KNOWLEDGE BASED SOFTWARE FOR LOADING AND STABILITY OF SHIPS

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ABSTRACT

Loading and Stability calculations of ships became a more and more complicated and time consuming process as the ship sizes and design complexity increased. Accurate and efficient methods of evaluating and analysing stability of ships for a given loading condition became very important as the safety become equally comparable with efficiency of operation. These requirements lead to introduction of dedicated computer systems onboard ships for loading and stability monitoring in the past. At present Ports-State Control requires details of loading and stability of the ship as it arrives to a particular port. With the development of the personal computer and windows environment, it is now possible to demonstrate actual loading and stability not only on onboard computer, but also at the shore based offices of the shipping agencies that do cargo planning. Any loading condition can be studied together with required stability prior to actual loading taking place. Alterations of loading can be suggested to optimize any loading condition. Although there are specialized producers of such software to the global shipping industries, this paper presents development of such software for a local ship owner.

INTRODUCTION

Complexity of "Loading and Stability" software depends upon the ship size and configuration, specially when the ship has more tanks and compartments with integrated cargo loading. Loading sequence should satisfy the strength requirements (limits of shear forces and bending moments) and stability of the ship at harbour condition and sea-going condition. Manual calculation and assessing of strength and stability becomes a cumbersome process if the ship is to be loaded with hundreds of containers. It is impossible to perform same calculation manually for alternative loading arrangements. In practice, experiences of a few loading conditions and stability calculations and their results are used to make judgement on any other situation with a level of uncertainty. The risk involved with such approximation and judgement may depend upon the type of ship and the loaded draft. However, when an onboard computer is available to study all possible and practical options of loading, cargo spaces can be utilized to an optimum level without risk and uncertainty. This paper presents development of such software on windows environment using Visual Basic as the programming language.

DATABASE NEEDED FOR THE DEVELOPMENT

General Arrangement of the Ship

The General Arrangement and subdivisions of the vessel into different tanks and cargo holds are required. This information is used to obtain tank and cargo hold locations, capacities, their vertical and longitudinal centers of gravity and free surfaces as the capacity varies from zero to maximum. Container profile plan (elevation of tiers) and bay plans (cross sections of bays) are required if the ship is a container ship. Container planning would be based on the profile plan and bay plans.

Hydrostatics Particulars and Cross Curves of Stability.

The following particulars of the underwater hullform are used to calculate the trim and stability of the vessel. These data are stored against set of draft or displacement and interpolated where necessary.

i. Volume of displacement
ii. Waterplane area and their location of centre of gravity (LCF – Longitudinal Centre of Floatation)
iii. Longitudinal Centre of Buoyancy of the underwater volume (LCB)
iv. Vertical Center of Buoyancy of the underwater volume (VCB)
v. Height to Metacentre from the keel (KM)
vi. Moment to Change Trim by a Centimetre (MCTC)
vii. Stability lever (KN) for different displacements as the ship heel increases (Cross-curves of stability).

The above data are used to determine trim, drafts and centre of buoyancy and stability of the ship for a given loading condition. Instantaneous values of all the particulars are calculated to check the stability of the vessel as the ship displacement is changed even by a very small value.

Types of Load and Loading Data.

In the case of tank loading, the type of liquid in each tank is needed to estimate the weight of the liquid when volumetric capacity is given as the loading data. Stowage factor and weight of cargo are required in case of Bale or Grain cargo loading. If Grain cargo is carried, heeling moment due to grain shifting should be taken into consideration when estimating the stability of the vessel. Container cargo loading should include weight, size, type of cargo and port of discharge. Sequence of container loading depends on the weight and port of discharge in order to facilitate quick discharging.

Distribution of Structural Weight of the Lightship.

The distribution of the lightweight of the ship should be added to the distribution of other loads (tank load, cargo loads) to calculate total weight distribution along the ship length. Shear Force and Bending Moment estimation involve the determination of resultant force distribution as the difference between the weight and buoyancy. This is further discussed in the section on shear force and bending moment.

Loadline and Stability Criteria

There are statutory criteria to be satisfied by the ship for each loading condition. The loaded draft should not exceed the maximum draft specified by the Loadline Rules and stability criteria applicable to all weather conditions should be satisfied. In addition, maximum values of shear force and bending moment should not exceed the allowable values for harbour condition and sea-going condition.

BACKGROUND OF THE DEVELOPMENT

Particulars of the lightship and all hydrostatics particulars are stored in the program and user is not allowed to change these data. Displacement, center of gravity and all hydrostatics particulars relevant to the displacement are calculated when there is an addition or subtraction of any item. Trim and stability criteria are assessed and a warning displayed if any criterion fails. The load, shear force and bending moment variation along the length of the ship are assessed and displayed graphically against frames of the ship structure.

For each type of tank loading, a window is displayed. This window provides the information on default data and data to be input for each tank. Any item can be loaded as its volume or weight, and the specific gravity value is set default. Fig.1 shows an algorithm of tank loading. A similar algorithm is used for cargo loading as well.

Stability Criteria

In general, all ships should satisfy certain stability criteria. These criteria are imposed to ensure stability of the ship, or in other words, resistance to capsize under any weather condition. These criteria are specified with respect to the righting lever and area under the righting lever that represent the potential energy of the ship at any angle of inclination (Fig 2).

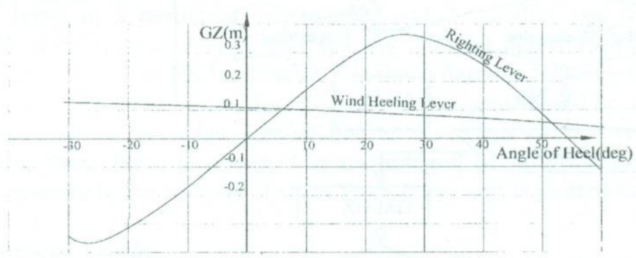


Fig.2:- Righting Lever of a Ship

The following intact stability criteria are recommended by IMO (International Maritime Organization):

1. Initial metacentric height GM should be not less than 0.15 m.
2. Righting lever should be at least 0.2 m at an angle of heel equal to 30 deg.
3. Area under the righting lever curve should be not less than 0.055 m.rad upto an angle of heel of 30 deg.
4. Area under the righting lever curve should be not less than 0.09 m.rad. upto an angle of heel of 40 deg. or upto an angle where the non-weathertight openings come under water (whichever is less)
5. Area under the righting lever curve should be not less than 0.03 m.rad. between the angles of heel of 30 to 40 deg. or such lesser angle mentioned under criterion 4.
6. Maximum righting lever should occur at an angle of heel exceeding 30 deg.
7. Angle of heel due to turning of the vessel should be less than 10.
8. Wind heeling moment criterion should be satisfied.

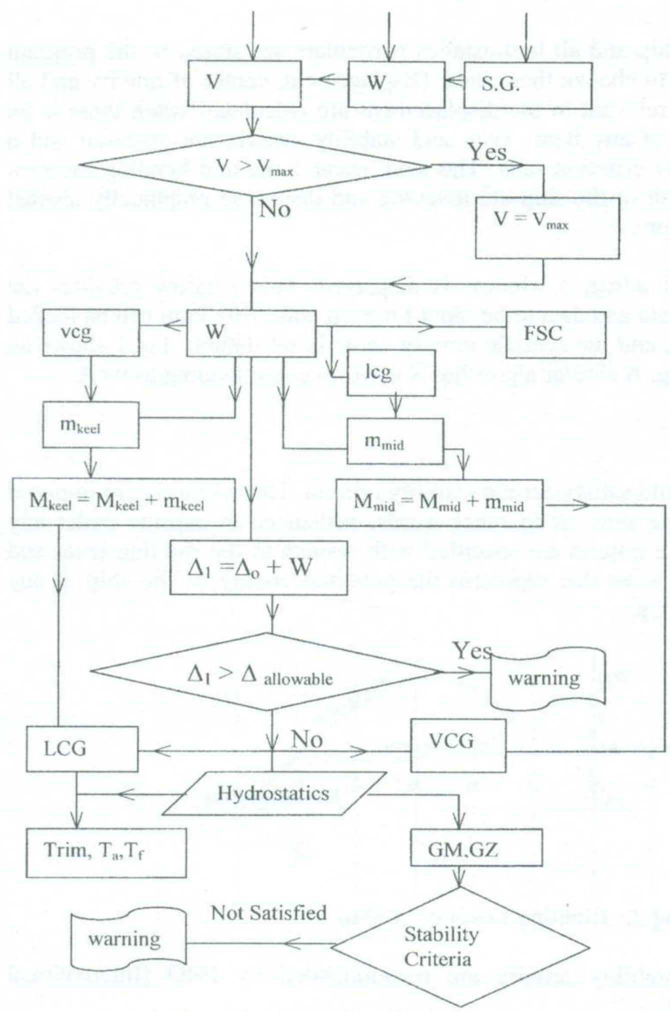


Fig. 1:- Algorithm for Tank Loading

V-Volume of liquid loaded
S.G.= Specific Gravity of liquid loaded
W- Weight of liquid loaded
Vmax = Maximum volume of the tank
Δ_o = Original displacement
lcg = longitudinal centre of gravity of liquid loaded
Δ_I= New displacement
vcg = vertical centre of gravity of liquid loaded
$\Delta_{allowable}$ = Allowable displacement for the specified loadline
FSC = Free surface correction of liquid
m_{keel} = moment of weight of liquid about keel
M_{keel} = moment of the ship about keel
m_{mid} = moment of weight of liquid about midship
M_{mid} = moment of the ship about midship
Trim = trim of the ship
VCG = vcg of the ship
T_a and T_f = Draft aft and forward
LCG = lcg of the ship
GM = Metacentric height of the ship
GZ= Righting lever of the ship

Shear Force and Bending Moment.

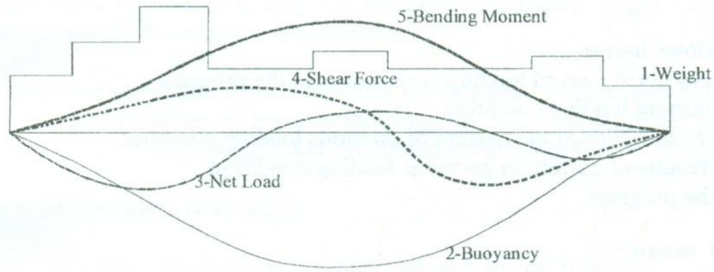


Fig. 3- Shear Force and Bending Moment Distribution

Figure 3 illustrates typical longitudinal distributions of weight and buoyancy for a ship afloat in calm water. Curve 2 represents buoyancy force variation in still water condition. Curve 1 is the distribution of the weight. Areas under these two curves should be equal, as the weight is equal to the buoyancy force.

In this procedure, the length of the ship is divided into a number of equal frame spaces corresponding to frame sections. All of the weights of hull, equipment and contents lying in a particular spacing are added together and treated as a single uniformly distributed load over this spacing. Having determined the buoyancy and weight distribution, the net load curve 3 is the difference between the two. Under the condition of static equilibrium, the net area of this curve should be zero and the center of buoyancy be on the same vertical line as the center of gravity. As in any beam calculation, shear force is obtained as the integral of resultant load (Curve-4). The bending moment is the integral of shear force curve and is plotted as Curve 5.

Wave Induced Loads

The calculation of the bending moment, shear force and torsional loading on a ship hull in waves require a knowledge of the time-varying distribution of fluid forces over the wetted surface of the hull together with the distribution of inertial reaction loads. The fluid load corresponds to the wave induced motion of the water and the corresponding motion of the ship. The inertial forces equal to the product of the local mass of the ship and absolute acceleration. The shear force and bending moments are obtained based on these combined forces and then become time-varying force and moment.

However, experiments have shown that worst case for an average sea going condition can be assumed to be when either the crest or trough of a wave whose length is equal to ship length L, and height is L/20 is at the midship. This approach is used here in calculating shear force and bending moment at sea-going condition.

PROGRAM STRUCTURE & FEATURES

The program is structured into the following main menus (see Annexes)

1. File menu

This menu allows user to :

i. load previously saved loading condition into the program
ii. save current loading condition
iii. open results files of the current or previous loading condition
iv. print results of current or previous loading condition
v. quit the program

2. Deadweight menu

This menu allows user to load

(a) Consumables as follows (Annex-A)

i. load or unload Fresh Water tanks either by volume or weight.(Specific gravity is a default value. However user can alter this value if he wishes)
ii. load or unload Heavy Fuel tanks with the facilities given in i
iii. load or unload Diesel Oil tanks with the facilities given in i.
iv. load or unload Ballast Water tanks with the facilities given in i.
v. load or unload Miscellaneous tanks with the facilities given in i.
vi. load or unload Lubrication oil tanks with the facilities given in i.
vii. 10%, 98% or 100% of the capacity as stated in the ship stability booklet can be loaded with single mouse click.

(b) Cargo as follows (Annex-B)

i. load or unload Cargo Holds with either Bale cargo or Grain cargo. Cargo can be loaded either by volume and stowage factor or weight.
ii. to load or unload containers.
Profile plan of the container stowage is displayed when containers are to be loaded. Each slot in Bay of containers can be selected for loading. Container information can be loaded either as (Annex-C)
1) weight of the container only
or 2) weight and discharge port of the container
or 3) weight, discharge port and container number
Containers can be unloaded by a double clicking of the mouse.

3. Crane Loading menu

This menu provides the facility of using onboard Cranes for loading and unloading of cargo. Options are provided to understand the effect of loading or discharging either by a single crane or both cranes simultaneously from both port side and starboard side of the ship. Any adverse heeling or stability of the ship while using these cranes is warned. Program provides the information on Ballast to be loaded or unloaded to correct the adverse heel while using these cranes. Officer in-charge of loading the ship is made knowledgeable on any dangerous situation and precautions can be taken before actual loading or unloading commences.

4. **Sounding and Draft Survey menu** (Annex-D)

This menu provides information on existing volume or weight of liquid in each tank when the sounding height is the input. Sounding height can be obtained as the results if the weight is fed as input.

Existing deadweight of the vessel can be estimated when measured draft values of the vessel are given as input to the program. At the same time, any discrepancy between actual deadweight and calculated deadweight is warned against.

Advanced Features (Fail safe)

1. The program calculates the centers of gravity of respective volume of liquid loaded and hence user does not need to input these values.
2. Specific gravity of different liquids (Diesel, Heavy Fuel, Lubrication oil) can be altered by the user, however warning is displayed in message box, if these values are out of range.
3. Stowage factor of cargo is checked against recommended values.
4. Empty upper slot of a container-bay is inactive until the slot just below is loaded.
5. Loaded slot of a container-bay is inactive until the slot just above is unloaded.
6. The port of discharge of containers can be selected with a color. This color appears in all loaded slots with containers belonging to the same port of discharge.
7. If loading of the ship continues without selecting an operating draft (loadline), program warns to select an operating draft when the loaded draft reaches the minimum recommended loadline.
8. Program does not permit to load any item if the vessel's draft exceed operating draft.

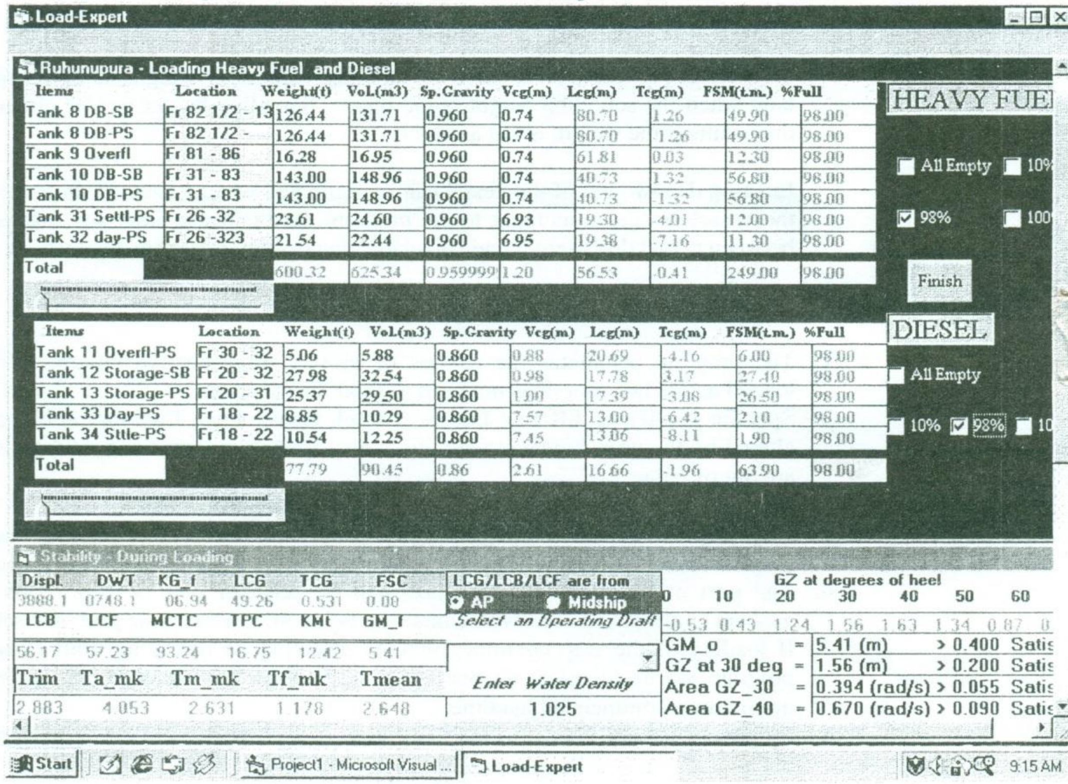
CONCLUSION

This is the first attempt to develop window-based ships loading software by the author and it is fully successful to the owner's requirements. The results of the software have been validated and in agreement with the calculation given in the stability booklet of the ship. The software could be further improved by adding animated graphical display of the ship and its position with respect to waterplane as loading or unloading take place. Also tank loading and unloading can be integrated with feed pumps parameters to estimate the time of loading or unloading tanks.
Further, this software is already used in the Division of Maritime Studies for teaching purposes and to demonstrate variation trim and stability of a ship during loading and unloading.

REFERENCES

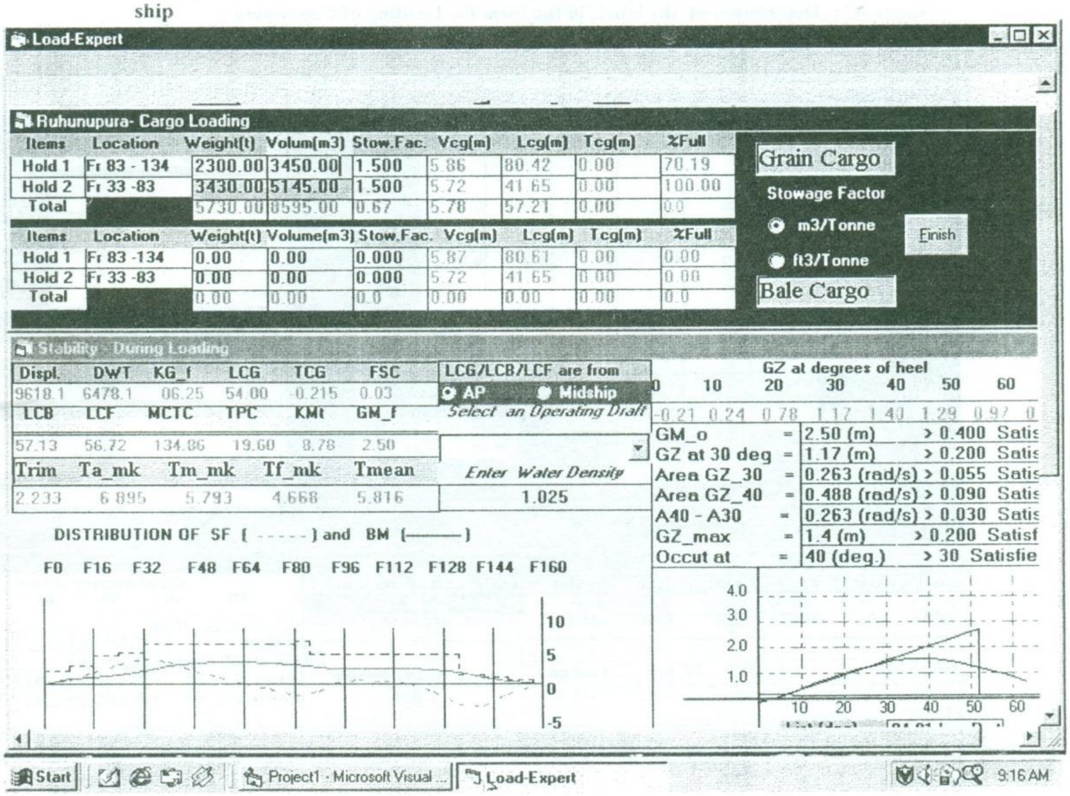
1. General Arrangement Plan of the Ship
2. Capacity Plan of the Ship
3. Stability Booklet of the Ship
4. Principles of Naval Architecture, Volume I, 1988, Published by The Society of Naval Architects and Marine Engineers.

Annex –A :- Description of the labels in the form for loading of Tanks



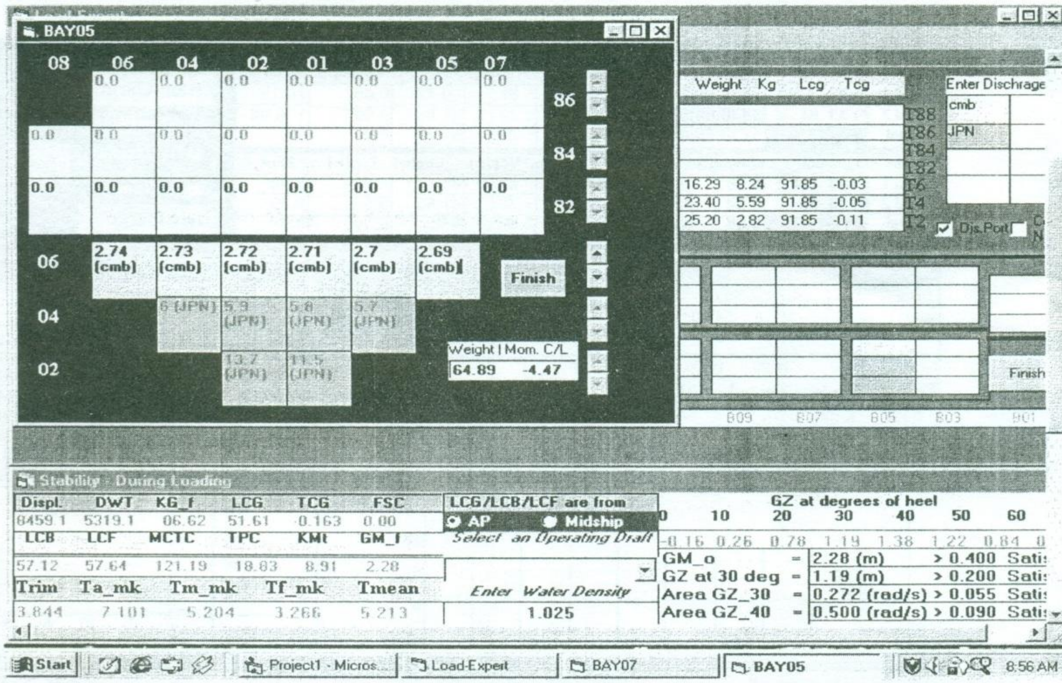
Label	Description
Item	Name of each tank (ex: Tank 8DB-SB – Tank no 8 double bottom starboard)
Location	Location of the tank in the ship with respect to the frames
Weight	Weight of liquid
Vol	Volume of liquid in the tank
Sp.Gravity	Specific gravity of the liquid
VCG	Vertical Centre of gravity of the liquid in the tank
LCG	Longitudinal centre of gravity of the liquid in the tank
TCG	Transverse centre of gravity of the liquid in the tank
FSM	Free surface moment of the liquid
%Full	% of the filled volume of the tanks

Annex –B :- Description of the labels in the form for Loading of Cargo Stability details of the ship



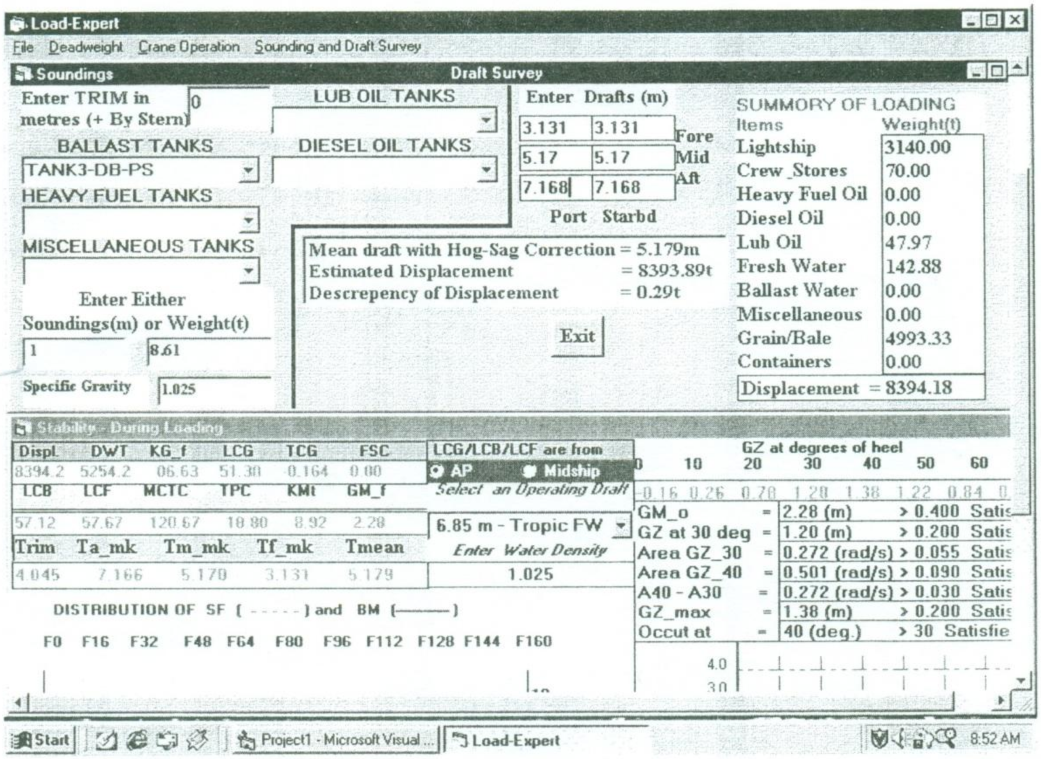
Label	Description
Displ	Displacement of the loaded ship
DWT	Deadweight of the loaded ship
KG_f	Vertical Centre of gravity (fluid) of the loaded ship
LCG	Longitudinal centre of gravity of the loaded ship
TCG	Transverse centre of gravity of the loaded ship
FSC	Free surface correction of the ship
LCB	Longitudinal centre of buoyancy of the ship
LCF	Longitudinal centre of floatation of the loaded ship
TPC	Tonnes per centimeter immersion of the ship
KMt	Height to the transverse metacentre from the keel
GM_f	Metacentric height (fluid)
Trim	Trim of the ship
Ta_mk	Draft aft marks
Tm_mk	Draft midship mark
Tf_mk	Draft forward mark
Tmean	Draft mean draft
GZ	Righting lever
AreaGZ_30	Area of GZ curve up to 30deg of heel
A40-A30	Area of GZ betwwen 30 and 40 degrees
GZ_max	Maximum value of GZ

Annex -C :- Description of the labels in the form for Loading of Containers



Label	Description
B01 – B27	Container Bay number
Form B05	Cross section of the bay 5
T2- T86	Tier numbers
No	Number of containers in each tier
Weight	Weight of containers in each tier
Kg	Equivalent vertical centre of gravity of containers in each tier
Lcg	Equivalent longitudinal centre of gravity of containers in each tier
Tcg	Equivalent transverse centre of gravity of containers in each tier

Annex -D :- Description of the labels in the form for Sounding and Draft Survey



1. This frame can be used to find the amount of fluid (Fuel oil, Freshwater, Lubrication oil and Ballast water in each tank when the sounding value of the tank is input.

2. When the actual draft values of the ship are input the displacement of the ship displayed.

Drop down menu show the different tank carrying different type of fluids.

Label	Description
Sounding	Reading of the sounding of a particular tank
Weight	Weight of liquid
Sp.Gravity	Specific gravity of the liquid
Fore	Forward of the ship
Mid	Midship of the ship
Aft	Aft of the ship