SSC-227

TANKER TRANSVERSE STRENGTH ANALYSIS USER'S MANUAL

SHIP STRUCTURE COMMITTEE

1972

SHIP STRUCTURE COMMITTEE

AN INTERAGENCY ADVISORY
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SHIP STRUCTURE COMMITTEE
U.S. COAST GUARD HEADQUARTERS
WASHINGTON, D.C. 20591

SR-196
1972

Dear Sir:

One of the most important goals of the Ship Structure Committee is the improvement of methods for design and analysis of ship hull structures. This report is the third in a sequence of four Ship Structure Committee reports on a project directed toward development of an accurate, but less expensive, computer aided structural analysis method.

This report contains the User's Manual for the transverse strength analysis portion of the program. Other reports of this project are:

SSC-225 - Structural Analysis of Longitudinally Framed Ships

SSC-226 - Tanker Longitudinal Strength Analysis--User's Manual and Computer Program

SSC-228 - Tanker Transverse Strength Analysis--Programmer's Manual

Comments on this report would be welcomed.

Sincerely,

W. F. REA, III
Rear Admiral, U. S. Coast Guard
Chairman, Ship Structure Committee

SSC-227

Final Report

on

Project SR-196, "Computer Design of
Longitudinally Framed Ships"

to the

Ship Structure Committee

TANKER TRANSVERSE STRENGTH ANALYSIS

USER'S MANUAL

by

R. Nielson, P. Y. Chang, and L. C. Deschamps
COM/CODE Corporation

under

Department of the Navy
Naval Ship Engineering Center
Contract No. N00024-70-C-5219

U. S. Coast Guard Headquarters
Washington, D. C.
1972

ABSTRACT

This report, the third in a sequence of four Ship Structure Committee Reports on a method for performing structural analysis of a tanker hull, contains the User's Manual for the transverse strength analysis portion of the program.

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INTRODUCTION:

This user's manual is applicable to the transverse analysis program only. What follows defines all necessary input parameters and the formats in which they are to be entered into the computer. No attempt has been made to instruct the user in the optimum modeling techniques for a given analysis study.

PROGRAM DESCRIPTION:

The transverse strength analysis for longitudinally framed ships combines the techniques of finite elements with a newly developed method of uncoupling the three dimensional structure so as to reduce computational time and to permit a finer mesh analysis without the usual resulting degradation in numerical precision.

Transverse members are modeled with appropriate quadrilateral plate (linearly varying stress) elements and bar (axially elastic) stiffeners. Near the edges of the transverse openings, triangular plate (constant stress) elements may also be generated. All longitudinal members spanning transverses are represented by by-planar beam elements which carry all external loads directly onto the transverses. Shear loads upon the transverse members as developed by the side shell and webbing of the longitudinal bulkhead are treated as additional loading functions upon the ship's structure.

Most finite elements are generated automatically by the program. Various other convenience features such as printer simulated plots of the transverse finite element definition have been implemented.

Output from the analysis include both plate and bar stresses within the transverse member's structure.

While the present analysis capability is limited to loading conditions which are symmetric about the hull centerline, the unsymmetric cases may be analyzed by manual superposition of the antisymmetric component solutions.

GENERAL GUIDELINES:

1. Each data card (except for appropriate system control cards) must begin with the proper label. The label must begin in Column 1 exactly as given in the data sheets that follow. A label must not exceed 10 characters in length.
2. No blank cards are permitted between data cards.
3. All numerical information must be entered per the appropriate format. All field lengths for numerical data are 10 columns.
4. All numerical data must be given with a decimal point. No data is presumed to be integer.
5. The program initiates a large number of data checks, primarily with regard to the order of the input cards. Any error detected by the program will cause a premature program termination at the conclusion of the given data input subject to where the error was found.
6. It is recommended that the user allow the program to make at least one complete pass through the entire data card deck before a complete stress solution is attempted. The user may make such a preliminary pass by omitting the EIGENS card which normally follows the last data card defining the loading condition upon the structure. See sample execution times.

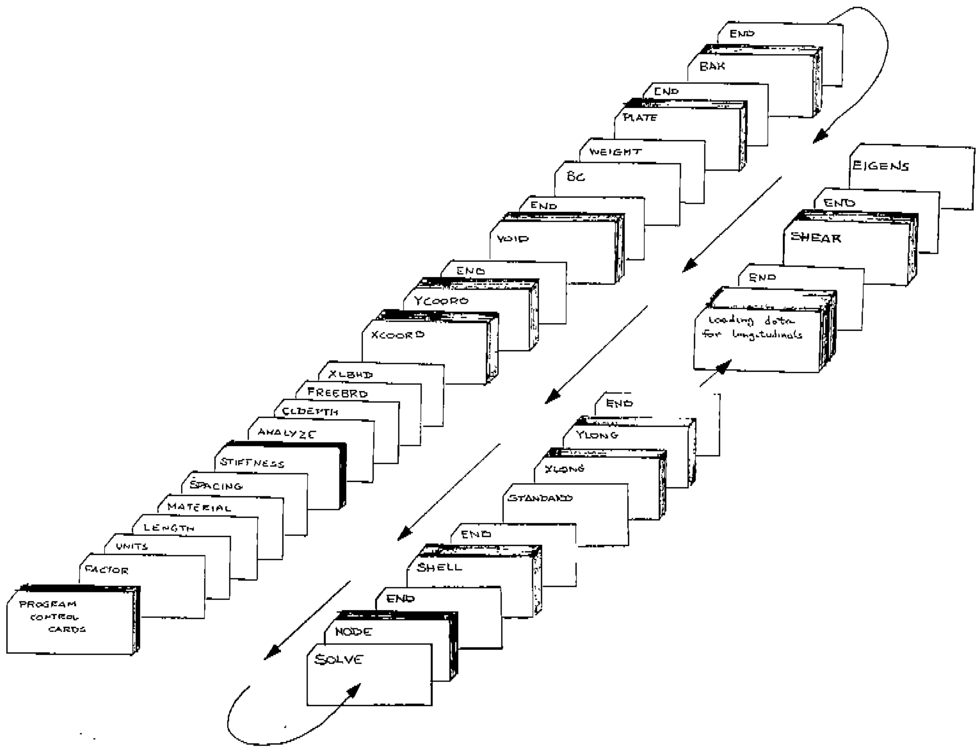


Fig. 1. Order of Card Input for Transverse Analysis

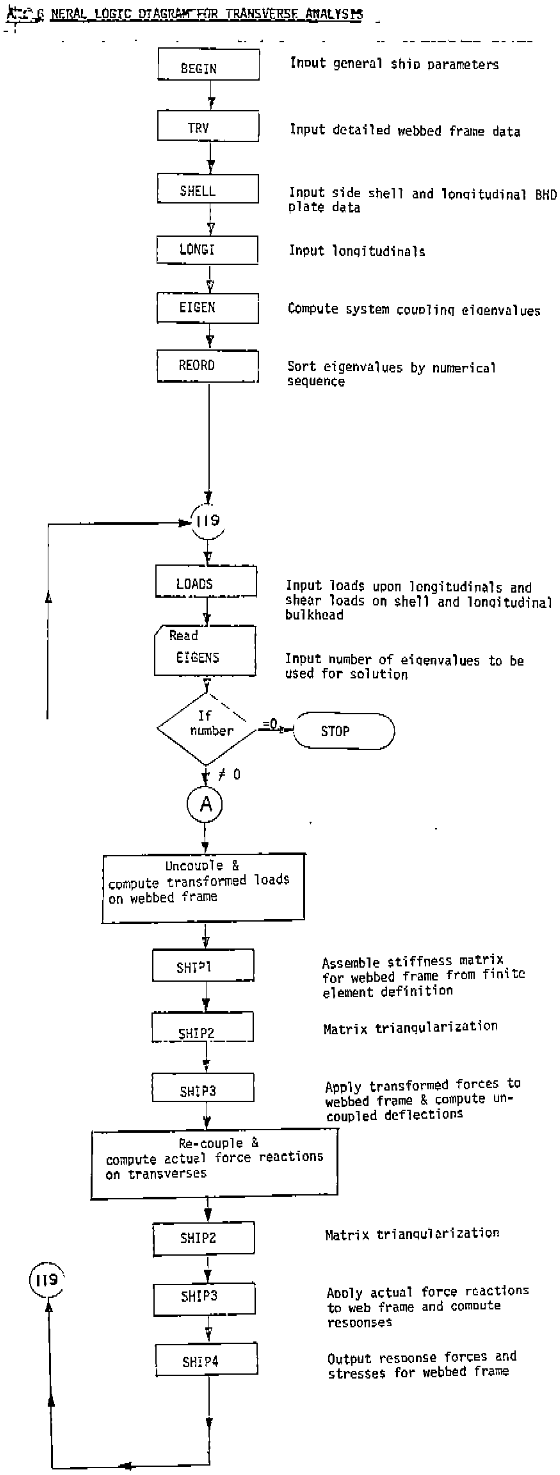
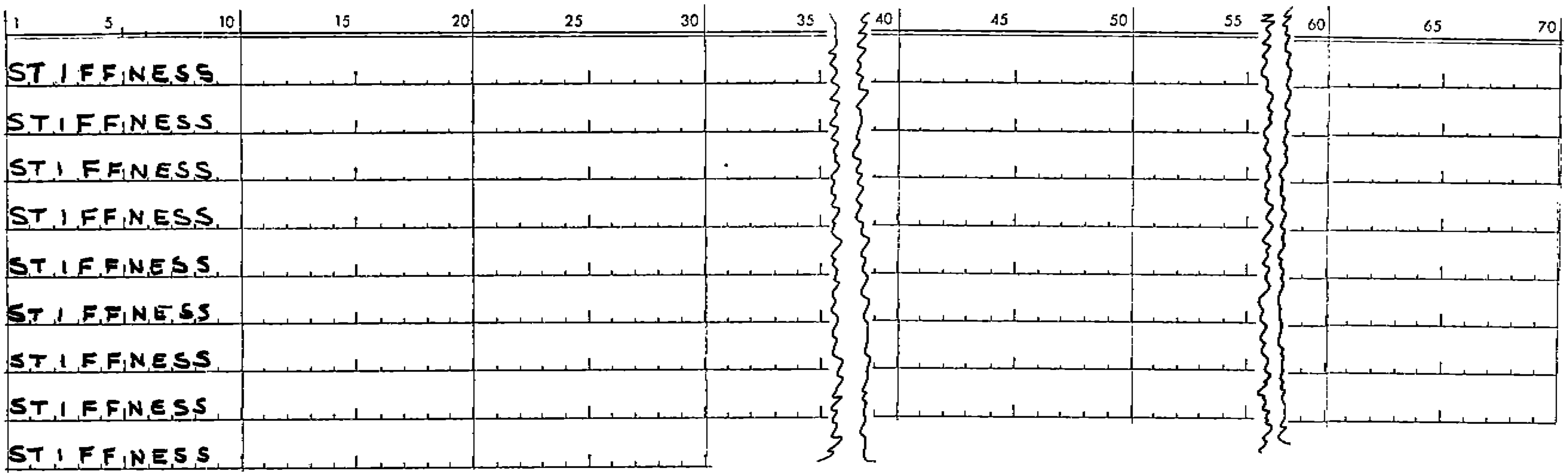


Fig. 1a. General Logic Diagram For Transverse Analysis

Card				Description
	1 5 10	15 20	25 30	
FACTOR				Conversion factor to be multiplied by the program to all units of length of all data items that have a length dimension. This includes Young's modulus and distributed loads.
		force	length	
UNITS				Alphanumeric labels for the output force units (cc 11-20) and the output length units after conversion (cc 21-30)
LENGTH				Length of ship's section under analysis
		E	μ	
MATERIAL				Material properties:E(cc 11-20), and Poisson's (cc 21-30)
SPACING				Spacing for transverse members (assumed equal)

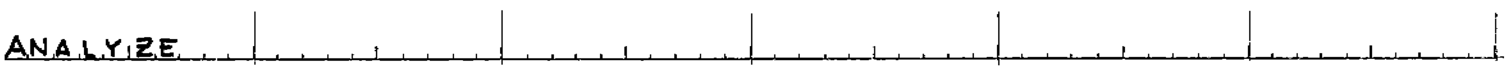
NOTE: a given ship's section can have no more than 50 transverse members (not including the ends)

STIFFNESS is a measure of each transverse member's relative stiffness when modeled as a shear beam. Normally, the web frame is assigned a nominal stiffness of 1.0. The more substantial members such as the oil-tight bulkhead, then, would be given an appropriately higher value. Enter these relative stiffness ratios in position order of transverses starting with the aft-most member in the ship section being included in the analysis. Use only enough STIFFNESS cards to complete the stiffness definition of all transverses involved (maximum = 50).



No END card is needed in this section. The computer will be looking for a total of (LENGTH/SPACING) + 1 ratios to be entered. Do not enter blank ratios within the list (from card columns 11 through 70 per card) unless the list is exhausted on the last STIFFNESS card.

The ANALYZE card permits the user to select up to 5 different transverse members within the ship's section for detailed analysis of the stresses. Enter those transverses by their relative position from the aft end of the section.



Columns 1–20	
CLDEPTH	Depth of transverse at ℄
FREEBRD	Vertical height of transverse from bottom to outboard edge of deck
XLBHD	Horizontal distance of longitudinal bulkhead from side shell

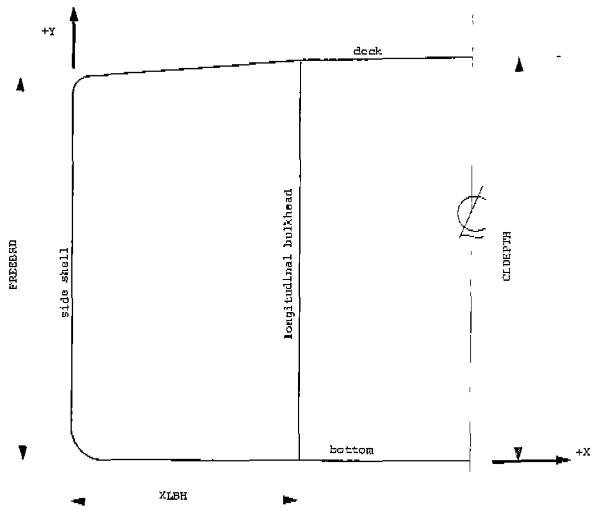


Fig. 2. General Parameters for a Transverse Section

<u>FINITE ELEMENT DEFINITION OF THE TRANSVERSES SUBMITTED FOR ANALYSIS:</u>

The user will create a rectangular grid system for the automatic generation of the plate and bar finite elements comprising the given transverse member. This pattern must be developed from horizontal/vertical rows and columns, which normally fit quite well the pattern arrangement for tanker longitudinals within the midbody section. A finer element mesh is possible by including extra rows and columns. Not all longitudinals need coincide with the row/column intersections (called nodes), but those that do not should reflect this condition by adjusting their moments of inertia. It is also possible to lump longitudinals at a given node, although some loss in accuracy should be expected particularly near the area of such modeling approximation.

The following figure illustrates a sample web frame that has been defined within the row/column network.

All nodes are assumed to be the joining points for all plate and bar elements. All longitudinals are assumed to pass through appropriate nodes.

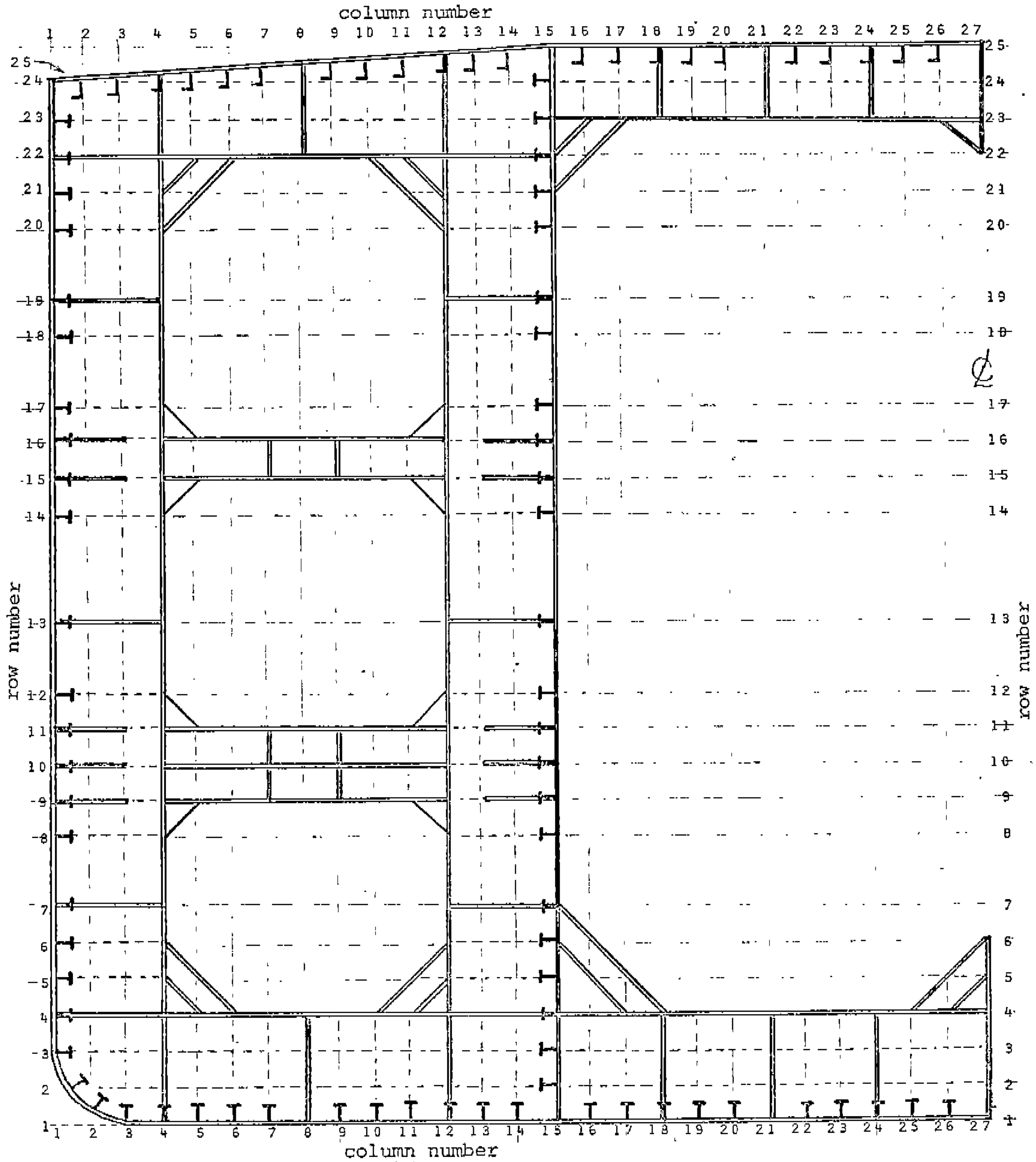


Fig. 3. Finite Element Grid Definition for Transverse Frame

XCOORD cards define the X-coordinates of the bottom longitudinals as measured horizontally from the side shell. Use only as many of these cards as needed (maximum = 40). Each of these coordinates will mark a <u>column</u> in the finite element grid for the transverses. The program will automatically assemble all XCOORD's in numerical order starting at the side shell.

1 5 10	15 20
XCOORD	
XCOORD	
XCOORD	
XCOORD	
XCOORD	
XCOORD	
XCOORD	
XCOORD	
XCOORD	
XCOORD	
XCOORD	
XCOORD	
XCOORD	
XCOORD	
XCOORD	
XCOORD	
XCOORD	
XCOORD	
XCOORD	
XCOORD	

1 5 10	15 20
XCOORD	
XCOORD	
XCOORD	
XCOORD	
XCOORD	
XCOORD	
XCOORD	
XCOORD	
XCOORD	
XCOORD	
XCOORD	
XCOORD	
XCOORD	
XCOORD	
XCOORD	
XCOORD	
XCOORD	
XCOORD	
XCOORD	
XCOORD	

YCOORD cards define the Y-coordinates of the shell longitudinals as measured vertically from the bottom (or base line). Use only as many of these cards as needed (maximum = 25). Each of these coordinates will mark a row in the finite element grid for the transverses. The program will automatically arrange all YCOORDs in numerical order starting from the bottom.

An END card is required after all coordinates have been entered.

1 5 10	15 20
YCOORD	
YCOORD	
YCOORD	
YCOORD	
YCOORD	
YCOORD	
YCOORD	
YCOORD	
YCOORD	
YCOORD	
YCOORD	
YCOORD	
YCOORD	
YCOORD	
YCOORD	
YCOORD	
YCOORD	
YCOORD	
YCOORD	
YCOORD	

1 5 10	15 20
YCOORD	
YCOORD	
YCOORD	
YCOORD	
YCOORD	

END	

The VOID cards permit selective areas of the grid nodes within the transverse rectangular grid pattern to be declared void of plate elements. Normally, a quadrilateral plate element will be generated within the boundaries of each 4-node rectangle. If one of the nodes (located by its row/column coordinates) has been declared void, a suitable triangular plate element will be generated instead. If any two nodes are voided, no plate element will be generated for that grid rectangle. Voided areas, however, will not affect bar elements spaning nodes so declared. Any number of VOID cards are permitted. An END card must follow.

1 5 10	start row 15 20	end row 25 30	start column 35 40	end column 45 50
VOID				
VOID				
VOID				
VOID				
VOID				
VOID				
VOID				
VOID				
VOID				
VOID				
VOID				
VOID				
VOID				
VOID				
VOID				
VOID				
VOID				
VOID				
VOID				
VOID				
VOID				

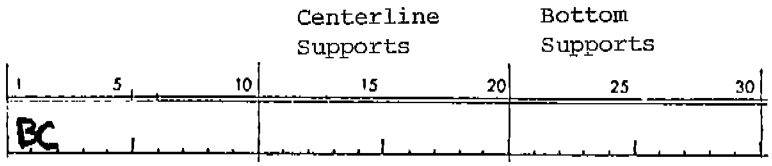
END

Boundary Conditions:

The BC card (for Boundary Conditions) defines what direction deflections are presumed restricted along the hull center line and at the support assumed located at the bottom longitudinal beneath the longitudinal bulkhead. As input to this card, a special code is used:

1.0 means restricted x-deflections (normally at C.L.)

0.0 means restricted y-deflections (normally at bottom)



The WEIGHT card prescribes the weighting factor applied to the boundary supports, which are not treated as indeterminants. Normally a weighting factor of 1.0 is used; a larger number holds the support more firmly, although care should be taken not to use too high a value since numerical problems may result.

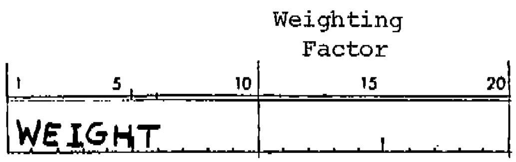


PLATE cards define various plate thickness areas within the grid pattern. Plate so defined covering VOID areas, however, will automatically be ignored.

Different plate thicknesses should not be defined for the same area of the transverse section since only the first thickness will be used.

The order given for the start and end rows and columns is quite arbitrary. These coordinates merely provide the edge boundaries for the given plate thickness.

Use as many PLATE cards as needed (maximum = 50).

An END card is required to follow.

1–10	thickness (11–20)	start row (21–30)	end row (31–40)	start column (41–50)
PLATE				
PLATE				
PLATE				
PLATE				
PLATE				
PLATE				
PLATE				
PLATE				
PLATE				
PLATE				
PLATE				
PLATE				
PLATE				
PLATE				
PLATE				
PLATE				
PLATE				
PLATE				
PLATE				
PLATE				
PLATE				

END

BAR cards define various bar element cross-sectional areas for all stiffeners, face plates, and flanges normal to the transverse plane. Included in this list of elements should be portions of deck, bottom, side shell, and longitudinal bulkhead plate material which contribute to stiffening adjacent transverse plating.

Different bar areas should not be defined for the same node spans since only the first area entered in the input stream will be used.

A given bar may span any number of nodes as long as the nodes are all in the same row, or all in the same column, or on a 1:1 diagonal within the grid network.

Since bars are uni-directional, care must be taken in specifying the start and end rows and columns. The start row must coincide with the same node as the start column; the same applies for the end node.

Use as many BAR cards as needed (maximum = 100).

An END card is required to follow the last BAR card.

1 5 10	area 15	start row 25	end row 30 35	start column 45 50	end column 55 60
BAR					
B.A.R					
B.A.R					
B.A.R					
B.A.R					
B.A.R					
B.A.R					
B.A.R					
B.A.R					
B.A.R					
B.A.R					
B.A.R					
B.A.R					
B.A.R					
B.A.R					
B.A.R					
B.A.R					
B.A.R					
B.A.R					
B.A.R					
BAR					

END

The SOLVE card allows the user to select the type of solution output desired. Enter one of the following options available:

1.0 for node forces only

2.0 for node forces and element stresses

3.0 for element stresses only

1 5 10	15 20
SOLVE	

NODE cards define those nodes that have been selected for output. A maximum of 100 may be so selected. If element forces are to be generated for output, all elements joining the given NODE will automatically have stresses provided in the output.

1 5 10	row 15 20	column 25 30
NODE		
NODE		
NODE		
NODE		
NODE		
NODE		
NODE		
NODE		
NODE		
NODE		
NODE		
NODE		
NODE		
NODE		
NODE		
NODE		
NODE		
NODE		
NODE		
NODE		

1 5 10	row 15 20	node 25 30
NODE		
NODE		
NODE		
NODE		
NODE		
NODE		
NODE		
NODE		
NODE		
NODE		
NODE		
NODE		
NODE		
NODE		
NODE		
NODE		
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NODE		
NODE		
NODE		
NODE		
NODE		
NODE		
NODE		
NODE		
NODE		
NODE		
NODE		
NODE		

END

SHELL defines the shell plate length and thickness for longitudinals along both the side shell and along the longitudinal bulkhead. This data is used to distribute the shear loads generated by the longitudinal strength analysis onto the transverse members.

An END card _is_ required following the last SHELL card.

1 5 10	row 15	20 plate length 25 30	shell thickness 35 40	bulkhead thickness 45 50
SHELL				
SHELL				
SHELL				
SHELL				
SHELL				
SHELL				
SHELL				
SHELL				
SHELL				
SHELL				
SHELL				
SHELL				
SHELL				
SHELL				
SHELL				
SHELL				
SHELL				
SHELL				
SHELL				
SHELL				
SHELL				

END

DEFINITION OF LONGITUDINALS:

STANDARD defines the moment of inertia and cross-sectional area of the standard or typical longitudinal within the ship structure. Only for this particular longitudinal will influence coefficients be computed. With usually very little loss of solution accuracy, the corresponding influence coefficients for the remaining longitudinals are obtained by a simple stiffness proportioning. This procedure greatly reduces overall computational time during the analysis uncoupling.

1 5 10	moment of inertia 15 20	area 25 30
STANDARD		

The following data sheets define all longitudinal members to be modeled. Use as many appropriate cards as needed. Note that two types of cards may be used: XLONG and YLONG. If a number of longitudinals are identical along a given row and occur in sequence, use XLONG. If a number of longitudinals are identical along a given column and occur in sequence, use YLONG. Either XLONG or YLONG may be used for longitudinals which follow no such sequence but must be defined independently.

There is no required order to the use of XLONG and YLONG cards. However, an END card must follow the last of this set.

1 – 10	15 I_x	25 I_y	30 – 35 row	40 – 50 start column	50 – 60 end column
XLONG					
XLONG					
XLONG					
XLONG					
XLONG					
XLONG					
XLONG					
XLONG					
XLONG					
XLONG					
XLONG					
XLONG					
XLONG					
XLONG					
XLONG					
XLONG					
XLONG					
XLONG					
XLONG					
XLONG					
XLONG					

	I_y	I_x	column	start row	end row
1 5 10	15 20	25	30 35	40 45	50 55 60
YLONG					
YLONG					
YLONG					
YLONG					
YLONG					
YLONG					
YLONG					
YLONG					
YLONG					
YLONG					
YLONG					
YLONG					
YLONG					
YLONG					
YLONG					
YLONG					
YLONG					
YLONG					
YLONG					
YLONG					
YLONG					
END					

DEFINITION OF LOADING CONDITIONS:

All loads acting upon the ship section are assumed to be acting upon only the longitudinals. Along the length of a longitudinal, loads may be almost any combination of concentrated and uniformly distributed forces which act at any arbitrary location on the member. All forces are defined as either X or Y components relative to the global coordinate system prescribed for the transverses.

The general order of loading input is as follows:

1. Define all loading forces of a common direction sense, both concentrated and/or uniform, as applied to a given longitudinal.
2. List all longitudinals so loaded. If there are longitudinals which have similar loads that differ only by a proportional factor, these too may be entered in the list.
3. Repeat steps 1. and 2. above for each set of longitudinal loadings.
4. END card.

The following are the available load cards:

XFORCE, concentrated force acting in the X-direction
YFORCE, concentrated force acting in the Y-direction
XUNIFORM, uniformly distributed load acting in X-direction
YUNIFORM, UNIFORMLY distributed load acting in Y-direction

Note that under step 1 above, X and Y force components cannot be mixed, but must be entered separately.

The listing of longitudinals under a given set of loading forces is done via XLONG and YLONG cards. Note that these cards are somewhat different from those of the same label used to define the longitudinals. However, their use here for loadings is much the same idea as where strings of longitudinals in a horizontal (XLONG) or vertical (YLONG) sequence may be listed in one statement. These cards also provide for proportional factors which will be applied to the load magnitudes directly. Note that if this factor is left blank, or zero, the program will assume a factor of 1.0.

An END card is required after the last XLONG or YLONG which concludes the last loading set.

The following prescribes the formats for each of the loading cards. The loads are given in sub-sets of location (or starting location) from the aft-end of the longitudinal and the corresponding signed magnitude. All loads listed in this manner per card should be entered in location order; the program will ignore all blank or zero location entries past the first one entered on a given card. Note that the uniform loads are listed by their start location; their end location is assumed to be either the forward end of the longitudinal or the start location for the next uniform load.

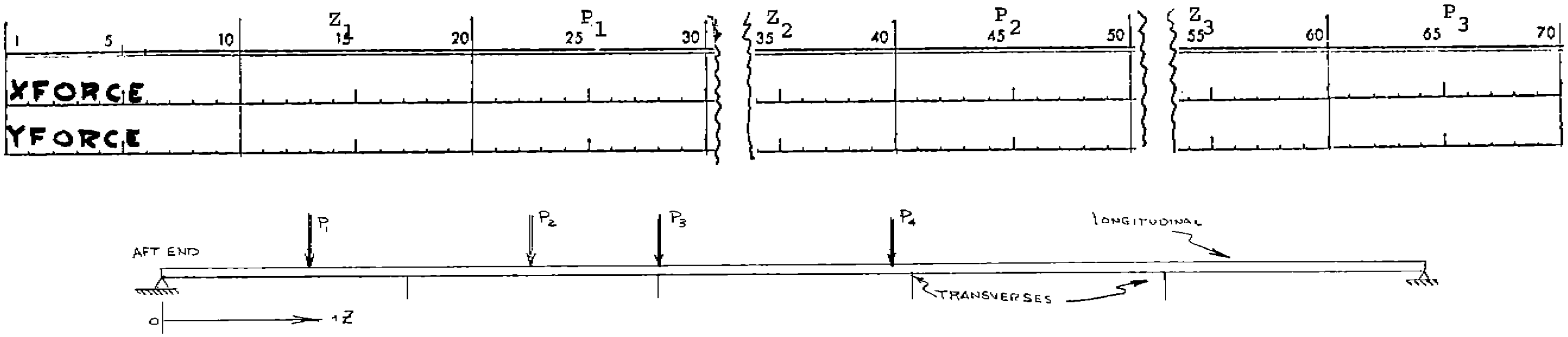


Fig. 4. Concentrated Forces on Longitudinals

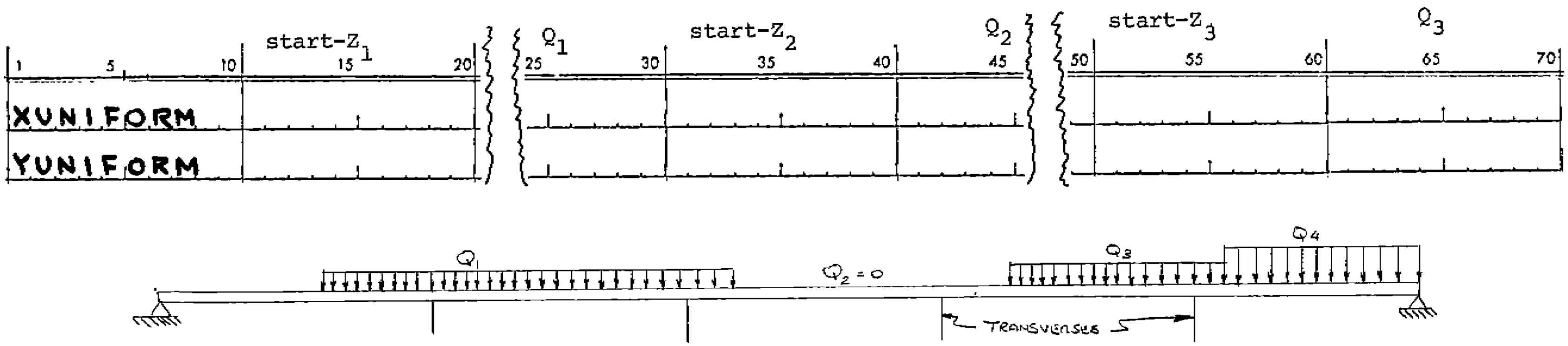
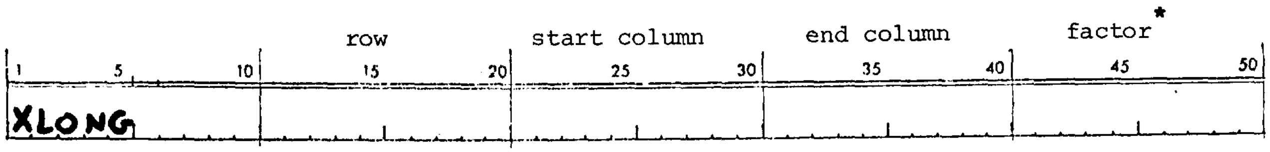
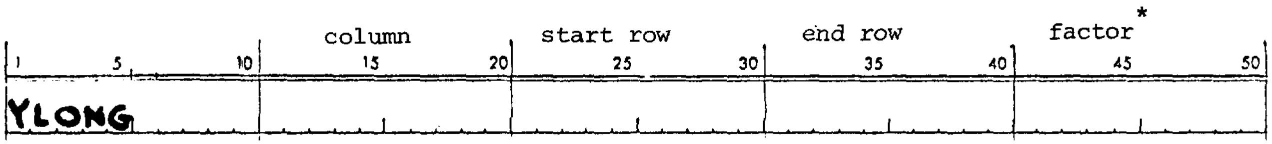


Fig. 5. Uniformly Distributed Loads on Longitudinals

The following prescribes the formats for each of the XLONG and YLONG cards that define what longitudinals specifically pertain to the given loading subset.





A given longitudinal (or sets of identically or similarly loaded longitudinals) may have any number of X and Y loads applied. However, for any given load set, all forces must be of the same component direction; the complimentary set of loads will have to follow with these longitudinals re-stated with the appropriate XLONG and YLONG cards. Also, within a given component load set, the user is limited to 50 concentrated forces and 20 uniform loads, which are entered with the appropriate number of X(Y)FORCE and X(Y)UNIFORM cards. If still more loads exist, they must be entered as a separate load set with the longitudinals re-stated.

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* The proportional factor permits the given loading subset condition to be adjusted by a constant proportion for the given set of longitudinals. If the

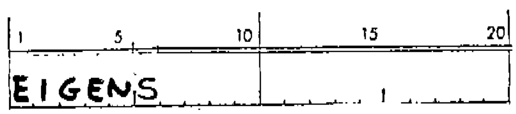
ser must insert the appropriate combinations of XFORCE, YFORCE, XUNIFORM and YUNIFORM data cards with the nding XLONG and YLONG cards below. The last card for this set of loading cards must be an End card. LABEL

SHEAR cards define shear loads upon the transverses as computed from the longitudinal strength calculations. These loads are actually the shear drops across each transverse as computed along both the side shell and the longitudinal bulkhead.

An END card is required following the last SHEAR card.

1 5 10	transverse number from astern 15 20	side shell shear 25 30	bulkhead shear 35 40
SHEAR			
SHEAR			
SHEAR			
SHEAR			
SHEAR			
SHEAR			
SHEAR			
SHEAR			
SHEAR			
SHEAR			
SHEAR			
SHEAR			
SHEAR			
SHEAR			
SHEAR			
SHEAR			
SHEAR			
SHEAR			
SHEAR			

EIGENS is the last card for the complete loading condition definition, after all load sets have been entered with their appropriate X(Y)LONG CARDS. The EIGEN card permits the user to employ some judgment in selecting the number of EIGEN modes which should be necessary to provide adequate solutions. Theoretically, there are an equal number of EIGEN modes as there are transverse members in the ship section. However, it is often not necessary to employ all of these modes within the solution process, particularly if the loading condition is not too irregular along the length of the section. For example, if the overall loading pattern is uniform over the entire section, only the first mode should be necessary. If the load pattern changes direction only once along the length of the section, probably just two modes will suffice. However, if the loading pattern is considerably irregular in that it changes directional sign frequently along the length of the section, it may be best to use all modes (= number of transverses).



NOTE: All input should be checked first by the transverse analysis program before a complete solution is attempted. Omitting the EIGENS card will cause the program to terminate prior to the execution of the larger part of the stress solution processing. See sample execution times.

SAMPLE PROBLEM

The following pages offer a sample of the input phase of the program. Portions of the output have been omitted for the purpose of clarifying the input data. The webbed frame of this sample problem is illustrated in Figure 3.

TRANSVERSE STRENGTH ANALYSIS OF LONGITUDINALLY FRAMED SHIPS
BY COM/CODE CORPORATION
****

CONVERSION FACTOR IS APPLIED TO ALL DIMENSIONAL UNITS OF LENGTH
FACTOR 1.000
UNITS K G C M

LENGTH OF SHIP SECTION TO BE ANALYZED
LENGTH 15402.000

YOUNGS MODULUS, POISSONS RATIO
MATERI .205E+04 .300

SPACING BETWEEN TRANSVERSES
SPACIN 513.400

STIFFNESS FACTORS OF ALL TRANSVERSES IN ORDER FROM STERN

STIFFN	1.000	1.000	2.460	1.000	1.000	5.600
STIFFN	1.000	1.000	2.460	1.000	1.000	5.600
STIFFN	1.000	1.000	2.460	1.000	1.000	2.460
STIFFN	1.000	1.000	5.600	1.000	1.000	2.460
STIFFN	1.000	1.000	2.460	1.000	1.000	

LIST TRANSVERSE BY POSITION FROM STERN THAT ARE TO BE ANALYZED
ANALYZ 16.000

FINITE ELEMENT DEFINITION OF TRANSVERSE
****

CLDEPT	2565.000	XCOORD	2344.000
FREEBR	2450.000	XCOORD	2438.000
XLBHD	1310.000	YCOORD	0.000
XCOORD	0.000	YCOORD	90.000
XCOORD	89.000	YCOORD	180.000
XCOORD	182.000	YCOORD	264.000
XCOORD	276.000	YCOORD	348.000
XCOORD	370.000	YCOORD	432.000
XCOORD	464.000	YCOORD	516.000
XCOORD	558.000	YCOORD	684.000
XCOORD	652.000	YCOORD	768.000
XCOORD	746.000	YCOORD	852.000
XCOORD	840.000	YCOORD	936.000
XCOORD	934.000	YCOORD	1020.000
XCOORD	1028.000	YCOORD	1188.000
XCOORD	1122.000	YCOORD	1440.000
XCOORD	1216.000	YCOORD	1524.000
XCOORD	1310.000	YCOORD	1608.000
XCOORD	1404.000	YCOORD	1692.000
XCOORD	1498.000	YCOORD	1860.000
XCOORD	1592.000	YCOORD	1944.000
XCOORD	1686.000	YCOORD	2112.000
XCOORD	1780.000	YCOORD	2196.000
XCOORD	1874.000	YCOORD	2280.000
XCOORD	1968.000	YCOORD	2364.000
XCOORD	2062.000	YCOORD	2450.000
XCOORD	2156.000	YCOORD	2565.000
XCOORD	2250.000	END	-0.000

DEFINITION OF VOID AREAS OF TRANSVERSE
****

	START ROW	END ROW	START COL	END COL
VOID	7.	21.	16.	27.
VOID	22.	22.	17.	26.
VOID	6.	6.	17.	26.
VOID	5.	5.	18.	25.
VOID	6.	8.	5.	11.
VOID	5.	5.	6.	10.
VOID	12.	14.	5.	11.
VOID	17.	20.	5.	11.
VOID	21.	21.	6.	10.
VOID	1.	1.	1.	1.
END	-0.	-0.	-0.	-0.

```
 1   * * * * * * * * * * * * * * * * * * * * * * * *
 2 * * * * * * * * * * * * * * * * * * * * * * * * *
 3 * * * * * * * * * * * * * * * * * * * * * * * * *
 4 * * * * * * * * * * * * * * * * * * * * * * * * *
 5 * * * * *           * * *       * *       * * * * *
 6 * * * *             * * *       * *         * * * *
 7 * * * *             * * *       * *         * * * *
 8 * * * *             * * *       * *         * * * *
 9 * * * *             * * *       * *         * * * *
10 * * * *             * * *       * *         * * * *
11 * * * * *           * * *       * *       * * * * *
12 * * * * * * * * * * * * * * * * * * * * * * * * *
13 * * * * * * * * * * * * * * * * * * * * * * * * *
14 * * * * * * * * * * * * * * * * * * * * * * * * *
15 * * * * * * * * * * * * * * * * * * * * * * * * *
16 * * * * * *                                 * * * *
17 * * * * *                                     * * *
18 * * * *                                       * * *
19 * * * *                                       * * *
20 * * * *                                       * * *
21 * * * *                                       * * *
22 * * * *                                       * * *
23 * * * *                                       * * *
24 * * * *                                       * * *
25 * * * *                                       * * *
26 * * * * *                                     * * *
27 * * * * * *                                 * * * *
```

```
     BOUNDARY CONDITIONS
***************************************************

          RESTRICTED X-DEFLECTION = 1
          RESTRICTED Y-DEFLECTION = 0

              C.L.      BOTTOM
           SUPPORTS  SUPPORTS
BC              1.000     0.000
WEIGHT          1.000

    THERE ARE 10 C.L. SUPPORTS

    C.L. SUPPORTS ARE DEFINED FOR ROWS
 1  2  3  4  5  6 22 23 24 25

    SUPPORT  AT BOTTOM IS LOCATED ON COL 15 (NODE14)
```

ROW NUMBERING SYSTEM

COL	ROW 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
2	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
3	2	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
4	3	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
5	4	5	5	5	5	0	0	0	5	5	5	0	0	0	5	5	0	0	0	0	5	5	5	5	5
6	5	6	6	6	0	0	0	0	6	6	6	0	0	0	6	6	0	0	0	0	0	6	6	6	6
7	6	7	7	7	0	0	0	0	7	7	7	0	0	0	7	7	0	0	0	0	0	7	7	7	7
8	7	8	8	8	0	0	0	0	8	8	8	0	0	0	8	8	0	0	0	0	0	8	8	8	8
9	8	9	9	9	0	0	0	0	9	9	9	0	0	0	9	9	0	0	0	0	0	9	9	9	9
10	9	10	10	10	0	0	0	0	10	10	10	0	0	0	10	10	0	0	0	0	0	10	10	10	10
11	10	11	11	11	6	0	0	0	11	11	11	0	0	0	11	11	0	0	0	0	6	11	11	11	11
12	11	12	12	12	7	5	5	5	12	12	12	5	5	5	12	12	5	5	5	5	7	12	12	12	12
13	12	13	13	13	8	6	6	6	13	13	13	6	6	6	13	13	6	6	6	6	8	13	13	13	13
14	13	14	14	14	9	7	7	7	14	14	14	7	7	7	14	14	7	7	7	7	9	14	14	14	14
15	14	15	15	15	10	8	8	8	15	15	15	8	8	8	15	15	8	8	8	8	10	15	15	15	15
16	15	16	16	16	11	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	16	16	16	16
17	16	17	17	17	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	17	17	17
18	17	18	18	18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	18	18	18
19	18	19	19	19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	19	19	19
20	19	20	20	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	20	20	20
21	20	21	21	21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	21	21	21
22	21	22	22	22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	22	22	22
23	22	23	23	23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	23	23	23
24	23	24	24	24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	24	24	24
25	24	25	25	25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	25	25	25
26	25	26	26	26	13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	26	26	26
27	26	27	27	27	14	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	17	27	27	27

DEFINITION OF PLATE THICKNESSES

	THICKNESS	START ROW	END ROW	START COL	END COL	PLATE NO.
PLATE	1.200	22.	25.	1.	15.	(1)
PLATE	1.200	23.	25.	15.	27.	(2)
PLATE	1.400	11.	22.	1.	4.	(3)
PLATE	1.400	11.	22.	12.	15.	(4)
PLATE	1.600	4.	11.	1.	4.	(5)
PLATE	1.600	4.	11.	12.	15.	(6)
PLATE	1.800	1.	4.	1.	8.	(7)
PLATE	1.400	1.	4.	8.	15.	(8)
PLATE	2.350	1.	4.	15.	21.	(9)
PLATE	1.600	1.	4.	21.	27.	(10)
PLATE	2.100	4.	6.	4.	12.	(11)
PLATE	1.400	8.	15.	4.	12.	(12)
PLATE	1.500	15.	16.	4.	12.	(13)
PLATE	1.400	16.	22.	4.	12.	(14)
PLATE	1.400	21.	23.	15.	17.	(15)
PLATE	1.200	22.	23.	26.	27.	(16)
PLATE	2.100	4.	7.	15.	18.	(17)
PLATE	1.400	4.	6.	25.	27.	(18)
END	-0.000	-0.	-0.	-0.	-0.	(19)

NO. OF AREAS OF COMMON THICKNESSES (50) =18

DEFINITION OF PLATE THICKNESSES

****

COL	ROW 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
1	0	7	7	7	5	5	5	5	5	5	5	3	3	3	3	3	3	3	3	3	3	3	1	1	1
2	7	7	7	7	5	5	5	5	5	5	5	3	3	3	3	3	3	3	3	3	3	3	1	1	1
3	7	7	7	7	5	5	5	5	5	5	5	3	3	3	3	3	3	3	3	3	3	3	1	1	1
4	7	7	7	11	11	11	5	12	12	12	12	12	12	12	13	14	14	14	14	14	14	14	1	1	1
5	7	7	7	11	11	0	0	0	12	12	12	0	0	0	13	14	0	0	0	0	14	14	1	1	1
6	7	7	7	11	0	0	0	0	12	12	12	0	0	0	13	14	0	0	0	0	0	14	1	1	1
7	7	7	7	11	0	0	0	0	12	12	12	0	0	0	13	14	0	0	0	0	0	14	1	1	1
8	8	8	8	11	0	0	0	0	12	12	12	0	0	0	13	14	0	0	0	0	0	14	1	1	1
9	8	8	8	11	0	0	0	0	12	12	12	0	0	0	13	14	0	0	0	0	0	14	1	1	1
10	8	8	8	11	0	0	0	0	12	12	12	0	0	0	13	14	0	0	0	0	0	14	1	1	1
11	8	8	8	11	11	0	0	0	12	12	12	0	0	0	13	14	0	0	0	0	14	14	1	1	1
12	8	8	8	11	11	11	6	12	12	12	12	12	12	12	13	14	14	14	14	14	14	14	1	1	1
13	8	8	8	8	6	6	6	6	6	6	6	4	4	4	4	4	4	4	4	4	4	4	1	1	1
14	8	8	8	8	6	6	6	6	6	6	6	4	4	4	4	4	4	4	4	4	4	4	1	1	1
15	9	9	9	17	17	17	17	6	6	6	6	4	4	4	4	4	4	4	4	4	15	15	15	2	2
16	9	9	9	17	17	17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	15	15	2	2
17	9	9	9	17	17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	15	2	2
18	9	9	9	17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2	2
19	9	9	9	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2	2
20	9	9	9	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2	2
21	10	10	10	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2	2
22	10	10	10	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2	2
23	10	10	10	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2	2
24	10	10	10	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2	2
25	10	10	10	18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2	2
26	10	10	10	18	18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	16	2	2
27	10	10	10	18	18	18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	16	16	2	2

DEFINITION OF BAR ELEMENTS

****

	AX	START ROW	END ROW	START COL	END COL	
BAR	1257.830	1.	1.	2.	27.	(1)
BAR	1257.830	1.	2.	2.	1.	(2)
BAR	1257.830	2.	4.	1.	1.	(3)
BAR	1232.160	4.	24.	1.	1.	(4)
BAR	1309.170	25.	25.	1.	27.	(5)
BAR	135.000	1.	25.	4.	4.	(6)
BAR	135.000	1.	25.	12.	12.	(7)
BAR	40.000	23.	23.	15.	27.	(8)
BAR	40.000	22.	22.	1.	15.	(9)
BAR	718.760	22.	25.	8.	8.	(10)
BAR	718.760	23.	25.	21.	21.	(11)
BAR	795.770	1.	4.	8.	8.	(12)
BAR	795.770	1.	4.	21.	21.	(13)
BAR	130.000	9.	9.	4.	12.	(14)
BAR	130.000	10.	10.	4.	12.	(15)
BAR	130.000	11.	11.	4.	12.	(16)
BAR	140.000	15.	15.	4.	12.	(17)
BAR	140.000	16.	16.	4.	12.	(18)
BAR	63.250	9.	11.	7.	7.	(19)
BAR	63.250	9.	11.	9.	9.	(20)
BAR	63.250	15.	16.	7.	7.	(21)
BAR	63.250	15.	16.	9.	9.	(22)
BAR	75.000	4.	4.	1.	15.	(23)
BAR	744.430	1.	6.	27.	27.	(24)
BAR	744.430	22.	25.	27.	27.	(25)
BAR	24.000	20.	22.	4.	6.	(26)
BAR	24.000	20.	22.	12.	10.	(27)
BAR	24.000	21.	23.	15.	17.	(28)
BAR	18.000	21.	22.	4.	5.	(29)
BAR	18.000	21.	22.	12.	11.	(30)
BAR	18.000	22.	23.	15.	16.	(31)
BAR	18.000	22.	23.	27.	26.	(32)
BAR	18.000	4.	5.	5.	4.	(33)
BAR	18.000	4.	5.	11.	12.	(34)
BAR	18.000	4.	5.	26.	27.	(35)
BAR	75.000	4.	6.	6.	4.	(36)
BAR	75.000	4.	6.	10.	12.	(37)
BAR	75.000	4.	7.	18.	15.	(38)
BAR	21.600	4.	6.	17.	15.	(39)
BAR	50.000	4.	6.	25.	27.	(40)
BAR	273.000	4.	4.	15.	27.	(41)
BAR	75.000	1.	4.	18.	18.	(42)
BAP	75.000	1.	4.	24.	24.	(43)
BAR	70.000	23.	25.	18.	18.	(44)
BAR	70.000	23.	25.	24.	24.	(45)
BAR	75.000	7.	7.	1.	4.	(46)
BAR	75.000	7.	7.	12.	15.	(47)
BAR	75.000	13.	13.	1.	4.	(48)
BAR	75.000	13.	13.	12.	15.	(49)
BAR	75.000	19.	19.	1.	4.	(50)
BAR	75.000	19.	19.	12.	15.	(51)
BAR	75.000	9.	9.	1.	3.	(52)
BAR	75.000	9.	9.	13.	15.	(53)
BAR	75.000	10.	10.	1.	3.	(54)
BAR	75.000	10.	10.	13.	15.	(55)
BAR	75.000	11.	11.	1.	3.	(56)
BAR	75.000	11.	11.	13.	15.	(57)
BAR	75.000	15.	15.	1.	3.	(58)
BAR	75.000	15.	15.	13.	15.	(59)
BAR	21.600	1.	4.	5.	5.	(60)
BAR	75.000	16.	16.	1.	3.	(61)
BAR	75.000	16.	16.	13.	15.	(62)
END	-0.000	-0.	-0.	-0.	-0.	(63)

NO. BAR ELEMENTS (100) 62

OUTPUT SPECIFICATIONS
****

NODF FORE ONLY = 1
FORCE AND STRFSS = 2
STRESS ONLY = 3

SOLVE 2.000

NODES SELECTED FOR OUTPUT

	ROW	COL			
NODE	1.	6.	NODE	5.	13.
NODE	2.	6.	NODE	5.	14.
NODE	3.	6.	NODE	5.	15.
NODE	4.	6.	NODE	7.	12.
NODE	1.	10.	NODE	7.	13.
NODE	2.	10.	NODE	7.	14.
NODE	3.	10.	NODE	7.	15.
NODE	4.	10.	NODE	15.	1.
NODE	1.	19.	NODE	15.	2.
NODE	2.	19.	NODE	15.	3.
NODE	3.	19.	NODE	15.	4.
NODE	4.	19.	NODE	15.	12.
NODE	1.	23.	NODE	15.	13.
NODE	2.	23.	NODE	15.	14.
NODE	3.	23.	NODE	15.	15.
NODE	4.	23.	NODE	20.	1.
NODE	1.	25.	NODE	20.	2.
NODE	2.	25.	NODE	20.	3.
NODE	3.	25.	NODE	20.	4.
NODE	4.	25.	NODE	20.	13.
NODE	5.	1.	NODE	20.	14.
NODE	5.	2.	NODE	20.	15.
NODE	5.	3.	NODE	22.	6.
NODE	5.	4.	NODE	23.	6.
NODE	7.	1.	NODE	24.	6.
NODE	7.	2.	NODE	25.	6.
NODE	7.	3.	NODE	23.	18.
NODE	7.	4.	NODE	24.	18.
NODE	5.	12.	NODE	25.	18.
			END	-0.	-0.

	ROW	PLATE LENGTH	SHELL THICK	BHD THICK
SHELL	2.000	84.000	2.450	1.850
SHELL	3.000	84.000	2.450	1.850
SHELL	4.000	84.000	2.450	1.900
SHELL	5.000	84.000	2.400	1.900
SHELL	6.000	84.000	2.400	1.900
SHELL	7.000	126.000	2.400	1.850
SHELL	8.000	126.000	2.400	1.800
SHELL	9.000	84.000	2.400	1.800
SHELL	10.000	84.000	2.400	1.650
SHELL	11.000	84.000	2.400	1.650
SHELL	12.000	126.000	2.400	1.650
SHELL	13.000	210.000	2.400	1.550
SHELL	14.000	168.000	2.400	1.400
SHELL	15.000	84.000	2.400	1.400
SHELL	16.000	84.000	2.400	1.350
SHELL	17.000	126.000	2.400	1.350
SHELL	18.000	126.000	2.400	1.300
SHELL	19.000	126.000	2.400	1.250
SHELL	20.000	126.000	2.400	1.250
SHELL	21.000	84.000	2.400	1.250
SHELL	22.000	84.000	2.400	1.425
SHELL	23.000	87.000	2.400	1.600
SHELL	24.000	158.000	0.000	1.600
END	-0.000	-0.000	-0.000	-0.000

18	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0378
19	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0379
20	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0380
21	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0381

DEFINITION OF LONGITUDINALS

****

	I	AX			
STANDA	171926.000	393.000			

	IX	IY	ROW (COL)	STRT COL (STRT ROW)	END COL (END ROW)
XLONG	.23000E+04	.30000E+06	1.	22.	26.
XLONG	.23000E+04	.35000E+06	1.	16.	20.
XLONG	.23000E+04	.41000F+06	1.	12.	14.
XLONG	.23000E+04	.45000E+06	1.	9.	11.
XLONG	.23000E+04	.53000F+06	1.	6.	7.
XLONG	.23000E+04	.59000E+06	1.	4.	5.
XLONG	.23000E+04	.61000E+06	1.	2.	3.
XLONG	.12300E+06	.32800E+08	1.	27.	27.
XLONG	.36400E+05	.95200E+07	1.	21.	21.
XLONG	.33300E+05	.92100E+07	1.	8.	8.
XLONG	.10000E+02	.66462E+05	25.	2.	7.
XLONG	.10000E+02	.66462E+05	25.	9.	14.
XLONG	.10000E+02	.66462E+05	25.	16.	20.
XLONG	.10000E+02	.66462E+05	25.	22.	26.
XLONG	.45000E+04	.79300E+07	25.	27.	27.
XLONG	.26000E+04	.32870E+07	25.	21.	21.
XLONG	.26000E+04	.43700E+07	25.	8.	8.
YLONG	.23500E+06	.30000E+04	1.	2.	2.
YLONG	.21000E+06	.30000E+04	1.	3.	4.
YLONG	.19000E+06	.30000E+04	1.	5.	5.
YLONG	.15500E+06	.30000E+04	1.	6.	6.
YLONG	.23200E+06	.30000E+04	1.	7.	8.
YLONG	.15500E+06	.30000E+04	1.	9.	10.
YLONG	.12650E+06	.30000E+04	1.	11.	11.
YLONG	.18900E+06	.30000E+04	1.	12.	12.
YLONG	.37900E+06	.30000E+04	1.	13.	13.
YLONG	.21000F+06	.30000E+04	1.	14.	14.
YLONG	.90000E+05	.30000E+04	1.	15.	16.
YLONG	.84000E+05	.30000E+04	1.	17.	18.
YLONG	.60000E+05	.30000E+04	1.	19.	20.
YLONG	.21000E+05	.20000E+04	1.	21.	23.
YLONG	.32000E+05	.20000E+04	15.	2.	2.
YLONG	.14500E+06	.20000E+04	15.	3.	4.
YLONG	.15800E+06	.20000E+04	15.	5.	6.
YLONG	.23700E+06	.20000F+04	15.	7.	8.
YLONG	.15800E+06	.20000F+04	15.	9.	10.
YLONG	.90000E+05	.20000E+04	15.	11.	11.
YLONG	.13500E+06	.20000E+04	15.	12.	12.
YLONG	.19000E+06	.20000F+04	15.	13.	13.
YLONG	.10000E+06	.20000E+04	15.	14.	14.
YLONG	.50000E+05	.20000F+04	15.	15.	16.
YLONG	.70000E+05	.20000E+04	15.	17.	18.
YLONG	.50000E+05	.20000F+04	15.	19.	20.
YLONG	.21000F+05	.20000E+04	15.	21.	23.
YLONG	.15000E+05	.10000E+04	15.	24.	24.
END	-0.	-0.	-0.	-0.	-0.

**THERE ARE A TOTAL OF 95 LONGITUDINALS

LONGITUDINAL NUMBERING SYSTEM
****

C
O
L ROW

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
1	27	54	81	108	122	132	140	148	163	178	193	201	209	217	232	247	255	263	271	279	289	306	0	0
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	361
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	362
3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	363
4	0	0	0	0	1	1	1	0	0	0	1	1	1	0	0	1	1	1	1	0	0	0	0	364
5	0	0	0	1	1	1	1	0	0	0	1	1	1	0	0	1	1	1	1	1	0	0	0	365
6	0	0	0	1	1	1	1	0	0	0	1	1	1	0	0	1	1	1	1	1	0	0	0	366
7	0	0	0	1	1	1	1	0	0	0	1	1	1	0	0	1	1	1	1	1	0	0	0	367
8	0	0	0	1	1	1	1	0	0	0	1	1	1	0	0	1	1	1	1	1	0	0	0	368
9	0	0	0	1	1	1	1	0	0	0	1	1	1	0	0	1	1	1	1	1	0	0	0	369
10	0	0	0	0	1	1	1	0	0	0	1	1	1	0	0	1	1	1	1	0	0	0	0	370
11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	371
12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	372
13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	373
0	41	68	95	117	129	139	147	162	177	192	200	208	216	231	246	254	262	270	278	288	303	320	347	0
15	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	375
16	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	376
17	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	377
18	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	378
19	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	379
20	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	380
21	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	381
22	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	382
23	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	383
24	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	384
25	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	385
26	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	386

```
     LOADING CONDITION
******************************************************************************
YUNIFO          0.000    135.773  3080.400  -103.428  6160.800    135.773
YUNIFO      10781.400   -101.764


XLONG           1.        16.       26.        1.000
YUNIFO          0.000    -98.728  3080.400   135.773  6160.800    -98.703
YUNIFO      10781.400     -9.969


XLONG           1.         2.       14.        1.000
XUNIFO          0.000    -92.680  3080.400   129.990  6160.800    -92.680
XUNIFO      10781.400     -4.640


XLONG           1.         2.        2.        1.000
XUNIFO          0.000    -92.680  3080.400   129.990  6160.800    -92.680
XUNIFO      10781.400     -4.640


YLONG           1.         2.        2.        1.000
XUNIFO          0.000    -84.210  3080.400   129.990  6160.800    -84.210
XUNIFO      10781.400      3.430


YLONG           1.         3.        3.        1.000
XUNIFO          0.000    -70.940  3081.400   121.330  6160.800    -70.940
XUNIFO      10781.400     10.850


YLONG           1.         4.        4.        1.000
XUNIFO          0.000    -63.570  3081.400   121.330  6160.800    -63.570
XUNIFO      10781.400     16.730


YLONG           1.         5.        5.        1.000
XUNIFO          0.000    -56.570  3081.400   121.330  6160.800    -56.570
XUNIFO      10781.400     22.600


YLONG           1.         6.        6.        1.000
XUNIFO          0.000    -52.000  3081.400   118.283  6160.800    -52.000
XUNIFO      10781.400     28.470


YLONG           1.         7.        7.        1.000
XUNIFO          0.000    -52.000  3081.400   118.283  6160.800    -52.000
XUNIFO      10781.400     28.470


YLONG           1.         8.        8.        1.000
XUNIFO          0.000    -48.058  3081.330   100.433  6160.800    -48.050
XUNIFO      10781.400     33.750


YLONG           1.         9.        9.        1.000
XUNIFO          0.000    -48.050  3081.400   100.433  6160.800    -48.050
XUNIFO      10781.400     33.750


YLONG           1.        10.       10.        1.000
XUNIFO          0.000    -48.050  3081.400    93.233  6160.800    -48.050
XUNIFO      10781.400     33.750


YLONG           1.        11.       11.        1.000
XUNIFO      10781.400     33.750
XUNIFO          0.000    -48.050


YLONG           1.        12.       12.        1.000
XUNIFO          0.000    -96.090  3081.400    92.783  6160.800    -96.090
XUNIFO      10781.400     67.500


YLONG           1.        13.       13.        1.000
XUNIFO          0.000    -96.090  3081.400    92.783  6160.800    -96.090
XUNIFO      10781.400     67.500


YLONG           1.        14.       14.        1.000
XUNIFO          0.000    -48.050  3081.400    35.583  6160.800    -48.050
XUNIFO      10781.400     33.750


YLONG           1.        15.       15.        1.000
```

YLONG	1.	16.	16.	1.000
XUNIFO	0.000	-48.050	3081.400	21.17
XUNIFO	10781.400	22.490		
YLONG	1.	17.	17.	1.000
XUNIFO	0.000	-96.090	3081.400	13.96
XUNIFO	10781.400	14.990		
YLONG	1.	18.	18.	1.000
XUNIFO	0.000	-54.750	3081.400	6.76
XUNIFO	10781.400	7.480		
YLONG	1.	19.	19.	1.000
XUNIFO	0.000	-88.700	3081.400	-0.000
XUNIFO	10781.400	.020		
YLONG	1.	20.	20.	1.000
XUNIFO	0.000	-33.940	3081.400	-0.000
YLONG	1.	21.	21.	1.000
XUNIFO	0.000	-27.000	3081.400	-0.000
YLONG	1.	22.	22.	1.000
XUNIFO	0.000	-37.760	3081.400	-0.000
YLONG	1.	23.	23.	1.000
XUNIFO	0.000	223.000	3080.400	-223.000
XUNIFO	10781.400	-88.150		
YLONG	15.	2.	2.	1.000
XUNIFO	0.000	215.030	3080.400	-215.030
XUNIFO	10781.400	-88.150		
YLONG	15.	3.	3.	1.000
XUNIFO	0.000	193.510	3080.400	-193.510
XUNIFO	10781.400	-82.280		
YLONG	15.	4.	4.	1.000
XUNIFO	0.000	186.570	3080.400	-186.570
XUNIFO	10781.400	-82.280		
YLONG	15.	5.	5.	1.000
XUNIFO	0.000	179.630	3080.400	-179.630
XUNIFO	10781.400	-82.280		
YLONG	15.	6.	6.	1.000
XUNIFO	0.000	172.690	3080.400	-172.690
XUNIFO	10781.400	-82.280		
YLONG	15.	7.	7.	1.000
XUNIFO	0.000	172.690	3080.400	-172.690
XUNIFO	10781.400	-82.280		
YLONG	15.	8.	8.	1.00
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

```
YLONG        15.       11.       11.        1.000
XUNIFO        0.000   131.070  3080.400  -131.070   6160.800   131.070
XUNIFO    10781.400   -82.280

YLONG        15.       12.       12.        1.000
XUNIFO        0.000   199.700  3080.400  -199.700   6160.800   199.700
XUNIFO    10781.400  -164.550

YLONG        15.       13.       13.        1.000
XUNIFO        0.000   199.700  3080.400  -199.700   6160.800   199.700
XUNIFO    10781.400  -164.550

YLONG        15.       14.       14.        1.000
XUNIFO        0.000    89.450  3080.400   -89.450   6160.800    89.450
XUNIFO    10781.400   -82.280

YLONG        15.       15.       15.        1.000
XUNIFO        0.000    82.500  3080.400   -82.500   6160.800    82.500
XUNIFO    10781.400   -82.500

YLONG        15.       16.       16.        1.000
XUNIFO        0.000    75.570  3080.400   -75.570   6160.800    75.570
XUNIFO    10781.400   -75.570

YLONG        15.       17.       17.        1.000
XUNIFO        0.000   130.330  3080.400  -130.330   6160.800   130.330
XUNIFO    10781.400  -103.330

YLONG        15.       18.       18.        1.000
XUNIFO        0.000    54.750  3080.400   -54.750   6160.800    54.750
XUNIFO    10781.400   -54.750

YLONG        15.       19.       19.        1.000
XUNIFO        0.000    88.700  3080.400   -88.700   6160.800    88.700
XUNIFO    10781.400   -88.700

YLONG        15.       20.       20.        1.000
XUNIFO        0.000    33.940  3080.400   -33.940   6160.800    33.940
XUNIFO    10781.400   -33.940

YLONG        15.       21.       21.        1.000
XUNIFO    10781.400   -37.000
XUNIFO        0.000    37.000

YLONG        15.       22.       22.        1.000
XUNIFO        0.000    39.360  3080.400   -39.360   6160.800    39.360
XUNIFO    10781.400   -39.360

YLONG        15.       23.       23.        1.000
YUNIFO        0.000     9.840  3080.400    -0.000   6160.800     9.840

XLONG        25.        2.        2.        1.000
YUNIFO        0.000     9.750  3080.400    -0.000   6160.800     9.750

XLONG        25.        3.        3.        1.000
YUNIFO        0.000     8.970  3080.400    -0.000   6160.800     8.970

XLONG        25.        4.        4.        1.000
YUNIFO        0.000     8.190  3080.400    -0.000   6160.800     8.190

XLONG        25.        5.        5.        1.000
END
```

SHEAR LOADS ON TRANSVERSES

	TRANSV.	SHELL SHEAR	BHD SHEAR
SHEAR	.10000E+01	-.85715E+05	.25537E+06
SHEAR	.20000E+01	.43520E+04	-.14017E+06
SHEAR	.30000E+01	.20857E+06	-.58370E+05
SHEAR	.40000E+01	.73500E+04	.14527E+06
SHEAR	.50000E+01	-.93507E+05	.23078E+06
SHEAR	.60000E+01	.16439E+06	.78511E+05
SHEAR	.70000E+01	.33053E+06	.18267E+05
SHEAR	.80000E+01	.23506E+06	.97579E+05
SHEAR	.90000E+01	.97556E+05	.24047E+06
SHEAR	.10000E+02	.23501E+06	.97625E+05
SHEAR	.11000E+02	.33049E+06	.18337E+05
SHEAR	.12000E+02	.16409E+06	.78563E+05
SHEAR	.13000E+02	-.93485E+05	.23007E+06
SHEAR	.14000E+02	.73120E+04	.14519E+06
SHEAR	.15000E+02	.21831E+06	-.70167E+05
SHEAR	.16000E+02	.13206E+05	.13645E+06
SHEAR	.17000E+02	.13016E+06	.13495E+06
SHEAR	.18000E+02	.22457E+06	-.71362E+05
SHEAR	.19000E+02	.11510E+04	.13279E+06
SHEAR	.20000E+02	-.55349E+05	.26110E+06
SHEAR	.21000E+02	-.12921E+06	-.14439E+06
SHEAR	.22000E+02	-.26237E+06	-.49057E+06
SHEAR	.23000E+02	-.31564E+06	-.36653E+06
SHEAR	.24000E+02	-.49983E+06	-.20042E+06
SHEAR	.25000E+02	-.32807E+06	-.36763E+06
SHEAR	.26000E+02	-.32784E+06	-.36697E+06
SHEAR	.27000E+02	-.50378E+06	-.19915E+06
SHEAR	.28000E+02	-.31189E+06	-.35945E+06
SHEAR	.29000E+02	-.29217E+06	-.49742E+06
END	-0.	-0.	-0.

Program Execution Times

Execution time varies according to the structural and loading definitions.

The table below provides sample computer times for the CDC6600 and the UNIVAC 1108 (EXEC II) computers.

Table 1. CDC 6600 Program Execution Times

	No. Transverses	No. Frame Elements	No. Longitudinals	No. Equivalent Elements	No. Eigenvalues Used	CP Seconds	System Secon
Complete Analysis	29	618	95	20,772	1	129.656	975.
" "	28	699	95	22,327	1	129.052	1038.
" "	29	699	95	· 23,121	1	129.029	1043.
" "	3	66	"	242	1	14,409	72.
Stripped Package*	3	36	"	141	1	3.403	20.
CDC/EASE**	-Quarter Model-		"	92	N.A.	10.977	41.
Data Check	28	699	94	22,298	-0-***	16.008	25/

* This stripped package does not have input routines amenable for convenient use of the transverse analys capabilities.

** Since the problem analyzed was symmetrical fore-n-aft as well as about the hull centerline, the CDC/EAS Analysis could be simplified to a quarter-hull model. The tanker transverse program, on the other hand analyzed the whole half-section. Nevertheless, note the significant difference in computer times betwe the two analyses. The additional computer time required for execution of the complete tanker progra (as opposed to the stripped version) is mainly due to the extensive input processing which greatly facilitates the problem definition.

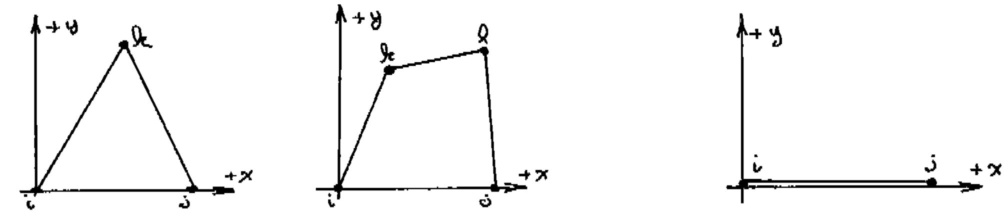
*** If the EIGENS card is omitted, the program will function in data checking only. This procedure is recommended before a complete stress analysis is attempted.

Table 2. UNIVAC 1108 (Exec II) Program Execution Times

	No. Transverses	No. Frame Elements	No. Longitudinals	No. Equivalent Elements	No. Eigenvalues Used	CP Seconds	System Second
Complete Analysis	29	444	77	15,186	1	363	N/A

OUTPUT DESCRIPTION:

The plate and bar element stresses are given along the locally defined element axes as established by the program's automatic element generation. Figure 6 below illustrates the local axes for each type of element:



Triangular Plate Quadrilateral Plate Bar

Fig. 6. Local Coordinate System for Finite Elements

The positive local x-direction extends from node i to j for all elements. The positive y-direction is always 90° counter-clockwise.

The following table as generated by the program provides the row, node coordinates for each element node i,j,k, and l as appropriate. Note that the node number given corresponds to the column number except that where void nodes exist on the given row, the node number is a re-sequenced column number with **all** void nodes omitted from the count from the global x=0.

Table 3.

MEMBER DATA

				OUTPUT VARIABLES				i ROW	i NODE	j ROW	j NODE	k ROW	k NODE	l ROW	l NODE	PLATE THICKNESS OR BAR X-SECTIONAL AREA
MFMNO	MFMTYP	IEGNU	IFSF	IFI	IFJ	IFK	IFL	INI	JNI	INJ	JNJ	INK	JNK	INL	JNL	P1
1	1	0	2	0	0	0	0	1	1	2	1	2	2	0	0	1.80000
2	5	0	2	0	0	0	0	1	1	2	1	0	0	0	0	1257.83000
3	2	0	2	0	0	0	0	1	1	1	2	2	2	2	3	1.80000
4	5	0	2	0	0	0	0	1	1	1	2	0	0	0	0	1257.83000
5	2	0	2	0	0	0	0	1	2	1	3	2	3	2	4	1.80000
6	5	0	2	0	0	0	0	1	2	1	3	0	0	0	0	1257.83000
7	2	0	2	0	0	0	0	1	3	1	4	2	4	2	5	1.80000
8	5	0	2	0	0	0	0	1	3	2	4	0	0	0	0	135.00000
9	5	0	2	0	0	0	0	1	3	1	4	0	0	0	0	1257.83000
10	2	0	2	0	1	0	1	1	4	1	5	2	5	2	6	1.80000

MEMTYP indicates the type of element generated by the program: 1 = triangular plate; 2 = quadrilateral plate; and 5 = bar element. The member numbers are relative to the given row only.

Table 4 lists the stress solutions for the sample web frame elements defined in Table 3. The x-stress, for the bar element, is always directed along the axis of the bar (from node i to node j).

The quadrilateral plate stresses are always given in the same directional (x-y) sense as the global coordinate axes of the web frame, which is basically an orthogonal, rectangular grid network. Stresses, however, may be interpolated to locations within the quadrilateral element by using the following equations:

$$\sigma_x = \sigma_{xi} + \gamma_x \cdot y$$

$$\sigma_y = \sigma_{yi} + \gamma_y \cdot x$$

where x and y are the relative distances of the interior point in the element from the i^{th} node (lower left hand corner of the element).

Stresses within the triangular plate element, however, are somewhat more difficult to transpose to the coordinate system of the web frame. The stress, assumed constant for this type of element, may be computed from the following equation:

$$\sigma = \sigma_x \cos^2\alpha + \sigma_y \sin^2\alpha + 2\tau_{xy} \sin\alpha \cos\alpha$$

where α is the angle between the x-axis of the triangular element (see Figure 6) and the x-axis of the web frame (horizontal and directed left-to-right).

Table 4.

MEMBER STRESSES IN KG PER SQUARE CM

LOAD SYSTEM	ROW	MEMBER TYPE AND NUMBER		σ_x X-STRESS (TRIANG PLATE) / σ_{xi} X-STRESS (QUAD PLATE) / σ_x X-STRESS (BAR)	σ_y Y-STRESS / δ_x X-GRAD	τ_{xy} SHEAR STRESS / σ_{yi} Y-STRESS	1ST PRINC STR / δ_y Y-GRAD	2ND PRINC STR / τ_{xy} SHEAR STRESS	ANGLE 1ST PRINC STRESS TO X-AXIS
1	1	TRIANG PLATE	1	-.866627E+03	-.272493E+04	.983988E+03	-.442428E+03	-.314912E+04	23.3209 DEG
1	1	BAR	2	-.491491E+02					
1	1	QUAD PLATE	3	-.283881E+03	.101335E+02	-.247101E+04	.361794E+02	-.160762E+03	
1	1	BAR	4	-.472798E+02					
1	1	QUAD PLATE	5	.122356E+03	.282870E+00	.882559E+03	-.690638E+01	.196259E+02	
1	1	BAR	6	-.450321E+02					
1	1	QUAD PLATE	7	.705261E+02	.331108E+00	.218462E+03	.146913E+01	-.407095E+03	
1	1	BAR	8	.192834E+03					
1	1	BAR	9	-.157270E+02					
1	1	QUAD PLATE	10	.142271E+03	-.666457E+00	.364616E+03	-.842156E+00	-.532266E+03	
1	1	BAR	11	.330932E+03					
1	1	BAR	12	.447602E+02					
1	1	QUAD PLATE	13	.199936E+03	-.119272E+01	.295648E+03	-.400055E+00	-.580134E+03	
1	1	BAR	14	.251769E+03					
1	1	BAR	15	.116882E+03					
1	1	QUAD PLATE	16	.238587E+03	-.161659E+01	.263916E+03	-.197141E+01	-.490311E+03	
1	1	BAR	17	.214164E+03					
1	1	BAR	18	.187209E+03					
1	1	QUAD PLATE	19	.300920E+03	-.199119E+01	.922462E+02	.193693E+01	-.516085E+03	
1	1	BAR	20	.288513E+02					
1	1	BAR	21	.247345E+03					
1	1	QUAD PLATE	22	.364085E+03	-.344753E+01	.264207E+03	-.115805E+00	-.250201E+03	
1	1	BAR	23	.201523E+03					
1	1	BAR	24	.286456E+03					
1	1	QUAD PLATE	25	.383513E+03	-.379952E+01	.254398E+03	.426107E+00	-.398679E+02	

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13. ABSTRACT

This report, the third in a sequence of four Ship Structure Committee Reports on a method for performing structural analysis of a tanker hull, contains the User's Manual for the transverse strength analysis portion of the program.

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SSC-216, *Program "Tranship" - A Computer Program for the Design of the Midship Section of a Transversely-Framed Dry Cargo Ship - Part Two.* by Manley St. Denis. 1972.

SSC-217, *Compressive Strength of Ship Hull Girders - Part I - Unstiffened Plates* by H. Becker, R. Goldman, and J. Pozerycki. 1971. AD 717590.

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