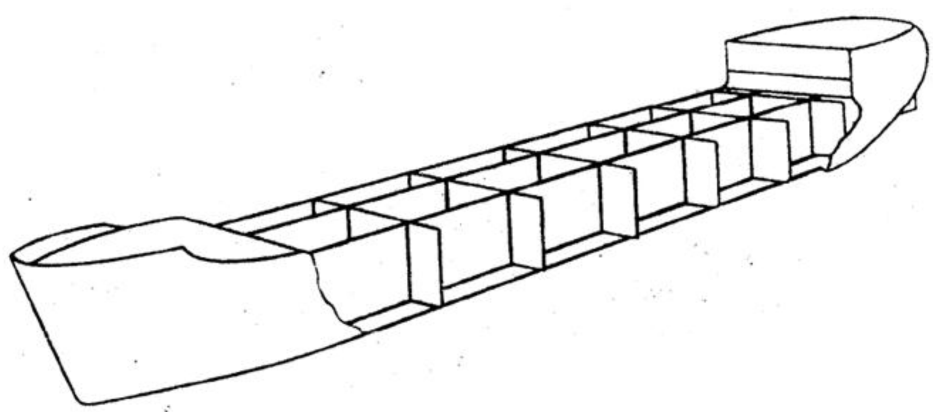
Basic Ship Theory - Module V

Subdivision

All types of ships and boats are subject to the risk of sinking if they lose their watertight integrity, whether by collision, grounding or internal accident such as an explosion.

Such accidents are frequent enough in practice that **some degree of protection against the effects of accidental flooding is an essential.**

The most effective protection is provided by **internal subdivision** by means of watertight transverse and/or longitudinal bulkheads, and by some horizontal subdivision— double bottoms in commercial ships and watertight flats in naval vessels.



The is a need for an internal watertight subdivision of the hull in compartments to resist the effect of damage (breach) of the hull, or loss of water tightness, and the subsequent flooding is in itself evident.

There are many **uncertainties** in providing adequate subdivision.

- The location and extent of damage to be protected against is unknown in advance.
- The amount, type and location of cargo and liquids in the ship varies both during and between voyages.
- The designer cannot be sure that corrective measures that might be followed by the ship's officers in an emergency will be taken or that hazardous steps might be adopted by mistake.

subdivision **adds to the cost of the ship** and may interfere with its ability to perform its function economically. In fact, a ship so ideally compartmented as to be virtually unsinkable might be of no economic or military value whatsoever.

Subdivision involves a compromise between safety and cost. -- development of national and international standards of what is considered acceptable.

- **The bulkhead deck** is the uppermost weathertight deck to which transverse watertight bulkheads are carried.

Fundamental Effects of damage:-

If the shell of *a* ship is damaged so as to open one or more internal spaces to the sea, leakage will take place between the sea and these spaces until stable equilibrium is established or until the ship sinks or capsizes.

It is impractical to design a ship to withstand any possible damage due to collision, grounding or military action. The degree to which a vessel approaches this ideal is the true measure of its safety.

Effects of flooding:

(a). Sinkage (Change of draft). The draft will change so that the displacement of the remaining unflooded part of the ship is equal to the displacement of the ship before damage less the weight of any liquids which were in the space opened to the sea.

(b) Change of trim. The ship will trim until the center of buoyancy of the remaining unflooded part of the ship lies in a transverse plane through the ship's center of gravity and perpendicular to the equilibrium waterline.

(c) Heel. If the flooded space is unsymmetrical with respect to the centerline, the ship will heel until the center of buoyancy of the remaining unflooded part of the ship lies in a fore-and-aft plane through the ship's center of gravity and perpendicular to the equilibrium waterline (*If the in the flooded condition is negative, the flooded ship will be unstable in the upright condition, and even though the flooded space is symmetrical, the ship will either heel until a stable heeled condition is reached or capsize).* Trim and heel may result in further flooding through immersion of openings in bulkheads, side shell or decks (downflooding).

(d) Change of Stability. Flooding changes both the transverse and the longitudinal stability. The initial metacentric height is given by, GM = KB + BM – KG.

- When a **ship is flooded, both KB and BM will change**.
- Sinkage results in an increase in KB. If there is sufficient trim, there may also be an appreciable further increase in KB.

- (BM tends to decrease because of the loss of the loss of moment of inertia of the flooded part of the waterplane. However, sinkage usually results in an increase in the moment of inertia of the undamaged part of the waterplane, thus tending to compensate for the loss. Also, trim by the stern usually increases the transverse moment of inertia of the undamaged waterplane, and vice versa).
- For ocean-going ships of usual proportions and arrangements, the combined effect of these factors is usually a net decrease in GM.

(e) <u>Change of Freeboard</u>. The increase in draft after flooding results in a decrease in the amount of free board.

- Even though the residual GM may be positive, if the freeboard is minimal and the waterline is close to the deck edge, submerging the deck edge at small angles of heel greatly reduces the range of positive righting arm GZ, and leaves the vessel vulnerable to the forces of wind and sea.

(f) Increase of loads on ship structure

(g) <u>Loss of Ship</u>. Where changes in draft, trim and/ or heel necessary to attain stable equilibrium are such as to immerse non-watertight portions of a ship, equilibrium will not be reached because of progressive flooding and the ship will sink either with or without capsizing.
(Where the loss in is such that the remaining maximum righting arm is less than any existing heeling arm, capsizing will occur. Even if there were no heeling arm, capsizing could be expected if the in the damaged condition were negative and if the maximum righting arm were so small as to result in negative dynamical stability. Practically, even for symmetrical flooding, there is always some heeling arm due to unsymmetrical weights and/or wind).

<u>No of bulkheads depends on the length of the ship</u>. The following table gives no of transverse bulkheads for a passenger ship.

L (m)	ENGINE AMIDSHIP	ENGINE AFT
< 65 m	4	3
> 65 <=85m	4	4
> 85 <=105m	5	5
> 105 <= 115m	6	5
> 115 <=125m	6	6

> 125 <= 145m	7	6
> 145 <=165m	8	7
> 165 <=190m	9	8
> 190 m	should be considered individually	

Collision bulkhead – about 0.05L from FP

<u>Notes</u>

- *So far the consequence of flooding in a particular compartment has been studied.*
- *The problem can be looked at the other way by asking what* ***length of ship can be flooded without loss of the ship?***
- *The bulkhead deck is the uppermost weathertight deck to which transverse watertight bulkheads are carried.*

<u>Margin Line</u>

- A margin is desirable and the limit is taken when the waterline is tangent to a line drawn 76mm (3 inches) below the bulkhead deck at side. This line is called the margin line.

<u>Floodable Length</u>

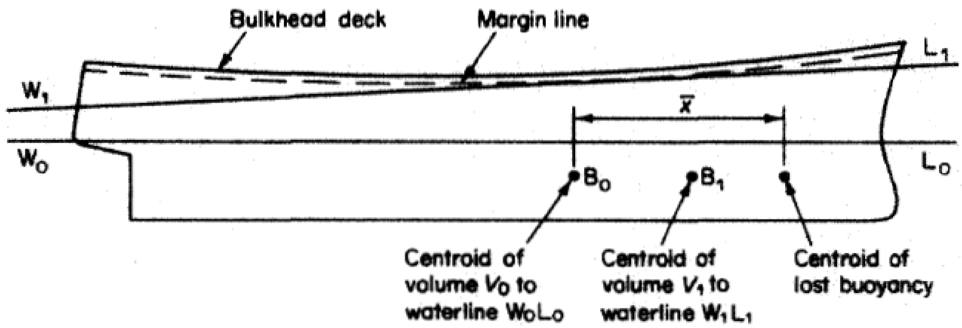
The *floodable length* at any point in the length of the ship is defined as the maximum portion of the length, having its center at the point in question, that can be symmetrically flooded at the prescribed permeability, without immersing the margin line, which is generally 7.5 cm (3 in.) below the top of the bulkhead deck at the side.

usually plotted to a vertical scale equal to the longitudinal scale.

The accurate determination of the floodable length requires an analysis of sinkage, trim, and heel to determine that the margin line is not immersed.

They are a very valuable tool in the preliminary design stage for any class of ship.

- give the designer a quick visual indication of the probable allowable lengths of compartments.
- Helps in placing of bulkheads

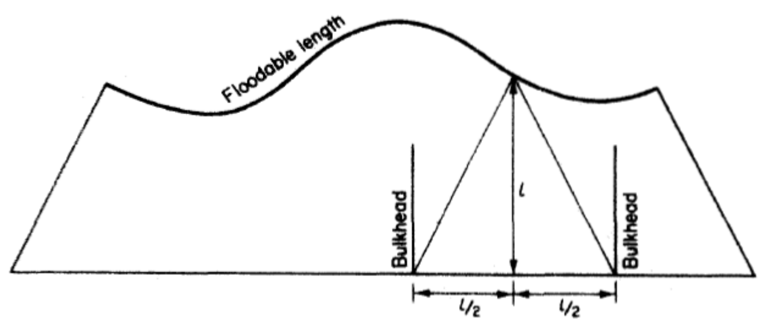


- Subscripts 0 and 1 to denote the intact ship data for **the intact and damaged waterlines**.

- Loss of buoyancy = V_1-V_0 and this must be at such a position that B_1 again below G.

Hence: $$\bar{x} = \frac{V_1 \times B_0B_1}{V_1 - V_0}$$

- This then gives the centroid of the lost buoyancy and, knowing (V_1 - V_0,) it is possible to convert this into a length of ship that can be flooded.
- The calculation would be one of reiteration until reasonable figures are obtained.
- The calculations can be repeated for a series of waterlines tangent to the margin line at different positions along the length. This will lead to a curve of floodable length shown below:-



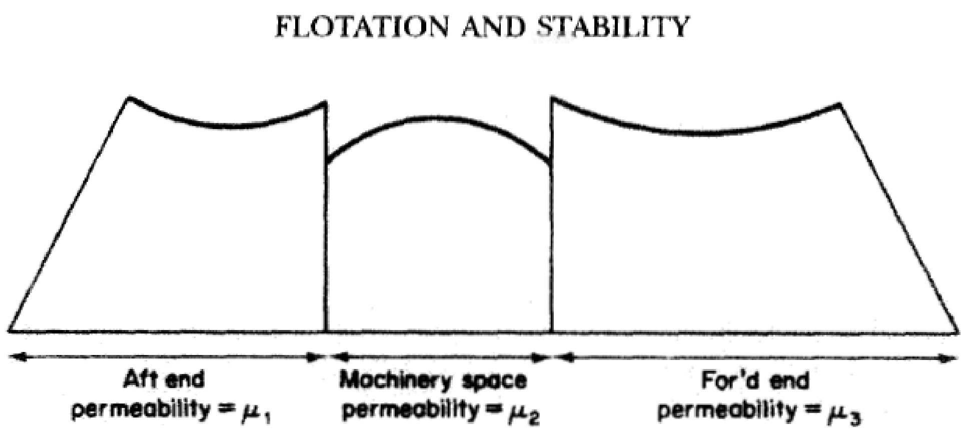
The **ordinate at any point represents the length which can be flooded with the centre at the point concerned**. Thus if ‘l’ is the floodable length at some point the positions of bulkheads giving the required compartment length are given by setting off distances 1/2 ‘l’ either side of the point.

The permeabilities of compartments will affect the floodable length and it is usual to work out average permeability figures for the machinery spaces and for each of the two regions forward and aft.

Permeability - The volume permeability of a space is the percentage of the space that can be occupied by water. Surface permeability is the percentage of a waterplane that can be occupied by water.

Typical permeability values:-

- 0.95 for voids (empty spaces), tanks, and living spaces
- 0.85 for machinery spaces
- 0.60 for spaces allocated to stores.



Floodable length with permeability

This leads to three curves for the complete ship as shown in Figure. The condition that a ship should be able to float with any one compartment open to the sea is a minimum requirement for ocean going passenger ships. The Merchant Shipping Regulations set out formulae for calculating permeabilities and a factor of subdivision which must be applied to the floodable length curves giving permissible length.

Criterion of Service. The criterion of service is a numeral intended to express the degree to which a vessel is a passenger vessel. In principle, a numeral of 23 corresponds to a vessel engaged primarily in carrying cargo, with accommodations for a small number of passengers, while a numeral of 123 is intended to apply to a vessel engaged solely, or very nearly so, in the carriage of passengers.

This numeral represents the criterion of service of the ship and takes account of the number of passengers, the volumes of the machinery and accommodation spaces and the total ship volume. It decreases in a regular and continuous manner with the ship length and factors related to whether the ship carries predominantly cargo or passengers.

The criterion numeral for ships to which this section applies shall be determined by the following formulae:-

(1) when P1 is greater than P, $C_s = 72 (M + 2P1)/ (V + P1 – P)$

(2) and in all other cases $C_s = 72 (M + 2P)/V$

where - Cs = the criterion numeral;

L = the length of the ship (metres)

M = the volume of the machinery space with the addition of the volume of any permanent oil fuel bunkers which may be situated above the inner bottom and before or abaft the machinery space;

V = the volume of ship below the margin line;

N = number of passengers for which the ship is certified

P1 = 0.056L.N

P=The vol of passengers and crew spaces below margin line.

Factor of Subdivision. Broadly, the factor of subdivision ensures that one, two or three compartments can be flooded before the margin line is immersed leading to what are called one-, two- or three-compartment ships.

Permissible Length. The permissible length at any point is obtained by multiplying the floodable length at that point by the factor of subdivision.

The permissible length is the product of the floodable length and the factor of subdivision. The factor of subdivision depends upon the length of the ship and a criterion of service numeral or more simply criterion numeral.

That is, compartment standard is the inverse of the factor of subdivision. In general terms the factor of subdivision decreases with length of ship and is lower for passenger ships than cargo ships.

The survivability in damage condition is directly related to the main watertight subdivision below the bulkhead deck.

A first approach to the assessment of the damage condition is to find the floodable length at a given point of the ship length, multiplied by a number called *factor of subdivision*.

- A factor of subdivision equal to 1 means that the margin line should not submerge if one compartment is submerged

- A factor of subdivision equal to 0.5 means that the margin line should not submerge when two adjacent compartments are flooded.

This approach is still used for design purposes in order to identify any issues regarding the location of bulkheads before carrying on further and more complex calculations. The assessment is based on two assumptions:

- The ship is subject to symmetrical flooding only as the hull is subdivided only by transverse bulkheads. This is a simplification as the ship subdivision is usually more complex and includes also longitudinal bulkheads that play a very important role in the flooding process.

- The method takes into consideration only floatability without checking the residual stability after damage. It may happen that for certain waterlines tangent to the margin line the residual stability is insufficient.

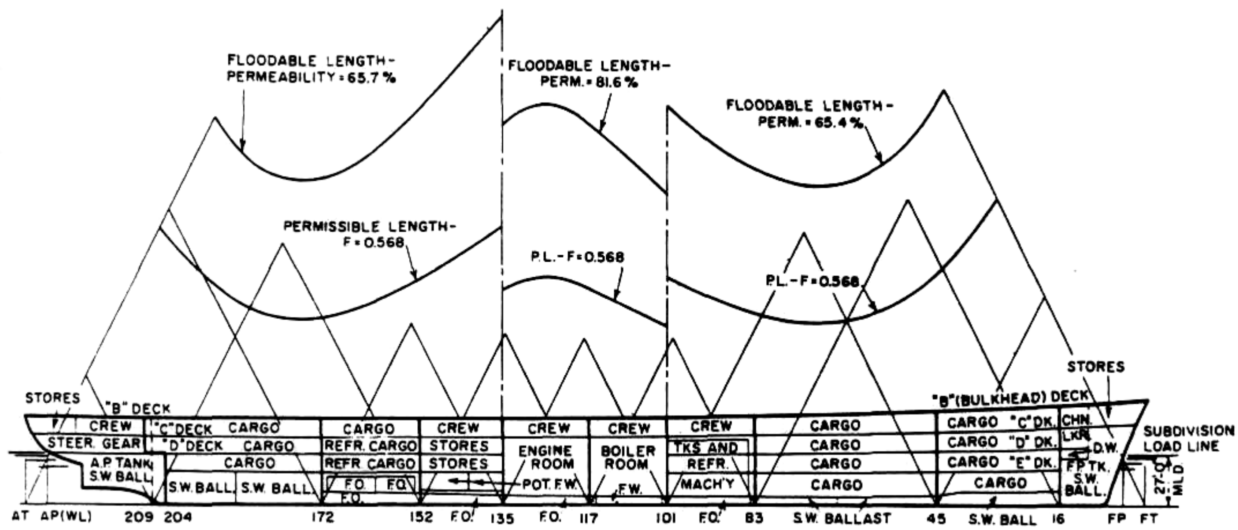
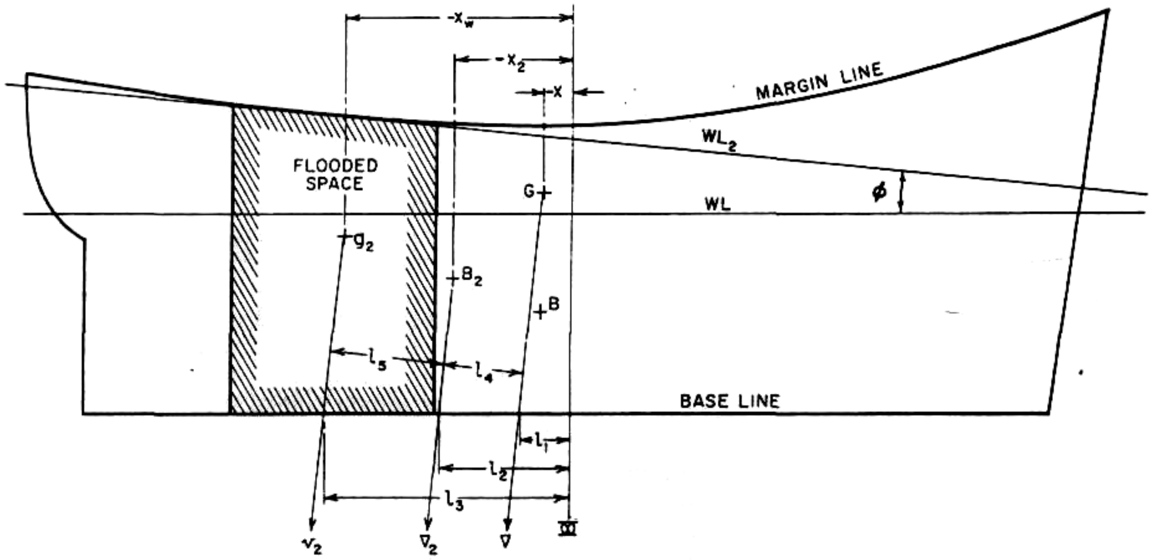


Fig – Typical F.L and P.L over a ship's profile

Damage stability- It is a comprehensive term applying to the calculation of the related changes in draft, trim, heel, and stability as a result of damage to one or more specific compartments of a ship.

(It also relates to calculation of the intact stability and buoyancy necessary to attain any particular assumed equilibrium damaged condition, as well as to the stability characteristics in that damaged condition.)



WL1 – initial WL, WL2 – Final WL due to flooding

In this figure Δ is displacement volume to WL, B is initial center of buoyancy, G is initial center of gravity, v2 is net volume of flooding water upto WL2 (i.e., gross vol. x μ), g2 is center of gravity of v2, B2 is center of buoyancy of entire immersed volume up to WL2, Δ2 is entire displacement volume to WL2, μ is permeability, the percentage of a space that can be occupied by water.

$$v_2 = \nabla_2 - \nabla;\; v_2 l_5 = \nabla l_4;\; \text{therefore } v_2 = \frac{\nabla l_4}{l_5}$$

$$l_1 = x + \overline{KG} \tan\theta$$

Where

$$l_2 = x_2 + \overline{KB}_2 \tan\theta$$
$$l_3 = x_w + \overline{KG}_2 \tan\theta$$
$$l_4 = [x_2 - x + \tan\theta\,(\overline{KB}_2 - \overline{KG})]\cos\theta$$
$$l_5 = [x_w = x_2 + \tan\theta\,(\overline{Kg}_2 - \overline{KB}_2)]\cos\theta$$

Therefore

$$v_2 = \nabla_2 - \nabla = \frac{\nabla[x_2 - x + \tan\theta\,(\overline{KB}_2 - \overline{KG})]}{[x_w - x_2 + \tan\theta(\overline{Kg}_2 - \overline{KB}_2)]}$$

Transposing and rearranging, one gets

$$x_w = \frac{(\nabla_2 x_2 - \nabla \mathrm{x})}{(\nabla_2 - \nabla)} - \tan\theta \left[\overline{Kg}_2 - \frac{(\nabla_2 \overline{KB}_2 - \nabla \overline{KG})}{(\nabla_2 - \nabla)} \right]$$

<u>volume and location of the flooding water that would immerse the ship to the margin line.</u>

$$v_2 = \nabla_2 - \nabla = \frac{\nabla(x_2 - x)}{(x_w - x_2)}$$

and

$$x_w = \frac{(\nabla_2 x_2 - \nabla x)}{(\nabla_2 - \nabla)}$$

Method –

- On a profile drawing showing the margin line and a number of transverse stations, Bonjean curves are plotted from a low draft to the margin line.
- The subdivision load line is drawn on the profile
- The trim line parallel to the subdivision load line is drawn tangent to the margin line at its lowest point.
- D be depth from baseline to margin line (at lowest point).
- The draft from baseline to subdivision load line H = 1.6D - 1.57.
- At perpendiculars at the extremities of the subdivision length, the distances H/ 3, 2H/3, and H are laid off and tangents are drawn to the margin line from these points.
- For example, 3F is the tangent drawn from a point on the after perpendicular at a distance of H below the parallel trim line.
- The area of each station up to the trim line is first read from the Bonjean curves
- These areas are then integrated by use of Simpson's rule or other rule to obtain the volume of displacement and the distance of LCB from some convenient station such as amidships.
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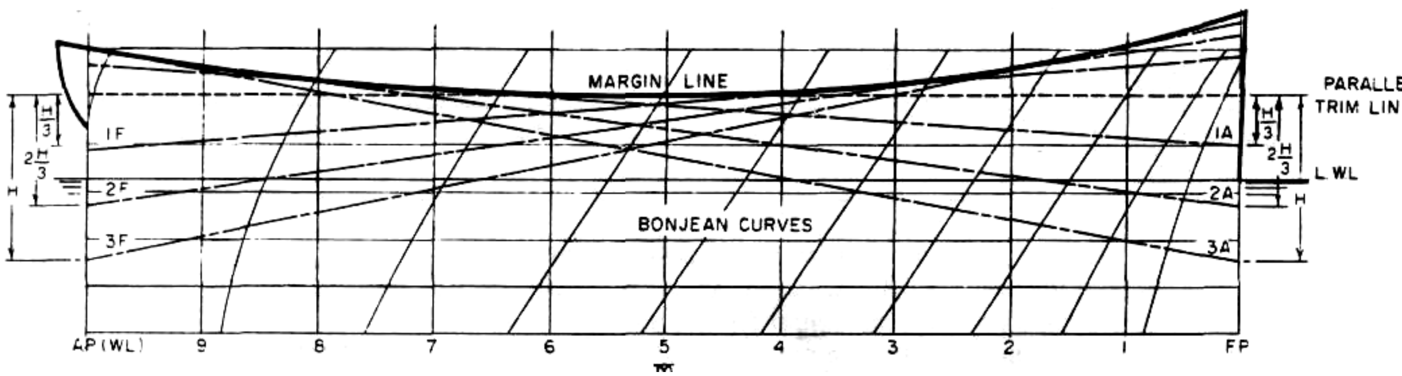
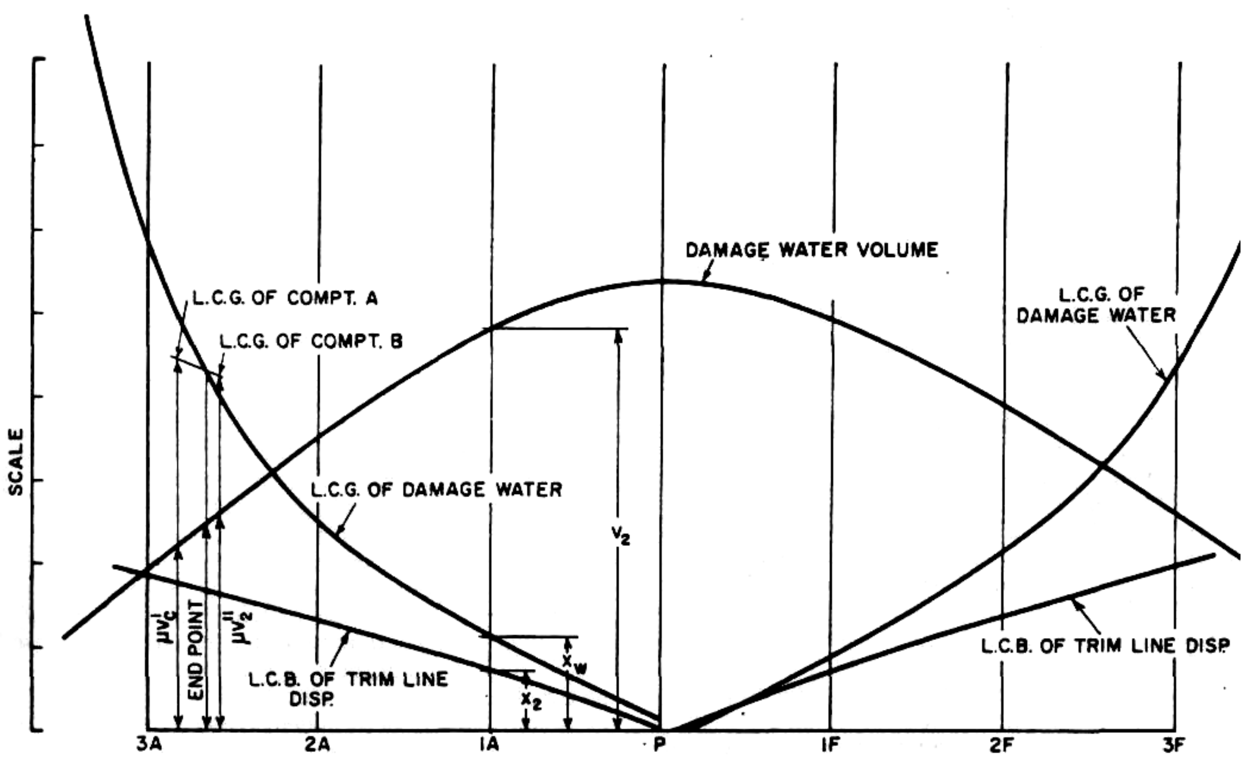


MARGIN LINE
PARALLEL TRIM LINE
$\frac{H}{3}$
$2\frac{H}{3}$
H
1F
2F
3F
1A
2A
3A
L.WL
BONJEAN CURVES
AP (WL)
9
8
7
6
5
4
3
2
1
FP



SCALE
DAMAGE WATER VOLUME
L.C.G. OF COMPT. A
L.C.G. OF COMPT. B
L.C.G. OF DAMAGE WATER
L.C.G. OF DAMAGE WATER
V_2
μV_C^I
END POINT
μV_2^{II}
X_W
X_2
L.C.B. OF TRIM LINE DISP.
L.C.B. OF TRIM LINE DISP.
3A
2A
1A
P
1F
2F
3F