CHAPTER 31

STABILITY OF THE DAMAGED SHIP

CONTENTS

ANNEX

CHAPTER 31

STABILITY OF THE DAMAGED SHIP

3101. General

a. Complete assessment of a ships overall stability after damage involves very complicated mathematical calculations, which take a lot of time and are therefore impractical during the immediate period after an incident. The ships CBRNDC Class Book provides a number of examples for typical damage that can be consulted to give a quick and sure answer in these circumstances. However, in practice the actual extent of damage is unlikely to conveniently match one of these examples exactly and so knowledge of how to predict the stability of the ship in situations other than those provided is necessary.

b. The paragraphs that follow are intended to provide the background knowledge required to carry out calculations to predict stability after damage. It should be remembered that completing these calculations accurately is a lengthy process and requires a large amount of concentration and this should be taken into account before attempting to start them in the noisy environment of HQ1 at State 1. In order to reduce the time required to carry out these calculations and to provide quicker indications of the state of the ships stability, carpet plots are often provided with the ships stability information and these are discussed at the end of the chapter. In the event of an incident leading to the requirement for rapid Naval Architecture support from the relevant Platform IPT (PIPT) the Naval Architecture Incident Form (NAIIF) is to be utilised (see Para 3102).

3102. Naval Architecture Support

a. In order to formalise the manner in which essential Naval Architecture and Ship Condition information is provided to Platform IPTs (PIPTs) the Naval Architecture Incident Information Form (NAIIF) and the Ship Condition Report (SCR) has been developed (see Annex 31A). This form is to be used in all future incidents where it is necessary to provide information to the relevant Platform Design Authority IPT for the purposes of Naval Architecture support.

b. The form aims to capture all essential and other relevant information to allow PIPTs, S&MO IPT and other authorities to assess the incident. It includes a generic section which is to be completed, followed by the relevant Ship Condition Report (SCR) sheets for each Class of vessel.

c. Instructions in the use of the form, and guidance on the data/information required is included in the spreadsheet. The information may be provided to the PIPT by e-mail attachment, FAX, signal, or telephone (as is most suitable in the circumstances), provided that the format of the NAIIF/SCR is followed.

d. RN ships whose primary emergency response is provided by Classification Societies will continue to follow the LR SERS or DNV ERS processes as appropriate. However these ships are also included in the NAIIF as a back-up to the ERS and to facilitate direct communication of incident details to PIPTs when necessary.

The NAIIF/SCR should also to be used in accident response exercises (eg PURPLE QUIVER) to gain experience of its use.

e. A copy of the NAIIF form is to be retained in the Class Book held in HQ1. The spreadsheet file is to be held on NavyStar/DII and be available for immediate use in the event of an incident requiring Naval Architecture support. Paper copies of the spreadsheet forms should be held in the Bridge File, the Navigation Data Book, the Class book, and the MEO's CBRN File for action/emergency situations.

3103. Estimating Stability after Damage

a. When ships is damaged to the extent that some length of her is open to the sea, and as far as watertight bulkheads permit, she is flooded to the waterline, there will be resulting sinkage and probably trim and heel. Chapter 30 explained how to carry out some useful calculations for the effects of modest loadings on heel and trim. This is largely possible because under normal loadings the changes in heel and trim can often be assumed to be 'small' and:

(1) Hydrostatics can be assumed unchanged through small angles of heel or trim.

(2) Cross-coupling effects on hydrostatics between heel and trim can be ignored.

When extensive flooding occurs in a ship the effects are often so substantial that these assumptions would give a false analysis.

b. There are two methods by which damage stability may be calculated:

(1) The added weight method.

(2) The lost buoyancy method.

The first method is the more simple and logical method and draws very much on the principles discussed in Chapter 30. The floodwater is treated as an added weight and any free surface effects taken account of by an effective reduction in GM. This method is particularly useful for compartments below the waterline that will free flood and present only small free surface effects. The problem with this method is that it involves a lot of iteration if the compartment is large and cuts the waterline of the ship, because the level of water in the compartment will only rise to the waterline and as it does the ship will sink further until an equilibrium is reached. In these circumstances the second method that relies on calculating the loss of buoyancy due to the flood provides a better answer, however, it is a lengthy calculation.

3104. Permeability

If a compartment is filled with water and an attempt to estimate the weight of water within it is made, an allowance must be made for the volume of the compartment that is occupied by such things as fittings, equipment, stores and machinery. This allowance is called the permeability of the compartment as is expressed as a percentage of the gross volume of the compartment.

The exact value of permeability will obviously change from compartment to compartment and from day to day and therefore a good approximation is required in order to carry out damage stability calculations. The following figures are given as a guide and adjustments should be made based on ships knowledge, experience and loading conditions:

Watertight compartments	97%
Accommodation Spaces	95%
Machinery Spaces	85%
Stores	60%

3105. The Added Weight Method

The added weight method is the simplest to understand but can be quite lengthy, particularly if the flood is large, because of the iterations required. It is fundamentally the same as the methods described in Chapter 30 for adding a liquid weight to the ship and involves a parallel sinkage and adjustment to the centre of gravity and metacentre and then an allowance for free surface effects. The method is as follows; refer to Chapter 30 for further explanation.

a. Estimate the volume of water in the compartment to the waterline. An allowance should be made for permeability (the percentage of the compartment not occupied by fittings, equipments, stores, etc). For this the added weight of floodwater can be estimated.

b. Knowing the added weight calculate the parallel sinkage, using TPC for hydrostatic data at the original draught.

c. From the new draught a second iteration can then be made of the weight of floodwater up to this level (it will be more than the first iteration), and again the parallel sinkage calculated and the new draught found.

d. At this new draught find the position of the metacentre (KM_1) from the hydrostatic data and calculate the new position of the centre of gravity (KG_1).

e. The metacentric height can then be calculated as if the floodwater was a solid weight:

$$GM = KM_1 - KG_1$$

f. Now make an adjustment to the GM for any free surface effects, assuming the compartment is rectangular:

$$GM_{Fluid} = \frac{GM - ab^3 \times 1.025}{(12 \times \Delta)}$$

g. It is quite possible under severe cases of damage that the GM will become negative and the ship will loll. Because the shipside is free flooding, as the ship rolls there is likely to be a change in the weight of floodwater and so further iterations will be required.

Ultimately an accurate result can be obtained by this method. In spite of the tedium of the iterations required it has its merit in that at each iteration an accurate assessment of the changing weight of flood water can be made, in particular allowing for watertight decks overhead which may be able to restrict flooding vertically.

3106. The Lost Buoyancy Method

a. The alternative approach is to consider that as a result of damage the volume of the hull and area of the waterplane that contribute to the buoyancy and hydrostatics of the ship have been modified. The method involves transferring the buoyancy previously provided by the new flooded compartment to a new layer of buoyancy above the original waterline and reducing the waterplane area. These have the effects of:

(1) Altering transverse and longitudinal GMs.

(2) Sinking the ship lower in the water.

(3) Heeling the ship.

(4) Trimming the ship.

b. The analysis of the results of damage can be calculated in three distinct stages:

(1) Estimate sinkage.

(2) Estimate damaged transverse metacentre and heel.

(3) Estimate damaged longitudinal metacentre and trim.

3107. Sinkage

a. As with the added weight method, first an estimate of the weight of floodwater must be made, this is also the loss of buoyancy (w), also the position and the size of the compartment must be estimated.

b. Estimate the area of the waterplane lost by assuming the compartment is a rectangle (length a, breadth b):

Lost WPA = a x b

c. Find the remaining TPC from the formula that transforms the lost WPA to a weight of seawater 1 cm thick:

$$\text{Remaining TPC} = \text{TPC} - \frac{\text{lost WPA}}{97.5}$$

d. Calculate the parallel sinkage (s) in cm:

$$s = \frac{w}{\text{remaining TPC}}$$

3108. Heel

a. Estimate the shift of the centre of flotation off the centreline caused by the loss of waterplane area:

$$FF1 = \frac{a \times fF}{A - a}$$

where:

A = original WPA (TPC x 97.5)

A = lost WPA (a x b)

fF = distance from the centreline of the middle of the flooded compartment.

b. Calculate the second moment of area of the lost waterplane area from the fore and aft axis through the new centre of flotation. For a rectangular compartment (length a, breadth b) a distance d from the new centre of flotation's axis:

$$i = a \times b \times d^2 + \frac{(a + b^3)}{12}$$

c. Find the fall in the transverse metacentre (MT) due to the lost waterplane area:

$$\text{Fall of } M_T = \frac{I \times \rho}{\nabla}$$

d. Find the rise of the centre of buoyancy due to the parallel sinkage:

$$\text{Rise of B} = \frac{w \times Bb}{\nabla}$$

where: Bb = distance from the original centre of buoyancy (found from hydrostatic data) to the centre of the parallel sinkage $\left[\frac{T + s}{200}\right]$

e. The centre of gravity is unchanged so the transverse metacentric height is only changed by the fall in metacentre and rise in centre of buoyancy:

$$GM_T(\text{damaged}) = GM_{original} - \text{fall of } M_T + \text{rise of B}$$

f. The angle of heel can now be found. The heeling moment is given by the loss of buoyancy, w, multiplied by the distance from the centre of the lost waterplane area to the fore and after axis of the centre of flotation:

$$\tan\varphi = \frac{\text{heeling moment}}{\Delta \times GM_T\ (\text{damaged})}$$

3109. Trim

a. Calculation of trim is similar to calculation of heel:

(1) Estimate the fore or aft shift of the centre of flotation due to the lost waterplane area (Para 3108 sub para a).

(2) Calculate the loss of second moment of area of the waterplane where the centre of the compartment is a distance, e, from the athwartships axis through the new centre of flotation. The formula in Para 3108 sub para b becomes:

$$i = a \times b \times e^2 + \frac{(b \times a^3)}{12}$$

(3) Find the fall in longitudinal metacentre due to the loss of waterplane area:

$$\text{Fall of } M_L = \frac{i \times \rho}{\Delta}$$

(4) The rise in centre of buoyancy due to parallel sinkage is the same as in the transverse case therefore:

$$GM_L(\text{damaged}) = GM_{\text{original}} - \text{fall of } M_L + \text{rise of B}$$

where:

$GM_{L\ \text{original}}$ can be found from:

$$GM_{L\ \text{original}} = \frac{MCT1cmBP_{\text{original}} \times L_{BP}}{\Delta}$$

(5) Now the MCT1cmBP for the damaged ship can be calculated:

$$MCT1cmBP_{\text{damaged}} = \frac{\Delta \times GM_{L\ \text{damaged}}}{L_{BP}}$$

(6) The trimming moment is found by multiplying the lost buoyancy by the longitudinal distance between the centre of the flooded compartment and the new centre of flotation. Therefore:

$$\text{Change of Trim} = \frac{\text{trimming moment}}{MCT1cmBP_{\text{damaged}}}$$

b. Both of these methods will allow prediction of ship stability with reasonable accuracy up to approximately 15° of heel. At greater angles of heel or at large angles of trim, particularly if the deck edge is immersed or large areas of weather deck are submerged forward or aft, improvement of stability must be of prime importance and reference should be made to the damage examples given in the CBRNDC Class Book.

c. As can be seen above both of these methods are extremely long and tedious and fraught with the risk of calculation errors particularly during the stress of State 1. Therefore every attempt should be made by the officers responsible to fully familiarise themselves with the examples in the CBRNDC Class Book and attain a suitable level of ships stability knowledge to recognise when an incident may start to present a stability problem and should be studied more closely.

3110. Carpet Plots

To make the task of assessing the effect of flooding on ships stability very much quicker and less likely to create an error, carpet plots are often issued to ships to aid the HQ1 team. These plots provide a quick visual guide to the state of the ships stability dependent on the length of the flood. These diagrams give a worse case scenario, with all flooding adjacent and unrestricted vertically between the forward and after flooding boundary. They will only tell you whether the ship is lost, has poor stability or acceptable stability. With reference to Fig 31-1 to use the diagram, mark on the forward flooding boundary and follow the line down to the bottom of the diagram. Trace this line across to the other side of the diagram. Mark on the after flooding boundary and follow this line down. At the point where the lines cross read off stability condition.

Fig 31-1. Carpet Plot