STRENGTH OF SHIPS - ON THE NEUTRAL AXIS LOCATION

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ABSTRACT

This work is an attempt at determining the optimum neutral axis location in the midship section of a vessel, using as a model for the calculations a box girder, subject to several different conditions of sagging and hogging bending moments; several values of design stress are also considered and in the end what happens when lateral hydrostatic load is considered along with different values assigned to the design stress in tension and in compression is also analysed.

Thesis Supervisor: J. Harvey Evans

Title: Professor of Naval Architecture

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I want to express my gratitude to Professor Evans for his expert advice and guidance that encouraged me throughout this work.

I want to thank God for giving me the strength to proceed for many years in the path He was so kind to make available to achieve my present education.

My gratitude is here expressed to my wife as well for her patience to accompany and help me to reach my graduation.

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LIST OF SYMBOLS

a	- distance between transverse stiffening members
AL	- length of box girder or vessel
B	- beam
BOT	- thickness of the plating on the bottom
BM	- bending moment
D	- depth
DIBOT	- distance of the bottom from the neutral axis
DITOP	- distance of the top from the neutral axis
DSC	- design stress in compression
DST	- design stress in tension; also design stress without discrimination when DSC=DST
H	- head of sea water (lateral load)
HB	- head of sea water on the bottom
HM	- hogging bending moment
HT	- head of sea water on the top
I	- moment of inertia of the cross section with respect to the neutral axis (GMI in the program)
LBS	- longitudinal bending stress
S	- spacing of longitudinal stiffening members
SBCRIT	- critical stress on bottom
SBH	- stress on bottom due to hogging
SBS	- stress on bottom due to sagging
SM	- sagging bending moment
STCRIT	- critical stress on top
STH	- stress on top due to hogging
STR	- stress

STR1 - primary stress = LBS

STR2 - secondary stress

STR3 - tertiary stress

STR3B - tertiary stress on bottom

STR3T - tertiary stress on top

STRCR - critical stress

STS - stress on top due to sagging

t - thickness of theplate

T - draft

TOP - thickness of the plating on the top

TS - thickness of the side plating

TSTH - total stress on top in hogging

TSTS - total stress on top in sagging

TSBH - total stress on bottom in hogging

TSBS - total stress on bottom in sagging

INTRODUCTION

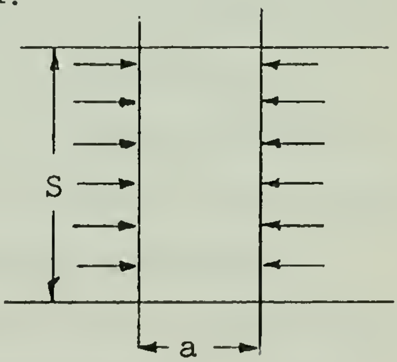
It is frequently found in the literature related with the strenght of ships such statements as:

"In general the neutral axis is expected to be at 40% of the depth (D) above the base line ... a preliminary estimate of the thickness required for the bottom plating (BOT) can be obtained from

$$1.875\left(\frac{0.4D}{0.6D}\right)2240\sqrt[3]{AL} = \frac{40300}{1+\frac{1}{950}\left(\frac{S}{BOT}\right)^{1.75}}$$

where the Montgomerie's expression is being considered to determine the critical stress (SBCRIT psi) and the short edges are assumed far apart and simply supported.

$$SBCRIT = \frac{40300}{1+\frac{1}{950}\left(\frac{S}{BOT}\right)^{1.75}}$$



$S \geqslant 4a$

a- distance between transverse stiffening members (inches)

1.875 accounts for a factor of safety

Tobin's expression was considered in the above formula to give the maximum permissible bending stress (LBS, psi)

$$LBS = 2240\sqrt[3]{AL}$$

We see thus that this procedure allows for an estimate of the bottom thickness to be obtained after knowing the length and assuming a longitudinal frame spacing. What may be questioned here is the reason why one assumes the neutral axis 0.4D above the base line and also the reasons behind the choice of a frame spacing.

In the following a procedure to estimate the scantlings of longitudinal members is described; this procedure can also be found frequently in the literature dealing with the subject.

..."For a particular set of principal dimensions , general arrangement and frame spacing, plate panel thicknesses for one after another of the amidships longitudinally continuous elements are selected for an assumed position of the neutral axis at 40% of the depth above the keel. The composite midship section assemblage is thentested for the adequacy of its section modulus when ranged alongside some standard value, such as given by the Load Line Regulations or some function of it. Thus the modulus is judged sufficient to limit ship bending stresses to the value previously set and incorporated into the design equations.

For all but the deepest ships the modulus will undoubtedly need to be increased and a small arbitrary increment is added to the upper deck or bottom whichever happens still to be farther from the true neutral axis location found after the first design cycle. The shift of neutral axis resulting from the scantling increment requires a compensating increment in the opposite flan-

ge with the obvious outcome that the neutral axis is shifted in reverse with attendant effect on the scantling chosen first; a cyclic process is then begun. More trials will be necessary before the match of available to required section modulus is achieved."

From this transcript, we may again note the initial statement "...for a particular set of principal dimensions, general arrangement and frame spacing..." and question whether or not the frame spacing should be chosen as an input or rather be left as a variable and be obtained as a result of a structural design procedure. It is here aknowledged though that in these procedures an acceptable solution can be worked out and each new cycle is an improvement over the precedent ones. What may be questionable though is whether the first cycle, due to the assumptions made at its beginning, has or not a strong influence in the outcome leading to a solution among the various possible ones which in the end does not lead to"the optimum design" whatever its definition may be.

It seems that this trial procedure can be looked at as a "weakness" of the structural design procedure for the determination of scantlings and it is perhaps reasonable to make some effort in order to work out a process that could give the scantlings in a direct manner and be at the same time in agreement with what can be considered "the optimum design", (usually based on economic considerations).

Nowadays much concern is given to economics in ship design and naturally the strength calculations of a ship are also made with economical optimization in mind. With this respect, we can realize that in ships structures there is a desirability to minimize structural weight and some define structural efficiency as being the least weight structure capable of resisting the loads for which they are designed.

It should be clear that the cost of construction and of maintenance and repair are inter related factors together with least weight, to be considered when bringing economics into ship structural design. Also other matters such as accessibility, weldability and availability of material must be considered as well.

In the following sections an attempt is made to obtain without any interactions the scantlings for the plating of a box girder. It is hoped that through this simple model some helpful conclusions can be made in view of their application to a vessel's structure. Each of the different situations analized will be exhaustively explained in the following sections.

PRELIMINARY CALCULATIONS

The model used in this section and also throughout this work with only very small additional considerations is a box girder which cross section is pictured in figure 1.

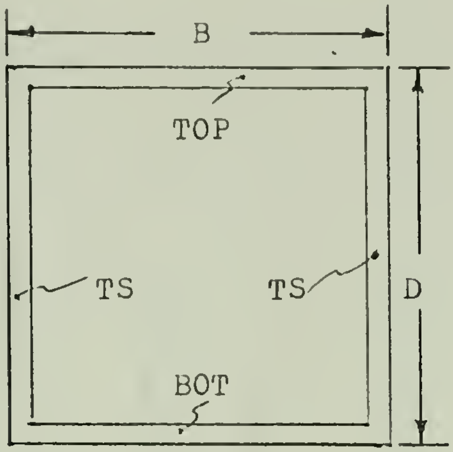


Fig. 1

As will be seen in the calculations of the following sections, the dimensional parameters used are of the order of magnitude of those considered in ship design.

This model was chosen due to its simplicity for the performance of the following calculations as can be understood immediately from its geometrically symmetrical cross section.

The objective of this section is to determine the necessary formulation to be used in future sections.

The formulation dealt with in this section is related only to the particular model chosen and the geometry of its cross section.

MEMBER	SCANTLINGS inches (in)	AREA A $(in)^2$	DISTANCE TO BOTTOM (ft)	A*d (in^2*ft)	A*d*d $(in*ft)^2$	WIDTH of member b(in)	HEIGHT OF MEMBER H(ft)	b, H; $I=b*H^3$ $(in*ft^2)$
TOP	B*TOP	B*TOP	D/12	B*TOP*D/12	$B*TOP*(D/12)^2$	B	-	-
SIDE	2*TS*D	2*TS*D	D/(2*12)	TS*D*D/12	$TS*D*(D/12)^2/12$	2*TS	D/12	$2*TS*(D/12)^3$
BOTTOM	B*BOT	B*BOT	-	-	-	b	-	-

$\Sigma A=$ $\Sigma(A*d)=$ $\Sigma(A*d*d)=$ $\Sigma I=$

$+ \Sigma I=$

$I_{BOT}=$

$-\Sigma A*(DIBOT')^2=$

$$DIBOT=\frac{\Sigma(A*d)}{\Sigma A}*12$$

$$DIBOT'=\frac{\Sigma(A*d)}{\Sigma A}$$

$\Sigma A=B*TOP+2*TS*D+B*BOT=2*D*TS+B*(TOP+BOT)$

DIBOT =Neutral axis location above bottom (in)

DIBOT'= " " " " " (ft)

I_{BOT} =Moment of inertia with respect to the bottom

I = " " " " " " " neutral axis

$\Sigma(A*d)=(D/12)*(B*TOP+D*TS)$

$I=\Sigma(A*d*d)+\Sigma I-(\Sigma(A*d))^2/(\Sigma A)$

DIBOT=D*(B*TOP+D*TS)/(2*D*TS+B*(TOP+BOT))

This formula will give DIBOT in inches if D and B are expressed in inches; it will give DIBOT in feet in the event that D and B are expressed in feet.

DITOP=D-DIBOT

DITOP=D*(B*BOT+D*TS)/(2*D*TS+B(TOP+BOT))

DITOP in units of inches or feet as explained for DIBOT

The following formula will give I in units of $(in*ft)^2$ for B and D given in inches.

$$I=\frac{(D/12)^2*(3*B*B*TOP*BOT+(D*TS)^2+2*B*D*TS*(TOP+BOT))}{3*(2*D*TS+B*(TOP+BOT))}$$

Next formula gives I in units of $(in*ft)^2$ for B and D given in feet.

$$I=\frac{4*D*D*(3*B^2*TOP*BOT+(D*TS)^2+2*B*D*TS*(TOP+BOT))}{2*D*TS+B*(TOP+BOT)}$$

These expressions will be used in most of the following sections with B and D expressed in feet.

NOTE: TS which is defined as the thickness of the side plating is considered throughout this work to be uniform and will always be equal to the larger of the thicknesses obtained for the top and for the bottom plating.

FORMULAS USED IN THE ANALYSIS

BEAM EQUATION

Assuming pure bending, the stresses in the cross section of the box girder are given by

$$STR=\frac{BM*y}{I}$$

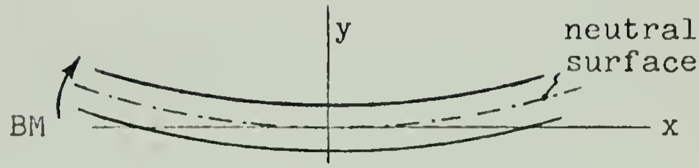


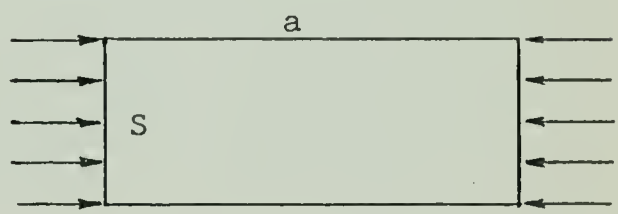
Fig. 2

where y is the distance from the neutral axis to the point where the stress is being determined.

The neutral surface indicated in fig. 2 is composed of all the points which are not subjected to any stress in pure bending.

BRYAN EQUATION - Plate under inplane load

$$STRCR=K*\frac{(\pi)^2*E*(t)^2}{12*(1-(POI)^2)*(S)^2}$$



When $a/S>2$ then $K=4$

STRCR given in psi for t andS expressed in inches and E in psi.

$\pi=3.1416$

PLATE UNDER LATERAL LOAD

$$STR3=0.5*K*\rho*H*\left(\frac{S}{t}\right)^2*\frac{1}{144}$$

STR3 - tertiary stress

ρ - density of sea water (64 lb/ft^3)

H - head of sea water (ft)

a - long dimension of plate (in)

S - short dimension of plate (in) = distance between longitudinal stiffeners

t - plate thickness (in)

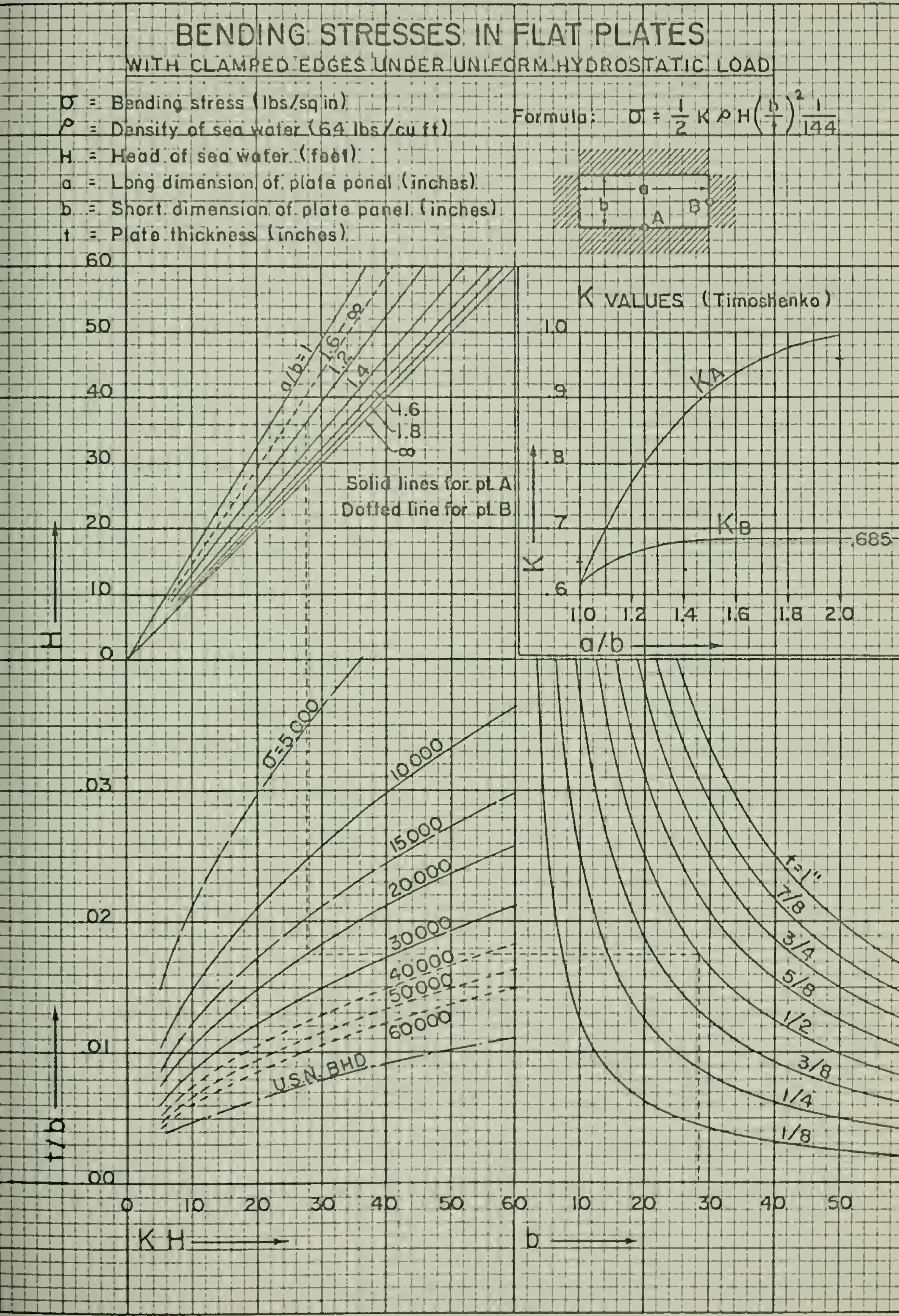
The stresses are more severe at points A and B but we are particularly interested in the stresses at point B because there they will combine with the stresses resulting from bending also called primary stresses.

Note that for a panel under lateral load, the direction of the stresses is, at the edges, perpendicular to them, so at B they are directed "longitudinally".

For $a/S>2$ we have $K=0.685$

Replacing all the numbers in the above formula, we obtain

$$STR3=0.152222*H*\left(\frac{S}{t}\right)^2$$


BENDING STRESSES IN FLAT PLATES
WITH CLAMPED EDGES UNDER UNIFORM HYDROSTATIC LOAD
σ = Bending stress (lbs/sq in)
ρ = Density of sea water (64 lbs/cu ft)
H = Head of sea water (feet)
a = Long dimension of plate panel (inches)
b = Short dimension of plate panel (inches)
t = Plate thickness (inches)
Formula: $\sigma = \frac{1}{2} K \rho H \left(\frac{b}{t}\right)^2 \frac{1}{144}$
a
b
A
B
K VALUES (Timoshenko)
KA
KB
.685
K
a/b
a/b=1
1.6
1.2
∞
1.4
1.6
1.8
∞
Solid lines for pt. A
Dotted line for pt. B
H
σ=5,000
10,000
15,000
20,000
30,000
40,000
50,000
60,000
U.S.N. BHD
t=1"
7/8
3/4
5/8
1/2
3/8
1/4
1/8
t/b
K H
b

The following stress definitions and figures 3 and 4 will help understanding the reasons behind the calculations made in many of the following sections.

STRESS DEFINITIONS

STR1 - SHIP BENDING STRESS or PRIMARY STRESS

Since this stress is directly proportional to distance from the ship's neutral axis, it is substantially constant at any point on the cross section of the bottom or top plating when the vessel is in an upright attitude. For distinction, this stress may be termed a primary stress or an area stress in this location and under such a condition. While the longitudinal direction is implied in the foregoing comments, they are equally applicable transversely.

STR2 - GIRDER BENDING STRESS or SECONDARY STRESS

Girder bending stress arises from the reaction of a plating stiffener combination to a loading normal to the plating such as may be due to water pressure. Following the usual concept, the plating acts as one flange of the composite girder and so is stressed. Due to shear lag, this secondary stress in the plating is a maximum in way of the stiffener and diminishes with distance from it.

For the previous case of bottom plating and vessel upright, the transverse variation of fore and aft stress will be sensibly constant for some distance from the stiffener but will vary significantly through the plating thickness as the plate thickness is a substantial part of the distance to the neutral axis

of the plate stiffener combination. For convenience such a stress may be termed a line stress although for a wide spacing of stiffeners with consequently greater deviation from uniform distribution some inaccuracy of concept is introduced by using this term.

For girders continuous over several supports, such as transverse bulkheads, maximum bending moments occur at the supports and will readily be in the order of twice the field moment.

STR3 - PLATE BENDING STRESS - TERTIARY STRESS

Proceeding in turn to ever more elemental portions of the ship's structure concludes with the simple plate panel supported on its four edges. In such a plate under lateral or normal loads, bending stresses are created which are variable from point to point on the panel and through its thickness with maxima occurring at one or the other surface. Since any such stress is effective at a point only, it may be called a point stress or tertiary stress.

Each elemental panel of ship's plating is generally one of a repeating pattern. Quite apart from any rotational restraint provided by the panel supports consisting of floors, frames, longitudinals, etc., there is the restraint afforded by the continuity of the plating and its loading. For pratical purposes then, a condition of edge clamping exists with maximum stresses being found at the midlength of the longer panel edges and secondary maxima at the midlength of the shorter edges. In both cases these stresses are normal to their respective edges.

BENDING STRESSES IN SHIPS

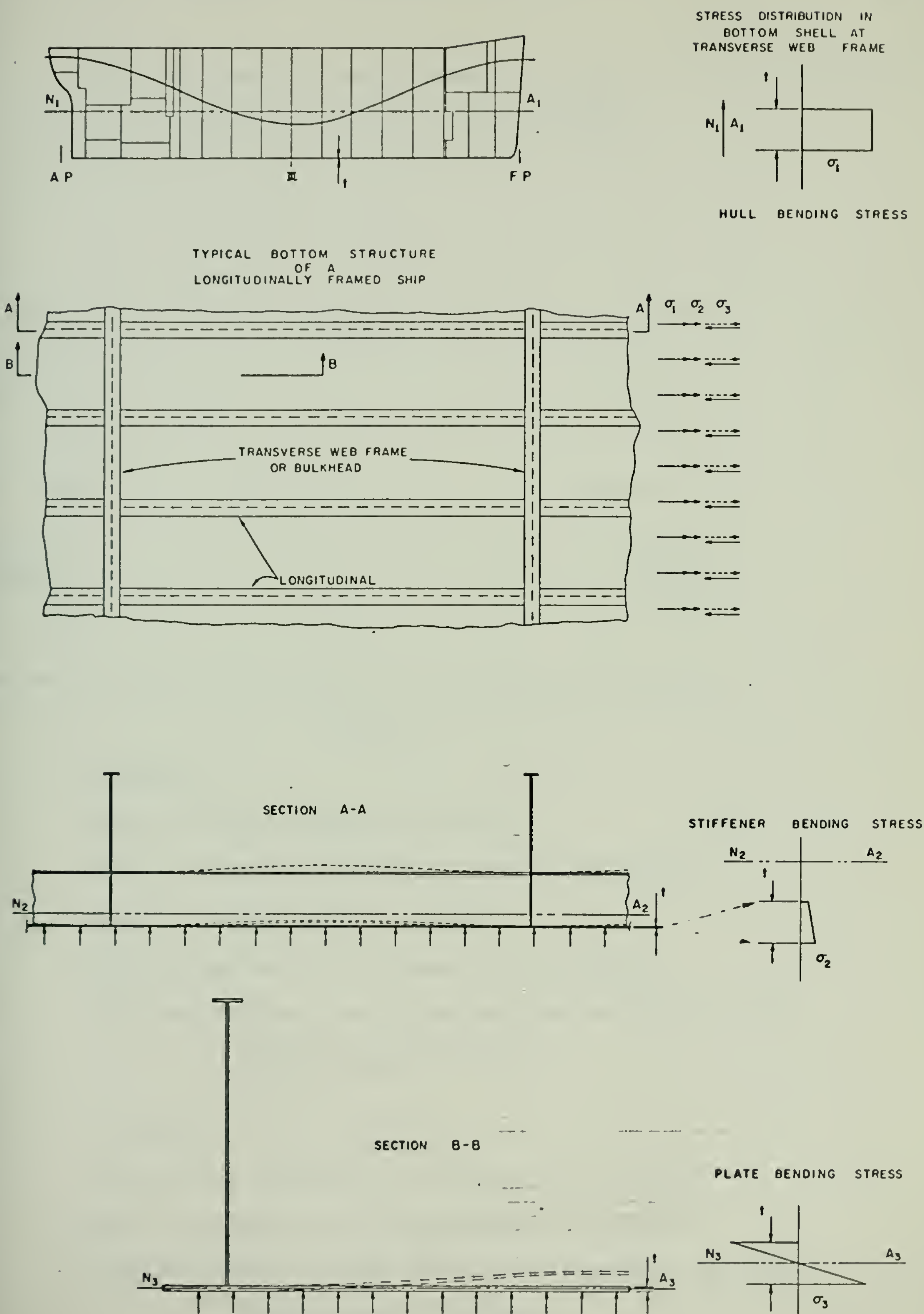


FIGURE 3

From the previous definitions and figure 3 we may summarize in figure 4 the effect of STR1, STR2 and STR3.

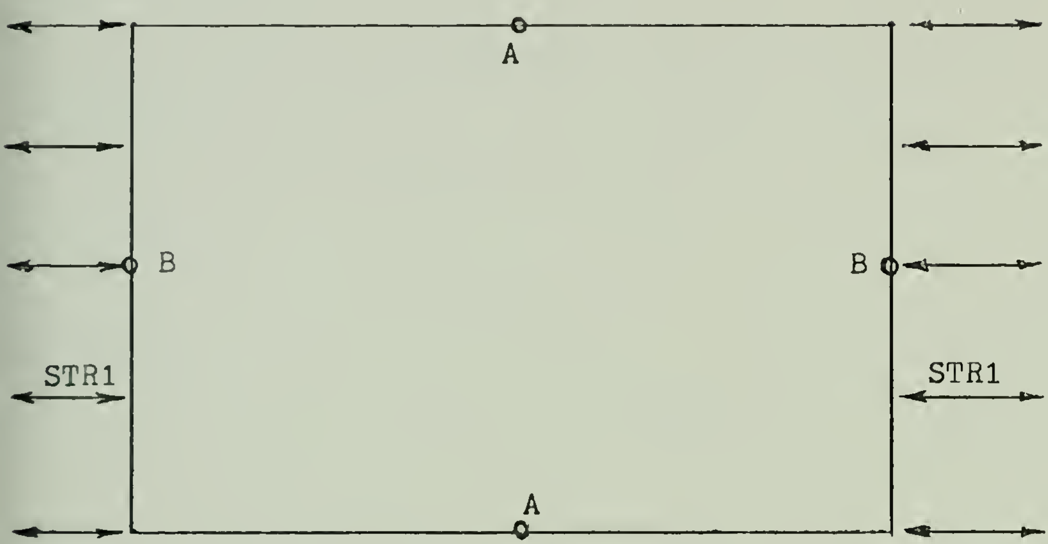


Fig. 4

At point A

STR2 is larger than at point B

STR2 is acting in the longitudinal direction

STR3 is larger than at point B

STR3 is acting in the transverse direction

STR1 and STR2 are here combined acting both in the longitudinal direction

At point B

STR2 may be acting in the tansverse direction

STR3 is acting in the longitudinal direction

STR1 and STR3 are here combined acting both in the longitudinal direction.

Usually STR2 is attributed a constant value and can be taken into account by automatically decreasing the design stress by the value assigned to STR2.

THE BENDING MOMENT EQUATION

The bending moment equation used is derived from

$$BM = \Delta * AL/35 \qquad ton*ft$$

knowing that

$$\Delta = \nabla/35 \qquad ton$$

and that

$$\nabla = B*T*AL*C_b$$

and using

$$C_b = 0.75$$

we obtain

$$BM = \frac{0.75}{35*35} *B*T*AL*AL \qquad ton*ft$$

where AL = is the length in ft

B = is the beam in ft

T = is the draft in ft

C_b = is the block coefficient

or multiplying by 2240 we obtain

$$BM = 1.37143*B*T*AL*AL \qquad lb*ft$$

Note:

∇ is the displacement volume and Δ is the corresponding displacement weight.

MOMENT ACTING IN ONE DIRECTION

NO RESTRICTION IMPOSED ON THE COMPRESSION STRESS

Considering the box girder subjected to a bending moment acting in hogging BM, we will observe as a consequence that the top will be subjected to tension and the bottom to compression. These stresses are given by the already introduced formula

$$STR = \frac{BM*Y}{I}$$

or in this case, being interested on the top and bottom,

$$STH = \frac{BM*DIBTOP}{I}$$

$$SBH = \frac{BM*DIBOT}{I}$$

In this introductory study it was decided not to limit the value of the stress in compression. Only the value of the stress in tension, here STH will be requested to be equal to the value chosen for the design stress in tension (or smaller).

SBH will be a consequence of the value of DST and also of the S value chosen.

So, we will basically have 3 equations

DST = STH $\leftrightarrow$ TOP   Bending equation

S $\leftrightarrow$ SBH $\leftrightarrow$ BOT   Bending equation + Bryan formula

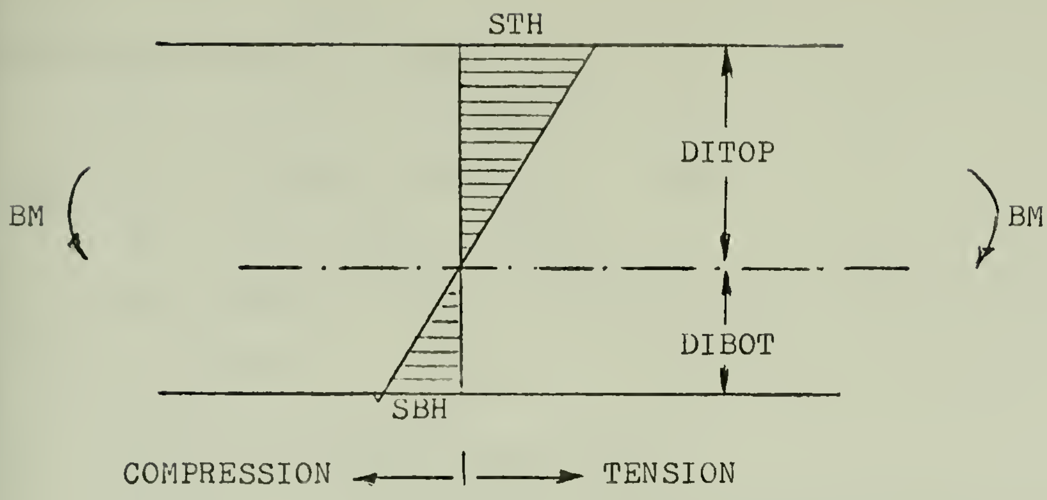


Fig. 5

The three equations that can be obtained will allow one to determine the three unknowns which are BOT,SBH,TOP.

By replacing in the equations already mentioned the expressions derived previously for DIBOT, DITOP and I and solving for BOT,TOP and SBH we obtain after a lengthy but simple process the equations in their final format as we will see.

Note here that in order to solve the three equations, the thickness of the side plates TS was made equal to the larger TOP or BOT; since TOP and BOT were not known and had to be determined after deciding on TS, the equations had to be solved twice. First the equations are solved assuming that TOP > BOT this simply implying that the neutral axis is going to be chosen already closer to the top and TS = TOP. Second, the equations are solved assuming BOT > TOP thus making TS = BOT.

As will be seen, only one solution is possible, the other being rejected by giving a result that does not agreee with the

assumption just mentioned.

TOP , BOT , S (inches)

B , D , DITOP , DIBOT , AL (ft)

DST , STH , SBH , E (psi)

BM (ton*ft)

I $(in*ft)^2$

$$DST \geqslant STH = \frac{560*BM*(B*BOT+D*TS)}{D*(3*B*B*TOP*BOT+2*B*D*TS*(TOP+BOT)=(D*TS)^2)}$$

$$SBH = \frac{560*BM*(B*TOP+D*TS)}{\text{Same denominator}}$$

$$BOT = \sqrt{G}\ \sqrt{SBH}$$

$$G = 0.30396*\frac{(S)^2*(1-(POI)^2)}{E}$$

$$\frac{DST}{SBH} = \frac{B*BOT+D*TS}{B*TOP+D*TS}$$

Making

$$A = \frac{9*B*B*D}{140*BM}$$

$$C = \frac{3*B*D*D}{70*BM}$$

$$F = \frac{3*D*D*D}{140*BM}$$

we will obtain, by assuming first TOP > BOT

$$DIBOT = \frac{D*(B+D)*TOP}{(2*D+B)*TOP+B*BOT}$$

$$DITOP = \frac{D*(B*BOT+D*TOP)}{\text{Same denominator}}$$

$$I = 4*D*D*\frac{(2*B*D+D*D)*TOP*TOP+(2*B*D+3*B*B)*TOP*BOT}{\text{Same denominator}}$$

$$TOP = \frac{B*(BOT)^3}{(B+D)*G*DST-D*(BOT)^2}$$

$$BOT = \frac{TOP*(12*D-(C+F)*DST*TOP)}{DST*(A+C)*TOP-12*B}$$

Before going to the equations obtained when BOT > TOP is assumed, we call the attention of the reader to the fact that the values of BOT and TOP have to be obtained from the two above equations. Substitution of one into the other would result in an equation of degree higher than at least 5^{th} degree, unsuitable for direct solution. As will be later exemplified, the solution is here obtained by assigning values to either one of BOT and TOP and through the two equations, we obtain the respective values for TOP and BOT. The ploting of these values BOT vs TOP will give one line for each of the two equations. The intersection of the two lines thus obtained allows the solution to be read from the plot.

This solution will be acceptable if the intersection lies in the sector TOP > BOT otherwise the intersection must be rejected.

Assuming now BOT > TOP we make TS = BOT and obtain:

$$DIBOT = \frac{D*(B*TOP+D*BOT)}{(2*D+B)*BOT+B*TOP}$$

$$DITOP = \frac{D*(B+D)*BOT}{\text{Same denominator}}$$

$$I = 4*D*D*\frac{(2*B*D+D*D)*(BOT)^2+(2*B*D+3*B*B)*TOP*BOT}{\text{Same denominator}}$$

$$TOP = \frac{(B+D)*(BOT)^3-D*G*DST*BOT}{B*G*DST}$$

$$BOT = \frac{12*(B+D)-(A+C)*DST*TOP}{(C+F)*DST}$$

In this form the equations can be used in a very simple computer program that will give the set of values TOP vs BOT suitable for ploting. At this stage we are hoping that if the intersection obtained in the situation where we assumed TOP> BOT is acceptable,the two lines resulting from the case BOT> TOP will not intersect or if they do that the intersection must be rejected due to the fact that they will violate the assumption from which they were derived

As can be observed from the several cases run in the computer, the case where two acceptable solutions exist never happened and it can only happen if TOP = BOT where then both solutions are acceptable and coincide as in the case of one of the following runs.

In the following pages the computer printouts are included. The first run is explained in detail to make the interested reader familiar with the problems encountered in determining the intersections and the respective thicknesses.

The other runs are here presented as well to serve as proof that a simple solution can always be obtained and also to give an idea of the range of thicknesses expected in each case.

In all runs only a bending moment acting in hogging was considered.

The program used is a direct application of the equations here derived to a particular set of values chosen as the input. From the results obtained, some conclusions were drawn that allowed for the improvements made in following sections.

No further explanation on the program shall here be given because it is self explanatory in the comment statements included.

```
C       *AL* IS THE LENGHT
        AL=500.
        B=AL/8.
C       *DRA* IS THE DRAFT
        DRA=B/3.
        D=AL/9.
C       *POI* IS THE POISSON'S RATIO OF THE MATERIAL
C       FOR STEEL
        POI=0.3
C       *E* IS THE YOUNG'S MODULUS OF THE MATERIAL
C       FOR STEEL
        E=30.*10.**6
C       *DST* IS THE DESIGN STRESS
        DST=20000.
C       *S* IS THE SPACING OF LONGITUDINAL STIFFENING MEMBERS
        S=10.
C       *BM* IS THE BENDING MOMENT
        BM=(B*DRA*AL*AL*0.75)/(35.*35.)
        G=7.3/396*S*S*(1.-POI*POI)/E
        A=B.*B*B*D/(140.*BM)
        C=3.*B*D*D/(72.*BM)
        F=3.*D*D*D/(14.*BM)
C       THICKNESS OF TOP ASSUMED LARGER THAN BOTTOM THICKNESS
        WRITE(5,10)
     10 FORMAT('1',20X,'TOP ASSUMED LARGER THAN BOTTOM')
C       *TOP* IS THE THICKNESS OF THE TOP PLATING
C       *BOT* IS THE THICKNESS OF THE BOTTOM PLATING
        BOT1=0.1
     11 TOP1=B*BOT1*BOT1*BOT1/((B+D)*G*DST-D*BOT1*BOT1)
        WRITE(5,20)TOP1,BOT1
     20 FORMAT(' ',25X,'TOP1='F9.4,5X,'BOT1='F9.4)
        BOT1=BOT1+0.005
        IF(BOT1.GT.0.2)GO TO 30
        GO TO 11
     30 TOP2=0.1
     31 BOT2=TOP2*(12.*D-(C+F)*DST*TOP2)/(DST*(A+C)*TOP2-12.*B)
        WRITE(5,40)TOP2,BOT2
     40 FORMAT(' ',25X,'TOP2='F9.4,5X,'BOT2='F9.4)
        TOP2=TOP2+0.05
        IF(TOP2.GT.1.)GO TO 50
        GO TO 31
     50 CONTINUE
C       THICKNESS OF BOTTOM ASSUMED LARGER THAN TOP
        WRITE(5,60)
     60 FORMAT('1',20X,'BOTTOM ASSUMED LARGER THAN TOP')
        BOT3=0.1
     61 TOP3=((B+D)*BOT3*BOT3*BOT3-D*G*DST*BOT3)/(B*G*DST)
        WRITE(5,70)TOP3,BOT3
     70 FORMAT(' ',25X,'TOP3='F9.4,5X,'BOT3='F9.4)
        BOT3=BOT3+0.05
        IF(BOT3.GT.1.)GO TO 80
        GO TO 61
```

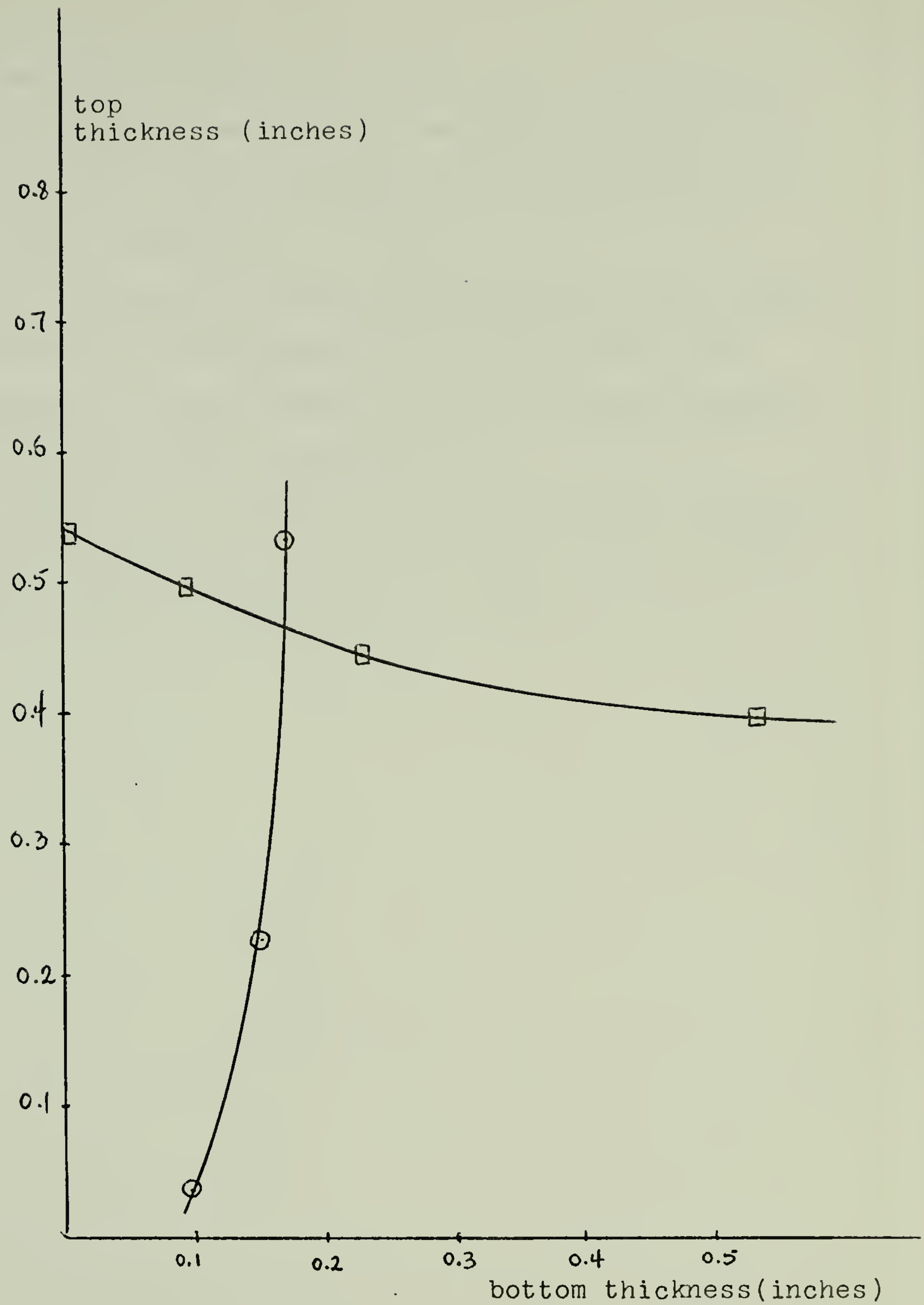
```
Ø4Ø2        8Ø  TOP4=Ø.1
Ø4ØA        81  BOT4=(12.*(B+D)-(A+C)*DST*TOP4)/((C+F)*DST)
Ø44E            WRITE(5,9Ø)TOP4,BOT4
Ø472        9Ø  FORMAT(' ',25X,'TOP4='F9.4,5X,'BOT4='F9.4)
Ø49A            TOP4=TOP4+Ø.Ø5
Ø4A6            IF(TOP4.GT.1.)GO TO 1ØØ
Ø4B8            GO TO 81
Ø4BC       1ØØ  CONTINUE
Ø4BC            END
ØØØ[S] .U       Ø4CØ[V] AL      Ø4C8[V] B       Ø4DØ[V] DRA     Ø4D8[V] D
Ø4EØ[V] POI     Ø4E8[V] E       ØØØØ[S] .R      Ø4F8[V] DST     Ø5ØØ[V] S
Ø5Ø4[V] BM      Ø518[V] G       Ø524[V] A       Ø52C[V] C       Ø534[V] F
Ø14Ø[L] 1Ø      ØØØØ[S] @I      Ø538[V] BOT1    Ø176[L] 11      Ø54Ø[V] TOP1
Ø152[L] 2Ø      Ø22C[L] 3Ø      Ø554[V] TOP2    Ø234[L] 31      Ø558[V] BOT2
Ø284[L] 4Ø      Ø2FF[L] 5Ø      Ø312[L] 6Ø      Ø56C[V] BOT3    Ø348[L] 61
Ø57Ø[V] TOP3    Ø388[L] 7Ø      Ø4Ø2[L] 8Ø      Ø574[V] TOP4    Ø4ØA[L] 81
Ø578[V] BOT4    Ø472[L] 9Ø      Ø4BC[L] 1ØØ     ØØØØ[S] .V
/XEQ          L
EOF


PROGRAM LABELS:
 2Ø7Ø *MAIN*    2CØC .V         2A3C .COMP      2C1A @I         25EC .R         2BØ4 .ZE
 2A62 $6        262C .A         2B6Ø .MES       29DE .W         27E6 EXP        296C AI
 26DE ALOG      2AA4 .RARG      2BØØ .5         27E6 AEXP       2BØ8 .ERCNT     2AD6 $8
 2BØ8 .O        2BDE .U         3D36


ENTRY-POINTS:
 25EC .R        262C .A         26DE ALOG       27E6 AEXP       27E6 EXP        296C AI
 29DE .W        2A3C .COMP      2A62 $6         2AA4 .RARG      2AD6 $8         2BØØ .5
 2BØ4 .ZERO     2BØ8 .ERCNT     2B2A .O         2B6Ø .MES       2BEA .U         2C1Ø .V
 2C14 @I


COMMON-BLOCKS:
NONE


UNDEFINED SUBROUTINES:
NONE


TRANSFER ADDRESS 2Ø7Ø
EXECUTION BEGINS:
```

TOP ASSUMED LARGER THAN BOTTOM

TOP1=	0.0385	BOT1=	0.1000
TOP1=	0.0462	BOT1=	0.1050
TOP1=	0.0553	BOT1=	0.1100
TOP1=	0.0659	BOT1=	0.1150
TOP1=	0.0784	BOT1=	0.1200
TOP1=	0.0933	BOT1=	0.1250
TOP1=	0.1109	BOT1=	0.1300
TOP1=	0.1321	BOT1=	0.1350
TOP1=	0.1576	BOT1=	0.1400
TOP1=	0.1889	BOT1=	0.1450
TOP1=	0.2276	BOT1=	0.1500
TOP1=	0.2763	BOT1=	0.1550
TOP1=	0.3392	BOT1=	0.1600
TOP1=	0.4225	BOT1=	0.1650
TOP1=	0.5374	BOT1=	0.1700
TOP1=	0.7043	BOT1=	0.1750
TOP1=	0.9669	BOT1=	0.1800
TOP1=	1.4359	BOT1=	0.1850
TOP1=	2.5007	BOT1=	0.1900
TOP1=	7.1867	BOT1=	0.1950
TOP1=	-11.0527	BOT1=	0.2000
TOP2=	0.1000	BOT2=	-0.1038
TOP2=	0.1500	BOT2=	-0.1758
TOP2=	0.2000	BOT2=	-0.2808
TOP2=	0.2500	BOT2=	-0.4765
TOP2=	0.3000	BOT2=	-1.1361
TOP2=	0.3500	BOT2=	2.8493
TOP2=	0.4000	BOT2=	0.5282
TOP2=	0.4500	BOT2=	0.2263
TOP2=	0.5000	BOT2=	0.0925
TOP2=	0.5500	BOT2=	0.0287
TOP2=	0.6000	BOT2=	-0.0534
TOP2=	0.6500	BOT2=	-0.1044
TOP2=	0.7000	BOT2=	-0.1487
TOP2=	0.7500	BOT2=	-0.1888
TOP2=	0.8000	BOT2=	-0.2260
TOP2=	0.8500	BOT2=	-0.2612
TOP2=	0.9000	BOT2=	-0.2950
TOP2=	0.9500	BOT2=	-0.3276
TOP2=	1.0000	BOT2=	-0.3593

```
BOTTOM ASSUMED LARGER THAN TOP
          TOP3=    Ø.Ø135      BOT3=    Ø.1ØØØ
          TOP3=    Ø.2124      BOT3=    Ø.15ØØ
          TOP3=    Ø.6417      BOT3=    Ø.2ØØØ
          TOP3=    1.3783      BOT3=    Ø.25ØØ
          TOP3=    2.499Ø      BOT3=    Ø.3ØØØ
          TOP3=    4.Ø8Ø7      BOT3=    Ø.35ØØ
          TOP3=    6.2ØØ1      BOT3=    Ø.4ØØØ
          TOP3=    8.9341      BOT3=    Ø.45ØØ
          TOP3=   12.3596      BOT3=    Ø.5ØØØ
          TOP3=   16.6533      BOT3=    Ø.55ØØ
          TOP3=   21.592Ø      BOT3=    Ø.6ØØØ
          TOP3=   27.5527      BOT3=    Ø.65ØØ
          TOP3=   34.5121      BOT3=    Ø.7ØØØ
          TOP3=   42.547Ø      BOT3=    Ø.75ØØ
          TOP3=   51.7342      BOT3=    Ø.8ØØØ
          TOP3=   62.15Ø7      BOT3=    Ø.85ØØ
          TOP3=   73.8731      BOT3=    Ø.9ØØØ
          TOP3=   86.9784      BOT3=    Ø.95ØØ
          TOP3=  1Ø1.5434      BOT3=    1.ØØØØ
          TOP4=    Ø.1ØØØ      BOT4=    Ø.9961
          TOP4=    Ø.15ØØ      BOT4=    Ø.9Ø31
          TOP4=    Ø.2ØØØ      BOT4=    Ø.81Ø1
          TOP4=    Ø.25ØØ      BOT4=    Ø.717Ø
          TOP4=    Ø.3ØØØ      BOT4=    Ø.624Ø
          TOP4=    Ø.35ØØ      BOT4=    Ø.531Ø
          TOP4=    Ø.4ØØØ      BOT4=    Ø.4379
          TOP4=    Ø.45ØØ      BOT4=    Ø.3449
          TOP4=    Ø.5ØØØ      BOT4=    Ø.2519
          TOP4=    Ø.55ØØ      BOT4=    Ø.1589
          TOP4=    Ø.6ØØØ      BOT4=    Ø.Ø658
          TOP4=    Ø.65ØØ      BOT4=   -Ø.Ø272
          TOP4=    Ø.7ØØØ      BOT4=   -Ø.12Ø2
          TOP4=    Ø.75ØØ      BOT4=   -Ø.2133
          TOP4=    Ø.8ØØØ      BOT4=   -Ø.3 63
          TOP4=    Ø.85ØØ      BOT4=   -Ø.3993
          TOP4=    Ø.9ØØØ      BOT4=   -Ø.4923
          TOP4=    Ø.95ØØ      BOT4=   -Ø.5854
          TOP4=    1.ØØØØ      BOT4=   -Ø.6784
END

CF VIC OPERATING SYSTEM VERSION 1 REVISION  Ø12 Ø3/Ø4/74 GENERATED  Ø5/Ø6/74

JOB HANDLING CHARGE    $   .35 / JOB        .35
175 LINES PRINTED PR2  $  1.25 / K LN       .22
 67 CARDS READ         $  1.5Ø / K CD       .1Ø
 ØØ PLOTTER VECTORS    $   .25 / 1ØØØ       .ØØ
 15 MODEL 7Ø SECONDS   $25.ØØ / HOUR        .1Ø
 ØØ MODEL 8Ø SECONDS   $12.5Ø / HOUR        .ØØ
                    TOTAL CHARGE $          .77

PREIR 49Ø 14731  LOGGED OUT Ø5/Ø6/74 15:14.  $  14.1Ø LEFT AFTER    17 LOGINS.
```

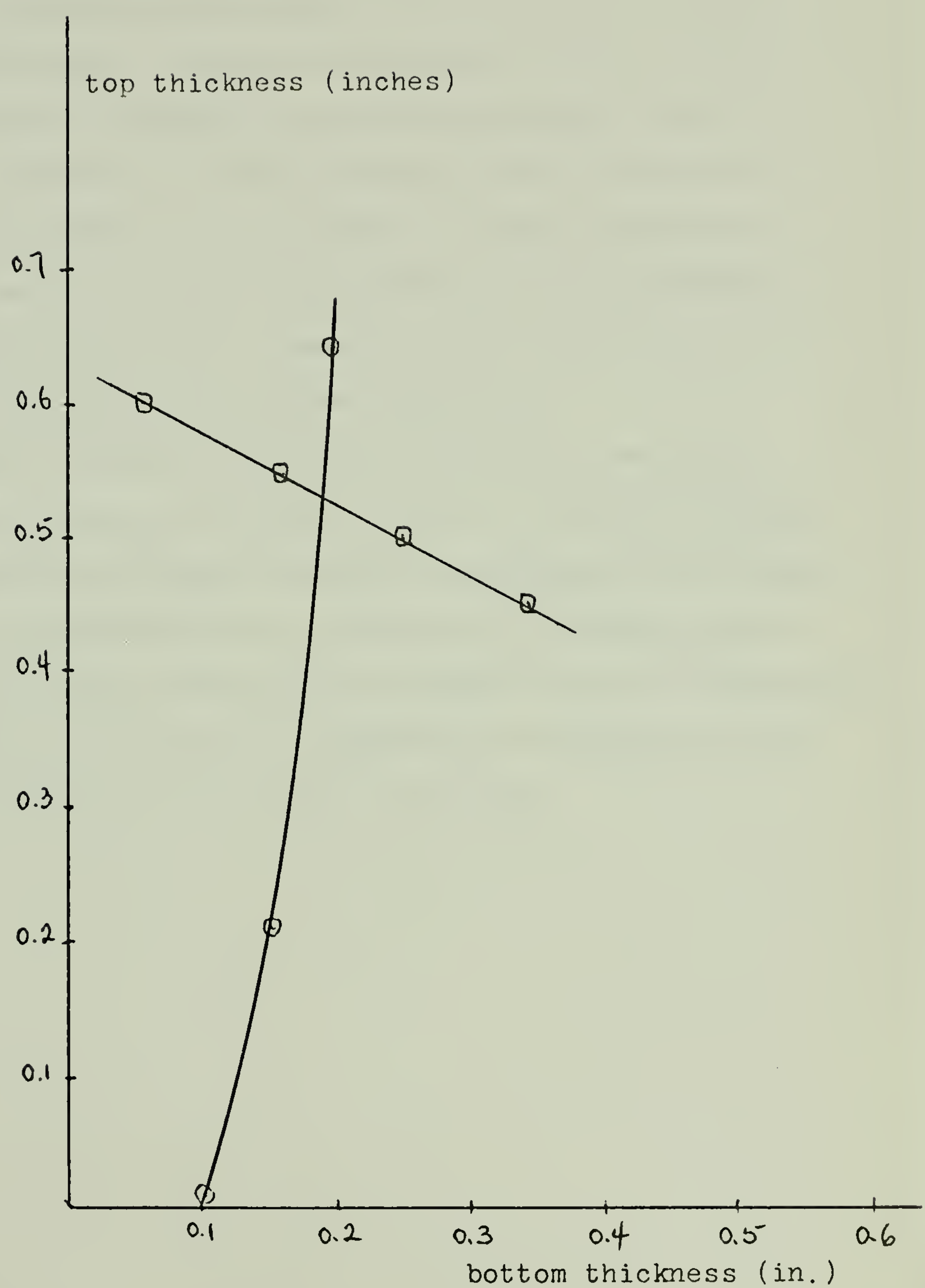
From these lists of thickness values printed by the computer, we can see that the acceptable ones are those marked with a $\overline{\underline{\|}}$ sign. Plotting these corresponding pairs of values properly, as is next exemplified, allows for one to read from the intersection of the two lines, which falls within the range set by the assumption that originated it, the values of thicknesses at the top and at the bottom which satisfy the model we started with.


top
thickness (inches)
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.1
0.2
0.3
0.4
0.5
bottom thickness(inches)

We can see that the thickness values are easily read from the intersection obtained and they are acceptable because they fall within the range assumed to derive the formulas that originated them namely TOP$>$ BOT.

Next will be plotted the case BOT$>$TOP and as can be seen, again an intersection is obtained which in this case is not acceptable because it occurs within the range TOP$>$ BOT contrary to the assumed BOT$>$TOP that originated it.

With a little more experience, this can be seen immediatly from the computer printouts, thus avoiding loss of time doing a plot that will lead to a nonacceptable result.


top thickness (inches)
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.1
0.2
0.3
0.4
0.5
0.6
bottom thickness (in.)

Now having obtained the values for the thicknesses from the plots, we verify them through the use of the next program based on the formulation previously derived. As can be noted, we obtain an acceptable value for the stress at the top (since we are considering a hogging bending moment) which we said before in the derivation of the equations should not exceed the design stress in tension. In this case the design stress was DST=20000 psi and we see that the stress at the top STH=20037.5 the 37.5 coming possibly from inaccuracy when reading the thicknesses from the plot, and computer roundoffs.

Note that the stress at the bottom, since there was no limit placed on it except the Bryan formula to resist buckling caused by compressive inplane loading, is attaining a too large value which is unacceptable and unrealistic. Here again there should be no difference between SBH and SBCRIT and the difference that can be noted is also due to inaccuracy in reading the thicknesses from the plot and computer round-offs.

```
C       *ZL* IS THE LENGTH
        ZL=[illegible].
        B=ZL/[illegible].
C       *DRAFT* IS THE DRAFT
        DRAFT=ZL/[illegible].
        D=ZL/[illegible].
C       *POI* IS THE POISSON'S RATIO OF THE MATERIAL
C       FOR STEEL
        POI=.3
C       *E* IS THE YOUNG'S MODULUS OF THE MATERIAL
C       FOR STEEL
        E=3[illegible]
C       *DST* IS THE DESIGN STRESS
        DST=[illegible].
C       *S* IS THE SPACING OF LONGITUDINAL STIFFENING MEMBERS
        S=1[illegible].
C       *BM* IS THE [illegible] MOMENT
        BM=([illegible]/ZL*AL[illegible])/([illegible].*35.)
        C=[illegible]
C       *TOP* IS THE THICKNESS OF THE TOP PLATING
C       *BOT* IS THE THICKNESS OF THE BOTTOM PLATING
        TOP= .4[illegible]
        BOT= .1[illegible]
        A=5[illegible]*(D*BOT+B*TOP)
        ZI=[illegible]*BOT+B*D**3+D*TOP*(TOP+BOT)+(D*B*TOP*TO[illegible]))
C       *STH* IS THE STRESS ON TOP DUE TO HOGGING
        STH=[illegible]
        WRITE(5,6)STH
    6   FORMAT(' ',2[illegible]X,'STH=',F1[illegible].3)
        C=5[illegible]*(B*TOP+[illegible])
C       *SBH* IS THE STRESS ON BOT DUE TO HOGGING
        SBH=C/[illegible]
        WRITE(5,[illegible])SBH
  [illegible]   FORMAT(' ',2[illegible]X,'SBH=',F1[illegible].3)
C       *SBCRIT* IS THE CRITICAL STRESS ON BOT
        SBCRIT=[illegible]T*BOT/[illegible]
        WRITE(5,11)SBCRIT
  11    FORMAT(' ',17X,'SBCRIT=',F1[illegible].3)
        P=2.[illegible]*[illegible]*B*(T[illegible])
C       *DITOP* IS THE DISTANCE OF THE TOP FROM THE NEUTRAL AXIS
        DITOP=[illegible](D*BOT+[illegible]*TOP)/P
        WRITE(5,4)DITOP
    4   FORMAT(' ',18X,'DITOP=',F12.4)
C       *DIBOT* IS THE DISTANCE OF THE BOTTOM FROM THE NEUTRAL AXIS
        DIBOT=[illegible]*TOP+[illegible]*TOP)/P
        WRITE(5,[illegible])DIBOT
  [illegible]   FORMAT(' ',18X,'DIBOT=',F12.4)
        END
```

[illegible] [S] [illegible]	0324 [V] ZL	[illegible] [V] B	0334 [V] DRA	033C [V] D
[illegible] [V] POI	034C [V] E	[illegible] [S] .R	035C [V] DST	0364 [V] S
[illegible] [V] [illegible]	0370 [V] C	[illegible] [V] TOP	[illegible] [V] BOT	0398 [V] A
[illegible] [V] [illegible]	0388 [V] STH	[illegible] [ ] [illegible]	[illegible] [S] [illegible]	03BC [V] C

ST-- C.T -F S- I-S--- I-- ---T-- --I- LOCATI - PAGE 2

RC [V] ... 1-- [-] ... ... [V] ... ... [L] 11- ... [V] P
RC [V] ... ... [L] ... ... [V] ... ... [L] ... ... [- .V

PROGRAM LABELS:

2444 .H 2350 .7
2638 EXP 2704 AT
2538 ..XP 2969 ..RC.I1 292E S

ENTRY-POINTS:

2444 .. 2638 EXP 2638 EXP 2704 AT
2A42 .H 2368 .
2A72

END

... OPERATING SYSTEM VERSION ... REVISION 12 3/74 GENERATED 5/6/74

JOB HANDLING CHARGE ...
55 LINES PRINTED ...
54 CARDS READ ...
PLOTTER VECTORS ...
13 ... SECONDS ...
... SECONDS ...
TOTAL CHARGE ...

R-SIP 4.. 14731 LOGGED OUT .5/.6/74 15:43. $ 11.79 LEFT AFTER ... LOGINS.

SUMMARY FOR THE PRECEDING CASE

Length	=	500 ft
Beam	=	AL/8
Draft	=	B/3
Depth	=	AL/9
DST	=	20000 psi
S	=	10 inches
Material	-	STEEL
TOP	=	0.468 inches
BOT	=	0.166 inches
STH	=	20037.45
SBH	=	30434.89
SBCRIT	=	29886.80
DITOP	=	22.06 ft
DIBOT	=	33.50 ft

We can already notice here that the stress in the bottom is attaining a too large value due to the fact that, since no limit was imposed on it, it is dependent only on the chosen value for S and the respective capacity to resist buckling provided by S and BOT while at the same time stressing the top plate to its maximum allowed DST.

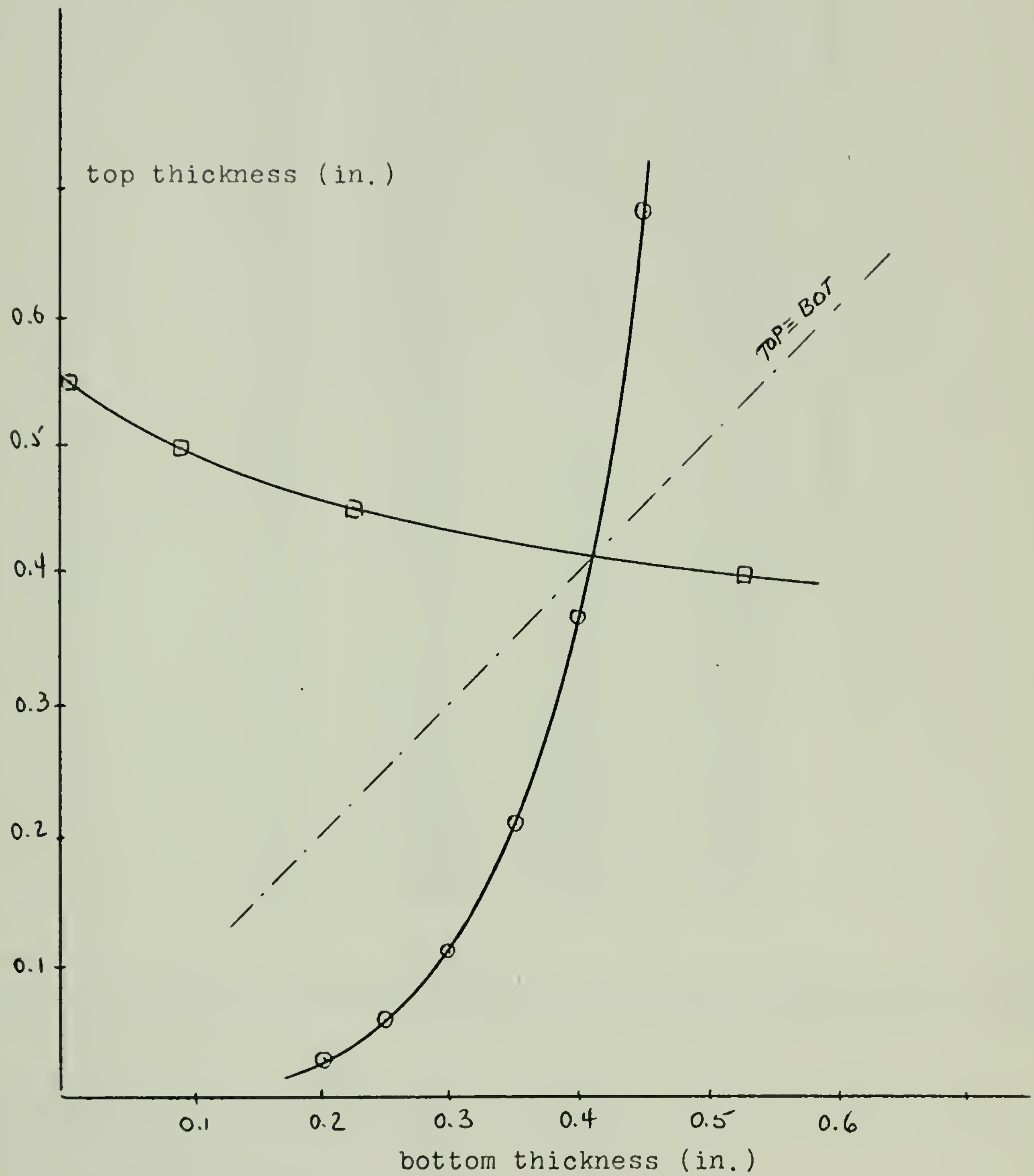
In the following two cases only the spacing S between the longitudinal stiffening members will be allowed to change and the results obtained are simply stated as previously exemplified and were determined in a similar way.

From the results obtained we can note the effect caused by the change of S.

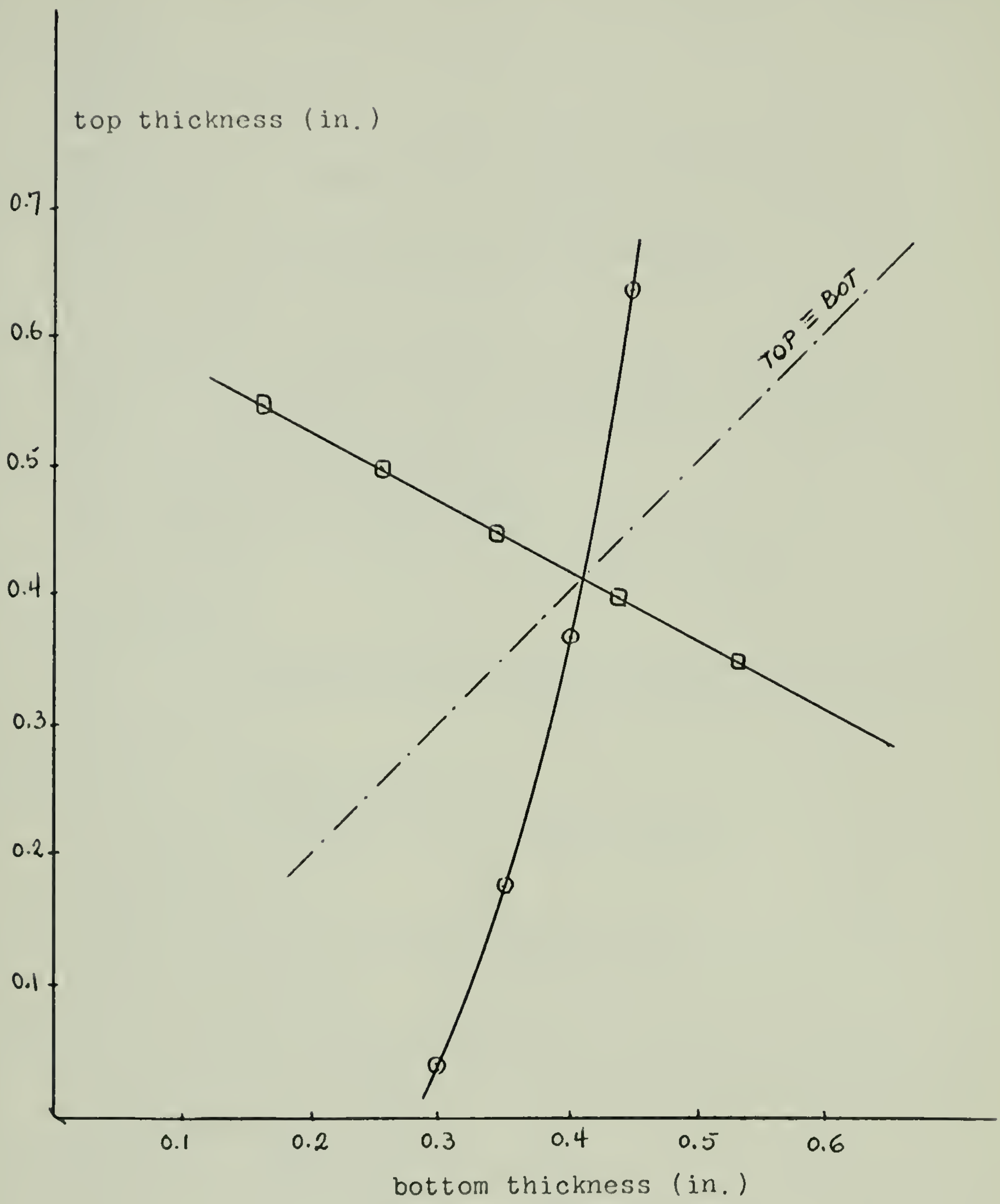
```
      C       *AL* IS THE LENGHT
              AL=500.
              B=AL/8.
      C       *DRA* IS THE DRAFT
              DRA=B/3.
              D=AL/9.
      C       *POI* IS THE POISSON'S RATIO OF THE MATERIAL
      C       FOR STEEL
              POI=0.3
      C       *E* IS THE YOUNG'S MODULUS OF THE MATERIAL
      C       FOR STEEL
              E=30.*10.**6
      C       *DST* IS THE DESIGN STRESS
              DST=20000.
      C       *S* IS THE SPACING OF LONGITUDINAL STIFFENING MEMBERS
              S=30.
      C       *BM* IS THE BENDING MOMENT
              BM=(B*DRA*AL*AL*0.75)/(35.*35.)
              G=0.30396*S*S*(1.-POI*POI)/E
              A=9.*B*B*D/(140.*BM)
              C=3.*B*D*D/(70.*BM)
              F=3.*D*D*D/(140.*BM)
      C       THICKNESS OF TOP ASSUMED LARGER THAN BOTTOM THICKNESS
              WRITE(5,10)
           10 FORMAT('1',25X,'TOP ASSUMED LARGER THAN BOTTOM')
      C       *TOP* IS THE THICKNESS OF THE TOP PLATING
      C       *BOT* IS THE THICKNESS OF THE BOTTOM PLATING
              BOT1=0.1
           11 TOP1=B*BOT1*BOT1*BOT1/((B+D)*G*DST-D*BOT1*BOT1)
              WRITE(5,20)TOP1,BOT1
           20 FORMAT(' ',25X,'TOP1='F9.4,5X,'BOT1='F9.4)
              BOT1=BOT1+0.05
              IF(BOT1.GT.1.)GO TO 30
              GO TO 11
           30 TOP2=0.1
           31 BOT2=TOP2*(12.*D-(C+F)*DST*TOP2)/(DST*(A+C)*TOP2-12.*B)
              WRITE(5,40)TOP2,BOT2
           40 FORMAT(' ',25X,'TOP2='F9.4,5X,'BOT2='F9.4)
              TOP2=TOP2+0.05
              IF(TOP2.GT.1.)GO TO 50
              GO TO 31
           50 CONTINUE
      C       THICKNESS OF BOTTOM ASSUMED LARGER THAN TOP
              WRITE(5,60)
           60 FORMAT('1',25X,'BOTTOM ASSUMED LARGER THAN TOP')
              BOT3=0.1
           61 TOP3=((B+D)*BOT3*BOT3*BOT3-D*G*DST*BOT3)/(B*G*DST)
              WRITE(5,70)TOP3,BOT3
           70 FORMAT(' ',25X,'TOP3='F9.4,5X,'BOT3='F9.4)
              BOT3=BOT3+0.05
              IF(BOT3.GT.1.)GO TO 80
              GO TO 61
```

```
0482         80 TOP4=0.1
048A         81 BOT4=(12.*(B+D)-(A+C)*DST*TOP4)/((C+F)*DST)
044E            WRITE(5,90)TOP4,BOT4
0472         90 FORMAT(' ',25X,'TOP4='F9.4,5X,'BOT4='F9.4)
049A            TOP4=TOP4+0.75
04A6            IF(TOP4.GT.1.)GO TO 100
04B8            GO TO 81
04BC        100 CONTINUE
04BC            END
00[S] .U        04C0[V] AL       04C8[V] B        04D0[V] DRA      04D8[V] D
E0[V] POI       04E8[V] E        0000[S] .F       04F8[V] DST      0500[V] S
24[V] BM        0518[V] G        0524[V] A        052C[V] C        0534[V] F
42[L] 10        0000[S] @I       0538[V] BOT1     0176[L] 11       0542[V] TOP1
E2[L] 20        022C[L] 30       055 [V] TOP2     0234[L] 31       0554[V] BOT2
B4[L] 40        02FF[L] 50       0312[L] 60       0564[V] BOT3     0348[L] 61
6F[V] TOP3      03B8[L] 70       0402[L] 80       056C[V] TOP4     040A[L] 81
70[V] BOT4      0472[L] 90       04BC[L] 100      0000[S] .V
 XEQ         L
OF

ROGRAM LABELS:
 2070 *MAIN*    2C04 .V        2A34 .COMP      2C12 @I        25E4 .R        2AFC .ZE
 2A5A $6        2624 .A        2B58 .MES       29D6 .W        27DE EXP       2964 AIN
 2606 ALOG      2A9C .RARG     2AF8 .5         27DE AEXP      2B00 .ERCNT    2ACE $8
 2870 .O        2BD6 .U        3D2E

NTRY-POINTS:
 25E4 .R        2624 .A        2606 ALOG       27DE AEXP      27DE EXP       2964 AIN
 29D6 .W        2A34 .COMP     2A5A $6         2A9C .RARG     2ACE $8        2AF8 .5
 2AFC .ZERO     2B00 .ERCNT    2B72 .O         2B58 .MES      2BE2 .U        2C08 .V
 2C12 @I

OMMON-BLOCKS:
ONE

NDEFINED SUBROUTINES:
ONE

RANSFER ADDRESS 2072
ECUTION BEGINS:
```

```
TOP ASSUMED LARGER THAN BOTTOM
TOP1=     0.0033       BOT1=     0.1200
TOP1=     0.0115       BOT1=     0.1500
TOP1=     0.0288       BOT1=     0.2000
TOP1=     0.0626       BOT1=     0.2500
TOP1=     0.1156       BOT1=     0.3000
TOP1=     0.2096       BOT1=     0.3500
TOP1=     0.3737       BOT1=     0.4000
TOP1=     0.6827       BOT1=     0.4500
TOP1=     1.3697       BOT1=     0.5000
TOP1=     3.7376       BOT1=     0.5500
TOP1=   -33.1585       BOT1=     0.6000
TOP1=    -4.4245       BOT1=     0.6500
TOP1=    -2.8099       BOT1=     0.7000
TOP1=    -2.2619       BOT1=     0.7500
TOP1=    -2.0047       BOT1=     0.8000
TOP1=    -1.8681       BOT1=     0.8500
TOP1=    -1.7933       BOT1=     0.9000
TOP1=    -1.7543       BOT1=     0.9500
TOP1=    -1.7379       BOT1=     1.0000
TOP2=     0.1000       BOT2=    -0.1038
TOP2=     0.1500       BOT2=    -0.1758
TOP2=     0.2000       BOT2=    -0.2808
TOP2=     0.2500       BOT2=    -0.4765
TOP2=     0.3000       BOT2=    -1.1361
TOP2=     0.3500       BOT2=     2.8493
TOP2=     0.4000       BOT2=     0.5222
TOP2=     0.4500       BOT2=     0.2263
TOP2=     0.5000       BOT2=     0.0925
TOP2=     0.5500       BOT2=     0.0287
TOP2=     0.6000       BOT2=    -0.0534
TOP2=     0.6500       BOT2=    -0.1044
TOP2=     0.7000       BOT2=    -0.1487
TOP2=     0.7500       BOT2=    -0.1888
TOP2=     0.8000       BOT2=    -0.2260
TOP2=     0.8500       BOT2=    -0.2612
TOP2=     0.9000       BOT2=    -0.2950
TOP2=     0.9500       BOT2=    -0.3276
TOP2=     1.0000       BOT2=    -0.3593
```


top thickness (in.)
0.6
0.5
0.4
0.3
0.2
0.1
TOP=BOT
0.1
0.2
0.3
0.4
0.5
0.6
bottom thickness (in.)

```
BOTTOM ASSUMED LARGER THAN TOP
TOP3=  -0.2775      BOT3=   0.1000
TOP3=  -0.0949      BOT3=   0.1500
TOP3=  -0.0867      BOT3=   0.2000
TOP3=  -0.0444      BOT3=   0.2500
TOP3=   0.0406      BOT3=   0.3000
TOP3=   0.1769      BOT3=   0.3500
TOP3=   0.3729      BOT3=   0.4000
TOP3=   0.6371      BOT3=   0.4500
TOP3=   0.9782      BOT3=   0.5000
TOP3=   1.4047      BOT3=   0.5500
TOP3=   1.9250      BOT3=   0.6000
TOP3=   2.5478      BOT3=   0.6500
TOP3=   3.2816      BOT3=   0.7000
TOP3=   4.1349      BOT3=   0.7500
TOP3=   5.1162      BOT3=   0.8000
TOP3=   6.2340      BOT3=   0.8500
TOP3=   7.4970      BOT3=   0.9000
TOP3=   8.9137      BOT3=   0.9500
TOP3=  10.4925      BOT3=   1.0000
TOP4=   0.1000      BOT4=   0.9961
TOP4=   0.1500      BOT4=   0.9031
TOP4=   0.2000      BOT4=   0.8101
TOP4=   0.2500      BOT4=   0.7170
TOP4=   0.3000      BOT4=   0.6240
TOP4=   0.3500      BOT4=   0.5310
TOP4=   0.4000      BOT4=   0.4379
TOP4=   0.4500      BOT4=   0.3449
TOP4=   0.5000      BOT4=   0.2519
TOP4=   0.5500      BOT4=   0.1589
TOP4=   0.6000      BOT4=   0.0658
TOP4=   0.6500      BOT4=  -0.0272
TOP4=   0.7000      BOT4=  -0.1202
TOP4=   0.7500      BOT4=  -0.2133
TOP4=   0.8000      BOT4=  -0.3063
TOP4=   0.8500      BOT4=  -0.3993
TOP4=   0.9000      BOT4=  -0.4923
TOP4=   0.9500      BOT4=  -0.5854
TOP4=   1.0000      BOT4=  -0.6784
END

F VIC OPERATING SYSTEM VERSION 1 REVISION 012 03/04/74 GENERATED 05/06/74 0

JOB HANDLING CHARGE    $   .35 / JOB        .35
173 LINES PRINTED PR2 $ 1.25 / K LN        .22
 67 CARDS READ         $ 1.50 / K CD        .10
 00 PLOTTER VECTORS    $   .25 / 1000       .00
 20 MODEL 70 SECONDS   $25.00 / HOUR        .14
 00 MODEL 80 SECONDS   $12.50 / HOUR        .00
                        TOTAL CHARGE $      .81

REIR 490 14731  LOGGED OUT 05/06/74 15:20.  $  13.29 LEFT AFTER    18 LOGINS.
```


top thickness (in.)
0.7
0.6
0.5
0.4
0.3
0.2
0.1
TOP = BOT
0.1
0.2
0.3
0.4
0.5
0.6
bottom thickness (in.)

```
      C     *AL* IS THE LENGHT
            AL=500.
            B=AL/8.
      C     *DRA* IS THE DRAFT
            DRA=B/3.
            D=AL/9.
      C     *POI* IS THE POISSON'S RATIO OF THE MATERIAL
      C     FOR STEEL
            POI=0.3
      C     *E* IS THE YOUNG'S MODULUS OF THE MATERIAL
      C     FOR STEEL
            E=30.*10.**6
      C     *DST* IS THE DESIGN STRESS
            DST=20000.
      C     *S* IS THE SPACING OF LONGITUDINAL STIFFENING MEMBERS
            S=32.
      C     *BM* IS THE BENDING MOMENT
            BM=(B*DRA*AL*AL*0.75)/(35.*35.)
            G=2.30396*B*S*(1.-POI*POI)/E
      C     *TOP* IS THE THICKNESS OF THE TOP PLATING
      C     *BOT* IS THE THICKNESS OF THE BOTTOM PLATING
            TOP=0.4125
            BOT=0.4125
            A=560.*BM*(B*BOT+D*TOP)
            DEN=D*(3.*B*B*TOP*BOT+2.*B*D*TOP*(TOP+BOT)+(D*D*TOP*TOP))
      C     *STH* IS THE STRESS ON TOP DUE TO HOGGING
            STH=A/DEN
            WRITE(5,60)STH
         60 FORMAT(' ',20X,'STH='F10.3)
            C=560.*BM*(B*TOP+D*TOP)
      C     *SBH* IS THE STRESS ON BOT DUE TO HOGGING
            SBH=C/DEN
            WRITE(5,90)SBH
         90 FORMAT(' ',20X,'SBH='F10.3)
      C     *SBCRIT* IS THE CRITICAL STRESS ON BOT
            SBCRIT=BOT*BOT/G
            WRITE(5,110)SBCRIT
        110 FORMAT(' ',17X,'SBCRIT='F10.3)
            P=2.*D*TOP+B*(TOP+BOT)
      C     *DITOP* IS THE DISTANCE OF THE TOP FROM THE NEUTRAL AXIS
            DITOP=D*(B*BOT+D*TOP)/P
            WRITE(5,40)DITOP
         40 FORMAT(' ',18X,'DITOP='F10.4)
      C     *DIBOT* IS THE DISTANCE OF THE BOTTOM FROM THE NEUTRAL AXIS
            DIBOT=D*(B*TOP+D*TOP)/P
            WRITE(5,50)DIBOT
         50 FORMAT(' ',18X,'DIBOT='F10.4)
            END
   [S] .U     0324[V] AL     032C[V] B      0334[V] DRA    033C[V] D
   [V] POI    034C[V] E      0000[S] .R     035C[V] DST    0364[V] S
   [V] BM     037C[V] G      0388[V] TOP    0390[V] BOT    0394[V] A
   [V] DEN    0384[V] ST     0174[L] 60     0000[S] @I     0388[V] C
```

```
C[V] SBH      01E2[L] 92       03C [V] SBCRIT  0228[L] 110     03C4[V] P
 [V] DITOP    02A8[L] 46       03CC[V] DIBOT   0304[L] 50      0000[S] .V
 EQ              L
 F


OGR  LABELS:
2870 *MAIN*    2A60 .V        2890 .COMP     2A6E @I        2440 .R        2958 .ZE
2886 $6        2480 .A        2984 .MES      2832 .W        263A EXP       27C0 AIN
2532 ALOG      28F8 .RARG     2954 .5        263A AEXP      295C .ERCNT    292A $8
295C .O        2A32 .U        3B8A


TRY-POINTS:
2440 .R        2480 .A        2532 ALOG      263A AEXP      263A EXP       27C0 AIN
2832 .W        2890 .COMP     2886 $6        28F8 .RARG     292A $8        2954 .5
2958 .ZERO     295C .ERCNT    295E .O        2984 .MES      2A3E .U        2A64 .V
2A6E @I


 MO -BLOCKS:
 E


DEFINED SUBROUTINES:
 E


ANSFER ADDRESS 2870
CUTION BEGINS:

               STH= 2 037.113
               SBH= 2 037.113
            SBCRIT= 2 505.348
             DITOP=   27.7778
             DIBOT=   27.7778
END

F VIC OPERATING SYSTEM VERSION 1 REVISION  012 03/04/74 GENERATED  05/06/74  0


JOB HANDLING CHARGE    $   .35 / JOB        .35
 85 LINES PRINTED PR2  $ 1.25 / K LN        .11
 54 CARDS READ         $ 1.50 / K CD        .08
 00 PLOTTER VECTORS    $   .25 / 1000       .00
 13 MODEL 70 SECONDS   $25.00 / HOUR        .09
 00 MODEL 80 SECONDS   $12.50 / HOUR        .00
                        TOTAL CHARGE $      .63

PEIR 490 14731  LOGGED OUT 05/06/74 15:46.  $  11.16 LEFT AFTER    21 LOGINS.
```

SUMMARY

Length	=	500 ft
Beam	=	AL/8
Draft	=	B/3
Depth	=	AL/9
DST	=	20000 psi
S	=	30"
Material	-	STEEL
TOP	=	0.4125"
BOT	=	0.4125"
STH	=	20037.11
SBH	=	20037.11
SBCRIT	=	20505.43
DITOP	=	27.78'
DIBOT	=	27.78'

Note that this is the case where two acceptable solutions exist although they end up being the same because TOP=BOT.

Note that the neutral axis is located half way between top and bottom and the stress is the same at the top and at the bottom, as it was expected beforehand.

```
C      *AL* IS THE LENGHT
       AL=500.
       B=AL/8.
C      *DRA* IS THE DRAFT
       DRA=B/3.
       D=AL/9.
C      *POI* IS THE POISSON'S RATIO OF THE MATERIAL
C      FOR STEEL
       POI=0.3
C      *E* IS THE YOUNG'S MODULUS OF THE MATERIAL
C      FOR STEEL
       E=30.*10.**6
C      *DST* IS THE DESIGN STRESS
       DST=20000.
C      *S* IS THE SPACING OF LONGITUDINAL STIFFENING MEMBERS
       S=120.
C      *BM* IS THE BENDING MOMENT
       BM=(B*DRA*AL*AL*0.75)/(35.*35.)
       G=0.30396*S*S*(1.-POI*POI)/E
       A=9.*B*B*D/(144.*BM)
       C=3.*B*D*D/(72.*BM)
       F=3.*D*D*D/(144.*BM)
C      THICKNESS OF TOP ASSUMED LARGER THAN BOTTOM THICKNESS
       WRITE(5,10)
    10 FORMAT('1',25X,'TOP ASSUMED LARGER THAN BOTTOM')
C      *TOP* IS THE THICKNESS OF THE TOP PLATING
C      *BOT* IS THE THICKNESS OF THE BOTTOM PLATING
       BOT1=1.
    11 TOP1=B*BOT1*BOT1*BOT1/((B+D)*G*DST-D*BOT1*BOT1)
       WRITE(5,20)TOP1,BOT1
    20 FORMAT(' ',25X,'TOP1='F9.4,5X,'BOT1='F9.4)
       BOT1=BOT1+0.25
       IF(BOT1.GT.2.)GO TO 30
       GO TO 11
    30 TOP2=0.02
    31 BOT2=TOP2*(12.*D-(C+F)*DST*TOP2)/(DST*(A+C)*TOP2-12.*B)
       WRITE(5,40)TOP2,BOT2
    40 FORMAT(' ',25X,'TOP2='F9.4,5X,'BOT2='F9.4)
       TOP2=TOP2+0.02
       IF(TOP2.GT.1.)GO TO 50
       GO TO 31
    50 CONTINUE
C      THICKNESS OF BOTTOM ASSUMED LARGER THAN TOP
       WRITE(5,60)
    60 FORMAT('1',25X,'BOTTOM ASSUMED LARGER THAN TOP')
       BOT3=1.
    61 TOP3=((B+D)*BOT3*BOT3*BOT3-D*G*DST*BOT3)/(B*G*DST)
       WRITE(5,70)TOP3,BOT3
    70 FORMAT(' ',25X,'TOP3='F9.4,5X,'BOT3='F9.4)
       BOT3=BOT3+0.25
       IF(BOT3.GT.2.)GO TO 80
       GO TO 61
```

```
'402        80 TOP4=0.02
'40A        81 BOT4=(12.*(B+D)-(A+C)*DST*TOP4)/((C+F)*DST)
'44E           WRITE(5,90)TOP4,BOT4
'472        90 FORMAT(' ',25X,'TOP4='F9.4,5X,'BOT4='F9.4)
'49A           TOP4=TOP4+0.02
'4A6           IF(TOP4.GT.1.)GO TO 100
'4B8           GO TO 81
'4BC       100 CONTINUE
'4BC           END
00[S] .U      04C0[V] AL     04C8[V] B      04D0[V] DRA     04D8[V] D
E0[V] POI     04E8[V] E      0000[S] .R     04F8[V] DST     0500[V] S
28[V] BM      051C[V] G      0528[V] A      0530[V] C       0538[V] F
40[L] 10      0000[S] @I     053C[V] BOT1   0176[L] 11      0540[V] TOP1
22[L] 20      022C[L] 30     0554[V] TOP2   0234[L] 31      055C[V] BOT2
34[L] 40      02FE[L] 50     0312[L] 60     056C[V] BOT3    0348[L] 61
70[V] TOP3    03B8[L] 70     0402[L] 80     0574[V] TOP4    040A[L] 81
78[V] BOT4    0472[L] 90     04BC[L] 100    0000[S] .V
 XEQ        L
OF


ROGRAM LABELS:
 2070 *MAIN*   2C0C .V       2A3C .COMP    2C1A @I       25EC .R       2B04 .ZE
 2A62 $6       262C .A       2B60 .MES     29DE .W       27E6 EXP      296C AI
 26DE ALOG     2AA4 .RARG    2B00 .5       27E6 AEXP     2B08 .ERCNT   2AD6 $8
 2B0A .0       2BDE .U       3D36


NTRY-POINTS:
 25EC .R       262C .A       26DE ALOG     27E6 AEXP     27E6 EXP      296C AI
 29DE .W       2A3C .COMP    2A62 $6       2AA4 .RARG    2AD6 $8       2B00 .5
 2B04 .ZERO    2B08 .ERCNT   2B0A .0       2B60 .MES     2BEA .U       2C10 .V
 2C1A @I


OMMON-BLOCKS:
ONE


NDEFINED SUBROUTINES:
ONE


RANSFER ADDRESS 2070
ECUTION BEGINS:
```

TOP ASSUMED LARGER THAN BOTTOM

TOP1=	0.2423	BOT1=	1.0000
TOP1=	0.2868	BOT1=	1.0500
TOP1=	0.3378	BOT1=	1.1000
TOP1=	0.3960	BOT1=	1.1500
TOP1=	0.4626	BOT1=	1.2000
TOP1=	0.5385	BOT1=	1.2500
TOP1=	0.6253	BOT1=	1.3000
TOP1=	0.7245	BOT1=	1.3500
TOP1=	0.8382	BOT1=	1.4000
TOP1=	0.9688	BOT1=	1.4500
TOP1=	1.1191	BOT1=	1.5000
TOP1=	1.2929	BOT1=	1.5500
TOP1=	1.4947	BOT1=	1.6000
TOP1=	1.7305	BOT1=	1.6500
TOP1=	2.0078	BOT1=	1.7000
TOP1=	2.3366	BOT1=	1.7500
TOP1=	2.7305	BOT1=	1.8000
TOP1=	3.2081	BOT1=	1.8500
TOP1=	3.7959	BOT1=	1.9000
TOP1=	4.5327	BOT1=	1.9500
TOP1=	5.4783	BOT1=	2.0000
TOP2=	0.0200	BOT2=	-0.0182
TOP2=	0.0400	BOT2=	-0.0375
TOP2=	0.0600	BOT2=	-0.0579
TOP2=	0.0800	BOT2=	-0.0799
TOP2=	0.1000	BOT2=	-0.1038
TOP2=	0.1200	BOT2=	-0.1301
TOP2=	0.1400	BOT2=	-0.1595
TOP2=	0.1600	BOT2=	-0.1932
TOP2=	0.1800	BOT2=	-0.2328
TOP2=	0.2000	BOT2=	-0.2808
TOP2=	0.2200	BOT2=	-0.3417
TOP2=	0.2400	BOT2=	-0.4234
TOP2=	0.2600	BOT2=	-0.5421
TOP2=	0.2800	BOT2=	-0.7376
TOP2=	0.3000	BOT2=	-1.1361
TOP2=	0.3200	BOT2=	-2.4815
TOP2=	0.3400	BOT2=	10.9162
TOP2=	0.3600	BOT2=	1.6081
TOP2=	0.3800	BOT2=	0.8255
TOP2=	0.4000	BOT2=	0.5282
TOP2=	0.4200	BOT2=	0.3680
TOP2=	0.4400	BOT2=	0.2655
TOP2=	0.4600	BOT2=	0.1926
TOP2=	0.4800	BOT2=	0.1371
TOP2=	0.5000	BOT2=	0.0925
TOP2=	0.5200	BOT2=	0.0553
TOP2=	0.5400	BOT2=	0.0233
TOP2=	0.5600	BOT2=	-0.0050
TOP2=	0.5800	BOT2=	-0.0303
TOP2=	0.6000	BOT2=	-0.0534
TOP2=	0.6200	BOT2=	-0.0748
TOP2=	0.6400	BOT2=	-0.0948
TOP2=	0.6600	BOT2=	-0.1136
TOP2=	0.6800	BOT2=	-0.1315

TOP2=	0.7000	BOT2=	-0.1487
TOP2=	0.7200	BOT2=	-0.1651
TOP2=	0.7400	BOT2=	-0.1810
TOP2=	0.7600	BOT2=	-0.1964
TOP2=	0.7800	BOT2=	-0.2114
TOP2=	0.8000	BOT2=	-0.2260
TOP2=	0.8200	BOT2=	-0.2403
TOP2=	0.8400	BOT2=	-0.2543
TOP2=	0.8600	BOT2=	-0.2681
TOP2=	0.8800	BOT2=	-0.2816
TOP2=	0.9000	BOT2=	-0.2950
TOP2=	0.9200	BOT2=	-0.3081
TOP2=	0.9400	BOT2=	-0.3211
TOP2=	0.9600	BOT2=	-0.3340
TOP2=	0.9800	BOT2=	-0.3467
TOP2=	1.0000	BOT2=	-0.3593

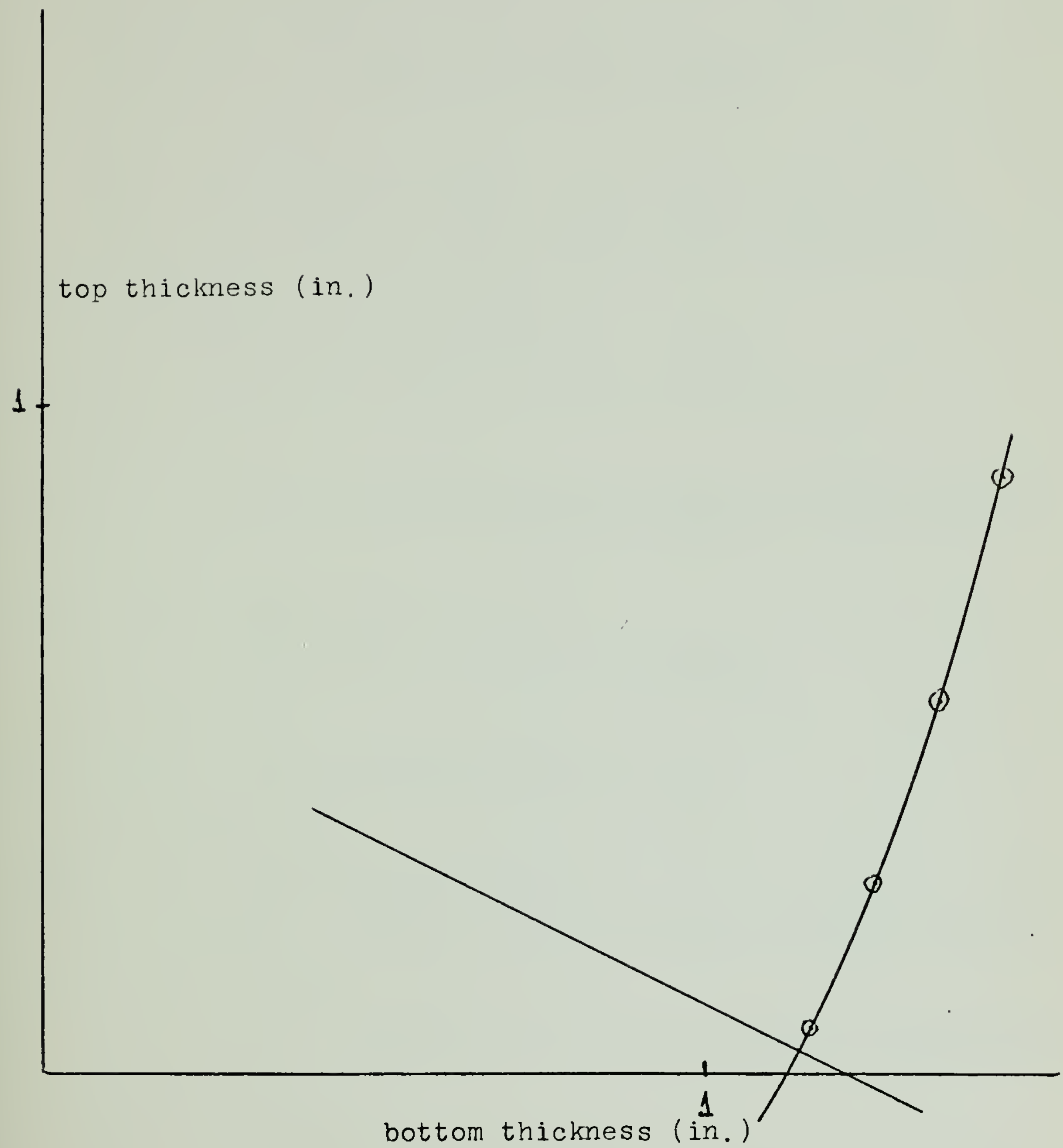
Note that in this case by simple inspection of the coordinates of the points to be ploted we can see that the intersection will occur outside the acceptable range.

Note also that in order to obtain the coordinates of the points within a range of interest where the intersection may occur, different ranges and increments are considered in each program. This could be improved if at that time these printouts were available and a better idea of the thicknesses that should be expected existed.

BOTTOM ASSUMED LARGER THAN TOP

TOP3=	-0.1776	BOT3=	1.0000
TOP3=	-0.1099	BOT3=	1.0500
TOP3=	-0.0310	BOT3=	1.1000
TOP3=	0.0596	BOT3=	1.1500
TOP3=	0.1625	BOT3=	1.2000
TOP3=	0.2782	BOT3=	1.2500
TOP3=	0.4072	BOT3=	1.3000
TOP3=	0.5501	BOT3=	1.3500
TOP3=	0.7074	BOT3=	1.4000
TOP3=	0.8797	BOT3=	1.4500
TOP3=	1.0674	BOT3=	1.5000
TOP3=	1.2711	BOT3=	1.5500
TOP3=	1.4914	BOT3=	1.6000
TOP3=	1.7287	BOT3=	1.6500
TOP3=	1.9836	BOT3=	1.7000
TOP3=	2.2567	BOT3=	1.7500
TOP3=	2.5484	BOT3=	1.8000
TOP3=	2.8594	BOT3=	1.8500
TOP3=	3.1901	BOT3=	1.9000
TOP3=	3.5410	BOT3=	1.9500
TOP3=	3.9128	BOT3=	2.0000
TOP4=	0.0200	BOT4=	1.145
TOP4=	0.0400	BOT4=	1.1078
TOP4=	0.0600	BOT4=	1.0705
TOP4=	0.0800	BOT4=	1.0333
TOP4=	0.1000	BOT4=	0.9961
TOP4=	0.1200	BOT4=	0.9589
TOP4=	0.1400	BOT4=	0.9217
TOP4=	0.1600	BOT4=	0.8845
TOP4=	0.1800	BOT4=	0.8473
TOP4=	0.2000	BOT4=	0.8101
TOP4=	0.2200	BOT4=	0.7728
TOP4=	0.2400	BOT4=	0.7356
TOP4=	0.2600	BOT4=	0.6984
TOP4=	0.2800	BOT4=	0.6612
TOP4=	0.3000	BOT4=	0.6240
TOP4=	0.3200	BOT4=	0.5868
TOP4=	0.3400	BOT4=	0.5496
TOP4=	0.3600	BOT4=	0.5124
TOP4=	0.3800	BOT4=	0.4752
TOP4=	0.4000	BOT4=	0.4379
TOP4=	0.4200	BOT4=	0.4007
TOP4=	0.4400	BOT4=	0.3635
TOP4=	0.4600	BOT4=	0.3263
TOP4=	0.4800	BOT4=	0.2891
TOP4=	0.5000	BOT4=	0.2519
TOP4=	0.5200	BOT4=	0.2147
TOP4=	0.5400	BOT4=	0.1775
TOP4=	0.5600	BOT4=	0.1403
TOP4=	0.5800	BOT4=	0.1030
TOP4=	0.6000	BOT4=	0.0658
TOP4=	0.6200	BOT4=	0.0286
TOP4=	0.6400	BOT4=	-0.0086
TOP4=	0.6600	BOT4=	-0.0458
TOP4=	0.6800	BOT4=	-0.0830

```
                    TOP4=     0.7000        BOT4=    -0.1202
                    TOP4=     0.7200        BOT4=    -0.1574
                    TOP4=     0.7400        BOT4=    -0.1946
                    TOP4=     0.7600        BOT4=    -0.2319
                    TOP4=     0.7800        BOT4=    -0.2691
                    TOP4=     0.8000        BOT4=    -0.3063
                    TOP4=     0.8200        BOT4=    -0.3435
                    TOP4=     0.8400        BOT4=    -0.3807
                    TOP4=     0.8600        BOT4=    -0.4179
                    TOP4=     0.8800        BOT4=    -0.4551
                    TOP4=     0.9000        BOT4=    -0.4923
                    TOP4=     0.9200        BOT4=    -0.5296
                    TOP4=     0.9400        BOT4=    -0.5668
                    TOP4=     0.9600        BOT4=    -0.6040
                    TOP4=     0.9800        BOT4=    -0.6412
                    TOP4=     1.0000        BOT4=    -0.6784
END

CF VIO OPERATING SYSTEM VERSION 1 REVISION  012 03/04/74 GENERATED  05/06/74  C

 JOB HANDLING CHARGE    $   .35 / JOB        .35
239 LINES PRINTED PR2 $ 1.25 / K LN        .30
 67 CARDS READ          $ 1.50 / K CD        .10
 00 PLOTTER VECTORS     $   .25 / 1000       .00
 17 MODEL 70 SECONDS    $25.00 / HOUR        .12
 00 MODEL 80 SECONDS    $12.50 / HOUR        .00
                          TOTAL CHARGE $     .87

RFEIR 490 14731  LOGGED OUT 05/06/74 15:25.  $  12.42 LEFT AFTER    19 LOGINS.
```


top thickness (in.)
1
1
bottom thickness (in.)

```
C        *AL* IS THE LEN[illegible]
         AL=[illegible].
         [illegible]=AL/[illegible].
C        *[illegible]* IS THE [illegible]
         [illegible]=[illegible]/3.
         [illegible]=AL/[illegible].
C        *[illegible]* [illegible] THE POISSON'S RATIO OF THE MATERIAL
C        FOR STEEL
         P[illegible]I= .3
C        *E* IS THE YOUNG'S MODULUS OF THE MATERIAL
C        FOR STEEL
         E=3[illegible].*1[illegible].**6
C        *[illegible]* IS THE [illegible] STRESS
         [illegible]ST=[illegible].
C        *S* IS THE SPAC[illegible] OF LONGITUDINAL STIFFENING MEMBERS
         S=1[illegible].
C        *[illegible]* IS THE [illegible] COEF[illegible]ENT
         [illegible]=([illegible]*AL*[illegible].[illegible])/(3[illegible].*3[illegible].)
         [illegible]=[illegible].[illegible]*S*[illegible](1.-P[illegible]I+[illegible]T)/E
C        *T[illegible]* [illegible] THE TH[illegible]CKNESS [illegible]F THE T[illegible] PLATING
C        *[illegible]* [illegible] THE THICKNESS [illegible]F THE BOTTOM PLATING
         T[illegible]= .[illegible]
         B[illegible]T=1.[illegible]
         A=[illegible].*[illegible]*(E*BOT+D*BOT)
         [illegible]=[illegible]*([illegible].*[illegible]*[illegible]T[illegible]*[illegible])+2.*B*D*B[illegible]T*(TOP+BOT)+(D*D*BOT*BOT))
C        *STH* IS THE STRESS ON TOP DUE TO HOGGING
         ST[illegible]=[illegible]/[illegible]
         WRITE(3,[illegible])STH
     [illegible]  F[illegible]MAT(' ',2[illegible]X,'STH='F1[illegible].3)
         [illegible]=[illegible].*[illegible]*(TOP+D*BOT)
C        *S[illegible]* IS THE STRESS ON BOT DUE TO HOGGING
         S[illegible]=[illegible]/[illegible]
         WRITE(3,[illegible])S[illegible]
     [illegible]  FORMAT(' ',2[illegible]X,'SBH='F1[illegible].3)
C        *SCRIT* IS THE CRITICAL STRESS ON BOT
         SCRIT= [illegible]
         WRITE(3,11)SCRIT
     11  FORMAT(' ',17X,'SCRIT='F1[illegible].3)
         D=[illegible].*[illegible]+[illegible]*(T[illegible]+[illegible])
C        *DITOP* IS THE DISTANCE OF THE TOP FROM THE NEUTRAL AXIS
         DITOP=[illegible]([illegible]BOT+[illegible]T)/[illegible]
         WRITE(3,4[illegible])DITOP
     [illegible]  FORMAT(' ',1[illegible]X,'DITOP='F1[illegible].4)
C        *DIBOT* IS THE DISTANCE OF THE BOTTOM FROM THE NEUTRAL AXIS
         DIBOT=D*([illegible]TOP+[illegible]BOT)/[illegible]
         WRITE(3,[illegible])DIBOT
     [illegible]  FORMAT(' ',1[illegible]X,'DIBOT='F10.4)
         END
```

[S]	[illegible]	[illegible]24[V]	[illegible]	3[illegible]C[V]	B	[illegible]3[illegible]4[V]	DRA	233C[V]	D
[V]	P[illegible]I	[illegible]34C[V]	[illegible]	[illegible][S]	.R	3[illegible]C[V]	DST	2364[V]	S
[V]	[illegible]	[illegible]3[illegible][V]	[illegible]	3[illegible][V]	TOP	[illegible]3[illegible]4[V]	BOT	239C[V]	A
[V]	[illegible]	[illegible]C[V]	STH	174[illegible]	6[illegible]	[illegible][S]	@I	23C[illegible][V]	C

```
STRE [illegible] AXIS LOCATION                                  PAGE  2

[V] [illegible]        [illegible]        3??[V] SECRIT  (2?3[L] 11(       33CC[V] P
[V] [illegible]        [illegible]        304[V] [illegible]  (3?4[L] 5(    [illegible][S  .V

[illegible] LABEL :
.70 [illegible]        [illegible]        [illegible]    2?76  I      2441 .R       2?6? .7
[illegible]            [illegible]        [illegible]    [illegible]  2642 EXP      ?7C8 A
[illegible]            [illegible]        [illegible]    2?42 EXP     2964 .FRCNT   2?32

[illegible]
[illegible]            [illegible]        [illegible]    2?42 /EXP    2642 EXP      ?7C8 A
[illegible]            [illegible]        [illegible]    2??? .RARG   2932 [illegible]  2?5C .
[illegible]            [illegible]        [illegible]    2?3C .[illegible]  264? .[illegible]  2?6C .

[illegible]

[illegible]

          S1 = 15771.57?
        [illegible] = [illegible]7?.??1
      SECRIT= ?7??.??3
        [illegible] = 37.4??2
        [illegible] = 15.1??3

[illegible] OPERATING SYSTEM VERSION 1 REVISION ?12  3/?4/74 GENERATED ?5/?6/74

[illegible]                    .35 / [illegible]          .3?
[illegible]                  1.5? / [illegible]           .11
[illegible]                  1.?? / [illegible]           .??
[illegible]                   .25 / [illegible]           .?
[illegible] SECONDS          ?.?? / [illegible]           .11
[illegible] SECONDS        ?12.5? / [illegible]           .?
                          TOTAL [illegible]               .6

[illegible] 14?31 [illegible] ?/?6/74 15:40. $ 14.51 LEFT AFTER ?2 LOGINS.
```

SUMMARY

Length	=	500'
Beam	=	AL/8
Draft	=	B/3
Depth	=	AL/9
DST	=	20000 psi
S	=	120"
Material	-	STEEL
TOP	=	0.03"
BOT	=	1.14"
STH	=	19771.88
SBH	=	9579.87
SBCRIT	=	9788.37
DITOP	=	37.42'
DIBOT	=	18.13'

Note in this case the large value chosen for S and associated with it the large value required for the thickness at the bottom to avoid buckling which nevertheless does not resist stresses larger than 9788 psi in compression.

If we look now at these three cases, all for the same material and set of dimensions (same bending moment) we can see how the thicknesses and neutral axis position changed as the value of S was changed.

CASE	S inches	TOP inches	BOT inches	SBH psi	SBCRIT psi	DITOP ft	DIBOT ft
1	10	0.468	0.166	30000	30000	22.06	33.05
2	30	0.4125	0.4125	20000	20000	27.78	27.78
3	120	0.03	1.14	9700	9700	37.43	18.13

In this table, we can more readily make conclusions on the influence of the value chosen for S on the neutral axis location, and also a quick look at the resulting values for the thicknesses may give an idea of the weight associated with each case.

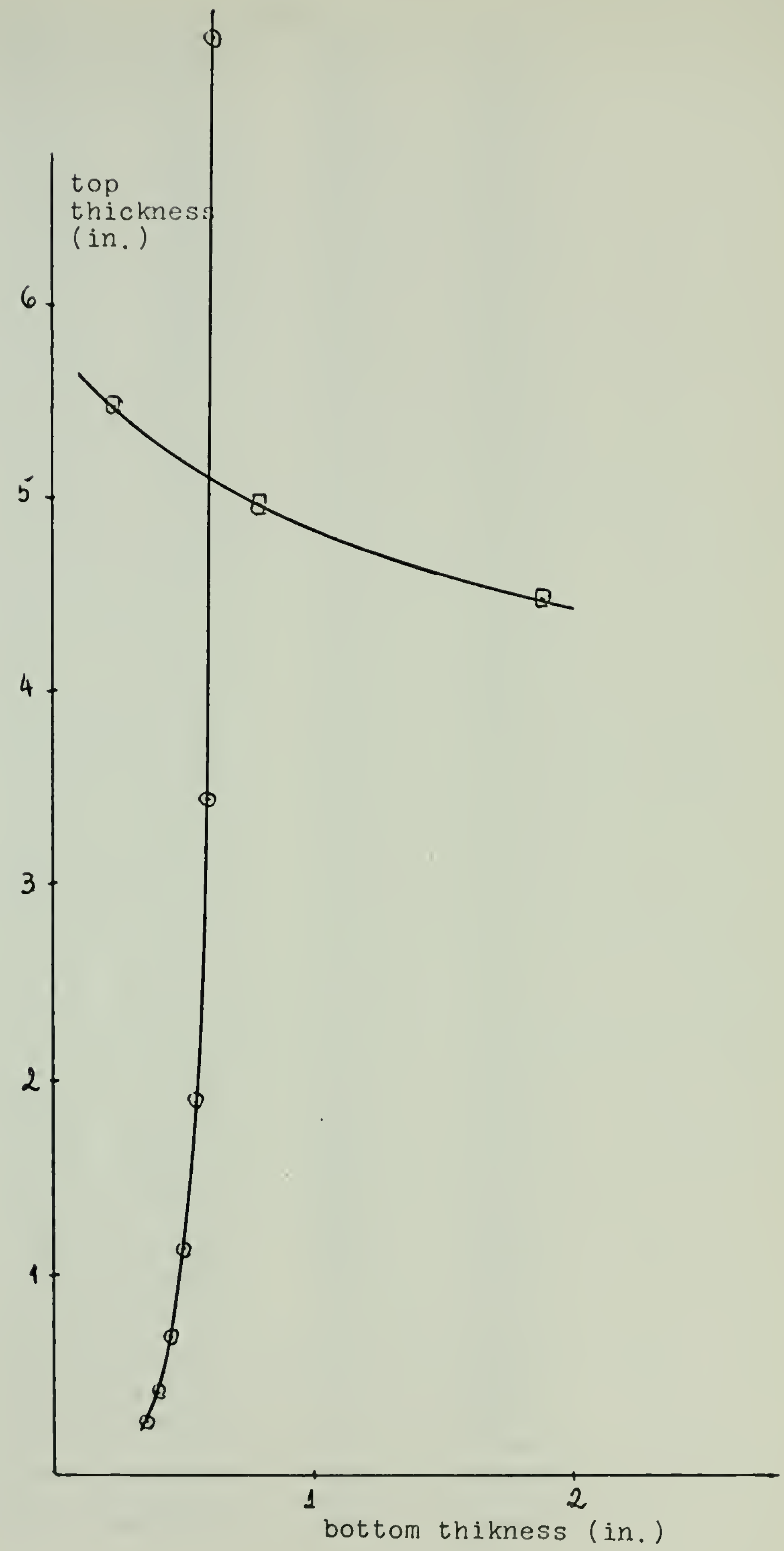
In the following cases the dimension parameters are changed (increased) and consequently the bending moment and the thicknesses of plating will be higher.

```
      C       *AL* IS THE LENGHT
              AL=1ØØØ.
              B=AL/5.75
      C       *DRA* IS THE DRAFT
              DRA=B/3.3
              D=AL/14.
      C       *POI* IS THE POISSON'S RATIO OF THE MATERIAL
      C       FOR STEEL
              POI=Ø.3
      C       *E* IS THE YOUNG'S MODULUS OF THE MATERIAL
      C       FOR STEEL
              E=3Ø.*1Ø.**6
      C       *DST* IS THE DESIGN STRESS
              DST=18ØØØ.
      C       *S* IS THE SPACING OF LONGITUDINAL STIFFENING MEMBERS
              S=3Ø.
      C       *BM* IS THE BENDING MOMENT
              BM=(B*DRA*AL*AL*Ø.75)/(35.*35.)
              G=Ø.3Ø396*S*S*(1.-POI*POI)/E
              A=9.*B*B*D/(14Ø.*BM)
              C=3.*B*D*D/(7Ø.*BM)
              F=3.*D*D*D/(14Ø.*BM)
      C       THICKNESS OF TOP ASSUMED LARGER THAN BOTTOM THICKNESS
              WRITE(5,1Ø)
           1Ø FORMAT('1',25X,'TOP ASSUMED LARGER THAN BOTTOM')
      C       *TOP* IS THE THICKNESS OF THE TOP PLATING
      C       *BOT* IS THE THICKNESS OF THE BOTTOM PLATING
              BOT1=Ø.1
           11 TOP1=5*BOT1*BOT1*BOT1/((B+D)*G*DST-D*BOT1*BOT1)
              WRITE(5,2Ø)TOP1,BOT1
           2Ø FORMAT(' ',25X,'TOP1='F9.4,5X,'BOT1='F9.4)
              BOT1=BOT1+Ø.25
              IF(BOT1.GT.2.)GO TO 3Ø
              GO TO 11
           3Ø TOP2=1.
           31 BOT2=TOP2*(12.*D-(C+F)*DST*TOP2)/(DST*(A+C)*TOP2-12.*B)
              WRITE(5,4Ø)TOP2,BOT2
           4Ø FORMAT(' ',25X,'TOP2='F9.4,5X,'BOT2='F9.4)
              TOP2=TOP2+Ø.5
              IF(TOP2.GT.15.)GO TO 5Ø
              GO TO 31
           5Ø CONTINUE
      C       THICKNESS OF BOTTOM ASSUMED LARGER THAN TOP
              WRITE(5,6Ø)
           6Ø FORMAT('1',25X,'BOTTOM ASSUMED LARGER THAN TOP')
              BOT3=Ø.1
           61 TOP3=((B+D)*BOT3*BOT3*BOT3-D*G*DST*BOT3)/(B*G*DST)
              WRITE(5,7Ø)TOP3,BOT3
           7Ø FORMAT(' ',25X,'TOP3='F9.4,5X,'BOT3='F9.4)
              BOT3=BOT3+Ø.25
              IF(BOT3.GT.3.)GO TO 8Ø
              GO TO 61
```

```
.02          80 TOP4=1.
..A          81 BOT4=(12.*(B+D)-(A+C)*DST*TOP4)/((C+F)*DST)
.4E             WRITE(5,90)TOP4,BOT4
.72          90 FORMAT(' ',25X,'TOP4='F9.4,5X,'BOT4='F9.4)
.9A             TOP4=TOP4+ .5
.A6             IF(TOP4.GT.15.)GO TO 100
.B8             GO TO 81
.BC         100 CONTINUE
.8C             END
[S] .U       04C0[V] AL     04C8[V] B       04D0[V] DRA     04D8[V] D
[V] POI      04F8[V] E      0000[S] .R      04F8[V] DST     0500[V] S
[V] BM       0518[V] G      0524[V] A       0530[V] C       053C[V] F
[L] 10       0200[S] @I     0540[V] BOT1    0176[L] 11      0548[V] TOP1
[L] 20       022C[L] 30     055C[V] TOP2    0234[L] 31      0560[V] BOT2
[L] 42       02FE[L] 50     0312[L] 60      0578[V] BOT3    0348[L] 61
[V] TOP3     0388[L] 70     0402[L] 80      0580[V] TOP4    040A[L] 81
[V] BOT4     0472[L] 90     048C[L] 100     0200[S] .V
E.0          L


GRAM LABELS:
207. *MAIN*   2C18 .V       2A48 .COMP    2C26 @I       25F8 .R       2B10 .ZE
A6E $6        2638 .A       2B6C .MES     29EA .W       27F2 EXP      2978 AIN
6EA ALOG      2AB0 .RARG    2B0C .5       27F2 AEXP     2B14 .ERCNT   2AE2 $8
B14 .0        2BEA .U       3D42


RY-POINTS:
5F8 .R        2638 .A       26EA ALOG     27F2 AEXP     27F2 EXP      2978 AIN
9EA .W        2A48 .COMP    2A6E $6       2AB0 .RARG    2AE2 $8       2B0C .5
B10 .ZERO     2B14 .ERCNT   2B16 .0       2B6C .MES     2BF6 .U       2C1C .V
C26 @I


MON-BLOCKS:
E


EFINED SUBROUTINES:
E


NSFER ADDRESS 2070
UTION BEGINS:
```

```
TOP ASSUMED LARGER THAN BOTTOM
TOP1=    0.0048        BOT1=    0.1000
TOP1=    0.0168        BOT1=    0.1500
TOP1=    0.0412        BOT1=    0.2000
TOP1=    0.0844        BOT1=    0.2500
TOP1=    0.1554        BOT1=    0.3000
TOP1=    0.2673        BOT1=    0.3500
TOP1=    0.4414        BOT1=    0.4000
TOP1=    0.7145        BOT1=    0.4500
TOP1=    1.1570        BOT1=    0.5000
TOP1=    1.9240        BOT1=    0.5500
TOP1=    3.4364        BOT1=    0.6000
TOP1=    7.3849        BOT1=    0.6500
TOP1=   36.2430        BOT1=    0.7000
TOP1=  -20.7688        BOT1=    0.7500
TOP1=   -9.8191        BOT1=    0.8000
TOP1=   -7.1387        BOT1=    0.8500
TOP1=   -5.9771        BOT1=    0.9000
TOP1=   -5.3601        BOT1=    0.9500
TOP1=   -5.0000        BOT1=    1.0000
TOP1=   -4.7816        BOT1=    1.0500
TOP1=   -4.6498        BOT1=    1.1000
TOP1=   -4.5747        BOT1=    1.1500
TOP1=   -4.5388        BOT1=    1.2000
TOP1=   -4.5313        BOT1=    1.2500
TOP1=   -4.5450        BOT1=    1.3000
TOP1=   -4.5748        BOT1=    1.3500
TOP1=   -4.6173        BOT1=    1.4000
TOP1=   -4.6700        BOT1=    1.4500
TOP1=   -4.7309        BOT1=    1.5000
TOP1=   -4.7986        BOT1=    1.5500
TOP1=   -4.8720        BOT1=    1.6000
TOP1=   -4.9502        BOT1=    1.6500
TOP1=   -5.0325        BOT1=    1.7000
TOP1=   -5.1183        BOT1=    1.7500
TOP1=   -5.2071        BOT1=    1.8000
TOP1=   -5.2986        BOT1=    1.8500
TOP1=   -5.3924        BOT1=    1.9000
TOP1=   -5.4883        BOT1=    1.9500
TOP1=   -5.5860        BOT1=    2.0000
TOP2=    1.0000        BOT2=   -0.4673
TOP2=    1.5000        BOT2=   -0.7727
TOP2=    2.0000        BOT2=   -1.1829
TOP2=    2.5000        BOT2=   -1.8315
TOP2=    3.0000        BOT2=   -3.2461
TOP2=    3.5000        BOT2=  -11.8971
TOP2=    4.0000        BOT2=    5.8810
TOP2=    4.5000        BOT2=    1.8850
TOP2=    5.0000        BOT2=    0.8127
TOP2=    5.5000        BOT2=    0.2578
TOP2=    6.0000        BOT2=   -0.1140
TOP2=    6.5000        BOT2=   -0.4000
TOP2=    7.0000        BOT2=   -0.6389
TOP2=    7.5000        BOT2=   -0.8492
TOP2=    8.0000        BOT2=   -1.0408
TOP2=    8.5000        BOT2=   -1.2195
```

TOP2=	9.0000	BOT2=	-1.3890
TOP2=	9.5000	BOT2=	-1.5516
TOP2=	10.0000	BOT2=	-1.7090
TOP2=	10.5000	BOT2=	-1.8623
TOP2=	11.0000	BOT2=	-2.0124
TOP2=	11.5000	BOT2=	-2.1599
TOP2=	12.0000	BOT2=	-2.3052
TOP2=	12.5000	BOT2=	-2.4487
TOP2=	13.0000	BOT2=	-2.5907
TOP2=	13.5000	BOT2=	-2.7314
TOP2=	14.0000	BOT2=	-2.8711
TOP2=	14.5000	BOT2=	-3.0098
TOP2=	15.0000	BOT2=	-3.1477


top
thickness
(in.)
6
5
4
3
2
1
1
2
bottom thikness (in.)

```
BOTTOM ASSUMED LARGER THAN TOP
TOP3=   -0.0316        BOT3=   0.1000
TOP3=   -0.0297        BOT3=   0.1500
TOP3=   -0.0066        BOT3=   0.2000
TOP3=    0. 449        BOT3=   0.2500
TOP3=    0.1318        BOT3=   0.3000
TOP3=    0.2612        BOT3=   0.3500
TOP3=    0.4402        BOT3=   0.4000
TOP3=    0.6758        BOT3=   0.4500
TOP3=    0.9742        BOT3=   0.5000
TOP3=    1.3455        BOT3=   0.5500
TOP3=    1.7936        BOT3=   0.6000
TOP3=    2.3268        BOT3=   0.6500
TOP3=    2.9520        BOT3=   0.7000
TOP3=    3.6764        BOT3=   0.7500
TOP3=    4.5071        BOT3=   0.8000
TOP3=    5.4511        BOT3=   0.8500
TOP3=    6.5155        BOT3=   0.9000
TOP3=    7.7074        BOT3=   0.9500
TOP3=    9.0329        BOT3=   1.0000
TOP3=   10.5021        BOT3=   1.0500
TOP3=   12.1150        BOT3=   1.1000
TOP3=   13.7917        BOT3=   1.1500
TOP3=   15.2273        BOT3=   1.2000
TOP3=   17.9330        BOT3=   1.2500
TOP3=   20.2157        BOT3=   1.3000
TOP3=   22.4826        BOT3=   1.3500
TOP3=   25.3427        BOT3=   1.4000
TOP3=   28.1972        BOT3=   1.4500
TOP3=   31.2591        BOT3=   1.5000
TOP3=   34.5334        BOT3=   1.5500
TOP3=   38.[illegible]274        BOT3=   1.6000
TOP3=   41.7430        BOT3=   1.6500
TOP3=   45.7024        BOT3=   1.7000
TOP3=   49.8976        BOT3=   1.7500
TOP3=   54.3427        BOT3=   1.8000
TOP3=   59.0358        BOT3=   1.8500
TOP3=   63.9990        BOT3=   1.9000
TOP3=   69.2283        BOT3=   1.9500
TOP3=   74.7339        BOT3=   2.0000
TOP3=   80.5228        BOT3=   2.0500
TOP3=   86.6022        BOT3=   2.1000
TOP3=   92.9790        BOT3=   2.1500
TOP3=   99.6624        BOT3=   2.2000
TOP3=  106.6534        BOT3=   2.2500
TOP3=  113.9652        BOT3=   2.3000
TOP3=  121.6029        BOT3=   2.3500
TOP3=  129.5735        BOT3=   2.4000
TOP3=  137.9842        BOT3=   2.4500
TOP3=  146.5416        BOT3=   2.5000
TOP3=  155.5534        BOT3=   2.5500
TOP3=  164.9265        BOT3=   2.6000
TOP3=  174.6679        BOT3=   2.6500
TOP3=  184.7845        BOT3=   2.7000
TOP3=  195.2838        BOT3=   2.7500
TOP3=  206.1726        BOT3=   2.8000
```

TOP3=	217.4581	BOT3=	2.8500
TOP3=	229.1475	BOT3=	2.9000
TOP3=	241.2473	BOT3=	2.9500
TOP3=	253.7654	BOT3=	3.0000
TOP4=	1.0000	BOT4=	16.1639
TOP4=	1.5000	BOT4=	14.2342
TOP4=	2.0000	BOT4=	12.3044
TOP4=	2.5000	BOT4=	10.3746
TOP4=	3.0000	BOT4=	8.4448
TOP4=	3.5000	BOT4=	6.5150
TOP4=	4.0000	BOT4=	4.5852
TOP4=	4.5000	BOT4=	2.6554
TOP4=	5.0000	BOT4=	0.7256
TOP4=	5.5000	BOT4=	-1.2042
TOP4=	6.0000	BOT4=	-3.1340
TOP4=	6.5000	BOT4=	-5.0638
TOP4=	7.0000	BOT4=	-6.9936
TOP4=	7.5000	BOT4=	-8.9234
TOP4=	8.0000	BOT4=	-10.8532
TOP4=	8.5000	BOT4=	-12.7829
TOP4=	9.0000	BOT4=	-14.7127
TOP4=	9.5000	BOT4=	-16.6425
TOP4=	10.0000	BOT4=	-18.5723
TOP4=	10.5000	BOT4=	-20.5021
TOP4=	11.0000	BOT4=	-22.4319
TOP4=	11.5000	BOT4=	-24.3617
TOP4=	12.0000	BOT4=	-26.2915
TOP4=	12.5000	BOT4=	-28.2213
TOP4=	13.0000	BOT4=	-30.1511
TOP4=	13.5000	BOT4=	-32.0808
TOP4=	14.0000	BOT4=	-34.0106
TOP4=	14.5000	BOT4=	-35.9404
TOP4=	15.0000	BOT4=	-37.8702

ND

VIC OPERATING SYSTEM VERSION 1 REVISION 012 03/04/74 GENERATED 05/06/74 0

```
OB HANDLING CHARGE    $  .35 / JOB      .35
53 LINES PRINTED PR2  $ 1.25 / K LN     .32
67 CARDS READ         $ 1.50 / K CD     .10
00 PLOTTER VECTORS    $  .25 / 1000     .00
17 MODEL 70 SECONDS   $25.00 / HOUR     .12
00 MODEL 80 SECONDS   $12.50 / HOUR     .00
                 TOTAL CHARGE $         .89
```

EIR 490 14731 LOGGED OUT 05/06/74 17:26. $ 9.62 LEFT AFTER 23 LOGINS.

```
      C     *AL* IS THE LENGHT
            AL=1000.
            B=AL/5.75
      C     *DRA* IS THE DRAFT
            DRA=B/3.3
            D=AL/14.
      C     *POI* IS THE POISSON'S RATIO OF THE MATERIAL
      C     FOR STEEL
            POI=0.3
      C     *E* IS THE YOUNG'S MODULUS OF THE MATERIAL
      C     FOR STEEL
            E=30.*10.**6
      C     *DST* IS THE DESIGN STRESS
            DST=18000.
      C     *S* IS THE SPACING OF LONGITUDINAL STIFFENING MEMBERS
            S=30.
      C     *BM* IS THE BENDING MOMENT
            BM=(B*DRA*AL*AL*0.75)/(35.*35.)
            G=0.30396*S*S*(1.-POI*POI)/E
      C     *TOP* IS THE THICKNESS OF THE TOP PLATING
      C     *BOT* IS THE THICKNESS OF THE BOTTOM PLATING
            TOP=5.12
            BOT=0.62
            A=560.*BM*(B*BOT+D*TOP)
            DEN=D*(3.*B*B*TOP*BOT+2.*B*D*TOP*(TOP+BOT)+(D*D*TOP*TOP))
      C     *STH* IS THE STRESS ON TOP DUE TO HOGGING
            STH=A/DEN
            WRITE(5,60)STH
         60 FORMAT(' ',20X,'STH='F10.3)
            C=560.*BM*(B*TOP+D*TOP)
      C     *SBH* IS THE STRESS ON BOT DUE TO HOGGING
            SBH=C/DEN
            WRITE(5,90)SBH
         90 FORMAT(' ',20X,'SBH='F10.3)
      C     *SBCRIT* IS THE CRITICAL STRESS ON BOT
            SBCRIT=BOT*BOT/G
            WRITE(5,110)SBCRIT
        110 FORMAT(' ',17X,'SBCRIT='F10.3)
            P=2.*D*TOP+B*(TOP+BOT)
      C     *DITOP* IS THE DISTANCE OF THE TOP FROM THE NEUTRAL AXIS
            DITOP=D*(B*BOT+D*TOP)/P
            WRITE(5,40)DITOP
         40 FORMAT(' ',18X,'DITOP='F10.4)
      C     *DIBOT* IS THE DISTANCE OF THE BOTTOM FROM THE NEUTRAL AXIS
            DIBOT=D*(B*TOP+D*TOP)/P
            WRITE(5,50)DIBOT
         50 FORMAT(' ',18X,'DIBOT='F10.4)
            END
 [S] .U      0324 [V] AL     032C [V] B      0334 [V] DRA    033C [V] D
 [V] POI     034C [V] E      0000 [S] .R     035C [V] DST    0364 [V] S
 [V] BM      037C [V] G      0388 [V] TOP    0390 [V] BOT    0398 [V] A
 [V] DEN     03BC [V] STH    0174 [L] 60     0000 [S] @I     03C0 [V] C
```

```
:4(V) SaH      Ø1E2(L) 90      Ø3C8(V) SBCRIT  Ø228(L) 110     Ø3CC(V) P
)Ø(V) DITOP    Ø2A8(L) 40      Ø3D4(V) DIBOT   Ø304(L) 50      ØØØØ(S) .V
.EQ         L
)F

ROGRAM LABELS:
2Ø7Ø *MAIN*    2A68 .V         2898 .COMP      2A76 @I         2448 .R         296Ø .Z
28BE $6        2488 .A         29BC .MES       283A .W         2642 EXP        27C8 AI
253A ALOG      29ØØ .RARG      295C .5         2642 AEXP       2964 .ERCNT     2932 $8
2964 .O        2A3A .U         3B92

TRY-POINTS:
2446 .R        2488 .A         253A ALOG       2642 AEXP       2642 EXP        27C8 AI
283A .W        2898 .COMP      28BE $6         29ØØ .RARG      2932 $8         295C .5
296Ø .ZERO     2964 .ERCNT     2966 .O         29BC .MES       2A46 .U         2A6C .V
2A76 @I

MMON-BLOCKS:
NE

DEFINED SUBROUTINES:
NE

ANSFER ADDRESS 2Ø7Ø
CUTION BEGINS:

             STH= 18Ø85.Ø23
             SBH= 47973.711
          SBCRIT= 46323.625
           DITOP=    19.5551
           DIBOT=    51.8734
END

F VIO OPERATING SYSTEM VERSION 1 REVISION  Ø12 Ø3/Ø4/74 GENERATED  Ø5/Ø6/74

JOB HANDLING CHARGE      $   .35 / JOB         .35
 85 LINES PRINTED PR1    $ 1.25 / K LN         .11
 54 CARDS READ           $ 1.5Ø / K CD         .Ø8
 ØØ PLOTTER VECTORS      $   .25 / 1ØØØ        .ØØ
 13 MODEL 7Ø SECONDS     $25.ØØ / HOUR         .Ø9
 ØØ MODEL 8Ø SECONDS     $12.5Ø / HOUR         .ØØ
                      TOTAL CHARGE $           .63

REIR 49Ø 14731  LOGGED OUT Ø5/Ø6/74 17:36.  $   8.11 LEFT AFTER    Ø5 LOGINS.
```

SUMMARY

Length	=	1000 ft
Beam	=	AL/5.75
Draft	=	B/3.3
Depth	=	AL/14
DST	=	18000 psi
S	=	30"
Material	-	STEEL
TOP	=	5.12"
BOT	=	0.62"
STH	=	18085.02
SBH	=	47973.71
SBCRIT	=	46323.82
DITOP	=	19.55'
DIBOT	=	51.87'

We might say here that the value chosen for S is small and this accounts for the compression at the bottom to reach such a high value.

In the next case, the value chosen for S is increased to 60 inches.

```
C       *AL* IS THE LENGHT
        AL=1000.
        B=AL/5.75
C       *DRA* IS THE DRAFT
        DRA=B/3.3
        D=AL/14.
C       *POI* IS THE POISSON'S RATIO OF THE MATERIAL
C       FOR STEEL
        POI=0.3
C       *E* IS THE YOUNG'S MODULUS OF THE MATERIAL
C       FOR STEEL
        E=30.*10.**6
C       *DST* IS THE DESIGN STRESS
        DST=18000.
C       *S* IS THE SPACING OF LONGITUDINAL STIFFENING MEMBERS
        S=60.
C       *BM* IS THE BENDING MOMENT
        BM=(B*DRA*AL*AL*0.75)/(35.*35.)
        G=0.30396*S*S*(1.-POI*POI)/E
        A=9.*B*B*D/(140.*BM)
        C=3.*B*D*D/(70.*BM)
        F=3.*D*D*D/(140.*BM)
C       THICKNESS OF TOP ASSUMED LARGER THAN BOTTOM THICKNESS
        WRITE(5,10)
     10 FORMAT('1',25X,'TOP ASSUMED LARGER THAN BOTTOM')
C       *TOP* IS THE THICKNESS OF THE TOP PLATING
C       *BOT* IS THE THICKNESS OF THE BOTTOM PLATING
        BOT1=0.02
     11 TOP1=B*BOT1*BOT1*BOT1/((B+D)*G*DST-D*BOT1*BOT1)
        WRITE(5,20)TOP1,BOT1
     20 FORMAT(' ',25X,'TOP1=',F9.4,5X,'BOT1='F9.4)
        BOT1=BOT1+0.02
        IF(BOT1.GT.2.)GO TO 30
        GO TO 11
     30 TOP2=1.
     31 BOT2=TOP2*(12.*D-(C+F)*DST*TOP2)/(DST*(A+C)*TOP2-12.*B)
        WRITE(5,40)TOP2,BOT2
     40 FORMAT(' ',25X,'TOP2=',F9.4,5X,'BOT2='F9.4)
        TOP2=TOP2+0.2
        IF(TOP2.GT.6. ) GO TO 50
        GO TO 31
     50 CONTINUE
C       THICKNESS OF BOTTOM ASSUMED LARGER THAN TOP
        WRITE(5,60)
     60 FORMAT('1',25X,'BOTTOM ASSUMED LARGER THAN TOP')
        BOT3=0.4
     61 TOP3=((B+D)*BOT3*BOT3*BOT3-D*G*DST*BOT3)/(B*G*DST)
        WRITE(5,70)TOP3,BOT3
     70 FORMAT(' ',25X,'TOP3=',F9.4,5X,'BOT3='F9.4)
        BOT3=BOT3+0.02
        IF(BOT3.GT..85)GO TO 80
     80 TOP4=1.
```

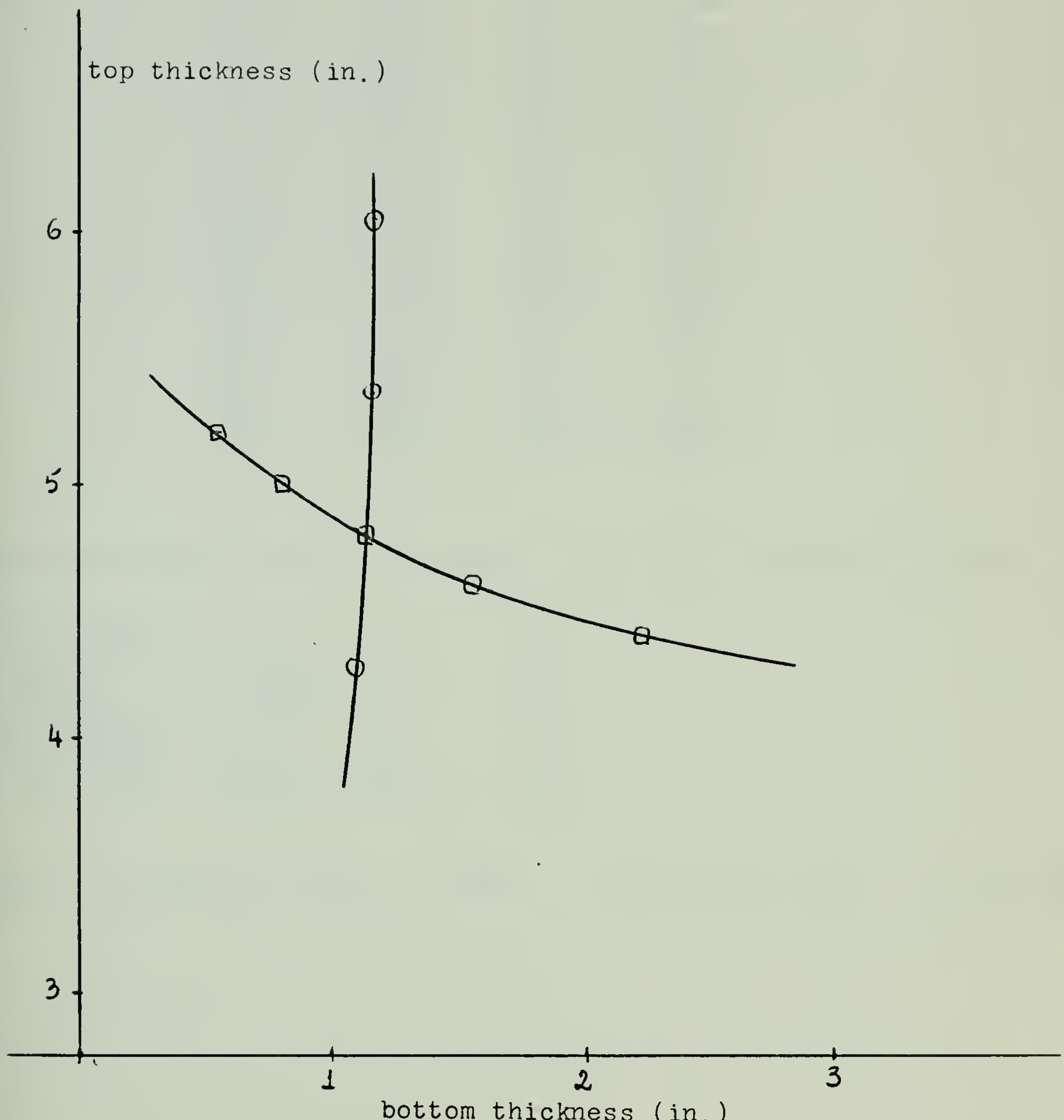
```
:406       81 BOT4=(12.*(B+D)-(A+C)*DST*TOP4)/((C+F)*DST)
:44A          WRITE(5,90)TOP4,BOT4
:46E       90 FORMAT(' ',25X,'TOP4=',F9.4,5X,'BOT4='F9.4)
:496          TOP4=TOP4+0.2
:4A2          IF(TOP4.GT.5.5)GO TO 100
:4B4          GO TO 81
:4B8      100 CONTINUE
:4B8          END
.(S] .U      04BC[V] AL      04C4[V] B       04CC[V] DRA     04D4[V] D
C[V] POI     04E4[V] E       0000[S] .R      04F4[V] DST     04FC[V] S
.[V] BM      0518[V] G       0524[V] A       0530[V] C       053C[V] F
.[L] 10      0000[S] @I      0540[V] BOT1    0176[L] 11      0548[V] TOP1
.[L] 20      022C[L] 30      0558[V] TOP2    0234[L] 31      055C[V] BOT2
.[L] 40      02FE[L] 50      0312[L] 60      0574[V] BOT3    0348[L] 61
C[V] TOP3    0388[L] 70      03FE[L] 80      0584[V] TOP4    0406[L] 81
.[V] BOT4    046E[L] 90      0488[L] 100     0000[S] .V
.E0          L
F

GRAM LABELS:
2270 *MAIN*    2C20 .V        2A50 .COMP     2C2E @I        2600 .R        2B18 .7
2A76 $6        2640 .A        2B74 .MES      29F2 .W        27FA EXP       2980 AI
26F2 ALOG      2AB8 .RARG     2B14 .5        27FA AEXP      2B1C .ERCNT    2AEA $8
2B1C .0        2BF2 .U        3D4A

RY-POINTS:
2600 .R        2640 .A        26F2 ALOG      27FA AEXP      27FA EXP       2980 AI
29F2 .W        2A50 .COMP     2A76 $6        2AB8 .RARG     2AEA $8        2B14 .5
2B18 .ZERO     2B1C .ERCNT    2B1E .0        2B74 .MES      2BFE .U        2C24 .V
2C2E @I

MON-BLOCKS:
NE

EFINED SUBROUTINES:
NE

ANSFER ADDRESS 2070
CUTION BEGINS:
```

TOP ASSUMED LARGER THAN BOTTOM

TOP1=	0.0000	BOT1=	0.0200
TOP1=	0.0001	BOT1=	0.0400
TOP1=	0.0003	BOT1=	0.0600
TOP1=	0.0006	BOT1=	0.0800
TOP1=	0.0012	BOT1=	0.1000
TOP1=	0.0021	BOT1=	0.1200
TOP1=	0.0033	BOT1=	0.1400
TOP1=	0.0049	BOT1=	0.1600
TOP1=	0.0070	BOT1=	0.1800
TOP1=	0.0097	BOT1=	0.2000
TOP1=	0.0129	BOT1=	0.2200
TOP1=	0.0169	BOT1=	0.2400
TOP1=	0.0216	BOT1=	0.2600
TOP1=	0.0271	BOT1=	0.2800
TOP1=	0.0335	BOT1=	0.3000
TOP1=	0.0409	BOT1=	0.3200
TOP1=	0.0494	BOT1=	0.3400
TOP1=	0.0591	BOT1=	0.3600
TOP1=	0.0700	BOT1=	0.3800
TOP1=	0.0824	BOT1=	0.4000
TOP1=	0.0962	BOT1=	0.4200
TOP1=	0.1116	BOT1=	0.4400
TOP1=	0.1288	BOT1=	0.4600
TOP1=	0.1478	BOT1=	0.4800
TOP1=	0.1689	BOT1=	0.5000
TOP1=	0.1921	BOT1=	0.5200
TOP1=	0.2178	BOT1=	0.5400
TOP1=	0.2459	BOT1=	0.5600
TOP1=	0.2769	BOT1=	0.5800
TOP1=	0.3108	BOT1=	0.6000
TOP1=	0.3479	BOT1=	0.6200
TOP1=	0.3886	BOT1=	0.6400
TOP1=	0.4330	BOT1=	0.6600
TOP1=	0.4816	BOT1=	0.6800
TOP1=	0.5346	BOT1=	0.7000
TOP1=	0.5925	BO-1=	0.7200
TOP1=	0.6558	BOT1=	0.7400
TOP1=	0.7248	BOT1=	0.7600
TOP1=	0.8003	BOT1=	0.7800
TOP1=	0.8828	BOT1=	0.8000
TOP1=	0.9730	BOT1=	0.8200
TOP1=	1.0717	BOT1=	0.8400
TOP1=	1.1799	BOT1=	0.8600
TOP1=	1.2985	BOT1=	0.8800
TOP1=	1.4289	BOT1=	0.9000
TOP1=	1.5724	BOT1=	0.9200
TOP1=	1.7306	BOT1=	0.9400
TOP1=	1.9054	BOT1=	0.9600
TOP1=	2.0990	BOT1=	0.9800
TOP1=	2.3141	BOT1=	1.0000
TOP1=	2.5537	BOT1=	1.0200
TOP1=	2.8218	BOT1=	1.0400
TOP1=	3.1229	BOT1=	1.0600
TOP1=	3.4626	BOT1=	1.0800
TOP1=	3.8480	BOT1=	1.1000

TOP1=	4.2678	BOT1= 1.1200
TOP1=	4.7931	BOT1= 1.1400
TOP1=	5.3786	BOT1= 1.1600
TOP1=	6.0632	BOT1= 1.1800
TOP1=	6.8726	BOT1= 1.2000
TOP1=	7.8419	BOT1= 1.2200
TOP1=	9.0212	BOT1= 1.2400
TOP1=	10.4833	BOT1= 1.2600
TOP1=	12.3398	BOT1= 1.2800
TOP1=	14.7689	BOT1= 1.3000
TOP1=	18.0742	BOT1= 1.3200
TOP1=	22.8310	BOT1= 1.3400
TOP1=	30.2304	BOT1= 1.3600
TOP1=	43.2943	BOT1= 1.3800
TOP1=	72.4639	BOT1= 1.4000
TOP1=	194.7422	BOT1= 1.4200
TOP1=	-339.7143	BOT1= 1.4400
TOP1=	-95.4322	BOT1= 1.4600
TOP1=	-57.1133	BOT1= 1.4800
TOP1=	-41.5440	BOT1= 1.5000
TOP1=	-33.1158	BOT1= 1.5200
TOP1=	-27.8412	BOT1= 1.5400
TOP1=	-24.2356	BOT1= 1.5600
TOP1=	-21.6199	BOT1= 1.5800
TOP1=	-19.6394	BOT1= 1.6000
TOP1=	-18.0908	BOT1= 1.6200
TOP1=	-16.8492	BOT1= 1.6400
TOP1=	-15.8337	BOT1= 1.6600
TOP1=	-14.9894	BOT1= 1.6800
TOP1=	-14.2780	BOT1= 1.7000
TOP1=	-13.6717	BOT1= 1.7200
TOP1=	-13.1500	BOT1= 1.7400
TOP1=	-12.6974	BOT1= 1.7600
TOP1=	-12.3021	BOT1= 1.7800
TOP1=	-11.9546	BOT1= 1.8000
TOP1=	-11.6475	BOT1= 1.8200
TOP1=	-11.3750	BOT1= 1.8400
TOP1=	-11.1322	BOT1= 1.8600
TOP1=	-10.9151	BOT1= 1.8800
TOP1=	-10.7203	BOT1= 1.9000
TOP1=	-10.5453	BOT1= 1.9200
TOP1=	-10.3875	BOT1= 1.9400
TOP1=	-10.2452	BOT1= 1.9600
TOP1=	-10.1145	BOT1= 1.9800
TOP1=	-10.0001	BOT1= 2.0000
TOP2=	1.0000	BOT2= -0.4673
TOP2=	1.2000	BOT2= -0.5810
TOP2=	1.4000	BOT2= -0.7055
TOP2=	1.6000	BOT2= -0.8440
TOP2=	1.8000	BOT2= -1.0009
TOP2=	2.0000	BOT2= -1.1829
TOP2=	2.2000	BOT2= -1.4002
TOP2=	2.4000	BOT2= -1.6693
TOP2=	2.6000	BOT2= -2.0190
TOP2=	2.8000	BOT2= -2.5045
TOP2=	3.0000	BOT2= -3.2460

```
TOP2=   3.2000     BOT2=   -4.5652
TOP2=   3.4000     BOT2=   -7.7108
TOP2=   3.6000     BOT2=  -26.8087
TOP2=   3.8000     BOT2=   16.3226
TOP2=   4.0000     BOT2=    5.8811
TOP2=   4.2000     BOT2=    3.3945
TOP2=   4.4000     BOT2=    2.2560
TOP2=   4.6000     BOT2=    1.5888
TOP2=   4.8000     BOT2=    1.1408
TOP2=   5.0000     BOT2=    0.8127
TOP2=   5.2000     BOT2=    0.5572
TOP2=   5.4000     BOT2=    0.3490
TOP2=   5.6000     BO·2=    0.1733
TOP2=   5.8000     BOT2=    0.0210
TOP2=   6.0000     BOT2=   -0.1140
```


top thickness (in.)
6
5
4
3
1
2
3
bottom thickness (in.)

```
BOTTOM ASSUMED LARGER THAN TOP
TOP3=  -0.0132      BOT3=   0.4000
TOP4=   1.0000      BOT4=  16.1639
TOP4=   1.2000      BOT4=  15.3920
TOP4=   1.4000      BOT4=  14.6201
TOP4=   1.6000      BOT4=  13.8482
TOP4=   1.8000      BOT4=  13.0763
TOP4=   2.0000      BOT4=  12.3044
TOP4=   2.2000      BOT4=  11.5324
TOP4=   2.4000      BOT4=  10.7605
TOP4=   2.6000      BOT4=   9.9886
TOP4=   2.8000      BOT4=   9.2167
TOP4=   3.0000      BOT4=   8.4448
TOP4=   3.2000      BOT4=   7.6729
TOP4=   3.4000      BOT4=   6.9010
TOP4=   3.6000      BOT4=   6.1290
TOP4=   3.8000      BOT4=   5.3571
TOP4=   4.0000      BOT4=   4.5852
TOP4=   4.2000      BOT4=   3.8133
TOP4=   4.4000      BOT4=   3.0414
TOP4=   4.6000      BOT4=   2.2695
TOP4=   4.8000      BOT4=   1.4975
TOP4=   5.0000      BOT4=   0.7256
TOP4=   5.2000      BOT4=  -0.0463
TOP4=   5.4000      BOT4=  -0.8182
END

 VIO OPERATING SYSTEM VERSION 1 REVISION  012 03/04/74 GENERATED  05/06/74

JOB HANDLING CHARGE   $   .35 / JOB        .35
246 LINES PRINTED PR1 $ 1.25 / K LN        .31
 66 CARDS READ        $ 1.50 / K CD        .10
 00 PLOTTER VECTORS   $   .25 / 1000       .00
 17 MODEL 72 SECONDS  $25.00 / HOUR        .12
 00 MODEL 80 SECONDS  $12.50 / HOUR        .00
                 TOTAL CHARGE $            .88

PEIR 490 14731  LOGGED OUT 05/06/74 17:28.  $   8.74 LEFT AFTER    24 LOGINS.
```

```
      C     *AL* IS THE LENGHT
            AL=1000.
            B=AL/5.75
      C     *DRA* IS THE DRAFT
            DRA=B/3.3
            D=AL/14.
      C     *POI* IS THE POISSON'S RATIO OF THE MATERIAL
      C     FOR STEEL
            POI=0.3
      C     *E* IS THE YOUNG'S MODULUS OF THE MATERIAL
      C     FOR STEEL
            E=30.*10.**6
      C     *DST* IS THE DESIGN STRESS
            DST=18000.
      C     *S* IS THE SPACING OF LONGITUDINAL STIFFENING MEMBERS
            S=60.
      C     *BM* IS THE BENDING MOMENT
            BM=(B*DRA*AL*AL*0.75)/(35.*35.)
            G=0.30396*S*S*(1.-POI*POI)/E
      C     *TOP* IS THE THICKNESS OF THE TOP PLATING
      C     *BOT* IS THE THICKNESS OF THE BOTTOM PLATING
            TOP=4.79
            BOT=1.15
            A=560.*BM*(B*BOT+D*TOP)
            DEN=D*(3.*B*B*TOP*BOT+2.*B*D*TOP*(TOP+BOT)+(D*D*TOP*TOP))
      C     *STH* IS THE STRESS ON TOP DUE TO HOGGING
            STH=A/DEN
            WRITE(5,60)STH
         60 FORMAT(' ',20X,'STH='F10.3)
            C=560.*BM*(B*TOP+D*TOP)
      C     *SBH* IS THE STRESS ON BOT DUE TO HOGGING
            SBH=C/DEN
            WRITE(5,90)SBH
         90 FORMAT(' ',20X,'SBH='F10.3)
      C     *SBCRIT* IS THE CRITICAL STRESS ON BOT
            SBCRIT=BOT*BOT/G
            WRITE(5,110)SBCRIT
        110 FORMAT(' ',17X,'SBCRIT='F10.3)
            P=2.*D*TOP+B*(TOP+BOT)
      C     *DITOP* IS THE DISTANCE OF THE TOP FROM THE NEUTRAL AXIS
            DITOP=D*(B*BOT+D*TOP)/P
            WRITE(5,40)DITOP
         40 FORMAT(' ',18X,'DITOP='F10.4)
      C     *DIBOT* IS THE DISTANCE OF THE BOTTOM FROM THE NEUTRAL AXIS
            DIBOT=D*(B*TOP+D*TOP)/P
            WRITE(5,50)DIBOT
         50 FORMAT(' ',18X,'DIBOT='F10.4)
            END
[S] .U      0324[V] AL     032C[V] B     0334[V] DRA    033C[V] D
[V] POI     034C[V] E      0000[S] .R    035C[V] DST    0364[V] S
[V] BM      0382[V] G      038C[V] TOP   0394[V] BOT    039C[V] A
[V] DEN     03C0[V] STH    0174[L] 60    0000[S] @I     03C4[V] C
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   STRENGHT OF SHIPS-ON THE NEUTRAL AXIS LOCATION                              PAGE  2

:R(V] SBH       01E2(L] 90      03CC(V] SBCRIT   0228(L] 110      03D0(V] P
)4(V] DITOP     02A8(L] 40      03D8(V] DIBOT    0304(L] 50       0000(S  .V
.XEQ          L
)F

ROGRAM LABELS:
2070 *MAIN*     2A6C .V          289C .COMP     2A7A @I        244C .R        2964 .Z
28C2 $6         248C .A          29C0 .MES      283E .W        2646 EXP       27CC AI
253E ALOG       2904 .RARG       2960 .5        2646 AEXP      2968 .ERCNT    2936 $8
2968 .O         2A3E .U          3896

TRY-POINTS:
244C .R         248C .A          253E ALOG      2646 AEXP      2646 EXP       27CC AI
283E .W         289C .COMP       28C2 $6        2904 .RARG     2936 $8        2960 .5
2964 .ZERO      2968 .ERCNT      296A .O        29C0 .MES      2A4A .U        2A70 .V
2A7A @I

MON-BLOCKS:
NE

DEFINED SUBROUTINES:
NE

ANSFER ADDRESS 2070
CUTION BEGINS:

                STH= 18017.242
                SBH= 39055.434
             SBCRIT= 39843.250
              DITOP=    22.5492
              DIBOT=    48.8793
END

 VIO OPERATING SYSTEM VERSION 1 REVISION  012 03/04/74 GENERATED  05/06/74

JOB HANDLING CHARGE     $   .35 / JOB        .35
85 LINES PRINTED PR1    $ 1.25 / K LN        .11
54 CARDS READ           $ 1.50 / K CD        .08
00 PLOTTER VECTORS      $   .25 / 1000       .00
13 MODEL 70 SECONDS     $25.00 / HOUR        .09
00 MODEL 80 SECONDS     $12.50 / HOUR        .00
                          TOTAL CHARGE $     .63

EIR 490 14731  LOGGED OUT 05/06/74 17:37.  $   7.48 LEFT AFTER    26 LOGINS.
```

SUMMARY

Length	=	1000'
Beam	=	AL/5.75
Draft	=	B/3.3
Depth	=	AL/14
DST	=	18000 psi
S	=	60"
Material	-	STEEL
TOP	=	4.79"
BOT	=	1.15"
STH	=	18017.24
SBH	=	39055.43
SBCRIT	=	39843.44
DITOP	=	22.55'
DIBOT	=	48.88'

Since sometimes it is desirable to use aluminum alloys in the structure of ships, due to their light weight, high corrosion resistance and non-magnetic characteristics, in the following runs, the material considered is aluminum. The necessary change is made in the input to account for the properties of this material.

When considering aluminum as the structural material, we must keep in mind that the aluminum hull will be more flexible than a corresponding steel ship. The modulus of elasticity of aluminum is about one third that of steel, and if scantlings were identical, the deflection of an aluminum ship, under a given load, would be three times those of a steel ship.

However, to obtain a factor of safety on ultimate strength equal to that in steel, the area of an aluminum member in direct stress, or the section modulus of an aluminum member in bending would be about 1.5 times that of the corresponding steel member (based on an ultimate strength of about 60000 psi in medium steel and of about 40000 psi across the welds of a welded aluminum structure).

A section modulus of 1.5 times that in steel, with the same depth being considered in both cases, would result in a deflection in aluminum about twice that in steel. However, the lower modulus of elasticity of aluminum reduces its ability to resist buckling , and for the same factor of safety both the section modulus and the moment of inertia in aluminum would in

general be somewhat more than 1.5 times those in steel, so that the deflection of the aluminum structure would in general be somewhat less than twice that of the steel structure.

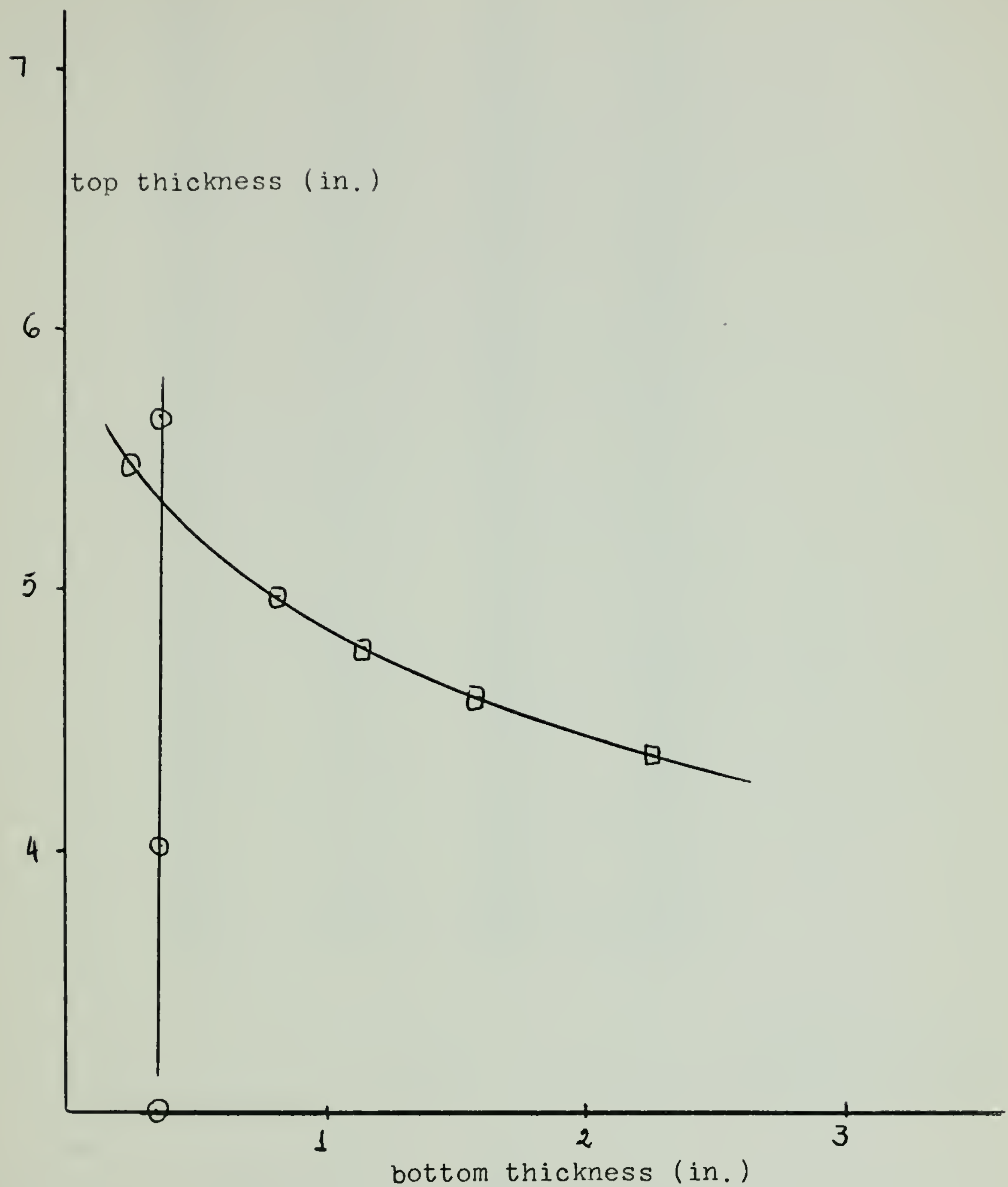
The greater deflection would reduce the natural frequency of hull vibration, and sowould affect the interaction of slamming stress and bending moment stress. It could also affect shaft bearing pressures. It has been proposed as an arbitrary basis of design that aluminum ships be designed for a deflection about 1.5 times that of steel ships. This would require a moment of inertia of twice the value of that in the steel hull girder, and would automatically result in a section modulus substantially more than 1.5 times that in steel, and a factor of safety correspondingly greater than in steel.

```
      C      *AL* IS THE LENGHT
             AL=1000.
             B=AL/5.75
      C      *DRA* IS THE DRAFT
             DRA=B/3.3
             D=AL/14.
      C      *POI* IS THE POISSON'S RATIO OF THE MATERIAL
      C      FOR ALUMINUM
             POI=0.33
      C      *E* IS THE YOUNG'S MODULUS OF THE MATERIAL
      C      FOR ALUMINUM
             E=10.*10.**6
      C      *DST* IS THE DESIGN STRESS
             DST=18000.
      C      *S* IS THE SPACING OF LONGITUDINAL STIFFENING MEMBERS
             S=10.
      C      *BM* IS THE BENDING MOMENT
             BM=(B*DRA*AL*AL*0.75)/(35.*35.)
             G=0.30396*S*S*(1.-POI*POI)/E
             A=9.*B*B*D/(140.*BM)
             C=3.*B*D*D/(70.*BM)
             F=3.*D*D*D/(140.*BM)
      C      THICKNESS OF TOP ASSUMED LARGER THAN BOTTOM THICKNESS
             WRITE(5,10)
          10 FORMAT('1',25X,'TOP ASSUMED LARGER THAN BOTTOM')
      C      *TOP* IS THE THICKNESS OF THE TOP PLATING
      C      *BOT* IS THE THICKNESS OF THE BOTTOM PLATING
             BOT1=0.2
          11 TOP1=B*BOT1*BOT1*BOT1/((B+D)*G*DST-D*BOT1*BOT1)
             WRITE(5,20)TOP1,BOT1
          20 FORMAT(' ',25X,'TOP1=',F9.4,5X,'BOT1='F9.4)
             BOT1=BOT1+0.01
             IF(BOT1.GT.0.4)GO TO30
             GO TO 11
          30 TOP2=1.
          31 BOT2=TOP2*(12.*D-(C+F)*DST*TOP2)/(DST*(A+C)*TOP2-12.*B)
             WRITE(5,40)TOP2,BOT2
          40 FORMAT(' ',25X,'TOP2=',F9.4,5X,'BOT2='F9.4)
             TOP2=TOP2+0.2
             IF(TOP2.GT.5. ) GO TO 50
             GO TO 31
          50 CONTINUE
      C      THICKNESS OF BOTTOM ASSUMED LARGER THAN TOP
             WRITE(5,60)
          60 FORMAT('1',25X,'BOTTOM ASSUMED LARGER THAN TOP')
             BOT3=0.1
          61 TOP3=((B+D)*BOT3*BOT3*BOT3-D*G*DST*BOT3)/(B*G*DST)
             WRITE(5,70)TOP3,BOT3
          70 FORMAT(' ',25X,'TOP3=',F9.4,5X,'BOT3='F9.4)
             BOT3=BOT3+0.01
             IF(BOT3.GT..24)GO TO 80
             GO TO 61
```

```
0402      80  TOP4=1.
0404      81  BOT4=(12.*(B+D)-(A+C)*DST*TOP4)/((C+F)*DST)
044E          WRITE(5,90)TOP4,BOT4
0472      90  FORMAT(' ',25X,'TOP4=',F9.4,5X,'BOT4='F9.4)
049A          TOP4=TOP4+0.2
04A6          IF(TOP4.GT.5.5)GO TO 100
04B8          GO TO 81
04BC     100  CONTINUE
04BC          END
  [S] .U       04C0[V] AL       04C8[V] B        04D0[V] DRA      04D8[V] D
E [V] ...I     04E8[V] E        04F0[S] .R       04F4[V] DST      04FC[V] S
  [V] ..       0514[V] G        0520[V] A        052C[V] C        0538[V] F
  [L] 10       0220[S] 0I       053C[V] BOT1     0176[L] 11       0544[V] TOP1
  [L] 20       022C[L] 30       0550[V] TOP2     0234[L] 31       055C[V] BOT2
  [L] 40       02FE[L] 50       0312[L] 60       0570[V] BOT3     0348[L] 61
  [V] TOP3     0335[L] 70       0402[L] 80       0580[V] TOP4     040A[L] 81
  [V] BOT4     0472[L] 90       04BC[L] 100      0000[S] .V
 EC            L
C

 GRAM LABELS:
 2270 ..MAIN.  2C1C .V     2A4C .COMP   2C2A AI      25FC .R      2B14 .Z
 2A72 $6       263C .A     2B70 .MES    29EE .W      27F6 EXP     297C AI
 26EE ALOG     2AB4 .HARG  2B10 .5      27F6 AEXP    2B18 .ERCNT  2AE6 $8
 2B1A .C       2BEE .U     3D46

NTRY-POINTS:
 25FC .R       263C .A     26EE ALOG    27F6 AEXP    27F6 EXP     297C AI
 29EE .W       2A4C .COMP  2A72 $6      2AB4 .HARG   2AE6 $8      2B10 .5
 2B14 .ZERO    2B18 .ERCNT 2B1A .C      2B70 .MES    2BFA .U      2C20 .V
 2C2A AI

COMMON-BLOCKS:
ONE

UNDEFINED SUBROUTINES:
ONE

RANSFER ADDRESS 2270
ECUTION BEGINS:
```

TOP ASSUMED LARGER THAN BOTTOM

TOP1=	0.15[illegible]8	BOT1=	0.2000
TOP1=	0.18[illegible]8	BOT1=	0.2100
TOP1=	0.21[illegible]7	BOT1=	0.2200
TOP1=	0.25[illegible]6	BOT1=	0.2300
TOP1=	0.3[illegible][illegible]4	BOT1=	0.2400
TOP1=	0.36[illegible]4	BOT1=	0.2500
TOP1=	0.4[illegible][illegible]5	BOT1=	0.2600
TOP1=	0.5[illegible][illegible]8	BOT1=	0.2700
TOP1=	0.6[illegible][illegible]1	BOT1=	0.2800
TOP1=	0.71[illegible]3	BOT1=	0.2900
TOP1=	0.84[illegible]7	BOT1=	0.3000
TOP1=	1.01[illegible]4	BOT1=	0.3100
TOP1=	1.22[illegible]3	BOT1=	0.3200
TOP1=	1.4941	BOT1=	0.3300
TOP1=	1.845[illegible]	BOT1=	0.3400
TOP1=	2.32[illegible]8	BOT1=	0.3500
TOP1=	3.0[illegible][illegible]3	BOT1=	0.3600
TOP1=	4.[illegible]3[illegible]3	BOT1=	0.3700
TOP1=	5.79[illegible]1	BOT1=	0.3800
TOP1=	9.4[illegible][illegible]6	BOT1=	0.3900
TOP1=	20.8[illegible][illegible]1	BOT1=	0.4000
TOP2=	1.0000	BOT2=	-0.4673
TOP2=	1.2000	BOT2=	-0.5810
TOP2=	1.4000	BOT2=	-0.7055
TOP2=	1.6000	BOT2=	-0.8440
TOP2=	1.8000	BOT2=	-1.0009
TOP2=	2.0000	BOT2=	-1.1829
TOP2=	2.2000	BOT2=	-1.4002
TOP2=	2.4000	BOT2=	-1.6693
TOP2=	2.6000	BOT2=	-2.0190
TOP2=	2.8000	BOT2=	-2.5045
TOP2=	3.0000	BOT2=	-3.2460
TOP2=	3.2000	BOT2=	-4.5652
TOP2=	3.4000	BOT2=	-7.7108
TOP2=	3.6000	BOT2=	-26.8087
TOP2=	3.8000	BOT2=	16.3226
TOP2=	4.0000	BOT2=	5.8811
TOP2=	4.2000	BOT2=	3.3945
TOP2=	4.4000	BOT2=	2.2560
TOP2=	4.6000	BOT2=	1.5888
TOP2=	4.8000	BOT2=	1.1408
TOP2=	5.0000	BOT2=	0.8127
TOP 2=	5.5000	BOT 2=	0.2578


7
top thickness (in.)
6
5
4
1
2
3
bottom thickness (in.)

BOTTOM ASSUMED LARGER THAN TOP

TOP3=	-0.0121	BOT3=	0.1000
TOP3=	-0.0067	BOT3=	0.1100
TOP3=	0.0007	BOT3=	0.1200
TOP3=	0.0102	BOT3=	0.1300
TOP3=	0.0219	BOT3=	0.1400
TOP3=	0.0360	BOT3=	0.1500
TOP3=	0.0528	BOT3=	0.1600
TOP3=	0.0723	BOT3=	0.1700
TOP3=	0.0948	BOT3=	0.1800
TOP3=	0.1204	BOT3=	0.1900
TOP3=	0.1493	BOT3=	0.2000
TOP3=	0.1817	BOT3=	0.2100
TOP3=	0.2177	BOT3=	0.2200
TOP3=	0.2576	BOT3=	0.2300
TOP3=	0.3014	BOT3=	0.2400
TOP4=	1.0000	BOT4=	16.1639
TOP4=	1.2000	BOT4=	15.3920
TOP4=	1.4000	BOT4=	14.6201
TOP4=	1.6000	BOT4=	13.8482
TOP4=	1.8000	BOT4=	13.0763
TOP4=	2.0000	BOT4=	12.3044
TOP4=	2.2000	BOT4=	11.5324
TOP4=	2.4000	BOT4=	10.7605
TOP4=	2.6000	BOT4=	9.9886
TOP4=	2.8000	BOT4=	9.2167
TOP4=	3.0000	BOT4=	8.4448
TOP4=	3.2000	BOT4=	7.6729
TOP4=	3.4000	BOT4=	6.9010
TOP4=	3.6000	BOT4=	6.1290
TOP4=	3.8000	BOT4=	5.3571
TOP4=	4.0000	BOT4=	4.5852
TOP4=	4.2000	BOT4=	3.8133
TOP4=	4.4000	BOT4=	3.0414
TOP4=	4.6000	BOT4=	2.2695
TOP4=	4.8000	BOT4=	1.4975
TOP4=	5.0000	BOT4=	0.7256
TOP4=	5.2000	BOT4=	-0.0463
TOP4=	5.4000	BOT4=	-0.8182

END

VIO OPERATING SYSTEM VERSION 1 REVISION 012 03/04/74 GENERATED 05/06/74

JOB HANDLING CHARGE	$ .35 / JOB	.35
177 LINES PRINTED PR1	$ 1.25 / K LN	.22
67 CARDS READ	$ 1.50 / K CD	.10
20 PLOTTER VECTORS	$ .25 / 1000	.00
20 MODEL 7. SECONDS	$25.00 / HOUR	.14
00 MODEL 8. SECONDS	$12.50 / HOUR	.00
	TOTAL CHARGE $	.81

EIR 402 14731 LOGGED OUT 05/06/74 19:37. $ 6.67 LEFT AFTER 27 LOGINS.

```
      C     *AL* IS THE LENGHT
            AL=100.
            B=AL/5.75
      C     *DRA* IS THE DRAFT
            DRA=B/3.3
            D=AL/14.
      C     *POI* IS THE POISSON'S RATIO OF THE MATERIAL
      C     FOR ALUMINUM
            POI=0.33
      C     *E* IS THE YOUNG'S MODULUS OF THE MATERIAL
      C     FOR ALUMINUM
            E=10.*10.**6
      C     *DST* IS THE DESIGN STRESS
            DST=180.0.
      C     *S* IS THE SPACING OF LONGITUDINAL STIFFENING MEMBERS
            S=10.
      C     *BM* IS THE BENDING MOMENT
            BM=(B*DRA*AL*AL*0.75)/(35.*35.)
            G=0.38394*S*S*(1.-POI*POI)/E
      C     *TOP* IS THE THICKNESS OF THE TOP PLATING
      C     *BOT* IS THE THICKNESS OF THE BOTTOM PLATING
            TOP=5.35
            BOT=0.383
            A=560.*BM*(B*BOT+D*TOP)
            DEN=D*(3.*B*B*TOP*BOT+2.*B*D*TOP*(TOP+BOT)+(D*D*TOP*TOP))
      C     *STH* IS THE STRESS ON TOP DUE TO HOGGING
            STH=A/DEN
            WRITE(5,60)STH
   60       FORMAT(' ',22X,'STH='F10.3)
            C=560.*BM*(B*TOP+D*TOP)
      C     *SBH* IS THE STRESS ON BOT DUE TO HOGGING
            SBH=C/DEN
            WRITE(5,90)SBH
   90       FORMAT(' ',22X,'SBH='F10.3)
      C     *SBCRIT* IS THE CRITICAL STRESS ON BOT
            SBCRIT=BOT*BOT/G
            WRITE(5,110)SBCRIT
  110       FORMAT(' ',17X,'SBCRIT='F10.3)
            P=2.*D*TOP+B*(TOP+BOT)
      C     *DITOP* IS THE DISTANCE OF THE TOP FROM THE NEUTRAL AXIS
            DITOP=D*(B*BOT+D*TOP)/P
            WRITE(5,40)DITOP
   40       FORMAT(' ',18X,'DITOP='F10.4)
      C     *DIBOT* IS THE DISTANCE OF THE BOTTOM FROM THE NEUTRAL AXIS
            DIBOT=D*(B*TOP+D*TOP)/P
            WRITE(5,50)DIBOT
   50       FORMAT(' ',18X,'DIBOT='F10.4)
            END
```

[S]	[illegible]	0324 [V]	AL	032C [V]	B	0334 [V]	DRA	033C [V]	D
[V]	POI	034C [V]	E	[illegible] [S]	.R	0358 [V]	DST	0360 [V]	S
[V]	BM	0370 [V]	G	0384 [V]	TOP	038C [V]	BOT	0394 [V]	A
[V]	DEN	03B8 [V]	STH	0174 [L]	60	0000 [S]	@I	03BC [V]	C

```
[V] SBH      ,1E2[L] 92       3C4[V] SBCRIT  0228[L] 110      03C8[V] P
[V] DITOP    2A8[L] 40        3D0[V] DIBOT   03C4[L] 50       0000[S] .V
ED           L



GRAM LABELS:
.70  *MAIN*    2A64 .V        2894 .COMP     2A72 AI        2444 .R        295C .ZE
9AA  56        2484 .A        2988 .MES      2936 .W        263E EXP       27C4 AI
536  ALOG      28FC .MARG     2958 .5        263E AEXP      2960 .ERCNT    292E $8
968  .-        2A36 .U        2A8F

RY-POINTS:
444  .R        2484 .A        2536 ALOG      263E AEXP      263E EXP       27C4 AI
236  .         2894 .COMP     28AA 56        28FC .MARG     292E $8        2958 .5
95C  .ZERO     2960 .ERCNT    2962 .0        2988 .MES      2A42 .U        2A68 .V
A72  AI


MON-BLOCKS:
E


EFINED SUBROUTINES:
E


NSFER ADDRESS 2870
UTION BEGINS:

              STH= 18111.179
              SBH= 53387.980
           SBCRIT= 48640.414
            DITOP=    18.0932
            DIBOT=    53.3053
D


VIO OPERATING SYSTEM VERSION 1 REVISION  012 03/04/74 GENERATED  05/06/74


OB HANDLING CHARGE     $   .35 / JOB          .35
85 LINES PRINTED PR1   $ 1.25 / K LN          .11
54 CARDS READ          $ 1.50 / K CD          .08
00 PLOTTER VECTORS     $   .25 / 1000         .00
17 MODEL 70 SECONDS    $25.00 / HOUR          .12
00 MODEL 44 SECONDS    $12.50 / HOUR          .00
                         TOTAL CHARGE $       .66


EIR 402 14731  LOGGED OUT 25/06/74 19:56.  $    3.43 LEFT AFTER     31 LOGINS.
```

SUMMARY

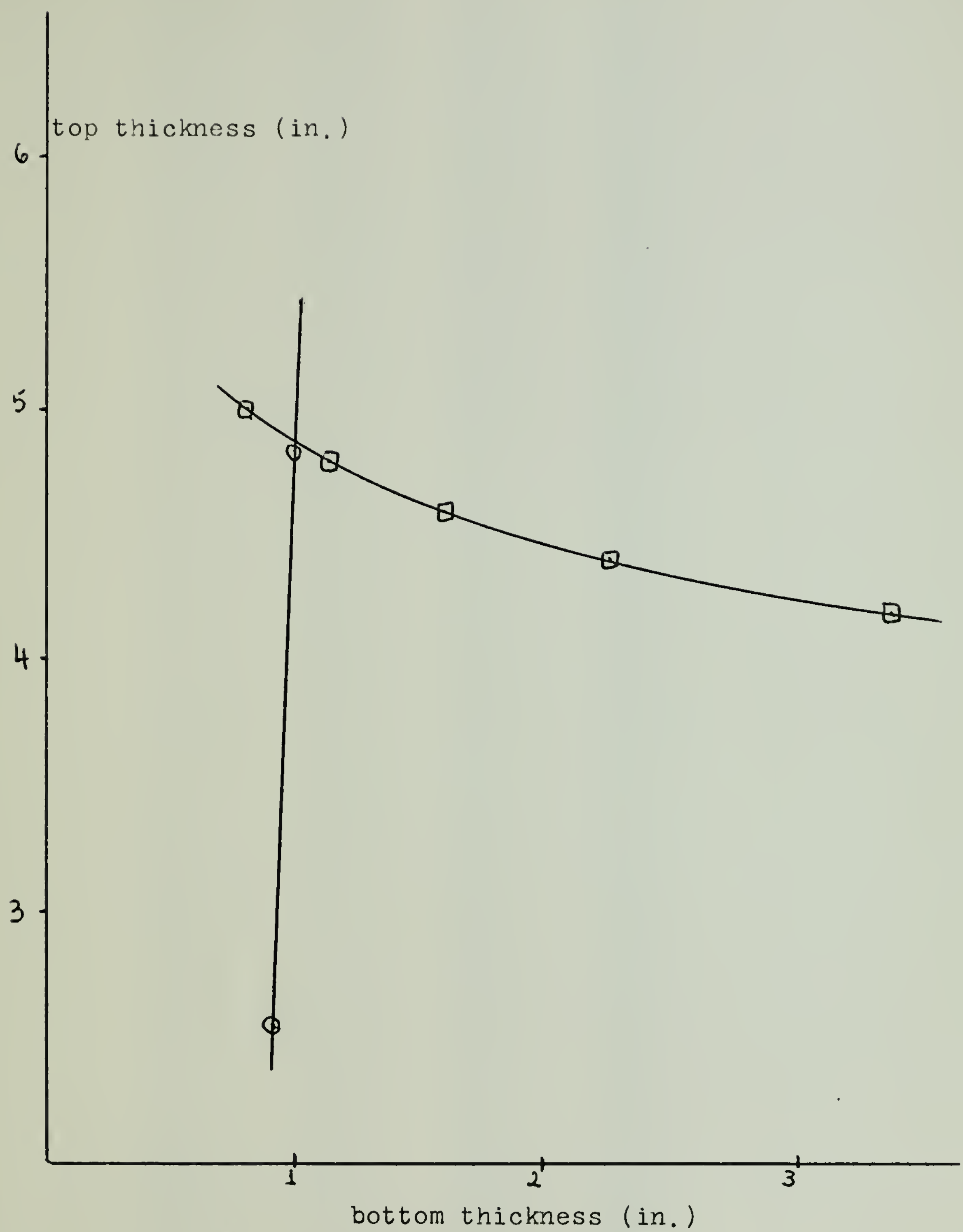
Length	=	1000'
Beam	=	AL/5.75
Draft	=	B/3.3
Depth	=	AL/14
DST	=	18000 psi
S	=	10"
Material	-	ALUMINUM
TOP	=	5.35"
BOT	=	0.363"
STH	=	18111.11
SBH	=	53387.98
SBCRIT	=	48648.64
DITOP	=	18.09'
DIBOT	=	53.34'

```
      C       *AL* IS THE LENGHT
              AL=1000.
              B=AL/5.75
      C       *DRA* IS THE DRAFT
              DRA=B/3.3
              D=AL/14.
      C       *POI* IS THE POISSON'S RATIO OF THE MATERIAL
      C       FOR ALUMINUM
              POI=0.33
      C       *E* IS THE YOUNG'S MODULUS OF THE MATERIAL
      C       FOR ALUMINUM
              E=10.*10.**6
      C       *DST* IS THE DESIGN STRESS
              DST=18000.
      C       *S* IS THE SPACING OF LONGITUDINAL STIFFENING MEMBERS
              S=30.
      C       *BM* IS THE BENDING MOMENT
              BM=(B*DRA*AL*AL**2.75)/(35.*35.)
              G=0.30396*S*S*(1.-POI*POI)/E
              A=9.*B*D*D/(140.*BM)
              C=3.*B*D*D/(70.*BM)
              F=3.*D*D*D/(140.*BM)
      C       THICKNESS OF TOP ASSUMED LARGER THAN BOTTOM THICKNESS
              WRITE(5,10)
           10 FORMAT('1',25X,'TOP ASSUMED LARGER THAN BOTTOM')
      C       *TOP* IS THE THICKNESS OF THE TOP PLATING
      C       *BOT* IS THE THICKNESS OF THE BOTTOM PLATING
              BOT1=0.2
           11 TOP1=B*BOT1*BOT1*BOT1/((B+D)*G*DST-D*BOT1*BOT1)
              WRITE(5,20)TOP1,BOT1
           20 FORMAT(' ',25X,'TOP1=',F9.4,5X,'BOT1='F9.4)
              BOT1=BOT1+0.1
              IF(BOT1.GT.2.5)GO TO30
              GO TO 11
           30 TOP2=1.
           31 BOT2=TOP2*(12.*D-(C+F)*DST*TOP2)/(DST*(A+C)*TOP2-12.*B)
              WRITE(5,40)TOP2,BOT2
           40 FORMAT(' ',25X,'TOP2=',F9.4,5X,'BOT2='F9.4)
              TOP2=TOP2+0.2
              IF(TOP2.GT.6.  ) GO TO 50
              GO TO 31
           50 CONTINUE
      C       THICKNESS OF BOTTOM ASSUMED LARGER THAN TOP
              WRITE(5,60)
           60 FORMAT('1',25X,'BOTTOM ASSUMED LARGER THAN TOP')
              BOT3=0.1
           61 TOP3=((B+D)*BOT3*BOT3*BOT3-D*G*DST*BOT3)/(B*G*DST)
              WRITE(5,70)TOP3,BOT3
           70 FORMAT(' ',25X,'TOP3=',F9.4,5X,'BOT3='F9.4)
              BOT3=BOT3+0.01
              IF(BOT3.GT.1.5)GO TO 80
              GO TO 61
```

```
-12         80  TOP4=1.
-2A         81  BOT4=(12.*(B+D)-(A+C)*DST*TOP4)/((C+F)*DST)
-4E             WRITE(5,90)TOP4,BOT4
-72         90  FORMAT(' ',25X,'TOP4=',F9.4,5X,'BOT4='F9.4)
-9A             TOP4=TOP4+0.2
-A6             IF(TOP4.GT.5.5)GO TO 100
-B3             GO TO 81
-BC        100  CONTINUE
-BC             END
 [S] .U      04C0[V] AL       04C8[V] B        04D0[V] DRA      04D8[V] D
 [V] POI     04E8[V] E        0000[S] .R       04F4[V] DST      04FC[V] S
 [V] SM      0518[V] G        0524[V] A        0530[V] C        053C[V] F
 [L] 10      0000[S] .I       0540[V] BOT1     0176[L] 11       0548[V] TOP1
 [L] 20      022C[L] 30       0550[V] TOP2     0234[L] 31       0560[V] BOT2
 [L] 40      02FF[L] 50       0312[L] 60       0574[V] BOT3     0346[L] 61
 [V] TOP3    0398[L] 70       0402[L] 80       0584[V] TOP4     040A[L] 81
 [V] BOT4    0472[L] 90       04BC[L] 100      0000[S] .V
 EN             L


GRAM LABELS:
.70 *MAIN*   2C22 .V      2A50 .COMP    2C2E .I      2600 .P      2B18 .ZE
A76 $6       2640 .A      2B74 .MES     29F2 .W      27FA EXP     2980 AIN
6F2 ALOG     2AB8 .RARG   2B14 .S       27FA AEXP    2B1C .ERCNT  2AEA $8
B1C .O       2BFE .U      304A


RY-POINTS:
600 .P       2640 .A      26F2 ALOG     27FA AEXP    27FA EXP     2980 AIN
9F2 .W       2A50 .COMP   2A76 $6       2AB8 .RARG   2AEA $8      2B14 .S
B18 .ZERO    2B1C .ERCNT  2B1E .O       2B74 .MES    2BFE .U      2C24 .V
C2E .I


MON-BLOCKS:
E


EFINED SUBROUTINES:
E


SFER ADDRESS 2C70
TION BEGINS:
```

TOP ASSUMED LARGER THAN BOTTOM

TOP1=	0.0193	BOT1=	0.2000
TOP1=	0.0464	BOT1=	0.3000
TOP1=	0.1157	BOT1=	0.4000
TOP1=	0.2451	BOT1=	0.5000
TOP1=	0.4594	BOT1=	0.6000
TOP1=	0.8210	BOT1=	0.7000
TOP1=	1.4376	BOT1=	0.8000
TOP1=	2.5460	BOT1=	0.9000
TOP1=	4.8048	BOT1=	1.0000
TOP1=	10.9055	BOT1=	1.1000
TOP1=	62.6441	BOT1=	1.2000
TOP1=	-29.2067	BOT1=	1.3000
TOP1=	-14.7538	BOT1=	1.4000
TOP1=	-11.0622	BOT1=	1.5000
TOP1=	-9.4724	BOT1=	1.6000
TOP1=	-8.6564	BOT1=	1.7000
TOP1=	-8.1945	BOT1=	1.8000
TOP1=	-7.9417	BOT1=	1.9000
TOP1=	-7.8137	BOT1=	2.0000
TOP1=	-7.7677	BOT1=	2.1000
TOP1=	-7.7798	BOT1=	2.2000
TOP1=	-7.8311	BOT1=	2.3000
TOP1=	-7.9143	BOT1=	2.4000
TOP1=	-8.0212	BOT1=	2.5000
TOP2=	1.0000	BOT2=	-0.4673
TOP2=	1.2000	BOT2=	-0.5810
TOP2=	1.4000	BOT2=	-0.7055
TOP2=	1.6000	BOT2=	-0.8440
TOP2=	1.8000	BOT2=	-1.0009
TOP2=	2.0000	BOT2=	-1.1829
TOP2=	2.2000	BOT2=	-1.4002
TOP2=	2.4000	BOT2=	-1.6693
TOP2=	2.6000	BOT2=	-2.0190
TOP2=	2.8000	BOT2=	-2.5045
TOP2=	3.0000	BOT2=	-3.2460
TOP2=	3.2000	BOT2=	-4.5652
TOP2=	3.4000	BOT2=	-7.7108
TOP2=	3.6000	BOT2=	-26.8087
TOP2=	3.8000	BOT2=	16.3226
TOP2=	4.0000	BOT2=	5.8811
TOP2=	4.2000	BOT2=	3.3945
TOP2=	4.4000	BOT2=	2.2560
TOP2=	4.6000	BOT2=	1.5888
TOP2=	4.8000	BOT2=	1.1408
TOP2=	5.0000	BOT2=	0.8127
TOP2=	5.2000	BOT2=	0.5572
TOP2=	5.4000	BOT2=	0.3490
TOP2=	5.6000	BOT2=	0.1733
TOP2=	5.8000	BOT2=	0.0210
TOP2=	6.0000	BOT2=	-0.1140


top thickness (in.)
6
5
4
3
1
2
3
bottom thickness (in.)

BOTTOM ASSUMED LARGER THAN TOP

TOP3=	-0.0379	BOT3=	0.1000
TOP3=	-0.0409	BOT3=	0.1100
TOP3=	-0.0437	BOT3=	0.1200
TOP3=	-0.0463	BOT3=	0.1300
TOP3=	-0.0487	BOT3=	0.1400
TOP3=	-0.0508	BOT3=	0.1500
TOP3=	-0.0525	BOT3=	0.1600
TOP3=	-0.0540	BOT3=	0.1700
TOP3=	-0.0552	BOT3=	0.1800
TOP3=	-0.0560	BOT3=	0.1900
TOP3=	-0.0564	BOT3=	0.2000
TOP3=	-0.0565	BOT3=	0.2100
TOP3=	-0.0561	BOT3=	0.2200
TOP3=	-0.0553	BOT3=	0.2300
TOP3=	-0.0541	BOT3=	0.2400
TOP3=	-0.0524	BOT3=	0.2500
TOP3=	-0.0503	BOT3=	0.2600
TOP3=	-0.0476	BOT3=	0.2700
TOP3=	-0.0444	BOT3=	0.2800
TOP3=	-0.0407	BOT3=	0.2900
TOP3=	-0.0364	BOT3=	0.3000
TOP3=	-0.0315	BOT3=	0.3100
TOP3=	-0.0261	BOT3=	0.3200
TOP3=	-0.0206	BOT3=	0.3300
TOP3=	-0.0133	BOT3=	0.3400
TOP3=	-0.0059	BOT3=	0.3500
TOP3=	0.0021	BOT3=	0.3600
TOP3=	0.0109	BOT3=	0.3700
TOP3=	0.0203	BOT3=	0.3800
TOP3=	0.0305	BOT3=	0.3900
TOP3=	0.0415	BOT3=	0.4000
TOP3=	0.0532	BOT3=	0.4100
TOP3=	0.0657	BOT3=	0.4200
TOP3=	0.0790	BOT3=	0.4300
TOP3=	0.0932	BOT3=	0.4400
TOP3=	0.1081	BOT3=	0.4500
TOP3=	0.1240	BOT3=	0.4600
TOP3=	0.1408	BOT3=	0.4700
TOP3=	0.1584	BOT3=	0.4800
TOP3=	0.1770	BOT3=	0.4900
TOP3=	0.1965	BOT3=	0.5000
TOP3=	0.2170	BOT3=	0.5100
TOP3=	0.2385	BOT3=	0.5200
TOP3=	0.2610	BOT3=	0.5300
TOP3=	0.2845	BOT3=	0.5400
TOP3=	0.3090	BOT3=	0.5500
TOP3=	0.3346	BOT3=	0.5600
TOP3=	0.3613	BOT3=	0.5700
TOP3=	0.3891	BOT3=	0.5800
TOP3=	0.4180	BOT3=	0.5900
TOP3=	0.4480	BOT3=	0.6000
TOP3=	0.4792	BOT3=	0.6100
TOP3=	0.5116	BOT3=	0.6200
TOP3=	0.5451	BOT3=	0.6300
TOP3=	0.5799	BOT3=	0.6400
TOP3=	0.6159	BOT3=	0.6500

TOP3=	0.6592	BOT3=	0.6600
TOP3=	0.6918	BOT3=	0.6700
TOP3=	0.7316	BOT3=	0.6800
TOP3=	0.7728	BOT3=	0.6900
TOP3=	0.8152	BOT3=	0.7000
TOP3=	0.8591	BOT3=	0.7100
TOP3=	0.9043	BOT3=	0.7200
TOP3=	0.9509	BOT3=	0.7300
TOP3=	0.9989	BOT3=	0.7400
TOP3=	1.0463	BOT3=	0.7500
TOP3=	1.0992	BOT3=	0.7600
TOP3=	1.1515	BOT3=	0.7700
TOP3=	1.2053	BOT3=	0.7800
TOP3=	1.2606	BOT3=	0.7900
TOP3=	1.3175	BOT3=	0.8000
TOP3=	1.3759	BOT3=	0.8100
TOP3=	1.4369	BOT3=	0.8200
TOP3=	1.4994	BOT3=	0.8300
TOP3=	1.5625	BOT3=	0.8400
TOP3=	1.6263	BOT3=	0.8500
TOP3=	1.6917	BOT3=	0.8600
TOP3=	1.7598	BOT3=	0.8700
TOP3=	1.8295	BOT3=	0.8800
TOP3=	1.9009	BOT3=	0.8900
TOP3=	1.9741	BOT3=	0.9000
TOP3=	2.0490	BOT3=	0.9100
TOP3=	2.1256	BO 3=	0.9200
TOP3=	2.2040	BOT3=	0.9300
TOP3=	2.2842	BOT3=	0.9400
TOP3=	2.3663	BOT3=	0.9500
TOP3=	2.4501	BOT3=	0.9600
TOP3=	2.5358	BOT3=	0.9700
TOP3=	2.6234	BO 3=	0.9800
TOP3=	2.7129	BOT3=	0.9900
TOP3=	2.8043	BOT3=	1.0000
TOP3=	2.8976	BOT3=	1.0100
TOP3=	2.9928	BOT3=	1.0200
TOP3=	3.0900	BOT3=	1.0300
TOP3=	3.1892	BOT3=	1.0400
TOP3=	3.2905	BOT3=	1.0500
TOP3=	3.3937	BOT3=	1.0600
TOP3=	3.4990	BOT3=	1.0700
TOP3=	3.6063	BOT3=	1.0800
TOP3=	3.7157	BOT3=	1.0900
TOP3=	3.8273	BOT3=	1.1000
TOP3=	3.9409	BOT3=	1.1100
TOP3=	4.0567	BOT3=	1.1200
TOP3=	4.1747	BOT3=	1.1300
TOP3=	4.2948	BOT3=	1.1400
TOP3=	4.4171	BOT3=	1.1500
TOP3=	4.5417	BOT3=	1.1600
TOP3=	4.6685	BOT3=	1.1700
TOP3=	4.7975	BOT3=	1.1800
TOP3=	4.9288	BOT3=	1.1900
TOP3=	5.0624	BOT3=	1.2000
TOP3=	5.1984	BOT3=	1.2100
TOP3=	5.3346	BOT3=	1.2200

TOP3=	5.4772	BOT3=	1.2300
TOP3=	5.6202	BOT3=	1.2400
TOP3=	5.7656	BOT3=	1.2500
TOP3=	5.9134	BOT3=	1.2600
TOP3=	6.0636	BOT3=	1.2700
TOP3=	6.2163	BOT3=	1.2800
TOP3=	6.3714	BOT3=	1.2900
TOP3=	6.5290	BOT3=	1.3000
TOP3=	6.6892	BOT3=	1.3100
TOP3=	6.8518	BOT3=	1.3200
TOP3=	7.0170	BOT3=	1.3300
TOP3=	7.1848	BOT3=	1.3400
TOP3=	7.3552	BOT3=	1.3500
TOP3=	7.5281	BOT3=	1.3600
TOP3=	7.7037	BOT3=	1.3700
TOP3=	7.8819	BOT3=	1.3800
TOP3=	8.0628	BOT3=	1.3900
TOP3=	8.2464	BOT3=	1.4000
TOP3=	8.4326	BOT3=	1.4100
TOP3=	8.6216	BOT3=	1.4200
TOP3=	8.8133	BOT3=	1.4300
TOP3=	9.0078	BOT3=	1.4400
TOP3=	9.2051	BOT3=	1.4500
TOP3=	9.4051	BOT3=	1.4600
TOP3=	9.6080	BOT3=	1.4700
TOP3=	9.8137	BOT3=	1.4800
TOP3=	10.0223	BOT3=	1.4900
TOP3=	10.2337	BOT3=	1.5000
TOP4=	1.0000	BOT4=	16.1639
TOP4=	1.2000	BOT4=	15.3920
TOP4=	1.4000	BOT4=	14.6201
TOP4=	1.6000	BOT4=	13.8482
TOP4=	1.8000	BOT4=	13.0763
TOP4=	2.0000	BOT4=	12.3044
TOP4=	2.2000	BOT4=	11.5324
TOP4=	2.4000	BOT4=	10.7605
TOP4=	2.6000	BOT4=	9.9886
TOP4=	2.8000	BOT4=	9.2167
TOP4=	3.0000	BOT4=	8.4448
TOP4=	3.2000	BOT4=	7.6729
TOP4=	3.4000	BOT4=	6.9010
TOP4=	3.6000	BOT4=	6.1290
TOP4=	3.8000	BOT4=	5.3571
TOP4=	4.0000	BOT4=	4.5852
TOP4=	4.2000	BOT4=	3.8133
TOP4=	4.4000	BOT4=	3.0414
TOP4=	4.6000	BOT4=	2.2695
TOP4=	4.8000	BOT4=	1.4975
TOP4=	5.0000	BOT4=	0.7256
TOP4=	5.2000	BOT4=	-0.0463
TOP4=	5.4000	BOT4=	-0.8182

O OPERATING SYSTEM VERSION 1 REVISION 012 03/04/74 GENERATED 05/06/74 0

```
CR HANDLING CHARGE     $   .35 / JOB          .35
11 LINES PRINTED PR1   $ 1.25 / K LN          .39
67 CARDS READ          $ 1.50 / K CD          .1?
?? PLOTTER VECTORS     $   .25 / 10??         .0?
22 MODEL 7: SECONDS    $25.?0 / HOUR          .15
?? MODEL 8: SECONDS    $12.50 / HOUR          .0?
                        TOTAL CHARGE $        .99

EIR 4?? 14731  LOGGED OUT 05/26/74 19:42.  $    5.68 LEFT AFTER    28 LOGINS.
```

```
      C     *AL* IS THE LENGHT
            AL=100.
            B=AL/5.75
      C     *DRA* IS THE DRAFT
            DRA=B/3.3
            D=AL/14.
      C     *POI* IS THE POISSON'S RATIO OF THE MATERIAL
      C     FOR ALUMINUM
            POI=0.33
      C     *E* IS THE YOUNG'S MODULUS OF THE MATERIAL
      C     FOR ALUMINUM
            E=10.*10.**6
      C     *DST* IS THE DESIGN STRESS
            DST=15000.
      C     *S* IS THE SPACING OF LONGITUDINAL STIFFENING MEMBERS
            S=30.
      C     *BM* IS THE BENDING MOMENT
            BM=(B*DRA*AL*AL*0.75)/(35.*35.)
            G=0.30396*S*S*(1.-POI*POI)/E
      C     *TOP* IS THE THICKNESS OF THE TOP PLATING
      C     *BOT* IS THE THICKNESS OF THE BOTTOM PLATING
            TOP=4.86
            BOT=1.
            A=560.*BM*(B*BOT+D*TOP)
            DEN=D*(2.*B*B*TOP*BOT+2.*B*D*TOP*(TOP+BOT)+(D*D*TOP*TOP))
      C     *STH* IS THE STRESS ON TOP DUE TO HOGGING
            STH=A/DEN
            WRITE(5,60)STH
         60 FORMAT(' ',20X,'STH='F10.3)
            C=560.*BM*(B*TOP+D*TOP)
      C     *SBH* IS THE STRESS ON BOT DUE TO HOGGING
            SBH=C/DEN
            WRITE(5,90)SBH
         90 FORMAT(' ',20X,'SBH='F10.3)
      C     *SBCRIT* IS THE CRITICAL STRESS ON BOT
            SBCRIT=BOT*BOT/G
            WRITE(5,110)SBCRIT
        110 FORMAT(' ',17X,'SBCRIT='F10.3)
            P=2.*D*TOP+B*(TOP+BOT)
      C     *DITOP* IS THE DISTANCE OF THE TOP FROM THE NEUTRAL AXIS
            DITOP=D*(B*BOT+D*TOP)/P
            WRITE(5,40)DITOP
         40 FORMAT(' ',18X,'DITOP='F10.4)
      C     *DIBOT* IS THE DISTANCE OF THE BOTTOM FROM THE NEUTRAL AXIS
            DIBOT=D*(B*TOP+D*TOP)/P
            WRITE(5,50)DIBOT
         50 FORMAT(' ',18X,'DIBOT='F10.4)
            END
 [S] .U        0324[V] AL      032C[V] B       0334[V] DRA     033C[V] D
 [V] POI       034C[V] E       0000[S] .R      0358[V] DST     0360[V] S
 [V] BM        037C[V] G       0388[V] TOP     0390[V] BOT     0394[V] A
 [V] DEN       0388[V] STH     0174[L] 60      0000[S] @I      03BC[V] C
```

```
 [V] SBH      01F2[L] 92        03C4[V] SBCRIT   0228[L] 110      03C8[V. P
 [V] DITCP    02A8[L] 49        .30?[V] DIBOT    03?4[L] 50       0002[S] .V
 EL           L

GRAM LABELS:
2770 *MAIN*    2A64 .V         2894 .COMP      2A72 AI        2444 .R        295C .Z
2SCA SA        2484 .A         2088 .MES       2936 .W        263F EXP       27C4 AI
2536 ALOG      2AFC .RARG      2959 .5         263E AEXP      2960 .ERCNT    292E $8
2962 .D        2A26 .          2A8F

ENTRY-POINTS:
2444 .R        2484 .A         2536 ALOG       263E AEXP      263F EXP       27C4 AI
2536 .         2894 .COMP      28BA SA         2AFC .RARG     292F $8        2958 .5
295C .ZERO     2960 .ERCNT     2962 .D         2088 .MES      2A42 .U        2468 .V
2A72 AI

COMMON-BLOCKS:
E

DEFINED SUBROUTINES:
E

TRANSFER ADDRESS 2770
EXECUTION BEGINS:

                  STH= 18863.154
                  SBH= 41334.957
               SBCRIT= 41021.625
                DITCP=    21.7217
                DIBOT=    49.7269
END

VIO OPERATING SYSTEM VERSION 1 REVISION 012 03/04/74 GENERATED 05/06/74

JOB HANDLING CHARGE       $  .35 / JOB         .35
 85 LINES PRINTED PR1     $ 1.25 / K LN        .11
 54 CARDS READ            $ 1.50 / K CD        .08
 00 PLOTTER VECTORS       $  .25 / 1000        .00
 16 MODEL 70 SECONDS      $25.00 / HOUR        .11
 02 MODEL 8? SECONDS      $12.50 / HOUR        .00
                          TOTAL CHARGE $       .65

FEIR 49? 14731  LOGGED OUT 05/06/74 19:58.  $   2.78 LEFT AFTER    32 LOGINS.
```

SUMMARY

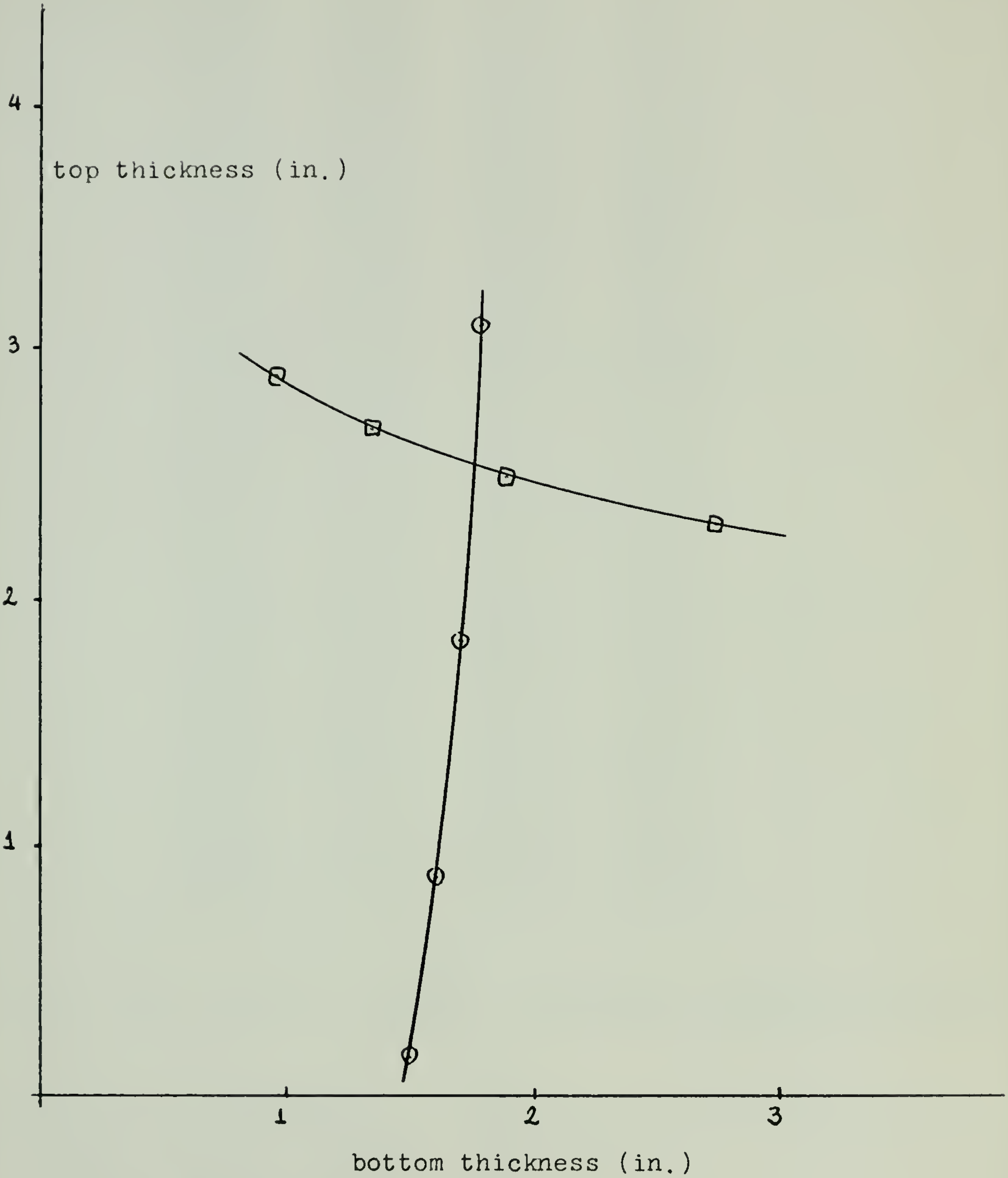
Length	=	1000'
Beam	=	AL/5.75
Draft	=	B/3.3
Depth	=	AL/14
DST	=	18000 psi
S	=	30"
Material	-	ALUMINUM
TOP	=	4.86"
BOT	=	1.00"
STH	=	18063.18
SBH	=	41334.96
SBCRIT	=	41021.80
DITOP	=	21.72'
DIBOT	=	49.71'

```
C          *AL* IS THE LENGHT
           AL=1000.
           B=AL/5.75
C          *DRA* IS THE DRAFT
           DRA=B/3.3
           D=AL/14.
C          *POI* IS THE POISSON'S RATIO OF THE MATERIAL
C          FOR ALUMINUM
           POI=0.33
C          *E* IS THE YOUNG'S MODULUS OF THE MATERIAL
C          FOR ALUMINUM
           E=10.*10.**6
C          *DST* IS THE DESIGN STRESS
           DST=1300 0.
C          *S* IS THE SPACING OF LUNGITUDINAL STIFFENING MEMBERS
           S=60.
C          *BM* IS THE BENDING MOMENT
           BM=(B*DRA*AL*AL*0.75)/(35.*35.)
           G=0.30376*S*S*(1.-POI*POI)/E
           A=9.*B*[illegible]*D/(140.*BM)
           C=3.*[illegible]*D/(70.*[illegible])
           F=3.*B*L*D/(140.*BM)
C          THICKNESS OF TOP ASSUMED LARGER THAN BOTTOM THICKNESS
           WRITE(5,10)
       10  FORMAT('1',25X,'TOP ASSUMED LARGER THAN BOTTOM')
C          *TOP* IS THE THICKNESS OF THE TOP PLATING
C          *BOT* IS THE THICKNESS OF THE BOTTOM PLATING
           BOT1=1.
       11  TOP1=B*BOT1*BOT1*BOT1/((B+D)*G*DST-D*BOT1*BOT1)
           WRITE(5,20)TOP1,BOT1
       20  FORMAT(' ',25X,'TOP1=',F9.4,5X,'BOT1='F9.4)
           BOT1=BOT1+0.1
           IF(BOT1.GT.2.5)GO TO30
           GO TO 11
       30  TOP2=3.5
       31  BOT2=TOP2*(12.*D-(C+F)*DST*TOP2)/(DST*(A+C)*TOP2-12.*B)
           WRITE(5,40)TOP2,BOT2
       40  FORMAT(' ',25X,'TOP2=',F9.4,5X,'BOT2='F9.4)
           TOP2=TOP2+0.2
           IF(TOP2.GT.6. ) GO TO 50
           GO TO 31
       50  CONTINUE
C          THICKNESS OF BOTTOM ASSUMED LARGER THAN TOP
           WRITE(5,60)
       60  FORMAT('1',25X,'BOTTOM ASSUMED LARGER THAN TOP')
           BOT3=0.7
       61  TOP3=((B+D)*BOT3*BOT3*BOT3-D*G*DST*BOT3)/(B*G*DST)
           WRITE(5,70)TOP3,BOT3
       70  FORMAT(' ',25X,'TOP3=',F9.4,5X,'BOT3='F9.4)
           BOT3=BOT3+0.05
           IF(BOT3.GT.1.5)GO TO 80
           GO TO 61
```

```
4E2        80 TOP4=1.
4EA        81 BOT4=(16.*(B+D)-(A+C)-DST*TOP4)/((C+F)*DST)
-4E           WRITE(5,90)TOP4,BOT4
-72        90 FORMAT(' ',25X,'TOP4=',F9.4,5X,'BOT4='F9.4)
-9A           TOP4=TOP4+0.2
-A6           IF(TOP4.GT.5.)GO TO 100
-B8           GO TO 81
BC        100 CONTINUE
-BC           END
 [S] .I     04C0[V] AL        04C8[V] B        04D4[V] DRA       04D8[V] D
 [V] P I    04E8[V] E         0470[S] .R       04F4[V] DST       04FC[V] S
 [V] 8      0518[V] G         0524[V] A        0530[V] C         053C[V] F
 [L] 1      0000[S] .I        0540[V] BOT1     0176[L] 11        0544[V] TOP1
 [L] 2      022C[L] 30        0550[V] TOP2     0234[L] 31        0560[V] BOT2
 [L] 4      02EE[L] 50        0312[L] 60       0578[V] BOT3      0348[L] 61
 [V] TOP3   0398[L] 70        0410[L] 80       058C[V] TOP4      040A[L] 81
 [V] BOT4   0472[L] 90        04B0[L] 100      0004[S] .V
EG           L

GRAM LABELS:
270 *MAIN*    2C28 .V      2A58 .COMP     2C36 FI       2608 .R        2B20 .Z
A7E 76        2648 .A      2A7C .MES      29FA .W       2802 EXP       2988 AI
6FA ALOG      2AC0 .RARG   2B1C .5        2802 AEXP     2B24 .ERCNT    2AF2 $8
2824 .0       2BFA .L      3052

TRY-POINTS:
2608 .R       2648 .A      26FA ALOG      2802 AEXP     2802 EXP       2988 AI
29FA .W       2A58 .COMP   2A7E 76        2AC0 .RARG    2AF2 $8        2B1C .5
2B20 .ZERO    2B24 .ERCNT  2B24 .0        2A7C .MES     2C06 .U        2C2C .V
2C36 FI

MON-BLOCKS:
E

DEFINED SUBROUTINES:
E

ANSFER ADDRESS 2270
ECUTION BEGINS:
```

TOP ASSUMED LARGER THAN BOTTOM

TOP1=	[illegible].4842	BOT1=	1.0000
TOP1=	[illegible].67[illegible]5	BOT1=	1.1000
TOP1=	[illegible].9149	BOT1=	1.2000
TOP1=	1.[illegible]3[illegible]9	BOT1=	1.3000
TOP1=	1.[illegible]4[illegible]1	BOT1=	1.4000
TOP1=	2.1747	BOT1=	1.5000
TOP1=	2.[illegible]751	BOT1=	1.6000
TOP1=	3.[illegible]112	BOT1=	1.7000
TOP1=	5.[illegible]9[illegible]9	BOT1=	1.8000
TOP1=	6.9[illegible]47	BOT1=	1.9000
TOP1=	[illegible].6[illegible]5	BOT1=	2.0000
TOP1=	13.9[illegible]2	BOT1=	2.1000
TOP1=	21.[illegible]1[illegible]5	BOT1=	2.2000
TOP1=	4[illegible].1[illegible]43	BOT1=	2.3000
TOP1=	125.2754	BOT1=	2.4000
TOP1=	-171.[illegible]08	BOT1=	2.5000
TOP2=	3.5[illegible]	BOT2=	-11.8971
TOP2=	3.7[illegible]	BOT2=	91.[illegible]296
TOP2=	3.9[illegible]	BOT2=	[illegible].7662
TOP2=	4.1[illegible]	BOT2=	4.3496
TOP2=	4.3[illegible]	BOT2=	2.7380
TOP2=	4.[illegible]	BOT2=	1.5850
TOP2=	4.7[illegible]	BOT2=	1.3454
TOP2=	4.9[illegible]	BOT2=	0.9655
TOP2=	5.1[illegible]	BOT2=	0.6778
TOP2=	5.3[illegible]	BOT2=	0.4483
TOP2=	5.5[illegible]	BOT2=	0.2578
TOP2=	5.7[illegible]	BOT2=	0.[illegible]947
TOP2=	5.9[illegible]	BOT2=	-0.[illegible]484


4
top thickness (in.)
3
2
1
1
2
3
bottom thickness (in.)

```
BOTTOM ASSUMED LARGER THAN TOP
TOP3=   -0.2118        BOT3=    0.7000
TOP3=    0.0310        BOT3=    0.7500
TOP3=    1.0829        BOT3=    0.8000
TOP3=    1.1445        BOT3=    0.8500
TOP3=    1.2143        BOT3=    0.9000
TOP3=    1.2909        BOT3=    0.9500
TOP3=    1.3930        BOT3=    1.0000
TOP3=    1.4932        BOT3=    1.0500
TOP3=    1.6100        BOT3=    1.1000
TOP3=    1.7531        BOT3=    1.1500
TOP3=    0.8940        BOT3=    1.2000
TOP3=    1.0564        BOT3=    1.2500
TOP3=    1.2319        BOT3=    1.3000
TOP3=    1.4[illegible]0        BOT3=    1.3500
TOP3=    1.63[illegible]5        BOT3=    1.4000
TOP3=    1.8548        BOT3=    1.4500
TOP3=    2.[illegible]945        BOT3=    1.5000
TOP4=    1.[illegible]0        BOT4=   16.1639
TOP4=    1.2[illegible]0        BOT4=   15.3920
TOP4=    1.4[illegible]0        BOT4=   14.6201
TOP4=    1.6[illegible]0        BOT4=   13.8482
TOP4=    1.8[illegible]0        BOT4=   13.0763
TOP4=    2.0[illegible]0        BOT4=   12.3044
TOP4=    2.2[illegible]0        BOT4=   11.5324
TOP4=    2.4[illegible]0        BOT4=   10.7605
TOP4=    2.6[illegible]0        BOT4=    9.9886
TOP4=    2.8[illegible]0        BOT4=    9.2167
TOP4=    3.0[illegible]0        BOT4=    8.4448
TOP4=    3.2[illegible]0        BOT4=    7.6729
TOP4=    3.4[illegible]0        BOT4=    6.9010
TOP4=    3.6[illegible]0        BOT4=    6.1290
TOP4=    3.8[illegible]0        BOT4=    5.3571
TOP4=    4.0[illegible]0        BOT4=    4.5852
TOP4=    4.2[illegible]0        BOT4=    3.8133
TOP4=    4.4[illegible]0        BOT4=    3.0414
TOP4=    4.6[illegible]0        BOT4=    2.2695
TOP4=    4.8[illegible]0        BOT4=    1.4975
TOP4=    5.0[illegible]0        BOT4=    0.7256
END

VIO OPERATING SYSTEM VERSION 1 REVISION  12 03/04/74 GENERATED  05/06/74

JOB HANDLING CHARGE     $   .35 / JOB        .35
164 LINES PRINTED PR1   $ 1.25 / K LN        .21
 67 CARDS READ          $ 1.50 / K CD        .10
 00 PLOTTER VECTORS     $  .25 / 10.0        .00
 19 MODEL 7  SECONDS    $25.00 / HOUR        .13
 00 MODEL 2- SECONDS    $12.50 / HOUR        .00
                         TOTAL CHARGE $      .79

EIP 4-2 14731  LOGGED OUT 05/06/74 19:48.  $   4.89 LEFT AFTER    29 LOGINS.
```

```
      C     *AL* IS THE LENGHT
            AL=1000.
            B=AL/5.75
      C     *DRA* IS THE DRAFT
            DRA=B/3.3
            D=AL/14.
      C     *POI* IS THE POISSON'S RATIO OF THE MATERIAL
      C     FOR ALUMINUM
            POI=0.33
      C     *E* IS THE YOUNG'S MODULUS OF THE MATERIAL
      C     FOR ALUMINUM
            E=10.*10.**6
      C     *DST* IS THE DESIGN STRESS
            DST=18000.
      C     *S* IS THE SPACING OF LONGITUDINAL STIFFENING MEMBERS
            S=60.
      C     *BM* IS THE BENDING MOMENT
            BM=(B*DRA*AL*AL*0.75)/(35.*35.)
            G=0.3.396*S*S*(1.-POI*POI)/E
      C     *TOP* IS THE THICKNESS OF THE TOP PLATING
      C     *BOT* IS THE THICKNESS OF THE BOTTOM PLATING
            TOP=4.53
            BOT=1.76
            A=560.*BM*(B*BOT+D*TOP)
            DEN=D*(2.*B*B*TOP*BOT+2.*B*D*TOP*(TOP+BOT)+(D*D*TOP*TOP))
      C     *STH* IS THE STRESS ON TOP DUE TO HOGGING
            STH=A/DEN
            WRITE(5,60)STH
         60 FORMAT(' ',20X,'STH='F10.3)
            C=560.*BM*(B*TOP+D*TOP)
      C     *SBH* IS THE STRESS ON BOT DUE TO HOGGING
            SBH=C/DEN
            WRITE(5,90)SBH
         90 FORMAT(' ',20X,'SBH='F10.3)
      C     *SBCRIT* IS THE CRITICAL STRESS ON BOT
            SBCRIT=BOT*BOT/G
            WRITE(5,110)SBCRIT
        110 FORMAT(' ',17X,'SBCRIT='F10.3)
            P=2.*D*TOP+B*(TOP+BOT)
      C     *DITOP* IS THE DISTANCE OF THE TOP FROM THE NEUTRAL AXIS
            DITOP=D*(B*BOT+D*TOP)/P
            WRITE(5,40)DITOP
         40 FORMAT(' ',18X,'DITOP='F10.4)
      C     *DIBOT* IS THE DISTANCE OF THE BOTTOM FROM THE NEUTRAL AXIS
            DIBOT=D*(B*TCP+D*TOP)/P
            WRITE(5,50)DIBOT
         50 FORMAT(' ',18X,'DIBOT='F10.4)
            END
 [S] .U       0324[V] AL      032C[V] B      0334[V] DRA     033C[V] D
 [V] POI      034C[V] E       0000[S] .R     0358[V] DST     0360[V] S
 [V] BM       037C[V] G       0388[V] TOP    0390[V] BOT     0398[V] A
 [V] DEN      03BC[V] STH     0174[L] 60     0000[S] @I      03C0[V] C
```

```
[V] SBH      01E2[L] 90      03C8[V] SBCRIT  0228[L] 110      03CC[V] P
[V] DITOP    02A8[L] 40      03D4[V] DIBOT   0304[L] 50       0000[S] .V
  L

GRAM LABELS:
2070 *MAIN*   2A68 .V        2898 .COMP     2A76 @I      2448 .R       2960 .ZE
2B8E $6       2438 .A        29BC .MES      283A .W      2642 EXP      27C8 AIN
253A ALOG     2900 .RARG     295C .S        2642 AEXP    2964 .ERCNT   2932 $8
2964 .O       2A3A .U        3892

RY-POINTS:
2448 .R       2438 .A        253A ALOG      2642 AEXP    2642 EXP      27C8 AIN
283A .W       2898 .COMP     2B8E $6        2900 .RARG   2932 $8       295C .S
2960 .ZERO    2964 .ERCNT    2964 .O        29BC .MES    2A46 .U       2A6C .V
2A76 @I

-BLOCKS:


FINED SUBROUTINES:


NSFER ADDRESS 2070
CUTION BEGINS:

           STH= 18034.023
           SBH= 31831.496
        SBCRIT= 31767.121
         DITOP=    25.8324
         DIBOT=    45.5962
END

VIC OPERATING SYSTEM VERSION 1 REVISION  012 03/04/74 GENERATED  05/06/74

JOB HANDLING CHARGE    $   .35 / JOB          .35
 85 LINES PRINTED PR2  $ 1.25 / K LN          .11
 54 CARDS READ         $ 1.50 / K CD          .08
 02 PLOTTER VECTORS    $   .25 / 1000         .00
 14 MODEL 70 SECONDS   $25.00 / HOUR          .10
 07 MODEL 80 SECONDS   $12.50 / HOUR          .00
                         TOTAL CHARGE $       .64

490 14731  LOGGED OUT 05/26/74 20:01.  $   2.14 LEFT AFTER    33 LOGINS.
```

SUMMARY

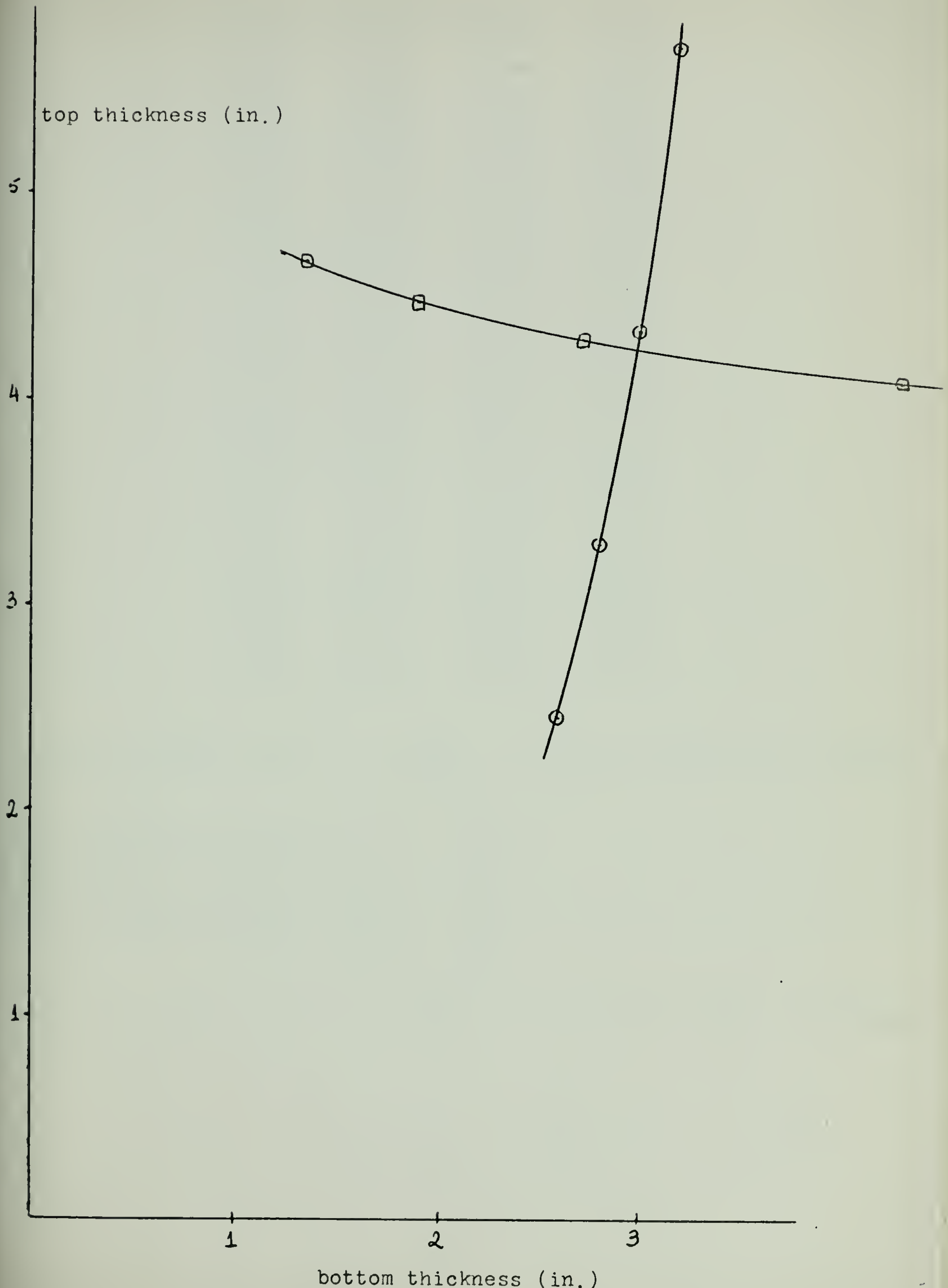
Length	=	1000'
Beam	=	AL/5.75
Draft	=	B/3.3
Depth	=	AL/14
DST	=	18000 psi
S	=	60"
Material	-	ALUMINUM
TOP	=	4.53"
BOT	=	1.76"
STH	=	18034.02
SBH	=	31831.49
SBCRIT	=	31767.27
DITOP	=	25.83'
DIBOT	=	45.60'

```
      C     *AL* IS THE LENGHT
            AL=1000.
            B=AL/5.75
      C     *DRA* IS THE DRAFT
            DRA=B/3.3
            D=AL/14.
      C     *POI* IS THE POISSON'S RATIO OF THE MATERIAL
      C     FOR ALUMINUM
            POI=0.33
      C     *E* IS THE YOUNG'S MODULUS OF THE MATERIAL
      C     FOR ALUMINUM
            E=10.*10.**6
      C     *DST* IS THE DESIGN STRESS
            DST=18000.
      C     *S* IS THE SPACING OF LONGITUDINAL STIFFENING MEMBERS
            S=120.
      C     *BM* IS THE BENDING MOMENT
            BM=(B*DRA*AL*AL*0.75)/(35.*35.)
            G=0.30396*S*S*(1.-POI*POI)/E
            A=9.*B*B*D/(140.*BM)
            C=3.*B*D*D/(70.*BM)
            F=3.*D*D*D/(140.*BM)
      C     THICKNESS OF TOP ASSUMED LARGER THAN BOTTOM THICKNESS
            WRITE(5,10)
   10       FORMAT('1',25X,'TOP ASSUMED LARGER THAN BOTTOM')
      C     *TOP* IS THE THICKNESS OF THE TOP PLATING
      C     *BOT* IS THE THICKNESS OF THE BOTTOM PLATING
            BOT1=2.
   11       TOP1=B*BOT1*BOT1*BOT1/((B+D)*G*DST-D*BOT1*BOT1)
            WRITE(5,20)TOP1,BOT1
   20       FORMAT(' ',25X,'TOP1=',F9.4,5X,'BOT1='F9.4)
            BOT1=BOT1+0.2
            IF(BOT1.GT.7. )GO TO30
            GO TO 11
   30       TOP2=3.5
   31       BOT2=TOP2*(12.*B-(C+F)*DST*TOP2)/(DST*(A+C)*TOP2-12.*B)
            WRITE(5,40)TOP2,BOT2
   40       FORMAT(' ',25X,'TOP2=',F9.4,5X,'BOT2='F9.4)
            TOP2=TOP2+0.2
            IF(TOP2.GT.6. ) GO TO 50
            GO TO 31
   50       CONTINUE
      C     THICKNESS OF BOTTOM ASSUMED LARGER THAN TOP
            WRITE(5,60)
   60       FORMAT('1',25X,'BOTTOM ASSUMED LARGER THAN TOP')
            BOT3=1.
   61       TOP3=((B+D)*BOT3*BOT3*BOT3-D*G*DST*BOT3)/(B*G*DST)
            WRITE(5,70)TOP3,BOT3
   70       FORMAT(' ',25X,'TOP3=',F9.4,5X,'BOT3='F9.4)
            BOT3=BOT3+0.2
            IF(BOT3.GT.3.5)GO TO 80
            GO TO 61
```

```
472        80  TOP4=1.
47A        81  BOT4=(12.*(B+D)-(A+C)*DST*TOP4)/((C+F)*DST)
48E            WRITE(5,90)TOP4,BOT4
492        90  FORMAT(' ',25X,'TOP4=',F9.4,5X,'BOT4='F9.4)
49A            TOP4=TOP4+0.2
4A6            IF(TOP4.GT.4.5)GO TO 100
4B8            GO TO 81
4BC       100  CONTINUE
4BC            END
 [S] .U        24C0 [V]  AL        24C8 [V]  B          04D0 [V]  DRA     04D8 [V]  D
 [V] PCT       24E8 [V]  E         2020 [G]  .R         04F4 [V]  DST     04FC [V]  S
 [V] SV        2518 [V]  G         2524 [V]  A          0530 [V]  C       053C [V]  F
 [L] 1         2000 [S]  AI        2540 [V]  BOT1       0176 [L]  11      0548 [V]  TOP1
 [L] 2         2220 [L]  30        255C [V]  TOP2       0234 [L]  31      0564 [V]  BOT2
 [L] 4         22FE [L]  50        2312 [L]  60         0578 [V]  BOT3    0348 [L]  61
 [V] TOP3      2398 [L]  70        240C [L]  80         0580 [V]  TOP4    040A [L]  81
 [V] BOT4      2472 [L]  90        24BC [L]  100        00CA [S]  .V
EG             L

GRAM LABELS:
2272 *MAIN*    2C1C .V        2A4C .COMP     2C2A AI       25FC .R        2B14 .Z
2A72 $A        263C .A        2B72 .MES      2BEE .W       27F6 EXP       297C AI
6EE ALOG       2A84 .RARG     2B1A .E        27F6 AEXP     2B18 .ERCNT    2AE6 $8
2B13 .C        2BFE .U        3C46

RY-POINTS:
2EFC .R        263C .A        26EE ALOG      27F6 AEXP     27F6 EXP       297C AIN
29EE .W        2A4C .COMP     2A72 $A        2A84 .RARG    2AE6 $8        2B10 .5
2B14 .ZERO     2B18 .ERCNT    2B1A .E        2B70 .MES     2BFA .U        2C20 .V
C2A GT

MON-BLOCKS:
E

EFINED SUBROUTINES:
E

NSFER ADDRESS 2472
UTION BEGINS:
```

TOP ASSUMED LARGER THAN BOTTOM

TOP1=	0.0684	BOT1=	2.0000
TOP1=	1.2451	BOT1=	2.2000
TOP1=	1.8338	BOT1=	2.4000
TOP1=	2.4658	BOT1=	2.6000
TOP1=	3.2[illegible]42	BOT1=	2.8000
TOP1=	4.3404	BOT1=	3.0000
TOP1=	5.7503	BOT1=	3.2000
TOP1=	7.6205	BOT1=	3.4000
TOP1=	11.1[illegible]59	BOT1=	3.6000
TOP1=	13.8[illegible]05	BOT1=	3.8000
TOP1=	19.2[illegible]2	BOT1=	4.0000
TOP1=	27.[illegible]	BOT1=	4.2000
TOP1=	43.[illegible]2	BOT1=	4.4000
TOP1=	[illegible].[illegible]119	BOT1=	4.6000
TOP1=	25[illegible].[illegible]8	BOT1=	4.8000
TOP1=	-3[illegible]3.73[illegible]4	BOT1=	5.0000
TOP1=	-117.[illegible]2	BOT1=	5.2000
TOP1=	-75.9[illegible]76	BOT1=	5.4000
TOP1=	-59.[illegible]147	BOT1=	5.6000
TOP1=	-49.8724	BOT1=	5.8000
TOP1=	-44.2485	BOT1=	6.0000
TOP1=	-40.[illegible]28	BOT1=	6.2000
TOP1=	-37.[illegible]4	BOT1=	6.4000
TOP1=	-35.[illegible]77	BOT1=	6.6000
TOP1=	-34.[illegible]15	BOT1=	6.8000
TOP1=	-33.5[illegible]	BOT1=	7.0000
TOP2=	3.[illegible]00	BOT2=	-11.8971
TOP2=	3.7[illegible]00	BOT2=	91.0296
TOP2=	3.9[illegible]00	BOT2=	8.7662
TOP2=	4.1[illegible]00	BOT2=	4.3496
TOP2=	4.3[illegible]00	BOT2=	2.7380
TOP2=	4.5[illegible]00	BOT2=	1.8850
TOP2=	4.7[illegible]00	BOT2=	1.3454
TOP2=	4.9[illegible]00	BOT2=	0.9655
TOP2=	5.1[illegible]00	BOT2=	0.6778
TOP2=	5.3[illegible]00	BOT2=	0.4483
TOP2=	5.5[illegible]00	BOT2=	0.2578
TOP2=	5.7[illegible]00	BOT2=	0.0947
TOP2=	5.9[illegible]00	BOT2=	-0.0484


top thickness (in.)
5
4
3
2
1
1
2
3
bottom thickness (in.)

```
BOTTOM ASSUMED LARGER THAN TOP
TOP3=   -[illegible].2[illegible]98      BOT3=   1.2000
TOP3=   -0.1456      BOT3=   1.2000
TOP3=   -0.0[illegible]36      BOT3=   1.4000
TOP3=    0.1[illegible]59      BOT3=   1.6000
TOP3=    0.4326      BOT3=   1.8000
TOP3=    0.7[illegible]41      BOT3=   2.0000
TOP3=    1.23[illegible]0      BOT3=   2.2000
TOP3=    1.79[illegible]0      BOT3=   2.4000
TOP3=    2.46[illegible]8      BOT3=   2.6000
TOP3=    3.2[illegible]1[illegible]      BOT3=   2.8000
TOP3=    4.1931      BOT3=   3.0000
TOP3=    5.27[illegible]0      BOT3=   3.2000
TOP3=    6.[illegible]12      BOT3=   3.4000
TOP4=    1.[illegible]      BOT4=  16.1639
TOP4=    1.2[illegible]      BOT4=  15.3920
TOP4=    1.4[illegible]      BOT4=  14.6201
TOP4=    1.6[illegible]      BOT4=  13.8482
TOP4=    1.[illegible]      BOT4=  13.0763
TOP4=    2.[illegible]      BOT4=  12.3044
TOP4=    2.2[illegible]      BOT4=  11.5324
TOP4=    2.4[illegible]      BOT4=  10.7605
TOP4=    2.6[illegible]      BOT4=   9.9886
TOP4=    2.[illegible]      BOT4=   9.2167
TOP4=    3.[illegible]      BOT4=   8.4448
TOP4=    3.[illegible]      BOT4=   7.6729
TOP4=    3.4[illegible]      BOT4=   6.9010
TOP4=    3.6[illegible]      BOT4=   6.1290
TOP4=    3.8[illegible]      BOT4=   5.3571
TOP4=    4.0[illegible]      BOT4=   4.5852
TOP4=    4.2[illegible]      BOT4=   3.8133
TOP4=    4.4[illegible]      BOT4=   3.0414
```

```
[illegible]D

[illegible] VIO OPERATING SYSTEM VERSION 1 REVISION  012 03/04/74 GENERATED  05/06/74

[illegible]OB HANDLING CHARGE    $   .35 / JOB         .35
[illegible]67 LINES PRINTED PR1  $ 1.25 / K LN         .21
[illegible]67 CARDS READ         $ 1.50 / K CD         .1[illegible]
[illegible]0 PLOTTER VECTORS     $   .25 / 1000        .0[illegible]
[illegible]20 MODEL [illegible] SECONDS   $25.00 / HOUR        .14
[illegible]00 MODEL [illegible] SECONDS   $12.50 / HOUR        .[illegible]
                        TOTAL CHARGE $    .80

EIP 4[illegible] 14731  LOGGED OUT 05/06/74 19:52.  $    4.09 LEFT AFTER    30 LOGINS.
```

```
      C     .AL. IS THE LENGHT
            AL=100.
            B=AL/5.75
      C     .DRA. IS THE DRAFT
            DRA=B/3.3
            D=AL/14.
      C     .POI. IS THE POISSON'S RATIO OF THE MATERIAL
      C     FOR ALUMINUM
            POI=0.33
      C     .E. IS THE YOUNG'S MODULUS OF THE MATERIAL
      C     FOR ALUMINUM
            E=10.*10.**6
      C     .DST. IS THE DESIGN STRESS
            DST=10.0.
      C     .S. IS THE SPACING OF LONGITUDINAL STIFFENING MEMBERS
            S=12..
      C     .BM. IS THE BENDING MOMENT
            BM=(B*DRA*AL*AL*1.75)/(35.*35.)
            G=0.3025*S*S*(1.-POI*POI)/E
      C     .TOP. IS THE THICKNESS OF THE TOP PLATING
      C     .BOT. IS THE THICKNESS OF THE BOTTOM PLATING
            TOP=4.27
            BOT=2.95
            A=560.*BM*(B*BOT+D*TOP)
            DEN=D*(3.*B*B*BOT*TOP+BOT*2.*B*D*TOP*(TOP+BOT)+(D*D*TOP*TOP))
      C     .STH. IS THE STRESS ON TOP DUE TO HOGGING
            STH=A/DEN
            WRITE(5,60)STH
         60 FORMAT(' ',20X,'STH='F10.3)
            C=560.*BM*(B*TOP+D*TOP)
      C     .SBH. IS THE STRESS ON BOT DUE TO HOGGING
            SBH=C/DEN
            WRITE(5,90)SBH
         90 FORMAT(' ',20X,'SBH='F10.3)
      C     .SBCRIT. IS THE CRITICAL STRESS ON BOT
            SBCRIT=BOT*BOT/G
            WRITE(5,110)SBCRIT
        110 FORMAT(' ',17X,'SBCRIT='F10.3)
            P=2.*D*TOP+B*(TOP+BOT)
      C     .DITOP. IS THE DISTANCE OF THE TOP FROM THE NEUTRAL AXIS
            DITOP=D*(B*BOT+D*TOP)/P
            WRITE(5,40)DITOP
         40 FORMAT(' ',18X,'DITOP='F10.4)
      C     .DIBOT. IS THE DISTANCE OF THE BOTTOM FROM THE NEUTRAL AXIS
            DIBOT=D*(B*TOP+D*TOP)/P
            WRITE(5,50)DIBOT
         50 FORMAT(' ',18X,'DIBOT='F10.4)
            END
```

[S] ... 0324 [V] AL	032C [V] B	0334 [V] DRA	033C [V] D
[V] POI 0340 [V] E	0000 [S] .R	0358 [V] DST	0360 [V] S
[V] BM 0370 [V] G	0388 [V] TOP	0390 [V] BOT	0398 [V] A
[V] DEN 03B0 [V] STH	0174 [L] 60	0000 [S] @I	03C0 [V] C

```
STRENGHT OF SHIPS-CT THE NEUTRAL AXIS LOCATION                                PAGE  2

[V] S?H       ?]E2[L] ?0          3C?[V] SBCRIT  ?2??[L] 11?        ?3CC[V? P
[V] ?ITC=     ?2??[L] ?V          3C?[V] DIPOT   ?3?4[L] 5?         ????[S? .V

?AM LABELS:
?? ???     2??? .V     2??? .?ONP    2?76 ?I      2448 .R       2960 .Z?
??? ??     2??? .?     2??C .?ES     2?3A .W      2642 EXP      2708 AI
??A ????   2??? .?ARG  2?5C .5       2642 ?EXP    2?64 .ERCNT   2932 $8
??? .?     2?3? .?     ????

??-???TS:
??? .?     2??? .?     2??? ?LOG     2642 AEXP    2642 EXP      2708 AI
??A .      2??? .???P  ???? ?A       2??? .RARG   2932 $8       295C .5
??? .???   2964 .?ERCNT 2?6? .?      2?8C .MES    2?46 .U       2A?C .V
??6 ??

?????????:
?

?FINE? SUBROUTINES:
?

????? A??RESS 227?
?UTI?? ?EGI??:

            STH= 17955.7?3
            SE?= 22852.766
         SBCRIT= 22759.  8
          ?IT??=    31.4516
          ?IBCT=    39.9?7?
???

? ?IO OPERATING SYSTEM VERSION 1 REVISION  ?12 ?3/?4/74 GENERATED   5/?6/74

?? HANDLING CHARGE     $  .35 / JOB          .35
?? LINES PRINTED PR1   $ 1.?? / ? L?         .11
?? CARDS READ          $ 1.?? / ? C?         .??
?? PLOTTED VECTORS     $  .?? / 1???         .??
1? MODEL 7? SECONDS   $25.?? / HOUR          .11
?? MODEL ?? SECONDS   $12.?? / HOUR          .??
                      TOTAL CHARGE $         .65

?IR 4?? 14731  LOGGED OUT ??/?6/74 20:?3.  $    1.49 LEFT AFTER    34 LOGINS.
```

SUMMARY

Length	=	1000'
Beam	=	AL/5.75
Draft	=	B/3.3
Depth	=	AL/14
DST	=	18000 psi
S	=	120"
Material	-	ALUMINUM
TOP	=	4.27"
BOT	=	2.98"
STH	=	17958.79
SBH	=	22852.76
SBCRIT	=	22768.12
DITOP	=	31.43'
DIBOT	=	39.99' or 40.00'

Looking at the following table we can also observe for the aluminum the effect of changing S on the neutral axis location and the compressive stresses resulting on thebottom plating.

CASE	S inches	TOP inches	BOT inches	SBH psi	SBCRIT psi	DITOP ft	DIBOT ft
1	10	5.35	0.363	53000	49000*	18.09	53.34
2	30	4.86	1.00	41000	41000	21.72	49.71
3	60	4.53	1.76	32000	32000	25.83	45.60
4	120	4.27	2.98	23000	23000	31.43	40.00

(*) This difference may result from inaccuracy in reading the plot.

Here again the values of TOP and BOT may allow for a quick evaluation of the weight relationship between the four cases.

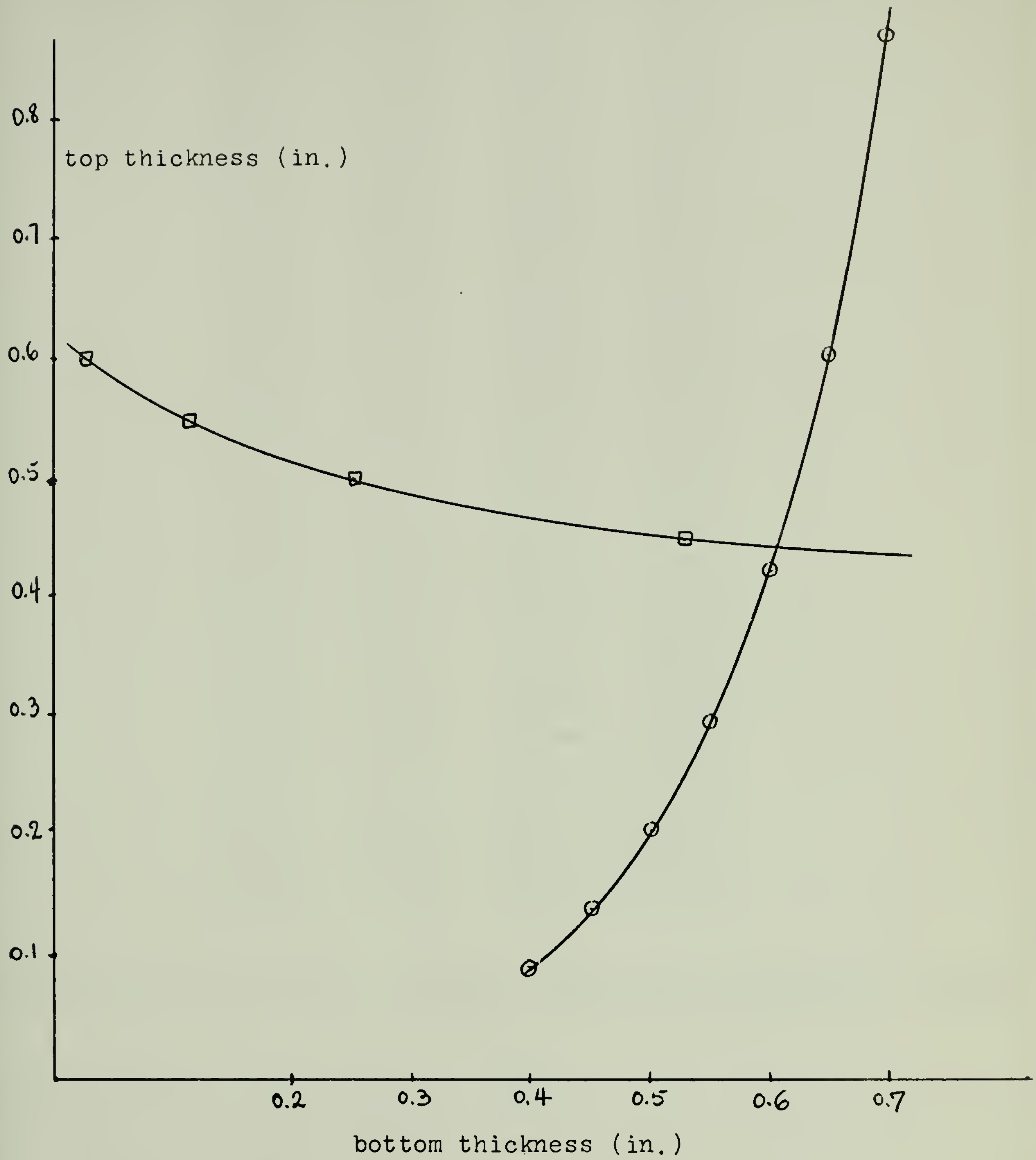
One run was also made in the case of the aluminum for AL=500 ft and the results are here included.

```
      C    *AL* IS THE LENGTH
           AL=500.
           B=AL/8.
      C    *DRA* IS THE DRAFT
           DRA=B/3.
           D=AL/9.
      C    *POI* IS THE POISSON'S RATIO OF THE MATERIAL
      C    FOR ALUMINUM
           POI=0.33
      C    *E* IS THE YOUNG'S MODULUS OF THE MATERIAL
      C    FOR ALUMINUM
           E=1.0*10.**6
      C    *DST* IS THE DESIGN STRESS
           DST=10000.
      C    *S* IS THE SPACING OF LONGITUDINAL STIFFENING MEMBERS
           S=30.
      C    *BM* IS THE BENDING MOMENT
           BM=(B*DRA*AL*AL*0.75)/(35.*35.)
           G=0.3[illegible]396*S*S*(1.-POI*POI)/E
           A=9.*[illegible]*D/(140.*BM)
           C=3.*[illegible]*D/(70.*BM)
           F=3.*[illegible]*D/(140.*BM)
      C    THICKNESS OF TOP ASSUMED LARGER THAN BOTTOM THICKNESS
           WRITE(5,10)
        10 FORMAT('1',25X,'TOP ASSUMED LARGER THAN BOTTOM')
      C    *TOP* IS THE THICKNESS OF THE TOP PLATING
      C    *BOT* IS THE THICKNESS OF THE BOTTOM PLATING
           BOT1=0.1
        11 TOP1=B*BOT1*BOT1*BOT1/((B+D)*G*DST-D*BOT1*BOT1)
           WRITE(5,20)TOP1,BOT1
        20 FORMAT(' ',25X,'TOP1=',F9.4,5X,'BOT1='F9.4)
           BOT1=BOT1+0.05
           IF(BOT1.GT.1.)GO TO 30
           GO TO 11
        30 TOP2=0.1
        31 BOT2=TOP2*(12.*B-(C+F)*DST*TOP2)/(DST*(A+C)*TOP2-12.*B)
           WRITE(5,40)TOP2,BOT2
        40 FORMAT(' ',25X,'TOP2=',F9.4,5X,'BOT2='F9.4)
           TOP2=TOP2+0.05
           IF(TOP2.GT.1.)GO TO 50
           GO TO 31
        50 CONTINUE
      C    THICKNESS OF BOTTOM ASSUMED LARGER THAN TOP
           WRITE(5,60)
        60 FORMAT('1',25X,'BOTTOM ASSUMED LARGER THAN TOP')
           BOT3=0.1
        61 TOP3=((B+D)*BOT3*BOT3*BOT3-D*G*DST*BOT3)/(B*G*DST)
           WRITE(5,70)TOP3,BOT3
        70 FORMAT(' ',25X,'TOP3=',F9.4,5X,'BOT3='F9.4)
           BOT3=BOT3+0.25
           IF(BOT3.GT.1.)GO TO 80
           GO TO 61
```

```
-82        90 TOP4=0.1
-.\         91 BOT4=(12.*(B+D)-(A+C)*DST*TOP4)/((C+F)*DST)
-4E            WRITE(5,92)TOP4,BOT4
-72        92 FORMAT(' ',25X,'TOP4='F9.4,5X,'BOT4='F9.4)
-91           TOP4=TOP4+0.05
-A            IF(TOP4.GT.1.)GO TO 100
-           GO TO 91
-       100 CONTINUE
-           END
[ ] .       0400[V] AL        0408[V] B        0470[V] DRA      04D8[V] D
[ ]         04E8[V] E         04  [ ] .R       0474[V] DST      04FC[V] S
[V]         0518[V] C         0524[V] A        052C[V] C        0534[V] F
[L]         0   [S]  I        053 [V] BOT1     0176[L] 11       0540[V] TOP1
[L]         02CC[L] 30        055 [V] TOP2     0234[L] 31       0554[V] BOT2
[L]         02E [L] 40        031 [L] 60       0564[V] BOT3     0348[L] 61
[V]         0358[L] 70        04  [L] 80       056C[V] TOP4     040A[L] 81
[V]         0472[L] 9         044 [L] 100      00  [S] .V
.            1.

M LABELS:
270       20 4 .        2A34 .COMP       2C12  I         25E4 .R       2AFC .Z
          2  4 .        2 5  .MES        2906 .4         27DF EXP      2964 AI
6 6       2A5C .RARG    2AF2 .6          27DF AEXP       2B0  .ERCNT   2ACE $8
   .      2  6 .        2C2F

Y-POINTS:
   4 .    2624 .        2606 ALOG        27DE AEXP       27DE EXP      2964 AI
   6 .    2A34 .COMP    2A5A $6          2A9C .RARG      2ACE $8       2AF8 .5
AFC .ZERO 2B   .ERCNT   2B 2 .6          2958 .MES       2BE2 .U       2C28 .V
C12 AI

ON-BLOCKS:
E

EFINED SUBROUTINES:
E

NSFER ADDRESS 2070
UTION BEGINS:
```

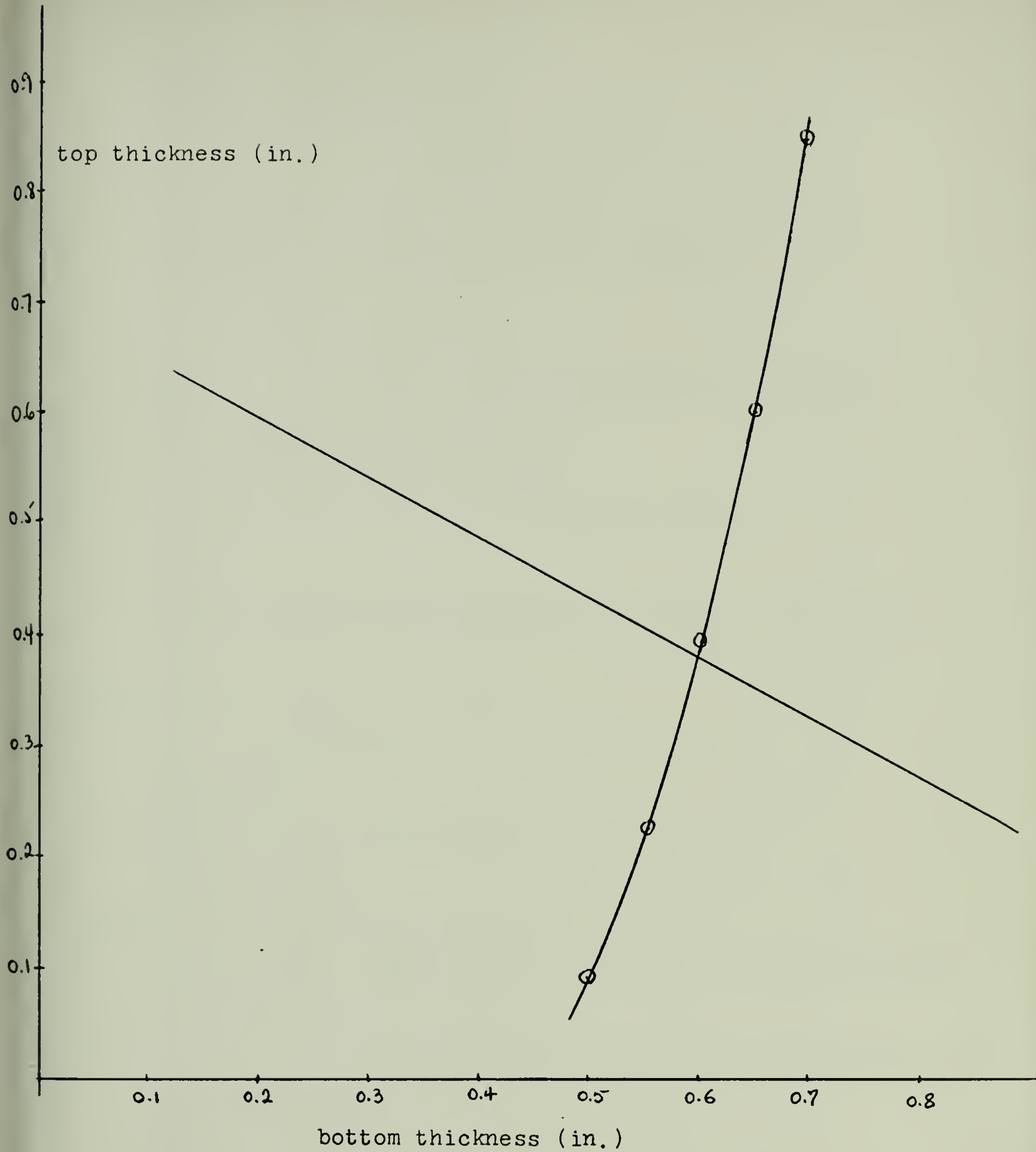
TOP ASSUMED LARGER THAN BOTTOM

TOP1=	[illegible]	BOT1=	0.1000
TOP1=	[illegible]	BOT1=	0.1500
TOP1=	[illegible]	BOT1=	0.2000
TOP1=	[illegible]	BOT1=	0.2500
TOP1=	[illegible]	BOT1=	0.3000
TOP1=	[illegible]	BOT1=	0.3500
TOP1=	[illegible]	BOT1=	0.4000
TOP1=	[illegible]	BOT1=	0.4500
TOP1=	[illegible]	BOT1=	0.5000
TOP1=	[illegible]	BOT1=	0.5500
TOP1=	[illegible]	BOT1=	0.6000
TOP1=	[illegible]	BOT1=	0.6500
TOP1=	[illegible]	BOT1=	0.7000
TOP1=	[illegible]	BOT1=	0.7500
TOP1=	[illegible]	BOT1=	0.8000
TOP1=	[illegible]	BOT1=	0.8500
TOP1=	[illegible]	BOT1=	0.9000
TOP1=	[illegible]	BOT1=	0.9500
TOP1=	[illegible]	BOT1=	1.0000
TOP2=	[illegible]	BOT2=	-0.1017
TOP2=	[illegible]	BOT2=	-0.1687
TOP2=	[illegible]	BOT2=	-0.2587
TOP2=	[illegible]	BOT2=	-0.3997
TOP2=	[illegible]	BOT2=	-0.6955
TOP2=	[illegible]	BOT2=	-2.1234
TOP2=	[illegible]	BOT2=	1.7868
TOP2=	[illegible]	BOT2=	0.5333
TOP2=	[illegible]	BOT2=	0.2515
TOP2=	[illegible]	BOT2=	0.1143
TOP2=	[illegible]	BOT2=	0.0258
TOP2=	[illegible]	BOT2=	-0.0403
TOP2=	[illegible]	BOT2=	-0.0944
TOP2=	[illegible]	BOT2=	-0.1413
TOP2=	[illegible]	BOT2=	-0.1835
TOP2=	[illegible]	BOT2=	-0.2224
TOP2=	[illegible]	BOT2=	-0.2591
TOP2=	[illegible]	BOT2=	-0.2941
TOP2=	[illegible]	BOT2=	-0.3277



Intersection not accepted; assumed Top > Bot ended up with Bot > Top.

```
BOTTOM ASSUMED LARGER THAN TOP
TOP3=  -0.0[illegible]46     BOT3=   0.1000
TOP3=  -0.11[illegible]7     BOT3=   0.1500
TOP3=  -0.14[illegible]3     BOT3=   0.2000
TOP3=  -0.15[illegible]      BOT3=   0.2500
TOP3=  -0.15[illegible]4     BOT3=   0.3000
TOP3=  -0.1[illegible]65     BOT3=   0.3500
TOP3=  -0.0[illegible]1      BOT3=   0.4000
TOP3=  -0.0[illegible]77     BOT3=   0.4500
TOP3=   0.0[illegible]56     BOT3=   0.5000
TOP3=   0.2[illegible]73     BOT3=   0.5500
TOP3=   0.39[illegible]5     BOT3=   0.6000
TOP3=   0.6[illegible]44     BOT3=   0.6500
TOP3=   0.8543     BOT3=   0.7000
TOP3=   1.14[illegible]4     BOT3=   0.7500
TOP3=   1.49[illegible]9     BOT3=   0.8000
TOP3=   1.8[illegible]1      BOT3=   0.8500
TOP3=   2.[illegible]1       BOT3=   0.9000
TOP3=   2.[illegible]63      BOT3=   0.9500
TOP3=   3.41[illegible]8     BOT3=   1.0000
TOP4=   0.1000     BOT4=   1.1275
TOP4=   0.1500     BOT4=   1.0344
TOP4=   0.2000     BOT4=   0.9414
TOP4=   0.2500     BOT4=   0.8484
TOP4=   0.3000     BOT4=   0.7554
TOP4=   0.3500     BOT4=   0.6623
TOP4=   0.4000     BOT4=   0.5693
TOP4=   0.4500     BOT4=   0.4763
TOP4=   0.5000     BOT4=   0.3832
TOP4=   0.5500     BOT4=   0.2902
TOP4=   0.6000     BOT4=   0.1972
TOP4=   0.6500     BOT4=   0.1042
TOP4=   0.7000     BOT4=   0.0111
TOP4=   0.7500     BOT4=  -0.0819
TOP4=   0.8000     BOT4=  -0.1749
TOP4=   0.8500     BOT4=  -0.2680
TOP4=   0.9000     BOT4=  -0.3610
TOP4=   0.9500     BOT4=  -0.4540
TOP4=   1.0000     BOT4=  -0.5470
END

VIO OPERATING SYSTEM VERSION 1 REVISION  012 03/04/74 GENERATED  05/06/74

JOB HANDLING CHARGE    $  .35 / JOB        .35
173 LINES PRINTED PR1  $ 1.25 / K LN       .22
 67 CARDS READ         $ 1.50 / K CD       .1
 [illegible] PLOTTER VECTORS    $  .25 / 1000       .00
 2[illegible] MODEL 7[illegible] SECONDS   $25.00 / HOUR       .14
 2[illegible] MODEL 8[illegible] SECONDS   $12.50 / HOUR       .00
                 TOTAL CHARGE $    .81

EIR 4[illegible] 14731  LOGGED OUT 05/06/74 20:09.  $    .68 LEFT AFTER    25 LOGINS.
```



this intersection is acceptable Bot > Top

```
      C       *AL* IS THE LENGHT
              AL=500.
              B=AL/8.
      C       *DRA* IS THE DRAFT
              DRA=B/3.
              D=AL/9.
      C       *POI* IS THE POISSON'S RATIO OF THE MATERIAL
      C       FOR ALUMINUM
              POI=0.33
      C       *E* IS THE YOUNG'S MODULUS OF THE MATERIAL
      C       FOR ALUMINUM
              E=10.*10.**6
      C       *DST* IS THE DESIGN STRESS
              DST=10000.
      C       *S* IS THE SPACING OF LONGITUDINAL STIFFENING MEMBERS
              S=30.
      C       *BM* IS THE BENDING MOMENT
              BM=(B*DRA*AL*AL*0.75)/(35.*35.)
              G=0.30326*S*S*(1.-POI*POI)/E
      C       *TOP* IS THE THICKNESS OF THE TOP PLATING
      C       *BOT* IS THE THICKNESS OF THE BOTTOM PLATING
              TOP=0.30
              BOT=0.6
              A=864.*BM*(B*BOT+D*BOT)
              DEN=D*(3.*B*B*TOP*BOT+2.*B*D*BOT*(TOP+BOT)+(D*D*BOT*BOT))
      C       *STH* IS THE STRESS ON TOP DUE TO HOGGING
              STH=A/DEN
              WRITE(5,60)STH
          60  FORMAT(' ',20X,'STH='F10.3)
              C=864.*BM*(B*TOP+D*BOT)
      C       *SBH* IS THE STRESS ON BOT DUE TO HOGGING
              SBH=C/DEN
              WRITE(5,90)SBH
          90  FORMAT(' ',20X,'SBH='F10.3)
      C       *SBCRIT* IS THE CRITICAL STRESS ON BOT
              SBCRIT=BOT*BOT/G
              WRITE(5,110)SBCRIT
         110  FORMAT(' ',17X,'SBCRIT='F10.3)
              P=2.*D*BOT+B*(TOP+BOT)
      C       *DITOP* IS THE DISTANCE OF THE TOP FROM THE NEUTRAL AXIS
              DITOP=D*(B*BOT+D*BOT)/P
              WRITE(5,40)DITOP
          40  FORMAT(' ',18X,'DITOP='F10.4)
      C       *DIBOT* IS THE DISTANCE OF THE BOTTOM FROM THE NEUTRAL AXIS
              DIBOT=D*(B*TOP+D*BOT)/P
              WRITE(5,50)DIBOT
          50  FORMAT(' ',18X,'DIBOT='F10.4)
              END
[S] .U        0324 [V] AL       032C [V] B      0334 [V] DRA     033C [V] D
[V] POI       034C [V] E        0000 [S] .R     0358 [V] DST     0360 [V] S
[V] BM        0370 [V] G        0388 [V] TOP    0390 [V] BOT     0398 [V] A
[V] DEN       03B8 [V] STH      0174 [L] 60     0000 [S] @I      038C [V] C
```

```
[V] SBH      01F2[L] 90       03C4[V] SBCRIT  0228[L] 110      03C8[V] P
[V] DITOP    02A6[L] 40       03D0[V] DIBOT   0304[L] 50       0000[S] .V
EC           L.

GRAM LABELS:
270 *MAI] ..   2A64 .V       2894 .COMP    2A72 @I       2444 .R       295C .ZE
2BA $6         2A24 .A       2982 .MES     2936 .W       263E EXP      27C4 AIN
2C6 ALOG       25FC .RARG    2959 .5       263E AEXP     2960 .ERCNT   292E $8
9AC .D         2A36 .U       2B8E

SYMBOL TS:
444 .R         2464 ..       2536 ALOG     263E AEXP     263E EXP      27C4 AIN
B6 .           2894 .COMP    29BA $6       25FC .RARG    292E $8       2958 .5
95C .ZER       2960 .ERCNT   2962 .D       2938 .MES     2A42 .U       2A68 .V
A72 @I

UNDEFINED S:
E

UNDEFINED SUBROUTINES:
E

SLEEP ADDRESS 2070
UTION BEGINS:

          STH= 18580.664
          SBH= 14570.137
       SBCRIT= 14767.777
        DITOP=    34.7037
        DIBOT=    24.7019
ND

VIO OPERATING SYSTEM VERSION 1 REVISION  012 03/04/74 GENERATED  05/06/74  (

UE HANDLING CHARGE     $  .05 / JOB         .35
85 LINES PRINTED PR1   $ 1.05 / K LN        .11
54 CARDS READ          $ 1.00 / K CD        .08
00 PLOTTER VECTORS     $  .05 / 10K         .00
16 MODEL 7? SECONDS    $25.00 / HOUR        .11
00 MODEL ?? SECONDS    $12.50 / HOUR        .00
                  TOTAL CHARGE $            .65

EIF 45? 14731  LOGGED OUT 05/06/74 20:13.  $    .03 LEFT AFTER    36 LOGINS.
```

SUMMARY

Length	=	500'
Beam	=	AL/8
Draft	=	B/3
Depth	=	AL/9
DST	=	18000 psi
S	=	30"
Material	-	ALUMINUM
TOP	=	0.38"
BOT	=	0.6"
STH	=	18089.66
SBH	=	14578.14
SBCRIT	=	14767.85
DITOP	=	30.76"
DIBOT	=	24.79"

HOGGING BENDING MOMENT=SAGGING BENDING MOMENT

DESIGN STRESS IN TENSION=DESIGN STRESS IN COMPRESSION

From the preceding section we can understand the need to put some limit on the value of the compressive stresses, and perhaps also the inefficiency of considering the value of S (the spacing between longitudinal stiffening members) as an input to the problem.

In this section we will consider a bending moment of the same magnitude in both hogging and in sagging and the stress in either tension or compression will have as upper limit the design stress.

Since the bending moment is the same, it is intuitive that the thickness required to resist tension on top and compression on bottom (buckling) when the hogging moment is acting will also be respectively the thicknesses to resist tension on bottom and buckling on top when we consider the sagging moment. We would end up then with a thickness on top required by the hogging moment TOPH, a thickness on bottom required by the hogging moment, as well as a thickness on top required by the sagging moment TOPS and a thickness on bottom required by the sagging moment BOTS.

Since HM = SM we must obtain

TOPS = BOTH = t1 and BOTS = TOPH = t2

and we will end up considering the largest t1 or t2, to be the thickness of the top and bottom simultaneously.

Assume for instance that $t1 > t2$ then if we decide on t1for

thickness of the top as well as at the bottom, we will verify that we have overdesigned because TOPS = t1 corresponds to BOTS = t2 which plugged into the expression for I gives a smaller value than using TOPS = t1 with BOTH = t1 that will give a larger value for I; this larger I value when used in

$$STR = \frac{BM*Y}{I}$$

will give a smaller STR value than the design stress and we could use a smaller thickness, may be between t1 and t2 for both the top and bottom and satisfy the DST requirement.

This means that we must incorporate in this analysis the fact already known that when BM (hogging) is equal to BM (sagging) we will have to consider the neutral axis half way between top and bottom which means that the thickness of the top shall be equal to the thickness of the bottom for a geometrically symmetrical cross section.

Let's determine the formulas that will best serve this case then:

HM = SM = BM

DITOP = DIBOT = D*(B*t+D*t)/(2*D*t+B*(2*t))

t = TOP = BOT = TS

$$I = 2*D*D*t*\frac{3*B*B+D*D+4*B*D}{D+B}$$

Now we can write $$STR = \frac{BM*DITOP}{I} = \frac{BM*DIBOT}{I} = DST$$

and the instability formula

$$t = S*\sqrt{0.30396*\frac{1-POI*POI}{E}*DST}$$

Where S is the spacing between longitudinals.

We see thus that we cannot have more than two equations and so we must seek for two variables. A quick inspection and one can see that knowing BM, B, D, the material properties and the design stress DST we have left to determine what should be the thickness of the plating (t) and the corresponding frame spacing (S). Solving the equations with this in mind, we obtain

$$BM = 1.37143*B*T*AL*AL \quad lb*ft$$

and from $STR = \frac{BM*Y}{I}$ we obtain

$$DST = \frac{BM*(D+B)}{4*D*t(3*B*B+D*D+4*B*D)}$$

which gives

$$t = \frac{BM*(D+B)}{4*D*DST*(3*B*B+D*D+4*B*D)}$$

and also

$$S = \frac{t}{\sqrt{\frac{0.30396*(1-POI*POI)*DST}{E}}}$$

These formulas will give for a prescribed set of dimensions (ft) and a particular material subject to bending BM (lb*ft) the thickness t (inches) and the spacing of longitudinal stiffening members S (inches) required.

HOGGING MOMENT AND SAGGING MOMENT OF
DIFFERENT MAGNITUDES
THE DESIGN STRESS IS THE SAME IN TENSION AND
IN COMPRESSION

Let's consider now the case where the magnitude of HM is different than the value for SM.

We have in this case:

$$DITOP = \frac{D*(B*BOT+D*TS)}{2*D*TS+B*(TOP+BOT)}$$

$$DIBOT = \frac{D*(B*TOP=D*TS)}{SAME\ DENOMINATOR}$$

$$I = 4*D*D* \frac{3*B*B*TOP*BOT+(D*TS)^2+2*B*D*TS*(TOP+BOT)}{SAME\ DENOMINATOR}$$

$$STH = \frac{HM*DITOP}{I} \qquad STS = \frac{SM*DITOP}{I}$$

$$SBH = \frac{HM*DIBOT}{I} \qquad SBS = \frac{SM*DIBOT}{I}$$

$$BOT = \sqrt{G}\ \sqrt{SBH} \qquad TOP = \sqrt{G}\ \sqrt{STS}$$

where $$G = 0.30396*\frac{S^2*(1-POI*POI)}{E}$$

Looking at these equations, we know that the result obtained for the thicknesses is going to determine the value of DITOP, DIBOT and I. If furthermore we restrain the stresses from being larger than DST we will undoubtedly want them to end up being DST otherwise if they are smaller we are not using the material efficiently.

We thus have

DST = STH = HM*K1 DST = STS = SM*K1 where K1 = DITOP/I

DST = SBH = HM*K2 DST = SBS = SM*K2 where K2 = DIBOT/I

This tells us that if for instance HM > SM

we should be considering DST = STH = HM*K1

and DST = SBH = HM*K2

because the other two equations will determine lower stresses and are thus within the requirement of not exceeding the design stress, being automatically satisfied.

Now from these equations we can see that if the design stress required for the top, (in tension for the case of HM > SM; note that for the case SM > HM the other two equations should be considered and the conclusions are similar), is going to be the same one as required for the bottom (in compression), we must have K1 = K2 and so DITOP = DIBOT and the neutral axis will again end up being located halfway between top and bottom for a geometrically symmetrical cross section.

We can here use the same two equations derived in the previous section to determine (t) and (S). The moment to be considered here will be the larger of HM or SM instead of BM.

HOGGING MOMENT LARGER THAN SAGGING MOMENT

DESIGN STRESS IN COMPRESSION LARGER THAN DESIGN STRESS IN TENSION

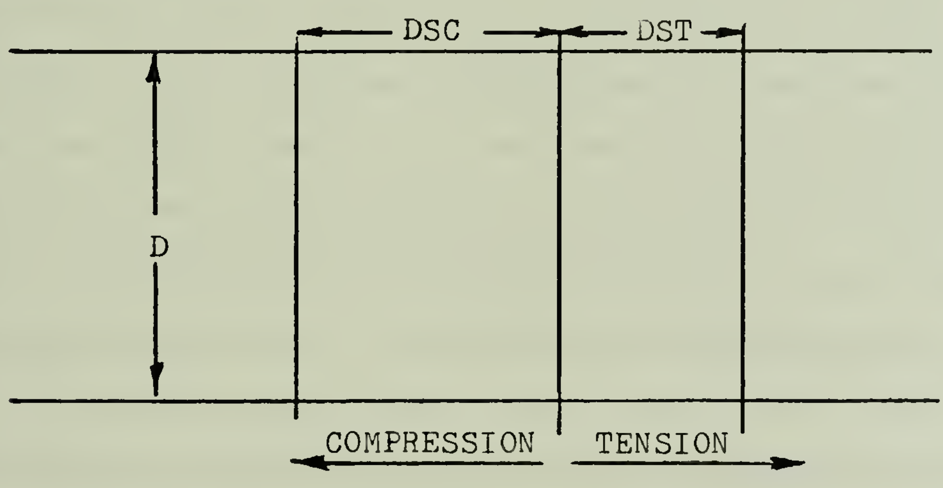
Thesituation we are analysing in this section

$$HM > SM$$

$$DSC > DST$$

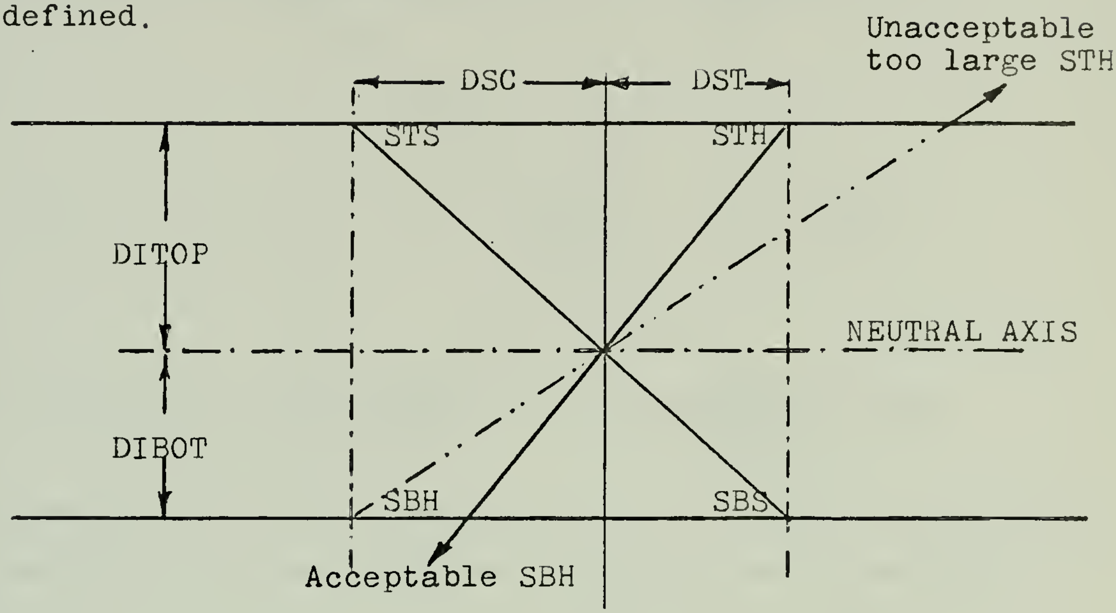
is perhaps more interesting than the previous ones because its study provided us with a much simpler method for determining the thicknesses and the neutral axis location; we call here the attention of the reader to fully understand the steps of this section because the following sections till the end of this work will use this same method of analysis applied totheir own particular case.

Indicated in the next diagram are the ranges within which we may stress the material in order to satisfy the requirement of not exceeding DSC or DST.



Let's consider now that we will try to determine the best position for the neutral axis by first gaining some insight into

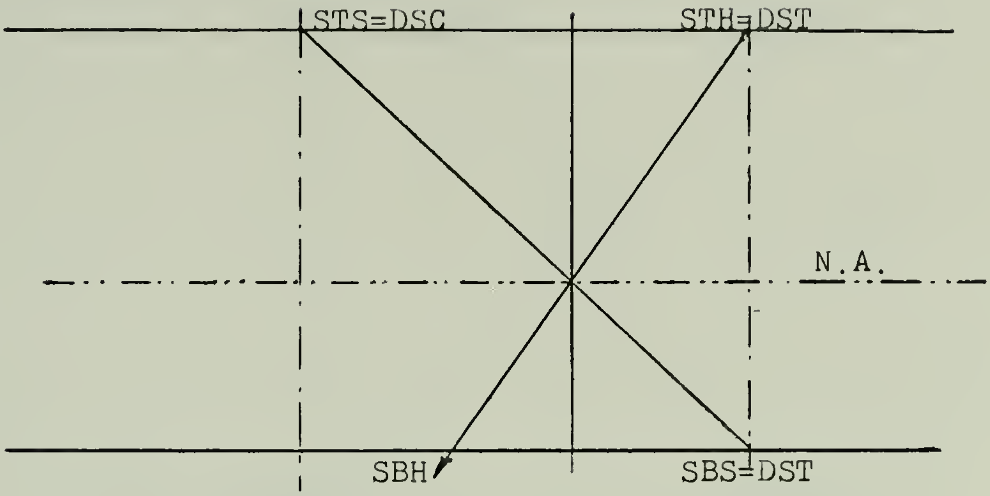
the geometry of the stress distributions and the stress limits already defined.



From the previous diagram we may easily understand that if we decide to stress the material to its maximum in tension and compression when under the effect of a sagging bending moment (SBS - STS) we end up with a neutral axis closer to the bottom due to the fact that DST < DSC and we see that when considering the hogging moment the only possible alternative left is to limit the stress caused by this moment in tension on top STH=DST; in this case the compressive stress on the bottom SBH would automatically fall inside the acceptable range.

If for the hogging moment we choose to allow the stress in compression on the bottom to attain its maximum value SBH=DSC we see from thediagram that we are forcing the STH to fall outside of the acceptable range. We are left in this situation with an acceptable solution so far and we must investigate it further.

At this stage we have



We may see from the diagram that we are asking for SBS=STH==DST to have the same value and at the same time to have the neutral axis located closer to the bottom DITOP > DIBOT.

We note that the equations that give STH and SBS are

STH = HM*DITOP/I

and SBS = SM*DIBOT/I

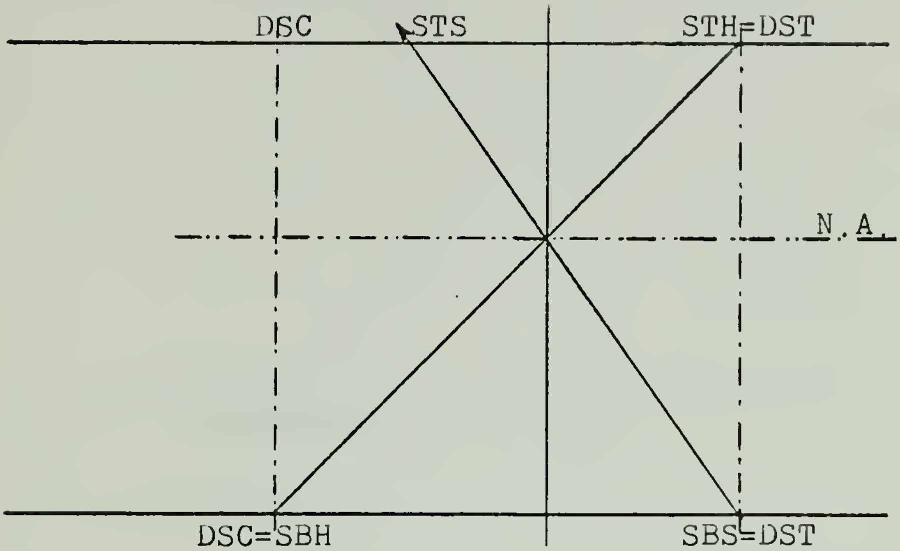
and since I is the same STH can never be of the same magnitude as SBS because

STH = HM*DITOP/I > SBS = SM*DIBOT/I

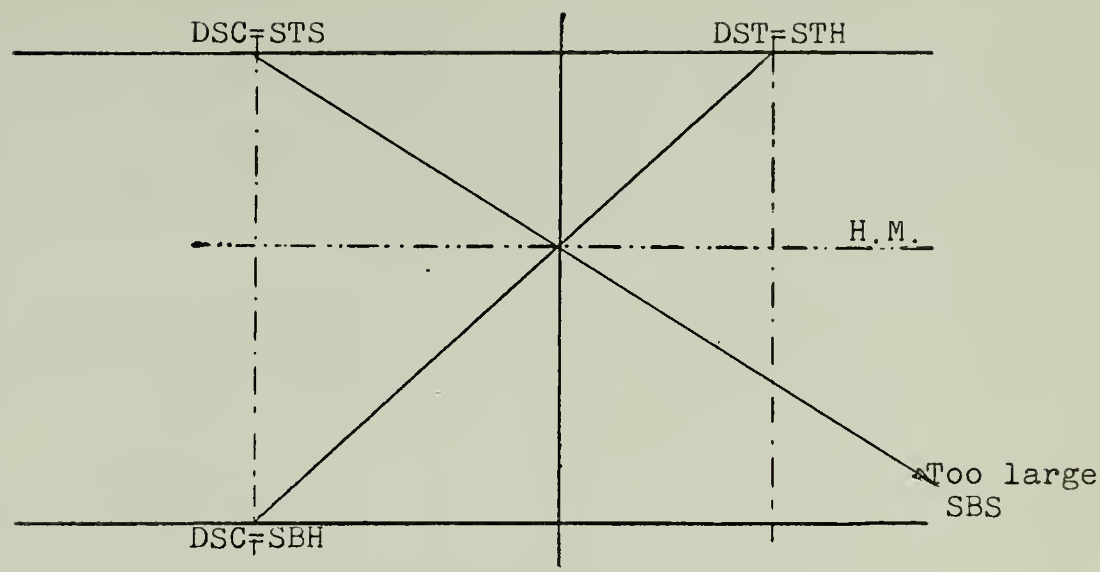
both because DITOP is being set larger than DIBOT and also because we are considering HM > SM to begin with. Thus we are left with the alternative of making DIBOT larger than DITOP to make it possible to satisfy

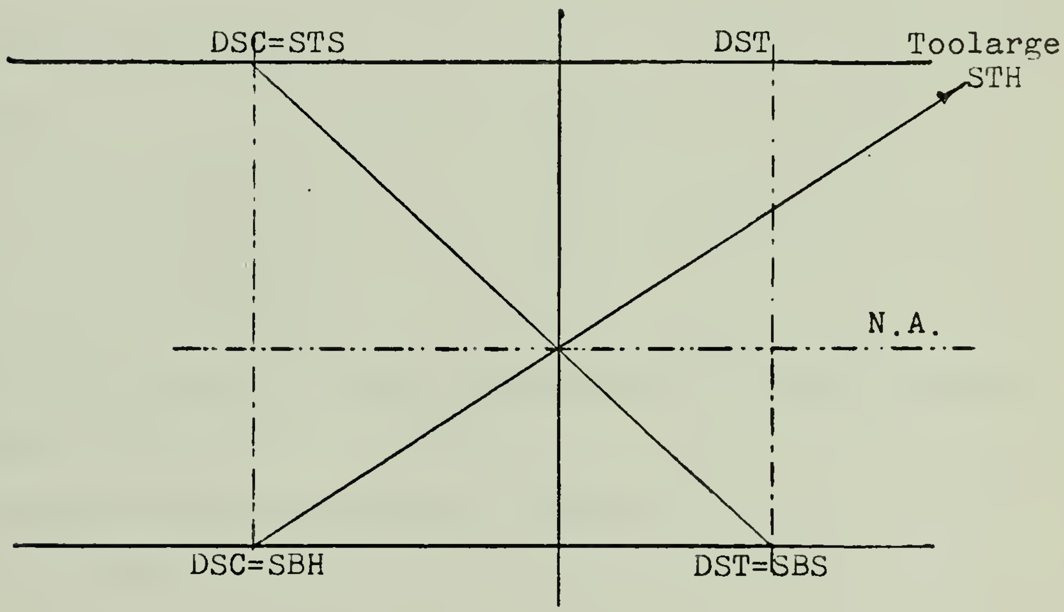
STH = HM*DITOP/I = SBS= SM*DIBOT/I

Thesituation would then be



Besides this is only natural because what we are doing here is to make the material to be stressed to its allowable limit while resisting the larger of the two moments; hogging in this case. This situation will be worked out here as an example and it seems to be quite clear that similarly, cases where SM > HM or DST > DSC or other situation like DST > DSC with HM > SM or DST < DSC with SM > HM could be solved applying a similar reasoning. So, having HM > SM and DSC > DST we should consider the smaller design stress, in this case DST, and have the material stressed to this upper limit. Why?, because if the larger is considered, DSC in this case, there is no way we can have the material stressed to this higher limit in both hogging and sagging while considering the smaller we may attempt to do so. This can be better understood from the two next diagrams.





So, considering the lower design stress, in this case DST, we will stress the material to this maximum in both hogging and sagging thus giving

STH = HM*DITOP/I = DST

SBS = SM*DIBOT/I = DST

Note here that we already know that the neutral axis will

be closer to the top DITOP < DIBOT which means that we must obtain a thickness for the plating at the top larger than at the bottom and so TS=TOP which means that we will be using the following formulas

$$DITOP = \frac{D*(B*BOT+D*TOP)}{P}$$

$$DIBOT = \frac{D*TOP*(B+D)}{P}$$

$$I = \frac{4*D^2*TOP*((3*B^2+2*B*D)*BOT+(D^2+2*B*D)*TOP)}{P}$$

where P =(2*D+B)*TOP+B*BOT

we have also

STH = DST = HM*DITOP/I

SBS = DST = SM*DIBOT/I

SBH = DSC = HM*DIBOT/I

From these three equations we may combine the two first to obtain

HM*DITOP = SM*DIBOT

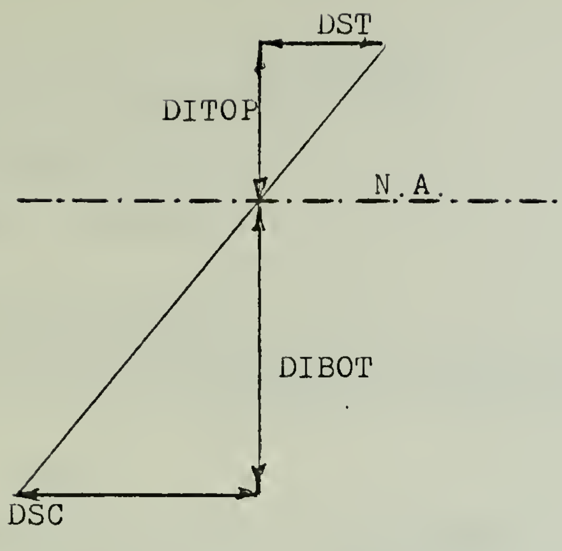
and combining the second and third we obtain

DST*HM = DSC*SM

After combining these two equations we obtain

DST*DIBOT = DSC*DITOP

This equation could have been obtained more easily just by looking at the diagram we are considering and notice the similar triangles



Note also that what we obtain from this equation is to determine the N.A. location by making DITOP and DIBOT proportional to DST And DSC.

Proceeding with this equation we obtain:

DST*(D*TOP*(B+D))/P + DSC*(D*B*BOT+D^2*TOP)/P

TOP*(DST*B+DST*D-DSC*D) = DSC*B*BOT

and making

AC = DST/DSC+D*(DST-DSC)/(DSC*B)

we obtain

BOT = AC*TOP

We need now an equation to stress the material to its design limit and this can be done by either using

STH = DST = HM*DITOP/I

or SBH = DSC = HM*DIBOT/I

From these two equations I prefer to use the second especially because it will simplify the calculations that follow as can be understood from the simpler expression that gives DIBOT as

compared with the one that gives DITOP.

We will then consider here

$$SBH = DSC = HM*DIBOT/I$$

which gives

$$DSC = \frac{HM*D*TOP*(B+D)}{4*D^2*TOP((3*B^2+2*B*D)*BOT+(D^2+2*B*D)*TOP)}$$

Simplifying we obtain

$$TOP = \frac{HM*(B+D)}{DSC*4*D*(D^2+2*B*D)} - \frac{3*B^2+2*B*D}{D^2+2*B*D} *BOT$$

or making

$$A = HM*(B+D)/(DSC*4*D*(D^2+2*B*D))$$

$$AB = (3*B^2+2*B*D)/(D^2+2*B*D)$$

we have

$$TOP = A-AB*BOT$$

replacing here

$$BOT = AC*TOP$$

we obtain

$$TOP = \frac{A}{1+AB*AC}$$

Having already found TOP and BOT we may use Bryan's formula to determine S;since the thickness of plating is for this case smaller at the bottom we must consider this thickness and along with it DSC because this will be the larger compressive stress the bottom will be subjected to.

From $DSC = \dfrac{E}{0.30396*(1-POI*POI)} * \dfrac{BOT^2}{S^2}$

We obtain

$$S = \frac{1}{\sqrt{0.30396*\dfrac{1-POI*POI}{E}*DSC}}*BOT$$

or making

$$Z = \frac{1}{\sqrt{0.30396*\dfrac{1-POI*POI}{E}*DSC}}$$

we have

$$S = Z*BOT$$

A computer program was written and applied to two particular sets of dimensions and two different materials namely steel and aluminum. The results are presented next in the computer printouts.

```
C     *AL* IS THE LENGHT
      AL=500.
      B=AL/8.
C     *DRA* IS THE DRAFT
      DRA=B/3.
      D=AL/9.
C     *POI* IS THE POISSON'S RATIO OF THE MATERIAL
C     FOR STEEL
      POI=0.3
C     *E* IS THE YOUNG'S MODULUS OF THE MATERIAL
C     FOR STEEL
      E=30.*10.**6
C     *DST* IS THE DESIGN STRESS IN TENSION
      DST=25000.
C     *DSC* IS THE DESIGN STRESS IN COMPRESSION
      DSC=30000.
C     *HM* IS THE HOGGING BENDING MOMENT
      HM=1.37143*B*DRA*AL*AL
C     *SM* IS THE SAGGING BENDING MOMENT
      SM=B*DRA*AL*AL
      W=0.30396*(1.-POI*POI)*DSC/E
      U=SQRT(W)
      Z=1./U
      A=HM*(B+D)/(DSC*4.*D*(D*D+2.*B*D))
      AB=(3.*B*B+2.*B*D)/(D*D+2.*B*D)
      AC=DST/DSC+D*(DST-DSC)/(DSC*B)
C     *TOP* IS THE THICKNESS OF THE TOP PLATING
C     *BOT* IS THE THICKNESS OF THE BOTTOM PLATING
      TOP=A/(1.+AB*AC)
      BOT=AC*TOP
      WRITE(5,10)TOP
   10 FORMAT('1',22X,'TOP=',F10.4)
      WRITE(5,20)BOT
   20 FORMAT(' ',22X,'BOT=',F10.4)
C     *S* IS THE SPACING OF LONGITUDINAL STIFFENING MEMBERS
      S=Z*BOT
      WRITE(5,30)S
   30 FORMAT(' ',22X,'S=',F10.4)
      P=2.*D*TOP+B*(TOP+BOT)
C     *DITOP* IS THE DISTANCE OF THE TOP FROM THE NEUTRAL AXIS
      DITOP=D*(B*BOT+D*TOP)/P
      WRITE(5,40)DITOP
   40 FORMAT(' ',18X,'DITOP=',F10.4)
C     *DIBOT* IS THE DISTANCE OF THE BOTTOM FROM THE NEUTRAL AXIS
      DIBOT=D*(B*TOP+D*TOP)/P
      WRITE(5,50)DIBOT
   50 FORMAT(' ',18X,'DIBOT=',F10.4)
C     *GMI* IS THE MOMENT OF INERTIA OF THE X SECTION ABOUT N.A.
      GMI=4.*D*D*((3.*B*B+2.*B*D)*TOP*BOT+(D*D+2.*B*D)*TOP*TOP)/P
C     *STH* IS THE STRESS ON TOP DUE TO HOGGING
C     *STS* IS THE STRESS ON TOP DUE TO SAGGING
C     *SBH* IS THE STRESS ON BOT DUE TO HOGGING
```

```
A8    C      *SBS* IS THE STRESS ON BOT DUE TO SAGGING
A8    C      *STCRIT* IS THE CRITICAL STRESS ON TOP
A8    C      *SBCRIT* IS THE CRITICAL STRESS ON BOT
A8           STH=HM*DITOP/GMI
B8           STS=SM*DITOP/GMI
C8           SBH=HM*DIBOT/GMI
D8           SBS=SM*DIBOT/GMI
E8           STCRIT=TOP*TOP*E/(0.30396*S*S*(1.-POI*POI))
28           SBCRIT=BOT*BOT*E/(0.30396*S*S* 1.-POI*POI))
68           WRITE(5,60)STH
84        60 FORMAT(' ',20X,'STH='F10.3)
9E           WRITE(5,70)STS
BA        70 FORMAT(' ',20X,'STS='F10.3)
D4           WRITE(5,80)STCRIT
F0        80 FORMAT(' ',17X,'STCRIT='F10.3)
2C           WRITE(5,90)SBH
28        90 FORMAT(' ',20X,'SBH='F10.3)
42           WRITE(5,100)SBS
5E       100 FORMAT(' ',20X,'SBS='F10.3)
78           WRITE(5,110)SBCRIT
94       110 FORMAT(' ',17X,'SBCRIT='F10.3)
38           END
[S] .U       0584[V] AL      05BC[V] B       05C4[V] DPA     05CC[V] D
[V] POI      05DC[V] E       0000[S] .P      05EC[V] DST     05F4[V] DSC
[V] HM       0624[V] SM      0608[V] W       0614[V] U       0000[S] SQRT
[V] Z        061C[V] A       0640[V] AB      0644[V] AC      0648[V] TOP
[V] BOT      01CC[L] 10      0000[S] @I      0202[L] 20      0650[V] S
[L] 30       0654[V] P       0658[V] DITOP   0200[L] 40      065C[V] DIBOT
[L] 50       0660[V] GMI     066C[V] STH     0670[V] STS     0674[V] SBH
[V] SBS      067C[V] STCRIT  0680[V] SBCRIT  04C4[L] 60      048A[L] 70
[L] 80       0528[L] 90      055E[L] 100     0594[L] 110     0000[S] .V
3            L


PAM LABELS:
70 *MAIN*    2DBA .V        2BBA .COMP     2BDC ALOG      2D98 @I        2AF4 .P
82 .ZERO     2BE0 $6        2734 .A        2CDE .MES      2BEC .W        29E4 EX
FA AINT      27E6 SQRT      2C22 .PARG     2 7F .5        2C54 $8        2C36 .F
86 .O        2C5C .U        3EB4


Y-POINTS:
F4 .P        2734 .A        27E6 SQRT      2BDC ALOG      29E4 EXP       2AFA AI
5C .W        2BBA .COMP     2BEC $6        2 22 .PARG     2C54 $8        2C7E .5
82 .ZERO     2C86 .FRCNT    2C88 .O        2CDE .MES      2C68 .U        2D3E .V
98 @I


ON-BLOCKS:


FINED SUBROUTINES:
```

```
        TOP=     0.3464
        BOT=     0.2374
          S=    14.2732
      DITOP=    25.2525
      DIBOT=    30.3030
        STH= 25000.000
        STS= 18220.152
     STCRIT= 63900.609
        SBH= 30010.012
        SBS= 21874.992
     SBCRIT= 29990.961


08 HANDLING CHARGE    $   .35 / JOB         .35
18 LINES PRINTED PR1  $ 1.25 / K LN         .1
80 CARDS READ         $ 1.50 / K CD         .1
00 PLOTTER VECTORS    $   .25 / 1000        .00
19 MODEL 70 SECONDS   $25.00 / HOUR         .1
00 MODEL 80 SECONDS   $12.50 / HOUR         .00
                        TOTAL CHARGE $      .7

EIR 400 14731  LOGGED OUT 04/21/74 20:22.  $    9.05 LEFT AFTER    34 LOGINS.
```

```
C       *AL* IS THE LENGHT
        AL=5. .
        B=AL/ .
C       *DRA* IS T E DRAFT
        DRA=B/ .
        D=AL/ .
C       *POI* IS T E POISSO IS RATIO OF THE MATERIAL
C       FOR AL  I
        POI= .35
C       *E* I. THE YOUNG'S  ODULUS OF THE MATERIAL
C       FOR AL  IN
        E=1  . 1 .  5
C       *DST* IS T E DESI   STRESS IN TENSION
        DST=
C       *DSC* IS T E DESIG  STRESS IN COMPRESSION
        DSC=3.
C       *HM* IS THE HOGGI G BENDING MOMENT
        HM=1. /1 .3  +DRA*AL*AL
C       *SM* IS THE SAGGI G BENDING MOMENT
        SM=  *AL*AL
        = .2    (1.-POI*POI)*DSC/E
        U=SQRT( )
        Z=1./U
        A=HM*( + )/(DSC*4. *(D+D+2.*B*D))
        AB=(   +  *D)/(D*D+2.*B*D)
        AC=DST/DSC-  (DST+DSC)/(DSC*B)
C       *TOP* IS T E THICKNESS OF THE TOP PLATING
C       *BOT* IS T E THICKNESS OF THE BOTTOM PLATING
        TOP=A/(1.+  *AC)
        BOT=AC*TOP
        WRITE( ,1 )TOP
    10  FORMAT(' ', X,'TOP='F12.4)
        WRITE( ,2 )BOT
    20  FORMAT(' ', X,'BOT='F1 .4)
C       *S* IS THE SPACING OF LONGITUDINAL STIFFENING MEMBERS
        S=Z*BOT
        WRITE(5,3 )S
    30  FORMAT(' ',22X,'S=' 10.4)
        P=2.* *TOP+ *(TOP+B T)
C       *DITOP* IS THE DISTANCE OF THE TOP FROM THE NEUTRAL AXIS
        DITOP=D*( BOT+D*TOP)/P
        WRITE( ,4 )DITOP
    40  FORMAT(' ',1 X,'DITOP='F10.4)
C       *DIBOT* IS THE DISTANCE OF THE BOTTOM FROM THE NEUTRAL AXIS
        DIBOT=D*( TOP+D*TOP)/P
        WRITE(5,5 )DIBOT
    50  FORMAT(' ',1 X,'DIB T='F12.4)
C       *GMI* IS T E MOMENT OF INERTIA OF THE X SECTION ABOUT N.A.
        GMI=4.*D*D*((3.*B*B+2.*B*D)*TOP*BOT+(D*D+2.*B*D)*TOP*TOP)/P
C       *STH* IS T E STRESS ON TOP DUE TO HOGGING
C       *STS* IS T E STRESS ON TOP DUE TO SAGGI G
C       *SBH* IS T E STRESS ON BOT DUE TO HOGGING
```

```
      C       *SBS* IS THE STRESS ON BOT DUE TO SAGGING
      C       *STCRIT* IS THE CRITICAL STRESS,ON TOP
      C       *SBCRIT* IS THE CRITICAL STRESS ON BOT
              STH=HM*DIT  /GI
              STS=SM*DIT  /GI
              SBH=HM*DIB  /GI
              SBS=SM*DIB  /GI
              STCRIT=T  TIP*E/( .30396*S*S*(1.-POI*POI))
              SBCRIT=B  BOT*E/( .30396*S*S*(1.-POI*POI))
              WRITE(5,60 )STH
           60 FORMAT(' ',2 X,'STH='F1  .3)
              WRITE(5,70 )STS
           70 FORMAT(' ',2 X,'STS='F1 .3)
              WRITE(5,8  )STCRIT
           80 FORMAT(' ',17X,'STCRIT='F1 .3)
              WRITE(5,9  )SBH
           90 FORMAT(' ',2 X,'SBH='F1  .3)
              WRITE(5,1  )SBS
          100 FORMAT(' ',2 X,'SBS='F1 .3)
              WRITE(5,11 )SBCRIT
          110 FORMAT(' ',17X,'SBCRIT='F1  .3)
              END
```

```
 .U        25P4[ ] .L        [V] B          25C4[V] DFA      65CC[V] D
 POI       5EC [ ] F         [S] .R         25E8[V] DS1      5F  [V] DSC
 .P        61 [V] SP        6  [V] W        261 [V] U        0  [S] SQRT
 Z          F15 [V] 1       630[V] AF       2644[V] AC       2644[V] TOP
 ACT       2100[ ] 1        [S] @I          0202[L] 20       264C[V] S
 SM        265 [V] B        264 [V] DITOP   02C [L] 40       265 [V] DIBOT
 SV        265C[V] DIT      26  [V] STH     266C[V] STS      267 [V] SBH
 SBS       267 [V] STCRIT   267 [V] SBCRIT  0484[L] 60       048A[L] 70
 [L] 8     0528[L]          055 [L] 100     0594[L] 110      00  [S] .V
              L
```

```
 LABELS:
 .7  *MAI *     2D   .V        2B   .COMP     2BD8 ALOG     2D94 @I     26F0 .R
 7   .ZER       2B C  H6       27   .A        2CDA .MES     2B58 .W     29E0 EXP
     AINT       27 2  SQRT     2C1E .RARG     2C7A .5       2C50 $8     2C32 .EF
     .O         2C 8  .L       3E
```

```
 ENTRY POINTS:
     .R     273  .           27 2 SQRT     2BD8 ALOG     29E0 EXP     2AE6 AI
     .W     2B 6 .C          2B C $6       2C1E .RARG    2C50 $8      2C7A .5
     .ZERO  2C 2 .ERCT       2C   .C       2CDA .MES     2D64 .U      2D8A .V
 D94 @I
```

```
 COMMON BLOCKS:
```

```
 CALLED SUBROUTINES:
```

```
     TCP=      .2464
     HCT=      .F374
       S=    [illegible].[illegible]27[illegible]
   DITIME=    [illegible].[illegible]5[illegible]
   DIHCT=    [illegible] .[illegible]
     STM=  [illegible]
     ST =  1 [illegible].1[illegible]
  STCHCT=  [illegible].7[illegible]
     S  =  [illegible]1[illegible]
     S  =  [illegible]7[illegible].[illegible]
  SECHCT=  [illegible]

[illegible]ANDLING CHARGE       .35 / JOB         .35
[illegible]INES PRINTED [illegible] 1.25 / K LI   .15
[illegible]ARDS READ           1.5  / K CD        .12
[illegible]LOTT[illegible] VECTORS [illegible] / 1[illegible]   .[illegible]
[illegible]CDEL 7[illegible] SECONDS [illegible] / HOUR   .1[illegible]
[illegible]CDEL [illegible] SECONDS [illegible].5 / HOUR   .[illegible]
                  TOTAL CHARGE $           .72

[illegible] 49[illegible] 14731  LOG[illegible] AT 4/[illegible]1/74 20:2[illegible].  $   9.8[illegible] LEFT AFTER   33 LOGINS.
```

```
C       *AL* IS THE LENGHT
        AL=1000.
        B=AL/5.75
C       *DRA* IS THE DRAFT
        DRA=B/3.3
        D=AL/14.
C       *POI* IS THE POISSON'S RATIO OF THE MATERIAL
C       FOR STEEL
        POI=0.3
C       *E* IS THE YOUNG'S MODULUS OF THE MATERIAL
C       FOR STEEL
        E=30.*10.**6
C       *DST* IS THE DESIGN STRESS IN TENSION
        DST=25000.
C       *DSC* IS THE DESIGN STRESS IN COMPRESSION
        DSC=30000.
C       *HM* IS THE HOGGING BENDING MOMENT
        HM=1.37143*B*DRA*AL*AL
C       *SM* IS THE SAGGING BENDING MOMENT
        SM=B*DRA*AL*AL
        W=0.30396*(1.-POI*POI)*DSC/E
        U=SQRT(W)
        Z=1./U
        A=HM*(B+D)/(DSC*4.*D*(D*D+2.*B*D))
        AB=(3.*B*B+2.*B*D)/(D*D+2.*B*D)
        AC=DST/DSC+D*(DST-DSC)/(DSC*B)
C       *TOP* IS THE THICKNESS OF THE TOP PLATING
C       *BOT* IS THE THICKNESS OF THE BOTTOM PLATING
        TOP=A/(1.+AB*AC)
        BOT=AC*TOP
        WRITE(5,10)TOP
     10 FORMAT('1',20X,'TOP=',F10.4)
        WRITE(5,20)BOT
     20 FORMAT(' ',20X,'BOT=',F10.4)
C       *S* IS THE SPACING OF LONGITUDINAL STIFFENING MEMBERS
        S=Z*BOT
        WRITE(5,30)S
     30 FORMAT(' ',22X,'S=',F10.4)
        P=2.*D*TOP+B*(TOP+BOT)
C       *DITOP* IS THE DISTANCE OF THE TOP FROM THE NEUTRAL AXIS
        DITOP=D*(B*BOT+D*TOP)/P
        WRITE(5,40)DITOP
     40 FORMAT(' ',18X,'DITOP=',F10.4)
C       *DIBOT* IS THE DISTANCE OF THE BOTTOM FROM THE NEUTRAL AXIS
        DIBOT=D*(B*TOP+D*TOP)/P
        WRITE(5,50)DIBOT
     50 FORMAT(' ',18X,'DIBOT=',F10.4)
C       *GMI* IS THE MOMENT OF INERTIA OF THE X SECTION ABOUT N.A.
        GMI=4.*D*D*((3.*B*B+2.*B*D)*TOP*BOT+(D*D+2.*B*D)*TOP*TOP)/P
C       *STH* IS THE STRESS ON TOP DUE TO HOGGING
C       *STS* IS THE STRESS ON TOP DUE TO SAGGING
C       *SBH* IS THE STRESS ON BOT DUE TO HOGGING
```

```
13A8    C       *SBS* IS THE STRESS ON BOT DUE TO SAGGING
13A8    C       *STCRIT* IS THE CRITICAL STRESS ON TOP
13A8    C       *SBCRIT* IS THE CRITICAL STRESS ON BOT
13A8            STH=HM*DITOP/GMI
3B8             STS=SM*DITOP/GMI
3C8             SBH=HM*DIBOT/GMI
3D8             SBS=SM*DIBOT/GMI
3E8             STCRIT=TOP*TOP*E/(0.30396*S*S*(1.-POI*POI))
428             SBCRIT=BOT*BOT*E/(0.30396*S*S*(1.-POI*POI))
468             WRITE(5,60)STH
484          60 FORMAT(' ',20X,'STH='F10.3)
49E             WRITE(5,70)STS
4BA          70 FORMAT(' ',20X,'STS='F10.3)
4D4             WRITE(5,80)STCRIT
4F0          80 FORMAT(' ',17X,'STCRIT='F10.3)
52C             WRITE(5,90)SBH
528          90 FORMAT(' ',20X,'SBH='F10.3)
542             WRITE(5,100)SBS
55F         100 FORMAT(' ',20X,'SBS='F10.3)
578             WRITE(5,110)SBCRIT
594         110 FORMAT(' ',17X,'SBCRIT='F10.3)
5B0             END
[S]  .U      05B4[V] AL        05BC[V] B         05C4[V] DRA       05CC[V] D
[V]  POI     05DC[V] E         0070[S] .R        05EC[V] DST       05F4[V] DSC
[V]  HM      0604[V] SM        0608[V] W         0614[V] U         0030[S] SQRT
[V]  Z       061C[V] A         0640[V] AB        0648[V] AC        064C[V] TOP
[V]  BOT     01CC[L] 10        0000[S] @I        0202[L] 20        0654[V] S
[L]  30      0658[V] P         065C[V] DITOP     0203[L] 40        0660[V] DIBOT
[L]  50      0664[V] GMI       0670[V] STH       0674[V] STS       0678[V] SBH
[V]  SBS     0680[V] STCRIT    0684[V] SBCRIT    0484[L] 60        04BA[L] 70
[L]  80      0528[L] 90        055F[L] 100       05B4[L] 110       00BX[S] .V
ERR         L


GRAM LABELS:
270 *MAIN*   208E .V        2BBE .COMP     2BE0 ALOG      2D9C @I       26F8 .P
C86 .ZERO    2BE4 $F        2738 .A        2CE2 .MES      2B60 .W       29E8 EX
AEE AINT     27EA SQRT      2C26 .RARG     2C82 .5        2C58 $8       2C8A .E
C8A .O       2D6C .U        2E88


RY-POINTS:
6F8 .P       2738 .A        27EA SQRT      2BE0 ALOG      29E8 EXP      2AEE AI
860 .W       2BBE .COMP     2BE4 $F        2C26 .RARG     2C58 $8       2C82 .5
C86 .ZERO    2C8A .ERCNT    2C8C .O        2CE2 .MES      2D6C .U       2D92 .V
D9C @I


MON-BLOCKS:
E


EFINED SUBROUTINES:
```

```
          TOP=     3.0399
          BOT=     2.3252
            S=   139.8065
        DITOP=    32.4675
        DIBOT=    38.9610
          STH= 25000.000
          STS= 18220.152
       STCRIT= 51278.250
          SBH= 29999.996
          SBS= 21874.984
       SBCRIT= 29999.961

OB HANDLING CHARGE     $   .25 / JOB         .25
18 LINES PRINTED PR1   $  1.25 / K LN        .15
80 CARDS READ          $  1.50 / K CD        .12
00 PLOTTER VECTORS     $   .25 / 1000        .00
14 MODEL 70 SECONDS    $25.00 / HOUR         .1
00 MODEL 80 SECONDS    $12.50 / HOUR         .0
                         TOTAL CHARGE $      .72

EIR 400 14731  LOGGED OUT 04/21/74 20:27.  $    7.58 LEFT AFTER    36 LOGINS.
```

```
      C     *AL* IS THE LENGHT
            AL=1000.
            B=AL/5.75
      C     *DRA* IS THE DRAFT
            DRA=B/3.3
            D=AL/14.
      C     *POI* IS THE POISSON'S RATIO OF THE MATERIAL
      C     FOR ALUMINUM
            POI=0.33
      C     *E* IS THE YOUNG'S MODULUS OF THE MATERIAL
      C     FOR ALUMINUM
            E=10.*10.**6
      C     *DST* IS THE DESIGN STRESS IN TENSION
            DST=25000.
      C     *DSC* IS THE DESIGN STRESS IN COMPRESSION
            DSC=30000.
      C     *HM* IS THE HOGGING BENDING MOMENT
            HM=1.37143*B*DRA*AL*AL
      C     *SM* IS THE SAGGING BENDING MOMENT
            SM=B*DRA*AL*AL
            W=0.30396*(1.-POI*POI)*DSC/E
            U=SQRT(W)
            Z=1./U
            A=HM*(B+D)/(DSC*4.*D*(D*D+2.*B*D))
            AB=(3.*B*B+2.*B*D)/(D*D+2.*B*D)
            AC=DST/DSC+D*(DST-DSC)/(DSC*B)
      C     *TOP* IS THE THICKNESS OF THE TOP PLATING
      C     *BOT* IS THE THICKNESS OF THE BOTTOM PLATING
            TOP=A/(1.+AB*AC)
            BOT=AC*TOP
            WRITE(5,10)TOP
         10 FORMAT('1',20X,'TOP=',F10.4)
            WRITE(5,20)BOT
         20 FORMAT(' ',22X,'BOT=',F10.4)
      C     *S* IS THE SPACING OF LONGITUDINAL STIFFENING MEMBERS
            S=Z*BOT
            WRITE(5,30)S
         30 FORMAT(' ',22X,'S=',F10.4)
            P=2.*D*TOP+B*(TOP+BOT)
      C     *DITOP* IS THE DISTANCE OF THE TOP FROM THE NEUTRAL AXIS
            DITOP=D*(B*BOT+D*TOP)/P
            WRITE(5,40)DITOP
         40 FORMAT(' ',18X,'DITOP=',F10.4)
      C     *DIBOT* IS THE DISTANCE OF THE BOTTOM FROM THE NEUTRAL AXIS
            DIBOT=D*(B*TOP+D*TOP)/P
            WRITE(5,50)DIBOT
         50 FORMAT(' ',18X,'DIBOT=',F10.4)
      C     *GMI* IS THE MOMENT OF INERTIA OF THE X SECTION ABOUT N.A.
            GMI=4.*D*D*((3.*B*P+2.*B*D)*TOP*BOT+(D*D+2.*B*D)*TOP*TOP)/P
      C     *STH* IS THE STRESS ON TOP DUE TO HOGGING
      C     *STS* IS THE STRESS ON TOP DUE TO SAGGING
      C     *SBH* IS THE STRESS ON BOT DUE TO HOGGING
```

```
3A8     C       *SBS* IS THE STRESS ON BOT DUE TO SAGGING
3A8     C       *STCRIT* IS THE CRITICAL STRESS ON TOP
3A8     C       *SBCRIT* IS THE CRITICAL STRESS ON BOT
3A8             STH=HM*DITOP/GMI
3B8             STS=SM*DITOP/GMI
3C8             SBH=HM*DIBOT/GMI
3D8             SBS=SM*DIBOT/GMI
3E8             STCRIT=TOP*TOP*E/(0.30396*S*S*(1.-POI*POI))
428             SBCRIT=BOT*BOT*E/(0.30396*S*S*(1.-POI*POI))
468             WRITE(5,60)STH
484          60 FORMAT(' ',23X,'STH='F10.3)
49E             WRITE(5,70)STS
BA           70 FORMAT(' ',23X,'STS='F10.3)
D04             WRITE(5,80)STCRIT
LF0          80 FORMAT(' ',17X,'STCRIT='F10.3)
20C             WRITE(5,90)SBH
28           90 FORMAT(' ',23X,'SBH='F10.3)
42              WRITE(5,100)SBS
5E          100 FORMAT(' ',23X,'SBS='F10.3)
78              WRITE(5,110)SBCRIT
94          110 FORMAT(' ',17X,'SBCRIT='F10.3)
B0              END
(S] .U          05B4 [V] AL         05B8 [V] B          05C4 [V] DPA        05CC [V] D
(V] POI         05DC [V] E          0000 [S] .P         05E8 [V] DST        05F0 [V] DSC
(V] HM          0600 [V] SM         0604 [V] W          0610 [V] U          0000 [S] SQRT
(V] Z           0618 [V] A          063C [V] AB         0644 [V] AC         0648 [V] TOP
(V] BOT         01CC [L] 10         0000 [S] @I         0202 [L] 20         0650 [V] S
(L] 30          0654 [V] P          0658 [V] DITOP      0204 [L] 40         065C [V] DIBOT
(L] 50          0660 [V] GMI        066C [V] STH        0670 [V] STS        0674 [V] SBH
(V] SBS         067C [V] STCRIT     0680 [V] SBCRIT     0484 [L] 60         04BA [L] 70
(L] 80          0528 [L] 90         055E [L] 100        0594 [L] 110        0000 [S] .V
EO          L


GRAM LABELS:
0070 *MAIN*     2D8A .V         2BBA .COMP      28DC ALOG       2D98 @I         26F4 .P
2C82 .ZERO      2BE0 $A         2734 .A         2CDE .MES       2B5C .W         29E4 EX
2AFA AINT       27E6 SQRT       2C22 .BARG      2C7E .5         2C54 *8         2C86 .F
2C86 .O         2D5C .U         3F84


RY-POINTS:
26F4 .P         2734 .A         27E6 SQRT       28DC ALOG       29E4 EXP        2AFA AI
2B5C .W         2BBA .COMP      2BE0 $A         2C22 .BARG      2C54 *8         2C7E .5
2C82 .ZERO      2C86 .FRCNT     2C88 .O         2CDE .MES       2D68 .U         2D8E .V
2D98 @I


MON-BLOCKS:
E


EFINED SUBROUTINES:
```

```
          TOP=      3.0399
          BOT=      2.3252
            S=     81.5687
        DITOP=     32.4675
        DIBOT=     33.9610
          STH=  25070.203
          STS=  19225.152
       STCRIT=  51270.323
          SBH=  29999.996
          SBS=  21874.984
       SBCRIT=  32000.035

0F HANDLING CHARGE    $  .35 / JOB        .35
18 LINES PRINTED PR1  $ 1.25 / K LN       .15
80 CARDS READ         $ 1.50 / K CD       .12
00 PLOTTER VECTORS    $  .25 / 1000       .0
19 MODEL 70 SECONDS   $25.00 / HOUR       .13
00 MODEL 80 SECONDS   $12.50 / HOUR       .00
                        TOTAL CHARGE $    .7

FIR 490 14731  LOGGED OUT 04/21/74 20:24.  $   8.30 LEFT AFTER    35 LOGINS.
```

HOGGING MOMENT AND SAGGING MOMENT OF EQUAL MAGNITUDE DESIGN STRESS IN TENSION AND DESIGN STRESS IN COMPRESSION OF EQUAL VALUE; LATERAL LOAD ALSO CONSIDERED

The lateral load being here considered will be a "head" of salt water of eight feet on the top plating (HTOP=8 ft) and a "head" of salt water equal to the draft on the bottom plating (HBOT=DRA).

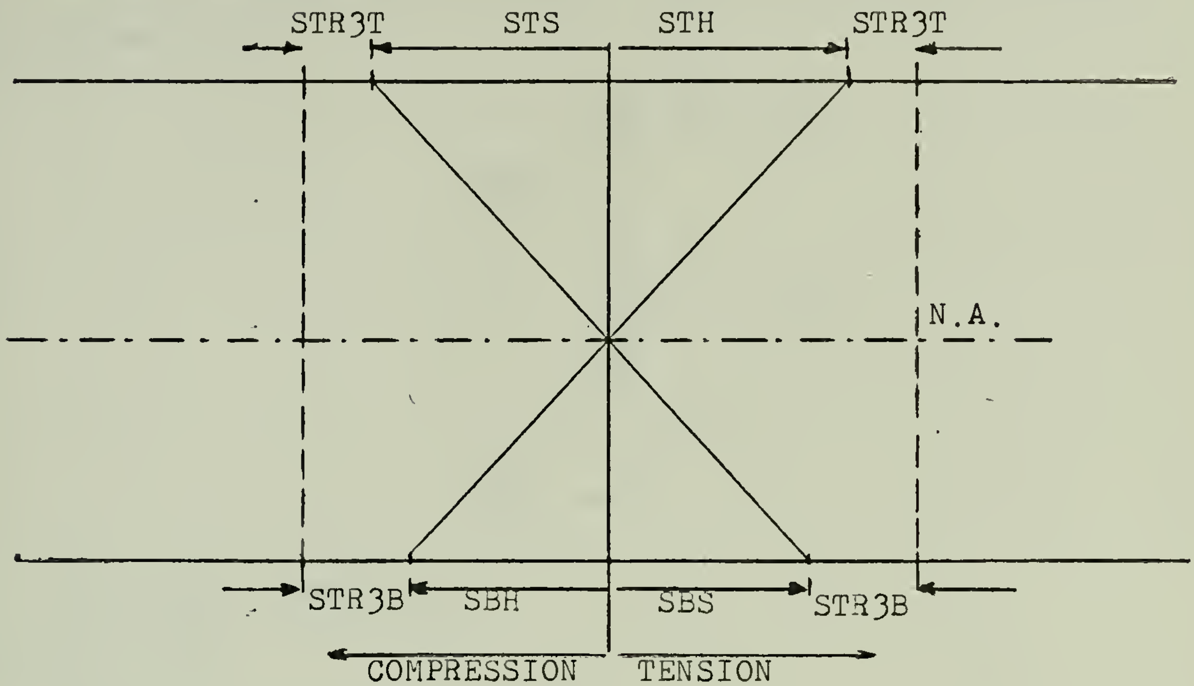
We will use here the simplified approach as suggested in the following note; this simplified approach is at least conservative.

Note: Bleich, from his experiments and theoretical studies on the effect of normal pressure in the buckling strength of thin panels, concluded that the buckling strength is increased when combined with a sufficiently large normal load, and that the increase is greater for thesimply supported edges situation than with fixed edges. For heavier plating , where thedeflection does not exceed half of the plating thickness, the increase in buckling strength resulting from normal load is negligible. It was therefore suggested, for simplicity, that the critical stress be computed for in plane loading only.

The tertiary stresses we are interested in considering here are those exerted at points B directed longitudinally; these will combine with the longitudinal bending stresses or primary stresses as described in a previous section.

Since now we have DST=DSC and HM=SM=BM we may think of

a diagram for the stress distributions as indicated next figure:



From this diagram we may understand that the neutral axis should be located closer to the bottom which means that the thickness at the bottom will be larger than at the top BOT > TOP . So, we may already write the following formulas where TS was replaced by BOT

DITOP = D*(B+D)*BOT/P

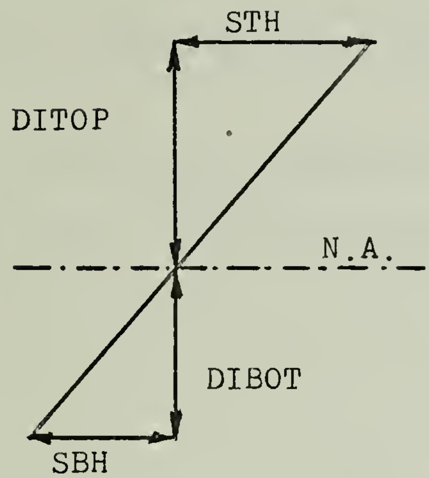
DIBOT = D*(B*TOP+D*BOT)/P

I = 4*D*D*((3*B^2+2*B*D)*TOP+(D^2+2*B*D)*BOT)*BOT/P

where

P = 2*D*BOT+B*(TOP+BOT)

We may now think of the following relationships to determine TOP and BOT.



$$STH*DIBOT = SBH*DITOP$$

or knowing that

$$STR3T = 0.152222*HTOP*\left(\frac{S}{TOP}\right)^2$$

$$STR3B = 0.152222*HBOT*\left(\frac{S}{BOT}\right)^2$$

and anticipating

$$S = Z*TOP$$

where

$$Z = 1/\left(\sqrt{0.30396*\frac{1-POI*POI}{E}*DST}\right)$$

we have

$$Z^2 = \left(\frac{S}{TOP}\right)^2$$

If we now make $\left(\frac{S}{BOT}\right)^2 = Z^2$

in order to simplify the equations, we see that when we do this, since

$$\left(\frac{S}{BOT}\right)^2 < \left(\frac{S}{TOP}\right)^2$$

we are increasing the value of STR3B and this means that since

DST = SBH+STR3B

we are decreasing"slightly" the value of SBH that could be allowed to reach a larger value; so , the substitution

$$\left(\frac{S}{BOT}\right)^2 = Z^2$$

is on the safe side and has the advantage of simplifying the equations considerably.

So we may write

STH = DST-STR3T

SBH = DST-STR3B

STR3T = 0.152222*HTOP*Z^2

STR3B = 0.152222*HBOT*Z^2

A = DST-STR3T

AB = DST-STR3B

so

A*DIBOT = AB*DITOP

and we obtain replacing DITOP and DIBOT by their equations, and simplifying

$$TOP = \frac{AB*(B+D)-A*D}{A*B}*BOT$$

or making

AC = (AB*(B+D)-A*D)/(A*B)

we finally obtain

TOP = AC*BOT

Now in order to stress the material to its design stress we may either consider STH, STS, SBH, SBS.

Due to ease of calculation we may either choose STS or STH; the expressions will be exactly the same. I will consider here

STH = BM*DITOP/I

and

STH = DST-STR3T = A

Substituting for DITOP and I we obtain

$$A = \frac{BM*D*(B+D)*BOT}{4*D^2*BOT*((3*B^2+2*B*D)*TOP+(D^2+2*B*D)*BOT)}$$

and after simplifying we arrive at

$$BOT = \frac{BM*(B+D)}{A*4*D*(D^2+2*B*D)} - \frac{3*B^2+2*B*D}{D^2+2*B*D}*TOP$$

Making

$AD = BM*(B+D)/(A*4*D*(D^2+2*B*D))$

$AE = (3*B^2+2*B*D)/(D^2+2*B*D)$

we obtain

BOT = AD-AE*TOP

substituting

$$TOP = AC*BOT$$

we obtain

$$BOT = \frac{AD}{1+AC*AE}$$

Considering now the instability formula (BRYAN) we notice that since the top will have the thinner plating we will consider TOP stressed to the maximum allowed DST.
So we start with

$$Z = 1/(\sqrt{0.30396*\frac{1-POI*POI}{E}*DST})$$

$$S = Z*TOP$$

The total stresses will then be given by

$$TSTH = BM*DITOP/I+STR3T$$

$$TSTS = BM*DITOP/I+STR3T$$

$$TSBH = BM*DIBOT/I+0.152222*HBOT*S^2/BOT^2$$

$$TSBS = BM*DIBOT/I+0.152222*HBOT*S^2/BOT^2$$

The computer printouts for the same cases analysed in theprevious section are presented next.

```
      C       *AL* IS THE LENGHT
              AL=500.
              B=AL/8.
      C       *DRA* IS THE DRAFT
              DRA=B/3.
              D=AL/9.
      C       *POI* IS THE POISSON'S RATIO OF THE MATERIAL
      C       FOR STEEL
              POI=0.3
      C       *E* IS THE YOUNG'S MODULUS OF THE MATERIAL
      C       FOR STEEL
              E=30.*10.**6
      C       *DST* IS THE DESIGN STRESS
              DST=25000.
      C       *BM* IS THE BENDING MOMENT
              BM=1.37143*B*DRA*AL*AL
              W=0.30396*(1.-POI*POI)*DST/E
              U=SQRT(W)
              Z=1./U
              *HTOP* IS THE HEAD OF WATER ON DECK
              HTOP=8.
              *HBOT* IS THE  HEAD OF WATER ON BOTTOM
              HBOT=DRA
              STR3T=0.152222*HTOP*Z*Z
              STR3B=0.152222*HBOT*Z*Z
              A=DST-STR3T
              AB=DST-STR3B
              AC=(AB*(B+D)-A*D)/(A*B)
              AD=BM*(B+D)/(A*4.*D*(D*D+2.*B*D))
              AE=(3.*B*B+2.*B*D)/(D*D+2.*B*D)
      C       *TOP* IS THE THICKNESS OF THE TOP PLATING
      C       *BOT* IS THE THICKNESS OF THE BOTTOM PLATING
              BOT=AD/(1.+AC*AE)
              TOP=AC*BOT
              WRITE(5,10)TOP
           10 FORMAT('1',20X,'TOP='F10.4)
              WRITE(5,20)BOT
           20 FORMAT(' ',20X,'BOT='F10.4)
      C       *S* IS THE SPACING OF LONGITUDINAL STIFFENING MEMBERS
              S=Z*TOP
              WRITE(5,30)S
           30 FORMAT(' ',22X,'S='F10.4)
              P=2.*D*BOT+B*(TOP+BOT)
      C       *DITOP* IS THE DISTANCE OF THE TOP FROM THE NEUTRAL AXIS
              DITOP=D*(B*BOT+D*BOT)/P
              WRITE(5,40)DITOP
           40 FORMAT(' ',18X,'DITOP='F10.4)
      C       *DIBOT* IS THE DISTANCE OF THE BOTTOM FROM THE NEUTRAL AXIS
              DIBOT=D*(B*TOP+D*BOT)/P
              WRITE(5,50)DIBOT
           50 FORMAT(' ',18X,'DIBOT='F10.4)
      C       *GMI* IS THE MOMENT OF INERTIA OF THE X SECTION ABOUT N.A.
```

```
)270          GMI=4.*D*D*((3.*B*B+2.*B*D)*TOP*BOT+(D*D+2.*B*D)*BOT*BOT)/P
13E0     C    *TSTH*IS THE STRESS ON TOP DUE TO HOGGING
13E0     C    *TSTS*IS THE STRESS ON TOP DUE TO SAGGING
13E0     C    *TSBH*IS THE STRESS ON BOT DUE TO HOGGING
13E0     C    *TSBS*IS THE STRESS ON BOT DUE TO SAGGING
13E0     C    *STCRIT* IS THE CRITICAL STRESS ON TOP
13E0     C    *SBCRIT* IS THE CRITICAL STRESS ON BOT
3E0           TSTH=BM*DITOP/GMI+STR3T
3F4           TSTS=BM*DITOP/GMI+STR3T
408           STCRIT=TOP*TOP*E/(0.30396*S*S*(1.-POI*POI))
448           WRITE(5,60)TSTH
464        60 FORMAT(' ',19X,'TSTH=',F10.3)
47E           WRITE(5,70)TSTS
49A        70 FORMAT(' ',19X,'TSTS=',F10.3)
4B4           WRITE(5,80)STCRIT
4D0        80 FORMAT(' ',17X,'STCRIT='F10.3)
4EC           TSBH=BM*DIBOT/GMI+0.152222*HBOT*S*S/(BOT*BOT)
528           TSBS=BM*DIBOT/GMI+0.152222*HBOT*S*S/(BOT*BOT)
564           SBCRIT=BOT*BOT*E/(0.30396*S*S*(1.-POI*POI))
5A4           WRITE(5,90)TSBH
5C0        90 FORMAT(' ',19X,'TSBH=',F10.3)
5DA           WRITE(5,100)TSBS
5F6       100 FORMAT(' ',19X,'TSBS=',F10.3)
610           WRITE(5,110)SBCRIT
62C       110 FORMAT(' ',17X,'SBCRIT='F10.3)
648           END
0[S]  .U      064C[V] AL      0654[V] B       06BC[V] DRA     0664[V] D
C[V]  POI     0674[V] E       0000[S] .R      0684[V] DST     068C[V] BM
4[V]  W       06A0[V] U       0000[S] SQRT    06A4[V] Z       06A8[V] HTOP
C[V]  HBOT    06B0[V] STR3T   06B8[V] STR3B   06BC[V] A       06C0[V] AB
4[V]  AC      06D8[V] AD      06EC[V] AE      06F0[V] BOT     06F4[V] TOP
4[L]  10      0000[S] @I      023A[L] 20      06F8[V] S       027C[L] 30
C[V]  P       0700[V] DITOP   02F8[L] 40      0704[V] DIBOT   0354[L] 50
8[V]  GMI     0714[V] TSTH    0718[V] TSTS    071C[V] STCRIT  0464[L] 60
4[L]  70      04D0[L] 80      0720[V] TSBH    0724[V] TSBS    0728[V] SBCRIT
0[L]  90      05F6[L] 100     062C[L] 110     0000[S] .V
XEQ         L
F


OGRAM LABELS:
2070 *MAIN*   2EB2 .V      2CE2 .COMP   2984 ALOG    2EC0 @I      279C .F
2DAA .ZERO    2D08 $6      27DC .A      2E06 .MES    2C84 .W      2A8C E
2C12 AINT     288E SQRT    2D4A .RARG   2DA6 .5      2A8C AEXP    2DAE .F
2D7C $8       2DAE .0      2E84 .U      3FDC


TRY-POINTS:
279C .R       27DC .A      288E SQRT    2984 ALOG    2A8C AEXP    2A8C E
2C12 AINT     2C84 .W      2CE2 .COMP   2D08 $6      2D4A .RARG   2D7C $
2DA6 .5       2DAA .ZERO   2DAE .ERCNT  2D80 .0      2E06 .MES    2E90 .
2EB6 .V       2EC0 @I
```

```
               TOP=    0.1671
               BOT=    0.8383
                 S=   11.0049
             DITOP=   35.3820
             DIBOT=   20.1736
              TSTH= 25000.012
              TSTS= 25000.012
            STCRIT= 25000.000
              TSBH= 11728.668
              TSBS= 11728.668
            SBCRIT=706635.250
END

F VIO OPERATING SYSTEM VERSION 1 REVISION  012 03/04/74 GENERATED  04/27/74

JOB HANDLING CHARGE    $   .35 / JOB        .35
125 LINES PRINTED PR1  $ 1.25 / K LN        .16
 84 CARDS READ         $ 1.50 / K CD        .13
 00 PLOTTER VECTORS    $   .25 / 1000       .00
 15 MODEL 70 SECONDS   $25.00 / HOUR        .10
 00 MODEL 80 SECONDS   $12.50 / HOUR        .00
                       TOTAL CHARGE $       .74

REIR 490 14731  LOGGED OUT 04/29/74 18:35.  $  33.19 LEFT AFTER    42 LOGINS.
```

Note here that because we have in this run BOT>> TOP the approximation made to simplify the formulas, namely

$$Z = \frac{S}{BOT}$$

becomes very inaccurate compared to what the actual value should be

$$Z = \frac{S}{TOP}$$

this is the cause for obtaining such low stresses at the bottom. We might refine the result for this case as is done for the "1000 ft steel case" also included in this section which presented still another difficulty. Since all steps to have the bottom stressed to DST are explained in detail for such case they will be omited here.

```
C       *AL* IS THE LENGHT
        AL=500.
        B=AL/8.
C       *DRA* IS THE DRAFT
        DRA=D/2.
        D=AL/9.
C       *POI* IS THE POISSON'S RATIO OF THE MATERIAL
C       FOR ALUMINUM
        POI=0.3
C       *E* IS THE YOUNG'S MODULUS OF THE MATERIAL
C       FOR ALUMINUM
        E=10.*10.**6
C       *DST* IS THE DESIGN STRESS
        DST=2500.
C       *BM* IS THE BENDING MOMENT
        BM=1.37143*E*DRA*AL*AL
        U=1.2903*(1.-POI*POI)*DST/E
        U=SQRT(U)
        Z=1./U
        *HTOP* IS THE HEAD OF WATER ON DECK
        HTOP=8.
        *HBOT* IS THE HEAD OF WATER ON BOTTOM
        HBOT=80.
        STR31=0.15262*HTOP*Z*Z
        STR32=0.15262*HBOT*Z*Z
        A=DST-STR31
        AB=DST-STR32
        AC=(AB*(D+B)-A*B)/(A*D)
        AD=-BM*(D+B)/(A*D*(D*AC+2.*B*D))
        AE=(3.*AC*B+2.*B*D)/(D*D+2.*B*D)
C       *TOP* IS THE THICKNESS OF THE TOP PLATING
C       *BOT* IS THE THICKNESS OF THE BOTTOM PLATING
        BOT=AD/(1.+AC*AE)
        TOP=AC*BOT
        WRITE(5,10)TOP
     10 FORMAT('1',23X,'TOP='F10.4)
        WRITE(5,20)BOT
     20 FORMAT(' ',23X,'BOT='F10.4)
C       *S* IS THE SPACING OF LONGITUDINAL STIFFENING MEMBERS
        S=Z*TOP
        WRITE(5,30)S
     30 FORMAT(' ',22X,'S='F10.4)
        P=2.*D*BOT+B*(TOP+BOT)
C       *DITOP* IS THE DISTANCE OF THE TOP FROM THE NEUTRAL AXIS
        DITOP=D*(B*BOT+D*BOT)/P
        WRITE(5,40)DITOP
     40 FORMAT(' ',18X,'DITOP='F10.4)
C       *DIBOT* IS THE DISTANCE OF THE BOTTOM FROM THE NEUTRAL AXIS
        DIBOT=D*(B*TOP+D*BOT)/P
        WRITE(5,50)DIBOT
     50 FORMAT(' ',18X,'DIBOT='F10.4)
C       *GMI* IS THE MOMENT OF INERTIA OF THE X SECTION ABOUT N.A.
```

```
      GMI=4.*...*(( ... +2.* ...*D)*T...*BOT+(D*D+2.*B*D)*BOT*BOT)/P
C     *ISTH*IS THE STRESS ON TOP DUE TO HOGGING
C     *ISTS*IS THE STRESS ON TOP DUE TO SAGGING
C     *ISBH*IS THE STRESS ON BOT DUE TO HOGGING
C     *ISBS*IS THE STRESS ON BOT DUE TO SAGGING
C     *STCRIT IS THE CRITICAL STRESS ON TOP
C     *SBCRIT IS THE CRITICAL STRESS ON BOT
      TSTH=...*HITOP/... I+ST...T
      TSTS=...*HITOP/... I+ST...T
      STCRIT=...*T...*/(...3...6*S*S*(1.-POI*POI))
      WRITE(5,60)TSTH
   60 FORMAT(' ',17X,'TSTH='F10.3)
      WRITE(5,70)TSTS
   70 FORMAT(' ',17X,'TSTS='F10.3)
      WRITE(5,80)STCRIT
   80 FORMAT(' ',17X,'STCRIT='F10.3)
      TSBH=...*HBOT/... I+...1.5...22*HBOT*S*.../(BOT*BOT)
      TSBS=...*HBOT/... I+...1.5...22*HBOT*S*.../(BOT*BOT)
      SBCRIT=...T...*E/(...3...3...6*S*S*(1.-POI*POI))
      WRITE(5,90)TSBH
   90 FORMAT(' ',17X,'TSBH='F10.3)
      WRITE(5,100)TSBS
  100 FORMAT(' ',17X,'TSBS='F10.3)
      WRITE(5,110)SBCRIT
  110 FORMAT(' ',17X,'SBCRIT='F10.3)
      END
```

[S] .	64C [V] HL	... [V] B	065C [V] DRA	0664 [V] D
[V] P...	0674 [V] E	... [S] .R	06.. [V] DST	0638 [V] BM
[V] ...	069C [V] ...	... [S] SQRT	06.. [V] Z	0644 [V] HTOP
[V] ...	06AC [V] STHST	06.4 [V] STHSB	06.. [V] A	06BC [V] AB
[V] A...	06.4 [V] AC	06.. [V] AE	06.C [V] BOT	06F2 [V] TOP
[L] 1	... [S] I	23.. [L] 2.	06.4 [V] S	027C [L] 3.
[V] F	06FC [V] HITOP	2F.. [L] 4.	07.. [V] DIPOT	0354 [L] 50
[V] ...T	071. [V] TSTH	0714 [V] TSTS	07.. [V] STCRIT	0464 [L] 60
[L] 7.	0400 [L] 8.	071C [V] TSBH	072. [V] TSBS	0724 [V] SBCRIT
[L] 9	05F6 [L] 10.	062C [L] 11.	00.. [S] .V	
ED	L			

PROGRAM LABELS:

2A70 ...	2E.E ...	2CDE .C...P	2980 ALOG	2EBC 0I	2798 .
2DA6 .ZERO	2C04 ...	2798 ...	2E42 .MES	2C8C .W	2A88 E
2C0E AINT	2E8A S...T	2D46 .RARG	2DA2 .5	2A8E AEXP	2DAA .
2078 $...	2.7A .	2E32 ...	3FD8		

ENTRY-POINTS:

2798 ...	27D2 ...	2..8A SQRT	298C ALOG	2A82 AEXP	2A88 E.
2C0E AINT	2C3. .	2CDE .C...P	2.44 6	2D46 .RARG	2D78 $
2DA2 ..	2DA6 .ZERO	2.AA .ERCNT	2.AC .0	2E02 .MES	2E8C .
2E32 .V	2ECC 0I				

COMMON BLOCKS:

```
      TOP=      [illegible].3217
      BOT=       [illegible].4215
        S=     17.3632
   LITOP=     29.6132
   LIBOT=     29.9348
    TSTB= [illegible].[illegible]
    TSTS= [illegible].[illegible]
  STCRIT= [illegible].[illegible]
    TSPB= 2325[illegible].4[illegible]1
    TSPS= 23[illegible].4[illegible]1
  SPCRIT= 43[illegible].[illegible]52
END

VIO OPERATING SYSTEM VERSION J REVISION  312 03/04/74 GENERATED  04/27/74

[illegible] HANDLING CHARGE     [illegible] .35 / JOB          .37
25 LINES PRINTED [illegible]      1.[illegible] / K L[illegible]          .1[illegible]
84 CARDS READ                [illegible] 1.[illegible] / K CD          .1[illegible]
[illegible] PLOTTER VECTORS        .[illegible]5 / 1[illegible]          .[illegible]
15 [illegible] SECONDS         [illegible]25.[illegible] / HOUR          .1
[illegible] MODEL [illegible] SECONDS      [illegible]12.[illegible] / HOUR          .[illegible]
                         TOTAL CHARGE $     .74

[illegible]FIR [illegible]  14731  LOGGED OUT 04/2[illegible]/74 18:05.  $  [illegible].17 LEFT AFTER     38 LOGINS.
```

This case gave a result close to the correct solution with the bottom stressed to almost DST.

Next is presented the "1000 ft steel case" where still another difficulty was encountered and a procedure to have the bottom stressed to DST is exemplified.

```
STRENGHT OF SHIPS-ON THE NEUTRAL AXIS LOCATION                    PAGE   1

      C       *AL* IS THE LENGHT
              AL=1000.
              B=AL/5.75
      C       *DRA* IS THE DRAFT
              DRA=B/3.3
              D=AL/14.
      C       *POI* IS THE POISSON'S RATIO OF THE MATERIAL
      C       FOR STEEL
              POI=0.3
      C       *E* IS THE YOUNG'S MODULUS OF THE MATERIAL
      C       FOR STEEL
              E=30.*10.**6
      C       *DST* IS THE DESIGN STRESS
              DST=25000.
      C       *BM* IS THE BENDING MOMENT
              BM=1.37143*B*DRA*AL*AL
              W=0.30396*(1.-POI*POI)*DST/E
              U=SQRT(W)
              Z=1./U
              *HTOP* IS THE HEAD OF WATER ON DECK
              HTOP=8.
              *HBOT* IS THE  HEAD OF WATER ON BOTTOM
              HBOT=DRA
              STR3T=0.152222*HTOP*Z*Z
              STR3B=0.152222*HBOT*Z*Z
              A=DST-STR3T
              AB=DST-STR3B
              AC=(AB*(B+D)-A*D)/(A*B)
              AD=BM*(B+D)/(A*4.*D*(D*D+2.*B*D))
              AE=(3.*B*B+2.*B*D)/(D*D+2.*B*D)
      C       *TOP* IS THE THICKNESS OF THE TOP PLATING
      C       *BOT* IS THE THICKNESS OF THE BOTTOM PLATING
              BOT=AD/(1.+AC*AE)
              TOP=AC*BOT
              WRITE(5,10)TOP
           10 FORMAT('1',20X,'TOP='F10.4)
              WRITE(5,20)BOT
           20 FORMAT(' ',20X,'BOT='F10.4)
      C       *S* IS THE SPACING OF LONGITUDINAL STIFFENING MEMBERS
              S=Z*TOP
              WRITE(5,30)S
           30 FORMAT(' ',22X,'S='F10.4)
              P=2.*D*BOT+B*(TOP+BOT)
      C       *DITOP* IS THE DISTANCE OF THE TOP FROM THE NEUTRAL AXIS
              DITOP=D*(B*BOT+D*BOT)/P
              WRITE(5,40)DITOP
           40 FORMAT(' ',18X,'DITOP='F10.4)
      C       *DIBOT* IS THE DISTANCE OF THE BOTTOM FROM THE NEUTRAL AXIS
              DIBOT=D*(B*TOP+D*BOT)/P
              WRITE(5,50)DIBOT
           50 FORMAT(' ',18X,'DIBOT='F10.4)
      C       *GMI* IS THE MOMENT OF INERTIA OF THE X SECTION ABOUT N.A.
```

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```
170             GMI=4.*D*D*((3.*B*B+2.*B*D)*TOP*BOT+(D*D+2.*B*D)*BOT*BOT)/P
1E0     C       *TSTH*IS THE STRESS ON TOP DUE TO HOGGING
.E0     C       *TSTS*IS THE STRESS ON TOP DUE TO SAGGING
E0      C       *TSBH*IS THE STRESS ON BOT DUE TO HOGGING
E0      C       *TSBS*IS THE STRESS ON BOT DUE TO SAGGING
E0      C       *STCRIT* IS THE CRITICAL STRESS ON TOP
E0      C       *SBCRIT* IS THE CRITICAL STRESS ON BOT
E0              TSTH=BM*DITOP/GMI+STR3T
F4              TSTS=BM*DITOP/GMI+STR3T
28              STCRIT=TOP*TOP*E/(0.30396*S*S*(1.-POI*POI))
48              WRITE(5,60)TSTH
64          60  FORMAT(' ',19X,'TSTH='F10.3)
7E              WRITE(5,70)TSTS
9A          70  FORMAT(' ',19X,'TSTS='F10.3)
B4              WRITE(5,80)STCRIT
D0          80  FORMAT(' ',17X,'STCRIT='F10.3)
EC              TSBH=BM*DIBOT/GMI+0.152222*HBOT*S*S/(BOT*BOT)
28              TSBS=BM*DIBOT/GMI+0.152222*HBOT*S*S/(BOT*BOT)
64              SBCRIT=BOT*BOT*E/(0.30396*S*S*(1.-POI*POI))
A4              WRITE(5,90)TSBH
C0          90  FORMAT(' ',19X,'TSBH='F10.3)
DA              WRITE(5,100)TSBS
F6         100  FORMAT(' ',19X,'TSBS='F10.3)
10              WRITE(5,110)SBCRIT
2C         110  FORMAT(' ',17X,'SBCRIT='F10.3)
48              END
[S] .U          264C[V] AL       0654[V] B        065C[V] DRA      0664[V] D
[V] POI         0674[V] E        0000[S] .R       0684[V] DST      068C[V] BM
[V] W           06A0[V] U        0000[S] SQRT     06A4[V] Z        06A8[V] HTOP
[V] HBOT        06B4[V] STR3T    06BC[V] STR3B    06C0[V] A        06C4[V] AB
[V] AC          06DC[V] AD       06F0[V] AE       06F8[V] BOT      06FC[V] TOP
[L] 10          0000[S] @I       023A[L] 20       0700[V] S        027C[L] 30
[V] P           0708[V] DITOP    02F8[L] 40       070C[V] DIBOT    0354[L] 50
[V] GMI         071C[V] TSTH     0720[V] TSTS     0724[V] STCRIT   0464[L] 60
[L] 70          04D0[L] 80       0728[V] TSBH     072C[V] TSBS     0730[V] SBCRIT
[L] 90          05F6[L] 100      062C[L] 110      0000[S] .V
I0          L


RAM LABELS:
70 *MAIN*    2E3A .V        2C6A .COMP     298C ALOG      2E48 @I        27A4 .R
32 .ZERO     2C90 $6        27E4 .A        2D8E .MES      2C0C .W        2A94 EX
9A AINT      2896 SQRT      2CD2 .RARG     2D2E .5        2D04 $8        2D36 .E
36 .0        2E0C .U        3F64


Y-POINTS:
44 .R        27E4 .A        2896 SQRT      298C ALOG      2A94 EXP       289A AI
0C .W        2C6A .COMP     2C90 $6        2CD2 .RARG     2D04 $8        2D2E .5
32 .ZERO     2D36 .ERCNT    2D38 .0        2D8E .MES      2E18 .U        2E3E .V
48 @I
```

```
         TOP=    6.1748
         BOT=   -5.5523
           S=  406.7124
       DITOP=  142.0614
       DIBOT=  -70.6328
        TSTH= 24999.992
        TSTS= 24999.992
      STCRIT= 24999.988
        TSBH= 33241.840
        TSBS= 33241.840
      SBCRIT= 2 213.250
ND

VIC OPERATING SYSTEM VERSION 1 REVISION  012 03/04/74 GENERATED  04/30/74

OB HANDLING CHARGE    $   .35 / JOB        .35
25 LINES PRINTED PR2  $ 1.25 / K LN        .16
54 CARDS READ         $ 1.50 / K CD        .13
70 PLOTTER VECTORS    $   .25 / 1000       .00
21 MODEL 70 SECONDS   $25.00 / HOUR        .15
10 MODEL 80 SECONDS   $12.50 / HOUR        .00
                         TOTAL CHARGE $    .79

RCIR 490 14731  LOGGED OUT 04/30/74 21:26.  $  27.07 LEFT AFTER    50 LOGINS.
```

It does not come as a surprise that the program does not work for the "1000 ft steel case" since in this situation we obtain STR3B DST which cannot be accepted and also this program is not prepared to handle.

AL = 1000

B = AL/5.75 = 173.913

DRA = B/3.3 = 52.7

POI = 0.3

E = 30*10^{6}

DST = 25000

BM = 1.37143*B*DRA*AL^{2} = 12569.45*10^{6}

W = 0.30396*(1-POI^{2})*DST/E = 230.503*10^{-6}

U = W = 15.182*10^{-3}

Z = 1/U = 65.867

HBOT = DRA = 52.7

STR3B = 0.152222*HBOT*Z^{2} = 34803.57 DST

Since we understand that the program should work for DST $>$ STR3B we make the next run with DST = 35000 to prove that in such case a solution is obtained, and after proceed to obtain the actual solution for the case we were considering with DST = 25000.

```
      C       *AL* IS THE LENGHT
              AL=1000.
              B=AL/5.75
      C       *DRA* IS THE DRAFT
              DRA=B/3.3
              D=AL/14.
      C       *POI* IS THE POISSON'S RATIO OF THE MATERIAL
      C       FOR STEEL
              POI=0.3
      C       *E* IS THE YOUNG'S MODULUS OF THE MATERIAL
      C       FOR STEEL
              E=30.*10.**6
      C       *DST* IS THE DESIGN STRESS
              DST=35000.
      C       *BM* IS THE BENDING MOMENT
              BM=1.37143*B*DRA*AL*AL
              W=0.30396*(1.-POI*POI)*DST/E
              U=SQRT(W)
              Z=1./U
              *HTOP* IS THE HEAD OF WATER ON DECK
              HTOP=8.
              *HBOT* IS THE  HEAD OF WATER ON BOTTOM
              HBOT=DRA
              STR3T=0.152222*HTOP*Z*Z
              STR3B=0.152222*HBOT*Z*Z
              A=DST-STR3T
              AB=DST-STR3B
              AC=(AB*(B+D)-A*D)/(A*B)
              AD=BM*(B+D)/(A*4.*D*(D*D+2.*B*D))
              AE=(3.*B*D+2.*B*D)/ D*D+2.*B*D)
      C       *TOP* IS THE THICKNESS OF THE TOP PLATING
      C       *BOT* IS THE THICKNESS OF THE BOTTOM PLATING
              BOT=AD/(1.+AC*AE)
              TOP=AC*BOT
              WRITE(5,10)TOP
           10 FORMAT('1',22X,'TOP='F10.4)
              WRITE(5,20)BOT
           20 FORMAT(' ',22X,'BOT='F10.4)
      C       *S* IS THE SPACING OF LONGITUDINAL STIFFENING MEMBERS
              S=Z*TOP
              WRITE(5,30)S
           30 FORMAT(' ',22X,'S='F10.4)
              P=2.*D*BOT+B*(TOP+BOT)
      C       *DITOP* IS THE DISTANCE OF THE TOP FROM THE NEUTRAL AXIS
              DITOP=D*(B*BOT+D*BOT)/P
              WRITE(5,40)DITOP
           40 FORMAT(' ',18X,'DITOP='F10.4)
      C       *DIBOT* IS THE DISTANCE OF THE BOTTOM FROM THE NEUTRAL AXIS
              DIBOT=D*(B*TOP+D*BOT)/P
              WRITE(5,50)DIBOT
           50 FORMAT(' ',18X,'DIBOT='F10.4)
      C       *GMI* IS THE MOMENT OF INERTIA OF THE X SECTION ABOUT N.A.
```

```
70            GMI=4.*D*D*((3.*B*B+2.*B*D)*TOP*BOT+(D*D+2.*B*D)*BOT*BOT)/P
E0      C     *TSTH*IS THE STRESS ON TOP DUE TO HOGGING
E0      C     *TSTS*IS THE STRESS ON TOP DUE TO SAGGING
E0      C     *TSBH*IS THE STRESS ON BOT DUE TO HOGGING
E0      C     *TSBS*IS THE STRESS ON BOT DUE TO SAGGING
E0      C     *STCRIT* IS THE CRITICAL STRESS ON TOP
E0      C     *SBCRIT* IS THE CRITICAL STRESS ON BOT
E0            TSTH=BM*DITOP/GMI+STR3T
F4            TSTS=BM*DITOP/GMI+STR3T
08            STCRIT=TOP*TOP*E/(0.30396*S*S*(1.-POI*POI))
48            WRITE(5,60)TSTH
64         60 FORMAT(' ',19X,'TSTH='F10.3)
7E            WRITE(5,70)TSTS
9A         70 FORMAT(' ',19X,'TSTS='F10.3)
B4            WRITE(5,80)STCRIT
D0         80 FORMAT(' ',17X,'STCRIT='F10.3)
EC            TSBH=BM*DIBOT/GMI+0.152222*HBOT*S*S/(BOT*BOT)
28            TSBS=BM*DIBOT/GMI+0.152222*HBOT*S*S/(BOT*BOT)
64            SBCRIT=BOT*BOT*E/(0.30396*S*S*(1.-POI*POI))
A4            WRITE(5,90)TSBH
C0         90 FORMAT(' ',19X,'TSBH='F10.3)
DA            WRITE(5,100)TSBS
F6        100 FORMAT(' ',19X,'TSBS='F10.3)
10            WRITE(5,110)SBCRIT
2C        110 FORMAT(' ',17X,'SBCRIT='F10.3)
48            END
[S] .U        064C[V] AL       0654[V] B        065C[V] DRA      0664[V] D
[V] POI       0674[V] E        0000[S] .R       0684[V] DST      068C[V] BM
[V] W         06A0[V] U        0000[S] SQRT     06A4[V] Z        06A8[V] HTOP
[V] HBOT      06B4[V] STR3T    06BC[V] STR3B    06C0[V] A        06C4[V] AB
[V] AC        06DC[V] AD       06F [V] AE       06F8[V] BOT      06FC[V] TOP
[L] 10        0000[S] @I       023A[L] 20       0700[V] S        027C[L] 30
[V] F         0708[V] DITOP    02F8[L] 40       070C[V] DIBOT    0354[L] 50
[V] GMI       071C[V] TSTH     0720[V] TSTS     0724[V] STCRIT   0464[L] 60
[L] 70        04D0[L] 80       0728[V] TSBH     072C[V] TSBS     0730[V] SBCRIT
[L] 90        05F6[L] 100      062C[L] 110      0000[S] .V
  D           L

RAM LABELS:
70 *MAIN*     2EBA .V          2CEA .COMP       298C ALOG        2EC8 @I          27A4 .R
B2 .ZERO      2D10 $6          27E4 .A          2E0E .MES        2C8C .W          2A94 EXP
1A AINT       2896 SQRT        2D52 .RARG       2DAE .5          2A94 AEXP        2D86 .E
84 $8         2DB6 .C          2E8C .U          3FE4

Y-POINTS:
A4 .R         27E4 .A          2896 SQRT        298C ALOG        2A94 AEXP        2A94 EXP
1A AINT       2C8C .W          2CEA .COMP       2D10 $6          2D52 .RARG       2D84 $8
AE .5         2DB2 .ZERO       2DB6 .ERCNT      2DB8 .C          2E0E .MES        2E98 .U
BE .V         2EC8 @I
```

```
        TCP=     0.4626
        BCT=     9.7569
          S=    25.7509
      DITCP=    53.9186
      DIBCT=    17.5099
       TSTH= 34999.977
       TSTS= 34999.977
     STCRIT= 35000.016
       TSPH= 1 196.547
       TSBS= 1 196.547
     SBCRIT=********** (TOO HIGH OUTSIDE FORMAT RANGE)
ND

VIC OPERATING SYSTEM VERSION 1 REVISION  012 03/04/74 GENERATED 04/27/74

OB HANDLING CHARGE    $   .35 / JOB        .35
25 LINES PRINTED FRP  $ 1.25 / K LN        .16
64 CARDS READ         $ 1.50 / K CD        .13
00 PLOTTER VECTORS    $   .25 / 1000       .00
15 MODEL 70 SECONDS   $25.20 / HOUR        .10
00 MODEL 80 SECONDS   $12.50 / HOUR        .00
                       TOTAL CHARGE $      .74

EIR 490 14731  LOGGED OUT 04/29/74 20:46.  $  32.45 LEFT AFTER    43 LOGINS.
```

Now let's consider our situation with DST = 25000. Once the situation is such that due to the approximation made in

$$\frac{S}{BOT} = Z$$

we end up with a STR3B > DST we must consider a value Z1 lower than Z to bring STR3B down. This can be also understood since it is acceptable to make here

$$\frac{S}{TOP} = Z$$

but because we obtain with the program as is TOP $\ll$ BOT, making the approximation

$$\frac{S}{BOT} = Z$$

makes Z attain a much larger value than it actually should. We must then consider Z1 < Z = 65.8 and may start by trying

Z1 = 35

The computer printout in this case is as follows.

```
C       *AL* IS THE LENGTH
        AL=1??.
        B=AL/5.75
C       *DRA* IS THE DRAFT
        DRA=B/3.3
        D=AL/14.
C       *POI* IS THE POISSON'S RATIO OF THE MATERIAL
C       FOR STEEL
        POI=0.3
C       *E* IS THE YOUNG'S MODULUS OF THE MATERIAL
C       FOR STEEL
        E=30.*10.**6
C       *DST* IS THE DESIGN STRESS
        DST=...
C       *BM* IS THE BENDING MOMENT
        BM=1.37143*B*... AL*AL
        W=?.?0396*(1.-POI*POI)*DST/E
        W=SQRT(W)
        Z=1./W
C       *HTOP* IS THE HEAD OF WATER ON DECK
        HTOP=5.
C       *HBOT* IS THE HEAD OF WATER ON BOTTOM
        HBOT=DRA
        STRBT=0.152272*HTOP*Z*Z
        Z1=35.
        STRBB=0.152272*HBOT*Z1*Z1
        A=DST-STRBT
        AB=DST-STRBB
        AC=(AB*(B+D)-A*D)/(A*B)
        AA=BM*(B+D)/(A*4.*D*(D*D+2.*B*D))
        AB=(3.*B*B+2.*B*D)/(D*D+2.*B*D)
C       *TOP* IS THE THICKNESS OF THE TOP PLATING
C       *BOT* IS THE THICKNESS OF THE BOTTOM PLATING
        BOT=AC/(1.+AC*AB)
        TOP=AC*BOT
        WRITE(5,10)TOP
     10 FORMAT('1',20X,'TOP='F10.4)
        WRITE(5,20)BOT
     20 FORMAT(' ',20X,'BOT='F10.4)
C       *S* IS THE SPACING OF LONGITUDINAL STIFFENING MEMBERS
        S=Z*TOP
        WRITE(5,30)S
     30 FORMAT(' ',22X,'S='F10.4)
        P=2.*D*BOT+B*(TOP+BOT)
C       *DITOP* IS THE DISTANCE OF THE TOP FROM THE NEUTRAL AXIS
        DITOP=D*(B*BOT+D*BOT)/P
        WRITE(5,40)DITOP
     40 FORMAT(' ',18X,'DITOP='F10.4)
C       *DIBOT* IS THE DISTANCE OF THE BOTTOM FROM THE NEUTRAL AXIS
        DIBOT=D*(B*TOP+D*BOT)/P
        WRITE(5,50)DIBOT
     50 FORMAT(' ',18X,'DIBOT='F10.4)
```

```
C      *GMI* IS THE MOMENT OF INERTIA OF THE X SECTION ABOUT N.A.
       GMI=4.*AL*D*((D./ *B+2.*B*D)*TOP*BOT+(D*D+2.*B*F)*B*T*BOT)/P
C      *TSTH* IS THE STRESS ON TOP DUE TO HOGGING
C      *TSTS* IS THE STRESS ON TOP DUE TO SAGGING
C      *TSBH* IS THE STRESS ON BOT DUE TO HOGGING
C      *TSBS* IS THE STRESS ON BOT DUE TO SAGGING
C      *STCRIT* IS THE CRITICAL STRESS ON TOP
C      *SBCRIT* IS THE CRITICAL STRESS ON BOT
       TSTH=BM*DITOP/GMI+STR3T
       TSTS=BM*DITOP/GMI+STR3T
       STCRIT=TOP*TOP*E/(.3*396*S*S*(1.-POI*POI))
       WRITE(5,60)TSTH
    60 FORMAT(' ',19X,'TSTH=',F10.3)
       WRITE(5,70)TSTS
    70 FORMAT(' ',19X,'TSTS=',F10.3)
       WRITE(5,80)STCRIT
    80 FORMAT(' ',17X,'STCRIT=',F10.3)
       TSBH=BM*DIBOT/GMI+.152222*HBOT*S*S/(BOT*BOT)
       TSBS=BM*DIBOT/GMI+.152222*HBOT*S*S/(BOT*BOT)
       SBCRIT=BOT*BOT*E/(.3*396*S*S*(1.-POI*POI))
       WRITE(5,90)TSBH
    90 FORMAT(' ',19X,'TSBH=',F10.3)
       WRITE(5,100)TSBS
   100 FORMAT(' ',19X,'TSBS=',F10.3)
       WRITE(5,110)SBCRIT
   110 FORMAT(' ',17X,'SBCRIT=',F10.3)
       END
[S] .        0654[V] AL       0650[V] B        0674[V] DRA      066C[V] D
[V] POI      067C[V] E        0000[S] .F       065C[V] DST      0694[V] BM
[V] ?        06A8[V] U        0000[S] SQRT     0670[V] Z        0680[V] HTOP
[V] HBOT     0680[V] STR3T    06C4[V] Z1       06CC[V] STR3B    06D0[V] ?
[V] A        06D8[V] AC       06EC[V] AD       07 0[V] AE       0708[V] BOT
[V] TOP      02A0[L] 10       0000[S] ?I       0242[L] 20       0710[V] S
[L] 30       0714[V] P        0718[V] DITOP    0300[L] 40       071C[V] DIBOT
[L] 50       0720[V] GMI      0720[V] TSTH     0730[V] TSTS     0734[V] STCRIT
[L] 60       04A8[L] 70       0508[L] 80       0738[V] TSBH     073C[V] TSBS
[V] SBCRIT   05C8[L] 90       05FE[L] 100      0634[L] 110      0000[S] .V
ES     L

GRAM LABELS:
2270 *MAIN*     2ECA .\       2CFA .COMP     2090 ALOG     2ED8 ?I     2784 .?
?C2 .ZERO       2E24 $6       27F4 .A        2C1E .MES     2C90 .W     2AA4 E?
C2A ATNT        2AA6 SQRT     2A62 .RARG     20BF .5       2AA4 AEXP   2DC6 .E
?94 ??          2DC6 .C       2E9C .U        3FF4

ENTRY-POINTS:
7E4 .R          27F4 .A       2AA6 SQRT      2090 ALOG     2AA4 AEXP   2AA4 EX
C2A ATNT        2C9C .W       2CFA .COMP     2020 $6       2DA2 .RARG  2094 $?
?2E .F          2DC2 .ZERO    2DC6 .ERCNT    2DC2 .C       2E1E .MES   2EA8 .U
?CF .V          2ED8 ?I
```

```
        TOP=    3.4?24
        BOT=    5.?711
          S=  225.41??
      LITCB=    4?.3??8
      LIFCT=   31.?4?3
      TSTLH= 24990.??3
      TSTLB= 24990.??3
    STCSITE= 24990.??3
      TSCHH= 31029.?45
      TSCHB= 31029.?45
    SBCHITE= 54897.211
ND

VID OPERATING SYSTEM VERSION 1 REVISION ?12 3/04/74 GENERATED 4/27/74

03 HANDLING CHARGE     $  .35 / JOB         .3?
26 LINES PRINTED PRI   $ 1.25 / ? LN        .14
25 CARDS READ          $ 1.?? / ? CD        .1?
?? PLOTTER VECTORS     $  .?? / 1???        .??
21 MODEL ?  SECONDS    $25.?? / HOUR        .1?
?? MODEL ?? SECONDS    $12.?? / HOUR        .?
                      TOTAL CHARGE $        .7?

?EIR 49? 14731 LOGGED OUT ?4/2?/74 2?:59. $ ??.?8 LEFT AFTER ?? LOGINS.
```

This time we obtained a realistic but still unacceptable result; we notice that the bottom is being stressed to 31000 psi when it can only go up to 25000 psi; besides we assumed

$$Z1 = \frac{S}{BOT} = 35$$

and end up with

$$\frac{S}{BOT} = \frac{225.4}{5.07} = 44.46$$

This means that the Z1 value should be higher.

We may now try Z1 = 40; the computer results for this case are shown next.

```
C         */L* IS THE LENGHT
          AL=1001.
          B=AL/5.75
C         *DRA* IS THE DRAFT
          DRA=B/3.3
          D=AL/14.
C         *POI* IS THE POISSON'S RATIO OF THE MATERIAL
C         FOR STEEL
          POI=0.3
C         *E* IS THE YOUNG'S MODULUS OF THE MATERIAL
C         FOR STEEL
          E=30.*10.**6
C         *DST* IS THE DESIGN STRESS
          DST=2530.
C         *BM* IS THE BENDING MOMENT
          BM=1.37143*B*DRA*AL*AL
          W=0.32396*(1.-POI*POI)*DST/E
          U=SQRT(W)
          Z=1./U
          *HTOP* IS THE HEAD OF WATER ON DEC.
          HTOP=8.
          *HBOT* IS THE  HEAD OF WATER ON BOTTOM
          HBOT=DRA
          STR3T=0.152222*HTOP*Z*Z
          Z1=40.
          STR3B=0.152222*HBOT*Z1*Z1
          A=DST-STR3T
          AB=DST-STR3B
          AC=(AB*(B+D)-A*D)/(A*B)
          AD=BM*(B+D)/(A*4.*D*(D*D+2.*B*D))
          AE=(3.*B*B+2.*B*D)/(D*D+2.*B*D)
C         *TOP* IS THE THICKNESS OF THE TOP PLATING
C         *BOT* IS THE THICKNESS OF THE BOTTOM PLATING
          BOT=AD/(1.+AC*AE)
          TOP=AC*BOT
          WRITE(5,10)TOP
       10 FORMAT('1',20X,'TOP='F10.4)
          WRITE(5,20)BOT
       20 FORMAT(' ',20X,'BOT='F10.4)
C         *S* IS THE SPACING OF LONGITUDINAL STIFFENING MEMBERS
          S=Z*TOP
          WRITE(5,30)S
       30 FORMAT(' ',22X,'S='F10.4)
          P=2.*D*BOT+B*(TOP+BOT)
C         *DITOP* IS THE DISTANCE OF THE TOP FROM THE NEUTRAL AXIS
          DITOP=D*(D*BOT+B*BOT)/P
          WRITE(5,40)DITOP
       40 FORMAT(' ',18X,'DITOP='F10.4)
C         *DIBOT* IS THE DISTANCE OF THE BOTTOM FROM THE NEUTRAL AXIS
          DIBOT=D*(D*TOP+B*BOT)/P
          WRITE(5,50)DIBOT
       50 FORMAT(' ',18X,'DIBOT='F10.4)
```

```
278      C      *GMI* IS THE MOMENT OF INERTIA OF THE X SECTION ABOUT N.A.
278             GMI=4.*D*D*((3.*B*B+2.*B*D)*TOP*BOT+(D*D+2.*B*D)*BOT*BOT)/P
2E8      C      *TSTH*IS THE STRESS ON TOP DUE TO HOGGING
2E8      C      *TSTS*IS THE STRESS ON TOP DUE TO SAGGING
2E8      C      *TSBH*IS THE STRESS ON BOT DUE TO HOGGING
2E8      C      *TSBS*IS THE STRESS ON BOT DUE TO SAGGING
2E8      C      *STCRIT* IS THE CRITICAL STRESS ON TOP
2E8      C      *SBCRIT* IS THE CRITICAL STRESS ON BOT
2E8             TSTH=BM*DITOP/GMI+STH3T
2FC             TSTS=-BM*DITOP/GMI+STH3T
314             STCRIT=TOP*TOP*E/(0.30396*S*S*(1.-POI*POI))
352             WRITE(5,60)TSTH
36C          60 FORMAT(' ',19X,'TSTH=',F10.3)
386             WRITE(5,70)TSTS
3A2          70 FORMAT(' ',19X,'TSTS=',F10.3)
3BC             WRITE(5,80)STCRIT
3D8          80 FORMAT(' ',17X,'STCRIT=',F10.3)
3F4             TSBH=BM*DIBOT/GMI+0.152222*HBOT*S*S/(BOT*BOT)
43A             TSBS=BM*DIBOT/GMI+0.152222*HBOT*S*S/(BOT*BOT)
46C             SBCRIT=BOT*BOT*E/(0.30396*S*S*(1.-POI*POI))
4AC             WRITE(5,90)TSBH
4C8          90 FORMAT(' ',19X,'TSBH=',F10.3)
4E2             WRITE(5,100)TSBS
4FE         100 FORMAT(' ',19X,'TSBS=',F10.3)
518             WRITE(5,110)SBCRIT
534         110 FORMAT(' ',17X,'SBCRIT=',F10.3)
550             END
[S] ..       0654 [V] AL        0650 [V] B       0674 [V] DRA     066C [V] D
[V] POI      0670 [V] E         0000 [S] .R      066C [V] DST     0694 [V] BM
[V] .        06A4 [V] '         0000 [S] SQRT    06AC [V] Z       0680 [V] HTOP
[V] HBOT     06BC [V] STH3T     06C4 [V] Z1      06CC [V] STR3B   06D0 [V] A
[V] ..       06D8 [V] AC        06FC [V] AD      0700 [V] AE      0708 [V] BOT
[V] TOP      0270 [L] 10        0000 [S] @I      02A2 [L] 20      0710 [V] S
[L] 3.       0714 [V] P         0718 [V] DITOP   0300 [L] 40      071C [V] DIBOT
[L] ..       0720 [V] GMI       0728 [V] TSTH    0730 [V] TSTS    0734 [V] STCRIT
[L] 6.       04A2 [L] 70        04D8 [L] 80      0738 [V] TSBH    073C [V] TSBS
[V] SBCRIT   05C8 [L] 90        05FE [L] 100     0634 [L] 110     0000 [S] .V
EG

PROGRAM LABELS:
2070 **MAIN*    2ECA .V       2CEA .COMF     299C ALOG     2ED8 @I       2784 ..
2DC2 .ZERO      2020 $6       27F4 .A        2E1F .MES     2C9C .W       2A44 E
2C2A ATNT       2BA6 SQRT     2D62 .RARG     2DEE .5       2AA4 AEXP     2DC6 ..
2094 ..         2DC6 .C       2E9C .U        2EF4

ENTRY-POINTS:
2754 ..         27F4 .A       2BA6 SQRT      299C ALOG     2AA4 AEXP     2A44 EX
2C2A ATNT       2C9C .W       2CEA .COMP     2D20 $6       2D62 .RARG    2D94 $
2DEE .5         2DC2 .ZERO    2DC6 .ERCNT    2DC8 .D       2E1E .MES     2EA8 .
2ECE .V         2ED8 @I
```

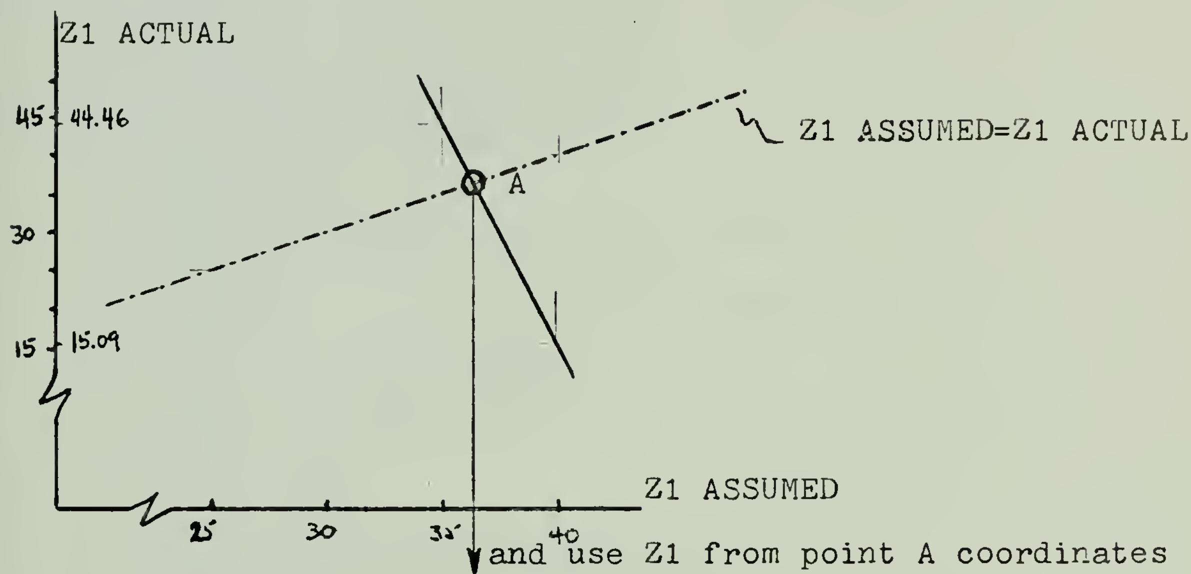
```
         TOP=     3.2259
         BOT=     6.5653
           S=   199.4064
      CITOP=     44.1743
      CIBOT=     27.2593
       TSTH= 24999.054
       TSTS= 24999.054
    STCRIT= 24999.054
       TSBH= 19514.034
       TSBS= 19514.034
    SBCRIT=118337.  1
ND

E VIO OPERATING SYSTEM VERSION 1 REVISION  012 03/04/74 GENERATED   4/27/74

JOB HANDLING CHARGE     $   .35 / JOB          .35
126 LINES PRINTED PR1   $ 1.25 / K LN          .16
 86 CARDS READ          $ 1.50 / K CD          .13
  . PLOTTING VECTORS    $   .25 / 10.0         .0
 15 MODEL 7  SECONDS    $25.00 / HOUR          .1
 2  MODEL 5  SECONDS    $12.50 / HOUR          .0
                    TOTAL CHARGE $             .74

EIR 434 14731  LOGGED OUT 04/29/74 21:22.  $  58.60 LEFT AFTER    8 LOGINS.
```

In this case we assumed Z1 = 40 and ended up with

$$\frac{S}{BOT} = \frac{199.5}{6.59} = 15.09$$

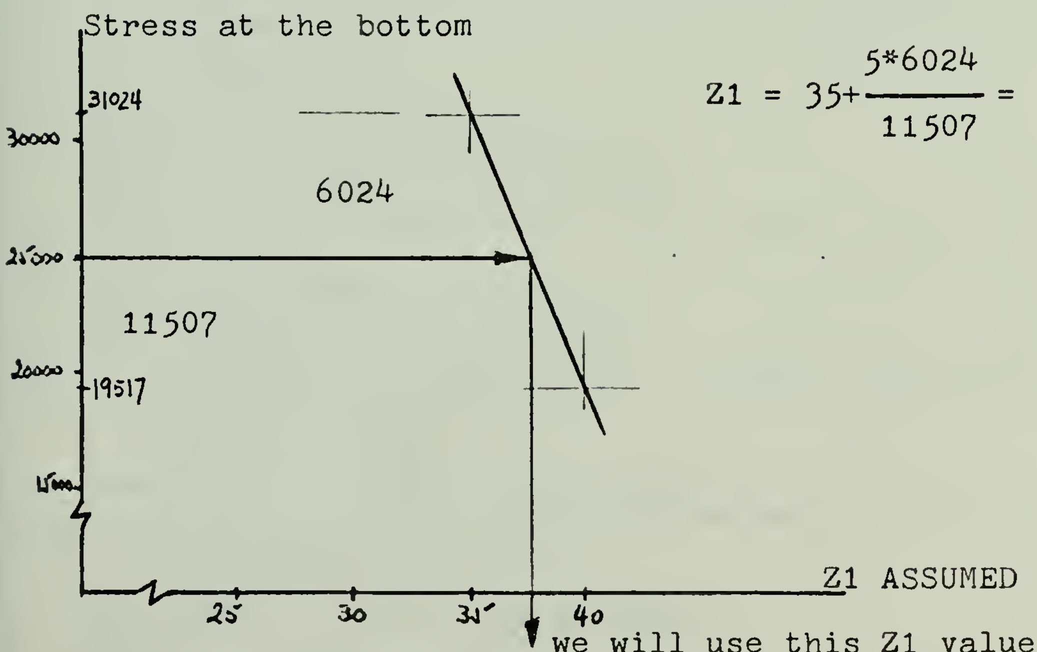
and a stress at the bottom of only 19000 psi which is too small.

We may now try to use a better Z1 value and can do the following:



and use Z1 from point A coordinates

or which is "the same":



$$Z1 = 35 + \frac{5*6024}{11507} = 37.617$$

we will use this Z1 value

The results obtained with this Z1 value are the following:

```
      C     *AL* IS THE LENGHT
            AL=1000.
            B=AL/5.75
      C     *DRA* IS THE DRAFT
            DRA=B/3.3
            D=AL/14.
      C     *POI* IS THE POISSON'S RATIO OF THE MATERIAL
      C     FOR STEEL
            POI=0.3
      C     *E* IS THE YOUNG'S MODULUS OF THE MATERIAL
      C     FOR STEEL
            E=30.*10.**6
      C     *DST* IS THE DESIGN STRESS
            DST=25000.
      C     *BM* IS THE BENDING MOMENT
            BM=1.37143*B*DRA*AL*AL
            W=0.36396*(1.-POI*POI)*DST/E
            U=SQRT(W)
            Z=1./U
            *HTOP* IS THE HEAD OF WATER ON DECK
            HTOP=8.
            *HBOT* IS THE  HEAD OF WATER ON BOTTOM
            HBOT=DRA
            STR3T=0.152222*HTOP*Z*Z
            Z1=35.+5.*6024./11537.
            STR3B=0.152222*HBOT*Z1*Z1
            A=DST-STR3T
            AB=DST-STR3B
            AC=(AB*(B+D)-A*D)/(A*B)
            AD=BM*(B+D)/(A*4.*D*(D*D+2.*B*D))
            AE=(3.*B*B+2.*B*D)/(D*D+2.*B*D)
      C     *TOP* IS THE THICKNESS OF THE TOP PLATING
      C     *BOT* IS THE THICKNESS OF THE BOTTOM PLATING
            BOT=AD/(1.+AC*AE)
            TOP=AC*BOT
            WRITE(5,10)TOP
         10 FORMAT('1',20X,'TOP='F10.4)
            WRITE(5,20)BOT
         20 FORMAT(' ',20X,'BOT='F10.4)
      C     *S* IS THE SPACING OF LONGITUDINAL STIFFENING MEMBERS
            S=Z*TOP
            WRITE(5,30)S
         30 FORMAT(' ',22X,'S='F10.4)
            P=2.*D*BOT+B*(TOP+BOT)
      C     *DITOP* IS THE DISTANCE OF THE TOP FROM THE NEUTRAL AXIS
            DITOP=D*(B*BOT+D*BOT)/P
            WRITE(5,40)DITOP
         40 FORMAT(' ',18X,'DITOP='F10.4)
      C     *DIBOT* IS THE DISTANCE OF THE BOTTOM FROM THE NEUTRAL AXIS
            DIBOT=D*(B*TOP+D*BOT)/P
            WRITE(5,50)DIBOT
         50 FORMAT(' ',18X,'DIBOT='F10.4)
```

```
384     C       *GMI* IS THE MOMENT OF INERTIA OF THE X SECTION ABOUT N.A.
384             GMI=4.*D*D*((3.*B*B+2.*B*D)*TOP*BOT+(D*D+2.*B*D)*BOT*BOT)/P
3F4     C       *TSTH*IS THE STRESS ON TOP DUE TO HOGGING
3F4     C       *TSTS*IS THE STRESS ON TOP DUE TO SAGGING
3F4     C       *TSBH*IS THE STRESS ON BOT DUE TO HOGGING
3F4     C       *TSBS*IS THE STRESS ON BOT DUE TO SAGGING
3F4     C       *STCRIT* IS THE CRITICAL STRESS ON TOP
3F4     C       *SBCRIT* IS THE CRITICAL STRESS ON BOT
3F4             TSTH=BM*DITOP/GMI+STR3T
408             TSTS=BM*DITOP/GMI+STR3T
41C             STCRIT=TOP*TOP*E/(0.30396*S*S*(1.-POI*POI))
45C             WRITE(5,60)TSTH
478          60 FORMAT(' ',19X,'TSTH='F10.3)
492             WRITE(5,70)TSTS
4AE          70 FORMAT(' ',19X,'TSTS='F10.3)
4C8             WRITE(5,80)STCRIT
4E4          80 FORMAT(' ',17X,'STCRIT='F10.3)
500             TSBH=BM*DIBOT/GMI+0.152222*HBOT*S*S/(BOT*BOT)
53C             TSBS=BM*DIBOT/GMI+0.152222*HBOT*S*S/(BOT*BOT)
578             SBCRIT=BOT*BOT*E/(0.30396*S*S*(1.-POI*POI))
5B8             WRITE(5,90)TSBH
5D4          90 FORMAT(' ',19X,'TSBH='F10.3)
5EE             WRITE(5,100)TSBS
60A         100 FORMAT(' ',19X,'TSBS='F10.3)
624             WRITE(5,110)SBCRIT
640         110 FORMAT(' ',17X,'SBCRIT='F10.3)
65C             END
[S] .U       0660[V] AL      0668[V] B       0670[V] DRA     0678[V] D
[V] POI      0688[V] E       0000[S] .R      0698[V] DST     06A0[V] BM
[V] W        06B4[V] U       0000[S] SQRT    06B8[V] Z       06BC[V] HTOP
[V] HBOT     06C8[V] STR3T   06D0[V] Z1      06E4[V] STR3B   06F8[V] A
[V] AB       06F0[V] AC      0704[V] AD      0718[V] AE      0720[V] BOT
[V] TOP      0218[L] 10      0000[S] @I      024E[L] 20      0728[V] S
[L] 30       072C[V] P       0730[V] DITOP   030C[L] 40      0734[V] DIBOT
[L] 50       0738[V] GMI     0744[V] TSTH    0748[V] TSTS    074C[V] STCRIT
[L] 60       04AE[L] 70      04E4[L] 80      0750[V] TSBH    0754[V] TSBS
[V] SBCRIT   05D4[L] 90      060A[L] 100     0640[L] 110     2000[S] .V
EQ        L


GRAM LABELS:
070 *MAIN*   2EE2 .V        2D12 .COMP     29B4 ALOG      2EF0 @I        27CC .R
DDA .ZERO    2D38 $6        280C .A        2E36 .MES      2CB4 .W        2A8C EXP
C42 AINT     28BE SQRT      2D7A .RARG     2DD6 .5        2ABC AEXP      2DCE .ER
DAC $8       2DDE .O        2EB4 .U        400C


RY-POINTS:
7CC .R       280C .A        28BE SQRT      29B4 ALOG      2ABC AEXP      2A8C EXP
C42 AINT     2CB4 .W        2D12 .COMP     2D38 $6        2D7A .RARG     2DAC $8
D06 .5       2DDA .ZERO     2DCE .ERCNT    2DE0 .O        2E36 .MES      2EC4 .U
EE6 .V       2EF0 @I
```

```
          TOP=     3.2486
          BOT=     5.7418
            S=   213.9701
        DITOP=    42.2107
        DIBOT=    29.2179
         TSTH= 25000.000
         TSTS= 25000.000
       STCRIT= 24999.992
         TSBH= 24788.316
         TSBS= 24788.316
       SBCRIT= 75100.937
END

VIO OPERATING SYSTEM VERSION 1 REVISION  012 03/04/74 GENERATED  04/27/74

JOB HANDLING CHARGE    $   .35 / JOB          .35
 26 LINES PRINTED PR2  $ 1.25 / K LN          .16
 85 CARDS READ         $ 1.50 / K CD          .13
 00 PLOTTER VECTORS    $   .25 / 1000         .00
 15 MODEL 70 SECONDS   $25.00 / HOUR          .10
 00 MODEL 80 SECONDS   $12.50 / HOUR          .02
                          TOTAL CHARGE $      .74

EIR 490 14731  LOGGED OUT 04/29/74 21:30.  $  27.86 LEFT AFTER    40 LOGINS.
```

The results show that we have obtained

$$Z1 = \frac{S}{BOT} = \frac{213.9701}{5.7418} = 37.265$$

while it was assumed

$$Z1 = 37.617$$

We could further correct the result until Z1 assumed and Z1 actual would coincide but it seems that there is no need to refine more the solution for the purpose here involved.

Note that this procedure should also be followed for the other cases in order to bring the stress at the bottom to its maximum allowed DST for such cases as well.

```
C     *AL* IS THE LENGHT
      AL=1[illegible].
      B=AL/[illegible].7
C     *DRA* IS THE DRAFT
      DRA=B/3.3
      D=AL/1[illegible].
C     *POI* IS THE POISSON'S RATIO OF THE MATERIAL
C     FOR ALUMINUM
      POI=[illegible].33
C     *E* IS THE YOUNG'S MODULUS OF THE MATERIAL
C     FOR ALUMINUM
      E=1[illegible].*1[illegible].**6
C     *DST* IS THE DESIGN STRESS
      DST=[illegible].
C     *BM* IS THE BENDING MOMENT
      BM=1.37143*B*DRA*AL*AL
      U=[illegible].3[illegible]96*(1.-POI*POI)*DST/E
      U=SQRT(U)
      Z=1./U
C     *HTOP* IS THE HEAD OF WATER ON DECK
      HTOP=[illegible].
C     *HBOT* IS THE HEAD OF WATER ON BOTTOM
      HBOT=DRA
      STRST=[illegible].[illegible]5[illegible]222*HTOP*Z*Z
      STRSB=[illegible].15[illegible]222*HBOT*Z*Z
      A=DST-STRST
      B=DST-STRSB
      AC=(A[illegible]*(B+[illegible])-A*D)/(A*B)
      AD=BM*(B+D)/(A*4.*D*(D*D+2.*B*D))
      AF=(3.*B*B+2.*B*D)/(D*D+2.*B*D)
C     *TOP* IS THE THICKNESS OF THE TOP PLATING
C     *BOT* IS THE THICKNESS OF THE BOTTOM PLATING
      BOT=AD/(1.+AC*AF)
      TOP=AC*BOT
      WRITE(6,10)TOP
   10 FORMAT('1',2[illegible]X,'TOP='F1[illegible].4)
      WRITE(6,20)BOT
   20 FORMAT(' ',2[illegible]X,'BOT='F1[illegible].4)
C     *S* IS THE SPACING OF LONGITUDINAL STIFFENING MEMBERS
      S=Z*TOP
      WRITE(6,30)S
   30 FORMAT(' ',22X,'S='F1[illegible].4)
      P=2.*D*BOT+B*(TOP+BOT)
C     *DITOP* IS THE DISTANCE OF THE TOP FROM THE NEUTRAL AXIS
      DITOP=D*(B*BOT+D*BOT)/P
      WRITE(6,40)DITOP
   40 FORMAT(' ',18X,'DITOP='F1[illegible].4)
C     *DIBOT* IS THE DISTANCE OF THE BOTTOM FROM THE NEUTRAL AXIS
      DIBOT=D*(B*TOP+D*BOT)/P
      WRITE(6,50)DIBOT
   50 FORMAT(' ',18X,'DIBOT='F1[illegible].4)
C     *SMI* IS THE MOMENT OF INERTIA OF THE X SECTION ABOUT N.A.
```

```
            SMI=4.*D*D*((3.*B*B+2.*B*D)*TOP*BOT+(D*D+2.*B*D)*BOT*BOT)/P
      C     *TSTH* IS THE STRESS ON TOP DUE TO HOGGING
      C     *TSTS* IS THE STRESS ON TOP DUE TO SAGGING
      C     *TSBH* IS THE STRESS ON BOT DUE TO HOGGING
      C     *TSBS* IS THE STRESS ON BOT DUE TO SAGGING
      C     *STCRIT* IS THE CRITICAL STRESS ON TOP
      C     *SBCRIT* IS THE CRITICAL STRESS ON BOT
            TSTH=BM*DITOP/GMI+S-BOT
            TSTS=BM*DITOP/GMI+S-BOT
            STCRIT=TOP*TOP*E/(Ø.32396*S*S*(1.-POI*POI))
            WRITE(5,6Ø)TSTH
         6Ø FORMAT(' ',1ØX,'TSTH='F1Ø.3)
            WRITE(5,7Ø)TSTS
         7Ø FORMAT(' ',1ØX,'TSTS='F1Ø.3)
            WRITE(5,8Ø)STCRIT
         8Ø FORMAT(' ',1ØX,'STCRIT='F1Ø.3)
            TSBH=BM*DIBOT/GMI+Ø.152222*HBOT*S*S/(BOT*BOT)
            TSBS=BM*DIBOT/GMI-Ø.152222*HBOT*S*S/(BOT*BOT)
            SBCRIT=BOT*BOT*E/(Ø.32396*S*S*(1.-POI*POI))
            WRITE(5,9Ø)TSBH
         9Ø FORMAT(' ',1ØX,'TSBH='F1Ø.3)
            WRITE(5,1ØØ)TSBS
        1ØØ FORMAT(' ',1ØX,'TSBS='F1Ø.3)
            WRITE(5,11Ø)SBCRIT
        11Ø FORMAT(' ',1ØX,'SBCRIT='F1Ø.3)
            END
[S] .U        [V] AL        [V] B         Ø65C[V] DRA      Ø664[V] D
[V] POI       [V] E         [S] .R        Ø684[V] DST      Ø688[V] BM
[V] W         [V] H         [S] SQRT      Ø6AØ[V] Z        Ø6A4[V] HTOP
[V] HBOT      [V] STBBT     [V] STBBB     Ø6BC[V] A        Ø6CØ[V] AB
[V] AC        [V] AD        [V] AE        Ø6F4[V] BOT      Ø6F8[V] TOP
[L] 1Ø        [S] .I        [L] 2Ø        Ø6FC[V] S        Ø27C[L] 3Ø
[V] P         [V] DITOP     [L] 4Ø        Ø7Ø8[V] DIBOT    Ø354[L] 5Ø
[V] GMI       [V] TSTH      Ø71C[V] TSTS  Ø72Ø[V] STCRIT   Ø464[L] 6Ø
[L] 7Ø        [L] 8Ø        Ø724[V] TSBH  Ø728[V] TSBS     Ø72C[V] SBCRIT
[L] 9Ø        [L] 1ØØ       [L] 11Ø       ØØØØ[S] .V
            L

PROGRAM LABELS:
27Ø *MAIN*    .V            .COMP         2988 ALOG        2EC4 $I      27AØ .R
.ZERO         $6            .A            2EØA .MES        2C88 .W      2A9Ø EX
AINT          SQRT          .PARG         2DAA .5          2A9Ø AEXP    2DB2 .E
$8            .O            .U            3FEØ

ENTRY-POINTS:
27A0 .R       .A            SQRT          2988 ALOG        2A9Ø AEXP    2A9Ø EX
AINT          .W            .COMP         2DØC $6          2D4E .RARG   2D8Ø $8
.5            .ZERO         .ERCNT        2DB4 .O          2EØA .MES    2E94 .U
.V            $I
```

```
      T[illegible]=     2.[illegible]15[illegible]
      [illegible]IT=     6.21 2
        S=     [illegible]
     [illegible] P=     [illegible]
     [illegible]=     [illegible]42[illegible]
     TST[illegible]= 2[illegible]
     TSTS= 25[illegible]
   STC[illegible]= [illegible]
     TS[illegible]= 1[illegible]945.727
     TS[illegible]S= 1 [illegible]45.72[illegible]
   [illegible]=1[illegible]1[illegible].2[illegible]
[illegible]

[illegible]VIC OPERATING SYSTEM VERSION 1 REVISION  312 03/04/74 GENERATED  04/27/74

[illegible] HANDLING CHARGE    $  .35 / JOB        .35
[illegible] LINES PRINTED [illegible] $ 1.25 / K LN    .14
[illegible] CARDS READ          [illegible].5[illegible] / [illegible] CD     .13
[illegible] PLOTTER V[illegible]     .25 / 1000       [illegible]
1[illegible] MODEL 72 SECONDS  [illegible]5.[illegible] / HOUR      .12
[illegible] MODEL 8[illegible] SECONDS   [illegible]2.5[illegible] / HOUR     [illegible]
                      TOTAL CHARGE $     .76

[illegible]TR 49[illegible] 1473[illegible]  LOGGED OUT [illegible]4/2[illegible]/74 18:28.  $  34.67 LEFT AFTER     40 LOGINS.
```

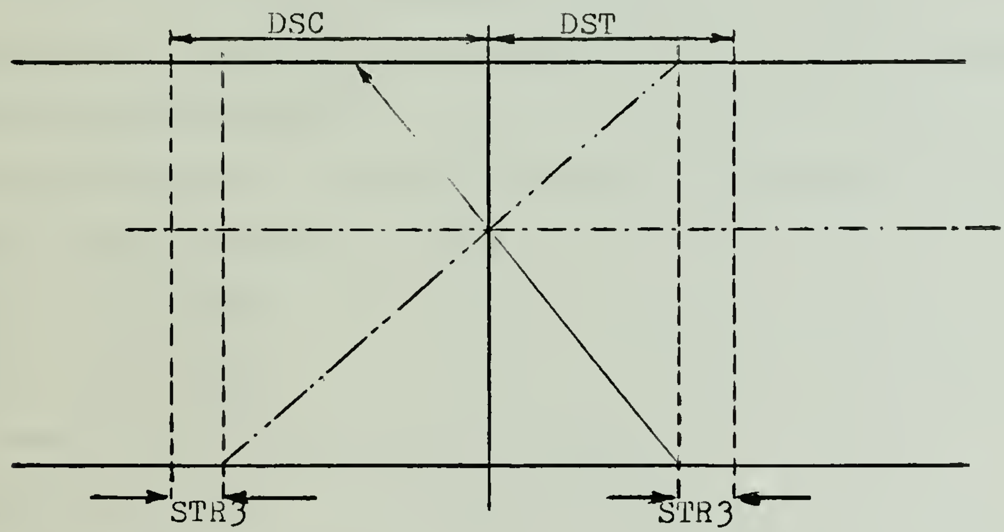
This 1000 ft aluminum case shows again a stress at the bottom much lower than DST. It should be corrected as done for "1000 ft steel" in the previous situation.

HOGGING MOMENT LARGER THAN SAGGING MOMENT

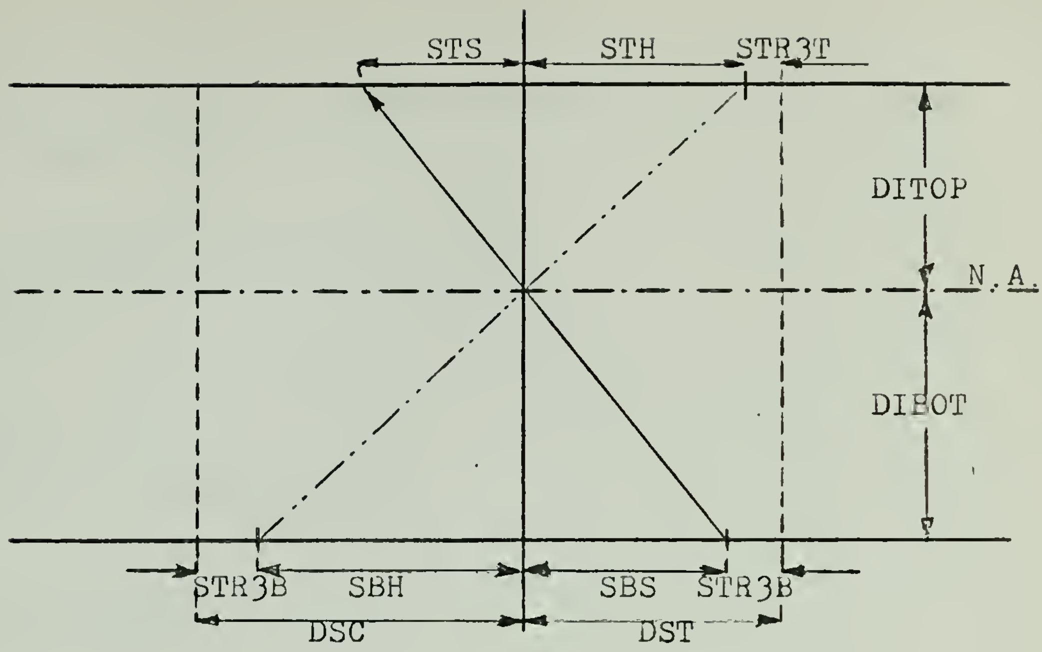
DESIGN STRESS IN COMPRESSION LARGER THAN DESIGN STRESS IN TENSION

LATERAL LOAD ALSO CONSIDERED

With the help of what was understood for the similar situation without the lateral load being included, we may here proceed at once to look at what the diagram of stress distributions might look like. Actually, the diagram that will be considered first is basically the same with only a small change due to the addition of the tertiary stresses; since these will probably be of the same magnitude on both top or bottom and assuming that their actual value does not differ considerably, what we may start looking into is a diagram as follows:



We would consider here the same basic distribution of longitudinal bending stresses thus obtaining



We will then expect to obtain TOP> BOT and DITOP< DIBOT and we may already consider the respective expressions for DITOP, DIBOT and I with TS replaced by TOP

From the diagram we may consider thefollowing equations:

STH*DIBOT=SBH*DITOP

and notice here that if we want to stress the material to the allowable design stresses we have

STH = DST-STR3T

SBH = DSC-STR3B

we may combine these equations to obtain

(DST-STR3T)*DIBOT = (DSC-STR3B)*DITOP

STR3T and STR3B are given by

$$STR3T = 0.152222*HTOP*\left(\frac{S}{TOP}\right)^2$$

$$STR3B = 0.152222*HBOT*\left(\frac{S}{BOT}\right)^2$$

anticipating here that S = Z*BOT because BOT is the thinner plating we have

$$\left(\frac{S}{BOT}\right)^2 = Z^2$$

and thus may write

STR3B = 0.152222*HBOT*Z^2

Since

$$\left(\frac{S}{TOP}\right)^2 < \left(\frac{S}{BOT}\right)^2$$

because TOP > BOT, if we make

$$\left(\frac{S}{TOP}\right)^2 = Z^2$$

to simplify the equations that will follow we will understand that in doing so we are only increasing the value of STR3T. This as we see fron

STH = DST-STR3T

will make us have STH with a slightly lower value than the one that is allowed, so we are on the safe side when we consider

$$\left(\frac{S}{TOP}\right)^2 = Z^2$$

Now if we end up too much on the safe side and we have a TSTH too low we may bring it to a value closer to DST by considering a Z1 value as done and exemplified in the previous section and done again in this section for the case 1000 ft steel where for this particular exemple it is TSBH that needs correction as explained in detail .

We may then write

$$Z = \frac{1}{\sqrt{0.30396*\frac{1-POI*POI}{E}*DSC}}$$

$$STR3T = 0.152222*HTOP*Z^2$$

$$STR3B = 0.152222*HBOT*Z^2$$

and from

(DST-STR3T)*DIBOT = (DSC-STR3B)*DITOP

we have if we make

A = DST-STR3T

AB = DSC-STR3B

P = (2*D+B)*TOP+B*BOT

$$A*\frac{D*TOP*(B+D)}{P} = AB*\frac{D*(B*BOT+D*TOP)}{P}$$

which gives after simplification

A*((B+D)-AB*D)*TOP = AB*B*BOT

and making

AC = (A*(B+D)-AB*D)/(AB*B)

we have

BOT = AC*TOP

Following th e suggestions of a previous section we will also use the equation that will make the bottom to be stressed the most in compression under the larger of the moments being considered (HM in this case).

We obtain

SBH = HM*DIBOT/I = AB

Replacing DIBOT and I by their expressions we obtain

$$AB = \frac{HM*D*TOP*(B+D)}{4*D^2*TOP*((3*B^2+2*B*D)*BOT+(D^2+2*B*D)*TOP)}$$

simplifying we end up with

$$TOP = \frac{HM*(B+D)}{AB*4*D*(D^2+2*B*D)} - \frac{3*B^2+2*B*D}{D^2+2*B*D}*BOT$$

now making

$$AD = HM*(B+D)/(AB*4*D*(D^2+2*B*D))$$

$$AE = (3*B^2+2*B*D)/(D^2+2*B*D)$$

we have

$$TOP = AD-AE*BOT$$

substituting here

$$BOT = AC*TOP$$

we obtain finally

$$TOP = \frac{AD}{1+AC*AE}$$

Considering here again the bottom as the location of the thinner plating (in this particular situation we are looking at), and knowing that it will be subject to a compressive stress of magnitude as large as DSC we may again write $S = Z*BOT$

We finally obtain the total stress on top and bottom in both tension and compression by adding the longitudinal bending stresses to the tertiary stresses.

$$TSTH = HM*DITOP/I+0.152222*HTOP*S^2/TOP^2$$

$$TSTS = SM*DITOP/I+0.152222*HTOP*S^2/TOP^2$$

$$TSBH = HM*DIBOT/I+STR3B$$

$$TSBS = SM*DIBOT/I+STR3B$$

NOTE: since usually the secondary stresses are assigned a constant value like 2000 psi or 3000 psi they can be accounted for when giving a value to the design stresses.

```
0004   C      *AL* IS THE LENGHT
0004          AL=500.
000C          B=AL/8.
0018   C      *DRA* IS THE DRAFT
0018          DRA=B/3.
0024          D=AL/9.
0030   C      *POI* IS THE POISSON'S RATIO OF THE MATERIAL
0030   C      FOR ALUMINUM
0030          POI=0.33
0038   C      *E* IS THE YOUNG'S MODULUS OF THE MATERIAL
0038   C      FOR ALUMINUM
0038          E=10.*10.**6
004C   C      *DST* IS THE DESIGN STRESS IN TENSION
004C          DST=2500.0.
0054   C      *DSC* IS THE DESIGN STRESS IN COMPRESSION
0054          DSC=5000.0.
005C   C      *HM* IS THE HOGGING BENDING MOMENT
005C          HM=1.37143*B*DRA*AL*AL
0074   C      *SM* IS THE SAGGING BENDING MOMENT
0074          SM=B*DRA*AL*AL
0088          U=0.3036*(1.-POI*POI)*DSC/E
00A8          U=SQRT(U)
00B4          Z=1./U
00C0          *HTOP* IS THE HEAD OF WATER ON DECK
00C0          HTOP=8.
00C8          *HBOT* IS THE HEAD OF WATER ON BOTTOM
00C8          HBOT=DRA
00D0          STR3T=0.15222*HTOP*Z*Z
00E4          STR3B=0.15222*HBOT*Z*Z
00F8          A=DST-STR3T
0104          AB=DSC-STR3B
0110          AC=(A*(B+D)-AB*D)/(AB*B)
0148          AD=HM*(B+D)/(AB*4.*D*(B*D+2.*B*D))
0194          AE=(2.*B*B+2.*B*D)/(B*D+2.*B*D)
01E0   C      *TOP* IS THE THICKNESS OF THE TOP PLATING
01E0   C      *BOT* IS THE THICKNESS OF THE BOTTOM PLATING
01E0          TOP=AD/(1.+AC*AE)
01F8          BOT=AC*TOP
0204          WRITE(5,10)TOP
0220       10 FORMAT('1',20X,'TOP='E10.4)
023A          WRITE(5,20)BOT
0256       20 FORMAT(' ',20X,'BOT='E10.4)
0270   C      *S* IS THE SPACING OF LONGITUDINAL STIFFENING MEMBERS
0270          S=Z*BOT
027C          WRITE(5,30)S
0298       30 FORMAT(' ',20X,'S='E10.4)
02B0          P=2.*D*TOP+B*(TOP+BOT)
02D4   C      *DITOP* IS THE DISTANCE OF THE TOP FROM THE NEUTRAL AXIS
02D4          DITOP=D*(B*BOT+D*TOP)/P
02F8          WRITE(5,40)DITOP
0314       40 FORMAT(' ',18X,'DITOP='E12.4)
0330   C      *DIBOT* IS THE DISTANCE OF THE BOTTOM FROM THE NEUTRAL AXIS
```

```
0330             DIRCT=D*(B*TOP+ *TOP)/F
0354             WRITE(5,50)DIRCT
0370          5  FORMAT(' ',19X,'DIRCT='F10.4)
038C      C      *SMI* IS THE MOMENT OF INERTIA OF THE X SECTION ABOUT  ./.
038C             SMI=4.*D*B*((3.* *2+ .* *L)*TOP*HOT+(D*D+2.*B*D)*TOP*TOP)/
03FC      C      *TSTH*IS THE STRESS ON TOP DUE TO HOGGING
03FC      C      *TSTS*IS THE STRESS ON TOP DUE TO SAGGING
03FC      C      *TSBH*IS THE STRESS ON BOT DUE TO HOGGING
03FC      C      *TSBS*IS THE STRESS ON BOT DUE TO SAGGING
03FC      C      *STCRIT* IS THE CRITICAL STRESS ON TOP
03FC      C      *SBCRIT* IS THE CRITICAL STRESS ON BOT
03FC             TSTH=HM*DITOP/S (1+ .1 2222*HTOP*S*S/(TOP*TOP)
0438             TSTS=SM*DITOP/S (1+ .1 2222*HTOP*S*S/(TOP*TOP)
0474             STCRIT=TOP*TOP* /( .3 396*S*S*(1.-POI*POI))
0484             WRITE(5,60)TSTH
04D0          6  FORMAT(' ',19X,'TSTH=,F10.3)
04EA             WRITE(5,70)TSTS
0506          7  FORMAT(' ',19X,'TSTS=,F10.3)
0522             WRITE(5,80)STCRIT
053C          8  FORMAT(' ',17X,'STCRIT='F10.3)
0558             TSBH=HM*DIRCT/S  T+3T  B
056C             TSBS=SM*DIRCT/S  T+3T  B
0582             SBCRIT=  T*BOT* /( .3 396*S*S*(1.-POI*POI))
05C0             WRITE(5,90)TSBH
05DC          9  FORMAT(' ',19X,'TSBH=,F10.3)
05F6             WRITE(5,100)TSBS
0612        10   FORMAT(' ',19X,'TSBS=,F10.3)
062C             WRITE(5,110)SBCRIT
0648        11   FORMAT(' ',17X,'SBCRIT='F10.3)
0664             END
  [S]  .U       068[V]  AL        670[V]  B         0670[V]  DRA      068 [V]  D
 8[V]  POI      68 [V]  E            [V]  .R        069C[V]  DST      6A4[V]  DSC
 C[V]  HM       6 4[V]  SM        6 8[V]  W         06C4[V]  U           [S]  SQRT
 8[V]  Z        6CC[V]  HTOP      6  [V]  HBOT      06C4[V]  STF3T    06DC[V]  ST 0B
 C[V]  A        6E4[V]  AB        6F [V]  AC        06FC[V]  AD       071 [V]  AE
 4[V]  TOP      718[V]  BOT       220[L]  10        0720[S]  @I       0256[L]  2
  [V]  S        0290[L]  30       0720[V]  P        0724[V]  DITOP    0314[L]  4
 2[V]  DIRCT    037 [L]  5        0720[V]  SMI      0728[V]  TSTH     0730[V]  TSTS
 4[V]  STCRIT   04D0[L]  6        05 6[L]  70       053C[L]  80       0744[V]  TSBH
 4[V]  TSBS     074C[V]  SBCRIT   05 C[L]  90       0612[L]  100      0648[L]  110
  [S]  .V
 XEQ          L
 OF

 OGRAM LABELS:
 2070 *MAIN*    2F56 .V       2C84 .COMP     2AA8 /LOG      2E64 @T       27C0 .
 2D4E .ZERO     2CAC $$       2  2 .A        2FAA .MES      2C28 .U       2A30 EX
 2BB6 AINT      2852 SQRT     2CEE .DARG     2 4A .5        2D20 $8       2052 .
 2D52 .D        2E78 .U       3F8

 TRY-POINTS:
 27C0 .R        2800 .A       2832 SQRT     '29A8 ALOG      2AB  EXP      2BB6 AI
```

```
          TOP=      1.3[illegible]
          BOT=      [illegible]
            S=     1[illegible].[illegible]1
        DITOP=     26.3[illegible]
        DIBOT=     2[illegible]
         TSTH= 244[illegible].7[illegible]
         TSTS= 1[illegible]1[illegible].7 1
       STCRIT= 454[illegible].3[illegible]
         TSPH= 2[illegible].[illegible]
         TSPS= 22931.[illegible]
       SPCRIT= 3[illegible].[illegible]
/ END

[illegible]F VIO OPERATING SYSTEM VERSION 1 REVISION 12 3/[illegible]/7[illegible] GENERATED [illegible]/3[illegible]/74

 JOB HANDLING CHARGE     $  .[illegible] / JOB          .3[illegible]
 130 LINES PRINTED PR1   $ 1.[illegible] / K L[illegible]        .1[illegible]
  88 CARDS READ          $ 1.[illegible] / [illegible]        .1[illegible]
  00 PLOTTER VECTORS     $  .[illegible] / 1[illegible]         .[illegible]
  15 MODEL 7 SECONDS     $2[illegible].[illegible] / H[illegible]       .1[illegible]
  00 MODEL [illegible] SECONDS     $12.[illegible] / HOUR         .[illegible]
                            TOTAL CHARGE =      .7[illegible]

[illegible]REIR 490 1[illegible]1 LOGGED OUT [illegible]/[illegible]/7[illegible] 22:19. $ 26.33 LEFT AFTER [illegible]1 LOGINS.
```

As we see the results obtained for the 500 ft aluminum case are acceptable and agree with all our considerations in the derivation of the formulas, namely TOP$>$BOT.

The following two runs, for 500 ft steel and 1000 ft aluminum show that the results are in disagreement with TOP$>$BOT used in the formulas. We will see next why this happens and derive the proper set of formulas to be used for such cases.

```
      C       *AL* IS THE LENGHT
              AL=500.
              B=AL/8.
      C       *DRA* IS THE DRAFT
              DRA=B/3.
              D=AL/9.
      C       *POI* IS THE POISSON'S RATIO OF THE MATERIAL
      C       FOR STEEL
              POI=0.3
      C       *E* IS THE YOUNG'S MODULUS OF THE MATERIAL
      C       FOR STEEL
              E=30.*10.**6
      C       *DST* IS THE DESIGN STRESS IN TENSION
              DST=25000.
      C       *DSC* IS THE DESIGN STRESS IN COMPRESSION
              DSC=30000.
      C       *HM* IS THE HOGGING BENDING MOMENT
              HM=1.37143*B*DRA*AL*AL
      C       *SM* IS THE SAGGING BENDING MOMENT
              SM=B*DRA*AL*AL
              W=0.30396*(1.-POI*POI)*DSC/E
              U=SQRT(W)
              Z=1./U
              *HTOP* IS THE HEAD OF WATER ON DECK
              HTOP=8.
              *HBOT* IS THE HEAD OF WATER ON BOTTOM
              HBOT=DRA
              STR3T=0.152222*HTOP*Z*Z
              STR3B=0.152222*HBOT*Z*Z
              A=DST-STR3T
              AB=DSC-STR3B
              AC=(A*(B+D)-AB*D)/(AB*B)
              AD=HM*(B+D)/(AB*4.*D*(D*D+2.*B*D))
              AE=(3.*B*D+2.*B*D)/(D*D+2.*B*D)
      C       *TOP* IS THE THICKNESS OF THE TOP PLATING
      C       *BOT* IS THE THICKNESS OF THE BOTTOM PLATING
              TOP=AD/(1.+AC*AE)
              BOT=AC*TOP
              WRITE(5,10)TOP
           10 FORMAT('1',20X,'TOP='F10.4)
              WRITE(5,20)BOT
           20 FORMAT(' ',20X,'BOT='F10.4)
      C       *S* IS THE SPACING OF LONGITUDINAL STIFFENING MEMBERS
              S=Z*BOT
              WRITE(5,30)S
           30 FORMAT(' ',22X,'S='F10.4)
              P=2.*D*TOP+B*(TOP+BOT)
      C       *DITOP* IS THE DISTANCE OF THE TOP FROM THE NEUTRAL AXIS
              DITOP=D*(B*BOT+D*TOP)/P
              WRITE(5,40)DITOP
           40 FORMAT(' ',18X,'DITOP='F10.4)
      C       *DIBOT* IS THE DISTANCE OF THE BOTTOM FROM THE NEUTRAL AXIS
```

```
0330          DIBOT=D*(B*TOP+D*TOP)/P
2354          WRITE(5,50)DIBOT
2370       50 FORMAT(' ',18X,'DIBOT='F10.4)
238C    C     *GMI* IS THE MOMENT OF INERTIA OF THE X SECTION ABOUT N.A.
238C          GMI=4.*D*D*((3.*B*B+2.*B*D)*TOP*BOT+(D*D+2.*B*D)*TOP*TOP)/P
23FC    C     *TSTH*IS THE STRESS ON TOP DUE TO HOGGING
23FC    C     *TSTS*IS THE STRESS ON TOP DUE TO SAGGING
23FC    C     *TSBH*IS THE STRESS ON BOT DUE TO HOGGING
23FC    C     *TSBS*IS THE STRESS ON BOT DUE TO SAGGING
23FC    C     *STCRIT* IS THE CRITICAL STRESS ON TOP
23FC    C     *SBCRIT* IS THE CRITICAL STRESS ON BOT
23FC          TSTH=HM*DITOP/GMI+0.152222*HTOP*S*S/(TOP*TOP)
2438          TSTS=SM*DITOP/GMI+0.152222*HTOP*S*S/(TOP*TOP)
2474          STCRIT=TOP*TOP*E/(0.30396*S*S*(1.-POI*POI))
24B4          WRITE(5,60)TSTH
24D0       60 FORMAT(' ',19X,'TSTH='F10.3)
24EA          WRITE(5,70)TSTS
2506       70 FORMAT(' ',19X,'TSTS='F10.3)
2520          WRITE(5,80)STCRIT
253C       80 FORMAT(' ',17X,'STCRIT='F10.3)
2558          TSBH=HM*DIBOT/GMI+STR3B
256C          TSBS=SM*DIBOT/GMI+STR3B
2580          SBCRIT=BOT*BOT*E/(0.30396*S*S*(1.-POI*POI))
25C0          WRITE(5,90)TSBH
25DC       90 FORMAT(' ',19X,'TSBH='F10.3)
25F6          WRITE(5,100)TSBS
2612      100 FORMAT(' ',19X,'TSBS='F10.3)
262C          WRITE(5,110)SBCRIT
2648      110 FORMAT(' ',17X,'SBCRIT='F10.3)
2664          END
 [S] .U       0668[V] AL      067 [V] B      0678[V] DRA     068 [V] D
 [V] POI      0690[V] E       00  [S] .R     06A0[V] DST     06A3[V] DSC
 [V] HM       0688[V] SM      068C[V] W      06C8[V] U       00  [S] SQRT
 [V] Z        06D0[V] HTOP    06D4[V] HBOT   06D8[V] STR3T   06E [V] STR3B
 [V] A        06E8[V] AB      06EC[V] AC     0700[V] AD      0714[V] AE
 [V] TOP      071C[V] BOT     0220[L] 10     0000[S] @I      0256[L] 20
 [V] S        0298[L] 30      0724[V] P      0728[V] DITOP   0314[L] 40
 [V] DIBOT    0370[L] 50      0730[V] GMI    073C[V] TSTH    074 [V] TSTS
 [V] STCRIT   04D0[L] 60      0506[L] 70     053C[L] 80      074 [V] TSBH
 [V] TSBS     0750[V] SBCRIT  05DC[L] 90.    0612[L] 100     0648[L] 110
 [S] .V
XEQ        L
F

OGRAM LABELS:
2070 *MAIN*   2E5A .V     2C8A .COMP   29AC ALOG   2E68 @I   27C4 .R
2D52 .ZERO    2CB0 $6     2804 .A      2DAE .MES   2C2C .W   2AB4 EX
2BBA AINT     2886 SQRT   2CF2 .RARG   2D4E .5     2D24 $8   2D56 .E
2D56 .O       2E2C .U     3F84

TRY-POINTS:
27C4 .R       2804 .A     2886 SQRT    29AC ALOG   2AB4 EXP  2BBA AI
```

```
          TOP=    0.3923
          BOT=    0.4748
            S=   28.5459
        DITOP=   29.2419
        DIBOT=   26.3137
         TSTH= 27045.305
         TSTS= 21466.824
       STCRIT= 20483.910
         TSBH= 30000.012
         TSBS= 24990.129
       SBCRIT= 29999.953
END

 VIO OPERATING SYSTEM VERSION 1 REVISION  012 03/04/74 GENERATED  04/30/74

JOB HANDLING CHARGE    $  .35 / JOB        .35
30 LINES PRINTED PR2   $ 1.25 / K LN       .16
88 CARDS READ          $ 1.50 / K CD       .13
00 PLOTTER VECTORS     $  .25 / 1 00       .00
15 MODEL 70 SECONDS    $25.00 / HOUR       .10
00 MODEL 80 SECONDS    $12.50 / HOUR       .00
                         TOTAL CHARGE $    .74

EIR 490 14731  LOGGED OUT 05/21/74 22:23.  $  25.59 LEFT AFTER    02 LOGINS.
```

```
C      *AL* IS THE LENGHT
       AL=1000.
       B=AL/5.75
C      *DRA* IS THE DRAFT
       DRA=B/3.3
       D=AL/14.
C      *POI* IS THE POISSON'S RATIO OF THE MATERIAL
C      FOR ALUMINUM
       POI=0.33
C      *E* IS THE YOUNG'S MODULUS OF THE MATERIAL
C      FOR ALUMINUM
       E=10.*10.**6
C      *DST* IS THE DESIGN STRESS IN TENSION
       DST=25000.
C      *DSC* IS THE DESIGN STRESS IN COMPRESSION
       DSC=30000.
C      *HM* IS THE HOGGING BENDING MOMENT
       HM=1.37143*B*DRA*AL*AL
C      *SM* IS THE SAGGING BENDING MOMENT
       SM=B*DRA*AL*AL
       W=0.30396*(1.-POI*POI)*DSC/E
       U=SQRT(W)
       Z=1./U
       *HTOP* IS THE HEAD OF WATER ON DECK
       HTOP=8.
       *HBOT* IS THE  HEAD OF WATER ON BOTTOM
       HBOT=DRA
       STP3T=0.152222*HTOP*Z*Z
       STP3B=0.152222*HBOT*Z*Z
       A=DST-STR3T
       AB=DSC-STR3B
       AC=(A*(B+D)-AB*D)/(AB*B)
       AD=HM*(B+D)/(AB*4.*(D*D+2.*B*D))
       AE=(3.*B*B+2.*B*D)/(D*D+2.*B*D)
C      *TOP* IS THE THICKN SS OF THE TOP PLATING
C      *BOT* IS THE THICKNESS OF THE BOTTOM PLATING
       TOP=AD/(1.+AC*AE)
       BOT=AC*TOP
       WRITE(5,10)TOP
    10 FORMAT('1',20X,'TOP='F10.4)
       WRITE(5,20)BOT
    20 FORMAT(' ',20X,'BOT='F10.4)
C      *S* IS THE SPACING OF LONGITUDINAL STIFFENING MEMBERS
       S=Z*BOT
       WRITE(5,30)S
    30 FORMAT(' ',22X,'S='F10.4)
       P=2.*D*TOP+B*(TOP+BOT)
C      *DITOP* IS THE DISTANCE OF THE TOP FROM THE NEUTRAL AXIS
       DITOP=D*(B*BOT+D*TOP)/P
       WRITE(5,40)DITOP
    40 FORMAT(' ',18X,'DITOP='F10.4)
C      *DIBOT* IS THE DISTANCE OF THE BOTTOM FROM THE NEUTRAL AXIS
```

```
330            DIBOT=D*(B*TOF+D*TOP)/P
354            WRITE(5,50)DIBOT
370         50 FORMAT(' ',18X,'DIBOT='F10.4)
38C      C     *GMI* IS THE MOMENT OF INERTIA OF THE X SECTION ABOUT N.A.
38C            GMI=4.*D*D*((3.*B*B+2.*B*D)*TOP*BOT+(D*D+2.*B*D)*TOP*TOP)/P
FC       C     *TSTH*IS THE STRESS ON TOP DUE TO HOGGING
FC       C     *TSTS*IS THE STRESS ON TOP DUE TO SAGGING
FC       C     *TSBH*IS THE STRESS ON BOT DUE TO HOGGING
FC       C     *TSBS*IS THE STRESS ON BOT DUE TO SAGGING
FC       C     *STCRIT* IS THE CRITICAL STRESS ON TOP
FC       C     *SBCRIT* IS THE CRITICAL STRESS ON BOT
FC             TSTH=HM*DITOP/GMI+0.152222*HTOP*S*S/(TOP*TOP)
38             TSTS=SM*DITOP/GMI+0.152222*HTOP*S*S/(TOP*TOP)
74             STCRIT=TOP*TOP*E/(0.30396*S*S*(1.-POI*POI))
84             WRITE(5,60)TSTH
D0          60 FORMAT(' ',19X,'TSTH='F10.3)
EA             WRITE(5,70)TSTS
06          70 FORMAT(' ',19X,'TSTS='F10.3)
20             WRITE(5,80)STCRIT
3C          80 FORMAT(' ',17X,'STCRIT='F10.3)
58             TSBH=HM*DIBOT/GMI+STR3B
6C             TSBS=SM*DIBOT/GMI+STR3B
80             SBCRIT=BOT*BOT*E/(0.30396*S*S*(1.-POI*POI))
C0             WRITE(5,90)TSBH
DC          90 FORMAT(' ',19X,'TSBH='F10.3)
F6             WRITE(5,100)TSBS
12         100 FORMAT(' ',19X,'TSBS='F10.3)
2C             WRITE(5,110)SBCRIT
48         110 FORMAT(' ',17X,'SBCRIT='F10.3)
64             END
[S] .U       0668[V] AL       0670[V] B        0678[V] DRA      0680[V] D
[V] POI      0690[V] E        0000[S] .R       069C[V] DST      06A4[V] DSC
[V] HM       06B4[V] SM       06BC[V] W        06C4[V] U        0000[S] SQRT
[V] Z        06CC[V] HTOP     06D4[V] HBOT     06D8[V] STR3T    06E0[V] STR3B
[V] A        06E8[V] AB       06EC[V] AC       0700[V] AD       0714[V] AE
[V] TOP      0720[V] BOT      0722[L] 10       0000[S] @I       0256[L] 20
[V] S        0298[L] 30       0728[V] P        072C[V] DITOP    0314[L] 40
[V] DIBOT    0370[L] 50       0734[V] GMI      0740[V] TSTH     0744[V] TSTS
[V] STCRIT   04D0[L] 60       050A[L] 70       053C[L] 80       074C[V] TSBH
[V] TSBS     0754[V] SBCRIT   05DC[L] 90       0612[L] 100      0648[L] 110
[S] .V
0          L


RAM LABELS:
70 *MAIN*    2E5E .V          2CPE .COMP       2980 ALOG        2E6C @I          27C8 .R
56 .ZERO     2C84 $6          2808 .A          2DB2 .MES        2C30 .W          2AB8 EXP
BE AINT      288A SQRT        2CF6 .RAFG       2D52 .5          2D28 $8          2D5A .ER(
5A .O        2E30 .U          3F88


Y-POINTS:
C8 .R        2808 .A          288A SQRT        2980 ALOG        2AB8 EXP         28BE AINT
```

```
         TOP=     3.1023
         BOT=     3.8359
           S=   134.5649
       DITOP=    38.4762
       DIBOT=    32.9524
        TSTH= 25792.578
        TSTS= 19427.625
      STCRIT= 19622.289
        TSBH= 29999.980
        TSBS= 24548.805
      SBCRIT= 30000.031
END

 VIO OPERATING SYSTEM VERSION 1 REVISION  012 03/04/74 GENERATED  04/30/74  1

JOB HANDLING CHARGE    $   .35 / JOB          .35
30 LINES PRINTED PR2  $ 1.25 / K LN          .15
88 CARDS READ          $ 1.50 / K CD          .13
00 PLOTTER VECTORS     $   .25 / 1000         .02
22 MODEL 70 SECONDS    $25.00 / HOUR          .15
00 MODEL 80 SECONDS    $12.50 / HOUR          .00
                        TOTAL CHARGE $        .79

EIR 490 14731  LOGGED OUT 25/01/74 22:26.  $  24.80 LEFT AFTER    03 LOGINS.
```

STEEL

POI = 0.3

$E = 30*10^6$

AL = 500

B = AL/8 = 62.5

DRA = B/3 = 20.833

D = AL/9=55.556

$HM = 1.37143*B*DRA*AL^2 = 44642.187*10^4$

$SM = B*DRA*AL^2 = 32551.562*10^4$

$W = 0.30396*(1-POI^2)*DSC/E = 276.6*10^{-6}$

Z = 60.129

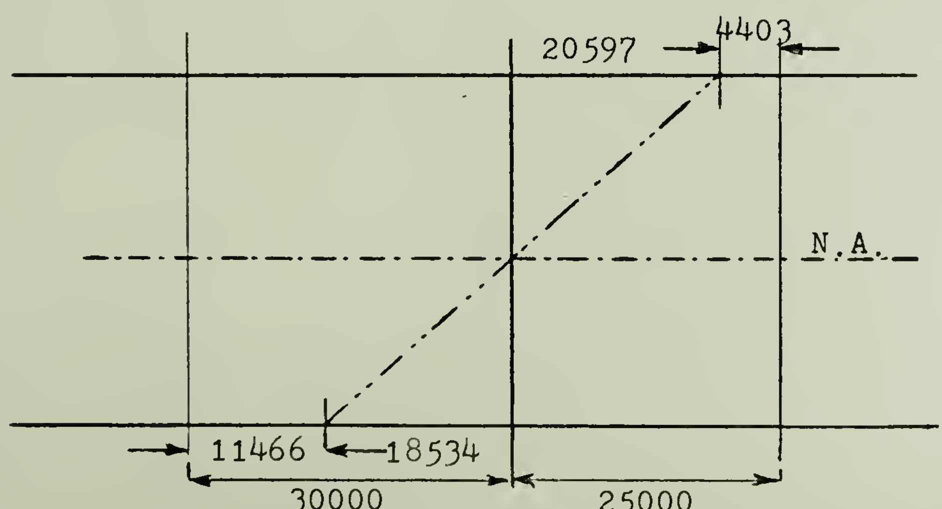
HTOP = 8

HBOT = 20.833

$STR3T = 0.152222*HTOP*Z^2 = 4402.865$ note that this value should be corrected for the Z approximation and actually is slightly smaller

$STR3B = 0.152222*HBOT*Z^2 = 11465.61$

We see from the tertiary stresses obtained that we end up with the following diagram of stress distributions:



From the diagram we see that theneutral axis will end up closer to the bottom and so we must consider BOT > TOP in the formulas.

The same type of diagram will be obtained for 1000'aluminum case since the tertiary stresses obtained in such case are

STR3T = 1498.73

STR3B = 9873.078

For the 1000' steel case the same type of diagram will occur due to the tertiary stresses being

STR3T = 4402.86

STR3B = 29004.

Besides this situation requiring us also to consider the neutral axis closer to the bottom, still another problem arises since STR3B is larger than DST=25000. This case is solved by properly correcting the inaccuracy that was introduced by the Z approximation as exemplified next.

Now let's derive the formulas capable of handling the 500' steel case, the 1000' steel case and the 1000' aluminum case. We must consider BOT > TOP and DITOP > DIBOT

DITOP = D*(B+D)*BOT/P

DIBOT = D*(B*TOP+D*BOT)/P

$I = 4*D^2*BOT*((3*B^2+2*B*D)*TOP+(D^2+2*B*D)*BOT)/P$

where

P = 2*D*BOT+B*(TOP+BOT)

Starting again with the equation

STH*DIBOT = SBH*DITOP

and making

A = DST-STR3T

AB = DSC-STR3B

we obtain

A*DIBOT = AB*DITOP

Knowing that now the top is the thinner plating we anticipate

S = Z*TOP

and may write

$STR3T = 0.152222*HTOP*Z^2$

$STR3B = 0.152222*HBOT*Z^2$

where the Z value in STR3B should be $\frac{S}{BOT}$ which has a smaller value than Z.

We then obtain:

A*D*(B*TOP+D*BOT)/P = AB*D*(B+D)*BOT/P

Simplifying and making

$$AC = (AB*(B+D)-A*D)/(A*B)$$

we obtain

$$TOP = AC*BOT$$

Making now the top to be stressed the most in tension we have.

$$STH = HM*DITOP/I = A$$

Replacing DITOP and I by their equations we have

$$A = \frac{HM*D*(B+D)*BOT}{4*D^2*BOT*((3*B^b+2*B*D)*TOP+(D^2+2*B*D)*BOT)}$$

and obtain

$$BOT = \frac{HM*(B+D)}{A*4*D*(D^2+2*B*D)} - \frac{3*B^2+2*B*D}{D^2+2*B*D}*TOP$$

Making

$$AD = HM*(B+D)/(A*4*D*(D^2+2*B*D))$$

$$AE = (3*B^2+2*B*D)/(D^2+2*B*D)$$

the formulas become

$$BOT = AD-AE*TOP$$

and substituting

$$TOP = AC*BOT$$

we finally have

$$BOT = \frac{AD}{1+AC*AE}$$

The results obtained for the examples chosen are presented next:

```
C     *AL* IS THE LENGHT
      AL=500.
      B=AL/8.
C     *DRA* IS THE DRAFT
      DRA=B/3.
      D=AL/9.
C     *POI* IS THE POISSON'S RATIO OF THE MATERIAL
C     FOR STEEL
      POI=0.3
C     *E* IS THE YOUNG'S MODULUS OF THE MATERIAL
C     FOR STEEL
      E=30.*10.**6
C     *DST* IS THE DESIGN STRESS IN TENSION
      DST=25000.
C     *DSC* IS THE DESIGN STRESS IN COMPRESSION
      DSC=30000.
C     *HM* IS THE HOGGING BENDING MOMENT
      HM=1.37142*B*DRA*AL*AL
C     *SM* IS THE SAGGING BENDING MOMENT
      SM=C*DRA*AL*AL
      A=1.30986*(1.-POI*POI)*DSC/E
      U=SQRT(A)
      Z=1./U
C     *HTOP* IS THE HEAD OF WATER ON DECK
      HTOP=8.
C     *HBOT* IS THE HEAD OF WATER ON BOTTOM
      HBOT=D
      STR3T= .152222*HTOP*Z*Z
      STR38= .152222*HBOT*Z*Z
      A=DST-STR3T
      AB=DSC-STR38
      AC=(AB*(B+D)-A*D)/(A*B)
      AD=HM*(D+B)/(A*4.*D*(D*D+2.*B*D))
      AE=(3.*D*B+2.*B*B)/(D*D+2.*B*D)
C     *TOP* IS THE THICKNESS OF THE TOP PLATING
C     *BOT* IS THE THICKNESS OF THE BOTTOM PLATING
      BOT=AD/(1.+AC*AE)
      TOP=AC*BOT
      WRITE(5,10)TOP
   10 FORMAT('1',22X,'TOP='F10.4)
      WRITE(5,20)BOT
   20 FORMAT(' ',22X,'BOT='F10.4)
C     *S* IS THE SPACING OF LONGITUDINAL STIFFENING MEMBERS
      S=Z*TOP
      WRITE(5,30)S
   30 FORMAT(' ',22X,'S='F10.4)
      P=2.*D*BOT+B*(TOP+BOT)
C     *DITOP* IS THE DISTANCE OF THE TOP FROM THE NEUTRAL AXIS
      DITOP=D*(B*BOT+D*BOT)/P
      WRITE(5,40)DITOP
   40 FORMAT(' ',18X,'DITOP='F10.4)
C     *DIBOT* IS THE DISTANCE OF THE BOTTOM FROM THE NEUTRAL AXIS
```

```
330          DIBOT=A*(2*TOP+ *BOT)/P
354          WRITE(5,52)DIBOT
370       52 FORMAT(' ',18X,'DIBOT='F10.4)
38C   C      *GMI* IS THE MOMENT OF INERTIA OF THE Y SECTION ABOUT *A*
38C          GMI=A*A*A*( *((3.* *+2.*D*D)*TOP*BOT+(D*D+2.*B*F)*BOT*B T)/P
3FC   C      *TSTH*IS THE STRESS ON TOP DUE TO HOGGING
3FC   C      *TSTS*IS THE STRESS ON TOP DUE TO SAGGING
3FC   C      *TSBH*IS THE STRESS ON BOT DUE TO HOGGING
3FC   C      *TSBS*IS THE STRESS ON BOT DUE TO SAGGING
3FC   C      *STCRIT* IS THE CRITICAL STRESS ON TOP
3FC   C      *SBCRIT* IS THE CRITICAL STRESS ON BOT
3FC          TSTH=H *DITOP/G I+STH T
41C          TSTS=S *DITOP/G I+STH T
424          STCRIT=TOP*TOP*E/( .3 396*S*S*(1.-POI*POI))
464          WRITE(5,62)TSTH
48           62 FORMAT(' ',19X,'TSTH=',F10.3)
49A          WRITE(5,72)TSTS
4B6       72 FORMAT(' ',19X,'TSTS=',F10.3)
4D          WRITE(5,82)STCRIT
4EC       82 FORMAT(' ',17X,'STCRIT='F10.3)
528          TSBH=H *DIBOT/G I+ .1 2222*HBOT*S*S/(BOT*BOT)
544          TSBS=S *DIBOT/G I+ .1 2222*HBOT*S*S/(BOT*BOT)
580          SBCRIT= (BOT*BOT*E/( .3 396*S*S*(1.-POI*POI))
5C          WRITE(5,92)TSBH
5DC       92 FORMAT(' ',19X,'TSBH=',F10.3)
5F6          WRITE(5,100)TSBS
612      100 FORMAT(' ',19X,'TSBS=',F10.3)
62C          WRITE(5,110)SBCRIT
648      110 FORMAT(' ',17X,'SBCRIT='F10.3)
664          END
 [S] .U        668[V] AL      672[V] B       0678[V] DRA      0680[V] D
 [V] POI       669 [V] E      069 [S] .R     06 [V] DST       06A8[V] DSC
 [V] HW        6 [V] SY       06 C[V] H      0603[V] U        06  [S] SQRT
 [V] Z         6  [V] HTOP    06 4[V] HBOT   06 3[V] STR3T    06E [V] STR3B
 [V] A         6  [V] AB      06 C[V] AC     07  [V] AD       0714[V] AE
 [V] BOT       071C[V] TOP    022 [L] 10     0  0[S] @I       0256[L] 2
 [V] S         0  8[L] 3      0724[V] P      0728[V] DITOP    0314[L] 4
 [V] DIBOT     3  [L] 52      073 [V] GMI    073C[V] TSTH     074 [V] TSTS
 [V] STCRIT    4  [L] 62      048 [L] 70     04EC[L] 80       0748[V] TSBH
 [V] TSBS      07  [V] SBCRIT 05  [L] 90     0612[L] 100      0648[L] 110
 [S] .V
 EG        L
```

GRAM LABELS:

```
 270 *MAIN*   2EDA .V      2D A .COMP   29AC ALOG   2EE @I     27C4 .R
 002 .ZERO    2 3  $6      2 04 .A      2E2E .MES   2CAC .W    2AB4 EX
 C3A AINT     2 6 SQRT     2072 .BARG   2DCE .S     2AB4 AEXP  2DD6 .E
 DA4 $9       2C 6 .C      2EAC .U      4004
```

RY-POINTS:

```
 7C4 .R       2 C4 .A      2886 SQRT    29AC ALOG   2AB4 AEXP  2AB4 EX
```

```
        IOP=     .971
        BOT=    .4576
          S=   22.3
     DIIOP=   29.2413
     DIBOT=   26.3134
       TST = 2.949.
      TSTS= 19421.
    STCHIT= 2999.
      TSPH= 26072.14
      TSPS= 21059.
    SNCHIT= 45627.762
```

```
VIO OPERATING SYSTEM VERSION 1 REVISION 12 03/04/74 GENERATED 5/02/74

    HANDLING CHARGE      $  .35 / JOB          .3
 37 LINES PRINTED        $ 1.25 / K L          .14
 88 CARDS READ           $ 1.50 / K            .1
    PLOTTER              $  .25 / 10           .0
 21 MODEL 7  SECONDS     $25.00 /              .1
    MODEL 8  SECONDS     $12.60 /              .
                         TOTAL CHARGE          .79

EIR 49  14731  LOGGED OUT 29/09/75 22:41.  $ 17.92 LEFT AFTER    12 LOGINS.
```

We could have obtained TSBH = 30000 by correcting the approximation used Z = S/BOT as is done for the 1000' steel case that follows next.

In this case we already anticipate the use of a Z1 value as done in the previous section and according to the output obtained we will then obtain the correct result.

```
      C       *AL* IS THE LENGHT
              AL=100.
              B=AL/5.75
      C       *DRA* IS THE DRAFT
              DRA=B/3.3
              D=AL/14.
      C       *POI* IS THE POISSON'S RATIO OF THE MATERIAL
      C       FOR STEEL
              POI=0.3
      C       *E* IS THE YOUNG'S MODULUS OF THE MATERIAL
      C       FOR STEEL
              E=30.*10.**6
      C       *DST* IS THE DESIGN STRESS IN TENSION
              DST=25000.
      C       *DSC* IS THE DESIGN STRESS IN COMPRESSION
              DSC=30000.
      C       *HM* IS THE HOGGING BENDING MOMENT
              HM=1.?7143.**DRA*AL*AL
      C       *SM* IS THE SAGGING BENDING MOMENT
              SM=?*DRA*AL*AL
              W=?.3*(1.-POI*POI)*DSC/E
              U=SQRT(W)
              Z=1./U
      C       *HTOP* IS THE HEAD OF WATER ON DECK
              HTOP=8.
      C       *HBOT* IS THE HEAD OF WATER ON BOTTOM
              HBOT=DRA
              STRBT= .152222*HTOP*Z*Z
              Z1=35.
              STRBP= .152222*HBOT*Z1*Z1
              A=DST-STRBT
              A =DSC-STRBP
              AC=(A*(D+D)*A*D)/(A*B)
              AC=HM*(D+D)/(A*4.*D*(D*D+2.*B*D))
              AE=(3.*D*D+2.*B*D)/(D*D+2.*B*D)
      C       *TOP* IS THE THICKNESS OF THE TOP PLATING
      C       *BOT* IS THE THICKNESS OF THE BOTTOM PLATING
              BOT=AC/(1.+AC*AE)
              TOP=AC*BOT
              WRITE(5,10)TOP
           10 FORMAT('1',20X,'TOP='F10.4)
              WRITE(5,20)BOT
           20 FORMAT(' ',20X,'BOT='F10.4)
      C       *S* IS THE SPACING OF LONGITUDINAL STIFFENING MEMBERS
              S=Z*TOP
              WRITE(5,30)S
           30 FORMAT(' ',20X,'S='F10.4)
              P=2.*D*BOT+B*(TOP+BOT)
      C       *DITOP* IS THE DISTANCE OF THE TOP FROM THE NEUTRAL AXIS
              DITOP=D*(B*BOT+D*BOT)/P
              WRITE(5,40)DITOP
           40 FORMAT(' ',10X,'DITOP='F10.4)
```

```
0333      C       *DIBOT* IS THE DISTANCE OF THE BOTTOM FROM THE NEUTRAL AXIS
0333              DIBOT=D*(B*TOP+D*BOT)/P
035C              WRITE(5,50)DIBOT
0372           50 FORMAT(' ',19X,'DIBOT='F10.4)
0394      C       *GMI* IS THE MOMENT OF INERTIA OF THE X SECTION ABOUT N.A.
0394              GMI=4.*(*D*((3.*B*B+2.*B*D)*TOP*BOT+(D*D+2.*B*D)*BOT*BOT)/P
0404      C       *TSTH* IS THE STRESS ON TOP DUE TO HOGGING
0404      C       *TSTS* IS THE STRESS ON TOP DUE TO SAGGING
0404      C       *TSBH* IS THE STRESS ON BOT DUE TO HOGGING
0404      C       *TSBS* IS THE STRESS ON BOT DUE TO SAGGING
0404      C       *STCRIT* IS THE CRITICAL STRESS ON TOP
0404      C       *SBCRIT* IS THE CRITICAL STRESS ON BOT
0404              TSTH=HM*DITOP/GMI+STRBT
0418              TSTS=SM*DITOP/GMI+STRBT
042C              STCRIT=TOP*TOP*E/(0.30396*S*S*(1.-POI*POI))
046C              WRITE(5,60)TSTH
0478           60 FORMAT(' ',19X,'TSTH='F10.3)
0492              WRITE(5,70)TSTS
04BE           70 FORMAT(' ',19X,'TSTS='F10.3)
04D8              WRITE(5,80)STCRIT
04F4           80 FORMAT(' ',17X,'STCRIT='F10.3)
0510              TSBH=HM*DIBOT/GMI+0.158222*HBOT*S*S/(BOT*BOT)
0540              TSBS=SM*DIBOT/GMI+0.158222*HBOT*S*S/(BOT*BOT)
0588              SBCRIT=BOT*BOT*E/(0.30396*S*S*(1.-POI*POI))
05C8              WRITE(5,90)TSBH
05E4           90 FORMAT(' ',19X,'TSBH='F10.3)
05FE              WRITE(5,100)TSBS
061A          100 FORMAT(' ',19X,'TSBS='F10.3)
0634              WRITE(5,110)SBCRIT
0650          110 FORMAT(' ',17X,'SBCRIT='F10.3)
066C              END
0000[S] .U        0670[V] AL        0678[V] B         0680[V] DRA       0688[V] D
0690[V] POI       0698[V] E         0000[S] .R        06A8[V] DST       06B0[V] DSC
06B8[V] HM        06C0[V] SM        06C8[V] W         06D0[V] U         0000[S] SQRT
06D4[V] Z         06D8[V] HTOP      06E0[V] HBOT      06E4[V] STRBT     06EC[V] Z1
06F4[V] STRBH     06F8[V] A         06FC[V] AB        0700[V] AC        0714[V] AD
0728[V] AE        0730[V] BOT       0734[V] TOP       0228[L] 10        0000[S] @I
025F[L] 20        0738[V] S         02A0[L] 30        073C[V] P         0740[V] DITOP
02C0[L] 40        0744[V] DIBOT     0372[L] 50        0748[V] GMI       0754[V] TSTH
0758[V] TSTS      075C[V] STCRIT    0478[L] 60        04BE[L] 70        04F4[L] 80
0760[V] TSBH      0764[V] TSBS      0768[V] SBCRIT    05E4[L] 90        061A[L] 100
0650[L] 110       0000[S] .V
 XEQ          L
 OF
```

PROGRAM LABELS:

```
207C *MAIN*   2EF2 .V      2D22 .COMP   29C4 ALOG    2F00 @I      27DC .
2DEA .ZERO    2D42 36      281C .A      2E46 .MES    2CC4 .W      2ACC E
2C52 AINT     28CE SQRT    2D2A .RARG   2DE6 .5      2ACC AEXP    2DEE .
2DBC $8       2DEE .C      2EC4 .U      421C
```

ENTRY-POINTS:

```
     TCP=      3.5788
     BCT=      3.6860
       S=    215.1802
   DITCP=     36.0863
   DIHCT=     35.3423
    TSTH= 2[illegible]620.[illegible]
    TSTS= 1 421.523
  STCRIT= 2[illegible]909.98[illegible]
    TSFH= 47512.793
    TSFS= 4.[illegible]49.323
  SBCRIT= 31[illegible]24.254
END

CE VIL OPERATING SYSTEM VERSION 1 REVISION  012 03/04/74 GENERATED  05/02/74

 JOB HANDLING CHARGE     $    .35 / JOB          .35
 131 LINES PRINTED PRP  $ 1.25 / K LN          .16
  69 CARDS READ          $ 1.52 / K CD          .13
  00 PLOTTER VECTORS     $    .25 / 1000          .00
  15 MODEL 7[illegible] SECONDS   $5.[illegible] / HOUR          .10
  00  MODEL [illegible] SECONDS   $12.57 / HOUR          .00
                         TOTAL CHARGE $         .74

PEIR 492 14731  LOGGED OUT 29/[illegible]/75 02:48.  $  16.44 LEFT AFTER    14 LOGINS
```

```
C      *AL* IS THE LENGHT
       AL=1000.
       B=AL/5.75
C      *DRA* IS THE DRAFT
       DRA=B/3.3
       D=AL/14.
C      *POI* IS THE POISSON'S RATIO OF THE MATERIAL
C      FOR STEEL
       POI= .3
C      *E* IS THE YOUNG'S MODULUS OF THE MATERIAL
C      FOR STEEL
       E=30.*10.**6
C      *DST* IS THE DESIGN STRESS IN TENSION
       DST=25000.
C      *DSC* IS THE DESIGN STRESS IN COMPRESSION
       DSC=30000.
C      *HM* IS THE HOGGING BENDING MOMENT
       HM=1.37143*B*DRA*AL*AL
C      *SM* IS THE SAGGING BENDING MOMENT
       SM=B*DRA*AL*AL
       W=0.3*3*(1.-POI*POI)*DSC/E
       U=SQRT(W)
       Z=1./U
       *HTOP* IS THE HEAD OF WATER ON DECK
       HTOP=5.
       *HBOT* IS THE HEAD OF WATER ON BOTTOM
       HBOT=DRA
       STRST= .152222*HTOP*Z*Z
       Z1=40.
       STRSB= .152222*HBOT*Z1*Z1
       A=DST-STRST
       AB=DSC-STRSB
       AC=(AB*(D+D)-A*D)/(A*B)
       AD=HM*(D+D)/(A*D*D*(D*D+2.*B*D))
       AE=(3.*D*D+2.*B*D)/(D*D+2.*B*D)
C      *TOP* IS THE THICKNESS OF THE TOP PLATING
C      *BOT* IS THE THICKNESS OF THE BOTTOM PLATING
       BOT=AD/(1.+AC*AE)
       TOP=AC*BOT
       WRITE(5,10)TOP
    1  FORMAT('1',20X,'TOP='F10.4)
       WRITE(5,20)BOT
    20 FORMAT(' ',20X,'BOT='F10.4)
C      *S* IS THE SPACING OF LONGITUDINAL STIFFENING MEMBERS
       S=Z*TOP
       WRITE(5,30)S
    30 FORMAT(' ',22X,'S='F10.4)
       P=2.*D*BOT+B*(TOP+BOT)
C      *DITOP* IS THE DISTANCE OF THE TOP FROM THE NEUTRAL AXIS
       DITOP=D*(B*BOT+D*BOT)/P
       WRITE(5,40)DITOP
    40 FORMAT(' ',18X,'DITOP='F10.4)
```

```
0338      C      *DIBOT* IS THE DISTANCE OF THE BOTTOM FROM THE NEUTRAL AXIS
0338             DIBOT=D*(B*TOP+D*BOT)/P
035C             WRITE(5,50)DIBOT
0378          5  FORMAT(' ',18X,'DIBOT=',F10.4)
0394      C      *GMI* IS THE MOMENT OF INERTIA OF THE X SECTION ABOUT N.A.
0394             GMI=4.*B*D*((D.*B+3.*B*D)*TOP*BOT+(D*D+2.*B*D)*BOT*B*T)/P
0404      C      *ISTH*IS THE STRESS ON TOP DUE TO HOGGING
0404      C      *ISTS*IS THE STRESS ON TOP DUE TO SAGGING
0404      C      *ISBH*IS THE STRESS ON BOT DUE TO HOGGING
0404      C      *ISBS*IS THE STRESS ON BOT DUE TO SAGGING
0404      C      *STCRIT IS THE CRITICAL STRESS ON TOP
0404      C      *SBCRIT IS THE CRITICAL STRESS ON BOT
0404             TSTH=HM*DITOP/GMI+STR3T
0418             TSTS=SM*DITOP/GMI+STR3T
042C             STCRIT=[illegible]/(0.3*394*S*S*(1.-POI*POI))
046C             WRITE(5,60)TSTH
0488          6  FORMAT(' ',19X,'TSTH=',F10.3)
04A2             WRITE(5,70)TSTS
04BE          7  FORMAT(' ',19X,'TSTS=',F10.3)
04D8             WRITE(5,80)STCRIT
04F4          8  FORMAT(' ',17X,'STCRIT=',F10.3)
0510             TSBH=HM*DIBOT/GMI+0.1562[illegible]*HBOT*S*S/(BOT*BOT)
054C             TSBS=SM*DIBOT/GMI+0.1562[illegible]*HBOT*S*S/(BOT*BOT)
0588             SBCRIT=[illegible]/(0.3*3*6*S*S*(1.-POI*POI))
05C8             WRITE(5,90)TSBH
05E4          9  FORMAT(' ',19X,'TSBH=',F10.3)
05FE             WRITE(5,100)TSBS
061A        100  FORMAT(' ',19X,'TSBS=',F10.3)
0634             WRITE(5,110)SBCRIT
0650         11  FORMAT(' ',17X,'SBCRIT=',F10.3)
066C             END
0 [S] .U      0674 [V] AL      0678 [V] B      06[illegible] [V] DRA      06[illegible] [V] D
9[illegible] [V] POI    0698 [V] E      0[illegible] [S] .R     06[illegible] [V] CST    06B [V] [illegible]
B[illegible] [V] HM     06C[illegible] [V] SM     06[illegible] [V] I      06[illegible] [V] U     0[illegible] [S] S[illegible]T
D4 [V] Z      06D8 [V] HTOP    06[illegible] [V] HBOT   06F4 [V] STR3T   06EC [V] Z1
F4 [V] STR3B   06F8 [V] A      0[illegible] [V] AB     07[illegible] [V] AC     0714 [V] AD
2[illegible] [V] AE     073[illegible] [V] BOT    073[illegible] [V] TOP    02[illegible] [L] 10     0[illegible] [S] [illegible]
5E [L] 20     0738 [V] S      0[illegible] [L] 30     073C [V] P      074[illegible] [V] DITOP
1C [L] 40     0744 [V] DIBOT   037[illegible] [L] 50     074[illegible] [V] GMI    0754 [V] TSTH
58 [V] TSTS    075C [V] STCRIT  0[illegible] [L] 60     041E [L] 70     04F4 [L] 80
6[illegible] [V] TSBH   0764 [V] TSBS    07[illegible] [V] SBCRIT  05[illegible]4 [L] 90     061A [L] 1[illegible]
5[illegible] [L] 110    0[illegible] [S] .V
XEQ        L
OF


ROGRAM LABELS:
2070 *MAIN*   2FF2 .V        2C22 .COMP     2CC4 ALOG     2F0C 0T       27DC .[illegible]
2DEA .ZERO    2D4A [illegible]        2[illegible]1C .A       2E46 .MES     2CC4 .[illegible]      2ACC E[illegible]
2C52 AINT     2ECE SQRT      2[illegible] .DARG     2DE6 .5       2ACC AEXP     2DEE .[illegible]
2D8C $8       2DEE .[illegible]        2EC[illegible] .U      4[illegible]1C


ITRY-POINTS:
27DC .R       281C .A        2[illegible] SQRT      2CC4 ALOG     2ACC AEXP     2ACC EX
```

```
          TCP=     3.3[illegible]6
          BOT=     4.4277
            S=   2[illegible]3.6[illegible]
       DITCP=    32.9[illegible]11
       DIRCT=    32.4[illegible]74
        TSTH=  2[illegible]
        TSTS=  1[illegible]421.[illegible]3
      STCRIT=  2[illegible]
        TSBH=  34131.[illegible]5
        TSBS=  [illegible]44[illegible].1[illegible]
      SBCRIT=  5127[illegible]

// END

JCF VIO OPERATING SYSTEM VERSION 1 REVISION [illegible]12 [illegible]3/[illegible]4/74 GENERATED  5/ 2/74

 JOB HANDLING CHARGE   [illegible] / J[illegible]      .35
 131 LINES PRINTED [illegible] 1.25 / K [illegible]      .16
  89 CARDS READ      [illegible] 1.[illegible] / [illegible]      .1[illegible]
  00 PLOTTING VECTORS  [illegible] / 1[illegible]      .[illegible]
  20 MODEL 7 SECONDS [illegible] / [illegible]      .1[illegible]
  00 MODEL [illegible] SECONDS [illegible]12.[illegible] / [illegible]      .[illegible]
                 TOTAL CHARGE [illegible]      .7[illegible]

ERREIR 49[illegible] 14/31 LOGGED OUT [illegible]3/ 9/75 2:[illegible] . [illegible] 15.66 LEFT AFTER [illegible]5 LOGINS
```

Now we see that with an assumed value Z1 = 35 we obtain

S = 215.1808

BOT = 3.686 so Z1 actual = 58.38

TSBH = 47512.793 (too high)

TSBS also too high

The Z1 actual value obtained suggests that we should have assumed an higher Z1 value and with an assumed value Z1 = 40 we then obtain

S = 203.626

BOT = 4.428 so Z1 actual = 45.98

TSBH = 34131.855 (too high)

TSBS also too high

This suggests an assumed Z1 value higher than 40 but now we may interpolate with the two results already obtained and determine the Z1 value that will bring TSBH = DSC = 30000 psi and done properly this new Z1 assumed will end up being Z1 actual.

From interpolation we obtain

$$Z1 = 40 + \frac{(40-35)*(34131.855-30000)}{(47512.793-34131.855)} = 41.544$$

and now assume this value obtaining the following result:

```
0004    C     *AL* IS THE LENGHT
0004          AL=1.[illegible].
000C          B=AL/5.75
0018    C     *DRA* IS THE DRAFT
0018          DRA=B/3.3
0024          D=AL/14.
0030    C     *POI* IS THE POISSON'S RATIO OF THE MATERIAL
0030    C     FOR STEEL
0030          POI=0.3
0030    C     *E* IS THE YOUNG'S MODULUS OF THE MATERIAL
0030    C     FOR STEEL
0030          E=30.*10.**6
0040    C     *DST* IS THE DESIGN STRESS IN TENSION
0040          DST=2[illegible].
0054    C     *DSC* IS THE DESIGN STRESS IN COMPRESSION
0054          DSC=2[illegible].
005C    C     *BM* IS THE HOGGING BENDING MOMENT
005C          BM=1.37143*[illegible]*AL*[illegible])
0074    C     *SM* IS THE SAGGING BENDING MOMENT
0074          SM=[illegible]
0088          [illegible]=0.3[illegible]*(1.-POI*POI)*DSC/E
00A8          [illegible]=SQRT([illegible])
00B4          Z=1./[illegible]
00C0          *HTOP* IS THE HEAD OF WATER ON DECK
00C0          HTOP=[illegible].
00C0          *HBOT* IS THE HEAD OF WATER ON BOTTOM
00C8          HBOT=D+
00DC          STRS1=[illegible].15272+[illegible]TOP*Z+7
00E4          Z1=4.[illegible].+[illegible].*4131.[illegible]55/1[illegible] .938
00F8          STRS =[illegible].15272+[illegible]BOT*Z1*Z1
010C          A=DST-STRS1
0118          AB=DSC-STRS[illegible]
0124          AC=(AB*(B+D)-A*D)/(A*B)
015C          AD=[illegible]*(B+D)/(A*4.*D*(D*[illegible]+2.*B*D))
01A8          AE=(3.*[illegible]+2.*B*D)/([illegible]+2.*B*D)
01F4    C     *TOP* IS THE THICKNESS OF THE TOP PLATING
01F4    C     *BOT* IS THE THICKNESS OF THE BOTTOM PLATING
01F4          BOT=AD/(1.+AC*AE)
020C          TOP=AC*BOT
0218          WRITE(5,10)TOP
0234       10 FORMAT('1',22X,'TOP='F10.4)
024E          WRITE(5,20)BOT
026A       20 FORMAT(' ',22X,'BOT='F10.4)
0284    C     *S* IS THE SPACING OF LONGITUDINAL STIFFENING MEMBERS
0284          S=Z*TOP
0290          WRITE(5,30)S
02AC       30 FORMAT(' ',22X,'S='F10.4)
02C4          P=2.*D*BOT+B*(TOP+BOT)
02E8    C     *DITOP* IS THE DISTANCE OF THE TOP FROM THE NEUTRAL AXIS
02E8          DITOP=[illegible](B*BOT+[illegible]*BOT)/P
02FC          WRITE(5,40)DITOP
0328       40 FORMAT(' ',18X,'DITOP='F10.4)
```

```
0344     C      .DIBOT. IS THE DISTANCE OF THE BOTTOM FROM THE NEUTRAL AXIS
0344            DIBOT=..(B*TOP+ .BOT),F
0368            WRITE(5,50)DIBOT
0384       50   FORMAT(' ',19X,'DIBOT='F10.4)
03AC     C      *GMI* IS THE MOMENT OF INERTIA OF THE X SECTION ABOUT .A.
03AC            GMI=4.*...*F*((..*..*F+2.*D*D)*TOP*BOT+(D*D+2.*B*F)*BOT*.. T)/P
0410     C      *TSTH*IS THE STRESS ON TOP DUE TO HOGGING
0410     C      *TSTS*IS THE STRESS ON TOP DUE TO SAGGING
0410     C      *TSBH*IS THE STRESS ON BOT DUE TO HOGGING
0410     C      *TSBS*IS THE STRESS ON BOT DUE TO SAGGING
0410     C      *STCRIT* IS THE CRITICAL STRESS ON TOP
0410     C      *SBCRIT* IS THE CRITICAL STRESS ON BOT
0410            TSTH=H..DITOP/GMI+STH3T
0424            TSTS=S..DITOP/GMI+STH3T
0438            STCRIT=E*TOP.../(.3.396*S*S*(1.-POI*POI))
0478            WRITE(5,60)TSTH
0494       60   FORMAT(' ',19X,'TSTH=,F10.3)
04AE            WRITE(5,70)TSTS
04CA       70   FORMAT(' ',19X,'TSTS=,F10.3)
04E4            WRITE(5,80)STCRIT
0500       80   FORMAT(' ',17X,'STCRIT='F10.3)
0510            TSBH=H...DIBOT/G..I+..1.2222*HBOT*S*S/(BOT*BOT)
0558            TSBS=S...DIBOT/G..I+..1.2222*HBOT*S*S/(BOT*BOT)
0594            SBCRIT=E.BOT*BOT*./(..3396*S*S*(1.-POI*POI))
05D4            WRITE(5,90)TSBH
05F.       9    FORMAT(' ',19X,'TSBH=,F10.3)
0.0A            WRITE(5,100)TSBS
0626      100   FORMAT(' ',19X,'TSBS=,F10.3)
0640            WRITE(5,110)SBCRIT
065C      110   FORMAT(' ',17X,'SBCRIT='F10.3)
0678            END
0..[S] .H       067C[V] AL       0684[V] B        06.C[V] DRA      0694[V] P
0.[V] POI       06A4[V] E        0000[S] .P       06F4[V] DST      06BC[V] DSC
.C4[V] HM       06CC[V] SM       06D.[V] W        06FC[V] U        0000[S] S..T
.E [V] Z        06E4[V] HTOP     06EC[V] HBOT     06F.[V] STH3T    06F.[V] Z1
.0C[V] STB3B    0710[V] A        0714[V] AB       0718[V] AC       072C[V] A.
.4.[V] AF       074.[V] BOT      074C[V] TOP      0234[L] 10       0000[S] .I
.6 [L] 20       0750[V] S        2AC[L] 30        07F4[V] P        0758[V] DITOP
.2.[L] 40       075C[V] DIBOT    38.[L] 50        0764[V] GMI      076C[V] TSTH
.7 [V] TSTS     0774[V] STCRIT   0494[L] 60       04CA[L] 70       0500[L] 80
.7 [V] TSBH     077C[V] TSBS     078.[V] SBCRIT   05F0[L] 90       0626[L] 100
.5C[L] 110      0000[S] .V
.NEG        L
.F


.ROGRAM LABELS:
 2070 *MAIN*    2F.A .V     203A .COMP    290C ALOG     2F18 @I      27F4 .9
 2E02 .ZERO     21.. *F     2.34 .A       2F5F .MES     2CDC .N      2AE4 E.
 2C6A AINT      2.FA SQRT   2.A2 .RANG    2.FF .5       2AF4 AEXP    2E.6 .F
 2004 *R        2F.6 .L     2EDC .H       4734


.TRY-POINTS:
```

```
      TOP=    3.3 35
      BOT=    4.74 4
        S=  193.62
   DITOP=    49.831
   DIBOT=    31.3947
    TSTH= 24959.9 3
    TSTS= 19421.516
  STCKIT= 29956.9 2
     TSB = 3 191.643
    TSBS= 25817.  4
  SBCKIT= 61955. 23
```

CP VIO OPERATING SYSTEM VERSION 1 REVISION 012 03/04/74 GENERATED 5/ /74

```
 CR HANDLING CHARGE     $  .35 / JOB        .35
131 LINES PRINTED      $ 1.25 / K L       .16
 89 CARDS READ          $ 1.  / K C       .1
 CP PLOTTER VECTORS     $  .0  / 1         .0
 22 MODEL 70 SECONDS    $25.   / HR        .15
 CP MODEL 80 SECONDS    $12.   / HR        .0
                        TOTAL CHARGE       .79
```

EIR 400 14731 LOGGED OUT 09/ /7 03:01. $ 14.87 LEFT AFTER 6 LOGINS.

We see that TSBH is just a little too high and the same happens with TSBS; here it might be the case that TSBS should have been the one under consideration for the choice of a Z1 value. Nevertheless for the purpose of this work this example shows the procedure to be used along with the equation derived. The accuracy obtained can be total. Here we assumed Z1 = 41.544 and ended up with Z1 actual = 41.83 which is close enough for our purpose and TSBH and TSBS is very close to what it should be to use the material effectively.

```
C       *AL* IS THE LENGHT
        AL=1000.
        B=AL/5.75
C       *DRA* IS THE DRAFT
        DRA=B/3.3
        D=AL/14.
C       *POI* IS THE POISSON'S RATIO OF THE MATERIAL
C       FOR ALUMINUM
        POI=0.33
C       *E* IS THE YOUNG'S MODULUS OF THE MATERIAL
C       FOR ALUMINUM
        E=10.*10.**6
C       *DST* IS THE DESIGN STRESS IN TENSION
        DST=25 .0.
C       *DSC* IS THE DESIGN STRESS IN COMPRESSION
        DSC=31000.
C       *HM* IS THE HOGGING BENDING MOMENT
        HM=1.37143*B*DRA*AL*AL
C       *SM* IS THE SAGGING BENDING MOMENT
        SM=B*DRA*AL*AL
        W=0.30396*(1.-POI*POI)*DSC/E
        U=SQRT(W)
        Z=1./U
C       *HTOP* IS THE HEAD OF WATER ON DECK
        HTOP=5.
C       *HBOT* IS THE  HEAD OF WATER ON BOTTOM
        HBOT=DRA
        STR3T=7.15222*HTOP*Z*Z
        STR3B=7.15222*HBOT*Z*Z
        A=DST-STR3T
        AB=DSC-STR3B
        AC=(AB*(B+D)-A*D)/(A*B)
        AD=HM*(B+D)/(A*4.*D*(D*D+2.*B*D))
        AE=(3.*B*B+2.*B*D)/(D*D+2.*B*D)
C       *TOP* IS THE THICKNESS OF THE TOP PLATING
C       *BOT* IS THE THICKNESS OF THE BOTTOM PLATING
        BOT=AD/(1.+AC*AE)
        TOP=AC*BOT
        WRITE(5,10)TOP
     10 FORMAT('1',20X,'TOP='F10.4)
        WRITE(5,20)BOT
     20 FORMAT(' ',20X,'BOT='F10.4)
C       *S* IS THE SPACING OF LONGITUDINAL STIFFENING MEMBERS
        S=Z*TOP
        WRITE(5,30)S
     30 FORMAT(' ',22X,'S='F10.4)
        P=2.*D*BOT+B*(TOP+BOT)
C       *DITOP* IS THE DISTANCE OF THE TOP FROM THE NEUTRAL AXIS
        DITOP=D*(B*BOT+D*BOT)/P
        WRITE(5,40)DITOP
     40 FORMAT(' ',18X,'DITOP='F10.4)
C       *DIBOT* IS THE DISTANCE OF THE BOTTOM FROM THE NEUTRAL AXIS
```

```
0330            DIBOT=D*(B*TOP+D*BOT)/P
0354            WRITE(5,50)DIBOT
0370         50 FORMAT(' ',18X,'DIBOT='F10.4)
038C      C     *GMI* IS THE MOMENT OF INERTIA OF THE X SECTION ABOUT N.A.
038C            GMI=4.*D*D*((3.*B*B+2.*B*D)*TOP*BOT+(D*D+2.*B*D)*BOT*BOT)/P
03FC      C     *TSTH*IS THE STRESS ON TOP DUE TO HOGGING
03FC      C     *TSTS*IS THE STRESS ON TOP DUE TO SAGGING
03FC      C     *TSBH*IS THE STRESS ON BOT DUE TO HOGGING
03FC      C     *TSBS*IS THE STRESS ON BOT DUE TO SAGGING
03FC      C     *STCRIT* IS THE CRITICAL STRESS ON TOP
03FC      C     *SBCRIT* IS THE CRITICAL STRESS ON BOT
03FC            TSTH=HM*DITOP/GMI+STR3T
0412            TSTS=SM*DITOP/GMI+STR3T
0424            STCRIT=TOP*TOP*E/(0.30396*S*S*(1.-POI*POI))
0464            WRITE(5,60)TSTH
0480         60 FORMAT(' ',19X,'TSTH='F10.3)
049A            WRITE(5,70)TSTS
04B6         70 FORMAT(' ',19X,'TSTS='F10.3)
04D0            WRITE(5,80)STCRIT
04EC         80 FORMAT(' ',17X,'STCRIT='F10.3)
0508            TSBH=HM*DIBOT/GMI+0.152222*HBOT*S*S/(BOT*BOT)
0544            TSBS=SM*DIBOT/GMI+0.152222*HBOT*S*S/(BOT*BOT)
0580            SBCRIT=BOT*BOT*E/(0.30396*S*S*(1.-POI*POI))
05C0            WRITE(5,90)TSBH
05DC         90 FORMAT(' ',19X,'TSBH='F10.3)
05F6            WRITE(5,100)TSBS
0612        100 FORMAT(' ',19X,'TSBS='F10.3)
062C            WRITE(5,110)SBCRIT
0648        110 FORMAT(' ',17X,'SBCRIT='F10.3)
0664            END
0[S] .U       0668[V] AL     0670[V] B       0678[V] DRA     0680[V] D
8[V] POI      0690[V] F      0000[S] .R      069C[V] DST     06A4[V] DSC
C[V] HM       06B4[V] SM     06B8[V] W       06C4[V] U       0000[S] SQRT
8[V] Z        06CC[V] HTOP   06D4[V] HBOT    06D8[V] STR3T   06E0[V] STR3B
4[V] A        06E8[V] AB     06EC[V] AC      0700[V] AD      0714[V] AE
C[V] BOT      0720[V] TOP    0224[L] 10      0000[S] @I      0256[L] 20
4[V] S        0298[L] 30     0728[V] P       072C[V] DITOP   0314[L] 40
0[V] DIBOT    0370[L] 50     0734[V] GMI     0740[V] TSTH    0744[V] TSTS
8[V] STCRIT   0480[L] 60     04B6[L] 70      04EC[L] 80      074C[V] TSBH
0[V] TSBS     0754[V] SBCRIT 05DC[L] 90      0612[L] 100     0648[L] 110
0[S] .V
XEQ        L

OGRAM LABELS:
2070 *MAIN*   2EDE .V        2D0E .COMP      29B0 ALOG       2EEC @I        27C8 .R
2DD6 .ZERO    2D34 $6        2808 .A         2E32 .MES       2CB0 .W        2AB8 EXP
2C3E AINT     28BA SQRT      2D76 .FARG      2DD2 .5         2AB8 AEXP      2DDA .ER
2DA8 $8       2DDA .O        2EB0 .U         4008

RY-POINTS:
27C8 .R       2808 .A        28BA SQRT       29B0 ALOG       2AB8 AEXP      2AB8 EXP
```

```
          TOP=     2.9992
          BOT=     3.7608
            S=   105.2122
        DITOP=    32.4761
        DIBOT=    32.9524
         TSTH= 24999.988
         TSTS= 18635.031
       STCRIT= 3 020.004
         TSPH= 24476.047
         TSPS= 2 954.855
       SPCRIT= 47172.344
END

CF VIC OPERATING SYSTEM VERSION 1 REVISION 012 03/04/74 GENERATED 05/02/74

JOB HANDLING CHARGE      $   .35 / JOB          .35
132 LINES PRINTED PR2   $ 1.25 / K LN           .16
 88 CARDS READ          $ 1.50 / K CC           .13
 00 PLOTTER VECTORS     $  .25 / 1 00           .00
 15 ODEL 70 SECONDS     $25.00 / HOUR           .10
 00 ODEL 50 SECONDS     $12.50 / HOUR           .00
                         TOTAL CHARGE $         .74

RREIR 492 14731  LOGGED OUT 09/09/74 02:45.  $  17.18 LEFT AFTER   13 LOGINS.
```

This last example shows that TSBH is low and the Z approximation used in the formulas here again should be corrected as already exemplified in order to bring it closer to the DSC value.

CONCLUSION

From this work the author is led to conclude that there is no simplified approach to the neutral axis location in the midship section, capable of handling properly all or only a majority of cases. It is advisable to look into each particular situation by first gaining some insight at what the diagrams of stress distributions may look like as exemplified in several sections. The two last sections exemplify well why this may be of some advantage and specially the last section which shows that while at first it was expected for the examples studied a neutral axis closer to the top, actually the results ended up requiring a neutral axis closer to the bottom and a new set of formulas had to be derived.

As a future development for this work it is here suggested that a more ship like cross section could be analysed as a step forward towards obtaining a method of determination of scantlings as direct as possible. This next step should consider the derivation of proper formulas for DITOP, DIBOT and I involving only the plate thicknesses as unknowns. It should be considered then, in order to simplify the problem., a standard type of frame and its scantlings should be constant throughout the midship section.

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Thesis
D16175
153771
Da Silva
Strength of ships -
on the neutral axis
location.