A POSTPROCESSOR SYSTEM FOR THE DATA REDUCTION AND POST ANALYSIS OF NASTRAN RESULTS

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SUMMARY

A post-processor system for the data reduction and post analysis of NASTRAN results is described. NASTRAN analysis results are scanned to determine maximum and minimum displacements, forces and stresses. Allowables and margins of safety are computed, and in the case of multiple loading conditions, envelopes for displacements, forces, stresses and margins of safety are also produced for specified element sets. Graphical plots of the reduced or the regular NASTRAN results may be obtained superimposed either on a developed fuselage strip or on a projection of any specified part of the finite element model. The use of the data reduction, post analysis and graphical plotting capabilities provide the analyst with a fast and convenient tool for the study of NASTRAN analysis results and their presentation for project documentation.

INTRODUCTION

The high computational speed and large storage capacity of modern computers have enabled the analysis of large and complex structures subjected to multiple loadings and various boundary conditions. As a consequence, the structural engineer is bound to devote a substantial portion of his time in scanning and interpreting a large amount of output data, a process which is time consuming, error prone and hence inefficient. The way to alleviate this problem is to automate, wherever possible, the scanning and interpretation of the results, and to give the analyst the option to reduce the amount of computer output according to his engineering requirements. For further efficiency, this should be done in conjunction with graphical display of the reduced finite element analysis results. Additional help for the analyst can be obtained through the automation of certain standard post analysis procedures such as the computations of allowable stresses and margins of safety for the structural elements used in the finite element analysis.

The need for these capabilities has been felt for some time and as a result a large number of post-processors have been developed. However, most of these satellite programs are generally limited in scope, usually serving one particular purpose only, such as plotting (reference 1), or scanning (reference 2). At Israel Aircraft Industries an attempt has been made to integrate data reduction, post analysis, and graphic visualization into one package which has been especially devised to be engineering oriented.

This paper describes two interrelated software modules for the post processing, post analysis and graphical presentation of NASTRAN analysis results. Emphasis is put on the fact, that both modules are easy to apply, demanding a minimum of information from the user, yet leaving him with enough options to answer his design oriented requirements. The first of the two modules, NASDAT (reference 3) performs the post-processing and post analysis of the NASTRAN results; the second module, GRAS, plots any of the regular or reduced results in a graphical form.

DESCRIPTION OF MAIN MODULES

Description Of The NASDAT Module

The execution of the NASDAT module, illustrated in figure 1, may be subdivided into three main phases.

a) In phase one, regular NASTRAN output data blocks are sorted and stored in a compact form on a disk file for subsequent use. This file may be saved after termination of NASDAT execution. Thus, a restart file, which contains all necessary I/O information of the NASTRAN analysis, is created to be used in phases 2 and 3.

b) In phase two, the packed and sorted NASTRAN output is scanned, and efficient data reduction performed in accordance with the user's requirements.

c) Finally, in phase three, post analysis of results including computations of allowables and margins of safety are performed.

NASDAT may be run either in conjunction with NASTRAN as a single job, or as a separate run following a NASTRAN analysis for which the necessary output data blocks have been saved. NASDAT may be restarted as many times as required.

NASDAT Capabilities

Presently, using NASDAT capabilities, the user may obtain:

* Maxima and minima values
* Envelopes of displacements, forces, stresses and/or margins of safety
* Output in preferred sequence and format
* Computations of allowables and margins of safety

The following is a brief description of the different options mentioned above:

a) *Maximum and Minimum Values*

The user may define a given set of elements and/or gridpoints from which the program will single out and identify those elements and grid points bearing extreme values of force, stress and displacement; the magnitude of these extrema is also produced. In addition, it is possible to specify the upper and lower bounds beyond which the search for maximum and minimum values is to begin.

b) *Envelopes of Displacements, Forces, Stresses and Margins of Safety*

When analyzing several loading cases or checking various boundary condition configurations, the user has the option of obtaining envelopes of displacements, forces, stresses and margins of safety for a specified set of grid points and elements.

c) *Output In A Preferred Sequence And Format*

In some cases the user may require the results in a certain region of interest to be printed out separately in a specified sequence. In addition, if upper and lower bounds on the output values are also defined, then only those elements of the set with results above these bounds are printed.

d) *Computations Of Allowables And Margins Of Safety*

The margins of safety of any Rod, Shear Panel or Membrane element can be computed using allowables either defined by the user or automatically computed by the program. For the latter option the user may either define the section properties via manual input or allow the program to retrieve the geometrical and mechanical properties of these sections from tables generated in the NASTRAN analysis.

The NASDAT Input

In order to generate the main input for NASDAT the following DMAP statements for static analysis, must be included into the Executive Control Deck of the NASTRAN deck:

```
1.  ALTER 121
2.  OUTPUT2     CASECC, EST, MPT, GPL,/C,N,-1/C,N,11/C,N,UTAPE  $
3.  OUTPUT2     OUGV1, OQG1, OEF1, OES1,/C,N,0/C,N,11  $
4.  ENDALTER
```

Statement 2 saves the necessary geometrical and mechanical properties of the structure on NASTRAN Fortran file UT1 and Statement 3 saves all the analysis results.

As can be noted, the main input to NASDAT comes from the above mentioned data blocks stored on file. However, additional input is required to specify the user's request for data reduction, post analysis and graphical presentation of results. This is prepared in a form similar to the NASTRAN input (reference 4). The NASDAT data deck consists therefore of an Executive Control Deck, a Case Control Deck and a Bulk Data Deck.

The Executive Control Deck contains that information required by NASDAT to decide if the NASTRAN output files are to be sorted and/or checkpointed for restart purposes.

The Case Control Deck consists only of SET cards needed to define the element and grid sets referred to in the Bulk Data Deck, and TITLE cards which produce output labels for the preferred sequence option.

The Bulk Data Deck contains the main information required for the data reduction and post analysis. The format and order of input is similar to that of NASTRAN, i.e. data is input in 8 column fields with freedom to arrange the input cards in any sequence. Facsimiles of input cards for the data reduction and definition of lower and upper bounds are shown for Bar and Shear elements in figures 2, 3 and 4 respectively. Facsimiles of input cards for the automatic computation of margins of safety for Rod and Shear elements are shown in figures 5 and 6 respectively.

Description Of The GRAS Module

This is the off-line graphical postprocessing module, which is used to display graphically either the reduced results produced by NASDAT or the regular NASTRAN output. Input for the GRAS module is generated by NASDAT.

At present, GRAS is run in a batch mode environment and uses a Calcomp drum plotter. The plotting capabilities can take one of the following forms:

a) *Developed Fuselage Strip*

Using this option, a segment of the fuselage of an aircraft is developed into a flat strip upon which the values of the reduced or regular results are plotted.

b) *Bulkhead Plots*

Using this option graphical displays of bending moments, bending stresses and transverse shear forces in Bar elements may be obtained.

c) *Projection Plots*

The user may obtain a graphical display of the projection of any specified part of the structure on any one of the three principal planes. The stress values are then plotted on this projection. Figure 7 shows stresses in Rods plotted on a projected view of an aircraft delta wing in the XY plane.

NUMERICAL APPLICATIONS

The NASDAT and GRAS modules were first utilized in the data reduction and post analysis of the results obtained from the NASTRAN analysis of the IAI Westwind 1124 aft fuselage (reference 5). The structure was idealized using Shear Panels to represent the skins, Rod elements to represent the stringers and Bar elements offset from the skins to represent the bulkheads. The complete mathematical model, shown in figure 8, consisted of 460 BAR elements, 1670 ROD elements, 1030 SHEAR elements and 1250 GRID points representing a total of 3650 unconstrained degrees of freedom. The structure was subjected to 18 loading conditions. Because of the size of the structure a substructuring technique (reference 6) was employed, subdividing the aft-fuselage into 5 substructures.

Based on engineering considerations related to the structural configuration and loading conditions the analyst has asked for (presented here as an example) information relative to extreme values of average shear stresses, data relative to critical regions affected by shear buckling of skin panels, and margins of safety of Rod elements. In order to get the full picture of the internal load distribution in a bulkhead of interest, the preferred sequence option has been used to output results in this region. In addition, graphical capabilities have also been employed to display moments, shear stresses and axial stresses. Finally, a plot to represent the envelope of shear stresses has been required.

A listing of the complete input required to perform this type of data reduction and post analysis for substructure 1 (figure 9), is given in figure 10. Based on the user's request, the following data was obtained:

(i) Twenty extreme absolute values for average stresses in Shear Panels and axial stresses in Rod elements (figure 11).

(ii) Buckling stresses, diagonal tension factors and related margins of safety for Shear Panels located in the left hand side of the fuselage structure.

Since the actual skin panels between bulkheads were represented in the idealization as a mesh of NASTRAN Shear Panels, it should be noted that the aspect ratio (a/b) referred to the *actual* skin panels and not to the dimensions of an idealized element. Therefore, in this case, the user had to input the aspect ratio manually. The critical stresses, diagonal tension factors and margins of safety, shown in figure 12 were computed using criteria defined in references 7 and 8.

(iii) Euler buckling stresses, ultimate tensile stresses and related margins of safety for Rod elements located in the left hand side of the fuselage structure.

In this case the necessary geometric material and cross section properties of the rod elements were retrieved from the NASTRAN tables using the automatic procedure (via the FLAG=2 option). Computer output is shown in figure 13.

Note that this output is presented for illustration only. Usually, the user will request only a print-out for those elements having negative margins of safety.

(iv) A table of the internal load distribution for a bulkhead as requested via the preferred sequence option. Computer output is shown in figure 14.

(v) Graphical display needed for project documentation including (a) plot of bending stresses for a bulkhead as shown in figure 15; (b) presentation of envelopes for maximum and minimum shear stresses as shown in figure 16 and 17 respectively, (c) presentation of stresses in Rod elements and Shear Panels as shown in figures 18 and 19 respectively.

Since the original height of the Calcomp plots was 29 inches (73.6 cm) only a part of the plot (the left hand side) is presented.

The total amount of computer output for the complete NASTRAN finite element analysis consisted of about 5000 pages. Scanning, hand reduction, post analysis and drawing of results would have required several man months of engineering work. In contrast, meaningful engineering-oriented output and data reduction as presented above could be accomplished in the span of a few days.

CURRENT DEVELOPMENTS

Current developments of NASDAT include the expansion of the options which deal with computations of the allowables. These will incorporate bending elements as well as stiffened panels.

The NASDAT/GRAS modules are presently converted to operate in a time-sharing mode using low cost graphic display terminals, and together with NASTRAN will be included as modules in Israel Aircraft Industries' ISSAS, (Interfaced Software System for Sizing and Analysis of aircraft Structures) (reference 9).

CONCLUSION

Scanning of analysis results and computations of allowables and margins of safety, which are especially error prone and time consuming, may be performed with the aid of NASDAT and results graphically displayed by GRAS in an automated fashion, thus freeing the analyst to devote a larger portion of his time to engineering decision-making based upon results which are obtained in an organized form.

The use of the presented data reduction, post analysis and graphical plotting capabilities provide the analyst with an efficient and convenient tool for the study of NASTRAN analysis results and their presentation for project documentation.

REFERENCES

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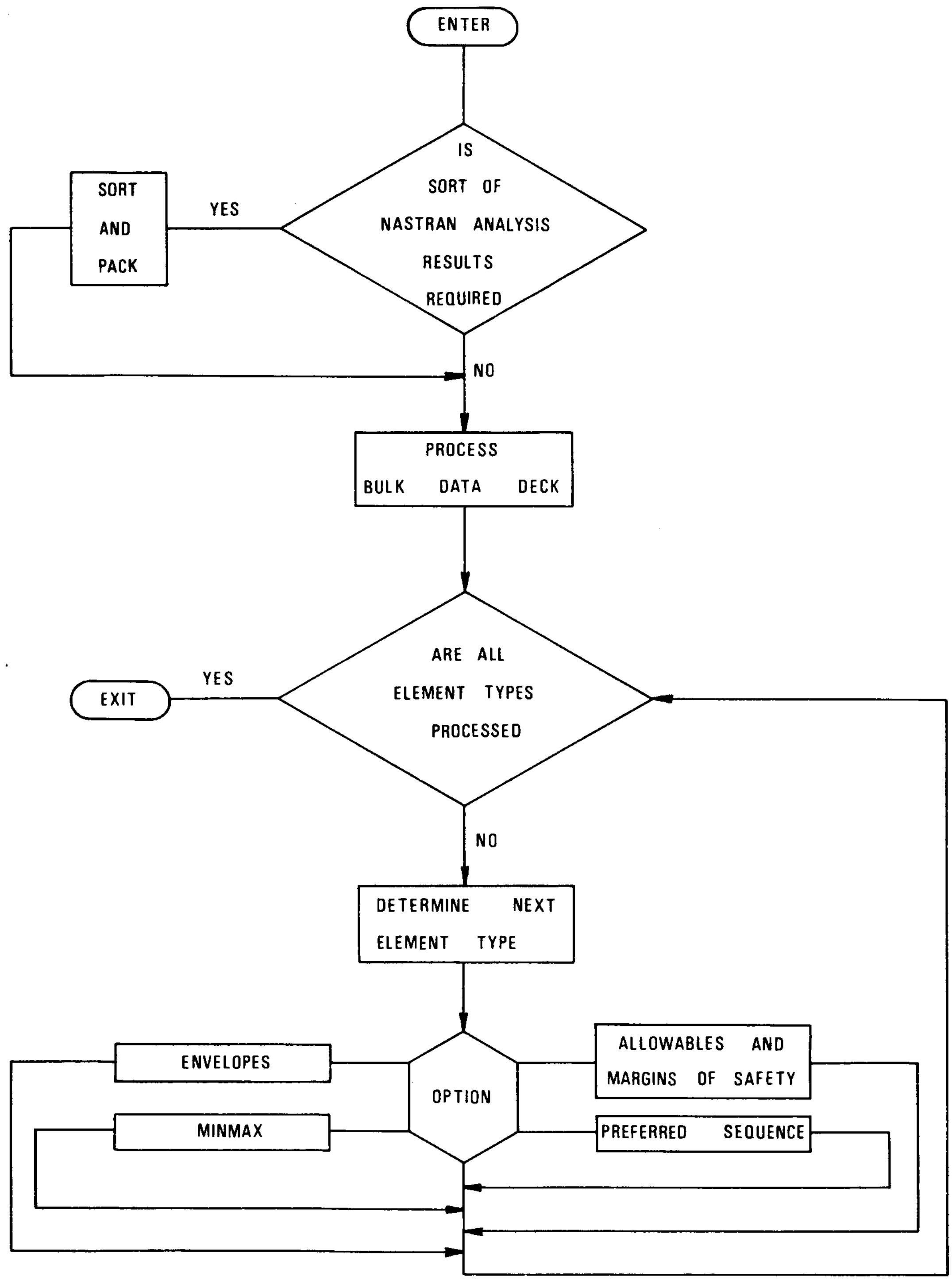


FIGURE 1: FLOW DIAGRAM FOR THE NASDAT MODULE

Bulk Data Card BAR Data reduction for CBAR elements

Description: Defines the option and the element set for which data reduction is requested.

Format and Example

1	2	3	4	5	6	7	8	9	10
BAR	SID	COMPON	SUBCASE	SSID	OPTION	MINSET	MAXSET	NMINMAX	PLOT
BAR	16	15678	4		PREFSEQ				YES

Alternate Form

BAR	SID	COMPON	SUBCASE	SSID	OPTION	MINSET	MAXSET	NMINMAX	PLOT
BAR	ALL	ALL		ALL	ENVEL				

Field	Contents
SID	Element set identification number (Integer > 0)
COMPON	Component number for which data reduction is requested. Any unique combinations of the digits 1-8 (with no imbedded blanks)
SUBCASE	Single Subcase identification number for which data reduction is requested (Integer > 0 or blank)
OPTION	Data reduction option; one of the BCD values "ENVEL", MINMAX", "MS" or "PREFSEQ"
ENVEL	Stress or force envelope
MINMAX	Scan for minimum (negative) or maximum (positive) values per Subcase.
MS	Margin of Safety computations
PREFSEQ	Preferred sequence in output set
MINSET, MAXSET	Identification number of a BARMIN or BARMAX (Integer > 0 or blank).
NMINMAX	Number of minimum or maximum extreme stress or force values required (Integer > 0 or blank)
PLØT	Generate input for the plot modules "YES" - generate "NO" - do not generate (Default)

Remarks:

1. The element set identification number must be defined in the Case Control Deck (SET SID = ...) to be used by NASDAT
2. In order to reduce the NASTRAN output for CBAR elements the user has the option to define the following output components to be output or plotted.

Component	Value
1	Moment in plane 1 at end A and B
2	Moment in plane 2 at end A and B
3	Transverse shear in plane 1 and 2
4	Torsional moment
5	Axial force
6	Axial stress
7	Maximum normal stress at end A and B
8	Minimum normal stress at end A and B

FIGURE 2: NASDAT BULK DATA CARD BAR

Bulk Data Cards **BARMIN: BARMAX**

Negative (BARMIN) or positive (BARMAX) bounds for force and stress values of CBAR elements.

Description: Defines the smallest negative (BARMIN) or largest positive (BARMAX) stress or force value for CBAR elements. Output consists of negative values or positive values larger than those defined on the BARMIN or BARMAX card.

Format and Example

1	2	3	4	5	6	7	8	9	10
BARMIN	SID	M1A	M1B	M2A	M2B	SF1	SF2	MT	ABCD
BARMIN	5	-100.0	-100.0			-50.0			CØN1
+BCD	AF	AS	SMAXA	SMAXB	SMINA	SMINB			
+ØN1	-1000.	-2500.			-3000.	-3500.			

Field	Contents
Type	One of the BCD values "BARMIN" or "BARMAX"
SID	MINSET (BARMIN) OR MAXSET (BARMAX) identification number (**Integer** > 0)
M1A; M1B	Extreme value of moment in plane 1 at end -A- and -B- (Real ≥ 0.0 (BARMAX); Real ≤ 0.0 (BARMIN))
M2A; M2B	Extreme value of moment in plane 2 at end -A- and -B- (Real ≥ 0.0 (BARMAX): Real ≤ 0.0 (BARMIN))
SF1; SF2	Extreme value of transverse shear in plane 1 and plane 2 (Real ≥ 0.0 (BARMAX); Real ≤ (BARMIN))
MT	Extreme value of torsional moment (Real ≥ 0.0 (BARMAX), Real ≤ 0.0 (BARMIN))
AF	**Extreme value of axial force** (Real ≥ 0.0 (BARMAX); Real ≤ 0.0.(BARMIN))
AS	Extreme value of axial stress (Real ≥ 0.0 (BARMAX); Real ≤ 0.0 (BARMIN))
SMAXA: SMAXB	Extreme value of maximum combined normal stress at end -A- and -B- (Real ≥ 0.0 (BARMAX); Real ≤ 0.0 (BARMIN))
SMINA: SMINB	Extreme value of minimum combined normal stress at end -A- and -B- (Real ≥ 0.0 (BARMAX); Real ≤ 0.0 (BARMIN))

Remarks:

1. The values defined on the BARMIN and BARMAX are used in the following manner:

   a. If the related BAR card defines OPTION ="MS" then the values defined are considered to be critical ones and the margins of safety is computed.

   b. If the related BAR card defines OPTION = "ENVEL", "MINMAX" or "PREFSEQ" then the values are considered as criteria to output values larger than those defined on the BARMIN or BARMAX card.

FIGURE 3: NASDAT BULK DATA CARD BARMIN

Bulk Data Card SHEAR Data reduction for CSHEAR elements

Description: Defines the option and element set for which data reduction is requested.

Format and Example

1	2	3	4	5	6	7	8	9	10
SHEAR	SID	X	SUBCASE	SSID	OPTION	SMIN	SMAX	NMINMAX	PLOT
SHEAR	18		4		MINMAX		3000	20	

Alternate Form

SHEAR	SID	X	SUBCASE	SSID	OPTION	SMIN	SMAX	NMINMAX	PLØT
SHEAR	ALL			21	ENVEL				YES

Field	Contents
SID	Element set identification number (Integer > 0)
SUBCASE	Single Subcase identification number for which data reduction is requested (Integer > 0 or blank)
SSID	Subcase set identification number (Integer > 0 or blank).
OPTIØN	Data reduction option ; one of the BCD values "ENVEL", "MINMAX", "MS" or PREFSEQ" "ENVEL" - Stress envelope "MINMAX" - Scan for minimum (negative) or maximum (positive) values per subcase "MS" - Computes margin of safety "PREFSEQ" - Set output in preferred sequence
SMIN: SMAX	Define the negative (SMIN) and positive (SMAX) boundary values for the average shear stresses Output consists of negative values or positive values larger than those defined by SMIN or SMAX (Real $\geq$ 0.0 (SMAX); Real $\leq$ 0.0 (SMIN)).
NMINMAX	Number of minimum and maximum extreme stress values required (Integer > 0 or blank)
PLØT	Generate input for the plot modules, YES - Generate; NØ - do not generate (Default)

Remarks:

1. The element set identification number must be defined in the Case Control Deck (SET SID =........) to be used by NASDAT.

2. If OPTION = "MS" then the entry for SMAX is considered to be the critical stress for the shear panels defined in the element set.

FIGURE 4: NASDAT BULK DATA CARD SHEAR

Bulk Data Card | ALRØD Computations of Allowables and related margins of safety for Rod elements.

Description | Defines the properties of CROD and CONROD elements needed to compute their Euler buckling and ultimate tensile stresses and to evaluate their margins of safety.

Format and Example:

1	2	3	4	5	6	7	8	9	10
ALROD	SID	I	L	E	A	R	FTU	FLAG	SUBCASE
ALROD	1	0.132				1.0	63000.	2	4

Field	Contents
SID	Element set identification number (Integer > 0)
I	Minimum moment of inertia (Real > 0.0)
L	Length of rod element (Real > 0.0 or blank; see below)
E	Young's modulus (Real > 0.0 or blank; see below)
A	Cross sectional area of rod element (Real > 0.0 or blank; see below)
R	Flag to specify the support condition of the rod element (Real > 0.0, see remark 2)
FTU	Ultimate stress for rod element material (Real > 0.0)
FLAG	Flag to specify the nature of fields 4-6 as follows:

	4	5	6
FLAG=1	L	A	E
FLAG=2			

If FLAG=1 Then the user defines the values required to perform the computations of the allowables.

If FLAG=2 Then the program takes the data from the appropriate NASTRAN tables

SUBCASE Single subcase identification number for which data reduction is requested (Integer > 0)

Remarks:

1. The element set identification number must be defined in the Case Control Deck (SET SID = ...) to be used by NASDAT
2. Program assumes uniform cross section and computes the Euler or Ultimate stress and the margins of safety for the rod elements.

   R may have one of the following values

Boundary Condition			R
Simple	-	Simple	1.0
fixed	-	fixed	2.0
fixed	-	free	0.5
fixed	-	simple	1.43

FIGURE 5: NASDAT BULK DATA CARD ALROD

Bulk Data Card ALSHEAR Computations of Allowables and related margins of safety for Shear elements.

Description: Defines the properties of CSHEAR elements needed to compute the buckling stress of shear panels and to evaluate their margins of safety.

Format and Example:

1	2	3	4	5	6	7	8	9	10
ALSHEAR	SID	A/B	T	E	NU	R		FLAG	SUBCASE
ALSHEAR	5	3.0	0.04	10.5E+6	0.3			1	5

Field	Contents
SID	Element set identification number (Integer > 0)
A/B	Aspect ratio of shear panel (Real > 0.0 or blank; see below)
T	Thickness of shear panel (Real > 0.0 or blank; see below)
E	Young's modulus (Real > 0.0 or blank; see below)
NU	Poisson's ratio (Real > 0.0 or blank; see below)
R	Radius of curvature of portion of skin under investigation (Real > 0.0 or blank)
FLAG	Flag to specify the nature of fields 3-6 as follows:

	3	4	5	6
FLAG=1	A/B	T	E	NU
Flag=2				

If FLAG=1 Then the user defines the values required to perform computations for the allowables of the shear panels.

If FLAG=2 Then the program takes the data from the appropriate NASTRAN tables.

SUBCASE	Single Subcase identification number for which data reduction is requested (Integer > 0)

Remarks:

1. The element set identification number must be defined in the Case Control Deck (SET SID =.....) to be used by NASDAT

2. Presently, the program assumes that the panel is simply supported on four sides.

FIGURE 6: NASDAT BULK DATA CARD ALSHEAR

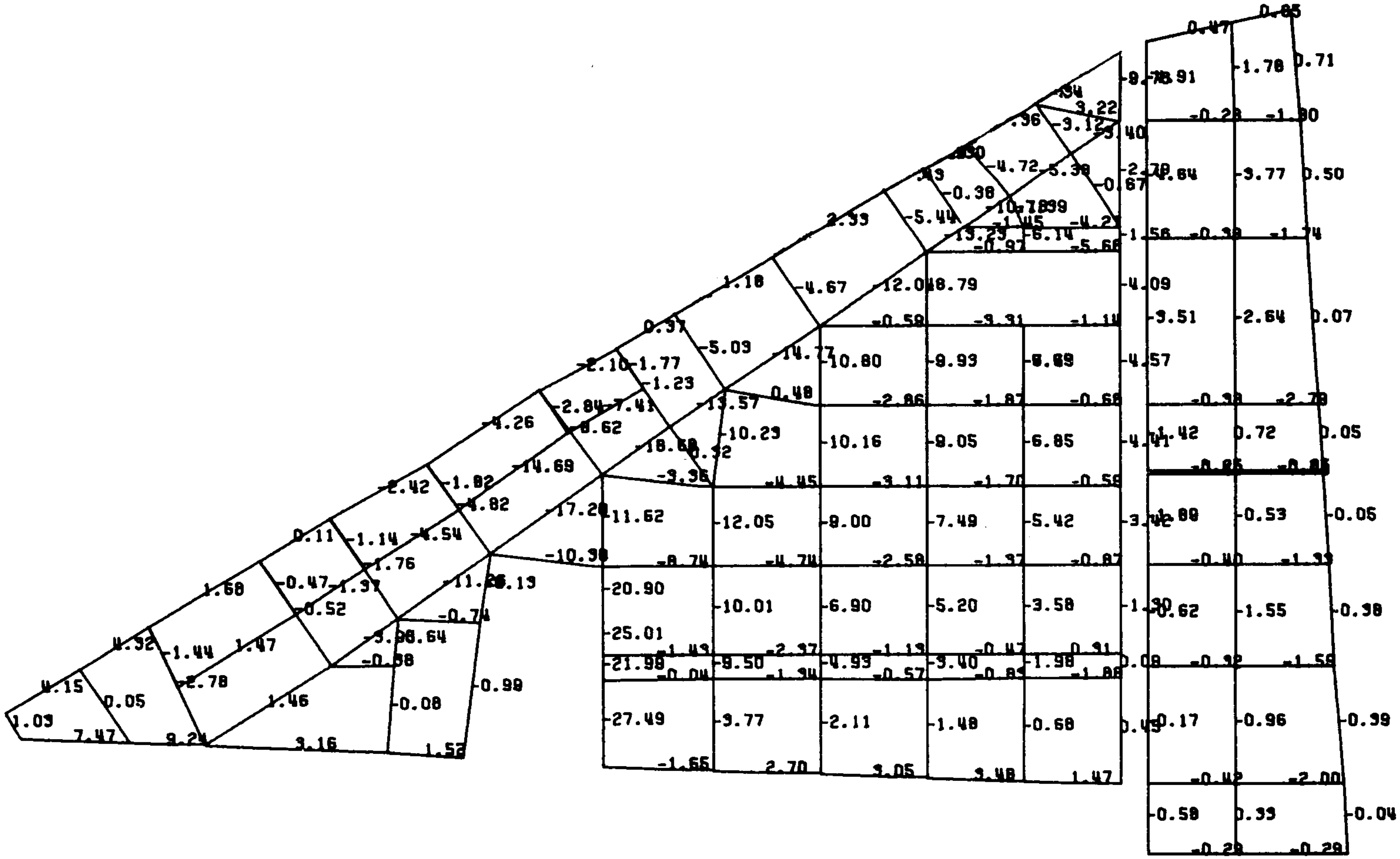


FIGURE 7: ROD STRESSES DISPLAYED ON A PROJECTED VIEW OF A DELTA WING

ROTO X-45 Y-45 Z-45
DIS

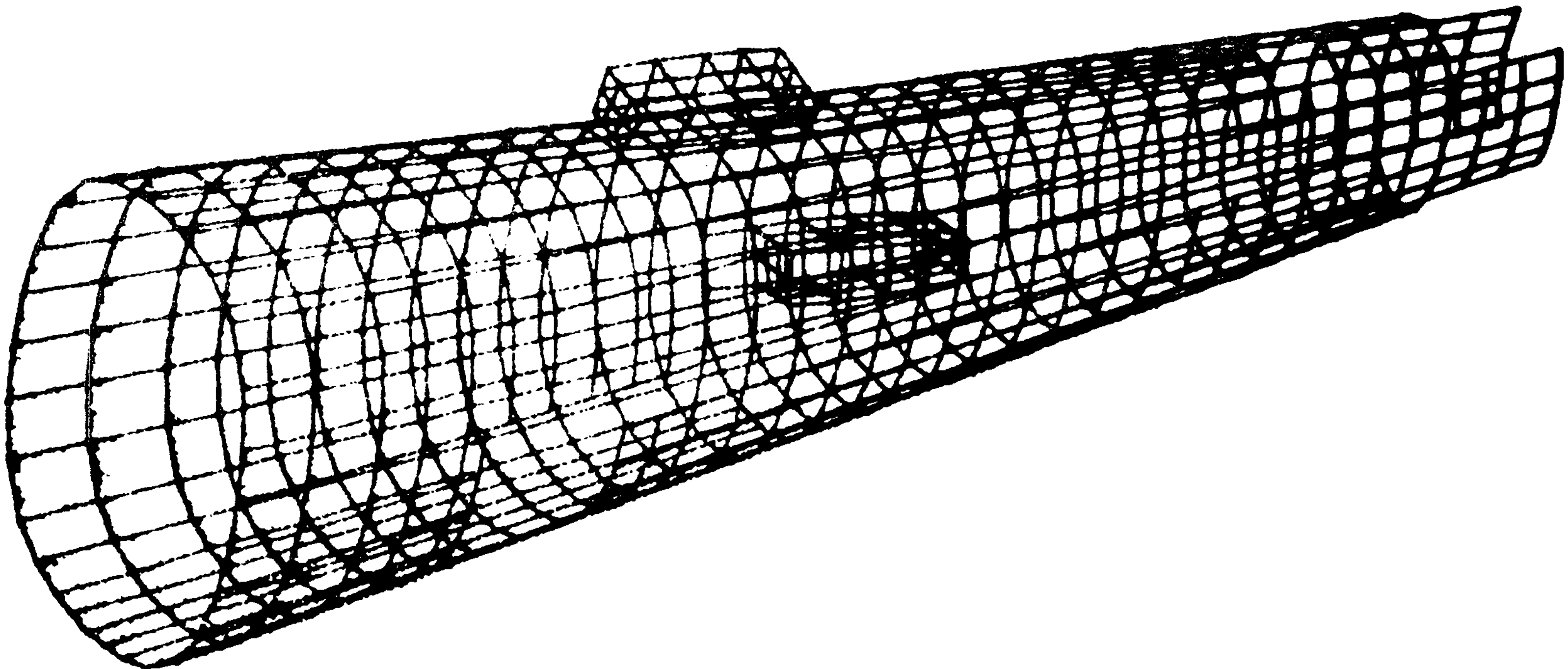
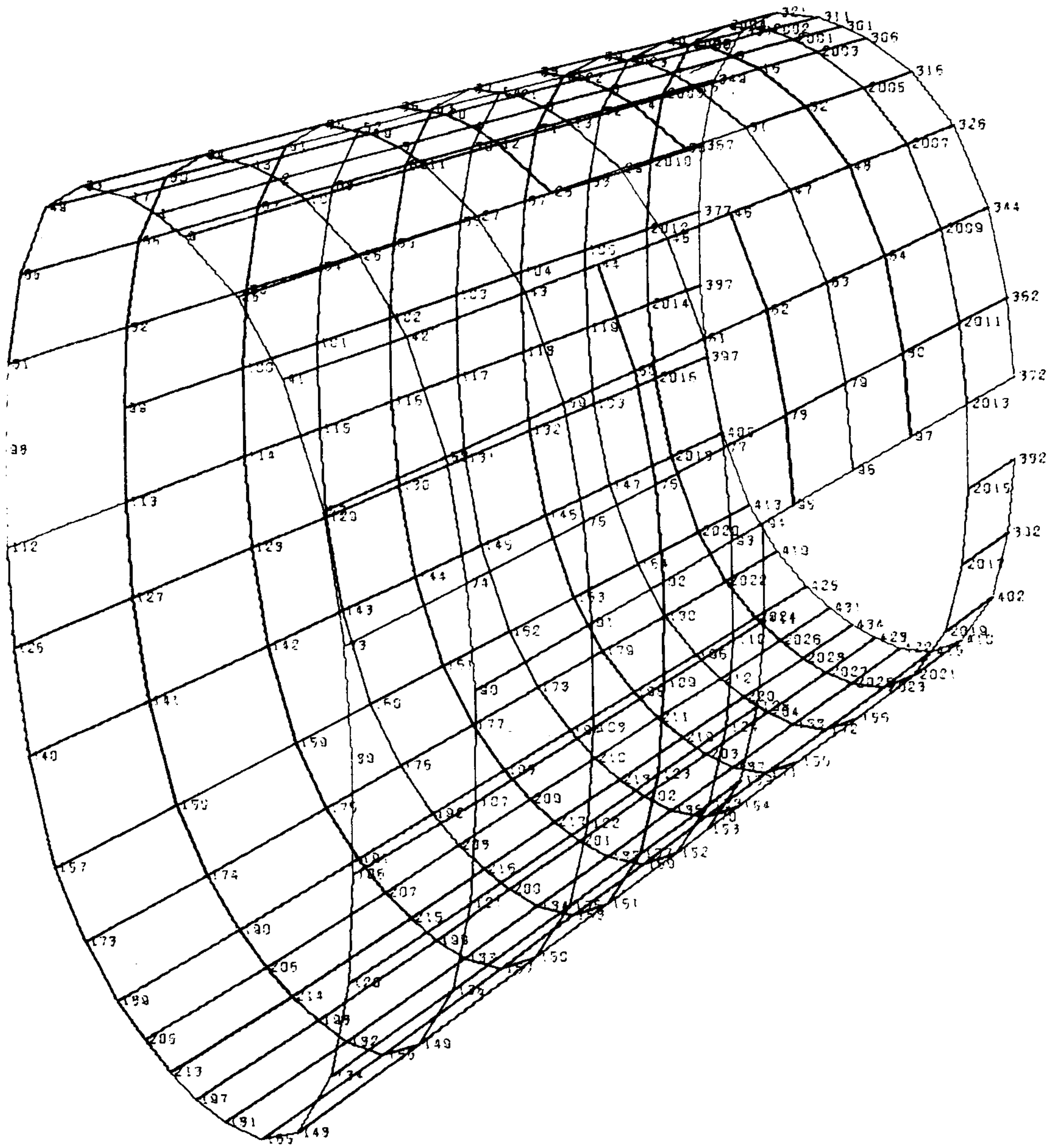


FIGURE 8: FINITE ELEMENT MODEL OF WESTWIND 1124 AFT FUSELAGE (COMPLETE MODEL)



WESTWIND-SUBSTRUCTURE 1

UNDEFORMED SHAPE

FIGURE 9: FINITE ELEMENT MODEL OF WESTWIND 1124 AFT FUSELAGE (SUBSTRUCTURE 1)

N A S D A T   E X E C U T I V E   C O N T R O L   D E C K   E C H O

```
ID POST,PROCESSOR
SORT YES
CHKPNT YES
CEND
```

N A S D A T   C A S E   C O N T R O L   D E C K   E C H O

```
SET 1=1121 THRU 1162 EXCEPT 1143,1144,1151,1152,1160,1170,1174,1175,
      1179 THRU 1184,1199 THRU 1206,1495,1557
SET 2=1143,1144,1151,1152,1160,1168,1169,1172,1173,1176,1177,1178,
      1287,1501,1507,1521,1527,1541,1545,1549
SET 3=1165,1166,1167,1185 THRU 1190
SET 4=1191 THRU 1198,1553
SET 5=3113,3114
SET 6=3115 THRU 3118,3181,3182,3189,3190,3199 THRU 3212 EXCEPT 3205,3206,
      3557,3561
SET 7=3120
SET 8=3121,3122,3129,3130,3166,3167,3171,3172,3176,3177,3187,3188,3195,
      3196,3549,3553,3557,3561
SET 9=3123 THRU 3128,3135,3136,3164,3168,3169,3491,3545
SET 10=3138,3146,3191 THRU 3194
SET 11=3139 THRU 3151 EXCEPT 3145,3146,3503,3517,3523,3529,3539
SET 12=3154,3162
SET 13=3197,3198,3205,3206
SET 14=3152 THRU 3162,3173 THRU 3175,3178 THRU 3180
SET 15=3183 THRU 3186
TITLE=FRAME AT STATION 340  - SUBSTRUCTURE 1 -
SET 25=2 THRU 11
SET 21=57 THRU 84
BEGIN BULK
```

N A S D A T   S O R T E D   B U L K   D A T A   E C H O

CARD COUNT									
1	ALROD	1	0.132					2	4
2	ALROD	2	0.167					2	4
3	ALROD	3	0.488					2	4
4	ALROD	4	0.452					2	4
5	ALSHEAR	5	6.0	0.04	10.5E+6	0.3		1	5
6	ALSHEAR	6	3.8	0.04	10.5E+6	0.3		1	5
7	ALSHEAR	7	3.4	0.04	10.5E+6	0.3		1	5
8	ALSHEAR	8	3.0	0.04	10.5E+6	0.3		1	5
9	ALSHEAR	9	2.0	0.04	10.5E+6	0.3		1	5
10	ALSHEAR	10	1.5	0.04	10.5E+6	0.3		1	5
11	ALSHEAR	11	1.0	0.04	10.5E+6	0.3		1	5
12	ALSHEAR	12	1.0	0.04	10.5E+6	0.3		1	5
13	ALSHEAR	13	5.0	0.04	10.5E+6	0.3		1	5
14	ALSHEAR	14	2.5	0.072	10.5E+6	0.3		1	5
15	ALSHEAR	15	1.5	0.072	10.5E+6	0.3		1	5
16	BAR	21	15678	4		PREFSEQ			YES
17	ROD	ALL	2	4		MINMAX	1	20	
18	ROD	ALL	2	4		PREFSEQ	1	20	
19	RODMIN	1		-40000.					
20	SHEAR	ALL		4		MINMAX		20	
21	SHEAR	ALL		4		PREFSEQ			YES
22	SHEAR	ALL			25	ENVEL			YES
23	ENDDATA								

FIGURE 10: TYPICAL INPUT DATA DECK FOR NASDAT

THE FOLLOWING LIST PRESENTS THE EXTREME STRESSES IN C S H E A R ELEMENTS FOR S U B C A S E 4

20 EXTREME VALUES ARE REQUESTED - 10 VALUES ARE FOUND TO BE POSITIVE, 10 ARE NEGATIVE

****
MAXIMUM (POSITIVE) STRESSES
****

ELEMENT ID.	AVG STRESS	ELEMENT ID.	AVG STRESS
3151	1.1645E+04	3150	1.0372E+04
3196	1.0367E+04	3158	1.0170E+04
3149	9.9385E+03	3195	9.8036E+03
3194	9.5829E+03	3193	8.9942E+03
3166	8.9071E+03	3188	8.5570E+03

****
MINIMUM (NEGATIVE) STRESSES
****

ELEMENT ID.	AVG STRESS	ELEMENT ID.	AVG STRESS
3049	-9.4084E+03	3066	-8.4594E+03
3073	-7.7787E+03	3048	-7.6788E+03
3040	-7.6418E+03	3060	-7.4885E+03
3056	-7.3720E+03	3032	-7.3580E+03
3036	-7.3221E+03	3047	-7.3046E+03

THE FOLLOWING LIST PRESENTS THE EXTREME AXIAL STRESSES IN C R O D ELEMENTS FOR S U B C A S E 4

20 EXTREME VALUES ARE REQUEST - 20 VALUES ARE FOUND TO BE POSITIVE, -0 ARE NEGATIVE

****
MAXIMUM (POSITIVE) STRESSES
****

ELEMENT ID.	AXIAL STRESS	ELEMENT ID.	AXIAL STRESS
1139	4.9660E+04	1097	4.8070E+04
1138	4.7072E+04	1089	4.6432E+04
1113	4.6383E+04	1090	4.6018E+04
1121	4.5952E+04	1129	4.5700E+04
1091	4.5455E+04	1114	4.5029E+04
1122	4.4157E+04	1134	4.4011E+04
1115	4.3012E+04	1123	4.2808E+04
1105	4.2489E+04	1133	4.1843E+04
1102	4.1757E+04	1140	4.1635E+04
1124	4.0831E+04	1135	4.0641E+04

FIGURE 11: MAXIMUM AND MINIMUM STRESSES IN SHEAR PANELS AND ROD ELEMENTS

AVERAGE STRESSES, CRITICAL STRESSES, DIAGONAL TENSION FACTOR AND MARGINS OF SAFETY FOR C S H E A R ELEMENTS

SUBCASE 5

ELEMENT ID.	AVG SHEAR	CRITICAL SHEAR	DIAG TENSION FACTOR	MARGIN OF SAFETY	ELEMENT ID.	AVG SHEAR	CRITICAL SHEAR	DIAG TENSION FACTOR	MARGIN OF SAFETY
3113	1.4250E+03	3.9474E+03	0.	1.77E+00	3114	1.1210E+03	4.3999E+03	0.	2.92E+00
3115	2.7490E+03	5.3184E+03	0.	9.35E-01	3116	2.9340E+03	5.6291E+03	0.	9.19E-01
3117	1.1490E+03	6.0665E+03	0.	4.28E+00	3118	1.2330E+03	6.4194E+03	0.	4.21E+00
3119	1.3400E+02	6.8070E+03	0.	4.98E+01	3120	1.4300E+02	7.2341E+03	0.	4.96E+01
3121	2.7150E+03	1.4025E+03	1.42E-01	-4.83E-01	3122	1.4480E+03	1.4812E+03	0.	2.29E-02
3123	3.7670E+03	1.8252E+03	1.56E-01	-5.15E-01	3124	4.0130E+03	1.9281E+03	1.58E-01	-5.20E-01
3125	2.0300E+03	2.0805E+03	0.	2.49E-02	3126	2.1620E+03	2.2000E+03	0.	1.76E-02
3127	1.2290E+03	2.3294E+03	0.	8.95E-01	3128	1.3220E+03	2.4660E+03	0.	8.65E-01
3129	3.7220E+03	1.6792E+03	1.71E-01	-5.49E-01	3130	7.8540E+03	1.6646E+03	3.25E-01	-7.88E-01
3135	7.8000E+03	2.4047E+03	2.50E-01	-6.92E-01	3136	8.2780E+03	2.5285E+03	2.52E-01	-6.95E-01
3137	4.9350E+03	1.1965E+03	2.98E-01	-7.58E-01	3138	1.7160E+03	1.3094E+03	5.87E-02	-2.37E-01
3139	5.3060E+03	1.6320E+03	2.51E-01	-6.92E-01	3140	5.5710E+03	1.7017E+03	2.52E-01	-6.95E-01
3141	6.9690E+03	1.8100E+03	2.85E-01	-7.40E-01	3142	7.3070E+03	1.8854E+03	2.86E-01	-7.42E-01
3143	7.0000E+03	1.9656E+03	2.69E-01	-7.19E-01	3144	4.0860E+03	6.6482E+03	0.	6.27E-01
3145	6.1930E+03	1.2899E+03	3.28E-01	-7.92E-01	3146	2.1820E+03	1.3393E+03	1.06E-01	-3.86E-01
3147	3.3040E+03	1.6084E+03	1.55E-01	-5.13E-01	3148	3.4470E+03	1.6689E+03	1.56E-01	-5.16E-01
3149	1.0800E+04	1.7660E+03	3.74E-01	-8.36E-01	3150	1.1283E+04	1.8306E+03	3.76E-01	-8.38E-01
3151	1.2700E+04	1.8990E+03	3.91E-01	-8.50E-01	3152	7.3250E+03	6.3880E+03	2.97E-02	-1.28E-01
3154	5.6960E+03	5.5935E+03	3.94E-03	-1.80E-02	3155	2.4040E+03	6.6386E+03	0.	1.76E+00
3156	1.3650E+03	6.8423E+03	0.	4.01E+00	3157	5.3450E+03	7.2018E+03	0.	3.47E-01
3158	1.0900E+04	7.4128E+03	8.35E-02	-3.20E-01	3159	7.8460E+03	7.6366E+03	5.88E-03	-2.67E-02
3160	7.9270E+03	7.8700E+03	1.57E-03	-7.19E-03	3162	6.5700E+03	1.5050E+03	3.10E-01	-7.71E-01
3163	4.6760E+03	5.8301E+03	0.	2.47E-01	3164	8.2960E+03	5.9979E+03	7.03E-02	-2.77E-01
3165	5.5000E+03	7.2158E+03	0.	3.12E-01	3166	9.4530E+03	1.4760E+03	3.83E-01	-8.44E-01
3167	6.9300E+03	1.5500E+03	3.14E-01	-7.76E-01	3168	5.0240E+03	6.0835E+03	0.	2.11E-01
3169	5.2300E+03	6.3134E+03	0.	2.07E-01	3170	2.1260E+03	7.7225E+03	0.	2.63E+00
3171	8.7190E+03	1.4167E+03	3.75E-01	-8.38E-01	3172	7.4120E+03	1.4862E+03	3.35E-01	-7.99E-01
3173	3.7770E+03	5.8343E+03	0.	5.45E-01	3174	3.9410E+03	6.0558E+03	0.	5.37E-01
3175	1.7200E+03	7.3807E+03	0.	3.29E+00	3176	7.2890E+03	1.3934E+03	3.45E-01	-8.09E-01
3177	5.2160E+03	1.4702E+03	2.68E-01	-7.18E-01	3178	2.1480E+03	5.7903E+03	0.	1.70E+00
3179	3.0910E+03	6.0505E+03	0.	9.57E-01	3180	1.8620E+03	7.4379E+03	0.	2.99E+00
3181	5.2190E+03	2.2984E+03	1.76E-01	-5.60E-01	3182	3.5710E+03	2.4221E+03	8.41E-02	-3.22E-01
3183	1.0000E+02	9.4659E+03	0.	9.37E+01	3184	1.3140E+03	9.9414E+03	0.	6.57E+00
3185	5.4180E+03	1.0668E+04	0.	9.69E-01	3186	8.1530E+03	1.1228E+04	0.	3.77E-01
3187	8.2340E+03	1.1832E+04	0.	4.37E-01	3188	8.7110E+03	1.2426E+04	0.	4.26E-01
3189	2.9300E+03	2.6419E+03	2.25E-02	-9.83E-02	3190	3.2800E+03	2.7978E+03	3.45E-02	-1.47E-01
3191	2.8180E+03	3.3554E+03	0.	1.91E-01	3192	2.9860E+03	3.5283E+03	0.	1.82E-01
3193	9.2710E+03	3.7871E+03	1.92E-01	-5.92E-01	3194	9.8770E+03	3.9740E+03	1.95E-01	-5.98E-01
3195	1.0305E+04	4.1762E+03	1.94E-01	-5.95E-01	3196	1.0899E+04	4.4098E+03	1.94E-01	-5.95E-01
3197	2.2870E+03	4.0430E+03	0.	7.68E-01	3198	2.0120E+03	4.2991E+03	0.	1.14E+00
3199	2.3770E+03	5.1000E+03	0.	1.15E+00	3200	2.5120E+03	5.3989E+03	0.	1.15E+00
3201	4.2550E+03	5.8246E+03	0.	3.69E-01	3202	4.5200E+03	6.1649E+03	0.	3.64E-01
3203	4.1850E+03	6.5387E+03	0.	5.62E-01	3204	4.5190E+03	6.9528E+03	0.	5.39E-01
3205	1.0670E+03	4.7247E+03	0.	3.43E+00	3206	1.2560E+03	5.0460E+03	0.	3.02E+00
3207	2.3770E+03	5.8886E+03	0.	1.48E+00	3208	2.5510E+03	6.2245E+03	0.	1.44E+00
3209	2.4400E+03	6.6842E+03	0.	1.74E+00	3210	2.5990E+03	7.0616E+03	0.	1.72E+00
3211	2.7040E+03	7.4749E+03	0.	1.76E+00	3212	2.8870E+03	7.9287E+03	0.	1.75E+00
3485	2.6730E+03	7.9805E+03	0.	1.99E+00	3491	5.3510E+03	2.7320E+03	1.45E-01	-4.89E-01
3497	7.4480E+03	2.7835E+03	2.11E-01	-6.26E-01	3503	5.9550E+03	3.4940E+03	1.15E-01	-4.13E-01
3517	3.4310E+03	3.3362E+03	6.09E-03	-2.76E-02	3523	5.5000E+02	8.4831E+03	0.	1.44E+01
3529	5.8030E+03	8.1391E+03	0.	4.03E-01	3539	6.7890E+03	7.7675E+03	0.	1.44E-01
3545	9.5230E+03	8.0738E+03	3.58E-02	-1.52E-01	3549	2.0770E+03	1.3665E+04	0.	5.58E+00
3553	2.5090E+03	4.8658E+03	0.	9.39E-01	3557	3.1500E+02	7.6745E+03	0.	2.34E+01

FIGURE 12: AVERAGE STRESSES, BUCKLING STRESSES, DIAGONAL TENSION FACTORS AND MARGINS OF SAFETY FOR SHEAR PANELS

CRITICAL STRESSES AND SAFETY MARGINS FOR C R O D AND C O N R O D ELEMENTS

SUBCASE 4

ELEMENT ID.	AXIAL STRESS	CRITICAL STRESS	MARGIN OF SAFETY	ELEMENT ID.	AXIAL STRESS	CRITICAL STRESS	MARGIN OF SAFETY
1121	4.5952E+04	6.3000E+04	3.71E-01	1122	4.4157E+04	6.3000E+04	4.27E-01
1123	4.2808E+04	6.3000E+04	4.72E-01	1124	4.0831E+04	6.3000E+04	5.43E-01
1125	3.8921E+04	6.3000E+04	6.19E-01	1126	3.7087E+04	6.3000E+04	6.99E-01
1127	3.5340E+04	6.3000E+04	7.83E-01	1128	3.3674E+04	6.3000E+04	8.71E-01
1129	4.5700E+04	6.3000E+04	3.79E-01	1130	3.7796E+04	6.3000E+04	6.67E-01
1131	3.3243E+04	6.3000E+04	8.95E-01	1132	3.8220E+04	6.3000E+04	6.48E-01
1133	4.1843E+04	6.3000E+04	5.06E-01	1134	4.4011E+04	6.3000E+04	4.31E-01
1135	4.0641E+04	6.3000E+04	5.50E-01	1136	3.1402E+04	6.3000E+04	1.01E+00
1137	4.2424E+04	6.3000E+04	4.85E-01	1138	4.7072E+04	6.3000E+04	3.38E-01
1139	4.9660E+04	6.3000E+04	2.69E-01	1140	4.1635E+04	6.3000E+04	5.13E-01
1141	3.2667E+04	6.3000E+04	9.29E-01	1142	2.2714E+04	6.3000E+04	1.77E+00
1143	1.6800E+04	6.3000E+04	2.75E+00	1144	1.6578E+04	6.3000E+04	2.80E+00
1145	3.1339E+04	6.3000E+04	1.01E+00	1146	2.8888E+04	6.3000E+04	1.18E+00
1147	2.9498E+04	6.3000E+04	1.14E+00	1148	3.2423E+04	6.3000E+04	9.43E-01
1149	3.1210E+04	6.3000E+04	1.02E+00	1150	2.5675E+04	6.3000E+04	1.45E+00
1151	1.7413E+04	6.3000E+04	2.62E+00	1152	9.0450E+03	6.3000E+04	5.97E+00
1153	1.5262E+04	6.3000E+04	3.13E+00	1154	1.7667E+04	6.3000E+04	2.57E+00
1155	1.1765E+04	6.3000E+04	4.35E+00	1156	1.5191E+04	6.3000E+04	3.15E+00
1157	2.0445E+04	6.3000E+04	2.08E+00	1158	1.5263E+04	6.3000E+04	3.13E+00
1159	8.2030E+03	6.3000E+04	6.68E+00	1160	5.9990E+03	6.3000E+04	9.50E+00
1162	4.6000E+02	6.3000E+04	1.36E+02	1165	1.4490E+03	6.3000E+04	4.25E+01
1166	-3.2450E+03	4.1505E+05	1.27E+02	1167	-5.6720E+03	1.2104E+06	2.12E+02
1168	-6.7860E+03	1.3806E+06	2.02E+02	1169	-1.7060E+03	6.3428E+06	3.72E+03
1170	-8.3780E+03	5.4371E+05	6.39E+01	1171	-8.1460E+03	5.1895E+05	6.27E+01
1172	-6.1430E+03	1.4781E+06	2.40E+02	1173	-2.2900E+03	1.3746E+06	5.99E+02
1174	-1.7244E+04	5.4106E+05	3.04E+01	1175	-1.2869E+04	5.1644E+05	3.91E+01
1176	-6.4970E+03	1.4717E+06	2.26E+02	1177	-2.0160E+03	1.3686E+06	6.78E+02
1178	-2.3700E+02	6.2843E+06	2.65E+04	1179	-2.4851E+04	5.3919E+05	2.07E+01
1180	-2.1027E+04	5.1453E+05	2.35E+01	1183	-2.8673E+04	5.3949E+05	1.78E+01
1184	-2.5788E+04	5.1427E+05	1.89E+01	1185	-1.6496E+04	1.4180E+06	8.50E+01
1186	-2.0531E+04	1.4180E+06	6.81E+01	1187	-2.2884E+04	1.6280E+06	7.01E+01
1188	-2.0475E+04	1.6280E+06	7.85E+01	1189	-1.6220E+04	1.6277E+06	9.94E+01
1190	-1.1795E+04	1.6277E+06	1.37E+02	1191	-3.1848E+04	6.0624E+05	1.80E+01
1192	-2.4863E+04	5.5245E+05	2.12E+01	1193	-2.6296E+04	1.3578E+06	5.06E+01
1194	-2.5676E+04	1.3578E+06	5.19E+01	1195	-2.4067E+04	1.5587E+06	6.38E+01
1196	-2.1399E+04	1.5587E+06	7.18E+01	1197	-1.8456E+04	1.5587E+06	8.35E+01
1198	-1.5254E+04	1.5587E+06	1.01E+02	1199	-3.1835E+04	5.4082E+05	1.60E+01
1200	-2.8743E+04	5.1463E+05	1.69E+01	1201	-2.7402E+04	1.2464E+06	4.45E+01
1202	-2.7234E+04	1.2464E+06	4.48E+01	1203	-2.5667E+04	1.4309E+06	5.47E+01
1204	-2.2585E+04	1.4309E+06	6.24E+01	1205	-1.9922E+04	1.4308E+06	7.08E+01
1206	-1.7654E+04	1.4308E+06	8.00E+01	1287	-2.2800E+02	6.3117E+06	2.77E+04
1489	3.0985E+04	6.3000E+04	1.03E+00	1495	2.5233E+04	6.3000E+04	1.50E+00
1501	1.7339E+04	6.3000E+04	2.63E+00	1507	7.5840E+03	6.3000E+04	7.31E+00
1521	6.9690E+03	6.3000E+04	8.04E+00	1527	-1.4130E+03	2.1482E+06	1.52E+03
1541	-3.4710E+03	2.1384E+06	6.15E+02	1549	-1.7532E+04	2.1254E+06	1.20E+02
1553	-1.3834E+04	2.1694E+06	1.56E+02	1557	-1.7866E+04	1.9475E+06	1.08E+02

FIGURE 13: AXIAL STRESSES, EULER/ULTIMATE STRESSES AND MARGINS OF SAFETY FOR ROD ELEMENTS

FRAME AT STATION 340 - SUBSTRUCTURE 1 - SUBCASE 4

CBAR	M1(A)	M1(B)	AXIAL FORCE	AXIAL STRESS	SIGMAX(A)	SIGMAX(B)	SIGMIN(A)	SIGMIN(B)
57	-2.972E+02	4.317E+02	1.056E+03	2.080E+03	2.907E+03	1.728E+03	2.898E+03	1.572E+02
58	2.087E+02	1.125E+03	7.458E+02	1.469E+04	1.824E+03	6.364E+02	3.380E+03	-3.020E+03
59	7.185E+02	1.360E+03	2.670E+02	5.654E+02	1.786E+03	-2.302E+03	2.875E+03	-4.861E+03
60	6.332E+02	1.054E+03	-5.055E+02	-9.959E+02	7.977E+01	-3.523E+03	7.955E+02	-5.204E+03
61	1.633E+03	-[illegible].283E+02	1.533E+02	2.404E+02	2.497E+03	-2.654E+03	1.354E+03	-6.279E+02
62	-3.094E+02	4.037E+02	4.034E+02	6.125E+02	1.161E+03	1.649E+02	1.170E+03	-1.032E+02
63	-8.870E+02	-1.301E+03	-5.255E+02	-7.205E+02	2.549E+02	-1.469E+03	7.761E+02	-1.869E+03
64	-8.122E+02	-1.691E+03	-2.402E+02	-3.092E+02	3.798E+02	-8.402E+02	1.125E+03	-1.415E+03
65	-1.480E+03	-1.459E+03	-1.499E+02	-2.004E+02	1.210E+03	-1.193E+03	1.695E+03	-1.534E+03
66	-1.603E+03	-2.590E+03	2.945E+01	2.527E+01	1.728E+03	-1.006E+03	2.775E+03	-1.640E+03
67	-1.353E+03	-1.914E+03	7.376E+02	1.120E+04	3.519E+03	-7.507E+02	4.512E+03	-1.525E+03
68	-2.606E+03	[illegible].725E+02	-4.449E+01	-8.764E+01	1.031E+04	-4.515E+03	1.395E+03	-3.570E+03
69	2.840E+02	1.297E+03	-7.599E+02	-1.497E+04	-1.015E+03	-2.630E+03	7.069E+02	-6.675E+03
70	1.565E+03	1.707E+03	-4.930E+02	-9.712E+02	1.687E+03	-7.216E+03	1.928E+03	-7.783E+03
71	1.681E+03	1.668E+03	-5.211E+02	-1.027E+04	1.829E+03	-7.736E+03	1.807E+03	-7.683E+03
72	1.316E+03	4.715E+02	-8.812E+02	-1.736E+04	4.996E+02	-6.988E+03	-9.349E+02	-3.618E+03
73	1.191E+03	-2.263E+03	-2.370E+01	-4.669E+01	1.976E+03	-4.799E+03	8.984E+03	-3.890E+03
74	-1.634E+03	-1.155E+03	7.460E+02	1.132E+03	4.029E+03	-1.126E+03	3.180E+03	-4.636E+02
75	-2.052E+03	-1.176E+03	7.338E+01	6.296E+01	2.241E+03	-1.256E+03	1.312E+03	-6.933E+02
76	-9.744E+02	-1.129E+02	1.633E+02	2.183E+02	1.147E+03	-4.350E+02	3.259E+02	1.425E+02
77	-1.934E+02	1.164E+03	1.179E+02	1.518E+02	3.158E+02	2.536E+01	9.130E+02	-8.357E+02
78	-4.259E+02	[illegible].151E+02	-5.500E+02	-7.541E+02	-2.858E+02	-1.113E+03	-6.644E+01	-1.650E+03
79	4.517E+02	4.445E+02	-7.510E+02	-1.140E+04	-5.158E+02	-1.941E+03	-5.257E+02	-1.928E+03
80	1.144E+03	-5.680E+02	-1.982E+02	-3.009E+02	1.240E+03	-2.328E+03	6.832E+02	-1.224E+03
81	4.214E+02	-1.267E+03	6.527E+02	1.286E+03	2.002E+03	-3.958E+02	6.343E+03	-8.666E+02
82	-7.904E+02	-7.912E+02	1.210E+03	2.383E+03	5.538E+03	1.041E+03	5.541E+03	1.039E+03
83	-7.109E+02	-5.172E+02	1.292E+03	2.546E+03	5.383E+03	1.338E+03	4.610E+03	1.667E+03
84	-5.666E+02	-5.479E+01	1.230E+03	2.423E+03	4.685E+03	1.460E+03	2.642E+03	2.330E+03

FIGURE 14: INTERNAL LOAD DISTRIBUTION IN A BULKHEAD

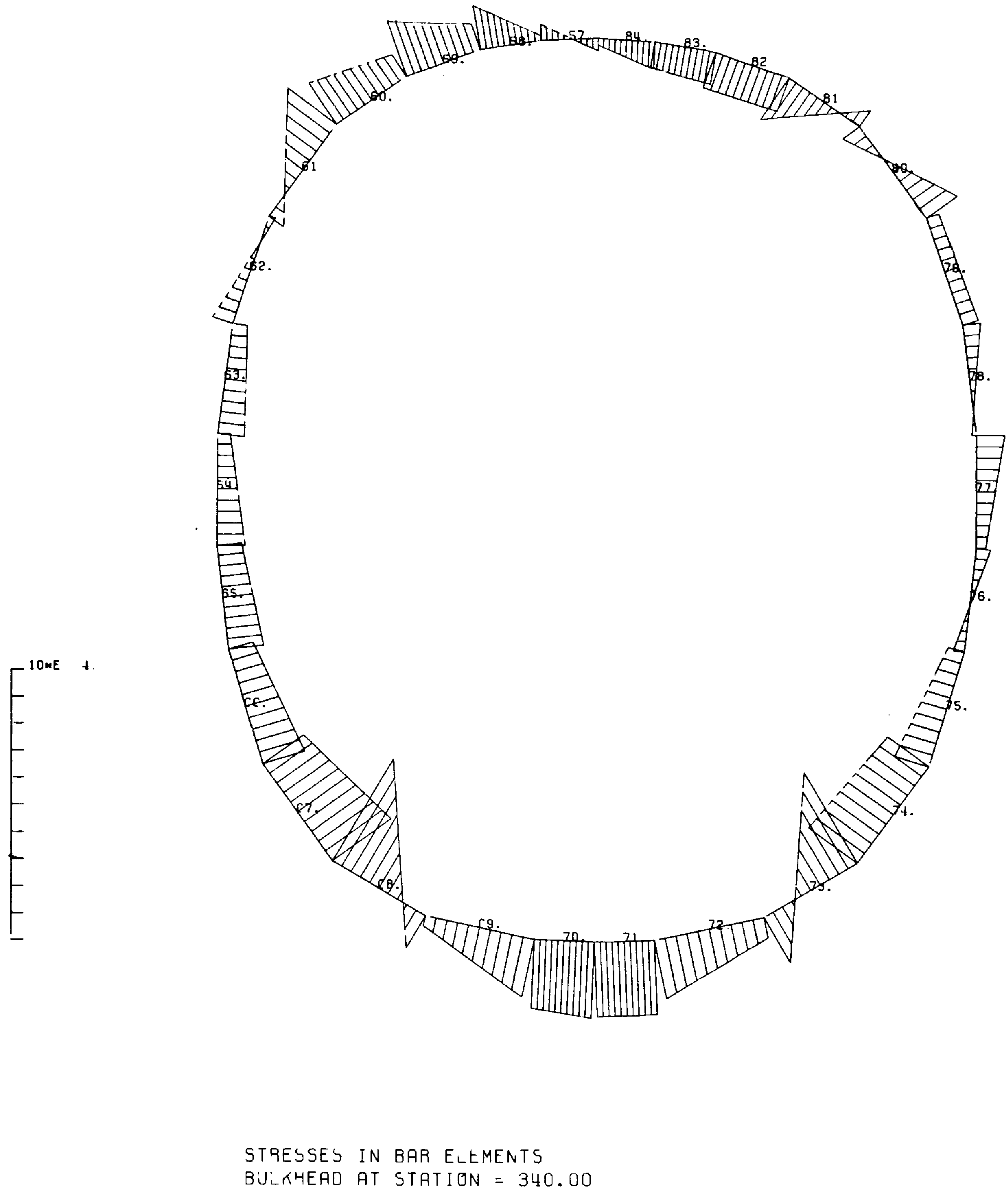
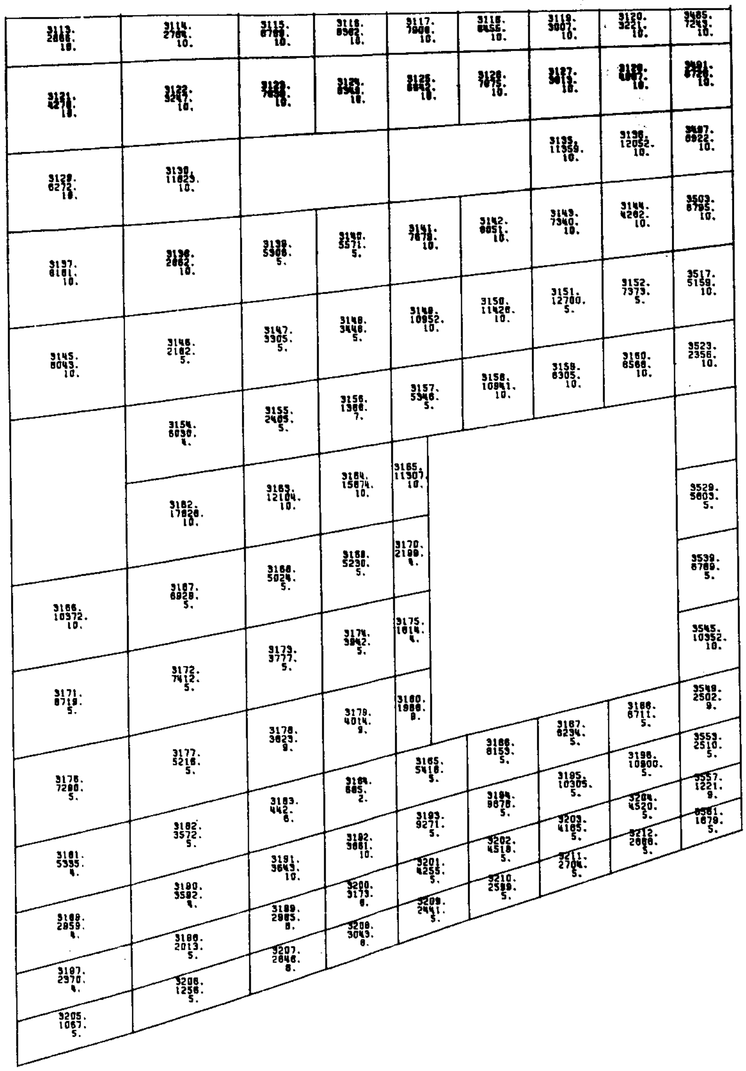


FIGURE 15: BENDING STRESSES DIAGRAM FOR A BULKHEAD



WESTWIND SUBSTRUCTURE 1
ENVELOPE FOR MAXIMUM
SHEAR STRESS IN PANELS

FIGURE 16: POSITIVE SHEAR STRESSES ENVELOPE DISPLAYED ON A DEVELOPED STRIP OF THE FUSELAGE

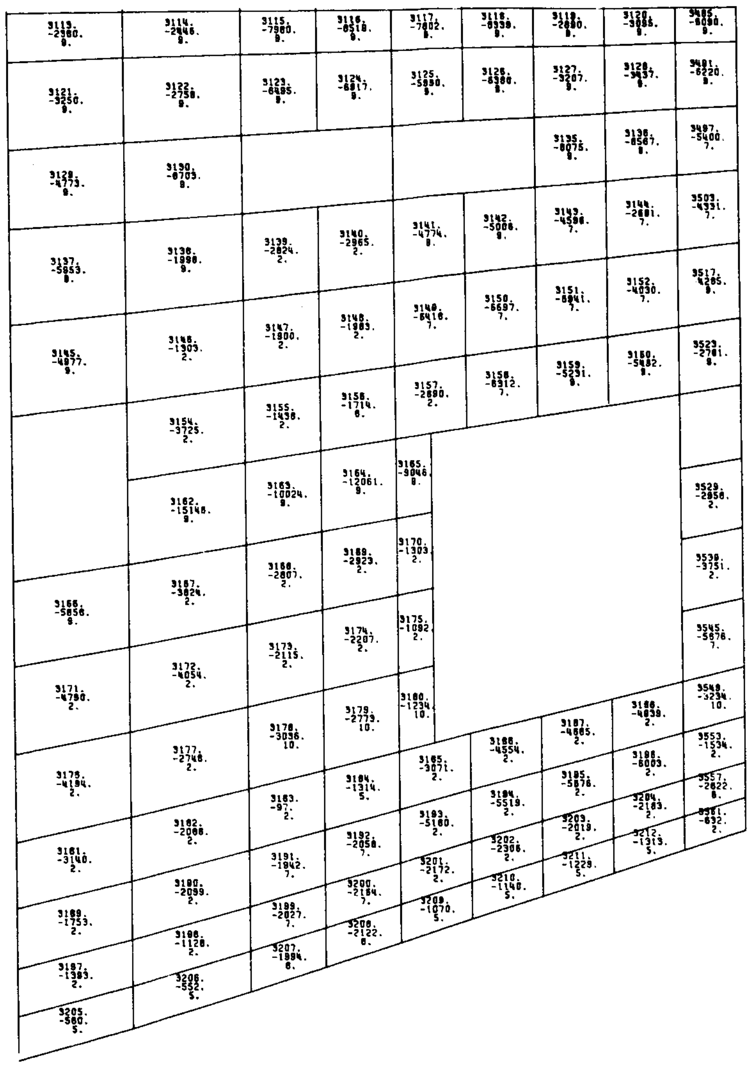
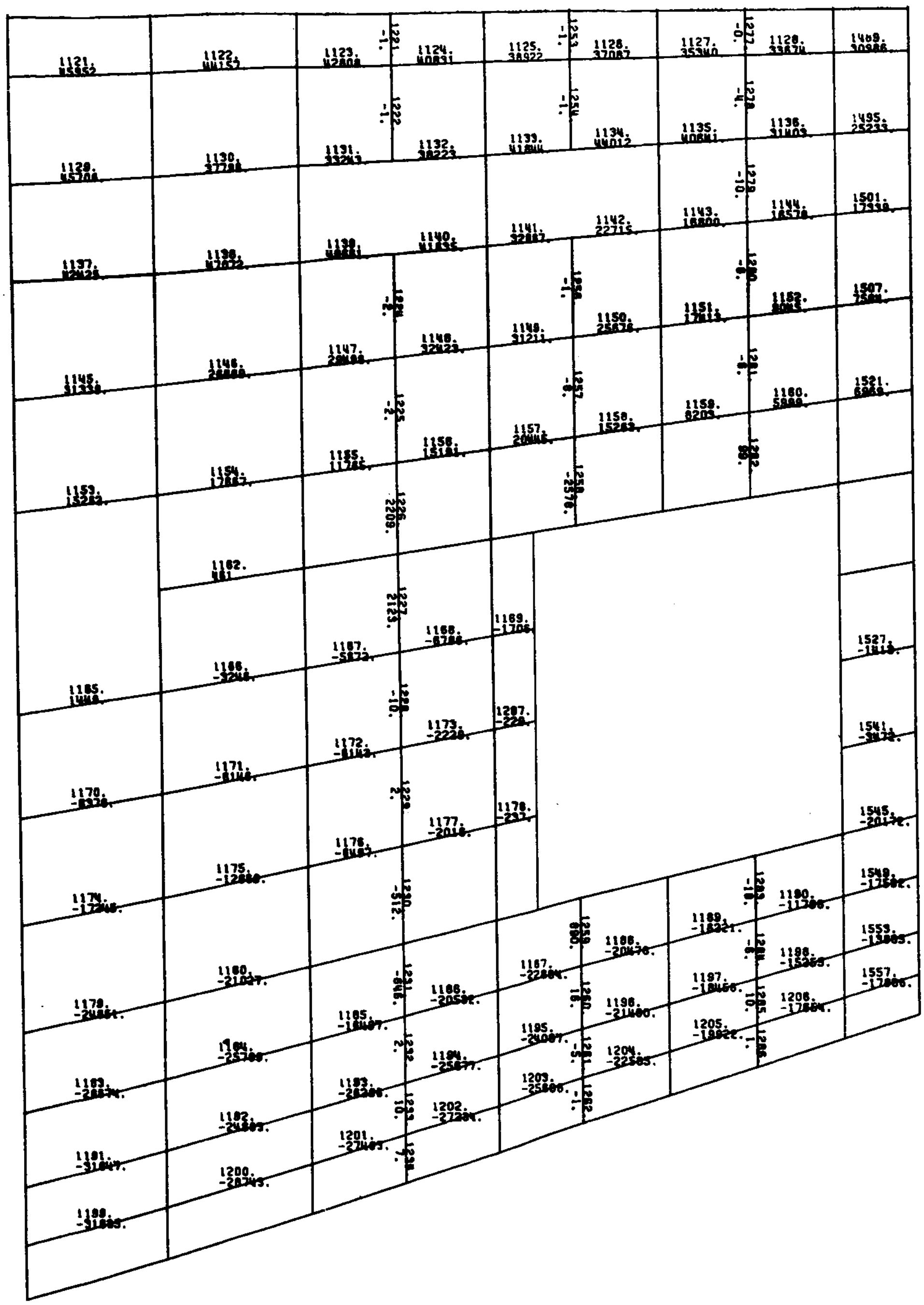
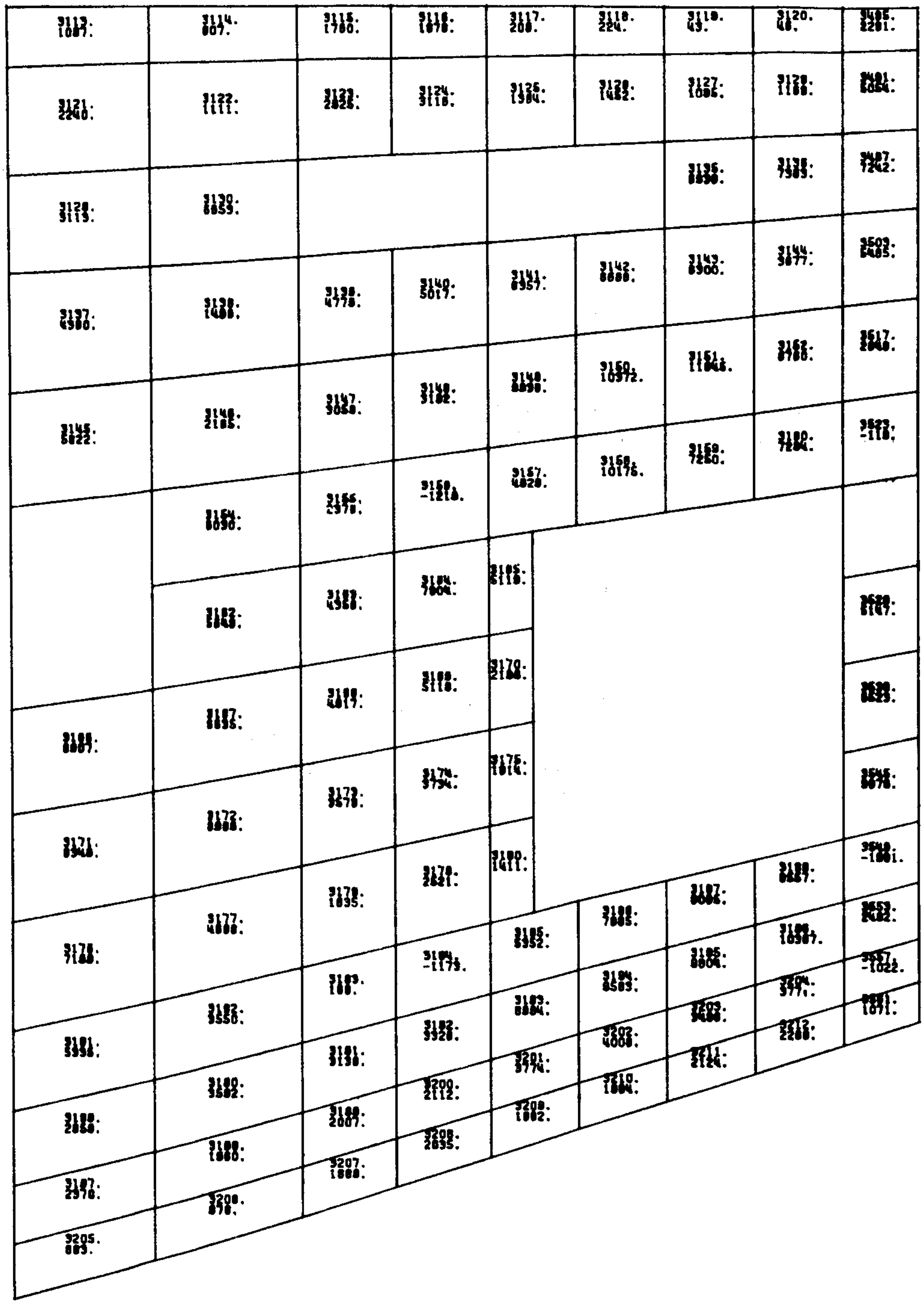


FIGURE 17: NEGATIVE SHEAR STRESSES ENVELOPE DISPLAYED ON A DEVELOPED STRIP OF THE FUSELAGE



WESTWIND SUBSTRUCTURE 1
SUBCASE 4 -UPGUST CONDITION CONFIG. 5-
STRESSES IN ROD ELEMENTS

FIGURE 18: ROD STRESSES DISPLAYED ON A DEVELOPED STRIP OF THE FUSELAGE



WESTWIND SUBSTRUCTURE 1
SUBCASE 4 -UPGUST CONDITION CONFIG. 5-
SHEAR STRESS IN PANELS

FIGURE 19: SHEAR STRESSES DISPLAYED ON A DEVELOPED STRIP OF THE FUSELAGE