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COMOC: THREE DIMENSIONAL BOUNDARY REGION VARIANT

PROGRAMMER'S MANUAL

by J. A. Orzechowski and A. J. Baker

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TABLE OF CONTENTS

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FIGURES

TABLES

COMOC: THREE-DIMENSIONAL BOUNDARY REGION VARIANT
PROGRAMMER'S MANUAL

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SUMMARY

The Three-Dimensional Boundary Region Variant of the COMOC computer program system solves the partial differential equation system governing certain three-dimensional flows of a viscous, heat conducting, multiple-species, compressible fluid including combustion. The solution is established in physical variables, and employs a finite element solution algorithm for the boundary value portion of the problem description in combination with an explicit marching technique for the initial value character. The computational lattice may be arbitrarily non-regular, and boundary condition constraints are readily applied. The programmer's manual contains a brief capsule of the mathematical problem description and the theoretical foundation of the solution algorithm. It presents a detailed description on the construction and operational sequence of the program, and provides complete instructions on the utilization of the many optional features of the code. A more complete description of the theoretical foundation of the finite element solution algorithm, and a detailed discussion of computational results for several sample problems in fluid mechanics is contained in the theoretical guide and user's manual [Ref. 1].

INTRODUCTION

The finite element methodology for numerical solution of initial-boundary value problems in continuum mechanics is growing rapidly. Formerly constrained to solution of structural problems, or other linear field problems wherein an equivalent extremum principle exists, the theoretical support is now sufficiently generalized to render the method directly applicable to explicitly nonlinear problems, including viscous fluid mechanics [Ref. 1-3]. The COMOC computer program system is being developed to transmit this rapid theoretical progress into a viable numerical solution capability. On the way to generation of this general purpose concept, several Variants of COMOC have been developed for specific problem classes including transient thermal analysis [Ref. 4] and the two-dimensional Navier Stokes equations [Ref. 5].

The Three-Dimensional Boundary Region (3DBR) Variant of COMOC, to which this programmer's manual is addressed, solves the three-dimensional boundary region equations for flow of a viscous, heat conducting, multiple-species, compressible fluid including combustion. The flow may be external or confined, subsonic or supersonic, laminar and/or turbulent, and can contain up to nine or more distinct species in frozen composition or undergoing equilibrium chemical reaction for a hydrogen/oxygen/air system. The finite element solution procedure marches the discretized equivalent of the governing equation system in the direction parallel to the predominant flow. It numerically establishes the complete three-dimensional distributions of the three scalar velocity components, enthalpy, temperature, density, viscosity, and all applicable species mass fractions. Initial distributions of all dependent variables may be arbitrarily specified, and boundary condition constraints for each dependent variable are user-specifiable on arbitrarily disjoint segments of the solution domain closure. The solutions for each dependent variable, and all computed parameters, are established at node points lying on a specifiably non-regular computational lattice formed by plane triangulation of the elliptic solution domain.

All Variants of the COMOC system are built upon the macrostructure illustrated in Fig. 1. The main executive routine allocates core, using a variable dimensioning scheme, based upon the total degrees of freedom of the problem. The size of the largest problem that can be solved is thus limited by the core size of the computer in use. The precise mix between number of dependent variables (and parameters), and fineness of the discretization, is user-specifiable and widely variable. The Input module serves its standard function for all dependent variable, parameter, and geometric coordinate arrays. The Discretization module forms the finite element discretization of the solution domain, and evaluates all required finite element non-standard matrices and standard-matrix multipliers. The Initialization module computes the remaining initial parametric data required to start the solution. The Integration Module constitutes the primary execution sequence of problem solution. It is based upon an explicit finite difference integration algorithm for the column vector of unknowns of the solution, for which the discretized description is initial-valued. Calls to auxiliary routines for parameter evaluation, e.g., viscosity, Prandtl number, source terms, combustion parameters, etc., as specified functions of dependent and/or independent variables are governed by the Integration Module. The user has considerable latitude to adapt COMOC to the specifics of his particular problem at this point, by directly inserting easily written subroutines into COMOC to compute special forms of these parameters. The Output module is similarly addressed from the integration sequence and serves

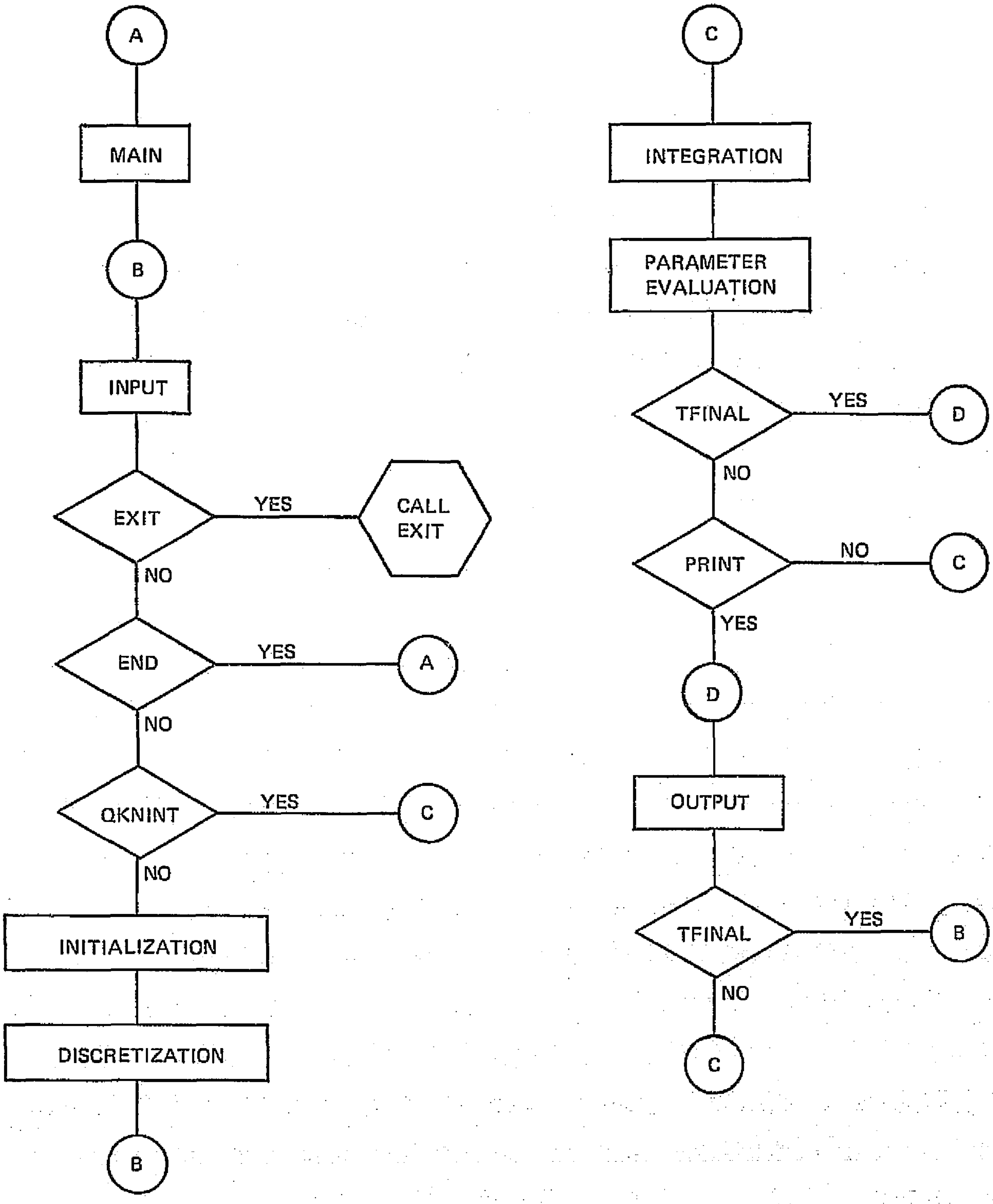


Figure 1. COMOC Macro Structure

its standard function via a highly automated array display algorithm. COMOC can execute distinct problems in sequence and contains an automatic restart capability to continue solutions.

The 3DBR Variant of COMOC, as a direct consequence of the expansive problem class to which it may be addressed, is a fairly large and complex computer program. This programmer's manual presents a brief introduction to the partial differential equation system being solved, and summarizes the theoretical foundations for the combined finite element-finite difference procedures used to establish the desired numerical solution. This is followed by a complete description of 3DBR COMOC including environment, program specifications, link and subroutine structure, program comments and detailed flow charts. The instructions for machine set-up and execution of the code are included, and sample output for the standard test cases is fully discussed. A complete discussion on the technical aspect of solutions for the standard test cases is presented in the user's guide [Ref. 1].

PROBLEM TASK DESCRIPTION

The system of partial differential equations governing the three-dimensional boundary region flow of a compressible fluid is obtained from the parabolic approximation to the full Navier-Stokes equations. The parabolic approximation, i.e., "parabolic Navier-Stokes equations," describe steady, three-dimensional flows wherein, 1) a predominant flow direction is uniformly discernible, 2) in this direction (only), diffusion processes are negligible compared to convection, and 3) no disturbances are propagated upstream antiparallel to this direction. The boundary region equation system is obtained from parabolic Navier-Stokes with the single additional assumption that a known pressure distribution is superimposed upon the flow field. It is the numerical solution of this equation system to which 3DBR COMOC is addressed. Identify the three-dimensional velocity vector

$$u_i \equiv u_1\hat{i} + u_2\hat{j} + u_3\hat{k} \qquad (1)$$

For development of the differential equation system, assume that $\hat{i}$ is aligned parallel to the predominant flow direction. Identify a two-dimensional vector differential operator as

$$(\ )_{,k} \equiv \hat{j}(\ )_{,2} + \hat{k}(\ )_{,3} \qquad (2)$$

where the comma identifies the gradient operator. Employing Cartesian tensor notation, with summation over 2 and 3 for repeated latin subscripts, the three-dimensional boundary region equation system for a multiple-species, compressible, reacting flow takes the form

$$0 = (\rho u_i)_{,i} + (\rho u_1)_{,1} \tag{3}$$

$$\rho u_1 Y^{\alpha}_{,1} = \left[\frac{\mu^e}{Sc \cdot Re} Y^{\alpha}_{,k}\right]_{,k} - \rho u_k Y^{\alpha}_{,k} + S^{\alpha} \tag{4}$$

$$\rho u_1 u_{1,1} = \left[\frac{\mu^e}{Re} u_{1,k}\right]_{,k} - \rho u_k u_{1,k} - p_{,1} \tag{5}$$

$$\rho u_1 u_{3,1} = \left[\frac{\mu^e}{Re} u_{3,k}\right]_{,k} - \rho u_k u_{3,k} - p_{,3} \tag{6}$$

$$\rho u_1 H_{,1} = \left[\frac{\mu^e}{Re \cdot Pr} H_{,k}\right]_{,k} - \rho u_k H_{,k} - M_{\infty}^2 \left[\frac{1-Pr}{Pr} \frac{\mu^e}{2Re} (u_j u_j)_{,k}\right]_{,k} - \left[\frac{Sc-Pr}{Sc \cdot Pr} \frac{\mu^e}{Re} \sum_{\alpha} h^{\alpha} Y^{\alpha}_{,k}\right]_{,k} \tag{7}$$

The variables appearing in Eq. (3)-(7) are non-dimensionalized with respect to ρ_{∞}, U_{∞}, $c_{p_{\infty}}$, T_{∞}, and a length constant L, and have their usual interpretation in fluid mechanics. The Reynolds (Re), Prandtl (Pr), and Schmidt (Sc) numbers are defined with respect to the effective diffusion coefficient, μ^e, in algebraic combination with the laminar and turbulent contributions as, for example

$$\frac{\mu^e}{Pr} \equiv \frac{\mu}{Pr} + \frac{\rho\varepsilon}{Pr_T} \tag{8}$$

In Eq. (8), μ is the laminar viscosity, ε is the kinematic eddy viscosity, and subscript T denotes a turbulent reference parameter. The stagnation enthalpy is defined in terms of species static enthalpies as

$$H \equiv \sum_{\alpha} h^{\alpha} Y^{\alpha} + \frac{1}{2} u_k u_k \qquad (9)$$

The static enthalpy includes the heat of formation, h_o^{α}, of the species in its definition as

$$h^{\alpha} \equiv \int_{T_o}^{T} c_p^{\alpha} dT + h_o^{\alpha} \qquad (10)$$

An equation of state is required to close the system. Assuming perfect gas behavior for each species, from Dalton's law, obtain

$$p = \rho R T \sum_{\alpha} \frac{Y^{\alpha}}{W^{\alpha}} \qquad (11)$$

where R is the universal gas constant and W^{α} is the molecular weight of the α-th species.

Equilibrium combustion of hydrogen/oxygen/air systems in three-dimensional boundary region flow is operational in 3DBR COMOC. The following reactions are assumed operative.

$$2H + O \rightleftarrows H_2O$$

$$2H \rightleftarrows H_2$$

$$2O \rightleftarrows O_2$$

$$H + O \rightleftarrows OH$$

$$N_2 + 2O \rightleftarrows 2NO \qquad (12)$$

The equilibrium composition of the combustion by-products is determined by applying the Law of Mass Action [Ref. 6] to each reaction defined in Eq. (12). This yields definition of a set of equilibrium rate constants, K, which, for the simple reaction $nA + mB \rightleftarrows \ell C$, are expressed in terms of species mole fraction, X^{α}, as

$$K \equiv \frac{[X^A]^n [X^B]^m}{[X^C]^\ell} \quad (13)$$

Solution of Eq. (12) with (13), and coupled with conservation of total and elemental mass, yields an algebraic equation system for determination of the equilibrium composition of the system, of the form.

$$[N_\alpha^\beta]\{X^\alpha\} = \{\text{const.}\} \quad (14)$$

In Eq. (14), the elements of the matrix $[N_\alpha^\beta]$ account for the particular species mole fraction distribution, $\{X^\alpha\}$, containing the β^{th} elemental material, e.g., O, H, and N.

METHOD OF SOLUTION

The three-dimensional boundary region equation system, except for global continuity, Eq. (3), is uniformly an initial-boundary value problem of mathematical physics. Each of the partial differential equations, Eq. (4)-(7), is a special case of the general second-order, nonlinear partial differential equation

$$L(q) \equiv \kappa[K(q)q_{,k}]_{,k} + f(q,q_{,i},x_i) - g(q,\chi) = 0 \quad (15)$$

where q is a generalized dependent variable identifiable with each computational dependent variable. In Eq. (15), f and g are specified functions of their arguments, χ is identified with x_1 for boundary region flows, and x_i are the coordinates for which second order derivatives exist in the lead term. The finite element solution algorithm is based upon the assumption that L(q) is uniformly parabolic within a bounded open domain Ω, i.e., the lead term in Eq. (15) is uniformly elliptic within its domain R, with closure ∂R, where

$$\Omega = R \times [\chi_0, \chi) \quad (16)$$

and $\chi_0 \leq \chi < \infty$. For Eq. (15) uniformly parabolic, unique solutions for q are obtained pending specification of boundary constraints on ∂R and an initial condition on $R \cup \partial R$. For the former, the general form relates the function and its normal derivative everywhere on the closure, ∂R, as

$$\ell(q) \equiv a^{(1)} q(\bar{x}_i, \chi) + a^{(2)} K q(\bar{x}_i, \chi)_{,k} n_k - a^{(3)} = 0 \quad (17)$$

In Eq. (17), the $a^{(i)}(\bar{x}_i, \chi)$ are user specified coefficients, the superscript bar notation constrains x_i to ∂R, and n_k is the local outward-pointing unit normal vector. For an initial distribution, assume given throughout $R \cup \partial R \times \chi_o$,

$$q(x_i, \chi_o) \equiv q_o(x_i) \quad (18)$$

The finite element solution algorithm is established for the equation system (15)-(18), using the Method of Weighted Residuals (MWR) formulated on a local basis. Since Eq. (15) is valid throughout R, it is valid within disjoint interior subdomains, R_m, described by $(x_i, \chi) \epsilon R_m \times [\chi_o, \chi)$ called "finite elements," wherein $\cup R_m = R$. Form an approximate solution for q within $R_m \times [\chi_o, \chi)$, called $q_m^*(x_i, \chi)$, by expansion into a series solution of the form

$$q_m^*(x_i, \chi) \equiv \{\phi(x_i)\}^T \{Q(\chi)\}_m \quad (19)$$

wherein the functionals $\phi_k(x_i)$ are members of a function set complete in R_m, and the unknown expansion coefficients, $Q_k(\chi)$, represent the χ-dependent values of $q_m^*(x_i, \chi)$ at specific locations interior to R_m and on the closure, ∂R_m, called "nodes."

To establish the values taken by the expansion coefficients in Eq. (19), require that the local error in the approximate solution to both the differential equation, $L(q_m^*)$, and the boundary condition statement, $\ell(q_m^*)$, for $\partial R_m \cap \partial R$, be rendered orthogonal to the space of the approximation functions. Employing an unknown algebraic multiplier, λ, the resultant equation sets can be combined as

$$\int_{R_m} \{\phi(x_i)\} L(q_m^*) d\tau - \lambda \int_{\partial R_m \cap \partial R} \{\phi(x_i)\} \ell(q_m^*) d\sigma \equiv 0 \quad (20)$$

The number of equations (20) is identical to the number of node points of the finite element, R_m.

Equation (20) forms the basic operation of the finite element solution algorithm and of 3DBR COMOC. Establishment of the global solution algorithm, and determination of λ, is accomplished by evaluating Eq. (20) in each of the M finite elements of the discretized solution domain, and assembly of these $M \times n$ equations into a global matrix system using Boolean algebra. The lead term can be rearranged, using a Green-Gauss Theorem, to yield

$$\int_{R_m} \{\phi(x_i)\}\kappa[K q^*_{m},_k],_k d\tau = \kappa \oint_{\partial R_m} \{\phi(x_i)\} K q^*_{m},_k n_k d\sigma$$

$$- \kappa \int_{R_m} \{\phi(x_i)\},_k K q^*_{m},_k d\tau \qquad (21)$$

For $\partial R \cap \partial R_m$ nonvanishing, Eq. (21), the corresponding segment of the closed surface integral will cancel the boundary condition contribution, Eq. (20), by identifying $\lambda a^{(2)}$ with κ of Eq. (15). The contributions to the closed surface integral, Eq. (21), where $\partial R_m \cap \partial R = 0$ can be made to vanish. Hence, combining Eq. (17)-(21), the globally assembled finite element solution algorithm for the representative partial differential equation system description becomes

$$\bigcup \Bigg[- \kappa \int_{R_m} \{\phi\},_k K q^*_{m},_k d\tau + \int_{R_m} \{\phi\}(f^*_m - g^*_m) d\tau$$

$$- \kappa \int_{\partial R_m \, \partial R} \{\phi\}\left(a_m^{(1)} q^*_m - a_m^{(3)}\right) d\sigma \Bigg] = \{0\} \qquad (22)$$

The rank of the global equation system, Eq. (22), is identical to the total number of node points on $R \cup \partial R$ for which the dependent variable requires solution. Equation (22) is a first-order, ordinary differential system, and the matrix structure is sparse and banded. Solution of the ordinary differential equation system is obtained using a finite difference numerical integration procedure.

The solution algorithm for the global continuity equation is similarly derived. Recognizing that Eq. (3) is an initial value problem on ρu_2 as a function of x_2, with x_1 and x_3 appearing as parameters, the approximation function need span only the transverse coordinate direction as

$$q_m^* = \{\phi(x_2)\}^T\{Q(x_1,x_3)\}_m \tag{23}$$

The matrix elements Q_k are nodal values of ρu_2^*; their functional dependence requires solution of Eq. (3) along lines (x_1,x_3) equal a constant. The solution algorithm for Eq. (3) is directly specified as

$$\int_{R_m}\{\Phi\}L(\rho u_2^*)d\sigma = 0 \tag{24}$$

where the matrix elements of $\{\Phi\}$ are not coincidential with those of $\{\phi\}$, Eq. (23), and the segments R_m correspond to lines of (x_1,x_3) equal to a constant.

The functional flow chart for 3DBR COMOC is presented as Fig. 1. MAIN initializes execution of COMOC and allocates core using a variable dimensioning procedure for the problem at hand. The first steps within INPUT evaluate if a problem solution has been completed, and if so, whether execution of an additional problem is to be initiated. QKNINT is the calling routine that begins execution of a problem. The first step is INITIALIZATION which includes reading of title cards as well as integer and floating point NAMELIST input.

DISCRETIZATION is then called to establish a finite element gridwork of the elliptic solution domain as specified in INPUT. 3DBR Variant of COMOC employs simplex (linear) functionals spanning triangular shaped two-dimensional finite elements as approximation functions, Eq. (19). Using a natural coordinate function specification [Ref. 1, 7], accurate determination of the finite element matrices is achieved including those that are highly nonlinear. All matrix expressions are determined in terms of standard matrices and/or standard matrix multipliers. For example, the first term in Eq. (22) is standard for all dependent variables. Assuming the generalized diffusion coefficient is distributed over the m^{th} element as a dependent variable, obtain

$$\kappa\int_{R_m}\{\phi\}_{,k}Kq^*_{m,k}d\tau = \kappa\int_{R_m}\{\phi\}_{,k}\{K\}^T_m\{\phi\}\{\phi\}^T_{,k}\{Q\}d\tau$$

$$= \kappa\{K\}^T_m\{B10\}[B211S]\{Q\}_m \qquad (25)$$

In Eq. (25) and the following, matrices with B prefixes are standard two-dimensional forms defined in Table 1. For Eq. (22) identified with each dependent variable, f^*_m and g^*_m universally contain the nonlinear convection term and the initial-value operator as dominant terms. The finite element equivalent for convection is

$$\int_{R_m}\{\phi\}\rho u^*_k q^*_{,k}d\tau = \int_{R_m}\{\phi\}\{\phi\}^T\{\rho u^{\prime}_k\}_m\{\phi\}^T_{,k}\{Q\}_m d\tau$$

$$= [B200S]\{\rho U^{\prime}\}_m\{B11\}^T\{Q\}_m \qquad (26)$$

where the elements of the vector, $\{\rho u^{\prime}_k\}$, are nodal values of the planar mass flux transformed to a local coordinate system. The initial-value operator, which comprises the mainstream convection term, similarly becomes

$$\int_{R_m}\{\phi\}\rho u^*_1 q^*_{,1}d\tau = \int_{R_m}\{\phi\}\{\phi\}^T\{\rho U1\}_m\{L\}^T\{Q\}^{\prime}_m d\tau$$

$$= \{\rho U1\}^T_m[B3000S]\{Q\}^{\prime}_m \qquad (27)$$

where the matrix elements of [B3000S] are column matrices, see Table 1. The superscript prime exterior to a matrix denotes an ordinary derivative.

Computational entry to the INTEGRATION module, for each dependent variable, is made through the inhomogeneous term in the differential equation, Eq. (15). For mainstream momentum, Eq. (5), this is the specified longitudinal pressure gradient. Therefore, in finite element matrix form

TABLE 1

STANDARD FINITE ELEMENT MATRIX FORMS FOR SIMPLEX FUNCTIONALS IN ONE- AND TWO-DIMENSIONAL SPACE

Matrix Name[1]	Matrix Function	Matrix Evaluation[2],[3],[4]
{B10}	$\int_{R_m} \{\phi\} d\tau$	$\frac{A^m}{3} \begin{Bmatrix} 1 \\ 1 \\ 1 \end{Bmatrix}$
[B211S]	$\{\phi\},_k \{\phi\}^T,_k$	$\left(\frac{1}{X2P2}\right)^2 \begin{bmatrix} 1 & -1 & 0 \\ & 1 & 0 \\ & & 0 \end{bmatrix} + \left(\frac{1}{X3P3}\right)^2 \begin{bmatrix} \left(\frac{X3P3}{X2P2} - 1\right)^2, & \frac{X3P3}{X2P2}\left(\frac{X3P3}{X2P2} - 1\right), & \left(\frac{X3P3}{X2P2} - 1\right) \\ & \left(\frac{X3P3}{X2P2}\right)^2, & -\left(\frac{X3P3}{X2P2}\right) \\ & & 1 \end{bmatrix}$
[B200S]	$\int_{R_m} \{\phi\}\{\phi\}^T d\sigma$	$\frac{A^m}{12} \begin{bmatrix} 2 & 1 & 1 \\ & 2 & 1 \\ & & 2 \end{bmatrix}$
[B3000S]	$\int_{R_m} \{\phi\}\{\phi\}\{\phi\}^T d\tau$	$\frac{A^m}{60} \begin{bmatrix} \begin{Bmatrix} 6 \\ 2 \\ 2 \end{Bmatrix} & \begin{Bmatrix} 2 \\ 2 \\ 1 \end{Bmatrix} & \begin{Bmatrix} 2 \\ 1 \\ 2 \end{Bmatrix} \\ & \begin{Bmatrix} 2 \\ 6 \\ 2 \end{Bmatrix} & \begin{Bmatrix} 1 \\ 2 \\ 2 \end{Bmatrix} \\ & & \begin{Bmatrix} 2 \\ 2 \\ 6 \end{Bmatrix} \end{bmatrix}$
{B11}	$\{\phi\},_k$	$\hat{e}_2 \begin{Bmatrix} \phi_1 \\ \phi_2 \\ \phi_3 \end{Bmatrix},_2 + \hat{e}_3 \begin{Bmatrix} \phi_1 \\ \phi_2 \\ \phi_3 \end{Bmatrix},_3$
[A200S]	$\int_{\partial R_m} \{\phi\}\{\phi\}^T d\sigma$	$\frac{\ell^m}{6} \begin{bmatrix} 2 & 1 \\ & 2 \end{bmatrix}$
{A10}	$\int_{\partial R_m} \{\phi\} d\sigma$	$\frac{\ell^m}{2} \begin{Bmatrix} 1 \\ 1 \end{Bmatrix}$

(1) Matrix names are a 6 digit code covering dimensionality, nonlinearity, degree of differentiation and special matrix properties, as [a, b, c, d, e, f] where:
a = A, B, C for spaces of one-, two-, and three-dimensions,
b = number of coordinate functions appearing in integral or matrix,
c, d, e = (0,1) Boolean counters indicating (no, yes) differentiation of each function,
e or f = S, A, Δ for matrix symmetric, antisymmetric or general.

(2) Symmetric matrices are written in upper triangular form.

(3) A^m = 1/2 (X2P2)(X3P3), the plane area of the triangular finite element.
X2P2 = the x_2 prime coordinate of node 2.
X3P3 = the x_3 prime coordinate of node 3.

(4) ℓ^m = length of side for boundary condition (=X2P2).

$$\int_{R_m} \{\phi\} p_{,1} d\tau = \{B10\} p_{,1} \tag{28}$$

For each species mass fraction, the equivalent expression involves the element distributed source term, S^α, as

$$\int_{R_m} \{\phi\} S^\alpha d\tau = [B200S]\{S^\alpha\}_m \tag{29}$$

For non-constant, but equal Prandtl and Schmidt numbers, the energy equation, Eq. (7), has one source term. An integration using a Green-Gauss Theorem is appropriate; the generated surface integral vanishes yielding

$$\int_{R_m} \{\phi\} \left[\frac{M_\infty^2}{2Re}\left(\frac{1-Pr}{Pr}\right)\mu^e (u_j u_j)_{,k}\right]_{,k} d\tau$$

$$= -\frac{M_\infty^2}{Re}\int_{R_m} \{\phi\}_{,k}\left(\frac{1-Pr}{Pr}\right)^* \mu^{e*} u_j^* u_{j,k}^* d\tau$$

$$= -\frac{M_\infty^2}{Re}\{XMU\}_m^T\{PR\}_m^T[B3000S]\sum_{j=1}^{3}\{U_j\}_m[B211S]\{U_j\}_m \tag{30}$$

Solution of the matrix equivalent of Eq. (22) occurs in the INTEGRATION module, and is achieved using an explicit finite difference integration algorithm for large systems of nonlinear, first-order ordinary differential equations. 3DBR COMOC employs a first order accurate, predictor-multiple corrector algorithm with an extended stability interval [Ref. 1, 8]. Identifying p_{n+1}^1 and p_{n+1}^2 as the sequentially predicted values of the dependent variable q_{n+1} at the $n+1^{st}$ x_1 station, the integration algoithm is

$$p_{n+1}^{1} = a_1^1 q_n + hb_1^1 q_n'$$

$$p_{n+1}^{2} = a_1^2 q_n + h[b_1^2 p_{n+1}^{1\prime} + b_2^2 q_n']$$

$$q_{n+1} = a_1^3 q_n + h[b_1^3 p_{n+1}^{2\prime} + b_2^3 q_n'] \qquad (31)$$

The a_i and b_i are fixed coefficients, and h is the current integration step-size, Δx_1. The integration algorithm attempts to extremize integration step-size automatically, based upon internal error control. An estimation of relative truncation error is used of the form

$$|RTE| \approx \frac{|p_{n+1}^{2\prime} - q_n|}{|q_{n+1}|} \qquad (32)$$

If the relative truncation error associated with using the given integration step-size, h, to estimate the $(n+1)^{st}$ value of the dependent variable, is less than the user-supplied acceptable limit, the $(n+1)^{st}$ estimate for the dependent variable is accepted. If the computed relative error exceeds the limit, the predicted values are discarded, a smaller step-size selected, and the operations of Eq. (31) repeated.

Following an integration sequence, entrance into the PARAMETER module is made to evaluate the remaining solution parameters and functions in terms of the newest distribution of dependent variables. Evaluation of node point density and static temperature is made first; for binary, isoenergetic flows with temperature-independent specific heats, a simple quick running subroutine may be addressed. For the more complex case, COMOC can handle arbitrary frozen flow compositions, as well as the equilibrium composition of combustion of hydrogen/oxygen/air mixtures as a function of temperature, pressure, and relative concentrations of the elements, H_2, O_2, N_2, and Ar [Ref. 9]. The species considered are H_2O, O_2, H_2, N_2, Ar, O, H, NO, and OH. Since all thermophysical properties are temperature dependent, initialization is based upon a user input total temperature distribution. As a function of input pressure at initialization and the built-in tables of thermodynamic data, distributions of static temperature, frozen specific heat, and stagnation enthalpy corresponding to input total temperature are determined using an iteration algorithm based upon the method of false position. All solutions following initialization are based upon iteration to equilibrium composition using computed nodal static temperature as the convergence parameter. The iteration on temperature is assumed to have converged when the difference between successive iterates is less than 0.001 non-dimensional.

After convergence to a static temperature, the equilibrium constants for chemical reaction are calculated from the Gibbs' function. Composition is then determined using a modified Newton-Raphson iterative procedure for solution of a system of nonlinear algebraic equations. Once the nodal species equilibrium (or frozen) composition is determined, enthalpy, entropy, molecular weight, and specific heat are calculated for mixtures of ideal gases in terms of the computed species mole fractions, X^{α}. The computed composition, X^{α}, is based upon solution of the nonlinear equilibrium equations for mole fraction of hydrogen, atomic oxygen, and the square root of molecular nitrogen at nodes of the discretization, using a Newton-Raphson iteration algorithm. A maximum of thirty iterations are allowed for the solution to converge within 10^{-5}. In only a few cases has non-convergence occurred, always within a few degrees of the threshold temperature for dissociation. For these solutions, the equations are resolved assuming that dissociation is negligible, i.e., the mole fractions of H, O, OH, and NO are negligibly small in comparison to H_2, O_2, N_2, and H_2O.

The next parameter evaluation is solution of the continuity equation for u_2. An evaluation of $(\rho u_1^*)_{,1}$ is first required, since no streamwise derivatives of a dependent variable can be formed before the distribution of all variables is known in a plane. In the discretized solution, the actual requirement is to establish $\{\rho U1\}'$; the following second-order accurate finite difference formula is employed.

$$\{\rho U1\}'_{n+1} = \frac{1}{h_n h_{n+1}(h_n + h_{n+1})} \Big[h_n(2h_{n+1} + h_n)\{\rho U1\}_{n+1} - (h_n + h_{n+1})^2 \{\rho U1\}_n + h^2_{n+1}\{\rho U1\}_{n-1} \Big] \quad (33)$$

In Eq. (33), h_{n+1} and h_n are the x_1 integration step-sizes, respectively, between the current x_1 station, x_{n+1}, and the previous two stations. An analytic expression is then established for the x_2 distributions of mass flux derivative using a 2nd order running-smoothing polynomial generator over appropriate sequential panels of data. Using a unit step for the weighting function, Φ, Eq. (24) is integrated directly as

$$\Delta(\rho u_2^*) = \sum_{k=0}^{2} a_k(x_3) \frac{x_2^{k+1}}{k+1} \quad (34)$$

Evaluation of Eq. (34) is repeated along each node column at each x_1 station.

Several additional subroutine calls then complete the parameter evaluation phase. Included herein is evaluation of an integral mixing parameter, pertinent to cold flow hydrogen-air mixing problems, and the skin friction and wall Stanton number distributions. Additional calls are made to evaluate the two-dimensional distribution of Prandtl and Schmidt numbers. An input data table is interrogated to evaluate the local static pressure and the longitudinal pressure gradient. The nodal distribution of laminar viscosity, as well as turbulent eddy viscosity if being used, is then determined. The parametric sequence is terminated with a call to subroutine SOURCE which evaluates the dependent variable initialization arrays for the next integration step forward. The integration execution phase is then completed, Fig. 1, with a test to establish if the solution is complete and/or if an output call is required. Following these tests, execution is returned to INTEGRATION to repeat the same sequence of operations.

PROGRAM DESCRIPTION

The 3DBR Variant of COMOC is written to be readily executed on any large scale computer such as an IBM 360, 370, CDC 6600, or UNIVAC 1108. It is programmed in FORTRAN IV exclusively, except for certain machine-dependent routines, e.g., date, address, error handling, etc. With overlay, COMOC uses about 60K words on an IBM 360 for a solution region involving about 200 nodes and about twelve degrees of freedom per node. Output can be stored on tape or punched cards for future restarts.

Considerable effort has been devoted to construction of 3DBR COMOC in a uniform and consistent manner. A comprehensive subroutine substructure is utilized to allow functional processing in a consistent and readily followed sequence. Input formats are consistent and flexible, and program input controls are standardized. Consistent notation of variable names is employed in all subroutines, and only three major arrays are maintained. The common block /VARBLE/ contains the IARRAY and the RARRAY. The IARRAY contains a list of all the integers used in common throughout the program in locations 1 thru 200. Locations 201 thru 400 contain the entry locations in the IZ array where dimensioned variables are stored. The RARRAY contains a list of all the real scalers used in common throughout the program. The common block /ARRAYS/ contains the IZ array. This array contains all the variable dimensioned vectors, matrices and hollerith data which are used by the program. Shown in Table 2 is a listing of the MAIN link of COMOC, and Table 3 presents the overlay structure of the program for the IBM 360/65 computer.

The source listing of 3DBR COMOC is not included in this document due to its excessive length. The following pages of this section contain descriptions of the subroutines of 3DBR COMOC, followed by macro-flow charts of their functional sequencing.

TABLE 2

MAIN LINK OF COMOC

BDINPT	LINK3	LOC	OUTVEC
SCHPRN	MAIN	LOCATE	PSIBC
SUTHLD	LINK4	LOOK	RECIP
SETDIF	ABSAVE	MATSUM	RESET
LINK2	ASMVEC	MINMAX	SETVAL
RITE	AVRG	MPRD	TENDA
LINK5	GENDA	MTRA	VARMAX
LINK1	GMADD	NBNDRY	VECTA
READER	INITBL	OUTNOD	XYSCAL

TABLE 3

OVERLAY STRUCTURE OF COMOC FOR IBM 360/65 COMPUTER

```
OVERLAY ALPHA
INSERT   REDCEL
INSERT  REORDR
OVERLAY ALPHA
INSERT   FEDIMN,FENAME,DIMEN,CRINIT,GETALC,COMOC,NMELST
INSERT  DRDXCR
OVERLAY ALPHA
INSERT   SETUP,DSCRTZ,ROWS,COLS,ORDER,DELETE
INSERT   GETRND,RNDSET,ADDDEL,DELADD,DELELM,DELNOD,NODELM
INSERT  ELEM,MNMX,NDECRD
OVERLAY ALPHA
INSERT   GEOMEL,OUTPG,INITNS,DESCRP
INSERT  DINIT,DIN01,DIN02,DIN03,DIN04,DIN05,DIN06,DIN07
OVERLAY ALPHA
INSERT   FINCRE,ICOND
OVERLAY ALPHA
INSERT   STOUT1,OKNINT,REOUTP,OKNUIN,PBLANK,PLTLNK,SETSCL
INSERT  SCALEV,DECENS,DECREQ
INSERT  WLELXS,TAUW
INSERT  SOURCE,GETPRP,ENERSC,STOREV
OVERLAY ALPHA
INSERT  PROCSS,THERMO,GAS,GRAHET,GASRHO,SIMQ,NUMR,CONST
OVERLAY ALPHA
INSERT  DERUCL
OVERLAY ALPHA
INSERT  DERVAL,DERSET
INSERT  DECFAL,H2MIX,O3CONC,SCHMDT
OVERLAY ALPHA
INSERT   PRPLOT,WRTAPE
OVERLAY ALPHA
INSERT  CONTFS,MISRIV,LSET,POLY,INTERP
ENTRY    MAIN
```

THE FOLLOWING PAGES CONTAIN A BRIEF DESCRIPTION OF THE SUBROUTINES IN THE COMOC COMPUTER PROGRAM.

NAMES IN PARENTHESES INDICATE CALLING ROUTINES. IF NO NAME IS ENTERRED THEN SEVERAL ROUTINES PLACE CALL.

MAIN

THIS IS THE MAIN CONTROL PROGRAM TO INITIALIZE THE IZ ARRAY THE RARRAY AND THE IARRAY TO ZEROES.

TO INCREASE THE CAPACITY OF THE PROGRAM TO HANDLE MORE NODES IT IS ONLY NECESSARY TO INCREASE THE DIMENSION OF THE IZ ARRAY.

AFTER INITIALIZATION THE CONTROL ROUTINE BDINPT IS CALLED.

BDINPT (MAIN)

THIS IS THE CONTROL ROUTINE TO INITIALIZE VECTORS AND TO CONTROL THE FLOW OF THE PROGRAM ACCORDING TO USER INPUT.

A CONTROL CARD WITH THE FOLLOWING PARAMETERS IS READ IN -

PARAMETER	FORMAT	CARD COLS.	DESCRIPTION
V1	A8	1 - 8	CONTROL VARIABLE.
NX	I2	9 - 10	INDEX FOR ROUTINE OR CALL LIST.
NPCD	I5	11 - 15	START POS. FOR PDUMP.
NREPET	I5	16 - 20	END POS. FOR PDUMP.
NMUL	10I5	21 - 70	A. NMUL(1) = RESTART TAPE. NMUL(2) = RESTART PRINT NO. NMUL(3) = NEW RESTART TAPE. B. NMUL(1) THRU NMUL(8) ARE SCANNED TO FORM A MULTIPLIER FOR REAL INPUT. IF ALL ZERO THEN 1.0 IS USED.
RTNE	A8	71 - 78	ASSOC. WITH V1 = LINK1 THRU LINK5. DENOTES NAME OF ROUTINE TO BE CALLED. (NOT USED BY PROGRAM)

IF KDUMP = 1 IN NAME01, THEN THE ENTIRE INPUT CARD IS PRINTED IMMEDIATELY AFTER BEING READ FOLLOWED BY THE DATA THAT IS BEING STORED ALONG WITH THE DATA'S ENTRY POSITION IN THE IZ ARRAY.

THIS ROUTINE LOOKS FIRST FOR A MATCH OF V1 WITH CERTAIN KEY WORDS WHICH WILL EITHER CAUSE A SUBROUTINE TO BE CALLED OR PROGRAM FLOW TO OCCUR.

THE KEY WORDS THAT ARE SCANNED ARE -

BBBBB (BLANK)	-	RETURN TO SCAN ANOTHER CARD.
COMOC	-	PRINT THE COMOC TITLE PAGE TWO TIMES.
COMTITLE	-	READ A TITLE CARD WHICH WILL APPEAR ON COMOC.
DESCRIPT NX	-	CALL DSCRPT AND PROCESS ACCORDING TO NX.

```
END               -  RETURN CONTROL TO MAIN PROGRAM, RESET ARRAYS
                     AND RETURN TO BDINPT.
EXIT              -  CALL EXIT.
FEBL              -  SET IBL = 1.
FEDIMN            -  CALL DIMENSIONALIZATION ROUTINE FEDIMN.

FENAME            -  CALL FENAME TO SET DEFAULT SCALARS AND THEN
                     CALL NMELST TO READ IN NAME01 AND NAME02
                     NAMELISTS.
FENS              -  SET IBL = 0.
ICOND             -  CALL ICOND TO PRINT REAL AND ITEGER SCALARS.
INTEGER           -  ALLOWS NEW VALUES TO BE READ INTO A SEQUENCE
                     OF LOCATIONS IN THE BORDER, IPLACE AND LOC
                     VECTORS.
KBNO      NX      -  ENTER BOUNDARY NODES FOR DEP. VAR. NX.
LINK1     NX      -  CALL LINK1(NX)
LINK2     NX      -  CALL LINK2(NX)
LINK3     NX      -  CALL LINK3(NX)
LINK4     NX      -  CALL LINK4(NX)
LINK5     NX      -  CALL LINK5(NX)
NAMELIST          -  CALL NMELST TO READ IN NAME01 AND NAME02
                     NAMELISTS.
PDUMP     NX      -  CALL PDUMP (IZ(NPCD), IZ(NREPET), NX )
QKNINT            -  CHECK FOR DRHOBL OR DRHOGS USAGE.
                     COMPUTE DIFFUSION COEFFICIENTS.
                     COMPUTE SKIN FRICTION AND STANTON NUMBER.
                     INITIALIZE GAS ROUTINES.
                     PRINT INITIALIZATION CONTROLS.
                     CALL QKNINT.
REAL              -  ALLOWS NEW VALUES TO BE READ INTO A SEQUENCE
                     OF LOCATIONS IN THE VALUE AND NPLACE VECTORS.
RESTART           -  ALLOWS USER TO USE OUTPUT FROM A PREVIOUS
                     RUN FOR RESTARTING AND ALSO TO DEFINE A NEW
                     DATA SET TO SAVE OUTPUT FOR A FUTURE RESTART.
HOLIST            -  READ IN A SEQUENCE OF TITLES TO COINCIDE
                     WITH A SCALAR OUTPUT LIST WHICH WILL APPEAR
                     AT THE BEGINNING OF EACH OUTPUT DISPLAY.
VYYEND    NX      -  DENOTES END OF INPUT FOR DEP. VAR. NX.
VYYRDF    NX      -  ALLOWS USER TO REDEFINE SELECTED ENTRIES
                     EITHER IN A DEPENDENT VARIABLE OR ONE OF
                     THE OTHER REAL VECTORS.
```

IF NEITHER SITUATION OCCURS,
THE VECTORS BORDER AND VALUE ARE SCANNED UNTIL A MATCH IS FOUND AND THE LOCATION IS STORED IN THE PARAMETER 'K'.

BORDER IS A VECTOR OF CONTROL NAMES WHICH IS SCANNED WITH THE USER INPUT CONTROL FOR INTEGER INPUT.

IARRAY(IPLACE(K)) = LOCATION IN THE IZ ARRAY AT WHICH TO BEGIN
STORING INTEGER ENTRIES.
IARRAY(LOC(K)) = NUMBER OF ENTRIES STORED STARTING AT
IARRAY(IPLACE(K)).

IF NX .NE. -1, CALL GETBND TO ENTER INTEGER DATA.
IF NX .EQ. -1, CALL ADDDEL TO ENTER INTEGER DATA.
SEE GETBND FOR INPUT DESCRIPTION.

BORDER	IPLACE	LOC	
THICK	268	93	ELEMENT THICKNESS VECTOR.
IPINT	205	31	SOLUTION SEQUENCE VECTOR.
PLOTS	311	113	PLOT VARIABLE AVECTOR.
NMAT	315	98	MATERIAL NUMBER VECTOR.
MELEM	316	14	MATERIAL TYPE/ELEMENT VECTOR.
PLOTYP	312	113	TYPE OF PLOT/VARIABLE VECTOR.
ICALL	321	125	LINK NOS. TO BE CALLED AT END OF QKNUIN.
ICALLS	322	125	ENTRY IN LINK TO BE CALLED.
IOMULT	323	60	OUTPUT VARIABLE MULTIPLIER FROM RARRAY.
IOSAVE	324	60	VARIABLE LIST TO BE DISPLAYED AT OUTPUT.
CNTPTS	327	47	CONTOURS NODES TO BE USED IN CONTES AND DFCFBL.
CNTNDS	328	128	NO. OF NODES IN EACH CONTOUR LINE.
IBORD	238	131	COUNTER-CLOCKWISE LIST OF BOUNDARY.
IONUMB	331	142	LIST OF ENTRIES IN RARRAY TO BE DISPLAYED AT START OF EACH OUTPUT.
MPARA	335	142	LIST OF MULTIPLIERS IN RARRAY USED TO MULTIPLY IONUMB ENTRIES.

VALUE IS A VECTOR OF CONTROL NAMES WHICH IS SCANNED WITH THE USER
INPUT CONTROL FOR REAL INPUT.

IARRAY(NPLACE(K)) = LOCATION IN THE IZ ARRAY AT WHICH TO BEGIN
STORING REAL ENTRIES.

ROUTINE REDREL IS CALLED AT THIS TIME TO ENTER DATA.

VALUE	NPLACE	
VTHICK	270	VALUE OF ELEMENT THICKNESSES. DEFAULT = 1.0 / ALC
VRHO	284	DENSITY AT NODE POINTS. DEFAULT = RHOINF
VTTAB	219	TABLE LOOK-UP TEMPERATURES. DEFAULT = 1090.0
VCPTAB	218	TABLE LOOK-UP SPECIFIC HEATS. DEFAULT = 0.24
VX1COR	289	X1-COORDINATES AT NODE POINTS. DEFAULT = 0.0

```
    VX2COR     290       X2-COORDINATES AT NODE POINTS.
                         DEFAULT = 0.0
    VH         279       ENTHALPY DISTRIBUTION AT NODE POINTS.
                          DEFAULT = 0.0
    VPSTAT     281       STATIC PRESSURE AT NODE POINTS.
                         DEFAULT = PINF / (RHOINF * UINF**2 )
    VPLTSCL    313       SCALE FACTORS FOR PLOT VARIABLES.
                         DEFAULT = 1.0
    VAKTAB     317
                         DEFAULT = 1.0
    VAK2TAB    318
                         DEFAULT = 1.0
    VPRESS     291       PRESSURE VALUES AT NODE POINTS.
                         DEFAULT = PINF
    VSCHMIDT   314       SCHMIDT NO. DIST. AT NODE POINTS.
                          DEFAULT = 0.7
    VYY        282       DEPENDENT VAR. DIST. AT NODE POINTS.
                         DEFAULT = 0.0
    VTEMP      285       TEMPERATURE DIST. AT NODE POINTS.
                         DEFAULT = TOFINF
    VTK        288       THICKNESS OF ELEMENTS IN THICK VECTOR.
                         DEFAULT = 1.0 / ALC
    VSUTHLD    333       MUREF, TREF, TCON AND EXP ENTRIES FOR SUTHLD.
                          DEFAULT = .1163F-4, 494.0, 204.0, 1.5
    VPRANDTL   334       PRANDTL NO. DIST. AT NODE POINTS.
                          DEFAULT = 0.7
    VX3ST      339       DOWNSTREAM STATIONS AT WHICH PRESSURE IS DEFINED.
    VPVSX      340       DOWNSTREAM PRESSURES AT VX3ST.
    VEPSILON   336       TURBULENT VISCOSITY AT NODE POINTS.
                          DEFAULT = 0.0
LINK1
    PLACE CALLS TO THE FOLLOWING ROUTINES.
         1. SETUP
         2. NODELM
         3. GEOMFL
         4. DPDXTB
         5. GETPPR
         6. SOURCE
         8. DERVBL
LINK2
    PLACE CALLS TO THE FOLLOWING ROUTINES.
         1. DFCFNS
         2. DFCFBL
         3. WLFLXS
         4. CONTES
         5. REDUTP
         6. FEOUTP
     IF RESTART CODE 'NRTAPE' IS GREATER THAN 0, WRITE RESTART
     CONDITIONS ON TAPE 'NRTAPE'.
        10. DRHOBL
```

```
          11. DRHOGS
          12. H2MIX
LINK3
    PLACE CALLS TO THE FOLLOWING ROUTINES.
         1. NBNDRY
         2. RITE   - PRINT OUTPUT HEADING
         4. DIMEN
LINK4
    PLACE CALLS TO THE FOLLOWING ROUTINES.
         2. QKNUIN
         6. INITNS
         7. INITBL
LINK5
    PLACE CALLS TO THE FOLLOWING ROUTINES.
         2. CALL ROUTINES FROM ICALLS LIST IN LINK FROM ICALL LIST.
         3. CPINIT
         5. SCHPRN
         6. SETDIF

ABSAVE (CERVBL)
     COMPUTE THE SUM OF ABSOLUTE VALUES OF A SEQUENCE OF NUMBERS.
ADDDEL (ELEM, GETBND, SETUP)
     ADD OR DELETE ENTRIES IN AN INTEGER ARRAY DEPENDING ON THE
     VALUE OF 'KODE'.
     KODE = 1, DELETE
     KODE = 2, ADD
AVRG
     COMPUTE THE ARITHMETIC AVERAGE OF 'NUMB' ENTRIES IN AN ARRAY.
BNDSET (GETBND)
     DETERMINE NODES TO BE INSERTED INTO BOUNDARY ARRAY.
COLS (DSCRTZ)
     COMPUTE THE NUMBER OF COLUMNS, 'LCOL', IN THE OUTPUT DISPLAY
     AND SET UP THE FOLLOWING ARRAY,
       INCOL  - NO. OF NODES IN COLUMN J.
COMOC (BDINPT)
     THIS ROUTINE PRINTS TWO TITLE PAGES ALONG WITH THE DATE.

CONTES (LINK2(4))
    RUNNING SMOOTH CONTINUITY EQUATION SOLVER TO COMPUTE V AND W
      UP A COLUMN OF NODES AFTER VSTART HAS BEEN REACHED.  IF NCOORD
      EQUALS 1, INPUT NODES (READ IN AS CNTPTS AND CNTNDS ) ARE USED
      INSTEAD.
CPINIT (DIMEN)
     COMPUTE  CPINF AT  TSINF.
     THE VECTOR CP IS RESET TO CPINF.
DELADD (ADDDEL)
     ADD ENTRIES TO AN INTEGER ARRAY 'NSIDE' AT A TIME.
DELELM (DELNOD)
     DELETE ENTRIES IN AN INTEGER ARRAY 'NSIDE' AT A TIME.
DELETE (DSCRTZ)
```

```
     DELETE NODES THAT ARE NOT CONNECTED TO ANY ELEMENTS.
DELNOD (ADDDEL)
     SET UP CALL TO DELFLM AND SUPPRESS ZERO ENTRIES IN ARRAY.
DERSET (DERVBL)
    COMPUTE Q*RHO FOR Q = U,V, OR W.
DERVBL (LINK1(8))
    FORM THE DERIVATIVE OF THE ORDINARY DIFFERENTIAL EQUATION FIRST
      ON U-VELOCITY (GLOBAL CONTINUITY) AND THEN ON OTHER DEPENDENT
      VARIABLES INCLUDING SPECIES CONTINUITY, ENERGY, LONGTITUDINAL
      AND LATERAL MOMENTUM, IF REQUIRED.


DESCRP(N) (BDINPT)
    N = 0,1  READ TITLE FOR OUTPUT.
    N = 2    READ HEADINGS FOR OUTPUT VARIABLES.
    N = 3    READ AND WRITE SELECTED VARIABLES FROM IARRAY OR RARRAY
                  FOR PROBLEM DESCRIPTION.
                  IF ENTRY IS NEGATIVE - SELECT IARRAY ENTRY
                  IF ENTRY IS POSITIVE - SELECT RARRAY ENTRY.
DFCFBL (LINK2(2))
    COMPUTE MIXING LENGTH DIFFUSION COEFFICIENTS FOR DEPENDENT VARIABLES.
     IF NE1E2 = 1 THE TURBULENT CURVE E1 IS USED.
     IF NE1E2 = 2 THE TURBULENT CURVE E1 IS USED UNTIL ROW IMAX
       IS REACHED AND THEN THE LAMINAR FLOW CURVE E2 IS USED.
DFCFNS (LINK2(1))
     SET THE TEMPERATURE AND DENSITY IF NOT INITIALIZED.
     CALL DFCOFO TO COMPUTE VISCOSITY (AMU VECTOR).
DFCOFO (DFCFNS)
     ESTABLISH THE NODAL VALUES OF VISCOSITY USING SUTHERLAND'S
       EQUATION FOR AIR.
DIMEN (LINK3(4))
     COMPUTE 'ALC' IF NOT INITIALIZED IN 'NAME02'.
     PUNCH COORDINATE CARDS, IF DESIRED (NPUNCH = 7).
       COL     - X1 COORDINATE OF COLUMN J.
       ROW     - X2 COORDINATE OF ROW I.
DPDXTB (LINK1(4))
    COMPUTE DPDX FROM PRESSURE TABLE, DPDX IS CONSTANT OVER INTERVALS.
DRHCBL (LINK2(10))
    CALLED IF IGAS = 0 IN NAME01.
    COMPUTES THE TEMPERATURE AND DENSITY USING A SIMPLIFIED
      ENERGY EQUATION.
DRHOGS (LINK2(11))
    CALLED IF IGAS = 1 IN NAME01.
    COMPUTES THE THEMERATURE, DENSITY AND SPECIFIC HEAT ON A NODAL
      BASIS AS A FUNCTION OF ENTHALPY, VELOCITY AND SPECIES
      COMPOSITION.
      IF NGETH = 1 IN NAME01, THE FIRST PASS THROUGH THIS ROUTINE
      WILL RETURN ENTHALPY WHEN GIVEN THE TOTAL TEMPERATURE AT
      AT THE NODES.
DSCRTZ (SETUP)
```

```
     SET UP REGION DISCRETIZATION.
     GENERATE ARRAYS USED FOR FINDING OUTPUT LOCATIONS.
ELEM (DSCRTZ)
    IF NELEM = 0 IN NAMEO1, GENERATES ELEMENTS AS A FUNCTION OF
      NODE COORDINATE INPUT.  USED PRIMARILY FOR RECTANGULAR DOMAIN.
ENERSC (SOURCE)
    COMPUTE SOURCE TERMS FOR ENERGY EQUATION.
ERRSET (MAIN)
     IBM 360 ERROR HANDLING ROUTINE TO SUPPRESS OVERFLOWS ETC.
FEDIMN (BDINPT)
     SET UP DIMENSIONS OF VARIABLE LENGTH ARRAYS USED IN THE
     SYSTEM.  FINDS LOCATIONS OF OUTPUT ARRAYS FOR 'FEOUTP'.
     PRINT LOCATION OF ENTRY POINTS IN 'IZ' ARRAY IF KDUMP = 1.
FENAME (BDINPT)
     THIS ROUTINE CONTAINS A LIST OF ALL EQUIVALENCE VARIABLES ALONG
     WITH AN ALPHABETICAL CROSS-REFERENCE.
     CALL NMELST TO READ IN NAMEO1 AND NAMEO2 NAMELISTS.
     MOST DEFAULTED PARAMETERS ARE SET ALSO SET HERE.
FEPLOT (STOUT1)
     AT PRESENT, ALLOWS FOR PUNCHING DATA AT PLOT STATIONS.
FINDBE (BDINPT)
    DETERMINE A SERIES OF BOUNDARY ELEMENTS AS A FUNCTION OF
      OF INPUTTING BOUNDARY NODES IN COUNTER-CLOCKWISE ORDER.
      ON FIRST PASS, FIND BORDER ELEMENTS IF READ INTO IBCRD VECTOR.
FSTAE (MAIN)
     IBM 360 ROUTINE TO SUPPRESS FORTRAN ERRORS.
GAS (GPAHFT)
    DETERMINE COMPOSITION AT SPECIFIC TEMPERATURE TO CREATE
      ENTHALPY REQUIRED FOR CONVERGENCE.
GASBUG (GAS)
    PRINT DEBUG INFORMATION FOR GAS ROUTINE.
GENDA
     ASSEMBLE AN ELEMENT VECTOR WHEN GIVEN THE GLOBAL VECTOR AND
     A LIST OF NODES PERTAINING TO THE ELEMENT VECTOR.


GEOMFL (LINK1(3))
     SET UP THICKNESS ARRAY.
     GENERATE THE TRANSFORMED LENGTH OF ELEMENT AND STORE IN X12 VECTOR.
     GENERATE THE TRANSFORMED HEIGHT OF ELEMENT AND STORE IN X23 VECTOR.
     GENERATE THE V PART OF THE B2001 MATRIX AND STORE IN GEOM1 MATRIX.
     GENERATE THE W PART OF THE B2001 MATRIX AND STORE IN GEOM2 MATRIX.
     GENERATE LENGTH * THICKNESS ARRAY.
     GENERATE AREA * THICKNESS ARRAY.
     GENERATE THE NON-STANDARD ELEMENT MATRICES B211 AND B211S.
     IF KODG IS GREATER THAN 0, PRINT ELEMENT NO., NODES OF ELEMENT,
     COORDINATES OF NODES AND B211S ENTRIES FOR ELEMENT.  AFTER
     THE ELEMENT LOOP IS COMPLETED, PRINT THE VECTORS AND MATRICES
     THAT WERE GENERATED IN THE ELEMENT LOOP.
GETADD (FEDIMN)
```

360 ASSEMBLER ROUTINE TO GET MACHINE ADDRESS OF VARIABLE.

GETALC (DIMEN)

COMPUTE 'ALC' AS THE SHORTEST SIDE OF ALL THE ELEMENTS IF IT IS NOT READ IN.

GETBND (BDINPT)

BOUNDARY OR INTEGER GENERATION ROUTINE USING EITHER THE WORDS 'ADD' OR 'DELETE' OR SIMPLE GEOMETRY OF THE PROBLEM WITH THE FOLLOWING KEYWORDS AND CODES -

EACH CARD IS DIVIDED INTO FOUR IDENTICAL BLOCKS OF 20 COLUMNS EACH. ALL BLOCKS ARE SCANNED FOR SIMILAR INFORMATION SO A DESCRIPTION OF ONE BLOCK WILL BE GIVEN. THE BLOCKS START IN COL. 1, COL. 21, COL. 41 AND COL. 61.

KEYWORD	FORMAT	BLOCK COLS.	DESCRIPTION
(BLANK)	A8	1 - 8	IGNORE BLOCK
ADD	A8	1 - 8	CALL ADDDEL TO INSERT ENTRIES. IGNORE COL. 9 - 20.
DELETE	A8	1 - 8	CALL ADDDEL TO DELETE ENTRIES. IGNORE COL. 9 - 20.

FOR THE FOLLOWING KEYWORDS, THE THREE CODES (WE'LL CALL THEM KODE1, KODE2 AND KODE3 FOR CONVENIENCE) WILL DETERMINE WHICH NODES WILL BE SELECTED)

KODE1	I4	9 - 12	ROW OR COLUMN DISPLACEMENT FROM EDGE BEING DESCRIBED.
KODE2	I4	13 - 16	POS. IN LINE TO START (DEF. = FIRST).
KODE3	I4	17 - 20	POS. IN LINE TO END (DEF. = LAST).

KEYWORD	FORMAT	BLOCK COLS.	DESCRIPTION
TOP	A8	1 - 8	ACROSS TOP FROM LEFT TO RIGHT.
-TOP	A8	1 - 8	ACROSS TOP FROM RIGHT TO LEFT.
BOTTOM	A8	1 - 8	ACROSS BOTTOM FROM LEFT TO RIGHT.
-BOTTOM	A8	1 - 8	ACROSS BOTTOM FROM RIGHT TO LEFT.
RIGHT	A8	1 - 8	UP RIGHT HAND SIDE.
-RIGHT	A8	1 - 8	DOWN RIGHT HAND SIDE.
LEFT	A8	1 - 8	UP LEFT HAND SIDE.
-LEFT	A8	1 - 8	DOWN LEFT HAND SIDE.

GETPPR (LINK1(5))

TABLE LOOK-UP OF PRESSURE AND DPDX AS FUNCTION OF DOWNSTREAM STATION.

GMADD

GENERAL MATRIX ADDITION. C = A + B

GPAHFT (THFRMO)

IF NGETH = 1, COMPUTE ENTHALPY DISTRIBUTION.

IF NGETH = 0, COMPUTE CPCINF AND RHOINF.

IF NGETH .LT. 0, DETERMINE NODAL TEMPERATURE GIVEN PRESSURE, COMPOSITION AND ENTHALPY.

H2MIX (LINK2(12))

COMPUTE THE MIXING EFFICIENCY HRSDOT AND THE MASS FLOW HDOT.

ICOND (BDINPT)

```
     PRINT INTEGER AND REAL INITIAL CONDITIONS.
     IARRAY(1) - IARRAY(200)
     RARRAY(1) - RARRAY(200)

INITNS (LINK4(6))
     INITIALIZE DEPENDENT VARIABLES.
      THIS ROUTINE GOES THROUGH AN ELEMENT LOOP IN CASE THE VALUES
      OF THE DEPENDENT VARIABLES DEPEND ON THE GEOMETRY OF THE PRCBLEM.
LOC (MPRD)
     COMPUTE VECTOR SUBSCRIPT FOR AN ELEMENT IN A MATRIX OF
       SPECIFIED STORAGE MODE.
LOCATE
      FIND THE LOCATION OF 'M' IN THE ARRAY 'NA' AND STORE IT IN 'N'.
LOOK (CPINIT, DRHONS)
      LINEAR INTERPOLATION ROUTINE (USED ONLY FOR 'CP' AT PRESENT).
LSFT (MISDIV)
     GENERATE A LEAST SQUARES FIT THRU A SERIES OF POINTS.
MATSUM
      COMPUTE A(I) = B(I) + COEFF * C(I), I = 1, N
MINMAX (DSCRTZ, ORDER, SETSCL)
      COMPUTE THE MINIMUM 'MN' AND MAXIMUM 'MX' ENTRIES IN AN ARRAY
      AT LOCATION 'IMN' AND 'IMX' IN THE ARRAY.
MISDIV (CONTES)
     POLYMIAL FIT THRU NPT POINTS TO THE MTH ORDER.
      NPT MUST BE AN ODD NUMBER.
MLTPLY (PRESUR)
     INTERMEDIATE MULTIPLICATION FOR PRESUR ROUTINE.
MNMX (ELEM)
     FROM A VECTOR 'INA' CONTAINING 'NN' ENTRIES, STORE THE FOLLOWING-
       LOW  -  POSITION IN INA OF MINIMUM.
       LHI  -  POSITION IN INA OF MAXIMUM.
       MN   -  MINIMUM VALUE IN INA.
       MX   -  MAXIMUM VALUE IN INA.
MPRD
     MULTIPLY TWO MATRICES AND STORE IN RESULTANT MATRIX.
       R = A * B
MTRA (GEOMFL)
     FIND THE TRANSPOSE OF A GENERAL MATRIX.

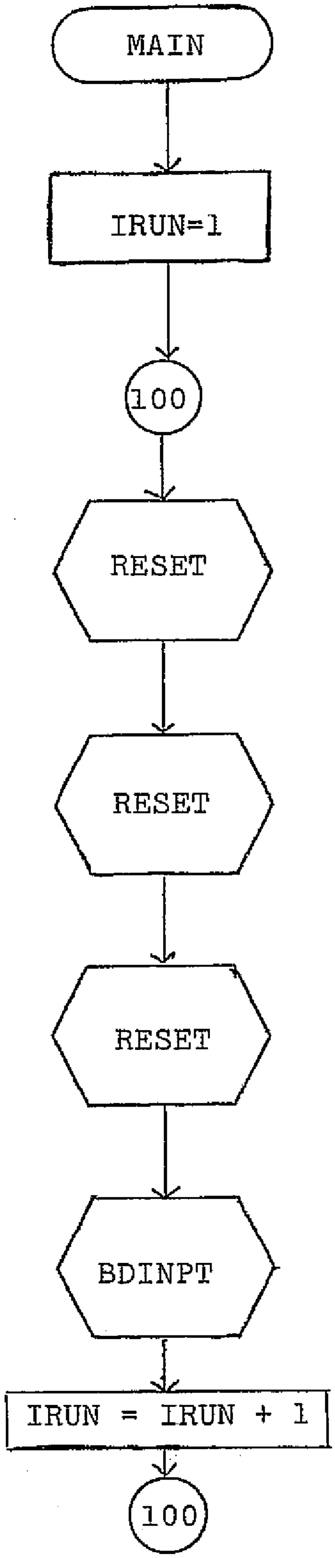
NBNDRY (LINK3(1))
      THE VALUE OF 'NBSET' DETERMINES THE OPERATION OF  HIS ROUTINE,
      -1 = SET UP INTEGRATION NODES AND STORE DEPENDENT VARIABLE
           INTO 'YY' ARRAY.
      +1 = SET UP AND PRINT INTEGRATION NODES AND STORE DEPENDENT
           VARIABLE INTO 'YY' ARRAY.
       0 = SET UP INTEGRATION NODES AND RETRIEVE DEPENDENT VARIABLE
           FROM 'YY' ARRAY.
NDECRD (DSCRTZ)
     GENERATE NODE COORDINATES, IF NNODE = 0 IN NAME01.
NMELST (FENAME, BDINPT)
```

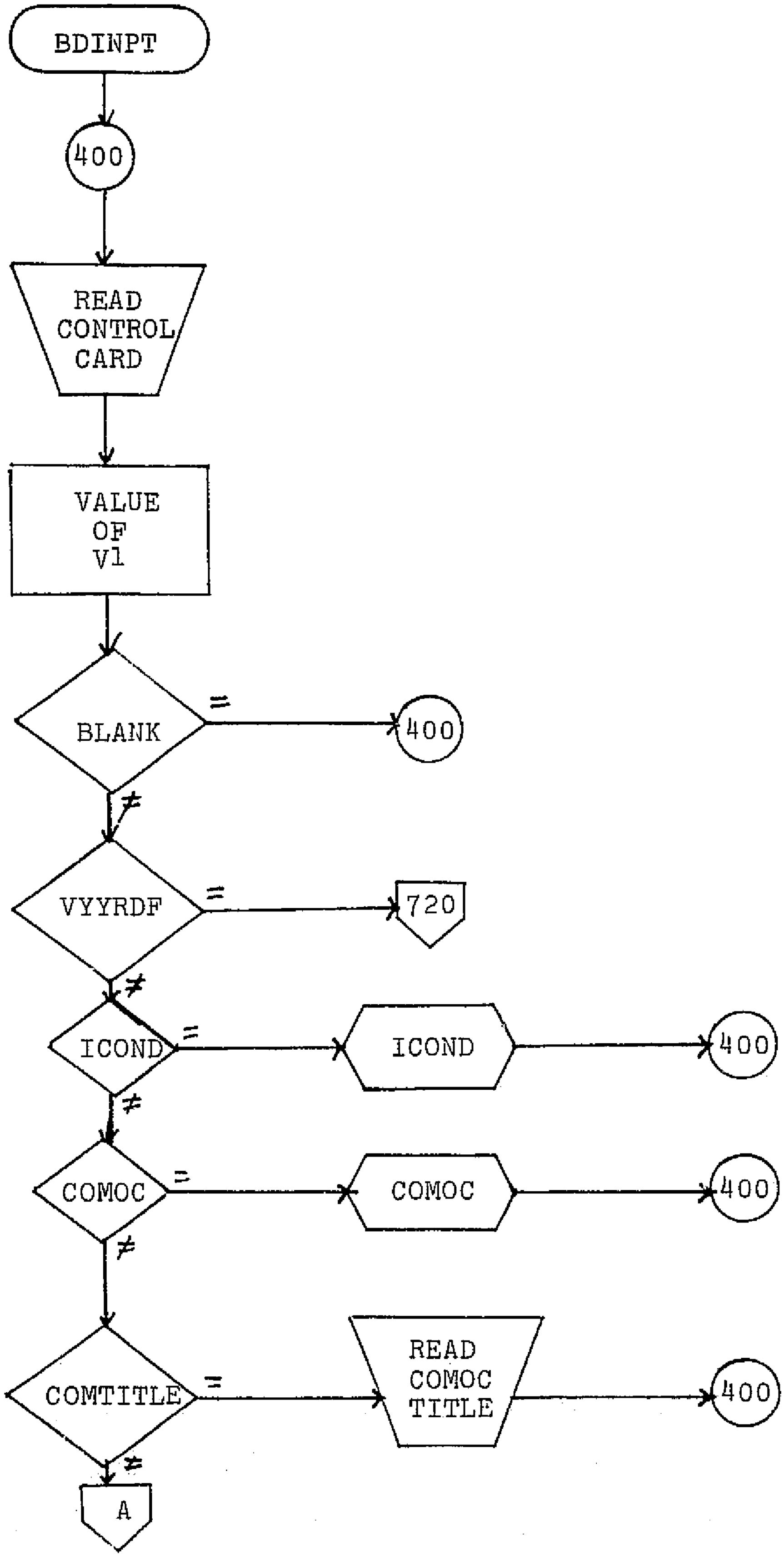
```
    READ NAMELIST DATA INPUT.
    NAME01 = INTEGER INPUT.
    NAME02 = REAL INPUT.
NODELM (LINK1(2))
    SET UP THE ARRAY IELS TO BE USED IN DRHONS.
      IELS = NO. OF ELEMENTS CONNECTED TO NODE N.
ORDER (COLS, ROWS, XYSCAL)
     ORDER 3 ARRAYS ACCORDING TO THEIR X1 AND X2 COORDINATES.  THE
     THIRD ARRAY WILL CONTAIN THEIR ARRAY LOCATIONS.
OUTNOD
     PRINT AN INTEGER ARRAY ALONG WITH A 32 CHARACTER TITLE.
OUTPG (GEOMFL)
     PRINT THE ELEMENT NO. AND NODE CONNECTIONS AND NODE COORDINATES
     FROM THE GEOMETRY ROUTINE 'GEOMHT'.
OUTVEC
     PRINT A REAL ARRAY ALONG WITH A 32 CHARACTER TITLE.
PBLANK (REOUTP)
     INSERT BLANKS IN THE OUTPUT VECTOR 'P' (USED IN 'REOUTP').
PLILNK (REOUTP)
      CONVERT A FLOATING POINT NUMBER INTO 'A' FORMAT.
POLY (MISDIV)
    FUNCTION TO GENERATE COEFFICIENTS C(I) IN Y = C(I) * X**M
QINIT (INITBL)
     CALL QINO1 THRU QIN(NEQ) DEPENDING ON VALUE OF 'NP'.
QINO1 (QINIT)
    INITIALIZE DEPENDENT VARIABLE 1 (U-VELOCITY).
    THE VALUES ARE EITHER STORED IN A DATA STATEMENT OR COMPUTED
      ON THE GEOMETRY AND THEN ENTERRED INTO THE ELEMENT LOCATIONS.
QINO2 THRU QIN(NEQ) (QINIT)
    SAME AS QINO1 BUT FOR DEPENDENT VARIABLE NP.
QKNINT (BDINPT)
    PRINT DISCRETIZATION OF REGION ALONG WITH NODE NUMBER LOCATIONS.
     CALL 'QKNUIN' AND TRANSFER CALL TO 'FECUTP' AT PROPER TIMES.
QKNUIN (LINK4(2))
     INITIALIAZE INTEGRATION CONSTANTS ON FIRST PASS.
     COMPUTE STEP SIZE AND NEW VALUE OF DEPENDENT VARIABLES.
    COMPUTE NEW DENSITIES, DIFFUSSION COEFFICIENTS, VISCOSITY
      AND OTHER PARAMETERS DEPENDENT ON THE NEW VALUES OF THE
      DEPENDENT VARIABLES.
    FIND THE MAXIMUM VALUE OF THE DEPENDENT VARIABLES AND STORE IN ZMAX.
      IF ZMAX IS LESS THAN ZTEST THE TIME WILL BE SET TO TF AND THE
      PROBLEM WILL TERMINATE AFTER THE NEXT PRINTOUT.

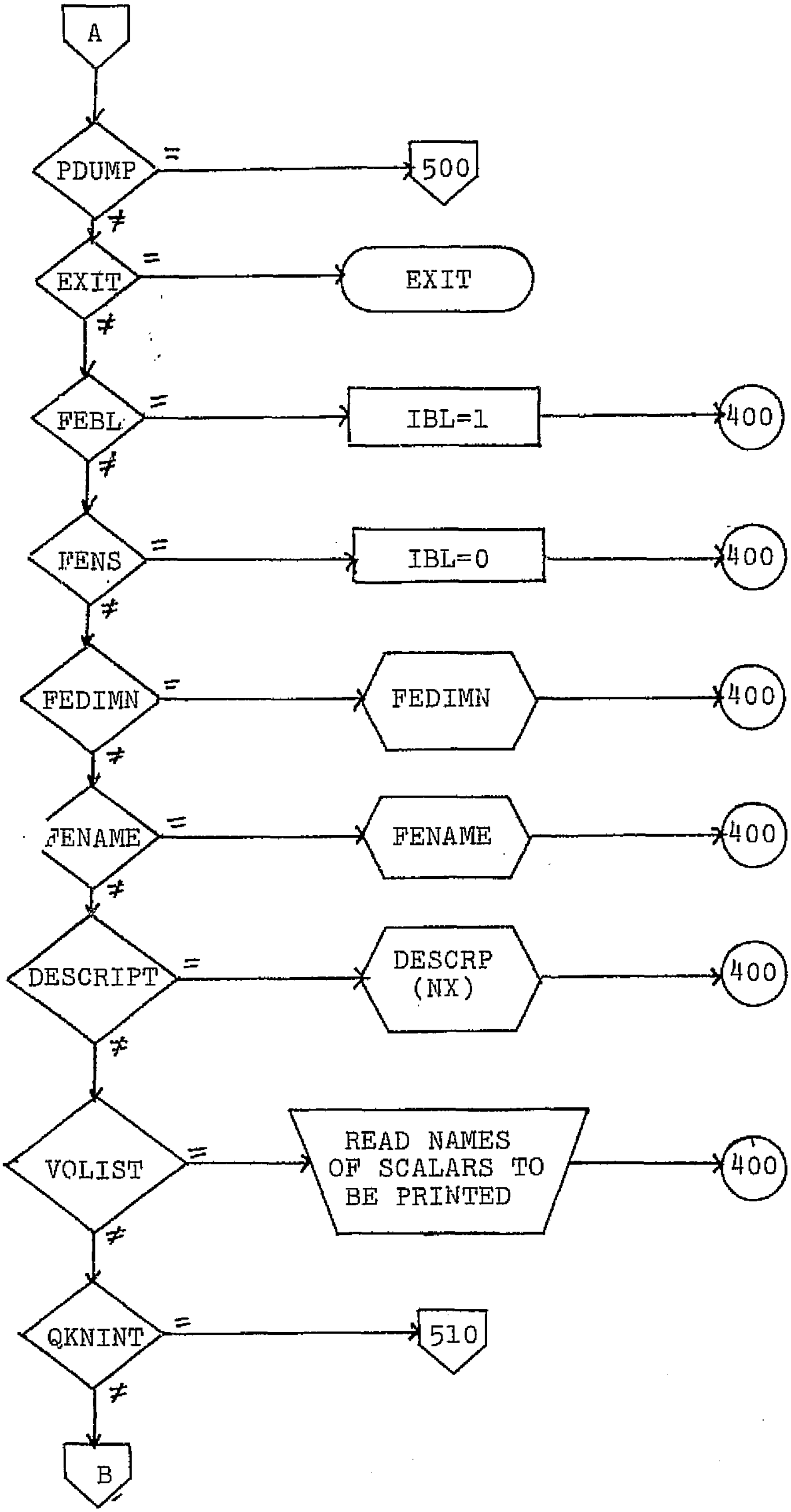

Q3CONC (DFCFBL)
    COMPUTE A ROUGH APPROXIMATION OF THE AREA OF H2 CONCENTRATION AND
      STORE IN AREA.  COMPUTE THE MASS DEFECT XMSDF = ROUALC * (AREA-XSUM)
      WHERE XSUM = AMOUNT OF H2 PRESENT AND ROUALC = RHOINF * ALC * UINF**2
RDATE (COMOC, RITE)
     ASSEMBLER ROUTINE TO GET MACHINE DATE AND STORE IN 2A4 FORMAT.
```

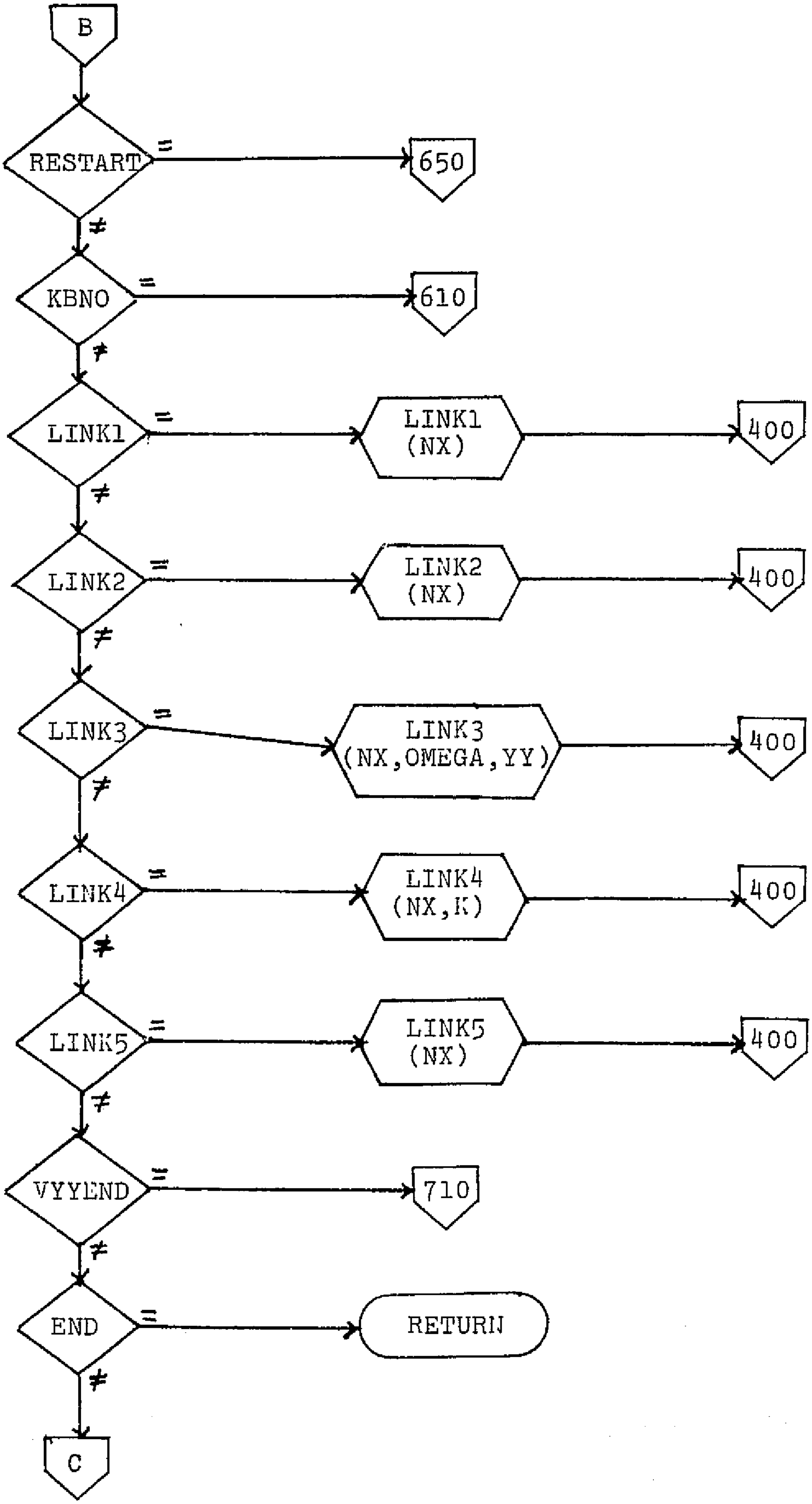
```
RECIP (DFCFNS, STOUT1)
     COMPUTE THE RECIPROCAL OF AN ARRAY AND STORE IT INTO ITSELF.
REDREL (BDINPT, ADDDEL)
    SCAN AN 80 CHARACTER CARD IMAGE AND CONVERT THE INFORMATION THERON
      INTO REAL OR INTEGER NUMBERS ACCORDING TO THE FORMAT PRESCRIBED.
REORDR (FINDBE)
    REORDER THE NODES OF AN ELEMENT SO THAT THE FIRST TWO WILL BE
      BOUNDARY NODES AND THEIR ORDER WILL BE COUNTER-CLOCKWISE.
      IN ORDER FOR THIS FEATURE TO OPERATE IT IS NECESSARY TO
      INPUT THE ORDER OF BOUNDARY NODES INTO THE IBORD VECTOR
      IN A COUNTER-CLOCKWISE ORDER.
REOUTP (LINK2(5))
    PRINT THE ARRAY GEOMETRY AND NODE NUMBERS IN A PATTERN THAT
      RESEMBLES PROBLEM GEOMETRY.
(FEOUTP) (LINK2(6)) FEOUTP IS AN ENTRY POINT IN REOUTP.
     PRINT OUTPUT PARAMETERS IN A PATTERN THAT RESEMBLES PROBLEM GEOMETRY.
     IF MAXIMUM SCALE FACTOR EXCEEDS 'NSM' (DEFAULT = 10), TERMINATE
     THE PROBLEM.
     IF OUTPUT PRINT NO. 'KOUNT', EXCEEDS PRINT LIMIT 'LPRINT' (DEFAULT =100)
     TERMINATE THE PROBLEM.
RESET
     RESET 'NN' ENTRIES OF ARRAY 'A' TO THE VALUE 'V'.
RITE (LINK3(2))
     COMPUTE ' NUMBER = (KEY-1)*10 + NMB '
     GO TO STATEMENT ACCORDING TO VALUE OF 'NUMBER'.
     IF 'NUMBER' IS OUT OF RANGE, WRITE TITLE INFORMATION.
SCALEV (FEOUTP)
     CALL SCALE ROUTINE FOR 10 OUTPUT VARIABLES.
SCHPRN (LINK5(5))
     COMPUTE THE SCHMIDT AND PRANDTL NUMBERS ON A NODE BASIS.
ROWS (DSCRTZ)
     COMPUTE THE NUMBER OF ROWS, 'KROW', IN THE OUTPUT DISPLAY
     AND SET UP THE FOLLOWING ARRAYS,
       INROW  - NO. OF NODES IN ROW I.
       INDRW  - COLUMN NUMBERS OF NODES IN ROW I.
       INDEX  - ROW NUMBERS OF NODES IN COLUMN J.
       NOCOL  - STARTING COLUMN NO. FOR ROW I.
SETSCL (SCALEV)
     SET SCALE FACTOR FOR AN ARRAY OF REAL NUMBERS, THUS NORMALIZING
SETUP (LINK1(1))
    IF NELEM .GT. 0,
     READ ELEMENT CONNECTIONS AND COUNT ELEMENTS ('NELEM').
    IF NNODE .GT. 0,
     READ NODE GEOMETRY AND COUNT NODES ('NNODE').
     CALL 'DSCRTZ' TO SET UP OUTPUT DISPLAY ARRAYS.
    READ TITLE CARDS UNTIL THE WORD 'DONE' APPEARS IN COL. 1-4.
      THE DEFAULT NO. OF CARDS TO BE ENTERRED IS 10, IF MORE NEED TO
      BE READ THEN SET 'NTITL' IN NAME01 EQUAL TO OR GREATER THAN THE
      NUMBER OF CARDS TO BE READ.
SETVAL
```

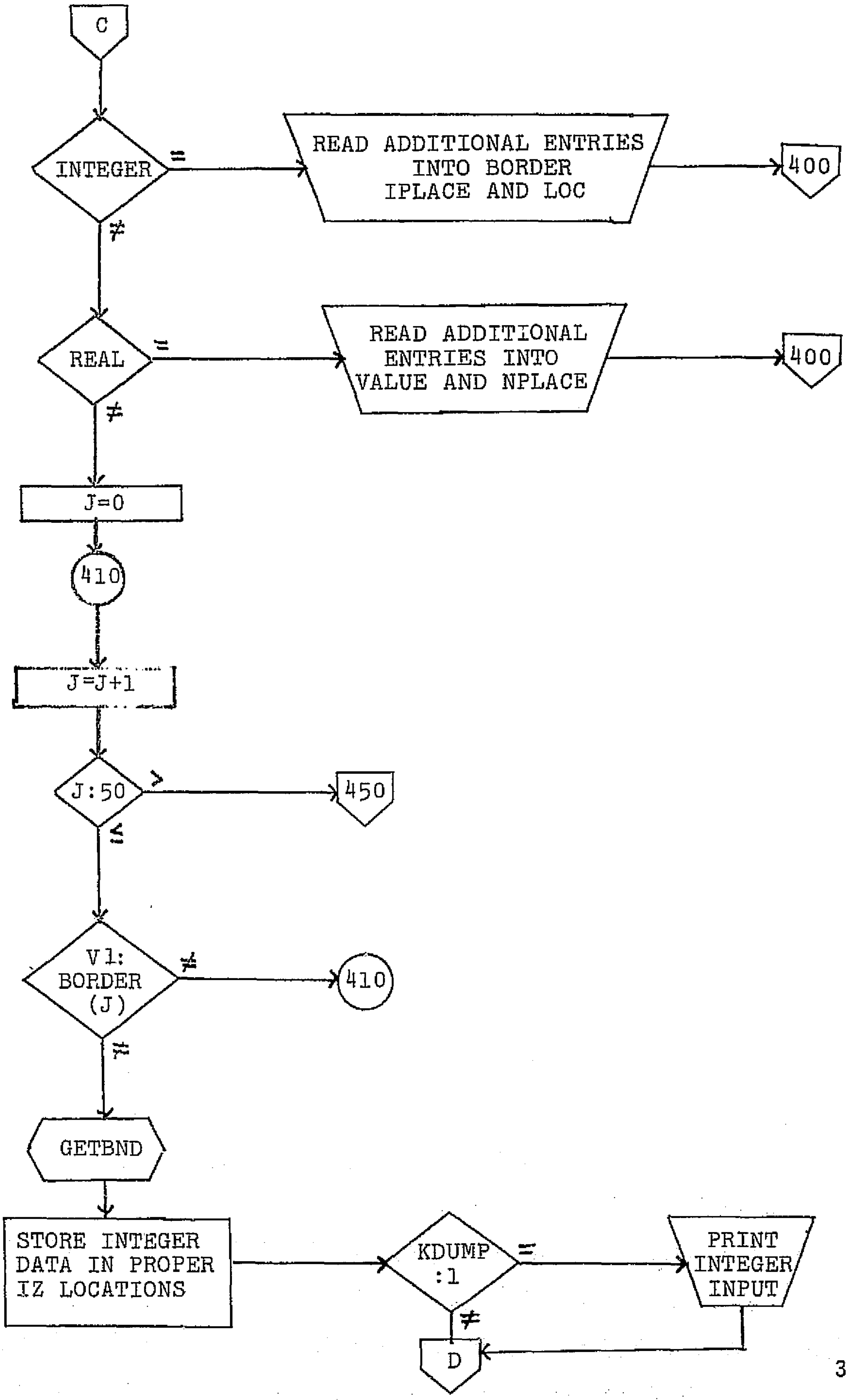
```
     COMPUTE A(I) = B(I) * C + D
SIMQ (GAS)
    SIMULTANEOUS LINEAR EQUATION SOLVER USED IN GAS.
SCURCE (LINK1(6))
    COMPUTE SOURCE TERMS FOR RIGHT HAND SIDE OF DIFFERENTIAL FQUATIONS.
STOREV (SOURCE)
    STORE APPROPRIATE VARIABLES IN DUMMY ARRAY FOR SOURCE COMPUTATICN.
STOUT1 (FEOUTP)
     DIMENSIONALIZE OUTPUT VARIABLES FOR DISPLAY PURPOSES.
    CALL PLOT ROUTINE AT APPROPRIATE TIME, IF REQUESTED.
SUTHLD (DIMEN, DFCOFO)
     COMPUTE VISCOSITY USING SUTHERLAND'S VISCOSITY LAW FOR AIR.
TAUW (WLFLXS)
    FIND TAU ALONG THE WALL FOR SKIN FRICTICN COMPUTATIONS.
TENDA
     ASSEMBLE GLOBAL VECTOR WHEN GIVE THE ELEMENT VECTOR AND
     A LIST OF NODES PERTAINING TO THE FLEMENT VECTOR.
THERMO (DRHOGS)
    INITIATE CALL TO GPAHFT.
VARMAX (FEPLOT)
     IF 'NK' .GT. 0, FIND MAXIMUM ENTRY IN ARRAY.
     IF 'NK' .LT. 0, FIND MINIMUM ENTRY IN ARRAY.
VECMAT (PRESUR)
    MULTIPLY A SYMMETRIC MATRIX OF VECTORS BY A VECTOR OF LENGTH NN.
VECTA
     BOOLEAN ASSEMBLY OF AN ELEMENT VECTOR INTO A GLOBAL VECTOR
     USING INTEGRATION NODE SEQUENCE.
WLFLXS (LINK2(3))
     COMPUTE THE SKIN FRICTION DISTRIBUTION AND HEAT TRANSFER DISTRIBUTION
       ALONG THE WALL.
XYSCAL (CSCRTZ)
     COMPRESS AN ARRAY OF NUMBERS 'X1' BY SCALE FACTOR 'SCFT'.
     FIND 'XYD= MAX(X1)-MIN(X1) * SCFT'
     IF TWO ADJACENT POINTS IF ARRAY 'X1' ARE WITHIN 'XYD' OF EACH
     OTHER, SET THE UPPER VALUF EQUAL TO THE LOWER VALUE.
```

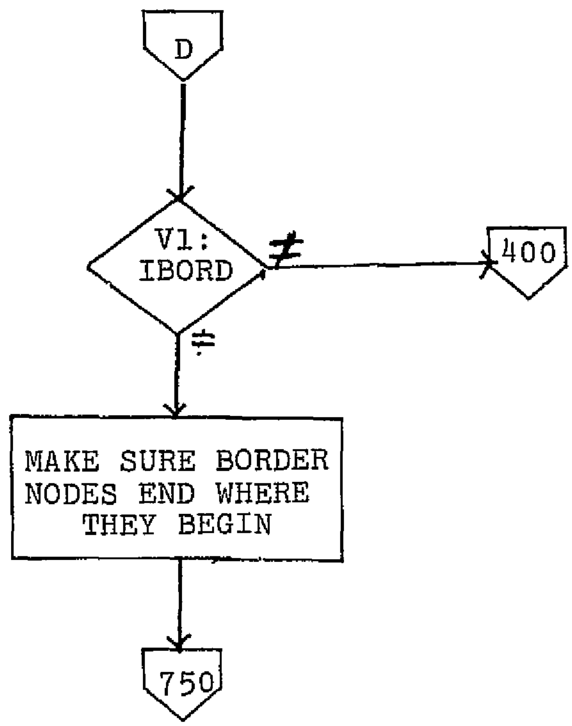

MAIN
IRUN=1
100
RESET
RESET
RESET
BDINPT
IRUN = IRUN + 1
100

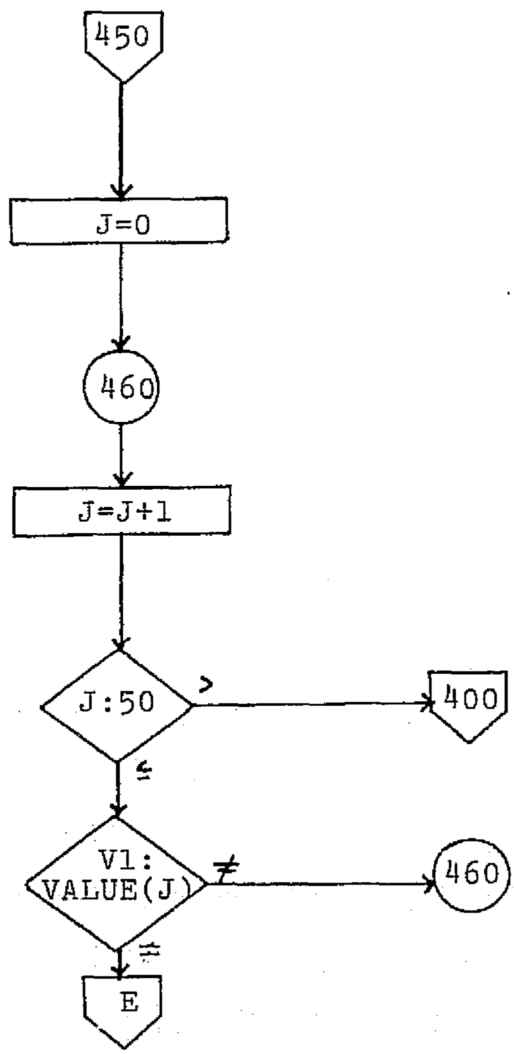

BDINPT
400
READ CONTROL CARD
VALUE OF V1
BLANK
=
400
≠
VYYRDF
=
720
≠
ICOND
=
ICOND
400
≠
COMOC
=
COMOC
400
≠
COMTITLE
=
READ COMOC TITLE
400
≠
A

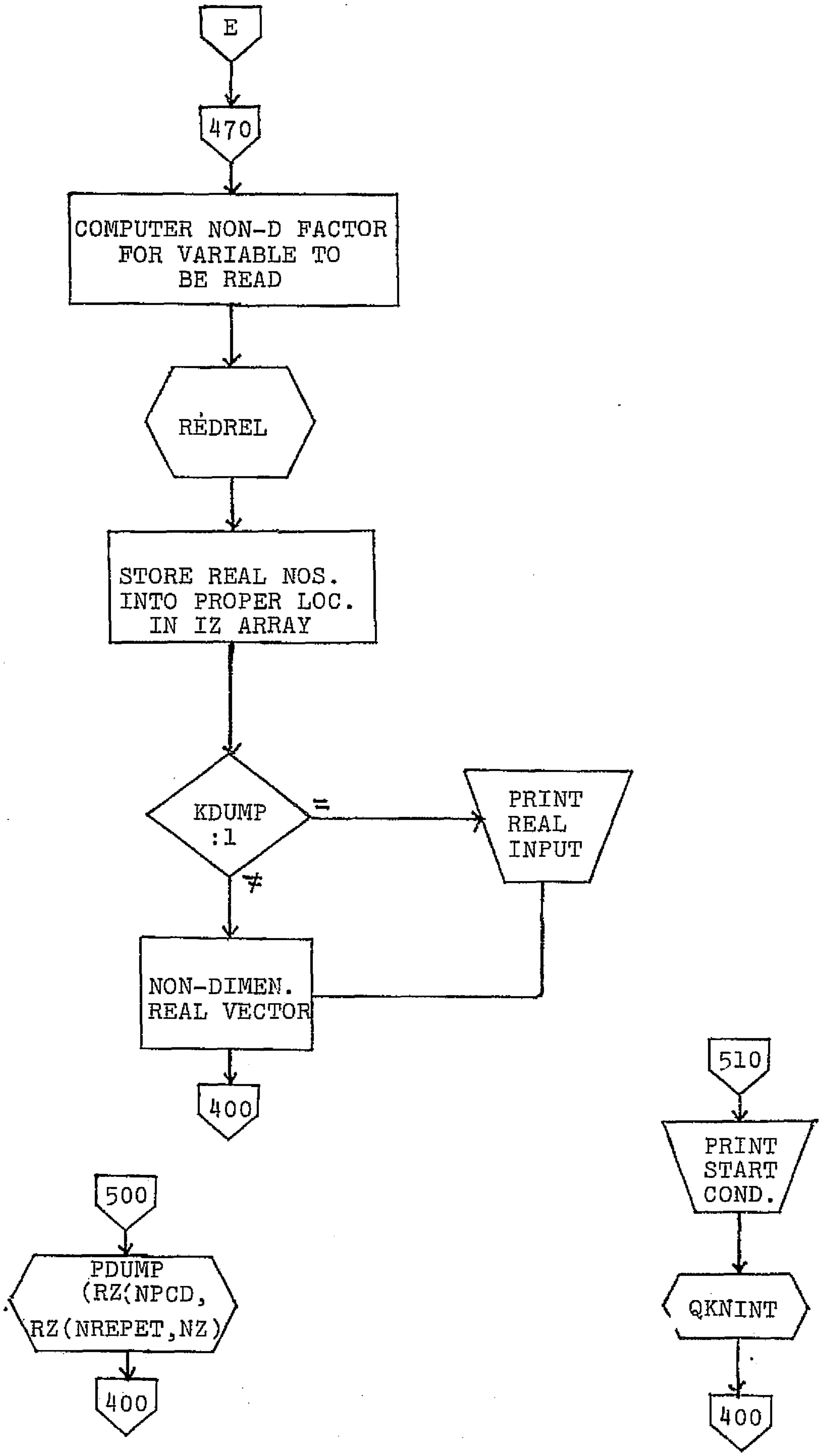

A
PDUMP
=
≠
500
EXIT
=
≠
EXIT
FEBL
=
≠
IBL=1
400
FENS
=
≠
IBL=0
400
FEDIMN
=
≠
FEDIMN
400
FENAME
=
≠
FENAME
400
DESCRIPT
=
≠
DESCRP
(NX)
400
VOLIST
=
≠
READ NAMES
OF SCALARS TO
BE PRINTED
400
QKNINT
=
≠
510
B

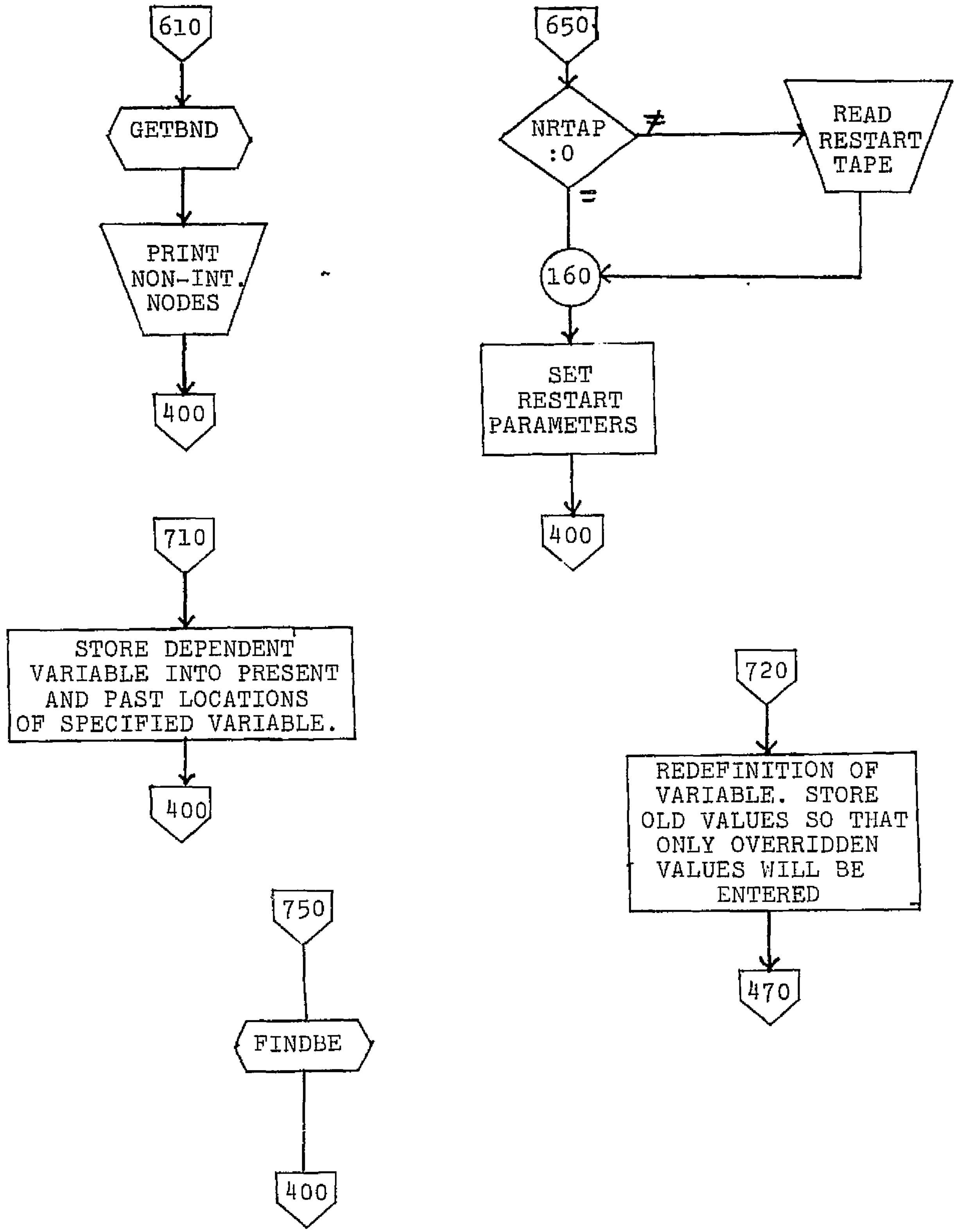

B
RESTART
=
≠
650
KBNO
610
LINK1
LINK1 (NX)
400
LINK2
LINK2 (NX)
LINK3
LINK3 (NX,OMEGA,YY)
LINK4
LINK4 (NX,K)
LINK5
LINK5 (NX)
VYYEND
710
END
RETURN
C


C
INTEGER
=
READ ADDITIONAL ENTRIES INTO BORDER IPLACE AND LOC
400
≠
REAL
=
READ ADDITIONAL ENTRIES INTO VALUE AND NPLACE
400
≠
J=0
410
J=J+1
J:50
>
450
≤
V1: BORDER (J)
≠
410
=
GETBND
STORE INTEGER DATA IN PROPER IZ LOCATIONS
KDUMP :1
=
PRINT INTEGER INPUT
≠
D

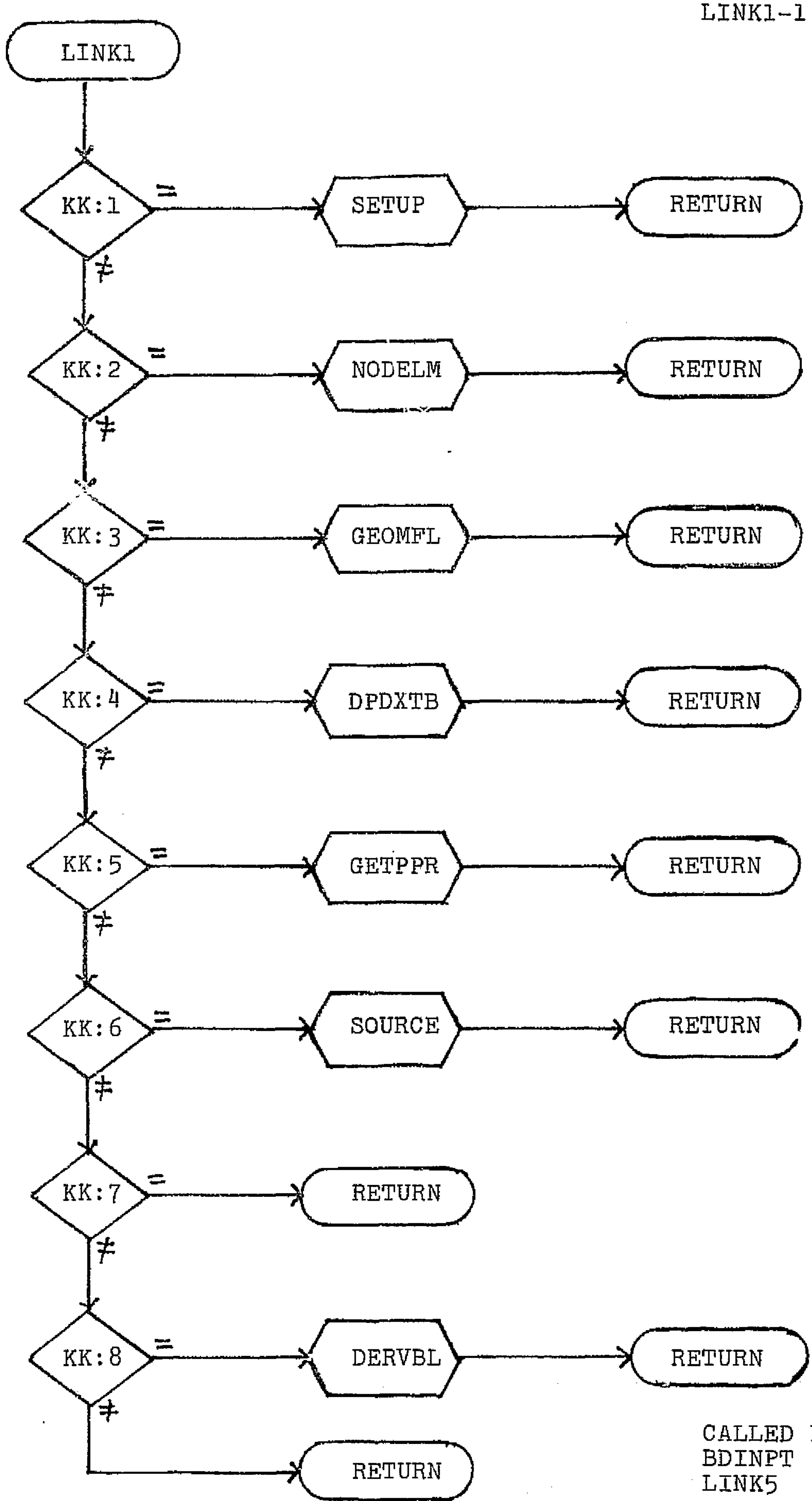

D
V1:
IBORD
≠
400
=
MAKE SURE BORDER
NODES END WHERE
THEY BEGIN
750


450
J=0
460
J=J+1
J:50
>
400
≤
V1:
VALUE(J)
≠
460
=
E

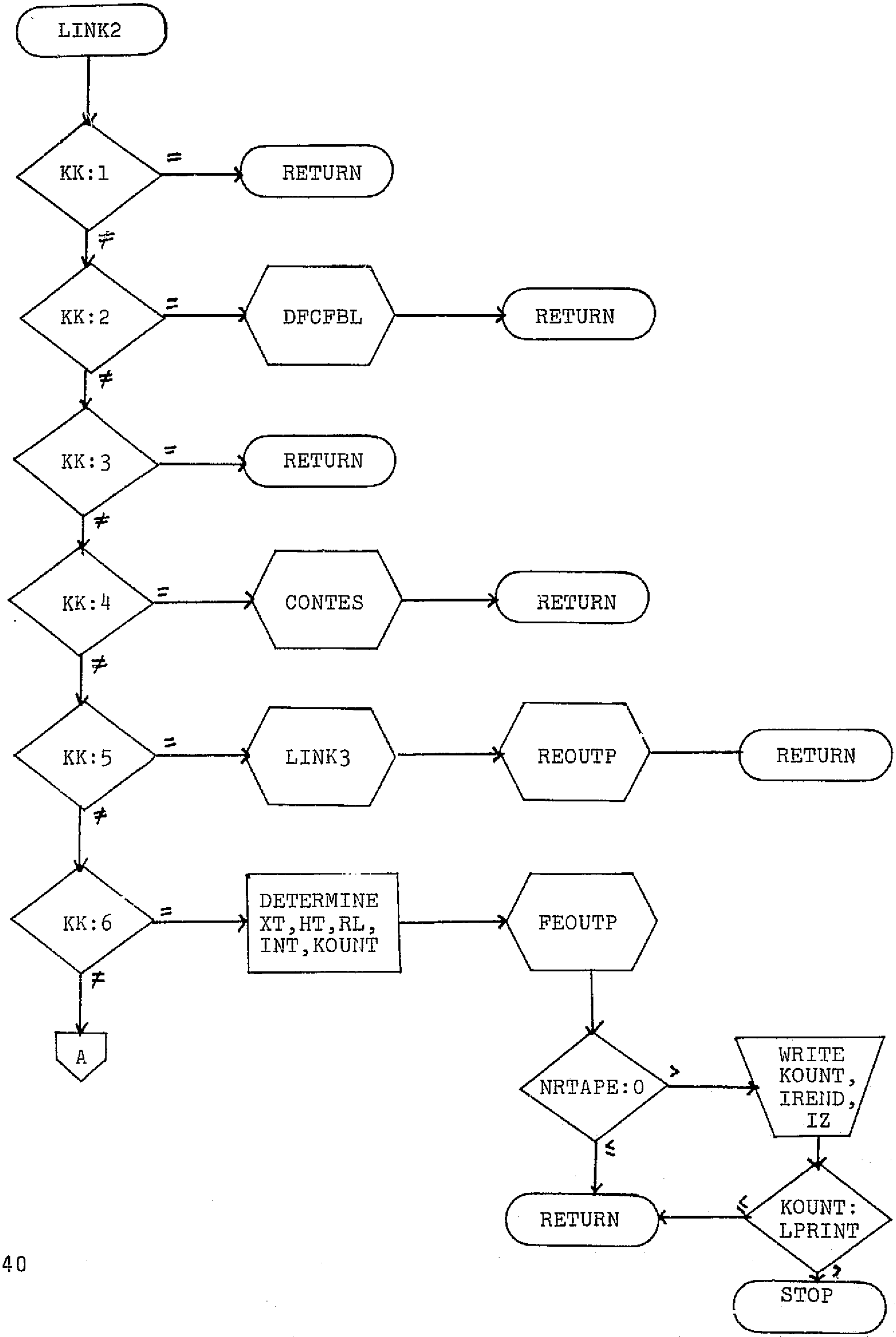

E
470
COMPUTER NON-D FACTOR FOR VARIABLE TO BE READ
REDREL
STORE REAL NOS. INTO PROPER LOC. IN IZ ARRAY
KDUMP :1
=
≠
PRINT REAL INPUT
NON-DIMEN. REAL VECTOR
400
500
PDUMP (RZ(NPCD, RZ(NREPET,NZ)
400
510
PRINT START COND.
QKNINT
400

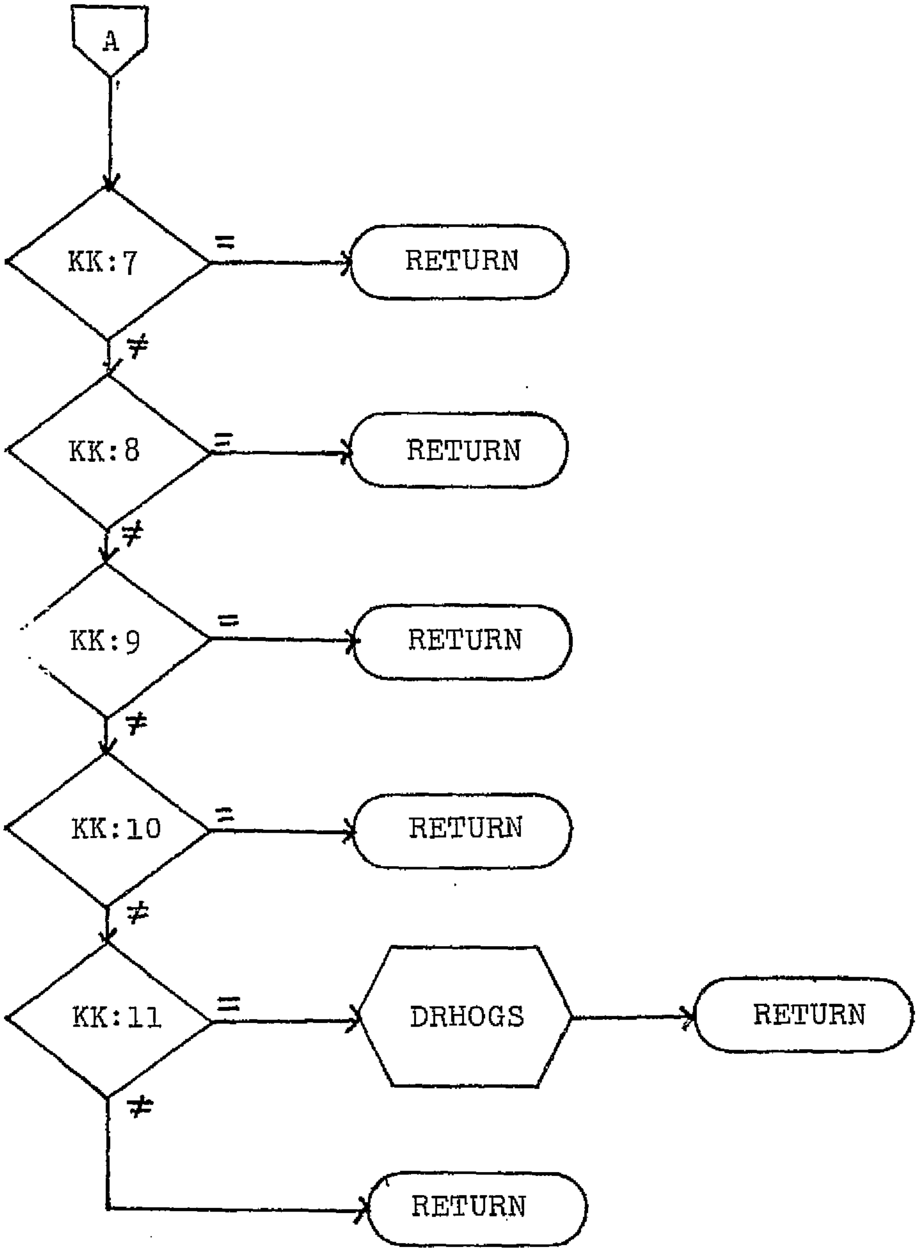


CALLED BY:
MAIN

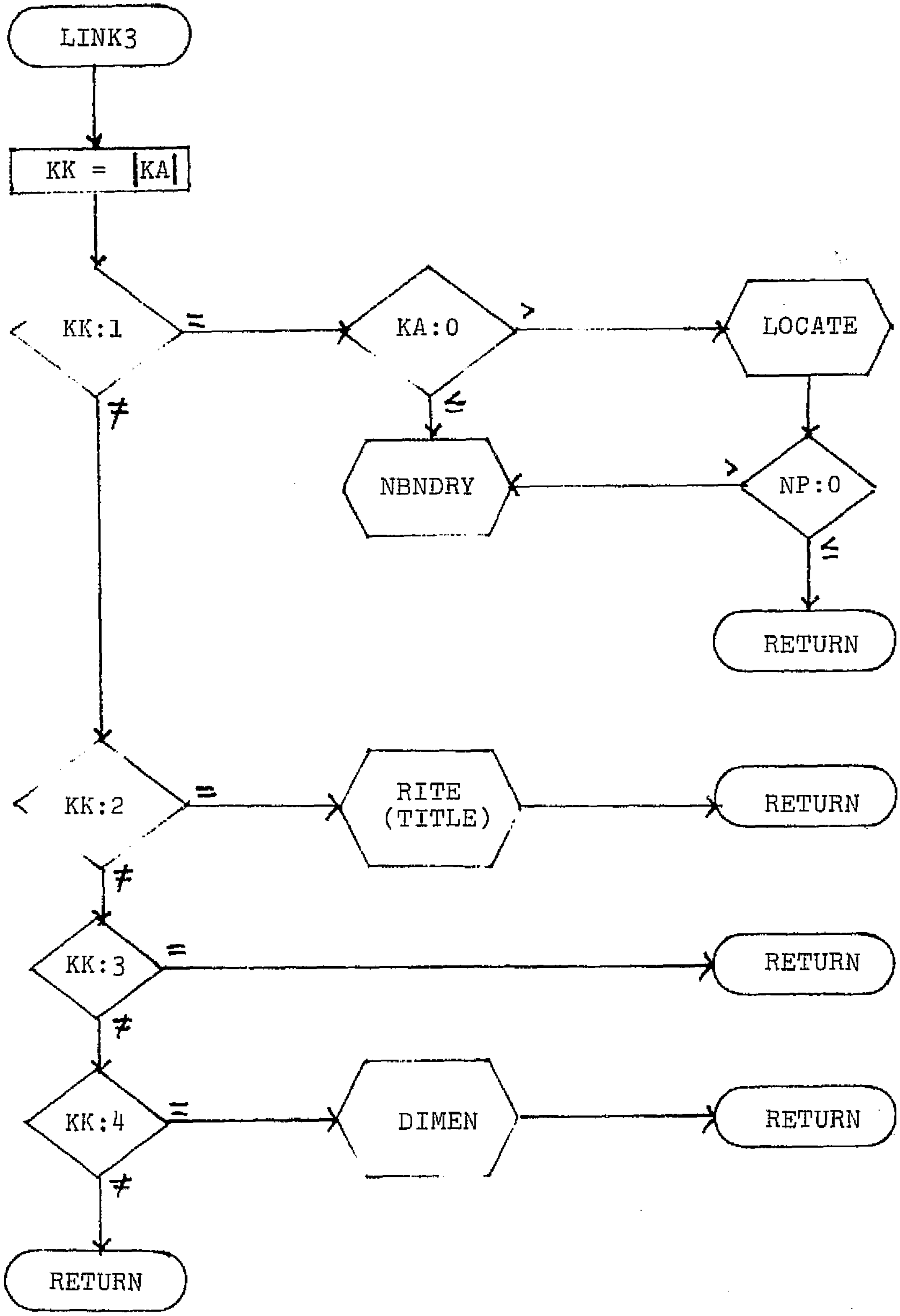


CALLED BY:
BDINPT
LINK5
QKNINT
QKNUIN

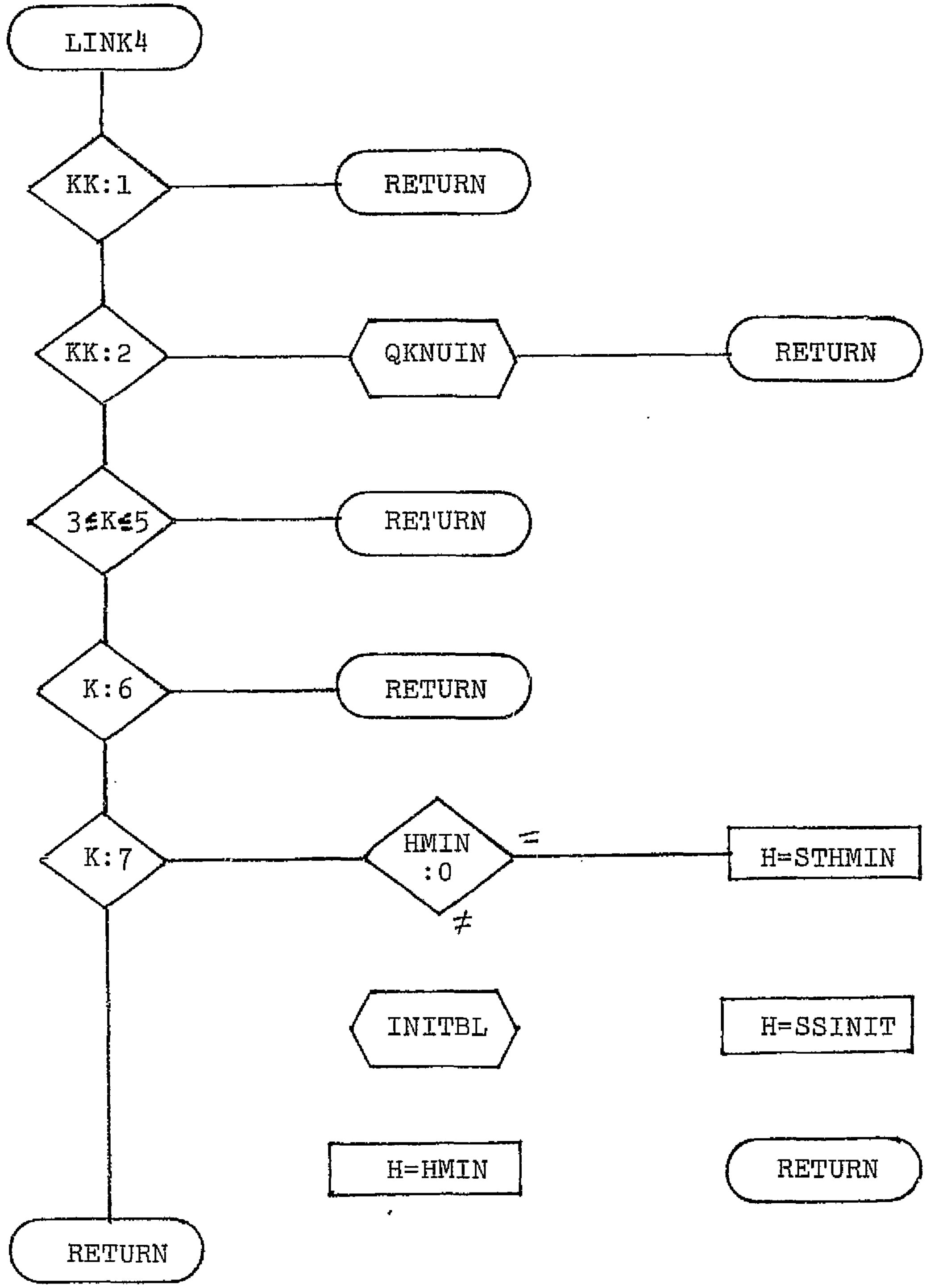

LINK2
KK:1
=
RETURN
≠
KK:2
=
DFCFBL
RETURN
≠
KK:3
=
RETURN
≠
KK:4
=
CONTES
RETURN
≠
KK:5
=
LINK3
REOUTP
RETURN
≠
KK:6
=
DETERMINE XT,HT,RL, INT,KOUNT
FEOUTP
≠
A
NRTAPE:0
>
WRITE KOUNT, IREND, IZ
≤
RETURN
KOUNT: LPRINT
≤
>
STOP



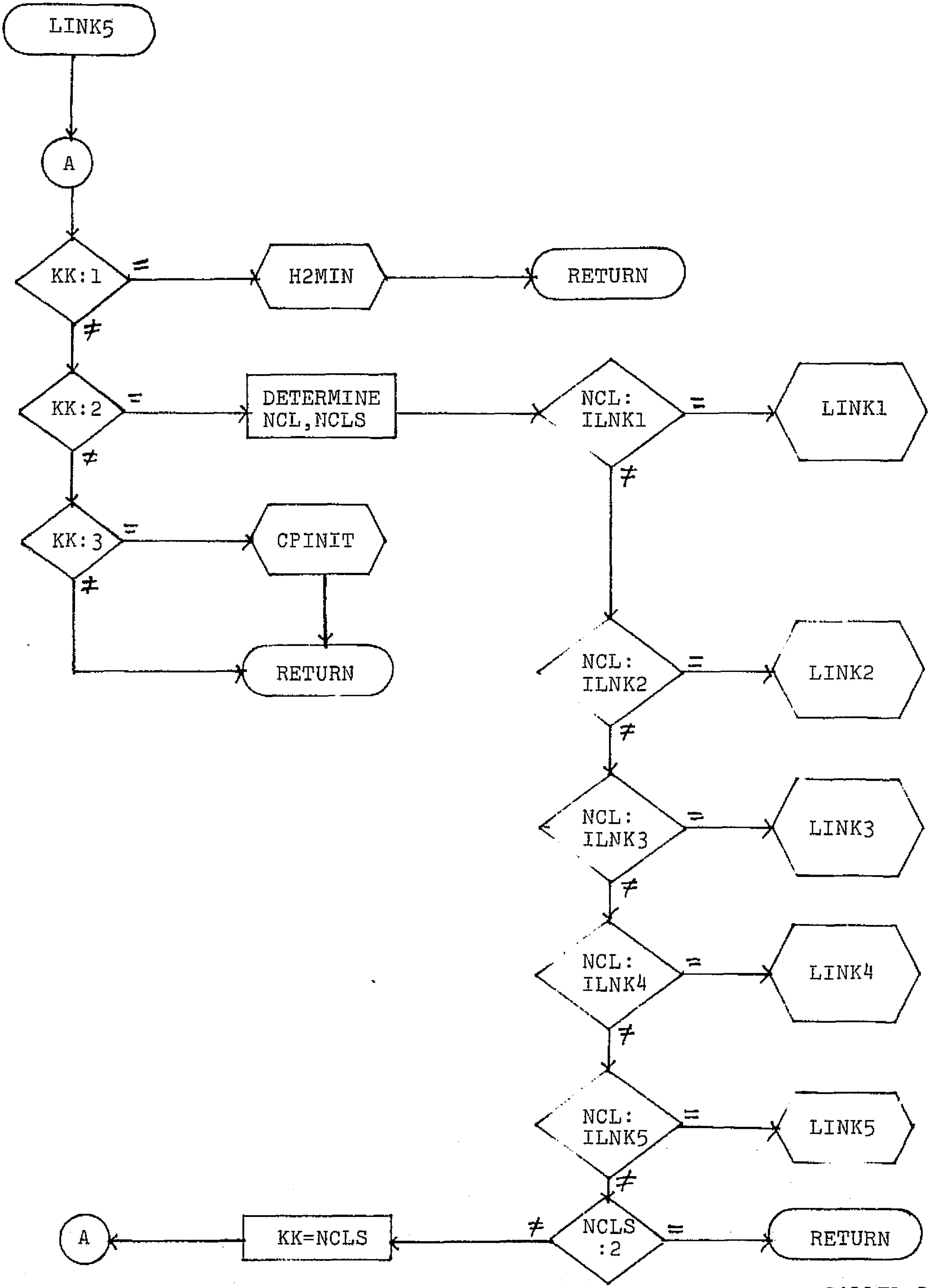
CALLED BY:
BDINPT
GPAHFT
LINK5
QKNINT



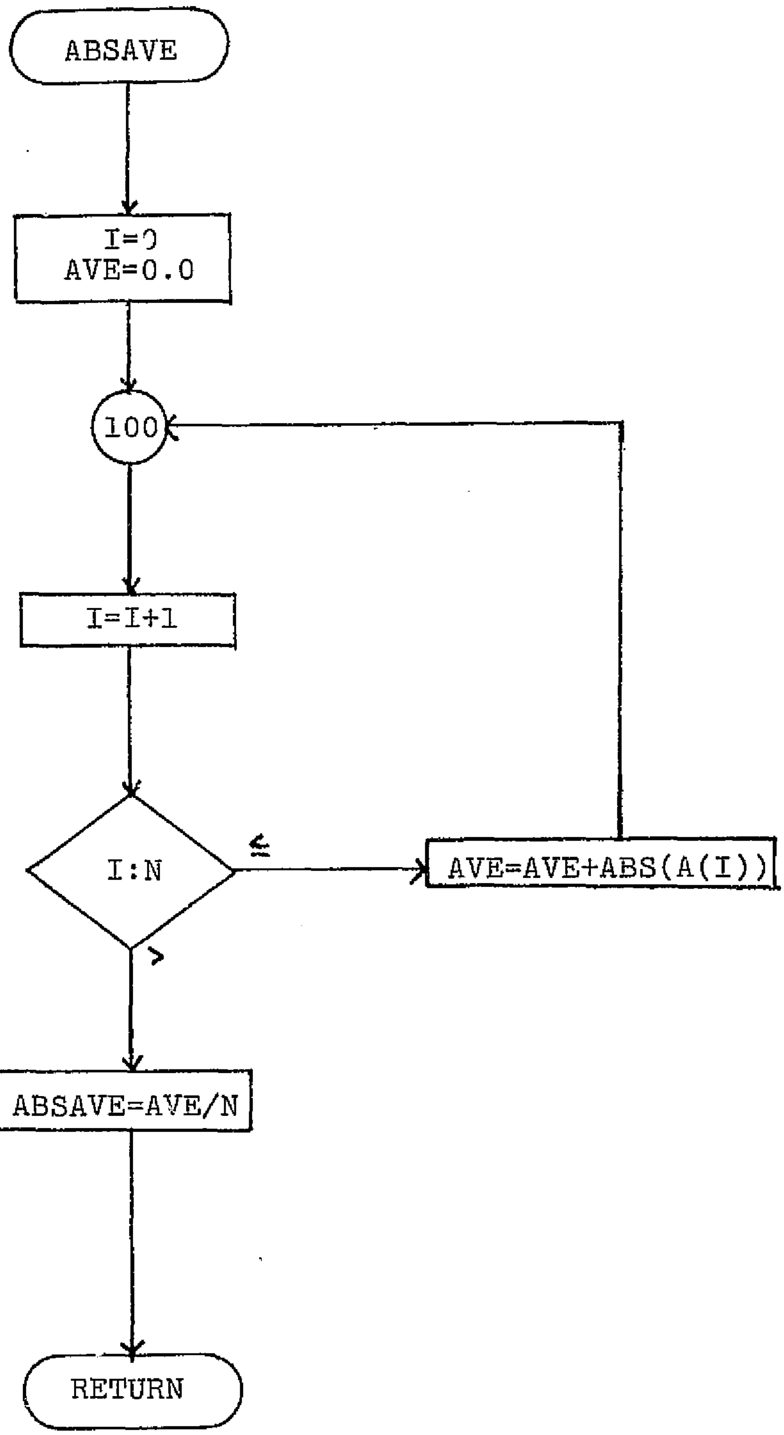
CALLED BY:
MANY
ROUTINES



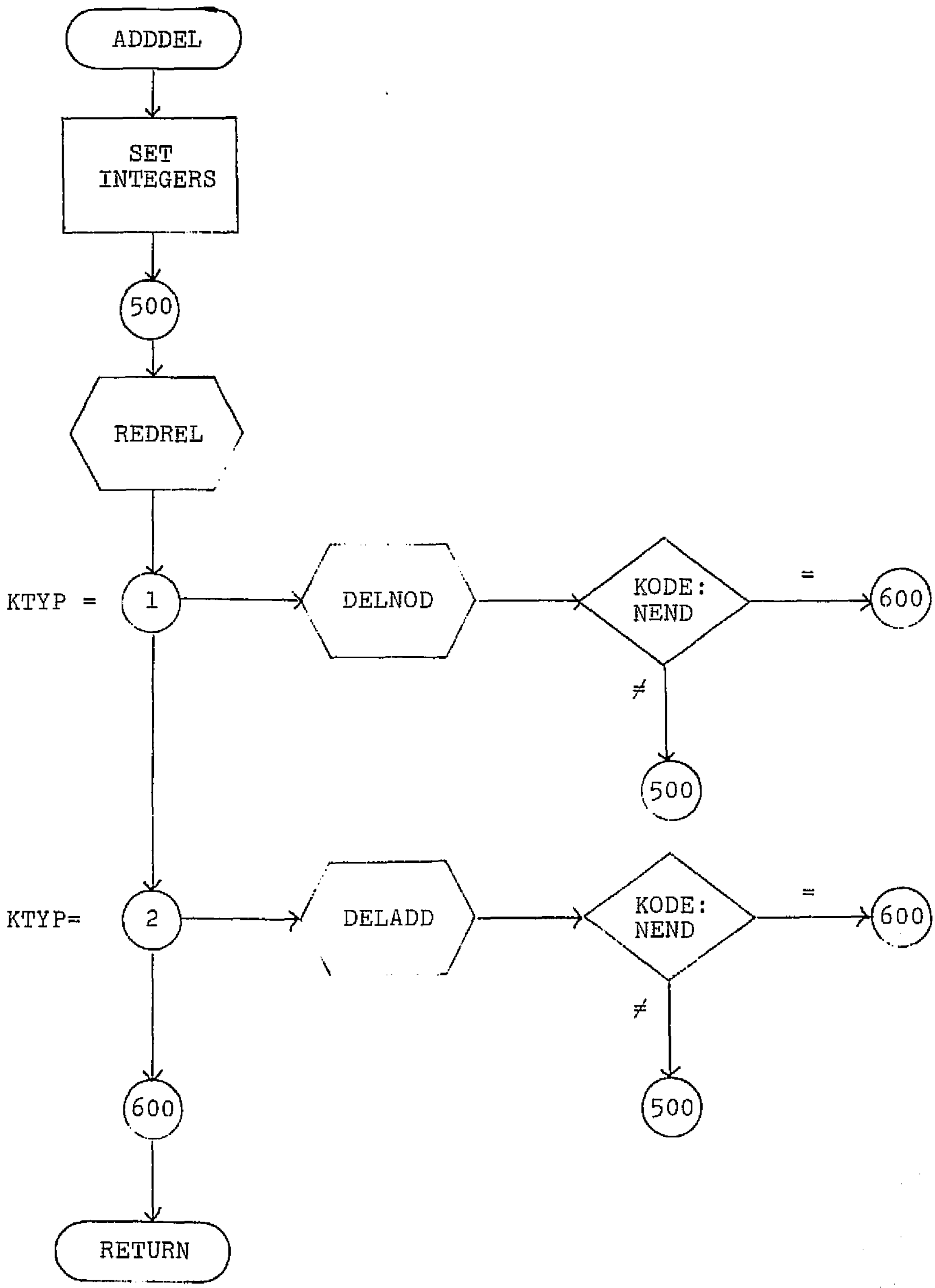
CALLED BY:
BDINPT
LINK5
QKNINT



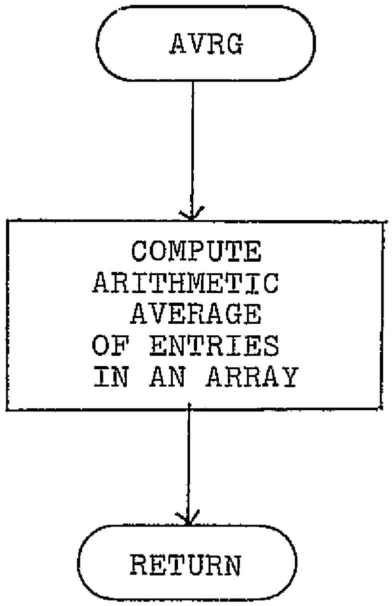
CALLED BY:
BDINPT
DIMEN
QKNUIN



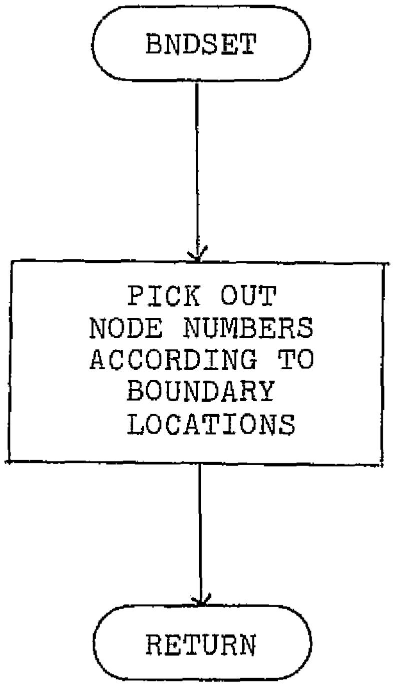
CALLED BY:
DERVBL
Q3CONC



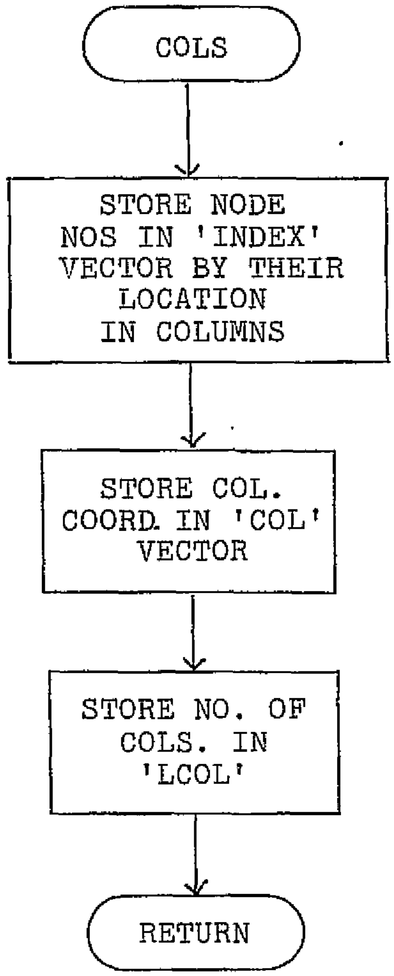
CALLED BY:
ELEM
GETBND
SETUP
BDINPT
DSCRTZ



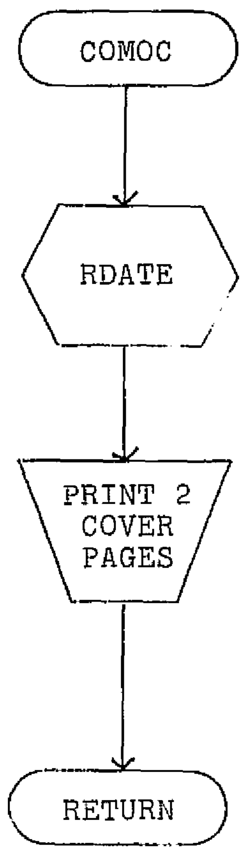
CALLED BY:
GEOMFL



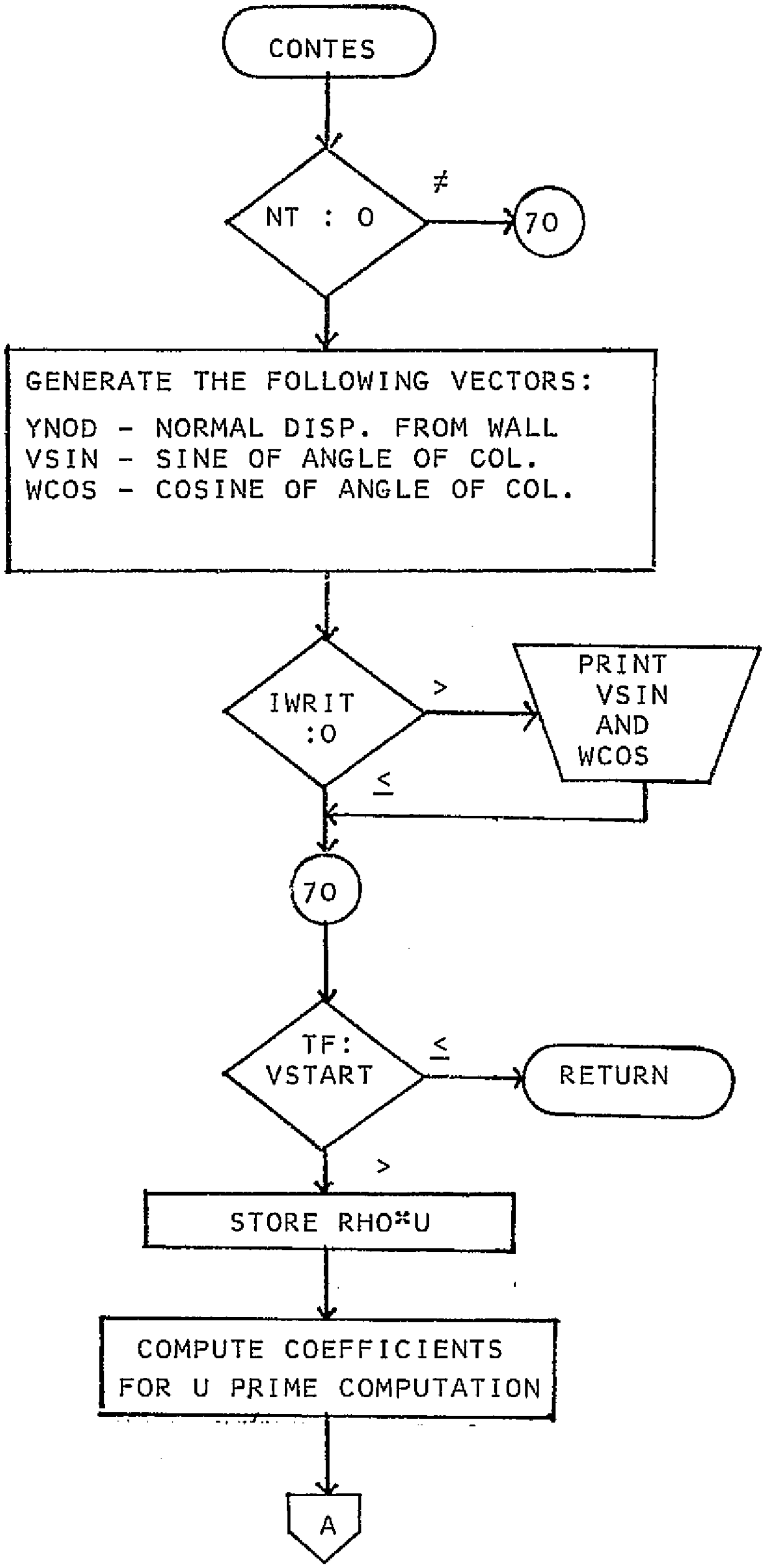
CALLED BY:
GETBND

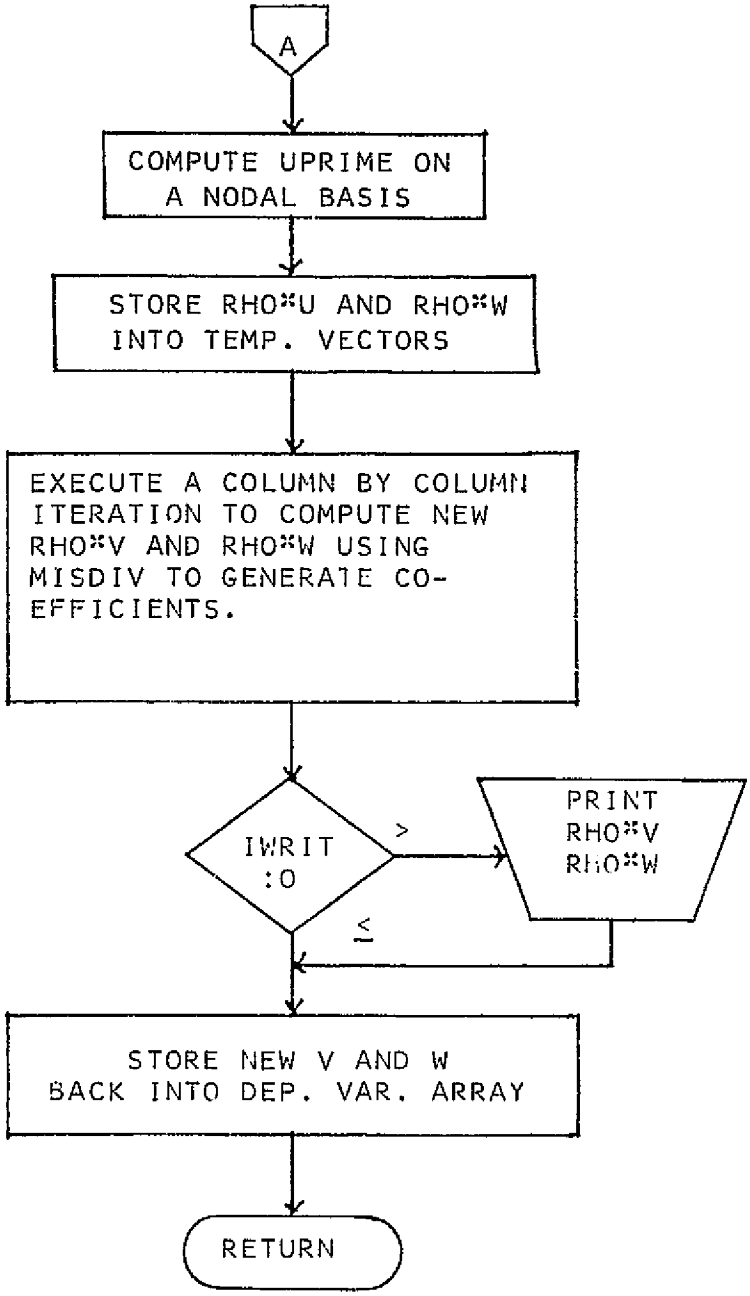


CALLED BY:
DSCRTZ

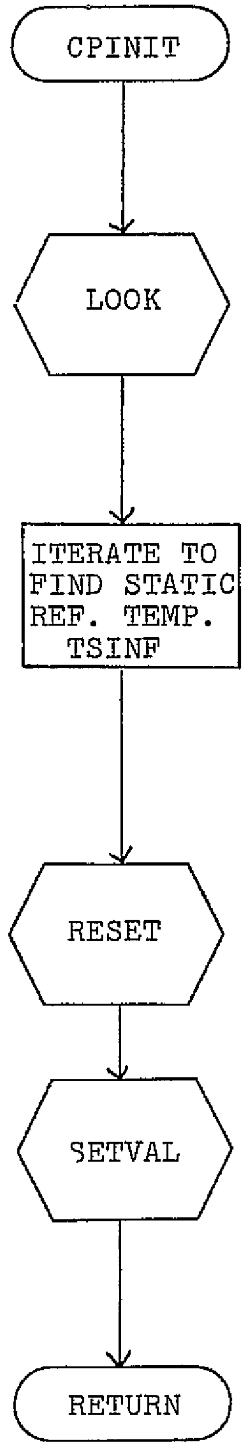


CALLED BY:
BDINPT

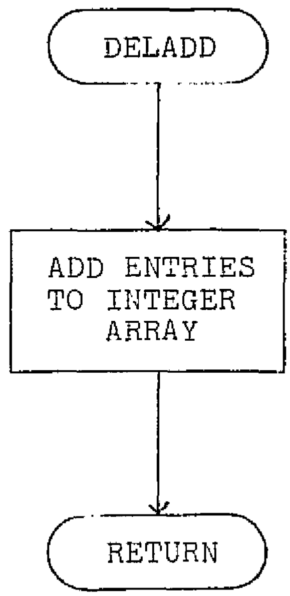

CONTES
NT : O
≠
70
GENERATE THE FOLLOWING VECTORS:
YNOD - NORMAL DISP. FROM WALL
VSIN - SINE OF ANGLE OF COL.
WCOS - COSINE OF ANGLE OF COL.
IWRIT :O
>
PRINT VSIN AND WCOS
≤
70
TF: VSTART
≤
RETURN
>
STORE RHO*U
COMPUTE COEFFICIENTS FOR U PRIME COMPUTATION
A



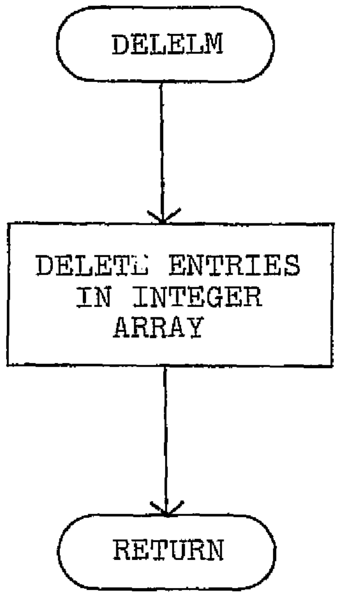
CALLED BY:
LINK2



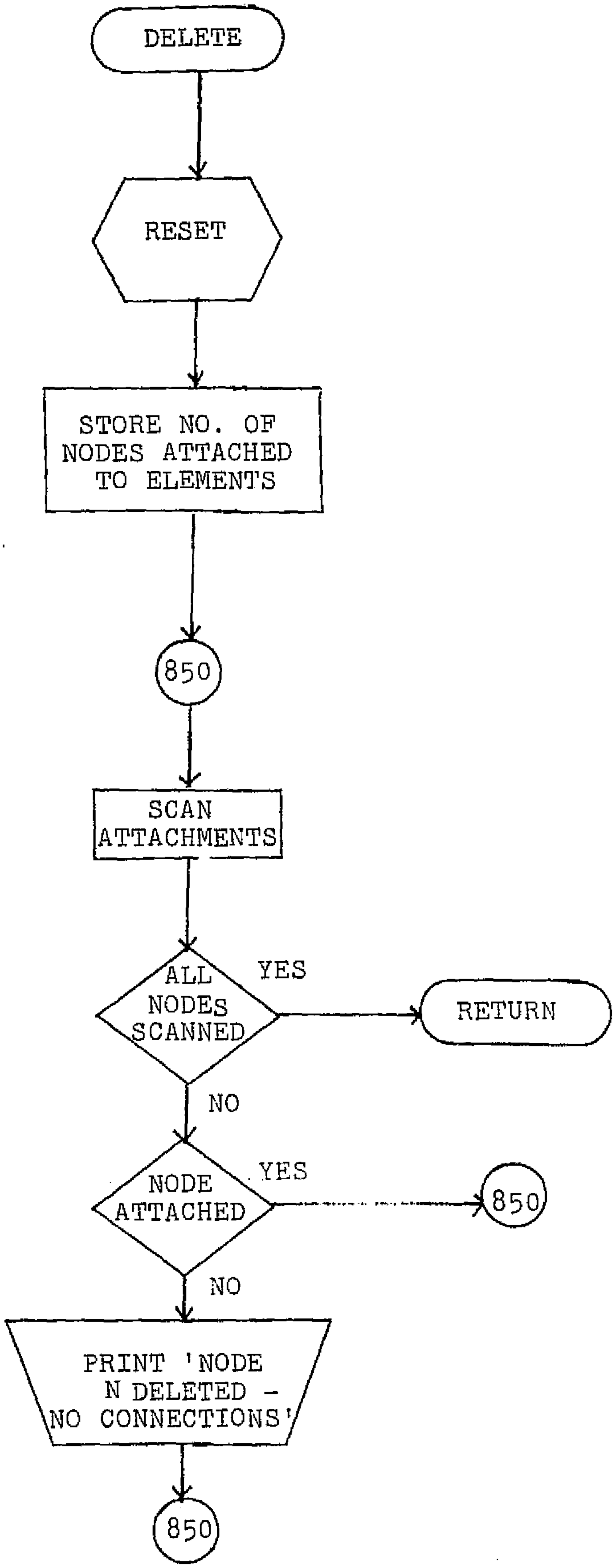
CALLED BY:
DIMEN



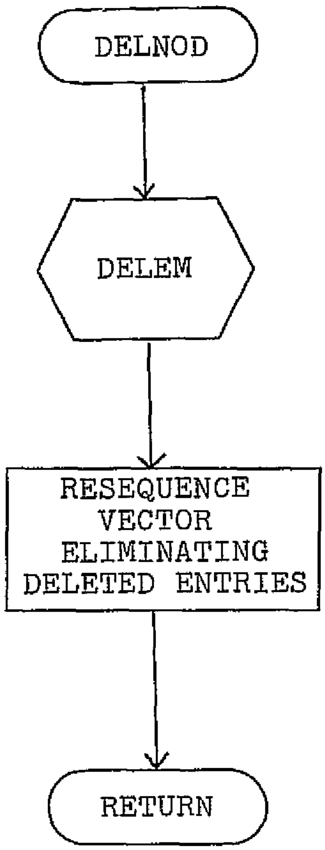
CALLED BY:
ADDDEL



CALLED BY:
DELNOD



CALLED BY:
DSCRTZ



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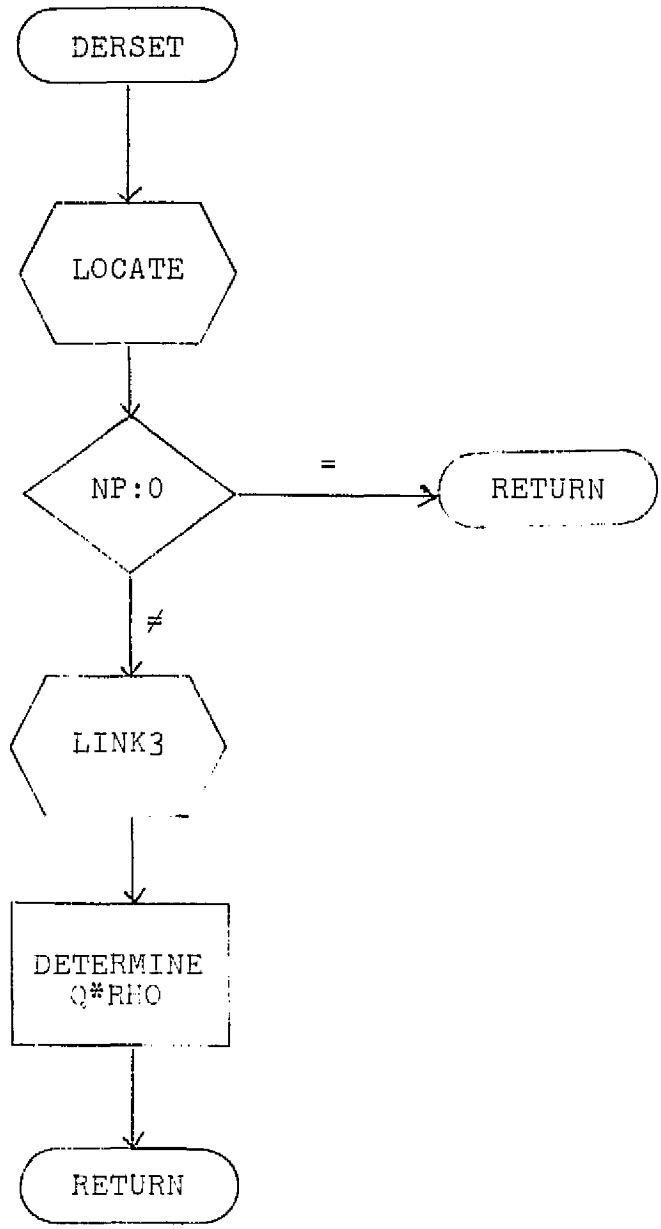
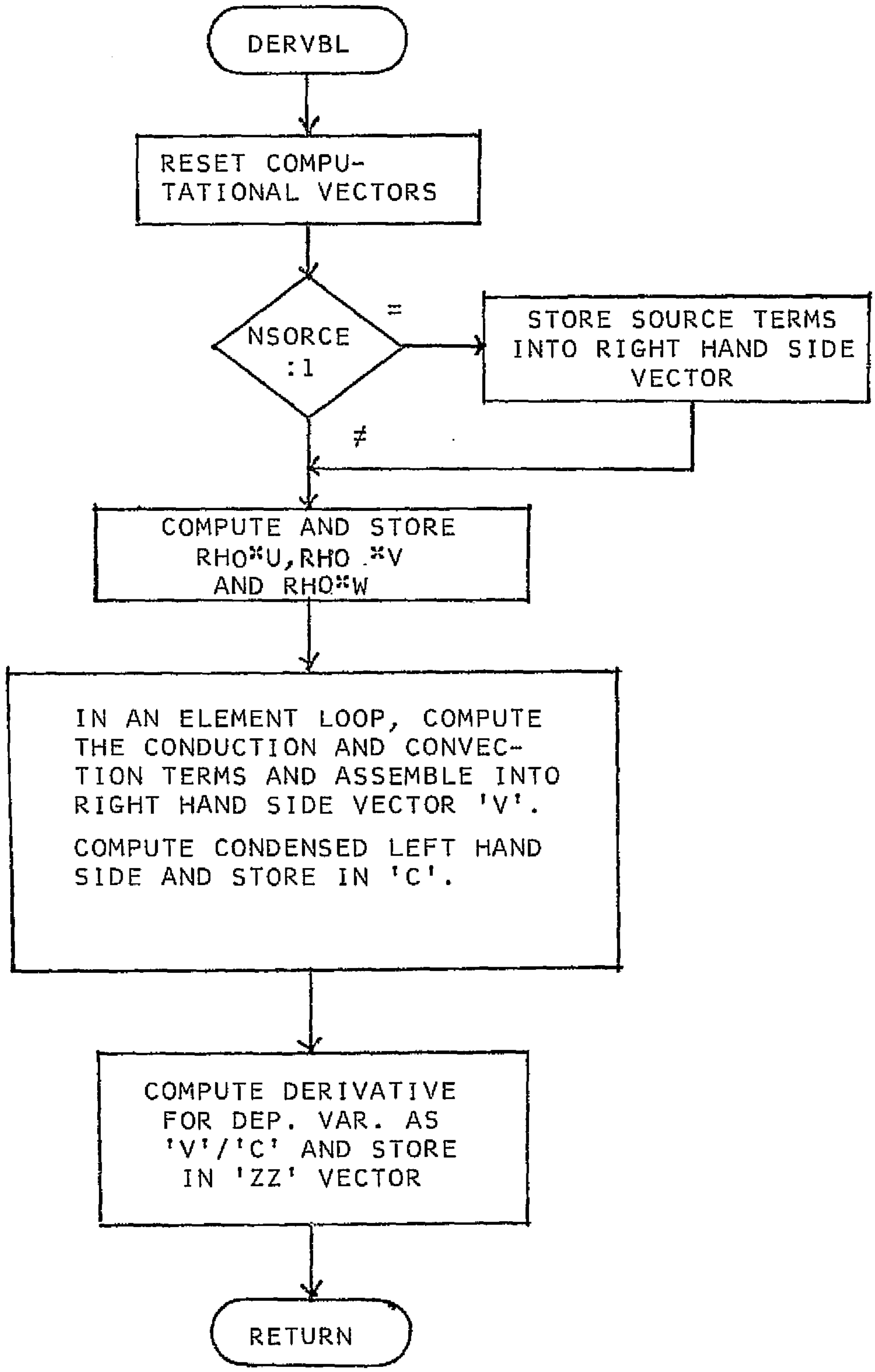
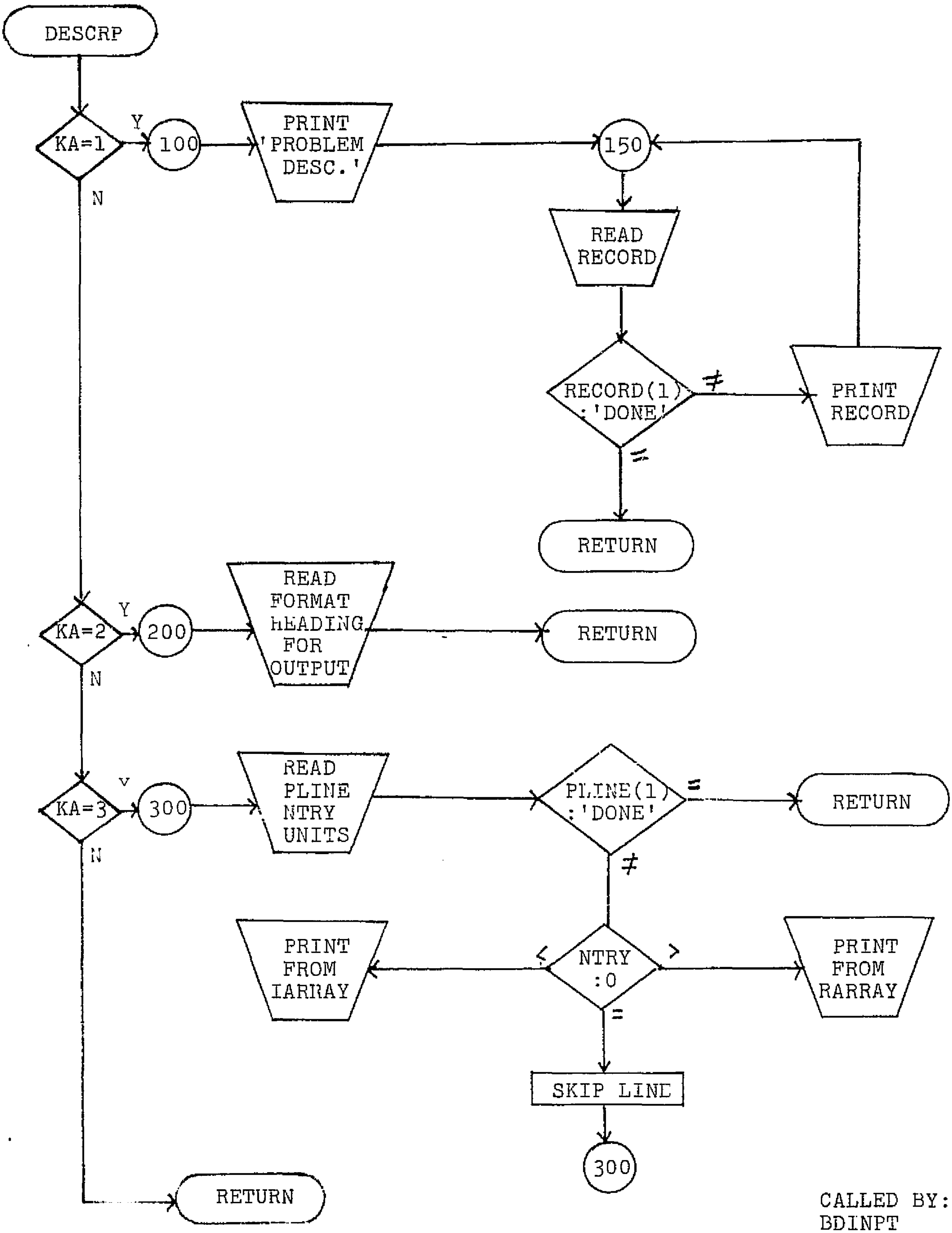
ADDDEL



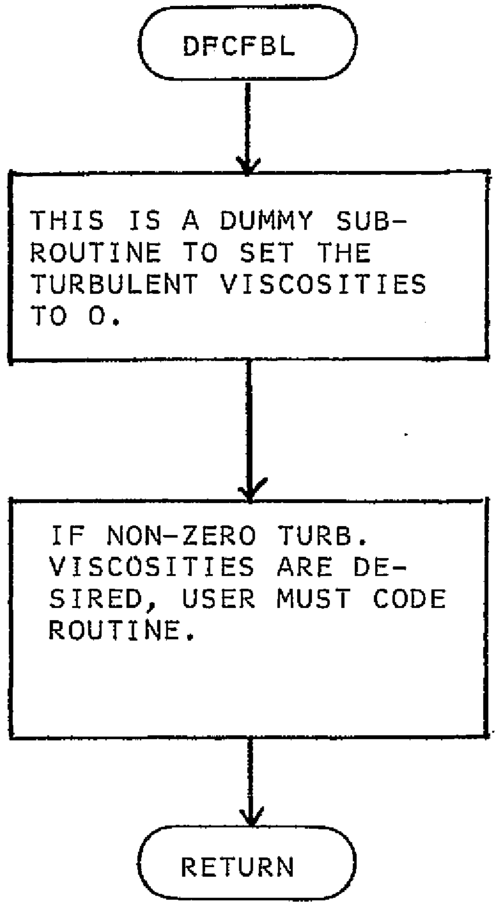
CALLED BY:
DERVBL



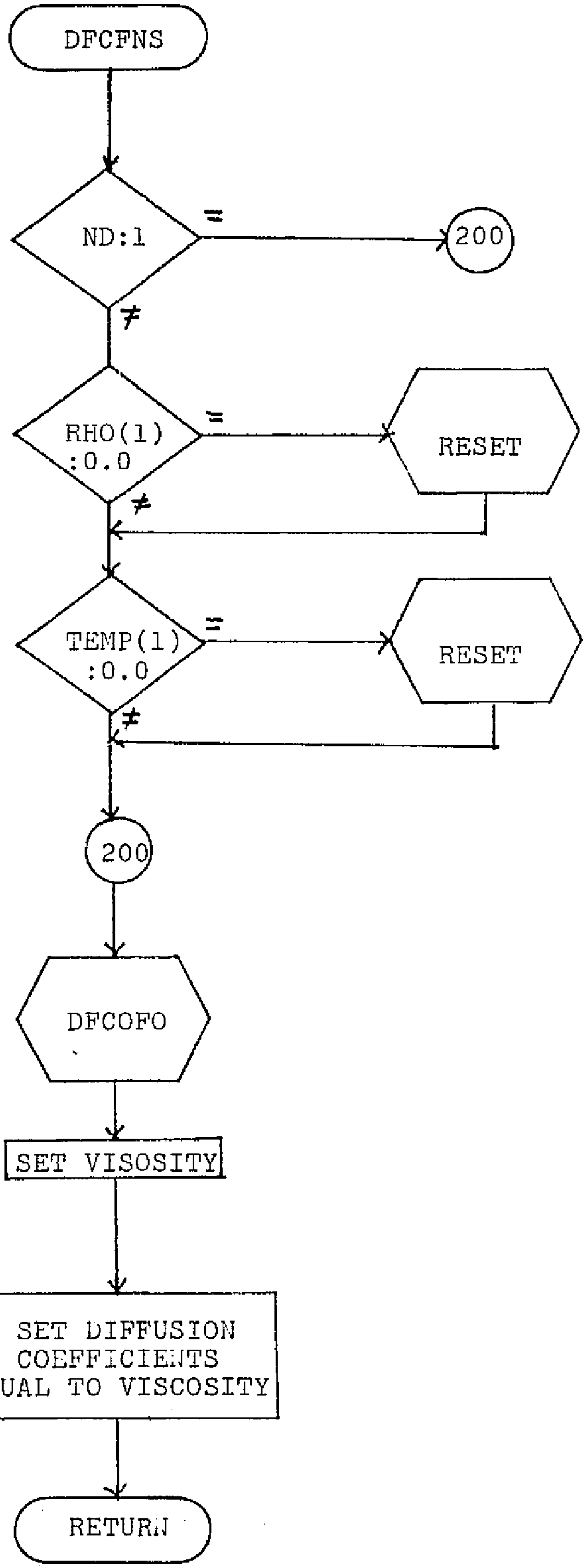
CALLED BY:
QKNINT, QKNUIN



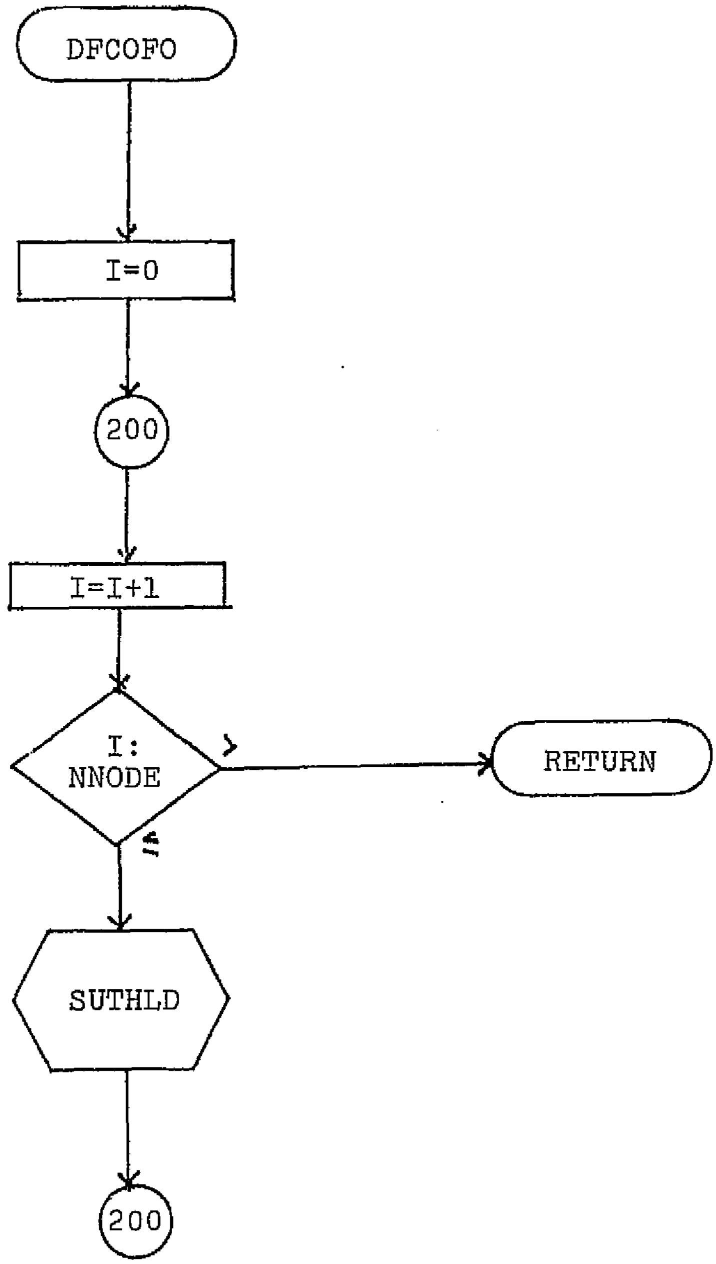
CALLED BY:
BDINPT



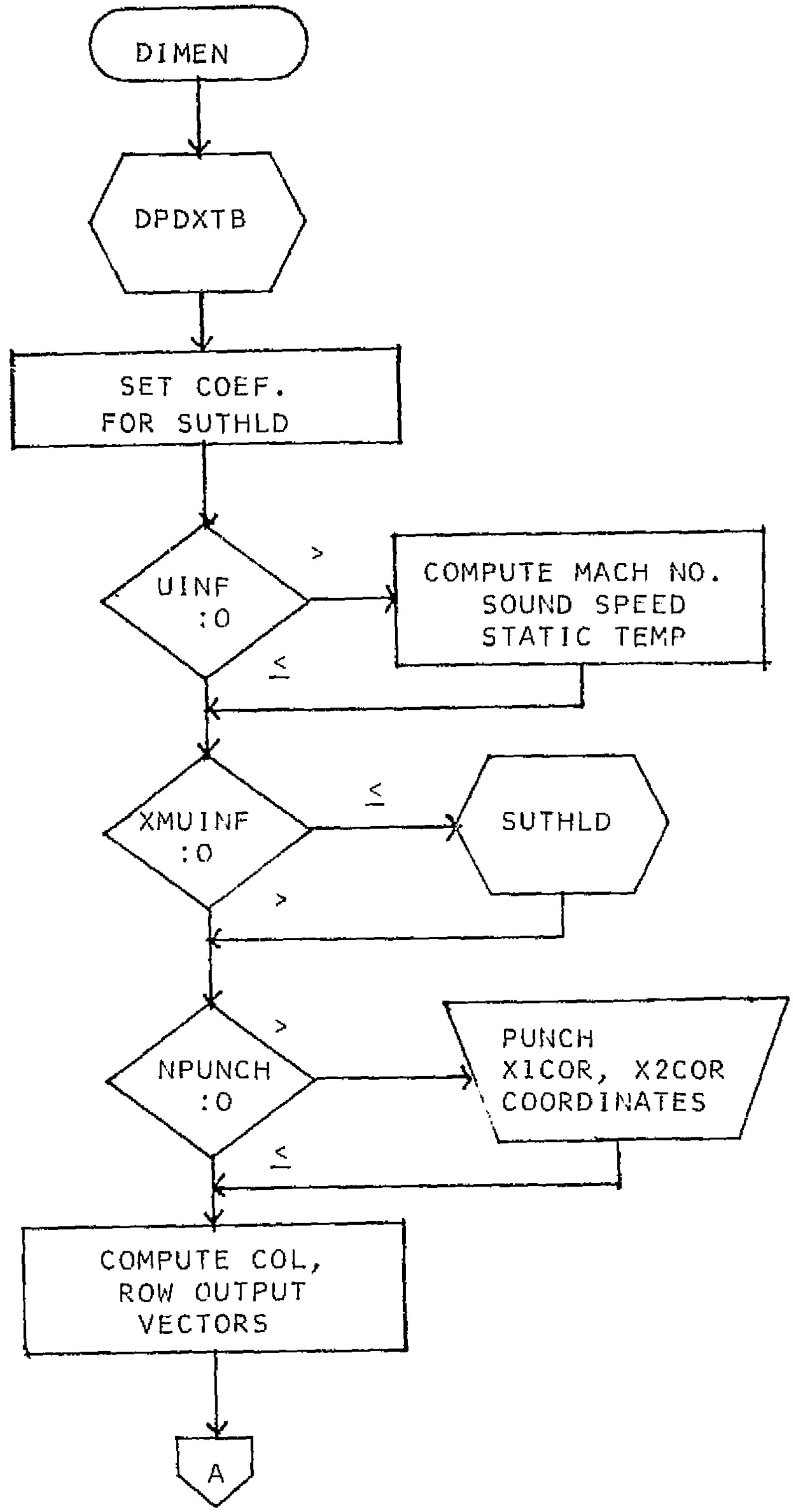
CALLED BY:
LINK2

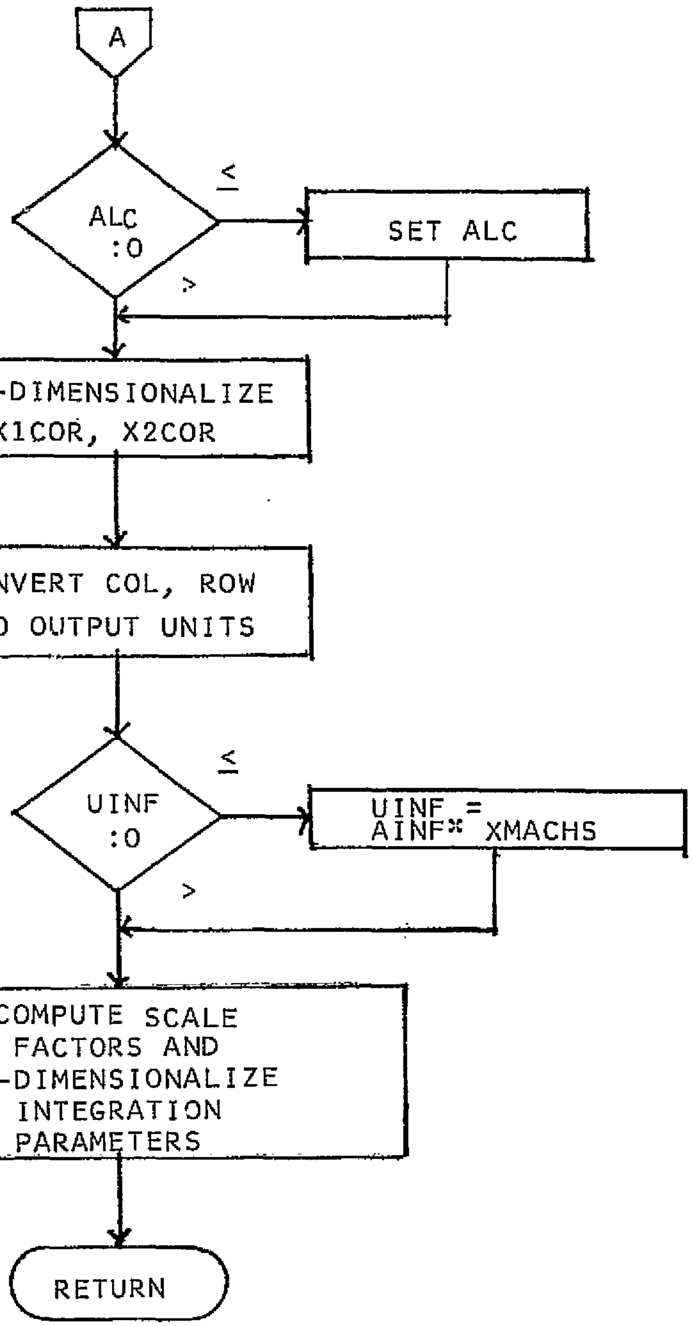


CALLED BY:
LINK2

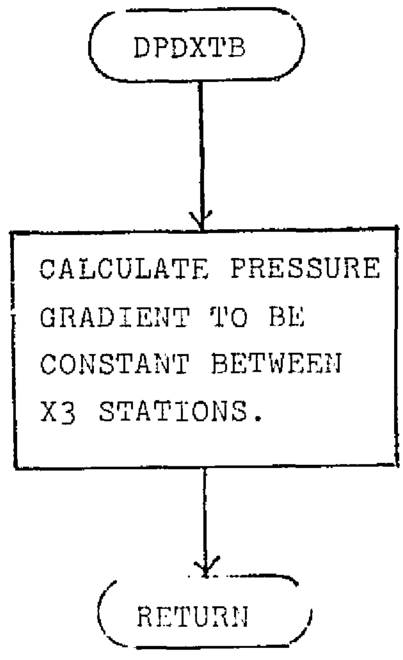


CALLED BY:
DFCFNS

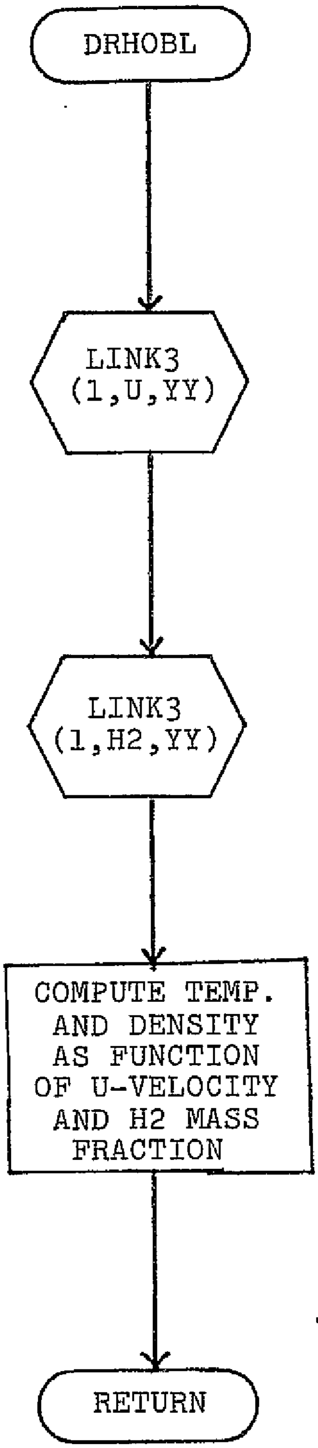

DIMEN
DPDXTB
SET COEF. FOR SUTHLD
UINF :0
>
COMPUTE MACH NO. SOUND SPEED STATIC TEMP
≤
XMUINF :0
≤
SUTHLD
>
NPUNCH :0
>
PUNCH X1COR, X2COR COORDINATES
≤
COMPUTE COL, ROW OUTPUT VECTORS
A



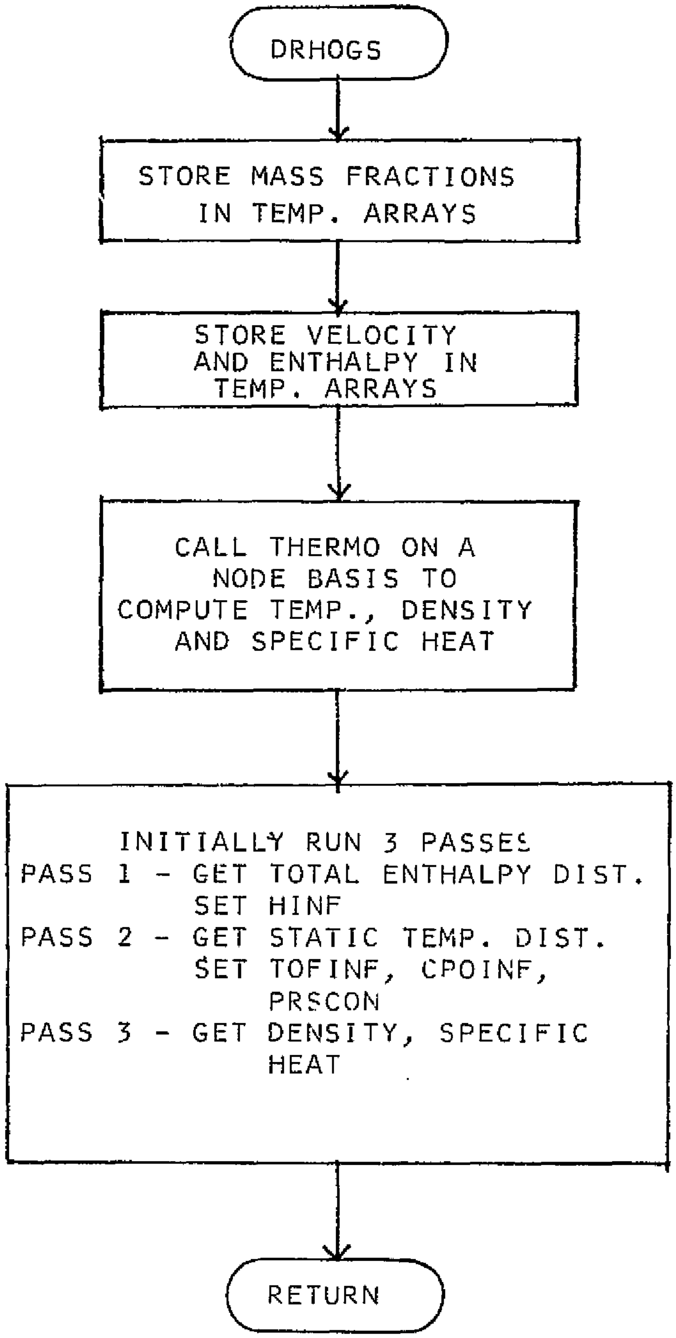
CALLED BY:
BDINPT



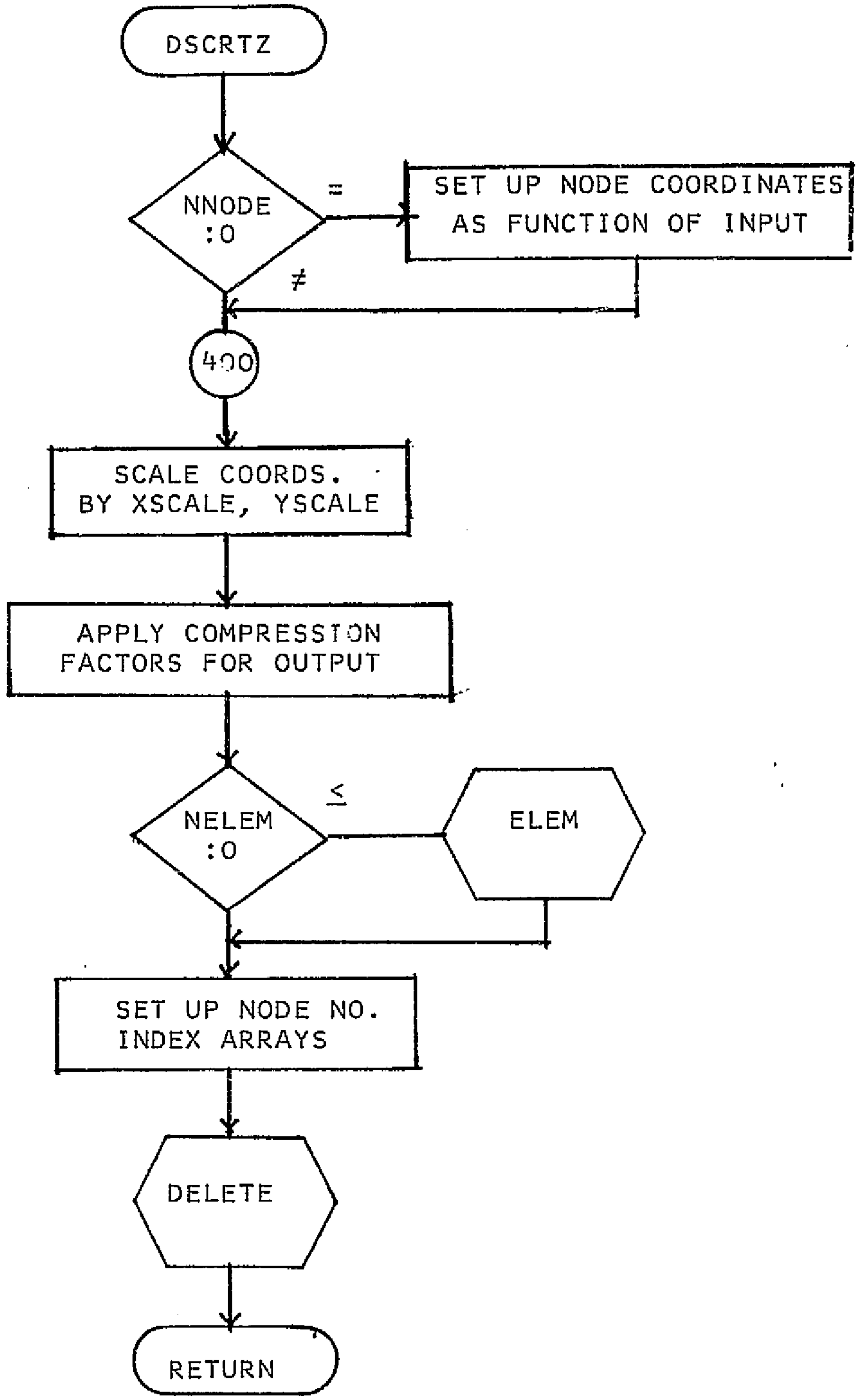
CALLED BY:
LINK1



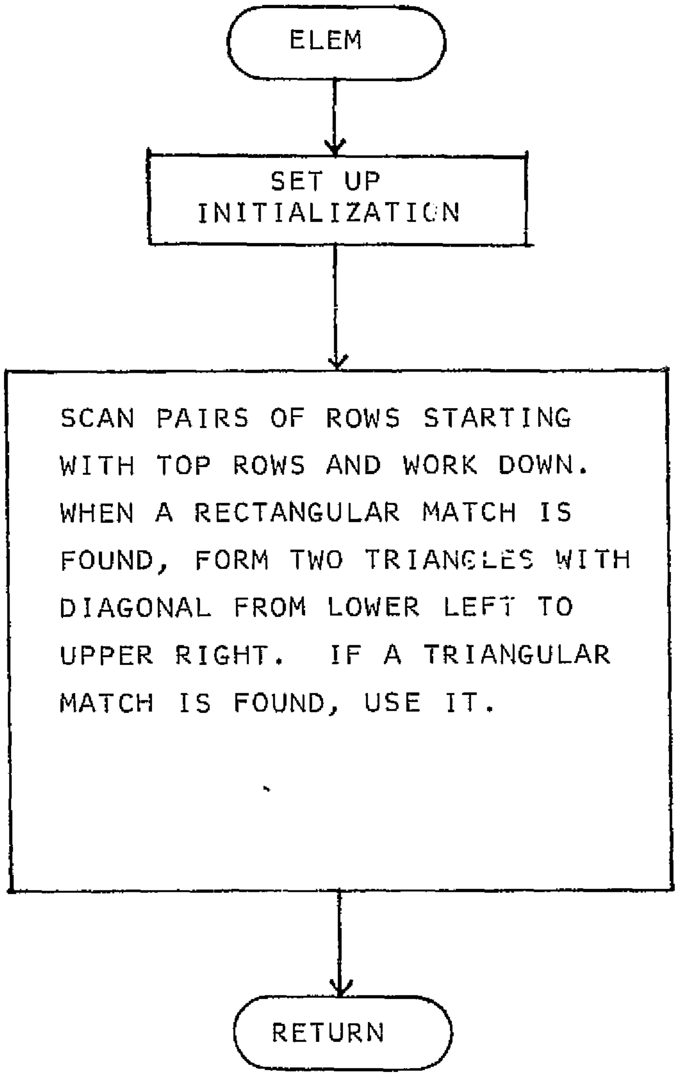
CALLED BY:
LINK2



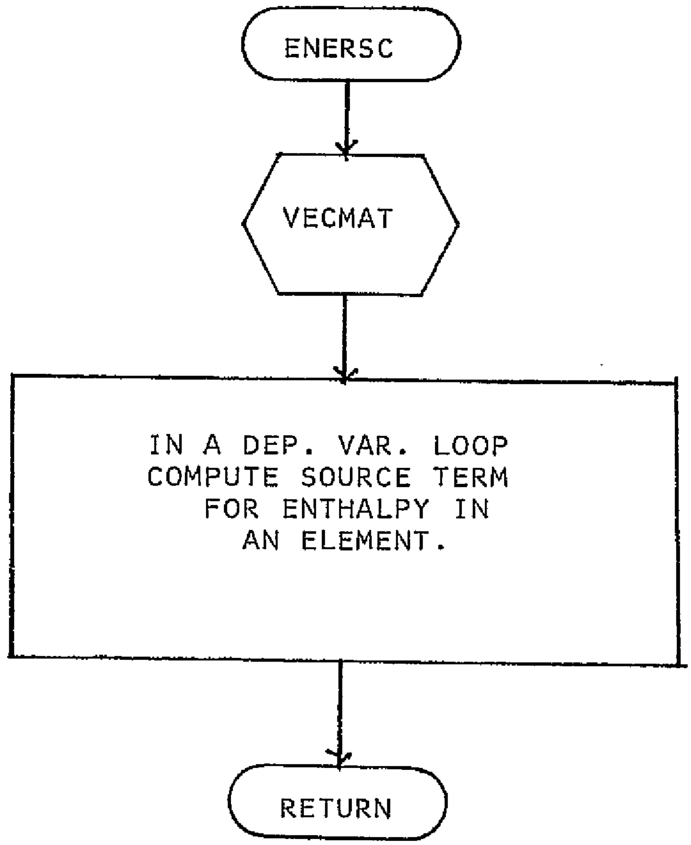
CALLED BY:
LINK2



CALLED BY:
SETUP



CALLED BY:
DSCRTZ



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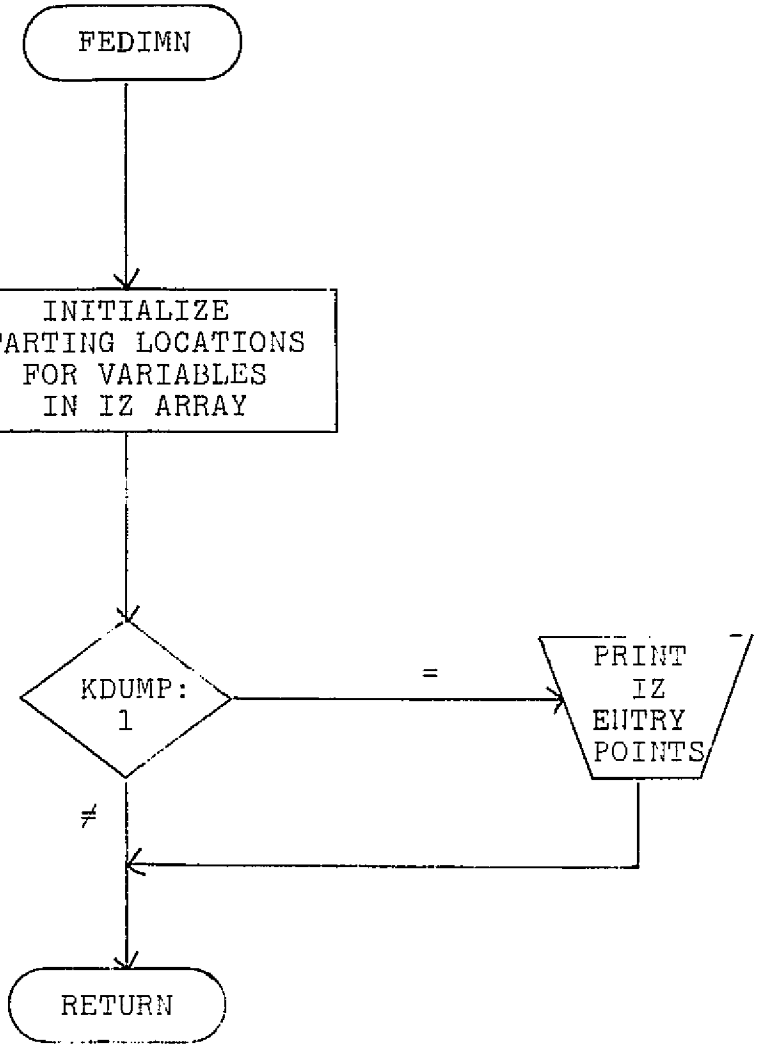

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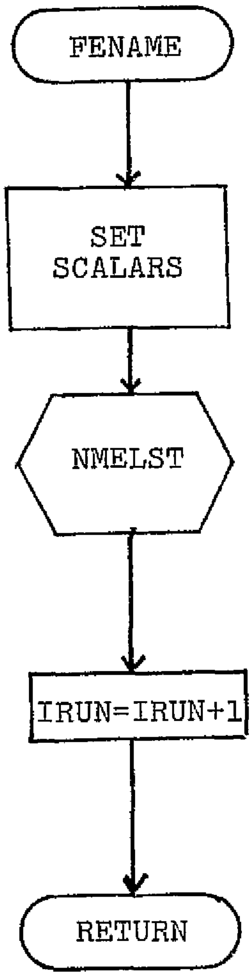

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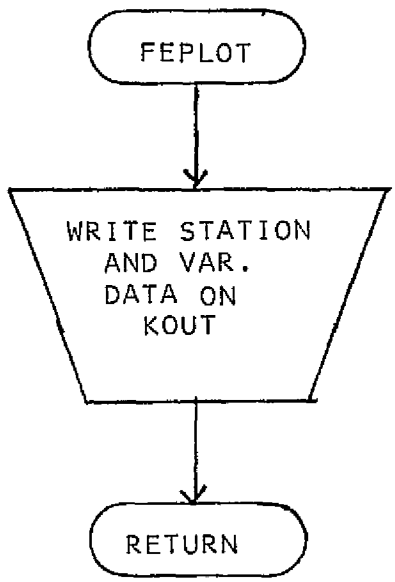

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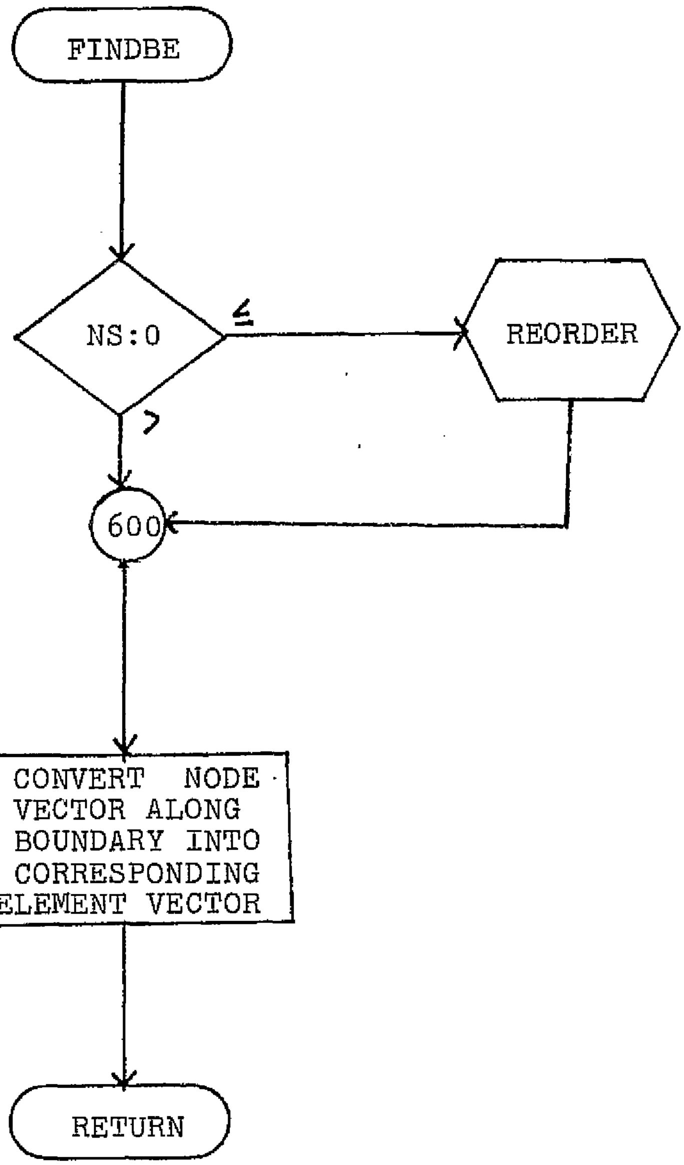

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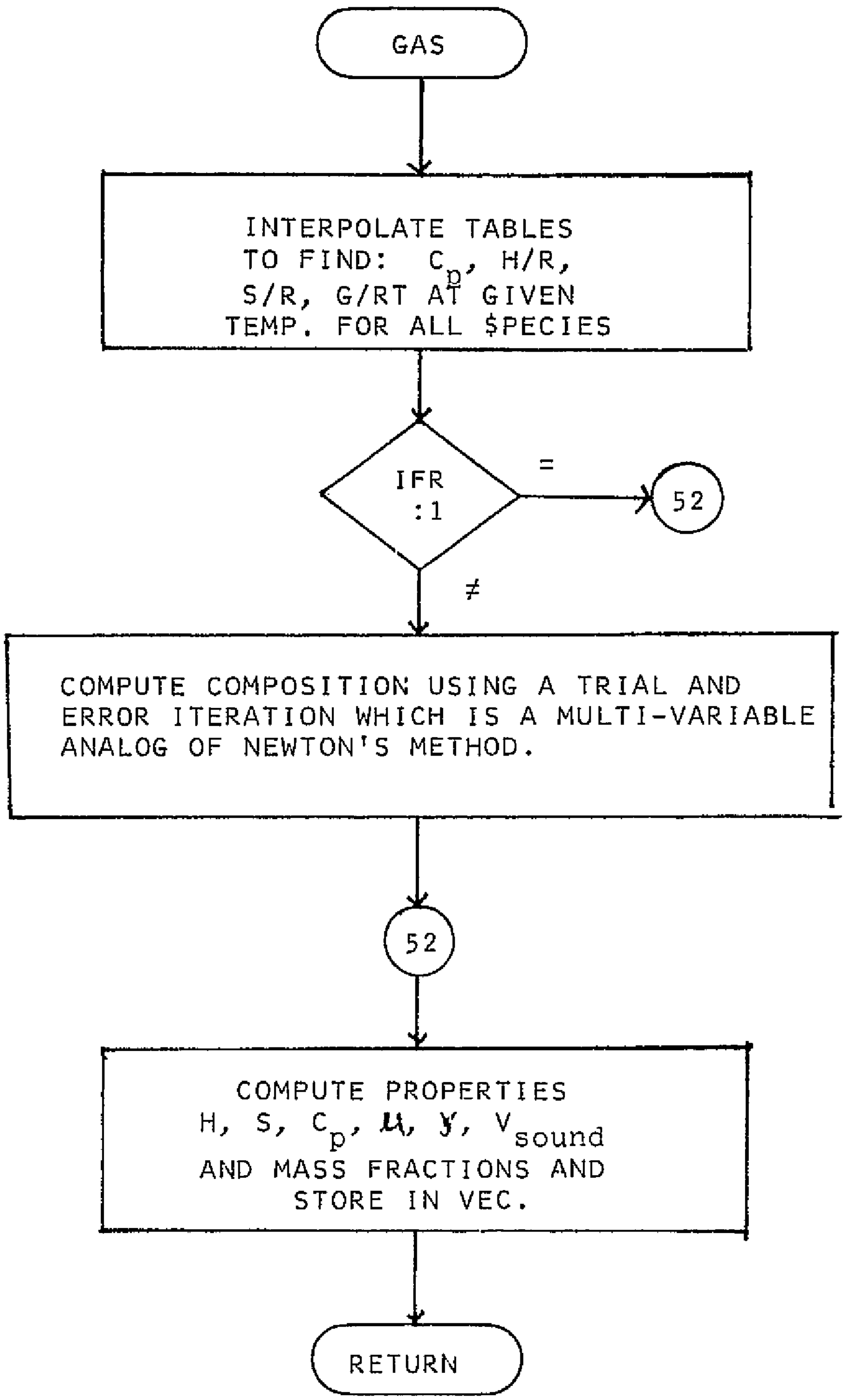

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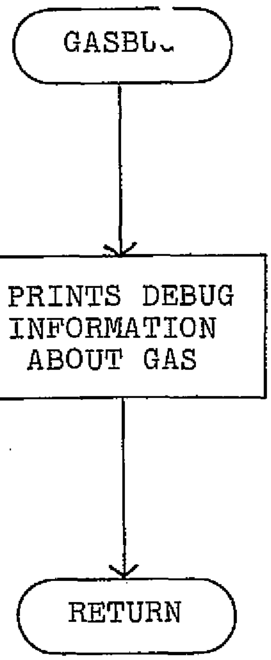

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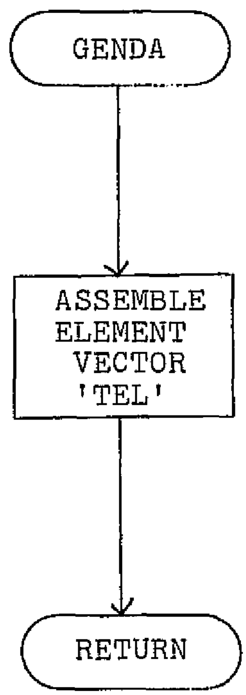

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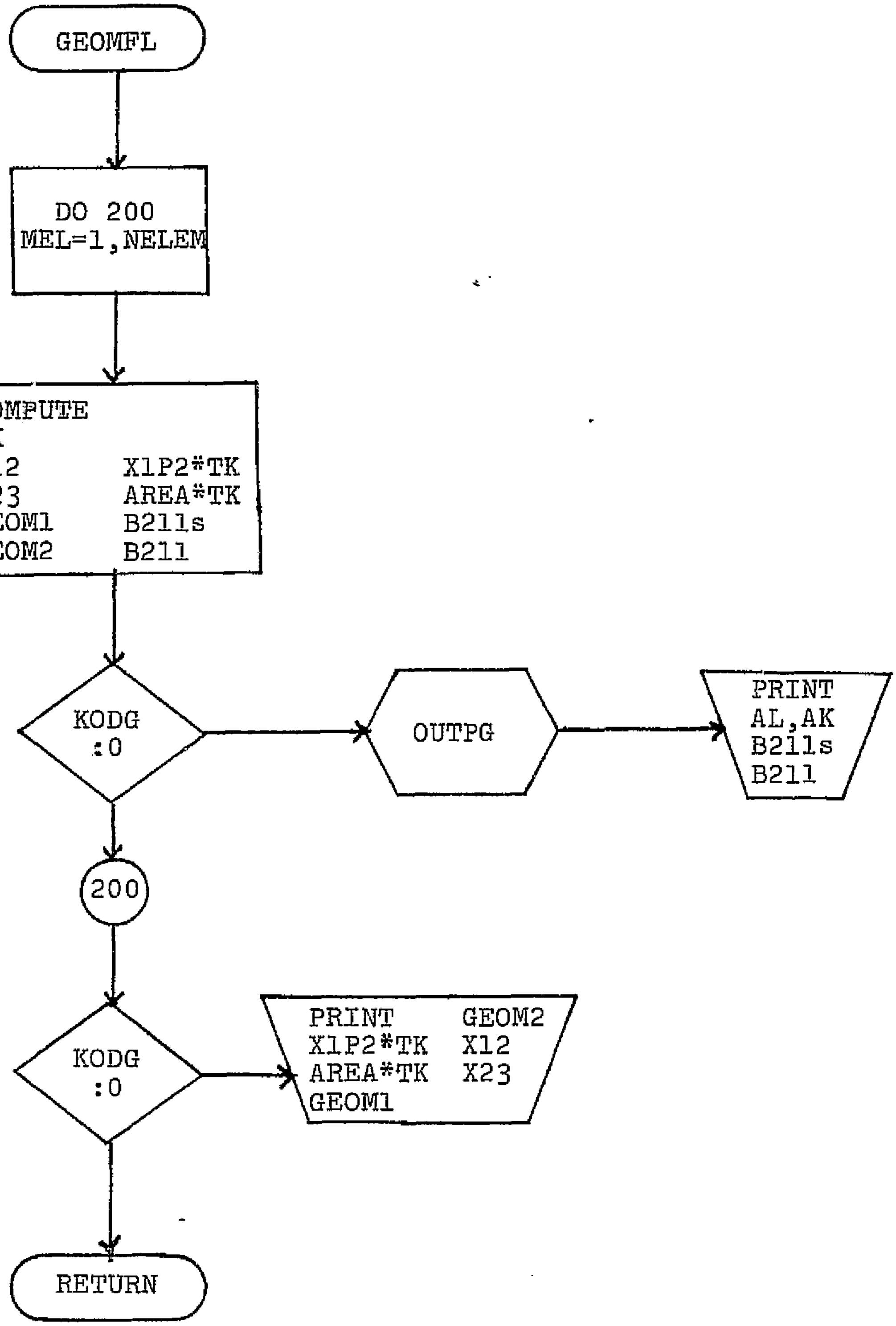

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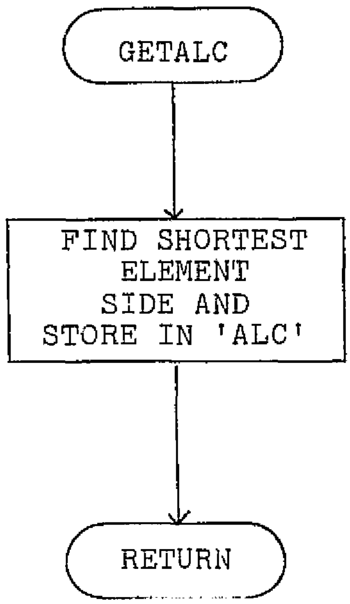

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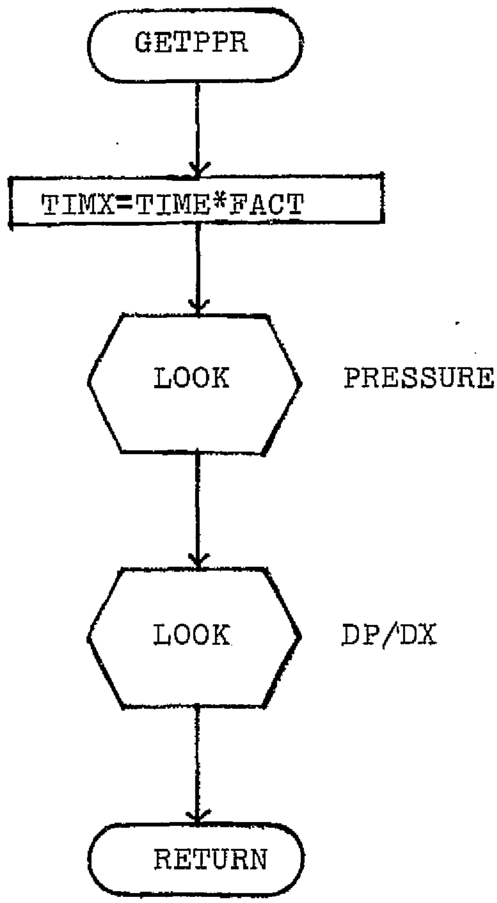

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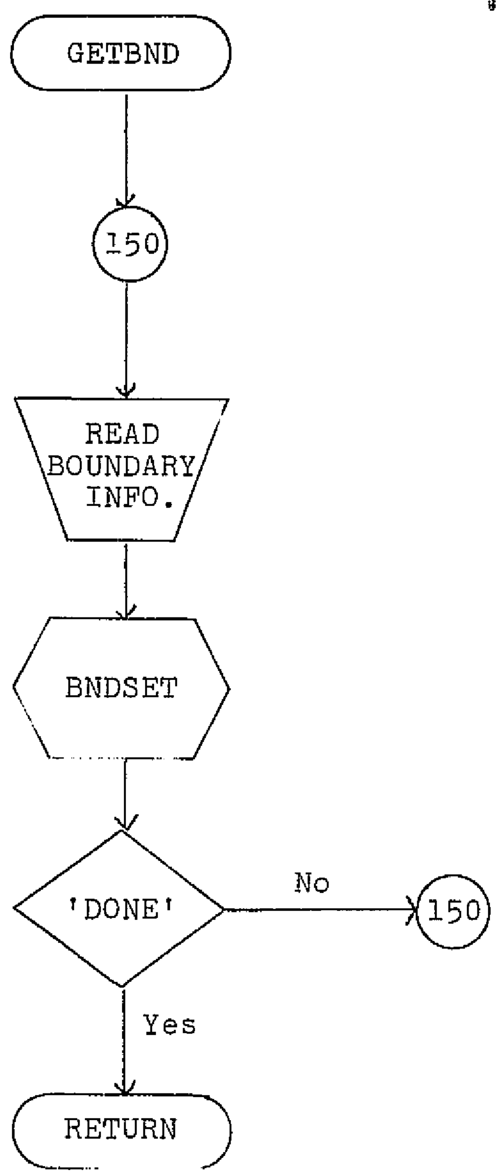

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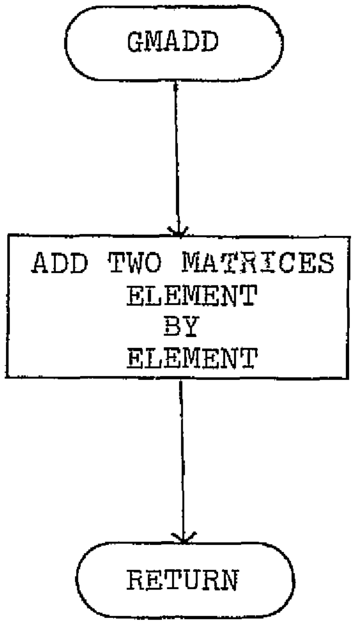

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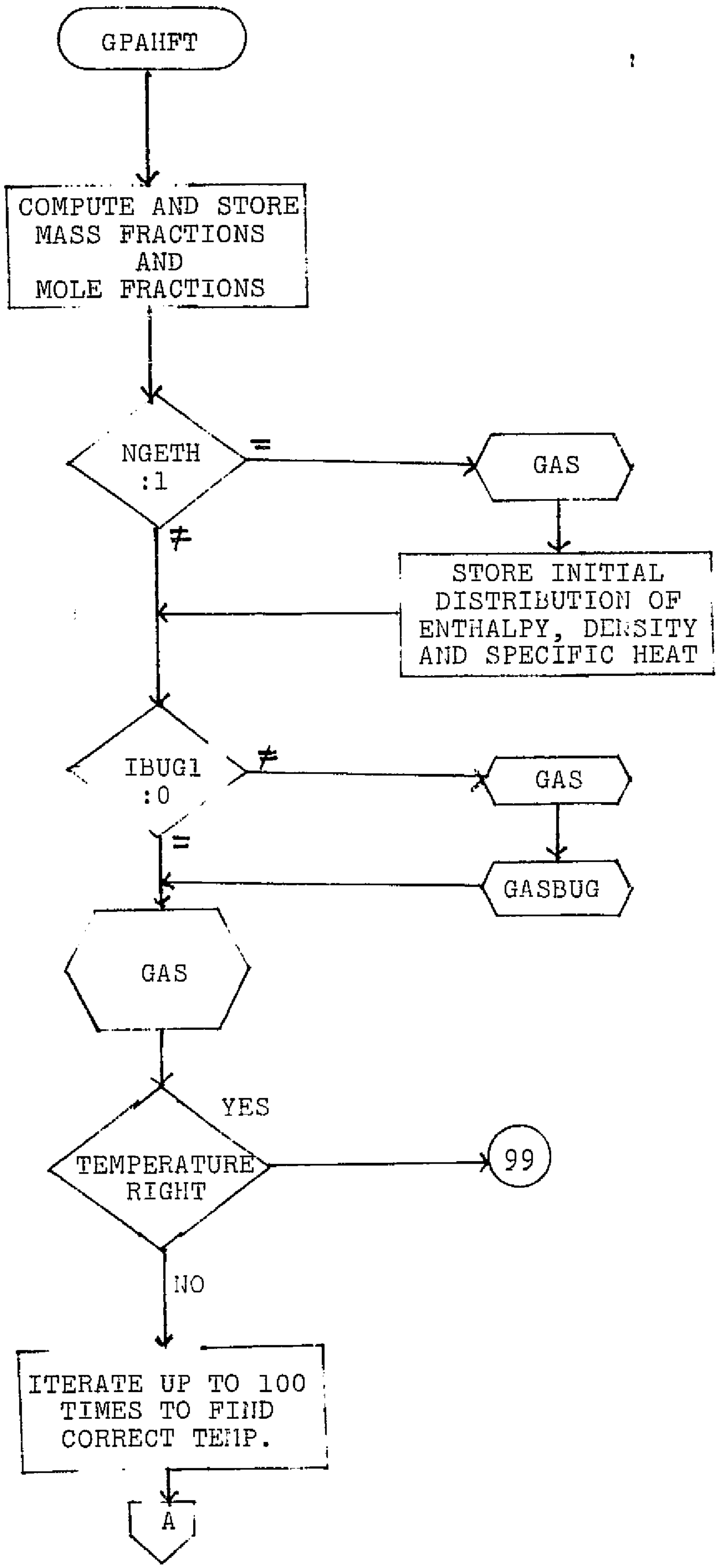
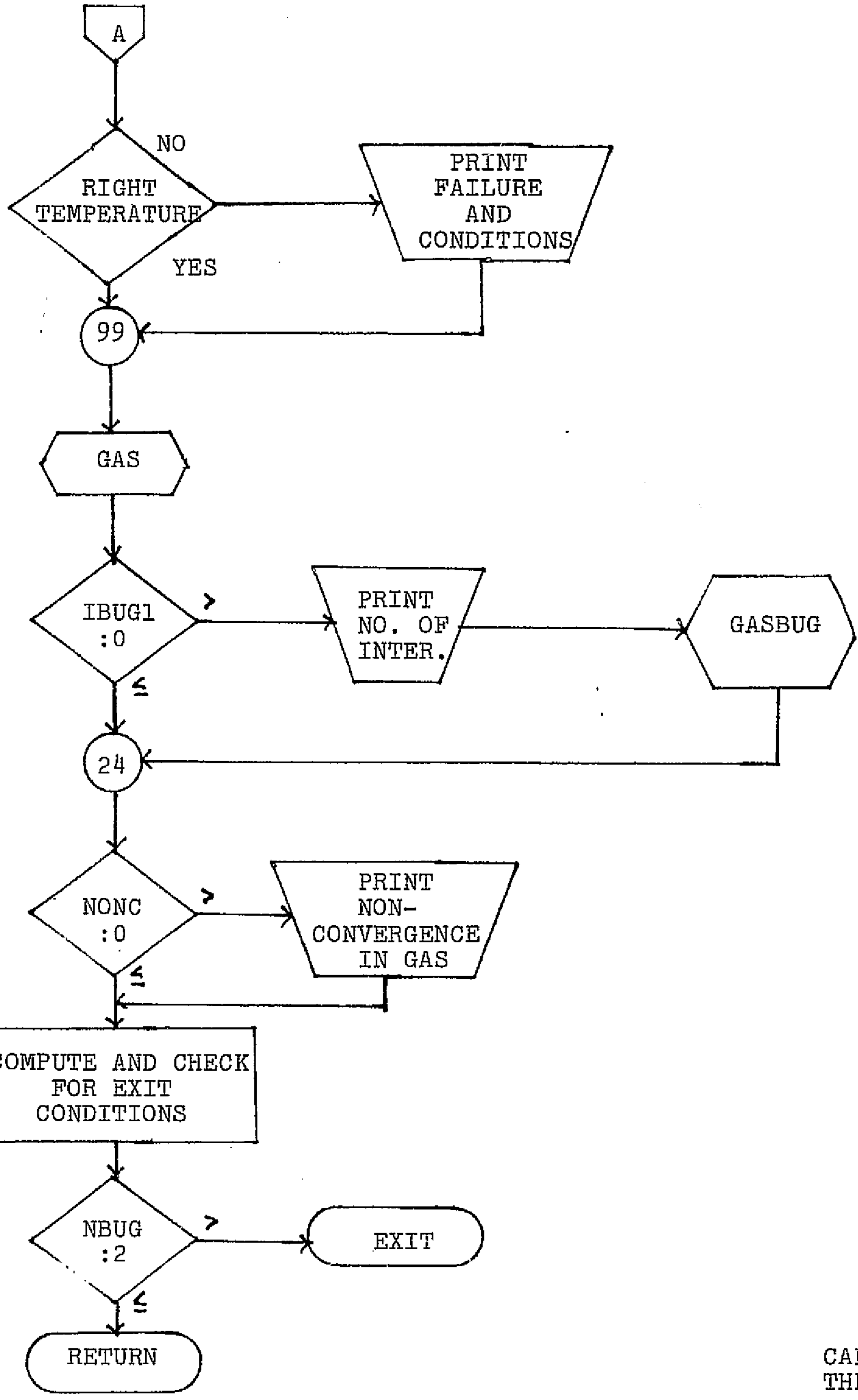

GPAHFT
COMPUTE AND STORE MASS FRACTIONS AND MOLE FRACTIONS
NGETH :1
=
GAS
≠
STORE INITIAL DISTRIBUTION OF ENTHALPY, DENSITY AND SPECIFIC HEAT
IBUG1 :0
≠
GAS
=
GASBUG
GAS
YES
TEMPERATURE RIGHT
99
NO
ITERATE UP TO 100 TIMES TO FIND CORRECT TEMP.
A



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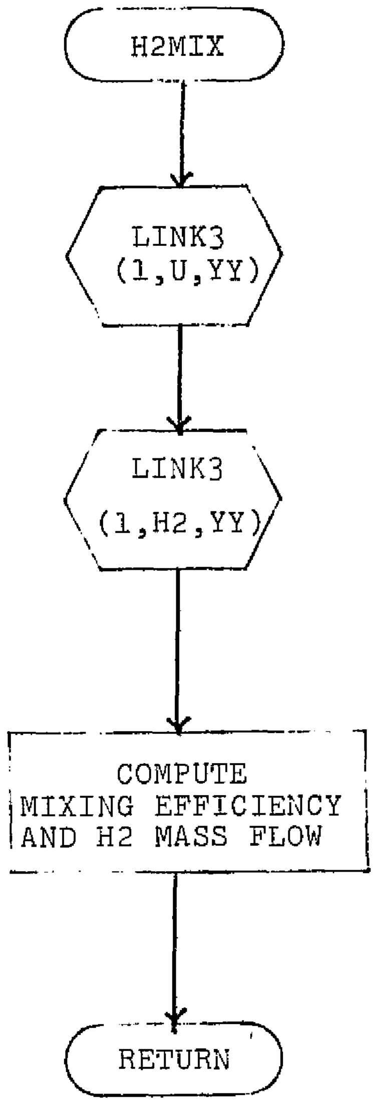

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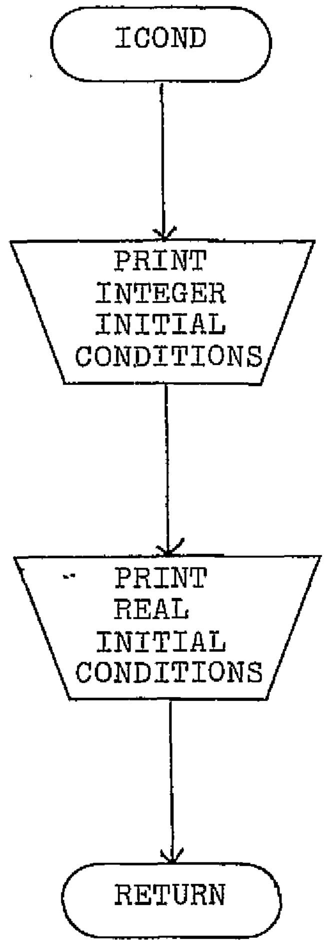

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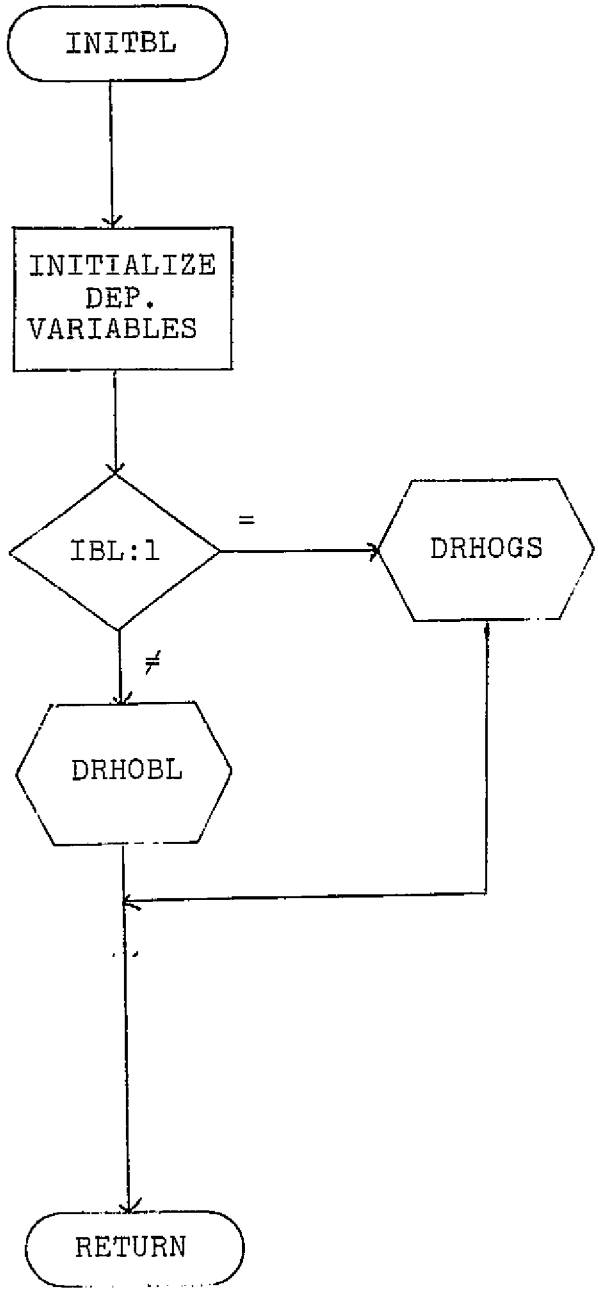

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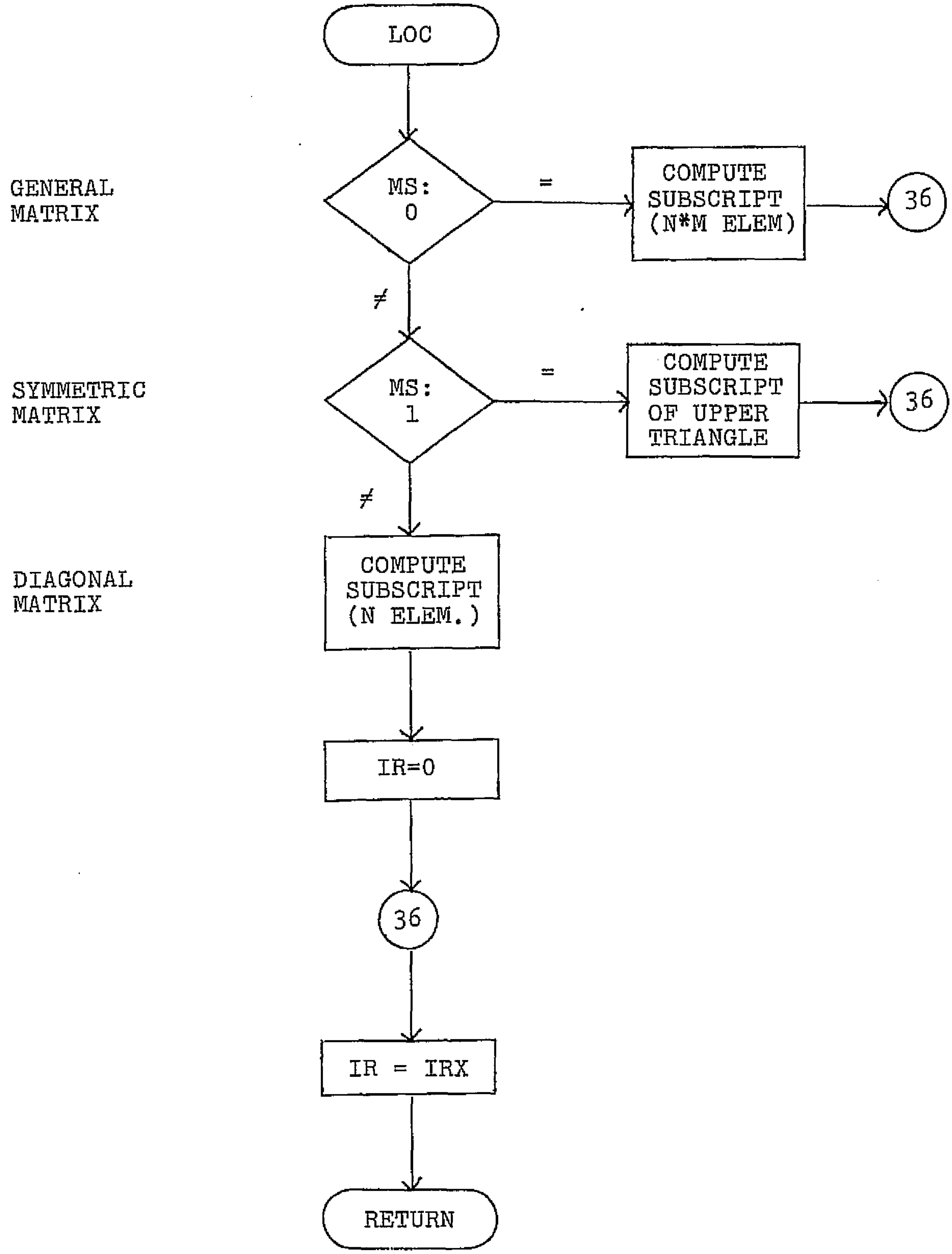

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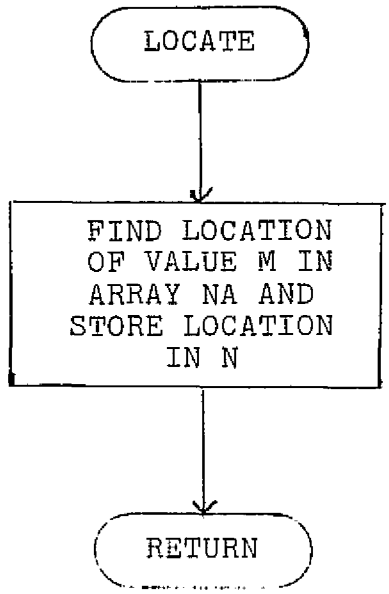

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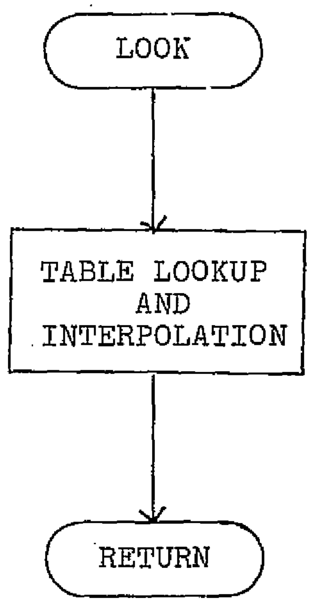

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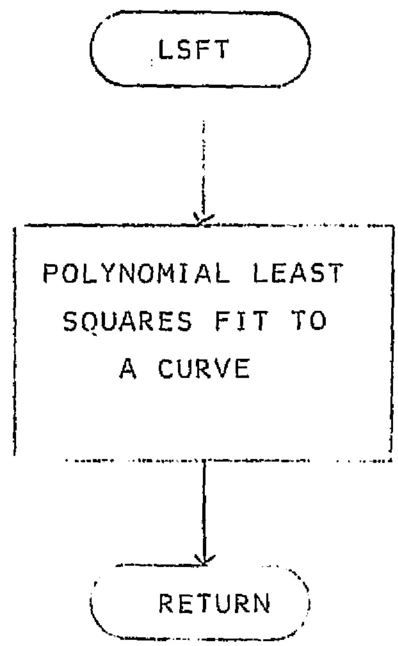

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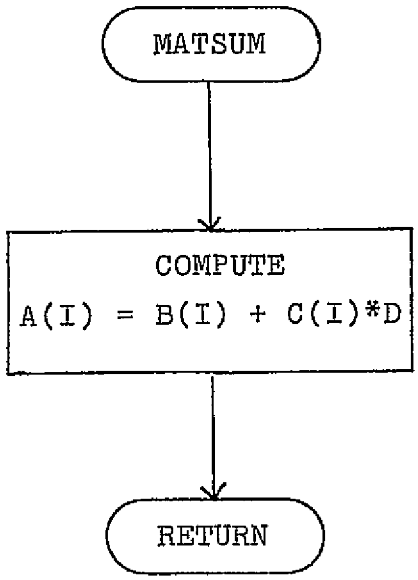

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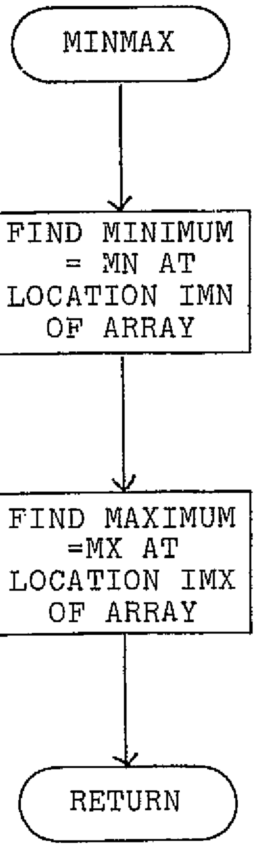
QKNUIN
ENERSC
SETDIF



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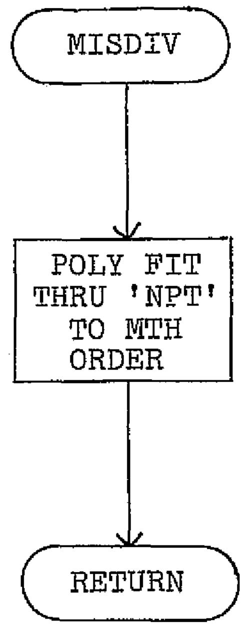
ORDER
SETSCL



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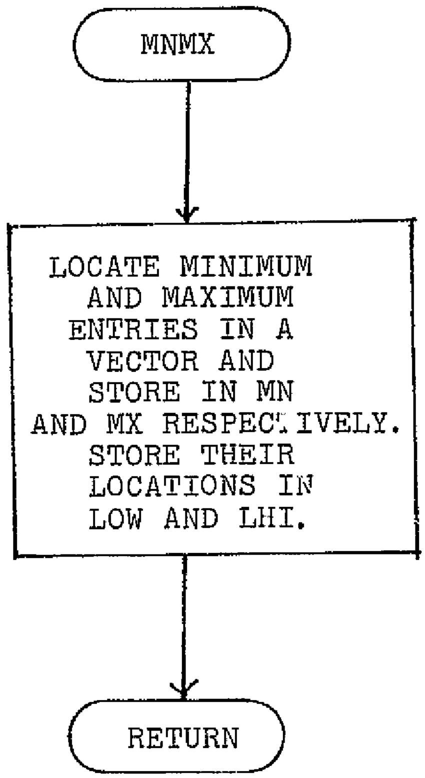
C-8



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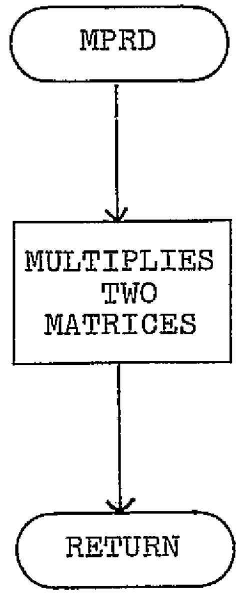

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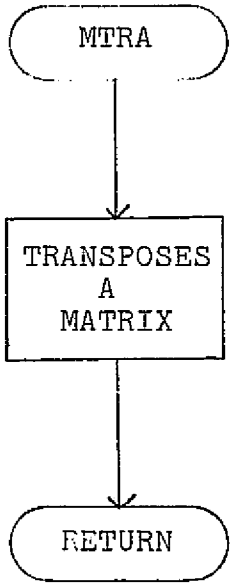

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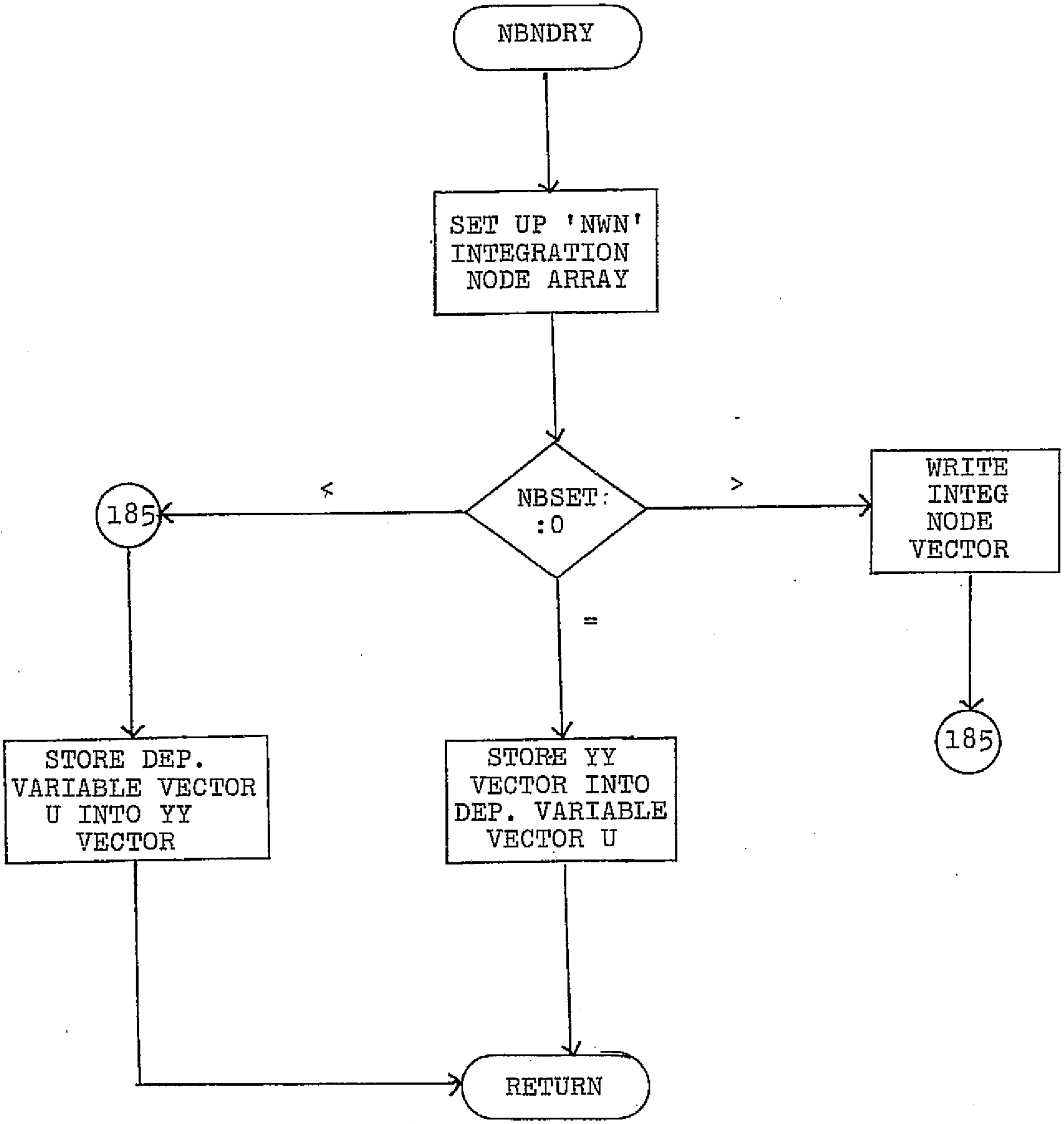

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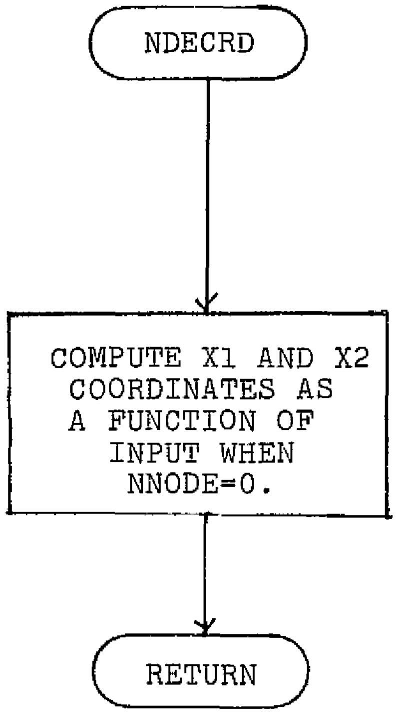

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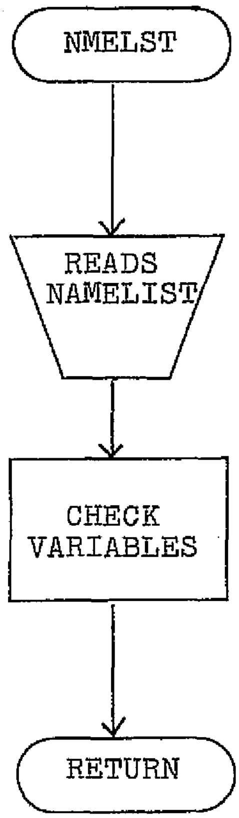

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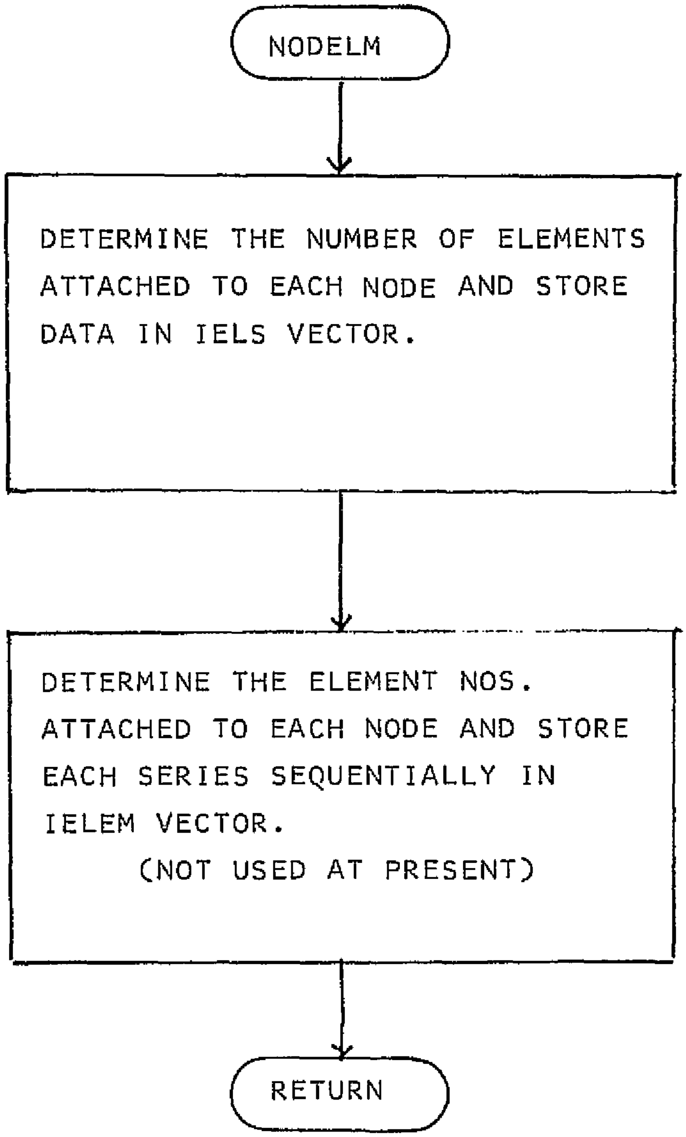

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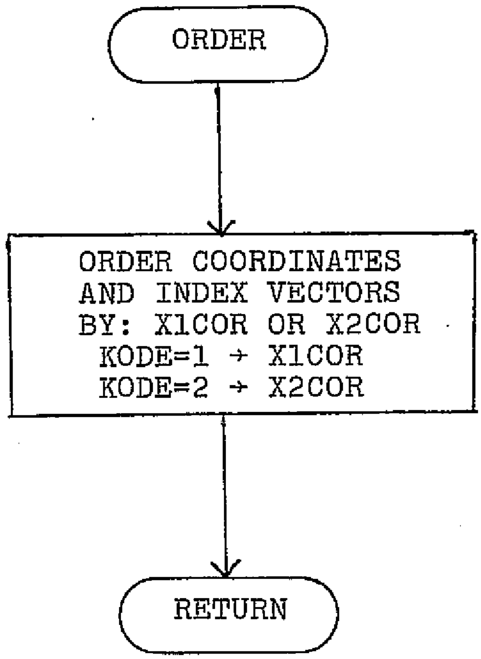

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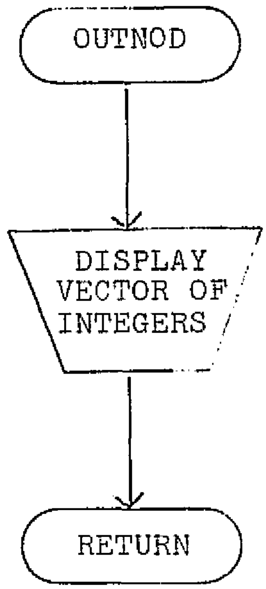

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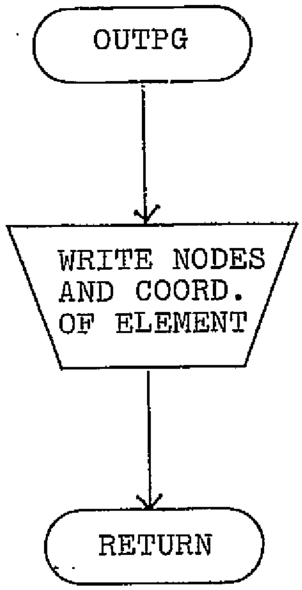

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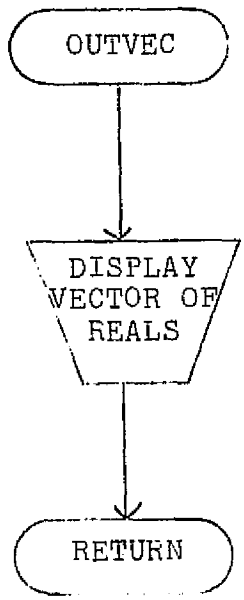

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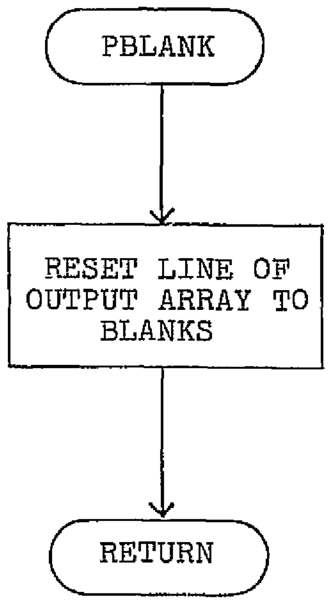

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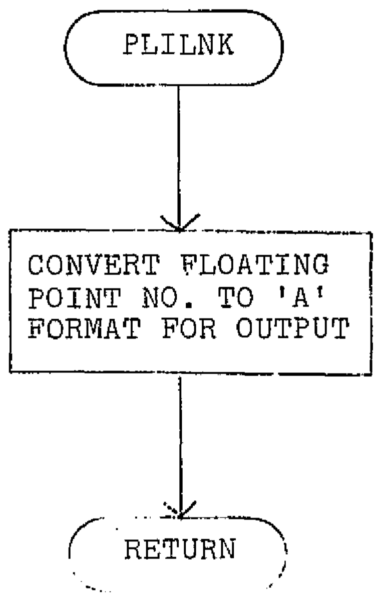

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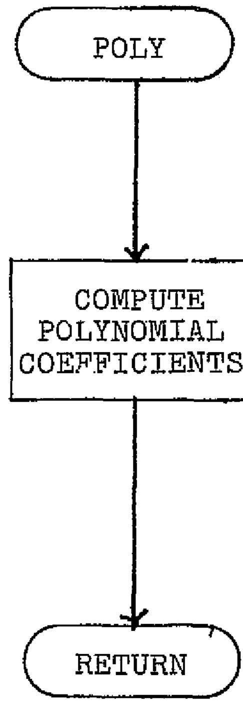

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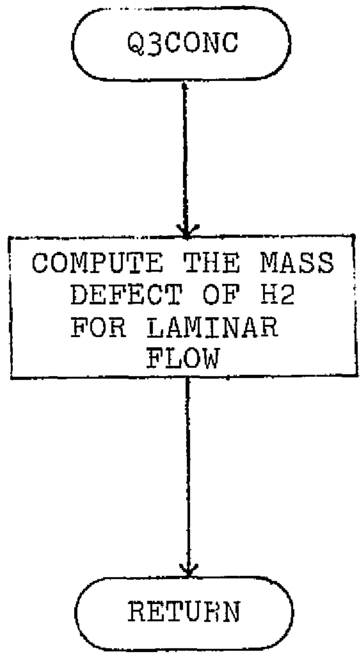

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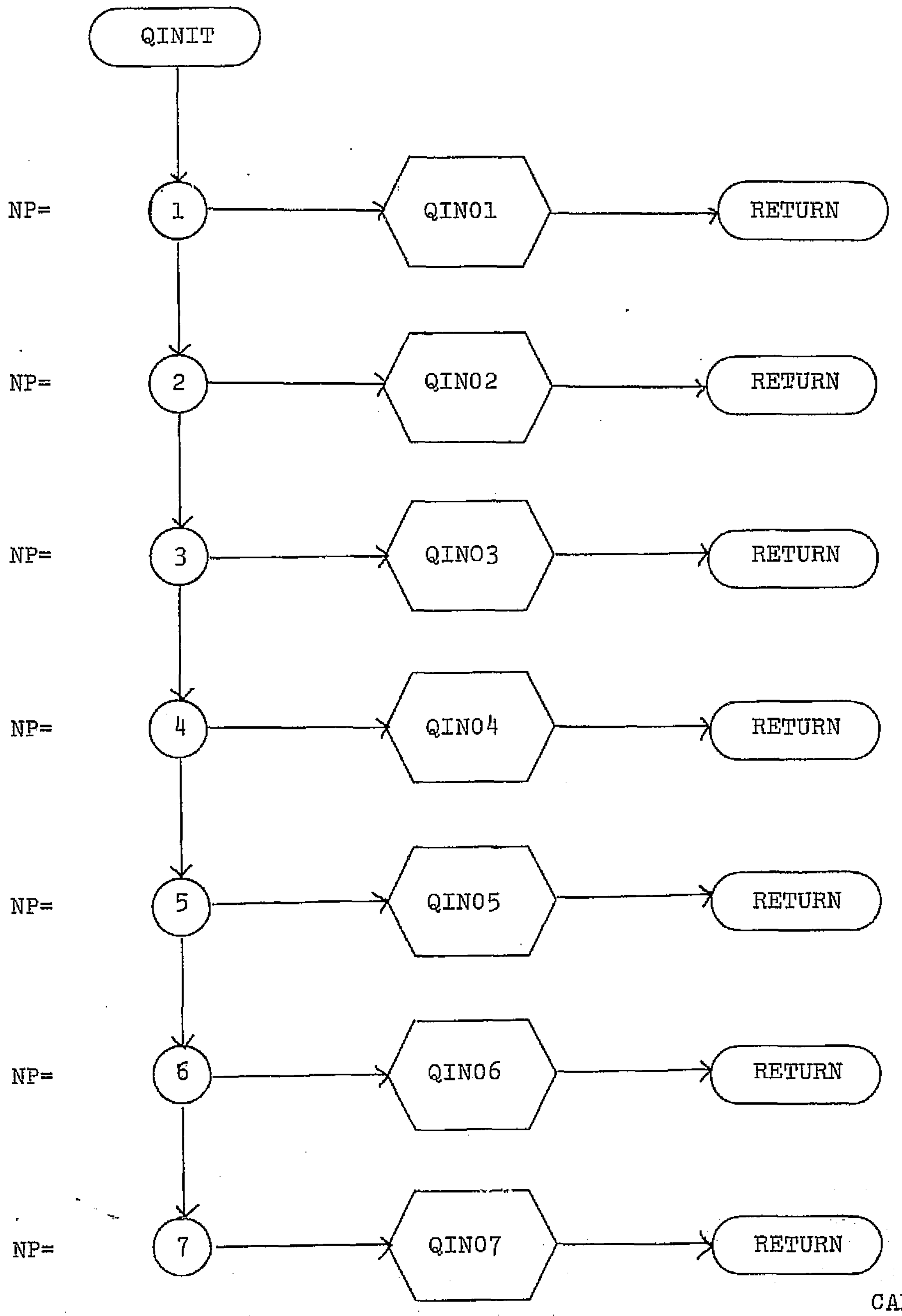

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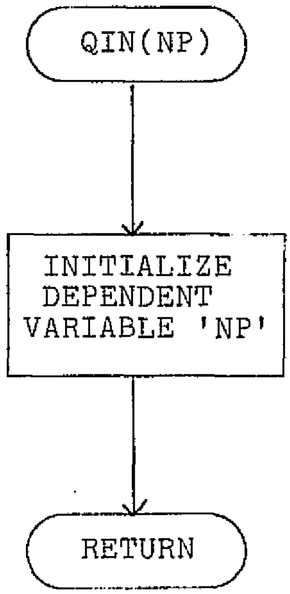

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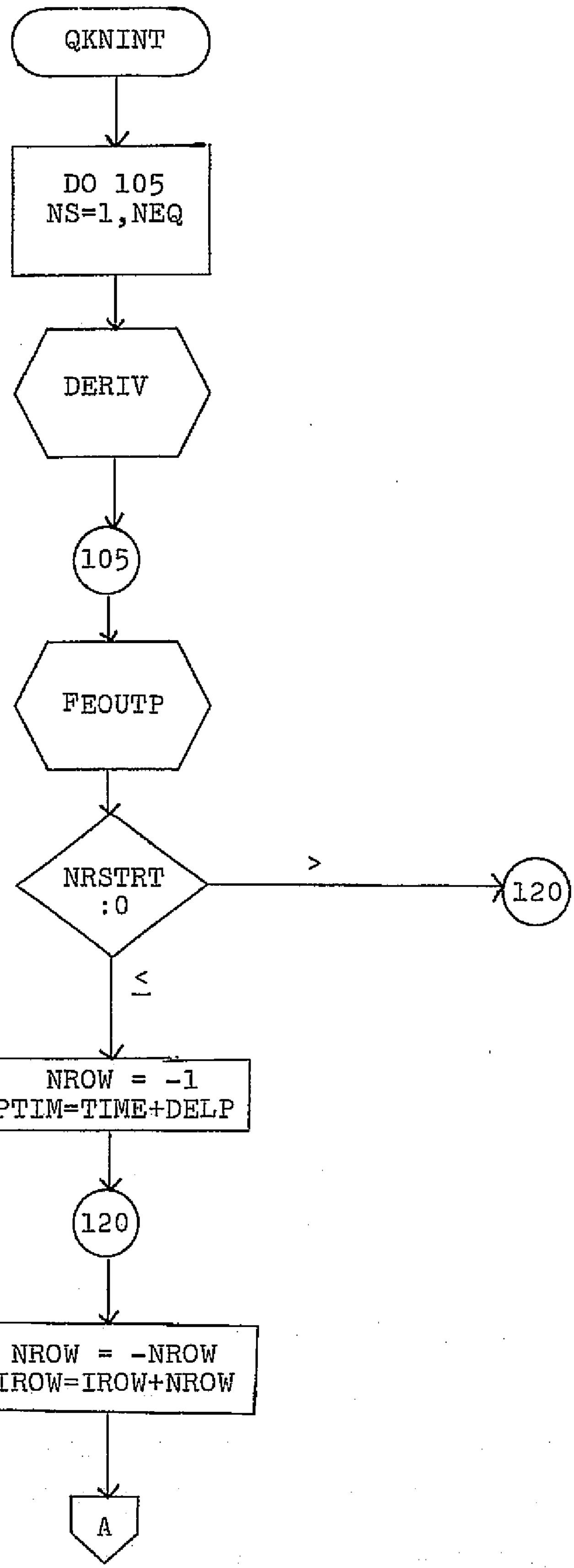
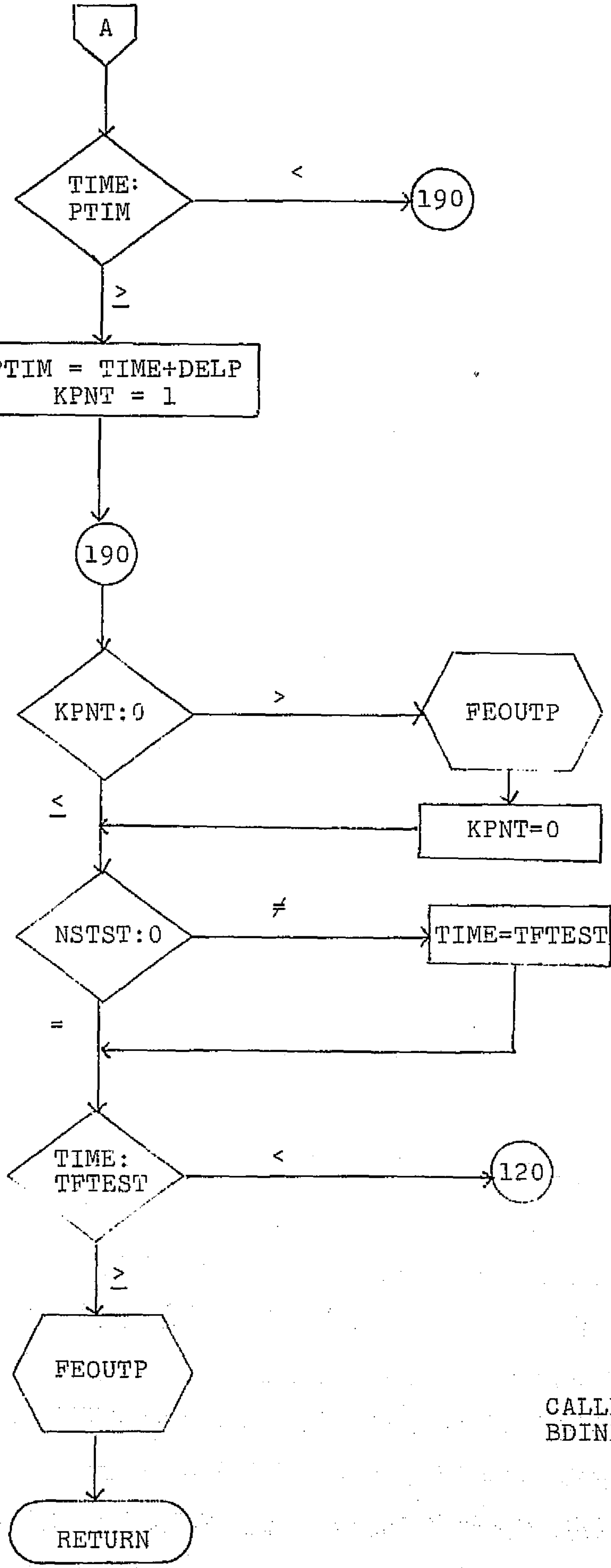

QKNINT
DO 105
NS=1,NEQ
DERIV
105
FEOUTP
NRSTRT
:0
>
120
≤
NROW = -1
PTIM=TIME+DELP
120
NROW = -NROW
IROW=IROW+NROW
A



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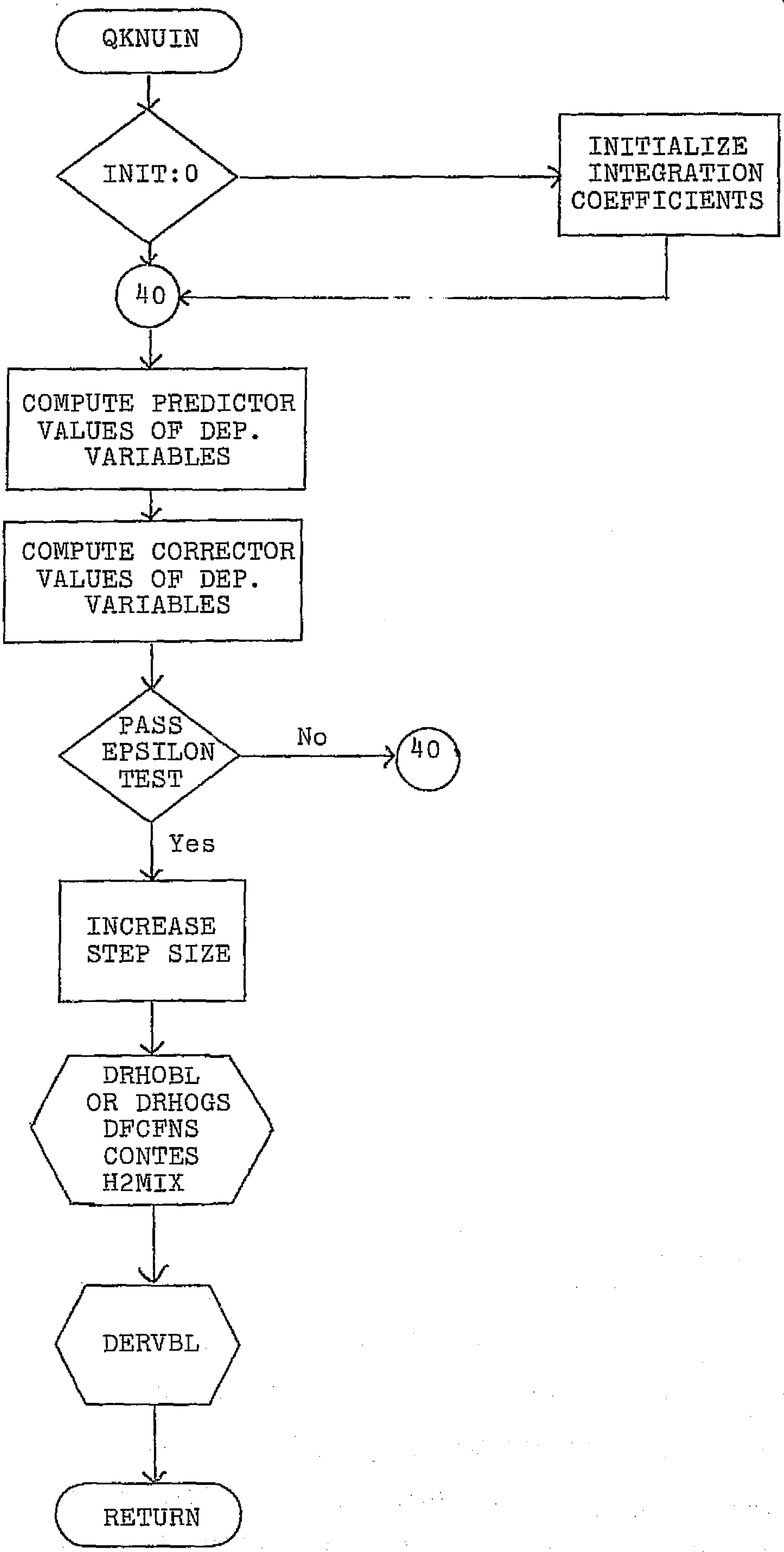

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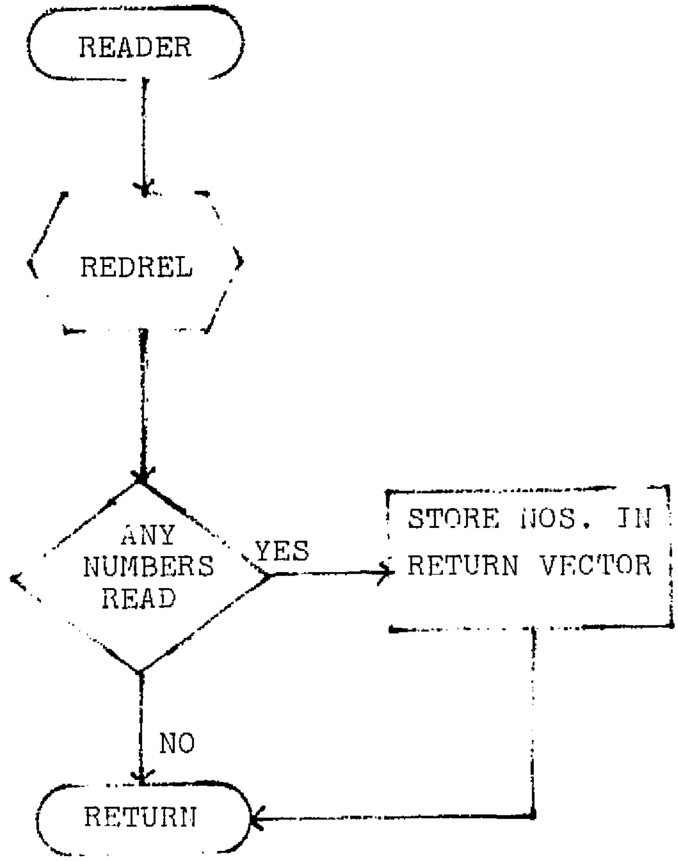

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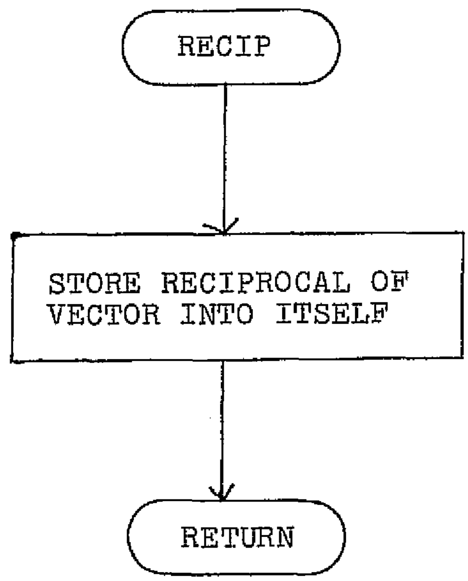

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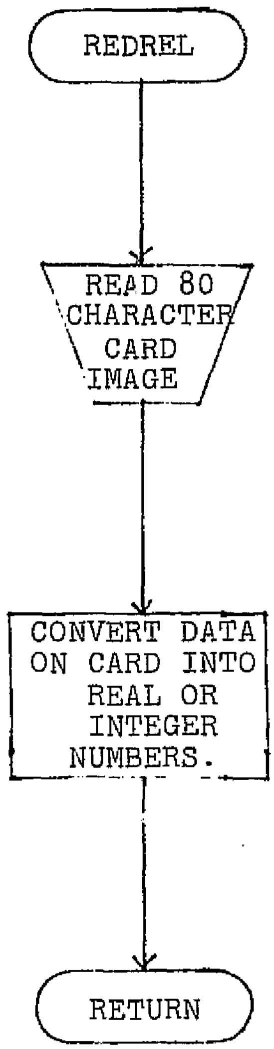
DFCFNS



CALLED BY:
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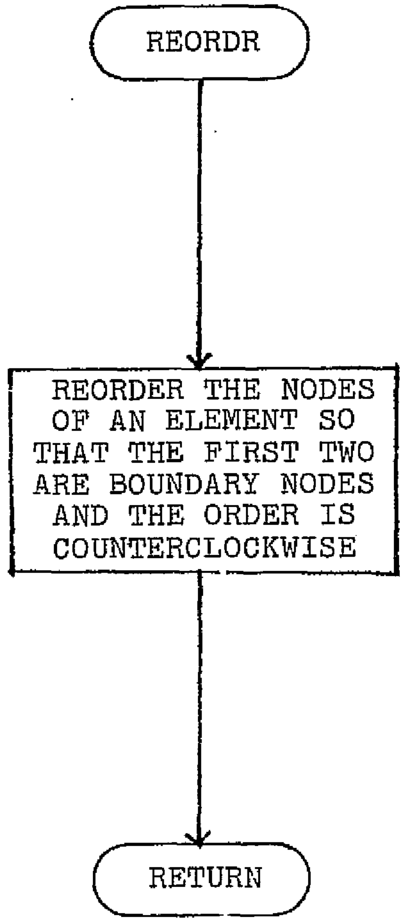
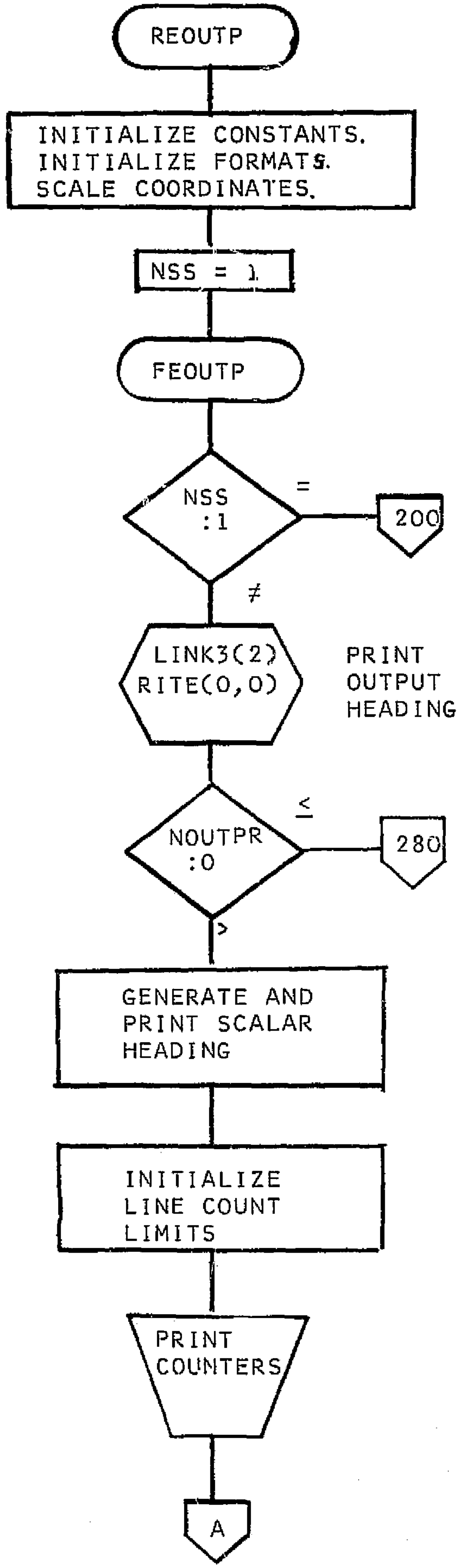
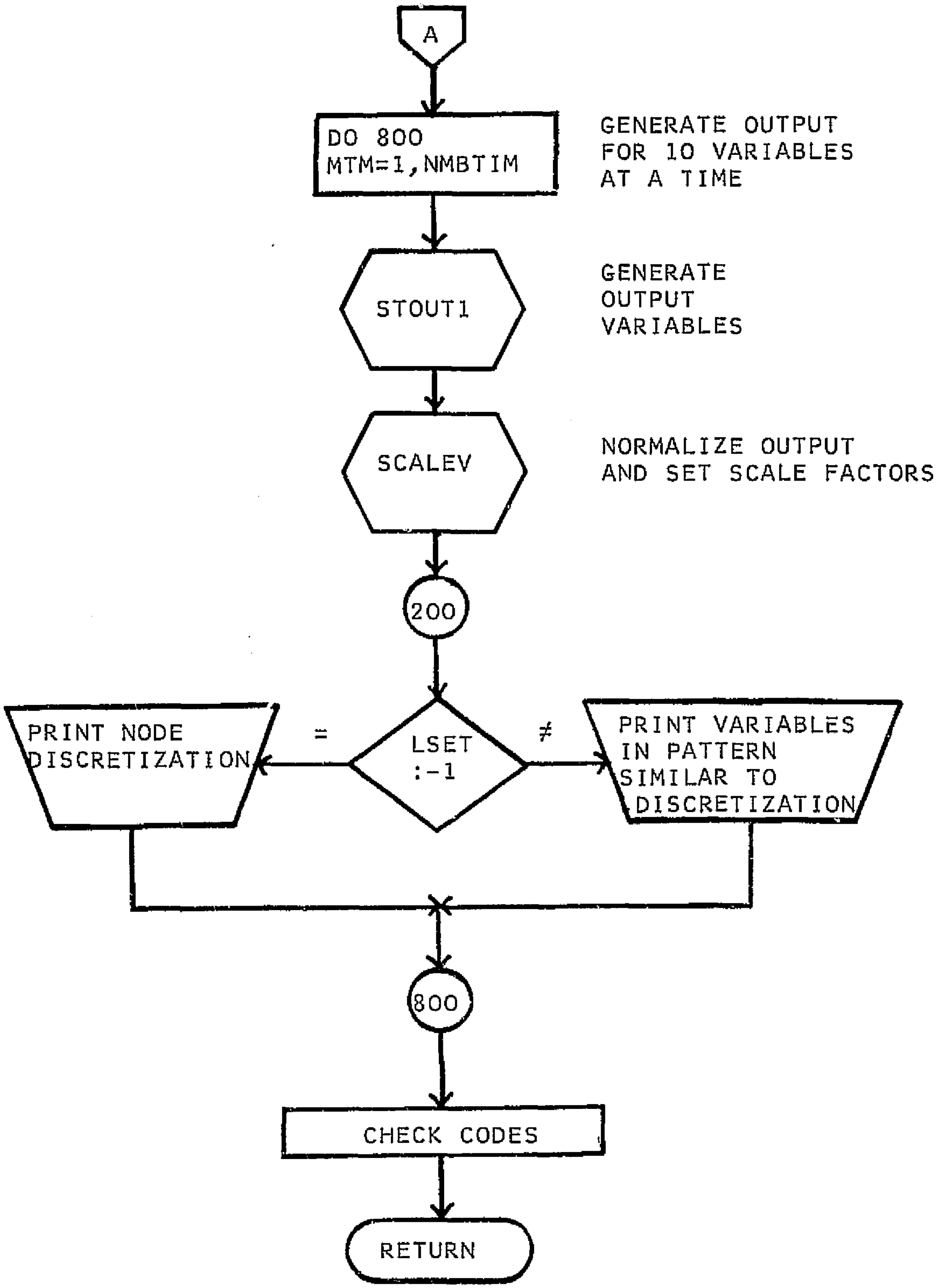
BDINPT
READER



CALLED BY:
FINDBE

REOUTP-1
ENTRY POINT
FEOUTP





CALLED BY
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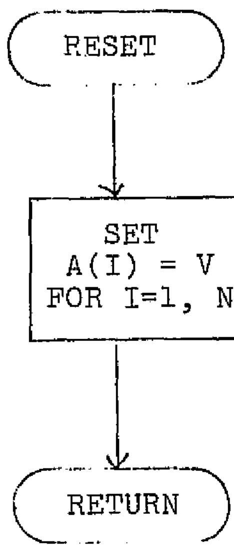
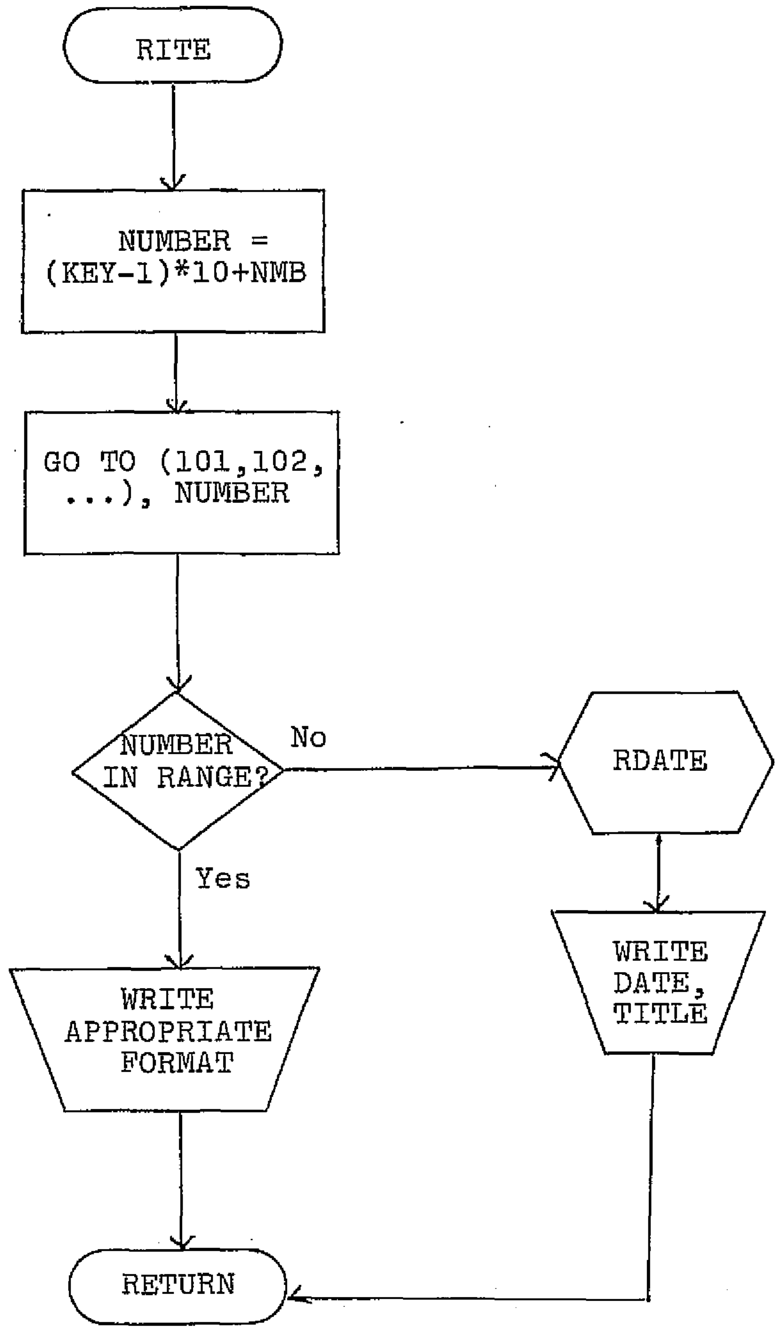


CALLED BY:
MANY
ROUTINES



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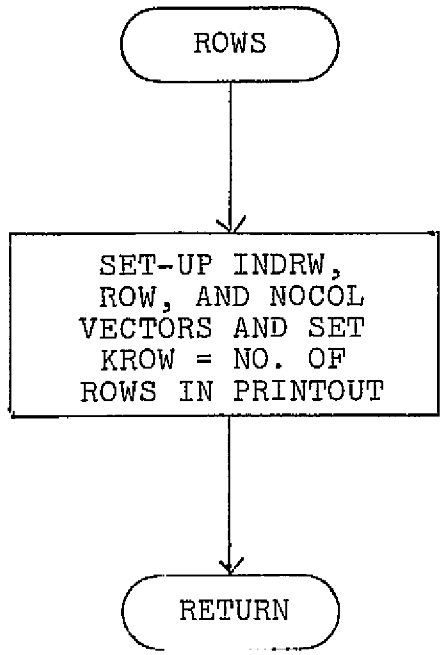

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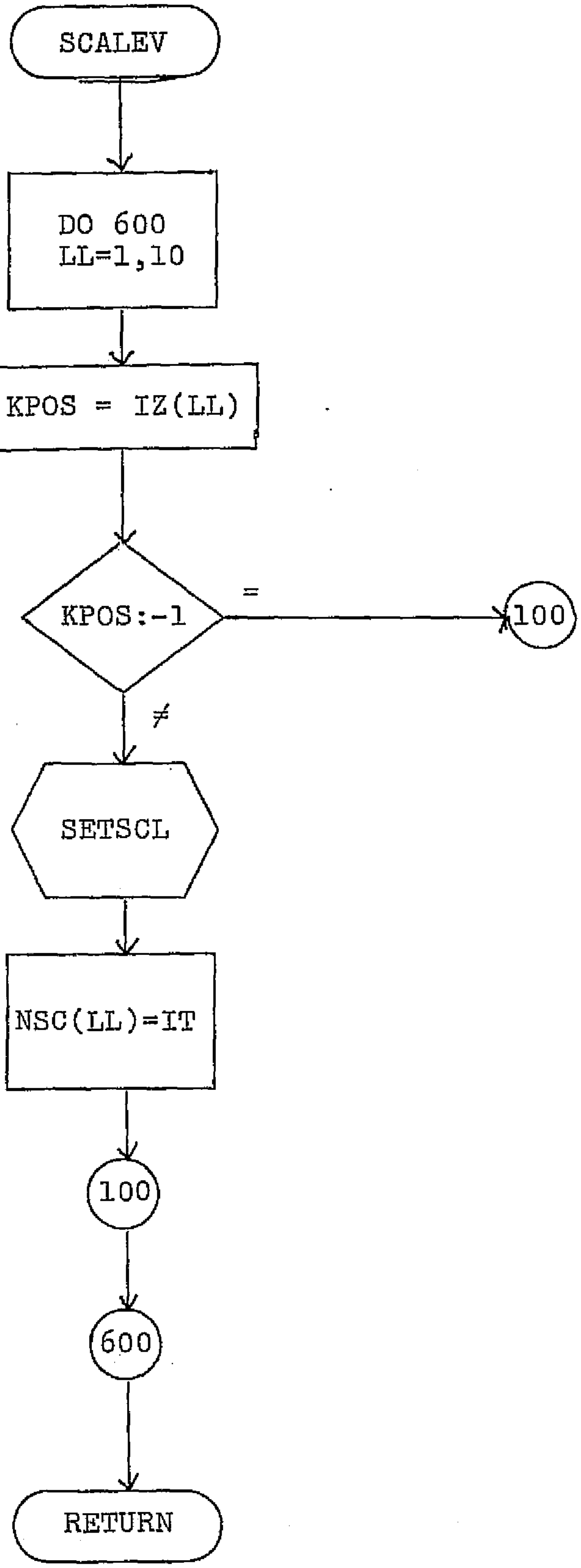

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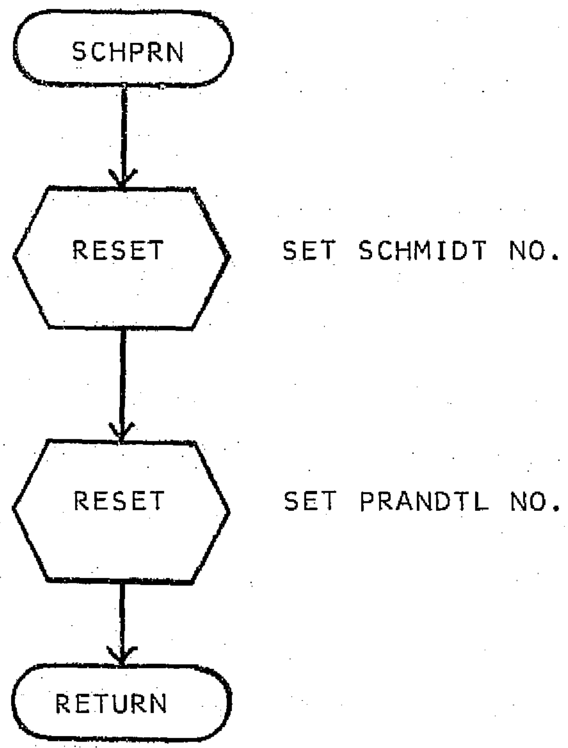

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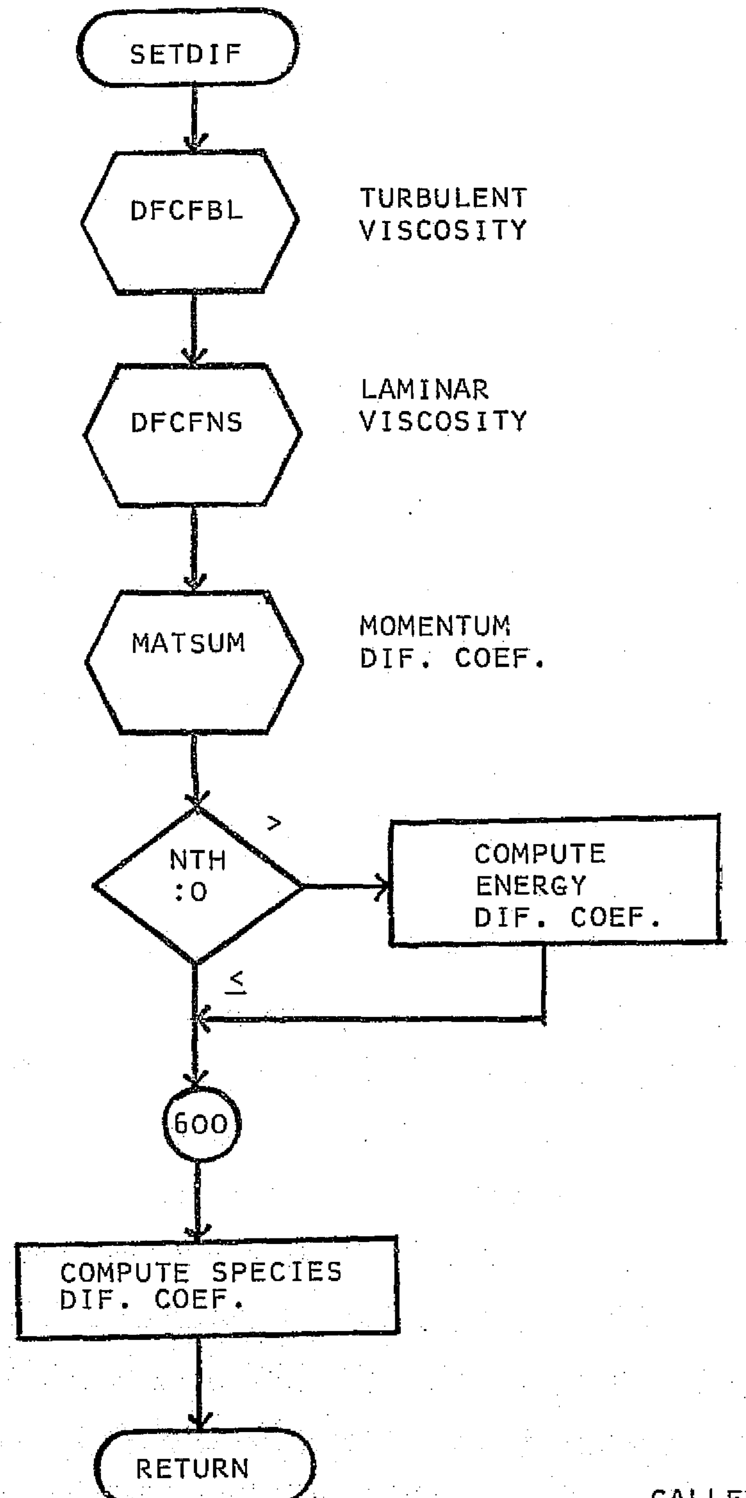

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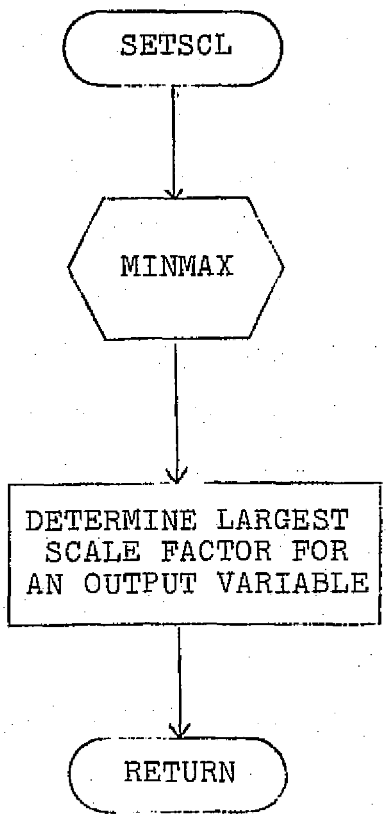
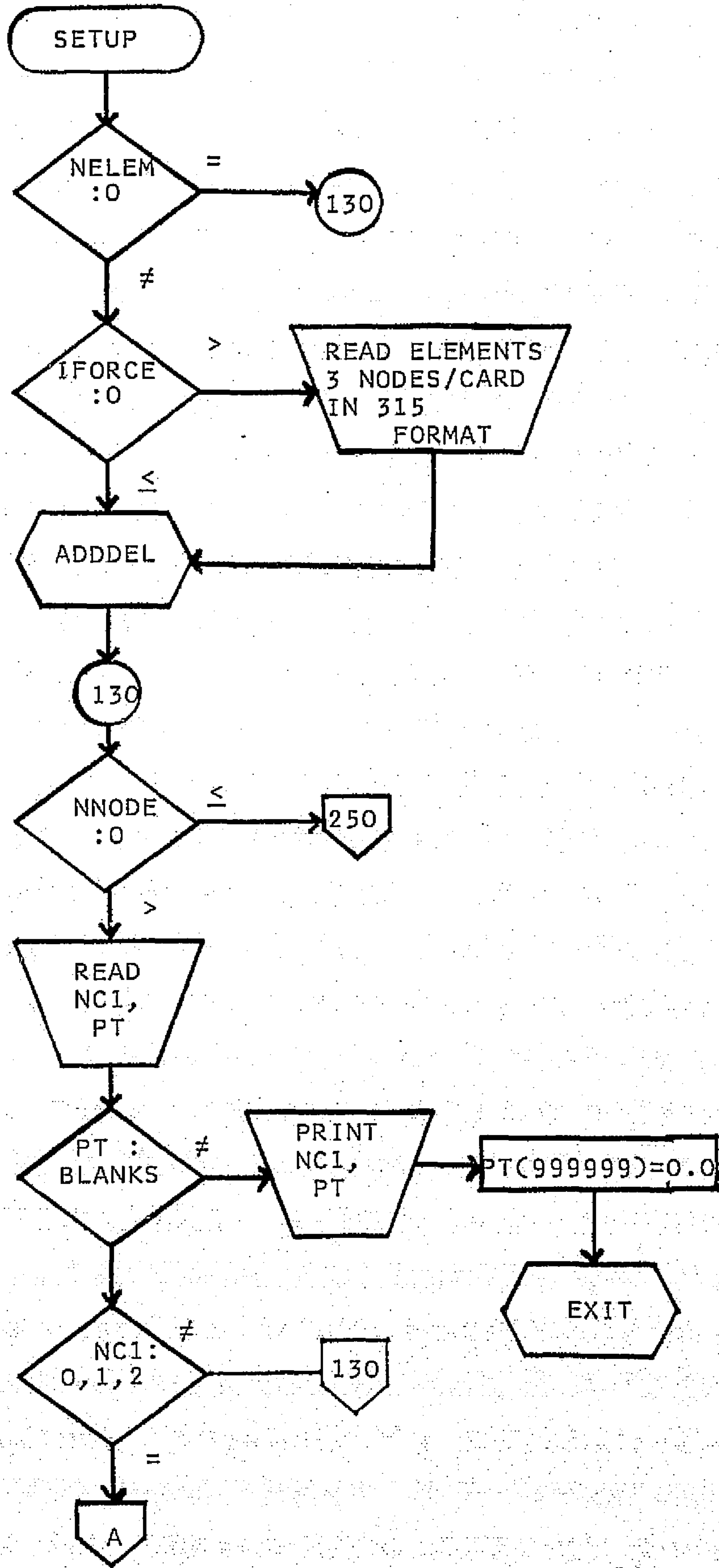
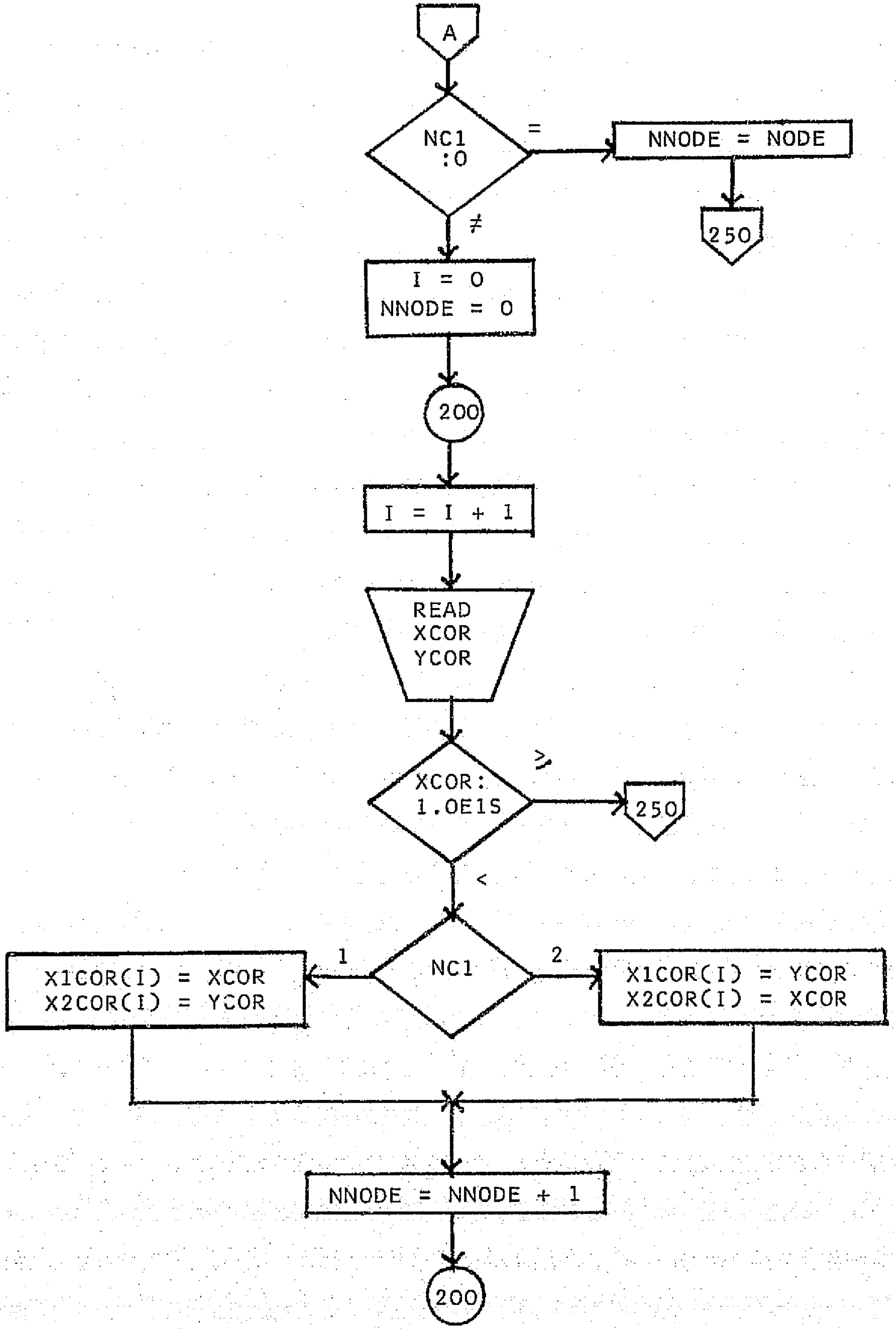
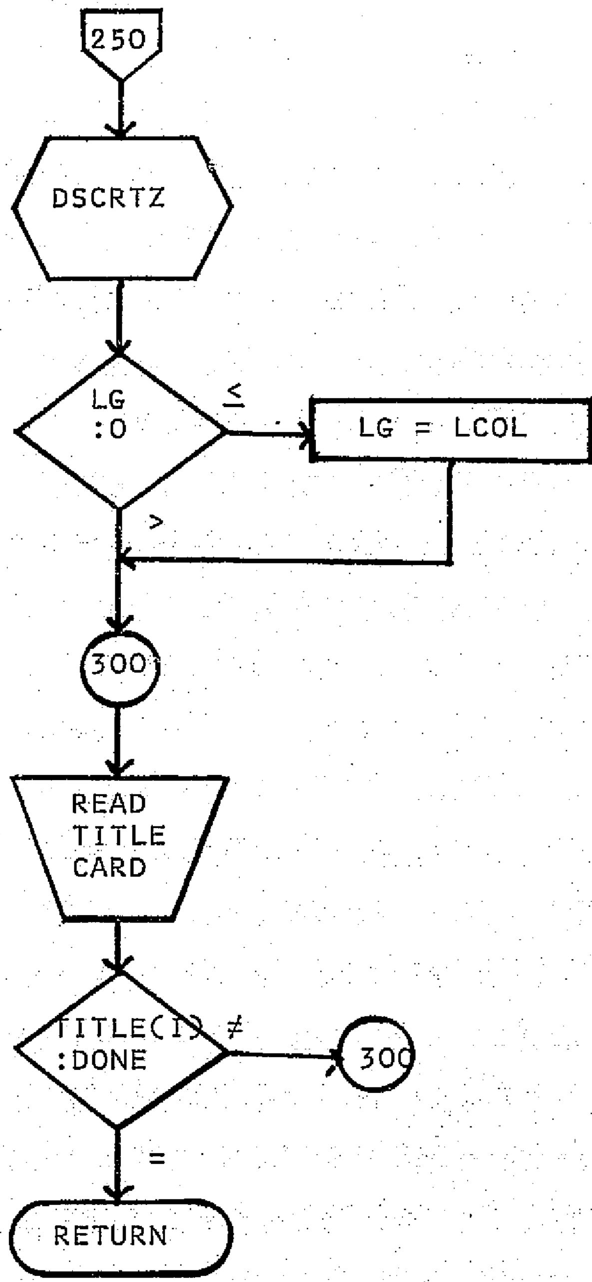


CALLED BY:
REOUTP
SCALEV


SETUP
NELEM :0
=
130
≠
IFORCE :0
>
READ ELEMENTS 3 NODES/CARD IN 3I5 FORMAT
≤
ADDDEL
130
NNODE :0
≤
250
>
READ NC1, PT
PT : BLANKS
≠
PRINT NC1, PT
PT(999999)=0.0
EXIT
NC1: 0,1,2
≠
130
=
A


A
NC1
:0
=
NNODE = NODE
250
≠
I = 0
NNODE = 0
200
I = I + 1
READ
XCOR
YCOR
XCOR:
1.0E15
≥
250
<
NC1
1
X1COR(I) = XCOR
X2COR(I) = YCOR
2
X1COR(I) = YCOR
X2COR(I) = XCOR
NNODE = NNODE + 1
200



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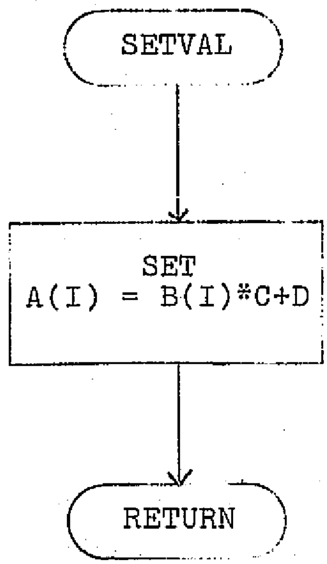
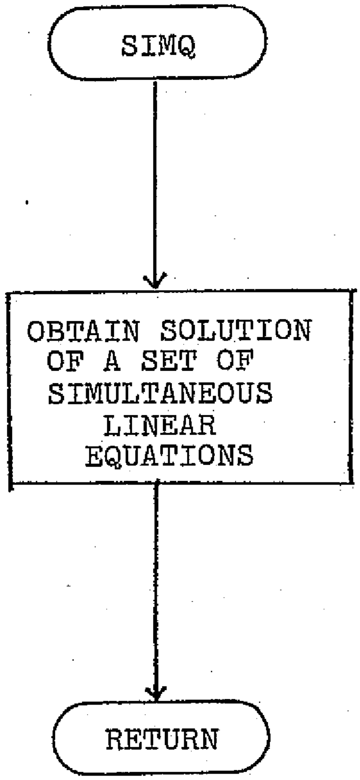


CALLED BY:
MANY
ROUTINES



CALLED BY:
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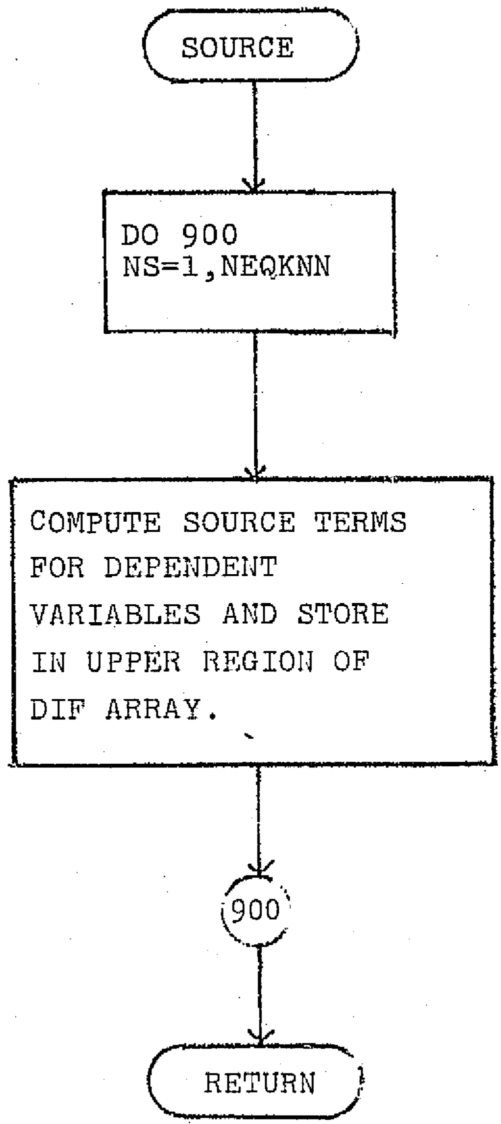

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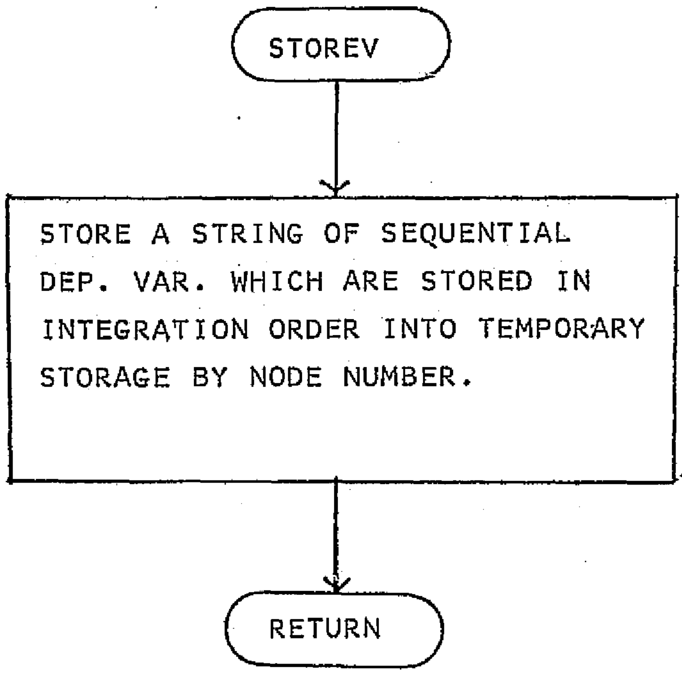
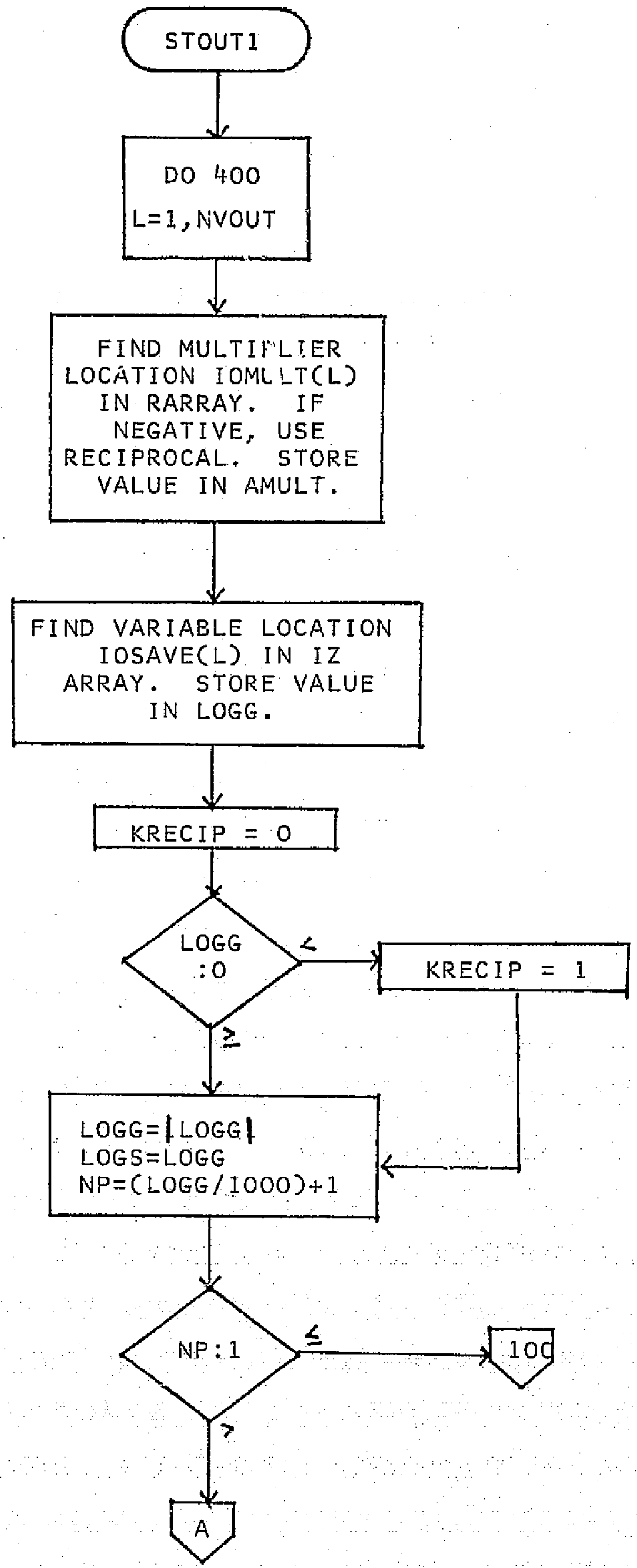


CALLED BY:
SOURCE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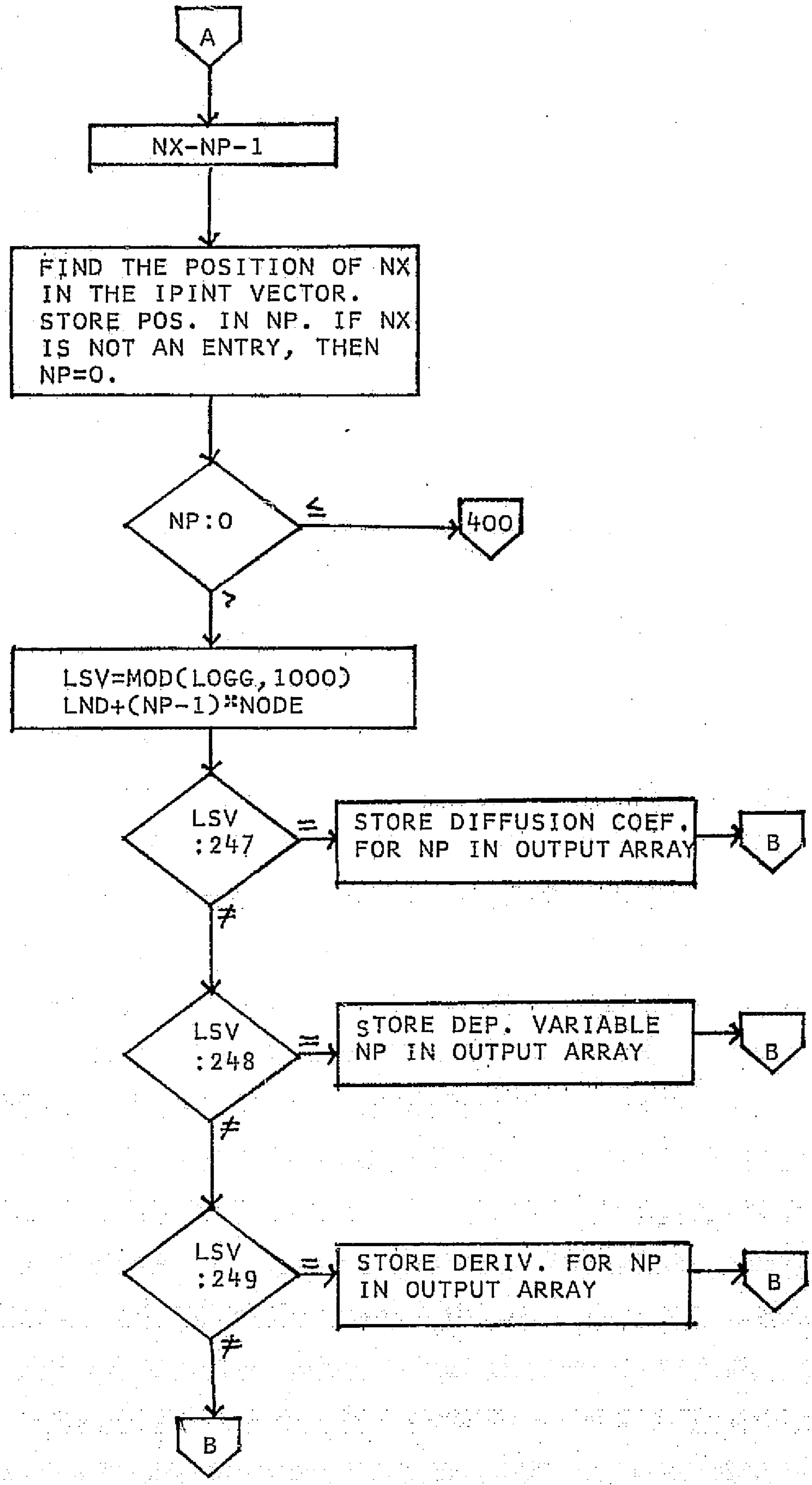
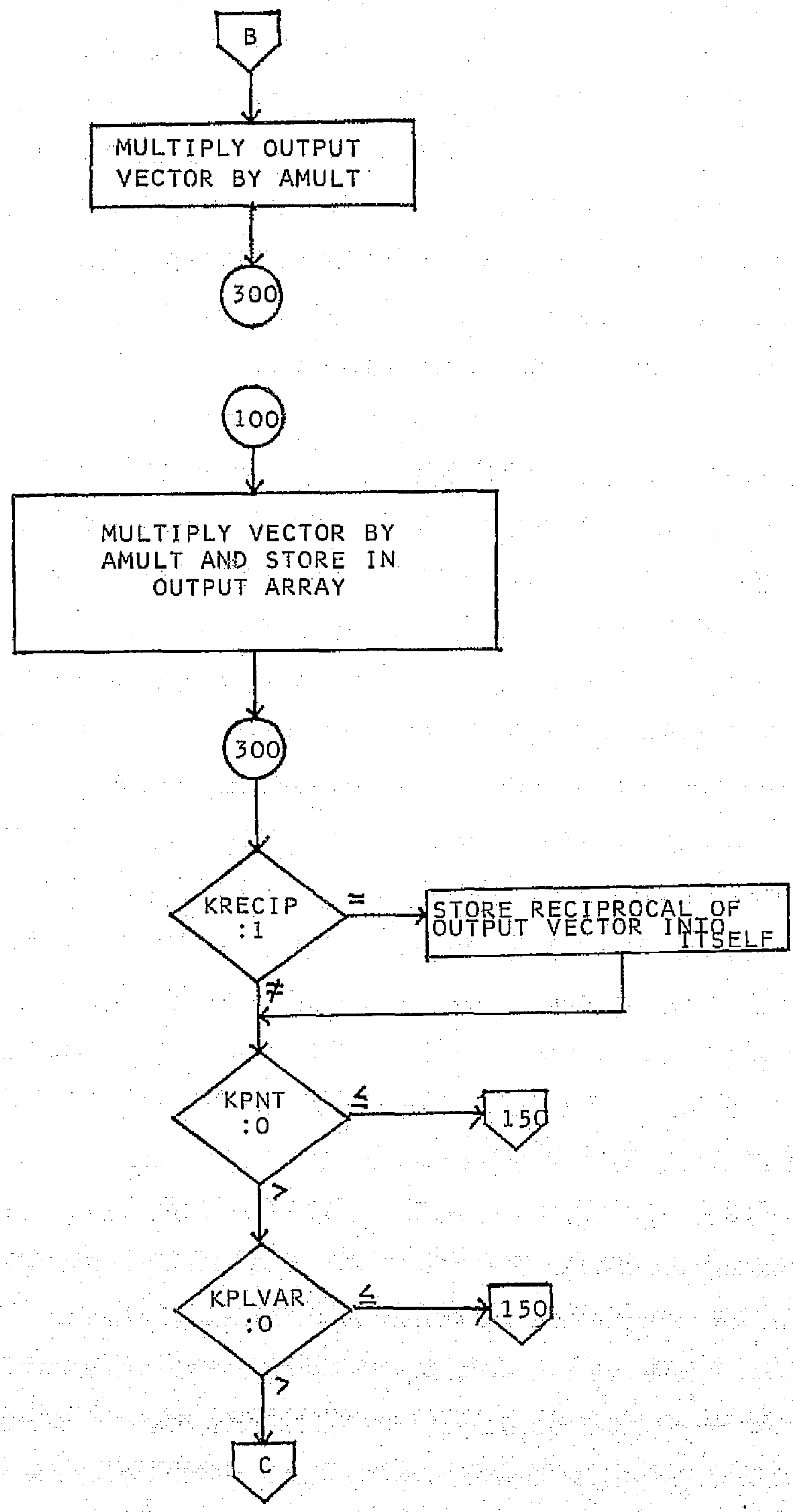
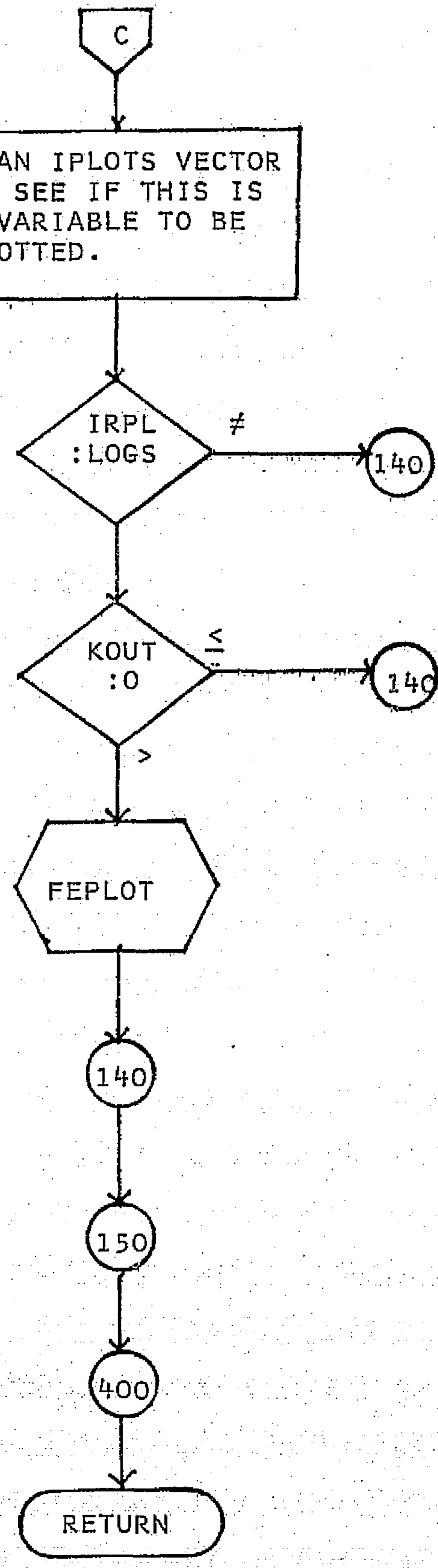
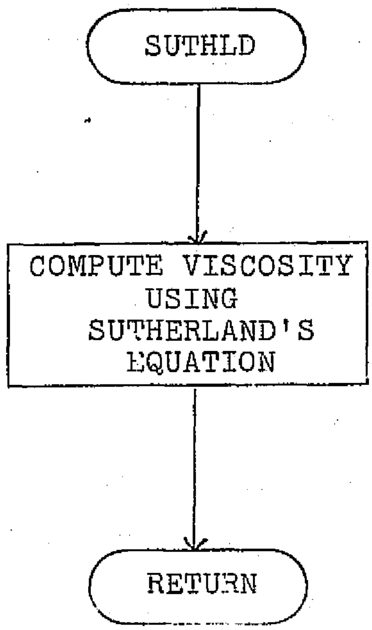
DO 400
L=1,NVOUT
FIND MULTIPLIER LOCATION IOMULT(L) IN RARRAY. IF NEGATIVE, USE RECIPROCAL. STORE VALUE IN AMULT.
FIND VARIABLE LOCATION IOSAVE(L) IN IZ ARRAY. STORE VALUE IN LOGG.
KRECIP = 0
LOGG :0
<
KRECIP = 1
≥
LOGG=|LOGG|
LOGS=LOGG
NP=(LOGG/1000)+1
NP:1
≤
100
>
A


A
NX-NP-1
FIND THE POSITION OF NX IN THE IPINT VECTOR. STORE POS. IN NP. IF NX IS NOT AN ENTRY, THEN NP=0.
NP:0
≤
400
>
LSV=MOD(LOGG,1000)
LND+(NP-1)*NODE
LSV :247
=
STORE DIFFUSION COEF. FOR NP IN OUTPUT ARRAY
B
≠
LSV :248
=
STORE DEP. VARIABLE NP IN OUTPUT ARRAY
B
≠
LSV :249
=
STORE DERIV. FOR NP IN OUTPUT ARRAY
B
≠
B

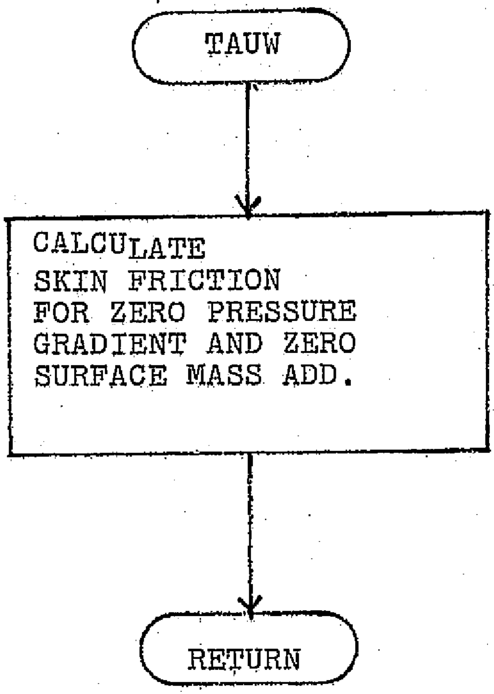

B
MULTIPLY OUTPUT VECTOR BY AMULT
300
100
MULTIPLY VECTOR BY AMULT AND STORE IN OUTPUT ARRAY
300
KRECIP :1
=
≠
STORE RECIPROCAL OF OUTPUT VECTOR INTO ITSELF
KPNT :0
≤
150
>
KPLVAR :0
≤
150
>
C



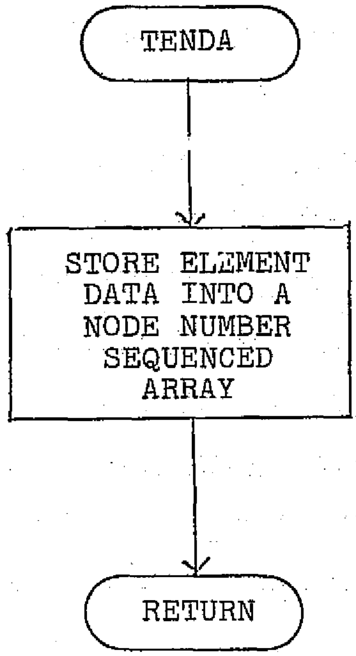
CALLED BY:
FEOUTP



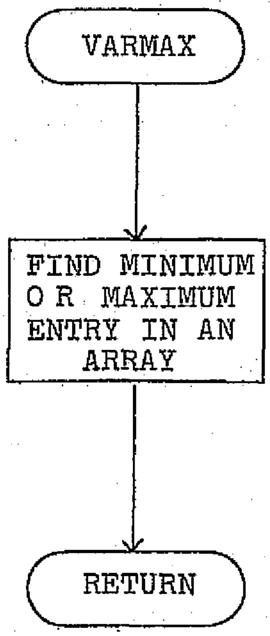
CALLED BY:
DFCOFO
DIMEN



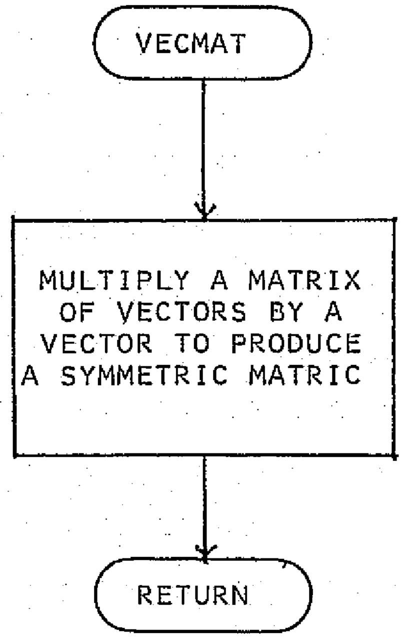
CALLED BY:
WLFLXS



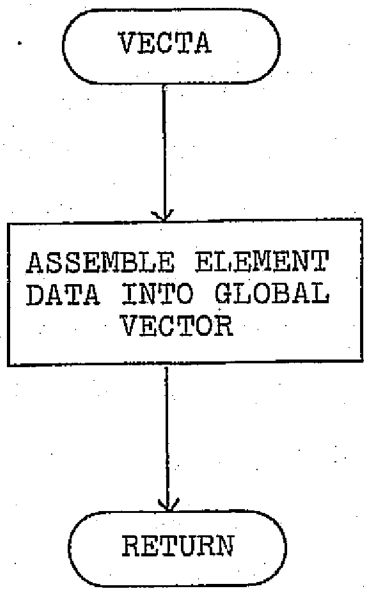
CALLED BY:
INITNS



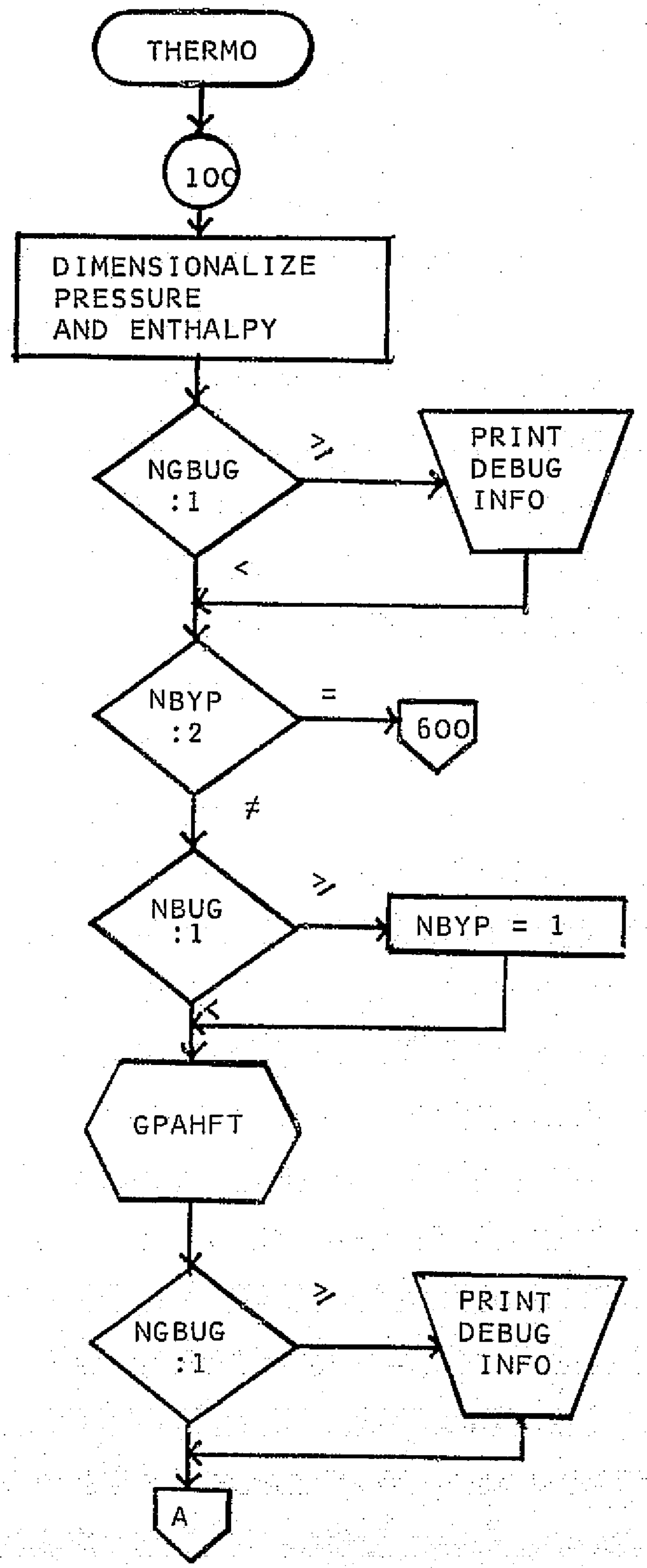
CALLED BY:
DRHOGS
FEPLOT
QKNUIN
LINK2

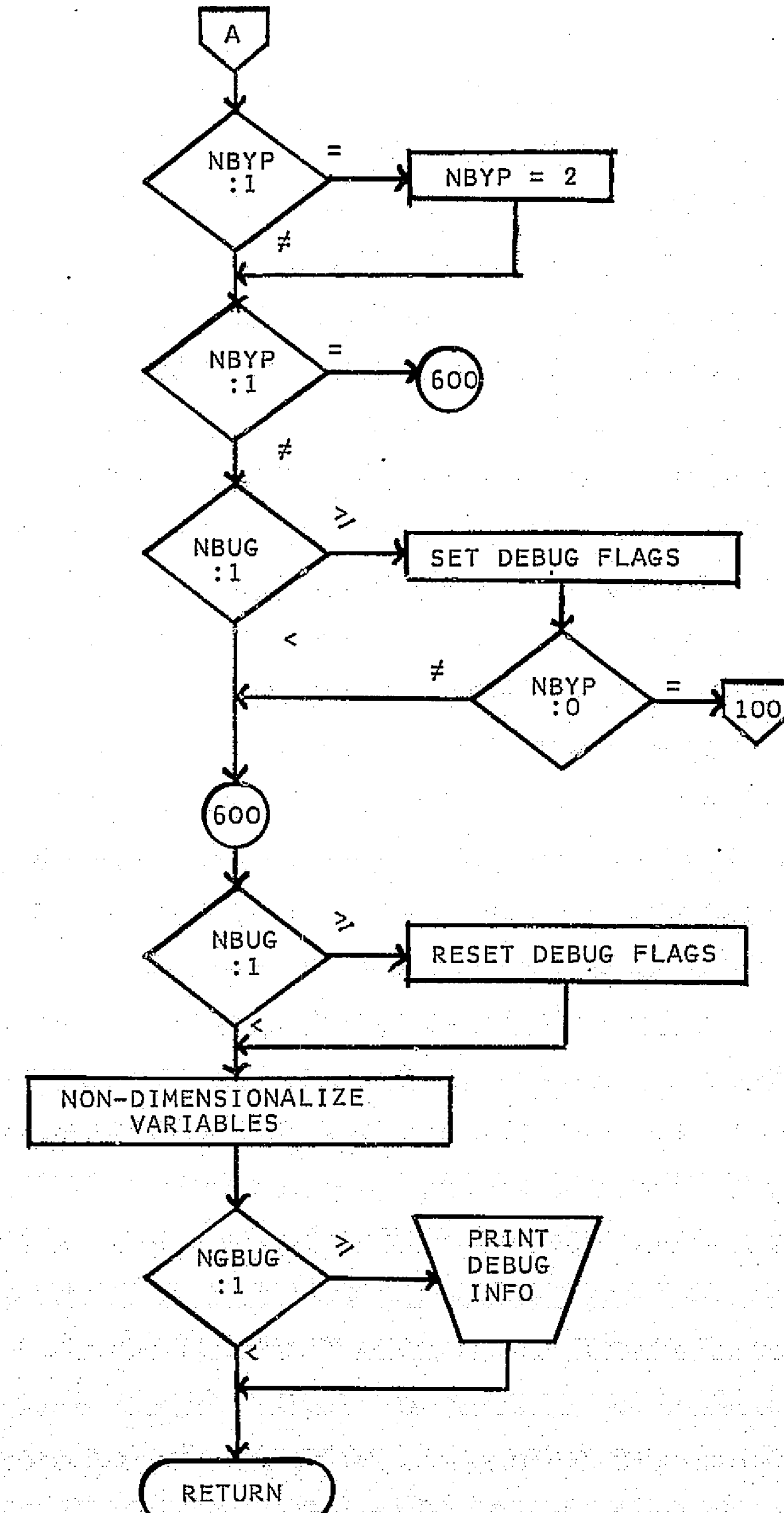


CALLED BY:
ENERSC

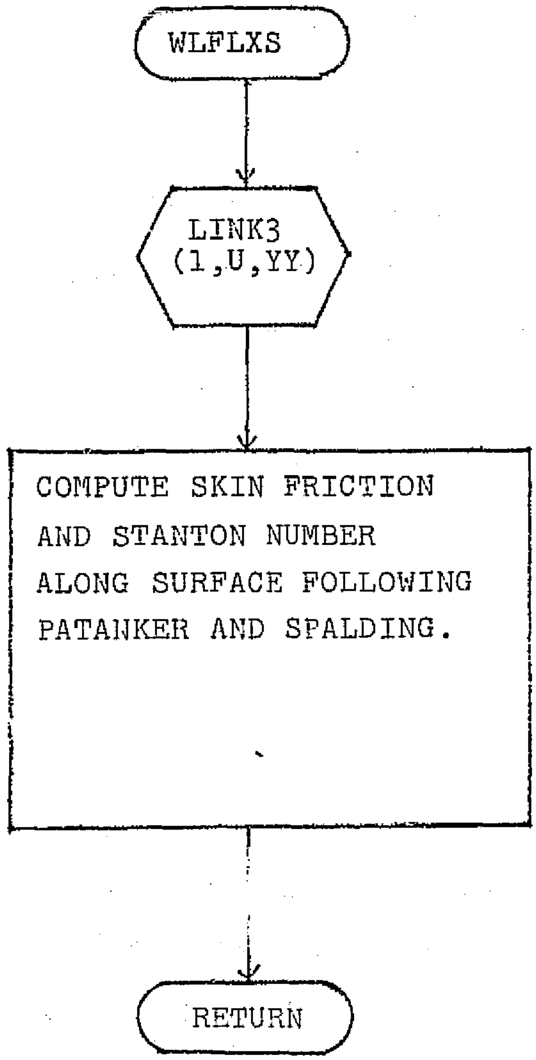


CALLED BY:
DERVBL
SOURCE

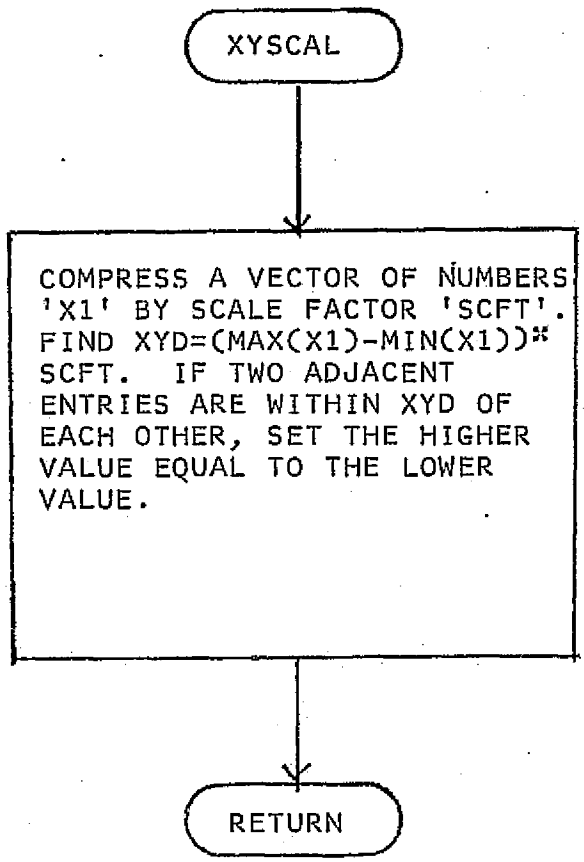

THERMO
100
DIMENSIONALIZE PRESSURE AND ENTHALPY
NGBUG :1
≥
PRINT DEBUG INFO
<
NBYP :2
=
600
≠
NBUG :1
≥
NBYP = 1
<
GPAHFT
NGBUG :1
≥
PRINT DEBUG INFO
A



CALLED BY:
DRHOGS



CALLED BY:
LINK2



CALLED BY:
DSCRTZ

OPERATING INSTRUCTIONS

The 3DBR Variant of COMOC constitutes approximately 10,000 cards. Considerable effort has been placed on minimizing input/output complexity and on providing the user with considerable latitude in data deck preparation. This section describes deck set-up, input procedures, output files and procedures, internal diagnostics that can be used to debug operating phases, and a description of the data decks for the test cases.

Deck Set-Up

Shown in Fig. 2 is an illustration of the deck set-up for 3DBR COMOC. Any user-written subroutines should be compiled first. The various machine requirements for the program are listed below.

Tape: RESTART defines an input and/or output tape which will be used for a restart condition or to store data for a future restart. The integer ending in column 25 defines a restart tape and the integer ending in column 30 defines the output print number that will be used for restarting. The integer ending in column 35 defines a tape that will be used to store outputs for future restarts. This number may be the same as in column 25.

Print: Printed output is sent to unit 6.

Punch: If NPUNCH = 7, in NAME01, node coordinates and element connections are punched on unit 7. If KOUT.gt.0and KPLVAR .gt. 0 in NAME01, then data generated for the variables defined by the PLOTS card will be output from the FEPLOT routine.

Reader: Card reading is executed from unit 5.

Disc: No internal requirements by program

Input

Unless a restart condition exists, all data are read on unit 5. All data which are strictly scalar information are read in free format style. Delimeters on these input cards can be either blanks, commas or column 80. Many features enable input data to be read in a simplified fashion.

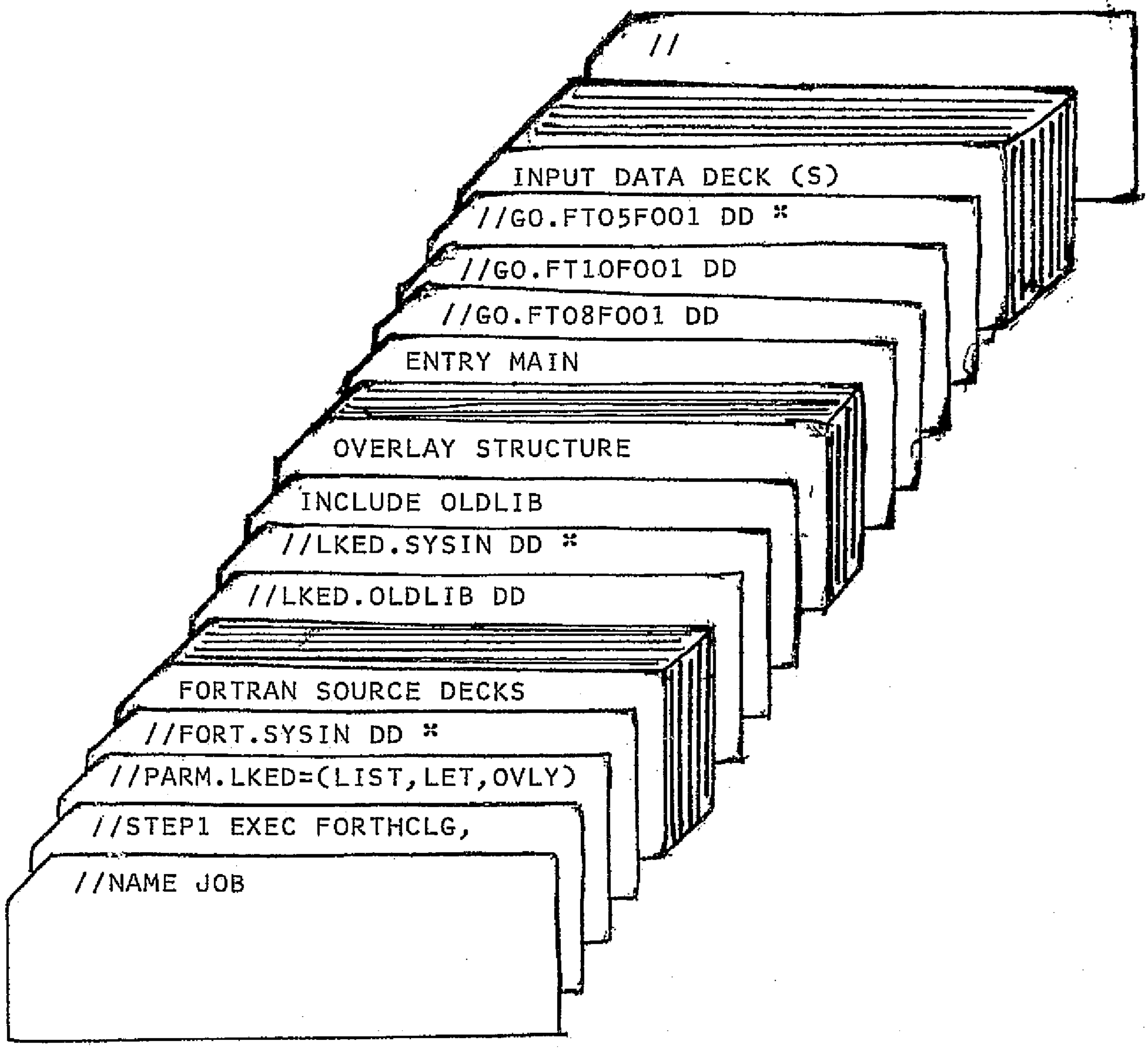


Fig. 2 IBM/360 DECK SETUP FOR PROGRAM

e.g.

Symbols	Interpretation
5*I3 12,	12, 15, 18, 21, 24
3*I-.5 3.1E3,	3100.0, 3099.5, 3099.0
6*23.2,	23.2, 23.2, 23.2, 23.2, 23.2, 23.2

A T at the end of input or a blank card will terminate the read cycle for a particular input parameter.

e.g.

```
ICALLS    -1
    2 2 4 5 1  4    2 5    T
```

stores the numbers 2 2 4 5 1 4 2 5 in the CALLS vector.

```
VTEMP
   42*533.0
blank card
```

stores 42 temperatures of 533.0 in the TEMP vector.

Output

Output for 3DBR COMOC is standardized to the format of the test cases. A highly adaptive output subroutine automatically scales data and allows for widely variable field size displays. Output formats are generated in the input deck by specification of which dependent variables, parameters, and scalars are to be printed during the output phase. Addition of an output array to the standard output is presented after the discussion of the data deck for the test case.

Restrictions and Limitations

Size of problem to be solved depends on the amount of storage available in core. The program contains a variable dimensioning scheme so that the total size can be specified by adjusting the dimension of the IZ array in MAIN.

Editing and Diagnostics

There are several flags that can be user set to provide detailed intermediate output for debug purposes, including KDUMP, NGBUG, IBUG1, IBUG2, IWRIT, IDIFRT, KODG and KOD5. In the following, each of these is discussed with respect to sample representative output from COMOC.

KDUMP .eq. 1 printout from BDINPT.

```
  VTEMP    0    0    0    0  -58    0    0    0    0    0    0    0    0

     VTEMP        66 ENTRIES.      NON-0 FACTOR =  0.18762E-02
  18415-    0.53300E 03 18416-    0.53300E 03 18417-    0.53300E 03 18418-    0.53300E 03 18419-    0.53300E 03
  18420-    0.53300E 03 18421-    0.53300E 03 18422-    0.53300E 03 18423-    0.53300E 03 18424-    0.53300E 03
  18425-    0.53300E 03 18426-    0.53300E 03 18427-    0.53300E 03 18428-    0.53300E 03 18429-    0.53300E 03
  18430-    0.53300E 03 18431-    0.53300E 03 18432-    0.53300E 03 18433-    0.53300E 03 18434-    0.53300E 03
  18435-    0.53300E 03 18436-    0.53300E 03 18437-    0.53300E 03 18438-    0.53300E 03 18439-    0.53300E 03
  18440-    0.53300E 03 18441-    0.53300E 03 18442-    0.53300E 03 18443-    0.53300E 03 18444-    0.53300E 03
  18445-    0.53300E 03 18446-    0.53300E 03 18447-    0.53300E 03 18448-    0.53300E 03 18449-    0.53300E 03
  18450-    0.53300E 03 18451-    0.53300E 03 18452-    0.53300E 03 18453-    0.53300E 03 18454-    0.53300E 03
  18455-    0.53300E 03 18456-    0.53300E 03 18457-    0.53300E 03 18458-    0.53300E 03 18459-    0.53300E 03
  18460-    0.53300E 03 18461-    0.53300E 03 18462-    0.53300E 03 18463-    0.53300E 03 18464-    0.53300E 03
  18465-    0.53300E 03 18466-    0.53300E 03 18467-    0.53300E 03 18468-    0.53300E 03 18469-    0.53300E 03
  18470-    0.53300E 03 18471-    0.53300E 03 18472-    0.53300E 03 18473-    0.53300E 03 18474-    0.53300E 03
  18475-    0.53300E 03 18476-    0.53300E 03 18477-    0.53300E 03 18478-    0.53300E 03 18479-    0.53300E 03
  18480-    0.53300E 03

  VYY      0    0    0  -27    0    0    0    0    0    0    0    0    0

     VYY          66 ENTRIES.      NON-0 FACTOR =  0.43995E-03
  17965-    0.0         17966-    0.0         17967-    0.0         17968-    0.0         17969-    0.0
  17970-    0.0         17971-    0.15030E 04 17972-    0.15030E 04 17973-    0.15030E 04 17974-    0.15030E 04
  17975-    0.15030E 04 17976-    0.15030E 04 17977-    0.16600E 04 17978-    0.16600E 04 17979-    0.16600E 04
  17980-    0.16600E 04 17981-    0.16600E 04 17982-    0.16600E 04 17983-    0.15500E 04 17984-    0.15500E 04
  17985-    0.17590E 04 17986-    0.17590E 04 17987-    0.17590E 04 17988-    0.17590E 04 17989-    0.15500E 04
  17990-    0.15500E 04 17991-    0.18330E 04 17992-    0.18330E 04 17993-    0.18330E 04 17994-    0.18330E 04
  17995-    0.15500E 04 17996-    0.15500E 04 17997-    0.18920E 04 17998-    0.18920E 04 17999-    0.18920E 04
  18000-    0.18920E 04 18001-    0.22720E 04 18002-    0.22720E 04 18003-    0.19420E 04 18004-    0.19420E 04
  18005-    0.19420E 04 18006-    0.19420E 04 18007-    0.22720E 04 18008-    0.22720E 04 18009-    0.19850E 04
  18010-    0.19850E 04 18011-    0.19850E 04 18012-    0.19850E 04 18013-    0.22720E 04 18014-    0.22720E 04
  18015-    0.20740E 04 18016-    0.20740E 04 18017-    0.20740E 04 18018-    0.20740E 04 18019-    0.22720E 04
  18020-    0.22720E 04 18021-    0.21690E 04 18022-    0.21690E 04 18023-    0.21690E 04 18024-    0.21690E 04
  18025-    0.22720E 04 18026-    0.22720E 04 18027-    0.22720E 04 18028-    0.22720E 04 18029-    0.22720E 04
  18030-    0.22720E 04

  VYYEND   1    0    0    0    0    0    0    0    0    0    0    0    0

    60 INTEGRATION NODES FOR VARIABLE    1
```

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```
KDUMP .eq. 1 debug output from FEDITN.
       Below is a hexadecimal dump of the vector entry points in the IZ array.
077748          0

07911C   00077748 00077790 00077928 00077808 00077E78 00077EA0 00077744 00077744 00077744 00077EC8 00077F18 000780A8
07914C   000780A8 000780A8 000780A8 000780A8 00078046 000780A8 000780AC 000780B0 00077744 CC077744 00078308 00078560
07917C   000787F3 00079115 00079DCC 0007A024 0007A27C 0007A4D4 0007A72C 00076350 0C078638 0C07B890 0007BAEB 0007BD40
0791AC   00078F98 0007DF98 0007C1F0 0007C448 0007C6A0 0007ECBC 00077744 00077744 00080624 00077744 00080548 00082970
0791DC   00085850 00086FCC 000873FC 0C077744 00077744 00077744 00077744 00077744 0C077744 CC077744 00077744 00077744
07920C   000873FC 00087404 0008740C 00087414 0008741C 00087424 0008742C 00087434 0008743C 0CC87444 0008744C 000876A4
07923C   000878FC 00087654 000870AC 00088004 0008825C 00088698 00088BF0 00088848 0C088DA0 00088FF8 00089250 000894A8
07926C   00089700 00089958 00077744 00089E08 0008A244 0008A49C 0008A6F4 0008A94C 0CC6ARA4 C008ADFC 00077744 00077744
07929C   00077744 00077744 00077744 0C077744 00088054 0008B2AC 0008B504 0008B75C 0008B9B4 C008B9B4 0008BDF0 0009C22C
0792CC   0008C484 0008D134 000800EC C0080DF4 0008D9FC 0008DE04 0008F05C 0008E060 0C08E49C 0008E4A4 0008E4AC 0008F9C4
0792FC   0008FC1C 0008FC44 0008FCCC 0C08FCD4 0008F96C 00077744 00077EC3 00078638 0CC9140C CCC9152C 0009157C 0009166C
07932C   0009142C 00091494 00091CAC CC091D9C 00091FF4 00092044 00092094 0009209C 0CC920A4 000920BC 00077744 00077744
07935C   00077744 00077744 00077744 0C077744 00077744 00077744 00077744 00077744 0C077744 00077744 00077744 00077744
07938C   00077744 00077744 00077744 0C077744 00077744 00077744 00077744 00077744 00077744 CC077744 00077744 00077744
0793BC   00077744 00077744 00077744 00077744 00077744 00077744 00077744 00077744 0C077744 CC077744 00077744 00077744
0793EC   00077744 00077744 00077744 0C077744 00077744 00077744 00077744 00077744 0C077744 00077744 00077744 00077744
07941C   00077744 00077744 00077744 0C077744 00092004 00092004 00077744 00077744
        Below is a printout of locations 201-400 of the IARRAY vector.
      IZ ENTRY POINTS FOR VECTORS

   1-     1     2-    21     3-   121     4-   241     5-   461     6-   471     7-     0     8-     C     9-     0    10-   481
  11-   501    12-   601    13-   601    14-   601    15-   601    16-   601    17-   601    18-   601    19-   602    20-   603
  21-     0    22-     0    23-   753    24-   903    25-  1053    26-  1655    27-  2466    28-  2616    29-  2766    30-  2916
  31-  3925    32-  3875    33-  4029    34-  4179    35-  4329    36-  4479    37-  4629    38-  4629    39-  4779    40-  4929
  41-  5079    42-  7515    43-     0    44-     0    45-  9144    46-     0    47-  9153    48- 11403    49- 14403    50- 15903
  51- 16174    52-     C    53-     0    54-     0    55-     0    56-     0    57-     0    58-     0    59-     0    60-     0
  61- 16174    62- 16176    63- 16178    64- 16180    65- 16182    66- 16184    67- 16186    68- 16188    69- 16190    70- 16192
  71- 16194    72- 16344    73- 16494    74- 16644    75- 16794    76- 16944    77- 17094    78- 17365    79- 17515    80- 17665
  81- 17815    82- 17965    83- 18115    84- 18265    85- 18415    86- 18565    87-     0    88- 18865    89- 19136    90- 19286
  91- 19436    92- 19536    93- 19736    94- 19886    95-     0    96-     0    97-     0    98-     0    99-     0   100-     0
 101- 20336   102- 20186   103- 20336   104- 20486   105- 20636   106- 20636   107- 20907   108- 21178   109- 21328   110- 22141
 111- 22954   112- 22956   113- 22958   114- 22960   115- 23110   116- 23111   117- 23382   118- 23384   119- 23386   120- 24736
 121- 24886   122- 24896   123- 24906   124- 24936   125- 24970   126-     0   127-   461   128-  4025   129- 26470   130- 26490
 131- 26510   132- 26570   133- 26810   134- 26920   135- 26970   136- 27030   137- 27180   138- 27200   139- 27220   140- 27222
 141- 27224   142- 27230   143-     0   144-     0   145-     0   146-     0   147-     0   148-     0   149-     0   150-     0
 151-     0   152-     0   153-     0   154-     0   155-     0   156-     0   157-     0   158-     0   159-     0   160-     0
 161-     0   162-     0   163-     0   164-     0   165-     0   166-     0   167-     0   168-     0   169-     0   170-     0
 171-     0   172-     0   173-     0   174-     0   175-     0   176-     0   177-     0   178-     0   179-     0   180-     0
 181-     0   182-     0   183-     0   184-     0   185-     0   186-     0   187-     0   188-     0   189-     0   190-     0
 191-     0   192-     C   193-     0   194-     0   195-     0   196-     0   197- 27236   198- 27236   199-     0   200-     0

    LINK1   1   0   0   0   C   0   0   0   0   0   0   0   OSETUP
```

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KDUMP .eq. 1 debug from DSCRTZ.

NODE COORDINATES

NODE	X1COR	X2COR	NODE	X1COR	X2COR	NODE	X1COR	X2COR
1	0.0	0.0	2	0.25000E-02	0.0	3	0.41667E-02	0.0
4	0.83333E-02	0.0	5	0.13333E-01	0.0	6	0.20833E-01	0.0
7	0.0	0.16667E-02	8	0.25000E-02	0.16667E-02	9	0.41667E-02	0.16667E-02
10	0.83333E-02	0.16667E-02	11	0.13333E-01	0.16667E-02	12	0.20833E-01	0.16667E-02
13	0.0	0.33333E-02	14	0.25000E-02	0.33333E-02	15	0.41667E-02	0.33333E-02
16	0.83333E-02	0.33333E-02	17	0.13333E-01	0.33333E-02	18	0.20833E-01	0.33333E-02
19	0.0	0.50000E-02	20	0.25000E-02	0.50000E-02	21	0.41667E-02	0.50000E-02
22	0.83333E-02	0.50000E-02	23	0.13333E-01	0.50000E-02	24	0.20833E-01	0.50000E-02
25	0.0	0.66667E-02	26	0.25000E-02	0.66667E-02	27	0.41667E-02	0.66667E-02
28	0.83333E-02	0.66667E-02	29	0.13333E-01	0.66667E-02	30	0.20833E-01	0.66667E-02
31	0.0	0.83333E-02	32	0.25000E-02	0.83333E-02	33	0.41667E-02	0.83333E-02
34	0.83333E-02	0.83333E-02	35	0.13333E-01	0.83333E-02	36	0.20833E-01	0.83333E-02
37	0.0	0.10000E-01	38	0.25000E-02	0.10000E-01	39	0.41667E-02	0.10000E-01
40	0.83333E-02	0.10000E-01	41	0.13333E-01	0.10000E-01	42	0.20833E-01	0.10000E-01
43	0.0	0.11667E-01	44	0.25000E-02	0.11667E-01	45	0.41667E-02	0.11667E-01
46	0.83333E-02	0.11667E-01	47	0.13333E-01	0.11667E-01	48	0.20833E-01	0.11667E-01
49	0.0	0.15833E-01	50	0.25000E-02	0.15833E-01	51	0.41667E-02	0.15833E-01
52	0.83333E-02	0.15833E-01	53	0.13333E-01	0.15833E-01	54	0.20833E-01	0.15833E-01
55	0.0	0.21667E-01	56	0.25000E-02	0.21667E-01	57	0.41667E-02	0.21667E-01
58	0.83333E-02	0.21667E-01	59	0.13333E-01	0.21667E-01	60	0.20833E-01	0.21667E-01
61	0.0	0.30000E-01	62	0.25000E-02	0.30000E-01	63	0.41667E-02	0.30000E-01
64	0.83333E-02	0.30000E-01	65	0.13333E-01	0.30000E-01	66	0.20833E-01	0.30000E-01

KDUMP .eq. 1 printout from BDINPT.

```
MPARA  -1   0   0   0   0   0   0   0   0   0   0   0   0

MPARA     49 ENTRIES.
26970-     2 26971-     2 26972-   162 26973-   164 26974-   163 26975-     2 26976-     2 26977-     2 26978-   164 26979-   163
26980-     2 26981-     2 26982-     2 26983-   170 26984-   174 26985-     2 26986-     2 26987-     2 26988-   165 26989-     2
26990-     2 26991-  -175 26992-     2 26993-     2 26994-     2 26995-     2 26996-     2 26997-     2 26998-   176 26999-     2
27000-     2 27001-     2 27002-     2 27003-   177 27004-   178 27005-     2 27006-     2 27007-   169 27008-   168 27009-   167
27010-     2 27011-     2 27012-     2 27013-     2 27014-     2 27015-     2 27016-     2 27017-     2 27018-     2

NCLIST   0   0   0   0   0   0   0   0   0   0   0   0   0

IONUMB  -1   0   0   0   0   0   0   0   0   0   0   0   0

IONUMB    50 ENTRIES.
26510-   203 26511-    43 26512-    43 26513-    43 26514-    43 26515-   200 26516-    27 26517-   200 26518-    27 26519-    27
26520-   200 26521-    10 26522-   200 26523-    10 26524-    10 26525-   200 26526-    58 26527-   200 26528-    58 26529-   200
26530-   200 26531-    97 26532-   200 26533-    97 26534-   200 26535-   200 26536-    30 26537-   200 26538-    30 26539-   200
26540-   200 26541-    38 26542-   200 26543-    38 26544-    38 26545-   999 26546-   200 26547-    36 26548-    36 26549-    36
26550-    36 26551-   200 26552-    61 26553-   100 26554-   134 26555-   122 26556-    11 26557-    12 26558-    14 26559-    85

IOSAVE  -1   0   0   0   0   0   0   0   0   0   0   0   0

IOSAVE    14 ENTRIES.
24936-  1248 24937-   285 24938-   323 24939-   284 24940- 10248 24941-  2248 24942-   278 24943-  4248 24944-  9248 24945-  8248
24946-  1247 24947-   334 24948-   292 24949-   314

ICMULT  -1   0   0   0   0   0   0   0   0   0   0   0   0

ICMULT    14 ENTRIES.
24906-     2 24907-     2 24908-     2 24909-     2 24910-     2 24911-     2 24912-     2 24913-     2 24914-     2 24915-     2
24916-     2 24917-     2 24918-     2 24919-     2
```

KDMP .eq. 1 debug printout from ELEM or FINDBE.

100 ELEMENTS.

ELEMENTS . . . 3 NODES / ELEMENT. . . 5 ELEMENTS / ROW

55	62	61	55	56	62	56	63	62	56	57	63	57	64	63
57	58	64	58	65	64	58	59	65	59	66	65	59	60	66
49	56	55	49	50	56	50	57	56	50	51	57	51	58	57
51	52	58	52	59	58	52	53	59	53	60	59	53	54	60
43	50	49	43	44	50	44	51	50	44	45	51	45	52	51
45	46	52	46	53	52	46	47	53	47	54	53	47	48	54
37	44	43	37	38	44	38	45	44	38	39	45	39	46	45
39	40	46	40	47	46	40	41	47	41	48	47	41	42	48
31	38	37	31	32	38	32	39	38	32	33	39	33	40	39
33	34	40	34	41	40	34	35	41	35	42	41	35	36	42
25	32	31	25	26	32	26	33	32	26	27	33	27	34	33
27	28	34	28	35	34	28	29	35	29	36	35	29	30	36
19	26	25	19	20	26	20	27	26	20	21	27	21	28	27
21	22	28	22	29	28	22	23	29	23	30	29	23	24	30
13	20	19	13	14	20	14	21	20	14	15	21	15	22	21
15	16	22	16	23	22	16	17	23	17	24	23	17	18	24
7	14	13	7	8	14	8	15	14	8	9	15	9	16	15
9	10	16	10	17	16	10	11	17	11	18	17	11	12	18
1	8	7	1	2	8	2	9	8	2	3	9	3	10	9
3	4	10	4	11	10	4	5	11	5	12	11	5	6	12

Debug printout from THERMO and GPAHFT.

If IBUG2 .gt. IBUG1 then set IBUG1 = IBUG2.
If IBUG1 .gt. NGBUG then set NGBUG = IBUG1.

NGBUG .gt. 0 prints debug information from THERMO.
IBUG1 .gt. 0 prints input and output stations from GPAHFT.
IBUG2 .gt. 0 prints iteration loop data from GPAHFT.

All three flags are decremented by 1 with each pass thru DRHOGS; print stops when flags reduce to 0 or lower.

If NDUMP .GT. 0 then certain failures in GAS will turn on NGBUG AND IBUG1 thus causing printout at failure conditions. Some conditions will be fatal and create a node coordinate printout followed by a dependent variable printout.

```
        INPUT NODE   1          INPUT NODE   1          INPUT NODE   1          INPUT NODE   1          INPUT NODE   1

   MASS FRACTIONS
   Y( 2) =    0.0             Y( 3) =   0.23300E 00  Y( 4) =   0.0             Y( 5) =   0.76700E 00  Y( 6) =   0.0
   Y( 7) =    0.0             Y( 8) =   0.0          Y( 9) =   0.0             Y( 10) =  0.0          Y(
   P =       0.34265E-01 H =     0.0
   PPR =     0.91192E-01 HPR =   0.0           VELZ =   0.0            HSPR =    0.0
      PRESS(ATM)      TEMP(R)         ALPH            PHI          A(M/SEC) CP(JOULE/KGDK)
    0.91192E-01    0.53300E 03    0.25098E 00    0.10000E 01    0.34533E 03    0.10114E 04

      H(JOULE/KG)      GAMMA          MOL.WT.       RHO(KG/M3)  S(JOULE/KGDK)VISC(NT.SEC/M2
     0.55505E 06    0.13981E 01    0.28853E 02    0.10032E 00    0.75666E 04    0.18278E-04

                                    -MASS FRACTION-

   H2O          O2          H2          N2          AR          O          H          NO          OH
   0.0        0.233E 00  0.0        0.767E 00  0.0        0.0        0.0        0.0        0.0

                                    -MOLE FRACTIONS-

   H2O          O2          H2          N2          AR          O          H          NO          OH
   0.0        0.210E 00  0.0        0.790E 00  0.0        0.0        0.0        0.0        0.0

        OUTPUT NODE   1     OUTPUT NODE   1     OUTPUT NODE   1     OUTPUT NODE   1     OUTPUT NODE   1

   MASS FRACTIONS
   Y( 2) =    0.0             Y( 3) =   0.23300E 00  Y( 4) =   0.0             Y( 5) =   0.76700E 00  Y( 6) =   0.0
   Y( 7) =    0.0             Y( 8) =   0.0          Y( 9) =   0.0             Y( 10) =  0.0          Y(

   HSPR =     0.55505E 06 RHOPR =    0.10832E 00 CPFPR =    0.10114E 04 TPR =    0.53300E 03
   HS =       0.55505E 06 T =        0.10000E 01 RHO =      0.19277E 00 CPF =    0.10067E 01
```

NGBUG .GT. 0 (input node mass fractions)

IBUG1 .gt. 0

NGETH = 1

Compute enthalpy as a function of total temperature.

NGBUG .gt. 0 (output node)

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```
INPUT NODE   1     INPUT NODE   1     INPUT NODE   1     INPUT NODE   1     INPUT NODE   1

MASS FRACTIONS
Y(  2) =    0.0          Y(  3) =   0.23300E 00  Y(  4) =   0.0          Y(  5) =   0.76700E 00  Y(  6) =   0.0
Y(  7) =    0.0          Y(  8) =   0.0          Y(  9) =   0.0          Y( 10) =   0.0          Y(
P =     0.34265E-01 H =      0.38543E+02
PPR =   0.91192E-01 HPR =    0.55505E 06 VEL2 =     0.0        HSPR =    0.55505E 06
  PRESS(ATM)       TEMP(R)          ALPH             PHI        A(M/SEC) CP(JOULE/KGDK)
 0.91192E-01     0.53300E 03     0.25098E 00     0.10000E 01     0.34533E 03     0.10114E 04

 H(JOULE/KG)       GAMMA           MOL.WT.        RHO(KG/M3)  S(JOULE/KGDK)VISC(NT.SEC/M2
 0.55505E 06     0.13981E 01     0.28853E 02     0.10832E 00     0.75666E 04     0.18278E-04
--------------------------------------------------------------------------------------------
                                  -MASS FRACTION-
--------------------------------------------------------------------------------------------
H2O        O2        H2        N2        AR        O         H         NO        OH


0.0        0.233E 00 0.0       0.767E 00 0.0       0.0       0.0       0.0       0.0
--------------------------------------------------------------------------------------------
                                  -MOLE FRACTIONS-
--------------------------------------------------------------------------------------------
H2O        O2        H2        N2        AR        O         H         NO        OH
0.0        0.210E 00 0.0       0.790E 00 0.0       0.0       0.0       0.0       0.0
  PRESS(ATM)       TEMP(R)          ALPH             PHI        A(M/SEC) CP(JOULE/KGDK)
 0.91192E-01     0.53300E 03     0.25098E 00     0.10000E 01     0.34533E 03     0.10114E 04

 H(JOULE/KG)       GAMMA           MOL.WT.        RHO(KG/M3)  S(JOULE/KGDK)VISC(NT.SEC/M2
 0.55505E 06     0.13981E 01     0.28853E 02     0.10832E 00     0.75666E 04     0.18278E-04
--------------------------------------------------------------------------------------------
                                  -MASS FRACTION-
--------------------------------------------------------------------------------------------
H2O        O2        H2        N2        AR        O         H         NO        OH
0.0        0.233E 00 0.0       0.767E 00 0.0       0.0       0.0       0.0       0.0
--------------------------------------------------------------------------------------------
                                  -MOLE FRACTIONS-
--------------------------------------------------------------------------------------------
H2O        O2        H2        N2        AR        O         H         NO        OH
0.0        0.210E 00 0.0       0.790E 00 0.0       0.0       0.0       0.0       0.0

OUTPUT NODE   1     OUTPUT NODE   1     OUTPUT NODE   1     OUTPUT NODE   1     OUTPUT NODE   1

MASS FRACTIONS
Y(  2) =    0.0          Y(  3) =   0.23300E 00  Y(  4) =   0.0          Y(  5) =   0.76700E 00  Y(  6) =   0.0
Y(  7) =    0.0          Y(  8) =   0.0          Y(  9) =   0.0          Y( 10) =   0.0          Y(
HSPR =    0.55505E 06 RHOPR =   0.10832E 00 CPFPR =    0.10114E 04 TPR =    0.53300E 03
HS =      0.38543E-02 T =       0.10000E 01 RHO =      0.67618E-02 CPF =    0.24162E 00
```

NGBUG .gt. 0

IBUG1 .gt. 0

NGETH = 0

Compute temperature, specific heat, and density as function of enthalpy, pressure and mass fractions.

1st and last passes are printed when IBUG1 .gt. 0;

when IBUG2.gt. 0 all intermediate passes are shown.

NGBUG .gt. 0

IWRIT .gt. 0 debug output from CONTES.
IWRIT is decremented by 1 for each pass thru CONTES; when IWRIT .le. 0 debug print stops.

If IWRIT is still .gt. 0 when VSTART is passed, then more debug information containing the RHO*Vs is printed out.

The vectors VSIN and WCOS are printed on the first pass thru CONTES.

VSIN (SINE of angle between lowest and highest node in column)

1	0.10000E 01	2	0.10000E 01	3	0.10000E 01	4	0.10000E 01	5	0.10000E 01

WCOS (COSINE of angle between lowest and highest node in column.)

1	0.0	2	0.0	3	0.0	4	0.0	5	0.0

Present value of RHO*U RHO*U	Last value of RHO*U RHO*ULAST	2nd last change in RHO*U DELRHOU	Last change in RHO*U UPLAST	Downstream derivative UPRIME	Coord. of normal node X2	Line counter L	Node number being processed K	
0.0	0.0	0.0	0.0	0.0	0.0	1	1	Data for Column no. 1
0.20020E 00	0.20020E 00	-0.40531E-05	0.20020E 00	-0.33367E 05	0.83333E-01	2	7	
0.25074E 00	0.25077E 00	-0.32723E-04	0.25077E 00	-0.41797E 05	0.16667E 00	3	13	
0.90522E-02	0.90516E-02	0.56252E-06	0.90516E-02	-0.15086E 04	0.25000E 00	4	19	
0.90517E-02	0.90515E-02	0.37253E-08	0.90515E-02	-0.15086E 04	0.33333E 00	5	25	
0.90413E-02	0.90531E-02	0.81245E-05	0.90531E-02	-0.15083E 04	0.41667E 00	6	31	
0.98610E 00	0.10004E 01	-0.14316E-01	0.10004E 01	-0.16779E 06	0.50000E 00	7	37	
0.10009E 01	0.10009E 01	0.0	0.10009E 01	-0.16682E 06	0.58333E 00	8	43	
0.10009E 01	0.10009E 01	0.0	0.10009E 01	-0.16682E 06	0.79167E 00	9	49	
0.10009E 01	0.10009E 01	0.0	0.10009E 01	-0.16682E 06	0.10833E 01	10	55	
0.10009E 01	0.10009E 01	0.0	0.10009E 01	-0.16682E 06	0.15000E 01	11	61	
0.0	0.0	0.0	0.0	0.0	0.0	12	2	Data for Column no. 2
0.20020E 00	0.20020E 00	-0.32187E-05	0.20020E 00	-0.33367E 05	0.83333E-01	13	8	
0.25071E 00	0.25076E 00	-0.53644E-04	0.25076E 00	-0.41798E 05	0.16667E 00	14	14	
0.90522E-02	0.90516E-02	0.54017E-06	0.90516E-02	-0.15086E 04	0.25000E 00	15	20	
0.90519E-02	0.90516E-02	0.34273E-06	0.90516E-02	-0.15086E 04	0.33333E 00	16	26	
0.90549E-02	0.90529E-02	0.69849E-05	0.90529E-02	-0.15083E 04	0.41667E 00	17	32	
0.99144E 00	0.10006E 01	-0.91314E-02	0.10006E 01	-0.16744E 06	0.50000E 00	18	38	
0.10009E 01	0.10009E 01	-0.95367E-06	0.10009E 01	-0.16682E 06	0.58333E 00	19	44	
0.10009E 01	0.10009E 01	-0.95367E-06	0.10009E 01	-0.16682E 06	0.79167E 00	20	50	
0.10009E 01	0.10009E 01	0.0	0.10009E 01	-0.16682E 06	0.10833E 01	21	56	
0.10009E 01	0.10009E 01	0.0	0.10009E 01	-0.16682E 06	0.15000E 01	22	62	

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IWRIT .gt. 0 debug output from user's DFCFBL.
IWRIT is decremented by 1 in CONTES for each pass thru CONTES; when IWRIT .le. 0 debug print stops.

Eddy viscosity, mixing length (inner region) EL(LL)	Mixing length AL(LL)	Intermittancy factor GAMMA(LL)	Velocity at upper node U(I)	Velocity at lower node	Coordinate of upper node Y(KT+I)	Coordinate of lower node Y(KT+I-1)	Density at upper node RHO(I)
2	2	2	7	1	2	1	7
0.26[illegible]E-02	0.33333E-01	0.10000E 01	0.66165E 00	0.0	0.83333E-01	0.0	0.30258E 00
3	3	3	13	7	3	2	13
0.12[illegible]E-02	0.66667E-01	0.10000E 01	0.73052E 00	0.66165E 00	0.16667E 00	0.83333E-01	0.34329E 00
4	4	4	19	13	4	3	19
0.11[illegible]E-03	0.10000E 00	0.10000E 01	0.65990E 00	0.73052E 00	0.25000E 00	0.16667E 00	0.13716E-01
5	5	5	25	19	5	4	25
0.0	0.13333E 00	0.10000E 01	0.65990E 00	0.65990E 00	0.33333E 00	0.25000E 00	0.13716E-01
6	6	6	31	25	6	5	31
0.0	0.13500E 00	0.99959E 00	0.65990E 00	0.65990E 00	0.41667E 00	0.33333E 00	0.13716E-01
7	7	7	37	31	7	6	37
0.74[illegible]E-01	0.13500E 00	0.99095E 00	0.10000E 01	0.65990E 00	0.50000E 00	0.41667E 00	0.10009E 01
8	8	8	43	37	8	7	43
0.0	0.13500E 00	0.99980E 00	0.10000E 01	0.10000E 01	0.58333E 00	0.50000E 00	0.10009E 01
9	9	9	49	43	9	8	49
0.0	0.13500E 00	0.99283E 00	0.10000E 01	0.10000E 01	0.79167E 00	0.58333E 00	0.10009E 01
10	10	10	55	49	10	9	55
0.0	0.13500E 00	0.94925E 00	0.10000E 01	0.10000E 01	0.10833E 01	0.79167E 00	0.10009E 01
11	11	11	61	55	11	10	61
0.0	0.13500E 00	0.50000E 00	0.10000E 01	0.10000E 01	0.15000E 01	0.10833E 01	0.10009E 01

E2(1) = 0.41961E-02 E2(2) = 0.41961E-02 E2(3) = 0.41961E-02 E2(4) = 0.41961E-02 E2(5) = 0.41961E-02
E2(6) = 0.41960E-02 E2(7) = 0.41959E-02 E2(8) = 0.41952E-02 E2(9) = 0.41828E-02 E2(10) = 0.39831E-02
E2(11) = 0.20[illegible]E-02 E2(

} Eddy visc. Mass defect (outer region)

IDIFRT .GT. 0 Debug output.

IDIFRT is decremented by 1 for each pass thru WLFLXS, when IDIFRT .LE. 0 debug print stops.

Pos. of node in INDIX vector	Column no.	No. of nodes in column	No. of top node	No. of node just off wall	Non-dim. height of column	Dim. density just off wall	Dim. u1 velocity just off wall	Dim. height of node just off wall	Local Reynold's number
KT	KK	M	N	NN	H	RHOCF	UCF	YCF	REY
1	1	11	61	7	0.12000E 02	0.10415E-01	0.15030E 04	0.16667E-02	0.87173E 01
		TAUWL = 0.26219E 04 UEDGR = 0.22720E 04							
		Y(61) = 0.12000E 02 Y(7) = 0.66667E 00 Y(1) = 0.0							
12	2	11	62	8	0.12000E 02	0.10415E-01	0.15030E 04	0.16667E-02	0.87173E 01
		TAUWL = 0.26219E 04 UEDGR = 0.22720E 04							
		Y(62) = 0.12000E 02 Y(8) = 0.66667E 00 Y(2) = 0.0							
23	3	11	63	9	0.12000E 02	0.10415E-01	0.15030E 04	0.16667E-02	0.87173E 01
		TAUWL = 0.26219E 04 UEDGR = 0.22720E 04							
		Y(63) = 0.12000E 02 Y(9) = 0.66667E 00 Y(3) = 0.0							
34	4	11	64	10	0.12000E 02	0.10415E-01	0.15030E 04	0.16667E-02	0.87173E 01
		TAUWL = 0.26219E 04 UEDGR = 0.22720E 04							
		Y(64) = 0.12000E 02 Y(10) = 0.66667E 00 Y(4) = 0.0							
45	5	11	65	11	0.12000E 02	0.10415E-01	0.15030E 04	0.16667E-02	0.87173E 01
		TAUWL = 0.26219E 04 UEDGR = 0.22720E 04							
		Y(65) = 0.12000E 02 Y(11) = 0.66667E 00 Y(5) = 0.0							
56	6	11	66	12	0.12000E 02	0.10415E-01	0.15030E 04	0.16667E-02	0.87173E 01
		TAUWL = 0.26219E 04 UEDGR = 0.22720E 04							
		Y(66) = 0.12000E 02 Y(12) = 0.66667E 00 Y(6) = 0.0							

KODG .gt. 0 debug printout from GEOMFL.

ELEMENT 100 NODE 5 NODE 6 NODE 12

X1	0.53333E 01	0.83333E 01	0.83333E 01	(non-dim. transverse coordinate)
X2	0.0	0.0	0.66667E 00	(non-dim. norman coordinate)

AL (L-matrix)

1	-0.33333E 00	2	0.33333E 00	3	0.0	4	0.0	5	-0.15000E 01
6	0.15000E 01								

AK TRAN (K-cranspose matrix)

1	0.10000E 01	2	0.0	3	0.0	4	0.10000E 01

B211S

1	0.11111E 00	2	-0.11111E 00	3	0.23611E 01	4	0.0	5	-0.22500E 01
6	0.22500E 01								

B211

1	0.11111E 00	2	-0.11111E 00	3	0.0	4	-0.11111E 00	5	0.23611E 01
6	-0.22500E 01	7	0.0	8	-0.22500E 01	9	0.22500E 01		

LENGTH TIMES THICKNESS (non-dimensional)

1	0.34601E 01	2	0.10000E 01	3	0.33993E 01	4	0.66667E 00	5	0.37269E 01
6	0.16667E 01	7	0.38873E 01	8	0.20000E 01	9	0.44845E 01	10	0.30000E 01
11	0.25346E 01	12	0.10000E 01	13	0.24267E 01	14	0.66667E 00	15	0.28674E 01
16	0.16667E 01	17	0.30732E 01	18	0.20000E 01	19	0.38006E 01	20	0.30000E 01
21	0.17436E 01	22	0.10000E 01	23	0.17951E 01	24	0.66667E 00	25	0.23570E 01
26	0.16667E 01	27	0.26034E 01	28	0.20000E 01	29	0.34319E 01	30	0.30000E 01

KODG .at. 0 debug printout from GEOMFL.

AREA TIMES THICKNESS (non-dimensional)

1	0.16667E 01	2	0.16667E 01	3	0.11111E 01	4	0.11111E 01	5	0.27778E 01
6	0.27778E 01	7	0.33333E 01	8	0.33333E 01	9	0.50000E 01	10	0.50000E 01
11	0.11667E 01	12	0.11667E 01	13	0.77778E 00	14	0.77778E 00	15	0.19444E 01
16	0.19444E 01	17	0.23333E 01	18	0.23333E 01	19	0.35000E 01	20	0.35000E 01
21	0.83333E 00	22	0.83333E 00	23	0.55555E 00	24	0.55555E 00	25	0.13889E 01
26	0.13889E 01	27	0.16667E 01	28	0.16667E 01	29	0.25000E 01	30	0.25000E 01

GEOM1 (1st part of B2001 matrix)

1	-0.41667E-01	2	0.37253E-08	3	0.41667E-01	4	0.0	5	-0.41667E-01
6	0.41667E-01	7	-0.27778E-01	8	0.37253E-08	9	0.27778E-01	10	0.0
11	-0.27778E-01	12	0.27778E-01	13	-0.69444E-01	14	0.37253E-07	15	0.69444E-01
16	0.0	17	-0.69444E-01	18	0.69444E-01	19	-0.83333E-01	20	0.48429E-07
21	0.83333E-01	22	0.0	23	-0.83333E-01	24	0.83333E-01	25	-0.12500E 00
26	0.59605E-07	27	0.12500E 00	28	0.0	29	-0.12500E 00	30	0.12500E 00

GEOM2 (2nd part of B2001 matrix)

1	-0.18626E-07	2	0.13889E 00	3	-0.13889E 00	4	-0.13889E 00	5	0.13889E 00
6	0.0	7	-0.22352E-07	8	0.13889E 00	9	-0.13889E 00	10	-0.13889E 00
11	0.13889E 00	12	0.0	13	-0.37253E-08	14	0.13889E 00	15	-0.13899E 00
16	-0.13889E 00	17	0.13889E 00	18	0.0	19	0.22352E-07	20	0.13889E 00
21	-0.13889E 00	22	-0.13889E 00	23	0.13889E 00	24	0.0	25	-0.48429E-07
26	0.13889E 00	27	-0.13889E 00	28	-0.13989E 00	29	0.13889E 00	30	0.0

X12 (base of transformed triangle)

1	0.34801E 01	2	0.10000E 01	3	0.33993E 01	4	0.66667E 00	5	0.37268E 01
6	0.16667E 01	7	0.38873E 01	8	0.20000E 01	9	0.44845E 01	10	0.30000E 01
11	0.25386E 01	12	0.10000E 01	13	0.24267E 01	14	0.66667E 00	15	0.26674E 01
16	0.16667E 01	17	0.30732E 01	18	0.20000E 01	19	0.38006E 01	20	0.30000E 01
21	0.19436E 01	22	0.10000E 01	23	0.17951E 01	24	0.66667E 00	25	0.23570E 01
26	0.16667E 01	27	0.26034E 01	28	0.20000E 01	29	0.34319E 01	30	0.30000E 01

X23 (height of transformed triangle)

1	0.95743E 00	2	0.33333E 01	3	0.65372E 00	4	0.33333E 01	5	0.14907E 01
6	0.33333E 01	7	0.17150E 01	8	0.33333E 01	9	0.22299E 01	10	0.33333E 01
11	0.91914E 00	12	0.23333E 01	13	0.64101E 00	14	0.23333E 01	15	0.13562E 01
16	0.23333E 01	17	0.15185E 01	18	0.23333E 01	19	0.18418E 01	20	0.23333E 01
21	0.85749E 00	22	0.16667E 01	23	0.61898E 00	24	0.16667E 01	25	0.11785E 01
26	0.16667E 01	27	0.12804E 01	28	0.16667E 01	29	0.14569E 01	30	0.16667E 01

KOD5 .gt. 0 debug outputfrom DERVBL
KOD5 is decremented by 1 for each NEQKIN passes thru DERVBL when KOD5 .le. 0 debug print stops.

U GLOBAL VECTOR (Non-dim. nodal values of dependent variable being computed at this time.)

1	0.0	2	0.0	3	0.0	4	0.0	5	0.0
6	0.0	7	0.66124E 00	8	0.66124E 00	9	0.66124E 00	10	0.66124E 00
11	0.66124E 00	12	0.66124E 00	13	0.73031E 00	14	0.73031E 00	15	0.73031E 00
16	0.73031E 00	17	0.73031E 00	18	0.73031E 00	19	0.63192E 00	20	0.68192E 00
21	0.77387E 00	22	0.77387E 00	23	0.77387E 00	24	0.77387E 00	25	0.68192E 00
26	0.68192E 00	27	0.80642E 00	28	0.80642E 00	29	0.80642E 00	30	0.80642E 00
31	0.68192E 00	32	0.68192E 00	33	0.83238E 00	34	0.83238E 00	35	0.83238E 00
36	0.83238E 00	37	0.99956E 00	38	0.99956E 00	39	0.85438E 00	40	0.85438E 00
41	0.85438E 00	42	0.85438E 00	43	0.99956E 00	44	0.99956E 00	45	0.87329E 00
46	0.87329E 00	47	0.87329E 00	48	0.87329E 00	49	0.99956E 00	50	0.99956E 00
51	0.91245E 00	52	0.91245E 00	53	0.91245E 00	54	0.91245E 00	55	0.99956E 00
56	[illegible]	57	0.95425E 00	58	0.95425E 00	59	0.95425E 00	60	0.95425E 00
61	[illegible]	62	0.99956E 00	63	0.99956E 00	64	0.99956E 00	65	0.99956E 00
66	[illegible]								

C ASSEMBLED [illegible] (Condensed C-Matrix from left hand side. Boundary nodes 1-6 are placed at the end so that position 1 refers to node 7 which is 1st node integrated)

1	0.45503E-01	2	0.55708E-01	3	0.14353E 00	4	0.21690E 00	5	0.29958E 00
6	0.15467E 00	7	0.42158E-01	8	0.12480E 00	9	0.19689E 00	10	0.30621E 00
11	[illegible]	12	0.24211E 00	13	0.93470E-02	14	0.52312E-01	15	0.21978E 00
16	[illegible]	17	0.49007E 00	18	0.28593E 00	19	0.31268E-02	20	0.30476E-01
21	0.21766E 00	22	0.40506E 00	23	0.55487E 00	24	0.32535E 00	25	0.85642E-01
26	0.74057E-01	27	0.26375E 00	28	0.45162E 00	29	0.61696E 00	30	0.36278E 00
31	[illegible]	32	0.41190E 00	33	0.32662E 00	34	0.49706E 00	35	0.67895E 00
36	0.39735E 00	37	0.66637E 00	38	0.86574E 00	39	0.73447E 00	40	0.10074E 01
41	0.13942E 01	42	0.47720E 00	43	0.10551E 01	44	0.15579E 01	45	0.14659E 01
46	0.20703E 01	47	0.28517E 01	48	0.15225E 01	49	0.14993E 01	50	0.22853E 01
51	[illegible]	52	0.38701E 01	53	0.53403E 01	54	0.27893E 01	55	0.55531E 00
56	0.14908E 01	57	0.15541E 01	58	0.26711E 01	59	0.35136E 01	60	0.29583E 01
61	0.16710E-01	62	0.16710E-01	63	0.31563E-01	64	0.42702E-01	65	0.61269E-01
66	0.16710E-01								

RHS ASSEMBLED [illegible] (Assembled contributions to right hand side. Boundary nodes 1-6 are placed at the end so that position 1 refers to node 7 which is 1st node integrated)

1	-0.44089E-02	2	-0.48402E-02	3	-0.86897E-02	4	-0.12039E-01	5	-0.17128E-01
6	-0.55827E-02	7	-0.60448E-03	8	-0.13093E-02	9	-0.55309E-03	10	-0.98025E-03
11	-0.12878E-02	12	-0.10757E-02	13	0.98686E-04	14	0.10422E-02	15	-0.69328E-03
16	0.12132E-03	17	0.16526E-03	18	0.10529E-03	19	0.86659E-10	20	0.97197E-03
21	-0.11346E-02	22	-0.14836E-03	23	-0.21654E-03	24	-0.35502E-04	25	0.61788E-01
26	0.53213E-01	27	-0.11807E-02	28	-0.26063E-03	29	-0.35382E-03	30	-0.22195E-03
31	-0.61788E-01	32	-0.71912E-01	33	0.20862E-01	34	-0.17394E-03	35	-0.23651E-03
36	-0.14603E-03	37	0.12367E-06	38	-0.96569E-02	39	0.83519E-02	40	-0.14049E-03
41	-0.15305E-03	42	-0.12021E-03	43	0.10934E-10	44	-0.15136E-02	45	0.14285E-02
46	-0.14532E-03	47	-0.19456E-03	48	-0.11563E-03	49	0.11576E-10	50	-0.86683E-03
51	[illegible]	52	-0.15744E-03	53	-0.21933E-03	54	-0.11901E-03	55	0.12348E-10
56	-0.37531E-06	57	-0.10442E-03	58	-0.19483E-03	59	-0.26279E-03	60	-0.17664E-03
61	0.49747E-02	62	0.58192E-02	63	0.99596E-02	64	0.14121E-01	65	0.19929E-01
66	0.75082E-02								

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Test Case

Two data decks, generating a nominal Mach 5 isoenergetic boundary layer flow and the three-dimensional virtual source simulation [Ref. 1], come as standard test cases for 3DBR COMOC. The listings of these data decks are included in Appendices A and B. Another problem specification can be readily adapted from these decks, since approximately one-third of a data deck is associated with standard call sequences and output format specification and arrangement instructions. Instructions for additions to these standard data outputs follows discussion of the data decks. This discussion covers details pertinent to the data deck for the Mach 5 test case. Comments and descriptions should be interpreted with reference to Appendix A. Subsequently, the alterations required to establish the non-uniformly discretized virtual source problem data deck from the Mach 5 test case are presented and discussed.

Preparation of the data deck is subdivided into four phases.

Phase I. Reference Conditions and Control Parameter Specification

Call	Parameter	Code	Function
FEBL			Starts execution of COMOC
COMTITLE			Reads one title card to appear on cover page of output
FENAME			Initialization
&NAME01			Integer parameter input
	NEQKNN		Number of dependent variables to be integrated in X1 direction
	IGAS	0	Isoenergetic flow with constant c_p
		1	General flows
	IFR	0	Equilibrium composition (IGAS≡1)
		1	Frozen composition
	KDUMP	0	Suppress debug output
		1	Print debug output
	NPVSX		No. of entries in pressure table
	NSCX	0	Uniform X3 interval in discretization
		1	Non-uniform X3 interval in discretization
	NSCY	0	Uniform X2 interval in discretization
		1	Non-uniform X2 interval in discretization
&NAME02			Floating point parameter input
	UINF		Reference (freestream) velocity (F/S)
	TØFINF		Reference stagnation temperature (°R)
	REFL		Reference length (F)
	TØ		Initial X1 station (F)

Call	Parameter Code	Function
	TD	Length of X1 solution, starting at TØ (F)
	DELP	Percent of TD at which output is desired
	EPS	Integration control parameter (.01 to .0001)
	VSTART	Percent of TD at which transverse velocity (U2) computation starts
	XSCALE YSCALE	Multipliers to convert discretization to feet
	CPA,CPH TØA,TØH XMA,XMH	Specific heats, stagnation temperatures, and molecular weights for two-component, isoenergetic, frozen flow mixing (IGAS≡0)
FEDIMN		Generate vector lengths and array entry points.

Phase II. Finite Element Discretization

LINK1 1 This call generates the finite element discretization of the X2X3 plane. The data are read in free format fields. A "T" terminates any sequence.

A. Automatic Uniform Discretization

Occurs for NSCX = NSCY = 0
Set XSCALE = desired element width in the X3 direction
Set YSCALE = desired element height in the X2 direction
Read selection keys

```
e.g. YSCALE = 0.004
     XSCALE = 0.002
     1  21,   1  2,
     T
```

Generates discretization made up of 21 node rows × 2 node columns, or 40 elements (× 1 element). Elements are 0.004 F high by 0.002 F wide.

B. Automatic Non-Uniform Discretization

Occurs for NSCX = 1 and NSCY = 1
Set X3 discretization first, X2 discretization second. Data are used in sets of 3 integers at a time. First integer identifies finite element interval concerned, next two indicate element width (or height) as ratio in feet, e.g., 3 1200 ≡ 3/1200 (F).

```
e.g. 1  3 1200,2  1 600,3  5 1200,...
     T
     1  1 600,7  1 600,8  7 1200,...
     T
     1  11, 1  4,
     T
```

This generates a finite element discretization of 11 node rows × 4 node columns. The element widths (intervals between node columns) are respectively 3/1200 (F), 1/600 (F), ... The height of the first 7 element rows is uniformly 1/600 (F), eighth is 7/1200 (F), etc.

Phase III. Output Specification

Following the discretization phase, the user can input up to 10 title cards to head each generated output sequence.
The next ~65 input cards specify output format, see Appendix A, and are typically not to be changed without reference to the programmer's manual.
Up to 10 title cards can follow the standard output specification to fully describe the problem being solved. This output will occur once, directly after printing of the cover page.

DONE   Calls end to output specification phase

Phase IV. Solution Parameters, Boundary Conditions, and Initial Distributions

Call	Function
VX3ST	Establishes NPVSX entries into static pressure table as function of X1
e.g. 11*I0.05 0.1	Eleven pressure values at intervals ΔX1 of 0.05, starting at X1 = 0.1.
VPVSX	Read pressures in PSFA
e.g. 4.3494 3.41...	
IPINT -1	Standard Input consisting of integer array of numbers corresponding to dependent variables. Program will integrate first NEQKNN of them, plus U2.
KBNO (N) . . . . KBNO (NN)	KBNO (N) establishes fixed boundary conditions for dependent variables N through NN.
e.g. KBNO 4 BOTTOM DONE	Fixes variable 4 nodes on bottom of discretization at their initial input values.

Call	Function
ICALL -1 ICALLS -1 LINK3 4 LINK1 3	Fixed calling sequence for internal evaluations, not to be changed.
VTEMP -58	Read initial nodal total temperature distribution. Non-dimensionalize entries by number in location 58 (TREF).
e.g. VTEMP 82*1800. T	Read: first 82 nodes at T_o = 1800°R
VYY -(X) . . . . VYYEND (N)	Reads initial conditions for dependent variable N. Non-dimensionalize entries by number in |X|.
e.g. VYY -27 42*0.0 T VYYEND 2	Initial U2 distribution is all zeros. Non-dimensionalize entries by number in location 27 (UREF)
e.g. VYY -27 2*0.0 2*1654... ......72*4004.8 T VYYEND 1	Initial U1 distribution is zero at first two nodes, 1654 F/S at second two,..., last 72 nodes have 4004.8 F/S. Non-dimensionalize entries by number in location 27 (UREF).
QKNINT DESCRIPT DONE DESCRIPT 3 . . . . DONE COMOC END	Standard completion of data deck
EXIT	If a second test case is desired, insert data deck starting with COMTITLE before EXIT card.

Listed in Table 9 are the changes to the Mach 5 test case data deck required to establish the three-dimensional virtual source data deck. The complete listing of the latter is included as Appendix B. The following explains the alterations with respect to input phase and the line numbers in Table 9.

Input Phase	Line No.	Description
I	1	Title card for output cover page
	2 . . 7	Reference condition and control parameters for combustion calculations using five dependent variables
II	8 . . 13	Form non-uniform discretization, using 11 node rows × 6 node columns, producing 100 finite elements
III	14	Title card to head each output call
	15 . . 22	Detailed problem description
IV	23	Entry locations of longitudinal pressure
	24	distribution (constant)
	25	66 nodes have uniform stagnation temperature
	26 . . . 36	Initial U1 distribution
	37	Initial U2 distribution is zero
	38	Initial O2 distribution reflects location of virtual source
	39	Initial N2 distribution
	40	Initial H2 distribution

Hence, establishing the data deck for a multiple dependent variable, three-dimensional problem using a non-uniform finite element discretization is readily accomplished. In this case, only forty data card changes were required, using the two-dimensional Mach 5 data deck as a master deck.

TABLE 4

DATA DECK CHANGES TO PRODUCE VIRTUAL SOURCE SIMULATION

```
Line

01       COMOC CHECK CASE FOR THREE DIMENSIONAL REACTING BOUNDARY REGION FLOW
02             NFOKNN=5,             IGAS=1,               IFR=0,                KDUMP=0,
03             NPVSX=2,              NSCX=1,               NSCY=1,
04         NE1F2=1,
05             UINF=2272.,           TOFINF=533.0,         REFL=.003333333,
06             TD=0.0,               TD=0.10,              DELP=5.0,             EPS=0.01,
07             XSCALE=C.003333333, YSCALF=0.003333333, VSTART=101.0,
08         1 75  100, 2  50  100, 3  125  100, 4  150  100, 5  225  100,
09     T   INCREMENTS BETWEEN X3, NODE-NUMERATOR-DENOMINATOR
10         1  5  10, 7  5  10, 8  125  100, 9  175  100, 10  250  100,
11     T   INCREMENTS BETWEEN X2
12         1  11, 1  6,
13     T   11 ROWS AND 6 COLUMNS NORMALIZED BY LREF,HENCE X-Y SCALES =LREF
14       CHECK CASE,THREE DIMENSIONAL REACTING BOUNDARY REGION - VIRTUAL SOURCE
15       CHECK CASE,THREE DIMENSIONAL REACTING BOUNDARY REGION - VIRTUAL SOURCE
16       (H2/O2/AIR SYSTEM WITH EQUILIBRIUM CHEMISTRY). PROBLEM CONSIDERED
17       REPRESENTS TRANSVERSE H2 INJECTION INTO A SUPERSONIC AIR STREAM
18       CHARACTERISTIC OF SCRAMJET FUEL INJECTION,SEE ROGERS NASA TND-6114,
19       1971 AND NASA TND-6476,1971 FOR EXPERIMENTAL STUDY OF THIS PROBLEM.
20       TURBULENCE MODEL EMPLOYED IS DESCRIBED IN USER'S MANUAL NASA CR-132450,1974.
21       CALCULATIONS ARE STARTED USING VIRTUAL SOURCE CONCEPT TO REPLACE
22       COMPLEX NEAR INJECTION FLOW FIELD.
23        0.0       100.      T X1 TABLE FOR PRESSURE
24        193.      193.      T PRESSURE  TABLE PSF
25          66*533.
26         6*0.0
27         6*1503.
28         6*1660.
29         2*1550.   4*1759.
30         2*1550.   4*1833.
31         2*1550.   4*1892.
32         2*2272.   4*1942.
33         2*2272.   4*1985.
34         2*2272.   4*2074.
35         2*2272.   4*2169.
36         6*2272.
37         66*C.0
38        18*.233         2*0.0     4*.233    2*0.0     4*.233    2*0.0     34*.233
39        18*.767         2*0.0     4*.767    2*0.0     4*.767    2*0.0     34*.767
40        18*0.0          2*1.0     4*0.0     2*1.0     4*0.0     2*1.0     34*0.0
```

Sample output for the three-dimensional virtual source test case is presented in Appendix D. The processing of pre-solution output is identical to the Mach 5 test case, and complete solution outputs are presented for the initial and final solution station. For the aspect ratio of this particular discretization, COMOC ascertained the six outputs could be placed on a page as illustrated. Appendix E contains listings of the specifically written subroutines for eddy viscosity, laminar viscosity, and effective Schmidt and Prandtl number for the virtual source simulation.

An additional output array can be readily provided by COMOC during the output phase of execution. For example, referring to Appendix A, suppose that the array U3/UREF is to be printed. Then, in IØSAVE -1, before the card headed by T, add 3248 to card headed by 1247. The "3" refers to dependent variable number three, which is U3 in the YY array, and 248 is the entry position in the YY matrix in the IZ array. Also, in IØMULT -1, change entry to 15*2. Finally, in DESCRIPT2, on third card headed EFF.MU/MUREF, add U3/UREF in columns 65-80.

SYMBOLS

CROSS REFERENCE LIST FOR EQUIVALENCED VARIABLES

```
 57 IASVEC - CONTROL PAR. IN 'STREF' FOR GENERATING DCUTP.
 59 IBL    - 1 = BOUNDARY LAYER PROGRAM.
           - 0 = NAVIER-STOKES PROGRAM.
117 IBUG1  - PRINT INPUT AND OUTPUT FOR GAS IN GRAHET.
118 IBUG2  - PRINT INTERMEDIATE STEPS IN GRAHET.
128 ICNINP - NO. OF NODES FOR AXIS-SYM. CONTES.
127 IDIFRT - NO. OF TIMES TO PRINT INTER. OUTPUT IN WLFLXS.
115 IFORCE - READ XCOR, YCOR IN 2E15.5 FORMAT IN SETUP.
120 IFR    - 1 = FROZEN CALCULATION IN THERMO.
123 IGAS   - 1 = CALL DPHOGS.
           - 0 = CALL DRHORL.
116 IGINIT - INITIALIZATION PARAMETER IN THERMC.
 58 IMAT   - NO. OF MATERIALS IN PROBLEM.
125 IMATAB - NO. OF ENTRIES IN MATERIAL TABLE.
111 IMAX   - HIGHEST NODE IN COL. AT WHICH TO USE FL CURVE.
130 INGAS  - STARTUP PARAMETER IN GAS.
158 INITCN - INITIALIZER IN CONTES.
 28 IPASS  - NO. OF CALLS TO DERIV.
132 IPWRIT - COUNTER IN PRESUR FOR INTER. OUTPUT.
103 IRFND  - END POSITION IN 'IZ' ARRAY.
  3 IROW   - 1 OR 2 = INDEX FOR PRESENT OR PAST VALUE OF DEP.
                      VARIABLE AND DERIVATIVE. (SET IN GKNUTN)
 29 IRUN   - PROBLEM NO. BEING RUN. (USUALLY ONLY 1 )
126 ISPEED - 1 = COMPUTE SPEED BEFORE ENTERING OUTPUT RTNE.
 32 ISUB   - NOT USED.
149 IT     - TEMPERATURE ITERATION COUNT IN GRAHET.
133 ITOP   - NO. OF ELEMENTS FOR WHICH TO PRINT IN PRESUR.
141 KALLO3 - CODE TO DECIDE TO USE SPECIES AREA OR HEIGHT IN H2.
 61 KDUMP  - PRINT INPUT CARDS AND DATA GENERATED IN PRINPT.
  4 KEYMTD - INTEGRATION TECHNIQUE.
           - 1 = MAXIMUM ABSOLUTE STABILITY.
           - 2 = MAXIMUM RELATIVE STABILITY.
 25 KIND   - KIND OF ELEMENT. (USED IN LAH)        DEF. = 4
 12 KINIT  - NOT USED.
  6 KODG   - PRINT GEOMETRY OUTPUT IF = 1.
  7 KODA   - PRINT INTER. DERIV OUTPUT KODA TIMES.
 16 KOUNT  - RUNNING COUNT OF OUTPUT. (LIMITED BY LPRINT)
102 KOUT   - PLOT TAPE NUMBER OR PUNCH UNIT NO.
113 KPLVAR - NO. OF VARIABLES TO BE PLOTTED OR PUNCHED.
 56 KPNT   - PRINT OPTION (SET DURING EXECUTION).
             0 - NO CALL TO 'RESULT'
             1 - CALL 'RESULT'
 52 KROW   - NO. OF ROWS IN DISCRETIZATION.             DEF. = 100
```

```
136 KSAV    - PLOT TAPE NO. SAVED IN QKNINT.
 50 LCOL    - NO. OF COLUMNS IN DISCRETIZATION.        DEF. = 20
156 LFIL    - FILL PARAMETER USED IN ELEM.
 47 LG      - NO. OF COLS. USED IN CONTES AND DFCFBL.
 34 LPRINT  - LIMIT ON OUTPUT COUNT.                   DEF. = 100
137 LPSIAI  - PSIBC INPUT 1 = POINT, 2 = SLOPE  AT LOWER NODE
138 LPSIAM  - PSIBC INPUT 1 = POINT, 2 = SLOPE  AT UPPER NODE
157 LRS     - DISCRETIZATION PARAMETER USED IN ELEM.
103 MTM     - NO. OF PASSES IN FECLTP.
 23 NB      - NO. OF  CHAR. IN EACH WORD OF OUTPUT VAR. TITLE.
131 NBORD   - NO. OF NODES AROUND BORDER OF DISCRETIZATION.
 69 NBSET   -  1 = STORE DEP. VARIABLE INTO YY ARRAY AND PRINT
                   INTEGRATION NODES. (USED IN 'NBNDRY')
               0 = STORE YY ENTRY IN DEP. VARIABLE.
              -1 = STORE DEP. VARIABLE INTO YY ARRAY.
 33 NBUG    - 1 = PRINT OUTPUT FROM 'L7H' ROUTINES.
 22 NC      - NO. OF CHARACTERS IN OUTPUT FORMAT.       DEF. =  8
125 NCALLS  - NO. OF ROUTINES TO CALL AT END OF QKNUIN.
 13 NCOORD  - 0 = TWO DIMENSIONAL.
              1 = AXI-SYMMETRIC (NOT OPERATIONAL)
 59 NCPTAB  - NO. OF ENTRIES IN SPECIFIC HEAT TABLE.
  1 ND      -INITIALIZATION PARAMETER IN DFCFNS.
 51 NDBL    - QKNUIN CODE TO DETERMINE MINIMUM STEP SIZE.
124 NDERIV  - 7 = CALL DERVNS.  8 = CALL DERVBL.
 48 NDOF    - NO. OF DEGREES OF FREEDOM. (USED IN L7H)
 56 NDOUTZ  - 0 = SET UP DOUTP VECTOR IN 'STRF' ONLY ONCE.
 92 NDOZ    - APPROX. LENGTH OF DOUTP VECTOR.     DEF. = 5000
162 NDPVSX  - NO. OF DPDX'S IN PPRIME TABLE.
155 NELADD  - SET = 1 IF ELEMENTS ARE TO BE ADDED IN ELEM.
154 NELDEL  - SET = 1 IF ELEMENTS ARE TO BE DELETED IN ELEM.
 14 NELEM   - NUMBER OF ELEMENTS ( TRIANGLES ).
 89 NEMD    - STARTING LOC. PAR. IN DIF ARRAY.
 31 NEQ     - NO. OF DEP. VARIABLES TO BE SOLVED.
 58 NEQKNN  - NO. OF DEP. VARIABLES TO BE INTEG. USING 'QKNINT'.
 45 NEXP    - NO. OF BOUNDARY NODES IN JBOUND ARRAY. (L7H)
107 NF1F2   - 1 = USE F1 CURVE FOR EPSILON.
              2 = USE F1 AND F2 CURVE FOR EPSILON IN DFCFBL.
 46 NF      = NO. OF 'NB' BYTE WORDS IN TITLE FOR EACH DEP. VAR.
 96 NFIRCL  - CONTROL PAR. IN 'RANCHO' FOR 1ST OR SUBS. PASSES.
104 NFLIP   - PLOT PARAMETER TO MIRROR OUTPUT. ( 2=MIRROR)
119 NGBUG   - PRINT INPUT AND OUTPUT IN THERMO.
130 NGETH   - COUNTER IN DRHOGS TO INIT. VARIABLES IN GAS.
 95 NH      - NO. OF ELEMENTS CONTAINING BOUNDARY GRADIENT
              INFORMATION FOR 'LH', 'TREF' AND 'F'.
 53 NH2     - NO. OF INCREASES IN STEP SIZE IN QKNUIN.
 54 NHHALF  - NO. OF DECREASES IN STEP SIZE IN QKNUIN.
 68 NI      - STARTING LOC. IN YY ARRAY FOR DEP. VAR. NP.
 63 NIND    - 'IZ' ARRAY STARTING LOC. PAR.   APPROX. = 5*NODE
 65 NJ      - STARTING LOC. IN ZZ ARRAY FOR DEP. VAR. NP.
 88 NLINE   - LINE COUNT FOR OUTPUT CONTROL.            DEF. = 60
 60 NMBOUT  - NO. OF VARIABLES TO BE PRINTED.
 15 NN      - LINEAR APPROX. INDEX.                     DEF. =  3
 16 NNODE   - NUMBER OF NODES.
```

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```
 17 NNS     - LINEAR APPROX. INDEX                        DEF. =  6
 55 NODE    - 'IZ' ARRAY STARTING LOC. PARAMETER. MIN.=NNODE + 3
150 NODNO   - NODE NO. AT WHICH DRHOGS IS COMPUTING.
 19 NOF     - NO. OF EQUATION BEING SOLVED FOR DEP. VAR. 'NP'.
  5 NOMEGB  - NO. OF BOUNDARY NODES TO TO SOLVED FOR IN 'CMEGBC'
148 NONC    - NON-CONVERGENCE CODE IN GAS.
142 NOUTPR  - NO. OF SCALARS TO PRINT IN OUTPUT.
 30 NP      - DEP. VARIABLE BEING SOLVED.
 18 NPART   - NO. OF PARTITIONS (USED IN 'L7H')     DEF. = 2
101 NPRESS  - NO. OF NODES AT WHICH PRESSURE IS COMPUTED.
 20 NPRNT   - NO. OF PRINT POSITIONS ON A LINE OF OUTPUT. D =132
135 NPSBDL  - NO. OF BOUNDARIES TO COMPUTE PSIBC.
134 NPSIBD  - NO. OF NODES READ IN FOR PSIBC.
  2 NPSICC  - NO. OF FIXED  SI LOC. (USED IN 'STRE')
 11 NPTDOF  - NO. OF POINTS / DEG. OF FREEDOM. (JHCUNC PAR. )
 24 NPTEL   - NO. OF POINTS / ELEMENT. (L7H)                DEF. = 3
153 NPUNCH  - SET = 1 IF ELEMENTS AND NODES ARE TO BE PUNCHED.
161 NPVSX   - NO. OF PRESSURES IN P VS X TABLE.
 49 NQEL    - NO. OF POINTS / ELEMENT. (L7H)          DEF. = 3
 66 NRHOSS  - STEADY STATE PARAMETER IN 'DERIV'.
 21 NROW    - DEP. VAR. AND DERIVATIVE ALTERNATOR IN CKNINT.
  9 NRSTRT  - LOGICAL TAPE NO. TO READ RESTART COND. IN 'RDINPT'
 47 NRTAPE  - LOGICAL TAPE NO. TO STORE RESTART COND. IN 'LINK2'
 67 NS      - PRINTOUT COUNT PARAMETER.
151 NSCX    - SET = 1 IF INTERVAL INPUT IS TO BE READ FOR
              X1COR IN DSCRTZ.
152 NSCY    - SET = 1 IF INTERVAL INPUT IS TO BE READ FOR
              X2COR IN DSCRTZ.
144 NSDFBL  - RESET SWITCH TO CHANGE NELEZ IN DFCFBL.
146 NSFDBF  - RESET CONDITION FLAG IN FINDBF.
 27 NSKIP   - NO. OF BOUND. LOCATIONS / DEP. VARIABLE.
                                                 DEF. = NNODE / 3
 54 NSM     - STOP PROGRAM IF OUTPUT EXP. GT NSM.        DEF. = 10
159 NSORCE  - SET = 1 IF SOURCE DATA IS TO BE USED ON
              RIGHT HAND SIDE IN DERVBL.
121 NSPEC   - NO. OF SPECIES IN SOLUTION.          DEFAULT = 9.
160 NSPRSC  - 0 = NO SOURCE COMPUTATION FOR ENTHALPY.
              1 = USE PHI1 SOURCE COMPUTATION.
              2 = USE PHI + PHI2 SOURCE COMP. ( NOT USED )
145 NS2FBL  - RESET SWITCH TO CHANGE C9ED IN DFCFBL.
140 NTCNTS  - STARTUP PARAMETER IN CONTES.
143 NTDFBL  - STARTUP PARAMETER IN DFCFBL.
 62 NTITL   - NO. OF TITLE CARDS TO BE READ IN 'SETUP' AND
              PRINTED AT THE BEGINNING OF EACH OUTPUT SET.
 93 NTK     - NO. OF ELEMENTS HAVING NON-CONSTANT THICKNESS.
 94 NUPARA  - NO. OF L-PARALLEL ELEMENTS IN STRE.
 74 NVH     - DEP. VARIABLE NO. FOR ENTHALPY.                DEF. = 4
 70 NVP     - DEP. VARIABLE NO. FOR PSI.                     DEF. = 5
 71 NVU     - DEP. VARIABLE NO. FOR OMEGA.                   DEF. = 1
 72 NVV     - DEP. VARIABLE NO. FOR VELOCITY 1.              DEF. = 2
 73 NVW     - DEP. VARIABLE NO. FOR VELOCITY 2.              DEF. = 3
 90 NYY     - NO. OF TIME PERIODS TO STORE YY.               MUST = 2
 91 NZZ     - NO. OF TIME PERIODS TO STORE ZZ.               MUST = 2
```

RARRAY

ENTRIES

```
156 AINF   - REFERENCE SPEED OF SOUND.
             IF UINF .LE. 0. AINF = SQRT(G*GAMMAF*PINF/RHOINF)
             IF UINF .GT. 0.
             AINF = SQRT (G*GAMMAF*RUNIV*TOFINF/XMA)
  5 AJ     - JOULES CONSTANT. 778.28
  3 ALC    - CHARACTERISTIC ELEMENT SIZE.     DEF. = MIN. SIDE
115 BSTART - NOT USED
176 CBTOKJ - SPECIFIC HEAT BRITISH TO MKS           4.184
83  COMPX  - COMPRESSION FACTOR FOR OUTPUT COL VECTOR.
             INDICATES PERCENT OF X1 AXIS TO BE USED TO SHORTEN
             PRINT SPACING INTERVALS.    DEFAULT - 0.0
84  COMPY  - COMPRESSION FACTOR FOR OUTPUT ROW VECTOR.
             SAME AS COMPC, BUT FOR X2 AXIS.
124 CON    - CONSTANT USED IN DFCFBL         DEFAULT = 0.4
 70 CONRHO - IF GT 0.0, SET ALL RHO = CONRHO.
62  CONV   - OUTPUT SCALE FACTOR = 1.0 / REFL
77  CON1   - ALC / (RE*CPOINF*XMUINF)
78  CON2   - CON1 / TOFINF
158 CPA    - SPECIFIC HEAT OF AIR.          DEFAULT = 0.24
159 CPH    - SPECIFIC HEAT OF HYDROGEN.     DEFAULT = 3.445
160 CPINF  - SPECIFIC HEAT COMPUTED IN CPINIT.
 30 CPOINF - REFERENCE SPECIFIC HEAT.
153 CVCP   - SPEC. HEAT CONV. USED IN THERMO. DEF. = 4186.0
148 CVH    - ENTHALPY CONVERSION USED IN THERMO. DEFAULT = 1.0
151 CVP    - PRESSURE CONV. USED IN THERMO.  DEF. = .4725 E-3
152 CVRHO  - DENSITY CONV. USED IN THERMO.   DEF. = 16.02
150 CVT    - TEMP. CONVERSION USED IN THERMO.    DEFAULT = 1.0
149 CVU    - VELOCITY CONVERSION USED IN THERMO. DEF. = 0.3048
130 C4ED   - CONSTANT USED IN DFCFBL        DEFAULT = 0.00023
143 C4EDSW - PERCENT OF TO AT WHICH TO SWITCH C4ED IN DFCFBL.
144 C4FACT - MULTIPLIER FOR NEW C4ED AFTER C4EDSW OCCURS.
 13 DELP   - PERCENT INTERVAL FOR PRINTOUT.          DEF. = 2.0
103 DEPLT  - PERCENT OF TO TO BE USED FOR PLOTTING STATIONS.
111 DELX3  - TIME STEP USED IN CENTES.
113 DLAST  - TIME STEP USED IN CENTES.
114 DLXM1  - TIME STEP USED IN CENTES.
161 DPINF  - RHOINF * UINF**2
165 DRTODK - DEGREES RANKINE TO DEGREES KELVIN   5.0/9.0
175 EBTOKJ - ENTHALPY BRITISH TO MKS                2.3244
137 ELIPSA - NOT USED
138 ELIPSB - NOT USED
135 ELIPSH - NOT USED
136 ELIPSK - NOT USED
 14 EPS    - ACCURACY TEST BETWEEN PREDICTOR-CORRECTOR FORMULAS
145 E1E2SW - PERCENT OF TO AT WHICH TO SWITCH FROM E1 TO E2
  1 FACT   - NON-DIM  FACTOR = ALC / UINF
80  FACTH  - 1.0 / (CPOINF*TOFINF)
59  FACTMU - RHOINF * UINF * ALC
```

```
79  FACTP   - 1.0 / FACTML
163 FTTOCM  - FEET TO CENTIMETERS                           30.48
162 FTTOIN  - FEET TO INCHES                                12.0
164 FTTOMT  - FEET TO METERS                                 0.3048
 31 G       - GRAVITATION CONSTANT.                         32.174
 60 GAMMAF  - FACTOR (1.4) IN GAS LAWS.
 15 H       - CURRENT TRIAL STEP SIZE.
12  HD      - OUTPUT VARIABLE FOR TIME STEP = HS * FACT / REFL
121 HDOT    - H2 MASS FLOW COMPUTED IN H2MIX.
88  HHMIN   - USED IN CKNUIN FOR TIME STEP DETERMINATION.
97  HINF    - REFERENCE ENTHALPY. COMPUTED IN DRHCGS.
 16 HMAX    - MAX. STEP SIZE ALLOWED.              DEF. = 0.05 * TD
 17 HMIN    - MINIMUM INTEGRATION STEP SIZE.
  6 HMINIT  - NOT USED
132 HRCON   - CONSTANT USED IN H2MIX          DEFAULT = 0.29126
122 HRSDOT  - MIXING EFFICIENCY COMPUTED IN H2MIX.
 45 HS      - CURRENT STEP SIZE.
 7  HSINIT  - START INTEGRATION STEP SIZE AT THIS VALUE.
              DEFAULT = 0.1 E-4
  2 ONE     - FLOATING POINT 1.0. ( SCALE FACTOR IN STOUTL )
 18 OUTERS  - ACCURACY TEST PARAMETER IN *OKNUIN*.
123 PCNT    - PERCENT OF H2 AT WHICH TO LIMIT FL CURVE IN CHCF3L.
106 PCTH    - NOT USED
174 PCFTOC  - POUNDS/FT**3 TO GRAMS/CM**3                    0.01602
170 PCFTOK  - POUNDS/FT**3 TO KILO/M**3                     16.02
35  PDIMM   - DIMENSIONAL PRESSURE = PEDGE * PRSCON
37  PEDGE   - NON-DIM. PRESSURE AT PRESENT STATION.
 9  PINF    - FREESTREAM PRESSURE. DEFAULT = 1ST VALUE IN P TAB.
              IF NOT INITIALIZED SET = PINF/(RTCON3*TSINF)
 19 PNTERS  - ACCURACY TEST PARAMETER IN *OKNUIN*.
60  PPRCON  - PRSCON / ALC
100 PPRIME  - PRESSURE GRADIENT COMPUTED IN GETPPR.
171 PRSCON  - RHOINF * UINF**2 / G
166 PSFTOA  - POUNDS/FT**2 TO PSIA                          .4725 E-3
169 PSFTOI  - POUNDS/FT**2 TO POUNDS/IN**2                  .006944
168 PSFTON  - POUNDS/FT**2 TO NEWTONS/M**2                 47.88
167 PSFTOT  - POUNDS/FT**2 TO TORR                          .3591
 20 PTIM    - PRINT TIME PARAMETER IN *OKNINT*.
123 QR      - DYNAMIC PRESSURE RATIO.          DEFAULT = 1.0
134 Q3MAX   - MAXIMUM H2 CONC. FOUND AT PRESENT STATION.
 21 RE      - REYNOLDS NUMBER.
 42 REDGE   - MAXIMUM DENSITY.
 43 REFL    - REFERENCE LENGTH.
 10 RHOINF  - FREESTREAM DENSITY.
157 RHOUIN  - RHOINF * UINF
 3  RMINS1  - PROGRAM CONSTANT.             DEFAULT = -1.0
105 RMOSE   - XMA / XMH - 1.0
110 RUUALC  - RHOINF * UINF * ALC**2
116 RP      - CPH / CPA
32  RTCON1  - 2.0 * G * XJ
33  RTCON2  - G * GAMMAF / 2.0
34  RTCON3  - RUNIV / XMA
55  RTCON4  - RTCON2 * XMACHS**2
```

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```
56  RTCON5 - UINF**2 / (RTCON1*CPCINF*TCFINF)
57  RTCON6 - 2.0 * RTCON4
117 RTOHMI - RR *  ( TOH/TOA - 1.0 )
 28 RUNIV  - UNIVERSAL GAS CONSTANT.                    DEF. = 1545.33
129 SCT    - CONSTANT SCHMIDT NUMBER       DEFAULT = 0.7
108 SCTMIN - NOT USED
107 SCTMLT - NOT USED
131 SPLIT  - CUTOFF USED IN H2MIX          DEFAULT = 0.02835
 44 SQ2    - SQRT(2.0)
51  STHMIN - NOT USED
73  STLCCR - REF. CON. TEMP. IN SUTHERLAND.DEFAULT = 204.0
74  STLDEX - EXPONENT   IN SUTHERLAND.      DEFAULT =   1.5
72  STLDTR - REF. TEMP. IN SUTHERLAND.      DEFAULT = 492.0
71  STLDVR - VISCOSITY USED IN SUTHERLAND.  DEFAULT = .1163 E-4
50  SSINIT - HSINIT / FACT
 35 TD     - TOTAL SOLUTION TIME FROM TO.
47  TEDGE  - MINIMUM TEMPERATURE.
 22 TF     - FINAL TIME = TO + TD
  4 THK    - DEFAULT NON-DIM. THICKNESS OF ELEMENTS. (1.0)
 23 TIME   - CURRENT TIME.
 24 TO     - STARTING TIME.
146 TOA    - AIR TEMPERATURE FOR COMPUTATIONS IN DIMEN.
 59 TOFINF - REFERENCE TEMPERATURE.
147 TOH    - HYDROGEN TEMPERATURE FOR COMPUTATIONS IN DIMEN.
40  TRATIO - 1.0 + (GAMMAF-1.0) * XMACHS**2 / 2.0
 25 TRNC   - INTEGRATION PARAMETER IN 'CKNUIN'.
155 TSINF  - STATIC TEMPERATURE COM IN CPINIT.
 26 TWOPI  - PI * 2.0
46  UEDGE  - MAXIMUM U VELOCITY.
 27 UINF   - VELOCITY (FREESTREAM)
141 VA     - MAJOR AXIS OF ELLIPSE FOR VIRTUAL SOURCE.
142 VB     - MINOR AXIS OF ELLIPSE FOR VIRTUAL SOURCE.
104 VELCST - UINF**2 / (2.0*G*AJ*CPA*TOA)
139 VH     - CENTER OF H2 ELLIPSE FOR VIRTUAL SOURCE.
140 VK     - CENTER OF H2 ELLIPSE FOR VIRTUAL SOURCE.
177 VLBTON - VISCOSITY BRITISH TO MKS                 1.488
178 VLBTOP - VISCOSITY BRITISH TO CGS                14.88
102 VSTART - PERCENT OF TD AT WHICH TO START V COMP. IN CONTES
81  XI     - INITIAL COORD. ON XI AXIS.      DEFAULT = 0.0
125 XLAM   - CONSTANT USED IN CFCFBL       DEFAULT = 0.09
37  XLE    - LEWIS NUMBER.  DEFAULT = 1.0
109 XMA    - MOLECULAR WEIGHT OF AIR.   DEFAULT = 28.97
61  XMACHO - LOCAL MACH NUMBER.
154 XMACHS - INITIAL MACH NO. USED IN DIMEN.
 66 XMF    - MASS FRACTION OF FLUID.
172 XMFACT - UINF * SQRT (XMA/(TCFINO*GAMMAF*G*RUNIV))
110 XMH    - MOLECULAR WEIGHT OF HYDROGEN.   DEFAULT = 2.016
118 XMSDF  - MASS DEFECT COMPUTED IN Q3CONC.
126 XMUAIR - VISCOSITY OF AIR.              0.0000115
127 XMUH2  - NOT USED
 38 XMUINF - VISCOSITY (FREESTREAM)
128 XMUP5  - NOT USED
98  XPRIME - NON-DIM. PRESSURE GRADIENT AT PRESENT STATION.
```

```
52  XSCALE - X1COR SCALE FACTOR.   DEFAULT = 1.0
 41 XSHFT  - SHIFT X-COORDINATE.   DEFAULT = 0.0
76  XT     - OUTPUT STATION = TIME * FACT / REFL
112 X3LAST - LAST TIME STEP USED IN CONTES.
82  YI     - INITIAL COORD. ON X2 AXIS.     DEFAULT = 0.0
53  YSCALE - X2COR SCALE FACTOR.   DEFAULT = 1.0
 42 YSHFT  - SHIFT Y-COORDINATE.   DEFAULT = 0.0
101 YUP    - UPPER Y IN DECEBL.
173 ZMAX   - MAX. DERIVATIVE COMPUTED IN QKNUIN.
 29 ZT     - DIMENSIONAL CURRENT TIME.
 65 ZTEST  - STOP PROGRAM WHEN MAX.(ZZ) LE ZTEST.  DEF. = .1E-4
```

IZARRAY

DEFINITION   ENTRY POINTS IN IZ ARRAY.

IARRAY ENTRY			
201	ICOL	---	OUTPUT COLUMN VECTOR USED IN FEOUTP.
202	IROW	---	OUTPUT ROW VECTOR USED IN FEOUTP.
203	IFMTHD	---	HEADINGS FOR OUTPUT VARIABLES.
204	ITITLE	---	TITLE FOR START OF EACH OUTPUT PHASE.
205	IIPINT	---	LIST OF DEPENDENT VARIABLES.
206	IKBNO	---	NO. OF BOUNDARY NODES / DEP. VARIABLE.
210	IINCOL	---	NO. OF NODES PER COLUMN.
211	IINROW	---	NO. OF NODES PER ROW.
218	ICPTAB	---	SPECIFIC HEAT TABLE ENTRIES
219	ITTAB	---	TEMPERATURE TABLE ENTRIES.
220	IIUSED	---	COUNTER USED FOR OUTPUT IN FEOUTP.
223	IX1POS	---	TEMPORARY STORAGE FOR X1COR COORDINATES.
224	IX2POS	---	TEMPORARY STORAGE FOR X2COR COORDINATES.
225	IIBND	---	ARRAY OF BOUNDARY NODES FOR DEPENDENT VARIABLES.
226	IINODE	---	LIST OF ELEMENT CONNECTIONS (3/ELEMENT).
232	INWN	---	SOLUTION ORDER OF NODES FOR DEP. VAR. IN DERIV.
233	IINDEX	---	ORDER OF NODES BY COLUMNS FROM LEFT TO RIGHT.
234	IINDRW	--	ORDER OF NODES BY ROWS FROM TOP TO BOTTOM.
235	INOCOL	---	OUTPUT COLUMN POSITION OF NODES.
236	IIELS	---	NO. OF ELEMENTS CONNECTED TO NODES.
237	IELEM	---	NOT USED.
238	IIBORD	---	LIST OF BORDER NODES IN CCW ORDER.
241	IB211	---	B211 MATRIX COMPUTED IN GEOMFL.
242	IB211S	---	B211S MATRIX COMPUTED IN GEOMFL.
245	IB211A	---	B211A ANTI-SYMMETRIC MATRIX.
247	IDIF	---	FIRST HALF USED TO STORE DIFFUSION COEFFICIENTS. 2ND HALF USED TO STORE SOURCE TERMS.
248	IYY	---	STORAGE FOR 2 VALUES OF DEPENDENT VARIABLES.
249	IZZ	---	STORAGE FOR 2 VALUES OF DERIVATIVES FOR DEP. VAR.
250	IX1P2	---	ELEMENT LENGTHS COMPUTED IN GEOMFL.
271	IOUT1	---	TEMPORARY STORAGE.
TO			
276	IOUT6	---	TEMPORARY STORAGE.
277	IAREA	---	AREA OF ELEMENTS TIMES THICKNESS COMP. IN GEOMFL.
278	ICP	---	NODAL VALUES OF SPECIFIC HEAT.

```
279 IH     ---  NODAL VALUES OF ENTHALPY.
282 IO     ---  TEMPORARY STORAGE FOR DEPENDENT VARIABLE.
283 IOP    ---  TEMPORARY STORAGE FOR DERIVATIVE OF DEP. VAR.
284 IRHO   ---  NODAL VALUES OF DENSITY.
285 ITEMP  ---  NODAL VALUES OF TEMPERATURE.
288 ITK    ---  ELEMENT THICKNESS DISTRIBUTION.
289 IX1COR ---  NODAL VALUES OF TRANSVERSE COORDINATES.
290 IX2COR ---  NODAL VALUES OF NORMAL COORDINATES.
291 IPRESS ---  NODAL VALUES OF PRESSURE.
292 IAMU   ---  NODAL VALUES OF VISCOSITY.
301 IOL    ---  RHO*ULAST STORAGE FOR CONTES.
302 IOPL   ---  DELU STORAGE FOR CONTES.
303 IVEL   ---  RHO*V STORAGE IN CONTES.


304 IW     ---  RHO*W STORAGE IN CONTES.
306 IX12   ---  TRANSFORMED X-AXIS OF ELEMENTS.
307 IX23   ---  TRANSFORMED Y-AXIS OF ELEMENTS.
308 IYNOO  ---  Y-COORD. USED IN CONTES AND DFCFBL.
309 IGEOM1 ---  1ST TERM OF B2001  ELEMENT MATRIX.
310 IGEOM2 ---  2ND TERM OF B2001  ELEMENT MATRIX.
311 IPLOTS ---  LIST OF VARIABLES TO BE PLOTTED.
312 IPLTYP ---  TYPE OF PLOT TO BE GENERATED.
313 IPLSCL ---  SCALE FACTORS TO BE USED FOR PLOT.
314 ISCHMT ---  NODAL VALUES OF SCHMIDT NUMBERS.
315 INMAT  ---  LIST OF MATERIALS IN REGION.
316 IMELEM ---  ELEMENT VALUE OF MATERIAL.
319 ISRCE  ---  NOT USED.
320 IHSTAT ---  NODAL VALUES OF STATIC ENTHALPY.
321 ICALL  ---  LIST OF LINK NOS. TO CALL AT END OF QKNIIN.
322 ICALLS ---  LIST OF ROUTINE NOS. IN ASSOC. LINK TO BE CALLED.
323 IOMULT ---  LIST OF MULTIPLIERS FOR OUTPUT VARIABLES.
324 IOSAVE ---  LIST OF VARIABLES TO BE PRINTED IN OUTPUT.
325 INOUT  ---  TEMPORARY STORAGE FOR OUTPUT VAR. AND SOURCE DATA.
327 IICNCL ---  LIST OF NODES / COL. IN AXI-SYM. CONTES.
328 IICNOX ---  LIST OF NODES TO BE USED IN SOLVING AXI-S. CONTES.
329 IWCOS  ---  COSINE OF ANGLE / COL. IN AXI-SYM. CONTES.
330 IVSIN  ---  SINE OF ANGLE / COL. IN AXI-SYM. CONTES.
331 IIPAR  ---  LIST OF PARAMETERS TO PRINT AT START OF OUTPUT.
332 IOPAR  ---  HOLLERITH DESC. OF PAR. AT START OF OUTPUT.
333 ISUTLD ---  LIST OF CONSTANTS TO BE USED IN SUTHLD.
334 IPR    ---  NODAL VALUES OF PRANDTL NUMBER.
335 IMPAR  ---  LIST OF MULT. FOR PARAM. AT START OF OUTPUT.
336 IEPS   ---  NODAL VALUES OF TURB. VISC. COMPUTED IN DFCFBL.
337 ISKNFR ---  LIST OF SKIN FRICTION PARA. COMP. IN WLFLXS.
338 ISTN   ---  LIST OF STANTON NOS. COMPUTED IN WLFLXS.
339 IX3ST  ---  LIST OF DOWNSTREAM STATIONS IN PRESSURE TABLE.
340 IPVSX  ---  LIST OF DOWNSTREAM PRESSURES IN PRESSURE TABLE.
341 IDPX3  ---  LIST OF DOWNSTREAM STATIONS IN PRESS. GRAD. TABLE.
342 IDPVX  ---  LIST OF DOWNSTREAM PRESS. GRAD. IN PR. GR. TABLE.
```

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APPENDIX A

DATA DECK LISTING FOR MACH 5 TWO-DIMENSIONAL FLOW CHECK CASE

```
FEBL
COMTITLE
 CHECK CASE,TWO DIMENSIONAL SUPERSONIC FLOW WITH PRESSURE GRADIENT
FENAME
 &NAME01
          NEQKNN=2,           IGAS=0,             IFR=0,              KDUMP=0,
          NPVSX=11,           NSCX=1,             NSCY=1,
 &END
 &NAME02
          UINF=4004.8,        TOFINF=1800.,       REFL=.0132
          TO=0.1,             TD=0.2,             DELP=5.0,           EPS=.01,
          VSTART=5.0,         CPA=0.24,           CPH=3.445,          TOA=1800.,
          TOH=0.0,            XMA=28.97,          XMH=2.016,
          XSCALE=1.0,         YSCALE=1.0,
 &END
FEDIMN
LINK1     1                                                          SETUP
  1   2 1000,     2  2 1000,
  T
  1   2 1000,    21  2 1000,
  T
  1 21,  1 2,
  T
 CHECK CASE,TWO DIMENSIONAL SUPERSONIC FLOW WITH PRESSURE GRADIENT

 REFERENCE       ENGLISH-FT       ENGLISH-IN       M-K-S        C-G-S
 ---------       ----------       ----------       -----        -----

DONE
MPARA     -1
   2    2    162    164    163
   2    2      2    164    163
   2    2      2    170    174
   2    2      2    165      2
   2  -175     2      2      2
   2    2      2    176      2
   2    2      2    177    178
   2    2    169    168    167
   2    2      2      2      2
   2    2    2    2

HOLIST
 LENGTH.........    .FT.........    .IN.........    .M..........    .CM.........
 VELOCITY.......    .FT/S.......    .N.A........    .M/S........    .CM/S.......
 DENSITY........    .LBM/FT3....    .N.A........    .KG/M3......    .G/CC.......
 TEMPERATURE....    .RANKINE....    .N.A........    .KELVIN.....    .N.A........
 ENTHALPY.......    .BTU/LBM....    .N.A........    .KJ/KG......    .N.A........
 FROZ.SPEC. HEAT    .BTU/LBM-R..    .N.A........    .KJ/KG-K....    .N.A........
 VISCOSITY......    .LBM/FT-S...    .N.A........    .NT-S/M2....    .POISE......
 LOCAL PRESSURE     .PSF........    .PSI........    .NT/M2......    .TORR.......
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```
 LOCAL  SOLUTION       MACH NC.       DPDX1(LBF/FT3) MAX. H2 CONC.   MIX EFF.(ETA)
 X1/LREF              DX1/LREF            EPSILON       DX1MIN/LREF
IONUMB  -1
  200    4*43    200  27   200  2*27
  200    10  200   2*10    200    58    200    58  200
  200   97  200  97  200    200  30    200   30  200
  200   38  200  2*38
 999
  200   36    36   36   36
 200
   61      100   134     122
  11   12   14    85

IOSAVE  -1
 1248  285  320  284  10248
 2248  278  4248  9248   8248
 1247  334   292  314
 T U,T,HS,RHO,N2,V,CP,HTOT,H2,O2,DIFU,PR NO.,LAM.VISC.,SCT.NO.
IOMULT  -1
 14*2
 T U,T,HS,RHO,N2,V,CP,HTOT,H2,O2,DIFU,PR NO.,LAM.VISC.,SCT.NO.
DESCRIPT 2
U1/UREF          T/TREF           HSTAT/HREF        RHO/RHOREF       ELEM.N2 MAS.FRAC
U2/UREF          CPF/CPFREF       HTOT/HREF         ELEM.H2 MAS.FRACELEM.O2 MAS.FRAC
EFF.MU/MUREF     EFF. PRANDTL NO.MU/MUREF           EFF.SCHMIDT NO.
COMOC
DESCRIPT
  COMOC CHECK CASE FOR TWO-DIMENSIONAL FLOW WITH PRESSURE GRADIENT.
 A COMPARABLE SIMILARITY SOLUTION HAS BEEN REPORTED BY CHRISTIAN ET AL,
 ARL 70-0023. SPECIFIC CASE CONSIDERED CORRESPONDS TO MACH NO.5 BETA=0.5,
 S(0)=0 (ADIABATIC WALL). SOLUTION STARTED AT X=0.10 FT. WITH SIMILAR
 SOLUTION PROFILE.LAMINAR FLOW WITH VISCOSITY FROM SUTHERLANDS LAW.
 DISCRETIZATION SPANS THREE TIMES INITIAL BOUNDARY LAYER THICKNESS.
 ISOENERGETIC FLOW WITH TOTAL TEMPERATURE = 1800 R.
DONE
VX3ST
     11*I0.05  0.1                        T  X1 TABLE FOR PRESSURE
VPVSX
  4.3494  3.41  2.846  2.46  2.2176  2.02  1.857  1.73  1.6178  1.53  1.4451
 T
IPINT   -1
    1    4    8   10    9    3    2  T INTEGRATE U1,ENTH.,O2,N2,H2,U3,U2
KBNO    1
BOTTOM             DONE
       FIXES U1 (VARIABLE NO. 1) ALONG WALL TO INITIAL VALUE
KBNO    2
BOTTOM             DONE
       FIXES U2 (VARIABLE NO. 2) ALONG WALL TO INITIAL VALUE
KBNO    4
BOTTOM             DONE
```

```
          FIXES H  (VARIABLE NO. 4) ALONG WALL TO INITIAL VALUE
ICALL    -1
   2     5     2     2  1 1  2  T
ICALLS   -1
  10     6     4    12  5 6  3  T
LINK3    4                                                              DIMEN
LINK1    3                                                              GEOMFL
VTEMP                      -58
    42*1800.
 T  INITIAL  TOTAL TEMPERATURE PROFILE
VYY                      -27
 2*0.0  2*865.    2*1654.   2*2373.   2*3004.   2*3550.   2*3879.
        2*3992.   2*4CC4.2            24*4004.8
 T  INITIAL U1 PROFILE
VYYEND   1
VYY                      -27
   2*0.0      2*2.12    2*20.14   2*53.52   2*83.2    2*109.3   2*165.
   2*253.     2*447.    24*45C.
 T  INITIAL U2 PROFILE
VYYEND   2
VYY
          42*.233C
 T INITIAL O2 MASS FRACTICN PROFILE
VYYEND   8
VYY
          42*.767C
 T INITIAL N2 MASS FRACTICN PROFILE
VYYEND  10
VYY
          42*0.C
 T INITIAL H2 MASS FRACTICN PROFILE
VYYEND   9
OKNINT
DESCRIPT
DONE
DESCRIPT 3
 REFERENCE LENGTH,LREF                                   43 FT.
 REFERENCE VISCOSITY,LAMINAR VALUE
 EVALUATED AT REF. TEMPERATURE.                          38 LBM/FT-S
 FREESTREAM VELOCITY AT XO(=LREF)                        27 FT/S
 STAGNATION TEMPERATURE (CONSTANT,=TREF)                 58 DEG R
 FREESTREAM DENSITY AT XO(=RHOREF)                       10 LBM/FT3
 FREESTREAM MACH NUMBER AT XO                           154
 STATIC PRESSURE AT XC                                    9 PSF
 NUMBER OF NODES                                        -16
 NUMBER OF FINITE ELEMENTS                              -14
DONE
CCMOC
END
EXIT
```

APPENDIX B

DATA DECK LISTING FOR VIRTUAL SOURCE THREE-DIMENSIONAL CHECK CASE

```
FEBL
CONTITLE
  COMOC CHECK CASE FOR THREE DIMENSIONAL REACTING BOUNDARY REGION FLOW
FENAME
 &NAME01
          NEOKNN=5,            IGAS=1,              IFR=0,               KDUMP=0,
          NPVSX=2,             NSCX=1,              NSCY=1,
    NE1E2=1,
 &END
 &NAME02
          UINF=2272.,          TCFINF=533.0,        REFL=.003333333,
          TO=0.0,              TD=0.10,             DELP=5.0,            EPS=0.01,
          XSCALE=0.003333333,  YSCALE=0.003333333,  VSTART=101.0,
 &END
FEDTMN
LINK1    1                                                               SETUP
    1 75  100, 2  50  100, 3  125  100, 4  150  100, 5  225  100,
T   INCREMENTS BETWEEN X3, NODE-NUMERATOR-DENOMINATOR
    1  5  10, 7  5  10, 8  125  100, 9  175  100, 10  250  100,
T   INCREMENTS BETWEEN X2
    1  11, 1  6,
T   11 ROWS AND 6 COLUMNS NORMALIZED BY LREF,HENCE X-Y SCALES =LREF
  CHECK CASE,THREE DIMENSIONAL REACTING BOUNDARY REGION - VIRTUAL SOURCE

 REFERENCE      ENGLISH-FT       ENGLISH-IN        M-K-S           C-G-S
----------     -----------      -----------       -------         -------

DONE
MPARA    -1
   2     2    162    164    163
   2     2     2     164    163
   2     2     2     170    174
   2     2     2     165     2
   2  -175     2      2      2
   2     2     2      176    2
   2     2     2     177     178
   2     2    169    168    167
   2     2     2      2      2
   2     2     2    2

HOLIST
 LENGTH.........    .FT.........    .IN.........      .M..........     .CM.........
 VELOCITY.......    .FT/S.......    .N.A........      .M/S........     .CM/S.......
 DENSITY........    .LBM/FT3....    .N.A........      .KG/M3......     .G/CC.......
 TEMPERATURE....    .RANKINE....    .N.A........      .KELVIN.....     .N.A........
 ENTHALPY.......    .BTU/LBM....    .N.A........      .KJ/KG......     .N.A........
 FROZ.SPEC. HEAT    .BTU/LBM-R..    .N.A........      .KJ/KG-K....     .N.A........
 VISCOSITY......    .LBM/FT-S...    .N.A........      .NT-S/M2....     .POISE......
 LOCAL PRESSURE     .PSF........    .PSI........      .NT/M2......     .TORR.......
 LOCAL SOLUTION      MACH NO.       DPDXL(LBF/FT3)  MAX. H2 CONC.    MIX EFF.(ETA)
```

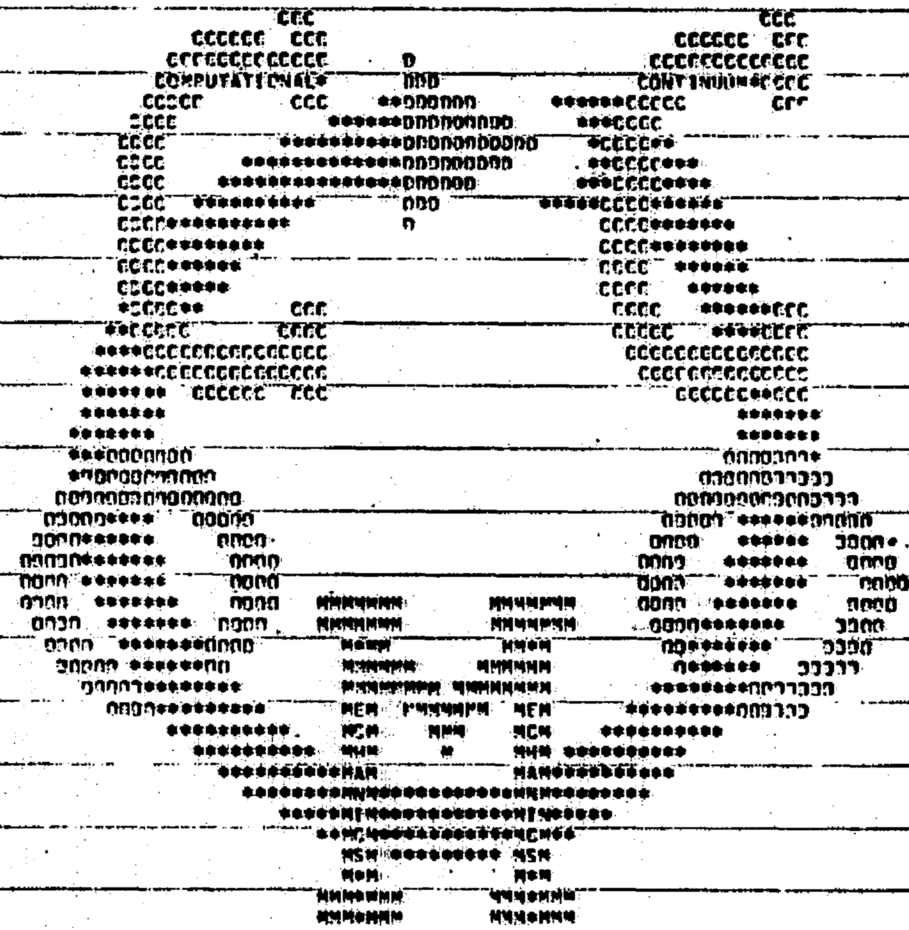
```
 X1/LREF              DX1/LREF              EPSILON      DX1MIN/LREF
IONUMB   -1
  200    4*43     200  27    200  2*27
  200    10  200    2*10     200    58     200   58  200
  200    97  200  97  200       200  30    200   30  200
  200    38  200  2*38
 999
  200    36    36    36    36
 200
   61       100    134     122
  11    12    14    85

IOSAVE   -1
 1248   285   320   284   10248
 2248   278   4248   9248   8248
 1247   334    252   314
 T U,T,HS,RHO,N2,V,CP,HTOT,H2,O2,DIFU,PR NO.,LAM.VISC.,SCT.NO.
IOMULT   -1
 14*2
 T U,T,HS,RHO,N2,V,CP,HTOT,H2,O2,DIFU,PR NO.,LAM.VISC.,SCT.NO.
DESCRIPT 2
U1/UREF           T/TREF             HSTAT/HREF          RHO/RHOREF       ELEM.N2 MAS.FRAC
U2/UREF           CPF/CPFREF         HTOT/HREF           ELEM.H2 MAS.FRACELEM.O2 MAS.FRAC
EFF.MU/MUREF      EFF. PRANDTL NO.MU/MUREF               EFF.SCHMIDT NO.
COMOC
DESCRIPT
  CHECK CASE,THREE DIMENSIONAL REACTING BOUNDARY REGION - VIRTUAL SOURCE
  (H2/O2/AIR SYSTEM WITH EQUILIBRIUM CHEMISTRY). PROBLEM CONSIDERED
  REPRESENTS TRANSVERSE H2 INJECTION INTO A SUPERSONIC AIR STREAM
  CHARACTERISTIC OF SCRAMJET FUEL INJECTION,SEE ROGERS NASA TND-6114,
  1971 AND NASA TND-6476,1971 FOR EXPERIMENTAL STUDY OF THIS PROBLEM.
  TURBULENCE MODEL EMPLOYED IS DESCRIBED IN USER'S MANUAL NASA CR-132450,1974.
  CALCULATIONS ARE STARTED USING VIRTUAL SOURCE CONCEPT TO REPLACE
  COMPLEX NEAR INJECTION FLOW FIELD.
DONE
VX3ST
   0.0       100.       T X1 TABLE FOR PRESSURE
VPVSX
   193.      193.       T PRESSURE  TABLE PSF
IPINT    -1
    1      4     8    10     9     3     2  T INTEGRATE U1,ENTH.,C2,N2,H2,U3,U2
KBNO      1
BOTTOM                 DONE
         FIXES U1 (VARIABLE NO. 1) ALONG WALL TO INITIAL VALUE
KBNO      2
BOTTOM                 DONE
         FIXES U2 (VARIABLE NO. 2) ALONG WALL TO INITIAL VALUE
KBNO      4
BOTTOM                 30DONE
         FIXES H  (VARIABLE NO. 4) ALONG WALL TO INITIAL VALUE
```

```
KBNO      8
BOTTOM              3DONE
          FIXES H  (VARIABLE NO. 8) ALONG WALL TO INITIAL VALUE
KBNO      9
BOTTOM              3DONE
          FIXFS H  (VARIABLE NO. 9) ALCNG WALL TO INITIAL VALUE
KBNO      10
BOTTOM              3DONE
          FIXFS H  (VARIABLE NO. 10 ALONG WALL TO INITIAL VALUE
ICALL    -1
   2      5     2    2  1 1  2  T
ICALLS   -1
   10     6     4    12  5 6  3  T
LINK3     4                                                            DIMEN
LINK1     3                                                            GEOMFL
VTEMP                     -58
     66*533.
 T  INITIAL TOTAL TEMPERATURE PROFILE
VVY                   -27
    6*0.0
    6*1503.
    6*1660.
    2*1550.    4*1759.
    2*1550.    4*1833.
    2*1550.    4*1892.
    2*2272.    4*1942.
    2*2272.    4*1985.
    2*2272.    4*2C74.
    2*2272.    4*2169.
    6*2272.
 T  INITIAL U1 PROFILE
VVYEND    1
VVY                   -27
    66*0.0
 T  INITIAL U2 PROFILE
VVYEND    2
VVY
   18*.233        2*0.0    4*.233    2*0.0     4*.233    2*0.0    34*.233
 T INITIAL O2 MASS FRACTION PROFILE
VVYEND    8
VVY
   18*.767        2*0.0    4*.767    2*0.0     4*.767    2*0.0    34*.767
 T INITIAL N2 MASS FRACTION PROFILE
VVYEND   10
VVY
   18*0.0         2*1.0    4*G.0     2*1.0     4*0.0     2*1.0    34*0.0
 T INITIAL H2 MASS FRACTICN PROFILE
VVYEND    9
QMNINT
DESCRIPT
DONE
DESCRIPT 3
 REFERENCE LENGTH,LREF                          43 FT.
 REFERFNCE VISCOSITY,LAMINAR VALUE
 EVALUATED AT REF. TEMPERATURE.                 38 LBM/FT-S
 FREESTREAM VELOCITY AT XO(=UREF)               27 FT/S
 STAGNATION TEMPERATURE (CONSTANT,=TREF)        58 DEG R
 FREESTREAM DENSITY AT XO(=RHOREF)              10 LBM/FT3
 FREESTREAM MACH NUMBER AT XO                  154
 STATIC PRESSURE AT XO                           9 PSF
 NUMBER OF NODES                               -16
 NUMBER OF FINITE ELEMENTS                     -14
DONE
END
EXIT
```

APPENDIX C

SAMPLE OUTPUT FOR MACH 5 TWO-DIMENSIONAL FLOW CHECK CASE



C O M O C

COMPUTATIONAL CONTINUUM MECHANICS
THREE-DIMENSIONAL BOUNDARY REGION VARIANT

CHECK CASE, TWO DIMENSIONAL SUPERSONIC FLOW WITH PRESSURE GRADIENT 06/25/74

```
PROBLEM DESCRIPTION

 CONMOR CHECK CASE FOR TWO-DIMENSIONAL FLOW WITH PRESSURE GRADIENT.
A COMPARABLE SIMILARITY SOLUTION HAS BEEN REPORTED BY CHRISTIAN ET AL.
APL 73-0923. SPECIFIC CASE CONSIDERED CORRESPONDS TO MACH NO.5 BETA=0.5.
SIDI=0 (ADIABATIC WALL). SOLUTION STARTED AT X=0.10 FT. WITH SIMILAR
SOLUTION PROFILE.LAMINAR FLOW WITH VISCOSITY FROM SUTHERLANDS LAW.
DISCRETIZATION SPANS THREE TIMES INITIAL BOUNDARY LAYER THICKNESS.
ISOENERGETIC FLOW WITH TOTAL TEMPERATURE = 1800 R.

 2 NON-INT. NODES FOR VARIABLE   1

   1    2

 2 NON-INT. NODES FOR VARIABLE   2

   1    2

 2 NON-INT. NODES FOR VARIABLE   6

   1    2

40 INTEGRATION NODES FOR VARIABLE   1

   3    4    5    6    7    8    9   10   11   12
  13   14   15   16   17   18   19   20   21   22
  23   24   25   26   27   28   29   30   31   32
  33   34   35   36   37   38   39   40   41   42

40 INTEGRATION NODES FOR VARIABLE   2

   3    4    5    6    7    8    9   10   11   12
  13   14   15   16   17   18   19   20   21   22
  23   24   25   26   27   28   29   30   31   32
  33   34   35   36   37   38   39   40   41   42

42 INTEGRATION NODES FOR VARIABLE   8

   1    2    3    4    5    6    7    8    9   10
  11   12   13   14   15   16   17   18   19   20
  21   22   23   24   25   26   27   28   29   30
  31   32   33   34   35   36   37   38   39   40
  41   42

42 INTEGRATION NODES FOR VARIABLE  10

   1    2    3    4    5    6    7    8    9   10
  11   12   13   14   15   16   17   18   19   20
  21   22   23   24   25   26   27   28   29   30
  31   32   33   34   35   36   37   38   39   40
  41   42
```

```
 42 INTEGRATION NODES FOR VARIABLE    9

      1    2    3    4    5    6    7    8    9   10
     11   12   13   14   15   16   17   18   19   20
     21   22   23   24   25   26   27   28   29   30
     31   32   33   34   35   36   37   38   39   40
     41   42

               2 VARIABLES BEING INTEGRATED.
  1    4

                7 VARIABLES IN SOLUTION.
  1    4    8   10    9    3    2

         LINK1( 9) = DERIV USED.

ORDER OF CALLS AT END OF OKSUTN
  LINK2(10)   LINK5( 6)   LINK2( 4)   LINK2(12)   LINK1( 5)
  LINK1( 6)   LINK2( 3)   LINK
```

C-3

INITIAL CONDITIONS

1	ND	= 1	2		= 0	3	IROW	= 1	4	KEYMTD	= 1	5	NOMEGR	= 0
6	KODS	= 0	7	KODS	= 0	8	KPRINT	= 0	9	NRSTRT	= 0	10	NV	= 0
11	NTDOF	= 1	12	KINIT	= 0	13	NCOORD	= 0	14	NELEM	= 40	15	NN	= 3
16	NNDOF	= 42	17	NVS	= 6	18	NPART	= 2	19	NDF	= 40	20	NPRNT	= 132
21	NROW	= 2	22	NC	= 8	23	NB	= 4	24	NPTFL	= 3	25	KIND	= 4
26	NTINT	= 1	27	NSKIP	= 60	28	IPASS	= 1	29	IRUN	= 0	30	NP	= 2
31	NEQ	= 7	32	ISUB	= 0	33	NBUG	= 0	34	LPRINT	= 100	35	KPT1	= 0
36	KPT2	= 0	37	KPT3	= 0	38	KPT4	= 0	39	KPT5	= 0	40	KPT6	= 0
41	KPT7	= 0	42	KPT8	= 0	43	KPT9	= 0	44	KPT10	= 0	45	NEXP	= 0
46	NF	= 6	47	LG	= 2	48	NDDF	= 0	49	NDEL	= 3	50	LCOL	= 2
51	NROL	= 0	52	KROW	= 21	53	NH2	= 0	54	NHHALF	= 0	55	NODF	= 150
56	NOHITT	= 2	57	IYSVEC	= 0	58	NFOKNN	= 2	59	NCPTAB	= 1	60	NMBOUT	= 14
61	KOUMP	= 0	62	NTITL	= 5	63	NIND	= 813	64	NSM	= 10	65	NJ	= 0
66	NDOSS	= 0	67	NS	= 0	68	NT	= 301	69	NASET	= 0	70	NVP	= 9
71	NVU	= 1	72	NVV	= 2	73	NVK	= 3	74	NVH	= 4	75		= 0
76		= 0	77	H2O	= 7	78	O2	= 8	79	H2	= 9	80	N2	= 10
81	A	= 11	82	O	= 12	83	H	= 13	84	NO	= 14	85	OH	= 15
86	KPNT	= 0	87	NRTAPE	= 0	88	NLINE	= 60	89	NEMD	= 271	90	NVY	= 2
91	NZZ	= 2	92	NDDZ	= 0	93	NTK	= 2	94	NJPARA	= 2	95	NH	= 2
96	NEIRCL	= 3	97		= 0	98	IMAT	= 1	99	YBL	= 1	100	IRENO	= 25949
101	NPRESS	= 3	102	KOUT	= 0	103	MTM	= 0	104	NFLIP	= 1	105	KSCT	= 107
106	KSETSO	= 1	107	NEIC2	= 2	108	NUO3	= 0	109	IVIRT	= 0	110		= 0
111	IMAX	= 3	112	KALLMD	= 0	113	KPLVAR	= 2	114	NOND	= 0	115	IFORCE	= 0
116	IRINIT	= 0	117	IBUG1	= 0	118	IBUG2	= 0	119	NGBUG	= 0	120	IFR	= 0
121	NSPEC	= 0	122	IWRIT	= -1	123	IGAS	= 0	124	NDERIV	= 8	125	NCALLS	= 7
126	ISPEED	= 0	127	IDIFRT	= -1	128	ICNTMD	= 150	129	IMATAB	= 2	130	NGETH	= 1
131	NDRAD	= 0	132	IRWRIT	= 0	133	ITOP	= 0	134	NPSTAD	= 0	135	NPSAML	= 0
136	KSAV	= 0	137	LPSTAT	= 0	138	LPSTAY	= 0	139	IGAS	= 0	140	NTCNTS	= 1
141	KALLO3	= 0	142	NOUTPR	= 59	143	NTDEBL	= 0	144	NSDFBL	= 0	145	NS2DBL	= 0
146		= 0	147		= 0	148	NONC	= 0	149	IT	= 0	150	NODND	= 0
151	NSCX	= 5	152	NSCY	= 6	153	NPUNCH	= 0	154	NELDEL	= 0	155	NELADD	= 0
156	EPIL	= 1	157	I25	= 20	158	INITCN	= 0	159	NSORCE	= 1	160	NSPRSC	= 0
161	NDVSK	= 11	162	NOPVSK	= 20	163		= 0	164		= 0	165		= 0
166		= 0	167		= 0	168		= 0	169		= 0	170		= 0
171		= 0	172		= 0	173		= 0	174		= 0	175		= 0
176		= 0	177		= 0	178		= 0	179		= 0	180		= 0
181		= 0	182		= 0	183		= 0	184		= 0	185		= 0
186		= 0	187		= 0	188		= 0	189		= 0	190		= 0
191		= 0	192		= 0	193		= 0	194		= 0	195		= 0
196		= 0	197		= 0	198		= 0	199		= 0	200		= 0

INITIAL CONDITIONS

1	FACT	= 0.2000E-02	2	ONE	= 0.1000E 01	3	ALC	= 0.2330E-02	4	THK	= 0.5000E 03	5	AJ	= 0.7793E 03
6	HMINIT	= 0.0	7	HSINIT	= 0.1000E-06	8	RMINS1	= -0.1000E 01	9	PINF	= 0.4349E 01	10	RHOINF	= 0.1751E-03
11	XT	= 0.0	12	HT	= 0.0	13	DELP	= 0.5000E 01	14	EPS	= 0.1000E-03	15	H	= 0.5000E-04
16	HMAX	= 0.5000E 01	17	HMIN	= 0.0	18	OOTEPS	= 0.0	19	PNTEPS	= 0.0	20	PTIM	= 0.0
21	RF	= 0.4962E 02	22	TF	= 0.1500E 03	23	TIME	= 0.5000E 02	24	TO	= 0.5000E 02	25	TRNC	= 0.0
26	TWOPI	= 0.6283E 01	27	UINF	= 0.4005E 04	28	RUNIV	= 0.1545E 04	29	ZT	= 0.0	30	CPOINF	= 0.2400E 00
31	G	= 0.3217E 02	32	RTCON1	= 0.5008E 05	33	RTCON2	= 0.2252E 02	34	RTCON3	= 0.5334E 02	35	TO	= 0.1000E 03
36	PERDIM	= 0.4349E 01	37	XLE	= 0.1000E 01	38	XMUINF	= 0.2827E-04	39	PEDGE	= 0.4982E-01	40	TRATIO	= 0.3853E 01
41	XSHFT	= 0.0	42	YSHFT	= 0.0	43	REFL	= 0.1320E-01	44	SQ2	= 0.1414E 01	45	HS	= 0.0
46	UEDGE	= 0.0	47	TEDGE	= 0.0	48	REDGE	= 0.0	49		= 0.0	50	SSINIT	= 0.5000E-04
51	STHMIN	= -0.7237E 76	52	XSCALE	= 0.1000E 01	53	YSCALE	= 0.1000E 01	54		= 0.0	55	RTCON4	= 0.3213E 03
56	RTCON5	= 0.7413E 00	57	RTCON6	= 0.6426E 03	58	TOFINF	= 0.1800E 04	59	FACTMU	= 0.1403E-02	60	GAMMAF	= 0.1400E 01
61	XMACHO	= 0.0	62	CONV	= 0.7576E 02	63		= 0.0	64		= 0.0	65	ZTEST	= 0.1000E-04
66	XMF	= 0.2940E 02	67	PR	= 0.1000E 01	68		= 0.0	69		= 0.0	70	CONRHO	= 0.0
71	STLOVR	= 0.1163E-04	72	STLDTR	= 0.4920E 03	73	STLDCR	= 0.2040E 03	74	STLDEX	= 0.1500E 01	75		= 0.0
76	XT	= 0.0	77	CON1	= 0.5941E 01	78	CON2	= 0.3301E-02	79	FACTP	= 0.7130E 03	80	FACTH	= 0.2315E-02
81	XI	= 0.0	82	YI	= 0.0	83	COMPX	= 0.0	84	COMPY	= 0.0	85	HMIND	= 0.0
86		= 0.0	87		= 0.0	88	HHMIN	= 0.0	89		= 0.0	90		= 0.0
91		= 0.0	92		= 0.0	93		= 0.0	94		= 0.0	95		= 0.0
96		= 0.0	97	HINF	= 0.1000E 01	98	XPRIME	= -0.4305E-03	99	PPRCON	= 0.4365E 05	100	PPRIME	= -0.1879E 02
101	VHO	= 0.0	102	VSTART	= 0.5000E 01	103	DEPLT	= 0.1310E 03	104	VELCST	= 0.7413E 00	105	ROCST	= 0.1337E 02
106	RCTH	= 0.1010E 01	107	SCTMLT	= 0.1000E 01	108	SCTMIN	= 0.2000E 00	109	XMA	= 0.2897E 02	110	XMH	= 0.2015E 01
111	DELX3	= 0.0	112	X3LAST	= 0.5000E 02	113	DLAST	= 0.0	114	DLXM1	= 0.0	115	RSTART	= 0.1010E 03
116	RR3	= 0.1435E 02	117	RTOHM1	= -0.1000E 01	118	XMSDF	= 0.0	119	ROUALC	= 0.2805E-05	120		= 0.0
121	HDOT	= 0.0	122	HRSDOT	= 0.0	123	QR	= 0.1000E 01	124	CON	= 0.4000E 00	125	XLAM	= 0.9000E-01
126	XMUAIR	= 0.1150E-04	127	XMUH2	= 0.5600E-05	128	XMUP5	= 0.7300E-05	129	SCT	= 0.7000E 00	130	C4ED	= 0.2300E-03
131	SPLIT	= 0.2835E-01	132	HRCON	= 0.2913E-01	133	PCNT	= 0.0	134	Q3MAX	= 0.0	135	FLIPSH	= 0.0
136	FLIPSK	= 0.3000E 01	137	FLIPSA	= 0.6000E 01	138	ELIPSB	= 0.2500E 01	139	VH	= 0.0	140	VK	= 0.2000E 01
141	VA	= 0.1510E 01	142	VB	= 0.6750E 00	143	C4EDSW	= 0.3000E 05	144	C4FACT	= 0.1000E 01	145	F1F2SW	= 0.3000E 05
146	TOA	= 0.1800E 04	147	TOH	= 0.0	148	CVH	= 0.1000E 01	149	CVU	= 0.3048E 00	150	CVT	= 0.1000E 01
151	CVP	= 0.4725E-03	152	CVRHO	= 0.1602E 02	153	CVCP	= 0.4186E 04	154	XMACHS	= 0.3777E 01	155	TSINF	= 0.4655E 03
156	AINF	= 0.1059E 04	157	RHOUIN	= 0.7013E 00	158	CPA	= 0.2400E 00	159	CPH	= 0.3445E 01	160	CPINF	= 0.2400E 00
161	PPINF	= 0.2809E 04	162	FTTOIN	= 0.1200E 02	163	FTTOCM	= 0.3048E 02	164	FTTOMT	= 0.3048E 00	165	DRTOOK	= 0.5556E 00
166	PSFTOA	= 0.4725E-03	167	PSFTOT	= 0.3591E 00	168	PSFTON	= 0.4788E 02	169	PSFTOI	= 0.6944E-02	170	PDFTOK	= 0.1602E 02
171	PASCON	= 0.8720E 02	172	XMFACT	= 0.1940E 01	173	ZMAX	= 0.0	174	PDFTOC	= 0.1602E-01	175	FRTOKJ	= 0.2324E 01
176	CRTOKJ	= 0.4184E 01	177	VLBTON	= 0.1488E 01	178	VLBTOP	= 0.1488E 02	179		= 0.0	180		= 0.0
181		= 0.0	182		= 0.0	183		= 0.0	184		= 0.0	185		= 0.0
186		= 0.0	187		= 0.0	188		= 0.0	189		= 0.0	190		= 0.0
191		= 0.0	192		= 0.0	193		= 0.0	194		= 0.0	195		= 0.0
196		= 0.0	197		= 0.0	198		= 0.0	199		= 0.0	200		= 0.0

NODE AND COORDINATE MAP OF DISCRETIZATION

X2COR
SCALE
FACTOR
......
X2COR ...NODE NUMBERS...
......

X1COR
SCALE ... X1COR ...
FACTOR

- X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X -

E 1		
0.30303	0.41	0.42
0.28788	0.39	0.40
0.27273	0.37	0.38
0.25758	0.35	0.36
0.24242	0.33	0.34
0.22727	0.31	0.32
0.21212	0.29	0.30
0.19697	0.27	0.28
0.18182	0.25	0.26
0.16667	0.23	0.24
0.15151	0.21	0.22
0.13636	0.19	0.20
0.12121	0.17	0.18
0.10606	0.15	0.16
0.09091	0.13	0.14
0.07576	0.11	0.12
0.06061	0.09	0.10
0.04545	0.07	0.08
0.03030	0.05	0.06
0.01515	0.03	0.04
0.00000	0.01	0.02
E 0	0.00000	0.15152

- X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X -

ORIGINAL PAGE IS
OF POOR QUALITY

C O M O C

THREE-DIMENSIONAL BOUNDARY REGION VARIANT 04/25/74

CHECK CASE,TWO DIMENSIONAL SUPERSONIC FLOW WITH PRESSURE GRADIENT

REFERENCE	ENGLISH-FT	ENGLISH-IN	M-K-S	C-G-S
LENGTH..........	.FT..........	.IN..........	.M...........	.CM..........
0.0	0.13200E-01	0.15840E 00	0.40234E-02	0.40234E 00
VELOCITY.......	.FT/S........	.N.A.........	.M/S.........	.CM/S........
0.0	0.40048E 04	0.0	0.12207E 04	0.12207E 06
DENSITY........	.LBM/FT3....	.N.A.........	.KG/M3......	.G/CC.......
0.0	0.17512E-03	0.0	0.28054E-02	0.28054E-05
TEMPERATURE....	.RANKINE....	.N.A.........	.KELVIN.....	.N.A.........
0.0	0.18000E 04	0.0	0.10000E 04	0.0
ENTHALPY.......	.BTU/LBM....	.N.A.........	.KJ/KG......	.N.A.........
0.0	0.43022E 00	0.0	0.10000E 01	0.0
FROZ.SPEC. HEAT	.BTU/LBM-R..	.N.A.........	.KJ/KG-K....	.N.A.........
0.0	0.24000E 00	0.0	0.10042E 01	0.0
VISCOSITY......	.LBM/FT-S...	.N.A.........	.NT-S/M2....	.POISE......
0.0	0.28265E-04	0.0	0.42059E-04	0.42059E-03

X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X -

LOCAL PRESSURE	.PSF........	.PSI........	.NT/M2......	.TORR.......
0.0	0.43494E 01	0.30202E-01	0.20825E 03	0.15619E 01
LOCAL SOLUTION	MACH NO.	DPDXI(LBF/FT3)	MAX. H2 CONC.	MIX EFF.(ETA)
0.0	0.38143E 01	-0.18788E 02	0.0	0.0
XI/LREF	DXI/LREF	EPSILON	DXIMIN/LREF	
0.75757E 01	0.0	0.10000E-03	0.0	

- X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X -

N-	N+	PASSES	PRINT	OF
0	0	2	1	100

E 1	U1/UREF	E 1	U2/UREF	E 0
0.30303	0.10000	0.10000	0.11236	0.11236
0.28788	0.10000	0.10000	0.11236	0.11236
0.27273	0.10000	0.10000	0.11236	0.11236
0.25758	0.10000	0.10000	0.11236	0.11236
0.24242	0.10000	0.10000	0.11236	0.11236
0.22727	0.10000	0.10000	0.11236	0.11236
0.21212	0.10000	0.10000	0.11236	0.11236
0.19697	0.10000	0.10000	0.11236	0.11236
0.18182	0.10000	0.10000	0.11236	0.11236
0.16667	0.10000	0.10000	0.11236	0.11236
0.15151	0.10000	0.10000	0.11236	0.11236
0.13636	0.10000	0.10000	0.11236	0.11236
0.12121	0.09998	0.09998	0.11162	0.11162
0.10606	0.09968	0.09968	0.06317	0.06317
0.09091	0.09686	0.09686	0.04120	0.04120
0.07576	0.08864	0.08864	0.02729	0.02729
0.06061	0.07501	0.07501	0.02078	0.02078
0.04545	0.05925	0.05925	0.01336	0.01336
0.03030	0.04130	0.04130	0.00503	0.00503
0.01515	0.02160	0.02160	0.00053	0.00053
0.00000	0.00000	0.00000	0.00000	0.00000
E 0	0.00000	0.15152	0.00000	0.15152

ORIGINAL PAGE IS
OF POOR QUALITY

T/TREF F 1 — CPF/CPFREF F 1

F 1	T/TREF		CPF/CPFREF	
0.30303	0.02587	0.02587	0.10000	0.10000
0.28788	0.02587	0.02587	0.10000	0.10000
0.27273	0.02587	0.02587	0.10000	0.10000
0.25758	0.02587	0.02587	0.10000	0.10000
0.24242	0.02587	0.02587	0.10000	0.10000
0.22727	0.02587	0.02587	0.10000	0.10000
0.21212	0.02587	0.02587	0.10000	0.10000
0.19697	0.02587	0.02587	0.10000	0.10000
0.18182	0.02587	0.02587	0.10000	0.10000
0.16667	0.02587	0.02587	0.10000	0.10000
0.15151	0.02587	0.02587	0.10000	0.10000
0.13636	0.02587	0.02587	0.10000	0.10000
0.12121	0.02589	0.02589	0.10000	0.10000
0.10606	0.02634	0.02634	0.10000	0.10000
0.09091	0.03045	0.03045	0.10000	0.10000
0.07576	0.04175	0.04175	0.10000	0.10000
0.06061	0.05929	0.05929	0.10000	0.10000
0.04545	0.07397	0.07397	0.10000	0.10000
0.03030	0.08736	0.08736	0.10000	0.10000
0.01515	0.09654	0.09654	0.10000	0.10000
0.00000	0.10000	0.10000	0.10000	0.10000
F 0	0.00000	0.15152	0.00000	0.15152

HSTAT/HREF F 0 — HTOT/HREF F 0

F 1	HSTAT/HREF		HTOT/HREF	
0.30303	0.00000	0.00000	0.00000	0.00000
0.28788	0.00000	0.00000	0.00000	0.00000
0.27273	0.00000	0.00000	0.00000	0.00000
0.25758	0.00000	0.00000	0.00000	0.00000
0.24242	0.00000	0.00000	0.00000	0.00000
0.22727	0.00000	0.00000	0.00000	0.00000
0.21212	0.00000	0.00000	0.00000	0.00000
0.19697	0.00000	0.00000	0.00000	0.00000
0.18182	0.00000	0.00000	0.00000	0.00000
0.16667	0.00000	0.00000	0.00000	0.00000
0.15151	0.00000	0.00000	0.00000	0.00000
0.13636	0.00000	0.00000	0.00000	0.00000
0.12121	0.00000	0.00000	0.00000	0.00000
0.10606	0.00000	0.00000	0.00000	0.00000
0.09091	0.00000	0.00000	0.00000	0.00000
0.07576	0.00000	0.00000	0.00000	0.00000
0.06061	0.00000	0.00000	0.00000	0.00000
0.04545	0.00000	0.00000	0.00000	0.00000
0.03030	0.00000	0.00000	0.00000	0.00000
0.01515	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000
F 0	0.00000	0.15152	0.00000	0.15152

F 1	RHO/RHOREF F 0		FLEM.H2 MAS.FRAC F 0	
0.30303	0.99838	0.99838	0.00000	0.00000
0.28788	0.99838	0.99838	0.00000	0.00000
0.27273	0.99838	0.99838	0.00000	0.00000
0.25758	0.99838	0.99838	0.00000	0.00000
0.24242	0.99838	0.99838	0.00000	0.00000
0.22727	0.99838	0.99838	0.00000	0.00000
0.21212	0.99838	0.99838	0.00000	0.00000
0.19697	0.99838	0.99838	0.00000	0.00000
0.18182	0.99838	0.99838	0.00000	0.00000
0.16667	0.99838	0.99838	0.00000	0.00000
0.15151	0.99838	0.99838	0.00000	0.00000
0.13636	0.99838	0.99838	0.00000	0.00000
0.12121	0.99753	0.99753	0.00000	0.00000
0.10606	0.98045	0.98045	0.00000	0.00000
0.09091	0.84809	0.84809	0.00000	0.00000
0.07576	0.61860	0.61860	0.00000	0.00000
0.06061	0.44306	0.44306	0.00000	0.00000
0.04545	0.34913	0.34913	0.00000	0.00000
0.03030	0.29564	0.29564	0.00000	0.00000
0.01515	0.26751	0.26751	0.00000	0.00000
0.00000	0.25826	0.25826	0.00000	0.00000
F 0	0.00000	0.15152	0.00000	0.15152

F 1	FLEM.N2 MAS.FRAC F 0		FLEM.O2 MAS.FRAC F 0	
0.30303	0.76700	0.76700	0.23300	0.23300
0.28788	0.76700	0.76700	0.23300	0.23300
0.27273	0.76700	0.76700	0.23300	0.23300
0.25758	0.76700	0.76700	0.23300	0.23300
0.24242	0.76700	0.76700	0.23300	0.23300
0.22727	0.76700	0.76700	0.23300	0.23300
0.21212	0.76700	0.76700	0.23300	0.23300
0.19697	0.76700	0.76700	0.23300	0.23300
0.18182	0.76700	0.76700	0.23300	0.23300
0.16667	0.76700	0.76700	0.23300	0.23300
0.15151	0.76700	0.76700	0.23300	0.23300
0.13636	0.76700	0.76700	0.23300	0.23300
0.12121	0.76700	0.76700	0.23300	0.23300
0.10606	0.76700	0.76700	0.23300	0.23300
0.09091	0.76700	0.76700	0.23300	0.23300
0.07576	0.76700	0.76700	0.23300	0.23300
0.06061	0.76700	0.76700	0.23300	0.23300
0.04545	0.76700	0.76700	0.23300	0.23300
0.03030	0.76700	0.76700	0.23300	0.23300
0.01515	0.76700	0.76700	0.23300	0.23300
0.00000	0.76700	0.76700	0.23300	0.23300
F 0	0.00000	0.15152	0.00000	0.15152

E 1	EFF.MU/MUREF E 1		MU/MUREF E 1	
0.30303	0.03937	0.03937	0.03937	0.03937
0.28788	0.03937	0.03937	0.03937	0.03937
0.27273	0.03937	0.03937	0.03937	0.03937
0.25758	0.03937	0.03937	0.03937	0.03937
0.24242	0.03937	0.03937	0.03937	0.03937
0.22727	0.03937	0.03937	0.03937	0.03937
0.21212	0.03937	0.03937	0.03937	0.03937
0.19697	0.03937	0.03937	0.03937	0.03937
0.18182	0.03937	0.03937	0.03937	0.03937
0.16667	0.03937	0.03937	0.03937	0.03937
0.15151	0.03937	0.03937	0.03937	0.03937
0.13636	0.03937	0.03937	0.03937	0.03937
0.12121	0.03940	0.03940	0.03940	0.03940
0.10606	0.03995	0.03995	0.03995	0.03995
0.09091	0.04477	0.04477	0.04477	0.04477
0.07576	0.05658	0.05658	0.05658	0.05658
0.06061	0.07116	0.07116	0.07116	0.07116
0.04545	0.08303	0.08303	0.08303	0.08303
0.03030	0.09211	0.09211	0.09211	0.09211
0.01515	0.09790	0.09790	0.09790	0.09790
0.00000	0.10000	0.10000	0.10000	0.10000
E 0	0.00000	0.15152	0.00000	0.15152

E 1	EFF. PRANDTL NO. E 1		EFF.SCHMIDT NO. E 1	
0.30303	0.10000	0.10000	0.10000	0.10000
0.28788	0.10000	0.10000	0.10000	0.10000
0.27273	0.10000	0.10000	0.10000	0.10000
0.25758	0.10000	0.10000	0.10000	0.10000
0.24242	0.10000	0.10000	0.10000	0.10000
0.22727	0.10000	0.10000	0.10000	0.10000
0.21212	0.10000	0.10000	0.10000	0.10000
0.19697	0.10000	0.10000	0.10000	0.10000
0.18182	0.10000	0.10000	0.10000	0.10000
0.16667	0.10000	0.10000	0.10000	0.10000
0.15151	0.10000	0.10000	0.10000	0.10000
0.13636	0.10000	0.10000	0.10000	0.10000
0.12121	0.10000	0.10000	0.10000	0.10000
0.10606	0.10000	0.10000	0.10000	0.10000
0.09091	0.10000	0.10000	0.10000	0.10000
0.07576	0.10000	0.10000	0.10000	0.10000
0.06061	0.10000	0.10000	0.10000	0.10000
0.04545	0.10000	0.10000	0.10000	0.10000
0.03030	0.10000	0.10000	0.10000	0.10000
0.01515	0.10000	0.10000	0.10000	0.10000
0.00000	0.10000	0.10000	0.10000	0.10000
E 0	0.00000	0.15152	0.00000	0.15152

SKIN FRICTION DISTRIBUTION(CF/2)

1	0.43438E-02	2	0.43438E-02

C O M O C

THREE-DIMENSIONAL BOUNDARY REGION VARIANT 04/25/74

CHECK CASE,TWO DIMENSIONAL SUPERSONIC FLOW WITH PRESSURE GRADIENT

REFERENCE	ENGLISH-FT	ENGLISH-IN	M-K-S	C-G-S
LENGTH.........	.FT..........	.IN..........	.M..........	.CM..........
0.0	0.13200E-01	0.15840E 00	0.40234E-02	0.40234E 00
VELOCITY.......	.FT/S........	.N.A.........	.M/S........	.CM/S........
0.0	0.40048E 04	0.0	0.12207E 04	0.12207E 06
DENSITY........	.LBM/FT3....	.N.A.........	.KG/M3......	.G/CC.......
0.0	0.17512E-03	0.0	0.28054E-02	0.28054E-05
TEMPERATURE....	.RANKINE....	.N.A.........	.KELVIN.....	.N.A........
0.0	0.18000E 04	0.0	0.10000E 04	0.0
ENTHALPY.......	.BTU/LBM....	.N.A.........	.KJ/KG......	.N.A........
0.0	0.43022E 00	0.0	0.10000E 01	0.0
FROZ.SPEC. HEAT	.BTU/LBM-R..	.N.A.........	.KJ/KG-K....	.N.A........
0.0	0.24000E 00	0.0	0.10042E 01	0.0
VISCOSITY......	.LBM/FT-S...	.N.A.........	.NT-S/M2....	.POISE......
0.0	0.28265E-04	0.0	0.42059E-04	0.42059E-03

X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X -

LOCAL PRESSURE	.PSF........	.PSI........	.NT/M2......	.TORR.......
0.0	0.22143E 01	0.15376E-01	0.10602E 03	0.79515E 00
LOCAL SOLUTION	MACH NO.	DPDXI(LBF/FT3)	MAX. H2 CONC.	MIX EFF.(FTA)
0.0	0.43159E 01	-0.39520E 01	0.0	0.0
XI/LREF	DXI/LREF	EPSILON	DXIMIN/LREF	
0.22790E 02	0.13171E 00	0.10000E-03	0.14903E-01	

- X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X -

N-	N+	PASSES	PRINT	OF
35	58	467	22	100

F 1	U1/UREF		U2/UREF F -1	
0.30303	0.10296	0.10295	0.98227	0.98147
0.28788	0.10292	0.10290	0.94698	0.94673
0.27273	0.10282	0.10278	0.91222	0.91147
0.25758	0.10259	0.10251	0.87526	0.87383
0.24242	0.10213	0.10199	0.83445	0.83193
0.22727	0.10125	0.10103	0.78682	0.78296
0.21212	0.09965	0.09935	0.72925	0.72430
0.19697	0.09700	0.09669	0.65988	0.65479
0.18182	0.09306	0.09283	0.58014	0.57603
0.16667	0.08791	0.08781	0.49499	0.49258
0.15151	0.08190	0.08188	0.41105	0.41022
0.13636	0.07532	0.07533	0.33299	0.33324
0.12121	0.06830	0.06832	0.26260	0.26358
0.10606	0.06091	0.06093	0.20045	0.20187
0.09091	0.05320	0.05322	0.14674	0.14832
0.07576	0.04519	0.04520	0.10152	0.10295
0.06061	0.03686	0.03687	0.06463	0.06575
0.04545	0.02822	0.02823	0.03596	0.03664
0.03030	0.01923	0.01924	0.01562	0.01593
0.01515	0.00985	0.00985	0.00376	0.00384
0.00000	0.00000	0.00000	0.00000	0.00000
F 0	0.00000	0.15152	0.00000	0.15152

ORIGINAL PAGE IS
OF POOR QUALITY

F 1	T/TREF F 1		CPE/CPEREF F 1	
0.30303	0.02142	0.02142	0.10000	0.10000
0.28788	0.02147	0.02150	0.10000	0.10000
0.27273	0.02163	0.02179	0.10000	0.10000
0.25758	0.02197	0.02210	0.10000	0.10000
0.24242	0.02267	0.02288	0.10000	0.10000
0.22727	0.02400	0.02434	0.10000	0.10000
0.21212	0.02638	0.02682	0.10000	0.10000
0.19697	0.03025	0.03070	0.10000	0.10000
0.18182	0.03531	0.03612	0.10000	0.10000
0.16667	0.04271	0.04295	0.10000	0.10000
0.15151	0.05027	0.05030	0.10000	0.10000
0.13636	0.05794	0.05793	0.10000	0.10000
0.12121	0.06547	0.06540	0.10000	0.10000
0.10606	0.07249	0.07249	0.10000	0.10000
0.09091	0.07900	0.07900	0.10000	0.10000
0.07576	0.08487	0.08436	0.10000	0.10000
0.06061	0.08997	0.09002	0.10000	0.10000
0.04545	0.09410	0.09409	0.10000	0.10000
0.03030	0.09726	0.09726	0.10000	0.10000
0.01515	0.09923	0.09928	0.10000	0.10000
0.00000	0.10000	0.10000	0.10000	0.10000
F 0	0.00000	0.15152	0.00000	0.15152

F 0	HSTAT/HREF F 0		HTOT/HREF F 0	
0.30303	0.00000	0.00000	0.00000	0.00000
0.28788	0.00000	0.00000	0.00000	0.00000
0.27273	0.00000	0.00000	0.00000	0.00000
0.25758	0.00000	0.00000	0.00000	0.00000
0.24242	0.00000	0.00000	0.00000	0.00000
0.22727	0.00000	0.00000	0.00000	0.00000
0.21212	0.00000	0.00000	0.00000	0.00000
0.19697	0.00000	0.00000	0.00000	0.00000
0.18182	0.00000	0.00000	0.00000	0.00000
0.16667	0.00000	0.00000	0.00000	0.00000
0.15151	0.00000	0.00000	0.00000	0.00000
0.13636	0.00000	0.00000	0.00000	0.00000
0.12121	0.00000	0.00000	0.00000	0.00000
0.10606	0.00000	0.00000	0.00000	0.00000
0.09091	0.00000	0.00000	0.00000	0.00000
0.07576	0.00000	0.00000	0.00000	0.00000
0.06061	0.00000	0.00000	0.00000	0.00000
0.04545	0.00000	0.00000	0.00000	0.00000
0.03030	0.00000	0.00000	0.00000	0.00000
0.01515	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000
F 0	0.00000	0.15152	0.00000	0.15152

E 1	RHO/RHOREF E 0		ELEM.H2 MAS.FRAC E 0	
0.30303	0.61602	0.61583	0.00000	0.00000
0.28788	0.61458	0.61360	0.00000	0.00000
0.27273	0.60989	0.60914	0.00000	0.00000
0.25758	0.60042	0.59711	0.00000	0.00000
0.24242	0.59197	0.57654	0.00000	0.00000
0.22727	0.54953	0.54209	0.00000	0.00000
0.21212	0.50099	0.49190	0.00000	0.00000
0.19697	0.43617	0.42982	0.00000	0.00000
0.18182	0.36847	0.36529	0.00000	0.00000
0.16667	0.30891	0.30794	0.00000	0.00000
0.15151	0.26245	0.26230	0.00000	0.00000
0.13636	0.22770	0.22774	0.00000	0.00000
0.12121	0.20168	0.20174	0.00000	0.00000
0.10606	0.18200	0.18204	0.00000	0.00000
0.09091	0.16697	0.16700	0.00000	0.00000
0.07576	0.15546	0.15548	0.00000	0.00000
0.06061	0.14671	0.14673	0.00000	0.00000
0.04545	0.14021	0.14022	0.00000	0.00000
0.03030	0.13566	0.13566	0.00000	0.00000
0.01515	0.13299	0.13289	0.00000	0.00000
0.00000	0.13194	0.13194	0.00000	0.00000
E 0	0.00000	0.15152	0.00000	0.15152

E 1	ELEM.N2 MAS.FRAC E 0		ELEM.O2 MAS.FRAC E 0	
0.30303	0.76700	0.76700	0.23300	0.23300
0.28788	0.76700	0.76700	0.23300	0.23300
0.27273	0.76700	0.76700	0.23300	0.23300
0.25758	0.76700	0.76700	0.23300	0.23300
0.24242	0.76700	0.76700	0.23300	0.23300
0.22727	0.76700	0.76700	0.23300	0.23300
0.21212	0.76700	0.76700	0.23300	0.23300
0.19697	0.76700	0.76700	0.23300	0.23300
0.18182	0.76700	0.76700	0.23300	0.23300
0.16667	0.76700	0.76700	0.23300	0.23300
0.15151	0.76700	0.76700	0.23300	0.23300
0.13636	0.76700	0.76700	0.23300	0.23300
0.12121	0.76700	0.76700	0.23300	0.23300
0.10606	0.76700	0.76700	0.23300	0.23300
0.09091	0.76700	0.76700	0.23300	0.23300
0.07576	0.76700	0.76700	0.23300	0.23300
0.06061	0.76700	0.76700	0.23300	0.23300
0.04545	0.76700	0.76700	0.23300	0.23300
0.03030	0.76700	0.76700	0.23300	0.23300
0.01515	0.76700	0.76700	0.23300	0.23300
0.00000	0.76700	0.76700	0.23300	0.23300
E 0	0.00000	0.15152	0.00000	0.15152

F 1	EFF.MU/MUREF F 1		MU/MUREF F 1	
0.30303	0.03369	0.03370	0.03369	0.03370
0.28788	0.03376	0.03381	0.03376	0.03381
0.27273	0.03398	0.03406	0.03398	0.03406
0.25758	0.03443	0.03459	0.03443	0.03459
0.24242	0.03534	0.03562	0.03534	0.03562
0.22727	0.03705	0.03747	0.03705	0.03747
0.21212	0.04000	0.04053	0.04000	0.04053
0.19697	0.04454	0.04505	0.04454	0.04505
0.18182	0.05060	0.05093	0.05060	0.05093
0.16667	0.05750	0.05763	0.05750	0.05763
0.15151	0.06442	0.06444	0.06442	0.06444
0.13636	0.07088	0.07088	0.07088	0.07088
0.12121	0.07675	0.07674	0.07675	0.07674
0.10606	0.08198	0.08196	0.08198	0.08196
0.09091	0.08655	0.08654	0.08655	0.08654
0.07576	0.09048	0.09047	0.09048	0.09047
0.06061	0.09376	0.09376	0.09376	0.09376
0.04545	0.09639	0.09639	0.09639	0.09639
0.03030	0.09834	0.09834	0.09834	0.09834
0.01515	0.09957	0.09957	0.09957	0.09957
0.00000	0.10000	0.10000	0.10000	0.10000
F 0	0.00000	0.15152	0.00000	0.15152

F 1	EFF. PRANDTL NO. F 1		EFF.SCHMIDT NO. F 1	
0.30303	0.10000	0.10000	0.10000	0.10000
0.28788	0.10000	0.10000	0.10000	0.10000
0.27273	0.10000	0.10000	0.10000	0.10000
0.25758	0.10000	0.10000	0.10000	0.10000
0.24242	0.10000	0.10000	0.10000	0.10000
0.22727	0.10000	0.10000	0.10000	0.10000
0.21212	0.10000	0.10000	0.10000	0.10000
0.19697	0.10000	0.10000	0.10000	0.10000
0.18182	0.10000	0.10000	0.10000	0.10000
0.16667	0.10000	0.10000	0.10000	0.10000
0.15151	0.10000	0.10000	0.10000	0.10000
0.13636	0.10000	0.10000	0.10000	0.10000
0.12121	0.10000	0.10000	0.10000	0.10000
0.10606	0.10000	0.10000	0.10000	0.10000
0.09091	0.10000	0.10000	0.10000	0.10000
0.07576	0.10000	0.10000	0.10000	0.10000
0.06061	0.10000	0.10000	0.10000	0.10000
0.04545	0.10000	0.10000	0.10000	0.10000
0.03030	0.10000	0.10000	0.10000	0.10000
0.01515	0.10000	0.10000	0.10000	0.10000
0.00000	0.10000	0.10000	0.10000	0.10000
F 0	0.00000	0.15152	0.00000	0.15152

SKIN FRICTION DISTRIBUTION(CF/2)

1 0.30288E-02 2 0.30322E-02

APPENDIX D

SAMPLE OUTPUT FOR VIRTUAL SOURCE THREE-DIMENSIONAL FLOW CHECK CASE

C C M C

COMPUTATIONAL CONTINUUM MECHANICS
THREE-DIMENSIONAL BOUNDARY REGION VARIANT

CHECK CASE, THREE DIMENSIONAL REACTING BOUNDARY REGION - VIRTUAL SOURCE 04/26/74

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PROBLEM DESCRIPTION

COMOC CHECK CASE FOR THREE DIMENSIONAL REACTING BOUNDARY REGION FLOW
(H2/O2/AIR SYSTEM WITH EQUILIBRIUM CHEMISTRY). PROBLEM CONSIDERED
REPRESENTS TRANSVERSE H2 INJECTION INTO A SUPERSONIC AIR STREAM
CHARACTERISTIC OF SCRAMJET FUEL INJECTION,SEE ROGERS NASA TND-6114,
1971 AND NASA TND-6476,1971 FOR EXPERIMENTAL STUDY OF THIS PROBLEM.
TURBULENCE MODEL EMPLOYED IS DESCRIBED IN USER'S MANUAL NASA CR------.
CALCULATIONS ARE STARTED USING VIRTUAL SOURCE CONCEPT TO REPLACE
COMPLEX NEAR INJECTION FLOW FIELD.

6 NON-INT. NODES FOR VARIABLE   1

   1    2    3    4    5    6

6 NON-INT. NODES FOR VARIABLE   2

   1    2    3    4    5    6

3 NON-INT. NODES FOR VARIABLE   4

   1    2    3

3 NON-INT. NODES FOR VARIABLE   8

   1    2    3

6 NON-INT. NODES FOR VARIABLE   9

   1    2    3    4    5    6

3 NON-INT. NODES FOR VARIABLE  10

   1    2    3

60 INTEGRATION NODES FOR VARIABLE   1

   7    8    9   10   11   12   13   14   15   16
  17   18   19   20   21   22   23   24   25   26
  27   28   29   30   31   32   33   34   35   36
  37   38   39   40   41   42   43   44   45   46
  47   48   49   50   51   52   53   54   55   56
  57   58   59   60   61   62   63   64   65   66

60 INTEGRATION NODES FOR VARIABLE   2

   7    8    9   10   11   12   13   14   15   16
  17   18   19   20   21   22   23   24   25   26
  27   28   29   30   31   32   33   34   35   36
  37   38   39   40   41   42   43   44   45   46
  47   48   49   50   51   52   53   54   55   56
```

```
  57   58   59   60   61   62   63   64   65   66

 63 INTEGRATION NODES FOR VARIABLE    9

   4    5    6    7    8    9   10   11   12   13
  14   15   16   17   18   19   20   21   22   23
  24   25   26   27   28   29   30   31   32   33
  34   35   36   37   38   39   40   41   42   43
  44   45   46   47   48   49   50   51   52   53
  54   55   56   57   58   59   60   61   62   63
  64   65   66

 63 INTEGRATION NODES FOR VARIABLE   10

   4    5    6    7    8    9   10   11   12   13
  14   15   16   17   18   19   20   21   22   23
  24   25   26   27   28   29   30   31   32   33
  34   35   36   37   38   39   40   41   42   43
  44   45   46   47   48   49   50   51   52   53
  54   55   56   57   58   59   60   61   62   63
  64   65   66

 60 INTEGRATION NODES FOR VARIABLE    9

   7    8    9   10   11   12   13   14   15   16
  17   18   19   20   21   22   23   24   25   26
  27   28   29   30   31   32   33   34   35   36
  37   38   39   40   41   42   43   44   45   46
  47   48   49   50   51   52   53   54   55   56
  57   58   59   60   61   62   63   64   65   66


          5 VARIABLES BEING INTEGRATED.
   1    4    6   10    9

          7 VARIABLES IN SOLUTION.
   1    4    6   10    9    3    2

        LINK1( 6) = DERIV USED.

ORDER CALLS AT END OF DERIV
 LINK  (  )   LINK5( 6)   LINK2( 4)   LINK2(12)   LINK1( 5)
 LINK  (  )   LINK2( 3)   LINK
```

INITIAL CONDITIONS

1	ND	1	2		0	3	IROW	1	4	KEYMTD	1	5	NOMEGB	0
6	NCDG	0	7	KOD5	0	8	KPRINT	0	9	NRSTRT	0	10	NV	0
11	NPTCOF	1	12	KINIT	0	13	NCOORD	0	14	NELEM	100	15	NN	3
16	NNLDF	66	17	NNS	6	18	NPART	2	19	NOF	60	20	NPRNT	132
21	NROW	2	22	NC	8	23	NB	4	24	NPTEL	3	25	KIND	4
26	KOUNT	1	27	NSKIP	60	28	IPASS	1	29	IRUN	0	30	NP	5
31	NFQ	7	32	ISUB	0	33	NBUG	0	34	LPRINT	100	35	KPT1	0
36	KPT2	0	37	KPT3	0	38	KPT4	0	39	KPT5	0	40	KPT6	0
41	KPT7	0	42	KPT8	0	43	KPT9	0	44	KPT10	0	45	NEXP	0
46	NF	4	47	LG	6	48	NDOF	0	49	NQEL	3	50	LCOL	6
51	NCL	0	52	KROW	11	53	NH2	0	54	NHHALF	0	55	NODE	150
56	NDOUTZ	0	57	IASVEC	0	58	NEQKNN	5	59	NCPTAB	1	60	NMBOUT	14
61	KDUMP	0	62	NTITL	5	63	NIND	813	64	NSM	10	65	NJ	0
66	NRHOSS	0	67	NS	0	68	NI	1201	69	NBSET	0	70	NVP	9
71	NVU	1	72	NVV	2	73	NVW	3	74	NVH	4	75		0
76	[illegible]	0	77	H2O	7	78	O2	8	79	H2	9	80	N2	10
81	A	11	82	O	12	83	H	13	84	NO	14	85	OH	15
86	KPNT	0	87	NRTAPE	0	88	NLINE	60	89	NEMD	271	90	NYY	2
91	N27	2	92	NDOZ	0	93	NTK	2	94	NUPARA	2	95	NH	2
96	NFIRCL	0	97		0	98	IMAT	1	99	IBL	1	100	IREND	27236
101	NPRESS	0	102	KOUT	0	103	MTM	0	104	NFLIP	1	105	KSCT	107
106	KSCTSQ	1	107	NELEZ	1	108	NUQ3	0	109	IVIRT	0	110		0
111	IMAX	2	112	KALLMD	0	113	KPLVAR	2	114	NCND	0	115	IFORCE	0
116	IGINIT	0	117	IBUG1	-3	118	IBUG2	-3	119	NGBUG	-3	120	IFP	1
121	NSUEC	9	122	IWRIT	4	123	IGAS	1	124	NDERIV	8	125	NCALLS	7
126	ISPEED	0	127	IDIFRT	-1	128	ICNIND	150	129	IMATAB	2	130	NGETH	-2
131	NPPRD	0	132	IPWRIT	0	133	ITOP	0	134	NPSIBU	0	135	NPSBOL	0
136	KSAV	0	137	LPSTAT	0	138	LPSTAM	0	139	IGAS	1	140	NTCNTS	1
141	KALLM3	0	142	IOUTPR	51	143	NTDFBL	0	144	NSDFBL	0	145	NS2DBL	0
146		0	147		0	148	NONC	0	149	IT	3	150	NODND	67
151	NS2X	15	152	NSCY	15	153	NPUNCH	0	154	NELDEL	0	155	NELADD	0
156	LFIL	1	157	LRS	10	158	INITCN	0	159	NSORCE	1	160	NSPRSC	0
161	NPVSX	2	162	NDPVSX	2	163		0	164		0	165		0
166		0	167		0	168		0	169		0	170		0
171		0	172		0	173		0	174		0	175		0
176		0	177		0	178		0	179		0	180		0
181		0	182		0	183		0	184		0	185		0
186		0	187		0	188		0	189		0	190		0
191		0	192		0	193		0	194		0	195		0
196		0	197		0	198		0	199		0	200		0

INITIAL CONDITIONS

1	FACT	= 0.2500E-02	2	[illegible]NF	= 0.1000E 01	3	ALC	= 0.2500E-02	4	THK	= 0.4000E 03	5	AJ	= 0.7783E 03
6	RMINIT	= 0.0	7	HSINIT	= 0.1000E-06	8	RMINS1	= -0.1000E 01	9	PINF	= 0.1930E 03	10	RHOINF	= 0.3435E-01
11	XT	= 0.0	12	HT	= 0.0	13	DELP	= 0.1600E 01	14	EPS	= 0.1000E-01	15	H	= 0.4000E-04
16	HMAX	= 0.4[illegible]E 01	17	HMIN	= 0.0	18	OUTEPS	= 0.0	19	PNTEPS	= 0.0	20	PTIM	= 0.0
21	RF	= 0.1[illegible] 05	22	TF	= 0.8000E 02	23	TIME	= 0.0	24	TO	= 0.0	25	THNC	= 0.0
26	T[illegible]PI	= 0.[illegible]E 01	27	UIFF	= 0.2272E 04	28	RUNIV	= 0.1545E 04	29	ZT	= 0.0	30	CPOINF	= 0.2407E 00
31	[illegible]	= 0.3217E 02	32	RTCON1	= 0.5000E 05	33	RTCON2	= 0.2252E 02	34	RTCON3	= 0.5334E 02	35	TD	= 0.8000E 02
36	[illegible]	= 0.1930E 03	37	XLE	= 0.1000E 01	38	XMUINF	= 0.1238E-04	39	PEDGE	= 0.3502E-01	40	TRATIO	= 0.4994E 01
41	XSHFT	= 0.0	42	YSHFT	= 0.0	43	REFL	= 0.3333E-02	44	SQ2	= 0.1414E 01	45	HS	= 0.0
46	[illegible]	= 0.0	47	TEDGE	= 0.0	48	REDGE	= 0.0	49		= 0.0	50	SSINIT	= 0.4000E-04
51	[illegible]	= 0.0	52	XSCALE	= 0.3333E-02	53	YSCALE	= 0.3333E-02	54		= 0.0	55	RTCON4	= 0.4498E 03
56	RTCON5	= 0.[illegible] 00	57	RTCON6	= 0.8996E 03	58	TCFINF	= 0.5330E 03	59	FACTMU	= 0.1985E 00	60	GAMMAF	= 0.1400E 01
61	[illegible]	= 0.0	62	CONV	= 0.3000E 03	63		= 0.0	64		= 0.0	65	ZTEST	= 0.1000E-04
66	XMF	= 0.2[illegible]E 02	67	PR	= 0.1000E 01	68		= 0.0	69		= 0.0	70	CONRHO	= 0.0
71	STLOV[illegible]	= 0.11[illegible]E-04	72	STLOTK	= 0.4920E 03	73	STLOCR	= 0.2040E 03	74	STLDEX	= 0.1500E 01	75		= 0.0
76	ZT	= 0.0	77	CON1	= 0.5248E-01	78	CON2	= 0.9845E-04	79	FACTP	= 0.5038E 01	80	FACTH	= 0.7817E-02
81	XI	= 0.0	82	YI	= 0.0	83	COMPX	= 0.0	84	COMPY	= 0.0	85	HMIND	= 0.0
86		= 0.0	87		= 0.0	88	HHMIN	= 0.0	89		= 0.0	90		= 0.0
91		= 0.0	92		= 0.0	93		= 0.0	94		= 0.0	95		= 0.0
96		= 0.0	97	[illegible]INF	= 0.1440E 09	98	XPRIME	= 0.0	99	PPRCON	= 0.2204E 07	100	PPRIME	= 0.0
101	YIP	= 0.12[illegible] 02	102	VSTART	= 0.4000E 02	103	DEPLT	= 0.8080E 02	104	VELCST	= 0.8058E 00	105	RDCST	= 0.1337E 02
106	RCTH	= 0.1510E 01	107	SCTMLT	= 0.1000E 01	108	SCTMIN	= 0.2000E 00	109	XMA	= 0.2897E 02	110	XMH	= 0.2016E 01
111	[illegible]X3	= 0.0	112	XSLAST	= 0.0	113	PLAST	= 0.0	114	DLXM1	= 0.0	115	RSTART	= 0.1010E 03
116	[illegible]	= 0.14[illegible] 02	117	[illegible]	= 0.1300E 02	118	XMSDF	= 0.3423E 01	119	ROQALC	= 0.4963E-03	120		= 0.0
121	[illegible]T	= 0.0	122	[illegible]	= 0.0	123	OR	= 0.1000E 01	124	CON	= 0.4000E 00	125	XLAM	= 0.9000E-01
126	[illegible]	= 0.115[illegible]E-04	127	XM[illegible]	= 0.5600E-05	128	XMUP5	= 0.7300E-05	129	SCI	= 0.7000E 00	130	C4FD	= 0.1000E 00
131	[illegible]	= 0.[illegible]E-01	132	[illegible]	= 0.2913E-01	133	PCNT	= 0.1000E 01	134	D3MAX	= 0.1000E 01	135	ELIPSH	= 0.0
136	ELIPSK	= 0.3[illegible] 01	137	ELIPSA	= 0.6000E 01	138	ELIPSB	= 0.2500E 01	139	VH	= 0.0	140	VK	= 0.2000E 01
141	VA	= 0.1[illegible] 01	142	VB	= 0.6750E 00	143	C4EDSW	= 0.3000E 05	144	C4FACT	= 0.1000E 01	145	E1E2SW	= 0.2600E-01
146	T[illegible]A	= 0.5530E 03	147	TC[illegible]	= 0.5200E 03	148	CVH	= 0.1000E 01	149	CVD	= 0.3048E 00	150	CVT	= 0.1000E 01
151	CVP	= 0.4[illegible]E-03	152	CVRHO	= 0.1602E 02	153	CVCP	= 0.4186E 04	154	XMACHS	= 0.4469E 01	155	TSINF	= 0.1035E 03
156	AINF	= 0.5[illegible] 03	157	[illegible]BIN	= 0.7940E 02	158	CPA	= 0.2400E 00	159	CPH	= 0.3445E 01	160	CPINF	= 0.2400E 00
161	[illegible]INF	= 0.1[illegible]	162	FTTBIN	= 0.1200E 02	163	FTTCCM	= 0.3048E 02	164	FTTOMT	= 0.3048E 00	165	DRTODK	= 0.5556E 00
166	[illegible]	= 0.4725E-03	167	PSFTFT	= 0.3591E 00	168	PSFTCN	= 0.4788E 02	169	PSFTDI	= 0.6944E-02	170	PDFTCK	= 0.1602E 02
171	[illegible]	= 0.[illegible]E 04	172	XMFACT	= 0.2023E 01	173	ZMAX	= 0.0	174	PDFTDC	= 0.1602E-01	175	EBTOKJ	= 0.2324E 01
176	[illegible]KJ	= 0.41[illegible] 01	177	VE[illegible]	= 0.1488E 01	178	VLBTCP	= 0.1488E 02	179		= 0.0	180		= 0.0
181		= 0.0	182		= 0.0	183		= 0.0	184		= 0.0	185		= 0.0
186		= 0.0	187		= 0.0	188		= 0.0	189		= 0.0	190		= 0.0
191		= 0.0	192		= 0.0	193		= 0.0	194		= 0.0	195		= 0.0
196		= 0.0	197		= 0.0	198		= 0.0	199		= 0.0	200		= 0.0

NODE AND COORDINATE MAP OF DISCRETIZATION

X2COR
SCALE
FACTOR

....
X2COR ...NODE NUMBERS...
....

X1COR
SCALE ... X1COR ...
FACTOR

- X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X -

E 1						
0.90000	0.61	0.62	0.63	0.64	0.65	0.66
0.65000	0.55	0.56	0.57	0.58	0.59	0.60
0.47500	0.49	0.50	0.51	0.52	0.53	0.54
0.35000	0.43	0.44	0.45	0.46	0.47	0.48
0.30000	0.37	0.38	0.39	0.40	0.41	0.42
0.25000	0.31	0.32	0.33	0.34	0.35	0.36
0.20000	0.25	0.26	0.27	0.28	0.29	0.30
0.15000	0.19	0.20	0.21	0.22	0.23	0.24
0.10000	0.13	0.14	0.15	0.16	0.17	0.18
0.05000	0.07	0.08	0.09	0.10	0.11	0.12
0.00000	0.01	0.02	0.03	0.04	0.05	0.06
E 1	0.00000	0.07500	0.12500	0.25000	0.40000	0.62500

- X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X -

THREE-DIMENSIONAL BOUNDARY REGION VARIANT 04/26/74

CHECK CASE,THREE DIMENSIONAL REACTING BOUNDARY REGION - VIRTUAL SOURCE

REFERENCE	ENGLISH-FT	ENGLISH-IN	M-K-S	C-G-S
LENGTH.........	.FT..........	.IN..........	.M...........	.CM..........
0.0	0.33333E-02	0.40000E-01	0.10160E-02	0.10160E 00
VELOCITY.......	.FT/S........	.N.A.........	.M/S.........	.CM/S........
0.0	0.22720E 04	0.0	0.69251E 03	0.69251E 05
DENSITY........	.LBM/FT3....	.N.A.........	.KG/M3.......	.G/CC........
0.0	0.34346E-01	0.0	0.55022E 00	0.55022E-03
TEMPERATURE....	.RANKINE....	.N.A.........	.KELVIN.....	.N.A.........
0.0	0.53300E 03	0.0	0.29611E 03	0.0
ENTHALPY.......	.BTU/LBM....	.N.A.........	.KJ/KG.......	.N.A.........
0.0	0.61955E 08	0.0	0.14401E 09	0.0
FROZ.SPEC. HEAT	.BTU/LB-R...	.N.A.........	.KJ/KG-K....	.N.A.........
0.0	0.24073E 00	0.0	0.10072E 01	0.0
VISCOSITY......	.LBM/FT-S...	.N.A.........	.NT-S/M2....	.POISE......
0.0	0.12384E-04	0.0	0.18428E-04	0.18428E-03

X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X -

LOCAL PRESSURE	.PSF........	.PSI.........	.NT/M2......	.TORR.......
0.0	0.19300E 03	0.13402E 01	0.92403E 04	0.69306E 02
LOCAL SOLUTION	MACH NO.	DPOXI(LBF/FT3)	MAX. H2 CONC.	MIX EFF.(ETA)
0.0	0.45583E 01	0.0	0.10000E 01	0.0
XI/LREF	DXI/LREF	EPSILON	DXIMIN/LREF	
0.0	0.0	0.10000E-01	0.0	

X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X -

N-	N+	PASSES	PRINT	OF
0	0	2	1	100

U1/UREF E 1

E 1						
0.[illegible] 00	0.10000	0.10000	0.10000	0.10000	0.10000	0.10000
0.6[illegible] 00	0.10000	0.10000	0.09547	0.09547	0.09547	0.09547
0.47 00	0.10000	0.10000	0.09129	0.09129	0.09129	0.09129
0.35 00	0.10000	0.10000	0.08737	0.08737	0.08737	0.08737
0.30 00	0.10000	0.10000	0.08548	0.08548	0.08548	0.08548
0.25 00	0.08922	0.[illegible]	0.08327	0.08327	0.08327	0.08327
0.20 00	0.08022	0.08022	0.08068	0.08068	0.08068	0.08068
0.15 00	0.08022	0.08022	0.07742	0.07742	0.07742	0.07742
0.10 00	0.07306	0.07306	0.07306	0.07306	0.07306	0.07306
0.05 00	0.06615	0.06615	0.06615	0.06615	0.06615	0.06615
0.00 00	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
F 1	0.00000	0.07500	0.12500	0.25000	0.40000	0.62500

U2/UREF E 0

0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.07500	0.12500	0.25000	0.40000	0.62500

T/TREF E 1

E 1						
0.90000	0.01969	0.01969	0.01969	0.01969	0.01969	0.01969
0.65000	0.01969	0.01969	0.02681	0.02681	0.02681	0.02681
0.47500	0.01969	0.01969	0.03309	0.03309	0.03309	0.03309
0.35000	0.01969	0.01969	0.03871	0.03871	0.03871	0.03871
0.30000	0.01969	0.01969	0.04144	0.04144	0.04144	0.04144
0.25000	0.10000	0.10000	0.04442	0.04442	0.04442	0.04442
0.20000	0.10000	0.10000	0.04783	0.04783	0.04783	0.04783
0.15000	0.10000	0.10000	0.05196	0.05196	0.05196	0.05196
0.10000	0.05721	0.05721	0.05721	0.05721	0.05721	0.05721
0.05000	0.06492	0.06492	0.06492	0.06492	0.06492	0.06492
0.00000	0.10000	0.10000	0.10000	0.10000	0.10000	0.10000
E 1	0.00000	0.07500	0.12500	0.25000	0.40000	0.62500

CPF/CPFREF E 2

0.01000	0.01000	0.01000	0.01000	0.01000	0.01000
0.01000	0.01000	0.01000	0.01000	0.01000	0.01000
0.01000	0.01000	0.01000	0.01000	0.01000	0.01000
0.01000	0.01000	0.01000	0.01000	0.01000	0.01000
0.01000	0.01000	0.01000	0.01000	0.01000	0.01000
0.14115	0.14115	0.01000	0.01000	0.01000	0.01000
0.14115	0.14115	0.01000	0.01000	0.01000	0.01000
0.14115	0.14115	0.01001	0.01001	0.01001	0.01001
0.01001	0.01001	0.01001	0.01001	0.01001	0.01001
0.01001	0.01001	0.01001	0.01001	0.01001	0.01001
0.01004	0.01004	0.01004	0.01004	0.01004	0.01004
0.00000	0.07500	0.12500	0.25000	0.40000	0.62500

HSTAT/HREF E 0

E 1						
0.90000	0.00219	0.00219	0.00219	0.00219	0.00219	0.00219
0.65000	0.00219	0.00219	0.00234	0.00234	0.00234	0.00234
0.47500	0.00219	0.00219	0.00247	0.00247	0.00247	0.00247
0.35000	0.00219	0.00219	0.00258	0.00258	0.00258	0.00258
0.30000	0.00219	0.00219	0.00264	0.00264	0.00264	0.00264
0.25000	0.99922	0.99922	0.00270	0.00270	0.00270	0.00270
0.20000	0.99922	0.99922	0.00277	0.00277	0.00277	0.00277
0.15000	0.99922	0.99922	0.00286	0.00286	0.00286	0.00286
0.10000	0.00297	0.00297	0.00297	0.00297	0.00297	0.00297
0.05000	0.00313	0.00313	0.00313	0.00313	0.00313	0.00313
0.00000	0.00385	0.00385	0.00385	0.00385	0.00385	0.00385
E 1	0.00000	0.07500	0.12500	0.25000	0.40000	0.62500

HTOT/HREF E 1

0.00039	0.00039	0.00039	0.00039	0.00039	0.00039
0.00039	0.00039	0.00039	0.00039	0.00039	0.00039
0.00039	0.00039	0.00039	0.00039	0.00039	0.00039
0.00039	0.00039	0.00039	0.00039	0.00039	0.00039
0.00039	0.00039	0.00039	0.00039	0.00039	0.00039
0.10000	0.10000	0.00039	0.00039	0.00039	0.00039
0.10000	0.10000	0.00039	0.00039	0.00039	0.00039
0.10000	0.10000	0.00039	0.00039	0.00039	0.00039
0.00039	0.00039	0.00039	0.00039	0.00039	0.00039
0.00039	0.00039	0.00039	0.00039	0.00039	0.00039
0.00039	0.00039	0.00039	0.00039	0.00039	0.00039
0.00000	0.07500	0.12500	0.25000	0.40000	0.62500

RHO/RHOREF E 1

E 1						
0.90000	0.10000	0.10000	0.10000	0.10000	0.10000	0.10000
0.65000	0.10000	0.10000	0.07343	0.07343	0.07343	0.07343
0.47500	0.10000	0.10000	0.05950	0.05950	0.05950	0.05950
0.35000	0.10000	0.10000	0.05085	0.05085	0.05085	0.05085
0.30000	0.10000	0.10000	0.04751	0.04751	0.04751	0.04751
0.25000	0.00138	0.00138	0.04433	0.04433	0.04433	0.04433
0.20000	0.00138	0.00138	0.04116	0.04116	0.04116	0.04116
0.15000	0.00138	0.00138	0.03789	0.03789	0.03789	0.03789
0.10000	0.03441	0.03441	0.03441	0.03441	0.03441	0.03441
0.05000	0.03032	0.03032	0.03032	0.03032	0.03032	0.03032
0.00000	0.01969	0.01969	0.01969	0.01969	0.01969	0.01969
E 1	0.00000	0.07500	0.12500	0.25000	0.40000	0.62500

ELEM.H2 MAS.FRAC E 1

0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.10000	0.10000	0.00000	0.00000	0.00000	0.00000
0.10000	0.10000	0.00000	0.00000	0.00000	0.00000
0.10000	0.10000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.07500	0.12500	0.25000	0.40000	0.62500

ELEM.N2 MAS.FRAC E 0

F 1						
0.90000	0.76700	0.76700	0.76700	0.76700	0.76700	0.76700
0.65000	0.76700	0.76700	0.76700	0.76700	0.76700	0.76700
0.47500	0.76700	0.76700	0.76700	0.76700	0.76700	0.76700
0.35000	0.76700	0.76700	0.76700	0.76700	0.76700	0.76700
0.30000	0.76700	0.76700	0.76700	0.76700	0.76700	0.76700
0.25000	0.00000	0.00000	0.76700	0.76700	0.76700	0.76700
0.20000	0.00000	0.00000	0.76700	0.76700	0.76700	0.76700
0.15000	0.00000	0.00000	0.76700	0.76700	0.76700	0.76700
0.10000	0.76700	0.76700	0.76700	0.76700	0.76700	0.76700
0.05000	0.76700	0.76700	0.76700	0.76700	0.76700	0.76700
0.00000	0.76700	0.76700	0.76700	0.76700	0.76700	0.76700
E 1	0.00000	0.07500	0.12500	0.25000	0.40000	0.62500

ELEM.O2 MAS.FRAC E 0

0.23300	0.23300	0.23300	0.23300	0.23300	0.23300
0.23300	0.23300	0.23300	0.23300	0.23300	0.23300
0.23300	0.23300	0.23300	0.23300	0.23300	0.23300
0.23300	0.23300	0.23300	0.23300	0.23300	0.23300
0.23300	0.23300	0.23300	0.23300	0.23300	0.23300
0.00000	0.00000	0.23300	0.23300	0.23300	0.23300
0.00000	0.00000	0.23300	0.23300	0.23300	0.23300
0.00000	0.00000	0.23300	0.23300	0.23300	0.23300
0.23300	0.23300	0.23300	0.23300	0.23300	0.23300
0.23300	0.23300	0.23300	0.23300	0.23300	0.23300
0.23300	0.23300	0.23300	0.23300	0.23300	0.23300
0.00000	0.07500	0.12500	0.25000	0.40000	0.62500

FFF.MG/MURFF E 4

F 1						
0.90000	0.00002	0.00002	0.00892	0.00892	0.00892	0.00892
0.65000	0.00002	0.00002	0.01639	0.01639	0.01638	0.01638
0.47500	0.00002	0.00002	0.01828	0.01828	0.01828	0.01828
0.35000	0.00002	0.00002	0.01893	0.01893	0.01893	0.01893
0.30000	0.62583	0.62333	0.02057	0.02057	0.02057	0.02057
0.25000	0.00010	0.00010	0.02265	0.02265	0.02265	0.02265
0.20000	0.00010	0.00010	0.02573	0.02573	0.02573	0.02573
0.15000	0.00082	0.00082	0.01784	0.01784	0.01784	0.01784
0.10000	0.01145	0.01145	0.01145	0.01145	0.01145	0.01145
0.05000	0.02408	0.02408	0.02408	0.02408	0.02408	0.02408
0.00000	0.00010	0.00010	0.00010	0.00010	0.00010	0.00010
F 1	0.00000	0.07500	0.12500	0.25000	0.40000	0.62500

MU/MUREF E 1

0.02084	0.02084	0.02084	0.02084	0.02084	0.02084
0.02084	0.02084	0.02949	0.02949	0.02949	0.02949
0.02084	0.02084	0.03688	0.03688	0.03688	0.03688
0.02084	0.02084	0.04326	0.04326	0.04326	0.04326
0.02084	0.02084	0.04627	0.04627	0.04627	0.04627
0.10000	0.10000	0.04950	0.04950	0.04950	0.04950
0.10000	0.10000	0.05312	0.05312	0.05312	0.05312
0.10000	0.10000	0.05739	0.05739	0.05739	0.05739
0.06267	0.06267	0.06267	0.06267	0.06267	0.06267
0.07009	0.07009	0.07009	0.07009	0.07009	0.07009
0.10000	0.10000	0.10000	0.10000	0.10000	0.10000
0.00000	0.07500	0.12500	0.25000	0.40000	0.62500

EFF. PRANDTL NF. E 0

F 1						
0.90000	0.70000	0.70000	0.70000	0.70000	0.70000	0.70000
0.65000	0.70000	0.70000	0.70000	0.70000	0.70000	0.70000
0.47500	0.70000	0.70000	0.70000	0.70000	0.70000	0.70000
0.35000	0.70000	0.70000	0.70000	0.70000	0.70000	0.70000
0.30000	0.70000	0.70000	0.70000	0.70000	0.70000	0.70000
0.25000	0.70000	0.70000	0.70000	0.70000	0.70000	0.70000
0.20000	0.70000	0.70000	0.70000	0.70000	0.70000	0.70000
0.15000	0.70000	0.70000	0.70000	0.70000	0.70000	0.70000
0.10000	0.70000	0.70000	0.70000	0.70000	0.70000	0.70000
0.05000	0.70000	0.70000	0.70000	0.70000	0.70000	0.70000
0.00000	0.70000	0.70000	0.70000	0.70000	0.70000	0.70000
E 1	0.00000	0.07500	0.12500	0.25000	0.40000	0.62500

EFF.SCHMIDT NO. E 0

0.70000	0.70000	0.70000	0.70000	0.70000	0.70000
0.70000	0.70000	0.70000	0.70000	0.70000	0.70000
0.70000	0.70000	0.70000	0.70000	0.70000	0.70000
0.70000	0.70000	0.70000	0.70000	0.70000	0.70000
0.70000	0.70000	0.70000	0.70000	0.70000	0.70000
0.70000	0.70000	0.70000	0.70000	0.70000	0.70000
0.70000	0.70000	0.70000	0.70000	0.70000	0.70000
0.70000	0.70000	0.70000	0.70000	0.70000	0.70000
0.70000	0.70000	0.70000	0.70000	0.70000	0.70000
0.70000	0.70000	0.70000	0.70000	0.70000	0.70000
0.70000	0.70000	0.70000	0.70000	0.70000	0.70000
0.00000	0.07500	0.12500	0.25000	0.40000	0.62500

SKIN FRICTION DISTRIBUTION(CF/2)

1 0.14735E-01 2 0.14735E-01 3 0.14735E-01 4 0.14735E-01 5 0.14735E-01
6 0.14735E-01

ORIGINAL PAGE IS
OF POOR QUALITY

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THREE-DIMENSIONAL BOUNDARY REGION VARIANT                                    04/29/74

CHECK CASE,THREE DIMENSIONAL REACTING BOUNDARY REGION - VIRTUAL SOURCE

REFERENCE        ENGLISH-FT       ENGLISH-IN       M-K-S            C-G-S
---------        ----------       ----------       -----            -----

LENGTH.........  .FT..........   .IN..........    .M...........    .CM..........
   0.0           0.33333E-02      0.40000E-01      0.10160E-02      0.10160F 00
VELOCITY.......  .FT/S........    .N.A.........    .M/S.........    .CM/S........
   0.0           0.22720F 04      0.0              0.69251E 03      0.69251E 05
DENSITY........  .LBM/FT3.....    .N.A.........    .KG/M3.......    .G/CC........
   0.0           0.34346E-01      0.0              0.55022E 00      0.55022E-03
TEMPERATURE....  .RANKINE.....    .N.A.........    .KELVIN......    .N.A.........
   0.0           0.53300E 03      0.0              0.29611E 03      0.0
ENTHALPY.......  .BTU/LBM.....    .N.A.........    .KJ/KG.......    .N.A.........
   0.0           0.61955F 08      0.0              0.14401F 09      0.0
FROZ.SPEC. HEAT  .BTU/LBM-R...    .N.A.........    .KJ/KG-K.....    .N.A.........
   0.0           0.24073E 00      0.0              0.10072E 01      0.0
VISCOSITY......  .LBM/FT-S....    .N.A.........    .NT-S/M2.....    .PCISE.......
   0.0           0.12384E-04      0.0              0.18428E-04      0.18428E-03
X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X -
LOCAL PRESSURE   .PSF.........    .PSI.........    .NT/M2.......    .TORR........
   0.0           0.19300E 03      0.13402E 01      0.92408E 04      0.69306E 02
LOCAL SOLUTION   MACH NO.         DPDX1(LBF/FT3)   MAX. H2 CONC.    MIX EFF.(ETA)
   0.0           0.45578F 01      0.0              0.41687E-01      0.57290E 00
X1/LREF          DX1/LREF         EPSILON          DX1MIN/LREF
   0.61032E 02   0.14399E 01      0.10000E-01      0.37500E-02
- X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X - X -
                                                                     N-    N+ PASSES    PRINT    OF
                                                                      3    64   289        23    100

                 U1/UREF            E  0                                    U2/UREF            E -1
    E  1
0.90000     0.94988 0.99930 0.99669 0.99223 0.99048 0.99070       0.12501 0.00001 0.00348 0.00642 0.16702 0.07580
0.65000     0.99822 0.98887 0.95948 0.94643 0.94498 0.94430       -.00363 -.04036 0.00520 -.00046 0.19643 0.03750
0.47500     0.99285 0.97203 0.93201 0.90254 0.89945 0.89838       -.01998 -.01364 -.00003 0.00396 0.16207 0.08203
0.35000     0.96057 0.93234 0.89836 0.85792 0.85318 0.85128       -.02413 -.02089 -.01892 0.05498 0.10697 0.08884
0.30000     0.90964 0.88774 0.85904 0.82253 0.81994 0.81874       -.02918 -.02520 -.02377 0.03105 0.09093 0.08016
0.25000     0.83100 0.81452 0.79273 0.76767 0.76993 0.76834       -.02388 -.02070 -.01990 0.01040 0.07322 0.06327
0.20000     0.71596 0.70425 0.68895 0.67566 0.68171 0.68119       -.01420 -.01276 -.01261 0.01504 0.04863 0.03948
0.15000     0.56612 0.55865 0.54863 0.54019 0.54286 0.54783       -.00612 -.00560 -.00509 0.01163 0.02598 0.01619
0.10000     0.39347 0.39128 0.38484 0.37798 0.37221 0.38664       -.00147 -.00140 -.00081 0.00476 0.00870 0.00501
0.05000     0.22677 0.24370 0.23321 0.23343 0.22100 0.26731       -.00002 -.00001 0.00014 0.00111 0.00059 0.00146
0.00000     0.00000 0.00000 0.00000 0.00000 0.00000 0.00000       0.00000 0.00000 0.00000 0.00000 0.00000 0.00000

E 1         0.00000 0.07500 0.12500 0.25000 0.40000 0.62500       0.00000 0.07500 0.12500 0.25000 0.40000 0.62500
```


ORIGINAL PAGE IS
OF POOR QUALITY

T/TREF E 0

F 1						
0.90000	0.19687	0.19302	0.20129	0.20841	0.21163	0.21175
0.65000	0.20032	0.21447	0.26171	0.28019	0.28302	0.28317
0.47500	0.22720	0.25953	0.31901	0.35193	0.35149	0.35122
0.35000	0.43052	0.45374	0.46874	0.44035	0.41948	0.41880
0.30000	0.54217	0.55429	0.56554	0.50810	0.46679	0.46275
0.25000	0.64348	0.64546	0.64711	0.57474	0.53219	0.52736
0.20000	0.73729	0.73729	0.73315	0.67903	0.63573	0.62928
0.15000	0.83110	0.81234	0.82933	0.79276	0.77120	0.76115
0.10000	0.89852	0.90203	0.91205	0.89416	0.89316	0.83029
0.05000	0.97211	0.95509	0.96227	0.95729	0.96137	0.94205
0.00000	0.99976	0.99995	0.99976	0.99996	0.99996	0.99996
E 1	0.00000	0.07500	0.12500	0.25000	0.40000	0.62500

CPF/CPFREF E 1

0.10000	0.10000	0.10000	0.10001	0.10000	0.10000
0.10006	0.10009	0.10009	0.10007	0.10003	0.10002
0.10211	0.10721	0.10219	0.10098	0.10018	0.10006
0.12873	0.12488	0.12058	0.10535	0.10064	0.10013
0.14130	0.13727	0.13236	0.10958	0.10116	0.10020
0.15038	0.14595	0.14021	0.11293	0.10165	0.10030
0.15182	0.14758	0.14161	0.11513	0.10234	0.10049
0.14438	0.14068	0.13611	0.11579	0.10329	0.10083
0.13191	0.12782	0.12668	0.11494	0.10421	0.10133
0.11870	0.11895	0.11684	0.11386	0.10470	0.10163
0.10037	0.10037	0.10037	0.11302	0.10484	0.10182
0.00000	0.07500	0.12500	0.25000	0.40000	0.62500

HSTAT/HREF E -1

F 1						
0.90000	0.02192	0.02195	0.02203	0.02219	0.02223	0.02221
0.65000	0.02259	[illegible]	0.02460	0.02424	0.02383	0.02374
0.47500	0.04407	0.04528	0.04548	0.03418	0.02652	0.02539
0.35000	[illegible]	0.25076	0.21099	0.07513	0.03203	0.02738
0.30000	[illegible]	[illegible]	0.30375	0.11168	0.03741	0.02877
0.25000	0.44231	[illegible]	0.35377	0.13843	0.04261	0.03084
0.20000	0.43771	0.41454	0.35251	0.15293	0.04959	0.03429
0.15000	0.37590	0.34977	0.31218	0.15563	0.05642	0.03924
0.10000	[illegible]	0.26326	[illegible]	0.14919	0.06669	0.04451
0.05000	0.17768	0.17990	0.16369	0.14100	0.07111	0.04746
0.00000	0.03854	0.03854	0.03854	0.13469	0.07251	0.04958
F 1	0.00000	0.07500	0.12500	0.25000	0.40000	0.62500

HTOT/HREF E -1

0.03837	0.03858	0.03857	0.03858	0.03856	0.03855
0.03918	0.03943	0.03933	0.03915	0.03870	0.03859
0.06049	0.06102	0.05994	0.04774	0.03999	0.03882
0.30385	0.26525	0.22443	0.08738	0.04415	0.03944
0.39735	0.36012	0.31604	0.12295	0.04660	0.03993
0.45380	0.41716	0.36924	0.14824	0.05248	0.04067
0.44624	0.41280	0.36641	0.16054	0.05732	0.04202
0.38123	0.35497	0.31719	0.16049	0.06333	0.04423
0.28198	0.26581	0.24129	0.15157	0.06899	0.04700
0.17854	0.18089	0.16459	0.14191	0.07192	0.04865
0.03854	0.03854	0.03854	0.13469	0.07251	0.04958
0.00000	0.07500	0.12500	0.25000	0.40000	0.62500

RHO/RHOREF E 0

F 1						
0.90000	[illegible]	[illegible]	[illegible]	0.94459	0.93025	0.92973
0.65000	[illegible]	[illegible]	0.75147	0.70207	0.69546	0.69521
0.47500	[illegible]	[illegible]	0.59599	0.55277	0.55902	0.56033
0.35000	0.33736	[illegible]	0.33643	0.41969	0.46533	0.46952
0.30000	0.24544	0.24442	0.25376	0.34819	0.41616	0.42465
0.25000	[illegible]	0.20316	0.21055	0.29617	0.36316	0.37226
0.20000	[illegible]	[illegible]	0.19672	0.24929	0.30210	0.31141
0.15000	[illegible]	0.17033	[illegible]	0.21354	0.24710	0.25670
0.10000	[illegible]	0.16741	0.16983	0.19128	0.21180	0.22115
0.05000	0.17060	[illegible]	0.17510	0.16070	0.19604	0.20620
0.00000	0.19688	0.19688	0.19688	0.17446	0.18833	0.19402
E 1	0.00000	0.07500	0.12500	0.25000	0.40000	0.62500

ELEM.H2 MAS.FRAC E -1

0.00002	0.00003	0.00003	0.00004	0.00002	0.00001
0.00064	0.00089	0.00079	0.00061	0.00015	0.00005
0.02203	0.02256	0.02148	0.00924	0.00146	0.00028
0.26634	0.22758	0.18661	0.04903	0.00563	0.00090
0.36019	0.32283	0.27857	0.08473	0.01010	0.00140
0.41667	0.38008	0.33196	0.11012	0.01400	0.00213
0.40928	0.37570	0.32914	0.12247	0.01886	0.00349
0.34402	0.31765	0.27972	0.12242	0.02488	0.00571
0.24438	0.22815	0.20353	0.11346	0.03057	0.00849
0.14053	0.14290	0.12654	0.10377	0.03351	0.01015
0.00000	0.00000	0.00000	0.09652	0.03410	0.01108
0.00000	0.07500	0.12500	0.25000	0.40000	0.62500

E 1	ELEM.N2 MAS.FRAC E 0					
0.90000	0.76700	0.76700	0.76700	0.76699	0.76700	0.76700
0.65000	0.76695	0.76693	0.76694	0.76695	0.76699	0.76699
0.47500	0.76531	0.76526	0.76535	0.76629	0.76688	0.76698
0.35000	0.74657	0.74554	0.75268	0.76323	0.76656	0.76693
0.30000	0.73937	0.74223	0.74563	0.76050	0.76622	0.76689
0.25000	0.73502	0.73784	0.74153	0.75855	0.76592	0.76683
0.20000	0.73560	0.73818	0.74175	0.75760	0.76555	0.76673
0.15000	0.74061	0.74263	0.74554	0.75761	0.76509	0.76656
0.10000	0.74825	0.74950	0.75159	0.75829	0.76465	0.76635
0.05000	0.75622	0.75604	0.75729	0.75904	0.76443	0.76622
0.00000	0.76700	0.76700	0.76700	0.75960	0.76438	0.76615
E 1	0.00000	0.07500	0.12500	0.25000	0.40000	0.62500

ELEM.O2 MAS.FRAC E 0					
0.23300	0.23300	0.23300	0.23300	0.23300	0.23300
0.23298	0.23297	0.23298	0.23298	0.23299	0.23300
0.23240	0.23247	0.23249	0.23278	0.23296	0.23299
0.22679	0.22769	0.22865	0.23185	0.23286	0.23298
0.22460	0.22547	0.22650	0.23102	0.23276	0.23296
0.22328	0.22414	0.22526	0.23043	0.23267	0.23295
0.22346	0.22424	0.22533	0.23014	0.23256	0.23292
0.22498	0.22559	0.22648	0.23014	0.23242	0.23286
0.22730	0.22768	0.22825	0.23035	0.23228	0.23280
0.22972	0.22967	0.23005	0.23058	0.23222	0.23276
0.23300	0.23300	0.23300	0.23075	0.23220	0.23274
0.00000	0.07500	0.12500	0.25000	0.40000	0.62500

E 1	EFF.MU/MUREF E 2					
0.90000	0.18497	0.18439	0.18503	0.18511	0.18515	0.18515
0.65000	0.34934	0.34952	0.35009	0.35031	0.35034	0.35034
0.47500	0.36707	0.36747	0.36817	0.36855	0.36854	0.36854
0.35000	0.37051	0.37076	0.37091	0.37061	0.37039	0.37038
0.30000	0.37173	0.37185	0.37196	0.37138	0.37095	0.37091
0.25000	0.37273	0.37273	0.37276	0.37212	0.37164	0.37159
0.20000	0.37359	0.37359	0.37356	0.37306	0.37266	0.37260
0.15000	0.37441	0.37425	0.37439	0.37408	0.37389	0.37380
0.10000	0.37497	0.37500	0.37508	0.37493	0.37492	0.37482
0.05000	0.47280	0.51478	0.49843	0.51450	0.52822	0.66923
0.00000	0.01000	0.01000	0.01000	0.01000	0.01000	0.01000
E 1	0.00000	0.07500	0.12500	0.25000	0.40000	0.62500

MU/MUREF E 0					
0.20839	0.20980	0.21381	0.22255	0.22649	0.22664
0.21263	0.23046	0.28726	0.30935	0.31272	0.31289
0.24551	0.28470	0.35502	0.39283	0.39245	0.39213
0.48062	0.50546	0.52116	0.49090	0.46829	0.46755
0.59682	0.60896	0.62055	0.56217	0.51909	0.51481
0.69551	0.69551	0.69893	0.63416	0.58675	0.58185
0.78157	0.78157	0.77788	0.72869	0.68818	0.68205
0.86310	0.84713	0.86159	0.83029	0.81153	0.80272
0.91916	0.92203	0.93022	0.91560	0.91479	0.90420
0.97819	0.96473	0.97042	0.96647	0.96971	0.95434
0.99996	0.99996	0.99996	0.99996	0.99996	0.99996
0.00000	0.07500	0.12500	0.25000	0.40000	0.62500

E 1	EFF. PRANDTL NO. E 0					
0.90000	0.70000	0.70000	0.70000	0.70000	0.70000	0.70000
0.65000	0.70000	0.70000	0.70000	0.70000	0.70000	0.70000
0.47500	0.70000	0.70000	0.70000	0.70000	0.70000	0.70000
0.35000	0.70000	0.70000	0.70000	0.70000	0.70000	0.70000
0.30000	0.70000	0.70000	0.70000	0.70000	0.70000	0.70000
0.25000	0.70000	0.70000	0.70000	0.70000	0.70000	0.70000
0.20000	0.70000	0.70000	0.70000	0.70000	0.70000	0.70000
0.15000	0.70000	0.70000	0.70000	0.70000	0.70000	0.70000
0.10000	0.70000	0.70000	0.70000	0.70000	0.70000	0.70000
0.05000	0.70000	0.70000	0.70000	0.70000	0.70000	0.70000
0.00000	0.70000	0.70000	0.70000	0.70000	0.70000	0.70000
E 1	0.00000	0.07500	0.12500	0.25000	0.40000	0.62500

EFF.SCHMIDT NO. E 0					
0.70000	0.70000	0.70000	0.70000	0.70000	0.70000
0.70000	0.70000	0.70000	0.70000	0.70000	0.70000
0.70000	0.70000	0.70000	0.70000	0.70000	0.70000
0.70000	0.70000	0.70000	0.70000	0.70000	0.70000
0.70000	0.70000	0.70000	0.70000	0.70000	0.70000
0.70000	0.70000	0.70000	0.70000	0.70000	0.70000
0.70000	0.70000	0.70000	0.70000	0.70000	0.70000
0.70000	0.70000	0.70000	0.70000	0.70000	0.70000
0.70000	0.70000	0.70000	0.70000	0.70000	0.70000
0.70000	0.70000	0.70000	0.70000	0.70000	0.70000
0.70000	0.70000	0.70000	0.70000	0.70000	0.70000
0.00000	0.07500	0.12500	0.25000	0.40000	0.62500

SKIN FRICTION DISTRIBUTION(CF/2)

1	0.99181E-03	2	0.11687E-02	3	0.11065E-02	4	0.11944E-02	5	0.11830E-02
6	0.18132E-02								

APPENDIX E

LISTINGS OF AUXILIARY USER-WRITTEN SUBROUTINES FOR EDDY VISCOSITY, PRANDTL NUMBER, SCHMIDT NUMBER, AND LAMINAR VISCOSITY FOR VIRTUAL SOURCE SIMULATION.

```
      SUBROUTINE CFCEBL
     * ( INCOL, INDEX, INODE, IPINT, X1COR, X2COR, AREA, RHO, RHOU,
     1  U, W, Y,EPSLN,YY, SCHMT, E1, E2, AL, GAMMA ,CFOV2 )
C
C      TWO LAYER EDDY VISCOSITY MODEL FOR COLD FLOW HYDROGEN MIXING
C      E1 = MIXING LENGTH MODEL
C      E2 = MASS DEFECT MODEL
C      COMPUTE EDDY VISCOSITY IN TERMS OF NON-DIMENSIONAL PARAMETERS
C       BEFORE LEAVING SUBROUTINE,DIMENSIONALIZE BY
C      FACTMU = ALC * RHOREF * UREF
C      Y(X2)- NON-DIMENSIONALIZED BY ALC
C      U(U1)- NON-DIMENSIONALIZED BY UREF
C      RHO  - NON-DIMENSIONALIZED BY RHOREF
C
C      CON  = MIXING LENGTH CONSTANT
C      C4ED = MASS DEFECT CONSTANT
C      OMEGA  = VAN DRIEST DAMPING FACTOR
C      GAMMA  = INTERMITTENCY FACTOR
C      XMSDF  = MASS DEFECT IN REGIONS CONTAINING ONE PERCENT OR MORE H2
C               (NOT THE USUAL DEFINITION OF MASS DEFECT).
C      ARR    = AREA OF FLOW CONTAINING ONE PERCENT OR MORE H2.
C      E1E2SW IS LOCATION DOWNSTREAM (FT) WHERE THE TURBULENCE MODEL
C      SWITCHES FROM COMPLETELY MIXING LENGTH TO THE TWO LAYER MODEL.
C       E1E2SW USED ONLY FOR VIRTUAL SOURCE SIMULATION
C      PCNT IS THE PERCENT OF H2 DEFINING THE OUTER EDGE OF
C      THE MIXING ZONE.
C      NOTE - SPECIAL SUBSCRIPTING TECHNIQUE USED TO LOCATE Y(X2),U(U1)
C      AND RHO RUNNING UP COLUMNS OF NODES. THIS WAS REQUIRED FOR
C      COMPUTING MIXING LENGTHS AND DERIVATIVES OF U1 WITH RESPECT TO THE
C      NORMAL TO THE WALL,(X2).
C      NOTE - CONSTANTS WERE DETERMINED BY FITTING PREDICTIONS TO DATA OF
C       ROGERS,NASA TND - 6114,1971.
C
C      IF DEBUG PRINT OUT FOR E1 AND E2 COMPUTATIONS IS REQUESTED,
C      SET IWRIT = 1
C
      DIMENSION  Y(1), RHO(1), U(1), ALF(1), TEMP(1)
      DIMENSION  INCOL(1), INDEX(1), AREA(1), INODE(1)
      DIMENSION  X1COR(1), X2COR(1), RHOU(1), W(1), YY(1), EPSLN(1)
      DIMENSION  E1(1), E2(1), AL(1), GAMMA(1),CFOV2(1)
      DIMENSION  SCHMT(1)
      COMMON  / VARBLE / RARRAY(00200), IARRAY(0400)
      EQUIVALENCE ( IARRAY(00016), NNODE  )
      EQUIVALENCE ( IARRAY(00030), NP     )
      EQUIVALENCE ( IARRAY(00047),    LG )
      EQUIVALENCE ( IARRAY(00070), NVQ3 )
      EQUIVALENCE ( IARRAY(00071), NVU )
      EQUIVALENCE ( IARRAY(00086), KPNT )
      EQUIVALENCE ( IARRAY(00107), NE1E2  )
      EQUIVALENCE ( IARRAY(00108), NUQ3   )
      EQUIVALENCE ( IARRAY(00111), IMAX   )
      EQUIVALENCE ( IARRAY(00122), IWRIT  )
      EQUIVALENCE ( IARRAY(00141), KALLQ3 )
      EQUIVALENCE ( IARRAY(00143), NT     )
      EQUIVALENCE ( IARRAY(00144), NS     )
      EQUIVALENCE ( IARRAY(00145), NS2    )
      EQUIVALENCE ( RARRAY(00003), ALC     )
      EQUIVALENCE ( RARRAY(00021), RE      )
      EQUIVALENCE ( RARRAY(00023), TIME    )
      EQUIVALENCE ( RARRAY(00038), XMUINF )
      EQUIVALENCE ( RARRAY(00059), FACTMU )
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      EQUIVALENCE ( RARRAY(00101), YUP     )
      EQUIVALENCE ( RARRAY(00118), XMSDF   )
      EQUIVALENCE ( RARRAY(00124), CON     )
      EQUIVALENCE ( RARRAY(00125), XLAM    )
      EQUIVALENCE ( RARRAY(00126), XMUAIR  )
      EQUIVALENCE ( RARRAY(00127), XMUH2   )
      EQUIVALENCE ( RARRAY(00128), XMUP5   )
      EQUIVALENCE ( RARRAY(00129), SCT     )
      EQUIVALENCE ( RARRAY(00130), C4ED    )
      EQUIVALENCE ( RARRAY(00133), PCNT    )
      EQUIVALENCE ( RARRAY(00134), Q3MAX   )
      EQUIVALENCE ( RARRAY(00143), C4EDSW  )
      EQUIVALENCE ( RARRAY(00144), C4FACT  )
      EQUIVALENCE ( RARRAY(00145), E1E2SW  )
      EQUIVALENCE ( RARRAY(00010), RHOREF  )
      EQUIVALENCE ( RARRAY(00027), UREF )
      EQUIVALENCE ( RARRAY(00046), UE      )
      EQUIVALENCE ( RARRAY(00048), RHOE )
C
C     SET CONSTANTS FOR TURBULENCE MODEL
C
      AVD   =  25.3
      CON=0.335
      C4ED=0.0007
      E1E2SW=0.02
      PCNT=1.0
      USAR     =  FACTMU
      XLAM=0.0753
      XMUW     =  AVD / XMUAIR
      IMAX=2
      FRAC     =  XLAM / CON*.7
C
C     DEBUG OUTPUT HEADINGS
C
C
      IF ( NT .EQ. 0.AND.IWRIT.GT.0) WRITE(6,9600)
 9600 FORMAT (1H1, 9X,6HE1(LL) , 9X,6HAL(LL) , 6X,9HGAMMA(LL) , 10X,
     *5HU(II) ,22X,8HY(KT&II) ,5X,10HY(KT&II-1) , 9X,6HRHO(I)  / )
 9610 FORMAT ( 1H0, 8I15 / 8E15.5 )
 9620 FORMAT ( 1H , 5( 4H E2(, I3, 3H) =, E13.5) )
C
C     INITIALIZE ARRAY COUNTERS
C
      XT       =  TIME * ALC
      IF ( NS .GT. 0 ) GO TO 30
      IF ( XT .LT. E1E2SW ) GO TO 30
      NE1E2    =  3 - NE1E2
      KPNT     =  1
      NS       =  1
   30 CONTINUE
      IF ( NS2.GT. 0 ) GO TO 40
      IF ( XT .LT. C4EDSW ) GO TO 40
      KPNT     =  1
      NS2      =  1
   40 CONTINUE
C
C        SET UP ARRAY INDICES.
C
      NP       =  NVU
      CALL LINK3 (  1, U(1), YY( 1) )
      NP       =  NVQ3
      CALL LINK3 (  1, W(1), YY( 1) )
      DO 100 K = 1, NNODE
  100 RHOU(K)  = U(K) * RHO(K)
```

```
C
C     COMPUTE MAX. H2 MASS FRACTION.COMPUTE AREA CONTAINING H2 LEVELS
C      .GT.1.0 PERCENT
C        COMPUTE MASS DEFFCT.
C
      CALL Q3CONC ( INODE, AREA, W, RHOU, ARR )
C
      ARR      =  SQRT (ARR)
      KT       =  1
C
C     COMPUTE MIXING LENGTH MODEL
C        E1 = L**2 * OMEGA * GAMMA * ABS(DU/DY).
C
      DO 600 KK = 1, LG
      M        =  INCOL(KK)
      IF ( M .LT. 2 ) GO TO 600
      N        =  INDEX(KT&M-1)
C
C       VAN DRIEST  DAMPING FACTOR
C
      RHOED    =  RHOE * RHOREF
      UED      =  UE   * UREF
      TAUW     =  CFOV2(KK) * RHOED * UED * UED
      OMEGA = 1.0
      GAMMA(1) = 1.0
      E1(1) = 0.0
      AL( 1) = CON * Y(KT)
      DO 200 LL = 2, M
      II  =  LL - 1
      I        =  INDEX(KT&II-1)
      IP1      =  INDEX(KT&II)
      YUP      =  Y(KT&M-1)
      MM2      =  M - 2
      IU       =  INDEX(KT&M-1)
      DO 160 IJ = 1, MM2
      IL       =  INDEX(KT&M-IJ-1)
      VAL      =  ABS ( U(IL) / U(IU) - 1.0 )
C
C        DETERMINE UPPER BOUNDARY OF HYDROGEN CONCENTRATION
C
      IF ( NUQ3 .EQ. 3 )
     *VAL      =  ABS ( W(IL) / Q3MAX )
      IF ( VAL .GT. PCNT ) YUP = Y(KT&M-IJ-1)
      IF ( VAL .GT. PCNT ) IMAX = M - IJ
      IF ( VAL .GT. PCNT ) GO TO 170
  160 CONTINUE
  170 CONTINUE
      XI = Y(KT&LL-1) / Y(KT&M-1)
      AL(LL) = CON * Y(KT&LL-1)
      IF ( Y(KT&LL-1) .LT. FRAC*YUP ) GO TO 190
      AL(LL)   =  XLAM * YUP
  190 CONTINUE
      GAMMA(LL) = 1. / ( 1. & XI **9)
      RHOVD = RHO(IP1)*  RHOREF
      YVD    =  Y(KT+LL-1)*ALC
      IF(  TAUW .GT. 0.0 )
     *OMEGA    =  OMEGA - EXP ( - YVD * XMUW * ( TAUW * RHOVD )**.5 )
C
C     COMPUTE E1 AND E2.  BOTH ARE VECTORS WHICH WILL BE FILLED.
C     VISCOSITY SELECTED FROM E1 OR E2
C
      E1(LL) = AL(LL)*AL(LL)*OMEGA*GAMMA(LL)*ABS( (U(IP1)-U(I))/
     1 ( Y(KT&II) - Y(KT&II-1))) * RHO(IP1)
      KTPI     =  KT & II
```

```
      KTPM     = KT & II - 1
      IF ( NT .NE. 0 ) GO TO 250
      IF ( IWRIT .LE. 0 ) GO TO 250
      WRITE ( 6, 9610 ) LL, LL, LL, IP1, I, KTPI, KTPM, IP1,
     * E1(LL), AL(LL), GAMMA(LL),U(IP1),U(I),Y(KTPI), Y(KTPM ),RHO(IP1)
  250 CONTINUE
  200 CONTINUE
      IF ( KALLO3 .EQ. 0 ) ARR = Y(KT&M-1)
      TEMP1    =  C4ED * XMSDF / ARR
      DO 400 J = 1, M
      E2(J)    =  GAMMA(J) * TEMP1
  400 CONTINUE
      IF ( IWRIT .GT. 0 .AND. NT .EQ. 0 )
     *WRITE ( 6, 9620 ) ( K, E2(K), K = 1, M )
C
C     IF E1 IS LESS THAN E2,  USE E1. WHEN E1 BECOMES GREATER THAN E2 US
C     E2 FOR THE REMAINDER OF THE COEFFICIENTS.
C
      KODE = 0
      DO 500 K = 1, M
      J = K
      I        =  INDEX(KT&K-1)
      IF (KODE .EQ. 1) GO TO 450
      IF ( K .GT. IMAX ) GO TO 450
      EPSLN(I)  =  E1(J) * USAR
      GO TO 475
  450 CONTINUE
      KODE = 1
      IF ( NE1E2 .NE. 2 ) EPSLN(I) = E1(J) * USAR
      IF ( NE1E2 .EQ. 2 ) EPSLN(I) = E2(J) * USAR
  475 CONTINUE
  500 CONTINUE
      KT       =  KT & M
  600 CONTINUE
      NT       =  1
      RETURN
      END
```