2. The Basics

2.1 General

A lump of steel placed in a bucket of water will sink quickly to the bottom. How is it then that a steel ship can float? Since it clearly does, other questions to be answered are:

- At what draughts will it float? That is, how much of the ship will be below the waterline?
- How will the draughts change with different loading conditions of the ship?
- How can we ensure that the ship will float in an upright position in still water?
- Will it overturn in rough weather?

These fundamental questions will be dealt with in the first few chapters of this module.

2.2 Buoyancy and Displacement

It was Archimedes (212bc – 287bc) who first realised, in his renowned "eureka" moment, that a body that is immersed completely in water will displace a volume of water equal to the volume of the body and that the apparent weight of the body, when immersed, will be reduced by the weight of the water displaced. If the body weighs less than the weight of a volume of water equal to its own total volume, then it will not become immersed completely.

It will float with part of its own volume above the water surface such that the weight of the displaced water equals the weight of the body. The reader will be aware that a cork, which is of low density, bobs about in water with most of its volume above the surface. On the other hand, an iceberg, being of high density, floats with most of its volume submerged. That is why it is such a hazard to shipping. A body, floating freely in water, as shown in figure 1, will be acted upon by forces due to the water pressure at each point of its wetted (submerged) surface.

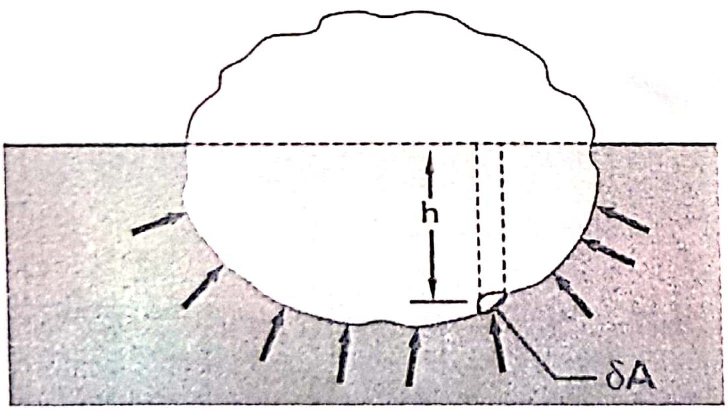


Figure 1: Buoyancy and displacement.

The resultant of these forces will be an upward force equal to the weight of the water displaced by the body. This is the body's displacement, often denoted by the symbol Δ (Greek Alphabet "Delta"). If the water density is ρ (Greek Alphabet "Rho") then the pressure acting upon a small area δA, at depth h below the surface, will be ρh and the force will be $\rho h \delta A$. By integrating (summing) over the whole of the wetted surface the total force on the body is $\sum \rho h \rho \delta A = \rho V$ where V is the volume of the body below water (called the volume of displacement).

This total force is termed the buoyancy force, or simply the buoyancy. For equilibrium this force must act vertically as any resultant horizontal force would cause the body to move in the direction of that resultant force. Also, for equilibrium, the buoyancy force must be equal to and oppose the weight of the body. If this were not so the body would move up or down (as per Newtons third law of motion). The two forces must act in the same line (plane) otherwise there would exist a moment causing the body to rotate.

2.3 Defining the Ship Geometry

As with any engineering product, precision is necessary in defining the geometry of a ship. In common with most disciplines, an internationally recognised terminology has developed over the years to aid this definition. Some of the terms will be unfamiliar to those coming new to the maritime industry. Others will be familiar from everyday usage, but they may have a very precise meaning in naval architecture.

A ship's hull is three dimensional and here it is assumed to be symmetrical about its longitudinal middle line plane. The hull shape is defined by its intersections with three planes at right angles to each other. The intersections of the hull with horizontal planes (known as waterplanes), are known as water lines.

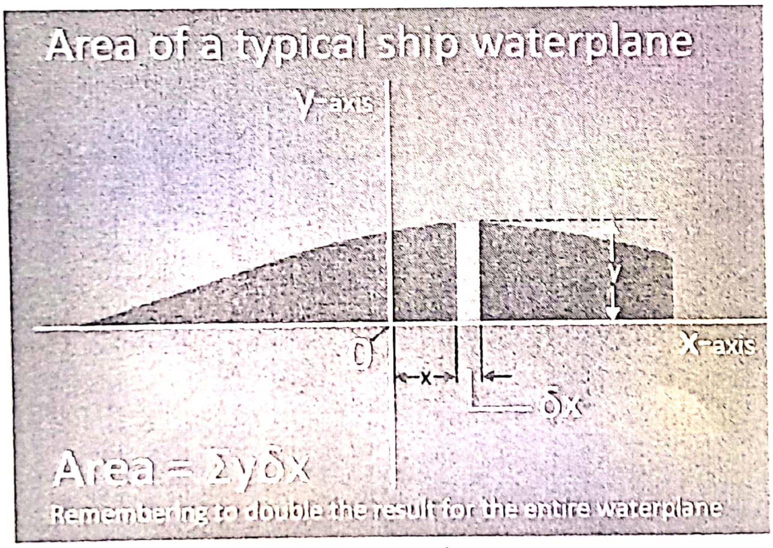


Figure 2: Area of a typical ship waterplane.

Those with the athwartships planes define the transverse sections of the hull and planes parallel to the middle line plane lead to what are termed bow and buttock lines, which help the designer visualise the flow of water over the hull and into the propellers and rudders.

These intersections can be used to help fair the hull form. The hull is 'fair' when all the individual lines are fair and mutually compatible. That is, the distances from the centreline plane are the same in each view.

The external hull shape can be defined by these distances (called offsets) of the hull surface from the centreline plane at each transverse section and waterplane. In tabular form these are known as a table of offsets. Each offset is normal to the centreline plane. The shape of the hull is important as many aspects of a ship's performance are governed by it – stability, powering, manoeuvring and ship motions. An example of a table of offsets is shown in Section 2.9 of this module.

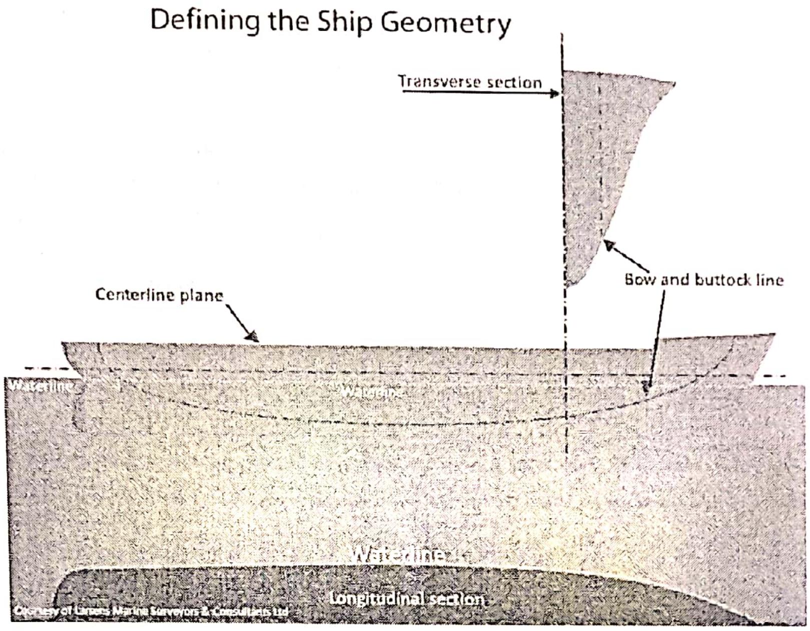


Figure 3: Defining the ship geometry

2.3.1 Defining the Length

There are four lengths commonly referred to (Figure 4).

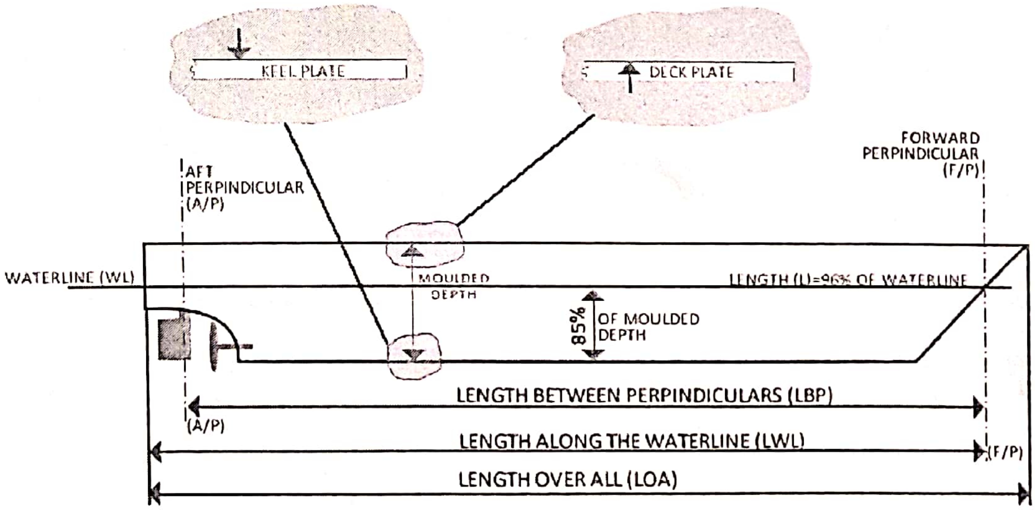


Figure 4: Defining the ship form.

Length Overall, LOA
This is the distance between the forward-most and after-most points of the hull.

Length on the Waterline, LWL
This will vary with the draught at which a ship is floating but, unless otherwise specified, should be taken as the length on the design waterline, usually the summer load waterline.

Length Between Perpendiculars, LBP
The perpendiculars are vertical lines located near the bow and stern. The fore perpendicular is a vertical line at the intersection of the bow with the summer load waterline (Referred to as FP). The after perpendicular (referred to as AP) is a line through some convenient point aft, usually through the rudder stock centreline. The point midway between the perpendiculars is known as amidships.

Scantling Length
Used in classification society rules to determine the required scantling. Scantling length is the length between perpendiculars but not less than 96%, nor more than 97% of the length on the waterline, LWL.

Load Line Length
The load line length is used to calculate the ship's freeboard. The load line length is measured on the waterline at 85% of the vessel's least moulded depth "D". The load line length is either 96% of the total waterline length, or the waterline length from the FP (forward side of the stem) to the axis of the rudder stock, whichever is longer.

Normally, load line length differs from scantling length. Load line length shown above is for a continuous single deck ship; other designs may require a more complicated calculation.
The upper deck often rises towards the ends of the ship to contribute to protecting the deck from waves. This rise is known as sheer. Some features in a transverse view are inclined to the vertical.

This inclination is known as rake as shown in figure 5.

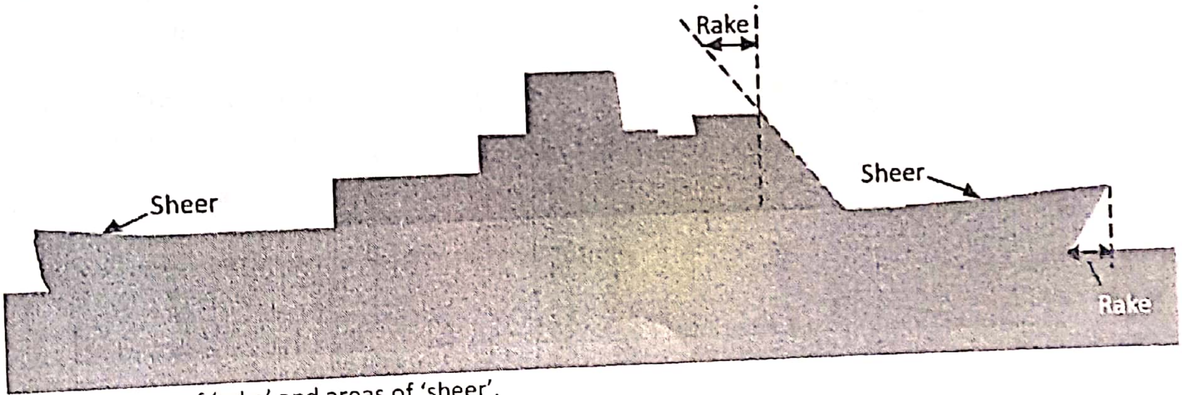


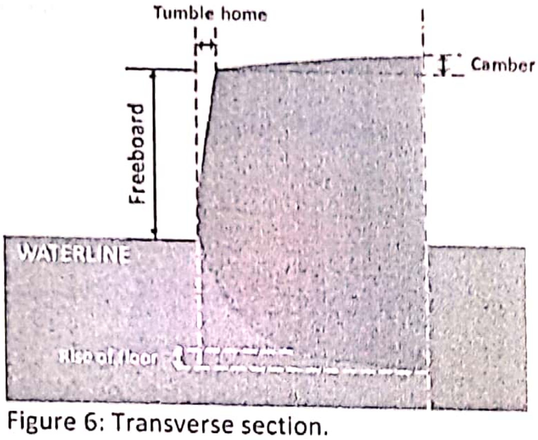
Figure 5: Areas of 'rake' and areas of 'sheer'.

2.3.2 Defining the Transverse Section

Figure 6 shows typical cross-sections of a ship near amidships and near the bow. The main features of a transverse section are the beam and depth of hull. The beam is the maximum width of the ship at any point along its length.

For many purposes, the figure quoted is the width on the design waterline at amidships, that is the mid- point between the fore and aft perpendiculars. The extreme breadth is usually greater and often occurs at the upper deck. The depth of the ship is the vertical distance between the keel and the upper deck of the main hull. If moulded beam or depth are referred to, these dimensions will be to the inside rather than the outside of the plating.

Defining the Transverse Section



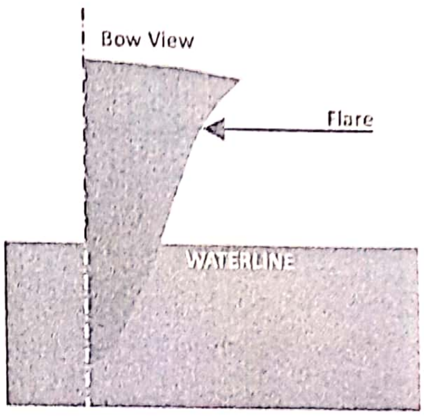


Figure 6: Transverse section.

Other features to be noted in Figure 6 are:

- The upper, weather, deck is curved so that any water will drain to the sides. The amount by which the centre of the deck is above the side is known as the camber. Decks other than the weather deck usually have no camber, to facilitate construction.
- The beam at the deck may be less than that at the waterline. The difference is termed the tumble home. If the beam at the deck is greater than that at the waterline the difference is said to be the flare.
- The bottom of the hull may rise from the keel to the turn of bilge. This rise is defined by what is known as the rise of floor.
- The distance of the deck at side above the waterline is known as the freeboard. The greater the freeboard the greater the volume of the hull above water. Assuming this volume is watertight, it represents a reserve of buoyancy should the ship take on extra weight or lose buoyancy due to partial flooding of the main hull.

2.3.3 Coefficients of Fineness

The overall dimensions of length, breadth and draught determine whether a ship can use a given dry dock or negotiate a specific canal or harbour. The table of offsets accurately defines the hull shape. However, neither set of data provides an immediate feel of the main characteristics of the hull shape, e.g. how "full" it is.

There are some "coefficients" which can be obtained for the underwater hull which provide clues as to its general nature and its likely behaviour at sea. They are derived by relating certain areas and volumes to their circumscribing rectangles or prisms. These coefficients are known as the coefficients of fineness as shown in figure 7. If:

V is the volume of displacement.
A is the waterplane area.
A is the underwater area of the midship section.
L, B and T are the length, beam and draught.

Then the coefficients of fineness are defined as follows:

Block coefficient, CB	=	V/LBT
Waterplane coefficient, CWP	=	AW/LB
Midship area coefficient, CM	=	AM/BT
Horizontal prismatic coefficient, CP	=	V/AML
Vertical prismatic coefficient, CVP	=	V/AWT

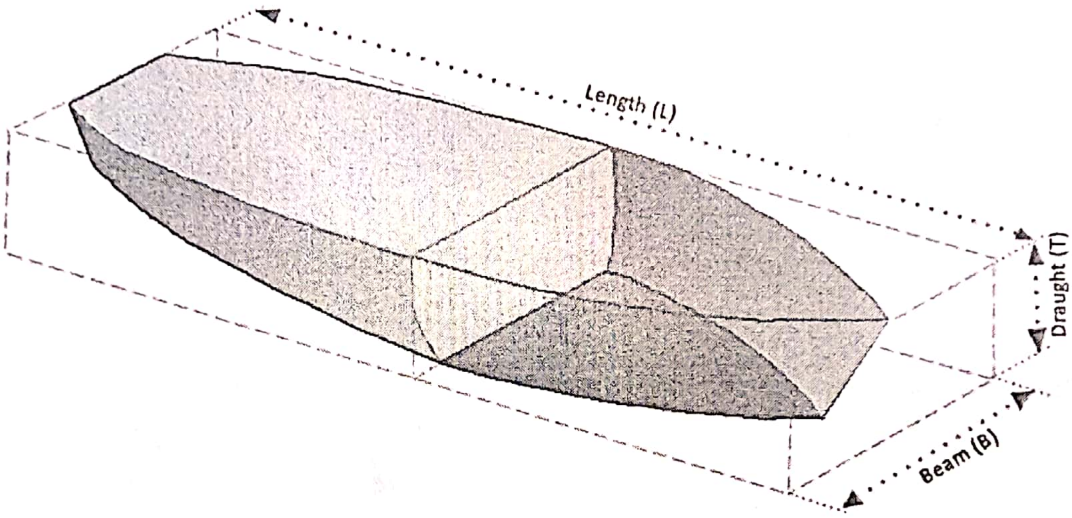


Figure 7: Coefficients of fineness.

In comparing values of these coefficients between ships, it is important to ensure that the same definitions of L, B and T are used. Usually L is the length between perpendiculars except for the waterplane coefficient where the length on the waterline is taken. B is usually the maximum beam on the waterline which may be greater than that amidships. T is usually the mean draught between perpendiculars.

Also, usually L, B and T are taken as defining the external hull, but sometimes moulded dimensions are used, that is to the inside of the plating. The external hull dimensions, and shape help to determine the behaviour of a ship in responding to the thrust of the propellers, to waves and to the movements of control surfaces, such as rudders and stabilisers.

The moulded dimensions assist in finding the internal volume available for equipment, accommodation and cargo.

Example

A ship of length 150 m and beam 18 m floats at a mean draught of 7.5 m when in water of density 1.025 tonnes/m^3.

Assuming her block coefficient is 0.5 and her waterplane coefficient of fineness is 0.6, calculate the ship's displacement and her approximate draught when it enters water of 1.015 tonnes/m^3.

Solution

- Volume of circumscribing rectangular solid = 150 × 18 × 7.5 = 20,250 m^3
- Volume of displacement 0.5 × 20,250 = 10,125 m^3
- Hence displacement 10,125 × 1.025 = 10,378 tonnes.
- The waterplane area = 0.6 × 150 × 18 = 1,620 m^2

In the less dense water, the ship must displace more water to produce a buoyancy force equal to its weight.

- New volume in the less dense water = 10,378/1.015 = 10,225 m^3
- The ship will sink in the water to compensate for the added volume
- Added volume = 10,225 – 10,125 = 100 m^3
- Sinkage = 100/1,620 =0.0617m (6.17cm)
- New draught is approximately 7.56 m

[Note, when performing calculations always include the dimensions used (m, cm, mm etc)].

2.4 Areas and Volumes

It is clear that to define a ship's main features, it is necessary to calculate a number of areas and volumes. Other areas and volumes are needed to calculate the weight of decks and bulkheads or to calculate the volume of tanks carrying liquids.

These areas or volumes may be symmetrical about a central line or plane, in which case the value of half can be calculated, and the answer doubled to give the total area or volume. This device can simplify the arithmetic of the calculation which was an important consideration in the days before computers became available.

2.4.1 Area

Take a shape, such as that shown in figure 8 below. A general shape is shown, although ship type shapes will tend to be more regular.

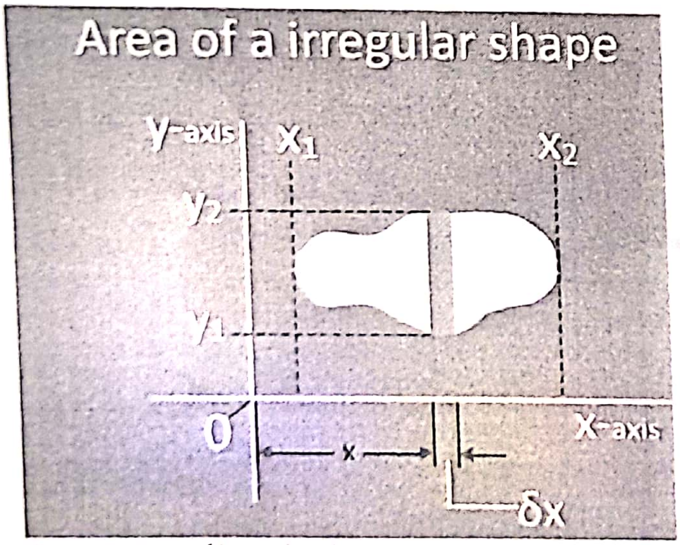


Figure 8: Area of irregular shape.

- The area of the shaded element is $(y_2 - y_1)\ \delta x$
- The area within the curve is obtained by summing all the elements between the extreme values of x.
- For summation, the symbol Σ is used in equations.
- Area $\Sigma\ (y_2 - y_1)\delta x$ the sum being over the distance x_1 to x_2

CamScanner

This is simply a convenient mathematical way of saying that the total area is the sum of all elements such as that shown as shaded areas in figure 8 and 9. Although the equations may seem complicated, they are merely a convenient shorthand way of representing relatively simple concepts which are lengthy to describe in words.

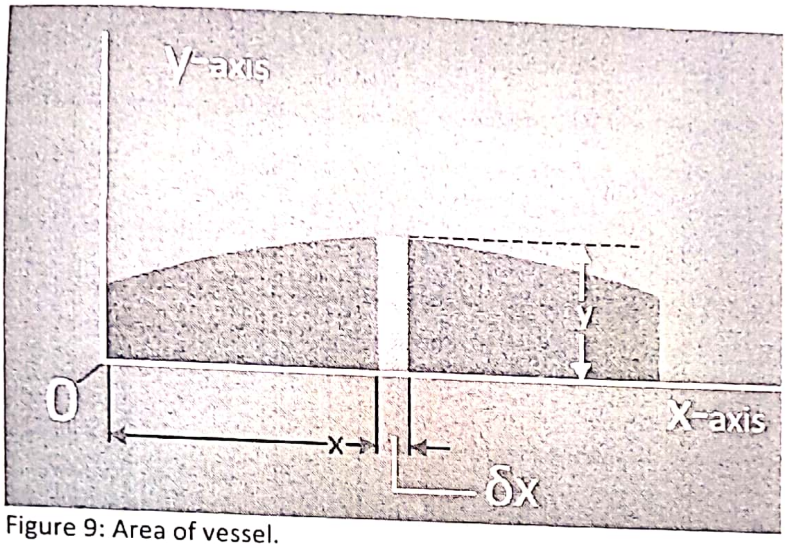


Figure 9: Area of vessel.

Let us now consider a typical ship waterplane. Generally, it will be symmetrical about the centreline of the ship. One half of such a waterplane can be represented by a series of ordinates, y, normal to the centreline as shown in figure 9.

Following the general area calculation above, the area defined by all the ordinates will be given by a summation of a large number of shaded elements:

Area = $\Sigma y\delta x$, remembering to double the result for the entire waterplane.

2.4.2 Volume

Volumes of a three-dimensional body can be calculated in the same way, except that in this case a number of 'slices' are taken through the body. If the area of a slice is A and its thickness is δx, then the volume of the disc, represented by the slice, is $A\delta x$ and the total volume of the body is given by: Volume = $\Sigma A\delta x$, where the summation is carried out over the range of x occupied by the body. Again, this is merely stating that the total volume of a body will be the sum of many thin slices taken through the body.

2.5 Moments

2.5.1 First Moments of Area

Besides the area of a plane figure, it is necessary to establish its centroid of area. If the plane area were a uniform steel plate, say, the centroid would be the centre of gravity of the plate. To find the centroid requires the first moment of area about the two principal axes, Ox and Oy.

Returning to Figure 8, the distances (or levers) for the shaded area are x from Oy and $(y2 + y1)/2$ from Ox. That is, the lever is the distance from the axis to the centre of the area. Hence, the first moments of area will be:

About Ox = $\Sigma(y2 - y1)\,[(y2 + y1)/2]\delta x$ About Oy = $\Sigma(y2 - y1)x\delta x$

For the waterplane in figure 9, the first moments of area for the half water-plane are:

About Ox = $\Sigma y(y/2)\delta x = (1/2)\,\Sigma y2\delta x$ About Oy = $\Sigma yx\delta x$

The centroid of the waterplane can be found by dividing the total moment about each axis by the area. For a waterplane, this centroid is known as the Centre of Flotation (CF). For a symmetrical waterplane, the CF will lie on the centreline. For most ship forms, the CF lies aft of amidships.

2.5.2 Second Moments of Area (Moment of Inertia)

The second moment or, as it is often called, the inertia of a waterplane is needed in calculations to establish how stable a ship is. The second moment of area is obtained by multiplying the small area elements by the square of the lever.

You are asked to accept this and should a proof of this, and information on calculating the second moment, be required, reference should be made to a textbook on naval architecture. An example would be a barge, with length L and breadth B. Its waterplane inertia would be I = LB3/12 about the centreline.

2.5.3 Moments of Volume

Moments of volume can be calculated in a similar way to the moments of area. If the slice defining the cross-section of the three-dimensional body is the distance x from the y-axis, the moment of the slice about the y-axis will be:

- Moment = $A\delta x$
- The total moment of the body about Oy is obtained by summation:
- Total moment = $\Sigma A\delta x$

The centroid of the volume is obtained by dividing the total moment by the total volume. In general, to define the centroid position, three distances are needed – those from three orthogonal axes since we are dealing with a three-dimensional body.

2.6 Approximate Integration

The summation of small elements to produce a total area, volume or moment is known as integration. In practice it is convenient to use approximate methods of integration, that is summation, which have been developed. The most common of these are Simpson's Rules, which use evenly spaced ordinates to define a curve with an ordinate at each end of the curve. The accuracy of the result will increase as more ordinates are used.

The rules state that:

- For three ordinates, y1, y2 and y3 (one at each end and one in the middle) the area is:
  Area = h (y1 + 4 y2 + y3)/3 where h is the spacing between ordinates, that is the curve extends over a distance 2h
- For four ordinates, the area is:
  Area = 3h (y1 + 3 y2 + 3 y3 + y4)/8 the area extending over a length 3h

- When there are three ordinates, y1, y2 and y3, the area between y1 and y2 is: Area = h(5 y1 + 8 y2 – y3)/12

With the first two rules, the moments about an axis parallel to the ordinates can be obtained by multiplying each ordinate by a lever representing its distance from the axis about which moments are needed.

In the case of a waterplane, this is usually amidships. For a symmetrical waterplane, first moments are not needed about a fore and aft axis as the centroid will lie on the centreline.

Often ship type curves, for example waterlines, have greater curvature towards the ends and it is desirable to introduce intermediate ordinates to define them more accurately. This can be done by adjusting the multipliers to suit.

Often also, in practice, the ordinates define the hull between the perpendiculars (see later) and there will be a small area of waterplane aft of the aftermost ordinate. In such cases, the main area and moment are calculated and then additions made for the small additional area.

These rules can be extended to any odd or even number of ordinates by successive applications. Thus, for seven ordinates:

- Area between y1 and y3 = h (y1 + 4 y2 + y3)/3
- Area between y3 and y5 = h (y3 + 4 y4 + y5)/3
- Area between y5 and y7 = h (y5 + 4 y6 + y7)/3
- Thus, the total area is h (y1 + 4 y2 + 2 y3 + 4 y4 + 2 y5 + 4 y6 + y7)/3

The same principles can be applied to moment calculations. The calculations are best done in tabular form as illustrated in the following example.

Example
Calculate the area between the curve defined by the ordinates of figure 10 and the straight line forming the x- axis.

Find the first moments of area about the baseline Ox and about the first ordinate (Oy).

X(m)	0	2	4	6	8	10	12
y(m)	2	3	4	4.5	4	3	2

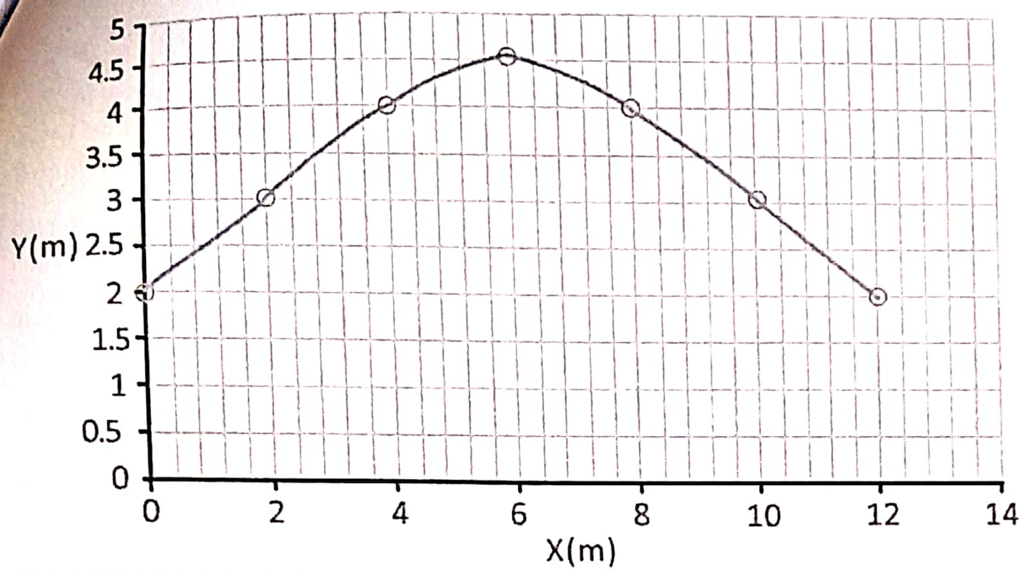


Figure 10: Moment calculations.

X	Y	SM	F(Area)	Lever from Oy	F(M)y	Lever from Ox	F(M)x
0	2.0	1	2	0	0	1.00	2.0
2	3.0	4	12	2	24	1.50	18.0
4	4.0	2	8	4	32	2.00	16.0
6	4.5	4	18	6	108	2.25	40.5
8	4.0	2	8	8	64	2.00	16.0
10	3.0	4	12	10	120	1.50	18.0
12	2.0	1	2	12	24	1.00	2
Total			**62**		**372**		**112.5**

Table 1

In this table:

- SM Simpson Multiplier.
- F(A) Function of area – the term "function" is merely a mathematical way of saying that the numbers in the column are related to the area.
- F(M)x Function of first moment of area about Ox.
- F(M)y Function of first moment of area about Oy.
  Applying Simpson's Rules:
  Ÿ Area under curve = 2 × 62 × 1/3 = 124/3 = 41.33 m^2
- Table 1 reflects the fact that the ordinates are 2 m apart (i.e. h = 2), the 62 is the sum of the values of F(A) and the 1/3 is the Simpson Multiplier.
- First moment of area about Oy = 2 × 372 × 1/3 = 248 m^3
- Distance of centroid from Oy = 248/41.33 = 6.00 m

It is prudent to check these answers against the expected result. The average ordinate seems to be about 3.5 so the area should be about 12 × 3.5 = 40.8 m². The area is symmetrical about the middle ordinate, so the centroid should be halfway along, about 6 m from Oy.

First moment of area about Ox = 2 × 112.5 × 1/3 = 75 m³ Distance of centroid from Ox = 75/41.33 = 1.81 m

In the above example, the area considered lay on one side of the x-axis. In the typical waterplane calculations, the ordinates would be half ordinates representing one half of the waterplane. In this case, the figures derived from the table would need to be doubled for the complete waterplane and the total moment about Ox will be zero.

It will be realised that any irregular shape can be divided by a straight line and the areas and moments calculated for each part of the shape, on the two sides of the line, and the results combined.

Volumes of a body can be found by sectioning the body at regular intervals, calculating the area of each section and then applying approximate integration methods to find the volume from the areas. For a ship's hull, the waterplanes or the transverse sections provide convenient areas for calculating the volume of displacement.

2.7 Spreadsheets

With the use of spreadsheets being common and most surveyors being competent in the use of programs such as Microsoft Excel, the use of a spreadsheet is illustrated in the example below (Table 2).

Example
Calculate the area and the centre of flotation of the waterplane defined by the following half breadths. The half breadths are numbered from the stern forward and are 11.2 metres apart.

Coastal Tanker LBP = 112.0 metres Offsets taken at the load waterline

Station	Half-breadth	SM	Function for areas f(A)	Levers	Function for Moments f(M)
0 (AP)	2.31	1/2	1.2	0	0.0
1/2	5.09	2	10.2	1/2	5.1
1	7.20	1 1/2	10.8	1	10.8
2	9.49	4	38.0	2	75.9
3	10.00	2	20.0	3	60.0
4	10.00	4	40.0	4	160.0

5 (Amids)	10.00	2	20.0	5	100.0
6	10.00	4	40.0	6	240.0
7	10.00	2	20.0	7	140.0
8	9.95	4	39.8	8	318.4
9	7.40	1 1/2	11.1	9	99.9
9 1/2	4.39	2	8.8	9 1/2	83.4
10 (FP)	0.00	1	0.0	10	0.0

Table 2

Common interval = h = 112/10 = 11.2

Waterplane Area = A = f(A) × h/3 × 2 (for both sides) = 259.8 × 11.2/3 × 2 = 1940 sq m
First moment about AP = M = f(M) × h/3 × h x 2 = 1293.5 × 11.2/3 × 11.2 x 2 =108171 Centre of floatation from AP = M/A = 108171/1940 = 55.76m fwd of AP

A rough check on the figure obtained should ensure that the doubling has not been forgotten. In all calculations of area of waterplanes, it is wise to check the answer obtained by assessing an average beam and multiplying by the length of the waterline.

If the waterplane is defined by half-ordinates, this must be allowed for.

2.8 Centres of Gravity and Buoyancy

Fundamental to determining the draughts at which a ship will float, along with its stability, is a knowledge of the locations of the overall centres of gravity and buoyancy. To determine the Centre of Gravity (CG), the ship is split into a large number of individual weights, the sum of which will be its total weight and hence also the displacement.

The distance of the CG of the ship from any axis (or plane) is found by adding the moments of all the individual weights about that axis (or plane) and dividing by the total weight. In the same way, to find the Centre of Buoyancy (CB):

- The total displaced volume is split into many small volumes.
- The moments of these individual volumes about any axis are obtained by multiplying each by its distance from that axis.
- The moments are added up and the sum is divided by the total volume.

2.8.1 Centre of Gravity

In the simple case of two concentrated weights, w1 and w2, the combined Centre of Gravity (CG) will lie on the line joining the two weights (or more precisely their CGs) and its distance from w1 will be:

W2x/ (w1 + w2) where x is the distance between the two weights.

This can be generalised to give the distance of the combined CG from an arbitrary point along the line as given by:

(w1 x1 + w2 x2)/(w1 + w2)

Where x1 and x2 are the distances of the individual weights from the arbitrary point.

The same principle can be extended to cover any number of weights in the same straight line. If the weights are not in a single line but are in the same plane, the overall CG can be found relative to a pair of orthogonal axes by taking moments about those axes. If the weights are distributed in three dimensions the moments must be taken about three orthogonal axes.

For a ship, the three axes are taken as vertical (z-axis), fore and aft (x-axis) and transverse (y-axis) with an origin at the keel amidships. Thus, the resultant CG position along the z-axis gives the vertical CG (the KG value, the distance of the CG above the keel). Since the hull is symmetrical about the centreline plane the overall CG must lie in that plane if the ship is to float upright.

Example
A board weighing 5 kg is 4 m long and 2 m wide. Weights of 2, 3, 4, 5, 6 and 7 kg are placed on the board such that their distances from the short edge are 0.5, 1.0, 1.5, 2.0, 2.5 and 3 m and their distances from the long edge are 0.2, 0.4, 0.6, 0.8, 1.0 and 1.2 m respectively.

Find the total weight of the board with the weights added and the position of the centre of gravity of the whole.

Solution
The solution is best set out in tabular form. Total weight of assembly 32 kg.

Weight (kg)	Dist. from Short Edge (m)	Moment About Short Edge (kg.m)	Dist. from Long Edge (m)	Moment About Long Edge (kg.m)
5 (board)	2	10	1.0	5.0
2	0.5	1	0.2	0.4
3	1.0	3	0.4	1.2
4	1.5	6	0.6	2.4
5	2.0	10	0.8	4.0
6	2.5	15	1.0	6.0
7	3.0	21	1.2	8.4
32		66		27.4

Table 3

The centre of gravity is 66/32 = 2.063 m from the short edge, and 27.4/32 = 0.856 m from the long edge. The distances of individual weights from the edges of the board are referred to as their levers for the purpose of taking moments.

2.8.2 Centre of Buoyancy

Assuming the water in which the ship is floating is homogeneous in density the Centre of Buoyancy (CB) will be at the centre of volume of the water displaced, that is of the underwater hull form. As already explained, in calculating the CB position, the total volume is divided up into a number of sections and the volume of each section is then calculated. The overall CB is obtained by taking moments as in the case of finding the overall CG of a group of weights.

A ship's buoyancy and the point through which its buoyancy acts depend only upon the geometry of the underwater form of its watertight boundary. This can be taken initially as the underwater hull shape and then allowance made for any internal volumes open to the sea.

The weight of the water displaced, and hence the weight of ship it can support, is dependent on the density of the water. The density of water depends upon temperature and salinity but, for standard calculations, it is usual to take the following figures:

- Fresh water: density 1.000 tonnes per cubic metre.
- Saltwater: density 1.025 tonnes per cubic metre.

2.9 The Table of Offsets

The external area of the hull of the ship is a three-dimensional envelope which can be defined by the distance of the envelope from the centreline plane at a large number of points. The distances are known as offsets. It has been shown that the hull can be defined by a series of waterplanes and transverse sections. It is the intersections of these with each other, which are used as the offsets to define the hull.

They can be arranged in tabular form as a table of offsets, each column defining a waterplane and each row defining a transverse section. The transverse sections are usually taken at regular intervals so that offsets are uniformly spaced along the length of the ship.

However, due to the relatively rapid changes in shape which can occur right forward and right aft, additional sections (and offsets) may be introduced in these regions to provide greater accuracy. Also, waterplanes are usually equally spaced so that offsets are equally spaced in the depth of the ship, but an additional waterplane may be introduced low down to help define the turn of the bilge (that is, the lower outboard corners of the hull) more accurately.

Waterplanes are drawn for the full depth of the hull so, as to define the hull shape above and below the waterplane at which the ship is intended to float. It is important that the upper part of the hull, which is normally out of the water, should also be fair. This will aid construction, appearance, reduce air resistance and reduce wave impact loads.

Example
OFFSET TABLE (for the waterlines)
Main Particulars: LOA = 117.2 m; LBP = 112.0 m; B mld = 20.0 m; D mld = 10.0 m; LWL = 7.5 m Station spacing 11.2m

Stn\WL	0	0.5	1	1.5	2	3	4	5	1	7	LWL	8	10
0	0	0	0	0	0	0	0	0	0	1.69	2.31	2.75	3.84
0.5	0.10	0.50	0.68	0.81	0.94	1.24	1.60	2.31	3.46	4.58	5.09	5.45	6.45
1	1.04	1.50	2.31	2.76	3.20	4.06	4.88	5.61	6.32	6.90	7.20	7.44	8.35
2	3.92	5.10	6.04	6.58	7.03	7.38	8.29	8.78	9.09	9.39	9.49	9.59	9.84

3	6.19	8.05	8.80	9.27	9.52	9.85	9.92	10	10	10	10	10	10
4	7.05	9.38	9.80	9.98	10	10	10	10	10	10	10	10	10
5	7.85	9.45	10	10	10	10	10	10	10	10	10	10	10
6	8.60	9.43	10	10	10	10	10	10	10	10	10	10	10
7	8.57	9.41	9.72	9.91	9.99	10	10	10	10	10	10	10	10
8	7.20	8.00	8.55	8.94	9.21	9.54	9.70	9.80	9.89	9.92	9.95	9.99	10
9	2.67	4.65	5.34	5.71	6.03	6.51	6.82	7.01	7.13	7.27	7.40	7.57	8.24
9.5	0.60	2.25	2.32	3.10	3.38	3.70	3.79	3.87	4.00	4.21	4.39	4.52	5.34
10	0	0.84	1.21	1.40	1.48	1.32	1.04	0.70	0.32	0.06	0	0.03	0.72

Table 4

Directed Learning

- The following exercise will assist students in becoming familiar with this type of calculation,
- A ship has a length of 158 m, a beam of 17 m and a draught of 6.75 m with a displacement of 10,000 tonnes and an immersed midship section area of 104 m^2.
  Assuming a water density of 1.025 tonnes per cubic metre, find the block, longitudinal prismatic and midship-section coefficients.
- Extend the Simpson's Rules to cover 10 ordinates using the 1, 3, 3, 1 Rule and deduce a rule for the number of ordinates for which it can be used.
  For three ordinates apply the 5, 8, 1 Rule to the areas between y1 and y2 and then to the area between y2 and y3 to show that the total area is in accordance with the 1, 4, 1 Rule.
- A curve is defined by the following ordinates, y, spaced 3 metres apart.

X	0	3	6	9	12	15	18	21
Y	1.2	1.5	1.7	1.8	1.8	1.7	1.6	1.4

  Find the area between the curve and the x-axis by using Simpson's 1, 3, 3, 1 rule to find the area from x = 0 to x = 9, and the 1, 4, 1 rule for the area from x = 9 to x = 21.
- A barge 50 m long by 8 m beam floats in water of density 1.025 tonnes/m^3. The centre of gravity of the barge itself is on the centreline amidships. Weights are added at the positions indicated in the table below.
  - Where must an additional weight of 15 tonnes be added so that the barge will sink bodily without heel or trim?
  - What will be the increase in draught?

Weight Tonnes	Distance Forward of Amidships (m)	Distance to Starboard of Centreline (m)
20	15	2
15	10	-1
12.5	-12	1.5
20	-18	-3
25	5	0.5

Table 5

3. Draughts

3.1 The Metacentre and the Metacentric Diagram

So far, the ship has been considered as floating in a state of equilibrium, upright and at the design draught. It is now necessary to consider departures from this state. First take the case when a ship is heeled through a small angle as in figure 11.

The centre of buoyancy moves to a new position B1 and the buoyancy force, which acts vertically, that is, normal to the new waterline, acts through a point M on the centreline. M is known as the transverse metacentre. For angles of up to about 10 degrees, M can be regarded as a fixed point.

Transverse Stability, Large Angles

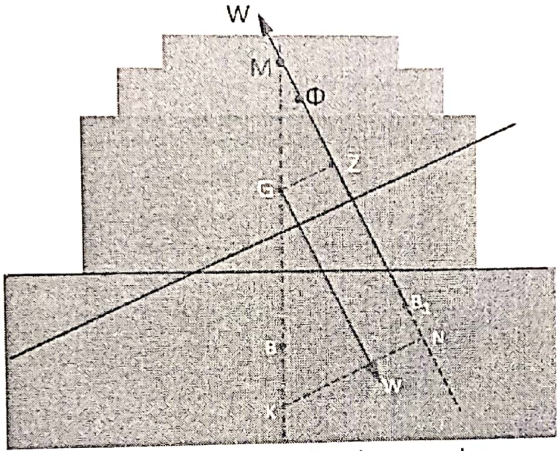


Figure 11: Transverse stability, large angles

The positions of B and M depend only upon the geometry of the ship and are fixed for the draught at which it is floating. The designer can provide information on B and M for each mean draught, assuming the waterline is parallel to the design waterline. Small departures from this state are unlikely to be significant. With such a plot, known as a metacentric diagram, a ships Master can find M and B for the ships condition as demonstrated in figure 12.

We have seen how the centre of buoyancy, the centroid of the volume of the displaced water, can be found. BM is given by:

BM = I/V, where I is the transverse second moment, or inertia, of the waterplane and V is the volume of displacement.

A mathematical proof of this relationship can be found in standard textbooks on naval architecture. You are asked to accept it and to note that BM will vary directly with the square of the beam and inversely with the draught. A large beam and shallow draught would lead to a very stable ship – one difficult to roll over.

However, there would be disadvantages in terms of rapid rolling in waves and slamming (see later). Also, the high angle stability would be poor. The designer has to balance up a number of factors in deciding upon the degree of stability to build into a ship. Usually these will be in line with internationally agreed standards. The concept of stability is addressed in more detail in the next chapter.

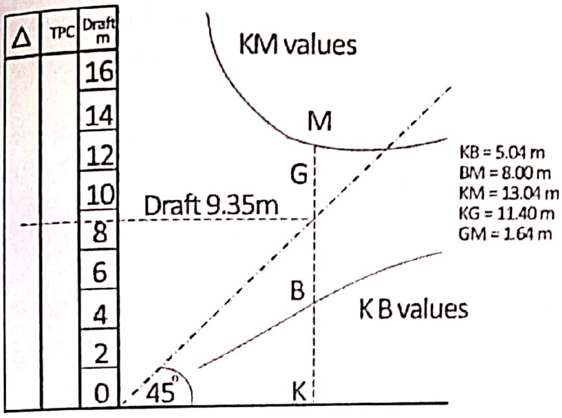


Figure 12: Metacentric diagram.

There is a corresponding longitudinal metacentre for small changes in angle about a transverse axis. It will be shown later that the two metacentres are critical to a study of a ship's stability. The position of the longitudinal metacentre, ML is defined by:

BML = IL/V, where IL is the longitudinal inertia of the waterplane about a transverse axis through the centroid of the area of the waterplane.

Example
Consider a uniform rectangular solid, length L, beam B and depth D, floating in water with its long dimension horizontal. Assuming the solid's density is k times that of water, discuss the form of the metacentric diagram for a range of k values. The second moment (or inertia) of a rectangle about a longitudinal axis is B3L/12.

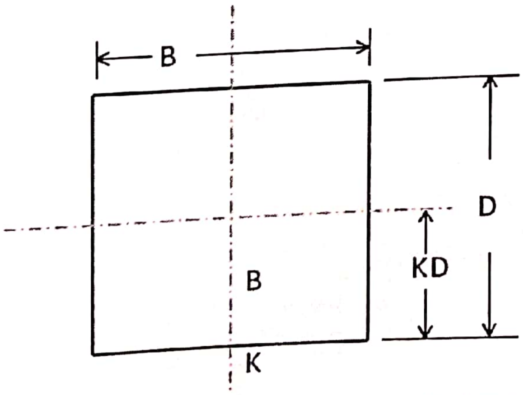


Figure 13: Diagram showing rectangular beam

Solution
- The solid will float at a draught T where: T = kD
- For a rectangular cross-section: KB = draught/2 = kD/2
- Thus, for this case KB increases linearly with D and its plot will be a straight line passing through the origin and with slope tan1 1/2
- For a rectangular waterplane: I = B3L/12 (you are asked to accept this)
- Now BM = I/V = [B3L/12]/LBT = B2/12T = B2/12kD
- BM will reduce as, k increases, i.e. as the displacement increases.

Example

Showing the derivation of a metacentric diagram:

Calculate, for a range of k values, the above metacentric diagram assuming:

B = 24 m; and

D = 10 m in this case;

KB = kD/2 = 5k

BM = B2/12kD = (24)2/ (12) (10)k = 4.8/k

A table can now be constructed as shown below.

k	T = kD	KB = T/2	BM = 4.8/k	KM = KB + BM
0	solid with no weight	0		
0.2	2	1	24	25
0.4	4	2	12	14
0.6	6	3	8	11
0.8	8	4	6	10
1.0	solid with no buoyancy			

Table 6

The metacentric diagram can now be drawn. As, k increases the M curve will approach the B line more closely.

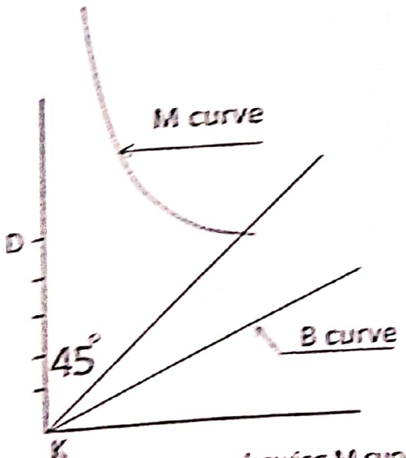


Figure 14: Diagram showing M curve and B curve.

3.2 Hydrostatic Curves

For a given loading condition, the draughts at which a ship will float are determined by:

- the geometry of the ship;
- the distribution of weights within the ship; and
- the density of the water in which the ship is floating. Standard mass densities used are 1.025 tonne/m³ for saltwater and 1.000 tonne/m³ for fresh water.

3.2.1 Longitudinal Centre of Floatation (LCF)

Whilst the distribution of weights is constantly varying during a ship's service, the geometry is fixed by the design. A very useful set of curves can be produced based on the hull form. A series of waterplanes parallel to the design waterline is taken, covering the full depth of the hull. The area of each waterplane and its Centre of Flotation (CF), that is its centroid, can be found.

Consider a small weight placed on the ship vertically above the CF. The ship will sink bodily by a small amount, say δT. The extra volume of water displaced is $A\delta T$ where A is the area of the waterplane. The centre of buoyancy of this extra water will be above the CF provided the waterplane shape stays the same as the ship sinks slightly. Thus, the buoyancy force of the extra water will directly oppose the added weight with no moment to cause the ship to trim.

The CF is the centroid of area of the waterplane so the moment of the area of the waterplane forward of the CF equals that aft. As a ship trims through a small angle about a transverse axis through the CF, the volumes of emerged and immersed wedges are equal, and the overall displacement remains unchanged.

3.2.2 Displacement and Centres of Buoyancy (KB and LCB)

From the form of the ship, the volume of displacement up to any waterplane, and the corresponding Vertical position of the Centre of Buoyancy (VCB) can be calculated by using the waterplane areas and Simpson's Rules to obtain the volume and taking moments about the keel up to that draught. In a similar way, the immersed area of each transverse section up to each waterplane can be found.

By integrating along the length and taking moments the volume of displacement and position of the Longitudinal Centre of Buoyancy (LCB) can be found. A curve of the area of any cross-section to various draughts plotted against draught is useful in a number of calculations. It is known as a Bonjean curve and an example of this is provided in figure 15.

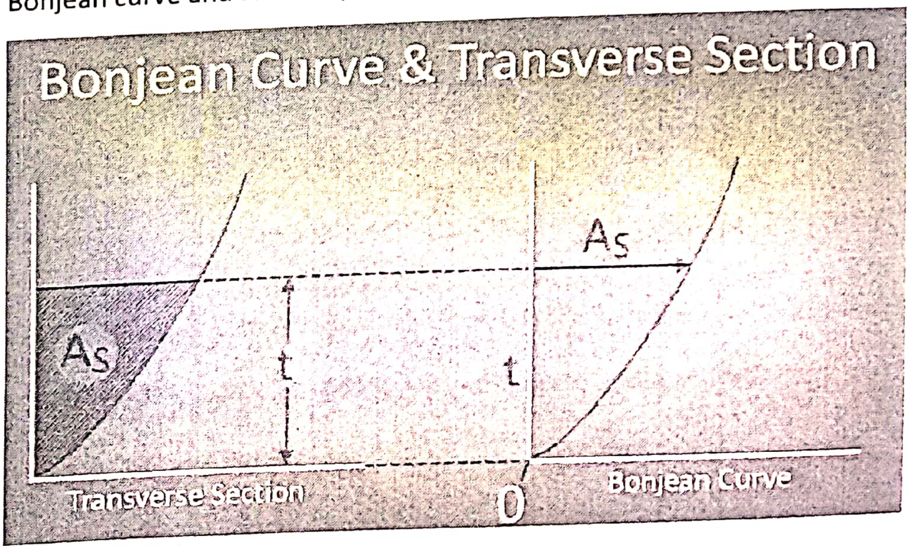


Figure 15: Bonjean curve.

3.2.3 Tonnes Per Centimetre Immersion (TPC)

For each waterplane the area defines, for a given density of water, the change in buoyancy in tonnes experienced due to unit increase or decrease in draught. The unit of draught change considered is usually one centimetre (but a metre may be used, and it is important to note which), giving the

Tonnes Per Cm immersion (TPC). The other term that is sometimes used is TPI, standing for tonnes per unit immersion. If the area of a waterplane is A m^2 and the water density is ρ tonnes per m^3, then the TPC will be Aρ/100.

3.2.4 Moment to Change Trim One Metre (MCT)

Now consider departures from the steady state by rotation about a transverse axis, that is when the ship is trimmed. Let it trim through a small angle, θ, about an axis through the CF, extra buoyancy will be created at the end of the ship at which the draught increases and a loss of buoyancy at the end which emerges from the water. The forces due to these buoyancy forces will produce a moment which will act so as to oppose the change of trim. The total buoyancy will remain constant and equal to the ship's weight, W, otherwise the ship would move up or down. If ML is the longitudinal metacentre, the righting movement will be W.GML.θ.

This will be the moment required to hold the ship at the new trim angle. If the trim change is one metre between perpendiculars, the moment is referred to as the Moment to Change Trim one metre (MCT). It will be noted that the MCT does depend upon the position of G, so it will vary with the loading of the ship. However, BML (IL/V) is large, typically of the order of the length of the ship. It will be appreciated that the variation in the height of G above the keel will be small compared with GML.

Hence, GML will not vary much with the loading of the ship. You will now appreciate why, in the previous chapter, the transverse and longitudinal inertias of the waterplane were mentioned. They are important in defining the heights of the transverse and longitudinal metacentres above the centre of buoyancy.

We have seen that for small changes in trim about the CF, there is no change in overall displacement. For larger changes a correction has to be made to the draft at amidships (mean draft). This change will be an increase in displacement when the trim is such that the draught at the CF position increases. This change will be a decrease in displacement when the trim is such that the draught at the CF position decreases.

For the trim, ϕ, there will be a change of draught at the CF given by:

a.ϕ where a is the distance of the CF from amidships there will be a corresponding change in displacement given by:

100.a.ϕ.TPC   (Note: This assumes a is in metres)

3.2.5 Transverse Metacentre above the Keel (KM)

The distance of the transverse metacentre above the keel (KM) is given by:
KM = KB + BM

KB is the distance of the centre of buoyancy above the keel and may be found by the method shown in Section 3.2.2.

BM is the distance of the metacentre above the centre of buoyancy and may be found by the method shown in Section 3.1.

A plot of the above data against draught gives rise to a set of curves known as the hydrostatic curves or simply hydrostatics, shown in figure 16.

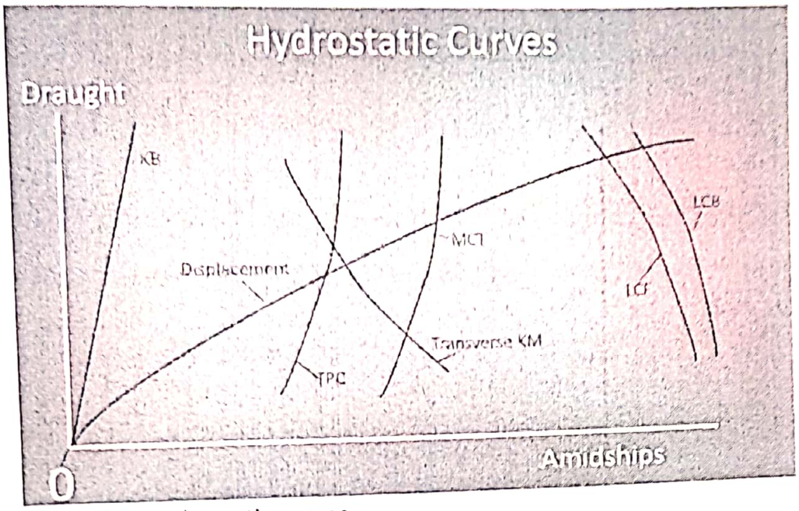


Figure 16: Hydrostatic curves.

Example
The Tonnes Per Cm immersion (TPC) for a ship in water of density 1.025 tonnes/m^3 at waterlines 1 m apart starting at the load water line (LWL) and moving down are:

12.48, 12.00, 11.32, 10.48, 9.36, 7.80 and 5.16 tonnes/cm

Find the displacement between the LWL and the lowermost waterline defined and the distance of the centre of buoyancy below the LWL, ignoring the section of ship below the lowermost defined water line.

What would be the corresponding displacement in water of density 1.000 tonnes/m^3?

Solution
A table can be constructed as below:

TPC	SM	F(Disp)	Lever	F(Moment)
12.48	1	12.48	0	0.00
12.00	4	48.00	1	48.00
11.32	2	22.64	2	45.28
10.48	4	41.92	3	125.76
9.36	2	18.72	4	74.88
7.80	4	31.20	5	156.00
5.16	1	5.16	6	30.96
Totals		**180.12**		**480.88**

Table 7

Hence, displacement (1/3) (180.12) (100) = 6,004 tonnes.
The centre of buoyancy below LWL = 480.88/180.12 = 2.67 metres.

In water of density 1.000 tonnes/m^3 the displacement to the LWL would be: 6,004/1.025 = 5,858 tonnes.

3.3 Weights

The weight of a ship can be considered as comprising:

- weights that are constant during a voyage, such as the weights of the hull structure and machinery.
    - These constitute what is often referred to as the light ship;
- variable weights such as the weights of fuel, stores and cargo. These can be defined for a variety of conditions but will change during a voyage.

By summing all the individual weights of components, fittings and so on, the total weight and position of CG can be obtained by the methods outlined earlier.

3.4 Finding a Ship's Draughts

Knowing the weight and CG position for any given ship condition, the draughts can be found by:

- using the hydrostatics, the draught amidships at design trim corresponding to the weight can be read off together with the LCB position.

Then:

- The weight multiplied by the distance between the Longitudinal Centre of Gravity (LCG) and Longitudinal Centre of Buoyancy (LCB) gives a moment taking the ship away from its design trim. The change of trim will be by the bow or by the stern depending upon whether the LCG is forward or aft of the LCB respectively. It is best to produce a small sketch of the ship to show which way moments act and hence the way the ship trims.
- The trim change between perpendiculars in metres is found by dividing the trimming moment by the MCT. This trim will be about the LCF (or CF) the position of which must be noted from the hydrostatics. The draughts at the perpendiculars or at the draught marks can be calculated.

If the overall change in draughts between perpendiculars, L apart, is t, say, the change of draught per unit length along the ship is t/L. If a set of draught marks is at a distance k from the CF, the change of draught at those marks will be tk/L. Whether this is an increase or decrease will depend upon the way the trim is changing and whether the marks are forward or aft of the CF. A simple diagram will assist you in determining which.

It should be noted that the draughts obtained from the above will only be reasonably accurate if any change from the design trim is relatively small. If the change of trim is significant, a new amidships draught must be found and the process repeated.

3.5 Fore and Aft Movement of Weight

If a weight already on the ship is moved forward or aft the effect is to move the LCG and, the draught will increase at the end of the ship towards which the weight is moved. If the weight is w and it is moved a distance d forward the trimming moment created will be wd, that is the product of the two as demonstrated in figure 17.

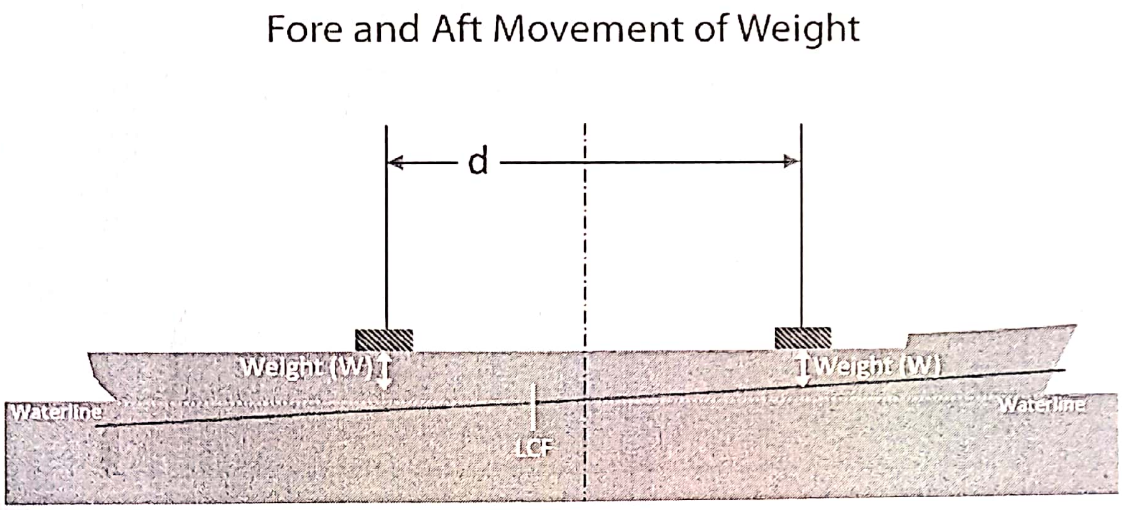


Figure 17: Fore and aft movement of weight.

The ship must trim to compensate, that is the new LCB must move so as to be in line with the new LCG. The change in trim is found by dividing the moment by the MCT.

Since the weight was already on board, the displacement of the ship is constant, so the trim will be about the CF position and the new draughts can be found.

3.6 Adding Weight

If a weight is added, or taken off, as shown in figure 18, there are two effects:

- The ship will sink (or rise) a little so that the increased (decreased) buoyancy equals the change in weight.
- The ship will trim due to the fore and aft movement of the overall ship LCG.

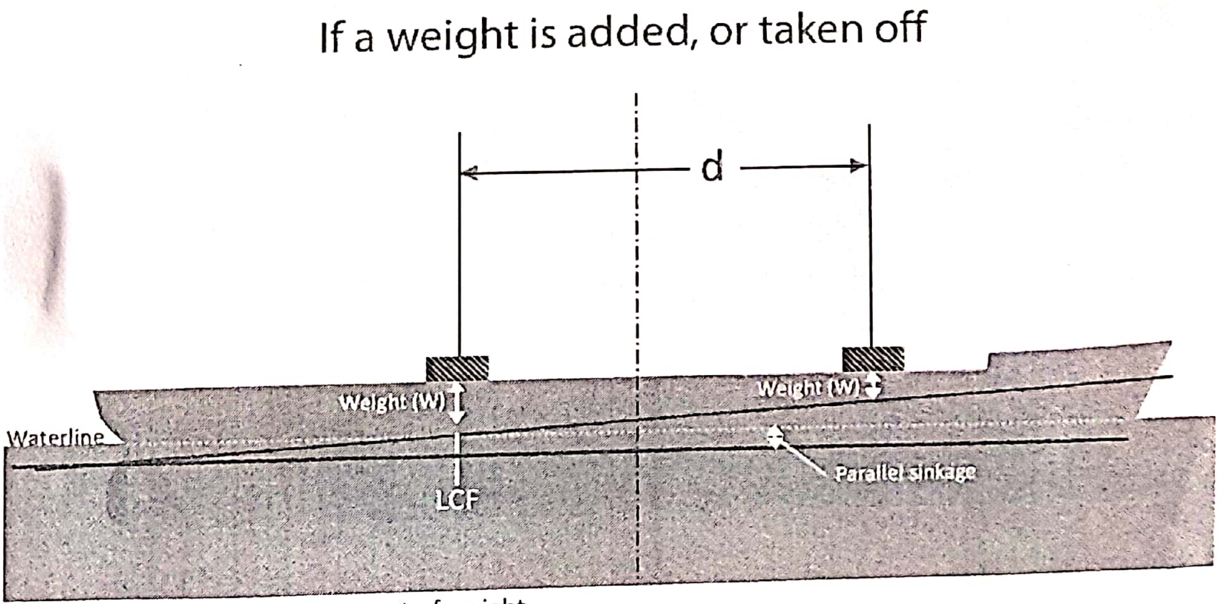


Figure 18: Fore and aft movement of weight.

PROMISE WILLIAMS

2. Role of the Surveyor

2.1 Purpose and Overview of the Casualty Investigation Code

Accidents on board ships can occur anywhere in the world and therefore, under the jurisdiction of various national governments and/or legal systems. This has led in the past to a lack of continuity in the subsequent accident investigations.

The matter of interest by different governments and the problems of differing laws and requirements is further compounded by the fact that various nationalities of personnel and various governments may be involved in a single accident. We can use a simple example to demonstrate this.

Scenario (fictitious), a Very Large Crude Carrier (VLCC) collides with a bulk carrier in the Southern North Sea. Officers and crew are killed on both vessels and pollution reaches the shores of France and Belgium. Figure 1 shows a very real possibility:

	VLCC	Bulk Carrier	Involved Nation
Accident Location	UK Waters		United Kingdom
Registered	Spain	Australia	Spain Australia
Pollution of shore	France and Belgium		France Belgium
Officers' nationality	Dutch	Croatian	Holland Croatia
Crew nationality	Filipino	Indian	Philippines India

Figure 1: A possible scenario for the number of nationalities involved in an accident.

From this incident, involving two vessels, it is possible that the national authorities of the United Kingdom, Spain, Australia, France, Belgium, Holland, Croatia, The Philippines and India may all require to conduct an accident investigation – involving nine different nations, nine different sets of national laws and nine different investigating bodies as well countries in four different world time zones.

This would, of course, lead to a huge logistical problem as well as possible repetition of interviews and much disruption for all concerned.

In an effort to simplify the matter of accident investigations involving ships, the IMO published the previously mentioned "Casualty Investigation Code". This code, to give it its full and correct title is the "Code of International Standards and Recommended Practices for a Safety Investigation into a Marine Casualty or Marine Incident"

This code was intended to serve as a more developed document than its predecessor, namely the "Code for the Investigation of Marine Casualties and Incidents" which was adopted in 1997 by the IMO under Resolution A.849(20). (IMO, 2008)

In addition to Resolution A.849(20), the following were also published by the IMO as shown in figure 2:

Resolution A.173	Participation in official enquiries into marine casualties	Adopted 1968
Resolution A.322	The conduct of investigations into casualties	Adopted 1975
Resolution A.440	Exchange of information for investigations into marine casualties	Adopted 1979
Resolution A.442	Personnel and material resource needs of Administrations for the investigation of casualties and the contravention of conventions	Adopted 1979
Resolution A.637	Co-operation in maritime casualty investigations	Adopted 1989
Resolution MSC.255(84)	Adoption of the code of the international standards and recommended practices for a safety investigation into a marine casualty or marine incident (Casualty Investigation Code)	Adopted 2008

Figure 2: Sample of resolutions from the IMO. (IMO, 2019)

The resolutions listed above were later combined and re-issued as the Code for the investigation of marine casualties and incidents, and this was adopted by the IMO in November 1999 as Resolution A.884(21). This resolution was later amended by the IMO on 04th February 2000 and this formed resolution A.849(20) mentioned above.

In the latest update, new regulations were introduced on 01st January 2010. The primary change in this edition of the regulations was to highlight that a Flag State Administration need only cause an investigation to happen when it judges that an investigation of any casualty occurring to any of its ships "may assist in determining what changes in the present regulations might be desirable". The code now also requires an investigation to be conducted into every very serious marine casualty.

The matter of accident investigation was also included in SOLAS) in 1960 and later, also in the International Convention on Load Lines 1966.

In addition, to bring some order to the procedures and requirements for accident investigations on board ships, the Casualty Investigation Code also provides information as to when such investigations should be performed.

The Casualty Investigation Code includes three parts as follows:
Part 1: General provisions (of the code).
Part 2: Mandatory standards.
Part 3: Recommended practices.

Initially, only Part 2 of the code was mandatory, and it is this section that provides the greatest benefit with the best possibility of providing opportunities for improvements to safety. Part 3 of the code is not mandatory but is applied by numerous flag state administrations for the benefit of all concerned.

The International Convention for the Safety of Life at Sea (SOLAS) was later amended to make Part One of the Casualty Investigation Code also mandatory and this is included in SOLAS Chapter XI-1, Regulation 6, 6.1 which states:
"The provisions of parts I and II of the Casualty Investigation Code shall be fully complied with"

(IMO, 2014).

As with many regulatory documents the Casualty Investigation Code was written with a specific purpose. That purpose was to bring a uniformity on approach by all member states (members of the IMO) to their methodology for performing investigations. The code also stipulates that these investigations **are not to be used for apportioning blame**, but instead to have a clear focus on the prevention of marine accidents. This is a very important factor which will be discussed later in this module.

The code also provides for a flow of information between different flag state administrations and in fact the wider industry, in order that lessons learned can be applied as widely as possible, thus benefiting and helping to protect the maximum number of people and assets.

Further, the code prevents marine accident investigations from being conducted as part of any other investigation, thereby removing any chance of influence or distortion of facts from other investigations taking place. It would, however, be counterproductive to hinder, prevent or fail to assist in those investigations being conducted by flag administrations into civil, criminal and administrative proceedings and the code, therefore, allows a reporting by accident investigators to take place in these cases.

There exists an important acknowledgement made by the Casualty Investigation Code. This being that flag state administrations have a duty to perform investigations into any casualties and incidents if the flag state considers that it would provide information that could be used to prevent further accidents. This means that only the investigation of very serious marine casualties must be investigated but others may also be, as the flag state deem necessary. It is also acknowledged however, that the flag administration may not be the only state which has an interest in performing an investigation and that other states have the right to do so, where a genuine interest in the accident exists.

2.2 The Casualty Investigation Code – Definitions

The Casualty Investigation Code contains a nomenclature which is quite commonplace in the maritime industries. Some of these definitions are of cardinal importance in understanding the requirements of the code.

Selected definitions are provided below from the IMO Casualty Investigation Code (IMO, 2008):

Causal Factor
"A causal factor means actions, omissions, events or conditions without which:
The marine casualty or marine incident would not have occurred; or
Adverse consequences associated with the marine casualty or marine incident would probably not have occurred or have been so serious; or
Another action, omission, event or condition, associated with an outcome in 1 or 2, would probably not have occurred."

Coastal State
"A coastal State means a State in whose territory, including its territorial sea, a marine casualty or marine incident occurs."

Marine Casualty
"A marine casualty means an event, or a sequence of events, that has resulted in any of the following, which has occurred directly in connection with the operation of a ship:

1. The death of, or serious injury to, a person;

2. The loss of a person from a ship;
3. The loss presumed loss or abandonment of a ship;
4. material damage to a ship;
5. the stranding or disabling of a ship, or the involvement of a ship in a collision;
6. material damage to marine infrastructure external to a ship, that could seriously endanger the safety of the ship, another ship or an individual; or
7. severe damage to the environment, or the potential for severe damage to the environment, brought about by the damage of a ship or ships."

Marine Incident

"A marine incident means an event, or sequence of events, other than a marine casualty, which has occurred directly in connection with the operations of a ship that endangered or, if not corrected, would endanger the safety of the ship, an individual or the environment."

Marine Safety Investigating State(s)

"Marine safety investigating State means the flag State or, where relevant, the State or States that take the responsibility for the conduct of the marine safety investigation as mutually agreed in accordance with this Code."

Substantially Interested State

"Substantially interested State means a State:

1. which is the flag State involved in a marine casualty or marine incident; or
2. which is the coastal State involved in a marine casualty or marine incident; or
3. whose environment was severely or significantly damaged by a marine casualty (including the environment of its waters and territories recognised under international law); or
4. where the consequences of a marine casualty or marine incident caused, or threatened, serious harm to that state or to artificial islands, installations, or structures over which it is entitled to exercise jurisdiction; or
5. where, as a result of a marine casualty, nationals of that State lost their lives or received serious injuries; or
6. that has important information at its disposal that the marine safety investigating State(s) consider useful to the investigation; or
7. that for some other reason establishes an interest that is considered significant by the marine safety investigating State(s)."

Very Serious Marine Casualty

"A very serious marine casualty means a marine casualty involving the total loss of the ship or a death or severe damage to the environment."

Directed Learning

- Locate a marine accident investigation report (available online) and discuss how the ISM system may have failed in such a way as to contribute to the chosen incident occurring.
- Consider what recommendations you as an investigator may make with regards to your chosen report.

3. The Casualty Investigation Code

3.1 Introduction

The Casualty Investigation Code encourages, and in fact demands by mandatory application, that information is readily passed between the substantially interested states: Part 2.2 provides a definition for "substantially interested party" at the time of a marine casualty.

This communication is initiated by the flag state administration of the vessel (or vessels) involved and should be initiated as soon as practicably possible. However, it should be recalled that at the time of the accident the flag state administration is likely to be involved in the immediate management of the accident, and communication with other substantially interested states may be necessarily delayed.

When the initial communication is made, this must be provided in a format provided by the Casualty Investigation Code and must include:

- The name of the vessel and details of its flag state administration.
- The vessel's IMO number.
- Details of the accident/incident/casualty.
- Location of the accident/incident/casualty.
- Time and date of the accident/incident/casualty.
- Details of the number of persons seriously injured or killed.
- Consequences of the accident/incident/casualty.
- Details of any other vessel(s) involved.

In the case where one or more of the vessels involved is in territorial waters other than those belonging to its flag state administration, then the flag state administration and coastal state administration will communicate between each other and jointly notify all of the other substantially interested states.

The code allows for each substantially interested state to conduct its own independent investigation, but it also recommends that co-operation between the investigating states and other investigating bodies or persons is ensured.

This co-operation prevents undue pressure on the persons involved in the accident, and simultaneously minimises disruption to the vessel's operations. Such co-operation is of importance when interviewing witnesses who may have been involved in, or witnessed a disturbing, frightening or unpleasant event, and for whom discussing and recalling detail may be very traumatic.

Good co-operation between the investigating states will also allow for easier access to evidence with greater confidence that this has not been previously disturbed or affected by other investigators.

3.2 The Role of Marine Safety Investigating States

The Casualty Investigation Code definition of 'marine safety investigating states' is provided in Section 2.2 above. To fully explain this, we shall now consider this further.

As discussed, many bodies may have an interest in a marine accident. These include the flag state administration, coastal state administration and the states who have their national citizens on board, as well as those states whose environment could be affected by the accident (such as by a pollution incident). It will often be the case that only one of these states or "substantially interested states" will conduct the actual investigation, but the results and outcome will be communicated to the other substantially interested states.

The marine safety investigating states are bound to comply with the mandatory parts of the Casualty Investigation Code (Part 1 and Part 2 of the code), but it is often the case that these states will apply more stringent requirements than those required by the code.

SOLAS and the Casualty Investigation Code state the requirements for conducting an accident investigation.

The Casualty Investigation Code states that an investigation shall be conducted into every "very serious" marine casualty (you will recall that a very serious marine casualty means a marine casualty involving the total loss of the ship or a death or severe damage to the environment). The flag states are responsible for ensuring that the investigation is initiated and also for ensuring that the requirements for the code are subsequently fulfilled.

SOLAS states that each flag state administration undertakes to conduct an investigation of any casualty occurring to any of its ships, subject to the provisions of the convention when it judges that such an investigation may assist in determining what changes in the present regulations may be desirable.

Each contracting government undertakes to supply the IMO with pertinent information concerning the findings of such investigations. No reports or recommendations of the organization, based upon such information, shall disclose the identity or nationality of the ships concerned, or in any manner fix or imply responsibility upon any ship or person.

The marine safety investigating state(s) are also required to:

- Be independent in its organisation, legal structure and decision making of any party whose interests could conflict with the task entrusted to it.
- Carry out investigations in an unbiased manner.
- Ensure that the investigation is performed by suitably qualified investigators, who are competent in the tasks required of them.
- Provide investigators for the purpose of conducting the required investigation to any global location.
- Provide competent and qualified investigators regardless of the incident type.
- Ensure co-operation with substantially interested states.
- Identify contributing factors which led to the accident occurring.
- Should save all information from charts, logs, voyage data recorders (VDR) etc. relating to the period preceding, during and after an accident.
- Should obtain survey records and relevant records held by the flag state, classification societies or any other relevant party whenever those parties or their representatives are established in the member state.
- Protect witnesses and witness statements, in order to ensure that the evidence provided by them is used only for the purposes of the investigation.
- Ensure that the investigation is performed by an independent body.
- Ensure that the independent bodies performing the investigation have the necessary powers and authority to conduct the investigation. This includes the power to board a vessel and interview its master, officers and crew as well as any other person involved in the matter. The investigators' authority must also allow them to obtain evidence, such as documentation and physical material.
- Ensure that investigators have free access to any relevant area or casualty site as well as to any ship, wreck or structure including cargo, equipment or debris.

- Ensure immediate listing of evidence and controlled search for removal of wreckage, debris or other components or substances for examination or analysis and require the analysis of such to which they should have free access to results.
- Avoid conflicts of interest.
- Ensure that the investigators can work under the best possible conditions.
- Provide protection to witnesses to prevent the evidence obtained being used against them. It is essential to ensure that witnesses cannot self-incriminate, as this may prevent them from providing all of the facts of the accident.
- Inform witnesses that they have the right to remain silent.
- Where the flag state is not capable of performing an investigation, or has insufficient resources to do so, the flag state should delegate the responsibility to another member state.
- Ensure that the purpose of the investigation and the subsequent report serve the purpose of preventing future similar accidents.
- Ensure that the accident report does not apportion blame.
- Provide a draft copy of the marine safety investigation report when requested to interested parties and allow them 30 days to make comment. The investigating state may then decide whether or not to act on the comments received.
- Ensure that the final report is not used as evidence admissible in any case which could lead to disciplinary measures, criminal conviction or determination of civil liability.
- Make recommendations to interested parties which will improve the safety of the vessel or prevent a reoccurrence of the accident.

3.3 The Role of Substantially Interested States

Substantially interested states, it should be recalled, have the right to conduct their own investigations. In cases where the substantially interested state decides to perform its own investigation it will still require to comply with the requirements of the Casualty Investigation Code as outlined in Section 3.2 above.

In addition to the above, it is reinforced by the Casualty Investigation Code that substantially interested states which are conducting their own investigation in parallel with the main investigation, must make every effort to ensure that they co-ordinate their tasks with those of the main investigation. All involved states must work together to avoid overburdening the persons involved, witnesses and access to evidence.

When parallel investigations are taking place, the marine safety investigating states are to ensure that their investigation recognises other formal investigations and offer all practical assistance and co-operation to it.

3.4 Mandatory Standards of the Casualty Investigation Code

The Casualty Investigation Code part II forms the mandatory standards of the code. These mandatory standards include the following topics:

Contact information to be provided to the IMO
It is the responsibility of each state to ensure that IMO is provided with detailed contact information of the organisations performing investigations on behalf of the state.

The need for flag states administrations to contact substantially interested states

The flag state and/or coastal state administrations are to notify all other substantially interested states. This does not limit the rights of the flag state administration. Each state may conduct its own investigation or delegate to a single state.

Communication between flag state administration, coastal state administration and substantially interested states.
When a casualty occurs, which is within the scope to initiate an investigation, the substantially interested states are to communicate with one another.

Format and content for notification messages from flag state to other states
When notifying another state, the sender of the information has to abide by the code requirements for minimum details as follows:

- Ship's name and flag.
- Type of casualty.
- IMO number of vessels involved.
- Location of the incident.
- Time and date information of the incident.
- Number of fatalities or injuries.
- Consequences of the incident on property and the environment.

Requirements to investigate very serious accidents
All "very serious marine casualties", as defined, shall be investigated.

Agreement between states for conducting marine safety investigations
Two or more states may reach an agreement between them as to how a marine safety investigation will be performed, roles of each party and resources to be provided.
Any agreement between states does not limit the rights of any of the agreeing parties.

Powers required to conduct an investigation
Investigating bodies are to be provided with the necessary powers required to conduct an effective investigation.

Conducting parallel investigations
More than one marine safety investigation may take place and with similar schedules, these are known as parallel investigations.

Co-operation between states
Where investigations are being conducted in parallel the states involved are to co-operate throughout the investigation.

Investigations not subject to external direction
Investigations are to be conducted without interference from any source, person or organisation. No source, person or organisation should be permitted to pervert the course of the investigation or its outcome.

Evidence and obtaining this from seafarers
This is a very important section of the code as it protects personnel involved in the incident.
Witnesses should be made fully aware of their rights.
Evidence should not be interfered with.

Marine safety investigation reports – draft
When requested, the investigating state is to provide a copy of the draft investigation report to substantially interested states.

The substantially interested state receiving the draft report must ensure and guarantee that the documents are not made public, issued or circulated without the approval of the investigating state.

Substantially interested parties may comment on the draft report. The period for doing so should be agreed between the parties but normally this period is set at 30 days.

The investigating state is to ensure that every effort is made for the draft and final report to be accurate.

Marine safety investigation report
For every investigation into a very serious marine casualty the investigating state provides a full report to the IMO.

The investigating state shall also provide the IMO with reports of investigations into incidents other than very serious marine casualties if the investigating state believes that the contents of the report may be of benefit to future reviews of regulations.

3.5 Recommended Practices of the Casualty Investigation Code

The Casualty Investigation Code, Part 3, forms the recommended practices of the code. These recommendations include the following topics:

Administrative responsibility
The investigating states should be capable of providing all necessary material, finance and resources to perform the investigations which they are responsible for.

Investigators who are qualified and experienced in the tasks expected of the investigation should be appointed.

Investigators should be familiar with, and abide by, the Casualty Investigation Code.

Principles of investigation
All investigations should be unbiased.

Information should be made readily available to investigators.

The investigation should be independent from any investigation which is seeking to apportion blame for the purposes of prosecution.

Investigations should be conducted without interference. Investigations should be safety focused. All states and parties involved in the investigation should be co-operate fully with each of the other parties involved.

Marine safety investigations should be conducted with the same level of importance as other investigations, such as those being conducted for prosecution matters.
The following documents should be made readily available to investigators:

- Statutory certificates.
- Classification certificates.

- Survey records
- Voyage data recorder information.
- Evidence relating to the incident.

Investigation of casualties which are not very serious casualties
Where a casualty or incident occurs, which is not a very serious marine casualty but where an investigation may be beneficial for future safety, these incidents may also be investigated.

Matters to be considered in forming an agreement between states for a marine safety investigation to be performed
States should consider the following when considering entering into an agreement:

- Where the incident occurred.
- Territorial waters involved either at the time of the incident or affected by it.
- Available resources.
- Ability to perform a satisfactory investigation of each party.
- Consequences of the incident.
- Nationality of the ship's officers.
- Nationality of the ship's crew.
- Nationality of passengers.
- Nationality of other persons affected.

Acts of unlawful interference
In any case where it becomes known that an unlawful act has occurred which affects the investigation, the states involved in the investigation should inform the authorities of the other states concerned with reference to the "Suppression of Unlawful Acts Against the Safety of Maritime Navigation 1988 Act" and the 2005 Protocol to this.

Co-ordinating an investigation
The investigating state is responsible for ensuring that:

- A lead investigator is appointed.
- The lead investigator is provided with support as required.
- A method of communication is agreed between the involved states.
- That the investigation complies with the requirements of the IMO.
- That the investigation includes the International Safety Management code aspects of the ship(s) and the managers.
- All substantially interested states are permitted to participate in the investigation.
- The availability of witnesses is coordinated.

Collecting evidence
Collection of physical evidence is detailed later in the module.

Confidentiality
Information obtained from marine safety records during an investigation should only be disclosed under certain circumstances. Generally, this will only occur when there is an immediate need in the interest of safety for the information to be circulated.

Witnesses – protection
Witnesses are detailed later in this module.

Involved parties – protection
Involved parties are detailed later in this module.

Re-opening of investigations

If and when new evidence or information becomes available following the closing of an investigation, the states should consider the re-opening of the investigation.

Directed Learning

- Explain under what circumstances a flag state administration may initiate an investigation into the death of a crew member on board a ship.

PROMISE'S L1

3. Performing Surveys and Security Surveys

3.1 Methodology

Safety and security surveys take place generally using a standardised checklist that covers all of the requirements of the Code(s) that are being surveyed/audited (such as SOLAS, ISM Code). A good checklist will not however be a "tick and flick" where questions are "closed" questions.

A sample of a closed question in such checklists is:

"Are navigational charts up to date?"

This type of question does not allow the surveyor to adequately review and address the situation regarding navigational charts. A better question, and a more open one, would be:

"How are navigational charts kept up-to-date, and when was the last update completed?"

This question will ensure that verification is undertaken into how the ship's personnel receive information on chart updates and then proceed to undertake the necessary corrections.

A good surveyor will not only review written evidence but will also inspect the ship for adequate safety and security measures, as well as witnessing ship operations such as the conducting of emergency drills.

All evidence sighted should be documented on checklists, and where appropriate, copies taken (including photographs) for later review and recording.

All surveys/audits should take place with an approach to risk management. A risk-based approach is designed to be used throughout the survey/audit to efficiently and effectively focus the nature, timing and extent of the survey procedures to those areas that have the most potential to create safety or security issues.

The risk-based approach requires the surveyor to first understand the entity and its environment to identify risks that may result in safety or security issues. The assessment involves considering many factors such as the nature of the risks, relevant internal controls and the required level of survey evidence.

3.2 Evidence and Records

Records and evidence that should be reviewed during a survey, and which can provide proof of conformity (or non-conformity) with rules and regulations, include:

- Drill schedules.
- Completed drill reports, analysis of such drills for identification of improvement.
- Permits to work.
- Confined space entries.
- Ship certificates – in date.
- Statutory surveys – in date.
- Checks of life-saving equipment – including life rafts, life jackets, Emergency Position Indicating Radio Beacons, Search and Rescue Transponders (SARTs) etc, – in date.
- Master's review of the ISM Safety Management System (SMS).
- Incident/accident reports.
- Policies, including safety, security and environment.

- On-board procedures – Including navigational, deck, engineering, food and hygiene, cargo procedures.
- Emergency preparedness and response procedures.
- General housekeeping of decks, engine rooms, cargo holds, galley, living accommodation.
- Results of previous internal and external surveys – addressing of non-conformities raised.
- Crew qualifications.
- Viewing of an emergency drill.
- Oil spill equipment – type and amount of.
- Chart corrections.
- Marine orders (or equivalent for the flag of the ship).
- Registration records.

3.3 Reports

Reports should include at least the following details:

- Declared scope of audit.
- Standard(s) or code(s) surveyed/audited against.
- Audit date(s).
- Audit time(s).
- Names of auditees.
- Details of opening and closing meeting.
- Lead auditor.
- Accompanying auditor(s).
- Audit process.
- Summary of audit findings/audit report.
- Conclusions and recommendations.
- Information on non- conformities and observations raised.
- Copy of the audit checklist.
- Samples of different types of reports are detailed in the relevant section of this material.

3.4 Deficiencies

Deficiencies are raised where there is evidence that the ship's systems are not conforming to the standard or code that is being surveyed/audited. There are three main types of deficiencies identified:

- Non-conformity
- Major Non-conformity
- Observation

These will be explained in the following sections.

3.4.1 Non-conformity

An observed situation where objective evidence indicates the non-fulfilment of a specified requirement.

3.4.2 Major Non-conformity

An identifiable deviation that poses a serious threat to the safety and/or security of personnel or the ship, or a serious risk to the environment that requires immediate corrective action and includes the lack of effective and systematic implementation of a requirement of the Code(s).

- On-board procedures – Including navigational, deck, engineering, food and hygiene, cargo procedures.
- Emergency preparedness and response procedures.
- General housekeeping of decks, engine rooms, cargo holds, galley, living accommodation.
- Results of previous internal and external surveys – addressing of non-conformities raised.
- Crew qualifications.
- Viewing of an emergency drill.
- Oil spill equipment – type and amount of.
- Chart corrections.
- Marine orders (or equivalent for the flag of the ship).
- Registration records.

3.3 Reports

Reports should include at least the following details:

- Declared scope of audit.
- Standard(s) or code(s) surveyed/audited against.
- Audit date(s).
- Audit time(s).
- Names of auditees.
- Details of opening and closing meeting.
- Lead auditor.
- Accompanying auditor(s).
- Audit process.
- Summary of audit findings/audit report.
- Conclusions and recommendations.
- Information on non- conformities and observations raised.
- Copy of the audit checklist.
- Samples of different types of reports are detailed in the relevant section of this material.

3.4 Deficiencies

Deficiencies are raised where there is evidence that the ship's systems are not conforming to the standard or code that is being surveyed/audited. There are three main types of deficiencies identified:

- Non-conformity
- Major Non-conformity
- Observation

These will be explained in the following sections.

3.4.1 Non-conformity

An observed situation where objective evidence indicates the non-fulfilment of a specified requirement.

3.4.2 Major Non-conformity

An identifiable deviation that poses a serious threat to the safety and/or security of personnel or the ship, or a serious risk to the environment that requires immediate corrective action and includes the lack of effective and systematic implementation of a requirement of the Code(s).

As a point of note. Some individuals and organisations may raise a "minor" non-conformity. It should be noted that the ISM Code does not contain a definition for this. It is advisable therefore not to use this term which would be difficult to explain or defend if challenged.

3.4.3 Observation

An observed situation where there is the potential that the continuation of that situation could lead to the non-fulfilment of a specified requirement. If the observation is not addressed appropriately, it may lead to either a non-conformity, or a major non-conformity.

Deficiencies are generally raised as a Non-conformities Report (NCR) such as the one shown in figure 1, or a "corrective action report" (CAR), where the following is to be addressed:

- Date of audit.
- Code(s) audited/surveyed.
- Concise description of the non-conformity or observation raised.
- Signature of auditor.
- Acceptance by auditee.
- Root cause identification of the non-conformities or observation.
- Corrective and preventive action to be taken.
- Date within which the deficiency will be rectified (generally three months).
- Details of the close out of the non-conformity report.

The issuance of a major non-conformity (MNC) will result in the ship being detained in port and must be treated with the utmost urgency and importance.

Note – As mentioned previously, it is quite common to find the term "Minor Non- Conformity" used in an audit report. This is not good practice as no definition is provided by the ISM Code for this term. (IMO,2019a). It is a misconception that a non-conformity can be "minor". It is strongly recommended that surveyors / auditors refrain from the use of this term as, if challenged (perhaps in court), there is no ISM Code definition to which one could refer.

NON-CONFORMITY/CORRECTIVE ACTION REPORT		
Date	Code (•)/Ciaue (•),	II'CR No
Area:		
Details of Non -conformance		
Signature: .... Auditor	.... Ship Rep	
Root Cause:		
Corrective Action to be Taken		
Agreed date for completion of corrective action:		

4. International Safety and Security Standards

4.1 International Convention for the Safety of Life at Sea (SOLAS)

4.1.1 Introduction and History

SOLAS, in its successive forms is generally regarded as the most important of all international treaties concerning the safety of merchant ships.

The first version was adopted in 1914, in response to the Titanic disaster, the second in 1929, the third in 1948 and the fourth in 1960. A completely new Convention was adopted in 1974 which included the amendments agreed up until that date and entered into force in 1980.

The SOLAS Convention is sometimes referred to as "SOLAS 1974, as amended".

4.2 SOLAS Overview -Technical Provisions

The main objective of the SOLAS Convention is to specify minimum standards for the construction, equipment and operation of ships, compatible with their safety. Flag states are responsible for ensuring that ships under their flag comply with its requirements, and a number of certificates are prescribed in the Convention as proof that this has been done.

Control provisions also allow contracting governments to inspect ships of other contracting states if there are clear grounds for believing that the ship and its equipment do not substantially comply with the requirements of the Convention – this procedure is known as Port State Control (PSC).

The current SOLAS Convention includes Articles setting out general obligations, amendment procedure and so on, followed by an Annex divided into 12 chapters.

4.2.1 Chapter I – General Provisions

This chapter includes regulations concerning the survey of the various types of ships and the issuing of documents signifying that the ship meets the requirements of the Convention. The chapter also includes provisions for the control of ships in ports of other contracting governments (ie PSC).

4.2.2 Chapter II-1 – Construction – Subdivision and Stability, Machinery and Electrical Installations

The subdivision of passenger ships into watertight compartments must be such that after assumed damage to the ship's hull the vessel will remain afloat and stable. Requirements for watertight integrity and bilge pumping arrangements for passenger ships are also laid down as well as stability requirements for both passenger and cargo ships.

The degree of subdivision – measured by the maximum permissible distance between two adjacent bulkheads – varies with ship's length and the service in which it is engaged. The highest degree of subdivision applies to passenger ships.

Requirements covering machinery and electrical installations are designed to ensure that services which are essential for the safety of the ship, passengers and crew are maintained under various emergency conditions. The steering gear requirements of this chapter are particularly important.

4.2.3 Chapter II-2 – Fire Protection, Fire Detection and Fire Extinction

This chapter includes detailed fire safety provisions for all ships and specific measures for passenger ships, cargo ships and tankers.

They include the following principles:

- Division of the ship into main and vertical zones by thermal and structural boundaries.
- Separation of accommodation spaces from the remainder of the ship by thermal and structural boundaries.
- Restricted use of combustible materials.
- Detection of any fire in the zone of origin.
- Containment and extinction of any fire in the space of origin.
- Protection of the means of escape or of access for firefighting purposes.
- Ready availability of fire-extinguishing appliances.
- Minimisation of the possibility of ignition of flammable cargo vapour.

4.2.4 Chapter III – Life-saving Appliances and Arrangements

This chapter includes requirements for life-saving appliances and arrangements, including requirements for lifeboats, rescue boats and life jackets according to type of ship.

The International Life-Saving Appliance (LSA) Code gives specific technical requirements for LSAs and is mandatory under Regulation 34, which states that all life-saving appliances and arrangements shall comply with the applicable requirements of the LSA Code. It should be noted that the LSA Code has been updated and the 2017 Edition is now applicable.

4.2.5 Chapter IV – Radiocommunications

This chapter incorporates the Global Maritime Distress and Safety System (GMDSS). All passenger ships and all cargo ships of 300 gross tonnage and upwards on international voyages are required to carry equipment designed to improve the chances of rescue following an accident, including satellite Emergency Position Indicating Radio Beacons (EPIRBs) and Search And Rescue Transponders (SARTs) for the location of the ship or survival craft.

Regulations in Chapter IV cover undertakings by contracting governments to provide radio communication services, as well as ship requirements for carriage of radio communications equipment. The chapter is closely linked to the Radio Regulations of the International Telecommunication Union.

4.2.6 Chapter V – Safety of Navigation

Chapter V identifies certain navigation safety services which should be provided by contracting governments and sets forth provisions of an operational nature applicable in general to all ships on all voyages. This is in contrast to the Convention as a whole, which only applies to certain classes of ship engaged on international voyages.

There are however also some exceptions to the term "all ships" and these are as follows:

- Warships.
- Naval Auxiliaries.
- Other ships owned or operated by a contracting government for non-commercial service.
- Ships solely navigating the Great Lakes of North America and their connecting and tributary waters as far east as the lower exit of the St. Lambert Lock at Montreal on the Province of Quebec, Canada.

The subjects covered include:

- The maintenance of meteorological services for ships.
- The ice patrol service.
- Routeing of ships.
- The maintenance of search and rescue services.

This chapter also includes a general obligation for Masters to proceed to the assistance of those in distress* and for contracting governments to ensure that all ships shall be sufficiently and efficiently manned from a safety point of view.

* Chapter V, Regulation 33, contains the following requirement:

"The master of a ship at sea which is in a position to be able to provide assistance, on receiving information from any source that persons are in distress at sea, is bound to proceed with all speed to their assistance..." (IMO, 2014b)

As this Chapter V of SOLAS is applicable to all vessels it is worthwhile detailing the safety topics specifically covered by it. These are as follows:

- Navigational warnings.
- Meteorological services and warnings.
- Ice patrol service.
- Search and rescue services.
- Lifesaving signals.
- Hydrographic services.
- Ships' routeing.
- Ship reporting systems.
- Vessel traffic services.
- Establishment and operation of aids to navigation.
- Ships' manning.
- Principles relating to bridge design.
- Maintenance of equipment.
- Electromagnetic compatibility.
- Approvals, surveys and performance standards of navigation systems, and equipment and voyage data recorders.
- Carriage requirements for shipborne navigational systems and equipment.
- Long range identification and tracking of ships.
- Voyage data recorders.
- International code of signals.
- International Aeronautical and Maritime Search and Rescue (IAMSAR) Manual.
- Navigation bridge visibility.
- Use of heading and / or track control systems.
- Operation of steering gear.
- Steering gear; testing and drills.
- Nautical charts and nautical publications.
- Records of navigational activities and daily reporting.
- Lifesaving signals to be used by ships, aircraft and persons in distress.
- Operational limitations.
- Danger messages.
- Information required in danger messages.
- Distress situations: obligations and procedures.
- Safe navigation and avoidance of dangerous situations.
- Master's discretion.
- Misuse of distress signals.
- Rules for the management, operation and financing of the North Atlantic Ice Patrol.

4.2.7 4.4.7 Chapter VI – Carriage of Cargoes

This chapter covers all types of cargo (except liquids and gases in bulk) "which, owing to their particular hazards to ships or persons on board, may require special precautions".

The regulations include requirements for stowage and securing of cargo or cargo units (such as containers).

The chapter requires cargo ships carrying grain to comply with the International Grain Code.

4.2.8 4.4.8 Chapter VII – Carriage of Dangerous Goods

The regulations are contained in four parts:

Part A:

Carriage of dangerous goods in packaged form – Includes provisions for the classification, packing, marking, labelling and placarding, documentation and stowage of dangerous goods. Contracting governments are required to issue instructions at the national level and the chapter makes mandatory the International Maritime Dangerous Goods (IMDG) Code, developed by IMO, which is constantly updated to accommodate new dangerous goods and to supplement or revise existing provisions.

Part A-1:
Carriage of dangerous goods in solid form in bulk – covers the documentation, stowage and segregation requirements for these goods and requires reporting of incidents involving such goods.

Part B:
Covers Construction and equipment of ships carrying dangerous liquid chemicals in bulk and requires chemical tankers built after 1 July 1986 to comply with the International Bulk Chemical Code (IBC Code).

Part C:
Covers Construction and equipment of ships carrying liquefied gases in bulk and gas carriers constructed after 1 July 1986 to comply with the requirements of the International Gas Carrier Code (IGC Code).

Part D:
Includes special requirements for the carriage of packaged irradiated nuclear fuel, plutonium and high-level radioactive wastes on board ships and requires ships carrying such products to comply with the International Code for the Safe Carriage of Packaged Irradiated Nuclear Fuel, Plutonium and High- Level Radioactive Wastes on Board Ships (INF Code).

The chapter requires carriage of dangerous goods to be in compliance with the relevant provisions of the IMDG Code. The IMDG Code was first adopted by IMO in 1965 and has been kept up to date by regular amendments, including those needed to keep it in line with United Nations Recommendations on the Transport of Dangerous Goods which sets the basic requirements for all the transport modes.

4.2.9 Chapter VIII – Nuclear Ships

This chapter gives basic requirements for nuclear-powered ships and is particularly concerned with radiation hazards. It refers to the detailed and comprehensive Code of Safety for Nuclear Merchant Ships which was adopted by the IMO Assembly in 1981.

4.2.10 Chapter IX – Management for the Safe Operation of Ships

This chapter makes mandatory the International Safety Management (ISM) Code, which requires a safety management system to be established by the shipowner or any person who has assumed responsibility for the ship (the "company").

4.2.11 Chapter X – Safety Measures for High-speed Craft

This chapter makes mandatory the International Code of Safety for High-Speed Craft (HSC Code).

4.2.12 Chapter XI-1 – Special Measures to Enhance Maritime Safety

This chapter clarifies requirements relating to:

- Authorisation of recognised organisations (responsible for carrying out surveys and inspections on administrations' behalves).

- Enhanced surveys.
- Ship identification number scheme.
- Port state control on operational requirements.

4.2.13 Chapter XI-2 – Special Measures to Enhance Maritime Security

This chapter was adopted in December 2002 and entered into force on 1 July 2004. Regulation XI-2/3 of the new chapter enshrines the International Ship and Port Facilities Security Code (ISPS Code). Part A of the Code is mandatory and part B contains guidance as to how best to comply with the mandatory requirements.

The regulation requires administrations to set security levels and ensure the provision of security level information to ships entitled to fly their flag. Prior to entering a port, or whilst in a port, within the territory of a contracting government, a ship shall comply with the requirements for the security level set by that contracting government, if that security level is higher than the security level set by the administration for that ship.

Regulation XI-2/8 confirms the role of the master in exercising his professional judgement over decisions necessary to maintain the security of the ship. It says he shall not be constrained by the company, the charterer or any other person in this respect.

Regulation XI-2/5 required all ships to be provided with a ship security alert system (SSAS), according to a strict timetable that required most vessels to have the system fitted by 2004 and the remainder by 2006. When activated the SSAS shall initiate and transmit a ship-to-shore security alert to a competent authority designated by the administration, identifying the ship, its location and indicating that the security of the ship is under threat or it has been compromised. Very importantly the system will not raise any alarm on board the ship. The ship security alert system shall be capable of being activated from the navigation bridge and in at least one other location.

Regulation XI-2/6 covers requirements for port facilities, providing among other things for contracting governments to ensure that port facility security assessments are carried out and that port facility security plans are developed, implemented and reviewed in accordance with the ISPS.

Other regulations in this chapter cover the provision of information to IMO, the control of ships in port (including measures such as the delay, detention, restriction of operations including movement within the port, or expulsion of a ship from port), and the specific responsibility of companies.

4.2.14 Chapter XII – Additional safety Measures for Bulk Carriers

This chapter includes structural requirements for bulk carriers over 150 metres in length. SOLAS Regulation XI-1/7 entered into force on 1 July 2016, requiring the carriage of an appropriate atmosphere testing instrument or instruments for enclosed space entry.

These portable testing instruments will not be used as part of personal protective safety equipment, but as part of the ship's equipment. They will be used to test enclosed spaces from the outside to make sure that they are safe to enter and will cover, as a minimum, the following gases:

- Oxygen.
- Flammable gasses or vapours.
- Carbon monoxide.
- Hydrogen sulphide.

Suitable means must be provided to calibrate them.

5. Collisions Regulations (COLREGs)

5.1 Introduction

The International Regulations for Preventing Collisions at Sea 1972 (COLREGs) is published by the IMO and sets out navigational rules to be followed by ships and other vessels at sea to prevent collisions between two or more vessels. The COLREGs are derived from a multilateral treaty. Although rules for navigating vessels inland may differ, the international rules specify that they should be as closely in line with the international rules as possible.

5.2 History

Prior to the development of a single set of international rules and practices, there existed separate practices, various conventions and informal procedures in all different areas of the world, making it difficult to provide a consistent approach to safety. There were even some contradictions that increased the risk of accidental collisions. Confusion was also common, with limited clarity on use of vessel navigational lights and markings.

With the advent of steam-powered ships in the mid-19th century, sailing vessel rules needed to be updated to include requirements for power driven vessel navigation. Sailing vessels are limited as to their manoeuvrability and, therefore, provisions needed to be put in place for this.

The timeframe for the Implementation of COLREGs is shown in figure 2.

1840	In London, the Trinity House drew up a set of regulations which were enacted by Parliament in 1846. The Trinity House rules were included in the Steam Navigation Act 1846, and the Admiralty regulations regarding lights for steam ships were included in
1850	English Maritime Law was adopted by the United States.
1863	A new set of rules was drawn up by the British Board of Trade, in consultation with the French government. By 1864, the Regulations had been adopted by more than thirty maritime countries.
1967	Thomas Gray, assistant secretary to the Maritime Department of the Board of Trade, wrote, the "Rule of the Road", a pamphlet that became famous for its well- known mnemonic verses.
1880	The 1863 Articles were supplemented with whistle signals and in 1884 a new set of international regulations was implemented.
1889	The United States convened the first international maritime conference in Washington, DC. The resulting rules were adopted in 1890 and effected in 1897.
1948	SOLAS International Conference made several recommendations, which became effective in 1954. Further recommendations were made at a SOLAS Conference in London in 1960 which became effective in 1965.
1972	The International Rules for Preventing Collisions at Sea were adopted as a convention by the IMO on 20 October 1972 and entered into force on 15 July 1977. This updated and replaced the Collision Regulations of 1960.

Figure 2: Timeframe for the Implementation of COLREGs.

Directed Learning

- Locate online, the IMO Convention on the International Regulations for Preventing Collisions at Sea, 1972 (COLREGs)
- Make a list of the lights and sound signal equipment which you would expect to find onboard a powered vessel of 110m LOA.
-

6. International Management Code for the Safe Operation of Ships and for the Pollution Prevention (ISM Code)

6.1 Introduction and History

The Townsend Thoresen owned Herald of Free Enterprise capsized on 6 March 1987 whilst leaving the Port of Zeebrugge, Belgium, killing 193 passengers and crew, figure 3 refers. This was the highest death-count of any peacetime maritime disaster involving a British registered ship since the sinking of the RMS Empress of Ireland in 1914. The vessel is shown in figure 5. Note that the bow doors are open.

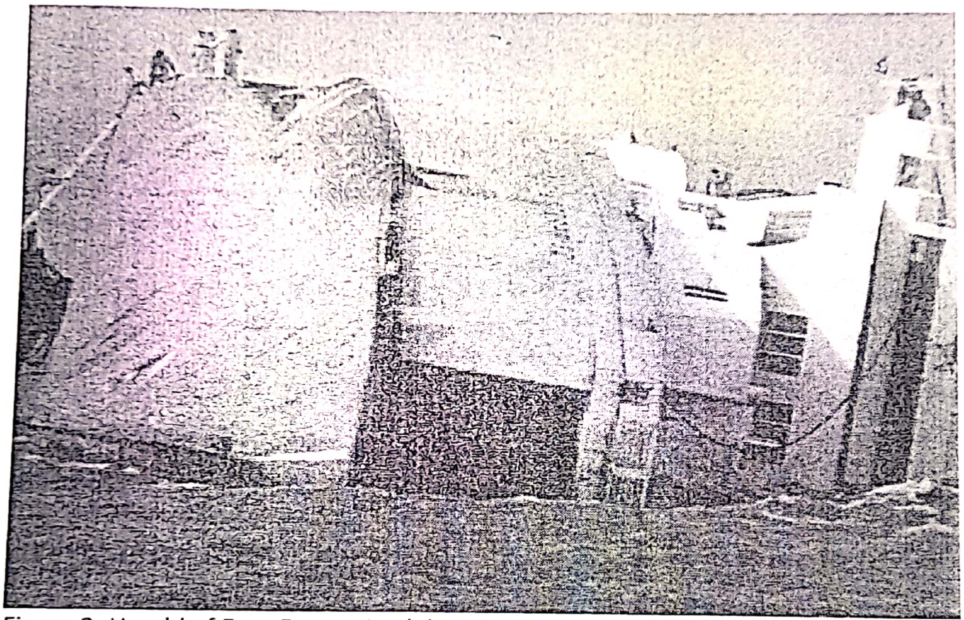


Figure 3: Herald of Free Enterprise (Photograph provided by MAIB (MAIB 1987)

The then modern 8-deck car and passenger ferry had been designed for rapid loading and unloading on the competitive cross-channel route, and there were no watertight compartments within the vehicle area. When the ship left harbour with her bow-door open, the sea flooded the car decks, and within minutes she was lying on her side in shallow water.

The immediate cause of the sinking was found to be negligence by the assistant boatswain, asleep in his cabin when he should have been closing the bow-doors. But the official enquiry placed more blame on his supervisors and a general culture of poor communication within Townsend Thoresen.

As a result of the incident, the IMO embarked on a mission to review the world's safety standards for fleets and implement a safety management system that could be adapted to any type of vessel, for any operation, for any location.

The IMO organised a select committee to complete this, and to document a Code that would provide a regulated system for vessels. And so, the "International Management Code for the Safe Operation of Ships and for Pollution Prevention", more commonly known as the "International Safety Management Code" (ISM Code) was born.

The ISM Code was adopted by the IMO by Resolution A.741(18) in 1993. SOLAS adopted the ISM Code and incorporated it into Chapter IX, making it mandatory. By 1998 much of the commercial shipping community was required to be in compliance with the ISM Code. As shown in figure 4, by 2002 almost all of the international shipping community was required to comply as shown in figure 4.

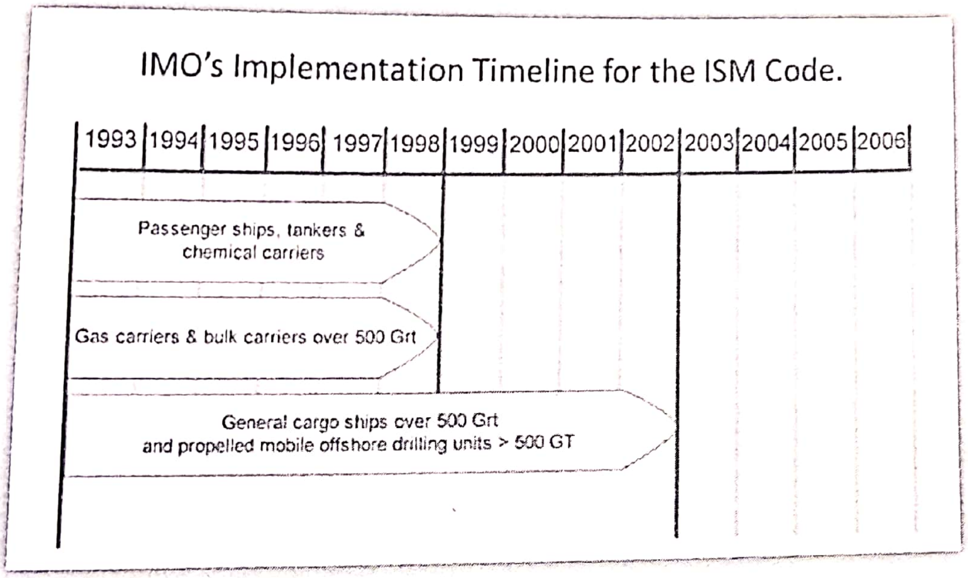


Figure 4 IMO's implementation timeline for the ISM Code.

6.2 Purpose of the Code

The ISM Code provides an international standard for the safe management and operation of ships and for pollution prevention.

The purpose of the ISM Code is to:

- Ensure safety at sea.
- Prevent human injury or loss of life.
- Avoid damage to the environment and to the ship.

In order to comply with the ISM Code, each ship class must have an effective Safety Management System (SMS). Each SMS consists of the following elements:

- Commitment from top management.
- A top tier policy manual.
- A procedures manual that documents what is done on board the ship, during normal operations and in emergency situations.
- Procedures for conducting both internal and external audits to ensure the ship is doing what is documented in the procedure's manual.
- A Designated Person Ashore (DPA) to serve as the link between the ships and shore staff and to verify the SMS implementation.
- A system for identifying where actual processes do not meet those that are documented and for implementing associated corrective action.
- Regular management reviews.

Another requirement of the ISM Code is for the ship to be maintained in conformity with the provisions of relevant rules and regulations and with any additional requirements which may be established by the company. The requirements of the ISM Code may be applied to all ships.

6.3 Breakdown of the Sections of the Code

The ISM Code 2014 is broken into 12 sections, with a brief description, as follows:

- **Section 1 – General:**
    - Definitions.
    - Objectives.
    - Application (may be applied to all ships).
    - Functional requirements of an SMS.
- **Section 2 – Safety and Environmental Protection Policy:**
    - Prevention of human injury or loss of life.
    - Avoidance of damage to the environment, in particular to the marine environment.
    - Avoidance of damage to property.
    - Management commitment.
    - Corrective action.
    - ALL personnel to be involved in potential hazard identification.
- **Section 3 – Company Responsibilities and Authority:**
    - Responsibilities.
    - Authority.
    - Required level(s) of competence.
    - Relevant qualifications and experience.
- **Section 4 – Designated Person(s):**
    - To ensure the safe operation of each ship and to provide a link between the company and those on board, every company, as appropriate, should designate a person or persons ashore having direct access to the highest level of management.
    - The responsibility and authority of the designated person or person should include monitoring the safety and pollution prevention aspects of the operation of each ship and ensuring that adequate resources and shore-based support are applied, as required.
- **Section 5 – Master's Responsibility and Authority:**
    - The company should clearly define and document the master's responsibility.
    - The company should ensure that the SMS operating on board the ship contains a clear statement emphasising the master's authority. The company should establish in the SMS that the master has the overriding authority and the responsibility to make decisions with respect to safety and pollution prevention and to request the company's assistance as may be necessary.
- **Section 6 – Resources and Personnel:**
    - Master's qualifications and other requirements.
    - Ensuring ships are manned with qualified and medically fit seafarers.
    - Procedures need to be available for familiarisation of seafarers with vessel and tasks.
    - Procedures for identification of training needs.
    - Procedures for effective communication, including ensuring that the SMS is written in a language that is understood by all.
- **Section 7 – Shipboard Operations:**
    - The company should establish procedures, plans and instructions, including checklists as appropriate, for key shipboard operations concerning the safety of the personnel, ship and protection of the environment. The various tasks should be defined and assigned to qualified personnel.
- **Section 8 – Emergency Preparedness:**
    - Requirement for company to identify potential emergency shipboard situations and establish procedures to respond to them.
    - Requirement for company to establish programs for drills and exercises.
    - Ensuring that the company (both ship and shore) can respond at any time to hazards, accidents and emergency situations involving its ships.

- **Section 9 – Reports and Analysis of Non-conformities, Accidents and Hazardous Occurrences:**
    - Requires procedures ensuring that non-conformities, accidents and hazardous situations are reported, investigated and analysed.
    - Requires implementation of corrective and preventive action.
- **Section 10 – Maintenance of Ship and Equipment:**
    - Identification of equipment and technical systems, the sudden operational failure of which may result in hazardous situations.
    - The safety management system to provide for specific measures aimed at promoting the reliability of such equipment or systems.
    - These measures to include the regular testing of stand-by arrangements and equipment or technical systems that are not in continuous use.
- **Section 11 – Documentation:**
    - Discusses requirements for the SMS.
    - Documents to be made available.
    - Document changes and obsolete documentation to be strictly controlled.
- **Section 12 – Company Verification, Review and Evaluation:**
    - Carrying out of internal audits.
    - Master's reviews of SMS.
    - Reviewing of the effectiveness of the SMS.

6.4 Documents of Compliance

6.4.1 Document of Compliance (DOC)

A Document of Compliance (DOC) shall be issued to a 'company' following an initial or renewal verification of compliance with the requirements of the ISM Code.

The company shall make available copies of the DOC to each office location and each ship covered by the Safety Management System (SMS).

On completion of the audit, to facilitate the review of the auditor's report prior to the issue of the full- term certificate, a DOC with validity not exceeding five months may be issued by the auditor.

6.4.2 Safety Management Certificate (SMC)

A Safety Management Certificate (SMC) shall be issued to a ship following an initial or renewal verification of compliance with the requirements of the ISM Code.
A copy of the SMC shall be available at the company's head office. The issue of an SMC is conditional upon:

- The existence of a full-term DOC (not interim), valid for that type of ship.
- The maintenance of compliance with the requirements of a classification society which meets the requirements of IMO Resolution A.237(65), as may be amended, or with the national regulatory requirements of an administration which provide an equivalent level of safety.
- The maintenance of valid statutory certificates.

On completion of the audit, to facilitate the review of the auditor's report prior to the issue of the full- term certificate, an SMC with validity not exceeding five months may be issued by the auditor.

6.4.3 Interim and Initial Verification

Interim verification for the issue of an interim DOC to a company and interim SMC for a ship is carried out as described in ISM Code Section 14. The interim verification for issuance of an interim DOC includes a review of the safety management system documentation.

Initial verification for the issue of a DOC to a company consists of the following steps:

A satisfactory review of any changes made to the documented SMS since the interim DOC was issued.

Verification of the effective functioning of the SMS, including objective evidence that the company's SMS has been in operation for at least three months on board at least one ship of each type operated by the company. The objective evidence shall include records from the internal audits performed by the company ashore and on board and the statutory and classification records for at least one ship of each type operated by the company.

The initial verification for issuing of an SMC to a ship consists of the following steps:

- Verification that the company holds a valid DOC applicable to the ship type and that the other provisions of paragraph 3.2.1.3 of the ISM Code are complied with. Only after on-board confirmation of the existence of a valid DOC can the verification proceed.
- Verification of the effective functioning of the SMS, including objective evidence that the SMS has been in operation for at least three months on board the ship. The objective evidence should also include records of the internal audits performed by the company.

6.4.4 Annual Verification or Renewal of the DOC

The purpose of these audits is, inter alia, to verify:

- The effective functioning of the SMS.
- That any modifications made to the SMS comply with the requirements of the ISM Code.
- That corrective action has been implemented.
- That statutory and classification certificates are valid and that no surveys are overdue.

The statutory and classification certification for at least one ship of each type identified on the DOC shall be verified.

6.4.5 Intermediate Verification or Renewal of SMC

The purpose of these audits is, inter alia, to verify:

- The effective functioning of the SMS.
- That any modifications made to the SMS comply with the requirements of the ISM Code.
- That corrective action has been implemented.
- That statutory and classification certificates are valid and that no surveys are overdue.

Directed Learning

- What were the incidents that led to (and a catalyst for) the development and implementation of the ISM Code? How could those incidents have been prevented if the ISM Code was in place at that time (consider various scenarios)? Discuss on the ~~forum.~~ below

7. International Ship and Port Facility Security Code (ISPS)

7.1 Introduction

The International Ship and Port Facility Security Code (ISPS Code) is an amendment to the SOLAS Convention, setting out minimum security arrangements for ships, ports and government agencies. Having come into force in 2004, it prescribes responsibilities to governments, shipping companies, shipboard personnel, and port/facility personnel to "detect security threats and take preventative measures against security incidents affecting ships or port facilities used in international trade".

7.2 Purpose and History

The IMO states that the ISPS Code is a comprehensive set of measures to enhance the security of the ships and port facilities, developed in response to perceived threats to ships and port facilities in the wake of the 9/11 attacks in the United Sates when the twin towers in New York were attacked.

The purpose of the Code is to provide a standardised, consistent framework for evaluating risk, enabling governments to offset changes in threat with changes in vulnerability for ships and port facilities through determination of appropriate security levels and corresponding security measures.

Development and implementation were sped up dramatically in reaction to the 9/11 (2001) attacks in New York, and the bombing of the French oil tanker "Limburg". The US Coast Guard, as the lead agency in the United States delegation to the IMO, advocated for the measure. The Code was agreed at a meeting of the 108 signatories to the SOLAS Convention in London in December 2002.

7.3 Objectives, Scope and Application

The Code is a two-part document describing minimum requirements for the security of ships and ports. Part A provides mandatory requirements, and Part B provides guidance for implementation.

The ISPS Code applies to ships on international voyages, of 500 GT and upwards, and also to port facilities that are serving such ships. The ISPS Code is part of SOLAS so compliance is mandatory for the 148 contracting parties to SOLAS.

The main objectives of the ISPS Code are:

- to detect security threats and implement security measures;
- to establish roles and responsibilities concerning maritime security for governments, local administrations, ship and port industries at the national and international level;
- to collate and promulgate security-related information; and
- to provide a methodology for security assessments to have in place plans and procedures to react to changing security levels.

7.4 Security Levels

There are three different security levels described under the ISPS Code and a description of these follows below. It should be noted that these levels are set not by the vessel but by the vessels flag state administration.

7.4.1 Security Level 1

Normal, the level at which the ship or port facility normally operates. Security Level 1 means the level for which minimum appropriate protective security measures shall be maintained in the day to day normal operation of the ship. This level is set when no conformed threat exists.

7.4.2 Security Level 2

Heightened, the level applying for as long as there is a heightened risk of a security incident. Security Level 2 means the level for which appropriate additional protective security measures shall be maintained for a period of time as a result of heightened risk of a security incident. Usually set when a threat is known but the target is unknown.

7.4.3 Security Level 3

Exceptional, the level applying for the period of time when there is the probable or imminent risk of a security incident. Security Level 3 means the level for which further specific protective security measures shall be maintained for a limited period of time when a security incident is probable or imminent. This level is set when both the threat and the target are known.

Setting Security Level 3 should be an exceptional measure applying only when there is credible information that a security incident is probable or imminent. Security Level 3 should only be set for the duration of the identified security threat or actual security incident. While the security levels may change from Security Level 1, through Security Level 2 to Security Level 3, it is also possible that the security levels will change directly from Security Level 1 to Security Level 3.

When the contracting government (Flag State Administration) set a security level they will consider the following:

- How likely is it that the threat is credible?
- To what level has the threat information been collaborated?
- How specific is the threat information and is the threat imminent?
- The possible consequences of the threat should it occur.

7.5 Requirements

The Code does not specify measures that each port and ship must take to ensure the safety of the facility against terrorism because of the many different types and sizes of these facilities. Instead it outlines "a standardised, consistent framework for evaluating risk, enabling governments to offset changes in threat with changes in vulnerability for ships and port facilities".

For ships the framework includes requirements for:

- Ship security plans.
- Ship security officers.
- Company security officers.
- Certain on-board equipment.

For port facilities, the requirements include:

- Port facility security plans.
- Port facility security officers.
- Certain security equipment.

In addition, the requirements for ships and port facilities include:

- Monitoring and controlling access.
- Monitoring the activities of people and cargo.