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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Technical Memorandum 33-466

Volume II

VISCEL–A General-Purpose Computer Program for Analysis of Linear Viscoelastic Structures

Program Manual

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(NASA-CR-127750) VISCEL: A GENERAL PURPOSE COMPUTER PROGRAM FOR ANALYSIS OF LINEAR VISCOELASTIC STRUCTURES, VOLUME 2 K.K. Gupta, et al (Jet Propulsion Lab.) 15 Jul. 1972 50 p CSCL 20K G3/32

N72-29918

Unclas 37093

JET PROPULSION LABORATORY

CALIFORNIA INSTITUTE OF TECHNOLOGY

PASADENA, CALIFORNIA

July 15, 1972

Vol. I N71-18931

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Prepared Under Contract No. NAS 7-100
National Aeronautics and Space Administration

PREFACE

The work described in this report was performed by the Engineering Mechanics Division of the Jet Propulsion Laboratory.

ACKNOWLEDGMENT

The authors wish to thank Mr. G. W. Lewis and Mr. E. N. Duran of the Propulsion Division for providing continued support throughout the entire work program. Thanks are also due to Dr. M. R. Trubert and Dr. A. M. Salama for their support and assistance in the preparation of this work.

Editorial suggestions of Mr. Harold M. Yamamoto are acknowledged with sincere appreciation.

CONTENTS

ABSTRACT

VISCEL is a general-purpose computer program developed for the equilibrium analysis of linear viscoelastic structures. The program is written in FORTRAN V language to operate on the UNIVAC 1108 computer under the EXEC 8 operating system. VISCEL, an extension of the linear equilibrium problem solver ELAS, is an updated and extended version of its earlier form written for the IBM 7094 computer. The users may change the size of labeled COMMON to accommodate the particular problem to be solved without recompilation; it is possible to utilize up to 195K core memory in a 260K UNIVAC 1108/EXEC 8 machine. The physical program, consisting of approximately 7200 instructions, is stored on magnetic tape and is available from the Computer Software Management and Information Center (COSMIC), the NASA agency for the distribution of computer programs.

Finite element matrix displacement approach coupled with the synchronized material property concept, utilizing incremental time steps, has been adopted for the present solution. The step-by-step procedure involves solution of recursive equations in the time domain, which takes into account the memory of material properties. Incremental and accumulative displacements and stresses are obtained at the end of each such time step. In order to minimize the extent of computations resulting from accumulative effects of material memory, the program provides an option which enables the employment of constant time steps in the logarithmic scale. Volume I (revised) of this report describes the user's manual, whereas the present volume is concerned with program documentation.

VISCEL – A GENERAL-PURPOSE COMPUTER PROGRAM FOR ANALYSIS OF LINEAR VISCOELASTIC STRUCTURES

PROGRAM MANUAL

I. INTRODUCTION

The program VISCEL is derived originally from ELAS (Ref. 1) and prepared in FORTRAN V language. The program contains all the subroutines in ELAS, partly in modified form, and some additional subroutines. It has been developed for the UNIVAC 1108 computer with 36-bit words, operating under the EXEC 8 system. In addition to the standard system, chain and input/output (I/O) FORTRAN V units, the program uses units numbered 3, 4, 9, 10, 11, 12, 13, 14, and 15 as additional storage during the execution of the program. Each system unit stores specific type of data; descriptive information about the nature of data in each tape is given in Section II-B.

The program can be used for both elastic and viscoelastic analyses; the capability for the viscoelastic analysis is provided for by the use of two variables: (1) ISUCA, which is read in; and (2) ISTEPA, which is computed by the program. The alphabetically sequenced listing of the names of important variables is presented in Table 1. For each variable recorded in the table, the name of the subroutine in which the variable has been initially computed, the location of the variable in equivalence table with array AA or IA, and a short description for its function are presented. This complete list of symbol names may be used as additional information to that described in Ref. 1.

In Table 2, general information for main program MAIN and common subprograms has been summarized. Tables 3 through 6 present details of each subroutine in the four links of the program. In addition, the program contains various procedure elements CMAP10, CMAP11, CMAP21, CMAP31, CMAP32, CMAP41, CMAP42, and CMAP43, a block data program COMBK, and the segmentation element MAPEL. In addition, a summarized information about the storage organization is given in Section II-A.

The link structure permitted by FORTRAN II language has been replaced by the more versatile overlay structure of FORTRAN V. In order to preserve the natural correspondence between VISCEL in FORTRAN V and ELAS in FORTRAN II, the flow charts and listings of the program are grouped in conformity with the four subroutines, ELAS1, ELAS2, ELAS3, and ELAS4 corresponding to the four links of ELAS.

II. GENERAL INFORMATION ON STORAGE ORGANIZATION

For linear elastic problems the program uses only one scratch tape as supplementary storage. The basic operations, such as reading of data, assembly of stiffness matrix, solution of equations, and stress computations, are performed in-core during relevant stages in the program.

For viscoelastic problems, core memory is used for basic operations of each time step. The time-dependent physical properties and loading at each step is stored in the nine additional system units. The information is brought into the core memory in accordance with the recursive computation scheme of the viscoelastic incremental relations as described in Ref. 2.

The core memory organization for the linear elastic problems and for each solution step of viscoelastic problems is given in Section II-A; the use of system units as additional storage for viscoelastic problems is described in Section II-B.

A. Storage in Core Memory

The present version of VISCEL has been developed for a 260K UNIVAC 1108 machine. A labeled COMMON called COMEL is utilized by the program, and it is possible to request up to approximately 195K total core memory. A parameter LDATA is used to define the required COMMON size which will vary for different problems. COMMON COMEL is preceded by another COMMON, called COMDEF, storing an array DEF (5000), which is used as an additional storage for deformations.

In all four links the first 350 locations are used for basic or changing parameters of the programs, such as IN, IT, ... , pointers, type numbers, etc. IA (351) is equivalenced with element stiffness matrix array S(1), which may have variable length for different types of problems. Other arrays containing input and computed data are located by the use of variable pointers, the meanings and locations of which are given in Table 1. Schematic representation of the IA array containing all input and computed data is illustrated in Fig. 1. In this figure the constants and variable pointers are recorded at the upper side of the blocks representing the various arrays equivalenced with the IA array. The variable sizes of these arrays are recorded on the lower side.

B. Storage in Out-of-Core Memory Units

The program uses out-of-core memory units for viscoelastic analysis. In general the input data and the computed results are stored in the units whenever the use of their values in the later steps of analysis is required.

In unit 3, the element set information is recorded. Each record contains information concerning one node. The records are not conserved from one step to the next.

In unit 4, the computed deflections are written in successive order. Each record corresponding to one time step contains the reduced incremental deflection vector corresponding to the step considered, i. e., the block between variables IDEF and IU of Fig. 1. The deflections are recorded for all values of ISTEP. For the first time step group, i. e., ISUC = 1 and ISTEP = 1, the computed incremental deflections are added to the initial deflection vector and the first record contains this sum during the first time step group.

In unit 9, viscoelastic material properties are written corresponding to each step in successive order. Each record contains one set of values for viscoelastic material properties, i. e., the block between IID and IIA in Fig. 1, for each step in each time step group.

In unit 10, the dilatational constants are written for the material corresponding to each step in successive order. Each record contains one set of values for dilatation constants, i. e., the block between IIA and IPR for each step in each time step group.

In unit 11, the temperature change values are written corresponding to each step in successive order. The step temperature change at the initial time is not allowable. Each record contains one set of values for temperature change, i. e., the block between IDT and IDY in Fig. 1 for each step in each time step group.

Only units 9, 10, and 11 contain input data information, and these data are recorded on the units only when ISUC $\neq 0$ at the input reading stage in ELAS1.

In unit 12, information is written concerning each element at each step in successive order. Each record contains element number, computation variables, labels of vertices, element stiffness matrix, and loading vectors of the elements or subelements. At each step the number of records are determined by the number of elements in the problem, IT, and the number of subelements of each element. The element information is recorded when ISTEP > 1 at the assembly stage in ELAS2.

In unit 13, the reduced stiffness matrix is written for each step in successive order, starting from ISTEP = 2. The stiffness matrix for the first step is recorded only for the first time step group. One record corresponds to the block between IST and IST + IORD of Fig. 1. The stiffness matrices are recorded when ISTEP $\geq$ 1 in ELAS2, after the assembly is completed.

Unit 14 is used as a temporary storage area. In subroutine STEP of ELAS1, when ISUC $\geq$ 2, the element stiffness matrices corresponding to the ith time step are transferred to the beginning of unit 12, at the end of one time step group, by the use of unit 14. Also in ELAS3, when ISTEP = 1, the unit 14 contains the deflection vector for the computation of the residual vector.

In unit 15, the inverse of the stiffness matrix is written as a single record. The inverse of the stiffness matrix is recorded only when ISUC = 1, ISTEP = 1, and ISUC $\geq$ 2, ISTEP = 2, in ELAS3.

III. FLOW CHARTS OF COMMON SUBROUTINES

Flow charts for programs modified or written for VISCEL are presented in Figs. 2 through 12. The titles of the flow charts identify the appropriate subroutine.

REFERENCES

1. Utku, S., and Akyuz, F. A., ELAS — A General-Purpose Computer Program for the Equilibrium Problems of Linear Structures: Vol. I. User's Manual (Feb. 1, 1968) and Vol. II. Documentation of the Program (Sept. 15, 1969), Technical Report 32-1240. Jet Propulsion Laboratory, Pasadena, Calif.

2. Gupta, K. K., VISCEL — A General-Purpose Computer Program for Analysis of Linear Viscoelastic Structures: Vol. I. User's Manual (Revision 1), Technical Memorandum 33-466. Jet Propulsion Laboratory, Pasadena, Calif. (to be published).

Table 1. Definition of symbols

Variable and dimension	Subroutine computed in	Location in equivalence table with AA	Description
A (90, 7)	ABEQ		Coefficient of equations for stress boundary condition in ABEQ
AA (1)	A11	1	One-dimensional array which contains all the equivalenced variables used in the program
ACEL	Input	39	Body force per unit volume
AL1	ELAS2	83	Thermal expansion coefficient of an element in first material direction
AL2	ELAS2	84	Thermal expansion coefficient of an element in second material direction
AL3	ELAS2	85	Thermal expansion coefficient of an element in third material direction
ANGLE	QUAD	211	Angle defining principal curvature direction with respect to the axis passing from nodes 1 and 2 (KSI)
ARE	BOFI	205	Boundary area corresponding to a node
AST	ELAS4	203	Indicator for boundary node for stress printout (one asterisk)

Table 1 (contd)

Variable and dimension	Subroutine computed in	Location in equivalence table with AA	Description
B (8, 8)	REVO		Coefficient of equations for determining best-fit surface on polynomial in shells
BAS (3)	INLZ	271	Components of base vector for an element, i. e., connecting first and second vertices
BB (999, 6)	ELAS3 and ELAS4	25000	Two-dimensional array for 6 deflection components of the nodal points
BIR (3)	BOFI	220	Components of outer normal at a node on the boundary
BST	ELAS4	217	Indicator for stress resultants in the output if they are in local coordinate system (two asterisks)
C (8, 2)	QUAD, REVO		Right-hand side of equations for best-fit surface or curve in shells; after solution it contains six components of strain tensor
CCCI (25)	DARN	250	Constants for deflection boundary condition, to be introduced in the element stiffness matrices of elements during assembly
CCCJ (25)	DARN	275	CCCI operates on rows, CCCJ operates on columns

Table 1 (contd)

Variable and dimension	Subroutine computed in	Location in equivalence table with AA	Description
CFE	ELAS2	327	Constant to compensate the summation of element stiffness matrix for quadrilateral and hexahedral elements
C1T	ELAS1, 2, 3, 4		Time elapsed in seconds
CONS	S01, S02, S04, S05, S07, S09, S15	45	Volume times magnitude of the acceleration vector
CTES	ELAS1		Contains END and used for detection of END card
DD (6, 6)	META		Material matrix for stress computations
DEF (5000)	ELAS3	Not in AA	Additional storage for deflection components for computation of accumulative deflections
DG	ELAS2	82	Temperature gradient for an element in direction y local axis
DGY	ELAS2	332	DGY = DG
DGZ	ELAS2	331	Temperature gradient for an element in direction z local axis

Table 1 (contd)

Variable and dimension	Subroutine computed in	Location in equivalence table with AA	Description
DIN (3, 3)	QUAD	226	Cosine directrices of local coordinate system with respect to overall in shells
DT	ELAS2	81	Value of temperature change for an element
DUM	All		Dummy variable for locating the records which will be read next from the system units
DUMMY (5000)	ELAS1	25000	Temporary storage area for input
D21 (21)	ELAS2	86	Material constants in general material case for an element
D33 (3, 3)	ELAS2	86	Material constants in orthotropic material case for an element
E	ELAS2, META		Modulus of elasticity (E)
EL	ELDI	236	Length of a one-dimensional element
E22 (3, 3)	ELAS2	95	Material constants associated with shear deformations
FF (1)	ELAS4 and subroutines		General storage area for various arrays used in ELAS4 and associated subroutines

Table 1 (contd)

Variable and dimension	Subroutine computed in	Location in equivalence table with AA	Description
G	ELAS2, META		Shear modulus (G)
G1 (1)	Input	47	Cosine of the angle of acceleration vector with X axis
G2	Input	48	Cosine of the angle of acceleration vector with Y axis
G3	Input	49	Cosine of the angle of acceleration vector with Z axis
IA (1)	All	1	One-dimensional array which contains all the equivalenced variables used in the program
IARE	Input for elastic problems	16	Total number of cross-sectional area type input
IARES	Input for viscoelastic problems	258	Total number of cross-sectional area type input which is being changed for visco-elastic analysis
IBB	ELAS1	59	Pointer for IBB array which contains information concerning boundary conditions; current row labels of the deflection components
IBN (25)	Input	2	Total number of deflection boundary condition units

Table 1 (contd)

Variable and dimension	Subroutine computed in	Location in equivalence table with AA	Description
IBO	ELAS1	60	Pointer for IBO array which contains information concerning boundary conditions; indicator for retained or eliminated deflection component
IBS	DARN	200	Array which contains labels of the related unknowns to the unknown under question, operates on rows
IBUN	Input	327	Indicator for displacement boundary condition generation
IC	BOFI	209	Index for class type number at a node
ICAR	ELAS1	66	Pointer for cross-sectional area array
ICAS	ELAS4	212	Class type of an element at a node
ICFI	ELAS1	70	Pointer for angle array
ICIX	ELAS1	67	Pointer for torsional constants array
ICIY	ELAS1	68	Pointer for y moments of inertia array
ICIZ	ELAS1	69	Pointer for z moments of inertia array

Table 1 (contd)

Variable and dimension	Subroutine computed in	Location in equivalence table with AA	Description
ICLA	ELAS4	206	Maximum number of class types associated with a material type on a given node
ICLAS (4)	GENE	274	Maximum number of class types associated with the material types on a given node
ICOL	INLZ	295	Constant related to the number of stress components at a node
ICON	ABEQ, SETA	210	Counter for strain equations
ICOR	Input	328	Indicator for coordinate generation
ICN	ELAS4	201	Label of current node for stress computation
ID	VELAS		Count of diagonal element in the overall stiffness matrix components
IDEF	ELAS1	75	Pointer for load array initially and computed deflections array after the equations are solved
IDEG	Input	8	Number of degrees of freedom at a mesh point
IDR	INLZ	297	Constant which distinguishes plate case for stress computation

Table 1 (contd)

Variable and dimension	Subroutine computed in	Location in equivalence table with AA	Description
IDS	ELAS1, ELAS2	36	Maximum possible order for the element stiffness matrices of the problem in ELAS1; order of actual element stiffness matrix in ELAS2
IDS2	ELAS1, ELAS2		IDS*IDS number of elements in stiffness matrix of an element
IDT	ELAS1	63	Pointer for temperature change array
IDUM (5000)	ELAS1	25000	Temporary storage area for input
IDY	ELAS1	64	Pointer for temperature gradient array (y direction)
IDZ	ELAS1	334	Pointer for temperature gradient array (z direction)
IE	REVO	213	Number of elements corresponding to Ith material type and to Jth class type
IELT	TOPO1, 2, 4	28	Element type number
IERR	All	79	Error indicator for all purposes, IERR $\neq$ 0 indicates occurrence of an error
IGEM	Input	78	Geometry indicator: IGEM = 0, two-dimensional problem ($Z \equiv 0$); IGEM = 1, three-dimensional problem

Table 1 (contd)

Variable and dimension	Subroutine computed in	Location in equivalence table with AA	Description
IH	Input	10	Maximum number of vertices in the elements used
IIA	ELAS1	62	Pointer for thermal expansion coefficient array
IIC	ELAS1	74	Pointer for deflection boundary condition unit constant array
IID	ELAS1	77	Pointer for material constant array
IIS	ELAS1	77	Pointer for element stiffness matrix
IM	ELAS4	208	Counter for material types for stress computations
IMAT	Input for elastic problems	7	Total number of material type input
IMATS	Input for viscoelastic problems	253	Total number of material type input which is changed in the step considered for visco-elastic analysis
IMEL	GENE	207	Maximum number of material types associated with a nodal point
IMES	Input	326	Indicator for element data generation
IMET	TOPO1, 2, 4	34	Material type number

Table 1 (contd)

Variable and dimension	Subroutine computed in	Location in equivalence table with AA	Description
IMFI	Input for elastic problems	15	Total number of angle type input fixing local y and z axes
IMFIS	Input for viscoelastic problems	262	Total number of angle type input fixing local y and z axes which are changed in the step considered for viscoelastic analysis
IMMX	Input for elastic problems	12	Total number of torsional constant type input
IMMXS	Input for viscoelastic problems	259	Total number of torsional constant type input which is changed in the step considered for viscoelastic analysis
IMMY	Input for elastic problems	13	Total number of moment of inertia type input (about local y axis)
IMMYS	Input for viscoelastic problems	260	Total number of moment of inertia type input (about local y axis) in the step considered for viscoelastic analysis
IMMZ	Input for elastic problems	14	Total number of moment of inertia type input (about local z axis)

Table 1 (contd)

Variable and dimension	Subroutine computed in	Location in equivalence table with AA	Description
IMMZS	Input for viscoelastic problems	261	Total number of moment of inertia type input (about local z axis) in the step considered for viscoelastic analysis
IMS	ELAS2, ELAS4	34	Number of vertices of current element
IN	Input	1	Total number of nodal points
INBON		204	
IND	ELAS1	33	Total number of equations before the reduction using boundary conditions; IND = IDEG*IN
IND1	ELAS1		IND1 = IND + 1
INP	Input	42	Printout indicator: 0 = minimum, 1 = intermediate, 2 = detailed output
INX	Input	9	Number of link after which return-to-beginning is done
IONE	ELST	200	Number of one-dimensional elements in the structure
IORD	SRAT	37	Number of words allocated for the reduced stiffness matrix
IORD1	All	38	IORD + 1
IP	Input for elastic problems	4	Total number of concentrated load components

Table 1 (contd)

Variable and dimension	Subroutine computed in	Location in equivalence table with AA	Description
IPBG	S01, S02, S03, S04, S05, S07, S09, S11, S15, S17	43	Integer constant for element load vector, IPBG ≠ 0 if there are nonzero components
IPEN	S01, S02, S03, S04, S05, S07, S09, S11, S15, S17	44	Range of degree of freedom with nonzero element load vector component
IPIR	Input	329	Local coordinate selection indicator for shells
IPR	ELAS1	333	Pointer for pressure array
IPRS	Input for elastic problems	5	Total number of pressure type input
IPRSS	Input for viscoelastic problems	252	Total number of pressure types which are changed in the step considered for viscoelastic analysis
IPS	Input for viscoelastic problems	251	Total number of concentrated load components which are changed in the step considered for viscoelastic analysis
IRIG	INLZ	296	Indicator for existence of stress couple, i.e., for shell with membrane and bending

Table 1 (contd)

Variable and dimension	Subroutine computed in	Location in equivalence table with AA	Description
IROT	ELAS4, INLZ	216	Indicator for transformation of stress components from overall to local (transformation occurs if IROT $\neq$ 0)
ISDT	Input for elastic problems	348	Total number of temperature change type input
ISDTS	Input for viscoelastic problems	255	Total number of temperature change types in the step considered for viscoelastic analysis
ISDY	Input for elastic problems	347	Total number of temperature gradient type input along local y axis
ISDYS	Input for viscoelastic problems	256	Total number of temperature gradient types along local y axis which are changed in the step considered for viscoelastic analysis
ISDZ	Input for elastic problems	346	Number of temperature gradient type input along local z axis
ISDZS	Input for viscoelastic problems	257	Total number of temperature gradient types along local z axis which are changed in the step considered for viscoelastic analysis

Table 1 (contd)

Variable and dimension	Subroutine computed in	Location in equivalence table with AA	Description
ISHUF	Input for elastic problems	35	Relabeling indicator
ISIR (540)	E1AR		The order of the new labels of nodal points obtained by ARAN in ELAS
IST	ELAS1	76	Pointer for reduced stiffness matrix of the whole structure
ISTEP	ELAS1, 2, 3, 4		Number of time steps for viscoelastic study (ISTEP = ISTEPA - 100*ISTEPP)
ISTEPA	ELAS4	58	Contains number of time steps at the first digit and previous time step number at the third digit
ISTEPP	ELAS1, 2, 3, 4	27	Number of previous time step: ISTEPP = ISTEPA/100
ISTR	Input for elastic problems		Indicator for plane strain case: ISTR = 0 plane stress ISTR = 1 plane stress
ISUC	ELAS1, 2, 3, 4		Number of time step groups for viscoelastic study: ISUC = ISUCA - 100*ISUCP

Table 1 (contd)

Variable and dimension	Subroutine computed in	Location in equivalence table with AA	Description
ISUCA	Input for viscoelastic problems	26	Contains number of time step group at the first digit and previous time step group number at the third digit, read in the last card of input
ISUCP	ELAS1, 2, 3, 4		Number of previous time step group: ISUCP = ISUCA/100
ISUCT			Not used
ISUM	SRAT	32	Number of equations
IT	Input	3	Total number of elements
ITAP	Input	41	Chain tape number for program; program assumes ITAP = 2 if it is not assigned by the user
ITAS	Input	335	Scratch tape number for temporary storage
ITE	ELAS1	65	Pointer for thickness array
ITEM	TOPO1, 2, 4	29	Temperature change type number
ITIC	TOPO1, 2, 4	30	Thickness type number
ITIM	ELAS1, 2, 3, 4		Integer time counter which is equivalent to 1/60 second

Table 1 (contd)

Variable and dimension	Subroutine computed in	Location in equivalence table with AA	Description
ITTM	CUTE		Maximum number of subelements in quadrilateral and hexahedral elements; ITTM = 1 for one-dimensional and line element
ITTT	ELAS2	325	Counter for subelements in quadrilateral and hexahedral elements
ITYPE	Input	6	Material indicator: 0 = isotropic, 1 = orthotropic, 2 = general
IU	ELAS1, VELAS	46	Pointer for diagonal element count vector
IW	VELAS		Number of nonzero elements in a row of the overall stiffness matrix
IWG (90)	ABEQ, SETA		Weight for strain equation along nodal lines
IWRT	ELAS2		Indicator which governs the assembly of load vector for viscoelastic problems
IXX	ELAS1	71	Pointer for X coordinate array
IYY	ELAS1	72	Pointer for Y coordinate array
IZZ	ELAS1	73	Pointer for Z coordinate array
I8	Input	11	Maximum number of words for the description of elements

Table 1 (contd)

Variable and dimension	Subroutine computed in	Location in equivalence table with AA	Description
JARE	TOPO1, 2, 4	340	Type number of cross-sectional area
JBS (25)	DARN	225	Array which contains labels of the related unknowns to the unknown under question, operates on columns
JMFI	TOPO1, 2, 4	336	Type number of angle defining local coordinate of a frame member
JMMX	TOPO1, 2, 4	339	Type number of the torsional constant about local x axis
JMMY	TOPO1, 2, 4	338	Type number of the sectional moment of inertia about local y axis
JMMZ	TOPO1, 2, 4	337	Type number of the sectional moment of inertia about local z axis
JM1	BOFI	293	Sequence number of node before the current node
JPRS	TOPO1, 2, 4	343	Type number of pressure
JP1	BOFI	292	Sequence number of node after the current node
JSDY	TOPO1, 2, 4	342	Type number of temperature gradient in local y direction
JSDZ	TOPO1, 2, 4	341	Type number of temperature gradient in local z direction

Table 1 (contd)

Variable and dimension	Subroutine computed in	Location in equivalence table with AA	Description
JSTEP	ELAS1, 2, 3, 4		Counter for summation of products in viscoelastic problems
JS1	BOFI	294	Sequence number of node above the current node
J1	ELAS1	50	Pointer for the first word for the description of elements (J1W)
J2	ELAS1	51	Pointer for the second word for the description of elements (J2W)
J3	ELAS1	52	Pointer for the third word for the description of elements (J3W)
J4	ELAS1	53	Pointer for the fourth word for the description of elements (J4W)
J5	ELAS1	54	Pointer for the fifth word for the description of elements (J5W)
J6	ELAS1	55	Pointer for the sixth word for the description of elements (J6W)
J7	ELAS1	56	Pointer for the seventh word for the description of elements (J7W)

Table 1 (contd)

Variable and dimension	Subroutine computed in	Location in equivalence table with AA	Description
J8	ELAS1	57	Pointer for the eighth word for the description of elements (J8W)
J9	ELAS1	58	Pointer for the ninth word for the description of elements (J9W)
J10	ELAS1	59	Pointer for the tenth word for the description of elements (J10W)
LDATA	MAIN		Defines data size of problem to be solved
LM	ELST	202	Number of non-one-dimensional element at a node
M	ELAS2	25	Label of the current element
MAC (4, 4, 20)	GENE		Contains material and class types of elements connected to a node
MAX	VELAS		Pointer for the last element of the overall stiffness matrix
MB	BOFI	215	Number of adjacent boundary node to the current boundary node
N (8)	ELAS2	17	Labels of the vertices of an element

Table 1 (contd)

Variable and dimension	Subroutine computed in	Location in equivalence table with AA	Description
NAV	ELAS2	328	Counter for summation and averaging stiffness matrices of subelements in quadrilateral and hexahedral elements
NB	BOFI	214	Number of nodes adjacent to the current node
NBAN (10)	BOFI	278	List of nodes on the boundary adjacent to the current node (for stress computations)
NEL (20, 17)	GENE		Contains intrinsic property type numbers and label of vertices of all elements connected to a node
NES		295	
NOO (20)	ELAS2	300	Labels of vertices of subelements in sequence for quadrilateral and hexahedral elements
NSET (100)	BOFI		List of nodes adjacent to the current node (for stress computation)
NSTEP	ELAS1, 2, 3, 4	328	Range of dummy tape reading for summation of products in viscoelastic problems

Table 1 (contd)

Variable and dimension	Subroutine computed in	Location in equivalence table with AA	Description
NT (10)	ELAS2		Contains IT (number of elements) in the I8 (maximum number of vertices) first element; used for computation of pointers J1, J2, . . .
NTIC	Input for elastic problems	349	Total number of thickness type input
NTICS	Input for viscoelastic problems	254	Total number of thickness type input which is changed in the step considered
NU (3)	BOFI	292	Contains sequence number of nodes relative to the current node [NU(1) = JP1; NU(2) = JM1; NU(3) = JS1]
P (24)	ELAS2	107	Loading vector for an element
PD (3)	ELDI	291	Component of unit loading vector from pressure
PRCO	S01, S02, S04, S05, S07, S09, S15	324	Constant for computing load vector due to pressure loading
PRES	TOPO1, 2, 4	330	Pressure value for an element
PU	ELAS2, META		Poisson's ratio

Table 1 (contd)

Variable and dimension	Subroutine computed in	Location in equivalence table with AA	Description
PV (24)	ELAS2	275	Complete loading vector when P contains only temperature loading
QF (6)	FINDQ	253	Deflection of the current
QN (6)	FINDQ	247	Deflection of the adjacent nodes
RED (6)	REVO, SETA	265	Cosine directrices for the approximate direction of middle surface tangent (KSI axis), or relative deflection of adjacent node
REM (13)	ELAS1		Contains alphameric information on the first card of input data for a problem
RES (6)	ABEQ	259	Contains residual forces at the current node
S (1)	ELAS2	351	Stiffness matrix of an element
SIR (3)	ABEQ	223	Components of residual vector in local system
SR (6)	ABEQ, STRS	235	Six components of stress tensor
TE	ELAS2	80	Value of thickness for an element
TEST	ELAS1		The contents of data cards at the 78-80th columns

Table 1 (contd)

Variable and dimension	Subroutine computed in	Location in equivalence table with AA	Description
UV (24)	ELAS2	131	Deflection due to temperature change for an element
W (3,3)	ROTA		Direction cosines of new material axes with respect to original material axes
X (8)	ELAS2	155	Overall X coordinates of vertices of an element
XD (7)	ELAS2	179	Local x coordinates of vertices of an element; local coordinates referred to the axes passing by the first vertex and parallel to the overall coordinate axes
XF (3)	FINDX	244	Relative coordinate of the adjacent nodes
XN (3)	FINDX	241	Coordinates of a node
Y (8)	ELAS2	163	Overall Y coordinates of vertices of an element
YD (7)	ELAS2	186	Local y coordinates of vertices of an element; local coordinates referred to the axes passing by the first vertex and parallel to the overall coordinate axes
Z (8)	ELAS2	171	Overall Z coordinates of vertices of an element

Table 1 (contd)

Variable and dimension	Subroutine computed in	Location in equivalence table with AA	Description
ZD (7)	ELAS2	193	Local z coordinates of vertices of an element; local coordinates referred to the axes passing by the first vertex and parallel to the overall coordinate axes
ZGEM	ELAS1	40	Floating point equivalent of geometry indicator: ZGEM = 0, two-dimensional; ZGEM = 1, three-dimensional problem

Table 2. Main program and common subprograms

Program	Function
MAIN	Calls ELAS1, ELAS2, ELAS3, ELAS4 in successive order
BUFF.[a]	
BUFF*[a]	
ITIME.[a]	Reads clock
TICK*	Sets time 0 and measures time

[a]In FAP language.

Table 3. Programs associated with ELAS1

Program	Function
ELAS1[a]	Reads, stores, and checks input data, computes storage allocation pointers, reads program parameters (i.e., ISUC)
ARAN	Relabels mesh points for bandwidth minimization
BAND	Generates IBAND vector
BUNG	Dummy subroutine for boundary condition generator
COOR	Reads and stores coordinates
CORG	Dummy subroutine for coordinate generator
EXCH	Interchanges consecutive rows and columns of connectivity matrix
LEBIN[b]	Checks whether a binary bit is 0 or 1
MATE[a]	Reads and stores material properties
MBIN	Generates ABIN binary matrix
MESG	Dummy subroutine for mesh generator
MEST	Reads and stores mesh topology data
OUTPT	Prints information related with relabeling
PTAB	Reads and prints physical property tables
SEBIN[b]	Stores 1 or 0 to prescribed binary bit
SRAT	Generates connectivity matrix and determines the topological properties of reduced stiffness matrix
STEP[a]	Reorders the contents of storage units at the beginning of each time step group

Table 3 (contd)

Program	Function
TABL	Prints the title and control constants in tabular form
TOPO1	Prepares element property and vertex labels
XLOC	Determines storage location of a variable

[a]Programs modified or written for VISCEL.

[b]In FAP language.

Table 4. Programs associated with ELAS2

Program	Function
ELAS2[a]	Generates stiffness matrix and loading vector
ADM	Adds submatrices to form element stiffness matrix
ASMEL	Assembles elemental matrices
BEAM	Generates stiffness matrices for beam element in local coordinates
CAS2	Dummy subroutine
CODI2	Obtains coordinate transformation matrix for line element
CORT	Obtains coordinates of triangular shell element in local coordinates
CUTE	Subdivides quadrilaterals and hexahedrons into triangles and tetrahedrons
DARN	Prepares information related to boundary conditions
DMM	Obtains product of element stiffness matrix and a vector
ELCOR	Generates element vertex coordinates
ELDI	Obtains unit vector of pressure for line elements
ELMAT	Generates element material constants
ELPTY	Generates element properties other than coordinates and material properties
PLBE	Generates submatrices for grid and space frame line elements

Table 4 (contd)

Program	Function
RLOC	Adds submatrices to form element stiffness matrix for line elements
S01	Generates stiffness and load matrices for truss element
S02	Generates stiffness and load matrices for planar frame element
S03	Generates stiffness and load matrices for gridwork frame element
S04	Generates stiffness and load matrices for space frame element
S05	Generates stiffness and load matrices for plane stress/strain element
S07	Generates stiffness and load matrices for plate element
S09	Generates stiffness and load matrices for three-dimensional element
S11	Generates stiffness and load matrices for general shell bending element
S13	Generates stiffness and load matrices for general shell membrane element
S15	Generates stiffness and load matrices for solid of revolution
S17	Generates stiffness and load matrices for shell of revolution membrane element
S18	Generates stiffness and load matrices for shell of revolution bending element
STFS	Selects proper subroutine for generation of element matrices

Table 4 (contd)

Program	Function
STRA2	Transforms element stiffness matrices from local to overall coordinates
TOPO2	Prepares element property and vertex labels
TRAN2	Transforms a vector from local to overall coordinates
TRIM	Generates M, N, and L matrices of thin triangular elements
TRM	Performs triple matrix product of order 3

[a]Program modified for VISCEL.

Table 5. Programs associated with ELAS3

Program	Function
ELAS3[a]	Obtains deflection components in overall coordinates, writes and reads storage units
CMP3[a]	Obtains complete deflection vector from reduced deflection vector
ELST	Computes and writes on tape ITAS element set information
EPAN	Generates shell node sets for material groups
NCOM	Completes formation of deflection vector
PLELT	Generates records for mesh plots
PROD[a]	Computes product of stiffness matrix by the deflection vectors
PUNC	Dummy subroutine
RESI	Computes residual forces at the nodes
RESW	Prints residual forces at the nodes
TAPE[a]	Reads deflections from unit 4 for accumulative residual forces in viscoelastic case
VELAS[a]	Solves governing equations by variable-bandwidth Cholesky method

[a]Program modified or written for VISCEL.

Table 6. Programs associated with ELAS4

Program	Function
ELAS4[a]	Obtains stresses at mesh points
ABEQ[a]	Generates equations for stress boundary conditions at a node
AGEL	Dummy subroutine
BEST	Obtains best-fit plane segment at a boundary node
BOFI	Finds if a node is on boundary
CAS4	Dummy subroutine
CMP4[a]	Obtains complete deflection vector from reduced deflection vector
CODI4	Obtains coordinate transformation matrix for line element
DIMI	Generates stresses for line elements
DINA	Obtains local coordinate axes at a node in shells
FINDQ	Obtains deflection of a node in overall coordinates
FINDX	Obtains overall coordinates of a node
GENE	Generates information concerning nodes and elements adjacent to the current node
INER	Obtains a vector heading toward the structure at a boundary node
INLZ	Initializes scalars, vectors, and matrices at a node
INV	Inverts matrices up to order 8 by Gauss elimination

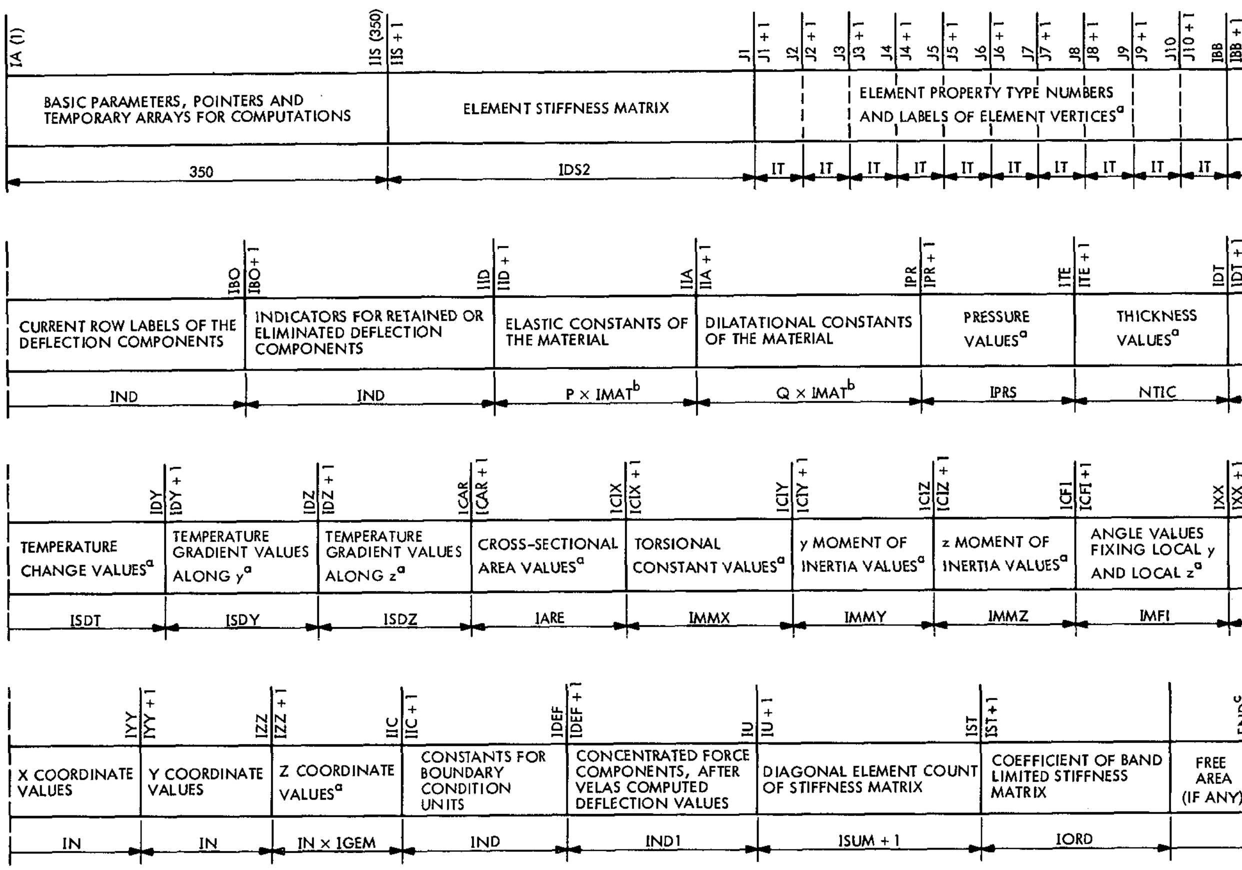
Table 6 (contd)

Program	Function
LEST	Obtains strain components by least squares at a node
MDIN	Orients local axes properly at a boundary node in shells
META	Generates material matrix in local coordinates in the 1, 2, 12, 3, 13, 23 order at a node
QUAD	Finds local axes by best-fit quadratic surface at a shell node
REVO	Finds local axes by best-fit fourth-order polynomial at a node of shell of revolution
ROTA	Expresses material matrix in local axes
SAME	Expresses stress tensor in overall coordinate system
SCAL	Performs scalar vector product
SETA	Generates stress-deflection relationship at a nodal line
STRS	Computes stresses from strains
TEMP	Computes nodal line vector in original material axes
TOPO4	Prepares element properties and vertex labels
TRAN4	Transforms a vector from local to overall coordinates

Table 6 (contd)

Program	Function
UNIT	Obtains a unit vector along a line segment
VECT	Performs vectorial vector product

[a]Program modified or written for VISCEL.



[a]DEPENDING ON INPUT DATA THESE AREAS MAY SHRINK TO ZERO.

[b]P = 2, Q = 1 FOR ISOTROPIC; P = 9, Q = 2 FOR ORTHOTROPIC; P = 21, Q = 3 FOR GENERAL MATERIAL.

[c]END OF DIMENSIONED IA ARRAY IN BLOCK DATA ROUTINE.

Fig. 1. Schematic representation of IA array

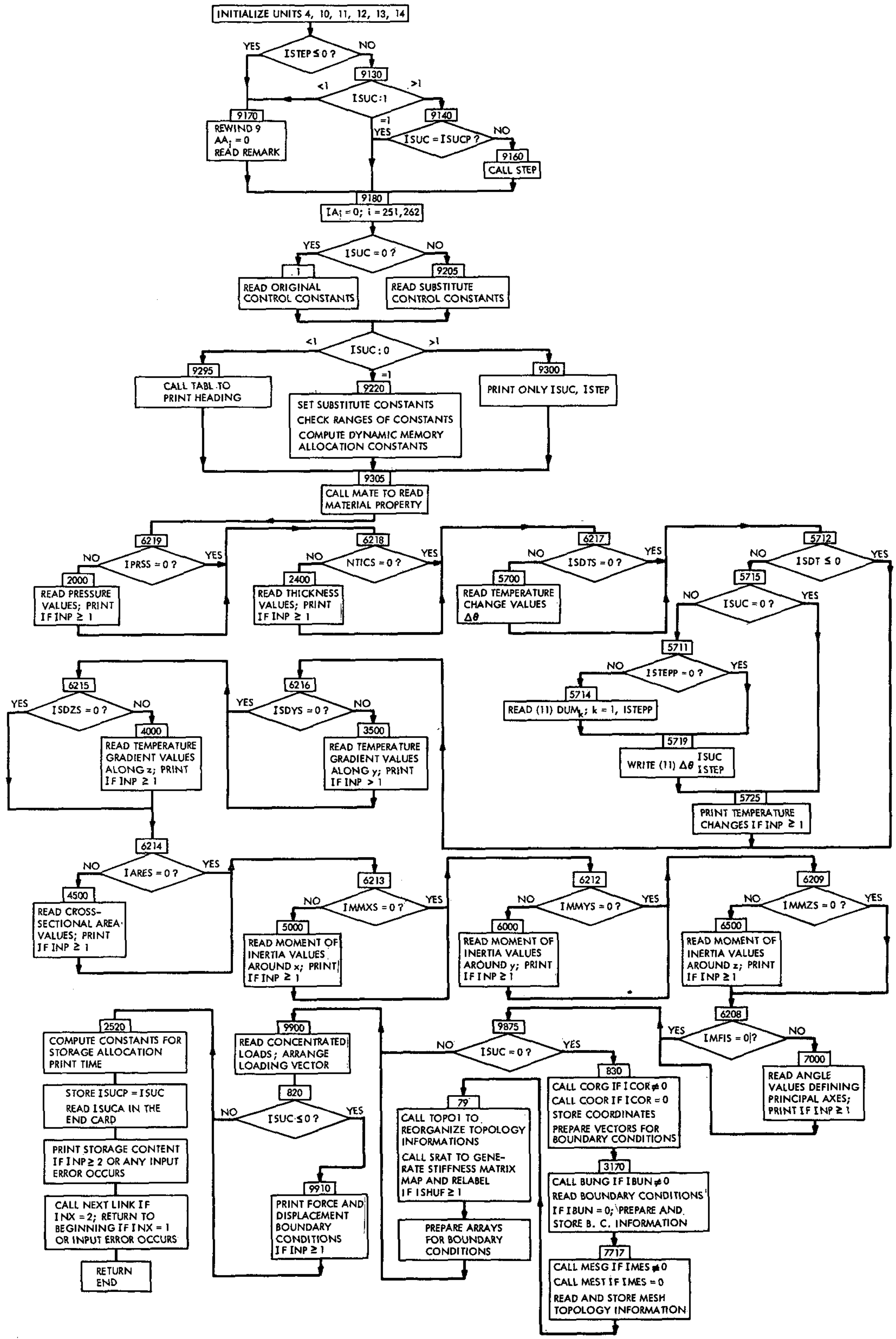


Fig. 2. Flow chart for subroutine ELAS1

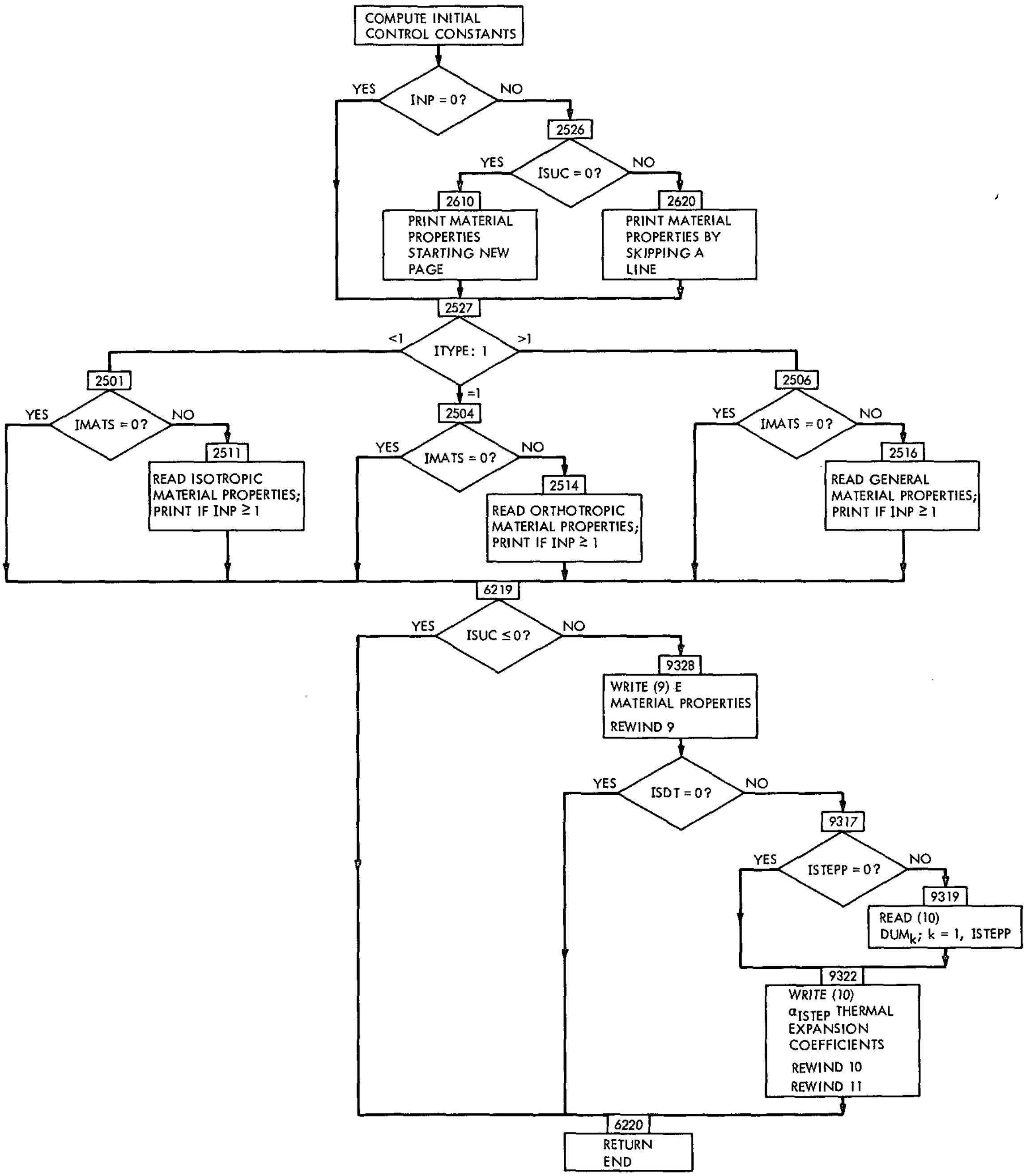


Fig. 3. Flow chart for subroutine MATE

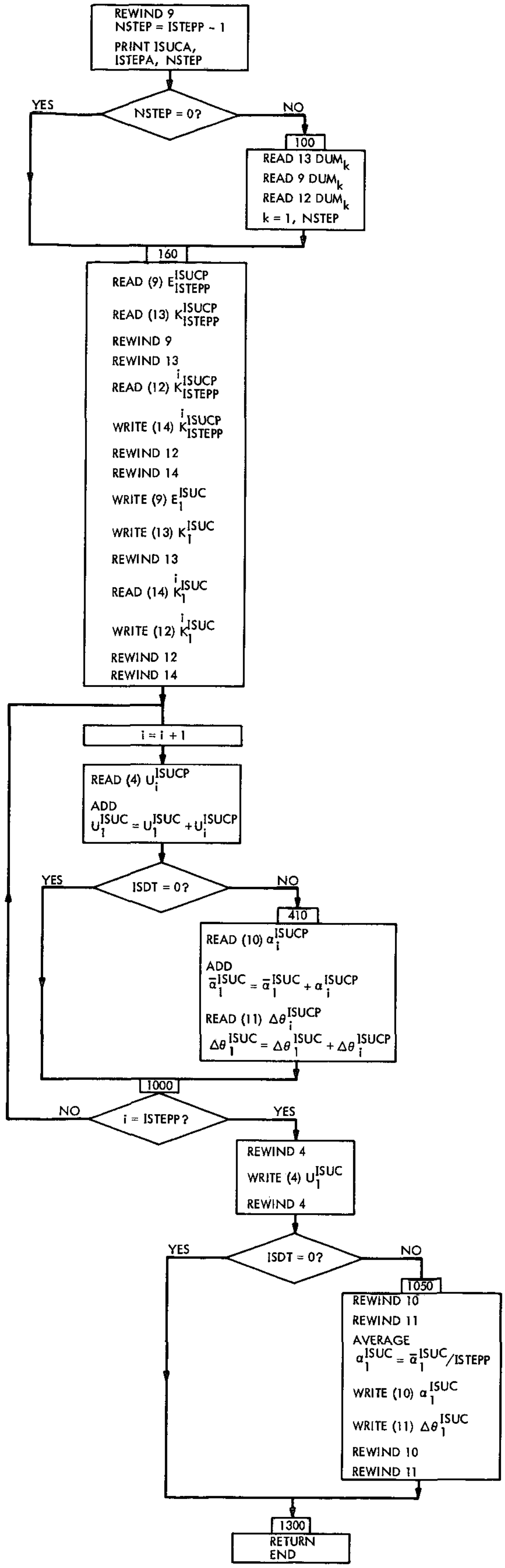


Fig. 4. Flow chart for subroutine STEP

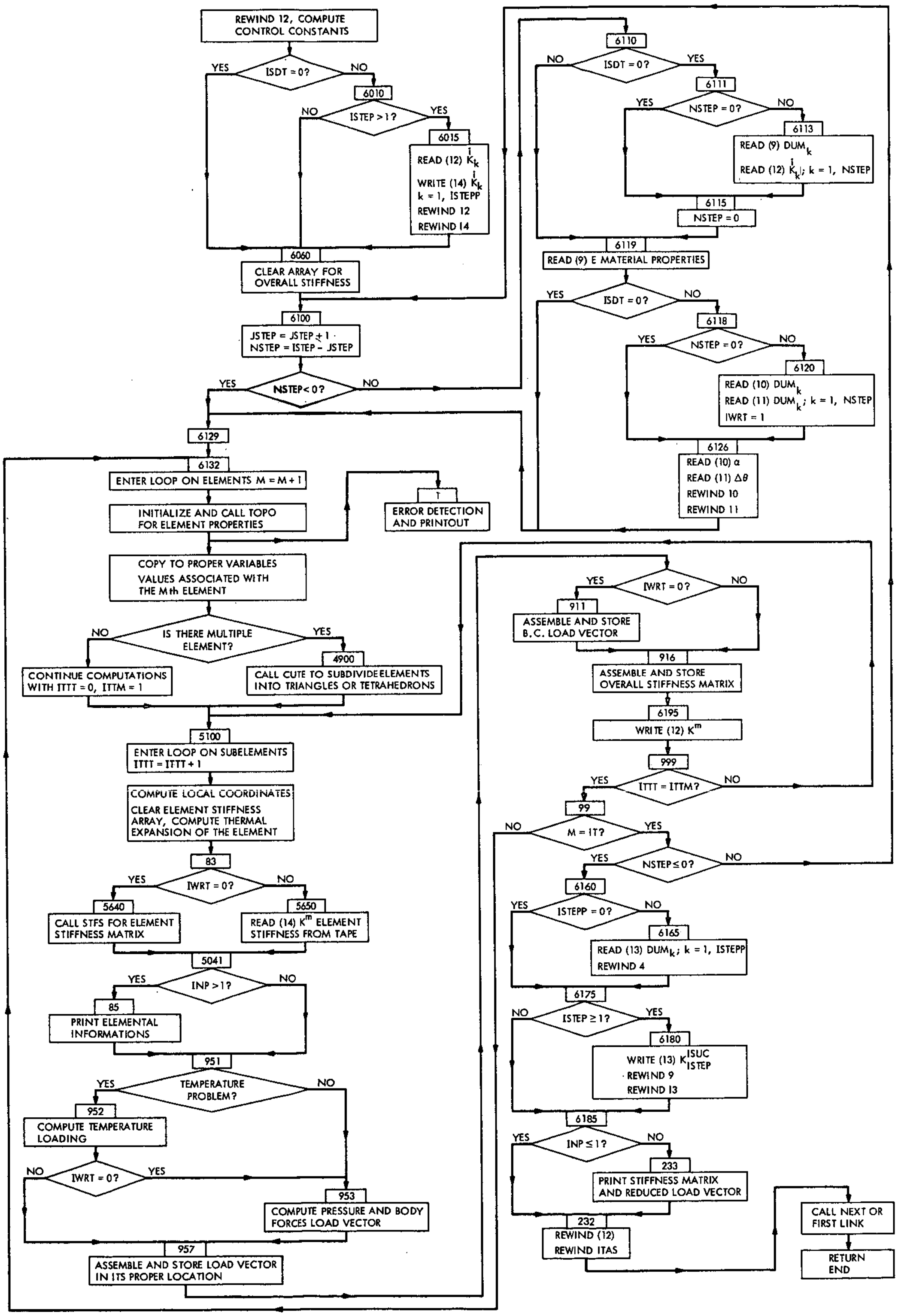


Fig. 5. Flow chart for subroutine ELAS2

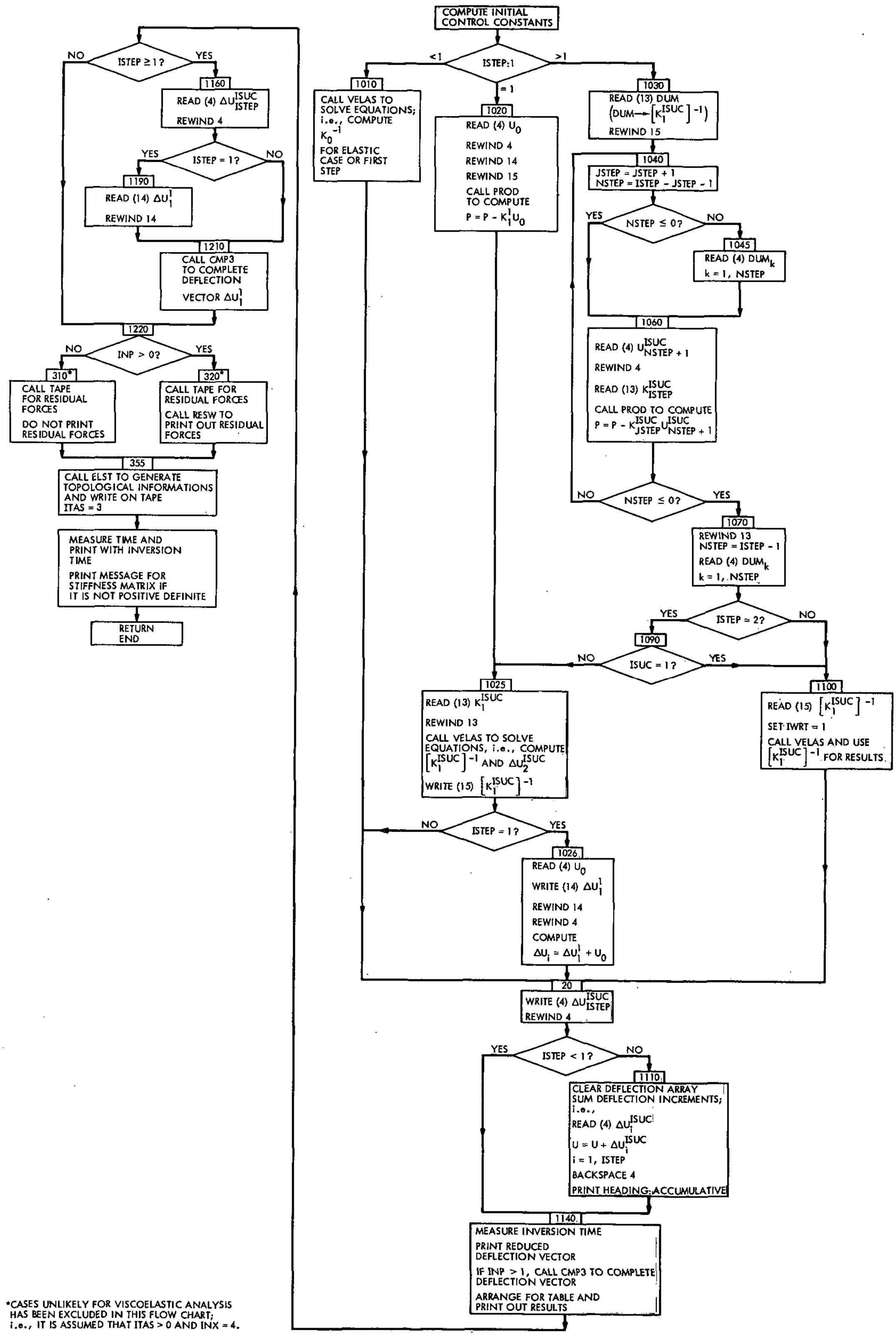
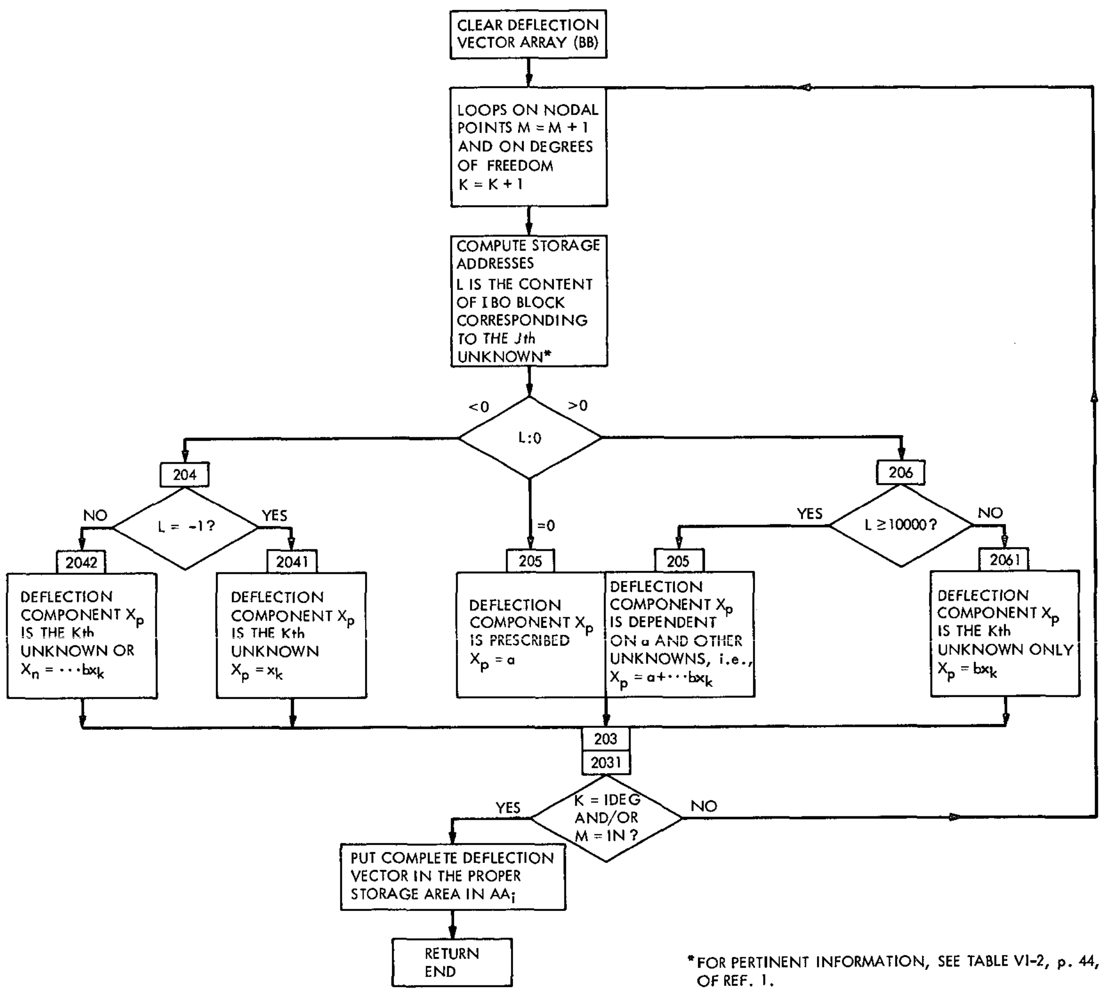


Fig. 6. Flow chart for subroutine ELAS3



*FOR PERTINENT INFORMATION, SEE TABLE VI-2, p. 44, OF REF. 1.

Fig. 7. Flow chart for subroutine CMP3

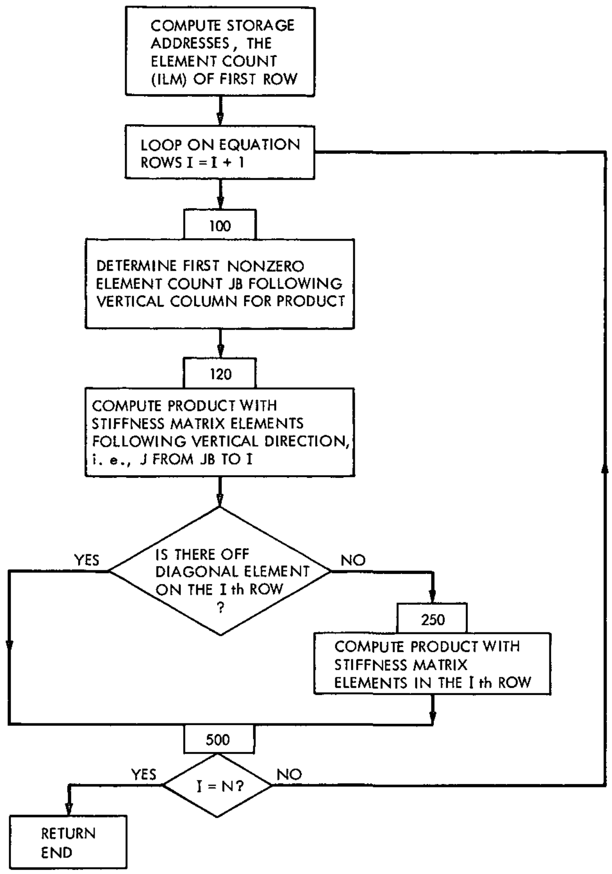


Fig. 8. Flow chart for subroutine PROD

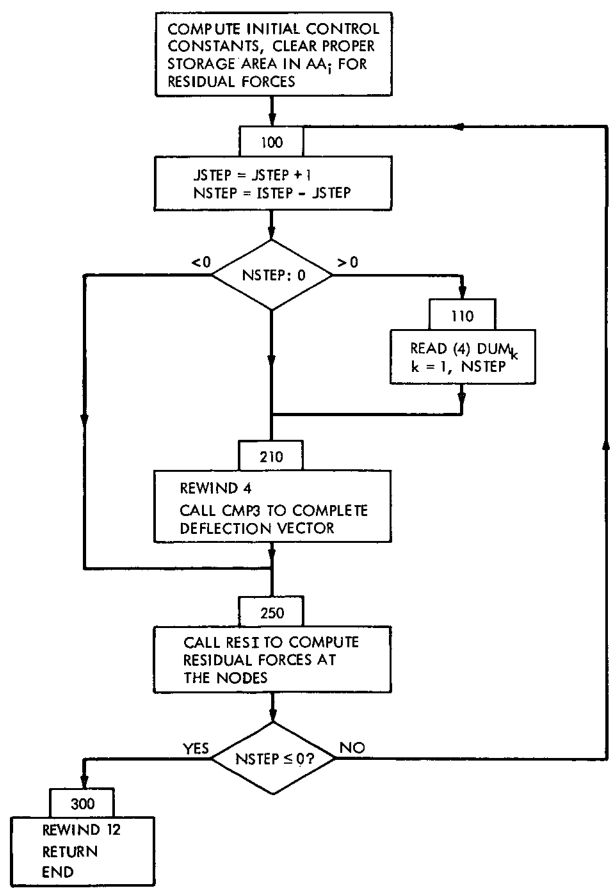


Fig. 9. Flow chart for subroutine TAPE

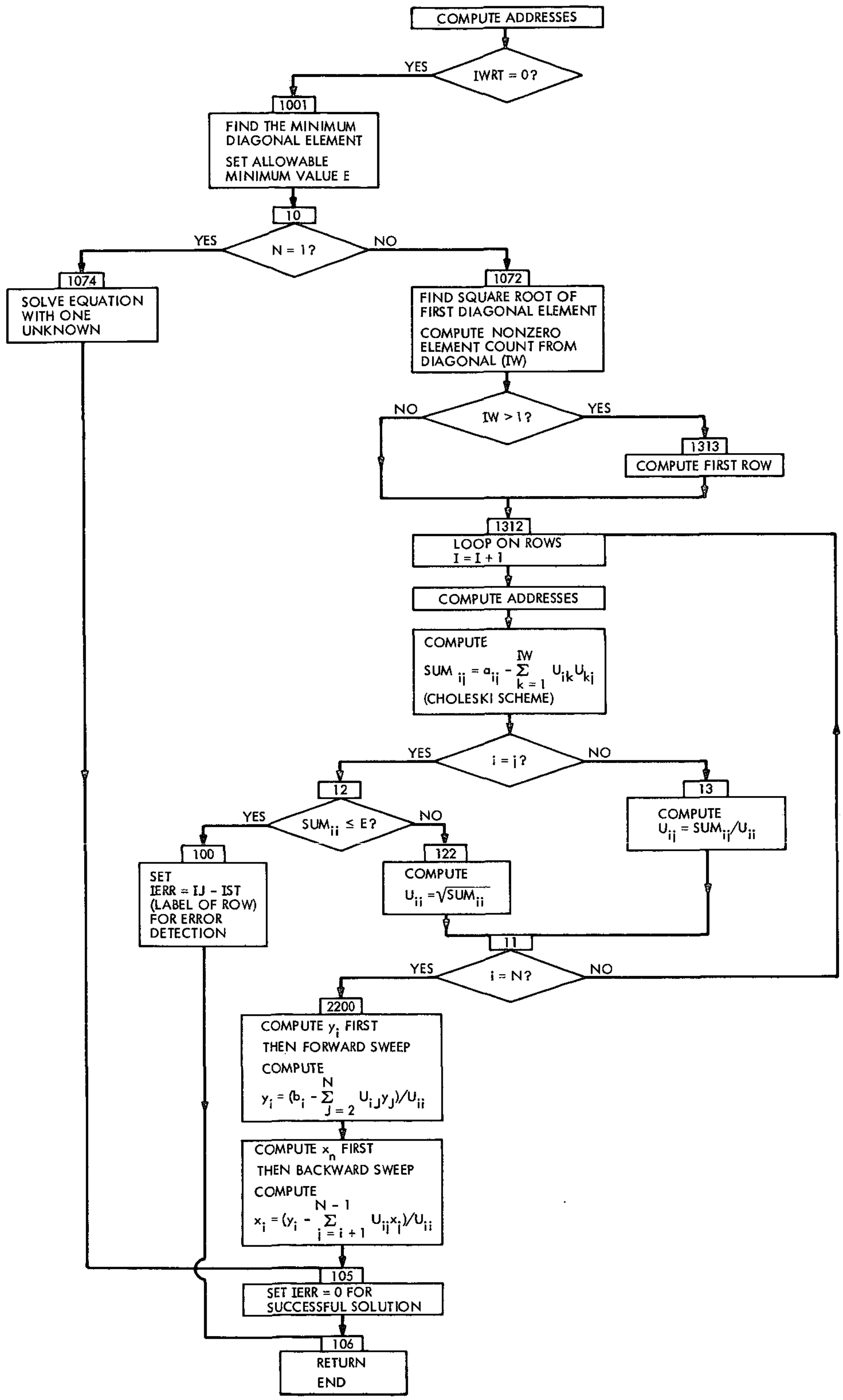


Fig. 10. Flow chart for subroutine VELAS

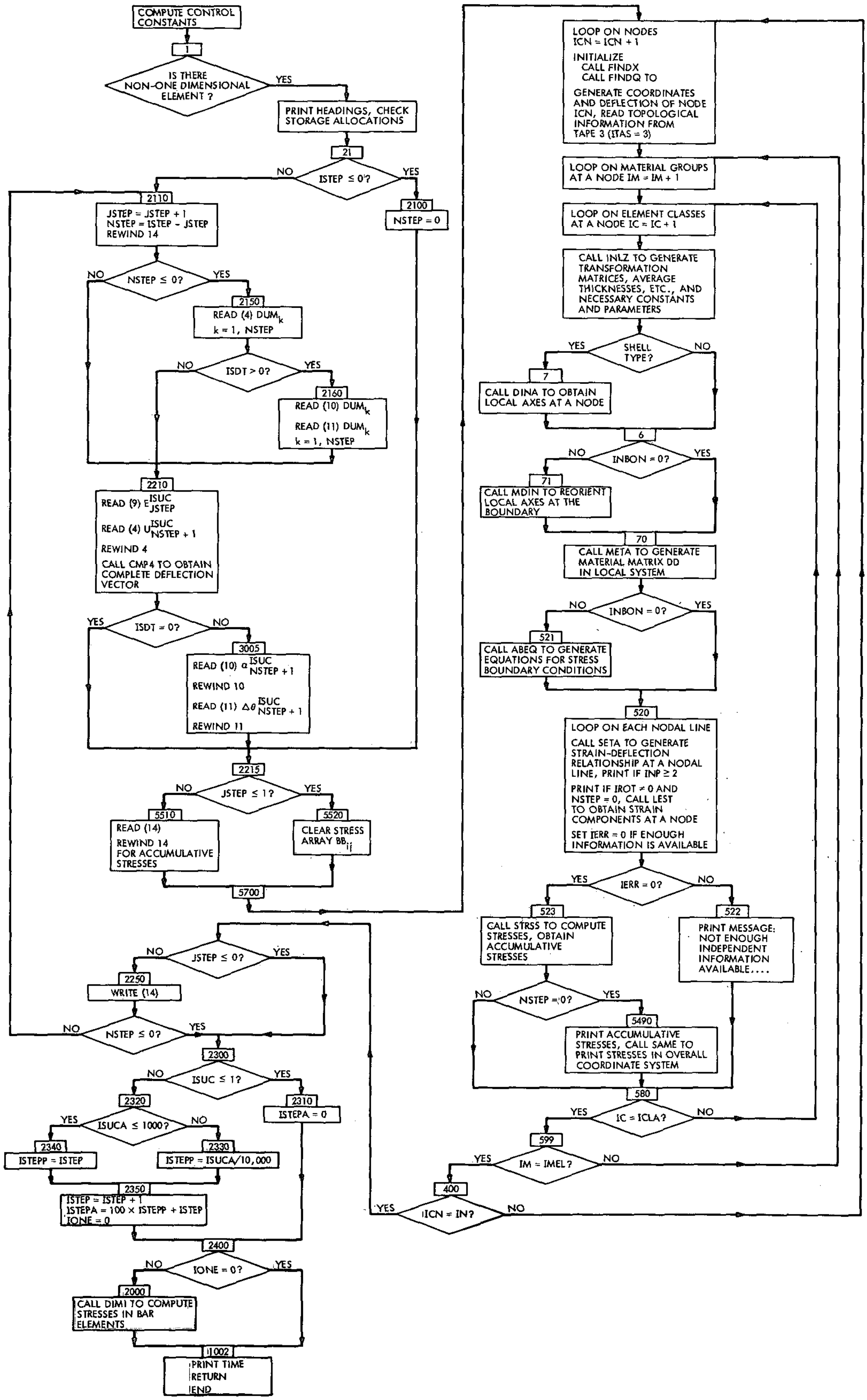


Fig. 11. Flow chart for subroutine ELAS4

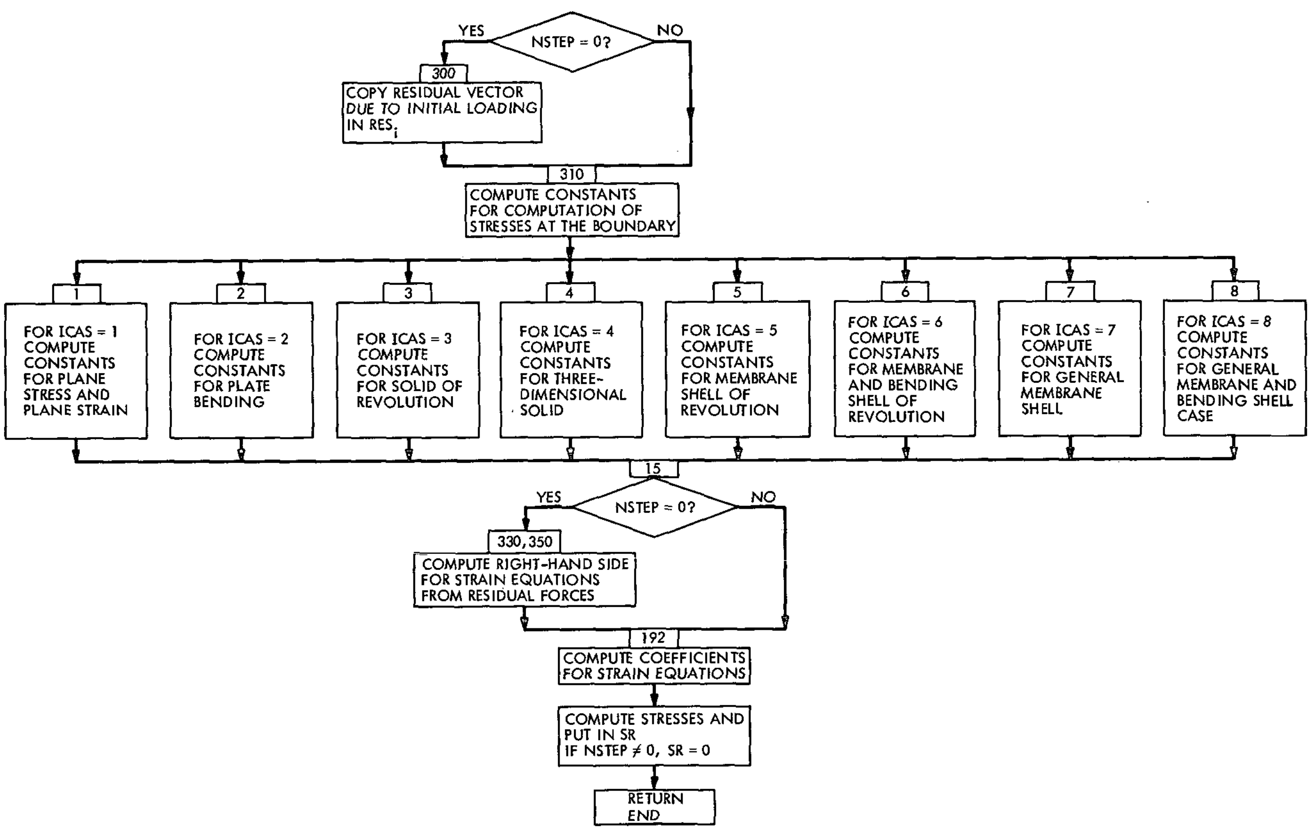


Fig. 12. Flow chart for subroutine ABEQ

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