Vol. 1 Programming Manual

Expansion and Improvement of the FORMA System for Response and Load Analysis

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EXPANSION AND IMPROVEMENT OF THE FORMA
SYSTEM FOR RESPONSE AND LOAD ANALYSIS

Volume I - Programming Manual

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FOREWORD

This report presents results of the expansion and improvement of the FORMA system for response and load analysis. The acronym FORMA stands for FORTRAN Matrix Analysis. The study, performed from 16 May 1975 through 17 May 1976 was conducted by the Analytical Mechanics Department, Martin Marietta Corporation, Denver Division, under the contract NAS8-31376. The program was administered by the National Aeronautics and Space Administration, George C. Marshall Space Flight Center, Huntsville, Alabama under the direction of Dr. John R. Admire, Structural Dynamics Division, Systems Dynamics Laboratory.

This report is published in seven volumes:

Volume I - Programming Manual,
Volume IIA - Listings, Dense FORMA Subroutines,
Volume IIB - Listings, Sparse FORMA Subroutines,
Volume IIC - Listings, Finite Element FORMA Subroutines,
Volume IIIA - Explanations, Dense FORMA Subroutines,
Volume IIIB - Explanations, Sparse FORMA Subroutines, and
Volume IIIC - Explanations, Finite Element FORMA Subroutines.
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ABSTRACT

This report presents techniques for the solution of structural dynamic systems on an electronic digital computer using FORMA (FORTRAN Matrix Analysis).

FORMA is a library of subroutines coded in FORTRAN IV for the efficient solution of structural dynamics problems. These subroutines are in the form of building blocks that can be put together to solve a large variety of structural dynamics problems. The obvious advantage of the building block approach is that programming and checkout time are limited to that required for putting the blocks together in the proper order.

The FORMA method has advantageous features such as:

1. subroutines in the library have been used extensively for many years and as a result are well checked out and debugged;
2. method will work on any computer with a FORTRAN IV compiler;
3. incorporation of new subroutines is no problem;
4. basic FORTRAN statements may be used to give extreme flexibility in writing a program.

Two programming techniques are used in FORMA: dense and sparse.
ACKNOWLEDGMENTS

The editor expresses his appreciation to those individuals whose assistance was necessary for the successful completion of this report. Dr. John R. Admire was instrumental in the definition of the program scope and contributed many valuable suggestions. Messrs. Carl Bodley, Wilcomb Benfield, Darrell Devers, Richard Hruda, Roger Philippus, and Herbert Wilkening, all of the Analytical Mechanics Department, Denver Division of Martin Marietta Corporation, have contributed ideas, as well as subroutines, in the formulation of the FORMA library.

The editor also expresses his appreciation to those persons who developed FORTRAN, particularly the subroutine concept of that programming tool.
The formulation and solution of most structural dynamics problems involves the use of matrix analysis and an electronic digital computer. Matrix analysis is used because it allows complicated arithmetical operations to be formulated systematically and provides a compact form of bookkeeping. The electronic digital computer is used in the solution of the problem because of its low cost per calculation.

After the analyst has formulated a problem in matrix notation, he is faced with the practical consideration of obtaining numerical answers using numerical input to the equation. The analyst must therefore translate (i.e., program) the equations into a form recognizable by the computer. Two computer programming approaches are available to the analyst. One is to program the computer to solve a specific type problem using a basic programming language such as ALGOL or FORTRAN. This approach can yield a very efficient computer program but the development of such a program is very time consuming. Thus, such an approach is practical only if the program will be used extensively. The second approach involves a library of matrix analysis operations in subroutine form that allows the analyst to set up his own program using a "building block" concept. This second approach allows the acquisition of quick results from problems of quite different types and is the approach considered in this report.

The validity of the second approach becomes evident from a study of structural dynamic analysis methods. This study reveals that for most types of problems, the mathematical operations required for solutions are limited in number. Thus, these mathematical operations can be programmed in the form of computer subroutines resulting in a library of "building blocks" that can be put together to solve a large variety of structural dynamics problems. The obvious advantage of the building block approach is that the only programming and checkout time required is putting the necessary blocks together in the proper order.

The building block approach described in this report uses FORTRAN call statements with subroutines from a library of subroutines entitled FORMA (FORTRAN Matrix Analysis). Development of subroutines in the FORMA library was started in 1964 by engineers in the Dynamics and Loads Section of Martin Marietta Corporation, Denver Division, to solve a wide variety of structural dynamics analyses of aerospace vehicles such as the Titan booster and Skylab orbiting laboratory. These subroutines were programmed specifically for the solution of small and medium size structural dynamics problems of up to approximately 150 degrees of freedom. Since this beginning, the FORMA library has been expanded to include the solution of large size structural dynamics problems of up to approximately 6000 degrees of freedom. These subroutines for the analysis of large size structures have been used by engineers in the Dynamics
and Loads Section in the analysis of Viking and Space Shuttle. The FORMA library as included here consists of over 200 subroutines. Listing and explanations of these subroutines are given in Volumes II and III respectively. A division is made in those two volumes for dense programming logic subroutines, sparse programming logic subroutines and finite element subroutines.

The FORMA library includes subroutines for mass matrix calculations, stiffness matrix calculations, vibration modal solutions, time response solutions as well as the basic matrix algebra subroutines. A list of available subroutines is given in Appendices A, B, and C of this volume.

The subroutines in this library have been used extensively and as a result are well checked out and debugged. The FORMA method has advantageous features such as:

1. method will work on any computer with a FORTRAN IV compiler. It has been used on the IBM 7044, IBM 7094, GE 625/635, CDC 6400/6500, and UNIVAC 1108 with only minor modifications;

2. computer times are reasonable;

3. incorporation of new subroutines is no problem;

4. basic FORTRAN statements may be used to give extreme flexibility in writing a program;

5. an analyst can program relatively complex problems with very little programming experience; and

6. the method of programming is closely related to the manner of the mathematical formulation of the physical problem.

In conclusion, this report expands and improves the FORMA system for response and loads analysis by combing existing and adding new dense, sparse and finite element subroutines to the FORMA library. Modifications for MSFC requirements are included where necessary.
I. INTRODUCTION

This volume presents the programming techniques and summarizes the subroutines available in the FORMA library that will enable an analyst to convert his matrix equations into a computer program. It is assumed that the analyst has a basic knowledge of Fortran.

Using the FORMA method, a computer program is coded using CALL statements for the desired subroutines from the FORMA library. Two programming techniques (dense and sparse) are utilized to describe the matrices. In dense programming, all elements of the matrix, both zero and non-zero, are used. The maximum size of a matrix is, thus, limited by the core size of the computer. For example, with an available computer core size of 50,000, the maximum square matrix size is approximately 150 (when two matrices are used). To get around this size restriction, a sparse programming technique was devised. In sparse programming (subroutines begin with the letter "Y") only the non-zero matrix elements are used. In the sparse technique, the matrix size is nominally unlimited because partitions of a matrix are stored on disk.

A list of available subroutines is included in Appendix A (dense), Appendix B (sparse), and Appendix C (finite element) grouped according to function (e.g., input, output, algebraic calculation, etc.).

As with all skills, the more experienced and skillful the analyst is, the "better" the FORMA program he will code. A "better" program is defined to be one that has the maximum possible matrix sizes, checks the input data for mistakes (where possible), and uses the least computer time. Probably the best means of improving FORMA skills is by becoming familiar with Fortran capabilities through reading of a Fortran coding manual. It should be emphasized, however, that any FORMA program will work, some programs are just "better" than others.
II. PROGRAMMING TECHNIQUE (DENSE PROGRAMMING LOGIC)

1. Transfer of Data

Transfer of matrix data to and from the subroutines is made by subroutine arguments. Transfer of page heading data is made by a labeled COMMON block as explained in subroutine START.

Input matrix data for programs using dense FORMA subroutines are read using Subroutine READ for real numbers (a Fortran term for numbers with a decimal point) or Subroutine READIM for integer numbers. A special-purpose subroutine (READO) is available but is not needed for most programs. The only other subroutines that read input data are (a) Subroutine START 3 cards for (1) run number, and user's name, (2) title card 1, and (3) title card 2; (b) Subroutine COMENT for comment cards; (c) Subroutine UPDATE for tape updating data; (d) Subroutine RBTTAB for data defining degrees of freedom and coordinate locations for a structural system. No other subroutines read input data.

Printed output data for programs using dense FORMA subroutines are generally obtained by using Subroutine WRITE for real numbers or Subroutine WRITIM for integer numbers. Exceptions to this are the time response subroutines and frequency response subroutines. Here the volume of calculated data is too great to be transferred out of the subroutine and is automatically printed in the subroutine. Other exceptions are CKMAS 1, CKSTF1 and RBTTAB which provide specially formatted output.

In the development of FORMA it was recognized that the matrix sizes and row dimensions could be eliminated from the subroutine arguments to give simpler CALL statements. However, by doing this, considerable programming skill is then required by the analyst if in his program he wishes to refer to a particular element of a matrix. Considering the advantages and disadvantages of (1) more arguments in CALL statement but easy matrix element referral in main program against (2) less arguments in CALL statement but difficult matrix element referral in main program, it was decided to use the first approach.
2. Coding Procedure - Sample Problem

Perhaps the best means of demonstrating the use of FORMA is through a sample problem. Assume the matrix equation

\[ [Z]_{N1 \times N3} = \left( 3 \cdot [P]_{N1 \times N2} + [Q]_{N1 \times N2} \right) [R]_{N2 \times N3} \]  

is to be programmed. Matrices \([P], [Q],\) and \([R]\) are to be input data to the program. The answer matrix \([Z]\) is to be printed. The maximum sizes expected are \(N1 = 50, N2 = 45,\) and \(N3 = 60.\) However, the particular sizes of \(N1, N2,\) and \(N3\) will be determined at run time and could be any value between 1 and the maximum size expected.

The following steps are used to code the program. The program will be written on a sheet of coding paper to facilitate keypunching the information to cards. A typical coding sheet with the steps listed below is shown in Figure 1.

The names for data in a program are alphanumeric, but the first character must be alphabetic. A first letter of \(I, J, K, L, M,\) or \(N\) indicates an integer, while the rest of the alphabet in the first letter indicates a real number.

**Step (1)** - Call Subroutine START to read three input data cards for (1) run number and user's name, (2) title card 1, and (3) title card 2.

**Step (2)** - Write the CALL statements based on the above equation (1) using the subroutines listed in Appendix A. This is shown in Figure 1 where \(K1\) is a symbol used to designate the maximum size expected for \(N1.\) Similarly for \(K2, N2\) and \(K3, N3.\)

**Step (3)** - Write the DIMENSION statements for the matrices. This indicates the maximum size expected for each matrix. Note that an intermediate matrix \([PPQ] = 3 \cdot [P] + [Q]\) is formed in Subroutine AABB and must be dimensioned. The numerical values for \(K1, K2,\) and \(K3\) are also defined.

**Step (4)** - Shift back to Subroutine START by using the Fortran statement \(GO TO 1.\) This procedure allows for "stacked" problems. The run is terminated by a STOP data card (see Subroutine START writeup) after the data of the last problem.

**Step (5)** - The end of the Fortran source deck is indicated with the Fortran statement END.
FIGURE 1. FORMA COMPUTER PROGRAM FOR SAMPLE PROBLEM 1
The input data to the sample problem is also written on a coding form and is shown in Figure 2. The input matrices are assumed to be:

\[
P_{2 \times 3} = \begin{bmatrix}
1 & 2 & 3 \\
4 & 5 & 6 \\
\end{bmatrix},
\]

\[
Q_{2 \times 3} = \begin{bmatrix}
7 & 8 & 9 \\
0 & 0 & 0 \\
\end{bmatrix},
\]

\[
R_{3 \times 6} = \begin{bmatrix}
10 & 11 & 12 & 13 & 14 & 15 \\
0 & 0 & 0 & 0 & 0 & 26 \\
31 & 0 & 33 & 0 & 35 & 0 \\
\end{bmatrix}.
\]

The first three cards of input data contain the following information:


Card 2: Title 1 in columns 1-72.

Card 3: Title 2 in columns 1-72.

The input form for each matrix is:

First Card: Matrix name in columns 1-6. Matrix row size in columns 7-10 (right justified), Matrix column size in columns 11-15 (right justified).

Middle Cards: Matrix row number in columns 1-5 (right justified) of data. Matrix column number in columns 6-10 (right justified) of data in next field. Matrix data in four fields in columns 11-27, 28-44, 45-61, and 62-78.

Last Card: Ten zeros in columns 1-10.

The last input card is STOP in columns 1-4.
FIGURE 2. INPUT DATA FOR SAMPLE PROBLEM 1
3. Coding a Better Program

If the analyst is satisfied with the program he has coded, this section can be skipped. However, if large size matrices are to be used or if it is desired to check the sizes of the input matrices then this section should be consulted.

Equivaleuce - If the analyst wished to increase the maximum expected sizes in the program of Figure 1 to \(K_1 = K_2 = K_3 = 100\), the 100,000 core locations would be required for the matrices alone. If this size requirement exceeds the capacity of the computer being used, then core locations will have to be shared between matrices where possible. This is accomplished by using Fortran EQUIVALENCEx. Equivalencing is a very sensitive operation because it is easy to wipe out numbers of a matrix before being finished with the matrix. Mistakes of this type will not stop the running of the problem and can only be noticed (hopefully!) by "incorrect-looking" answers.

There are several methods of equivalencing. In the first method, the various matrices are equivalenced to locations in a large dummy matrix. In the second method, the various matrices are equivalenced to each other. The third method is a "manual equivalencing" procedure and is recommended over the other two methods because it is easier to code and understand. In this manual equivalencing method, only two or three matrices are dimensioned [e.g., DIMENSION A(100,100), B(190,100), C(100,100)]. The entire program is coded using only the names A, B, or C. The particular meaning of A, B, or C should then be given in Columns 73 thru 80. By this third method, the EQUIVALENCE statements are kept to a minimum and may not be needed at all.

It is advisable to equivalence only the larger matrices of a program. The possibility of mistakes introduced by equivalencing scalars and the smaller matrices is not worth the small amount of core that will be saved.

To demonstrate the manual equivalencing method, assume the dimensions of the program of Figure 1 are to be increased to \(K_1 = K_2 = K_3 = 100\). Assume that the resulting 50,000 core locations exceeds the capacity of the computer being used.

In the first example of manual equivalencing, Subroutine MULT is retained in the program. Thus a minimum of three matrices will be needed. The resulting program is shown in Figure 3. The core requirements for this program are only 30,000 for the matrices. The input data of Figure 2 is still the same. The same results as the program shown in Figure 1 will still be obtained.
<table>
<thead>
<tr>
<th>LINE</th>
<th>DESCRIPTION</th>
<th>PARAMETERS</th>
<th>FUNCTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>DIMEN A(100,100), B(100,100), C(100,100)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>K, 100</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>CALL START</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>CALL READ</td>
<td>(A, N1, N2, N1, N2)</td>
<td>A*P</td>
</tr>
<tr>
<td>5</td>
<td>CALL READ</td>
<td>(B, N1, N2, K, K)</td>
<td>B*P</td>
</tr>
<tr>
<td>6</td>
<td>CALL AREAD</td>
<td>(A, N1, N2, K, K)</td>
<td>A*P</td>
</tr>
<tr>
<td>7</td>
<td>CALL READ</td>
<td>(A, N1, N2, K, K)</td>
<td>A*P</td>
</tr>
<tr>
<td>8</td>
<td>CALL MULT</td>
<td>(A, B, C, N1, N2, N3, N1, N2)</td>
<td>C*Z</td>
</tr>
<tr>
<td>9</td>
<td>CALL WRITE</td>
<td>(C, N1, N2, X1, X2, W1, W2)</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>END</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**FIGURE 3.** FORMA COMPUTER PROGRAM FOR SAMPLE PROBLEM 1
THREE MATRICES DIMENSIONED
In the second example of manual equivalencing, the program of Figure 3 is modified to use only two matrices. This requires that Subroutine MULT be replaced with either Subroutine MULTA or MULTB. The resulting program is shown in Figure 4. The core requirements for this program are only 20,000 for the matrices. The input data of Figure 2 is still the same. The same results as the program shown in Figure 1 will still be obtained.

Size Check - Any of the three programs just coded will run even if there is a mistake in the matrix sizes in the input data. The modifications to the program of Figure 4 to check the sizes of the input matrix data are shown in Figure 5. This is the "near" program for the sample problem given by equation (1). The input data of Figure 2 is still the same. The same results as the program shown in Figure 1 will still be obtained.
<table>
<thead>
<tr>
<th>CALL</th>
<th>Dimensions A(1,100,100), B(1,100,100)</th>
<th>A(100,100)</th>
<th>B(100,100)</th>
</tr>
</thead>
<tbody>
<tr>
<td>DIM</td>
<td>K = 100</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CALL</td>
<td>START</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CALL</td>
<td>READ (R, N1, N2, R, K, K)</td>
<td>A=P</td>
<td></td>
</tr>
<tr>
<td>CALL</td>
<td>READ (R, N1, N2, K, K)</td>
<td>B=Q</td>
<td></td>
</tr>
<tr>
<td>CALL</td>
<td>ADD (R, A = R, A, K, N1, N2, K)</td>
<td>A*P</td>
<td></td>
</tr>
<tr>
<td>CALL</td>
<td>READ (R, N1, N2, R, K, K)</td>
<td>A<em>3</em>K</td>
<td></td>
</tr>
<tr>
<td>CALL</td>
<td>WRITE (A, N1, N2, A*2-N107, K)</td>
<td>A*Z</td>
<td></td>
</tr>
</tbody>
</table>

**Figure 4.** FORMA computer program for sample problem 1

Two matrices dimensioned
<table>
<thead>
<tr>
<th>Line</th>
<th>Code</th>
<th>Description</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>CALL</td>
<td>START</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>CALL</td>
<td>READ (A, N1, N2, K, K)</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>CALL</td>
<td>READ (B, M1, M2, E, E)</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>IF (N1 = N) .NE. N1, 63, N2 = N2, M2, E )</td>
<td>GO TO 999</td>
<td>A = P, 9 = Q, \text{ERROR = 1}</td>
</tr>
<tr>
<td>5</td>
<td>CALL</td>
<td>MMA (B, A, E, A, K1, K2, K)</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>CALL</td>
<td>READ (B, NAX, NAX, E, E)</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>IF (NAX = NAX) .NE. NAX, 64, TA = 999</td>
<td></td>
<td>A = 31 + Q, \text{ERROR = 2}</td>
</tr>
<tr>
<td>8</td>
<td>CALL</td>
<td>MMA (A, B, K1, N1, K2, N2, E, E)</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>CALL</td>
<td>MAXTE (A, N1, N2, END, E, E)</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>END</td>
<td></td>
<td>A = 2</td>
</tr>
</tbody>
</table>

**Figure 5.** FORMA Computer Program for Sample Problem 1

Two matrices dimensional
Size checks incorporated
4. Sample Problem 2

To further illustrate the use of FORMA, a second sample problem is coded in this section. The coding techniques described in Section 4 to obtain a "better" program will be used.

In this problem, the "free-free" mode shapes and frequencies of the beam shown in Figure 6 are to be calculated and printed. Two degrees of freedom, translation and rotation, are assumed at each of the five panel points (also called collocation points). The input data to the computer program are the beam panel points, the beam weight distribution, and the beam stiffness distribution. For this sample problem the distributed rotary inertia, any concentrated weights, and the shear stiffness are ignored.

The following steps are used to code the computer program. The program will be written on a sheet of coding paper to facilitate keypunching the information to cards. A typical coding sheet with the steps listed below is shown in Figure 7.

As mentioned previously, the names for data in a program are alphanumeric, but the first character must be alphabetic. A first letter of I, J, K, L, M, or N indicates an integer, while the rest of the alphabet in the first letter indicates a real number.

**Step (1)** - Call Subroutine START to read three input data cards for (1) run number and user's name, (2) title card 1, and (3) title card 2.

**Step (2)** - Write the CALL statements to read in the panel points, weight distribution, and stiffness distribution. Checks on the column size are made. Write the CALL statements to calculate and write the mass and stiffness matrices, and to calculate and write the mode shapes and frequencies. \( K_1 \) is a symbol used to designate the maximum number of degrees of freedom allowed. \( K_2 \) is a symbol used to designate the maximum number of panel points allowed. \( K_3 \) is a symbol used to designate the maximum number of rows of distributed data.

**Step (3)** - Write the DIMENSION statements for the matrices. This indicates the maximum size expected for each matrix. Even though this sample problem has five panel points, the computer program is written assuming that there could be as many as 50 panel points and thus 100 degrees of freedom. Also, a maximum of 40 rows of distributed data is allowed by the dimension given to the matrix \( D \). The corresponding values for \( K_1, K_2, \) and \( K_3 \) are defined.
Figure 6. Beam for Sample Problem 2
<table>
<thead>
<tr>
<th>FORMA</th>
<th>Wahlom</th>
</tr>
</thead>
<tbody>
<tr>
<td>DIMENSION A(I,100,100), B(I,100,100), P(I,20), D(40,4), N(100), FREQ(100)</td>
<td></td>
</tr>
<tr>
<td>M</td>
<td>M2(100), M1(100), FREQ(100)</td>
</tr>
<tr>
<td>CALL</td>
<td>K1, K2, K3</td>
</tr>
<tr>
<td>M</td>
<td>100, 33, M8</td>
</tr>
<tr>
<td>CALL</td>
<td>START</td>
</tr>
<tr>
<td>CALL READ</td>
<td>(P, I, MFP, L, K2)</td>
</tr>
<tr>
<td>CALL READ</td>
<td>(D, NDF, IN, K3, G)</td>
</tr>
<tr>
<td>IF. ((M, IN, N) AND TO 799)</td>
<td>IF. ((M, IN, N) AND TO 799)</td>
</tr>
<tr>
<td>CALL MASE2</td>
<td>(P, D, O, L, 1/3.6, A, MFP, NDF, O, M, K2, O, G, K1)</td>
</tr>
<tr>
<td>CALL READ</td>
<td>(D, MDF, IN, K3, G)</td>
</tr>
<tr>
<td>IF. ((M, IN, N) AND TO 799)</td>
<td>IF. ((M, IN, N) AND TO 799)</td>
</tr>
<tr>
<td>CALL MASE2</td>
<td>(P, O, D, 1, MFP, O, NDF, N, O, K2, K1)</td>
</tr>
<tr>
<td>CALL WRITE</td>
<td>(A, M, K1, KM, K1)</td>
</tr>
<tr>
<td>CALL WRITE</td>
<td>(A, M, K1, KM, E, F, K1)</td>
</tr>
<tr>
<td>CALL WRITE</td>
<td>(A, M, K1, KM, E, F, K1)</td>
</tr>
<tr>
<td>CALL WRITE</td>
<td>(A, M, K1, KM, E, F, K1)</td>
</tr>
<tr>
<td>CALL WRITE</td>
<td>(A, M, K1, KM, E, F, K1)</td>
</tr>
<tr>
<td>999</td>
<td>999</td>
</tr>
<tr>
<td>END</td>
<td></td>
</tr>
</tbody>
</table>

FIGURE 7. FORMA COMPUTER PROGRAM FOR SAMPLE PROBLEM 2
Step (4) - Shift back to Subroutine START by using the Fortran statement GO TO 1. This procedure allows for "stacked" problems. The run is terminated by a STOP data card (see Subroutine START writeup) after the data of the last problem.

Step (5) - The end of the Fortran source deck is indicated with the Fortran statement END.

The input data to sample problem 2 is also written on a coding form as shown in Figure 8. The first three cards of input data contain the following information:

Card 2: Title 1 in columns 1-72.
Card 3: Title 2 in columns 1-72.

The input form for each matrix is:


Middle Cards: Matrix row number in columns 1-5 (right justified) of data. Matrix column number in columns 6-10 (right justified) of data in next field. Matrix data in four fields in columns 11-27, 28-44, 45-61, and 61-78.

Last Card: Ten zeros in columns 1-10.

The matrix data consists of:

1) Matrix of panel point stations from Figure 6(a).
2) Matrix of end point coordinates of the line segments representing the distributed weight from Figure 6(b).
3) Matrix of end point coordinates of the line segments representing the distributed bending stiffness from Figure 6(c).
The end point coordinates of each nonvertical straight line for the distributed data is given as a row in the matrix of distributed data. Each row has the form:

Matrix column 1 - station \( x_i \), i.e., the abscissa of the line segment originating point.

Matrix column 2 - station \( x_{i+1} \), i.e., the abscissa of the line segment terminating point.

Matrix column 3 - value at \( x_i (+) \), i.e., the ordinate of the line segment originating point.

Matrix column 4 - value at \( x_{i+1} (-) \), i.e., the ordinate of the line segment terminating point.

The last input card is STOP in card columns 1-4.
III. PROGRAMMING TECHNIQUE (SPARSE PROGRAMMING LOGIC)

1. Transfer of Data

Matrix data for the sparse nuboutines is stored on disk with a disk number (representing a matrix) being transferred to and from the subrou-
tines by argument. Transfer of page heading data is made by a labeled
COMMON block as explained in subroutine START.

Input matrix data is read using subroutine YREAD and printed output
data is obtained using subroutine YWRITE.

2. Coding Procedure

The same example will be used here that was used for sample problem 1
for the dense programming logic. The example is repeated from page 3:

\[
\left[ Z \right]_{N1 \times N3} = \left( 3 \left[ P \right]_{N1 \times N2} + \left[ Q \right]_{N1 \times N2} \right) \left[ R \right]_{N2 \times N3} (1)
\]

As before, matrices \([P], [Q], [R]\) are to be input data to the
program. The answer \([Z]\) is to be printed.

The following steps are used to code the program. The program is
written on a sheet of coding paper to facilitate key punching the in-
formation to cards. A typical coding sheet with the steps listed below
is shown in Figure 9.

**Step (1)** - Dimension workspaces \(V\) and \(LV\) at least 3 times the largest
row or column size expected. The larger the dimension size the faster
the computer time. Indicate the dimension size with \(KV\).

**Step (2)** - Set the tape names to numbers.

**Step (3)** - Call subroutine START to read three input data cards for
(1) run number and user's name, (2) title card 1, and (3) title card 2.

**Step (4)** - Write the CALL statements based on the above equation (1)
using the subroutines listed in Appendix B.

**Step (5)** - Shift back to subroutine START by using the Fortran statement
GO TO 1. This procedure allows for "stacked" problems. The run is ter-
minated by a STOP data card (see subroutine START writeup) after the
data of the last problem.

**Step (6)** - The end of the Fortran source deck is indicated with the
Fortran statement END.
The input data for this sparse program is identical to the input data previously used on pages 5 and 6 (Figure 2) for the dense program.

The techniques of pages 7 through 11 for coding a better dense program are not pertinent for a sparse program because equivalence is not needed. The size checks could be made with the sparse program but is not shown here.
**FIGURE 9.** FORMA COMPUTER PROGRAM, SPARSE PROGRAMMING LOGIC
APPENDIX A. SUMMARY OF CALLING INSTRUCTIONS - DENSE FORMA SUBROUTINES.

IN THE ARGUMENTS OF THE SUBROUTINES BELOW IT IS ASSUMED THAT THERE IS CORRESPONDENCE IN SIZE AND ROW DIMENSION OF COMPATIBLE MATRICES. FOR INSTANCE IN SUBROUTINE MULTI, NRA=NRZ, NCA=NRE, NCB=NCZ, KA=KZ.

A 6H ARGUMENT MAY ALSO BE A VARIABLE READ WITH AN A6 FORMAT OR OBTAINED WITH A DATA STATEMENT.

*** LIST OF SYMBOLS ***

A = INPUT MATRIX
B = INPUT MATRIX
ALPHA = INPUT SCALAR
BETA = INPUT SCALAR
AVFC = INPUT VECTOR (ROW OR COLUMN MATRIX)
IVFC = INPUT VECTOR (ROW OR COLUMN MATRIX), INTEGER
TAP = INPUT TAPE (MATRIX WITH INCOMPLETE COLUMNS IN SOME ROWS)
Z = RESULT MATRIX
ZVFC = RESULT VECTOR
N = SIZE (FDP VECTOR OR SQUARE MATRIX)
NR = NUMBER OF ROWS
NC = NUMBER OF COLUMNS
K = ROW DIMENSION
KR = ROW DIMENSION
KC = COLUMN DIMENSION
V = VECTOR WORK SPACE
LV = VECTOR WORK SPACE, INTEGER
KV = V, LV DIMENSION
NUTI = LOGICAL NUMBER OF ITH UTILITY TAPE
NTAPE = SYMBOILIC NUMBER OF TAPE. FOR EXAMPLE, 1

A SINGLY DIMENSIONED VARIABLE IS REFERRED TO AS A VECTOR IN THIS REPORT.
A DUCUPLY DIMENSIONED VARIABLE IS REFERRED TO AS A MATRIX IN THIS REPORT.
A VECTOR MAY BE HANDLED AS EITHER A ROW OR COLUMN MATRIX.
THE ROW DIMENSION OF A VECTOR IN THE ARGUMENTS OF THE CALL STATEMENTS IS ANALOGOUS TO THE ROWS OF THE VECTOR. THAT IS,
   IF THE VECTOR IS HANDLED AS A ROW, THEN KR=1
   IF THE VECTOR IS HANDLED AS A COL, THEN KR=DIMENSION SIZE

EXAMPLE

DIMENSION A(IC)
CALL READ (A, N1,N2, 1, IC)
    OR CALL READ (A, N2,N1, 10, 1)

PRECEDING PAGE BLANK NOT FILMED
01 MISCELLANEOUS

01.01 PROGRAM INITIALIZATION
    CALL START

01.02 PROGRAM PAGE HEADING
    CALL PAGEHD

01.03 PROGRAM POMROUT
    CALL Z2F30MB (6HSUENAM, MERROR)

01.04 PROGRAM COMMENTS
    CALL COMMENT

01.05 CONVERSION
    CALL YOTOG (A, NUTZ, NR, NC, KR, KC, V, LV, KV, NUTI)
    USES YIN, YINI, YOUT, YOUTI, YPART, Z2F30MB.

01.06 MATRIX ELEMENT COMPARISON
    CALL COMPAR (A, RFF, NR, NC, NIG, CTL, 6HANIMF, 6HRFFNAM, KA, KREF)

01.07 TIME CHECK
    CALL TIMCHK (6HNMCHK)

01.08 ORDERING
    CALL XLERD (V, LV, LAS, NNZA)
    CALL ORDALS (IMAT, NR, NC, NCAI, WMAT, KPI, KCI)

01.09 MERGE NAME AND NUMBER (FUNCTION)
    NAME (6HNAME, NUM)
.02 INPUT

.02.01 REAL NUMBERS
USES INTAPE, LTAPE, PAGEHD, RTAPE, WRITE, WTAPE, Z2EOME.
*NR, NC WILL BE DEFINED BY INPUT. USE SYMBOLS.
CARD INPUT
FIRST CARD  - ZNAME, NR, NC WITH A6, I4, I5 FORMAT.
             REMARKS IN COLUMNS 16-6G.
$ IN COL 72 FOR WRITE TAPE INITIALIZE.
     BLANK, REWIND, LIST, OR TAPEID (FOR WRITE TAPE, IN COLUMNS 73-7E).
     NWTAPE IN COLUMNS 79-80.
MIDDLE CARDS - DATA WITH 215, 4E17 FORMAT.
LAST CARD  - TEN ZEROS IN COLUMNS 1-10.
TAPE INPUT
ONE CARD  - ZNAME, I6 OR LOCATION, NRTAPE (WITH - FOR
             NO WRITE OUT), ZRUNNING WITH
             A6, I4, I5, A6 FORMAT.
             BLANK, REWIND, OR LIST (FOR READ TAPE)
             IN COLUMNS 22-27.
             REMARKS IN COLUMNS 28-60.
$ IN COL 72 FOR WRITE TAPE INITIALIZE.
     BLANK, REWIND, LIST, OR TAPEID (FOR WRITE TAPE) IN COLUMNS 73-78.
     NWTAPE IN COLUMNS 79-80.

.02.02 INTEGER NUMBERS
USES INTAPE, LTAPE, PAGEHD, RTAPE, WRITE, WTAPE, Z2EOME.
*NR, NC WILL BE DEFINED BY INPUT. USE SYMBOLS.
CARD INPUT
FIRST CARD  - IZNAME, NR, NC WITH A6, I4, I5 FORMAT.
             REMARKS IN COLUMNS 16-6G.
$ IN COL 72 FOR WRITE TAPE INITIALIZE.
     BLANK, REWIND, LIST, OR TAPEID (FOR WRITE TAPE)
             IN COLUMNS 73-7E.
     NWTAPE IN COLUMNS 79-80.
MIDDLE CARDS - DATA WITH 215, 4I15 FORMAT.
LAST CARD  - TEN ZEROS IN COLUMNS 1-10.
TAPE INPUT
(SAME AS SUBROUTINE READ ABOVE).

.02.03 OCTAL NUMBERS
*NR, NC WILL BE DEFINED BY INPUT. USE SYMBOLS.
FIRST CARD  - ZNAME, NR, NC WITH A6, I4, I5 FORMAT.
             REMARKS IN COLUMNS 16-6G.
MIDDLE CARDS - DATA WITH 215, 2(3Y, 02C) FORMAT.
LAST CARD  - TEN ZEROS IN COLUMNS 1-10.
02.04   ALPHA-NUMERIC CHARACTERS
         CALL READAN (IZ,NR,NC,KF,KC)
         USES ITAPE,LTAPF,PAGEHD,RTAPE,WRITAN,WTAPF,ZZCME.
         *NR,NC WILL BE DEFINED BY INPUT. USE SYMBOLS.
         CARD INPUT
         FIRST CARD  - IZNAME,NR,NC WITH A6,14,15 FORMAT.
                      REMARKS IN COLUMNS 16-69.
                      $ IN COL 72 FOR WRITE TAPE INITIALIZE.
                      BLANK,REWIND,LIST,CR TAPEID (FOR WRITE
                      TAPE) IN COLUMNS 73-78.
                      NWTAPE IN COLUMNS 79-80.
         MIDDLE CARDS - DATA WITH 215,10A6 FORMAT.
         LAST CARD  - TEN ZEROS IN COLUMNS 1-10.
                      TAPE INPUT
                      (SAME AS SUBROUTINE READ AFCVE).
OUTPUT

PRINT REAL NUMBERS
CALL WRITE (A,NR,NC,6HNAME-,K)

PRINT INTEGER NUMBERS
CALL WRITIM (IA,NF,NC,6HNAMEF,K)

PRINT ALPHA-NUMERIC CHARACTERS
CALL WRITAN (IA,NK,NC,6HNAMEF,K)

PLOT
CALL PLOT1 (XVEC,YMAT,NRY,NCY,XSTART,XDELTA,6HNAME-, YNAME,PITLE,IFSAME,IFCURV,IFLIT, K)
USES PLOTSS.
HAVE -CALL HPLT (0,2HLC) IN MP USED ONCE/RUN.
MAX NCY = 3
CALL PLOT2 (XVEC,YMAT,NRY,NCY,6HNAME-,6HNAME-, PITLE,IPLOT,IVY, KY)
MAX NCY=10
CALL PLOT3 (CLOC,MLUC,COFLUC,VPLOCC,PANGLE,CANGLE, EDIST,IFJNUM,LRFYE,NVIEW,IFFA,PITLE, NC,NP,KC,KM)
USES VCROSS,VDCT.
CALL PLOTSS (YMAX,YMIN,YTOP,TFOT)

PUNCH
CALL PUNCAN (IA,NP,NC,6HNAMEF,K)
CALL PUNCH (A,NK,NC,6HNAMEF-,K)
CALL PUNCHO (A,NF,NC,6HNAMEF-,K)
CALL PUNCHIM (IA,NF,NC,6HNAMEF,K)
TAPE OPERATIONS

REWIND TAPE AT BEGINNING OF MAIN PROGRAM.

.04.01 INITIALIZATION
   CALL INTAPE (NTAPE,6HTAPEID)

.04.02 READING
   CALL RTAPE (6HZRUNNC,6HZNAME-,Z,*NR,*NC,KR,KC,NTAPE)
   *NR,NC WILL BE DEFINED BY TAPE DATA. USE SYMBOLS.
   USES LTAPE.

.04.03 WRITING
   CALL WTAPE (A,NR,NC,6CHANAME-,K,NTAPE)

.04.04 LISTING OF HEADERS
   CALL LTAPE (NTAPE)

.04.05 UPDATING
   CALL UPDATE

.04.06 CORE/TAPE DATA TRANSFER
   CALL IN (NTAPE,Z,N)
   CALL OUT (NTAPE,A,N)
   CALL KWND (NTAPE)
   CALL SKPR (NTAPE,NREC)
05 GENERATION

05.01 BASIC

CALL ONES (Z*NR, NC, K)
CALL SIGMA (Z*N, K)
CALL UNITY (Z, N, K)
CALL ZFPO (Z*NR, NC, K)
.06 ALGEBRA

.06.01 SCALAR PRODUCT
    CALL ALPHAA (ALPHA, A, Z, NR, NC, KA, KZ)
    CALL PA (P, A, Z, NR, NC, KA, KZ)

.06.02 ADDITION, SUBTRACTION
    CALL AAPP (ALPHA, A, ETA, P, Z, NR, NC, KAPZ)
    CALL PACP (P, A, O, P, Z, NR, NC, KA, KP, KZ)

.06.03A MULTIPLICATION - GENERAL
    CALL MULT (A, B, Z, NRA, NPP, NCP, KA, KZ)
    CALL MULTA (AZ, P, NRA, NPP, NCE, KA, KB)
    MAX NRE = 500
    CALL MULTB (A, B, Z, NRA, NPE, NCE, KA, KEB)
    MAX NRE = 500

.06.03F MULTIPLICATION - SPECIAL
    CALL API (A, F, Z, NRA, NCA, NCF, KA, KP, KZ)
    MAX NCA = 500
    CALL AP2 (A, B, Z, NRA, NCA, NCB, KA, KB, KZ)
    MAX NCA = 500
    CALL ARC1 (A, B, C, Z, NRA, NCA, NCB, KA, KB, KC, KZ)
    MAX NCA = 500
    CALL ARC2 (A, E, C, Z, NRA, NCA, NCB, KA, KB, KC, KZ)
    MAX NCA = 500
    CALL ATP1 (A, P, Z, NRA, NCA, NCF, KA, KP, KZ)
    MAX NPA = 500
    CALL ATP2 (A, F, Z, NRA, NCA, NCF, KA, KB, KZ)
    MAX NRA = 500
    CALL ATC1 (A, B, C, Z, NRA, NPA, NCF, KA, KB, KC, KZ)
    MAX NRA = 500
    CALL ATC2 (A, B, C, Z, NRA, NPA, NCF, KA, KB, KC, KZ)
    MAX NRA = 500
    CALL ATX1 (A, Z, E, NRA, NPP, NCF, KA, KB, KZ)
    MAX NCF = 500
    CALL ATXR (A, P, Z, NRA, NPP, NCF, KA, KB, KZ)
    MAX NPA = 500
    CALL ATXH1 (A, E, Z, NRA, NPP, NCF, KA, KB, KZ)
    MAX NRH = 500
    CALL ATXH2 (A, F, Z, NPP, NCF, KA, KB, KZ)
    MAX NCF = 500
    CALL AXEA1 (A, Z, E, NRA, NCA, KA, KB, KZ)
    MAX NCA = 500
    CALL AXEA2 (A, Z, E, KA, KB, KZ)
    MAX N = 500
    CALL AXFA1 (A, Z, P, NFF, NCF, KA, KB, KZ)
    MAX NFF = 500
    CALL DB1 (D, P, Z, NRE, NCF, KA, KB, KZ)
.06 ALGEBRA (CONTINUED)

.06.04A TRIPLE MATRIX PRODUCT - GENERAL
CALL PART (A,P,Z,NRP,NCP,KA,KPZ)
MAX NCP = 500 (SIZE OF A)
CALL BNATB (A,Z,F,NRP,NCF,KAZ,KP)
MAX NCP = 500 (SIZE OF A)
CALL RTAR (A,R,Z,NRP,NCP,KAP,KZ)
MAX NRP = 500 (SIZE OF A)
CALL PTAP (A,Z,NRP,NCF,KAZ,KP)
MAX NRP,NCP = 500 (SIZE OF MATRICES A,Z)

.06.04B TRIPLE MATRIX PRODUCT - SPECIAL
CALL ETAE1 (A,P,Z,NRP,NCP,KA,KPZ)
MAX NRP = 500 (SIZE OF MATRIX A)
CALL BTAPA (A,Z,F,NRP)
MAX N = 500 (SIZE OF MATRICES A,R,Z)
CALL BTAPC1 (A,F,C,Z,NRP,NCF,KA,KP,KC,KZ)
MAX NRP = 500
CALL BTDBA (D,B,Z,NRP,NCP)
MAX NRP = 500
CALL BTDC1 (D,B,C,Z,NRP,NCF,KR,KC,KZ)
CALL UTAU (A,U,Z,N,KA,KU,KZ)
MAX N = 500
CALL UTAUC1 (A,U,C,Z,N,KA,KU,KC,KZ)
MAX N = 500

.06.05 INVERSION
CALL INV1 (A,Z,N,KAZ)
MAX N = 250
CALL INV2 (A,Z,N,KAZ)
MAX N = 250
CALL INV3 (A,Z,N,KAZ)
USES DCOM1,1INV4
MAX N = 250
CALL INV4 (A,Z,N,KAZ)

.06.06 SIMULTANEOUS EQUATIONS
CALL SMQ1 (*A,*PVEC,ZVEC,N,KA)
*A,PVEC ARE DESTROYED.

.06.07 EIGENVALUE, EIGENVECTOR
CALL EIGN1 (*A,ZVAL,ZVEC,N,FCD,KAZ)
*A IS DESTROYED.
CALL EIGN2 (*A,ZVAL,ZVEC,NIN,CV,KAZ)
*A IS DESTROYED.
.06 ALGFFRA (CONTINUED)

.06.08 DECOMPOSITION
   CALL DCOM1 (A,Z,N,KAZ)

.06.09 ROW, COLUMN OPERATIONS
   CALL ROWMLT (AVEC, R, Z, NR, NC, KPZ)
   CALL COLMLT (AVEC, R, Z, NR, NC, KPZ)

.06.10 VECTOR OPERATIONS
   CALL VDOT (VA, VB, PRODCT, VAMAG, VFMAG, COSAR)
   CALL VCROSS (VA, VB, VZ, VAMAG, VFMAG, VZMAG, SINA)
.07 MODIFICATION

.07.01 ASSEMBLY
   CALL ASSEM (A, I2, J2, *Z, NPA, NCA, NR2, NC2, KA, K2)
   *BE SURE Z IS DEFINED. (EG CALL ZIFE TO CLEAR Z).

.07.02 DISASSEMBLY
   CALL DISA (A, IA, JA, Z, NRA, NCA, NRZ, NCZ, KA, K2)

.07.03 REVISION
   CALL REVADD (ALPHA, A, IVEC, JVEC, *Z, NPA, NCA, NRZ, NCZ, KA, K2)
   *BE SURE Z IS DEFINED. (EG CALL ZERD TO CLEAR Z).
   CALL REVII (A2, IVEC, JVEC, NRA, NCA, NRZ, NCZ, KRA2)

.07.04 TRANSPOSE
   CALL AT1 (A, Z, NPA, NCA, KA, K2)
   MAX NCA = 500
   CALL TRANS (A, Z, NRA, NCA, KA, K2)

.07.05 SYMMETRIZE
   CALL SYMLH (A, Z, N, K)
   CALL SYMUH (A, Z, N, K)

.07.06 NULLIFY
   CALL ZFPOLH (A, Z, N, K)
   CALL ZEROUH (A, Z, N, K)

.07.07 DIAGONALIZE
   CALL DIAG (AVEC, Z, N, K2)
.08 INTERPOLATION, DIFFERENTIATION

.08.01 INTERPOLATION
CALL TERR1 (XA, XZ, A, Z, NXA, MXZ, NCA, KA, K2)
CALL TERR2 (XA, XZ, A, Z, NXA, NXZ, NCA, KA, K2)

.08.02 DIFFERENTIATION
CALL DIFF1 (XA, XZ, A, Z, NXA, MXZ, NCA, KA, K2)
CALL DIFF2 (XA, XZ, A, Z, NXA, NXZ, NCA, KA, K2)
.09 AIRLOAD

.09.01 LATERAL
CALL ALC01 (PP, DIST, CONC, CONVRT, ZVEC, NPP, ND, NC, RD, KC)

.09.02 AXIAL
CALL ALC02 (PP, DIST, CONC, CONVRT, ZVEC, NPP, ND, NC, KC, KC)
.10 MASS

.10.01 PCD
CALL MASS1 (PP, DMASS, DRIN, CONC, CONVRT, Z, NPP, NDM, NDI, NC, KDM, KDI, KC, KZ)

.10.02 FFAM
CALL MASS2 (PP, DMASS, DRIN, CONC, CONVRT, Z, NPP, NDM, NDI, NC, *NZ, KDM, KDI, KC, KZ)
*NZ=2NPP WILL BE DEFINED BY MASS2. USE SYMFL.

.10.03 FLUID
CALL MASS2A (PP, DMASS, EQSM, FLEVEL, CONVRT, Z, NPP, NCM, *NZ, KDM, KZ)
*NZ=2NPP+1 WILL BE DEFINED BY MASS2A. USE SYMFL.
.11 STIFFNESS

.11.01 FOD
CALL STIF1 (PP, DAE, Z, NPP, NDAE, K2AE, KZ)

.11.02 RFAM
CALL STIF2 (PP, DKAG, DEI, Z, NPP, KDKAG, NDEI, *NZ, K2DAG, KDEI, KZ)
*NZ=2NPP WILL BE DEFINED BY STIF2. USE SYMEOL.

.11.03 REDUCTION
CALL SRED1 (A, R, T, N, NR, IF1, KART)
CALL SRED2 (A, P, T, N, NF, IF1, KART)
CALL SRED3 (A, IV, F, T, N, NF, IF1, KAF1)
.12 MODAL

.12.01 JACPER

CALL MODE1 (*AMASS,**STIF,W2,W,FRFC,N,FCD,KAS,NUTAPF)
*AMASS IS REPLACED BY MODE SHAPES.
**STIF IS DESTROYED.
USES ETAFA,DCOM1,FIGN1,INV4.
MAX N = 500

CALL MODE1A (*AMASS,**STIF,W2,W,FRFC,N,FCD,KAS,NUTAPF)
*AMASS IS REPLACED BY MODE SHAPES.
**STIF IS DESTROYED.
USES ETAFA,DCOM1,FIGN1,INV4.
MAX N = 500

CALL MODE1B (*AMASS,**FLEX,W2,W,FRFC,N,FCD,KAF,NUTAPF)
*AMASS IS REPLACED BY MODE SHAPES.
**FLEX IS DESTROYED.
USES ETAFA,DCOM1,FIGN1,INV4,MULTA.
MAX N = 500
.13 RIGID BODY MODES

.13.01 CALCULATION
   CALL RPTG1 (XYZ, XYZREF, JDOF, JVEC, Z, NNODEF, *NRZ, *NCZ, XXJ, KZ)
   *NRZ, NCZ WILL BE DEFINED BY RPTG1. USES SYMBOL.
   USES RFVADD.
   CALL RPTG2 (XRT, XYZREF, JDOF, JVEC, Z, NNODEF, *NRZ, *NCZ, XXJ, KZ)
   *NRZ, NCZ WILL BE DEFINED BY RPTG2. USES SYMBOL.
   USES RFVADD.

.13.02 ORTHO-NORMALIZATION
   CALL ONREF (PPMODE, AMASS, N, NPPMODE, KRA)
   USES BTAE, FICNI, MULT.
   MAX N = 250
   MAX NPPMODE = 6
INERTIAL TRANSFORMATION

CALL UMAMI (AMASS, RMODE, Z, N, NRBMOD, KARZ)
USES PRT, PRTAP, INV, MULT
MAX N = 250
MAX NRBMOD = 6
.15  INTERNAL LOADS

.15.01  RFAM - SHEAR, MOMENT LOADS
        CALL VM1 (XVEC, DIST, CONG, AMPl, AMP2, CONVRT, ZVECv, ZVECM,
                NX, N0, NC, NA1, NA2, K0, KC, KA1, KA2)

.15.02  RFAP - SHEAR, MOMENT TRANSFORMATION
        CALL VMTR1 (PP, Z, NPP, *NZ, KZ)
        *NZ=2*NPP WILL BE DEFINED BY VMTR1. USE SYMEO1.
TIME RESPONSE

.16.01  FORCE IS OBTAINED BY LINEAR INTERPOLATION USING TAF1,TAFF
        CALL TRSP1 (*,*,*,*,*,TAF1,TAFF,XOC,NO,STARTT,DELTAT,
                     ENDT,NWRITE,NX,NRTAF,NCTAB,CHXNAME,KAFCO,
                     KTAF,NXTAPE,NUTI)
        *MATRICES A,F,C,D ARE DESTROYED.
        USES INV1,MULTB.
        MAX NX = 250
        MAX NRTAF = 500
        CALL TRSP2 (*,*,*,*,*,*,TAF1,TAFF,XOC,NO,STARTT,DELTAT,
                     ENDT,NWRITE,NX,NRTAF,NCTAB,CHXNAME,KAFCO,
                     KTAF,NXTAPE,NUTI)
        MAX NX = 250
        MAX NRTAF = 500
        CALL TRSP2 (*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*
.16  TIME RESPONSE (CONTINUED)

.16.03  ADDITIONAL EQUATIONS.
        CALL TRAE2 (6HXRUNNC,6HXNAME,IFA,IFF,P,IFC,C,IFC,D,
                     IFF,E,ZTMM,STAPTT,ENDT,MLTXTP,NWPITL,*ZIDENT,
                     **STA,6HXNAME,N2,KZ,NXTAPE,N2TAPE,STOREZ)
        *Z HEADING (12A6 FORMAT).
        **STATIONS (A6 FORMAT).
        MAX NX = 250

.16.04  TIME RESPONSE MAX-MINS
        CALL TRMM  (6HXRUNNC,6HXNAME,XTMM,STAPTT,ENDT,*NX,
                     RX,NXTAPE)
        *NX IS DEFINED IN SUPROUTINE, USE SYMRL.
        MAX NX = 250

.16.05  POWER SPECTRAL DENSITY OF ADDITIONAL EQUATIONS
        CALL TRPSD (6HXRUNNC,6HXNAME,IFA,IEXP,STAPTT,MLTXTP,
                     ZPSD,NFRFO,TIMPER,NXTAPE,WRKVI)
.17  FREQUENCY RESPONSE

.17.01  RESPONSE SOLUTION
       CALL FRI  (*A,*B,*C,*D,*TAPE,*TAPEF,CEGA,NX,NOMEGA,
         NRTAPE,NCTAP,KAECN,KTAB,WRKPTAPE)
       *MATRICES A,B,C,D ARE DESTROYED.
       R MUST BE NON-SICULAR.
       USES INV1,MULT,MULT1.
       MAX NX  = 50
       MAX NRTAPE  = 80

.17.02  ADDITIONAL EQUATIONS
       CALL FRAE1 (A,*STA,**ZIDENT,NZ,NX,NOMEGA,KA,NXTAPE,
         NZTAPE)
       *STATIONS (*6 FORMAT).
       **Z HEADING (12A6 FORMAT).
       MAX NZ  = 80
       MAX NX  = 50
APPENDIX B. SUMMARY OF CALLING INSTRUCTIONS - SPARSE FORMA SUBROUTINES.

*** LIST OF SYMBOLS ***

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>INPUT MATRIX</td>
</tr>
<tr>
<td>ALPHA</td>
<td>INPUT SCALAR</td>
</tr>
<tr>
<td>ETA</td>
<td>INPUT SCALAR</td>
</tr>
<tr>
<td>NUTA</td>
<td>LOGICAL NUMBER OF UTILITY TAPE CONTAINING INPUT MATRIX A</td>
</tr>
<tr>
<td>NUTE</td>
<td>LOGICAL NUMBER OF UTILITY TAPE CONTAINING INPUT MATRIX B</td>
</tr>
<tr>
<td>NUTZ</td>
<td>LOGICAL NUMBER OF UTILITY TAPE CONTAINING OUTPUT MATRIX Z</td>
</tr>
<tr>
<td>AVEC</td>
<td>INPUT VECTOR (ROW OR COLUMN MATRIX)</td>
</tr>
<tr>
<td>IVEC</td>
<td>INPUT VECTOR (ROW OR COLUMN MATRIX), INTEGER</td>
</tr>
<tr>
<td>Z</td>
<td>RESULT MATRIX</td>
</tr>
<tr>
<td>ZVEC</td>
<td>RESULT VECTOR</td>
</tr>
<tr>
<td>W</td>
<td>MATRIX WORK SPACE</td>
</tr>
<tr>
<td>NR</td>
<td>NUMBER OF ROWS</td>
</tr>
<tr>
<td>NC</td>
<td>NUMBER OF COLUMNS</td>
</tr>
<tr>
<td>KR</td>
<td>ROW DIMENSION</td>
</tr>
<tr>
<td>KC</td>
<td>COLUMN DIMENSION</td>
</tr>
<tr>
<td>V</td>
<td>VECTOR WORK SPACE</td>
</tr>
<tr>
<td>LV</td>
<td>VECTOR WORK SPACE, INTEGER</td>
</tr>
<tr>
<td>KV</td>
<td>V, LV DIMENSION</td>
</tr>
<tr>
<td>NUTI</td>
<td>LOGICAL NUMBER OF ITH UTILITY TAPE</td>
</tr>
<tr>
<td>NTAPE</td>
<td>LOGICAL NUMBER OF FORMA RESERVE TAPE</td>
</tr>
</tbody>
</table>
.01 MISCELLANEOUS

.01.01 CONVERSION
CALL YSTOD (NUTA,Z,NR,NC,KF,KC,V,LV,KV,NUTI)
*NR, NC WILL BE DEFINED BY YSTOD. USE SYMBOLS.
USES YIN,YINI,ZZEBOMM.

.01.02 ORDER MATRIX NON-ZERO ELEMENT LOCATIONS ROWWISE
CALL YLQFD (NUTAVLV,KV,NUTI,NUTZ)
USES YIN,YINI,YOUT,YOUT1,YPART,ZZEBOMM.

.01.03 ELIMINATE ZERO ELEMENTS
CALL YMCZK (NUTA,V,LV,KV,NUTI)
USES YIN,YINI,YOUT,YOUT1,YPART,ZZEBOMM.

.01.04 REPARTITION
CALL YPART (NUTA,V,LV,KV,NUTI)
USES YIN,YINI,YOUT,YOUT1,YPART,ZZEBOMM.

.01.05 COPY TO ANOTHER TAPE
CALL EQUAL (NUTA,NUTZ,V,LV,KV)
.02  INPUT

.02.01  REAL NUMBERS

CALL YREAD (NUTZ,V;LV,KV;NUT1)

USES INTAPE,TAPE,PAGEHO,YIN,YIN1,YOUT,YOUT1,YPART;

YRTAPE,YWRITE,YWTAPE,ZZROMP.

CARD INPUT (SAME AS READ EXCEPT SHAPE)

FIRST CARD  - ZNAME,NR,NC WITH A6,14,1: FORMAT.

MATRIX SHAPE IN COLUMNS 16-71.

REMARKS IN COLUMNS 22-69.

$ IN COL 72 FOR WRITE TAPE INITIALIZATION.

BLANK,REWIND,LIST, OR TAPEID (FOR WRITE TAPE) IN COLUMNS 73-78.

NEWTAPE IN COLUMNS 79-80.

MIDDLE CARDS  - DATA WITH 515,4F17 FORMAT.

LAST CARD  - TEN ZEROS IN COLUMNS 1-10.

TAPE INPUT (SAME AS READ)

ONE CARD  - ZNAME, G OR -LOCATION, NRTAPE (WITH - FOR

NO WRITE OUT), ZRUNNING WITH

A6,15, A6 'FORMAT

BLANK,REWIND, OR LIST (FOR READ TAPE)

IN COLUMNS 22-27.

REMARKS IN COLUMNS 28-69.

$ IN COL 72 FOR WRITE TAPE INITIALIZATION.

BLANK,REWIND, LIST, OR TAPEID (FOR WRITE TAPE) IN COLUMNS 73-78.

NEWTAPE IN COLUMNS 79-80.
.03 OUTPUT

.03.01 PRINT REAL NUMBERS
    CALL YWRITE (NUTA,6H ANAMF,V,LV,KV)
    USES PAGEHD,YIN,YINI,ZZFOMP.

.03.02 PUNCH REAL NUMBERS
    CALL YPUNCH (NUTA,6H ANAMF,V,LV,KV)
    USES YIN,YINI,ZZROMP.
TAPE OPERATIONS

REWIND NRITAPE, NWTAPE AT BEGINNING OF MAIN PROGRAM.
SEE APPENDIX A FOR TAPE INITIALIZING, LISTING, AND UPDATING.

.04.01 READING
CALL YRTAPE (6H2RUNNC, 6H ZNAME, NUT2, V, LV, KV, *NRITAPE, NUTJ)
*NRITAPE MUST BE A READ, WRITE TAPE ONLY.
USES LTAPF, YIN, YINI, YOUT, YOUTI, ZZPCMF.
CALL YIN  (NUTA, ZVEC, LS, LE)
CALL YINI  (NUT, IA, NS, NF)

.04.02 WRITING
CALL YWTAPE (N'TA, 6H ANAME, V, LV, KV, *NWTAPE)
*NWTAPE MUST BE A READ, WRITE TAPE ONLY.
USES YIN, YINI, ZZPCMF.
CALL YOUT  (NUTA, AVEC, LS, LE)
CALL YOUTI  (NUT, IA, NS, NF)
.05 GENERATION

.05.01 BASIS
   CALL YUNITY (NUTZ, NP, V, LV, KV)
   USES YOUT, YOUTI
   CALL YZERO (NUTZ, NR, NC)
   USES YOUT, YOUTI

.05.02 RAYLEIGH VECTORS
   CALL YPVI (NUTZ, N, NU, V, LV, KV, NUT1, NUT2, NUT3)
   USES YIN, YINI, YLORD, YOUT, YOUTI, YFART, YTRANS, ZZBOMP
ALGEEPA

SCALAR PRODUCT
CALL YAA (ALPHA,NUTA,NUT2,V,LV,KV,NUT1,NUT2)
USES YIN,YINI,YLORD,YNC2FR,YOUT,YOUT1,YPART,ZZFCMPF.

ADDITION, SUBTRACTION
CALL YAAH (ALPHA,NUTA,BETA,NUTP,NUT2,V,LV,KV,NUT1,NUT2)
USES YLORD,YIN,YINI,YLORD,YNC2FR,YOUT,YOUT1,YPART,
YSYMLH,YSYMHU,ZZFCMPF.

MULTIPLICATION - BASIC
CALL YMULTI (NUTA,NUTF,NUT2,V,LV,KV,NUT1)
USES YIN,YINI,YLORD,YNC2FR,YOUT,YOUT1,YPART,YSYMLH,
YSYMHU,ZZFCMPF.

MULTIPLICATION - SPECIAL
CALL YMULTI (NUTA,NUTF,NUT2,V,LV,KV,NUT1)
USES YIN,YINI,YLORD,YNC2FR,YOUT,YOUT1,YPART,YSYMLH,
YSYMHU,ZZFCMPF.
CALL YMUL2 (NUTA,NUTF,NUTZ,W2,V,lv,KV,NUT1)
USES YOUTS,YIN,YINI,YLCRF,YNC2FP,YOUT,YOUT1,YPART,
YSYMLH,YSYMHU,ZZFCMPF.
CALL YMUL4 (NUTA,NUTZ,W2,V,lv,KV,KW,NUT1)
USES YIN,YINI,YLCRD,YOUT,YOUT1,YPART,ZZFCMPF.

TRIPLE MATRIX PRODUCT
CALL YBTAE (NUTA,NUTF,NUT2,V,LV,KV,NUT1,NUT2)
USES YIN,YINI,YLORD,YMULI,YNC2FR,YOUT,YOUT1,YPART,
YSYMLH,YSYMHU,ZZFCMPF.

DECOMPOSITION
CALL YDOM3A (NUTA,NUTU,NUTI,V,lv,KV,NUT1,NUT2)
USES YIN,YINI,YLORD,YOUT,YOUT1,YPART,YTRANS,ZZFCMPF.
CALL YDOM3 (NUTA,NUTU,NUTI,V,lv,KV,NUT1,NUT2)
USES YIN,YINI,YLORD,YOUT,YOUT1,YPART,YTRANS,ZZFCMPF.

PACK SOLUTION
CALL YESL3A (NUTU,NUTP,NUTF,NUTZ,V,lv,KV,NUT1,NUT2)
USES YIN,YINI,YLORD,YOUT,YOUT1,YPART,YTRANS.
.07 MODIFICATION

.07.01 ASSEMBLY
CALL YASSEM (NUTA, IFZ, JC2, *NUT2, V, LV, KV, NUT1, NUT2, NUT3)
*IF NUT2 IS DEFINED, CALL YZFC TO CLEAR NUTZ.
USING YIN, YIN1, YLORD, YUT1, YOUT, YPART, YSYM1, YSYM2, Z2PCMF.

.07.01 DISASSEMBLY
CALL YDISA (NUTA, IFZ, JC2, *NUT2, NUTZ, NCF, NCV, LV, V, NUT1)
USING YIN, YIN1, YLORD, YUT1, YOUT, YPART, Z2PCMF.

.07.02 REVISION
CALL YRFVA (ALPHA, NUTA, JVEG, JVEC, *NUT2, V, LV, KV, NUT1, NUT2, NUT3, NUT4)
*IF NUT2 IS DEFINED, CALL YZFC TO CLEAR NUTZ.
USING YLORD, YASP, YIN, YIN1, YLORD, YNOZ, YOUT, YOUT1, YPART, YSYM1, YSYM2, Z2PCMF.
CALL YRFVA1 (ALPHA, A, JVEG, *NUT2, NPA, V, LV, KV, KA, NUT1, NUT2, NUT3, NUT4)
*IF NUT2 IS DEFINED, CALL YZFC TO CLEAR NUTZ.
USING YLORD, YASP, YIN, YIN1, YLORD, YNOZ, YOUT, YOUT1, YPART, YSYM1, YSYM2, Z2PCMF.

.07.03 CALL YRFVA2 (NUTA, NUTZ, NCF, V, LV, KV, V, NUT1, NUT2, NUT3, NUT4)
USING YIN, YIN1, YOUT, YOUT1, YPART, Z2PCMF.
CALL YRFVA3 (NUTA, NUTZ, NCF, NCV, V, LV, KV, NUT1, NUT2, NUT3, NUT4)
USING YIN, YIN1, YOUT, YOUT1, YPART, Z2PCMF.
CALL YRFV1 (JVEG, NUTA, NCF, NCA, NCV, V, LV, KV, V, VV, KA)
USING YLORD, YOUT, YOUT1, Z2PCMF.
CALL YRFV2 (NUTA, JVEG, JVEC, Z, NCF, NCV, V, LV, KV, V, VV)
USING YIN, YIN1, Z2PCMF.

.07.04 TRANSPOSE
CALL YTRANS (NUTA, NUTZ, V, LV, KV, NUT1, NUT2)
USING YIN, YIN1, YLORD, YOUT, YOUT1, YPART, Z2PCMF.

.07.05 SYMPHONIZE
CALL YSYM1 (NUTA, V, LV, KV, NUT1, NUT2)
USING YIN, YIN1, YLORD, YNOZ, YOUT, YOUT1, YPART.
CALL YSYM2 (NUTA, V, LV, KV, NUT1, NUT2)
USING YIN, YIN1, YLORD, YNOZ, YOUT, YOUT1, YPART.

.07.06 NULLIFY
CALL YZFR1 (NUTA, V, LV, KV, NUT1, NUT2)
USING YIN, YIN1, YLORD, YOUT, YOUT1, YPART, Z2PCMF.
CALL YZFR2 (NUTA, V, LV, KV, NUT1, NUT2)
USING YIN, YIN1, YLORD, YOUT, YOUT1, YPART, Z2PCMF.

.07.07 DIAGONALIZE
CALL YDIAG (NUTA, NUTZ, V, LV, KV)
USING YIN, YIN1, YOUT, YOUT1, Z2PCMF.
**CR**  STIFFNESS

**CR.01** REDUCTION

CALL YSPEED2 (NUTA, Nu, NUT1, NUT2, NUT3, NUT4)

USES YASSFD, YD15A, Y1N, Y1I, YLORD, YNC2FR, YOUT, YOUT1,
YPARF, YSYM1H, YSYM2H, YTRANS, YUNITY, YZEOC, ZZECMP.)
MODAL

ITERATIVE RAYLEIGH-RITZ
CALL YMOD2A (NUTM,NUTK,NUTZ,W2,W,FOCO,NW,NU,SHIFT,TOLZ,
             TOLW2,MAXIT,IPRINT,V,LV,A,S,KVNA,K,
             NUT1,NUT2,NUT3,NUT4,NUT5,NUT6)
USES ETABA2,IGNIA,INV4,MODE1X,NAME,PAGETO,TIMCHK,
WRITE,WRITTIM,XLORD,YAAFF,YSL3A,YDCM3A,YDCS,YIN,
YINI,YLORD,YMULT1,YMULT2,YMULT4,YMCSF,YOUT,YCUT1,
YPART,YRVI,YS100,YSMHL,YSYM1H,YTRANS,YWRITE,ZZCOMP
APPENDIX C. SUMMARY OF CALLING INSTRUCTIONS -
FINITE ELEMENT ROUTINES.

A 6H ARGUMENT MAY ALSO BE A VARIABLE READ WITH AN A6 FORMAT OR
OBTAINED WITH A DATA STATEMENT.

*** LIST OF SYMBOLS ***

NUTE = LOGICAL NUMBER OF UTILITY TAPE ON WHICH ELEMENT UNIT LOAD
RUCKLING MATRICES AND IVECS ARE OUTPUT.
NUTE MAY BE ZERO IF RUCKLING MATRICES ARE NOT FORMED.
USES FORTRAN READ, WRITE.

NUTEL = LOGICAL NUMBER OF TAPE CONTAINING ELEMENT INPUT DATA FOR
THIS SUBROUTINE AND SUBROUTINES AXIAL, ETC GIVEN BY NAMET.
IF NUTEL = 5, DATA WILL BE READ FROM CARDS.

NUTK = LOGICAL NUMBER OF UTILITY TAPE ON WHICH ASSEMBLED
STIFFNESS MATRIX IS OUTPUT IN SPARSE NOTATION.
NUTK MAY BE ZERO IF STIFFNESS MATRIX IS NOT FORMED.
USES FORTRAN READ, WRITE.

NUTKX = LOGICAL NUMBER OF UTILITY TAPE ON WHICH ELEMENT
STIFFNESS MATRICES (SAME AS GLOBAL LOADS TRANSFORMATION
MATRICES) AND IVECS ARE STORED.
NUTKX MAY BE ZERO IF STIFFNESS MATRIX IS NOT FORMED.
USES FORTRAN READ, WRITE.

NULTT = LOGICAL NUMBER OF UTILITY TAPE ON WHICH ELEMENT LOCAL
LOAD TRANSFORMATION MATRICES AND IVECS ARE OUTPUT.
NULTT MAY BE ZERO IF LOAD TRANSFORMATIONS ARE NOT FORMED.
USES FORTRAN READ, WRITE.

NUTM = LOGICAL NUMBER OF UTILITY TAPE ON WHICH ASSEMBLED
MASS MATRIX IS OUTPUT IN SPARSE NOTATION.
NUTM MAY BE ZERO IF MASS MATRIX IS NOT FORMED.
USES FORTRAN READ, WRITE.

NUTMX = LOGICAL NUMBER OF UTILITY TAPE ON WHICH ELEMENT
MASS MATRICES AND IVECS ARE STORED.
NUTMX MAY BE ZERO IF MASS MATRIX IS NOT FORMED.
USES FORTRAN READ, WRITE.

NUTST = LOGICAL NUMBER OF UTILITY TAPE ON WHICH ELEMENT
STRESS TRANSFORMATION MATRICES AND IVECS ARE OUTPUT.
NUTST MAY BE ZERO IF STRESS TRANSFORMATIONS ARE NOT FORMED.
USES FORTRAN READ, WRITE.
.01 MISCELLANEOUS

.01.01 DIRECTION COSINES
   CALL DCOS1A (CJ, FJ, Z, KCJ, KFJ, KZ)
   USES EULER, MULTF, ZZPOMP.
   CALL DCOS1R (CJ, FJ, Z, KCJ, KFJ, KZ)
   USES EULER, MULTR, ZZPOMP.
   CALL DCOS2 (CJ, FJ, Z, KCJ, KFJ, KZ)
   USES EULER, MULTF, ZZPOMP.
   CALL DCOS3C (CJ, FJ, Z, KCJ, KEJ, KZ)
   USES EULER, MULTR, ZZPOMP.

.01.02 EULER ANGLES
   CALL EULER (F, R, KR)

.01.03 TETRAHEDRON GEOMETRY
   CALL TECOM (CJ, JM, VL, DV, KCJ, IFRAD)
   USES VCROSS, VDOT.
.p2

FINITE ELEMENT MASS, STIFFNESS, PUCKLING, LOAD TRANSFORMATION,
STRESS TRANSFORMATION

CALL FINEL (XYZ, JDOF, FUL, NUTFL, NJ, NUTM, NUTK, NUTLT,
NUTST, NUTR, V, LV, KV, KRX, KRE, NUTMX, NUTKX,
NUT1, NUT2, NUT3)
USES AXIAL, FAF, FLUID, GRAVITY, PGEFHD, QUAD, PECTSP, TPNL0,
YFVAD2, ZZFCME.

CALL AXIAL (XYZ, JD0F, FUL, NUTFL, NJ, NUTMX, NUTKX, NUTLT,
NUTST, W, T, S, XX, KJ, KE, KW)
USES ATXPA1, ATXHE, DCOS2, EULER, K1A1, M1A1, M1A2, MAS1A,
MULTA, MULTB, PGEFHD, STF1A, ZZFCME.

CALL BAP (XYZ, JD0F, FUL, NUTFL, NJ, NUTMX, NUTKX, NUTFX,
NUTLT, NUTST, W, T, S, XX, KJ, KE, KW)
USES ATXPA1, PIA1, B1A2, PTABA, BUCIR, DCOSIR, EULER, K1A1,
K1P1, K1C1, M1A1, M1A2, M1H1, M1H2, MIC1, MIC2, MAS1B,
MULTA, MULTB, PGEFHD, STF1E, ZZFCME.

CALL FLUID (XYZ, JD0F, FUL, NUTFL, NJ, NUTMX, NUTKX, NUTLT, NUTST,
W, T, S, XX, KJ, KE, KW)
USES TEGEOM, VCR0SS, VDOT, ZZFCME.

CALL GRAVITY (XYZ, JD0F, FUL, NUTFL, NJ, NUTMX, W, T, S, XX, KJ, KE, KW)
USES KGRAV, MULTA, MULTB, VCR0SS, ZZFCME.

CALL QUAD (XYZ, JD0F, FUL, NUTFL, NJ, NUTMX, NUTKX, NUTBX,
NUTLT, NUTST, W, T, S, XX, KJ, KE, KW)
USES ATXFA1, PTABA, DCOS2, EULER, K2A1, K2E1, M2A1,
M2A2, M2E1, M2B2, MAS2, MAS3, MULTA, MULTB, PGEFHD,
REVADD, STF2, STF3, ZZFCME.

CALL PECTSP (XYZ, JD0F, FUL, NUTFL, NJ, NUTMX, NUTKX, NUTLT, NUTST,
W, T, S, XX, KJ, KE, KW)
USES MAS3A, PGEFHD, STF3A, ZZFCME.

CALL TPNL0 (XYZ, JD0F, FUL, NUTFL, NJ, NUTMX, NUTKX, NUTBX,
NUTLT, NUTST, W, T, S, XX, KJ, KE, KW)
USES ATXFA1, ETABA, DCOS2, EULER, K2A1, K2B1, M2A1,
M2A2, M2P1, M2F2, MAS2, MULTA, MULTB, PGEFHD, STF2, ZZFCME.
.03 MASS

.03.01 POP
CALL MAS1A (CJ, FJ, A1, A2, RC, 6, HNAMEM, Z, W, KF, K1, K2)
USFS AT, P1, EULER, M1A1, M1A2, ZZPOMP.
CALL M1A1 (A1, A2, RL, RC, Z, KZ)
CALL M1A2 (A1, A2, RL, RD, Z, KZ)
CALL M1C1 (P11, P12, RL, RC, Z, KZ)
CALL M1C2 (P11, P12, RL, RD, Z, KZ)

.03.02 RBEAM
CALL MAS1P (CJ, FJ, A1, A2, P11, P12, RC, 6, HNAMEM, Z, W, KF, K1, K2, KW)
USFS RTAPA, DC, 518, EULER, M1A1, M1A2, M2P1, M2P2, M1C1, M1C2, MULTP, ZZPOMP.
CALL M1R1 (A1, A2, RL, RC, Z, KZ)
CALL M1R2 (A1, A2, RL, RC, Z, KZ)

.03.03 TRIANGLE
CALL MAS2 (CJ, FJ, TMA5, RC, 6, HNAMEM, Z, W1, W2, KF, K1, K2, KW)
USFS RTAPA, DC, 518, EULER, M2A1, M2A2, M2P1, M2P2, MULTP, ZZPOMP.
CALL M2A1 (X2, Y3, TH, PO, Z, KZ)
USFS RTAPA.
CALL M2P1 (X2, Y3, TH, PO, Z, KZ)
USFS RTAPA.

.03.04 QUADRILATERAL
CALL MAS3 (CJ, FJ, TMA5, RC, 6, HNAMEM, Z, W1, W2, KF, K1, K2, KW)
USFS RTAPA, DC, 518, EULER, M2A1, M2A2, M2P1, M2P2, MAS2, MULTP, ZZPOMP.

.03.05 RECTANGULAR SHEAR PANEL
CALL MAS3A (CJ, FJ, TMA5, RC, 6, HNAMEM, Z, W1, W2, KF, K1, K2, KW1, KW2)
USFS RTAPA, DC, 518, M3C1, ZZPOMP.
CALL M3C1 (X3, Y3, TH, PO, Z, KZ)
04 STIFFNESS

04.01 ROD
CALL STF1A (CJ,FJ,AI,A2,FX,6HNAMEK,6HNAMEST,S,TL,TS,NRST,
KCJ,KEJ,KS,KTL,KT)
USES ATXBA1,DCOSA1,EULEP,KIA1,MULTA,MULTF,ZZFOMP.
CALL KIA1 (AI,A2,RL,E,Z,TS,KZ,KT)
CALL K11A (TJ1,TJ2,P1,P2,RL,E,Z,TS,KZ,KT)

04.02 BEAM
CALL STF1B (CJ,FJ,KODE,AI,A2,TLI,TL2,PI1,PI2,PI1X,P1Y1,
PI2X,PI2,Y1,CI2,CZ2,CL,6HNAMEK,6HNAMEST,S,TL,TS,NRST,
KCJ,KEJ,KS,KTL,KT)
USES ATXBA1,DCOS1,KIA1,K111,KIC1,MULTA,MULTP,ZZFOMP.
CALL K111 (PI1,PI2,CI1,CZ1,AI,A2,SL,EL,E,G,Z,TS,KZ,KT)

04.03 TRIANGLE
CALL STF2 (CJ,FJ,TMEM,TFEM,F,ANU,6HNAMEK,6HNAMEST,S,TL,TS,
NRST,KCJ,KEJ,KS,KTL,KT)
USES ATXBA1,DCOS2,EULEP,KP1,KP2,KP3,MULTA,MULTP,ZZFOMP.
CALL K2A1 (X2,X3,Y3,TH,F,ANU,Z,T,P,KZ,KT,PE)
USES ETAFA,MULTA,ZZFOMP.
CALL K2P1 (X2,X3,Y3,TH,F,ANU,Z,T,E,Z,KZ,KT)
USES ETAFA,MULTA,ZZFOMP.

04.04 QUADRILATERAL
CALL STF3 (CJ,FJ,TMEM,THFN,F,ANU,6HNAMEK,6HNAMEST,S,TL,TS,
NRST,KCJ,KEJ,KS,KTL,KT)
USES ATXBA1,DCOS2,EULEP,KP1,KP2,KP3,MULTA,MULTF,REVADD,
STF2,ZZFOMP.

04.05 RECTANGULAR SHEAR PANEL
CALL STF3A (CJ,FJ,TS,6HNAMEK,6HNAMEST,S,TL,TS,NRST,KCJ,
KEJ,KS,KTL,KT)
USES ATXBA1,DCOS3,C3CI,MULTA,ZZFOMP.
CALL K3CI (X3,Y3,TH,G,Z,T,KZ,KT)

04.06 FLUID
CALL KGPAV (CJ,JK,FV,AW,KW,KCJ)
USES MULTA,MULTF,VCROSS.
CALL BUCIR (CJ, EJ, KCDER, 6HNAME, Z, W, WC, KE, KZ, KW)
USES F1A1, F1A2, ETAFA, DCOS1P, EULER, MULTB, ZZCOMB.
CALL F1A1 (PL, Z, KZ)
CALL F1A2 (PL, Z, KZ)
06  FLUID PRESSURE

CALL PRESS (CJ,T,NJM,NCCL,KCJ,KW)
USES REVADD,INV1NP,MULTH.