at intermediate port = 111 t

FW on board = 144 - 16 x 7.5 = 24 t

FW required on sailing = (3 + 2 day res.) x 16 = 80 t

FW to receive = 56 t

Fuel and FW received at intermediate port = 111 + 56

= + 167 t

Deadweight on sailing = 13536 + 167 = 13703 t
Winter displacement = 13651 t
} Excess cargo = 52 t

Deadweight on dep. = 14117 - (206 + 52) = 13859 t

Total non cargo on departure load port = 324 + 144 + 90+210

= 668 t

∴ ***Cargo to load at load port = 13191 t***

STABILITY REQUIREMENTS FOR SHIPS LOADED WITH GRAIN IN BULK

113. *A vessel is loaded with grain in bulk of stowage factor 1.80 m^3/t has displacement of 68012 t, a KM of 11.40 m and FSM 4220 mt. Two holds are partly filled and their combined VHM, as read off from the curves is 3009 m^4. All other holds are full and their total VHM is 18981 m^4. The KG of the ship calculated assuming the CG of the cargoes in the filled compartments are at the volumetric centroid of each of those compartments is 10.50 m^4. The angle of flooding is 41^0.*

The KN values for her displacement are as follows:-

Heel ^{0}	12	15	30	40	45	60	75	90
KN m	2.782	3.508	7.033	9.356	10.206	11.288	11.270	10.385

Determine whether the ship satisfies the intact stability criteria for vessels laden with grain in bulk.

KG = 10.5 m

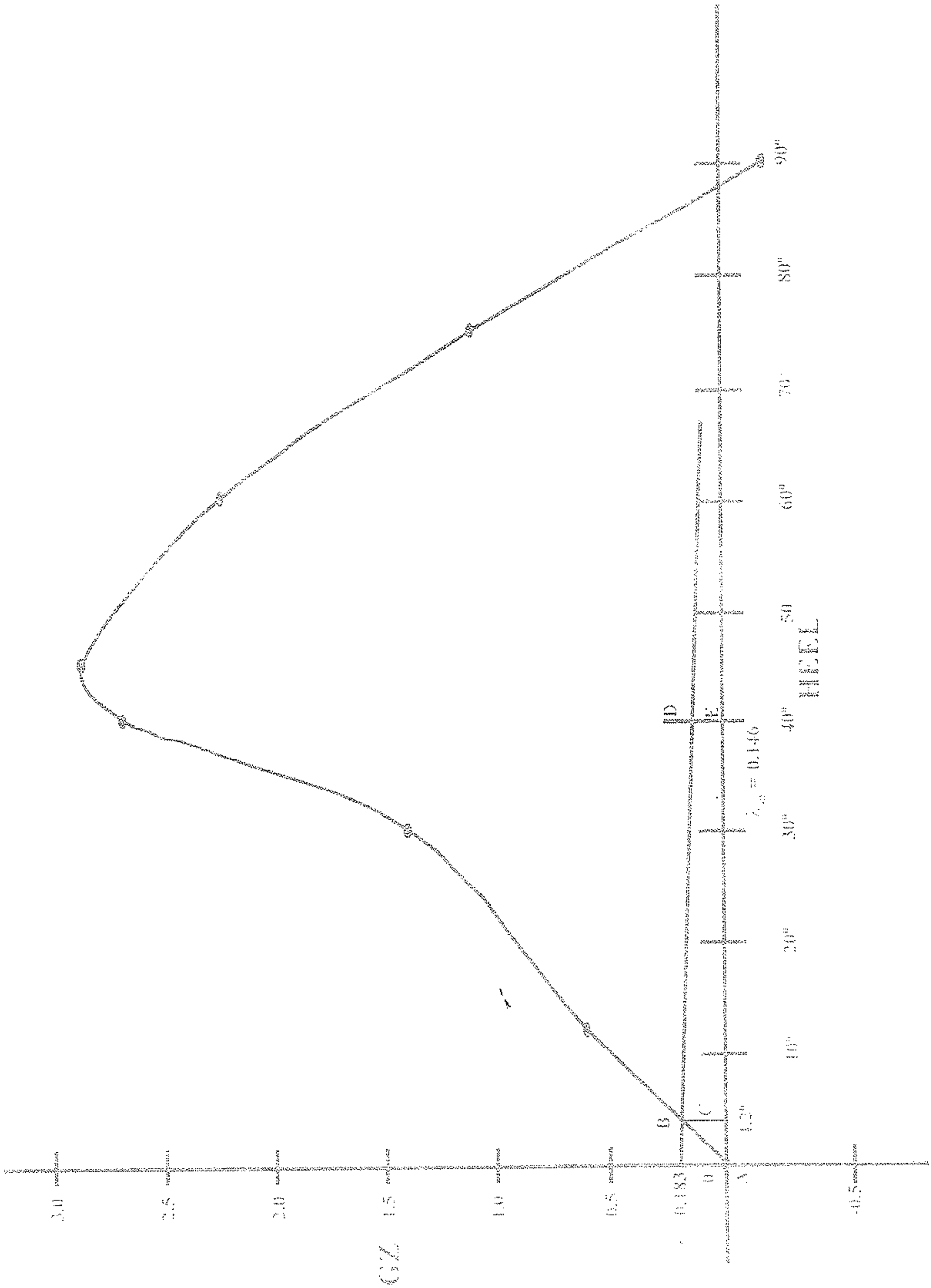
$$FSC = \frac{4220}{68012} = 0.062 \text{ m}$$

Corrected KG = 10.562 m

KM = 11.400 m

GM Fluid = 0.838 m

$$\lambda_0 = \frac{22351}{1.80 \times 68012} = 0.183 \text{ m} \qquad \lambda_{40} = 0.183 \times 0.8 = 0.146 \text{ m}$$



From the curve, angle of heel = 4.2^0

GZ at 10^0 (measured from curve) = 0.450 m

GZ at 20^0 (measured from curve) = 1.025 m

Max. separation between heeling arm curve and righting arm curve occurs at 45^0.

Angle of flooding occurs at 41^0.

∴ Residual area between the curves is to be obtained upto 40^0.

Heel	GZ	SM	Product for Area
0^0	0.000	1	0.000
10^0	0.450	4	1.800
20^0	1.025	2	2.050
30^0	1.752	4	7.008
40^0	2.657	1	2.567
			13.425

Total Area under GZ curve upto 40^0 = $13.425 \times \frac{10}{57.3} \times \frac{1}{3}$ = 0.781 mrad

Area of Δ ABC = $\frac{4.2 \times 0.175}{2 \times 57.3}$ = - 0.006 mrad

Area of trapezium CBDE = $\frac{0.175 + 0.146}{2} \times \frac{35.8}{57.3}$

= - 0.100 mrad

Residual area between righting arm curve and heeling arm curve upto 40^0 = 0.494 mrad

GM Fluid = 0.838 is > 0.30m

Angle of heel (from curves) = 4.2^0 is < 12^0.

Residual area = 0.494 mrad is > 0.075 mrad

∴ *She satisfies all criteria, provided she is upright on sailing.*

114. *A vessel laden with grain in bulk of stowage factor 1.184m³/t has a displacement of 87284 t. Her KG calculated assuming the Cg of the cargoes in the filled holds to be at the volumetric centroids of the compartments is 10.36 m. FSM 2643 mt, KM 13.20 m. The VHM of all filled holds is 5864 m⁴ and that of a hold which is partly filled is 14400 m⁴. The angle of flooding is 37⁰.*

Her KN values are as follows:

Heel⁰	*12*	*15*	*30*	*40*	*45*
KN m	*2.730*	*3.440*	*6.857*	*8.584*	*9.292*

Ascertain whether the ship satisfies the stability criteria for vessels laden with grain in bulk.

KG = 10.36 m

FSC = $\frac{2643}{87284}$ = 0.030 m

Corrected KG = 10.390 m

KM = 13.200 m

GM (Fluid) = 2.810 m

Heel	12⁰	15⁰	30⁰	40⁰	45⁰
KN	2.730	3.440	6.857	8.584	9.292
(-) Corr. (10.39 sin θ)	2.160	2.689	5.195	6.679	7.347
GZ	0.570	0.751	1.662	1.905	1.945

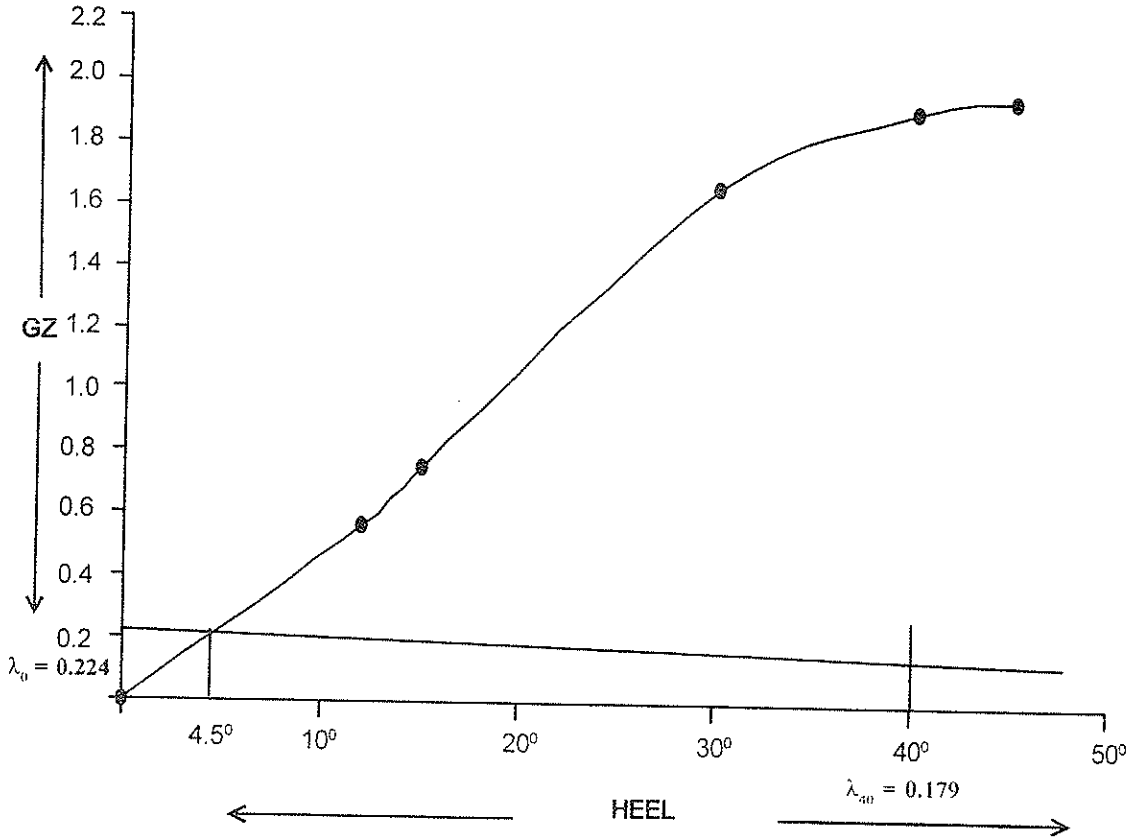
VHM of filled holds = 5864 m⁴

VHM of partly filled hold = 14400 x 1.2 = 17280 m⁴

Total VHM = 23144 m⁴

$\lambda_0 = \frac{23144}{1.184 \times 87284}$ = 0.224 m

λ_{40} = 0.224 x 0.8 = 0.179 m



Since maximum separation, between the two curves occurs above 40^0, of θ_f, 40^0 or angle of max. separation $\theta_f = 37^0$ is least, the residual area to be considered is upto 37^0.

From the curve, angle of heel = 4.5^0.

Calculation of total area under righting arm curve upto 37^0.

Take common interval 9.25^0.

Heel	0.0	9.25	18.5	27.75	37.0
GZ (measured from curve)	0.00	0.44	0.96	1.52	1.86
SM	1	4	2	4	1
Product for Area	0.00	1.76	1.92	6.08	1.86

Sum of Products = 11.62

Total Area upto 37^0 = $11.62 \times \frac{9.25}{57.3} \times \frac{1}{3}$ = 0.625 mrad

$$\text{Total Area upto } 37^0 = 11.62 \times \frac{9.25}{57.3} \times \frac{1}{3} = 0.625 \text{ mrad}$$

$$\text{Area of triangle} = \frac{0.2 \times 4.5}{57.3 \times 2} = -\ 0.008 \text{ mrad}$$

$$\text{Area of trapezium} = \frac{0.2 + 0.164}{2} \times \frac{32.5}{57.3} = -\ 0.103 \text{ mrad}$$

$$\text{Residual area} = 0.514 \text{ mrad}$$

Since GM Fluid = 2.810 > 0.3, angle of heel = $4.5^0 < 12^0$ and residual area upto θ_f = 0.514 > 0.075.

She satisfies all criteria for vessels laden with grain in bulk.

SHIP SQUAT

Squat is the decrease in under-keel water, that is, the difference between her under-keel clearance when making way and when stopped over the water. It is not the increase in draft as visually read or as shown on draft indicators.

Bernoulli's theorem states that in any moving fluid, the sum of the potential energy, the kinetic energy and the pressure energy is a constant. The fact that the ship is floating in that water does not alter the level or height of water there. Therefore the potential energy of that water is unchanged. As the vessel makes way through the water, she leaves behind a hollow in the water, The water therefore flows aft along the ship's side and under her bottom to fill in the hollow left behind the ship. As the water flows aft, its kinetic energy increases. According to Bernoulli's theorem, when the kinetic energy of the water increases, it's pressure energy must reduces. Since the ship is supported by the pressure energy of the water, as the pressure energy has reduced, the ship sinks to a longer draft. In addition to the bodily sinkage that occurs, the ship also trims by the head or by the stern. With a static even keel trim, full form vessels such as tankers and bulk carriers with C_b more than 0.7 trim by the head. Fine form vessels such as passenger ships and containers vessels with C_b less than 0.7 trim by the stern. With a C_b of 0.7 the squat is only due to bodily sinkage. The overall decrease in under-keel clearance due to sinkage and trim is the squat forward or aft.

The factors that affect the amount of squat are

1) **The ships speed over the water.**

The squat varies approximately directly as the speed over the water in knots squared. Squat occurs even when the ship is moored, if a tide is running. As stated under the chapter on draft surveys, this should be taken into account when conducting draft surveys. Also, when loading to a particular draft, squat could result in under loading if the drafts are read when a tide is running.

2) **The block coefficient, C_b**

The squat varies directly as the C_b. The C_b values generally vary from about 0.85 for very large tankers to about 0.75 for bulkers, about 0.7 for general cargo vessels to about 0.6 or less for passenger vessels and container ships.

3) **The blockage factor, S**

The blockage factor, S, is the ratio between the immersed cross sectional area of the vessel and the cross sectional area of the water in the canal.

$$S = \frac{b \times \text{static draft}}{B \times \text{depth of water}}$$

Where

'b' is the breadth of the ship and

'B' is the width of the canal.

Even in open waters, this factor is to be considered using the width of influence B' in place of the width of the canal B. The width of influence B' in open waters is obtained as

$$B' = [7.7 + 20\ (1 - C_b)^2]\ b$$

where 'b' is the breadth of of ship.

The B' value in open waters varies from about 8 b for large tankers to about 9.5 b for general cargo vessels to about 12 b for container and passenger ships.

In open waters where the depth of water to draft of ship ratio is about 1.2, the value of the blockage factor S will be around 0.1.

4) The static under keel clearance

The lesser the under-keel clearance, the more is the squat because the stream lines of return flow aft of the water, past the vessel increases due to the reduced clearance under the vessel. This increases the kinetic energy and therefore further reduces the pressure energy of the water. Thus as the ratio of depth of water to draft of ship reduces, the squat increases.

5) The at rest trim of the vessel

The squat at the bow increases to a greater extant if her at rest trim was by the head. The squat at the stern will increase to a greater extent if her at rest trim was by the stern. The calculated maximum squat should therefore be applied to the greater of the two end drafts to obtain the minimum under keel clearance.

6) Passing another ship in a river or canal

When the ship is passing or overtaking another vessel in a river or canal, the squat can increase upto twice the normal value as the combined blockage factor, S, becomes the sum of the blockage factor of each ship.

7) **The squat increases if the ship is close to the bank of a river or canal**

Various empirical formulae have been suggested for estimating the maximum squat. As there are so many variables and so many factors, the exact values of which may not be readily available, none of the formulae are likely to provide absolutely accurate squat values. However, from the analysis of many measured squat values on ships and results of ship model tests some empirical formulae have been developed for satisfactorily estimating the maximum squat is confined and open waters. Obviously the squat is greater in confined waters and lesser in open waters.

For a vessel at an even keel static trim when the ratio of the depth of water to the draft of ship is in the range of 1.1 to 1.4, the maximum squat in open or confined waters may be predicted fairly accurately by either of the expressions:-

1) $$\text{Maximum squat} = \frac{C_b \times S^{0.81} \times V^{2.08}}{20}$$

or

2) $$\text{Maximum squat} = \frac{C_b \times S_2^{2/3} \times V^{2.08}}{30}$$

where $$'S_2' = \frac{S}{1-S} = \frac{A_S}{A_C - A_S}$$

In the above expressions:

'S' is the blockage factor.

'V' is the ship's speed over the water in knots.

'S_2' is the velocity return factor.

'A_S' is the immersed cross sectional area of the ship.

'A_C' is the cross sectional area of the water in the canal.

Other approximate formulae are:-

1) Maximum squat in open waters $= \dfrac{C_b \times V^2}{100}$

2) Maximum squat in confined waters

where S is between 0.1 and 0.265) $= \dfrac{C_b \times V^2}{50}$

Both the above approximate formulae slightly over estimates the maximum squat thereby erring on the safer side.

Indications that the ship is in shallow waters include

1) Wave making by the ship, especially forward, increases.

2) Manoeuvring becomes sluggish.

3) The propeller RPM reduces.

4) The ship's speed over the water reduces.

5) Stopping distances and time increases.

6) The diameter of the turning circle increases to a great extent.

7) Rolling and pitching reduces.

8) The ship may start to vibrate.

At this point, a consideration may arise as to the depth of water which can be considered shallow. This depends on the depth of influence of the ship, which is approximately $\dfrac{5}{C_b} \times \text{draft}$. In depths above the depth of influence the ship may be considered to be in deep waters. In depths below the depth of influence, the ship may be considered in shallow waters. Since the depth of influence is more than 5 times the draft, though the ship's squat may commence to increase slightly at such depths it is not of much consequence. The increase in squat is significant when the depth to draft ratio is less than 2. It is much more pronounced and of consequence when this ratio is less than 1.5.

The best course of action to reduce squat is to reduce the ship's speed, because the squat varies directly as the ship's speed squared. Halving the speed will reduce the squat to a quarter. However, the fact that manoeuvring which is already sluggish in shallow waters may deteriorate further should also be considered when reducing the speed.

115. a) *A vessel of beam 42 m at an even keel draft of 12.2 m has C_b 0.8. Calculate the maximum squat and minimum under keel clearance when doing 12 kts. over the water in open waters of depth 15 m.*

b) *Estimate her maximum draft and minimum under keel clearance if the speed is reduced to 6 kts.*

a) Width of influence = B' = $[7.7 + 20\ (1-C_b)^2]\ b$

$= [7.7 + 20\ (0.2)^2] \times 42 = 357$ m

$$S = \frac{b \times \text{draft}}{B' \times \text{depth}} = \frac{42 \times 12.2}{357 \times 15} = 0.0957$$

$$\text{Maximum squat by method (1)} = \frac{C_b \times S^{0.81} \times V^{2.08}}{20}$$

$$= \frac{0.8 \times 0.0957^{0.81} \times 12^{2.08}}{20}$$

= ***1.050 (at the bow as C_b = 0.8 > 0.7)***

Remaining under keel clearance = 15 - (12.0 + 1.050)

= 1.95 m

Max. squat by method (2)

$$S_2 = \frac{S}{1 - S} = \frac{0.0957}{1 - 0.0957} = 0.10583$$

$$\text{Max. squat} = \frac{C_b \times S_2^{2/3} \times V^{2.08}}{30} = \frac{0.8 \times 0.10583^{2/3} \times 12^{2.08}}{30}$$

= 1.048 m (at the bow as C_b = 0.8 > 0.7)

Remaining under keel clearance = 15 - (12 + 1.048)

= 1.952 m

By the approximate method

$$\text{Max. squat} = \frac{C_b \times V^2}{100} = \frac{0.8 \times 12^2}{100} = \mathit{1.152\ m}$$

(at the bow as $C_b = 0.8 > 0.7$)

This is slight over-estimation of their squat - on the safer side.

Min. under-keel clearance = 15 - (12 + 1.152) = 1.848 m

b) Max. squat at 6 kts. by method (1)

$$\text{Max. squat} = \frac{C_b \times S^{0.81} \times V^{2.08}}{20} = \frac{0.8 \times 0.0597^{0.81} \times 6^{2.08}}{20}$$

= 0.248 m (at the bow as Cb = 0.8 > 0.7)

Min. under keel clearance = 15 - (12 + 0.248) = 2.752 m

Note: By halving the speed, the squat has reduced to approximately quarter of the original squat.

A ship of breadth 52 m, Cb = 0.85, at an even keel static draft of 13 m is proceeding at a speed of 10 kts. in a river of width 450 m and depth 15.2 m. Calculate her maximum squat.

Width of influence $B' = [7.7 + 20\ (1-\ Cb)^2]\ b$

$= [7.7 + 20\ (0.5)^2]\ 52 = 423.8$

Since the width of influence is lesser than the width of the river, she is considered to be in open waters. For the same draft and depth of water, the squat in any width of water greater than the width of influence will be the same.

By method (1)

$$\text{Blockage factor, } S = \frac{b \times \text{draft}}{B' \times \text{depth}} = \frac{52 \times 13}{423.8 \times 15.2} = 0.1049$$

Maximum squat $= \dfrac{C_b \times S^{0.81} \times V^{2.08}}{20} = \dfrac{0.85 \times 0.1049^{0.81} \times 10^{2.08}}{20}$

$=$ ***0.823 m (at the bow as C_b = 0.85 > 0.7)***

By method (2)

Velocity return factor $S_2 = \dfrac{S}{1-S} = \dfrac{0.1049}{0.8951} = 0.1172$

Maximum squat $= \dfrac{C_b \times S_2^{2/3} \times V^{2.08}}{30} = \dfrac{0.85 \times 0.1172^{2/3} \times 10^{2.08}}{30}$

$=$ 0.516 m (at the bow as C_b = 0.85 > 0.7)

By approximate method

Maximum squat $= \dfrac{C_b \times V^2}{100} = \dfrac{65 \times 10^2}{100}$

= 0.85 m (at the bow as Cb > 0.7)

(This again is slightly over estimation of the squat)

117. a) ***A vessel 'A' of breadth 46 m, C_b 0.82 at a static even keel draft of 11.7 m is proceeding at 10 kts along a canal of width 170 m and depth 15 m. Calculate her maximum squat and minimum under keel clearance.***

b) ***Calculate the maximum squat of each vessel when vessel 'A' is abreast of an oncoming vessel 'B' of breadth 32 m, C_b 0.61 at a static draft of 11.2 m proceeding at 9.6 kts.***

a) Width of influence $B' = [7.7 + 20 (1 - C_b)^2]$ b

$= [7.7 + 20 (0.18)^2]$ 46 $= 384$ m

Since the width of the canal is lesser than the width of influence, we have to use the width of the canal for obtaining factor S.

Blockage factor S $= \dfrac{b \times \text{draft}}{B \times \text{depth}} = \dfrac{46 \times 11.7}{170 \times 15} = 0.2111$

By method (1)

Maximum squat $= \dfrac{C_b \times S^{0.81} \times V^{2.08}}{20}$

$$= \frac{0.82 \times 0.2111^{0.81} \times 10^{2.08}}{20}$$

= 1.398 m (at the bow as $C_b = 0.82 > 0.7$)

Min. under keel clearance *= 15 - (11.7 + 1.398) = 1.902 m*

By method (2)

Velocity return factor, $S_2 = \frac{S}{1-S} = \frac{0.2111}{0.7889} = 0.2676$

Maximum squat $= \frac{C_b \times S_2^{2/3} \times V^{2.08}}{30}$

$$= \frac{0.82 \times 0.2676^{2/3} \times 10^{2.08}}{30}$$

= 1.365 m (at the bow as $C_b = 0.82 > 0.7$)

By approximate formula

Maximum squat $= \frac{C_b \times V^2}{50} = \frac{0.82 \times 10^2}{50} =$ ***1.64 m***

(This again is an over estimation of the squat)

Min. under keel clearance = 15 (11.7 + 1.64) = 1.66 m

b) Blockage factor S $= \frac{b_A \times draft_A + b_B \times draft_B}{B \times depth}$

$$= \frac{46 \times 11.7 + 31 \times 11.2}{170 \times 15} = 0.3472$$

By method (1)

Maximum squat of ship A $= \frac{C_b \times S^{0.81} \times V^{2.08}}{20}$

$$= \frac{0.82 \times 0.3472^{0.81} \times 10^{2.08}}{20}$$

= 2.093 m (at the bow as $C_b = 0.82 > 0.7$)

Note: The presence of ship B abreast has increased the squat of ship A from 1.398 m to 2.093 m.

Max. squat of ship B $= \dfrac{C_b \times S^{0.81} \times V^{2.08}}{20}$

$= \dfrac{0.82 \times 0.3472^{0.81} \times 10^{2.08}}{20}$

= *1.430 m (at the stern as C_b = 0.61 < 0.7)*

By method (2)

Velocity return factor $S_2 = \dfrac{S}{1-S} = \dfrac{0.3472}{0.6528} = 0.5319$

Max. squat of ship A $= \dfrac{C_b \times S_2^{2/3} \times V^{2.08}}{30}$

$= \dfrac{0.82 \times 0.5319^{2/3} \times 10^{2.08}}{30}$

= *2.157 m (at the bow as C_b = 0.82 > 0.7)*

Max. squat of ship B $= \dfrac{0.82 \times 0.5319^{2/3} \times 10^{2.08}}{30}$

$= \dfrac{0.61 \times 0.5319^{2/3} \times 9.6^{2.08}}{30}$

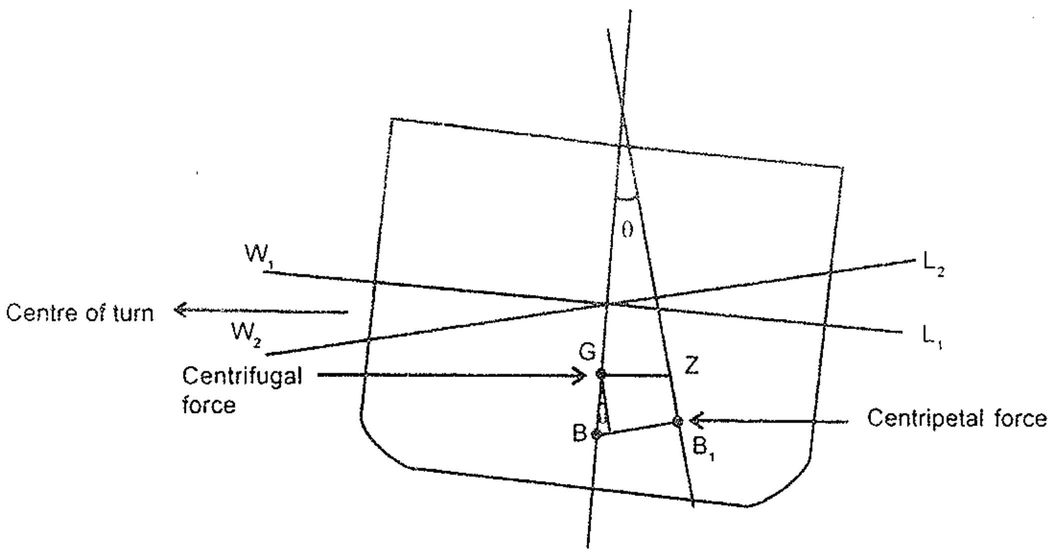
= *1.474 m (at the stern as C_b = 0.61 > 0.7)*

Heel due to interaction also occurs when passing or overtaking another vessel in a narrow channel and also when close to a bank. In shallow waters, heel due to turning may also increase, further reducing the under-keel clearance. This fact should be borne in mind when turning wide bodied vessels, with small GM at relatively large speeds. The increase in draft due to heel, list or rolling can be surprisingly large and in shallow waters it could cause grounding at the bilge strake of the middle body for instance, the increase in draft, given by the expression

(Old draft cos θ + 1/2 beam sin θ) - old draft for a 50 m beam vessel with a draft of 12 m at a small heel of 3^0 is 1.3 m.

HEEL DUE TO TURNING

When a body moves in a circular path, it experiences an acceleration towards the centre of the circle $\frac{v^2}{r}$, where v is the velocity of the body in m/sec and r is the radius of the circle in meters. The force required to produce this acceleration is $\frac{mv^2}{r}$, where m is the mass of the body. This force called the centripetal force acts at the centre of lateral resistance of the ship i.e. at the centroid of the projected underwater lateral area of the ship, which is a point at about the level of the centre of buoyancy or at about half the draft. This force is provided by the water acting on the side of the ship away from the centre of the turning circle.



For equilibrium, there must be an equal and opposite force acting on the ship. This force called the centrifugal force acts at the centre of gravity of the ship, in a direction away from the centre of turn.

These two equal and opposite forces, i.e. centripetal force and centrifugal force produce a heeling couple

$$= \frac{mv^2}{r} \times B_1Z$$

The ship will then heel until the righting moment, W x GZ equals the heeling couple.

Therefore, when equilibrium is attained

W x GZ which is m . g . GZ = $\frac{mv^2}{r} \times B_1Z$ where $B_1Z = BG \cos\theta$

Since GZ = GM sin θ

$$m \cdot g \cdot GM \sin\theta = \frac{mv^2}{r} \cdot BG \cos\theta$$

$$\therefore g \cdot GM \sin\theta = \frac{v^2}{r} \cdot BG \cos\theta$$

$$GM \sin\theta = \frac{v^2}{g \cdot r} \cdot BG \cos\theta$$

$$\text{i.e. } \tan\theta = \frac{v^2 \cdot BG}{g \cdot r \cdot GM}$$

Since B is at about half the draft,

$$\tan\theta \text{ also } = \frac{v^2\left(KG \sim \frac{d}{2}\right)}{g \cdot r \cdot GM}$$

In the normal case, where G is above B, the ship will heel away from the centre of turn. In rare cases, where G is below B, the ship will heel towards the centre of turn.

118. *A ship with KM 7.2m, KG 6.8 m, KB 3.9 m, turns in a circle of radius 420 m, at a speed of 13 kts. Calculate the heel produced.*

GM = 0.4 m, BG = 2.9 m

$$\tan\theta = \frac{v^2 \cdot BG}{g \cdot r \cdot GM} = \frac{\left(\frac{13 \times 1852.3}{60 \times 60}\right)^2 \times 2.9}{9.81 \times 420 \times 0.4} = 0.078727$$

Heel produced = 4.5°.

119. *A ship at a draft of 7.2 m, KG 6.7 m, KM 7.2 m turns in a circle of radius 530 m at a speed of 15 kts. Calculate the angle to which she would heel.*

GM = 0.5 m, $\left(KG \sim \frac{d}{2}\right)$ = 3.1 m

$$\tan\theta = \frac{v^2\left(KG \sim \frac{d}{2}\right)}{g \cdot r \cdot GM} = \frac{\left(\frac{15 \times 1852.3}{60 \times 60}\right)^2 \times 3.1}{9.81 \times 530 \times 0.5} = 0.071031$$

Angle of heel = 4.06^0

120. *M.V. Hindship at a draft of F 7.23 m, A 8.79 m, KG 7.42 m, FSM 1732 tm. turns in a circle of radius 380 m at a speed of 13.2 Kts. Calculate the angle of heel produced.*

F 7.23 m
A 8.79 m } trim = 1.56 m by stern
M 8.01 m LCF = 70.586 m

Corn. to A draft	= $\frac{1.56 \times 70.586}{143.16}$	= 0.769 m	
Hydrostatic draft	= 8.79 - 0.769	= 8.021 m	
For 8.021 m			
Displacement	= 16685.5 t		
KB	= 4.263 m		
KM	= 8.252 m		
FSC	= $\frac{1732}{16685.5}$		
	= 0.104 m		
KG	= 7.420 m	KB	= 4.263 m
GM (Solid)	= 0.832 m	BG	= 3.157 m
FSC	= 0.104 m		
GM (Fluid)	= 0.728 m		

a) $\tan\theta = \dfrac{v^2 . BG}{g . r . GM} = \left(\dfrac{13.2 \times 1852.3}{60 \times 60}\right)^2 \times \dfrac{3.415}{9.81 \times 380 \times 0.728}$

$\theta = 3.07^0$

b) KG $= 7.420$ m

$\dfrac{d}{2} = \underline{4.005}$ m

$\left(KG \sim \dfrac{d}{2}\right) = 3.415$ m

$$\tan\theta = \frac{V^2\left(KG \sim \frac{d}{2}\right)}{g . r . GM} = \left(\frac{13.2 \times 18523}{60 \times 60}\right)^2 \times \frac{3.415}{9.81 \times 380 \times 0.728}$$

$\theta = 3.32^0$

To comply with the intact stability criteria, the heel due to turning on passenger ships as calculated by the expression,

$$\text{heeling moment} = 0.02 \ \frac{V^2}{L}\left(KG - \frac{d}{2}\right) W$$

where V = service speed in m/sec,

L = length of the ship at the water line in m,

W = displacement in t,

d = mean draft in m, and KG is in m, is not to exceed 10^0.

121. *A passenger vessel of length 210 m, displacement 20800 t, draft 9.8 m, KG 7.9 m, KM 8.80 m, has a service speed of 24 kts. Does she satisfy the intact stability criterion regarding heel due to turning?*

$$\text{Heeling moment} = 0.02 \ \frac{V^2}{L} \ \left(KG - \frac{d}{2}\right) W$$

$$= 0.02 \left(\frac{24 \times 1852 \quad .3}{60 \times 60} \right)^2 \times \frac{(7.9 - 4.9)}{210} \times 20800$$

$$= 664.56 \text{ mt}$$

$$\text{Heeling arm, } GG_1 = \frac{HM}{W} = \frac{664.56}{20800}$$

$$= 0.03195 \text{ m}$$

$$\tan\theta = \frac{GG_1}{GM} = \frac{0.03195}{0.9}$$

$$\theta = 2.03^0$$

Since heel = $2.03^0 < 10^0$, she satisfies the criterion.

ROLLING PERIOD

The unresisted rolling period of a ship in still water

$$T = \frac{2\Pi K}{\sqrt{g.GM}}$$

This expression should not be used to estimate her GM from her period of roll at sea, as her actual rolling period is that of resisted rolling and not unresisted rolling. Also, when rolling at sea, the water is not still and the rolling may be forced oscillations due to a seaway and not entirely free oscillations. Further, the radius of gyration K can at best be only an approximation.

Determination of GM_0 by Means of Rolling Period Tests (for ships upto 70 m in length)

An approximation of the initial GM in small ships (upto 70 m in length) may be obtained by the expression $GM_0 = \left(\frac{f.B}{Tr}\right)^2$ where

'f' is the rolling coefficient (which varies from about 0.88 for the ship in ballast to about 0.73 for the fully loaded vessel with about 5% of the deadweight being liquids in tanks,

'B' = breadth of the ship in m and

'Tr' = period of roll in seconds.

The rolling coefficient varies with the radius of gyration. A long rolling period corresponding to a GM of 0.2 m or lesser indicates low stability, but the accuracy of the GM obtained is reduced. The rolling period test should be conducted in port, in still water.

Determination of GM by rolling period test in open disturbed waters, even provided the oscillations are free and not forced oscillations due to a seaway must be considered as a very approximate estimation only.

The above expression for GM_0 may be reduced to

$$GM_0 = \frac{F}{Tr^2} \quad \text{where}$$

$$'F' = (f.\ B)^2$$

122. *A coaster of length 60 m, breadth 7 m, has a rolling period of 8 seconds. If her rolling coefficient is 0.78, calculate her approximate GM_0.*

$$GM_0 = \left(\frac{f.B}{Tr}\right)^2 = \left(\frac{0.78 \times 7}{8}\right)^2 = 0.466 \ m$$

123. *A ship of L 150 m, B 24 m, draft 10 m, Cb 0.7 has a windage area of 1600 m^2 including deck cargo. The centroid of the windage area is 6.75 m above the WL. GM (Fluid) = 0.6 m. Angle of flooding is 42^0. During the voyage, consumption of fuel and FW was compensated by water ballast creating an additional FSM of 3410 tm without change in displacement or KG. Investigate whether her dynamical stability satisfies the weather criterion, if her rolling angle in waves is 20^0.*

The GZ values on departure were:-

Heel^0	*10*	*20*	*30*	*40*	*50*
GZ m	*0.12*	*0.31*	*0.52*	*0.45*	*0.16*

Displacement $= 150 \times 24 \times 10 \times 0.7 \times 1.025$

$= 25{,}830$ t

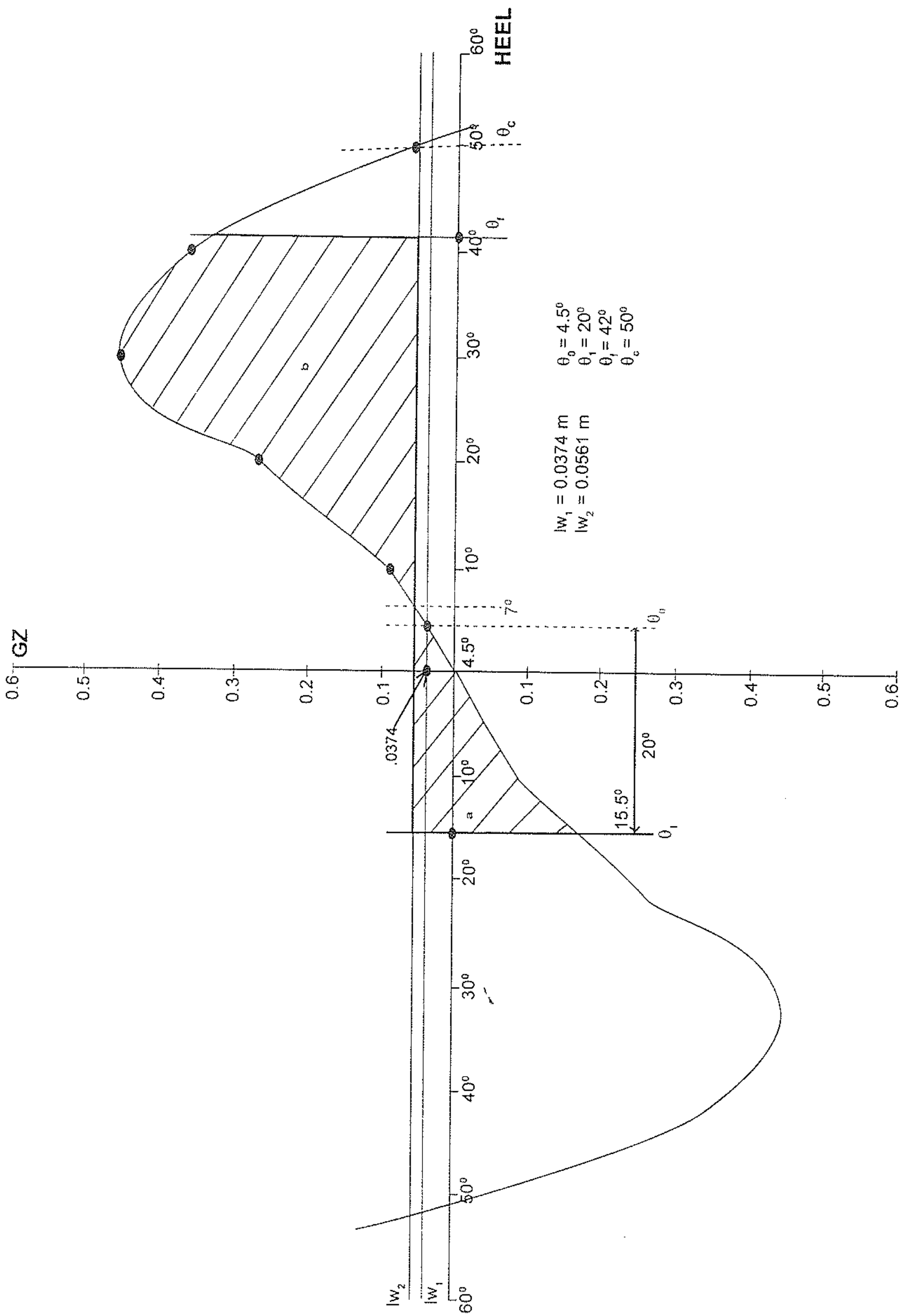
$\therefore$ Additional FSC $= \dfrac{3410}{25830} = 0.132$ m

Heel	10^0	20^0	30^0	40^0	50^0
Original GZ	0.12	0.31	0.52	0.45	0.16
Corn. for FSC					
- (0.132 x sin θ)	0.023	0.045	0.066	0.085	0.101
Corrected GZ	0.097	0.265	0.454	0.365	0.059

Wind heeling lever $lw_1 = \dfrac{PAZ}{1000\, g.W} = \dfrac{504 \times 1600\,(6.75 + 5)}{1000 \times 9.81 \times 25830}$

$= 0.0374$ m

Gust wind lever $lw_2 = 0.0374 \times 1.5 = 0.0561$ m



GZ
HEEL
lw₁ = 0.0374 m
lw₂ = 0.0561 m
θ₀ = 4.5°
θ₁ = 20°
θf = 42°
θc = 50°
.0374
4.5°
7°
15.5°
20°
a
b
lw₁
lw₂

From the curves, of 50^0, $\theta_f = 42^0$ or $\theta_c = 50^0$, since θ_f is the least, the area to be considered is upto θ_f.

Calculation of area 'a': from 15.5^0 to 7^0 on the other side = 22.5^0 take common interval of 7.5^0.

Heel	15.5^0	8^0	0.5^0	7^0
Lever (measured from curve)	0.24	0.13	0.06	0.00
SM	1	3	3	1
Product for area	0.24	0.39	0.18	0.00

Sum of Products = 0.81

Area 'a' = $0.81 \times \frac{7.5}{57.3} \times \frac{3}{8}$ = 0.0398 mrad

Calculation of area 'b': from 7^0 to 42^0 = 35^0

take common interval of 8.75^0

Heel	7^0	15.75^0	24.5^0	33.25^0	42^0
Lever (measured from curve)	0.00	0.12	0.29	0.38	0.25
SM	1	4	2	4	1
Product for Area	0.00	0.48	0.58	1.52	0.25

Sum of Products = 2.83

Area 'b' = $2.83 \times \frac{8.75}{57.3} \times \frac{1}{3}$ = 0.144 mrad

Since area 'b' = 0.144 > area 'a' = 0.0398

She satisfies the weather criterion.

DAMAGED STABILITY OF PASSENGER SHIPS

The ship shall meet the damaged stability criteria under the following assumptions:

a) The ship is in the worst anticipated service condition as regards stability.

b) The permeability of the various compartments are as follows:

Cargo, coal and store spaces	:	60%
Accommodation spaces	:	95%
Machinery spaces	:	85%
Liquid Tanks:	:	0% or 95% whichever results in least stability.

c) i) The longitudinal extent of damage is 3m + 3% of the ships length or 11 m, whichever is lesser. Where the factor of subdivision is 0.33 or less, the longintudinal extent shall be increased as necessary to include two transverse bulkheads.

ii) The transverse extent of damage is one fifth the ship's breadth.

iii) The vertical extent of damage is from the base, upward without limit.

Where the ship's factor of subdivision is **more than 0.5**, she should be able to withstand the flooding of any one compartment. Where two adjacent compartments are separated by a stepped bulkhead, she should be able to withstand the flooding of the two adjacent compartments.

Where the ships factor of subdivision is **0.5 or less but more than 0.33** she should be able to withstand the flooding of any two adjacent compartments.

Where the ship's factor of subdivision is **0.33 or less**, she should be able to withstand the flooding of any three adjacent compartments.

DAMAGED STABILITY CRITERIA TO BE SATISFIED BY PASSENGER SHIPS IN THE FINAL CONDITION AFTER DAMAGE AND AFTER EQUALISATION MEASURES

1. In the case of symmetrical flooding, she shall have a residual GM of at least 50 mm.

2. In the case of unsymmetrical flooding the angle of heel shall not exceed 7^0 for one compartment flooding and 12^0 for two or more compartment flooding.

3. The margin line shall not be submerged at any point.

4. The GZ curve to have a positive range of at least 15^0 beyond ANGLE OF EQUILIBRIUM.

5. Area under the GZ curve to be atleast 0.015 mrad between Angle of Equilibrium and lesser of

   - Either angle of progressive flooding

     or

   - 22^0 in case of flooding of one compartment; 27° in case of flooding of more than one adjacent compartments

6. A residual righting lever is to be obtained of at least 0.1 m within the range specified in 4. above, taking into account the greatest of the following heeling moments.

   - Heeling moment due to crowding of passengers onto one side

     or

   - Heeling moment due to launching of fully loaded davit launched survival crafts on one side

     or

   - Due to wind pressure.

As calculated by the formula

$$GZ = \frac{\text{Heeling Moment}}{\text{Displacement}} + 0.04$$

ASSUMPTIONS FOR CALCULATION OF HEELING MOMENT

For calculating the heeling moments, the following assumptions shall be made.

1. Heeling moment due to crowding of passengers to one side.

   - 4 persons per square metre.
   - mass of each passenger = 75 kg
   - passengers at their muster stations on that side of the ship to which she is listed

or

2. Heeling moment due to launching of fully loaded davit launched survival crafts on one side.

   - Maximum heeling moment due to all lifeboats and rescue boats on the side to which the vessel has heeled because of damage are swung out fully loaded and ready for lowering.
   - A fully loaded davit launched life raft is swung out on each davit on the side to which she is listed.
   - For lifeboats which are launched fully loaded from the stowed position, the maximum heeling moment is to be taken.
   - Persons not in life saving appliances which are swung out shall not provide heeling or righting moments.
   - Life saving appliances on the other side are to be assumed to be in the stowed position.

or

3. Heeling moment due to wind pressure

   - The wind pressure shall be assumed to be 120 N/m^2
   - The windage area is her projected lateral area above the water line, in the intact condition.
   - The heeling arm is the vertical distance between the centroid of the windage area and half of the mean draft in the intact condition.

At intermediate stages of flooding the maximum righting lever shall be at least 0.05 m and the range of stability shall be at least 7^0.

Unsymmetrical flooding is to be kept to a minimum. Where it is necessary to correct large angles of heel due to unsymmetrical flooding, the means adopted shall be self acting where practicable. But where controls are provided to cross flooding fittings, they must be operable from above the bulkhead deck. Where cross flooding fittings are provded, the time for equalisation should not exceed 15 minutes. The maximum angle of heel after flooding, but before equalisation shall not exceed 15^0.

The master shall be supplied with necessary data to maintain sufficient intact stability to enable the ship to withstand the assumed damage. This shall include the maximum permissible KG or minimum permissible GM for a range of service drafts/displacements.

Measurement of cargo

On board a tanker the method of calculating the quantity of oil on board is different from those as used in case of other ships. Here the volume of oil in cargo oil tanks (C.O.T.) is tabulated against different ullages for varying conditions of trim and list. It is required of the ship's personnel to take the ullages, waterdip of the tanks and note down the trim and list of the vessel. Now referring to the ullages tables of the vessel concerned volume of oil in different tanks is obtained.

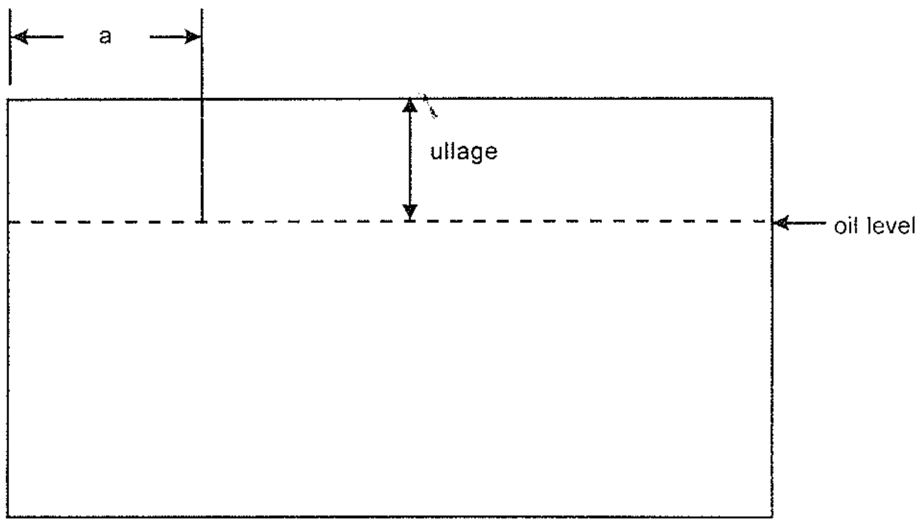
On board a tanker there are different methods of measuring ullages. Some of them are with an ullage tape, Ullage Temperature Interface (UTI)/MMC/Sonic tape, whessoe gauge, radar gauge etc. Similarly sounding can also be obtained using a sounding rod, sounding tape etc. Waterdip/ watercut is also measured with a UTI/MMC.

Corrections to the Observed Ullage

The ullage that is obtained by using any of the above methods is to be corrected for the present trim and list of the vessel. Also the location of ullage port is taken into account, i.e., its height, how far it is forward of the after bulkhead of the tank and by what distance it is displaced from the centerline of the tank.

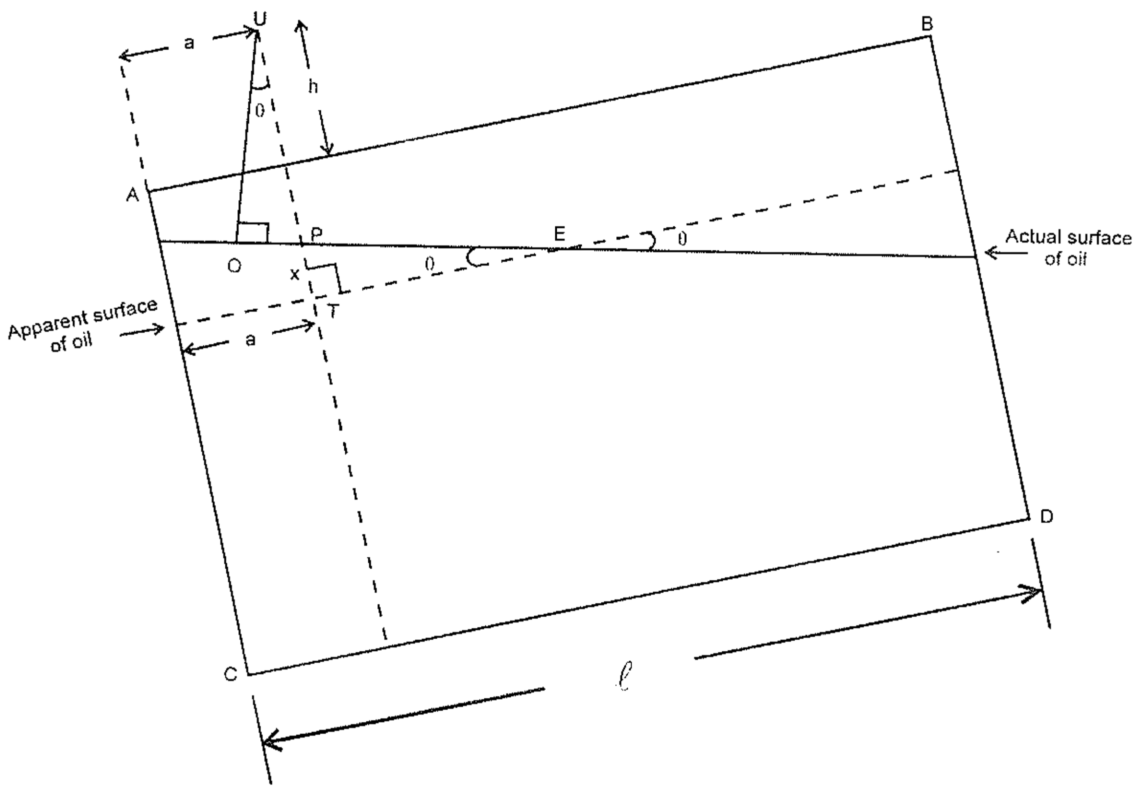
The Liquid Surface Inside The Tank Remains Horizontal Irrespective Of The Trim And List Of The Vessel.

Consider a vessel on even keel and upright. Since the liquid surface will be horizontal, the same ullage will be obtained irrespective of where the ullage port is located.



A cargo oil tank

Now consider the same vessel trimmed by stern



'ℓ' Length of the tank ABCD

'UO' Observed ullage

'UP' Ullage corrected for tape correction

'UT' Ullaged corrected for tape and trim correction

'θ' Trim angle

If the ullage is measured with the help of an ullage tape or MMC/UTI/ Sonic tape, due to the trim of the vessel it will touch the 'actual oil surface' at right angles and hence the observed ullage would be 'UO'. Thus the observed ullage is to be corrected for both tape and trim corrections.

If a whessoe gauge or radar gauge had been used the float in case of a whessoe and the radar beam in case of radar gauge would have travelled parallel to the bulkhead of the tank and the observed ullage would be 'UP'. Thus the observed ullage is to be corrected for trim correction only. No tape correction is necessary.

In both the cases the corrected ullage is 'UT' as shown above.

Tape Correction

$$\frac{UO}{UP} = \cos\theta$$

$$UP = UO \times \sec\theta$$

$$\tan\theta = \frac{\text{trim}}{\text{LBP}}$$

$$\text{Thus } UP = UO \times \sec\left\{\tan^{-1}\left(\frac{\text{trim}}{\text{LBP}}\right)\right\}$$

Hence Ullage corrected for tape correction

$$= \textit{observed ullage} \times \sec\left\{\tan^{-1}\left(\frac{trim}{LBP}\right)\right\}$$

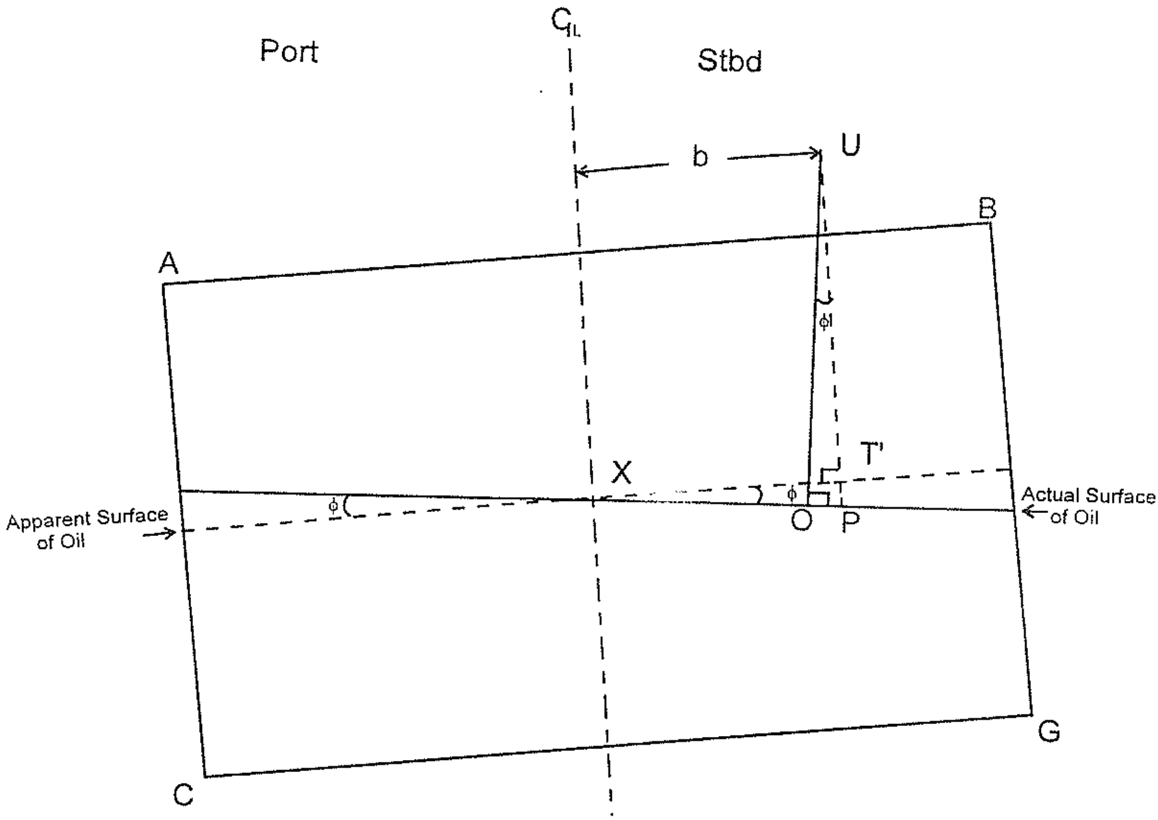
$$\tan\theta = \frac{trim}{LBP}\times\left(\frac{\ell}{2}-a\right)$$

$$\text{Thus } UT = UP + x$$

$$\textit{Hence } UT = UP + \left(\frac{\ell}{2}-a\right)\times\frac{trim}{LBP}$$

At the same time if the vessel was also listed to port and the ullage port was located 'b' m to starboard of the centreline of the tank, then the ullage corrected for the tape and trim corrections is to be corrected for list also.

As shown in the fig. Below consider the same vessel to be listed ϕ to port.



$$\frac{T'P}{XT'} = \tan \phi$$

$$T'P = XT' \times \tan \phi$$

$$\text{List Corr.} = b \times \tan \phi$$

Since in this case, the ullage port is located to the starboard of centre line, and the vessel is listed to port, the list correction is to be subtracted.

Had the list and the location of ullage port been to the same side of center line, the list correction has to be added to obtain the true ullage.

Thus finally the corrected ullage, taking into account, both list and trim correction is to obtained as follows: -

1. Correct the observed ullage for tape correction.
2. To this corrected ullage apply trim and list correction.

- Trim correction to be added if the vessel is trimmed by stern.
- List correction to be added if list and location of ullage port is to same side of centerline otherwise if of different name, then to be subtracted.

$$\textit{Corrected Ullage} = \textit{Observed Ullage} \times \sec\left\{\tan^{-1}\left(\frac{trim}{LBP}\right)\right\}$$

$$+ \quad \left[\left(\frac{\ell}{2} - a\right) \times \frac{trim}{LBP}\right] \pm b \times \tan\phi$$

Where

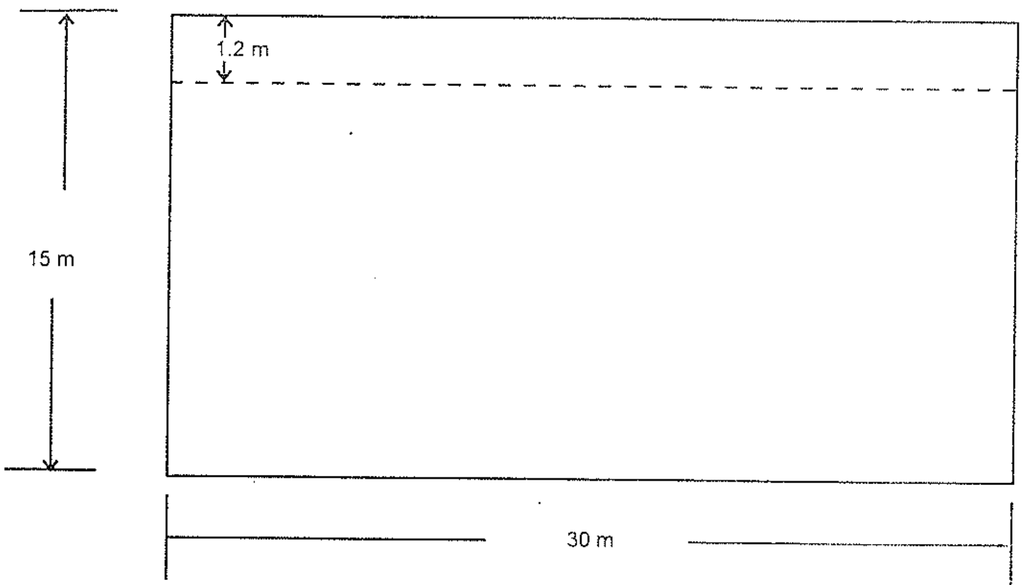
'ℓ' Length of the tank

'a' Location of ullage port forward of a bulkhead

'b' Location of ullage port away from centre line

'ϕ' Angle of list

124. *A vessel at even keel has a tank of dimensions 30m x 20m x 15m deep containing crude oil of R.D. 0.8345 at an ullage of 1.2m. Calculate the quantity of oil in the tank.*



Vol. of oil in tank = 30 x 20 x (15 - 1.2)

= 8280 m^3

Quantity of oil = vol. x R. D.

= 8280 x 0.8345

Quantity of oil = 6909.7 M.T.

125. *An oil tanker has a tank of dimensions 30m x 20m x 20m deep and is loading oil at 38⁰ C. It is desired to leave 2% of the volume of tank for expansion. Calculate the quantity of oil and final ullage assuming that the vessel is at an even keel on completion. Given that R. D. of oil at 25⁰ C = 0.8540.*

Co-efficient of volume expansion = 0.0006/⁰C.

Volume of the tank = 30 x 20 x 20

= 12000 m^3

Vol. to be left for expansion = $\frac{2}{100} \times 12000$

= 240 m^3

Vol. of oil in tank = 12000 - 240

= 11760 m^3

Sounding of oil in tank = $\frac{11760}{30 \times 20}$

= 19.6 m

Ullage = 20 - 19.6

= 0.4 m

As the temp. will increase R.D. of oil will decrease.

Thus R.D. at 38^0 C = 0.8540 - [(38 - 25) x 0.0006]

= 0.8462

Thus quantity of oil in tank = vol. x R.D.

= 11760 x 0.8462

= ***9951.3 M.T.***

126. *A tank of dimensions 20m x 15m x 10m is being loaded with an oil at 30^0 C (relative density at 20^0 C = 0.8681). It is desired to leave 3% of the vol. of oil for expansion. Calculate the ullage of the oil and quantity of oil loaded. Given that Co-efficient of vol. expansion = 0.0005/ ^{0}C.*

Vol. of tank = 20 x 15 x 10

= 3000 m^3

Let 'v' be the vol. of oil loaded in tank

Vol. of oil = vol. of tank - vol. left for expansion vol. left for expansion = $\frac{3v}{100}$

3000 = $\frac{103v}{100}$

Volume = 2912.621 m^3

Sounding of oil in tank = $\frac{2912.621}{20 \times 15}$

= 9.709 m

Ullage = 10 - 9.709

= 0.291 m

R.D. of oil at 30^0 C = 0.8681 - [(30 - 20) x 0.0005]

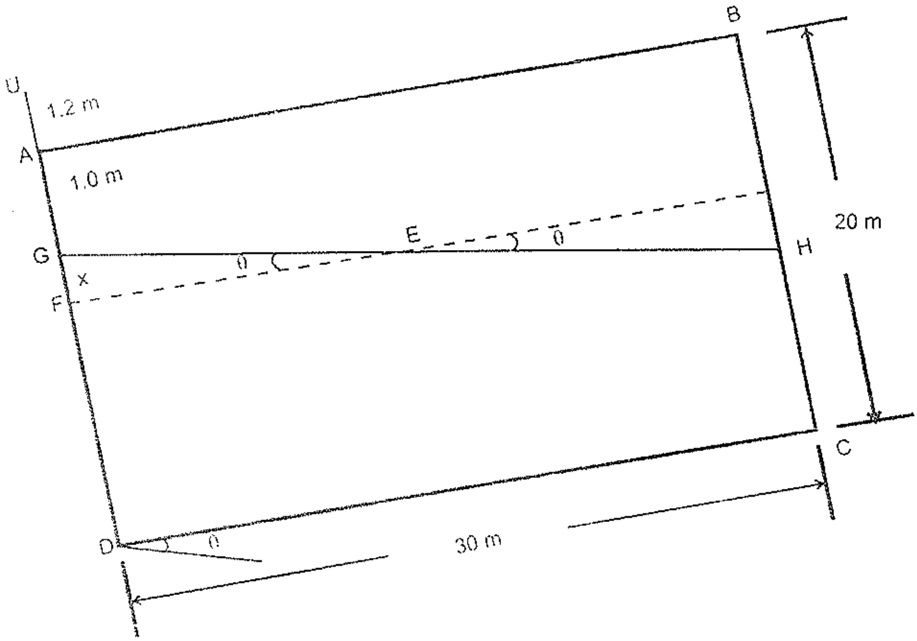
= 0.8631

Quantity of oil loaded = vol. x density

= 2912.621 x 0.8631

Quantity of oil loaded = ***2513.9 M.T.***

127. *A crude oil tanker of LBP 250 m has a tank of dimensions L 30 m x B 20 m x D 20 m and is trimmed 3 m by stern. The ullage port is in line with aft bulkhead and its height is 1.2 m above the deck. The ullage of the cargo as measured from ullage port is 2.2 m using a sonic tape. Calculate the net observed volume of oil and the quantity of oil. Given that density @ 15⁰ C = 0.8550 and the loading temp. is 31⁰ C.*



ABCD is the TANK of GIVEN DIMENSIONS. GHCD is the SHAPE of OIL in the tank. WITH THE VESSEL TRIMMED 3 m by stern. UA is the Ht. of ULLAGE PORT ABOVE DECK.

GF is the correction to be added to observed ullage and is called Trim CORRECTION.

$$\tan\theta = \frac{\text{trim}}{\text{LBP}} = \frac{GF}{FE}$$

$$FE = \frac{\ell}{2} = \frac{30}{2} = 15 \text{ m}$$

$$\text{Thus} \quad \frac{3}{250} = \frac{x}{15}$$

x = 0.18 m

Thus corrected Ullage = 2.2 + 0.18

= 2.38 m

Sounding of oil = 20 - (1.0 + 0.18)

= 18.82 m

Vol. of oil in tank at 31^0 C (Gross Observed Volume)

= 30 x 20 x 18.82

= 11292 m^3

Entering Table 54 of 'PETROLEUM MEASUREMENT TABLE' with density @ 15^0 C and the observed temp. of 31^0 C.

Vol. Reduction Factor = 0.9873

N.O.V. = 11292 X 0.9873
(Net Observed Volume)

= 11148.592 m^3

Weight reduction factor = density @ 15^0 C - 0.0011

= 0.8550 - 0.0011

= 0.8539

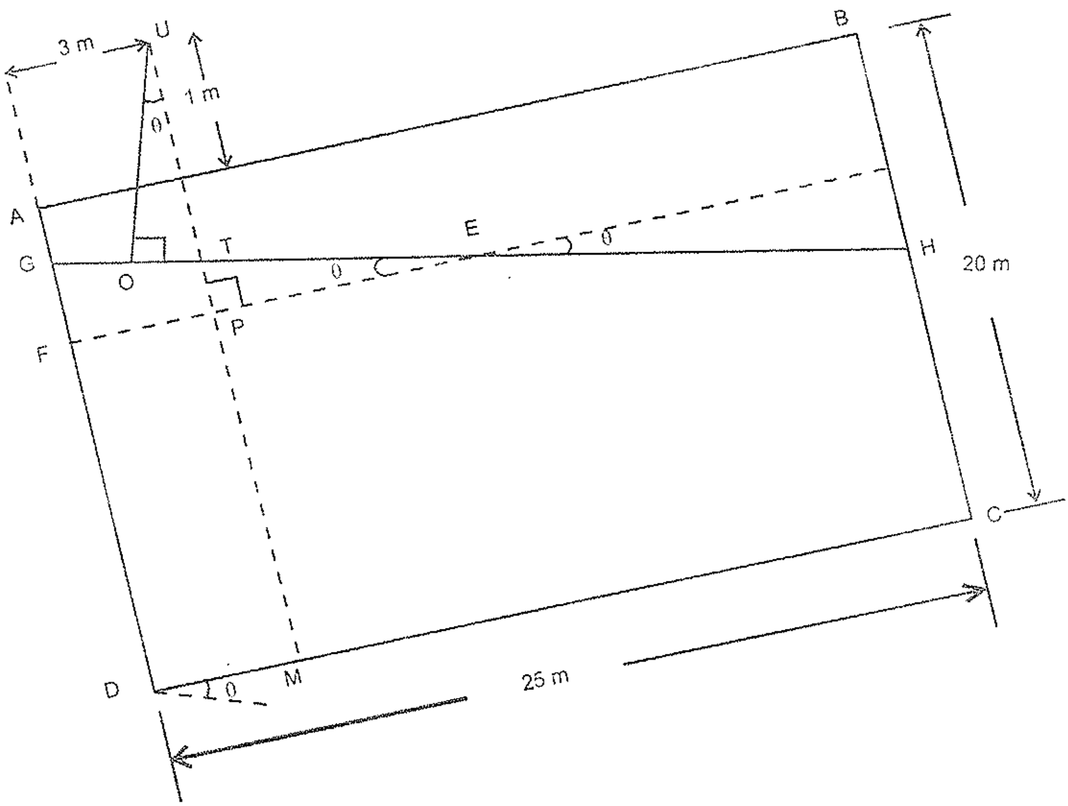
Thus quantity of oil = 11148.592 x 0.8539

= ***9519.8 M.T.***

Note: On board in order to determine the volume reduction factor table 54 'A' is referred for crude oil and 54 'B' is referred for products of ASTM tables.

Both the tables are entered with density @ 15^0 C and the observed temp. to obtain volume reduction factor.

128. *An oil tanker of LBP 180 m is loading oil at 35° C in one of her tanks of dimensions L 25 m x B 20 m x D 18 m. On completion of loading vessel is trimmed 1 m by stern and ullage of the cargo in tank was observed to be 1.8 m using a sonic tape. The ullage port is located 3 m for'd of the aft bulkhead and is 1 m above the deck. Calculate the Net observed vol. of oil in the tank. Given that density @ 15° C = 0.7850.*



UO is the Observed Ullage

UT is the Corrected Ullage

After applying Tape Correction to Observed Ullage

Given that UO = 1.8 m

$$\text{Cos } \theta = \frac{\text{Observed Ullage}}{\text{Corrected Ullage}} = \frac{UO}{UT}$$

Ullage corrected = Observed Ullage x Sec θ

for tape corrn.

Where $\tan\theta = \frac{trim}{LBP} = \frac{1}{80}$

Corrected Ullage $= 1.8 \times \sec\left\{\tan^{-1}\left(\frac{1}{180}\right)\right\}$

$= 1.80003$ m

≈ 1.8 m

Trim Correction

$$\frac{TP}{PE} = \tan\theta = \frac{trim}{LBP}$$

PE = L/2 - distance of ullage port from aft bulkhead

$$\frac{1}{80} = \frac{TP}{\frac{25}{2} - 3}$$

TP = 0.053 m

Thus Ullage corrected for trim correction = 1.8 + 0.053

= 1.853 m

Sounding = 18 - (0.853)

= 17.147 m

Vol. of oil @ 35^0 C = 25 x 20 x 17.147

= 8573.5 m^3

USING TABLE 54 OF PETROLEUM MEASUREMENT TABLE

Volume Correction Factor (V.C.F) = 0.9809

Thus Net Observed Volume = 8573.5 x 0.9809

= 8409.746 m^3

V.C.F. or V.R.F. is one and same thing.

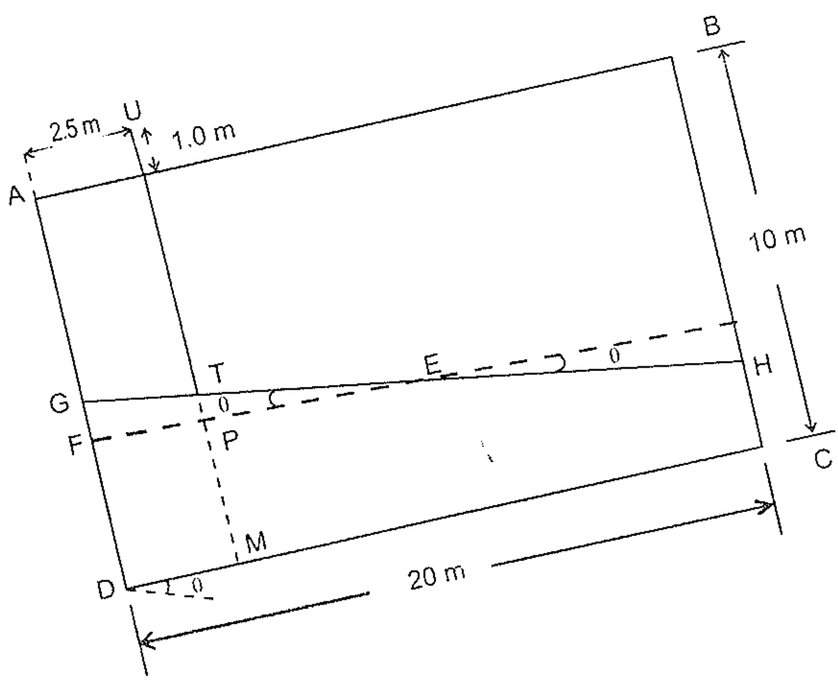
Note: If Ullage is measured with the help of Ullage tape or sonic tape or the sounding is measured with the help of a sounding rod 'TAPE CORRECTION" is applicable because the float / sensor will be affected by the trim of the vessel.

If ullage is measured with the help of Whessoe Gauge or Radar Beam, the Guide Wires in case of Whessoe Gauge and the Radar Beam remains, Parallel to the Sides of the Tank and 'hence Tape Correction is not applicable'.

129. *An oil tanker of LBP 175 m has a tank of dimensions L 20 m × B 15 m × 10 m in which oil is loaded having a density @ 15° C = 0.7925. While loading the ullage was measured with Whessoe Gauge and a reading of 8.5 m was obtained. Trim of the vessel at time of measurement was 1.5 m. Calculate the volume of the cargo given that Whessoe Gauge was located 2.5 m from aft bulkhead and was 1 m above the deck.*

ii) *Also calculate the N.O.V. of the oil and Quantity in M.T. if vessel was on even keel on completion of loading and the ullage observed was 1.8 m using an ullage tape. Ullage port located 5 m from the aft bulk head and was 1.2 m above the deck. Temperature of oil = 28° C.*

(i) Since at 8.5 m ullage, it is observed with a Whessoe Gauge hence tape correction is not applicable.



Given that UT = 8.5 m

$$\tan\theta = \frac{TP}{PE} = \frac{trim}{LBP}$$

$$\frac{TP}{\frac{20}{2} - 2.5} = \frac{1.5}{175}$$

$$TP = 0.064 \text{ m}$$

Thus corrected ullage for trim correction

$$= 8.5 + 0.064$$

$$= 8.564 \text{ m}$$

Sounding PM $= 10 + 1 - 8.564$

$$= 2.436 \text{ m}$$

or

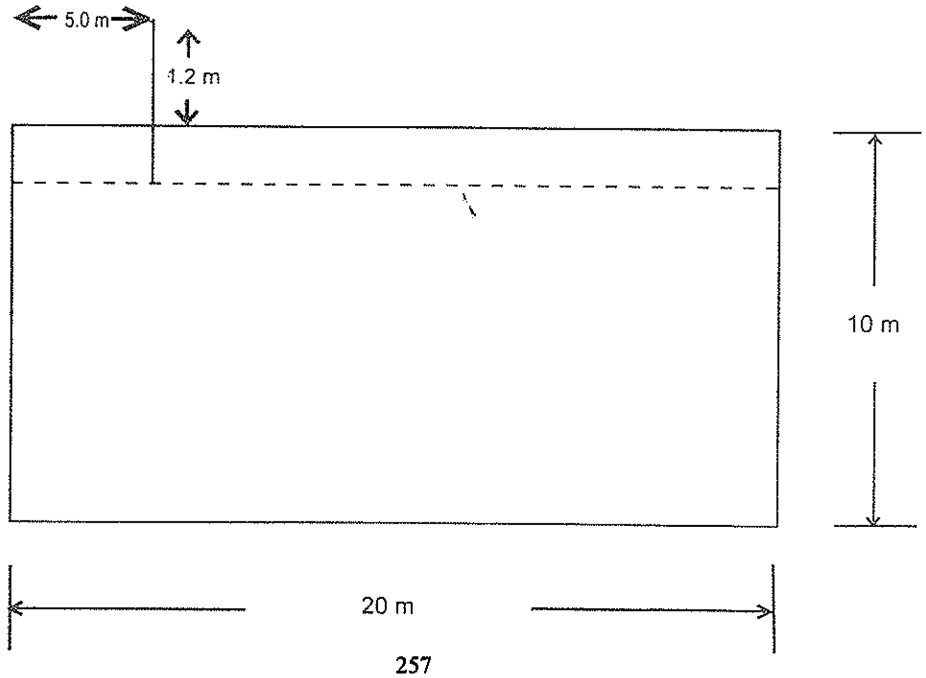
PM $= 10 - (8.564 - 1)$

$$= 2.436 \text{ m}$$

Vol. of oil $= 20 \times 15 \times 2.436$

$$= \mathbf{\mathit{730.8\ m^3}}$$

ii)

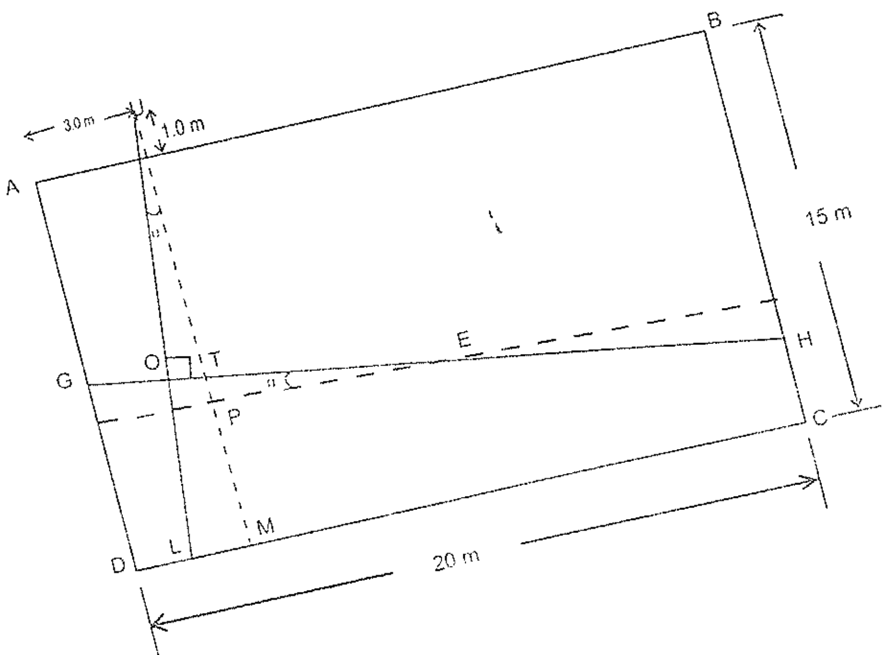


Sounding of oil in tank	=	10 + 1.2 - 1.8
	=	9.4 m
Vol. of oil in tank	=	20 x 15 x 9.4
	=	2820 m^3

From table 54 of Petroleum Measurement Table

V.C.F.	=	0.9879
Thus Net Observed Volume	=	2820 x 0.9879
	=	2785.878 m^3
W.R.F	=	0.7925 - 0.0011
	=	0.7914
Quantity of oil	=	2785.878 x 0.7914
	=	**2204.7 M.T.**

130. *While discharging oil from an oil tanker of LBP 175 m, sounding of a tank was obtained as 80 cm using a sounding rod.The dimensions of the tank are L 20 m × B 15 m × D 15 m. The vessel was trimmed 1.5 m by stern and the sounding pipe is located 3 m from aft bulkhead and extends 1.0 m above deck. Assuming no wedge formed, calculate the quantity of oil in the tank.*



$$\text{Given that } OL = 0.8 \text{ m}$$

$$\tan\theta = \frac{\text{trim}}{LBP} = \frac{1.5}{175}$$

$$\cos\theta = \frac{UM}{UL}$$

$$UL = UM \sec\theta$$

$$= (15+1)\sec\left\{\tan^{-1}\left(\frac{1.5}{175}\right)\right\}$$

$$= 16.001 \text{ m}$$

$$UO = UL - OL$$

$$= 16.001 - 0.80$$

$$= 15.201 \text{ m}$$

$$\frac{UO}{UT} = \cos\theta$$

$$UT = UO \sec\theta$$

$$= 15.201 \times \sec\left\{\tan^{-1}\left(\frac{1.5}{175}\right)\right\}$$

$$= 15.202 \text{ m}$$

$$\tan\theta = \frac{TP}{PE} = \frac{\text{trim}}{LBP}$$

$$\frac{TP}{\frac{20}{2} - 3} = \frac{1.5}{175}$$

$$TP = 0.06 \text{ m}$$

$$UM = UT + TP + PM$$

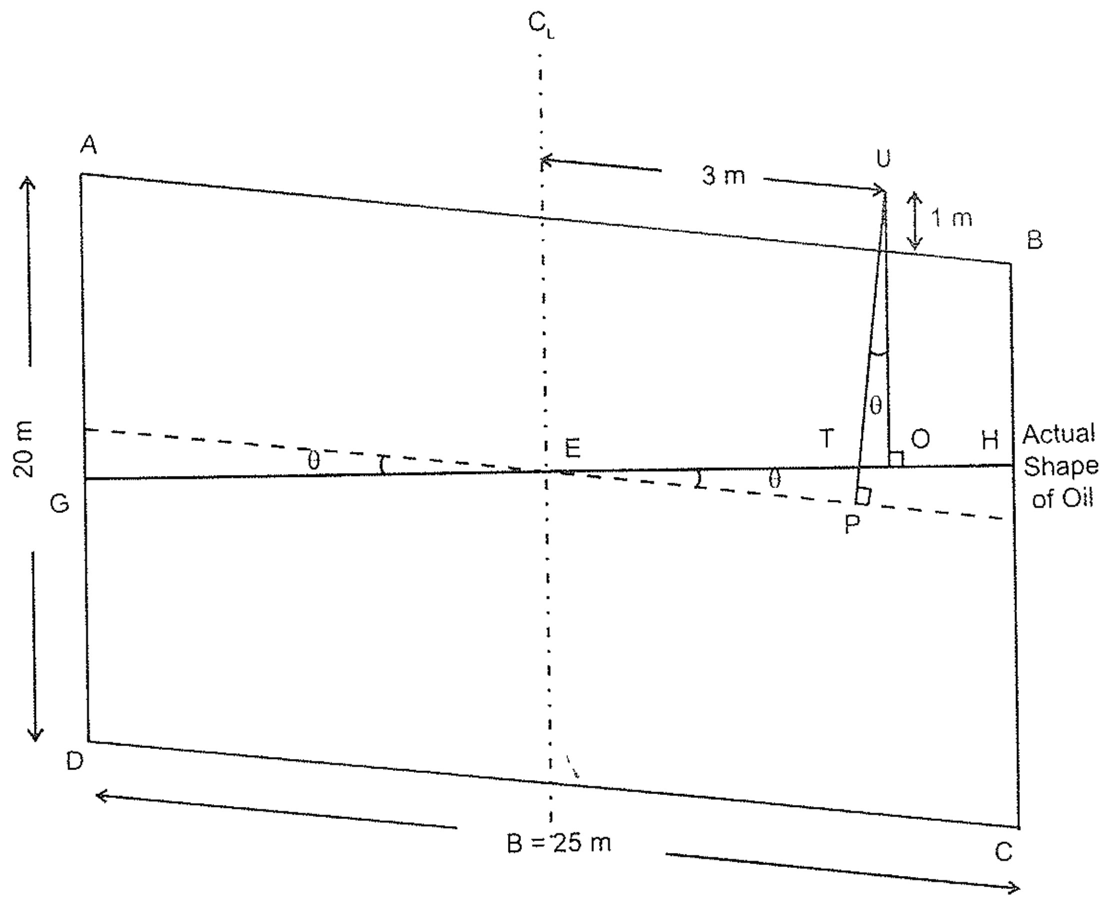
$$PM = (15 + 1) - (15.202 + 0.06)$$

$$= 0.738 \text{ m}$$

Thus vol. of oil in tank = 20 x 15 x 0.738

= **221.4 m^3**

131. *A vessel of LBP 235 m has a tank of dimensions L 30 m × B 25 m × D 20 m is loading oil of density @ 15°C 0.8150. On completion of loading vessel is listed 1° stbd and the ullage as observed using a sonic tape was found to be 1.8 m. Ullage port is located 3 m to starboard of the centreline and 1 m above the deck. Vessel is on an keel on completion and temp. of oil to observed to be 32° C. Calculate the quantity of oil.*



θ = Angle of list = 10

UO is observed ullage = 1.8 m

UT is ullage corrected for Tape Correction.

$$\frac{UO}{UT} = \cos\ \theta$$

or $UT = UO\ \sec$

$= 1.8\ \sec\ 1^0$

$= 1.8003\ m$

$\approx 1.8\ m$

$$\frac{TP}{PE} = \tan\ \theta$$

or $TP = PE\ \tan\ \theta$

$= 3\ \tan\ 1^0$

$= 0.052\ m$

TP List Correction

Ullage corrected for list = UT + TP

= 1.8 + 0.052

= 1.852 m

Thus sounding = 20 + 1 - 1.852

= 19.148 m

Vol. of oil @ 32^0 C = 30 x 25 x 19.148

= 14361 m^3

V.C.F. = 0.9852

N.O.V. = 14361 x 0.9852

= 14148.457 m^3

W.R.F. = 0.8150 - 0.0011

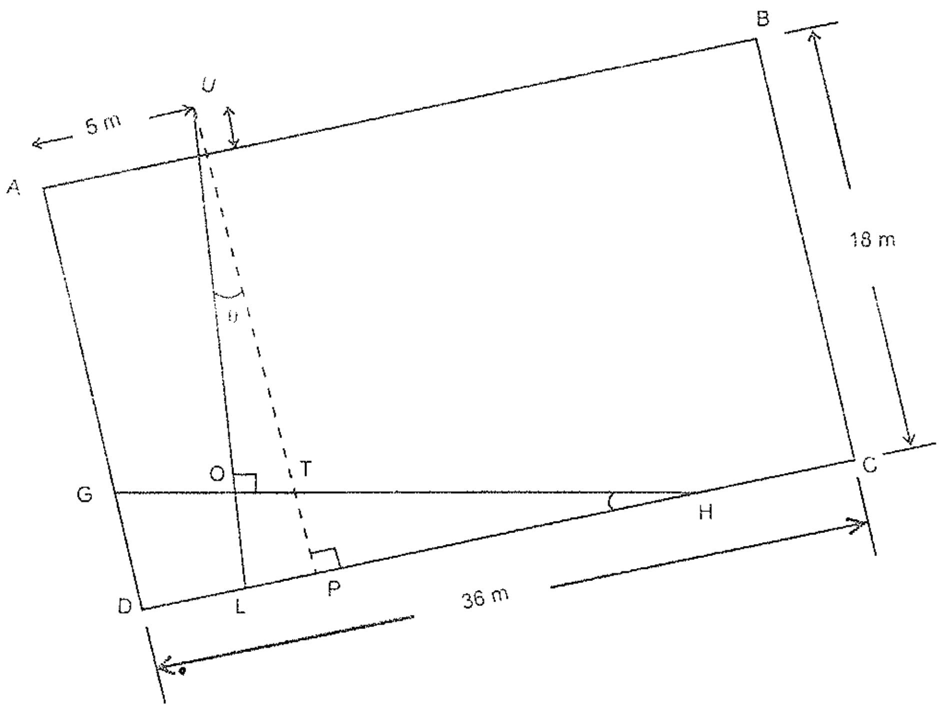
= 0.8139

Quantity of oil loaded = 14148.457 x 0.8139

= ***11515.4 M.T.***

Note: List correction is to be added to the ullage if list and location of ullage port from C.L. are of same name. If they are to opposite sides the list correction to be subtracted from the ullage.

132. *On completion of cargo, at the time of sounding the tanks, dip was observed to be 9 cm. The vessel was upright and trimmed 3 m by stern. Dimensions of the tank were 36 m × 27 m × 18 m. LBP of the vessel was 270 m. Calculate the on board quantity (OBQ), given that the sounding pipe was located 5 m from the aft bulkhead and 0.9 m above deck.*



Aim to ensure whether DH is less than 36 m or more

Given that OL = 0.09 m

$$\frac{UP}{UL} = \cos\theta \;, \text{ where } \theta = \tan^{-1}\left(\frac{\text{trim}}{\text{LBP}}\right)$$

$$UL = UP \sec\theta$$

$$= (18 + 0.9)\sec\left\{\tan^{-1}\left(\frac{3}{270}\right)\right\}$$

$$= 18.901 \text{ m}$$

$$= UO = UL - OL$$

$$= 18.901 - 0.09$$

$$= 18.811 \text{ m}$$

$$\cos\theta = \frac{UO}{UT}$$

$$UT = UO \sec\theta$$

$$= 18.811 \sec\left\{\tan^{-1}\left(\frac{3}{270}\right)\right\}$$

$$= 18.812 \text{ m}$$

$$TP = UP - UT$$

$$= 18.9 - 18.812$$

$$= 0.088 \text{ m}$$

$$\frac{TP}{PH} = \tan\theta = \frac{3}{270}$$

$$\frac{0.088}{PH} = \frac{3}{270}$$

$$PH = 7.92 \text{ m}$$

$$DH = DP + PH$$

$$= 5 + 7.92$$

$$= 12.92 \text{ m}$$

Now as DH is less than 36 m, the oil forms a wedge.

Volume of oil = Area of triangle GDH x Breadth of tank

$$\text{Area of triangle GDH} = \frac{1}{2} GD \times DH$$

$$\frac{GD}{DH} = \tan\theta = \frac{3}{270}$$

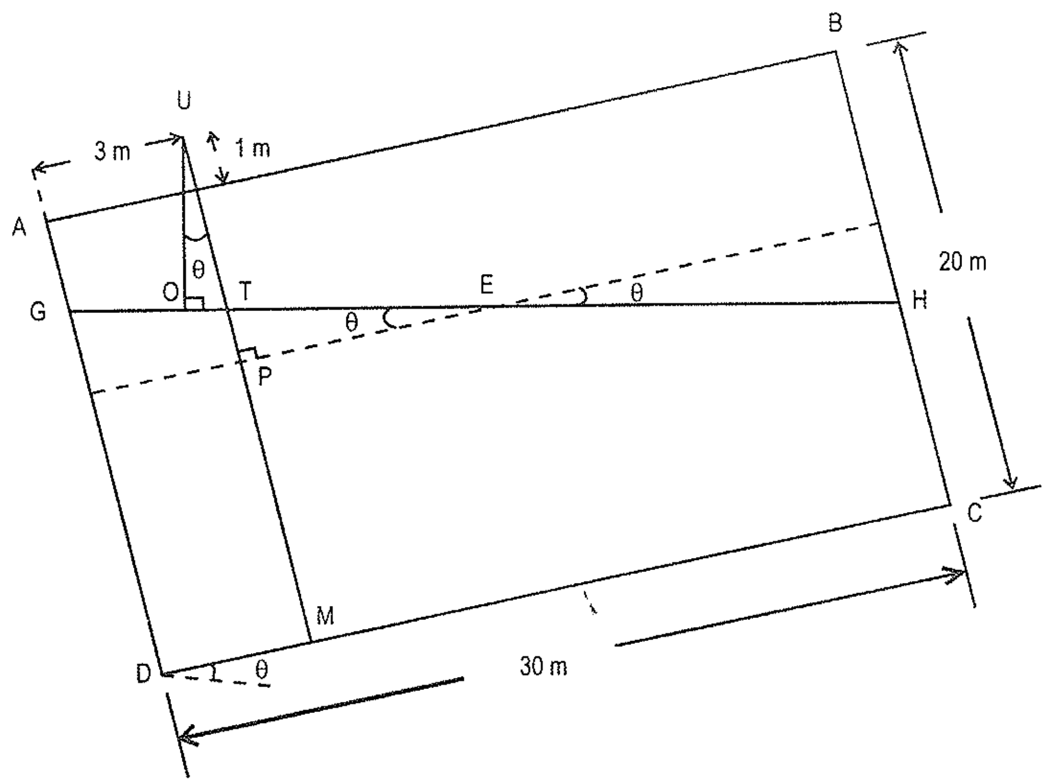
$$GD = 12.92 \times \frac{3}{270}$$

$$= 0.144 \text{ m}$$

$$\text{Thus vol. of tank} = \frac{1}{2} \times 0.144 \times 12.92 \times 27$$

$$= \mathbf{25.116\ m^3}$$

133. *A box shaped tank L 30 m × B 18 m × 20 m containing crude oil of density at 15⁰ C = 0.8275 t/m³ had an ullage of 1.80 m as measured by a Sonic Tape. The ullage port was located 3 m fwd of the aft bulkhead, 1 m above the tank top and 2 m to port of centreline of tank. Trim observed was 3 m* and the *vessel listed 1⁰ to starboard. Observed temp 32.5⁰ C. Calculate the quantity of oil in tank if the LBP of vessel was 215 m.*



In such type of problem trim and list should be dealt with separately.

i) First, the tape correction should be obtained and applied to the observed ullage.

ii) Using the corrected ullage (ullage corrected for tape correction), trim correction should be obtained.

iii) Using the corrected ullage (ullage corrected for tape correction), list correction should be obtained. List correction is additive to ullage if both the list and location of ullage port from centreline are to the same side. Otherwise it is subtracted.

iv) Trim correction and list correction is then applied to corrected ullage (ullage corrected for tape correction) to obtain actual ullage.

v) Now the sounding is obtained and the volume of oil in the tank calculated.

Tape Correction

$$\tan \theta = \frac{\text{trim}}{\text{LBP}} = \frac{3}{215}$$

$$UT = UO \times \sec \theta$$

$$UT = 1.8 \times \sec\left\{\tan^{-1}\left(\frac{\text{trim}}{\text{LBP}}\right)\right\}$$

$$= 1.8 \times \sec\left\{\tan^{-1}\left(\frac{3}{215}\right)\right\}$$

$$= 1.8002 \text{ m}$$

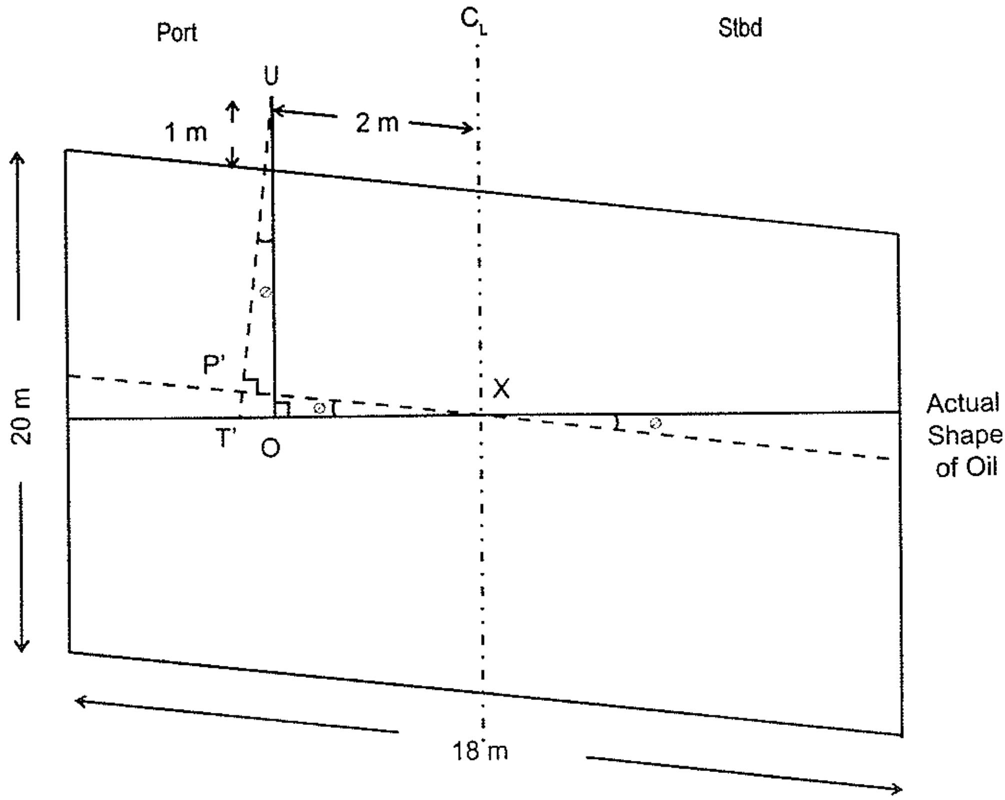
$$\approx 1.8 \text{ m}$$

Trim Correction

$$\frac{TP}{PE} = \tan \theta = \frac{\text{trim}}{\text{LBP}}$$

$$\frac{TP}{\frac{30}{2} - 3} = \frac{3}{215}$$

$$TP = 0.167 \text{ m}$$



'Ø' is the angle of list

$$\frac{UO}{UT'} = \cos Ø$$

$$UT' = UO \sec Ø$$

$$= 1.8 \sec 1^0$$

$$= 1.8003 \text{ m}$$

$$\approx 1.8 \text{ m}$$

List Correction

$$\frac{T'P'}{P'X} = \tan Ø$$

$$T'P' = 2 \tan 1^0$$

$$= 0.035$$

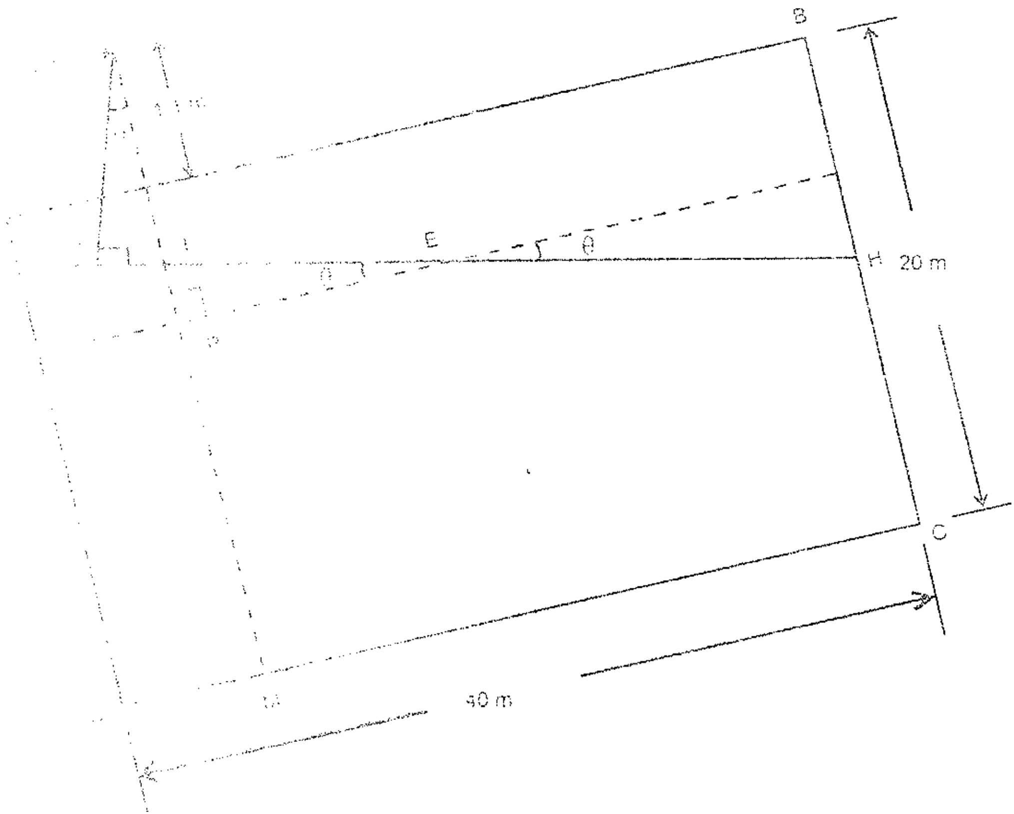
Since ullage port is on the port side of centre line and vessel is listed to starboard, thus List Correction is to be subtracted. Hence

Corrected Ullage	=	Ullage Corrected for Tape Correction + Trim Correction - List Correction
	=	1.8 + 0.167 - 0.035
	=	1.932 m
Sounding	=	(20 + 1) - 1.932
	=	19.068 m
Vol. of oil	=	30 x 18 x 19.068
	=	***10296.72***

Entering into Table 54 of Petroleum Measurement Tables for density = 0.8275 t/m^3 and temp 32.5^0.

V.R.F	=	0.9852
N.O.V	=	10296.72 x 0.9852
	=	10144.328 m3
W.C.F.	=	0.8275 - 0.0011
	=	0.8264
Quantity of oil	=	10144.328 x 0.8264
	=	***8383.3 M.T.***

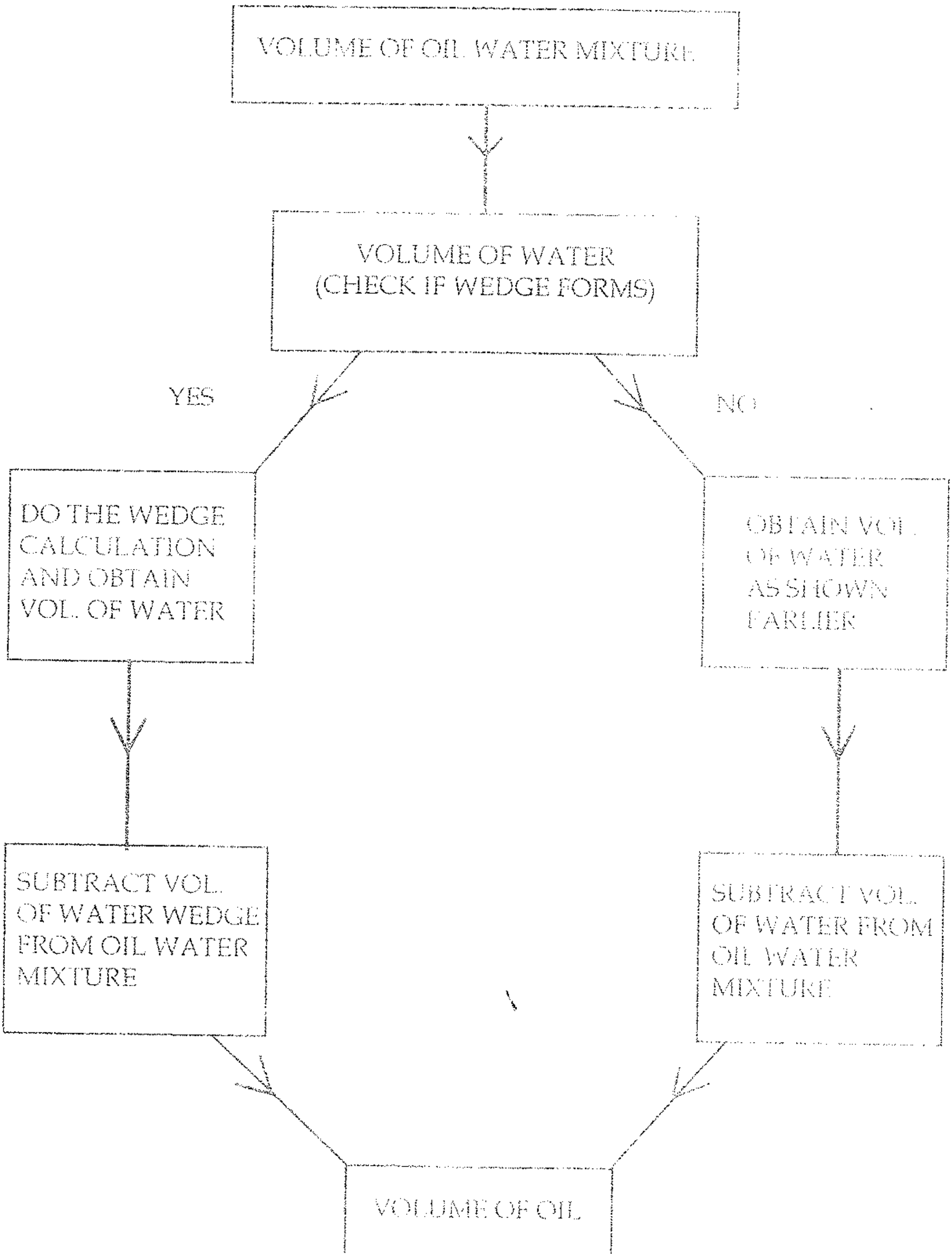
134. An oil tanker of LBP 200 m has a box shaped tank of dimensions L 40 m × B 20 m × D 20 m and is loaded with oil. On completion ullage as measured from a sonic tape was observed to be 1.24 m and temp. was 37°C. A water dip ullage of 20.94 m was also found. The ullage port was located 1.1 m above the tank top and 1.0 m fwd of aft bulkhead. Vessel was trimmed 3 m by stern. Terminal gave the density of oil @ 15° C as 0.8145 t/m³ Determine the quantity of oil in the tank.



1) In this type of question, first obtain the volume of oil and water mixture in the tank.

2) Then consider the water alone and establish whether a wedge forms or not. If it forms, do the wedge calculation and obtain volume of water.

3) Subtract the volume of water obtained from volume of oil and water mixture and obtain the volume of oil.


VOLUME OF OIL WATER MIXTURE
VOLUME OF WATER (CHECK IF WEDGE FORMS)
YES
NO
DO THE WEDGE CALCULATION AND OBTAIN VOL. OF WATER
OBTAIN VOL. OF WATER AS SHOWN EARLIER
SUBTRACT VOL. OF WATER WEDGE FROM OIL WATER MIXTURE
SUBTRACT VOL. OF WATER FROM OIL WATER MIXTURE
VOLUME OF OIL

Tape Correction

$$UT = \sec\left\{\tan^{-1}\left(\frac{trim}{LBP}\right)\right\} \times UO$$

$$UT = 1.24 \times \sec\left\{\tan^{-1}\left(\frac{3}{200}\right)\right\}$$

$$= 1.2401 \text{ m}$$

$$\approx 1.240 \text{ m}$$

$$\frac{TP}{PE} = \frac{trim}{LBP} = \frac{3}{200}$$

$$\frac{TP}{\frac{40}{2} - 1.6} = \frac{3}{200} \quad TP = 0.276 \text{ m}$$

Corrected Ullage $= 1.240 + 0.276$

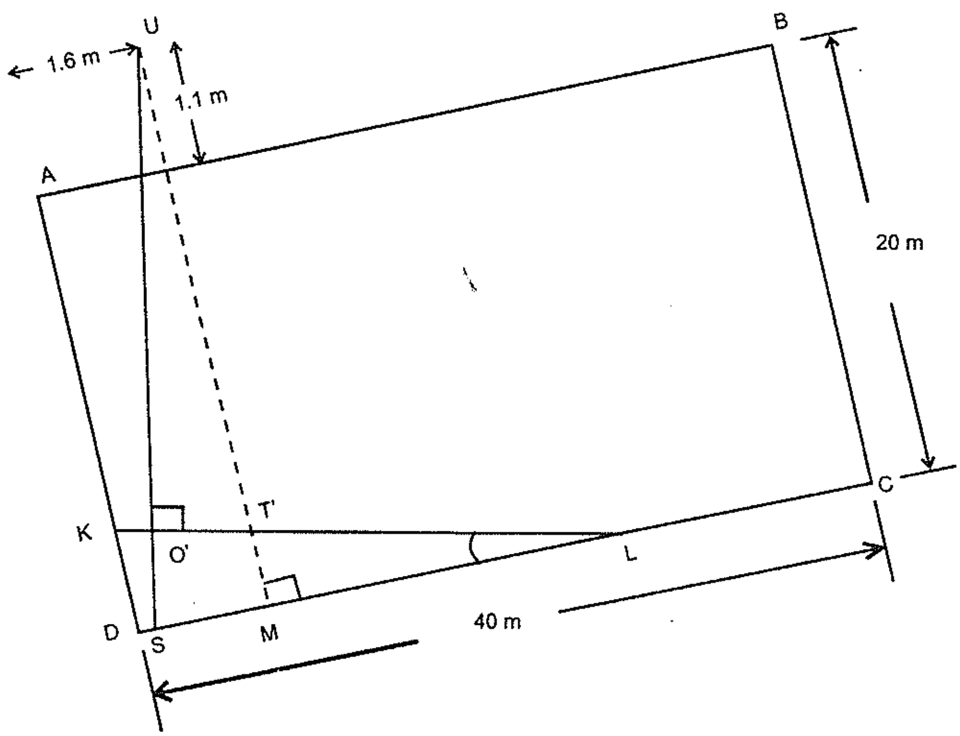
$= 1.516$ m

Sounding $= (20 + 1.1) - 1.516$

$= 19.584$ m

Vol. of oil and water $= 40 \times 20 \times 19.584$

$= 15667.2 \text{ m}^3$



KL is the shape of water plane.

To establish if DL is less than 40 m

Given that

$$UO' = 20.94 \text{ m}$$

$$UT' = UO' \sec\left\{\tan^{-1}\left(\frac{3}{200}\right)\right\}$$

$$= 20.942 \text{ m}$$

$$T'M = UM - UT'$$

$$= 20 + 1.1 - 20.942$$

$$= 0.158 \text{ m}$$

$$\frac{T'M}{ML} = \tan\theta = \frac{\text{trim}}{\text{LBP}}$$

$$\frac{0.158}{ML} = \frac{3}{200}$$

$$ML = 10.533 \text{ m}$$

$$DL = DM + ML$$

$$= 1.6 + 10.533$$

$$= 12.133 \text{ m}$$

DL < 40 m hence wedge forms

$$\frac{KD}{DL} = \tan\theta = \frac{\text{trim}}{\text{LBP}}$$

$$KD = 12.133 \times \frac{3}{200}$$

$$= 0.182 \text{ m}$$

Volume of Wedge $= \left(\frac{1}{2} \times 0.182 \times 12.133\right) \times 20 = 22.082 \text{ m}^3$

Vol. of oil	=	15667.2 - 22.082
	=	15645.1 m^3

Entering Table 54 of Petroleum Measurement Table with density 0.8145 t/m^3 and temp. 37^0 C.

V.R.F	=	0.9808
N.O.V	=	15645.1 x 0.9808
	=	15344.7 m^3
W.R.F.	=	0.8146 - 0.0011
	=	0.8135
Quantity	=	15344.7 x 0.8135
	=	***12482.9 M.T.***

USE OF ULLAGE TABLES

Onboard oil tankers method of calculating the quantity of oil is different from those as used in case of other ships. Here the volume of oil in cargo oil tanks is tabulated against different ullages for different conditions of trim and list. Ship's personnel take the ullages, water dip of the tanks and note down the trim and list of the vessel. Now referring to these tables the volume of oil in different tanks is obtained.

The following pages contain the ullage tables for an oil tanker drawn below. This tanker has five set of wing tanks and a pair of slop tanks. The LBP of the vessel is 200 m. The 100% volume for the tanks is as follows:

Tank	100% Volume
1 w/s	8100 m^3
2 w/s	9720 m^3
3 w/s	9720 m^3
4 w/s	9720 m^3
5 w/s	8100 m^3
Slops	3240 m^3

The depth of all the tanks is 18 m.

135. *On completion of loading, the ullages observed were as follows.*

1P - 1.43 m, 1S - 1.45 m, 2P - 1.70 m, 2S - 1.67 m

3P - 2.45 m, 3S - 2.45 m, 4P - 1.65 m, 4S - 1.62 m

5P - 1.53 m, 5S - 1.51 m, Slop (P) - 1.8 m, Slop (S) - 1.82 m

Water cut for all the tanks was nil. Trim was observed to be 0.50 m by stern. Determine the gross volume of oil loaded.

Tank	Ullage (m)	Volume (m^3)	
1P	1.43	7444.685	
1S	1.43	7435.685	
2P	1.70	8784.447	
2S	1.67	8800.647	Interpolating between 2.40 m and 2.50 m ullage
3P	2.45	8379.446	
3S	2.45	8379.446	
4P	1.65	8811.447	
4S	1.62	8827.647	
5P	1.53	7399.685	
5S	1.51	7408.685	
Slop (P)	1.8	2912.849	
Slop (S)	1.82	2911.049	
		87495.718 m^3	

Hence gross observed volume = 87495.718 m^3

BALLAST SPACES			BALLAST SPACES
	1 Port 8100 m³	1 stbd 8100 m³	
	2 Port 9720 m³	2 stbd 9720 m³	
	3 Port 9720 m³	3 stbd 9720 m³	
	4 Port 9720 m³	4 stbd 9720 m³	
	5 Port 8100 m³	5 stbd 8100 m³	
	Slop Port 3720 m³	Slop stbd 3720 m³	

Ullage Tables for 1 & 5 w/s

Ullage	Trim by stern in (m)						Even Keel	Trim by head in (m)	
	0.500	1.000	1.500	2.000	2.500	3.000		-0.500	-1.000
0.000	8088.188	8076.375	8064.563	8052.750	8040.938	8029.125	8100.000	8099.910	8099.820
0.010	8083.687	8071.875	8060.062	8048.250	8036.437	8024.624	8095.500	8099.190	8099.280
0.020	8079.187	8067.375	8055.562	8043.750	8031.937	8020.124	8091.000	8097.750	8098.380
0.030	8074.687	8062.875	8051.062	8039.249	8027.436	8015.623	8086.500	8095.590	8097.120
0.040	8070.187	8058.375	8046.562	8034.749	8022.936	8011.123	8082.000	8092.710	8095.500
0.050	8065.687	8053.875	8042.062	8030.249	8018.436	8006.622	8077.500	8089.110	8093.520
0.060	8061.187	8049.375	8037.562	8025.749	8013.935	8002.122	8073.000	8084.812	8091.180
0.070	8056.687	8044.875	8033.062	8021.248	8009.435	7997.621	8068.500	8080.312	8088.480
0.080	8052.187	8040.375	8028.561	8016.748	8004.935	7993.121	8064.000	8075.812	8084.040
0.090	8047.687	8035.874	8024.061	8012.248	8000.434	7988.620	8059.500	8071.312	8082.000
0.100	8043.187	8031.374	8019.561	8007.748	7995.934	7984.120	8055.000	8066.812	8078.220
0.110	8038.687	8026.874	8015.061	8003.248	7991.434	7979.619	8050.500	8062.312	8074.080
0.120	8034.187	8022.374	8010.561	7998.747	7986.933	7975.119	8046.000	8057.812	8069.624
0.130	8029.687	8017.874	8006.061	7994.247	7982.433	7970.618	8041.500	8053.312	8065.124
0.140	8025.187	8013.374	8001.561	7989.747	7977.933	7966.118	8037.000	8048.812	8060.624
0.150	8020.687	8008.874	7997.061	7985.247	7973.432	7961.617	8032.500	8044.312	8056.124
0.160	8016.187	8004.374	7992.560	7980.746	7968.932	7957.117	8028.000	8039.812	8051.624
0.170	8011.687	7999.874	7988.060	7976.246	7964.432	7952.616	8023.500	8035.312	8047.124
0.180	8007.187	7995.374	7983.560	7971.746	7959.931	7948.116	8019.000	8030.812	8042.624
0.190	8002.687	7990.874	7979.060	7967.246	7955.431	7943.615	8014.500	8026.312	8038.124
0.200	7998.187	7986.374	7974.560	7962.746	7950.930	7939.115	8010.000	8021.812	8033.624
0.210	7993.687	7981.874	7970.060	7958.245	7946.430	7934.614	8005.500	8017.312	8029.124
0.220	7989.187	7977.374	7965.560	7953.745	7941.930	7930.114	8001.000	8012.812	8024.624
0.230	7984.687	7972.874	7961.060	7949.245	7937.429	7925.613	7996.500	8008.312	8020.124
0.240	7980.187	7968.374	7956.559	7944.745	7932.929	7921.113	7992.000	8003.812	8015.624
0.250	7975.687	7963.874	7952.059	7940.244	7928.429	7916.612	7987.500	7999.312	8011.124
0.260	7971.187	7959.374	7947.559	7935.744	7923.928	7912.112	7983.000	7994.812	8006.624
0.270	7966.687	7954.873	7943.059	7931.244	7919.428	7907.611	7978.500	7990.312	8002.123
0.280	7962.187	7950.373	7938.559	7926.744	7914.928	7903.111	7974.000	7985.812	7997.623
0.290	7957.687	7945.873	7934.059	7922.243	7910.427	7898.610	7969.500	7981.312	7993.123
0.300	7953.187	7941.373	7929.559	7917.743	7905.927	7894.110	7965.000	7976.812	7988.623
0.310	7948.687	7936.873	7925.059	7913.243	7901.427	7889.609	7960.500	7972.312	7984.123
0.320	7944.187	7932.373	7920.558	7908.743	7896.926	7885.109	7956.000	7967.812	7979.623
0.330	7939.687	7927.873	7916.058	7904.243	7892.426	7880.608	7951.500	7963.312	7975.123
0.340	7935.187	7923.373	7911.558	7899.742	7887.926	7876.108	7947.000	7958.812	7970.623
0.350	7930.687	7918.873	7907.058	7895.242	7883.425	7871.607	7942.500	7954.312	7966.123
0.360	7926.187	7914.373	7902.558	7890.742	7878.925	7867.107	7938.000	7949.812	7961.623
0.370	7921.687	7909.873	7898.058	7886.242	7874.424	7862.606	7933.500	7945.312	7957.123
0.380	7917.187	7905.373	7893.558	7881.741	7869.924	7858.106	7929.000	7940.812	7952.623
0.390	7912.687	7900.873	7889.058	7877.241	7865.424	7853.605	7924.500	7936.312	7948.123
0.400	7908.187	7896.373	7884.557	7872.741	7860.923	7849.105	7920.000	7931.812	7943.623
0.410	7903.687	7891.873	7880.057	7868.241	7856.423	7844.604	7915.500	7927.312	7939.123
0.420	7899.187	7887.373	7875.557	7863.741	7851.923	7840.104	7911.000	7922.812	7934.623
0.430	7894.687	7882.873	7871.057	7859.240	7847.422	7835.603	7906.500	7918.312	7930.123
0.440	7890.187	7878.373	7866.557	7854.740	7842.922	7831.103	7902.000	7913.812	7925.623
0.450	7885.687	7873.872	7862.057	7850.240	7838.422	7826.602	7897.500	7909.312	7921.122

Ullage	Trim by stern in (m)						Even Keel	Trim by head in (m)	
	0.500	1.000	1.500	2.000	2.500	3.000		-0.500	-1.000
0.460	7881.187	7869.372	7857.557	7845.740	7833.921	7822.102	7893.000	7904.812	7916.622
0.470	7876.687	7864.872	7853.057	7841.239	7829.421	7817.601	7888.500	7900.312	7912.122
0.480	7872.187	7860.372	7848.556	7836.739	7824.921	7813.101	7884.000	7895.812	7907.622
0.490	7867.687	7855.872	7844.056	7832.239	7820.420	7808.600	7879.500	7891.312	7903.122
0.500	7863.187	7851.372	7839.556	7827.739	7815.920	7804.100	7875.000	7886.812	7898.622
0.510	7858.687	7846.872	7835.056	7823.239	7811.420	7799.599	7870.500	7882.312	7894.122
0.520	7854.187	7842.372	7830.556	7818.738	7806.919	7795.099	7866.000	7877.812	7889.622
0.530	7849.687	7837.872	7826.056	7814.238	7802.419	7790.598	7861.500	7873.312	7885.122
0.540	7845.187	7833.372	7821.556	7809.738	7797.919	7786.098	7857.000	7868.812	7880.622
0.550	7840.687	7828.872	7817.056	7805.238	7793.418	7781.597	7852.500	7864.312	7876.122
0.560	7836.187	7824.372	7812.555	7800.737	7788.918	7777.097	7848.000	7859.812	7871.622
0.570	7831.687	7819.872	7808.055	7796.237	7784.417	7772.596	7843.500	7855.312	7867.122
0.580	7827.187	7815.372	7803.555	7791.737	7779.917	7768.096	7839.000	7850.812	7862.622
0.590	7822.687	7810.872	7799.055	7787.237	7775.417	7763.595	7834.500	7846.312	7858.122
0.600	7818.187	7806.372	7794.555	7782.737	7770.916	7759.095	7830.000	7841.812	7853.622
0.610	7813.687	7801.872	7790.055	7778.236	7766.416	7754.594	7825.500	7837.312	7849.122
0.620	7809.187	7797.372	7785.555	7773.736	7761.916	7750.094	7821.000	7832.812	7844.622
0.630	7804.687	7792.871	7781.055	7769.236	7757.415	7745.593	7816.500	7828.312	7840.121
0.640	7800.187	7788.371	7776.554	7764.736	7752.915	7741.093	7812.000	7823.812	7835.621
0.650	7795.687	7783.871	7772.054	7760.235	7748.415	7736.592	7807.500	7819.312	7831.121
0.660	7791.187	7779.371	7767.554	7755.735	7743.914	7732.092	7803.000	7814.812	7826.621
0.670	7786.687	7774.871	7763.054	7751.235	7739.414	7727.591	7798.500	7810.312	7822.121
0.680	7782.187	7770.371	7758.554	7746.735	7734.914	7723.091	7794.000	7805.812	7817.621
0.690	7777.687	7765.871	7754.054	7742.234	7730.413	7718.590	7789.500	7801.312	7813.121
0.700	7773.187	7761.371	7749.554	7737.734	7725.913	7714.090	7785.000	7796.812	7808.621
0.710	7768.687	7756.871	7745.054	7733.234	7721.413	7709.589	7780.500	7792.312	7804.121
0.720	7764.186	7752.371	7740.553	7728.734	7716.912	7705.089	7776.000	7787.811	7799.621
0.730	7759.686	7747.871	7736.053	7724.234	7712.412	7700.588	7771.500	7783.311	7795.121
0.740	7755.186	7743.371	7731.553	7719.733	7707.911	7696.088	7767.000	7778.811	7790.621
0.750	7750.686	7738.871	7727.053	7715.233	7703.411	7691.587	7762.500	7774.311	7786.121
0.760	7746.186	7734.371	7722.553	7710.733	7698.911	7687.087	7758.000	7769.811	7781.621
0.770	7741.686	7729.871	7718.053	7706.233	7694.410	7682.586	7753.500	7765.311	7777.121
0.780	7737.186	7725.371	7713.553	7701.732	7689.910	7678.086	7749.000	7760.811	7772.621
0.790	7732.686	7720.871	7709.053	7697.232	7685.410	7673.585	7744.500	7756.311	7768.121
0.800	7728.186	7716.371	7704.552	7692.732	7680.909	7669.085	7740.000	7751.811	7763.621
0.810	7723.686	7711.870	7700.052	7688.232	7676.409	7664.584	7735.500	7747.311	7759.120
0.820	7719.186	7707.370	7695.552	7683.732	7671.909	7660.083	7731.000	7742.811	7754.620
0.830	7714.686	7702.870	7691.052	7679.231	7667.408	7655.583	7726.500	7738.311	7750.120
0.840	7710.186	7698.370	7686.552	7674.731	7662.908	7651.082	7722.000	7733.811	7745.620
0.850	7705.686	7693.870	7682.052	7670.231	7658.408	7646.582	7717.500	7729.311	7741.120
0.860	7701.186	7689.370	7677.552	7665.731	7653.907	7642.081	7713.000	7724.811	7736.620
0.870	7696.686	7684.870	7673.051	7661.230	7649.407	7637.581	7708.500	7720.311	7732.120
0.880	7692.186	7680.370	7668.551	7656.730	7644.907	7633.080	7704.000	7715.811	7727.620
0.890	7687.686	7675.870	7664.051	7652.230	7640.406	7628.580	7699.500	7711.311	7723.120
0.900	7683.186	7671.370	7659.551	7647.730	7635.906	7624.079	7695.000	7706.811	7718.620
0.910	7678.686	7666.870	7655.051	7643.230	7631.406	7619.579	7690.500	7702.311	7714.120
0.920	7674.186	7662.370	7650.551	7638.729	7626.905	7615.078	7686.000	7697.811	7709.620

Ullage	Trim by stern in (m)						Even Keel	Trim by head in (m)	
	0.500	1.000	1.500	2.000	2.500	3.000		-0.500	-1.000
0.930	7669.686	7657.870	7646.051	7634.229	7622.405	7610.578	7681.500	7693.311	7705.120
0.940	7665.186	7653.370	7641.551	7629.729	7617.904	7606.077	7677.000	7688.811	7700.620
0.950	7660.686	7648.870	7637.050	7625.229	7613.404	7601.577	7672.500	7684.311	7696.120
0.960	7656.186	7644.370	7632.550	7620.728	7608.904	7597.076	7668.000	7679.811	7691.620
0.970	7651.686	7639.870	7628.050	7616.228	7604.403	7592.576	7663.500	7675.311	7687.120
0.980	7647.186	7635.369	7623.550	7611.728	7599.903	7588.075	7659.000	7670.811	7682.619
0.990	7642.686	7630.869	7619.050	7607.228	7595.403	7583.575	7654.500	7666.311	7678.119
1.000	7638.186	7626.369	7614.550	7602.728	7590.902	7579.074	7650.000	7661.811	7673.619
1.010	7633.686	7621.869	7610.050	7598.227	7586.402	7574.574	7645.500	7657.311	7669.119
1.020	7629.186	7617.369	7605.550	7593.727	7581.902	7570.073	7641.000	7652.811	7664.619
1.030	7624.686	7612.869	7601.049	7589.227	7577.401	7565.573	7636.500	7648.311	7660.119
1.040	7620.186	7608.369	7596.549	7584.727	7572.901	7561.072	7632.000	7643.811	7655.619
1.050	7615.686	7603.869	7592.049	7580.226	7568.401	7556.572	7627.500	7639.311	7651.119
1.060	7611.186	7599.369	7587.549	7575.726	7563.900	7552.071	7623.000	7634.811	7646.619
1.070	7606.686	7594.869	7583.049	7571.226	7559.400	7547.571	7618.500	7630.311	7642.119
1.080	7602.186	7590.369	7578.549	7566.726	7554.900	7543.070	7614.000	7625.811	7637.619
1.090	7597.686	7585.869	7574.049	7562.225	7550.399	7538.570	7609.500	7621.311	7633.119
1.100	7593.186	7581.369	7569.549	7557.725	7545.899	7534.069	7605.000	7616.811	7628.619
1.110	7588.686	7576.869	7565.048	7553.225	7541.398	7529.569	7600.500	7612.311	7624.119
1.120	7584.186	7572.369	7560.548	7548.725	7536.898	7525.068	7596.000	7607.811	7619.619
1.130	7579.686	7567.869	7556.048	7544.225	7532.398	7520.568	7591.500	7603.311	7615.119
1.140	7575.186	7563.369	7551.548	7539.724	7527.897	7516.067	7587.000	7598.811	7610.619
1.150	7570.686	7558.869	7547.048	7535.224	7523.397	7511.567	7582.500	7594.311	7606.119
1.160	7566.186	7554.368	7542.548	7530.724	7518.897	7507.066	7578.000	7589.811	7601.618
1.170	7561.686	7549.868	7538.048	7526.224	7514.396	7502.566	7573.500	7585.311	7597.118
1.180	7557.186	7545.368	7533.548	7521.723	7509.896	7498.065	7569.000	7580.811	7592.618
1.190	7552.686	7540.868	7529.047	7517.223	7505.396	7493.565	7564.500	7576.311	7588.118
1.200	7548.186	7536.368	7524.547	7512.723	7500.895	7489.064	7560.000	7571.811	7583.618
1.210	7543.686	7531.868	7520.047	7508.223	7496.395	7484.564	7555.500	7567.311	7579.118
1.220	7539.186	7527.368	7515.547	7503.723	7491.895	7480.063	7551.000	7562.811	7574.618
1.230	7534.686	7522.868	7511.047	7499.222	7487.394	7475.563	7546.500	7558.311	7570.118
1.240	7530.186	7518.368	7506.547	7494.722	7482.894	7471.062	7542.000	7553.811	7565.618
1.250	7525.686	7513.868	7502.047	7490.222	7478.394	7466.562	7537.500	7549.311	7561.118
1.260	7521.186	7509.368	7497.547	7485.722	7473.893	7462.061	7533.000	7544.811	7556.618
1.270	7516.686	7504.868	7493.046	7481.221	7469.393	7457.561	7528.500	7540.311	7552.118
1.280	7512.186	7500.368	7488.546	7476.721	7464.893	7453.060	7524.000	7535.811	7547.618
1.290	7507.686	7495.868	7484.046	7472.221	7460.392	7448.560	7519.500	7531.311	7543.118
1.300	7503.186	7491.368	7479.546	7467.721	7455.892	7444.059	7515.000	7526.811	7538.618
1.310	7498.686	7486.868	7475.046	7463.221	7451.391	7439.559	7510.500	7522.311	7534.118
1.320	7494.186	7482.368	7470.546	7458.720	7446.891	7435.058	7506.000	7517.811	7529.618
1.330	7489.686	7477.868	7466.046	7454.220	7442.391	7430.558	7501.500	7513.311	7525.118
1.340	7485.186	7473.367	7461.546	7449.720	7437.890	7426.057	7497.000	7508.811	7520.617
1.350	7480.686	7468.867	7457.045	7445.220	7433.390	7421.557	7492.500	7504.311	7516.117
1.360	7476.186	7464.367	7452.545	7440.719	7428.890	7417.056	7488.000	7499.811	7511.617
1.370	7471.686	7459.867	7448.045	7436.219	7424.389	7412.556	7483.500	7495.311	7507.117
1.380	7467.186	7455.367	7443.545	7431.719	7419.889	7408.055	7479.000	7490.811	7502.617
1.390	7462.686	7450.867	7439.045	7427.219	7415.389	7403.555	7474.500	7486.311	7498.117

Ullage	Trim by stern in (m)						Even Keel	Trim by head in (m)	
	0.500	1.000	1.500	2.000	2.500	3.000		-0.500	-1.000
1.400	7458.186	7446.367	7434.545	7422.719	7410.888	7399.054	7470.000	7481.811	7493.617
1.410	7453.686	7441.867	7430.045	7418.218	7406.388	7394.554	7465.500	7477.311	7489.117
1.420	7449.186	7437.367	7425.545	7413.718	7401.888	7390.053	7461.000	7472.811	7484.617
1.430	7444.685	7432.867	7421.044	7409.218	7397.387	7385.553	7456.500	7468.310	7480.117
1.440	7440.185	7428.367	7416.544	7404.718	7392.887	7381.052	7452.000	7463.810	7475.617
1.450	7435.685	7423.867	7412.044	7400.217	7388.387	7376.552	7447.500	7459.310	7471.117
1.460	7431.185	7419.367	7407.544	7395.717	7383.886	7372.051	7443.000	7454.810	7466.617
1.470	7426.685	7414.867	7403.044	7391.217	7379.386	7367.551	7438.500	7450.310	7462.117
1.480	7422.185	7410.367	7398.544	7386.717	7374.885	7363.050	7434.000	7445.810	7457.617
1.490	7417.685	7405.867	7394.044	7382.216	7370.385	7358.550	7429.500	7441.310	7453.117
1.500	7413.185	7401.367	7389.544	7377.716	7365.885	7354.049	7425.000	7436.810	7448.617
1.510	7408.685	7396.867	7385.043	7373.216	7361.384	7349.549	7420.500	7432.310	7444.117
1.520	7404.185	7392.366	7380.543	7368.716	7356.884	7345.048	7416.000	7427.810	7439.616
1.530	7399.685	7387.866	7376.043	7364.216	7352.384	7340.548	7411.500	7423.310	7435.116
1.540	7395.185	7383.366	7371.543	7359.715	7347.883	7336.047	7407.000	7418.810	7430.616
1.550	7390.685	7378.866	7367.043	7355.215	7343.383	7331.547	7402.500	7414.310	7426.116
1.560	7386.185	7374.366	7362.543	7350.715	7338.883	7327.046	7398.000	7409.810	7421.616
1.570	7381.685	7369.866	7358.043	7346.215	7334.382	7322.546	7393.500	7405.310	7417.116
1.580	7377.185	7365.366	7353.543	7341.714	7329.882	7318.045	7389.000	7400.810	7412.616
1.590	7372.685	7360.866	7349.042	7337.214	7325.382	7313.545	7384.500	7396.310	7408.116
1.600	7368.185	7356.366	7344.542	7332.714	7320.881	7309.044	7380.000	7391.810	7403.616
1.610	7363.685	7351.866	7340.042	7328.214	7316.381	7304.543	7375.500	7387.310	7399.116
1.620	7359.185	7347.366	7335.542	7323.714	7311.881	7300.043	7371.000	7382.810	7394.616
1.630	7354.685	7342.866	7331.042	7319.213	7307.380	7295.542	7366.500	7378,310	7390.116
1.640	7350.185	7338.366	7326.542	7314.713	7302.880	7291.042	7362.000	7373.810	7385.616
1.650	7345.685	7333.866	7322.042	7310.213	7298.379	7286.541	7357.500	7369.310	7381.116
1.660	7341.185	7329.366	7317.541	7305.713	7293.879	7282.041	7353.000	7364.810	7376.616
1.670	7336.685	7324.866	7313.041	7301.212	7289.379	7277.540	7348.500	7360.310	7372.116
1.680	7332.185	7320.366	7308.541	7296.712	7284.878	7273.040	7344.000	7355.810	7367.616
1.690	7327.685	7315.865	7304.041	7292.212	7280.378	7268.539	7339.500	7351.310	7363.115
1.700	7323.185	7311.365	7299.541	7287.712	7275.878	7264.039	7335.000	7346.810	7358.615
1.710	7318.685	7306.865	7295.041	7283.212	7271.377	7259.538	7330.500	7342.310	7354.115
1.720	7314.185	7302.365	7290.541	7278.711	7266.877	7255.038	7326.000	7337.810	7349.615
1.730	7309.685	7297.865	7286.041	7274.211	7262.377	7250.537	7321.500	7333.310	7345.115
1.740	7305.185	7293.365	7281.540	7269.711	7257.876	7246.037	7317.000	7328.810	7340.615
1.750	7300.685	7288.865	7277.040	7265.211	7253.376	7241.536	7312.500	7324.310	7336.115
1.760	7296.185	7284.365	7272.540	7260.710	7248.876	7237.036	7308.000	7319.810	7331.615
1.770	7291.685	7279.865	7268.040	7256.210	7244.375	7232.535	7303.500	7315.310	7327.115
1.780	7287.185	7275.365	7263.540	7251.710	7239.875	7228.035	7299.000	7310.810	7322.615
1.790	7282.685	7270.865	7259.040	7247.210	7235.375	7223.534	7294.500	7306.310	7318.115
1.800	7278.185	7266.365	7254.540	7242.710	7230.874	7219.034	7290.000	7301.810	7313.615
1.810	7273.685	7261.865	7250.040	7238.209	7226.374	7214.533	7285.500	7297.310	7309.115
1.820	7269.185	7257.365	7245.539	7233.709	7221.874	7210.033	7281.000	7292.810	7304.615
1.830	7264.685	7252.865	7241.039	7229.209	7217.373	7205.532	7276.500	7288.310	7300.115
1.840	7260.185	7248.365	7236.539	7224.709	7212.873	7201.032	7272.000	7283.810	7295.615
1.850	7255.685	7243.865	7232.039	7220.208	7208.372	7196.531	7267.500	7279.310	7291.115
1.860	7251.185	7239.365	7227.539	7215.708	7203.872	7192.031	7263.000	7274.810	7286.615

Ullage	Trim by stern in (m)						Even Keel	Trim by head in (m)	
	0.500	1.000	1.500	2.000	2.500	3.000		-0.500	-1.000
1.870	7246.685	7234.864	7223.039	7211.208	7199.372	7187.530	7258.500	7270.310	7282.114
1.880	7242.185	7230.364	7218.539	7206.708	7194.871	7183.030	7254.000	7265.810	7277.614
1.890	7237.685	7225.864	7214.039	7202.207	7190.371	7178.529	7249.500	7261.310	7273.114
1.900	7233.185	7221.364	7209.538	7197.707	7185.871	7174.029	7245.000	7256.810	7268.614
1.910	7228.685	7216.864	7205.038	7193.207	7181.370	7169.528	7240.500	7252.310	7264.114
1.920	7224.185	7212.364	7200.538	7188.707	7176.870	7165.028	7236.000	7247.810	7259.614
1.930	7219.685	7207.864	7196.038	7184.207	7172.370	7160.527	7231.500	7243.310	7255.114
1.940	7215.185	7203.364	7191.538	7179.706	7167.869	7156.027	7227.000	7238.810	7250.614
1.950	7210.685	7198.864	7187.038	7175.206	7163.369	7151.526	7222.500	7234.310	7246.114
1.960	7206.185	7194.364	7182.538	7170.706	7158.869	7147.026	7218.000	7229.810	7241.614
1.970	7201.685	7189.864	7178.038	7166.206	7154.368	7142.525	7213.500	7225.310	7237.114
1.980	7197.185	7185.364	7173.537	7161.705	7149.868	7138.025	7209.000	7220.810	7232.614
1.990	7192.685	7180.864	7169.037	7157.205	7145.368	7133.524	7204.500	7216.310	7228.114
2.000	7188.185	7176.364	7164.537	7152.705	7140.867	7129.024	7200.000	7211.810	7223.614
2.100	7143.185	7131.363	7119.536	7107.703	7095.864	7084.019	7155.000	7166.810	7178.613
2.200	7098.184	7086.363	7074.535	7062.701	7050.860	7039.014	7110.000	7121.809	7133.613
2.300	7053.184	7041.362	7029.533	7017.698	7005.857	6994.009	7065.000	7076.809	7088.612
2.400	7008.184	6996.362	6984.532	6972.696	6960.853	6949.004	7020.000	7031.809	7043.612
2.500	6963.184	6951.361	6939.531	6927.694	6915.850	6903.998	6975.000	6986.809	6998.611
2.600	6918.184	6906.360	6894.530	6882.692	6870.846	6858.993	6930.000	6941.809	6953.610
2.700	6873.184	6861.360	6849.528	6837.689	6825.843	6813.988	6885.000	6896.809	6908.610
2.800	6828.184	6816.359	6804.527	6792.687	6780.839	6768.983	6840.000	6851.809	6863.609
2.900	6783.183	6771.359	6759.526	6747.685	6735.836	6723.978	6795.000	6806.808	6818.609
3.000	6738.183	6726.358	6714.525	6702.683	6690.832	6678.973	6750.000	6761.808	6773.608
3.100	6693.183	6681.358	6669.523	6657.680	6645.829	6633.968	6705.000	6716.808	6728.608
3.200	6648.183	6636.357	6624.522	6612.678	6600.825	6588.963	6660.000	6671.808	6683.607
3.300	6603.183	6591.356	6579.521	6567.676	6555.821	6543.958	6615.000	6626.808	6638.606
3.400	6558.183	6546.356	6534.519	6522.674	6510.818	6498.953	6570.000	6581.808	6593.606
3.500	6513.183	6501.355	6489.518	6477.671	6465.814	6453.948	6525.000	6536.808	6548.605
3.600	6468.182	6456.355	6444.517	6432.669	6420.811	6408.943	6480.000	6491.807	6503.605
3.700	6423.182	6411.354	6399.516	6387.667	6375.807	6363.938	6435.000	6446.807	6458.604
3.800	6378.182	6366.354	6354.514	6342.665	6330.804	6318.933	6390.000	6401.807	6413.604
3.900	6333.182	6321.353	6309.513	6297.662	6285.800	6273.928	6345.000	6356.807	6368.603
4.000	6288.182	6276.353	6264.512	6252.660	6240.797	6228.923	6300.000	6311.807	6323.603
4.100	6243.182	6231.352	6219.511	6207.658	6195.793	6183.917	6255.000	6266.807	6278.602
4.200	6198.182	6186.351	6174.509	6162.656	6150.790	6138.912	6210.000	6221.807	6233.601
4.300	6153.181	6141.351	6129.508	6117.653	6105.786	6093.907	6165.000	6176.806	6188.601
4.400	6108.181	6096.350	6084.507	6072.651	6060.783	6048.902	6120.000	6131.806	6143.600
4.500	6063.181	6051.350	6039.506	6027.649	6015.779	6003.897	6075.000	6086.806	6098.600
4.600	6018.181	6006.349	5994.504	5982.647	5970.776	5958.892	6030.000	6041.806	6053.599
4.700	5973.181	5961.349	5949.503	5937.644	5925.772	5913.887	5985.000	5996.806	6008.599
4.800	5928.181	5916.348	5904.502	5892.642	5880.769	5868.882	5940.000	5951.806	5963.598
4.900	5883.181	5871.347	5859.500	5847.640	5835.765	5823.877	5895.000	5906.806	5918.597
5.000	5838.180	5826.347	5814.499	5802.638	5790.762	5778.872	5850.000	5861.805	5873.597
5.100	5793.180	5781.346	5769.498	5757.635	5745.758	5733.867	5805.000	5816.805	5828.596
5.200	5748.180	5736.346	5724.497	5712.633	5700.755	5688.862	5760.000	5771.805	5783.596
5.300	5703.180	5691.345	5679.495	5667.631	5655.751	5643.857	5715.000	5726.805	5738.595

Ullage	Trim by stern in (m)						Even Keel	Trim by head in (m)	
	0.500	1.000	1.500	2.000	2.500	3.000		-0.500	-1.000
5.400	5658.180	5646.345	5634.494	5622.629	5610.748	5598.852	5670.000	5681.805	5693.595
5.500	5613.180	5601.344	5589.493	5577.626	5565.744	5553.847	5625.000	5636.805	5648.594
5.600	5568.180	5556.344	5544.492	5532.624	5520.741	5508.842	5580.000	5591.805	5603.594
5.700	5523.179	5511.343	5499.490	5487.622	5475.737	5463.836	5535.000	5546.804	5558.593
5.800	5478.179	5466.342	5454.489	5442.620	5430.734	5418.831	5490.000	5501.804	5513.592
5.900	5433.179	5421.342	5409.488	5397.617	5385.730	5373.826	5445.000	5456.804	5468.592
6.000	5388.179	5376.341	5364.487	5352.615	5340.727	5328.821	5400.000	5411.804	5423.591
6.100	5343.179	5331.341	5319.485	5307.613	5295.723	5283.816	5355.000	5366.804	5378.591
6.200	5298.179	5286.340	5274.484	5262.611	5250.720	5238.811	5310.000	5321.804	5333.590
6.300	5253.179	5241.340	5229.483	5217.608	5205.716	5193.806	5265.000	5276.804	5288.590
6.400	5208.179	5196.339	5184.482	5172.606	5160.713	5148.801	5220.000	5231.804	5243.589
6.500	5163.178	5151.338	5139.480	5127.604	5115.709	5103.796	5175.000	5186.803	5198.588
6.600	5118.178	5106.338	5094.479	5082.602	5070.705	5058.791	5130.000	5141.803	5153.588
6.700	5073.178	5061.337	5049.478	5037.599	5025.702	5013.786	5085.000	5096.803	5108.587
6.800	5028.178	5016.337	5004.476	4992.597	4980.698	4968.781	5040.000	5051.803	5063.587
6.900	4983.178	4971.336	4959.475	4947.595	4935.695	4923.776	4995.000	5006.803	5018.586
7.000	4938.178	4926.336	4914.474	4902.593	4890.691	4878.771	4950.000	4961.803	4973.586
7.100	4893.178	4881.335	4869.473	4857.590	4845.688	4833.766	4905.000	4916.803	4928.585
7.200	4848.177	4836.335	4824.471	4812.588	4800.684	4788.761	4860.000	4871.802	4883.585
7.300	4803.177	4791.334	4779.470	4767.586	4755.681	4743.755	4815.000	4826.802	4838.584
7.400	4758.177	4746.333	4734.469	4722.584	4710.677	4698.750	4770.000	4781.802	4793.583
7.500	4713.177	4701.333	4689.468	4677.581	4665.674	4653.745	4725.000	4736.802	4748.583
7.600	4668.177	4656.332	4644.466	4632.579	4620.670	4608.740	4680.000	4691.802	4703.582
7.700	4623.177	4611.332	4599.465	4587.577	4575.667	4563.735	4635.000	4646.802	4658.582
7.800	4578.177	4566.331	4554.464	4542.575	4530.663	4518.730	4590.000	4601.802	4613.581
7.900	4533.176	4521.331	4509.463	4497.572	4485.660	4473.725	4545.000	4556.801	4568.581
8.000	4488.176	4476.330	4464.461	4452.570	4440.656	4428.720	4500.000	4511.801	4523.580
8.100	4443.176	4431.329	4419.460	4407.568	4395.653	4383.715	4455.000	4466.801	4478.579
8.200	4398.176	4386.329	4374.459	4362.566	4350.649	4338.710	4410.000	4421.801	4433.579
8.300	4353.176	4341.328	4329.457	4317.563	4305.646	4293.705	4365.000	4376.801	4388.578
8.400	4308.176	4296.328	4284.456	4272.561	4260.642	4248.700	4320.000	4331.801	4343.578
8.500	4263.176	4251.327	4239.455	4227.559	4215.639	4203.695	4275.000	4286.801	4298.577
8.600	4218.175	4206.327	4194.454	4182.557	4170.635	4158.690	4230.000	4241.800	4253.577
8.700	4173.175	4161.326	4149.452	4137.554	4125.632	4113.685	4185.000	4196.800	4208.576
8.800	4128.175	4116.326	4104.451	4092.552	4080.628	4068.680	4140.000	4151.800	4163.576
8.900	4083.175	4071.325	4059.450	4047.550	4035.625	4023.674	4095.000	4106.800	4118.575
9.000	4038.175	4026.324	4014.449	4002.548	3990.621	3978.669	4050.000	4061.800	4073.574
9.100	3993.175	3981.324	3969.447	3957.545	3945.618	3933.664	4005.000	4016.800	4028.574
9.200	3948.175	3936.323	3924.446	3912.543	3900.614	3888.659	3960.000	3971.800	3983.573
9.300	3903.174	3891.323	3879.445	3867.541	3855.611	3843.654	3915.000	3926.799	3938.573
9.400	3858.174	3846.322	3834.444	3822.539	3810.607	3798.649	3870.000	3881.799	3893.572
9.500	3813.174	3801.322	3789.442	3777.536	3765.604	3753.644	3825.000	3836.799	3848.572
9.600	3768.174	3756.321	3744.441	3732.534	3720.600	3708.639	3780.000	3791.799	3803.571
9.700	3723.174	3711.320	3699.440	3687.532	3675.596	3663.634	3735.000	3746.799	3758.570
9.800	3678.174	3666.320	3654.438	3642.530	3630.593	3618.629	3690.000	3701.799	3713.570
9.900	3633.174	3621.319	3609.437	3597.527	3585.589	3573.624	3645.000	3656.799	3668.569
10.000	3588.173	3576.319	3564.436	3552.525	3540.586	3528.619	3600.000	3611.798	3623.569

Ullage	Trim by stern in (m)						Even Keel	Trim by head in (m)	
	0.500	1.000	1.500	2.000	2.500	3.000		-0.500	-1.000
10.100	3543.173	3531.318	3519.435	3507.523	3495.582	3483.614	3555.000	3566.798	3578.568
10.200	3498.173	3486.318	3474.433	3462.521	3450.579	3438.609	3510.000	3521.798	3533.568
10.300	3453.173	3441.317	3429.432	3417.518	3405.575	3393.604	3465.000	3476.798	3488.567
10.400	3408.173	3396.317	3384.431	3372.516	3360.572	3348.599	3420.000	3431.798	3443.567
10.500	3363.173	3351.316	3339.430	3327.514	3315.568	3303.593	3375.000	3386.798	3398.566
10.600	3318.173	3306.315	3294.428	3282.512	3270.565	3258.588	3330.000	3341.798	3353.565
10.700	3273.172	3261.315	3249.427	3237.509	3225.561	3213.583	3285.000	3296.797	3308.565
10.800	3228.172	3216.314	3204.426	3192.507	3180.558	3168.578	3240.000	3251.797	3263.564
10.900	3183.172	3171.314	3159.425	3147.505	3135.554	3123.573	3195.000	3206.797	3218.564
11.000	3138.172	3126.313	3114.423	3102.503	3090.551	3078.568	3150.000	3161.797	3173.563
11.100	3093.172	3081.313	3069.422	3057.500	3045.547	3033.563	3105.000	3116.797	3128.563
11.200	3048.172	3036.312	3024.421	3012.498	3000.544	2988.558	3060.000	3071.797	3083.562
11.300	3003.172	2991.311	2979.419	2967.496	2955.540	2943.553	3015.000	3026.797	3038.561
11.400	2958.171	2946.311	2934.418	2922.494	2910.537	2898.548	2970.000	2981.796	2993.561
11.500	2913.171	2901.310	2889.417	2877.491	2865.533	2853.543	2925.000	2936.796	2948.560
11.600	2868.171	2856.310	2844.416	2832.489	2820.530	2808.538	2880.000	2891.796	2903.560
11.700	2823.171	2811.309	2799.414	2787.487	2775.526	2763.533	2835.000	2846.796	2858.559
11.800	2778.171	2766.309	2754.413	2742.485	2730.523	2718.528	2790.000	2801.796	2813.559
11.900	2733.171	2721.308	2709.412	2697.482	2685.519	2673.523	2745.000	2756.796	2768.558
12.000	2688.171	2676.308	2664.411	2652.480	2640.516	2628.518	2700.000	2711.796	2723.558
12.100	2643.170	2631.307	2619.409	2607.478	2595.512	2583.512	2655.000	2666.795	2678.557
12.200	2598.170	2586.306	2574.408	2562.476	2550.509	2538.507	2610.000	2621.795	2633.556
12.300	2553.170	2541.306	2529.407	2517.473	2505.505	2493.502	2565.000	2576.795	2588.556
12.400	2508.170	2496.305	2484.406	2472.471	2460.502	2448.497	2520.000	2531.795	2543.555
12.500	2463.170	2451.305	2439.404	2427.469	2415.498	2403.492	2475.000	2486.795	2498.555
12.600	2418.170	2406.304	2394.403	2382.467	2370.495	2358.487	2430.000	2441.795	2453.554
12.700	2373.170	2361.304	2349.402	2337.464	2325.491	2313.482	2385.000	2396.795	2408.554
12.800	2328.170	2316.303	2304.401	2292.462	2280.488	2268.477	2340.000	2351.795	2363.553
12.900	2283.169	2271.302	2259.399	2247.460	2235.484	2223.472	2295.000	2306.794	2318.552
13.000	2238.169	2226.302	2214.398	2202.458	2190.480	2178.467	2250.000	2261.794	2273.552
13.100	2193.169	2181.301	2169.397	2157.455	2145.477	2133.462	2205.000	2216.794	2228.551
13.200	2148.169	2136.301	2124.395	2112.453	2100.473	2088.457	2160.000	2171.794	2183.551
13.300	2103.169	2091.300	2079.394	2067.451	2055.470	2043.452	2115.000	2126.794	2138.550
13.400	2058.169	2046.300	2034.393	2022.449	2010.466	1998.447	2070.000	2081.794	2093.550
13.500	2013.169	2001.299	1989.392	1977.446	1965.463	1953.442	2025.000	2036.794	2048.549
13.600	1968.168	1956.299	1944.390	1932.444	1920.459	1908.437	1980.000	1991.793	2003.549
13.700	1923.168	1911.298	1899.389	1887.442	1875.456	1863.431	1935.000	1946.793	1958.548
13.800	1878.168	1866.297	1854.388	1842.440	1830.452	1818.426	1890.000	1901.793	1913.547
13.900	1833.168	1821.297	1809.387	1797.437	1785.449	1773.421	1845.000	1856.793	1868.547
14.000	1788.168	1776.296	1764.385	1752.435	1740.445	1728.416	1800.000	1811.793	1823.546
14.100	1743.168	1731.296	1719.384	1707.433	1695.442	1683.411	1755.000	1766.793	1778.546
14.200	1698.168	1686.295	1674.383	1662.431	1650.438	1638.406	1710.000	1721.793	1733.545
14.300	1653.167	1641.295	1629.382	1617.428	1605.435	1593.401	1665.000	1676.792	1688.545
14.400	1608.167	1596.294	1584.380	1572.426	1560.431	1548.396	1620.000	1631.792	1643.544
14.500	1563.167	1551.293	1539.379	1527.424	1515.428	1503.391	1575.000	1586.792	1598.543
14.600	1518.167	1506.293	1494.378	1482.422	1470.424	1458.386	1530.000	1541.792	1553.543
14.700	1473.167	1461.292	1449.376	1437.419	1425.421	1413.381	1485.000	1496.792	1508.542

Ullage	Trim by stern in (m)						Even Keel	Trim by head in (m)	
	0.500	1.000	1.500	2.000	2.500	3.000		-0.500	-1.000
14.800	1428.167	1416.292	1404.375	1392.417	1380.417	1368.376	1440.000	1451.792	1463.542
14.900	1383.167	1371.291	1359.374	1347.415	1335.414	1323.371	1395.000	1406.792	1418.541
15.000	1338.166	1326.291	1314.373	1302.413	1290.410	1278.366	1350.000	1361.791	1373.541
15.100	1293.166	1281.290	1269.371	1257.410	1245.407	1233.361	1305.000	1316.791	1328.540
15.200	1248.166	1236.290	1224.370	1212.408	1200.403	1188.356	1260.000	1271.791	1283.540
15.300	1203.166	1191.289	1179.369	1167.406	1155.400	1143.350	1215.000	1226.791	1238.539
15.400	1158.166	1146.288	1134.368	1122.404	1110.396	1098.345	1170.000	1181.791	1193.538
15.500	1113.166	1101.288	1089.366	1077.401	1065.393	1053.340	1125.000	1136.791	1148.538
15.600	1068.166	1056.287	1044.365	1032.399	1020.389	1008.335	1080.000	1091.791	1103.537
15.700	1023.165	1011.287	999.364	987.397	975.386	963.330	1035.000	1046.790	1058.537
15.800	978.165	966.286	954.363	942.395	930.382	918.325	990.000	1001.790	1013.536
15.900	933.165	921.286	909.361	897.392	885.379	873.320	945.000	956.790	968.536
16.000	888.165	876.285	864.360	852.390	840.375	828.315	900.000	911.790	923.535
16.100	843.165	831.284	819.359	807.388	795.372	783.310	855.000	866.790	878.534
16.200	798.165	786.284	774.357	762.386	750.368	738.305	810.000	821.790	833.534
16.300	753.165	741.283	729.356	717.383	705.364	693.300	765.000	776.790	788.533
16.400	708.164	696.283	684.355	672.381	660.361	648.295	720.000	731.789	743.533
16.500	663.164	651.282	639.354	627.379	615.357	603.290	675.000	686.789	698.532
16.600	618.164	606.282	594.352	582.377	570.354	558.285	630.000	641.789	653.532
16.700	573.164	561.281	549.351	537.374	525.350	513.280	585.000	596.789	608.531
16.800	528.164	516.281	504.350	492.372	480.347	468.275	540.000	551.789	563.530
16.900	483.164	471.280	459.349	447.370	435.343	423.269	495.000	506.789	518.530
17.000	438.164	426.279	414.347	402.368	390.340	378.264	450.000	461.789	473.529
17.100	393.163	381.279	369.346	357.365	345.336	333.259	405.000	416.788	428.529
17.200	348.163	336.278	324.345	312.363	300.333	288.254	360.000	371.788	383.528
17.300	303.163	291.278	279.344	267.361	255.329	243.249	315.000	326.788	338.528
17.400	258.163	246.277	234.342	222.359	210.326	198.244	270.000	281.788	293.527
17.500	213.163	201.277	189.341	177.356	165.322	153.239	225.000	236.788	248.527
17.600	168.163	156.276	144.340	132.354	120.319	109.921	180.000	191.788	203.526
17.650	145.663	133.776	121.839	109.853	100.507	85.737	157.500	169.288	181.026
17.700	123.163	111.275	99.338	87.352	75.404	64.554	135.000	146.788	158.525
17.750	100.663	88.775	76.838	65.179	53.902	46.371	112.500	124.288	136.025
17.800	78.162	66.275	55.212	43.208	36.001	31.190	90.000	101.787	113.525
17.850	55.662	43.775	32.471	25.738	21.700	19.009	67.500	79.287	91.025
17.900	33.162	21.691	15.731	12.767	11.000	9.828	45.000	56.787	68.524
17.950	10.868	6.432	4.992	4.298	3.900	3.649	22.500	34.287	46.024
18.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Ullage Tables for 2 , 3 , 4 w/s Tanks

Ullage	Trim by stern in (m)						Even Keel	Trim by head in (m)	
	0.500	1.000	1.500	2.000	2.500	3.000		-0.500	-1.000
0.000	9702.450	9684.900	9667.350	9649.800	9632.250	9614.700	9720.000	9719.910	9719.820
0.010	9697.050	9679.500	9661.950	9644.400	9626.850	9609.299	9714.600	9719.190	9719.280
0.020	9691.650	9674.100	9656.550	9638.999	9621.449	9603.899	9709.200	9718.200	9718.380
0.030	9686.250	9668.700	9651.150	9633.599	9616.049	9598.498	9703.800	9715.590	9717.120
0.040	9680.850	9663.300	9645.749	9628.199	9610.648	9593.098	9698.400	9713.520	9715.500
0.050	9675.450	9657.900	9640.349	9622.799	9605.248	9587.697	9693.000	9709.110	9713.520
0.060	9670.050	9652.500	9634.949	9617.398	9599.847	9582.296	9687.600	9705.960	9711.180
0.070	9664.650	9647.100	9629.549	9611.998	9594.447	9576.896	9682.200	9699.750	9708.480
0.080	9659.250	9641.699	9624.149	9606.598	9589.047	9571.495	9676.800	9694.350	9705.420
0.090	9653.850	9636.299	9618.749	9601.198	9583.646	9566.095	9671.400	9688.950	9702.000
0.100	9648.450	9630.899	9613.348	9595.797	9578.246	9560.694	9666.000	9683.550	9698.220
0.110	9643.050	9625.499	9607.948	9590.397	9572.845	9555.293	9660.600	9678.150	9694.080
0.120	9637.650	9620.099	9602.548	9584.997	9567.445	9549.893	9655.200	9672.750	9689.580
0.130	9632.250	9614.699	9597.148	9579.596	9562.045	9544.492	9649.800	9667.350	9684.720
0.140	9626.850	9609.299	9591.748	9574.196	9556.644	9539.091	9644.400	9661.950	9679.500
0.150	9621.450	9603.899	9586.348	9568.796	9551.244	9533.691	9639.000	9656.550	9674.099
0.160	9616.050	9598.499	9580.948	9563.396	9545.843	9528.290	9633.600	9651.150	9668.699
0.170	9610.650	9593.099	9575.547	9557.995	9540.443	9522.890	9628.200	9645.750	9663.299
0.180	9605.250	9587.699	9570.147	9552.595	9535.042	9517.489	9622.800	9640.350	9657.899
0.190	9599.850	9582.299	9564.747	9547.195	9529.642	9512.088	9617.400	9634.950	9652.499
0.200	9594.450	9576.899	9559.347	9541.795	9524.242	9506.688	9612.000	9629.550	9647.099
0.210	9589.050	9571.499	9553.947	9536.394	9518.841	9501.287	9606.600	9624.150	9641.699
0.220	9583.650	9566.099	9548.547	9530.994	9513.441	9495.887	9601.200	9618.750	9636.299
0.230	9578.250	9560.698	9543.147	9525.594	9508.040	9490.486	9595.800	9613.350	9630.898
0.240	9572.850	9555.298	9537.746	9520.194	9502.640	9485.085	9590.400	9607.950	9625.498
0.250	9567.450	9549.898	9532.346	9514.793	9497.239	9479.685	9585.000	9602.550	9620.098
0.260	9562.050	9544.498	9526.946	9509.393	9491.839	9474.284	9579.600	9597.150	9614.698
0.270	9556.650	9539.098	9521.546	9503.993	9486.439	9468.884	9574.200	9591.750	9609.298
0.280	9551.250	9533.698	9516.146	9498.592	9481.038	9463.483	9568.800	9586.350	9603.898
0.290	9545.850	9528.298	9510.746	9493.192	9475.638	9458.082	9563.400	9580.950	9598.498
0.300	9540.449	9522.898	9505.345	9487.792	9470.237	9452.682	9558.000	9575.549	9593.098
0.310	9535.049	9517.498	9499.945	9482.392	9464.837	9447.281	9552.600	9570.149	9587.698
0.320	9529.649	9512.098	9494.545	9476.991	9459.437	9441.881	9547.200	9564.749	9582.298
0.330	9524.249	9506.698	9489.145	9471.591	9454.036	9436.480	9541.800	9559.349	9576.898
0.340	9518.849	9501.298	9483.745	9466.191	9448.636	9431.079	9536.400	9553.949	9571.498
0.350	9513.449	9495.898	9478.345	9460.791	9443.235	9425.679	9531.000	9548.549	9566.098
0.360	9508.049	9490.498	9472.945	9455.390	9437.835	9420.278	9525.600	9543.149	9560.698
0.370	9502.649	9485.098	9467.544	9449.990	9432.434	9414.878	9520.200	9537.749	9555.298
0.380	9497.249	9479.697	9462.144	9444.590	9427.034	9409.477	9514.800	9532.349	9549.897
0.390	9491.849	9474.297	9456.744	9439.189	9421.634	9404.076	9509.400	9526.949	9544.497
0.400	9486.449	9468.897	9451.344	9433.789	9416.233	9398.676	9504.000	9521.549	9539.097
0.410	9481.049	9463.497	9445.944	9428.389	9410.833	9393.275	9498.600	9516.149	9533.697
0.420	9475.649	9458.097	9440.544	9422.989	9405.432	9387.874	9493.200	9510.749	9528.297
0.430	9470.249	9452.697	9435.143	9417.588	9400.032	9382.474	9487.800	9505.349	9522.897
0.440	9464.849	9447.297	9429.743	9412.188	9394.631	9377.073	9482.400	9499.949	9517.497

Ullage	Trim by stern in (m)						Even Keel	Trim by head in (m)	
	0.500	1.000	1.500	2.000	2.500	3.000		-0.500	-1.000
0.450	9459.449	9441.897	9424.343	9406.788	9389.231	9371.673	9477.000	9494.549	9512.097
0.460	9454.049	9436.497	9418.943	9401.388	9383.831	9366.272	9471.600	9489.149	9506.697
0.470	9448.649	9431.097	9413.543	9395.987	9378.430	9360.871	9466.200	9483.749	9501.297
0.480	9443.249	9425.697	9408.143	9390.587	9373.030	9355.471	9460.800	9478.349	9495.897
0.490	9437.849	9420.297	9402.743	9385.187	9367.629	9350.070	9455.400	9472.949	9490.497
0.500	9432.449	9414.897	9397.342	9379.787	9362.229	9344.670	9450.000	9467.549	9485.097
0.510	9427.049	9409.497	9391.942	9374.386	9356.828	9339.269	9444.600	9462.149	9479.697
0.520	9421.649	9404.096	9386.542	9368.986	9351.428	9333.868	9439.200	9456.749	9474.296
0.530	9416.249	9398.696	9381.142	9363.586	9346.028	9328.468	9433.800	9451.349	9468.896
0.540	9410.849	9393.296	9375.742	9358.185	9340.627	9323.067	9428.400	9445.949	9463.496
0.550	9405.449	9387.896	9370.342	9352.785	9335.227	9317.667	9423.000	9440.549	9458.096
0.560	9400.049	9382.496	9364.941	9347.385	9329.826	9312.266	9417.600	9435.149	9452.696
0.570	9394.649	9377.096	9359.541	9341.985	9324.426	9306.865	9412.200	9429.749	9447.296
0.580	9389.249	9371.696	9354.141	9336.584	9319.026	9301.465	9406.800	9424.349	9441.896
0.590	9383.849	9366.296	9348.741	9331.184	9313.625	9296.064	9401.400	9418.949	9436.496
0.600	9378.449	9360.896	9343.341	9325.784	9308.225	9290.664	9396.000	9413.549	9431.096
0.610	9373.049	9355.496	9337.941	9320.384	9302.824	9285.263	9390.600	9408.149	9425.696
0.620	9367.649	9350.096	9332.541	9314.983	9297.424	9279.862	9385.200	9402.749	9420.296
0.630	9362.249	9344.696	9327.140	9309.583	9292.023	9274.462	9379.800	9397.349	9414.896
0.640	9356.849	9339.296	9321.740	9304.183	9286.623	9269.061	9374.400	9391.949	9409.496
0.650	9351.449	9333.896	9316.340	9298.782	9281.223	9263.661	9369.000	9386.549	9404.096
0.660	9346.049	9328.496	9310.940	9293.382	9275.822	9258.260	9363.600	9381.149	9398.696
0.670	9340.649	9323.095	9305.540	9287.982	9270.422	9252.859	9358.200	9375.749	9393.295
0.680	9335.249	9317.695	9300.140	9282.582	9265.021	9247.459	9352.800	9370.349	9387.895
0.690	9329.849	9312.295	9294.740	9277.181	9259.621	9242.058	9347.400	9364.949	9382.495
0.700	9324.449	9306.895	9289.339	9271.781	9254.220	9236.657	9342.000	9359.549	9377.095
0.710	9319.049	9301.495	9283.939	9266.381	9248.820	9231.257	9336.600	9354.149	9371.695
0.720	9313.649	9296.095	9278.539	9260.981	9243.420	9225.856	9331.200	9348.749	9366.295
0.730	9308.249	9290.695	9273.139	9255.580	9238.019	9220.456	9325.800	9343.349	9360.895
0.740	9302.849	9285.295	9267.739	9250.180	9232.619	9215.055	9320.400	9337.949	9355.495
0.750	9297.449	9279.895	9262.339	9244.780	9227.218	9209.654	9315.000	9332.549	9350.095
0.760	9292.049	9274.495	9256.938	9239.379	9221.818	9204.254	9309.600	9327.149	9344.695
0.770	9286.649	9269.095	9251.538	9233.979	9216.418	9198.853	9304.200	9321.749	9339.295
0.780	9281.249	9263.695	9246.138	9228.579	9211.017	9193.453	9298.800	9316.349	9333.895
0.790	9275.849	9258.295	9240.738	9223.179	9205.617	9188.052	9293.400	9310.949	9328.495
0.800	9270.449	9252.895	9235.338	9217.778	9200.216	9182.651	9288.000	9305.549	9323.095
0.810	9265.049	9247.495	9229.938	9212.378	9194.816	9177.251	9282.600	9300.149	9317.695
0.820	9259.649	9242.094	9224.538	9206.978	9189.415	9171.850	9277.200	9294.749	9312.294
0.830	9254.249	9236.694	9219.137	9201.578	9184.015	9166.450	9271.800	9289.349	9306.894
0.840	9248.849	9231.294	9213.737	9196.177	9178.615	9161.049	9266.400	9283.949	9301.494
0.850	9243.449	9225.894	9208.337	9190.777	9173.214	9155.648	9261.000	9278.549	9296.094
0.860	9238.049	9220.494	9202.937	9185.377	9167.814	9150.248	9255.600	9273.149	9290.694
0.870	9232.649	9215.094	9197.537	9179.977	9162.413	9144.847	9250.200	9267.749	9285.294
0.880	9227.249	9209.694	9192.137	9174.576	9157.013	9139.447	9244.800	9262.349	9279.894
0.890	9221.848	9204.294	9186.736	9169.176	9151.612	9134.046	9239.400	9256.948	9274.494
0.900	9216.448	9198.894	9181.336	9163.776	9146.212	9128.645	9234.000	9251.548	9269.094
0.910	9211.048	9193.494	9175.936	9158.375	9140.812	9123.245	9228.600	9246.148	9263.694

Ullage	Trim by stern in (m)						Even Keel	Trim by head in (m)	
	0.500	1.000	1.500	2.000	2.500	3.000		-0.500	-1.000
0.920	9205.648	9188.094	9170.536	9152.975	9135.411	9117.844	9223.200	9240.748	9258.294
0.930	9200.248	9182.694	9165.136	9147.575	9130.011	9112.444	9217.800	9235.348	9252.894
0.940	9194.848	9177.294	9159.736	9142.175	9124.610	9107.043	9212.400	9229.948	9247.494
0.950	9189.448	9171.894	9154.336	9136.774	9119.210	9101.642	9207.000	9224.548	9242.094
0.960	9184.048	9166.494	9148.935	9131.374	9113.810	9096.242	9201.600	9219.148	9236.694
0.970	9178.648	9161.093	9143.535	9125.974	9108.409	9090.841	9196.200	9213.748	9231.293
0.980	9173.248	9155.693	9138.135	9120.574	9103.009	9085.440	9190.800	9208.348	9225.893
0.990	9167.848	9150.293	9132.735	9115.173	9097.608	9080.040	9185.400	9202.948	9220.493
1.000	9162.448	9144.893	9127.335	9109.773	9092.208	9074.639	9180.000	9197.548	9215.093
1.010	9157.048	9139.493	9121.935	9104.373	9086.807	9069.239	9174.600	9192.148	9209.693
1.020	9151.648	9134.093	9116.535	9098.972	9081.407	9063.838	9169.200	9186.748	9204.293
1.030	9146.248	9128.693	9111.134	9093.572	9076.007	9058.437	9163.800	9181.348	9198.893
1.040	9140.848	9123.293	9105.734	9088.172	9070.606	9053.037	9158.400	9175.948	9193.493
1.050	9135.448	9117.893	9100.334	9082.772	9065.206	9047.636	9153.000	9170.548	9188.093
1.060	9130.048	9112.493	9094.934	9077.371	9059.805	9042.236	9147.600	9165.148	9182.693
1.070	9124.648	9107.093	9089.534	9071.971	9054.405	9036.835	9142.200	9159.748	9177.293
1.080	9119.248	9101.693	9084.134	9066.571	9049.004	9031.434	9136.800	9154.348	9171.893
1.090	9113.848	9096.293	9078.733	9061.171	9043.604	9026.034	9131.400	9148.948	9166.493
1.100	9108.448	9090.893	9073.333	9055.770	9038.204	9020.633	9126.000	9143.548	9161.093
1.110	9103.048	9085.493	9067.933	9050.370	9032.803	9015.233	9120.600	9138.148	9155.693
1.120	9097.648	9080.092	9062.533	9044.970	9027.403	9009.832	9115.200	9132.748	9150.292
1.130	9092.248	9074.692	9057.133	9039.569	9022.002	9004.431	9109.800	9127.348	9144.892
1.140	9086.848	9069.292	9051.733	9034.169	9016.602	8999.031	9104.400	9121.948	9139.492
1.150	9081.448	9063.892	9046.333	9028.769	9011.201	8993.630	9099.000	9116.548	9134.092
1.160	9076.048	9058.492	9040.932	9023.369	9005.801	8988.230	9093.600	9111.148	9128.692
1.170	9070.648	9053.092	9035.532	9017.968	9000.401	8982.829	9088.200	9105.748	9123.292
1.180	9065.248	9047.692	9030.132	9012.568	8995.000	8977.428	9082.800	9100.348	9117.892
1.190	9059.848	9042.292	9024.732	9007.168	8989.600	8972.028	9077.400	9094.948	9112.492
1.200	9054.448	9036.892	9019.332	9001.768	8984.199	8966.627	9072.000	9089.548	9107.092
1.210	9049.048	9031.492	9013.932	8996.367	8978.799	8961.226	9066.600	9084.148	9101.692
1.220	9043.648	9026.092	9008.531	8990.967	8973.399	8955.826	9061.200	9078.748	9096.292
1.230	9038.248	9020.692	9003.131	8985.567	8967.998	8950.425	9055.800	9073.348	9090.892
1.240	9032.848	9015.292	8997.731	8980.167	8962.598	8945.025	9050.400	9067.948	9085.492
1.250	9027.448	9009.892	8992.331	8974.766	8957.197	8939.624	9045.000	9062.548	9080.092
1.260	9022.048	9004.491	8986.931	8969.366	8951.797	8934.223	9039.600	9057.148	9074.691
1.270	9016.648	8999.091	8981.531	8963.966	8946.396	8928.823	9034.200	9051.748	9069.291
1.280	9011.248	8993.691	8976.131	8958.565	8940.996	8923.422	9028.800	9046.348	9063.891
1.290	9005.848	8988.291	8970.730	8953.165	8935.596	8918.022	9023.400	9040.948	9058.491
1.300	9000.448	8982.891	8965.330	8947.765	8930.195	8912.621	9018.000	9035.548	9053.091
1.310	8995.048	8977.491	8959.930	8942.365	8924.795	8907.220	9012.600	9030.148	9047.691
1.320	8989.648	8972.091	8954.530	8936.964	8919.394	8901.820	9007.200	9024.748	9042.291
1.330	8984.248	8966.691	8949.130	8931.564	8913.994	8896.419	9001.800	9019.348	9036.891
1.340	8978.848	8961.291	8943.730	8926.164	8908.593	8891.019	8996.400	9013.948	9031.491
1.350	8973.448	8955.891	8938.329	8920.764	8903.193	8885.618	8991.000	9008.548	9026.091
1.360	8968.048	8950.491	8932.929	8915.363	8897.793	8880.217	8985.600	9003.148	9020.691
1.370	8962.648	8945.091	8927.529	8909.963	8892.392	8874.817	8980.200	8997.748	9015.291
1.380	8957.248	8939.691	8922.129	8904.563	8886.992	8869.416	8974.800	8992.348	9009.891

Ullage	Trim by stern in (m)						Even Keel	Trim by head in (m)	
	0.500	1.000	1.500	2.000	2.500	3.000		-0.500	-1.000
1.390	8951.848	8934.291	8916.729	8899.162	8881.591	8864.016	8969.400	8986.948	9004.491
1.400	8946.448	8928.891	8911.329	8893.762	8876.191	8858.615	8964.000	8981.548	8999.091
1.410	8941.048	8923.490	8905.929	8888.362	8870.791	8853.214	8958.600	8976.148	8993.690
1.420	8935.648	8918.090	8900.528	8882.962	8865.390	8847.814	8953.200	8970.748	8988.290
1.430	8930.248	8912.690	8895.128	8877.561	8859.990	8842.413	8947.800	8965.348	8982.890
1.440	8924.848	8907.290	8889.728	8872.161	8854.589	8837.013	8942.400	8959.948	8977.490
1.450	8919.448	8901.890	8884.328	8866.761	8849.189	8831.612	8937.000	8954.548	8972.090
1.460	8914.048	8896.490	8878.928	8861.361	8843.788	8826.211	8931.600	8949.148	8966.690
1.470	8908.648	8891.090	8873.528	8855.960	8838.388	8820.811	8926.200	8943.748	8961.290
1.480	8903.248	8885.690	8868.128	8850.560	8832.988	8815.410	8920.800	8938.348	8955.890
1.490	8897.847	8880.290	8862.727	8845.160	8827.587	8810.009	8915.400	8932.947	8950.490
1.500	8892.447	8874.890	8857.327	8839.760	8822.187	8804.609	8910.000	8927.547	8945.090
1.510	8887.047	8869.490	8851.927	8834.359	8816.786	8799.208	8904.600	8922.147	8939.690
1.520	8881.647	8864.090	8846.527	8828.959	8811.386	8793.808	8899.200	8916.747	8934.290
1.530	8876.247	8858.690	8841.127	8823.559	8805.985	8788.407	8893.800	8911.347	8928.890
1.540	8870.847	8853.290	8835.727	8818.158	8800.585	8783.006	8888.400	8905.947	8923.490
1.550	8865.447	8847.890	8830.326	8812.758	8795.185	8777.606	8883.000	8900.547	8918.090
1.560	8860.047	8842.489	8824.926	8807.358	8789.784	8772.205	8877.600	8895.147	8912.689
1.570	8854.647	8837.089	8819.526	8801.958	8784.384	8766.805	8872.200	8889.747	8907.289
1.580	8849.247	8831.689	8814.126	8796.557	8778.983	8761.404	8866.800	8884.347	8901.889
1.590	8843.847	8826.289	8808.726	8791.157	8773.583	8756.003	8861.400	8878.947	8896.489
1.600	8838.447	8820.889	8803.326	8785.757	8768.183	8750.603	8856.000	8873.547	8891.089
1.610	8833.047	8815.489	8797.926	8780.357	8762.782	8745.202	8850.600	8868.147	8885.689
1.620	8827.647	8810.089	8792.525	8774.956	8757.382	8739.802	8845.200	8862.747	8880.289
1.630	8822.247	8804.689	8787.125	8769.556	8751.981	8734.401	8839.800	8857.347	8874.889
1.640	8816.847	8799.289	8781.725	8764.156	8746.581	8729.000	8834.400	8851.947	8869.489
1.650	8811.447	8793.889	8776.325	8758.755	8741.180	8723.600	8829.000	8846.547	8864.089
1.660	8806.047	8788.489	8770.925	8753.355	8735.780	8718.199	8823.600	8841.147	8858.689
1.670	8800.647	8783.089	8765.525	8747.955	8730.380	8712.799	8818.200	8835.747	8853.289
1.680	8795.247	8777.689	8760.124	8742.555	8724.979	8707.398	8812.800	8830.347	8847.889
1.690	8789.847	8772.289	8754.724	8737.154	8719.579	8701.997	8807.400	8824.947	8842.489
1.700	8784.447	8766.889	8749.324	8731.754	8714.178	8696.597	8802.000	8819.547	8837.089
1.710	8779.047	8761.488	8743.924	8726.354	8708.778	8691.196	8796.600	8814.147	8831.688
1.720	8773.647	8756.088	8738.524	8720.954	8703.377	8685.796	8791.200	8808.747	8826.288
1.730	8768.247	8750.688	8733.124	8715.553	8697.977	8680.395	8785.800	8803.347	8820.888
1.740	8762.847	8745.288	8727.724	8710.153	8692.577	8674.994	8780.400	8797.947	8815.488
1.750	8757.447	8739.888	8722.323	8704.753	8687.176	8669.594	8775.000	8792.547	8810.088
1.760	8752.047	8734.488	8716.923	8699.352	8681.776	8664.193	8769.600	8787.147	8804.688
1.770	8746.647	8729.088	8711.523	8693.952	8676.375	8658.792	8764.200	8781.747	8799.288
1.780	8741.247	8723.688	8706.123	8688.552	8670.975	8653.392	8758.800	8776.347	8793.888
1.790	8735.847	8718.288	8700.723	8683.152	8665.574	8647.991	8753.400	8770.947	8788.488
1.800	8730.447	8712.888	8695.323	8677.751	8660.174	8642.591	8748.000	8765.547	8783.088
1.810	8725.047	8707.488	8689.923	8672.351	8654.774	8637.190	8742.600	8760.147	8777.688
1.820	8719.647	8702.088	8684.522	8666.951	8649.373	8631.789	8737.200	8754.747	8772.288
1.830	8714.247	8696.688	8679.122	8661.551	8643.973	8626.389	8731.800	8749.347	8766.888
1.840	8708.847	8691.288	8673.722	8656.150	8638.572	8620.988	8726.400	8743.947	8761.488

Ullage	Trim by stern in (m)						Even Keel	Trim by head in (m)	
	0.500	1.000	1.500	2.000	2.500	3.000		-0.500	-1.000
1.850	8703.447	8685.888	8668.322	8650.750	8633.172	8615.588	8721.000	8738.547	8756.088
1.860	8698.047	8680.487	8662.922	8645.350	8627.772	8610.187	8715.600	8733.147	8750.687
1.870	8692.647	8675.087	8657.522	8639.950	8622.371	8604.786	8710.200	8727.747	8745.287
1.880	8687.247	8669.687	8652.121	8634.549	8616.971	8599.386	8704.800	8722.347	8739.887
1.890	8681.847	8664.287	8646.721	8629.149	8611.570	8593.985	8699.400	8716.947	8734.487
1.900	8676.447	8658.887	8641.321	8623.749	8606.170	8588.585	8694.000	8711.547	8729.087
1.910	8671.047	8653.487	8635.921	8618.348	8600.769	8583.184	8688.600	8706.147	8723.687
1.920	8665.647	8648.087	8630.521	8612.948	8595.369	8577.783	8683.200	8700.747	8718.287
1.930	8660.247	8642.687	8625.121	8607.548	8589.969	8572.383	8677.800	8695.347	8712.887
1.940	8654.847	8637.287	8619.721	8602.148	8584.568	8566.982	8672.400	8689.947	8707.487
1.950	8649.447	8631.887	8614.320	8596.747	8579.168	8561.582	8667.000	8684.547	8702.087
1.960	8644.047	8626.487	8608.920	8591.347	8573.767	8556.181	8661.600	8679.147	8696.687
1.970	8638.647	8621.087	8603.520	8585.947	8568.367	8550.780	8656.200	8673.747	8691.287
1.980	8633.247	8615.687	8598.120	8580.547	8562.966	8545.380	8650.800	8668.347	8685.887
1.990	8627.847	8610.287	8592.720	8575.146	8557.566	8539.979	8645.400	8662.947	8680.487
2.000	8622.447	8604.887	8587.320	8569.746	8552.166	8534.579	8640.000	8657.547	8675.087
2.100	8568.446	8550.886	8533.318	8515.743	8498.161	8480.572	8586.000	8603.546	8621.086
2.200	8514.446	8496.885	8479.317	8461.741	8444.157	8426.566	8532.000	8549.546	8567.085
2.300	8460.446	8442.884	8425.315	8407.738	8390.153	8372.560	8478.000	8495.546	8513.084
2.400	8406.446	8388.884	8371.314	8353.735	8336.149	8318.554	8424.000	8441.546	8459.084
2.500	8352.446	8334.883	8317.312	8299.733	8282.145	8264.548	8370.000	8387.546	8405.083
2.600	8298.446	8280.882	8263.311	8245.730	8228.140	8210.542	8316.000	8333.546	8351.082
2.700	8244.445	8226.882	8209.309	8191.727	8174.136	8156.536	8262.000	8279.545	8297.082
2.800	8190.445	8172.881	8155.307	8137.724	8120.132	8102.530	8208.000	8225.545	8243.081
2.900	8136.445	8118.880	8101.306	8083.722	8066.128	8048.524	8154.000	8171.545	8189.080
3.000	8082.445	8064.880	8047.304	8029.719	8012.123	7994.518	8100.000	8117.545	8135.080
3.100	8028.445	8010.879	7993.303	7975.716	7958.119	7940.512	8046.000	8063.545	8081.079
3.200	7974.445	7956.878	7939.301	7921.714	7904.115	7886.506	7992.000	8009.545	8027.078
3.300	7920.444	7902.878	7885.300	7867.711	7850.111	7832.500	7938.000	7955.544	7973.078
3.400	7866.444	7848.877	7831.298	7813.708	7796.107	7778.493	7884.000	7901.544	7919.077
3.500	7812.444	7794.876	7777.297	7759.706	7742.102	7724.487	7830.000	7847.544	7865.076
3.600	7758.444	7740.876	7723.295	7705.703	7688.098	7670.481	7776.000	7793.544	7811.076
3.700	7704.444	7686.875	7669.294	7651.700	7634.094	7616.475	7722.000	7739.544	7757.075
3.800	7650.444	7632.874	7615.292	7597.697	7580.090	7562.469	7668.000	7685.544	7703.074
3.900	7596.443	7578.874	7561.291	7543.695	7526.085	7508.463	7614.000	7631.543	7649.074
4.000	7542.443	7524.873	7507.289	7489.692	7472.081	7454.457	7560.000	7577.543	7595.073
4.100	7488.443	7470.872	7453.288	7435.689	7418.077	7400.451	7506.000	7523.543	7541.072
4.200	7434.443	7416.872	7399.286	7381.687	7364.073	7346.445	7452.000	7469.543	7487.072
4.300	7380.443	7362.871	7345.285	7327.684	7310.069	7292.439	7398.000	7415.543	7433.071
4.400	7326.443	7308.870	7291.283	7273.681	7256.064	7238.433	7344.000	7361.543	7379.070
4.500	7272.442	7254.870	7237.282	7219.679	7202.060	7184.427	7290.000	7307.542	7325.070
4.600	7218.442	7200.869	7183.280	7165.676	7148.056	7130.421	7236.000	7253.542	7271.069
4.700	7164.442	7146.868	7129.279	7111.673	7094.052	7076.414	7182.000	7199.542	7217.068
4.800	7110.442	7092.868	7075.277	7057.670	7040.048	7022.408	7128.000	7145.542	7163.068
4.900	7056.442	7038.867	7021.276	7003.668	6986.043	6968.402	7074.000	7091.542	7109.067
5.000	7002.442	6984.866	6967.274	6949.665	6932.039	6914.396	7020.000	7037.542	7055.066

Ullage	Trim by stern in (m)						Even Keel	Trim by head in (m)	
	0.500	1.000	1.500	2.000	2.500	3.000		-0.500	-1.000
5.100	6948.441	6930.866	6913.273	6895.662	6878.035	6860.390	6966.000	6983.541	7001.066
5.200	6894.441	6876.865	6859.271	6841.660	6824.031	6806.384	6912.000	6929.541	6947.065
5.300	6840.441	6822.864	6805.270	6787.657	6770.026	6752.378	6858.000	6875.541	6893.064
5.400	6786.441	6768.864	6751.268	6733.654	6716.022	6698.372	6804.000	6821.541	6839.064
5.500	6732.441	6714.863	6697.266	6679.652	6662.018	6644.366	6750.000	6767.541	6785.063
5.600	6678.441	6660.862	6643.265	6625.649	6608.014	6590.360	6696.000	6713.541	6731.062
5.700	6624.440	6606.862	6589.263	6571.646	6554.010	6536.354	6642.000	6659.540	6677.062
5.800	6570.440	6552.861	6535.262	6517.643	6500.005	6482.348	6588.000	6605.540	6623.061
5.900	6516.440	6498.860	6481.260	6463.641	6446.001	6428.342	6534.000	6551.540	6569.060
6.000	6462.440	6444.860	6427.259	6409.638	6391.997	6374.336	6480.000	6497.540	6515.060
6.100	6408.440	6390.859	6373.257	6355.635	6337.993	6320.329	6426.000	6443.540	6461.059
6.200	6354.440	6336.858	6319.256	6301.633	6283.988	6266.323	6372.000	6389.540	6407.058
6.300	6300.439	6282.857	6265.254	6247.630	6229.984	6212.317	6318.000	6335.539	6353.057
6.400	6246.439	6228.857	6211.253	6193.627	6175.980	6158.311	6264.000	6281.539	6299.057
6.500	6192.439	6174.856	6157.251	6139.625	6121.976	6104.305	6210.000	6227.539	6245.056
6.600	6138.439	6120.855	6103.250	6085.622	6067.972	6050.299	6156.000	6173.539	6191.055
6.700	6084.439	6066.855	6049.248	6031.619	6013.967	5996.293	6102.000	6119.539	6137.055
6.800	6030.439	6012.854	5995.247	5977.616	5959.963	5942.287	6048.000	6065.539	6083.054
6.900	5976.438	5958.853	5941.245	5923.614	5905.959	5888.281	5994.000	6011.538	6029.053
7.000	5922.438	5904.853	5887.244	5869.611	5851.955	5834.275	5940.000	5957.538	5975.053
7.100	5868.438	5850.852	5833.242	5815.608	5797.950	5780.269	5886.000	5903.538	5921.052
7.200	5814.438	5796.851	5779.241	5761.606	5743.946	5726.263	5832.000	5849.538	5867.051
7.300	5760.438	5742.851	5725.239	5707.603	5689.942	5672.257	5778.000	5795.538	5813.051
7.400	5706.438	5688.850	5671.238	5653.600	5635.938	5618.250	5724.000	5741.538	5759.050
7.500	5652.437	5634.849	5617.236	5599.598	5581.934	5564.244	5670.000	5687.537	5705.049
7.600	5598.437	5580.849	5563.235	5545.595	5527.929	5510.238	5616.000	5633.537	5651.049
7.700	5544.437	5526.848	5509.233	5491.592	5473.925	5456.232	5562.000	5579.537	5597.048
7.800	5490.437	5472.847	5455.232	5437.589	5419.921	5402.226	5508.000	5525.537	5543.047
7.900	5436.437	5418.847	5401.230	5383.587	5365.917	5348.220	5454.000	5471.537	5489.047
8.000	5382.436	5364.846	5347.228	5329.584	5311.913	5294.214	5400.000	5417.536	5435.046
8.100	5328.436	5310.845	5293.227	5275.581	5257.908	5240.208	5346.000	5363.536	5381.045
8.200	5274.436	5256.845	5239.225	5221.579	5203.904	5186.202	5292.000	5309.536	5327.045
8.300	5220.436	5202.844	5185.224	5167.576	5149.900	5132.196	5238.000	5255.536	5273.044
8.400	5166.436	5148.843	5131.222	5113.573	5095.896	5078.190	5184.000	5201.536	5219.043
8.500	5112.436	5094.843	5077.221	5059.571	5041.891	5024.184	5130.000	5147.536	5165.043
8.600	5058.435	5040.842	5023.219	5005.568	4987.887	4970.178	5076.000	5093.535	5111.042
8.700	5004.435	4986.841	4969.218	4951.565	4933.883	4916.172	5022.000	5039.535	5057.041
8.800	4950.435	4932.841	4915.216	4897.562	4879.879	4862.165	4968.000	4985.535	5003.041
8.900	4896.435	4878.840	4861.215	4843.560	4825.875	4808.159	4914.000	4931.535	4949.040
9.000	4842.435	4824.839	4807.213	4789.557	4771.870	4754.153	4860.000	4877.535	4895.039
9.100	4788.435	4770.839	4753.212	4735.554	4717.866	4700.147	4806.000	4823.535	4841.039
9.200	4734.434	4716.838	4699.210	4681.552	4663.862	4646.141	4752.000	4769.534	4787.038
9.300	4680.434	4662.837	4645.209	4627.549	4609.858	4592.135	4698.000	4715.534	4733.037
9.400	4626.434	4608.837	4591.207	4573.546	4555.853	4538.129	4644.000	4661.534	4679.037
9.500	4572.434	4554.836	4537.206	4519.544	4501.849	4484.123	4590.000	4607.534	4625.036
9.600	4518.434	4500.835	4483.204	4465.541	4447.845	4430.117	4536.000	4553.534	4571.035

Ullage	Trim by stern in (m)						Even Keel	Trim by head in (m)	
	0.500	1.000	1.500	2.000	2.500	3.000		-0.500	-1.000
9.700	4464.434	4446.835	4429.203	4411.538	4393.841	4376.111	4482.000	4499.534	4517.035
9.800	4410.433	4392.834	4375.201	4357.535	4339.837	4322.105	4428.000	4445.533	4463.034
9.900	4356.433	4338.833	4321.200	4303.533	4285.832	4268.099	4374.000	4391.533	4409.033
10.000	4302.433	4284.833	4267.198	4249.530	4231.828	4214.093	4320.000	4337.533	4355.033
10.100	4248.433	4230.832	4213.197	4195.527	4177.824	4160.086	4266.000	4283.533	4301.032
10.200	4194.433	4176.831	4159.195	4141.525	4123.820	4106.080	4212.000	4229.533	4247.031
10.300	4140.433	4122.830	4105.194	4087.522	4069.815	4052.074	4158.000	4175.533	4193.030
10.400	4086.432	4068.830	4051.192	4033.519	4015.811	3998.068	4104.000	4121.532	4139.030
10.500	4032.432	4014.829	3997.191	3979.517	3961.807	3944.062	4050.000	4067.532	4085.029
10.600	3978.432	3960.828	3943.189	3925.514	3907.803	3890.056	3996.000	4013.532	4031.028
10.700	3924.432	3906.828	3889.187	3871.511	3853.799	3836.050	3942.000	3959.532	3977.028
10.800	3870.432	3852.827	3835.186	3817.508	3799.794	3782.044	3888.000	3905.532	3923.027
10.900	3816.432	3798.826	3781.184	3763.506	3745.790	3728.038	3834.000	3851.532	3869.026
11.000	3762.431	3744.826	3727.183	3709.503	3691.786	3674.032	3780.000	3797.531	3815.026
11.100	3708.431	3690.825	3673.181	3655.500	3637.782	3620.026	3726.000	3743.531	3761.025
11.200	3654.431	3636.824	3619.180	3601.498	3583.778	3566.020	3672.000	3689.531	3707.024
11.300	3600.431	3582.824	3565.178	3547.495	3529.773	3512.014	3618.000	3635.531	3653.024
11.400	3546.431	3528.823	3511.177	3493.492	3475.769	3458.007	3564.000	3581.531	3599.023
11.500	3492.431	3474.822	3457.175	3439.490	3421.765	3404.001	3510.000	3527.531	3545.022
11.600	3438.430	3420.822	3403.174	3385.487	3367.761	3349.995	3456.000	3473.530	3491.022
11.700	3384.430	3366.821	3349.172	3331.484	3313.756	3295.989	3402.000	3419.530	3437.021
11.800	3330.430	3312.820	3295.171	3277.481	3259.752	3241.983	3348.000	3365.530	3383.020
11.900	3276.430	3258.820	3241.169	3223.479	3205.748	3187.977	3294.000	3311.530	3329.020
12.000	3222.430	3204.819	3187.168	3169.476	3151.744	3133.971	3240.000	3257.530	3275.019
12.100	3168.430	3150.818	3133.166	3115.473	3097.740	3079.965	3186.000	3203.530	3221.018
12.200	3114.429	3096.818	3079.165	3061.471	3043.735	3025.959	3132.000	3149.529	3167.018
12.300	3060.429	3042.817	3025.163	3007.468	2989.731	2971.953	3078.000	3095.529	3113.017
12.400	3006.429	2988.816	2971.162	2953.465	2935.727	2917.947	3024.000	3041.529	3059.016
12.500	2952.429	2934.816	2917.160	2899.463	2881.723	2863.941	2970.000	2987.529	3005.016
12.600	2898.429	2880.815	2863.159	2845.460	2827.718	2809.935	2916.000	2933.529	2951.015
12.700	2844.429	2826.814	2809.157	2791.457	2773.714	2755.929	2862.000	2879.529	2897.014
12.800	2790.428	2772.814	2755.156	2737.454	2719.710	2701.922	2808.000	2825.528	2843.014
12.900	2736.428	2718.813	2701.154	2683.452	2665.706	2647.916	2754.000	2771.528	2789.013
13.000	2682.428	2664.812	2647.153	2629.449	2611.702	2593.910	2700.000	2717.528	2735.012
13.100	2628.428	2610.812	2593.151	2575.446	2557.697	2539.904	2646.000	2663.528	2681.012
13.200	2574.428	2556.811	2539.150	2521.444	2503.693	2485.898	2592.000	2609.528	2627.011
13.300	2520.428	2502.810	2485.148	2467.441	2449.689	2431.892	2538.000	2555.528	2573.010
13.400	2466.427	2448.810	2431.146	2413.438	2395.685	2377.886	2484.000	2501.527	2519.010
13.500	2412.427	2394.809	2377.145	2359.436	2341.680	2323.880	2430.000	2447.527	2465.009
13.600	2358.427	2340.808	2323.143	2305.433	2287.676	2269.874	2376.000	2393.527	2411.008
13.700	2304.427	2286.808	2269.142	2251.430	2233.672	2215.868	2322.000	2339.527	2357.008
13.800	2250.427	2232.807	2215.140	2197.427	2179.668	2161.862	2268.000	2285.527	2303.007
13.900	2196.427	2178.806	2161.139	2143.425	2125.664	2107.856	2214.000	2231.527	2249.006
14.000	2142.426	2124.806	2107.137	2089.422	2071.659	2053.850	2160.000	2177.526	2195.006
14.100	2088.426	2070.805	2053.136	2035.419	2017.655	1999.843	2106.000	2123.526	2141.005
14.200	2034.426	2016.804	1999.134	1981.417	1963.651	1945.837	2052.000	2069.526	2087.004
14.300	1980.426	1962.803	1945.133	1927.414	1909.647	1891.831	1998.000	2015.526	2033.003

Ullage	Trim by stern in (m)						Even Keel	Trim by head in (m)	
	0.500	1.000	1.500	2.000	2.500	3.000		-0.500	-1.000
14.400	1926.426	1908.803	1891.131	1873.411	1855.643	1837.825	1944.000	1961.526	1979.003
14.500	1872.426	1854.802	1837.130	1819.409	1801.638	1783.819	1890.000	1907.526	1925.002
14.600	1818.425	1800.801	1783.128	1765.406	1747.634	1729.813	1836.000	1853.525	1871.001
14.700	1764.425	1746.801	1729.127	1711.403	1693.630	1675.807	1782.000	1799.525	1817.001
14.800	1710.425	1692.800	1675.125	1657.400	1639.626	1621.801	1728.000	1745.525	1763.000
14.900	1656.425	1638.799	1621.124	1603.398	1585.621	1567.795	1674.000	1691.525	1708.999
15.000	1602.425	1584.799	1567.122	1549.395	1531.617	1513.789	1620.000	1637.525	1654.999
15.100	1548.425	1530.798	1513.121	1495.392	1477.613	1459.783	1566.000	1583.525	1600.998
15.200	1494.424	1476.797	1459.119	1441.390	1423.609	1405.777	1512.000	1529.524	1546.997
15.300	1440.424	1422.797	1405.118	1387.387	1369.605	1351.771	1458.000	1475.524	1492.997
15.400	1386.424	1368.796	1351.116	1333.384	1315.600	1297.764	1404.000	1421.524	1438.996
15.500	1332.424	1314.795	1297.115	1279.382	1261.596	1243.758	1350.000	1367.524	1384.995
15.600	1278.424	1260.795	1243.113	1225.379	1207.592	1189.752	1296.000	1313.524	1330.995
15.700	1224.424	1206.794	1189.112	1171.376	1153.588	1135.746	1242.000	1259.524	1276.994
15.800	1170.423	1152.793	1135.110	1117.373	1099.583	1081.740	1188.000	1205.523	1222.993
15.900	1116.423	1098.793	1081.109	1063.371	1045.579	1027.734	1134.000	1151.523	1168.993
16.000	1062.423	1044.792	1027.107	1009.368	991.575	973.728	1080.000	1097.523	1114.992
16.100	1008.423	990.791	973.105	955.365	937.571	919.722	1026.000	1043.523	1060.991
16.200	954.423	936.791	919.104	901.363	883.567	865.716	972.000	989.523	1006.991
16.300	900.422	882.790	865.102	847.360	829.562	811.710	918.000	935.522	952.990
16.400	846.422	828.789	811.101	793.357	775.558	757.704	864.000	881.522	898.989
16.500	792.422	774.789	757.099	739.355	721.554	703.698	810.000	827.522	844.989
16.600	738.422	720.788	703.098	685.352	667.550	649.692	756.000	773.522	790.988
16.700	684.422	666.787	649.096	631.349	613.545	595.686	702.000	719.522	736.987
16.800	630.422	612.787	595.095	577.346	559.541	541.679	648.000	665.522	682.987
16.900	576.421	558.786	541.093	523.344	505.537	487.673	594.000	611.521	628.986
17.000	522.421	504.785	487.092	469.341	451.533	433.667	540.000	557.521	574.985
17.100	468.421	450.785	433.090	415.338	397.529	379.661	486.000	503.521	520.985
17.200	414.421	396.784	379.089	361.336	343.524	325.655	432.000	449.521	466.984
17.300	360.421	342.783	325.087	307.333	289.520	271.649	378.000	395.521	412.983
17.400	306.421	288.783	271.086	253.330	235.516	217.643	324.000	341.521	358.983
17.500	252.420	234.782	217.084	199.328	181.512	163.637	270.000	287.520	304.982
17.600	198.420	180.781	163.083	145.325	127.508	109.921	216.000	233.520	250.981
17.650	171.420	153.781	136.082	118.323	100.507	85.737	189.000	206.520	223.981
17.700	144.420	126.781	109.081	91.322	75.404	64.554	162.000	179.520	196.981
17.750	117.420	99.780	82.080	65.179	53.902	46.371	135.000	152.520	169.980
17.800	90.420	72.780	55.212	43.208	36.001	31.190	108.000	125.520	142.980
17.850	63.420	45.780	32.471	25.738	21.700	19.009	81.000	98.520	115.980
17.900	36.420	21.691	15.731	12.767	11.000	9.828	54.000	71.520	88.979
17.950	10.868	6.432	4.992	4.298	3.900	3.649	27.000	44.520	61.979
18.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Ullage Tables for Slop Tanks

Ullage	Trim by stern in (m) 0.500	1.000	1.500	2.000	2.500	3.000	Even Keel	Trim by head in (m) -0.500	-1.000
0.000	3238.650	3237.300	3235.950	3234.600	3233.250	3231.900	3240.000	3239.910	3239.820
0.010	3236.850	3235.500	3234.150	3232.800	3231.450	3230.100	3238.200	3239.190	3239.280
0.020	3235.050	3233.700	3232.350	3231.000	3229.650	3228.300	3236.400	3238.200	3238.380
0.030	3233.250	3231.900	3230.550	3229.200	3227.850	3226.499	3234.600	3235.950	3237.120
0.040	3231.450	3230.100	3228.750	3227.400	3226.049	3224.699	3232.800	3234.150	3235.500
0.050	3229.650	3228.300	3226.950	3225.600	3224.249	3222.899	3231.000	3232.350	3233.700
0.060	3227.850	3226.500	3225.150	3223.799	3222.449	3221.099	3229.200	3230.550	3231.900
0.070	3226.050	3224.700	3223.350	3221.999	3220.649	3219.299	3227.400	3228.750	3230.100
0.080	3224.250	3222.900	3221.550	3220.199	3218.849	3217.498	3225.600	3226.950	3228.300
0.090	3222.450	3221.100	3219.750	3218.399	3217.049	3215.698	3223.800	3225.150	3226.500
0.100	3220.650	3219.300	3217.949	3216.599	3215.249	3213.898	3222.000	3223.350	3224.700
0.110	3218.850	3217.500	3216.149	3214.799	3213.448	3212.098	3220.200	3221.550	3222.900
0.120	3217.050	3215.700	3214.349	3212.999	3211.648	3210.298	3218.400	3219.750	3221.100
0.130	3215.250	3213.900	3212.549	3211.199	3209.848	3208.497	3216.600	3217.950	3219.300
0.140	3213.450	3212.100	3210.749	3209.399	3208.048	3206.697	3214.800	3216.150	3217.500
0.150	3211.650	3210.300	3208.949	3207.599	3206.248	3204.897	3213.000	3214.350	3215.700
0.160	3209.850	3208.500	3207.149	3205.799	3204.448	3203.097	3211.200	3212.550	3213.900
0.170	3208.050	3206.700	3205.349	3203.998	3202.648	3201.297	3209.400	3210.750	3212.100
0.180	3206.250	3204.900	3203.549	3202.198	3200.847	3199.496	3207.600	3208.950	3210.300
0.190	3204.450	3203.100	3201.749	3200.398	3199.047	3197.696	3205.800	3207.150	3208.500
0.200	3202.650	3201.300	3199.949	3198.598	3197.247	3195.896	3204.000	3205.350	3206.700
0.210	3200.850	3199.500	3198.149	3196.798	3195.447	3194.096	3202.200	3203.550	3204.900
0.220	3199.050	3197.700	3196.349	3194.998	3193.647	3192.296	3200.400	3201.750	3203.100
0.230	3197.250	3195.899	3194.549	3193.198	3191.847	3190.495	3198.600	3199.950	3201.299
0.240	3195.450	3194.099	3192.749	3191.398	3190.047	3188.695	3196.800	3198.150	3199.499
0.250	3193.650	3192.299	3190.949	3189.598	3188.246	3186.895	3195.000	3196.350	3197.699
0.260	3191.850	3190.499	3189.149	3187.798	3186.446	3185.095	3193.200	3194.550	3195.899
0.270	3190.050	3188.699	3187.349	3185.998	3184.646	3183.295	3191.400	3192.750	3194.099
0.280	3188.250	3186.899	3185.549	3184.197	3182.846	3181.494	3189.600	3190.950	3192.299
0.290	3186.450	3185.099	3183.749	3182.397	3181.046	3179.694	3187.800	3189.150	3190.499
0.300	3184.650	3183.299	3181.948	3180.597	3179.246	3177.894	3186.000	3187.350	3188.699
0.310	3182.850	3181.499	3180.148	3178.797	3177.446	3176.094	3184.200	3185.550	3186.899
0.320	3181.050	3179.699	3178.348	3176.997	3175.646	3174.294	3182.400	3183.750	3185.099
0.330	3179.250	3177.899	3176.548	3175.197	3173.845	3172.493	3180.600	3181.950	3183.299
0.340	3177.450	3176.099	3174.748	3173.397	3172.045	3170.693	3178.800	3180.150	3181.499
0.350	3175.650	3174.299	3172.948	3171.597	3170.245	3168.893	3177.000	3178.350	3179.699
0.360	3173.850	3172.499	3171.148	3169.797	3168.445	3167.093	3175.200	3176.550	3177.899
0.370	3172.050	3170.699	3169.348	3167.997	3166.645	3165.293	3173.400	3174.750	3176.099
0.380	3170.250	3168.899	3167.548	3166.197	3164.845	3163.492	3171.600	3172.950	3174.299
0.390	3168.450	3167.099	3165.748	3164.396	3163.045	3161.692	3169.800	3171.150	3172.499
0.400	3166.650	3165.299	3163.948	3162.596	3161.244	3159.892	3168.000	3169.350	3170.699
0.410	3164.850	3163.499	3162.148	3160.796	3159.444	3158.092	3166.200	3167.550	3168.899
0.420	3163.050	3161.699	3160.348	3158.996	3157.644	3156.291	3164.400	3165.750	3167.099
0.430	3161.250	3159.899	3158.548	3157.196	3155.844	3154.491	3162.600	3163.950	3165.299
0.440	3159.450	3158.099	3156.748	3155.396	3154.044	3152.691	3160.800	3162.150	3163.499
0.450	3157.650	3156.299	3154.948	3153.596	3152.244	3150.891	3159.000	3160.350	3161.699

Ullage	Trim by stern in (m)						Even Keel	Trim by head in (m)	
	0.500	1.000	1.500	2.000	2.500	3.000		-0.500	-1.000
0.460	3155.850	3154.499	3153.148	3151.796	3150.444	3149.091	3157.200	3158.550	3159.899
0.470	3154.050	3152.699	3151.348	3149.996	3148.643	3147.290	3155.400	3156.750	3158.099
0.480	3152.250	3150.899	3149.548	3148.196	3146.843	3145.490	3153.600	3154.950	3156.299
0.490	3150.450	3149.099	3147.748	3146.396	3145.043	3143.690	3151.800	3153.150	3154.499
0.500	3148.650	3147.299	3145.947	3144.596	3143.243	3141.890	3150.000	3151.350	3152.699
0.510	3146.850	3145.499	3144.147	3142.795	3141.443	3140.090	3148.200	3149.550	3150.899
0.520	3145.050	3143.699	3142.347	3140.995	3139.643	3138.289	3146.400	3147.750	3149.099
0.530	3143.250	3141.899	3140.547	3139.195	3137.843	3136.489	3144.600	3145.950	3147.299
0.540	3141.450	3140.099	3138.747	3137.395	3136.042	3134.689	3142.800	3144.150	3145.499
0.550	3139.650	3138.299	3136.947	3135.595	3134.242	3132.889	3141.000	3142.350	3143.699
0.560	3137.850	3136.499	3135.147	3133.795	3132.442	3131.089	3139.200	3140.550	3141.899
0.570	3136.050	3134.699	3133.347	3131.995	3130.642	3129.288	3137.400	3138.750	3140.099
0.580	3134.250	3132.899	3131.547	3130.195	3128.842	3127.488	3135.600	3136.950	3138.299
0.590	3132.450	3131.099	3129.747	3128.395	3127.042	3125.688	3133.800	3135.150	3136.499
0.600	3130.650	3129.299	3127.947	3126.595	3125.242	3123.888	3132.000	3133.350	3134.699
0.610	3128.850	3127.499	3126.147	3124.795	3123.441	3122.088	3130.200	3131.550	3132.899
0.620	3127.050	3125.699	3124.347	3122.994	3121.641	3120.287	3128.400	3129.750	3131.099
0.630	3125.250	3123.899	3122.547	3121.194	3119.841	3118.487	3126.600	3127.950	3129.299
0.640	3123.450	3122.099	3120.747	3119.394	3118.041	3116.687	3124.800	3126.150	3127.499
0.650	3121.650	3120.299	3118.947	3117.594	3116.241	3114.887	3123.000	3124.350	3125.699
0.660	3119.850	3118.499	3117.147	3115.794	3114.441	3113.087	3121.200	3122.550	3123.899
0.670	3118.050	3116.698	3115.347	3113.994	3112.641	3111.286	3119.400	3120.750	3122.098
0.680	3116.250	3114.898	3113.547	3112.194	3110.840	3109.486	3117.600	3118.950	3120.298
0.690	3114.450	3113.098	3111.747	3110.394	3109.040	3107.686	3115.800	3117.150	3118.498
0.700	3112.650	3111.298	3109.946	3108.594	3107.240	3105.886	3114.000	3115.350	3116.698
0.710	3110.850	3109.498	3108.146	3106.794	3105.440	3104.086	3112.200	3113.550	3114.898
0.720	3109.050	3107.698	3106.346	3104.994	3103.640	3102.285	3110.400	3111.750	3113.098
0.730	3107.250	3105.898	3104.546	3103.193	3101.840	3100.485	3108.600	3109.950	3111.298
0.740	3105.450	3104.098	3102.746	3101.393	3100.040	3098.685	3106.800	3108.150	3109.498
0.750	3103.650	3102.298	3100.946	3099.593	3098.239	3096.885	3105.000	3106.350	3107.698
0.760	3101.850	3100.498	3099.146	3097.793	3096.439	3095.085	3103.200	3104.550	3105.898
0.770	3100.050	3098.698	3097.346	3095.993	3094.639	3093.284	3101.400	3102.750	3104.098
0.780	3098.250	3096.898	3095.546	3094.193	3092.839	3091.484	3099.600	3100.950	3102.298
0.790	3096.450	3095.098	3093.746	3092.393	3091.039	3089.684	3097.800	3099.150	3100.498
0.800	3094.650	3093.298	3091.946	3090.593	3089.239	3087.884	3096.000	3097.350	3098.698
0.810	3092.850	3091.498	3090.146	3088.793	3087.439	3086.084	3094.200	3095.550	3096.898
0.820	3091.050	3089.698	3088.346	3086.993	3085.638	3084.283	3092.400	3093.750	3095.098
0.830	3089.250	3087.898	3086.546	3085.193	3083.838	3082.483	3090.600	3091.950	3093.298
0.840	3087.450	3086.098	3084.746	3083.392	3082.038	3080.683	3088.800	3090.150	3091.498
0.850	3085.650	3084.298	3082.946	3081.592	3080.238	3078.883	3087.000	3088.350	3089.698
0.860	3083.850	3082.498	3081.146	3079.792	3078.438	3077.083	3085.200	3086.550	3087.898
0.870	3082.050	3080.698	3079.346	3077.992	3076.638	3075.282	3083.400	3084.750	3086.098
0.880	3080.250	3078.898	3077.546	3076.192	3074.838	3073.482	3081.600	3082.950	3084.298
0.890	3078.449	3077.098	3075.745	3074.392	3073.037	3071.682	3079.800	3081.149	3082.498
0.900	3076.649	3075.298	3073.945	3072.592	3071.237	3069.882	3078.000	3079.349	3080.698
0.910	3074.849	3073.498	3072.145	3070.792	3069.437	3068.082	3076.200	3077.549	3078.898
0.920	3073.049	3071.698	3070.345	3068.992	3067.637	3066.281	3074.400	3075.749	3077.098

Ullage	Trim by stern in (m)						Even Keel	Trim by head in (m)	
	0.500	1.000	1.500	2.000	2.500	3.000		-0.500	-1.000
0.930	3071.249	3069.898	3068.545	3067.192	3065.837	3064.481	3072.600	3073.949	3075.298
0.940	3069.449	3068.098	3066.745	3065.392	3064.037	3062.681	3070.800	3072.149	3073.498
0.950	3067.649	3066.298	3064.945	3063.591	3062.237	3060.881	3069.000	3070.349	3071.698
0.960	3065.849	3064.498	3063.145	3061.791	3060.437	3059.081	3067.200	3068.549	3069.898
0.970	3064.049	3062.698	3061.345	3059.991	3058.636	3057.280	3065.400	3066.749	3068.098
0.980	3062.249	3060.898	3059.545	3058.191	3056.836	3055.480	3063.600	3064.949	3066.298
0.990	3060.449	3059.098	3057.745	3056.391	3055.036	3053.680	3061.800	3063.149	3064.498
1.000	3058.649	3057.298	3055.945	3054.591	3053.236	3051.880	3060.000	3061.349	3062.698
1.010	3056.849	3055.498	3054.145	3052.791	3051.436	3050.080	3058.200	3059.549	3060.898
1.020	3055.049	3053.698	3052.345	3050.991	3049.636	3048.279	3056.400	3057.749	3059.098
1.030	3053.249	3051.898	3050.545	3049.191	3047.836	3046.479	3054.600	3055.949	3057.298
1.040	3051.449	3050.098	3048.745	3047.391	3046.035	3044.679	3052.800	3054.149	3055.498
1.050	3049.649	3048.298	3046.945	3045.591	3044.235	3042.879	3051.000	3052.349	3053.698
1.060	3047.849	3046.498	3045.145	3043.790	3042.435	3041.079	3049.200	3050.549	3051.898
1.070	3046.049	3044.698	3043.345	3041.990	3040.635	3039.278	3047.400	3048.749	3050.098
1.080	3044.249	3042.898	3041.545	3040.190	3038.835	3037.478	3045.600	3046.949	3048.298
1.090	3042.449	3041.098	3039.744	3038.390	3037.035	3035.678	3043.800	3045.149	3046.498
1.100	3040.649	3039.298	3037.944	3036.590	3035.235	3033.878	3042.000	3043.349	3044.698
1.110	3038.849	3037.498	3036.144	3034.790	3033.434	3032.078	3040.200	3041.549	3042.898
1.120	3037.049	3035.697	3034.344	3032.990	3031.634	3030.277	3038.400	3039.749	3041.097
1.130	3035.249	3033.897	3032.544	3031.190	3029.834	3028.477	3036.600	3037.949	3039.297
1.140	3033.449	3032.097	3030.744	3029.390	3028.034	3026.677	3034.800	3036.149	3037.497
1.150	3031.649	3030.297	3028.944	3027.590	3026.234	3024.877	3033.000	3034.349	3035.697
1.160	3029.849	3028.497	3027.144	3025.790	3024.434	3023.077	3031.200	3032.549	3033.897
1.170	3028.049	3026.697	3025.344	3023.989	3022.634	3021.276	3029.400	3030.749	3032.097
1.180	3026.249	3024.897	3023.544	3022.189	3020.833	3019.476	3027.600	3028.949	3030.297
1.190	3024.449	3023.097	3021.744	3020.389	3019.033	3017.676	3025.800	3027.149	3028.497
1.200	3022.649	3021.297	3019.944	3018.589	3017.233	3015.876	3024.000	3025.349	3026.697
1.210	3020.849	3019.497	3018.144	3016.789	3015.433	3014.075	3022.200	3023.549	3024.897
1.220	3019.049	3017.697	3016.344	3014.989	3013.633	3012.275	3020.400	3021.749	3023.097
1.230	3017.249	3015.897	3014.544	3013.189	3011.833	3010.475	3018.600	3019.949	3021.297
1.240	3015.449	3014.097	3012.744	3011.389	3010.033	3008.675	3016.800	3018.149	3019.497
1.250	3013.649	3012.297	3010.944	3009.589	3008.232	3006.875	3015.000	3016.349	3017.697
1.260	3011.849	3010.497	3009.144	3007.789	3006.432	3005.074	3013.200	3014.549	3015.897
1.270	3010.049	3008.697	3007.344	3005.989	3004.632	3003.274	3011.400	3012.749	3014.097
1.280	3008.249	3006.897	3005.544	3004.188	3002.832	3001.474	3009.600	3010.949	3012.297
1.290	3006.449	3005.097	3003.743	3002.388	3001.032	2999.674	3007.800	3009.149	3010.497
1.300	3004.649	3003.297	3001.943	3000.588	2999.232	2997.874	3006.000	3007.349	3008.697
1.310	3002.849	3001.497	3000.143	2998.788	2997.432	2996.073	3004.200	3005.549	3006.897
1.320	3001.049	2999.697	2998.343	2996.988	2995.631	2994.273	3002.400	3003.749	3005.097
1.330	2999.249	2997.897	2996.543	2995.188	2993.831	2992.473	3000.600	3001.949	3003.297
1.340	2997.449	2996.097	2994.743	2993.388	2992.031	2990.673	2998.800	3000.149	3001.497
1.350	2995.649	2994.297	2992.943	2991.588	2990.231	2988.873	2997.000	2998.349	2999.697
1.360	2993.849	2992.497	2991.143	2989.788	2988.431	2987.072	2995.200	2996.549	2997.897
1.370	2992.049	2990.697	2989.343	2987.988	2986.631	2985.272	2993.400	2994.749	2996.097
1.380	2990.249	2988.897	2987.543	2986.188	2984.831	2983.472	2991.600	2992.949	2994.297
1.390	2988.449	2987.097	2985.743	2984.387	2983.030	2981.672	2989.800	2991.149	2992.497

Ullage	Trim by stern in (m)						Even Keel	Trim by head in (m)	
	0.500	1.000	1.500	2.000	2.500	3.000		-0.500	-1.000
1.400	2986.649	2985.297	2983.943	2982.587	2981.230	2979.872	2988.000	2989.349	2990.697
1.410	2984.849	2983.497	2982.143	2980.787	2979.430	2978.071	2986.200	2987.549	2988.897
1.420	2983.049	2981.697	2980.343	2978.987	2977.630	2976.271	2984.400	2985.749	2987.097
1.430	2981.249	2979.897	2978.543	2977.187	2975.830	2974.471	2982.600	2983.949	2985.297
1.440	2979.449	2978.097	2976.743	2975.387	2974.030	2972.671	2980.800	2982.149	2983.497
1.450	2977.649	2976.297	2974.943	2973.587	2972.230	2970.871	2979.000	2980.349	2981.697
1.460	2975.849	2974.497	2973.143	2971.787	2970.429	2969.070	2977.200	2978.549	2979.897
1.470	2974.049	2972.697	2971.343	2969.987	2968.629	2967.270	2975.400	2976.749	2978.097
1.480	2972.249	2970.897	2969.543	2968.187	2966.829	2965.470	2973.600	2974.949	2976.297
1.490	2970.449	2969.097	2967.742	2966.387	2965.029	2963.670	2971.800	2973.149	2974.497
1.500	2968.649	2967.297	2965.942	2964.587	2963.229	2961.870	2970.000	2971.349	2972.697
1.510	2966.849	2965.497	2964.142	2962.786	2961.429	2960.069	2968.200	2969.549	2970.897
1.520	2965.049	2963.697	2962.342	2960.986	2959.629	2958.269	2966.400	2967.749	2969.097
1.530	2963.249	2961.897	2960.542	2959.186	2957.828	2956.469	2964.600	2965.949	2967.297
1.540	2961.449	2960.097	2958.742	2957.386	2956.028	2954.669	2962.800	2964.149	2965.497
1.550	2959.649	2958.297	2956.942	2955.586	2954.228	2952.869	2961.000	2962.349	2963.697
1.560	2957.849	2956.496	2955.142	2953.786	2952.428	2951.068	2959.200	2960.549	2961.896
1.570	2956.049	2954.696	2953.342	2951.986	2950.628	2949.268	2957.400	2958.749	2960.096
1.580	2954.249	2952.896	2951.542	2950.186	2948.828	2947.468	2955.600	2956.949	2958.296
1.590	2952.449	2951.096	2949.742	2948.386	2947.028	2945.668	2953.800	2955.149	2956.496
1.600	2950.649	2949.296	2947.942	2946.586	2945.228	2943.868	2952.000	2953.349	2954.696
1.610	2948.849	2947.496	2946.142	2944.786	2943.427	2942.067	2950.200	2951.549	2952.896
1.620	2947.049	2945.696	2944.342	2942.985	2941.627	2940.267	2948.400	2949.749	2951.096
1.630	2945.249	2943.896	2942.542	2941.185	2939.827	2938.467	2946.600	2947.949	2949.296
1.640	2943.449	2942.096	2940.742	2939.385	2938.027	2936.667	2944.800	2946.149	2947.496
1.650	2941.649	2940.296	2938.942	2937.585	2936.227	2934.867	2943.000	2944.349	2945.696
1.660	2939.849	2938.496	2937.142	2935.785	2934.427	2933.066	2941.200	2942.549	2943.896
1.670	2938.049	2936.696	2935.342	2933.985	2932.627	2931.266	2939.400	2940.749	2942.096
1.680	2936.249	2934.896	2933.541	2932.185	2930.826	2929.466	2937.600	2938.949	2940.296
1.690	2934.449	2933.096	2931.741	2930.385	2929.026	2927.666	2935.800	2937.149	2938.496
1.700	2932.649	2931.296	2929.941	2928.585	2927.226	2925.866	2934.000	2935.349	2936.696
1.710	2930.849	2929.496	2928.141	2926.785	2925.426	2924.065	2932.200	2933.549	2934.896
1.720	2929.049	2927.696	2926.341	2924.985	2923.626	2922.265	2930.400	2931.749	2933.096
1.730	2927.249	2925.896	2924.541	2923.184	2921.826	2920.465	2928.600	2929.949	2931.296
1.740	2925.449	2924.096	2922.741	2921.384	2920.026	2918.665	2926.800	2928.149	2929.496
1.750	2923.649	2922.296	2920.941	2919.584	2918.225	2916.865	2925.000	2926.349	2927.696
1.760	2921.849	2920.496	2919.141	2917.784	2916.425	2915.064	2923.200	2924.549	2925.896
1.770	2920.049	2918.696	2917.341	2915.984	2914.625	2913.264	2921.400	2922.749	2924.096
1.780	2918.249	2916.896	2915.541	2914.184	2912.825	2911.464	2919.600	2920.949	2922.296
1.790	2916.449	2915.096	2913.741	2912.384	2911.025	2909.664	2917.800	2919.149	2920.496
1.800	2914.649	2913.296	2911.941	2910.584	2909.225	2907.864	2916.000	2917.349	2918.696
1.810	2912.849	2911.496	2910.141	2908.784	2907.425	2906.063	2914.200	2915.549	2916.896
1.820	2911.049	2909.696	2908.341	2906.984	2905.624	2904.263	2912.400	2913.749	2915.096
1.830	2909.249	2907.896	2906.541	2905.184	2903.824	2902.463	2910.600	2911.949	2913.296
1.840	2907.449	2906.096	2904.741	2903.383	2902.024	2900.663	2908.800	2910.149	2911.496
1.850	2905.649	2904.296	2902.941	2901.583	2900.224	2898.863	2907.000	2908.349	2909.696
1.860	2903.849	2902.496	2901.141	2899.783	2898.424	2897.062	2905.200	2906.549	2907.896

Ullage	Trim by stern in (m)						Even Keel	Trim by head in (m)	
	0.500	1.000	1.500	2.000	2.500	3.000		-0.500	-1.000
1.870	2902.049	2900.696	2899.341	2897.983	2896.624	2895.262	2903.400	2904.749	2906.096
1.880	2900.249	2898.896	2897.540	2896.183	2894.824	2893.462	2901.600	2902.949	2904.296
1.890	2898.449	2897.096	2895.740	2894.383	2893.023	2891.662	2899.800	2901.149	2902.496
1.900	2896.649	2895.296	2893.940	2892.583	2891.223	2889.862	2898.000	2899.349	2900.696
1.910	2894.849	2893.496	2892.140	2890.783	2889.423	2888.061	2896.200	2897.549	2898.896
1.920	2893.049	2891.696	2890.340	2888.983	2887.623	2886.261	2894.400	2895.749	2897.096
1.930	2891.249	2889.896	2888.540	2887.183	2885.823	2884.461	2892.600	2893.949	2895.296
1.940	2889.449	2888.096	2886.740	2885.383	2884.023	2882.661	2890.800	2892.149	2893.496
1.950	2887.649	2886.296	2884.940	2883.582	2882.223	2880.861	2889.000	2890.349	2891.696
1.960	2885.849	2884.496	2883.140	2881.782	2880.422	2879.060	2887.200	2888.549	2889.896
1.970	2884.049	2882.696	2881.340	2879.982	2878.622	2877.260	2885.400	2886.749	2888.096
1.980	2882.249	2880.896	2879.540	2878.182	2876.822	2875.460	2883.600	2884.949	2886.296
1.990	2880.449	2879.096	2877.740	2876.382	2875.022	2873.660	2881.800	2883.149	2884.496
2.000	2878.649	2877.296	2875.940	2874.582	2873.222	2871.860	2880.000	2881.349	2882.696
2.100	2860.649	2859.295	2857.939	2856.581	2855.220	2853.857	2862.000	2863.349	2864.695
2.200	2842.649	2841.295	2839.939	2838.580	2837.219	2835.855	2844.000	2845.349	2846.695
2.300	2824.649	2823.295	2821.938	2820.579	2819.218	2817.853	2826.000	2827.349	2828.695
2.400	2806.649	2805.295	2803.938	2802.578	2801.216	2799.851	2808.000	2809.349	2810.695
2.500	2788.649	2787.294	2785.937	2784.578	2783.215	2781.849	2790.000	2791.349	2792.694
2.600	2770.649	2769.294	2767.937	2766.577	2765.213	2763.847	2772.000	2773.349	2774.694
2.700	2752.648	2751.294	2749.936	2748.576	2747.212	2745.845	2754.000	2755.348	2756.694
2.800	2734.648	2733.294	2731.936	2730.575	2729.211	2727.843	2736.000	2737.348	2738.694
2.900	2716.648	2715.293	2713.935	2712.574	2711.209	2709.841	2718.000	2719.348	2720.693
3.000	2698.648	2697.293	2695.935	2694.573	2693.208	2691.839	2700.000	2701.348	2702.693
3.100	2680.648	2679.293	2677.934	2676.572	2675.206	2673.837	2682.000	2683.348	2684.693
3.200	2662.648	2661.293	2659.934	2658.571	2657.205	2655.835	2664.000	2665.348	2666.693
3.300	2644.648	2643.293	2641.933	2640.570	2639.204	2637.833	2646.000	2647.348	2648.693
3.400	2626.648	2625.292	2623.933	2622.569	2621.202	2619.831	2628.000	2629.348	2630.692
3.500	2608.648	2607.292	2605.932	2604.569	2603.201	2601.829	2610.000	2611.348	2612.692
3.600	2590.648	2589.292	2587.932	2586.568	2585.199	2583.827	2592.000	2593.348	2594.692
3.700	2572.648	2571.292	2569.931	2568.567	2567.198	2565.825	2574.000	2575.348	2576.692
3.800	2554.648	2553.291	2551.931	2550.566	2549.197	2547.823	2556.000	2557.348	2558.691
3.900	2536.648	2535.291	2533.930	2532.565	2531.195	2529.821	2538.000	2539.348	2540.691
4.000	2518.648	2517.291	2515.930	2514.564	2513.194	2511.819	2520.000	2521.348	2522.691
4.100	2500.648	2499.291	2497.929	2496.563	2495.192	2493.817	2502.000	2503.348	2504.691
4.200	2482.648	2481.291	2479.929	2478.562	2477.191	2475.815	2484.000	2485.348	2486.691
4.300	2464.648	2463.290	2461.928	2460.561	2459.190	2457.813	2466.000	2467.348	2468.690
4.400	2446.648	2445.290	2443.928	2442.560	2441.188	2439.811	2448.000	2449.348	2450.690
4.500	2428.647	2427.290	2425.927	2424.560	2423.187	2421.809	2430.000	2431.347	2432.690
4.600	2410.647	2409.290	2407.927	2406.559	2405.185	2403.807	2412.000	2413.347	2414.690
4.700	2392.647	2391.289	2389.926	2388.558	2387.184	2385.805	2394.000	2395.347	2396.689
4.800	2374.647	2373.289	2371.926	2370.557	2369.183	2367.803	2376.000	2377.347	2378.689
4.900	2356.647	2355.289	2353.925	2352.556	2351.181	2349.801	2358.000	2359.347	2360.689
5.000	2338.647	2337.289	2335.925	2334.555	2333.180	2331.799	2340.000	2341.347	2342.689
5.100	2320.647	2319.289	2317.924	2316.554	2315.178	2313.797	2322.000	2323.347	2324.689
5.200	2302.647	2301.288	2299.924	2298.553	2297.177	2295.795	2304.000	2305.347	2306.688
5.300	2284.647	2283.288	2281.923	2280.552	2279.175	2277.793	2286.000	2287.347	2288.688

Ullage	Trim by stern in (m)						Even Keel	Trim by head in (m)	
	0.500	1.000	1.500	2.000	2.500	3.000		-0.500	-1.000
5.400	2266.647	2265.288	2263.923	2262.551	2261.174	2259.791	2268.000	2269.347	2270.688
5.500	2248.647	2247.288	2245.922	2244.551	2243.173	2241.789	2250.000	2251.347	2252.688
5.600	2230.647	2229.287	2227.922	2226.550	2225.171	2223.787	2232.000	2233.347	2234.687
5.700	2212.647	2211.287	2209.921	2208.549	2207.170	2205.785	2214.000	2215.347	2216.687
5.800	2194.647	2193.287	2191.921	2190.548	2189.168	2187.783	2196.000	2197.347	2198.687
5.900	2176.647	2175.287	2173.920	2172.547	2171.167	2169.781	2178.000	2179.347	2180.687
6.000	2158.647	2157.287	2155.920	2154.546	2153.166	2151.779	2160.000	2161.347	2162.687
6.100	2140.647	2139.286	2137.919	2136.545	2135.164	2133.776	2142.000	2143.347	2144.686
6.200	2122.647	2121.286	2119.919	2118.544	2117.163	2115.774	2124.000	2125.347	2126.686
6.300	2104.646	2103.286	2101.918	2100.543	2099.161	2097.772	2106.000	2107.346	2108.686
6.400	2086.646	2085.286	2083.918	2082.542	2081.160	2079.770	2088.000	2089.346	2090.686
6.500	2068.646	2067.285	2065.917	2064.542	2063.159	2061.768	2070.000	2071.346	2072.685
6.600	2050.646	2049.285	2047.917	2046.541	2045.157	2043.766	2052.000	2053.346	2054.685
6.700	2032.646	2031.285	2029.916	2028.540	2027.156	2025.764	2034.000	2035.346	2036.685
6.800	2014.646	2013.285	2011.916	2010.539	2009.154	2007.762	2016.000	2017.346	2018.685
6.900	1996.646	1995.284	1993.915	1992.538	1991.153	1989.760	1998.000	1999.346	2000.684
7.000	1978.646	1977.284	1975.915	1974.537	1973.152	1971.758	1980.000	1981.346	1982.684
7.100	1960.646	1959.284	1957.914	1956.536	1955.150	1953.756	1962.000	1963.346	1964.684
7.200	1942.646	1941.284	1939.914	1938.535	1937.149	1935.754	1944.000	1945.346	1946.684
7.300	1924.646	1923.284	1921.913	1920.534	1919.147	1917.752	1926.000	1927.346	1928.684
7.400	1906.646	1905.283	1903.913	1902.533	1901.146	1899.750	1908.000	1909.346	1910.683
7.500	1888.646	1887.283	1885.912	1884.533	1883.145	1881.748	1890.000	1891.346	1892.683
7.600	1870.646	1869.283	1867.912	1866.532	1865.143	1863.746	1872.000	1873.346	1874.683
7.700	1852.646	1851.283	1849.911	1848.531	1847.142	1845.744	1854.000	1855.346	1856.683
7.800	1834.646	1833.282	1831.911	1830.530	1829.140	1827.742	1836.000	1837.346	1838.682
7.900	1816.646	1815.282	1813.910	1812.529	1811.139	1809.740	1818.000	1819.346	1820.682
8.000	1798.646	1797.282	1795.910	1794.528	1793.138	1791.738	1800.000	1801.346	1802.682
8.100	1780.645	1779.282	1777.909	1776.527	1775.136	1773.736	1782.000	1783.345	1784.682
8.200	1762.645	1761.282	1759.908	1758.526	1757.135	1755.734	1764.000	1765.345	1766.682
8.300	1744.645	1743.281	1741.908	1740.525	1739.133	1737.732	1746.000	1747.345	1748.681
8.400	1726.645	1725.281	1723.907	1722.524	1721.132	1719.730	1728.000	1729.345	1730.681
8.500	1708.645	1707.281	1705.907	1704.524	1703.130	1701.728	1710.000	1711.345	1712.681
8.600	1690.645	1689.281	1687.906	1686.523	1685.129	1683.726	1692.000	1693.345	1694.681
8.700	1672.645	1671.280	1669.906	1668.522	1667.128	1665.724	1674.000	1675.345	1676.680
8.800	1654.645	1653.280	1651.905	1650.521	1649.126	1647.722	1656.000	1657.345	1658.680
8.900	1636.645	1635.280	1633.905	1632.520	1631.125	1629.720	1638.000	1639.345	1640.680
9.000	1618.645	1617.280	1615.904	1614.519	1613.123	1611.718	1620.000	1621.345	1622.680
9.100	1600.645	1599.280	1597.904	1596.518	1595.122	1593.716	1602.000	1603.345	1604.680
9.200	1582.645	1581.279	1579.903	1578.517	1577.121	1575.714	1584.000	1585.345	1586.679
9.300	1564.645	1563.279	1561.903	1560.516	1559.119	1557.712	1566.000	1567.345	1568.679
9.400	1546.645	1545.279	1543.902	1542.515	1541.118	1539.710	1548.000	1549.345	1550.679
9.500	1528.645	1527.279	1525.902	1524.515	1523.116	1521.708	1530.000	1531.345	1532.679
9.600	1510.645	1509.278	1507.901	1506.514	1505.115	1503.706	1512.000	1513.345	1514.678
9.700	1492.645	1491.278	1489.901	1488.513	1487.114	1485.704	1494.000	1495.345	1496.678
9.800	1474.644	1473.278	1471.900	1470.512	1469.112	1467.702	1476.000	1477.344	1478.678
9.900	1456.644	1455.278	1453.900	1452.511	1451.111	1449.700	1458.000	1459.344	1460.678
10.000	1438.644	1437.278	1435.899	1434.510	1433.109	1431.698	1440.000	1441.344	1442.678

Ullage	Trim by stern in (m)						Even Keel	Trim by head in (m)	
	0.500	1.000	1.500	2.000	2.500	3.000		-0.500	-1.000
10.100	1420.644	1419.277	1417.899	1416.509	1415.108	1413.695	1422.000	1423.344	1424.677
10.200	1402.644	1401.277	1399.898	1398.508	1397.107	1395.693	1404.000	1405.344	1406.677
10.300	1384.644	1383.277	1381.898	1380.507	1379.105	1377.691	1386.000	1387.344	1388.677
10.400	1366.644	1365.277	1363.897	1362.506	1361.104	1359.689	1368.000	1369.344	1370.677
10.500	1348.644	1347.276	1345.897	1344.506	1343.102	1341.687	1350.000	1351.344	1352.676
10.600	1330.644	1329.276	1327.896	1326.505	1325.101	1323.685	1332.000	1333.344	1334.676
10.700	1312.644	1311.276	1309.896	1308.504	1307.100	1305.683	1314.000	1315.344	1316.676
10.800	1294.644	1293.276	1291.895	1290.503	1289.098	1287.681	1296.000	1297.344	1298.676
10.900	1276.644	1275.275	1273.895	1272.502	1271.097	1269.679	1278.000	1279.344	1280.675
11.000	1258.644	1257.275	1255.894	1254.501	1253.095	1251.677	1260.000	1261.344	1262.675
11.100	1240.644	1239.275	1237.894	1236.500	1235.094	1233.675	1242.000	1243.344	1244.675
11.200	1222.644	1221.275	1219.893	1218.499	1217.093	1215.673	1224.000	1225.344	1226.675
11.300	1204.644	1203.275	1201.893	1200.498	1199.091	1197.671	1206.000	1207.344	1208.675
11.400	1186.644	1185.274	1183.892	1182.497	1181.090	1179.669	1188.000	1189.344	1190.674
11.500	1168.644	1167.274	1165.892	1164.497	1163.088	1161.667	1170.000	1171.344	1172.674
11.600	1150.643	1149.274	1147.891	1146.496	1145.087	1143.665	1152.000	1153.343	1154.674
11.700	1132.643	1131.274	1129.891	1128.495	1127.085	1125.663	1134.000	1135.343	1136.674
11.800	1114.643	1113.273	1111.890	1110.494	1109.084	1107.661	1116.000	1117.343	1118.673
11.900	1096.643	1095.273	1093.890	1092.493	1091.083	1089.659	1098.000	1099.343	1100.673
12.000	1078.643	1077.273	1075.889	1074.492	1073.081	1071.657	1080.000	1081.343	1082.673
12.100	1060.643	1059.273	1057.889	1056.491	1055.080	1053.655	1062.000	1063.343	1064.673
12.200	1042.643	1041.273	1039.888	1038.490	1037.078	1035.653	1044.000	1045.343	1046.673
12.300	1024.643	1023.272	1021.888	1020.489	1019.077	1017.651	1026.000	1027.343	1028.672
12.400	1006.643	1005.272	1003.887	1002.488	1001.076	999.649	1008.000	1009.343	1010.672
12.500	988.643	987.272	985.887	984.488	983.074	981.647	990.000	991.343	992.672
12.600	970.643	969.272	967.886	966.487	965.073	963.645	972.000	973.343	974.672
12.700	952.643	951.271	949.886	948.486	947.071	945.643	954.000	955.343	956.671
12.800	934.643	933.271	931.885	930.485	929.070	927.641	936.000	937.343	938.671
12.900	916.643	915.271	913.885	912.484	911.069	909.639	918.000	919.343	920.671
13.000	898.643	897.271	895.884	894.483	893.067	891.637	900.000	901.343	902.671
13.100	880.643	879.271	877.884	876.482	875.066	873.635	882.000	883.343	884.671
13.200	862.643	861.270	859.883	858.481	857.064	855.633	864.000	865.343	866.670
13.300	844.643	843.270	841.883	840.480	839.063	837.631	846.000	847.343	848.670
13.400	826.642	825.270	823.882	822.479	821.062	819.629	828.000	829.342	830.670
13.500	808.642	807.270	805.882	804.479	803.060	801.627	810.000	811.342	812.670
13.600	790.642	789.269	787.881	786.478	785.059	783.625	792.000	793.342	794.669
13.700	772.642	771.269	769.881	768.477	767.057	765.623	774.000	775.342	776.669
13.800	754.642	753.269	751.880	750.476	749.056	747.621	756.000	757.342	758.669
13.900	736.642	735.269	733.880	732.475	731.055	729.619	738.000	739.342	740.669
14.000	718.642	717.269	715.879	714.474	713.053	711.617	720.000	721.342	722.669
14.100	700.642	699.268	697.879	696.473	695.052	693.614	702.000	703.342	704.668
14.200	682.642	681.268	679.878	678.472	677.050	675.612	684.000	685.342	686.668
14.300	664.642	663.268	661.878	660.471	659.049	657.610	666.000	667.342	668.668
14.400	646.642	645.268	643.877	642.470	641.048	639.608	648.000	649.342	650.668
14.500	628.642	627.267	625.877	624.470	623.046	621.606	630.000	631.342	632.667
14.600	610.642	609.267	607.876	606.469	605.045	603.604	612.000	613.342	614.667
14.700	592.642	591.267	589.876	588.468	587.043	585.602	594.000	595.342	596.667

Ullage	Trim by stern in (m)						Even Keel	Trim by head in (m)	
	0.500	1.000	1.500	2.000	2.500	3.000		-0.500	-1.000
14.800	574.642	573.267	571.875	570.467	569.042	567.600	576.000	577.342	578.667
14.900	556.642	555.266	553.875	552.466	551.040	549.598	558.000	559.342	560.666
15.000	538.642	537.266	535.874	534.465	533.039	531.596	540.000	541.342	542.666
15.100	520.642	519.266	517.874	516.464	515.038	513.594	522.000	523.342	524.666
15.200	502.641	501.266	499.873	498.463	497.036	495.592	504.000	505.341	506.666
15.300	484.641	483.266	481.873	480.462	479.035	477.590	486.000	487.341	488.666
15.400	466.641	465.265	463.872	462.461	461.033	459.588	468.000	469.341	470.665
15.500	448.641	447.265	445.872	444.461	443.032	441.586	450.000	451.341	452.665
15.600	430.641	429.265	427.871	426.460	425.031	423.584	432.000	433.341	434.665
15.700	412.641	411.265	409.871	408.459	407.029	405.582	414.000	415.341	416.665
15.800	394.641	393.264	391.870	390.458	389.028	387.580	396.000	397.341	398.664
15.900	376.641	375.264	373.870	372.457	371.026	369.578	378.000	379.341	380.664
16.000	358.641	357.264	355.869	354.456	353.025	351.576	360.000	361.341	362.664
16.100	340.641	339.264	337.868	336.455	335.024	333.574	342.000	343.341	344.664
16.200	322.641	321.264	319.868	318.454	317.022	315.572	324.000	325.341	326.664
16.300	304.641	303.263	301.867	300.453	299.021	297.570	306.000	307.341	308.663
16.400	286.641	285.263	283.867	282.452	281.019	279.568	288.000	289.341	290.663
16.500	268.641	267.263	265.866	264.452	263.018	261.566	270.000	271.341	272.663
16.600	250.641	249.263	247.866	246.451	245.017	243.564	252.000	253.341	254.663
16.700	232.641	231.262	229.865	228.450	227.015	225.562	234.000	235.341	236.662
16.800	214.641	213.262	211.865	210.449	209.014	207.560	216.000	217.341	218.662
16.900	196.640	195.262	193.864	192.448	191.012	189.558	198.000	199.340	200.662
17.000	178.640	177.262	175.864	174.447	173.011	171.556	180.000	181.340	182.662
17.100	160.640	159.262	157.863	156.446	155.010	153.554	162.000	163.340	164.662
17.200	142.640	141.261	139.863	138.445	137.008	135.552	144.000	145.340	146.661
17.300	124.640	123.261	121.862	120.444	119.007	117.550	126.000	127.340	128.661
17.400	106.640	105.261	103.862	102.443	101.005	99.548	108.000	109.340	110.661
17.500	88.640	87.261	85.861	84.443	83.004	81.546	90.000	91.340	92.661
17.600	70.640	69.260	67.861	66.442	65.003	63.544	72.000	73.340	74.660
17.650	61.640	60.260	58.861	57.441	56.002	54.543	63.000	64.340	65.660
17.700	52.640	51.260	49.860	48.441	47.001	45.542	54.000	55.340	56.660
17.750	43.640	42.260	40.860	39.440	38.000	36.541	45.000	46.340	47.660
17.800	34.640	33.260	31.860	30.440	29.000	27.540	36.000	37.340	38.660
17.850	25.640	24.260	22.860	21.439	19.999	18.539	27.000	28.340	29.660
17.900	16.640	15.260	13.859	12.439	11.000	9.828	18.000	19.340	20.660
17.950	7.640	6.260	4.992	4.298	3.900	3.649	9.000	10.340	11.660
18.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

STABILITY FORMULAE

Waterplane Coefficient $C_w = \frac{A_w}{L \times B}$ Block Coefficient $C_b = \frac{V}{L \times B \times d}$

Midship section Coefficient = $C_m \frac{A_m}{B \times d}$ Prismatic Coefficient $C_p = \frac{V}{A_m \times L}$

$$C_p = \frac{C_b}{C_m}$$

Displacement = Volume of displacement x density

For box shaped vessels

(Density remaining constant) $\frac{\text{New displacement}}{\text{Old displacement}} = \frac{\text{New draft}}{\text{Old draft}}$

For box shaped vessels

(Displacement remaining constant) $\frac{\text{New draft}}{\text{Old draft}} = \frac{\text{Old density}}{\text{New density}}$

For all vessels

(Draft remaining constant) $\frac{\text{New displacement}}{\text{Old displacement}} = \frac{\text{New density}}{\text{Old density}}$

$$\text{TPC} = \frac{1.025\ A}{100}$$

$$\text{FWA (in mms)} = \frac{W}{4\ \text{TPC}}$$

$$\text{Dockwater allowance} = \frac{\text{FWA} \times (\text{Difference of densities})}{(1.025 - 1.000)}$$

$$GG_1 = \frac{w \times d}{\text{Final W}}$$

$$\text{Final KG} = \frac{\text{Final Vertical Moment}}{\text{Final Weight}}$$

$$\text{Final LCG} = \frac{\text{Final Longitudinal Moment}}{\text{Final Weight}}$$

$$GM = KM - KG$$

$$GM_L = KM_L - KG$$

$$\tan \text{ list} = \frac{GG_1}{GM} \text{ (for small angles of heel only)}$$

$$GZ = GM \times \sin\theta \text{ (for small angles of heel only)}$$

Wall Sided Formula

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

$$GZ = KN - KG \sin\theta$$

$$\text{New } GZ = \text{Old } GZ \pm \text{Vertical } GG_1 \sin\theta$$

$$\text{New } GZ = \text{Old } GZ - \text{Horizontal } GG_1 \cos\theta$$

Righting Moment or Moment of Statical Stability = W x GZ.

Dynamical Stability = Area under the curve of statical stability x W

Dynamical Stability = 2 x W x Hav θ (GM + BM Hav θ sec θ)

F. S. Moment = I x δ

$$\text{F. S. Correction} = \frac{\text{F.S. Moment}}{\text{Displacement}}$$

$$\text{F.S.C. for rectangular tanks} = \frac{lb^3}{12V} \times \frac{\delta_t}{\delta_r} \times \frac{1}{n^2}$$

$$\text{For rectangular waterplane } I = \frac{LB^3}{12}$$

$$BM = \frac{I_{CL}}{V}$$

For box shaped Vessels BM $= \frac{B^2}{12d}$

For box shaped vessels KB $= \frac{d}{2}$

For vessels of triangular cross section BM $= \frac{B^2}{6d}$

For vessels of triangular cross section KB $= \frac{2}{3}d$

For rectangular waterplanes $I_L = \frac{BL^2}{12}$

$BM_L = \frac{I_L}{V}$

For box shaped vessels $BM_L = \frac{L^2}{12d}$

For vessels of triangular crossection $BM_L = \frac{L^2}{6d}$

Simpson Rules,

Rule 1. for odd numbers

Simpson's multipliers 1, 4, 2, 4, 2 ... ... 4, 1

Common multiplier $\frac{h}{3}$

Rule 2. for (4 + 3n)

Simpsons multipliers 1, 3, 3, 2, 3, 3 ... ... 2, 3, 3, 1

Common multiplier $\frac{3h}{8}$

Rule 3.

Simpsons multipliers 5, 8, -1

Common multiplier $\frac{h}{12}$

Moment of Area or volume, for Rule 3,

Simpsons multiplier 3, 10, -1

Common multiplier $\frac{h^2}{24}$

Formulae for Draft Survey

Corr. for Position of Draft Marks

$$\frac{t}{(LBP - a + b)} = \frac{\text{corn.F}}{a} = \frac{\text{corn.}\otimes}{c} = \frac{\text{corn.A}}{b}$$

Corr. for Hull Deformation $= \left(\dfrac{\text{F.draft} + \text{A draft} + 6 \times \text{Amidships draft}}{8}\right)$

First Trim Corr. $= \dfrac{\text{trim x dist of CF from mid po int between perpendiculars}}{\text{LBP}}$

Second Trim Corr. $= \dfrac{50 \times (\text{trim in m})^2 \times (MCTC_1 \sim MCTC_2)}{LBP}$

List Corr. $= 6\ (d_1 - d_2)\ (TPC_1 - TPC_2)$

Density Corr. $= \dfrac{\text{scale displacement} \times \text{density of water}}{\text{density used for displacement scale}}$

Constant = (0.5 + 0.05n) % of the ship's deadweight

Centre of Gravity of Area or Volume $= \dfrac{\text{Moment of Area or Volume}}{\text{Area or volume}}$

Mean Sinkage or rise in cms. $= \dfrac{W}{TPC}$

MCTC $= \dfrac{W \times GM_L}{100 \times L}$

Trimming Moment = w x d (from CF)

Total change of trim $= \dfrac{\text{trim min g Moment}}{\text{MCTC}}$

After trim $= \text{total trim} \times \dfrac{LCF}{LBP}$

$$= \frac{1}{2} \text{ total trim when CF is amidships}$$

Fwd trim = total trim - after trim

Correction to mean draft to obtain true mean draft.

$$\text{Correction} = \pm \frac{\text{distance (between CF \& midships)} \times \text{trim}}{\text{Length}}$$

Inclining Experiment

$$GM = \frac{w \times d}{W \times \tan\theta} = \frac{GG_1 \times \text{Length of pendulam}}{\text{deflection}}$$

Increase in draft due to list

$$\text{New draft} = (\text{old draft} - \text{rise of floor}) \times \cos\theta + \frac{1}{2} \text{ Beam } \sin\theta$$

Effect of trim on tank Sounding:

$$\text{difference between ford and after Soundings} = \frac{l \times t}{L}$$

Dry Docking

$$P = \frac{t \times MCTC}{a}$$

P = original displacement - virtual displacement

$$\text{Virtual loss of GM} = \frac{P \times KM}{W}$$

$$\text{Virtual loss of GM} = \frac{P \times KG}{W - P}$$

Bilging

$$\text{Permeability} = \frac{\text{Broken Stowage} \times 100}{\text{Stowage factor}} \%$$

Mean Sinkage $= \dfrac{\text{Volume of lost buoyancy}}{\text{Intact waterplane area}} = \dfrac{V}{(A-a)}$

Sinkage with permeability $= \dfrac{p \times v}{(A - p\,a)}$

trim $= \dfrac{\text{trimming moment}}{\text{MCTC in bilged condition}}$

Total Pressure or Thrust = A x δ x head x t.

Depth of CP below WL $= \dfrac{I_{WL}}{A \times \text{head}}$

Theorem of Parallel Axis

$$I_{XX} = I_{CG} + Ah^2$$

tan angle of loll $= \sqrt{\dfrac{2\,GM}{BM}}$ (for wall sided v/ls)

Positive GM at angle of loll = 2 x initial GM x sec. loll

(for wallsided v/ls)

List with Zero GM

tan list $= \sqrt[3]{\dfrac{2 \times w \times d}{W \times BM}} =$ (for wallsided v/ls.)

Corrected KG = KG + FSC

GM (Solid) = KM - KG

GM (Fluid) = GM (Solid) - FSC

tan list $= \dfrac{GG_1}{GM\,(\text{Fluid})}$ (for small angles of heel)

GZ = KN - Corrected KG x sin θ.

Hydrostatic draft = draft aft ± Corrn.

where corrn. = $\dfrac{\text{trim} \times \text{LCF}}{\text{LBP}}$

total trim 't' = $\dfrac{\text{LCB} - \text{LCG}}{\text{MCTC} \times 100} \times$ Displacement

$'t_a'$ = $\dfrac{t \times \text{LCF}}{\text{LBP}}$

$'t_f'$ = $t - t_a$

Draft Aft = Hydrostatic draft + t_a

Draft Forward = Hydrostatic draft - t_f

Squat Formulae

S = $\dfrac{b \times \text{static draft}}{B \times \text{depth of water}}$

B' = $[7.7 + 20 (1- C_b)^2]$ bWind heeling lever l_1

1) Max. squat = $\dfrac{C_b \times S^{0.81} \times V^{2.08}}{20}$

or

2) Max. squat = $\dfrac{C_b \times {S_2}^{2/3} \times V^{2.08}}{30}$

where $'S_2'$ = $\dfrac{S}{1-S} = \dfrac{A_S}{A_C - A_S}$

Other approximate formulae are:-

1) Maximum squat in open waters = $\dfrac{C_b \times V^2}{100}$

2) Maximum squat in confined waters

where S is between 0.1 and 0.265) $= \dfrac{C_b \times V^2}{50}$

Wind heeling lever $l_1 = \dfrac{P.A.Z}{1000.g.W}$

Gust wind lever $l_2 = 1.5\ l_1$

Heel due to turning

$$\tan\ \theta = \frac{V^2.BG}{g.r.GM} \text{ or } \frac{V^2\left(KG \sim \frac{d}{2}\right)}{g.r.GM}$$

For passenger ships to satisfy intact stability criterion regarding heel due to turning

Heeling moment $= 0.02\ \dfrac{V^2}{L}\left(KG - \dfrac{d}{2}\right) W$

Unresisted still water rolling period T $= \dfrac{2 \Pi K}{\sqrt{g.GM}}$

Corrected Ullage = Observed Ullage $\times \sec\left\{\tan^{-1}\left(\dfrac{trim}{LBP}\right)\right\}$

$$+ \left[\left(\frac{\ell}{2} - a\right) \times \frac{trim}{LBP}\right] \pm b \times \tan\phi$$

TEST YOURSELF

1. *M.V. 'Hindship' arrives port in Condition No. 7. One of the locomotives, weighing 76 tonnes is to be discharged, using the ship's jumbo derrick, the head of which is 25 metre above keel. Find her GM (Fluid)*

   i) *when the locomotive is hanging on the derrick 0.5 metre above the deck.*

   ii) *when the locomotive has been discharged.*

   i) 0.413 m   ii) 0.478 m.

2. *M.V. 'Hindship' displacing 13530 t in water of density 1.015 t/m^3, KG 7.344 m, FSC 0.076 m, shifts a weight of 30 tonnes from 3 metres off the centre line on the port side to 4.5 m off the centre line on the stbd. side. Calculate the resultant list.*

   (1^0 06' to stbd)

3. *M.V. 'Hindship' arrives port in Condition No. 11. She then loads discharges as follows:-*

Compartment	*Disch. (t)*	*Load (t)*	*Kg. (m)*	*V.Moments (mt)*
Locomotives on Deck	*760*		*13.83*	*10510*
2 TD	*400*		*10.70*	*4280*
4 TD	*200*		*10.40*	*2080*
2 TD		*300*	*10.70*	*3210*
4 TD		*150*	*10.40*	*1560*

   Assuming the FSC in the final condition was 0.107 m and bunker consumption was negligible, calculate the GM (Fluid), after the above operations.

   (0.765 m)

4. *M.V. 'Hindship' loads to her Summer mark, in Fresh Water and proceeds down river to another port consuming 30 tonnes of bunkers and water. At this port, she loads some cargo and is again at her Summer draft in water of RD 1.016. Find the number of tonnes of cargo loaded at the second port.*

   (336.2 t)

5. *A passenger vessel of length 210 m, displacement 20800 t, draft 9.8 m, KG 7.9 m, KM 8.80 m, has a service speed of 24 kts. Does she satisfy the intact stability criterion regarding heel due to turning?*

(heel = $2.03^0 < 10^0$, she satisfies the criterion)

6. *M.V. 'Hindship' displacing 16398 t, KG 7.15 m, FSC 0.08 m discharged 280 t, Kg 6.20 m, Cg 1.4 m off the CL to stbd, and loaded 280 t, Kg 6.20 m, Cg 3.5 m to stbd off CL. A 70 t parcel of cargo was shifted horizontally from 3.6 m port of CL to 1.2 m port of CL. Calculate the resultant list.*

(2^0 36, to stbd.)

7. *M.V. 'Hindship' in Condition No. 4, discharges the entire cargo from No.1 TD and No. 3 TD. The entire HFO from the settling and service tank P & S is shifted to No. 4 DB tank centre. Find the final KG and GM (Fluid).*

(KG 6.932 m, GM (Fluid) 1.235 m)

8. *M.V. 'Hindship' arrives at a port in water of RD, 1.012 with drafts F 6.15 m, A 7.22 m. Her sailing draft in water of RD 1.025 was F 5.33 m, A 5.98 m. Calculate the weight of cargo discharged at that port, if 85 tonnes of fuel and fresh water were consumed in the port.*

(2083.3 t)

9. *M.V. Hindship arrived at a load port in tropical zone with 480 t of bunkers, 290 t of FW, 80 t of stores and a constant of 110 t. She is to sail with maximum cargo after 5 days port stay. She will enter summer zone 3 1/2 days after departure and after a further 5 1/2 days she will re-enter tropical zone. Two days thereafter she is to call at a port for 12 hours to receive 120t of FW and the maximum amount of bunkers. 5 days after departure from the bunkering port, she will re-enter summer zone. Calculate the maximum amount of cargo she can load at the load port and thereafter, the maximum amount of bunkers she can receive at the bunkering port. Fuel and FW consumption are 35t and 16t respectively at sea and 5t and 16t respectively in port.*

(cargo 13440.5 t) (bunkers 528.0 t)

10. *M.V. 'Hindship' floating in water RD 1.025 at a draft of F 7.23 m, A 7.93 m loads 940 t and sails to another port consuming 130 t of fuel and FW. Find her arrival hydrostatic draft at the second port*

(8.036 m)

11. *A ship of L 150 m, B 24 m, draft 10 m, Cb 0.7 has a windage area of 1600 m^2 including deck cargo. The centroid of the windage area is 6.75 m above the WL. GM (Fluid) = 0.6 m. Angle of flooding is 42^0. During the voyage, consumption of fuel and FW was compensated by water ballast creating an additional FSM of 3410 tm without change in displacement or KG. Investigate whether her dynamical stability satisfies the weather criterion, if her rolling angle in waves is 22.5^0.*

The GZ values on departure were:-

Heel^0	*10*	*20*	*30*	*40*	*50*
GZ m	*0.12*	*0.31*	*0.52*	*0.45*	*0.16*

(She satisfies the weather criterion)

12. *M.V. 'Hindship' displacing 12,400 t in water of RD 1.010, has a GM (Fluid) of 0.68 m. FSM 1530 mt. She loads 620 t in No. 2 Hold, kg 5.02 m No. 2 DB tanks P & S which contained 50 t in each SW ballast was pumped out. A 150 t parcel of cargo was shifted from No. 2 Hold to No. 3 TD. Calculate her final GM (Fluid).*

(0.661 m)

13. *M.V. 'Hindship' is in Condition No. 2. Find her GM (Fluid) after the following operations are carried out:*

Loads	*1 TD*	*601 tonnes*	
Loads	*3 Hold*	*1520 tonnes*	*Kg 1.70 m*
Loads	*5 Hold*	*420 tonnes*	

Pumps out F. Pk. Tank

Pumps out No. 4 DB tanks (P&S)

FSC in the final condition is 0.155 m

(2.118 m)

14. *M.V. 'Hindship' is at a draft of F 7.98 of F 7.98 m, KG 7.059 m FSC 0.089 m. Using the table of Cross curves of Stability Particulars, calculate her righting levers upto 750 heel. Assuming the angle of heel at which flooding occurs is 44, state whether she satisfies each stability requirement of the International Load Line Rules.*

(Satisfies all Criteria)

15. *M.V. 'Hindship' is floating at a draft F 8.68 m, A 8.88 m in water of density 1.010 tonnes/m3. LCG 72.129 m, It is desired to obtain an LCG of 71.129 m by discharging 400 t of cargo. Calculate the posi-*

tion from where the weight should be discharged.

(82.348 m, ford of AP)

16. *M.V. 'Hindship' in condition No. 7 pumps out 60 tonnes of ballast each from No. 4 DB tanks P and S. The entire diesel oil in No. 5 DB tank P is consumed in shifting to the dock. Calculate her GM (Fluid) on arriving in the dock where the RD of water is 1.007.*

(0.397 m)

17. *M.V. 'Hindship' is floating at a draft of F 7.40 m, A 6.60 m, in dock water of RD 1.016. Calculate her*

(i) hydrostatic draft (ii) displacement, (iii) dead weight.

(i) 7.00 m (ii) 14173.4 t (iii) 8673.6 t

18. *M.V. 'Hindship' floating in water of RD 1.025, at an even keel draft of 3.9 m. Calculate the hydrostatic draft at which she will float, in water of RD 1.011 at the same displacement:- (i) using FWA, calculated for the draft in question (ii) without the use of FWA.*

(i) 3.948 m (ii) 3.948 m

19. *M.V. 'Hindship' berthed in dock where RD of the water is 1.007 at a draft of F 7.87 m. A 8.32 m, Kg 7.45 m FSM 970 mt. She discharges 410 t of cargo from 2 TD. A 60t case is shifted from deck Kg 14.7m to No. 2 Hold, 110 t of water was received in No. 8 P and S tanks Kg 2.77 m, filling them completely. Calculated her GM (Fluid), if additional FSE was created in No. 3 DB tank (C) containing HFO.*

(0.822 m)

20. *M.V. 'Hindship' loading in dockwater of density 1008 Kg/m³ is to sail into a Summer Zone. She is floating with her starboard plimsol 2 cms above water line and port plimsol 6 cms below water line. Calculate the amount cargo that can be loaded before she commences her voyage.*

(284.12 t)

21. *M.V. 'Hindship' in condition No. 5 receives 100 tonnes of D.O. in No.7 port DB tank, cg 5 meters off the centre line. Calculate the resulting list.*

(2^0 2' to Port)

22. *M.V. 'Hindship' floating on an even keel in dock water of RD 1.017 with her starboard plimsol 15 cms above water and port plimsol 11.6cms*

above water is to sail from the dock with a maximum even keel draft of 9.2m. Calculate (i) The maximum amount of cargo that can be loaded.
(ii) her draft on reaching the sea.

(241.1 t, 9.137 m)

23. *M.V. 'Hindship' is floating at a draft of F 7.2 m, A 7.8 m.*
   (a) Find, where with respect to AP 200 tonnes of cargo is to be loaded to bring her on an even keel.

   (b) if instead of loading as in (a), the even keel condition was to be achieved by shifting cargo from No. 5 Hold to No. 3 Hold, find the amount of cargo to be shifted.

(a) 128.19 m ford of AP, (b) 180.5 t

24. *M.V. 'Hindship' is floating at a displacement of 19150 tonnes, KG 6.65 m, FSC 0.042 m, has yet to load 2 locomotives weighing 76 tonnes each, with her own gear. The first locomotive is placed on deck (quay side). Cg 13.83 m above the base and 6 metres from CL. The derrick then plumps the quay with it's head 21.5 m above the base and 13 m from CL and lifts the second locomotive to be placed on deck, on the other side. Calculate the maximum list during the operation.*

(2^0 38')

25. *M.V. 'Hindship' in Condition No. 7 discharges the entire cargo in No.2 TD, and fills in the bulbous bow with 186.6 tonnes of water ballast, Kg 3.52 Lcg 139.6 m ford of AP. Assume theoretically that the deck cargo of locomotive was shifted to No. 2 TD. A negligible quantity of water was inadvertently pumped out from No.4 P&S DB tanks, causing them to become slack. Calculate her GM (Fluid) and drafts F&A in the final condition.*

(0.723 m, F 8.225 m, A 8.617 m)

26. *M.V. 'Hindship' in condition No. 9, pumps out, 100 tonnes of ballast each from No. 2 (P) and No. 2 (S), DB tanks.*

   (i) Calculate her righting levers at 10^0 intervals upto an angle of heel of 40^0.

   (ii) Calculate her dynamical stability at an angle of heel of 40^0.

   (iii) Also state, whether the ship fulfills criteria A, B and C the minimum stability requirements of the International Load Line Regulations, given angle of flooding as 42^0.

(i) 0.175, 0.361, 0.608 (ii) 4228.4 tm (iii) satisfies

27. *On completion of loading, the ullages observed were as follows.*

1P - 1.43 m, 1S - 1.45 m, 2P - 1.70 m, 2S - 1.67 m

3P - 2.45 m 3S- 2.45 m, 4P - 1.65 m, 4S - 1.62 m

5P - 1.53 m 5S - 1.51 m, Slop (P) - 1.8 m, Slop (S) - 1.82 m.

Water cut for all the tanks was nil. Trim was obseved to be 0.50 m by stern. Determine the gross volume of oil loaded.

(87495.718 m^3)

28. *M.V. 'Hindship'. in Condition No. 2 has to load 220 tonnes of cargo. Where should this be loaded to keep her after draft unchanged?*

(84.557 m ford of AP)

29. *M.V. 'Hindship' is at an even keel draft of 9.35 m in dock water of RD 1.004. calculate her drafts F&A on reaching the sea. assume fuel and fresh water consumption negligible.*

(F 9.158 m, AP 9.207 m)

30. *M.V. 'Hindship' is at a draft of F 6.38 m, A 7.24 m, KG 8.06 m, FSM 1172 mt. 100 t of ballast is run into No. 3 (P) DB tank Cg. 8.0 m from CL. Draw the curve of statical stability and from it, determine the angle of list.*

($6\frac{1}{4}^0$ to Port)

31. *M.V. 'Hindship' at a displacement of 13750 t, KG 7.32 m, FS Moment 1146 mt, is listed $2\frac{1}{2}^0$ to starbd and has yet to load 380 tonnes of cargo. Space is available in No. 3 TD, 1.5 metres to starbd of centre line, and in No. 5 UTD, 6.2 metres to port of CL. Find the amount of cargo to be loaded in each space, so that the shipwill be upright on consumption.*

(Port side 142.79 t Starbd side 237.21 t)

32. *M.V. 'Hindship' at a draft of F 5.38 m, A 6.17 m, has GM (Fluid) 0.83 m and FSC 0.092 m. She discharges 430 t from No. 3 TD. VCg 10.2 m, LCg 78.5 m and loads 250 t in No. 5 LTD 300 t of fuel oil was received equally distributed in No. 2 DB tanks P&S. Calculate her final drafts F&A and GM (Fluid)*

(F 5.220 m, A 6.443 m, 0.905 m)

33. *M.V. 'Hindship' loading in river water of RD 1.012 is at a draft of F 5.16 m A 6.02 m. She then pumps out the entire ballast in No.1*

and 4 (P, C & S) DB tanks, which were filled in earlier at the same berth. No. 3 (P & S) and No. 5 DB tanks which were empty are filled with H.F.O. Calculate to the nearest tonne the maximum quantity of cargo that can be loaded, so that the vessel will be at her summer draft on reaching the open sea. Allow fuel and water consumption as follows, 50 tonnes in port and 70 tonnes for river passage. Also calculate to the nearest .01 m, the even keel sailing draft at the loading berth, in river water.

(9215 t, 9.37 m)

34. *M.V. 'Hindship' loading in dock water, RD 1.018 is on an even keel draft of 8.4 m, with a GM (Solid) of 0.45 m. She is to sail on an even keel at her summer draft in SW. Space has been allocated for the following parcels:-*

400 t in No. 2	*Kg 11 m*	*LCg 107 m*
350 t in No. 4	*Kg 9.8 m*	*LCg 53 m*
650 t in No. 5 TD	*Kg 10 m*	*LCg 18 m*

The remaining cargo is to be loaded in No. 1, Kg 5.5 m, LCg 122m and No. 5 Hold Kg 6 m, LCg 15 m. Calculate the amount to be loaded in each of these spaces and the final GM (Fluid) of the vessel, if her FSM was 2500 mt.

(No. 1: 614.7 t, No. 5; 124.5 t, 0.380 m)

35. *M.V. 'Hindship' in dock water of density 1.007t/m3 is at a draft of 7.62m, A 7.94 m. She has to load 450 t of cargo. Calculate the position with respect to AP, where this weight should be loaded so that she would be trimmed 1 m by the stern on completion.*

(41.352 m ford of AP)

36. *A vessel laden with grain in bulk of stowage factor 1.184m^3/t has a displacement of 87284 t. Her KG calculated assuming the Cg of the cargoes in the filled holds to be at the volumetric centroids of the compartments is 10.36 m. FSM 2643 mt, KM 13.20 m. The VHM of all filled holds is 5864 m^4 and that of a hold which is partly filled is 14400 m^4. The angle of flooding is 37^0.*

Her KN values are as follows:

Heel^0	*12*	*15*	*30*	*40*	*45*
KN m	*2.730*	*3.440*	*6.857*	*8.584*	*9.292*

Ascertain whether the ship satisfies the stability criteria for vessels laden with grain in bulk.

(She satisfies all criteria, provided she is upright on sailing)

37. *M.V. 'Hindship' in Fresh Water is at a draft of F 6.32 m, A 7.18m. Calculate the position with respect to AP, from where 140 t should be discharged to reduce her fold, draft by 32 cms.*

(136.747 m ford of AP)

38. *M.V. 'Hindship' arrives in Condition No. 7 and discharges the entire cargo from No. 4 TD. Given change in LCB due to ballasting in negligible, find the amount of ballast to be run into the A. Pk tank to bring her on an even keel. Also calculate the drafts F&A after ballasting.*

(48.87 t, F&A drafts 8.684 m)

39. *M.V. 'Hindship' in Condition No. 5, shifted some weight vertically upwards, so that her KG increased by 0.22 m.*

    (i) *Using GZ ordinates at 10^0 intervals, draw her statical stability curve, upto a heel of 30^0.*

    (ii) *From the curve drawn, estimate her initial metacentric height.*

    (iii) *Calculate the dynamical stability of the vessel, at an angle of heel of 30^0.*

(GM 0.50 m, D.S. 2150 tm)

40. *M.V. 'Hindship' floating at a draft of F 5.70 m, A 7.60 m, discharges the entire cargo from No. 4 TD which was full. The stowage factor of the cargo in No. 4 TD was 2/3 cubic metre per tonne. Calculate the drafts F&A, after discharge.*

(F 5.667 m, A 6.968 m)

41. *M.V. 'Hindship' in Condition No. 8 has to discharge 300 tonnes prior to sailing. Calculate the position with respect of AP, from where, this weight is to be discharged to enable her to sail trimmed 1.5 metres by the stern. Also find the sailing drafts F & A.*

(27.577 m ford of AP, F 6.903 m, A 8.403 m)

42. *M.V. 'Hindship' berthed in a dock where RD of water is 1.007, at a draft of F 7.87 m, A 8.32 m, KG 7.45 m, FSM 970 mt. She discharged 410 t of cargo from 2 TD. A 60 t case is shifted from deck, Kg 14.7 m, LCg 58.6 m to No. 2 Hold 110 t water Kg 2.77 m, LCg 16.23 m was received in No. 8 (P&S) tanks, filling them completely. Calculate the draft F&A at which she would sail from the dock. Also calculate*

her sailing GM (Fluid) if additional FSE was created in No. 3 DB tank (centre) which contained HFO.

(0.822 m, F 7.297 m A 8.627 m)

43. *M.V. 'Hindship' is in Condition No. 7 in water of RD 1.025, Rough weather causes 400 tonnes of cargo to shift horizontally through a distance of 8.5 meters and vertically downwards through a distance of 3 meters. Draw the Curve of Statical stability upto a heel of 40^0, after the shift of cargo has taken place. From the Curve estimate the resulting angle of list.*

(12^0)

44. *M.V. 'Hindship' in SW at a draft of 7.25 m ford and 8.10 m aft, has to load 170 t of cargo. Where with respect to AP should this cargo be loaded so that her ford draft would remain the same in water of RD 1.015.*

(38.126 m ford of AP)

45. *M.V. 'Hindship' at a draft F 5.80 m, A 6.36 m, KG 7.2 m, FSM 1190 mt. bilged her No.2 hold with permeability 60%.The No. 2 DB tank, 1.3 m deep, beneath the hold remained intact. The hold is of length 26 m, and of mean width 19 m. Calculate her GM (Fluid) and drafts F & A after the bilging.*

(GM (Fluid) 0.831 m F 8.172 m A 5.600 m)

46. *M.V. 'Hindship' displacing 18.529 tonnes, KG 7.539 m FSC 0.084 m.*

(i) Find her GM (Fluid)

(ii) Draw the statical stability curve for this condition.

(iii) From the curve find

(a) The maximum GZ and the angle of heel at which it occurs.

(b) The angle of vanishing stability.

(c) The change in the range of stability, when an upsetting moment of 4500 tonnes metre is caused.

(d) The list produced by the above upsetting moment.

(iv) State whether the ship fulfills criterion A of the Minimum Stability Requirements of the International Load Line Convention.

(i) 0.726 m (iii) (a) 0.61 m (b) 77^0 (c) 22^0 (d) 13^0

(iv) Satisfies.

47. *M.V. 'Hindship' in Condition No. 10 has to load 800 tonnes of cargo. Space is available in No. 1 TD, 125 metres ford of AP and in No. 3 TD, 80 metres ford of AP. Find the amount of cargo to load in each space to finish the ship on an even keel. State also the final drafts F & A.*

1 TD: 679.3 t   3 TD: 120.7 t.   Drafts F & A 8.124 m.

48. *M.V. 'Hindship' in Condition No. 3, sustained damage aft. To effect repairs, it is required to reduce the after draft to 4.5 meters by loading 518 tonnes in the fore part of the vessel. Find how far abaft the fore perpendicular, this weight should be loaded.*

(27.237 m from FP)

49. *M.V. 'Hindship' floating at a displacement of 18,820 tonnes, KG 7.728 m, FSC 0.092 m, is to be drydocked. Find her MCTC, LCF and KM.*

(a) *Assuming that these value remain constant over the range of drafts involved and that the vessel takes the blocks for and aft at the fore and after perpendiculars respectively, calculate the maximum trim by the stern allowable to ensure a virtual GM of at least 0.3 m on taking the blocks fore and aft.*

(b) *At the maximum permissible, find*

(i) *Her drafts F&A, on entering dry dock*

(ii) *The draft forward, at which the head would take the blocks.*

(iii) *The fall in water level between taking blocks Aft and taking blocks For'd.*

(a) 1.872 m or 1.964 m   b) F 7.946 m A 9.818 m

or F 7.899 m A 9.863 m

ii) 8.672 m or 8.661 m   iii) 1.146 m or 1.202 m.

50. *M.V. 'Hindship' loading in dock water of RD 1.010, is floating at a mean draft of 8.9 m. Calculate the amount of cargo she can load prior to sailing into a Winter Zone, if 120 tonnes of bunkers is yet to be received and 45 tonnes of FW and fuel is expected to be consumed before sailing.*

(543.3 t)

51. *M.V. 'Hindship' in Condition No. 7 struck a rock piercing her outer bottom in way of No. 4P, C & S and No. 5 P & S DB tanks. Calculate*

the drafts F & A at which she will float and her GM (Fluid) after bilging.

(0.626 m, F 8.782 m, A 9.060 m)

52. *M.V. 'Hindship' floating at a draft of F 5.73 m, A 6.42 m, is at an angle of loll of 4^0, FS Moment 1563 mt. Assuming the ship to be wallsided, calculate her KG.*

(8.304 m)

53. *M.V. 'Hindship' was floating with all compartments empty except as follows:-*

No. 2 (P&S) DB tanks full with water ballast No. 1 DB tank contained 100 tonnes of H.F.O. An inclining experiment was conducted in this condition. A weight of 10 tonnes KG 10.2 m, shifted transversely through a distance of 17.6 m, caused a deflection of 8.3 cms in plumb line 8.5 m in length. Calculate the GM (Solid) and the KG of the light ship.

(KG 8.735 m) (GM 2.916 m)

54. *M.V. 'Hindship' displacing 9540 tonnes and trimmed 0.78 by the stern is to be drydocked for bottom inspection. The hull has remained watertight and no flooding has occured. KG 7.826 m, FSC 0.164 m.*

(i) Obtain her KM, MCTC and position of LCF.

Assuming that these values and the FSC remain constant over the range of drafts involved, and that the vessel takes the blocks fore and aft at the fore and after perpendiculars respectively, calculate the following:-

(ii) The GM (Fluid) of the vessel before entering dry dock.

(iii) The virtual GM of the vessel when her keel takes the block all along the length of the vessel.

(iv) The ford and after aft, at which the virtual GM of the vessel becomes zero.

(v) The fall in water level, between the vessel taking blocks all over and her virtual Gm becoming zero.

(i) KM 8.970 m, MCTC 166.0 mt, LCF 72.949 m

(ii) 0.980 m, iii) 0.832 m or 0.813 m

(iv) F&A drafts 4.402 m or 4.411 m

(v) 0.404 m or 0.395 m

55. *M.V. 'Hindship' is loading in tropical zone in water of R.D. 1.010. She is to enter a port in summer zone after 5 days steaming, where she is to receive 300 t of fuel and 100 t of FW. She is expected to enter winter zone after a further 7 days steaming. Calculate the maximum amount of cargo she can load if she has 230 t of fuel, 150 t of FW, 100 t of stores and 20 t of unpumpable ballast. Her constant is 120 t and daily consumption is 36 t of fuel and 15 t of FW.*

(13243 t)

56. *A vessel is loaded with grain in bulk of stowage factor 1.80 m^3/t has displacement of 68012 t, a KM of 11.40 m and FSM 4220 mt. Two holds are partly filled and their combined VHM, as read off from the curves is 3009 m^4. All other holds are full and their total VHM is 18981 m^4. The KG of the ship calculated assuming the CG of the cargoes in the filled compartments are at the volumetric centroid of each of those compartments is 10.50 m^4. The angle of flooding is 41^0.*

The KN values for her displacement are as follows:-

Heel ^{0}	*12*	*15*	*30*	*40*	*45*	*60*	*75*	*90*
KN m	*2.782*	*3.508*	*7.033*	*9.356*	*10.206*	*11.288*	*11.270*	*10.385*

Determine whether the ship satisfies the intact stability criteria for vessels laden with grain in bulk.

(She satisfies all criteria, provided she is upright on sailing)

57. *M.V. 'Hindship' is a draft of F 8.778 m, A 8.792 m, LCG 72.34 m ford of AP. She discharges 206 tonnes of cargo from No. 5 LTD. Calculate the drafts F and A.*

(F 8.961 m A 8.451 m)

58. *M.V. 'Hindship' arrived port with the following drafts F 8.65 m, A 8.89m, Mid 8.81 m. Density of dockwater 1.018 weights on board: H.O. 250 t, D.O. 85 t, FW 112 t, L.O 18 t, and unpumpable ballast 45 t. If the constant and stores as determined on completion of discharge was 150 t. Calculate the quantity of cargo discharged. Draft marks are located 2m aft of FP, 4m ford of AP and 1m ford of midship.*

(12290.8 t)

59. *M.V. 'Hindship' floating at a mean draft of 5.5 m, Kg 7.53 m FSC in the final condition 0.104 m, has to load 1200 tonnes of cargo in No.2 TD. Find the amount of cargo to be loaded in each space to complete the ship with a GM (Fluid) of 1 m.*

(No. 2 Hold = 1098.9 t) (No. 2 TD = 101.1 t)

60. *A box shaped tank L 30 m × B 18 m × 20 m containing crude oil of density at 15^0 C = 0.8275 t/m^3 had an ullage of 1.80 m as measured by a Sonic Tape. The ullage port was located 3 m fwd of the aft bulkhead, 1 m above the tank top and 2 m to port of centreline of tank. Trim observed was 3 m* and the *vessel listed 1^0 to starboard. Observed temp 32.5^0 C. Calculate the quantity of oil in tank if the LBP of vessel was 215 m.*

(8383.3 M.T.)

61. *M.V. 'Hindship' floating at a displacement of 13750 tonnes, KG 6.2m, FSC 0.12 m is listed 1½^0 starbd. Find the amount of cargo to be loaded in No. 4 TD, 6 m off the centre line to bring the vessel upright.*

(117.9 tonnes)

62. *M.V. 'Hindship' arrived port in a partly loaded condition with drafts F 6.65 m, A 6.95 m and mid 6.76 m in water of density 1.010 t/m^3. Calculate the quantity of cargo she can load if she is to sail into a summer zone on an even keel in SW, with an expected sag of 8 cms. 56 t of fuel and FW is expected to be consumed in port and 20 t during the down river passage. The draft marks are 2 m for'd of FP, 2 m abaft midship, and 3 m abaft AP.*

Also find the sailing draft F & A in DW.

(F 9.299 m A 9.263 m)

63. *M.V. 'Hindship' floating at a mean draft of 7.12 m in water of RD 1.008, KG 6.12 m loads 900 t of cargo in 3 TD, 2 m off CL to port and 200 t in No. 4 TD, 2.5 m to strbd of CL. An 80 t lift is discharged from deck kg 14.1 m, cg 4 m to port of CL. Calculate her final mean draft and angle of list if the FSC in the final condition was 0.12 m.*

(7.566 m, 2^0 07' to Port)

64. *Find the Moment of Stability of M.V. 'Hindship' at an angle of heel of 7^0, when displacing 16133 t, KG 7.57 m, FSC 0.085 m.*

(1968.23 mt)

65. *M.V. 'Hindship' loading in FW is at a hydrostatic draft of 7.30 m, KG 7.90 m, 1300 tonnes of cargo is to be loaded. What should be the kg of the cargo to be loaded so that her final GM is 0.5m i) in SW (ii) in FW.*

(5.927 m, 5.976 m)

66. *An oil tanker of LBP 200 m has a box shaped tank of dimensions L 40 m × B 20 m × D 20 m and is loaded with oil. On completion ullage as measured from a sonic tape was observed to be 1.24 m and*

temp. was 37^{0}C. A water dip ullage of 20.94 m was also found. The ullage port was located 1.1 m above the tank top and 1.6 m fwd of aft bulkhead. Vessel was trimmed 3 m by stern. Terminal gave the density of oil @ 15^0 C as 0.8145 t/m^3. *Determine the quantity of oil in the tank.*

(12482.9 M.T.)