LOAD LINE CALCULATION FOR A TANKER VESSEL: (A CASE STUDY OF MT AILSA CRAIG 1 VESSEL)

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ABSTRACT

All vessels are required to be surveyed and marked with permanent load line in accordance with the International Convention on Load Lines, 1966 as modified in 1988. The principal purpose of load line calculation is to ensure that the ship always has sufficient reserve buoyancy and intact stability when proceeding to sea (Load Lines, 2002). Sufficient intact stability means compliance with standards recommended by the relevant flag state administration or those of classification societies taking into account the ship's size and type. A brief review of load line calculations, major features, and principal purposes of load lines for a tanker vessel were considered. Major conditions of freeboard application to all tanker vessels are discussed. The required load line calculation was carried out with a case study of MT AILSA CRAIG 1 of full displacement at summer 309,204MT. The following results were obtained using appropriate formulae; summer mark = 5204mm, tropical freeboard= 487mm above the summer mark, fresh water freeboard = 523.7mm above the summer mark, tropical freshwater =1011mm above summer mark, winter = 487mm below the summer mark and winter North Atlantic = 437mm below the winter mark. Note the diameter of the disc is 300mm, thickness of the lines is 25.mm and the distance from the centre of the disc to freeboard lines is 540mm. hence these values were calculated with respect to the load line rules and regulations.

Keywords: load line, tanker vessel, reserves buoyancy, freeboard, overloading, validation, semi-empirical

1. INTRODUCTION

The potential dangers of overloading a tanker ship have been recognized by the maritime world and international laws to be catastrophic. Taking an overloaded ship to sea has been a criminal offence in most of the developed part of the world like Britain for over one hundred years.

At the annual meeting of the Society of Naval Architects and Marine Engineers held in 1920, a paper on the Rules and Regulations for Freeboard was presented. At that time a compulsory load line bill which was confidently expected to become law was under consideration by Congress. In this paper the development of load line regulations was traced, and the report of the British Load Line Committee 1913-1915 was dealt with at some length, but since the United States Load Line Committee 1919-1921 had not completed its investigations, only a brief mention of its work could properly be made. Now that load line legislation is an accomplished fact, the load line question becomes important to the various shipping interests, and it was considered that a further contribution to our Transactions which 'dealt with the recent International Load Line Convention and the preparatory work for that conference would be of interest to the members of this Society. In order to provide the essential background for a proper understanding of the Convention it appears desirable to first make some reference to the work of various load line committees during the last decade, each of which contributed to laying the foundation for the International Load Line Convention, 1930.(Board of Trade 1906)

Ships designed specifically to carry bulk liquid cargoes are generally referred to as tankers. Tankers are commonly associated with the carriage of oil, but a wide variety of liquids are carried in smaller tank vessels and there are a considerable number of larger tank vessels dedicated to carrying chemicals in bulk.

Load Line is a special mark positioned amidships. All vessels of 24 meters and more are required to have this Load line mark at the centre of the length of summer load water line. The fundamental purpose of a Load Line is to allot a maximum legal limit up to which a ship can be loaded. By prescribing such limits, the risk of having the vessel sailing with inadequate freeboard and buoyancy can be limited. A vessel should have sufficient freeboard at all times. Any exceptions made will result to stability problem and create excessive stress on the ship's hull. This is where load lines play an important role, as it makes the task of detecting whether the vessel is over-loaded or not. (ICLL, 1966)

However, since the buoyancy and immersion of the vessel largely depends on the type of water and its density, it is not practical to define a standard freeboard limit for the ship at all times. For this reason, the convention has put regulations which divide the world into different geographical zones each having different prescribed load line. For example, a vessel sailing in winter on North Atlantic Ocean will have a greater freeboard than on a voyage in Tropical Zones and Fresh waters. Standard load line marking (This is applicable to all types of vessels). (Chemcode, 1971) And Timber load line markings (This is applicable to vessels carrying timber cargo) are the basic two types of load line markings. These marks shall be punched on the surface of the hull making it visible even if the ship side paint fades out. The marks shall again be painted with white or yellow color on a dark background / black on a light background.

1.1 PARTS OF LOAD LINE

Complete Load line markings consist of 3 vital parts:
Deck Line – It is a horizontal line measuring 300mm by 25mm. It passes through the upper surface of the freeboard.
Load Line Disc – It is 300mm diameter and 25mm thick round shaped disc. It is intersected by a horizontal line. The upper edge of the horizontal line marks the 'summer salt water line' also known as 'Plimsol Line'.
Load Lines – Load lines are horizontal lines extending forward and aft from a vertical line placed at a distance of 540mm from the centre of the disc. They measure 230mm by 23mm. The upper surfaces of the load lines indicate the maximum depths to which the ships maybe submerged in different seasons and circumstances.
S –Summer: - It is the basic freeboard line at the same level as the Plimsol Line. Other load lines are marked based on this summer freeboard line.
T –Tropical: - It is 1/48th of summer draft marked above the summer load line.
W –Winter: - It is 1/48th of summer draft marked below the summer load line.
WNA–Winter North Atlantic: - It is marked 50mm below the winter load line. It applies to voyages in North Atlantic (above 36 degrees of latitude) during winter months.
F–Fresh Water: - It is the summer fresh water load line. The distance between S and F is the Fresh Water Allowance (FWA).
TF – Tropical Fresh Water: - It is the fresh water load line in Tropical. It is marked above the T at an amount equal to FWA.
Timber Load Line Markings
Ships engaged in the timber deck cargo trade are required to have a special set of Load lines known as the Timber Load lines. Such vessels shall comply with the Code of Safe Practices for Ships Carrying Timber Deck Cargo in construction and other requirements obtaining greater reserve buoyancy and lesser summer freeboard.
Timber cargo vessels will have a second set of Load Lines marked similar to the standard load lines positioned 540mm abaft the centre load line disc.
The letter marking of the timber load line are different and are prefixed by 'L' meaning 'Lumber'.
LS – Lumber summer: - Its upper edge marks the summer salt water timber load line. It is situated at a specified level above the Plimsol line.
LW – Lumber Winter: - It is 1/36th of the lumber summer draft below LS.
LT – Lumber Tropical: - It is 1/48th of the lumber summer draft above LS.
LWNA – Lumber Winter North Atlantic: - It is at the same level as WNA.
LF – Lumber Fresh water: - It is situated above the LS by an amount equal FWA.
LTF – Lumber Tropical Fresh Water: - It is positioned above LT by an amount equal to FWA.

2.0 RESEARCH METHODOLOGY

There are three essential methods adopted for this type of research. These are: Analytical method, experimental method, instrumentation of test equipment method. In this work, the analytical method is used.

MATERIAL AND METHODS

2.1 Analytical Method

This method can also be known as an approach which is rational, questioning, testing, detailing, searching, organized, exact, precise, expository and interpretative. This method applies the use of algebra and other methods of mathematical analysis. This involves the use of mathematical equations which are relevant to achieve the required load line and also enable the ship have a reserve buoyancy to remain afloat.

In order to calculate or assign a load line for a tanker vessel, a case study of M/T AILSA CRAIG1 with the following ship particulars was used:

Table 1: Ship particulars of MT AILSA CRAIG 1

Length(LOA/LBP)	335.20/322.20m
Breadth	55.0m
Depth	28.55m
Total height	65.51m
Parallel body	Loaded:194.05M/Ballast:175.55m
Max. draft(summer/tropical)	19.467M/19.872M
Gross/Net tonnage	150,340/82,795 tons
Deadweight(summer)	274,990MT (270,647LT)
Displacement full load (summer/trop)	309,204/316367 MT
Light weight	34,214MT

Details of the ship are contained in the appendix.

However, in order to achieve the required calculation the followings are necessary from the point of view of this research: ship type, ship stability and zones and seasons.

2.2 Ship Type

Basically, there are two types of ship - type 'A' ship and type 'B' ship

2.2.1 Type 'A' Ship

These are designed primarily for the carriage of liquid cargoes in bulk, such as tankers, chemicals carriers, LPG and LNG carriers.

Type 'B' Ship are ships which do not satisfy the condition of type 'A' ship. In the case of type 'B' ship, the sea water will run into the damaged compartment(s) resulting in an increase in displacement and reduction in the freeboard Type 'A' ships has the following features;

- Is designed to carry only liquid cargoes in bulk.
- Has a high integrity of the exposed deck with only small access openings to cargo compartments, closed by watertight gasket covers of steel or equivalent material.
- Has a low permeability of loaded cargo compartments.

A type 'A' ship of over 50M in length to which a freeboard less than type B has been assigned, when loaded in accordance with the assumed initial condition of loading, can be able to withstand any loading compartment(s) with an assumed permeability of 0.95, consequent upon damage conditions specified, and shall remain afloat in a satisfactory condition of equilibrium. In such a ship the machinery space shall be treated as a floodable compartment, but with a permeability of 0.85. (Peter Y. and John K., 2001)

2.2.2 Loading Condition before Flooding

The initial condition of loading before flooding shall be determined as follows;

a) The ship is loaded to its summer load waterline on an imaginary even keel.
b) When calculating the vertical centre of gravity, the following principles apply;

- Homogeneous cargo is carried.
- All cargo compartments intended to be partially filled shall be considered fully loaded except that in the case of fluid cargoes. Such cargo shall be treated as 98% full.
- If the ship is intended to operate at summer waterline with empty compartments, such compartments shall be considered empty provided the height of the centre of gravity so calculated is not less than that obtained at 98% full.
- At an angle of heel of not more than 5^0 in each compartments containing liquid, as prescribe in (ii) above except that in the case of compartments containing consumable fluids, the maximum free surface effect shall be taken into account.
- Weight shall be calculated on the basis of the following values for specific gravities as follows: salt water – 1.025; fresh water – 1.000; Oil fuel – 0.950; diesel oil – 0.900; lubricating oil – 0.9000.

2.2.3 Loading Condition after Flooding

The condition of equilibrium after flooding shall be considered as satisfactory provided that;

a) The final waterline after flooding, taking into account sinkage, heel and trim, is below the edge of any opening through which progressive down flooding may take place.
b) If pipes, ducts or tunnels are situated within the assumed extent of damage penetration as defined by the transverse extent of damage, arrangement shall be made so that progressive flooding cannot thereby extend to compartments other than those assumed to be floodable in the calculation for each case of damage.
c) The angle of heel due to unsymmetrical flooding does not exceed 15^0. If no part of the deck is immersed, an angle heel of up to 17^0 may be accepted.
d) The metacentric height in the flooded condition is positive.
e) The administration is satisfied that the stability is sufficient during intermediate stage of flooding.

Note: MCA requires that the GM must be at least 50mm.

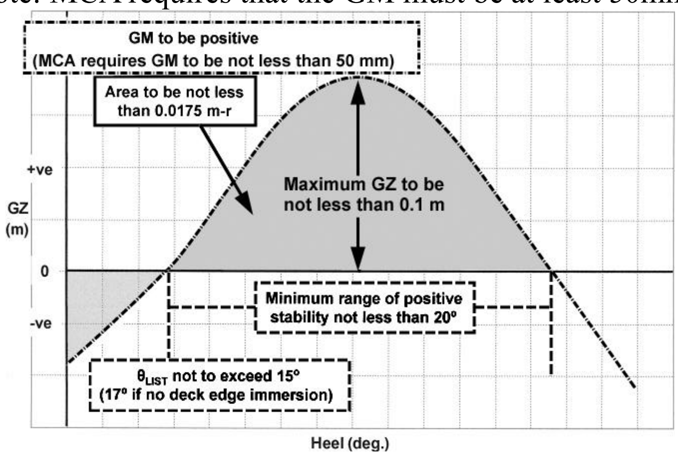


Figure 1 GZ curve for stability analysis

Based on the definitions of type ‘A’ and type ‘B’, I will be considering a type ‘A’ ships in this work.

2.2.4 Terms Associated With Loadline

However, in designing a loadline, the following parameters corrections are needed:

Block coefficient C_B:- the standard block coefficient is 0.68. If C_B is greater than this value, the freeboard must be increases with corresponding value. This increase can be achieved by;

$$\text{Tabular freeboard } \times \frac{C_B+0\cdot 68}{1\cdot 36} \quad (1)$$

This is due to the corresponding increase in the underwater volume, so freeboard must be increased in order to maintain the reserve buoyancy which amounts to the same percentage of the greater displaced volume as it would have been had when the C_B is 0.68.

$$\text{If } C_B > 0{\cdot}68$$

$$C_B = \frac{\Delta}{L \times B \times d} \qquad 2$$

Correction for C_B is obtained as; 3

$$C_B = \frac{C_B + 0 \cdot 68}{1 \cdot 36}$$

Where: $\Delta = the\ moulded\ displacement\ at\ a\ draft\ d$

L = freeboard length

B = breadth

Also, coefficient of fineness is given as, $C = \frac{35 \times \Delta}{L \times B \times d}$ 4

Depth of Freeboard Correction

$$D = d + T\left(\frac{L - S}{L}\right) \qquad 5$$

Where; T = Mean thickness of the exposed deck clear of deck opening
S = Total length of superstructure

Depth Correction

The standard ship has L/D ratio of 15. If the L/D ratio is less than 15, which is usually the case, the freeboard is increased. If the L/D ratio is greater than 15, then the freeboard may be reduced provided that the ship has an enclosed superstructure covering at least 0·6L amidship, a complete trunk or a combination of detached enclosed superstructures and trunks which extends all fore and aft. (Group of Authorities, 1980)

Correction factor = $\left(D - \frac{L}{15}\right) R$ 6

Where R is 250, if length of the ship is 120m, and above.

But, if length of ship is less than 120m, load line rule states that R = $\frac{L}{0{\cdot}48}$ 7

Where: $\frac{L}{15}$ = standard depth

Consider the following ships shown below;

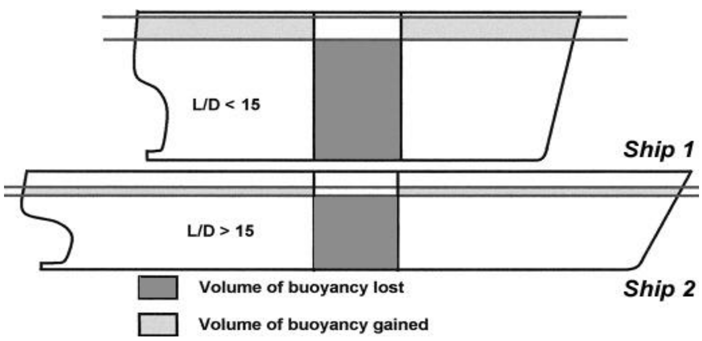


Figure 2 comparison of sinkage of two damaged ships

If the ships in fig.2 above are considered, where an amidships compartments extending the full depth of the hull were flooded due to damage, ship '1' would experience greater sinkage and loss of freeboard than ship

2, since in each case, the volume of buoyancy that has been lost must be required by the remaining intact parts of the hull.

Sheer Correction
Sheer is defined as being the curvature of the freeboard deck in fore and aft direction.

Sheer correction = $\frac{Difference}{16}\left(0 \cdot 75 - \frac{5}{2L}\right)$ 8

Advantages of sheer include;

- Greater reserve buoyancy at the end of the ship, particularly forward, ensuring good lift in a head/following sea.
- Reduces water shipped on deck
- Reduces risks of foredeck being submerged after collision, thus, improving survivability in the damaged condition and helps to maintain an acceptable angle of heel at which progressive down flooding takes place.

Superstructure Correction: Enclosed superstructures of a significant height are important in providing reserve buoyancy above the freeboard deck.

Freeboard deductions are allowed for effective enclosed superstructure length as a proportion of the ship's freeboard length.

Regulation 33 defines the standard height of superstructure as given in the table below.

Table 2: Superstructure Deduction

	STANDARD HEIGHT (m)	
L(m)	Raised Quarterdeck	All other superstructure
30 or less	0· 90	1· 80
75	1· 20	1· 80
125 0r more	1· 80	2· 30

Trunk:-A trunk may be considered as a structure having equivalent bulkhead strength as that of a superstructure that opens directly into the space below the freeboard deck and having an average width of at least 60%of the ship at the position in which they are situated.

Correction Factor
Height of trunk = h+ $h_c - h_{rc}$ 9
h = actual height of the trunk
h_c = actual hatch coaming height
h_{rc} = required hatch coaming height
$h_{cmx} = h_{rc}$
Bow Height Correction
When the vessel is floating to the summer load at its design trim, a minimum allowable bow height must be maintained. To ensure that the minimum bow height requirements are met, the assigned summer freeboard for a vessel must be increased.
The following formulae are used to determine the minimum bow height (H_B) measured at the forward perpendicular at the summer waterline.

$$H_B = 56L\left(1 - \frac{L}{500}\right) \times \frac{1{\cdot}36}{C_B + 0{\cdot}68}\,\text{mm, if } L < 250m \qquad 10$$

$$H_B = 7000 \times \frac{1{\cdot}36}{C_B + 0{\cdot}68} \text{mm, if } L \geq 250\text{m}$$

$$H_B = 0 \cdot 672L\left(1 - \frac{L}{16400}\right) \times \frac{1{\cdot}36}{C_B + 0{\cdot}68} \text{mm, if } L < 820ft$$

$$H_B = 275 \cdot 6 \times \frac{1{\cdot}36}{C_B + 0{\cdot}68} \text{mm, if } L \geq 820\text{ft}$$

Where:

L is the length of the vessel in feet or meters

C_B is block coefficient which is to be taken as not less than 0·68

Actual Bow Height: To determine the actual bow height of a vessel, the following may be considered;

- Summer freeboard: this includes the stringer plate thickness on vessels to which timber freeboards are assigned the summer freeboard should relate to the normal load waterline and not the timber load waterline.
- Sheer on the freeboard deck provided the sheer extends for 15% of the length of the vessel abaft the forward perpendicular.
- Design trim of the vessel (at the FP) can be credited, however, a restriction for the maximum draft.

Deckline Correction: Where the actual depth to the upper edge of the deck line is greater or less than D_f, the difference between the depth is to be added to or deducted from the freeboard.

Straight line chamber

Deck line correction= $C\left(\frac{S_s + t}{I_c + t}\right)$ 11

Parabola chamber

Deck line correction = $\left(\frac{I_C + S_s + t}{I_C}\right)^2 - C$ 12

Where:

C = camber$(mm \text{ or } {}^{o}m)$

I_C = Length of camber in the moulded half breadth of the vessel

$$S_s \quad = Sheer\ strake\ thickness$$

2.3 Seasonal, Fresh-Water and Timber Freeboard Marks

Zones and Season: The oceans of the world are divided under the regulations into various zones and seasons according to the probable severity of the weather. In certain areas and times of the year where during the winter more severe weather may be expected, the vessel is required not to load as deeply as is permitted in the summer. These areas are the seasonal winter zones.

Winter is traditionally the fourth of the four major seasons, typically regarded as being from December 23 to march 20 in continental regions of the Northern hemisphere or the month of June , July and August in the Southern hemisphere. It is the time when the sun is lowest in the sky, resulting in short days, and the time of the year when the atmospheric temperature for the region is lowest.

During other times of the year, the summer mark at the center of the ring is applicable. Other zones, roughly corresponding to the temperate zone in the northern and southern hemisphere, are permanent summer zones under the regulations where summer mark is applicable in the years around. Another

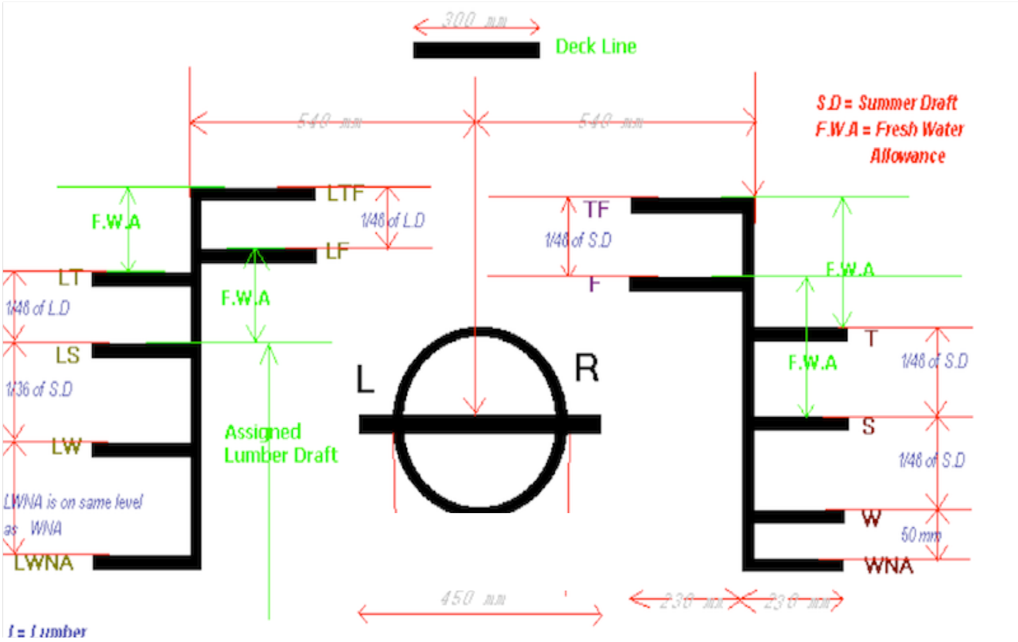


FIG 3 Load Line Marks

A typical set of freeboard marks is shown in Figure **S** is the summer watermark for water of 1.025t/m3 density. It is determined by the Department for Transport (DfT) Tabulated Freeboard values, based on the vessel's freeboard length and various corrections. It is placed at the summer load water line (draft moulded).

Where:
T is the Tropical watermark and is 1/48 of the summer load draft *above* the S mark.
F is the Fresh watermark and F watermark is W/(4×TPC_{sw}) *or* 1/48 of the Summer load draft *above* the S mark. W and TPC_{sw} are values applicable at the summer load water line.
TF is the Tropical Fresh watermark and is the (T+F) marks *above* the S mark.
W is the winter watermark. It is 1/48 of the summer load draft *below* the S mark.
WNA is the Winter North Atlantic watermark. It is *not* marked on the ship sides for a vessel equal to or more than 100 m freeboard length. If the vessel is less than 100 m floodable length, then the WNA is placed 50mm *below* the W mark. Hence WNA is (W-50mm)
The loadlines and freeboard deck line must be painted in *white* or yellow on a dark background, or in black on a light coloured background. The letters on each side of the load Line disc, indicating the assigning authority, should be 115 mm in height and 75 mm in width.

Seasonal allowances depend on a DfT World zone map (at rear of their freeboard Regulations) and on three factors, these three factors being:

- Time of year.
- Geographical location of the ship.
- LBP the ship, relative to a demarcation value of 100 m.

2.3.1 Freeboard formulas:

- Summer load draft (S) =Freeboard tab. + CB corr. + Depth corr. + ded.for superstructure + sheer corr.

- Tropical Freeboard (T) = $\frac{Summer\ load\ draft}{48}$ Or $\frac{SLWL}{48}$ $above\ S\ mark$ 13
- Fresh watermark (F) = $\frac{Summer\ load\ draft}{48}$ or $\frac{w}{4 \times TPC}$ $above\ S\ mark$ 14
- Tropical Fresh watermark (TF) = (T+F) above the S mark 15
- Winter watermark (W) = $\frac{Summer\ load\ draft}{48}$ or $\frac{SLWL}{48}$ $below\ the\ S\ mark$ 16
- Winter North Atlantic watermark (WNA) = 50mm below W or W-50mm 17
- Lumber Tropical watermark (LT) = $\frac{Summer\ timber\ load\ draft}{48}$ $above\ the\ LS\ mark$ 18
- Lumber Fresh watermark (LF) = W/ (4×TPC_{SW}) = $\frac{Smmer\ load\ timber\ load\ draft}{48}$ 19
- Lumber Tropical Fresh watermark (LTF) = (LT+LF) marks above LS mark 20
- Lumber winter watermark (LW) = $\frac{Summer\ load\ timber\ load\ draft}{36}$ $below\ the\ LS$ 21
- Lumber winter North Atlantic (LWNA) =WNA=W-50mm 22

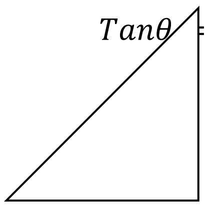
2.4 Ship Stability

Ship stability is the condition of being stable or in equilibrium. It is also the resistance to change.

2.4.1 Principle of ship Stability

The following are principles of ship stability;

- **Gravity**: This is the force exerted on a body drawing towards the centre of the earth. It acts through the centre of gravity of the body (G).
- **Buoyancy:** An object or ship floating in liquid displaces a volume of liquid equal to the volume of the submerged body. During the immersion, the body (ship) exerts an opposite force to the liquid which is opposite to the force of gravity exerted by the centre of the earth. This force exerted by the ship is called the buoyant force.
- **Archimedes Principle**: This brings about the upthrust which states that objects (ship) submerged in water or fluid is buoyed up by a force which is equal to the weight it displaces.
- **Displacement**: Weight of ship equal to weight of water displaced by volume of underwater body of ship.
  Displacement depends on density of the water (salt or fresh).



$Tan\theta = \frac{GZ}{MZ}$

$\theta = tan^{-1}\left(\frac{GZ}{MZ}\right)$

Fig 4 Stability Triangle

Where θ is the angle of heel.
Positive: M above G
Neutral: M and G same position
Negative: M below G
Fig. A, stable condition, G is below M and Fig. B, Unstable condition, G is above M.

2.4.2 Angle of Heel, Angle of Loll and Angle of List

When a ship with negative initial metacentric height is inclined to a small angle, the righting lever is negative, resulting in a capsizing moment. This effect is shown in fig B above and can be seen that ship will tend to heel further. (Rawson K.J. and Tupper E.C., 2001)

Angle of Loll: If by heeling further, the centre of buoyancy can move out far enough to lie vertically under

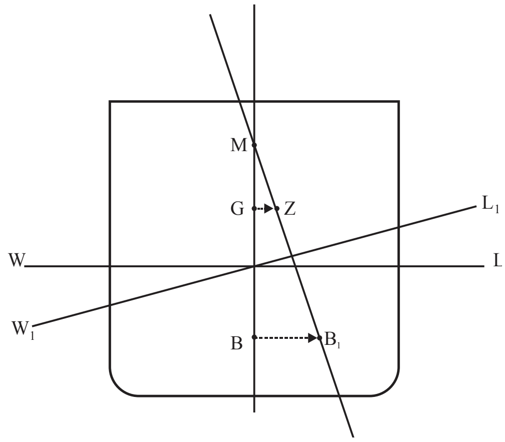


Fig 5 Determination of center of buoyancy

G the centre of gravity as shown in the fig. below, the righting lever and thus the righting moment will be zero. The angle of heel at which this occurs is known as the **angle of loll.** (Society of Naval Architects and Marine Engineers, 1988)

Hence, Angle of loll may be defined as the angle to which a ship with negative initial metacentric height will lie at rest in still water. If the ship should have to be inclined at an angle greater than the angle of loll, as shown in Fig. C above, the righting lever will be positive, giving a moment to return the ship to the angle of loll.

When the vessel is wall-sided between the upright and inclined waterlines, the GZ may be found using the formula;

$$GZ = Sin\theta\left(GM + \frac{1}{2}BMtan^2\theta\right) \qquad 23$$

At the angle of loll;

GZ= 0

∴ either sinθ= 0

Or $\left(GM + \frac{1}{2}BMtan^2\theta\right) = 0$

sinθ = 0

$\theta = 0$

But the angle of loll cannot be zero, therefore;

$$\left(GM + \frac{1}{2}BMtan^2\theta\right) = 0 \qquad 24$$

$$\frac{1}{2}BMtan^2\theta = -GM$$

$$tan^2\theta = \frac{-2GM}{BM} \qquad 25$$

$$\tan\theta = \sqrt{\frac{-2GM}{BM}}$$

The angle of loll is caused by the negative GM, therefore;

$$\tan\theta = \sqrt{\frac{-2(-GM)}{BM}} \qquad 26$$

$$\tan\theta = \sqrt{\frac{2GM}{BM}}$$

$$\theta = tan^{-1}\left(\sqrt{\frac{2GM}{BM}}\right) \qquad 27$$

Where $\theta = Angle\ of\ loll$

GM = A negative initial metacentric height

BM = The BM when upright

2.4.3 Angle of List

'G' the centroid of the loaded weight, has moved off the centre line due to a shift of cargo or bilging effects, says to the portside of the ship or starboard side.GM is positive when the G is below 'M'. In fact, GM will increase at the angle of list compared to GM when the ship is upright. (Tupper, 2002)
In heavy weather conditions, the ship will roll about this fixed angle of list, say 3^0 P, but will stop at 3^0 S. to bring the ship back to upright, load weight on the other side of the ship, for example if she list 3^0P add weight onto starboard side of ship. (ICLL, 1966)

RESULTS AND FINDINGS

The vessel Ailsa Craig I is a foreign going vessel, and with the obtained load line results below it is clear that the vessel can safely move from one region of the world to another at different seasons. The results show that least loading will be done in Tropical Fresh water regions and maximum loading is expected in Winter North Atlantic.

Table 3 Freeboard Marks of Ailsa Craig I ship

LOADLINE MARKS	FORMULAR	VALUES (mm)	MOULDED DEPTH (mm)	FREE BOARD (mm)	DRAFT OBTAINED	% of Freeboard
Freeboard deduction		1070				
Summer	Freeboard ded + Ship correction	5204	28571	5204	23367	18.2
Tropical	D/48 above S	487	28571	4717	23854	16.5
FWA	$\frac{\Delta}{4TPC}$	523.7	28571	4680	23891	16.0
TF	T + F	1011	28571	4193	24378	14.7
W	D/48 below S	487	28571	5691	22880	19.9
WNA	W-50mm below W	437	28571	6128	22443	21.4

$$\text{For summer } \frac{S}{28571} x\ 360 = \frac{5204}{28571} x\ 360 = 65.6^0$$

$$\text{For T} = \frac{T}{38571} x\ 360\ \frac{4717}{28571} x\ 360 = 59.0$$

$$\text{For FWA} = \frac{FWA}{28571} x\ 360 = \frac{4680}{28571} x\ 360 = 59.0$$

$$\text{For TF} = {}^{TF}/_{28571}\ x\ 360 = \frac{4193}{28571} x\ 360 = 52.8$$

$$\text{For W} = {}^{W}/_{23367}\ x\ 360 = \frac{5691}{28571} x\ 360 = 71.7$$

$$\text{For WNA} = \frac{WNA}{28571}\ x\ 360 = \frac{6128}{28571} x\ 360 = 77.$$

Calculations for KB, KM and BM at a different draft due to change in water lines.

Table 4 Result of BM, KB and KM

Load line marks	**Draft (m)**	**BM (m)**	**KB (m)**	**KM (m)**
Summer	23.367	10.79	11.68	22.47
Tropical	23.854	10.57	11.93	22.57
FWA	23.891	10.55	11.95	22.50
TF	24.378	10.34	12.19	22.53
W	22.880	11.02	11.44	22.46
WNA	22.443	11.23	11.22	22.45

$$KB = \frac{d}{2},\ BM = \frac{B^2}{12Xd},\ KM = KB + BM$$

$$KB_S = \frac{d_S}{2} = \frac{23.367}{2} = 11.68m$$

$$BM_S = \frac{B^2}{d_s} = \frac{55^2}{12x23.367} = 10.79m$$

$$KM_S = KB_s + BM_s = 22.47m$$

$$KB_T = \frac{d_T}{2} = \frac{23.854}{2} = 11.93m$$

$$BM_T = \frac{B^2}{12xd_T} = \frac{55^2}{12x23.854} = 10.57m$$

$$KM_T = KB_T + BM_T = 22.50$$

$$KB_{FWA} = \frac{d_{FWA}}{2} = \frac{23.891}{2} = 11.95m$$

$$BM_{FWA} = \frac{B^2}{12xd_{FWA}} = \frac{55^2}{12\ x23.891} = 10.55m$$

$$KM_{FWA} = KB_{FWA} + BM_{FWA} = 22.50m$$

$$KB_{TF} = \frac{d_{TF}}{2} = \frac{24.378}{2} = 12.19m$$

$$BM_{TF} = \frac{B^2}{12\ x\ d_{TF}} = \frac{55^2}{12\ x24.378} = 10.34$$

$$KM_{TF} = KB_{TF} + BM_{TF} = 22.\ 53m$$

$$KB_W = \frac{d_W}{2} = \frac{22.880}{2} = 11.44m$$

$$BM_W = \frac{B^2}{12d_w} = \frac{55^2}{12\ x22.880} = 11.02m$$

$$KM_W = KB_W + BM_W = 22.46m$$

$$KB_{WNA} = \frac{d_{WNA}}{2} = \frac{22.443}{2} = 11.22m$$

$$BM_{WNA} = \frac{B^2}{12\ xd_{WNA}} = \frac{55^2}{12\ x\ 22.443} = 11.33m$$

$$KM_{WNA} = KB_{WNA} + BM_{WNA} = 22.45m$$

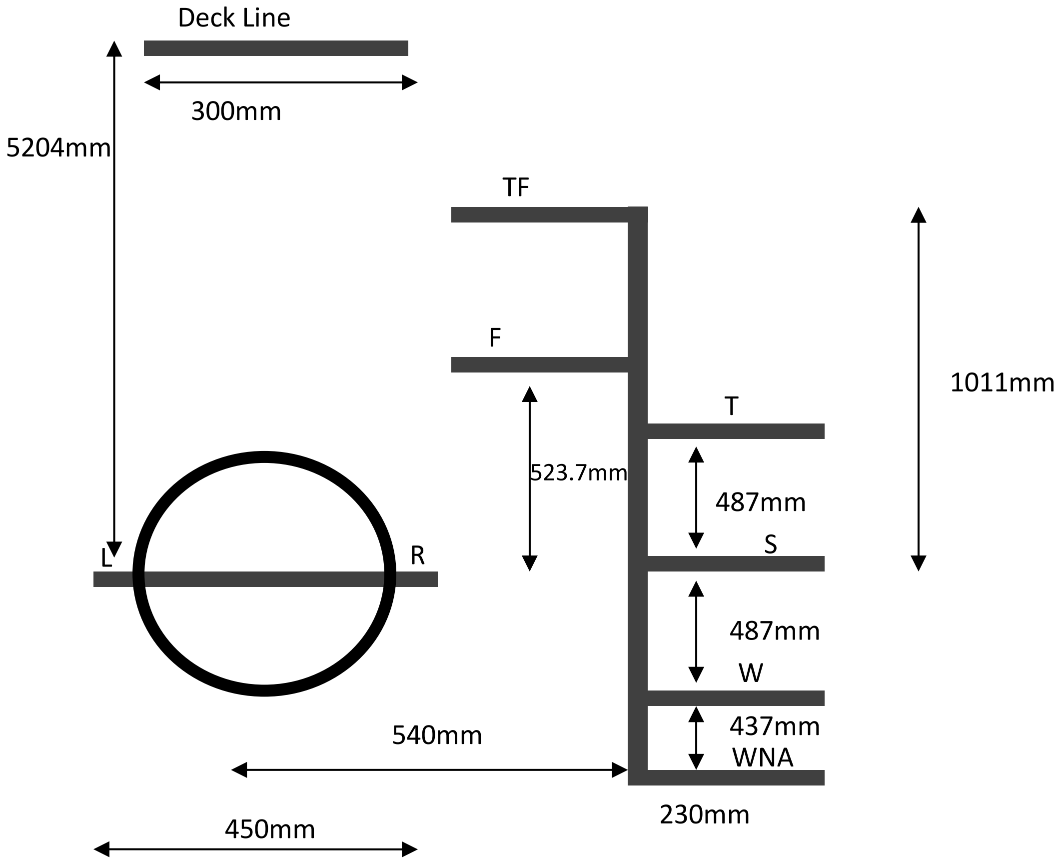


Figure 6: Freeboard Marks of Ailsa Craig 1 Ship
ALL LINES ARE 25MM IN THICKNESS

3.1 SUMMARY

The design of load line marks on a vessel is a complex and important practice. Over some decades ago, records of ships flooding and damages were made. This is due to some errors resulting from the computation of freeboard or load line marks.

In order to correct or reduce these loss and expenses, the idea of freeboard computation becomes necessary. Every sailing ships needs to be surveyed so as to know if it has the necessary loadline marks marked on the body at the mid ship region. This is because sailing ships travel from on geographical area to another, from one water body to another and as well travel in summer winter, tropical season to another.

In this, project, some mathematical models or equations were discussed which will provide adequate knowledge of load line to the designer and provide adequate and reserve buoyancy to the ship and to keep the ship afloat irrespective of the weather condition.

Also, the design of freeboard is obtained from the correction of ship's hull form, such as, the tabulated freeboard reduction, block coefficient correction, depth correction sheer correction and superstructure deduction.

3.2 CONCLUSION

In order to design an adequate freeboard that can withstand and remain afloat and largely dry on its decks under any weather condition, I ensured that all the necessary corrections in regards to the vessel's safety were made and requirement were also met. The required load line marks are represented in table and pie chart as shown in chapter four.

3.3 RECOMMENDATION

The calculation and design of freeboard of tanker ship is very important in order for the ship to have reserve buoyancy and remain afloat at any sea weather condition for the safety of the crew (officers and cadet) and of the ship.

Safety of the ship by

1. Avoiding grounding,
2. Avoiding overloading
3. Avoiding damage condition
4. Having adequate structural strength
5. Having enough reserve buoyancy
6. Meet the regulatory standard

I hereby recommend that before any ship whether of type 'A' or 'B' be cleared to sail in both international and inland water ways, the regulatory body should ensure that the ship meets all the standard and calculation above.

References

Chemcode. (1971). *Code for the construction and Equipment of Ships Carrying Dangerous in Bulk Resolution A. 212(XII).* London: IMCO.

Clark, I. C. (2002). *The Management of Merchant Ship Stabilities, Trim and Strenght.* London: Nautical Institute.

Group of Authorities. (1980). *Ship Design and Constructiion.* New York: Society of Naval Architects and Marine Engineers.

Harold and Norton F. (1942). *Principles of Naval Architecture.* New York: SNAME.

ICLL. (1966). *International Convention on Load Lines.* London: IMCO.

Peter Y. and John K. (2001). *ship stability third edition.* London: Dr C.B.Barrass.

Rawson K.J. and Tupper E.C. (2001). *Basic Ship theory.* Oxford: Butterworth Heinemann.

Society of Naval Architects and Marine Engineers. (1988). The Coastwise Load Line Act of 1935. *Principles of Naval Architects*, Public law 93-115.

Tupper, E. (2002). *Introduction to Naval Architecture.* Oxford: Butterworth Heinemann.

Vassalos D, Hamamoto M, Papanikolau A and Molyneux D. . (2000). *Contemprory ideas on ship stability.* Oxford: Elsevier.