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COMPUTER CODE FOR THE ANALYSIS OF MULTILAYERED FIBER COMPOSITES - USERS MANUAL

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16. Abstract

A FORTRAN IV computer code for the micromechanics, macromechanics, and laminate analysis of multilayered fiber composite structural components is described. The code can be used either individually or as a subroutine within a complex structural analysis/synthesis program. The inputs to the code are constituent materials properties, composite geometry, and loading conditions. The outputs are various properties for ply and composite; composite structural response, including bending-stretching coupling; and composite stress analysis, including comparisons with failure criteria for combined stress. The code was used successfully in the analysis and structural synthesis of flat panels, in the buckling analysis of flat panels, in multilayered composite material failure studies, and lamination residual stresses analysis.

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COMPUTER CODE FOR THE ANALYSIS OF MULTILAYERED FIBER COMPOSITES - USERS MANUAL*

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SUMMARY

A computer code to carry out the multilevel linear analysis required to efficiently design structural components made from multilayered fiber composites is described. The inputs to the code are constituent materials properties, some factors reflecting the fabrication process, and composite geometry. The code performs the micromechanics, macromechanics, and laminate analysis of fiber composites. The code outputs are the various ply and composite properties, composite structural response (accounting for bending-stretching coupling etc.), and the composite stress analysis results, including the results of the combined-stress strength criteria. The code is in FORTRAN IV compiler language and can be used efficiently as a package in complex-structural analyses, finite-element methods, buckling and vibration studies, and structural syntheses. The input-output format is described extensively. Required input data to the code for various fiber-matrix composites are given. The FORTRAN compiled listing and sample trial cases are included to aid the designer or analyst in using this code. The code consists of two parts. In the first part, the mechanics to use the code are described; in the second part the equations programmed are described. The code has been used successfully in the analysis of various fiber matrix multilayered composites. It was also used (and proved to be efficient) in the structural synthesis of multilayered thornel/epoxy composite plates, in buckling studies of simply supported multilayered fiber-composite plates, and in the computation of lamination residual stresses in angle ply composites. Selection of correlation coefficients for new composite systems is described. Possible extensions for temperature-dependent properties, material nonlinearities and failure load envelopes are indicated.

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INTRODUCTION

The importance and need of a multilevel analysis in designing structural components with multilayered fiber composites are documented in reference 1. A multilevel analysis which was found to be efficient in predicting the structural response of multilayered fiber-composites (with the constituent materials properties, the fabrication process, and the composite geometry known) is also documented in reference 1.

The multilevel analysis presented in reference 1 consists of (1) micromechanics theories for the thermoelastic properties and the stress-level limit of the single ply as functions of constituent materials properties and the particular fabrication process, (2) the combined-stress strength criterion of the single ply, and (3) multilayered composite structural response and analysis (macromechanics or laminate analyses) where the interply layer effects are taken into account. The computer code, to carry out this multilevel analysis and supplemented as noted by the additional references, is described herein.

The computer code has been programmed in FORTRAN IV and has been extensively used in the UNIVAC 1107, 1108, and IBM 7094. Since this report is to serve as a user's manual, the code is divided into two parts. In the first part, the mechanics of using the code are described with respect to program format, input-output, sample input data sheets, and tables of input data for several fiber composites. In the second part, the program is described. Sample case runs of Thornel-50/epoxy composites with unidirectional and angle plies are included with the compiled listing in appendix B. Sample cases for bending, stretching, coupling, and lamination residual stresses are also included.

The format of the program is described in the section MAIN PROGRAM and follows the FORTRAN IV program format for the 7094. The subroutines required to carry out the various levels of analysis are described individually in their respective sections. In these subroutines, the equations programmed are given, the various alternatives for establishing certain properties (such as strain magnification factors, longitudinal compressive stress limit, and combined-stress strength criterion) are discussed, and the subroutine input-outputs and the global storage locations (common to all parts of the program) are identified. The input-output format is described in detail separately in the sections Input Ply Properties and Output. These descriptions are quite extensive so that designers and analysts with little or no programming experience as well as experienced programmers can easily use the code.

In appendix A the FORTRAN symbols are defined. The definitions include such information as in which part of the program each global variable is generated. The input data in tables IV to XIII (currently acceptable for the analysis of several fiber composites) provide for immediate use of the code. The inclusion of the compiled FORTRAN lsting (appendix B) with the sample trial cases (appendix C) should further amplify the detail descriptions. Filament and fiber are used interchangeably in the description and in the discussion. Ply, unidirectional laminate, and unidirectional composite are also used interchangeably.

It is noted that the global storage of the composite and ply properties is very important when this multilevel analysis is to be used as a subroutine package to generate structural behavior properties for structural analysis purposes.

This code has been used successfully in predicting the ply thermoelastic constants (refs. 1 to 3) in laminate analysis (boron, graphite, carbon, and glass-filament-epoxy composites; refs. 1, and 3 to 5) buckling analysis (ref. 6) and structural synthesis (ref. 1). It has also been used to calculate the lamination residual stresses in angle-ply composites (ref. 7).

Mr. Tom Delivuk, then with the same center, converted the original ALGOL CODE to the initial FORTRAN IV CODE which resulted into the CODE described herein.

SYMBOLS

A_{cx}	composite axial stiffness
A^{R}_{cx}	reduced axial stiffness
BIDE	Boolean-true if interply effects are included
C_{cx}	composite coupling stiffness
C_{e1}	string with force variables
C_{e2}	string with displacement variables
CSANB	Boolean-true if membrane and axial symmetry exists
D_{cx}	composite flexural rigidities
D^{R}_{cx}	reduced bending rigidities
D_{v}	displacement vector
d_{f}	filament equivalent diameter
E_{f}, E_{cf}	filament elastic constants
$E_{\ell}, E_{c\ell}$	ply elastic constants
E_{m}, E_{cm}	matrix elastic constants
E_{f11}, etc.	fiber normal modulus
$E_{\ell 11}$, etc.	ply normal modulus

E_{m11}, etc.	matrix normal modulus
G_{f12}, etc.	fiber shear modulus
$G_{\ell 12}$, etc.	ply shear modulus
G_{m12}, etc.	matrix shear modulus
H_j	interply distortion energy coefficient
H_{kc}	array of constituents heat conductivities
h_c	composite heat capacity
i, j	index, generally ply or interply
$K_{c11, c22, c33}$	composite three-dimensional heat conductivities
$K_{cxy, cyy, cxy}$	composite two-dimensional heat conductivities
K_{f11}	fiber heat conductivity
$K_{\ell 11}$	ply heat conductivity
K_{m11}	matrix heat conductivity
k_f	apparent filament volume ratio
k_m	apparent matrix volume ratio
k_v	apparent void volume ratio
$\bar{k}_f$	actual fiber volume ratio
$\bar{k}_m$	actual matrix volume ratios
$k_{f\ell}$	ply apparent fiber volume ratio
$k_{v\ell}$	ply apparent void volume ratio
L_{sc}	array of limiting conditions
M_{cx}	applied moment
$M_{c\,\Delta Tx}$	thermal moments
m	load condition index
$\bar{N}_{cx}$	applied membrane loads
$N_{c\,\Delta Tx}$	thermal force
N_f	number of fibers per end
N_ℓ	number of plies
$N_{\ell c}$	number of load conditions
N_{pc}	string PROPC length

$N_{p\ell}$	string PROP length
P_c	composite properties array
P_ℓ	ply properties array
P_{cp}	string PROPC
$P_{\ell p}$	string PROP main program
$Q_{f,i,p,r,s}$	indices to print out string PROP
R	transformation matrix
RINDV	Boolean-TRUE true if displacements are known
$S_{\ell 11T}$etc.	ply limit stresses
t_ℓ	ply thickness
TLINP	FALSE if ply thickness is calculated internally
w_{cb}	composite local curvature changes
x, y, z	structural reference axes
α_c	composite coefficient of thermal expansion
α_f	fiber thermal coefficient of expansion
α_ℓ	ply thermal coefficients of expansion
α_m	matrix thermal coefficient of expansion
β_e, β_ϵ	correlation factors for ply thermoelastic properties
β_h	correlation factors for ply heat conductivities
β_s	correlation factors for ply strength
β_v	matrix strain magnification due to ply strain in the presence of voids
δ_ℓ	interply layer thickness
ϵ_{csx}	reference plane membrane strains
ϵ_ℓ	ply strains
θ_{cs}	angle between composite material and structural axes
$\theta_{\ell i}, \theta_{\ell c}$	angle between ply material and composite axes
ν_{f12}, etc.	fiber Poisson's ratio
$\nu_{\ell 12}$, etc.	ply Poisson's ratio
ν_{m12}, etc.	matrix Poisson's ratio
π	constant

$\rho_{f,m}$	filament and matrix weight density
σ_l	ply stresses
φ_i	matrix strain magnification due to ply strain
1,2,3	material reference axes

USERS MANUAL

The mechanics required to use this code for the analysis of multilayered fiber composites are described in this part of the manual. Here, it is assumed that the user is interested in using the code as a tool only and that he has available to him a FORTRAN IV manual. The theory on which the code is based is described in the second part of the report.

The physical representation of the code is illustrated in figure 1. The geometry of the constituents, the ply, and the composite are defined in this figure. The required input properties, correlation coefficients, and computed properties are summarized in figure 1 in symbolic form.

The physical arrangement of the code is illustrated in figure 2. The numbers given in each block of cards are for subsequent discussion and do not appear on the code. Four steps are required to use the code in the user's computer facility:

(1) Obtain the code.
(2) Make it operational in the user's computer facility.
(3) Supply the input data.
(4) Interpret the code output results.

Obtain the Code

The code could be obtained in cards. If this is not convenient or possible, then the cards can be punched from the compiled listing (see appendix B).

Make It Operational

Making the program operational requires the availability of a FORTRAN compiler in the user's computer facility, certain control cards at the beginning of the code, and the card that preceeds each subroutine. Consult your computer group about these items. The control cards present in the code are only for the Lewis IBM 7044/7094 direct couple system. Once the deck of cards has been assembled as is shown in figure 2 (except Input Data) with the proper control cards, the user is ready to compile the code in his facility. The compilation will indicate whether any additional modifications are needed. Most modifications will be minor and will usually deal with certain logical statements peculiar to each compiler. Consult your computer group for these modifications.

Supply the Input Data

The physical arrangement of the input data cards is illustrated in figure 3. The numbers in the group of cards are for identification purposes in this description and do not appear on the cards. Details in preparing the input data cards are summarized in table I. A detailed description of these cards is given subsequently. A sample for preparing input data sheets is illustrated in table II for the Thornel-50/epoxy composite system.

Listings of input data for several composite systems appear in tables III to XII. These systems are shown graphically in figure 4. The input data for these systems can be punched from the listings, and the cards that need alterations for the specific problem can be modified accordingly.

Input data for additional composite systems may be easily prepared. This is done by selecting a related system from those in tables III to XII and modifying those entries that need modification. Table I and the section Detail Description of Input Data explain where and how each entry is read in.

After the input data have been properly assembled (as is shown in fig. 3), it is placed in its physical position (fig. 2), and the code is ready to be run for results.

Detailed Description of Input Data

The card group numbers referred to here are given in figure 3 and table I. The sequential order of the entries in each card group is given in table I.

(1) Composite system card. - The composite system title is punched on this card. The title can be 55 characters long including blanks.

(2) Data control card. - The number of plies N_l, number of ply properties N_{pl}, number of composite properties N_{pc}, the number of fibers per end N_f, and the number of load conditions N_{pc} are entered in this card. The number of ply properties and the number of composite properties are always the same: they are $N_{pl} = 71$ and $N_{pc} = 54$. The others have to be entered according to the composite system and the load conditions.

(3) Constituent materials elastic properties. - The constituent elastic properties are entered in this group of cards. The fiber properties are entered first and then the ma-

rix. Enter only extension moduli, Poisson's ratios, and zero values for shear moduli when the constituent material is isotropic. For example, in a glass/epoxy system, $E_{f33} = E_{f22} = E_{f11}$ and $\nu_{f23} = \nu_{f13} = \nu_{f12}$. The shear moduli $G_{f23} = G_{f13} = G_{f12}$ are computed internally.

(4) Correlation coefficients for ply elastic constants, expansion coefficients, and strain magnification factors. - The correlation coefficients that make theory agree with experiment are entered in this group of cards. The first entry in this group is β_m. It is selected so that predicted extensional moduli and Poisson's ratios correlate with measured values. The procedure for selecting β_m is iterative. First the code is run with β_m equal to some initial value. Experience has proven that $\beta_m = 4$ is usually a good approximation for the initial value. For many systems this is also the terminal value. Next, obtain values for β_m greater and smaller than four, and select the proper value for β_m by interpolation. The aforementioned description for selecting β_m applies to the selection of all correlation coefficients in this code.

The second entry in this card group is β'_m, which is the correlation coefficient for the ply shear moduli G_{l12} and G_{l13}. The third entry is β''_m which is the correlation coefficient for G_{l13}. The fourth entry is $\bar{\beta}_m$ which is the correlation coefficient for the ply thermal coefficients of expansion. The next three entries, β_ϵ, β'_ϵ, and β''_ϵ, are correlation coefficients for strain magnification factors $\varphi_{\mu 22}$, $\varphi_{\mu 12}$, and $\varphi_{\mu 23}$, respectively. These coefficients are entered as zeros. Experience with several composite systems has shown that the correlation coefficients β_ϵ are not needed. However, they are provided for possible future use.

The coefficient β_t is the ratio of the thickness-to-width of the rectangle formed by an in-situ end or tow of fibers. Another way to visualize this is that β_t is the ratio of ply-thickness per end or tow-ply width. The value for β_t is obtained from electron photomicrographs or indirectly as described in reference 5. Entries 9 and 10 are entered as zeros; these fields are empty and are available for future use. Entries 11 to 14 are for the coefficients γ_m; these coefficients are alternates to β_m and are to be used if the β_m coefficients do not provide the desired correlation. Note that when a β_m coefficient is used, the corresponding γ_m coefficient is entered as zero and vice versa.

Entries 15 to 17 are for the coefficients γ_ϵ, which are alternates to coefficients β_ϵ. Note that when a β_ϵ coefficient is used the corresponding γ_ϵ coefficient is zero and vice versa. The γ_ϵ coefficients are entered with values of one. Entries 18 to 20 are entered as zeros. These are empty fields and are available for future use.

Experience with the code thus far has shown that all the correlation coefficients except β_t are approximately the same for several composite systems. (See tables III to XII.)

(5) Fiber thermal coefficients of expansion. - The coefficients α_{f11}, α_{f22}, and α_{f33} are entered on this card. If the fiber is isotropic, then $\alpha_{f33} = \alpha_{f22} = \alpha_{f11}$.

(6) Matrix thermal coefficients of expansion. - The coefficients α_{m11}, α_{m22}, and α_{m33} are entered in this card. When the matrix is isotropic, $\alpha_{m33} = \alpha_{m22} = \alpha_{m11}$.

(7) Constituent heat conductivities and heat capacities. - The first four entries in this group are for the fiber heat conductivities K_{f11}, K_{f22}, K_{f33}, and heat capacity h_{cf}. The next four are for the corresponding matrix properties. The next three are zero entries, and the last one is the heat conductivity K_v for air. (See card group 7 of table I.)

(8) Correlation coefficients for heat conductivities. - The four entries in this card are for the correlation coefficients β_{hv}, β_{h1}, β_{h2}, and β_{h3}, respectively. These coefficients are as follows: β_{kv} is for matrix with voids, β_{k1} for $K_{\ell 11}$, β_{k2} for $K_{\ell 22}$, and β_{k3} for $K_{\ell 33}$. They are selected as was described in β_m in card group (4).

(9) Constant π. - The value for π is entered in this card.

(10) Boolean for thickness. - The letter T is entered in this card if the ply thickness is supplied. The letter F is entered if the ply thickness is computed internally.

(11) Boolean for membrane and bending symmetry. - The letter T is entered in this card if the composite has both membrane and bending symmetry; otherwise the letter F is entered.

(12) Boolean for interply layer contribution. - The letter T is entered in the card if the interply layer contributions on the composite are desired; otherwise, the letter F is entered.

(13) Boolean for input displacements. - The letter T is entered in this card if the displacements are inputs; otherwise, the letter F is entered.

(14) Composite angle, constituent densities, and fiber equivalent diameter. - The composite angle (angle between composite material 1-axis and structural x-axis (fig. 5) is the first entry in this card. The fiber and matrix densities are the second and third entries. The fourth entry is the fiber equivalent diameter.

(15) Ply void volume ratio. - The void volume ratio of the plies is entered in this group of cards; the first entry is for the first ply, and the last entry is for the last ply. The bottom or the inner ply in the composite is selected as the first ply for convenience. The number of entries is equal to the number of plies in the composite. (See tables I and II.)

(16) Ply fiber volume ratio. - The ply fiber volume ratio is entered in this group of cards. The first entry is for the first ply, which is the bottom or inner ply in the composite. The last entry is for the last ply. The number of entries equals the number of plies. (See tables I and II.)

(17) Ply orientation angle. - The ply angle (measured from the composite material 1-axis to the ply material 1-axis (fig. 5)) is entered in these cards. The first entry is for the first ply which is the bottom or inner ply in the composite. The last entry is for the last ply. The number of entries equals the number of plies. (See tables I and II.)

(18) Ply thickness. - The ply thicknesses are entered in this group of cards. Two options are available. When the Boolean TLINP is F, the ply thicknesses are computed internally. In this case, the values entered do not correspond to the actual ply thicknesses. When the Boolean TLINP is T, the ply thicknesses are supplied through the input. In this case the values entered correspond to the ply actual thicknesses. The first value entered is the thickness for the bottom or inner ply of the composite. The last value entered is for the last ply and the number of values entered equals the number of plies in the composite. (See tables I and II.)

(19) Ply temperature difference. - The ply temperature difference $\Delta T_{\ell i}$ (the difference between cure or processing temperature and i^{th} ply temperature) is entered in this group of cards. The first entry is for the first ply (which is the bottom or inner ply), and the last entry is for the last ply. The number of entries equals the number of plies. (See tables I and II.) There are three special cases associated with the temperature difference in addition to the general case just described:

(a) The residual stress case at room temperature where $\Delta T_{\ell i}$ equals the difference between cure or process temperature and room temperature.

(b) The zero temperature effects case where $\Delta T_{\ell i} = 0$.

(c) The no residual stress case where $\Delta T_{\ell i}$ equals the difference between i^{th} ply temperature and room temperature.

(20) Correlation coefficients for strength. - The coefficients that correlate predicted and measured values for strength are entered in this group of cards (see table I). These coefficients are selected in the same manner as was described for β_m in card group (4). The first two entries are the coefficients β_{fT} and β_{mT}, which are for the ply longitudinal-tensile strength. The third entry is β_{22T}, which is for ply transverse-tensile strength. The fourth entry β_{12S} is for the ply intralaminar shear strength. The fifth entry β_{23S} is for the ply transverse shear strength. The sixth entry β_{del} is for interply delamination limit strain. Entries seven and eight are the coefficients $K'_{\ell 12TT}$ and $K'_{\ell 12TC}$, which are for ply combined-stress strength in the tension-tension and tension-compression quadrants, respectively. Entries 9 and 10 β_{fC} and β_{mC} are for the ply longitudinal compressive strength. Entry 11 β_{22C} is for the ply transverse compressive stress. Entries 12 and 13 a_1 and a_2 are coefficients for an alternate method to compute the ply longitudinal compressive strength (see section Subroutine GLLSC(J)). Entry 15 is entered as unity. This field is allocated for possible future use. Entries 15 and 16 $K'_{\ell 12CT}$ and $K'_{\ell 12CC}$ are for ply combined-stress strength in the compression-tension and compression-compression quadrants, respectively. (See tables I and II.)

(21) Constituent strength properties. - The constituent strength properties are entered in these two cards. The six entries are, sequentially, in-situ fiber bundle strength S_{fT}, in-situ matrix compressive strengths S_{mC}, in-situ allowable matrix transverse tensile strain ϵ_{mpT}, in-situ allowable matrix transverse compressive strain ϵ_{mpC},

in-situ allowable matrix shear strain ϵ_{mpS}, in-situ allowable matrix torsional strain ϵ_{mpTor}. (See also tables I and II.)

(22) Membrane loads. - The membrane (in-plane) loads are entered in these cards. The first entry is the value for $\overline{N}_{cxx}$ for the first load condition. The second entry is the value for $\overline{N}_{cxx}$ for the second load condition, and so on until N_{lc} values for $\overline{N}_{cxx}$ have been entered. Continue with N_{lc} values for $\overline{N}_{cyy}$ and after that with N_{lc} values for $\overline{N}_{cxy}$. A total of $3N_{lc}$ values are entered sequentially. Note that no empty fields are allowed because they will be interpreted as zero values for the load conditions by the code. Note also that zero values for $\overline{N}_{cxx}$, $\overline{N}_{cyy}$, and $\overline{N}_{cxy}$ have to be entered even if the displacements are read in. This is the case when RINDV equals T (TRUE). (See tables I and II.)

(23) Moments. - The local bending moments are entered in these cards. The description is analogous to that for the forces (card group (22)).

(24) Displacements. - The local reference plane strains (ϵ_{csxx}, ϵ_{csyy}, and ϵ_{cxy}) and curvatures (w_{cbxx}, w_{cbyy}, and w_{cbxy}) are entered in these cards. The first six entries are for the first load condition and are entered sequentially starting with ϵ_{csxx} and ending with w_{cbxy}. The next six entries are for the second load condition, and so on. (See tables I and II.) No blank fields are permitted in the displacement cards. Blank fields are interpreted to be zero values by the code.

Note that zero values are to be entered for the displacements even when the loads are inputs. This is the case when the Boolean (RINDV) equals T (TRUE).

Input Ply Properties

There could be cases when the user would prefer to supply some of his own ply properties instead of using the code to compute them. The user has to provide his own formats for these cases. They are analogous to those for reading in the ply temperature difference ΔT_{li} (card group (19)). The physical location for these statements is described in the section MAIN PROGRAM and by a comment (after DO loop 155) in the compiled listing (see appendix B).

Output

The program output consists of printing out (1) the input data, (2) the composite three-dimension strain-stress and stress-strain relations about the structural axes, (3) the composite properties generated in array PC, (4) the composite constitutive equations about the structural axes, (5) the reduced bending and axial stiffness,

(6) displacement-force relations, (7) the current load or displacement condition, and (8) the ply properties generated in array PL.

The printout of the input data is preceded by its code name. The first and second lines of printout (see table XIII for corresponding FORMATS) are

```
THORNEL-50/EPOXY

NL, NPL, NPC, NFPE, NLC

8     71     54     1420     1
```

The output of the composite three-dimensional strain-stress temperature relations and composite stress-strain relations about the structural axes are printed under the headings

3-D COMPOSITE STRAIN STRESS RELATIONS - STRUCTURAL AXES

The matrices $[E_c]_s^{-1}$ and $\{\alpha_c\}_s$ in the equation

$$\{\epsilon_c\}_s = [E_c]_s^{-1} \{\sigma_c\} - \Delta T \{\alpha_c\}_s$$

are printed out in FORMATS 454 and 457 of subroutine GACD3.

3-D STRESS STRAIN RELATIONS - STRUCTURAL AXES

The matrix $[E_c]_s$ in

$$\{\sigma_c\}_s = [E_c]_s \{\epsilon_c\}_s$$

is printed out FORMATS 456 and 458 in GACD3. The subscript s in the preceding equations indicates that the relations are written about the structural axes. It is noted that these properties are only local to subroutine GACD3. They can be made global if needed.

The output of the composite properties, generated in array PC are printed under the heading

COMPOSITE PROPERTIES - VALID ONLY FOR CONSTANT TEMPERATURE THROUGH THICKNESS

LINES 1 TO 31 3-D COMPOSITE PROPERTIES ABOUT MATERIAL AXES

LINES 33 TO 54 2-D COMPOSITE PROPERTIES ABOUT STRUCTURAL AXES

Fifty-four entries are printed under this heading as follows:

PC(1)	ρ_c	weight density
PC(2)	t_c	thickness
PC(3) to PC(11)	$[E_c]$	three-dimensional stress-strain relations about material axes
PC(12) to PC(14)	$\{\alpha_c\}$	three-dimensional coefficients of expansion about material axes
PC(15) to PC(18)	$\{K_c\}$, H_c	three-dimensional heat conductivities and heat capacity along material axes
PC(19) to PC(30)	E_{c11}, G_{c12}, ν_{c12}	three-dimensional constants about material axes
PC(31)	$\bar{z}$	distance to reference plane from bottom of composite
PC(32)	---------------	blank
PC(33) to PC(38)	$[E_c]^{-1}$	two-dimensional stress-strain relations about structural axes
PC(39) to PC(47)	E_{c11}, G_{c12}, ν_{c12}	two-dimensional elastic constants along structural axes
PC(48) to PC(54)	$\{\alpha_c\}$, K_c, H_c	two-dimensional coefficients of thermal expansion, heat conductivities, and heat capacity along structural axes

Array PC, its corresponding string, and headings are controlled by the following formats in subroutine GOCFD2: Headings FORMATS 225, 226, and 227; and string and array PC FORMAT 320.

The output for the composite constitutive equations are printed under the heading

$$\begin{array}{ccccccc} \text{FORCES} & & \text{FORCE DISPLACEMENT RELATIONS} & & \text{DISPL} & & \text{THERMAL FORCES} \\ \begin{Bmatrix} \{N_{cx}\} \\ \\ \{M_{cx}\} \end{Bmatrix} & = & \begin{bmatrix} [A_{cx}] & [C_{cx}] \\ \\ [C_{cx}] & [D_{cx}] \end{bmatrix} & & \begin{Bmatrix} \{\epsilon_{csx}\} \\ \\ \{w_{cb}\} \end{Bmatrix} & - & \begin{Bmatrix} \{N_{c\Delta Tx}\} \\ \\ \{M_{c\Delta Tx}\} \end{Bmatrix} \end{array}$$

The elements of matrices A_{cx}, C_{cx}, $N_{c\Delta Tx}$, and $M_{c\Delta Tx}$ are printed out. The FORMATS are 220 and 330 in GPCFD2 and STRING RESF in BLOCK DATA.

The output for the reduced bending rigidities is printed under the heading

REDUCED BENDING RIGIDITIES

The elements of D^R_{cx} are printed out in one line. The corresponding FORMATS are 355 and 360 in GPCFD2.

The output for the reduced axial stiffness A^R_{cx} is printed out under the heading

REDUCED STIFFNESS MATRIX

The corresponding FORMATS are 364 and 360 in GPCFD2.

The inverse of the constitutive equations is printed out under the heading

$$\begin{array}{cccc} \text{DISP} & & \text{DISPLACEMENT FORCE RELATIONS} & \text{FORCES} \\ \begin{Bmatrix} \{\epsilon_{cax}\} \\ \\ \{w_{cb}\} \end{Bmatrix} & = & \begin{bmatrix} [A_{cx}] & [C_{cx}] \\ \\ [C_{cx}] & [D_{cx}] \end{bmatrix}^{-1} & \begin{Bmatrix} \{N_{cx}\} \\ \\ \{M_{cx}\} \end{Bmatrix} \end{array}$$

The elements of this inverse are printed out. The FORMATS are 682 and 683 in COMSA and STRING DISP in BLOCK DATA.

The output for the current load condition is printed next to the headings

FOR THIS CASE NBS(X, Y, XY-M) IS

and

FOR THIS CASE MBS (X,.Y, XY-M) IS

The current values of $\overline{N}_{cx}$, $\overline{N}_{cy}$, $\overline{N}_{cxy}$, $\overline{M}_{cx}$, $\overline{M}_{cy}$, and $\overline{M}_{cxy}$ are printed out under these headings. The FORMATS are 161 and 162 in the main program.

The output for the current displacement conditions is printed under the heading

FOR THIS CASE THE DISPLACEMENTS DISV (ECSXX, ECSYY, ECSXY, WCBXX, WCBYY, WCBXY) ARE

The FORMAT is 163 in MAIN PROGRAM.

The output of the ply properties generated in array PL are printed out under the heading

LAYER PROPERTIES, ROWS-PROPERTY, COLUMNS-LAYER

according to FORMAT 20 in MAIN PROGRAM.

Seventy-one entries are printed out under this heading as follows:

PL(1,I)	k_v	ply void content
PL(2,I)	k_f	ply apparent fiber content
PL(3,I)	$\bar{k}_f$	ply actual fiber content
PL(4,I)	k_m	ply apparent matrix content
PL(5,I)	$\bar{k}_m$	ply actual matrix content
PL(6,I)	ρ_l	ply weight density
PL(7,I)	t_l	ply layer thickness
PL(8,I)	δ_l	ply and interply layer thickness
PL(9,I)	H_j	interply layer distortion energy coefficient
PL(10,I)	$\bar{z}$	distance from bottom of composite to ply centroid
PL(11,I)	z_{cg}	distance from reference plane to ply centroid
PL(12,I)	θ_{cs}	angle from structural axes to composite material axes (same for all plies), fig. 2
PL(13,I)	θ_l	angle from ply material axes to composite material axes (fig. 2)

PL(14,I)	$\theta_{\ell s}$	angle from ply material axes to composite structural axes (fig. 2)
PL(15,I) to PL(23,I)	$[E_\ell]^{-1}$	ply stress-strain relations
PL(24,I) to PL(26,I)	$\{\alpha_\ell\}$	ply thermal coefficients of expansion
PL(27,I) to PL(29,I)	$\{K_\ell\}$	ply heat conductivities
PL(30,I)	$H_{c\ell}$	ply heat capacity
PL(31,I) to PL(32,I)	$E_{\ell 11}$, $\nu_{\ell 12}$, $G_{\ell 12}$	ply elastic constants
PL(43,I) to PL(48,I)	$\rho_{\mu 22}$, $\rho_{\mu 12}$, $\rho_{\mu 13}$	ply strain magnification factors
PL(49,I)	$\rho_{\mu de\ell}$	interply delamination factor
PL(50,I)	ΔT	ply temperature
PL(51,I) to PL(60,I)	$S_{\ell 11T}$, etc.	ply limiting stresses
PL(61,I)	$K_{\ell 12\alpha\beta}$	coefficient in combined-stress - strength criterion
PL(62,I)	---------------	combined-stress - strength criterion
PL(63,I)	---------------	interply delamination criterion
PL(64,I) to PL(69,I)	$\{\epsilon_\ell\}$, $\{\sigma_\ell\}$	ply applied strains and stresses
PL(70,I)	$\Delta\rho_j$	adjacent ply relative rotation
PL(70,I)	---------------	Hoffman's failure criterion

The FORMAT for this output is 25 and STRING PROP in MAIN PROGRAM.

PROGRAM DESCRIPTION

The main program (or control program) and theoretical equations programmed in the code are described in this portion of the report. The main control program is described first, followed by descriptions of the various subroutines in their physical sequential order (fig. 2). It is assumed that the user of this portion of the code has a working knowledge of computer programming and that he is familiar with the terminology, such as, micromechanics, macromechanics, and laminate analysis of multilayered fiber composites.

The assumptions and details leading to the derivation of the equations programmed in the code are not included here. However, they are described in the references cited. It is suggested that the interested user have these references available to him.

The information provided in this portion of the code together with the compiled listing should be sufficient to enable the user to modify, implement, and extend the code according to his needs.

MAIN PROGRAM

The main program contains the global variables, the various subroutines, the input data and format, the various program control statements, and the output. These are discussed subsequently. The flow chart of the main program is shown in figure 6.

The global variables are given in the following list (for substitution and definition, see appendix A):

Boolean	TLINP, CSANB, BIDE, RINDV
Integers	N_l, N_{pl}, N_{pc}, N_f, N_{lc}, M, Q_i, Q_s, Q_p, Q_r, Q_f
Real	θ_{cs}, ρ_f, ρ_m, $d_f(E, \nu, G)_{f,m}$, π
Real arrays (maximum dimensions)	K_{vl}, K_{fl}, θ_{lc}, t_l, (1×50), P_l(71×50), P_c(1×54), E_{cl}, E_{cf}, E_{cm}, A_{cx}, C_{cx}, D_{cx}, D^R_{cx}, A^R_{cx} (3×3), α_f, α_m, α_l, $N_{c\Delta Tx}$, $M_{c\Delta Tx}$, ϵ_{csx}, ϵ_{cbx}(1×3), β_s(2×8), β_e(2×10), β_h(1×4), L_{sc}(1×6), H_{kc}(3×4), $\overline{M}$, $\overline{N}(3\times N_{lc})$, D_v(10×6)
String arrays	C_s(55· · spaces per field, composite system title) Read in. P_l(eight spaces per field, N_{pl} fields) C_{e1} (six spaces per field, six fields) C_{e2} (six spaces per field, six fields) P_{cp} (six spaces per field, N_{pc} fields)
Current dimensions	N_l, N_{pl}, N_{pc}, N_f
Real arrays (current dimensions)	K_{vl}, K_{fl}, θ_{lc}, $t_l(1\times N_l)$; $P_l(71, N_l)$; $P_c(N_{pc}\times 1)$

The subroutines are as follows:

INVA	inverse of an array
GLLSC	generates ply stress-limit conditions
GACD3	generates composite three-dimensional elastic and thermal properties and the two-dimensional thermal properties
BLOCK DATA	DISP (string) and RESF (string)

GPCFD2	generates composite two-dimensional elastic constants and constitutive equations
GPHK	generates heat conductivities of the ply
GECL	generates some ply basic properties and the ply thermoelastic constants
GSMF	generates ply strain magnification factors
COMPSA	generates the ply strain and stress states due to applied loads and check for ply failure and interply delamination

These subroutines are described in detail in the next section. The strings of code identifier DATA are

C_s	Read in according to format 4 in MAIN PROGRAM
P_{lp}	PROP internally defined; PLHD, PLF, PLL output
C_{e1}	RESF internally defined; FDRHD, FDRF, FDRL output
C_{e2}	DISP internally defined; FDRF, MDRL output
P_{cp}	PROPC internally defined; PCHD, PCF, PCL output.

The strings and arrays P_{lp} are printed out in the main program, and C_{e1}, C_{e2}, and P_{cp} are printed out in subroutine GPCFD2. All other input-outputs are operated by standard FORTRAN formats.

Input	composite system title, N_l, N_{pl}, N_{pc}, N_f, $(E, \nu, G)_{f,m}$, β_e, α_f, α_m; H_{kc}, β_h; π; TLINP; CSANB; BIDE; RINDV; θ_{cs}, ρ_f, ρ_m, d_f; k_{vl}, k_{fl}, θ_{lc}, t_l, ΔT_l; β_s; L_{sc}; $\overline{N}_{cx}$; $\overline{M}_{cx}$; D_v
Control program	See portion of flow chart after CONTROL PROGRAM block in figure 6.

SUBROUTINE DESCRIPTION

Subroutine INVA(N, A, C)

This procedure computes the inverse of a square matrix A by Gauss elimination and stores it in C. The check

$$|A| \neq 0$$

is made and, if satisfied, the program continues; otherwise, the message "SINGULAR MATRIX" is displayed. The subroutine inputs are N, A order and array, respectively. The output is

$$A^{-1} \rightarrow C$$

Subroutine GLLSC (A)

This subroutine generates the simple limit stress of the single-ply. The limit stresses for the i^{th} ply are generated from the following equations:

$$S_{l11T} = S_{fT}\left[\beta_{fT}\bar{k}_f + \beta_{mT}\bar{k}_m\left(\frac{E_{m11}}{E_{f11}}\right)\right]$$

$$S_{l11C} = \min\left\{S_{mc}\left(\beta_{mC}\bar{k}_m + \beta_{fC}\bar{k}_f\,\frac{E_{f11}}{E_{m11}}\right), \left[\frac{E_{m12}}{\left[(1 - k_f) + k_f\left(\frac{E_{m12}}{E_{f12}}\right)\right]}\right] \times \left[\frac{1 - 2\left(\frac{k_v}{1 - k_f}\right) + \left(\frac{k_v}{1 - k_f}\right)^2}{1 + \left(\frac{k_v}{1 - k_f}\right)}\right]\right\}$$

The second part of the preceding equation was proposed in reference 8.

$$S_{l11CD} = a_1 S_{l12S} + a_2$$

$$S_{l22T} = \beta_{22T}\left(\frac{\epsilon_{mpT}}{\beta_v\varphi_{\mu 22}}\right)E_{l22}$$

$$S_{\ell 22C} = \beta_{22C}\left(\frac{\epsilon_{mpC}}{\beta_v \varphi_{\mu 22}}\right)E_{\ell 22}$$

$$S_{\ell 13S} = S_{\ell 12S} = \beta_{12S}\left(\frac{\epsilon_{mpS}}{\beta_v \varphi_{\mu 12}}\right)G_{\ell 12}$$

$$S_{\ell 23S} = \beta_{23S}\left(\frac{\epsilon_{mpS}}{\beta_v \varphi_{\mu 23}}\right)G_{\ell 23}$$

The transverse shear limiting conditions for the j^{th} interply layer are not generated here. However, provisions for them are made in PL(58,I) and PL(59,I) (where I denotes the column (ply) index). The limiting stresses $S_{\ell 11T}$ - $S_{\ell 23S}$ and $\varphi_{\mu del}$ are stored in PL(51,I) to PL(57,I) and in PL(60,I), respectively. The required input to the procedure is global and is stored in the following arrays:

$$LSC = [S_{ft}, S_{mC}, \epsilon_{mpT}, \epsilon_{mpC}, \epsilon_{mpS}, \epsilon_{mptor}]$$

$$BET = \begin{bmatrix} \beta_{fT}, & \beta_{mT}, & \beta_{22T}, & \beta_{12S}, & \beta_{23S}, & \beta_{del}, & K'_{\ell 12TT} & K'_{\ell 12TC} \\ \beta_{fC}, & \beta_{mC}, & \beta_{22C}, & a_1, & a_2, & \beta_S, & K'_{\ell 12CT} & K'_{\ell 12CC} \end{bmatrix}$$

The fiber and matrix moduli are input data. The ply moduli $E_{\ell 22}$, $G_{\ell 12}$, $G_{\ell 23}$ and the products of $\beta_v \varphi_\mu$ are stored in PL(32,I), PL(36,I), PL(34,I), and PL(43,I) to PL(48,I), respectively. The ply moduli and the strain magnification factors are generated in subroutines GECL and GSMF.

Subroutine GACD3(C)

This subroutine generates the three-dimensional thermoelastic properties of the composite about its structural (x, y, z) and material (1, 2, 3) axes. The angle θ is measured from x of the structural axes system. (See fig. 5.) In figure 5 replace xx etc. by 11 etc., and measure θ from the material axes for properties about the material axes. These composite properties are generated from the following equations:

$$[E_c] = \frac{1}{t_c}\left[\sum_{i=1}^{N_l}(z_{li+1} - z_{li})[R_{li}]^T[E_{li}][R_{li}] + \sum_{j=1}^{N_l-1} H_j[S_j]\right]$$

$$\{\alpha_c\} = \frac{1}{t_c}[E_c]\sum_{i=1}^{N_l}(z_{li+1} - z_{li})[R_{li}]^T[E_{li}]\{\alpha_{li}\}$$

The arrays $\{\alpha_c\}$ and $\{\alpha_{li}\}$ in the preceding equations are given by

$$\{\alpha_c\} = \lfloor \alpha_{cxx}\alpha_{cyy}\alpha_{czz}\alpha_{cyz}\alpha_{czx}\alpha_{cxy}\rfloor^T$$

and

$$\{\alpha_{li}\} = \lfloor \alpha_{l11}\alpha_{l22}\alpha_{l33}\ 0\ 0\ 0\rfloor^T$$

For all practical purposes the two-dimensional thermal coefficients of expansion about the composite structural axes are the same as α_{cxx}, α_{cyy}, and α_{cxy} in the array $\{\alpha_c\}$ for the three-dimensional case.

The matrices $[E_c]$, $[E_{li}]$, $[R_{li}]$, and $[S_j]$ are given by

$$[E_c]^{-1} = \begin{bmatrix} \frac{1}{E_{c11}} & -\frac{\nu_{c21}}{E_{c22}} & -\frac{\nu_{c31}}{E_{c33}} & 0 & 0 & 0 \\ -\frac{\nu_{c12}}{E_{c11}} & \frac{1}{E_{c22}} & -\frac{\nu_{c32}}{E_{c33}} & 0 & 0 & 0 \\ -\frac{\nu_{c13}}{E_{c11}} & -\frac{\nu_{c23}}{E_{c22}} & \frac{1}{E_{c33}} & 0 & 0 & 0 \\ 0 & 0 & 0 & \frac{1}{E_{c23}} & 0 & 0 \\ 0 & 0 & 0 & 0 & \frac{1}{E_{c31}} & 0 \\ 0 & 0 & 0 & 0 & 0 & \frac{1}{E_{c12}} \end{bmatrix}$$

Note that for the case of an anisotropic material, the elements (1,6) (2,6) (3,6) (4,5), and their symmetric parts will not be zero.

$$[E_{\ell i}]^{-1} = \begin{bmatrix} \frac{1}{E_{\ell 11}} & -\frac{\nu_{\ell 21}}{E_{\ell 22}} & -\frac{\nu_{\ell 31}}{E_{\ell 33}} & 0 & 0 & 0 \\ -\frac{\nu_{\ell 12}}{E_{\ell 11}} & \frac{1}{E_{\ell 22}} & -\frac{\nu_{\ell 32}}{E_{\ell 33}} & 0 & 0 & 0 \\ -\frac{\nu_{\ell 13}}{E_{\ell 11}} & -\frac{\nu_{\ell 23}}{E_{\ell 22}} & \frac{1}{E_{\ell 33}} & 0 & 0 & 0 \\ 0 & 0 & 0 & \frac{1}{E_{\ell 23}} & 0 & 0 \\ 0 & 0 & 0 & 0 & \frac{1}{E_{\ell 31}} & 0 \\ 0 & 0 & 0 & 0 & 0 & \frac{1}{E_{\ell 12}} \end{bmatrix}_i$$

$$[R_{\ell i}] = \begin{bmatrix} \cos^2\theta & \sin^2\theta & 0 & 0 & 0 & \frac{1}{2}\sin 2\theta \\ \sin^2\theta & \cos^2\theta & 0 & 0 & 0 & -\frac{1}{2}\sin 2\theta \\ 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & \cos\theta & \sin\theta & 0 \\ 0 & 0 & 0 & -\sin\theta & \cos\theta & 0 \\ -\sin 2\theta & \sin 2\theta & 0 & 0 & 0 & \cos 2\theta \end{bmatrix}$$

where $\theta = \theta_{\ell i}$ for properties about the composite material and $\theta = \theta_{\ell i} + \theta_{cs}$ for properties about the composite structural axes (see fig. 5).

$$[S_j] = \frac{1}{4}\begin{bmatrix} (\sin 2\theta_i - \sin 2\theta_{i-1})^2 & -(\sin 2\theta_i - \sin 2\theta_{i-1})^2 & 0 & 0 & 0 & [-(\sin 2\theta_i - \sin 2\theta_{i-1}) \times (\cos 2\theta_i - \cos 2\theta_{i-1})] \\ -(\sin 2\theta_i - \sin 2\theta_{i-1})^2 & (\sin 2\theta_i - \sin 2\theta_{i-1})^2 & 0 & 0 & 0 & [(\sin 2\theta_i - \sin 2\theta_{i-1}) \times (\cos 2\theta_i - \cos 2\theta_{i-1})] \\ 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ -[(\sin 2\theta_i - \sin 2\theta_{i-1}) \times (\cos 2\theta_i - \cos 2\theta_{i-1})] & [(\sin 2\theta_i - \sin 2\theta_{i-1}) \times (\cos 2\theta_i - \cos 2\theta_{i-1})] & 0 & 0 & 0 & (\cos 2\theta_i - \cos 2\theta_{i-1})^2 \end{bmatrix}$$

where $i > 1$ and denotes the ply index. The angles θ_i and θ_{i-1} (fig. 5) are given by

$$\theta_i = \theta_{li} + \theta_{cs}$$

$$\theta_{i-1} = \theta_{li-1} + \theta_{cs}$$

The composite heat capacity is the same for both the three- and the two-dimensional cases. It is given by

$$h_c = \frac{1}{t_c} \sum_{i=1}^{N_l} h_{li} t_{li}$$

and t_c is given by

$$t_c = \sum_{i=1}^{N_l} t_{li}$$

The composite three-dimensional heat conductivities along the composite material axes, assuming an orthotropic composite, are given by

$$K_{c11} = \frac{1}{t_c} \sum_{i=1}^{N_l} t_{li} \left(K_{l11} \cos^2 \theta_l + K_{l22} \sin^2 \theta_l \right)_i$$

$$K_{c22} = \frac{1}{t_c} \sum_{i=1}^{N_l} t_{li} \left(K_{l11} \sin^2 \theta_l + K_{l22} \cos^2 \theta_l \right)_i$$

$$\frac{1}{K_{c33}} = \frac{1}{t_c} \sum_{i=1}^{N_l} \left(\frac{t_l}{K_{l33}} \right)_i$$

The angle θ_l is measured from the material axes (fig. 5).

The composite two-dimensional heat conductivities along the composite structural axes are given by (see ref. 9 for the transformation equations)

$$K_{cxx} = \frac{1}{t_c} \sum_{i=1}^{N_l} t_{li} \; K_{l11} \cos^2 \theta + K_{l22} \sin^2 \theta \Big)_i$$

$$K_{cyy} = \frac{1}{t_c} \sum_{i=1}^{N_l} t_{li} \left(K_{l11} \sin^2 \theta + K_{l22} \cos^2 \theta \right)_i$$

$$K_{cyx} = K_{cxy} = \frac{1}{t_c} \sum_{i=1}^{N_l} t_{li} \left(K_{l22} - K_{l11} \right)_i \sin 2\theta_i$$

$$K_{czz} = K_{c33}$$

The angle θ in the last set of equations is measured from the composite structural axes and is equal to $\theta_{cs} + \theta_l$. The inputs to the subroutine are N_l, z_{li+1}, z_{li}, θ_{cs}, θ_{li}, $[E_i]$, H_j, $\{\alpha_{li}\}$, h_{li}, and $\{K_{li}\}$ which are all global. The variable N_l is input data. The remaining quantities are either generated or are transferred from information stored in PL(11,I), PL(13,I), PL(15-23,I), PL(8,I), PL(24,I) to PL(26,I) PL(30,I), and PL(27,I) PL(29,I). The outputs are t_c and the arrays are $[E_c]^{-1}$, $\{\alpha_c\}$, $[E_c]$, h_c, and $\{K_c\}$. The composite thickness t_c is stored in PC(2). The arrays $[E_c]^{-1}$, $\{\alpha_c\}$, and $[E_c]$ for both composite material and structural axes are printed out under the headings:

3-D COMPOSITE STRAIN STRESS TEMPERATURE RELATIONS - STRUCTURAL AXES

and

3-D COMPOSITE STRESS STRAIN RELATIONS - STRUCTURAL AXES

The composite material axes properties $[E_c]$ and $\{\alpha_c\}$ are stored in PC(3) to PC(14) as global variables. The corresponding moduli are stored in PC(19) to PC(30). The three-dimensional heat conductivities and heat capacity along the material axes are stored in PC(15) to PC(18). The two-dimensional thermal coefficients of expansion along the structural axes are stored in PC(48) to PC(50). The two-dimensional heat conductivities and heat capacity along the structural axes are stored in PC(51) to PC(54). Note that the heat capacity is a scalar quantity and is independent of the reference axes. Therefore, PC(54) equals PC(18).

Subroutine BLOCK DATA

In this block, the strings C_{e1} and C_{e2} which are printed out with the composite constitutive equations are defined. The string C_{e1} contains the resultant force notation N_{cx}, N_{cy}, N_{cxy}, M_{cx}, M_{cy}, and M_{cxy}. The string C_{e2} contains the notation for the corresponding displacements.

Subroutine GPCFD2(RESF, DISP, PROPC)

This subroutine generates the required section properties and the force-deformation-temperature relations for a two-dimensional multilayered composite. It also generates the plane-stress elastic constants for the composite. The force-deformation-temperature relations generated in this procedure are defined in the following equation:

$$\left\{\begin{array}{c}\{N_{cx}\}\\ \hdashline \{M_{cx}\}\end{array}\right\} = \left[\begin{array}{c:c}[A_{cx}] & [C_{cx}]\\ \hdashline [C_{cx}] & [D_{cx}]\end{array}\right]\left\{\begin{array}{c}\epsilon_{csx}\\ \hdashline w_{cbx}\end{array}\right\} - \left\{\begin{array}{c}\{N_{c\Delta Tx}\}\\ \hdashline \{M_{c\Delta Tx}\}\end{array}\right\}$$

The generic equations for the elements in the arrays $[A_{cx}]$, $[C_{cx}]$, $[D_{cx}]$, $\{N_{c\Delta Tx}\}$, and $\{M_{c\Delta Tx}\}$ are

$$[A_{cx}] = \sum_{i=1}^{N_l} \Delta T_{li}(z_{li+1} - z_{li})[R_{li}]^T [E_{li}]^{-1} [R_{li}] + \sum_{j=1}^{N_l-1} H_j[S_j]$$

$$[C_{cx}] = \sum_{i=1}^{N_l} \Delta T_{li}(z_{li+1}^2 - z_{li}^2)[R_{li}]^T [E_{li}]^{-1} [R_{li}] + \sum_{j=1}^{N_l-1} z_{rpj} H_j[S_j]$$

$$[D_{cx}] = \sum_{i=1}^{N_l} \Delta T_{li}(z_{li+1}^3 - z_{li}^3)[R_{li}]^T [E_{li}]^{-1} [R_{li}] + \sum_{j=1}^{N_l-1} z_{rpj}^2 H_j[S_j]$$

$$\{N_{c\,\Delta Tx}\} = \sum_{i=1}^{N_l} \Delta T_{li}(z_{li+1} - z_{li})[R_{li}][E_{li}]^{-1} \ \{\alpha_{li}\}$$

$$\{M_{c\,\Delta Tx}\} = \sum_{i=1}^{N_l} \Delta T_{li}(z_{li+1}^2 - z_{li}^2)[R_{li}]^T [E_{li}]^{-1} \ \{\alpha_{li}\}$$

The arrays $\{\alpha_{li}\}$, $[R_{li}]$, $[E_{li}]$, and $[S_j]$ are

$$\{\alpha_{li}\} = \lfloor \alpha_{11} \quad \alpha_{22} \quad 0 \rfloor_i^T$$

$$[R_{li}] = \begin{bmatrix} \cos^2\theta & \sin^2\theta & \frac{1}{2}\sin 2\theta \\ \sin^2\theta & \cos^2\theta & -\frac{1}{2}\sin 2\theta \\ -\sin 2\theta & \sin 2\theta & \cos 2\theta \end{bmatrix}_i$$

$$[E_{li}] = \begin{bmatrix} \frac{1}{E_{l11}} & -\frac{\nu_{l21}}{E_{l22}} & 0 \\ -\frac{\nu_{l12}}{E_{l11}} & \frac{1}{E_{l22}} & 0 \\ 0 & 0 & \frac{1}{G_{l12}} \end{bmatrix}_i$$

$$S_{j22} = S_{j11} = \frac{1}{4} (\sin 2\theta_i - \sin 2\theta_{i-1})^2$$

$$S_{j21} = S_{j12} = - S_{j11}$$

$$S_{j32} = S_{j23} = \frac{1}{4} (\sin 2\theta_i - \sin 2\theta_{i-1})(\cos 2\theta_i - \cos 2\theta_{i-1})$$

$$S_{j31} = S_{j13} = - S_{j23}$$

$$S_{j33} = \frac{1}{4} (\cos 2\theta_i - \cos 2\theta_{i-1})^2$$

Here θ_i equals the $\theta_{cs} + \theta_l$ in figure 5. The reduced bending rigidities (ref. 6) are generated in this procedure according to the equation

$$D_{cx}^R = \left[D_{cx} - C_{cx}A_{cx}^{-1}C_{cx}\right]$$

The reduced axial stiffnesses are generated in the procedure according to the equation

$$A_{cx}^R = \left[A_{cx} - C_{cx}D_{cx}^{-1}C_{cx}\right]$$

The two-dimensional composite elastic constants are generated from the following equation (assuming $\Delta T_{li} = \Delta T$ for $i = 1(1)N_l$):

$$[E_{cx}]^{-1} = \frac{1}{t_c}\left\langle \sum_{i=1}^{N_l} (z_{li+1} - z_{li})[R_{li}]^T [E_{li}]^{-1} [R_{li}] + \sum_{j=1}^{N_l - 1} H_j [S_j] \right\rangle$$

where

$$t_c = \sum_{i=1}^{N_l} t_{li}$$

The inputs to this subroutine are t_{li}, ΔT_{li}, θ_i (relative to composite structural axes), H_j, and the ply elastic constants. These quantities are global and are located, respectively, in PL(7,I), (50,I), (14,I), (9,I), and (31,I) to (42,I). The arrays $[R_{li}]^T [E_{li}]^{-1}$, $[R_{li}]$, and $[S_j]$ and the dimensions z_{li} are generated within subroutine.

The outputs are the force-deformation-temperature relations, which are stored in the global arrays ACX = A_{cx}, RAC = A^R_{cx}, CPC = C_{cx}, FLX = D_{cx}, RDC = D^R_{cx}, NSDT = $N_{c\Delta Tx}$, and MSDT = $M_{c\Delta Tx}$. These are printed out under the heading

FORCES FORCE DISPLACEMENT RELATIONS DISPL THERMAL FORCES

The reduced bending rigidities are printed out under the heading

REDUCED BENDING RIGIDITIES

The reduced axial stiffnesses are printed out under the heading

REDUCED STIFFNESS MATRIX

The inverse of the constitutive equations

$$\left[\begin{array}{c|c} [A_{cx}] & [C_{cx}] \\ \hline [C_{cx}] & [D_{cx}] \end{array}\right]^{-1}$$

are printed out under the heading

DISP DISPLACEMENT FORCE RELATIONS FORCES

The distances $\bar{z}_c$, $\bar{z}_{li}$, z_{li} are stored, respectively, in PC(31), PL(10,I), and PL(11,I). The two-dimensional composite stress-strain relations is stored in PC(33) to PC(38) and the two-dimensional composite moduli and Poisson's ratio are stored in PC(39) to PC(47). The two-dimensional thermal properties are stored in PC(48) to PC(54) as is described in the section Subroutine GACD3.

Subroutine GPH (CF, CM, R, Q, CP)

This subroutine is used to calculate the ply conductivities K_{l22} and K_{l33}. The specific equation programmed in this subroutine is

$$K_{l\alpha\alpha} = \bar{K}_{m\alpha\alpha}\left[1 - \beta_{k\alpha}\sqrt{\bar{k}_f} + \frac{1}{\dfrac{1}{\beta_{k\alpha}\sqrt{\bar{k}_f}} - \left(1 - \dfrac{\bar{K}_{m\alpha\alpha}}{K_{f\alpha\alpha}}\right)}\right]$$

where α takes the values 2 and 3. The subroutine is called from subroutine GECL. The subroutine input variables CF, CM, R, and Q and the output variable CP are defined in the call statement in GECL. They denote, respectively, fiber conductivity $K_{f\alpha\alpha}$, matrix conductivity $\bar{K}_{m\alpha\alpha}$ (modified for void effects), actual fiber volume ratio $\bar{k}_f$, correlation factor $\beta_{k\alpha}$, and the computed conductivity $K_{l\alpha\alpha}$ which is the subroutine output.

Subroutine GECL (KV, KF)

The thermoelastic properties of the single ply are generated in this procedure. In addition the actual fiber and matrix volume content, the ply thickness, density, and the interfiber spacing are generated. The equations programmed to generate basic ply properties are

$$\bar{k}_f = (1.0 - k_v)k_f$$

$$\bar{k}_m = (1.0 - k_v)(1 - k_f)$$

$$\rho_l = \rho_f\bar{k}_f + \rho_m\bar{k}_m$$

$$t_l = \begin{Bmatrix} (\pi N_f/4\beta_t \bar{k}_f)^{1/2}\ d_f \text{ if Boolean TLINP = F(FALSE)} \\ \text{Read in value if Boolean TLINP = T(TRUE)} \end{Bmatrix}$$

$$\delta_l = \left[\left(\frac{\pi}{4\bar{k}_f}\right)^{1/2} - 1\right] d_f$$

where k_v and k_f are read in globally. The equations programmed to generate the extensional moduli and the thermal coefficients of expansion are

$$[E_l] = [C_{fl}]^T [E_f][C_{fl}]\bar{k}_f + [C_{ml}]^T [E_m][C_{ml}]\bar{k}_m$$

and

$$\{\alpha_l\} = [C_{fl}]^T \{\alpha_f\}\bar{k}_f + [C_m]^T \{\alpha_m\}\,\bar{k}_m$$

The arrays in the last two equations are given by

$$[E_{l,f,m}] = \begin{bmatrix} \frac{1}{E_{l11}} & -\frac{\nu_{l21}}{E_{l22}} & -\frac{\nu_{l31}}{E_{l33}} \\ -\frac{\nu_{l12}}{E_{l11}} & \frac{1}{E_{l22}} & -\frac{\nu_{l32}}{E_{l33}} \\ -\frac{\nu_{l13}}{E_{l11}} & -\frac{\nu_{l23}}{E_{l22}} & \frac{1}{E_{l33}} \end{bmatrix}_{l,f,m}$$

and

$$\{\alpha_{l,f,m}\} = [\alpha_1,\ \alpha_2,\ \alpha_3]_{l,f,m}$$

The arrays $[E_l]$, $[E_f]$, and $[E_m]$ are generated locally in the arrays ECL, ECF, and ECM, respectively. The arrays $[C_{fl}]$ and $[C_{ml}]$ and the constants in them are given by

$$[C_{f\ell}] = \begin{bmatrix} \dfrac{1}{AE_{m11}\bar{k}_m} & \dfrac{1}{A}\left(\dfrac{\nu_{f21}}{C_f E_{f22}} - \dfrac{\nu_{m21}}{C_m E_{m22}}\right) & \dfrac{1}{A}\left(\dfrac{\nu_{f31}}{C_f E_{f33}} - \dfrac{\nu_{m31}}{C_m E_{m33}}\right) \\ 0 & \dfrac{1}{C_f} & 0 \\ 0 & 0 & \dfrac{1}{C_f} \end{bmatrix}$$

and

$$[C_{m\ell}] = \begin{bmatrix} \dfrac{1}{BE_{f11}\bar{k}_f} & \dfrac{1}{B}\left(\dfrac{\nu_{m21}}{C_m E_{m22}} - \dfrac{\nu_{f21}}{C_f E_{f22}}\right) & \dfrac{1}{B}\left(\dfrac{\nu_{m31}}{C_m E_{m33}} - \dfrac{\nu_{f31}}{C_f E_{f33}}\right) \\ 0 & \dfrac{1}{C_m} & 0 \\ 0 & 0 & \dfrac{1}{C_m} \end{bmatrix}$$

where

$$A = \left(\frac{1}{E_{f11}} + \frac{\bar{k}_m}{E_{m11}}\,\bar{k}_f\right)$$

$$B = \left(\frac{1}{E_{m11}} + \frac{\bar{k}}{E_{f11}}\,\bar{k}_m\right)$$

$$C_f = \left(\frac{\bar{k}_f}{k_f}\right)\beta_f$$

$$C_m = \left(\frac{\bar{k}_m}{k_m}\right)\beta_m = (1 - k_v)\,\beta_m$$

$$\beta_f = 1.0$$

$$\beta_m = \begin{cases} \left(\dfrac{1.0}{k_m}\right)^{1/\mathrm{VCF}(1,1)} & \text{if VCF}(1,1) \neq 0 \\ \mathrm{VCF}(2,1) & \text{if VCF}(1,1) = 0 \end{cases}$$

The variables VCF(1, 1) and VCF(2, 1) are empirical (adjustment) factors and are read in. Here and subsequently, the elements in the array VCF constitute experiment-theory correlation (semiempirical) factors and are selected so that the predicted and experimental results for a particular fiber-matrix system from a particular fabrication process are in good agreement. The variable β_f could be selected to be different from unity if additional adjustment is needed.

The elements in the arrays $[\tilde{C}_{fl}]$ and $[\tilde{C}_{ml}]$ are generated by substituting

$$\tilde{\beta}_f = 1.0$$

$$\tilde{\beta}_m = \begin{cases} \left(\dfrac{1.0}{k_m}\right)^{1/\mathrm{VCF}(1,4)} & \text{if VCF}(1,4) \neq 0 \\ \mathrm{VCF}(2,4) & \text{if VCF}(2,4) = 0 \end{cases}$$

The equations programmed to generate the shear moduli are

$$G_{l12} = \frac{G_{m12}}{\dfrac{G_{m12}}{C_f'^2 G_{f12}} \bar{k}_f + \dfrac{\bar{k}_m}{C_m'^2}}$$

$$G_{l13} = \frac{G_{m13}}{\dfrac{G_{m13}}{C_f'^2 G_{f13}} \bar{k}_f + \dfrac{\bar{k}_m}{C_m'^2}}$$

and

$$G_{l23} = \frac{G_{m23}}{\dfrac{G_{m23}}{C_m''^2 G_{f23}}\,\bar{k}_f + \dfrac{\bar{k}_m}{C_m''^2}}$$

where

$$C_f' = \left(\frac{\bar{k}_f}{k_f}\right)\beta_f'$$

$$C_m' = \left(\frac{\bar{k}_m}{k_m}\right)\beta_m'$$

$$C_f'' = \left(\frac{\bar{k}_f}{k_f}\right)\beta_f''$$

and

$$C_m'' = \left(\frac{\bar{k}_m}{k_m}\right)\beta_m''$$

The variables β_f', β_m', β_f'', and β_m'', respectively, are

$$\beta_f' = 1.0$$

$$\beta_m' = \begin{cases} \left(\dfrac{1.0}{k_m}\right)^{1/\mathrm{VCF}(1,2)} & \text{if VCF}(1,2) \neq 0 \\ \mathrm{VCF}(2,2) & \text{if VCF}(2,2) = 0 \end{cases}$$

$$\beta_f'' = 1.0$$

$$\beta''_m = \begin{cases} \left(\dfrac{1.0}{k_m}\right)^{1/VCF(1,3)} & \text{if } VCF(1,3) \neq 0 \\ VCF(2,3) & \text{if } VCF(2,3) = 0 \end{cases}$$

The equations programmed for the ply heat capacity and the ply heat conductivities are

$$H_{c\mathit{l}i} = \frac{1}{\rho_{\mathit{l}i}} \left(H_{cf}\rho_f\bar{k}_f + H_{cm}\rho_m\bar{k}_m\right)$$

$$\bar{K}_{m\alpha\alpha} = K_{m\alpha\alpha} \left[\frac{2\beta_{kv}K_{m\alpha\alpha} + K_v - 2k_v(K_{m\alpha\alpha} - K_v)}{2K_{m\alpha\alpha} + K_v - k_v(K_{m\alpha\alpha} - K_v)}\right]$$

and

$$K_{\mathit{l}11} = \beta_{k1}\bar{k}_f K_{f11} + k_m\bar{K}_{m11}$$

The subscript α takes the values (1, 2, and 3). The remaining variables are read in globally in the arrays

$$BTA = (\beta_{kv}, \beta_{k1}, \beta_{k2}, \beta_{k3})$$

and

$$CHK = \begin{bmatrix} K_{f11} & K_{f22} & K_{f33} & H_{cf} \\ K_{m11} & K_{m22} & K_{m33} & H_{cm} \\ 0 & 0 & 0 & K_v \end{bmatrix}$$

The small subroutine GPHK(CF, CM, R, Q, CP) preceding subroutine GECL is used for programming convenience to compute the variables $K_{\mathit{l}22}$ and $K_{\mathit{l}33}$.

Inputs to subroutine GECL are the fiber and matrix material properties and the correlation factors. These properties are read in globally and are $(E, \nu, G, \rho, H_c, K, \alpha)_{f,m}$, N_f, d_f, VCF, BTA, TLINP, and $(k_v, k_f)_i$ (where $i = 1(1)N_{\mathit{l}}$ and N_{l} is the number of layers). For the corresponding code identifiers, see appendix A.

The outputs of subroutine GECL are the basic ply properties ($\bar{k}_f$, $\bar{k}_m$, ρ_l, t_l (if TLINP = FALSE), and δ_l) which are stored in PL(3,I) and in PL(5,I) to PL(8,I); the ply stress-strain relations, which are stored in PL(15,I) to PL(23,I); the ply thermal coefficients of expansion, heat conductivities, and heat capacity, which are stored in PL(24,I) to PL(30,I), and the ply moduli and Poisson's ratios, which are stored in PL(31,I) to PL(42,I).

Subroutine GSMF(SL11, SL22, SL12, SL23, KV, KF, J)

The strain magnification factors from which the ply unidirectional limiting stresses are constructed are generated in this subroutine. These factors are $\varphi_{\mu 22}$, $\varphi_{\mu 12}$, and $\varphi_{\mu 23}$ for constructing S_{l22}, S_{l12}, and S_{l23}, respectively.

Three methods are employed to compute $\varphi_{\mu 22}$: Kies's two-dimensional, Daniel's indirect, and Kies's one-dimensional method. Filament and matrix orthotropicity and the effects of voids are included in all of these methods as is described in reference 1. Kies's two-dimensional method is selected to construct S_{l22} in the current program. However, either of the other methods and even new ones (as they become available) could be chosen if, at some future date, they are found to be more appropriate. In addition, optional degrees of freedom for adjusting these factors can be read in globally. The options are given with the appropriate equation. The input and output subroutine information is discussed at the end of this section.

The equations programmed in this subroutine are

$$\beta_v = \frac{1.0}{\left[1 - \left(\frac{4k_v}{\pi k_m}\right)^{1/2}\right]}$$

$$\bar{k}_f = (1 - k_v)k_f$$

$$\bar{k}_m = (1 - k_v)(1 - k_f)$$

$$C_{f\varphi} = \frac{\bar{k}_f}{k_f}$$

and

$$C_{m\varphi} = \frac{\bar{k}_m}{(1 - k_f)}$$

Strain magnification factor $\varphi_{\mu 22}$. - The three methods used to compute the strain magnification factor $\varphi_{\mu 22}$ are given in the following:

(1) Kies's two-dimensional method:

$$p = \begin{cases} \bar{k}_f^{\,(1.0/\beta_\epsilon)} & \text{if } \beta_\epsilon \neq 0 \\ \left(\dfrac{4\bar{k}_f}{\pi}\right)^{1/2} \gamma_\epsilon & \text{if } \beta_\epsilon = 0 \end{cases}$$

$$\bar{A} = \frac{(1 - \nu_{f12}\nu_{f21})C_{m\varphi}E_{m22}}{(1 - \nu_{m12}\nu_{m21})C_{f\varphi}E_{f22}}$$

$$\bar{B} = \nu_{m12}\bar{A}$$

$$\frac{\epsilon_{m22}}{\epsilon_{l22}} = \left[\frac{1}{1 + p(A - 1)}\right]\left\{\frac{1}{E_{l22}}\left[1 - \nu_{l21}p(\nu_{f12} - \bar{B})\right]\sigma_{l22} + \frac{1}{E_{l11}}\left[p(\nu_{f12} - \bar{B}) - \nu_{l12}\right]\sigma_{l11}\right\}$$

$$\epsilon_{l22} = \frac{\sigma_{l22}}{E_{l22}} - \frac{\nu_{l12}\sigma_{l11}}{E_{l11}}$$

$$\varphi_{\mu 22} = \begin{cases} \dfrac{\epsilon_{m22}}{\epsilon_{l22}} & \text{if } \dfrac{\epsilon_{m22}}{\epsilon_{l22}} > 1.0 \\ 1.0 & \text{if } \dfrac{\epsilon_{m22}}{\epsilon_{l22}} \leq 1.0 \end{cases}$$

$$\varphi_{\mu 22}\beta_v \rightarrow \mathrm{PL}(45, J)$$

(2) Daniel's indirect method:

$$\varphi_{\mu 22} = k_{\sigma}\left(1 - \nu_{m23}^{2}\right)\frac{E_{l22}}{E_{m22}}$$

$$k_{\sigma} = 0.83\left[\left(\frac{\pi}{\bar{k}_f}\right) - 2\right]^{2} - 1.35\left[\left(\frac{\pi}{\bar{k}_f}\right)^{1/2} - 2\right] + 1.78$$

$$0.35 \leq \bar{k}_f \leq 0.75$$

$$\varphi_{\mu 22}\beta_v \rightarrow PL(44, J)$$

(3) Kies's one-dimensional method:

$$\varphi_{\mu 22} = \frac{1}{1 - p\left(1 - \dfrac{C_{m\varphi}E_{m22}}{C_{f\varphi}E_{f22}}\right)}$$

$$\varphi_{\mu 22}\beta_v \rightarrow PL(43, J)$$

Note that PL(46, J) is blank for any other method that might be of interest.

Strain magnification factor $\varphi_{\mu 12}$. -

$$p = \begin{cases} \bar{k}_f^{\,1.0/\beta'_{\epsilon}} & \text{if } \beta'_{\epsilon} \neq 0 \\ \left(\dfrac{4\bar{k}_f}{\pi}\right)^{1/2} \gamma'_{\epsilon} & \text{if } \beta'_{\epsilon} = 0 \end{cases}$$

$$\varphi_{\mu 12} = \frac{1}{1 - p\left(1 - \dfrac{C_{m\varphi}G_{m12}}{C_{f\varphi}G_{f12}}\right)}$$

$$\varphi_{\mu 12}\beta_v \rightarrow PL(47, J)$$

Strain magnification factor $\varphi_{\mu 23}$. -

$$p = \begin{cases} \bar{k}_f^{1/\beta''_\epsilon} & \text{if } \beta''_\epsilon \neq 0 \\ \left(\dfrac{4\bar{k}_f}{\pi}\right)^{1/2} \gamma''_\epsilon & \text{if } \beta''_\epsilon = 0 \end{cases}$$

$$\varphi_{\mu 23} = \frac{1}{2(1 - p) + (2p - 1)\dfrac{C_{m\varphi} G_{m23}}{C_{f\varphi} G_{f23}}}$$

$$\varphi_{\mu 23}\beta_v \rightarrow \mathrm{PL}(48, J)$$

Inputs to subroutine GSMF are the ply applied stresses (σ_{l11}, σ_{l22}, σ_{l12}, and σ_{l23}), the void and apparent fiber content, the ply index, and ply, fiber and matrix elastic constants. The stresses σ_{l11}, σ_{l22}, and σ_{l12} are transferred from PL(67,J) to PL(69,J), respectively. (J denotes ply index in this case.) The stresses σ_{l23} is assigned the value of unity. The void and fiber contents are transferred from PL(1,J) and PL(2,J). The ply elastic properties are transferred from PL(31,J), PL(32,J), PL(37,J), and PL(38,J). The fiber and matrix properties are read in globally. The coefficients β_ϵ are in VCF as follows:

$$\beta_\epsilon \rightarrow \mathrm{VCF} = \begin{bmatrix} \beta_m, & \beta'_m, & \beta''_m, & \tilde{\beta}_m, & \beta_\epsilon, & \beta'_\epsilon, & \beta''_\epsilon, & \beta_t, & 0.0, & 0.0 \\ \gamma_m, & \gamma'_m, & \gamma''_m, & \tilde{\gamma}_m, & \gamma_\epsilon, & \gamma'_\epsilon, & \gamma''_\epsilon, & 0.0, & 0.0, & 0.0 \end{bmatrix}$$

The outputs of subroutine GSMF are the magnification factors stored in PL(43-48,J) as previously described. It is important to note that the magnification factor $\varphi_{\mu 22}$ depends on the applied stress level; therefore, GSMF is called from the stress analysis subroutine COMPSA.

Subroutine COMPSA(M)

In this subroutine the stress and strain state of each ply are computed given the edge membrane forces, the ply temperature and the changes in curvature. In addition, two-ply combined-stress strength criteria and the interply delamination criterion are generated. The equations programmed for the i^{th} strain and stress states are

$$\{\epsilon_{li}\} = [R_{li}][A_{cx}]^{-1} < \{\bar{N}_{cx}\} + \{N_{c\Delta Tx}\} + [C_{cx}]\{w_{cbx}\} > -z[R_{li}]\{w_{cbx}\}$$

$$\{\sigma_{li}\} = [E_{li}]^{-1}[R_{li}][A_{cx}]^{-1}\left\langle\{\bar{N}_{cx}\} + \{N_{c\Delta Tx}\} + [C_{cx}]\{w_{cbx}\}\right\rangle - [E_{li}]^{-1}\left\langle\Delta T_{li}\{\alpha_{li}\} + z[R_{li}]\{w_{cbx}\}\right\rangle$$

The reference plane strains ϵ_{csx} and the changes curvatures are computed from

$$\left\{\begin{array}{c}\{\epsilon_{csx}\}\\ \hline \{w_{cbx}\}\end{array}\right\} = \left[\begin{array}{c|c}[A_{cx}] & [C_{cx}]\\ \hline [C_{cx}] & [D_{cx}]\end{array}\right]^{-1}\left\{\left\{\begin{array}{c}\{N_{cx}\}\\ \hline \{M_{cx}\}\end{array}\right\} + \left\{\begin{array}{c}\{N_{c\Delta Tx}\}\\ \hline \{M_{c\Delta Tx}\}\end{array}\right\}\right\}$$

when one or both of the membrane force and the moments are given.

The strains are generated locally in EPSL and SIGL, respectively, and are stored in PL(64,I) to PL(69,I). The matrices $[R_{li}]$ and $[E_{li}]$ are generated locally from information transferred from PL(14,I) and PL(31,I) to PL(42,I). The distance z_{li} and the ply temperature ΔT_{li} are transferred from PL(11,I) and PL(50,I), respectively. The remaining matrices are

$A_{cx} \rightarrow$ ACX

$C_{cx} \rightarrow$ CPC

$N_{c\Delta Tx} \rightarrow$ NSDT

$\bar{N}_{cx} \rightarrow \text{NSB}_m$

$\bar{M}_{cx} \rightarrow \text{MSB}_m$

$w_{cbx} \rightarrow \text{WXX}_m$ (local curvature from bending analysis)

where m denotes the load condition.

It is important to note that the stress analysis in the coded form also handles the case where both the reference plane membrane strains and the local curvatures are given. In this case the ply strains are given by

$$\{\epsilon_{cxi}\} = \{\epsilon_{csx}\} - z\{w_{cbx}\}$$

where $\{\epsilon_{cxi}\}$ are the i^{th} ply strains along the structural axis, $\{\epsilon_{csx}\}$ are the reference plane membrane strains, z is the distance from the reference plane to the centroid of the i^{th} ply, and $\{w_{cbx}\}$ are the local curvatures. They are read in the array D_{vm} where m denotes the load condition.

The corresponding i^{th} ply stresses are given by

$$\{\sigma_i\} = [E_{\ell i}]^{-1}\left\langle [R_{\ell i}]\{\epsilon_{cxi}\} - \Delta T_{\ell i}\{\alpha_{\ell i}\}\right\rangle$$

where $\{\sigma_{\ell i}\}$ are the i^{th} ply stresses along the material axes, $[E_{\ell i}]$ are the i^{th} ply elastic constants about the material axes, $[R_{\ell i}]$ is the transformation matrix of the i^{th} ply, $\{\epsilon_{cxi}\}$ are the i^{th} ply strains along the structural axes as given by a previous equation, $\Delta T_{\ell i}$ is the temperature of the i^{th} ply, and $\{\alpha_{\ell i}\}$ are the thermal coefficients of expansion of the i^{th} ply along the material axes.

The displacement force relations are printed out under the title

$$\begin{array}{ccc} \text{Displacement} & \text{Displacement force relations} & \text{Forces} \\ \left\{\begin{matrix} \{U_{cx}\} \\ \{W_{cx}\} \end{matrix}\right\} & \begin{bmatrix} [A_{cx}][C_{cx}] \\ [C_{cx}][D_{cx}] \end{bmatrix}^{-1} & \left\{\begin{matrix} \{N_{cx}\} \\ \{M_{cx}\} \end{matrix}\right\} \end{array}$$

Two similar sets are printed out. In the first set the displacement and force vectors are in symbolic form. In the second set the displacement and force vectors have their numerical values. See outputs of trial cases (appendix C).

The failure criterion may be determined by either of the following methods.

(1) Modified distortion energy

$$F = 1 - \left[\left(\frac{\sigma_{\ell 11\alpha}}{S_{\ell 11\alpha}}\right)^2 + \left(\frac{\sigma_{\ell 22\beta}}{S_{\ell 22\beta}}\right)^2 - K_{\ell 12\beta}\frac{\sigma_{\ell 11\alpha}}{|S_{\ell 11\alpha}|}\frac{\sigma_{\ell 22}}{|S_{\ell 22}|} + \left(\frac{\sigma_{\ell 12S}}{S_{\ell 12S}}\right)^2\right]_i \rightarrow \mathrm{PL}(62,\mathrm{I})$$

The parameters α and β are specified as follows:

$$\alpha = \begin{cases} T & \sigma_{l11} \geq 0 \\ C & \sigma_{l11} < 0 \end{cases}$$

$$\beta = \begin{cases} T & \sigma_{l22} \geq 0 \\ C & \sigma_{l22} < 0 \end{cases}$$

$$S_{l11\alpha} = \begin{cases} S_{l11T} & \alpha = T \\ \min(S_{l11C}, S_{l11CD}) & \alpha = C \end{cases}$$

$$S_{l22\alpha} = \begin{cases} S_{l22T} & \beta = T \\ S_{l22C} & \beta = C \end{cases}$$

$$K_{l12\alpha\beta} = K'_{l12\alpha\beta} \frac{(1 + 4\nu_{l12} - \nu_{l13})E_{l22} + (1 - \nu_{l23})E_{l11}}{\left[E_{l11}E_{l22}(2 + \nu_{l12} + \nu_{l13})(2 + \nu_{l21} + \nu_{l23})\right]^{1/2}}$$

$$K'_{l12\alpha\beta} = \begin{cases} \mathrm{BET}(1,7) & \alpha,\ \beta = T \\ \mathrm{BET}(2,7) & \alpha = C,\ \beta = T \\ \mathrm{BET}(1,8) & \alpha = T,\ \beta = C \\ \mathrm{BET}(2,8) & \alpha,\ \beta = C \end{cases}$$

The multiplyer of $K'_{l12\alpha\beta}$ was generated in subroutine GLLSC and is stored in PL(61,I). The constants $K'_{12\alpha\beta}$ constitute theory-experiment correlation factors.

(2) Hoffman's criterion (ref. 9):

$$S_{l11C} \leftarrow \mathrm{Min}(S_{l11C}, S_{l11CD})$$

$$F = 1 - \left[\frac{\sigma_{\ell 11}^2 - \sigma_{\ell 11}\sigma_{\ell 22}}{S_{\ell 11C}S_{\ell 11T}} + \frac{\sigma_{\ell 22}^2}{S_{\ell 22C}S_{\ell 22T}} + \frac{S_{\ell 11C} - S_{\ell 11T}}{S_{\ell 11C}S_{\ell 11T}}\sigma_{\ell 11} + \frac{S_{\ell 22C} - S_{\ell 22T}}{S_{\ell 22C}S_{\ell 22T}}\sigma_{\ell 22} + \frac{\sigma_{\ell 12}^2}{S_{\ell 12S}^2}\right]_i \rightarrow PL(71, I)$$

$F > 0$ no failure

$F = 0$ incipient failure

$F < 0$ failure

The interply delamination criterion for the j^{th} interply layer at the m^{th} load condition is governed by

$$\left[1 - \left(\frac{|\Delta\varphi|}{\Delta\varphi_{del}}\right)_j\right] \rightarrow PL(63, I) \qquad \text{when } i > 1$$

$$\Delta\varphi_j = \frac{1}{2}(\epsilon_{cyy} - \epsilon_{cxx})(\sin 2\theta_i - \sin 2\theta_{i-1}) + \frac{1}{2}\epsilon_{cxy}(\cos 2\theta_i - \cos 2\theta_{i-1})$$

$$\{\epsilon_{cx}\} = [A_{cx}]^{-1}\left\langle\{\overline{N}_{cx}\} + \{N_{c\Delta Tx}\} + [C_{cx}]\{w_{cbx}\}\right\rangle$$

or as given by the displacement force equation described previously.

The inputs to the subroutine are the ply angle measured from the structural axes (θ_i from PL(14, I)), the distance from the reference plane to centroid of the ply ($z_{\ell i}$ from PL(11, I)), the ply temperature ($\Delta T_{\ell i}$ from PL(50, I)), the interply delamination limit ($\Delta\varphi_{delj}$ from PL(60, I)), and the ply thermoelastic properties stored in PL(24 to 26, -I) and PL(31 to 42, I). The ply extensional and coupling rigidities A_{cx} = ACX and C_{cx} = CPC; the local curvatures w_{cbx} = WXX; the adjustment constants $K'_{\ell 12TT}$ = BET(1, 7), $K'_{\ell 12CT}$ = BET(2, 7), $K'_{\ell 12TC}$ = BET(1, 8), and $K'_{\ell 12CC}$ = BET(2, 8); and the load conditions $\overline{N}_{cx}$ = NBS(m).

The subroutine outputs are the modified distortion energy PL(62, I), Hoffman's criterion PL(71,I), the interply delamination criterion PL(63,I), and the adjacent ply relative rotation ($\Delta\varphi_j$ from PL(70,I)).

IMMEDIATE EXTENSIONS

The code can be modified and supplemented to handle nonlinear material response, temperature dependent properties, and load envelopes for various angle ply composites. The details of these modifications will become apparent once the user has some experience in using this code.

Lewis Research Center,
National Aeronautics and Space Administration,
Cleveland, Ohio, October 7, 1970,
129-03.

APPENDIX A

LIST OF CODE IDENTIFIERS

Engineering symbol	FORTRAN symbol code	Comment
A_{cx}	ACX	composite axial stiffness; generated in subroutine GPCFD2
A_{cx}^{R}	RAC	reduced axial stiffness; computed in subroutine GPCFD2
BIDE	Boolean	TRUE if interply effects are included; input
C_{cx}	CPC	composite coupling stiffness; generated in subroutine GPCFD2
C_{e1}	RESF	string with force variables in BLOCK DATA
C_{e2}	DISP	string with displacement variables in BLOCK DATA
CSANB	Boolean	TRUE if membrane and bending symmetry exists; input
C_s	String	composite title; MAIN PROGRAM format 4
D_{cx}	FLC	composite flexural rigidities; generated in subroutine GPCFD2
D_{cx}^{R}	RDC	reduced bending rigidities; computed in subroutine GPCFD2
D_v	DISV, DISVI	displacement vectors; DISVI is either read in MAIN PROGRAM, or is generated in subroutine COMPSA
d_f	DIAF	filament equivalent diameter; input
E_f, E_{cf}	ECF	filament elastic constants; generated in subroutine GECL
E_l, E_{cl}	ECL	ply elastic constants; generated in subroutine GECL
E_m, E_{cm}	ECM	matrix elastic constants; generated in subroutine GECL

Engineering symbol	FORTRAN symbol code	Comment
$E_{f11,\ell 11,m11}$	EF11, EL11, EM11	filament, ply, and matrix normal moduli; filament and matrix moduli input
$G_{f12,\ell 12,m11}$	EF12, EL12, EM12	filament, ply, and matrix shear moduli; filament and matrix shear moduli input
H_j	PL(9, I)	interply distortion energy coefficient; generated in MAIN PROGRAM
H_{kc}	CHK	array of constituents heat conductivities; input
h_c	HHC	composite heat capacity stored in PC(18) and PC(54)
i, j	I, J	index, generally ply or interply
$K_{c11,c22,c33}$	HK11, 22, 33	composite three-dimensional heat conductivities along the material axes in PC(15 to 17)
$K_{cxy,cyy,cxy}$	HK11, 22, 33	composite two-dimensional heat conductivities in PC(51 to 53)
$K_{f11,\ell 11,m11}$	CHK	see H_{kc}
$K_{f,v}$	KF, V	apparent fiber and void volume ratios; input
$\bar{k}_{f,m}$	KFB, MB	actual fiber and matrix volume ratios
$k_{f\ell,v\ell}$	KFL, VL	ply apparent fiber and void volume ratios; input
L_{sc}	LSC	array of limiting conditions; input
$M_{c\Delta Tx}$	MSDT	thermal moments; generated in GPCFD2
M_{cx}	MSB	applied moment; input
m	M	load condition index
$\bar{N}_{cx}$	NBS	applied membrane loads; input
$N_{c\Delta Tx}$	NSDT	thermal force; generated in GPCFD2

Engineering symbol	FORTRAN symbol code	Comment
N_f	NFPE	number of filaments per end; input
N_l	NL	number of plies; input
N_{lc}	NLC	number of load conditions; input
N_{pc}	NPC	string PROPC length; input
N_{pl}	NPL	string PROP length; input
P_c	PC	composite properties array; generated in GACD3 and GPCFD2
P_l	PL	ply properties array; portions generated in all parts of the program
P_{cp}	PROPC	string PROPC; composite properties identifiers in GDCFD2
P_{lp}	PROP	string PROP; ply properties identifiers in MAIN PROGRAM
$Q_{f,i,p,r,s}$	QF, I, P, R, S	indices to print out string PROP
R	R	transformation matrix; GACD3, GPCFD2, COMPSA
RINDV	Boolean	T(TRUE) if displacements are read in; input
S_{l11T} etc.	PL(51 to 59, I)	ply limit stresses; generated in GLLSC
t_l	TL	ply thickness; input if TLINP = TRUE, generated in GECL if TLINP = FALSE
TLINP	Boolean	F(FALSE) if ply thickness calculated internally; input
w_{cb}	w_{xx}	composite local curvatures relative to the structural axes
α_c	CTE	composite coefficient of thermal expansion; three-dimensional in PC(12 to 14), two-dimensional in PC(48 to 50)

Engineering symbol	FORTRAN symbol code	Comment
$\alpha_{f,l,m}$	VAF, AL, AM	filament, ply, and matrix thermal coefficients of expansion; input and VAL generated in GECL
β_e, γ_e	VCF	correlation factors for ply thermoelastic properties and strain magnification factors; input
β_h	BTA	correlation factors for ply heat conductivities; input
β_s	BET	correlation factors for ply strength; input
δ_l	PL(8, I)	interply layer thickness; generated in MAIN PROGRAM
ϵ_{csx}	UX	reference plane membrane strains; solved in terms of $\overline{N}_{cx}$ or input
ϵ_l	EPS, PL(64 to 66, I)	ply strains; generated in COMPSA
θ_{cs}	THCS	angle between composite material and structural axes; input
θ_{li}, θ_{lc}	THLC	angle between ply material and composite axes; input
$\nu_{f12, l12, m12}$	NUF12, L12, M12	filament, ply, and matrix Poisson's ratio; input
π	PIE	constant; input
$\rho_{f,m,l}$	RHOF, M, L	filament and matrix weight density; input and generated in GECL
σ_l	SIGL, PL(67 to 69, I)	ply stresses; generated in COMPSA

APPENDIX B

COMPILED LISTING

```
C      MULTILAYERED FILAMENTARY COMPOSITE ANALYSIS IS
C      A COMPUTER CODE FOR THE LINEAR ANALYSIS OF MULTILAYERED FIBER
C      COMPOSITES. THE ANALYSIS UTILIZES MICROMECHANICS, MACROMECHANICS,
C      AND LAMINATE THEORY. THE ANALYSIS IS RESTRICTED TO MEMBRANE,PLATE
C      AND THIN WALLED SHELL TYPE STRUCTURES. THE INPUTS ARE CONSTITUENT
C      MATERIAL PROPERTIES, CORRELATION COEFFICIENTS AND COMPOSITE GEOMET
C      RY. THE LOAD CONDITIONS ARE EITHER FORCES OR DISPLACEMENTS AND
C      TEMPERATURE AT THE DESIRED SECTION.  THE OUTPUTS ARE STRESS/STRAIN
C      /TEMPERATURE RELATIONS AND THEIR INVERSE, OTHER THERMAL
C      PROPERTIES, STRENGTH PROPERTIES, STRESS ANALYSIS RESULTS AND
C      THE MARGIN OF SAFETY.
C      MFCA - MAIN PROGRAM
       LOGICAL TLINP,CSANB,BIDE,RINDV
       INTEGER    QI,QS,QP,QR,QF
       REAL NUF12,NUF23,NUF13,NUF21,NUF32,NUF31,
      2     NUL12,NUL23,NUL13,NUL21,NUL32,NUL31,
      2     NUM12,NUM23,NUM13,NUM21,NUM32,NUM31,
      2     LSC,MLR,NBS,MBS,KVL,KFL,NSDT,MSDT,KVLJ,KFLJ
       COMMON/MAGE/J
       COMMON
      2  EM22,EM11,EM23,EM12,NUM21,NUM12,NUM23,
      2  EF22,EF11,EF23,EF12,NUF21,NUF12,NUF23,
      2  EM33,NUM13,RHOM,ECM(3,3),EM13,VAM(3),AXC(3,3),FLC(3,3),
      2  EF33,NUF13,RHOF,ECF(3,3),EF13,VAF(3),
      2  BET(2,8),NBS(3,10),PL(71,50),WXX(3),LSC(6),PC(54),CPC(3,3),
      2         CHK(3,4),BTA(4),TLINP,DIAF,NFPE,PIE,
      2         MBS(3,10),RAC(3,3),DISV1(10,6),
      2  CSANB,NPL,NL,NSDT(3),VCF(2,10),NUM32,BIDE,MSDT(3),RINDV
       DIMENSION KVL(50),KFL(50),THLC(50),TL(50),MLR(3,10),PROP(71)
     4 FORMAT(55H                                                       )
      3 CONTINUE
       READ(5,4)
       WRITE(6,15)
       WRITE(6,4)
       WRITE(6,30)
     5 FORMAT(5I5)
       READ(5,5) NL,NPL,NPC,NFPE,NLC
    10 FORMAT(5I5)
    11  FORMAT(20H NL,NPL,NPC,NFPE,NLC)
       WRITE(6,11)
       WRITE(6,10) NL,NPL,NPC,NFPE,NLC
        READ(5,35) EF11,EF22,EF33,NUF12,NUF23,NUF13,EF12,EF23,EF13,
      2            EM11,EM22,EM33,NUM12,NUM23,NUM13,EM12,EM23,EM13
       WRITE(6,70)
       WRITE(6,37) EF11,EF22,EF33,NUF12,NUF23,NUF13,EF12,EF23,EF13,
      2            EM11,EM22,EM33,NUM12,NUM23,NUM13,EM12,EM23,EM13
       DATA(PROP(I) , I = 1,71)/6HKV    ,6HKF    ,6HKFB   ,6HKM    ,
      2  6HKMB   ,6HRHOL  ,6HTL    ,
      2                    6HDELTA ,6HILDC  ,6HZB    ,6HZGC   ,6HTHCS  ,
      2  6HTHLC  ,6HTHLS  ,6HSC11  ,6HSC12  ,6HSC13  ,6HSC22  ,
      2  6HSC23  ,6HSC33  ,6HSC44  ,6HSC55  ,6HSC66  ,6HCTE11 ,
      2  6HCTE22 ,6HCTE33 ,6HHK11  ,6HHK22  ,6HHK33  ,6HHCL   ,
      2  6HEL11  ,6HEL22  ,6HEL33  ,6HGL23  ,6HGL13  ,6HGL12  ,
```

```
    2  6HNUL12 ,6HNUL21 ,6HNUL13 ,6HNUL31 ,6HNUL23 ,6HNUL32 ,
    2  6HSMFK22,6HSMFD22,6HSMFS22,6HSMFC22,6HSMFS12,6HSMFS23,
    2   6HILMFC ,6HTEMPD ,6HLSC11T,6HLSC11C,6HLSC11D,6HLSC22T,
    2  6HLSC22C,6HLSC12 ,6HLSC23 ,6HLSCC23,6HLSCC13,6HLSCDF ,
    2  6HKL12AB,6HMDEIE ,6HRELROT,6HEPS11 ,6HEPS22 ,6HEPS12 ,6HSIG11 ,
    2  6HSIG22 ,6HSIG12 ,6HDELFI ,6HHFC   /
15   FORMAT(1H1)
20   FORMAT(//47H LAYER PROPERTIES, ROWS-PROPERTY, COLUMNS-LAYER)
25   FORMAT(I3,3X,A6,2X,8E14.4)
30   FORMAT(//)
35   FORMAT(5E15.8)
37   FORMAT(10E13.5)
41   FORMAT(4H VCF)
     WRITE(6,41)
      READ(5,35) ((VCF(I,J),J = 1,10),I = 1,2)
     WRITE(6,37) ((VCF(I,J),J = 1,10),I = 1,2)
40   FORMAT(4H VAF)
     WRITE(6,40)
      READ(5,35) (VAF(I),I  = 1,3)
     WRITE(6,37) (VAF(I),I  = 1,3)
45   FORMAT(4H VAM)
     WRITE(6,45)
      READ(5,35) (VAM(I),I  = 1,3)
     WRITE(6,37) (VAM(I),I  = 1,3)
50   FORMAT(59H THERMAL CONDUCTIVITIES AND HEAT CAPACITIES OF CONSTITUE
    2NTS)
55   FORMAT(4H CHK)
     WRITE(6,55)
      READ(5,35) ((CHK(I,J),J = 1,4),I = 1,3)
     WRITE(6,37) ((CHK(I,J),J = 1,4),I = 1,3)
60   FORMAT(4H BTA)
     WRITE(6,60)
      READ(5,35) (BTA(I),I  = 1,4)
     WRITE(6,37) (BTA(I),I  = 1,4)
65   FORMAT(4H PIE)
     WRITE(6,65)
      READ(5,35) PIE
     WRITE(6,37) PIE
70   FORMAT(/96H EF11,EF22,EF33,NUF12,NUF23,NUF13,EF12,EF23,EF13,EM11,E
    2M22,EM33,NUM12,NUM23 NUM13,EM12,EM23,EM13)
80   FORMAT(/6H TLINP)
     WRITE(6,8C)
75   FORMAT(L6)
      READ(5,75) TLINP
     WRITE(6,75) TLINP
85   FORMAT(/6H CSANB)
     WRITE(6,85)
      READ(5,75) CSANB
     WRITE(6,75) CSANB
87   FORMAT(/5H BIDE)
     WRITE(6,87)
      READ(5,75) BIDE
     WRITE(6,75) BIDE
88   FORMAT(/6H RINDV)
     WRITE(6,88)
      READ(5,75) RINDV
     WRITE (6,75) RINDV
90   FORMAT(/20H THCS,RHOF,RHOM,DIAF)
     WRITE(6,90)
```

```
      READ(5,35) THCS,RHOF,RHOM,DIAF
     WRITE(6,37) THCS,RHOF,RHOM,DIAF
 95  FORMAT(4H KVL)
     WRITE(6, 95)
      READ(5,35) (KVL(I),I = 1,NL)
     WRITE(6,37) (KVL(I),I = 1,NL)
 100 FORMAT(4H KFL)
     WRITE(6,100)
      READ(5,35) (KFL(I),I = 1,NL)
     WRITE(6,37) (KFL(I),I = 1,NL )
 105 FORMAT(5H THLC)
     WRITE(6,105)
      READ(5,35) (THLC(I),I = 1,NL)
     WRITE(6,37) (THLC(I),I = 1,NL)
 110 FORMAT(3H TL)
     WRITE(6,110)
      READ(5,35) (TL(I),I = 1,NL)
     WRITE(6,37) (TL(I),I = 1,NL)
 111 FORMAT(6H PTEMP)
     WRITE(6,111)
     READ(5,35)  (PL(50,I), I=1,NL)
     WRITE(6,37) (PL(50,I), I=1,NL)
 115 FORMAT(/4H BET)
     WRITE(6,115)
      READ(5,35) ((BET(I,J),J = 1,8),I = 1,2)
     WRITE(6,37) ((BET(I,J),J = 1,8),I = 1,2)
 120 FORMAT(/4H LSC)
     WRITE(6,120)
      READ(5,35) (LSC(I),I = 1,6)
     WRITE(6,37) (LSC(I),I = 1,6)
 130 FORMAT(/4H NBS)
     WRITE(6,130)
       READ(5,35) ((NBS(I,J),J = 1,NLC),I = 1,3)
      WRITE(6,37) ((NBS(I,J),J = 1,NLC),I = 1,3)
 131 FORMAT(/4H MBS)
     WRITE(6,131)
      READ(5,35) ((MBS(I,J),J = 1,NLC),I = 1,3)
     WRITE(6,37) ((MBS(I,J),J = 1,NLC),I = 1,3)
 132 FORMAT(/6H DISV1)
     WRITE(6,132)
     READ(5,35) ((DISV1(I,J), J=1,6), I= 1,NLC)
     WRITE(6,37) ((DISV1(I,J), J= 1,6), I= 1,NLC)
 140 CONTINUE
 142 DO 145 J = 1,NL
     PL(1,J) = KVL(J)
     PL(2,J) = KFL(J)
     PL(7,J) = TL(J)
     PL(12,J) = THCS
     PL(13,J) = THLC(J)
     PL(14,J) = THCS+THLC(J)
     PL(13,J) = PL(13,J)*PIE/180.0
     PL(14,J) = PL(14,J)*PIE/180.0
     KVLJ = KVL(J)
     KFLJ = KFL(J)
 145 CALL GECL(KVLJ,KFLJ)
     DO 155 J = 2,NL
     PL(9,J) = 0.0
     INE = J-1
     IF (.NOT. BIDE) GO TO 155
```

```
      PL(9,J) = PL(8,J)+PL(8,INE)
      PL(9,J) = PL(9,J)*PL(9,J)
      PL(9,J) = (2.0*PL(8,J)*PL(8,INE))/PL(9,J)
      PL(9,J) = 0.0186 *(1.0-PL(9,J))*EM12
  155 PL(49,J) = 0.0093/(PL(8,J) + PL(8,INE))
C     READ IN DESIRED PLY PROPERTIES HERE. SEE FORMAT 111 AND THE
C     FOLLOWING THREE CARDS FOR SAMPLE  INPUT.
      CALL GACD3(3.0)
      CALL GPCFD2
      DO  195 M = 1,NLC
      CALL CCMSA(M)
  161 FORMAT(//33H FOR THIS CASE NBS(X,Y,XY-M) IS   , 3F10.0)
  162 FORMAT(//33H FOR THIS CASE MBS(X,Y,XY-M) IS   , 3F10.0)
  163 FORMAT(//79H FOR THIS CASE THE DISPLACEMENTS DISV(ECSXX,ECSYY,ECSX
     2Y,WCBXX,WCBYY,WCBXY) ARE ,/1H , 6E15.5)
      WRITE(6,15)
      IF ( RINDV) GO TO 165
      WRITE(6,161)  (NBS(I,M), I = 1,3)
      WRITE(6,162)  (MBS(I,M), I = 1,3)
      GO TO 166
  165 CONTINUE
      WRITE(6,163) (DISV1(M,J), J = 1,6)
  166 CONTINUE
      WRITE(6,20)
      WRITE(6,30)
      QF = 0
      QI = 0
      QR = 0
      QP = 0
      QP = NL/8
      QR = MOD(NL,8)
      IF (QP .LT. 1) GO TO 185
      DO 175 QS = 1,QP
       QI = (QS-1)*8+1
       QF = QS*8
       DO 170 I = 1,NPL
  170 WRITE(6,25) I,PROP(I),( PL(I,J),J = QI,QF)
  175  WRITE(6,15)
       IF(QR .LE. 0)  GO TO 185
       QI = NL-QR+1
       QF = NL
       DO 180 I   = 1,NPL
  180 WRITE(6 ,25) I,PROP(I),(PL(I,J),J = QI,QF)
  185 IF (( QP .NE. 0) .OR. (QR .LE. 0)) GO TO 195
        QI = 1
       QF = QR
       DO 190 I = 1,NPL
  190 WRITE(6,25) I,PROP(I),(PL(I,J),J = QI,QF)
  195 CONTINUE
      WRITE(6,15)
      GO TO 3
       END
```

```
      SUBROUTINE  INVA(N,A,C)
C     CALCULATES INVA IN C

      DIMENSION A(N,N),C(N,N),B(6,6),D(6,6)
      LOGICAL TLINP,CSANB,BIDE,RINDV
      REAL NUF12,NUF23,NUF13,NUF21,NUF32,NUF31,
     2     NUL12,NUL23,NUL13,NUL21,NUL32,NUL31,
     2     NUM12,NUM23,NUM13,NUM21,NUM32,NUM31,
     2     LSC,MLR,NBS,MBS,KVL,KFL,NSDT,MSDT
      COMMON
     2  EM22,EM11,EM23,EM12,NUM21,NUM12,NUM23,
     2  EF22,EF11,EF23,EF12,NUF21,NUF12,NUF23,
     2  EM33,NUM13,RHOM,ECM(3,3),EM13,VAM(3),AXC(3,3),FLC(3,3),
     2  EF33,NUF13,RHOF,ECF(3,3),EF13,VAF(3),
     2  BET(2,8),NBS(3,10),PL(71,50),WXX(3),LSC(6),PC(54),CPC(3,3),
     2          CHK(3,4),BTA(4),TLINP,DIAF,NFPE,PIE,
     2          MBS(3,10),RAC(3,3),DISV1(10,6),
     2  CSANB,NPL,NL,NSDT(3),VCF(2,10),NUM32,BIDE,MSDT(3),RINDV
      DO 365 I = 1,N
      DO 365 J = 1,N
      B(I,J) = A(I,J)
      C(I,J) = 0.0
      IF (I .NE.J) GO TO 365
      C(I,J) = 1.0
  365 CONTINUE
      N1 = N-1
      DO 395 I = 1,N1
      DO 380  K = I,N
      IF ( B(K,I) .EQ. 0.0) GO TO 380
      S1 = B(K,I)
       DO 370 J = I,N
  370  B(K,J) = B(K,J)/S1
      DO 375 J = 1,N
  375 C(K,J) = C(K,J)/S1
  380 CONTINUE
      IP1 = I+1
      DO 395 K = IP1,N
      IF (B(K,I) .EQ. 0.0) GO TO 395
      DO 385 J = 1,N
  385 B(K,J) = B(K,J)-B(I,J)
      DO 390 J = 1,N
  390 C(K,J) = C(K,J)-C(I,J)
  395 CONTINUE

C    I LOOP***

      S1 = B(N,N)
      IF (S1 .EQ. 0.0) GO TO 405
      B(N,N) = B(N,N)/S1
      DO 400 J = 1,N

  400 C(N,J) = C(N,J)/S1
  405 IF (S1 .NE. 0.0) GO TO 415
  410 FORMAT(16H SINGULAR MATRIX)
      WRITE(6,410)
      GO TO 430
  415 DO 420 II=2,N
      I=N+2-II
      IM1 = I-1
      DO 420 KK=1,IM1
```

```
      K=I-KK
      DO 421 J = 1,N
  421 C(K,J) = C(K,J)-C(I,J)*B( K,I)
  420 B(K,I) = 0.0
C     END UPPER TRIANGLE  REDUCTION
      DO 425 I =  1,N
      DO 425 J  = 1,N
      D(I,J)  = 0.0
      DO 425  K = 1,N
  425 D( I,J) = D(I,J)+A(I,K)*C(K,J)
  430 CONTINUE
       RETURN
      END
```

```
      SUBROUTINE GLLSC(J)
C     GENERATES LIMIT STRESS CONDITIONS FOR SINGLE LAYER
      LOGICAL TLINP,CSANB,BIDE,RINDV
      REAL NUF12,NUF23,NUF13,NUF21,NUF32,NUF31,
     2     NUL12,NUL23,NUL13,NUL21,NUL32,NUL31,
     2     NUM12,NUM23,NUM13,NUM21,NUM32,NUM31,
     2     LSC,MLR,NBS,MBS,KVL,KFL,NSDT,MSDT
      COMMON
     2 EM22,EM11,EM23,EM12,NUM21,NUM12,NUM23,
     2 EF22,EF11,EF23,EF12,NUF21,NUF12,NUF23,
     2 EF33,NUF13,RHOF,ECF(3,3),EF13,VAF(3),
     2 EM33,NUM13,RHOM,ECM(3,3),EM13,VAM(3),AXC(3,3),FLC(3,3),
     2 BET(2,8),NBS(3,10),PL(71,50),WXX(3),LSC(6),PC(54),CPC(3, 3),
     2          CHK(3,4),BTA(4),TLINP,DIAF,NFPE,PIE,
     2          MBS(3,10),RAC(3,3),DISV1(10,6),
     2 CSANB,NPL,NL,NSDT(3),VCF(2,10),NUM32,BIDE,MSDT(3),RINDV
      PL(51,J) = LSC(1)*(BET(1,1)*PL(3,J)+(BET(1,2)*PL(5,J)*EM11/EF11))
      PL(52,J) = LSC(2)*(BET(2,2)*PL(5,J)+(BET(2,1)*PL(3,J)*EF11/EM11))
      PL(54,J) = BET(1,3)*(LSC(3)/PL(45,J))*PL(32,J)
      PL(55,J) = BET(2,3)*(LSC(4)/PL(45,J))*PL(32,J)
      PL(56,J) = BET(1,4)*(LSC(5)/PL(47,J))*PL(36,J)
      PL(53,J) = BET(2,4)*PL(56,J) + BET(2,5)
      PL(57,J) = BET(1,5)*(LSC(5)/PL(48,J))*PL(34,J)
C        FOYE'S LONGITUDINAL COMPRESSIVE STRENGTH METHOD
      S1 = PL(2,J)*(-1.0 + EM12/EF12) + 1.0
      S1 = EM12/S1
      S3 = PL(1,J)/(1.0 - PL(2,J))
      S2 = 1.0 + S3
      S3 = 1.0 - 2.0*S3 + S3*S3
      S4 = S1*S3/S2/3.0
C        END FOYE'S METHOD
      I = S2
      PL( I,J) = AMIN1(PL( I,J),S4)
      IF (J .LE. 1) GO TO 445
      PL(60,J) = BET(1,6)*(LSC(6)/PL(49,J))
      JM1 = J-1
      S1 = PL(10,JM1)+(0.5*PL(7,JM1))
      S2 = 0.25*(PL(8,J)-PL(8,JM1))+PC(31)
      ZJ = S1+S2
      IF (ZJ .GE. 0.0) GO TO 435
      S4 = PC(31)
  435 IF (ZJ .LT. 0.0) GO TO 440
      S4 = PC(2)-PC(31)
  440 S3 = (S4*S4)-(ZJ*ZJ)
  445 S1 = (1.0+(4.0*PL(37,J))-PL(39,J))*PL(32,J)
      S2 = (1.0-PL(41,J))*PL(31,J)
      S3 = 2.0+PL(37,J)+PL(37,J)
      S3 = S3*(2.0+PL(38,J)+PL(41,J))

      S3 = S3*PL(31,J)*PL(32,J)
      S3 = SQRT(S3)
      S4 = (S1+S2)/S3
  450 PL(61,J) = S4
      RETURN
      END
```

```
$IBFTC GACD32  DEBUG,DECK

       SUBROUTINE GACD3(C)
C      GENERATES 3-D AXIAL AND THERMAL CONSTANTS
      DIMENSION EL(6,6),R(6,6),RT(6,6),S(6,6),D1(6,6),D2(6,6),
     2  EC(6,6),ECI(6,6),CTL(6),CTC(6),CTD(6)
      LOGICAL TLINP,CSANB,BIDE,RINDV,BWEC1
      REAL NUF12,NUF23,NUF13,NUF21,NUF32,NUF31,
     2     NUL12,NUL23,NUL13,NUL21,NUL32,NUL31,
     2     NUM12,NUM23,NUM13,NUM21,NUM32,NUM31,
     2     LSC,MLR,NBS,MBS,KVL,KFL,NSDT,MSDT
      COMMON
     2  EM22,EM11,EM23,EM12,NUM21,NUM12,NUM23,
     2  EF22,EF11,EF23,EF12,NUF21,NUF12,NUF23,
     2  EM33,NUM13,RHOM,ECM(3,3),EM13,VAM(3),AXC(3,3),FLC(3,3),
     2  EF33,NUF13,RHOF,ECF(3,3),EF13,VAF(3),
     2  BET(2,8),NBS(3,10),PL(71,50),WXX(3),LSC(6),PC(54),CPC(3,3),
     2         CHK(3,4),BTA(4),TLINP,DIAF,NFPE,PIE,
     2         MBS(3,10),RAC(3,3),DISV1(10,6),
     2  CSANB,NPL,NL,NSDT(3),VCF(2,10),NUM32,BIDE,MSDT(3),RINDV
  454 FORMAT(//27X,69H 3-D  COMPOSITE STRAIN STRESS TEMPERATURE RELATION
      2S - STRUCTURAL AXES//)
  456 FORMAT(//33X,56H 3-D COMPOSITE STRESS STRAIN RELATIONS - STRUCTURA
     2L AXES//)
  457 FORMAT(/11X,6E14.4,5X,1E14.4)
  458 FORMAT(/21X,6E14.4)
  459 FORMAT(1H1)
      BWEC1 = .TRUE.
  461 DO 455 I = 1,6
       CTL(I)=0.0
       CTC(I)=0.0
       CTD(I)=0.0
      DO 455 J = 1,6
  455 EC(I,J) = 0.0
       SRC = 0.0
       ST = 0.0
      DO 462 I = 15,18
  462 PC(I) = 0.0
      IF (.NOT. BWEC1) GO TO 464
      DO 463 I = 51,54
  463 PC(I) = 0.0
  464 CONTINUE
       DO 500 J = 1,NL
       ST = ST+PL(7,J)
       SRC = SRC+(PL(6,J)*PL(7,J))
       EL(1,1) = PL(15,J)
       EL(1,2) = PL(16,J)
       EL(1,3) = PL(17,J)
       EL(2,2) = PL(18,J)
       EL(2,3) = PL(19,J)
       EL(3,3) = PL(20,J)
       EL(4,4) = PL(21,J)
       EL(5,5) = PL(22,J)
       EL(6,6) = PL(23,J)
       CTL(1) = PL(24,J)
       CTL(2) = PL(25,J)
       CTL(3) = PL(26,J)
       TH = PL(13,J)
```

```
      IF (BWEC1) TH = PL(14,J)
       R( 2, 2 ) = COS(TH)*COS(TH)
       R( 1, 1 ) = R(2,2)
       R( 2, 1 ) =  SIN(TH)*SIN(TH)
       R( 1, 2 ) = R(2,1)
       R( 3, 3 ) = 1.0
      R(4,4) = COS(TH)
      R(5,4) = -SIN(TH)
      R(5,5) = COS(TH)
      R(4,5) =  SIN(TH)
       R( 1, 6 ) = 0.5 *SIN(2.0*TH)
       R( 2, 6 ) =  -R(1,6)
       R( 6, 2 )  = SIN(2.0*TH)
       R( 6,  6 ) = COS(2.0*TH)
       R(  6, 1 ) = -R(6,2)
        IF (J .LE. 1) GO TO 465
       TH1 = PL(13,J)
       JM1 = J-1
      TH2 = PL( 13,JM1)
      S1 = (SIN(2.0*TH1)-SIN(2.0*TH2))
      S2 = (COS(2.0*TH1)-COS(2.0*TH2))
       S( 2, 2 ) = S1*S1
       S( 1, 1 ) = S1*S1
       S( 2, 1 ) = -S1*S1
       S( 1, 2 ) = -S1*S1
       S( 6, 1 ) =-S1*S2
       S( 1, 6 ) =-S1*S2
       S( 6, 2 ) = S1*S2
       S( 2, 6 ) = S1*S2
       S( 6, 6 ) = S2*S2
       DO 460 K = 1,6
       DO 460 L = 1,6
  460 S(K,L) = 0.25*S(K,L)
  465 DO 470 K = 1,6
       DO 470 L = K,6
  470 EL(L,K) = EL(K,L)
       DO 475 K = 1,6
       DO 475 L = 1,6
  475 RT(K,L) = R(L,K)
       DO 480 K = 1,6
       DO 480 L = 1,6
       D1(K,L) = 0.0

      DO 480 M = 1,6
  480 D1(K,L) = D1(K,L)+(RT(K,M)*EL(M,L))
      DO 485 K = 1,6
      DO 485 L = 1,6
      D2(K,L) = 0.0
      DO 485 M = 1,6
  485 D2(K,L) = D2(K,L)+(D1(K,M)*R(M,L))
      S1 = PL(7,J)
      S2 = PL(9,J)
      DO 490 K = 1,6
      DO 490 L = 1,6
  490 EC(K,L) = EC(K,L) +(S1*D2(K,L))+(S2*S(K,L))
      PC( 15) = PC(15) +  PL(7,J)*(PL(27,J)*R(1,1)+ PL(28,J)*R(2, 1))
      PC( 16) = PC(16) +  PL(7,J)*(PL(27,J)*R(2,1)+ PL(28,J)*R(1, 1))
      PC( 17) = PC(17) +  PL(7,J)/PL(29,J)
      PC( 18) = PC(18) +  PL(7,J)*PL(30,J)
```

```
      PC(53) = PC(53) +  PL(7,J)*(PL(28,J) - PL(27,J))*R(6,2)/2.0
      DO 500 K = 1,6
      S3 = 0.0
      DO 495 L = 1,6
  495 S3 = S3+(S1*D1(K,L)*CTL(L))
  500 CTD(K) = CTD(K)+S3
C     END J LOOP
      DO 501 K = 1,6
      DO 501 L = 1,6
  501 EC(K,L) = (1.0/ST)*EC(K,L)
      SRC = SRC/ST
      CALL INVA(6,EC,ECI)
      DO 510 K = 1,6
      S3 = 0.0
      DO 505 L = 1,6
  505  S3 = S3+(ECI(K,L)*CTD(L))
  510 CTC(K) = CTC(K)+(1.0/ST)*S3
      IF (.NOT. BWEC1) GO TO 506
      PC(48) = CTC(1)
      PC(49)= CTC(2)
      PC(50) = CTC(6)
      PC(51) = PC(15)/ST
      PC(52) = PC(16)/ST
      PC(53) = PC(53)/ST
      PC(54) = PC(18)/ST
  506 CONTINUE
      IF (.NOT. BWEC1) GO TO 511
      WRITE(6,459)
      WRITE(6,454)
      WRITE(6,457) ((ECI(I,J),J = 1,6),CTC(I),I = 1,6)
      WRITE(6,456)
      WRITE(6,458) ((EC(I,J),J = 1,6),I = 1,6)
      WRITE(6,459)
      BWEC1 = .FALSE.
      GO TO 461
C     TRANSFER COMPOSITE PROPERTIES IN PC
  511 PC(1)  = SRC
      PC(2)   = ST
      PC( 3) = EC(1,1)
      PC( 4) = EC(1,2)
      PC( 5) = EC(1,3)
      PC( 6) = EC(2,2)
      PC( 7) = EC(2,3)
      PC( 8) = EC(3,3)
      PC( 9) = EC(4,4)
      PC(10) = EC(5,5)
      PC(11) = EC(6,6)
      PC(12) = CTC(1)
      PC(13) = CTC(2)
      PC(14) = CTC(3)
      DO 515 M = 15,18
  515 PC(M)  = PC(M)/ST
      PC(17) = 1.0/PC(17)
      PC(19) = 1.0/ECI(1,1)
      PC(20) = 1.0/ECI(2,2)
      PC(21) = 1.0/ECI(3,3)
      PC(22) = 1.0/ECI(4,4)
      PC(23) = 1.0/ECI(5,5)
      PC(24) = 1.0/ECI(6,6)
```

```
      PC(25) = -ECI(2,1)/ECI(1,1)
      PC(26) = -ECI(1,2)/ECI(2,2)
      PC(27) = -ECI(3,1)/ECI(1,1)
      PC(28) = -ECI(1,3)/ECI(3,3)
      PC(29) = -ECI(3,2)/ECI(2,2)
      PC(30) = -ECI(2,3)/ECI(3,3)
      RETURN
      END



$IBFTC BLOCK1  DECK,LIST

      BLOCK CATA
      COMMON/GPCOM/RESF(6),DISP(6)
      DATA(DISP(I),I = 1,6)/6HUX    ,6HVY    ,6HVXPUY ,6HWXX    ,
     2  6HWYY    ,6HWXY    /
      DATA(RESF(I),I = 1,6)/6HNX    ,6HNY    ,6HNXY   ,6HMX     ,
     2  6HMY     ,6HMXY    /
      END
```

```
      SUBROUTINE GPCFD2
C     GENERATES THE REQUIRED SECTION PROPERTIES FOR LINEAR BENDING
C     THEORY OF MULTILAYERED FILAMENTARY COMPOSITE
      REAL MT,NT
      DIMENSION EL(3,3),R(3,3),RT(3,3),S(3,3),EC(3,3),CC(3,3),
     2 FC(3,3),D1(3,3),D2(3,3),D3(3,3),D4(3),MT(3),NT(3),
     2 CTL(3),PROPC(54),RDC(3,3)
      LOGICAL TLINP,CSANB,BIDE,RINDV
      REAL NUF12,NUF23,NUF13,NUF21,NUF32,NUF31,
     2     NUL12,NUL23,NUL13,NUL21,NUL32,NUL31,
     2     NUM12,NUM23,NUM13,NUM21,NUM32,NUM31,
     2     LSC,MLR,NBS,MBS,KVL,KFL,NSDT,MSDT
      COMMON
     2 EM22,EM11,EM23,EM12,NUM21,NUM12,NUM23,
     2 EF22,EF11,EF23,EF12,NUF21,NUF12,NUF23,
     2 EM33,NUM13,RHOM,ECM(3,3),EM13,VAM(3),AXC(3,3),FLC(3,3),
     2 EF33,NUF13,RHOF,ECF(3,3),EF13,VAF(3),
     2 BET(2,8),NBS(3,10),PL(71,50),WXX(3),LSC(6),PC(54),CPC(3,3),
     2        CHK(3,4),BTA(4),TLINP,DIAF,NFPE,PIE,
     2        MBS(3,10),RAC(3,3),DISV1(10,6),
     2 CSANB,NPL,NL,NSDT(3),VCF(2,10),NUM32,BIDE,MSDT(3),RINDV
      COMMON/GPCOM/RESF(6),DISP(6)
      DATA(PROPC(I),I = 1,54)/6HRHOC  ,6HTC    ,6HCC11  ,6HCC12  ,
     2 6HCC13  ,6HCC22  ,6HCC23  ,6HCC33  ,6HCC44  ,6HCC55  ,6HCC66  ,
     2 6HCTE11 ,6HCTE22 ,6HCTE33 , 6HHK11  ,6HHK22  ,
     2 6HHK33  ,6HHHC   ,6HEC11  ,6HEC22  ,6HEC33  ,
     2 6HEC23  ,6HEC31  ,6HEC12  ,6HNUC12 ,6HNUC21 ,6HNUC13 ,
     2 6HNUC31 ,6HNUC23 ,6HNUC32 ,6HZCGC  ,6HB2DEC ,6HCC11  ,
     2 6HCC12  ,6HCC13  ,6HCC22  ,6HCC23  ,6HCC33  ,6HEC11  ,6HEC22  ,
     2 6HEC12  ,6HNUC12 ,6HNUC21 ,6HCSN13 ,6HCSN31 ,6HCSN23 ,
     2 6HCSN32 ,6HCTE11 ,6HCTE22 ,6HCTE12 ,6HHK11  ,6HHK22  ,6HHK12  ,
     2 6HHHC   /
  205 FORMAT(A6,4X,3E14.4,1X,3E14.4,A6,1E14.4)
  210 FORMAT(/)
  215 FORMAT(//)
  216 FORMAT(1H1)
  220 FORMAT(//7H FORCES,34X,29H FORCE DISPLACEMENT RELATIONS,
     2 29X,6H DISPL,7X,15H THERMAL FORCES)
  225 FORMAT(//77H COMPOSITE PROPERTIES - VALID ONLY FOR CONSTANT TEMPER
     2ATURE THROUGH THICKNESS)
  226 FORMAT(60H LINES  1 TO 31 3-D COMPOSITE PROPERTIES ABOUT MATERIAL
     2AXES)
  227 FORMAT(63H LINES  33 TO 54 2-D COMPOSITE PROPERTIES ABOUT STRUCTUR
     2AL AXES)
      CZ = 0.0
      DO 230 J = 1,NL
C     CG IS TAKEN AT THE GEOMETRIC CENTER
      CZ = CZ+PL(7,J)
  230 PL(10,J) = CZ-(0.5*PL(7,J))
      PC(31)  = CZ/2.0
      ZBC = PC(31)
      DO 235 I = 1,NL
  235 PL(11,I) = PL(10,I)-ZBC
C     END CALCULATIONS FOR CG
      DO 240 K = 1,3
      MT(K) = 0.0
  240 NT(K) = 0.0
      DO 245 K = 1,3
      DO 245 L = 1,3
```

```
      EC(K,L ) = 0.0
      FC(K,L ) = 0.0
      CC(K,L ) = 0.0
       S(K,L ) = 0.0
       R(K,L ) = 0.0
  245 FL(K,L ) = 0.0
C     BEGIN J LOOP****
      DO 290 J = 1,NL
      EL( 1, 1) = 1.0/PL(31,J)
      EL( 2, 2) = 1.0/PL(32,J)
      EL( 3, 3) = 1.0/PL(36,J)
      EL( 1, 2) = -PL(38,J)/PL(32,J)
      EL( 2, 1) = -PL(37,J)/PL(31,J)
      CALL INVA(3,EL,EL)
      TH = PL(14,J)
      R(1,1) = COS(TH)*COS(TH)
      R(2,2) = COS(TH)*COS(TH)
      R(1,2) = SIN(TH)*SIN(TH)
      R(2,1) = SIN(TH)*SIN(TH)
      R(1,3) = 0.5*SIN(2.0*TH)
      R(3,2) = SIN(2.0 *TH)
      R(3,3) = COS(2.0 *TH)
      R(2,3) = -R(1,3)
      R(3,1) = -R(3,2)
      DO 250 K = 1,3
      DO 250 L = 1,3
  250 RT(K,L ) = R(L,K)
      IF(J .LE. 1) GO TO 255
      S1 = SIN(2.0*TH)
      JM1 = J-1
      S2 = SIN(2.0*PL(13,JM1 ))
      S3 = COS(2.0*TH)
      S4 = COS(2.0*PL(13,JM1))
      S(2,2) = (S1-S2)*(S1-S2)
      S(1,1) = (S1-S2)*(S1-S2)
      S(2,1) = -S(1,1)
      S(1,2) = S(2,1)
      S(3,3) = (S3-S4)*(S3-S4)
      S(3,1) = -(S1-S2)*(S3-S4)
      S(1,3) = -(S1-S2)*(S3-S4)
      S(3,2) = (S1-S2)*(S3-S4)
      S(2,3) = S(3,2)
  255 S4 = 0.5*PL(7,J)
      S1 = PL(10,J)-PC(31)+S4
      S2 = PL(10,J)-PC(31)-S4
      S5 = 0.5*(S1*S1-S2*S2)
      IF (J .LE. 1) GO TO 265
      DO 260 K = 1,3
      DO 260 L = 1,3
  260 S(K,L ) = 0.25*PL(9,J)*S(K,L)
      S6 = 0.25*(PL(8,J)-PL(8,JM1))
      S6 = S6+S4+PL(10,JM1)-PC(31)
  265 IF (J .GT. 1) GO TO 270
       S6 = 0.0
  270 DO 275 K = 1,3
      DO 275 L = 1,3
       D1(K,L) = 0.0
       DO 275 M = 1,3
```

```
  275 D1(K,L ) =              D1(K,L)+(RT(K,M)*EL(M,L))
      DO 280 K = 1,3
      DO 280 L = 1,3
      D2(K,L ) = 0.0
      DO 280 M = 1,3
  280 D2(K,L ) = D2(K,L)+(D1(K,M)*R(M,L))
      DO 285 K = 1,3
      DO 285 L = 1,3
      S7 = 0.0
      S7 = ( S1- S2)*D2(K,L)+S(K,L)
      EC(K,L ) = EC(K,L) + S7
      S7 = 0.0
      S7 = S5*D2(K,L) +  S6*S(K,L)
      CC(K,L ) = CC(K,L)+S7
      S7 = 0.0
      S7 = (1.0/3.0)*((S1*S1*S1)-(S2*S2*S2))*D2(K,L)+((S6*S6)*S(K,L))
  285 FC(K,L ) = FC(K,L)+S7
      CTL(1) = PL(24,J)
      CTL(2) = PL(25,J)
      CTL(3) = 0.0
      DO 290 K = 1,3
      D4(K) = 0.0
      DO 291 L = 1,3
  291 D4(K) = D4(K)+(D1(K,L)*CTL(L))
      NT(K) = NT(K)+(PL(50,J)*D4(K)*PL(7,J))
  290 MT(K) = MT(K)+(S5*PL(50,J)*D4(K))
C     END J LOOP****
      DO 295 K = 1,3
      DO 295 L = 1,3
  295 D1(K,L ) = EC(K,L)/CZ
      CALL INVA(3,D1,D2)
      PC( 33) = D1(1,1)
      PC( 34) = D1(1,2)
      PC( 35) = D1(1,3)
      PC( 36) = D1(2,2)
      PC( 37) = D1(2,3)
      PC( 38) = D1(3,3)
      PC( 39) = 1.0/D2(1,1)
      PC( 40) = 1.0/D2(2,2)
      PC( 41) = 1.0/D2(3,3)
      PC( 42) = -D2(2,1)/D2(1,1)
      PC( 43) = -D2(1,2)/D2(2,2)
      PC( 44) = -D2(3,1)/D2(1,1)
      PC( 45) = -D2(1,3)/D2(3,3)
      PC( 46) = -D2(3,2)/D2(2,2)
      PC( 47) = -D2(2,3)/D2(3,3)
      DO 305 I = 1,3
      DO 300 J = 1,3
      AXC(I,J) = EC(I,J)
      CPC(I,J) = CC(I,J)
  300 FLC(I,J) = FC(I,J)
      NSDT(I) = NT(I)
  305 MSDT(I) = MT(I)
      WRITE(6,225)
      WRITE(6,226)
      WRITE(6,227)
      DO 310 I = 1,54
  310 WRITE(6,320) I,PROPC(I),PC(I)
```

```
320   FORMAT(I3,3X,A6,E14.4)
      WRITE(6,216)
      WRITE(6,220)
      WRITE(6,210)
330   FORMAT(2X,A6,4X,3E14.4,1X,3E14.4,3X,A6,4X,E14.4)
      DO 335 I = 1,3
      WRITE(6,210)
335   WRITE(6,330) RESF(I),(EC(I,J),J = 1,3),(CC(I,J),J = 1,3),
     2  DISP(I),NT(I)
      WRITE(6,210)
      DO 340 I = 4,6
      IM3 = I-3
      WRITE(6,210)
340   WRITE(6,330) RESF(I),(CC(J,IM3),J = 1,3),(FC(IM3,J),J = 1,3),
     2  DISP(I),MT(IM3)
      CALL  INVA(3,EC,EC)
      DO 345 I = 1,3
      DO 345 J = 1,3
      FC(I,J) = 0.0
      DO 345 K = 1,3
      DO 345 L = 1,3
345   FC(I,J) = FC(I,J)+CC(I,K)*EC(K,L)*CC(L,J)
      DO 350 I = 1,3
      DO 350 J = 1,3
350   RDC(I,J) = FLC(I,J) - FC(I,J)
      WRITE(6,215)
355   FORMAT(27H REDUCED BENDING REGIDITIES)
      WRITE(6,355)
      WRITE(6,210)
360   FORMAT(9E13.5)
      WRITE(6,360)  ((RDC(I,J), J = 1,3) , I = 1,3)
      WRITE(6,215)
      DO 361 I = 1,3
      DO 361 J = 1,3
361   FC(I,J) = FLC(I,J)
      CALL  INVA(3,FC,FC)
      DO 362 I = 1,3
      DO 362 J = 1,3
      D3(I,J) = 0.0
      DO 362 K = 1,3
      DO 362 L = 1,3
362   D3(I,J) = D3(I,J) + CC(I,K)*FC(K,L)*CC(L,J)
      DO 363 I = 1,3
      DO 363 J = 1,3
363   RAC(I,J) = AXC(I,J) - D3(I,J)
      WRITE(6,215)
364   FORMAT(25H REDUCED STIFFNESS MATRIX)
      WRITE(6,364)
      WRITE(6,360)  ((RAC(I,J),J = 1,3),I = 1,3)
      WRITE(6,215)
      RETURN
      END
```

```
      SUBROUTINE GPHK(CF,CM,R,Q,CP)
      REAL R
      LOGICAL TLINP,CSANB,BIDE,RINDV
      REAL NUF12,NUF23,NUF13,NUF21,NUF32,NUF31,
     2     NUL12,NUL23,NUL13,NUL21,NUL32,NUL31,
     2     NUM12,NUM23,NUM13,NUM21,NUM32,NUM31,
     2     LSC,MLR,NBS,MBS,KVL,KFL,NSDT,MSDT
      COMMON
     2 EM22,EM11,EM23,EM12,NUM21,NUM12,NUM23,
     2 EF22,EF11,EF23,EF12,NUF21,NUF12,NUF23,
     2 EM33,NUM13,RHOM,ECM(3,3),EM13,VAM(3),AXC(3,3),FLC(3,3),
     2 EF33,NUF13,RHOF,ECF(3,3),EF13,VAF(3),
     2 BET(2,8),NBS(3,10),PL(71,50),WXX(3),LSC(6),PC(54),CPC(3,3),
     2         CHK(3,4),BTA(4),TLINP,DIAF,NFPE,PIE,
     2         MBS(3,10),RAC(3,3),DISV1(10,6),
     2 CSANB,NPL,NL,NSDT(3),VCF(2,10),NUM32,BIDE,MSDT(3),RINDV
C     GENERATES PLY HEAT CONDUCTIVITIES
      S1 = (1.0-CM/CF)
      S2 = Q*SQRT(R)
      S1 = (1.0/S2)-S1
      IF(S1 .GT.0.0) GO TO 525
  520 FORMAT(23H BETA TOO LARGE IN GPHK)
      WRITE(6,520)
  525 IF (S1 .LE. 0.0) GO TO 530
      CP = 1.0-S2+(1.0/S1)
  530 CP = CP*CM
      RETURN
      END
```

```
      SUBROUTINE GECL(KV,KF)
C     GENERATES ECL FROM CONSTITUENT PROPERTIES
      REAL KV,KF,KFB,KMB,IM1,IM2,INVECL,KM
      DIMENSION CFL(3,3),VAL(3)    ,CML(3,3),CMLT(3,3),IM1(3,3),IM2(3,3),
     2  ECL(3,3),CFLT(3,3),INVECL(3,3)
      LOGICAL TLINP,CSANB,BIDE,RINDV
      REAL NUF12,NUF23,NUF13,NUF21,NUF32,NUF31,
     2     NUL12,NUL23,NUL13,NUL21,NUL32,NUL31,
     2     NUM12,NUM23,NUM13,NUM21,NUM32,NUM31,
     2     LSC,MLR,NBS,MBS,KVL,KFL,NSDT,MSDT
      COMMON/MAGE/J
      COMMON
     2  EM22,EM11,EM23,EM12,NUM21,NUM12,NUM23,
     2  EF22,EF11,EF23,EF12,NUF21,NUF12,NUF23,
     2  EM33,NUM13,RHOM,ECM(3,3),EM13,VAM(3),AXC(3,3),FLC(3,3),
     2  EF33,NUF13,RHOF,ECF(3,3),EF13,VAF(3),
     2  BET(2,8),NBS(3,10),PL(71,50),WXX(3),LSC(6),PC(54),CPC(3,3),
     2          CHK(3,4),BTA(4),TLINP,DIAF,NFPE,PIE,
     2          MBS(3,10),RAC(3,3),DISV1(10,6),
     2  CSANB,NPL,NL,NSDT(3),VCF(2,10),NUM32,BIDE,MSDT(3),RINDV
      IF (EF11 .NE. EF22) GO TO 535
      NUF21 = NUF12
      EF12 = EF11/(2.0*(1.0+NUF12))
  535 IF (EF11 .EQ.EF22) GO TO 540
      NUF21 = NUF12*(EF22/EF11)
  540 IF (EF11 .NE. EF33) GO TO 545
      NUF31 = NUF13
      EF13 = EF11/(2.0*(1.0+NUF13))
  545 IF (EF11 .EQ. EF33) GO TO 550
      NUF31 = NUF13*(EF33/EF11)
  550 IF (EF22 .NE. EF33) GO TO 555
      NUF32 = NUF23
      EF23 = EF22/(2.0*(1.0+NUF23))
  555 IF (EF22 .EQ. EF33) GO TO 560
      NUF32 = NUF23*(EF33/EF22)
  560 IF (EM11 .NE. EM22) GO TO 565
      NUM21 = NUM12
      EM12 = EM11/(2.0*(1.0+NUM12))
  565 IF (EM11 .EQ. EM22) GO TO 570
      NUM21 = NUM12*(EM22/EM11)
  570 IF(EM11 .NE. EM33) GO TO 575
      NUM31 = NUM13
      EM13 = EM11/(2.0*(1.0+NUM13))
  575 IF (EM11 .EQ. EM33) GO TO 580
      NUM31 = NUM13*(EM33/EM11)
  580 IF (EM22 .NE. EM33) GO TO 585
      NUM32 = NUM23
      EM23 = EM22/(2.0*(1.0+NUM23))
  585 IF (EM22 .EQ. EM33) GO TO 590
      NUM32 = NUM23*(EM33/EM22)
  590 KFB = (1.0-KV)*KF
      KMB = (1.0-KF)*(1.0-KV)
      CF = KFB/KF
      KM = 1.0-KF
      PL(3,J) = KFB
      PL(4,J) = 1.0-KF
      PL(5,J) = KMB
      PL(6,J) = RHOM*KMB+RHOF*KFB
      IF (.NOT. TLINP ) PL(7,J)=SQRT(PIE*(FLOAT(NFPE))/(4.0*KFB))*DIAF
      IF (.NOT. TLINP) PL(7,J) = PL(7,J)/SQRT(VCF(1,8))
      S1 = PIE/4.0/KFB
```

```
      S1 = SQRT(S1)-1.0
      PL(8,J) = S1*DIAF
      IF (VCF(1,1) .EQ. 0.0) GO TO 595
      CM = (1.0/KMB)**(1.0/VCF(1,1))
  595 IF (VCF(1,1) .NE. 0.0) GO TO 600
      CM = VCF(2,1)
  600 CM = (1.0-KV)*CM
      A = ((1.0/EF11)+(1.0/EM11)*(KFB/KMB))
      B = ((1.0/EM11)+(1.0/EF11)*(KMB/KFB))
      ECF(1,1) = 1.0/EF11
      ECM(1,1) = 1.0/EM11
      ECF(1,2) = -NUF21/EF22
      ECM(1,2) = -NUM21/EM22
      ECF(1,3) = -NUF31/EF33
      ECM(1,3) = -NUM31/EM33
      ECF(2,2) = 1.0/EF22
      ECM(2,2) = 1.0/EM22
      ECF(2,1) = -NUF12/EF11
      ECM(2,1) = -NUM12/EM11
      ECF(2,3) = -NUF32/EF33
      ECM(2,3) = -NUM32/EM33
      ECF(3,3) = 1.0/EF33
      ECM(3,3) = 1.0/EM33
      ECF(3,1) = -NUF13/EF11
      ECM(3,1) = -NUM13/EM11
      ECF(3,2) = -NUF23/EF22
      ECM(3,2) = -NUM23/EM22
      DO 605 I = 1,3
      DO 605 L = 1,3
      CML(I,L) = 0.0
  605 CFL(I,L) = 0.0
      CFL(1,1) = 1.0/(A*KMB*EM11)
      CFL(2,2) = 1.0/CF
      CFL(3,3) = 1.0/CF

      CFL(1,2) = (1.0/A)*((NUF21/(CF*EF22))-(NUM21/(CM*EM22)))
      CFL(1,3) = (1.0/A)*((NUF31/(CF*EF33))-(NUM31/(CM*EM33)))
      CML(1,1) = 1.0/(B*KFB*EF11)
      CML(2,2) = 1.0/CM
      CML(3,3) = 1.0/CM
      CML(1,2) = (1.0/B)*((NUM21/(CM*EM22))-(NUF21/(CF*EF22)))
      CML(1,3) = (1.0/B)*((NUM31/(CM*EM33))-(NUF31/(CF*EF33)))
      DO 610 I = 1,3
      DO 610 L = 1,3
      CFLT(I,L) = CFL(L,I)
  610 CMLT(I,L) = CML(L,I)
      DO 620 I = 1,3
      DO 620 L = 1,3
      IM2(I,L) = 0.0
      IM1(I,L) = 0.0
      DO 620 K = 1,3
      IM1(I,L) = IM1(I,L)+(CFLT(I,K)*ECF(K,L))
  620 IM2(I,L) = IM2(I,L)+(CMLT(I,K)*ECM(K,L))
      DO 635 I = 1,3
      DO 635 L = 1,3
      S2 = 0.0
      S1 = 0.0
      DO 630 K = 1,3
      S1 = S1+(IM1(I,K)*CFL(K,L))
```

```
630 S2 = S2+(IM2(I,K)*CML(K,L))
635 ECL(I,L) = S1*KFB+S2*KMB
    EL11 = 1.0/ECL(1,1)
    EL22 = 1.0/ECL(2,2)
    EL33 = 1.0/ECL(3,3)
    NUL12 = -ECL(2,1)/ECL(1,1)
    NUL21 = -ECL(1,2)/ECL(2,2)
    NUL13 = -ECL(3,1)/ECL(1,1)
    NUL31 = -ECL(1,3)/ECL(3,3)
    NUL23 = -ECL(3,2)/ECL(2,2)
    NUL32 = -ECL(2,3)/ECL(3,3)
    IF (VCF(1,2) .EQ. 0.0) GO TO 640
    CM = (1.0/KM )**(1.0/VCF(1,2))
640 IF (VCF(1,2) .NE. 0.0) GO TO 645
    CM = VCF(2,2)
645 CM = (1.0-KV)*CM
    S1 = (EM12/(CF*CF*EF12))*KFB
    S2 = KMB/(CM*CM)
    EL12 = EM12/(S1+S2)
    S1 = (EM13/(CF*CF*EF13))*KFB
    S2 = KMB/(CM*CM)
    EL13 = EM13/(S1+S2)
    IF (VCF(1,3) .EQ. 0.0) GO TO 650
    CM = (1.0/KM )**(1.0/VCF(1,3))
650 IF(VCF(1,3) .NE. 0.0) GO TO 655
    CM = VCF(2,3)
655 CM = (1.0-KV)*CM
    S1 = (EM23/(CF*CF*EF23))*KFB
    S2 = KMB/(CM*CM)
    EL23 = EM23/(S1+S2)
    IF (VCF(1,4) .EQ. 0.0) GO TO 656
    CM = (1.0/KM )**(1.0/VCF(1,4))
656 IF(VCF(1,4) .NE. 0.0) GO TO 657
    CM = VCF(2,4)
657 CM = (1.0-KV)*CM
    DO 658 I = 1,3
    DO 658 L = 1,3
    CFL(I,L) = 0.0
658 CML(I,L) = 0.0
    CFL(1,1) = 1.0/(A*KMB*EM11)
    CFL(2,2) = 1.0/CF
    CFL(3,3) = 1.0/CF
```

```
      CFL(1,2) = (1.0/A)*((NUF21/(CF*EF22))-(NUM21/(CM*EM22)))
      CFL(1,3) = (1.0/A)*((NUF31/(CF*EF33))-(NUM31/(CM*EM33)))
      CML(1,1) =  1.0/(B*KFB*EF11)
      CML(2,2) = 1.0/CM
      CML(3,3) = 1.0/CM
      CML(1,2) = (1.0/B)*((NUM21/(CM*EM22))-(NUF21/(CF*EF22)))
      CML(1,3) = (1.0/B)*((NUM31/(CM*EM33))-(NUF31/(CF*EF33)))
      DO 660 I = 1,3
      DO 660 L = 1,3
      CFLT(I,L) = CFL(L,I)
  660 CMLT(I,L) = CML(L,I)
      DO 661 I = 1,3
      VAL(I) = 0.0
      S1 = 0.0
      S2 = 0.0
      DO 661 L = 1,3
      S1 = S1+(CFLT(I,L)*VAF(L))
      S2 = S2+(CMLT(I,L)*VAM(L))
  661 VAL(I) = S1*KFB+S2*KMB
      CALL INVA(3,ECL,INVECL)
      PL(15,J) = INVECL(1,1)
      PL(16,J) = INVECL(1,2)
      PL(17,J) = INVECL(1,3)
      PL(18,J) = INVECL(2,2)
      PL(19,J) = INVECL(2,3)
      PL(20,J) = INVECL(3,3)
      PL(21,J) = EL23
      PL(22,J) = EL13
      PL(22,J) = EL23
      PL(23,J) = EL12
      PL(24,J) = VAL(1)
      PL(25,J) = VAL(2)
      PL(26,J) = VAL(2)
      PL(31,J) = EL11
      PL(32,J) = EL22
      PL(33,J) = EL33
      PL(34,J) = EL23
      PL(35,J) = EL12
      PL(36,J) = EL12
      PL(37,J) = NUL12
      PL(39,J) = NUL13
      PL(38,J) = NUL21
      PL(40,J) = NUL21
      PL(41,J) = NUL23
      PL(42,J) = NUL23
      PL(30,J) = (CHK(1,4)*RHOF*KFB+CHK(2,4)*RHOM *KMB)/PL(6,J)
      DO 665 L = 1,3
      S1 = 2.0* BTA(1)*CHK(2,L)+CHK(3,4)
      S2 = KV*(CHK(2,L)-CHK(3,4))
  665 CHK(3,L) = CHK(2,L)*(S1-2.0*S2)/(-S2+S1/BTA(1))
      PL(27,J) = BTA(2)*KFB*CHK(1,1)+(1.0-KF)*CHK(3,1)
      DO 670 L = 2,3
      L26 = 26+L
      CHK1L = CHK(1,L)
      CHK3L = CHK(3,L)
      LP1 = L+1
      BTAL = BTA(LP1)
      CALL GPHK(CHK1L,CHK3L,KFB,BTAL,PLL26J)
  670 PL(L26,J) = PLL26J
      RETURN
      END
```

```
      SUBROUTINE GSMF(SL11,SL22,SL12,SL23,KV,KF,J)
C     GENERATES TRANSVERSE AND TWO SHEAR MAGNIFICATION FACTORS
      REAL KV,KF,KFB,KMB,MF22,MF12,MF23
      DIMENSION VMF(10)
      LOGICAL TLINP,CSANB,BIDE,RINDV
      REAL NUF12,NUF23,NUF13,NUF21,NUF32,NUF31,
     2     NUL12,NUL23,NUL13,NUL21,NUL32,NUL31,
     2     NUM12,NUM23,NUM13,NUM21,NUM32,NUM31,
     2     LSC,MLR,NBS,MBS,KVL,KFL,NSDT,MSDT
      COMMON
     2  EM22,EM11,EM23,EM12,NUM21,NUM12,NUM23,
     2  EF22,EF11,EF23,EF12,NUF21,NUF12,NUF23,
     2  EF33,NUF13,RHOF,ECF(3,3),EF13,VAF(3),
     2  EM33,NUM13,RHOM,ECM(3,3),EM13,VAM(3),AXC(3,3),FLC(3,3),
     2  BET(2,8),NBS(3,10),PL(71,50),WXX(3),LSC(6),PC(54),CPC(3,3),
     2          CHK(3,4),BTA(4),TLINP,DIAF,NFPE,PIE,
     2          MBS(3,10),RAC(3,3),DISV1(10,6),
     2  CSANB,NPL,NL,NSDT(3),VCF(2,10),NUM32,BIDE,MSDT(3),RINDV
      EL11 = PL(31,J)
      EL22 = PL(32,J)
      NUL12 = PL(37,J)
      NUL21 = PL(38,J)
      VC = 4.0*KV/(PIE*(1.0-KF))
      VC = 1.0/(1.0-SQRT(VC))
      KFB = (1.0-KV)*KF
      KMB =  (1.0-KF)*(1.0-KV)
      CF = KFB/KF
      CM = KMB/(1.0-KF)
C     KIES EQUATION
      IF(VCF(1,5) .EQ. 0.0) GO TO 675
      P = SQRT(4.0/PIE)*(KFB**(VCF(1,5)))
  675 IF(VCF(1,5) .NE. 0.0) GO TO 680
      P = SQRT(4.0*KFB/PIE)*VCF(2,5)
  680 A = CM*EM22*(1.0-NUF12*NUF21)/(CF*EF22*(1.0-NUM12*NUM21))
      B = NUM12*CM*EM22*(1.0-NUF12*NUF21)/(CF*EF22*(1.0-NUM12*NUM21))
      S1 = (1.0-(NUL21*P*(NUF12-B)))*(1.0/EL22)*SL22
      S2 = (1.0/EL11)*(P*(NUF12-B)-NUL12)*SL11
      S3 = (1.0/(1.0+P*(A-1.0)))*(S1+S2)
      S4 = (SL22/EL22)-(NUL12*SL11/EL11)
      IF (ABS(S4) - 0.0)   681, 681, 682
  681 MF22 = 1.0
      GO TO 683
  682 MF22 = S3/S4
      IF (MF22 .LT. 1.0) GO TO 684
      GO TO 683
  684 MF22 = 1.0
  683 VMF(1) = MF22*VC
C     DANNIELS EQUATION
      S1 = SQRT(PIE/KFB)
      S1 = (S1-2.0)
      S1 = 0.83*S1*S1-1.35*S1+1.78
      MF22 = S1*(1.0-NUM23*NUM32)*(EL22/EM22)
      MF22 = MF22*VC
      VMF(2) = MF22
C     KIES 1-D MAGNIFICATION FACTOR
      P = SQRT(4.0*KFB/PIE)*VCF(2,5)
      S1 = CM*EM22/(CF*EF22)
      S1 = 1.0-P*(1.0-S1)
      MF22 = 1.0/S1
```

```
      FF22 = MF22*VC
      VMF(5) = MF22
      IF (VCF(1,6) .EQ. 0.0) GO TO 695
       P = KFB**(1.0/VCF(1,6))
  695 IF (VCF(1,6) .NE. 0.0) GO TO 700
      P = SQRT(4.0*KFB/PIE)*VCF(2,6)
  700 S1 = (CM*EM12/(CF*EF12))
      S3 = 1.0-(P*(1.0-S1))
      MF12 = 1.0/S3
      IF (VCF(1,7) .EQ. 0.0) GO TO 701
      P = KFB**(1.0/VCF(1,7))
  701 IF(VCF(1,7) .NE. 0.0) GO TO 702
      P = SQRT(4.0*KFB/PIE)*VCF(2,7)
  702 S1 = CM*EM23/(CF*EF23)
      S3 = 2.0*(1.0-P)+((2.0*P-1.0)*S1)
      MF23 = 1.0/S3
      VMF(6) = MF12*VC
      VMF(7) = MF23*VC
      PL(43,J) = VMF(5)
      PL(44,J) = VMF(2)
      PL(45,J) = VMF(1)
      PL(46,J) = VMF(3)
      PL(47,J) = VMF(6)
      PL(48,J) = VMF(7)
      RETURN
      END
```

```
      SUBROUTINE COMSA(M)
C     COMPUTES STRAIN AND STRESSES IN THE LAYERS GIVEN THE PRESCRIBED
C       EDGE FORCES,LAYER TEMP.AND CURVATURES
      REAL  KL12,NS,LV,MS
      DIMENSION          AIN(3,3),NS(3),RL(3,3),AL(3),FL(3,3),
     2CE(6,6),CEIN(6,6),LV(6),DISV(6),MS(3),
     2  TS1(3),TS2(3),SIGL(3),EPSL(3)
      LOGICAL TLINP,CSANB,BIDE,RINDV
  679 FORMAT(1H1)
  680 FORMAT(/)
  681 FORMAT(//)
  682 FORMAT(//6H DISP.,34X,29H DISPLACEMENT FORCE RELATIONS,43X,
     2  7H FORCES)
  683 FORMAT(2X,A6,4X,3E14.4,1X,3E14.4,15X,A6)
  684 FORMAT(    E12.4,8X,3E14.4,1X,3E14.4,3X,E14.4)
      REAL NUF12,NUF23,NUF13,NUF21,NUF32,NUF31,
     2     NUL12,NUL23,NUL13,NUL21,NUL32,NUL31,
     2     NUM12,NUM23,NUM13,NUM21,NUM32,NUM31,
     2     LSC,MLR,NBS,MBS,KVL,KFL,NSDT,MSDT
      COMMON
     2  EM22,EM11,EM23,EM12,NUM21,NUM12,NUM23,
     2  EF22,EF11,EF23,EF12,NUF21,NUF12,NUF23,
     2  EM33,NUM13,RHOM,ECM(3,3),EM13,VAM(3),AXC(3,3),FLC(3,3),
     2  EF33,NUF13,RHOF,ECF(3,3),EF13,VAF(3),
     2  BET(2,8),NBS(3,10),PL(71,50),WXX(3),LSC(6),PC(54),CPC(3,3),
     2           CHK(3,4),BTA(4),TLINP,DIAF,NFPE,PIE,
     2           MBS(3,10),RAC(3,3),DISV1(10,6),
     2  CSANB,NPL,NL,NSDT(3),VCF(2,10),NUM32,BIDE,MSDT(3),RINDV
      COMMON/GPCOM/RESF(6),DISP(6)
      CALL INVA(3,AXC,AIN)
      DO 685 I = 1,3
      MS(I) = MBS(I,M)
  685 NS(I) = NBS(I,M)
      CC=0.0
      DO 678 I= 1,3
  678 CC = AMAX1(CC,ABS(MS(I)))
      DO 688 I = 1,3
      DO 688 J = 1,3
      CE(I,J) = AXC(I,J)
      JP3 = J + 3
      IP3 = I + 3
      CE(I,JP3) = CPC(I,J)
      CE(IP3,J) = CPC(I,J)
  688 CE(IP3,JP3) = FLC(I,J)
      CALL INVA(6,CE,CEIN)
      IF (.NOT. RINDV) GO TO 677
      DO 675 J = 1,6
  675 DISV(J) = DISV1(M,J)
      GO TO 695
  677 CONTINUE
      DO 689 I = 1,3
      LV(I) = NS(I) + NSDT(I)
      IP3 = I + 3
  689 LV(IP3) = MS(I) + MSDT(I)
      DO 691 I = 1,6
      DISV(I) = 0.0
      DO 691 K = 1,6
  691 DISV(I) = DISV(I) + CEIN(I,K)*LV(K)
```

```
  695 CONTINUE
      DO 692 I = 1,3
      IP3 = I + 3
  692 WXX(I) = DISV(IP3)
      WRITE(6,679)
      WRITE(6,682)
      WRITE(6,680)
      DO 686 I = 1,3
      WRITE(6,680)
  686 WRITE(6,683)  DISP(I),(CEIN(I,J),J = 1,6),RESF(I)
      WRITE(6,680)
      DO 687 I = 4,6
      WRITE(6,680)
  687 WRITE(6,683) DISP(I),(CEIN(I,J),J = 1,6),RESF(I)
      IF (RINDV) GO TO 696
      DO 690 I = 1,6
      DISV(I) = 0.0
      DO 690 J = 1,6
  690 DISV(I) = DISV(I) + CEIN(I,J)*LV(J)
      GO TO 698
  696 CONTINUE
      CALL INVA(6,CEIN,CEIN)
      DO 697 I = 1,6
      LV(I) = 0.0
      DO 697 J = 1,6
  697 LV(I) = LV(I) + CEIN(I,J)*DISV(J)
      CALL INVA(6,CEIN,CEIN)
  698 CONTINUE
      WRITE(6,681)
      WRITE(6,682)
      WRITE(6,680)
      DO 693 I = 1,3
      WRITE(6,680)
  693 WRITE(6,684) DISV(I),(CEIN(I,J),J = 1,6),LV(I)
      WRITE(6,680)
      DO 694 I = 4,6
      WRITE(6,680)
  694 WRITE(6,684) DISV(I), (CEIN(I,J),J = 1,6),LV(I)
C     BEGIN I - LOOP
      DO 790 I = 1,NL
      TH = PL(14,I)
      RL(2,2) = COS(TH)*COS(TH)
      RL(1,1) = COS(TH)*COS(TH)
      RL(1,2) = SIN(TH)*SIN(TH)
      RL(2,1) = SIN(TH)*SIN(TH)
      S1 = SIN(2.0*TH)
      RL(2,3) = -0.5*S1
      RL(1,3) =  0.5*S1
      RL(3,1) = -S1
      RL(3,2) = S1
      RL(3,3) = COS(2.0*TH)
      AL(1) = PL(24,I)
      AL(2) = PL(25,I)
      AL(3) = 0.0
      DO 715 J = 1,3
      DO 715 K = 1,3
  715 EL(J,K) = 0.0
      EL(1,1) = 1.0/PL(31,I)
      EL(2,2) = 1.0/PL(32,I)
```

```
      EL(3,3) = 1.0/PL(36,I)
      EL(1,2) = -PL(38,I)/PL(32,I)
      EL(2,1) = -PL(37,I)/PL(31,I)
      CALL INVA(3,EL,EL)
      IF (RINDV) GO TO 699
      IF (CC .NE. 0.0) GO TO 699
      DO 725 J = 1,3
      S1 = 0.0
      DO 720 K = 1,3
  720 S1 = S1+CPC(J,K)*WXX(K)
  725 TS1(J) = NS(J)+S1+NSDT(J)
      DO 735 J = 1,3
      S1 = 0.0
      DO 730 K = 1,3
  730 S1 = S1+AIN(J,K)*TS1(K)
  735 TS2(J) = S1-PL(11,I)*WXX(J)
      DO 745 J = 1,3
      S1 = 0.0
      DO 740 K = 1,3
  740 S1 = S1+RL(J,K)*TS2(K)
  745 EPSL(J) = S1
      DO 748 J = 1,3
  748 TS1(J) = EPSL(J)-(AL(J)*PL(50,I))
      DO 755 J = 1,3
      S1 = 0.0
      DO 750 K = 1,3
  750 S1 = S1+EL(J,K)*TS1(K)
  755 SIGL(J) = S1
      GO TO 700
  699 CONTINUE
      DO 701 J = 1,3
      TS1(J) = 0.0
  701 TS1(J) = TS1(J) + DISV(J) + PL(11,I)*DISV(J+3)
      DO 703 J = 1,3
      EPSL(J) = 0.0
      DO 703 K = 1,3
  703 EPSL(J) = EPSL(J) + RL(J,K)*TS1(K)
      DO 705 J = 1,3
      SIGL(J) = 0.0
      TS2(J) = EPSL(J) - PL(50,I)*AL(J)
      DO 705 K = 1,3
  705 SIGL(J) = SIGL(J) + EL(J,K)*TS2(K)
  700 CONTINUE
C     CONSTRUCT LAYER,COMBINED STRESS LIMIT STRENGTH CRITERION
      SIGL1 = SIGL(1)
      SIGL2 = SIGL(2)
      SIGL3 = SIGL(3)
      PL1I = PL(1,I)
      PL2I = PL(2,I)
      IF (ABS(SIGL1) .EQ. 0.0)  SIGL1 = .0001
      CALL GSMF(SIGL1,SIGL2,SIGL3,1.0,PL1I,PL2I,I)
      CALL GLLSC(I)
      IF ((SIGL(1)*SIGL(2)) .LT. 0.0) GO TO 765
      IF (SIGL(1) .LT. 0.0) GO TO 760
      KL12 = BET(1,7)
      S1 = PL(51,I)
      S2 = PL(54,I)
      IF(SIGL(2) .LE. 0.0) GO TO 757
      S2 = PL(54,I)
```

```
  757 GO TO 780
  760 IF (SIGL(1) .GE. 0.0) GO TO 765
      KL12 = BET(2,8)
      S2 = PL(55,I)
      S1 = AMIN1(PL(52,I),PL(53,I))
      GO TO 780
  765 IF ((SIGL(1)*SIGL(2)) .GE. 0.0) GO TO 780
      IF (SIGL(1) .LT. 0.0) GO TO 775
      KL12 = BET(1,8)
      S1 = PL(51,I)
      S2 = PL(55,I)
      IF (SIGL(2) .GE. 0.0) GO TO 770
      S2 = PL(55,I)
  770 GO TO 780
  775 IF (SIGL(1) .GE. 0.0) GO TO 780
      KL12 = BET(2,7)
      S2 = PL(54,I)
      S1 = AMIN1(PL(52,I),PL(53,I))
      GO TO 780
  780 KL12 = KL12*PL(61,I)
      S1 = SIGL(1)/S1
      S2 = SIGL(2)/S2
      S3 = SIGL(3)/PL(56,I)
      S4 = (S1*S1)-(KL12*S1*S2)+(S2*S2)+(S3*S3)
      PL(62,I) = 1.0-S4
      S1 = AMIN1(PL(52,I),PL(53,I))
      S2 = PL(51,I)*S1
      S3 = PL(54,I)*PL(55,I)
      S2 = (SIGL(1)*SIGL(1)-SIGL(1)*SIGL(2)+(S1-PL(51,I))*SIGL(1))/S2
      S3 = (SIGL(2)*SIGL(2)+(PL(55,I)-PL(54,I))*SIGL(2))/S3
      PL(71,I) = 1.0-(S2+S3+(SIGL(3)*SIGL(3)/PL(56,I)/PL(56,I)))
      IF (I .LE. 1) GO TO 785
      IM1 = I-1
      S1 = SIN(2.0*TH)-SIN(2.0*PL(14,IM1))
      S3 = COS(2.0*TH)-COS(2.0*PL(14,IM1))
      S3 = TS2(2)-TS2(1)
      S4 = 0.5*(S1*S3+S2*TS2(3))
      PL(70,I) = S4
      PL(63,I) = (PL(60,I)-ABS(S4))/PL(60,I)
  785  PL(64,I) = EPSL(1)
      PL(65,I) = EPSL(2)
      PL(66,I) = EPSL(3)
      PL(67,I) = SIGL(1)
      PL(68,I) = SIGL(2)
      PL(69,I) = SIGL(3)
      IF (.NOT. CSANB  ) GO TO 790
      IF (I .NE. 2) GO TO 795
  790 CONTINUE
C     END I-LOOP
      GO TO 805
  795 DO 800 I = 62,NPL
      DO 800 J = 3,NL,2
      PL(I,J) = PL(I,1)
      JP1 = J+1
      IF (JP1 .GT. NL) GO TO 800
      PL(I,JP1) = PL(I,2)
  800 CONTINUE
  805  CONTINUE
      RETURN
      END
```

APPENDIX C

SAMPLE CASES

Unidirectional Composite

```
THORNEL-50/EPOXY


NL,NPL,NPC,NFPE,NLC
   8   71   54 1420    1

EF11,EF22,EF33,NUF12,NUF23,NUF13,EF12,EF23,EF13,EM11,EM22,EM33,NUM12,NUM23 NUM13,EM12,EM23,EM13
 0.50000E 08  0.10000E 07  0.10000E 07  0.20000E 00  0.25000E 00  0.20000E 00  0.13000E 07  0.70000E 06  0.13000E 07  0.57000E 06
 0.57000E 06  0.57000E 06  0.36000E 00  0.36000E 00  0.36000E 00  0.           0.           0.
VCF
 0.40000E 01  0.20000E 01  0.40000E 01  0.20000E 01  0.           0.           0.           0.23560E 01  0.           0.
 0.           0.           0.           0.           0.10000E 01  0.10000E 01  0.10000E 01  0.           0.           0.
VAF
-0.55000E-06  0.56000E-05  0.56000E-05
VAM
 0.42800E-04  0.42800E-04  0.42800E-04
CHK
 0.58000E 03  0.58000E 02  0.58000E 02  0.17000E 00  0.12500E 01  0.12500E 01  0.12500E C1  0.25000E 00  0.           0.
 0.           0.22500E 00
BTA
 0.10000E 01  0.10000E 01  0.10500E 01  0.10500E 01
PIE
 0.31416E 01

TLINP
    F

CSANB
    F

BIDE
    F

RINDV
    F

THCS,RHOF,RHCM,DIAF
 0.           0.59000E-01  0.44300E-01  0.26000E-03
KVL
 0.           0.           0.           0.           0.           0.           0.           0.
KFL
 0.50000E 00  0.50000E 00  0.50000E 00  0.50000E 00  0.50000E 00  0.50000E 00  0.50000E 00  0.50000E 00
THLC
 0.           0.           0.           0.           0.           0.           0.           0.
TL
 0.80500E-02  0.80500E-02  0.80000E-02  0.80000E-02  0.80000E-02  0.80500E-02  0.80500E-02  0.80000E-02
PTEMP
-0.30000E 03 -0.30000E 03 -0.30000E 03 -0.30000E 03 -0.30000E 03 -0.30000E 03 -0.30000E 03 -0.30000E 03

BET
 0.83000E 00  0.10000E 01  0.26000E 00  0.27000E 00  0.17000E 00  0.16500E 02  0.10000E 01  0.10000E 01  0.46500E-01  0.10000E 01
 0.50000E 00  0.13300E 02  0.31900E 05  0.10000E 01  0.10000E 01  0.10000E 01

LSC
 0.23000E 06  0.21000E 05  0.20000E-01  0.50000E-01  0.45000E-01  0.45000E-01

NBS
 0.50000E 04  0.           0.
MBS
 0.50000E 02  0.           0.

DISV1
 0.           0.           0.           0.           0.           0.
```

```
                    3-D  COMPOSITE STRAIN STRESS TEMPERATURE RELATIONS - STRUCTURAL AXES


             0.3955E-07   -0.9941E-08   -0.9941E-08   0.            0.            0.                -0.6138E-07

            -0.9941E-08    0.1042E-05   -0.4266E-06  -0.           -0.           -0.                 0.2334E-04

            -0.9941E-08   -0.4266E-06    0.1042E-05   0.            0.            0.                 0.2334E-04

             0.            0.            0.           0.2937E-05    0.            0.                 0.

             0.            0.            0.           0.            0.2937E-05    0.                 0.

             0.            0.            0.           0.            0.            0.1578E-05         0.
```

```
                         3-D COMPOSITE STRESS STRAIN RELATIONS - STRUCTURAL AXES

                   0.2549E/08   0.4118E 06   0.4118E 06   -0.           -0.           -0.

                   0.4118E 06   0.1160E 07   0.4787E 06   -0.           -0.            0.

                   0.4118E 06   0.4787E 06   0.1160E 07   -0.           -0.           -0.

                  -0.          -0.          -0.            0.3405E 06   -0.           -0.

                  -0.          -0.          -0.           -0.            0.3405E 06   -0.

                  -0.           0.          -0.           -0.           -0.            0.6339E 06


COMPOSITE PROPERTIES - VALID ONLY FOR CONSTANT TEMPERATURE THROUGH THICKNESS
LINES  1 TO 31 3-D COMPOSITE PROPERTIES ABOUT MATERIAL AXES
LINES  33 TO 54 2-D COMPOSITE PROPERTIES ABOUT STRUCTURAL AXES
  1   RHOC       0.5165E-01
  2   TC         0.6400E-01
  3   CC11       0.2549E 08
  4   CC12       0.4118E 06
  5   CC13       0.4118E 06
  6   CC22       0.1160E 07
  7   CC23       0.4787E 06
  8   CC33       0.1160E 07
  9   CC44       0.3405E 06
 10   CC55       0.3405E 06
 11   CC66       0.6339E 06
 12   CTE11     -0.6138E-07
 13   CTE22      0.2334E-04
 14   CTE33      0.2334E-04
 15   HK11       0.2906E 03
 16   HK22       0.3715E 01
 17   HK33       0.3715E 01
 18   HHC        0.2043E 00
 19   EC11       0.2528E 08
 20   EC22       0.9597E 06
 21   EC33       0.9597E 06
 22   EC23       0.3405E 06
 23   EC31       0.3405E 06
 24   EC12       0.6339E 06
 25   NUC12      0.2514E 00
 26   NUC21      0.9541E-02
 27   NUC13      0.2514E 00
 28   NUC31      0.9541E-02
 29   NUC23      0.4094E 00
 30   NUC32      0.4094E 00
 31   ZCGC       0.3200E-01
 32   B2DEC      0.
 33   CC11       0.2535E 08
 34   CC12       0.2418E 06
 35   CC13      -0.
 36   CC22       0.9620E 06
 37   CC23       0.
 38   CC33       0.6339E 06
 39   EC11       0.2528E 08
 40   EC22       0.9597E 06
 41   EC12       0.6339E 06
 42   NUC12      0.2514E 00
 43   NUC21      0.9541E-02
 44   CSN13     -0.
 45   CSN31     -0.
 46   CSN23     -0.
 47   CSN32      0.
 48   CTE11     -0.6138E-07
 49   CTE22      0.2334E-04
 50   CTE12      0.
 51   HK11       0.2906E 03
 52   HK22       0.3715E 01
 53   HK12      -0.
 54   HHC        0.2043E 00


FORCES                                   FORCE DISPLACEMENT RELATIONS                      DISPL       THERMAL FORCES

 NX          0.1622E 07   0.1548E 05   -0.          0.2441E-03   0.1907E-05   -0.          UX          -0.7849E 02

 NY          0.1548E 05   0.6157E 05    0.          0.2384E-05   0.5722E-05    0.          VX          -0.4308E 03

 NXY        -0.           0.            0.4057E 05  -0.           0.            0.5722E-05  VXPUY       -0.

 MX          0.2441E-03   0.2384E-05   -0.          0.5537E 03   0.5283E 01   -0.          WXX         -0.1490E-07

 MY          0.1907E-05   0.5722E-05    0.          0.5283E 01   0.2102E 02    0.          WYY         -0.5960E-07

 MXY        -0.           0.            0.5722E-05  -0.           0.            0.1385E 02  WXY         -0.

REDUCED BENDING REGIDITIES

 0.55369E 03  0.52825E 01 -0.          0.52825E 01  0.21016E 02  0.          -0.          0.          0.13847E 02
```

```
RECUCED STIFFNESS MATRIX
 0.16221E 07  0.15476E 05 -0.            0.15476E 05  0.61569E 05  0.          -0.            0.            0.40558E 05



DISP.                                       DISPLACEMENT FORCE RELATIONS                                        FORCES

 UX            0.6180E-06   -0.1553E-06    0.           -0.2723E-12   0.5466E-13  -0.                           NX

 VX           -0.1553E-06    0.1628E-04   -0.            0.4064E-13  -0.4429E-11   0.                           NY

 VXPUY        -0.            0.            0.2465E-04    0.          -0.          -0.1019E-10                   NXY


 WXX          -0.2723E-12    0.5466E-13   -0.            0.1810E-02  -0.4551E-03   0.                           MX

 WYY           0.4064E-13   -0.4429E-11    0.           -0.4551E-03   0.4770E-01  -0.                           MY

 WXY           0.            0.           -0.1019E-10    0.           0.           0.7222E-01                   MXY



DISP.                                       DISPLACEMENT FORCE RELATIONS                                        FORCES

 0.3108E-02             0.6180E-06   -0.1553E-06    0.           -0.2723E-12   0.5466E-13  -0.             0.4922E 04

-0.7778E-02            -0.1553E-06    0.1628E-04   -0.            0.4064E-13  -0.4429E-11   0.            -0.4308E 03

 0.                    -0.            0.            0.2465E-04    0.          -0.          -0.1019E-10    -0.


 0.9052E-01            -0.2723E-12    0.5466E-13   -0.            0.1810E-02  -0.4551E-03   0.             0.5000E 02

-0.2275E-01             0.4064E-13   -0.4429E-11    0.           -0.4551E-03   0.4770E-01  -0.            -0.5960E-07

-0.                     0.            0.           -0.1019E-10    0.           0.           0.7222E-01    -0.




FOR THIS CASE NBS(X,Y,XY-M) IS        5000.        0.        0.


FOR THIS CASE MBS(X,Y,XY-M) IS          50.        0.        0.

LAYER PROPERTIES, ROWS-PROPERTY, COLUMNS-LAYER


  1   KV        0.            0.            0.            0.            0.            0.            0.            0.
  2   KF        0.5000E 00    0.5000E 00    0.5000E 00    0.5000E 00    0.5000E 00    0.5000E 00    0.5000E 00    0.5000E 00
  3   KFB       0.5000E 00    0.5000E 00    0.5000E 00    0.5000E 00    0.5000E 00    0.5000E 00    0.5000E 00    0.5000E 00
  4   KM        0.5000E 00    0.5000E 00    0.5000E 00    0.5000E 00    0.5000E 00    0.5000E 00    0.5000E 00    0.5000E 00
  5   KMB       0.5000E 00    0.5000E 00    0.5000E 00    0.5000E 00    0.5000E 00    0.5000E 00    0.5000E 00    0.5000E 00
  6   RHOL      0.5165E-01    0.5165E-01    0.5165E-01    0.5165E-01    0.5165E-01    0.5165E-01    0.5165E-01    0.5165E-01
  7   TL        0.8000E-02    0.8000E-02    0.8000E-02    0.8000E-02    0.8000E-02    0.8000E-02    0.8000E-02    0.8000E-02
  8   DELTA     0.6586E-04    0.6586E-04    0.6586E-04    0.6586E-04    0.6586E-04    0.6586E-04    0.6586E-04    0.6586E-04
  9   ILOC     -0.0000E-19    0.            0.            0.            0.            0.            0.            0.
 10   ZB        0.4000E-02    0.1200E-01    0.2000E-01    0.2800E-01    0.3600E-01    0.4400E-01    0.5200E-01    0.6000E-01
 11   ZGC      -0.2800E-01   -0.2000E-01   -0.1200E-01   -0.4000E-02    0.4000E-02    0.1200E-01    0.2000E-01    0.2800E-01
 12   THCS      0.            0.            0.            0.            0.            0.            0.            0.
 13   THLC      0.            0.            0.            0.            0.            0.            0.            0.
 14   THLS      0.            0.            0.            0.            0.            0.            0.            0.
 15   SC11      0.2549E 08    0.2549E 08    0.2549E 08    0.2549E 08    0.2549E 08    0.2549E 08    0.2549E 08    0.2549E 08
 16   SC12      0.4118E 06    0.4118E 06    0.4118E 06    0.4118E 06    0.4119E 06    0.4118E 06    0.4118E 06    0.4118E 06
 17   SC13      0.4118E 06    0.4118E 06    0.4118E 06    0.4118E 06    0.4118E 06    0.4118E 06    0.4118E 06    0.4118E 06
 18   SC22      0.1160E 07    0.1160E 07    0.1160E 07    0.1160E 07    0.1160E 07    0.1160E 07    0.1160E 07    0.1160E 07
 19   SC23      0.4787E 06    0.4787E 06    0.4787E 06    0.4787E 06    0.4787E 06    0.4787E 06    0.4787E 06    0.4787E 06
 20   SC33      0.1160E 07    0.1160E 07    0.1160E 07    0.1160E 07    0.1160E 07    0.1160E 07    0.1160E 07    0.1160E 07
 21   SC44      0.3405E 06    0.3405E 06    0.3405E 06    0.3405E 06    0.3405E 06    0.3405E 06    0.3405E 06    0.3405E 06
 22   SC55      0.3405E 06    0.3405E 06    0.3405E 06    0.3405E 06    0.3405E 06    0.3405E 06    0.3405E 06    0.3405E 06
 23   SC66      0.6339E 06    0.6339E 06    0.6339E 06    0.6339E 06    0.6339E 06    0.6339E 06    0.6339E 06    0.6339E 06
 24   CTE11    -0.6138E-07   -0.6138E-07   -0.6138E-07   -0.6138E-07   -0.6138E-07   -0.6138E-07   -0.6138E-07   -0.6138E-07
 25   CTE22     0.2334E-04    0.2334E-04    0.2334E-04    0.2334E-04    0.2334E-04    0.2334E-04    0.2334E-04    0.2334E-04
 26   CTE33     0.2334E-04    0.2334E-04    0.2334E-04    0.2334E-04    0.2334E-04    0.2334E-04    0.2334E-04    0.2334E-04
 27   HK11      0.2906E 03    0.2906E 03    0.2906E 03    0.2906E 03    0.2906E 03    0.2906E 03    0.2906E 03    0.2906E 03
 28   HK22      0.3715E 01    0.3715E 01    0.3715E 01    0.3715E 01    0.3715E 01    0.3715E 01    0.3715E 01    0.3715E 01
 29   HK33      0.3715E 01    0.3715E 01    0.3715E 01    0.3715E 01    0.3715E 01    0.3715E 01    0.3715E 01    0.3715E 01
 30   HCL       0.2043E 00    0.2043E 00    0.2043E 00    0.2043E 00    0.2043E 00    0.2043E 00    0.2043E 00    0.2043E 00
 31   EL11      0.2528E 08    0.2528E 08    0.2528E 08    0.2528E 08    0.2528E 08    0.2528E 08    0.2528E 08    0.2528E 08
 32   EL22      0.9597E 06    0.9597E 06    0.9597E 06    0.9597E 06    0.9597E 06    0.9597E 06    0.9597E 06    0.9597E 06
 33   EL33      0.9597E 06    0.9597E 06    0.9597E 06    0.9597E 06    0.9597E 06    0.9597E 06    0.9597E 06    0.9597E 06
 34   GL23      0.3405E 06    0.3405E 06    0.3405E 06    0.3405E 06    0.3405E 06    0.3405E 06    0.3405E 06    0.3405E 06
 35   GL13      0.6339E 06    0.6339E 06    0.6339E 06    0.6339E 06    0.6339E 06    0.6339E 06    0.6339E 06    0.6339E 06
 36   GL12      0.6339E 06    0.6339E 06    0.6339E 06    0.6339E 06    0.6339E 06    0.6339E 06    0.6339E 06    0.6339E 06
 37   NUL12     0.2514E 00    0.2514E 00    0.2514E 00    0.2514E 00    0.2514E 00    0.2514E 00    0.2514E 00    0.2514E 00
 38   NUL21     0.9541E-02    0.9541E-02    0.9541E-02    0.9541E-02    0.9541E-02    0.9541E-02    0.9541E-02    0.9541E-02
 39   NUL13     0.2514E 00    0.2514E 00    0.2514E 00    0.2514E 00    0.2514E 00    0.2514E 00    0.2514E 00    0.2514E 00
 40   NUL31     0.9541E-02    0.9541E-02    0.9541E-02    0.9541E-02    0.9541E-02    0.9541E-02    0.9541E-02    0.9541E-02
```

```
 41   NUL23      0.4094E 00   0.4094E 00   0.4094E 00   0.4094E 00   0.4094E 00   0.4094E 00   0.4094E 00   0.4094E 00
 42   NUL32      0.4094E 00   0.4094E 00   0.4094E 00   0.4094E 00   0.4094E 00   0.4094E 00   0.4094E 00   0.4094E 00
 43   SMFK22     0.1522E 01   0.1522E 01   0.1522E 01   0.1522E 01   0.1522E 01   0.1522E 01   0.1522E 01   0.1522E 01
 44   SMFD22     0.1918E 01   0.1918E 01   0.1918E 01   0.1918E 01   0.1918E 01   0.1918E 01   0.1918E 01   0.1918E 01
 45   SMFS22     0.1537E 01   0.1537E 01   0.1537E 01   0.1537E 01   0.1537E 01   0.1537E 01   0.1537E 01   0.1537E 01
 46   SMFC22    -0.0000E-19  -0.0000E-19  -0.0000E-19  -0.0000E-19  -0.0000E-19  -0.0000E-19  -0.0000E-19  -0.0000E-19
 47   SMFS12     0.3024E 01   0.3024E 01   0.3024E 01   0.3024E 01   0.3024E 01   0.3024E 01   0.3024E 01   0.3024E 01
 48   SMFS23     0.1396E 01   0.1396E 01   0.1396E 01   0.1396E 01   0.1396E 01   0.1396E 01   0.1396E 01   0.1396E 01
 49   ILMFC     -0.0000E-19   0.7060E 02   0.7060E 02   0.7060E 02   0.7060E 02   0.7060E 02   0.7060E 02   0.7060E 02
 50   TEMPD     -0.3000E 03  -0.3000E 03  -0.3000E 03  -0.3000E 03  -0.3000E 03  -0.3000E 03  -0.3000E 03  -0.3000E 03
 51   LSC11T     0.9676E 05   0.9676E 05   0.9676E 05   0.9676E 05   0.9676E 05   0.9676E 05   0.9676E 05   0.9676E 05
 52   LSC11C     0.5333E 05   0.5333E 05   0.5333E 05   0.5333E 05   0.5333E 05   0.5333E 05   0.5333E 05   0.5333E 05
 53   LSC11D     0.6578E 05   0.6578E 05   0.6578E 05   0.6578E 05   0.6578E 05   0.6578E 05   0.6578E 05   0.6578E 05
 54   LSC22T     0.3248E 04   0.3248E 04   0.3248E 04   0.3248E 04   0.3248E 04   0.3248E 04   0.3248E 04   0.3248E 04
 55   LSC22C     0.1561E 05   0.1561E 05   0.1561E 05   0.1561E 05   0.1561E 05   0.1561E 05   0.1561E 05   0.1561E 05
 56   LSC12      0.2547E 04   0.2547E 04   0.2547E 04   0.2547E 04   0.2547E 04   0.2547E 04   0.2547E 04   0.2547E 04
 57   LSC23      0.1866E 04   0.1866E 04   0.1866E 04   0.1866E 04   0.1866E 04   0.1866E 04   0.1866E 04   0.1866E 04
 58   LSCC23    -0.0000E-19  -0.0000E-19  -0.0000E-19  -0.0000E-19  -0.0000E-19  -0.0000E-19  -0.0000E-19  -0.0000E-19
 59   LSCC13    -0.0000E-19  -0.0000E-19  -0.0000E-19  -0.0000E-19  -0.0000E-19  -0.0000E-19  -0.0000E-19  -0.0000E-19
 60   LSCDF     -0.0000E-19   0.1052E-01   0.1052E-01   0.1052E-01   0.1052E-01   0.1052E-01   0.1052E-01   0.1052E-01
 61   KL12AB     0.1371E 01   0.1371E 01   0.1371E 01   0.1371E 01   0.1371E 01   0.1371E 01   0.1371E 01   0.1371E 01
 62   MDEIE      0.9789E 00   0.8879E 00   0.7254E 00   0.4913E 00   0.1855E 00  -0.1918E 00  -0.6408E 00  -0.1161E 01
 63   RELROT    -0.0000E-19   0.1000E 01   0.1000E 01   0.1000E 01   0.1000E 01   0.1000E 01   0.1000E 01   0.1000E 01
 64   EPS11      0.5736E-03   0.1298E-02   0.2022E-02   0.2746E-02   0.3470E-02   0.4194E-02   0.4919E-02   0.5643E-02
 65   EPS22     -0.7141E-02  -0.7323E-02  -0.7505E-02  -0.7687E-02  -0.7869E-02  -0.8051E-02  -0.8233E-02  -0.8415E-02
 66   EPS12      0.           0.           0.           0.          -0.          -0.          -0.          -0.
 67   SIG11      0.1407E 05   0.3239E 05   0.5070E 05   0.6901E 05   0.8732E 05   0.1056E 06   0.1239E 06   0.1423E 06
 68   SIG22      0.4826E-03   0.4845E-03   0.4692E-03   0.4654E-03   0.5188E-03   0.4578E-03   0.5188E-03   0.4425E-03
 69   SIG12      0.           0.           0.           0.           0.           0.           0.           0.
 70   DELFI     -0.0000E-19   0.           0.           0.           0.           0.           0.           0.
 71   HFC        0.1080E 01   0.1069E 01   0.9285E 00   0.6579E 00   0.2572E 00  -0.2734E 00  -0.9339E 00  -0.1724E 01
```

Angle Ply Composite

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THORNEL-50/EPOXY


NL,NPL,NPC,NFPE,NLC
   8   71   54 1420     1

EF11,EF22,EF33,NUF12,NUF23,NUF13,EF12,EF23,EF13,EM11,EM22,EM33,NUM12,NUM23 NUM13,EM12,EM23,EM13
 0.50000E 08  0.10000E 07  0.10000E 07  0.20000E 00  0.25000E 00  0.20000E 00  0.13000E 07  0.70000E 06  0.13000E 07  0.57000E 06
 0.57000E 06  0.57000E 06  0.36000E 00  0.36000E 00  0.36000E 00  0.           0.           0.
VCF
 0.40000E 01  0.20000E 01  0.40000E 01  0.20000E 01  0.           0.           0.           0.23560E 01  0.           0.
 0.           0.           0.           0.           0.10000E 01  0.10000E 01  0.10000E 01  0.           0.           0.
VAF
-0.55000E-06  0.56000E-05  0.56000E-05
VAM
 0.42800E-04  0.42800E-04  0.42800E-04
CHK
 0.58000E 03  0.58000E 02  0.58000E 02  0.17000E 00  0.12500E 01  0.12500E 01  0.12500E 01  0.25000E 00  0.           0.
 0.           0.22500E 00
BTA
 0.10000E 01  0.10000E 01  0.10500E 01  0.10500E 01
PIE
 0.31416E 01

TLINP
     F

CSANB
     F

BIDE
     F

RINDV
     F

THCS,RHOF,RHOM,DIAF
 0.           0.59000E-01  0.44300E-01  0.26000E-03
KVL
 0.           0.           0.           0.           0.           0.           0.           0.
KFL
 0.50000E 00  0.50000E 00  0.50000E 00  0.50000E 00  0.50000E 00  0.50000E 00  0.50000E 00  0.50000E 00
THLC
 0.30000E 02 -0.30000E 02  0.30000E 02 -0.30000E 02 -0.30000E 02  0.30000E 02 -0.30000E 02  0.30000E 02
TL
 0.80500E-02  0.80500E-02  0.80000E-02  0.80000E-02  0.80000E-02  0.80500E-02  0.80500E-02  0.80000E-02
PTEMP
-0.30000E 03 -0.30000E 03 -0.30000E 03 -0.30000E 03 -0.30000E 03 -0.30000E 03 -0.30000E 03 -0.30000E 03

BET
 0.83000E 00  0.10000E 01  0.26000E 00  0.27000E 00  0.17000E 00  0.16500E 02  0.10000E 01  0.10000E 01  0.46500E-01  0.10000E 01
 0.50000E 00  0.13300E 02  0.31900E 05  0.10000E 01  0.10000E 01  0.10000E 01

LSC
 0.23000E 06  0.21000E 05  0.20000E-01  0.50000E-01  0.45000E-01  0.45000E-01

NBS
 0.50000E 04  0.           0.

MBS
 0.50000E 02  0.           0.

DISV1
 0.           0.           0.           0.           0.           0.
```

```
                3-D  COMPOSITE STRAIN STRESS TEMPERATURE RELATIONS - STRUCTURAL AXES

 0.1430E-06   -0.2449E-06   0.4471E-07   0.           0.           0.             -0.3131E-05
-0.2449E-06    0.7909E-06  -0.2246E-06  -0.          -0.          -0.              0.1199E-04
 0.4471E-07   -0.2246E-06   0.9353E-06   0.           0.           0.              0.2933E-04
 0.            0.           0.           0.2937E-05   0.           0.             -0.
 0.            0.           0.           0.           0.2937E-05   0.             -0.
 0.            0.           0.           0.           0.           0.2000E-06     -0.

                      3-D COMPOSITE STRESS STRAIN RELATIONS - STRUCTURAL AXES

           0.1504E 08    0.4779E 07    0.4285E 06   -0.           -0.            0.
           0.4779E 07    0.2875E 07    0.4620E 06   -0.           -0.            0.
           0.4285E 06    0.4620E 06    0.1160E 07   -0.           -0.           -0.
          -0.           -0.           -0.            0.3405E 06  -0.           -0.
          -0.           -0.           -0.           -0.            0.3405E 06   -0.
           0.            0.           -0.           -0.           -0.            0.5001E 07
```

```
COMPOSITE PROPERTIES - VALID ONLY FOR CONSTANT TEMPERATURE THROUGH THICKNESS
LINES  1 TO 31 3-D COMPOSITE PROPERTIES ABOUT MATERIAL AXES
LINES  33 TO 54 2-D COMPOSITE PROPERTIES ABOUT STRUCTURAL AXES
  1    RHOC       0.5165E-01
  2    TC         0.6400E-01
  3    CC11       0.1504E 08
  4    CC12       0.4779E 07
  5    CC13       0.4285E 06
  6    CC22       0.2875E 07
  7    CC23       0.4620E 06
  8    CC33       0.1160E 07
  9    CC44       0.3405E 06
 10    CC55       0.3405E 06
 11    CC66       0.5001E 07
 12    CTE11     -0.3131E-05
 13    CTE22      0.1199E-04
 14    CTE33      0.2933E-04
 15    HK11       0.2189E 03
 16    HK22       0.7544E 02
 17    HK33       0.3715E 01
 18    HHC        0.2043E 00
 19    EC11       0.6992E 07
 20    EC22       0.1264E 07
 21    EC33       0.1069E 07
 22    EC23       0.3405E 06
 23    EC31       0.3405E 06
 24    EC12       0.5001E 07
 25    NUC12      0.1712E 01
 26    NUC21      0.3096E 00
 27    NUC13     -0.3126E 00
 28    NUC31     -0.4780E-01
 29    NUC23      0.2839E 00
 30    NUC32      0.2401E 00
 31    ZCGC       0.3200E-01
 32    B2DEC      0.
 33    CC11       0.1488E 08
 34    CC12       0.4608E 07
 35    CC13       0.
 36    CC22       0.2691E 07
 37    CC23       0.
 38    CC33       0.5001E 07
 39    EC11       0.6992E 07
 40    EC22       0.1264E 07
 41    EC12       0.5001E 07
 42    NUC12      0.1712E 01
 43    NUC21      0.3096E 00
 44    CSN13     -0.
 45    CSN31     -0.
 46    CSN23     -0.
 47    CSN32      0.
 48    CTE11     -0.3131E-05
 49    CTE22      0.1199E-04
 50    CTE12     -0.
 51    HK11       0.2189E 03
 52    HK22       0.7544E 02
 53    HK12      -0.
 54    HHC        0.2043E 00
```

```
FORCES                              FORCE DISPLACEMENT RELATIONS                                  DISPL        THERMAL FORCES

 NX          0.9525E 06   0.2949E 06   0.           0.1221E-03   0.4578E-04   0.1068E-03   UX          -0.1666E 03

 NY          0.2949E 06   0.1722E 06   0.           0.4578E-04   0.2289E-04   0.3815E-04   VX          -0.3427E 03

 NXY         0.           0.           0.3200E 06   0.1068E-03   0.3815E-04   0.3052E-04   VXPUY        0.

 MX          0.1221E-03   0.4578E-04   0.1068E-03   0.3251E 03   0.1007E 03   0.6390E 02   WXX         -0.2235E-07

 MY          0.4578E-04   0.2289E-04   0.3815E-04   0.1007E 03   0.5879E 02   0.2260E 02   WYY         -0.2980E-07

 MXY         0.1068E-03   0.3815E-04   0.3052E-04   0.6390E 02   0.2260E 02   0.1092E 03   WXY          0.2980E-07

REDUCED BENDING REGIDITIES

 0.32513E 03  0.10067E 03  0.63900E 02  0.10067E 03  0.58793E 02  0.22595E 02  0.63900E 02  0.22595E 02  0.10924E 03


REDUCED STIFFNESS MATRIX
 0.95252E 06  0.29494E 06 -0.49233E-10  0.29494E 06  0.17225E 06 -0.19281E-10 -0.49233E-10 -0.19281E-10  0.32003E 06


DISP.                            DISPLACEMENT FORCE RELATIONS                                         FORCES

 UX          0.2235E-05  -0.3827E-05   0.1132E-21  -0.3456E-12   0.6409E-12  -0.7792E-12              NX

 VX         -0.3827E-05   0.1236E-04   0.1559E-21   0.6225E-12  -0.2756E-11  -0.3680E-12              NY

 VXPUY       0.1132E-21   0.1559E-21   0.3125E-05  -0.8006E-12  -0.5443E-12  -0.2920E-12              NXY

 WXX        -0.3456E-12   0.6225E-12  -0.8006E-12   0.6830E-02  -0.1104E-01  -0.1712E-02              MX

 WYY         0.6409E-12  -0.2756E-11  -0.5443E-12  -0.1104E-01   0.3631E-01  -0.1055E-02              MY

 WXY        -0.7792E-12  -0.3680E-12  -0.2920E-12  -0.1712E-02  -0.1055E-02   0.1037E-01              MXY


DISP.                            DISPLACEMENT FORCE RELATIONS                                         FORCES

 0.1211E-01          0.2235E-05  -0.3827E-05   0.1132E-21  -0.3456E-12   0.6409E-12  -0.7792E-12      0.4833E 04

-0.2273E-01         -0.3827E-05   0.1236E-04   0.1559E-21   0.6225E-12  -0.2756E-11  -0.3680E-12     -0.3427E 03

-0.4003E-10          0.1132E-21   0.1559E-21   0.3125E-05  -0.8006E-12  -0.5443E-12  -0.2920E-12      0.

 0.3415E 00         -0.3456E-12   0.6225E-12  -0.8006E-12   0.6830E-02  -0.1104E-01  -0.1712E-02      0.5000E 02

-0.5518E 00          0.6409E-12  -0.2756E-11  -0.5443E-12  -0.1104E-01   0.3631E-01  -0.1055E-02     -0.2980E-07

-0.8561E-01         -0.7792E-12  -0.3680E-12  -0.2920E-12  -0.1712E-02  -0.1055E-02   0.1037E-01      0.2980E-07


FOR THIS CASE NBS(X,Y,XY-M) IS        5000.       0.        0.

FOR THIS CASE MBS(X,Y,XY-M) IS          50.       0.        0.

LAYER PROPERTIES, ROWS-PROPERTY, COLUMNS-LAYER

 1  KV       0.           0.           0.           0.           0.           0.           0.           0.
 2  KF       0.5000E 00   0.5000E 00   0.5000E 00   0.5000E 00   0.5000E 00   0.5000E 00   0.5000E 00   0.5000E 00
 3  KFB      0.5000E 00   0.5000E 00   0.5000E 00   0.5000E 00   0.5000E 00   0.5000E 00   0.5000E 00   0.5000E 00
 4  KM       0.5000E 00   0.5000E 00   0.5000E 00   0.5000E 00   0.5000E 00   0.5000E 00   0.5000E 00   0.5000E 00
 5  KMB      0.5000E 00   0.5000E 00   0.5000E 00   0.5000E 00   0.5000E 00   0.5000E 00   0.5000E 00   0.5000E 00
 6  RHOL     0.5165E-01   0.5165E-01   0.5165E-01   0.5165E-01   0.5165E-01   0.5165E-01   0.5165E-01   0.5165E-01
 7  TL       0.8000E-02   0.8000E-02   0.8000E-02   0.8000E-02   0.8000E-02   0.8000E-02   0.8000E-02   0.8000E-02
 8  DELTA    0.6586E-04   0.6586E-04   0.6586E-04   0.6586E-04   0.6586E-04   0.6586E-04   0.6586E-04   0.6586E-04
 9  ILDC    -0.0000E-19   0.           0.           0.           0.           0.           0.           0.
10  ZB       0.4000E-02   0.1200E-01   0.2000E-01   0.2800E-01   0.3600E-01   0.4400E-01   0.5200E-01   0.6000E-01
11  ZGC     -0.2800E-01  -0.2000E-01  -0.1200E-01  -0.4000E-02   0.4000E-02   0.1200E-01   0.2000E-01   0.2800E-01
12  THCS     0.           0.           0.           0.           0.           0.           0.           0.
13  THLC     0.5236E 00  -0.5236E 00   0.5236E 00  -0.5236E 00  -0.5236E 00   0.5236E 00  -0.5236E 00   0.5236E 00
14  THLS     0.5236E 00  -0.5236E 00   0.5236E 00  -0.5236E 00  -0.5236E 00   0.5236E 00  -0.5236E 00   0.5236E 00
15  SC11     0.2549E 08   0.2549E 08   0.2549E 08   0.2549E 08   0.2549E 08   0.2549E 08   0.2549E 08   0.2549E 08
16  SC12     0.4118E 06   0.4118E 06   0.4118E 06   0.4118E 06   0.4118E 06   0.4118E 06   0.4118E 06   0.4118E 06
17  SC13     0.4118E 06   0.4118E 06   0.4118E 06   0.4118E 06   0.4118E 06   0.4118E 06   0.4118E 06   0.4118E 06
18  SC22     0.1160E 07   0.1160E 07   0.1160E 07   0.1160E 07   0.1160E 07   0.1160E 07   0.1160E 07   0.1160E 07
19  SC23     0.4787E 06   0.4787E 06   0.4787E 06   0.4787E 06   0.4787E 06   0.4787E 06   0.4787E 06   0.4787E 06
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20  SC33       0.1160E 07   0.1160E 07   0.1160E 07   0.1160E 07   0.1160E 07   0.1160E 07   0.1160E 07   0.1160E 07
21  SC44       0.3405E 06   0.3405E 06   0.3405E 06   0.3405E 06   0.3405E 06   0.3405E 06   0.3405E 06   0.3405E 06
22  SC55       0.3405E 06   0.3405E 06   0.3405E 06   0.3405E 06   0.3405E 06   0.3405E 06   0.3405E 06   0.3405E 06
23  SC66       0.6339E 06   0.6339E 06   0.6339E 06   0.6339E 06   0.6339E 06   0.6339E 06   0.6339E 06   0.6339E 06
24  CTE11     -0.6138E-07  -0.6138E-07  -0.6138E-07  -0.6138E-07  -0.6138E-07  -0.6138E-07  -0.6138E-07  -0.6138E-07
25  CTE22      0.2334E-04   0.2334E-04   0.2334E-04   0.2334E-04   0.2334E-04   0.2334E-04   0.2334E-04   0.2334E-04
26  CTE33      0.2334E-04   0.2334E-04   0.2334E-04   0.2334E-04   0.2334E-04   0.2334E-04   0.2334E-04   0.2334E-04
27  HK11       0.2906E 03   0.2906E 03   0.2906E 03   0.2906E 03   0.2906E 03   0.2906E 03   0.2906E 03   0.2906E 03
28  HK22       0.3715E 01   0.3715E 01   0.3715E 01   0.3715E 01   0.3715E 01   0.3715E 01   0.3715E 01   0.3715E 01
29  HK33       0.3715E 01   0.3715E 01   0.3715E 01   0.3715E 01   0.3715E 01   0.3715E 01   0.3715E 01   0.3715E 01
30  HCL        0.2043E 00   0.2043E 00   0.2043E 00   0.2043E 00   0.2043E 00   0.2043E 00   0.2043E 00   0.2043E 00
31  EL11       0.2528E 08   0.2528E 08   0.2528E 08   0.2528E 08   0.2528E 08   0.2528E 08   0.2528E 08   0.2528E 08
32  EL22       0.9597E 06   0.9597E 06   0.9597E 06   0.9597E 06   0.9597E 06   0.9597E 06   0.9597E 06   0.9597E 06
33  EL33       0.9597E 06   0.9597E 06   0.9597E 06   0.9597E 06   0.9597E 06   0.9597E 06   0.9597E 06   0.9597E 06
34  GL23       0.3405E 06   0.3405E 06   0.3405E 06   0.3405E 06   0.3405E 06   0.3405E 06   0.3405E 06   0.3405E 06
35  GL13       0.6339E 06   0.6339E 06   0.6339E 06   0.6339E 06   0.6339E 06   0.6339E 06   0.6339E 06   0.6339E 06
36  GL12       0.6339E 06   0.6339E 06   0.6339E 06   0.6339E 06   0.6339E 06   0.6339E 06   0.6339E 06   0.6339E 06
37  NUL12      0.2514E 00   0.2514E 00   0.2514E 00   0.2514E 00   0.2514E 00   0.2514E 00   0.2514E 00   0.2514E 00
38  NUL21      0.9541E-02   0.9541E-02   0.9541E-02   0.9541E-02   0.9541E-02   0.9541E-02   0.9541E-02   0.9541E-02
39  NUL13      0.2514E 00   0.2514E 00   0.2514E 00   0.2514E 00   0.2514E 00   0.2514E 00   0.2514E 00   0.2514E 00
40  NUL31      0.9541E-02   0.9541E-02   0.9541E-02   0.9541E-02   0.9541E-02   0.9541E-02   0.9541E-02   0.9541E-02
41  NUL23      0.4094E 00   0.4094E 00   0.4094E 00   0.4094E 00   0.4094E 00   0.4094E 00   0.4094E 00   0.4094E 00
42  NUL32      0.4094E 00   0.4094E 00   0.4094E 00   0.4094E 00   0.4094E 00   0.4094E 00   0.4094E 00   0.4094E 00
43  SMFK22     0.1522E 01   0.1522E 01   0.1522E 01   0.1522E 01   0.1522E 01   0.1522E 01   0.1522E 01   0.1522E 01
44  SMFD22     0.1918E 01   0.1918E 01   0.1918E 01   0.1918E 01   0.1918E 01   0.1918E 01   0.1918E 01   0.1918E 01
45  SMFS22     0.1344E 01   0.1342E 01   0.1408E 01   0.1400E 01   0.1399E 01   0.1397E 01   0.1399E 01   0.1395E 01
46  SMFC22    -0.0000E-19  -0.0000E-19  -0.0000E-19  -0.0000E-19  -0.0000E-19  -0.0000E-19  -0.0000E-19  -0.0000E-19
47  SMFS12     0.3024E 01   0.3024E 01   0.3024E 01   0.3024E 01   0.3024E 01   0.3024E 01   0.3024E 01   0.3024E 01
48  SMFS23     0.1396E 01   0.1396E 01   0.1396E 01   0.1396E 01   0.1396E 01   0.1396E 01   0.1396E 01   0.1396E 01
49  ILMFC     -0.0000E-19   0.7060E 02   0.7060E 02   0.7060E 02   0.7060E 02   0.7060E 02   0.7060E 02   0.7060E 02
50  TEMPD     -0.3000E 03  -0.3000E 03  -0.3000E 03  -0.3000E 03  -0.3000E 03  -0.3000E 03  -0.3000E 03  -0.3000E 03
51  LSC11T     0.9676E 05   0.9676E 05   0.9676E 05   0.9676E 05   0.9676E 05   0.9676E 05   0.9676E 05   0.9676E 05
52  LSC11C     0.5333E 05   0.5333E 05   0.5333E 05   0.5333E 05   0.5333E 05   0.5333E 05   0.5333E 05   0.5333E 05
53  LSC11D     0.6578E 05   0.6578E 05   0.6578E 05   0.6578E 05   0.6578E 05   0.6578E 05   0.6578E 05   0.6578E 05
54  LSC22T     0.3714E 04   0.3718E 04   0.3544E 04   0.3564E 04   0.3566E 04   0.3572E 04   0.3568E 04   0.3576E 04
55  LSC22C     0.1786E 05   0.1788E 05   0.1704E 05   0.1713E 05   0.1714E 05   0.1717E 05   0.1715E 05   0.1719E 05
56  LSC12      0.2547E 04   0.2547E 04   0.2547E 04   0.2547E 04   0.2547E 04   0.2547E 04   0.2547E 04   0.2547E 04
57  LSC23      0.1866E 04   0.1866E 04   0.1866E 04   0.1866E 04   0.1866E 04   0.1866E 04   0.1866E 04   0.1866E 04
58  LSCC23    -0.0000E-19  -0.0000E-19  -0.0000E-19  -0.0000E-19  -0.0000E-19  -0.0000E-19  -0.0000E-19  -0.0000E-19
59  LSCC13    -0.0000E-19  -0.0000E-19  -0.0000E-19  -0.0000E-19  -0.0000E-19  -0.0000E-19  -0.0000E-19  -0.0000E-19
60  LSCDF     -0.0000E-19   0.1052E-01   0.1052E-01   0.1052E-01   0.1052E-01   0.1052E-01   0.1052E-01   0.1052E-01
61  KL12AB     0.1371E 01   0.1371E 01   0.1371E 01   0.1371E 01   0.1371E 01   0.1371E 01   0.1371E 01   0.1371E 01
62  MDEIE     -0.2387E 01  -0.1400E 02  -0.2529E 02  -0.4584E 02  -0.6868E 02  -0.1003E 03  -0.1282E 03  -0.1774E 03
63  RELROT    -0.0000E-19   0.9605E 00   0.2757E 00  -0.2131E 00  -0.9518E 00  -0.3178E 01  -0.9446E 01  -0.8205E 01
64  EPS11      0.1132E-02   0.2974E-03   0.2429E-02   0.2781E-02   0.4023E-02   0.4375E-02   0.6506E-02   0.5672E-02
65  EPS22     -0.5860E-02  -0.6708E-02  -0.1052E-01  -0.1256E-01  -0.1548E-01  -0.1752E-01  -0.2133E-01  -0.2218E-01
66  EPS12     -0.7315E-02   0.1556E-01  -0.2038E-01   0.2725E-01   0.3310E-01  -0.3997E-01   0.4479E-01  -0.5303E-01
67  SIG11      0.2787E 05   0.7346E 04   0.6117E 05   0.6917E 05   0.1001E 06   0.1084E 06   0.1619E 06   0.1398E 06
68  SIG22      0.1368E 04   0.3495E 03  -0.2804E 04  -0.4677E 04  -0.7190E 04  -0.9062E 04  -0.1222E 05  -0.1323E 05
69  SIG12     -0.4637E 04   0.9862E 04  -0.1292E 05   0.1727E 05   0.2098E 05  -0.2534E 05   0.2839E 05  -0.3362E 05
70  DELFI     -0.0000E-19  -0.4159E-03  -0.7617E-02   0.1276E-01   0.2053E-01  -0.4394E-01   0.1099E 00  -0.9682E-01
71  HFC       -0.2542E 01  -0.1402E 02  -0.2446E 02  -0.4472E 02  -0.6733E 02  -0.9883E 02  -0.1271E 03  -0.1761E 03
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Angle Ply Pseudoisotropic Composite

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THORNEL-50/EPOXY


NL,NPL,NPC,NFPE,NLC
   8   71   54 1420    1

EF11,EF22,EF33,NUF12,NUF23,NUF13,EF12,EF23,EF13,EM11,EM22,EM33,NUM12,NUM23 NUM13,EM12,EM23,EM13
 0.50000E 08  0.10000E 07  0.10000E 07  0.20000E 00  0.25000E 00  0.20000E 00  0.13000E 07  0.70000E 06  0.13000E 07  0.57000E 06
 0.57000E 06  0.57000E 06  0.36000E 00  0.36000E 00  0.36000E 00  0.           0.           0.
VCF
 0.40000E 01  0.20000E 01  0.40000E 01  0.20000E 01  0.           0.           0.           0.23560E 01  0.           0.
 0.           0.           0.           0.           0.10000E 01  0.10000E 01  0.10000E 01  0.           0.           0.
VAF
-0.55000E-06  0.56000E-05  0.56000E-05
VAM
 0.42800E-04  0.42800E-04  0.42800E-04
CHK
 0.58000E 03  0.58000E 02  0.58000E 02  0.17000E 00  0.12500E 01  0.12500E 01  0.12500E 01  0.25000E 00  0.           0.
 0.           0.22500E 00
BTA
 0.10000E 01  0.10000E 01  0.10500E 01  0.10500E 01
PIE
 0.31416E 01

TLINP
     F

CSANB
     F

BIDE
     F

RINDV
     F

THCS,RHOF,RHCM,DIAF
 0.           0.59000E-01  0.44300E-01  0.26000E-03
```

```
KVL
 0.           0.           0.           0.           0.           0.           0.           0.
KFL
 0.50000E 00  0.50000E 00  0.50000E 00  0.50000E 00  0.50000E 00  0.50000E 00  0.50000E 00  0.50000E 00
THLC
 0.           0.45000E 02 -0.45000E 02  0.90000E 02  0.90000E 02 -0.45000E 02  0.45000E 02  0.
TL
 0.80500E-02  0.80500E-02  0.80000E-02  0.80000E-02  0.80000E-02  0.80500E-02  0.80500E-02  0.80000E-02
PTEMP
-0.30000E 03 -0.30000E 03 -0.30000E 03 -0.30000E 03 -0.30000E 03 -0.30000E 03 -0.30000E 03 -0.30000E 03

BET
 0.83000E 00  0.10000E 01  0.26000E 00  0.27000E 00  0.17000E 00  0.16500E 02  0.10000E 01  0.10000E 01  0.46500E-01  0.10000E 01
 0.50000E 00  0.13300E 02  0.31900E 05  0.10000E 01  0.10000E 01  0.10000E 01

LSC
 0.23000E 06  0.21000E 05  0.20000E-01  0.50000E-01  0.45000E-01  0.45000E-01

NBS
 0.50000E 04  0.           0.

MBS
 0.50000E 02  0.           0.

DISV1
 0.           0.           0.           0.           0.           0.


                              3-D  COMPOSITE STRAIN STRESS TEMPERATURE RELATIONS - STRUCTURAL AXES


            0.1078E-06  -0.3319E-07  -0.2866E-07   0.           0.          -0.1893E-12       0.9901E-06

           -0.3319E-07   0.1078E-06  -0.2866E-07  -0.          -0.           0.6595E-12       0.9901E-06

           -0.2866E-07  -0.2866E-07   0.8844E-06   0.           0.          -0.1954E-12       0.3219E-04

           -0.           0.          -0.           0.2937E-05   0.           0.               0.

           -0.           0.          -0.           0.           0.2937E-05   0.               0.

           -0.1893E-12   0.6595E-12  -0.1954E-12   0.           0.           0.2821E-06       0.1097E-10

                                   3-D COMPOSITE STRESS STRAIN RELATIONS - STRUCTURAL AXES


                       0.1041E 08    0.3323E 07    0.4452E 06   -0.           -0.           -0.4730E 00

                       0.3323E 07    0.1041E 08    0.4452E 06   -0.           -0.           -0.2181E 02

                       0.4452E 06    0.4452E 06    0.1160E 07   -0.           -0.            0.6121E-01

                      -0.           -0.           -0.            0.3405E 06   -0.           -0.

                      -0.           -0.           -0.           -0.            0.3405E 06   -0.

                      -0.4730E 00   -0.2181E 02    0.6121E-01   -0.           -0.            0.3545E 07


COMPOSITE PROPERTIES - VALID ONLY FOR CONSTANT TEMPERATURE THROUGH THICKNESS
LINES  1 TO 31 3-D COMPOSITE PROPERTIES ABOUT MATERIAL AXES
LINES  33 TO 54 2-D COMPOSITE PROPERTIES ABOUT STRUCTURAL AXES
 1   RHOC        0.5165E-01
 2   TC          0.6400E-01
 3   CC11        0.1041E 08
 4   CC12        0.3323E 07
 5   CC13        0.4452E 06
 6   CC22        0.1041E 08
 7   CC23        0.4452E 06
 8   CC33        0.1160E 07
 9   CC44        0.3405E 06
10   CC55        0.3405E 06
11   CC66        0.3545E 07
12   CTE11       0.9901E-06
13   CTE22       0.9901E-06
14   CTE33       0.3219E-04
15   HK11        0.1472E 03
16   HK22        0.1472E 03
17   HK33        0.3715E 01
18   HHC         0.2043E 00
19   EC11        0.9273E 07
20   EC22        0.9273E 07
21   EC33        0.1131E 07
22   EC23        0.3405E 06
23   EC31        0.3405E 06
24   EC12        0.3545E 07
25   NUC12       0.3078E 00
26   NUC21       0.3078E 00
27   NUC13       0.2658E 00
28   NUC31       0.3241E-01
29   NUC23       0.2658E 00
30   NUC32       0.3241E-01
31   ZCGC        0.3200E-01
32   B2DEC       0.
33   CC11        0.1024E 08
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34    CC12      0.3153E 07
35    CC13     -0.4807E 00
36    CC22      0.1024E 08
37    CC23     -0.2182E 02
38    CC33      0.3545E 07
39    EC11      0.9272E 07
40    EC22      0.9272E 07
41    EC12      0.3545E 07
42    NUC12     0.3078E 00
43    NUC21     0.3078E 00
44    CSN13     0.1759E-05
45    CSN31     0.6725E-06
46    CSN23    -0.6113E-05
47    CSN32    -0.2337E-05
48    CTE11     0.9901E-06
49    CTE22     0.9901E-06
50    CTE12     0.1097E-10
51    HK11      0.1472E 03
52    HK22      0.1472E 03
53    HK12      0.2794E-03
54    HHC       0.2043E 00


FORCES                                 FORCE DISPLACEMENT RELATIONS                              DISPL      THERMAL FORCES

 NX         0.6555E 06   0.2018E 06  -0.3076E-01   0.3662E-03   0.1955E-04   0.2289E-04   UX         -0.2546E 03

 NY         0.2018E 06   0.6555E 06  -0.1396E 01   0.2861E-04  -0.1087E-03   0.2289E-04   VX         -0.2546E 03

 NXY       -0.3076E-01  -0.1396E 01   0.2269E 06   0.2289E-04   0.2289E-04   0.3052E-04   VXPUY      -0.3226E-03


 MX         0.3662E-03   0.2861E-04   0.2289E-04   0.3855E 03   0.5695E 02   0.2497E 02   WXX         0.1490E-07

 MY         0.1955E-04  -0.1087E-03   0.2289E-04   0.5695E 02   0.8587E 02   0.2497E 02   WYY        -0.7451E-07

 MXY        0.2289E-04   0.2289E-04   0.3052E-04   0.2497E 02   0.2497E 02   0.6552E 02   WXY         0.1118E-07

RECUCED BENDING REGIDITIES

 0.38550E 03  0.56952E 02  0.24969E 02  0.56952E 02  0.85868E 02  0.24969E 02  0.24969E 02  0.24969E 02  0.65517E 02



RECUCED STIFFNESS MATRIX
 0.65554E 06  0.20179E 06 -0.30762E-01  0.20179E 06  0.65554E 06 -0.13965E 01 -0.30762E-01 -0.13965E 01  0.22688E 06


DISP.                                DISPLACEMENT FORCE RELATIONS                                          FORCES

 UX         0.1685E-05  -0.5187E-06  -0.2964E-11  -0.1567E-11  -0.6338E-13   0.2138E-12               NX

 VX        -0.5187E-06   0.1685E-05   0.1030E-10   0.7352E-13   0.2620E-11  -0.1434E-11               NY

 VXPUY     -0.2964E-11   0.1030E-10   0.4408E-05  -0.5423E-13  -0.6162E-12  -0.1798E-11               NXY


 WXX       -0.1553E-11   0.1092E-12  -0.5423E-13   0.2886E-02  -0.1793E-02  -0.4165E-03               MX

 WYY       -0.2719E-12   0.2659E-11  -0.6162E-12  -0.1793E-02   0.1421E-01  -0.4733E-02               MY

 WXY        0.2880E-12  -0.1463E-11  -0.1798E-11  -0.4165E-03  -0.4733E-02   0.1723E-01               MXY


DISP.                                DISPLACEMENT FORCE RELATIONS                                          FORCES

 0.8129E-02        0.1685E-05  -0.5187E-06  -0.2964E-11  -0.1567E-11  -0.6338E-13   0.2138E-12     0.4745E 04

-0.2891E-02       -0.5187E-06   0.1685E-05   0.1030E-10   0.7352E-13   0.2620E-11  -0.1434E-11    -0.2546E 03

-0.1811E-07       -0.2964E-11   0.1030E-10   0.4408E-05  -0.5423E-13  -0.6162E-12  -0.1798E-11    -0.3226E-03


 0.1443E 00       -0.1553E-11   0.1092E-12  -0.5423E-13   0.2886E-02  -0.1793E-02  -0.4165E-03     0.5000E 02

-0.8965E-01       -0.2719E-12   0.2659E-11  -0.6162E-12  -0.1793E-02   0.1421E-01  -0.4733E-02    -0.7451E-07

-0.2083E-01        0.2880E-12  -0.1463E-11  -0.1798E-11  -0.4165E-03  -0.4733E-02   0.1723E-01     0.1118E-07
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```
FOR THIS CASE VBS(X,Y,XY-M) IS        5000.        0.         0.

FOR THIS CASE MBS(X,Y,XY-M) IS          50.        0.         0.

LAYER PROPERTIES, ROWS-PROPERTY, COLUMNS-LAYER

 1  KV       0.            0.            0.            0.            0.            0.            0.            0.
 2  KF       0.5000E 00    0.5000E 00    0.5000E 00    0.5000E 00    0.5000E 00    0.5000E 00    0.5000E 00    0.5000E 00
 3  KFB      0.5000E 00    0.5000E 00    0.5000E 00    0.5000E 00    0.5000E 00    0.5000E 00    0.5000E 00    0.5000E 00
 4  KM       0.5000E 00    0.5000E 00    0.5000E 00    0.5000E 00    0.5000E 00    0.5000E 00    0.5000E 00    0.5000E 00
 5  KMB      0.5000E 00    0.5000E 00    0.5000E 00    0.5000E 00    0.5000E 00    0.5000E 00    0.5000E 00    0.5000E 00
 6  RHOL     0.5165E-01    0.5165E-01    0.5165E-01    0.5165E-01    0.5165E-01    0.5165E-01    0.5165E-01    0.5165E-01
 7  TL       0.8000E-02    0.8000E-02    0.8000E-02    0.8000E-02    0.8000E-02    0.8000E-02    0.8000E-02    0.8000E-02
 8  DELTA    0.6586E-04    0.6586E-04    0.6586E-04    0.6586E-04    0.6586E-04    0.6586E-04    0.6586E-04    0.6586E-04
 9  ILDC    -0.0000E-19    0.            0.            0.            0.            0.            0.            0.
10  ZB       0.4000E-02    0.1200E-01    0.2000E-01    0.2800E-01    0.3600E-01    0.4400E-01    0.5200E-01    0.6000E-01
11  ZGC     -0.2800E-01   -0.2000E-01   -0.1200E-01   -0.4000E-02    0.4000E-02    0.1200E-01    0.2000E-01    0.2800E-01
12  THCS     0.            0.            0.            0.            0.            0.            0.            0.
13  THLC     0.            0.7854E 00   -0.7854E 00    0.1571E 01    0.1571E 01   -0.7854E 00    0.7854E 00    0.
14  THLS     0.            0.7854E 00   -0.7854E 00    0.1571E 01    0.1571E 01   -0.7854E 00    0.7854E 00    0.
15  SC11     0.2549E 08    0.2549E 08    0.2549E 08    0.2549E 08    0.2549E 08    0.2549E 08    0.2549E 08    0.2549E 08
16  SC12     0.4118E 06    0.4118E 06    0.4118E 06    0.4118E 06    0.4118E 06    0.4118E 06    0.4118E 06    0.4118E 06
17  SC13     0.4118E 06    0.4118E 06    0.4118E 06    0.4118E 06    0.4118E 06    0.4118E 06    0.4118E 06    0.4118E 06
18  SC22     0.1160E 07    0.1160E 07    0.1160E 07    0.1160E 07    0.1160E 07    0.1160E 07    0.1160E 07    0.1160E 07
19  SC23     0.4787E 06    0.4787E 06    0.4787E 06    0.4787E 06    0.4787E 06    0.4787E 06    0.4787E 06    0.4787E 06
20  SC33     0.1160E 07    0.1160E 07    0.1160E 07    0.1160E 07    0.1160E 07    0.1160E 07    0.1160E 07    0.1160E 07
21  SC44     0.3405E 06    0.3405E 06    0.3405E 06    0.3405E 06    0.3405E 06    0.3405E 06    0.3405E 06    0.3405E 06
22  SC55     0.3405E 06    0.3405E 06    0.3405E 06    0.3405E 06    0.3405E 06    0.3405E 06    0.3405E 06    0.3405E 06
23  SC66     0.6339E 06    0.6339E 06    0.6339E 06    0.6339E 06    0.6339E 06    0.6339E 06    0.6339E 06    0.6339E 06
24  CTE11   -0.6138E-07   -0.6138E-07   -0.6138E-07   -0.6138E-07   -0.6138E-07   -0.6138E-07   -0.6138E-07   -0.6138E-07
25  CTE22    0.2334E-04    0.2334E-04    0.2334E-04    0.2334E-04    0.2334E-04    0.2334E-04    0.2334E-04    0.2334E-04
26  CTE33    0.2334E-04    0.2334E-04    0.2334E-04    0.2334E-04    0.2334E-04    0.2334E-04    0.2334E-04    0.2334E-04
27  HK11     0.2906E 03    0.2906E 03    0.2906E 03    0.2906E 03    0.2906E 03    0.2906E 03    0.2906E 03    0.2906E 03
28  HK22     0.3715E 01    0.3715E 01    0.3715E 01    0.3715E 01    0.3715E 01    0.3715E 01    0.3715E 01    0.3715E 01
29  HK33     0.3715E 01    0.3715E 01    0.3715E 01    0.3715E 01    0.3715E 01    0.3715E 01    0.3715E 01    0.3715E 01
30  HCL      0.2043E 00    0.2043E 00    0.2043E 00    0.2043E 00    0.2043E 00    0.2043E 00    0.2043E 00    0.2043E 00
31  EL11     0.2528E 08    0.2528E 08    0.2528E 08    0.2528E 08    0.2528E 08    0.2528E 08    0.2528E 08    0.2528E 08
32  EL22     0.9597E 06    0.9597E 06    0.9597E 06    0.9597E 06    0.9597E 06    0.9597E 06    0.9597E 06    0.9597E 06
33  EL33     0.9597E 06    0.9597E 06    0.9597E 06    0.9597E 06    0.9597E 06    0.9597E 06    0.9597E 06    0.9597E 06
34  GL23     0.3405E 06    0.3405E 06    0.3405E 06    0.3405E 06    0.3405E 06    0.3405E 06    0.3405E 06    0.3405E 06
35  GL13     0.6339E 06    0.6339E 06    0.6339E 06    0.6339E 06    0.6339E 06    0.6339E 06    0.6339E 06    0.6339E 06
36  GL12     0.6339E 06    0.6339E 06    0.6339E 06    0.6339E 06    0.6339E 06    0.6339E 06    0.6339E 06    0.6339E 06
37  NUL12    0.2514E 00    0.2514E 00    0.2514E 00    0.2514E 00    0.2514E 00    0.2514E 00    0.2514E 00    0.2514E 00
38  NUL21    0.9541E-02    0.9541E-02    0.9541E-02    0.9541E-02    0.9541E-02    0.9541E-02    0.9541E-02    0.9541E-02
39  NUL13    0.2514E 00    0.2514E 00    0.2514E 00    0.2514E 00    0.2514E 00    0.2514E 00    0.2514E 00    0.2514E 00
40  NUL31    0.9541E-02    0.9541E-02    0.9541E-02    0.9541E-02    0.9541E-02    0.9541E-02    0.9541E-02    0.9541E-02
41  NUL23    0.4094E 00    0.4094E 00    0.4094E 00    0.4094E 00    0.4094E 00    0.4094E 00    0.4094E 00    0.4094E 00
42  NUL32    0.4094E 00    0.4094E 00    0.4094E 00    0.4094E 00    0.4094E 00    0.4094E 00    0.4094E 00    0.4094E 00
43  SMFK22   0.1522E 01    0.1522E 01    0.1522E 01    0.1522E 01    0.1522E 01    0.1522E 01    0.1522E 01    0.1522E 01
44  SMFD22   0.1918E 01    0.1918E 01    0.1918E 01    0.1918E 01    0.1918E 01    0.1918E 01    0.1918E 01    0.1918E 01
45  SMFS22   0.1358E 01    0.1371E 01    0.1372E 01    0.1388E 01    0.1389E 01    0.1368E 01    0.1370E 01    0.1377E 01
46  SMFC22  -0.0000E-19   -0.0000E-19   -0.0000E-19   -0.0000E-19   -0.0000E-19   -0.0000E-19   -0.0000E-19   -0.0000E-19
47  SMFS12   0.3024E 01    0.3024E 01    0.3024E 01    0.3024E 01    0.3024E 01    0.3024E 01    0.3024E 01    0.3024E 01
48  SMFS23   0.1396E 01    0.1396E 01    0.1396E 01    0.1396E 01    0.1396E 01    0.1396E 01    0.1396E 01    0.1396E 01
49  ILMFC   -0.0000E-19    0.7060E 02    0.7060E 02    0.7060E 02    0.7060E 02    0.7060E 02    0.7060E 02    0.7060E 02
50  TEMPD   -0.3000E 03   -0.3000E 03   -0.3000E 03   -0.3000E 03   -0.3000E 03   -0.3000E 03   -0.3000E 03   -0.3000E 03
51  LSC11T   0.9676E 05    0.9676E 05    0.9676E 05    0.9676E 05    0.9676E 05    0.9676E 05    0.9676E 05    0.9676E 05
52  LSC11C   0.5333E 05    0.5333E 05    0.5333E 05    0.5333E 05    0.5333E 05    0.5333E 05    0.5333E 05    0.5333E 05
53  LSC11D   0.6578E 05    0.6578E 05    0.6578E 05    0.6578E 05    0.6578E 05    0.6578E 05    0.6578E 05    0.6578E 05
54  LSC22T   0.3674E 04    0.3640E 04    0.3638E 04    0.3596E 04    0.3593E 04    0.3647E 04    0.3643E 04    0.4532E 04
55  LSC22C   0.1767E 05    0.1750E 05    0.1749E 05    0.1729E 05    0.1727E 05    0.1753E 05    0.1752E 05    0.2227E 05
56  LSC12    0.2547E 04    0.2547E 04    0.2547E 04    0.2547E 04    0.2547E 04    0.2547E 04    0.2547E 04    0.2547E 04
57  LSC23    0.1866E 04    0.1866E 04    0.1866E 04    0.1866E 04    0.1866E 04    0.1866E 04    0.1866E 04    0.1866E 04
58  LSCC23  -0.0000E-19   -0.0000E-19   -0.0000E-19   -0.0000E-19   -0.0000E-19   -0.0000E-19   -0.0000E-19   -0.0000E-19
59  LSCC13  -0.0000E-19   -0.0000E-19   -0.0000E-19   -0.0000E-19   -0.0000E-19   -0.0000E-19   -0.0000E-19   -0.0000E-19
60  LSCDF   -0.0000E-19    0.1052E-01    0.1052E-01    0.1052E-01    0.1052E-01    0.1052E-01    0.1052E-01    0.1052E-01
61  KL12AB   0.1371E 01    0.1371E 01    0.1371E 01    0.1371E 01    0.1371E 01    0.1371E 01    0.1371E 01    0.1371E 01
62  MDEIE   -0.1262E 01   -0.5995E 01   -0.8342E 01   -0.2019E 02   -0.2522E 02   -0.1613E 02   -0.2031E 02   -0.5998E 01
63  RELROT  -0.0000E-19    0.7082E 00    0.3240E 00    0.1925E 00    0.9916E 00    0.9633E 00    0.5456E 00    0.9364E 00
64  EPS11    0.4088E-02    0.2281E-02    0.2166E-02   -0.2532E-02   -0.3249E-02    0.3072E-02    0.2957E-02    0.1217E-01
65  EPS22   -0.3804E-03    0.1864E-02    0.2416E-02    0.7551E-02    0.8706E-02    0.2822E-02    0.3374E-02   -0.5401E-02
66  EPS12    0.5831E-03   -0.6340E-02    0.8212E-02   -0.8321E-04    0.8341E-04    0.1383E-01   -0.1570E-01   -0.5832E-03
67  SIG11    0.9948E 05    0.5894E 05    0.5658E 05   -0.6236E 05   -0.7930E 05    0.8119E 05    0.7686E 05    0.3105E 06
68  SIG22    0.7354E 04    0.9076E 04    0.9579E 04    0.1338E 05    0.1432E 05    0.1019E 05    0.1069E 05    0.4478E 04
69  SIG12    0.3696E 03   -0.4019E 04    0.5205E 04   -0.5275E 02    0.5287E 02    0.8764E 04   -0.9951E 04   -0.3696E 03
70  DELFI   -0.0000E-19    0.3069E-02   -0.7109E-02    0.8492E-02    0.8784E-04   -0.3862E-03    0.4778E-02    0.6586E-03
71  HFC     -0.2378E 01   -0.4831E 01   -0.6743E 01   -0.6270E 01   -0.7568E 01   -0.1511E 02   -0.1872E 02   -0.1578E 02
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THORNEL-50/EPOXY


NL,NPL,NPC,NFPE,NLC
   8   71   54 1420    1

EF11,EF22,EF33,NUF12,NUF23,NUF13,EF12,EF23,EF13,EM11,EM22,EM33,NUM12,NUM23 NUM13,EM12,EM23,FM13
 0.50000E 08  0.10000E 07  0.10000E 07  0.20000E 00  0.25000E 00  0.20000E 00  0.13000E 07  0.70000E 06  0.13000E 07  0.57000E 06
 0.57000E 06  0.57000E 06  0.36000E 00  0.36000E 00  0.36000E 00  0.           0.           0.
VCF
 0.40000E 01  0.20000E 01  0.40000E 01  0.20000E 01  0.           0.           0.           0.23560E 01  0.           0.
 0.           0.           0.           0.           0.10000E 01  0.10000E 01  0.10000E 01  0.           0.           0.
VAF
-0.55000E-06  0.56000E-05  0.56000E-05
VAM
 0.42800E-04  0.42800E-04  0.42800E-04
CHK
 0.58000E 03  0.58000E 02  0.58000E 02  0.17000E 00  0.12500E 01  0.12500E 01  0.12500E 01  0.25000E 00  0.           0.
 0.           0.22500E 00
BTA
 0.10000E 01  0.10000E 01  0.10500E 01  0.10500E 01
PIE
 0.31416E 01

TLINP
    F

CSANB
    F

BIDE
    F

RINDV
    F

THCS,RHOF,RHCM,DIAF
 0.           0.59000E-01  0.44300E-01  0.26000E-03
KVL
 0.           0.           0.           0.           0.           0.           0.           0.
KFL
 0.50000E 00  0.50000E 00  0.50000E 00  0.50000E 00  0.50000E 00  0.50000E 00  0.50000E 00  0.50000E 00
THLC
 0.           0.90000E 02  0.           0.90000E 02  0.90000E 02  0.           0.90000E 02  0.
TL
 0.80500E-02  0.80500E-02  0.80000E-02  0.80000E-02  0.80000E-02  0.80500E-02  0.80500E-02  0.80000E-02
PTEMP
-0.30000E 03 -0.30000E 03 -0.30000E 03 -0.30000E 03 -0.30000E 03 -0.30000E 03 -0.30000E 03 -0.30000E 03

BET
 0.83000E 00  0.10000E 01  0.26000E 00  0.27000E 00  0.17000E 00  0.16500E 02  0.10000E 01  0.10000E 01  0.46500E-01  0.10000E 01
 0.50000E 00  0.13300E 02  0.31900E 05  0.10000E 01  0.10000E 01  0.10000E 01

LSC
 0.23000E 06  0.21000E 05  0.20000E-01  0.50000E-01  0.45000E-01  0.45000E-01

NBS
 0.50000E 04  0.           0.

MBS
 0.50000E 02  0.           0.

DISV1
 0.           0.           0.           0.           0.           0.


                          3-D  COMPOSITE STRAIN STRESS TEMPERATURE RELATIONS - STRUCTURAL AXES

             0.7604E-07   -0.1392E-08   -0.2866E-07    0.           0.            0.2400E-13      0.9901E-06

            -0.1392E-08    0.7604E-07   -0.2866E-07   -0.          -0.             0.5238E-11      0.9901E-06

            -0.2866E-07   -0.2866E-07    0.8844E-06    0.           0.           -0.2187E-11      0.3219E-04

             0.            0.           -0.            0.2937E-05   0.            0.              0.

             0.            0.           -0.            0.           0.2937E-05    0.              0.

             0.2400E-13    0.5238E-11   -0.2187E-11    0.           0.            0.1578E-05      0.1228E-09

                                3-D COMPOSITE STRESS STRAIN RELATIONS - STRUCTURAL AXES

                      0.1333E 08    0.4118E 06    0.4452E 06   -0.           -0.           -0.9527E 00

                      0.4118E 06    0.1333E 08    0.4452E 06   -0.           -0.           -0.4363E 02

                      0.4452E 06    0.4452E 06    0.1160E 07   -0.           -0.            0.1225E 00

                     -0.           -0.           -0.            0.3405E 06   -0.           -0.

                     -0.           -0.           -0.           -0.            0.3405E 06   -0.

                     -0.9527E 00   -0.4363E 02    0.1225E 00   -0.           -0.            0.6339E 06
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COMPOSITE PROPERTIES - VALID ONLY FOR CONSTANT TEMPERATURE THROUGH THICKNESS
LINES  1 TO 31 3-D COMPOSITE PROPERTIES ABOUT MATERIAL AXES
LINES  33 TO 54 2-D COMPOSITE PROPERTIES ABOUT STRUCTURAL AXES
  1   RHOC      0.5165E-01
  2   TC        C.6400E-01
  3   CC11      C.1333E 08
  4   CC12      0.4118E 06
  5   CC13      0.4452E 06
  6   CC22      0.1333E 08
  7   CC23      C.4452E C6
  8   CC33      0.1160E 07
  9   CC44      0.3405E 06
 10   CC55      0.3405E 06
 11   CC66      0.6339E 06
 12   CTE11     C.9901E-06
 13   CTE22     C.9901E-06
 14   CTE33     0.3219E-04
 15   HK11      0.1472E 03
 16   HK22      0.1472E 03
 17   HK33      0.3715E 01
 18   HHC       0.2043E 00
 19   EC11      0.1315E 08
 20   EC22      0.1315E 08
 21   EC33      0.1131E 07
 22   EC23      C.3405E 06
 23   EC31      C.3405E 06
 24   EC12      C.6339E 06
 25   NUC12     0.1831E-01
 26   NUC21     0.1831E-01
 27   NUC13     0.3769E 00
 28   NUC31     0.3241E-01
 29   NUC23     0.3769E 00
 30   NUC32     0.3241E-01
 31   ZCGC      C.3200E-01
 32   B2DEC     0.
 33   CC11      0.1315E 08
 34   CC12      0.2418E 06
 35   CC13     -C.1003E 01
 36   CC22      0.1315E 08
 37   CC23     -0.4368E 02
 38   CC33      C.6339E 06
 39   EC11      0.1315E 08
 40   EC22      0.1315E 08
 41   EC12      0.6339E 06
 42   NUC12     0.1838E-01
 43   NUC21     0.1838E-01
 44   CSN13    -C.3161E-06
 45   CSN31    -0.1524E-07
 46   CSN23    -C.6887E-04
 47   CSN32    -0.3320E-05
 48   CTE11     0.9901E-06
 49   CTE22     0.9901E-06
 50   CTE12     0.1228E-09
 51   HK11      0.1472E 03
 52   HK22      C.1472E 03
 53   HK12      0.5594E-03
 54   HHC       0.2043E 00


FORCES                          FORCE DISPLACEMENT RELATIONS                               DISPL        THERMAL FORCES

 NX          0.8419E 06   0.1548E 05  -0.6421E-01   0.3662E-03   0.2384E-05   0.1091E-10   UX          -0.2546E 03

 NY          0.1548E 05   0.8419E 06  -0.2795E 01   0.1907E-05   0.4387E-04   0.3492E-09   VX          -0.2546E 03

 NXY        -0.6421E-01  -0.2795E 01   0.4057E 05   0.1091E-10   0.4657E-09   0.5722E-05   VXPUY       -0.6456E-03

 MX          C.3662E-03   0.1907E-05   0.1091E-10   0.3872E 03   0.5283E 01  -0.1370E-04   WXX         -0.7451E-08

 MY          0.2384E-05   0.4387E-04   0.4657E-09   0.5283E 01   0.1875E 03  -0.5963E-03   WYY         -0.7451E-07

 MXY         0.1091E-10   0.3492E-09   0.5722E-05  -0.1370E-04  -0.5963E-03   0.1385E 02   WXY          0.8527E-13

REDUCED BENDING REGIDITIES

 0.38723E 03  0.52825E 01 -0.13698E-04  0.52825E 01  0.18748E 03 -0.59633E-03 -0.13698E-04 -0.59633E-03  0.13847E 02


REDUCED STIFFNESS MATRIX
 0.84185E 06  0.15476E 05 -0.64211E-01  0.15476E 05  0.84185E 06 -0.27953E 01 -0.64211E-01 -0.27953E 01  0.40558E 05


DISP.                           DISPLACEMENT FORCE RELATIONS                                            FORCES

 UX          0.1188E-05  -0.2184E-07   0.3756E-12  -0.1124E-11   0.2167E-13  -0.7195E-18                NX

 VX         -0.2184E-07   0.1188E-05   0.8184E-10   0.1860E-13  -0.2783E-12  -0.7574E-16                NY

 VXPUY       0.3756E-12   0.8184E-10   0.2465E-04  -0.2750E-18  -0.1128E-15  -0.1019E-10                NXY
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WXX        -0.1124E-11   0.1714E-13  -0.5847E-18   0.2583E-02  -0.7279E-04  -0.5792E-09              MX

WYY         0.2469E-13  -0.2783E-12  -0.9746E-16  -0.7279E-04   0.5336E-02   0.2297E-06              MY

WXY        -0.4057E-18  -0.8573E-16  -0.1019E-10  -0.5792E-09   0.2297E-06   0.7222E-01              MXY


DISP.                         DISPLACEMENT  FORCE RELATIONS                                    FORCES

 0.5644E-02          0.1188E-05  -0.2184E-07   0.3756E-12  -0.1124E-11   0.2167E-13  -0.7195E-18     0.4745E 04

-0.4062E-03         -0.2184E-07   0.1188E-05   0.8184E-10   0.1860E-13  -0.2783E-12  -0.7574E-16    -0.2546E 03

-0.3497E-07          0.3756E-12   0.8184E-10   0.2465E-04  -0.2750E-18  -0.1128E-15  -0.1019E-10    -0.6456E-03

 0.1292E 00         -0.1124E-11   0.1714E-13  -0.5847E-18   0.2583E-02  -0.7279E-04  -0.5792E-09     0.5000E 02

-0.3640E-02          0.2469E-13  -0.2783E-12  -0.9746E-16  -0.7279E-04   0.5336E-02   0.2297E-06    -0.7451E-07

-0.2896E-07         -0.4057E-18  -0.8573E-16  -0.1019E-10  -0.5792E-09   0.2297E-06   0.7222E-01     0.8527E-13


FOR THIS CASE NBS(X,Y,XY-M) IS      5000.       0.        0.

FOR THIS CASE MBS(X,Y,XY-M) IS       50.        0.        0.

LAYER PROPERTIES, ROWS-PROPERTY, COLUMNS-LAYER

 1   KV         0.           0.           0.           0.           0.           0.           0.           0.
 2   KF         0.5000E 00   0.5000E 00   0.5000E 00   0.5000E 00   0.5000E 00   0.5000E 00   0.5000E 00   0.5000E 00
 3   KF8        0.5000E 00   0.5000E 00   0.5000E 00   0.5000E 00   0.5000E 00   0.5000E 00   0.5000E 00   0.5000E 00
 4   KM         0.5000E 00   0.5000E 00   0.5000E 00   0.5000E 00   0.5000E 00   0.5000E 00   0.5000E 00   0.5000E 00
 5   KMB        0.5000E 00   0.5000E 00   0.5000E 00   0.5000E 00   0.5000E 00   0.5000E 00   0.5000E 00   0.5000E 00
 6   RHOL       0.5165E-01   0.5165E-01   0.5165E-01   0.5165E-01   0.5165E-01   0.5165E-01   0.5165E-01   0.5165E-01
 7   TL         0.8000E-02   0.8000E-02   0.8000E-02   0.8000E-02   0.8000E-02   0.8000E-02   0.8000E-02   0.8000E-02
 8   DELTA      0.6586E-04   0.6586E-04   0.6586E-04   0.6586E-04   0.6586E-04   0.6586E-04   0.6586E-04   0.6586E-04
 9   ILDC      -0.0000E-19   0.           0.           0.           0.           0.           0.           0.
10   ZB         0.4000E-02   0.1200E-01   0.2000E-01   0.2800E-01   0.3600E-01   0.4400E-01   0.5200E-01   0.6000E-01
11   ZGC       -0.2800E-01  -0.2000E-01  -0.1200E-01  -0.4000E-02   0.4000E-02   0.1200E-01   0.2000E-01   0.2800E-01
12   THCS       0.           0.           0.           0.           0.           0.           0.           0.
13   THLC       0.           0.1571E 01   0.           0.1571E 01   0.1571E 01   0.           0.1571E 01   0.
14   THLS       0.           0.1571E 01   0.           0.1571E 01   0.1571E 01   0.           0.1571E 01   0.
15   SC11       0.2549E 08   0.2549E 08   0.2549E 08   0.2549E 08   0.2549E 08   0.2549E 08   0.2549E 08   0.2549E 08
16   SC12       0.4118E 06   0.4118E 06   0.4118E 06   0.4118E 06   0.4118E 06   0.4118E 06   0.4118E 06   0.4118E 06
17   SC13       0.4118E 06   0.4118E 06   0.4118E 06   0.4118E 06   0.4118E 06   0.4118E 06   0.4118E 06   0.4118E 06
18   SC22       0.1160E 07   0.1160E 07   0.1160E 07   0.1160E 07   0.1160E 07   0.1160E 07   0.1160E 07   0.1160E 07
19   SC23       0.4787E 06   0.4787E 06   0.4787E 06   0.4787E 06   0.4787E 06   0.4787E 06   0.4787E 06   0.4787E 06
20   SC33       0.1160E 07   0.1160E 07   0.1160E 07   0.1160E 07   0.1160E 07   0.1160E 07   0.1160E 07   0.1160E 07
21   SC44       0.3405E 06   0.3405E 06   0.3405E 06   0.3405E 06   0.3405E 06   0.3405E 06   0.3405E 06   0.3405E 06
22   SC55       0.3405E 06   0.3405E 06   0.3405E 06   0.3405E 06   0.3405E 06   0.3405E 06   0.3405E 06   0.3405E 06
23   SC66       0.6339E 06   0.6339E 06   0.6339E 06   0.6339E 06   0.6339E 06   0.6339E 06   0.6339E 06   0.6339E 06
24   CTE11     -0.6138E-07  -0.6138E-07  -0.6138E-07  -0.6138E-07  -0.6138E-07  -0.6138E-07  -0.6138E-07  -0.6138E-07
25   CTE22      0.2334E-04   0.2334E-04   0.2334E-04   0.2334E-04   0.2334E-04   0.2334E-04   0.2334E-04   0.2334E-04
26   CTE33      0.2334E-04   0.2334E-04   0.2334E-04   0.2334E-04   0.2334E-04   0.2334E-04   0.2334E-04   0.2334E-04
27   HK11       0.2906E 03   0.2906E 03   0.2906E 03   0.2906E 03   0.2906E 03   0.2906E 03   0.2906E 03   0.2906E 03
28   HK22       0.3715E 01   0.3715E 01   0.3715E 01   0.3715E 01   0.3715E 01   0.3715E 01   0.3715E 01   0.3715E 01
29   HK33       0.3715E 01   0.3715E 01   0.3715E 01   0.3715E 01   0.3715E 01   0.3715E 01   0.3715E 01   0.3715E 01
30   HCL        0.2043E 00   0.2043E 00   0.2043E 00   0.2043E 00   0.2043E 00   0.2043E 00   0.2043E 00   0.2043E 00
31   EL11       0.2528E 08   0.2528E 08   0.2528E 08   0.2528E 08   0.2528E 08   0.2528E 08   0.2528E 08   0.2528E 08
32   EL22       0.9597E 06   0.9597E 06   0.9597E 06   0.9597E 06   0.9597E 06   0.9597E 06   0.9597E 06   0.9597E 06
33   EL33       0.9597E 06   0.9597E 06   0.9597E 06   0.9597E 06   0.9597E 06   0.9597E 06   0.9597E 06   0.9597E 06
34   GL23       0.3405E 06   0.3405E 06   0.3405E 06   0.3405E 06   0.3405E 06   0.3405E 06   0.3405E 06   0.3405E 06
35   GL13       0.6339E 06   0.6339E 06   0.6339E 06   0.6339E 06   0.6339E 06   0.6339E 06   0.6339E 06   0.6339E 06
36   GL12       0.6339E 06   0.6339E 06   0.6339E 06   0.6339E 06   0.6339E 06   0.6339E 06   0.6339E 06   0.6339E 06
37   NUL12      0.2514E 00   0.2514E 00   0.2514E 00   0.2514E 00   0.2514E 00   0.2514E 00   0.2514E 00   0.2514E 00
38   NUL21      0.9541E-02   0.9541E-02   0.9541E-02   0.9541E-02   0.9541E-02   0.9541E-02   0.9541E-02   0.9541E-02
39   NUL13      0.2514E 00   0.2514E 00   0.2514E 00   0.2514E 00   0.2514E 00   0.2514E 00   0.2514E 00   0.2514E 00
40   NUL31      0.9541E-02   0.9541E-02   0.9541E-02   0.9541E-02   0.9541E-02   0.9541E-02   0.9541E-02   0.9541E-02
41   NUL23      0.4094E 00   0.4094E 00   0.4094E 00   0.4094E 00   0.4094E 00   0.4094E 00   0.4094E 00   0.4094E 00
42   NUL32      0.4094E 00   0.4094E 00   0.4094E 00   0.4094E 00   0.4094E 00   0.4094E 00   0.4094E 00   0.4094E 00
43   SMFK22     0.1522E 01   0.1522E 01   0.1522E 01   0.1522E 01   0.1522E 01   0.1522E 01   0.1522E 01   0.1522E 01
44   SMFD22     0.1918E 01   0.1918E 01   0.1918E 01   0.1918E 01   0.1918E 01   0.1918E 01   0.1918E 01   0.1918E 01
45   SMFS22     0.1369E 01   0.1382E 01   0.1357E 01   0.1382E 01   0.1382E 01   0.1337E 01   0.1382E 01   0.1324E 01
46   SMFC22    -0.0000E-19  -0.0000E-19  -0.0000E-19  -0.0000E-19  -0.0000E-19  -0.0000E-19  -0.0000E-19  -0.0000E-19
47   SMFS12     0.3024E 01   0.3024E 01   0.3024E 01   0.3024E 01   0.3024E 01   0.3024E 01   0.3024E 01   0.3024E 01
48   SMFS23     0.1396E 01   0.1396E 01   0.1396E 01   0.1396E 01   0.1396E 01   0.1396E 01   0.1396E 01   0.1396E 01
49   ILMFC     -0.0000E-19   0.7060E 02   0.7060E 02   0.7060E 02   0.7060E 02   0.7060E 02   0.7060E 02   0.7060E 02
50   TEMPD     -0.3000E 03  -0.3000E 03  -0.3000E 03  -0.3000E 03  -0.3000E 03  -0.3000E 03  -0.3000E 03  -0.3000E 03
51   LSC11T     0.9676E 05   0.9676E 05   0.9676E 05   0.9676E 05   0.9676E 05   0.9676E 05   0.9676E 05   0.9676E 05
52   LSC11C     0.5333E 05   0.5333E 05   0.5333E 05   0.5333E 05   0.5333E 05   0.5333E 05   0.5333E 05   0.5333E 05
53   LSC11D     0.6578E 05   0.6578E 05   0.6578E 05   0.6578E 05   0.6578E 05   0.6578E 05   0.6578E 05   0.6578E 05
54   LSC22T     0.3644E 04   0.3610E 04   0.3679E 04   0.3610E 04   0.3611E 04   0.3731E 04   0.3610E 04   0.3768E 04
55   LSC22C     0.1752E 05   0.1736E 05   0.1769E 05   0.1736E 05   0.1736E 05   0.1794E 05   0.1736E 05   0.1812E 05
56   LSC12      0.2547E 04   0.2547E 04   0.2547E 04   0.2547E 04   0.2547E 04   0.2547E 04   0.2547E 04   0.2547E 04
57   LSC23      0.1866E 04   0.1866E 04   0.1866E 04   0.1866E 04   0.1866E 04   0.1866E 04   0.1866E 04   0.1866E 04
58   LSCC23    -0.0000E-19  -0.0000E-19  -0.0000E-19  -0.0000E-19  -0.0000E-19  -0.0000E-19  -0.0000E-19  -0.0000E-19
59   LSCC13    -0.0000E-19  -0.0000E-19  -0.0000E-19  -0.0000E-19  -0.0000E-19  -0.0000E-19  -0.0000E-19  -0.0000E-19
60   LSCDF     -0.0000E-19   0.1052E-01   0.1052E-01   0.1052E-01   0.1052E-01   0.1052E-01   0.1052E-01   0.1052E-01
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 61   KL12AB     0.1371E 01   0.1371E 01   0.1371E 01   0.1371E 01   0.1371E 01   0.1371E 01   0.1371E 01   0.1371E 01
 62   MDEIE     -0.1514E 01  -0.6581E 01  -0.1208E 01  -0.1002E 02  -0.1185E 02  -0.1650E 01  -0.1638E 02  -0.2525E 01
 63   RELROT    -0.0000E-19   0.1000E 01   0.1000E 01   0.1000E 01   0.1000E 01   0.1000E 01   0.1000E 01   0.1000E 01
 64   EPS11      0.2027E-02  -0.3334E-03   0.4094E-02  -0.3917E-03  -0.4208E-03   0.7194E-02  -0.4790E-03   0.9261E-02
 65   EPS22     -0.3043E-03   0.3061E-02  -0.3626E-03   0.5128E-02   0.6161E-02  -0.4499E-03   0.8228E-02  -0.5082E-03
 66   EPS12     -0.3416E-07   0.5927E-07  -0.3462E-07   0.7531E-07   0.8333E-07  -0.3532E-07   0.9936E-07  -0.3578E-07
 67   SIG11      0.5131E 05  -0.7299E 04   0.1057E 06  -0.8789E 04  -0.8199E 04   0.1851E 06  -0.1102E 05   0.2379E 06
 68   SIG22      0.6929E 04   0.9595E 04   0.7372E 04   0.1157E 05   0.1256E 05   0.8038E 04   0.1453E 05   0.8482E 04
 69   SIG12     -0.2165E-01   0.3757E-01  -0.2195E-01   0.4774E-01   0.5282E-01  -0.2239E-01   0.6298E-01  -0.2268E-01
 70   DELFI     -0.0000E-19  -0.3564E-07  -0.1009E-07  -0.4186E-07   0.4249E-08  -0.8689E-07  -0.5031E-07  -0.1635E-06
 71   HFC       -0.1267E 01  -0.2659E 01  -0.2548E 01  -0.3783E 01  -0.4372E 01  -0.6462E 01  -0.5704E 01  -0.1041E 02
```

Bidirectional Composite Residual Stresses Only

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THORNEL-50/EPOXY


NL,NPL,NPC,NFPE,NLC
   8   71   54 1420     1

EF11,EF22,EF33,NUF12,NUF23,NUF13,EF12,EF23,EF13,EM11,EM22,EM33,NUM12,NUM23 NUM13,EM12,EM23,EM13
 0.50000E 08  0.10000E 07  0.10000E 07  0.20000E 00  0.25000E 00  0.20000E 00  0.13000E 07  0.70000E 06  0.13000E 07  0.57000E 06
 0.57000E 06  0.57000E 06  0.36000E 00  0.36000E 00  0.36000E 00  0.           0.           0.
VCF
 0.40000E 01  0.20000E 01  0.40000E 01  0.20000E 01  0.           0.           0.           0.23560E 01  0.           0.
 0.           0.           0.           0.           0.10000E 01  0.10000E 01  0.10000E 01  0.           0.           0.
VAF
-0.55000E-06  0.56000E-05  0.56000E-05
VAM
 0.42800E-04  0.42800E-04  0.42800E-04
CHK
 0.58000E 03  0.58000E 02  0.58000E 02  0.17000E 00  0.12500E 01  0.12500E 01  0.12500E 01  0.25000E 00  0.           0.
 0.           0.22500E 00
BTA
 0.10000E 01  0.10000E 01  0.10500E 01  0.10500E 01
PIE
 0.31416E 01

TLINP
     F

CSANB
     F

BIDE
     F

RINDV
     F

THCS,RHOF,RHCM,DIAF
 0.           0.59000E-01  0.44300E-01  0.26000E-03
KVL
 0.           0.           0.           0.           0.           0.           0.           0.
KFL
 0.50000E 00  0.50000E 00  0.50000E 00  0.50000E 00  0.50000E 00  0.50000E 00  0.50000E 00  0.50000E 00
THLC
 0.           0.90000E 02  0.           0.90000E 02  0.90000E 02  0.           0.90000E 02  0.
TL
 0.80500E-02  0.80500E-02  0.80000E-02  0.80000E-02  0.80000E-02  0.80500E-02  0.80500E-02  0.80000E-02
PTEMP
-0.30000E 03 -0.30000E 03 -0.30000E 03 -0.30000E 03 -0.30000E 03 -0.30000E 03 -0.30000E 03 -0.30000E 03

BET
 0.83000E 00  0.10000E 01  0.26000E 00  0.27000E 00  0.17000E 00  0.16500E 02  0.10000E 01  0.10000E 01  0.46500E-01  0.10000E 01
 0.50000E 00  0.13300E 02  0.31900E 05  0.10000E 01  0.10000E 01  0.10000E 01

LSC
 0.23000E 06  0.21000E 05  0.20000E-01  0.50000E-01  0.45000E-01  0.45000E-01

NBS
 0.           0.           0.

MBS
 0.           0.           0.

DISV1
 0.           0.           0.           0.           0.           0.
```

```
                    3-D  COMPOSITE STRAIN STRESS TEMPERATURE RELATIONS - STRUCTURAL AXES

 0.7604E-07  -0.1392E-08  -0.2866E-07   0.           0.           0.2400E-13      0.9901E-06

-0.1392E-08   0.7604E-07  -0.2866E-07  -0.          -0.           0.5238E-11      0.9901E-06

-0.2866E-07  -0.2866E-07   0.8844E-06   0.           0.          -0.2187E-11      0.3219E-04

 0.           0.          -0.           0.2937E-05   0.           0.              0.

 0.           0.          -0.           0.           0.2937E-05   0.              0.

 0.2400E-13   0.5238E-11  -0.2187E-11   0.           0.           0.1578E-05      0.1228E-09

                         3-D COMPOSITE STRESS STRAIN RELATIONS - STRUCTURAL AXES

              0.1333E 08   0.4118E 06   0.4452E 06  -0.          -0.          -0.9527E 00

              0.4118E 06   0.1333E 08   0.4452E 06  -0.          -0.          -0.4363E 02

              0.4452E 06   0.4452E 06   0.1160E 07  -0.          -0.           0.1225E 00

             -0.          -0.          -0.           0.3405E 06  -0.          -0.

             -0.          -0.          -0.          -0.           0.3405E 06  -0.

             -0.9527E 00  -0.4363E 02   0.1225E 00  -0.          -0.           0.6339E 06


COMPOSITE PROPERTIES - VALID ONLY FOR CONSTANT TEMPERATURE THROUGH THICKNESS
LINES  1 TO 31 3-D COMPOSITE PROPERTIES ABOUT MATERIAL AXES
LINES  33 TO 54 2-D COMPOSITE PROPERTIES ABOUT STRUCTURAL AXES
  1   RHOC       0.5165E-01
  2   TC         0.6400E-01
  3   CC11       0.1333E 08
  4   CC12       0.4118E 06
  5   CC13       0.4452E 06
  6   CC22       0.1333E 08
  7   CC23       0.4452E 06
  8   CC33       0.1160E 07
  9   CC44       0.3405E 06
 10   CC55       0.3405E 06
 11   CC66       0.6339E 06
 12   CTE11      0.9901E-06
 13   CTE22      0.9901E-06
 14   CTE33      0.3219E-04
 15   HK11       0.1472E 03
 16   HK22       0.1472E 03
 17   HK33       0.3715E 01
 18   HHC        0.2043E 00
 19   EC11       0.1315E 08
 20   EC22       0.1315E 08
 21   EC33       0.1131E 07
 22   EC23       0.3405E 06
 23   EC31       0.3405E 06
 24   EC12       0.6339E 06
 25   NUC12      0.1831E-01
 26   NUC21      0.1831E-01
 27   NUC13      0.3769E 00
 28   NUC31      0.3241E-01
 29   NUC23      0.3769E 00
 30   NUC32      0.3241E-01
 31   ZCGC       0.3200E-01
 32   B2DEC      0.
 33   CC11       0.1315E 08
 34   CC12       0.2418E 06
 35   CC13      -0.1003E 01
 36   CC22       0.1315E 08
 37   CC23      -0.4368E 02
 38   CC33       0.6339E 06
 39   EC11       0.1315E 08
 40   EC22       0.1315E 08
 41   EC12       0.6339E 06
 42   NUC12      0.1838E-01
 43   NUC21      0.1838E-01
 44   CSN13     -0.3161E-06
 45   CSN31     -0.1524E-07
 46   CSN23     -0.6887E-04
 47   CSN32     -0.3320E-05
 48   CTE11      0.9901E-06
 49   CTE22      0.9901E-06
 50   CTE12      0.1228E-09
 51   HK11       0.1472E 03
 52   HK22       0.1472E 03
 53   HK12       0.5594E-03
 54   HHC        0.2043E 00
```

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FORCES                          FORCE DISPLACEMENT RELATIONS                                          DISPL        THERMAL FORCES

 NX            0.8419E 06    0.1548E 05   -0.6421E-01    0.3662E-03    0.2384E-05    0.1091E-10   UX           -0.2546E 03

 NY            0.1548E 05    0.8419E 06   -0.2795E 01    0.1907E-05    0.4387E-04    0.3492E-09   VX           -0.2546E 03

 NXY          -0.6421E-01   -0.2795E 01    0.4057E 05    0.1091E-10    0.4657E-09    0.5722E-05   VXPUY        -0.6456E-03

 MX            0.3662E-03    0.1907E-05    0.1091E-10    0.3872E 03    0.5283E 01   -0.1370E-04   WXX          -0.7451E-08

 MY            0.2384E-05    0.4387E-04    0.4657E-09    0.5283E 01    0.1875E 03   -0.5963E-03   WYY          -0.7451E-07

 MXY           0.1091E-10    0.3492E-09    0.5722E-05   -0.1370E-04   -0.5963E-03    0.1385E 02   WXY           0.8527E-13

REDUCED BENDING REGIDITIES

 0.38723E 03  0.52825E 01 -0.13698E-04  0.52825E 01  0.18748E 03 -0.59633E-03 -0.13698E-04 -0.59633E-03  0.13847E 02


REDUCED STIFFNESS MATRIX
 0.84185E 06  0.15476E 05 -0.64211E-01  0.15476E 05  0.84185E 06 -0.27953E 01 -0.64211E-01 -0.27953E 01  0.40568E 05


DISP.                           DISPLACEMENT FORCE RELATIONS                                                      FORCES

 UX            0.1188E-05   -0.2184E-07    0.3756E-12   -0.1124E-11    0.2167E-13   -0.7195E-18                    NX

 VX           -0.2184E-07    0.1188E-05    0.8184E-10    0.1860E-13   -0.2783E-12   -0.7574E-16                    NY

 VXPUY         0.3756E-12    0.8184E-10    0.2465E-04   -0.2750E-18   -0.1128E-15   -0.1019E-10                    NXY

 WXX          -0.1124E-11    0.1714E-13   -0.5847E-18    0.2583E-02   -0.7279E-04   -0.5792E-09                    MX

 WYY           0.2469E-13   -0.2783E-12   -0.9746E-16   -0.7279E-04    0.5336E-02    0.2297E-06                    MY

 WXY          -0.4057E-18   -0.8573E-16   -0.1019E-10   -0.5792E-09    0.2297E-06    0.7222E-01                    MXY


DISP.                           DISPLACEMENT FORCE RELATIONS                                                      FORCES

-0.2970E-03              0.1188E-05   -0.2184E-07    0.3756E-12   -0.1124E-11    0.2167E-13   -0.7195E-18        -0.2546E 03

-0.2970E-03             -0.2184E-07    0.1188E-05    0.8184E-10    0.1860E-13   -0.2783E-12   -0.7574E-16        -0.2546E 03

-0.3685E-07              0.3756E-12    0.8184E-10    0.2465E-04   -0.2750E-18   -0.1128E-15   -0.1019E-10        -0.6456E-03

 0.2680E-09             -0.1124E-11    0.1714E-13   -0.5847E-18    0.2583E-02   -0.7279E-04   -0.5792E-09        -0.7451E-08

-0.3324E-09              0.2469E-13   -0.2783E-12   -0.9746E-16   -0.7279E-04    0.5336E-02    0.2297E-06        -0.7451E-07

 0.1756E-13             -0.4057E-18   -0.8573E-16   -0.1019E-10   -0.5792E-09    0.2297E-06    0.7222E-01         0.8527E-13


FOR THIS CASE NBS(X,Y,XY-M) IS          0.         0.         0.

FOR THIS CASE MBS(X,Y,XY-M) IS          0.         0.         0.

LAYER PROPERTIES, ROWS-PROPERTY, COLUMNS-LAYER

 1   KV          0.            0.            0.            0.            0.            0.            0.            0.
 2   KF          0.5000E 00    0.5000E 00    0.5000E 00    0.5000E 00    0.5000E 00    0.5000E 00    0.5000E 00    0.5000E 00
 3   KFB         0.5000E 00    0.5000E 00    0.5000E 00    0.5000E 00    0.5000E 00    0.5000E 00    0.5000E 00    0.5000E 00
 4   KM          0.5000E 00    0.5000E 00    0.5000E 00    0.5000E 00    0.5000E 00    0.5000E 00    0.5000E 00    0.5000E 00
 5   KMB         0.5000E 00    0.5000E 00    0.5000E 00    0.5000E 00    0.5000E 00    0.5000E 00    0.5000E 00    0.5000E 00
 6   RHOL        0.5165E-01    0.5165E-01    0.5165E-01    0.5165E-01    0.5165E-01    0.5165E-01    0.5165E-01    0.5165E-01
 7   TL          0.8000E-02    0.8000E-02    0.8000E-02    0.8000E-02    0.8000E-02    0.8000E-02    0.8000E-02    0.8000E-02
 8   DELTA       0.6586E-04    0.6586E-04    0.6586E-04    0.6586E-04    0.6586E-04    0.6586E-04    0.6586E-04    0.6586E-04
 9   ILDC       -0.0000E-19    0.            0.            0.            0.            0.            0.            0.
10   ZB          0.4000E-02    0.1200E-01    0.2000E-01    0.2800E-01    0.3600E-01    0.4400E-01    0.5200E-01    0.6000E-01
11   ZGC        -0.2800E-01   -0.2000E-01   -0.1200E-01   -0.4000E-02    0.4000E-02    0.1200E-01    0.2000E-01    0.2800E-01
12   THCS        0.            0.            0.            0.            0.            0.            0.            0.
13   THLC        0.            0.1571E 01    0.            0.1571E 01    0.1571E 01    0.            0.1571E 01    0.
14   THLS        0.            0.1571E 01    0.            0.1571E 01    0.1571E 01    0.            0.1571E 01    0.
15   SC11        0.2549E 08    0.2549E 08    0.2549E 08    0.2549E 08    0.2549E 08    0.2549E 08    0.2549E 08    0.2549E 08
16   SC12        0.4118E 06    0.4118E 06    0.4118E 06    0.4118E 06    0.4118E 06    0.4118E 06    0.4118E 05    0.4119E 06
17   SC13        0.4118E 06    0.4118E 06    0.4118E 06    0.4118E 06    0.4118E 06    0.4118E 06    0.4118E 06    0.4118E 06
18   SC22        0.1160E 07    0.1160E 07    0.1160E 07    0.1160E 07    0.1160E 07    0.1160E 07    0.1160E 07    0.1160E 07
19   SC23        0.4787E 06    0.4787E 06    0.4787E 06    0.4787E 06    0.4787E 06    0.4787E 06    0.4787E 06    0.4787E 06
20   SC33        0.1160E 07    0.1160E 07    0.1160E 07    0.1160E 07    0.1160E 07    0.1160E 07    0.1160E 07    0.1160E 07
21   SC44        0.3405E 06    0.3405E 06    0.3405E 06    0.3405E 06    0.3405E 06    0.3405E 06    0.3405E 05    0.3405E 06
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22  SC55       0.3405E 06   0.3405E 06   0.3405E 06   0.3405E 06   0.3405E 06   0.3405E 06   0.3405E 06   0.3405E 06
23  SC66       0.6339E 06   0.6339E 06   0.6339E 06   0.6339E 06   0.6339E 06   0.6339E 06   0.6339E 06   0.6339E 06
24  CTE11     -0.6138E-07  -0.6138E-07  -0.6138E-07  -0.6138E-07  -0.6138E-07  -0.6138E-07  -0.6138E-07  -0.6138E-07
25  CTE22      0.2334E-04   0.2334E-04   0.2334E-04   0.2334E-04   0.2334E-04   0.2334E-04   0.2334E-04   0.2334E-04
26  CTE33      0.2334E-04   0.2334E-04   0.2334E-04   0.2334E-04   0.2334E-04   0.2334E-04   0.2334E-04   0.2334E-04
27  HK11       0.2906E 03   0.2906E 03   0.2906E 03   0.2906E 03   0.2906E 03   0.2906E 03   0.2906E 03   0.2906E 03
28  HK22       0.3715E 01   0.3715E 01   0.3715E 01   0.3715E 01   0.3715E 01   0.3715E 01   0.3715E 01   0.3715E 01
29  HK33       0.3715E 01   0.3715E 01   0.3715E 01   0.3715E 01   0.3715E 01   0.3715E 01   0.3715E 01   0.3715E 01
30  HCL        0.2043E 00   0.2043E 00   0.2043E 00   0.2043E 00   0.2043E 00   0.2043E 00   0.2043E 00   0.2043E 00
31  EL11       0.2528E 08   0.2528E 08   0.2528E 08   0.2528E 08   0.2528E 08   0.2528E 08   0.2528E 08   0.2528E 08
32  EL22       0.9597E 06   0.9597E 06   0.9597E 06   0.9597E 06   0.9597E 06   0.9597E 06   0.9597E 06   0.9597E 06
33  EL33       0.9597E 06   0.9597E 06   0.9597E 06   0.9597E 06   0.9597E 06   0.9597E 06   0.9597E 06   0.9597E 06
34  GL23       0.3405E 06   0.3405E 06   0.3405E 06   0.3405E 06   0.3405E 06   0.3405E 06   0.3405E 06   0.3405E 06
35  GL13       0.6339E 06   0.6339E 06   0.6339E 06   0.6339E 06   0.6339E 06   0.6339E 06   0.6339E 06   0.6339E 06
36  GL12       0.6339E 06   0.6339E 06   0.6339E 06   0.6339E 06   0.6339E 06   0.6339E 06   0.6339E 06   0.6339E 06
37  NUL12      0.2514E 00   0.2514E 00   0.2514E 00   0.2514E 00   0.2514E 00   0.2514E 00   0.2514E 00   0.2514E 00
38  NUL21      0.9541E-02   0.9541E-02   0.9541E-02   0.9541E-02   0.9541E-02   0.9541E-02   0.9541E-02   0.9541E-02
39  NUL13      0.2514E 00   0.2514E 00   0.2514E 00   0.2514E 00   0.2514E 00   0.2514E 00   0.2514E 00   0.2514E 00
40  NUL31      0.9541E-02   0.9541E-02   0.9541E-02   0.9541E-02   0.9541E-02   0.9541E-02   0.9541E-02   0.9541E-02
41  NUL23      0.4094E 00   0.4094E 00   0.4094E 00   0.4094E 00   0.4094E 00   0.4094E 00   0.4094E 00   0.4094E 00
42  NUL32      0.4094E 00   0.4094E 00   0.4094E 00   0.4094E 00   0.4094E 00   0.4094E 00   0.4094E 00   0.4094E 00
43  SMFK22     0.1522E 01   0.1522E 01   0.1522E 01   0.1522E 01   0.1522E 01   0.1522E 01   0.1522E 01   0.1522E 01
44  SMFD22     0.1918E 01   0.1918E 01   0.1918E 01   0.1918E 01   0.1918E 01   0.1918E 01   0.1918E 01   0.1918E 01
45  SMFS22     0.1383E 01   0.1383E 01   0.1383E 01   0.1383E 01   0.1383E 01   0.1383E 01   0.1383E 01   0.1383E 01
46  SMFC22    -0.0000E-19  -0.0000E-19  -0.0000E-19  -0.0000E-19  -0.0000E-19  -0.0000E-19  -0.0000E-19  -0.0000E-19
47  SMFS12     0.3024E 01   0.3024E 01   0.3024E 01   0.3024E 01   0.3024E 01   0.3024E 01   0.3024E 01   0.3024E 01
48  SMFS23     0.1396E 01   0.1396E 01   0.1396E 01   0.1396E 01   0.1396E 01   0.1396E 01   0.1396E 01   0.1396E 01
49  ILMFC     -0.0000E-19   0.7060E 02   0.7060E 02   0.7060E 02   0.7060E 02   0.7060E 02   0.7060E 02   0.7060E 02
50  TEMPD     -0.3000E 03  -0.3000E 03  -0.3000E 03  -0.3000E 03  -0.3000E 03  -0.3000E 03  -0.3000E 03  -0.3000E 03
51  LSC11T     0.9676E 05   0.9676E 05   0.9676E 05   0.9676E 05   0.9676E 05   0.9676E 05   0.9676E 05   0.9676E 05
52  LSC11C     0.5333E 05   0.5333E 05   0.5333E 05   0.5333E 05   0.5333E 05   0.5333E 05   0.5333E 05   0.5333E 05
53  LSC11D     0.6578E 05   0.6578E 05   0.6578E 05   0.6578E 05   0.6578E 05   0.6578E 05   0.6578E 05   0.6578E 05
54  LSC22T     0.3609E 04   0.3609E 04   0.3609E 04   0.3609E 04   0.3609E 04   0.3609E 04   0.3609E 04   0.3609E 04
55  LSC22C     0.1735E 05   0.1735E 05   0.1735E 05   0.1735E 05   0.1735E 05   0.1735E 05   0.1735E 05   0.1735E 05
56  LSC12      0.2547E 04   0.2547E 04   0.2547E 04   0.2547E 04   0.2547E 04   0.2547E 04   0.2547E 04   0.2547E 04
57  LSC23      0.1866E 04   0.1866E 04   0.1866E 04   0.1866E 04   0.1866E 04   0.1866E 04   0.1866E 04   0.1866E 04
58  LSCC23    -0.0000E-19  -0.0000E-19  -0.0000E-19  -0.0000E-19  -0.0000E-19  -0.0000E-19  -0.0000E-19  -0.0000E-19
59  LSCC13    -0.0000E-19  -0.0000E-19  -0.0000E-19  -0.0000E-19  -0.0000E-19  -0.0000E-19  -0.0000E-19  -0.0000E-19
60  LSCDF     -0.0000E-19   0.1052E-01   0.1052E-01   0.1052E-01   0.1052E-01   0.1052E-01   0.1052E-01   0.1052E-01
61  KL12AB     0.1371E 01   0.1371E 01   0.1371E 01   0.1371E 01   0.1371E 01   0.1371E 01   0.1371E 01   0.1371E 01
62  MDEIE     -0.2422E 01  -0.2422E 01  -0.2422E 01  -0.2422E 01  -0.2422E 01  -0.2422E 01  -0.2422E 01  -0.2422E 01
63  RELROT    -0.0000E-19   0.1000E 01   0.1000E 01   0.1000E 01   0.1000E 01   0.1000E 01   0.1000E 01   0.1000E 01
64  EPS11     -0.2970E-03  -0.2970E-03  -0.2970E-03  -0.2970E-03  -0.2970E-03  -0.2970E-03  -0.2970E-03  -0.2970E-03
65  EPS22     -0.2970E-03  -0.2970E-03  -0.2970E-03  -0.2970E-03  -0.2970E-03  -0.2970E-03  -0.2970E-03  -0.2970E-03
66  EPS12     -0.3685E-07   0.3685E-07  -0.3685E-07   0.3685E-07   0.3685E-07  -0.3685E-07   0.3685E-07  -0.3685E-07
67  SIG11     -0.6374E 04  -0.6374E 04  -0.6374E 04  -0.6374E 04  -0.6374E 04  -0.6374E 04  -0.6374E 04  -0.6374E 04
68  SIG22      0.6374E 04   0.6374E 04   0.6374E 04   0.6374E 04   0.6374E 04   0.6374E 04   0.6374E 04   0.6374E 04
69  SIG12     -0.2336E-01   0.2336E-01  -0.2336E-01   0.2336E-01   0.2336E-01  -0.2336E-01   0.2336E-01  -0.2336E-01
70  DELFI     -0.0000E-19  -0.1278E-08  -0.1278E-08  -0.1278E-08  -0.1278E-08  -0.1278E-08  -0.1278E-08  -0.1278E-08
71  FFC       -0.1117E 01  -0.1117E 01  -0.1117E 01  -0.1117E 01  -0.1117E 01  -0.1117E 01  -0.1117E 01  -0.1117E 01
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Bidirectional Composite with Bending-Stretching Coupling; Residual Stresses Only

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THORNEL-50/EPOXY

NL,NPL,NPC,NFPE,NLC
   8   71   54 1420    1

EF11,EF22,EF33,NUF12,NUF23,NUF13,EF12,EF23,EF13,EM11,EM22,EM33,NUM12,NUM23 NUM13,EM12,EM23,EM13
 0.50000E 08  0.10000E 07  0.10000E 07  0.20000E 00  0.25000E 00  0.20000E 00  0.13000E 07  0.70000E 06  0.13000E 07  0.57000E 06
 0.57000E 06  0.57000E 06  0.36000E 00  0.36000E 00  0.36000E 00  0.           0.           0.
VCF
 0.40000E 01  0.20000E 01  0.40000E 01  0.20000E 01  0.           0.           0.           0.23560E 01  0.           0.
 0.           0.           0.           0.           0.10000E 01  0.10000E 01  0.10000E 01  0.           0.           0.
VAF
-0.55000E-06  0.56000E-05  0.56000E-05
VAM
 0.42800E-04  0.42800E-04  0.42800E-04
CHK
 0.58000E 03  0.58000E 02  0.58000E 02  0.17000E 00  0.12500E 01  0.12500E 01  0.12500E 01  0.25000E 00  0.           0.
 0.           0.22500E 00
BTA
 0.10000E 01  0.10000E 01  0.10500E 01  0.10500E 01
PIE
 0.31416E 01

TLINP
    F

CSANB
    F

BIDE
    F

RINDV
    F
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THCS,RHOF,RHOM,DIAF
 0.          0.59000E-01  0.44300E-01  0.26000E-03
KVL
 0.          0.           0.           0.           0.           0.           0.           0.
KFL
 0.50000E 00 0.50000E 00  0.50000E 00  0.50000E 00  0.50000E 00  0.50000E 00  0.50000E 00  0.50000E 00
THLC
 0.          0.           0.           0.           0.90000E 02  0.90000E 02  0.90000E 02  0.90000E 02
TL
 0.80500E-02 0.80500E-02  0.80000E-02  0.80000E-02  0.80000E-02  0.80500E-02  0.80500E-02  0.80000E-02
PTEMP
-0.30000E 03 -0.30000E 03 -0.30000E 03 -0.30000E 03 -0.30000E 03 -0.30000E 03 -0.30000E 03 -0.30000E 03

BET
 0.83000E 00 0.10000E 01  0.26000E 00  0.27000E 00  0.17000E 00  0.16500E 02  0.10000E 01  0.10000E 01  0.46500E-01  0.10000E 01
 0.50000E 00 0.13300E 02  0.31900E 05  0.10000E 01  0.10000E 01  0.10000E 01

LSC
 0.23000E 06 0.21000E 05  0.20000E-01  0.50000E-01  0.45000E-01  0.45000E-01

NBS
 0.          0.           0.

MBS
 0.          0.           0.

DISV1
 0.          0.           0.           0.           0.           0.


                         3-D  COMPOSITE STRAIN STRESS TEMPERATURE RELATIONS - STRUCTURAL AXES

               0.7604E-07  -0.1392E-08  -0.2866E-07   0.           0.           0.2400E-13       0.9901E-06

              -0.1392E-08   0.7604E-07  -0.2866E-07  -0.          -0.           0.5238E-11       0.9901E-06

              -0.2866E-07  -0.2866E-07   0.8844E-06   0.           0.          -0.2187E-11       0.3219E-04

               0.           0.          -0.           0.2937E-05   0.           0.               0.

               0.           0.          -0.           0.           0.2937E-05   0.               0.

               0.2400E-13   0.5238E-11  -0.2187E-11   0.           0.           0.1578E-05       0.1228E-09

                              3-D COMPOSITE STRESS STRAIN RELATIONS - STRUCTURAL AXES

                      0.1333E 08   0.4118E 06   0.4452E 06  -0.          -0.          -0.9527E 00

                      0.4118E 06   0.1333E 08   0.4452E 06  -0.          -0.          -0.4363E 02

                      0.4452E 06   0.4452E 06   0.1160E 07  -0.          -0.           0.1225E 00

                     -0.          -0.          -0.           0.3405E 06  -0.          -0.

                     -0.          -0.          -0.          -0.           0.3405E 06  -0.

                     -0.9527E 00  -0.4363E 02   0.1225E 00  -0.          -0.           0.6339E 06


COMPOSITE PROPERTIES - VALID ONLY FOR CONSTANT TEMPERATURE THROUGH THICKNESS
LINES  1 TO 31 3-D COMPOSITE PROPERTIES ABOUT MATERIAL AXES
LINES  33 TO 54 2-D COMPOSITE PROPERTIES ABOUT STRUCTURAL AXES
  1   RHOC       0.5165E-01
  2   TC         0.6400E-01
  3   CC11       0.1333E 08
  4   CC12       0.4118E 06
  5   CC13       0.4452E 06
  6   CC22       0.1333E 08
  7   CC23       0.4452E 06
  8   CC33       0.1160E 07
  9   CC44       0.3405E 06
 10   CC55       0.3405E 06
 11   CC66       0.6339E 06
 12   CTE11      0.9901E-06
 13   CTE22      0.9901E-06
 14   CTE33      0.3219E-04
 15   HK11       0.1472E 03
 16   HK22       0.1472E 03
 17   HK33       0.3715E 01
 18   HHC        0.2043E 00
 19   EC11       0.1315E 08
 20   EC22       0.1315E 08
 21   EC33       0.1131E 07
 22   EC23       0.3405E 06
 23   EC31       0.3405E 06
 24   EC12       0.6339E 06
 25   NUC12      0.1831E-01
 26   NUC21      0.1831E-01
 27   NUC13      0.3769E 00
 28   NUC31      0.3241E-01
 29   NUC23      0.3769E 00
 30   NUC32      0.3241E-01
 31   ZCGC       0.3200E-01
 32   B2DEC      0.
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33   CC11        0.1315E 08
34   CC12        0.2418E 06
35   CC13       -0.1003E 01
36   CC22        0.1315E 08
37   CC23       -0.4368E 02
38   CC33        0.6339E 06
39   EC11        0.1315E 08
40   EC22        0.1315E 08
41   EC12        0.6339E 06
42   NUC12       0.1838E-01
43   NUC21       0.1838E-01
44   CSN13      -0.3161E-06
45   CSN31      -0.1524E-07
46   CSN23      -0.6887E-04
47   CSN32      -0.3320E-05
48   CTE11       0.9901E-06
49   CTE22       0.9901E-06
50   CTE12       0.1228E-09
51   HK11        0.1472E 03
52   HK22        0.1472E 03
53   HK12        0.5594E-03
54   HHC         0.2043E 00

FORCES                                   FORCE DISPLACEMENT RELATIONS                          DISPL      THERMAL FORCES

 NX            0.8419E 06    0.1548E 05   -0.6421E-01   -0.1248E 05    0.3338E-05   -0.1027E-02   UX          -0.2546E 03

 NY            0.1548E 05    0.8419E 06   -0.2795E 01   -0.9537E-06    0.1248E 05   -0.4472E-01   VX          -0.2546E 03

 NXY          -0.6421E-01   -0.2795E 01    0.4057E 05   -0.1027E-02   -0.4472E-01    0.5722E-05   VXPUY       -0.6456E-03


 MX           -0.1248E 05   -0.9537E-06   -0.1027E-02    0.2874E 03    0.5283E 01   -0.2192E-04   WXX         -0.2818E 01

 MY            0.3338E-05    0.1248E 05   -0.4472E-01    0.5283E 01    0.2874E 03   -0.9541E-03   WYY          0.2818E 01

 MXY          -0.1027E-02   -0.4472E-01    0.5722E-05   -0.2192E-04   -0.9541E-03    0.1385E 02   WXY         -0.1033E-04

REDUCED BENDING REGIDITIES

 0.10215E 03  0.18778E 01 -0.24961E-04  0.18778E 01  0.10215E 03 -0.29092E-03 -0.24961E-04 -0.29092E-03  0.13847E 02


REDUCED STIFFNESS MATRIX
 0.29926E 06  0.55014E 04 -0.73129E-01  0.55014E 04  0.29926E 06 -0.85231E 00 -0.73129E-01 -0.85231E 00  0.40568E 05


DISP.                                  DISPLACEMENT FORCE RELATIONS                                  FORCES

 UX            0.3343E-05   -0.6145E-07    0.4735E-11    0.1452E-03   -0.1137E-12    0.2794E-09               NX

 VX           -0.6145E-07    0.3343E-05    0.7012E-10   -0.5592E-13   -0.1452E-03    0.7851E-09               NY

 VXPUY         0.4735E-11    0.7012E-10    0.2465E-04    0.2794E-09    0.7851E-09   -0.9905E-11               NXY


 WXX           0.1452E-03   -0.5684E-13    0.2794E-09    0.9793E-02   -0.1800E-03    0.1387E-07               MX

 WYY           0.6770E-13   -0.1452E-03    0.7851E-09   -0.1800E-03    0.9793E-02    0.2054E-06               MY

 WXY           0.2794E-09    0.7851E-09   -0.9905E-11    0.1387E-07    0.2054E-06    0.7222E-01               MXY


DISP.                                  DISPLACEMENT FORCE RELATIONS                                  FORCES

-0.1245E-02           0.3343E-05   -0.6145E-07    0.4735E-11    0.1452E-03   -0.1137E-12    0.2794E-09    -0.2546E 03

-0.1245E-02          -0.6145E-07    0.3343E-05    0.7012E-10   -0.5592E-13   -0.1452E-03    0.7851E-09    -0.2546E 03

-0.3355E-07           0.4735E-11    0.7012E-10    0.2465E-04    0.2794E-09    0.7851E-09   -0.9905E-11    -0.6456E-03


-0.6509E-01           0.1452E-03   -0.5684E-13    0.2794E-09    0.9793E-02   -0.1800E-03    0.1387E-07    -0.2818E 01

 0.6509E-01           0.6770E-13   -0.1452E-03    0.7851E-09   -0.1800E-03    0.9793E-02    0.2054E-06     0.2818E 01

-0.4771E-06           0.2794E-09    0.7851E-09   -0.9905E-11    0.1387E-07    0.2054E-06    0.7222E-01    -0.1033E-04
```

```
FOR THIS CASE NBS(X,Y,XY-M) IS          0.          0.          0.

FOR THIS CASE MBS(X,Y,XY-M) IS          0.          0.          0.

LAYER PROPERTIES, ROWS-PROPERTY, COLUMNS-LAYER

 1  KV        0.            0.            0.            0.            0.            0.            0.            0.
 2  KF        0.5000E 00    0.5000E 00    0.5000E 00    0.5000E 00    0.5000E 00    0.5000E 00    0.5000E 00    0.5000E 00
 3  KFB       0.5000E 00    0.5000E 00    0.5000E 00    0.5000E 00    0.5000E 00    0.5000E 00    0.5000E 00    0.5000E 00
 4  KM        0.5000E 00    0.5000E 00    0.5000E 00    0.5000E 00    0.5000E 00    0.5000E 00    0.5000E 00    0.5000E 00
 5  KMB       0.5000E 00    0.5000E 00    0.5000E 00    0.5000E 00    0.5000E 00    0.5000E 00    0.5000E 00    0.5000E 00
 6  RHOL      0.5165E-01    0.5165E-01    0.5165E-01    0.5165E-01    0.5165E-01    0.5165E-01    0.5165E-01    0.5165E-01
 7  TL        0.8000E-02    0.8000E-02    0.8000E-02    0.8000E-02    0.8000E-02    0.8000E-02    0.8000E-02    0.8000E-02
 8  DELTA     0.6586E-04    0.6586E-04    0.6585E-04    0.6586E-04    0.6586E-04    0.6586E-04    0.6586E-04    0.6586E-04
 9  ILDC     -0.0000E-19    0.            0.            0.            0.            0.            0.            0.
10  ZB        0.4000E-02    0.1200E-01    0.2000E-01    0.2800E-01    0.3600E-01    0.4400E-01    0.5200E-01    0.6000E-01
11  ZGC      -0.2800E-01   -0.2000E-01   -0.1200E-01   -0.4000E-02    0.4000E-02    0.1200E-01    0.2000E-01    0.2800E-01
12  THCS      0.            0.            0.            0.            0.            0.            0.            0.
13  THLC      0.            0.            0.            0.            0.1571E 01    0.1571E 01    0.1571E 01    0.1571E 01
14  THLS      0.            0.            0.            0.            0.1571E 01    0.1571E 01    0.1571E 01    0.1571E 01
15  SC11      0.2549E 08    0.2549E 08    0.2549E 08    0.2549E 08    0.2549E 08    0.2549E 08    0.2549E 08    0.2549E 08
16  SC12      0.4118E 06    0.4118E 06    0.4118E 06    0.4118E 06    0.4118E 06    0.4118E 06    0.4118E 06    0.4118E 06
17  SC13      0.4118E 06    0.4118E 06    0.4118E 06    0.4118E 06    0.4118E 06    0.4118E 06    0.4118E 06    0.4118E 06
18  SC22      0.1160E 07    0.1160E 07    0.1160E 07    0.1160E 07    0.1160E 07    0.1160E 07    0.1160E 07    0.1160E 07
19  SC23      0.4787E 06    0.4787E 06    0.4787E 06    0.4787E 06    0.4787E 06    0.4787E 06    0.4787E 06    0.4787E 06
20  SC33      0.1160E 07    0.1160E 07    0.1160E 07    0.1160E 07    0.1160E 07    0.1160E 07    0.1160E 07    0.1160E 07
21  SC44      0.3405E 06    0.3405E 06    0.3405E 06    0.3405E 06    0.3405E 06    0.3405E 06    0.3405E 06    0.3405E 06
22  SC55      0.3405E 06    0.3405E 06    0.3405E 06    0.3405E 06    0.3405E 06    0.3405E 06    0.3405E 06    0.3405E 06
23  SC66      0.6339E 06    0.6339E 06    0.6339E 06    0.6339E 06    0.6339E 06    0.6339E 06    0.6339E 06    0.6339E 06
24  CTE11    -0.6138E-07   -0.6138E-07   -0.6138E-07   -0.6138E-07   -0.6138E-07   -0.6138E-07   -0.6138E-07   -0.6138E-07
25  CTE22     0.2334E-04    0.2334E-04    0.2334E-04    0.2334E-04    0.2334E-04    0.2334E-04    0.2334E-04    0.2334E-04
26  CTE33     0.2334E-04    0.2334E-04    0.2334E-04    0.2334E-04    0.2334E-04    0.2334E-04    0.2334E-04    0.2334E-04
27  HK11      0.2906E 03    0.2906E 03    0.2906E 03    0.2906E 03    0.2906E 03    0.2906E 03    0.2906E 03    0.2906E 03
28  HK22      0.3715E 01    0.3715E 01    0.3715E 01    0.3715E 01    0.3715E 01    0.3715E 01    0.3715E 01    0.3715E 01
29  HK33      0.3715E 01    0.3715E 01    0.3715E 01    0.3715E 01    0.3715E 01    0.3715E 01    0.3715E 01    0.3715E 01
30  HCL       0.2043E 00    0.2043E 00    0.2043E 00    0.2043E 00    0.2043E 00    0.2043E 00    0.2043E 00    0.2043E 00
31  EL11      0.2528E 08    0.2528E 08    0.2528E 08    0.2528E 08    0.2528E 08    0.2528E 08    0.2528E 08    0.2528E 08
32  EL22      0.9597E 06    0.9597E 06    0.9597E 06    0.9597E 06    0.9597E 06    0.9597E 06    0.9597E 06    0.9597E 06
33  EL33      0.9597E 06    0.9597E 06    0.9597E 06    0.9597E 06    0.9597E 06    0.9597E 06    0.9597E 06    0.9597E 06
34  GL23      0.3405E 06    0.3405E 06    0.3405E 06    0.3405E 06    0.3405E 06    0.3405E 06    0.3405E 06    0.3405E 06
35  GL13      0.6339E 06    0.6339E 06    0.6339E 06    0.6339E 06    0.6339E 06    0.6339E 06    0.6339E 06    0.6339E 06
36  GL12      0.6339E 06    0.6339E 06    0.6339E 06    0.6339E 06    0.6339E 06    0.6339E 06    0.6339E 06    0.6339E 06
37  NUL12     0.2514E 00    0.2514E 00    0.2514E 00    0.2514E 00    0.2514E 00    0.2514E 00    0.2514E 00    0.2514E 00
38  NUL21     0.9541E-02    0.9541E-02    0.9541E-02    0.9541E-02    0.9541E-02    0.9541E-02    0.9541E-02    0.9541E-02
39  NUL13     0.2514E 00    0.2514E 00    0.2514E 00    0.2514E 00    0.2514E 00    0.2514E 00    0.2514E 00    0.2514E 00
40  NUL31     0.9541E-02    0.9541E-02    0.9541E-02    0.9541E-02    0.9541E-02    0.9541E-02    0.9541E-02    0.9541E-02
41  NUL23     0.4094E 00    0.4094E 00    0.4094E 00    0.4094E 00    0.4094E 00    0.4094E 00    0.4094E 00    0.4094E 00
42  NUL32     0.4094E 00    0.4094E 00    0.4094E 00    0.4094E 00    0.4094E 00    0.4094E 00    0.4094E 00    0.4094E 00
43  SMFK22    0.1522E 01    0.1522E 01    0.1522E 01    0.1522E 01    0.1522E 01    0.1522E 01    0.1522E 01    0.1522E 01
44  SMFD22    0.1918E 01    0.1918E 01    0.1918E 01    0.1918E 01    0.1918E 01    0.1918E 01    0.1918E 01    0.1918E 01
45  SMFS22    0.1386E 01    0.1384E 01    0.1382E 01    0.1379E 01    0.1379E 01    0.1382E 01    0.1384E 01    0.1386E 01
46  SMFC22   -0.0000E-19   -0.0000E-19   -0.0000E-19   -0.0000E-19   -0.0000E-19   -0.0000E-19   -0.0000E-19   -0.0000E-19
47  SMFS12    0.3024E 01    0.3024E 01    0.3024E 01    0.3024E 01    0.3024E 01    0.3024E 01    0.3024E 01    0.3024E 01
48  SMFS23    0.1396E 01    0.1396E 01    0.1396E 01    0.1396E 01    0.1396E 01    0.1396E 01    0.1396E 01    0.1396E 01
49  ILMFC    -0.0000E-19    0.7060E 02    0.7060E 02    0.7060E 02    0.7060E 02    0.7060E 02    0.7060E 02    0.7060E 02
50  TEMPD    -0.3000E 03   -0.3000E 03   -0.3000E 03   -0.3000E 03   -0.3000E 03   -0.3000E 03   -0.3000E 03   -0.3000E 03
51  LSC11T    0.9676E 05    0.9676E 05    0.9676E 05    0.9676E 05    0.9676E 05    0.9676E 05    0.9676E 05    0.9676E 05
52  LSC11C    0.5333E 05    0.5333E 05    0.5333E 05    0.5333E 05    0.5333E 05    0.5333E 05    0.5333E 05    0.5333E 05
53  LSC11D    0.6578E 05    0.6578E 05    0.6578E 05    0.6578E 05    0.6578E 05    0.6578E 05    0.6578E 05    0.6578E 05
54  LSC22T    0.3601E 04    0.3607E 04    0.3612E 04    0.3619E 04    0.3619E 04    0.3612E 04    0.3607E 04    0.3601E 04
55  LSC22C    0.1731E 05    0.1734E 05    0.1737E 05    0.1740E 05    0.1740E 05    0.1737E 05    0.1734E 05    0.1731E 05
56  LSC12     0.2547E 04    0.2547E 04    0.2547E 04    0.2547E 04    0.2547E 04    0.2547E 04    0.2547E 04    0.2547E 04
57  LSC23     0.1866E 04    0.1866E 04    0.1866E 04    0.1866E 04    0.1866E 04    0.1866E 04    0.1866E 04    0.1865E 04
58  LSCC23   -0.0000E-19   -0.0000E-19   -0.0000E-19   -0.0000E-19   -0.0000E-19   -0.0000E-19   -0.0000E-19   -0.0000E-19
59  LSCC13   -0.0000E-19   -0.0000E-19   -0.0000E-19   -0.0000E-19   -0.0000E-19   -0.0000E-19   -0.0000E-19   -0.0000E-19
60  LSCDF    -0.0000E-19    0.1052E-01    0.1052E-01    0.1052E-01    0.1052E-01    0.1052E-01    0.1052E-01    0.1052E-01
61  KL12AB    0.1371E 01    0.1371E 01    0.1371E 01    0.1371E 01    0.1371E 01    0.1371E 01    0.1371E 01    0.1371E 01
62  MDEIE    -0.7038E 01   -0.5461E 01   -0.4100E 01   -0.3201E 01   -0.3201E 01   -0.4100E 01   -0.5461E 01   -0.7038E 01
63  RELROT   -0.0000E-19    0.1000E 01    0.1000E 01    0.1000E 01    0.1000E 01    0.1000E 01    0.1000E 01    0.1000E 01
64  EPS11    -0.1172E-02   -0.6510E-03   -0.1302E-03    0.3905E-03    0.3905E-03   -0.1302E-03   -0.6510E-03   -0.1172E-02
65  EPS22     0.2473E-02    0.1953E-02    0.1432E-02    0.9112E-03    0.9112E-03    0.1432E-02    0.1953E-02    0.2473E-02
66  EPS12    -0.5351E-07   -0.4969E-07   -0.4587E-07   -0.4206E-07    0.4206E-07    0.4587E-07    0.4969E-07    0.5351E-07
67  SIG11    -0.2787E 05   -0.1480E 05   -0.1729E 04    0.1134E 05    0.1134E 05   -0.1729E 04   -0.1480E 05   -0.2787E 05
68  SIG22     0.8827E 04    0.8452E 04    0.8077E 04    0.7702E 04    0.7702E 04    0.8077E 04    0.8452E 04    0.8827E 04
69  SIG12    -0.3392E-01   -0.3150E-01   -0.2908E-01   -0.2666E-01    0.2666E-01    0.2908E-01    0.3150E-01    0.3392E-01
70  DELFI    -0.0000E-19   -0.4752E-08   -0.4090E-09    0.1839E-08    0.3581E-08   -0.3070E-09   -0.2927E-08   -0.5798E-08
71  HFC      -0.2624E 01   -0.2190E 01   -0.1829E 01   -0.1540E 01   -0.1540E 01   -0.1829E 01   -0.2190E 01   -0.2624E 01
```

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TABLE I. - SUMMARY OF DETAILS FOR PREPARING INPUT DATA CARDS. (See also tables II to IV.)

Card group[a]	Identification	Code symbol	Number of entries	List of entries, sequential order	Card field columns	Format		Comments and engineering units
						Type	Number	
1	Composite system card		2 to 3 words	Alphabatic characters	1 - 55	55H	4	
2	Data control card	NL, NPL, NPC, NFPE, NLC	5	N_l, N_{Pl}, N_{PC}, N_f, N_{lC}	1 - 25	5(15)	5	
3	Constituent materials elasti properties	EF11, etc., NUF12, etc., EF12, etc., EM11, etc., NUM12, etc., EM12, etc.	18	E_{f11}, E_{f22}, E_{f33}, ν_{f12}, ν_{f23}, ν_{f13}, G_{f12}, G_{f23}, G_{f13}, E_{m11}, E_{m22}, E_{m33}, ν_{m12}, ν_{m23}, ν_{m13}, G_{m12}, G_{m23}, G_{m13}	1 - 75	5(E15.8)	35	E, G in psi ν is Poisson's ratio
4	Correlation coefficients for elastic constants, expansion coefficients, and strain magnification factors	VCF(2×10)	20	β_m, β'_m, β''_m, $\tilde{\beta}_m$, β_ϵ, β'_ϵ, β''_ϵ, β_t, 0.0, 0.0; γ_m, γ'_m, γ''_m, $\tilde{\gamma}_m$, γ_ϵ, γ'_ϵ, γ''_ϵ, 0.0, 0.0, 0.0	1 - 75	5(E15.8)	35	Ratios evaluated by trail and success
5	Fiber thermal expansion coefficient	VAF(3)	3	α_{f11}, α_{f22}, α_{f33}	1 - 45	5(E15.8)	35	in./in./°F
6	Matrix thermal expansion coefficient	VAM(3)	3	α_{m11}, α_{m22}, α_{m33}	1 - 45	5(E15.8)	35	in./in./°F
7	Constituent materials heat conductivities	CHK(3×4)	12	K_{f11}, K_{f22}, K_{f33}, h_{cf}, K_{m11}, K_{m22}, K_{m33}, h_{cm}, 0.0, 0.0, 0.0, K_ν	1 - 75	5(E15.8)	35	$K - \frac{\text{Btu}}{(\text{hr})(\text{ft}^2)(^\circ\text{F/in.})}$
	Heat capacity							$H_c - \frac{\text{Btu}}{(\text{lb})(^\circ\text{F})}$
8	Correlation coefficients for heat conductivities	BTA(4)	4	$\beta_{k\nu}$, β_{k1}, β_{k2}, β_{k3}	1 - 60	5(E15.8)	35	Ratios evaluated by trial and success
9	Constant π	PIE	1	π-(numerical value)	1 - 15	5(E15.8)	35	Ratio
10	Boolean for thickness	TLINP	1	---------------------	1 - 6	L6	75	T (true) if ply thickness is input; otherwise F(false)
11	Boolean for membrane and bending symmetry	CSANB	1	---------------------	1 - 6	L6	75	T (true) if symmetry exists; otherwise F (false)
12	Boolean for interply layer energy contribution	BIDE	1	---------------------	1 - 6	L6	75	T (true) if contributions are desired; otherwise F (false)

13	Boolean for input displacements	RINDV	1	---------------------	1 - 6	L6	75	T (true) if displacements are inputs; otherwise F (false)
14	Composite angle, constituents densities, and fiber diameter	THES, RHOF, RHOM, DIAF	4	θ_{cs}, ρ_f, ρ_m, d_f	1 - 60	5(E15. 8)	35	θ_{cs} in degrees (measured from composite structural axes), ρ in lb/in.^{3}, d_f in in.
15	Ply void volume ratio	KVL(N_ℓ)	N_ℓ	$k_{v\ell}i$ $i = 1(1)N_\ell$	1 - 75	5(E15. 8)	35	Ratio
16	Ply fiber volume ratio	KFL(N_ℓ)	N_ℓ	$k_{f\ell}i$ $i = 1(1)N_\ell$	1 - 75	5(E15. 8)	35	Ratio
17	Ply orientation angle	THLC(N_ℓ)	N_ℓ	$\theta_\ell i$ $i = 1(1)N_\ell$	1 - 75	5(E15. 8)	35	Degrees measured from composite material axes
18	Ply thickness	TL(N_ℓ)	N_ℓ	$t_\ell i$ $i = 1(1)N_\ell$	1 - 75	5(E15. 8)	35	t_ℓ-inches (values should be read here for both TLINP = T or F
19	Ply temperature difference	PL(50, J)	N_ℓ	$\Delta T_{\ell i}$ $i = 1(1)N_\ell$	1 - 75	5(E15. 8)	35	ΔT_ℓ IN $^\circ$F
20	Correlation coefficients for strength	BET(2, 8)	20	β_{fT}, β_{mT}, β_{22T}, β_{12S}, β_{23S}, $\beta_{de\ell}$, $K'_{\ell 12TT}$, $K'_{\ell 12TC}$, β_{fC}, β_{mC}, β_{22C}, a_1, a_2, 1.0, $K'_{\ell 12CT}$, $K'_{\ell 12CC}$	1 - 75	5(E15. 8)	35	Ratios (determined by trial and success)
21	Constituents strength properties	SLC	6	S_{fT}, S_{mC}, ϵ_{mPT}, ϵ_{mPC}, ϵ_{mPS}, ϵ_{mPTOR}	1 - 75	5(E15. 8)	35	S - psi; ϵ - in. /in.
22	Membrane loads	NBS	$3N_{\ell C}$	$\overline{N}_{cxxj}$ $j = 1(1)N_{\ell C}$, $\overline{N}_{cyyj}$ $j = 1(1)N_{\ell C}$, $\overline{N}_{cxyj}$ $j = 1(1)N_{\ell C}$	1 - 75	5(E15. 8)	35	lb/in.
23	Moments	MBS	$3N_{\ell C}$	$\overline{M}_{cxxj}$ $j = 1(1)N_{\ell C}$, $\overline{M}_{cyyj}$ $j = 1(1)N_{\ell C}$, $\overline{M}_{cxyj}$ $j = 1(1)N_{\ell C}$	1 - 75	5(E15. 8)	35	(lb-in.)/in.
24	Displacements	DISVI	6 per $N_{\ell C}$	ϵ_{csxx}, ϵ_{csyy}, ϵ_{csxy}, w_{cbxx}, w_{cbyy}, w_{cbxy}	1 - 75	5(E15. 8)	35	U in in. ; W in radians

[a] See fig. 3.

TABLE II. - MULTILAYERED FIBER COMPOSITE ANALYSIS INPUT DATA SAMPLE

```
THORNEL-50/EPOXY

    8    71    54 1420     1

     .50000E+08     .10000E+07     .10000E+07     .20000E+00     .25000E+00
     .20000E+00     .13000E+07     .70000E+06     .13000E+07     .57000E+06
     .57000E+06     .57000E+06     .36000E+00     .36000E+00     .36000E+00
     .00000E+00     .00000E+06     .00000E+00

     .40000E+01     .20000E+01     .40000E+01     .20000E+01     .00000E+00
     .00000E+00     .00000E+00     .10000E+01     .00000E+00     .00000E+00
     .00000E+00     .00000E+00     .00000E+00     .00000E+00     .10000E+00
     .10000E+01     .10000E+01     .00000E+00     .00000E+00     .00000E+00

    -.55000E-06     .56000E-05     .56000E-05

     .42800E-04     .42800E-04     .42800E-04

     .58000E+03     .58000E+02     .58000E+02     .17000E+00     .12500E+01
     .12500E+01     .12500E+01     .25000E+00     .00000E+00     .00000E+00
     .00000E+00     .22500E+00

     .10000E+01     .10000E+01     .10500E+01     .10500E+01

     .31416E+01
```

TABLE II. - Continued. MULTILAYERED FIBER COMPOSITE ANALYSIS INPUT DATA SAMPLE

```
F

F

F

F
   .00000E+00   .05900E+00   .04430E+00   .00026E+00

   .00000E+00   .00000E+00   .00000E+00   .00000E+00   .00000E+00
   .00000E+00   .00000E+00   .00000E+00

   .50000E+00   .50000E+00   .50000E+00   .50000E+00   .50000E+00
   .50000E+00   .50000E+00   .50000E+00

   .00000E+00   .45000E+02  -.45000E+02   .90000E+02   .90000E+02
  -.45000E+02   .45000E+02   .00000E+00

   .00805E+00   .00805E+00   .00805E+00   .00805E+00   .00805E+00
   .00805E+00   .00805E+00   .00805E+00

  -.30000E+03  -.30000E+03  -.30000E+03  -.30000E+03  -.30000E+03
  -.30000E+03  -.30000E+03  -.30000E+03
```

TABLE II. - Concluded. MULTILAYERED FIBER COMPOSITE ANALYSIS INPUT DATA SAMPLE

```
.83000E+00    .10000E+00    .26000E+00    .27000E+00    .17000E+00
.16500E+02    .10000E+01    .10000E+01    .04650E+00    .10000E+01
.50000E+00    .13300E+02    .31900E+05    .10000E+01    .10000E+01
.10000E+01

.23000E+06    .21500E+05    .02000E+00    .05000E+00    .04500E+00
.04500E+00

.50000E+04    .00000E+00    .00000E+00

.10000E+03    .00000E+00    .00000E+00

.00000E+00    .00000E+00    .00000E+00    .00000E+00    .00000E+00
.00000E+00
```

TABLE III. - INPUT DATA FOR BORON/ALUMINUM COMPOSITE

```
BORON/ALUMINUM
    8   71   54    1    1
     .60000E.08     .60000E.08     .60000E.08     .20000E.00     .20000E.00
     .20000E.00     .00000E.00     .00000E.00     .00000E.00     .10000E.08
     .10000E.08     .10000E.08     .33000E.00     .33000E.00     .33000E.00
     .00000E.00     .00000E.00     .00000E.00
     .40000E.01     .20000E.01     .40000E.01     .20000E.01     .00000E.00
     .00000E.00     .00000E.00     .10000E.01     .00000E.00     .00000E.00
     .00000E.00     .00000E.00     .00000E.00     .00000E.00     .10000E.01
     .10000E.01     .10000E.01     .00000E.00     .00000E.00     .00000E.00
     .28000E-05     .28000E-05     .28000E-05
     .12900E-04     .12900E-04     .12900E-04
     .22300E.02     .22300E.02     .22300E.02     .31000E.00     .10040E.04
     .10040E.04     .10040E.04     .23000E.00     .00000E.00     .00000E.00
     .00000E.00     .22500E.00
     .10000E.01     .10000E.01     .10000E.01     .10000E.01
     .31416E.01
 F
 F
 F
 F
     .00000E.00     .08500E.00     .09800E.00     .00400E.00
    0.00000E.00    0.00000E.00    0.00000E.00    0.00000E.00    0.00000E.00
    0.00000E.00    0.00000E.00    0.00000E.00
    0.50000E.00    0.50000E.00    0.50000E.00    0.50000E.00    0.50000E.00
    0.50000E.00    0.50000E.00    0.50000E.00
     .00000E.00     .45000E.02    -.45000E.02     .90000E.02     .90000E.02
    -.45000E.02     .45000E.02     .00000E.00
     .00500E.00     .00500E.00     .00500E.00     .00500E.00     .00500E.00
     .00500E.00     .00500E.00     .00500E.00
   -0.90000E.03   -0.90000E.03   -0.90000E.03   -0.90000E.03   -0.90000E.03
   -0.90000E.03   -0.90000E.03   -0.90000E.03
     .56000E.00     .10000E.01     .31300E.00     .46200E.00     .30000E.00
     .29200E.01     .10000E.01     .10000E.01     .10000E.01     .10000E.01
     .34300E.00     .83300E.01     .52000E.05     .10000E.01     .10000E.01
     .10000E.01
     .46000E.06     .52000E.05     .00520E.00     .00520E.00     .00905E.00
     .00905E.00
     .50000E.04     .00000E.00     .00000E.00
     .10000E.03     .00000E.00     .00000E.00
    0.00000E.00    0.00000E.00    0.00000E.00    0.00000E.00    0.00000E.00
    0.00000E.00
```

TABLE IV. - INPUT DATA FOR BORON/EPOXY COMPOSITE

```
BORON/EPOXY
   8   71   54    1    1
    .60000E.08     .60000E.08     .60000E.08     .20000E.00     .20000E.00
    .20000E.00     .00000E.00     .00000E.00     .00000E.00     .56000E.06
    .56000E.06     .56000E.06     .35000E.00     .35000E.00     .35000E.00
    .00000E.00     .00000E.00     .00000E.00
    .40000E.01     .20000E.01     .40000E.01     .20000E.01     .00000E.00
    .00000E.00     .00000E.00     .10000E.01     .00000E.00     .00000E.00
    .00000E.00     .00000E.00     .00000E.00     .00000E.00     .10000E.01
    .10000E.01     .10000E.01     .00000E.00     .00000E.00     .00000E.00
    .28000E-05     .28000E-05     .28000E-05
    .32000E-04     .32000E-04     .32000E-04
    .22300E.02     .22300E.02     .22300E.02     .31000E.00     .17000E.01
    .17000E.01     .17000E.01     .25000E.00     .00000E.00     .00000E.00
    .00000E.00     .22500E.00
    .10000E.01     .10000E.01     .10000E.01     .10000E.01
    .31416E.01
 F
 F
 F
 F
    .00000E.00     .08500E.00     .04400E.00     .00400E.00
    .00000E.00     .00000E.00     .00000E.00     .00000E.00     .00000E.00
   0.00000E.00    0.00000E.00    0.00000E.00
   0.50000E.00    0.50000E.00    0.50000E.00    0.50000E.00    0.50000E.00
   0.50000E.00    0.50000E.00    0.50000E.00
    .00000E.00     .45000E.02    -.45000E.02     .90000E.02     .90000E.02
   -.45000E.02     .45000E.02     .00000E.00
    .00500E.00     .00500E.00     .00500E.00     .00500E.00     .00500E.00
    .00500E.00     .00500E.00     .00500E.00
  -0.30000E.03   -0.30000E.03   -0.30000E.03   -0.30000E.03   -0.30000E.03
  -0.30000E.03   -0.30000E.03   -0.30000E.03
    .84000E.00     .10000E.01     .90000E.00     .15000E.01     .10500E.01
    .16500E.02     .10000E.01     .10000E.01     .12000E.00     .10000E.01
    .12200E.01     .13300E.02     .31900E.05     .10000E.01     .10000E.01
    .10000E.01
    .46000E.06     .25000E.05     .02700E.00     .07000E.00     .05300E.00
    .05300E.00
    .50000E.04     .00000E.00     .00000E.00
    .10000E.03     .00000E.00     .00000E.00
   0.00000E.00    0.00000E.00    0.00000E.00    0.00000E.00    0.00000E.00
   0.00000E.00
```

TABLE V. - INPUT DATA FOR E-GLASS/EPOXY COMPOSITE

```
E-GLASS/EPOXY
   8   71   54  204    1
      .10600E.08      .10600E.08      .10600E.08      .22000E.00      .22000E.00
      .22000E.00      .00000E.00      .00000E.00      .00000E.00      .50000E.06
      .50000E.06      .50000E.06      .35000E.00      .35000E.00      .35000E.00
      .00000E.00      .00000E.00      .00000E.00
      .40000E.01      .20000E.01      .40000E.01      .20000E.01      .00000E.00
      .00000E.00      .00000E.00      .10000E.01      .00000E.00      .00000E.00
      .00000E.00      .00000E.00      .00000E.00      .00000E.00      .10000E.01
      .10000E.01      .10000E.01      .00000E.00      .00000E.00      .00000E.00
      .28000E-05      .28000E-05      .28000E-05
      .32000E-04      .32000E-04      .32000E-04
      .75000E.01      .75000E.01      .75000E.01      .17000E.00      .15000E.01
      .15000E.01      .15000E.01      .25000E.00      .00000E.00      .00000E.00
      .00000E.00      .22500E.00
      .10000E.01      .10000E.01      .90000E.00      .90000E.00
      .31416E.01
 F
 F
 F
 F
      .00000E.00      .09000E.00      .04000E.00      .36000E-03
      .00000E.00      .00000E.00      .00000E.00      .00000E.00      .00000E.00
     0.00000E.00     0.00000E.00     0.00000E.00
     0.50000E.00     0.50000E.00     0.50000E.00     0.50000E.00     0.50000E.00
     0.50000E.00     0.50000E.00     0.50000E.00
     -.45000E.02      .45000E.02      .00000E.00
     -.45000E.02      .45000E.02      .00000E.00
      .00800E.00      .00800E.00      .00800E.00      .00800E.00      .00800E.00
      .00800E.00      .00800E.00      .00800E.00
    -0.30000E.03    -0.30000E.03    -0.30000E.03    -0.30000E.03    -0.30000E.03
    -0.30000E.03    -0.30000E.03    -0.30000E.03    -
      .82000E.00      .10000E.01      .55000E.00      .86000E.00      .82000E.00
      .16500E.02      .10000E.01      .10000E.01      .33000E.00      .10000E.01
      .11000E.01      .13300E.02      .31900E.05      .10000E.01      .10000E.01
      .10000E.01
      .36000E.06      .25000E.05      .02000E.00      .05000E.00      .03500E.00
      .03500E.00
      .50000E.04      .00000E.00      .00000E.00
      .10000E.03      .00000E.00      .00000E.00
     0.00000E.00     0.00000E.00     0.00000E.00     0.00000E.00     0.00000E.00
     0.00000E.00
```

TABLE VI. - INPUT DATA FOR S-GLASS/EPOXY COMPOSITE

```
S-GLASS/EPOXY
   8   71   54  204    1
    .12400E.08     .12400E.08     .12400E.08     .22000E.00     .22000E.00
    .22000E.00     .00000E.00     .00000E.00     .00000E.00     .50000E.06
    .50000E.06     .50000E.06     .35000E.00     .35000E.00     .35000E.00
    .00000E.00     .00000E.00     .00000E.00
    .40000E.01     .20000E.01     .40000E.01     .20000E.01     .00000E.00
    .00000E.00     .00000E.00     .10000E.01     .00000E.00     .00000E.00
    .00000E.00     .00000E.00     .00000E.00     .00000E.00     .10000E.01
    .10000E.01     .10000E.01     .00000E.00     .00000E.00     .00000E.00
    .28000E-05     .28000E-05     .28000E-05
    .32000E-04     .32000E-04     .32000E-04
    .75000E.01     .75000E.01     .75000E.01     .17000E.00     .17000E.01
    .17000E.01     .17000E.01     .25000E.00     .00000E.00     .00000E.00
    .00000E.00     .22500E.00
    .10000E.01     .10000E.01     .90000E.00     .90000E.00
    .31416E.01
 F
 F
 F
 F
    .00000E.00     .09000E.00     .04000E.00     .36000E-03
    .00000E.00     .00000E.00     .00000E.00     .00000E.00     .00000E.00
   0.00000E.00    0.00000E.00    0.00000E.00
   0.50000E.00    0.50000E.00    0.50000E.00    0.50000E.00    0.50000E.00
   0.50000E.00    0.50000E.00    0.50000E.00
    .00000E.00     .45000E.02    -.45000E.02     .90000E.02     .90000E.02
   -.45000E.02     .45000E.02     .00000E.00
    .01290E.00     .01290E.00     .01290E.00     .01290E.00     .01290E.00
    .01290E.00     .01290E.00     .01290E.00
  -0.30000E.03   -0.30000E.03   -0.30000E.03   -0.30000E.03   -0.30000E.03
  -0.30000E.03   -0.30000E.03   -0.30000E.03
    .10000E.01     .10000E.01     .66000E.00     .13000E.01     .11000E.01
    .16500E.02     .10000E.01     .10000E.01     .55000E.00     .10000E.01
    .17000E.01     .13300E.02     .31900E.05     .10000E.01     .10000E.01
    .10000E.01
    .36000E.06     .25000E.05     .02000E.00     .05000E.00     .03500E.00
    .03500E.00
    .50000E.04     .00000E.00     .00000E.00
    .10000E.03     .00000E.00     .00000E.00
   0.00000E.00    0.00000E.00    0.00000E.00    0.00000E.00    0.00000E.00
   0.00000E.00
```

TABLE VII. - INPUT DATA FOR THORNEL-25/EPOXY COMPOSITE

```
THORNEL-25/EPOXY
    8   71   54 1440    1
     .25000E.08     .20000E.07     .20000E.07     .20000E.00     .25000E.00
     .20000E.00     .20000E.07     .80000E.06     .20000E.07     .54000E.06
     .54600E.06     .54600E.06     .36000E.00     .36000E.00     .36000E.00
     .00000E.00     .00000E.00     .00000E.00
     .40000E.01     .20000E.01     .40000E.01     .20000E.01     .10000E.01
     .00000E.00     .00000E.00     .10000E.01     .00000E.00     .00000E.00
     .00000E.00     .00000E.00     .00000E.00     .00000E.00     .10000E.01
     .10000E.01     .10000E.01     .00000E.00     .00000E.00     .00000E.00
    -.55000E-06     .56000E-05     .56000E-05
     .42800E-04     .42800E-04     .42000E-04
     .58000E.03     .58000E.02     .58000E.02     .17000E.00     .12500E.01
     .12500E.01     .12500E.01     .25000E.00     .00000E.00     .00000E.00
     .00000E.00     .22500E.00
     .10000E.01     .10000E.01     .10500E.01     .10500E.01
     .31415E.01
 F
 F
 F
 F
     .00000E.00     .05200E.00     .04430E.00     .00029E.00
     .00000E.00     .00000E.00     .00000E.00     .00000E.00
    0.00000E.00    0.00000E.00    0.00000E.00
    0.50000E.00    0.50000E.00    0.50000E.00    0.50000E.00    0.50000E.00
    0.50000E.00    0.50000E.00    0.50000E.00
     .00000E.00     .45000E.02    -.45000E.02     .90000E.02     .90000E.02
    -.45000E.02     .45000E.02     .00000E.00
     .01300E.00     .01300E.00     .01300E.00     .01300E.02     .01300E.02
     .01300E.00     .01300E.00     .01300E.00
   -0.30000E.03   -0.30000E.03   -0.30000E.03   -0.30000E.03   -0.30000E.03
   -0.30000E.03   -0.30000E.03   -0.30000E.03
     .10000E.01     .10000E.01     .50000E-01     .48000E.00     .38000E.00
     .16500E.02     .10000E.01     .10000E.01     .12000E.00     .10000E.01
     .49000E.00     .13300E.02     .31900E.05     .10000E.01     .10000E.01
     .10000E.01
     .18000E.06     .21000E.05     .02000E.00     .05000E.00     .04500E.00
     .04500E.00
     .50000E.04     .00000E.00     .00000E.00
     .10000E.03     .00000E.00     .00000E.00
    0.00000E.00    0.00000E.00    0.00000E.00    0.00000E.00    0.00000E.00
    0.00000E.00
```

TABLE VIII. - INPUT DATA FOR THORNEL-40/EPOXY COMPOSITE

```
THORNEL-40/EPOXY
   8   71   54 1440    1
     .40000E.08     .11000E.07     .11000E.07     .20000E.00     .25000E.00
     .20000E.00     .15000E.07     .80000E.06     .15000E.07     .50000E.06
     .50000E.06     .50000E.06     .35000E.00     .35000E.00     .35000E.00
     .00000E.00     .00000E.00     .00000E.00
     .40000E.01     .20000E.01     .40000E.01     .20000E.01     .00000E.00
     .00000E.00     .00000E.00     .10000E.01     .00000E.00     .00000E.00
     .00000E.00     .00000E.00     .00000E.00     .00000E.00     .10000E.01
     .10000E.01     .10000E.01     .00000E.00     .00000E.00     .00000E.00
    -.55000E-06     .56000E-05     .56000E-05
     .42800E-04     .42800E-04     .42800E-04
     .58000E.03     .58000E.02     .58000E.02     .17000E.00     .12500E.01
     .12500E.01     .12500E.01     .25000E.00     .00000E.00     .00000E.00
     .00000E.00     .22500E.00
     .10000E.01     .10000E.01     .10500E.01     .10500E.01
     .31416E.01
 F
 F
 F
 F
     .00000E.00     .05600E.00     .04430E.00     .00027E.00
     .00000E.00     .00000E.00     .00000E.00     .00000E.00     .00000E.00
    0.00000E.00    0.00000E.00    0.00000E.00
    0.50000E.00    0.50000E.00    0.50000E.00    0.50000E.00    0.50000E.00
    0.50000E.00    0.50000E.00    0.50000E.00
     .00000E.00     .45000E.02    -.45000E.02     .90000E.02     .90000E.02
    -.45000E.02     .45000E.02     .00000E.00
     .00900E.00     .00900E.00     .00900E.00     .00900E.00     .00900E.00
     .00900E.00     .00900E.00     .00900E.00
   -0.30000E.03   -0.30000E.03   -0.30000E.03   -0.30000E.03   -0.30000E.03
   -0.30000E.03   -0.30000E.03   -0.30000E.03
     .84000E.00     .10000E.01     .08500E.00     .46000E.00     .27000E.00
     .16500E.02     .10000E.01     .10000E.01     .08000E.00     .10000E.01
     .50000E.00     .13300E.02     .31900E.05     .10000E.01     .10000E.01
     .10000E.01
     .25000E.06     .21000E.05     .02000E.00     .05000E.00     .04500E.00
     .04500E.00
     .50000E.04     .00000E.00     .00000E.00
     .10000E.03     .00000E.00     .00000E.00
    0.00000E.00    0.00000E.00    0.00000E.00    0.00000E.00    0.00000E.00
    0.00000E.00
```

TABLE IX. - INPUT DATA FOR THORNEL-50/EPOXY COMPOSITE

```
THORNEL-50/EPOXY
   8   71    54 1420       1
    .50000E.08     .10000E.07     .10000E.07     .20000E.00     .25000E.00
    .20000E.00     .13000E.07     .70000E.06     .13000E.07     .57000E.06
    .57000E.06     .57000E.06     .36000E.00     .36000E.00     .36000E.00
    .00000E.00     .00000E.00     .00000E.00
    .40000E.01     .20000E.01     .40000E.01     .20000E.01     .00000E.00
    .00000E.00     .00000E.00     .23560E.01     .00000E.00     .00000E.00
    .00000E.00     .00000E.00     .00000E.00     .00000E.00     .10000E.01
    .10000E.01     .10000E.01     .00000E.00     .00000E.00     .00000E.00
   -.55000E-06     .56000E-05     .56000E-05
    .42800E-04     .42800E-04     .42800E-04
    .58000E.03     .58000E.02     .58000E.02     .17000E.00     .12500E.01
    .12500E.01     .12500E.01     .25000E.00     .00000E.00     .00000E.00
    .00000E.00     .22500E.00
    .10000E.01     .10000E.01     .10500E.01     .10500E.01
    .31416E.01
 F
 F
 F
 F
    .00000E.00     .05900E.00     .04430E.00     .00026E.00
    .00000E.00     .00000E.00     .00000E.00     .00000E.00     .00000E.00
   0.00000E.00    0.00000E.00    0.00000E.00
   0.50000E.00    0.50000E.00    0.50000E.00    0.50000E.00    0.50000E.00
   0.50000E.00    0.50000E.00    0.50000E.00
    .00000E.00     .45000E.02    -.45000E.02     .90000E.02     .90000E.02
   -.45000E.02     .45000E.02     .00000E.00
    .00805E.00     .00805E.00     .00800E.00     .00800E.00     .00800E.00
    .00805E.00     .00805E.00     .00800E.00
  -0.30000E.03   -0.30000E.03   -0.30000E.03   -0.30000E.03   -0.30000E.03
  -0.30000E.03   -0.30000E.03   -0.30000E.03
    .83000E.00     .10000E.01     .26000E.00     .27000E.00     .17000E.00
    .16500E.02     .10000E.01     .10000E.01     .04650E.00     .10000E.01
    .50000E.00     .13300E.02     .31900E.05     .10000E.01     .10000E.01
    .10000E.01
    .23000E.06     .21000E.05     .02000E.00     .05000E.00     .04500E.00
    .04500E.00
    .50000E.04     .00000E.00     .00000E.00
    .10000E.03     .00000E.00     .00000E.00
   0.00000E.00    0.00000E.00    0.00000E.00    0.00000E.00    0.00000E.00
   0.00000E.00
```

TABLE X. - INPUT DATA FOR MODMOR-I/EPOXY COMPOSITE

```
MODMOR-I/EPOXY
   8   71   5410000     1
    .60000E.08    .09000E.07    .09000E.07    .20000E.00    .25000E.00
    .20000E.00    .11000E.07    .70000E.06    .11000E.07    .50000E.06
    .50000E.06    .50000E.06    .35000E.00    .35000E.00    .35000E.00
    .00000E.00    .00000E.00    .00000E.00
    .40000E.01    .20000E.01    .40000E.01    .20000E.01    .00000E.00
    .00000E.00    .00000E.00    .10000E.01    .00000E.00    .00000E.00
    .00000E.00    .00000E.00    .00000E.00    .00000E.00    .10000E.01
    .10000E.01    .10000E.01    .00000E.00    .00000E.00    .00000E.00
   -.55000E-06    .56000E-05    .56000E-05
    .42800E-04    .42800E-04    .42800E-04
    .58000E.03    .58000E.02    .58000E.02    .17000E.00    .12500E.01
    .12500E.01    .12500E.01    .25000E.00    .00000E.00    .00000E.00
    .00000E.00    .22500E.00
    .10000E.01    .10000E.01    .10500E.01    .10500E.01
    .31416E.01
 F
 F
 F
 F
    .00000E.00    .07200E.00    .04430E.00    .00030E.00
    .00000E.00    .00000E.00    .00000E.00    .00000E.00    .00000E.00
   0.00000E.00   0.00000E.00   0.00000E.00
   0.50000E.00   0.50000E.00   0.50000E.00   0.50000E.00   0.50000E.00
   0.50000E.00   0.50000E.00   0.50000E.00
    .00000E.00    .45000E.02   -.45000E.02    .90000E.02    .90000E.02
   -.45000E.02    .45000E.02    .00000E.00
    .01190E.00    .01190E.00    .01190E.00    .01190E.00    .01190E.00
    .01190E.00    .01190E.00    .01190E.00
  -0.30000E.03  -0.30000E.03  -0.30000E.03  -0.30000E.03  -0.30000E.03
  -0.30000E.03  -0.30000E.03  -0.30000E.03
    .10000E.01    .10000E.01    .50000E.00    .91000E.00    .50000E.00
    .16500E.02    .10000E.01    .10000E.01    .09200E.00    .10000E.01
    .65000E.00    .13300E.02    .31900E.05    .10000E.01    .10000E.01
    .10000E.01
    .25000E.06    .21000E.05    .02000E.00    .05000E.00    .04500E.00
    .04500E.00
    .50000E.04    .00000E.00    .00000E.00
    .10000E.03    .00000E.00    .00000E.00
   0.00000E.00   0.00000E.00   0.00000E.00   0.00000E.00   0.00000E.00
   0.00000E.00
```

TABLE XI. - INPUT DATA FOR MODMOR-II/EPOXY COMPOSITE

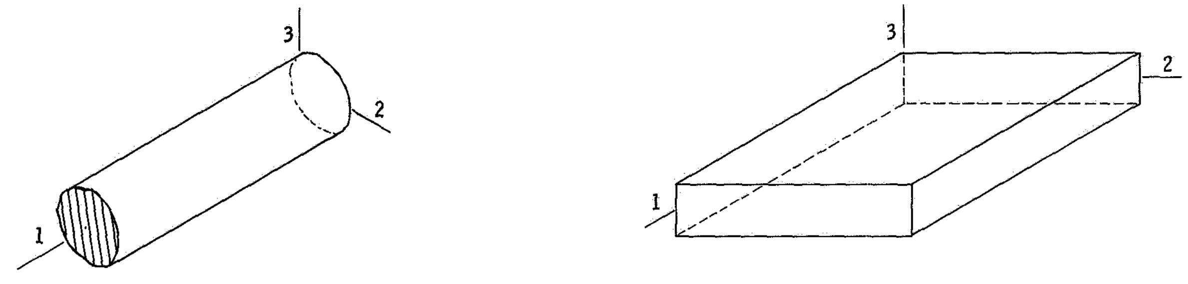
```
MODMOR-II/EPOXY
   8   71    5410000     1
    .38000E.08     .11000E.07     .11000E.07     .20000E.00     .25000E.00
    .20000E.00     .15000E.07     .80000E.06     .15000E.07     .50000E.06
    .50000E.06     .50000E.06     .35000E.00     .35000E.00     .35000E.00
    .00000E.00     .00000E.00     .00000E.00
    .40000E.01     .20000E.01     .40000E.01     .20000E.01     .00000E.00
    .00000E.00     .00000E.00     .10000E.01     .00000E.00     .00000E.00
    .00000E.00     .00000E.00     .00000E.00     .00000E.00     .10000E.01
    .10000E.01     .10000E.01     .00000E.00     .00000E.00     .00000E.00
   -.55000E-06     .56000E-05     .56000E-05
    .42800E-04     .42800E-04     .42800E-04
    .58000E.03     .58000E.02     .58000E.02     .17000E.00     .12500E.01
    .12500E.01     .12500E.01     .25000E.00     .00000E.00     .00000E.00
    .00000E.00     .22500E.00
    .10000E.01     .10000E.01     .10500E.01     .10500E.01
    .31416E.01
    .00000E.00     .06300E.00     .04430E.00     .00030E.00
 F
 F
 F
 F
    .00000E.00     .00000E.00     .00000E.00     .00000E.00     .00000E.00
    .00000E.00     .00000E.00     .00000E.00
   0.50000E.00    0.50000E.00    0.50000E.00    0.50000E.00    0.50000E.00
   0.50000E.00    0.50000E.00    0.50000E.00
    .00000E.00     .45000E.02    -.45000E.02     .90000E.02     .90000E.02
   -.45000E.02     .45000E.02     .00000E.00
    .01190E.00     .01190E.00     .01190E.00     .01190E.00     .01190E.00
    .01190E.00     .01190E.00     .01190E.00
  -0.30000E.03   -0.30000E.03   -0.30000E.03   -0.30000E.03   -0.30000E.03
  -0.30000E.03   -0.30000E.03   -0.30000E.03
    .84000E.00     .10000E.01     .70000E.00     .13700E.01     .80000E.00
    .16500E.02     .10000E.01     .10000E.01     .16000E.00     .10000E.01
    .70000E.00     .13300E.02     .31900E.05     .10000E.01     .10000E.01
    .10000E.01
    .35000E.06     .21000E.05     .02000E.00     .05000E.00     .04500E.00
    .04500E.00
    .50000E.04     .00000E.00     .00000E.00
    .10000E.03     .00000E.00     .00000E.00
   0.00000E.00    0.00000E.00    0.00000E.00    0.00000E.00    0.00000E.00
   0.00000E.00
```

TABLE XII. - INPUT DATA FOR BERYLLIUM/EPOXY COMPOSITE

```
BERYLLIUM/EPOXY
   8   71   54    1    1
    .44000E.08     .44000E.08     .44000E.08     .10000E.00     .10000E.00
    .10000E.00     .00000E.00     .00000E.00     .00000E.00     .52000E.06
    .52000E.06     .52000E.06     .35000E.00     .35000E.00     .35000E.00
    .00000E.00     .00000E.00     .00000E.00
    .40000E.01     .20000E.01     .40000E.01     .20000E.01     .00000E.00
    .00000E.00     .00000E.00     .10000E.01     .00000E.00     .00000E.00
    .00000E.00     .00000E.00     .00000E.00     .00000E.00     .10000E.01
    .10000E.01     .10000E.01     .00000E.00     .00000E.00     .00000E.00
    .64000E-05     .64000E-05     .64000E-05
    .32000E-04     .32000E-04     .32000E-04
    .10440E.04     .10440E.04     .10440E.04     .45000E.00     .17000E.01
    .17000E.01     .17000E.01     .25000E.00     .00000E.00     .00000E.00
    .00000E.00     .22500E.00
    .10000E.01     .10000E.01     .10000E.01     .10000E.01
    .31416E.01
 F
 F
 F
 F
    .00000E.00     .05700E.00     .04400E.00     .00500E.00
    .00000E.00     .00000E.00     .00000E.00     .00000E.00     .00000E.00
   0.00000E.00    0.00000E.00    0.00000E.00
   0.50000E.00    0.50000E.00    0.50000E.00    0.50000E.00    0.50000E.00
   0.50000E.00    0.50000E.00    0.50000E.00
    .00000E.00     .45000E.02    -.45000E.02     .90000E.02     .90000E.02
   -.45000E.02     .45000E.02     .00000E.00
    .00500E.00     .00500E.00     .00500E.00     .00500E.00     .00500E.00
    .00500E.00     .00500E.00     .00500E.00
  -0.30000E.03   -0.30000E.03   -0.30000E.03   -0.30000E.03   -0.30000E.03
  -0.30000E.03   -0.30000E.03   -0.30000E.03
    .10000E.01     .10000E.01     .53000E.00     .14000E.01     .10500E.01
    .16500E.02     .10000E.01     .10000E.01     .05200E.00     .10000E.01
    .90000E.00     .13300E.02     .31900E.05     .10000E.01     .10000E.01
    .10000E.01
    .13300E.06     .25000E.05     .02700E.00     .07000E.00     .05300E.00
    .05300E.00
    .50000E.04     .00000E.00     .00000E.00
    .10000E.03     .00000E.00     .00000E.00
   0.00000E.00    0.00000E.00    0.00000E.00    0.00000E.00    0.00000E.00
   0.00000E.00
```

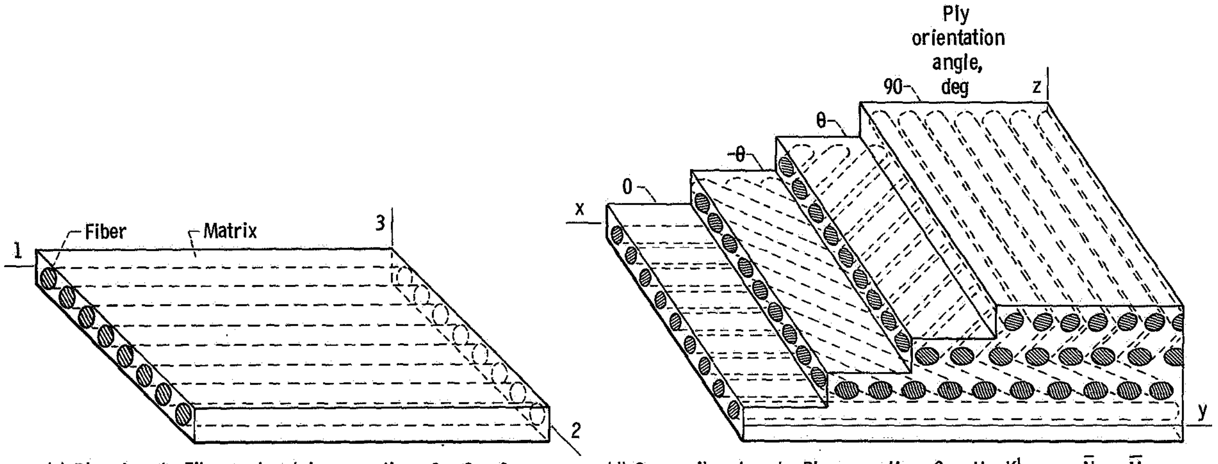
TABLE XIII. - INPUT-OUTPUT FORMAT IDENTIFICATION FOR INPUT DATA

Card first entry	Format statement number (see compiled listing)			Comments
	Output heading	Read	Write	
THORNEL 50/EPOXY	---	4	4	Composite system
NL	11	5	10	Integers
EF11 EM11	70	35	37	Fiber and matrix elastic constants are read in one statement
VCF	41	35	37	Correlation coefficients for thermoelastic
VAF	40	35	37	Fiber thermal coefficients of expansion
VAM	45	35	37	Matrix thermal coefficients of expansion
CHK	55	35	37	Constituent heat conductivities and capacities
BTA	60	35	37	Correlation coefficients for conductivities
PIE	65	35	37	Constant π
TLINP	80	75	75	Boolean for thickness
CSANB	85	75	75	Boolean for bending symmetry
BIDE	87	75	75	Boolean for interply layer effects
RINDV	88	75	75	Boolean for load conditions
THCS	90	35	37	Load angle, densities, equivalent fiber diameter
KVL	95	35	37	Ply void content
KFL	100	35	37	Ply fiber content
THCL	105	35	37	Ply orientation angle
TL	110	35	37	Ply thickness
PTEMP	111	35	37	Ply temperature
BET	115	35	37	Adjustment factors for limit conditions
LSC	120	35	37	Limit conditions - stress, strain
NBS	130	35	37	Load conditions - membrane forces
MBS	131	35	37	Load conditions - bending moments
DISV1	132	35	37	Displacements



(a) Fiber. Properties needed: $E_{f11,22,33}$; $\nu_{f12,23,13}$; $G_{f12,23,13}$; $\alpha_{f11,22,33}$; $K_{f11,22,33}$; H_{cf}, ρ_f, N_f; d_f; S_{ft}.

(b) Matrix. Properties needed: $E_{m11,22,33}$; $\nu_{m12,23,13}$; $G_{f12,23,13}$; $\alpha_{m11,22,33}$; $K_{m11,22,33}$; H_{cm}, ρ_m, S_{mc}, e_{mpt}, e_{mpc}, e_{mps}, e_{mpTOR}.



(c) Ply. Input: Fiber and matrix properties: β_e, β_h, β_s, ΔT. Properties computed: $E_{\ell 11,22,33}$; $\nu_{\ell 12,23,13}$; $G_{\ell 12,23,13}$; $\alpha_{\ell 11,22,33}$; $K_{\ell 11,22,33}$; $H_{c\ell}$, ρ_ℓ, t_ℓ, δ_ℓ, $S_{\ell 11T,11C,22T,22C,12S,23S}$; $K_{\ell 12}$. Stress analysis: $\epsilon_{\ell 11,22,12}$; $\sigma_{\ell 11,22,12}$; $1.0 - F(\sigma, S, K_{\ell 12})$.

(d) Composite. Input: Ply properties; $\theta_{\ell i}$; H_j, $K'_{\ell 12\alpha\beta}$; $\bar{N}_{cx}$, $\bar{M}_{cx}$ or U_{cx}, W_{cx}. Output: $\{\epsilon_{cx}\} = [E_c]\{\sigma_c\} + \Delta T\{\alpha_c\}$; $[E_c]^{-1}$; $K_{cxx,yy,xy}$, H_c, $\begin{Bmatrix}\bar{N}_{cx}\\ \bar{M}_{cx}\end{Bmatrix} = \begin{bmatrix}A_{cx}C_{cx}\\ C_{cx}D_{cx}\end{bmatrix}\begin{Bmatrix}U_{cx}\\ W_{cx}\end{Bmatrix} + \begin{Bmatrix}N_{cx\Delta T}\\ M_{cx\Delta T}\end{Bmatrix}$ and the inverse, $\Delta\varphi_{de\ell j}$.

Figure 1. - Typical multilayered fiber composite and some basic definitions.

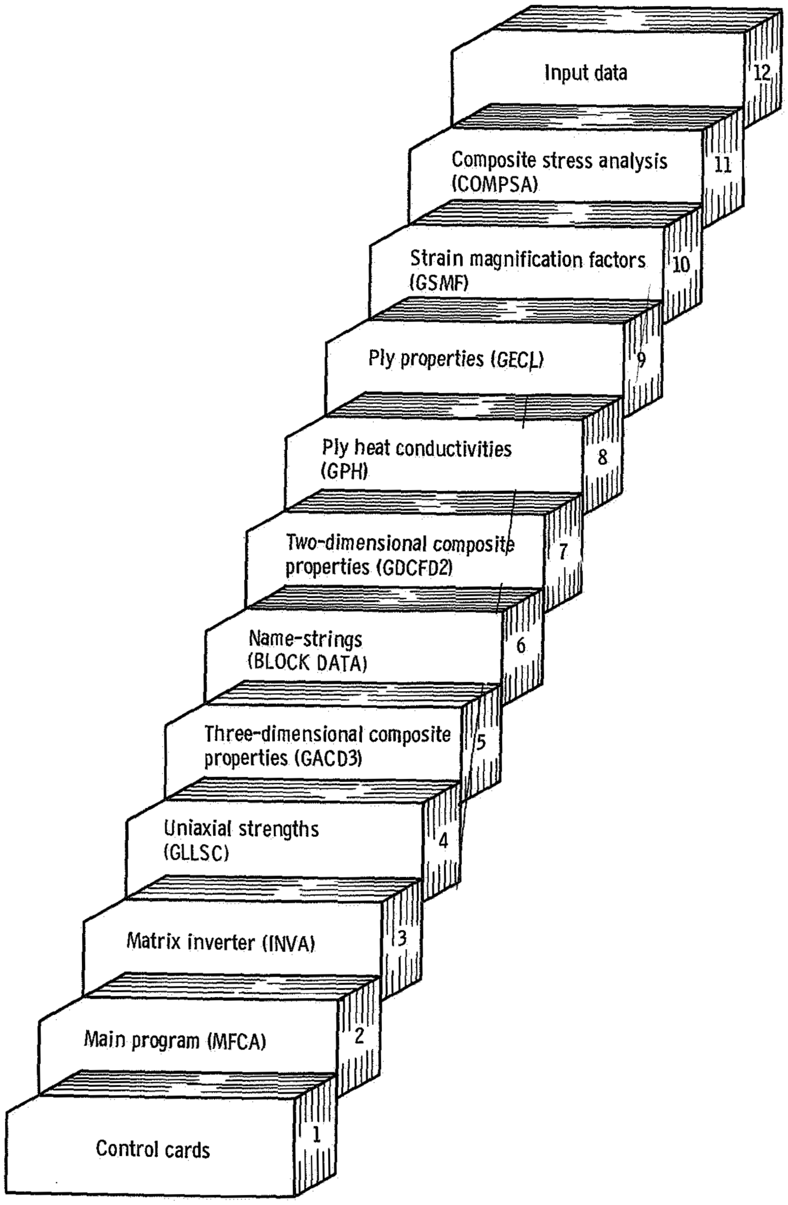


Figure 2. - Code physical arrangement.

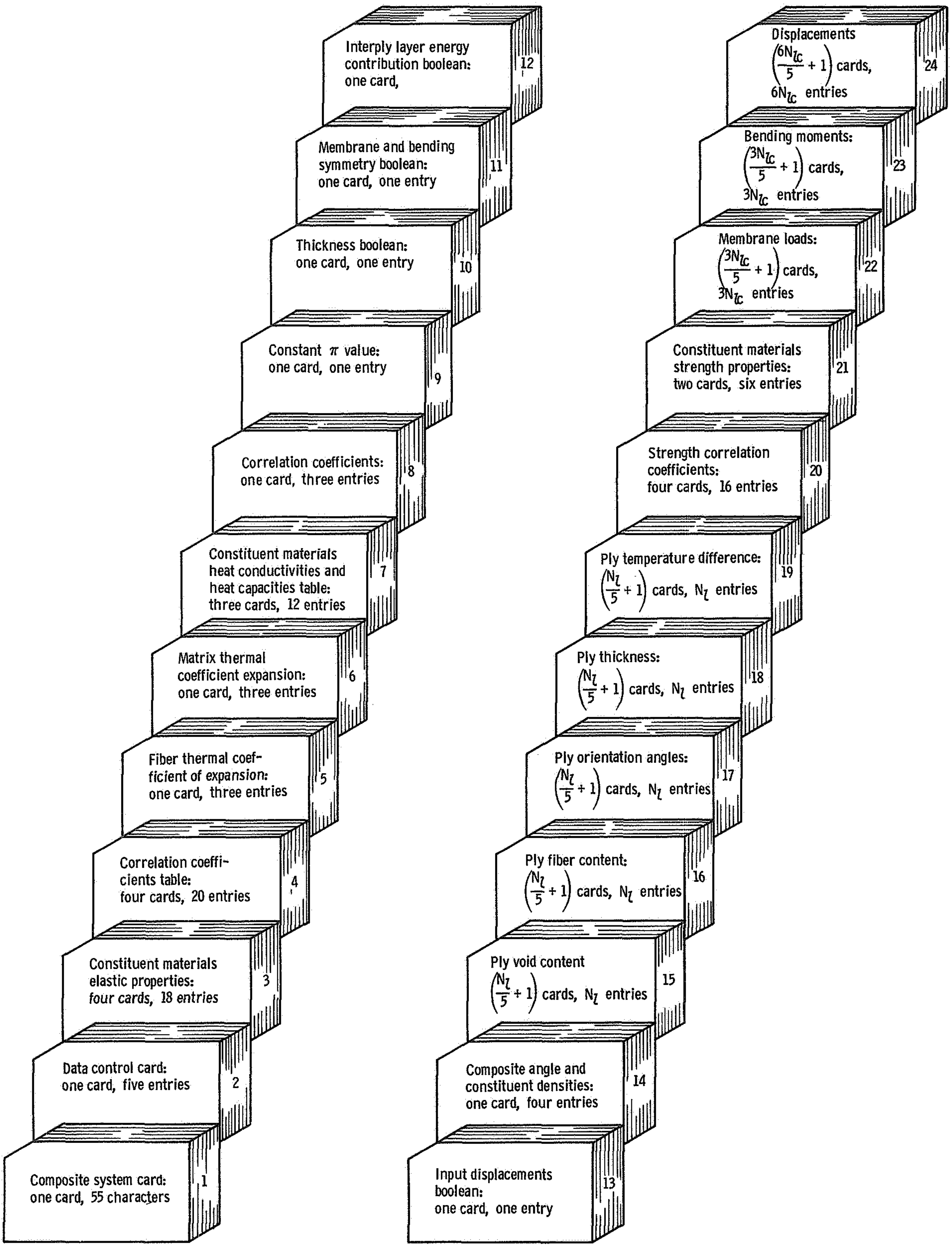


Figure 3. - Physical arrangement of input data cards.

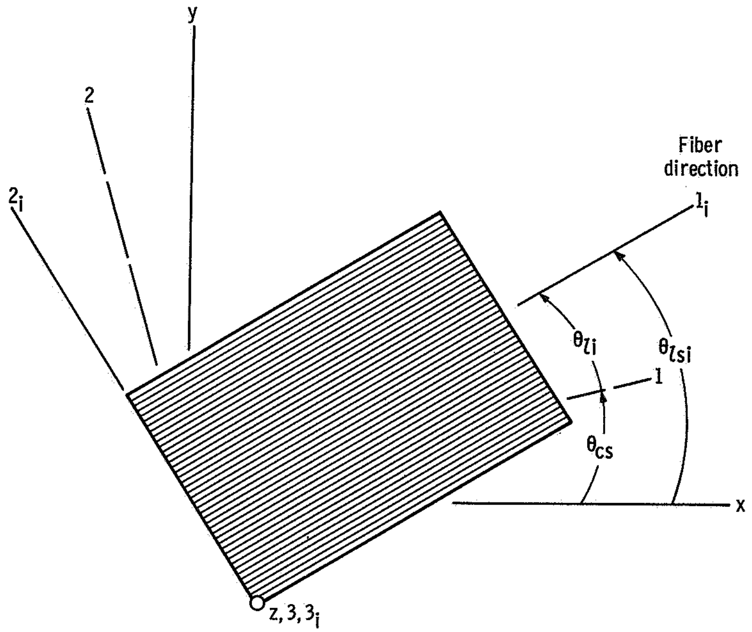


Figure 5. - Ply orientation geometry. Composite structural axes, x, y, z; composite material axes, 1, 2, 3; ply material axes (coincides with fiber direction, $1_i, 2_i, 3_i$).

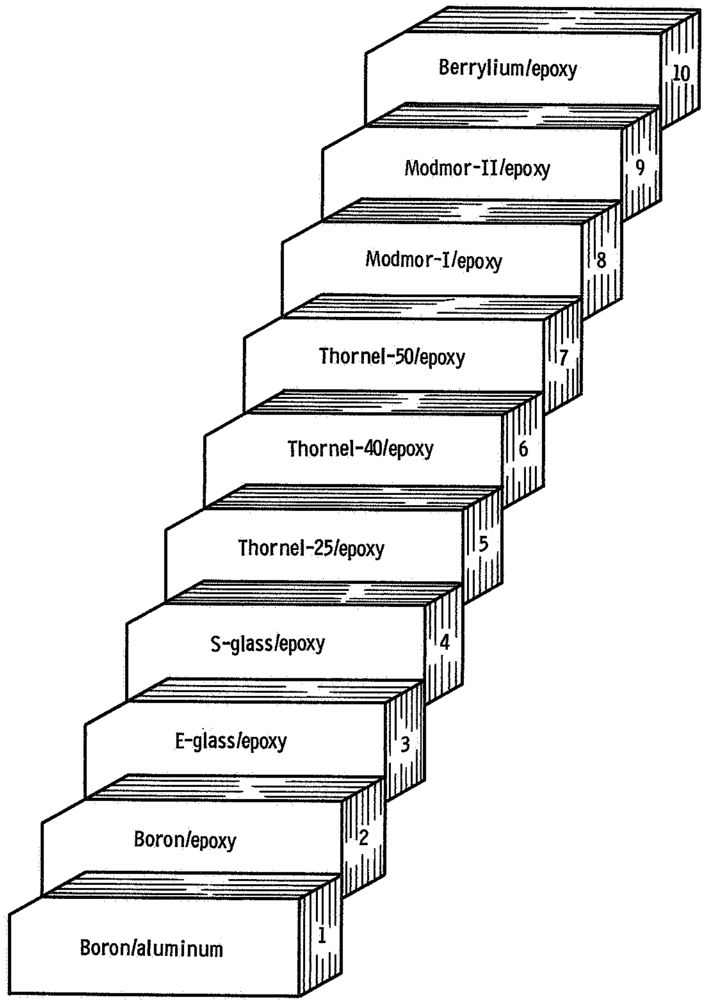


Figure 4. - Composite systems for which input data are supplied.

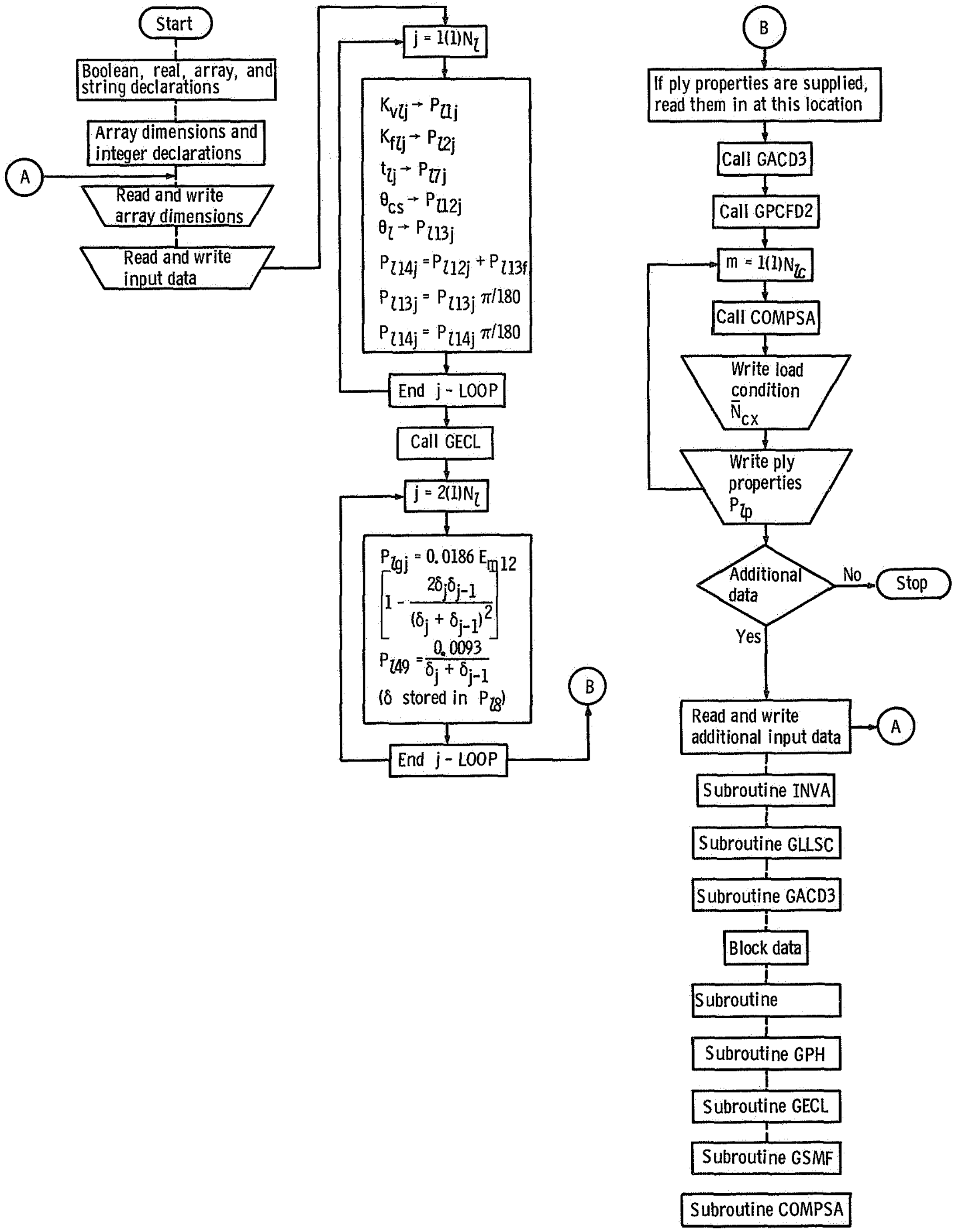


Figure 6. - Code MAIN PROGRAM flow chart.

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> — NATIONAL AERONAUTICS AND SPACE ACT OF 1958

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