# AN INVESTIGATION OF DESTROYER MIDSHIP SECTION DESIGN WITH VARYING LONGITUDINAL AND WEB FRAME SPACING

by

ROBERT OLIVER DULIN, JR.
B.S., UNITED STATES NAVAL ACADEMY
(1961)

SUBMITTED IN PARTIAL FULFILLMENT OF THE
REQUIREMENTS FOR THE
DEGREES OF MASTER OF SCIENCE AND NAVAL ENGINEER
at the
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ABSTRACT

AN INVESTIGATION OF DESTROYER MIDSHIP SECTION
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by

Robert Oliver Dulin, Jr.

Submitted to the Department of Naval Architecture and Marine Engineering on May 19, 1967, in partial fulfillment of the requirements for the Master of Science degree in Naval Architecture and Marine Engineering and the Professional degree, Naval Engineer.

The attractive possibility of minimizing ordering, handling, and warehousing problems by employing uniform longitudinal scantlings and constant plating thicknesses throughout the midship section led to the decision to carry out an investigation of such a design methodology. The design technique proved to be feasible, but less economical than conventional techniques of midship section design.

A computer tool for the systematic variation of longitudinal intervals has been developed and is now ready to be applied to midship section design with varying structural materials and different plating thicknesses and longitudinal scantlings.

Thesis Supervisor: J. Harvey Evans

Title: Professor of Naval Architecture

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# I. INTRODUCTION

"The quest for least weight, lowest cost, optimal ship structures has long been hampered by the lack of reliable quantitative data in adequate amount. And the problem has, so far, proven only partially susceptible to closed form solution. In no real sense, therefore, has it been possible to weigh the relative merits of new materials of construction, for example, or variations of frame spacing, different combinations of framing systems or alterations of principal dimensions (should they too be of interest)." [6] (Emphasis added)

The midship section design of longitudinally framed warships has long been carried out on the basis of a constant spacing of the longitudinal structural stiffeners, with varying stresses and loadings being accounted for by the variation of plating thicknesses and longitudinal scantlings.

This conventional procedure has resulted in the development of designs of adequate strength, but the goal of the optimum least weight, lowest cost ship structural design has proved to be an elusive one.

Current design techniques, although effective, add to the cost of ship construction by the price penalties involved in the procurement of a diversity of plates and shapes.

Similarly, parts handling and inventory control is complicated and rendered more difficult and expensive. These problems and deficiencies resulting from conventional midship section design procedures suggested the novel approach which is the subject of this investigation.

Fundamentally, in an evaluation of an extreme variation from current procedures, this modified design methodology generates a design with a uniform plating thickness throughout, with a uniform longitudinal scantling (exclusive of the keel) similarly selected. Variations in loading are compensated for by different intervals between longitudinals throughout the midship section.

In order to permit a reasonable inference as to the relative merits of this modified design methodology, the FORREST SHERMAN (DD-931) class destroyer midship section has been taken as a model for comparative purposes.

## II. PROCEDURE

For purposes of consistency with the techniques used in the original design of the FORREST SHERMAN, the design procedured elucidated in [1], have been used throughout this investigation, modified as necessary. The same basic stress criteria have been used, with the maximum primary compressive stresses on DD-931 specified as design limiting values. As for the FORREST SHERMAN, high tensile steel (HTS) has been used throughout the midship section.

The calculations required for this investigation have been carried out almost exclusively by a series of computer programs and subroutines, explained in detail in the Appendix.

Input data, including the plating molded offsets, are generated for eventual use in the main design program, RUNSCORE, and the main costing program, COSTDATA. Existing plates and scantlings were used throughout the investigation in order to permit a realistic evaluation of costs and structural characteristics. Actual costing criteria in use at the Boston Naval Shipyard were employed in conjunction with current Federal parts costing information.

Once the input information has been determined, the detailed design process is carried out. First, given the transverse frame spacing and the minimum tolerable longitudinal

spacing, the least possible plating thickness is calculated, and the resultant permissible longitudinal separation computed.

This permissible separation is applied at the keel, thereby locating the longitudinal adjacent to the keel. The permissible span to the next longitudinal and the required longitudinal are then determined. This computation is repeated until the deck-shell intersection is reached. At this time, the spacings are reduced if necessary to assure the existence of at least the minimum permissible spacing between the last shell longitudinal and the deck edge.

The deck longitudinals are located in a like manner. The arrangement is required to be symmetrical about the centerline, with either a longitudinal at the centerline or the centerline exactly at mid-span between longitudinals. If necessary, the interval between the deck longitudinals is reduced.

After all the midship section longitudinals have been located, the required scantlings at each location are calculated. The heaviest of these is then selected for use throughout the midship section.

With the plating thickness selected, longitudinals located and scantlings determined, the overall midship section characteristics are calculated. The maximum primary compressive stresses at the keel and deck centerline are determined, using the hull girder bending moments that

were calculated for the FORREST SHERMAN.

Should either of the calculated stresses exceed the comparable values actually existing on the DD-931 as built, the plating thickness is increased and the entire cycle is repeated with larger longitudinal spacings inevitably resulting. If the stresses are acceptable, the calculation is terminated.

The costing procedure evaluates the expense, per foot length, of building the midship section. Most of the charges are based on an arbitrary cost of $7.50 per man-hour (M-H) of work. This charge includes shipyard overhead expenses. Government price data is used to determine the acquisition costs for structural materials.

The weight and cost of the modified design is then compared with similarly-calculated values for the DD-931 as built.

## III. RESULTS

Two basic series of midship section design calculations were carried out by main program RUNSCORE. The first of these computed designs with the minimum acceptable interval between longitudinals fixed at 1.667 feet, while the transverse frame spacing varied from 6 to 8 to 10 feet. The second series calculated designs for a transverse frame spacing fixed at 8 feet with the interval between longitudinals stipulated to be a minimum of either 1.667, 2.000, or 2.333 feet.

Not surprisingly, the midship section designs developed with constant plating thicknesses and uniform longitudinal scantlings proved to be consistently heavier and, for less apparent reasons, which are discussed in the following section, more expensive to build.

The results of the calculations for different transverse frame intervals are presented in Table I, as well as similar data for the FORREST SHERMAN as built. Figure I shows a schematic plan of the DD-931 midship section as built, while Figure II shows a schematic for the midship section design resulting from a transverse frame spacing of 8 feet with a minimum specified longitudinal interval of 1.667 feet. Note the heavy plating, heavy longitudinals, and great in-

tervals between longitudinals in the new midship section design. Table I also provides detailed cost data for the three new designs as well as the original DD-931, using identical reference data for all four cases.

Detailed information as to the location of longitudinals and the intervals between longitudinals is provided in Table II, which delineates the designs developed by the first series of computations.

The second series of computer runs revealed this design methodology to be very insensitive to the specification of minimum tolerable intervals between longitudinals, with the exception of the minor effects caused by possible adjustments for the deck-shell intersection of the deck centerline criteria for longitudinal intervals. As a consequence, the designs for all intents and purposes were identical regardless of the specified minimum intervals between longitudinals.

# TABLE I

## MIDSHIP SECTION DESIGNS
## WEIGHT AND COST SUMMARIES

| DESIGN: | New Study | New Study | New Study | DD-931 (As Built) |
|---|---|---|---|---|
| FRM (Ft.) | 6.00 | 8.00 | 10.00 | 8.00 |
| THL (In.) | 0.75 | 0.75 | 0.75 | (Varies) |
| **WEIGHTS** (Pounds per foot hull length) | | | | |
| TOTAL: | 4736.6 | 4716.7 | 4748.0 | 3591.0 |
| Plating | 3854.0 | 3854.0 | 3854.0 | 2724.5 |
| Longitnls. | 505.3 | 505.3 | 548.5 | 509.1 |
| Tr. Framing | 377.2 | 357.4 | 345.5 | 357.4 |
| **COSTS** (Per foot hull length) | | | | |
| TOTAL: | $ 1568.01 | $ 1471.78 | $ 1417.65 | $ 1344.41 |
| Plating | 464.97 | 466.61 | 464.97 | 336.98 |
| Longitnls. | 66.30 | 66.30 | 70.20 | 70.50 |
| Keel | 27.56 | 27.56 | 27.56 | 27.56 |
| Tr. Framing | 404.96 | 303.72 | 242.98 | 303.72 |
| Pl. Welding | 298.64 | 301.33 | 298.64 | 256.67 |
| Pl. Cutting | 2.02 | 2.70 | 2.02 | 0.00 |
| Pl. Rolling | 23.40 | 23.40 | 23.40 | 19.18 |
| L. Welding | 113.50 | 113.50 | 120.18 | 142.50 |
| Fl. Cutting | 17.85 | 17.85 | 18.90 | 28.50 |
| Rigging | 148.80 | 148.80 | 148.80 | 148.80 |

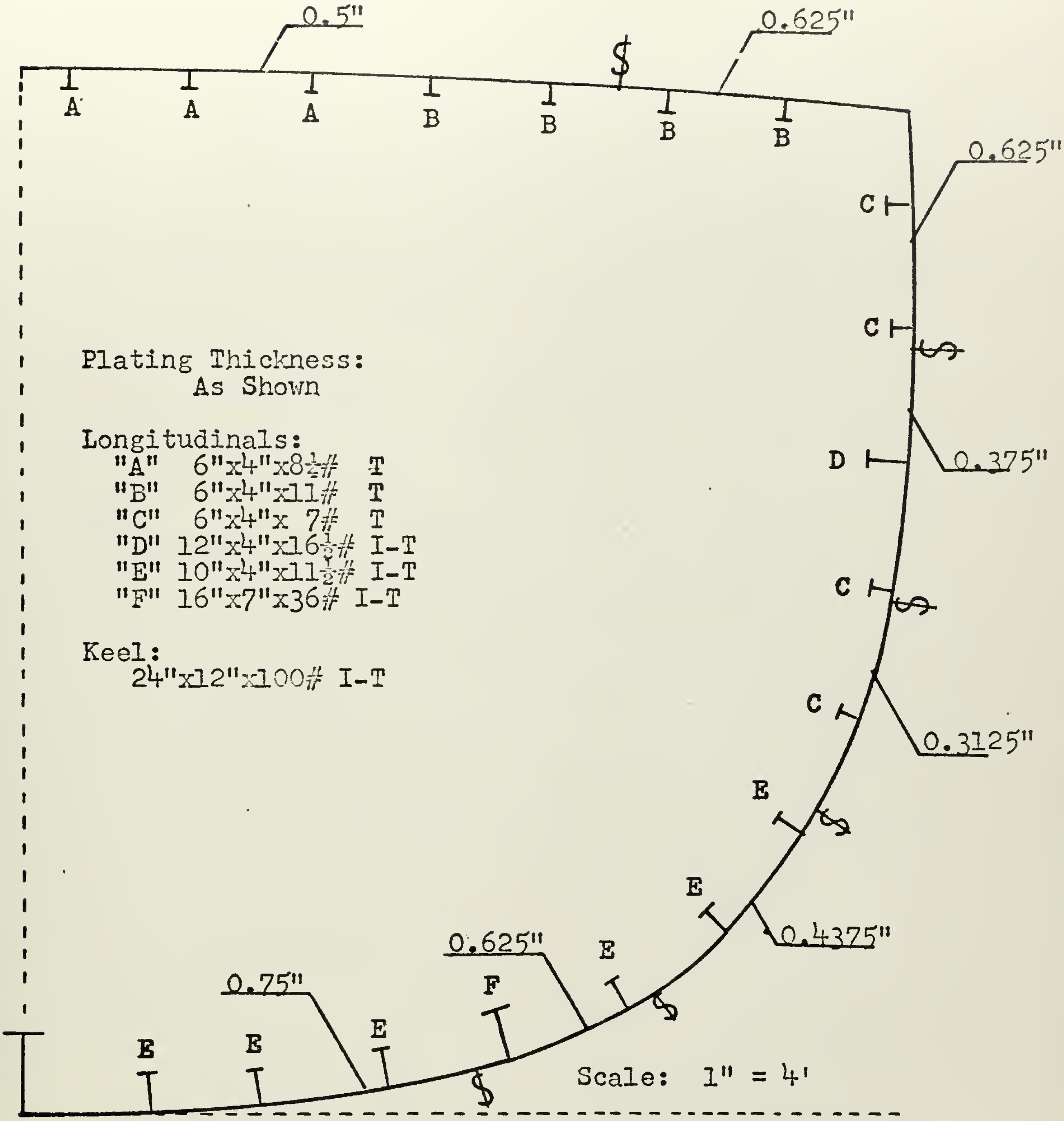



FIGURE I

THE ORIGINAL DD-931 MIDSHIP SECTION DESIGN [5]

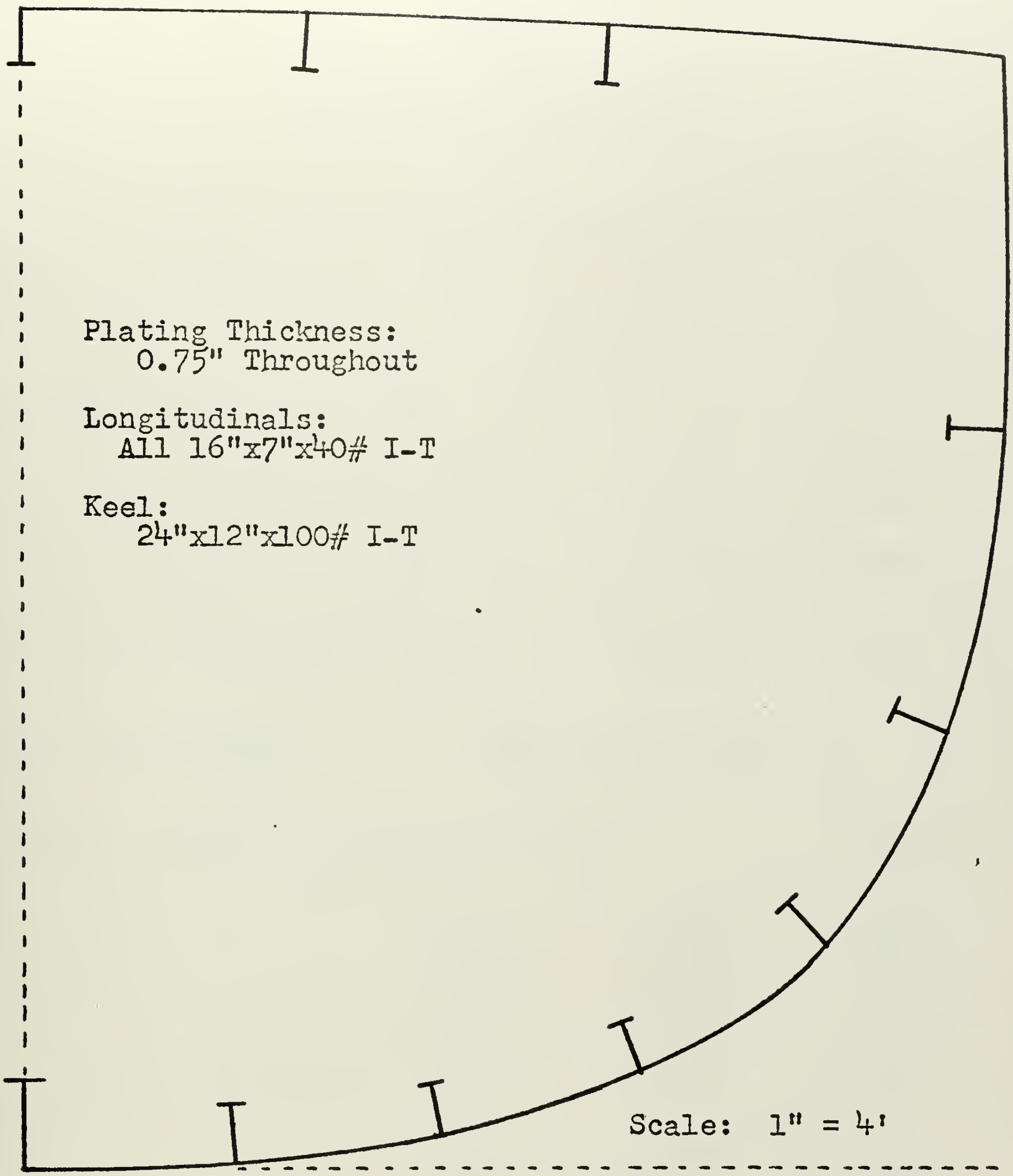



FIGURE II

MODIFIED DD-931 MIDSHIP SECTION DESIGN

TABLE II

MIDSHIP SECTION DESIGNS
STRUCTURAL DESCRIPTION

| | | | |
|---|---|---|---|
| Frame Spacing (Ft.) | 6.00 | 8.00 | 10.00 |
| Plating Thickness (In.) | 0.75 | 0.75 | 0.75 |
| **STRUCTURAL CHARACTERISTICS** | | | |
| Keel Stress (Tons/In.$^2$) | 7.43 | 7.43 | 7.43 |
| Deck Stress (Tons/In.$^2$) | 4.58 | 4.59 | 4.45 |
| Moment of Inertia (In.$^2$ Ft.$^2$) | 142,120 | 142,105 | 143,819 |
| N. A. above Base Line (Ft.) | 14.26 | 14.25 | 14.46 |
| Keel Longitudinal | 24" x 12" x 100# I-T | | |
| Other Longitudinals | 10" x 7" x 40# I-T | | |
| **INTERVALS BETWEEN LONGITUDINALS* (Feet)** | | | |
| | 4.717 | 4.717 | 4.717 |
| | 4.780 | 4.751 | 4.751 |
| | 4.888 | 4.852 | 4.852 |
| | 5.157 | 5.110 | 5.110 |
| | 5.837 | 5.724 | 5.724 |
| | 7.295 | 6.935 | 6.934 |
| Deck-Shell Intersection | 7.931 | 8.516 | 8.517 |
| | 9.831 | 9.079 | 8.687 |
| | 6.822 | 6.777 | 6.500 |
| | 5.717** | 6.514** | 6.350 |
| | | | 0.833*** |

*The first interval begins at the keel.
**A longitudinal lies on the deck centerline.
***The deck centerline lies midway between two longitudinals.

TABLE III

TYPICAL DESIGN SUMMARY*

| PLATE THICKNESS Inches | TOTAL WEIGHT Pounds | KEEL STRESS Tons/In.$^2$ | MOM. OF INERTIA In.$^2$ Ft.$^2$ | LONGITUDINALS NO. | LONGITUDINALS SCANTLING |
|---|---|---|---|---|---|
| 0.28125 | 2655.9 | 13.47 | 76,183 | 54 | 8x5.4x20 |
| | Stresses are excessive, design repeated. | | | | |
| 0.3125 | 2709.5 | 13.38 | 77,391 | 48 | 10x5.8x21 |
| | Stresses are excessive, design repeated. | | | | |
| 0.34375 | 2781.9 | 12.95 | 79,760 | 42 | 10x5.8x21 |
| | Stresses are excessive, design repeated. | | | | |
| 0.375 | 2898.4 | 12.43 | 83,690 | 39 | 10x5.8x21 |
| | Stresses are excessive, design repeated. | | | | |
| 0.4375 | 3131.4 | 11.45 | 91,387 | 33 | 10x5.8x21 |
| | Stresses are excessive, design repeated. | | | | |
| 0.500 | 3393.8 | 10.52 | 100,012 | 29 | 10x5.8x21 |
| | Stresses are excessive, design repeated. | | | | |
| 0.625 | 3918.8 | 9.03 | 117,352 | 23 | 12x 4 x16.5 |
| | Stresses are excessive, design repeated. | | | | |
| 0.750 | 4716.7 | 7.43 | 142,105 | 17 | 16x 7 x40 |
| | Design acceptable, calculations terminated. | | | | |

*Main program RUNSCORE computation for transverse frame spacing of 8.0 feet, specified minimum longitudinal interval of 1.667 feet.

## IV. CONCLUSIONS AND RECOMMENDATIONS

The midship section design of a longitudinally-framed warship with uniform longitudinal scantlings and constant plating thicknesses has been shown to be feasible.

Table I on page 8 vividly shows that the major contributor to the poor relative performance of this design methodology in terms of both weight and cost was the shell plating. Much of the added material near the neutral axis and on the deck (relative to the DD-931 as built) was very inefficiently applied, as is evident in the low stress levels existing in the deck structure of the new designs. Similarly, the cost of welding and fabrication of the shell plating was materially increased by the presence of the heavier plating throughout the girth of the midship section.

There appears to be a distinct reduction in cost per unit length as the interval between transverse frames is increased. This is apparently the consequence of the application of the cost of this framing to the overall structural cost. The cost per foot length of the transverse framing varies markedly as the interval between the frames is increased. Similarly, the weight of the transverse framing per foot hull length reduces as the interval between the frames is increased, although to a much smaller degree than the

cost varies.

No distinct trends in total weight per unit length were apparent in this investigation. The major factor leading to variations in weight was the number of longitudinals required, as both the selected plating thickness and longitudinal scantling were identical for all three cases examined in detail.

Unfortunately, no information was available to permit a reasonable estimation of the savings to be realized by the volume acquisition of identical structural members. This economy, along with the reduced handling and storage costs, should be incorporated in any such analysis as this, but is very doubtful that these savings would be of such magnitude as to offset the disparities existing between the new designs and the costs of consturction of the original DD-931 midship section design.

The traditional design concept of varying plating thicknesses and longitudinal scantlings is a sound one. This approach promises to be even more valuable when incorporated with the techniques developed in this investigation for the variation of the intervals between longitudinals. Furthermore, the use of different structural materials should be investigated in detail. Very frequently stability criteria dictate the plating thicknesses required when using high strength steels such as HY-80. The variation of longitudinal intervals would permit the use of much thinner plates in heavily stressed areas without the problems of plate stability

otherwise to be encountered. Appreciable weight economies should be realized from the superposition of the technique of variation of longitudinal intervals with the use of different structural materials while varying plating thicknesses and longitudinal scantlings.

The design of a midship section with a single plating thickness throughout and uniform longitudinal scantlings proved to be workable but less efficient than conventional techniques. The basic idea of varying longitudinal intervals is sound, and detailed studies of variations on this basic idea should be carried out.

# APPENDIX

# PROGRAM DOCUMENTATION

The structural and cost calculations for the midship section design were generated by a series of computer programs and subroutines, listed below, which are described and explained in detail on the following pages. A program listing, flow chart, and sample calculation accompanies the description of the operation of each program or subroutine.

All programs and subroutines were written in FORTRAN IV and were run on the IBM 360/65 computer.

Main Programs:

A. RUNSCORE
B. COSTDATA

Subroutines called by Main Programs.

C. TSLECT
D. HDWTR
E. CSPACE
F. CLONGL
G. PMINER

Subordinate Programs used to generate input data for Main Programs:

H. SHDATA
I. DKDATA
J. PTLGTH
K. WTSMOD
L. TSHAPE
M. COSTKL

## A. MAIN PROGRAM RUNSCORE

### 1. DESCRIPTION

#### Introduction

Main program RUNSCORE carries out the design calculation for the midship section of DD-931, selecting one plating thickness and one longitudinal scantling (except for the keel) to be used throughout the structure. The basic computational methods described by St. Denis [1] are used, modified as necessary.

This program is not designed to optimize the characteristics of the midship section. The required plating thickness is selected, the spans between the various longitudinals are determined, and the required longitudinal scantlings are evaluated. Once the structural design has been completed, the net section characteristics are evaluated and the resultant primary compressive stresses are compared with the design criteria. Should the design be overstressed, the next greater available plating thickness is selected, and the entire cycle is repeated. RUNSCORE uses existing HTS plating thicknesses and longitudinal scantlings, as opposed to any idealized materials with a continuous range of available sizes. This, inevitably,

results in overdesigned structures in many cases.

After the input phase has been completed, subroutine TSLECT determines the minimum permissible plating thickness, dictated by the minimum tolerable longitudinal spacing specified as an input to the program. This subroutine also determines the greatest permissible interval between longitudinals for the stresses and hydrostatic loadings existing at the keel.

Beginning at the keel, the program "climbs" the girth of the midship section. The first longitudinal is located using the maximum permissible interval determined by subroutine TSLECT. Subroutine CLONGL then calculates the required longitudinal scantling for this location, and subroutine CSPACE evaluates the span to the next longitudinal, and the cycle is repeated. When the shell-deck intersection is reached, the program is designed to assure that the span to the intersection is at least the minimum permissible value. The distance to the intersection is compared with this minimum and, if necessary, the span is increased by reducing the spacings between the preceding longitudinals in the shell structure. This longitudinal relocation algorithm is so structured as to prevent the inadvertent reduction of longitudinal spans to less than the minimum tolerable value. Once the location of all longitudinal-plating intersections on the shell has been satisfactorily completed, the program proceeds to the

similar location of the deck longitudinals.

The deck calculations are carried out in a manner identical to that used for the side shell. RUNSCORE is so structured that the midship section must be symmetrical, with a deck longitudinal on the centerline or the centerline exactly at mid-span between two deck longitudinals. As for the side shell, the spacings in all cases must be at least equal to the minimum permissible value. If necessary, provision is made for the systematic reduction of spans between longitudinals to insure that this is the case. Up to this point, the program has assumed that the longitudinals were of adequate strength, with no specific determination of scantlings.

With all longitudinal locations now determined, the required scantlings for each specific location are calculated, with the heaviest needed anywhere in the structure selected for use throughout the structure. Criteria as to the minimum radius of gyration, stiffener strength, stiffener critical strength, and the stability of the stiffener-plating combination must all be satisfied.

With the plating thickness and longitudinal scantlings determined, subroutine PMINER is called to provide the information needed to calculate the contribution of the plating to the moment of inertia and cross-sectional area of the overall midship section. The effects of the

longitudinals are combined with this to determine the total cross-sectional area and moment of inertia for the entire midship section.

The structural weight of the midship section is evaluated in some detail. The total weight per foot length, including an approximate valuation of the contribution of the transverse framing to the net weight, is calculated in pounds and tons. The contributions of the plating, longitudinals, and transverse framing are similarly determined, but only in terms of pounds per foot length.

With the overall section characteristics fixed, the actual hogging and sagging bending moments used in the design of the DD-931 are employed in the calculation of the actual primary compressive stresses exerted in the keel and deck structure. Should either of these exceed the design limiting values, the plating thickness is increased to the next greater value, and the entire computation is repeated. This iterative process is carried out until both primary compressive stresses are determined to be less than the maximum permissible values.

Inputs

| Symbol | Meaning |
|---|---|
| PTDATA(I,J,1) | Half breadth to point (I,J). (Feet) |
| PTDATA(I,J,2) | Height of point above base line. (Feet) |
| PTDATA(I,J,3) | Distance to next point on girth. (Feet) |

| Symbol | Meaning |
|---|---|
| ST1CRK | Maximum permissible stress at keel. (Tons/In.$^2$) |
| ST1CRD | Maximum permissible stress at deck centerline. (Tons/In.$^2$) |
| ST2EST | Estimated value of secondary stress. (Tons/In.$^2$) |
| SGMULT/SGMYLD | Yield stress of the plating. (Tons/In.$^2$) |
| A3HEEL | Specified maximum heel angle. (= 0.5236 radians) |
| D1 | Depth of hull. (= 26.231247 feet) |
| H1AMDK | Specified design head of water above main deck. (= 4.0 feet) |
| H1DFL | Design full load draft. (= 14.5 feet) |
| XLGTNL(I,1) | Maximum moment of inertia of stiffener (I). (In.$^4$) |
| XLGTNL(I,2) | Stiffener minimum moment of inertia. (In.$^4$) |
| XLGTNL(I,3) | Stiffener area. (In.$^2$) |
| XLGTNL(I,4) | VCG of stiffener from the cut flange. (In.) |
| XLGTNL(I,5) | Stiffener overall depth. (In.) |
| W5BMIN | Minimum permissible longitudinal spacing. (Feet) |
| FRM | Transverse frame spacing. (Feet) |

## Calculated Items

| Symbol | Meaning |
|---|---|
| XLONGL(I,1) | Half breadth of intersection of plating with longitudinal (I). (Feet) |
| XLONGL(I,2) | Height above keel of plating-longitudinal intersection. (Feet) |
| XLONGL(I,3) | Half breadth of point preceding the intersection. (Feet) |
| XLONGL(I,4) | Height above keel of point preceding the intersection. (Feet) |

| Symbol | Meaning |
|---|---|
| W5BACT | Tolerable longitudinal spacing for selected plating thickness. (Feet) |
| W5BPRC | Longitudinal span to longitudinal in question. (Feet) |
| W5BTOL | Permissible spacing to next longitudinal. (Feet) |
| SUMDST/DSTSUM/ DSUM | Sum of distances between points on girth. (Feet) |
| SUMCAL/SUMDIF | Distance to point preceding plating-longitudinal intersection. (Feet) |
| DIFF | Distance from point at SUMCAL/ SUMDIF to the intersection. (Feet) |
| ILONGL | An identifying number for longitudinals other than the keel. No. 1 adjacent to the keel. |
| ICOUNT | The value of ILONGL at deck-shell intersection. No longitudinal here. |
| SPAN(I) | Distance <u>to</u> longitudinal (I) from preceding longitudinal. (Feet) |
| BBDIST | Distance needed to be gained by reducing spans between shell longitudinals to permit W5BMIN distance from last shell longitudinal to deck intersection. (Feet) |
| STEP | Increment the span between longitudinals is reduced. (Feet) |
| IDIFF | Number of spans to be reduced on deck to obtain desired span at centerline. |
| AAA | Effective width of plating. (In.) |
| FF | Moment of longitudinal-plating combination about outer edge of the plating. ($In.^3$) |
| FFF | Total area of the longitudinal-plating combination. ($In.^2$) |

| Symbol | Meaning |
|---|---|
| CGCG(I) | Centroid of longitudinal - plating combination, in web axis. (In.) |
| XMINER(I) | Moment of inertia of longitudinal-plating combination about CGCG(I). ($In.^4$) |
| RGYR | Radius of gyration of longitudinal-plating combination. (In.) |
| EFSPAN | Effective span (supports fixed) for stiffener strength calculation . (Feet) |
| DVALUE | Flexural rigidity of plating. (Ton-In.) |
| STALL | Permissible sum of primary and secondary stresses. ($Tons/In.^2$) |
| ARM | Distance to outermost fiber of longitudinal-plating combination from CGCG(I). (Inches) |
| PRESS | Hydrostatic pressure at longitudinal. ($Tons/In.^2$) |
| BMOMNT | Maximum bending moment on the longitudinal-plating combination at mid-span. (Ton-In.) |
| ST1EST | Estimated primary stress. ($Tons/In.^2$) |
| ST2ALL | Allowable value of secondary stress. ($Tons/In.^2$) |
| REQMOD | Required section modulus of plating-longitudinal combination. ($In.^3$) |
| SMODMN(I) | Required section modulus for longitudinal (I)-plating combination at determined by subroutine CLONGL. ($In.^3$) |
| BVALUE | Rigidity. (EI) ($Ton-In.^2$) |
| BETA | Aspect ratio of plate. |
| GAMMA | Inertia factor. |
| DELTA | Area factor. |

| Symbol | Meaning |
|---|---|
| SUMTN | Intermediate value used in calculating critical strength of stiffened plating. (Tons/In.$^2$) |
| BETAPL | Used in calculating critical strength of stiffened plating. (BETA$^2$ + 1) |
| CRITST | Design stress criteria. (Tons/In.$^2$) (1.25 x (ST1EST + ST2EST)) |
| TOLSTR | Tolerable stress level determined by critical strength calculation. (Tons/In.$^2$) |
| AREAPT | Total cross section area of half breadth plating. (In.$^2$) |
| XLNGTL(1,I) | Characteristics of keel longitudinal. |
| XLNGTL(2,I) | Characteristics of other longitudinals. |
| SLOPE2(K) | Slope of the web of longitudinal (K). |
| ZZZ | Height of VCG of longitudinal above longitudinal-plating intersection. (Feet) |
| ZPOINT | Height of VCG of longitudinal above the base line. (Feet) |
| BASEMT(K) | Height of VCG of longitudinal above the base line. (Feet)<br>K = 1 Keel<br>K = 2,...40 (LONGL 1,...39) |
| BLMOM | Total moment about the base line. (In.$^2$ Feet) |
| XMOMIN | Total moment of inertia about the base line. (In.$^2$ Feet$^2$) |
| XINER | Moment of inertia of the midship section about the neutral axis. (In.$^2$ Feet$^2$) |
| ATHI | Plating thickness found to be insufficient, to be incremented. (Inches) |

Output

| Symbol | Meaning |
|---|---|
| WEIGHT | Weight contribution of the plating. (Pounds/Ft. length) |

| Symbol | Meaning |
|---|---|
| ZNAXIS | Height of neutral axis of midship section above base line. (Feet) |
| REQMIN | Required moment of inertia about original DD-931 neutral axis. ($In.^2$ $Ft.^2$) |
| ASTRSS | Actual primary compressive stress in keel. ($Tons/In.^2$) |
| BSTRESS | Actual primary compressive stress in deck. ($Tons/In.^2$) |
| WTOTLB | Total structural weight. (Pounds/ Ft. length) |
| WFRAME | Transverse frame weight. (Pounds/ Ft. length) |
| WTOTAL | Total weight. (Tons/Ft. length) |
| WLONGL | Total longitudinal weight. (Pounds/ Ft. length) |

<u>Sample Input/Output</u> (Refer to printout of typical computer run, following pages)

<u>Fundamental Equations</u> (Refer to program listing, following pages, and St. Denis [1])

THE FOLLOWING IS A REPRESENTATIVE SAMPLING OF EQUATIONS PARTICULARLY IMPORTANT TO MAIN PROGRAM RUNSCORE:

<u>Longitudinal location</u>

SUMDST = SUMDST + PTDATA(I,J,3)

SUMCAL = SUMDST - PTDATA(I,J,3)

DIFF = W5BPRC - SUMCAL

$$\text{XLONGL(ILONGL,1)} = \text{PTDATA(I,J,1)} + \frac{\text{DIFF} \times (\text{PTDATA(I,J+1,1)} - \text{PTDATA(I,J,1)})}{\text{PTDATA(I,J,3)}}$$

XLONGL(ILONGL,3) = PTDATA(I,J,1)

<u>Satisfy requirements as to minimum radius of gyration</u>

AAA = lesser, 12. x SPAN(I) or 50. x TH1

$$\text{FF} = \text{XLGTNL(J,3)} \times (\text{XLGTNL(J,4)} + \text{TH1}) + 0.5 \times \text{AAA} \times (\text{TH1}^2)$$

FFF = XLGTNG(J,3) + TH1 x AAA

CGCG(I) = FF / FFF

XMINER(I) = XLGTNL(J,1) + XLGTNL(J,3) x (XLGTNL(J,4) - CGCG(I))$^2$ + 0.08333 x AAA x TH1$^3$ + TH1 x AAA x (CGCG(I) - 0.5 x TH1)$^2$

$$\mathrm{RGYR} = \sqrt{\frac{\mathrm{XMINER(I)}}{\mathrm{FFF}}}$$

Satisfy requirements as to stiffener strength

EFSPAN = 12. x 0.577 x FRM

$$\mathrm{DVALUE} = \frac{13392.857 \times \mathrm{TH1}^3}{10.8}$$

BMOMNT = 216. x PRESS x SPAN(I) x FRM$^2$

REQMOD = BMOMNT / ST2ALL

BVALUE = 13392.857 x XMINER(I)

$$\mathrm{GAMMA} = \frac{\mathrm{BVALUE}}{12. \times \mathrm{SPAN(I)} \times \mathrm{DVALUE}}$$

$$\mathrm{DELTA} = \frac{\mathrm{XLGTNL(J,3)}}{12. \times \mathrm{SPAN(I)} \times \mathrm{TH1}}$$

$$\mathrm{SUMTN} = \frac{3.1416^2 \times \mathrm{DVALUE}}{144. \times \mathrm{TH1} \times \mathrm{SPAN(I)}^2}$$

BETAPL = 1.0 + BETA$^2$

CRITST = 1.25 x (ST1EST + ST2EST)

$$\mathrm{TOLSTR} = \frac{\mathrm{SUMTN} \times (\mathrm{BETAPL}^2 + 4. \times \mathrm{GAMMA})}{\mathrm{BETA}^2 \times (1. + 4. \times \mathrm{DELTA})}$$

Calculate the total moment of inertia of the midship section

$$\mathrm{ADINER} = \mathrm{XLNGTL(1,3)} \times \mathrm{BASEMT(K)}^2 + \mathrm{XLNGTL(1,2)}/144. + (\mathrm{XLNGTL(1,1)} - \mathrm{XLNGTL(1,2)})^2 \times 2. \times \left|\frac{\mathrm{Arctan(SLOPE2(K))}}{144. \times 3.1416}\right|$$

$$\mathrm{XINER} = \left|\frac{\mathrm{ZNAXIS} \times (\mathrm{BLMOM}^2 - \mathrm{AREAPT} \times \mathrm{XMOMIN})}{\mathrm{BLMOM}}\right|$$

<u>Add in the weight contribution of the main transverse frames</u>

$$WTOTLB = 3.4 \times AREAPT + \frac{2859. \times (1. + (0.833 \times (FRM - 8)/8))}{FRM}$$

<u>Sample Calculation</u> (Refer to program listing, flow chart, and printout of typical computer run, following pages)

```
      DIMENSION XLUNGL(40,4),SPAN(40),SMODMN(40),XLGTNL(9,5),XLNGTL(2,5)
     1,CGCG(40),XMINER(40),SLOPE2(40),PTDATA(30,10,3),BASEMT(40)
C
C     INPUT DATA AND INITIALIZE STORAGE VALUES
C
      W5BACT = 0.0
  954 FORMAT ('1         I          J          PTDATA(I,J,1)     PTDATA(I,J,2)
     1  PTDATA(I,J,3)')
  951 FORMAT (4X,I4,4X,I4,7X,3(F10.6,5X))
      WRITE (6, 954)
  901 FORMAT (23X,4(2X,F10.6))
      DO 907 I = 1,29
      DO 907 J = 1,10
  907 READ (5,901) PTDATA(I,J,1), PTDATA(I,J,2),PTDATA(I,J,3)
      DO 903 I = 1, 40
      DO 903 J = 1, 4
  903 XLUNGL(I,J) = 0.0
      DATA XL1BP,SUMDST,ILONGL,R5GYRA,W5BTOL/407.,0.,1,0.,0./
      I = 30
      J = 1
      READ (5,901)  PTDATA(I,J,1), PTDATA(I,J,2), PTDATA(I,J,3)
      DO 910 J = 2, 10
      DO 910 K = 1, 3
  910 PTDATA(I,J,K) = 0.0
      DO 941 J = 1, 2
      DO 941 K = 1, 5
  941 XLNGTL(J,K) = 0.0
  900 FORMAT (5F16.7)
  915 FORMAT ('1  REQUIRED MOMENT OF INERTIA =',F20.6,' IN**2  FT**2')
  916 FORMAT ('0  ACTUAL MOMENT OF INERTIA =',F20.6,' IN**2  FT**2')
  917 FORMAT ('0  MAX. TOLERABLE ST1CRK =',F10.7,' TONS PER SQ. INCH')
  918 FORMAT ('0  ACTUAL ST1CRK =',F10.7,' TONS PER SQ. INCH')
  919 FORMAT ('0  MAX. TOLERABLE ST1CRD =',F10.7,'TONS PER SQ. INCH')
  920 FORMAT ('0  ACTUAL ST1CRD =',F10.7,' TONS PER SQ. INCH')
  921 FORMAT ('0  TOTAL WEIGHT =', F10.7,' TONS PER FOOT LENGTH')
 1921 FORMAT ('0        PLATING WEIGHT =', F15.7,' POUNDS PER FOOT LENGTH'
     1)
 1922 FORMAT ('        LONGITUDINAL WEIGHT =', F15.7,' POUNDS PER FOOT LE
     1NGTH')
 1923 FORMAT ('        TRANSVERSE FRAME WEIGHT =',F15.7,' POUNDS PER FOOT
     1 LENGTH')
  922 FORMAT ('0  TOTAL WEIGHT =', F15.7,' POUNDS PER FOOT LENGTH')
  923 FORMAT ('0  NEUTRAL AXIS IS ',F10.7,' FEET ABOVE BASE LINE')
  924 FORMAT ('0      DESIGN IS ACCEPTABLE')
  934 FORMAT ('0     SPAN(',I2,')  =',F10.6)
  933 FORMAT ('1     SPAN(',I2,')  =',F10.6)
  925 FORMAT ('0        DESIGN REPEATED WITH TH1 INCREASED')
  926 FORMAT ('0        DESIGN IS NOT POSSIBLE UNLESS TH1 IS GREATER THAN
```

```
      1 ONE INCH.')
  928 FORMAT ('0  SCANTLING ',I3,'  SELECTED--CROSS-SECTION AREA IS',F1
     10.7,'  SQ. IN. AND WEB DEPTH IS ',F10.7,' INCHES.')
  929 FORMAT('0  KEEL HAS AN AREA OF',F10.7,' SQ. IN. AND A WEB DEPTH OF
     1 ',F10.7,' INCHES.')
      DO950 I = 1, 30
      DO 950 J = 1, 10
  950 WRITE(6,951) I,J,PTDATA(I,J,1),PTDATA(I,J,2),PTDATA(I,J,3)
      READ (5,900)  ST1CRK, ST1CRD, ST2EST, SGMULT, SGMYLD
  955 FORMAT ('0     INTERIM TH1 =',F10.6,' AND W5BACT =',F10.6)
  956 FORMAT ('      I =',I3,'     J =',I3,'      SUMDST =',F10.6)
  957 FORMAT ('0  SPAN(',I2,')  = ',F10.6,'    I = ',I2,'  J = ',I2)
  958 FORMAT ('0     I = ', I3,'     HM = ', F10.6)
  959 FORMAT ('0     XMINER(',I2,') ='    F15.6)
  960 FORMAT ('0     CGCG(',I2,')  = ', F10.6)
  961 FORMAT ('0     LONGITUDINAL (', I2,')  IS SELECTED')
  962 FORMAT ('0     BASEMT(', I2,')  = ',F10.6)
  963 FORMAT ('0     SELECTED PLATING THICKNESS = ',F10.6,' INCHES.  ')
      READ (5,900)  A3HEEL, D1, H1AMDK, H1DFL
  902 FORMAT (1H1,6X,'ST1CRK',9X,'ST1CRD',9X,'ST2EST',9X,'SGMULT',9X,
     1 'SGMYLD')
  904 FORMAT (5(5X,F10.6))
  905 FORMAT (5X,'W5BMIN  =',F10.6,'    FRM  =',F10.6)
  911 FORMAT (I3,6(2X,F13.6))
  912 FORMAT ('1I',4X,'      Y     ',5X,'     Z     ',5X,'     YPR    ',
     1 5X,'     ZPR     ',7X,'SPAN(I)',7X,'SMODMN(I)')
  913 FORMAT (5F16.7)
  964 FORMAT ('0  I     MAX. I.       MIN. I.          AREA            VCG
     1       DEPTH')
  975 FORMAT (2X, I2, 2X,F11.6, 4(3X,F10.6))
      WRITE (6, 964)
      DO 914 I = 1, 9
      READ (5,913) XLGTNL(I,1),XLGTNL(I,2),XLGTNL(I,3),XLGTNL(I,4),XLGTN
     1L(I,5)
  914 WRITE (6,975) I, XLGTNL(I,1), XLGTNL(I,2), XLGTNL(I,3), XLGTNL(I,4
     1), XLGTNL(I,5)
  965 FORMAT('0  W5BACT =',F10.6,'    W5BPRC =',F10.6,'    W5BTOL =',F10.6
     1)
  966 FORMAT('0    Y =',F10.6,'  Z =',F10.6,'  YPR =',F10.6,'  ZPR =',F10
     1.6)
  967 FORMAT ('0    CLONGL OUTPUT = ',4(F10.6,5X))
C
C     PROVIDE INPUT DATA TO CONTINUE CALCULATION INTERRUPTED IN PREVIOUS
C     COMPUTER RUN.   SOLUTION UP TO THIS TIME INDICATED FURTHER INCREMENTS
C     IN PLATING THICKNESS WERE NECESSARY.
C
  500 READ (5, 900) W5BMIN, FRM
      IF (W5BMIN .GT.  9.99)  GO TO 420
```

```
      W5BACT = 0.0
  400 WRITE  (6, 902)
      SUMDST = 0.0
      ILONGL = 1
      W5BTOL = 0.0
      IF (W5BACT .GT. 0.0) GO TO 668
C
C     DETERMINE PLATING THICKNESS
C
      CALL TSLECT (W5BMIN,ST1CRK,ST2EST,SGMULT,FRM,TH1,W5BACT)
      GO TO 667
  668 W5BACT = TH1 * W5BACT / ATH1
  667 DO 940 J = 1, 40
      SPAN(J) = 0.0
      SMODMN (J) = 0.0
      CGCG(J) = 0.0
      XMINER(J) = 0.0
      SLOPE2(J) = 0.0
  940 BASEMT(J) = 0.0
      DO 9940 J = 1, 40
      DO 9940 K = 1, 4
 9940 XLONGL(J,K) = 0.0
      WRITE (6,904) ST1CRK,ST1CRD,ST2EST,SGMULT,SGMYLD
      WRITE (6, 905) W5BMIN, FRM
      WRITE (6, 955)  TH1, W5BACT
      W5BPRC = W5BACT
      WRITE (6,965) W5BACT,W5BPRC,W5BTOL
C
C     DETERMINE ACCEPTABLE LONGITUDINAL SPACING FOR BOTH DECK AND SIDE
C     SHELL LONGITUDINALS.
C
  226 DO 200 I - 1, 30
      DO 200 J = 1, 10
      IF (ILONGL .GT. 1) GO TO 333
      W5BPRC = W5BACT
      GO TO 115
  333 W5BPRC = W5BTOL
  115 SUMDST = SUMDST + PTDATA (I, J, 3)
      WRITE (6, 956) I, J, SUMDST
      IF (I .EQ. 30) GO TO 225
      IF (I .EQ. 19) GO TO 205
      GO TO 207
  205 IF (J .EQ. 10) GO TO 204
  207 IF ((SUMDST - W5BPRC) .GT. 0.0) GO TO 201
      GO TO 200
  201 SUMCAL = SUMDST - PTDATA(I,J,3)
      DIFF = W5BPRC - SUMCAL
C
```

```
C     LOCATE THE LONGITUDINALS
C
      IF (J .EQ. 10) GO TO 202
      XLONGL(ILONGL,1)    = PTDATA(I,J,1) + (DIFF/PTDATA(I,J,3)) *
     1 (PTDATA(I,J+1,1) - PTDATA(I,J,1))
      XLONGL(ILONGL,2)= PTDATA(I,J,2) + (DIFF/PTDATA(I,J,3)) *
     1 (PTDATA(I,J+1,2) - PTDATA(I,J,2))
      XLONGL(ILONGL, 3) = PTDATA (I, J, 1)
      XLONGL(ILONGL, 4) = PTDATA (I, J, 2)
      SUMDST = SUMDST - W5BPRC
      WRITE(6,966)XLONGL(ILONGL,1),XLONGL(ILONGL,2),XLONGL(ILONGL,3),X
     1LONGL(ILONGL,4)
      GO TO 203
  202 XLONGL(ILONGL,1)= PTDATA(I,J,1) + (DIFF/PTDATA(I,J,3)) *
     1 (PTDATA(I+1,1,1) - PTDATA(I,J,1))
      XLONGL(ILONGL,2) = PTDATA(I,J,2) + (DIFF/PTDATA(I,J,3)) *
     1 (PTDATA(I+1,1,2) - PTDATA(I,J,2))
      XLONGL(ILONGL,3) = PTDATA(I,J,1)
      XLONGL(ILONGL, 4) = PTDATA (I, J, 2)
      SUMDST = SUMDST - W5BPRC
      WRITE(6,966)XLONGL(ILONGL,1),XLONGL(ILONGL,2),XLONGL(ILONGL,3),X
     1LONGL(ILONGL,4)
C
C     CALCULATE  R5GYRA  AND  SMODMN  REQUIRED FOR LONGITUDINALS
C
      WRITE (6, 965) W5BACT, W5BPRC, W5BTOL
  203 AAA = R5GYRA
      CALL CLONGL(ST1CRK,ST1CRD,ST2EST,SGMULT,FRM,TH1,W5BPRC,
     1 R5GYRA,SMODMN(ILONGL),XLONGL(ILONGL,1),XLONGL(ILONGL,2))
      WRITE (6, 967) R5GYRA,SMODMN(ILONGL),XLONGL(ILONGL,1),XLONGL(ILONG
     1L,2)
      WRITE (6, 965) W5BACT, W5BPRC, W5BTOL
      IF (R5GYRA .GT. AAA) GO TO 210
      R5GYRA = AAA
C
C     DETERMINE LONGITUDINAL SPACING.
C
  210 CALL CSPACE (ST1CRK,ST1CRD,ST2EST,SGMULT,FRM,TH1,
     1 XLONGL(ILONGL,1),XLONGL(ILONGL,2),W5BPRC,W5BTOL)
      SPAN(ILONGL) = W5BPRC
      WRITE (6, 957) ILONGL, SPAN(ILONGL),I, J
      WRITE (6, 965) W5BACT, W5BPRC, W5BTOL
      ILONGL = ILONGL + 1
      GO TO 200
C
C     ADJUST FOR DECK-SHELL INTERSECTION.
C
  204 ICOUNT = ILONGL
```

```
      IF (SUMDST .LT. W5BMIN) GO TO 208
      SPAN (ILONGL) = SUMDST
      WRITE (6, 957) ILONGL, SPAN(ILONGL), I, J
      SUMDST = 0.0
      XLONGL (ILONGL,1) = PTDATA(20, 1, 1)
      XLONGL (ILONGL,2) = PTDATA(20, 1, 2)
      XLONGL (ILONGL,3) = PTDATA(20, 1, 1)
      XLONGL (ILONGL,4) = PTDATA(20, 1, 2)
      WRITE(6,966)XLONGL(ILONGL,1),XLONGL(ILONGL,2),XLONGL(ILONGL,3),
     1 XLONGL(ILONGL,4)
      ILONGL = ILONGL + 1
      GO TO 200
  208 XX = ILONGL - 1
      BBDIST = W5BMIN - SUMDST
      STEP = BBDIST / XX
  214 JJ = 1
      IF ((SPAN(1) - W5BMIN) .GT. STEP) GO TO 216
C
C     ADJUST SPACING BY REDUCING THE SPAN.
C
      DO 98 JAJA=1, ILONGL
      CC = SPAN(JAJA) - W5BMIN
      BBDIST = BBDIST - CC
      IF (BBDIST .LT. 0.0) GO TO 97
   98 SPAN (JAJA) = W5BMIN
      WRITE (6, 957) JAJA, SPAN(JAJA), I, J
      IF (JAJA .EQ. ILONGL) GO TO 99
   97 SPAN (JAJA) = SPAN (JAJA) - CC - BBDIST
      WRITE (6, 957) JAJA, SPAN(JAJA), I, J
   99 STEP = 0.0
  216  DSTSUM = 0.0
  999 DO 215 IA = 1, 19
      DO 215 JA = 1, 10
      DSTSUM = DSTSUM + PTDATA (IA,JA,3)
      IF ((10*IA + JA) .EQ. 200) GO TO 110
      IF((SPAN(JJ) - DSTSUM) .LT. 0.0) GO TO 107
      GO TO 215
  107 SPAN(JJ) = SPAN(JJ) - STEP
      SUMDIF = DSTSUM - PTDATA(IA,JA,3)
      DIFF = SPAN(JJ) - SUMDIF
      WRITE (6, 957) JJ, SPAN(JJ), IA, JA
      IF (SPAN(JJ) .GT. 0.0) GO TO 127
      SPAN(JJ) = 0.0
       WRITE (6, 957) JJ, SPAN(JJ), IA, JA
      GO TO 110
  127 IF (JA .EQ. 10) GO TO 108
      XLONGL(JJ,1) = PTDATA(IA,JA,1)    +    (  DIFF    /
     1 PTDATA (IA,JA,3)) * (PTDATA(IA,JA+1,1) - PTDATA(IA,JA,1))
```

```
      XLONGL(JJ,2) =     PTDATA(IA,JA,2)    +    ( DIFF /
     1 PTDATA(IA,JA,3)) * (PTDATA(IA,JA+1,2) - PTDATA(IA,JA,2))
      XLONGL(JJ,3)= PTDATA (IA, JA, 1)
      XLONGL(JJ,4)= PTDATA (IA, JA, 2)
      WRITE(6,966)XLONGL(JJ,1),XLONGL(JJ,2),XLONGL(JJ,3),XLONGL(JJ,4)
      DSTSUM = DSTSUM - SPAN(JJ)
      JJ = JJ + 1
      GO TO 215
  108 XLONGL(JJ,1) = PTDATA(IA,JA,1)    +    (   DIFF    /
     1 PTDATA(IA,JA,3)) * (PTDATA(IA+1,1,1) - PTDATA(IA,JA,1))
      XLONGL(JJ,2) =     PTDATA(IA,JA,2)    +    ( DIFF /
     1 PTDATA(IA,JA,3))*(PTDATA(IA+1,1,2) - PTDATA(IA,JA,2))
      XLONGL(JJ,3)= PTDATA(IA,JA,1)
      XLONGL(JJ,4) = PTDATA(IA,JA,2)
      WRITE (6, 966) XLONGL(JJ,1),XLONGL(JJ,2),XLONGL(JJ,3),XLONGL(JJ,4)
      DSTSUM = DSTSUM - SPAN(JJ)
      JJ = JJ + 1
      GO TO 215
  110 XLONGL(JJ,1)= PTDATA (20,1,1)
      XLONGL(JJ,2) = PTDATA(20,1,2)
      XLONGL(JJ,3)= PTDATA (20,1,1)
      XLONGL(JJ,4)= PTDATA (20, 1, 2)
      SPAN(ILONGL) = W5BMIN
      WRITE (6, 966) XLONGL(JJ,1),XLONGL(JJ,2),XLONGL(JJ,3),XLONGL(JJ,4)
      WRITE (6, 957) JJ, SPAN(JJ), IA, JA
      ILONGL = ILONGL + 1
      SUMDST = 0.0
      GO TO 200
  215 CONTINUE
C
C     ADJUST DECK LONGITUDINAL SPACING TO FACILITATE SYMMETRY RELATIVE
C     TO THE CENTER LINE.
C
  225 IF (((0.5 * W5BMIN) - SUMDST) .GT. 0.0) GO TO 801
      GO TO 220
C
C     DECREASE SPAN TO OTHER DECK LONGITUDINALS TO PERMIT CENTERING SPAN
C     ON THE CENTERLINE.
C
  801 IDIFF = ILONGL - ICOUNT - 1
      XDIFF = IDIFF
      STEP = (0.5 * W5BMIN - SUMDST) / XDIFF
      SPAN(ILONGL) = 0.5 * W5BMIN
      ILONGL = ILONGL - 1
      IRKED = ICOUNT + 1
      DO 826 IA = IRKED, ILONGL, 1
      SPAN(IA) = SPAN(IA) - STEP
  826 WRITE (6,957) IA, SPAN(IA),II,JJ
```

```
      ILONGL = ILONGL + 1
      IA = ICOUNT + 1
      DO 227 II = 20, 29
      DO 227 JJ = 1, 10
      DSUM = DSUM + PTDATA(II,JJ,3)
      IF ((SPAN(IA) - DSUM) .LT. 0.0) GO TO 228
      GO TO 227
  228 IF (JJ .EQ. 10) GO TO 229
      SUMDIF = DSUM - PTDATA(II,JJ,3)
      DIFF = SPAN(IA) - SUMDIF
      XLONGL (IA, 1) =   PTDATA (II, JJ, 1)   +  ( DIFF  /
     1 PTDATA(II,JJ,3)) * (PTDATA(II,JJ+1,1) - PTDATA(II,JJ,1))
      XLONGL (IA, 2) =   PTDATA (II, JJ, 2)   +  ( DIFF  /
     1 PTDATA(II,JJ,3)) * (PTDATA(II,JJ+1,2) - PTDATA(II,JJ,2))
      XLONGL(IA,3)= PTDATA(II,JJ,1)
      XLONGL(IA,4)= PTDATA(II,JJ,2)
      WRITE(6,966)XLONGL(IA,1),XLONGL(IA,2),XLONGL(IA,3),XLONGL(IA,4)
      DSUM = DSUM - SPAN(IA)
      IA = IA + 1
      GO TO 227
  229 SUMDIF = DSUM - PTDATA (II, JJ, 3)
      DIFF = SPAN(IA) - SUMDIF
      XLONGL (IA, 1) =   PTDATA (II, JJ, 1)   +  ( DIFF  /
     1 PTDATA(II,JJ,3)) * (PTDATA(II+1,1,1) - PTDATA(II,JJ,1))
      XLONGL (IA, 2) =   PTDATA (II, JJ, 2)   +  ( DIFF  /
     1 PTDATA(II,JJ,3)) * (PTDATA(II+1,1,2) - PTDATA(II,JJ,2))
      XLONGL(IA,3)= PTDATA(II,JJ,1)
      XLONGL(IA,4) = PTDATA(II,JJ,2)
      WRITE(6,966)XLONGL(IA,1),XLONGL(IA,2),XLONGL(IA,3),XLONGL(IA,4)
      DSUM = DSUM - SPAN(IA)
      IA = IA + 1
  227 CONTINUE
      GO TO 300
  220 IF (SUMDST .GT. W5BMIN) GO TO 221
C
C     DECREASE SPANS TO OTHER DECK LONGITUDINALS TO PERMIT PLACING A
C     LONGITUDINAL ON THE DECK CENTERLINE.
C
      IF (SUMDST .LT. 0.5*W5BTOL) GO TO 520
      BBDIST = W5BMIN - SUMDST
      IA = ILONGL - ICOUNT - 1
      XIA = IA
      SPAN(ILONGL) = W5BMIN
      STEP = BBDIST / XIA
      ICOUNT = ICOUNT + 1
      DO 230 IAI = ICOUNT, ILONGL
  230 SPAN (IAI) = SPAN (IAI) - STEP
      ICOUNT = ICOUNT - 1
```

```
      WRITE (6, 957) IAI, SPAN(IAI), II, JJ
      IA = ICOUNT
      DO 237 II = 20, 29
      DO 237 JJ = 1, 10
      DSUM = DSUM + PTDATA(II,JJ,3)
      IF ((SPAN(IA) - DSUM) .LT. 0.0) GO TO 238
      GO TO 237
  238 IF (JJ .EQ. 10) GO TO 239
      SUMDIF = DSUM - PTDATA (II, JJ, 3)
      DIFF = SPAN(IA) - SUMDIF
      XLONGL (IA, 1) =   PTDATA (II, JJ, 1)   +  ( DIFF  /
     1 PTDATA(II,JJ,3)) * (PTDATA(II,JJ+1,1) - PTDATA(II,JJ,1))
      XLONGL (IA, 2) =   PTDATA (II, JJ, 2)   +  ( DIFF  /
     1 PTDATA(II,JJ,3)) * (PTDATA(II,JJ+1,2) - PTDATA(II,JJ,2))
      XLONGL(IA,3)= PTDATA(II,JJ,1)
      XLONGL(IA,4) = PTDATA(II,JJ,2)
      WRITE(6,966)XLONGL(IA,1),XLONGL(IA,2),XLONGL(IA,3),XLONGL(IA,4)
      DSUM = DSUM - SPAN(IA)
      IA = IA + 1
      GO TO 237
  239 SUMDIF = DSUM - PTDATA (II, JJ, 3)
      DIFF = SPAN(IA) - SUMDIF
      XLONGL (IA, 1) =   PTDATA (II, JJ, 1)   +  ( DIFF  /
     1 PTDATA(II,JJ,3)) * (PTDATA(II+1,1,1) - PTDATA(II,JJ,1))
      XLONGL (IA, 2) =   PTDATA (II, JJ, 2)   +  ( DIFF  /
     1 PTDATA(II,JJ,3)) * (PTDATA(II+1,1,2) - PTDATA(II,JJ,2))
      XLONGL(IA,3)= PTDATA(II,JJ,1)
      XLONGL(IA,4)= PTDATA(II,JJ,2)
      WRITE(6,966)XLONGL(IA,1),XLONGL(IA,2),XLONGL(IA,3),XLONGL(IA,4)
      DSUM = DSUM - SPAN(IA)
      IA = IA + 1
  237 CONTINUE
      GO TO 300
C
C     SPAN GREATER THAN W5BMIN, PLACE LONGITUDINAL ON THE CENTERLINE.
C
  221 SPAN(ILONGL) = SUMDST
      XLONGL(ILONGL,1) = PTDATA(30,1, 1)
      XLONGL(ILONGL,2) = PTDATA(30, 1, 2)
      XLONGL(ILONGL,3) = PTDATA(30,1, 1)
      XLONGL(ILONGL,4) = PTDATA(30, 1, 2)
      WRITE(6,966)XLONGL(ILONGL,1),XLONGL(ILONGL,2),XLONGL(ILONGL,3),
     1 XLONGL(ILONGL,4)
      GO TO 300
C
C     CURRENT LONGITUDINAL PLACEMENT OK.  CENTER SPAN ON CENTERLINE.
C
  520 SPAN(ILONGL) = SUMDST
```

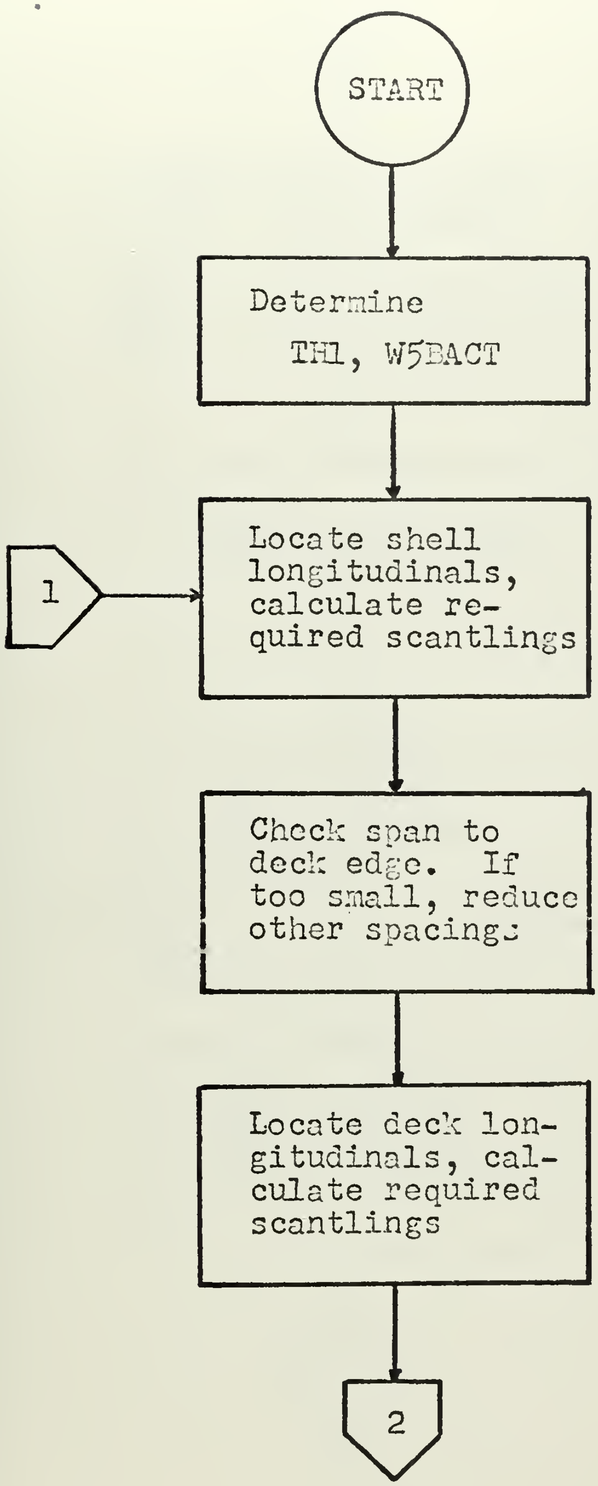
```
      GO TO 300
  200 CONTINUE
C
C     CALCULATE THE REQUIRED LONGITUDINAL SCANTLING.
C
  300 DO 310 I = 1, 5
  310 XLNGTL(1,I) =XLGTNL(9,I)
      WRITE (6, 912)
      DO 206 III = 2, 40
      IF (SPAN(III) .GT. 0.0) GO TO 206
      SPAN(III) = 0.0
      IF (SPAN(III - 1) .GT. 0.0) GO TO 206
      XLONGL(III,1) = 0.0
      XLONGL(III,2) = 0.0
      XLONGL(III,3) = 0.0
      XLONGL(III,4) = 0.0
  206 WRITE(6,911) III,XLONGL(III,1),XLONGL(III,2),XLONGL(III,3),
     1 XLONGL(III,4),SPAN(III),SMODMN(III)
C
C     SATISFY REQUIREMENTS AS TO MINIMUM RADIUS OF GYRATION.
C
      J = 1
      DO 320 I = 1, 40
      IF (SPAN(I) .EQ. 0.0) GO TO 323
      IF (XLONGL(I,2) .EQ. 0.0) GO TO 323
      IF (12.0*SPAN(I) .GT. 50.*TH1) GO TO 322
      AAA = 12.0 * SPAN(I)
      GO TO 321
  322 AAA = 50.*TH1
  321 FF = (XLGTNL(J,4) + TH1) * XLGTNL(J,3) + 0.5 * AAA * (TH1**2)
      FFF = XLGTNL(J,3) + TH1 * AAA
      CGCG(I) = FF/FFF
      WRITE (6, 960) I, CGCG(I)
      XMINER(I) = XLGTNL(J,1) + XLGTNL(J,3)*((XLGTNL(J,4)-CGCG(I))**2) +
     1 0.08333*AAA*(TH1**3) + TH1*AAA*((CGCG(I)-0.5*TH1)**2)
      RGYR = SQRT (XMINER(I) / FFF)
      WRITE (6, 961) J
      IF(R5GYRA .LT. RGYR) GO TO 320
      J = J + 1
      GO TO 321
  320 CONTINUE
C
C     SATISFY REQUIREMENTS AS TO STIFFENER STRENGTH.
C
  323 EFSPAN = 0.577 * FRM * 12.0
      DVALUE  = (13392.857 * (TH1**3)) / 10.8
      STALL = 38000. / 2240.
      DO 324 I = 1, 40
```

```
      IF (SPAN(I) .EQ. 0.0) GO TO 453
      IF (XLONGL(I,2) .EQ. 0.0) GO TO 453
  329 IF(((XLGTNL(J,5) + TH1) - CGCG(I)) .LT. CGCG(I)) GO TO 325
      ARM = CGCG(I)
      GO TO 326
  325 ARM = XLGTNL(J,5) + TH1 - CGCG(I)
  326 IF (12.0*SPAN(I) .GT. 50.*TH1) GO TO 327
      AAA = 12.0 * SPAN(I)
      GO TO 328
  327 AAA = 50.0 * TH1
  328 CALL HDWTR(A3HEEL,XLONGL(I,1),D1,H1AMDK,H1DFL,NBELTS,XL1BP,
     1 XLONGL(I,2),HM)
      WRITE (6, 958) I, HM
      PRESS = 0.445 * HM/2240.
       BMOMNT = 216. * PRESS * SPAN(I) * FRM**2
      ST1EST = 7.93 * ABS(XLONGL(I,2)-((7.93/13.93)*26.23125))
      ST2ALL = STALL - ST1EST
      REQMOD = BMOMNT / ST2ALL
      XMINER(I)=XLGTNL(J,1)+XLGTNL(J,3)*((XLGTNL(J,4)-CGCG(I))**2) +
     1 0.08333*AAA*(TH1**3) + TH1*AAA*((CGCG(I)-0.5*TH1)**2)
      WRITE (6, 961) J
      IF((XMINER(I)/ARM).LT.SMODMN(I)) GO TO 1324
      IF ((XMINER(I)/ARM) .GT. REQMOD) GO TO 324
 1324 J = J + 1
      WRITE (6, 961) J
      GO TO 329
  324 CONTINUE
C
C     SATISFY REQUIREMENTS AS TO STIFFENER CRITICAL STRENGTH.
C
  453 DO 330 I = 1, 40
      IF (SPAN(I) .EQ. 0.0) GO TO 451
      IF (XLONGL(I,2) .EQ. 0.0) GO TO 451
  336 IF (12.*SPAN(I) .GT. 50.*TH1) GO TO 337
      AAA = 12.0 * SPAN(I)
      GO TO 338
  337 AAA = 50.0 * TH1
  338 XMINER(I)=XLGTNL(J,1)+XLGTNL(J,3)*((XLGTNL(J,4)-CGCG(I))**2) +
     1 0.08333*AAA*(TH1**3) + TH1*AAA*((CGCG(I)-0.5*TH1)**2)
      BVALUE = 13392.857 * XMINER(I)
      BETA = FRM / SPAN(I)
      GAMMA = BVALUE / (SPAN(I) * 12. * DVALUE)
      DELTA = XLGTNL(J,3) / (12.0 * SPAN(I) * TH1)
      SUMTN = ((3.1416**2)*DVALUE)/(144. * TH1 * SPAN(I)**2)
      BETAPL = 1.0 + BETA**2
      ST1EST = 7.93* ABS(XLONGL(I,2)-((7.93/13.93)*26.23125))
      CRITST = 1.25 * (ST1EST + ST2EST)
      TOLSTR = SUMTN * (BETAPL**2 + 4.0*GAMMA)/((BETA**2)*(1.0 +
```

```
     1 4.0 * DELTA))
       WRITE (6, 959) I, XMINER(I)
       IF (TOLSTR .GT. CRITST) GO TO 330
       J = J + 1
       WRITE (6, 961) J
       GO TO 336
   330 CONTINUE
   451 WRITE (6, 961) J
C
C      CALCULATE THE TOTAL MOMENT OF INERTIA OF THE MIDSHIP SECTION.
C
       CALL PMINER(TH1,BLMOM,AREAPT,XMOMIN,XINER)
       WEIGHT = 6.8 * AREAPT
       DO 335 I = 1, 5
   335 XLNGTL(2,I) = XLGTNL(J,I)
       K = 1
       SLOPE2(K) = (XLONGL(K,3)-XLONGL(K,1))/(XLONGL(K,2)-XLONGL(K,4))
       ZZZ = XLNGTL(1,4)*(-SLOPE2(K))/(12.*SQRT(1.+(SLOPE2(K)**2)))
       ZPOINT = XLONGL(K,2) + ZZZ
       BASEMT(K) = ZPOINT
       WRITE (6, 962) K, BASEMT(K)
       DO 340 K = 2, 40
       IF (K .GT. ILONGL) GO TO 810
       IF (XLONGL(K,2) .EQ. 0.0) GO TO 810
       IF (K .LT. ICOUNT) GO TO 1811
       IF (K .GT. ICOUNT) GO TO 1811
       BASEMT(K) = 0.0
       GO TO 340
  1811 CONTINUE
       SLOPE2(K) = (XLONGL(K,3)-XLONGL(K,1))/(XLONGL(K,2)-XLONGL(K,4))
       ZZZ = XLNGTL(2,4)*(-SLOPE2(K))/(12.*SQRT(1.+(SLOPE2(K)**2)))
       ZPOINT = XLONGL(K,2) + ZZZ
       BASEMT(K) = ZPOINT
   340 WRITE(6, 962) K, BASEMT(K)
   810 AREAPT = 2.0 * AREAPT
       BLMOM = BLMOM * 2.0
       XMOMIN = 2.0 * XMOMIN
       K = 1
       ADINER = XLNGTL(1,3)*BASEMT(K)**2 + XLNGTL(1,2)/144. + (XLNGTL(1,1
     1) - XLNGTL(1,2))*2.*ABS(ATAN(SLOPE2(K))/(144.*3.1416))
       XMOMIN = XMOMIN + ADINER
       BLMOM = BLMOM + BASEMT(K)*XLNGTL(1,3)
       AREAPT = AREAPT + XLNGTL(1,3)
       DO 350 K = 2, 40
       IF (XLONGL(K,2) .EQ. 0.0) GO TO 351
       IF (K .GT. ILONGL) GO TO 351
       ADINER = XLNGTL(2,3)*BASEMT(K)**2 + XLNGTL(2,2)/144. + (XLNGTL(2,1
     1) - XLNGTL(2,2))*2.*ABS(ATAN(SLOPE2(K))/(144.*3.1416))
```

```
      IF (K .EQ. ILONGL) GO TO 352
      IF (K .EQ. ICOUNT) GO TO 350
  353 XMOMIN = XMOMIN + 2.0 * ADINER
      BLMOM = BLMOM + 2.0 * BASEMT(K)*XLNGTL(2,3)
      AREAPT = AREAPT + 2.0 * XLNGTL(2,3)
      GO TO 350
  352 IF (XLONGL(ILONGL,1) .GT. 0.0) GO TO 353
      XMOMIN = XMOMIN + ADINER
      BLMOM = BLMOM + BASEMT(K) * XLNGTL(2, 3)
      AREAPT = AREAPT + XLNGTL(2, 3)
  350 CONTINUE
  351 ZNAXIS = BLMOM / AREAPT
      XINER = ABS (ZNAXIS*((BLMOM**2) - AREAPT*XMOMIN)/BLMOM)
      REQMIN = 74100. * 26.231247 / 13.93
      DO 807 KK = 1, 40
      IF (SPAN(KK) .GT. 0.0) GO TO 807
      SPAN(KK) = 0.0
  807 CONTINUE
      IR = 1
      WRITE (6, 933) IR, SPAN(IR)
      DO 600 IR= 2, 40
  600 WRITE (6, 934) IR, SPAN(IR)
  804 WRITE(6,912)
      DO 806 KK= 1, 40
  806 WRITE(6,911) KK,XLONGL(KK,1),XLONGL(KK,2),XLONGL(KK,3),
     1 XLONGL(KK,4),SPAN(KK),SMODMN(KK)
      WRITE (6,915) REQMIN
      WRITE (6,916) XINER
      WRITE (6,917) STICRK
      ASTRSS = 74100. * ZNAXIS / XINER
      WRITE (6,918) ASTRSS
      WRITE (6,919) STICRD
      BSTRSS = 54400. * (26.231247 - ZNAXIS) / XINER
      WRITE (6, 920) BSTRSS
C
C     ADD IN THE WEIGHT CONTRIBUTION OF THE MAIN TRANSVERSE FRAMES.
C
      WTOTLB = AREAPT * 3.4 + 2859.*(1.0 + (0.8333*(FRM-8.)/8.)) /
     1 (FRM)
      WFRAME = WTOTLB - 3.4 * AREAPT
      WTOTAL = WTOTLB / 2240.
      WRITE (6,921) WTOTAL
      WRITE (6,922) WTOTLB
      WRITE (6, 1921) WEIGHT
      WLONGL = WTOTLB - WEIGHT - WFRAME
      WRITE (6, 1922) WLONGL
      WRITE (6,1923) WFRAME
      WRITE (6, 923) ZNAXIS
```

```
      WRITE (6,928) J,XLNGTL(2,3),XLNGTL(2,5)
      WRITE (6,929) XLNGTL(1,3),XLNGTL(1,5)
      WRITE (6, 963) TH1
      IF (ST1CRK .LT. ASTRSS) GO TO 421
      IF (ST1CRD .GT. BSTRSS) GO TO 500
  421 ATH1 = TH1
      WRITE (6, 925)
      IF (TH1 - 0.5) 401, 402, 403
  402 TH1 = 0.625
      GO TO 400
  403 IF (TH1 - 0.875) 404, 405, 406
  405 TH1 = 0.9375
      GO TO 400
  406 IF(TH1 - 0.9375) 405,407,408
  407 TH1 = 1.0
      GO TO 400
  408 WRITE (6, 926)
      GO TO 420
  401 IF(TH1 - 0.3125) 409, 410, 411
  410 TH1 = 0.34375
      GO TO 400
  409 IF (TH1 - 0.28125) 412, 413, 410
  413 TH1 = 0.3125
      GO TO 400
  412 TH1 = 0.28125
      GO TO 400
  411 IF (TH1 - 0.375) 414, 415, 416
  415 TH1 = 0.4375
      GO TO 400
  414 TH1 = 0.375
      GO TO 400
  416 TH1 = 0.500
      GO TO 400
  404 IF(TH1 - 0.75) 417, 418, 405
  418 TH1 = 0.875
      GO TO 400
  417 TH1 = 0.75
      GO TO 400
  420 STOP
      END
```




Calculate plating thickness, maximum span to first longitudinal.

Locate shell longitudinals.

Adjust locations if necessary.

Locate deck longitudinals.

FIGURE III

MAIN PROGRAM <u>RUNSCORE</u> FLOW CHART

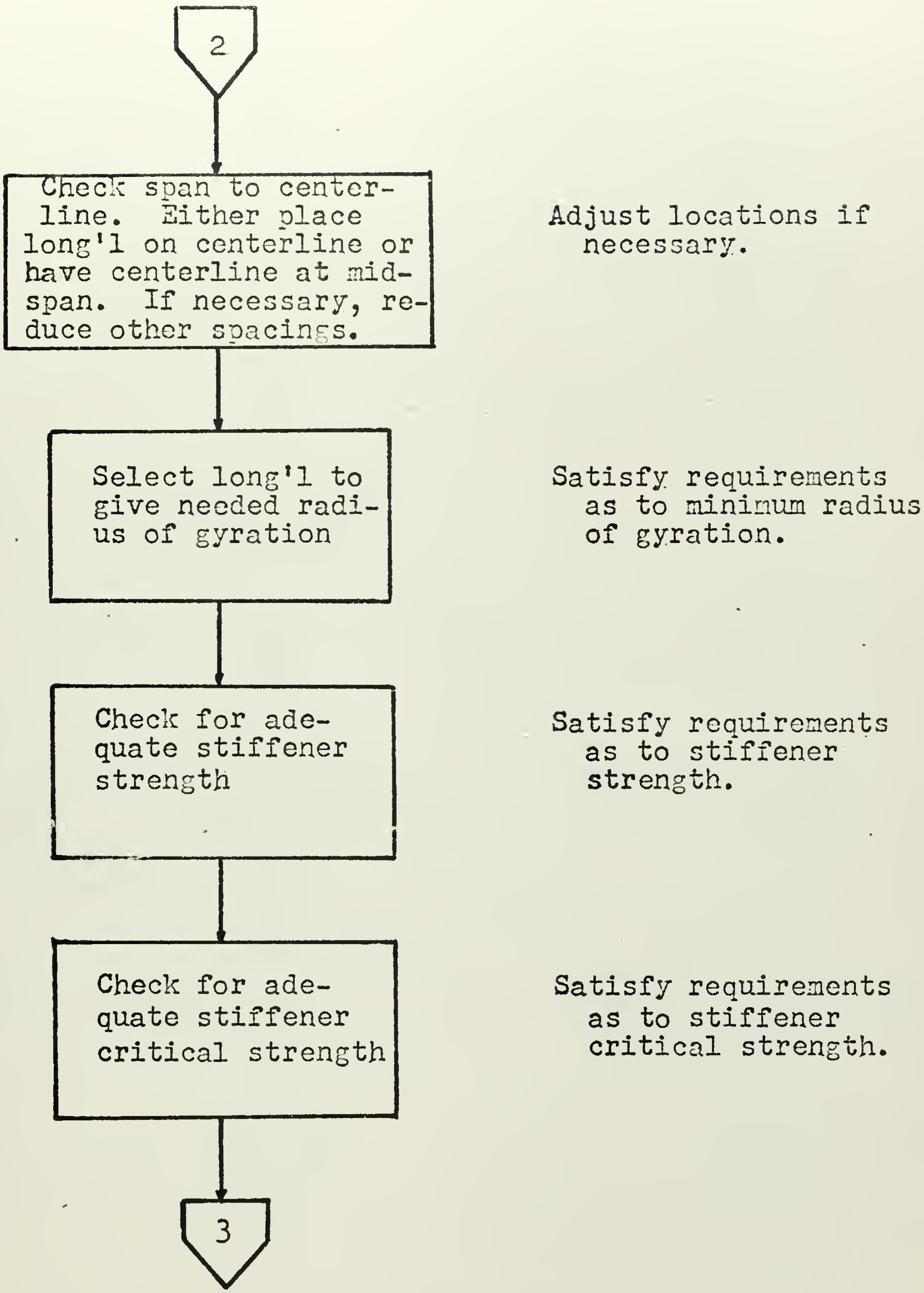
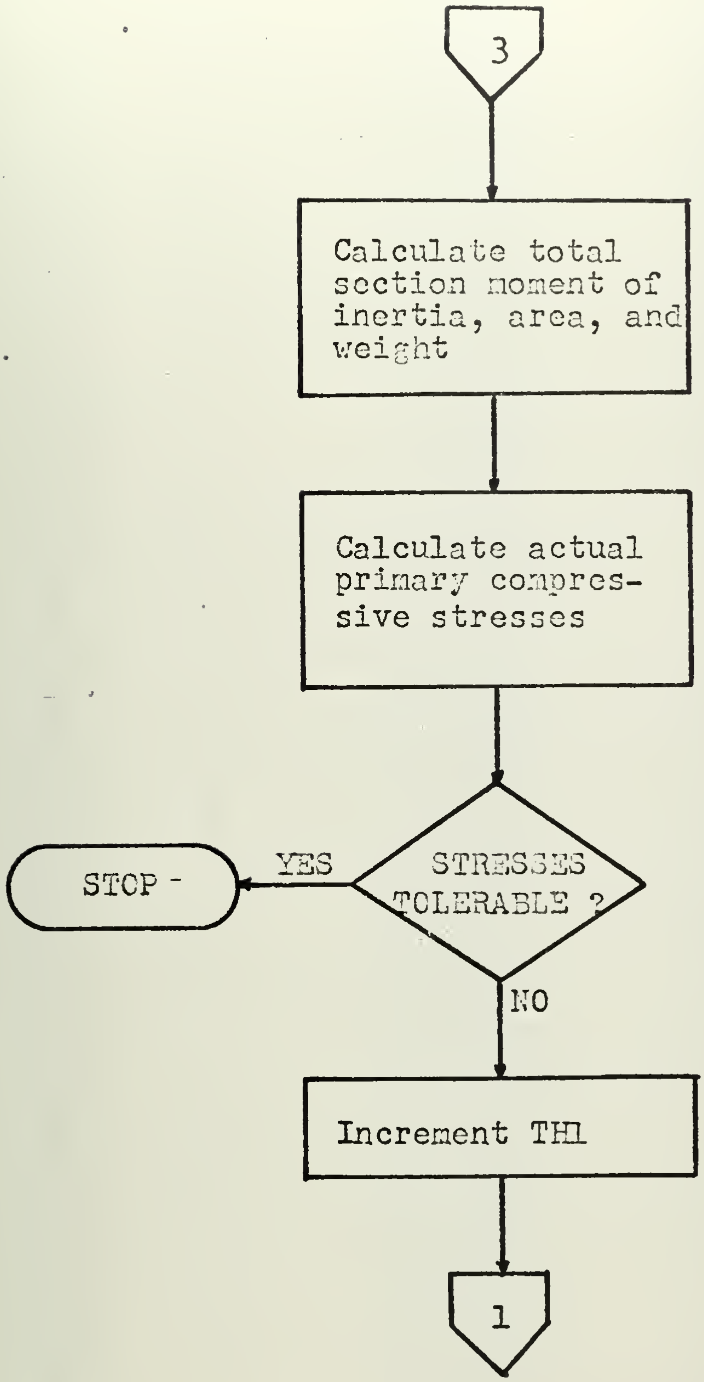



FIGURE III - Continued




Check total section characteristics.

Check for adequacy of midship section.

If stresses are too great, increase plating thickness, repeat calculation.

FIGURE III - Continued

| I | J | PTDATA(I,J,1) | PTDATA(I,J,2) | PTDATA(I,J,3) |
|---|---|---|---|---|
| 1 | 1 | 0.0 | 0.0 | 0.200056 |
| 1 | 2 | 0.200000 | 0.004743 | 0.200057 |
| 1 | 3 | 0.400000 | 0.009515 | 0.200058 |
| 1 | 4 | 0.600000 | 0.014343 | 0.200060 |
| 1 | 5 | 0.800000 | 0.019255 | 0.200063 |
| 1 | 6 | 1.000000 | 0.024282 | 0.200067 |
| 1 | 7 | 1.200000 | 0.029449 | 0.200071 |
| 1 | 8 | 1.400000 | 0.034787 | 0.200075 |
| 1 | 9 | 1.599998 | 0.040322 | 0.200083 |
| 1 | 10 | 1.799997 | 0.046084 | 0.200092 |
| 2 | 1 | 2.000000 | 0.052099 | 0.200099 |
| 2 | 2 | 2.200000 | 0.058402 | 0.200110 |
| 2 | 3 | 2.400000 | 0.065033 | 0.200121 |
| 2 | 4 | 2.599998 | 0.072038 | 0.200138 |
| 2 | 5 | 2.799997 | 0.079464 | 0.200155 |
| 2 | 6 | 2.999997 | 0.087355 | 0.200177 |
| 2 | 7 | 3.199999 | 0.095758 | 0.200200 |
| 2 | 8 | 3.399999 | 0.104718 | 0.200227 |
| 2 | 9 | 3.599998 | 0.114281 | 0.200260 |
| 2 | 10 | 3.799996 | 0.124493 | 0.200300 |
| 3 | 1 | 4.000000 | 0.135401 | 0.400720 |
| 3 | 2 | 4.400000 | 0.159419 | 0.400908 |
| 3 | 3 | 4.799997 | 0.186407 | 0.401122 |
| 3 | 4 | 5.199999 | 0.216375 | 0.401354 |
| 3 | 5 | 5.599998 | 0.249332 | 0.401612 |
| 3 | 6 | 5.999996 | 0.285289 | 0.401894 |
| 3 | 7 | 6.399998 | 0.324254 | 0.402196 |
| 3 | 8 | 6.799995 | 0.366238 | 0.402525 |
| 3 | 9 | 7.199997 | 0.411250 | 0.402875 |
| 3 | 10 | 7.599997 | 0.459301 | 0.403255 |
| 4 | 1 | 8.000000 | 0.510412 | 0.403664 |
| 4 | 2 | 8.400000 | 0.564682 | 0.404182 |
| 4 | 3 | 8.799997 | 0.622685 | 0.404840 |
| 4 | 4 | 9.199999 | 0.685097 | 0.405653 |
| 4 | 5 | 9.599998 | 0.752593 | 0.406652 |
| 4 | 6 | 9.999996 | 0.825849 | 0.407861 |
| 4 | 7 | 10.399998 | 0.905538 | 0.409308 |
| 4 | 8 | 10.799995 | 0.992337 | 0.411031 |
| 4 | 9 | 11.199997 | 1.086922 | 0.413059 |
| 4 | 10 | 11.599997 | 1.189965 | 0.415431 |
| 5 | 1 | 12.000000 | 1.302128 | 0.203281 |
| 5 | 2 | 12.194790 | 1.360265 | 0.203980 |
| 5 | 3 | 12.389580 | 1.420801 | 0.204727 |
| 5 | 4 | 12.584370 | 1.483809 | 0.205523 |
| 5 | 5 | 12.779160 | 1.549357 | 0.206371 |
| 5 | 6 | 12.973948 | 1.617520 | 0.207274 |
| 5 | 7 | 13.168737 | 1.688371 | 0.208232 |
| 5 | 8 | 13.363527 | 1.761974 | 0.209250 |
| 5 | 9 | 13.558317 | 1.838410 | 0.210327 |
| 5 | 10 | 13.753109 | 1.917747 | 0.210916 |
| 6 | 1 | 13.947900 | 1.998631 | 0.224085 |
| 6 | 2 | 14.153110 | 2.088647 | 0.225563 |
| 6 | 3 | 14.358317 | 2.182284 | 0.227193 |
| 6 | 4 | 14.563527 | 2.279781 | 0.229008 |
| 6 | 5 | 14.768739 | 2.381433 | 0.230972 |
| 6 | 6 | 14.973948 | 2.487440 | 0.233151 |
| 6 | 7 | 15.179156 | 2.598112 | 0.235502 |
| 6 | 8 | 15.384368 | 2.713654 | 0.238073 |
| 6 | 9 | 15.589578 | 2.834351 | 0.240840 |
| 6 | 10 | 15.794765 | 2.960419 | 0.250581 |
| 7 | 1 | 16.000000 | 3.104218 | 0.141439 |
| 7 | 2 | 16.117676 | 3.182663 | 0.142650 |
| 7 | [illegible] | [illegible] | [illegible] | [illegible] |

| | | | | |
|---|---|---|---|---|
| 7 | 4 | 16.353119 | 3.346128 | 0.145395 |
| 7 | 5 | 16.470810 | 3.431501 | 0.147028 |
| 7 | 6 | 16.588501 | 3.519608 | 0.149104 |
| 7 | 7 | 16.706238 | 3.611115 | 0.150991 |
| 7 | 8 | 16.823929 | 3.705704 | 0.153284 |
| 7 | 9 | 16.941620 | 3.803892 | 0.155638 |
| 7 | 10 | 17.059357 | 3.905701 | 0.150405 |
| 8 | 1 | 17.176529 | 4.000000 | 0.293348 |
| 8 | 2 | 17.391129 | 4.200000 | 0.287615 |
| 8 | 3 | 17.597809 | 4.400000 | 0.282204 |
| 8 | 4 | 17.796921 | 4.599998 | 0.277075 |
| 8 | 5 | 17.988678 | 4.799997 | 0.272213 |
| 8 | 6 | 18.173340 | 4.999997 | 0.267623 |
| 8 | 7 | 18.351166 | 5.199999 | 0.263299 |
| 8 | 8 | 18.522400 | 5.399999 | 0.259253 |
| 8 | 9 | 18.687378 | 5.599998 | 0.255442 |
| 8 | 10 | 18.846283 | 5.799996 | 0.252185 |
| 9 | 1 | 18.999878 | 6.000000 | 0.194464 |
| 9 | 2 | 19.115662 | 6.156250 | 0.192440 |
| 9 | 3 | 19.227997 | 6.312500 | 0.190448 |
| 9 | 4 | 19.336884 | 6.468750 | 0.188472 |
| 9 | 5 | 19.442261 | 6.625000 | 0.186540 |
| 9 | 6 | 19.544159 | 6.781250 | 0.184647 |
| 9 | 7 | 19.642563 | 6.937500 | 0.182745 |
| 9 | 8 | 19.737320 | 7.093750 | 0.180912 |
| 9 | 9 | 19.828522 | 7.250000 | 0.179094 |
| 9 | 10 | 19.916031 | 7.406250 | 0.176460 |
| 10 | 1 | 19.998047 | 7.562500 | 0.049333 |
| 10 | 2 | 20.020844 | 7.606250 | 0.049214 |
| 10 | 3 | 20.043381 | 7.650000 | 0.049094 |
| 10 | 4 | 20.065659 | 7.693748 | 0.048999 |
| 10 | 5 | 20.087723 | 7.737497 | 0.048896 |
| 10 | 6 | 20.109543 | 7.781247 | 0.048836 |
| 10 | 7 | 20.131241 | 7.824999 | 0.048767 |
| 10 | 8 | 20.152802 | 7.868749 | 0.048693 |
| 10 | 9 | 20.174164 | 7.912498 | 0.048647 |
| 10 | 10 | 20.195450 | 7.956246 | 0.049736 |
| 11 | 1 | 20.219101 | 8.000000 | 0.221883 |
| 11 | 2 | 20.315186 | 8.200000 | 0.221194 |
| 11 | 3 | 20.409668 | 8.400000 | 0.220430 |
| 11 | 4 | 20.502350 | 8.599998 | 0.219592 |
| 11 | 5 | 20.593018 | 8.799997 | 0.218688 |
| 11 | 6 | 20.681473 | 8.999997 | 0.217743 |
| 11 | 7 | 20.767563 | 9.199999 | 0.216706 |
| 11 | 8 | 20.850998 | 9.399999 | 0.215634 |
| 11 | 9 | 20.931595 | 9.599998 | 0.214540 |
| 11 | 10 | 21.009247 | 9.799996 | 0.213229 |
| 12 | 1 | 21.083176 | 10.000000 | 0.212228 |
| 12 | 2 | 21.154175 | 10.200000 | 0.211168 |
| 12 | 3 | 21.221924 | 10.400000 | 0.210194 |
| 12 | 4 | 21.286606 | 10.599998 | 0.209312 |
| 12 | 5 | 21.348343 | 10.799997 | 0.208509 |
| 12 | 6 | 21.407303 | 10.999997 | 0.207792 |
| 12 | 7 | 21.463669 | 11.199999 | 0.207150 |
| 12 | 8 | 21.517624 | 11.399999 | 0.206576 |
| 12 | 9 | 21.569336 | 11.599998 | 0.206064 |
| 12 | 10 | 21.618958 | 11.799996 | 0.205580 |
| 13 | 1 | 21.666504 | 12.000000 | 0.256441 |
| 13 | 2 | 21.723633 | 12.250000 | 0.255859 |
| 13 | 3 | 21.778061 | 12.500000 | 0.255320 |
| 13 | 4 | 21.829926 | 12.750000 | 0.254806 |
| 13 | 5 | 21.879181 | 13.000000 | 0.254342 |
| 13 | 6 | 21.925980 | 13.250000 | 0.253905 |
| 13 | 7 | 21.970337 | 13.500000 | 0.253502 |
| 13 | 8 | 22.012314 | 13.750000 | 0.253131 |
| 13 | 9 | 22.053002 | 14.000000 | 0.252791 |

| | | | | |
|---|---|---|---|---|
| 13 | 10 | 22.089478 | 14.250000 | 0.252494 |
| 14 | 1 | 22.124878 | 14.500000 | 0.151348 |
| 14 | 2 | 22.145035 | 14.650000 | 0.151247 |
| 14 | 3 | 22.164429 | 14.799997 | 0.151147 |
| 14 | 4 | 22.183014 | 14.949999 | 0.151059 |
| 14 | 5 | 22.200882 | 15.099998 | 0.150970 |
| 14 | 6 | 22.217972 | 15.249996 | 0.150882 |
| 14 | 7 | 22.234253 | 15.399998 | 0.150799 |
| 14 | 8 | 22.249756 | 15.549995 | 0.150726 |
| 14 | 9 | 22.264542 | 15.699997 | 0.150649 |
| 14 | 10 | 22.278519 | 15.849997 | 0.150584 |
| 15 | 1 | 22.291733 | 16.000000 | 0.200665 |
| 15 | 2 | 22.308075 | 16.199997 | 0.200564 |
| 15 | 3 | 22.323166 | 16.399994 | 0.200475 |
| 15 | 4 | 22.337006 | 16.599991 | 0.200399 |
| 15 | 5 | 22.349686 | 16.799988 | 0.200334 |
| 15 | 6 | 22.361298 | 16.999985 | 0.200279 |
| 15 | 7 | 22.371933 | 17.199982 | 0.200235 |
| 15 | 8 | 22.381699 | 17.399979 | 0.200195 |
| 15 | 9 | 22.390610 | 17.599976 | 0.200165 |
| 15 | 10 | 22.398804 | 17.799973 | 0.200165 |
| 16 | 1 | 22.406235 | 18.000000 | 0.200118 |
| 16 | 2 | 22.413193 | 18.199997 | 0.200099 |
| 16 | 3 | 22.419571 | 18.399994 | 0.200080 |
| 16 | 4 | 22.425339 | 18.599991 | 0.200064 |
| 16 | 5 | 22.430527 | 18.799988 | 0.200049 |
| 16 | 6 | 22.435074 | 18.999985 | 0.200035 |
| 16 | 7 | 22.438965 | 19.199982 | 0.200023 |
| 16 | 8 | 22.442200 | 19.399979 | 0.200013 |
| 16 | 9 | 22.444748 | 19.599976 | 0.200006 |
| 16 | 10 | 22.446671 | 19.799973 | 0.200029 |
| 17 | 1 | 22.447342 | 20.000000 | 0.199998 |
| 17 | 2 | 22.447861 | 20.199997 | 0.199997 |
| 17 | 3 | 22.447678 | 20.399994 | 0.199999 |
| 17 | 4 | 22.446869 | 20.599991 | 0.200002 |
| 17 | 5 | 22.445450 | 20.799988 | 0.200006 |
| 17 | 6 | 22.443497 | 20.999985 | 0.200012 |
| 17 | 7 | 22.441010 | 21.199982 | 0.200019 |
| 17 | 8 | 22.438019 | 21.399979 | 0.200025 |
| 17 | 9 | 22.434647 | 21.599976 | 0.200033 |
| 17 | 10 | 22.430832 | 21.799973 | 0.200072 |
| 18 | 1 | 22.426590 | 22.000000 | 0.200047 |
| 18 | 2 | 22.422104 | 22.199997 | 0.200054 |
| 18 | 3 | 22.417328 | 22.399994 | 0.200060 |
| 18 | 4 | 22.412308 | 22.599991 | 0.200064 |
| 18 | 5 | 22.407120 | 22.799988 | 0.200068 |
| 18 | 6 | 22.401764 | 22.999985 | 0.200070 |
| 18 | 7 | 22.396378 | 23.199982 | 0.200073 |
| 18 | 8 | 22.390854 | 23.399979 | 0.200072 |
| 18 | 9 | 22.385376 | 23.599976 | 0.200071 |
| 18 | 10 | 22.379944 | 23.799973 | 0.200092 |
| 19 | 1 | 22.374878 | 24.000000 | 0.123975 |
| 19 | 2 | 22.371613 | 24.123932 | 0.123989 |
| 19 | 3 | 22.368378 | 24.247864 | 0.123988 |
| 19 | 4 | 22.365189 | 24.371811 | 0.124003 |
| 19 | 5 | 22.362015 | 24.495789 | 0.123986 |
| 19 | 6 | 22.358902 | 24.619736 | 0.123985 |
| 19 | 7 | 22.355820 | 24.743683 | 0.123970 |
| 19 | 8 | 22.352753 | 24.867615 | 0.123985 |
| 19 | 9 | 22.349701 | 24.991562 | 0.123985 |
| 19 | 10 | 22.346634 | 25.115494 | 0.124117 |
| 20 | 1 | 22.343796 | 25.239594 | 0.224005 |
| 20 | 2 | 22.120331 | 25.255127 | 0.223993 |
| 20 | 3 | 21.896866 | 25.270737 | 0.223976 |
| 20 | 4 | 21.673447 | 25.286301 | 0.223989 |
| 20 | 5 | 21.449997 | 25.301819 | 0.224005 |

| | | | | |
|---|---|---|---|---|
| 20 | 6 | 21.226532 | 25.317333 | 0.223972 |
| 20 | 7 | 21.003098 | 25.332886 | 0.223988 |
| 20 | 8 | 20.779648 | 25.348404 | 0.223999 |
| 20 | 9 | 20.556183 | 25.363846 | 0.223983 |
| 20 | 10 | 20.332718 | 25.379303 | 0.223964 |
| 21 | 1 | 20.109299 | 25.394684 | 0.223978 |
| 21 | 2 | 19.885849 | 25.410080 | 0.223989 |
| 21 | 3 | 19.662369 | 25.425400 | 0.223956 |
| 21 | 4 | 19.438950 | 25.440674 | 0.223967 |
| 21 | 5 | 19.215500 | 25.455887 | 0.223981 |
| 21 | 6 | 18.992035 | 25.471085 | 0.223960 |
| 21 | 7 | 18.768570 | 25.486191 | 0.223940 |
| 21 | 8 | 18.545151 | 25.501236 | 0.223969 |
| 21 | 9 | 18.321686 | 25.516251 | 0.223947 |
| 21 | 10 | 18.098221 | 25.531174 | 0.223927 |
| 22 | 1 | 17.874802 | 25.546021 | 0.223937 |
| 22 | 2 | 17.651352 | 25.560776 | 0.223948 |
| 22 | 3 | 17.427887 | 25.575470 | 0.223911 |
| 22 | 4 | 17.204453 | 25.590088 | 0.223922 |
| 22 | 5 | 16.981003 | 25.604630 | 0.223932 |
| 22 | 6 | 16.757538 | 25.619080 | 0.223910 |
| 22 | 7 | 16.534073 | 25.633423 | 0.223887 |
| 22 | 8 | 16.310654 | 25.647629 | 0.223897 |
| 22 | 9 | 16.087204 | 25.661789 | 0.223880 |
| 22 | 10 | 15.863767 | 25.675858 | 0.223873 |
| 23 | 1 | 15.640326 | 25.689789 | 0.223865 |
| 23 | 2 | 15.416888 | 25.703583 | 0.223858 |
| 23 | 3 | 15.193452 | 25.717316 | 0.223851 |
| 23 | 4 | 14.970014 | 25.730896 | 0.223846 |
| 23 | 5 | 14.746573 | 25.744385 | 0.223836 |
| 23 | 6 | 14.523135 | 25.757721 | 0.223827 |
| 23 | 7 | 14.299699 | 25.770920 | 0.223821 |
| 23 | 8 | 14.076261 | 25.784012 | 0.223815 |
| 23 | 9 | 13.852820 | 25.796982 | 0.223805 |
| 23 | 10 | 13.629382 | 25.809784 | 0.223797 |
| 24 | 1 | 13.405946 | 25.822464 | 0.223788 |
| 24 | 2 | 13.182508 | 25.834961 | 0.223783 |
| 24 | 3 | 12.959067 | 25.847382 | 0.223771 |
| 24 | 4 | 12.735631 | 25.859604 | 0.223765 |
| 24 | 5 | 12.512193 | 25.871689 | 0.223757 |
| 24 | 6 | 12.288754 | 25.883606 | 0.223747 |
| 24 | 7 | 12.065314 | 25.895340 | 0.223739 |
| 24 | 8 | 11.841878 | 25.906952 | 0.223730 |
| 24 | 9 | 11.618440 | 25.918396 | 0.223724 |
| 24 | 10 | 11.395000 | 25.929688 | 0.223714 |
| 25 | 1 | 11.171561 | 25.940796 | 0.223703 |
| 25 | 2 | 10.948125 | 25.951706 | 0.223696 |
| 25 | 3 | 10.724687 | 25.962433 | 0.223690 |
| 25 | 4 | 10.501246 | 25.973038 | 0.223680 |
| 25 | 5 | 10.277808 | 25.983429 | 0.223670 |
| 25 | 6 | 10.054372 | 25.993622 | 0.223663 |
| 25 | 7 | 9.830934 | 26.003647 | 0.223656 |
| 25 | 8 | 9.607493 | 26.013489 | 0.223647 |
| 25 | 9 | 9.384055 | 26.023148 | 0.223637 |
| 25 | 10 | 9.160619 | 26.032593 | 0.223630 |
| 26 | 1 | 8.937181 | 26.041855 | 0.223622 |
| 26 | 2 | 8.713740 | 26.050873 | 0.223614 |
| 26 | 3 | 8.490304 | 26.059769 | 0.223605 |
| 26 | 4 | 8.266866 | 26.068390 | 0.223599 |
| 26 | 5 | 8.043427 | 26.076859 | 0.223591 |
| 26 | 6 | 7.819987 | 26.085114 | 0.223581 |
| 26 | 7 | 7.596551 | 26.093140 | 0.223575 |
| 26 | 8 | 7.373113 | 26.100937 | 0.223569 |
| 26 | 9 | 7.149673 | 26.108582 | 0.223560 |
| 26 | 10 | 6.926234 | 26.115947 | 0.223553 |
| 27 | 1 | 6.702798 | 26.123154 | 0.223547 |

| | | | | |
|---|---|---|---|---|
| 27 | 2 | 6.479360 | 26.130112 | 0.223540 |
| 27 | 3 | 6.255919 | 26.136841 | 0.223534 |
| 27 | 4 | 6.032481 | 26.143372 | 0.223526 |
| 27 | 5 | 5.809045 | 26.149643 | 0.223521 |
| 27 | 6 | 5.585607 | 26.155716 | 0.223516 |
| 27 | 7 | 5.362166 | 26.161591 | 0.223509 |
| 27 | 8 | 5.138728 | 26.167206 | 0.223502 |
| 27 | 9 | 4.915292 | 26.172577 | 0.223498 |
| 27 | 10 | 4.691854 | 26.177765 | 0.223493 |
| 28 | 1 | 4.468413 | 26.182663 | 0.223487 |
| 28 | 2 | 4.244977 | 26.187378 | 0.223483 |
| 28 | 3 | 4.021539 | 26.191849 | 0.223479 |
| 28 | 4 | 3.798100 | 26.196091 | 0.223473 |
| 28 | 5 | 3.574660 | 26.200058 | 0.223469 |
| 28 | 6 | 3.351224 | 26.203827 | 0.223466 |
| 28 | 7 | 3.127786 | 26.207352 | 0.223463 |
| 28 | 8 | 2.904346 | 26.210602 | 0.223459 |
| 28 | 9 | 2.680907 | 26.213669 | 0.223455 |
| 28 | 10 | 2.457471 | 26.216446 | 0.223453 |
| 29 | 1 | 2.234033 | 26.219025 | 0.223451 |
| 29 | 2 | 2.010592 | 26.221344 | 0.223448 |
| 29 | 3 | 1.787154 | 26.223404 | 0.223445 |
| 29 | 4 | 1.563718 | 26.225235 | 0.223444 |
| 29 | 5 | 1.340280 | 26.226822 | 0.223443 |
| 29 | 6 | 1.116839 | 26.228180 | 0.223440 |
| 29 | 7 | 0.893403 | 26.229279 | 0.223439 |
| 29 | 8 | 0.669966 | 26.230118 | 0.223439 |
| 29 | 9 | 0.446528 | 26.230713 | 0.223438 |
| 29 | 10 | 0.223090 | 26.231110 | 0.223090 |
| 30 | 1 | 0.0 | 26.231247 | 0.0 |
| 30 | 2 | 0.0 | 0.0 | 0.0 |
| 30 | 3 | 0.0 | 0.0 | 0.0 |
| 30 | 4 | 0.0 | 0.0 | 0.0 |
| 30 | 5 | 0.0 | 0.0 | 0.0 |
| 30 | 6 | 0.0 | 0.0 | 0.0 |
| 30 | 7 | 0.0 | 0.0 | 0.0 |
| 30 | 8 | 0.0 | 0.0 | 0.0 |
| 30 | 9 | 0.0 | 0.0 | 0.0 |
| 30 | 10 | 0.0 | 0.0 | 0.0 |

| I | MAX. I. | MIN. I. | AREA | VCG | DEPTH |
|---|---|---|---|---|---|
| 1 | 10.560399 | 1.404570 | 2.547919 | 4.102559 | 6.000000 |
| 2 | 17.253708 | 5.149980 | 4.553559 | 4.275189 | 6.000000 |
| 3 | 21.999649 | 1.267670 | 2.935920 | 5.179449 | 8.000000 |
| 4 | 32.151489 | 2.691560 | 4.428200 | 5.261410 | 8.000000 |
| 5 | 47.027786 | 3.848550 | 4.322120 | 6.916630 | 9.000000 |
| 6 | 64.834717 | 1.357809 | 3.913119 | 7.419299 | 12.000000 |
| 7 | 246.921356 | 12.129780 | 8.529169 | 10.944189 | 16.000000 |
| 8 | 393.407471 | 17.171539 | 10.781560 | 12.175449 | 18.000000 |
| 9 | 1309.426758 | 91.923447 | 20.686417 | 16.908249 | 24.000000 |

```
   STICRK           STICRD           ST2EST           SGMULT           SGMYLD
   7.929999         6.000000         1.339286         20.982132        20.982132
  W5BMIN  =  2.000000   FRM  =  8.000000

  INTERIM TH1  =  0.343750 AND W5BACT  =  2.162113

W5BACT  =  2.162113   W5BPRC  =  2.162113   W5BTOL  =  0.0
  I  =  1    J  =  1     SUMDST  =  0.200056
  I  =  1    J  =  2     SUMDST  =  0.400113
  I  =  1    J  =  3     SUMDST  =  0.600171
  I  =  1    J  =  4     SUMDST  =  0.800231
  I  =  1    J  =  5     SUMDST  =  1.000294
  I  =  1    J  =  6     SUMDST  =  1.200360
  I  =  1    J  =  7     SUMDST  =  1.400431
  I  =  1    J  =  8     SUMDST  =  1.600505
  I  =  1    J  =  9     SUMDST  =  1.800588
  I  =  1    J  = 10     SUMDST  =  2.000679
  I  =  2    J  =  1     SUMDST  =  2.200778

 Y  =  2.161354   Z  =  0.057184   YPR  =  2.000000   ZPR  =  0.052099

 CLONGL OUTPUT  =   3.096774     10.107035     2.161354     0.057184

W5BACT  =  2.162113   W5BPRC  =  2.162113   W5BTOL  =  0.0

SPAN( 1)  =   2.162113   I  =  2   J  =  1

W5BACT  =  2.162113   W5BPRC  =  2.162113   W5BTOL  =  2.166965
  I  =  2    J  =  2     SUMDST  =  0.238775
  I  =  2    J  =  3     SUMDST  =  0.438896
  I  =  2    J  =  4     SUMDST  =  0.639034
  I  =  2    J  =  5     SUMDST  =  0.839189
  I  =  2    J  =  6     SUMDST  =  1.039365
  I  =  2    J  =  7     SUMDST  =  1.239564
  I  =  2    J  =  8     SUMDST  =  1.439791
  I  =  2    J  =  9     SUMDST  =  1.640050
  I  =  2    J  = 10     SUMDST  =  1.840349
  I  =  3    J  =  1     SUMDST  =  2.241069

 Y  =  4.326030   Z  =  0.154977   YPR  =  4.000000   ZPR  =  0.135401

 CLONGL OUTPUT  =   3.096774     10.029918     4.326030     0.154977

W5BACT  =  2.162113   W5BPRC  =  2.166965   W5BTOL  =  2.166965

SPAN( 2)  =   2.166965   I  =  3   J  =  1

W5BACT  =  2.162113   W5BPRC  =  2.166965   W5BTOL  =  2.175280
  I  =  3    J  =  2     SUMDST  =  0.475011
  I  =  3    J  =  3     SUMDST  =  0.876133
  I  =  3    J  =  4     SUMDST  =  1.277487
  I  =  3    J  =  5     SUMDST  =  1.679098
  I  =  3    J  =  6     SUMDST  =  2.080992
  I  =  3    J  =  7     SUMDST  =  2.483188

 Y  =  6.493771   Z  =  0.334096   YPR  =  6.399998   ZPR  =  0.324254

 CLONGL OUTPUT  =   3.096774      9.890423     6.493771     0.334096

W5BACT  =  2.162113   W5BPRC  =  2.175280   W5BTOL  =  2.175280

SPAN( 3)  =   2.175280   I  =  3   J  =  7
```

```
  I =  3     J =  8      SUMDST =  0.710433
  I =  3     J =  9      SUMDST =  1.113308
  I =  3     J = 10      SUMDST =  1.516562
  I =  4     J =  1      SUMDST =  1.920226
  I =  4     J =  2      SUMDST =  2.324408

 Y =  8.667541  Z =  0.603478  YPR =  8.400000  ZPR =  0.564682

 CLONGL OUTPUT =   3.096774      9.684793      8.667541       0.603478

W5BACT =  2.162113   W5BPRC =  2.190565   W5BTOL =  2.190565

SPAN( 4)  =   2.190565   I =  4  J =  2

W5BACT =  2.162113   W5BPRC =  2.190565   W5BTOL =  2.213699
  I =  4     J =  3      SUMDST =  0.538682
  I =  4     J =  4      SUMDST =  0.944335
  I =  4     J =  5      SUMDST =  1.350987
  I =  4     J =  6      SUMDST =  1.758848
  I =  4     J =  7      SUMDST =  2.168156
  I =  4     J =  8      SUMDST =  2.579186

 Y = 10.844317  Z =  1.002817  YPR = 10.799995  ZPR =  0.992337

 CLONGL OUTPUT =   3.096774      9.388797     10.844317       1.002817

W5BACT =  2.162113   W5BPRC =  2.213699   W5BTOL =  2.213699

SPAN( 5)  =   2.213699   I =  4  J =  8

W5BACT =  2.162113   W5BPRC =  2.213699   W5BTOL =  2.248323
  I =  4     J =  9      SUMDST =  0.778546
  I =  4     J = 10      SUMDST =  1.193976
  I =  5     J =  1      SUMDST =  1.397257
  I =  5     J =  2      SUMDST =  1.601236
  I =  5     J =  3      SUMDST =  1.805963
  I =  5     J =  4      SUMDST =  2.011485
  I =  5     J =  5      SUMDST =  2.217855
  I =  5     J =  6      SUMDST =  2.425129

 Y = 13.002581  Z =  1.627934  YPR = 12.973948  ZPR =  1.617520

 CLONGL OUTPUT =   3.096774      8.945485     13.002581       1.627934

W5BACT =  2.162113   W5BPRC =  2.248323   W5BTOL =  2.248323

SPAN( 6)  =   2.248323   I =  5  J =  6

W5BACT =  2.162113   W5BPRC =  2.248323   W5BTOL =  2.303361
  I =  5     J =  7      SUMDST =  0.385037
  I =  5     J =  8      SUMDST =  0.594287
  I =  5     J =  9      SUMDST =  0.804614
  I =  5     J = 10      SUMDST =  1.015530
  I =  6     J =  1      SUMDST =  1.239614
  I =  6     J =  2      SUMDST =  1.465177
  I =  6     J =  3      SUMDST =  1.692369
  I =  6     J =  4      SUMDST =  1.921377
  I =  6     J =  5      SUMDST =  2.152349
  I =  6     J =  6      SUMDST =  2.385499

 Y = 15.106862  Z =  2.559123  YPR = 14.973948  ZPR =  2.487440

 CLONGL OUTPUT =   3.096774      8.326877     15.106862       2.559123

W5BACT =  2.162113   W5BPRC =  2.303361   W5BTOL =  2.303361
```

```
SPAN( 7)  =    2.303361   I = 6  J =  6
```



```
W5BACT =   2.162113    W5BPRC =   2.303361    W5BTOL =   2.387387
  I =   6      J =   7        SUMDST =  0.317640
  I =   6      J =   8        SUMDST =  0.555713
  I =   6      J =   9        SUMDST =  0.796553
  I =   6      J =  10        SUMDST =  1.047133
  I =   7      J =   1        SUMDST =  1.188572
  I =   7      J =   2        SUMDST =  1.331222
  I =   7      J =   3        SUMDST =  1.475191
  I =   7      J =   4        SUMDST =  1.620585
  I =   7      J =   5        SUMDST =  1.767613
  I =   7      J =   6        SUMDST =  1.916717
  I =   7      J =   7        SUMDST =  2.067707
  I =   7      J =   8        SUMDST =  2.220990
  I =   7      J =   9        SUMDST =  2.376628
  I =   7      J =  10        SUMDST =  2.527033

 Y = 17.067734  Z =   3.912447   YPR = 17.059357  ZPR =   3.905701

W5BACT =   2.162113    W5BPRC =   2.387387    W5BTOL =   2.387387

 CLONGL OUTPUT =    3.096774        7.506919        17.067734          3.912447

W5BACT =   2.162113    W5BPRC =   2.387387    W5BTOL =   2.387387

SPAN( 8)  =    2.387387   I =  7  J = 10

W5BACT =   2.162113    W5BPRC =   2.387387    W5BTOL =   2.514391
  I =   8      J =   1        SUMDST =  0.432994
  I =   8      J =   2        SUMDST =  0.720609
  I =   8      J =   3        SUMDST =  1.002813
  I =   8      J =   4        SUMDST =  1.279888
  I =   8      J =   5        SUMDST =  1.552101
  I =   8      J =   6        SUMDST =  1.819724
  I =   8      J =   7        SUMDST =  2.083023
  I =   8      J =   8        SUMDST =  2.342276
  I =   8      J =   9        SUMDST =  2.597717

 Y = 18.794434  Z =   5.734756   YPR = 18.687378  ZPR =   5.599998

 CLONGL OUTPUT =    3.096774        6.528984        18.794434          5.734756

W5BACT =   2.162113    W5BPRC =   2.514391    W5BTOL =   2.514391

SPAN( 9)  =    2.514391   I =  8  J =  9

W5BACT =   2.162113    W5BPRC =   2.514391    W5BTOL =   2.696131
  I =   8      J =  10        SUMDST =  0.335511
  I =   9      J =   1        SUMDST =  0.529975
  I =   9      J =   2        SUMDST =  0.722415
  I =   9      J =   3        SUMDST =  0.912863
  I =   9      J =   4        SUMDST =  1.101335
  I =   9      J =   5        SUMDST =  1.287874
  I =   9      J =   6        SUMDST =  1.472521
  I =   9      J =   7        SUMDST =  1.655266
  I =   9      J =   8        SUMDST =  1.836177
  I =   9      J =   9        SUMDST =  2.015270
  I =   9      J =  10        SUMDST =  2.191730
  I =  10      J =   1        SUMDST =  2.241062
  I =  10      J =   2        SUMDST =  2.290276
  I =  10      J =   3        SUMDST =  2.339369
  I =  10      J =   4        SUMDST =  2.388368
  I =  10      J =   5        SUMDST =  2.437263
  I =  10      J =   6        SUMDST =  2.486099
```

```
  I = 10     J =  8      SUMDST =  2.583558
  I = 10     J =  9      SUMDST =  2.632205
  I = 10     J = 10      SUMDST =  2.681940
  I = 11     J =  1      SUMDST =  2.903823

 Y = 20.225235  Z =  8.012792  YPR = 20.219101  ZPR =  8.000000

 CLONGL OUTPUT =   3.096774      5.473187      20.225235      8.012792

W5BACT =  2.162113   W5BPRC =  2.696131   W5BTOL =  2.696131

SPAN(10)  =   2.696131   I = 11  J =  1

W5BACT =  2.162113   W5BPRC =  2.696131   W5BTOL =  2.944719
  I = 11     J =  2      SUMDST =  0.428886
  I = 11     J =  3      SUMDST =  0.649316
  I = 11     J =  4      SUMDST =  0.868908
  I = 11     J =  5      SUMDST =  1.087596
  I = 11     J =  6      SUMDST =  1.305339
  I = 11     J =  7      SUMDST =  1.522044
  I = 11     J =  8      SUMDST =  1.737678
  I = 11     J =  9      SUMDST =  1.952217
  I = 11     J = 10      SUMDST =  2.165445
  I = 12     J =  1      SUMDST =  2.377673
  I = 12     J =  2      SUMDST =  2.588840
  I = 12     J =  3      SUMDST =  2.799034
  I = 12     J =  4      SUMDST =  3.008346

 Y = 21.329575  Z = 10.739202  YPR = 21.286606  ZPR = 10.599998

 CLONGL OUTPUT =   3.096774      4.402401      21.329575      10.739202

W5BACT =  2.162113   W5BPRC =  2.944719   W5BTOL =  2.944719

SPAN(11)  =   2.944719   I = 12  J =  4

W5BACT =  2.162113   W5BPRC =  2.944719   W5BTOL =  3.283364
  I = 12     J =  5      SUMDST =  0.272135
  I = 12     J =  6      SUMDST =  0.479927
  I = 12     J =  7      SUMDST =  0.687077
  I = 12     J =  8      SUMDST =  0.893653
  I = 12     J =  9      SUMDST =  1.099717
  I = 12     J = 10      SUMDST =  1.305297
  I = 13     J =  1      SUMDST =  1.561737
  I = 13     J =  2      SUMDST =  1.817595
  I = 13     J =  3      SUMDST =  2.072915
  I = 13     J =  4      SUMDST =  2.327721
  I = 13     J =  5      SUMDST =  2.582062
  I = 13     J =  6      SUMDST =  2.835966
  I = 13     J =  7      SUMDST =  3.089468
  I = 13     J =  8      SUMDST =  3.342599

 Y = 22.042709  Z = 13.941499  YPR = 22.012314  ZPR = 13.750000

 CLONGL OUTPUT =   3.096774      3.351851      22.042709      13.941499

W5BACT =  2.162113   W5BPRC =  3.283364   W5BTOL =  3.283364

SPAN(12)  =   3.283364   I = 13  J =  8

W5BACT =  2.162113   W5BPRC =  3.283364   W5BTOL =  3.762891
  I = 13     J =  9      SUMDST =  0.312026
  I = 13     J = 10      SUMDST =  0.564520
  I = 14     J =  1      SUMDST =  0.715868
  I = 14     J =  2      SUMDST =  0.867115
```

```
  I = 14     J =  4     SUMDST =  1.169319
  I = 14     J =  5     SUMDST =  1.320289
  I = 14     J =  6     SUMDST =  1.471170
  I = 14     J =  7     SUMDST =  1.621969
  I = 14     J =  8     SUMDST =  1.772695
  I = 14     J =  9     SUMDST =  1.923343
  I = 14     J = 10     SUMDST =  2.073926
  I = 15     J =  1     SUMDST =  2.274590
  I = 15     J =  2     SUMDST =  2.475154
  I = 15     J =  3     SUMDST =  2.675629
  I = 15     J =  4     SUMDST =  2.876027
  I = 15     J =  5     SUMDST =  3.076361
  I = 15     J =  6     SUMDST =  3.276639
  I = 15     J =  7     SUMDST =  3.476873
  I = 15     J =  8     SUMDST =  3.677068
  I = 15     J =  9     SUMDST =  3.877233

 Y = 22.394119  Z = 17.685715  YPR = 22.390610  ZPR = 17.599976

 CLONGL OUTPUT =    3.096774        2.714253       22.394119       17.685715

W5BACT =  2.162113   W5BPRC =  3.762891   W5BTOL =  3.762891

SPAN(13)  =    3.762891   I = 15  J =  9

W5BACT =  2.162113   W5BPRC =  3.762891   W5BTOL =  4.181564
  I = 15     J = 10     SUMDST =  0.314507
  I = 16     J =  1     SUMDST =  0.514625
  I = 16     J =  2     SUMDST =  0.714724
  I = 16     J =  3     SUMDST =  0.914804
  I = 16     J =  4     SUMDST =  1.114867
  I = 16     J =  5     SUMDST =  1.314916
  I = 16     J =  6     SUMDST =  1.514950
  I = 16     J =  7     SUMDST =  1.714972
  I = 16     J =  8     SUMDST =  1.914985
  I = 16     J =  9     SUMDST =  2.114990
  I = 16     J = 10     SUMDST =  2.315019
  I = 17     J =  1     SUMDST =  2.515017
  I = 17     J =  2     SUMDST =  2.715014
  I = 17     J =  3     SUMDST =  2.915012
  I = 17     J =  4     SUMDST =  3.115014
  I = 17     J =  5     SUMDST =  3.315020
  I = 17     J =  6     SUMDST =  3.515031
  I = 17     J =  7     SUMDST =  3.715050
  I = 17     J =  8     SUMDST =  3.915074
  I = 17     J =  9     SUMDST =  4.115107
  I = 17     J = 10     SUMDST =  4.315178

 Y = 22.429413  Z = 21.866409  YPR = 22.430832  ZPR = 21.799973

W5BACT =  2.162113   W5BPRC =  4.181564   W5BTOL =  4.181564

 CLONGL OUTPUT =    3.096774        2.061488       22.429413       21.866409

W5BACT =  2.162113   W5BPRC =  4.181564   W5BTOL =  4.181564

SPAN(14)  =    4.181564   I = 17  J = 10

W5BACT =  2.162113   W5BPRC =  4.181564   W5BTOL =  3.582268
  I = 18     J =  1     SUMDST =  0.333661
  I = 18     J =  2     SUMDST =  0.533715
  I = 18     J =  3     SUMDST =  0.733774
  I = 18     J =  4     SUMDST =  0.933838
  I = 18     J =  5     SUMDST =  1.133906
  I = 18     J =  6     SUMDST =  1.333976
```

```
  I = 18     J =  8      SUMDST =  1.734119
  I = 18     J =  9      SUMDST =  1.934190
  I = 18     J = 10      SUMDST =  2.134281
  I = 19     J =  1      SUMDST =  2.258256
  I = 19     J =  2      SUMDST =  2.382244
  I = 19     J =  3      SUMDST =  2.506231
  I = 19     J =  4      SUMDST =  2.630234
  I = 19     J =  5      SUMDST =  2.754219
  I = 19     J =  6      SUMDST =  2.878203
  I = 19     J =  7      SUMDST =  3.002172
  I = 19     J =  8      SUMDST =  3.126157
  I = 19     J =  9      SUMDST =  3.250141
  I = 19     J = 10      SUMDST =  3.374258

SPAN(15)  =   3.374258   I = 19   J = 10

 Y = 22.343796  Z = 25.239594  YPR = 22.343796  ZPR = 25.239594
  I = 20     J =  1      SUMDST =  0.224005
  I = 20     J =  2      SUMDST =  0.447998
  I = 20     J =  3      SUMDST =  0.671974
  I = 20     J =  4      SUMDST =  0.895963
  I = 20     J =  5      SUMDST =  1.119967
  I = 20     J =  6      SUMDST =  1.343939
  I = 20     J =  7      SUMDST =  1.567926
  I = 20     J =  8      SUMDST =  1.791924
  I = 20     J =  9      SUMDST =  2.015907
  I = 20     J = 10      SUMDST =  2.239871
  I = 21     J =  1      SUMDST =  2.463848
  I = 21     J =  2      SUMDST =  2.687837
  I = 21     J =  3      SUMDST =  2.911792
  I = 21     J =  4      SUMDST =  3.135758
  I = 21     J =  5      SUMDST =  3.359739
  I = 21     J =  6      SUMDST =  3.583699

 Y = 18.769989  Z = 25.486084  YPR = 18.992035  ZPR = 25.471065

 CLONGL OUTPUT =   3.096774       1.329552       18.769989       25.486084

W5BACT =   2.162113   W5BPRC =   3.582268   W5BTOL =   3.582268

SPAN(16)  =   3.582268   I = 21   J =  6

W5BACT =   2.162113   W5BPRC =   3.582268   W5BTOL =   3.019865
  I = 21     J =  7      SUMDST =  0.225371
  I = 21     J =  8      SUMDST =  0.449340
  I = 21     J =  9      SUMDST =  0.673287
  I = 21     J = 10      SUMDST =  0.897214
  I = 22     J =  1      SUMDST =  1.121151
  I = 22     J =  2      SUMDST =  1.345098
  I = 22     J =  3      SUMDST =  1.569009
  I = 22     J =  4      SUMDST =  1.792931
  I = 22     J =  5      SUMDST =  2.016862
  I = 22     J =  6      SUMDST =  2.240771
  I = 22     J =  7      SUMDST =  2.464658
  I = 22     J =  8      SUMDST =  2.688555
  I = 22     J =  9      SUMDST =  2.912435
  I = 22     J = 10      SUMDST =  3.136307

 Y = 15.756542  Z = 25.682541  YPR = 15.863767  ZPR = 25.675858

W5BACT =   2.162113   W5BPRC =   3.019865   W5BTOL =   3.019865

 CLONGL OUTPUT =   3.096774       1.284049       15.756542       25.682541

W5BACT =   2.162113   W5BPRC =   3.019865   W5BTOL =   3.019865
```

```
SPAN(17)   =     3.019865    I = 22   J = 10
```



```
W5BACT =   2.162113    W5BPRC =   3.019865    W5BTOL =   2.962949
  I = 23     J =  1       SUMDST =  0.340307
  I = 23     J =  2       SUMDST =  0.564165
  I = 23     J =  3       SUMDST =  0.788016
  I = 23     J =  4       SUMDST =  1.011861
  I = 23     J =  5       SUMDST =  1.235697
  I = 23     J =  6       SUMDST =  1.459523
  I = 23     J =  7       SUMDST =  1.683344
  I = 23     J =  8       SUMDST =  1.907159
  I = 23     J =  9       SUMDST =  2.130963
  I = 23     J = 10       SUMDST =  2.354760
  I = 24     J =  1       SUMDST =  2.578547
  I = 24     J =  2       SUMDST =  2.802330
  I = 24     J =  3       SUMDST =  3.026100

 Y = 12.798687  Z = 25.856140  YPR = 12.959067  ZPR = 25.847382

 CLONGL OUTPUT =    3.096774        1.243269       12.798687       25.856140

W5BACT =  2.162113   W5BPRC =  2.962949   W5BTOL =  2.962949

SPAN(18)   =     2.962949    I = 24   J =  3

W5BACT =   2.162113    W5BPRC =   2.962949    W5BTOL =   2.939541
  I = 24     J =  4       SUMDST =  0.286916
  I = 24     J =  5       SUMDST =  0.510673
  I = 24     J =  6       SUMDST =  0.734420
  I = 24     J =  7       SUMDST =  0.958159
  I = 24     J =  8       SUMDST =  1.181889
  I = 24     J =  9       SUMDST =  1.405612
  I = 24     J = 10       SUMDST =  1.629326
  I = 25     J =  1       SUMDST =  1.853028
  I = 25     J =  2       SUMDST =  2.076724
  I = 25     J =  3       SUMDST =  2.300413
  I = 25     J =  4       SUMDST =  2.524093
  I = 25     J =  5       SUMDST =  2.747762
  I = 25     J =  6       SUMDST =  2.971424

 Y =  9.862784  Z = 26.002213  YPR = 10.054372  ZPR = 25.993622

 CLONGL OUTPUT =    3.096774        1.208532        9.862784       26.002213

W5BACT =  2.162113   W5BPRC =  2.939541   W5BTOL =  2.939541

SPAN(19)   =     2.939541    I = 25   J =  6

W5BACT =   2.162113    W5BPRC =   2.939541    W5BTOL =   2.921926
  I = 25     J =  7       SUMDST =  0.255539
  I = 25     J =  8       SUMDST =  0.479186
  I = 25     J =  9       SUMDST =  0.702823
  I = 25     J = 10       SUMDST =  0.926453
  I = 26     J =  1       SUMDST =  1.150075
  I = 26     J =  2       SUMDST =  1.373689
  I = 26     J =  3       SUMDST =  1.597293
  I = 26     J =  4       SUMDST =  1.820891
  I = 26     J =  5       SUMDST =  2.044482
  I = 26     J =  6       SUMDST =  2.268063
  I = 26     J =  7       SUMDST =  2.491637
  I = 26     J =  8       SUMDST =  2.715206
  I = 26     J =  9       SUMDST =  2.938766

 Y =  6.943064  Z = 26.115402  YPR =  7.149673  ZPR = 26.108582
```

```
W5BACT =   2.162113   W5BPRC =   2.921926   W5BTOL =   2.921926

SPAN(20)   =    2.921926    I = 26   J =  9

W5BACT =   2.162113   W5BPRC =   2.921926   W5BTOL =   2.908485
  I = 26     J = 10      SUMDST =  0.240392
  I = 27     J =  1      SUMDST =  0.463939
  I = 27     J =  2      SUMDST =  0.687479
  I = 27     J =  3      SUMDST =  0.911013
  I = 27     J =  4      SUMDST =  1.134539
  I = 27     J =  5      SUMDST =  1.358059
  I = 27     J =  6      SUMDST =  1.581574
  I = 27     J =  7      SUMDST =  1.805083
  I = 27     J =  8      SUMDST =  2.028584
  I = 27     J =  9      SUMDST =  2.252082
  I = 27     J = 10      SUMDST =  2.475574
  I = 28     J =  1      SUMDST =  2.699061
  I = 28     J =  2      SUMDST =  2.922544

 Y =   4.035593  Z = 26.191559  YPR =   4.244977  ZPR = 26.187378

 CLONGL OUTPUT =   3.096774        1.162918        4.035593       26.191559

W5BACT =   2.162113   W5BPRC =   2.908485   W5BTOL =   2.908485

SPAN(21)   =    2.908485    I = 28   J =  2

W5BACT =   2.162113   W5BPRC =   2.908485   W5BTOL =   2.899400
  I = 28     J =  3      SUMDST =  0.237537
  I = 28     J =  4      SUMDST =  0.461010
  I = 28     J =  5      SUMDST =  0.684479
  I = 28     J =  6      SUMDST =  0.907945
  I = 28     J =  7      SUMDST =  1.131408
  I = 28     J =  8      SUMDST =  1.354866
  I = 28     J =  9      SUMDST =  1.578321
  I = 28     J = 10      SUMDST =  1.801773
  I = 29     J =  1      SUMDST =  2.025224
  I = 29     J =  2      SUMDST =  2.248672
  I = 29     J =  3      SUMDST =  2.472116
  I = 29     J =  4      SUMDST =  2.695560
  I = 29     J =  5      SUMDST =  2.919003

 Y =   1.136441  Z = 26.228058  YPR =   1.340280  ZPR = 26.226822

 CLONGL OUTPUT =   3.096774        1.154048        1.136441       26.228058

W5BACT =   2.162113   W5BPRC =   2.899400   W5BTOL =   2.899400

SPAN(22)   =    2.899400    I = 29   J =  5

W5BACT =   2.162113   W5BPRC =   2.899400   W5BTOL =   2.894860
  I = 29     J =  6      SUMDST =  0.243043
  I = 29     J =  7      SUMDST =  0.466482
  I = 29     J =  8      SUMDST =  0.689921
  I = 29     J =  9      SUMDST =  0.913359
  I = 29     J = 10      SUMDST =  1.136448
  I = 30     J =  1      SUMDST =  1.136448
```

| I | Y | Z | YPR | ZPR | SPAN(I) |
|---|---|---|---|---|---|
| 2 | 4.326030 | 0.154977 | 4.000000 | 0.135401 | 2.166965 |
| 3 | 6.493771 | 0.334096 | 6.399998 | 0.324254 | 2.175280 |
| 4 | 8.667541 | 0.603478 | 8.400000 | 0.584682 | 2.190565 |
| 5 | 10.844317 | 1.002817 | 10.799995 | 0.992337 | 2.213699 |
| 6 | 13.002581 | 1.627934 | 12.973948 | 1.617520 | 2.248325 |
| 7 | 15.106862 | 2.559123 | 14.973948 | 2.487440 | 2.303361 |
| 8 | 17.067734 | 3.912447 | 17.059357 | 3.905701 | 2.387387 |
| 9 | 18.794434 | 5.734756 | 18.687378 | 5.599998 | 2.514391 |
| 10 | 20.225235 | 8.012792 | 20.219101 | 8.000000 | 2.696131 |
| 11 | 21.329575 | 10.739202 | 21.286606 | 10.599998 | 2.944719 |
| 12 | 22.042709 | 13.941499 | 22.012314 | 13.750000 | 3.283364 |
| 13 | 22.394119 | 17.685715 | 22.390610 | 17.599976 | 3.762891 |
| 14 | 22.429413 | 21.866409 | 22.430832 | 21.799973 | 4.181564 |
| 15 | 22.343796 | 25.239594 | 22.343796 | 25.239594 | 3.374258 |
| 16 | 18.769989 | 25.486084 | 18.992035 | 25.471085 | 3.582268 |
| 17 | 15.756542 | 25.682541 | 15.863767 | 25.675858 | 3.019865 |
| 18 | 12.798687 | 25.856140 | 12.959067 | 25.847382 | 2.962949 |
| 19 | 9.862784 | 26.002213 | 10.054372 | 25.993622 | 2.939541 |
| 20 | 6.943064 | 26.115402 | 7.149673 | 26.108582 | 2.921926 |
| 21 | 4.035593 | 26.191559 | 4.244977 | 26.187378 | 2.908485 |
| 22 | 1.136441 | 26.228058 | 1.340280 | 26.226822 | 2.899400 |
| 23 | 0.0 | 0.0 | 0.0 | 0.0 | 1.136448 |
| 24 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 25 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 26 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 27 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 28 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 29 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 30 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 31 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 32 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 33 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 34 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 35 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 36 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 37 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 38 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 39 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 40 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |

CGCG( 1) = 1.459806

LONGITUDINAL ( 1) IS SELECTED

CGCG( 1) = 2.107491

LONGITUDINAL ( 2) IS SELECTED

CGCG( 1) = 1.948315

LONGITUDINAL ( 3) IS SELECTED

CGCG( 1) = 2.499537

LONGITUDINAL ( 4) IS SELECTED

CGCG( 1) = 3.166634

LONGITUDINAL ( 5) IS SELECTED

CGCG( 2) = 3.166634

```
CGCG( 3)  =   3.166634
LONGITUDINAL ( 5)  IS SELECTED
CGCG( 4)  =   3.166634
LONGITUDINAL ( 5)  IS SELECTED
CGCG( 5)  =   3.166634
LONGITUDINAL ( 5)  IS SELECTED
CGCG( 6)  =   3.166634
LONGITUDINAL ( 5)  IS SELECTED
CGCG( 7)  =   3.166634
LONGITUDINAL ( 5)  IS SELECTED
CGCG( 8)  =   3.166634
LONGITUDINAL ( 5)  IS SELECTED
CGCG( 9)  =   3.166634
LONGITUDINAL ( 5)  IS SELECTED
CGCG(10)  =   3.166634
LONGITUDINAL ( 5)  IS SELECTED
CGCG(11)  =   3.166634
LONGITUDINAL ( 5)  IS SELECTED
CGCG(12)  =   3.166634
LONGITUDINAL ( 5)  IS SELECTED
CGCG(13)  =   3.166634
LONGITUDINAL ( 5)  IS SELECTED
CGCG(14)  =   3.166634
LONGITUDINAL ( 5)  IS SELECTED
CGCG(15)  =   3.166634
LONGITUDINAL ( 5)  IS SELECTED
CGCG(16)  =   3.166634
LONGITUDINAL ( 5)  IS SELECTED
CGCG(17)  =   3.166634
LONGITUDINAL ( 5)  IS SELECTED
CGCG(18)  =   3.166634
LONGITUDINAL ( 5)  IS SELECTED
```

```
LONGITUDINAL ( 5)  IS SELECTED

CGCG(20)  =   3.166634

LONGITUDINAL ( 5)  IS SELECTED

CGCG(21)  =   3.166634

LONGITUDINAL ( 5)  IS SELECTED

CGCG(22)  =   3.166634

LONGITUDINAL ( 5)  IS SELECTED

I =   1     HM =  30.174057

LONGITUDINAL ( 5)  IS SELECTED

I =   2     HM =  30.076263

LONGITUDINAL ( 5)  IS SELECTED

I =   3     HM =  29.897141

LONGITUDINAL ( 5)  IS SELECTED

I =   4     HM =  29.627762

LONGITUDINAL ( 5)  IS SELECTED

I =   5     HM =  29.228424

LONGITUDINAL ( 5)  IS SELECTED

I =   6     HM =  28.603302

LONGITUDINAL ( 5)  IS SELECTED

I =   7     HM =  27.672119

LONGITUDINAL ( 5)  IS SELECTED

I =   8     HM =  26.318787

LONGITUDINAL ( 5)  IS SELECTED

I =   9     HM =  24.496490

LONGITUDINAL ( 5)  IS SELECTED

I =  10     HM =  22.218445

LONGITUDINAL ( 5)  IS SELECTED

I =  11     HM =  19.492035

LONGITUDINAL ( 5)  IS SELECTED

I =  12     HM =  16.289734

LONGITUDINAL ( 5)  IS SELECTED

I =  13     HM =  12.545532
```

```
I =  14    HM =   8.364838
LONGITUDINAL ( 5)  IS SELECTED
I =  15    HM =   4.991653
LONGITUDINAL ( 5)  IS SELECTED
I =  16    HM =   4.745163
LONGITUDINAL ( 5)  IS SELECTED
I =  17    HM =   4.548706
LONGITUDINAL ( 5)  IS SELECTED
I =  18    HM =   4.375107
LONGITUDINAL ( 5)  IS SELECTED
I =  19    HM =   4.229034
LONGITUDINAL ( 5)  IS SELECTED
I =  20    HM =   4.115845
LONGITUDINAL ( 5)  IS SELECTED
I =  21    HM =   4.039688
LONGITUDINAL ( 5)  IS SELECTED
I =  22    HM =   4.003189
LONGITUDINAL ( 5)  IS SELECTED
XMINER( 1) =     160.853806
XMINER( 2) =     160.853806
XMINER( 3) =     160.853806
XMINER( 4) =     160.853806
XMINER( 5) =     160.853806
XMINER( 6) =     160.853806
XMINER( 7) =     160.853806
XMINER( 8) =     160.853806
XMINER( 9) =     160.853806
XMINER(10) =     160.853806
XMINER(11) =     160.853806
XMINER(12) =     160.853806
XMINER(13) =     160.853806
XMINER(14) =     160.853806
```

```
XMINER(16) =      160.853806
XMINER(17) =      160.853806
XMINER(18) =      160.853806
XMINER(19) =      160.353806
XMINER(20) =      160.853806
XMINER(21) =      160.853806
XMINER(22) =      160.853806
LONGITUDINAL ( 5)  IS SELECTED
BASEMT( 1)  =   1.465505
BASEMT( 2)  =   0.730327
BASEMT( 3)  =   0.907333
BASEMT( 4)  =   1.173897
BASEMT( 5)  =   1.563735
BASEMT( 6)  =   2.169605
BASEMT( 7)  =   3.066433
BASEMT( 8)  =   4.361360
BASEMT( 9)  =   6.093286
BASEMT(10)  =   8.262015
BASEMT(11)  =  10.909203
BASEMT(12)  =  14.031854
BASEMT(13)  =  17.709274
BASEMT(14)  =  21.854095
BASEMT(15)  =   0.0
BASEMT(16)  =  24.910995
BASEMT(17)  =  25.107269
BASEMT(18)  =  25.280609
BASEMT(19)  =  25.426392
BASEMT(20)  =  25.539322
BASEMT(21)  =  25.615280
BASEMT(22)  =  25.651672
```

SPAN( 1) = 2.162113

SPAN( 2) = 2.166965

SPAN( 3) = 2.175280

SPAN( 4) = 2.190565

SPAN( 5) = 2.213699

SPAN( 6) = 2.248323

SPAN( 7) = 2.303361

SPAN( 8) = 2.387387

SPAN( 9) = 2.514391

SPAN(10) = 2.696131

SPAN(11) = 2.944719

SPAN(12) = 3.283364

SPAN(13) = 3.762891

SPAN(14) = 4.181564

SPAN(15) = 3.374258

SPAN(16) = 3.582268

SPAN(17) = 3.019865

SPAN(18) = 2.962949

SPAN(19) = 2.939541

SPAN(20) = 2.921926

SPAN(21) = 2.908485

SPAN(22) = 2.899400

SPAN(23) = 1.136448

SPAN(24) = 0.0

SPAN(25) = 0.0

SPAN(26) = 0.0

SPAN(27) = 0.0

SPAN(28) = 0.0

SPAN(29) = 0.0

SPAN(30) = 0.0

SPAN(31) = 0.0

SPAN(32) = 0.0

```
SPAN(33)  =  0.0
SPAN(34)  =  0.0
SPAN(35)  =  0.0
SPAN(36)  =  0.0
SPAN(37)  =  0.0
SPAN(38)  =  0.0
SPAN(39)  =  0.0
SPAN(40)  =  0.0
```

| I | Y | Z | YPR | ZPR | SPAN(I) |
|---|---|---|---|---|---|
| 1 | 2.161354 | 0.057184 | 2.000000 | 0.052099 | 2.162113 |
| 2 | 4.326030 | 0.154977 | 4.000000 | 0.135401 | 2.166965 |
| 3 | 6.493771 | 0.334096 | 6.399998 | 0.324254 | 2.175280 |
| 4 | 8.667541 | 0.603478 | 8.400000 | 0.564682 | 2.190565 |
| 5 | 10.844317 | 1.002817 | 10.799995 | 0.992337 | 2.213699 |
| 6 | 13.002581 | 1.627934 | 12.973948 | 1.617520 | 2.248323 |
| 7 | 15.106862 | 2.559123 | 14.973948 | 2.487440 | 2.303361 |
| 8 | 17.067734 | 3.912447 | 17.059357 | 3.905701 | 2.387387 |
| 9 | 18.794434 | 5.734756 | 18.687376 | 5.599998 | 2.514391 |
| 10 | 20.225235 | 8.012792 | 20.219101 | 8.000000 | 2.696131 |
| 11 | 21.329575 | 10.739202 | 21.286606 | 10.599998 | 2.944719 |
| 12 | 22.042709 | 13.941499 | 22.012314 | 13.750000 | 3.283364 |
| 13 | 22.394119 | 17.685715 | 22.390610 | 17.599976 | 3.762891 |
| 14 | 22.429413 | 21.866409 | 22.430832 | 21.799973 | 4.181564 |
| 15 | 22.343796 | 25.239594 | 22.343796 | 25.239594 | 3.374258 |
| 16 | 18.769989 | 25.486084 | 18.992035 | 25.471085 | 3.582268 |
| 17 | 15.756542 | 25.682541 | 15.863767 | 25.675858 | 3.019865 |
| 18 | 12.798687 | 25.856140 | 12.959067 | 25.847382 | 2.962949 |
| 19 | 9.862784 | 26.002213 | 10.054372 | 25.993622 | 2.939541 |
| 20 | 6.943064 | 26.115402 | 7.149673 | 26.108582 | 2.921926 |
| 21 | 4.035593 | 26.191559 | 4.244977 | 26.187378 | 2.908485 |
| 22 | 1.136441 | 26.228058 | 1.340280 | 26.226822 | 2.899400 |
| 23 | 0.0 | 0.0 | 0.0 | 0.0 | 1.136448 |
| 24 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 25 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 26 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 27 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 28 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 29 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 30 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 31 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 32 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 33 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 34 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 35 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 36 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 37 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 38 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 39 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 40 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |

```
REQUIRED MOMENT OF INERTIA =       139535.875000 IN**2  FT**2

ACTUAL MOMENT OF INERTIA =          79760.437500 IN**2  FT**2

MAX. TOLERABLE ST1CRK = 7.9299994 TONS PER SQ. INCH

ACTUAL ST1CRK =12.9492407 TONS PER SQ. INCH

MAX. TOLERABLE ST1CRD = 6.0000000TONS PER SQ. INCH

ACTUAL ST1CRD = 8.3842268 TONS PER SQ. INCH

TOTAL WEIGHT = 1.2419310 TONS PER FOOT LENGTH

TOTAL WEIGHT =   2781.9257812 POUNDS PER FOOT LENGTH

    PLATING WEIGHT =   1766.4226074 POUNDS PER FOOT LENGTH
    LONGITUDINAL WEIGHT =    658.1281738 POUNDS PER FOOT LENGTH
    TRANSVERSE FRAME WEIGHT =    357.3750000 POUNDS PER FOOT LENGTH

NEUTRAL AXIS IS 13.9384232 FEET ABOVE BASE LINE

SCANTLING   5  SELECTED--CROSS-SECTION AREA IS 4.3221197  SQ. IN. AND WEB DEPTH IS  9.0000000 INCHES.

KEEL HAS AN AREA OF20.6864166 SQ. IN. AND A WEB DEPTH OF 24.0000000 INCHES.

  SELECTED PLATING THICKNESS =   0.343750 INCHES.

    DESIGN REPEATED WITH TH1 INCREASED
```

## B. MAIN PROGRAM COSTDATA

### 1. DESCRIPTION

Introduction

Main program COSDATA carries out the cost calculation for the midship section of DD-931, using as inputs much of the design information generated by program RUNSCORE. Materials cost data, extracted from [3], are combined with various handling and erection costs to generate a total cost, per foot length of midship section, for the construction of DD-931 primary hull structure.

For reference purposes, the acquisition cost data for HTS structural members are listed in Table IV on the following pages. These members, when procured through the Federal supply system, are not discounted in price for quantity acquisitions.

The methods used by the cost estimators of the Boston Naval Shipyard were employed in main program COSDATA. All these charges are based on the cost of one man-hour of work, including yard overhead. For the purposes of this investigation, one man-hour has been arbitrarily assumed to cost $ 7.50.

Main program COSTDATA takes the series of intervals

# TABLE IV

## AVAILABLE PLATES AND SHAPES - DESCRIPTION AND ACQUISITION COSTS

Plates

| Thickness (Inches) | Width (Ft.) | Length (Ft.) | Cost Total | Cost Sq. Ft. |
|---|---|---|---|---|
| 0.25 | 8 | 20 | $ 169 | $ 1.058 |
| | 8 | 29 | 274 | 1.181 |
| | 5 | 20 | 128 | 1.28 |
| 0.28125 | 8 | 29 | 305 | 1.316 |
| 0.3125 | 6 | 29 | 238 | 1.37 |
| | 8 | 29 | 353 | 1.522 |
| 0.34375 | 8 | 29 | 383 | 1.651 |
| 0.375 | 8 | 20 | 254 | 1.587 |
| | 5 | 20 | 161 | 1.61 |
| | 6 | 29 | 281 | 1.618 |
| | 8 | 29 | 383 | 1.652 |
| 0.4375 | 6 | 29 | 394 | 2.264 |
| 0.50 | 8 | 33 | 569 | 2.158 |
| | 5 | 20 | 237 | 2.37 |
| | 8 | 29 | 551 | 2.375 |
| | 8 | 20 | 394 | 2.462 |
| | 6 | 29 | 483 | 2.796 |
| 0.625 | 8 | 33 | 818 | 2.984 |
| | 5 | 20 | 306 | 3.06 |
| | 6 | 29 | 532 | 3.06 |
| 0.75 | 8 | 33 | 959 | 3.635 |
| | 8 | 20 | 614 | 3.84 |
| 0.875 | 8 | 16 | 500 | 3.905 |
| | 6 | 20 | 498 | 4.15 |
| | 8 | 29 | 1030 | 4.44 |
| | 15 | 25.16 | 1958 | 5.19 |
| 0.9375 | 8 | 20 | 720 | 4.50 |
| 1.00 | 8 | 20 | 725 | 4.53 |
| | 5 | 20 | 481 | 4.81 |
| | 8 | 29 | 1233 | 5.32 |

TABLE IV - Continued

Shapes*

| No. | Depth (In.) | Flg. Width (In.) | Weight (Lb./Ft.) | Cost Per Ft. |
|---|---|---|---|---|
| 1 | 6 | 4 | 12.0 | $ 2.00 |
| 2 | 6 | 6.063 | 22.6 | 2.40 |
| 3 | 8 | 4 | 13.0 | 1.40 |
| 4 | 8 | 5.36 | 20.00 | 2.40 |
| 5 | 9.9 | 5.75 | 21.0 | 2.70 |
| 6 | 12 | 4 | 16.5 | 2.30 |
| 7 | 16 | 7 | 40.0 | 3.90 |
| 8 | 18 | 7.5 | 50.0 | 5.50 |
| 9 | 24 | 12 | 100.0 | 9.00 |

*All shapes have a length of 40 feet.

between longitudinals for half the midship section and generates a set of intervals for the entire section. This is designed to facilitate the later calculation of butt locations to insure a clearance of at least four inches between any given butt joint and a longitudinal-plating intersection.

The cost of welding any of the various possible size plates is calculated, using the input value of cost of butt welding the given thickness of shell plating (man-hours per foot length of weld).

| Plating Thickness (Inches) | Cost of Butt Weld[4]* (Man-Hours per Foot) |
|---|---|
| 0.25 | 0.38 |
| 0.28125 | 0.43 |
| 0.3125 | 0.48 |
| 0.34375 | 0.53 |
| 0.375 | 0.58 |
| 0.4375 | 0.68 |
| 0.50 | 0.76 |
| 0.625 | 1.22 |
| 0.75 | 1.60 |
| 0.875 | 2.02 |
| 0.9375 | 2.22 |
| 1.00 | 2.42 |

The program next calculates the number of plates required to go around the girth of the midship section. The alternate plate sizes of the appropriate thickness must be arranged in ascending order of cost per square foot area. The first plate is centered over the keel, and successive plates are added in progression around the girth of the midship section. Should a conflict arise in that a butt

---

*This information is for work on board ship under <u>difficult</u> conditions. Other conditions are <u>normal</u> and <u>complex</u>.

joint is too near to a longitudinal-plating intersection, the algorithm first attempts to select the next available plating size. If this proves to be impossible, then a cut of 0.7 feet is made from the end of the plate. The following charges are made for cutting plates:

| Plating Thickness (Inches) | Cost of Cut* (Man-Hours per Foot) | Type Cut |
|---|---|---|
| 0.25 | 0.05 | Flame cut |
| 0.375 | 0.06 | Flame cut |
| 0.50 | 0.07 | Flame cut |
| 0.625 | 0.08 | Flame cut |
| 0.75 | 0.09 | Flame cut |
| 0.875 | 0.10 | Flame cut |
| 1.00 | 0.11 | Flame cut |

The net cost of butt welding the plates is next calculated, given the total number of plates of each individual size employed in the midship section structure. The cost of any plate cuts is calculated, using the previously listed cost data per cut per foot plate length.

The cost of rolling the plates, using average man-hour charges allocated by the Boston Naval Shipyard, based on a plate length of twenty feet, is computed next. The standard charges for such plates (twenty feet long) are as follows:

| Plating Thickness (Inches) | Cost of Rolling (Man-Hours per Plate) |
|---|---|
| 0.25 | 2.9 |
| 0.50 | 2.9 |
| 0.75 | 3.9 |
| 1.00 | 3.9 |

*Information provided by Mr. Joseph Palange, a Planner and Estimator with the Boston Naval Shipyard.

Typical rigging costs are evaluated, using an arbitrarily specified "mix" of staging comprising two platforms twenty feet high, two fourteen feet high, two eight feet high, and two three feet high. Again, normal Boston Naval Shipyard charges based on staging five feet long are evaluated on the basis of the per-foot length costs.

The acquisition cost of the plating is computed, using the input data provided the program and the determined number of plates employed of each given size.

The expense involved in the procurement, cutting, and welding of longitudinal wide flange sections is next calculated. The previously defined cost criteria for plate cutting are used for evaluating the expenses involved in cutting the shape flanges. Next, the cost of welding the longitudinals is evaluated, using normal Boston Naval Shipyard charges similar to those described in terms of the cost of butt welds:

| Longitudinal Number | Welding Cost (Man-Hours per Foot) |
|---|---|
| 1 | 0.34 |
| 2 | 0.50 |
| 3 | 0.34 |
| 4 | 0.42 |
| 5 | 0.42 |
| 6 | 0.34 |
| 7 | 0.66 |
| 8 | 1.04 |

Additionally, for all welding operations, certain fixed charges are added. These allow for making ready

and putting away equipment, wire brushing, arc air, dye penetrant for weld inspection, and strip heaters for heat treating welds.

An approximate evaluation of the cost contribution of the transverse frame structure is made, estimating that the cost of the transverse frame, on the average, is seventy per cent that of the centerline vertical keel, per foot length.

Once all these individual costs are calculated, the total cost of the midship section structure, per foot length, is determined.

Inputs

| Symbol | Meaning |
|---|---|
| CWLDMH | Cost of butt weld. (Man-Hours per foot length) |
| THI | Plating thickness. (Inches) |
| XLGTNL | The number of longitudinals in the midship section. |
| CHGMNH | The cost of one man-hour of work. (Dollars) |
| COSTKL | The total cost of the keel structure. (Dollars per foot length) |
| TOTSPN | The total midship section girth. (Feet) |
| CROLL | The cost of rolling a plate twenty feet long. (Dollars) |
| CSTLGL | The acquisition cost of a longitudinal. (Dollars per foot length) |
| SPAN(I) | The interval to longitudinal (I). (Feet) |
| CWLGTL | The cost of welding a longitudinal. (Man-Hours per foot length) |

| Symbol | Meaning |
|---|---|
| PLT(I,1) | Width of plate(I). (Feet) |
| PLT(I,2) | Length of plate(I). (Feet) |
| PLT(I,3) | Cost of plate(I). (Dollars) |
| CLGCUT | The cost of cutting the flanges of a longitudinal. (Man-Hours per foot) |
| FRM | Transverse frame spacing. (Feet) |

Calculated Items

| Symbol | Meaning |
|---|---|
| TSPAN(I) | Span between longitudinals, for entire section. (Feet) |
| CWELD(I) | Cost of welding the plating, per butt per foot length. (Dollars) |
| DIST | Location of plate butts. (Feet) |
| DSUMS | Locations of longitudinals. (Feet) |
| LGL1/XLGL1...5 | Number of plates (1)...(5) required for midship section. |
| NOCUT/PTCUT | Number of times plates must be cut. |
| CPLTWD | Total cost of welding the plating, per foot length. (Dollars) |
| CPTCUT | Total cost of cutting the plates, per foot length. (Dollars) |
| TCROLL | Total cost of rolling the plates, per foot length. (Dollars) |
| CRIG | Total cost of providing the rigging, per foot length. (Dollars) |
| CPLTNG | Total acquisition cost of the plating, per foot length. (Dollars) |
| CTLGTL | Total acquisition cost of the longitudinals, per foot length. (Dollars) |
| CWLTNL | Total welding cost for the longitudinals, per foot length. (Dollars) |

| Symbol | Meaning |
|---|---|
| CCUTFT | The calculated cost of cutting the flanges of the longitudinals. (Dollars per foot length) |
| CTFRAM | Approximate cost per foot hull length for the transverse frame. (Dollars) |

Output

| Symbol | Meaning |
|---|---|
| CTOTAL | Total cost of building the midship section, per foot length. (Dollars) |

Sample Input/Output (Computer test run)

Input:

| | PLT(I,1) | PLT(I,2) | PLT(I,3) |
|---|---|---|---|
| I = 1 | 8.0 | 33.0 | 959.00 |
| 2 | 8.0 | 20.0 | 614.00 |
| 3 | ... | .... | ...... |
| 4 | ... | .... | ...... |
| 5 | ... | .... | ...... |

| | | |
|---|---|---|
| CWLDMH | 1.60 | Man-Hours/Foot |
| THI | 0.75 | Inches |
| XLGTNL | 17.0 | |
| CHGMNH | 7.50 | Dollars/Man-Hours |
| COSTKL | 27.56 | Dollars/Foot |
| TOTSPN | 125.95 | Feet |
| CROLL | 3.90 | Dollars |
| CSTLGL | 3.90 | Dollars/Foot |

| | SPAN(I) | SPAN(I+1) | SPAN(I+2) |
|---|---|---|---|
| I = 1 | 4.717 | 4.751 | 4.853 |
| I = 4 | 5.110 | 5.724 | 6.935 |
| I = 5 | 8.516 | 9.080 | 13.291 |

| | | |
|---|---|---|
| CWLGTL | 0.66 | Man-Hours/Foot |
| CLGCUT | 0.14 | Man-Hours/Foot |
| FRM | 8.00 | Feet |

Output: CTOTAL 1466.77 Dollars

Fundamental Equations

$$CWELD(I) = CHGMNH \times ((2 \times (PLT(I,1) + PLT(I,2))) \times \frac{(CWLDMH \times 1.12 + 0.144) + 5.5)}{2.0 \times PLT(I,2)}$$

DIST = DIST + PLT(I,1)

OR

= DIST - 0.7 + PLT(I+1,1)
(If too near a longitudinal)

CPLTWD = CWELD(1) x XLGL1 + CWELD(2) x XLGL2 + CWELD(3) x XLGL3 + CWELD(4) x XLGL4 + CWELD(5) x XLGL5

$$\text{CPTCUT} = \text{PTCUT} \times \text{CHGMNH} \times \left(0.05 + \frac{0.01 \times (\text{TH1} - 0.25)}{0.125}\right)$$

$$\text{TCROLL} = \frac{\text{CHGMNH}}{20.} \times \text{CROLL} \times (\text{XLGL1} + \text{XLGL2} + \text{XLGL3} + \text{XLGL4} + \text{XLGL5})$$

CRIG = 0.4 x (20. + 12.4 + 9.7 + 7.5) x CHGMNH

$$\text{CPLTNG} = \frac{\text{PLT(1,3)} \times \text{XLGL1}}{\text{PLT(1,2)}} + \frac{\text{PLT(2,3)} \times \text{XLGL2}}{\text{PLT(2,2)}} + \frac{\text{PLT(3,3)} \times \text{XLGL3}}{\text{PLT(3,2)}} + \frac{\text{PLT(4,3)} \times \text{XLGL4}}{\text{PLT(4,2)}} + \frac{\text{PLT(5,3)} \times \text{XLGL5}}{\text{PLT(5,2)}}$$

CTLGTL = XLGTNL x CSTLGL

CCUTFT = CLGCUT x XLGTNL x CHGMNH

$$\text{CTFRAM} = \frac{0.7 \times \text{COSTKL} \times \text{TOTSPN}}{\text{FRM}}$$

CTOTAL = CPLTWD + CPTCUT + TCROLL + CRIG + CPLTNG + CTLGTL + CWLTNL + CCUTFT + CTFRAM + COSTKL

Sample Calculation (Refer to program listing, flow chart, and printout of typical computer run, following pages)

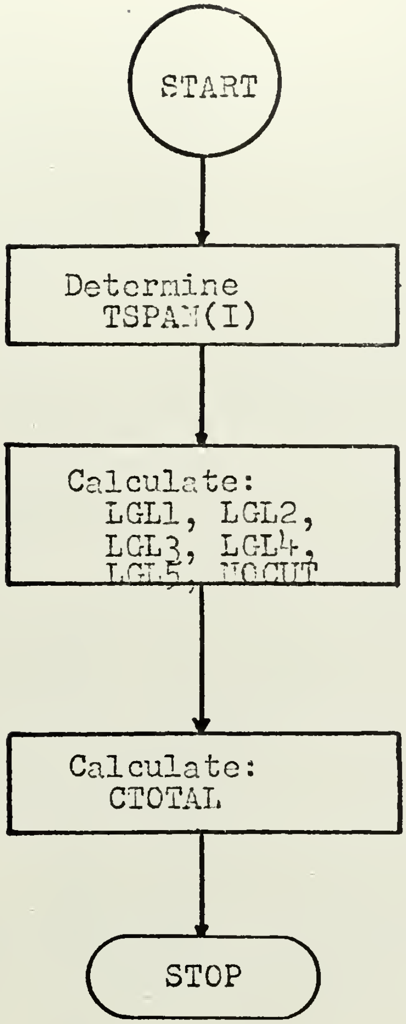
```
      DIMENSION PLT(5,3),SPAN(40),TSPAN(80),CWELD(5)
      DO 800 I = 1, 80
  800 TSPAN(I) = 0.0
  900 FORMAT (8F10.6)
      DATA LGL1,LGL2,LGL3,LGL4,LGL5,NOCUT/1,0,0,0,0,2/
  910 FORMAT (8I10)
      DO 400 I = 1, 5
      READ (5, 900) PLT(I,1), PLT(I,2), PLT(I,3)
      WRITE (6, 900) PLT(I,1), PLT(I,2), PLT(I,3)
      IF (PLT(I,1) .LT. 20.0) GO TO 400
      PLT(I,1) = 0.0
      PLT(I,2) = 0.0
      PLT(I,3) = 0.0
  400 CONTINUE
      READ (5,900) CWLDMH,THI,XLGTNL,CHGMNH,COSTKL,TOTSPN,CROLL,CSTLGL
      WRITE(6,900) CWLDMH,THI,XLGTNL,CHGMNH,COSTKL,TOTSPN,CROLL,CSTLGL
      DO 410 I = 1, 36, 5
      READ (5,900) SPAN(I), SPAN(I+1), SPAN(I+2), SPAN(I+3), SPAN(I + 4)
  410 WRITE(6,900) SPAN(I), SPAN(I+1), SPAN(I+2), SPAN(I+3), SPAN(I + 4)
      READ(5,900) CWLGTL,CLGCUT,FRM
      WRITE (6, 900) CWLGTL, CLGCUT, FRM
      DO 420 I = 1, 40
      TSPAN(I) = SPAN(I)
      IF(SPAN(I) .EQ. 0.0) GO TO 425
  420 CONTINUE
  425 IF (I .EQ. 40) GO TO 426
      DO 430 J = 1, 40
      TSPAN(I + J - 1) = SPAN(I - J)
      IF ((I-J-1) .EQ. 0) GO TO 435
  430 CONTINUE
  426 DO 431 J = 1, 40
  431 TSPAN(I + J) = SPAN(I - J + 1)
C
C     CALCULATE THE COST OF WELDING THE PLATING (PER BUTT PER FT. LGTH.)
C
  435 DO 440 I = 1, 5
      IF (PLT(I,1) .EQ. 0.0) GO TO 445
  440 CWELD(I) = CHGMNH * ((2.0*(PLT(I,1)+PLT(I,2)))*(CWLDMH*1.12 + 0.14
     14) + 5.5)/(PLT(I,2)*2.0)
  445 DO 446 J = 1, 5
  446 CWELD(J) = 0.0
C
C     CALCULATE THE NUMBER OF PLATES OF EACH SIZE USED FOR THE MIDSHIP
C     SECTION.
C
      DSUMS = 0.0
      I = 1
      J = 1
```

```
      DIST = 0.5 * PLT(1,1)
  933 FORMAT('0    DIST,DSUMS,J,LGL1,LGL2,LGL3,LGL4,LGL5,NOCUT')
  934 FORMAT (2(F10.6,4X),7(I3,4X))
  460 DSUMS = DSUMS + TSPAN(J)
      WRITE (6, 933)
      WRITE(6,934) DIST,DSUMS,J,LGL1,LGL2,LGL3,LGL4,LGL5,NOCUT
      IF ((TOTSPN - DIST) .LT. (0.5*PLT(1,1))) GO TO 600
      IF (DIST .GT. (DSUMS + 0.33)) GO TO 450
      IF (DIST.LT. (DSUMS - 0.33)) GO TO 452
      IF (PLT(2,1) .EQ. 0.0) GO TO 455
      DIST = DIST - PLT(1,1) + PLT(2,1)
      IF (DIST .GT. (DSUMS + 0.33)) GO TO 470
      IF (DIST.LT. (DSUMS - 0.33)) GO TO 472
      IF (PLT(3,1) .EQ. 0.0) GO TO 475
      DIST = DIST - PLT(2,1) + PLT(3,1)
      IF (DIST .GT. (DSUMS + 0.33)) GO TO 480
      IF (DIST.LT. (DSUMS - 0.33)) GO TO 482
      IF (PLT(4,1) .EQ. 0.0) GO TO 485
      DIST = DIST - PLT(3,1) + PLT(4,1)
      IF (DIST .GT. (DSUMS + 0.33)) GO TO 490
      IF (DIST.LT. (DSUMS - 0.33)) GO TO 492
      IF (PLT(5,1) .EQ. 0.0) GO TO 495
      DIST = DIST - PLT(4,1) + PLT(5,1)
      IF (DIST .GT. (DSUMS + 0.33)) GO TO 510
      IF (DIST.LT. (DSUMS - 0.33)) GO TO 512
      DIST = DIST - 0.7 + PLT(1,1)
      LGL5 = LGL5 + 1
      NOCUT = NOCUT + 1
      J = J + 1
      GO TO 460
  450 J = J + 1
      GO TO 460
  452 DIST = DIST + PLT(1,1)
      J = J + 1
      LGL1 = LGL1 + 1
      GO TO 460
  455 DIST = DIST - 0.7 + PLT(1,1)
      LGL1 = LGL1 + 1
      NOCUT = NOCUT + 1
      J = J + 1
      GO TO 460
  470 J = J + 1
      LGL2 = LGL2 + 1
      GO TO 460
  472 DIST = DIST + PLT(1,1)
      J = J + 1
      LGL2 = LGL2 + 1
      GO TO 460
```

```
  475 DIST = DIST - 0.7 + PLT(1.1)
      NOCUT = NOCUT + 1
      LGL2 = LGL2 + 1
      J = J + 1
      GO TO 460
  480 J = J + 1
      LGL3 = LGL3 + 1
      GO TO 460
  482 DIST = DIST + PLT(1,1)
      J = J + 1
      LGL3 = LGL3 + 1
      GO TO 460
  485 DIST = DIST - 0.7 + PLT(1,1)
      NOCUT = NOCUT + 1
      LGL3 = LGL3 + 1
      J = J + 1
      GO TO 460
  490 J = J + 1
      LGL4 = LGL4 + 1
      GO TO 460
  492 DIST = DIST + PLT(1,1)
      J = J + 1
      LGL4 = LGL4 + 1
      GO TO 460
  495 DIST = DIST - 0.4 - 0.3 + PLT(1,1)
      NOCUT = NOCUT + 1
      LGL4 = LGL4 + 1
      J = J + 1
      GO TO 460
  510 J = J + 1
      LGL5 = LGL5 + 1
      GO TO 460
  512 DIST = DIST + PLT(1,1)
      LGL5 = LGL5 + 1
      J = J + 1
      GO TO 460
  515 DIST = DIST + PLT(1,1) - 0.7
      LGL5 = LGL5 + 1
      NOCUT = NOCUT + 1
      J = J + 1
      GO TO 460
  600 NOCUT = NOCUT + 1
      XLGL1 = LGL1
      XLGL2 = LGL2
      XLGL3 = LGL3
      XLGL4 = LGL4
      XLGL5 = LGL5
      CPLTWD = CWELD(1)*XLGL1 + CWELD(2)*XLGL2 + CWELD(3)*XLGL3 +
```

```
      1CWELD(4)*XLGL4 + CWELD(5)*XLGL5
C
C     DETERMINE THE COST OF CUTTING THE PLATES.
C
      PTCUT = NOCUT
      CPTCUT = PTCUT * CHGMNH * (0.05 + 0.01*((TH1-0.25)/0.125))
C
C     DETERMINE THE COST OF ROLLING THE PLATES.
C
      TCROLL = CHGMNH * CROLL * (XLGL1+XLGL2+XLGL3+XLGL4+XLGL5)/20.0
C
C     CALCULATE THE COST OF PROVIDING STAGING.
C     HEIGHT OF 20', 14', 8', AND 3', TWO EACH, ARE PROVIDED.
C
      CRIG = 0.4 * (20.0 + 12.4 + 9.7 + 7.5) * CHGMNH
C
C     NOW CALCULATE THE ACQUISITION COST FOR THE PLATING.
C
      CPLTNG = PLT(1,3)*XLGL1/PLT(1,2) + PLT(2,3)*XLGL2/PLT(2,2) +
     1 PLT(3,3)*XLGL3/PLT(3,2) + PLT(4,3)*XLGL4/PLT(4,2) +
     2 PLT(5,3)*XLGL5 / PLT(5,2)
C
C     NOW CALCULATE THE ACQUISITION COST FOR THE LONGITUDINALS.
C
      CTLGTL = XLGTNL * CSTLGL
C
C     CALCULATE THE WELDING COST FOR THE LONGITUDINALS.
C
      CWLTNL = XLGTNL * CHGMNH *(CWLGTL*1.12 + 0.151)
C
C     CALCULATE THE COST OF CUTTING THE FLANGES OF THE LONGITUDINALS.
C
      CCUTFT = CLGCUT * XLGTNL * CHGMNH
C
C     CALCULATE THE APPROXIMATE COST (PER FOOT HULL LENGTH) FOR THE TRANSVE
C     FRAME.  ESTIMATE THAT, PER FT. GIRTH, CFRAME = 0.7 * COSTKL.
C
      CTFRAM = 0.7 * COSTKL * TOTSPN / FRM
C
C     CALCULATE THE TOTAL COST OF BUILDING THE MIDSHIP SECTION, DOLLARS
C     PER FOOT HULL LENGTH.
C
      CTOTAL = CPLTWD + CPTCUT + TCROLL + CRIG + CPLTNG + CTLGTL +
 →   1 CWLTNL + CCUTFT + CTFRAM + COSTKL
  920 FORMAT ('1    CPLTWD =',F15.6)
  921 FORMAT ('0    CPTCUT =',F15.6)
  922 FORMAT ('0    TCROLL =',F15.6)
  923 FORMAT ('0    CRIG   =',F15.6)
```

```
  924 FORMAT ('0     CPLTNG =',F15.6)
  925 FORMAT ('0     CTLGTL =',F15.6)
  926 FORMAT ('0     CWLTNL =',F15.6)
  927 FORMAT('0     CCUTFT =',F15.6)
  928 FORMAT ('0     CTFRAM =',F15.6)
  929 FORMAT ('0     CTOTAL =',F15.6)
  930 FORMAT ('0     LGL1 =',I2,'  LGL2 =',I2,'  LGL3 =', I2,'  LGL4 =',
     1 I2,'  LGL5 =', I2)
  931 FORMAT ('0     XLGL1 =',F5.2,'  XLGL2 =', F5.2,' XLGL3 =', F5.2,'
     1XLGL4 =', F5.2,' XLGL5 =', F5.2)
  932 FORMAT ('0     CWELD(I) =',5(F8.3,5X))
      WRITE (6, 932) CWELD(1), CWELD(2), CWELD(3), CWELD(4), CWELD(5)
      WRITE (6, 920) CPLTWD
      WRITE (6, 921)CPTCUT
      WRITE (6, 922) TCROLL
      WRITE (6, 923) CRIG
      WRITE (6, 930) LGL1, LGL2, LGL3, LGL4, LGL5
      WRITE (6, 931) XLGL1, XLGL2, XLGL3, XLGL4, XLGL5
      WRITE (6, 924) CPLTNG
      WRITE (6, 925) CTLGTL
      WRITE (6, 926) CWLTNL
      WRITE (6, 927) CCUTFT
      WRITE (6, 928)  CTFRAM
      WRITE (6, 929) CTOTAL
      STOP
      END
```




Generate an array of longitudinal intervals for the entire midship section.

Locate plates around the girth, assuring no conflicts with longitudinals. Cut plates if necessary.

Determine the total cost of building the midship section.

FIGURE IV

MAIN PROGRAM COSTDATA FLOW CHART

```
IEF285I    SYS1.UT1                                              KEPT
IEF285I    VOL SER NOS= CCSY03.
IEF285I    SYS1.FORTLIB                                          KEPT
IEF285I    VOL SER NOS= CCSY02.
IEF285I    SYS1.SSPLIB                                           KEPT
IEF285I    VOL SER NOS= CCSY03.
IEF285I    SYS1.MITLIB                                           KEPT
IEF285I    VOL SER NOS= CCSY03.
IEF285I    LMOD.COSTDATA                                         PASSED
IEF285I    VOL SER NOS= CCSY01.
IEF285I    TEMP.COSTDATA                                         PASSED
IEF285I    VOL SER NOS= CCSY01.
IEF285I    SYSOUT                                                SYSOUT
IEF285I    VOL SER NOS= .
*******    END OF STEP L           PGM = IEWL       70606.33  *******
//G        EXEC  PGM=*.L.SYSLMOD,COND=(4,LT)                              00000170
//SYSPRINT DD       SYSOUT=A                                              00000180
//FT05F001 DD     DDNAME=SYSIN                                            00000190
//FT06F001 DD     SYSOUT=A                                                00000200
//FT07F001 DD     UNIT=SYSCP                                              00000210
//G.SYSIN DD   *
IEF236I ALLOC. FOR COSTDATA G         SN1
IEF237I PGM=*.DD ON 191
IEF237I FT05F001 ON 200
IEF237I FT07F001 ON 200

 8.000000 33.000000959.000000
 8.000000 20.000000614.000000
 0.0       0.0       0.0
 0.0       0.0       0.0
 0.0       0.0       0.0
 1.599999  0.750000 17.000000  7.500000 27.559998125.947998  3.900000  3.900000
 4.717299  4.750799  4.652599  5.109500  5.724000
 6.934500  8.516100  9.079700 13.291200  0.0
 0.0       0.0       0.0       0.0       0.0
 0.0       0.0       0.0       0.0       0.0
 0.0       0.0       0.0       0.0       0.0
 0.0       0.0       0.0       0.0       0.0
 0.0       0.0       0.0       0.0       0.0
 0.0       0.0       0.0       0.0       0.0
 0.660000  0.140000  8.000000

  DIST,DSUMS,J,LGL1,LGL2,LGL3,LGL4,LGL5,NOCUT
 4.000000      4.717297     1     1     0     0     0     0     2

  DIST,DSUMS,J,LGL1,LGL2,LGL3,LGL4,LGL5,NOCUT
12.000000      9.468099     2     2     0     0     0     0     2

  DIST,DSUMS,J,LGL1,LGL2,LGL3,LGL4,LGL5,NOCUT
12.000000     14.320695     3     2     0     0     0     0     2

  DIST,DSUMS,J,LGL1,LGL2,LGL3,LGL4,LGL5,NOCUT
20.000000     19.430191     4     3     0     0     0     0     2

  DIST,DSUMS,J,LGL1,LGL2,LGL3,LGL4,LGL5,NOCUT
20.000000     25.154190     5     3     0     0     0     0     2

  DIST,DSUMS,J,LGL1,LGL2,LGL3,LGL4,LGL5,NOCUT
28.000000     32.068654     6     4     0     0     0     0     2

  DIST,DSUMS,J,LGL1,LGL2,LGL3,LGL4,LGL5,NOCUT
```

```
DIST,DSUMS,J,LGL1,LGL2,LGL3,LGL4,LGL5,NOCUT
44.000000      49.684479        8        6        0        0        0        0        2

DIST,DSUMS,J,LGL1,LGL2,LGL3,LGL4,LGL5,NOCUT
52.000000      62.975677        9        7        0        0        0        0        2

DIST,DSUMS,J,LGL1,LGL2,LGL3,LGL4,LGL5,NOCUT
60.000000      76.266376       10        8        0        0        0        0        2

DIST,DSUMS,J,LGL1,LGL2,LGL3,LGL4,LGL5,NOCUT
68.000000      85.346573       11        9        0        0        0        0        2

DIST,DSUMS,J,LGL1,LGL2,LGL3,LGL4,LGL5,NOCUT
76.000000      93.862671       12       10        0        0        0        0        2

DIST,DSUMS,J,LGL1,LGL2,LGL3,LGL4,LGL5,NOCUT
84.000000     100.797165       13       11        0        0        0        0        2

DIST,DSUMS,J,LGL1,LGL2,LGL3,LGL4,LGL5,NOCUT
92.000000     106.521164       14       12        0        0        0        0        2

DIST,DSUMS,J,LGL1,LGL2,LGL3,LGL4,LGL5,NOCUT
```

```
00.000000    111.630661    15    13    0    0    0    0    2
 DIST,DSUMS,J,LGL1,LGL2,LGL3,LGL4,LGL5,NOUT
```

```
8.000000     115.483246     16     14     0     0     0     0     2
 DIST,DSUMS,J,LGL1,LGL2,LGL3,LGL4,LGL5,NOCUT
```

```
6.000000     121.234039     17     15     0     0     0     0     2
 DIST,DSUMS,J,LGL1,LGL2,LGL3,LGL4,LGL5,NOCUT
```

```
24.000000    125.951324    18    16    0    0    0    0    2
IHC210I PROGRAM INTERRUPT--OLD PSW IS    FF15000FA200A938
IHC210I PROGRAM INTERRUPT--OLD PSW IS    FF15000FA200A944
IHC210I PROGRAM INTERRUPT--OLD PSW IS    FF15000FA200A952
   CWELD(1) =  15.665     21.359     0.0     0.0     0.0
```

```
CPLTWD =     298.559548

CPTCUT =       2.024994

TCROLL =      23.599979

CRIG   =     148.799350

LGL1 =16  LGL2 = 0  LGL3 = 0  LGL4 = 0  LGL5 = 0

XLGL1 =16.00  XLGL2 = 0.0  XLGL3 = 0.0  XLGL4 = 0.0  XLGL5 = 0.0

CPLTNG =     464.969482

CTLGTL =      66.299988

CWLTNL =     113.500473

CCUTFT =      17.349991

CFFRAM =     303.723389
COSTKL =      27.559998
CTOTAL =    1439.207031
         #  1466.767029
```

## C. SUBROUTINE TSLECT

### 1. DESCRIPTION

Introduction

Given the minimum tolerable spacing of longitudinals and the design stress criteria, this subroutine calculates the required plating thickness using criteria for the critical stress and tertiary stress levels. These two thicknesses are then compared, and the greater selected. This exact value of thickness is then used to select the minimum standard plate thickness that will satisfy the design requirements, and the minimum spacing is modified by the ratio of the selected thickness to the required thickness. This span is then used as the initial longitudinal spacing.

Inputs

| Symbol | Meaning |
|---|---|
| W5BMIN | Minimum permissible longitudinal spacing. (Feet) |
| ST1CRK | Maximum permissible stress at keel. (Tons/In.$^2$) |
| ST2EST | Estimated value of secondary stress. (Tons/In.$^2$) |
| SGMULT | Yield stress of the plating. (Tons/In.$^2$) |
| FRM | Transverse frame spacing. (Feet) |

Calculated Items

| Symbol | Meaning |
|---|---|
| SGMACR | Limiting stress intensity, defined as 1.25 x (ST1CAL + ST2EST) (Tons/In.$^2$) |
| ABAB | Plate aspect ratio. |
| C1CRIT | Coefficient used in calculating the critical strength of the plating. |
| CC1 | Intermediate calculation used in determining the required plating thickness based on critical stress criteria. |
| THPRIM | Plating thickness required to satisfy critical stress criteria. (Inches) |
| PRESS | Hydrostatic pressure at keel. (Tons/In.$^2$) |
| C3CRIT | Coefficient used in calculating the tertiary stress strength of the plating. (Tons/In.$^2$) |
| ST3MAX | Maximum tolerable intensity of the tertiary stress. (Tons/In.$^2$) |
| CC3 | Intermediate calculation used in determining the required plating thickness based on tertiary stress criteria. |
| THTER | Plating thickness required to satisfy tertiary stress criteria. (Inches) |
| TH | The greater of THPRIM or THTER. (Inches) |

Output

| Symbol | Meaning |
|---|---|
| TH1 | Plating thickness selected. This is the least existing thickness that exceeds the value TH. (Inches) |
| W5BACT | Tolerable longitudinal spacing for selected plating thickness. (Feet) |

Calling Sequence

Call TSLECT (W5BMIN, ST1CRK, ST2EST, SGMULT, FRM, TH1, W5BACT)

Sample Input/Output (Computer test run)

| | | | |
|---|---|---|---|
| Input: | W5BMIN | 1.667 | Feet |
| | ST1CRK | 7.93 | Tons/In.$^2$ |
| | ST2EST | 1.34 | Tons/In.$^2$ |
| | SGMULT | 20.98 | Tons/In.$^2$ |
| | FRM | 8.00 | Feet |
| Output: | TH1 | 0.28125 | Inches |
| | W5BACT | 1.769 | Feet |

Fundamental Equations

$$ABAB = \frac{FRM}{W5BMIN}$$

$$CC1 = \sqrt{\frac{C1CRIT \times 3.1416^2 \times 13392.857}{10.9 \times SGMACR}}$$

$$THPRIM = \frac{12.0 \times W5BMIN}{CC1}$$

$$PRESS = \frac{0.445 \times HM}{2240.}$$

$$CC3 = \sqrt{\frac{ST3MAX}{5.46 \times C3CRIT \times PRESS}}$$

$$THTER = \frac{12 \times W5BMIN}{CC3}$$

$$W5BACT = \frac{TH1 \times W5BMIN}{TH}$$

Sample Calculation (Refer to subroutine listing and flow chart, following pages)

$SGMACR = \underline{11.58}$

$ABAB = \underline{4.80}$

$C1CRIT = \underline{7.225}$

$$CC1 = \sqrt{\frac{(7.225 \times 9.87 \times 13392.857)}{126.4}}$$
$$= \underline{86.9}$$

$$THPRIM = \frac{20}{86.9}$$
$$= \underline{0.230}$$

$HM = \underline{30.23}$

PRESS = $\underline{0.00601}$

C3CRIT = $\underline{0.0627}$

ST3MAX = $\underline{11.71}$

$$CC3 = \sqrt{\frac{11.71}{5.46 \times .0627 \times .00601}}$$

$$= \underline{75.7}$$

$$THTER = \frac{20}{75.7} = \underline{0.264}$$

TH = $\underline{0.264}$

TH1 = $\underline{0.28125}$ inches

$$W5BACT = \frac{0.28125}{0.264} \times 1.667$$

$$= \underline{1.77} \text{ feet}$$

```
      SUBROUTINE TSLECT(W5BMIN,ST1CRK,ST2EST,SGMULT,FRM,TH1,W5BACT)
      SGMACR = 1.25 * (ST1CRK + ST2EST)
      ABAB = FRM / W5BMIN
      IF (ABAB - 7.0) 701, 703, 703
  703 C1CRIT = 7.0
      GO TO 780
  701 IF (ABAB - 3.5) 702, 704, 704
  704 C1CRIT = 7.0 + 0.4 * ((7.0 - ABAB)/3.5)
      GO TO 780
  702 IF(ABAB - 1.9) 705, 706, 706
  706 C1CRIT = 7.4 + 0.7 * (3.5 - ABAB)/1.6
      GO TO 780
  705 C1CRIT = 8.1 - (ABAB - 1.9) / 1.9
  780 ADULIN = C1CRIT * 3.1416 * 3.1416 * 13392.86
      BDULIN = 10.9 * SGMACR
      CC1 = SQRT (ADULIN/BDULIN)
      ST1CAL = ST1CRK
      THPRIM = (W5BMIN * 12.) / CC1
      YPTMIN = 0.0
      ZPTMIN = 0.0
C     TERTIARY STRESS CALCULATION
C
      A3HEEL = 0.5236
      D1 = 26.231247
      H1AMDK = 4.0
      H1DFL = 14.5
      XL1BP = 407.
      NBELTS = 1
      CALL HDWTR (A3HEEL,YPTMIN,D1,H1AMDK,H1DFL,NBELTS,XL1BP,ZPTMIN,HM)
      PRESS = (0.445 * HM) / 2240.
      IF (ABAB - 1.4) 901, 903, 903
  903 C3CRIT = 0.0627
      GO TO 980
  901 IF (ABAB - 1.2) 902, 904, 904
  904 C3CRIT = 0.0615 + 0.0012 * ((ABAB - 1.2) / 0.2)
      GO TO 980
  902 C3CRIT = 0.057 + 0.0009 * (ABAB - 1.0)
  980 ST3MAX = SGMULT - ST1CAL - ST2EST
      CC3 = SQRT (ST3MAX / (5.46 * C3CRIT * PRESS))
      THTER = (12.0 * W5BMIN) / CC3
      IF (THTER .GT. THPRIM) GO TO 600
      TH = THPRIM
      GO TO 16
  600 TH = THTER
   16 IF((TH - 0.375).GT. 0) GO TO 401
  405 IF ((TH - 0.25) .GT. 0) GO TO 407
      TH1 = 0.25
      GO TO 900
```

```
  407 IF ((TH - 0.28125) .GT. 0) GO TO 409
      TH1 = 0.28125
      GO TO 900
  409 IF((TH - 0.3125) .GT. 0) GO TO 411
      TH1 = 0.3125
      GO TO 900
  411 IF ((TH - 0.34375) .GT. 0) GO TO 413
      TH1 = 0.34375
      GO TO 900
  413 TH1 = 0.375
      GO TO 900
  401 IF((TH1 - 1.0).GT. 0) GO TO 501
   .  IF((TH - 0.4375).GT. 0) GO TO 503
      TH1 = 0.4375
      GO TO 900
  503 IF((TH - 0.50) .GT. 0) GO TO 505
      TH1 = 0.500
      GO TO 900
  505 IF ((TH - 0.625) .GT. 0) GO TO 507
      TH1 = 0.625
      GO TO 900
  507 IF((TH - 0.75).GT. 0) GO TO 509
      TH1 = 0.75
      GO TO 900
  509 IF((TH - 0.875) .GT. 0) GO TO 511
      TH1 = 0.875
      GO TO 900
  511 IF((TH - 0.9375) .GT. 0) GO TO 513
      TH1 = 0.9375
      GO TO 900
  513 TH1 = 1.000
   17 FORMAT ('REQUIRED PLATING THICKNESS EXCEEDS ONE INCH.')
  501 WRITE (6, 17)
  900 W5BACT = (TH1 * W5BMIN) / TH
      RETURN
      END
```

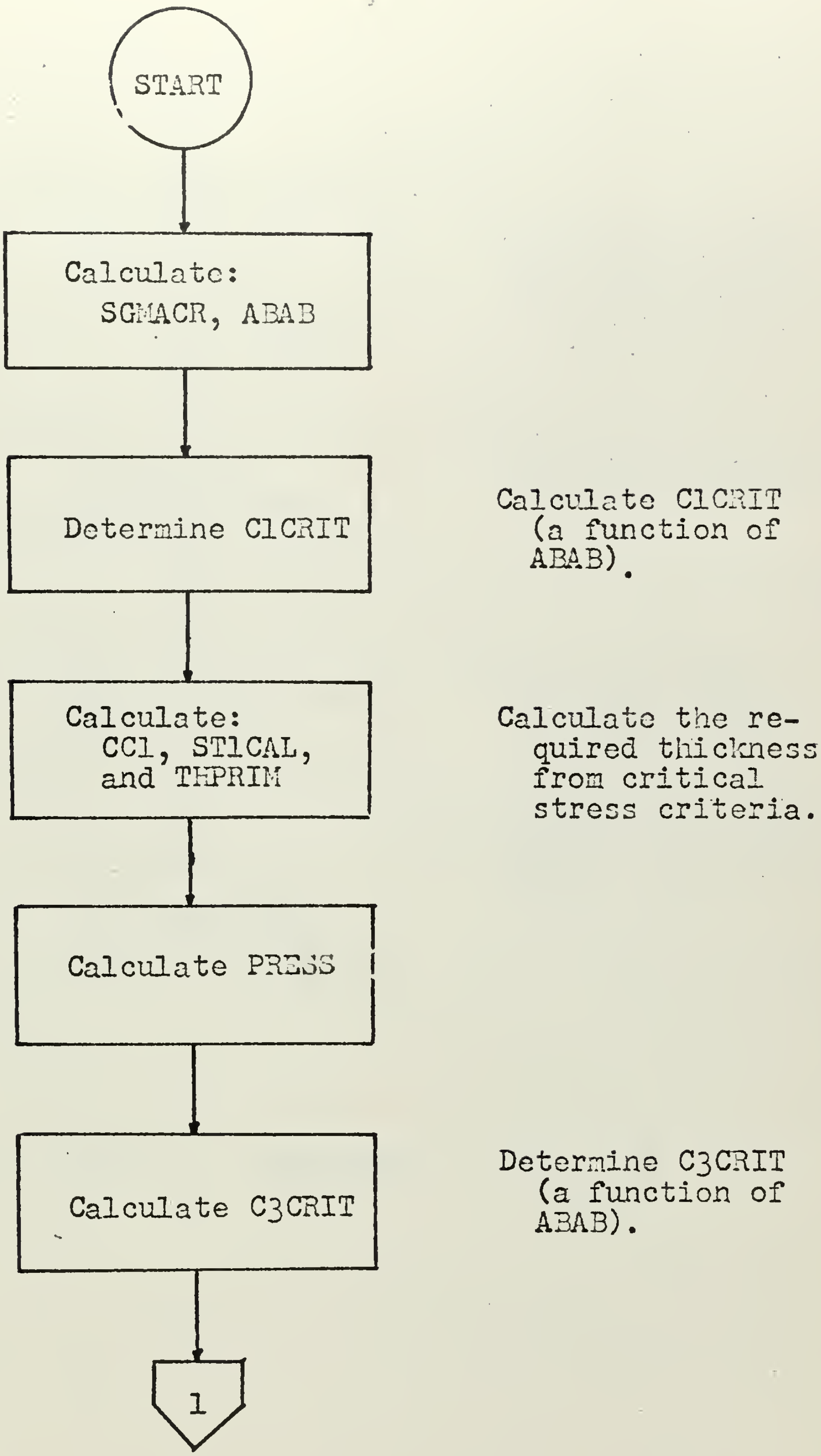



FIGURE V

SUBROUTINE TSLECT FLOW CHART

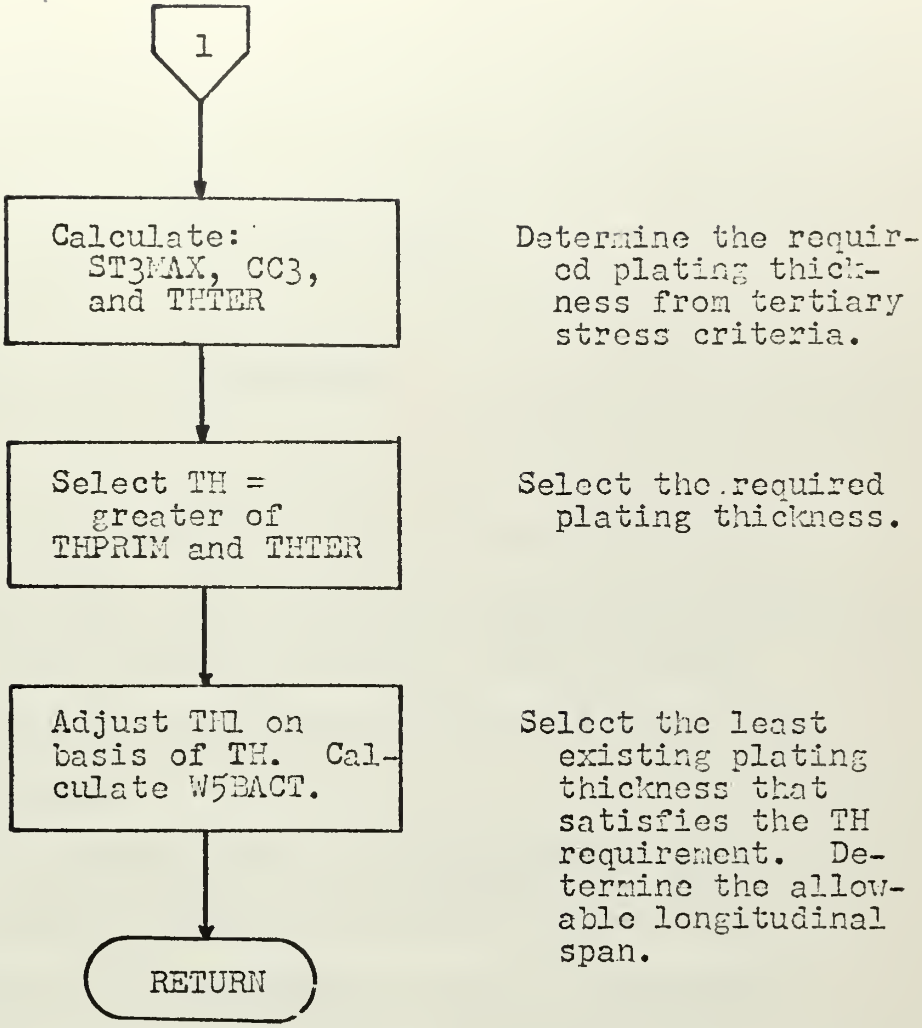



FIGURE V - Continued

## D. SUBROUTINE HDWTR*

### 1. DESCRIPTION

Introduction

This subroutine calculates the maximum hydrostatic head of water existing at a designated point on the shell. Three loading conditions are evaluated, using current procedures employed by the Naval Ship Systems Command in the design of ships:

1. The maximum head is calculated for the effects of the full load draft with half the height of a standard wave profile superposed.
2. The maximum head is calculated for the condition of the ship at full load draft heeled over some specified angle. In the case of this analysis, the heel angle is fixed at thirty degrees.
3. Finally, the maximum head resulting from the superposition of a specified design head of water on the main deck is computed.

---

*Subroutine HDWTR is based on a subroutine of the same name developed by the Applied Mathematics Laboratory of the David Taylor Model Basin, Washington, D. C. 20007.

After the individual heads are determined for the various conditions, the maximum value is selected as the output from the subroutine.

**Inputs**

| Symbol | Meaning |
|---|---|
| A3HEEL | Specified maximum heel angle. (Radians) |
| B3P | Half breadth of point. (Feet) |
| D1 | Depth of hull. (Feet) |
| H1AMDK | Specified design head of water above main deck. (Feet) |
| H1DFL | Design full load draft. (Feet) |
| NBELTS | Number of points. (= 1) |
| XL1BP | Length between perpindiculars. (Feet) |
| ZK1P | Height of point above keel. (Feet) |

**Calculated Items**

| Symbol | Meaning |
|---|---|
| HMAMDK | Head of water due to design head of water on main deck. (Feet) |
| HMHEEL | Head of water due to heel. (Feet) |
| HMO | Head of water due to wave profile. (Feet) |
| H1 | Draft due to standard wave profile. (Feet) |
| THM | Draft due to head of water above main deck. (Feet) |

**Output**

| Symbol | Meaning |
|---|---|
| HM | Maximum head of water to point. (Feet) |

**Calling Sequence**

Call HDWTR (A3HEEL, B3P, D1, H1AMDK, H1DFL, NBELTS, XL1BP, ZK1P, HM)

Sample Input/Output (Computer test run)

| | | | |
|---|---|---|---|
| Input: | A3HEEL | 0.5236 | radians |
| | B3P | 39.83 | feet |
| | D1 | 70.00 | feet |
| | H1AMDK | 0.00 | feet |
| | H1DFL | 26.00 | feet |
| | NBELTS | 1 | |
| | XL1BP | 580.00 | feet |
| | ZK1P | 14.00 | feet |
| Output: | HM | 30.31 | feet |

Fundamental Equations

$$H1 = H1DFL + 0.55 \times \sqrt{XL1BP}$$

$$HM0 = H1 - ZK1P$$

$$HMHEEL = D \times \text{Cos}\ (1.5708 - B - A3HEEL)$$

$$B = \text{Arctan}\ \frac{H1DFL - ZK1P}{B3P}$$

$$D = \sqrt{B3P^2 + (H1DFL - ZK1P)^2}$$

$$HMAMDK = THM - ZK1P$$

$$THM = D1 + H1AMDK$$

Sample Calculation (Refer to subroutine listing and flow chart, following pages)

$$H1 = 26.00 + 0.55 \times 24.08319$$
$$= \underline{39.2458}$$

$$HM0 = 39.2458 - 14.0$$
$$= \underline{25.2458}$$

$$D = \sqrt{1585.43 + 144}$$
$$= \underline{41.53}$$

$$B = \text{Arctan}\ (0.3012)$$
$$= \underline{0.2926}$$

$$HMHEEL = 41.53 \times \text{Cos}\ (0.7546)$$
$$= \underline{30.31}$$

$$HM = HMHEEL = \underline{30.31}\ \text{feet}$$

```
      SUBROUTINE HDWTR(A3HEEL,B3P,D1,H1AMDK,H1DFL,NBELTS,XL1BP,ZK1P,HM)
C
C     CALCULATE DRAFT TO STANDARD WAVE HEIGHT
C
      H1 = H1DFL + 0.55*SQRT(XL1BP)
      IF(ZK1P - H1) 1,2,2
    1 HMO = H1 - ZK1P
      GO TO 3
    2 HMO = 0.0
C
C     CALCULATE HEAD OF WATER DUE TO HEELED WATERLINE
C
    3 IF (ZK1P - H1DFL) 4,7,5
    4 D = SQRT(B3P**2 + (H1DFL - ZK1P)**2)
      IF (B3P) 19,19,18
   19 B = 1.5708
      GO TO 20
   18 B = ATAN ((H1DFL - ZK1P)/B3P)
   20 IF (B - 1.5708 + A3HEEL) 15, 16, 17
   15 HMHEEL = D*COS(1.5708 - A3HEEL - B)
      GO TO 10
   16 HMHEEL = D
      GO TO 10
   17 HMHEEL = D*COS(B - 1.5708 + A3HEEL)
      GO TO 10
    5 D = SQRT (B3P**2 + (ZK1P - H1DFL)**2)
      B = ATAN ((ZK1P - H1DFL)/B3P)
      IF ( B - A3HEEL) 6,8,8
    6 HMHEEL = D*COS(1.5708 - A3HEEL + B)
      GO TO 10
    7 HMHEEL = B3P * SIN(A3HEEL)
      GO TO 10
    8 HMHEEL = 0.0
C
C     COMPARE HEADS CALCULATED THUS FAR AND DETERMINE THE MAXIMUM
C
   10 IF (HMO - HMHEEL) 11, 12, 12
   11 HM = HMHEEL
      GO TO 100
   12 HM = HMO
  100 CONTINUE
      IF(H1AMDK) 40,40,41
C
C     CALCULATE DRAFT DUE TO HEAD OF WATER ABOVE MAIN DECK
C
   41 THM = D1 + H1AMDK
      HMAMDK = THM - ZK1P
C
```

```
C      COMPARE HEADS AND DETERMINE FINAL MAXIMUM HEAD AT POINT
C
       IF (HMAMDK - HM) 45,45,46
    46 HM = HMAMDK
    45 CONTINUE
    40 RETURN
       END
```

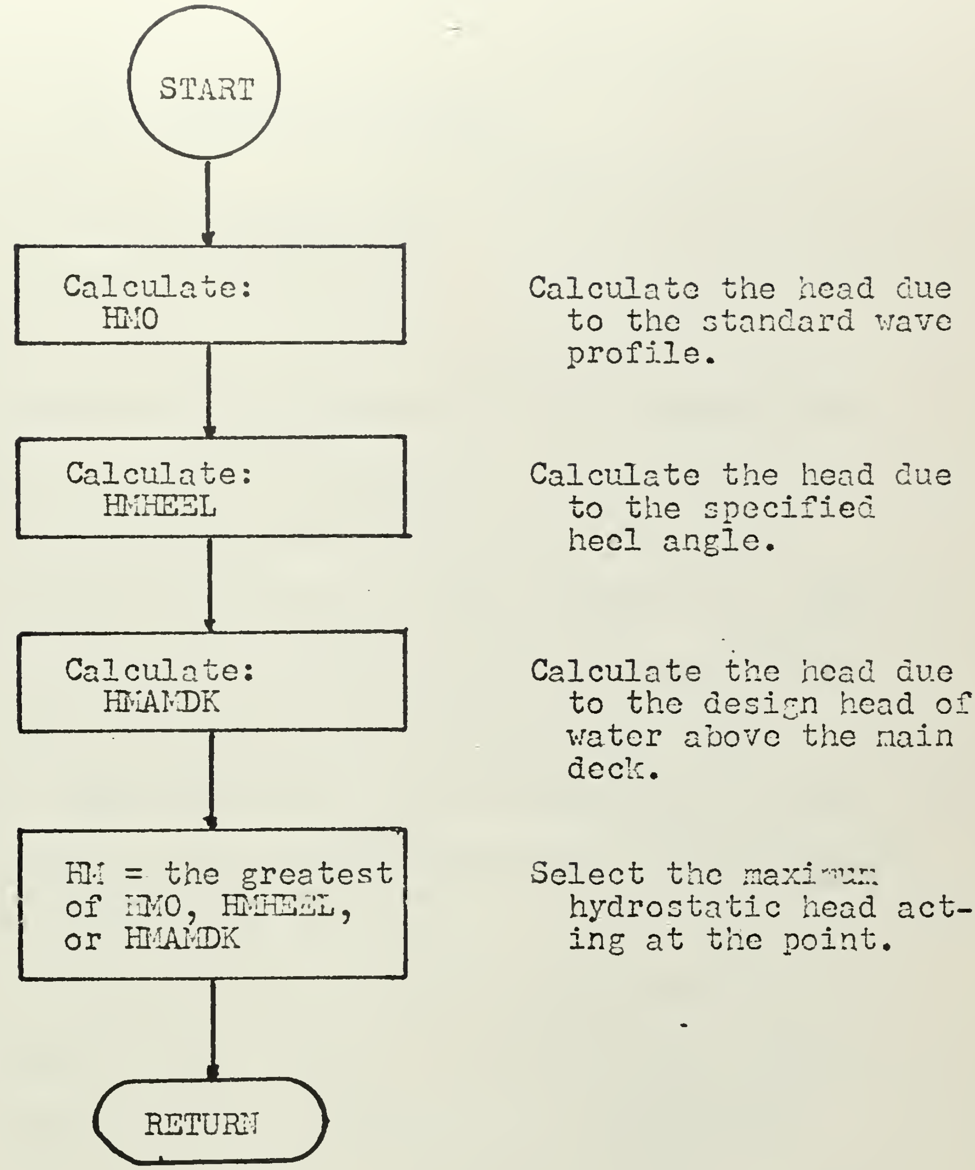



FIGURE VI

SUBROUTINE HDWTR FLOW CHART

## E. SUBROUTINE CSPACE

### 1. DESCRIPTION

Introduction

This subroutine calculates the maximum permissible span to the next (upper) longitudinal on the midship section. The hydrostatic head existing at the lower edge of the span is employed for this calculation. The permissible spacing is calculated on the basis of three different criteria, as described by St. Denis [1] :

1. The permissible span is calculated on the basis of the maximum compressive stress exerted on the plating.
2. The permissible span is calculated on the basis of the tolerable tertiary stress level - caused by plate binding due to hydrostatic pressure normal to the plate surface.
3. Finally, stability requirements for the unsupported plate are used to evaluate the permissible span between longitudinals.

Once the three values of the tolerable span have been determined, the lesser value of the three is selected as the limiting span.

Inputs

| Symbol | Meaning |
|---|---|
| ST1CRK | Maximum permissible stress at keel. (Tons/In.$^2$) |
| ST1CRD | Maximum permissible stress at deck centerline. (Tons/In.$^2$) |
| ST2EST | Estimated value of secondary stress. (Tons/In.$^2$) |
| SGMULT | Yield stress of the plating. (Tons/In.$^2$) |
| FRM | Transverse frame spacing. (Feet) |
| TH1 | Plating thickness. (Inches) |
| YPTMIN | Half breadth of preceding longitudinal. (Feet) |
| ZPTMIN | Height of preceding longitudinal above base line. (Feet) |
| W5BPRC | Span to preceding longitudinal. (Feet) |

Calculated Items

| Symbol | Meaning |
|---|---|
| ZNAXIS | Location of neutral axis of DD-931 midship section above base line. (Feet) |
| ST1CAL | Calculated primary compressive stress at preceding longitudinal. (Feet) |
| SGMACR | Limiting stress intensity, defined as 1.25 x (ST1CAL + ST2EST) (Tons/In.$^2$) |
| ABAB | Aspect ratio of preceding span. |
| C1CRIT | Coefficient used in calculating the critical strength of the plating. |
| W5BTL1 | Permissible span due to critical strength criteria. (Feet) |
| PRESS | Hydrostatic pressure at preceding longitudinal. (Tons/In.$^2$) |
| C3CRIT | Coefficient used in the tertiary stress calculation. |

| Symbol | Meaning |
|---|---|
| W5BTL3 | Permissible span due to the tertiary stress calculation. (Feet) |
| SGMCRT | Critical stress intensity for a panel of plating. (Tons/In.$^2$) |
| XNOSTF | Required number of stiffeners for a plate panel. |
| ST3MAX | Greatest tolerable tertiary stress. (Tons/In.$^2$) |
| W5BTLS | Tolerable span on basis of plate stability criteria. (Feet) |

Output

| Symbol | Meaning |
|---|---|
| W5BTOL | Maximum tolerable span to next longitudinal. (Feet) |

Calling Sequence

Call CSPACE (ST1CRK, ST1CRD, ST2EST, SGMULT, FRM, TH1, YPTMIN, ZPTMIN, W5BPRC, W5BTOL)

Sample Input/Output (Computer test run)

| | | | |
|---|---|---|---|
| Input: | ST1CRK | 7.93 | Tons/In.$^2$ |
| | ST1CRD | 6.00 | Tons/In.$^2$ |
| | ST2EST | 1.34 | Tons/In.$^2$ |
| | SGMULT | 20.98 | Tons/In.$^2$ |
| | FRM | 8.00 | Feet |
| | TH1 | 0.28125 | Inches |
| | YPTMIN | 1.768 | Feet |
| | ZPTMIN | 0.045 | Feet |
| | W5BPRC | 1.769 | Feet |
| Output: | W5BTOL | 1.772 | Feet |

Fundamental Equations

$$\text{ZNAXIS} = 26.23125 \times \left(\frac{\text{ST1CRK}}{\text{ST1CRK} + \text{ST1CRD}}\right)$$

$$\text{ST1CAL} = \text{ST1CRK} \times \left|\frac{\text{ZNAXIS} - \text{ZPTMIN}}{\text{ZNAXIS}}\right|$$

$$ABAB = FRM/W5BPRC$$

$$W5BTL1 = \frac{TH1 \times CC1}{12.0}$$

$$CC1 = \sqrt{\frac{C1CRIT \times 3.1416^2 \times 13392.86}{10.9 \times SGMACR}}$$

$$PRESS = 0.445 \times HM/2240.$$

$$ST3MAX = SGMULT - ST1CAL - ST2EST$$

$$W5BTL3 = \frac{TH1 \times CC3}{12.0}$$

$$CC3 = \sqrt{\frac{ST3MAX}{5.46 \times C3CRIT \times PRESS}}$$

$$SGMCRT = \frac{4.0 \times 3.1416^2 \times 13392.86 \times TH1^2}{10.8 \times 3600.}$$

$$XNOSTF = \sqrt{\frac{SGMACR}{SGMCRT}} - 1.0$$

$$W5BTLS = \frac{5.0}{XNOSTF}$$

<u>Sample Calculation</u> (Refer to subroutine listing and flow chart, following pages)

$$ZNAXIS = 26.23125 \times \frac{7.93}{13.93}$$
$$= \underline{14.92}$$

$$ST1CAL = 7.93 \times \left(\frac{14.885}{14.93}\right)$$
$$= \underline{7.90}$$

$$ABAB = 8.0/1.769$$
$$= \underline{4.52}$$

$$CC1 = \sqrt{\frac{7.283 \times 3.1416^2 \times 13392.86}{10.9 \times 11.56}}$$
$$= \underline{87.5}$$

$$W5BTL1 = \frac{0.28125 \times 87.5}{12.0}$$
$$= \underline{2.05}$$

$$PRESS = 0.445 \times 30.19/2240$$
$$= \underline{0.006}$$

$$ST3MAX = \underline{11.74}$$

$$CC3 = \sqrt{\frac{11.74}{5.45 \times .0627 \times .006}}$$
$$= \underline{75.7}$$

$$W5BTL3 = \frac{0.28125 \times 75.7}{12.0}$$
$$= \underline{1.772}$$

$$SGMCRT = \underline{1.076}$$

$$XNOSTF = \sqrt{\frac{11.56}{1.076}} - 1.0$$
$$= \underline{2.28}$$

$$W5BTLS = \underline{2.245}$$

$$W5BTOL = \underline{1.772} \text{ feet}$$

```
      SUBROUTINE CSPACE (ST1CRK,ST1CRD,ST2EST,SGMULT,FRM,TH1,YPTMIN,
     1ZPTMIN,W5BPRC,W5BTOL)
C
C     W5BTOL IS CALCULATED ON THE BASIS OF THE PRIMARY AND TERTIARY
C     STRESSES.  THE LESSER VALUE OF THE TWO IS THEN SELECTED.
C     THIS VALUE OF W5BTOL IS THEN COMPARED WITH THE MINIMUM SPAN
C     PERMITTED ON THE BASIS OF THE REQUIRED NUMBER OF STIFFENERS FOR A
C     PLATE WITH THICKNESS TH1 AND A WIDTH OF 5.0 FEET.
C
C     BASIC METHODOLOGY OF SUBROUTINE TSLECT IS USED FOR THE PRIMARY STRESS
C     CALCULATION.
C
      ZNAXIS = 26.23125 * (ST1CRK / (ST1CRK + ST1CRD))
      ST1CAL = ST1CRK * ABS ((ZNAXIS - ZPTMIN)/ZNAXIS)
      SGMACR = 1.25*(ST1CAL + ST2EST)
      ABAB = FRM / W5BPRC
      IF (ABAB - 7.0) 701, 703, 703
  703 C1CRIT = 7.0
      GO TO 780
  701 IF (ABAB - 3.5) 702, 704, 704
  704 C1CRIT = 7.0 + (0.4*((7.0-ABAB)/3.5))
      GO TO 780
  702 IF (ABAB-1.9) 705, 706, 706
  706 C1CRIT = 7.4 + 0.7*(3.5-ABAB)/1.6
      GO TO 780
  705 C1CRIT = 8.1 - (ABAB-1.9)/1.9
  780 ADULIN = C1CRIT * 3.1416 * 3.1416 * 13392.86
      BDULIN = 10.9 * SGMACR
      CC1 = SQRT (ADULIN/BDULIN)
      W5BTL1 = (TH1 * CC1)/ 12.
C
C     TERTIARY STRESS CALCULATION.
C
      DATA A3HEEL,D1,H1AMDK,H1DFL,NBELTS,XL1BP/.5236,26.23125,4.,14.5,1,
     1 407./
      CALL HDWTR (A3HEEL,YPTMIN,D1,H1AMDK,H1DFL,NBELTS,XL1BP,ZPTMIN,HM)
      PRESS = 0.445 * HM/2240.
      IF(ABAB - 1.4) 901, 903, 903
  903 C3CRIT = 0.0627
      GO TO 980
  901 IF(ABAB-1.2) 902, 904, 904
  904 C3CRIT = 0.0615 + 0.0012*((ABAB-1.2)/0.2)
      GO TO 980
  902 C3CRIT = 0.057 +  0.0225*(ABAB-1.0)
  980 ST3MAX = SGMULT - ST1CAL - ST2EST
      CC3 = SQRT (ST3MAX/(5.46*C3CRIT*PRESS))
      W5BTL3 = TH1 * CC3 / 12.0
      IF (W5BTL1 .GT. W5BTL3) GO TO 410
```

```
      W5BTOL = W5BTL1
      GO TO 600
  410 W5BTOL = W5BTL3
C
C     PROVIDE FOR ADEQUATE PLATE STABILITY BY LIMITING W5BTOL ON THE
C     BASIS OF THE NUMBER OF STIFFENERS REQUIRED FOR A PLATE WITH A
C     WIDTH OF FIVE FEET.
C
  600 SGMCRT=4.*(3.1416**2)*13392.86*(TH1**2)/(10.8 * 3600.)
      XNOSTF = SQRT (SGMACR / SGMCRT ) -  1.0
      W5BTLS = ABS (5.0/XNOSTF)
      IF (W5BTOL .LT. W5BTLS) GO TO 601
      W5BTOL = W5BTLS
  601 CONTINUE
      RETURN
      END
```

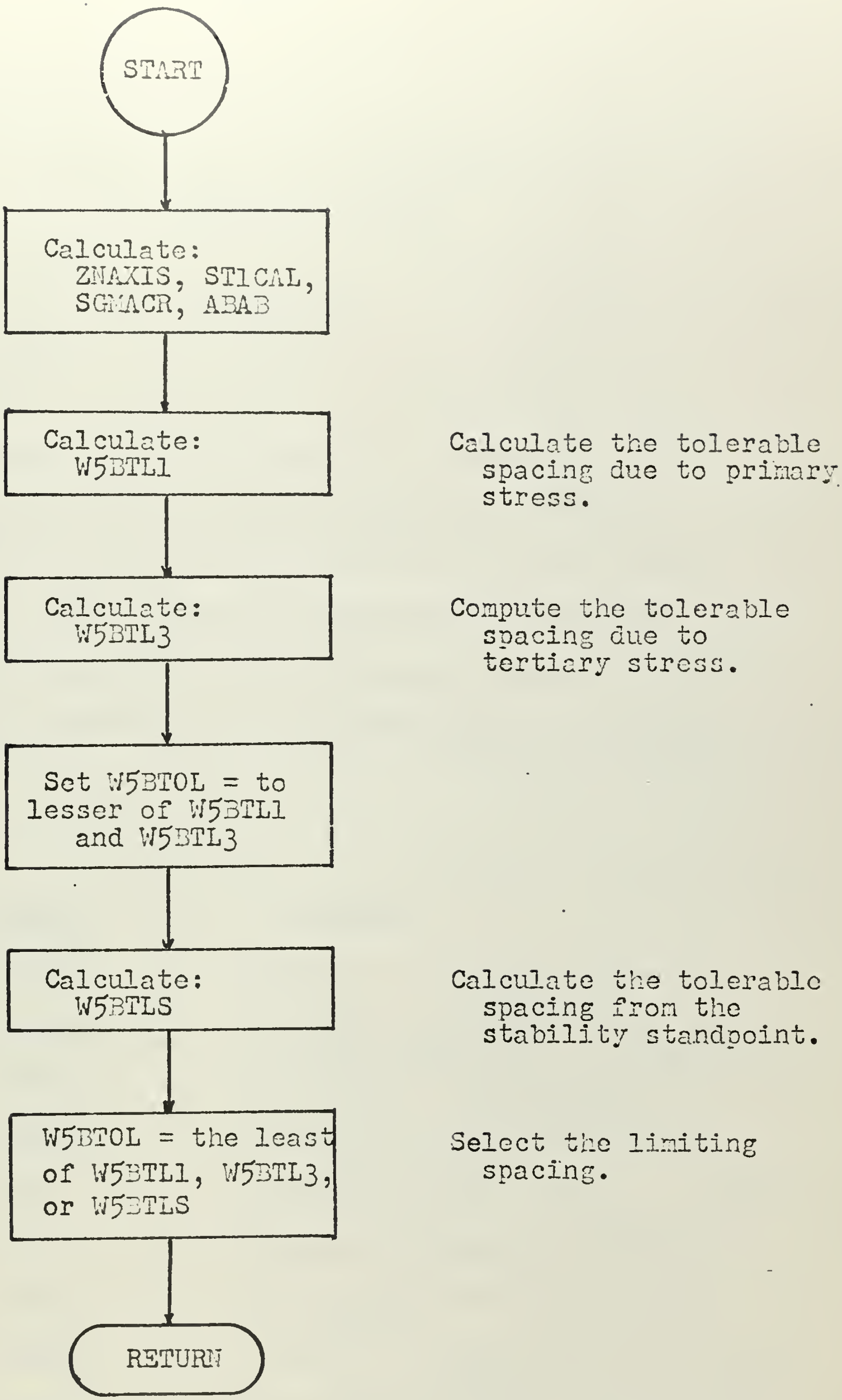



FIGURE VII

SUBROUTINE <u>CSPACE</u> FLOW CHART

# F. SUBROUTINE CLONGL

## 1. DESCRIPTION

### Introduction

Subroutine CLONGL is designed to calculate the required section modulus for the longitudinal-plating combination, as well as the minimum permissible radius of gyration. The resulting computation is concerned solely with strength criteria, as the criteria for plating-longitudinal stability are determined later in the main program.

### Inputs

| Symbol | Meaning |
|---|---|
| ST1CRK | Maximum permissible stress at keel. (Tons/In.$^2$) |
| ST1CRD | Maximum permissible stress at deck centerline. (Tons/In.$^2$) |
| ST2EST | Estimated value of secondary stress. (Tons/In.$^2$) |
| SGMULT | Yield stress of the plating. (Tons/In.$^2$) |
| FRM | Transverse frame spacing. (Feet) |
| TH1 | Plating thickness. (Inches) |
| YPTLOC | Half breadth of longitudinal. (Feet) |
| ZPTLOC | Height of longitudinal above base line. (Feet) |
| W5BPRC | Span from preceding longitudinal. (Feet) |

| Symbol | Meaning |
|---|---|
| R5GYRA | Required radius of gyration of plating-longitudinal combination. (Inches) |

Calculated Items

| Symbol | Meaning |
|---|---|
| XR5GYR | Calculated radius of gyration required for given longitudinal location. (Inches) |
| PRESS | Hydrostatic pressure at longitudinal. (Pounds/In.$^2$) |
| ZNAXIS | Location of neutral axis of DD-931 midship section above base line. (Feet) |
| ST1CAL | Calculated primary compressive stress at longitudinal. (Feet) |
| WIDTH | Permissible span for cases where span exceeds 50.0 x TH1. (Inches) |
| EWIDTH | Effective width of plating, dictated by the lesser of WIDTH and 12.0 x W5BPRC. (Inches) |
| XMB1LG | Bending moment at mid-span of plating-longitudinal combination. (Inch-Pounds) |
| ST3LGL | Tolerable level of tertiary stress. (Tons/In.$^2$ converted to Lb./In.$^2$) |

Output

| Symbol | Meaning |
|---|---|
| R5GYRA | Required radius of gyration of plating-longitudinal combination. (Inches) |
| XMD1MN | Required section modulus of plating-longitudinal combination. (In.$^3$) |

Calling Sequence

```
Call CLONGL (ST1CRK, ST1CRD, ST2EST, SGMULT, FRM,
             TH1, W5BPRC, R5GYRA, XMD1MN, YPTLOC,
             ZPTLOC)
```

**Sample Input/Output** (Computer test run)

| | | | |
|---|---|---|---|
| Input: | ST1CRK | 7.93 | Tons/In.$^2$ |
| | ST1CRD | 6.00 | Tons/In.$^2$ |
| | ST2EST | 1.34 | Tons/In.$^2$ |
| | SGMULT | 20.98 | Tons/In.$^2$ |
| | FRM | 8.00 | Feet |
| | THL | 0.28125 | Inches |
| | YPTLOC | 1.768 | Feet |
| | ZPTLOC | 0.045 | Feet |
| | W5BPRC | 1.769 | Feet |
| | R5GYRA | 3.097 | Inches |
| Output: | R5GYRA | 3.097 | Inches |
| | XMD1MN | 8.277 | In.$^3$ |

**Fundamental Equations**

$$\mathrm{XR5GYR} = \frac{12.0 \times \mathrm{FRM}}{31.}$$

$$\mathrm{PRESS} = 0.445 \times \mathrm{HM}$$

$$\mathrm{ZNAXIS} = 26.23125 \times \frac{\mathrm{ST1CRK}}{\mathrm{ST1CRK} + \mathrm{ST1CRD}}$$

$$\mathrm{ST1CAL} = \mathrm{ST1CRK} \times \left| \frac{\mathrm{ZNAXIS} - \mathrm{ZPTLOC}}{\mathrm{ZNAXIS}} \right|$$

$$\mathrm{WIDTH} = 50.0 \times \mathrm{THL}$$

$$\mathrm{XMB1LG} = 18.0 \times \mathrm{PRESS} \times \mathrm{EWIDTH} \times \mathrm{FRM}^2$$

$$\mathrm{ST3LGL} = \mathrm{SGMULT} - \mathrm{ST1CAL} - \mathrm{ST2EST}$$

$$\mathrm{ST3LGL} = 2240. \times \mathrm{ST3LGL}$$

$$\mathrm{XMD1MN} = \frac{\mathrm{XMB1LG}}{\mathrm{ST3LGL}}$$

**Sample Calculation** (Refer to subroutine listing and flow chart, following pages)

$$\mathrm{XR5GYR} = \frac{96.}{31.} = \underline{3.097}$$

$$\mathrm{PRESS} = 0.445 \times 30.14 = \underline{13.4}$$

$$\mathrm{ZNAXIS} = 26.23125 \times \frac{7.93}{13.93}$$

$$\mathrm{ST1CAL} = 7.93 \times \frac{14.94 - 0.045}{14.94} = \underline{7.90}$$

W5BPRC = <u>21.23</u> inches

WIDTH = <u>14.06</u>

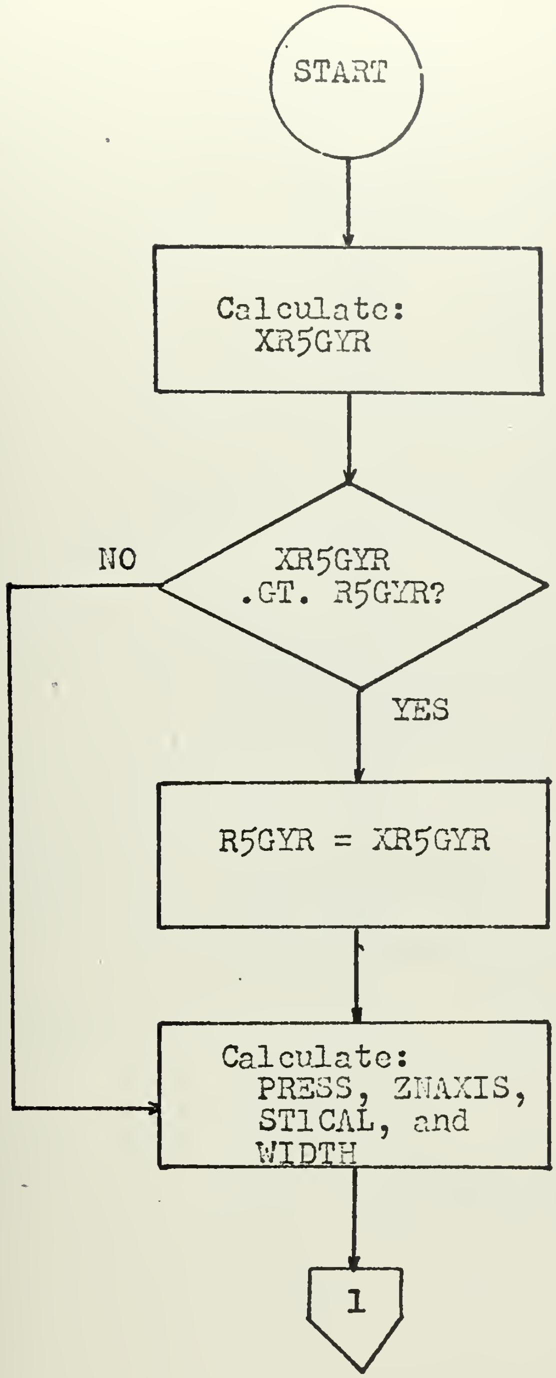
EWIDTH = WIDTH = <u>14.06</u>

XMB1LG = 18. x 13.4 x 14.06 x 64.
= <u>217,000</u>

ST3LGL = <u>26,320</u> psi

$$XMD1MN = \frac{217,000}{26,320}$$
= <u>8.28</u>

```
      SUBROUTINE CLONGL( ST1CRK,ST1CRD,ST2EST,SGMULT,FRM,TH1,W5BPRC,
     1 R5GYRA,XMD1MN,YPTLOC,ZPTLOC)
      XR5GYR = 12.0 * FRM / 31.0
      IF (XR5GYR - R5GYRA) 201, 203, 203
  203 R5GYRA = XR5GYR
  201 A3HEEL = 0.5236
      AAA = W5BPRC
      D1 = 26.231247
      H1AMDK = 4.0
      H1DFL = 14.5
      NBELTS = 1
      XL1BP = 407.
      CALL HDWTR (A3HEEL,YPTLOC,D1,H1AMDK,H1DFL,NBELTS,XL1BP,ZPTLOC,HM)
      PRESS = 0.445 * HM
      ZNAXIS = 26.231247 * ST1CRK / (ST1CRK + ST1CRD)
      ST1CAL = ST1CRK * ABS ((ZNAXIS - ZPTLOC)/ZNAXIS)
      W5BPRC = 12.0 * W5BPRC
      WIDTH = 50.0 * TH1
      IF (W5BPRC .LT. WIDTH) GO TO 600
      EWIDTH = WIDTH
      GO TO 601
  600 EWIDTH = W5BPRC
  601 XMB1LG = 18.0 * PRESS * EWIDTH * (FRM**2)
      ST3LGL = SGMULT - ST1CAL - ST2EST
      W5BPRC = AAA
      ST3LGL = 2240. * ST3LGL
      XMD1MN = XMB1LG / ST3LGL
      RETURN
      END
```

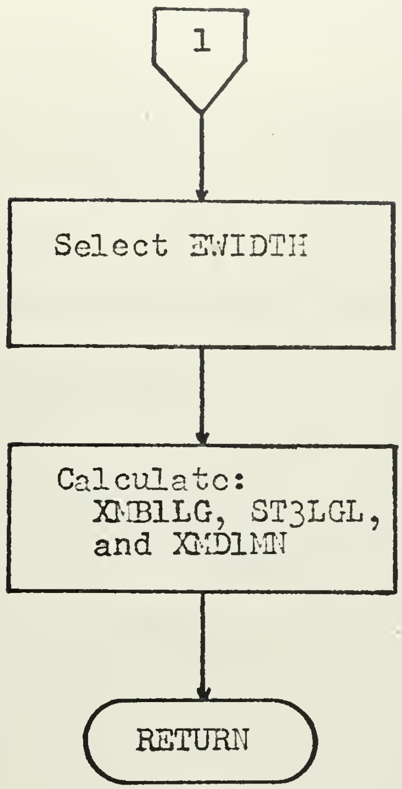



Determine the limiting value of the radius of gyration.

Do the preliminary computations for determining the effective width of plating.

FIGURE VIII

SUBROUTINE CLONGL FLOW CHART




Determine the required section modulus for the plating-longitudinal combination.

FIGURE VIII - Continued

## G. SUBROUTINE PMINER

### 1. DESCRIPTION

Introduction

The characteristic data delineating the contribution of the half breadth plating to the total area and section modulus of the midship section were generated by subroutine WTSMOD for all available plating thicknesses, up to one inch maximum. This information is imbedded in subroutine PMINER in such a way that, given an input of the plating thickness, the appropriate information detailing the effects of the plating on the total area and section modulus is provided.

Inputs

| Symbol | Meaning |
|---|---|
| THL | Plating thickness. (Inches) |

Calculated Items

None. Subroutine PMINER merely selects the correct values of BLMOM, AREAPT, XMOMIN, and XINER (defined below) for the given input value of plating thickness.

Output

| Symbol | Meaning |
|---|---|
| BLMOM | Moment about the base line for the half breadth plating. (Inches$^2$ Feet) |
| AREAPT | Total area for the half breadth plating. (Inches$^2$) |
| XMOMIN | Net moment of inertia about the base line for the half breadth plating. (Inches$^2$ Feet$^2$) |
| XINER | Moment of inertia of the <u>total</u> midship section plating about the neutral axis for the plating. (Inches$^2$ Feet$^2$) |

Calling Sequence

Call PMINER (TH1, BLMOM, AREAPT, XMOMIN, XINER)

Sample Input/Output (Computer test run)

| | | | |
|---|---|---|---|
| Input: | TH1 | 0.625 | inches |
| Output: | BLMOM | 6883.683+ | inches$^2$ feet |
| | AREAPT | 472.306+ | inches$^2$ |
| | XMOMIN | 153184.375 | inches$^2$ feet$^2$ |
| | XINER | 105714.562+ | inches$^2$ feet$^2$ |

Fundamental Equations

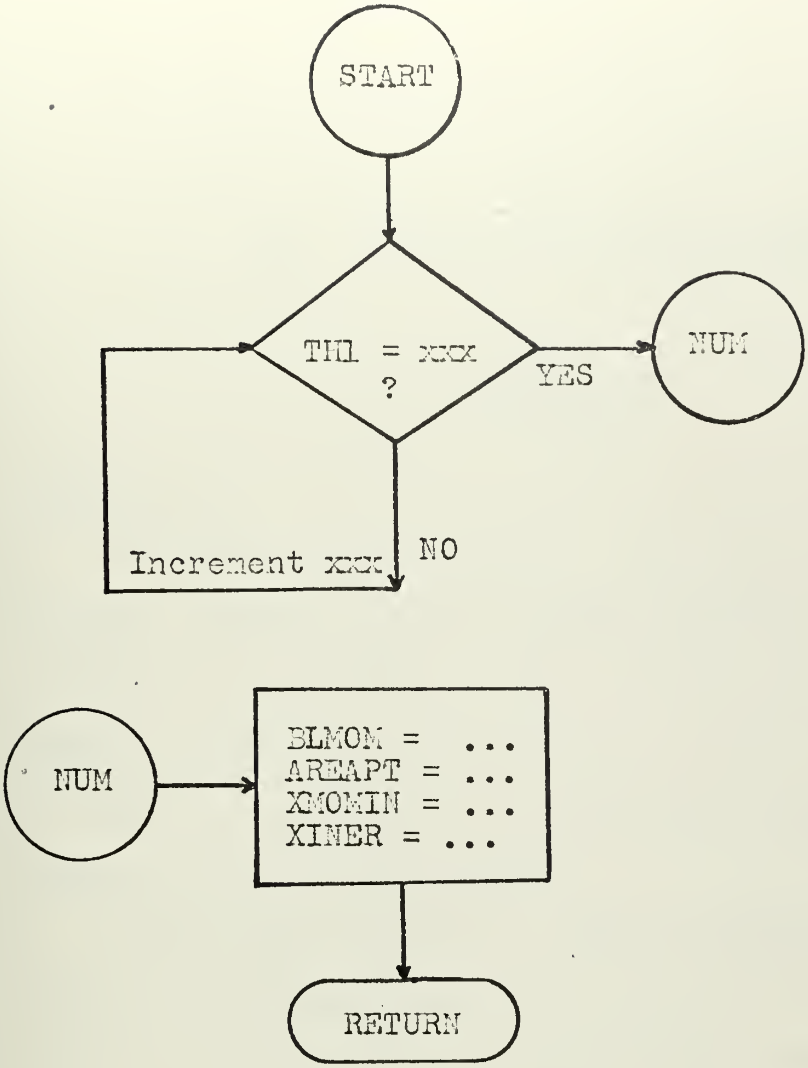
None.

Sample Calculation (Refer to subroutine listing and flow chart, following pages)

None.

```
      SUBROUTINE PMINER (TH1,BLMOM,AREAPT,XMOMIN,XINER)
      IF ((TH1 - 0.25000) .EQ. 0.0) GO TO 17
      IF ((TH1 - 0.28125) .EQ. 0.0) GO TO 18
      IF ((TH1 - 0.31250) .EQ. 0.0) GO TO 19
      IF ((TH1 - 0.34375) .EQ. 0.0) GO TO 20
      IF ((TH1 - 0.37500) .EQ. 0.0) GO TO 21
      IF ((TH1 - 0.43750) .EQ. 0.0) GO TO 22
      IF ((TH1 - 0.50000) .EQ. 0.0) GO TO 23
      IF ((TH1 - 0.62500) .EQ. 0.0) GO TO 24
      IF ((TH1 - 0.75000) .EQ. 0.0) GO TO 25
      IF ((TH1 - 0.87500) .EQ. 0.0) GO TO 26
      IF ((TH1 - 0.93750) .EQ. 0.0) GO TO 27
      IF ((TH1 - 1.00000) .EQ. 0.0) GO TO 28
   17 BLMOM   =  2753.5119629
      AREAPT =    188.9225464
      XMOMIN = 61274.3710937
      XINER   = 42284.8554687
      RETURN
   18 BLMOM   =  3097.7021484
      AREAPT =    212.5378418
      XMOMIN = 68933.5
      XINER   = 47570.0546875
      RETURN
   19 BLMOM =   3441.895752
      AREAPT =    236.1531372
      XMOMIN = 76592.5625
      XINER   = 52854.8671875
      RETURN
   20 BLMOM   =  3786.0852051
      AREAPT =    259.7683105
      XMOMIN = 84251.5625
      XINER =  58139.7304687
      RETURN
   21 BLMOM   =  4130.2734375
      AREAPT =    283.3835449
      XMOMIN = 91910.625
      XINER =  63424.9726562
      RETURN
   22 BLMOM   =  4818.6132812
      AREAPT =    330.6142578
      XMOMIN =107228.8125
      XINER   = 73997.5625
      RETURN
   23 BLMOM   =  5506.96875
      AREAPT =    377.8449707
      XMOMIN =122547.25
      XINER   = 84569.8125
      RETURN
```

```
 24   BLMOM   =  6883.6835937
      AREAPT  =   472.3061523
      XMOMIN =153184.375
      XINER =105714.5625
      RETURN
 25   BLMOM   =  8260.421875
      AREAPT  =   566.7675781
      XMOMIN =183821.125
      XINER   =126857.125
      RETURN
 26   BLMOM   =  9637.1679687
      AREAPT  =   661.2287598
      XMOMIN =214458.25
      XINER   =148000.
      RETURN
 27   BLMOM   = 10325.5351562
      AREAPT  =   708.4592285
      XMOMIN =229777.25
      XINER   =158572.5625
      RETURN
 28   BLMOM   = 11013.9257812
      AREAPT  =   755.6901855
      XMOMIN =245096.0625
      XINER =169143.625
      RETURN
      END
```




(Tabulated values, to be inserted above)

| xxx | NUM | BLMOM | AREAPT | XMOMIN | XINER |
|---|---|---|---|---|---|
| 0.25 | 17 | 2753.5+ | 118.9+ | 61274.+ | 42284.+ |
| 0.28125 | 18 | 3097.7+ | 212.5+ | 68933.+ | 47570.+ |
| 0.3125 | 19 | 3441.8+ | 236.1+ | 76592.+ | 52854.+ |
| 0.34375 | 20 | 3786.0+ | 259.7+ | 84251.+ | 58139.+ |
| 0.375 | 21 | 4130.2+ | 283.3+ | 91910.+ | 63424.+ |
| 0.4375 | 22 | 4818.6+ | 330.6+ | 107228.+ | 73997.+ |
| 0.5 | 23 | 5506.9+ | 377.8+ | 122547.+ | 84569.+ |
| 0.625 | 24 | 6883.6+ | 472.3+ | 153184.+ | 105714.+ |
| 0.75 | 25 | 8260.4+ | 566.7+ | 183821.+ | 126857.+ |
| 0.875 | 26 | 9637.1+ | 661.2+ | 214458.+ | 148000. |
| 0.9375 | 27 | 10325.5+ | 708.4+ | 229777.+ | 158572.+ |
| 1.0 | 28 | 11013.9+ | 755.6+ | 245096.+ | 169143.+ |

FIGURE IX

SUBROUTINE PMINER FLOW CHART

## H. SUBORDINATE PROGRAM SHDATA

### 1. DESCRIPTION

**Introduction**

Program SHDATA generates input data required for main program RUNSCORE (after further manipulation by subroutine PLTGTH). The midship section molded form of DD-931, originally defined by a series of nineteen cubic equations,* is defined in detail by a mesh of one hundred ninety-one points by subroutine SHDATA.

Each cubic equation, with one coordinate variable defined in terms of the other, is used to generate ten points on the surface of the midship section shell molded form. The final point defines the shell-plating intersection. The output of this subroutine is then used as an input to program PTLGTH, which calculates the distance between adjacent points.

**Inputs**

| Symbol | Meaning |
|---|---|
| COORD1 | The dependent variable. (Y or Z) |

---

*Provided by courtesy of Mr. Lee Mount of J. J. Henry Co., Inc.

| Symbol | Meaning |
|---|---|
| COORD2 | The independent variable. (Z or Y) |
| NOSEG | The number of the cubic equation. (From 1 through 19) |
| PTMIN | Minimum value of the independent variable. (Feet) |
| PTMAX | Maximum value of the independent variable. (Feet) |
| AA | Fixed quantity in the cubic equation. |
| BB | Coefficient of the first power independent variable. |
| CC | Coefficient of the second power independent variable. |
| DD | Coefficient of the third power independent variable. |

Calculated Items

| Symbol | Meaning |
|---|---|
| VV | The independent variable. (Feet) |
| SUM | The dependent variable. (Feet) |
| DIFF | Range of the independent variable. (Feet) |

Output

| Symbol | Meaning |
|---|---|
| EE | Half breadth of point. (Feet) |
| FF | Height of point above base line. (Feet) |

Sample Input/Output (Computer test run)

Input:

| | | |
|---|---|---|
| COORD1 | Z | |
| COORD2 | Y | |
| NOSEG | 1 | |
| PTMIN | 0.0 | Feet |
| PTMAX | 2.0 | Feet |
| AA | 0.0000 | |
| BB | 0.023692 | |
| CC | 0.0000 | |
| DD | 0.00058957 | |

Output:

| Segment | Point | Y | Z |
|---|---|---|---|
| 1 | 1 | 0.00 | 0.000000 |
| 1 | 2 | 0.20 | 0.004743 |
| 1 | 3 | 0.40 | 0.009515 |
| 1 | 4 | 0.60 | 0.014343 |
| 1 | 5 | 0.80 | 0.019255 |
| 1 | 6 | 1.00 | 0.024282 |
| 1 | 7 | 1.20 | 0.029449 |
| 1 | 8 | 1.40 | 0.034787 |
| 1 | 9 | 1.599999 | 0.040322 |
| 1 | 10 | 1.799999 | 0.046084 |

Fundamental Equations

$$SUM = AA + BB \times VV + CC \times VV^2 + DD \times VV^3$$

$$VV = VV + STEP$$

$$STEP = DIFF / 10.$$

$$DIFF = PTMAX - PTMIN$$

Sample Calculation (Refer to subordinate program listing and flow chart, following pages)

$$DIFF = PTMAX - PTMIN$$
$$= \underline{2.0}$$

$$STEP = 2.0 / 10.$$
$$= \underline{0.20}$$

$$VV = \underline{0.20}$$

$$SUM = 0.023692 \times VV + 0.00058957 \times VV^3$$
$$= \underline{0.004743}$$

```
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        COMPILER OPTIONS - NAME=  MAIN,OPT=00,LINECNT=50,SOURCE,BCD,NOLIST,DE

  ISN 0002        901 FORMAT (2A1,I3,6F10.5)
  ISN 0003        902 FORMAT (1H0,A1,15H A FUNCTION OF ,A1,9H SEGMENT ,I2,7H POI
                     1I4+H X= 205.500000,3H Y=,F10.6,3H Z=, F10.6)
  ISN 0004        903 READ (5,901) COORD1,COORD2,NOSEG,PTMIN,PTMAX,AA,BB,CC,DD
  ISN 0005            DIFF = PTMAX - PTMIN
  ISN 0006            STEP = DIFF / 10.
  ISN 0007            VV = PTMIN
  ISN 0008            DO 907 I = 1, 10
  ISN 0009            SUM = AA & BB*VV & CC*(VV**2) & DD*(VV**3)
  ISN 0010            IF (NOSEG .GT. 7) GO TO 905
  ISN 0012            EE = SUM
  ISN 0013            FF = VV
  ISN 0014            GO TO 906
  ISN 0015        905 EE = VV
  ISN 0016            FF = SUM
  ISN 0017        906 WRITE (6,902) COORD1,COORD2,NOSEG,I,FF,EE
  ISN 0018        904 WRITE (7,902) COORD1,COORD2,NOSEG,I,FF,EE
  ISN 0019        907 VV = VV & STEP
  ISN 0020            IF ((NOSEG - 22) .EQ. 0) GO TO 917
  ISN 0022            GO TO 903
  ISN 0023        917 STOP
  ISN 0024            END
```
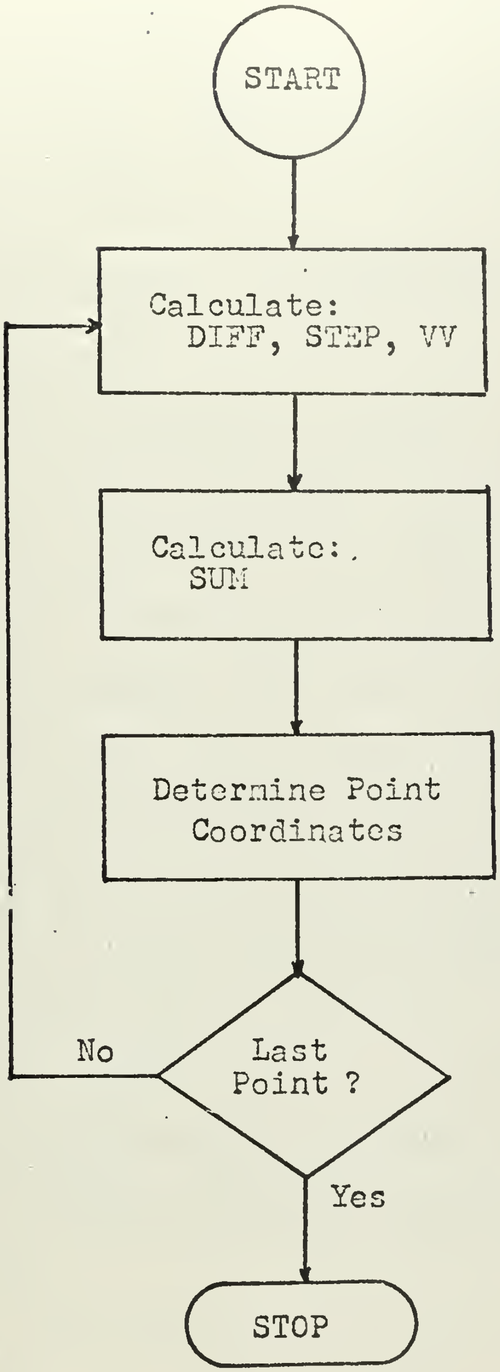

}




Solve the cubic equation for the value of the dependent variable.

Assign offset and height above base line for point.

Continue solving for shell structure.

FIGURE X

SUBORDINATE PROGRAM SHDATA FLOW CHART

# I. SUBORDINATE PROGRAM DKDATA

## 1. DESCRIPTION

### Introduction

Program DKDATA is designed to generate a series of points on the molded deck of the midship section of DD-931. The half breadths of the points are determined on the basis of the angle of the sine function used to define the height of the camber curve. For the deck edge, the sine equals zero, while the value is one at the centerline. A direct correlation between the angle involved and the half breadth is maintained—if the angle is forty-five degrees, the point defined exists at exactly half the maximum breadth of the molded deck plating.

One hundred points are defined, equivalent to ten cubic segments with ten points evaluated on each, as in program SHDATA. One added point defines the centerline of the deck.

### Inputs

| Symbol | Meaning |
|---|---|
| COORD1 | The dependent variable. (Z) |
| COORD2 | The independent variable. (Y) |
| ZMIN | The height of the deck edge above the base line. (Feet) |

| Symbol | Meaning |
|---|---|
| ZMAX | The height of the deck centerline above the base line. (Feet) |
| YMAX | The half breadth of the deck edge. (Feet) |

Calculated Items

| Symbol | Meaning |
|---|---|
| STEP | Angular increment for the sine function. (Radians) |
| YYY | Increment of the halfbreadth for adjacent points. (Feet) |
| FF/YBEG | Offsets of the point. (Feet) |
| DIFF | Height difference between the deck edge and the deck centerline. (Feet) |
| NOSEG | "Segment" number—for uniformity with SHDATA output. |
| I | "Point" number within the segment. |
| ANGLE | Angle to be used for the camber calculation of the height of the deck. (Radians) |

Output

| Symbol | Meaning |
|---|---|
| FF | Offsets to the point. (Feet) |
| EE | Height of the point above the base line. (Feet) |

Sample Input/Output (Computer test run)

| Input: | | | |
|---|---|---|---|
| | COORD1 | Z | |
| | COORD2 | Y | |
| | ZMIN | 25.239594 | Feet |
| | ZMAX | 26.231247 | Feet |
| | YMAX | 22.343796 | Feet |

| Output: | Segment | Point | Y | Z |
|---|---|---|---|---|
| | 20 | 1 | 22.343796 | 25.239594 |
| | 20 | 2 | 22.120346 | 25.255157 |
| | 20 | 3 | 21.896896 | 25.270737 |
| | 30 | 1 | -0.000348 | 26.231247 |

Fundamental Equations

STEP = THETA / 100.

YYY = YMAX / 100.

YBEG = YMAX, later = YBEG - YYY

DIFF = ZMAX - ZMIN

ANGLE = ANGLE + STEP

EE = ZMIN + DIFF x SIN(ANGLE)

FF = YBEG

Sample Calculation (Refer to subroutine listing and flow chart, following pages)

STEP = 0.015708

YYY = 0.22343796

YBEG = 22.343796

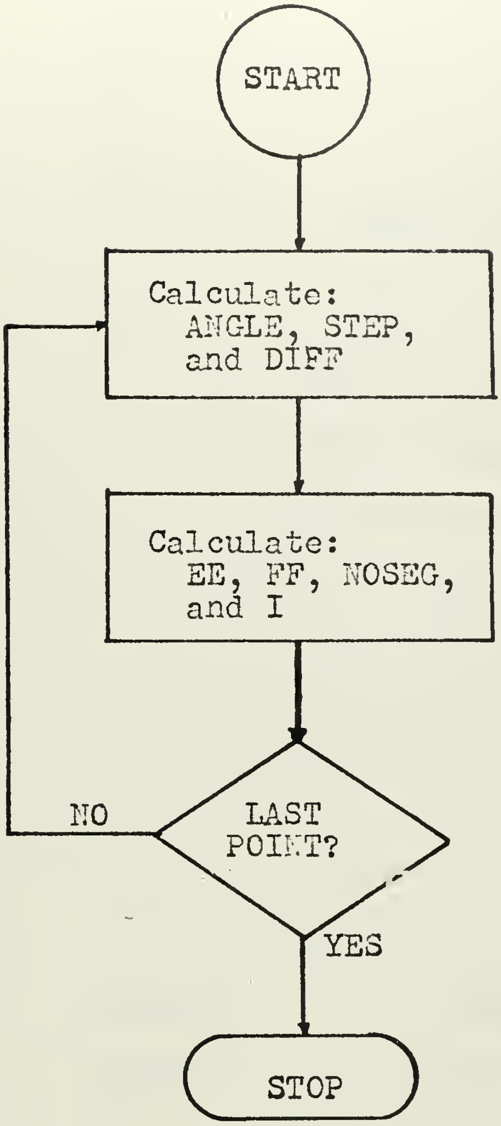
DIFF = 0.991653

EE = 25.239594 + 0.991653 x Sin (0.)
= 25.239594

FF = 22.343796

COMPILER OPTIONS - NAME= MAIN,OPT=00,LINECNT=50,SOURCE,BCD,NOLIST,DE

```
ISN 0002      901 FORMAT (2A1,3F10.6)
ISN 0003      902 FORMAT (1H0,A1,15H A FUNCTION OF , A1,9H SEGMENT ,I2,7H PO
                 114H X= 203.500000,3H Y=,F10.6,3H Z=, F10.6)
ISN 0004      903 READ (5,901) COORD1, COORD2, ZMIN , ZMAX, YMAX
ISN 0005          THETA = 0.5 * 3.1415927
ISN 0006          STEP = THETA / 100.
ISN 0007          FF = 0.0
ISN 0008          DIFF = ZMAX - ZMIN
ISN 0009          ANGLE = 0.0
ISN 0010          YYY = YMAX / 100.
ISN 0011          YBEG = YMAX
ISN 0012          AA = 0.05
ISN 0013          DO 907 J = 1, 101
ISN 0014          FF = YBEG
ISN 0015          EE = ZMIN & DIFF * SIN(ANGLE)
ISN 0016          NOSEG = AA
ISN 0017          K = AA
ISN 0018          AK = K
ISN 0019          I = 10.0 * (AA & 0.1) - 10.0 * AK
ISN 0020          IF (I .EQ. 0) GO TO 910
ISN 0022          GO TO 909
ISN 0023      910 I = 10
ISN 0024      909 AA = AA & 0.1
ISN 0025          NOSEG = NOSEG & 20
ISN 0026      904 WRITE (6,902) COORD1, COORD2, NOSEG, I, FF, EE
ISN 0027      905 WRITE (7,902) COORD1, COORD2, NOSEG, I, FF, EE
ISN 0028          YBEG = YBEG - YYY
ISN 0029      907 ANGLE = ANGLE & STEP
ISN 0030          STOP
ISN 0031          END
```




Determine the initial angle and the increments of the angles and offsets.

Determine the point coordinates.

FIGURE XI

SUBORDINATE PROGRAM DKDATA FLOW CHART

# J. SUBORDINATE PROGRAM PTLGTH

## 1. DESCRIPTION

### Introduction

Program PTLGTH uses the outputs of SHDATA and DKDATA to calculate the distance between adjacent points, based on the assumption that the distance between two points can be closely approximated by a straight line segment. In view of the short distances involved, this results in a relatively precise calculation. The center of gravity of the short segment so defined is evaluated by linear interpolation.

### Inputs

| Symbol | Meaning |
|---|---|
| NOSEG1 | Segment number of initial point. |
| I1 | Point number of initial point. |
| YPT1 | Half breadth of initial point. (Feet) |
| ZPT1 | Height of initial point above base line. (Feet) |
| NOSEG2 | Segment number of next point. |
| I2 | Point number of next point. |
| YPT2 | Half breadth of next point. (Feet) |
| ZPT2 | Height of next point above base line. (Feet) |

Output

| Symbol | Meaning |
|---|---|
| DIST | Distance from initial to next point. (Feet) |
| ZCGPT | Height of mid point of DIST above base line. (Feet) |

Sample Input/Output (Computer test run)

| | | | |
|---|---|---|---|
| Input: | NOSEG1 | 1 | |
| | I1 | 1 | |
| | YPT1 | 0.0 | Feet |
| | ZPT1 | 0.0 | Feet |
| | NOSEG2 | 1 | |
| | I2 | 2 | |
| | YPT2 | 0.200000 | Feet |
| | ZPT2 | 0.004743 | Feet |
| Output: | DIST | 0.200056 | Feet |
| | ZCGPT | 0.002371 | Feet |

Fundamental Equations

$$DIST = \sqrt{(YPT2 - YPT1)^2 + (ZPT2 - ZPT1)^2}$$

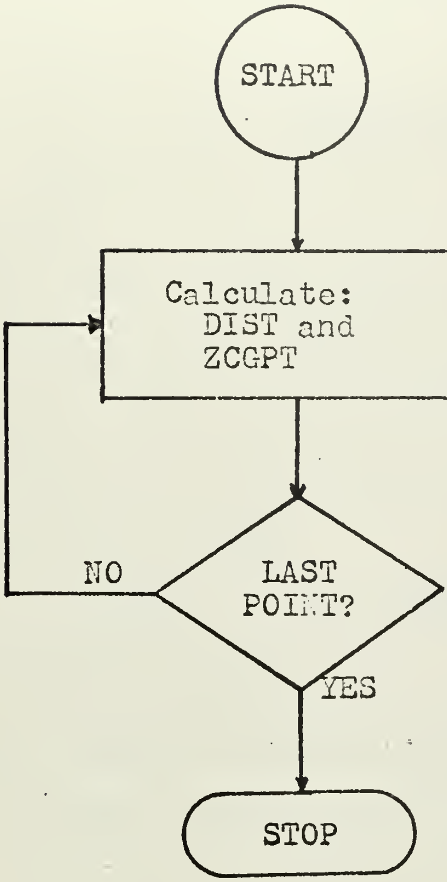
$$ZCGPT = 0.5 \times (ZPT1 + ZPT2)$$

Sample Calculation (Refer to subroutine listing and flow chart, following pages)

$$DIST = \sqrt{(0.20000)^2 + (0.004743)^2}$$
$$= \underline{0.200056}$$

$$ZCGPT = 0.5 \times (0.004743)$$
$$= \underline{0.002371}$$

```
LEVEL 02 NOV. 65                                          OS/360  FORTRAN H

        COMPILER OPTIONS - NAME=  MAIN,OPT=00,LINECNT=50,SOURCE,BCD,NOLIST,D

  ISN 0002          901 FORMAT (27X,I2,7X,I2,17X,F10.6,3X,F10.6)
  ISN 0003              READ (5,901) NOSEG1, I1, YPT1, ZPT1
  ISN 0004          902 READ (5, 901) NOSEG2, I2, YPT2, ZPT2
  ISN 0005              DIST = SQRT ((YPT2 - YPT1)**2 & (ZPT2 - ZPT1)**2)
  ISN 0006              ZCGPT = 0.5 * (ZPT1 & ZPT2)
  ISN 0007          904 FORMAT (1H0, 9H SEGMENT ,I2,9H   POINT , I2, 4(2X,F10.6))
  ISN 0008              WRITE (6,904) NOSEG1,I1,YPT1,ZPT1,DIST,ZCGPT
  ISN 0009              WRITE (7,904) NOSEG1,I1,YPT1,ZPT1,DIST,ZCGPT
  ISN 0010              IF ((NOSEG2 - 30) .EQ. 0) GO TO 911
  ISN 0012              NOSEG1 =NOSEG2
  ISN 0013              I1 = I2
  ISN 0014              YPT1 = YPT2
  ISN 0015              ZPT1 = ZPT2
  ISN 0016              GO TO 902
  ISN 0017          911 DIST = 0.0
  ISN 0018              WRITE (6,904) NOSEG2,I2,YPT2,ZPT2,DIST,ZPT2
  ISN 0019              WRITE (7,904) NOSEG2,I2,YPT2,ZPT2,DIST,ZPT2
  ISN 0020              STOP
  ISN 0021              END
```




Determine the distance between two points and the height of the mid-point above the base line.

FIGURE XII

SUBORDINATE PROGRAM <u>PTLGTH</u> FLOW CHART

## K. SUBORDINATE PROGRAM WTSMOD

### 1. DESCRIPTION

Introduction

Subordinate program WTSMOD calculates the total girth, plating weight, moment of inertia, and location of the neutral axis for the midship section plating. The calculation of the section modulus is based on the following equation: [2]

$$XMDIZ = 2.0 \times \frac{BLMOM^2 - (AREAPT \times XMOMIN)}{BLMOM - AREAPT \times ZCOORD}$$

The output of PTLGTH is used as an input to WTSMOD. Each small segment between points on the girth is treated as a rectangular segment with a width equal to the specified thickness of the plating. The component values used in the calculation of the section modulus are stored in Subroutine PMINER for eventual use in Main Program RUNSCORE.

Inputs

| Symbol | Meaning |
|---|---|
| PTDATA(I,J,1) | Half-breadth of point (I,J). (Feet) |
| PTDATA(I,J,2) | Height of point (I,J) above base line. (Feet) |
| PTDATA(I,J,3) | Distance from point (I,J) to next point. (Feet) |

| Symbol | Meaning |
|---|---|
| PTDATA(I,J,4) | Height of midpoint of PTDATA (I,J,3) above base line. (Feet) |
| WPERIN | Weight of the structural material. (Pounds per inch thickness of a one square foot plate) |
| TH1 | Plating thickness. (Inches) |

Calculated Items

| Symbol | Meaning |
|---|---|
| GIRTH | Total distance between points for the half breadth. (Feet) |
| AA | Intermediate value used in calculating XMOMIN. |
| BB | Intermediate value used in calculating XMOMIN. |

Output

| Symbol | Meaning |
|---|---|
| WTPRFT | Total weight of the plating. (Pounds or Tons per foot) |
| GIRX2 | Total circumference of the midship section plating. (Feet) |
| BLMOM | Moment of the plating about the base line. (In.$^2$ Feet) |
| AREAPT | Cross-sectional area of the plating. (In.$^2$) |
| XMOMIN | Moment of inertia of the plating about the base line. (In.$^2$ Ft.$^2$) |
| XMD1K | Section modulus at the keel. (In.$^2$ Feet) |
| XMD1D | Section modulus at the deck. (In.$^2$ Feet) |
| ZNAX | Height of the center of gravity of the plating above the base line. (Feet) |
| XINER | Moment of inertia of the plating about ZNAX. (In.$^2$ Ft.$^2$) |

Sample Input/Output (Computer test run)

Input:

| | | PTDATA(I,J,1) | PTDATA(I,J,2) | PTDATA(I,J,3) |
|---|---|---|---|---|
| I=1 | J=1 | 0.0 | 0.0 | 5.0 |
| | 2 | 3.0 | 4.0 | 5.0 |
| | 3 | 6.0 | 8.0 | 5.0 |
| | 4 | 9.0 | 12.0 | 5.0 |
| | 5 | 12.0 | 16.0 | 0.0 |

| | | |
|---|---|---|
| PTDATA(1,1,4) | 2.0 | Feet |
| PTDATA(1,2,4) | 6.0 | Feet |
| PTDATA(1,3,4) | 10.0 | Feet |
| PTDATA(1,4,4) | 14.0 | Feet |
| PTDATA(1,5,4) | 0.0 | Feet |
| WPERIN | 40.8 | Pounds per in. per sq. ft. |
| TH1 | 0.25 | Inches |

Output:

| | | |
|---|---|---|
| WTPRFT | 408.0 | Pounds per foot |
| GIRX2 | 40.0 | Feet |
| BLMOM | 480.0 | $\text{In.}^2$ Ft. |
| AREAPT | 60.0 | $\text{In.}^2$ |
| XMOMIN | 5120.0 | $\text{In.}^2\ \text{Ft.}^2$ |
| XMD1K | 320.0 | $\text{In.}^2$ Ft. |
| XMD1D | 140.42 | $\text{In.}^2$ Ft. |
| ZNAX | 8.0 | Feet |
| XINER | 2560.0 | $\text{In.}^2\ \text{Ft.}^2$ |

Fundamental Equations

$$\text{GIRTH} = \text{GIRTH} + \text{PTDATA(I,J,3)}$$

$$\text{WTPRFT} = 2.0 \times \text{GIRTH} \times \text{WPERIN} \times \text{TH1}$$

$$\text{GIRX2} = 2.0 \times \text{GIRTH}$$

$$\text{AA} = 0.08333 \times \text{TH1} \times \text{PTDATA(I,J,3)}$$

$$\text{BB} = \text{TH1}^2 \times \left(\frac{\text{PTDATA(I+1,1,1,)} - \text{PTDATA(I,J,1)}}{\text{PTDATA(I,J,3)}}\right)^2 + 144. \times (\text{PTDATA(I+1,1,2)} - \text{PTDATA(I,J,2)})^2$$

$$\text{BLMOM} = \text{BLMOM} + 12. \times \text{TH1} \times \text{PTDATA(I,J,3)} \times \text{PTDATA(I,J,4)}$$

$$\text{AREAPT} = 12. \times \text{GIRTH} \times \text{TH1}$$

$$\text{XMOMIN} = \text{XMOMIN} + 0.0833 \times \text{AA} \times \text{BB} + 12. \times \text{TH1} \times \text{PTDATA(I,J,3)} \times \text{PTDATA(I,J,4)}^2$$

$$\text{XMD1K} = 2.0 \times \left(\frac{\text{BLMOM}^2 - \text{AREAPT} \times \text{XMOMIN}}{\text{BLMOM}}\right)$$

$$XMD1D = 2.0 \times \frac{BLMOM^2 - AREAPT \times XMOMIN}{BLMOM - 26.23125 \times AREAPT}$$

$$ZNAX = \frac{BLMOM}{AREAPT}$$

$$XINER = XMD1K \times ZNAX$$

<u>Sample</u> <u>Calculation</u> (Refer to subroutine listing and flow chart, following pages)

$$XINER = \frac{1}{12} \times \frac{1}{4} \times 20 \times \left[\frac{1}{192} \times \left(\frac{3}{5}\right)^2 + 4800 \times \left(\frac{4}{5}\right)^2\right]$$

$$= \underline{2,560} \text{ in.}^2 \text{ ft.}^2$$

```
 COMPILER OPTIONS - NAME=  MAIN,OPT=00,LINECNT=50,SOURCE,BCD,NOLIST,DECK,LOAD,M
002          DIMENSION PTDATA (30,10,4)
003      900 FORMAT (2F20.7)
004      901 FORMAT (23X,4(2X,F10.6))
005          DO 907 I = 1, 29
006          DO 907 J=1, 10
007          READ (5, 901) PTDATA (I,J,1),PTDATA(I,J,2),PTDATA(I,J,3),
            1 PTDATA(I,J,4)
008      907 CONTINUE
009          I = 30
010          J = 1
011          READ (5, 901) PTDATA(I,J,1),PTDATA(I,J,2),PTDATA(I,J,3),
            1 PTDATA(I,J,4)
012          DO 910 J = 2, 10
013          DO 910 K = 1, 4
014      910 PTDATA (I,J,K) = 0.0
015      888 READ (5,900) WPERIN, TH1
016          IF ((WPERIN - 100.) .GT. 0) GO TO 999
018       84 FORMAT ('1  PLATING THICKNESS =',F10.6,' INCHES')
019       85 FORMAT ('   WEIGHT =',F10.6,' POUNDS PER SQ. FT. PER INCH THICKNES
            1S')
020          WRITE (6, 84) TH1
021          GIRTH = 0.0
022          DO 800 I = 1, 30
023          DO 800 J = 1, 10
024      800 GIRTH = GIRTH & PTDATA(I,J,3)
025          WTPRFT = 2.0 * GIRTH * WPERIN * TH1
026      801 FORMAT ('0 PLATING WEIGHT =',F20.7,' POUNDS PER FOOT')
027      802 FORMAT ('  PLATING WEIGHT =',F20.7,' TONS PER FOOT')
028      803 FORMAT ('0 TOTAL MIDSHIP SECTION GIRTH =',F15.7,' FEET')
029          GIRX2 = 2.0 * GIRTH
030          WRITE (6,803) GIRX2
031          WRITE (6,801) WTPRFT
032          WTPRFT = WTPRFT / 2240.
033          WRITE (6, 802) WTPRFT
034          WRITE (6,85) WPERIN
035          BLMOM = 0.0
036          AREAPT = GIRTH * TH1 * 12.0
037          DO 400 I = 1, 29
038          DO 400 J = 1, 10
039      400 BLMOM = BLMOM & 12. * TH1 * PTDATA(I,J,3) * PTDATA (I,J,4)
040          XMOMIN = 0.0
041          DO 500 I = 1, 29
042          DO 500 J = 1, 10
043          AA = 0.083333 * TH1 * PTDATA (I,J,3)
044          IF ((J - 10) .NE. 0) GO TO 501
046          BB = (TH1**2)*((PTDATA(I&1,1,1)-PTDATA(I,J,1))/PTDATA(I,J,3))**2 &
            1 ((PTDATA(I&1,1,2) - PTDATA(I,J,2))**2) * 144.
047          GO TO 600
048      501 BB = (TH1**2)*((PTDATA(I,J&1,1) - PTDATA(I,J,1))/PTDATA(I,J,3))**2
```

```
     1 & 144. * (PTDATA(I,J&1,2) - PTDATA(I,J,2))**2
 600 XMOMIN = 0.08333*AA*BB & XMOMIN & 12.* PTDATA(I,J,3)*TH1*PTDATA
    1(I,J,4)**2
 500 CONTINUE
     XMD1K = 2.0 * (((BLMOM**2) - (AREAPT * XMOMIN)) / BLMOM)
     XMD1D = (((BLMOM**2) - (AREAPT*XMOMIN)) /(BLMOM - 26.231247
    1 * AREAPT)) * 2.0
 304 FORMAT ('0  SECTION MODULUS--KEEL =',F20.7,' INCHES**2  FEET')
 305 FORMAT ('0  SECTION MODULUS--DECK =',F20.7,'  INCHES**2 FEET')
 307 FORMAT ('0  MOMENT OF INERTIA IS',F20.7,' INCHES**2  FEET**2')
     ZNAX = BLMOM / AREAPT
     XINER = XMD1K * ZNAX
     WRITE (6,307) XINER
 306 FORMAT ('0  NEUTRAL AXIS IS',F20.7,' FEET ABOVE BASE LINE')
 401 FORMAT ('0  BLMOM =',F20.7,' FT  IN**2')
 402 FORMAT ('0 AREAPT =',F20.7,' IN**2')
 403 FORMAT ('0 XMOMIN =',F20.7,' FT**2  IN**2')
     WRITE (6,401) BLMOM
     WRITE (6,402) AREAPT
     WRITE (6,403) XMOMIN
     WRITE (6,306) ZNAX
     WRITE (6, 304) XMD1K
     WRITE (6, 305) XMD1D
     GO TO 888
 999 STOP
     END
```

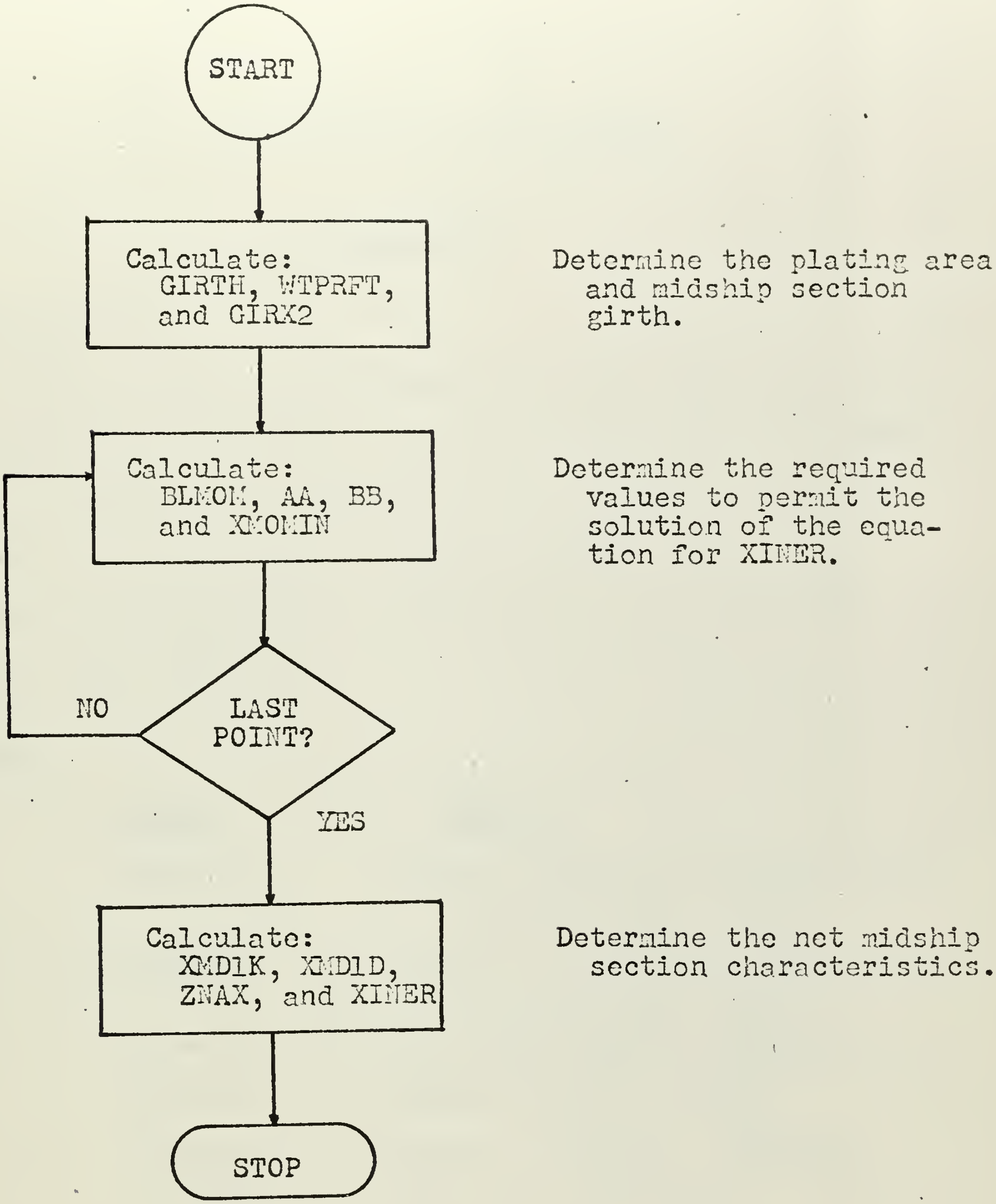



FIGURE XIII

SUBORDINATE PROGRAM <u>WTSMOD</u> FLOW CHART

# L. SUBORDINATE PROGRAM TSHAPE

## 1. DESCRIPTION

### Introduction

Subordinate program TSHAPE calculates the structural characteristics of wide flange sections cut to a T-section. For the purposes of calculating the maximum and minimum moments of inertia and the cross-sectional area, it is assumed that the flange is cut off at a distance 0.125 inches from the web.

### Inputs

| Symbol | Meaning |
|---|---|
| SMAXI(I) | Maximum moment of inertia of the original member, about its neutral axis. (In.$^4$) |
| SMINI(I) | Minimum moment of inertia of the original member, about its neutral axis. (In.$^4$) |
| SAREA(I) | Cross-sectional area of the original member. (In.$^2$) |
| SFLGW(I) | Flange width. (Inches) |
| SFLGTH(I) | Flange thickness. (Inches) |
| SDEPTH(I) | Web depth. (Inches) |
| SWEBTH(I) | Web thickness. (Inches) |
| SCOST(I) | Acquisition cost. (Dollars/Foot length) |

Calculated Items

| Symbol | Meaning |
|---|---|
| SM | Moment of the cut member about the cut flange. (In.$^3$) |
| SA | Cross-sectional area of the cut member. (In.$^2$) |
| SI | Moment of inertia of the cut member about the cut flange. (In.$^4$) |
| SMAXI(I) | Maximum moment of inertia of the cut member, about its neutral axis. (In.$^4$) |
| SMINI(I) | Minimum moment of inertia of the cut member, about its neutral axis. (In.$^4$) |
| SAREA(I) | Cross-sectional area of the cut member. (In.$^2$) |
| SFLGW(I) | Flange width. (Inches) |
| SFLGTH(I) | Flange thickness. (Inches) |
| SDEPTH(I) | Web depth. (Inches) |
| SWEBTH(I) | Web thickness. (Inches) |
| SCOST(I) | Acquisition cost. (Dollars/Foot length) |
| VCG(I) | Distance of the neutral axis from the cut flange. (Inches) |

Sample Input/Output (Computer test run)

| | | | |
|---|---|---|---|
| Input: | SMAXI(1) | 21.70 | In.$^4$ |
| | SMINI(1) | 2.89 | In.$^4$ |
| | SAREA(1) | 3.53 | In.$^2$ |
| | SFLGW(1) | 4.00 | In. |
| | SFLGTH(1) | 0.279 | In. |
| | SDEPTH(1) | 6.00 | In. |
| | SWEBTH(1) | 0.23 | In. |
| | SCOST(1) | 2.00 | Dollars/Foot |
| Output: | SMAXI(1) | 10.56 | In.$^4$ |
| | SMINI(1) | 1.40 | In.$^4$ |
| | SAREA(1) | 2.55 | In.$^2$ |
| | SFLGW(1) | 4.00 | In. |
| | SFLGTH(1) | 0.279 | In. |
| | SDEPTH(1) | 6.00 | In. |
| | SWEBTH(1) | 0.23 | In. |
| | SCOST(1) | 2.00 | Dollars/Foot |
| | VCG(1) | 4.10 | In. |

Fundamental Equations

$$VCG(I) = \left[ \frac{0.5 \times SDEPTH(I) \times SAREA(I) - 0.5 \times SFLGTH(I)^2 \times (SFLGW(I) - .25 - SWEBTH(I))}{SAREA(I) - SFLGTH(I) \times (SFLGW(I) - .25 - SWEBTH(I))} \right]$$

$$SM = 0.5 \times SDEPTH(I) \times SAREA(I) - 0.5 \times SFLGTH(I)^2 \times (SFLGW(I) - .25 - SWEBTH(I))$$

$$SA = SAREA(I) - SFLGTH(I) \times (SFLGW(I) - .25 - SWEBTH(I))$$

$$SI = SMAXI(I) + SAREA(I) \times (0.5 \times SDEPTH(I))^2 - 0.0833 \times (SFLGW(I) - .25 - SWEBTH(I)) \times SFLGTH(I)^3 - (SAREA(I) - SA) \times (0.5 \times SFLGTH(I))^2$$

$$SMAXI(I) = \frac{VCG(I) \times ((SA \times SI) - SM^2)}{SM}$$

$$SMINI(I) = SMINI(I) - 0.1667 \times SFLGTH(I) \times (0.5 \times (SFLGW(I) - .25 - SWEBTH(I)))^3 - (SAREA(I) - SA) \times (0.125 + 0.5 \times SWEBTH(I) + 0.25 \times (SFLGW(I) - .25 - SWEBTH(I)))^2$$

$$SAREA(I) = SAREA(I) - SFLGTH(I) \times (SFLGW(I) - .25 - SWEBTH(I))$$

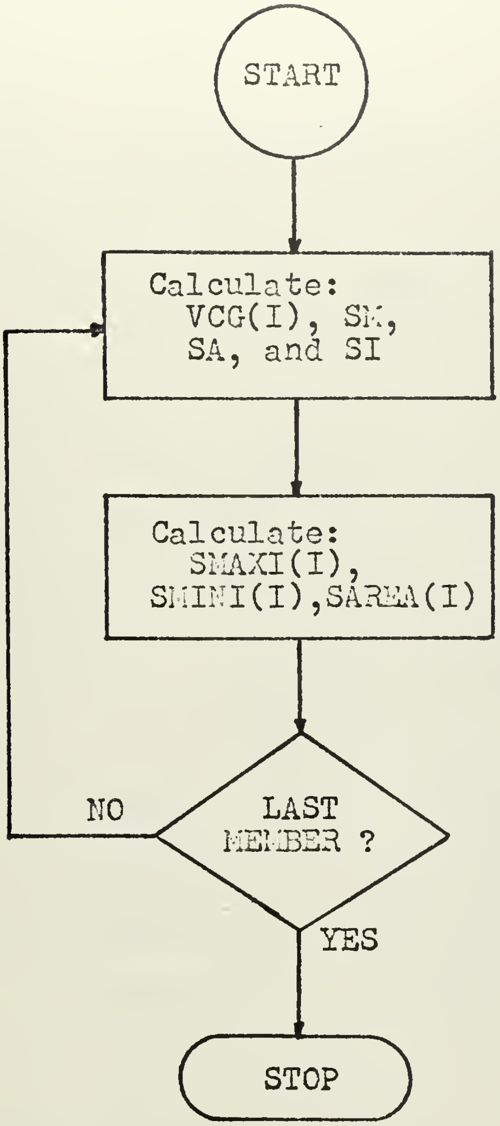
Sample Calculation (Refer to subordinate program listing and flow chart, following pages)

$$VCG(1) = \frac{0.5 \times 6. \times 3.53 - 0.5 \times .279^2 \times 3.52}{3.53 - 0.279 \times 3.52} = \underline{4.10}$$

$$SMAXI(1) = 21.70 - 0.1667 \times 1.76 \times 0.279^3 - (0.279 \times 3.52) \times (3.0 - 0.1395)^2 = \underline{10.56}$$

$$SMINI(I) = 2.89 - 0.1667 \times 0.279 \times 1.76^3 - (0.279 \times 3.52) \times 1.12^2 = \underline{1.40}$$

```
02 NOV. 65                                    OS/360  FORTRAN H

   COMPILER OPTIONS - NAME=  MAIN,OPT=00,LINECNT=50,SOURCE,BCD,NOLIST,DECK,LOAD
0002          DIMENSION SMAXI(9),SMINI(9),SAREA(9),SFLGW(9),SFLGTH(9),SDEPTH(9)
             1 SWEBTH(9),VCG(9),SCOST(9)
0003      400 FORMAT (8F10.5)
0004      401 FORMAT (1H1,3X,'MAX. INERTIA',3X,'MIN. INERTIA',7X,'AREA',7X,
             1 'FLANGE WIDTH', 4X,'THICKNESS',6X,'WEB DEPTH',6X,'THICKNESS',
             2 9X,'COST')
0005      402 FORMAT (1X,2(3X,'    IN**4    '),4X,'SQ. INCHES',7X,'INCHES',
             1 3(9X,'INCHES'),7X,'DOLLARS/FT.')
0006          WRITE (6,401)
0007          WRITE (6,402)
0008          DO 403 I=1,9
0009          READ (5,400) SMAXI(I),SMINI(I),SAREA(I),SFLGW(I),SFLGTH(I),SDEPTH
             1 (I),SWEBTH(I),SCOST(I)
0010      403 CONTINUE
0011      404 FORMAT (1H0,4X,F10.5,7(5X,F10.5))
0012          DO 405 I=1,9
0013          WRITE (6,404) SMAXI(I),SMINI(I),SAREA(I),SFLGW(I),SFLGTH(I),
             1 SDEPTH(I),SWEBTH(I),SCOST(I)
0014      405 CONTINUE
0015          DO 406 I = 1,9
0016          VCG(I) = ((0.5 * SDEPTH(I) * SAREA(I)) - (0.5 * (SFLGTH(I)**2) *
             1(SFLGW(I)-0.25-SWEBTH(I))))/(SAREA(I)-((SFLGW(I)-0.25-SWEBTH(I))*
             2 SFLGTH(I)))
0017          SA = SAREA(I)*(0.5*SDEPTH(I))-0.5*(SFLGTH(I)**2)*(SFLGW(I)-0.25-
             1 SWEBTH(I))
0018          SA = SAREA(I) - (SFLGW(I) - 0.25 - SWEBTH(I))*SFLGTH(I)
0019          SI = SMAXI(I) & SAREA(I)*(0.5*SDEPTH(I))**2 - 0.08333*(SFLGW(I) -
             1 0.25 - SWEBTH(I))*(SFLGTH(I)**3)-(SAREA(I)-SA)*(0.5 * SFLGTH(I))
             2 **2
0020          SMAXI(I) = VCG(I) * (((SA * SI) - (SM**2)) / SM )
0021          SMINI(I) = SMINI(I) - 0.16667*SFLGTH(I) * (0.5 * (SFLGW(I) - 0.25-
             1 SWEBTH(I)))**3 - (SAREA(I) - SA) * (0.1258 0.5*SWEBTH(I) & 0.25 *
             2 (SFLGW(I) - 0.25 - SWEBTH(I)))**2
0022          SAREA(I) = SAREA(I) - (SFLGW(I) - 0.25 -SWEBTH(I)) * SFLGTH(I)
0023      406 CONTINUE
0024          WRITE (6,401)
0025          WRITE (6,402)
0026      411 FORMAT (15X,'  SHAPE VCG IS ',E10.7,' INCHES FROM EDGE OF CUT FLAN
             1GE')
0027          DO 407 I=1,9
0028          WRITE (6,404) SMAXI(I),SMINI(I),SAREA(I),SFLGW(I),SFLGTH(I),
             1 SDEPTH(I),SWEBTH(I),SCOST(I)
0029          WRITE (6,411) VCG(I)
0030      407 CONTINUE
0031          STOP
0032          END
```




Determine the cut shape VCG and preliminary values for computing SMAXI(I).

Determine the net cut section area and moments of inertia.

FIGURE XIV

SUBORDINATE PROGRAM TSHAPE FLOW CHART

## M. SUBORDINATE SUBROUTINE COSTKL

### 1. DESCRIPTION

Introduction

Subordinate subroutine COSTKL is used to generate the total cost per foot length of the keel structure. The methodology and values used are explained at length in the description of main program COSTDATA.

Inputs

| Symbol | Meaning |
|---|---|
| CKLGTL | Acquisition cost of the keel longitudinal. (Dollars/Foot) |
| CHCMNH | The cost of one man-hour of work. (Dollars) |
| FKTHCK | Thickness of the flanges of the keel longitudinal. (Inches) |

Calculated Items

| Symbol | Meaning |
|---|---|
| CCUTF | Cost of cutting the keel flanges. (Dollars/Foot) |
| CWELD | Cost of welding the keel. (Dollars/Foot) |

Output

| Symbol | Meaning |
|---|---|
| CKEEL | Total cost of the keel structure. (Dollars/Foot) |

<u>Sample Input/Output</u> (Computer test run)

| | | | |
|---|---|---|---|
| Input: | CKLGTL | 9.00 | Dollars/Foot |
| | CHGMNH | 7.50 | Dollars/Hour |
| | FKTHCK | 0.468 | Inches |
| Output: | CKEEL | 27.56 | Dollars/Foot |

<u>Fundamental Equations</u>

CCUTF = 0.2 x CHGMNH

CWELD = 2.2748 x CHGMNH

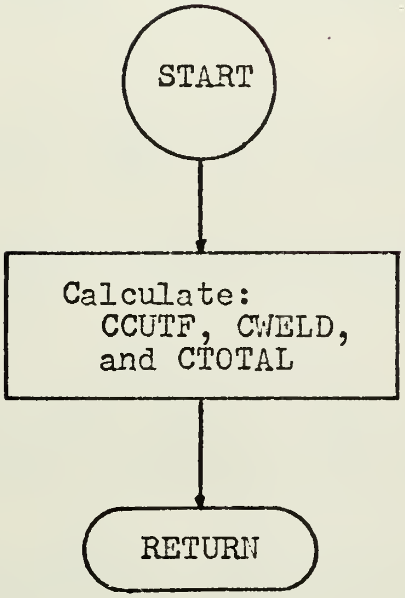
<u>Sample Calculation</u> (Refer to program listing and flow chart, following pages)

CCUTF = <u>1.50</u>

CWELD = <u>17.06</u>

CKEEL = <u>27.56</u>

```
  777 FORMAT (3F20.6)
      READ (5,777) CKLGTL, FKTHCK, CHGMNH
      CALL COSTKL (CKLGTL, FKTHCK, CHGMNH, CKEEL)
  778 FORMAT ('1    ACQUISITION COST =', F10.6)
  779 FORMAT ('0  CHARGE PER MANHOUR =', F10.6)
  780 FORMAT ('0      TOTAL KEEL COST =',F10.6)
      WRITE (6,778) CKLGTL
      WRITE (6,779) CHGMNH
      WRITE (6,780) CKEEL
      STOP
      END
      SUBROUTINE COSTKL (CKLGTL,FKTHCK,CHGMNH,CKEEL)
C
C     CALCULATE THE TOTAL COST CONTRIBUTION OF THE KEEL STRUCTURE.
C
C     FIRST, CALCULATE THE COST OF CUTTING THE FLANGES.
C
      CCUTF = 0.2 * CHGMNH
C
C     CALCULATE THE COST OF WELDING THE SHAPE TO THE PLATING.
C
      CWELD = 2.2748 * CHGMNH
C
C     THE MAN HOUR CHARGES ALLOW FOR MAKE READY AND PUT AWAY, THE WELDING
C     ITSELF, THE CONTINUOUS JOB ALLOWANCE, WIRE BRUSHING, ARC AIR, DYE
C     PENETRANT, AND STRIP HEATER.
C
C     CALCULATE THE TOTAL COST--ACQUISITION, PREPARATION, AND INSTALLATION.
C
      CKEEL = CKLGTL + CCUTF + CWELD
      RETURN
      END
/*
//G.SYSIN DD   *
         9.00                0.775                7.50
```




Determine the cost of the keel member, per foot length.

FIGURE XV

SUBORDINATE SUBROUTINE <u>COSTKL</u> FLOW CHART

REFERENCE LIST

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5. U.S. Navy. Bureau of Ships. Contract Drawing, No. DD 931-S0101-601895-Rev. A., Destroyer (DD931) Midship Section. Wash., D.C., 1952. (Declassified by OPNAV Instruction 5500.40B, dated 1 October 1962.)

6. Evans, J. Harvey. "Optimization of Midshipsection Structure." Paper presented at the Computer-Aided Ship Design and Construction Symposium, Wash., D.C., August 30-31, 1966. (Mimeographed.)

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