MERCHANT SHIPPING NOTICE

MSN 1715 (M)

Subdivision and Damage Stability of Cargo Ships of 80m in Length and Over

Notice to Shipbuilders, Shipowners, Ship repairers, Naval Architects, Masters and Officers.

This Notice Supersedes Merchant Shipping Notice No. M.1476.

Summary

This Notice advises all Shipbuilders, Shipowners, Shiprepairers, Naval Architects, Masters and Officers of subdivision and damage stability of cargo ships of 80m in length and over.

Key points:-

- Requirements for subdivision and damage stability for cargo ships, using the probabilistic method;
- categories of ship to which these requirements apply; and
- formulae used for calculating the subdivision indices.

1. Part B-1 of Chapter II-1 of the International Maritime Organisation Convention for the Safety of Life at Sea 1974, was amended and adopted by the Maritime Safety Committee of the International Maritime Organisation on the 25th May *1990* (MSC.58(25)) with effect from 1st July 1998 (MSC.47(66)).

2. The Merchant Shipping (Cargo Ship Construction) Regulations 1997 S.I. No.1509, as amended by the Merchant Shipping (Cargo Ship Construction)(Amendment) Regulations 1999, implement and interpret the above named regulations.

3. The regulations introduce requirements for subdivision and damage stability of cargo ships 100m in length and upwards built after 1 February 1992, and cargo ships 80m in length and upwards built after 1 July 1998, based on the probabilistic concept. They do not apply to such ships which comply with subdivision and damage stability requirements of other statutory instruments.

4. Annex 1 to this notice contains formulae for use in calculating the subdivision indices, and other related information.

5. Annex 11 contains explanatory notes prepared by the International Maritime Organisation for the purpose of calculating the subdivision indices. They should be read in conjunction with the following Annex.

6. Annex III contains the text adopted by the MSC resolutions referred to in paragraph 1 above.

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ANNEX I

ANNEX I

1. Definitions

For the purpose of this notice, unless expressly provided otherwise:

.1.1 Subdivision Load Line is a waterline used in determining the subdivision of the ship.

.1.2 Deepest subdivision load line is the subdivision load line which corresponds to the summer draught to be assigned to the ship.

.1.3 Partial load line is the light ship draught plus 60% of the difference between the light ship draught and deepest subdivision load line.

.2.1 Subdivision length of the ship (“L_s”) is the greatest projected moulded length of that part of the ship at or below deck or decks limiting the vertical extent of flooding with the ship at the deepest subdivision load line.

.2.2 Mid-length is the mid point of the subdivision length of the ship.

.2.3 Aft terminal is the aft limit of the subdivision length.

.2.4 Forward terminal is the forward limit of the subdivision length.

.3. Breadth (“B”) is the greatest moulded breadth of the ship at or below the deepest subdivision load line.

.4. Draught (“d”) is the vertical distance from the moulded baseline at mid-length to the water line in question.

.5. Permeability (“μ”) of the space is the proportion of the immersed volume of that space which can be occupied by water.

2. Required subdivision index "R"

.1 The degree of subdivision to be provided shall be determined by the required subdivision index "R", as follows:

.1.1 for ships over 100m in length;

$$R = (0.002 + 0.0009L_s)^{1/3}\text{; and}$$

.1.2 for ships of 80m in length and upwards, but not exceeding 100m in length;

$$R=1-\left[1-\left(1+\frac{L_s}{100}\cdot\frac{R_0}{1-R_0}\right)\right],$$

where R_0 is the value R as calculated in accordance with the formula in subparagraph 1.1.1, and “Ls” is the length of the ship in metres.

3. Attained subdivision index "A"

.1 The attained subdivision index "A" shall be calculated for the ship by the following formula:

$$A = \Sigma p_i s_i$$

where:

“i” represents each compartment or group of compartments under consideration,

“pi” accounts for the probability that only the compartment or group of compartments under consideration may be flooded, disregarding any horizontal subdivision,

“si” accounts for the probability of survival after flooding the compartment or group of compartments under consideration, including the effects of any horizontal subdivision.

.2 In calculating “A”, level trim shall be used.

.3 This summation covers only those cases of flooding which contribute to the value of the attained subdivision index “A”.

.4 The summation indicated by the above formula shall be taken over the ship’s length for all cases of flooding in which a single compartment or two or more adjacent compartments are involved.

.5 Wherever wing compartments are fitted, contribution to the summation indicated by the formula shall be taken for all cases of flooding in which wing compartments are involved; and additionally, for all cases of simultaneous flooding of a wing compartment or compartments and the adjacent inboard compartment or compartments, assuming a rectangular penetration which extends to the ship’s centreline, but excludes damage to any centreline bulkhead.

.6 The assumed vertical extent of damage is to extend from the baseline upwards to any watertight horizontal subdivision above the waterline or higher. However, if a lesser extent will give a more severe result, such extent is to be assumed.

.7 If pipes, ducts or tunnels are situated within assumed flooded compartments, arrangements are to be made to ensure that progressive flooding cannot thereby extend to compartments other than those assumed flooded. However, the Administration may permit minor progressive flooding if it is demonstrated that its effects can be easily controlled and the safety of the ship is not impaired.

.8 In the flooding calculations carried out according to the regulations, only one breach of the hull need be assumed.

4. Calculation of the factor “l2i”

.1. The factor "pi" shall be calculated according to paragraph .1.1 (below) as appropriate, using the following notations:

x_1 = the distance from the aft terminal of "Ls" to the foremost portion of the aft end of the compartment being considered;

x_2 = the distance from the aft terminal of "Ls" to the aftermost portion of the forward end of the compartment being considered;

E_1 = x_1 / L_s

E_2 = x_2 / L_s

E = $E_1 + E_2 - 1$

J = $E_2 - E_1$

J' = $J - E$, if $E \geq 0$

J' = $J + E$, if $E < 0$

The maximum non dimensional damage length, $J_{max} = 48 / L_s$, but not more than 0.24

The assumed distribution density of damage location along the ship's length

a = $1.2 + 0.8E$, but not more than 1.2

The assumed distribution function of damage location along the ship's length

F = $0.4 + 0.25\,E\,(1.2 + a)$

y = J / J_{max}

p = $F_1\,J_{max}$

q = $0.4\,F_2\,(J_{max})^2$

F_1 = $y^2 - \frac{y^3}{3}$, if $Y < 1$,

F_1 = $y - \frac{1}{3}$ otherwise;

F_2 = $\frac{y^3}{3} - \frac{y^4}{12}$, if $Y < 1$,

F_2 = $\frac{y^3}{2} - \frac{y}{3} + \frac{1}{12}$ otherwise.

.1.1 The factor "pi" is determined for each single compartment:

.1.1.1 Where the compartment considered extends over the entire ship length, "Ls":

$$pi = 1$$

.1.1.2 Where the aft limit of the compartment considered coincides with / the aft terminal:

$$pi = F + 0.5\,ap + q$$

.1.1.3 Where the forward limit of the compartment considered coincides with the forward terminal:

$$pi = 1 - F + 0.5ap$$

.1.1.4 When both ends of the compartment considered are inside the aft and forward terminals of the ship length, "Ls":

$$pi = ap$$

.1.1.5 In applying the formulae of paragraphs 4.1.1.2, 4.1.1.3 and 4.1.1.4, where the compartment considered extends over the "mid-length", these formulae values shall be reduced by an amount determined according to the formula for "q", in which "F_2" is calculated taking "y" to be J' / J_{max}.

.2. Wherever wing compartments are fitted, the "pi" – value for a wing compartment shall be obtained by multiplying the value, as determined in paragraph 3, by the reduction factor "r" according to subparagraph .2.2, which represents the probability that the inboard spaces will not be flooded.

.2.1 The "pi" – value for the case of simultaneous flooding of a wing and adjacent inboard compartment shall be obtained by using the formulae of paragraph 3, multiplied by the factor (1 – r).

.2.2 The reduction factor "r" shall be determined by the following formulae:
For $J \geq 0.2\, b/B$:

$$r = \frac{b}{B}\left(2.3 + \frac{0.08}{J + 0.02}\right) + 0.1, \qquad \text{if } b/B \leq 0.2$$

$$r = \left(\frac{0.016}{J + 0.02} + \frac{b}{B} + 0.36\right), \qquad \text{if } b/B > 0.2$$

For $J < 0.2\, b/B$ the reduction factor "r" shall be determined by linear interpolation between

$r = 1$, for $J = 0$

and

r = as for the case where $J \geq 0.2b/B$, for $J = 0.2\, b/B$,

where:

b = the mean transverse distance in metres measured at right angles to the centreline at the deepest subdivision load line between the shell and a portion of and parallel to that part of the longitudinal bulkhead which extends between the longitudinal limits used in calculating the factor "p_i".

.3. To evaluate "p_i" for compartments taken singly the formulae in paragraphs .1 and .2 shall be applied directly.

.3.1 To evaluate the "pi" – values attributable to groups of compartments the following applies:

for compartments taken by pairs:

$p_i = p_{12} - p_I - p_2$
$p_i = p_{23} - p_2 - p_3$, etc.

for compartments taken by groups of three:

$p_i = p_{l23} - p_{l2} - p_{23} + p_2$
$p_i = p_{234} - p_{23} - p_{34} + p_3$, etc.

for compartments taken by groups of four:

$p_i = p_{l234} - p_{123} - p_{234} + p_{23}$
$p_i = p_{2345} - p_{234} - p_{345} + p_{34}$, etc.

where:
p_{12}, p_{23}, p_{34}, etc,
p_{123}, p_{234}, p_{345}, etc and
p_{1234}, p_{2345}, p_{3456}, etc

shall be calculated according to the formulae in paragraphs 4.1 and 4.2 for a single compartment whose nondimensional length "J" corresponds to that of a group consisting of the compartments indicated by the indices assigned to "p".

.3.2 The factor "pi" for a group of three or more adjacent compartments equals zero if the non dimensional length of such a group minus the nondimensional length of the aftermost and foremost compartments in the group is greater than "J_{max}".

5. Calculation of factor "Si"

.1. The factor "si" shall be determined for each compartment or group of compartments according to the following:

.1.1 in general for any condition of flooding from any initial loading condition "s" shall be

$$S = C\sqrt{0.5\,(GZ_{max})(\text{range})}$$

with C = 1, if $\varnothing e \leqslant 25°$

with C = 0, if $\varnothing e > 30°$

$$C = \sqrt{\frac{30 - \varnothing e}{5}} \quad \text{otherwise}$$

GZ_{max} = maximum positive righting lever (in metres) within the range given below but not more than 0.lm;

range = range of positive righting levers beyond the angle of equilibrium (in degrees) but not more than 20°; however, the range shall be terminated at the angle where openings not capable of being closed weathertight are immersed;

$\varnothing e$ = final equilibrium angle of heel (in degrees);

.1.2 s = 0 where the final waterline taking into account sinkage, heel and trim, immerses the lower edge of openings through which progressive flooding may take place. Such opening shall include air pipes, ventilators and openings which are closed by means of weathertight doors or hatch covers, and may exclude those openings closed by means of watertight manhole covers and flush scuttles, small watertight hatch covers which maintain the high integrity of the deck, remotely operated sliding watertight doors, access doors and access hatch covers, of watertight integrity, normally closed at sea and sidescuttles of the non-opening type. However, if the compartments so flooded are taken into account in the calculations the requirements of this regulation shall be applied.

.1.3 For each compartment or group of compartments "s_i" shall be weighted according to draught considerations as follows:

$$s_i = 0.5\, S_\ell + 0.5\, S_p$$

where

"se" is the "s"-factor at the deepest subdivision load line
"sp" is the "s"-factor at the partial load line.

.2. For all compartments forward of the collision bulkhead, the "s"-value, calculated assuming the ship to be at its deepest subdivision load line and with assumed unlimited vertical extent of damage is to be equal to 1.

.3. Wherever a horizontal subdivision is fitted above the waterline in question the following applies.

.3.1 The "s"-value for the lower compartment or group of compartments shall be obtained by multiplying the value as determined in subparagraph 5.1.1 by the reduction factor "v" according to subparagraph 5.3.3, which represents the probability that the spaces above the horizontal subdivision will not be flooded.

.3.2 In cases of positive contribution to index "A" due to simultaneous flooding of the spaces above the horizontal subdivision, the resulting "s"-value for such a compartment or group of compartments shall be obtained by an increase of the value as determined by subparagraph 5.3.1 by the "s"-value for simultaneous flooding according to subparagraph 5.1.1, multiplied by the factor (1-v).

.3.3 The probability factor "v_i" shall be calculated according to:

$$v_i = \frac{H-d}{H_{max} - d},$$

for the assumed flooding up to the horizontal subdivision above the subdivision load line, where "H" is to be restricted to a height of "H_{max}",

$$v_i = 1,$$

if the uppermost horizontal subdivision in way of the assumed damaged region is below "H_{max}",

where:

"H" is the height of the horizontal subdivision above the baseline (in metres) which is assumed to limit the vertical extent of damage,

"Hmax" is the maximum possible vertical extent of damage above the baseline (in metres), or

$$H_{max} = d + 0.056\, L_s \left(1 - \frac{L_s}{500}\right),$$ if $L_s \leq 250$ m;

$$H_{max} = d + 7,$$ if $L_s > 250$m

whichever is less.

6. Permeability

For the purpose of the subdivision and damage stability calculations of the regulations, the permeability of each space or part of a space shall be as follows:

Spaces	Permeability
Appropriated to stores	0.60
Occupied by accommodation	0.95
Occupied by machinery	0.85
Void spaces	0.95
Dry cargo spaces	0.70
Intended for liquid	0 or 0.95[1]

7. Stability Information

.1 In providing the information and when determining the overall GM (or KG) values:

.1.1 in the case where intact stability requirements are more onerous they shall apply.

.1.2 in the case where values determined from considerations solely related to the subdivision index are more onerous then:

- .i the limiting GM value shall be varied linearly between the deepest subdivision load line and the partial load line; and

- .ii for draughts below the partial load line the GM value shall be assumed constant.

.1.3 in the case where values determined from both intact stability and the subdivision index apply then:

- .i the limiting GM shall be varied linearly between the deepest subdivision load line and the partial load line; and

- .ii for draughts below the partial load line the GM value shall be assumed constant where the subdivision index is more onerous otherwise intact stability requirements apply.

1 Whichever results in the more severe requirements.

ANNEX II
EXPLANATORY NOTES TO THE SOLAS REGULATIONS ON SUBDIVISION AND DAMAGE STABILITY OF CARGO SHIPS OF 100 METRES IN LENGTH AND OVER

These explanatory notes are divided into two parts. Part A describes the background to the method used whilst Part B contains explanation and amplification of individual regulations.

PART A

In this part of the explanatory notes, the background of the subdivision index is presented and then the calculation of the probability of damaged is developed.

Finally, the development of the calculation of the probability that a damaged ship will not capsize or sink is demonstrated.

1 INTRODUCTION

These regulations are based on the probabilistic concept which takes the probability of survival after collision as a measure of ship's safety in the damaged condition, hereinafter referred to as the "attained subdivision index A".

This is an objective measure of ship safety and therefore there is no need to supplement this index by any deterministic requirements. These new regulations, therefore, are primarily based on the probabilistic approach, with only very few deterministic elements which are necessary to make the concept practicable.

The philosophy behind the probabilistic concept is that two different ships with the same index of subdivision are of equal safety and therefore there is no need for special treatment for specific parts of the ship. The only areas which are given special attention in these regulations are the forward and bottom regions which are dealt with by special rules concerning subdivision, provided for the cases of ramming and grounding.

In order to develop the probabilistic concept of ship subdivision, it is assumed that the ship is damaged. Since the location and size of the damage is random, it is not possible to state which part of the ship becomes flooded. However, the probability of flooding a space can be determined if the probability of occurrence of certain damages is known. The probability of flooding a space is equal to the probability of occurrence of all such damages which just open the considered space. A space is a part of the volume of the ship which is bounded by undamaged watertight structural divisions.

Next, it is assumed that a particular space is flooded. In addition to some inherent characteristics of the ship, in such a case there are various factors which influence whether the ship can survive such flooding; they include the initial draught and GM, the permeability of the space and the weather conditions, all of which are random at the time when the ship is damaged. Provided that the limiting combinations of the aforementioned variables and the probability of their occurrence are known, the probability that the ship will not capsize or sink, with the considered space flooded, can be determined.

The probability of survival is given by the formula for entire probability as the sum of the products for each compartment or group of compartments of the probability that a space is flooded multiplied by the probability that the ship will not capsize or sink with the considered space flooded.

Although the ideas outlined above are very simple, their practical application in an exact manner would give rise to several difficulties. For example, for an extensive but still incomplete description of the damage, its longitudinal and vertical location as well as its longitudinal, vertical and transverse extent is necessary. Apart from the difficulties in handling such a five-dimensional random variable, it is impossible to determine its probability distribution with the presently available damage statistics. Similar conditions hold for the variables and physical relationships involved in the calculation of the probability that a ship with a flooded space will not capsize or sink.

In order to make the concept practicable, extensive simplifications are necessary. Although it is not possible to calculate on such a simplified basis the exact probability of survival, it is possible to develop a useful comparative measure of merit of the longitudinal, transverse and horizontal subdivision of the ship.

2 DETERMINATION OF THE PROBABILITY OF FLOODING OF SHIP SPACES

.1 Consideration of longitudinal damage location and extent only.

The simplest case is to consider the location and length of damage in the longitudinal direction. This would be sufficient for ships with no longitudinal and horizontal watertight structural divisions.

With the damage location “x” and damage length “y” as defined in figure 1, all possible damages can be represented by points in a triangle which is also shown in this figure.

All damages which open single compartments of length “ℓ_i" are represented in figure 1 by points in triangles with the base “ℓ_i”. Triangles with the base “ℓ_i” + “ℓ_i” (where j = i + 1) enclose points corresponding to damages opening either compartment “i”, or compartment “j”, or both of them. Correspondingly, the points in the parallelogram “ij” represent damages which open both the compartments “i” and “j”.

Damage location “x” and damage length “y” are random variables. Their distribution density f(x,y) can be derived from the damage statistics. The meaning of f(x,y) is as follows (see figure 2): the total volume between the x-y plane and the surface given by f(x,y) equals one and represents the probability that there is damage (this has been assumed to be certain). The volume above a triangle corresponding to damage which opens a compartment represents the probability that this compartment is opened. In a similar manner for all areas in the x-y plane which correspond to the opening of compartments or group of compartments, there are volumes which represent the probability that the considered compartments or group of compartments are opened.

The probability that a compartment or a group of adjacent compartments is opened is expressed by the factor “pi” as calculated according to regulation 25-5.

Consideration of damage location “x” and damage length “y” only would be fully correct in the case of ships with pure transverse subdivision. However, there are very few, if any, such ships – all normally have a double bottom, at least.

In such a case, the probability of flooding a compartment should be split up into the following three components: probability of flooding the double bottom only, probability of flooding the space above the double bottom only and probability of flooding both the space above and the double bottom itself (see figure 3). For each of these cases there may be a different probability that the ship will survive in the flooded condition. A way out of this dilemma, which may be used in applying these new regulations, is to assume that the most unfavourable vertical extent of damage (out of the three possibilities) occurs with the total probability “p”. Therefore the contribution to survival probability made by more favourable cases is neglected. That the concept is still meaningful for comparative purposes follows from the fact that the error made by neglecting favourable effects of horizontal subdivision is not great and the more important influence of longitudinal damage location and extension is fully covered.

Some examples for dealing with other cases of horizontal subdivision are given in appendix 1.

.2 Consideration of horizontal subdivision above a water line.

In the case where the ship has as a horizontal subdivision above a water line, the vertical extent of damage may be limited to the depth of that horizontal subdivision. The probability of not damaging the horizontal subdivision is represented by the factor “vi”, as calculated according to regulation 25-6. This factor represents the assumed distribution function of the vertical extent of damage and varies from zero for subdivision at the level of the waterplane, linearly upwards to the value of one at the level conforming to the minimum bow height according to the 1966 Load Line Convention (see figure 4).

.3 Consideration of damage penetration in addition to longitudinal damage location and extent.

With the simplifying assumption that the damage is rectangular and with the vertical extent of damage according to 2.2, the damage can be described by the damage location “x”, the damage length “y” and the damage penetration “z” (see figure 5). These variables can be represented in a three-dimensional co-ordinate system, as shown in figure 6. Each point in the prism, with triangular base, represents a damage.

All damages which open a side compartment correspond to the points of a smaller prism with height “b” equal to the distance of the longitudinal bulkhead from the ship's side, which is erected above a triangle with the base “i” equal to the length of the side compartment under consideration. It is not difficult to identify in figure 5 the volumes which correspond to such damage which flood other parts of the ship bounded by transverse and longitudinal watertight structural subdivisions.

Damage location “x”, damage length “y” and damage penetration “z” are random variables. The distribution density f(x,y,z) can be derived from damage statistics. This distribution density can be illustrated by assuming it to be a density which varies from point to point of the volume shown in figure 6. The “weight” of the total volume is one and represents the probability that there is a damage (which is assumed to be certain). The "weight" of a partial volume (representing the flooding of certain spaces) represents the probability that the spaces under consideration are opened.

The probability that a side compartment is opened can be expressed as “$p_i r$” where “p_i” is to be calculated according to regulation 25-5.1 and “r” according to regulation 25-5.2. The probability that a centre compartment (extending at least to the ship centrelines) is opened, in addition to the adjacent side compartment, can be expressed as $P_i(1-r)$.

Some examples for the calculation of the probability that side or side plus centre spaces are opened are given in appendix 2.

Again, it must be stated that the probability calculated on the basis of the simplifying assumptions mentioned above is not exact. Nevertheless, it gives a comparative measure of how the probability of opening spaces depends on transverse and longitudinal structural subdivisions, and thus takes account of the most essential influences, whilst neglecting secondary effects. Neglecting the random variation of longitudinal and transverse damage extent would be a much greater error than that which is caused by neglecting these secondary effects.

3. DAMAGE STATISTICS

.1 Source of data

The following considerations are based on the information contained in various IMO documents. They summarise casualty data reported to IMO on 811 damage cards. There are 296 cases of rammed ships which contained information on each of the following characteristics:

Ship length	-	L
Ship breadth	-	B
Damage location	-	x
Damage length	-	y
Damage penetration	-	z

In order to omit inconsistencies in the results derived from the data, which may be caused by the use of different samples, the following investigations have been based only on the aforementioned 296 cases. However, further investigations have been made using, in addition, the information given for other cases. Despite the random scatter, which is to be expected because of the use of different samples composed at random, they lead to the same conclusion. A different sample, which comprised 209 cases in which “L”, “y” and year of collision are given, was used for the investigation of the dependency of damage length on the year of collision.

.2 General consideration of damage extent.

It is clear that the principal factors affecting damage extent are:

.2.1 Structural characteristics of the rammed ship

.2.2 Structural characteristics of the ramming ship

.2.3 Mass of the rammed ship at time of collision

.2.4 Mass of the ramming ship at time of collision

.2.5 Speed of the rammed ship at time of collision

.2.6 Speed of the ramming ship at time of collision

.2.7 Relative course angle between rammed and ramming ship

.2.8 Location of damage relative to the ship’s length

From the point of view of the rammed ship only item .1 is predetermined; all other items are random. An investigation of the damage length of ships with different numbers of decks has shown that there is no significant influence. This does not prove that there is no influence. It is, however, valid to conclude that the influence of structural characteristics is relatively small. It therefore seems justifiable to neglect this influence.

The mass of the rammed ship depends on its size and its loading condition. The influence of the latter is small and therefore for the sake of simplicity it has been neglected. To account for the size of the rammed ship, damage length has been related to the ship and damage penetration to the ship breadth.

The following will show that the damage does not depend significantly on the place at which it occurs in the ship's length. From this it is concluded that the damage extent does not depend on the location of the damage, except at the ends of the ship, where damage length is bounded according to the definition of damage location as the centre of the damage.

Some comments on the mass of the ramming ship are given below.

.3 Distribution of damage length.

Preliminary investigations have lead to the conclusion that the distribution of the ratio damage length to ship length y/L is approximately independent of the ship length. A proof will be given below. As a consequence, y/L can be taken as independent of "L".

From theoretical considerations (using the central limit theorem) it follows that $y/L + \in y$ (where "$\in y$" is constant) is approximately log-normally distributed. This is confirmed by figures 7 and 8, in which good agreement is shown between the log-normal distribution function and distribution density on the one hand and the corresponding results of the damage statistics on the other.

Figure 9 shows the regression of y/L on "L" for $L \leq 200$m (five damages relate to ships with $L > 200$m). The regression line has a small negative slope which proved to be insignificant, and may be caused by samples taken at random. There might be a small dependence of y/L on the ship length, but if is so small that it cannot be derived from the given sample. It is therefore certainly no significant error to assume y/L to be independent of ship size for $L \leq 200$m.

An explanation of this independence might be that small vessels are more likely to meet mainly small vessels and large vessels are more likely to meet mainly large vessels. However, this reasoning cannot be extended to very large vessels because of the small total number of such ships. Because of the very few damage cases concerning ships with $L > 200$m, nothing can be said about the damage distribution of such ships. **It** seems reasonable to assume, as an approximation for ships with $L > 200$m, that the median *of* the damage length is constant and equal to the median for L = 200m. The latter equals $200*(y/L)_{50}$ where $(y/L)_{50}$ is the median *of* the non-dimensional damage length for ships with L = 200m.

The regression of the non-dimensional damage length y/L on the non-dimensional damage location is given in figure 10. This shows that there is no significant difference between the damage distribution in the forward and aft half of the ship, but simple geometric reasoning indicates that the damage length at the ends *of* the ship – forward as well as aft – is limited to smaller values than the central part of the ship. Therefore the log-normal distribution found for all values for y/L – independent of damage location -is the marginal distribution. The corresponding conditional distribution of y/L, on the condition that the damage location is given, does not need to be considered as for the practical application an approximation will be used, which allows establishment of a very simple relationship between the conditional and marginal damage length distribution.

.4 Dependence of damage length on year of collision.

The tendency in increasing speed and size of ships during recent years suggests that the average size of damage in cases of collision also is growing. In order to investigate this, a regression analysis of the logarithm of the non-dimensional damage length on the year of collision has been made. The result is shown in figure 11. This figure shows a significant positive slope of the regression line, which proves that, on average, the damage length increase with year of collision.

It therefore seems prudent not to use the distribution which results from all damage data independent of the year of collision. Assuming that the variance about the regression line is constant, it is possible to derive from the regression analysis the distribution function of non-dimensional damage length for any arbitrarily chosen year; such a function is determined by the mean (which is given by the regression line) and the variance about the regression line *of* the logarithm of $y/L + \in y$. Some samples are given in figures 12 and 13.

.5 Distribution of damage penetration.

Similar consideration as in the case of the damage length lead to the conclusion that $z/B + \in_z$ is approximately log-normally distributed and does not depend on the ship size, which in this connection is represented by the breadth "B" of the ship. Figures 14 and 15 show good agreement between the log-normal distribution and the corresponding values obtained from the damage statistics. Figure 16 proves that there is, in fact, no significant dependence of z/B on "B".

As is to be expected, there is a strong correlation between z/B and y/L. Figures 17 and 18 show that z/B increases on the average with increasing y/L. The joint distribution of the logarithm of (y/L + $\in_y$) and (z/B + $\in_z$) is a bivariate normal distribution. From that distribution the conditional distribution of zlB on the condition that the damage length assumes certain values y /L can be derived.

.6 Distribution of damage location.

Inspection of the histogram (figure 19) of the non-dimensional damage location show that damages in the forward half of the ship are more frequent than in the aft part. The only explanation which can be offered for the peaks of the histogram at approximately x/L = 0.45 and x/L = 0.95, is that they are random because of the limited sample.

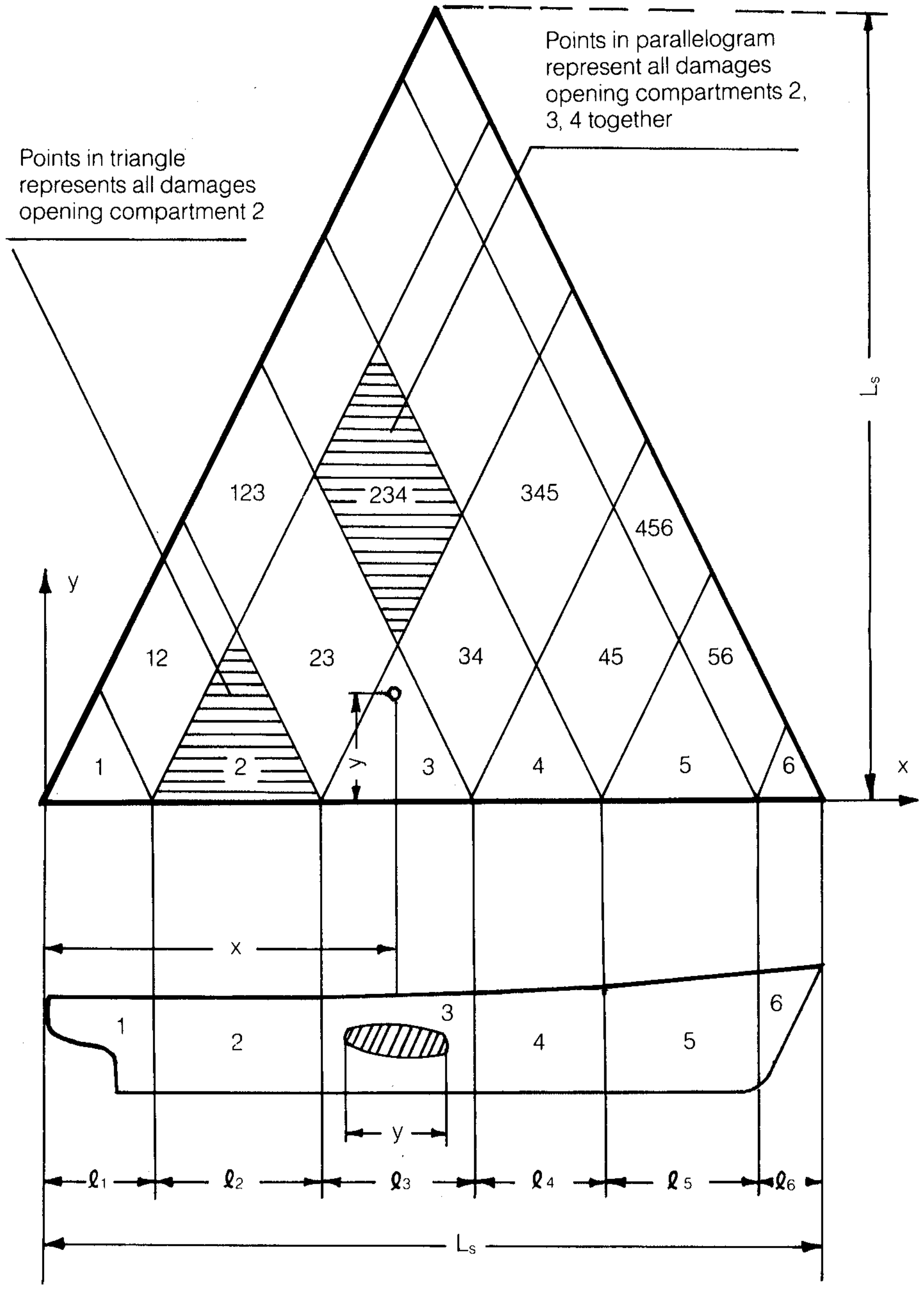
Because the damage location is defined as distance from the aft terminal of “L” to the centre of the damage, it is always a distance of y/2L from the ends of the ship. Starting with a simple assumption for the conditional distribution of x/L on the condition that y/L assumes certain values, the marginal distribution density has been derived and is shown as a curve in figure 19. The corresponding distribution function is given in figure 20.

4. PROBABILITY OF CAPSIZE

(Determination of the probability that a damaged ship will not capsize or sink -calculation of the "si' value)

.1 Criteria proposed to avoid capsizing or sinking.

It is not possible with the present state of knowledge to determine, with any degree of accuracy, criteria related to the probability of capsize of ships in waves. Therefore the formulae contained in these regulations are simplified and based on common standards used for damaged stability calculations.



Points in parallelogram represent all damages opening compartments 2, 3, 4 together
Points in triangle represents all damages opening compartment 2
123
234
345
456
12
23
34
45
56
1
2
3
4
5
6
y
x
L_s
x
y
1
2
3
4
5
6
y
ℓ_1
ℓ_2
ℓ_3
ℓ_4
ℓ_5
ℓ_6
L_s

FIGURE 1

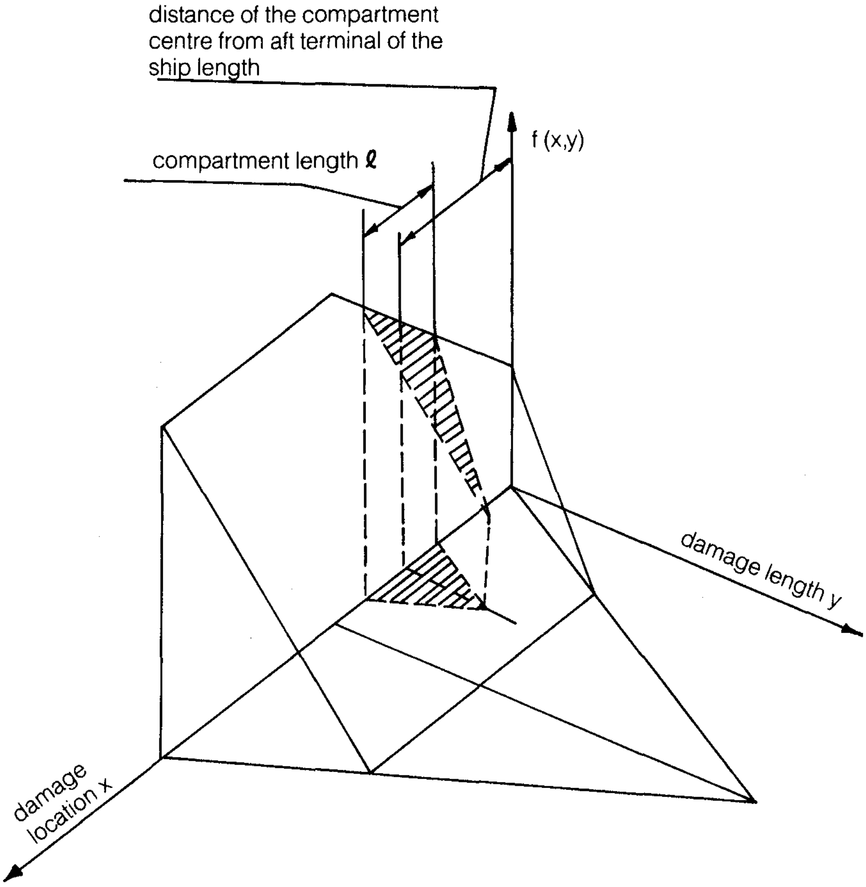

distance of the compartment
centre from aft terminal of the
ship length
compartment length ℓ
f (x,y)
damage length y
damage
location x

FIGURE 2

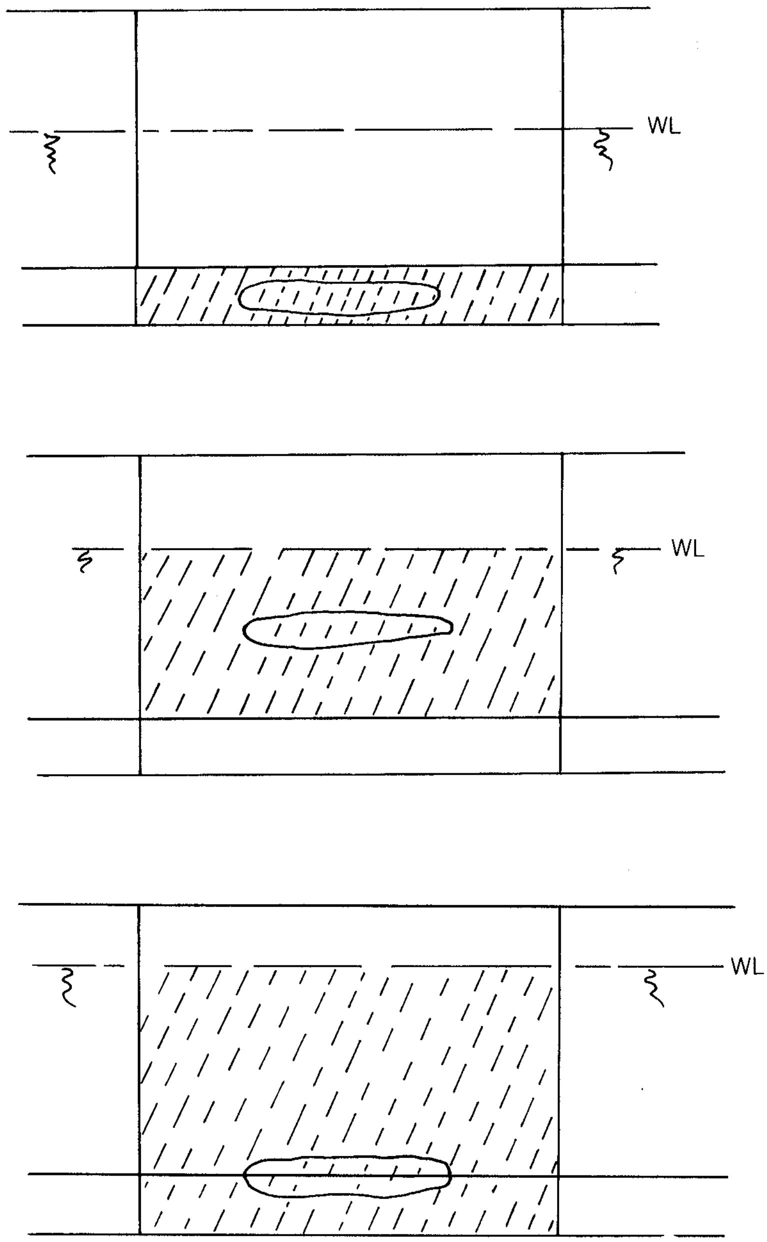


FIGURE 3

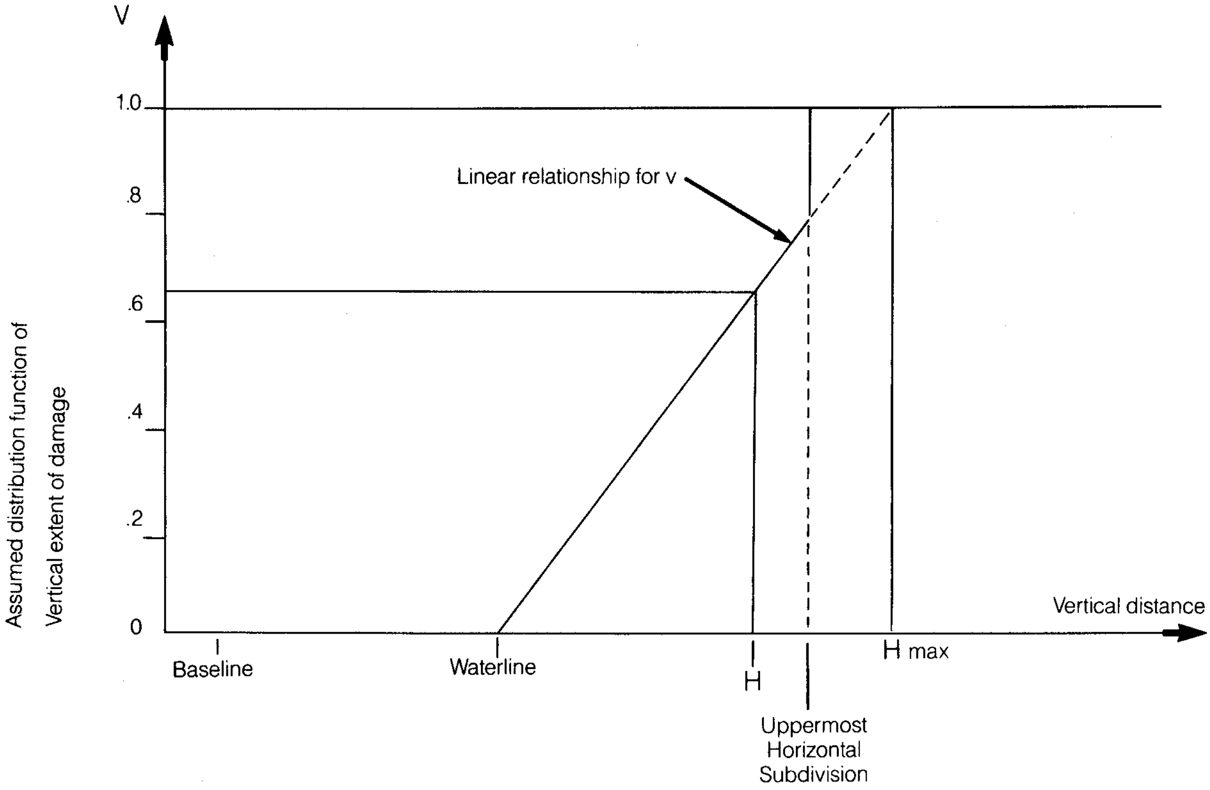

V
1.0
.8
.6
.4
.2
0
Assumed distribution function of
Vertical extent of damage
Linear relationship for v
Vertical distance
Baseline
Waterline
H
H max
Uppermost
Horizontal
Subdivision

FIGURE 4

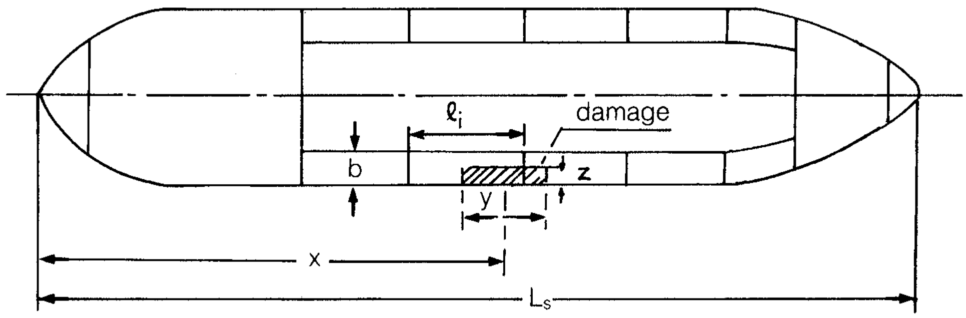


FIGURE 5

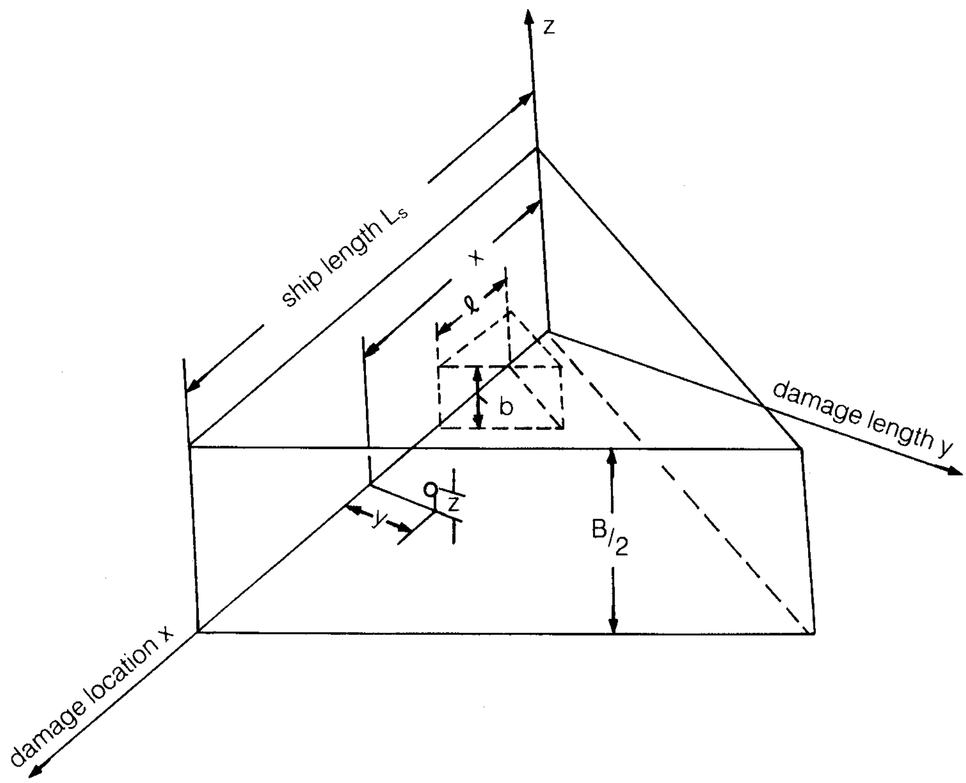


FIGURE 6

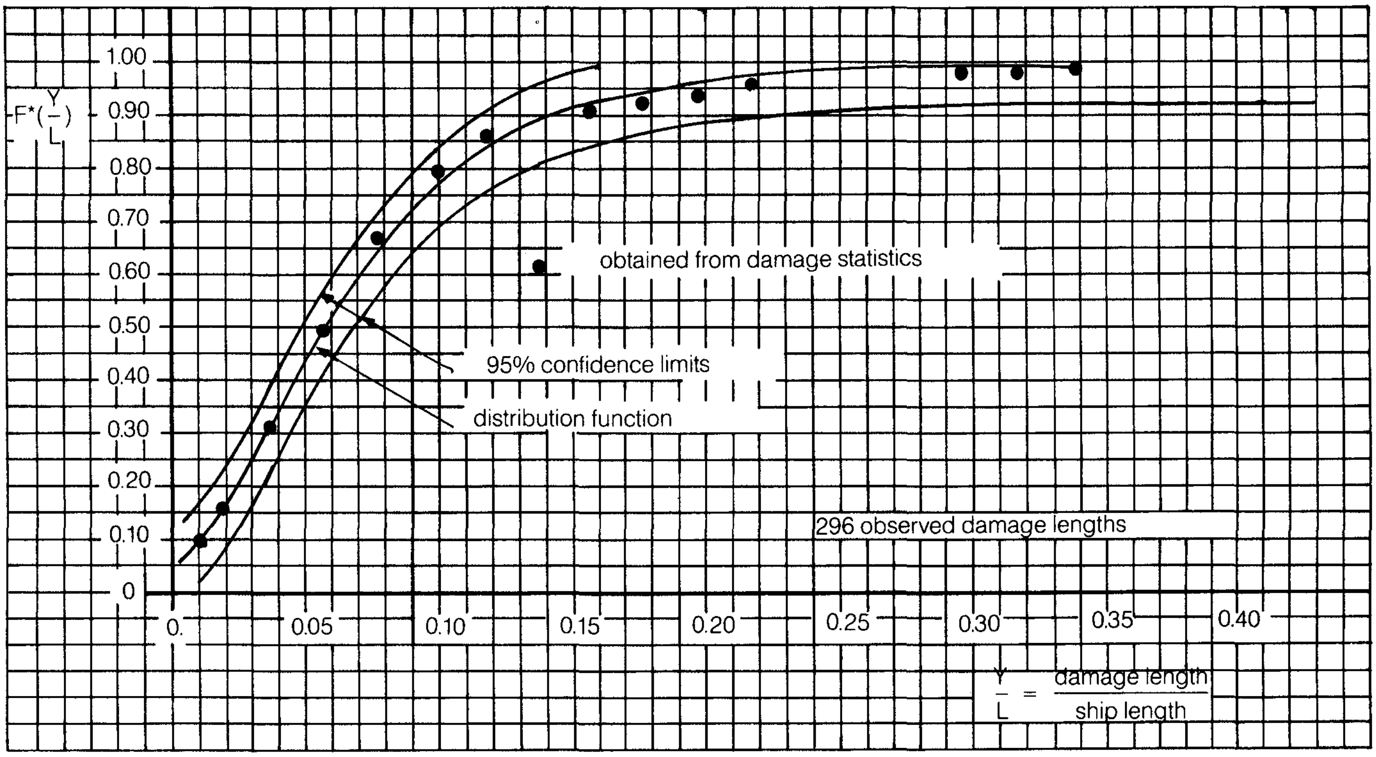


FIGURE 7 - DISTRIBUTION FUNCTION OF NON-DIMENSIONAL DAMAGE LENGTH

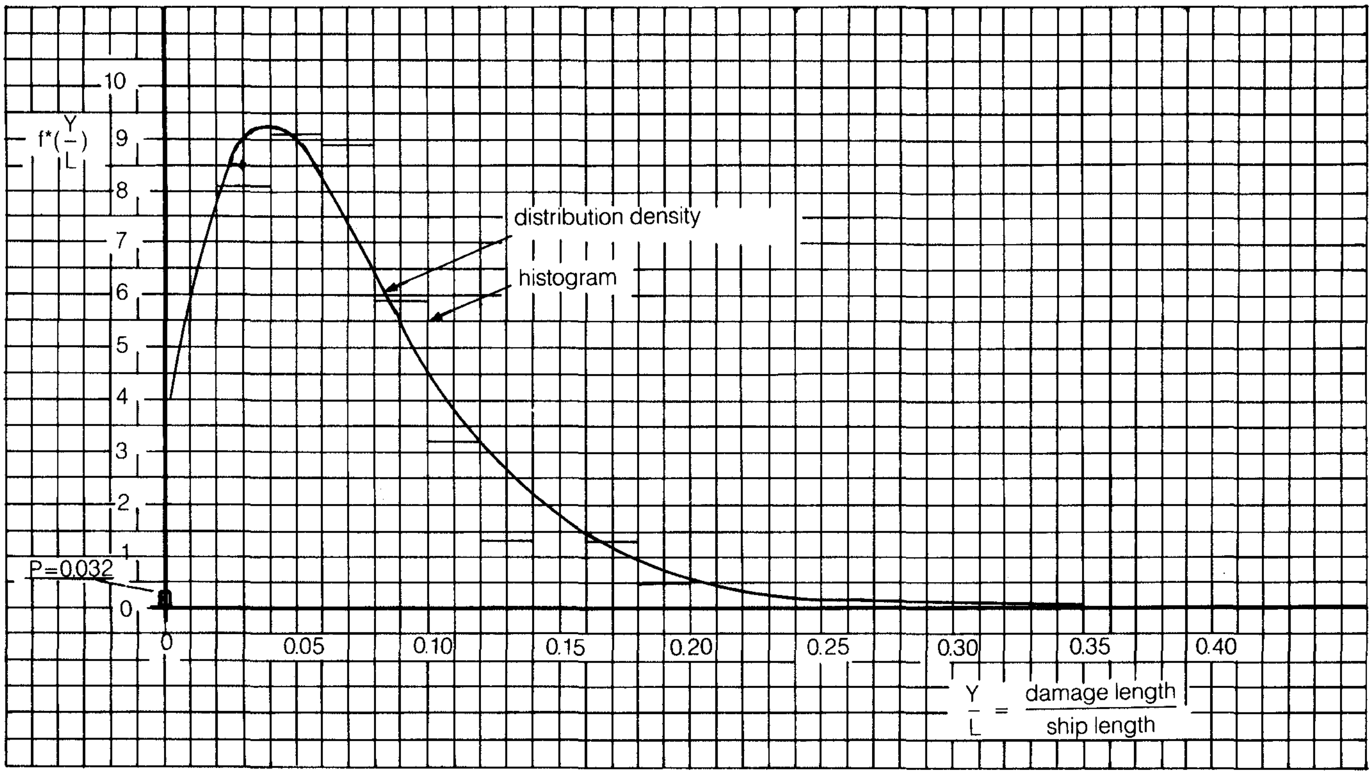


FIGURE 8 - DISTRIBUTION DENSITY OF NON-DIMENSIONAL DAMAGE LENGTH

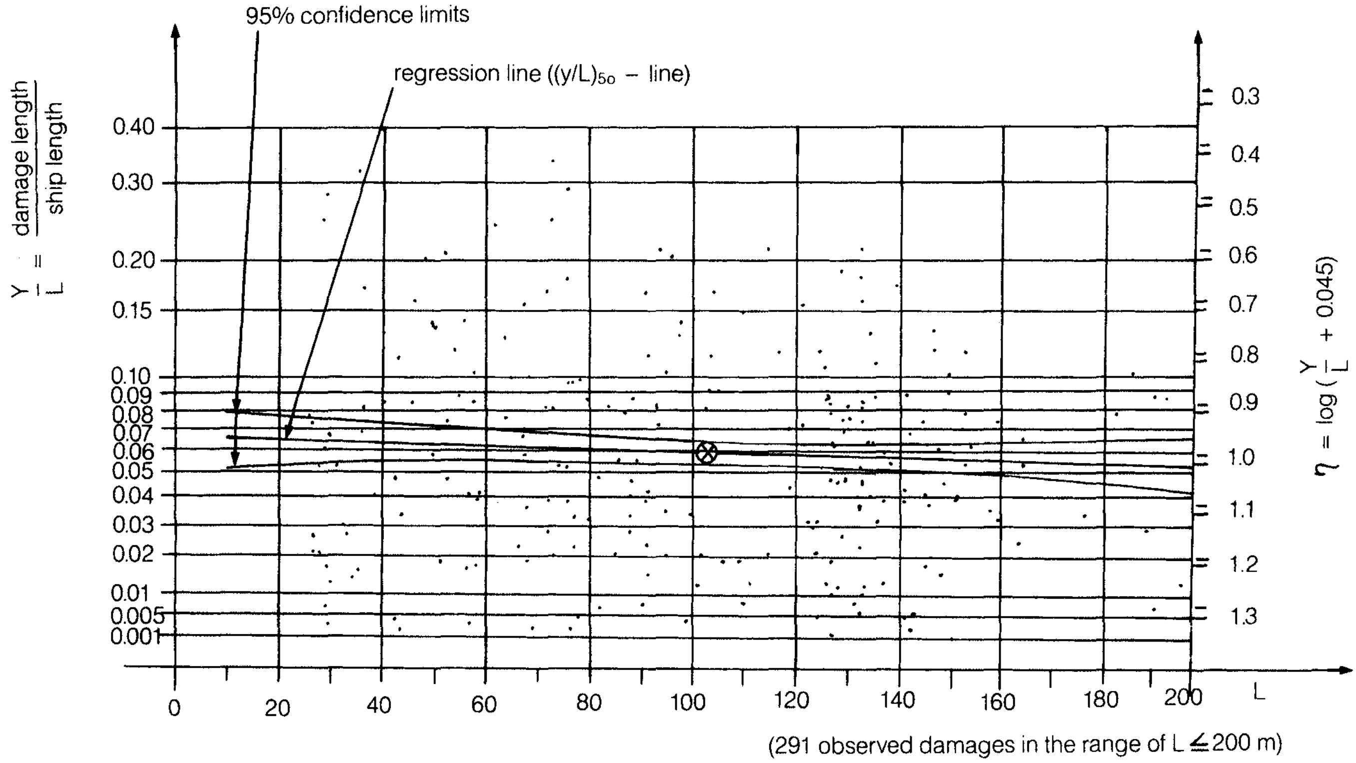


FIGURE 9 - REGRESSION OF NON-DIMENSIONAL DAMAGE LENGTH ON SHIP LENGTH

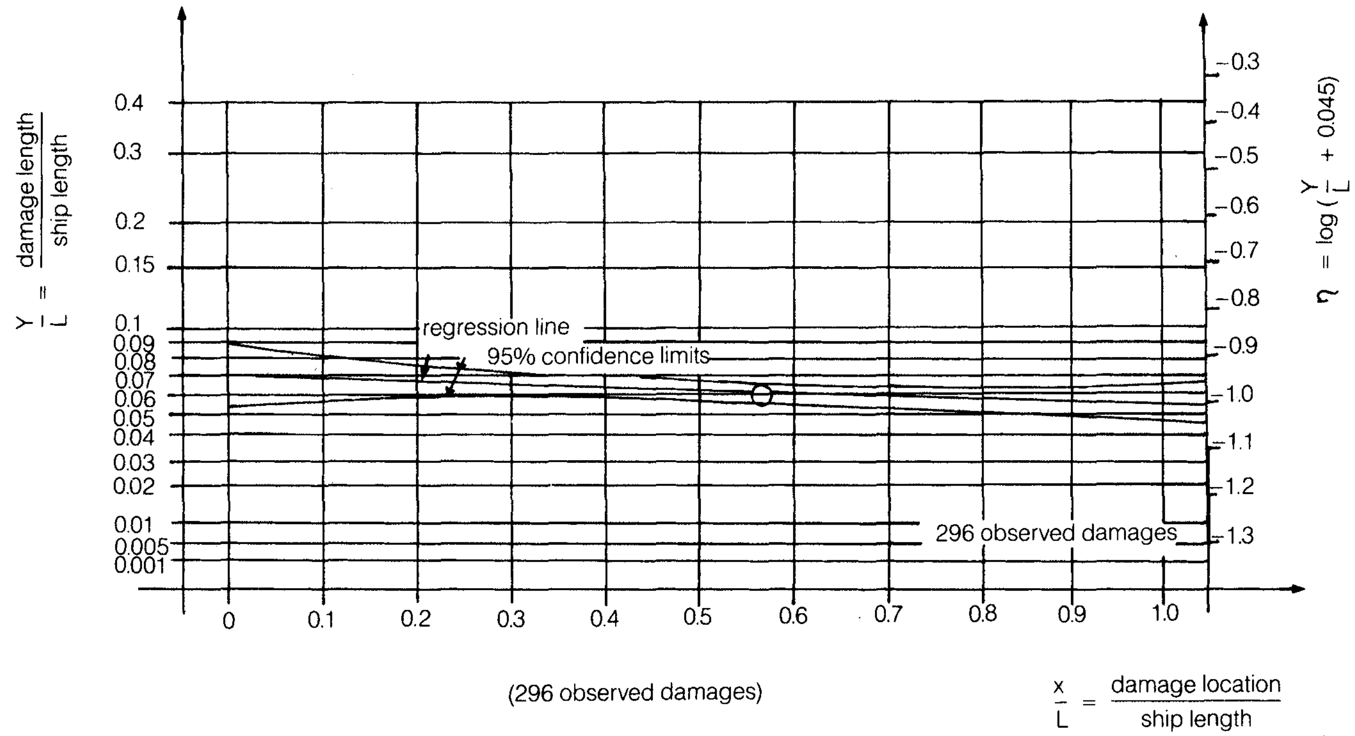


FIGURE 10 - REGRESSION OF NON-DIMENSIONAL DAMAGE LENGTH ON NON-DIMENSIONAL DAMAGE LOCATION

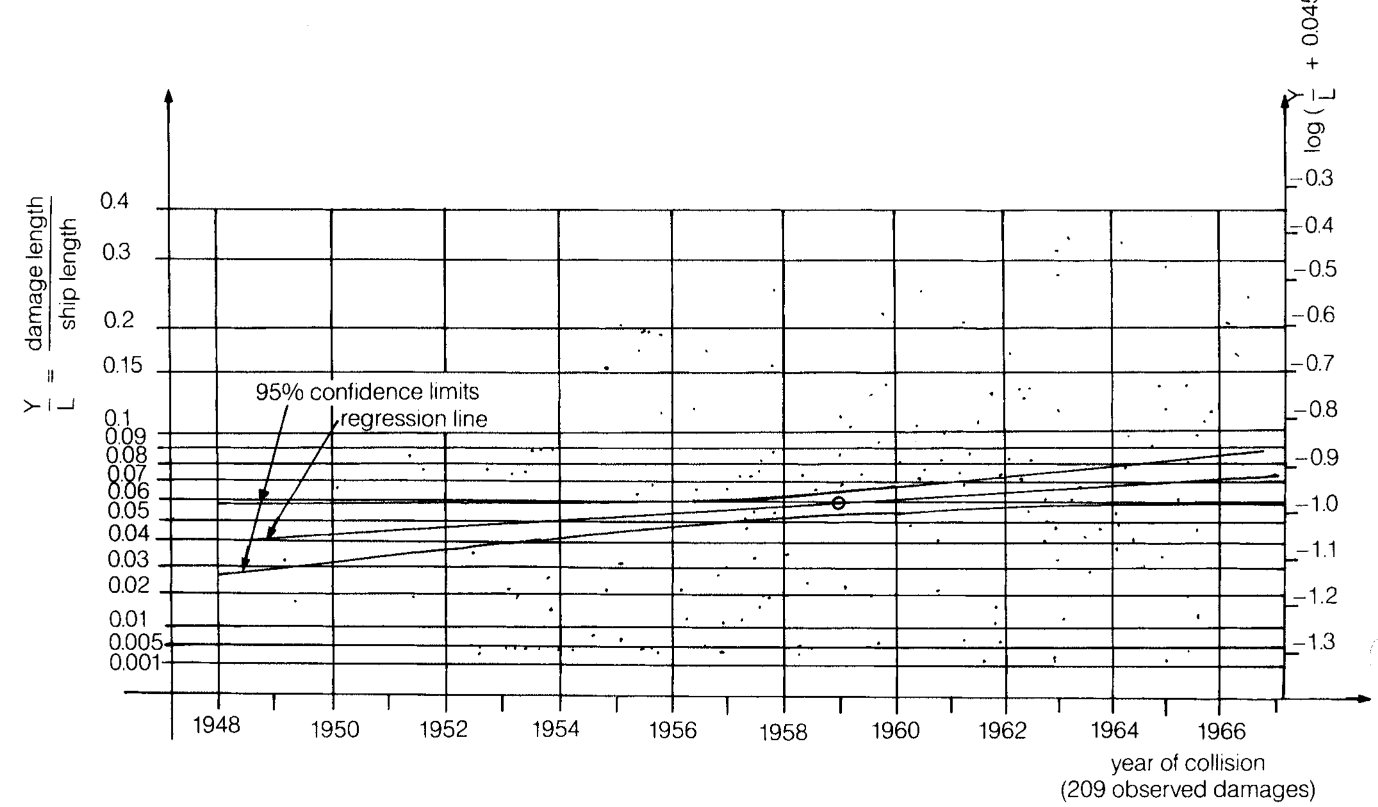


FIGURE 11 - REGRESSION OF NON-DIMENSIONAL DAMAGE LENGTH ON YEAR OF COLLISION

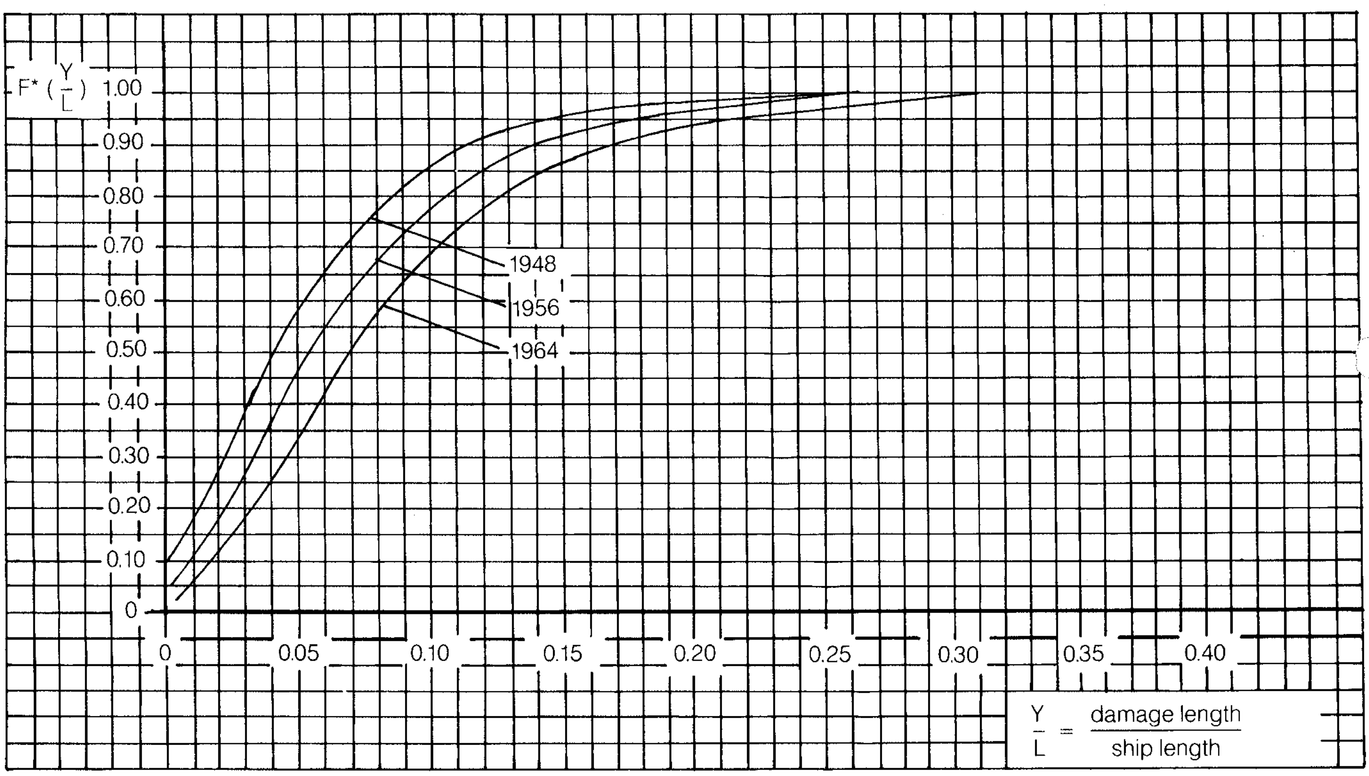


FIGURE 12 - DISTRIBUTION FUNCTION OF NON-DIMENSIONAL DAMAGE LENGTH FOR RESPECTIVE YEAR OF COLLISION

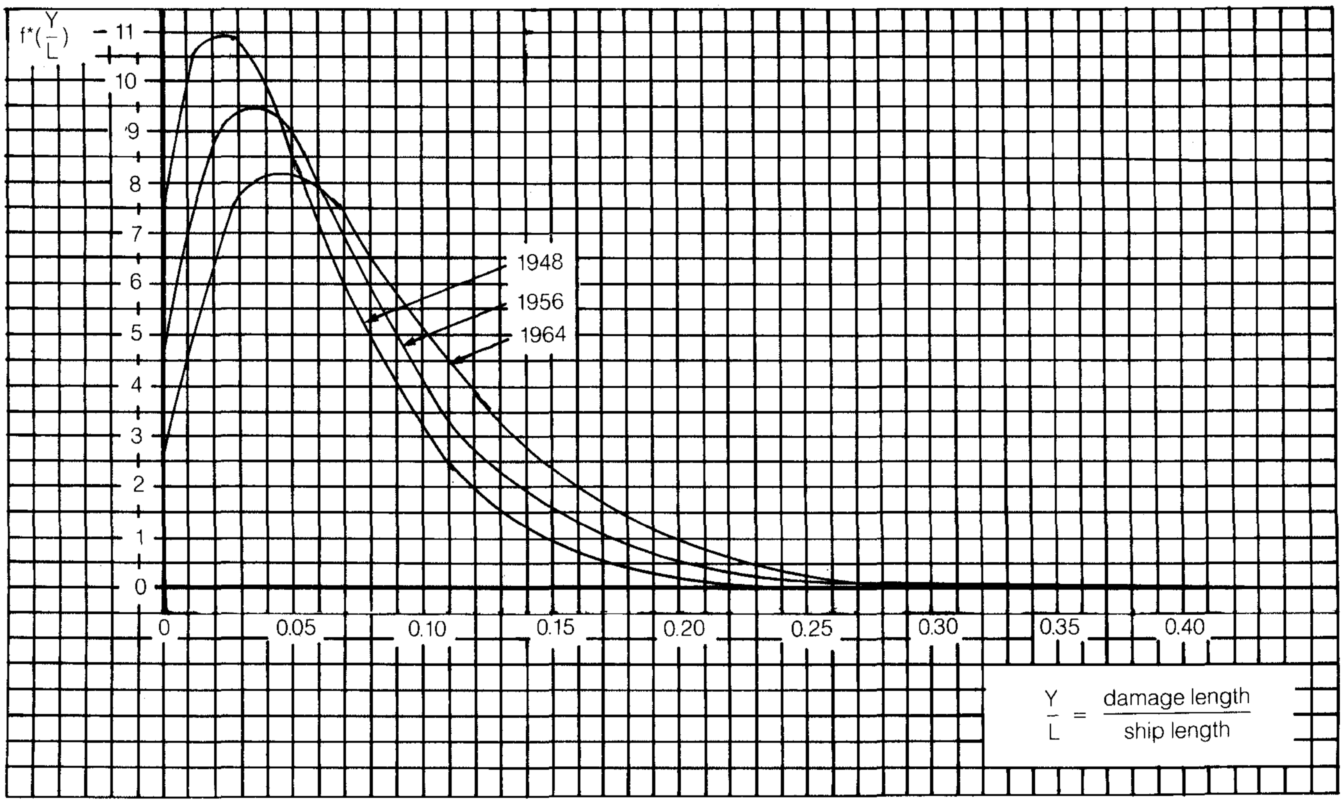


FIGURE 13 - DISTRIBUTION DENSITY OF NON-DIMENTSONAL DAMAGE LENGTH FOR RESPECTIVE YEAR OF COLLISION

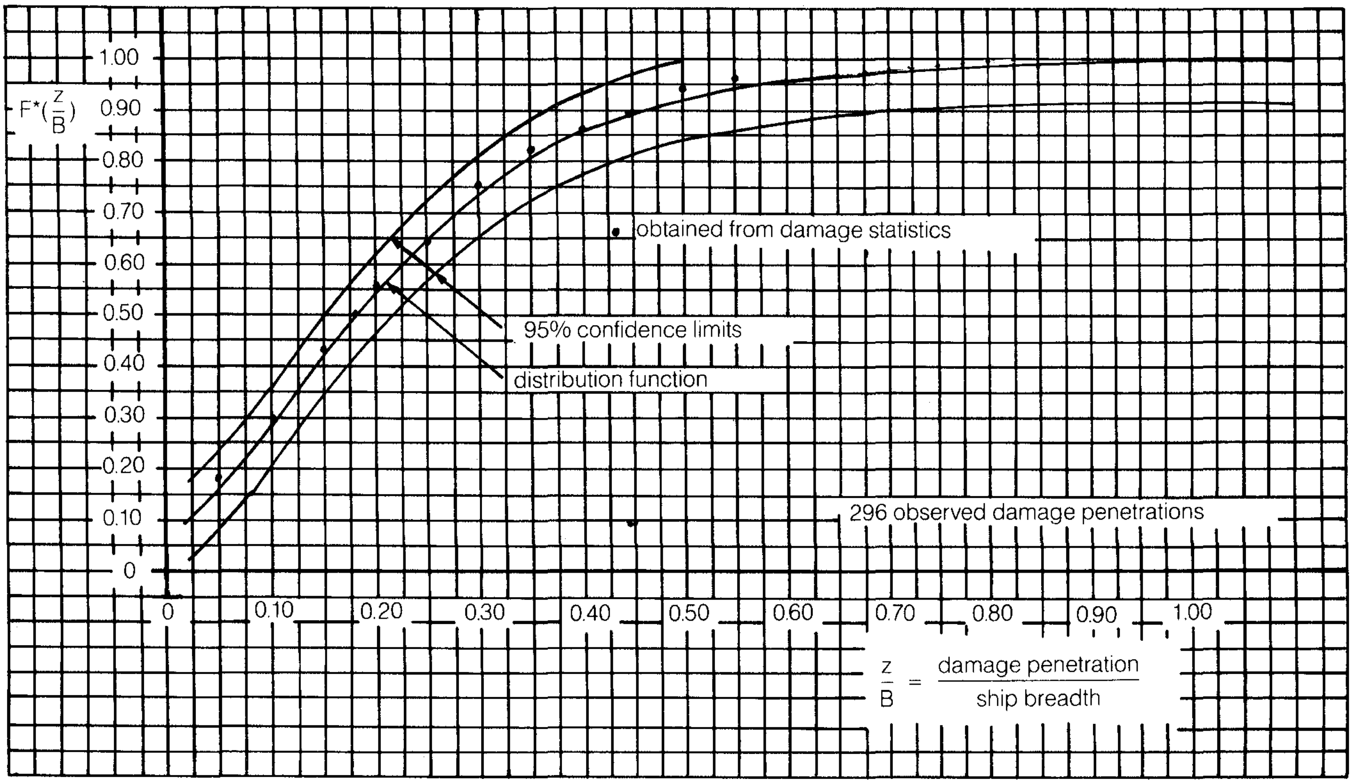


FIGURE 14 - DISTRIBUTION FUCTION OF NON-DIMENSIONAL DAMAGE PENETRATION

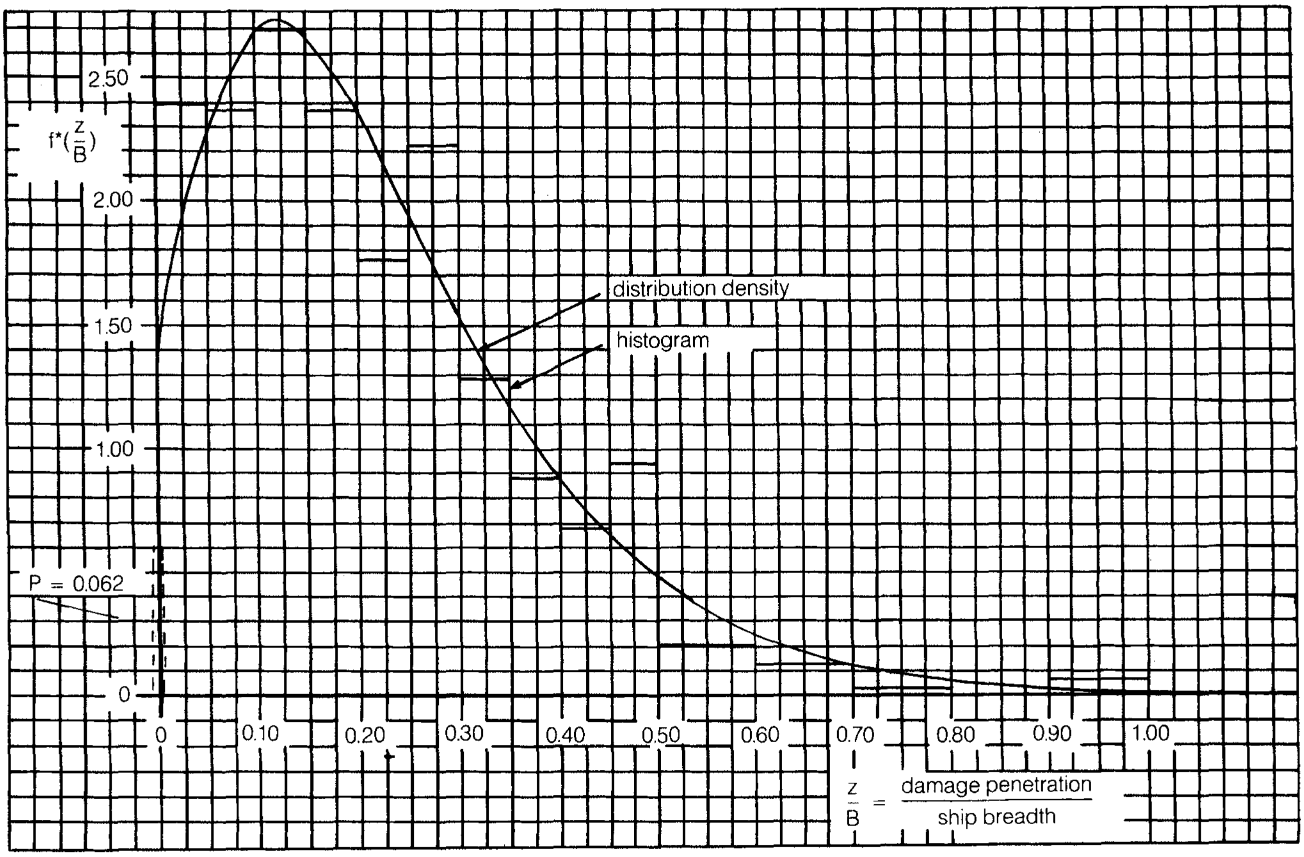


FIGURE 15 - DISTRIBUTION DENSITY OF NON-DIMENSIONAL DAMAGE PENETRATION

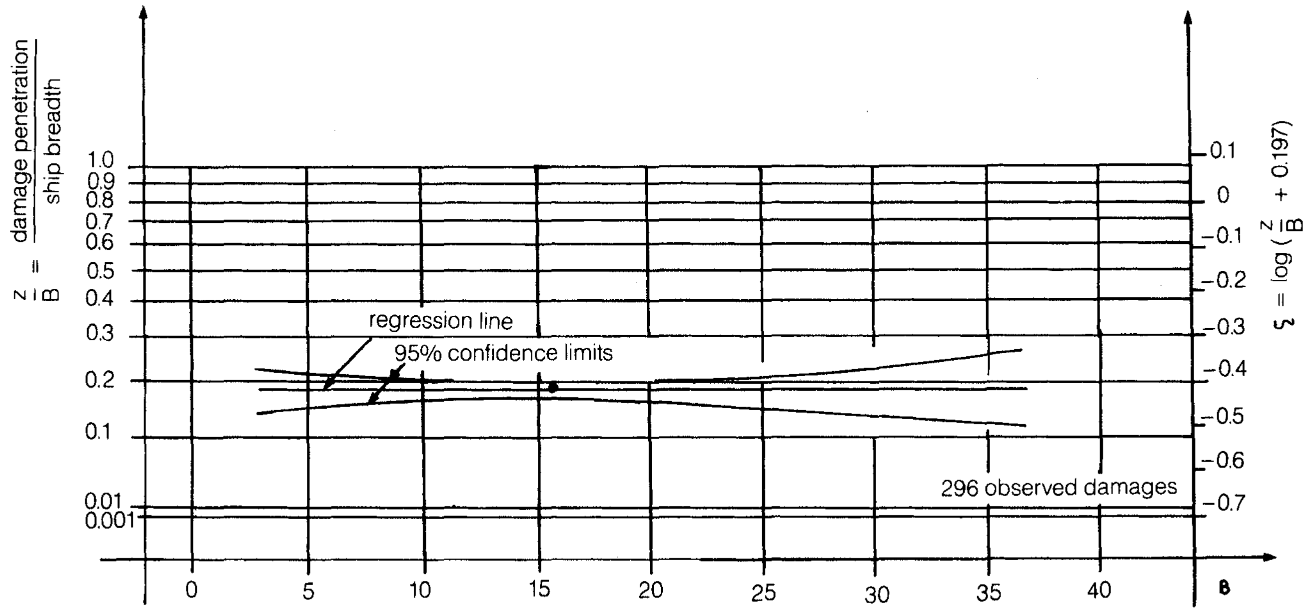


FIGURE 16 - REGRESSION OF NON-DIMENSIONAL DAMAGE PENETRATION ON SHIP BREADTH

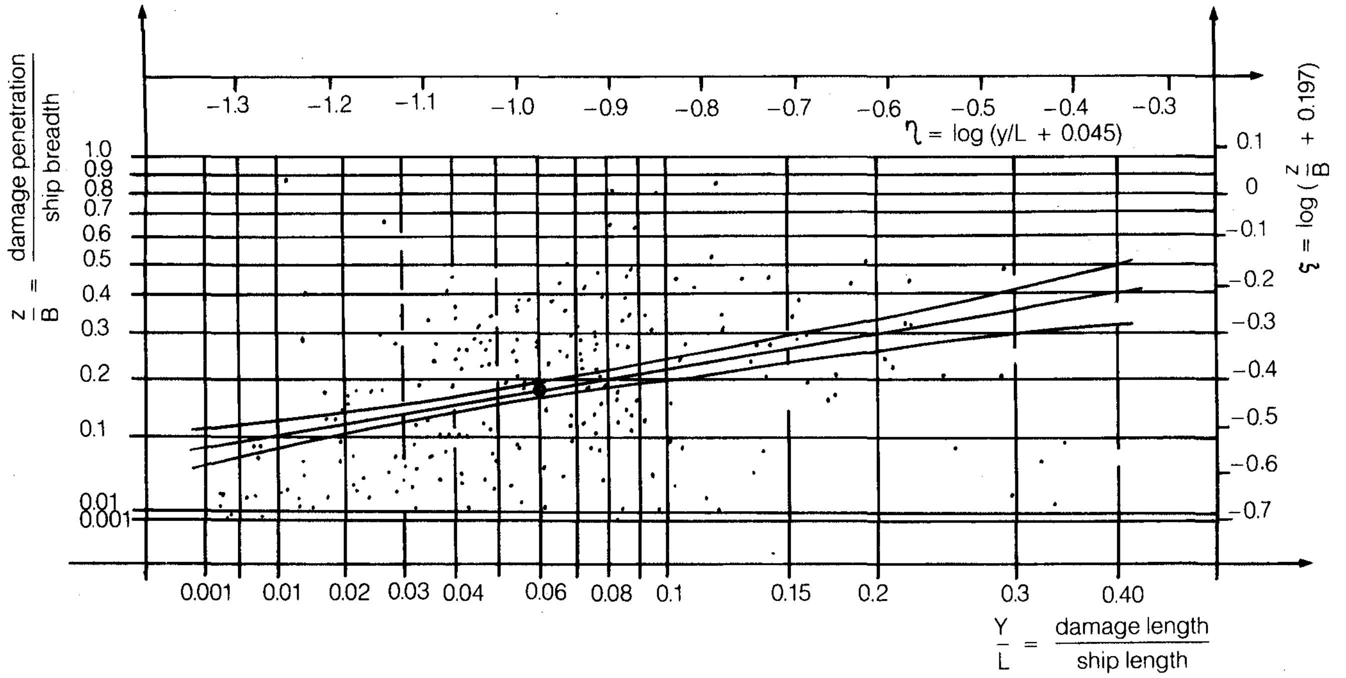


FIGURE 17

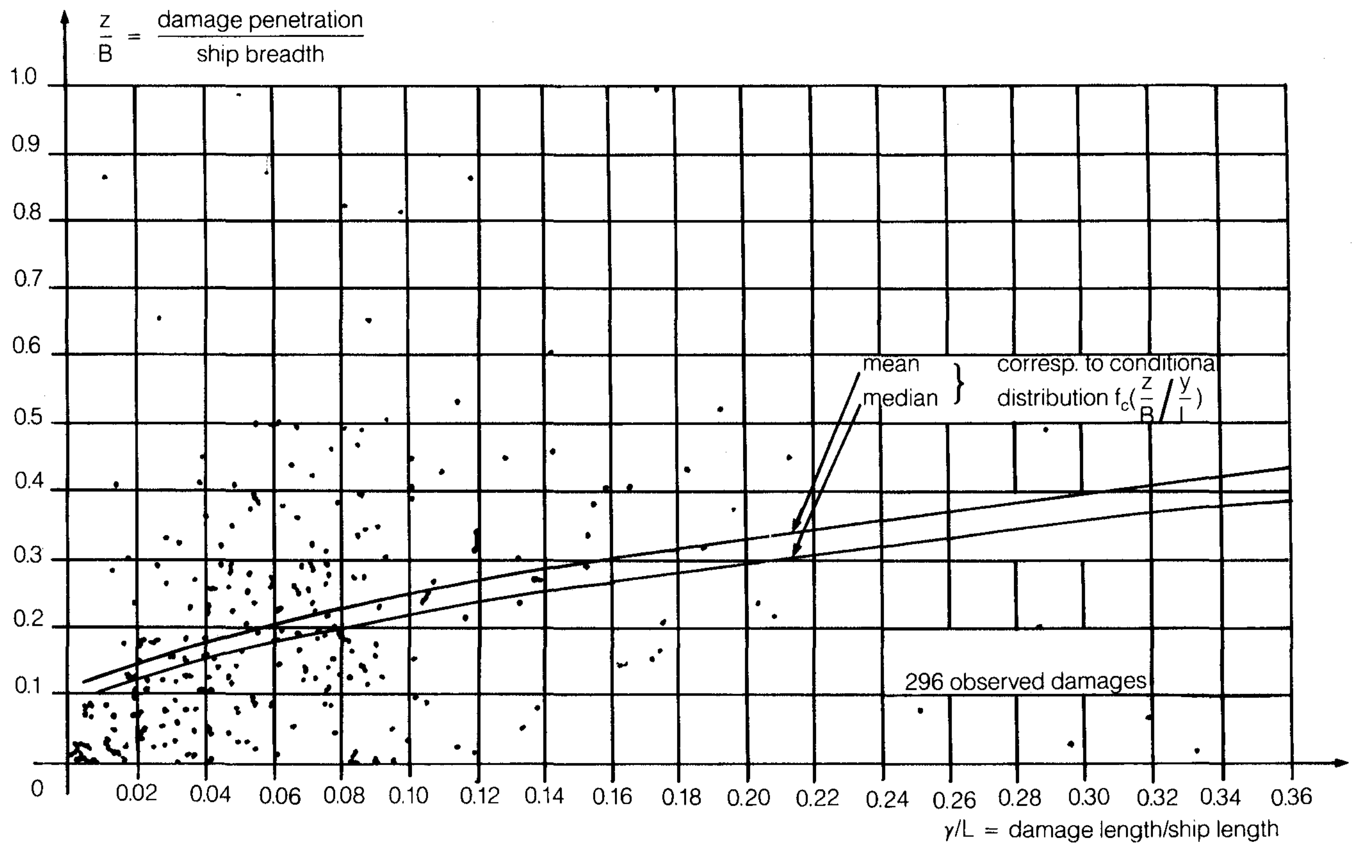


FIGURE 18

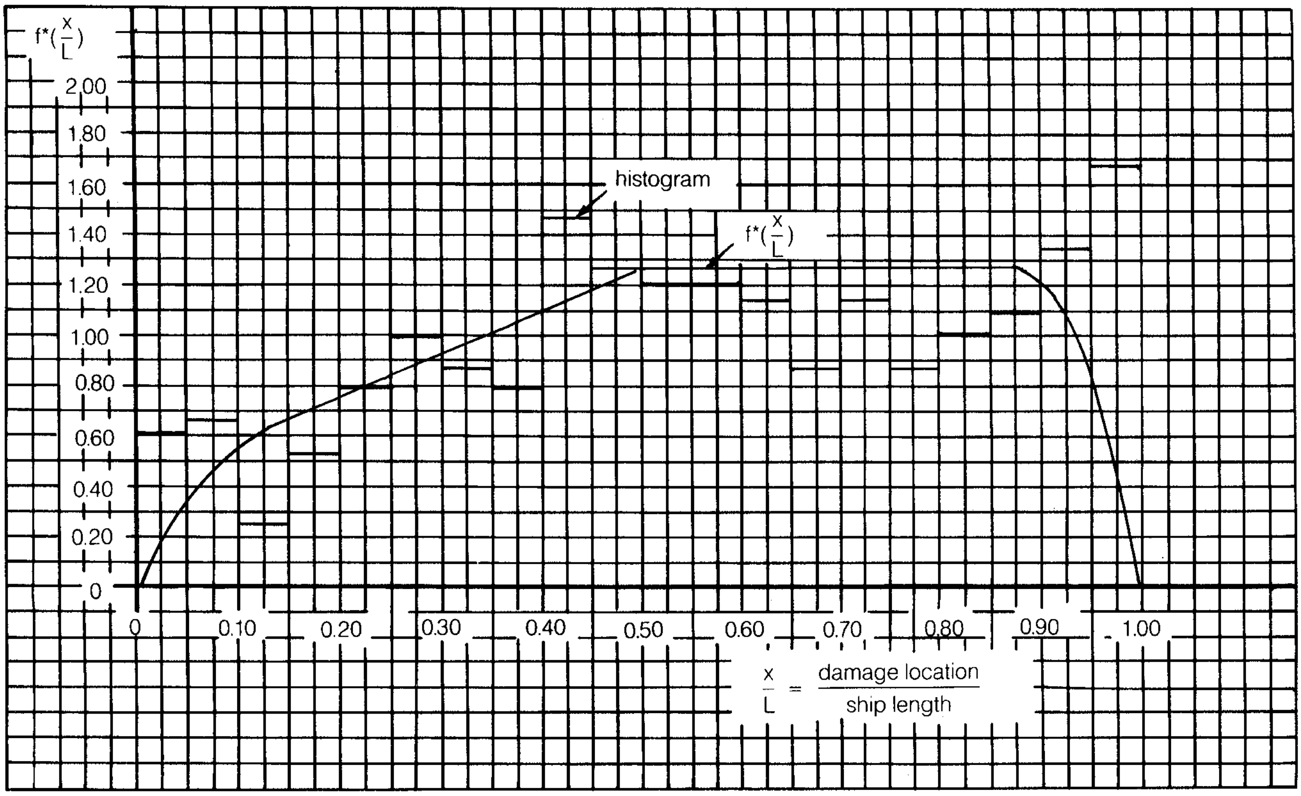


FIGURE 19 - DISTRIBUTION OF NON-DIMENSIONAL DAMAGE LOCATION

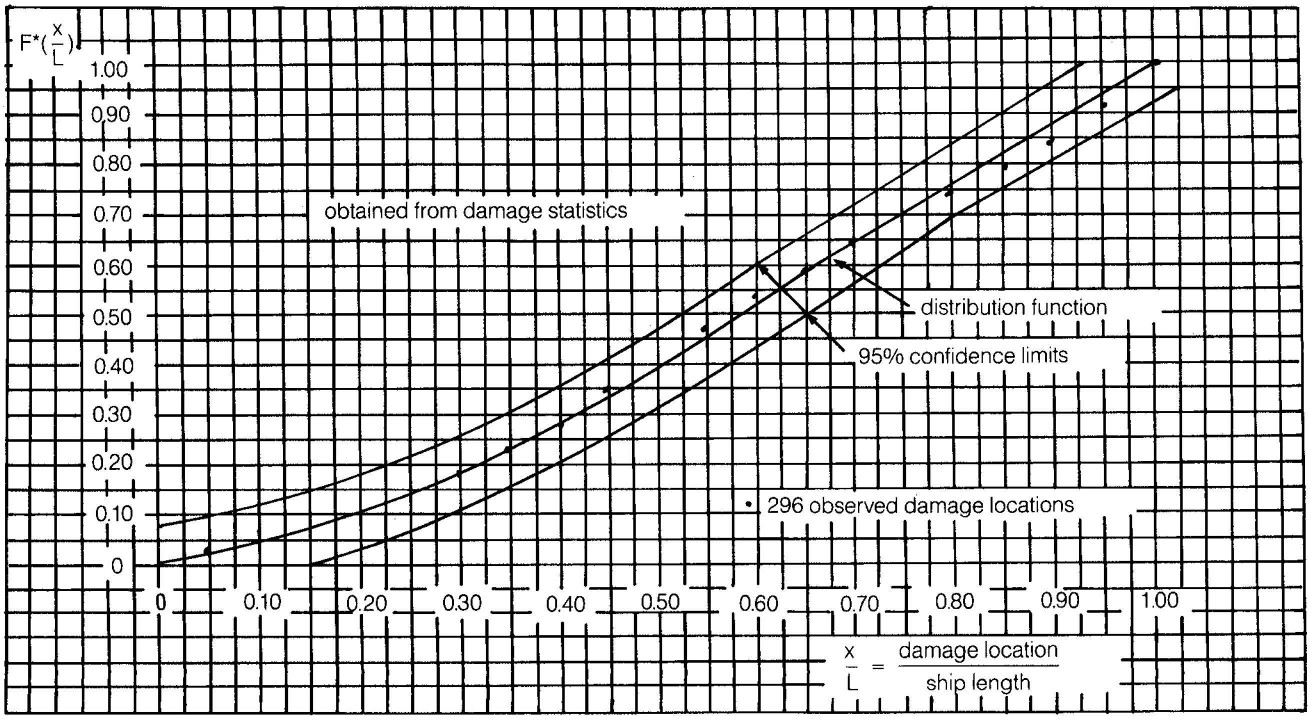


FIGURE 20 - DISTRIBUTION FUNCTION OF NON-DIMENSIONAL DAMAGE LOCATION

APPENDIX 1

TRANSVERSE SUBDIVISION

This Appendix illustrates, by means of examples, how to divide the ship length “L_s” into discrete damage zones. The subdivision of “L_s” into damage zones should not only take account of existing tranverse bulkheads, but also separate smaller local watertight compartments, the flooding of which have significant influence on the damage stability results.

1. Figure A-I shows the elevation of part of a ship containing two compartments named A and B. Compartment A is divided by local subdivision into the spaces Al and A2. For the purpose of calculating the products p*s, which contribute most favourably to the attained subdivsion index, three fictitious compartments or damage zones are considered. The basis for calculations of the ”p” and “s” values are given below:

.1 Zone 1 of length “ℓ_1”*:* — “p” based on “ℓ_1”

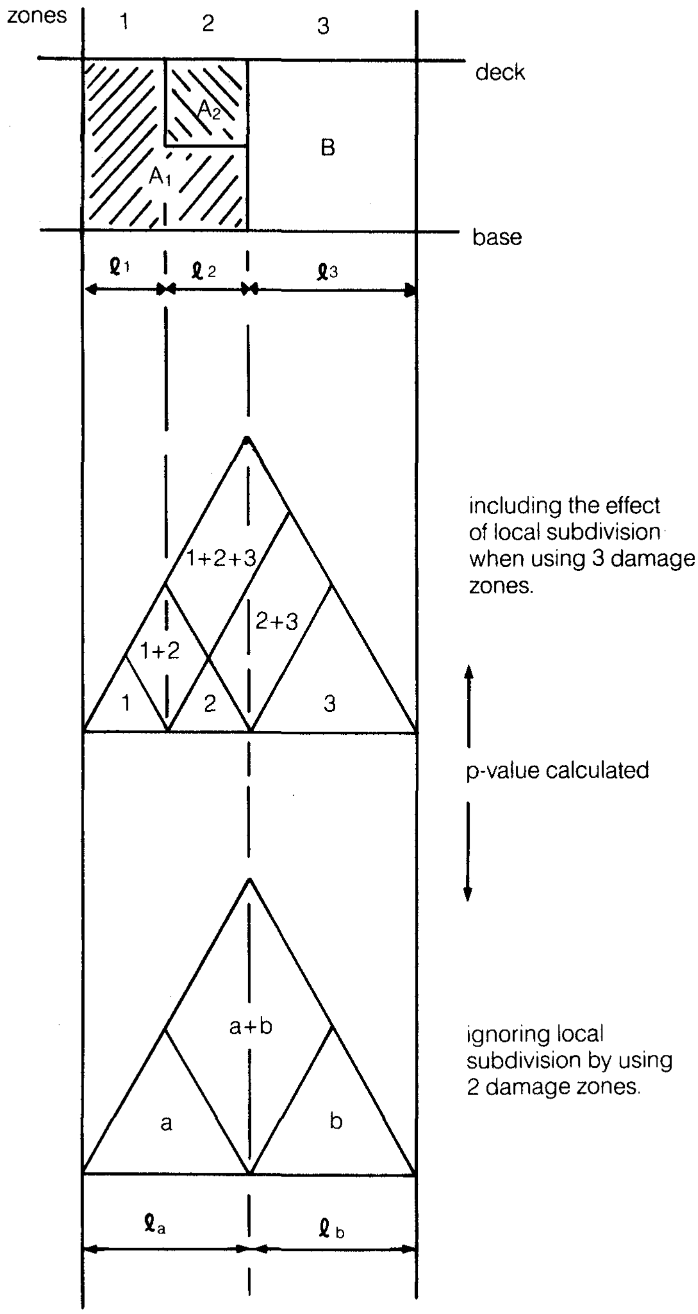
“s” based on flooding of Space A1

.2 Zone 2 of length “ℓ_2”*:* — “p” based on “ℓ_2”

“s” based on flooding of space A1 only
or of A2 only, or of
Al and A2, whichever results
in the least “s” value

“p” based on “ℓ_3”

.3 Zone 3 (or space B) of length “ℓ_3”: — “s” based on flooding of space B



zones
1
2
3
deck
A2
A1
B
base
ℓ1
ℓ2
ℓ3
1+2+3
2+3
1+2
1
2
3
including the effect of local subdivision when using 3 damage zones.
p-value calculated
a+b
a
b
ignoring local subdivision by using 2 damage zones.
ℓa
ℓb

FIGURE A-1

.4 Zones 1 + 2: “p” based on “ℓ_1” and “ℓ_2”

“s” based on flooding of A_1 <u>or</u> of A_1 and A_2, whichever results in the lesser “s” value

.5 Zones 2 + 3: “p” based on “ℓ_2” and “ℓ_3”

“s” based on flooding of A_1 and A_2 and B <u>or</u> of A_1 and B <u>or</u> of A_2 and B, whichever results in the least “s” value

.6 Zones 1 + 2 + 3: “p” based on “ℓ_1”, “ℓ_2” and “ℓ_3”

“s” based on flooding of A_1 and B <u>or</u> of A_1 and A_2 and B, whichever results in the lesser “s” value

2. It would also be compatible with the regulations to ignore the local subdivision with respect to the calculation of the “p” value. In this case, the following compartments and group of compartments would be considered.

.1 Zone a of length $\ell_3 = \ell_1 + \ell_2$: “p” based on “ℓ_a”

“s” based on flooding of space A_1 <u>or</u> of space A_2, <u>or</u> of spaces A_1 and A_2, whichever results in the least “s” value

.2 Zone b of length “ℓ_b” ($=\ell_3$): “p” based on “ℓ_b”

"s" based on flooding of space B

.3 Zones a + b: “p” based on “ℓ_a” and “ℓ_b”

“s” based on flooding of A_1 and B <u>or</u> of A_2 and B <u>or</u> of A_1 and A_2 and B, whichever results in the least “s” value

3. Obviously, the approach given in paragraph 1 above will generally lead to a higher (but at least the same) attained subdivision index than the approach of paragraph 2. Also, the error made by neglecting the actual distribution of damage in the vertical direction is much smaller in the first case.

4. Another example of local subdivision is shown in Figure A-2. The following tables illustrate how this can be handled.

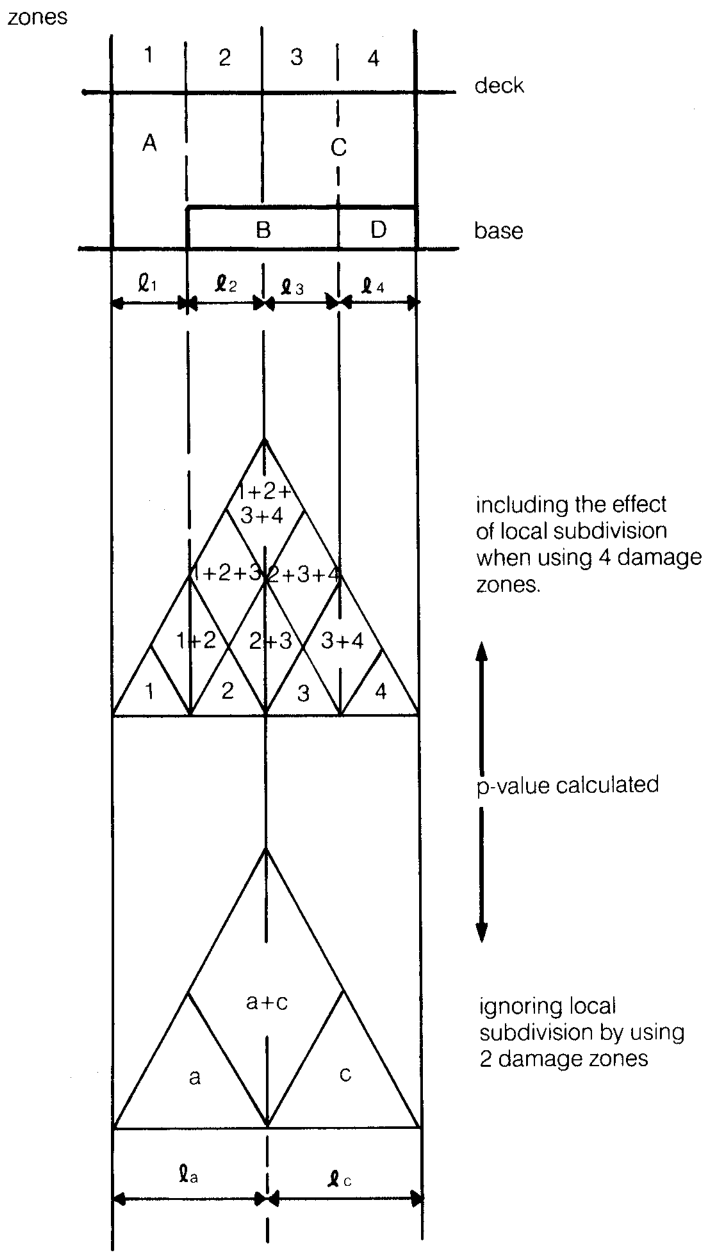

zones
1
2
3
4
deck
A
C
B
D
base
ℓ1
ℓ2
ℓ3
ℓ4
1+2+
3+4
1+2+3
2+3+4
1+2
2+3
3+4
1
2
3
4
including the effect
of local subdivision
when using 4 damage
zones.
p-value calculated
a+c
a
c
ignoring local
subdivision by using
2 damage zones
ℓa
ℓc

FIGURE A-2

TABLE Al

P -value calculated including the effect of local subdivision

Damage zones measuring length of space opened	p based on length(s)	S based on the flooding of space(s) resulting in the poorest stability
1	ℓ_1	space A
2	ℓ_2	space A or space B or spaces A and B*
3	ℓ_3	space B or space C or spaces Band C*
4	ℓ_4	space C or space D or spaces C and D*
1+2	ℓ_1, ℓ_2	space A or spaces A and B*
2+3	ℓ_2, ℓ_3	space B or spaces A and C or spaces A and Band C*
3+4	ℓ_3, ℓ_4	space C or spaces Band D or spaces Band C and D*
1+2+3	ℓ_1, ℓ_2, ℓ_3	spaces A and B or A and C or A and Band C*
2+3+4	ℓ_2, ℓ_3, ℓ_4	spaces A and C or Band D or A and Band C and D*
1+2+3+4	$\ell_1, \ell_2, \ell_3, \ell_4$	spaces A and C or A and Band D or A and Band C and D*

* – whichever results in a smaller ‘s’ value

TABLE A-2

p – value calculated ignoring local subdivision

Damage zones measuring length of space opened	P based on length(s)	S based on the flooding of space(s) resulting in the poorest stability
A	$\ell_A = \ell_1, + \ell_2$	space A or space B or spaces A and B*
C	$\ell_C = \ell_3 + \ell_4$	space C or space B or spaces D or spaces C and B or spaces Band D or spaces C and D spaces Band C and D*
A+C	ℓ_A, ℓ_C	space B or spaces A and C or spaces Band D or spaces A and B and or spaces A and Band D or spaces A and Band C and D*

* -whichever results in a smaller's' value

APPENDIX 2

I COMBINED TRANSVERSE, HORIZONTAL AND LONGITUDINAL SUBDIVISION

1. Provision has been included in the new regulations to permit evaluation and acceptance of ships with combined longitudinal and transverse subdivision. To facilitate a full understanding and correct and uniform application of the new provisions, some illustrative material is contained in this Appendix. The examples given are based on three different arrangements of combined longitudinal and transverse subdivision as shown in Figures A-3, A-4 and A-5.

2. The following nomenclature is used in this section:

$\ell_1, \ell_2, \ell_3 \ldots$ distance between bulkheads bounding either inboard or wing compartments as shown in Figures A-3, A-4 and A-5

$\ell_{12} = \ell_1 + \ell_2; + \ell_{23} = \ell_2 + \ell_3;\ \ell_{34} = \ell_3 + \ell_4$, etc.

$\ell_{1-3} = \ell_1 + \ell_2 + \ell_3; \ell_{2-4} = \ell_2 + \ell_3 + \ell_4$, etc.

$\ell_{2-5} = \ell_2 + \ell_3 + \ell_4 + \ell_5; \ell_{3-6} = \ell_3 + \ell_4 + \ell_5 + \ell_6$, etc.

p_1, p_2, p_3 etc. are "p" calculated according to regulation 25-5.1 using ℓ_1, ℓ_2, ℓ_3 etc, as "ℓ".

p_{l2}, p_{23}, p_{34}, etc. are "p" calculated according to regulation 25-5.1 using $\ell_{12}, \ell_{23}, \ell_{34}$ (1'34 etc, as "ℓ".

p_{l-3}, p_{2-4}, etc. are "p" calculated according to regulation 25-5.1 using ℓ_{1-3}, ℓ_{2-4}, etc, as "ℓ".

p_{2-5}, p_{3-6}, etc. are "p" calculated according to regulation 25-5.1 using ℓ_{2-5}, ℓ_{3-6}, etc, as "ℓ".

r_1, r_2, r_3, etc. are "r" calculated according to regulation 25-5.2 using ℓ_1, ℓ_2, ℓ_3 etc, as "ℓ" and "b" defined in regulation 25-5.2.

r_{l2}, r_{23}, r_{34}, etc. are "r" calculated according to regulation 25-5.2 using ℓ_{12}, ℓ_{23}, ℓ_{34} etc, as "ℓ" and "b" defined in regulation 25-5.2.

r_{2-5}, r_{3-6}, etc. are "r" calculated according to regulation 25-5.2 using ℓ_{2-5}, ℓ_{3-6}, etc, as "ℓ" and "b" as defined in regulation 25-5.2.

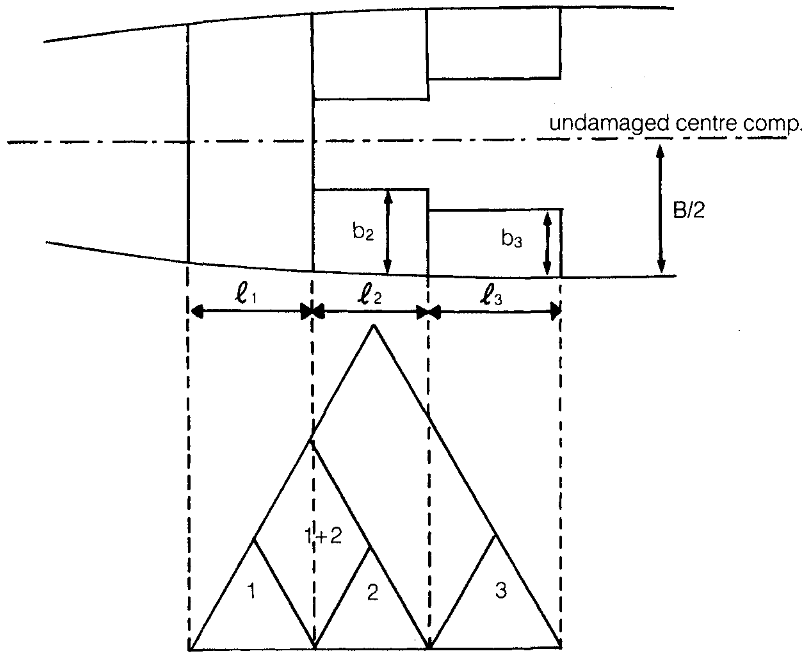
b as defined in regulation 25-5.2

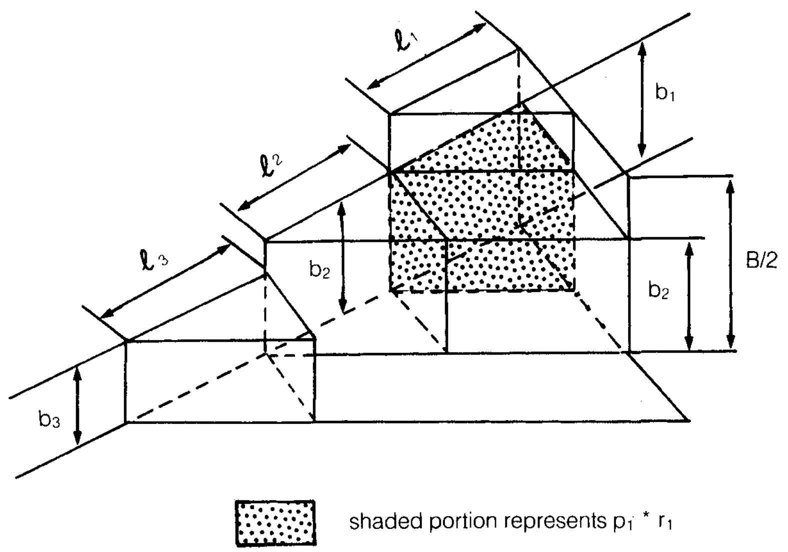
In calculating "r" values for a group of two or more adjacent compartments, the "b" value is common for all compartments in that group, and equal to the smallest "b" value in that group:

$$b = \min \{b_l, b_2 \ldots\ldots.. b_n\}$$

Where: "n" = number of wing compartments in that group;
"b_l", "b_2" ……. "b_n" are the mean values of "b" for individual wing compartments contained in the group.

When determining the factor "p" for simultaneous flooding of space 1, (in figures A-4 and A-5), and adjacent side compartment(s) the values "r_1", "r_{12}", etc. should be calculated according to regulation 25-5.2, taking "b" for space 1 equal to the breadth of the adjacent side compartment(s).





The p - factor for comp. 1 + 2 : $p = p_{12} * r_{12} - p_1 * r_1 - p_2 * r_2$

where r_1 is function of ℓ_1 and b_2
r_2 is function of ℓ_2 and b_2
r_{12} is function of $\ell_1 = \ell_2$ and b_2

FIGURE A-3 ILLUSTRATION OF COMBINED DAMAGE AT THE END OF UNDAMAGED CENTRE COMPARTMENT

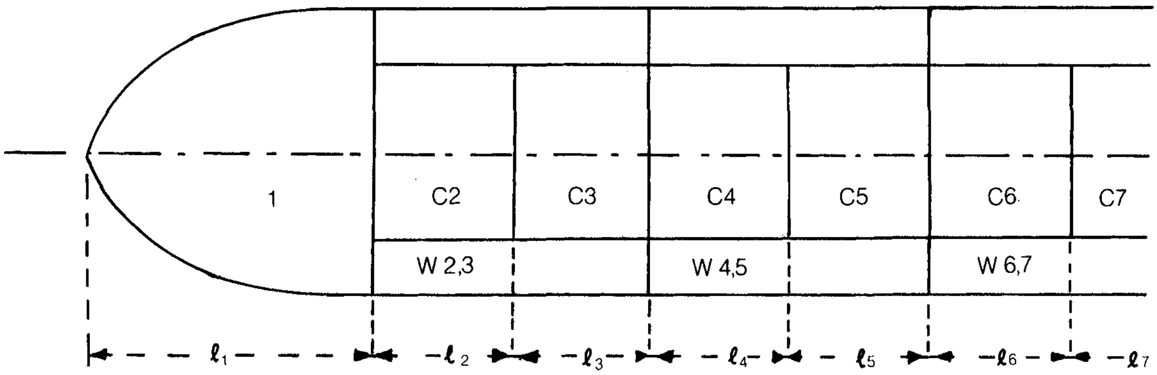


FIGURE A-4

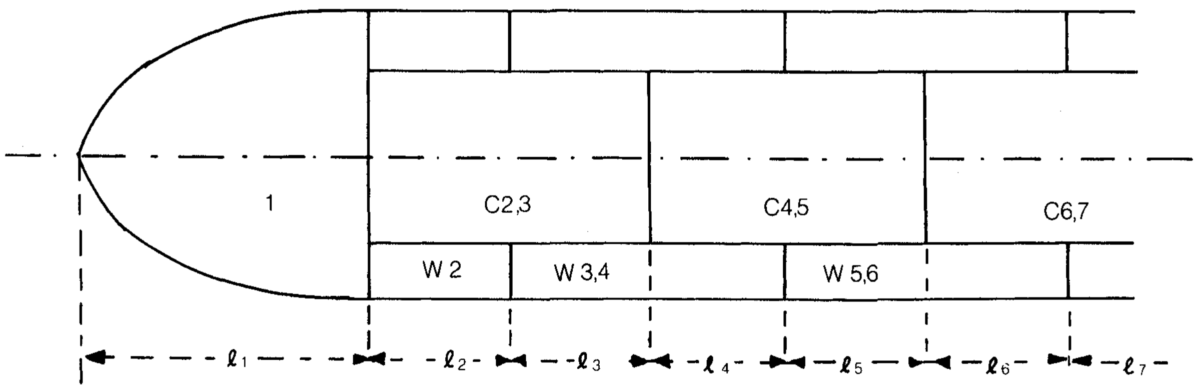


FIGURE A-5

TABLE A-3

Application of regulation 25-5* to subdivision arrangement shown in figure A-4

damage zone(s) as compartment or group of compartments**	p-factor	Distances XI and X2 for determination of factor P	
1	$p = p_1$	$x_1 = 0$	$x_2 = \ell_1$
W2,3	$p = p_{23}.r_{23}$	$x_1 = \ell_1$	$x_2 = \ell_{1-3}$
W4,5	$p = p_{45}.r_{45}$	$x_1 = \ell_{1-3}$	$x_2 = \ell_{1-5}$
1 and W 2,3	$p = p_{1-3}.r_{1-3} – p_1.r_1 - p_{23}.r_{23}$	$x_1 = 0$	$x_2 = \ell_{1-3}$
W 2,3 and W 4,5	$p = p_{2-5}.r_{2-5} - p_{23}.r_{23} - p_{45} - r_{45}$	$x_1 = \ell_1$	$x_2 = \ell_{1-5}$
1 and W 2,3 and W 4,5	$p = p_{1-5}.r_{1-5} – p_{1-3}.r_{1-3} - p_{2-5}.r_{2-5} + p_{23}.r_{23}$	$x_1 = 0$	$x_2 = \ell_{1-5}$
W 2,3 and W 4,5 and W 6,7	$p = p_{2-7}.r_{2-7} - p_{2-S}.r_{2-5} - p_{4-7}.r_{4-7} + p_{45}.r_{45}$	$x_1 = \ell_1$	$x_2 = \ell_{1-7}$

r_{1-5} is function of ℓ_{1-5} & b_{2-5}
r_{45} is function of ℓ_{45} & b_{2-7}

TABLE A-4

Application of regulation 25-5* to subdivision arrangement shown in figure A-4

damage zone(s) as compartment or group of compartments**	p-factor	Distances X_1 and X_2 for determination of factor P	
C2 and W 2,3	$p = p_2\ (1-r_2)$	$x_1 = \ell$	$x_2 = \ell_{12}$
C3 and W 2,3	$p = p_3\ (1-r_3)$	$x_1 = \ell_{12}$	$x_2 = \ell_{1-3}$
C4 and W 4,5	$p = p_4\ (1-r_4)$	$x_1 = \ell_{1-3}$	$x_2 = \ell_{1-4}$
1 and C2 and W 2,3	$p = p_{12}\ (1-r_{12}) – p_1\ (1-r_1) - p_2\ (1-r_2)$	$x_1 = 0$	$x_2 = \ell_{12}$
C2 and C3 and W 2,3	$p = p_{23}\ (1-r_{23}) - p_2\ (1-r_2) - p_3\ (1-r_3)$	x_1 = PI	$x_2 = \ell_{1-3}$
C3 and C4 and W 2,3 and W 4,5	$p = p_{34}\ (1-r_{34}) - p_3\ (1-r_3) - p_4\ (1-r_4)$	x_1 = A2	$x_2 = \ell_{1-4}$
1 and C2 and C3 and W 2,3	$P = p_{1-3}(1-r_{1-3})-p_{12}(1-r_{12})-p_{23}(1-r_{23})+p_2(1-r_2)$	$x_1 = 0$	$x_2 = \ell_{1-3}$
C2 and C3 and C4 and W 2,3 and W 4,5	$p = p_{2-4}(1-r_{2-4})-p_{23}(1-r_{23})-p_{34}(1-r_{34})+p_3(1-r_3)$	$x_1 = \ell_1$	$x_2 = \ell_{1-4}$

* **With particular reference to 25-5.1 and 25-5.2.1**
** **To be considered flooded for s-calculation.**

TABLE A-5

Application of regulation 25-5* to subdivision arrangement shown in figureA-5

damage zone(s) as compartment or group of compartments**	p-factor	Distances XI and X2 for determination of factor P	
1	$p = p_1$	$x_1 = 0$	$x_2 = \ell_1$
W2	$p = p_2.r_3$	$x_1 = \ell_1$	$x_2 = \ell_{12}$
W3,4	$p = p_{34}.r_{34}$	$x_1 = \ell_{12}$	$x_2 = \ell_{1\text{-}4}$
1 and W 2	$p = p_{12}.r_{12} – p_1.r_1 - p_2.r_2$	$x_1 = 0$	$x_2 = \ell_{12}$
W2andW3,4	$p = p_{24}.r_{24} - p_2.r_2 - p_{34}.r_{34}$	$x_1 = \ell_1$	$x_2 = \ell_{1\text{-}4}$
1 and W 2 and W 3,4	$P = p_{1\text{-}4}.r_{1\text{-}4} - p_{12}.r_{12} - p_{2\text{-}4}.r_{2\text{-}4} + p_2.r_2$	$x_1 = 0$	$x_2 = \ell_{1\text{-}4}$
W 2 and W 3,4 and W 5,6	$p = p_{2\text{-}6}.r_{2\text{-}6} - p_{24}.r_{24} - p_{3\text{-}6}.r_{3\text{-}6} + p_{34}.r_{34}$	$x_1 = \ell_1$	$x_2 = \ell_{1\text{-}6}$

TABLE A-6

Application of regulation 25-5* to subdivision arrangement shown in figure A-5

damage zone(s) as compartment or group of compartments**	p-factor	Distances Xl and X2 for determination of factor P	
C2,3 and W 2	$p = p_2\,(1\text{-}r_2)$	$x_1 = \ell_1$	$x_2 = \ell_{12}$
C2,3 and W 3,4	$p = p_3\,(1\text{-}r_3)$	$x_1 = \ell_{12}$	$x_2 = \ell_{1\text{-}3}$
C4,5 and W 3,4	$p = p_4\,(1\text{-}r_4)$	$x_1 = \ell_{1\text{-}3}$	$x_2 = \ell_{1\text{-}4}$
1 and C2,3 and W 2	$P = p_{12}\,(1\text{-}r_{12}) – p_1\,(1\text{-}r_1) - p_2\,(1\text{-}r_2)$	$x_1 = 0$	$x_2 = \ell_{12}$
1 and C2,3 and W 2 and W 3,4	$P = p_{1\text{-}3}(1\text{-}r_{1\text{-}3})\text{-}p_{12}(1\text{-}r_{12})\text{-}p_{23}(1\text{-}r_{23})\text{+}p2(1\text{-}r_2)$	$x_1 = 0$	$x_2 = \ell_{1\text{-}3}$
C2,3 and C4,5 and W 3,4	$P = p_{34}\,(1\text{-}r_{34})$	$x_2 = \ell_{12}$	$x_2 = \ell_{1\text{-}4}$
C2,3 and C4,5 and W 2 and W 3,4	$P = p_{2\text{-}4}(1\text{-}r_{2\text{-}4})\text{-}p_2(1\text{-}r_2)\text{-}p_{34}(1\text{-}r_{34})$	$x_1 = \ell_1$	$x_2 = \ell_{1\text{-}4}$
C2,3 and C4,5 and W 3,4 and W 5,6	$P = p_{3\text{-}5}(1\text{-}r_{3\text{-}5})\text{-}p_{34}(1\text{-}r_{34})\text{-}p3\,(1\text{-}r_3)$	$x_2 = \ell_{12}$	$x_2 = \ell_{1\text{-}5}$
C2,3 and C4,5 and W 2 and W 3,4 and W 5,6	$P = p_{2\text{-}5}(1\text{-}r_{2\text{-}5})\text{-}p_{24}(1\text{-}r_{24})\text{-}p_{3\text{-}5}(1\text{-}r_{3\text{-}5})\text{+}p_{34}(1\text{-}r_{34})$	$x_1 = \ell_1$	$x_2 = \ell_{1\text{-}5}$

* **With particular reference to 25-5.1 and 25-5.2.1**

** **To be considered flooded for s-calculation.**

II RECESSES

1. Recesses may be treated as actual or fictitious compartments using the example in Figure A-6.

2. The following nomenclature is used in this section:

ℓ_1, ℓ_2, ℓ_3	length of damage zones as shown in figure A-6;
p_1, p_2, p_3	are "p" calculated according to regulation 25-5.1, using ℓ_1, ℓ_2, ℓ_3 as "ℓ";
p_{12}, p_{23}	are "p" calculated according to regulation 25-5.1, using $\ell_1 + \ell_2$ and $\ell_2 + \ell_3$ as "ℓ";
p_{123}	is "p" calculated according to regulation 25-5.1, using $\ell_1 + \ell_2 + \ell_3$ as "ℓ";
r_1	is "r" calculated according to regulation 25-5.2, using ℓ_1 as "ℓ" and "b" as shown in Figure A-6; Z
r_2	is "r" calculated according to regulation 25-5.2, using ℓ_2 as "ℓ" and "b" as shown in Figure A-6;
r_{12}, r_{23}	is "r" calculated according to regulation 25-5.2, using $\ell_1 + \ell_2$ as "ℓ" and "b" as shown in Figure A-6;
r_{123}	are "r" calculated according to regulation 25-5.2, using $\ell_1 + \ell_2 + \ell_3$ as "ℓ" and "b" as shown in Figure A-6;

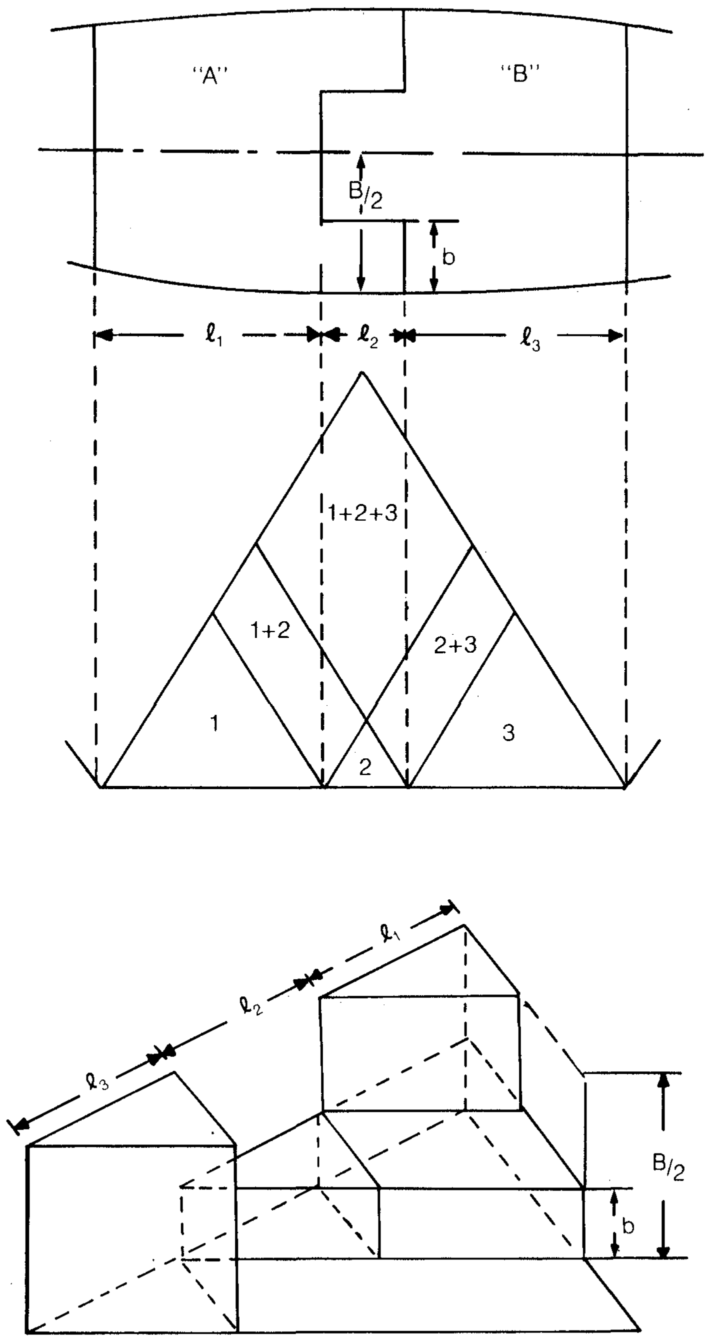


FIGURE A-6

3. Application to actual compartments:

Spaces to be considered flooded for s-calculation	p-factor to be used for calculating contribution to attained subdivision index
A	$p=p_{12}.r_{12}$
B	$p=p_3$
A and B	$p=p_{123} - p_{12}.r_{12\ -3}$
alternatively:	
A	$p=p_1$
B	$p=p_3$
A and B	$p=p_{123} - p_1 - p_3$

4. Application to fictitious compartments

A	$p=p_{12}.r_{12} + p_1 (1-r_1)$
B	$p=p_3$
A and B	$p=p_{12} - p_{12}.r_{12} - p_1.(1-r_1) - p_3$

III DAMAGE PENETRATION

For uniform application of these regulations the depth of penetration “b” should be determined using the following guidelines:

The mean transverse distance “b” shall be measured between the shell at the deepest subdivision load line and a vertical plane tangent to, or common with, all or a part of the longitudinal bulkhead but elsewhere outside thereof, and orientated so that this mean transverse distance to the shell is a maximum, except that in no case shall the maximum distance between this plane and the shell exceed twice the least distance between the plane and the shell.

When the longitudinal bulkhead terminates below the deepest subdivision load line the vertical plane referred to above is assumed to extend upwards to the deepest subdivision load line.

The following Figures A-7 and A-8 illustrates the application of this definition.

A damage zone containing abrupt changes of breadth may also be dealt with by subdividing into smaller zones, each having constant “b” values.

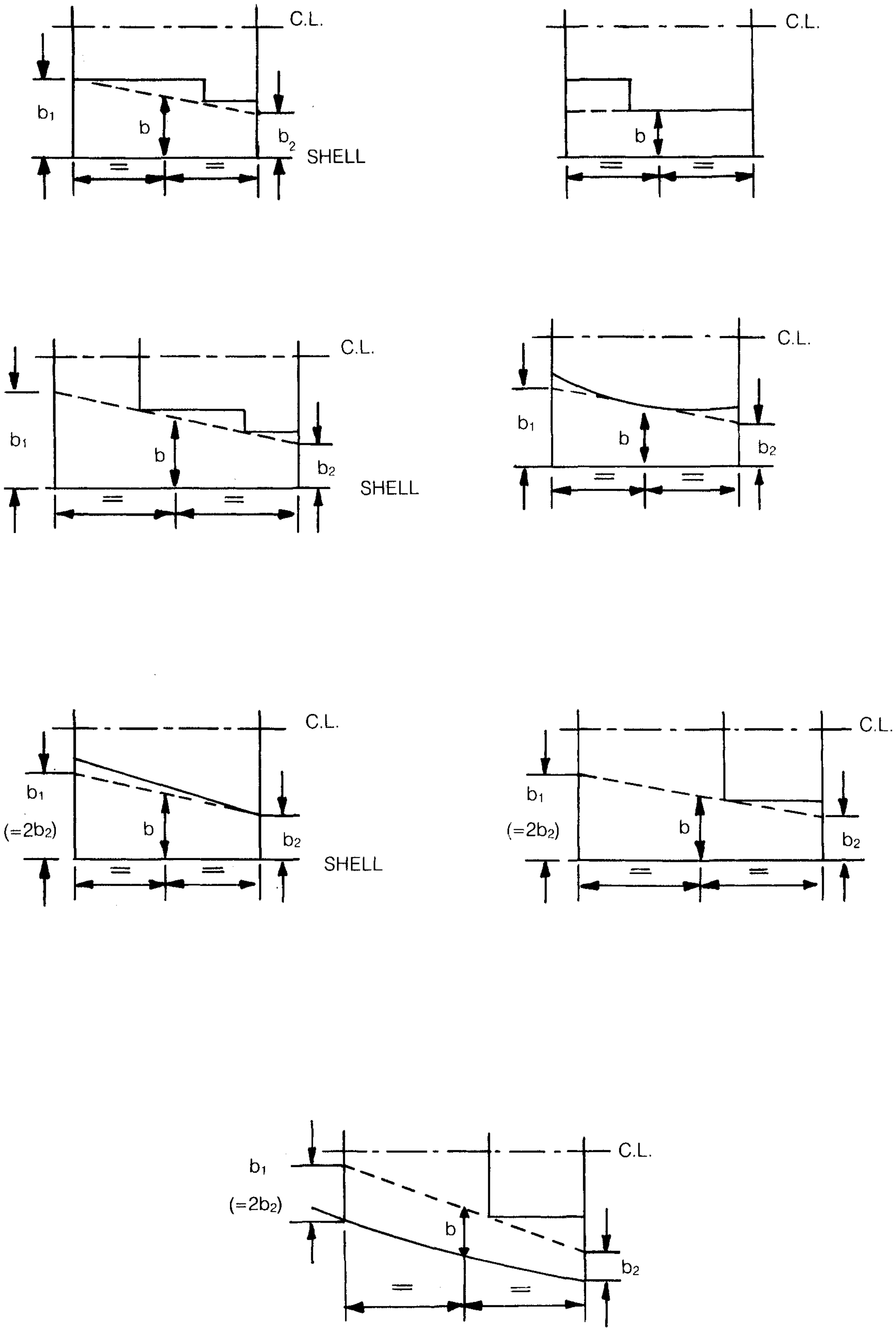

C.L.
b_1
b
b_2
SHELL
=
C.L.
b
=
C.L.
b_1
b
b_2
SHELL
=
C.L.
b_1
b
b_2
=
C.L.
b_1
$(=2b_2)$
b
b_2
SHELL
=
C.L.
b_1
$(=2b_2)$
b
b_2
=
C.L.
b_1
$(=2b_2)$
b
b_2
=

FIG A-7

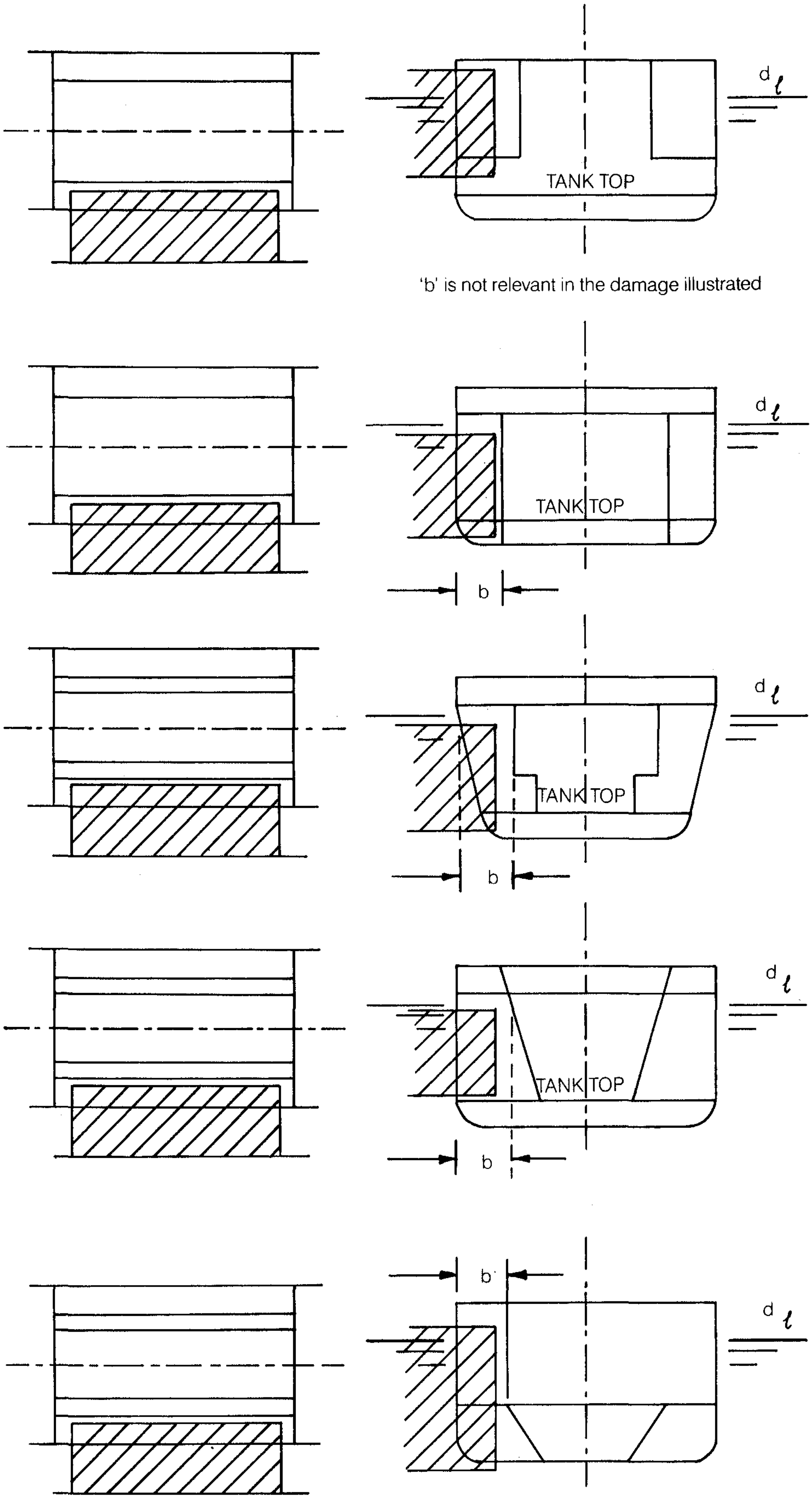

TANK TOP
'b' is not relevant in the damage illustrated
TANK TOP
b
TANK TOP
b
TANK TOP
b
b

FIG A-8

APPENDIX 3

1. Introduction

This appendix describes various possible watertight subdivision arrangements, the consequent flooding scenarios and the method of determining the relevant contribution "dA" to the attained index "A".

2. Definition of the Terms and Symbols used

Note: subscripts 1,2,3 etc below relate to the appropriate spaces in Figures A-9 *to* A-12.

eg. C_{123} is a space comprising compartments Cl, C2, C3
C_{345} is a space comprising compartments C3, C4, C5

S_{67} is the factor which accounts for the probability of survival after flooding compartments C6, C7 (etc).

---------->	indicates the direction of assumed side damage.
dA	gives the contribution *to* the attained index of the damage case being considered.
d	is the draught being considered and is either "$d\ell$" or "dp" (ie deepest subdivision load line or partial load line).
H_1, H_2	are the first and second horizontal subdivisions respectively viewed from the waterline upwards.
HU	is the uppermost boundary which limits the vertical extent of flooding.
V_1, V_2	are the first and second longitudinal subdivisions respectively viewed from the side where damage is assumed.
C	indicates a compartment bounded on all sides by watertight boundaries.
C_{123}	indicates a space which for the purpose of assumed flooding is treated as a single space comprising compartments Cl, C2 and C3.
•	indicates a compartment which lies outside the limits prescribed for all the damage scenarios (ie the compartment remains intact for all assumed damage cases) except for possible cross-flooding.
P_ℓ (reg 25.5.1)	is the factor which accounts for the probability that the longitudinal extent of damage does not exceed the length of the damage zone (length "l") being considered.

3. Contribution *to* the attained index "A" applying various forms of watertight subdivision.

This section details the contribution to the attained index "A" of various combinations of longitudinal and horizontal watertight subdivision and is included to illustrate the concepts of multiple horizontal and longitudinal subdivision.

For multiple longitudinal subdivisions with no horizontal subdivisions, the general formula is;

$dA=p_1 *[r_1 *s_1 + (r_2-r_1)*s_2 +.......+ (1-r_{m-1})*s_m]$

where

m = the number of longitudinal subdivisions, plus 1
ri = the "r" value as function of "bi"
si = the "s" factor for compartment n_i"

For multiple horizontal subdivisions, with no longitudinal subdivisions the general formula is;

dA = p_1*[v_1 *$Smin_1$ + (V_2-V_1) *$Smin_2$ +......+ (1 -v_{n-1}) $Smin_n$]

where

n = the number of horizontal subdivisions between the subdivision water line and Hmax, plus 1;

V_j = the "v" value as function of assumed damage height "H_j"

$Smin_j$ = the least "s" factor for all combinations of damages obtained when the assumed damage extends from the assumed damage height "H_j" downwards.

Generally, when there are combinations of longitudinal and horizontal subdivisions:

dA = p_1*{r_1*[V_1*$Smin_{11}$ + (v_2-v_1)*$Smin_{12}$ +......+ (1 - v_{n-1}) $Smin_{1n}$]
\+ (r_2-r_1)*[V_1 *$Smin_{21}$ + (v2-vI)*$Smin_{22}$ +......+ (1 - v_{n-1}) $Smin_{2n}$]
.
.
.
\+ (1-r_{m-1})*[V_1*$Smin_{m1}$ + (v_2-v_1)*$Smin_{m2}$ +......+ (1 - v_{n-1}) $Smin_{mn}$]

where

m = the number of longitudinal subdivisions, plus 1

n = the number of horizontal subdivisions (within each longitudinal subdivision) between the subdivision waterline and Hmax, plus 1;

r_i = the "r" factor as function of "b_i";

V_j = the "v" value as function of assumed damage height "H_j";

$Smin_{ij}$ = the least "s" factor for all combinations of damages obtained when the assumed damage extends from the shell to bi and from the assumed damage height "H_j" downwards.

The following examples illustrate how to deal with situations where there are combinations of longitudinal and horizontal subdivision, assuming the damage to occur between two consecutive watertight bulkheads only.

If however the damage extends beyond one or more transverse bulkheads then all terms p_i r_i for i = 1, 2.......m are calculated for a group *of* wing compartments as a function of "b_i".

3.1 Examples of longitudinal subdivision

Examples of longitudinal subdivision only are given in Figure A-9.

Each part of the figure illustrates the damage cases which would need to be evaluated for a particular arrangement of watertight boundaries.

The formulae for calculating the contribution to the attained index – "dA" - are given in each case.

3.2 Examples of horizontal subdivision

Examples of horizontal subdivision only are given in Figure A-10.

This illustrates the principles described in the previous section as applied to horizontal subdivision.

Regulation 25-4.7 specifies that in the event that a lesser vertical extent of damage means a lesser contribution to the "A" value, then this lesser extent is to be assumed in obtaining the requisite damage stability results.

3.3 Examples of longitudinal/horizontal subdivision

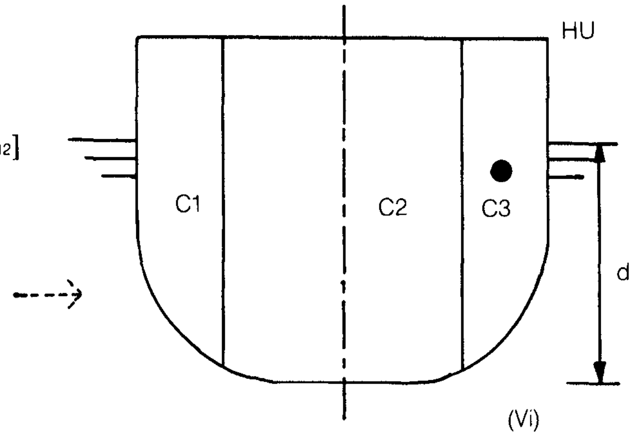
This section illustrates the principles used when combining the longitudinal and horizontal watertight subdivision described in the previous two sections. Examples are given in Figures A-11 and A-12.

To determine the contribution to the attained subdivision index ‘A’ –say dA - for various damage scenarios

Examples of Multiple Longitudinal Subdivision

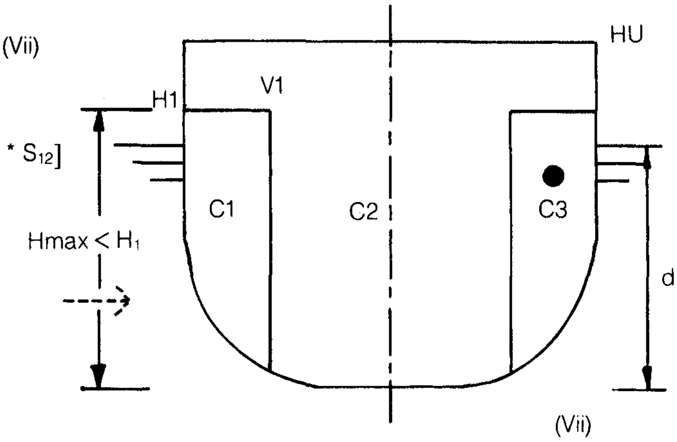
Referring to Figure (Vi)

$$dA = p_{\ell} * [\, r_1 * s_1 + (1 - r_1) * s_{12}]$$



Referring to Figure (Vii)

$$dA = p_{\ell} * [\, r_1 * s_1 + (1 - r_1) * S_{12}]$$



Referring to Figure (Viii)

$$dA = p_{\ell} * [\, r_1 * s_1 + (r_2 - r_1) * s_{12}) + (1 - r_2) * s_{123}]$$

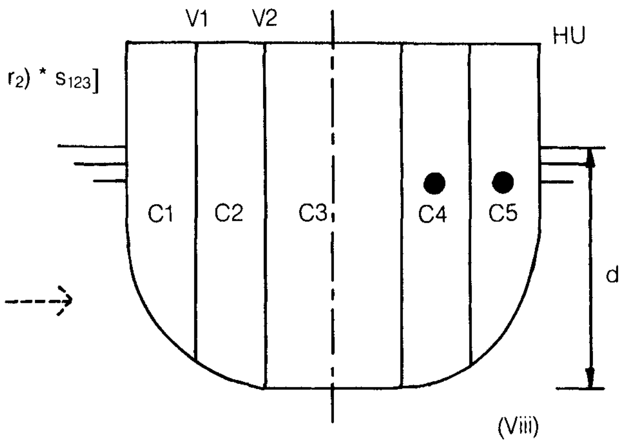


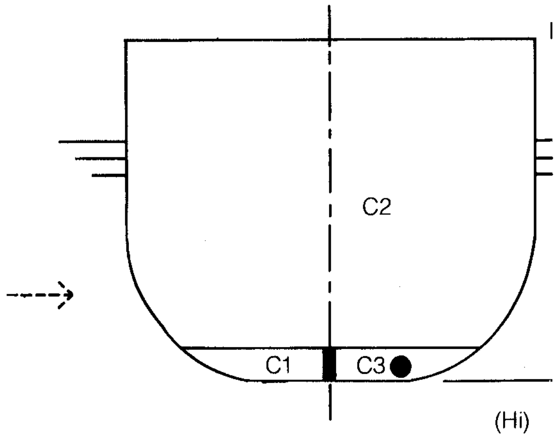
FIG A-9 INTERPRETATION OF LONGITUDINAL SUBDIVISION
(In all instances, v = **1)**

To determine the contribution to the attained subdivision index 'A' - say dA - for various damage scenarios.

Examples of Multiple Horizontal Subdivision.

Referring to Figure (Hi)

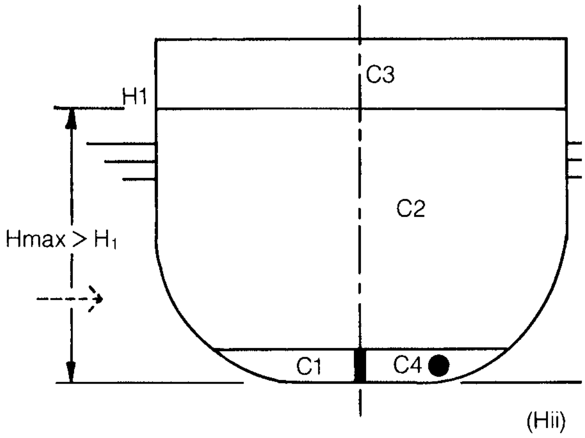
$dA = p_\ell * smin$
where
Smin= the lesser of s_{12} and s_2



(Hi)

Referring to Figure (Hii)

$dA = p_\ell * [\, v_1 * Smin_1 + (1 - V_1) * Smin_2]$
where
$Smin_1$ = the lesser of s_{12} and s_2
$Smin_2$ = the lesser of s_{123} and s_{23}

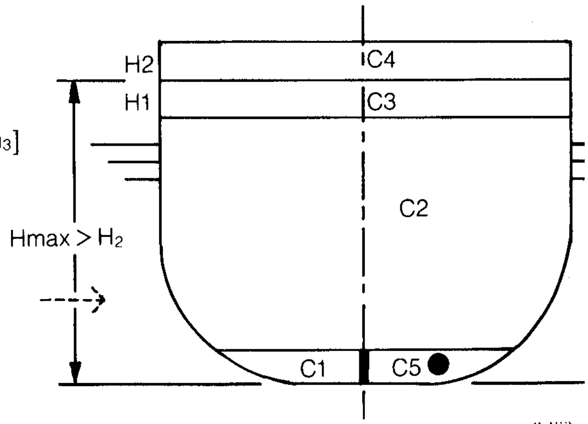


(Hii)

Referring to Figure (Hiii)

$dA = p_\ell * [\, v_1 * Smin_1 + (v_2 - v_1) * Smin_2 + (1 - v_2) * Smin_3]$

where
$Smin_1$ = the lesser of s_{12} and s_2
$Smin_2$ = the lesser of s_{123} and s_{23}
$Smin_3$ = the lesser of s_{1234} and s_{234}



(Hiii)

FIG A-10 INTERPRETATION OF MULTIPLE HORIZONTAL SUBDIVISION
(In all instances, r = 1)

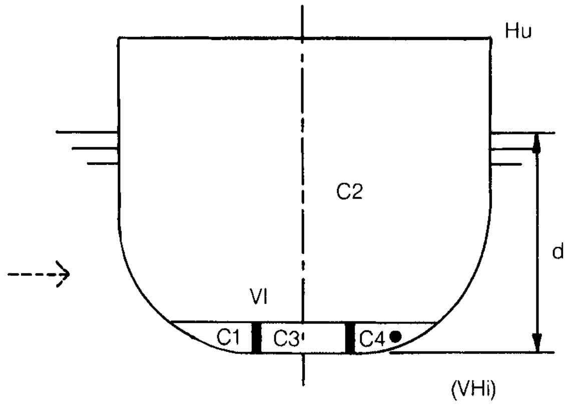
To determine the contribution to the attained subdivision index ‘A’ - say dA - for various damage scenarios.

Examples of Multiple Longitudinal/Horizontal Subdivision

Referring to Figure (VHi)

$$dA = p_\ell * [\, r_1 * Smin_1 + (1 - r_1) * Smin_2]$$

where
$Smin_1$ = the lesser of s_{12} and s_2
$Smin_2$ = the lesser of s_{123} and s_2

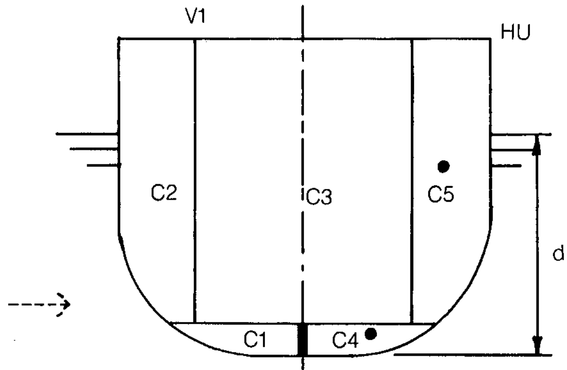


(VHi)

Referring to Figure (VHii)

$$dA = p_\ell * [\, r_1 * Smin_1 + (1 - r_1) * Smin_2]$$

where
$Smin_1$ = the lesser of s_{12} and s_2
$Smin_2$ = the lesser of s_{123} and s_{23}

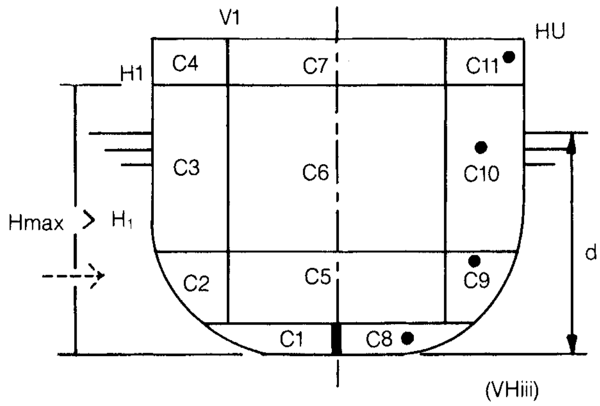


(VHii)

Referring to Figure (VHiii)

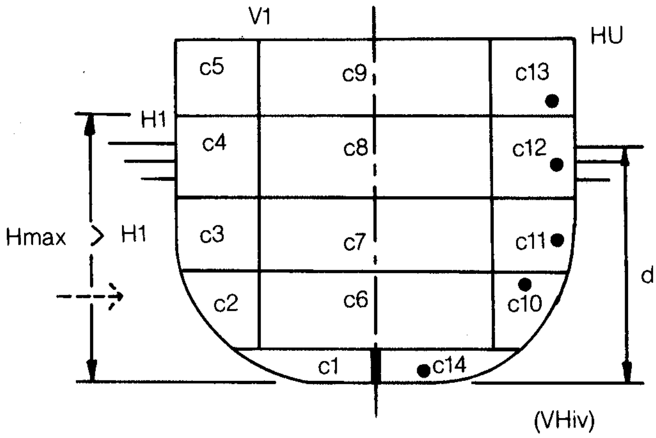
$$dA = p_\ell * \{ r_1 * [\, v_1 Smin_{11} + (1 - V_1) * Smin_{12}] + (1 - r_1) * [\, v_1 * Smin_{21} + (1 - v_1) * Smin_{22}] \}$$

where
$Smin_{11}$ = the least of s_{123} and s_{23} and s_3
$Smin_{12}$ = the least of s_{1234} and s_{234} and s_{34}
$Smin_{21}$ = the least of s_{12356} and s_{2356} and s_{36}
$Smin_{22}$ = the least of $s_{1234567}$ and s_{234567} and s_{3467}



(VHiii)

FIG A-11 INTERPRETATION OF COMBINED LONGITUDINAL & HORIZONTAL SUBDIVISION



Referring to Figure (VHiv)

$$dA = p\ell^* \{ r_1 * [v_1 Smin_{11} + (1 - v_1) * Smin_{12}] + (1 - r_1) * [v_1 * Smin_{21} + (1 - v_1) * Smin_{22}]\}$$

where

$Smin_{11}$ = the least of s_{1234} and s_{234} and s_{34} and s_4
$Smin_{12}$ = the least of s_{12345} and s_{2345} and s_{345} and s_{45}
$Smin_{21}$ = the least of $s_{1234678}$ and s_{234678} and s_{3478} and s_{48}
$Smin_{22}$ = the least of $s_{123456789}$ and $s_{23456789}$ and s_{345789} and s_{4589}

FIG A-12 INTERPRETATION OF COMBINED LONGITUDINAL & HORIZONTAL SUBDIVISION

EXPLANATORY NOTES TO THE SOLAS REGULATIONS ON SUBDIVISION AND DAMAGE STABILITY OF CARGO SHIPS OF 100 METRES IN LENGTH AND OVER

PART B

This part of the explanatory notes is intended to give some guidance on how to apply the individual regulations.

Regulation 25-1

The purpose of item 6 of the footnote to regulation 25-1 is to exclude from the application of the regulations on subdivision and damage stability of cargo ships (part B-1) only those ships which must comply with the damage stability requirements of the 1966 LL Convention in order to obtain a Type A or Type B-60 through to Type B-100 freeboard assignment.

Part B-1 regulations were developed and intended as a separate required standard for all cargo ships. Equivalency between the part B-1 and Load Line damage stability requirements is neither implied nor suggested.

Paragraph 3

The circumstances where this paragraph of the regulations might apply for example could be:

.1 ships constructed to a standard of damage stability with a set of damage criteria, agreed by the Administration;

.2 ships where the side-shell has been significantly strengthened by the provision of a "double-skin" where it may be agreed to use enhanced values of the reduction factor "r", regulation 25-5.2. In such a case supporting calculations indicating the superior energy-absorbing characteristics of the structural arrangement are to be provided;

.3 vessels of a multi-hull design, where the subdivision arrangements would need to be evaluated against the basic principles of the probabilistic method since the regulations have been written specifically for mono-hulls.

Regulation 25-2

Paragraph 1.2

This definition does not preclude loading the ship to deeper draughts permissible under load line assignments such as tropical, timber, etc.

Paragraph 1.3

The light ship draught is the draught, assuming level trim, corresponding to the ship lightweight. Lightweight is the displacement of a ship in tonnes without cargo, fuel, lubricating oil, ballast water, fresh water and feed water in tanks, consumable stores, plus crew I passenger and their effects.

The draught corresponding to the partial load line is given by the formula

$$d_p = d\ell_s + 0.6\,(d\ell - d\ell_s)$$

Where

d_p	=	draught corresponding to the partial load line, (m);
$d\ell$	=	draught corresponding to the deepest subdivision load line, (m);
$d\ell_s$		lightship draught (m);

Paragraph 2.1

The illustration of the definition of "L_s" according to paragraph 2.1 of regulation 25.2 is given in figure B-1.

For the forward deck limiting the vertical extent of flooding "H_{max}" is to be calculated in accordance with the draught ("dl") at the deepest subdivision load line, based on the corresponding formula in regulation 25-6, paragraph 3.3. The forward terminal position at the deepest subdivision load line is to be taken as indicated in figure B-2 and the after one in a similar manner.

Regulation 25-4

Paragraph 1

The regulations do not specify at which side of the ship damage should be assumed. Where there is 100% symmetry about the ship centreline of:

- the main hull,
- erections which are given credit for buoyancy in the damage stability calculations,
- the internal subdivision restricting the extent of flooding for the damage stability calculations,

it is clear that damage may be assumed on either the port or starboard sides, each producing the same value of "A".

It is rare for complete symmetry to exist and therefore, in theory, two calculations for "A" should be made, one assuming port damage and the other starboard damage.

However, the calculated "A" value may be taken as that which evidently gives the less favourable result. Otherwise the mean value obtained from calculations involving both sides is to be used.

Paragraph 2

$$A = \Sigma p_i S_i$$

Where

p_i	is independent of the draught, but includes the factor "r";
s_i	is dependent on the draught and includes the factor "v";

and is a weighted average of s-factors calculated at draughts of $d\ell$ and d_p.

It is recommended that the product "$p_i s_i$" should be calculated using five decimal places, whilst the final results, ie the indices "A" and "R" should be to at least three decimal places.

Paragraph 3

For any ship, including those with a raked keel, the design waterline shall be used as a reference for level trim.

Paragraph 6

See figures in Appendix 2, Part A

When there is more than one longitudinal subdivision to consider, penetration need not extend to the ship's centreline if such penetration does not provide any contribution to the attained subdivision index.

For example, when a pipe tunnel in the centre of a ship is fitted, damage to this tunnel may cause heavy progressive flooding leading to loss of the vessel. In this instance the penetration may be stopped outside the pipe tunnel, and the "p" factor multiplied by the factor "r", as calculated for a penetration in a wing compartment only. If a wing compartment is fitted in addition, it is possible to take account of two different penetrations, and applying the factor (r_2-r_1) rather than (1-r), as obtained when the damage is extended to the centreline.

"r_2" is then the "r" value for penetration to the pipe tunnel only, and "r_1" is the "r" value for penetration to the longitudinal bulkhead only. See figure A-11 (VHi).

<u>Regulation 25-5</u>

See figures and explanations in Part A, Appendices 2 and 3.

In particular, note when calculating "r" values for a group of two or more adjacent compartments (or zones) the "b" value must be the same for all compartments (or zones) in that group.

<u>Regulation 25-6</u>

Paragraph 1.2

If the final waterline immerses the lower edge of any opening through which progressive flooding takes place, the factor "s" may be re-calculated taking such flooding into account.
If the resulting "s" is greater than zero, the "dA" of the compartment or group of compartments may contribute to the index "A".

Paragraph 3.3

Where the height of the horizontal subdivision above the baseline is not constant, the height of the lowest point of the horizontal subdivision above the baseline be used in calculating "H".

The permeability value for cargo spaces is given in regulation 25-7.

Where a ship is fitted with significant quantities of cargo insulation, the permeabilities of the relevant cargo spaces and/or the void spaces surrounding such cargo spaces may be calculated, whilst giving consideration to the volume of insulation material in those spaces, provided that the insulating material is shown to comply with the following conditions:

.1 it is impermeable to water under hydrostatic pressure at least corresponding to the pressure caused by the assumed flooding;

.2 it will not crush or break up due to hydrostatic pressure at least corresponding to the pressure caused by the assumed flooding;

.3 it will not deteriorate or change its properties over the long term in the environment anticipated in the space it which it is installed;

.4 it is highly resistant to the action of hydrocarbons; and

.5 it will be adequately secured so that it will remain in position if subjected to collision damage and consequent displacement, distortion of its supporting and retaining structure, repeated rapid ingress and outflow of seawater and the buoyant forces caused by immersion following flooding.

<u>Regulation 25-8</u>

Paragraph 1.1

It is straightforward to obtain minimum GM (or maximum KG) values which comply with the relevant intact stability requirements, and can be expressed by a unique curve against ship draught.

However, it is not possible to obtain a unique set of minimum GM values for deepest load draught ("dl") and for partially loaded draught ("dp") which ensure compliance with regulation 25-1 to 25-6, because there are an infinite number of sets of GMs to meet the regulations.

Therefore, one approach might be to choose a GM value for the deepest loaded draught as close as possible to the minimum GM value relevant to the intact stability requirements based on a realistic loading condition, then vary the GM value for partial loaded draught whilst retaining a realistic loading condition and obtain a limiting value of GM to comply with the regulations 25-1 to 25-6.

Of course, other practical approaches may also be taken.

Paragraph 1.2

Where cross-flooding arrangements are fitted, calculations are to be carried out in accordance with IMO resolution A.266 (VIII).

The time for equalization shall not exceed ten minutes.

Paragraph 3

Curves of limiting GMs should be drawn as indicated in figures B-3 and B-4.

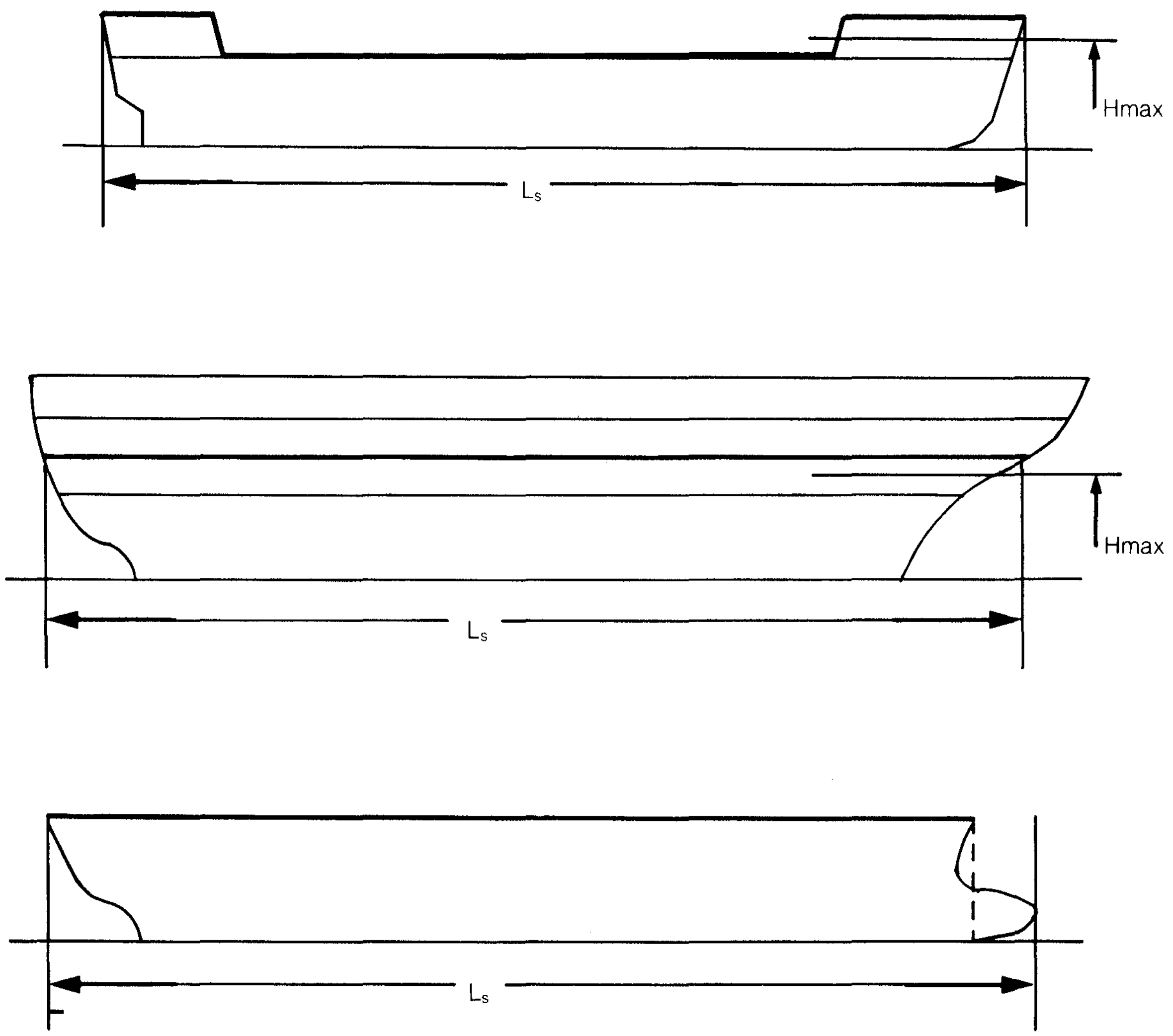
Linear interpolation should be applied to the GM values only between the deepest subdivision load line and the partial load line, when developing the curve of minimum operational Gms or corresponding maximum allowable KGs.

<u>Regulation 25-9</u>

Paragraph 4

The words "Satisfactory and essential" mean that scantlings and sealing requirements for those doors or ramps should be sufficient to withstand the maximum head of the water at the flooded waterline.

Illustration of the definition of "L_s" according to paragraph 2.1 of Regulation 25-2



a deck, or decks, which limit the highest vertical extent of flooding

Hmax as specified in Regulation 25-6 should be used for the definition of the vertical extent of flooding.

FIG B-1

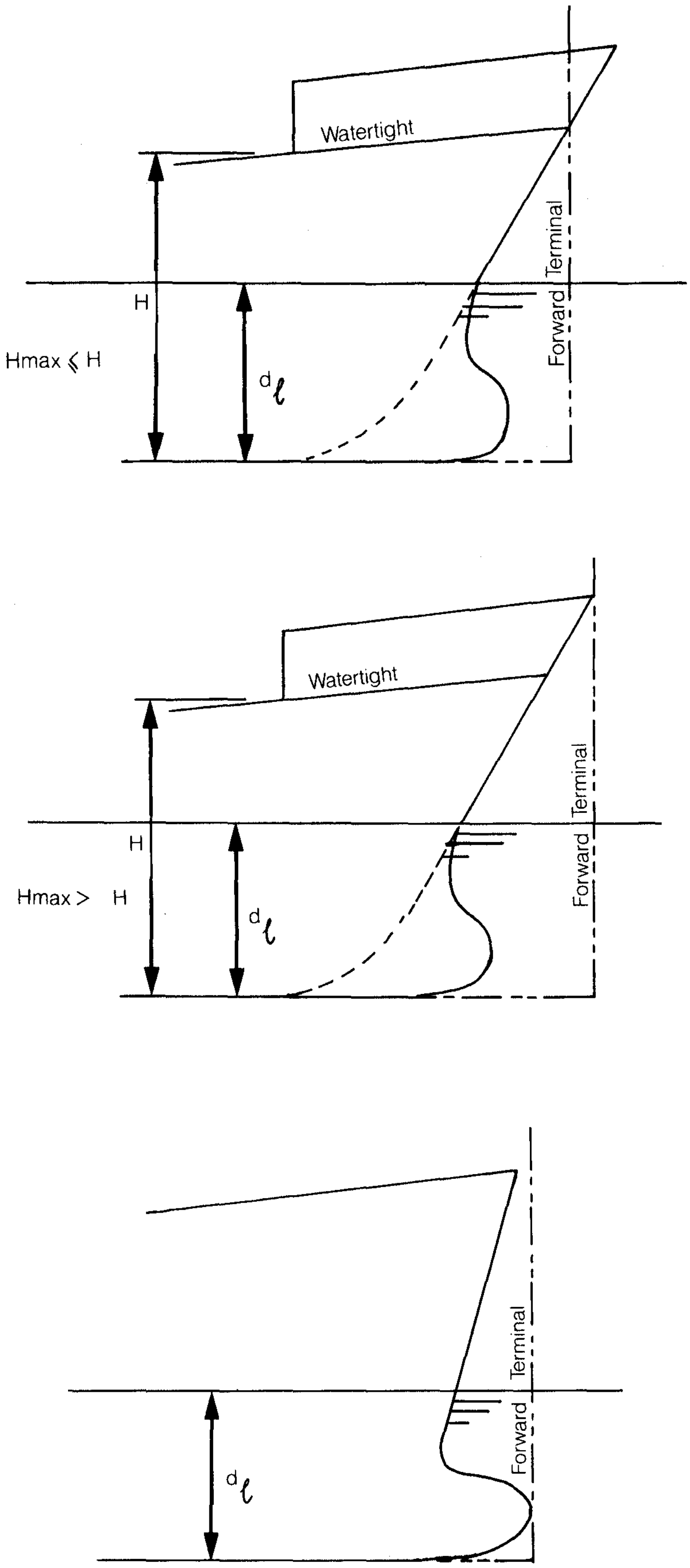

Watertight
Forward Terminal
H
Hmax ⩽ H
dℓ
Watertight
Forward Terminal
H
Hmax > H
dℓ
Forward Terminal
dℓ

FIG B-2

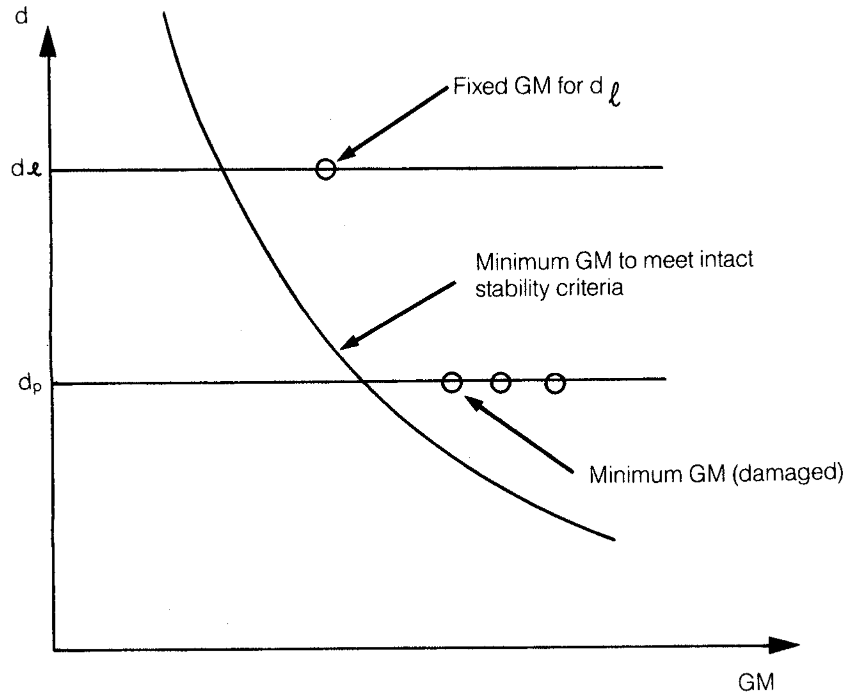

d
Fixed GM for d ℓ
dℓ
Minimum GM to meet intact stability criteria
dp
Minimum GM (damaged)
GM

FIG B-3

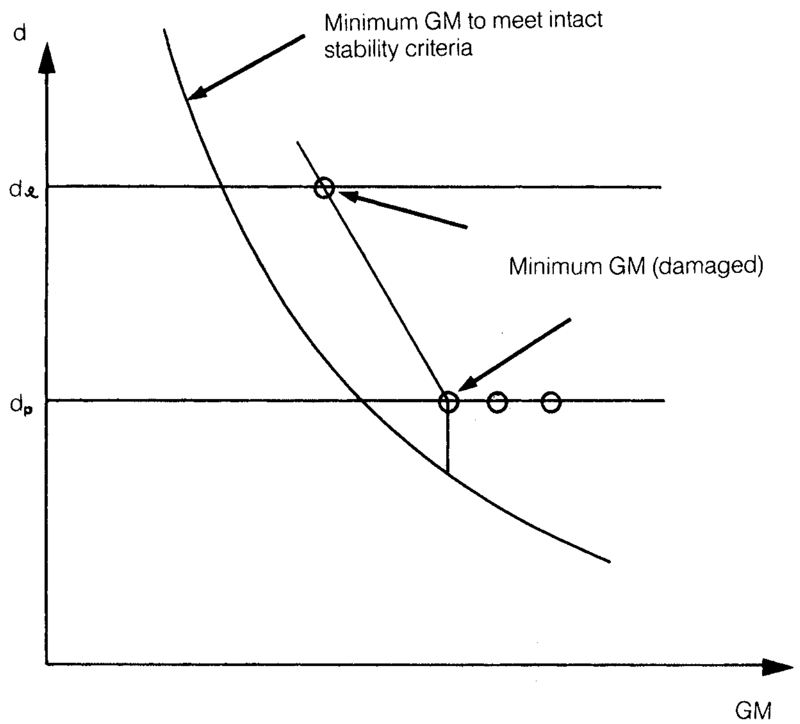

d
Minimum GM to meet intact stability criteria
dℓ
Minimum GM (damaged)
dp
GM

FIG B-4

ANNEX III

TEXT OF AMENDMENTS TO CHAPTER II-1 OF THE INTERNATIONAL CONVENTION FOR THE SAFETY OF LIFE AT SEA, 1974

Chapter II-1

CONSTRUCTION -SUBDIVISION AND STABILITY, MACHINERY AND ELECTRICAL INST ALLA TIONS

Insert the following new part B-1, comprising regulations 25-1 to 25-10, after existing part B:

PART B-1 -SUBDIVISION AND DAMAGE STABILITY OF CARGO SHIPS[2]

(This part applies to cargo ships constructed on or after 1 February 1992).

Regulation 25-1

Application

1. The requirements in this part shall apply to cargo ships over 100m in length ("Ls") but shall exclude those ships which are shown to comply with subdivision and damage stability regulations in other instruments[3] developed by the Organization. The requirements in this part shall apply to cargo ships of 80m in length ("Ls") and upwards but not exceeding 100m in length, if constructed on or after 1st July 1998.

2. Any reference hereinafter to regulations refers to the set of regulations contained in this part.

3. The Administration may for a particular ship or group of ships accept alternative arrangements, if it is satisfied that at least the same degree of safety as represented by these regulations is achieved. Any Administration which allows such alternative arrangements shall communicate to the Organization particulars thereof.

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[2] The Maritime Safety Committee, in adopting the regulations contained in part B-1, invited Administrations to note that the regulations should be applied in conjunction with the explanatory notes developed by the Organization in order to ensure their uniform application. (See Annex 11 of this Notice).

[3] Such as Annex I to MARPOL 73/78, IBC, IGC, BCH and GC Codes, Guidelines for the Design and Construction of Offshore Supply Vessels (resolution A. 469(XII), Code of Safety for Special Purpose Ships (resolution A.534(13» and regulation 27 of the 1966 LL Convention for bulk carriers assigned B-60 or B-100 freeboards.

Regulation 25-2

Definitions

For the purpose of these regulations, unless expressly provided otherwise:

1.1 Subdivision Load Line is a waterline used in determining the subdivision of the ship.

1.2 Deepest subdivision load line is the subdivision load line which corresponds to the summer draught to be assigned to the ship.

1.3 Partial load line is the light ship draught plus 60% of the difference between the light ship draught and deepest subdivision load line.

2.1 Subdivision length of the ship ("L_s") is the greatest projected moulded length of that part of the ship at or below deck or decks limiting the vertical extent of flooding with the ship at the deepest subdivision load line.

2.2 Mid-length is the mid point of the subdivision length of the ship.

2.3 Aft terminal is the aft limit of the subdivision length.

2.4 Forward terminal is the forward limit of the subdivision length.

3. Breadth ("B") is the greatest moulded breadth of the ship at or below the deepest subdivision load line.

4. Draught ("d") is the vertical distance from the moulded baseline at mid-length to the waterline in question.

5. Permeability ("μ") of the space is the proportion of the immersed volume of that space which can be occupied by water.

Regulation 25-3

ReQuired subdivision index "R"

1. These regulations are intended to provide ships with a minimum standard of subdivision.

2. The degree of subdivision to be provided shall be determined by the required subdivision index "R", as follows:

.1.1 for ships over 100m in length;

$$R = (0.002 + 0.0009L_s)^{1/3}\text{; and}$$

.1.2 for ships of 80m in length and upwards, but not exceeding 100m in length;

$$R=1-\left[1-\left(1+\frac{L_s}{100}\cdot\frac{R_0}{1-R_0}\right)\right]$$

where R_0 is the value R as calculated in accordance with the formula in subparagraph 1.1.1, and "L_s" is the length of the ship in metres.

Regulation 25-4

Attained subdivision index "A"

1. The attained subdivision index "A" calculated in accordance with this regulation, shall not be less than the required subdivision index "R", calculated in accordance with paragraph 2 of regulation 25-3.

2. The attained subdivision index "A" shall be calculated for the ship by the following formula:

$$A = \Sigma p_i s_i$$

where:

"i" represents each compartment or group of compartments under consideration,

"p_i" accounts for the probability that only the compartment or group of compartments under consideration may be flooded, disregarding any horizontal subdivision,

"s_i" accounts for the probability of survival after flooding the compartment or group of compartments under consideration, including the effects of any horizontal subdivision.

3. In calculating "A", level trim shall be used.

4. This summation covers only those cases of flooding which contribute to the value of the attained subdivision index "A".

5. The summation indicated by the above formula shall be taken over the ship's length for all cases of flooding in which a single compartment or two or more adjacent compartments are involved.

6. Wherever wing compartments are fitted, contribution to the summation indicated by the formula shall be taken for all cases of flooding in which wing compartments are involved; and additionally, for all cases of simultaneous flooding of a wing compartment or compartments and the adjacent inboard compartment or compartments, assuming a rectangular penetration which extends to the ship's centreline, but excludes damage to any centreline bulkhead.

7. The assumed vertical extent of damage is to extend from the baseline upwards to any watertight horizontal subdivision above the waterline or higher. However, if a lesser extent will give a more severe result, such extent is to be assumed.

8. If pipes, ducts or tunnels are situated within assumed flooded compartments, arrangements are to be made to ensure that progressive flooding cannot thereby extend to compartments other than those assumed flooded. However, the Administration may permit minor progressive flooding if it is demonstrated that its effects can be easily controlled and the safety of the ship is not impaired.

9. In the flooding calculations carried out according to the regulations, only one breach of the hull need be assumed.

Regulation 25-5

Calculation of the factor "p_i"

1. The factor "p_i" shall be calculated according to paragraph 1.1 as appropriate, using the following notations:

x_1 = the distance from the aft terminal of "L_s" to the foremost portion of the aft end of the compartment being considered;

x_2 = the distance from the aft terminal of "L_s" to the aftermost portion of the forward end of the compartment being considered;

E_1 = x/L_s

E_2 = x_2/L_s

E = $E_1 + E_2 - 1$

J = $E_2 - E_1$

J^1 = $J - E$, if $E \geq 0$

J^1 = $J + E$, if $E < 0$

The maximum nondimensional damage length, $J_{max} = 48/L_s$, but not more than 0.24

The assumed distribution density of damage location along the ship's length

a = $1.2 + 0.8E$, but not more than 1.2

The assumed distribution function of damage location along the ship's length

F = $0.4 + 0.25\,E\,(1.2 + a)$

y = J/J_{max}

p = $F_1\,J_{max}$

q = $0.4\,F_2\,(J_{max})^2$

F_1 = $y^2 - \frac{y^3}{3}$, if $y < 1$,

F_1 = $y - \frac{1}{3}$ otherwise;

F_2 = $\frac{y^3}{3} - \frac{y^4}{12}$, if $y < 1$,

F_2 = $\frac{y^3}{2} - \frac{y}{3} + \frac{1}{12}$ otherwise.

1.1 The factor "pi" is determined for each single compartment:

1.1.1 Where the compartment considered extends over the entire ship length, "L_s":

$$p_i = 1$$

1.1.2 Where the aft limit of the compartment considered coincides with the aft terminal:

$$p_i = F + 0.5\ ap + q$$

1.1.3 Where the forward limit of the compartment considered coincides with the forward terminal:

$$p_i = 1 - F + 0.5\ ap$$

1.1.4 When both ends of the compartment considered are inside the aft and forward terminals of the ship length, "L_s":

$$p_i = ap$$

1.1.5 In applying the formulae of paragraphs 1.1.2, 1.1.3 and 1.1.4, where the compartment considered extends over the "mid-length", these formulae values shall be reduced by an amount determined according to the formula for "q", in which "F_2" is calculated taking "y" to be J^1/J_{max}.

2. Wherever wing compartments are fitted, the "pi" - value for a wing compartment shall be obtained by multiplying the value, as determined in paragraph 3, by the reduction factor "r" according to subparagraph 2.2, which represents the probability that the inboard spaces will not be flooded.

2.1 The "p_i"- value for the case of simultaneous flooding of a wing and adjacent inboard compartment shall be obtained by using the formulae of paragraph 3, multiplied by the factor (1 -r).

2.2 The reduction factor "r" shall be determined by the following formulae:

For J < 0.2 b/B:

$$r = \frac{b}{B}\left(2.3 + \frac{0.08}{J + 0.02}\right) + 0.1, \qquad \text{if } \frac{b}{B} \leq 0.2$$

$$r = \left(\frac{0.016}{J + 0.02} + \frac{b}{B} + 0.36\right), \qquad \text{if } \frac{b}{B} \leq 0.2$$

For J < 0.2 b/B the reduction factor "r" shall be determined by linear interpolation between

$$r = 1, \text{ for } J = 0$$

and

r = as, for the case where $J \geq 0.2b/B$, for $J = 0.2\ b/B$,

Where:

b = the mean transverse distance in metres measured at right angles to the centreline at the deepest subdivision load line between the shell and a plane through the outermost portion of and parallel to that part of the longitudinal bulkhead which extends between the longitudinal limits used in calculating the factor "p_i".

3. To evaluate "p_i" for compartments taken singly the formulae in paragraphs 1 and 2 shall be applied directly.

3.1 To evaluate the "p_i"-values attributable to groups of compartments the following applies:

for compartments taken by pairs:

$p_i = p_{12} – p_1 – p_2$
$p_i = p_{23} – p_2 – p_3$, etc.

for compartments taken by groups of three:

$p_i = p_{123} – p_{12} – p_{12} + p_2$
$p_i = p_{234} – p_{23} – p_{34} + p_3$, etc.

for compartments taken by groups of four:

$p_i = p_{1234} – p_{123} - p_{234} + p_{23}$
$p_i = p_{2345} - p_{234} - p_{345} + p_{34}$, etc

where:

p_{12}, p_{23}, p_{34}, etc.,
p_{123}, p_{234}, p_{345}, etc and
p_{1234}, p_{2345}, p_{3456}, etc

shall be calculated according to the formulae in paragraphs 1 and 2 for a single compartment whose non dimensional length "J" corresponds to that of a group consisting of the compartments indicated by the indices assigned to "p".

3.2 The factor "p_i" for a group of three or more adjacent compartments equals zero if the nondimensionallength of such a group minus the non dimensional length of the aftermost and foremost compartments in the group is greater than "J_{max}".

Regulation 25-6

Calculation of factor "s_i"

1. The factor "s_i" shall be determined for each compartment or group of compartments according to the following:

1.1 in general for any condition of flooding from any initial loading condition "s" shall be

$$S = C\sqrt{0.5\,(GZ_{max})(\text{range})}$$

with $C = 1$, if $\varnothing e \leqslant 25°$

$C = 0$, if $\varnothing e > 30°$

$C = \sqrt{\dfrac{30 - \varnothing e}{5}}$ otherwise

GZ_{max} = maximum positive righting lever (in metres) within the range given below but not more than 0.1m;

range = range of positive righting levers beyond the angle of equilibrium (in degrees) but not more than 20°; however, the range shall be terminated at the angle where openings not capable of being closed weathertight are immersed;

$\varnothing e$ = final equilibrium angle of heel (in degrees);

1.2 s = 0 where the final waterline taking into account sinkage, heel and trim, immerses the lower edge of openings through which progressive flooding may take place. Such opening shall include air-pipes, ventilators and openings which are closed by means of weathertight doors or hatch covers, and may exclude those openings closed by means of watertight manhole covers and flush scuttles, small watertight hatch covers which maintain the high integrity of the deck, remotely operated sliding watertight doors, access doors and access hatch covers, of watertight integrity, normally closed at sea and sidescuttles of the non-opening type. However, if the compartments so flooded are taken into account in the calculations the requirements of this regulation shall be applied.

1.3 For each compartment or group of compartments "s_i" shall be weighted according to draught considerations as follows:

$$s_i = 0.5\, S_\ell + 0.5\, s_p$$

where

"s_ℓ" is the "s"-factor at the deepest subdivision load line
"s_p" is the "s"-factor at the partial load line.

2. For all compartments forward of the collision bulkhead, the "s"-value, calculated assuming the ship to be at its deepest subdivision load line and with assumed unlimited vertical extent of damage is to be equal to 1.

3. Wherever a horizontal subdivision is fitted above the waterline in question the following applies.

3.1 The "s"-value for the lower compartment or group of compartments shall be obtained by multiplying the value as determined in subparagraph 1.1 by the reduction factor "v" according to subparagraph 3.3, which represents the probability that the spaces above the horizontal subdivision will not be flooded.

3.2 In cases of positive contribution to index "A" due to simultaneous flooding *of* the spaces above the horizontal subdivision, the resulting "s"-value for such a compartment or group of compartments shall be obtained by an increase of the value as determined by subparagraph 3.1 by the "s"-value for simultaneous flooding according to sub paragraph 1.1, multiplied by the factor (1-v).

3.3 The probability factor "vi" shall be calculated according to:

$v_i = \dfrac{H-d}{H_{max} - d}$ for the assumed flooding up to the horizontal subdivision above the subdivision load line, where "H" is to be restricted to a height of "H_{max}",

$v_i = 1$, if the uppermost horizontal subdivision in way of the assumed damaged region is below "H_{max}", where:

"H" is the height of the horizontal subdivision above the baseline (in metres) which is assumed to limit the vertical extent of damage,

"Hmax" is the maximum possible vertical extent of damage above the baseline (in metres), or

$H_{max} = d + 0.056\, L_s\, (1 - \frac{L_s}{500})$, if $L_s \leq 250m$;

$H_{max} = d + 7$, if $L_s > 250m$

whichever is less.

Regulation 25-7

Permeability

For the purpose of the subdivision and damage stability calculations of the regulations, the permeability of each space or part of a space shall be as follows:

Spaces	Permeability
Appropriated to stores	0.60
Occupied by accommodation	0.95
Occupied by machinery	0.85
Void spaces	0.95
Dry cargo spaces	0.70
Intended for liquid	0 or 0.95[4]

Regulation 25-8

Stability information

1. The master of the ship shall be supplied with such reliable information as is necessary to enable him by rapid and simple means to obtain accurate guidance as to the stability of the ship under varying conditions of service. The information shall include:

.1 a curve of minimum operational metacentric height (GM) versus draught which assures compliance with the relevant intact stability requirements and the requirements of regulations 25-1 to 25-6, alternatively a corresponding curve of the maximum allowable vertical centre of gravity (KG) versus draught, or with the equivalents of either of these curves;

.2 instructions concerning the operation of cross-flooding arrangements; and

.3 all other data and aids which might be necessary to maintain stability after damage.

2. There shall be permanently exhibited, or readily available on the navigating bridge, for the guidance of the officer in charge of the ship, plans showing clearly for each deck and hold the boundaries of the watertight compartments, the openings therein with the means of closure and position of any controls thereof, and the arrangements for the correction of any list due to flooding. In addition, booklets containing the aforementioned information shall be made available to the officers of the ship.

[4] Whichever results in the more severe requirements.

3. In order to provide the information referred to in 1.1, the limiting GM (or KG) values to be used, if they have been determined from considerations related to the subdivision index, the limiting GM shall be varied linearly between the deepest subdivision load line and the partial load line. In such cases, for draughts below the partial load line if the minimum GM requirement at this draught results from the

calculation of the subdivision index, then this GM value shall be assumed for lesser draughts, unless the intact stability requirements apply.

Regulation 25-9

Openings in watertight bulkheads and internal decks in cargo ships

1. The number of openings in watertight subdivisions is to be kept to a minimum compatible with the design and proper working of the ship. Where penetrations of watertight bulkheads and internal decks are necessary for access, piping, ventilation, electrical cables, etc., arrangements are to be made to maintain the watertight integrity. The Administration may permit relaxation in the watertightness of openings above the freeboard deck, provided that it is demonstrated that any progressive flooding can be easily controlled and that the safety of the ship is not impaired.

2. Doors provided to ensure the watertight integrity of internal openings which are used while at sea are to be sliding watertight doors capable of being remotely closed from the bridge and are also to be operable locally from each side of the bulkhead. Indicators are to be provided at the control position showing whether the doors are open or closed, and an audible alarm is to be provided at the door closure. The power, control and indicators are to be operable in the event of main power failure. Particular attention is to be paid to minimize the effect of control system failure. Each power-operated sliding watertight door shall be provided with an individual hand-operated mechanism. It shall be possible to open and close the door by hand at the door itself from both sides.

3. Access doors and access hatch covers normally closed at sea, intended to ensure the watertight integrity of internal openings, shall be provided with means of indication locally and on the bridge showing whether these doors or hatch covers are open or closed. A notice is to be affixed to each such door or hatch cover to the effect that it is not to be left open. The use of such doors and hatch covers shall be authorized by the officer of the watch.

4. Watertight doors or ramps of satisfactory construction may be fitted to internally subdivide large cargo spaces, provided that the Administration is satisfied that such doors or ramps are essential. These doors or ramps may be hinged, rolling or sliding doors or ramps, but shall not be remotely controlled. Such doors or ramps shall be closed before the voyage commences and shall be kept closed during navigation; the time of opening such doors or ramps in port and of closing them before the ship leaves port shall be entered in the log book. Should any of the doors or ramps be accessible during the voyage, they shall be fitted with a device which prevents unauthorised opening.

5. Other closing appliances which are kept permanently closed at sea to ensure the watertight integrity of internal openings shall be provided with a notice which is to be affixed to each such closing appliance to the effect that it is to be kept closed. Manholes fitted with closely bolted covers need not be so marked.

Regulation 25-10

External openings in cargo ships

1. All external openings leading to compartments assumed intact in the damage analysis, which are below the final damage waterline, are required to be watertight.

2. External openings required to be watertight in accordance with paragraph 1 shall be of sufficient strength and, except for cargo hatch covers, shall be fitted with indicators on the bridge.

3. Openings in the shell plating below the deck limiting the vertical extent of damage shall be kept permanently closed while at sea. Should any of these openings be accessible during the voyage, they shall be fitted with a device which prevents unauthorized opening.

4. Notwithstanding the requirements of paragraph 3, the Administration may authorize that particular doors may be opened at the discretion of the master, if necessary for the operation of the ship and provided that the safety of the ship is not impaired.

5. Other closing appliances which are kept permanently closed at sea to ensure the watertight integrity of external openings shall be provided with a notice affixed to each appliance to the effect that it is to be kept closed. Manholes fitted with closely bolted covers need not be so marked.