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Stability Theory Course

Stability 1

Contents

Stability Theory (Stability 1)

Welcome to Aberdeen College and the Stability Theory Course.

The prime objective of the course is to enable students with little or no knowledge of basic stability theory to become familiar with the calculations required to assess the stability of a Mobile Offshore Unit and to manage the stability of such a unit in a safe condition.

The course content meets the requirements of the IADC/NI. IADC, in conjunction with the Nautical Institute, has developed a standard for a comprehensive stability training course based on IMO Assembly Resolution A.891 (21). The programme - Class A – Comprehensive stability instruction utilizing full-motion simulators to replicate extreme wind and sea conditions and emergency situations; would comply with regulations in the United Kingdom and Canada; flag state requirements, US Coast Guard (USCG) and the International Maritime Organization (IMO).

Stability Theory is part 1 of a 3 part course, part 2 is the 'Offshore Stability and Ballast Control for Semi-Submersibles (Stability 2)'. The semi-submersible simulator course (Stability 3) completes the suite of courses.

Students have been provided with a set of course notes; the notes have ample space to enable students to enter details of the worked examples and the notes are intended to serve as a reference document for students intending to progress to the Advanced Stability course (Stability 2)
Please make full use of the course notes and the worked examples.

There will be an assessment before completion of the course and the award of an internationally recognised course certificate is dependent that students obtain a 70% pass mark in the assessment.
Attendance on the Stability 2 course requires that Stability 1 has been successfully completed.

Reference to the course notes is allowed during the assessment; all the formulae required during the course will be provided.

It is hoped that the content of the course will be relevant to the work that students presently carry out or intend to take up and students are encouraged to request from the lecturer full explanation of any points that they are unsure of.

The course will commence at 0900 each day and continue until 1630 with a break of about an hour for lunch, which will be taken at a café bar close to the college.

General Notes

Calculations during the course will be worked using American Standard units.

i. e. Length, Breadth, Depth, Draft and Distance will be expressed in feet and decimal parts of a foot, 1 inch being $1/12^{th}$ of a foot.

Area will be expressed in square feet (ft^2)
Volume will be expressed in cubic feet. (ft^3)
Weights will be expressed in lbs. or short tons (2000 lbs. per short ton).
Moments will be expressed in foot/tons (ft/tons)

Density of Salt Water is assumed to be 64 lbs. per cubic foot.
Density of Fresh Water is assumed to be 62.5 lbs. per cubic foot.

Abbreviations

M	Metacentre
K	Keel (base line for vertical heights)
G	Centre of Gravity
B	Centre of Buoyancy
KB	Height of Centre of Buoyancy above the Keel (same as VCB)
KMT	Height of Transverse Metacentre above keel
KML	Height of Longitudinal Metacentre above keel
KG	Height of Centre of Gravity of unit or load above keel
VCG	Vertical Centre of Gravity (same as KG)
LCG	Longitudinal Centre of Gravity
TCG	Transverse Centre of Gravity
GMT	Transverse Metacentric Height (distance between G and MT)
GML	Longitudinal Metacentric Height (distance between G and ML)
GZ	Righting Arm or Lever
RM	Righting Moment
DMF	Draft Marks Forward
DMA	Draft Marks Aft
COD	Change of Draft
COT	Change of Trim
LCF or COF	Longitudinal Centre of Floatation
AMD	Arithmetical or Amidships Mean Draft
TMD	True Mean Draft
TP1”	Tons per Inch Immersion
MT1”	Moment to trim One Inch
Δ	Displacement
V	Volume of Displacement
CL	Centreline
ϕ	Amidships

Formulae

Shift of Centre of Gravity for a weight moved

G to G1 =	$\frac{w \times d}{\Delta}$	G to G1 = Shift of G
		w = weight moved
		d = distance moved
		Δ = total displacement of unit

Shift of Centre of Gravity for weight loaded / discharged

G to G1 =	$\frac{w \times d}{\Delta}$	G to G1 = Shift of G
		w = weight loaded / discharged
		d = distance from original C of G
		Δ = total displacement of unit

To calculate centre of Gravity (VCG / LCG / TCG)

Final Position of G =	$\frac{\text{Total moment of weight}}{\text{Total weight of unit}}$

To Calculate Displacement

Displacement = (lbs.)	Vol. of Displacement (cu/ft) x Density of liquid (lbs./cu.ft.)

To calculate Rolling / Pitching Period

T =	$\frac{\text{Constant}}{\sqrt{GM}}$	T = Rolling / Pitching period in seconds
		GM = Initial transverse / longitudinal metacentric height

To calculate TP1" immersion

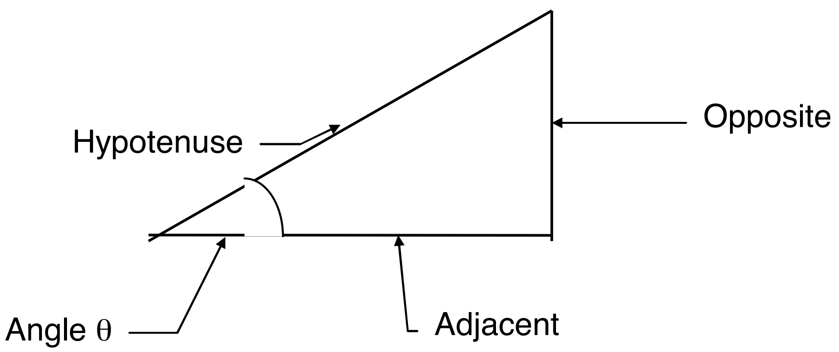
TP1" = (s.tons)	$\frac{\text{W.P.A.}}{374.63}$	W.P.A. = Area of waterplane in sq.ft.

Trig ratios (for right-angled triangles)

$$\text{Sine} = \frac{\text{Opposite}}{\text{Hypotenuse}}$$

$$\text{Cosine} = \frac{\text{Adjacent}}{\text{Hypotenuse}}$$

$$\text{Tangent} = \frac{\text{Opposite}}{\text{Adjacent}}$$



To calculate True Mean Draft (TMD)

$$\text{TMD} = \text{Mean Draft Aft} \pm \frac{\text{(Trim x Dist. from Aft Draft Marks to CoF)}}{\text{Length between draft marks}}$$

To calculate Moment to Trim 1" (MT1")

MT1" = (ft/tons)	$\frac{\Delta \times GML}{12 \times L}$	Δ - displacement
		GML - Longitudinal metacentric height
		L – Length between draft marks

To calculate MT1 Degree

MT1 Degree = Δ x GML x Tan 1 degree (ft/tons)

To Calculate Moment to Heel / List 1" (MH1")

MH1" = (ft/tons)	$\frac{\Delta \times GMt}{12 \times B}$	Δ - displacement
		GMt – Transverse metacentric height

B - Breadth between draft marks

To calculate Moment to Heel / List 1 degree

MH 1 degree =	Δ x GMt x Tan 1 degree (ft/tons)

To calculate GMt during inclining Experiment

GMt =	$\frac{w \times d}{\Delta}$	x $\frac{\text{Measured length of Pendulum (in feet)}}{\text{Measured deflection of Pendulum (in decimal parts of a foot)}}$

Where		
w	=	Weight moved in short tons
d	=	Distance weight moved in feet
Δ	=	Actual weight of unit at time of inclining

To calculate Free Surface Moments

FSM = (ft.tons)	$\frac{\text{Length} \times \text{Breadth}^3}{12}$ x Density

To calculate Virtual reduction in GMt due FSE

Virtual reduction = (in feet)	$\frac{\text{Free Surface Moments}}{\Delta}$

To calculate Bodily Sinkage / Rise

Sinkage / Rise = In inches (decimal / foot)	$\frac{\text{Weight Loaded / Discharged}}{\text{TP1”}}$

Definitions

Volume of Displacement Or 'V'	Volume of liquid displaced by a floating unit or underwater volume of unit. Usually expressed in cubic feet (ft^3)
Displacement Or Δ	Weight of liquid displaced by a floating unit, usually taken to be the total weight of the unit and the total load in any condition
Load Displacement	Weight of the unit when floating at the maximum allowable draft as defined by the loadline rules.
Light Displacement	Sometimes referred to as Lightship weight or Lightweight. It is the weight of the unit as built, in operational condition, but without any fuel, water, stores, ballast or drilling consumables on board.
Deadweight	Weight of cargo, fuel, stores, crew & crew effects, drilling consumables on the unit. (anything that is not included in the light weight)
Hull Load	That part of the deadweight that is loaded in the hull (pontoons) of semi-submersible unit. Includes ballast, fuel, drillwater etc.
Deck Load.	That part of the deadweight loaded on or above the deck of a semi. It will also include loads that are contained within the columns. Loads such as drilling loads (hook load) riser and anchor tensions are also included in deck load.
Inclining Experiment	Experiment carried out on newly built units to calculate the GMt of a unit in order that the Lightship weight and position of the centre of gravity in the light weight condition can be determined It may be required to be repeated if major structural alterations have been made to the unit
Deadweight Calculation	Carried out generally after modifications to the unit have been made over a period of time and a check on the current lightweight is required.
Centre of Gravity Or 'G'	The point in a unit through which the total weight of the unit and its contents are considered to be acting vertically downwards.

Buoyancy	The upward force on a floating unit due to water pressure on the hull. The upward force of buoyancy equals the downward force of gravity at any draft.
Centre of Buoyancy Or 'B'	Point through which the resultant buoyancy forces may be considered to act vertically upwards. This point is the geometric centre of the underwater volume.
Transverse Metacentre Or 'Mt'	The intersection of vertical lines through the centre of buoyancy in the initial and slightly inclined positions. May be assumed to be a fixed point for small angles of heel up to about 10 degrees.
Initial Metacentric Height - GMt	The distance between the Centre of Gravity and the Transverse Metacentre in a vertical sense.
Stability	The ability of a unit to return to the upright or original position after being inclined by an external for such as wind or waves.
List	The inclination of a unit transversely (i.e. to port or starboard) due to transverse shift of weight on board or the loading or removal of weight off the centreline.
Heel	The inclination of a unit transversely due to an external force such as wind or waves
Trim	The inclination of a unit in a fore and aft sense. The difference between the drafts at the bow and stern. If deeper at the bow then the unit is said to be 'trimmed by the head', if deeper aft then the unit is said to be' trimmed by the stern'.
Centre of Floatation or 'CoF' or 'F'	Point at which the unit balances along the longitudinal axis, not always at mid length.
Stable Equilibrium Or Positive GMt	The centre of gravity is positioned below the metacentre. In this condition the unit will return to upright after being inclined by an external force.

Neutral Equilibrium Or No GMt — The centre of gravity is at the same height above the keel as the metacentre. In this condition the unit will remain at any small angle of inclination after being inclined by an external force until other forces act upon it.

Unstable Equilibrium Or Negative GMt — The centre of gravity is above the position of the metacentre. The unit will heel over to a large angle and may even capsize. It may however become temporarily stable at an Angle of Loll but will heel rapidly in a different direction with changes in the environmental forces.

Moment — The product of a force (or weight) and a lever (distance) usually expressed in ft/lbs. or ft/tons.

Couple — Formed when two parallel forces are acting in opposite directions.

Moment of a Couple — The product of one of the forces forming a couple and the lever of the couple.

Lever — Perpendicular distance between the forces forming a couple.

Righting Lever Or 'GZ' — Distance between the lines of force of gravity and buoyancy. Also the lever of the couple tending to right a vessel heeled by an external force, (must have a positive GMt).

Capsizing lever (also 'GZ') — Again the distance between the lines of force of gravity and buoyancy but this time the unit has negative GMt.

Righting Moment or Moment of Statical Stability — The moment of a couple tending to right a unit heeled by external forces. The moment is the product of the displacement of the unit and the size of the righting lever. (Δ x GZ)

Upsetting Moment — The moment of a couple tending to incline a unit further from her present position

Bodily Sinkage or Bodily Rise — The change in the mean draft of the unit due to loading or offloading cargo. The change in the draft is calculated by dividing the weight of cargo by the TPI.

Tons per Inch Immersion or TPI	The number of tons required to change the mean draft by one inch. Found by reference to the unit's hydrostatic tables or curves.
Draft	The distance from the waterline to the base of the unit (keel)
Load Draft	The maximum draft the unit can be loaded to in accordance with the load line rules.
Freeboard	The vertical distance from the waterline in any condition of loading to the freeboard deck.
Minimum Freeboard	The minimum freeboard the unit is allowed to operate with in accordance with the load line rules.
Freeboard Deck	The uppermost continuous deck with permanent means of closing all openings through it and below which the hull is watertight. Usually the main deck on offshore units.
Reserve buoyancy	Potential buoyancy of the enclosed and watertight spaces above the waterline to the freeboard deck. Enables a unit to withstand the effects of accidental flooding or damage to internal spaces.
Free Surface	Any tank which contains a liquid which is neither full nor empty will have a free surface when the unit heels away from upright.
Free Surface Effect	The virtual rise in the position of the centre of gravity due to free surface in the tanks on the unit.

Section 1   Basic Stability

Objective: To introduce the elements of stability

Subjects will be covered in this section.

1. Lightweight, Deadweight and Displacement
2. Centres of Gravity, Buoyancy and the Metacentre
3. States of Equilibrium,
4. Trigonometric Ratios
5. Righting Levers and Righting Moments
6. Position of ‘B’, ‘G’, & ‘M’ in service
7. The Inclining Experiment
8. Rolling in a Seaway
9. Free Surface Effects

Basic Stability.

The **Principle of Archimedes** tells us that a body immersed in a liquid will experience an upthrust or apparent loss of weight equal to the weight of liquid displaced.

Thus a body floating in a liquid will displace it's own weight of liquid.

The **Volume of Displacement** is equal to the volume of the liquid displaced or submerged volume of a unit.

To calculate the submerged volume we need to know the dimensions of the submerged portion of the unit. So we must know the length and breadth also depth of the submerged portion, this is known as the **Draft** that the unit is floating at.

The **Displacement** is equal to the weight of liquid displaced or the weight of the unit in any given condition.

Density is defined as weight per unit volume. Different liquids will have different densities.

It is usual to assume **Salt Water** to have a density of **64 lbs/ft^3** (approx.) or 1025 oz/ft^3

It is usual to assume Fresh Water to have a density of **62.5 lbs/ft^3.** Or 1000 oz/ft^3

The formula used to calculate Displacement is as follows :-

Displacement Δ	=	Volume of Displacement V (ft^3)	x Density ρ (lbs/ft^3)

If any two of these particulars are known then the third can be found by transposing the formula

$$\text{Volume} = \frac{\text{Displacement}}{\text{Density}}$$

$$\text{Density} = \frac{\text{Displacement}}{\text{Volume}}$$

Using the above formulae complete the calculations on pages 3 & 4.

1. A unit has a volume of displacement of 48,000 ft^3 in salt water.

What is her displacement in short tons?

Displacement = V x Density

= 48,000ft³ x 64 lbs/ft³

=3072000lbs

= 3072000/2000

= 1536 short tons

2. A unit floating in fresh water has a displacement of 6,000 short tons, her volume of displacement would be?

Displacement = Volume of displacement x density

		ft³		lbs/ft³
6000st	=	X	x	62.5 lbs/ft³
X	=	6000 x 2000 lbs / 62.5 lbs/ft³		
	=	192,000 ft³		

3. A box shaped unit 200 ft. long, 40 ft. beam & 20 ft. deep floats at a draft of 10 ft. in salt water. What is her displacement ?

Displacement = Volume x density

= 200 x 40 x 10 x 64 lbs/ft³

= 80,000 ft³ x 64 lbs/ft³

= 5120000 / 2000

= 2560 stons

4. A box shaped unit, 100 ft. long, 20 ft. beam and 10 ft. deep, has a displacement of 312.5 short tons. What will be her draft in fresh water?

100 x 20 x X = 312.5st

100 x 20 x X = 312.5st x 2000

100 x 20 x X = 625,000lbs

2000 x X = 625,000/ 62.5

X = 10000/2000 = 5’

5. A unit 100 ft. long, 20 ft. beam and 10 foot deep has a displacement of 480 short tons. What will be her draft in salt water?

100 x 20 x X = 480 x 2000

2000 x X = 960000/64

X = 15000/2000 = 7.5’

6. A unit has a volume of displacement of 160,000 ft^3 when floating in water of density 63.2 lbs/ft^3. Calculate the density of water in which she would displace 158,000 ft^3 ?

V = Displacement/ Volume   Density = Displacement/ Volume

160000ft^3 x 63.2 = 1011200lbs

1011200 / 158000 = 64lbs/ft^3

Answers :-	1.	1536 s.tons	2.	192,000 ft^3
	3.	2560 s.tons	4.	5 ft.
	5.	7.50 ft.	6.	64 lbs/ft^3

Conversion Factors

1 U.S. Gallon	3.785 litres	0.1337 ft^3

1 U.K. Gallon	4.546 litres	0.1605 ft^3
1 U.S. Barrel	0.158987 m^3 (158.987 litres)	5.6146 ft^3

Using the above conversion factors complete the following calculations.

1. A fluid has a density of 64 lbs/ft^3, find the weight of one U.S. Gallon of the fluid.

64 x .1337 = 8.56 lbs

2. One U.S. Gallon of fluid has a net weight of 10 lbs., find the density of the fluid.

Density = Displacement / Volume

10 / .1337 = 74.79 lbs/ft^3

3. One U.S. Barrel has a net weight of 350 lbs., find the density of the fluid.

350 lbs / 5.6146 = 62.34 lbs/ft^3

4. Find the net weight of 600 U.S. Gallons of fluid density 60 lbs/ft^3.

600 US Gals x .1337ft^3 / gal = 80.22ft^3

80.22ft^3 x 60 lbs/ft^3 = 4813.2 lbs or 2.41st

5. One U.K. Gallon of fluid has a net weight of 10 lbs., find the density of the fluid.

Density = Displacement / Volume

10 / .1605 = 62.31 lbs/ft^3

6. Find the net weight of 40 U.S. Barrels of fluid density 55 lbs/ft^3.

40 x 5.6146 = 224.58ft^3 x 55 lbs/ft^3 = 12352.12lbs / 2000=

6.18st

7. If 10 U.S. Barrels has a net weight of 1.25 short tons, find the density of the fluid.

Density = Displacement / Volume

$= 10 \times 1.25 \times 2000 = 25000$

$= 10 \times 5.6146 = 56.15$

$25000 / 56.15 = 44.53$ lbs/ft³

Answers :

1. 8.56 lbs/U.S. G.
2. 74.8 lbs/ft^3
3. 62.34 lbs/ft^3
4. 4813.2 lbs. or 2.4 short tons
5. 62.3 lbs/ft^3
6. 12352 lbs. or 6.18 short tons
7. 44.53 lbs/ft^3

Lightweight, Deadweight and Displacement

The **lightweight,** sometimes referred to as **'Lightship'**, is the weight of the unit as built and delivered to the owner from the shipyard.

In this condition the unit is in working order with all operating equipment but does not have any deckload, hull load, stores, crew effects etc. onboard. In other words there are no drilling consumables such as drill pipe, bulk materials or chemicals. The ballast tanks are empty as are the fuel, drill water and fresh water tanks.

It is in this condition that the inclining experiment should be carried out to ascertain the unit stability particulars, however this is not always the case as we will discuss later in the course.

The list of all items that have been included in the lightweight should be defined in the stability information supplied to the unit. If there is any doubt concerning the status of any equipment, if it is not included in the lightweight equipment list then it should be considered to be part of the displacement.

The maintenance of the lightweight condition is extremely important and any structural changes or modifications should be carefully and accurately recorded.

Each unit should maintain a record of modifications on a record sheet , which must be forwarded at appropriate intervals to the Certifying Authority for their information. Major modifications will have to be authorised by the certifying authority before they are carried out to ensure that the structural strength and stability of the unit is not compromised.

The **Deadweight** of a unit is all the various loads that make up the total weight of the unit, in other words all the loads that we require to enable the unit to operate.

As the unit has a maximum draft that she can operate to then it follows that the deadweight will be restricted to a finite figure.

Therefore we can say that the **Displacement** of the unit will be made up from the lightweight plus the deadweight.

The **Tables of Hydrostatic Properties** will list the displacement for any draft the unit is floating at.

For a semi-submersible unit the deadweight is considered in two parts :

1. The total **deck load**.

2. The total **hull load**.

Deck load comprises any weight carried on or above the deck and within the columns, it includes riser and anchor tensions also drilling loads such as hook loads and mud weights.

Due to structural strength considerations there will be a maximum value for deck load, this maximum value must never be exceeded. In order to ensure safe operations a daily check of all loads must be carried out.

Operational conditions such as transit mode and survival mode will also place a restriction on the maximum deck load allowable.

Hull load is that part of the deadweight contained within the hull tanks, ballast, fuel, drill water etc. Hull loads are restricted only by the physical size of the tanks within the hull.

The Centre of Gravity

The centre of Gravity ‘G’ is the point at which the weight of a unit, and it’s contents, may be assumed to be concentrated, it is the point about which the unit will balance .The total weight of the unit will act vertically downwards through this point.

The position of ‘G’ will be fixed for lightweight but will vary for different conditions of loading. It will lie on the centreline if the unit is symmetrically loaded and will be midway along the length of the unit when floating on an even keel.

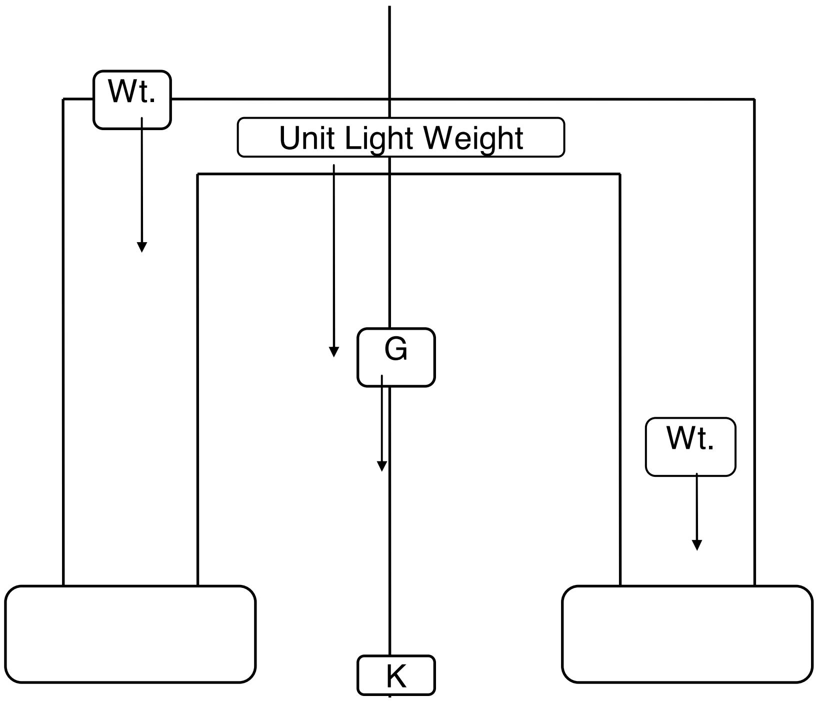
The position of the centre of gravity continually changes as we alter the position of weights on the unit.

When we are assessing the stability and attitude of a floating unit, we must consider the centre of gravity in three planes.
So we measure the position of the centre of gravity in the vertical plane (KG or VCG), longitudinal (LCG) and transverse plane (TCG).

VCG or KG is always measured from the keel or base of the unit.

LCG may be measured from mid-length or the bow or stern.

TCG is always measured from the centre line of the unit.



The Centre of Buoyancy

Buoyancy is defined as the apparent loss of weight of an object immersed in a fluid.

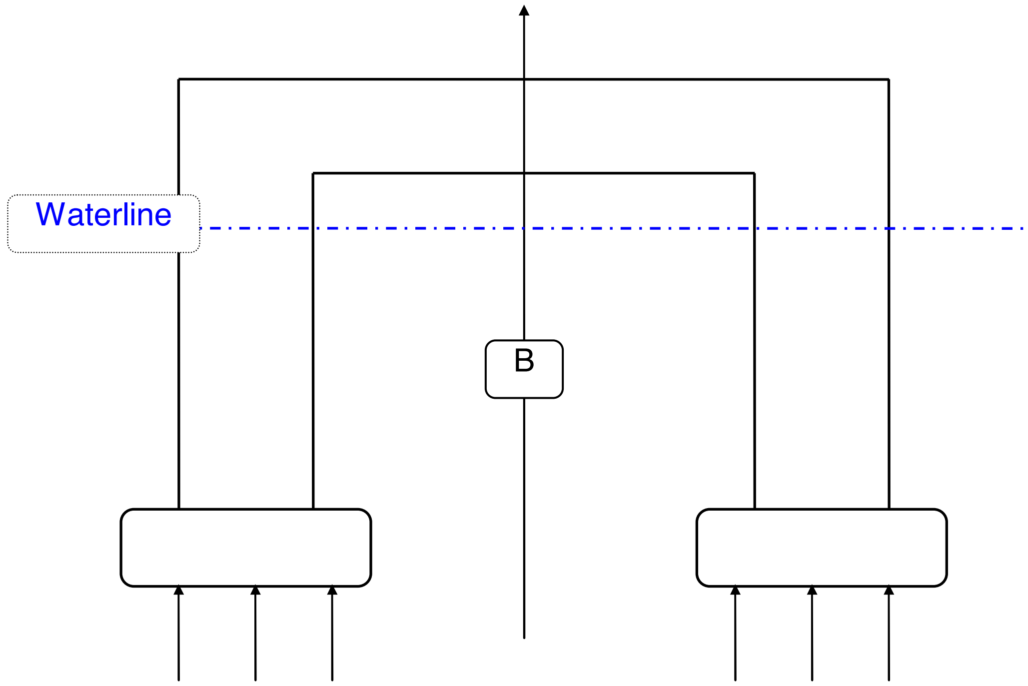
For a unit floating in a liquid the total upward force of buoyancy will be equal to the total downward force of gravity otherwise the unit will be unable to float. With the unit in equilibrium the lines of force of gravity and buoyancy will be on the same vertical line.

The centre of buoyancy 'B' is the geometric centre of the submerged volume of the unit and is the point through which the resultant buoyancy force may be assumed to act vertically upwards.

This point 'B' will normally lie on the centreline when the unit is upright as the unit is usually constructed symmetrically.

The centre of buoyancy will always be measured vertically upwards from the keel (KB or VCB) and will be defined for the lightweight position also tabulated in the tables of hydrostatic properties for a particular draft / displacement.

Hydrostatic curves for the unit will also allow the position of the centre of buoyancy to be defined for any given draft / displacement.



The Metacentre

The transverse inclination of a unit from the upright condition due to external forces, such as wind or waves, is known as heel.

When a unit is heeled the centre of buoyancy 'B' will move away from the centreline as it is always the geometric centre of the underwater (or submerged) volume of the unit.

A vertical line drawn from the new position of 'B' intersects the original vertical (or centreline of the unit in our diagram) at the position 'M'.

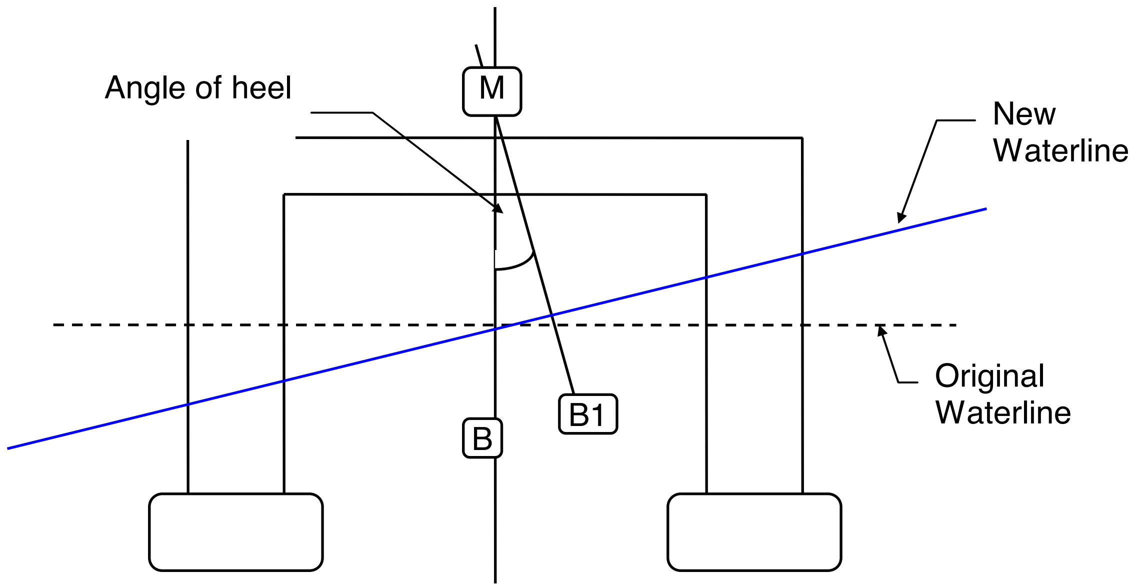
This point is called the metacentre and for small angles of heel (up to about 10 º) can be assumed to be a fixed point.

It is referred to as the 'Initial Metacentre' or 'Transverse Metacentre' (Mt).

When referring to the transverse metacentre it is always measured vertically upwards from the keel and can be obtained either from tables of hydrostatic properties or hydrostatic curves.

Occasionally a 'Longitudinal Metacentre' (KML) will be tabulated, to define the position of metacentre, due to the movement of the centre of buoyancy along the length of the unit, when being affected by pitch.

It can be seen from the diagram that the positions of 'M' and 'B' for a particular unit depend on the draft/displacement of the unit.



States of Equilibrium

Stability (or statical stability) is the tendency of a unit to return to its original position after it has been heeled by an external force such as wind or wave.

There are three possible conditions of equilibrium for a unit depending on the position of 'G' relative to the Metacentre.

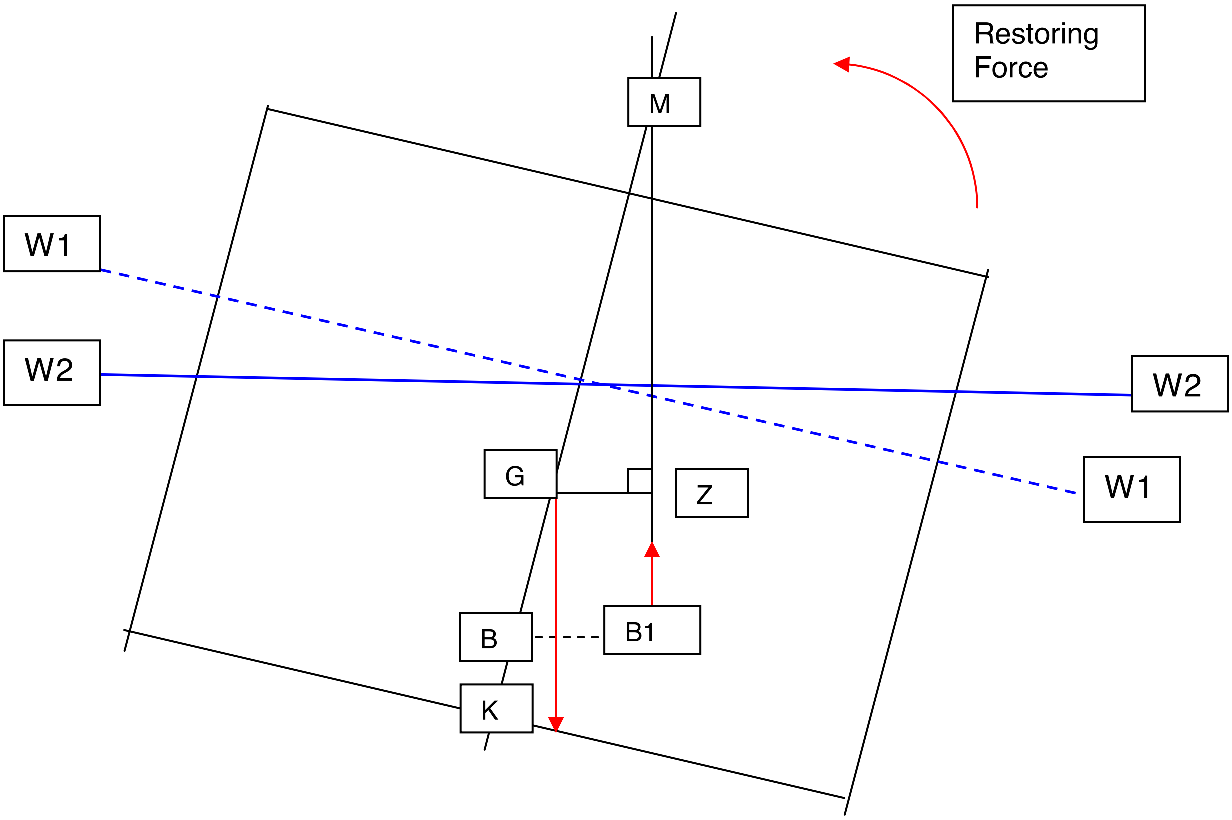
1. Stable Equilibrium

‘G’ lies below ‘M’

Righting Lever or Righting Arm   = ‘GZ’ ft,

Righting Moment or Moment of Statical Stability   = Δ (s.tons) x ‘GZ’ (ft.)

Unit will return to upright.

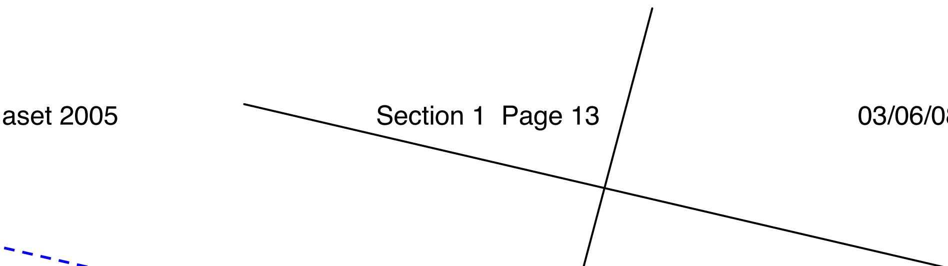


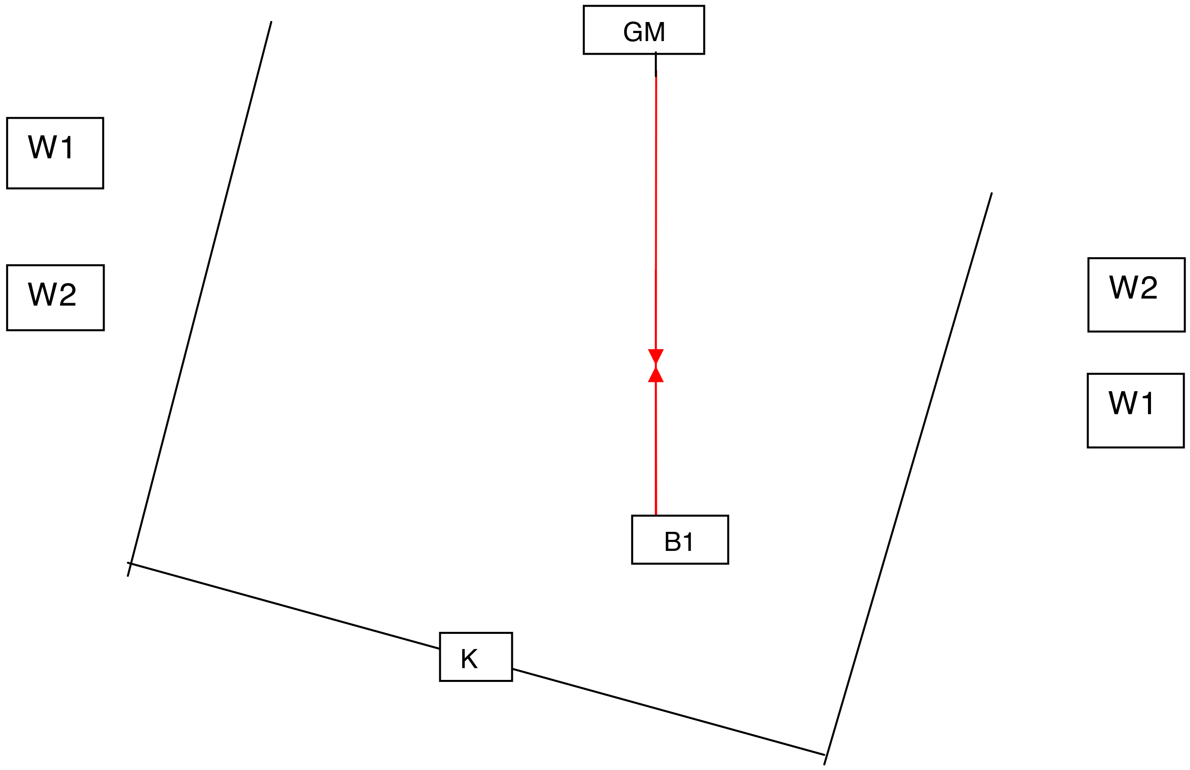
2. Neutral Equilibrium

‘G’ lies at the same position as ‘M’

Righting Lever = 0   Righting Moment = 0

Unit



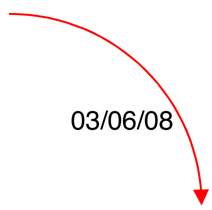


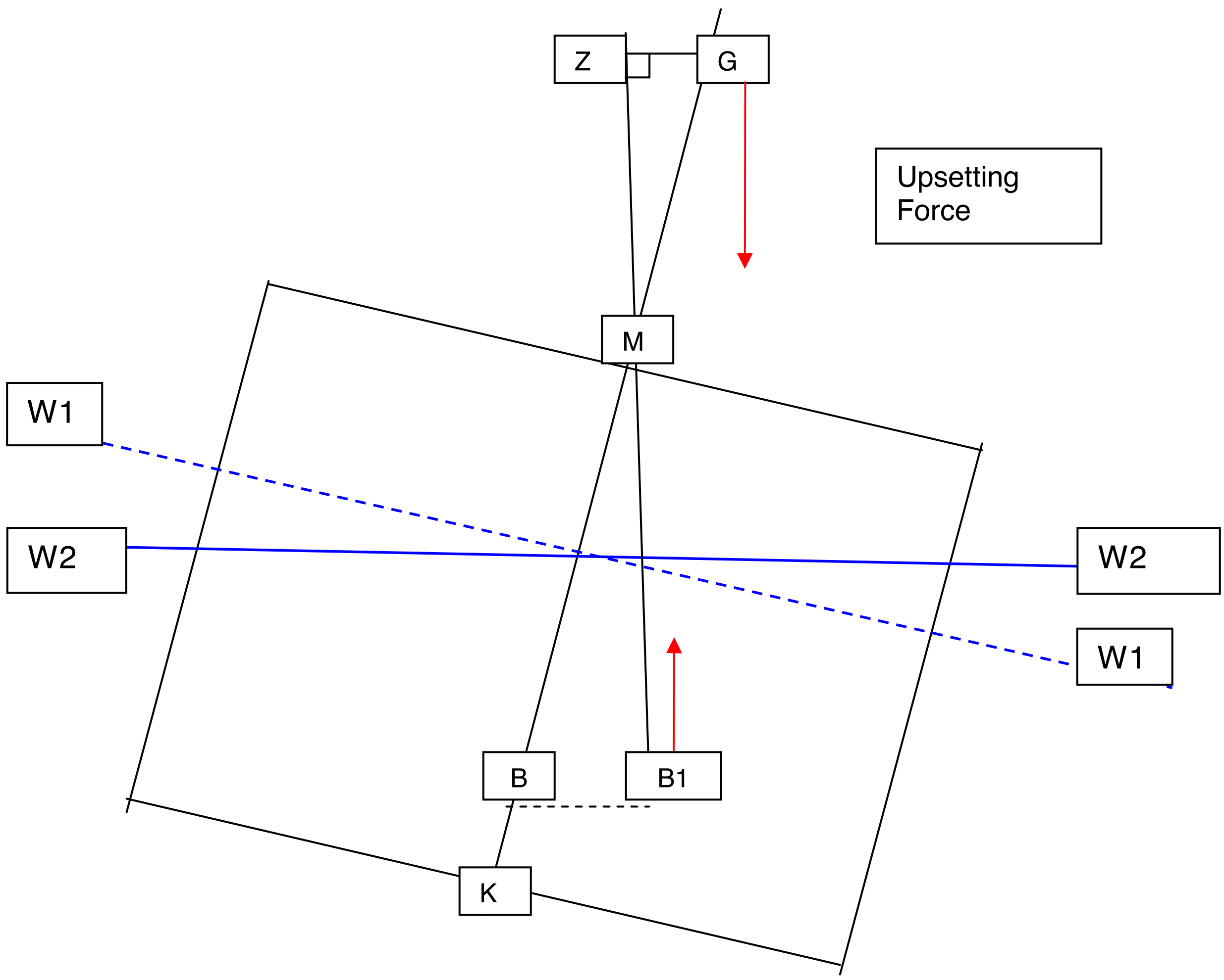
3. Unstable Equilibrium

'G' lies above 'M'

'GZ' is now an upsetting lever   Δ x 'GZ' is an upsetting moment

Unit will heel to some larger angle and **may** capsize.





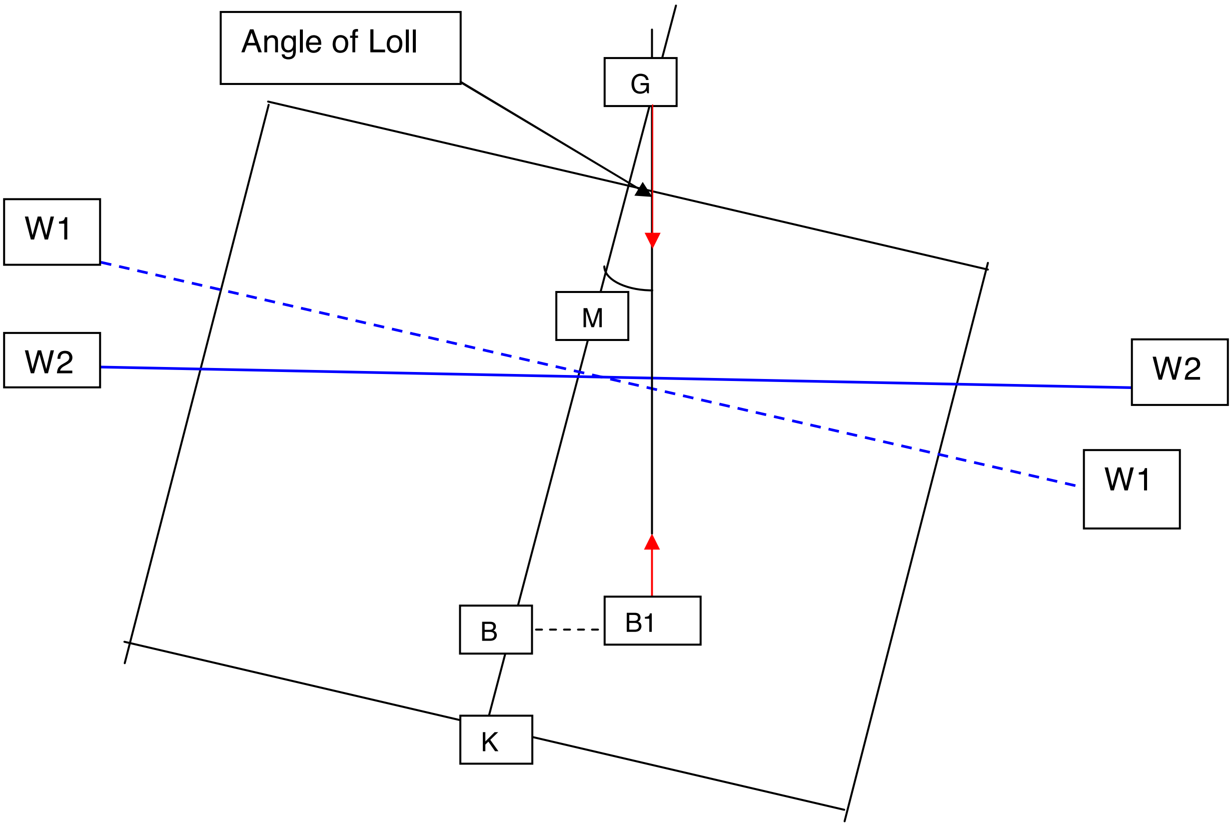
Angle of Loll

The angle to which a unit with unstable equilibrium heels to if it does not capsize is called the angle of loll.

In this case ‘B’ moves out until it is vertically under ‘G’ once more.

At an angle of loll a unit will be stable but the range of stability is reduced and the unit will flop from side to side.

Stability must be gained by lowering ‘G’; transferring weight across the unit from low to high side may be dangerous.



Summary

For a unit to float upright and return to upright after being heeled by an external force the following conditions must apply :-

1 The weight of liquid displaced must equal the weight of the unit.

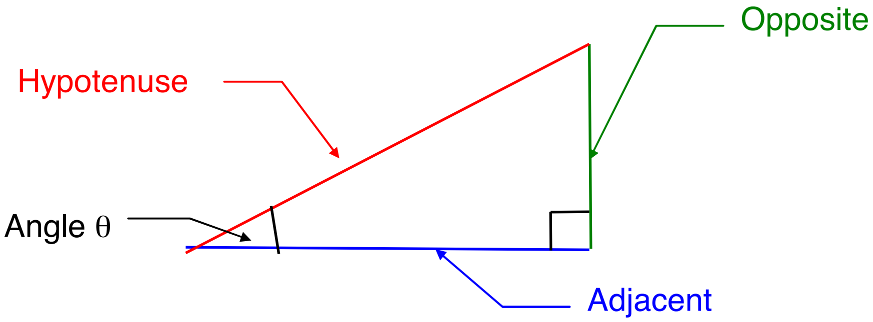
2 'B' and 'G' must lie in the same vertical line.

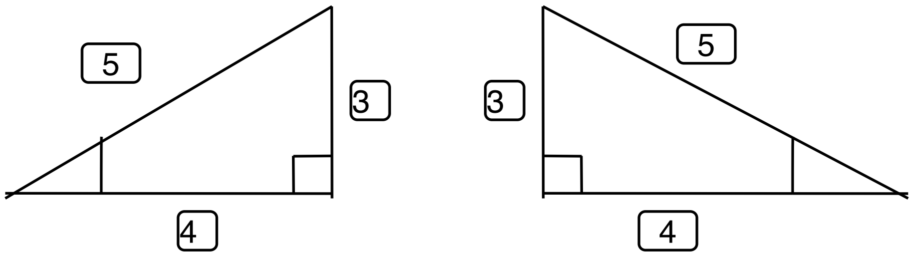
3 'G' must lie below 'M'.

Trigonometric Ratios.

In a Right Angled Triangle, for a given angle- Theta (θ), ratios of sides are constant irrespective of the size of the triangle.

$$\text{Sine } \theta = \frac{\text{Opposite}}{\text{Hypotenuse}} \qquad \text{Tangent } \theta = \frac{\text{Opposite}}{\text{Adjacent}}$$





In the triangles above solve for the Sin & Tan of the angle θ

Sin θ =	Opp = Hyp	0.6 =	Tan θ =	Opp = Adj	1.08 =
Angle θ =		36.87°	Angle θ =		47.32°

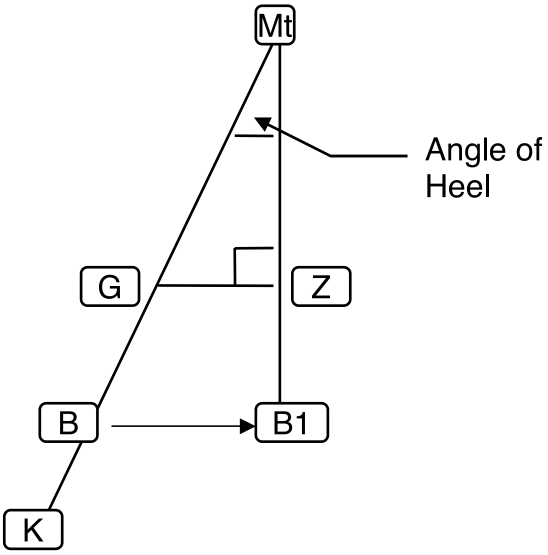
If Angle θ=	2 °	Sin θ = .03	&	Tan θ = .03
	2.5°	Sin θ = .04	&	Tan θ = .04
	4.75°	Sin θ = .08	&	Tan θ = .08
	6.25 °	Sin θ = 0.11	&	Tan θ = 0.11

Righting Levers and Righting Moments.

For small angles of heel up to about 10 ° where 'M' can be assumed to be a fixed point the righting lever for a unit may be calculated by means of trig. Ratios if the angle and 'GM' are known.

Sin Angle $\theta = \frac{GZ}{GMt}$ Righting Lever GZ = GMt x Sinθ

Righting Moment or Moment of Statical Stability = Δ x GZ



Example

A unit of 4000 s.tons displacement has a KG of 12.4 ft. and a KMt of 16.2 ft.

Find (a) her righting lever   (b) her righting moment

At an angle of 5 °.

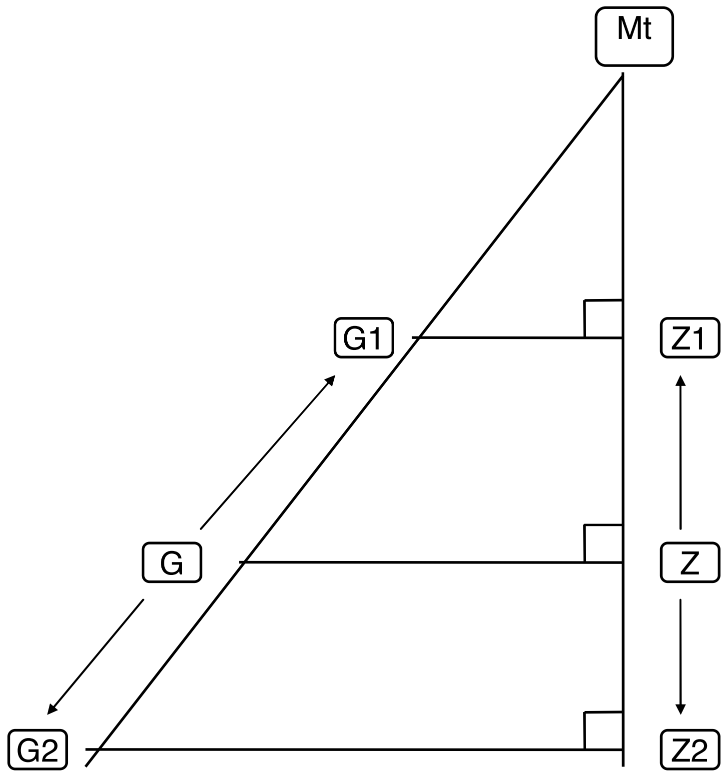
GMt = KMt - KG = 16.2 - 12.4 = 3.8 ft.

GZ = GMt x Sin θ = 3.8 x Sin 5 ° = 0.331 ft.

RM = Δ x GZ = 4000 x 0.331 = 1324.8 ft/tons.

Note :-

If ‘G’ is raised or lowered there will be a change in the value of ‘GMt’ and in the righting lever ‘GZ’ and a corresponding change in the value of the righting moment.



Example

A unit of 6000 s.tons displacement has a GMt of 4.2 ft.
If a movement of cargo results in a rise of G of 1.2 ft. calculate the loss in righting moment at 4 ° heel.

Original GZ = Orig. GMt x Sin θ = 4.2 x Sin 4° = 0.293 ft.

Original RM = Orig. GZ x Δ = 0.293 x 6000 = 1757.9 ft/tons.

$\therefore$ Original RM at 4° heel =1757.9 ft/tons

New GMt = Orig. GMt - Rise in GM = 4.2 - 1.2 = 3.0 ft.

New GZ = New GMt x Sin θ = 3 x Sin 4° = 0.209 ft.

New RM = New GZ x Δ = 0.209 x 6000 = 1255.6 ft/tons

$\therefore$ New RM at 4 ° heel = 1255.6 ft/tons

Loss in RM due shift of G = Original RM - New RM
= 1757.9 ft/tons – 1255.6 ft/tons
Loss in RM due shift of G = 502.3 ft/tons

The question can also be solved using the difference between the original and new values for GM, in other words the shift of G

Change in GZ = Shift of G x Sin θ = 1.2 x Sin 4° = 0.084 ft.

Loss of RM = Change in GZ x Δ = 0.084 x 6000 = 502.3 ft/tons

Complete the following Statical Stability calculations.

1.

A unit of 4000 s.tons displacement is heeled 8 °, if her KMt is 16.0 ft. and KG 13.5 ft. calculate the righting moment.

2.
A unit has a GMt of 3 ft. Redistribution of her deck cargo results in 'G' being raised 1 ft. Calculate the reduction of GZ at an angle of heel of 5 ° due to this redistribution.

3.
A unit when heeled 5 ° has a righting moment of 4800 ft. tons. If her GMt is 1.5 ft. calculate her displacement.

4.
A unit of 6000 s.tons displacement has a KG of 17.1 ft. and is heeled 10 ° by an external force. Calculate the righting lever and righting moment if it is know that for a KG of 16.1 ft. the GZ at 10 ° is 1.0ft.

5.
A unit of 11,000 s.tons displacement has a righting moment of 5200 ft.tons when heeled 5 °. Calculate the initial metacentric height.

6.
A unit of 6000 s.tons displacement has a KG of 15.1 ft. When heeled 10 ° her GZ is 0.43 ft. If the KG is lowered to 10.2 ft. calculate the righting moment at 10 ° heel.

Answers.

1. 1392 ft/tons	2. 0.087 ft.	3. 36641 s. tons
4. 0.826 ft. 4956 ft./tons	5. 5.427 ft.	6. 7686 ft/tons.

Position of 'B', 'G' & 'M' in service.

It has been shown that the positions of 'B' and 'M' both depend only on the unit's draft or displacement and for the upright and even keel condition their values may be obtained from hydrostatic curves or tables.

The position of the centre of gravity 'G' will be fixed for the lightweight condition but will move according to the position of the weight loaded / unloaded.

G will remain in that position unless more weight is loaded / offloaded or the position of weight already on board is changed.

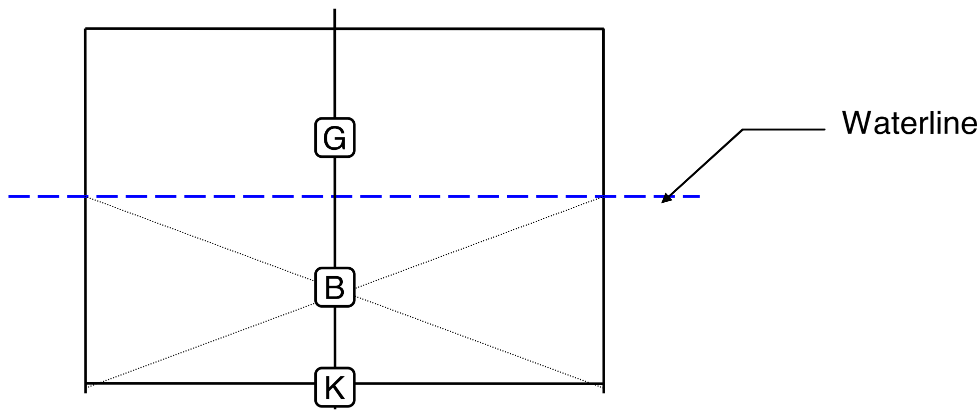
The centre of gravity 'G' will move directly **towards weight loaded** and directly **away from a weight unloaded**.

If weight is loaded / offloaded on or uniformly about the centreline then 'G' will move up or down the centreline. The unit will remain upright so long as 'G' remains below the metacentre 'Mt'.

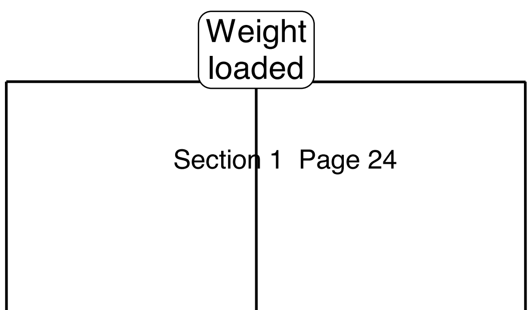
The centre of buoyancy will always be at the geometric centre of the underwater portion of the unit.

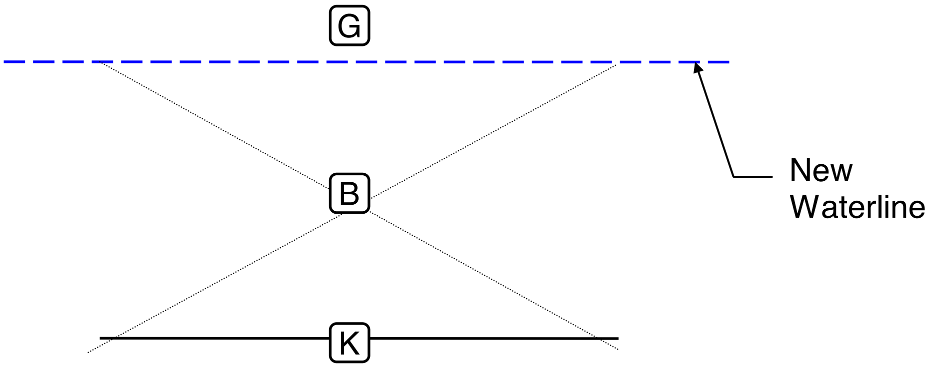
The distance KB (VCB), when the unit is upright, can be found by inspection of the hydrostatic tables.

Positions of G & B before loading a weight.



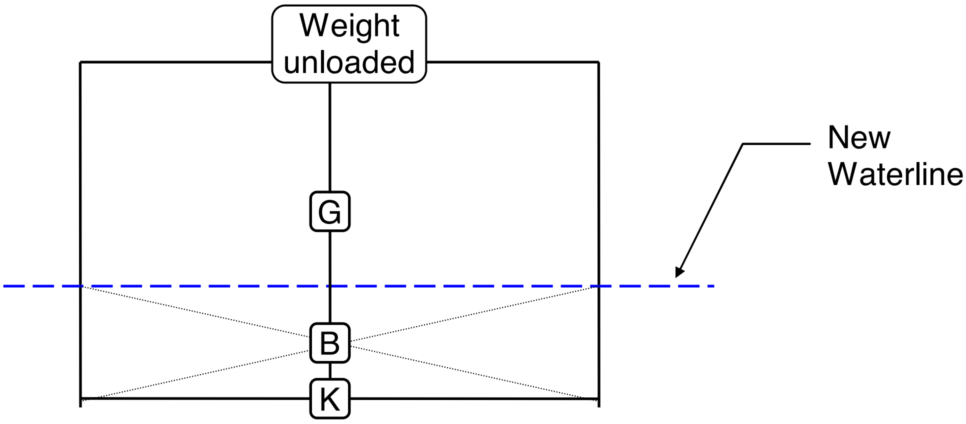
Positions of G & B after loading a weight on the centreline.





Due to the weight loaded, the unit increased draft and sunk to a new waterline.
The position of G changed upwards in this case as we loaded the weight above the position of the original centre of gravity.
(G always moves towards a weight loaded no matter where it is loaded on the unit).
B moved (upwards in this case) to take up a position at the centroid of the underwater portion of the unit.

Positions of G & B after unloading a weight from the centreline.



With the reduction of weight the draft has been reduced.

G has moved down in this case (away from the weight unloaded)

B has also moved down to be at the centroid of the underwater portion of the unit.

List.

If weight is loaded / unloaded from a position off the centreline then 'G' will move away from the centreline and the unit will move away from the upright condition. This condition is known as **List.**

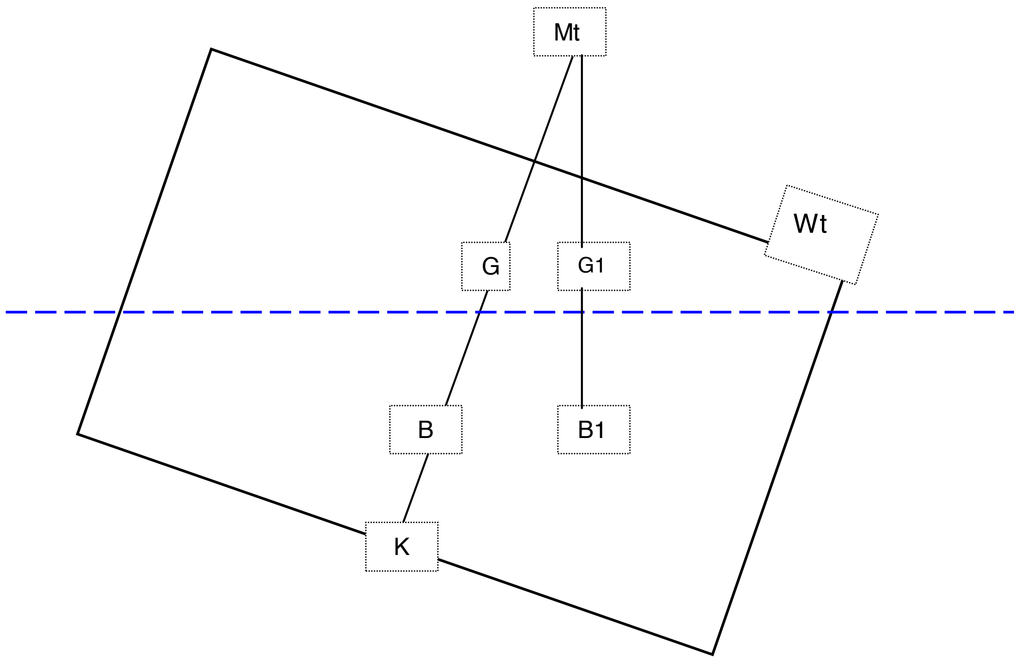
The centre of buoyancy 'B' will move to a new position vertically under the new position of the centre of gravity 'G' and the unit will remain at that attitude in still water or roll about it when affected by wind and waves.

The centre of gravity will always move in a direction parallel to the direction of the shift of weight.

It should be noted that if a weight is moved vertically (either up or down) and transversely, there will be a corresponding movement in the position of the centre of gravity.

The centre of buoyancy will also move to once again be at the centroid of the underwater portion of the unit.

Movement of G & B when a weight is loaded off the centreline



The centre of gravity has moved across towards the weight that has been loaded, it has also moved upwards towards the weight.

The unit will then be heavier on that particular side causing a list.

B will also move across towards the low side of the unit until it is directly below G1.

The angle of list caused by the loading of weight can then be calculated.

To do this the value of GMt and the distance that G has moved is required to be known.

GMt can be calculated from the formula :

KMt - KG = GMt

KMt can be obtained from the hydrostatic properties for the unit and KG can be found by calculation.

The distance that G has moved (known as the shift of G) can be calculated form the formula :

G to G1 = weight x distance ÷displacement.

Weight being the weight(s) of the object loaded/unloaded / moved.

Distance being the distance that the object has been loaded/unloaded away from the original centre of gravity or reference point.

Displacement being the total displacement after the loading/unloading /movement of the object has been completed.

The Inclining Experiment.

It is mandatory for an inclining experiment (or test) to be carried out on all units of novel design. In reality it is done on all new units and is usually required on units that have undergone major structural alterations.

The experiment is supervised by the appropriate authorities such as ABS, Lloyds etc. The work is often carried out by a team of competent engineers working for the unit builders.

The purpose of the experiment is to determine the exact Lightship weight and lightship position of the centre of gravity vertically (KG or VCG), transversely (TCG), and longitudinally (LCG).

Although values for lightweight and the position of ‘G’ may be estimated during the design stage, an inclining experiment is necessary to determine their exact values.

It is upon these figures that all other conditions of loading are based for determining drafts, stability, trim and list.

At the time of the inclining the unit should be as near complete as possible and all items required to be fitted to or removed from the unit carefully noted with their weight and position on the unit defined.

The unit stability information booklet will contain full details of how the experiment was carried out and the results that were obtained.

Once the experiment has been completed and the results verified against the designers estimates, the unit operator should be provided with a list of all items of equipment on the unit at the time of the incline that have been included in the lightweight calculation.

Any future modifications to the unit should be recorded on the ‘alterations to lightweight record’` mentioned previously.

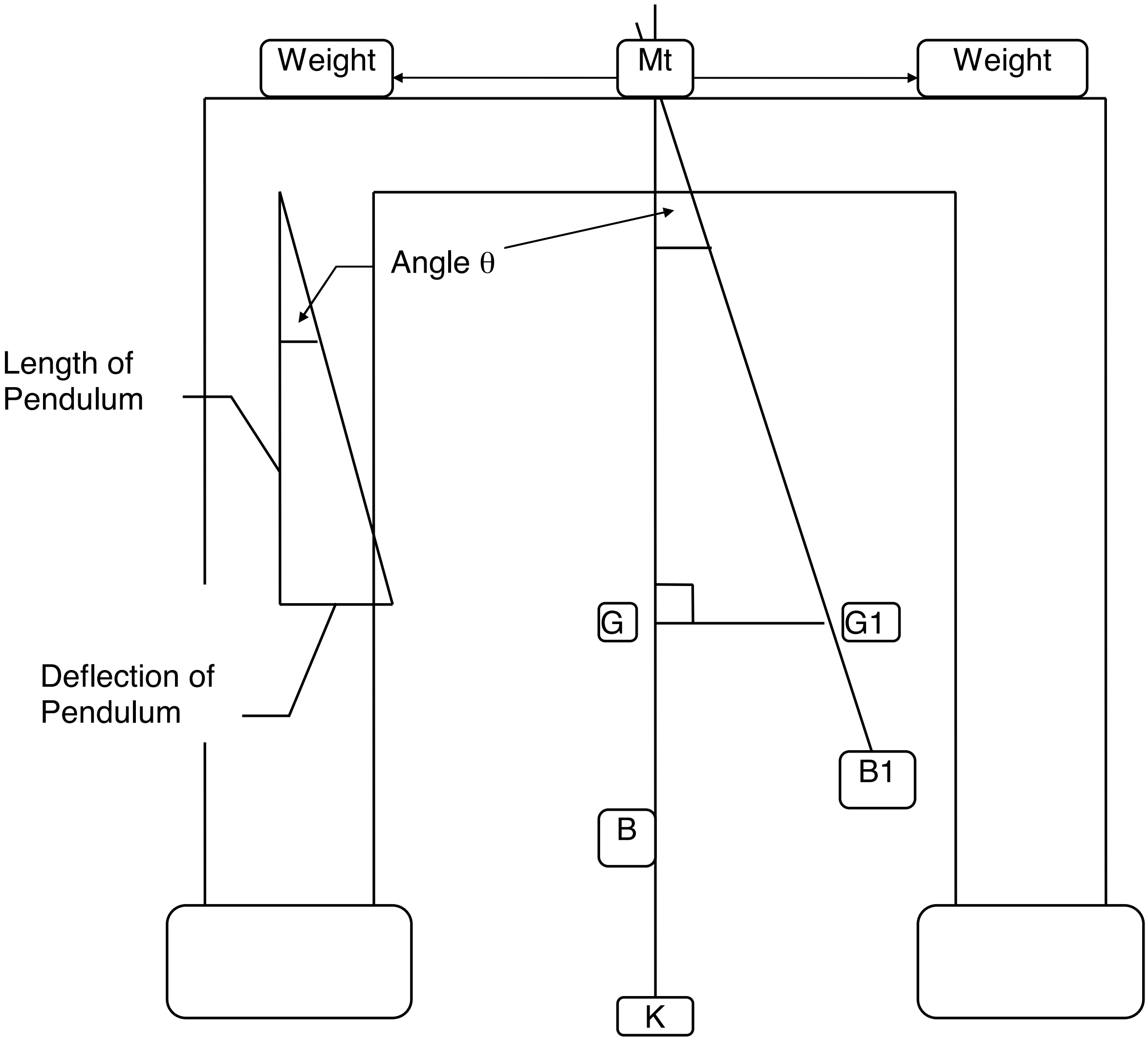
During the inclining experiment pendulums are set up at, usually at three places and a number of tests carried out to obtain a mean result.

In the Inclining Experiment a known weight (w) is moved a known distance (d) across the unit and the deflection (Þ) of a pendulum of known length (L) is measured to calculating the resultant angle of list.

GMt for the unit in this condition may be obtained from the formula :-

$$GMt = \frac{w \times d \times \text{measured length}}{\Delta \times \text{measured deflection}}$$

For clarity the unit is shown in the upright condition.



Using the formula in this example :-

Inclining weight	= 15 s. tons
Distance moved	= 60 ft.
Length of Pendulum	= 40 ft.
Deflection of pendulum	= 1.2 ft.
Displacement	= 5250 s. tons

$$GMt = \frac{\text{weight moved x distance moved x measured length of pendulum}}{\text{Displacement x deflection of pendulum}}$$

$$GMt = \frac{15 \text{ X } 60 \text{ X } 40}{5250 \text{ X } 1.2}$$

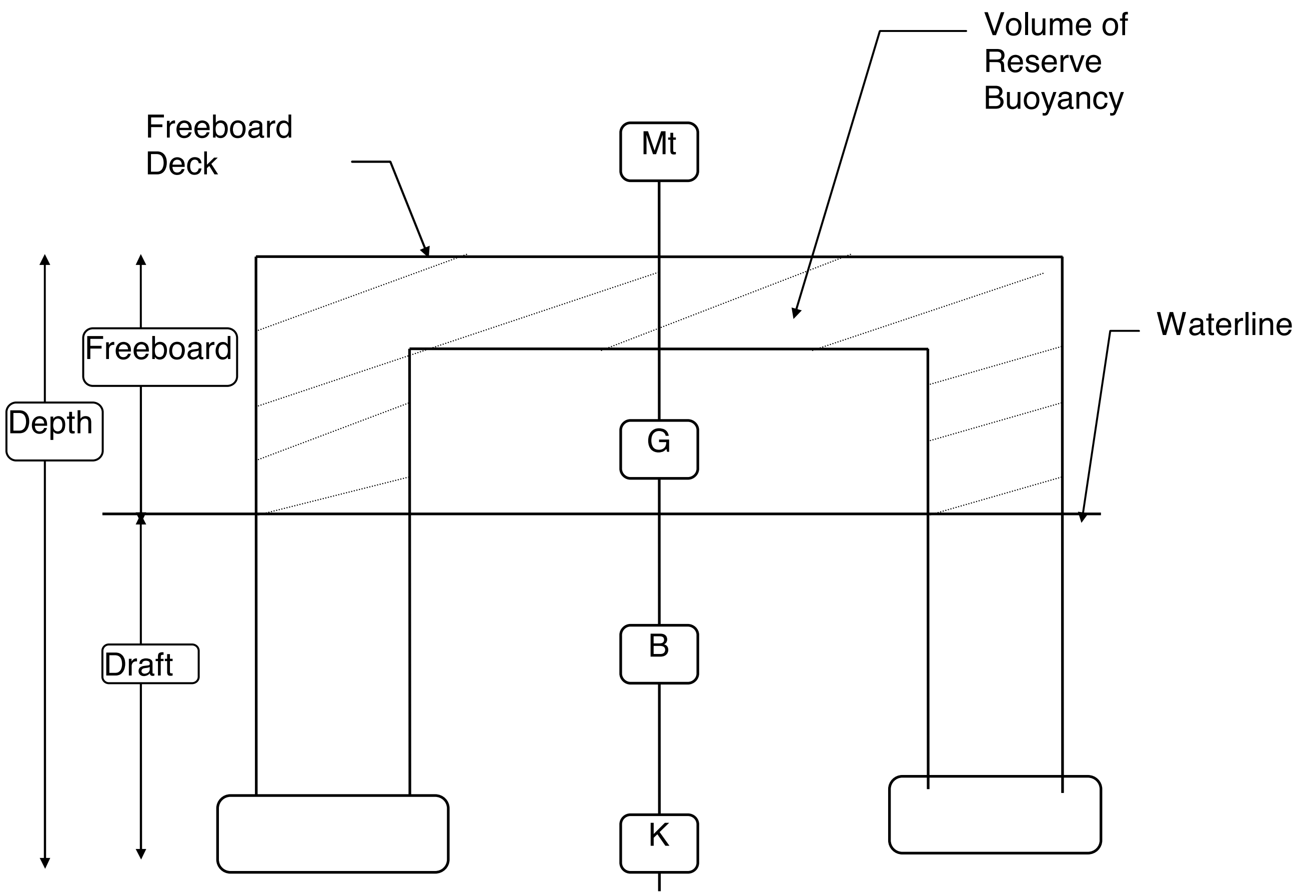
GMt = 5.7 ft.

KB or VCB	Vertical height of Centre of Buoyancy above Keel
KG or VCG	Vertical height of Centre of Gravity above Keel
KM	Vertical height of Metacentre above Keel
BM	Vertical distance between Centre of Buoyancy and Metacentre
GM	Vertical distance between Centre of Gravity and Metacentre

Note

KMt = KB + BMt

GMt = KMt– KG



Draft

This is the vertical distance between the underside of the unit, known as the keel, and the waterline at which the unit is floating in any given condition.

Thrusters extend below the underside of the unit and an allowance must be made to the unit draft when operating in shallow water.

Freeboard Deck

Is the deck with permanent means of closing all openings through it and below which the hull may be made intact.

It is generally the main deck and all openings must be fitted with watertight doors and hatches. Air pipes and sounding pipes must have closing devices.

Freeboard

The vertical distance between the waterline and the freeboard deck. It is required for the safety of the unit and all onboard. It is intended to keep the working deck clear of water.

Freeboard is a measure of Reserve Buoyancy and it is essential that the unit never operates with less than the minimum freeboard allowed by the loadline rules.

Reserve Buoyancy

The volume of the enclosed space between the waterline and the freeboard deck.

It may be expressed as a volume, displacement or as a percentage of the total buoyancy.

It is what the rig has in reserve to combat the effects of flooding of compartments, to ensure stability at large angles and to combat the effects of additional weight such as icing.

Calculation of Reserve Buoyancy.

A unit (box shaped) 40 ft. long, 10 ft. beam, depth 5 ft. floats in sea water at an even keel draft of 2 ft. Calculate her reserve buoyancy in short tons.

Vol. of Reserve Buoyancy = L x B X (Depth – Draft)
40 x 10 (5 - 2)
40 x 10 x 3

Vol. of Reserve Buoyancy = 1200 ft^3

$$\text{Reserve Buoyancy in short tons} = \frac{\text{Volume x 64}}{2000}$$

$$= \frac{1200 \times 64}{2000}$$

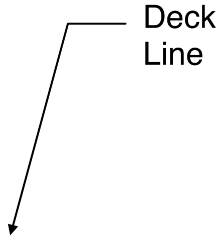
Reserve Buoyancy in short tons = 38.4

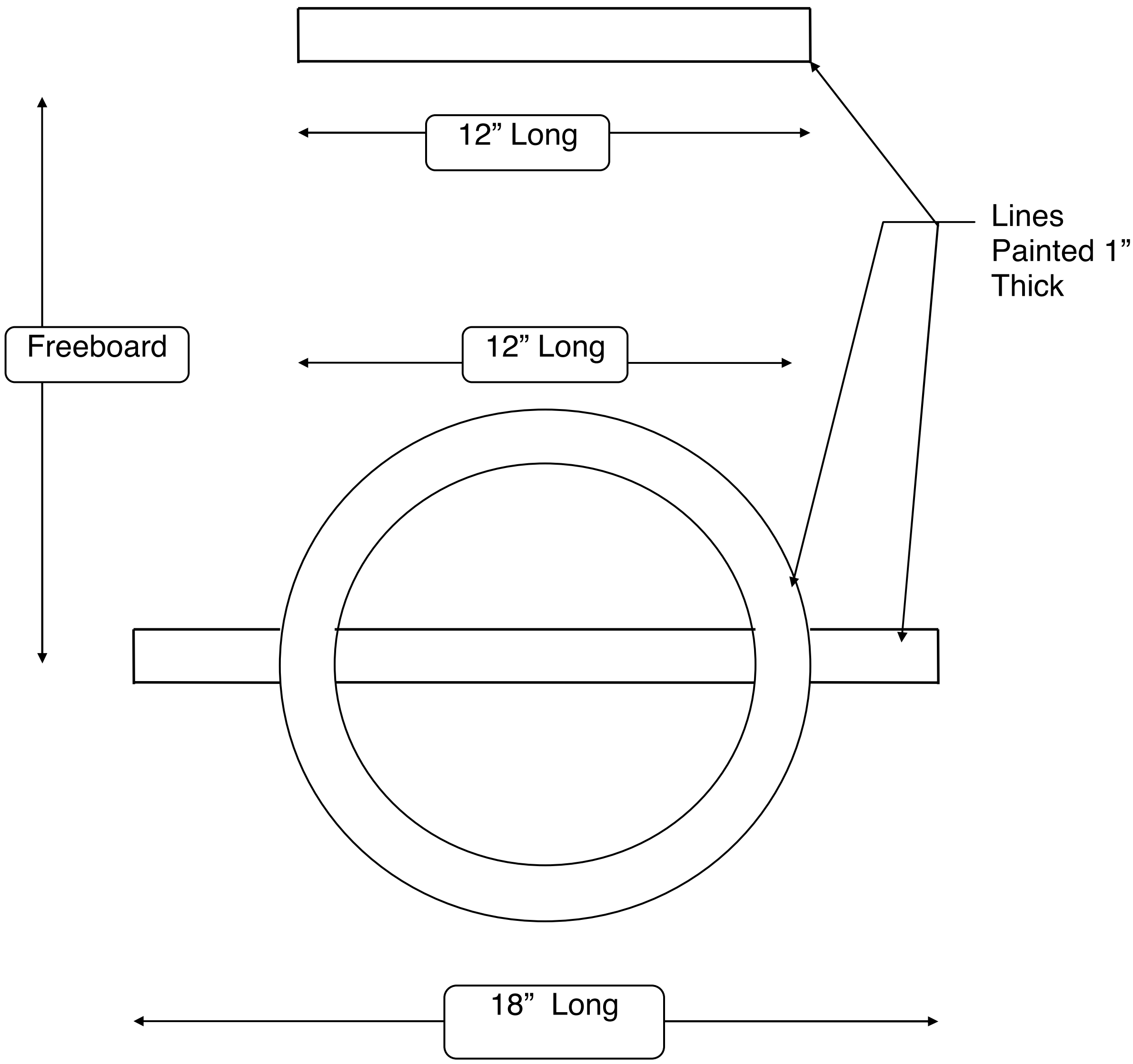
Plimsoll Mark

Classification Societies such as American Bureau of Shipping (ABS), Lloyds Register (LR), Det Norski Veritas (DNV) etc., will defines the freeboard to give the necessary position of the loadline in accordance with the loadline rules.

This position is indicated by the Plimsoll mark, which is shown in the diagram on the following page.

It follows therefore that all units will have a maximum draft to which they can be loaded and this draft must never be exceeded.





Rolling in a Seaway

The rolling period is the time for one complete roll.

That is the time, in seconds, to roll from the original position to hard over to one side, over to the other side and back to the original position.

For a unit of normal form (ship shape) the rolling period can be approximated from the formula:-

$$\text{Rolling Period} = \frac{0.44B}{\sqrt{GMt}}$$

T= Rolling Period in seconds
B = Beam in feet
GMt = Metacentric Height in feet.

Transposing this gives :-

$$GMt = \left[\frac{0.44 \times B}{T}\right]^2$$

Note:- This formula does not apply to semi-submersibles in the above form.

For units of unusual form it is possible to determine the roll period for a known GMt. These values can then be used in place of the constant 0.44B for more accurate results.

The formula varies to some extent with loading and is least accurate for small GMt values.

It does however have an important general application.

It indicates that the period of roll increases with reduction of GMt and this is true for any shape of unit.

If the unit hesitates at maximum roll angle as if reluctant to return to the original position it indicates that stability has seriously deteriorated. This is called the feel of the unit and is a useful indicator of a lack of stability.

The range of stability for a semi-submersible is usually in excess of 40 degrees and within this range the period of roll is more important than the amplitude or size of the roll.

Complete the calculations on the following page using the formula above.

1.

A unit has a GMt of 4 feet and a beam of 40 ft., estimate her roll period.

2.

A unit has a roll period of 7 seconds and a beam of 30 ft., estimate her GMt.

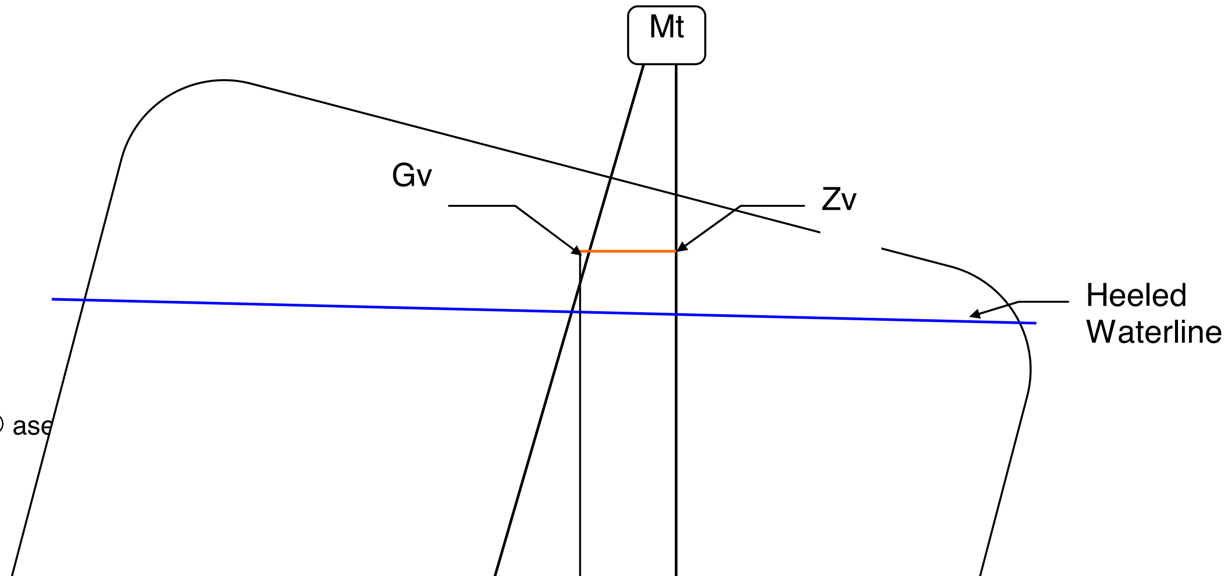
3.

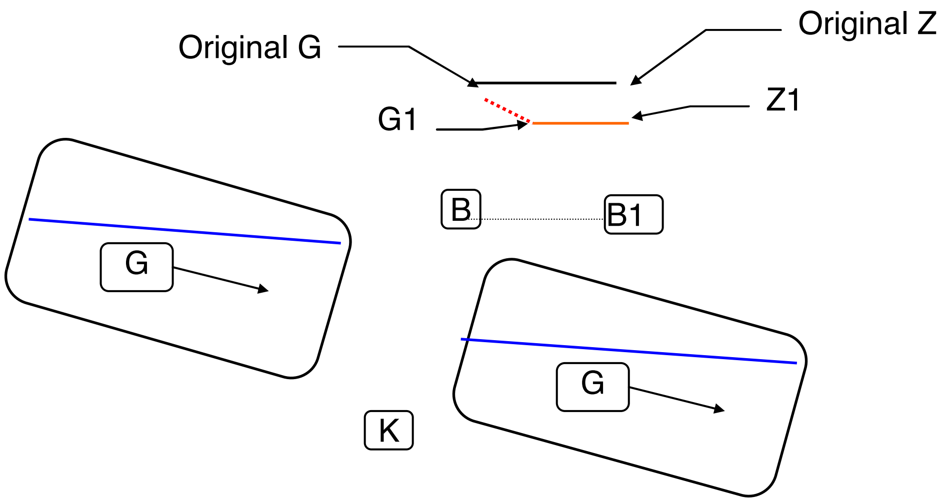
A unit has a roll period of 10 seconds when her GMt is 6 ft. Estimate
(a) Her GMt when the roll period is 16 seconds
(b) Her rolling period when the GMt is 9 ft.

Answers:-

1. 8.8 secs.   2. 3.56 ft.   3.(a) 2.34 ft. (b) 8.16 secs.

Free Surface Effect.





Movement of liquid in a slack tank as a unit rolls causes a movement of the centre of gravity of the liquid in the tanks which in turn causes the centre of gravity of the unit, G, to move to some point G 1 causing a reduction in Righting Lever.

The result is the same as if the virtual centre of gravity were at some higher point Gv.

i.e. **Free Surface** causes a **virtual rise in the unit's centre of gravity** or **a virtual reduction in GMt.**

Free surface effect is nearly constant from a tank almost full to almost empty.

It will be zero only with a tank pressed full or completely emptied.

The free surface effect increases :-

1. With size of tank particularly width.
2. With increase in density of the liquid in the tank.
3. With reduction in displacement of the unit.

Section 2 Centres of Gravity

Objective: **To understand the effect on the Centre of Gravity (VCG-LCG & TCG) when loading, discharging and moving weights.**

Subjects covered in this section.

1. **Resolution of Forces**

2. **Moments of Forces**

3. **Vertical Centre of Gravity (VCG)**

4. **Shifts of Centre of Gravity**

Forces & Moments

The solution of many of the problems concerning the stability of a floating unit involves an understanding of the resolution of forces and moments. For this reason a brief examination of these is given.

A force is defined as that which tends to move (or accelerate, decelerate or change the course of) a body.

Gravity is the force of attraction between a body and the Earth.

Mass is the amount of matter in a body and is measured in units such as pounds (lbs.) or short tons (2000 lbs.).

Weight is the attraction exerted by the Earth on a body, or the force of gravity on a body.

Weight is proportional to mass if gravity is constant and, as gravity varies by only about 0.5% over the earth's surface, weight can be said to be approximately proportional to mass at the earth's surface.

A **Scalar** quantity is one that can be measured and has **magnitude or size** only. For example – mass, temperature, energy, time etc.

A **Vector** quantity is one that can be measured and has both **magnitude and direction**, e.g. force/weight, velocity acceleration etc.

A vector quantity may be represented by a straight line drawn in the appropriate direction, the length of the line being proportional to the magnitude.

When a force is being considered, three things must be taken into account: -

- The magnitude of the force.
- The direction in which it is applied
- The point at or through which it is applied.

A force pushing in one direction has the same effect as an equal force pulling on the opposite side.

A point always tries to move directly away from a force pushing at it, or directly towards a force pulling on it.

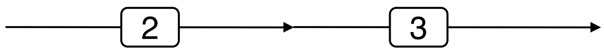
Resultant forces.

When two or more forces are acting at a point, their combined effect can be represented by one force, which will have the same effect as the component forces.

Such a force is referred to as the **resultant force,** and the process of finding it is called the **resolution of forces.**

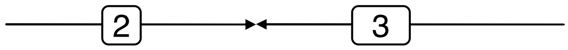
Resolving two forces which act in the same straight line

If both forces act in the same straight line and in the same direction, then the resultant is the sum of the forces.



Resultant = 5 to the right.

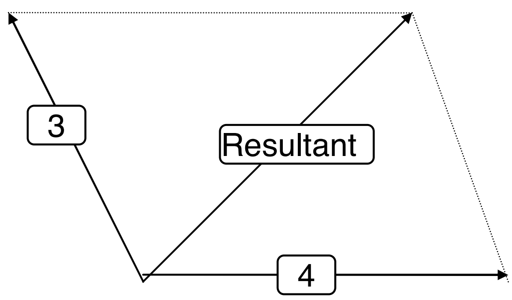
If the forces act in opposite directions, the resultant is the difference of the two forces and acts in the direction of the larger of the two forces.



Resultant = 1 to the left

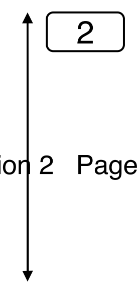
Resolving two forces that do not act in the same straight line

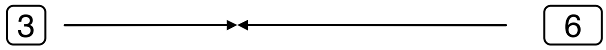
In this case we can calculate the resultant by completing a parallelogram of forces, drawn to scale.



Note that the components of the forces and the resultant force all act towards or away from the point of concern.

Similarly a single force can represent a number of forces and vice versa.

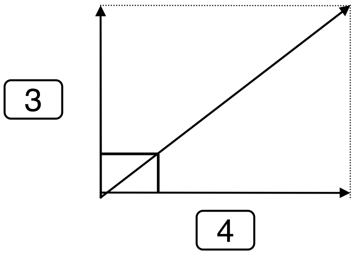




Resultant = 3 to the left 2

With a right angle triangle we can use Pythagoras theorem to calculate the resultant or we can draw a parallelogram to scale.

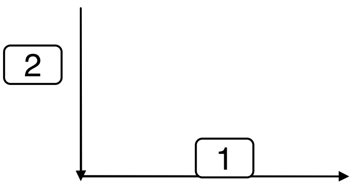
Pythagoras states ‘ the square on the hypotenuse is equal to the sum of the squares of the other two sides.



Resultant $^2 = 3^2 + 4^2$ $\quad R^2 = 9 + 16$ $\quad$ Resultant = 5

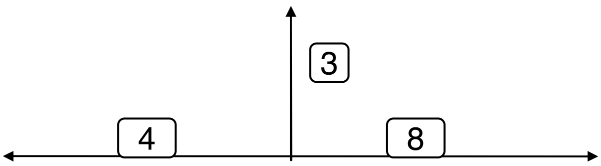
Calculate the resultant in the following questions: -

1.



Resultant =

2.



Resultant =

Answers 1. 2.236 2. 5.0

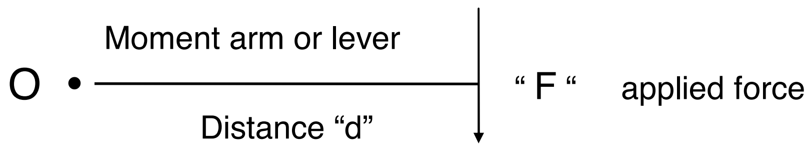
Moments of Forces.

The moment of a force is a measure of the turning effect of the force about a point or axis.

The turning effect will depend upon: -

(a) The magnitude (or size) of the force, and

(b) The length of the lever or perpendicular distance between the line of action of the force and the point about which the moment is being taken.



The magnitude of the moment is the product of the force "F" and the perpendicular distance "d".

So we can say Moment = F x d.

As with forces, moments of forces must be added in a particular way.

When two or more forces are acting about a point their combined effect can be represented by one moment called the resultant moment.

To calculate the resultant moment about a point or axis, find the sum of:

(a) The clockwise (CW) moments about the point or axis, and

(b) The anti-clockwise (ACW) moments about the point or axis.

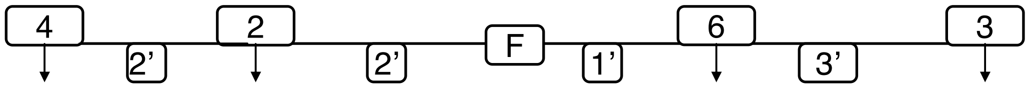
Note: -

A force has no moment about a point or axis through which it's line of action passes.

Note that 'F' in the following examples indicates the Fulcrum or balance point.

All measurements are taken from the Fulcrum.

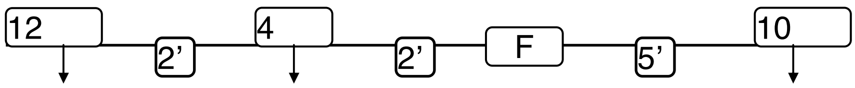
Example 1: (weights in lbs. distances in feet.)



Clockwise Moment = (6x1) + (3x4) = 6 + 12 = 18 ft/lbs.
Anti Clockwise Mmt = (2x2) + (4x4) = 4 + 16 = 20 ft/lbs.

Resultant Moment = 20 ft/lbs. – 18 ft/lbs. 2 ft/lbs. Anticlockwise.

Example 2: (weights in lbs. distances in feet.)



Clockwise Mmt. = 10 x 5 = 50 ft/lbs.
Anti.Clockwise Mmt. = (12x4) + (4x2) = 48 +8 = 56 ft/lbs.

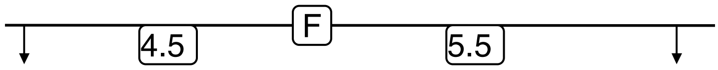
Resultant Moment = 56 ft/lbs. – 50 ft/lbs. = 6 ft/lbs. Anti clockwise

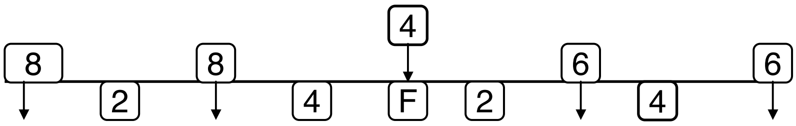
Calculate the resultant moments in the questions on the following page and define the direction, (clockwise or anticlockwise)

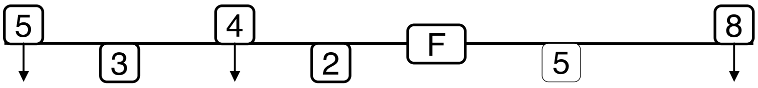
Moments Examples

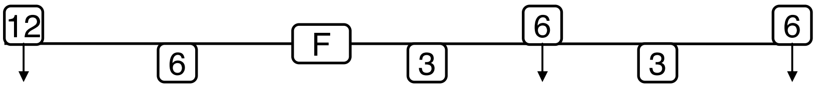
Find the resultant moment about fulcrum in each case - all weights in lbs. and distances in ft.

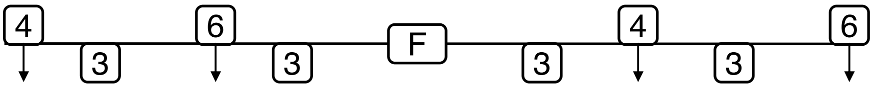
1.

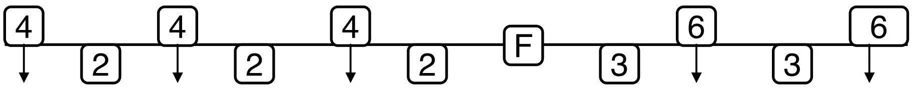


2. 

3. 

4. 

5. 

6. 

Answers:

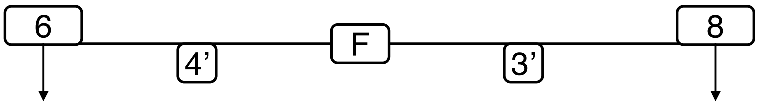
1. 1ft/lb. Clockwise
2. 32 ft/lbs. Anticlockwise
3. 7 ft/lbs. Clockwise
4. 18 ft/lbs. Anticlockwise
5. 6 ft/lbs. Clockwise.
6. 6 ft/lbs. Clockwise.

For a body to remain at rest i.e. in equilibrium, the resultant force acting on the body and the resultant moment of the forces acting on it must be zero.

We can illustrate this in two ways, by taking moments about the fulcrum (or pivot point) and we can also take moments from one end.

We will work from the left-hand end and be aware that the fulcrum is supporting the total load.

Example:

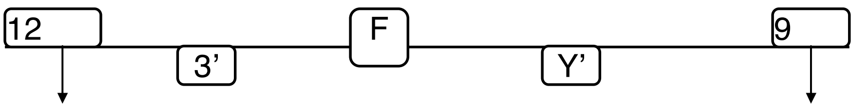


Fulcrum load = 14 lbs.

Moments @ fulcrum	Clockwise =	8 x 3 =	24 ft/lbs.
	Anticlockwise =	6 x4 =	24 ft/lbs.
	Resultant	Moment =	0
Moments @ Left-hand end	Clockwise =	8 x 7 =	56 ft/lbs.
	Anticlockwise	14 x 4 =	56 ft/lbs.
	Resultant	Moment =	0

For a system that is in equilibrium (i.e. the resultant moment will be zero) an unknown force or distance can be calculated.

Example:



The distance ‘Y’ is required to be from ‘F’ for the system to be in equilibrium has to be calculated.

For equilibrium Clockwise moments must equal Anti-clockwise moments.

Clockwise Mmts. = 9 x Y = 9 Y ft/lbs Anti-clockwise Mmts. = 12 x3 = 36 ft/lbs

9Y= 36

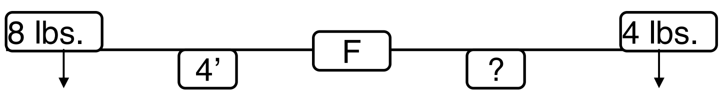
Y = 36 ÷ 9

Y = 4 ft.

Moments Examples

Find the unknown weight or distance in each case for equilibrium.

1



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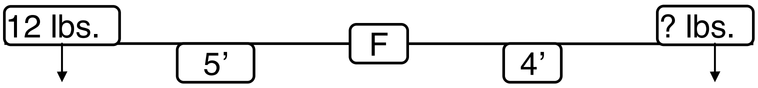

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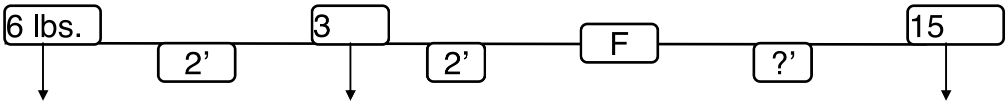

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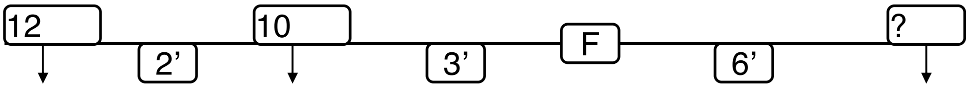

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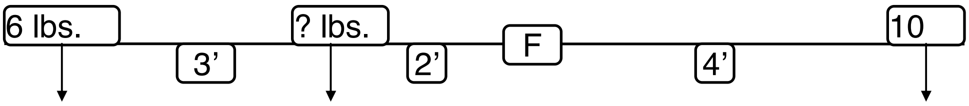

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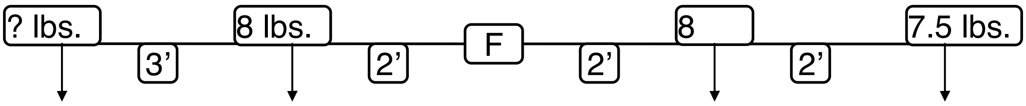
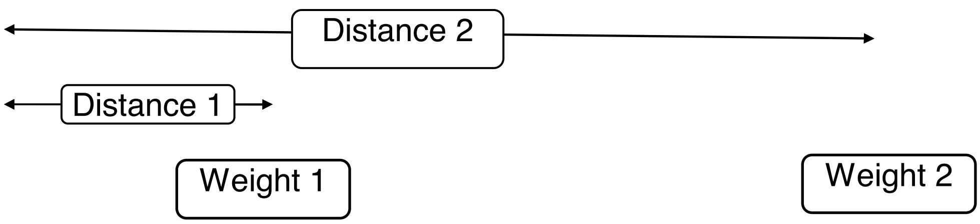
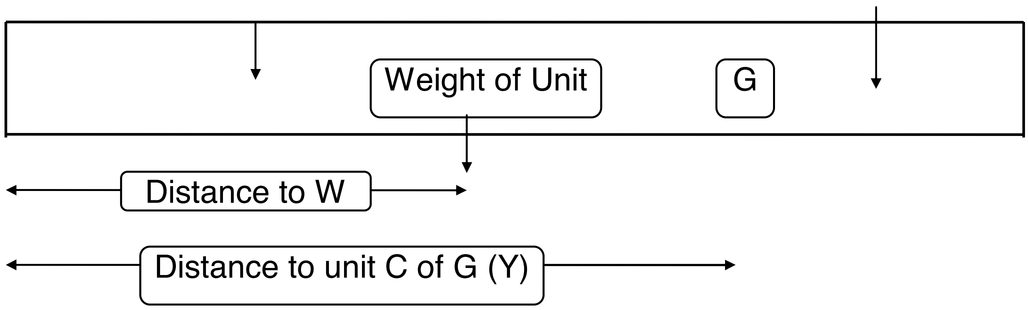


Answers:

(1) 8 ft**.**	**(2)** 15 lbs.	**(3)** 2 ft.
(4) 15 lbs.	**(5)** 5 lbs.	**(6)** 6 lbs.

To find the position of the Centre of Gravity for a number of weights of known centres (i.e. for a non-homogenous body).





Resultant load at the fulcrum 'G' = W + w1 + w2

By definition the centre of gravity is the point about which the system will balance and moments about its length or extension will equal zero.

Referring to the diagram above and taking moments about the left hand end:

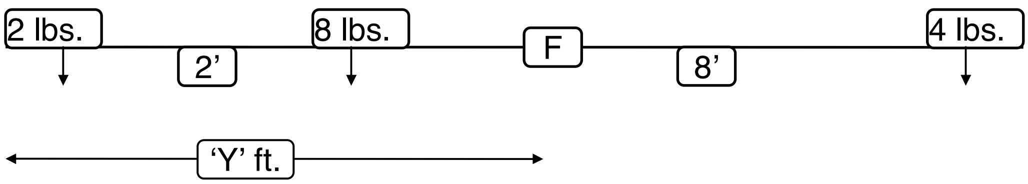
Clockwise Moments = (w1 x d1) + (W x d) + (w2 x d2)
Anti-clockwise moments = (W +w1 +w2) x 'Y'

For equilibrium = (W + w1 + w2) 'Y' = (w1xd1) + (Wxd) + w2xd2)
(CW Mmts. = AC Mmts.)

$$\text{Therefore 'Y'} = \frac{(w1xd1) + (Wxd) + w2xd2)}{(W + w1 + w2)}$$

i.e. The position of the centre of gravity from a given point = $\dfrac{\textbf{Total moment of weight} \text{ about that point}}{\textbf{Total weight}}$

Example:



Taking Moments about the left-hand end: -

Position of Fulcrum (or centre of gravity) $= \dfrac{\text{Total Moments}}{\text{Total weight}} = \dfrac{(2 \times 0) + (8 \times 2) + (4 \times 10)}{(2+8+4)}$

$$= \frac{16 + 40}{14} \quad = \frac{56}{14}$$

Position of Fulcrum $= 4$ ft.

Note: - moments may be taken about any convenient point or axis.

When taking moments to find the position of the centre of gravity for any unit it is usual to observe the following: -

For the calculation of Vertical Centre of Gravity – VCG – (also referred to as KG) moments are taken about the Keel.

For the calculation of Longitudinal Centre of Gravity –LCG- moments may be taken from Amidships, or the Bow or Stern.

The Marine Operations Manual or Stability Information Book will define where the measurements have been taken from for a particular unit.

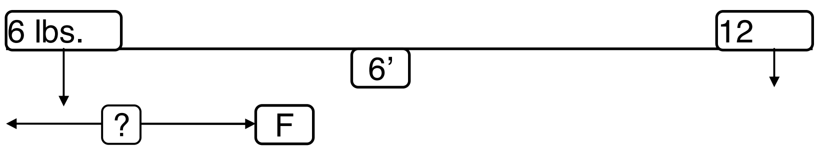
And for the calculation of the Transverse Centre of Gravity – TCG -it is usual for moments to port or starboard to be taken from the centreline of the unit.

Carry out the calculations on the following page.

Moments Examples

Find the position of Fulcrum for equilibrium

1.



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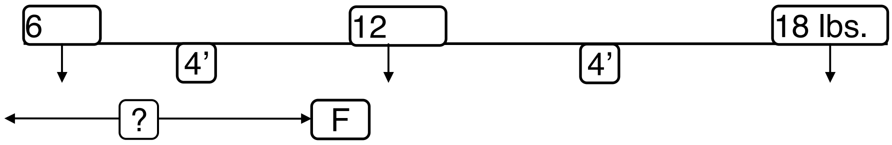

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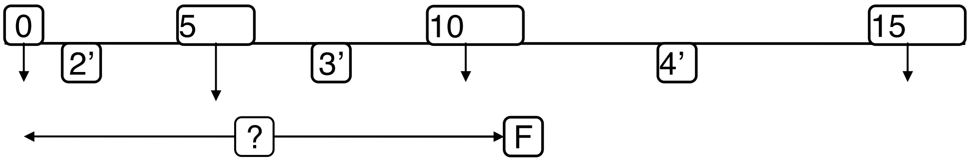

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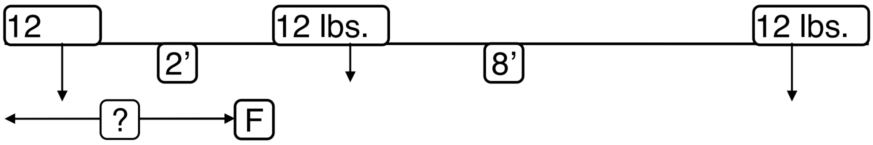

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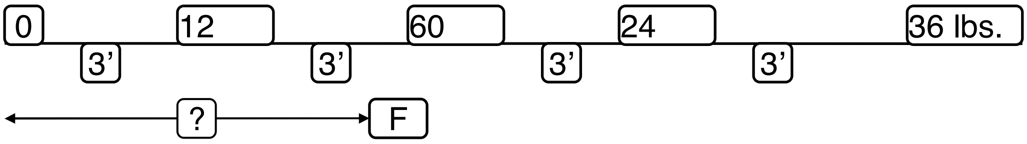


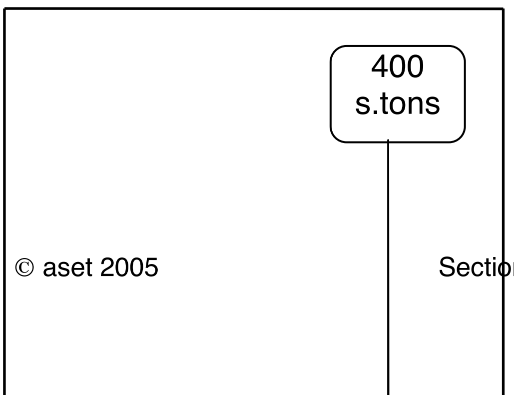
Answers :

(1) 4 ft.	(2) 5.33 ft	(3) 6.5 ft.
(4) 4 ft.	(5) 7.91 ft.	

Example:

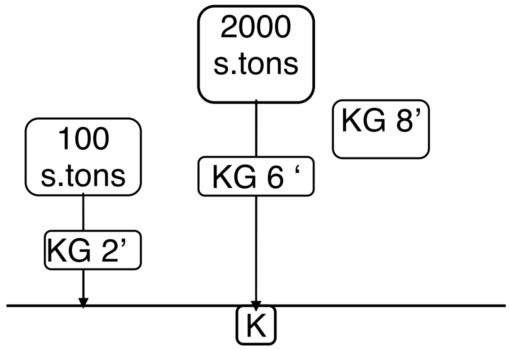
A unit of 2000 s.tons displacement and VCG 6 ft. loads 100 tons cargo at 2 feet above the keel and 400 tons at 8 ft. above the keel.

Calculate the final VCG (KG).



$$KG = \frac{\text{Total Moments}}{\text{Total Weight}}$$

$= \underline{(2000 \text{ X } 6) + (100 \text{ x } 2) + (400 \text{ x } 8)}$



2000 + 100 + 400

$$= \frac{12000 + 200 + 3200}{2500}$$

$$= \frac{15400}{2500}$$

KG = 6.16 ft.

The above problem could also have been solved by use of what is known as a KG table as illustrated below.

The KG is still the product of the total moments divided by the total weight.

Item	Weight	KG	Moment
Unit	2000	6	12000
Cargo	100	2	200
Cargo	400	8	3200
Total Weight	2500		15400

$$\text{Final KG} = \frac{\text{Total Moment}}{\text{Total Weight}}$$

$$= \frac{15400}{2500}$$

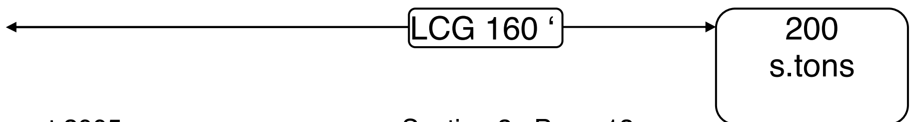
Final KG = 6.16 ft.

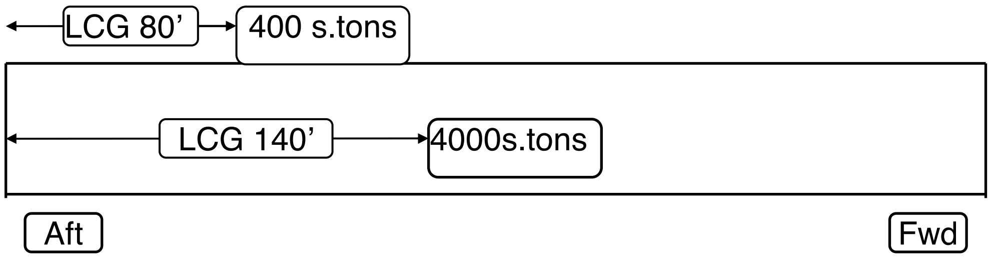
Example:

A unit of 4000 tons displacement has its LCG 140 ft. from the aft end. If 200 tons of cargo is loaded 160 ft. from aft and 400 tons is loaded 80 ft. from aft calculate the final LCG.

Again this problem is solved by dividing the total moments by the total weight to find the LCG.

Both methods of calculating the LCG are demonstrated.





New LCG from Aft = $\dfrac{(4000 \times 140) + (400 \times 80) + (200 \times 160)}{4000 + 400 + 200}$

= $\dfrac{560000 + 32000 + 32000}{4600}$

New LCG from Aft = $\dfrac{\text{Total Moments}}{\text{Total Weight}}$ $\dfrac{624000}{4600}$

New LCG from Aft = 135.65 ft from aft

Using the Table Method

Item	Weight	LCG fm Aft	Moment
Unit	4000	140	560000
Cargo	400	80	32000
Cargo	200	160	32000
Total Weight	4600		624000

New LCG from Aft = $\dfrac{\text{Total Moment}}{\text{Total Weight}} = \dfrac{624000}{4600}$

New LCG from Aft = 135.65 ft.

When calculating the TCG we have to use the centreline of the unit as our reference point.

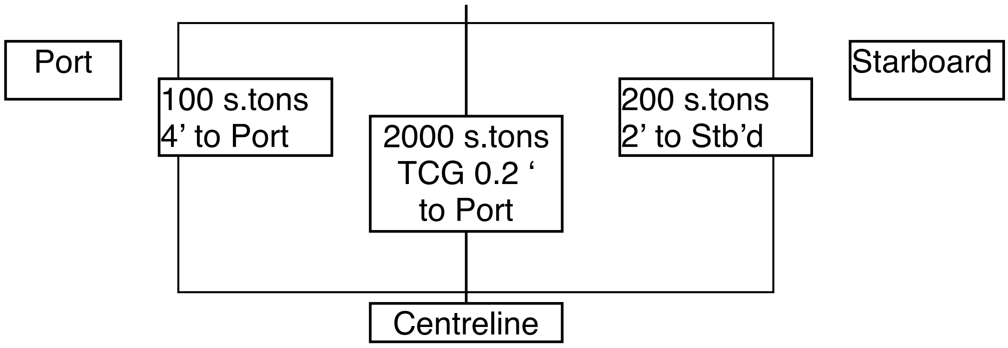
The method of calculation is to first obtain the moments to port of the centreline, and the moments to starboard, to ascertain which is the greater moment.
The TCG will then lie to that side of the centreline which has the greater moment, and the unit will have a list.

If however we have equal moments either side of the centreline, in this case the TCG will be on the centreline and the unit will be floating upright.

Again, dividing the moment found by the total weight of the unit, will give us the position of the TCG, in relation to the centreline.

Example:

A unit of 2000 tons displ. has its centre of gravity 0.2 ft to port of the centreline
If 100 tons is loaded at 4 ft. to port and 200 tons at 2 ft. to starboard, calculate the final position of the TCG in relation to the centreline



Calculate the moments to port and starboard using a table and find the excess moment produced.

Item	Weight	TCG	Port Mmts.	Stbd.Mmts.
Unit	2000	0.2 ft (Port)	400 ft/tons	
Cargo	100	4 ft (Port)	400 ft/tons	
Cargo	200	2 ft (stb'd)		400 ft/tons
Totals	2300		800 ft/tons (Port)	400 ft/tons (Stb'd)

Excess Moments = 800 (P) –400 (S) = 400 (Port)

Position of G from centreline	$= \frac{\text{Excess Moment}}{\text{Total Weight}}$	$= \frac{400}{2300}$	= 0.17 ft. to Port

Carry out the following centre of gravity calculations.

1.
A unit of 6000 s.tons displacement, VCG 18 ft. loads 2000 s.tons cargo at 12 ft. above the keel & 1000 s.tons at 20 ft. above the keel.
Calculate the final KG.

2.
A unit of 2800 s.tons displacement VCG 16 ft. loads 1200 s.tons cargo KG 8 ft. and 1000 s.tons cargo KG 20 ft.
Calculate the final KG

3.
A unit of 1200 s.tons displacement has its LCG situated 120 ft forward of the stern. She then loads 800 s.tons of cargo 160 ft forward of the stern and 600 s.tons of cargo 80 ft forward of the stern.
Calculate the final position of the LCG in relation to the stern.

4.
A unit of 6000 s.tons displacement has her LCG situated 20 ft aft of amidships. 2000 s.tons of cargo is loaded at 40 ft forward of amidships and 2000 s.tons of cargo is loaded at 50 ft aft of amidships.
Calculate the position of the final LCG in relation to amidships.

Answers:

1. 16.89 ft.	2. 14.88 ft.	3. 123.08 ft fwd. of stern
4. 14 ft aft of amidships		

Shift of the Centre of Gravity

When a single weight is loaded, discharged or moved onboard the unit it is sometimes more convenient to consider the shift of the centre of gravity (G) due to this change rather than to calculate the final position of G as we have done previously.

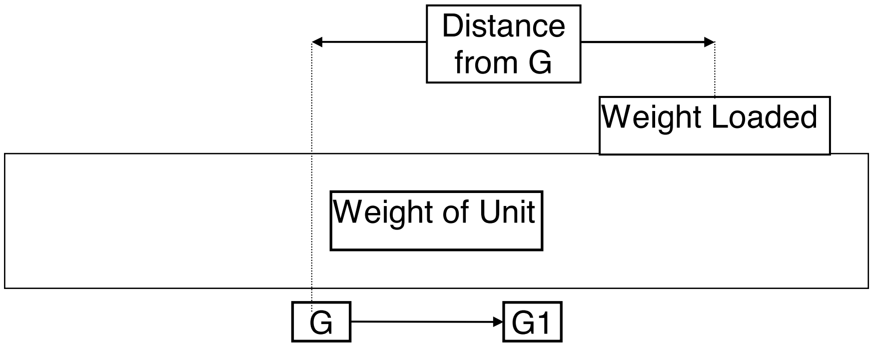
This means that if we have previously calculated the unit C of G in either the vertical (VCG), longitudinal (LCG) or transverse (TCG) planes, we can easily adjust this position by considering the effect of loading, discharging or moving a weight.

To do this we must know the exact weight of the load in question and its exact distance from a reference point.

We must also know the weight of the unit before we made the change.

Effect of adding a weight.

Whenever a weight is added to a unit the units C of G will move towards that weight.



To calculate the shift of the Centre of Gravity (G to G1) we must to find the moment that has been produced (weight x distance between the unit centre of gravity and the centre of gravity of the weight we have loaded). This moment must then be divided by the final weight of the unit.

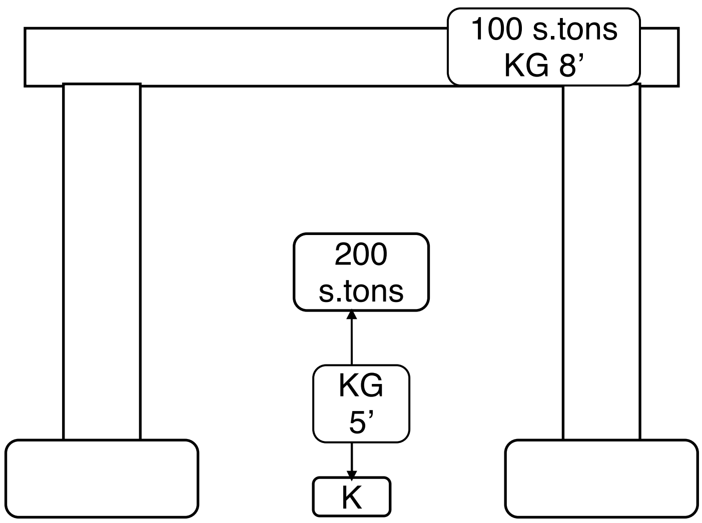
So with reference to the above diagram: -

$$\text{Shift of G (G to G1)} = \frac{\text{Weight added x Distance from Unit C of G}}{\text{Final weight of unit}} = \frac{w \times d}{W + w}$$

G will then move towards the position we have loaded the weight.

Example: -

A unit with displacement of 200 s.tons, KG of 5 ft. loads 100 s.tons at a KG of 8 ft.
Calculate the new position of the Centre of Gravity (KG).



Moment of weight loaded =
Weight of Load x Distance (difference between unit G and loaded weight G)

Shift of G = $\frac{\text{Moment of weight loaded}}{\text{Total weight}}$ = $\frac{100 \text{ X } (5 \sim 8)}{200 + 100}$ = $\frac{100 \text{ x } 3}{300}$ = 1 ft.
(G to G1)

As the weight was loaded above the unit C of G then G will move up towards the weight.

New position of G = 5 ft + 1 ft = 6 ft.

Or using the KG Table method

Item	Weight	KG	Moment
Unit	200	5 ft.	1000 ft/tons
Load	100	8 ft	800 ft/tons
Total	300		1800 ft/tons

New KG = $\frac{\text{Total Moment}}{\text{Total Weight}}$ = $\frac{1800 \text{ ft/tons}}{300 \text{ tons}}$

New KG = 6 ft.

So the end result is the same.

Carry out the calculations on the following page, always calculate the shift of G (G to G1), and then apply the shift to the original KG (VCG) if required to find the final KG (VCG).

1.

A unit of 4000s.tons displacement, VCG 16 ft., loads 2000 s.tons cargo at 12 ft. above the keel.
Calculate (a) shift of G. & (b) new KG.

2.

A unit of 6000 s.tons displacement loads 300 s.tons cargo on deck at 12 ft. above the unit's centre of gravity.
Calculate shift of G.

3.

A unit of 6000 s.tons displacement loads 600 s.tons fuel in tanks centred 8 ft. below the unit's centre of gravity.
Calculate shift of G.

Answers: -

1. (a) 1.33 ft. Down (b) 14.67 ft.	2. 0.57 ft Up	3. 0.73 ft. down

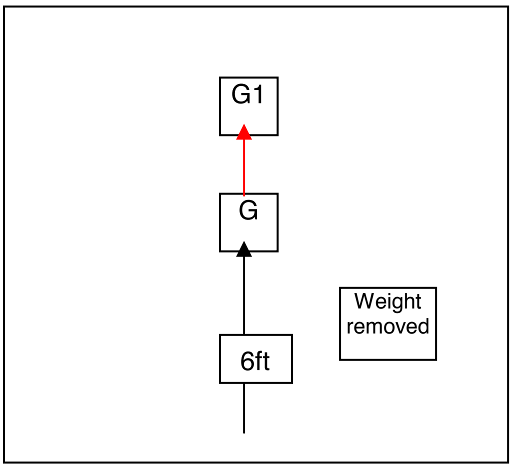
Effect of removing weight.

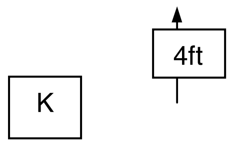
This is very similar to the calculation for loading weight but we must be aware of the following: -

When a load is removed from a unit, then the C of G of the unit will move away from that weight. Again we need to know the weight of the load; it's distance from the unit C of G, and the weight (displacement) of the unit.

The formula for calculating the shift of G now becomes:

Shift of G (G to G1) = $\frac{\text{Weight removed x Distance from unit C of G}}{\text{Final Weight}} = \frac{w \times d}{\Delta - w}$





G will move away from the unloaded weight

Example:

A unit 4000 s.tons displacement, VCG 6 ft. unloads 400 s.tons from 4ft. above the keel. Calculate (a) the shift of G and (b) the final KG.

$$\text{Shift of G (G to G1)} = \frac{\text{Weight unloaded x Dist. From G}}{\text{Final weight of Unit}} = \frac{400 \times (6\sim4)}{4000 - 400} = \frac{400 \times 2}{3600}$$

Shift of G = 0.22 ft Up   New KG = 6.00 + 0.22 = 6.22 ft.

Complete the calculations on the following page.

1.

A unit of 6000 s.tons displacement, VCG 16 ft. unloads 2000 s.tons cargo which has its centre of gravity 12 ft. above the keel.
Calculate (a) shift of G and (b) new KG.

2.

A unit of 8000 s.tons displacement discharges 400 s.tons fuel from 8 ft. below its centre of gravity.
Calculate the shift of G.

3.

A unit of 6000 s.tons displacement, VCG 18 ft. discharges 400 s.tons of drill water at a KG of 2 ft.
Calculate (a) shift of G and (b) the new KG.

Answers.

1.	(a) 2 ft up (b) 18 ft.
2.	0.42 ft. up
3.	(a) 1.14 ft. up (b) 19.14 ft.

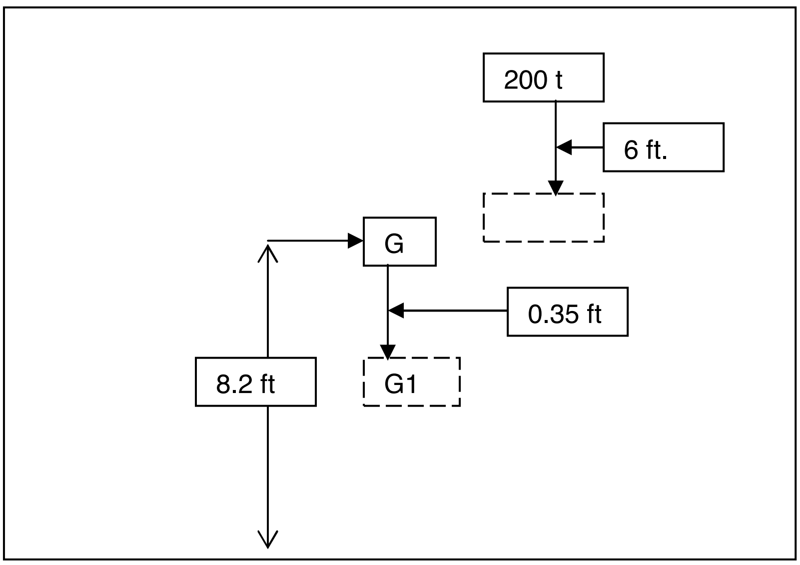
Effect of Shifting Weight

When a load is moved from one position to another on a unit the units centre of gravity will move in the same direction as the load.

As before we require the weight of the load, the distance moved and the weight of the unit.

It should be noted that there would be no change to the weight of the unit. The formula for calculating the Shift of G now becomes:

$$\text{Shift of G (G to G1)} = \frac{\text{Weight moved x distance moved}}{\text{Weight of Unit}} = \frac{w \times d}{\Delta}$$



K

Example:

A unit 3400 s.tons displacement, VCG 8.2 ft. lowers 200 s.tons of cargo through 6 ft. vertically.

Calculate (a) shift of G & (b) final VCG.

Shift of G (G to G1) $= \frac{w \times d}{\Delta} = \frac{200 \times 6}{3400} = \underline{0.35 \text{ ft.}}$

As the weight was moved down, then the unit VCG will move down

Shift of G is therefore – 0.35 ft.

Final VCG = 8.2 ft. – 0.35 ft. = 7.85 ft.

Complete the calculations on the following page.

1.

A unit of 4000 s.tons displacement, shifts 200 s.tons fuel from a tank KG 2 ft. to a tank KG 12 ft.
Calculate the shift in the unit Centre of Gravity.

2.

A unit of 3420 s.tons displacement, KG 10.6 ft., moves 240 s.tons cargo KG 20.6 ft. to a new position KG 12 ft.
Calculate (a) Shift of G & (b) Unit new KG.

3.

A unit of 4250 s.tons displacement, KG 12.6 ft., lowers 240 s.tons cargo through 8 ft. vertically.
Calculate (a) Shift of G & (b) Unit new KG

Answers:

1. 0.5 ft. upward.
2. 0.60 ft. downwards New KG = 10.0 ft.
3. 0.45 ft. downwards New KG = 12.15 ft.

Multiple changes of weight.

When more than one weight is added, removed or shifted on the unit, it is more convenient to calculate the final position of G (Final KG or VCG) from some convenient line or axis using the formula:

$$\text{Final position of G (KG or VCG)} = \frac{\text{Total moments}}{\text{Total weight}}$$

With a large number of changes the KG table method of calculating the final KG is the best method to employ.

Example:

A unit of 5000 s.tons displacement has a KG of 20 ft. She then carries out the following cargo operations:

	Weight s.tons	KG ft.
Loads	400	22
	600	8
Discharges	800	6
	200	24

Calculate the unit final KG.

Item	weight	KG	Moment
Unit	5000	20	100,000 +

Cargo	400 +	22	8800 +
Cargo	600 +	8	4800 +
Cargo	800 -	6	4800 -
Cargo	200 -	24	4800 -
Total	5000		104,000

Final KG = $\frac{\text{Total Moments}}{\text{Total Weight}}$

Final KG = $\frac{104,000}{5000}$

Final KG = 20.8 ft.

With a situation where the unit loads, discharges and moves cargo around, it is best to calculate the new KG after the loading and discharging operations. When this has been done the shifts of G due to the movements of cargo can be calculated and applied to the new KG to calculate the final KG.

Example:

A unit of 4000 s.tons displacement, KG 16 ft., carries out the following cargo operations:

	Weight s.tons	KG ft.
Loads	200	12
	400	20
Discharges	600	6
	800	18
Shifts	200	10 ft down
Shifts	100	From KG 3.8ft to KG 10.2 ft

Calculate the unit final KG after all operations have been carried out.

Item	Weight (s.tons)	KG (ft)	Moments
Unit	4000	16	64,000
Cargo	200+	12	2400 +
Cargo	400+	20	8000 +
Cargo	600-	6	3600 -
Cargo	800 -	18	14,400 -
Total	3200		56,400

KG (before moving cargo = $\frac{56,400}{3200}$ = 17.625 ft.

Shift of G due to first move	= $\frac{200 \times 10}{3200}$	= 0.625 ft. Down
Shift of G due to second move	= $\frac{100 \times (10.2 - 3.8)}{3200}$	= 0.2 ft. Up

Nett. movement of G = 0.625 ft. Down – 0.2 ft. Up= 0.425 ft Down

KG before moving cargo =	17.625 ft.
Shift of G due to cargo movement =	- 0.425 ft.
Final KG =	**17.200 ft.**

Carry out the following calculations

1.
A unit displaces 3009 s.tons and has a KG of 18 ft.
She then loads the following items of cargo:

595 s.tons	KG 15 ft.	408 s.tons	KG 26 ft.
121 s.tons	KG 31 ft.	937 s.tons	14 ft.
683 s.tons	KG 18 ft.		

Calculate her final KG after loading.

2.
A unit of 922 s.tons displacement has a KG of 5 ft.
She then discharges the following items of cargo:

176 s.tons	KG 8 ft.	44 s.tons	KG 11 ft.
435 s.tons	KG 4 ft.		

Calculate her final KG after cargo operations are completed.

3.
A unit loads and discharges the following weights:
Loads: 237 s.tons KG 3.6 ft,
Discharges: 154 s.tons KG 8.2 ft. & 298 s.tons KG 4.7 ft.
Calculate her final KG if her initial displacement was 712 s.tons and KG 6.6 ft.

4.

A unit is carrying out the following cargo operations before leaving location:
Her initial displacement was 6702 s.tons and her KG 22.3 ft.

Loads	1080 s.tons	KG 14 ft.	606 s.tons	KG 21 ft.
	772 s.tons	KG 3 ft.	77 s.tons	KG 37 ft.
Discharges	1378 s.tons	KG 15 ft	33 s.tons	KG 12 ft.
	463 s.tons	KG 29 ft.	33 s.tons	KG 3 ft.

She then moves to her new location and uses 926 s.tons fuel KG 3 ft. and 66 s.tons water KG 37 ft. during the move.
Calculate the change in the Centre of Gravity between leaving the old location and arriving at the new location.

5.
A unit has a KG of 21.3 ft. with a displacement of 6636 s.tons.
Calculate her final KG after the following cargo operations are carried out:

Loads	550 s.tons	KG 9.0 ft.
	940 s.tons	KG 15.0 ft.
	240 s.tons	KG 27.0 ft.
Discharges	330 s.tons	KG 17.0 ft.
	770 s.tons	KG 11.0 ft.

425 tons cargo is now moved from KG 12.5 ft. to KG 16 ft.

Answers:

1. 17.88 ft.	2. 3.66 ft.	3. 5.81 ft.
4. KG at Old Location 20.17 ft. KG at New Location 22.51 ft. Difference 2.34 ft.		
5. Final KG 21.24 ft.		

Moments of Forces – Conclusions.

A. Shift of the Centre of Gravity

1. The centre of gravity of any unit will move directly **towards** a weight **loaded.**

2. The centre of gravity of a unit will move directly **away** from a weight **discharged.**

3. The shift of the centre of gravity in either of the above cases is given by the formula:

$$\text{Shift of G (G to G1)} = \frac{w \times d}{\Delta}$$

Where
w = weight loaded or discharged in s.tons
d = distance between weight & the original C of G
Δ = final weight of the unit

4. The centre of gravity of a unit will move in a **direction parallel** to the **shift of the centre of gravity** of any **weight moved** on or within the unit

5. The shift of the centre of gravity of the unit in this case is given by the formula:

$$\text{Shift of G (G to G1)} = \frac{w \times d}{\Delta}$$

Where
w = weight moved
d = distance weight moved
Δ= final weight of the unit

B.

To calculate the Centre of Gravity (KG).

The final Centre of Gravity (KG) is given by the formula :

$$\text{Final KG} = \frac{\text{Total Moment}}{\text{Total Weight.}}$$

For weight loaded the unit:

$$\text{Final KG} = \frac{\text{Initial Moment + Added Moment}}{\text{Total Weight}}$$

For weight discharged from the unit:

$$\text{Final KG} = \frac{\text{Initial Moment – Discharged Moment}}{\text{Total Weight}}$$

For weight moved:

$$\text{Final KG} = \frac{\text{Initial Moment + Change of Moment}}{\text{Total Weight}}$$

If weights are loaded, discharged and moved:

First complete a KG table for weights added and discharged,

Then adjust the KG calculated by the shifts of G due to the movements of the weights

Section 3 Longitudinal Stability

Objective: **To understand the causes of trim and the effect of loading, discharging and moving weights longitudinally, on the trim and drafts of the unit.**

Subjects covered in this section.

1. **Longitudinal Centres of :-**
   Gravity,
   Buoyancy,
   Floatation
   Metacentre

2. **Trim, Change of Trim and Trimming Moment**

3. **True and Arithmetical Mean Draft**

4. **Tons per Inch Immersion**

Longitudinal Stability

This section deals with stability in a longitudinal sense, that is movements of the centre of gravity along the fore and aft axis of the unit.

This movement will cause the attitude of the unit to alter longitudinally, known as trimming.

The following definitions are used when dealing with longitudinal stability:

The **length** of a semi submersible is taken to refer to the **length between the draft marks.**

Amidships, denoted by the symbol ‘ϕ‘, is the **point midway between the forward and aft draft marks.**

Longitudinal Centre of Gravity (LCG) is the distance of the centre of gravity measured from the amidships point or from the draft marks at either end of the unit.

Longitudinal Centre of Buoyancy (LCB) is the distance measured in a similar manner to the centre of gravity.

Longitudinal Metacentre (ML) is the point of intersection of verticals through the longitudinal centre of buoyancy in the initial and slightly trimmed condition.

KML is the distance of the longitudinal metacentre (ML) above the keel. This will be a fixed value for a given draft or displacement and can be obtained from hydrostatic curves or tables.

GML is the Longitudinal Metacentric Height, i.e. the distance between the longitudinal centre of gravity (LCG) and the longitudinal metacentre (ML).

Because of the shape of the waterplane KML will usually be larger than KMt. Thus a unit’s initial transverse stability, as measured by GMt, is normally the limiting factor for a given VCG, rather than its initial longitudinal stability, measured by GML.

GML is however an important factor in trim calculations and in longitudinal motion (pitching) in a seaway.

Draft.

The **draft of the unit** is the depth of the submerged portion of the unit measured from the **keel to the waterline** in any condition.

Light draft is usually taken to mean the draft of the unit when in a light condition floating with the tops of the pontoons clear of the water; this is usually the condition when moving form one location to another and is often referred to as transit draft.

For a unit fitted with thrusters it must be remembered to add the depth of the thruster protruding from the bottom of the pontoons to the draft the unit is operating at.

Particularly important when in shallow water such as when entering port or in transit.

Deep draft is usually taken to refer to the draft the unit is floating at when in the drilling mode.

All units will have a **maximum allowable draft** which they are allowed to operate at, this will be defined on the Loadline Certificate and this draft must never be exceeded for safety reasons.

Survival draft is the draft that the unit must achieve in storm conditions so that there is sufficient air gap between the underside of the deck and the waterline to prevent wave damage to the unit.

The loading and stability of the unit must be calculated so that the unit can achieve this draft in a safe stability state.

Draft marks are permanently marked on a unit at the extreme corners.

When the unit is floating at light draft the draft marks are visible on the pontoons usually on the outboard side fore and aft.

At deep draft the markings are on the corner columns of the unit usually on the outboard side of the column.

Trim.

Trim can be defined as the difference between the drafts forward and aft.

A unit that is floating at the same draft forward and aft is said to be on an **even or level keel.**

If the draft at the forward end of the unit is a greater value than that at the aft end, then the unit is said to be **trimmed by the head** (or trimmed forward).

Trimmed by the stern (or trimmed aft) means that the aft draft is a greater value than the forward draft.

Change of trim is the difference between the original trim and the final trim in two conditions.

Rules to calculate the Change of Trim.

If the initial trim and final trim are in the same direction. Then Subtract the smaller trim from the larger.

If the initial trim and final trim are in different directions. Then Add the trims together.

Example:

Initial Drafts:	Fwd. 8 ft.	Aft 11 ft.	Trim = 3 ft. x stern (aft draft greater)
Final Drafts:	Fwd. 9 ft.	Aft 10 ft.	Trim = 1ft. x stern.

As the initial and final trims are in the same direction; we subtract the smaller trim from the larger and that will define the amount by which the trim has changed i.e. the change of trim.

The Change of Trim = 2 ft. and the direction the trim has changed is by the Head.

To decide the direction of change, that is by the head or the stern, then as in this case the stern trim of the unit has reduced, therefore the unit has trimmed (or tipped) by the head.

In other words the bow has gone down and the stern has come up.

The unit still remains however trimmed by the stern.

(f the unit had finished up with a greater stern trim than she had initially, then the change would have been by the stern.)

Example:

Initial Drafts	Fwd.18.5 ft.	Aft. 20.0 ft.	Trim = 1.5 ft. x stern
Final Drafts	Fwd. 20.5 ft	Aft. 19.5 ft.	Trim = 1 ft. x head

The initial and final trims are in different directions so the trims are added together.

The Change of Trim = 2.5 ft. and the direction is by the head.

In this case the unit was trimmed by the stern initially and ended up trimmed by the head so the direction of change is by the head.

The mean draft is exactly what it says; that is the mean of the drafts either between the forward draft marks and the aft draft marks or the mean between the 4 corner drafts of a semi-submersible unit.

Arithmetical Mean Draft Calculation:

To calculate the mean draft of a unit the drafts fwd and aft are added together and divided by 2.

Example:

Fwd draft 23 ft. aft draft 27.5 ft.
23 + 27.5 = 50.5 ÷2
Mean Draft = 25.25 ft.

With 4 drafts then add the drafts together and divide by 4 to get the arithmetical mean.

Port Fwd 79.50 ft	Stbd. Fwd 79.75 ft.
Port Aft. 80.50 ft.	Stbd. Aft 80.75 ft.

79.50 + 79.75 + 80.50 + 80.75 ÷ 4
Mean draft = 80.125 ft.

Complete the following calculations.

Follow the rules for change of trim described previously and in the answer define the direction of the change.

Change of Trim Problems.

1.

A unit's Initial drafts are 9 ft. fwd and 13 ft. aft.
After loading her final drafts are 10 ft. fwd and 12 ft. aft.

Calculate: (a) The change of trim. (b) The final mean draft

2.

A unit has initial drafts of 18 ft. fwd and 16 ft aft.
After loading her final drafts are 24 ft. fwd. And 25 ft. aft.

Calculate: (a) The change of trim. (b) The initial mean draft.

3.

A unit has initial drafts of 19.0 ft. fwd. And 21.5 ft. aft.
Her final drafts on completion of load are 19.25 ft. and 21.25 ft.

Calculate: (a) The change of trim
(b) The change in the mean draft amidships

4.

A unit has initial drafts of 14.25 ft. fwd. And 15.5 ft. aft
Her final drafts are 16.5 ft. fwd and 17.75 ft. aft.

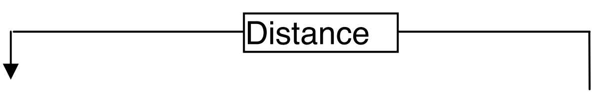
Calculate: (a) The change of trim
(b) The change in the mean draft amidships

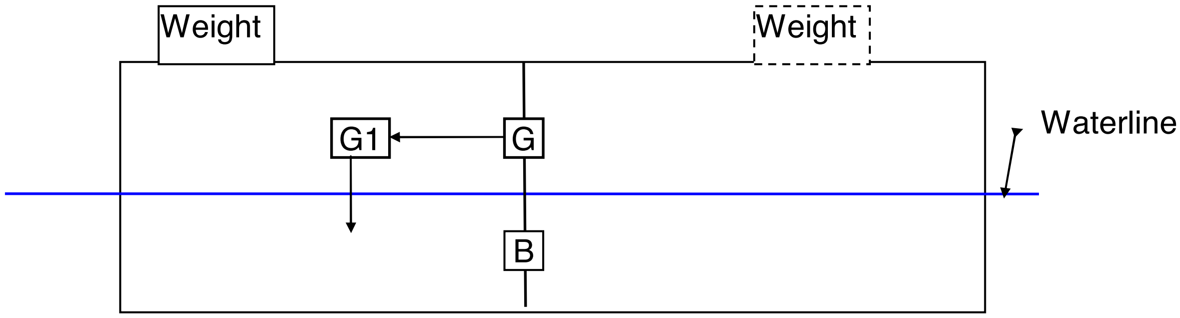
Answers:

1	2 ft. x head	11 ft.
2	3 ft. x stern	17 ft.
3	0.5 ft x head	Nil
4	Nil	2.25 ft.

Consider a unit floating at rest in still water on an even keel as shown.

(a barge shaped unit will be used for simplicity)



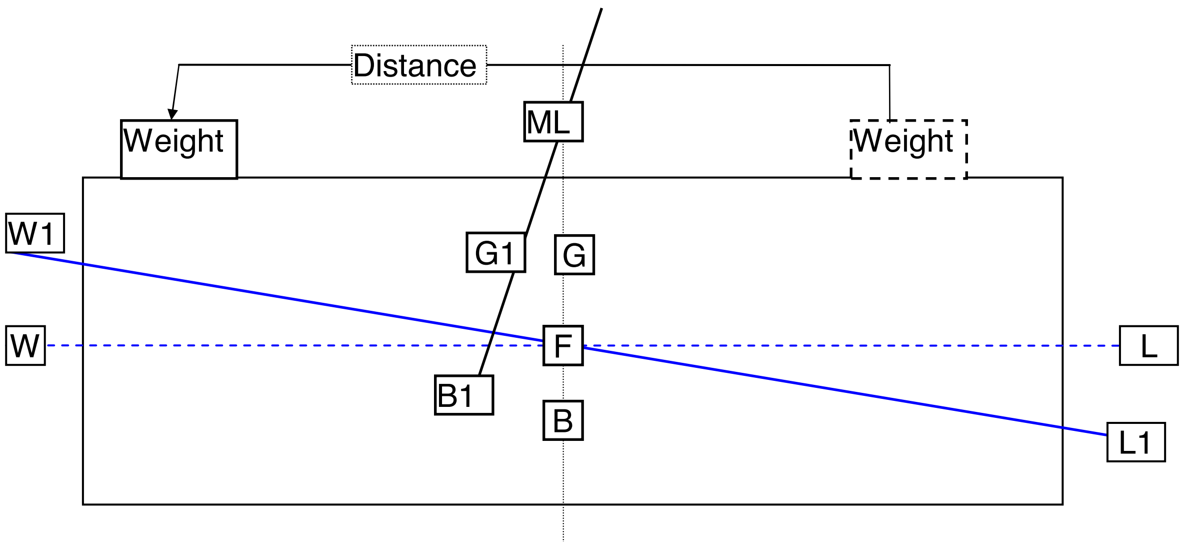


For equilibrium B & G will lie in the same vertical line and the unit will displace her own weight of water.

If a weight ‘w’ s.tons already onboard is moved a distance ’d’ ft. as shown, the centre of gravity ‘G’ will move to some point G1, such that:

$$G \text{ to } G1 = \frac{w \times d}{\Delta}$$

Thus a trimming moment (w x d) is produced and a change of trim will result until the new centre of gravity G1 and Buoyancy B1 lie in the same vertical line as shown.



Referring to the lower diagram since there is no change in the displacement of the unit when trimmed then the volume of the emerged wedge - LFL1- must equal the volume of the immersed wedge - WFW1.

When the unit changes trim the draft at one end will increase and will therefore decrease at the other end.

The point ‘F’ about which the unit trims is known as the :

Centre of Floatation or **Longitudinal Centre of Floatation** or **Tipping Centre**.

This point is the centroid of the waterplane area.

On a semi submersible unit the centre of floatation is usually very close to the centroid of the unit. It may change slightly with changes in displacement.

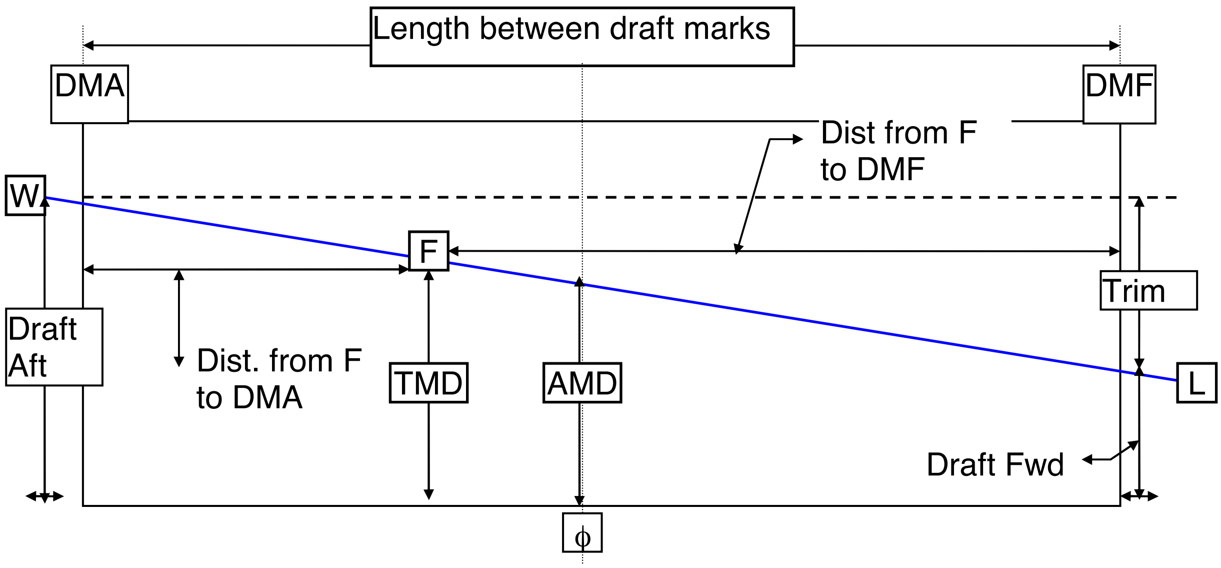
Its position is usually tabulated in relation to amidships or from one of the ends of the unit and can be obtained from hydrostatic curves or tables for the unit.

Hydrostatic curves and tables are normally produced for even keel drafts.

As there is no change in the draft at 'F' as a unit trims, this draft, known as the True Mean Draft (TMD), will be the one at which hydrostatic particulars should be obtained.

The Amidships (or arithmetical) Mean Draft (AMD) is exactly as it states, the mean draft at the amidships point of the unit.

Other abbreviations used are DMF - Draft Marks Fwd & DMA - Draft Marks Aft.



This unit is trimmed by the stern and it can be seen that with the centre of floatation being aft of amidships the TMD will be greater than the AMD.

To calculate the True Mean Draft (TMD). Method 1

$$\text{True Mean Draft} = \text{Draft Aft} \pm \left[\frac{\text{Trim}}{\text{Length}} \times \text{Distance from 'F' to Draft Marks Aft.} \right]$$

(+ if the trim is by head. - if trim is by stern)

Example:

A unit of length between draft marks of 300 ft. is floating at drafts of 20 ft. fwd and 23 ft. aft.

If the Longitudinal centre of floatation 'F' is 25 ft. aft of amidships calculate :

(a) The unit True Mean Draft

(b) The Amidships (or Arithmetical) Mean Draft.

First of all we have to calculate where 'F' is from the Draft Marks Aft.

As the unit is 300 ft. long, the distance from DMA to amidships is 150 ft.

But 'F' is 25 ft. aft of amidships so 'F' will be 150 - 25 = 125 ft from DMA.

The trim of the unit was 3 ft by the stern so the second part of the formula (in brackets) will be subtracted from the Draft Aft.

$$\text{True Mean Draft} = \text{Draft Aft} - \left[\frac{\text{Trim}}{\text{Length}} \times \text{Distance from 'F' to Draft Marks Aft.} \right]$$

$$\text{True Mean Draft} = 23.0\ \text{ft} - \left[\frac{3}{300} \times 125 \right]$$

$$23.0\ \text{ft} - 1.25\ \text{ft}$$

$$\text{True Mean Draft} = 21.75\ \text{ft.}$$

To Calculate the True Mean Draft (TMD) Method 2.

True Mean Draft = Arithmetical Mean draft + or - Correction

Calculation of the correction to the arithmetical mean draft.

$$\frac{\text{Trim}}{\text{Length}} \times \text{Distance from Centre of Floatation To Amidships}$$

Rules for applying the correction:-

\+ If the C of F is in the same direction as the deepest draft
\- If the C of F is in the opposite direction to the deepest draft

Using the same example as on the previous page

Length 300 ft. Draft Fwd. 20ft. Aft 23ft. C of F is 25 ft. aft of amidships.

Arithmetical Mean Draft = 20 + 23 ÷ 2 = 21.5 ft.

Correction =

$$\frac{\text{Trim}}{\text{Length}} \times \text{Distance from Centre of Floatation To Amidships}$$

$$\frac{3}{300} \times 25 = 0.25 \text{ ft.}$$

True Mean Draft = Arithmetical Mean draft + or - Correction

In this case the correction is plus (+) as the C of F is aft of amidships and the deepest draft is aft.

So:
TMD = 21.5 + 0.25 = 21.75.

This is the same answer as obtained using method 1.

Note :

If the centre of floatation is amidships then the True Mean Draft will be equal to the Amidships Mean Draft.
i.e. TMD = AMD.

Unless otherwise stated ‘F’ should be assumed to be amidships.

Carry out the following calculations.

1.
A unit of length 420 ft. is floating at drafts of 24.25 ft. Fwd and 29.25 ft. aft.
If the centre of floatation is 231 ft fwd of the aft draft marks what is:

(a) TMD &
(b) AMD

2.
A unit 650 ft. in length is floating at drafts of 28.75 ft. Fwd. and 33.08 ft. Aft.
If the centre of floatation is 25 ft. Fwd of amidships calculate :

(a) TMD &
(b) AMD

3.

A unit 720 ft. in length is floating at drafts of 36.17 ft. Fwd and 34.5 ft. Aft.
If the centre of floatation is 27 ft. fwd of amidships calculate:

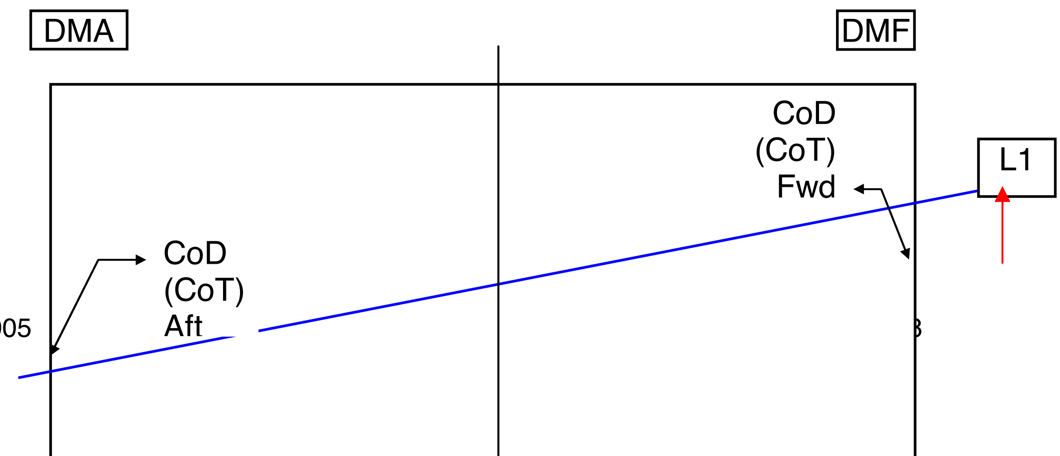
(a) TMD &
(b) AMD

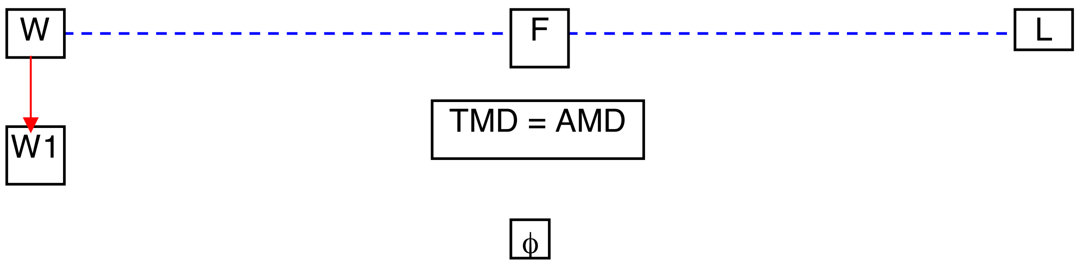
Answers:

1	(a)	26.5 ft.	(b)	26.75 ft.
2	(a)	30.75 ft.	(b)	30.92 ft.
3	(a)	35.4 ft.	(b)	35.33 ft.

If the LCF is situated amidships then :

The Change of Draft due to the Change of Trim or CoD (CoT) will be the same at each end of the unit.
i.e. ½ Total Change of Trim (CoT).





W – L Original waterline W1 – L1 New Waterline.

In the drawing above the unit has trimmed by the head i.e. the draft forward has increased and the draft aft decreased.

Example:

A unit has drafts of 9.25 ft. fwd and 12.5 ft aft.
Due to a shift of weight onboard the trim changes 2.5 ft. by the head..
Calculate the new drafts if the LCF is amidships.

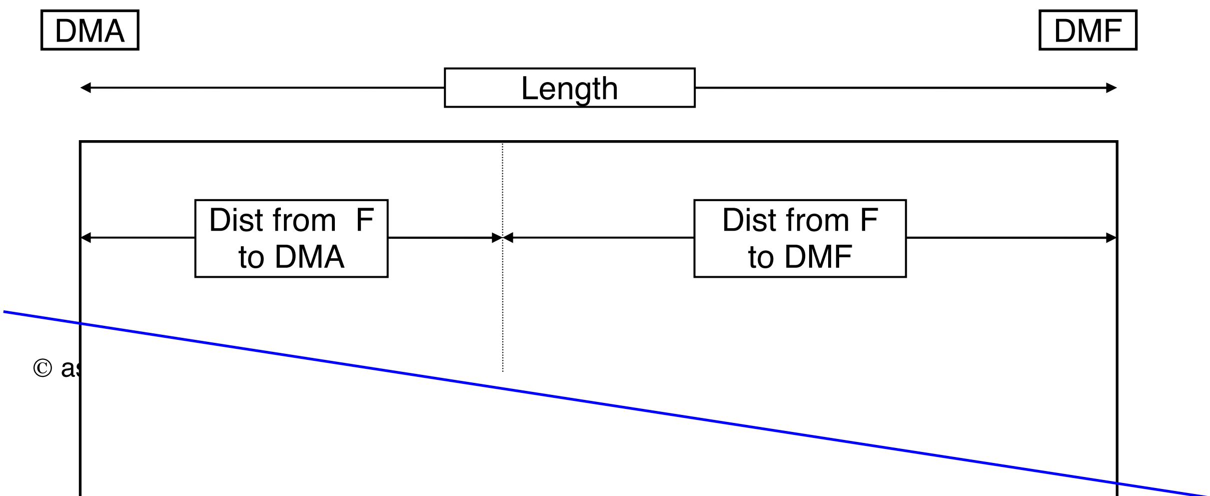
Total Change of Trim (CoT) = 2.5 ft x head

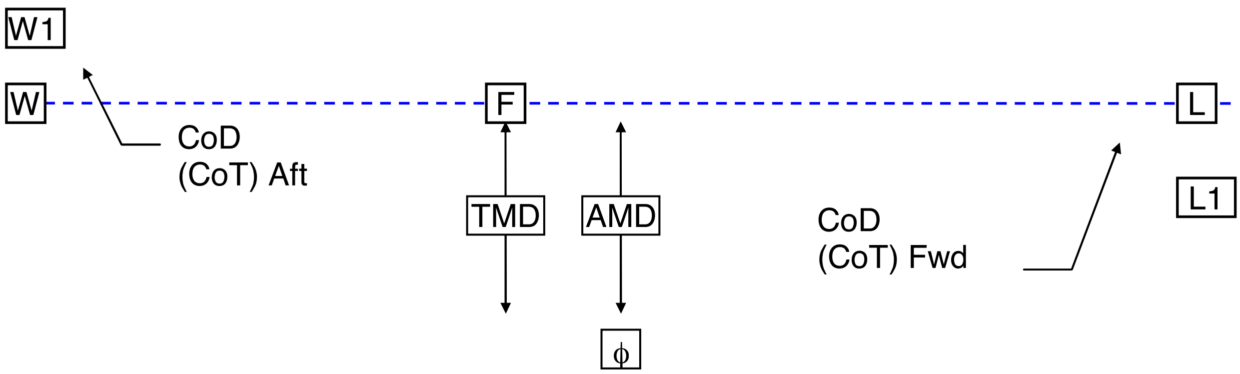
CoD (CoT) Fwd $= \frac{2.5}{2}$ = + 1.25 ft.

CoD (CoT) Aft $= \frac{2.5}{2}$ = - 1.25 ft.

	Fwd	Aft
Initial Drafts	9.25 ft.	12.5 ft.
CoD (CoT)	+1.25 ft	- 1.25 ft.
Final Drafts	**10.5 ft**	**11.25 ft.**

If the **LCF is not amidships** then the changes of draft due to the change of trim fwd. and aft will have to be obtained by proportion.





In the diagram the unit has trimmed by the stern, i.e. the forward draft has decreased and the aft draft increased.

W – L Original waterline   W1 – L1 New Waterline.

CoD (CoT) Fwd + CoD (CoT) Aft = Total CoT,
but now
CoD (CoT) Fwd ≠ CoD (CoT) Aft

$$\text{CoD (CoT) Fwd} = \frac{\text{CoT}}{\text{Length}} \times \text{Distance from 'F' to DMF}$$

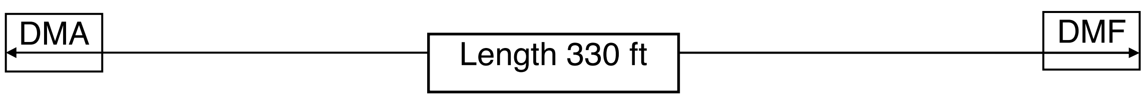
$$\text{CoD (CoT) Aft} = \frac{\text{CoT}}{\text{Length}} \times \text{Distance from 'F' to DMA}$$

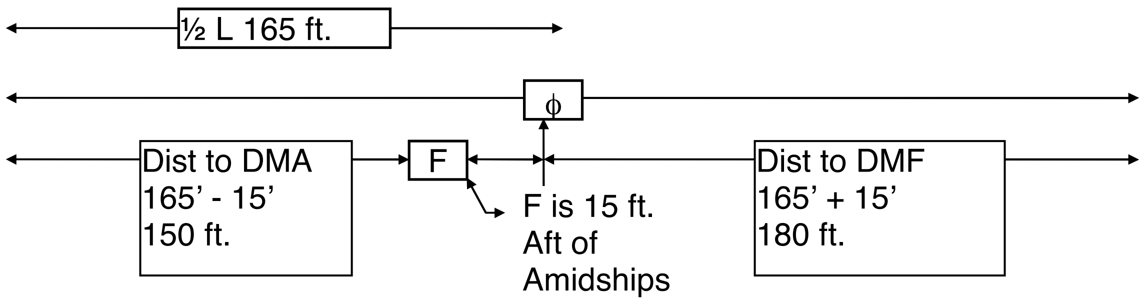
Example:

A unit 330 ft. in length has its LCF 15 ft. aft of amidships and floats at an even keel draft of 12 ft. Movement of cargo onboard causes a change of trim of 2.5 ft. by the stern. Calculate the final drafts Fwd. and Aft also the final TMD and AMD.

As the unit is 330 ft. long amidships will be 165 ft. So with the LCF being situated 15 ft. aft of amidships, the distance from F to DMF will be 180 ft. and to DMA 150 ft.

It is helpful to do a simple drawing to define the distances from the centre of floatation to the draft marks at each end of the unit





Cod (CoT)Fwd = $\frac{\text{Cot}}{\text{Length}}$ x dist. from 'F' to DMF $= \frac{2.5}{330} \times 180$ = - 1.36 ft.-

Cod (CoT)Aft = $\frac{\text{Cot}}{\text{Length}}$ x dist. From 'F' to DMA $= \frac{2.5}{330} \times 150$ = + 1.14 ft.

	Fwd.	Aft.
Initial Drafts	12.00 ft.	12.00 ft.
CoD (CoT)	- 1.36 ft.	+ 1.14 ft.
Final Drafts	**10.64 ft.**	**13.14 ft.**

Final TMD = Draft Aft - $\left[\frac{\text{Trim}}{\text{Length}} \times \text{distance from 'F' to DMA} \right]$

Final TMD = 13.14 ft - $\left[\frac{2.5}{330} \times 150 \right]$

Final TMD = 13.14 ft. - 1.14 ft. = **12.00 ft.**

Final AMD = $\frac{\text{Draft Fwd.} + \text{Draft Aft.}}{2}$ $\frac{10.64 \text{ ft.} + 13.14 \text{ ft.}}{2}$ = **11.89 ft.**

Carry out the following calculations.
1.

A unit has drafts of 13.75 ft. Fwd. and 15.09 ft. Aft.
Her LCF is amidships.
Cargo is shifted forward so that her trim changes by 1.34 ft.

What drafts is the unit now floating at.

2.

A unit is floating with drafts of 23.75 ft. Fwd. and 24.25 ft Aft.
Her LCF is amidships.
Due to weight being shifted from 55 ft forward of amidships to 10 ft aft of amidships her trim changes by 1.5 ft.

Calculate the new drafts.

3.

A unit has a length between draft marks of 460 ft. She is presently floating at drafts of 21.42 ft. Fwd and 21.83 ft. Aft.
Weights are shifted aft which cause a change of trim of 1.5 ft.

Calculate the new drafts given that the LCF is 26 ft. aft of amidships.

4.

A unit is floating on an even keel at a draft of 19.5 ft.
Due to transfer of cargo onboard the trim of the unit changes to become 2 ft. by the stern.
The LCF is 180 ft. fwd. of the Draft Marks Aft.

If the length of the unit is 394 ft. calculate the drafts the unit is now floating at.

Answers:

1	Fwd. 14.42 ft.	Aft. 14.42 ft.
2	Fwd. 23.00 ft.	Aft. 25.00 ft.
3	Fwd. 20.58 ft.	Aft. 22.50 ft.
4	Fwd. 18.41 ft.	Aft. 20.41 ft.

Trimming Moment.

When a weight is moved a distance along the length of a unit the resulting moment, called a trimming moment, causes a change of trim

For example if a weight of 80 s.tons is shifted a distance of 120 ft, then the resulting moment will be **80 x 120 = 9600 ft/tons.**

It should be noted that the initial and final position of the weight do not matter in the case of a shift of weight. The direction of the shift indicates the direction of the change, by the head or the stern.

If the amount of trimming moment required to cause a change of trim of 1 " is known then the total change of trim can be calculated.

Hydrostatic Curves or Tables provide the Moment to Change Trim 1" or MT1".

$$\textbf{Change of Trim} = \frac{\textbf{Trimming Moment}}{\textbf{MT1"}} \quad \textbf{(in inches)}$$

Example:

Calculate the Change of Trim if 100 s.tons is shifted 96 ft. aft on a unit with an MT1" of 800 ft/tons.

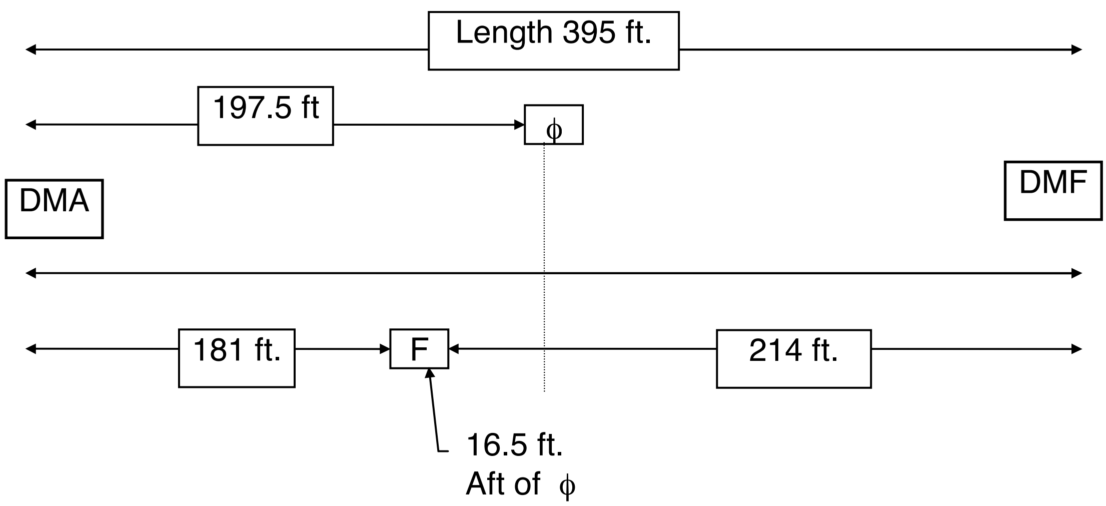
$$\text{CoT} = \frac{\text{Trimming Moment}}{\text{MT1"}} = \frac{100 \times 96}{800} = 12\text{"} \quad \text{or} \quad 1 \text{ ft.}$$

When calculating change of trim it is more satisfactory to convert the result from inches to feet and decimal parts of a foot.
Remember to do this we divide the number of inches by 12 and use 2 places of decimals.

Inches	Feet
1	0.08
2	0.17
3	0.25
4	0.33
5	0.42
6	0.50
7	0.58
8	0.67
9	0.75
10	0.83
11	0.92
12	1.00

Example:

A unit length 395 ft. floating at drafts of 14.25 ft. Fwd. and 15.75 ft. Aft. Shifts 80 s.tons of cargo 180 ft. fwd. If the LCF is 16.5 ft. aft of amidships and the MT1" is 800 ft/tons calculate the final drafts.



80 s.tons of cargo has been moved 180 ft. fwd. so the change of trim will be by the head.

$$CoT = \frac{\text{Trimming Moment}}{\text{MT1''}} = \frac{80 \times 180}{800} = 18\text{'' or } 1.5 \text{ ft x head}$$

$$CoD(CoT)\ Fwd. = \frac{1.5}{395} \times 214 = +\ 0.81 \text{ ft.}$$

$$CoD(CoT)\ Aft. = \frac{1.5}{395} \times 181 = -\ 0.69 \text{ ft.}$$

	Fwd.	Aft.
Initial Drafts	14.25	15.75
CoD(CoT)	+0.81	- 0.69
Final Drafts	**15.06**	**15.06**

Carry out the following calculations:

1.

A unit floats at drafts of 24.75 ft. Fwd. and 26.0 ft. Aft. Her MT1" is 7425 ft/tons and her LCF is amidships.

Calculate the change of trim and the new drafts if a weight of 440 s.tons is shifted forward through a distance of 270 ft.

2.

Calculate the change of trim and the new drafts if 525 s.tons of cargo is transferred from a position 78 ft. forward of amidships to a position 90 ft. aft of amidships.

The unit is floating at drafts of 17.0 ft. Fwd. and 16.16 ft. Aft. Her MT1” is 11025 ft/tons and the LCF is amidships.

3.

A unit 495 ft. long has her LCF positioned 225 ft. forward of the DMA. She is presently floating at drafts of 21.75 ft. Fwd and 22.0 ft. Aft.

Calculate the change of trim and the new drafts if a weight of 416 s.tons is shifted 328 ft. aft. The unit MT1” is 12400 ft/tons.

4.

Calculate the change of trim and the new drafts if 330 s.tons of ballast is transferred from aft to fwd, between tanks which are 272 ft. apart.

The unit is 525 ft. in length and is floating at drafts of 23.5 ft. Fwd and 28.5 ft. Aft.
The LCF is 242 ft. fwd of the DMA and her MT1" is 13775 ft/tons.

Answers:

	Change of trim	Draft Fwd	Draft Aft.
1	1.33 ft x head	25.42 ft.	25.33 ft.
2	0.67 ft. x stern	16.66 ft.	16.50 ft.
3	0.92 ft. x stern	21.25 ft.	22.42 ft.
4	0.54 ft. x head	23.8 ft.	28.25 ft.

Weights Loaded or Discharged.

If weights are loaded onto a unit, there will be a change to the units mean draft and, if the weight is loaded away from the LCF there will also be a change of trim.

If the weight is loaded the change in mean draft is referred to as " Bodily Sinkage" and if discharged, then the term is " Bodily Rise".

The sinkage /rise can be calculated by obtaining the Tons per Inch Immersion from the Hydrostatic curves or tables at the draft concerned. The weight loaded or discharged is then divided by the TP1" to obtain the change to the mean draft.

$$\text{Bodily Sinkage / Rise (in inches)} = \frac{\text{Weight Loaded / Discharged}}{\text{TP1"}}$$

If there is a large change of weight then the TP1" should be taken for the mean draft.

Example:

A unit with a TP1" of 40, loads 240 s.tons cargo over the LCF. Calculate the change to the mean draft and the final drafts if the unit was floating at drafts of 11.25 ft. Fwd and 14.75 ft. Aft.

$$\text{Bodily Sinkage} = \frac{\text{Weight Loaded}}{\text{TP1''}} = \frac{240}{40} = 6'' \text{ or } 0.5 \text{ ft.}$$

	Fwd.	Aft
Initial Drafts	11.25 ft.	14.75 ft.
Sinkage	+ 0.5 ft.	+ 0.5 ft.
Final Drafts	11.75 ft.	15.25 ft.

If the same quantity of cargo had been discharged, with the same TP1", then there would have been a bodily rise of 0.5 ft. and the final drafts would have been:

$$\text{Bodily Rise} = \frac{\text{Weight Discharged}}{\text{TP1''}} = \frac{240}{40} = 6'' \text{ or } 0.5 \text{ ft.}$$

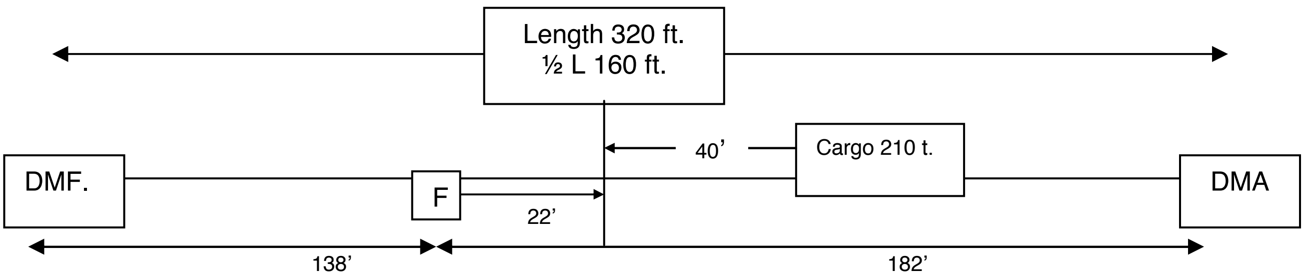
	Fwd.	Aft
Initial Drafts	11.25 ft.	14.75 ft.
Rise	- 0.5 ft.	- 0.5 ft.
Final Drafts	10.75 ft.	14.25 ft.

To calculate final draft when weight is loaded away from the LCF.

1. Add the weight at the LCF to obtain the bodily sinkage
2. Move the weight to it's final position and calculate the change of trim.
3. Calculate the change of draft due to the change of trim.
4. Apply the sinkage to the initial drafts.
5. Apply the change of draft to the drafts Fwd. & Aft to obtain the final drafts.

Example:
A unit with drafts of 12.25 ft Fwd. and 13.75 ft. Aft loads 210 s.tons cargo at a distance of 40 ft. aft of amidships.

Calculate the final drafts given the length of the unit is 320 ft. and the LCF is 22 ft. fwd. of amidships.TP1" = 30. And MT1" = 620 ft/tons.



Sinkage (in inches) = $\frac{\text{Weight Loaded}}{\text{TP1"}} = \frac{210}{30}$ = 7" or 0.58 ft.

Change of Trim (in inches) = $\frac{\text{Trimming Moment}}{\text{MT1"}} = \frac{210 \times (40+22)}{620}$ = 21" or 1.75 ft. x stern

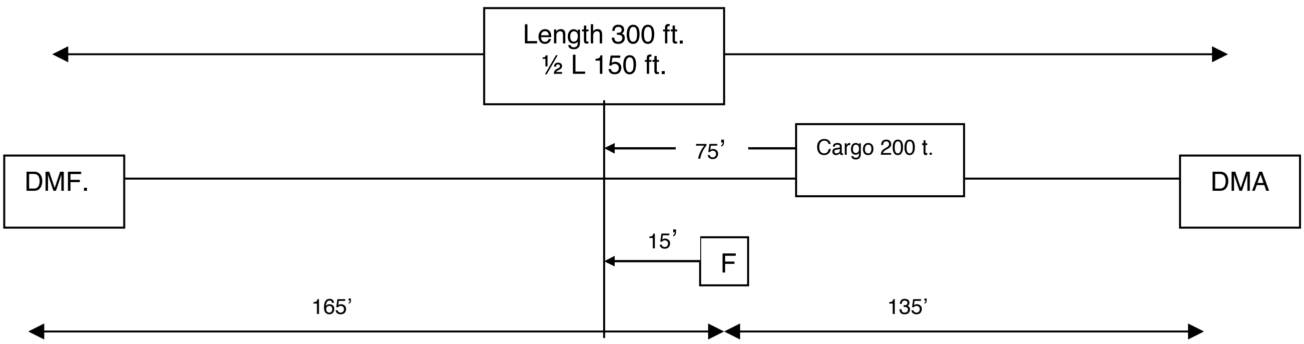
CoD(CoT) Fwd. = $\frac{\text{CoT}}{\text{L}}$ x Distance from F to DMF = $\frac{1.75}{320}$ x 138 = - 0.76 ft.

CoD(CoT) Aft. = $\frac{\text{CoT}}{\text{L}}$ x Distance from F to DMA = $\frac{1.75}{320}$ x 182 = + 0.99 ft.

	Fwd.	Aft.
Initial Drafts	12.25 ft.	13.75 ft.
Sinkage	+ 0.58 ft.	+ 0.58 ft.
	12.83 ft.	14.33 ft.
CoD(CoT)	- 0.76 ft.	+ 0.99 ft.
Final Drafts	12.07 ft.	15.32 ft.

To calculate final draft when weight is discharged away from the LCF.

1. Calculate the bodily rise due to the weight discharged.
2. Calculate the change of trim due to the weight discharged.
3. Calculate the change of draft due to the change of trim.
4. Apply the bodily rise to the initial drafts.
5. Apply the change of draft to obtain the final drafts.



Example:

A unit at drafts of 15.0 ft. Fwd and 18.0 ft. Aft, discharges 200 s.tons cargo from a position 75 ft. aft of amidships. Calculate the final drafts if the unit length is 300 ft. her LCF is 135 ft. forward of DMA. The TP1" = 40 and MT1" = 800 ft/tons.

$$\text{Bodily Rise (in inches)} = \frac{\text{Weight Discharged}}{\text{TP1"}} = \frac{200}{40} = -5\text{"} \quad \text{or } 0.42 \text{ ft.}$$

$$\text{Change of Trim (in inches)} = \frac{\text{Trimming Moment}}{\text{MT1"}} = \frac{200 \times (75-15)}{800} = 15\text{" x head} \quad \text{or } 1.25 \text{ ft. x head}$$

$$\text{CoD(CoT) Fwd.} = \frac{\text{CoT}}{\text{L}} \times \text{dist from F to DMF} = \frac{1.25}{300} \times 165 = +0.69 \text{ ft.}$$

$$\text{CoD(CoT) Aft.} = \frac{\text{CoT}}{\text{L}} \times \text{dist from F to DMA} = \frac{1.25}{300} \times 135 = -0.56 \text{ ft.}$$

	Fwd.	Aft.
Initial Drafts	15.00 ft.	18.00 ft.
Bodily Rise	- 0.42 ft.	- 0.42 ft.
	14.58 ft.	17.58 ft.
CoD(CoT)	+ 0.69 ft.	- 0.56 ft.
Final Drafts	**15.27 ft.**	**17.02 ft.**

Carry out the following calculations.

1.

A unit is 492 ft. in length and has a TP1" of 55 and an MT1" of 2300 ft/tons. She is floating at drafts of 17.08 ft. Fwd and 18.75 ft. Aft. 330 s.tons of cargo is loaded at a distance of 330 ft. from the DMA.
Calculate the new drafts if the LCF is amidships.

2.

The following particulars are known about a unit.

Length 482 ft., TP1” 44, MT1” 2400 ft/tons, LCF 226 ft. fwd of the DMA.
Drafts 23.17 ft. Fwd. and 23.5 ft. Aft.
Calculate the new drafts if 88 s.tons cargo is loaded at a distance of 124 ft. fwd of the DMA.

3.
A unit has drafts of 17.17 ft. Fwd. and 20.0 ft. Aft. 265 s.tons of ballast is loaded into a tank the centre of gravity of which is 450 ft. from the DMA. The length of the unit is 550 ft., her LCF is situated 256 ft. from the DMA. Calculate the new drafts if the TP1” is 62 and the MT1” is 7345 ft/tons.

4.

A unit with her LCF amidships is floating at drafts of 18.75 ft. Fwd. and 19.17 ft. Aft. Her length is 412 ft., TP1” is 42 and MT1” is 1305 ft/tons.
Calculate the final drafts after a weight of 126 s.tons is discharged from a space which is 398 ft. Fwd of the DMA.

Answers:

1.	18.08 ft Fwd.	18.75 ft. Aft.
2.	23.17 ft. Fwd.	23.81 ft. Aft.
3.	17.83 ft. Fwd.	20.08 ft. Aft.
4.	17.73 ft. Fwd.	19.69 ft. Aft.

Where more than one weight is to be loaded and/or discharged:

1. Make up a table with weights, trimming levers and moments defined.

2. Calculate the resultant weight loaded or discharged to find the bodily change in draft.

3. When defining the trimming levers use the convention + for Fwd. lever and - for Aft lever.

4. Calculate the resultant trimming moment to find the change of trim.

5. Use the convention + for Fwd. moments and - for Aft moments.

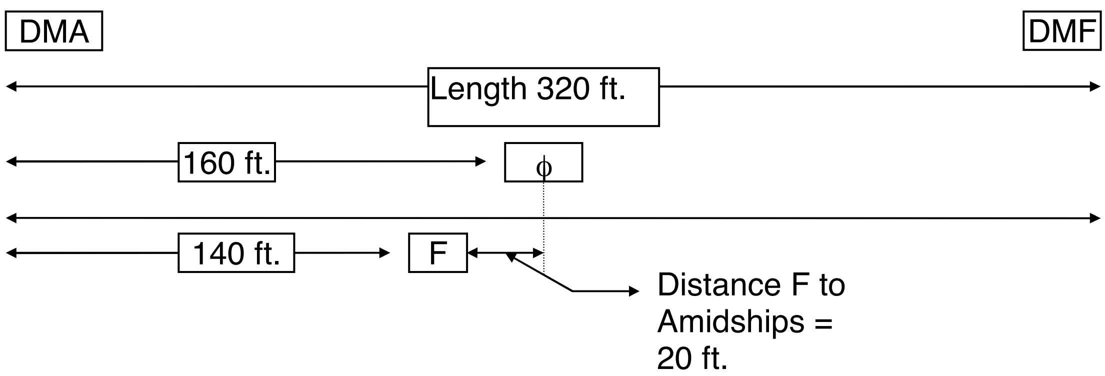
When calculating the trimming levers the position of the centre of floatation has to be taken into account.

In the example on the next page we have the following details given:

Length = 320 ft. LCF is 140 ft. fwd of DMA.

80 s.tons is loaded 120 ft. fwd of amidships and 60 s.tons loaded 60 ft. aft of amidships.

40 s.tons is discharged 30 ft. fwd of amidships and 70 s.tons is discharged 105 ft. aft of amidships.



F is 20 ft, aft of amidships, this will have an effect on the trimming lever as the length of the lever is measured from F.

Therefore the trimming lever for weights forward of amidships will have 20 ft. added to their distance from amidships, so 80 s.tons at 120 ft. fwd of amidships will have a trimming lever of 120 + 20 = 140 ft.

For weights aft of amidships will have 20 ft. deducted from their distance from amidships , so 60 s.tons at 60 ft. aft of amidships will have a trimming lever of 60 - 20 = 40 ft.

Example:

A unit has drafts of 14.5 ft. Fwd and 16.5 ft. Aft. Her length is 320 ft., LCF is 140 ft. fwd of DMA , TP1" is 40 and MT1" is 750 ft/tons.

She loads 80 s.tons 120 ft. fwd of amidships, and 60 s.tons 60 ft. aft of amidships.

She discharges 40 s.tons 30 ft. fwd. of amidships and 70 s.tons 105 ft. aft of amidships.

Calculate the final drafts.

Weight (s.tons)	Trimming Lever (ft.)	Trimming Moment
+ 80	(120+20) +140	+11200
+ 60	(60-20) - 40	-2400
- 40	(30+20) +50	-2000
-70	(105-20) - 85	+5950
+30		+12750

Bodily Sinkage = $\frac{\text{Weight loaded}}{\text{TP1''}} = \frac{30}{40}$ = 0.75" or 0.06 ft.

Change of Trim = $\frac{\text{Trimming Moment}}{\text{MT1''}} = \frac{12750}{750}$ = 17" or 1.42 ft. x head.

CoD(CoT) F = $\frac{\text{CoT}}{\text{L}}$ x Dist from F to DMF $= \frac{1.42}{320} \times 180$ = +0.80 ft.

CoD(CoT) A = $\frac{\text{CoT}}{\text{L}}$ x Dist from F to DMA $= \frac{1.42}{320} \times 140$ = - 0.62 ft.

	Fwd.	Aft.
Initial Drafts	14.50 ft.	16.50 ft.
Bodily Sinkage	+ 0.06 ft.	+ 0.06 ft.
CoD(CoT)	+ 0.80 ft.	- 0.62 ft.
Final Drafts	15.36 ft.	15.94 ft.

Carry out the following calculations:

1.
A unit which is 460 ft. in length has a TP1” of 58 and a MT1” of 8180 ft/tons. Her LCF is amidships and her drafts are 22.5 ft. Fwd. and 23.5 ft. Aft. Calculate the new drafts if 154 s.tons of cargo is loaded 350 ft. from the DMA and 62 s.tons is loaded at 130 ft. from the DMA.

2.
A unit is floating at drafts of 20.0 ft. Fwd. and 22.0 ft. Aft. The following cargo is now loaded:
22 s.tons at 100 ft. fwd of amidships. 51 s.tons at 80 ft. fwd of amidships.
67 s.tons at 50 ft. aft of amidships. 34 s.tons at 10 ft. aft of amidships.
Calculate the new drafts given that the LCF is amidships, MT1” is 2600 ft/tons & TP1” is 39.

3.

Calculate the final drafts after the following operations have been carried out:
Discharged - 441 s.tons at 243 ft. fwd of DMA, 44 s.tons at 436 ft. fwd of DMA, 77 s.tons at 220 ft. fwd of DMA.
Loaded - 303 s.tons at 253 ft. fwd of DMA.
LCF is 285 ft. fwd of DMA , TP1" is 86 & MT1" is 2620 ft/tons. Length = 520'
Drafts at present are Fwd. 23.17 ft. and Aft 25.83 ft.

4.
A unit 330 ft. in length, TP1"- 49, MT1" - 1140 ft/tons, has drafts of 21.33 ft. Fwd and 22.67 ft. Aft.
She loads - 230 s.tons at 155 ft. fwd of amidships, 800 s.tons at 49 ft. fwd of amidships and 500 s.tons at 82 ft. aft of amidships.
She discharges - 200 s.tons from 105 ft. fwd of amidships, 105 s.tons from 165 ft. fwd of amidships, 441 s.tons from 15 ft. aft of amidships and 147 s.tons from 20 ft. aft of amidships.
If the LCF is 15 ft. aft of amidships calculate final drafts.

Answers:

	Fwd	Aft
1	22.87 ft.	23.75 ft.
2	20.42 ft.	22.34 ft.
3	23.02 ft.	25.45 ft.
4	22.99 ft.	23.27 ft.

Trim Summary.

DMA - Draft Marks Aft **DMF** - Draft Marks Fwd.

Trim is the difference between drafts fwd and aft and is named as the greater.

Change of Trim(CoT) is the difference between the trims in two different conditions.

To find the Change of Trim

Add trims together if they are in different directions.
i.e. original trim 2 ft. x head - new trim 3 ft. by stern
Change of Trim 5 ft by stern.

Subtract trims if both trims are in the same direction.
i.e. original trim 3 ft. x head - new trim 2 ft. x head
Change of trim 1 ft. x stern

Change of Trim (CoT) will cause a Change of Draft (CoD) Fwd and Aft.

Trimming Moment is the product of a weight loaded or discharged at a known distance from the LCF. It is also the product of a weight that is moved along the length of a unit a known distance, (w x d).
It is expressed in " ft/tons".

LCF - Longitudinal Centre of Floatation, sometimes referred to as the Centre of Floatation (F) or Tipping Centre, is the centroid of the waterplane area in a longitudinal plane.

It is the point about which the unit will balance lengthways. and the unit will trim about this point.
The position of F can be obtained from hydrostatic curves or tables.

Arithmetical Mean Draft (AMD) is the mean value of the drafts that the unit is floating at; either simply the mean of the fwd and aft drafts or the mean of the drafts at however many number of points that the drafts have been recorded.

To calculate AMD - $\frac{\text{Draft Fwd + Draft Aft}}{2}$

True Mean Draft (TMD) is the draft at the centre of floatation (F) or LCF.

If the unit LCF is situated amidships then TMD = AMD.

To calculate the True Mean Draft (TMD). Method 1

$$TMD = \text{Draft Aft} \pm \frac{\text{Trim}}{\text{Length}} \times \text{Distance from F to DMA}$$

(+ if trim is x head - if trim x stern)

To Calculate the True Mean Draft (TMD) Method 2.

True Mean Draft = Arithmetical Mean draft + or - Correction

Calculation of the correction to the arithmetical mean draft.

$$\frac{\text{Trim}}{\text{Length}} \times \text{Distance from Centre of Floatation To Amidships}$$

Rules for applying the correction:-

+ If the C of F is in the same direction as the deepest draft
- If the C of F is in the opposite direction to the deepest draft

If the unit LCF is amidships then the Change of Draft due to the Change of Trim is given by:

CoD (CoT) Fwd = CoD (CoT) Aft = ½ CoT

If the unit LCF is NOT amidships then the change of Draft due to Change of Trim is given by:

$$\text{CoD(CoT) Fwd} = \frac{\text{CoT x Distance from F to DMF}}{\text{Length}}$$

$$\text{CoD(CoT) Aft} = \frac{\text{CoT x Distance from F to DMA}}{\text{Length}}$$

MT1" is the amount of trimming moment required to cause a change of trim of one inch.

$$\text{Change of Trim (in inches)} = \frac{\text{Trimming Moment}}{\text{MT1"}}$$

Weight loaded at the LCF will result in **Bodily Sinkage**

Weight discharged at the LCF will result in **Bodily Rise**

TP1" or Tons per Inch Immersion is the number of tons that must be loaded/discharged in order to cause the unit to sink/rise by one inch.

Bodily Sinkage = Weight Loaded / TP1" **(in inches**   **Bodily Rise = Weight Discharged / TP1"** **(in inches)**

Take care when using TP1" when weights loaded or discharged are large, and the TP1" is changing over a small range of draft.
Use an average TP1" over the drafts concerned.

Also when there is a large alteration to the waterplane area, such as when changing from pontoons to columns or vice-versa. In this case it is preferable to calculate the new draft using the new displacement and obtaining the draft from hydrostatic tables.

The use of these tables will be discussed later in the programme.

To calculate final drafts when a weight has been loaded.

1. Add the weight as though it was loaded at F and use the TP1" at the original or mean draft to find the bodily sinkage.

2. Calculate the trimming moment, (weight x distance loaded from F).

3. Calculate the change of trim using the trimming moment obtained and the MT1", (MT1" should be obtained at the new mean draft).

4. Calculate the Change of Draft (Fwd and Aft) due to Change of Trim using the appropriate formula.

5. Calculate Final draft after applying bodily sinkage and change of draft Fwd and Aft to the original drafts.

To calculate final drafts when a weight has been discharged.

1. Subtract the weight as though it was discharged at F and use the TP1" at the original or mean draft to find the bodily rise.

2. Calculate the trimming moment, (weight x distance loaded from F).

3. Calculate the change of trim using the trimming moment obtained and the MT1", (MT1" should be obtained at the new mean draft).

4. Calculate the Change of Draft (Fwd and Aft) due to Change of Trim using the appropriate formula.

5. Calculate Final draft after applying bodily rise and change of draft Fwd and Aft to the original drafts.

To calculate final drafts when more than one weight has been loaded and or discharged.

1.
Construct a table with weight loaded/discharged, trimming levers and trimming moments in the appropriate columns.

2.
Trimming levers are calculated by ascertaining the distance the weights are situated from the LCF.

3.
Calculate the resultant weight to loaded or discharged in order to calculate bodily sinkage or rise.

4.
Calculate the resultant trimming moment and then the change of trim using the MT1".

5.
Calculate the Change of Draft (Fwd and Aft) due to the change of trim using the appropriate formula.

6.
Calculate Final draft after applying bodily rise/sinkage and change of draft Fwd and Aft to the original drafts.

Section 4 List

Objective: **To understand the causes of list, calculation and correction of angles of list.**

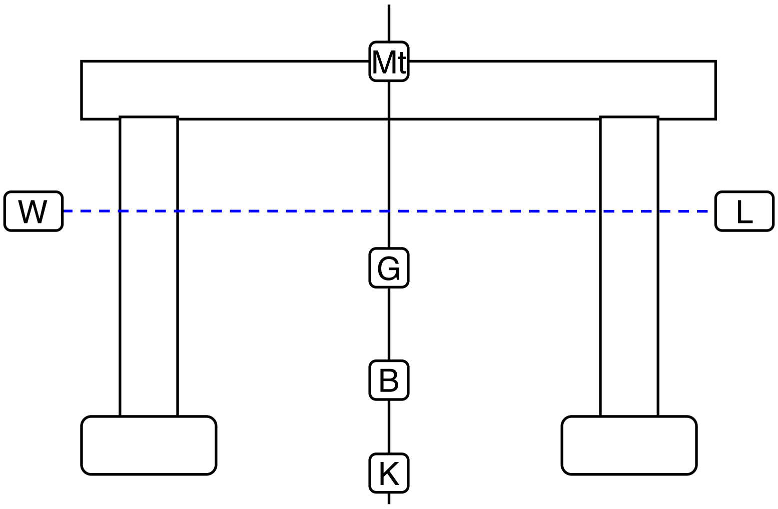
Subjects covered in this section.

1. **Angle of List Calculations**

2. **Correcting list**

List.

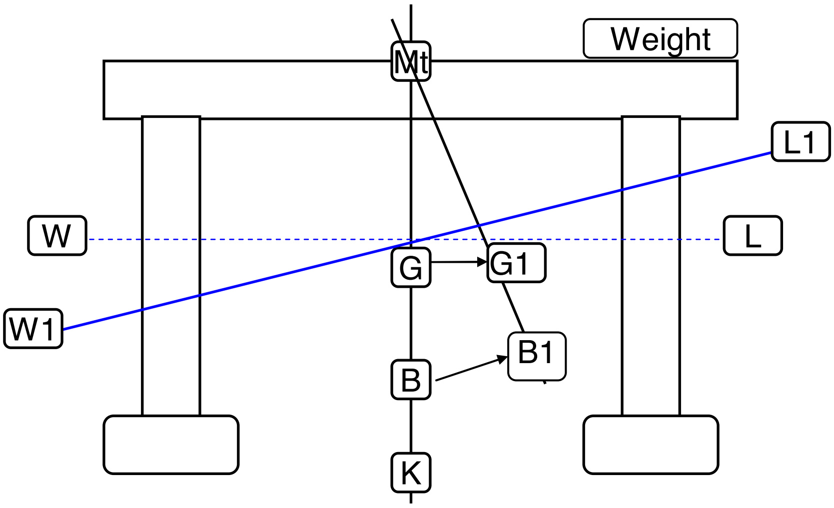
With a unit in the upright condition the centres of gravity and buoyancy will lie in the same vertical line and the unit will be in equilibrium so long as the centre of gravity is below the metacentre.



However if a load is placed off the centreline of the unit then the unit will list and the centre of gravity will move across towards the position of the weight.

The centre of buoyancy will also move towards the low side of the unit until the new position of the centre of gravity (G1) and the new position of the centre of Buoyancy (B1) are in the same vertical line.

We can assume that the Metacentre (M) remains in a fixed position for angles of list up to 10 °

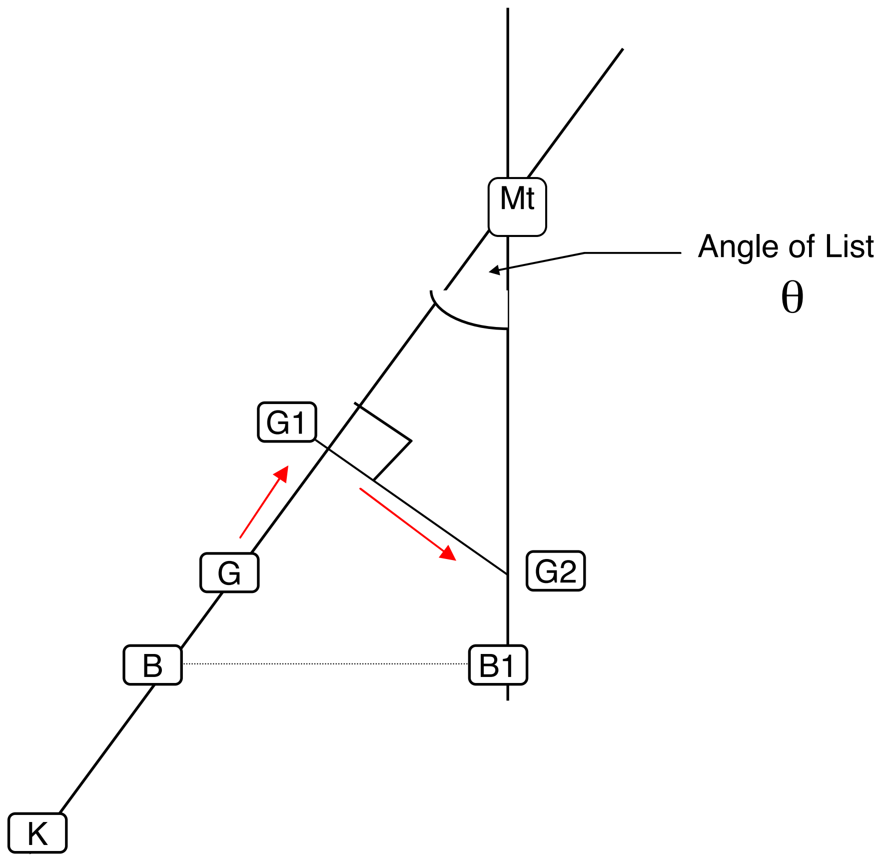


If the position of 'Mt' and 'G1' are known, or can be determined, the angle of list can be found by considering the triangle G, G1, Mt which is right-angled at G.

It may be necessary to find the final position of the centre of gravity and hence GMt by taking moments about the keel for the rise (or fall) of the vertical position of G, (that is G to G1in the diagram.

And about the centreline for the transverse position of G (G1 to G2) before the angle of list can be calculated.

It is more convenient when taking moments to find the position of G2 to consider the unit to be upright throughout the operation.



To calculate the angle of list the Tangent formula is used.

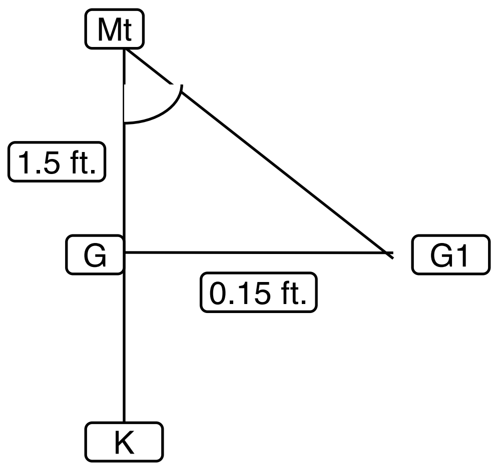
Tan Angle = $\frac{\text{Opposite}}{\text{Adjacent}}$ or in our case $\frac{\text{G to G1}}{\text{GMt}}$

Example:

A unit KMt 21.0 ft., KG 19.5 ft, has its centre of gravity 0.15 ft. off the centre line to starboard.

Calculate the angle of list.

GMt = KMt - KG = 21.0 ft. - 19.5 ft. = 1.5 ft.



Tan angle List $\frac{\text{G toG1}}{\text{GMt}}$ = $\frac{0.15}{1.5}$ = 0.1 = 5.7 °

Angle of List = 5.7 ° to Starboard

Example :

A unit of 5000 s.tons displacement is initially upright.

If a 25 s.ton weight onboard the unit is shifted 30 ft. across the deck from starboard to port, calculate the angle of list.

The unit has a KMt of 19.5 ft. and a KG of 16.5 ft.

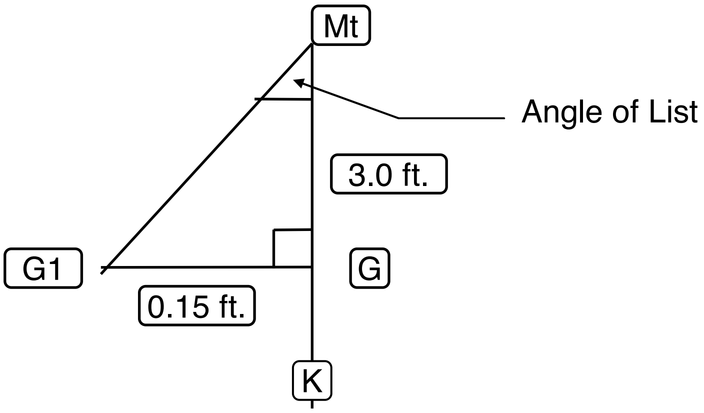
Before we can calculate the angle of list we need to find the GMt and the shift of G (G to G1).

GMt = KMt - KG
19.5 - 16.5
GMt = 3.0 ft.

$$\text{Shift of G} = \frac{w \times d}{\Delta} = \frac{25 \times 30}{5000}$$

Shift of G
(G to G1) = 0.15 ft.

We now have sufficient information to calculate the angle of list.



$$\text{Tan angle of List} = \frac{\text{G to G1}}{\text{GMt}} = \frac{0.15}{3.0} = 0.05 = 2.86\,°$$

Angle of List = 2.86 ° to Port

If a weight is **raised or lowered and moved** transversely onboard a unit then:

1.
Calculate the vertical movement of G due to raising or lowering the weight.

2.
Calculate the horizontal movement of G due to the transverse shift of the weight.

Example:

A unit of 5000 s.tons displacement has a KG of 15 ft. and a KMt of 18 ft. and is initially upright.
If a 20 s.ton weight onboard is shifted 3 ft. vertically upwards and 30 ft. across the deck to starboard, calculate the angle of list caused.

Find the vertical shift of G. (G to Gv)

Shift of G (G to Gv) = $\frac{w \times d}{\Delta}$ = $\frac{20 \times 3}{5000}$ = 0.012 ft. up

Find the new GMt.

Original GMt = KMt - KG = 18 - 15 = 3 ft.

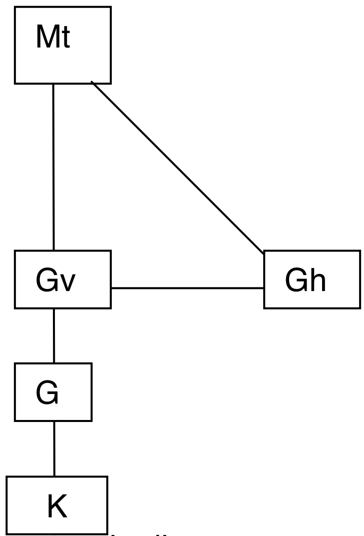
Original GMt - Shift of G = New GMt so 3.0 - 0.012 = 2.988 ft.

Find the horizontal shift of G. (Gv to Gh)

Shift of G (Gv to Gh) = $\frac{w \times d}{\Delta}$ = $\frac{20 \times 30}{5000}$ = 0.12 ft. to starboard

To find the angle of list.

Tan Angle = $\frac{Gv \text{ to } Gh}{GMt}$ = $\frac{0.12}{2.988}$ = 0.04 =2.29 °



Angle of List = 2.29 ° to starboard.

If a unit has an initial list , the amount of weight to be moved, a certain distance transversely, to correct the list can be calculated. Similarly we could calculate the distance a known weight would have to be moved to correct a list.

The units GMt, displacement, the weight to be moved or the distance to move it, will have to be known.

Example:

A unit of 5000 s.tons displacement has a GMt of 2.4 ft. Calculate the weight of cargo to be shifted 28 ft across the deck to correct a 4 ° list to port.

First calculate where the centre of gravity of the unit is in relation to the centreline, that is find G to G1.

$$\text{Tan angle list} = \frac{\text{G to G1}}{\text{GMt}}$$

We already know the angle of list and the unit GMt, so we can now transpose the above formula to find G - G1

$$\underset{\text{(Shift of G)}}{\text{G to G1}} = \text{GMt x Tan Angle} = 2.4 \text{ x Tan } 4° = 0.168 \text{ ft}$$

The shift of G is being caused by a weight being 28 ft. off the centreline of the unit. The shift of G formula is now used :

$$\underset{\text{(Shift of G)}}{\text{G to G1}} = \frac{\text{w x d}}{\Delta}$$

The shift of G (G to G1) is now known, the distance the weight can move is known, and the unit displacement is known, so once again by transposing the formula above we can calculate the weight

$$\text{Weight} = \frac{(\text{ G to G1 }) \text{ x } \Delta}{\text{d}} \quad \frac{0.168 \text{ x } 5000}{28} = 30$$

Weight to be moved a distance of 28 ft. = 30 s.tons.

The problem can be solved by another method, as we know that fro the unit to be upright then the moments on each side of the centreline must be equal.

First calculate where the centre of gravity of the unit is in relation to the centreline, that is find G to G1.

$$\text{Tan angle list} = \frac{\text{G to G1}}{\text{GMt}}$$

We already know the angle of list and the unit GMt, so we can now transpose the above formula to find G - G1

G to G1 = (Shift of G)	GMt x Tan Angle =	2.4 x Tan 4°	= 0.168 ft. to port of the centreline

Shift of G = List Moment ÷ Displacement

List Moment =	Shift of G x Displacement
	0.168 x 5000
List Moment =	840 ft. tons (causing the list to port).

For unit to be upright then moment to Starboard must equal moments to Port.

Port Moments	=	Starboard Moments
840 ft. tons	=	Starboard Moments
840 ft. tons	=	Weight x distance
840 ft. tons	=	Weight x 28 ft.
840 ft. tons ÷ 28ft.	=	Weight.
	=	**30 tons.**

So the answer is the same using either method.

Complete the questions on the following page.

1.
A unit of 1500 s.tons displacement has a KM of 10.2 ft. and a KG of 8.6 ft.
She is presently floating upright.

Calculate the list caused by shifting a 10 s.ton weight across the deck to starboard a distance of 33 ft.

2.
A unit of 6500 s.tons displacement with a GMt of 0.5 ft. is floating upright.
A weight already onboard is shifted from 4 ft to starboard across the deck to a position 20 ft. to starboard. The shift is then completed by moving the load 5 ft. downwards, calculate the angle of list caused after the shifts have been completed if the weight was 50 s.tons.

3.
From the following details calculate the amount of cargo, which is already onboard, to be shifted across the deck, in order to bring the unit into an upright condition.

Displacement 1600 s.tons. GMt 1.3 ft. List 7 ° to port.
Distance cargo can be shifted 14.4 ft.

4.
A unit of 8000 s.tons displacement shifts 80 tons of deck load 25 ft. across the deck to port and from a KG of 20 ft to a KG of 26.5 ft. If the initial GM was 1.7 ft. calculate the resulting angle of list. The unit was originally upright.

Answers:

1. 7.86 ° to starboard

2. 12.9 ° to starboard
3. 17.78 s.tons
4. 8.7 ° to port

If a weight is loaded / discharged off the centreline, onboard a unit that is initially upright, first add / remove it as though it had been loaded / discharged on the centreline to calculate the vertical movement in the centre of gravity.

Then shift the weight to its final position horizontally to obtain the transverse shift of G. The resulting angle of list can then be calculated.

Example:

A unit of 9500 s.tons displacement loads 500 s.tons cargo in a compartment KG 18 ft. and 6 ft. off the centreline to port.
Calculate the resulting list if the initial KG was 15 ft., the KM 18.5 ft. and the unit was initially in the upright condition.

First calculate the vertical shift in G. The cargo has been loaded above the original centre of gravity so we will have a rise in the position of G.

$$\text{Rise of G (G to Gv)} = \frac{\text{Weight x (dist. from original KG)}}{\text{New Displacement}} = \frac{500 \times (18 - 15)}{10{,}000} = 0.15 \text{ ft.}$$

We can now calculate the new GMt.

Orig. GMt = KM - KG = 18.5 - 15 = 3.5 ft.

New GMt = Orig. GMT - rise of G = 3.5 - 0.15 = 3.35 ft.

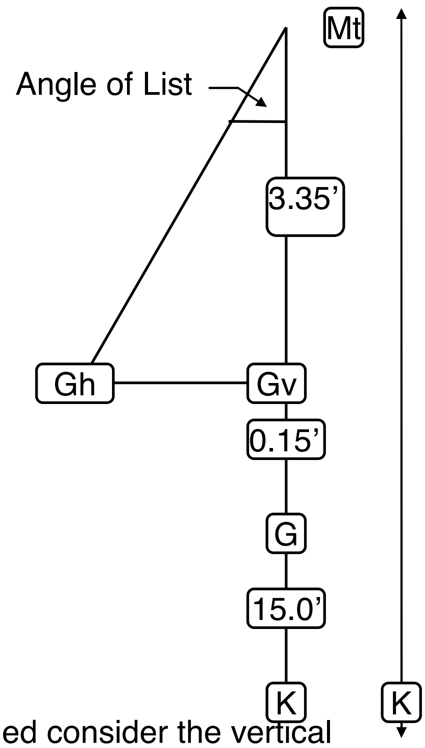
The transverse shift of G can now be calculated

$$\text{Transv. shift of G (Gv to Gh)} = \frac{w \times d}{\Delta} = \frac{500 \times 6}{10{,}000} = 0.3 \text{ ft.}$$

The angle of list can now be calculated.

$$\text{Tan angle} = \frac{\text{Gv to Gh}}{\text{GMt}} = \frac{0.3}{3.35} = 0.09 = 5.1\,°$$

Resulting angle of List = 5.1 ° to Port.



If a unit has an initial list and weight is loaded or discharged consider the vertical shift of G to obtain the new GMt.
Then calculate the moment causing the initial list also the moment resulting from the cargo being loaded/discharged off the centreline.
The resultant moment will indicate the final position of G off the centreline.
Note that to finish upright the moments on either side of the centreline must be equal.

Example:
A unit of 4000 s.tons displacement , KG 14.2 ft. KMt 15.5 ft. is listed 4 ° to port. Calculate the final list after 80 s.tons cargo is loaded at 22.5 ft. above the keel and 6.5 ft. to starboard of the centreline. Assume that the KMt is constant.

First calculate the original GMt. GMt = KMt - KG = 15.5 - 14.2 = 1.3 ft.

Calculate the initial list moment before the cargo is loaded.

Initial list moment = Displacement x Tan angle list x GMt
= 4000 x Tan 4 ° x 1.3 ft.
Initial list moment = 363.62 ft/tons to port.

Calculate the vertical shift of G and the new GMt.

$$\text{Vertical shift G (G to Gv)} = \frac{\text{w x diff unit KG / load KG}}{\text{new displacement}} = \frac{80 \times (14.2 \sim 22.5)}{4080} = 0.16 \text{ ft.}$$

∴ New GMt = Original GMt - rise in G = 1.3 - 0.16 = 1.14 ft.

Calculate the list moment caused by loading the cargo.

New list moment = weight x distance = 80 x 6.5 = 520 ft/tons
∴ New list moment is 520 ft/tons to starboard.

Resultant list moment = Original list moment ~ New list moment
= 363.62 ft/tons to port ~ 520 ft/tons to starboard.
Resultant list moment = 156.38 ft/tons to starboard

$$\therefore \text{New transverse position of G (G to Gh)} = \frac{\text{Result. list moment}}{\text{Displacement}} = \frac{156.38}{4080} = 0.04 \text{ ft to Stbd.}$$

To calculate the angle of list produced

$$\text{Tan angle list} = \frac{\text{G to Gh}}{\text{GMt}} = \frac{0.04}{1.14} = 0.035 = 2°$$

∴ Angle of list = 2 ° to Starboard

The problem can also be calculated using another method as follows :-

1.
Calculate the original transverse position of the centre of gravity causing the list.

2.
Calculate the new KG and TCG using the table method.

3.
With the transverse moments obtained calculate the new position of the TCG

4.
Calculate the angle of List.

A unit of 4000 s.tons displacement , KG 14.2 ft. KMt 15.5 ft. is listed 4 ° to port. Calculate the final list after 80 s.tons cargo is loaded at 22.5 ft. above the keel and 6.5 ft. to starboard of the centreline. Assume that the KMt is constant.

Original TCG = Tan Angle List x GMt
= Tan 4 ° x 1.3 ft.
Original TCG = 0.09 ft. to port

Weight	KG	Moment	TCG	Moment
4000	14.2	56800	0.09	360 to port
80	22.5	1800	6.5	520 to starb'd
4080		58600		160 to starb'd

$$KG = \frac{58600}{4080} = 14.36 \text{ ft.}$$

New GMt = KMt – KG = 15.50 – 14.36 = 1.14 ft.

$$\text{New TCG} = \frac{160}{4080} = 0.04 \text{ ft. to starb'd.}$$

$$\text{Angle of List} = \frac{TCG}{GMt} = \frac{0.04}{1.14} = 0.035 \tan = 2.01\,° \text{ to starboard}$$

So with either method of calculation the answer is the same.

Complete the following list calculations:
In all calculations assume that KMt is a constant value.

1.
A unit of 5000 s.tons displacement, KG 19.7 ft., KMt 21.3 ft. loads 50 s.tons on deck at a KG of 33 ft. and 20 ft. to starboard of the centreline.
Calculate the resulting list if the unit was upright before loading began.

Answer: 7.69 ° to Starboard.

2.

A unit displacement 6000 s.tons with a KG of 18 ft. & KMt 20 ft, is listed 3 ° to port.
Calculate the final list if 50 s.tons of cargo is now loaded 14 ft. to starboard of the centreline at a KG of 31 ft.

Answer: 0.29 ° to Starboard

3.
A unit 6000 s.tons displacement, loads 250 s.tons cargo on the centreline at a KG of 33.0 ft.. The original unit KG was 20 ft. & KMt 21.5 ft.
Before loading began the unit was listed to port 4 °. Calculate the final list after loading.

Answer: 5.7 ° to Port

4.

A unit 5000 s.tons displacement, initially in an upright conditions loads a 50 s.ton load with her port crane. The unit initial KG was 18.0 ft. & KMt 24.6 ft.
The head of the crane is 65 ft. above the keel of the unit and 40 ft. off the centreline of the unit.
The load is then landed on the deck of the unit at 26 ft KG and 10 ft off the centreline to starboard.

Calculate the list :
(a) with the load lifted on the crane. (b) with the load stowed on deck.

Answers : (a) 3.69 ° to Port (b) 0.87 ° to Starboard.

Section 5 Hydrostatics

Objectives: **To demonstrate the use of Hydrostatic Data in the calculation of stability.**

Subjects covered in this section.

1. **Hydrostatic Curves**
2. **Deadweight Scales**
3. **Tables of Hydrostatic Properties**

Hydrostatic Information.

In order to calculate the draft, trim, list or stability of any floating unit we have to be provided with what is termed hydrostatic information.

This information may be provided in a number of different formats and will form part of the unit stability information book or be presented as part of the Marine Operations Manual.

Whatever format it is presented in operators will have to be able to use the information provided to assess the stability, draft, list and trim of the unit.

In this section we will look at the following:

Deadweight Scales.

From these scales we will be able to obtain Draft, Displacement, Deadweight, Freeboard, Tons per Inch Immersion and Moment to trim 1 inch.

If we know either draft or displacement then it is a simple process to pick off the scale any of the other values.

Hydrostatic Curves.

With these curves the operator is able to ascertain more information than is possible from the deadweight scales.

Curves are drawn for the following:

Transverse Metacentre,
TP1",
Moment to Trim 1",
Centre of Buoyancy,
Position of the LCF & LCB.

Draft and Displacement scales are also provided and used to obtain other values.

Care must be taken when using these scales to obtain accurate results.

Hydrostatic Properties Tables.

As the name implies the information is contained in a tabular format and is relatively easy to use.

The tables present the following information:

Draft, Displacement, VCB, KML, KMT, TP1", MT1".

At drafts up to 21 ft. on sheets 1 to 3.
The drafts increase in 0.1 ft. steps so interpolation for values in-between these steps are easy to calculate.

A close look at the tables used in this section (for the Techco 700) will reveal that for drafts above 21 ft. (which is the top of the pontoon); the information supplied alters in content.

Once the unit submerges to a draft greater than 21 ft. the waterplane area is greatly reduced and for relatively small alterations in the distribution of weight on the unit will result in quite large values for heel and trim.

For this reason we are no longer given MT1" but Moment to Trim and Moment to Heel in degrees, also they are listed for VCG's of 50 ft., 60 ft. and 70 ft.

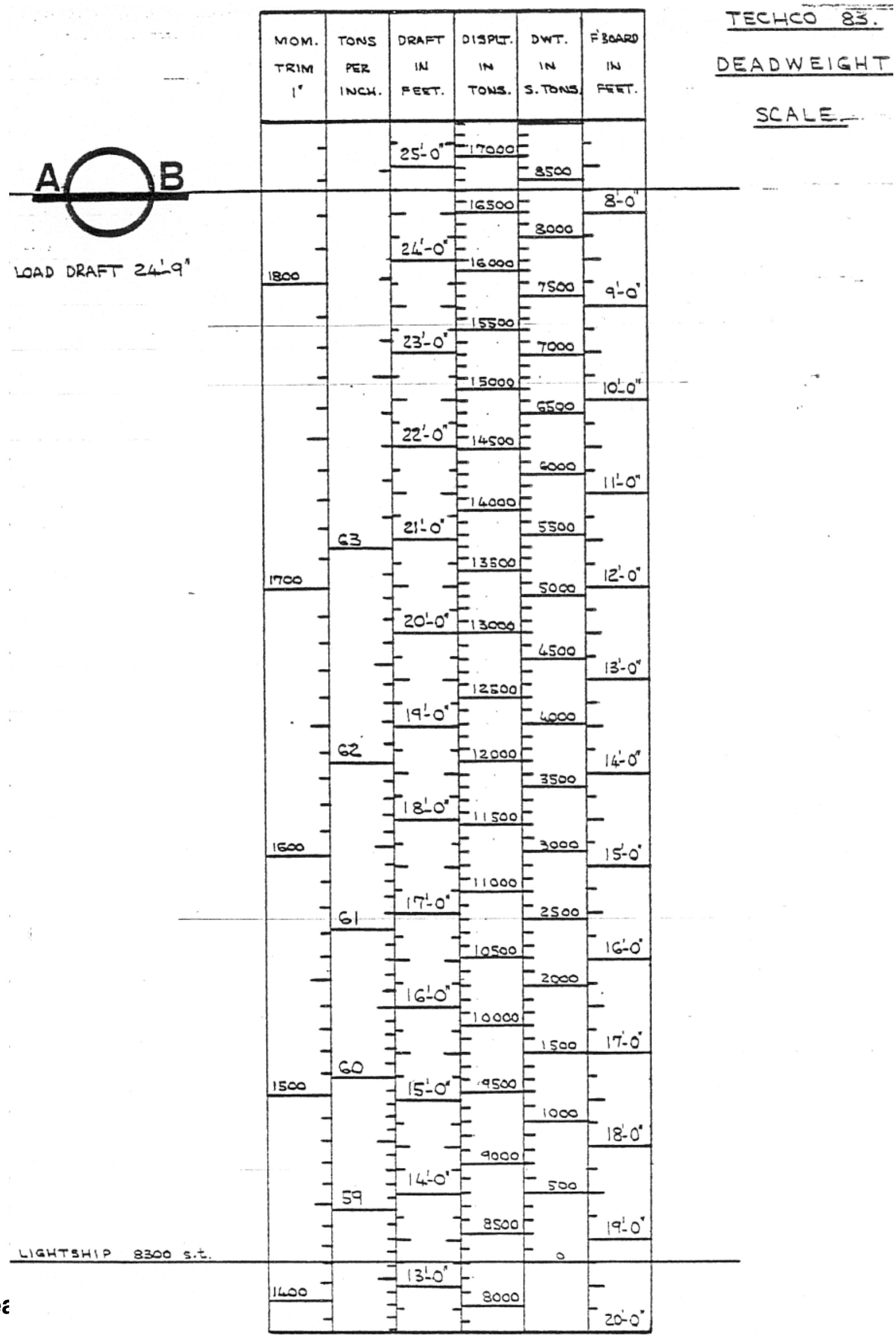
Drafts are now tabulated in steps of 1 ft. for drafts between 21 ft. and 70 ft. but watch out for 38 and 55 ft drafts, the waterplane area increases then decreases due to the anchor rack immersion at 38 ft and at 55 ft the lower tubular cross bracing's affect the waterplane area.

Between 70 ft. draft and the maximum allowable draft of 95 ft. the steps are 0.5 ft.

This means that a certain amount of interpolation will be required as it will be highly unlikely that the unit will be floating at one of the tabulated drafts and have a VCG of exactly 50, 60, or 70 ft!

On the following pages examples of each of the methods of obtaining hydrostatic information will be investigated.

Deadweight Scale


TECHCO 83.
DEADWEIGHT
SCALE
MOM. TRIM 1"
TONS PER INCH.
DRAFT IN FEET.
DISPLT. IN TONS.
DWT. IN S. TONS.
F'BOARD IN FEET.
A B
LOAD DRAFT 24'-9"
LIGHTSHIP 8300 s.t.

Dea

1. From the Deadweight scale what are the values for:

(a) Light displacement (b) Light draft (c) Light TP1”

(d) Light Freeboard (e) Light MT1”

2. At a draft of 14’ 03” what are the values from the scale for:

(a) Displacement (b) Deadweight (c) TP1”

(d) Freeboard (e) MT1”

3. At a displacement of 10,800 s.tons what are the values from the scale for:

(a) TP1” (b) Draft (c) Deadweight

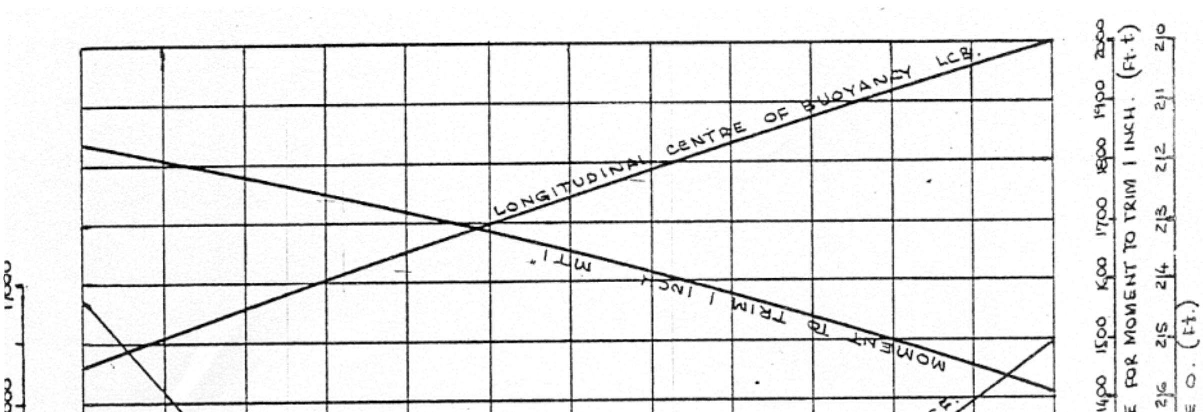
(d) MT1” (e) Freeboard

Answers.

Question	(a)	(b)	(c)	(d)	(e)
1	8300	13’ 03”	58.62	19’.03”	1420

2	8960	660	59.3	18’ 02”	1465
3	61.06	16’ 11”	2500	1575	15’ 07”

Hydrostatic Curves



Hydrostatic Curves.

1. Using the Hydrostatic Curves complete the following tables:

Draft (ft.)	16’ 00”

Displacement	
TP1”	
MT1”	
VCB	
KMt	
LCB	
LCF	

2. Complete the following tables using the curves.

Displacement (s.tons)	11,350
Mean Draft	
TP1”	
MT1”	
VCB	
KMt	
LCB	
LCF	

Answers:

1

Draft	16’ 00”
Displ.	10,100

2

11,350
17’ 09”

TP1”	60.5
MT1”	1540
VCB	8.5’
KMt	34.6’
LCB	211.2’
LCF	217.9’

61.55
1605
9.35
32.95
212.0’
219.35’

HYDROSTATIC PROPERTIES**

Sheet 1 of 7

DRAFT (FEET)	TOTAL DISPL. (S.T.)	VCB (FEET)	KM_L (FEET)	KM_T (FEET)	T/IN (S.T.)	*MT 1 IN.
15	12,375	7.8	470	670	70.4	1,540
15.1	12,459	7.85	466	664	70.2	1,538
15.2	12,543	7.9	462	658	70.1	1,536
15.3	12,627	7.95	458	652	70	1,534
15.4	12,711	8	454	646	69.9	1,532
15.5	12,795	8.05	450	640	69.7	1,530
15.6	12,879	8.1	446	634	69.6	1,527
15.7	12,963	8.15	442	628	69.5	1,524
15.8	13,047	8.2	438	622	69.4	1,521
15.9	13,131	8.25	434	616	69.3	1,518
16	13,215	8.3	430	610	69.2	1,515
16.1	13,297	8.35	427	605	69	1,512
16.2	13,379	8.4	424	600	68.8	1,509
16.3	13,461	8.45	421	595	68.6	1,506
16.4	13,543	8.5	418	590	68.4	1,503
16.5	13,625	8.55	415	585	68.2	1,500
16.6	13,707	8.6	411	579	68	1,497
16.7	13,789	8.64	407	573	67.8	1,494
16.8	13,871	8.69	403	567	67.6	1,491
16.9	13,953	8.74	399	561	67.4	1,488

* MT 1 IN. is listed for Condition VCG = VCB

** All properties listed are based on molded hull surface except displacement. Displacement accounts for additions to molded hull, such as plate thicknesses, anchor racks, thrusters.

HYDROSTATIC PROPERTIES** (Sheet 2 of 7)

DRAFT (FEET)	TOTAL DISPL. (S.T.)	VCB (FEET)	KM_L (FEET)	KM_T (FEET)	T/IN (S.T.)	*MT 1 IN.
17	14,035	8.78	395	555	67.2	1,485
17.1	14,113	8.82	392	551	67	1,482
17.2	14,191	8.87	389	547	66.8	1,479
17.3	14,269	8.91	386	543	66.6	1,476
17.4	14,347	8.95	383	539	66.3	1,473
17.5	14,425	9	380	535	66	1,470
17.6	14,503	9.05	376	531	55.8	1,466
17.7	14,581	9.1	372	527	65.6	1,462
17.8	14,659	9.15	368	523	65.3	1,458
17.9	14,737	9.2	364	519	65	1,454
18	14,815	9.25	360	515	64.7	1,450
18.1	14,893	9.3	357	511	64.4	1,446
18.2	14,971	9.35	354	507	64.1	1,442
18.3	15,049	9.4	351	503	63.8	1,438
18.4	15,127	9.45	348	499	63.5	1,434
18.5	15,205	9.5	345	495	63.2	1,430
18.6	15,283	9.55	342	491	62.9	1,425
18.7	15,361	9.6	339	487	62.5	1,420
18.8	15,439	9.65	336	483	62.1	1,415
18.9	15,517	9.7	333	479	61.7	1,410

* MT 1 IN. is listed for Condition VCG = VCB

** All properties listed are based on molded hull surface except displacement. Displacement accounts for additions to molded hull, such as plate thicknesses, anchor racks, thrusters.

HYDROSTATIC PROPERTIES**

(Sheet 3 of 7)

DRAFT (FEET)	TOTAL DISPL. (S.T.)	VCB (FEET)	KM_L (FEET)	KM_T (FEET)	T/IN (S.T.)	*MT 1 IN.
19	15,595	9.75	330	475	61.3	1,405
19.1	15,668	9.8	326	471	60.8	1,398
19.2	15,741	9.85	322	467	60.3	1,391
19.3	15,814	9.9	318	463	59.9	1,384
19.4	15,887	9.95	314	459	59.4	1,377
19.5	15,960	10	310	455	59	1,370
19.6	16,031	10.04	306	450	58.4	1,358
19.7	16,102	10.08	302	445	57.8	1,346
19.8	16,173	10.12	298	440	57.2	1,334
19.9	16,244	10.16	294	435	56.6	1,322
20	16,315	10.2	290	430	56	1,310
20.1	16,385	10.23	285	425	55	1,286
20.2	16,455	10.27	280	420	54	1,262
20.3	16,525	10.3	275	415	53.5	1,238
20.4	16,595	10.34	270	410	52	1,214
20.5	16,665	10.38	265	405	51	1,190
20.6	16,735	10.41	255	395	50	1,170
20.7	16,805	10.44	250	380	47.5	1,150
20.8	16,875	10.48	240	355	43	1,130
20.9	16,945	10.51	230	330	41	1,110
21	17,015	10.55	210	315	40	1,050

* MT 1 IN. is listed for Condition VCG = VCB

** All properties listed are based on molded hull surface except displacement. Displacement accounts for additions to molded hull, such as plate thicknesses, anchor racks, thrusters.

HYDROSTATIC PROPERTIES *

(Sheet 4 of 7)

DRAFT FEET	TOTAL DISPL. (S.T.)	VCB FEET	T/IN S.T.	KM_T FEET	KM_L FEET	MH 1° (FT-TONS)			MT 1° (FT-TONS)		
						VCG=50'	VCG=60'	VCG=70'	VCG=50'	VCG=60'	VCG=70'
21	16,955	10.55	10.83	79.9	81.47	8,825	5,800	2,860	9,285	6,340	3,320
22	17,090	10.64	10.83	79.5	81.05	8,750	5,735	2,770	9,235	6,260	3,220
23	17,225	10.73	10.83	79.1	80.65	8,675	5,670	2,680	9,185	6,180	3,120
24	17,360	10.82	14.16	78.7	80.25	8,600	5,605	2,600	9,135	6,105	3,020
25	17,530	10.9	14.16	78.3	79.85	8,540	5,535	2,510	9,080	6,030	2,925
26	17,700	11.02	14.16	77.95	79.46	8,475	5,465	2,420	5,030	5,955	2,830
27	17,830	11.14	10.83	77.6	79.09	8,425	5,390	2,320	8,980	5,880	2,740
28	17,960	11.25	10.83	77.25	78.73	8,360	5,310	2,210	8,935	5,805	2,650
29	18,085	11.36	10.83	76.9	78.37	8,310	5,230	2,090	8,890	5,735	2,560
30	18,215	11.47	10.42	76.55	78.01	8,260	5,150	1,980	8,845	5,665	2,470
31	18,340	11.64	10.42	76.24	77.67	8,210	5,070	1,870	8,800	5,600	2,380
32	18,465	11.82	10.42	75.93	77.34	8,160	4,980	1,760	8,755	5,535	2,290
33	18,585	11.99	15.41	75.62	77	8,110	4,880	1,660	8,710	5,470	2,200
34	18,770	12.16	15.41	75.31	76.68	8,065	4,810	1,565	8,665	5,405	2,110
35	18,955	12.34	15.41	75	76.36	8,035	4,740	1,470	8,620	5,345	2,025
36	19,140	12.51	15.41	74.69	76.05	8,010	4,685	1,380	8,580	5,285	1,940
37	19,325	12.68	15.41	74.38	75.77	7,990	4,645	1,295	8,545	5,230	1,860
37.9	19,440	12.83	10.65	74.07	75.51	7,975	4,610	1,230	8,510	5,175	1,790
38.1	19,470	12.89	10.65	74.07	76.38	7,975	4,610	1,230	8,815	5,565	2,150
39	19,580	13.03	10.65	73.76	76.33	7,965	4,580	1,170	8,850	5,475	2,075
40	19,710	13.2	10.65	73.45	76.11	7,960	4,560	1,120	8,835	5,440	2,020
41	19,835	13.4	10.65	73.38	75.89	7,965	4,545	1,085	8,820	5,405	1,965
42	19,965	13.59	10.65	73.31	75.68	7,970	4,530	1,050	8,805	5,370	1,910
43	20,095	13.79	10.65	73.24	75.48	7,980	4,520	1,025	8,790	5,340	1,855
44	20,220	13.98	10.65	73.17	75.28	8,000	4,515	1,000	8,780	5,310	1,790

* All properties listed are based on molded hull surface except displacement. Displacement accounts for additions to molded hull, such as plate thicknesses, anchor racks, thrusters.

HYDROSTATIC PROPERTIES *

(Sheet 5 of 7)

DRAFT FEET	TOTAL DISPL. (S.T.)	VCB FEET	T/IN S.T.	KM_T FEET	KM_L FEET	MH 1° FT-TONS			MT 1° FT-TONS		
						VCG=50'	VCG=60'	VCG=70'	VCG=50'	VCG=60'	VCG=70'
45	20,350	14.18	10.65	73.1	75.09	8,020	4,510	980	8,770	5,280	1,735
46	20,475	14.38	10.65	73.03	74.9	8,040	4,510	970	8,760	5,250	1,680
47	20,605	14.57	10.65	72.96	74.73	8,070	4,515	960	8,755	5,220	1,630
48	20,735	14.77	10.83	72.89	74.56	8,100	4,520	955	8,750	5,195	1,580
49	20,865	14.96	10.83	72.82	74.4	8,130	4,530	950	8,745	5,170	1,535
50	20,995	15.16	10.83	72.75	74.24	8,160	4,540	945	8,745	5,155	1,490
51	21,125	15.4	10.83	72.73	74.09	8,200	4,555	935	8,745	5,130	1,450
52	21,255	15.63	10.83	72.7	73.94	8,250	4,570	925	8,745	5,100	1,410
53	21,395	15.87	10.83	72.68	73.8	8,300	4,585	915	8,750	5,070	1,370
54	21,515	16.1	10.83	72.66	73.66	8,350	4,600	910	8,750	5,045	1,330
54.9	21,630	16.3	10.83	72.56	73.54	8,400	4,625	905	8,755	5,020	1,300
55.1	21,660	16.38	11.1	73.1	74.92	8,600	4,810	1,105	9,280	5,580	1,820
56	21,780	16.58	11.1	73	74.87	8,600	4,785	1,055	9,310	5,580	1,800
57	21,910	16.82	11.1	72.88	74.8	8,600	4,770	1,010	9,340	5,580	1,780
58	22,045	17.05	11.1	72.76	74.73	8,605	4,760	970	9,370	5,585	1,765
59	22,175	17.29	11.1	72.64	74.66	8,615	4,750	935	9,400	5,590	1,750
60	22,310	17.53	11.25	72.52	74.59	8,630	4,740	900	9,430	5,600	1,735
61	22,445	17.8	11.25	72.43	7,453	8,645	4,730	870	9,465	5,610	1,720
62	22,580	18.07	11.25	72.34	74.48	8,660	4,722	845	9,500	5,620	1,710
63	22,710	18.34	11.25	72.25	74.43	8,680	4,725	820	9,535	5,635	1,700
64	22,845	18.51	11.25	72.16	74.38	8,700	4,725	795	9,575	5,650	1,690
65	22,980	18.88	11.25	72.07	74.34	8,725	4,730	770	9,615	5,665	1,680
66	23,115	19.15	11.25	72.02	74.3	8,750	4,735	750	9,655	5,685	1,670
67	23,245	19.42	11.25	71.96	74.26	8,775	4,740	735	9,695	5,705	1,665
68	23,380	19.69	11.25	71.91	74.23	8,805	4,745	720	9,740	5,725	1,660
69	23,515	19.96	11.25	71.85	74.2	8,840	4,750	705	9,780	5,745	1,655

* All properties listed are based on molded hull surface except displacement. Displacement accounts for additions to molded hull, such as plate thicknesses, anchor racks, thrusters.

HYDROSTATIC PROPERTIES *

(Sheet 6 of 7)

DRAFT FEET	TOTAL DISPL. (S.T.)	VCB FEET	T/IN S.T.	KM_T FEET	KM_L FEET	MH 1° FT-TONS			MT 1° FT-TONS		
						VCG=50'	VCG=60'	VCG=70'	VCG=50'	VCG=60'	VCG=70'
70	23,736	20.22	11.25	71.8	74.16	8,880	4,760	695	9,825	5,765	1,650
70.5	23,803	20.35	11.25	71.79	74.15	8,895	4,770	690	9,850	5,775	1,650
71	23,869	20.5	11.25	71.78	74.14	8,915	4,775	685	9,875	5,785	1,650
71.5	23,936	20.65	11.25	71.77	74.13	8,935	4,780	680	9,900	5,800	1,650
72	24,003	20.8	11.25	71.76	74.12	8,955	4,790	680	9,925	5,815	1,650
72.5	24,070	20.95	11.25	71.75	74.12	8,975	4,800	675	9,950	5,830	1,650
73	24,136	21.1	11.25	71.74	74.12	8,995	4,810	675	9,975	5,845	1,650
73.5	24,203	21.25	11.25	71.73	74.11	9,015	4,820	670	10,000	5,865	1,655
74	24,270	21.4	11.25	71.72	74.11	9,035	4,830	670	10,025	5,880	1,560
74.5	24,336	21.55	11.25	71.71	74.11	9,055	4,840	670	10,050	5,895	1,665
75	24,403	21.7	11.25	71.7	74.11	9,080	4,850	670	10,080	5,910	1,670
75.5	24,470	21.85	11.25	71.7	74.11	9,105	4,860	670	10,110	5,925	1,675
76	24,536	22	11.25	71.71	74.11	9,130	4,870	675	10,140	5,940	1,680
75.5	24,603	22.15	11.25	71.71	74.12	9,155	4,880	675	10,170	5,955	1,685
77	24,670	22.3	11.25	71.72	74.13	9,180	4,890	675	10,200	5,975	1,690
77.5	24,736	22.45	11.25	71.72	74.12	9,205	4,900	680	10,225	5,995	1,700
78	24,803	22.6	11.25	71.73	74.12	9,230	4,915	680	10,255	6,015	1,710
78.5	24,870	22.75	11.25	71.73	74.13	9,255	4,930	685	10,285	6,035	1,720
79	24,937	22.9	11.25	71.74	74.15	9,280	4,945	690	10,320	6,055	1,730
79.5	25,003	23.05	11.25	71.74	74.16	9,305	4,960	695	10,355	6,075	1,740
80	25,070	23.2	11.25	71.75	74.18	9,330	4,965	700	10,390	6,095	1,750
80.5	25,137	23.35	11.25	71.77	74.2	9,355	4,990	705	10,425	6,115	1,760
81	25,204	23.5	11.25	71.79	74.2	9,380	5,010	710	10,455	6,140	1,770
81.5	25,270	23.65	11.25	71.81	74.21	9,410	5,030	715	10,485	6,165	1,785
82	25,337	23.8	11.25	71.83	74.22	9,440	5,050	725	10,520	6,190	1,800
82.5	25,404	23.97	11.25	71.85	74.24	9,470	5,070	735	10,555	6,215	1,815

* All properties listed are based on molded hull surface except displacement. Displacement accounts for additions to molded hull, such as plate thicknesses, anchor racks, thrusters.

HYDROSTATIC PROPERTIES * (Sheet 7 of 7)

DRAFT FEET	TOTAL DISPL. (S.T.)	VCB FEET	T/IN S.T.	KM_T FEET	KM_L FEET	MH 1° FT-TONS			MT 1° FT-TONS		
						VCG=50'	VCG=60'	VCG=70'	VCG=50'	VCG=60'	VCG=70'
83	25,471	24.15	11.25	71.87	74.27	9,500	5,090	745	10,595	6,240	1,830
83.5	25,538	24.3	11.25	71.89	74.29	9,535	5,110	755	10,635	6,265	1,845
84	25,604	24.45	11.25	71.91	74.32	9,570	5,130	765	10,675	6,290	1,860
84.5	25,671	24.6	11.25	71.92	74.35	9,605	5,155	775	10,715	6,315	1,875
85	25,738	24.75	11.25	71.94	74.38	9,640	5,180	790	10,755	6,345	1,890
85.5	25,805	24.9	11.25	71.97	74.4	9,675	5,210	805	10,795	6,375	1,910
86	25,871	25.05	11.25	72	74.43	9,715	5,240	820	10,835	6,405	1,930
86.5	25,938	25.22	11.25	72.03	74.46	9,755	5,270	835	10,880	6,435	1,950
87	26,005	25.4	11.25	72.06	74.5	9,795	5,305	855	10,925	6,470	1,970
87.5	26,072	25.57	11.25	72.09	74.54	9,835	5,340	875	10,970	6,505	1,990
88	26,138	25.75	11.25	72.12	74.58	9,875	5,375	890	11,015	6,540	2,010
88.5	26,205	25.9	11.25	72.15	74.63	9,915	5,410	915	11,065	6,575	2,030
89	26,272	26.05	11.25	72.18	74.66	9,955	5,445	940	11,110	6,610	2,050
89.5	26,338	26.2	11.25	72.71	74.7	9,994	5,480	965	11,155	6,650	2,075
90	26,405	26.35	11.25	72.24	74.74	10,040	5,510	990	11,200	6,690	2,130
90.5	26,472	26.52	11.25	72.28	74.76	10,085	5,545	1,008	11,240	6,725	2,155
91	26,538	26.68	11.25	72.32	74.79	10,130	5,580	1,025	11,280	6,760	2,180
91.5	26,605	26.85	11.25	72.36	74.83	10,175	5,615	1,047	11,330	6,800	2,210
92	26,672	27.01	11.25	72.4	74.88	10,220	5,650	1,070	11,380	6,840	2,240
92.5	26,738	27.18	11.25	72.44	74.93	10,270	5,685	1,092	11,430	6,875	2,270
93	26,805	27.34	11.25	72.48	74.98	10,320	5,720	1,115	11,480	6,810	2,300
93.5	26,872	27.5	11.25	72.52	75.03	10,360	5,760	1,138	11,530	6,945	2,325
94	26,939	27.67	11.25	72.56	75.07	10,400	5,800	1,160	11,580	6,980	2,350
94.5	27,005	27.83	11.25	72.6	75.12	10,450	5,832	1,192	11,630	7,010	2,375
95	27,072	28	11.25	72.64	75.18	10,500	5,865	1,225	11,680	7,040	2,400

* All properties listed are based on molded hull surface except displacement. Displacement accounts for additions to molded hull, such as plate thicknesses, anchor racks, thrusters.

Hydrostatic Properties

1.

Complete the following table giving the values required:

Draft (ft.)	16.5	39.0
Displacement		
TP1”		
MT1”		------------
VCB		
KMT		
KML		
MH 1° (at 50 ft. VCG)	------------	
MT 1° (at 50 ft. VCG)	------------	

2.

Complete the following table giving the values required:

Displacement	14737	22310
Mean Draft		
TP1”		
MT1”		-----------
VCB		
KMT		
KML		
MH 1° (at 60 ft. VCG)	-------------	
MT 1° (at 60 ft. VCG)	-------------	

Answers:

1.

Draft (ft.)	16.5	39.0
Displacement	13625	19580
TP1”	68.2	10.65
MT1”	1500	------------
VCB	8.55	13.03
KMT	585	73.76
KML	415	76.33
MH 1° (at 50 ft. VCG)	------------	7965
MT 1° (at 50 ft. VCG)	------------	8850

2.

Displacement	14737	22310
Mean Draft	17.9	60.00
TP1”	65.0	11.25
MT1”	1454	-----------
VCB	9.20	17.53
KMT	519	72.52
KML	364	74.59
MH 1° (at 60 ft. VCG)	-------------	4740
MT 1° (at 60 ft. VCG)	-------------	5600

In the previous examples we have been able to take the values from the tables as we were dealing with drafts and displacements that were listed in the tables.

If the drafts and displacements are not listed then interpolation is required to obtain accurate figures for the other values.

Example.

The unit is floating at a draft of 16.25 ft. Calculate the values for:
Displacement, VCB, KML, KMT, TP1” and MT1”.

Inspection of the tables indicates that the unit draft lies between the tabulated drafts of 16.2 ft. and 16.3 ft.

The values for the information we require are then listed against the tabulated drafts. Then calculate the differences between the two values in each column.

	Draft	Displ.	VCB	KML	KMT	TP1”	MT1”
	16.2 ft.	13379	8.40	424	600	68.8	1509
	16.3 ft	13461	8.45	421	595	68.6	1506
Difference	0.1 ft.	82	0.05	3	5	0.2	3

So for a difference in draft of 0.1 ft. we have the differences in the values in question and the unit draft is 16.25 ft. which gives a difference of 0.05 ft. from the listed draft of 16.2 ft.

In order to obtain the correction to the values listed for 16.2 ft. draft, the difference between the tabulated draft and the known draft (16.2 ~ 16.25 = 0.05) is divided by the difference between the two drafts which the values were listed for (16.2 ft ~ 16.3 ft. = 0.1 ft.) and the difference between the two values in the appropriate column.

Note that 0.05 ÷ 0.1 is equal to 0.5, so if we multiply the differences by 0.5 the correction that is to be applied to the listed values will be obtained.

For displacement 0.5 x 82 = 41 so 13379 + 41 = 13420

The correction is added to the displacement value for a draft of 16.2 ft.
The same method of calculating the correction is done for the other values.
When applying the correction it must be noted whether the values are increasing or decreasing.

For VCB	0.5 x .05	= 0.025	so	8.40 + 0.025	= 8.425
For KML	0.5 x 3	= 1.5	so	424 - 1.5	= 422.5
For KMT	0.5 x 5	= 2.5	so	600 - 2.5	= 597.5
For TP1”	0.5 x 0.2	= 0.1	so	68.8 - 0.1	= 68.7
For MT1”	0.5 x 3	= 1.5	so	1509 - 1.5	= 1507.5

If the displacement of the unit is known then we can interpolate from the tables the exact values of other information.

The unit displacement is 13420, by interpolation calculate the values for Draft, VCB, KML, KMT, TP1” and MT1”.

First take out the value of displacement either side of the known displacement, and list the values of the other information that correspond to these displacement values.

Then calculate the difference between the two values in each column.

	Displ.	Draft	VCB	KML	KMT	TP1”	MT1”
	13379	16.2	8.40	424	600	68.8	1509
	13461	16.3	8.45	421	595	68.6	1506
Difference	82	0.1	0.05	3	5	0.2	3

The difference between the known displacement 13420 and the displacement listed 13379 is 41 (13379 ~ 13420) and the difference in the listed displacements is 82. So to calculate the corrections to apply to the values for the other information we need to multiply the differences by 0.5, (41 ÷ 82 = 0.5).

Correction to apply to the tabulated values:

For Draft	0.5 x 0.1	= 0.05	so	16.2 + 0.05	= 16.25
For VCB	0.5 x 0.05	= 0.025	so	8.40 + 0.025	= 8.425
For KML	0.5 x 3	= 1.5	so	424 - 1.5	= 422.5
For KMT	0.5 x 5	= 2.5	so	600 - 2.5	= 597.5
For TP1”	0.5 x 0.2	= 0.1	so	68.8 - 0.1	= 68.7
For MT1”	0.5 x 3	= 1.5	so	1509 - 1.5	= 1507.5

Check if the corrections to the tabulated values are to be added or subtracted.

Interpolation for any draft or displacement can then be done by following the above methods.

There may be a requirement not only to calculate exact values for Displacement, Draft, VCB, KMT KML and TP1” but also exact values for MH1° and MT 1°.

As previously mentioned MH1° and MT1° vary with the VCG of the unit and are only listed for VCG’s of 50 ft., 60 ft. and 70 ft. so further interpolation is required.

Example

Techco 700 is floating at a draft of 70 ft. with a VCG of 53 ft.
Calculate the MH 1 ° and MT 1 ° at this draft and VCG

From the tables with a draft of 70 ft we will see values for MH1° and MT1° listed for VCG 50 ft. and VCG 60 ft.

As the unit VCG is 53 ft. the exact value for the VCG will lie between the values for VCG 50 ft. and VCG 60 ft.

To calculate MH 1 ° at 70 ft. draft and VCG 53 ft.

	MH 1 ° @ VCG 50 ft	MH 1 ° @ VCG 60 ft.	Difference
For 70 ft draft	8880	4760	4120

So for a difference in VCG of 10 ft. we have a difference in the moments of 4120
But we require the difference for 3 ft. (Difference VCG 53 ft. and VCG 50 ft.)

Therefore the fraction of the difference in the values will be 3/10ths. Or 0.3 of 4120. So to obtain the correction multiply 4120 by 0.3 and apply it to the listed value for VCG 50 ft.

So for 70 ft. draft. & VCG 53 ft	**MH 1 ° =**	4120 x 0.3	= 1236	so	8880 - 1236	= **7644**

A similar calculation is done to obtain the exact value for the MT 1 ° for draft 70 ft. and VCG 53 ft.

	MT 1 ° @ VCG 50 ft	Mt 1 ° @ VCG 60 ft.	Difference
For 70 ft draft	9825	5765	4060

Again the same fraction of the difference between the values for the two VCG's is used to calculate the correction.

So for 70 ft. draft. & VCG 53 ft	**MT 1 ° =**	4060 x 0.3	= 1218	so	9825 - 1218	= **8607**

Carry out the calculations on the following page.
1.

Techco 700 is at a draft of 63.3 ft. with a VCG of 50 ft.
Calculate the following values.

1.

(a)	Displacement	(b)	VCB	(c)	TP1”
(d)	KMT	(e)	KML	(f)	MH 1 °
(g)	MT 1 °				

2.

Techco 700 is at a draft of 75 ft. with a VCG of 57 ft.
Calculate values for:

(a) MH 1 ° (b) MT 1 °

3.

Techco 700 is at a draft of 45 ft with a VCG of 64.7 ft.
Calculate values for:

(a) MH1 ° (b) MT1 °

Answers:

1.

(a) 22750.5	(b) 18.39	(c) 11.25	(d) 72.22
(e) 74.41	(f) 8686	(g) 9547	

2.

75 ft. draft & 57 ft. VCG MH 1 ° = 6119 MT 1° = 7161

3.

45 ft. draft & 64.7 ft. VCG MH 1 ° = 2851 MT 1° = 3614