Computer analysis of longitudinal strength of ships

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COMPUTER ANALYSIS OF LONGITUDINAL STRENGTH OF SHIPS.

by

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ABSTRACT OF THESIS ON

COMPUTER ANALYSIS OF LONGITUDINAL STRENGTH OF SHIPS

The purpose of the work was to produce a programme to calculate as accurately as possible the distributions of weight and buoyancy of a vessel, leading to the determination of shear force and bending moment at each of 101 equally spaced ordinates overall.

Calculations may be performed for still water or sine wave conditions.

The programme, which provides tabular and/or graphical output, is written in Elliott Autocode and is in the Applications Group library of Elliott Automation Limited. It is extensively labelled and is flow charted throughout, the symbols used being those of the British Standards Institution, and illustrated in the glossary.

A fairly detailed look into the 'end lengths' suggested by Lloyd's (their Rpt. SR 64/15) has been undertaken in connection with the distribution of the continuous material.

Ordinate tilting has been used, in the main, as opposed to 'base swinging' techniques, the reasons being fully explained in the text.

The programme was approved by Lloyd's Register of Shipping in August 1966, (except for those parts relating to (i) the coffin method for the continuous material and (ii) the application in a sine wave -

which parts Lloyd's did not check). It has also been further successfully tested by them in November, 1966.

Comparisons with programmes written by Vickers Armstrongs Limited, Barrow in Furness, B.S.R.A., Wallsend, and the Naval Architecture Department of Glasgow University, on the same topic are included as an Appendix. Graphical results obtained by Lloyd's, B.S.R.A's and by this programme for one locally built vessel are included, for purposes of comparison.

Results illustrated in the thesis are in both tabular and graphical form throughout.

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INTRODUCTION

The structure of a ship is subjected to a variety of forces, which may be split into two main types : statical and dynamical. One of the effects of such forces is to cause the vessel to bend in a longitudinal vertical plane. The following thesis deals with this aspect only; i.e. it is an analysis of the longitudinal strength of vessels.

The vessel may be treated as a beam, subjected to forces which consist of:

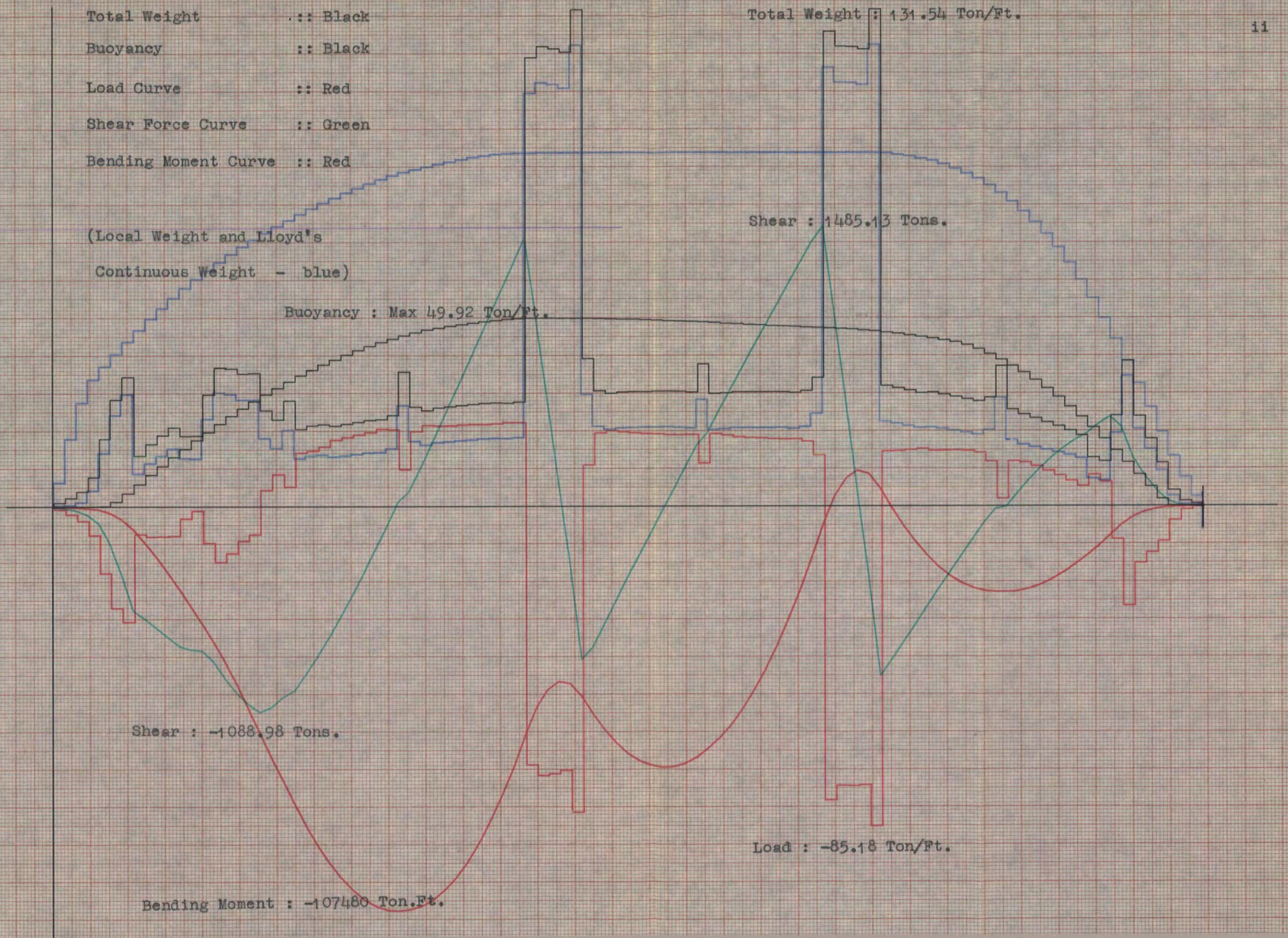
(i) its own weight ⎫
(ii) cargo, fuel, machinery, etc. ⎭ Total Weight.
(iii) buoyancy - (to equal Total Weight).

Bending occurs because weight and buoyancy are not, in general, equal at all points along the length of the vessel. There may be an excess of weight over buoyancy at some points (especially the ends), and an excess of buoyancy over weight at other points along the length.

The calculations are carried out by determining the weight and buoyancy distributions (curves) along the ship's length, and from these two the determination of LOAD curve which is the difference (with sign) between these curves.

Integration of the load curve gives the SHEAR FORCE curve, and a second integration gives the BENDING MOMENT curve.

Page (ii) shows the various curves for the ship considered in the thesis with vertical scales half of those of the separate graphs in the body of the thesis.


Total Weight :: Black
Buoyancy :: Black
Load Curve :: Red
Shear Force Curve :: Green
Bending Moment Curve :: Red
(Local Weight and Lloyd's
Continuous Weight - blue)
Total Weight : 131.54 Ton/Ft.
Shear : 1485.13 Tons.
Buoyancy : Max 49.92 Ton/Ft.
Shear : -1088.98 Tons.
Load : -85.18 Ton/Ft.
Bending Moment : -107480 Ton.Ft.

The programme calculates and prints out, if desired, ordinate values for Local Weights, Continuous Hull Weight, Total Weight, Buoyancy, Load Curve, Shear Force Curve and Bending Moment Curve over each of 100 equal divisions of the ship's overall length.

Weight, buoyancy and load curve ordinate values are averaged over every pair, progressively, throughout the whole length; ordinate values output are, therefore, projected forward over the appropriate division, in the first five tables mentioned above.

There are checks in the programme to ensure that extreme ends of local weights lie within the overall length of the vessel and also that the centre of gravity of each local weight lies within the centre $33^{1}/3\%$ of the length of the item. The programme waits if any item offends and may be continued if desired.

The graphs of the Weight, Buoyancy and Load Curves consist of a series of straight horizontal lines drawn forward from each ordinate in turn (in agreement with the tables mentioned above). In the case of the Shear Force and Bending Moment, however, continuous polygons are drawn.

If it is necessary to produce Shear Force graphs for several conditions, to a common scale (and similarly for Bending Moment curves), then an initial run of the conditions must be made to obtain the maximum positive and maximum negative values overall. Re-running the data with these values inserted will enable a common scale to be set for all conditions. See appendix 4, Page 183.

Since a large amount of output tape is required to draw axes and insert scales, it is left to the design office to insert the axes manually, and to write the scales in. (The size of scale is automatically output if the graphs are required).

The time taken to output all of the above listed tables is approximately 8 - 10 minutes. Output for the graph-plotter only, takes approximately two minutes per graph. Full output of all tables and graphs takes, therefore, approximately 22 minutes.

(A preliminary programme was first written, using as a basis a ship from a local yard for which results had already been calculated - using Biles' Coffin continuous weight distribution - and for which graphs had been plotted, by hand. This ship is referred to as Ship No. A827. The effects of buoyancy due to the stern and bow sections were ignored in this programme; the length between the perpendiculars was divided into ten equal parts, numbers 1, 2, 9 and 10 being further halved giving, in all, 15 stations. The programme uses the Biles' Coffin method to distribute the continuous weight.

Results output by this shorter programme have been superimposed on the graphs provided by the yard, for the still water calculations. See Appendix 2).

The main programme includes the stern and bow portions. Thirty one stations are used over all, of which 23 are within and include the perpendiculars, with 4 aft and 4 forward.

Since the work started Lloyd's have published their method for the distribution of the continuous weight entitled:-

CARGO SHIPS
DISTRIBUTION OF LIGHTWEIGHT
FOR STILL WATER BENDING
MOMENT CALCULATIONS
RPT. SR 64/15.

This method is included in the main programme, and the choice of distribution is left to the builder.
(It may be pointed out that for the present the report may be taken as applying to bulk carriers and tankers, though it is expected that a separate work will be published concerning these types of vessels).

Some interesting points arose in the choice of the stern and bow overhangs (and their respective weights) when considering the continuous weight distribution by both Lloyd's and Biles Coffin methods. Since the programme is to cater for the builder in the design stages, when such values are not known with certainty, Lloyd's suggest possible end values for their method. These were investigated, and the results may be examined on pages 57/61. Page 34 deals with the Biles Coffin aspect.

Checks are made in the resultant total weight curve for correct weight and L.C.G. position, and if any final error is present, it is ultimately corrected by the axis swinging technique known as 'swinging the base'. It is expected that such errors will be negligible, if Lloyd's method is used for the continuous weight. Checks included print out the errors and hold up the programme if the weight error is greater than $\pm$ .1% or if the L.C.G. error is greater than $\pm$ 1%, before 'swinging the base'.

Data from a second ship has been used to illustrate this main programme. This ship is referred to as Ship No. A.842.

Comparisons of outputs, in tabular and graphical forms, of the Continuous Weight distributions for A842, and consequent Total Weight, Load, Shear and Bending Moment curves, using Biles Coffin method and Lloyd's method are included.

Graphs of results using the former are shown in red, and those using Lloyd's method are in green.

Since finishing this work, the author has seen and examined three other programmes of a similar nature. One is from the Naval Architecture Department of the University of Glasgow and is entitled:-

RESEARCH REPORT NO. 10

A NOTE ON STILL WATER BENDING MOMENT CALCULATIONS

BY A DIGITAL COMPUTER.

BY C. KUO AND N.S. MILLER.

The report is not for publication.

The second programme is from Vickers Armstrong (Shipbuilders) Limited, Barrow-in-Furness, entitled:-

DETAILS OF
LONGITUDINAL STRENGTH PROGRAMME NA/4
WRITTEN IN MERCURY AUTOCODE.

The third is a report from B.S.R.A., Wallsend-on-Tyne, describing a Longitudinal Strength programme BSRA/NA/W5. Their programme is a modified version of the Vickers programme, made to satisfy Lloyd's Register requirements.

Comparisons of these three programmes with the Sunderland programme are set out in Appendix I of this thesis.

An outline flow chart for the whole of the programme follows on page xv. Separate flow charts, one for each part of the programme, will be found preceding the first pages of their respective chapters, with those for Subroutines 30 and 86 preceding the print-up of the programme, in Appendix 3.

Subroutines 29 (moments), 58 (Lagrange's 3 point interpolation) and 109, 110 (graph output), are elementary and have not been flow charted.

Presentation of data, and methods of operating the programme are set out in Appendix 4, and is a copy of the write-up now sent to Elliott's Application Group for general distribution.

Thanks are due to Mr. N. Tate, Senior Lecturer in Naval Architecture, Sunderland Technical College, for many valuable comments and help generally. Also to Mr. T. Case, until recently on the design staff of Messrs. Austin and Pickersgill Limited, Shipbuilders, Sunderland, and at present in the Research Department, Lloyd's Register of Shipping, for much valuable help and encouragement. I must also thank the design staffs of the several yards on the River Wear for their unstinted help in providing data as required. They have been extremely accommodating and encouraging. The cooperation of B.S.R.A., Wallsend, in providing results for comparison is greatly appreciated.

Finally my thanks to Lloyd's Register of Shipping for checking the results of this programme with their own programme for Longitudinal Strength. Lloyd's have accepted the programme for use in the initial design stages. Check computations must be performed by Lloyd's where Bending Moment results are required for plan approval, but where figures are supplied from this approved programme, no fee will be charged by Lloyd's.

GLOSSARY

(AND KEY TO FLOW CHARTS)

"a" - multipliers which enable the ordinates of the continuous weight curve to be obtained at each of 21 positions along the length of the vessel. These values are dependent upon the block coefficient at the appropriate load draught and they are given in graphical form in Lloyd's "Rpt. SR 64/15", Figures 3 and 4.
Copies of these figures are on pages 42/43.

base plane - horizontal plane through the origin.

block coefficient (C_B) - ratio of submerged volume at a given draught d, to the volume of the enclosing rectangular prism having dimensions length (LBP), breadth (2xGI) and draught (d).

Bonjean curve - curve of immersed areas for a given section, or station.

bow (and overhang of) - that portion of the vessel forward of the forward perpendicular. The horizontal distance between the forward perpendicular and the extreme forward point of the vessel is referred to as the "overhang of bow".

buttock heights - heights from the horizontal base plane to the moulded shell line.

centre of buoyancy - point through which the resultant of the buoyancy forces acts.

centre of flotation - centroid of the area of any given waterplane; when a vessel, floating at a waterline, is trimmed by a re-distribution of weights on board, the final and original waterplanes intersect in a line which passes through the centre of flotation.

centre of length (C/L) - centre point in the length of a local weight item.

continuous weight - weight of the ship structure when all concentrated items of structure and equipment are removed.

deadweight - total weight of all concentrated items (local items) additional to lightweight.

displacement - tonnage of sea water displaced for a given loading condition.

draught - vertical distance between the water surface and the moulded base line.

floating point - refers to a method of storage of numbers within the computer.

half breadth - horizontal distance from the longitudinal centre line plane to the moulded shell line.

hogging - a condition of the vessel wherein the buoyancy is more than the weight over approximately the midship halflength with less buoyancy than weight at both ends, so that the tendency of the vessel is to arch up or hog amidships.

integer - refers to a method of storage of numbers within the computer.

L.B.P. (or LBP) - horizontal length between the perpendiculars.

L.O.A. (or LOA) - extreme overall length of the vessel.

lightweight (lightship)	- continuous weight plus such concentrated items as engines, deckhouses, etc. (i.e. weight of unloaded vessel).
local weight	- weight of any item of structure, equipment or deadweight which is distributed over only a part of the length of the ship.
L.C.B. (LCB)	- longitudinal centre of buoyancy (measured longitudinally from the origin).
L.C.F. (or LCF)	- longitudinal centre of flotation (measured longitudinally from the origin).
L.C.G. (or LCG)	- longitudinal centre of gravity (measured longitudinally from the origin).
"m" value	- weight per foot of the ship structure over the midship section. (Refer to Lloyd's Rpt. SR 64/15)
midships	- centre of the distance between the perpendiculars.
moulded lines	- lines to which the ship is designed; the shell plating falls outside these lines. (See diagram - General Hull Terms : p.xiii)
origin	- vertical projection of the extreme aft point of stern onto the base line.
perpendicular (aft)	- vertical line through the after side of the rudder post, or if no rudder post is fitted, through the centre-line of the rudder stock.
perpendicular (fore)	- vertical line through the point where the stem of the vessel cuts the still waterline at the design draught.

rudder stock - vertical axis about which the rudder turns.

sagging - the condition opposite to hogging wherein the excess of weight over buoyancy amidships with a corresponding excess of buoyancy over-weight at the ends causes a tendency to arch down or sag at mid-length.

still water - surface of water is a horizontal plane.

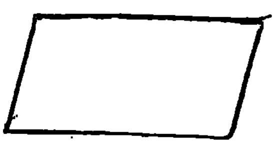
swinging the base - adding (or subtracting) a trapezoid of area to the base of the curve to adjust the area and centroid, thereby producing a new (tilted) base. Such areas represent weight.

trim - difference in draughts between the extreme ends of the vessel.

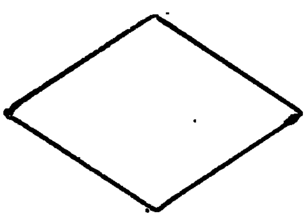
waterlines - intersections between the hull and horizontal planes (waterplanes) at draughts d.

Flow Chart Symbols

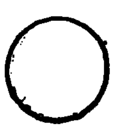
Any kind of processing function.



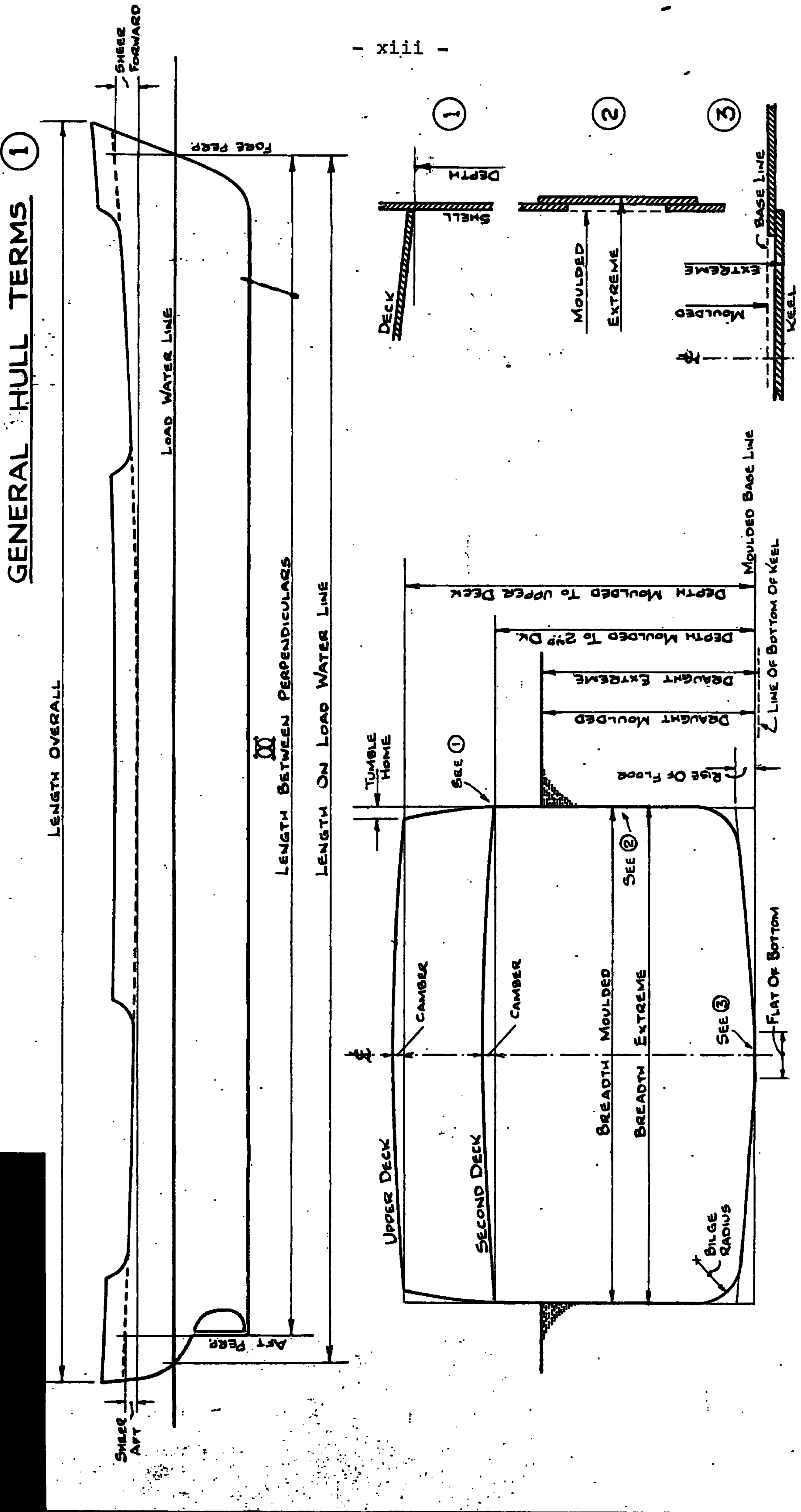
Input/Output.



Decision or switching type operation.

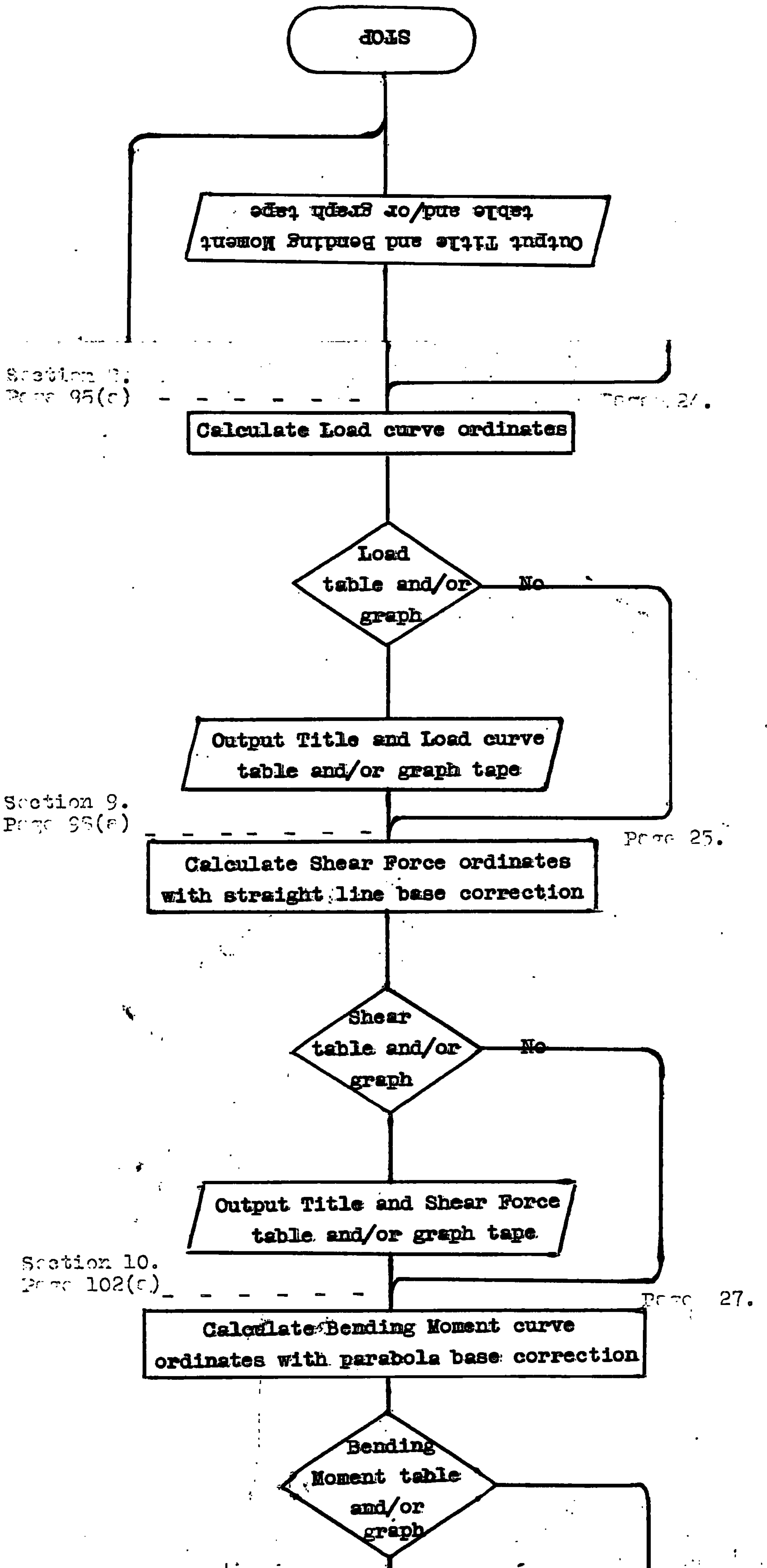


Connector. An exit to or entry from another part of the flowchart.


GENERAL HULL TERMS ①
SHEER FORWARD
FORE PERP.
LENGTH OVERALL
LOAD WATER LINE
LENGTH BETWEEN PERPENDICULARS
LENGTH ON LOAD WATER LINE
AFT PERP.
SHEER AFT
①
DEPTH
SHELL
DECK
②
MOULDED
EXTREME
③
BASE LINE
EXTREME
MOULDED
KEEL
MOULDED BASE LINE
DEPTH MOULDED TO UPPER DECK
DEPTH MOULDED TO 2ND DK.
DRAUGHT EXTREME
DRAUGHT MOULDED
LINE OF BOTTOM OF KEEL
TUMBLE HOME
SEE ①
RISE OF FLOOR
SEE ②
CAMBER
CAMBER
BREADTH MOULDED
BREADTH EXTREME
SEE ③
FLAT OF BOTTOM
UPPER DECK
SECOND DECK
BILGE RADIUS

LIST OF SUBROUTINES

29	-	Summation of Moments of Weight, or Buoyancy, ordinates about the extreme end of stern.
30	-	Calculates the area submerged up to the water surface for the section being considered.
58	-	Lagranges 3-point interpolation routine, to produce 100 equally spaced values. Finds values within the first interval over the first half of the range, and changes to the second interval for the remainder of the range.
86	-	Calculates and prints out:- (i) maximum positive and maximum negative values of ordinates (ii) range for Y-axis (iii) X-axis distance from base of graph paper (iv) vertical scale. It also prints out the horizontal scale from the value previously read in.
109	-	Produces a tape for the Benson-Lehner graph plotter for those 'curves' which are continuous polygons.
110	-	Produces a tape for the Benson-Lehner graph plotter for those 'curves' which show the ordinate values projected forward.
124 (inc. 34, 35, 36, 46, 64.)	-	Distributes the local weights over 100 equally spaced ordinates between the extreme ends of the vessel. Prints out error indications where the item lies outside the overall length (Q2 if to rear of stern, Q3 if forward of point of bow), and where L.C.G's of items are greater than one sixth the length of the item (indicated by the letter B), in both cases also giving the number of the item.



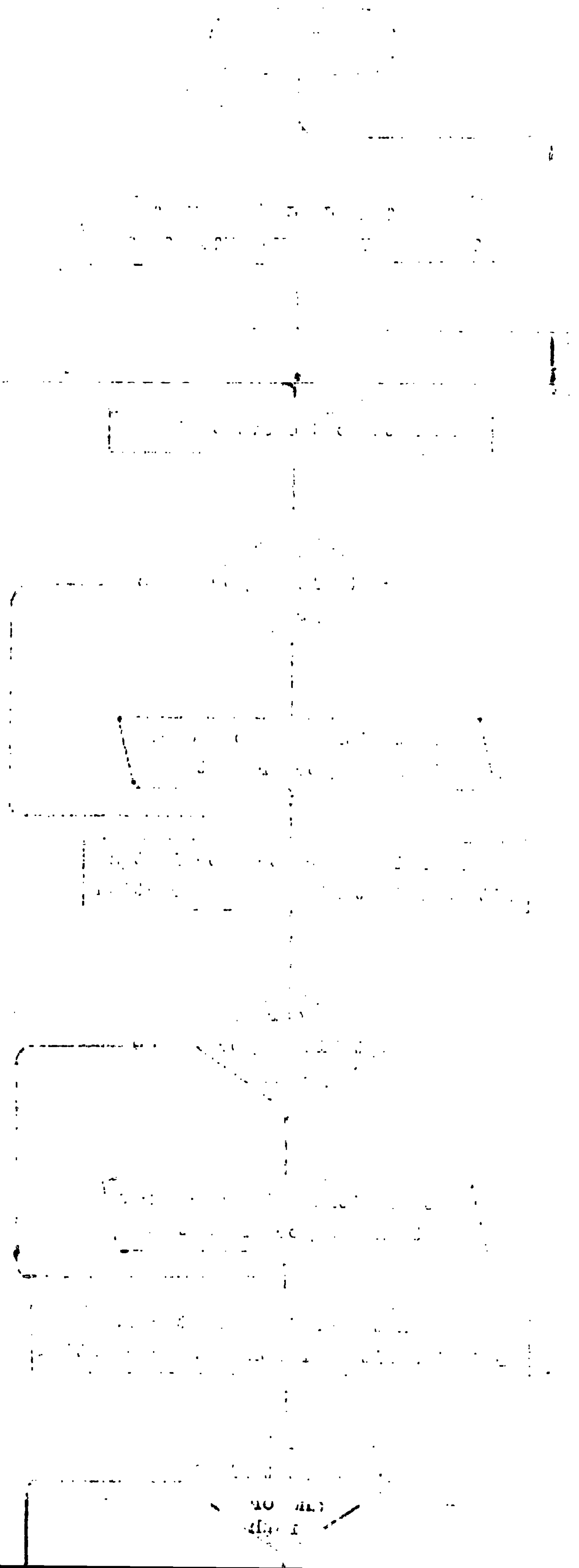
STOP
Output Title and Bending Moment table and/or graph tape
Section 9.
Page 95(c)
Page 24.
Calculate Load curve ordinates
Load table and/or graph
No
Output Title and Load curve table and/or graph tape
Section 9.
Page 98(a)
Page 25.
Calculate Shear Force ordinates with straight line base correction
Shear table and/or graph
No
Output Title and Shear Force table and/or graph tape
Section 10.
Page 102(c)
Page 27.
Calculate Bending Moment curve ordinates with parabola base correction
Bending Moment table and/or graph

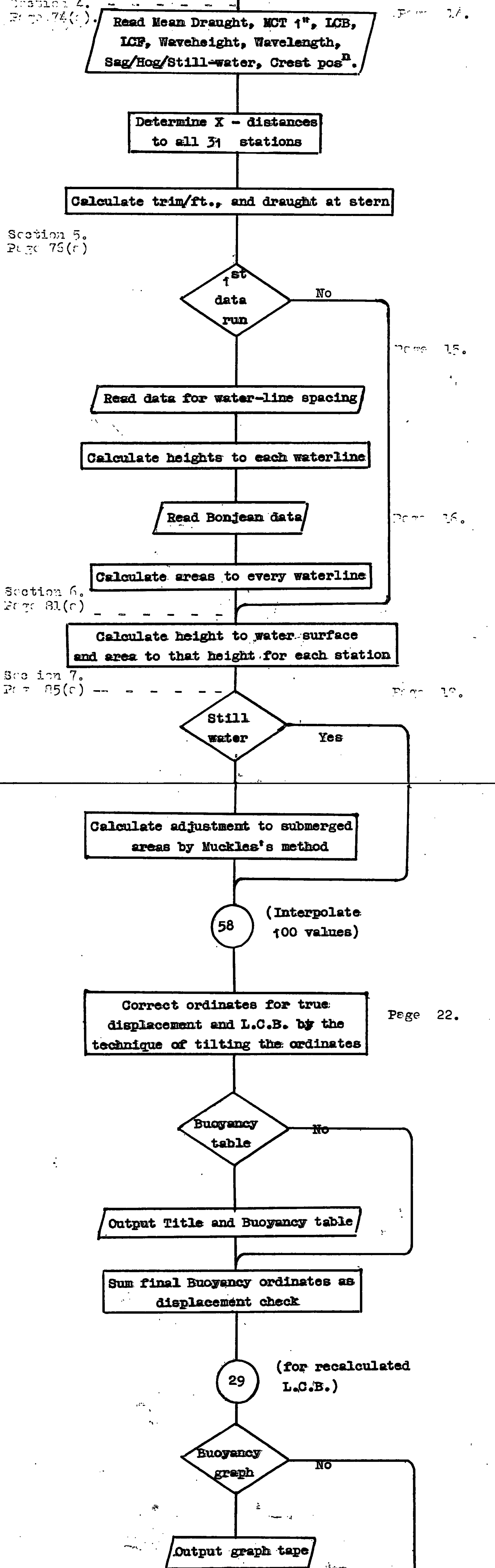
LONGITUDINAL STRENGTH

BENDING MOMENT CALCULATIONS

OVERALL FLOW-CHART.

F	O	L	D
D	O	W	N

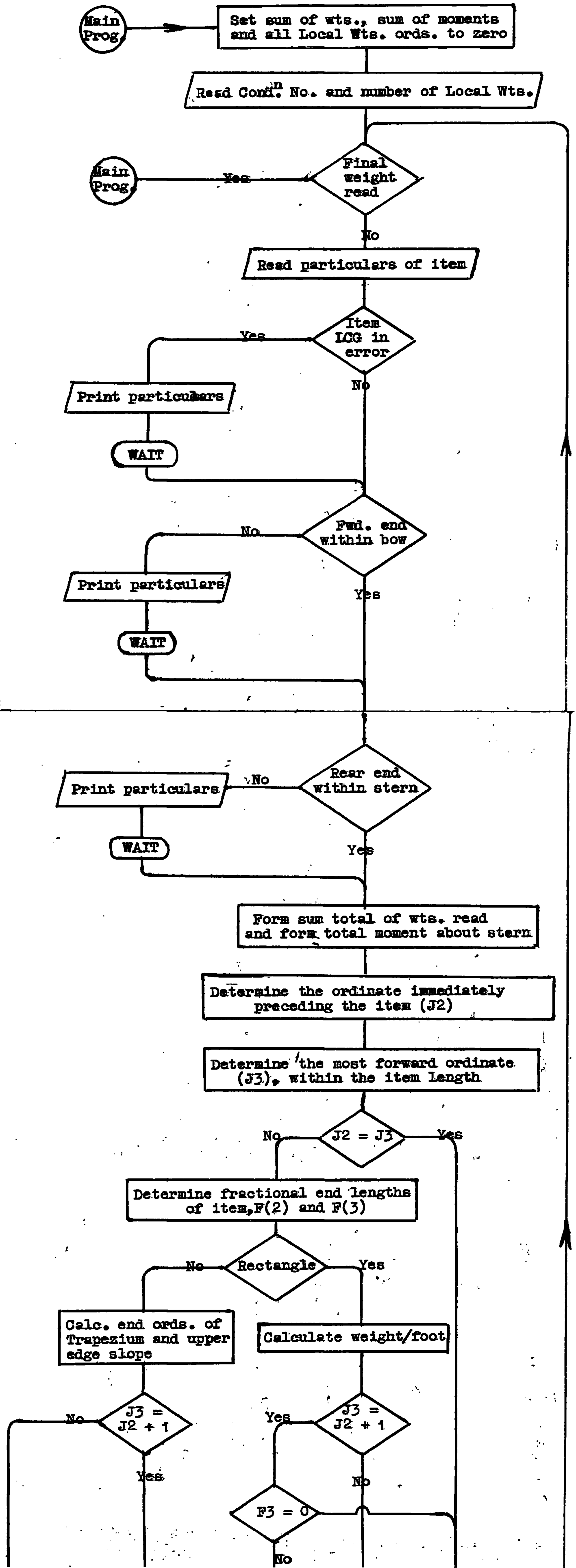




Section 4.
Page 74(c)
Page 14.
Read Mean Draught, MCT 1", LCB, LCF, Waveheight, Wavelength, Sag/Hog/Still-water, Crest pos^n.
Determine X - distances to all 31 stations
Calculate trim/ft., and draught at stern
Section 5.
Page 75(c)
1st data run
No
Page 15.
Read data for water-line spacing
Calculate heights to each waterline
Read Bonjean data
Page 16.
Calculate areas to every waterline
Section 6.
Page 81(c)
Calculate height to water surface and area to that height for each station
Section 7.
Page 85(c)
Page 19.
Still water
Yes
Calculate adjustment to submerged areas by Muckles's method
58
(Interpolate 100 values)
Correct ordinates for true displacement and L.C.B. by the technique of tilting the ordinates
Page 22.
Buoyancy table
No
Output Title and Buoyancy table
Sum final Buoyancy ordinates as displacement check
29
(for recalculated L.C.B.)
Buoyancy graph
No
Output graph tape

FLOW CHART (Programme Page 35)

LOCAL WEIGHTS SECTION (Subroutine 124)



FLOW CHART

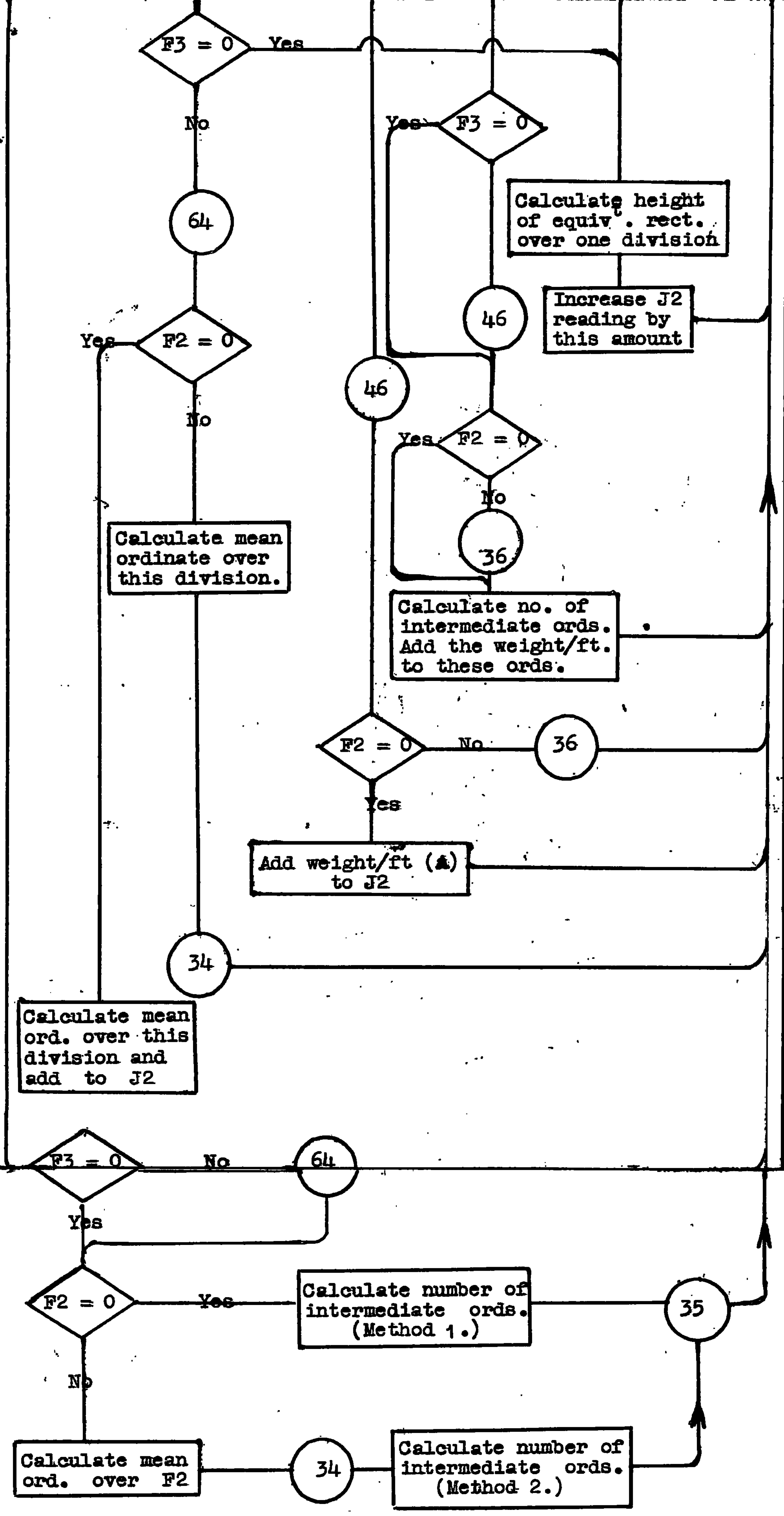
(Section 1).

LOCAL WEIGHTS SECTION

(Subroutine 124)

FOLD

DOWN

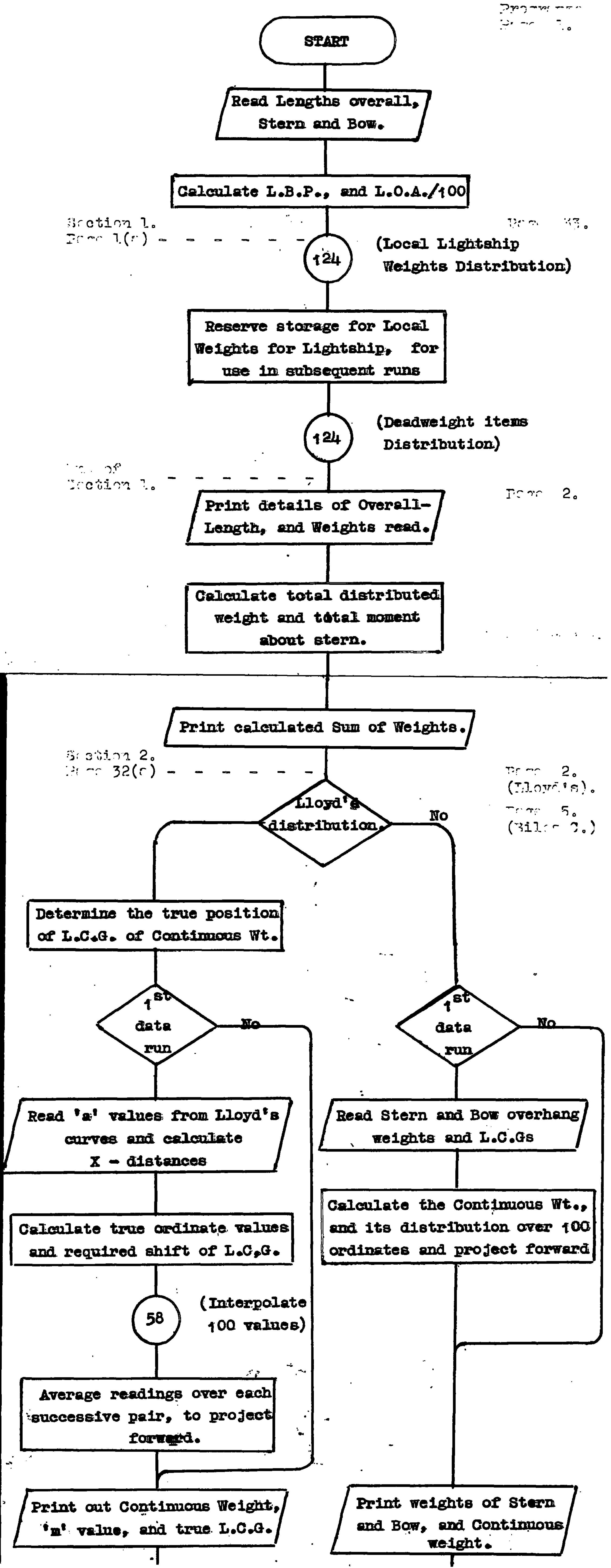


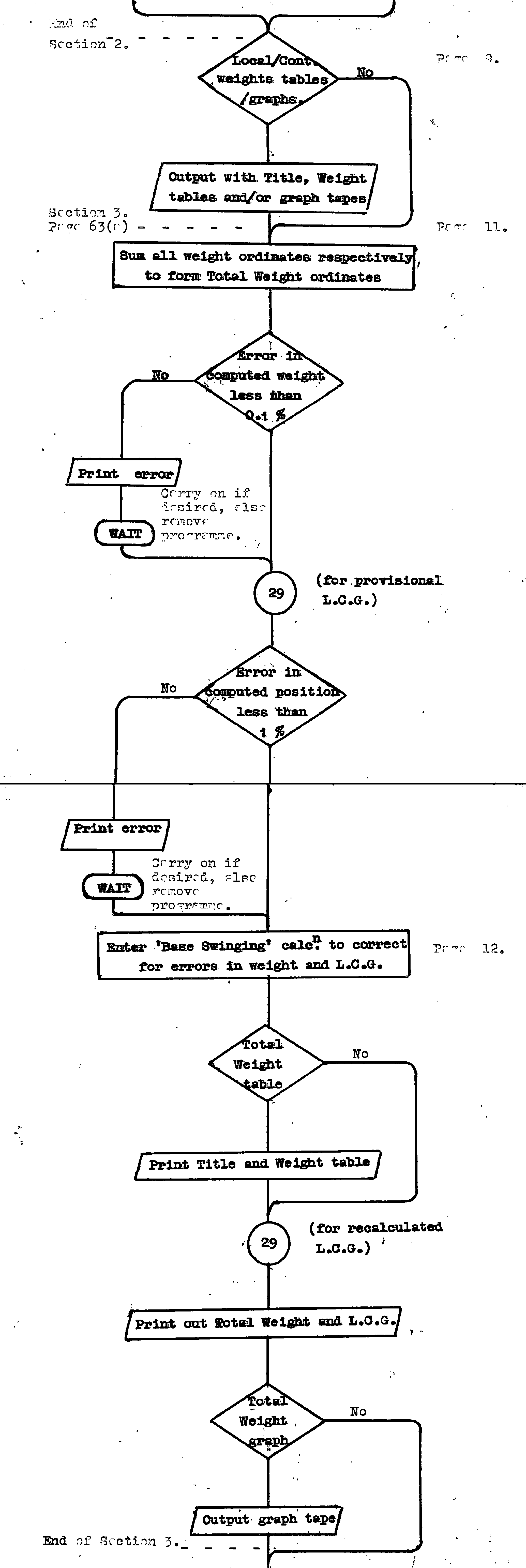
F3 = 0
Yes
No
64
F2 = 0
Yes
No
Calculate mean ordinate over this division.
46
F3 = 0
Yes
Calculate height of equiv. rect. over one division
Increase J2 reading by this amount
46
F2 = 0
Yes
No
36
Calculate no. of intermediate ords. Add the weight/ft. to these ords.
F2 = 0
No
36
Yes
Add weight/ft (A) to J2
34
Calculate mean ord. over this division and add to J2
F3 = 0
No
64
Yes
F2 = 0
Yes
Calculate number of intermediate ords. (Method 1.)
35
No
Calculate mean ord. over F2
34
Calculate number of intermediate ords. (Method 2.)

LONGITUDINAL STRENGTH

BENDING MOMENT CALCULATIONS

OVERALL FLOW-CHART





End of Section 2.
Page 9.
Local/Cont. weights tables /graphs.
No
Output with Title, Weight tables and/or graph tapes
Section 3. Page 63(c)
Page 11.
Sum all weight ordinates respectively to form Total Weight ordinates
Error in computed weight less than 0.1 %
No
Print error
Carry on if desired, else remove programme.
WAIT
29
(for provisional L.C.G.)
Error in computed position less than 1 %
No
Print error
Carry on if desired, else remove programme.
WAIT
Enter 'Base Swinging' calc.^{n} to correct for errors in weight and L.C.G.
Page 12.
Total Weight table
No
Print Title and Weight table
29
(for recalculated L.C.G.)
Print out Total Weight and L.C.G.
Total Weight graph
No
Output graph tape
End of Section 3.

PART 1

LOCAL WEIGHTS DISTRIBUTION

Local Weights are all the additions to the basic hull and include such items as cargo, masts, ballast, deckhouses, winches, wheelhouse, hatch-covers, engines, etc.

For the distribution of local weights the overall length of the ship (L.O.A) is divided into 100 equal parts, and the division marks, or ordinates numbered from 0(the stern) to 100 (the bow). Each weight item is then distributed over those divisions in which it lies, as a series of weight ordinates. The distribution of the actual weight in any particular case may be uniform over its length, or it may vary over its length either linearly or befitting some curve. The latter method was considered and rejected, it being decided that such distributions may be split into smaller portions which may be assumed to vary linearly. The actual weight distribution in a particular case, therefore, may be rectangular or trapezoidal. Each type is dealt with in the programme.

A series of test weights were used initially, and the details relating to them are set out on pages 13 to 22.

The weights relating to the actual ship under test (Ship A.842), were then used in the programme and these items are set out on pages 24 to 28. The ordinate values as output from the programme are on page 30 and the appropriate graph on page 31.

Note that ordinate values are averaged over every pair progressively throughout the whole length, the value being attributed to the rearmost ordinate; ordinate values output are, therefore, projected forward over the appropriate division.

Output of the table of values is optional, on the desire of the builder.

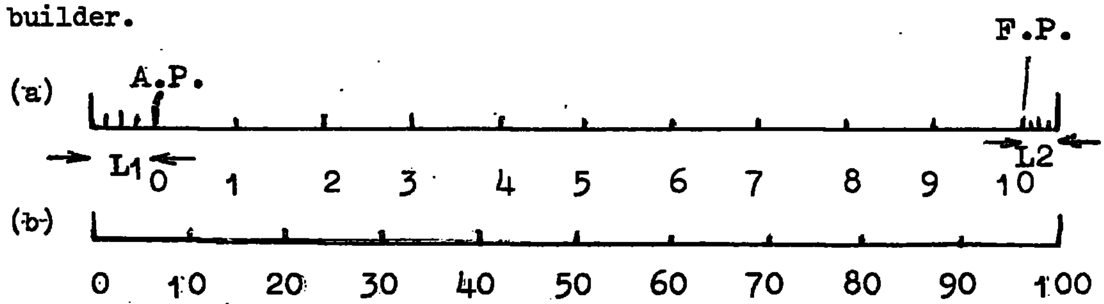
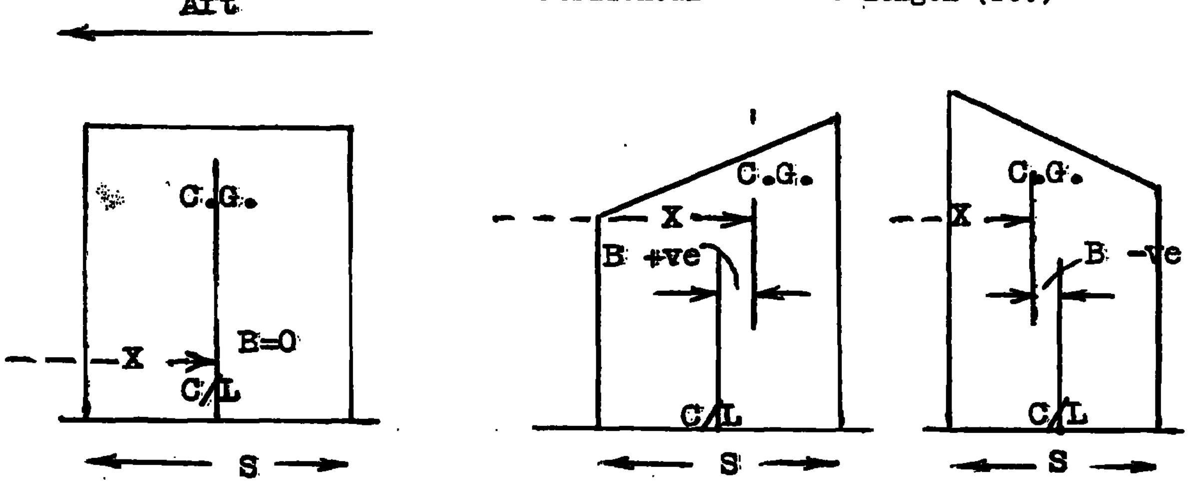


Fig. 1. Showing how the L.O.A. is divided into 100 equal parts (b), and the relationship to the normal 10 displacement stations (a).
L1 - overhang of stern. L2 - overhang of bow.

The relevant information for each weight is read in and consists of (a) the weight, (b) its length, (c) the distance of its centre of gravity from its centre of length (C/L) and (d) the distance of its centre of gravity from the Z axis through the extreme point of stern. F. Pt. variables are M, S, B and X respectively. B may be zero, positive or negative according as the weight plan is rectangular or otherwise. See fig. 2. (In this thesis W is used for local weights instead of M).

The calculations are performed within a VARY loop which covers the number of local weights to be dealt with (Int. variable N). Local weights read in are summed immediately (F. Pt. variable S1), as are their moments about the Z axis through the extreme point of stern. (F. Pt. variables M1 - individual, and T5 - sum).

Vertical ordinates: tons/ft. of length.
Horizontal " : length (ft.)



(Fig. 2).

With each weight it is necessary to determine the distances of its fore and aft ends from the Z axis through the stern in terms of the number of ship divisions (i.e. L.O.A./100). Fractional parts of such divisions at each end of the weight are calculated and in each case the relevant portion of the weight is then distributed over the whole of the division in which the fractional part lies. See fig. 3. Portions of weight lying wholly across a division are adjusted to be uniform in distribution if not already so, and the weight per foot of length is added to the rearmost ordinate. Since the horizontal lines drawn between the ordinates of the Weight Distribution Curves are drawn forward from each ordinate respectively, only the rear ordinate of each division is affected by the addition of the weight portion for that division. Ordinate values are a measure of the weight per foot length over that division.

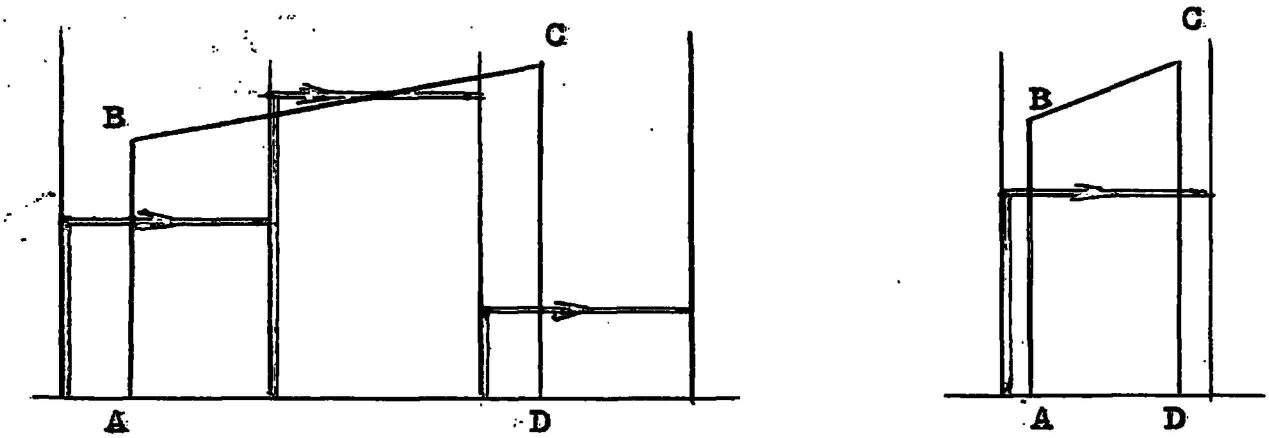


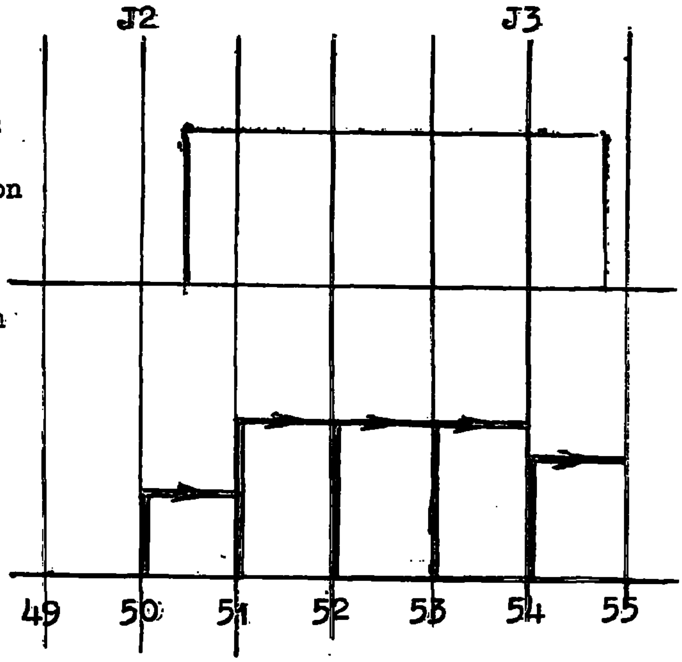
Fig. 3. ABCD - given form for weight item.
RED lines show the various portions distributed.
Product of ordinate value and ordinate separation for any division gives the weight distributed over that division.

It has already been mentioned that two types of weight distributions have been considered; (a) rectangular, (b) trapezoidal, details of which are on pages 13-22. There are thirty possible variations which must be taken into account in programming their distributions. For ease of checking, it has been assumed that each of the test weights lies within and between ordinate numbers 50 and 55, the lengths of the items varying between five full divisions down to part of one division. Rectangular and trapezoidal distributions are treated separately:

(1) Rectangular; typical item:

i) Initial weight, position and length.

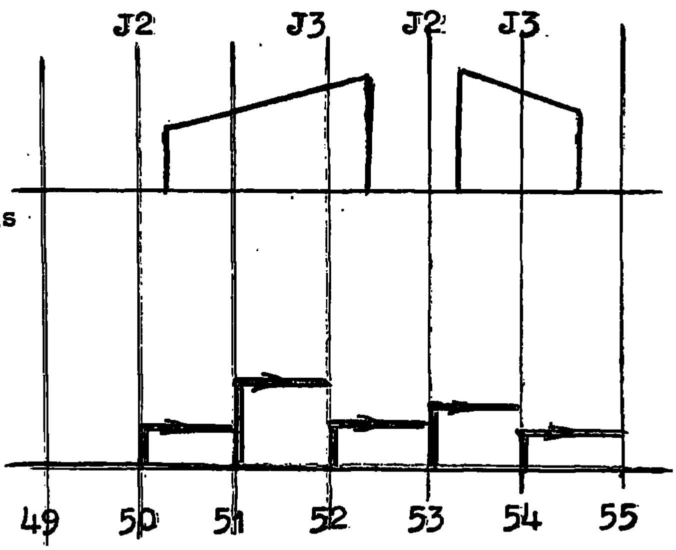
ii) Programmed distribution of weight.



(2) Trapezoidal (Positive and negative slopes)

i) Initial weights, positions and lengths.

ii) Programmed distributions of weights.



(Fig. 4)

Weights which lie wholly between two adjacent ordinates, no matter what type of distribution, affect only the rearmost ordinate of that division. See pages 13 and 15.

As an example of the manner in which the calculations are performed let us assume two local weights with the following particulars, on a ship whose L.O.A. is 500 ft.

1. Rectangular distribution:

Tons	Ft.	Ft.	Ft.
W = 36	S = 18	B = 0	X = 262

(See ex. 30 page 22)

L.O.A. = 500 ft. L/100 = 5 ft.

Since the distribution is rectangular (B = 0), each end of the item is 9 ft. from its centre, which is itself 262 ft. from the stern. Therefore

Dist. of aft end of item from stern = 253 ft.
(i.e. $^{253}/_5$ divs. from stern: i.e. between ordinates 50 and 51)

Dist. of fore end of item from stern = 271 ft.
(i.e. $^{271}/_5$ divs. from stern: i.e. between ordinates 54 and 55).

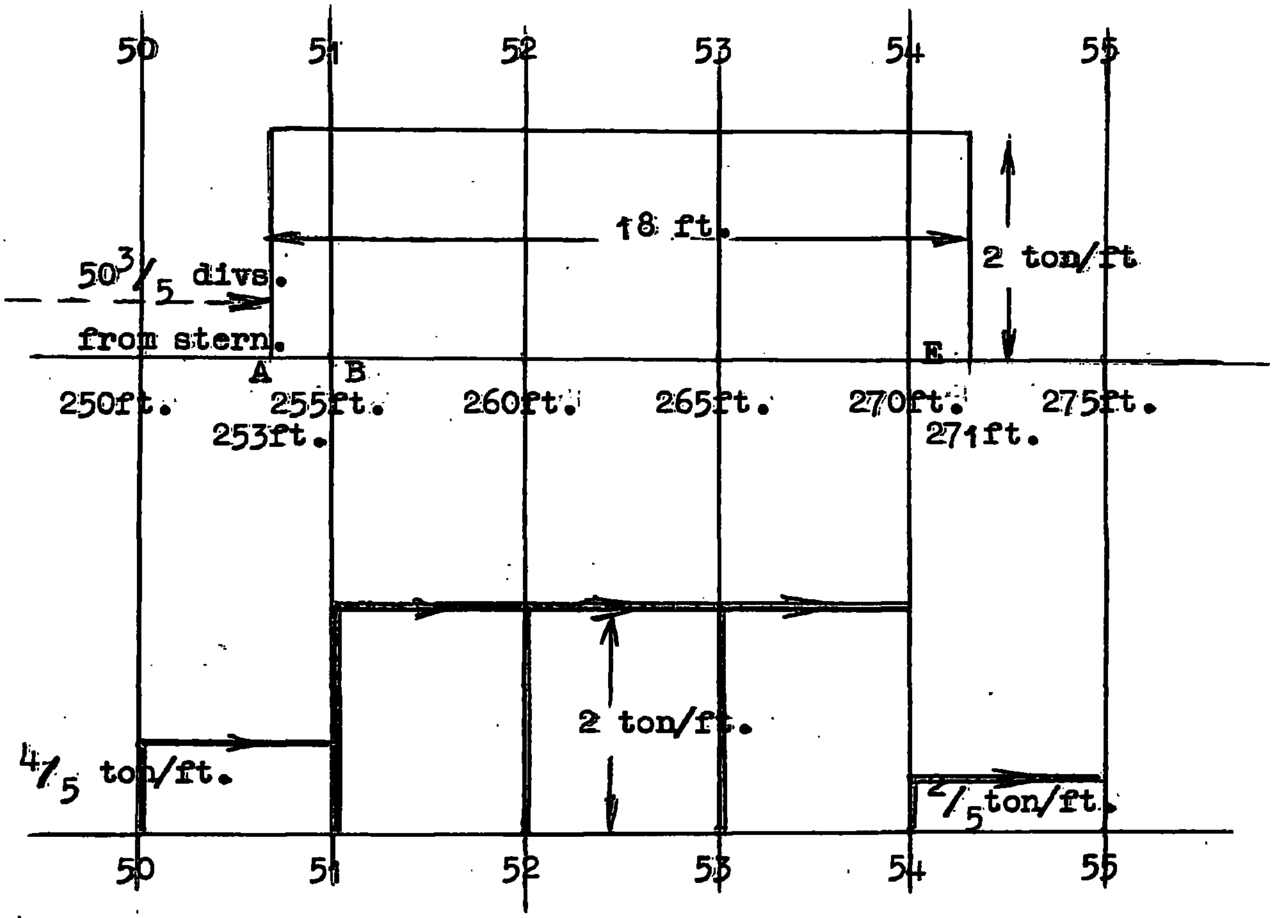


Fig. 5.

The portion AB of the weight occupies the foremost 2 ft. of division 50-51. Therefore 4 tons weight lies in this division. (i.e. 2 tons/ft. - original ordinate - over a dist. of 2 ft.) 4 tons spread evenly over the division gives an ordinate value 4/5 tons/ft. for division No. 50 - 51.

Ordinates 51, 52, 53 each have a value of 2 tons/ft.

The forward end E of the weight occupies 1/5 of the division 54 - 55. The portion of weight in this division is, therefore, 2 tons.

This weight spread over the whole division gives an ordinate value 2/5 tons/ft. for division No. 54 - 55.

In each case only the rearmost ordinate of the division is affected since values are 'projected forward'.

Results output would be of the form:

ORD. NO.	WEIGHT TON/FT	ORD. NO.	WEIGHT TON/FT	ORD. NO.	WEIGHT TON/FT	ORD. NO.	WEIGHT TON/FT
				50	0.800	51	2.000
52	2.000	53	2.000	54	0.400		

2. Trapezoidal distribution:

Tons	Ft.	Ft.	Ft.
W = 48	S = 24	B = +1	X = 264

(See ex. 19, page 21)

L.O.A. = 500 ft. --- L/100 = 5 ft.

The two end ordinates are found from the formulae:-

$$\text{Fwd. end } F = \left(\frac{6(B)}{S} + 1\right) x \frac{W}{S} \; ; \; \text{Aft. end } A = \left(\frac{2(W)}{S} - F\right)$$

See page 12 for derivation of formulae.

In the cases where B is negative, F is less than A.

The slope (H) of the upper edge is given by:

$$H = (F - A)/S$$

In our example, $F = \left[\frac{6 \times 1}{24} + 1\right] \frac{48}{24}$ and $A = \left[\frac{2 \times 48}{24} - F\right]$

$$\text{i.e. } F = \left[\frac{1}{4} + 1\right] \times 2 = 2.5 \text{ tons/ft.}$$

$$\text{and } A = (4 - 2.5) = 1.5 \text{ tons/ft.}$$

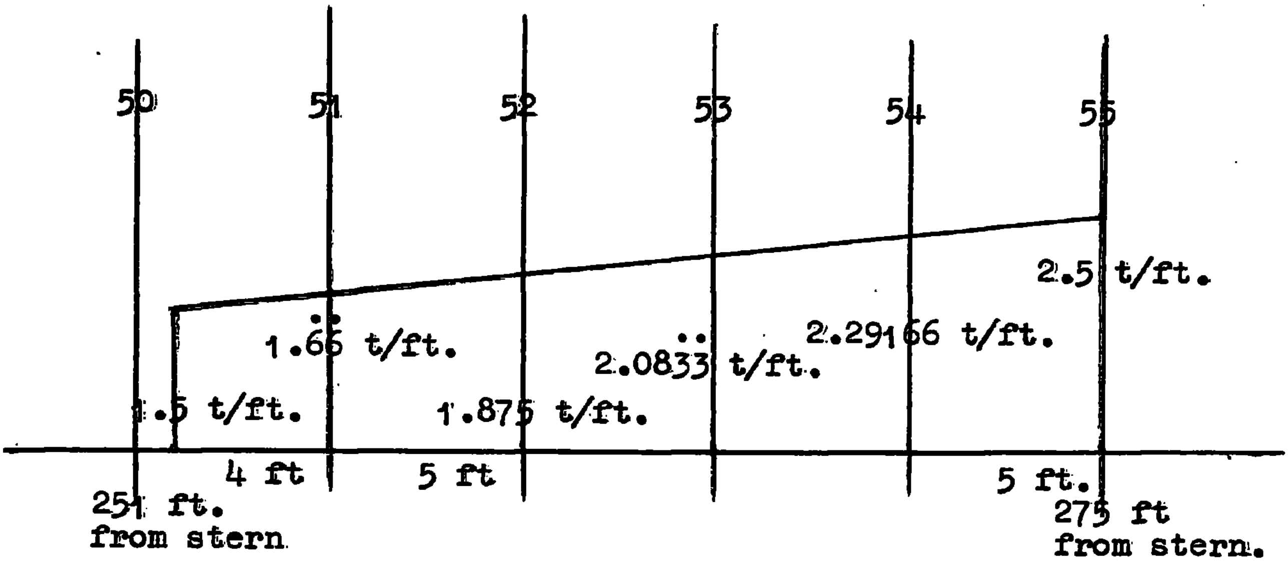
$$\text{and slope } H = \frac{(2.5 - 1.5)}{24} = \frac{1}{24} \text{ tons/ft/ft.}$$

The centre of length of the item is (264 - 1) ft. from the stern. Therefore, end A is (263 - 12) ft = 251 ft. from the stern, and fore end F is (263 + 12) ft. = 275 ft. from the stern.

End F is, therefore, coincident with ordinate No. 55, and end A is 1 ft. forward of ordinate No. 50.

Since end A ord. value is 1.5 units, lying 4 ft. aft of ord. 51, the value of ord. 51 is given by (1.5 + 4/24) = 1.66 units.

$$\text{Ord. } 52 = 1.\dot{6}\dot{6} + 5/24 = 1.875$$
$$\text{Ord. } 53 = 1.875 + 5/24 = 2.08\dot{3}\dot{3}$$
$$\text{Ord. } 54 = 2.08\dot{3}\dot{3} + 5/24 = 2.291\dot{6}\dot{6}\,.$$

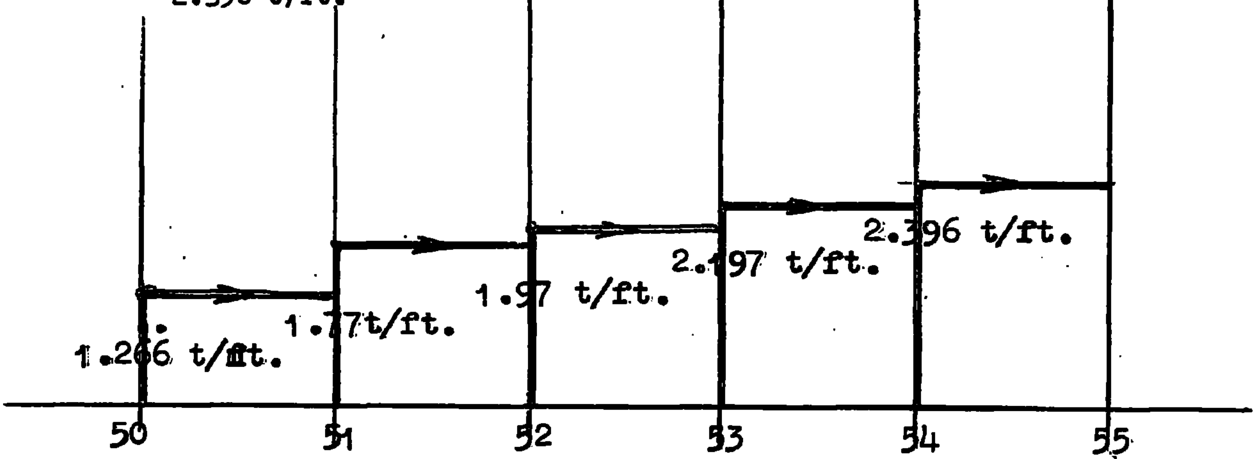


(Fig. 6 (a))

Portion of weight lying in div. 50 - 51 = $\frac{4}{2} \times (1.5 + 1.\dot{6}\dot{6}) = 6.\dot{3}\dot{3}$ ton.

Spread over the whole division, this gives a value for ord. 50 of $1.2\dot{6}\dot{6}$ t/ft. (which is, of course, projected forward).

Similarly, ordinate 51 has a value (projected forward) of $1.7708\dot{3}\dot{3}$ t/ft., ord. 52 $1.9791\dot{6}\dot{6}$ t/ft., ord. 53 $2.18749\dot{6}\dot{6}$ t/ft., and ord. 54 2.396 t/ft.



(Fig. 6 (b))

Results output are as in (1) above for the rectangle.

F.Pt. variable YR (R has all values 0 to 100) is used for ordinate values. On completion, ordinate values are summed (F. Pt. variable S), and the total weight distributed (again S) found by multiplying the sum value by a division length. Summing S in this fashion is effectively the same as producing one total ordinate (units - ton/ft); the product of this ordinate value and the ordinate separation (in feet) gives the total weight. This is printed out under the title

"Calculated Sum of Distributed Local Weights".

There follows now all the possibilities of weight distributions, both rectangular and trapezoidal (limited to a maximum size of five divisions purely for the sake of checking - the same principles apply to an item of any larger size.)

As mentioned on page 8, the end ordinates of trapezoidal distributions are given by:

$$F = \frac{W}{S}\left(\frac{6B}{S} + 1\right) \qquad \text{and}$$

$$A = \frac{2W}{S} - F = \frac{2W}{S} - \frac{W}{S}\left(\frac{6B}{S} + 1\right) = \frac{W}{S}\left(1 - \frac{6B}{S}\right).$$

These formulae are derived as follows:-

(Using W as a measure of the area)

C.G. of the area is given by

$$D = \frac{S}{3}\left[\frac{A + 2F}{A + F}\right] \text{ from end A.}$$

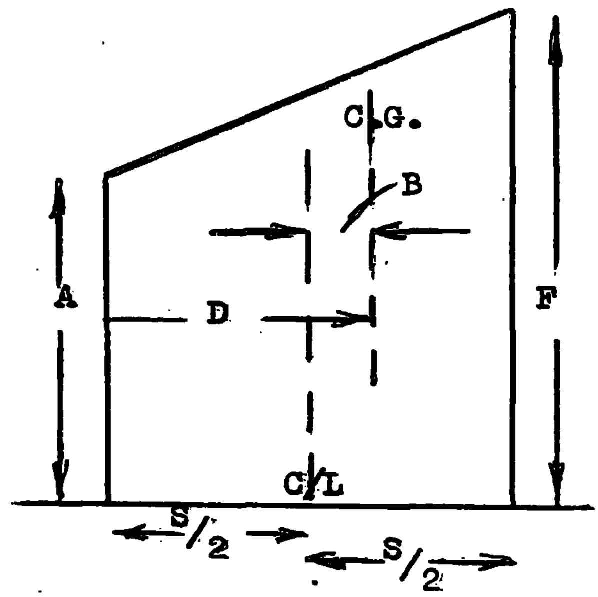
$$\text{i.e. } \frac{S}{2} + B = \frac{S}{3}\left[\frac{A + 2F}{A + F}\right] \text{ ...... (a)}$$

$$\text{Also } W = \left[\frac{A + F}{2}\right] S \text{ .... (b)}$$

From (b) $A = \frac{2W}{S} - F$ and

substituting this in (a) gives

$$F = \frac{W}{S}\left[\frac{6B}{S} + 1\right].$$



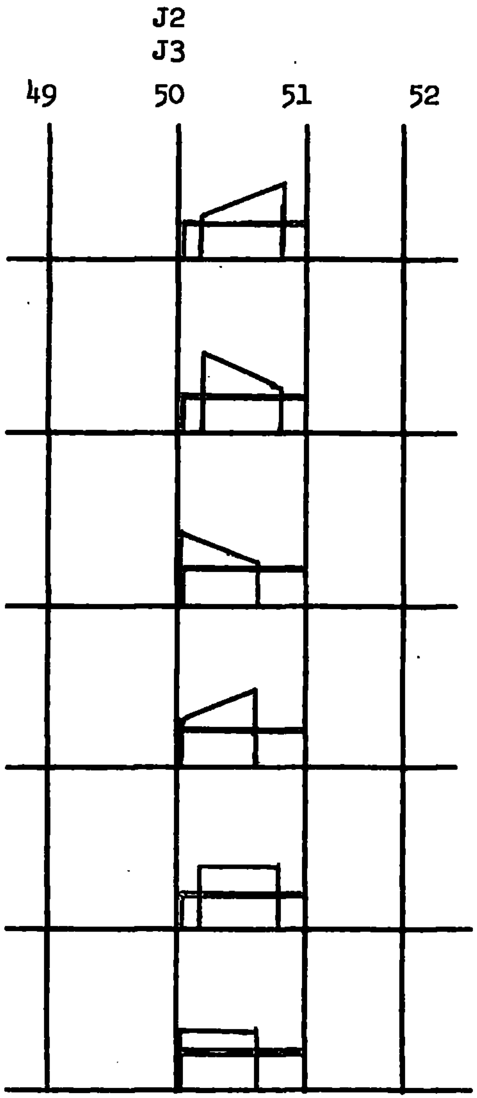
(Fig. 7)

The ordinate immediately preceding, or coincident with the aft end of the item is called J2 (both in the programme and in this exposition). The ordinate coincident with, or immediately aft of the fore end of the item is called J3. In certain instances it will be seen that J2 and J3 are one and the same ordinate. The following are the weight particulars with which the programme was tested. L.O.A. was taken as 500 ft., so that ordinates are 5 ft. apart throughout. Ordinate values are summed, assuming each weight is added in turn.

<u>Details of Local Weights Data</u>, (showing the resultant values on the various ordinates and the graphical interpretation of the distribution. (as given - black; redistributed - red). Values of A and F given overleaf are not calculated when J2 = J3.) :-

TYPE 1

ITEMS FOR WHICH J2 = J3 (ASSUMED = 50)



Ex	W	S	B	X	Resultant Values: 49	50	51	52
(i)	9	3	$0.1\dot{6}\dot{6}$	252		1.8 S1 = 1.8		
	A = 2 ; F = 4							
(ii)	9	3	$-0.1\dot{6}\dot{6}$	252		1.8 S1 = 3.6		
	A = 4 ; F = 2							
(iii)	9	3	$-0.1\dot{6}\dot{6}$	$251.\dot{3}\dot{3}$		1.8 S1 = 5.4		
	A = 4 ; F = 2							
(iv)	9	3	$0.1\dot{6}\dot{6}$	$251.\dot{6}\dot{6}$		1.8 S1 = 7.2		
	A = 2 ; F = 4							
(v)	9	3	0	252.5		1.8 S1 = 9.0		
	A = F = 3							
(vi)	9	3	0	251.5		1.8 S1 =10.8		
	A = F = 3							

TABLE 1.

In the cases listed on page 13, J2 and J3 (which are the integral parts of the numbers of divisions of their fore and aft boundary lines from the stern) are the same, as it can be seen that the whole of each item of weight lies within two adjacent ordinates. It is necessary only to average the weight over the enclosing division. End ordinates A and F are not calculated. These cases are dealt with under Ref. 3 in the programme.

The measure w to be added to the rearmost ordinate of the two (for local weight item No. 1) is given by w = W/L6 (where L6 = L.O.A/100). If J2 be ordinate number R in this case, then the new value of ordinate R is given by:

YR = YR + w   where YR is the resultant ordinate value at any time.

(new value = old value + addition).

e.g. if each of the above items were read into the programme in turn, the final value for ordinate number 50 would be 10.8 ton/ft.

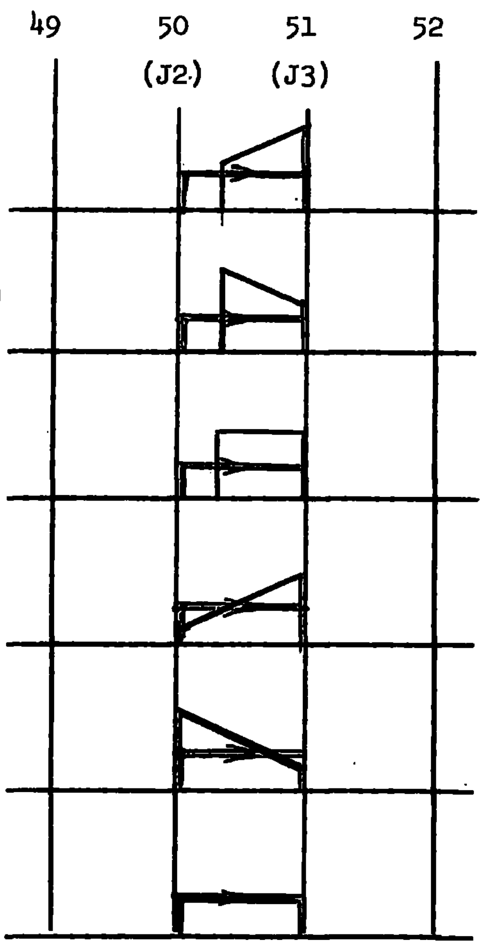
TYPE 2

(a) Items for which J3 = J2 + 1, where J3 is coincident with the fore end F of the item.

In these cases too, the whole of the weight lies between two adjacent ordinates: again if w is the measure to be added to the rear-

TYPE 2

(a) ITEMS FOR WHICH J3 = J2 + 1, WHERE J3 IS COINCIDENT WITH THE FORE END B OF THE ITEM



	W	S	B	X	49	50	51	52
Ex(vii)	9	3	$0.1\dot{6}\dot{6}$	$253.\dot{6}\dot{6}$		1.8		
					S1 =	12.6		
	A = 2		F = 4					
(viii)	9	3	$-0.1\dot{6}\dot{6}$	$253.\dot{3}\dot{3}$		1.8		
					S1 =	14.4		
	A = 4		F = 2					
(ix)	9	3	0	253.5		1.8		
					S1 =	16.2		
	A = F = 3							
(x)	10	5	0.5	253		2.0		
					S1 =	18.2		
	A = 0.8		F = 3.2					
(xi)	10	5	-0.5	252		2.0		
					S1 =	20.2		
	A = 3.2		F = 0.8					
(xii)	10	5	0	252.5		2.0		
					S1 =	22.2		
	A = F = 2							

TABLE 2

most ordiante, where w = W/L6 we have, for ordinate J2

$$YR = YR + w \qquad \text{i.e.} \quad Y50 = Y50 + w$$

as before.

Again, values of A and F given overleaf are not calculated in the programme. If w is the measure to be added to the rearmost ordinate, where w = W/L6 we have, for ordinate J2 (ordinate number R):

$$YR = YR + w \qquad \text{i.e.} \quad Y50 = Y50 + w$$

as before.

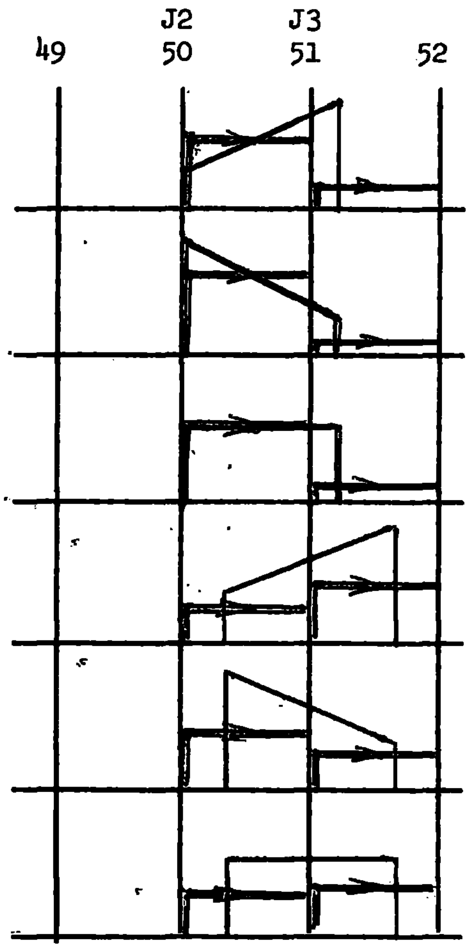
Adding each of the above items in turn into the programme would now give a resultant value for ordinate 50 of 22.2 ton/ft.

(b) Items for which J3 = J2 + 1, where J3 is not coincident with the fore end of the item.

In these cases the weight does not lie wholly between two ordinates. In examples 13, 14 and 15 there is a fractional part at the fore end, but the aft end coincides with the ordinate J2. In cases 16, 17 and 18 there are fractional parts both fore and aft. Forward fractional parts are labelled F3 and rear fractional parts F2 (both here and in the programme). Ends A and F have to be calculated for this and following types.

TYPE 2

(b) ITEMS FOR WHICH J3 = J2 + 1, WHERE J3 IS NOT COINCIDENT WITH THE FORE END OF THE ITEM



	W	S	B	X	49	50	51	52
(xiii)	24	6	0.5	253.5		3.668 S1= 25.868	1.14 S1 = 1.14	
	A = 2: F = 6							
(xiv)	24	6	-0.5	252.5		4.332 S1= 30.200	0.464 S1 = 1.604	
	A = 6: F = 2							
(xv)	24	6	0	253		4.000 S1 = 34.200	0.800 S1 = 2.404	
	A = F = 4							
(xvi)	24	6	0.5	255.5		1.800 S1 = 36.000	3.000 S1= 5.404	
	A = 2: F = 6							
(xvii)	24	6	-0.5	254.5		3.000 S1 = 39.000	1.800 S1= 7.204	
	A = 6: F = 2							
(xviii)	24	6	0	255		2.400 S1 = 41.400	2.400 S1 = 9.604	
	A = F = 4							

TABLE 3.

In rectangular distributions where J3 = J2 + 1:-
The original height of the rectangle is given by A = W/S.
The weight spread over the fractional distance F3 is, therefore, F3 x A, and the measure to be added to the J3 ordinate is given by A3 = (F3 x A)/L6.

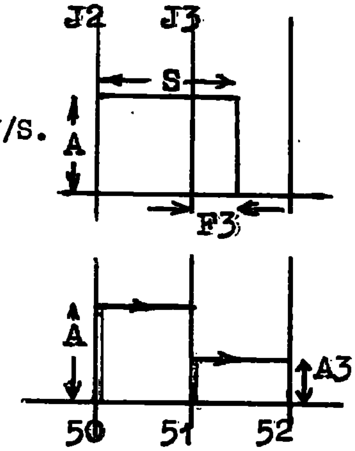


Fig. 8.

If R then, is the ordinate number of J3 we have, by the additon of this weight

YR = YR + A3.   e.g. Y51 = Y51 + A3.

Where F2 = 0 (Fig. 8), and the ordinate J2 has number R, then the new value for ordinate J2 is given by

YR = YR + A.   e.g. Y50 = Y50 + A.

Where F2 ≠ 0 (Fig. 9), then the portion of weight over F2 is given by A2 = F2 x A, and this spread over the whole division gives a final value A2 where

A2 = (F2 x A)/L6.

Again if R is the number of ordinate J2 then the new value of the ordinate is given by

YR = YR + A2.   e.g. Y50 = Y50 + A2.

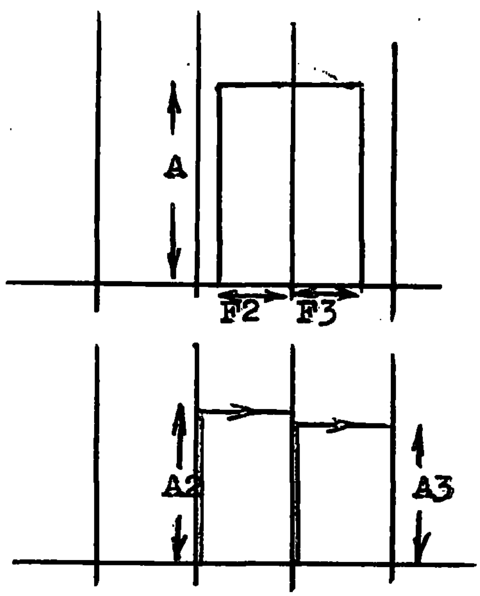


Fig. 9.

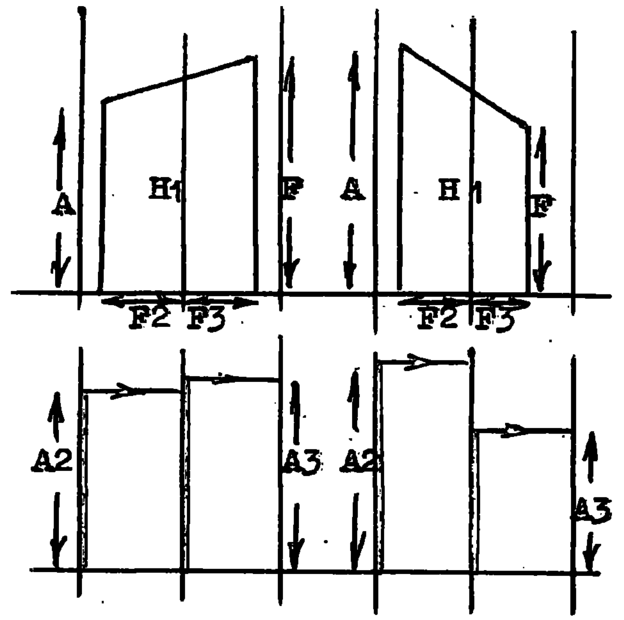


Fig. 10.

Where the weight distribution is a trapezium, A may be greater or less than F. The slope of the upper edge is always H in the programme, whether positive (A less than F) or negative (A greater than F). In examples 13, 14, 16 and 17 above the height H1 can be found from end F, the slope of the upper edge H, and the distance F3. Fig. 10.

The weight of the fractional part forward of J3 is now given by

$$A3 = (H3 + H1).\ F3/2$$

and spread over the whole division we have the value to be added to ordinate J3 given by A3 where A3 now has a new value:

$$A3 = \frac{H3 + H1}{L6} \cdot \frac{F3}{2}$$

If J3 is number R, then the new value of YR is given by

$$YR = YR + A3. \qquad \text{e.g. } Y51 = Y51 + A3.$$

TYPE 3

Items for which J3 - J2 is greater than 1.

The method above is used to find the fractional areas adjacent to J2 and J3. The remaining area which extends over one or more full divisions is treated as in the examples given on pages 21, 22. In the following examples J3 - J2 is taken to be 5, for the sake of uniformity. All possible cases are dealt with. (Figs. showing graphical output will now be discontinued).

* * * *

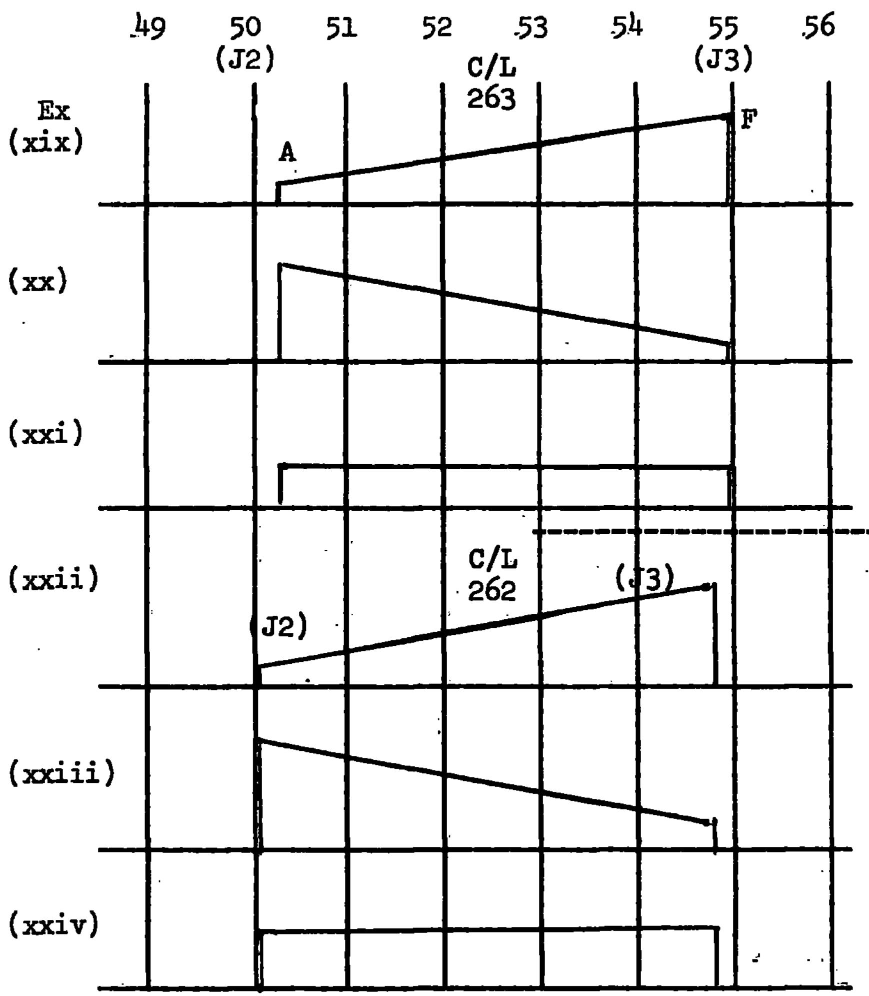
Page 24 to 28 shows the completed data sheets giving details of local weights for A.842.

Page 29 indicates the type of heading output before the tabulated results for weight, buoyancy, etc. Offending items, if any, in Local Weights lists (see page (iii) intro.) are output before all other headings.

Page 30 shows the tabulated output for the data of pages 24 to 28 and page 31 shows the output on the Benson-Lehner graph plotter for these results.

TYPE 3

ITEMS FOR WHICH J3 - J2 IS GREATER THAN 1

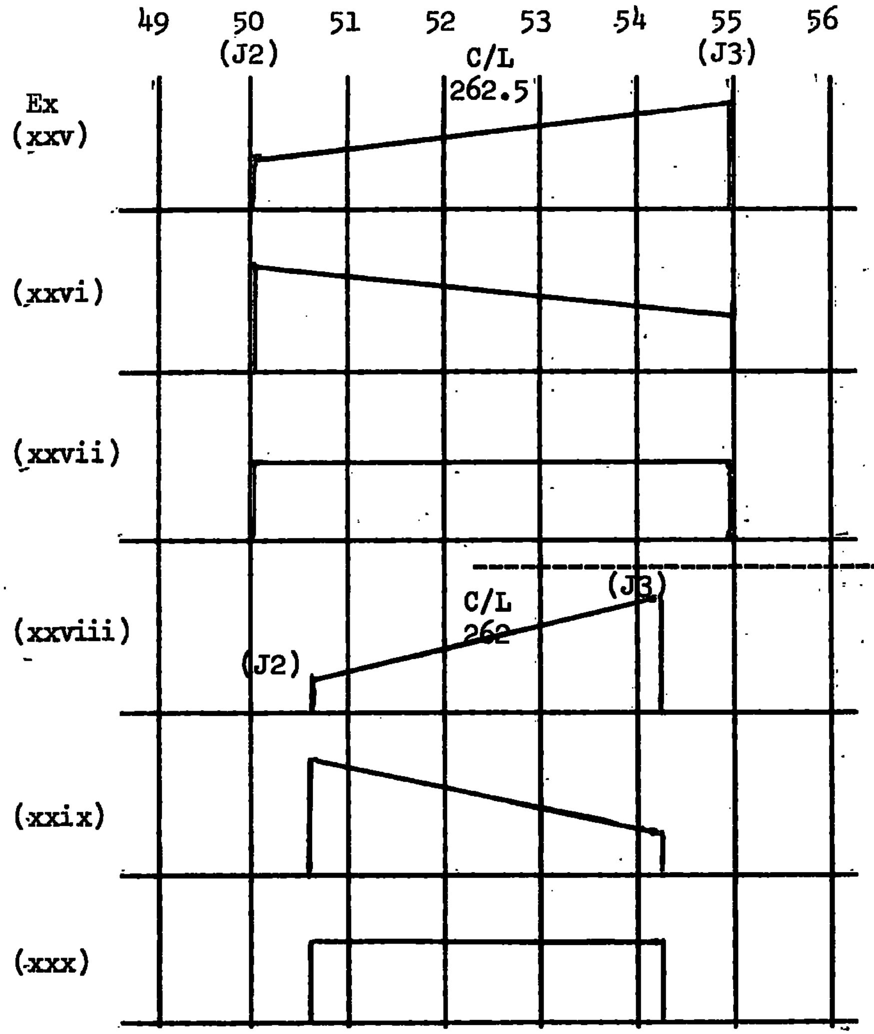


Ex	W	S	B	X	50	51	52	53	54
(xix)	48	24	1	264	1.267	1.771	1.980	2.188	2.396
				Sums =	25.267	4.172	1.980	2.188	2.396
	A = 1.5 ; F = 2.5								
(xx)	28	24	-1	262	1.933	2.229	2.021	1.812	1.604
				Sums =	27.200	6.401	4.001	4.000	4.000
	A = 2.5 ; F = 1.5								
(xxi)	48	24	0	263	1.600	2.000	2.000	2.000	2.000
				Sums =	28.800	8.401	6.001	6.000	6.000
	A = F = 2								
(xxii)	48	24	1	263	1.604	1.812	2.021	2.229	1.933
				Sums =	30.404	10.213	8.022	8.229	7.933
	A = 1.5 ; F = 2.5								
(xxiii)	48	24	-1	261	2.396	2.188	1.980	1.771	1.267
				Sums =	32.800	12.401	10.002	10.000	9.200
	A = 2.5 ; F = 1.5								
(xxiv)	48	24	0	262	2.000	2.000	2.000	2.000	1.600
				Sums =	34.800	14.401	12.002	12.000	10.800
	A = F = 2								

TABLE 4.

TYPE 3 (contd)

ITEMS FOR WHICH J3 - J2 IS GREATER THAN 1.



Ex	W	S	B	X	50	51	52	53	54
(xxv)	50	25	1.5	264	1.424	1.712	2.000	2.288	2.576
				Sums =	36.224	16.113	14.002	14.288	13.376
	A = 1.28; F = 2.72								
(xxvi)	50	25	-1.5	261	2.576	2.288	2.000	1.712	1.424
				Sums =	38.800	18.401	16.002	16.000	14.800
	A = 2.72; F = 1.28								
(xxvii)	50	25	0	262.5	2.000	2.000	2.000	2.000	2.000
				Sums =	40.800	20.401	18.002	18.000	16.800
	A = F = 2								
(xxviii)	36	18	1.5	263.5	0.444	1.499	2.056	2.611	0.589
				Sums =	41.244	21.899	20.058	20.611	17.389
	A = 1 ; F = 3								
(xxix)	36	18	-1.5	260.5	1.156	2.500	1.944	1.389	0.211
				Sums =	42.400	24.399	22.002	22.000	17.600
	A = 3 ; F = 1								
(xxx)	36	18	0	262	0.800	2.000	2.000	2.000	0.400
				Sums =	43.200	26.399	24.002	24.000	18.000
	A = F = 2								

TABLE 5.

Tape 1. (Required for FIRST data run only).

If some (or all) conditions are to be re-run in order to graph all Shear Force curves to the same scale (and similarly the Bending Moment curves), from the maximum values determined on a previous run, PUT 13 = 1.
IN ALL OTHER CASES, PUT 13 = 0.

	Programme Variable.
0	13

If 13 = 0, omit this section, and go on to the next section.
If 13 = 1, enter the appropriate maximum values from the previous runs. (If either one is not required, enter two zeros for that curve).

Maximum Shear Force (+ve) tons		S25
" " " (-ve) "		S26
Maximum Bending Moment (+ve) tons/ft.		M6
" " " (-ve) " "		M7

(PROGRAMME W A I T HERE)

0 for Lloyd's method: 1 for Biles Coffin	0	I1
Length Overall ft.	617	L
Length of Stern Overhang "	23	L1
Length of Bow Overhang "	14	L2

Enter 1 for full width graph, 0.5 for half width graph or 0 for no graph	1	S22
Horizontal Scale required (Convenient choice : 10, 20 or 40 - ft/cm.) Enter 0 if no graph required.	20	S27

Code Number for Lightship Concentrated Items	0	P4
Number of Concentrated Lightship Items	71	N

1 Sheet (ii)

ITEM	Weight (tons) (M)	Length (ft) (S)	Dist. of L.C.G. * from C/L of Item. (B)	L.C.G. from stern (X)
Lower Dk Bridge & Hse Below	75.17	94.50	-	81.75
Upper " " "	58.96	90.00	-	83.00
Boat " " "	47.09	78.50	-	88.25
Nav.Bridge " "	15.65	32.75	-	110.38
Wheel House	12.50	25.00	-	126.50
No. 1 Hatch	26.21	36.00	-	536.25
" 2 "	26.30	36.50	-	487.50
" 3 "	12.76	17.50	-	432.75
" 4 "	27.35	37.50	-	380.25
" 5 "	27.35	37.50	-	317.75
" 6 "	12.76	17.50	-	265.25
" 7 "	27.35	37.50	-	220.25
" 8 "	27.35	37.50	-	157.75
" 1 Hatch Cover Tracks	2.42	6.00	-	559.25
" 2/3 " " Post & Tracks	4.65	17.50	-	451.00
" 4/5 " " " "	5.87	25.00	-	349.00
" 6/7 " " " "	4.65	17.50	-	247.75
" 8 " " Tracks	2.42	6.00	-	136.00
" 1 Masthouse, Winches, etc.	28.30	15.75	-	508.13
" 2 " " "	27.90	15.00	-	411.50
" 3 " " "	27.90	15.00	-	286.50
" 4 " " "	27.90	15.00	-	189.00
" 1 Masthouse Derrick Posts, Derricks etc.	15.50	2.50	-	508.13
" 2 " " " "	15.50	2.50	-	411.50
" 3 " " " "	15.50	2.50	-	286.50
" 4 " " " "	15.50	2.50	-	189.00
Windlass	12.00	9.00	-	577.75
Anchors	11.63	6.00	-	592.50
Anchor Chain	59.95	8.00	-	576.00
Fcle.Dk.Ftgs.Bollards etc.	6.10	51.00	-8.50	580.0

* -ve if aft of Centre of Length.

1 Sheet (iii)

ITEM	Weight (tons) (M)	Length (ft) (S)	Dist. of L.C.G. * from C/L of Item. (B)	L.C.G. from stern (X)
Up.Dk.Aft. Fittings, Winch, etc.	16.00	34.50	5.75	23.00
Funnel	19.61	28.00	1.00	84.50
Lifeboats and Davits	7.50	26.00	-	87.50
Sternframe	22.40	19.00	2.00	33.00
Propeller	16.30	6.00	-	30.50
Rudder and fittings	10.20	12.25	-	20.38
Steering Gear	6.50	7.25	-	23.00
Upholstery	3.10	91.00	-	83.75
Deck Coverings etc.	30.00	91.00	-	83.75
Refrig. Machinery	3.50	6.00	-	48.00
Domestic Refrig. Insulation	13.00	19.50	1.75	46.00
Windows and Doors (Accom.)	10.00	91.00	-	83.75
Piping (Accom.)	12.00	91.00	-	83.75
Smithwork and Rivs.	35.00	580.00	-	313.00
Electrodes	85.75	580.00	-	313.00
Paint	20.00	580.00	-	313.00
Piping (Holds)	45.00	448.00	-	348.00
Main Engine	376.00	28.50	-1.33	95.42
Generators	42.60	16.33	-	61.50
Auxiliaries Incl. Seats.	258.47	80.00	12.43	96.43
Shafting and Bearings	26.43	40.00	-	54.00
Sterntube	6.00	10.00	-	39.00
E.R. Flat 25'-0" A.B.	42.36	80.00	-	84.00
" " 38'-3" "	40.80	80.00	-	84.00
House Front and Side Screens	69.18	98.50	34.00	113.25
Fcle.Dk. Stores & Fore End Bulw.	34.00	51.00	-8.50	580.00
Radar Mast and Fittings	1.50	4.00	1.00	110.50
Spare Prop.	15.45	18.25	-	60.00
" Tailshaft	11.50	16.75	-	59.00
" Anchor	5.81	8.00	2.50	416.50

* -ve if aft of Centre of Length.

1 Sheet (iv)

ITEM	Weight (tons) (M)	Length (ft) (S)	Dist. of L.C.G. * from C/L of Item. (B)	L.C.G. from stern (X)
W.T. Bhd. 10	8.00	1	-	44.00
" " 42	27.13	1.08	-	124.54
" " 68	45.77	2.17	-	187.92
" " 94	77.84	1.00	-	254.50
" " 106	77.84	1.00	-	283.50
" " 132	47.49	2.17	-	350.08
" " 158	77.84	1.00	-	414.50
" " 170	77.84	1.00	-	443.50
" " 197	45.18	2.25	-	510.12
" " 225	20.00	1.00	-	572.90
Capstans	5.48	4.00	-	284.00

* -ve if aft of Centre of Length.

TAPE 2

Programme Variable.

Code number for this Sheet - i.e. Condition Number. (1, 2, 3, ... etc.)	1	P4
Number of DEADWEIGHT Items for this condition	36	N

DEADWEIGHT ITEMS

ITEM	Weight (tons) (M)	Length (ft) (S)	Dist. of L.C.G. * from C/L of Item. (B)	L.C.G. from stern (X)
W.B. in No. 1 D.B. Tank (Across)	436.00	63.00	-3.87	536.63
" " 2 " " P & S	726.00	65.00	-1.34	475.16
" " 3 " " P & S	1162.00	95.00	.13	396.63
" " 4 " " P & S Outer	668.00	95.00	1.12	302.62
" " 4 " " P & S Inner	486.00	95.00	-.01	301.49
" " 1 Saddle Tank P & S	824.00	112.25	-5.00	495.12
" " 2 " " P & S	700.00	95.00	-	396.50
" " 3 " " P & S	700.00	95.00	-	301.50
" " 4 " " P & S	478.00	65.00	-	221.50
" " Fore Peak	454.00	31.70	-5.43	582.42
" " After Peak	290.00	20.00	2.16	35.16
" " No.3 Hold (Deep Tk.)	2738.00	30.00	-.08	429.08
" " No.6 Hold (" ")	2738.00	30.00	-.08	268.92
Heavy Oil in No.5 D.B.Tk.P&S Inner	233.24	65.00	-	221.50
" " " " 5 " " " Outer	348.88	65.00	2.62	224.12
" " " " 6 " " Port	194.04	67.50	3.60	158.85
" " " " 6 " " Starb.Outer	133.28	67.50	5.47	160.72
" " " " 5 Saddle Tk. P & S	415.52	65.00	.31	156.81
" " " Tank Aft. Clean Sett.	20.58	6.25	-	89.63
" " " " " " " Fwd.	20.58	6.25	-	95.88

* -ve if aft of Centre of Length.

2 Sheet (ii)

ITEM	Weight (tons) (M)	Length (ft) (S)	Dist. of L.C.G. * from C/L of Item. (B)	L.C.G. from stern (X)
Heavy Oil in Dirty Sett. Tk.	41.16	12.50	-	105.25
Diesel Oil in No.6 D.B.Tk.Stard.Inner	60.27	67.50	.37	154.88
" " " " 7 " " " Port	23.28	32.50	3.42	103.67
" " " " " " " " Star.	14.45	15.00	.60	109.60
" " " Clean Sett. Tank	12.00	3.75	-	113.38
" " " Dirty	11.52	3.75	-	117.13
Lub.Oil in D.B. Drain Tank	12.25	27.50	-	85.25
" " " Reserve Tank	5.88	3.33	-	65.67
" " " Cyl. Oil Tank	6.13	3.33	-	69.00
" " " " " "	6.13	3.33	-	72.33
" " " Clean L.O. Tank	13.96	7.50	-	77.75
" " " Renovating Tank	12.25	5.00	-	81.50
Fresh Water in No.8 D.B. Tk. Across	29.25	22.50	1.55	59.30
" " " Tanks Aft. P & S	55.00	14.00	-	37.00
Stores, Crew and Effects	100.00	80.00	-	88.00
Engineers, Spare Gear	40.00	80.00	-	72.45

* -ve if aft of Centre of Length.

SHIPYARD A. SHIP NO. 842

LONGITUDINAL STRENGTH CALCULATIONS

CONDITION 1, BALLAST DEPARTURE
FULL BUNKERS.

STILL WATER.

LENGTH OVERALL : 617.00 FT

SUM OF LIGHTSHIP LOCAL WEIGHTS READ IN = 2476.86 TONS

SUM OF EXTRA LOCAL WTS. FOR THIS CONDITION, READ IN = 14209.65 TONS

CALCULATED SUM OF DISTRIBUTED LOCAL WEIGHTS = 16686.51 TONS

CONTINUOUS WEIGHT TOTAL FOR LLOYDS' DISTRIBUTION = 4632.14 TONS

CALCULATED ''M'' -TONS/FT = 9.359

CALCULATED L.C.G.OF CONTINUOUS WEIGHT = 311.32 FT.

NOTE: ORDINATES IN THE FOLLOWING TABLES ARE NUMBERED FROM THE STERN (ORDINATE NO. 0) TO THE BOW (ORDINATE NO. 100).

SHIPYARD A. SHIP NO. 842

LOCAL WEIGHT ORDINATES (PROJECTED FORWARD).

ORD NO.	WEIGHT TON/FT	ORD NO.	WEIGHT TON/FT	ORD NO.	WEIGHT TON/FT	ORD NO.	WEIGHT TON/FT
0	0.08	1	0.25	2	0.99	3	4.14
4	14.04	5	24.10	6	29.72	7	8.47
8	11.29	9	13.31	10	15.21	11	12.63
12	12.51	13	23.12	14	30.15	15	29.60
16	28.05	17	28.07	18	17.92	19	15.27
20	20.18	21	12.50	22	13.34	23	13.51
24	12.95	25	13.33	26	13.70	27	14.07
28	14.16	29	15.17	30	26.55	31	17.15
32	16.06	33	16.79	34	17.04	35	17.28
36	17.53	37	17.78	38	17.90	39	17.81
40	18.05	41	109.27	42	112.11	43	111.57
44	110.60	45	121.97	46	29.45	47	20.98
48	20.23	49	20.63	50	20.69	51	20.76
52	20.82	53	20.89	54	20.72	55	20.52
56	28.05	57	20.09	58	20.31	59	20.61
60	20.62	61	20.64	62	20.65	63	20.66
64	20.43	65	20.93	66	24.42	67	116.09
68	112.10	69	112.04	70	111.45	71	122.17
72	22.20	73	21.73	74	21.12	75	20.50
76	20.71	77	20.27	78	9.79	79	19.31
80	18.84	81	19.99	82	28.60	83	17.26
84	16.14	85	15.42	86	14.71	87	13.99
88	13.28	89	12.44	90	6.98	91	6.50
92	19.23	93	34.30	94	20.22	95	14.83
96	9.18	97	2.44	98	0.19	99	0.03
100	0.00						

LOCAL WEIGHT ORDINATES (PROJECTED FORWARD)

X-AXIS DISTANCE (CMS) FROM BASE OF GRAPH PAPER = 0

HEIGHT OF Y-AXIS = 30

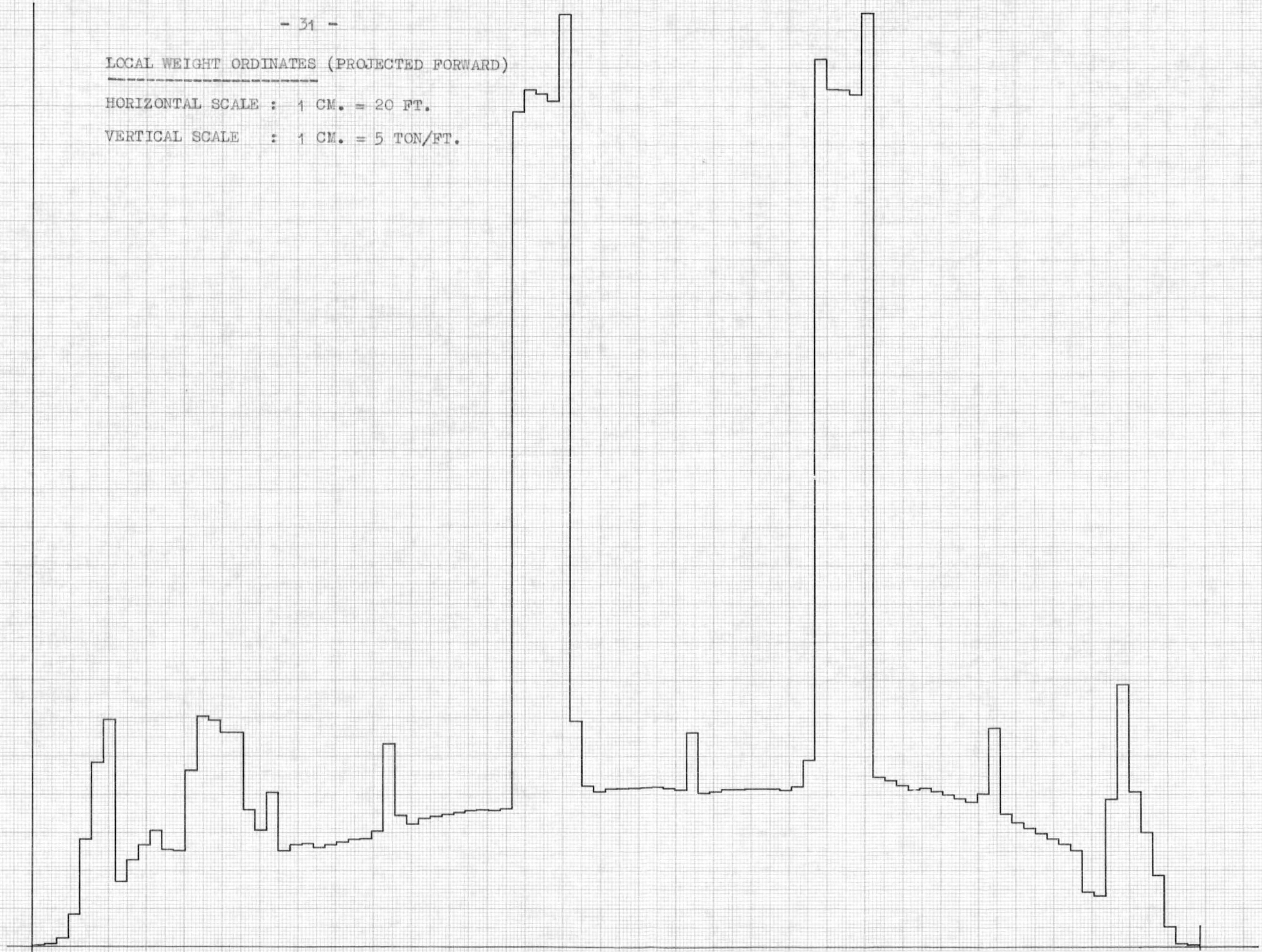
HORIZONTAL SCALE OF GRAPH --- 1 CM = 20 FT

VERTICAL SCALE OF GRAPH --- UNITS/CM:- 5.0

LOCAL WEIGHT ORDINATES (PROJECTED FORWARD)

HORIZONTAL SCALE : 1 CM. = 20 FT.

VERTICAL SCALE : 1 CM. = 5 TON/FT.

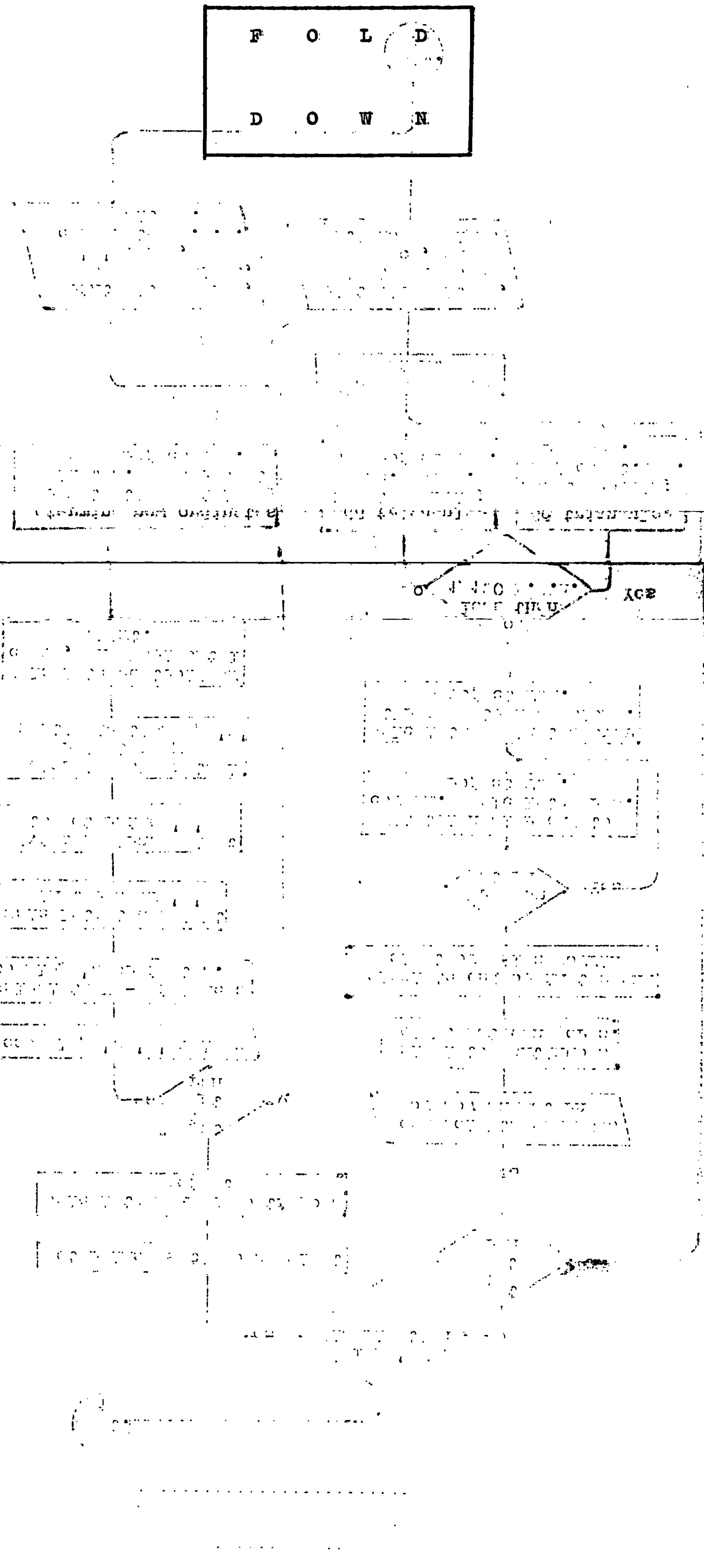


FLOW CHART

(Section 2).

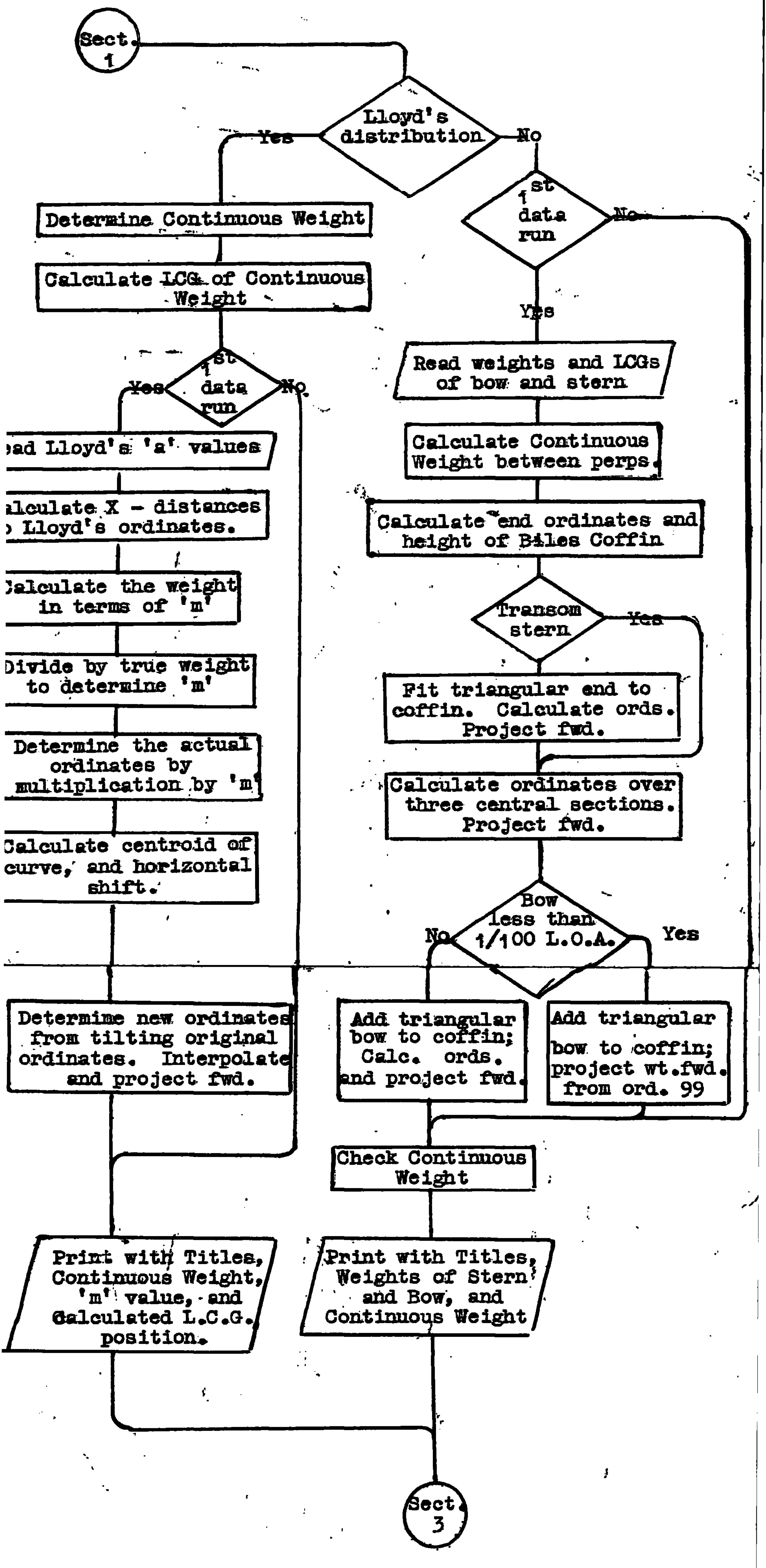
C O N T I N U O U S

W E I G H T   S E C T I O N



FLOW CHART (Programme Page 2)

CONTINUOUS WEIGHT SECTION (2)



PART 2

(a) BILES' COFFIN CONTINUOUS WEIGHT DISTRIBUTION

The continuous weight of that portion of the ship which lies between the perpendiculars (i.e. the full weight less the sum of the local weights and less the weights of stern and bow overhangs - programmed W32) is distributed over three equal divisions of the length between the perpendiculars (L_{BP}), such that end ordinates A and B are given by the formule:

$$\frac{W_{32}}{L_{BP}} \left(0.6 \pm \frac{54.k}{7L_{BP}} \right)$$

such that B takes the + sign, and where k is the distance of the L.C.G. of the continuous weight from midships. A is the rearmost ordinate and B the forward ord. in all cases.

If the L.C.G. is forward of midships, k is positive, and the forward ordinate (that at the F.P.) is the larger. If, however, k is to the rear of the midships, then k is itself negative, and A (the ordinate at the A.P.) is the larger. (See fig. 11)

C' and D' divide the length between the perpendiculars into three equal parts. CD is a horizontal line joining the ordinates at C' and D', each having a value given by:

$$CC' = DD' = 1.2 \left(\frac{W_{32}}{L_{BP}} \right) .$$

The stern and bow sections are represented by the triangular ends to the figure.

The total length of the ship (L.O.A.) is divided as before into 100 equal parts, and the weight ordinate at each division mark is calculated using straight line equations.

Ordinate values are amended by taking averages, as before, so that the weight distribution over each division (L6) may be represented by horizontal lines drawn forward from the rear ordinate of each division. No. 99 is the last ordinate with a value.

Floating point variables VR - (0 to 100) are used for ordinate values in this part of the programme.

Output of the table of values is again optional, as in part one; graph output is also optional.

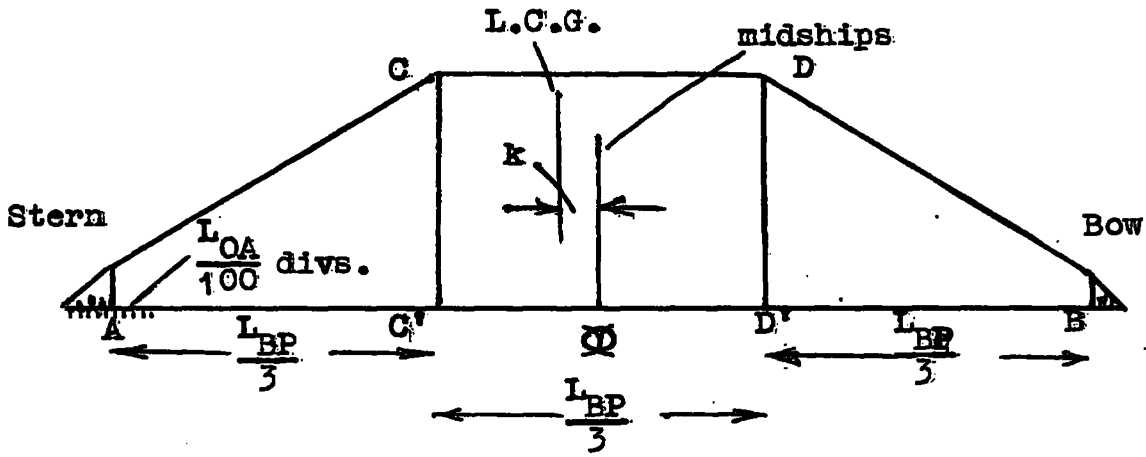


Fig. 11.
Biles Coffin distribution of Continuous Weight.
Note: k -ve and A greater than B.

Page 36 shows the input data when using Biles Coffin method for the distribution of the continuous material of A.842.

Tabulated output for this method is shown on page 37 and the corresponding graph output on page 38.

The use of Biles Coffin method may produce errors in the calculated weights of the overhangs of the bow and stern. In the initial design stages, at which time the actual end values may not be known, this is acceptable.

These errors (as with those which would occur using Lloyd's suggested end lengths - See Table 10, page 61) are corrected in the total weight section, by the technique known as "swinging the base" - See page 63.

2 Sheet (iii)

TITLE output at Head of Results

= crlf⁴

Name of firm

SHIPYARD A.

Ship No. 842

LONGITUDINAL STRENGTH CALCULATIONS

CONDITION No. 1.
BALLAST DEPARTURE
FULL BUNKERS

*STILL WATER
*~~S~~INE~~-~~WAV~~E~~ S~~A~~GGI~~N~~G
*~~S~~INE~~-~~WAV~~E~~ H~~O~~GGI~~N~~G

(delete those * not Required).

Programme Variable.

Displacement	21318.65	W31
L.C.G. forward of Stern	321.79	K3

2 Sheet (iv)

Tape 2 (Contd). (This part of Tape 2 not required after the first data run).

If Continuous Weight is to be distributed by Biles Coffin method, complete lines (a), (b), (c), (d) below, otherwise complete (e) from Lloyds tables SR 64/15.

For FIRST data run only:

		Programme Variable.
(a) Weight of Overhang of Stern. (tons)	49.37	W33
(b) Weight of Overhang of Bow. (tons)	7.67	W34
(c) L.C.G. of Overhang of Stern, from Stern. (ft)	17.5	L4
(d) L.C.G. of Overhang of Bow, from Stern. (ft)	608.5	L5

(e) For FIRST data run only:

	Stn. 0	Stn. 1	Stn. 2	Stn. 3	Stn. 4	Stn. 5	Stn. 6
0							
Stn. 7	Stn. 8	Stn. 9	Stn.10	Stn.11	Stn.12	Stn.13	Stn.14
Stn.15	Stn.16	Stn.17	Stn.18	Stn.19	Stn.20		
						0	

SHIPYARD A. SHIP NO.842

CONTINUOUS WEIGHT CURVE ORDINATES (PROJECTED FORWARD).

ORD NO.	WEIGHT TON/FT	ORD NO.	WEIGHT TON/FT	ORD NO.	WEIGHT TON/FT	ORD NO.	WEIGHT TON/FT
0	0.75	1	2.25	2	3.75	3	5.20
4	5.69	5	5.81	6	5.93	7	6.06
8	6.18	9	6.31	10	6.43	11	6.55
12	6.68	13	6.80	14	6.92	15	7.05
16	7.17	17	7.29	18	7.42	19	7.54
20	7.67	21	7.79	22	7.91	23	8.04
24	8.16	25	8.28	26	8.41	27	8.53
28	8.65	29	8.78	30	8.90	31	9.03
32	9.15	33	9.27	34	9.40	35	9.47
36	9.47	37	9.47	38	9.47	39	9.47
40	9.47	41	9.47	42	9.47	43	9.47
44	9.47	45	9.47	46	9.47	47	9.47
48	9.47	49	9.47	50	9.47	51	9.47
52	9.47	53	9.47	54	9.47	55	9.47
56	9.47	57	9.47	58	9.47	59	9.47
60	9.47	61	9.47	62	9.47	63	9.47
64	9.47	65	9.47	66	9.43	67	9.27
68	9.09	69	8.91	70	8.73	71	8.55
72	8.38	73	8.20	74	8.02	75	7.84
76	7.66	77	7.48	78	7.31	79	7.13
80	6.95	81	6.77	82	6.59	83	6.41
84	6.23	85	6.06	86	5.88	87	5.70
88	5.52	89	5.34	90	5.16	91	4.99
92	4.81	93	4.63	94	4.45	95	4.27
96	4.09	97	3.86	98	2.56	99	2.13
100	0.00						

Table 7.

CONTINUOUS WEIGHT CURVE ORDINATES (PROJECTED FORWARD).

X-AXIS DISTANCE (CMS) FROM BASE OF GRAPH PAPER = 0

HEIGHT OF Y-AXIS = 30

HORIZONTAL SCALE OF GRAPH --- 1 CM = 20 FT

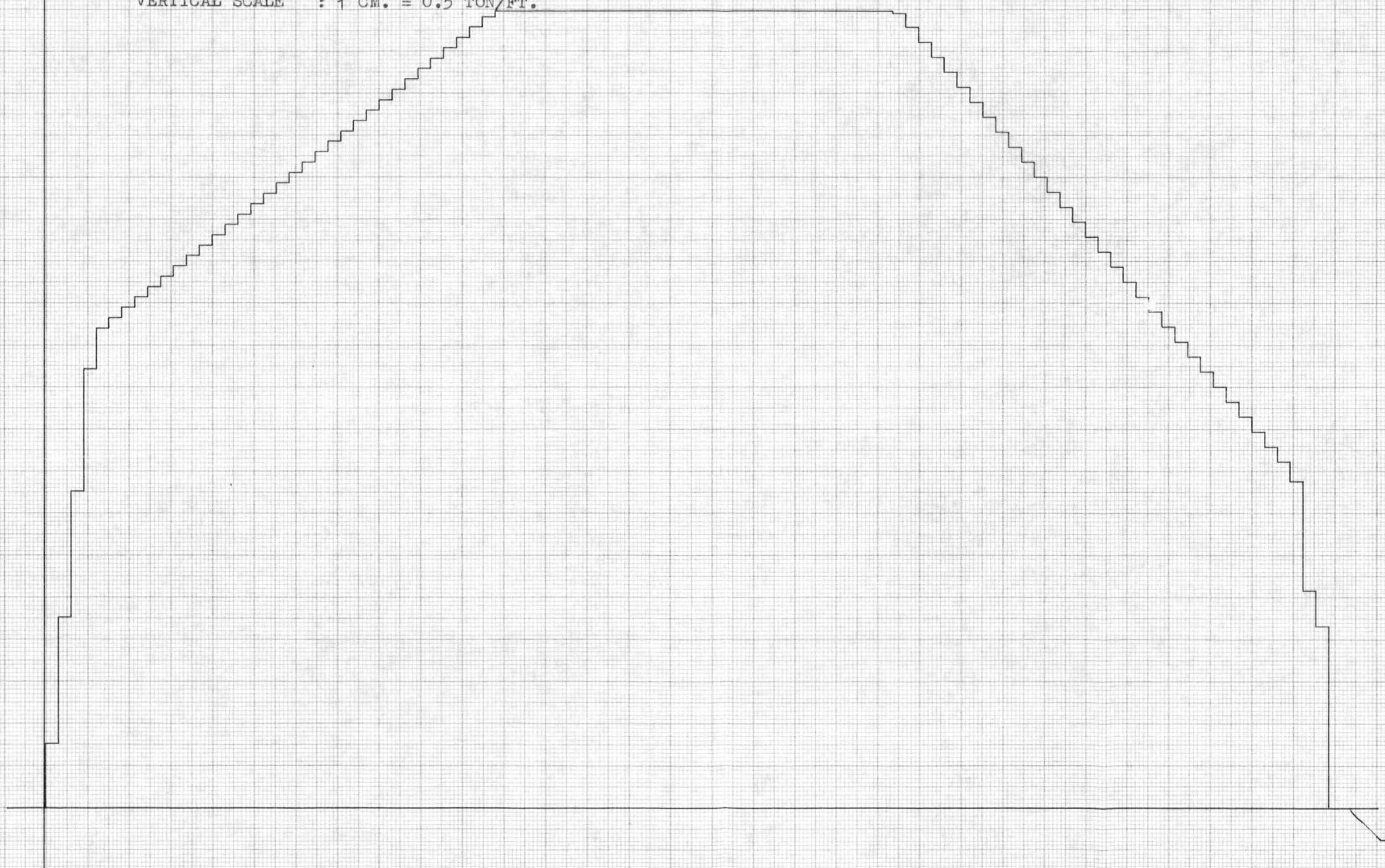
VERTICAL SCALE OF GRAPH --- UNITS/CM:- 0.5

CONTINUOUS WEIGHT ORDINATES (PROJECTED FORWARD)

(Biles Coffin)

HORIZONTAL SCALE : 1 CM. = 20 FT.

VERTICAL SCALE : 1 CM. = 0.5 TON/FT.



PART 2

(b) CONTINUOUS WEIGHT DISTRIBUTION

ACCORDING TO LLOYD'S REPORT SR 64/15

This is not the same continuous weight as is used in the Biles Coffin distribution; in this instance it includes the stern and bow sections. It is programmed as W32, and is obtained immediately after reading in the displacement (W31) by subtracting from it the calculated sum of the distributed local weights (S).

The distribution of this weight is considered to be a continuous curve over the whole length of the ship. The curve depends on the block coefficient at the load draught, and has the form shown below, fig.12a, where ordinates 0 to 20 are read from a set of curves produced by Lloyd's Register of Shipping.

These ordinates are called 'a' values, where a has a maximum value of unity. The true ordinate values for the weight curve are given by a_i x m ton/ft., where m is the measure in tons/ft. of the midship section, and i has values 0 - 20.

Lloyd's curves are reproduced on pages 42 and 43.

Note the end value suggested by Lloyd's and indicated in Fig. 12 (a).

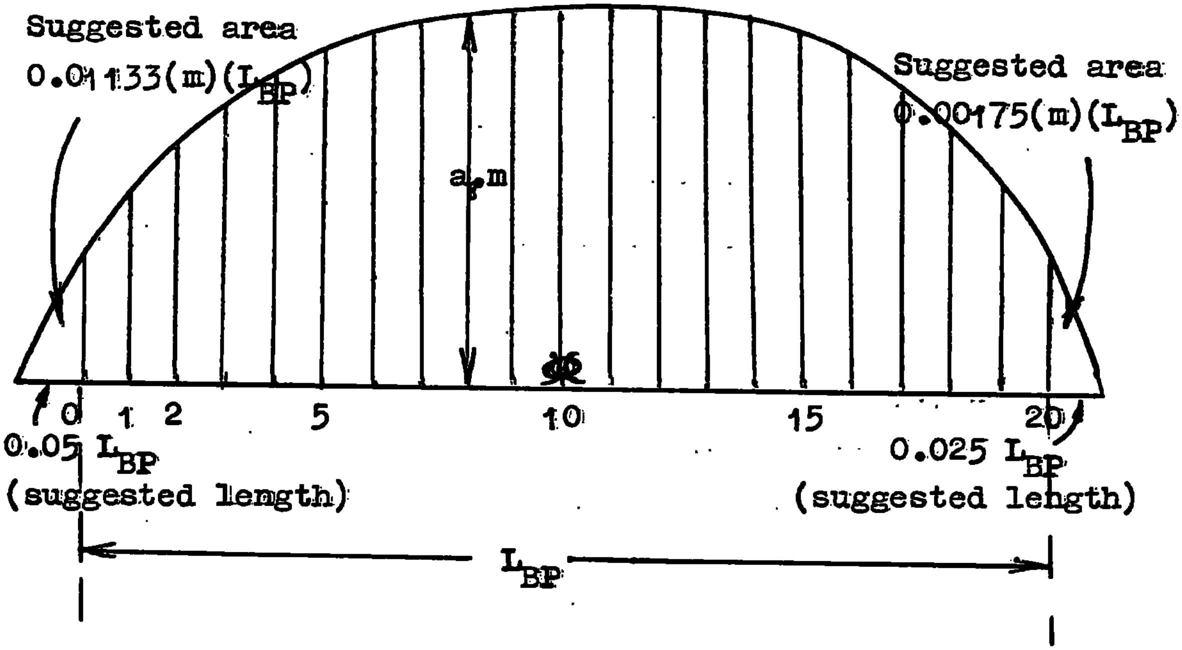


Fig. 12 (a)

Consider the ship under review. Block coefficient (C_B) given by the builder as 0.776. Reading from the given curves obtain the 'a' values as follows:

Section	'a' reading	Section	'a' reading	Section	'a' reading
0	0.340	1	0.495	2	0.625
3	0.727	4	0.815	5	0.884
6	0.940	7	0.976	8	0.998
9	1.000	10	1.000	11	1.000
12	1.000	13	1.000	14	1.000
15	1.000	16	0.975	17	0.903
18	0.766	19	0.505	20	0.14

Each of these ordinates must be multiplied by m such that the total weight found by integrating the curve is equal to the continuous weight. This is done by first of all integrating the curve in terms of 'm', and dividing this value into the known continuous weight (W32). This gives the value of m, and ordinate values 'a' are then multiplied throughout by m, to give the true weight/ft. ordinates. (The term 'a' values now incorporates 'm').

The curve is now true so far as weight representation is concerned but does not necessarily yield the true position of the L.C.G. of the continuous weight. The L.C.G. of the vessel for any given loaded condition having been given by the builder, together with the various values of weight and L.C.G. for each of the local weights, it is a simple matter to determine the L.C.G. of the continuous weight by addition and subtraction of moments. This done, it is unlikely that its position will coincide with the calculated L.C.G. of the given curve.

Before further analysis, correction must be made for any discrepancy between calculated and given L.C.G.'s. If the curve had been incorrect for both weight and L.C.G. it could have been corrected by raising (or lowering) the base - known as 'swinging the base'. However, this causes non-zero readings, in general, for ordinates 0 and 100, which may be either positive or negative.

Values of 'c' for After Body

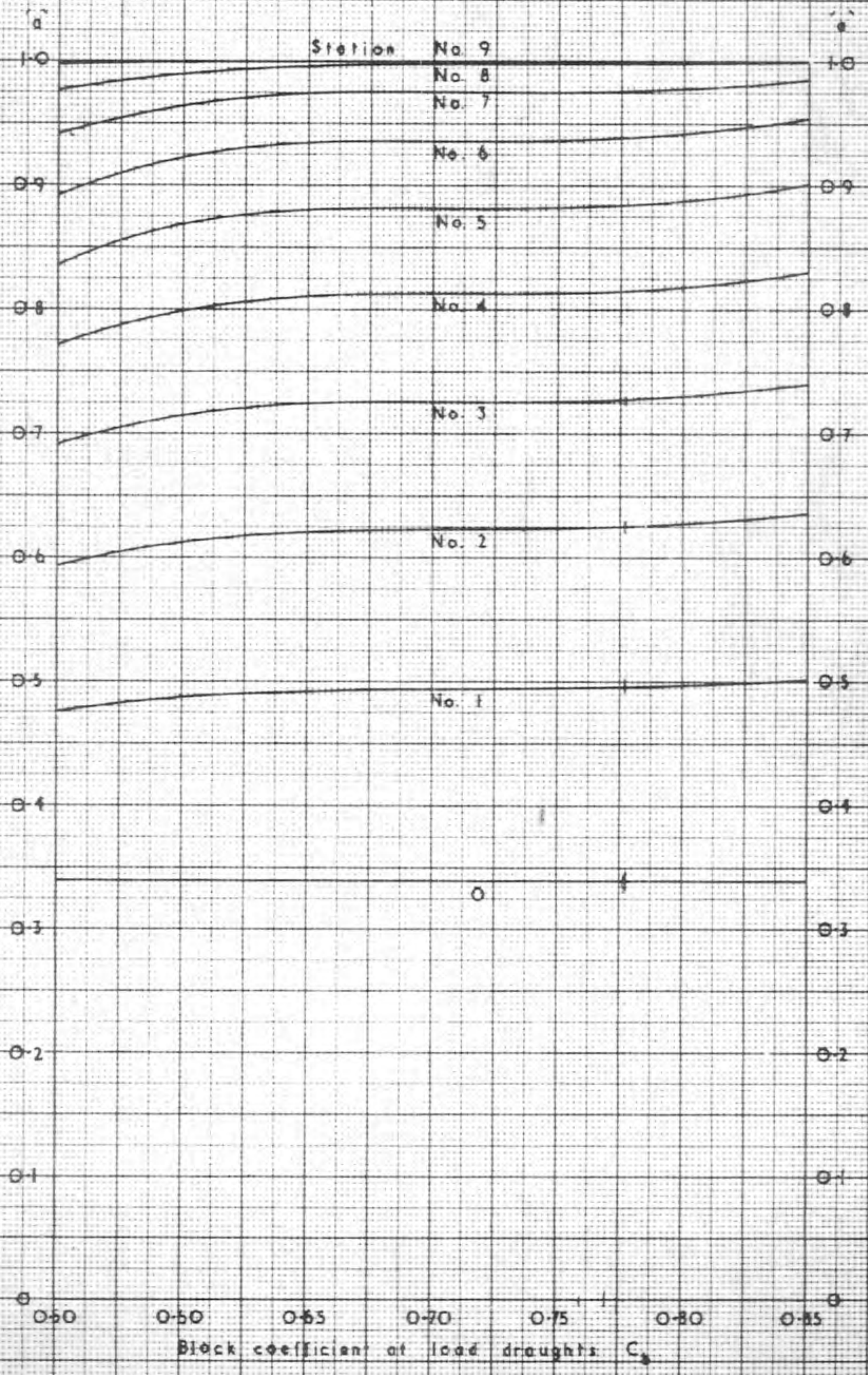


Fig. 3

Values of a for Fore Body

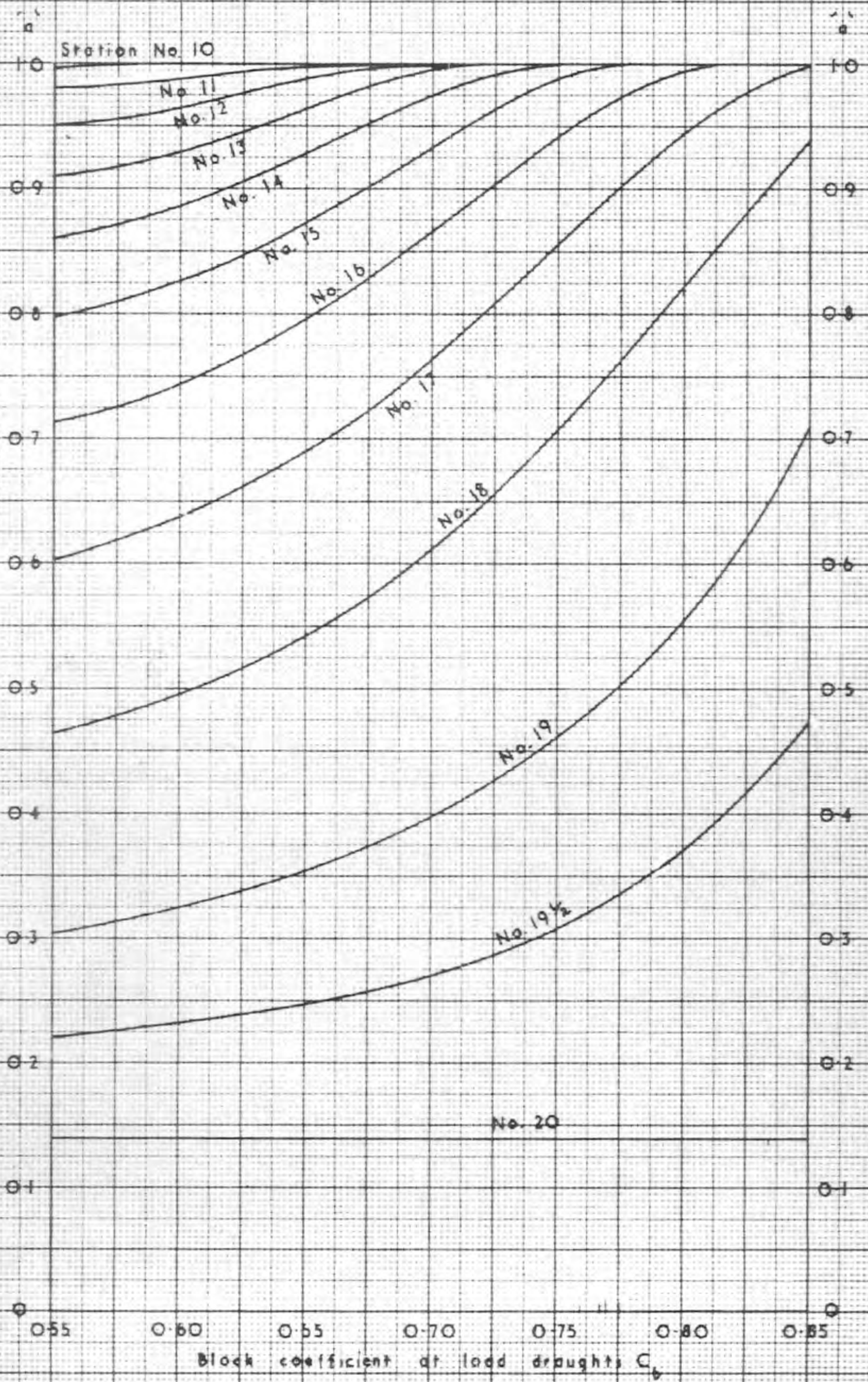


Fig 4

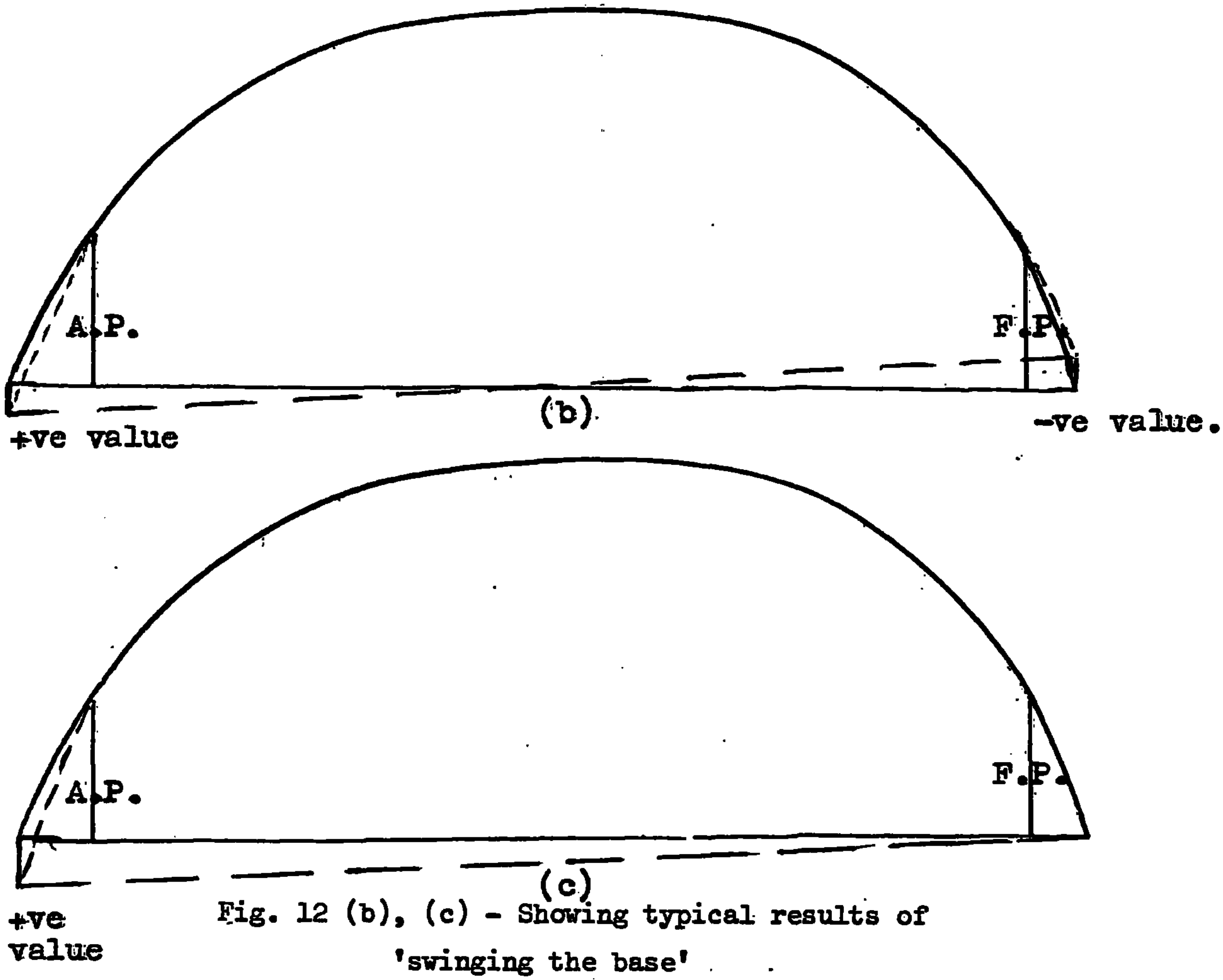


Fig. 12 (b), (c) - Showing typical results of 'swinging the base'

Further, it causes the greatest change in those ordinate values towards the ends, see fig. 12b (or at the least, in the ordinates towards one end, see fig. 12c), when in fact it would seem more reasonable to make the bulk of the change in those ordinates which contribute most to the total reading, namely the ordinates towards the centre.

Since the resultant ordinate values for Lloyd's curve are determined for the continuous material weight provided, the curve is correct for weight. But the shape of the basic weight curve in the first place is dependent upon the coefficients "a", coefficients which are derived using the assumption that certain standard relationships exist between block coefficient and the extent and position of the parallel mid-body. These relationships may be departed from in any given design, and it is logical to deduce that the L.C.G. derived from the continuous weight distribution curve will not, in general, be the same as that calculated by the programme using the addition and subtraction of moments in the usual way, and using the L.C.G. for the TOTAL weight distribution as given by the builder. An incorrect L.C.G. is the only measure to be corrected, therefore, as far as the distribution of the continuous material is concerned.

The above method of 'swinging the base' at this stage was, therefore, discarded in favour of a method of tilting (or displacing) the ordinates. By this method end ordinates remain of zero value, the weight under the curve is unaffected, (see page 47), and those ordinates which contribute most to the calculation of the L.C.G. (the larger, more central ordinates) are displaced most. Ordinates are, therefore, swung about their base line in the following manner:

From the curve, the vertical and horizontal measures of the centroid are computed. Let the position of the calculated centroid be G_1, and the known true position, for the continuous weight be

G. The horizontal movement required of the L.C.G. is, therefore, GG_1 ft. Let H be the vertical measure of G_1 from the base line of the curve. (Units for H are ton/ft) Let the ratio GG_1/H be called M, with units ft^2/ton.

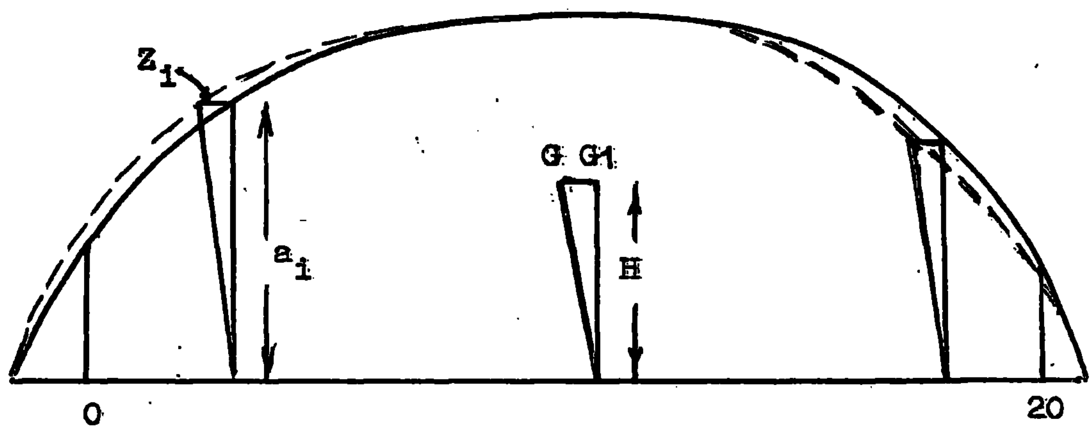


Fig. 13.

Multiplication of each ordinate of the curve by this ratio (in the same manner as a tangent ratio) gives the distance in feet, through which each ordinate respectively has to be moved horizontally. In the case of ordinate i, whose value is a_i ton/ft., we have:

$$a_i \text{ ton/ft.} \times M^{\text{ft}^2}/\text{ton} = (\text{say})\ z_i \text{ ft.}$$

where z_i is the horizontal shift required of a_i, in order that recalculation of the weight gives the same value as before, but now provides the correct L.C.G. position. (See fig. 13)

It can be seen from the following diagrams (fig. 14) that the "pushing over" of the weight curve does not alter the weight represented. Consider any element of area PQ.

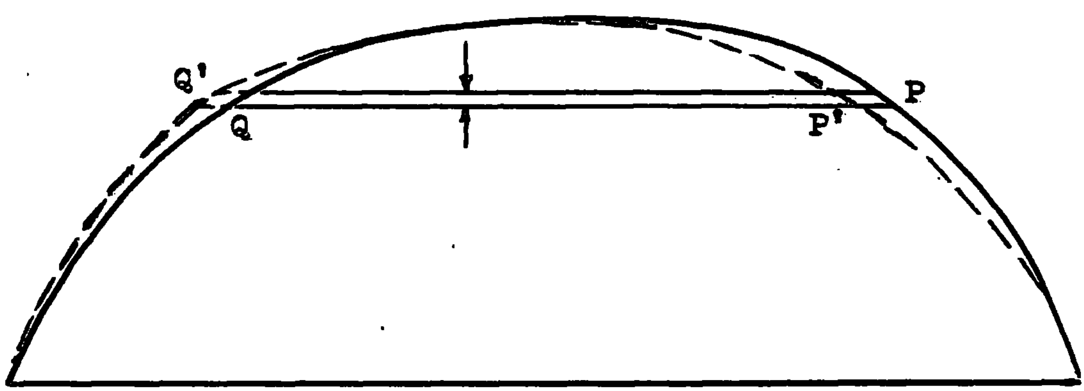
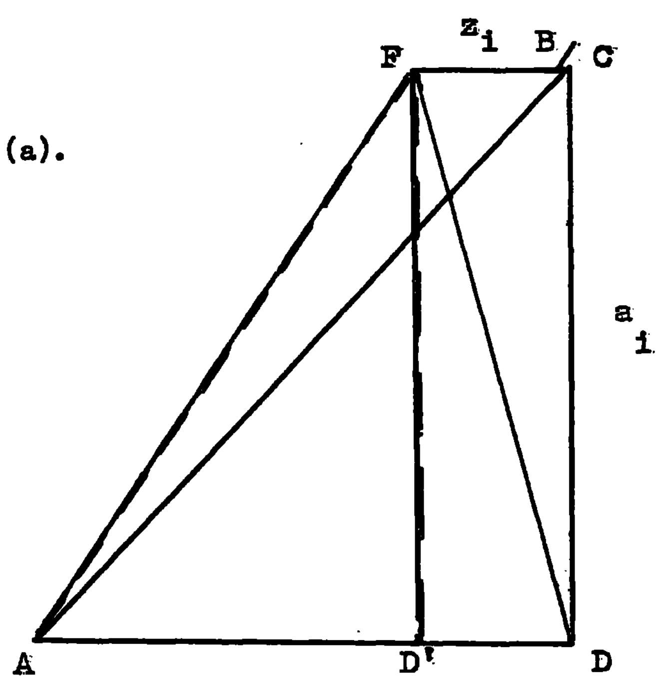


Fig. 14.

Since all points of the element are equidistant from the base line, the distance PP' must equal the distance QQ', and the distances PQ and P'Q' are equal. The area of the strip is, therefore, unchanged. Similarly for all strips.

An alternative method is to consider the element ABCD of fig. 15 - (a) triangular end and (b) any portion between the perpendiculars. The ordinates are sufficiently close to assume CB is a straight line fig. 15 (b); in fig. 15 (a) B and C are coincident.

Fig. 15 (a).



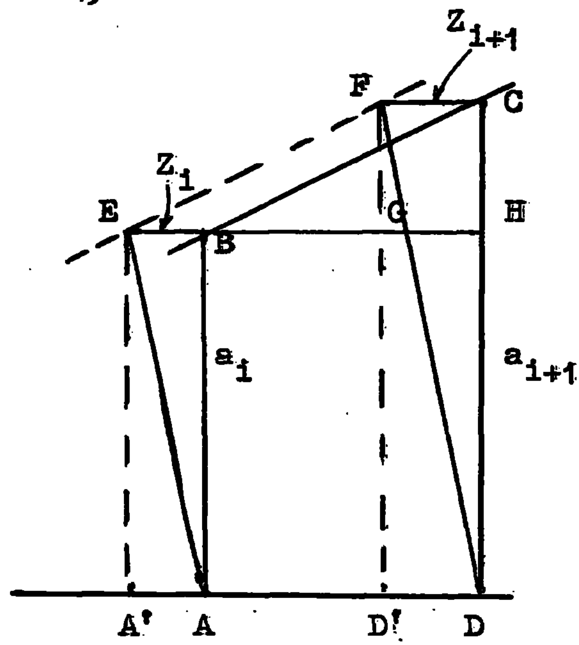


Fig. 15 (b)

Treating M in the same way as a tangent ratio, we have e.g. $a_5 \times M = z_5$, and $a_6 \times M = z_6$. In (b), E and F are the points on the new curve corresponding to B and C. Area EGDA equals area BHDA (since EG = BH = AD; parallel lines AE, DG and AB, DH). Also triangles BHC and EGF are equal. Therefore the new area equals the old area. Similarly for an end triangle as in (a). Considering the whole ordinate as moving across, we now have the new ordinate positions at A' and D' in (b), and at D' in (a).

At this stage in the programme the interpolation routine is entered to obtain ordinate values at every one-hundredth of the ship length over-all. Again ordinates are summed in pairs progressively throughout the whole length and the averages projected forward from the rearmost ordinate of each division.

Reference to fig. 16 will make it clear that the horizontal movements z_i of the ordinates of the curve cause the L.C.G. to be moved to the correct position.

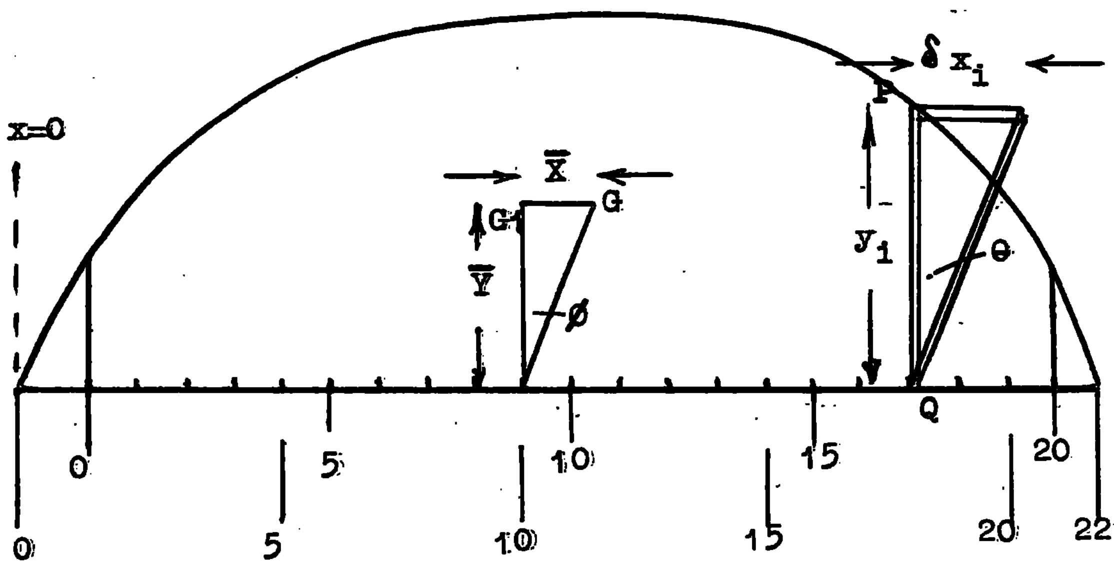


Fig. 16. (i) Showing Lloyds Station Numbers (upper) and the corresponding Programme Station Numbers (lower).

(ii) Indicating movement of L.C.G.

Let PQ be an element of area a_i and height y_i, and let it be tilted through angle θ about the base line.

The increase of moment about $x = 0$ is $a_i \frac{\delta x_i}{2}$, and the sum of all such moments is $\sum a_i \frac{\delta x_i}{2} = \sum a_i \frac{y_i}{2} \tan\theta = \tan\theta \, A \, \bar{y}$.

Also increase in moment of total area

$$= A\bar{\bar{X}} = A\,\bar{\bar{y}}\tan\phi$$

$$\therefore \theta = \phi$$

The graph on page 53 shows the initial points on the continuous weight distribution curve (shown as triangles), the displaced position as determined by the above theory (shown as squares), and the final smooth curve drawn through the points obtained through the interpolation routine.

Page 54 shows the relevant input data for A.842 using Lloyd's method for the distribution of the Continuous Material, and on page 55 may be seen the tabulated values for this distribution. Page 56 shows the corresponding graph output.

* * * * * *

Since we are concerned with obtaining values every one-hundredth of the overall actual, or estimated, length, it is better to consider such lengths throughout. When the interpolation routine is entered, 23 values of X_i and Y_i (actually X_i and A_i) are used from store, in order to determine the 101 equally spaced ordinates (including two end ordinates in each case, whose values are 0, 0). Lloyd's 'a' values are renumbered for this purpose as illustrated in fig. 16. The distance X_0X_1 is the actual, or estimated, length of the overhang of the stern.

Similarly, the distance X_{21} X_{22} is the actual, or estimated, length of the bow overhang.

The interpolation routine entered is a three point Lagrange method, which is also used for the Buoyancy Section.

101 ordinates are determined for absiscae at regular intervals along the ship length. For the first three points input, x_0, x_1, x_2, ordinates are determined for those absiscae, if any, which lie in the first portion, x_0 - x_1. If the absiscae lie in the second portion, x_1 - x_2, the first value input is dropped, and a fourth value is picked up, x_3. The three points used are now x_1, x_2, x_3 (which are renamed x_0, x_1, x_2 in the programme) and the ordinates required have absiscae lying in the new range x_0 - x_1, i.e. the leading portion. Each time a new input ordinate is adopted the new set become x_0, x_1, x_2.

This process is repeated until ordinate number 50 is reached, then the process is changed slightly to find ordinates in the second portion of each set. This ensures that ordinates are found up to the extreme fore end.

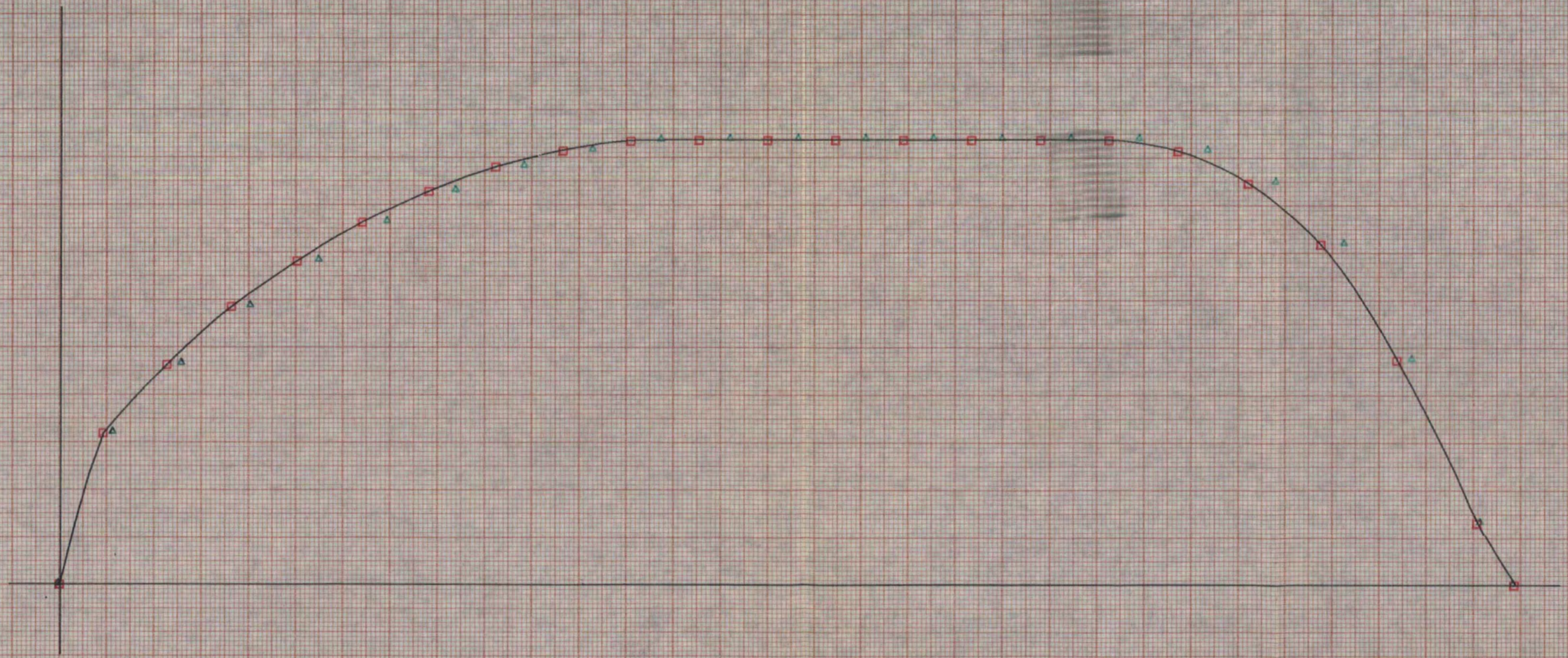
* * * * * *

A comparison of graph output for A.842 using both Biles Coffin method and Lloyd's method is shown on page 62 ; Biles Coffin curve is in red and Lloyd's curve in green. Reference will be made to this again in the Bending Moment Section, and in the Load Curve and Shear Force Curve Sections which lead up to it.

<u>CONTINUOUS WEIGHT CURVE</u>. (LLOYD'S METHOD)

ORIGINAL POSITION - TRIANGLES.

ADJUSTED POSITION - SQUARES.



2 Sheet (iv)

Tape 2 (Contd). (This part of Tape 2 not required after the first data run).

If Continuous Weight is to be distributed by Biles Coffin method, complete lines (a), (b), (c), (d) below, otherwise complete (e) from Lloyds tables SR 64/15.

For FIRST data run only:

	Programme Variable.
(a) Weight of Overhang of Stern.	W33
(b) Weight of Overhang of Bow.	W34
(c) L.C.G. of Overhang of Stern, from Stern.	L4
(d) L.C.G. of Overhang of Bow, from Stern.	L5

(e) For FIRST data run only:

	Stn. 0	Stn. 1	Stn. 2	Stn. 3	Stn. 4	Stn. 5	Stn. 6
0	0.340	0.495	0.625	0.727	0.815	0.884	0.940
Stn. 7	Stn. 8	Stn. 9	Stn.10	Stn.11	Stn.12	Stn.13	Stn.14
0.976	0.998	1.000	1.000	1.000	1.000	1.000	1.000
Stn.15	Stn.16	Stn.17	Stn.18	Stn.19	Stn.20		
1.000	0.975	0.903	0.766	0.505	0.140	0	

SHIPYARD A. SHIP NO. 842

CONTINUOUS WEIGHT CURVE ORDINATES (PROJECTED FORWARD).

(LLOYD'S DISTRIBUTION)

ORD NO.	WEIGHT TON/FT	ORD NO.	WEIGHT TON/FT	ORD NO.	WEIGHT TON/FT	ORD NO.	WEIGHT TON/FT
0	0.63	1	1.79	2	2.75	3	3.36
4	3.71	5	4.04	6	4.36	7	4.67
8	4.97	9	5.25	10	5.52	11	5.78
12	6.02	13	6.25	14	6.47	15	6.68
16	6.88	17	7.06	18	7.24	19	7.42
20	7.58	21	7.74	22	7.89	23	8.04
24	8.17	25	8.31	26	8.43	27	8.55
28	8.66	29	8.76	30	8.85	31	8.92
32	8.99	33	9.06	34	9.12	35	9.18
36	9.24	37	9.28	38	9.32	39	9.34
40	9.35	41	9.35	42	9.36	43	9.36
44	9.36	45	9.36	46	9.36	47	9.36
48	9.36	49	9.36	50	9.36	51	9.36
52	9.36	53	9.36	54	9.36	55	9.36
56	9.36	57	9.36	58	9.36	59	9.36
60	9.36	61	9.36	62	9.36	63	9.36
64	9.36	65	9.36	66	9.36	67	9.36
68	9.36	69	9.36	70	9.36	71	9.36
72	9.35	73	9.31	74	9.27	75	9.21
76	9.15	77	9.06	78	8.94	79	8.81
80	8.67	81	8.50	82	8.30	83	8.07
84	7.81	85	7.52	86	7.21	87	6.85
88	6.44	89	5.99	90	5.50	91	4.97
92	4.42	93	3.84	94	3.24	95	2.61
96	1.95	97	1.31	98	0.75	99	0.24
100	0.00						

Table 8.

CONTINUOUS WEIGHT CURVE ORDINATES (PROJECTED FORWARD).

X-AXIS DISTANCE (CMS) FROM BASE OF GRAPH PAPER = 0

HEIGHT OF Y-AXIS = 30

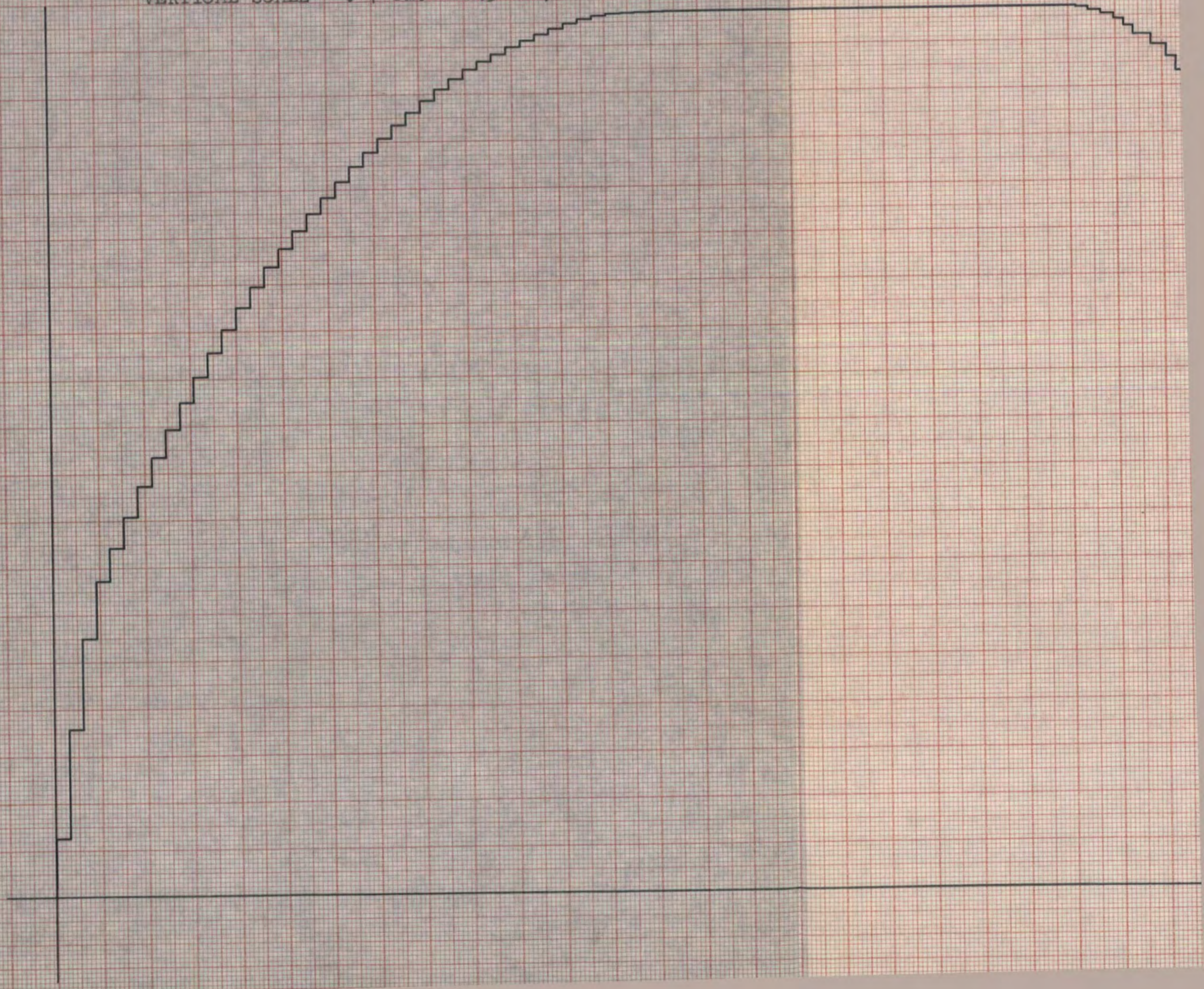
HORIZONTAL SCALE OF GRAPH --- 1 CM = 20 FT

VERTICAL SCALE OF GRAPH --- UNITS/CM:- 0.5

CONTINUOUS WEIGHT ORDINATES (PROJECTED FORWARD)
(Lloyd's)

HORIZONTAL SCALE : 1 CM. = 20 FT.

VERTICAL SCALE : 1 CM. = 0.5 TON/FT.



As mentioned on page (v) of the introduction, and remembering that the programme is to cater for the builder in the initial design stages, when end values may not be decided upon, Lloyd's suggest that the areas aft of their Station No. 0 and forward of Station No. 20 may be taken as $0.01133 \times m \times L_{BP}$, and $0.00175 \times m \times L_{BP}$ respectively, i.e. a total end area of $0.01308 \times m \times L_{BP}$.

Again, Lloyd's indicate that the overhangs of stern and bow may be taken as $0.05 \times L_{BP}$ and $0.025 \times L_{BP}$ respectively. The end areas calculated on these latter measures would be:-

Stern	$\frac{1}{2} \times 0.05 \times L_{BP} \times a_0$.
Bow	$\frac{1}{2} \times 0.025 \times L_{BP} \times a_{20}$.

However, if we take the true lengths of the overhangs, if known we have the end areas equal to:-

Stern	$\frac{1}{2} \times L_1 \times a_0$.
Bow	$\frac{1}{2} \times L_2 \times a_{20}$.

The effect on 'm' using these various values was investigated.

The following table of values has been drawn up, using these various formulae, for a number of different ships from four different shipyards on the River Wear. It will be noticed that the differences are of the order 0.04 to 0.05 ton/ft. for cont. wts. of 4000-5000 tons.

1. YARD A.

SHIP NO.	"M" Values as calculated from:-		
	$0.01308 \times L_{BP}$ (Lloyd's Areas)	$\frac{1}{2}\begin{pmatrix} 0.025 \times L_{BP} \cdot a_{20} \\ + \\ 0.05 \times L_{BP} \cdot a_0 \end{pmatrix}$ (Lloyd's ends)	$\frac{1}{2}\begin{pmatrix} L_1 \times a_0 \\ + \\ L_2 \times a_{20} \end{pmatrix}$ (Actual or estimated ends)
842	9.31	9.34	9.36
844	8.49	8.51	8.54
849	7.67	7.70	7.71
850	8.01	8.03	8.05
SD.14	6.94	6.97	7.00

2. YARD B.

408	7.19	7.22	7.24
409	7.61	7.64	7.67

3. YARD C.

721	15.11	15.16	15.21

4. YARD D.

873	7.29	7.32	7.33
837	4.81	4.83	4.85
843	6.29	6.31	6.31
849	6.14	6.16	6.16
850	6.17	6.19	6.19
889	5.52	5.54	5.54

Using 0.01133 x L_{BP} x m as the weight of overhang of stern, and 0.00175 x L_{BP} x m as that of the bow section, and since Lloyd's measures a_0 and a_{20} are fixed, we can find the equivalent lengths of stern and bow from the two triangular ends. Calling the lengths X_1 and X_2 respectively we have, for ship No. A.842.

Stern:
$$\frac{X_1 \times a_0 \times m}{2} = 0.01133 \times L_{BP} \times m$$

$$X_1 = \frac{0.02266 \times L_{BP}}{a_0} \text{ where } L_{BP} = 580 \text{ ft., and } a_0 = 0.34.$$

$$X_1 = \frac{0.02266 \times 580}{0.34} = \underline{38.66 \text{ ft}}.$$

In fact, the length X_1 is 23 ft.

Bow:
$$\frac{X_2 \times a_{20} \times m}{2} = 0.00175 \times L_{BP} \times m$$

$$X_2 = \frac{0.00175 \times 580 \times 2}{0.14} = \underline{14.5 \text{ ft}}.$$

In fact, X_2 is 14 ft.

Again, taking Lloyd's suggestion for the length of the overhangs as 0.05 x L_{BP}, and 0.025 x L_{BP} for the stern and bow, we have a stern overhang of 29 ft., and a bow overhang of 14.5 ft., against actual length of 23 ft. and 14 ft.

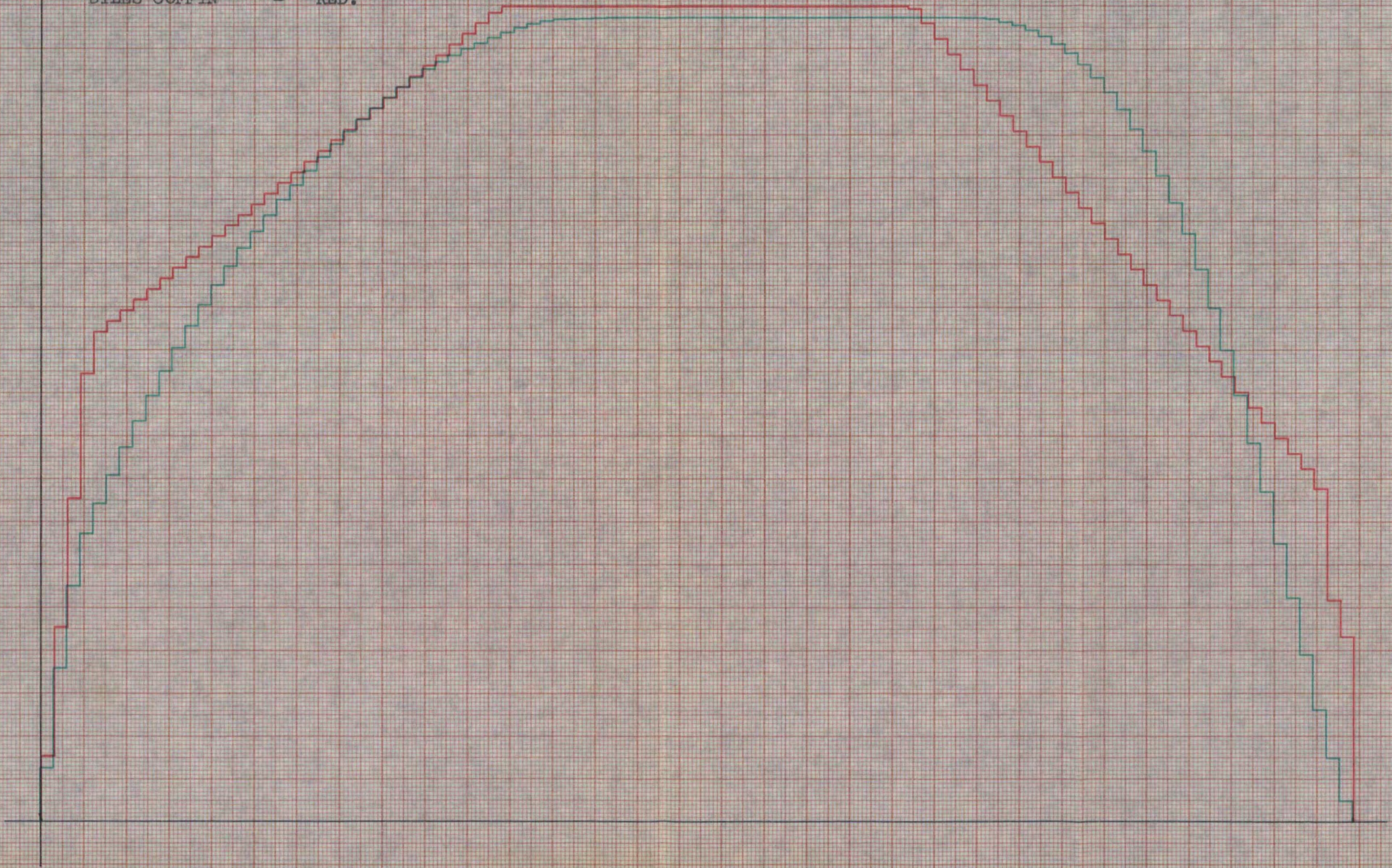
A check on the results for a number of ships, using these measures showed possible wide discrepancies in implied lengths of sterns (see Table 10). It was decided, therefore, not to use the recommended values, but to use estimated values (which are quite likely to be very near the actual final value). It was felt that such estimations would be much nearer the mark in each individual case and give a distribution more in line with that of the final plans. The last column in table 10 indicates the expected or estimated lengths, which in these instances are also the final actual lengths.

Implied Stern and Bow Overhangs calculated from:-						
Ship	End Areas		End Lengths		Actual (or estimated) Lengths	
	Stern	Bow	Stern	Bow	Stern	Bow
A.842	38.655	14.50	29.00	14.500	23.00	14.00
A.844	38.655	14.50	29.00	14.500	23.00	7.00
A.849	37.322	14.00	28.00	14.000	22.00	13.00
A.850	36.656	13.75	27.50	13.750	22.00	11.00
SD.14	29.325	11.00	22.00	11.000	12.50	10.00
B.408	30.324	11.375	22.750	11.375	15.85	13.3
B.409	32.257	12.100	24.200	12.100	16.73	6.00
C.721	50.652	18.865	38.00	19.000	27.36	10.58
D.873	28.743	10.827	21.500	10.750	18.25	8.25
D.837	27.992	10.500	21.000	10.500	13.00	7.04
D.843	33.324	12.500	25.000	12.500	21.59	17.77
D.849	32.657	12.250	24.500	12.250	21.00	21.01
D.850	31.991	12.000	24.000	12.000	22.79	15.57
D.889	29.991	11.250	22.500	11.250	20.42	16.58

CONTINUOUS WEIGHT DISTRIBUTIONS.

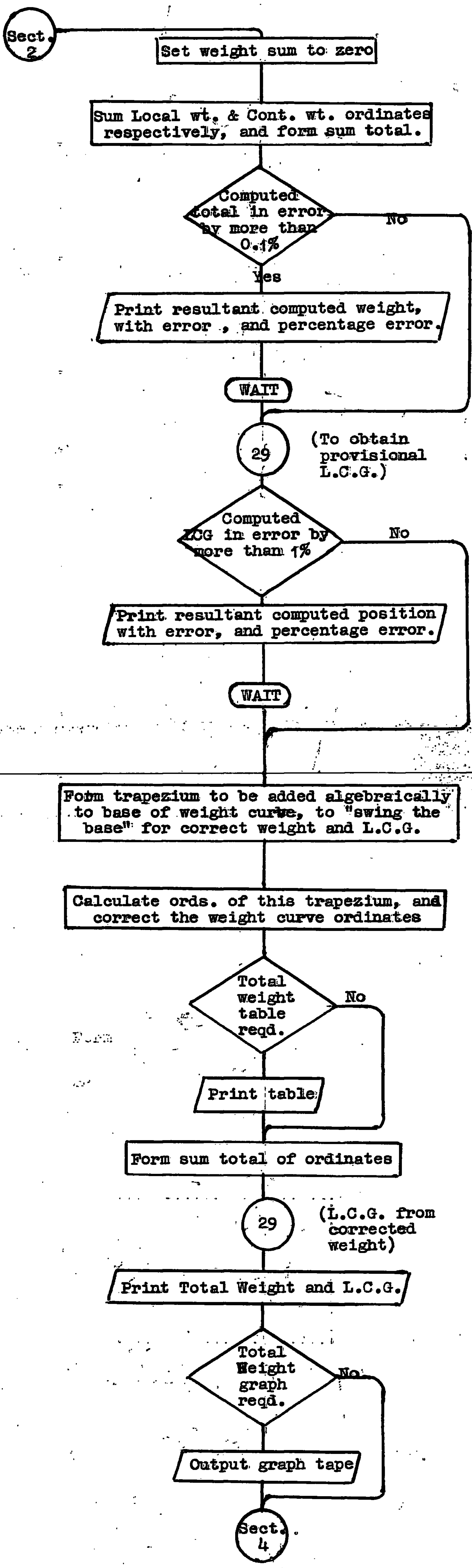
LLOYD'S METHOD - GREEN.

BILES COFFIN - RED.



FLOW CHART (Programme Page 11)

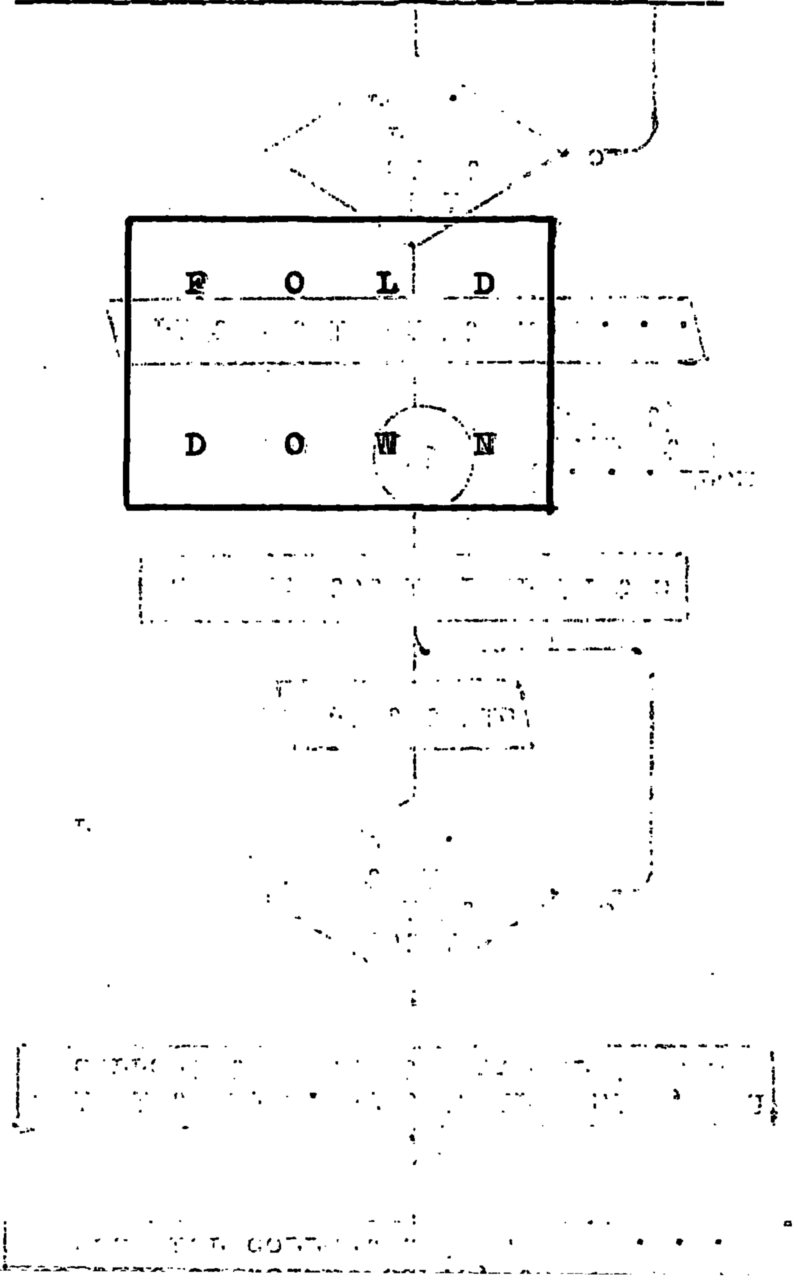
TOTAL WEIGHT SECTION (3)



FLOW CHART

(Section 3).

TOTAL WEIGHT SECTION.



PART 3

LOCAL WEIGHTS AND CONTINUOUS WEIGHT

COMBINED RESULTS

Ordinate values from the previous two parts of the programme (YR - local weights: VR - continuous weight) are now respectively summed in order, to produce Total Weight Curve ordinates, for all ordinates 0 - 99. (F. Pt. variables YR are used again for these summed ordinates). Calculation of total weight under this curve (which is computed as the product of the sum of the ordinates and their distance apart) yields a result which may differ slightly from the real displacement. Calculation of the longitudinal L.C.G. may differ very slightly from the actual value read in, especially if Biles Coffin method has been used. Before these Total Weight Curve ordinates are printed out, therefore, they are amended to ensure the correct positioning of the L.C.G., and to give a correct (or very nearly so) displacement. This is done by 'Swinging the Base'. If the weight value before swinging is in error by more than 0.1% it is output and the programme WAITS. A similar indication is made if the L.C.G. is out by 1%. The programme may be continued if so desired.

Swinging the Base

As mentioned above, the weight ordinates are summed and multiplied by the common interval (L6). This computes the total weight under the curve.

The longitudinal moment of weight about the stern is found by multiplying each ordinate in turn by its (forward) common interval (L6) and again by the distance from the stern to the centre of that common interval, and summing. These computed figures must be corrected, and this is done by raising or lowering, and tilting the base of the weight curve. This combined movement of the base line adjusts the weight (for each ordinate) and also adjusts the position of the L.C.G.

See below for method and formulae applied.

We now have in store the original weight ordinates and the corrections to be applied. These are respectively summed algebraically to obtain the corrected weight curve ordinates which are now printed out under the title:-

TOTAL WEIGHT CURVE ORDINATES (PROJECTED FORWARD)

Ord. No.	Weight ton/ft.	Ord. No.	Weight ton/ft.	Ord. No.	Weight ton/ft.	Ord. No.	Weight ton/ft.

See page 72 for the complete table of results.

After the 100 ordinate values are printed they are again summed (using F.Pt. variable S again) and their moments about the stern again calculated. From these two, the position of the L.C.G. is determined by division, and printed out together with the total weight. This allows checking with the read-in values of weight and L.C.G.

Method Used

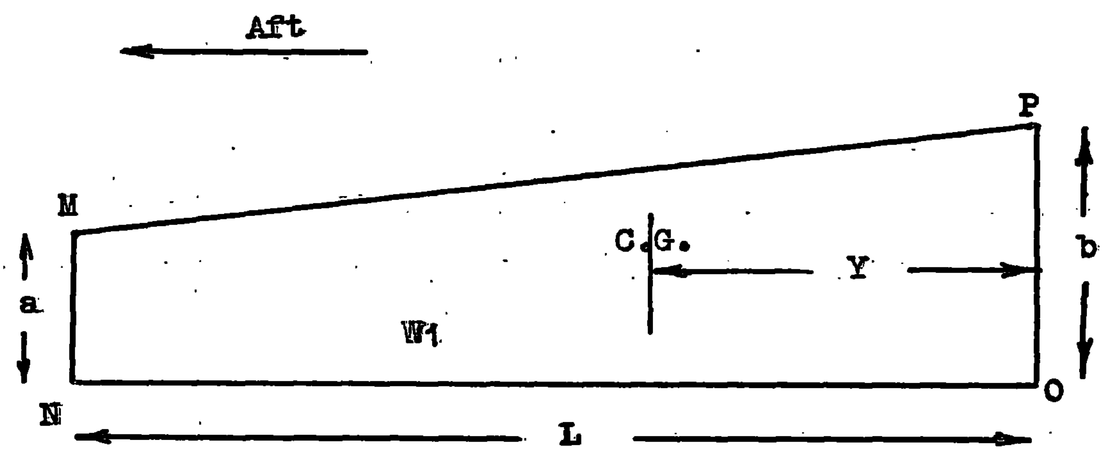


Fig. 18.

W1 is the difference between the true and the computed weights. (W1 in these notes is programmed as W32).

i.e. MNOP is the trapezium to be added (algebraically) to the base of the original weight curve. <u>a</u> and <u>b</u> are found using the formulae:-

$$a = \frac{W1}{L^2}(6Y - 2L). \qquad b = \frac{2(W1)}{L} - a.$$

where <u>a</u> is the smaller end.

<u>Note</u>: Y is always measured from the larger end, and therefore always less than L/2. In any given case, <u>a</u> may equal <u>b</u>. The programme provides for the aft ordinate of the trapezium to be called <u>D</u> and the forward end <u>A</u> in all cases, the difference giving a positive or negative slope as the case may be.

Each condition with its resultant corrective effect is listed below, where <u>S</u> is the computed weight and <u>W1</u> is the correction to be added. (i.e. W = W1 + S).

In all cases, values of DR obtained below are averaged for each pair of readings in turn, since values on the weight curve, etc., are projected forward.

<u>Case I</u> W1 positive. Both <u>D</u> and <u>A</u> positive. Also (D-A) positive.

B = D - A. (These are also the F.Pt. variables used).

B = B/100 (B is now the step per division length - L6).

Fig. 19 shows (D - A) positive. i.e. + ve slope for side OP. Any ordinate DR is now given by

DR = D - (R x B) where R takes all values 0 to 99 in turn.

DR decreases with increasing R. D100 = A.

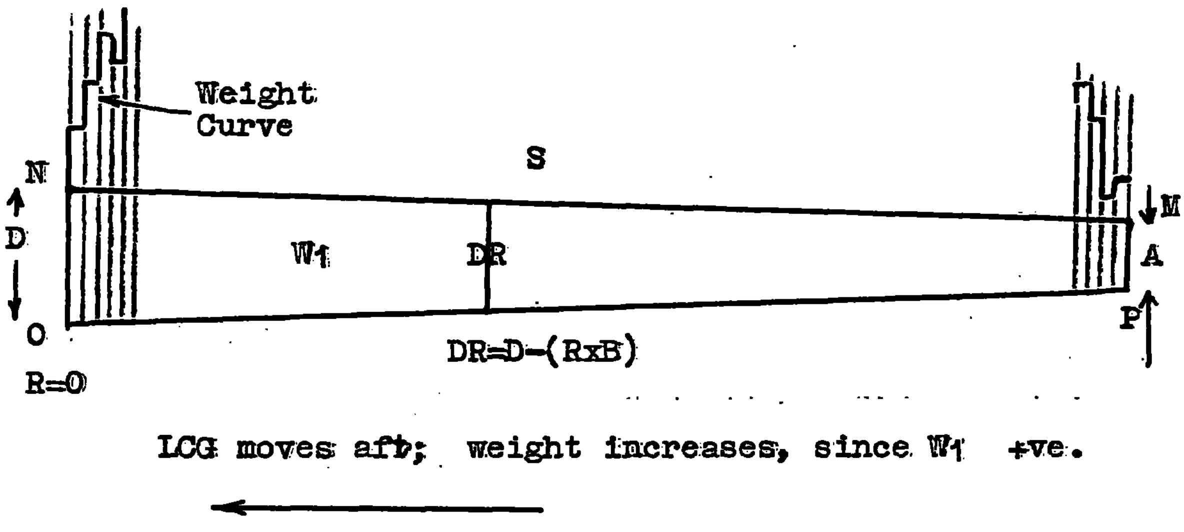


Fig. 19.

In fig. (19), fig. (20), etc., S is the computed sum of weights and the trapezium MNOP represents the weight W1 to be 'added'.

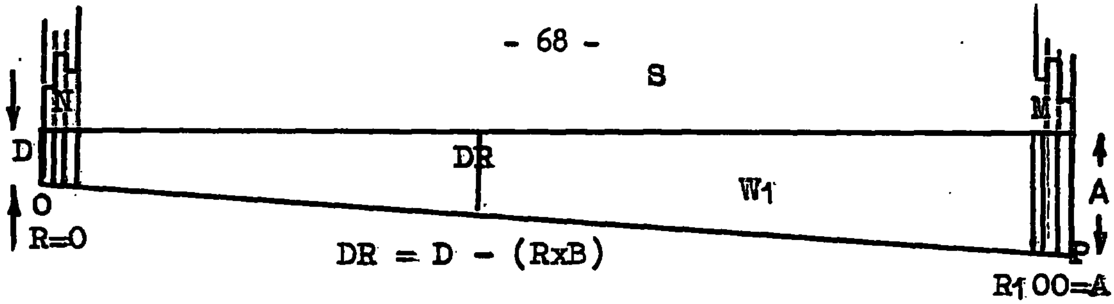
<u>Case II</u> W1 positive. Both <u>D</u> and <u>A</u> positive. But (D - A) negative. B is again the step per division length - L6.

Fig. (20) shows (D - A) negative. i.e. -ve slope for side OP.

Any ordinate is now given by

$$DR = D - (R \times B),$$

where B is - ve., so that DR increases with increasing R.



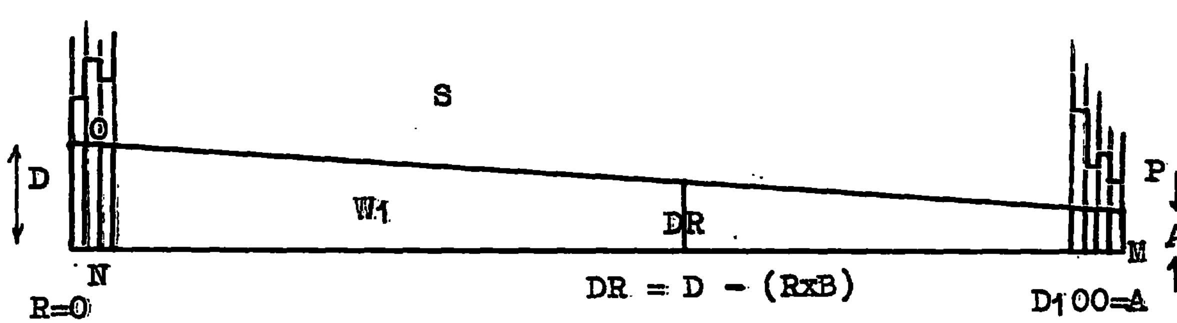
L.C.G. moves forward; weight increases since W1 +ve.

Fig. 20.

Case III W1 negative. Both D and A negative. Also (D - A) -ve. B (i.e. step division) negative. Fig. (21) shows this. Any ordinate is now given by

$$DR = D - (R \times B),$$

where B is -ve, so that DR is decreasing numerically (or becoming less negative) with increasing R.



L.C.G. moves forward; weight decreases since W1 -ve.

Fig. 21.

Case IV W1 negative. Both D and A negative. But (D - A) positive. B is now positive. Fig. (22).

Any ordinate is now given by

$$DR = D - (R \times B),$$

so that DR is increasing numerically (negatively) with increasing R.

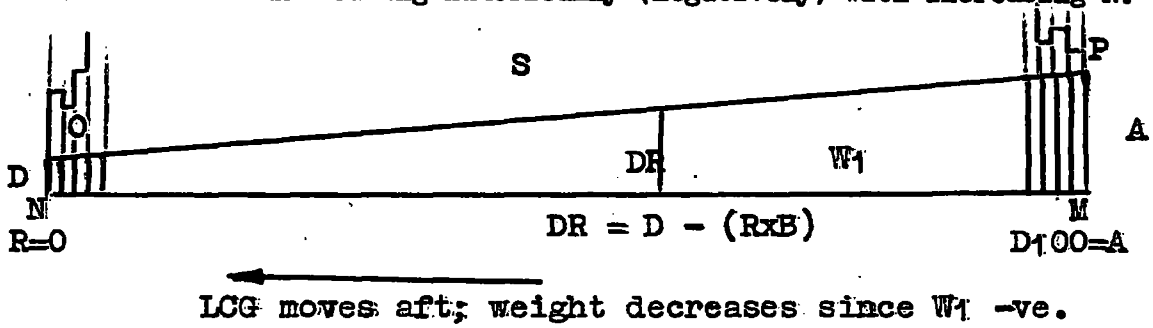


Fig. 22.

Case V D computed negative) A computed positive) A = -D if W1 = 0.

(D - A) negative in this case. OP has -ve slope; i.e. B -ve.

Any ordinate DR is given by

$$DR = D - (R \times B),$$

so that DR is becoming less negative with increasing R.

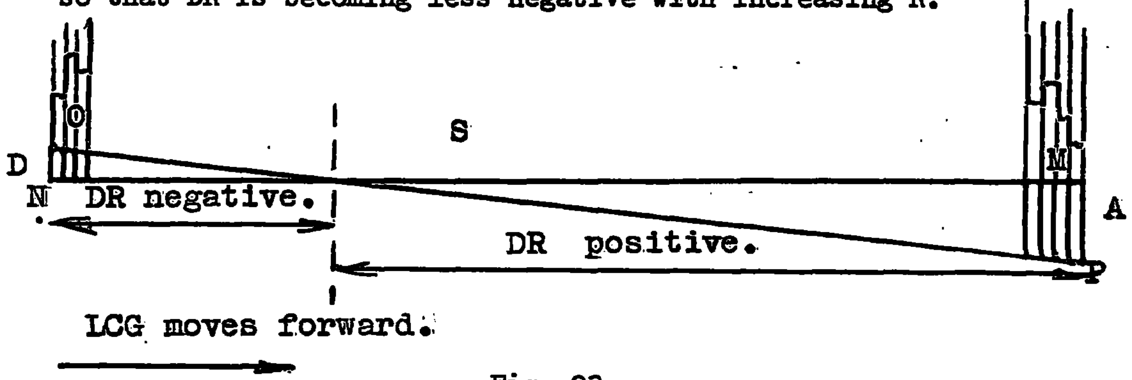


Fig. 23.

(i) Weight unchanged if $A = -D$.

(ii) If W1 -ve, then $|D|$ gr $|A|$.

(iii) If W1 positive, then $|D|$ less than $|A|$.

Case VI — D computed positive) A computed negative) $A = -D$ if $W1 = 0$.

$(D - A)$ positive in this case. OP has positive slope. i.e. B +ve.

Any ordinate DR is given by

$$DR = D - (R \times B),$$

so that DR decreases with increasing R.

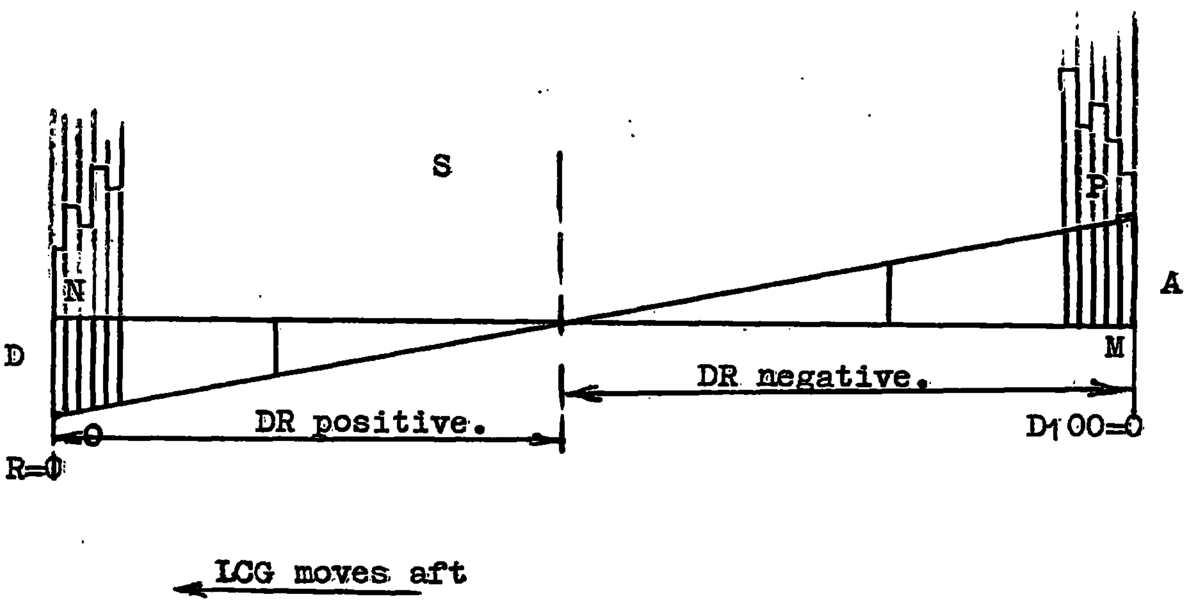


Fig. 24.

(i) Weight unchanged if $A = -D$. (ii) If W1 negative, then $|A|$ gr $|D|$.

(iii) If W1 positive, then $|A|$ less than $|D|$.

Note: In cases (v) and (vi), if the computed weight and the actual weight are the same, but the L.C.G. is incorrect, then A and D are equal in magnitude, but opposite in sign.

Page 72 shows the tabulated results for A842 (using Lloyd's method for the distribution of the Continuous material), and page 73 contains the corresponding graph output, in green.

Superimposed on page 73 is the graph output using Biles Coffin method for the Continuous Weight. This graph is shown in red, and the corresponding table is on page 72(a).

RESULTANT COMPUTED TOTAL WEIGHT = 21358.56 TONS
ERROR = 39.91 TONS % ERROR = 0.19

$$

TOTAL WEIGHT CURVE ORDINATES (PROJECTED FORWARD)

(BILES COFFIN DISTRIBUTION)

ORD NO.	WEIGHT TON/FT	ORD NO.	WEIGHT TON/FT	ORD NO.	WEIGHT TON/FT	ORD NO.	WEIGHT TON/FT
0	0.78	1	2.18	2	4.16	3	8.52
4	18.85	5	29.07	6	34.84	7	13.74
8	16.71	9	18.88	10	20.93	11	18.51
12	18.53	13	29.29	14	36.48	15	36.08
16	34.69	17	34.85	18	24.85	19	22.35
20	27.41	21	19.89	22	20.88	23	21.20
24	20.80	25	21.32	26	21.85	27	22.37
28	22.61	29	23.77	30	35.31	31	26.05
32	25.12	33	26.00	34	26.40	35	26.73
36	26.97	37	27.21	38	27.33	39	27.24
40	27.48	41	118.69	42	121.53	43	120.99
44	120.02	45	131.38	46	38.87	47	30.39
48	29.63	49	30.03	50	30.09	51	30.15
52	30.22	53	30.28	54	30.11	55	29.91
56	37.44	57	29.47	58	29.68	59	29.98
60	29.99	61	30.00	62	30.02	63	30.03
64	29.79	65	30.29	66	33.74	67	125.27
68	121.14	69	120.93	70	120.19	71	130.76
72	30.64	73	30.01	74	29.25	75	28.49
76	28.54	77	27.95	78	27.32	79	26.70
80	26.07	81	27.07	82	35.53	83	24.04
84	22.77	85	21.90	86	21.04	87	20.17
88	19.31	89	18.32	90	12.71	91	12.07
92	24.65	93	39.58	94	25.35	95	19.80
96	14.00	97	7.04	98	3.19	99	2.48

WEIGHT	L.C.G. FWD. A.E.
21318.65	321.79

Table 11(a).

TOTAL WEIGHT CURVE ORDINATES (PROJECTED FORWARD)

(LLOYD'S DISTRIBUTION)

ORD NO.	WEIGHT TON/FT	ORD NO.	WEIGHT TON/FT	ORD NO.	WEIGHT TON/FT	ORD NO.	WEIGHT TON/FT
0	0.69	1	2.01	2	3.72	3	7.48
4	17.72	5	28.12	6	34.06	7	13.12
8	16.24	9	18.54	10	20.71	11	18.39
12	18.51	13	29.35	14	36.60	15	36.26
16	34.91	17	35.11	18	25.15	19	22.67
20	27.74	21	20.22	22	21.21	23	21.53
24	21.11	25	21.62	26	22.12	27	22.61
28	22.80	29	23.92	30	35.39	31	26.06
32	25.05	33	25.84	34	26.15	35	26.46
36	26.76	37	27.05	38	27.21	39	27.14
40	27.39	41	118.61	42	121.45	43	120.92
44	119.95	45	131.32	46	38.81	47	30.34
48	29.58	49	29.98	50	30.05	51	30.11
52	30.18	53	30.24	54	30.08	55	29.88
56	37.41	57	29.45	58	29.67	59	29.97
60	29.98	61	30.00	62	30.01	63	30.03
64	29.80	65	30.29	66	33.78	67	125.45
68	121.47	69	121.41	70	120.82	71	131.54
72	31.56	73	31.05	74	30.40	75	29.73
76	29.87	77	29.34	78	28.75	79	28.14
80	27.51	81	28.50	82	36.91	83	25.34
84	23.96	85	22.96	86	21.93	87	20.86
88	19.73	89	18.44	90	12.50	91	11.48
92	23.66	93	38.16	94	23.49	95	17.46
96	11.15	97	3.77	98	0.96	99	0.29

WEIGHT	L.C.G. FWD. A.E.
21318.65	321.79

Table 11.

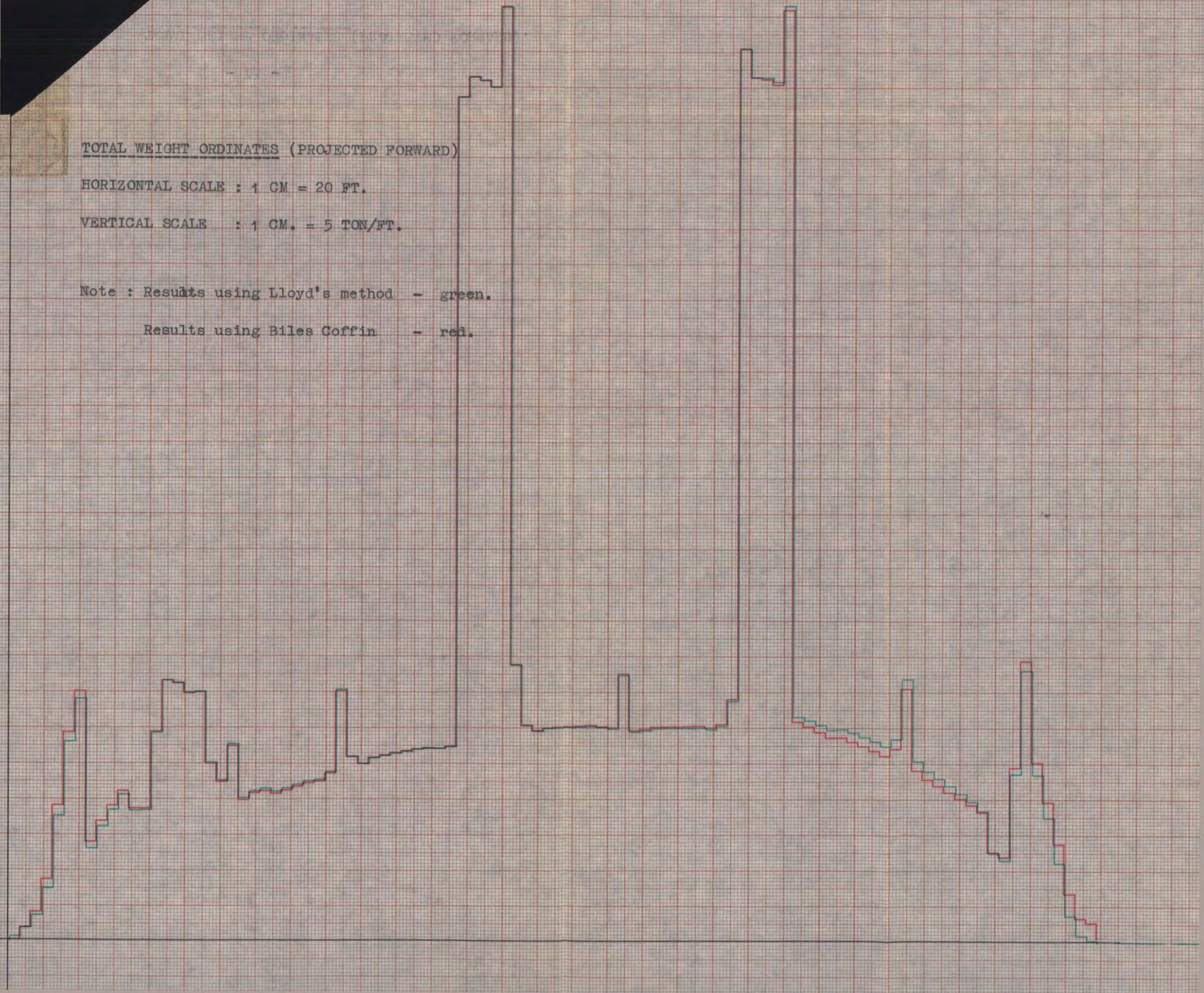
TOTAL WEIGHT CURVE ORDINATES (PROJECTED FORWARD)

X-AXIS DISTANCE (CMS) FROM BASE OF GRAPH PAPER = 0

HEIGHT OF Y-AXIS = 30

HORIZONTAL SCALE OF GRAPH --- 1.CM = 20 FT

VERTICAL SCALE OF GRAPH --- UNITS/CM:- 5.0


TOTAL WEIGHT ORDINATES (PROJECTED FORWARD)
HORIZONTAL SCALE : 1 CM = 20 FT.
VERTICAL SCALE : 1 CM. = 5 TON/FT.
Note : Results using Lloyd's method - green.
Results using Biles Coffin - red.

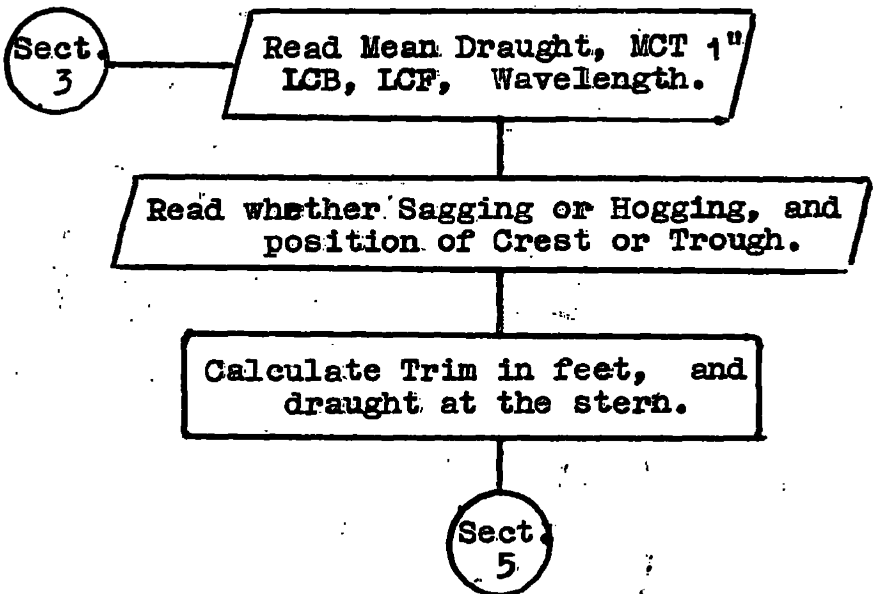
- 73 -

TOTAL WEIGHT ORDINATES (PROJECTED FORWARD).

FLOW CHART (Programme Page 14)

(Section 4).

COMPUTATION OF TRIM, AND DRAUGHT AT STERN.



PART 4

COMPUTATION OF TRIM AND DRAUGHT AT STERN

Computing Trim

(Note: the vessel trims about its L.C.F. at the draught considered). Consider the situation where the L.C.G. and L.C.B. are not coincident. There will be a moment tending to tilt (known as trimming) the ship lengthwise about the L.C.F. Fig. 25. Let the distance between the L.C.G. and L.C.B. be $\underline{d}$, and let the displacement of the vessel be Δ. Then the moment above will be $\Delta.d$. This will trim the ship until the two centres are coincident, and there will be some measure (in inches) by which the vessel at the after-perpendicular is more (or less) submerged than at the fore-perpendicular. Fig. 26. This is known as the trim in inches. Now the moment to change this trim by 1 inch is known as the MCT 1". Dividing the above moment by 12 x MCT 1" we obtain the trim in feet over the L_{BP}.

$$\text{i.e. Trim (in feet)} = \frac{\Delta.d}{12\text{xMCT } 1''}$$

Further division by L_{BP} gives the trim in ft. per foot, and since it trims about the L.C.F. we find:

$$\text{Draught at stern} = \text{Mean Draught} \pm \frac{(\text{Trim x L.C.F. fwd. of A.E})}{\text{Length}_{BP}}$$

The draught at any position along the length of the vessel is easily determined from its distance from the stern, in conjunction with the trim per ft.

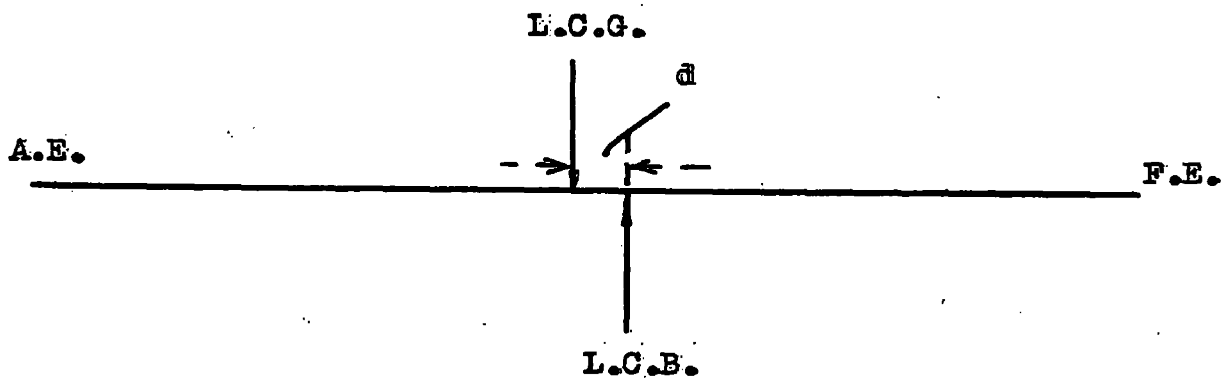


Fig. 25.

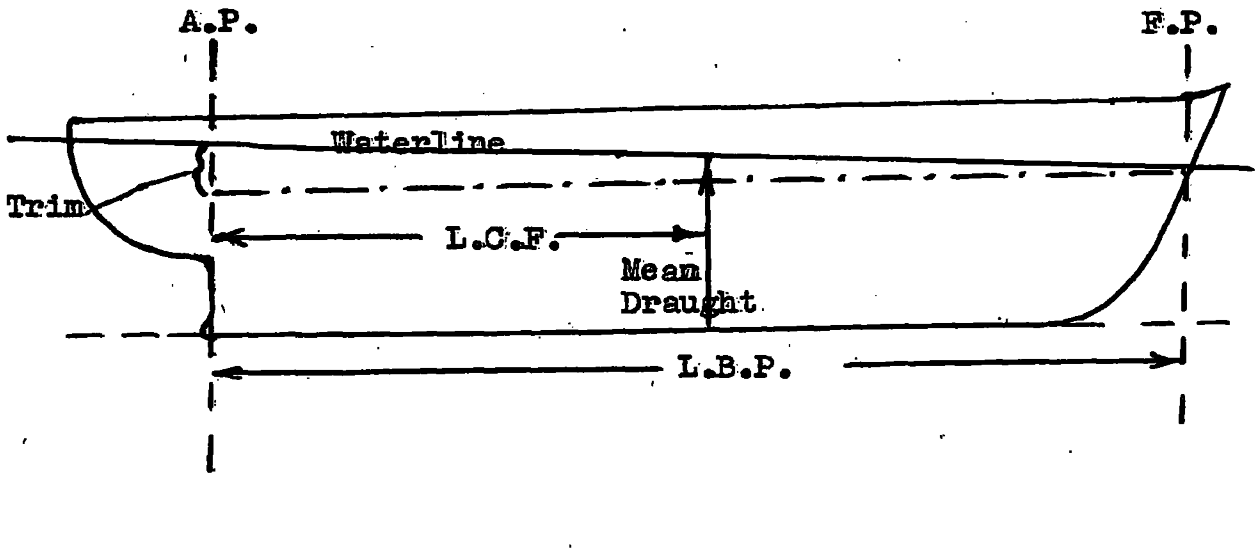


Fig. 26.

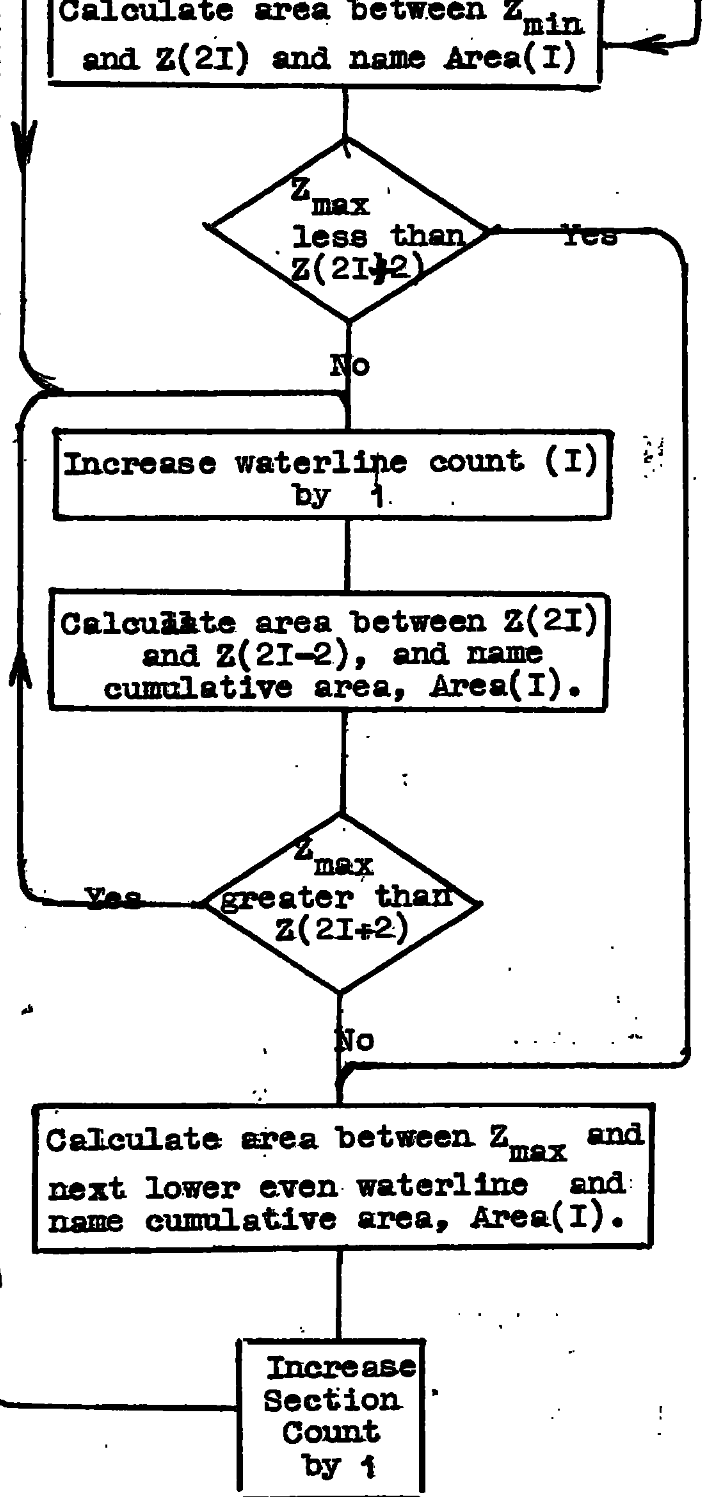
FLOW CHART

(Section 5).

SECTIONAL AREAS

F O L D

D O W N

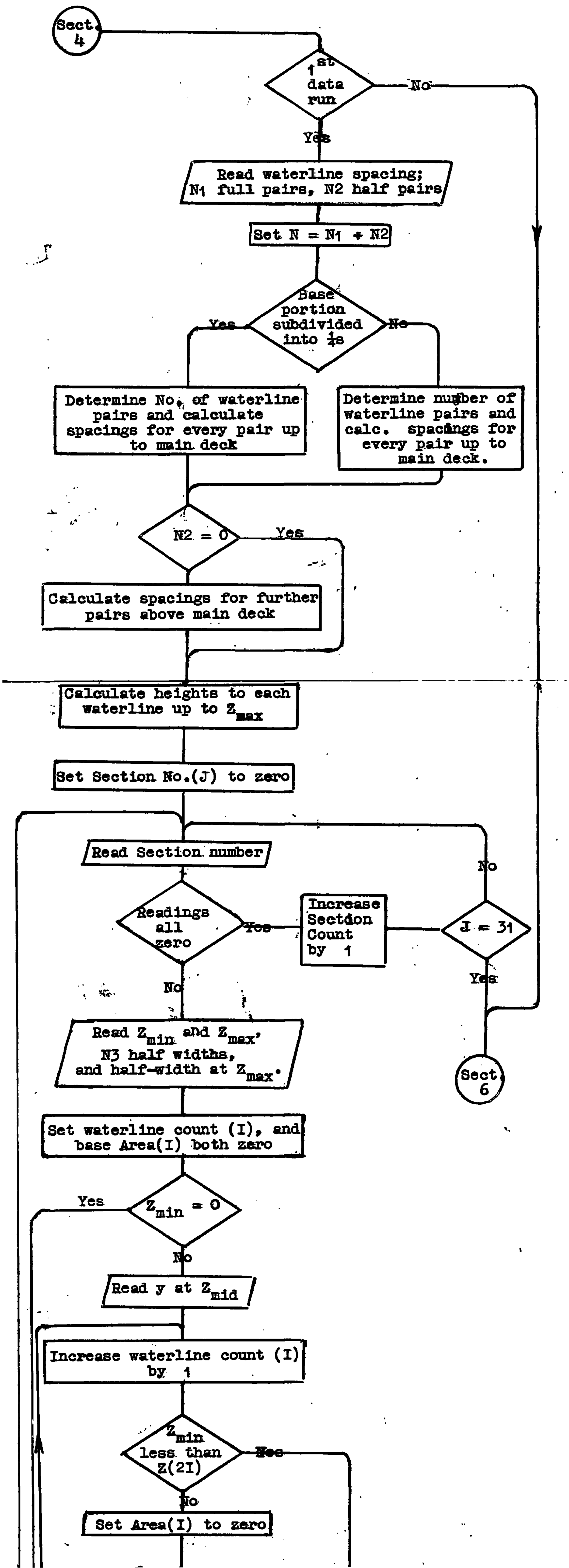


Calculate area between Z_{min} and $Z(2I)$ and name Area(I)
Z_{max} less than $Z(2I+2)$
Yes
No
Increase waterline count (I) by 1
Calculate area between $Z(2I)$ and $Z(2I-2)$, and name cumulative area, Area(I).
Z_{max} greater than $Z(2I+2)$
Yes
No
Calculate area between Z_{max} and next lower even waterline and name cumulative area, Area(I).
Increase Section Count by 1

FLOW CHART

(Section 5).

CALCULATION AND STORAGE OF IMMERSED SECTIONAL AREAS.



PART 5

CALCULATION AND STORAGE OF IMMERSED SECTIONAL AREAS TO EACH EVEN WATERLINE

This portion of the programme is an adaptation of Elliott Application programme LSB 3A. LSB 3A was sent to the computing laboratory of Sunderland Technical College in June 1963, for comments, and possible improvements. The writer amended the programme to produce more accurate results from lower waterline data, and the small portion of the programme affected is now used as a basis in this Longitudinal Strength programme to compute and store immersed sectional areas to each even waterline.

Process Used

The ship is divided as follows: Horizontal waterlines are taken, spaced at distance 'h' apart, and arranged so that an even number of spaces (2n) from the base reaches either to the upper deck at side or to a point just below the upper deck, at its lowest point.

i.e. $(2n).h \leq$ Height to main deck $< (2n + 1).h$.

The two lowest divisions may be subdivided in two ways, by setting a control constant, according to the shape of the bottom of the ship. For ships with flat (horizontal) bottoms, the waterlines should be, from the base upwards ; 4 spacings of h/4 and 2 spacings of h/2. The alternative is 4 spacings of h/8, 2 of h/4 and 2 of h/2.

Above the (2n)th waterline further waterlines are taken with spacings of h/2 until the maximum height of the ship is included in the last pair. See Fig. 27(a).

All waterlines (lettered i) are now grouped in pairs lettered q) starting from the base line. We have, therefore:-

1 pair (subdivided as above),

N1 pairs (of width 2h.) taking us up to the upper deck at side,

N2 pairs (of width h) taking us to the maximum height of the vessel.

The maximum value of q for the whole ship is N.

Spacings of waterlines (from i = 0 to i = 2N)	Waterline number, i. (from base upwards)	Group number, q. (from base upwards)
Method 1. N = N1 + N2 + 3		
h/4	1, 2, 3, 4.	1, 2.
h/2	5, 6.	3
h	7, 8 ... (2N1+6)	4, 5 .... (N1+3)
h/2	(2N1+7),(2N1+8)...2N	(N1+4) .... N
Method 2. N = N1+N2 + 4		
h/8	1, 2, 3, 4.	1, 2.
h/4	5, 6	3
h/2	7, 8	4
h	9, 10 ... (2N1+8)	5, 6 .... (N1+4)
h/2	(2N1+9),(2N1+10)...2N	(N1+5),(N1+6) .. N

Values of h, N1, N2 and the control for choice of Method 1, or Method 2 (Q1) are read in. Using Vary loops, heights to all waterlines (i values) are computed, using F.Pt. variable Z, and areas to all even waterlines computed and stored. 0(25J + P), (P = q), where J takes values 0 - 30 in the Loop.

The calculations are performed as follows:-

The shape of the vessel is defined by the ordinate g_{xz}, (the half width) given for each waterline (i). The integrals are calculated using Simpson's Rule and trapeziums. At the upper and lower edges, however, a slight variation is necessary. The half-width g_{max} must be given at the value of z_{max}. It is then assumed that the section curve is replaced by a straight line, and the area is obtained by treating the top part as a trapezium between the limits z_q and z_{max}. ($z_q < z_{max} \leq z_{q+1}$). At the lower edge, for $z_{min} > 0$, a half width g_{mid} is required such that

$$g_{mid} = g\left(\frac{z_q + z_{min}}{2}\right)$$

where $(z_q - 1) \leq z_{min} < z_q$ (See fig. 27b)

The integration of this portion is made between the limits z_{min} and z_q.

The areas are calculated according to the formulae:-

For a given q $\qquad\qquad$ $O(25J + P) =$

$z_{min} \geq z_q$	0
$z_{q-1} < z_{min} < z_q$	$2\left[\frac{1}{3}\left\{\frac{z_q - z_{min}}{2}\right\}(4y_{mid} + y_q)\right]$
$z_{min} < z_{q-1}$ and $z_q \leq z_{max}$	$O_{q-1} + 2\left[\frac{1}{3}(\delta z_i)(y_{q-1} + 4.y_{q-\frac{1}{2}} + y_q)\right]$
$z_q < z_{max} < z_{q+1}$	$O_q + \left[2(z_{max} - z_q)\left(\frac{y_{max} + y_q}{2}\right)\right]$

Areas are thus calculated to every even waterline for every section, where P is the waterline count in pairs.

e.g. $O(25J + P)$ where J is 3 and P is 7 is the area at Section 3 up to $q = 7$ (or $i = 14$).

(The use of P in these notes is purely for clarity, but the programme, in fact, overwrites I as the count variable for the waterline pairs).

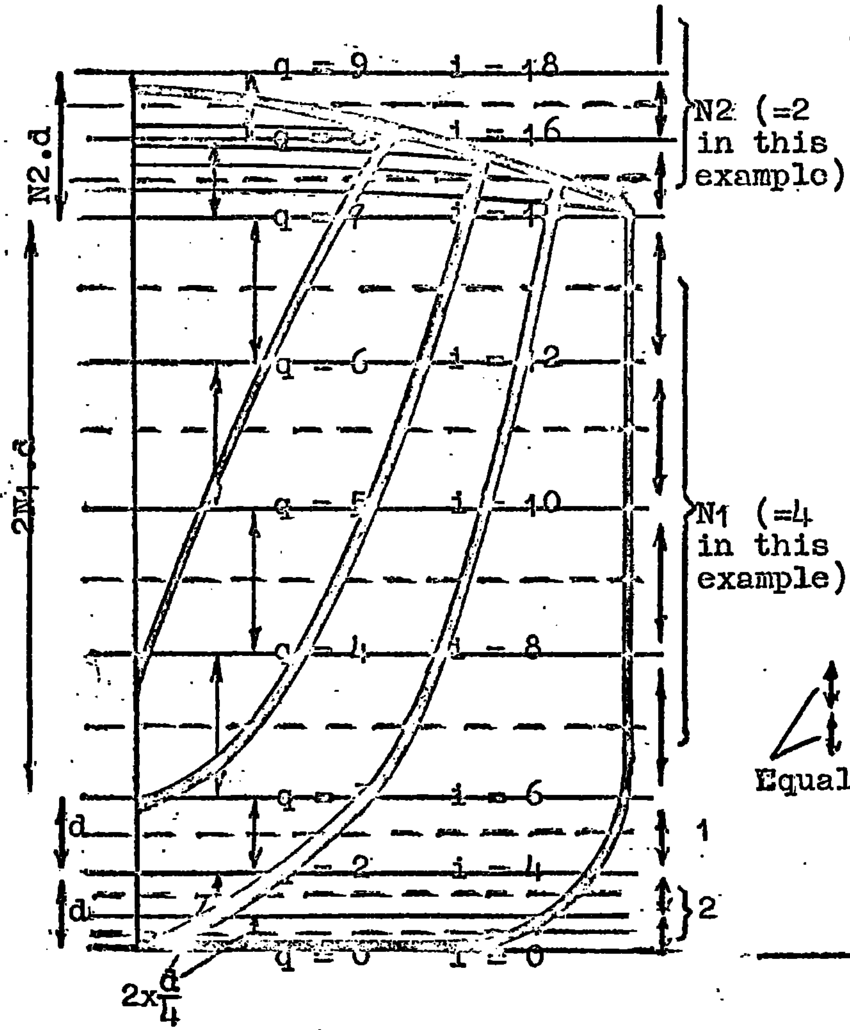


Fig 27(a) Waterline spacing.
(Method 1. See p77)

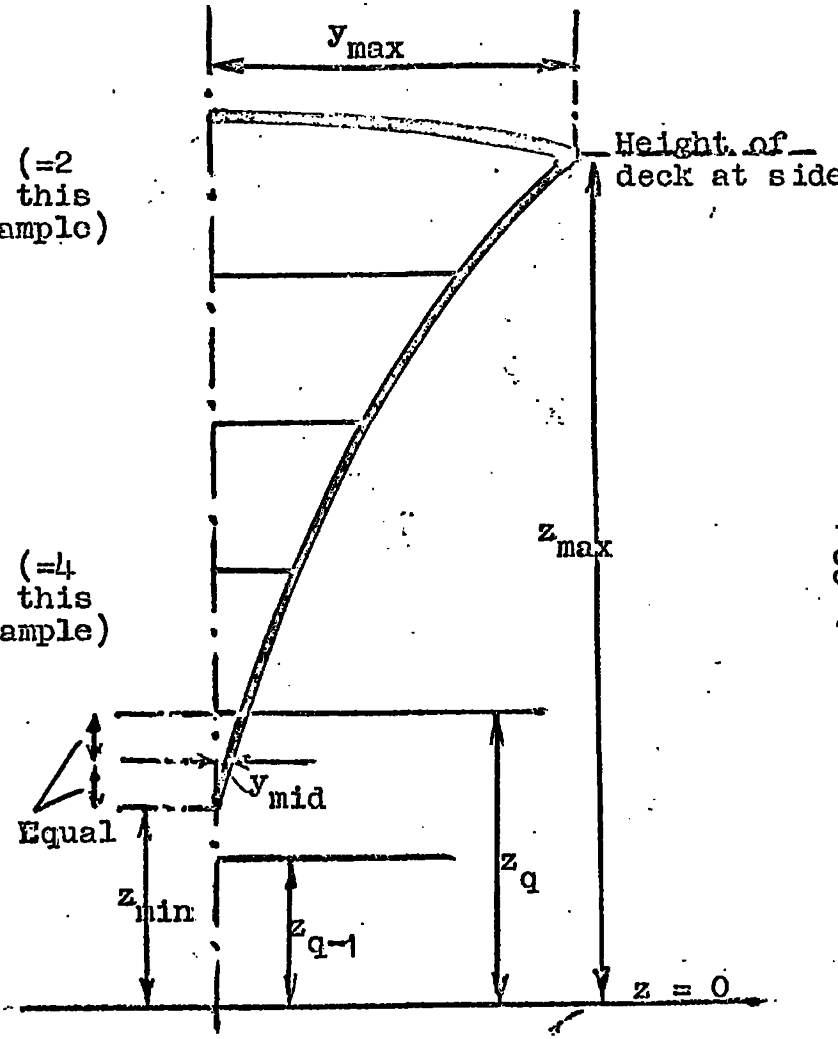
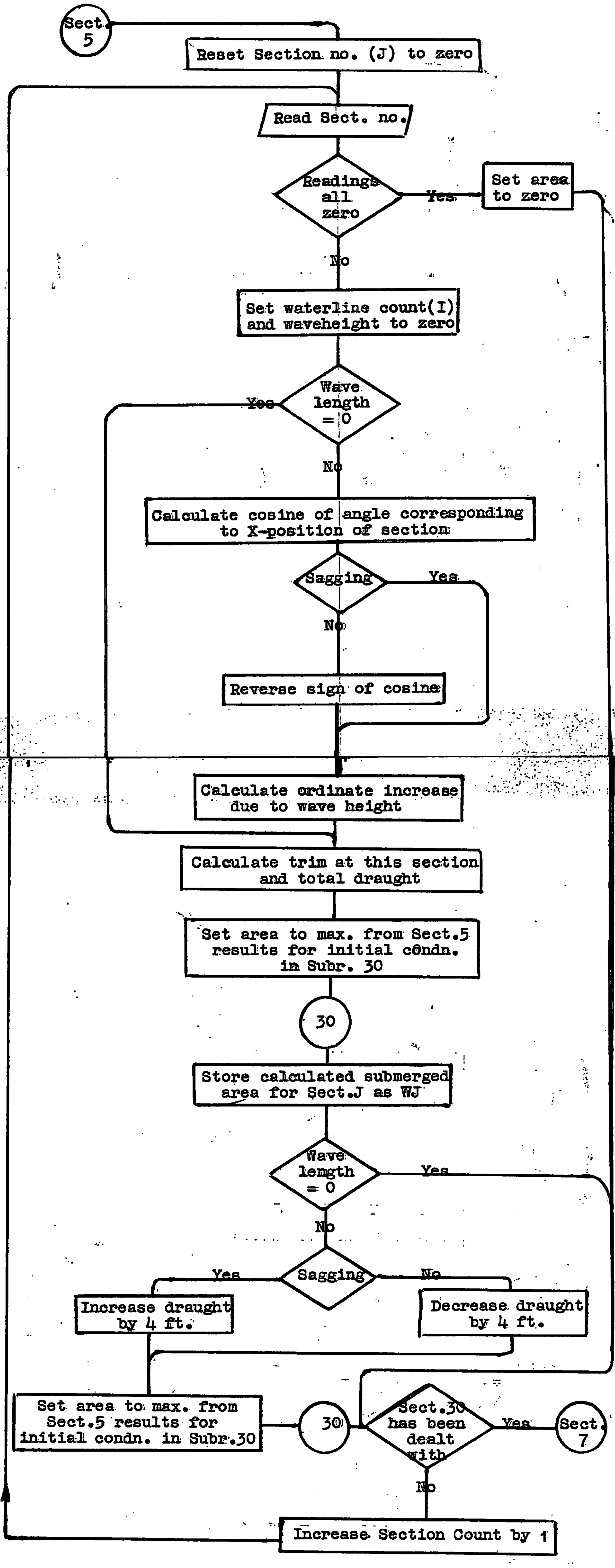


Fig 27(b)

FLOW CHART (Programme Page 17)

(Section 6).

DRAUGHTS AND IMMERSED SECTIONAL AREAS

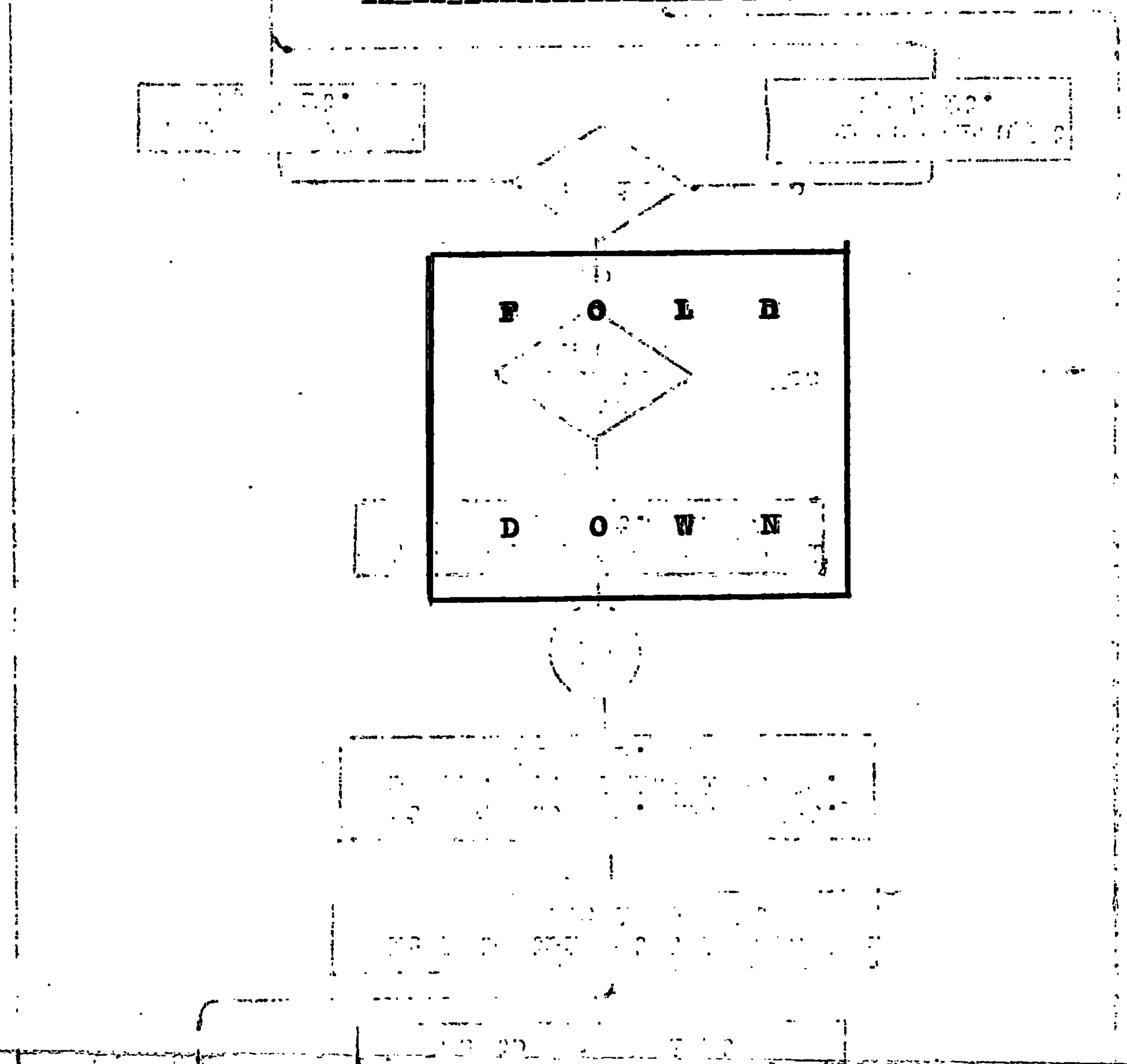


FLOW CHART

(Section 6).

DETERMINATION OF DRAUGHTS AND CONSEQUENT IMMERSED

SECTIONAL AREAS AT EACH STATION



PART 6

DETERMINATION OF DRAUGHTS AND CONSEQUENT IMMERSED SECTIONAL AREAS AT EACH STATION

Stations are taken in order, and the calculation for each station completed before dealing with the next station.

The draught to the still water level is determined (so far as Trim is concerned) as mentioned in Part 4. The programme provides, however, for the vessel to be in a sine wave, and the amended draughts to the water surface are now determined if this condition applies. For each station in turn, the draught is found by adding to the still water draught the corresponding ordinate of the sine wave.

The appropriate ordinate for a particular distance x from the stern is given by the formula:-

$$\text{Ordinate} = \pm a \cos \frac{2\pi(x - x')}{\lambda}$$

where a is the amplitude and x' the distance from the rearmost point of stern to the position of the first trough or crest.

Wave height, a, length, λ, and position relative to the ship, x', may be varied as required, but in these following examples, only two conditions have been taken, i.e. wavelength equal to L_{BP} and (i) first wave crest at the A.P., and (ii) first wave trough at the A.P.

Referring to Fig. 28 (a) and (b), and taking the wavelength to be L_{BP} the angular measure θ^c at any distance x is $\frac{2\pi(x - L1)}{L_{BP}}$.

Since zero angle corresponds to the position of the crest (if in 'sagging' condition, or the trough in the 'hogging' condition), then in this example zero angle is at the A.P. The angle corresponding to the extreme stern will be found from the following steps:-

$$X = XJ - L_1 \quad \text{i.e. } 0 - L_1 \text{ or } -L_1$$

Therefore $$\theta^c = \frac{2\pi(-L_1)}{\lambda}$$

and the ordinate to be added to the still-water height is

$$\cos \frac{2\pi\ (-L_1)}{\lambda} \cdot (\text{Amplitude})\ .$$

Similarly the ordinate at any position XJ is given by

$$\cos \frac{2\pi\ (XJ - L_1)}{\lambda} \cdot (\text{Amplitude})\ .$$

The Sectional area cut off at this total draught is calculated for each station respectively, and will be understood from fig. 29. Submerged areas are stored using F.Pt. variable WJ, where J is the station number.

Again, where a sine wave is considered, and not just the still-water line, the above procedure (for finding immersed areas) is repeated for positions of the wave $\pm$ 4 ft. from the basic position (for use in Muckle's method) the plus sign being operative where the 'sagging' condition is being considered, and the minus where we have 'hogging'. Such areas are stored as F.Pt. variable UJ.

We are now ready to calculate the volume displaced and where the sine wave is encountered, the first and second moment functions, for use in Muckle's method. The volume of displacement is very simply found at each station, by considering unit length at each station. The immersed area is now a measure of this volume and division by 35 gives the Buoyancy in ton/ft. at the point. This is repeated at each of the 31 stations, and where there is no sine wave, the interpolation routine is entered to obtain the buoyancy values at each one-hundredth of the ships length.

<u>Sagging Condition</u>

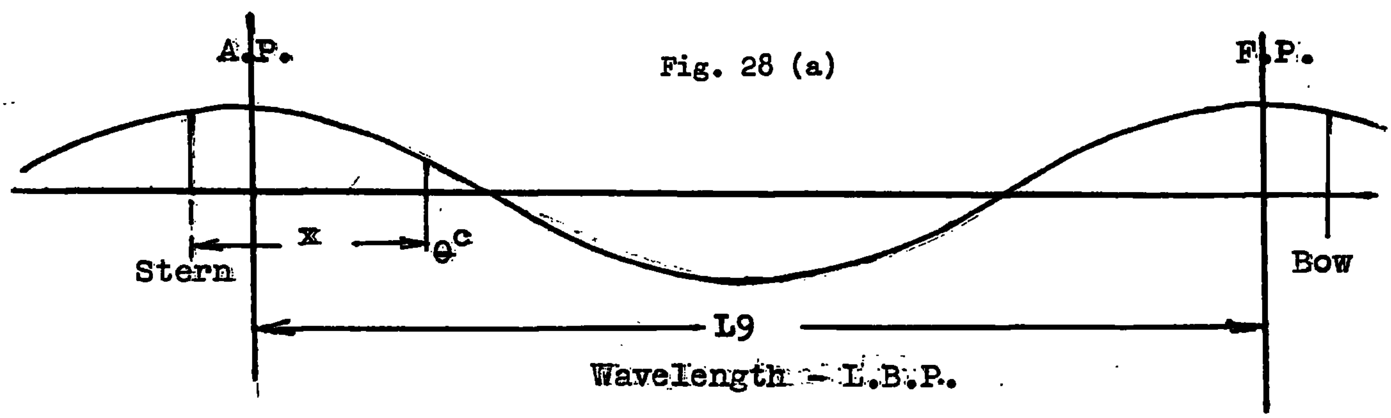


Fig. 28 (a)

<u>Hogging Condition.</u>

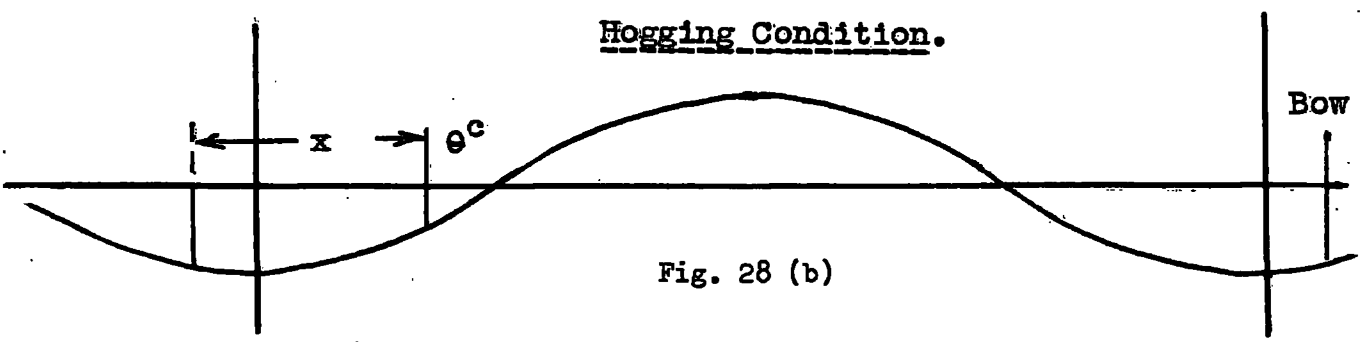
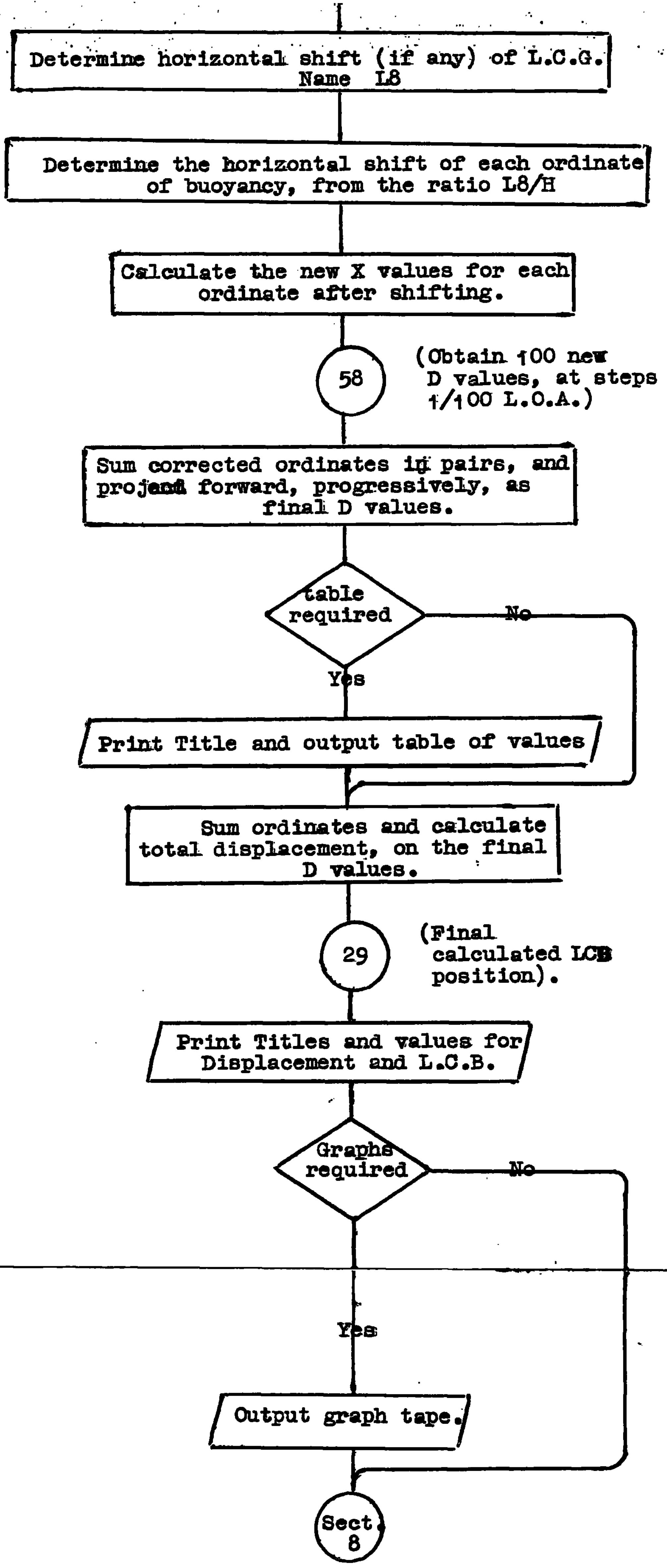


Fig. 28 (b)

Three point Lagrange interpolation is used. The first and last of the 31 stations which have a reading greater than zero are found, and these are numbered I and J. The interpolation is then carried out between stations (I - 1) and (J + 1).

After interpolation the total displacement is found (using Simpson's method). The value obtained may differ slightly from the known total buoyancy and if so, the calculated value is adjusted by adding, algebraically, small equal amounts to each ordinate. This may still leave the calculated L.C.G. in error (marginally) so ordinates are adjusted in the same manner as that employed in Lloyd's continuous weight distribution. See page 45.


Determine horizontal shift (if any) of L.C.G. Name L8
Determine the horizontal shift of each ordinate of buoyancy, from the ratio L8/H
Calculate the new X values for each ordinate after shifting.
58
(Obtain 100 new D values, at steps 1/100 L.O.A.)
Sum corrected ordinates in pairs, and project forward, progressively, as final D values.
table required
No
Yes
Print Title and output table of values
Sum ordinates and calculate total displacement, on the final D values.
29
(Final calculated LCB position).
Print Titles and values for Displacement and L.C.B.
Graphs required
No
Yes
Output graph tape.
Sect 8

FLOW CHART

(Section 7).

ADJUSTMENT OF SUBMERGED AREAS USING MUCKLE'S METHOD

AND DETERMINATION OF BUOYANCY ORDINATES

F O L D

D O W N

FLOW CHART (Programme Page 18)

(Section 7).

ADJUSTMENT OF SUBMERGED AREAS USING MUCKLE'S METHOD AND DETERMINATION OF BUOYANCY ORDINATES.

Sect. 6

Wave length. = 0

Yes

No

Set all volumes and moments for this section to zero, and I = 1

Form volume of displacement for Sections 2I, 2I-1, and 2I-2 (Simpson's), using submerged areas WJ as ordinates; also sum moments of these areas about the stern, and sum the 2nd moments of these areas about the stern.
Sum names : Q1, M and M3 respectively.

Repeat above calculations, using submerged areas UJ, and name ~~sums~~ : Q3, M1 and M4.

All Sections taken

No

Increase I by 1

Yes

Solve simultaneous equations from above coefficients to find rise and tilt, a and b

Calculate adjustments to each ordinate according to the formula

$$y = a + \frac{bx}{L}$$

Convert measures of area (WJ), to tons upthrust (AJ).

Set DR = 0, for R = 0:1:100

Determine the ordinates within which the Buoyancy values AJ are greater than zero. Lower and upper named I and J respectively.

Set the first three values of Buoyancy ordinates and corresponding X-distances, (for Subr.58), using value of I determined above.

58 (Interpolate 100 D values from origi

Integrate the buoyancy curve produced to determine the resultant displacement

Calculate the difference from the true displacement, and distribute this difference ~~uniformly~~ over those of the 100 ordinates which aready have values, other than zero

Re-integrate, (and check, if required)

Calculate semi-sum of ordinates in pairs and store as B-values projected forward.

29 (Obtain provisional L.C.G.)

Calculate vertical position of centroid of curve, using above 100 d-values.
Name H.

PART 7

MUCKLE'S METHOD FOR SUPERIMPOSED SINE WAVE: ADJUSTMENT OF BUOYANCY ORDINATES FOR CORRECT DISPLACEMENT AND L.C.F.

If the waterline is not a straight one, a further calculation must be performed to find the true buoyancy at each station. When a sine-wave is superimposed upon the still-water line in this fashion, the displacement cut off by the wave is not the required displacement. The wave must be adjusted for the required displacement, and so that the centre of buoyancy is in the same vertical line as the centre of gravity. The method used in the programme is one described by W. Muckle in "The Ship Builder and Marine Engine-Builder", February 1954 from which the following notes are taken.

If 'sagging' is being considered, then the wave must be raised and tilted. The amount which the wave must be raised at any position in the length of the ship may be written:

$$y = a + \frac{bx}{L},$$

where 'a' and 'b' are constants and x is measured from the rearmost point of the stern; L is the length overall of the vessel.

For any given station, let the area cut off by the wave, before adjustment, be Ao, and let the area at a position 4 ft. above that be A4. An examination of the Bonjean curves shows that the curve between these two positions could well be represented by a straight line, so that the area at any point 'y' above the initial wave position will be: (See fig. 29)

$$Ao + y \frac{(A4 - Ao)}{4} = Ao + \left(a + \frac{bx}{L}\right) \left(\frac{A4 - Ao}{4}\right)$$

The total volume after the wave has been shifted must be equal to the required volume 'V' corresponding to the loading condition.

$$\text{i.e.} \int Ao \, dx + \int \left[\left(a + \frac{bx}{L}\right) \left(\frac{A4 - Ao}{4}\right) \right] dx = V.$$

This may be written:

$$\int Aodx + a \int \left(\frac{A4 - Ao}{4}\right) dx + b \int \frac{x}{L} \left(\frac{A4 - Ao}{4}\right) dx = V \; \ldots\ldots\ldots \; \text{(i)}$$

Similarly the Moment of the area about the stern is given by:

$$Ao.x + \left(a + \frac{bx}{L}\right) \left(\frac{A4 - Ao}{4}\right) x \, ,$$

and the Moment of the Volume must equal $V.\bar{x}$ where $\bar{x}$ is the distance of the centre of buoyancy from the stern.

Therefore,

$$\int Ao.x \, dx + \int \left[\left(a + \frac{bx}{L}\right) \left(\frac{A4 - Ao}{4}\right) x \right] dx = V.\bar{x}$$

which may be written:

$$\int Ao.x \, dx + a \int x \left(\frac{A4 - Ao}{4}\right) dx + b \int \frac{x^2}{L} \left(\frac{A4 - Ao}{4}\right) dx = V\bar{x} \; \ldots \; \text{(ii)}$$

Equations (i) and (ii) will provide the solutions to the two unknowns 'a' and 'b'. $\int$ Ao. dx is the volume function and in the programming of (i) and (ii) above is the F.Pt. variable Q1.

$\int$ Ao.x dx is the 1st moment .... M.

$\int \left(\frac{A4 - Ao}{4}\right)$ dx is the volume function of the differences .... Q3.

$\int x\left(\frac{A4 - Ao}{4}\right)$ dx is the difference in 1st moment functions ... Q2.

$\int x^2\left(\frac{A4 - Ao}{4}\right)$ dx is the difference in 2nd moment functions .. Q5.

If 'hogging' is being considered, then the wave must be lowered and tilted. The amount by which the wave must be lowered at any point in the length of the ship is, as before, given by $y = a + \frac{bx}{L}$, and the same equations hold as for 'sagging'. Of course, A4 - Ao will be negative, since A4 is determined when the wave form is taken 4 ft. below the original position.

Having now found the true areas for the wave form condition, the buoyancy is found as previously mentioned (page 83) and the interpolation routine entered to find the buoyancy at every one-hundredth division of the ship's length.

In spite of Muckle's method being applied to the displacement and L.C.B. position, it is quite likely to leave the final results in slight error. This slight error, if any, is finally corrected by the method outlined on pages 84 and 45.

Buoyancy ordinates are now stored as DR and are printed out if required. (Ordinates are Projected forward as before). Graph output is optional.

Pages 89-92 show the Bonjean input data extracted from the complete Hull Definition Data Sheet as shown on page (169). After the initial BONJEAN head data, data is read vertically, column by column.

Page 93 shows the tabulated output for A842 and on page 94 may be seen the corresponding graph.

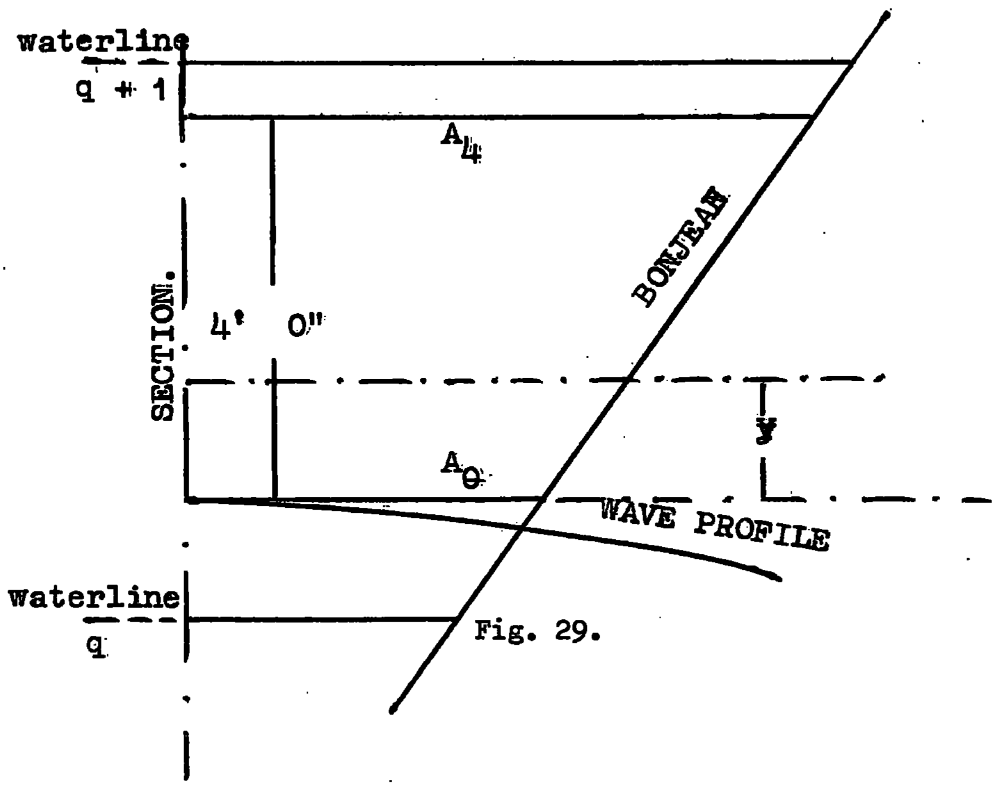


Fig. 29.

```
                                  (H  - waterline spacing
                                  (Q1 - choice of 1/8s or 1/4s.
3  .25  7  3  - - - - -           (N1 - pairs of full spacings
                                  (N2 - pairs of half spacings

                    (S19    - station number.
                    (P(J+5) - zero if no half widths.
0  0  - - - -       (Z(51+J)- Z min.
                  - (Z(82+J)- Z max

1  1  34.313  49.407
0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  2.25  5.167
7.583  9.75  11.646  0  0  0  0  0  0 (Half-widths:
12.447  1.396 - - - - - - - - -          27 in this case.
                                  (G52  -  G max
                                  (G51  -  G mid

2  1  29  49.290
0  0  0  0  0  0  0  0  0  0  0  0  0  1.573  4.88  7.969
10.677  13.031  15.063  16.813  0  0  0  0  0  0
17.465  1.037

3  1  26.292  49.181
0  0  0  0  0  0  0  0  0  0  0  0  0  1.38  5.162  8.755
11.901  14.583  16.932  18.906  20.589  0  0  0  0  0  0
21.184  2.917

4  1  24.304  48.985
0  0  0  0  0  0  0  0  0  0  0  0  0  4.229  8.234  11.969
15.130  17.802  20.094  22.042  23.703  0  0  0  0  0  0
24.196  4.55

5  1  21.865  48.740
0  0  0  0  0  0  0  0  0  0  0  0  3.365  7.667  11.693
15.412  18.568  21.214  23.458  25.37  27.042  0  0  0  0  0
27.395  1.750

6  1  0  48.598
1.042  1.083  1.109  1.12  1.13  1.146  1.162  1.182  1.208
1.245  1.557  3.162  6.802  10.885  14.839  18.427  21.479
24.078  26.271  28.12  29.745  0  0  0  0  0  0
30.021

7  1  0  48.48
1.047  1.51  1.813  2  2.151  2.385  2.583  2.917  3.281
3.807  4.818  6.802  10.109  13.932  17.702  21.109  24
26.505  28.625  30.391  31.912  0  0  0  0  0  0
32.124
```

8 1 0 48.394
1.406 2.063 2.537 2.880 3.172 3.625 4.005 4.651 5.354
6.37 7.901 10.219 13.313 16.880 20.401 23.521 26.292
28.646 30.641 32.281 33.656 0 0 0 0 0 0
33.818

9 1 0 48.25
2.12 3.469 4.219 4.813 5.307 6.162 6.88 8.224 9.687
11.453 13.687 16.323 19.224 22.307 25.234 27.885 30.245
32.255 33.932 35.255 36.313 0 0 0 0 0 0
36.391

10 1 0 48.154
3.13 5.266 6.245 7.037 7.724 8.875 9.922 11.964 14.073
16.354 18.849 21.583 24.323 26.984 29.422 31.599 33.5
35.083 36.344 37.333 38.115 0 0 0 0 0 0
38.142

11 1 0 48.04
6.406 9.724 11.182 12.313 13.307 15.099 16.698 19.615
22.339 24.974 27.531 29.948 32.099 34 35.630 36.99
38.104 38.927 39.526 39.969 40.276 0 0 0 0 0 0
40.273

12 1 0 48.00
11.078 15.0 16.854 18.302 19.542 21.662 23.448 26.542
29.182 31.488 33.531 35.328 36.818 38.068 39.068 39.828
40.354 40.693 40.875 40.974 41.00 0 0 0 0 0 0
41

13 1 0 48.00
21.552 26.24 28.281 29.807 31.037 32.969 34.479 36.693
38.198 39.24 39.964 40.448 40.766 40.938 41 41 41 41
41 41 41 0 0 0 0 0 0
41

14 1 0 48
30.813 34.547 36.12 37.24 38.109 39.349 40.146 40.88 4
41 41 41 41 41 41 41 41 41 41 41 41 0 0 0 0 00
41

21 1 0 53.809
6.927 10.828 12.488 13.719 14.729 16.318 17.531 19.313
20.516 21.422 22.115 22.698 23.208 23.672 24.125 24.578
25.073 25.563 26.146 26.771 27.427 27.771 28.141 28.516
0 0 0
28.851

22 1 0 54.828
2.74 5.656 7.031 8.052 8.88 10.208 11.219 12.687 13.67
14.443 15.047 15.552 16 16.438 16.87 17.344 17.87 18.5
19.104 19.849 20.672 21.109 21.568 22.047 22.583 0 0
22.875

BUOYANCY CURVES ORDINATES (PROJECTED FORWARD).

X-AXIS DISTANCE (CMS) FROM BASE OF GRAPH PAPER = 0

HEIGHT OF Y-AXIS = 30

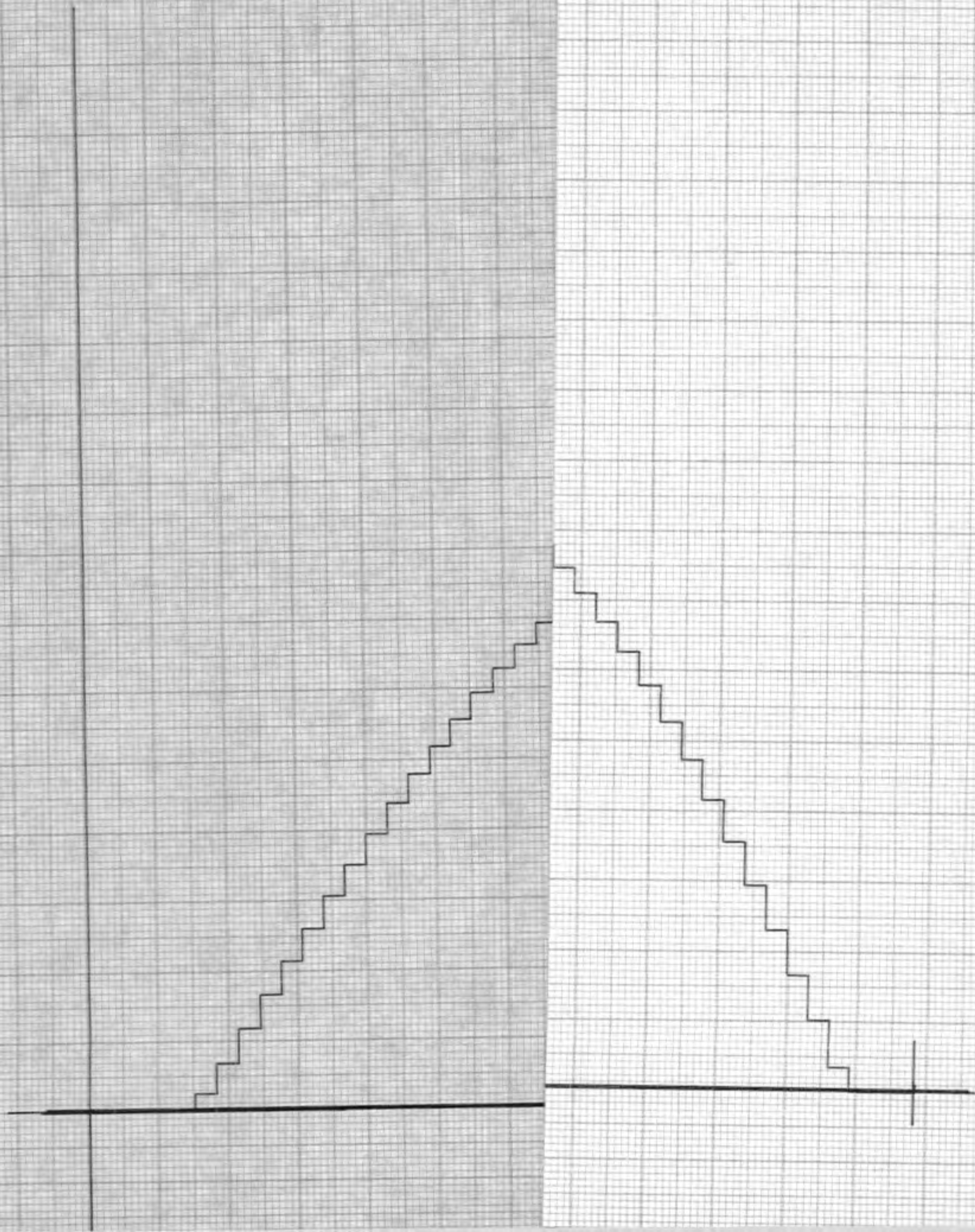
HORIZONTAL SCALE OF GRAPH --- 1 CM = 20 FT

VERTICAL SCALE OF GRAPH --- UNITS/CM:- 5.0

BUOYANCY CURVE ORDINATES

HORIZONTAL SCALE : 1 CM.

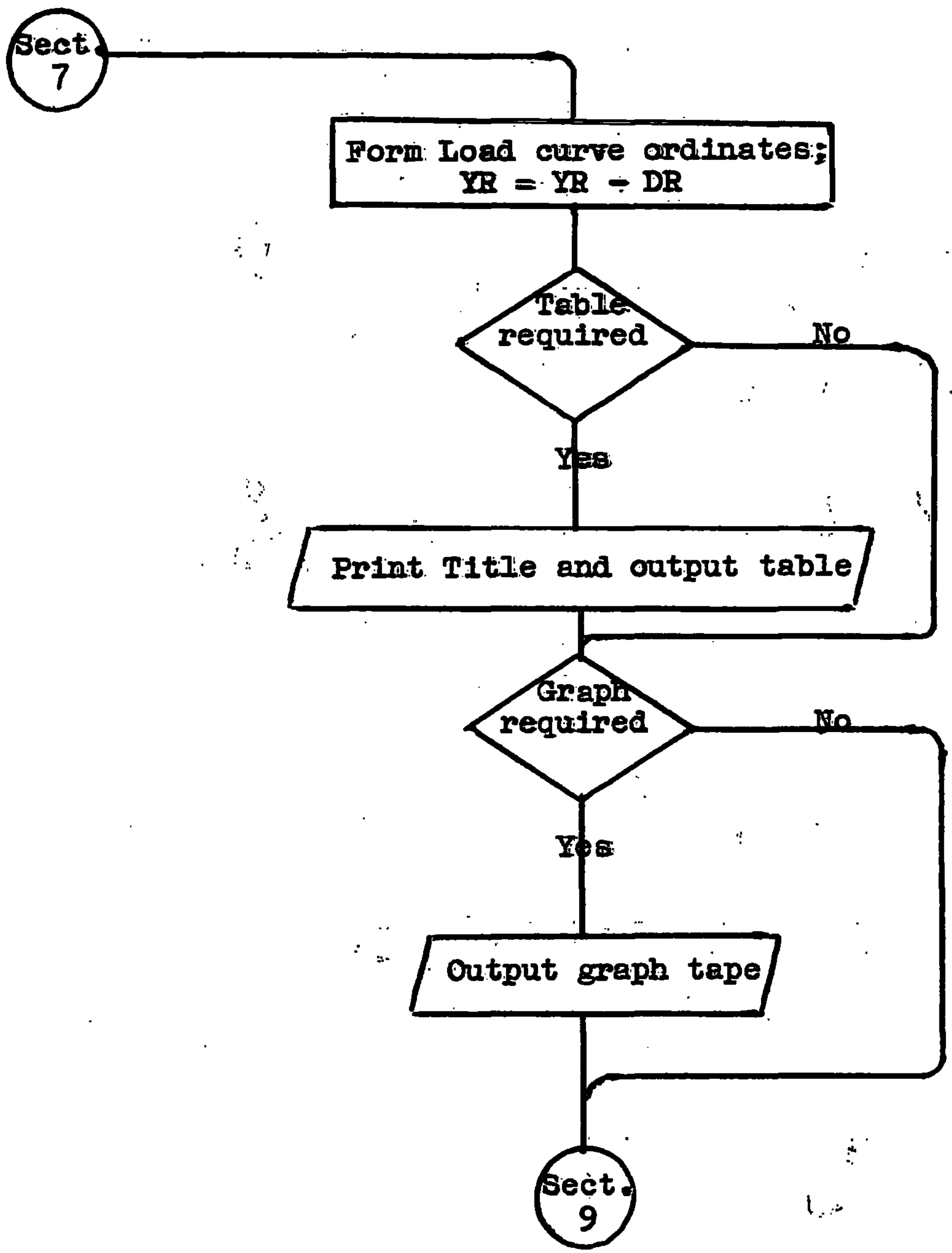
VERTICAL SCALE : 1 CM.



FLOW CHART (Programme Page 24)

(Section 8).

LOAD CURVE SECTION.



PART 8

LOAD CURVE

Load Curve ordinates are obtained by subtracting respectively the Total Weight ordinates from the Buoyancy ordinates. (These ordinates are projected forward like the Weight and Buoyancy ordinates). F.Pt. variable YR was used for Weight ordinates and DR for Buoyancy ordinates. The Load Curve ordinates are now held as YR(YR = YR - DR) and printed out if required. Graph output of the Load Curve is available if required.

The Load Curve tables for A842 are on pages 96 (using Lloyd's method) and 96(a) (using Biles Coffin), and the corresponding graphs (green for Lloyd's method - red for Biles Coffin) are on page 97.

LOAD CURVE ORDINATES (PROJECTED FORWARD)

(BILES COFFIN DISTRIBUTION)

ORD NO.	LOAD TON/FT	ORD NO.	LOAD TON/FT	ORD NO.	LOAD TON/FT	ORD NO.	LOAD TON/FT
0	-0.16	1	-1.84	2	-4.09	3	-8.70
4	-19.00	5	-28.01	6	-31.59	7	-8.01
8	-8.54	9	-8.31	10	-8.03	11	-3.31
12	-1.10	13	-9.66	14	-14.67	15	-12.19
16	-8.79	17	-7.03	18	4.80	19	9.05
20	5.67	21	14.79	22	15.31	23	16.42
24	18.18	25	18.93	26	19.60	27	20.20
28	21.01	29	20.82	30	10.18	31	20.25
32	21.86	33	21.53	34	21.63	35	21.74
36	21.87	37	21.96	38	22.13	39	22.48
40	22.44	41	-68.66	42	-71.49	43	-70.99
44	-70.08	45	-81.50	46	10.95	47	19.35
48	20.02	49	19.52	50	19.36	51	19.19
52	19.01	53	18.82	54	18.85	55	18.91
56	11.22	57	19.02	58	18.64	59	18.16
60	17.98	61	17.81	62	17.65	63	17.49
64	17.57	65	16.93	66	13.32	67	-78.33
68	-74.32	69	-74.25	70	-73.72	71	-84.57
72	15.24	73	15.54	74	15.93	75	16.31
76	15.84	77	15.99	78	16.14	79	16.01
80	15.51	81	13.21	82	3.31	83	13.21
84	12.70	85	11.57	86	10.26	87	8.77
88	7.11	89	5.42	90	8.20	91	5.88
92	-9.77	93	-27.85	94	-16.83	95	-14.49
96	-12.02	97	-6.81	98	-3.28	99	-2.70
100	0.00						

Table 13(a).

LOAD CURVE ORDINATES (PROJECTED FORWARD)

(LLOYD'S DISTRIBUTION)

ORD NO.	LOAD TON/FT	ORD NO.	LOAD TON/FT	ORD NO.	LOAD TON/FT	ORD NO.	LOAD TON/FT
0	-0.69	1	-2.01	2	-3.72	3	-7.48
4	-17.62	5	-26.84	6	-30.60	7	-7.19
8	-7.88	9	-7.80	10	-7.65	11	-3.06
12	-0.95	13	-9.60	14	-14.70	15	-12.29
16	-8.95	17	-7.25	18	4.54	19	8.76
20	5.34	21	14.44	22	14.94	23	16.04
24	17.80	25	18.55	26	19.24	27	19.85
28	20.69	29	20.53	30	9.94	31	20.07
32	21.74	33	21.48	34	21.65	35	21.78
36	21.87	37	21.93	38	22.08	39	22.41
40	22.38	41	-68.71	42	-71.54	43	-71.03
44	-70.10	45	-81.51	46	10.95	47	19.36
48	20.04	49	19.56	50	19.41	51	19.25
52	19.08	53	18.90	54	18.94	55	19.01
56	11.34	57	19.15	58	18.78	59	18.31
60	18.14	61	17.99	62	17.84	63	17.69
64	17.78	65	17.15	66	13.53	67	-78.28
68	-74.43	69	-74.53	70	-74.17	71	-85.18
72	14.47	73	14.63	74	14.91	75	15.17
76	14.61	77	14.68	78	14.77	79	14.60
80	14.09	81	11.78	82	1.93	83	11.89
84	11.47	85	10.46	86	9.29	87	7.99
88	6.58	89	5.17	90	8.27	91	6.32
92	-8.94	93	-26.62	94	-15.17	95	-12.36
96	-9.40	97	-3.77	98	-0.96	99	-0.29
100	0.00						

Table 13.

LOAD CURVE ORDINATES (PROJECTED FORWARD)

X-AXIS DISTANCE (CMS) FROM BASE OF GRAPH PAPER = 23

HEIGHT OF Y-AXIS = 30

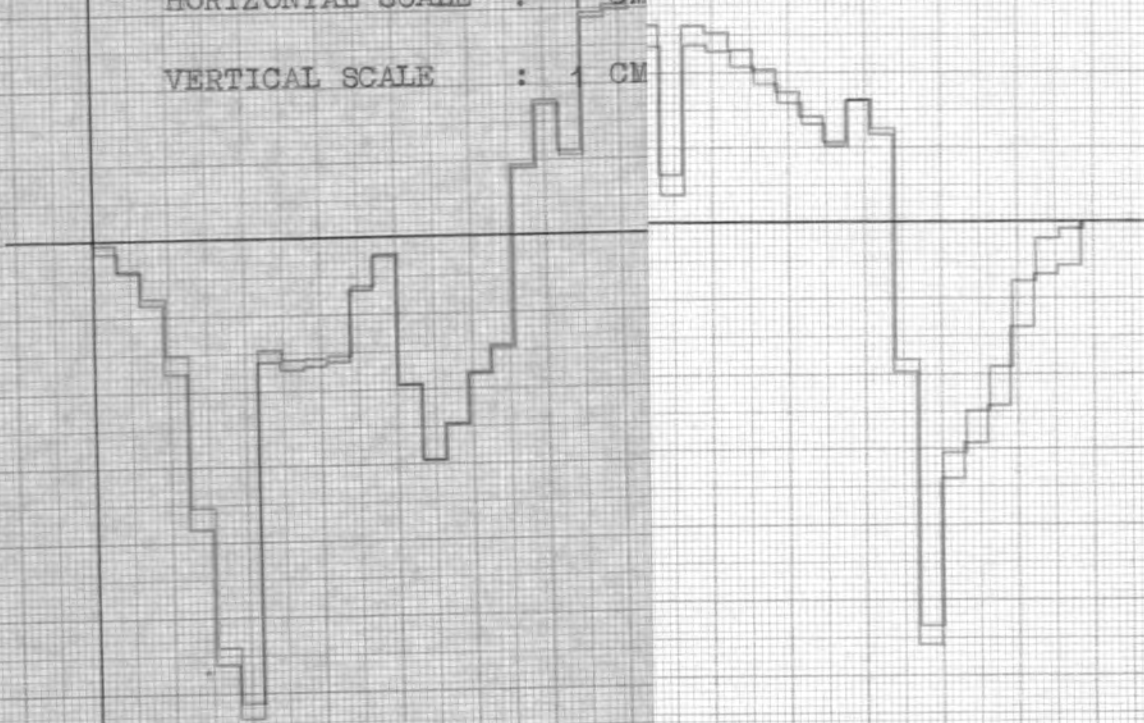
HORIZONTAL SCALE OF GRAPH --- 1 CM = 20 FT

VERTICAL SCALE OF GRAPH --- UNITS/CM:- 5.0

LOAD CURVE ORDINATES (PRO

HORIZONTAL SCALE : 1 CM

VERTICAL SCALE : 1 CM



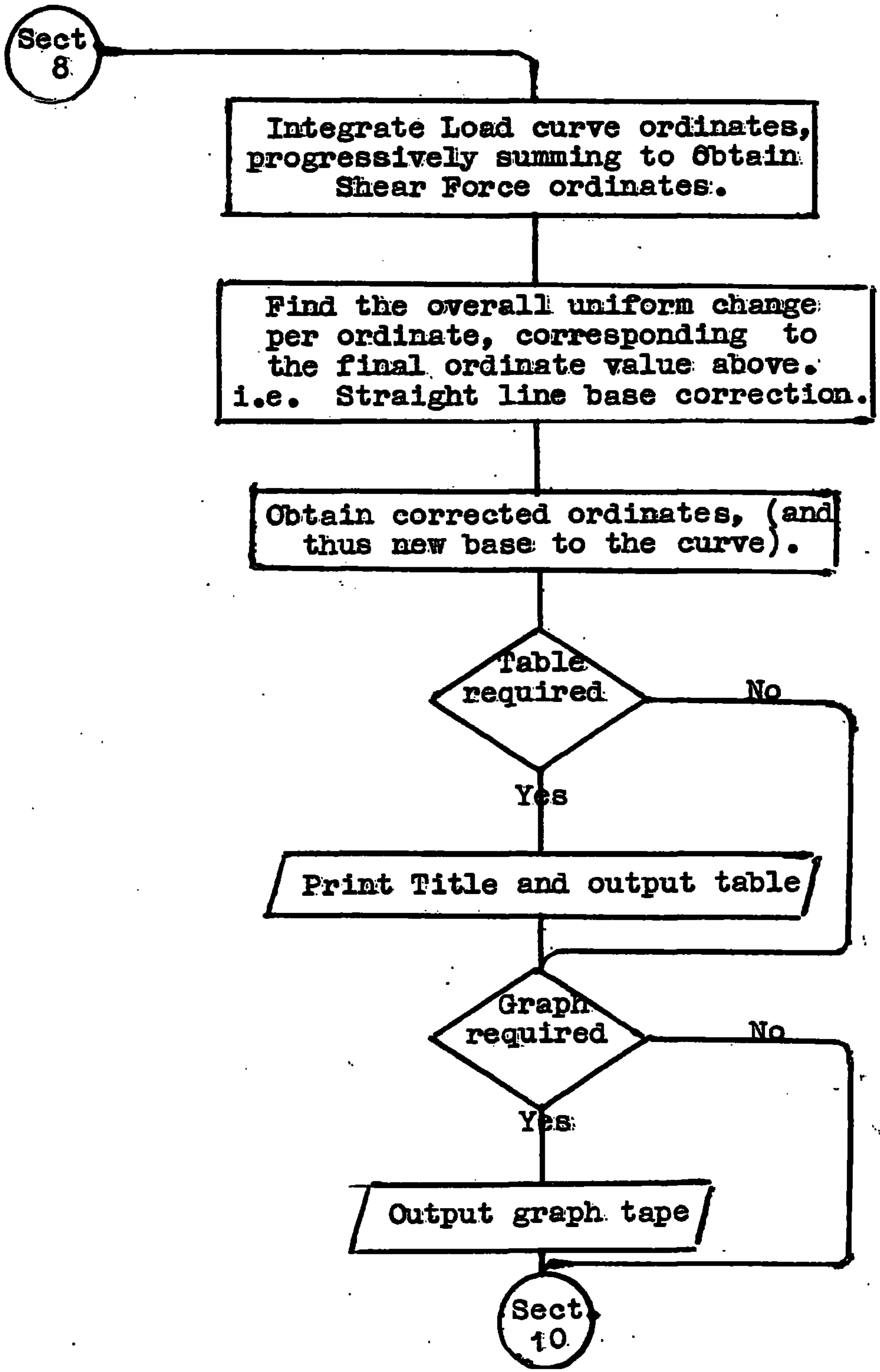
Note : Results using Lloy

Results using Bile

FLOW CHART (Programme Page 25)

(Section 9).

SHEAR FORCE CURVE SECTION.



PART 9

SHEAR FORCE (AND STRAIGHT LINE CORRECTION)

The shear force at any point (again held as YR) is the total weight to the left (or right) of the ordinate considered. The shear forces at the ends must be zero. Starting with zero shear force at ordinate number zero, the shear force at ordinate number one is the product of the Load at ordinate zero and the distance between the ordinates. The shear force at ordinate number two is the sum of that at ordinate number one together with the product of the load at ordinate number one and the distance between ordinates; and so on. To allow for any possible accumulation of error, any difference which may exist at ordinate No. 100, between the calculated shear force and zero, is made zero here and the remaining ordinates proportionately increased or reduced as the case may be. This means, in effect, tilting the base of the shear curve linearly, to obtain the true base.

On the ship under test, the error at the fore end (S100) was .39 tons, (by both methods), the maximum reading throughout the length of the vessel being of the order of 1400 tons.

Output of shear force tables is optional. The graph output for shear force is a continuous polygon, joining ordinate values by straight lines, and like the table is optional.

The Shear Force Curve table (using Lloyd's method) is on page 100 and the corresponding graph is on page 101, again in green. Results using Biles Coffin method are tabulated on page 100(a) and the appropriate graph superimposed in red on page 101.

SHEAR FORCE CURVE ORDINATES.

(BILES COFFIN DISTRIBUTION)

ORD NO.	S.F. TONS	ORD NO.	S.F. TONS	ORD NO.	S.F. TONS	ORD NO.	S.F. TONS
0	0	1	-1	2	-12	3	-38
4	-91	5	-208	6	-381	7	-576
8	-626	9	-678	10	-730	11	-779
12	-800	13	-806	14	-866	15	-957
16	-1032	17	-1086	18	-1129	19	-1100
20	-1044	21	-1009	22	-918	23	-823
24	-722	25	-610	26	-493	27	-372
28	-247	29	-118	30	11	31	74
32	199	33	333	34	466	35	600
36	734	37	869	38	1004	39	1141
40	1279	41	1418	42	994	43	553
44	115	45	-317	46	-820	47	-753
48	-633	49	-510	50	-389	51	-270
52	-151	53	-34	54	82	55	198
56	315	57	384	58	501	59	616
60	728	61	839	62	949	63	1058
64	1166	65	1274	66	1379	67	1461
68	978	69	519	70	61	71	-394
72	-915	73	-821	74	-726	75	-627
76	-527	77	-429	78	-330	79	-231
80	-132	81	-36	82	45	83	66
84	147	85	226	86	297	87	360
88	414	89	458	90	492	91	542
92	579	93	518	94	346	95	243
96	153	97	79	98	37	99	17
100	0						

Table 14(a).

SHEAR FORCE CURVE ORDINATES.

(LLOYD'S DISTRIBUTION)

ORD NO.	S.F. TONS	ORD NO.	S.F. TONS	ORD NO.	S.F. TONS	ORD NO.	S.F. TONS
0	0	1	-4	2	-17	3	-40
4	-86	5	-194	6	-360	7	-549
8	-593	9	-642	10	-690	11	-737
12	-756	13	-762	14	-821	15	-912
16	-988	17	-1043	18	-1088	19	-1060
20	-1006	21	-973	22	-884	23	-791
24	-692	25	-583	26	-468	27	-349
28	-227	29	-99	30	27	31	89
32	213	33	347	34	479	35	613
36	747	37	882	38	1017	39	1154
40	1292	41	1430	42	1006	43	565
44	126	45	-306	46	-809	47	-741
48	-622	49	-498	50	-378	51	-258
52	-139	53	-22	54	95	55	212
56	329	57	399	58	517	59	633
60	746	61	858	62	969	63	1079
64	1188	65	1298	66	1404	67	1487
68	1004	69	545	70	85	71	-372
72	-898	73	-809	74	-719	75	-627
76	-533	77	-443	78	-352	79	-261
80	-171	81	-84	82	-11	83	0
84	74	85	145	86	209	87	266
88	316	89	356	90	388	91	439
92	478	93	423	94	259	95	165
96	89	97	31	98	8	99	2
100	-0						

Table 14.

SHEAR FORCE CURVE

X-AXIS DISTANCE (CMS) FROM BASE OF GRAPH PAPER = 12

HEIGHT OF Y-AXIS = 30

HORIZONTAL SCALE OF GRAPH --- 1 CM = 20 FT

VERTICAL SCALE OF GRAPH --- UNITS/CM:- 100.0

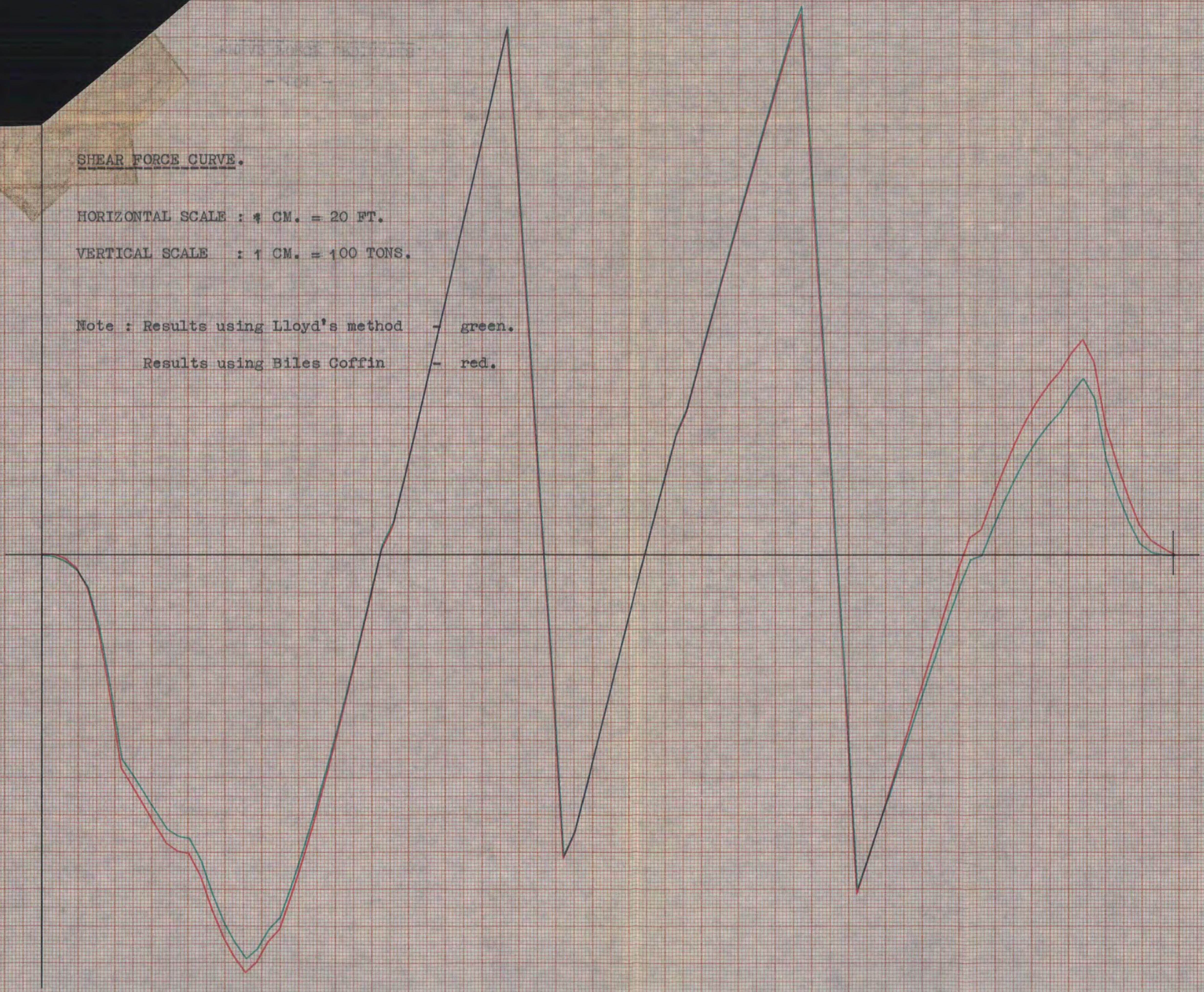
SHEAR FORCE CURVE.

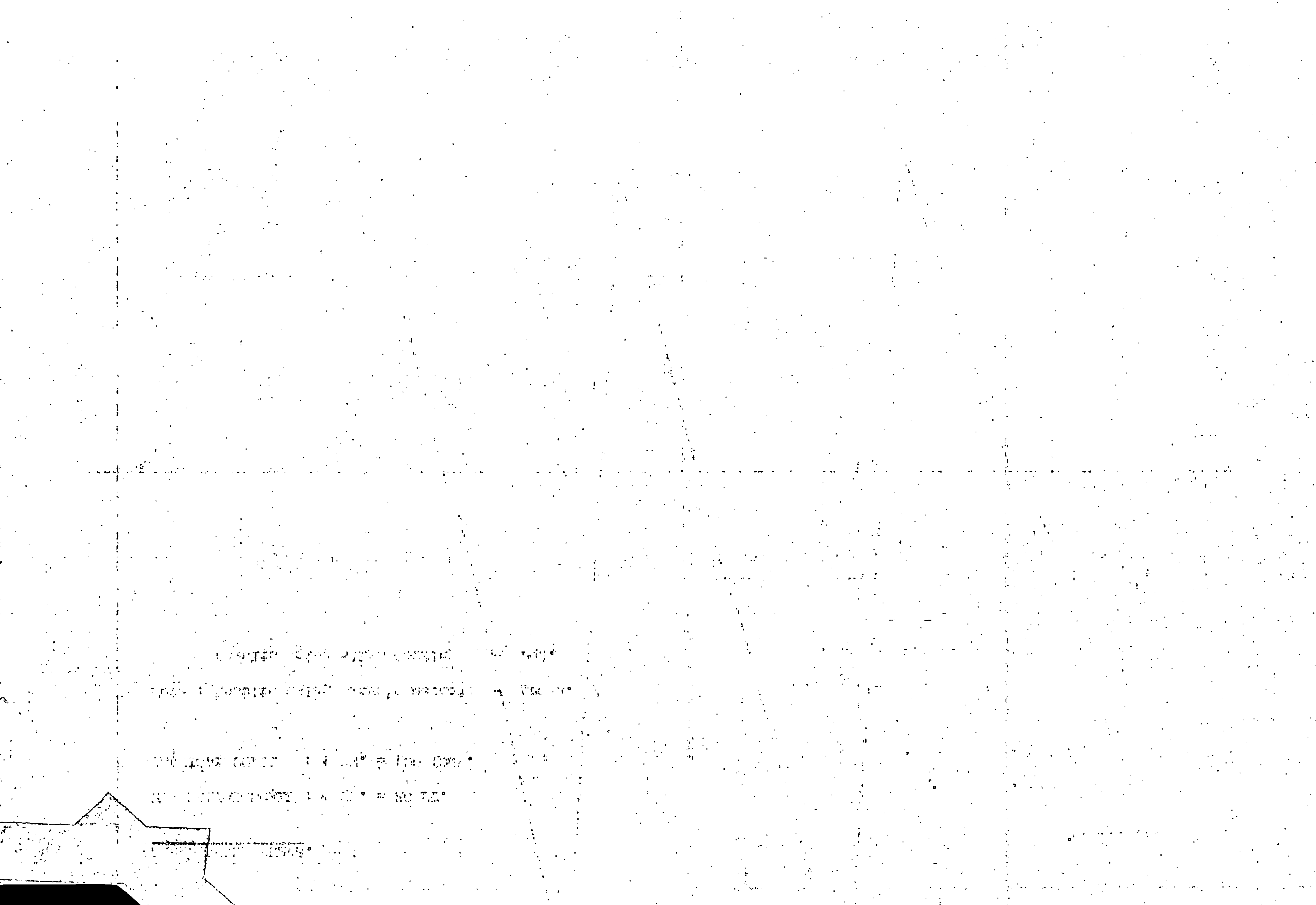
HORIZONTAL SCALE : 1 CM. = 20 FT.

VERTICAL SCALE : 1 CM. = 100 TONS.

Note : Results using Lloyd's method - green.

Results using Biles Coffin - red.



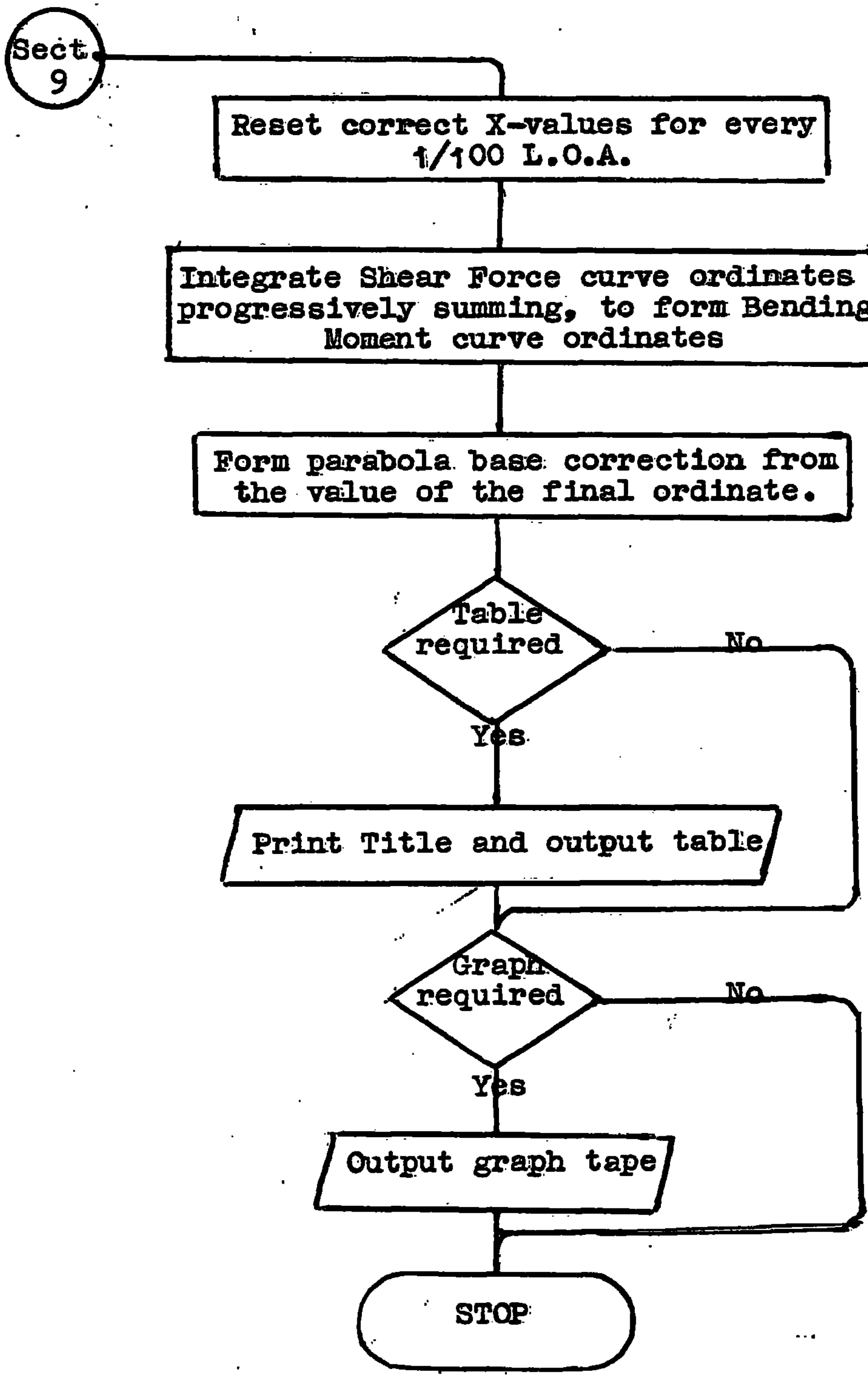


SHEAR FORCE ORDINATES.

FLOW CHART (Programme Page 27)

(Section 10).

BENDING MOMENT CURVE SECTION.



PART 10

BENDING MOMENT (WITH PARABOLA BASE CORRECTION)

The bending moment at any point (stored as BR) is the total area to the left (or right) under the shear force curve, up to the ordinate considered. That is, it is a second integration of the load curve.

The bending moments at the ends must be zero. Starting with zero bending moment at ordinate number zero, the bending moment at ordinate number one is the product of the mean shear force over the first division and the length of the division. The bending moment at ordinate number two is the sum of that at ordinate number one and the product of the mean shear over the second division and the length of the division; and so on.

Like the shear force curve the ordinate value at the forward end (R = 100) should be zero. Corrections to make this so are performed using a parabola base correction. See Fig. 30, where YR is the correction for ordinate No. R.

On the ship under test, the error at the reading R = 100 was 135 tons ft., the maximum reading throughout the length of the vessel being of the order of 110000 tons ft. (Percentage error 0.12%).

The bending moment graph is a continuous polygon.

The Bending Moment table using Lloyd's method is on page 104, with the graph output on page 105 (in green). Page 104 (a) shows results using Biles Coffin method, and the appropriate graph is in red on page 105.

$$\frac{YR}{x^2} = \frac{B(100)}{L^2} \quad \therefore \quad YR = \frac{B(100) \cdot x^2}{L^2}$$

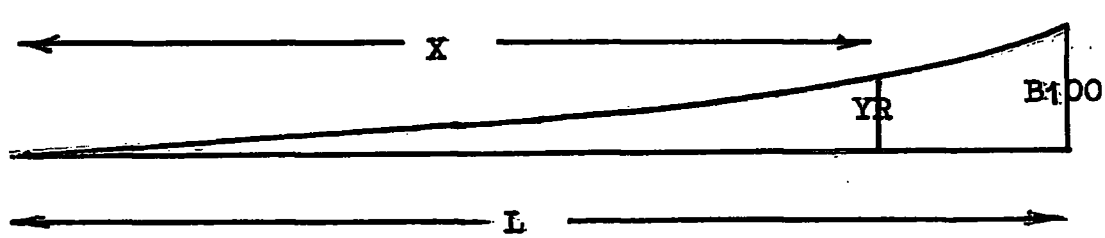


Fig. 30.

BENDING MOMENT CURVE ORDINATES.

(BILES COFFIN DISTRIBUTION)

ORD NO.	B.M. TON FT	ORD NO.	B.M. TON FT	ORD NO.	B.M. TON FT	ORD NO.	B.M. TON FT
0	0	1	-3	2	-44	3	-198
4	-595	5	-1520	6	-3340	7	-6294
8	-10002	9	-14025	10	-18369	11	-23024
12	-27895	13	-32850	14	-38010	15	-43633
16	-49767	17	-56300	18	-63135	19	-70012
20	-76625	21	-82959	22	-88902	23	-94273
24	-99040	25	-103149	26	-106551	27	-109220
28	-111132	29	-112259	30	-112589	31	-112330
32	-111492	33	-109852	34	-107386	35	-104099
36	-99986	37	-95043	38	-89266	39	-82650
40	-75185	41	-66865	42	-59425	43	-54652
44	-52592	45	-53217	46	-56727	47	-61580
48	-65857	49	-69384	50	-72159	51	-74193
52	-75494	53	-76068	54	-75923	55	-75060
56	-73479	57	-71324	58	-68594	59	-65147
60	-61000	61	-56165	62	-50649	63	-44458
64	-37598	65	-30071	66	-21887	67	-13127
68	-5605	69	-989	70	800	71	-228
72	-4269	73	-9629	74	-14404	75	-18580
76	-22142	77	-25092	78	-27436	79	-29168
80	-30289	81	-30810	82	-30784	83	-30444
84	-29789	85	-28641	86	-27031	87	-25006
88	-22618	89	-19928	90	-17000	91	-13813
92	-10358	93	-6977	94	-4312	95	-2497
96	-1279	97	-566	98	-211	99	-49
100	0						

Table 15(a)

BENDING MOMENT CURVE ORDINATES.

(LLOYD'S DISTRIBUTION)

ORD NO.	B.M. TON FT	ORD NO.	B.M. TON FT	ORD NO.	B.M. TON FT	ORD NO.	B.M. TON FT
0	0	1	-13	2	-78	3	-251
4	-638	5	-1502	6	-3213	7	-6017
8	-9540	9	-13350	10	-17459	11	-21861
12	-26468	13	-31151	14	-36034	15	-41381
16	-47241	17	-53505	18	-60078	19	-66702
20	-73074	21	-79177	22	-84904	23	-90071
24	-94649	25	-98583	26	-101825	27	-104348
28	-106127	29	-107134	30	-107357	31	-106999
32	-106071	33	-104346	34	-101799	35	-98431
36	-94236	37	-89210	38	-83351	39	-76654
40	-69110	41	-60714	42	-53199	43	-48354
44	-46223	45	-46778	46	-50219	47	-55004
48	-59211	49	-62669	50	-65373	51	-67335
52	-68562	53	-69059	54	-68833	55	-67888
56	-66219	57	-63974	58	-61148	59	-57600
60	-53346	61	-48398	62	-42763	63	-36446
64	-29452	65	-21784	66	-13451	67	-4534
68	3151	69	7928	70	9871	71	8982
72	5061	73	-207	74	-4920	75	-9072
76	-12651	77	-15663	78	-18118	79	-20012
80	-21348	81	-22137	82	-22434	83	-22470
84	-22243	85	-21572	86	-20483	87	-19018
88	-17224	89	-15153	90	-12859	91	-10308
92	-7480	93	-4702	94	-2601	95	-1295
96	-514	97	-146	98	-30	99	-3
100	0						

Table 15.

BENDING MOMENT CURVES

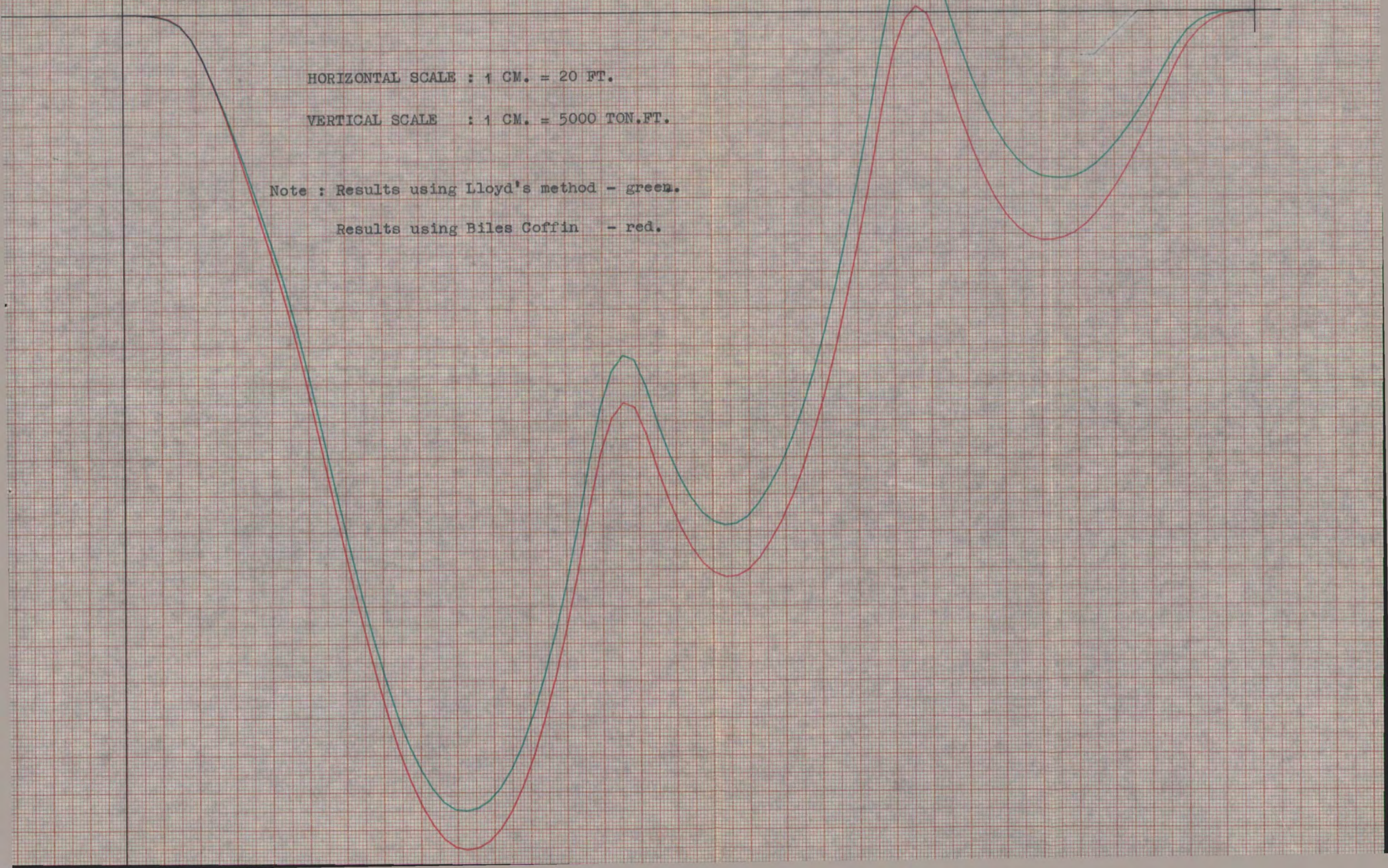
X-AXIS DISTANCE (CMS) FROM BASE OF GRAPH PAPER = 27

HEIGHT OF Y-AXIS KF 29

HORIZONTAL SCALE OF GRAPH --- 1 CM = 20 FT

VERTICAL SCALE OF GRAPH --- UNITS/CM:- 5000.0

BENDING MOMENT CURVES.



APPENDIX I

Set out below are details of the differences between the Sunderland Technical College programme and the programmes which are the subjects of the three reports mentioned on page vi of the Introduction.

Considering the Glasgow Programme first:

The first obvious point of difference is that Glasgow offers FIVE methods of continuous weight distribution (including the two offered in this programme). Since the author understands (unofficially) that Lloyd's are in the process of determining other types of distribution in certain cases, and since Lloyd's must eventually pass judgement on the programme, there seems no point in including what may eventually have to be discarded. The understanding (by the author) is that in certain cases Biles Coffin may have to be used. I have, therefore, satisfied myself with providing the one coffin method, besides Lloyd's method.

The three extra methods in Glasgow's programme are:-

(i) Cole or American Coffin diagram

(ii) Robb Dry Cargo Ship

(iii) Robb Tanker

Glasgow uses Coffin diagrams where the end ordinates are not zero. Biles end ordinates are taken to be $0.6 \frac{W}{L_{OA}}$. The alternative, used in the Sunderland programme, is to work with the weight between the perpendiculars, and to fit triangular ends, for stern and bow sections.

Glasgow makes a point that comparison of the results using their different methods suggests that the error in bending-moment will not exceed 0.01 x W x L_{OA}. In the case of Ship No. A842 considered in this thesis, this could be a matter of:

$$0.01 \times 4575 \times 580 = 26{,}535 \text{ ton ft.}$$

against a maximum value of about 110,000 ton ft. for Condition 1. A comparison of Biles Coffin results and Lloyd's results is made on page 105 of this thesis, in respect of Ship No. A842, where it will be seen that the difference is of the order of 5000 ton ft.

It would appear from Glasgow's write-up that with the one exception of the Robb Tanker method, end ordinates of the coffins are made equal (non zero). In our formula the ordinates at the perpendiculars are calculated, having been given the final position of L.C.G. (See page 32).

Also concerning local weights, Glasgow say they check that the C.G. of any item is within the centre 50% of the extent of the item, since trapezoidal distributions are assumed. In fact, looking at the formulae on page 12 of this thesis, it is seen that the C.G. must be within the centre $33^1/3$%. Our programme checks this and rejects the item if the condition is not fulfilled. It also prints out the offending item, and WAITS for further action by the operator. If the error may be ignored, the programme may be allowed to carry on. Otherwise the tape is removed and corrected.

Data for the Glasgow programme is presented in a somewhat different form from that for our programme, and the formulae used for the local weights, for example, are in a completely different style. However, the number of output stations is, like this programme, 100.

One other difference is that immersed sectional areas are given (21 in number) for each loading condition being considered, whereas in our programme areas are calculated from the position of the waterline which is itself calculated from the mean draught and trim. Thirty one stations are considered in the Sunderland programme.

The three main differences in the two programmes are:

(i) Glasgow required immersed sectional areas at 21 stations for every loading condition, whereas the Sunderland programme calculates and stores areas to every even waterline once only and calculates the required areas for any number of conditions.

(ii) In the Lloyd's method for continuous weight distribution, Glasgow uses polynomial equations to represent the curved portions of the fore and aft bodies and the equations are expressed as a function of block coefficient and distances along the length from midship. Various other items of data are required such as L.C.G. position, and the computer varies the lengths of the end curves to ensure correct L.C.G. position. In the Sunderland programme the yard provides the appropriate 'a' values for a known block coefficient at the load draught. This means one set of figures only. Everything else, such as the 'm' value, and the true and calculated positions of the L.C.G. of the continuous weight, together with the adjustment of the curve for correct L.C.G. and weight, is performed by the programme.

(iii) Glasgow do not include calculations in wave conditions.

There is no comparison of results using the two programmes; Glasgow do not say whether their programme satisfies Lloyd's Register of Shipping.

The Glasgow programme is written in KDF 9 Algol.

Comparison with the Vickers programme.

Vickers' programme performs the calculations for both still-water and for trochoidal wave forms.

Ordinates are calculated at intervals of L.B.P/100, as against the Sunderland programme using intervals of L.O.A/100. However, the three main differences in the programmes are:

(i) Vickers split up the continuous weight into separate blocks of volume called portions, and do not use Biles Coffin or Lloyd's method. The number of such portions may be unlimited, and basic data for each portion, such as length and weight are read in. The lower part of some hull sections is defined by the use of buttock heights rather than half breadths. The Sunderland programme does not use this system - half breadths are used throughout.

(ii) Complete hull definition data is read in, in the Vickers programme at the beginning, and this data, being stored, may be used for other programmes such as Hydrostatic and Bonjean calculations. The Sunderland programme stores the half-breadths for the station being considered and uses these to calculate immersed sectional areas to all even waterlines for that station, and stores this information for use in any number of loading conditions. Hydrostatics and Bonjean results can not be output.

One other small difference in the programme is that bossings are provided for in the Vickers programme, but not in the Sunderland programme.

(iii) For Bending Moments in wave forms, Vickers uses Trochoidal wave forms, whereas Sunderland uses Sine Wave.

There is no comparison of results using the two programmes (But see next section on B.S.R.A. notes).

Differences from the B.S.R.A. Programme.

The introduction to the B.S.R.A. notes says that the programme is a modification of that prepared by Vickers, (see last section). The modifications were made to satisfy Lloyd's Register of Shipping, to insert several checks thought necessary, and to provide graphical output.

The programme is written in Mercury Autocode, as was the Vickers' programme.

Lloyd's continuous weight distribution is performed by means of polynomials, as is the Glasgow programme, by feeding in the block coefficient and the station position along the ship length.

Equations used are of the form:-

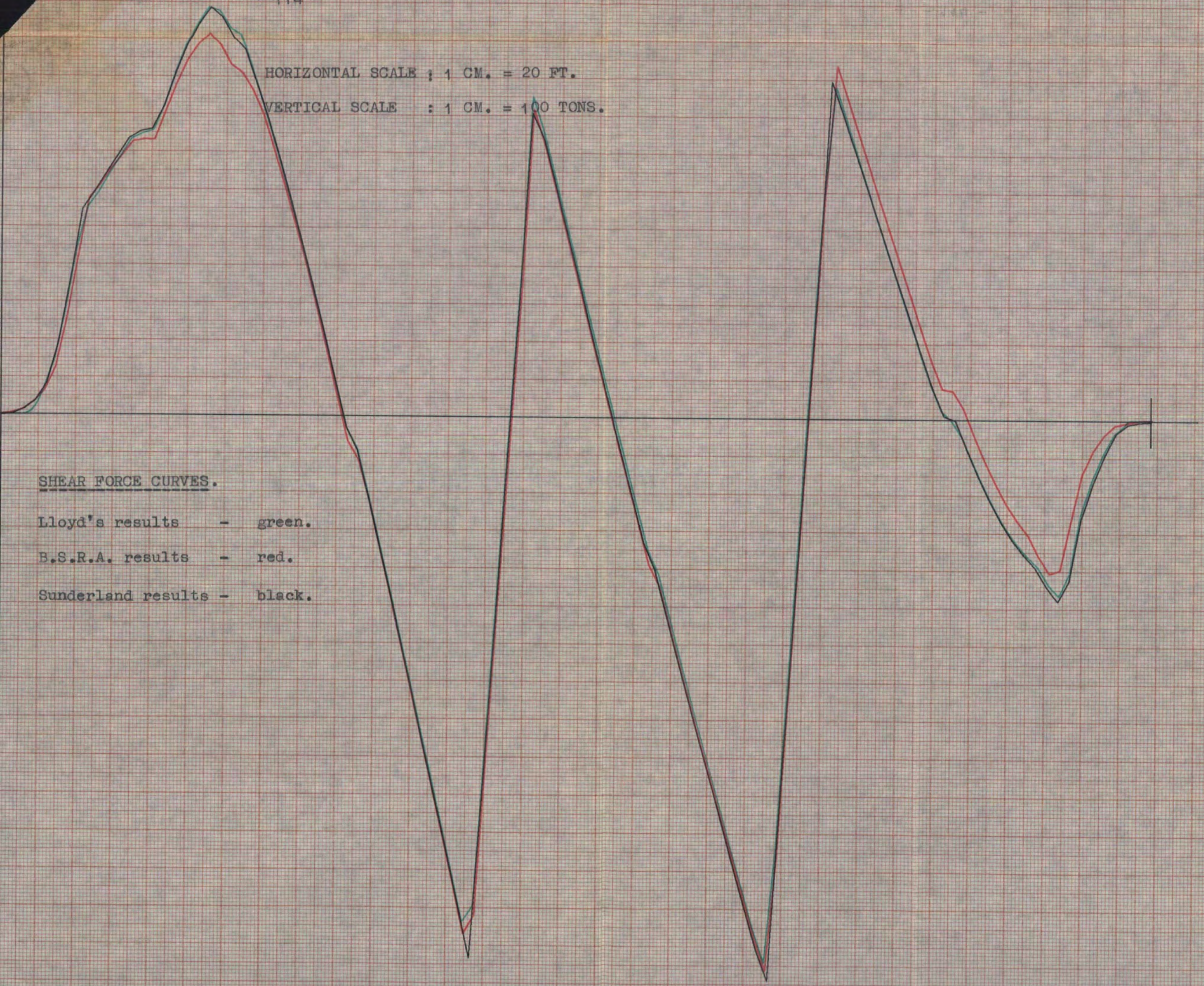
$$A = Y_o + (Y_1 - Y_o)X^2 + \sum_{M=0}^{M=4} \sum_{N=0}^{N=4} A_{mn}\, T_m(X)\, T_n(Z)$$

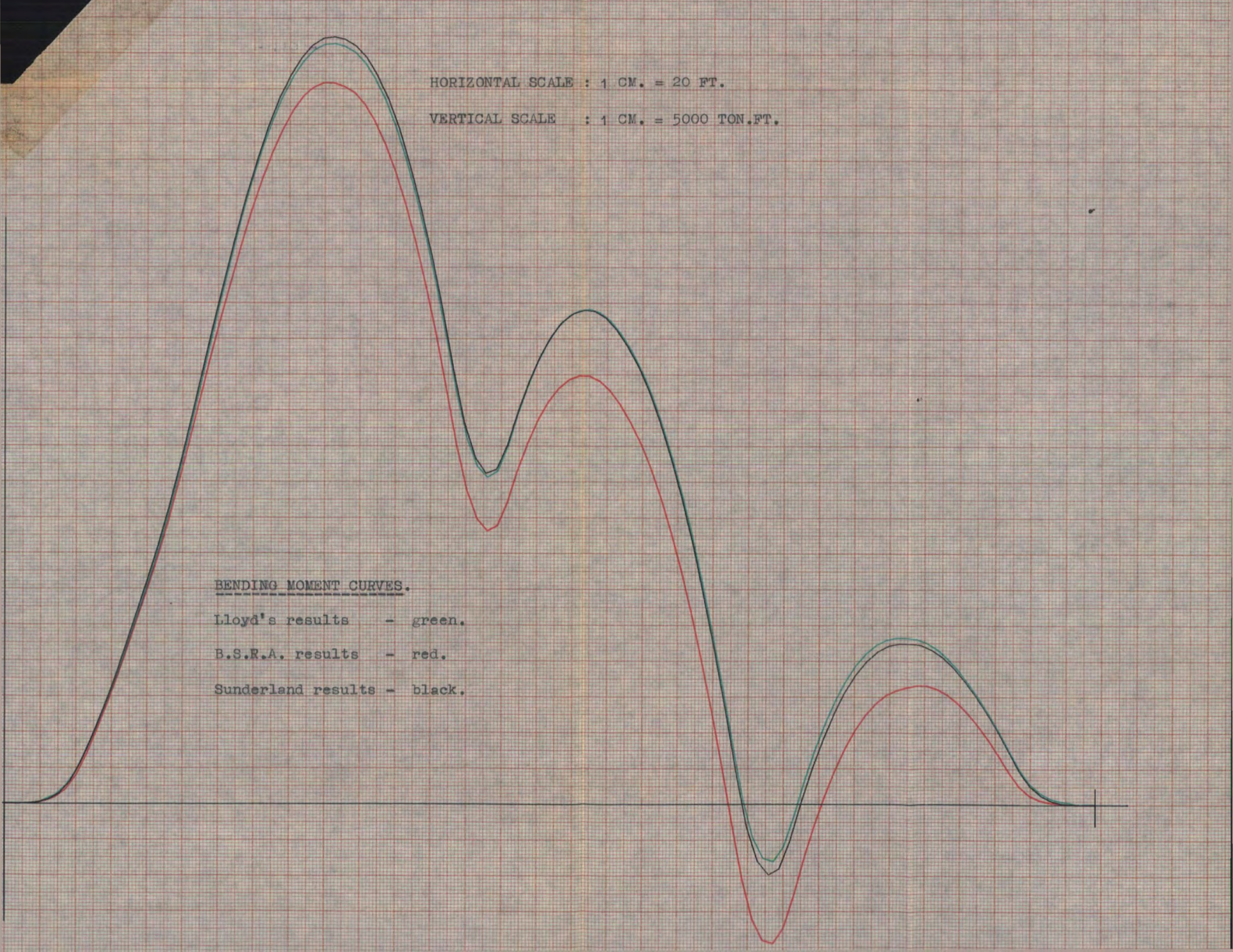
where $T_m(X)$ and $T_n(Z)$ are Chebysheve Polynomials, Y_o is a function of block coefficient, Y_1 is constant, X and Z are functions of block coefficient and station. The coefficients A_{mn} are different for the fore and after bodies.

It is considered that the amount of effort involved in reading-off one set of 20 'a' values from Lloyd's tables does not warrant the introduction of such methods as the above into the programme (especially as they are read in once only, no matter how many conditions are to be programmed). Reference to page 39 of this thesis will clarify the simpler method used in the Sunderland programme.

B.S.R.A. have provided the tabular outputs from their programme, as have Lloyd's, for purposes of comparison with those from the Sunderland programme.

Results from the three programmes may be compared from the graphs drawn on pages 114, 115. Page 114 shows the Shear Force curves and page 115 the Bending Moment curves. In both cases, Lloyd's results are in green, B.S.R.A's in red and Sunderland's in black.


HORIZONTAL SCALE : 1 CM. = 20 FT.
VERTICAL SCALE : 1 CM. = 100 TONS.
SHEAR FORCE CURVES.
Lloyd's results - green.
B.S.R.A. results - red.
Sunderland results - black.


HORIZONTAL SCALE : 1 CM. = 20 FT.
VERTICAL SCALE : 1 CM. = 5000 TON.FT.
BENDING MOMENT CURVES.
Lloyd's results - green.
B.S.R.A. results - red.
Sunderland results - black.

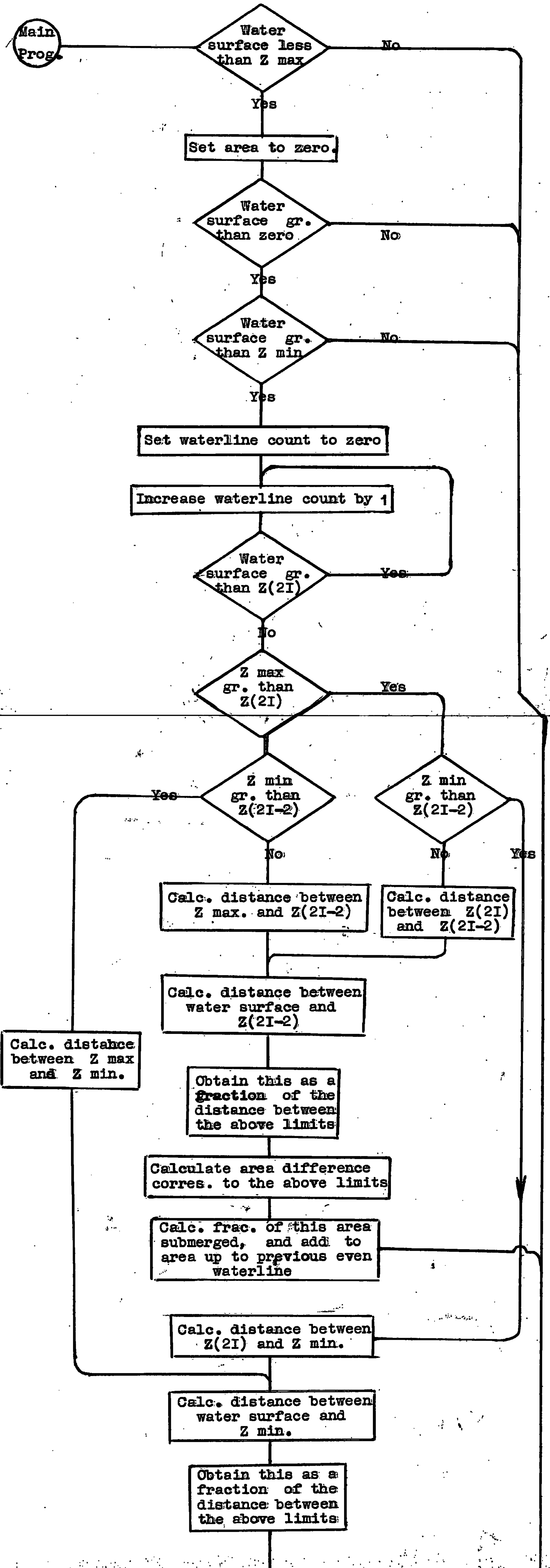
APPENDIX II

Page 117 shows the graphs drawn by the yard, from their own calculations, for ship No. A827. Superimposed on the graphs are the values produced by the 15 sections programme, mentioned on page iv of the introduction.

Since the latter half of 1966, the yard have accepted graphs drawn on the Benson Lehner graph plotter from tape produced by the Sunderland programme.

FLOW CHART

(Subr. 30, Programme p36)

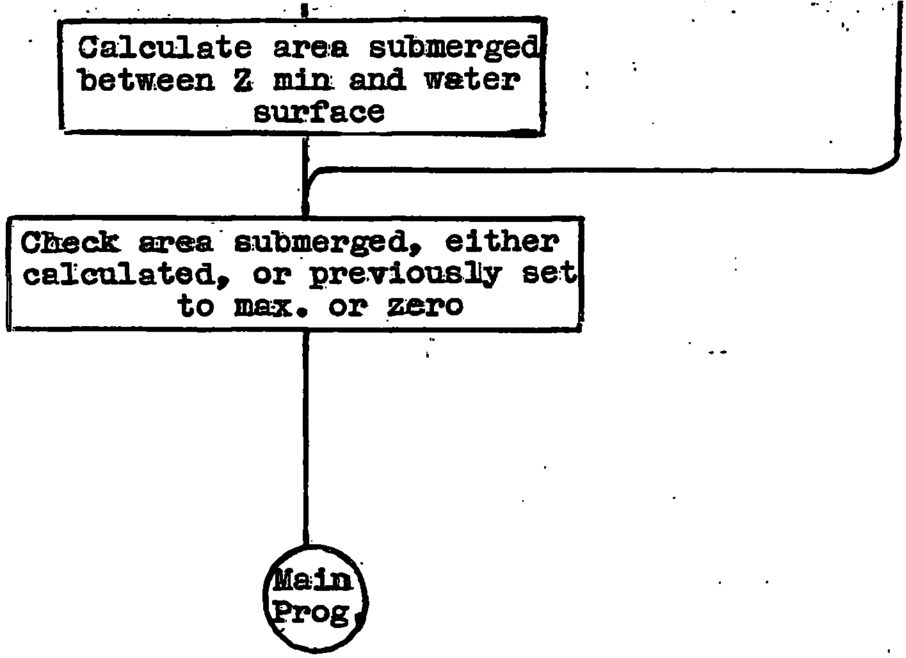


FLOW CHART

SUBROUTINE 30

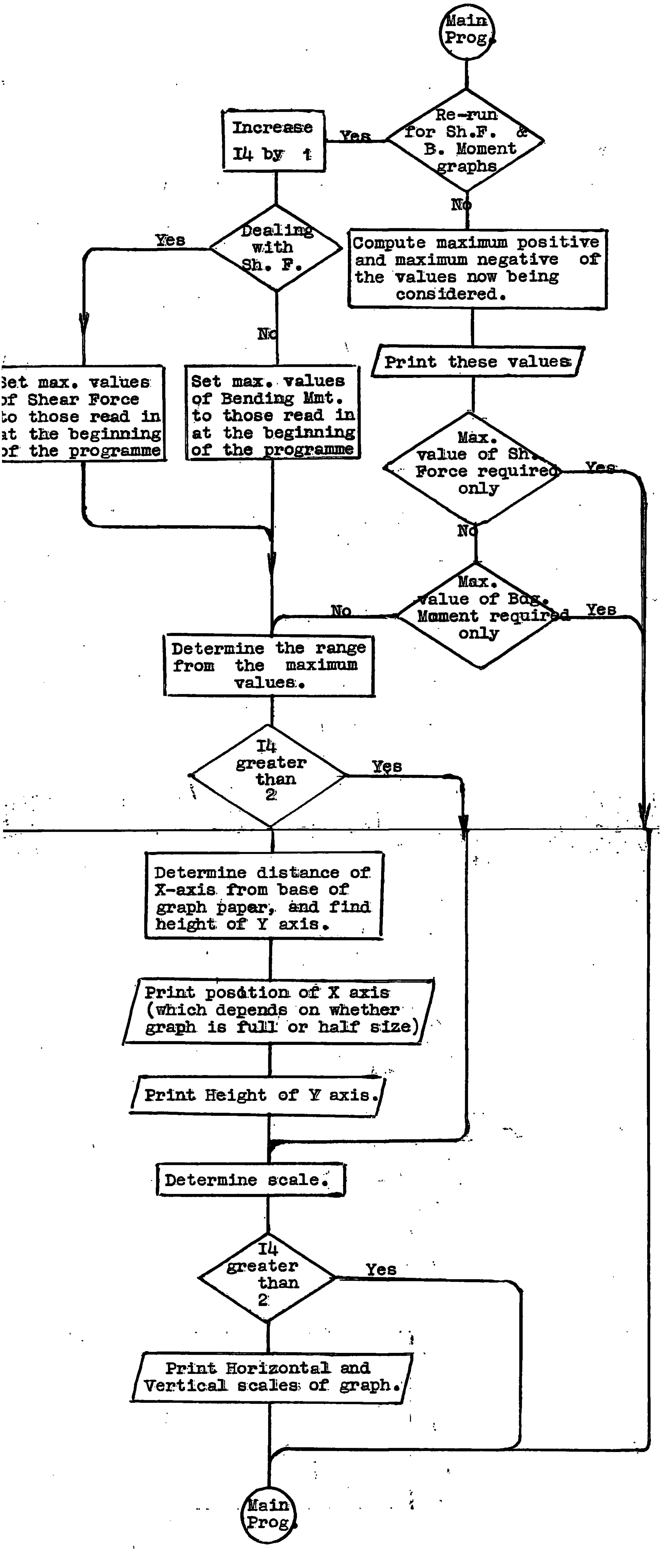
F O L D

D O W N


Calculate area submerged between Z min and water surface
Check area submerged, either calculated, or previously set to max. or zero
Main Prog

FLOW CHART

(Subr. 86, Programme B 30)



F L O W   C H A R T

S U B R O U T I N E   86

FOLD DOWN

```
::          L O N G I T U D I N A L   S T R E N G T H
::                        (JUNE  1967)
::      P R O G R A M M E   T O   C A L C U L A T E
::            B E N D I N G   M O M E N T S
::       (S T I L L - W A T E R / S I N E - W A V E)


SETS I(6)N(4)J(4)R(2)P(35)
SETV S(27)T(6)W(65)L(15)B(100)X(100)M(7)Q(9)F(6)A(100)K(7)Y(100)
H(30)D(100)E(100)V(100)C(4)U(30)Z(112)O(774)G(52)
SETF INT FRAC TRIG GRAPH PLOT
SETR 143


1)READ I3::      IF CONDITIONS HAVE NOT BEEN RUN, PUT I3 = 0.   IF ALL
I4=0::           CONDITIONS HAVE BEEN RUN, AND SHEAR FORCE CURVES  FO
JUMP IF I3=0@8::ALL CONDITIONS ARE TO BE REDRAWN ON SAME AXIS, TO THE
READ S25::       SAME SCALE (AND SIMILARLY FOR B.MMT. CURVES ), I3 =
READ S26:: THESE TWO, MAX. +VE AND MAX. -VE SHEAR OVER ALL CONDS.
READ M6
READ M7::        "   "   "   "    "   "   " B.MMT.  "   "   "

8)WAIT::FOR LIGHTSHIP LOCAL WEIGHTS TAPE
READ I1::         1 FOR BILES COFFIN,  0 FOR LLOYD'S METHOD
READ L::         LENGTH OVERALL
READ L1
READ L2
L3=L-L1
L3=L3-L2
L6=L/100
READ S22::  1 FOR FULL WIDTH GRAPH,  0.5 HALF WIDTH, 0 IF NO GRAPH
READ S27::  10,20 OR 40 (FT. PER CM.HORIZONTAL SCALE). 0 IF NO GRAPH
JUMP IF S27=0@143
S24=100/S27
143)SUBR 124

S21=S1
VARY R=0:1:101
ER=YR
REPEAT R
T6=T5

WAIT::           FOR 2ND DATA TAPE

126)SUBR 124:: ENTRY POINT FOR ALL CONDITIONS AFTER THE FIRST

READ W31
READ K3
```

```
LINE::
TITLE

LENGTH OVERALL :
PRINT L,4:2
TITLE FT

SUM OF LIGHTSHIP LOCAL WEIGHTS READ IN =
PRINT S21,5:2
TITLE  TONS-

SUM OF EXTRA LOCAL WTS.  FOR THIS CONDITION, READ IN =
PRINT S1,5:2
TITLE TONS

S=0
VARY R=0:1:101
YR=YR+ER
S=S+YR
REPEAT R
S=S*L6

TITLE

CALCULATED SUM OF DISTRIBUTED LOCAL WEIGHTS =
PRINT S,5:2
S3=S1+S21::ACTUAL SUM OF WEIGHTS INPUT
T5=T6+T5
Q6=W31*35::           FOR MUCKLE'S METHOD BELOW
JUMP IF I(1)=1@83::  FOR B C  CONT. WT. DISTRIBUTION
W32=W31-S3::CONTINUOUS WEIGHT - CHECKED EACH TIME ROUND
K6=W31*K3
K6=K6-T5
K6=K6/W32::LCG CONT.WT - CHECKED EACH TIME ROUND.
JUMP IF P4%1@54
VARY I=0:1:23
READ AI::A VALUES FROM LLOYDS GRAPHS
REPEAT I
L4=L3/20
L5=L4/3
X1=L1
X=0
VARY I=2:1:20
XI=X(I-1)+L4
REPEAT I
X22=X21+L2:: X - DISTANCES TO LLOYDS ORDINATES
```

```
Q=0::
VARY I=1:1:10
Q1=4*A(2I)
Q2=Q1+A(2I+1)
Q2=Q2+A(2I-1)
Q2=Q2*L5
Q=Q+Q2
REPEAT I
Q1=L1*A1
Q1=Q1/2
Q=Q+Q1
Q2=L2*A21
Q2=Q2/2
Q=Q+Q2::VALUE UNDER WEIGHT CURVE IN TERMS OF 'M'.
M5=W32/Q
VARY I=0:1:23
AI=AI*M5::ACTUAL ORDINATE VALUES
REPEAT I


M4=0
VARY I=1:1:10
M1=4*A(2I)
M1=M1*X(2I)
M2=A(2I+1)*X(2I+1)
M3=A(2I-1)*X(2I-1)
M1=M1+M2
M1=M1+M3
M1=M1*L5
M4=M4+M1
REPEAT I


Q1=Q1*M5
M1=Q1*L1
M1=M1*0.666666666
M4=M4+M1
Q2=Q2*M5
L7=L2*0.333333333
L7=L7+L1
L7=L7+L3
M1=Q2*L7
M4=M4+M1


L8=M4/W32::L.C.G. OF CONTINUOUS WEIGHT CURVE (HORIZONTAL).
L8=L8-K6::REQUIRED MOVEMENT OF L.C.G. TO BRING TO CORRECT POSITION.
CHECK L8
```

```
M4=0::
VARY I=1:1:20
JUMP IF A(I+1)$AI@117
K=A(I+1AI
M1=AI*AI
JUMP @118
117)K=AI-A(I+1)
M1=A(I+1)*A(I+1)
118)M1=M1*L4
M1=M1/2

M2=K*L4
M2=M2/2
K=K/3
JUMP IF A(I+1)$AI@49
K=K+AI
JUMP @50
49)K=K+A(I+1)
50)M2=M2*K
M4=M4+M1
M4=M4+M2
REPEAT I


H=M4/W32::CENTRE OF AREA OF CONT. WT. CURVE (VERT).
CHECK H
M=L8/H::RATIO TO AFFECT ALL AI VALUES
CHECK M
VARY I=0:1:23
K=AI*M
XI=XI-K
REPEAT I


VARY R=0:1:101
DR=0
REPEAT R
N1=1
J1=100
I=0::THESE 3 FOR SUBR 58.  I FOR EXTRA COUNT FOR XJ VALUES.


SUBR 58::INTERPOLATE 100 A VALUES - TO GIVE D VALUES


VARY R=0:1:100
J=R+1
S=DJ+DR
DR=S/2
VR=DR
REPEAT R
```

```
LINE::
54)TITLE  TONS

CONTINUOUS WEIGHT TOTAL FOR LLOYD'S DISTRIBUTION =
PRINT W32,5:2

TITLE  TONS

CALCULATED ''M'' - TONS/FT =
PRINT M5,2:3

TITLE

CALCULATED L.C.G. OF CONTINUOUS WEIGHT =
PRINT K6,3:2
TITLE FT.

JUMP @84
83)JUMP IF P4%1@125
READ W33:: WEIGHT OF OVERHANG OF STERN
READ W34::   '        '        '        BOW
READ L4::LCG OF W33
READ L5:: '  '  W34
T1=W33*L4
T2=W34*L5
W32=W31-S*
W32=W32-W33
W32=W32-W34

K=W31*K3
K1=K
K=K-T5
K=K-T1
K=K-T2
K=K/W32
K=K-L1
L7=L3/2
K=K-L7
H=W32/L3
A1=W32*K
A1=54*A1
A1=A1/7
A1=A1/L3
A1=A1/L3
A2=H*0.6
B=A2+A1
A=A2-A1
H1=1.2*H
CHECK A
CHECK B
CHECK H1
```

```
J=0::
VJ=0
JUMP IF L1=0@140::TRANSOM STERN
H2=H1-A
L10=L1/L6
J=INT L10
H3=A/L1
CHECK J
CHECK H3
CYCLE I=0:1:J
C=STAND I
C=C*L6
VI=H3*C
REPEAT I
CYCLE I=1:1:J
R=I-1
S=VR+VI
VR=S/2
REPEAT I
140)L11=L3/3
R=J+1
C=STAND R
C=C*L6
C=C-L1
H3=H2/L11::RISE PER FT
CHECK H3
C1=C*H3::RISE TO R
VR=A+C1
S=A+VR
S=S*C
S=S/2
C=L6-C
S1=VJ+A
S1=S1/2
S1=S1*C
VJ=S+S1
VJ=VJ/L6
L12=L11+L1
L13=L12/L6
J2=INT L13
CHECK J2
J1=R+1
CYCLE I=J1:1:J2
R2=I-R
C=STAND R2
C=C*L6
C=C*H3
VI=VR+C
REPEAT I
CYCLE I=J1:1:J2
J=I-1
S=VI+VJ
VJ=S/2
REPEAT I
```

```
R=J2::
C=STAND J2
C=C*L6
C=L12-C
S=VR+H1
S=S/2
S=S*C
R1=R+1
C=L6-C
S1=C*H1
S=S+S1
VR=S/L6
L13=2*L11
L13=L13+L1
L14=L13/L6
J3=INT L14
CHECK J3
CYCLE I=R1:1:J3
VI=H1
REPEAT I
H2=H1-B
H3=H2/L11
CHECK H3
C=STAND J3
C=C*L6
C=L13-C
S=H1*C
C=L6-C
C1=C*H3
R=J3+1
VR=H1-C1
S1=H1+VR
S1=S1*C
S1=S1/2
R=J3
VR=S+S1
VR=VR/L6
R=J3+1
L14=3*L11
L14=L14+L1
L15=L14/L6
J4=INT L15
R1=R+1
CHECK J4
CYCLE I=R1:1:J4
R2=I-R
C=STAND R2
C=C*L6
C=C*H3
VI=VR-C
REPEAT I
```

```
CYCLE I=R1:1:J4::
J=I-1
S=VJ+VI
VJ=S/2
REPEAT I
V100=0
JUMP IF J4=99@127
R=J4+1
H3=B/L2
CHECK H3
C1=H3*L6
CYCLE I=99:-1:R
J=100-I
C=STAND J
C=C*C1
VI=V100+C
REPEAT I
C=STAND J4
C=C*L6
C=L14-C
R=J4
S=VR+B
S=S/2
S=S*C
R=R+1
S1=VR+B
S1=S1/2
C=L6-C
S1=S1*C
S=S+S1
R=J4
VR=S/L6
R=R+1
CYCLE I=R:1:99
J=R+1
S=VR+VJ
VI=S/2
REPEAT I
JUMP @125
127)R=J4
C=99*L6
C=L14-C
S=V99+B
S=S*C
S=S/2
C=L6-C
S1=B*C
S1=S1/2
S=S+S1
V99=S/L6

125)W32=W31-S3
W32=W32-W33
W32=W32-W34
```

```
LINE::
TITLE  TONS

WEIGHT OF STERN OVERHANG          WEIGHT OF BOW OVERHANG

SPACES 8
PRINT W33,5:2
SPACES 15
PRINT W34
TITLE  TONS

CONTINUOUS WEIGHT TOTAL (BILES COFFIN DISTRIBUTION) =
PRINT W32

TITLE  TONS

84)WAIT::  FOR TAPE 3   -  CHOICE OF TABLES/GRAPHS FOR WEIGHT CURVES
I5=0
I6=0::FOR CONTROL IN SUBR 86

TITLE


NOTE:  ORDINATES IN THE FOLLOWING OUTPUT ARE NUMBERED FROM THE
EXTREME POINT OF STERN (ORDINATE NO. 0), TO THE POINT OF BOW
(ORDINATE NO. 100), AND ARE UNIFORMLY SPACED.

READ P1::1 FOR L.WEIGHTS TABLE, 0 IF TABLE NOT REQD.
JUMP IF P1=0@67
VARY I=1:1:50
OUTPUT 0
REPEAT I
TITLE



          LOCAL WEIGHT ORDINATES (PROJECTED FORWARD).


   ORD   WEIGHT    ORD   WEIGHT    ORD   WEIGHT    ORD   WEIGHT
   NO.   TON/FT    NO.   TON/FT    NO.   TON/FT    NO.   TON/FT

VARY R=0:1:101
K=STAND R
K=K/4
K=FRAC K
JUMP UNLESS K=0@65
LINE
65)PRINT R
PRINT YR,3:2
REPEAT R
```

```
67)READ P2::
JUMP IF P2=0@87::GRAPH NOT REQD.-(1 IF GRAPH REQD.)
VARY R=0:1:101
BR=YR
REPEAT R
VARY I=1:1:25
OUTPUT 0
REPEAT I

TITLE



LOCAL WEIGHT ORDINATES (PROJECTED FORWARD)
------------------------------------------

SUBR 86::  GRAPH SCALES
SUBR 110:: GRAPH OUTPUT
87)READ P1::1 FOR CONT. WEIGHT TABLE :0 IF OTHERWISE
JUMP IF P1=0@74
VARY I=1:1:50
OUTPUT 0
REPEAT I

TITLE



        CONTINUOUS WEIGHT CURVE ORDINATES (PROJECTED FORWARD).


   ORD   WEIGHT    ORD   WEIGHT    ORD   WEIGHT    ORD   WEIGHT
   NO.   TON/FT    NO.   TON/FT    NO.   TON/FT    NO.   TON/FT

S=0
VARY R=0:1:101
K=STAND R
K=K/4
K=FRAC K
JUMP UNLESS K=0@27
LINE
27)PRINT R
PRINT VR,3:2
S=S+VR
REPEAT R
S=S*L6
LINE
CHECK S
```

```
74)READ P2::
JUMP IF P2=0@73::0 IF GRAPH NOT REQD -(1 IF GRAPH REQD)
VARY R=0:1:101
BR=VR
REPEAT R
VARY I=1:1:25
OUTPUT 0
REPEAT I

TITLE



CONTINUOUS WEIGHT CURVE ORDINATES (PROJECTED FORWARD).
-----------------------------------------------------


SUBR 86::  GRAPH SCALES
SUBR 110:: GRAPH OUTPUT

73)S=0
VARY R=0:1:101
YR=YR+VR
BR=YR::FOR SUBR 29 BELOW (LCG POSITION).
S=S+YR
REPEAT R
S=S*L6
LINE
CHECK S
W32=W31-S
W3=MOD W32
JUMP UNLESS W3%W31/1000@51
TITLE

RESULTANT COMPUTED TOTAL WEIGHT =
PRINT S,5:2
TITLE TONS
ERROR =
W3=-W32
PRINT W3,2:2
TITLE TONS     % ERROR =
W3=W3/W31
W3=W3*100
PRINT W3,2:2
LINES 2
VARY I=0:1:50
OUTPUT 5
REPEAT I::INDICATES BY OUTPUT OF $$$$$$$$$$ WHEN ERROR GR THAN 0.1%
LINE

WAIT::IF ERROR IS ACCEPTABLE, PROGRAMME MAY BE CONTINUED.

51)SUBR 29::   TO OBTAIN PROVISIONAL L.C.G.
```

```
T2=T1-K3::
T3=MOD T2
JUMP UNLESS T3%K3/100@25
TITLE

RESULTANT COMPUTED LCG POSITION =
PRINT T1,3:2
TITLE FT FWD OF A.E.
ERROR =
PRINT T2,2:2
TITLE FT          % ERROR =
T3=T3/K3
T3=T3*100
PRINT T3,2:2
LINES 2
VARY I=0:1:50
OUTPUT 24
REPEAT I::INDICATES BY OUTPUT  OF @@@@@@@@@@ WHEN ERROR GR THAN 1%
LINES 2

WAIT::IF ERROR IS ACCEPTABLE, PROGRAMME MAY BE CONTINUED.


25)L8=L/2
K2=W31*K3
K2=K2-T
K2=K2/W32
K1=K2
A=W32/L
A=A/L
JUMP IF K2$L8@20
K2=L-K2
20)K2=K2*6
K2=K2-L
K2=K2-L
A=A*K2
B=2*W32
B=B/L
B=B-A
JUMP IF K1$L8@23
F=A
A=B
B=F
23)D=B
B=D-A
CHECK D
CHECK A
CHECK B
F=B/100
VARY R=0:1:101
S=STAND R
BR=S*F
BR=D-BR
REPEAT R
```

```
VARY R=0:1:100::
J=R+1
S=BR+BJ
S=S/2
BR=S
REPEAT R

READ P1::1 FOR WEIGHT CURVE ORDINATES: 0 IF OTHERWISE
JUMP IF P1=0@75
VARY I=1:1:50
OUTPUT 0
REPEAT I

TITLE




            TOTAL WEIGHT CURVE ORDINATES (PROJECTED FORWARD)


  ORD     WEIGHT    ORD     WEIGHT    ORD     WEIGHT    ORD     WEIGHT
  NO.     TON/FT    NO.     TON/FT    NO.     TON/FT    NO.     TON/FT


75)S=0
VARY R=0:1:100
YR=YR+BR
JUMP IF P1=0@76
K=STAND R
K=K/4
K=RAC K
JUMP UNLESS K=0@28
LINE
28)PRINT R
PRINT YR,3:2
76)BR=YR::FOR GRAPH OUTPUT AND FOR SUBR 29 (FOR LCG POSITION).
S=S+YR
REPEAT R
S=S*L6

SUBR 29::TO OBTAIN LCG

VARY I=1:1:25
OUTPUT 0
REPEAT I
```

```
READ P2::

TITLE


      WEIGHT        L.C.G. FWD. A.E.

SPACES 4
PRINT S,6:2
SPACES 9
PRINT T1,3:2

JUMP IF P2=0@90::0 IF GRAPH NOT REQD.

VARY I=1:1:25
OUTPUT 0
REPEAT I

TITLE



TOTAL WEIGHT CURVE ORDINATES (PROJECTED FORWARD)
------------------------------------------------


SUBR 86:: GRAPH SCALES
SUBR 110::GRAPH OUTPUT


90)READ S17::MEAN DRAUGHT
READ M2::MCT.1
READ L10::L.C.B.FWD.OF A.E.
READ L11::L.C.F.FWD.OF A.E.
READ S16::WAVE HEIGHT (CREST TO TROUGH)
READ L9:: WAVELENGTH  -  DATA SHEET 0 IF STILL WATER
READ P3:: 1 IF SAGGING,  0 IF HOGGING OR STILL WATER
READ S18: FT.FROM STERN WHERE CREST OR TROUGH OF WAVE FALLS

X1=L3/10
S1=L1/4
S2=S1
CYCLE I=3,4,12,13
SI=0.125*X1
REPEAT I
S5=0.25*X1
S11=S5
S6=0.5*X1
S10=0.5*X1
```

```
VARY I=7:1:3::
SI=X1
REPEAT I
S14=L2/4
S15=S14
X=0
CHECK X
VARY J=1:1:15
X(2J-1)=X(2J-2)+SJ
X(2J)=X(2J-1)+SJ
CHECK X(2J-1)
CHECK X(2J)
REPEAT J::X - VALUES TO 31 STATION POSITIONS.

L12=L10-K3::(LCB-LCG)
B2=W31*L12
B3=B2/M2::TRIMMING MOMENT / MCT1 = TRIM IN INCHES
B3=B3/12::TRIM IN FEET
F1=B3/L3::TRIM IN FT PER FT LENGTH
F6=F1*L11::TRIM IN FT OVER DISTANCE OF LCF FROM AE.
F6=S17+F6::DRAUGHT AT STERN  -  STILL WATER.

WAIT::  FOR TAPE 4   -   BONJEAN DATA.

JUMP IF P4%1@19


123)READ H::WATERLINE SPACING.
READ Q1::      FOR CHOICE OF 1/8THS OR 1/4S
READ N1
READ N2
N=N1+N2
JUMP IF Q1=0.125@10
N=N+3
N3=2*N
Z=0
H1=H/4
H2=H/4
H3=H/2
VARY I=4:1:N1
HI=H
REPEAT I
N4=N1+4
JUMP @16
10)N=N+4
N3=2*N
Z=0
H1=H/8
H2=H/8
H3=H/4
H4=H/2
```

```
VARY I=5:1:N1::
HI=H
REPEAT I
N4=N1+5
16)JUMP IF N2=0@6
VARY I=N4:1:N2
HI=H/2
REPEAT I
6)VARY I=1:1:N
Z(2I-1)=Z(2I-2)+HI
Z(2I)=Z(2I-1)+HI
CHECK Z(2I-1)
CHECK Z(2I)
REPEAT I
VARY J=0:1:31
READ S19::      SECTION NUMBER
CHECK S19
READ P(J+5)::          0 IF NO READINGS IN COLUMN, 1 OTHERWISE
JUMP IF P(J+5)=0@62
READ Z(51+J)::Z MIN
READ Z(82+J)::Z MAX.
CYCLE I=0:1:N3
READ GI
REPEAT I::ALF-WIDTHS.
READ G52::Y AT Z MAX.
I=0
O(25J+I)=0
CHECK I
CHECK O(25J+I)
JUMP IF Z(51+J)=0@33
READ G51
31)I=I+1
M=Z(51+J)-Z(2I)
M=MOD M
JUMP IF M$0.0001@42::ENSURES ZERO RESULT IF Z MIN SHOULD 'EQUAL'
JUMP IF Z(51+J)$Z(2I)@32::                  Z(2I), IN FL.PT.  MODE.
O(25J+I)=O(25J)
CHECK I
CHECK O(25J+I)
JUMP @31
42)Z(51+J)=Z(2I)
32)T=Z(2I)-Z(51+J)
T=T/3
T1=4*G51
T2=T1+G(2I)
S20=T2*T
R=I-1
O(25J+I)=O(25J+R)+S20
CHECK I
CHECK O(25J+I)
JUMP IF Z(82+J)$Z(2I+2)@120
```

```
33)I=I+1::
T=HI/1.5
T1=4•G(2I-1)
T2=T1+G(2I-2)
T2=T2+G(2I)
T2=T2•T
R=I-1
O(25J+I)=O(25J+R)+T2
CHECK I
CHECK O(25J+I)
JUMP IF Z(82+J)%Z(2I+2)@33
120)T=Z(82+J)-Z(2I)
T1=G(2I)+G52
T1=T1•T
R=I
I=I+1
O(25J+I)=O(25J+R)+T1
CHECK I
CHECK O(25J+I)
W(35+J)=O(25J+I)::MAX. AREA
62)REPEAT J

19)VARY J=0:1:31
JUMP IF P(J+5)=0@38
I=0
HJ=0
JUMP IF L9=0@39
C=XJ-S18
C=2•C
C=C/L9
C=COS C
JUMP IF P3=1@26
C=-C
26)HJ=S16/2
HJ=HJ•C
39)B=F1•XJ
B=-B+F6
HJ=HJ+B
CHECK HJ::                WAVE HEIGHT ABOVE KEEL
```

```
UJ=W(35+J)::
SUBR 30
WJ=UJ

JUMP IF L9=0@41
JUMP IF P3=0@71

HJ=HJ+4
JUMP @72
71)HJ=HJ-4
72)UJ=W(35+J)

SUBR 30

JUMP @41
38)WJ=0
UJ=0
CHECK WJ
CHECK UJ
41)REPEAT J

JUMP IF L9=0@56
M=0
M1=0
M3=0
M4=0
Q1=0
Q3=0


VARY I=1:1:15
T=SI/3
T1=4*W(2I-1)
T2=T1+W(2I)
T2=T2+W(2I-2)
T2=T2*T
Q1=Q1+T2

T1=T1*X(2I-1)
T2=W(2I)*X(2I)
T3=W(2I-2)*X(2I-2)
T4=T1+T2
T4=T4+T3
T4=T4*T
M=M+T4
```

```
T1=T1*X(2I-1)::
T2=T2*X(2I)
T3=T3*X(2I-2)
T4=T1+T2
T4=T4+T3
T4=T4*T
M3=M3+T4

T1=4*U(2I-1)
T2=T1+U(2I)
T2=T2+U(2I-2)
T2=T2*T
Q3=Q3+T2

T1=T1*X(2I-1)
T2=U(2I)*X(2I)
T3=U(2I-2)*X(2I-2)
T4=T1+T2
T4=T4+T3
T4=T4*T
M1=M1+T4

T1=T1*X(2I-1)
T2=T2*X(2I)
T3=T3*X(2I-2)
T4=T1+T2
T4=T4+T3
T4=T4*T
M4=M4+T4

REPEAT I

Q3=Q3-Q1
Q3=Q3/4
Q2=M1-M
Q2=Q2/4
Q4=Q2/L
Q5=M4-M3
Q5=Q5/4
Q5=Q5/L

Q7=Q6*K3
Q8=Q6-Q1
Q9=Q7-M
F2=Q4*Q2
F3=Q8*Q2
F4=Q3*Q5
F5=Q9*Q3
F2=F2-F4
F3=F3-F5
B=F3/F2
F1=Q4*B
Q8=Q8-F1
A=Q8/Q3
```

```
CHECK A::
CHECK B
VARY J=0:1:31
S=XJ*B
S=S/L
S=S+A
UJ=UJ-WJ
UJ=UJ/4
S=S*UJ
WJ=WJ+S
REPEAT J

56)VARY J=0:1:31
AJ=WJ/35
REPEAT J

VARY R=0:1:101
DR=0
REPEAT R

I=0::EXTRA COUNT FOR XJ IN SUBR 58
JUMP IF A%0@131
N=0
VARY R=1:1:10
JUMP IF N%0@132
S=AR-A(R-1)
JUMP IF S=0@132
N=R
I=N-1
132)REPEAT R
131)J=30
JUMP IF A30%0@133
VARY R=29:-1:10
JUMP IF J$30@134
S=AR-A(R+1)
JUMP IF S=0@134
J=R
134)REPEAT R

133)X=XI
X1=X(I+1)
X2=X(I+2)
A=AI
A1=A(I+1)
A2=A(I+2)

S=XI/L6
N1=INT S
N1=N1+1
S=XJ/L6
J=INT S
J1=J+1
```

```
I=0
138)S=0
VARY R=1:1:100
M1=DR+D(R-1)
M1=M1/2
S=S+M1
REPEAT R
S=S*L6
CHECK S
JUMP IF I=1@139
W32=W31-S
N2=J1-N1
CHECK N2
K=STAND N2
K=W32/K
K=K/L6

VARY R=N1:1:N2
DR=DR+K
REPEAT R

I=I+1
JUMP @138

139)VARY I=0:1:100
M1=DI+D(I+1)
BI=M1/2
REPEAT I

SUBR 29

M4=0

VARY I=0:1:100
JUMP IF D(I+1)$DI@12
K=D(I+1)-DI
M1=DI*DI
JUMP @142

12)K=DI-D(I+1)
M1=D(I+1)*D(I+1)
142)M1=M1*L6
M1=M1/2
M2=K*L6
M2=M2/2
K=K/3
JUMP IF D(I+1)$DI@141
```

```
K=K+DI::
JUMP @135
141)K=K+D(I+1)
135)M2=M2*K
M4=M4+M1
M4=M4+M2
REPEAT I::VERTICAL MOMENTS

VARY R=0:1:101
AR=DR
DR=0
REPEAT R

H=M4/S::CENTRE OF AREA OF BUOYANCY CURVE (VERT).
CHECK H

L8=T1-K3
M=L8/H::RATIO TO AFFECT ALL AI VALUES
CHECK M

X=0
VARY J=1:1:50
X(2J-1)=X(2J-2)+L6
X(2J)=X(2J-1)+L6
REPEAT J

VARY I=0:1:101
S=AI*M
XI=XI-S
REPEAT I

I=N1-1

X=XI
X1=X(I+1)
X2=X(I+2)
A=AI
A2=A(I+2)

SUBR 58

VARY R=0:1:100
J=R+1
S=DJ+DR
DR=S/2
REPEAT R
```

```
WAIT::FOR TAPE 5  -  CHOICE OF REMAINING TABLES/GRAPHS. PAGE 23

READ P1:: 1 FOR BUOYANCY TABLE REQD., -  0 OTHERWISE.
JUMP IF P1=0@77

VARY I=1:1:50
OUTPUT 0
REPEAT I

TITLE




         BUOYANCY  CURVE  ORDINATES  (PROJECTED  FORWARD).


  ORD    BUOY     ORD    BUOY     ORD    BUOY     ORD    BUOY
  NO.    TON/FT   NO.    TON/FT   NO.    TON/FT   NO.    TON/FT


77)S=0
VARY R=0:1:100
JUMP IF P1=0@119
K1=STAND R
K1=K1/4
K1=FRAC K1
JUMP UNLESS K1=0@61
LINE
61)PRINT R
119)JUMP IF DR$0@44
JUMP @43
44)DR=0
43)JUMP IF P1=0@78
PRINT DR,3:2
78)BR=DR::FOR GRAPH
S=S+DR
REPEAT R

S=S*L6
CHECK S
SUBR 29::  TO OBTAIN LCB.
VARY I=1:1:25
OUTPUT 0
REPEAT I
```

```
LINE::
TITLE


   DISPLACEMENT          L.C.B.
                         FWD.A.E.

SPACES 3
PRINT S,7:2
SPACES 7
PRINT T1,4:2
LINE
READ P2
JUMP IF P2=0@91
VARY I=1:1:25
OUTPUT 0
REPEAT I
TITLE



BUOYANCY CURVES ORDINATES  (PROJECTED FORWARD).
-----------------------------------------------
SUBR 86::  GRAPH SCALES
SUBR 110:: GRAPH OUTPUT

91)VARY R=0:1:101
YR=DR-YR
BR=YR
REPEAT R

READ P1:: 1 IF LOAD CURVE TABLE REQD. - 0 OTHERWISE.
JUMP IF P1=0@79
VARY I=1:1:50
OUTPUT 0
REPEAT I
TITLE



        LOAD  CURVE  ORDINATES (PROJECTED  FORWARD)


  ORD    LOAD      ORD    LOAD      ORD    LOAD      ORD    LOAD
  NO.    TON/FT    NO.    TON/FT    NO.    TON/FT    NO.    TON/FT
```

```
VARY R=0:1:101::
K1=STAND R
K1=K1/4
K1=FRAC K1
JUMP UNLESS K1=0@17
LINE
17)PRINT R
PRINT YR,3:2
REPEAT R

79)READ P2
JUMP IF P2=0@112

VARY I=1:1:25
OUTPUT 0
REPEAT I



TITLE



LOAD CURVE ORDINATES  (PROJECTED FORWARD)
-----------------------------------------
SUBR 86::  GRAPH SCALES
SUBR 110:: GRAPH OUTPUT
112)D=0
VARY J=0:1:100
R=J+1
A=YJ*L6
DR=DJ+A
REPEAT J
CHECK D100
F=D100/100
VARY J=0:1:101
JUMP IF J=0@21
K1=STAND J
YJ=K1*F
YJ=DJ-YJ
JUMP @113
21)Y=0
113)BJ=YJ
REPEAT J

READ P1::1 IF SHEAR FORCE TABLE REQD.- 0 OTHERWISE
JUMP IF P1=0@92
VARY I=1:1:50
OUTPUT 0
REPEAT I
```

```
LINE::                                                    PAGE 26

TITLE
```

SHEAR FORCE CURVE ORDINATES.

ORD NO.	S.F. TONS	ORD NO.	S.F. TONS	ORD NO.	S.F. TONS	ORD NO.	S.F. TONS

```
VARY J=0:1:101
K1=STAND J
K1=K1/4
K1=FRAC K1
JUMP UNLESS K1=0@40
LINE
40)PRINT J
PRINT YJ,5:0
REPEAT J

92)READ P2
READ I5::         FOR CONTROL IN SUBR 86  -  (FIRST SET TO ZERO ON
JUMP IF P2=1@114::          PAGE 9, FOR ALL PREVIOUS CURVES.
JUMP IF I5=0@15
114)VARY I=1:1:25
OUTPUT 0
REPEAT I
TITLE


SHEAR FORCE CURVE
-----------------
SUBR 86:: GRAPH SCALES
JUMP IF P2=0@15
SUBR 109:: GRAPH OUTPUT

15)X=0
VARY J=1:1:50
X(2J-1)=X(2J-2)+L6
X(2J)=X(2J-1)+L6
REPEAT J

B=0
```

```
VARY J=0:1:100::
R=J+1
A=YR+YJ
A=A*L6
A=A/2
BR=BJ+A
REPEAT J
CHECK B100
VARY J=0:1:101
JUMP IF J=0@55
K1=STAND J
YJ=L*L
YJ=B100/YJ
K2=XJ*XJ
YJ=YJ*K2
BJ=BJ-YJ
JUMP @115
55)B=0
115)REPEAT J

READ P1::1 FOR BENDING MOMENTS TABLE -0 OTHERWISE
JUMP IF P1=0@68
VARY I=1:1:50
OUTPUT 0
REPEAT I

TITLE




              BENDING  MOMENT  CURVE  ORDINATES.


   ORD      B.M.      ORD      B.M.      ORD      B.M.      ORD      B.M.
   NO.     TON FT     NO.     TON FT     NO.     TON FT     NO.     TON FT

VARY J=0:1:101
K1=STAND J
K7K1/4
K1=FRAC K1
JUMP UNLESS K1=0@66
LINE
66)PRINT J
PRINT BJ,6:0
REPEAT J
```

```
68)I5=0::
READ P2
READ I6:: FOR CONTROL IN SUBR 86  -  PREVIOUSLY SET TO ZERO ON
JUMP IF P2=1@93::GRAPH REQUIRED          ON PAGE 9.
JUMP IF I6=0@121
93)VARY I=1:1:25
OUTPUT 0
REPEAT I

TITLE
```

BENDING MOMENT CURVES

```
SUBR 86:: GRAPH SCALES
JUMP IF P2=0@121
SUBR 109:: GRAPH OUTPUT
121)STOP::        E N D   O F   P R O G R A M M E.
```

```
29)X=L6/2
T=0
VARY R=0:1:100
M=BR*L6
M=M*X
T=T+M
X=X+L6
REPEAT R
T1=T/S
EXIT
```

```
58)R=N1::
S=STAND N1
S=S*L6
N=2+I
85)Q6=S-X0
Q7=S-X1
Q8=S-X2
F0=Q6*Q7
F1=Q6*Q8
F2=Q7*Q8
Q=X2-X0
Q1=X2-X1
Q2=X1-X0
Q3=X1-X2
Q4=X0-X1
Q5=X0-X2
Q6=Q*Q1
Q7=Q2*Q3
Q8=Q4*Q5
F0=F0/Q6
F1=F1/Q7
F2=F2/Q8
F0=F0*A2
F1=F1*A1
F2=F2*A0
F=F+F1
F=F+F2
DR=F
CHECK DR
CHECK R
S=S+L6
R=R+1
JUMP IF R=J1@82
JUMP IF R%50@60
59)JUMP IF S%X1@81
60)JUMP IF S%X2@81
JUMP @85
81)X0=X1
X1=X2
A0=A1
A1=A2
N=N+1
X2=XN
A2=AN
JUMP IF R%50@60
JUMP @59
82)EXIT
```

```
86)JUMP IF I3%0@48::
K4=0
K5=0
VARY R=1:1:100
JUMP UNLESS BR%K5@88
K5=BR
88)JUMP UNLESS BR$K4@89
K4=BR
89)REPEAT R
TITLE

MAXIMUM POSITIVE VALUE =
PRINT K5,7:2
TITLE
MAXIMUM NEGATIVE VALUE =
PRINT K4
JUMP IF I5=1@45
JUMP IF I6=1@45
JUMP @57
48)I4=I4+1
JUMP IF I5=0@24
K5=S25
K4=S26
JUMP @57
24)K5=M6
K4=M7
57)K5=K5-K4::RANGE
JUMP IF I4%2@53::AVOIDS RE-PRINTING TNE FOLLOWING TITLES
K4=-K4/K5::FRACTION OF RANGE
K7=1-K4
K4=K4*30
K4=K4*S22::DIST(IN CMS)OF X-AXIS FROM BASE OF GRAPH PAGE
K7=K7*30
K7=K7*S22
K7=K7+K4::HEIGHT OF Y-AXIS
TITLE

X-AXIS DISTANCE (CMS) FROM BASE OF GRAPH PAPER =
JUMP IF S22=1@136::IF S22=0.5 ALL X-AXES MAY BE CENTRAL.
TITLE 16
JUMP @137
136)R=INT K4
PRINT R

137)TITLE

HEIGHT OF Y-AXIS =


R=INT K7
PRINT R
```

```
53)JUMP UNLESS K5%15@94::
JUMP UNLESS K5%30@95
JUMP UNLESS K5%150@96
JUMP UNLESS K5%300@97
JUMP UNLESS K5%600@98
JUMP UNLESS K5%1500@99
JUMP UNLESS K5%3000@100
JUMP UNLESS K5%6000@101
JUMP UNLESS K5%15000@102
JUMP UNLESS K5%30000@103
JUMP UNLESS K5%60000@104
JUMP UNLESS K5%150000@105
JUMP UNLESS K5%300000@106
JUMP UNLESS K5%600000@107
JUMP @108
94)S=200
JUMP @116
95)S=100
JUMP @116
96)S=20
JUMP @116
97)S=10
JUMP @116
98)S=5
JUMP @116
99)S=2
JUMP @116
100)S=1
JUMP @116
101)S=0.5
JUMP @116
102)S=0.2
JUMP @116
103)S=0.1
JUMP @116
104)S6.05
UMP @116
105)S=0.02
JUMP @116
106)S=0.01
JUMP @116
107)S=0.005
JUMP @116
108)S=0.002
116)S=S*S22::ADJUSTS FOR 30 CM. OR 15 CM. WIDE PAGE
JUMP IF I4%2@80:: AVOID RE-PRINTING THE FOLLOWING TITLES.
TITLE

HORIZONTAL SCALE OF GRAPH  ---  1 CM  =
PRINT S27,2
TITLE  FT

VERTICAL SCALE OF GRAPH   ---   UNITS/CM:-
S1=100/S
PRINT S1,5:1
TITLE

----------------------------------------
```

```
80)VARY R=0:1:200::
OUTPUT 0
REPEAT R
45)EXIT

109)C3=0
C4=0
C1=0
C2=0
F=GRAPH C1,C2:
CYCLE R=0:1:99
C1=L6*S24
C1=C1+C4
C2=B(R+1)-BR
C2=C2*S
C2=C2+C3
F=GRAPH C1,C2:
C4=C1
C3=C2:
REPEAT R
VARY R=1:1:200
OUTPUT 0
REPEAT R
EXIT


110)C1=0
C2=0
F=GRAPH C1,C2:
C2=B*S
F=GRAPH C1,C2:
C1=L6*S24
F=GRAPH C1,C2:
C4=C1
C3=C2:
VARY R=1:1:100
C2=BR-B(R-1)
C2=C2*S
C2=C2+C3
F=GRAPH C1,C2:
JUMP IF R=100@111
C1=L6*S24
C1=C1+C4
F=GRAPH C1,C2:
C4=C1
C3=C2:
111)REPEAT R
VARY R=1:1:200
OUTPUT 0
REPEAT R
EXIT
```

```
124)S1=0::
T5=0
VARY R=0:1:101
YR=0
REPEAT R
READ P4::0 FOR COMMON LOCAL WTS. TAPE: 1, 2, 3, 4 ETC FOR REST.
READ N::NUMBER OF WEIGHTS
VARY I=1:1:N
READ M
READ S
READ B
READ X
B2=S/6
B1=MOD B
JUMP UNLESS B1%B2@63
TITLE
OFFENDING ITEM -  B  -
PRINT I
LINE
VARY R=0:1:30
OUTPUT 23
REPEAT R::INDICATES BY OUTPUT OF /////////// WHEN ITEM OFFENDS.

WAIT::REMOVE TAPE AND CORRECT

63)Q=X-B
Q1=S/2
Q3=Q+Q1
JUMP UNLESS Q3%L@52
TITLE
OFFENDING ITEM -  Q3  -
PRINT I
LINE
VARY R=0:1:30
OUTPUT 23
REPEAT R::INDICATES BY OUTPUT OF /////////// WHEN ITEM OFFENDS.

WAIT::REMOVE TAPE AND CORRECT

52)Q2=Q-Q1
JUMP UNLESS Q2$0@122
TITLE
OFFENDING ITEM -  Q2  -
PRINT I
LINE
VARY R=0:1:30
OUTPUT 23
REPEAT R::INDICATES BY OUTPUT OF /////////// WHEN ITEM OFFENDS.
WAIT

122)S1=S1+M
M1=M*X
T5=T5+M1
CHECK S1
CHECK T5
```

```
Q2=Q2/L6::
Q3=Q3/L6
J2=INT Q2
J3=INT Q3
JUMP IF J2=J3@3::          ALL SHAPES
F2=FRAC Q2
F2=1-F2
F2=F2*L6
F3=FRAC Q3
F3=F3*L6
JUMP UNLESS B=0@9
A=M/S::                    RECTANGLE CALCULATIONS
JUMP UNLESS J3=J2+1@5
JUMP IF F3=0@3::CALCULATION WHEN RECTANGLE LENGTH LESS THAN 2L/100
SUBR 46
JUMP IF F2=0@4
SUBR 36
JUMP @22
3)A=M/L6
4)R=J2
YR=YR+A
JUMP @22
5)JUMP IF F3=0@2
SUBR 46
2)JUMP IF F2=0@7
SUBR 36
J2=J2+1
7)N1=J3-J2
VARY P=0:1:N1
R=J2+P
YR=YR+A
REPEAT P
JUMP @22

9)H3=6*B::                 TRAPEZIUM CALCULATIONS
H3=H3/S
H3=H3+1
H3=H3*M
H3=H3/S::FORE ORD.
H2=M*2
H2=H2/S
H2=H2-H3::REAR ORD.
H=H3-H2
H=H/S::SLOPE (PER FOOT)
JUMP UNLESS J3=J2+1@13
JUMP IF F3=0@3
```

```
SUBR 64::

JUMP IF F2=0@11

A2=H1+H2
A2=A2/2

SUBR 34

JUMP @22

11)A=H2+H1
A=A/2
R=J2
YR=YR+A
JUMP @22

13)A3=0
JUMP IF F3=0@14

SUBR 64


14)JUMP IF F2=0@18
H1=H*F2
H1=H2+H1
A2=H1+H2
A2=A2/2

SUBR 34

H2=H1
N1=J3-J2
N1=N1-1
N2=1

SUBR 35

JUMP @22
18)N1=J3-J2
N2=0

SUBR 35
22)REPEAT I

EXIT


46)A3=A*F3
A3=A3/L6
R=J3
YR=YR+A3
EXIT
```

```
36)A2=A*F2::
A2=A2/L6
R=J2
YR=YR+A2
EXIT

64)H1=H*F3
H1=H3-H1
A3=H1+H3
A3=A3/2
A3=A3*F3
A3=A3/L6
R=J3
YR=YR+A3
EXIT

34)A2=A2*F2
A2=A2/L6
R=J2
YR=YR+A2
EXIT

35)H=H*L6
VARY P=N2:1:N1
R=J2
R=R+P
H1=H2+H
A=H1+H2
A=A/2
H2=H1
YR=YR+A
REPEAT P
EXIT


30)JUMP UNLESS HJ$Z(82+J)@47
UJ=0
JUMP UNLESS HJ%0@47
JUMP UNLESS HJ%Z(51+J)@47
I=0
37)I=I+1
JUMP IF HJ%Z(2I)@37
JUMP IF Z(82+J)%Z(2I)@69
JUMP IF Z(51+J)%Z(2I-2)@128

UJ=Z(82+J)-Z(2I-2)
JUMP @70
128)UJ=Z(82+J)-Z(51+J)
JUMP @129
```

```
69)JUMP IF Z(51+J)%Z(2I-2)@130::
UJ=Z(2I)-Z(2I-2)
70)B=HJ-Z(2I-2)
B=B/UJ
R=I-1
UJ=O(25J+I)-O(25J+R)
UJ=UJ*B
UJ=O(25J+R)+UJ
JUMP @47
130)UJ=Z(2I)-Z(51+J)
129)B=HJ-Z(51+J)
B=B/UJ
UJ=O(25J+I)*B
47)CHECK UJ::AREA TO WAVE HEIGHT
EXIT

START 1
```

LONGITUDINAL STRENGTH OF SHIPS

BENDING MOMENT CALCULATIONS

(Programmed in Elliott Autocode for use on the
Elliott 803 Digital Computer)

The programme calculates and outputs any or all of the following tables and/or graphs:-

(i) Local Weights distribution.

(ii) Continuous Weight distribution
(a) Lloyd's method, (b) Biles Coffin method.

(iii) Total Weight distribution.

(iv) Buoyancy.

(v) Load curve.

(vi) Shear Force curve.

(viii) Bending Moment curve.

Ordinate values are given over each of 100 equal divisions of the ship's length overall. Values are averaged over every pair progressively and are projected forward over the appropriate division in the first five of the above tables.

Graph output on the Benson Lehner plotter is provided, if desired. Graphs of Shear Force and Bending Moment are continuous polygons, whereas the five other graphs consist of a series of straight horizontal lines drawn forward from each ordinate in turn.

In the case of Shear Force and Bending Moment, maximum positive and maximum negative values only may be output if required, in order that the data for several loading conditions may be re-run to produce, respectively, all graphs to fixed (preset) scales, dependent on these values.

Output of all of the above tables for one loading condition takes 8 - 10 minutes. Graph output averages about 2 mins. per graph.

Distribution of the Continuous Weight may be performed by either of two methods available : Biles Coffin or Lloyd's (see their RPT. SR 64/15).

31 sections are used overall in the Buoyancy calculations, of which 23 are within and include the perpendiculars, with four aft and four forward.

After the complete set of data has been read in for the first condition, it is only necessary to read in the relevant changes of data for subsequent conditions. The Lightship concentrated items are distributed and permanently stored, as are the calculated Bonjean areas to each even waterline, which follows the initial input of the buoyancy data. Subsequent buoyancy ordinates are determined by calculation from such items as mean draught, and MCT 1", items peculiar to each loading condition.

<u>Programme and Data Tapes</u> - Operating Instructions.

(Programme)

Enter Binary programme tape	4	0	0
	0	0	0
Follow with Autocode Plotter Tape 2, entered	4	0	0
	0	0	0

(Data)

Enter tape for first condition	4	0	1 6
	0	0	0
All subsequent tapes, enter	4	0	1 6
	0	0	12 6

<u>Notes on Data Tapes</u>

It is advisable to have one complete tape for the first condition, consisting of:-

Scales and Lightship concentrated items	(Tape 1)
Deadweight items, displacement, L.C.G., Lloyd's 'a' values (or Biles information)	(Tape 2)
Tables/Graphs output constants ; Trim data . .	(Tape 3)
Bonjean data	(Tape 4)
Tables/Graphs/Max. values output constants	(Tape 5)

each tape separated by several inches of blank tape.

Subsequent conditions require to have entered only the changed data of the deadweight items with the appropriate displacement and L.C.G. (Tape 2); Tables/Graphs constants, trim data (Tape 3); and Tables/Graphs/ Max. values constants (Tape 5); it is advisable to have these three tapes again as one complete tape. Thus instead of many small tapes, there is one complete tape per condition.

There are programme WAITS after each part of the above compound tapes, for greater control of the data. There is also an immediate WAIT at the beginning, just before the lightship data is fed in, to allow use of an amended tape for a graph re-run. WAIT will also be encountered, apart from those between the 'part tapes' of the subsequent conditions, at the stage when Tape 4 would be expected.

Presentation of Data

The following pages show the style and presentations of the data (partially completed), as submitted by the shipyard, and the same data when typed/punched for input to the computer.

Note: (i) Waterline spacings variable H in the Longitudinal Strength programme replaces variable D in the Bonjean data sheet.

(ii) Half-widths "YI" in the Bonjean data, are known as "GI" in this programme.

Tape 1. (Required for FIRST data run only). Sheet (i)

If some (or all) conditions are to be re-run in order to graph all Shear Force curves to the same scale (and similarly the Bending Moment curves), from the maximum values determined on a previous run, PUT 13 = 1.
IN ALL OTHER CASES, PUT 13 = 0.

	Programme Variable.
0	13

If 13 = 0, omit this section, and go on to the next section.
If 13 = 1, enter the appropriate maximum values from the previous runs. (If either one is not required, enter two zeros for that curve).

Maximum Shear Force (+ve) tons		S25
" " " (-ve) "		S26
Maximum Bending Moment (+ve) tons/ft.		M6
" " " (-ve) " "		M7

(PROGRAMME W A I T HERE)

0 for Lloyd's method: 1 for Biles Coffin	0	I1
Length Overall ft.	617	L
Length of Stern Overhang "	23	L1
Length of Bow Overhang "	14	L2

Enter 1 for full width graph, 0.5 for half width graph or 0 for no graph	1	S22
Horizontal Scale required (Convenient choice : 10, 20 or 40 - ft/cm.) Enter 0 if no graph required.	20	S27

Code Number for Lightship Concentrated Items	0	P4
Number of Concentrated Lightship Items	71	N

Tape 1 (Contd)

Sheet (ii)

	ITEM	Weight (tons) (M)	Length (ft) (S)	Dist. of L.C.G. * from C/L of Item. (B)	L.C.G. from stern (X)
1.	Lower Bdge Dk & Hse below	75.17	94.50	0	81.75
2.	Upper " " " "	58.96	90.00	0	
3.	Boat " " " "				
4.					
	etc. etc.				
	etc. etc.				
				0	443.50
		45.18	2.25	0	510.12
		20.00	1.00	0	572.00
71.	Capstans	5.48	4.00	0	284.00

* -ve if aft of Centre of Length.

Sheet (i)
Programme
Variable.

TAPE 2

Code number for this Sheet - i.e. Condition Number. (1, 2, 3, ... etc.)	1	P4
Number of DEADWEIGHT Items for this condition	36	N

DEADWEIGHT ITEMS

	ITEM	Weight (tons) (M)	Length (ft) (S)	Dist. of L.C.G. * from C/L of Item. (B)	L.C.G. from stern (X)
1	W.B. in No. 1 D.B. Tank	436.00	63.00	-3.87	536.63
2	" " 2 " "	726.00	65.00	-1.34	475.16
3	" " 3 " "	1162.00			
	etc. etc.				
	etc. etc.				
		100.00	80.00	0	88.00
36	Engineers Spare Gear	40.00	80.00	0	72.45

* -ve if aft of Centre of Length.

Tape 2 (contd) Sheet (ii)

TITLE output at Head of Results

= crlf[4]

Name of firm

SHIPYARD A.

Ship No. X

LONGITUDINAL STRENGTH CALCULATIONS

CONDITION No. 1
BALLAST DEPARTURE
FULL BUNKERS.

*STILL WATER
*~~SINE~~ WAVE SAGGING
*~~SINE~~ WAVE HOGGING

(delete those * not Required).

Programme Variable.

Displacement	(tons)	21318.65	W31
L.C.G. forward of Stern	(ft)	321.79	K3

Sheet (iii)

Tape 2 (Contd). (This part of Tape 2 not required after the first data run).

If Continuous Weight is to be distributed by Biles Coffin method, complete lines (a), (b), (c), (d) below, otherwise complete (e) from Lloyds tables SR 64/15.

For FIRST data run only:

	Programme Variable.
(a) Weight of Overhang of Stern.	W33
(b) Weight of Overhang of Bow.	W34
(c) L.C.G. of Overhang of Stern, from Stern.	L4
(d) L.C.G. of Overhang of Bow, from Stern.	L5

(e) For FIRST data run only:

	Stn. 0	Stn. 1	Stn. 2	Stn. 3	Stn. 4	Stn. 5	Stn. 6
0	.34	.495	.625	.73	.815	.885	.94
Stn. 7	Stn. 8	Stn. 9	Stn.10	Stn.11	Stn.12	Stn.13	Stn.14
.975	.998	1	1	1	1	1	1
Stn.15	Stn.16	Stn.17	Stn.18	Stn.19	Stn.20		
1	.975	.905	.765	.505	.14	0	

Tape 3

Choice of Output

	Control Constant	Programme Variable
1 if Local Weights Table required : 0 otherwise	1	P1
1 " " " Graph " : 0 otherwise	0	P2
1 " Cont. Weight Table " : 0 otherwise	1	P1
1 " " " " " : 0 otherwise	0	P2
1 " Total " " " : 0 otherwise	1	P1
1 " " " Graph " : 0 otherwise	0	P2

Mean Draught (ft)	21.245	S17
MCT 1" ton.ft.	3087	M2
L.C.B. fwd A.E. (ft)	331.22	L10
L.C.F. fwd A.E. (ft)	321.63	L11

Wave height (0 if still water) (ft)	0	S16
Wavelength (0 if still water) "	0	L19
Enter 1 if Sagging; 0 if hogging or still water	0	P3
Distance (ft) from extreme stern to FIRST crest or trough	0	S18

Tape 4.

There now follows the data from the Hull Definition Sheet:
(See p.13 and refer to Applications Group Programme LSB 3A)

(i)

D	Q1	N1	N2
3	0.25	7	3

(Bonjean headings Data item K is not required)

followed by the data for each Section in turn, as under:

(ii)

Section No.	P(J + 5) (1 or 0)	Z_{min}	Z_{max}

NOTE: Where P(J + 5) = ZERO, no further values of Z or half-widths (y) are entered. (LSB 3A does not show this variable)

(iii)

Appropriate number of half-widths (vertical columns)

i.e. if Q1 = 0.25 :- 2N + 1 Values where N = (N1 + N2 + 3)

if Q1 = 0.125:- 2N + 1 Values where N = (N1 + N2 + 4)

(iv)

Y_{max}	Y_{mid}

(NOTE: Y_{mid} only when $Z_{min} \neq 0$)

Tape 5

Choice of Output

	Control Constant	Programme Variable
1 if Buoyancy Table required : 0 otherwise	1	P1
1 " " Graph " : 0 "	0	P2
1 " Load Table " : 0 "	1	P1
1 " " Graph " : 0 "	0	P2
1 " Shear Table " : 0 "	1	P1
1 " " Graph " : 0 "	0	P2
If P2 = 0, but maximum positive and maximum negative values are to be output, PUT 15 = 1: If P2 = 1, and this is a re-run to obtain all graphs to a preset scale, PUT 15 = 1: Otherwise PUT 15 = 0	0	15
1 if Bending Moment Table required : 0 otherwise	1	P1
1 " " " Graph " : 0 "	0	P2
If P2 = 0, but maximum positive and maximum negative values are to be output, PUT 16 = 1: If P2 = 1, and this is a re-run to obtain all graphs to a preset scale, PUT 16 = 1: Otherwise PUT 16 = 0	0	16

SECTIONS.	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
	A.E.				0	1/8	1/4	3/8	1/2	3/4	1	1½	2	3	4	5	6	7	8	8½	9	9¼	9½	9⅝	9¾	9⅞	10				F.E.
P(J+5) ZERO IF NO 'Y' VALUE 1 OTHERWISE.	0	1	1	1	1	1	1																								
Z. MIN.		34.31	29.0	26.3	21.9																										
Z. MAX.		49.4	49.3	49.2																											

WATERLINES	X. MIN.	X. MAX.	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	Y' MID.	Y" MID.	Y. AFT.	Y. FWD.	MID-SHIP AREA.
0 F.O.B.				0	0																																	
1 9"				0	0																																	
2 1' 6"				0	0																																	
3 2' 3"				0	0																																	
4 3' 0"				0	0																																	
5 4' 6"				0	0																																	
6 6' 0"				0	0																																	
7 9' 0"				0	0																																	
8 12' 0"				0	0																																	
9 15' 0"				0	0																																	
10 18' 0"				0	0																																	
11 21' 0"				0	0																																	
12 24' 0"				0	0																																	
13 27' 0"				0	0																																	
14 30' 0"				0	1.57																																	
15 33' 0"				0	4.98																																	
16 36' 0"				2.25	7.97																																	
17 39' 0"				5.17	10.68																																	
18 42' 0"				7.58	13.03																																	
19 45' 0"				9.75	15.06																																	
20 48' 0"				11.65	16.83																																	
21 49' 6"				0	0																																	
22 51' 0"				0	0																																	
23 52' 6"				0	0																																	
24 54' 0"				0	0																																	
25 55' 6"				0	0																																	
26 57' 0"				0	0																																	
27																																						
28																																						
29																																						
30																																						

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Y. MAX.		12.45																													
Y. MID.		1.396																													

MAX DRAUGHT FOR COEFFICIENTS	

SHIP No

HULL DEFINITION DATA.

BONJEANS.

K.	D.	Q.I.	N.I.	N.2.
	3	0.25	7	3

HYDROSTATICS

L.B.P.	L.I.	L.2.	D.	Q.I.	N.I.	N.2.	Y.34.	K.26.	S.26.

STABILITY.

L.B.P.	L.I.	L.2.	D.	Q.I.	N.I.	N.2.	N.5.

S.I.

S.2.

T.

ANGLE.	A.I.	Z'.I.	A.2.	Z'.2.	A.3.	Z'.3.	A.4.	Z'.4.

ANGLE.	A.5.	Z'.5.	A.6.	Z'.6.	A.7.	Z'.7.	A.8.	Z'.8.

The overall pattern of the data is as follows:-

1st Condition. (Enter 40 16
00 0)

Tape 1. 13, (with S25, S26, M6, M7 only if I3 = 1).

WAIT

I1, L, L1, L2, S22, S27.

P4 (=0), N followed by M, S, B, X .... (N times).

WAIT

Tape 2.

P4 (=1), N followed by M, S, B, X .... (N times).

TITLE

W31, K3 followed by 23 "a" values (Lloyd's method) OR
W33, W34, L4, L5 (Biles Coffin method).

WAIT

Tape 3.

P1, P2, P1, P2, P1, P2. (1s or 0s)**

S17, M2, L10, L11, S16, L9, P3, S18.

(If tape misreads after ** it may be re-entered on 40 16
00 90)

WAIT

Tape 4. (In case of misread, re-enter 40 16
00 123)

H, Q1, N1, N2 followed, for each Section in turn, by:

S19, P(J+5), Z(51+J), Z(82+J)

Appropriate number of half widths (GI)

G52, (with G51 if Z(51+J) $\neq$ 0)

(Note:
If, for any section, P(J+5) = 0, no more values are entered for this section after H(J+5))

WAIT

Tape 5.

P1, P2, P1, P2, P1, P2, I5, P1, P2, I6.

2nd (and subsequent) Conditions.

Tape 1. Not required.

Tape 2. (Enter 40 0
00 126)

P4 (=2, 3, 4 etc., depending on Condition), N followed by:-

TITLE

M, S, B, X ...... (N times).

WAIT

Tape 3.

P1, P2, P1, P2, P1, P2. (1s or 0s) **

S17, M2, L10, L11, S16, L9, P3, S18.

(If tape misreads after ** it may be re-entered on 40 16
00 90)

WAIT

Tape 4. Not required.

WAIT

Tape 5.

P1, P2, P1, P2, P1, P2, I5, P1, P2, I6.

(Tape 1) Condition 1.

0	I3 (No max. values if zero)
0 617 23 14 0.5 20	I1, L, L1, L2, S22, S27.
0 71	P4, N.
75.17 94.5 0 81.75	M, S, B, X.......(N times)
58.96 90 0 83	
47.09 78.5 0 88.25	
15.65 32.75 0 110.38	
12.5 25 0 116.5	
26.21 36 0 536.25	
26.3 36.5 0 487.5	
12.76 17.5 0 432.75	
27.35 37.5 0 380.25	
27.35 37.5 0 317.75	
12.76 17.5 0 265.25	
27.35 37.5 0 220.25	
27.35 37.5 0 157.75	
2.42 6 0 559.25	
4.65 17.5 0 451.0	
5.87 25 0 349	
4.65 17.5 0 247.75	
2.42 6 0 136	
28.3 15.75 0 508.13	
27.9 15 0 411.5	
27.9 15 0 286.5	
27.9 15 0 189	
15.5 2.5 0 508.13	
15.5 2.5 0 411.5	
15.5 2.5 0 286.5	
15.5 2.5 0 189	
12 9 0 577.75	
11.63 6 0 592.5	
59.95 8 0 576	
6.1 51 -8.5 580	
16 34.5 +5.75 23	
19.61 28 +1 84.5	
7.5 26 0 87.5	
22.4 19 +2 33	
16.3 6 0 30.5	
10.2 12.25 0 20.38	
6.5 7.25 0 23	

(Tape 1 Cont.)

3.1	91	0	83.75
30	91	0	83.75
3.5	6	0	48
13	19.5	+1.75	46
10	91	0	83.75
12	91	0	83.75
35	580	0	313
85.75	580	0	313
20	580	0	313
45	448	0	348
376	28.5	-1.33	95.42
42.6	16.33	0	61.5
258.47	80	+12.43	96.43
26.43	40	0	54
6	10	0	39
42.36	80	0	84
40.8	80	0	84
69.18	98.5	16.416	113.25
34	51	-8.5	580
1.5	4	0.6666	110.5
15.45	18.25	0	60
11.5	16.75	0	59
5.81	8	1.3333	416.5
8	1	0	44
27.13	1.08	0	124.54
45.77	2.17	0	187.92
77.84	1	0	254.5
77.84	1	0	283.5
47.49	2.17	0	350.08
77.84	1	0	414.5
77.84	1	0	443.5
45.18	2.25	0	510.12
20	1	0	572
5.48	4	0	284

End of Tape 1.

(Tape 2).

1 36

P4, N.

M, S, B, X....(N times)
(i.e. 36 times)

436	63	-3.87	536.63
726	65	-1.34	475.16
1162	95	+0.13	396.63
668	95	+1.12	302.62
486	95	-0.01	301.49
824	112.25	-5	495.12
700	95	0	396.5
700	95	0	301.5
478	65	0	221.5
454	31.7	-5.283	582.42
290	20	+2.16	35.16
2738	30	-0.08	429.08
2738	30	-0.08	268.92
233.24	65	0	221.5
348.88	65	+2.62	224.12
194.04	67.5	+3.6	158.85
133.28	67.5	+5.47	160.72
415.52	65	+0.31	156.81
20.58	6.25	0	89.63
20.58	6.25	0	95.88
41.16	12.5	0	105.25
60.27	67.5	-0.37	154.88
23.28	32.5	+3.42	103.67
14.45	15	+0.6	109.6
12	3.75	0	113.38
11.52	3.75	0	117.13
12.25	27.5	0	85.25
5.88	3.33	0	65.67
6.13	3.33	0	69
6.13	3.33	0	72.33
13.96	7.5	0	77.75
12.25	5	0	81.5
29.25	22.5	+1.55	59.3
55	14	0	37
100	80	0	88
40	80	0	72.45

(Tape 2 Cont.)

=

SHIPYARD A. SHIP NO. X

LONGITUDINAL STRENGTH CALCULATIONS

CONDITION 1, BALLAST DEPARTURE
FULL BUNKERS.

STILL WATER.

21318.65 321.79 W31, K3.

0 .34 .495 .625 .73 .815 .885 .94 .975 .998 1 1 1
1 1 1 .975 .905 .765 .505 .14 0
(23 Lloyd's "a" values)

End of Tape 2.

- - - - -

(Tape 3)

1 0 1 0 1 0 P1, P2, P1, P2, P1, P2.

21.245 3087 331.22 321.63 0 0 0 0
S17, M2, L10, L11, S16, L9,
P3, S18.

End of Tape 3.

- - - - -

(Tape 4)

3 ·25 7 3   H, Q1, N1, N2.

0 0   S19, P(J+5), Z(51+J), Z(82+J)   No further rdgs. if P(J+5) = 0

1 1 34·313 49·407
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 2·25 5·167
7·583 9·75 11·646 0 0 0 0 0 0 (1+2(N1+N2+3)) half widths
12·447 1·396   G52, G51.

2 1 29 49·290
0 0 0 0 0 0 0 0 0 0 0 0 0 0 1·573 4·88 7·969
10·677 13·031 15·063 16·813 0 0 0 0 0 0
17·465 1·037

3 1 26·292 49·181
0 0 0 0 0 0 0 0 0 0 0 0 0 1·38 5·162 8·755
11·901 14·583 16·932 18·906 20·589 0 0 0 0 0 0
21·184 2·917

4 1 24·304 48·985
0 0 0 0 0 0 0 0 0 0 0 0 0 4·229 8·234 11·969
15·130 17·802 20·094 22·042 23·703 0 0 0 0 0 0
24·196 4·55

5 1 21·865 48·740
0 0 0 0 0 0 0 0 0 0 0 0 3·365 7·667 11·693
15·412 18·568 21·214 23·458 25·37 27·042 0 0 0 0 0
27·395 1·750

6 1 0 48·598
1·042 1·083 1·109 1·12 1·13 1·146 1·162 1·182 1·208
1·245 1·557 3·162 6·802 10·885 14·839 18·427 21·479
24·078 26·271 28·12 29·745 0 0 0 0 0 0
30·021

7 1 0 48·48
1·047 1·51 1·813 2 2·151 2·385 2·583 2·917 3·281
3·807 4·818 6·802 10·109 13·932 17·702 21·109 24
26·505 28·625 30·391 31·912 0 0 0 0 0 0
32·124

(Tape 4 Cont.)

8 1 0 48.394
1.406 2.063 2.537 2.880 3.172 3.625 4.005 4.651 5.354
6.37 7.901 10.219 13.313 16.880 20.401 23.521 26.292
28.646 30.641 32.281 33.656 0 0 0 0 0 0
33.818

9 1 0 48.25
2.12 3.469 4.219 4.813 5.307 6.162 6.88 8.224 9.687
11.453 13.687 16.323 19.224 22.307 25.234 27.885 30.245
32.255 33.932 35.255 36.313 0 0 0 0 0 0
36.391

10 1 0 48.154
3.13 5.266 6.245 7.037 7.724 8.875 9.922 11.964 14.073
16.354 18.849 21.583 24.323 26.984 29.422 31.599 33.5
35.083 36.344 37.333 38.115 0 0 0 0 0 0
38.142

11 1 0 48.04
6.406 9.724 11.182 12.313 13.307 15.099 16.698 19.615
22.339 24.974 27.531 29.948 32.099 34 35.630 36.99
38.104 38.927 39.526 39.969 40.276 0 0 0 0 0 0
40.273

12 1 0 48.00
11.078 15.0 16.854 18.302 19.542 21.662 23.448 26.542
29.182 31.488 33.531 35.328 36.818 38.068 39.068 39.828
40.354 40.693 40.875 40.974 41.00 0 0 0 0 0 0
41

13 1 0 48.00
21.552 26.24 28.281 29.807 31.037 32.969 34.479 36.693
38.198 39.24 39.964 40.448 40.766 40.938 41 41 41 41
41 41 41 0 0 0 0 0 0
41

14 1 0 48
30.813 34.547 36.12 37.24 38.109 39.349 40.146 40.88 4
41 41 41 41 41 41 41 41 41 41 41 41 0 0 0 0 00
41

15 1 0 48
34.5 37.537 38.656 39.427 39.979 40.688 40.979 41 41
41 41 41 41 41 41 41 41 41 41 41 41 0 0 0 0 0
0
41

16 1 0 48
34.5 37.537 38.656 39.427 39.979 40.688 40.979 41 41
41 41 41 41 41 41 41 41 41 41 41 41 0 0 0 0 0
0
41

17 1 0 48
34.5 37.537 38.656 39.427 39.979 40.688 40.979 41 41
41 41 41 41 41 41 41 41 41 41 41 41 0 0 0 0 0
41
41

18 1 0 49.666
28.76 32.776 34.307 35.370 36.188 37.401 38.24 39.276
39.781 40.042 40.188 40.281 40.339 40.396 40.448 40.5
40.552 40.604 40.656 40.714 40.760 40.787 0 0 0 0 0
40.787

19 1 0 51.175
20.807 25.359 27.271 28.609 29.667 31.26 32.448 34.109
35.193 35.901 36.412 36.792 37.104 37.359 37.573 37.76
37.932 38.12 38.292 38.464 38.63 38.719 38.802 0 0 00
38.815

20 1 0 52.865
11.469 15.958 17.74 19.078 20.188 21.901 23.25 25.177
26.458 27.396 28.151 28.74 29.24 29.688 30.12 30.51
30.896 31.302 31.719 32.135 32.583 32.813 33.063 33.307
33.31 0 0
33.37

21 1 0 53.809
6.927 10.828 12.488 13.719 14.729 16.318 17.531 19.313
20.516 21.422 22.115 22.698 23.208 23.672 24.125 24.578
25.073 25.563 26.146 26.771 27.427 27.771 28.141 28.516
0 0 0
28.851

22 1 0 54.828
2.74 5.656 7.031 8.052 8.88 10.208 11.219 12.687 13.67
14.443 15.047 15.552 16 16.438 16.87 17.344 17.87 18.5
19.104 19.849 20.672 21.109 21.568 22.047 22.583 0 0
22.875

(Tape 4 Cont.)

```
23  1  0  55.197
.964  3.063  4.25  5.135  5.849  6.995  7.885  9.156  10.042
10.698  11.193  11.635  12.047  12.464  12.885  13.359  13.885
14.474  15.125  15.875  16.729  17.188  17.677  18.203  18.740
0  0
19.198

24  1  .135  55.55
0  .698  1.505  2.162  2.734  3.708  4.448  5.542  6.297  6.83
7.240  7.620  7.979  8.354  8.740  9.162  9.651  10.188  10.83
11.583  12.427  12.875  13.375  13.891  14.458  15.063  0
15.093  .823

25  1  3.958  55.9
0  0  0  0  .302  .896  1.813  2.453  2.865  3.188  3.479
3.776  4.083  4.427  4.792  5.193  5.687  6.281  6.979  7.792
8.240  8.729  9.25  9.849  10.469  0
10.648  .521

26  1  33  56.25
0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0.63  1.063
1.573  2.182  2.917  3.349  3.807  4.323  4.875  5.479  0
5.766  0.427

27  1  42  56.334
0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
1.01  1.714  2.12  2.573  3.063  3.615  4.208  0
4.519  1.01

28  1  48.281  56.421
0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
0  0  0  1.323  1.781  2.333  2.901  0
3.326  .906

29  1  53.188  56.507
0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
0  0  0  0  0  .932  1.583  0
2.132  .667

30  0
```

End of Tape 4.

(Tape 5)

```
                                        P1, P2, P1, P2,
1  0  1  0  1  0  0  1  0  0            P1, P2, I5, P1, P2, I6.
194.04  667.5  +3.6  158.85
133.28  67.5  +5.47  160.72
415.52  65  +0.31  156.81
20.58  6.25  0  89.63
20.58  6.25  0  95.88
41.16  12.5  0  105.25
60.27  67.5  -0.37  154.88
23.28  32.5  +3.42  103.67
14.45  15  +0.6  109.6
12  3.75  0  113.38
11.52  3.75  0  117.13
12.25  27.5  0  85.25
5.88  3.33  0  65.67
6.13  3.33  0  69
6.13  3.33  0  72.33
13.96  7.5  0  77.75
12.25  5  0  81.5
29.25  22.5  +1.55  59.3
55  14  0  37
100  80  0  88
40  80  0  72.5
```

(Tape 5)

```
1  0  1  0  1  0  0  1  0  0
```

End of Tape 5 and Condition 3.

(Tape 2 Cont.)

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SHIPYARD A. SHIP NO. X

LONGITUDINAL STRENGTH CALCULATIONS
STILL WATER

CONDITION 5, LOADED DEPARTURE
HEAVY CARGO IN NOS. 1, 4, 5 AND 8 HOLDS.

FULL BUNKERS

34958.65
317.43

End of Tape 2.

(Tape 3).

0 0 0 0 0 0

33.083 3839 324.52 306.72 0 0 0 0

End of Tape 3.

(Tape 5).

0 0 0 0 0 0 1 0 0 1

End of Tape 5 and Condition 5.

Note concerning Shear Force and Bending Moment curves.

The programme will normally choose the scale to give the largest graph possible. This means that each Shear Force graph (for a set of conditions) will have its own scale. Similarly with the Bending Moment graphs.

It has been found convenient in the case of these two graphs to fix the scale, from previously output maximum positive and maximum negative shear force values.

To obtain these maximum values only, for each condition run, put I3 = 0, and I5 (for Shear Force) and I6 (for Bending Moment) both equal to 1, while P2 (for graph output) = 0 (no graph). This does not affect output of any of the tables (P1 = 1 for tables, 0 for no table), or any of the graphs preceding Shear Force (for which P2 = 1 for graphs, or 0 for no graph). The overall maximum values are noted.

On the re-run it is necessary to alter Tape 1; I3 is now made = 1, and the four maximum values follow this. (If ONLY Shear Force OR Bending Moment is wanted, the other two values must be put = 0). There is a programme WAIT here to allow the remainder of the original Tape 1 to be entered. It is now necessary to alter Tape 5, so that P2 for the required graphs = 1, with I5 = 1 for the Shear Force graph, and I6 = 1 for the Bending Moment graph. Subsequent conditions are entered as before, i.e. 40 16: 00 126. The new altered Tape 5 may be used as a common tape now for all conditions.

Only the output for Condition 1 will have the scales, etc., indicated in the print-up to the graph tape. All other conditions will merely have the words "<u>Shear Force Curve</u>" (or "<u>Bending Moment Curve</u>"), prior to the graph tape, as a record for future reference that the graph has been output to a preset scale.

LONGITUDINAL STRENGTH.

SHIP No. 827.

CONDITION – BALLAST ARRIVAL (DEEP TANK FULL).

SCALES:–

HORIZONTAL:– 1/16" = 1 FOOT   VERTICAL:– WEIGHT, LOAD & BUOYANCY CURVES 1/16" = 1 TON/FOOT
SHEAR FORCE 1/8" = 1 TON
BENDING MOMENT 1/8" = 10,000 TON FT

— SUPERIMPOSED COMPUTER VALUES FOR WEIGHT CURVE.
× " " BUOYANCY CURVE.
× " " BENDING MOMENT CURVE.