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Computer Aided Warship Stability Assessment

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ABSTRACT

Computer aided warship stability assessment, software program effectively puts a ship stability expert onboard and provides ship board personnel with a rapid and accurate means to assess changes in vessel's stability. These changes may be :

Routine – as the ship is loaded/unloaded in harbour or due to consumables enroute.

Emergency – when the ship suffers collision/battle damage underway and begins to take on water.

After assessing the stability status, the program helps the crew to determine the actions needed to restore optimum stability.

1. INTRODUCTION

Computers are fast replacing traditional methods in every branch of engineering. Their importance to modern technology needs no further elaboration. The potential of computers as an aid to stability assessment onboard the warship has led to a challenging discipline commonly being refered to as an aid to survivability and surveillance of a warship's integrity.

Stability is the resistance of a vessel to capsizing. Stability calculations for the loading and survivability of a ship are presently being performed manually and are both time consuming and subject to error. Under normal operating environment, the effect of loading of a ship are rarely studied, primarily because of the tedious nature of calculating the requisite stability parameters.

A study of ships lost as a result of accidents/action damage reveals that the cause is directly attributable to progressive flooding and a loss of stability which could have been prevented with the application of appropriate damage control procedures by the operating personnel. The post-damage correction strategy requires hours of hand calculations and in most cases the operating personnel do not have the time or the

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inclination to perform the required calculations immediately after a vessel suffers collision or battle damage.

The practical problems associated with control of battle damage in combatant ships have not been addressed in the design of ship systems, resulting in significant underutilization of existing damage control resources aboard ship[1]

Two divergent design approaches have not lead to the most effective implementation :

(a) Automation of propulsion, electrical and auxilliary control with attendant high performance and reduced manning.

(b) The labour intensive functions of damage control, with heavy reliance on information exchange and situational decision making to prioritize, coordinate and direct crew effort and equipment allocation.

2. REQUIREMENT FOR COMPUTERISED STABILITY ASSESSMENT

The vast majority of officers and the men of the Indian Navy have had little need to use their knowledge of the subject of ship stability for many years. This has led to a general lack of confidence in their ability to put their knowledge into practice and thus a general reluctance to carry out stability calculations for real or hypothetical ship conditions.

This situation is fast being remedied, but even when the relevant personnel have acquired sufficient confidence in their knowledge of the basic principles, there may remain a reluctance to use this knowledge due to the often tedious and repetitive nature of calculations concerning ship stability. A computer is ideally suited to such work, performing tedious calculations accurately, rapidly and reliably.

A computer can be programmed to perform such calculations, given a set of predetermined inputs from an unskilled operator. An operator need have no knowledge of the type of calculations the computer performs, but merely a knowledge of the inputs to be fed for requisite results. It would also provide a facility by which warship personnel can have an appreciation of the capabilities and limitations of their ship's fighting condition and survivability under adverse or hostile conditions.

In this paper these advantages and useful features of some form of ship borne stability computer software package would be sufficient to attract much interest within the Indian Navy. The work that is described in this paper, thus represents an attempt to provide a ship borne computer software package to aid stability calculations and provide stability assessment. However, since ships of different classes in operation with the Indian Navy differ significantly in their design parameters and geometrical configurations, the software package developed as a part of this project, pertains specifically to SNF class (Kaschin class Destroyers) of the Indian Navy..The program logic can however be adopted to meet the requirements of other class of ships after incorporating the necessary changes as regards to ships geometrical data.

3. EXISTING STABILITY CONTROL ORGANISATION ON BOARD IN SHIPS

In this paper, the exact damage control organisation as followed by IN ships cannot be elaborated in details for reasons of security of informations. However, the salient features of the existing organisation are as follows :

(a) The ship status in terms of its survivability is constantly monitored by a specialised team of personnel at the Damage Control Headquarters (DCHQ). The number and size of this headquarter would vary from ship to ship, depending upon the displacement, size, complexity and number of crew aboard.

(b) In the present organisation, the emphasis is laid on collection of information from section headquarters located at vital places onboard ships. Any unusual situation is reported immediately to DCHQ by the section HQ's either by messengers or telephones.

(c) The entire responsibility of working out the current stability status and remedial actions is worked out by the specialised team at DCHQ. However, this system has a tendency to be unreliable in cases where the desired personnel are not available in the DCHQ.

(d) As elaborated in the Introduction, the present organisation is extremely labour intensive with heavy reliance on information exchange and situational decision making. There is no time available to work out the exact modus operandi, using the laid down procedures and decisions are taken on the basis of intuition or experience of the DCHQ personnel.

(e) In the present organisation, the DCHQ becomes active only in hostile or adverse condition. Under normal operating conditions there is no organisation to apprise the command of the loading characteristics onboard and day to day stability assessment.

4. ADVANTAGES OF SHIP BORNE COMPUTERS IN STABILITY ASSESSMENT

The advent of electronic computer is one of the most intellectual advancement to have taken place in the human history. The ability of computers to process thousands of bits of information with speed, accuracy and reliably have made them inevitable components of many engineering problems involving extensive computations.

In the particular case of stability assessment of ship's, one of the important disadvantages of using manual methods is the tedious and monotonous nature of the job that leads to inherent inaccuracies in computation of desired results. The advantages of using a computer for stability assessment of a ship is evident from the details projected below (Table 1).

Table 1. Comparative summary of functional capability[2]

Function	Current methods	CASSA*
Computation time (for typical 14 main compartments problem)	Over 4 hours	5 minutes
Computation accuracy	70% at best	99%
Error sources	Input data : computation methods	Input data
Operator skill	Technical officer/senior sailor	Any officer/sailor
Stability status update	Poor	Excellent
Strategy formulation capability	Poor	Excellent
Decision criteria or methods	Educated guess (intuitive)	Fully analytical (quantitative)
Liquid load and free surface management	Limited and time consuming	Full inventory management capability
Operator training time	Extensive (several weeks)	Minimal (2 days)

* Computer aided ship stability assessment

5. INTRODUCTION TO SHIP STABILITY

This introduces some of the important parameters governing the ship stability.

The definition of ship stability may be expressed as a measure of the ability of a ship to return to the upright position, when distrubed from that position. The various factors affecting a change in stability of a ship are :

(a) Alterations in weights due to additions, removals or shifting of weights onboard.

(b) Consumption of liquid cargo like fuel, fresh water and feed water.

(c) Flooding and ballasting of compartments/tanks due to accident/collision/action damage.

(d) Missile firing and helicopter operations.

(e) Free surface effects of contained liquids or flooded spaces.

(f) Crew and crew effects.

(g) Stores and spare gears, etc.

The various stability parameters that require continuous monitoring are :

(a) Displacement can be regarded as the weight of the loaded ship. Normally, a warship has three states of loading, namely full load, standard load and normal load condition. The initial ship stability characteristics which is a function of the righting arm (GZ) varies with the loading characteirstics of the ship and are normally available in the form of graph known as the curve of statical stability which is a plot of GZ versus the displacement.

(b) The metacentric height (GM), which is the measure of the intial stability of the ship, is the distance between the centre of gravity and the transverse or longitudinal metacentre and is a function of displacement, mean draught, vertical moment due to weight change and the moment of inertia of the water plane. The change in transverse and longitudinal metacentric height for a flooding condition is given[3,4] by

$$GM_{(transverse)} = 1/DIS * \text{(MEAN DRAFT)} * \sum_{i=1}^{n} V - \sum_{i=1}^{n} V*Z - \sum_{i=1}^{n} S*I_x$$

$$GM_{(long)} = [(S*I_y + CF_x)*1/V]$$

Where DIS = Displacement in intact condition
V = Volume of flooded space
Z = Centroid of the flooded compartment in vertical plane
I = Second moment of inertia
CF_x = Abscissa of centre of flotation
i = number of flooded compartments

(c) Centre of gravity of the ship G is the point through which the weight of the ship acts in the vertical plane. Normally the location of G plays an important role in deciding the stability condition of the ship. If the centre of gravity G is below metacentre M, the metacentric height is positive and the ship is said to be in a stable equilibrium. The centre of gravity is normally referred to in conjunction with KG, which is the distance between the G and the keel as shown in Fig. 1.

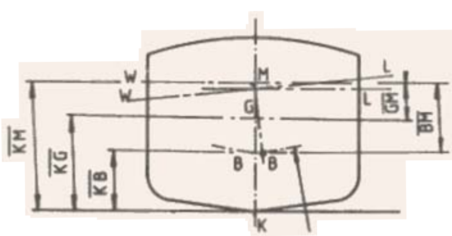

Figure 1. Transverse metacentric parameters.

(d) Trim between perpendiculars is the difference in forward and aft draughts. The trim is normally caused by the rotation of the ship about a point which is the centroid of water plane area at which the ship is floating. Normally the warships are designed to trim by aft. In case of flooding conditions the change in trim is obtained[3,4] by

$$DTRM = \sum_{i=1}^{n} V*X - WTL * CF_x * \text{(mean draft)} / DIS * (GML)$$

(e) Moment to change trim by one centimetre usually abbreviated as $MCT\,1CM$ is a useful parameter in calculations of trim and in the corrective strategy computations to decide upon the optimum counter flooding compartment S for righting the ship after the damage.

(f) Angle of heel/list is the transverse inclination of the ship due to disturbing moment caused by alterations in liquid weights or flooding of some compartments and is obtained by the relation :

$$LIST = (WMC - RMC) / [(DIS * GMT) / 57.3]$$

Where WMC = Weight moment about centre line
RMC = Righting line about centre line
GMT = Transverse metacentric height

The numerator is often termed as total heeling moment (THM) and the denominator is known as one degree heeling moment (OHM).

(g) Reserve buoyancy is defined as the watertight volume of a ship above the water line and is the ability of the ship to withstand the effect of flooding following damage. It is usually expressed as a percentage of load displacement. This parameter is one of the most critical parameter to be monitored prior to using any flooding corrective strategy as, a loss in reserve buoyancy can lead to the sinking of the ship.

In addition to the above explained stability parameters there are various other factors which have an effect on the stability of the ship in both intact and damage condition. All the parameters affecting the ship stability status have been dealt with in the application software package.

6. COMPUTER AIDED WARSHIP STABILITY ASSESSMENT SYSTEM

A microcomputer based interactive and user friendly application package has been developed for use onboard SNF class of ships of the Indian Navy. The package has been designed for use by non-computer specialists onboard, in a bid to :

(a) Provide an efficient liquid level management system.
(b) Reduce solution time drastically and simplify procedures for complete stability evaluation.
(c) Guarantee accuracy.
(d) Provide corrective strategy in a post damage environment.

The software package covers all major types of operating conditions that are likely to be encountered in the course of ship's operation. The software provides an arrangement for continuous monitoring of ship's stability in her operational environment at sea. In addition, the package also aids in assessing ship safety and therefore it's survivability and fighting ability during hostile conditions of flooding, damage, accident during peace time or in action.

7. DESIGN REQUIREMENTS OF THE SHIP STABILITY SOFTWARE PACKAGE

Design features for the ship borne microcomputer software package capable of aiding stability assessment must serve the following purpose :

(a) Speed and simplify computation of variation in ship loading and the effect on statical stability for the intact ship condition.

(b) Calculate stability status during a damaged condition and suggest corrective measures to the operator.

(c) Provide hydrostatic status of the ship at all loading conditions.

(d) Provide graphical representation of the tank status and damage condition of the ship for easy understanding by the user.

(e) Provide stability specifications for docking and undocking of the ship.

(f) The computed hydrostatic parameters under various loading and damage condition must provide optimal counter measures and choice of pumping and ballasting facilities for the affected compartments.

8. FUNCTIONAL DESCRIPTION

Consideration of the design requirements[5] (as discussed above) led to the formulation of a broad software design plan as shown by the flow diagram in Fig. 2.

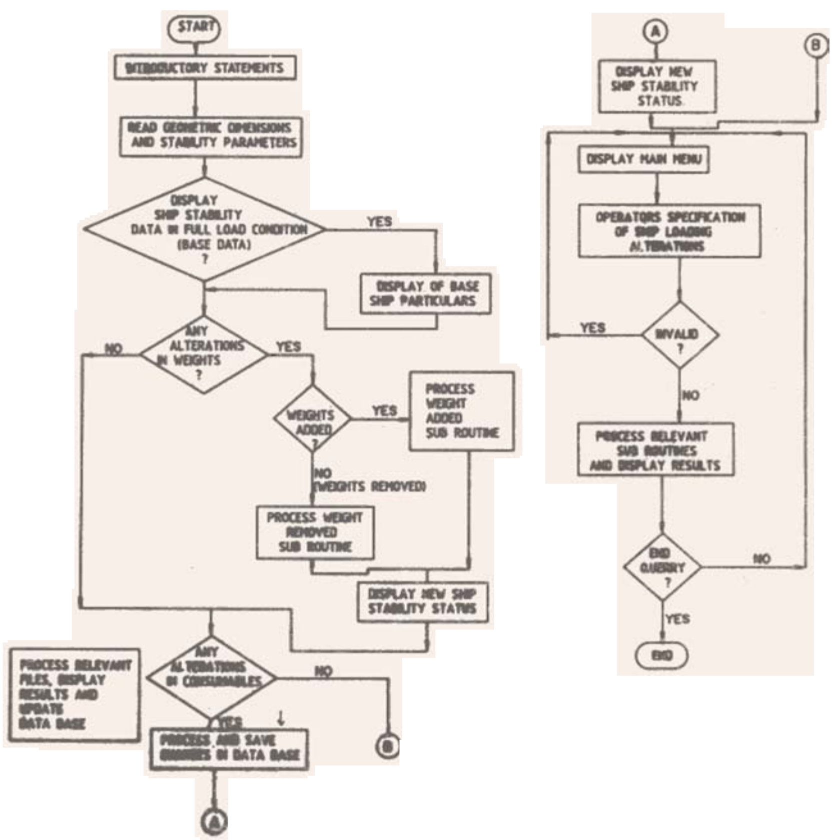

Figure 2. Flow diagram of broad software design plan.

The introductory statements as mentioned in the flow diagram, would include liquid loading restrictions and other significant remarks given in the 'Ship Buoyancy and Stability Particulars[7], for the SNF class of ships. This introductory statements would serve to give a brief description of the package sufficiently to allow the operator to appreciate the nature of the package and type of information he will receive.

The operational program is "platform independent" and can be used with virtually any floating vessel. The sytstem database is plaftorm independent and is categorised in this project for the SNF class of ships.

The software consists of four functional modules which comprise the basic operational program as shown in Fig. 3.

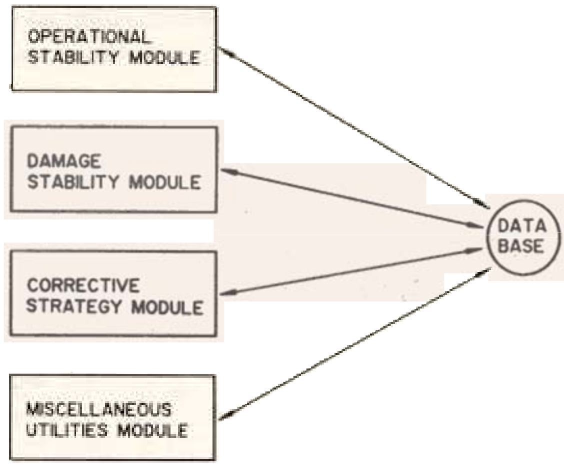

Figure 3. Program modules.

8.1 Operational stability module

This module provides a comprehensive operational stability function which enables operating personnel to rapidly adjust the stability of the vessel due to changes in the liquid or cargo load, and other weight shifts, additions or removals. This function is designed to operate during the normal operation and to assist operating personnel in determining optical cargo load and routine stability procedures such as 'ballisting down' for heavy weather.

Data input to the module is accomplished via menu driven data formats for such items as location and weight of cargo or tank number and type of liquids. Upon completion of data entry, the permanent ship data base is updated, and control is passed to the stability calculation algorithms of the stability assessment module. These agorithms determine changes to the various stability factors such as vertical moment, trim moment and inclining moment used to ascertain changes in metacentric height and the righting arms (*GZ*). All stability factors are calculated for 'free surface effects' and control is returned to the operational stability module for display on the computer's console or tabular print out. In addition to supporting the daily, Engineering Department's reporting requirements, the user of the software can request a printout of a liquid load inventory report and the ship stability status at any load condition The flow diagrams in Fig. 4 and Fig. 5 explain this module.

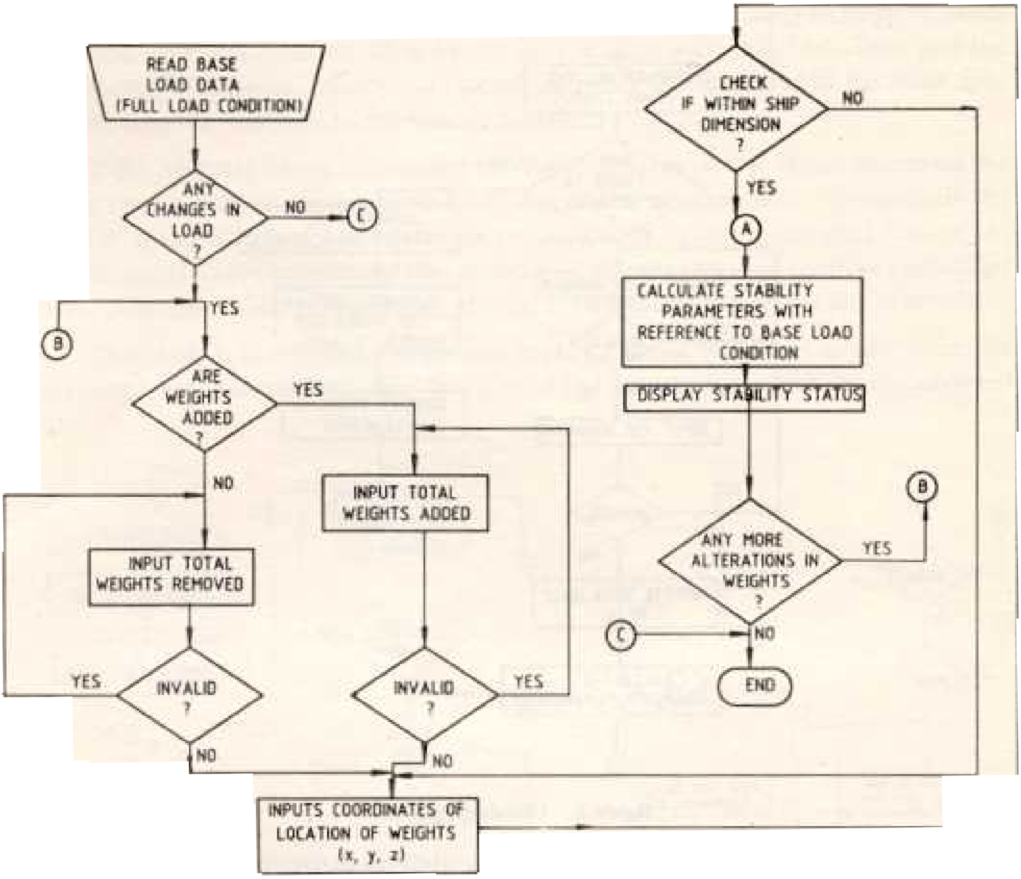

Figure 4. Ship loading alternations.

8.2 Stability assessment module

This module provides a rapid and accurate assessment of the vessels stability after damage is experienced due to collision, stranding. heavy weather or battle engagement. A graphical display of the flooded compartments is also displayed for clear visualisation and perception. In addition this module provides a perceptability of the ship's stability parameters which is further enhanced by presentation of the requisite parameters in the damage state together with those for an intact ship.

This module accepts the data input from the operator and calculates the stability parameters and displays trim between perpendiculars, list, reserve buoyancy, location of centre of gravity, metacentric height, one degree heeling moment. Tons per centimetre of immersion and the draughts of the ship at fore, aft, mean, at proximity of propeller and sonar dome. In this module the operator has an option to use either of the stability assessment methods, namely Added Weight Method or Lost Buoyancy Method.

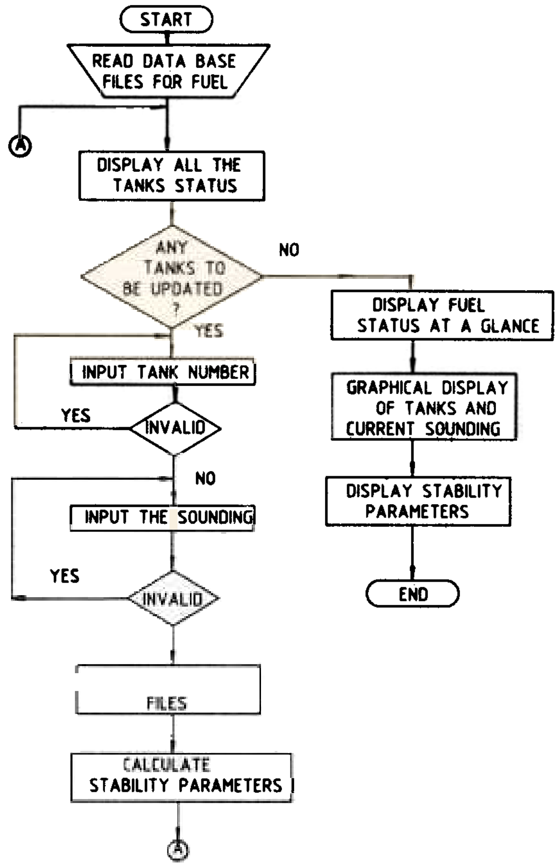

Figure 5. Updating fuel tank.

This system can also be utilised to provide solutions to questions regarding NBCD situations and it can display diagrams and list out various aids available for a situation.

8.3 Corrective strategy module

A ship exposed to the frequently hostile environment of the oceans is faced with many hazards, the most serious being the ultimate loss of reserve buoyancy which results in sinking. A variety of events can lead to this catastrophe. The most serious contributive factors are loss of stability through uncontrolled flooding resulting in capsizing and plunging or structural failure, which may or may not cause the ship to capsize before sinking.

In many cases the ship, loosing her stability, may be saved by proper damage control measures. The main corrective measures in this case is restoring the ship's stability and righting her.

The present trend on ships in the existing circumstances, is a trial and error method. During emergencies, the crew onboard the ship has neither the inclination nor the time to calculate the stability parameters. Even a reference to the stability monograms require a long time and also a large number of ship's current condition data, to obtain the optimum corrective strategy for a given environment.

With the aid of this module of the program. it is a matter of just a few minutes to arrive at the most optimum and a workable corrective solution, in the post damage environment. Fig. 6 shows the flow diagram for the counterflooding strategy by which the most optimum selection of compartments is done such that List, Trim and the Transverse stability are restored to that of the intact condition and at the same time maintaining the least loss in the reserve buoyancy.

If the operator enters a proposed corrective strategy, the program calculates the likely results of these actions in terms of ship stability parameters. Alternatively the 'HELP' features of the program can be requested for a plan of remedial actions. At this juncture, it is recommended that artificial intelligence method could be embedded in the program to enable the software provide a realistic and acceptable line of action.

The module throughout the process makes a series of reports available on the computer screen or on a printer so that a record of the events can be kept and analysed later.

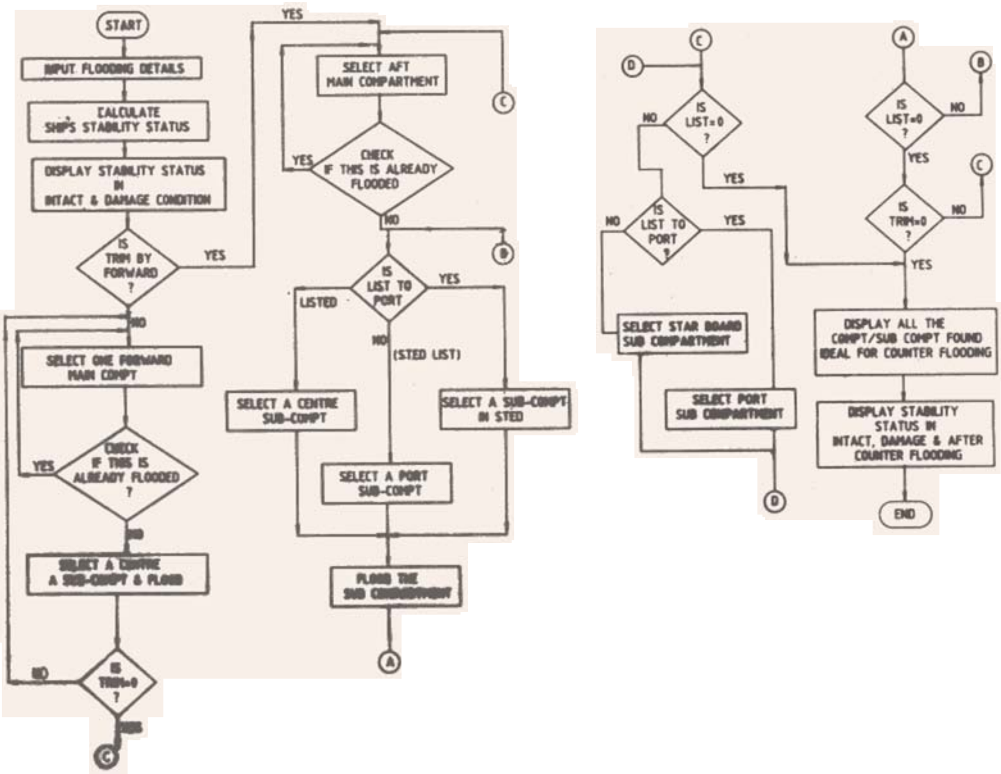

Figure 6. Selecting a righting compartment for counter floodings.

8.4 Miscellaneous utilities module

This module provides the following additional features which in addition to high applicability in day to day operation onboard the ship, add to the versatility and usefulness of the software package. These options are presented in the form of a MENU as shown below.

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