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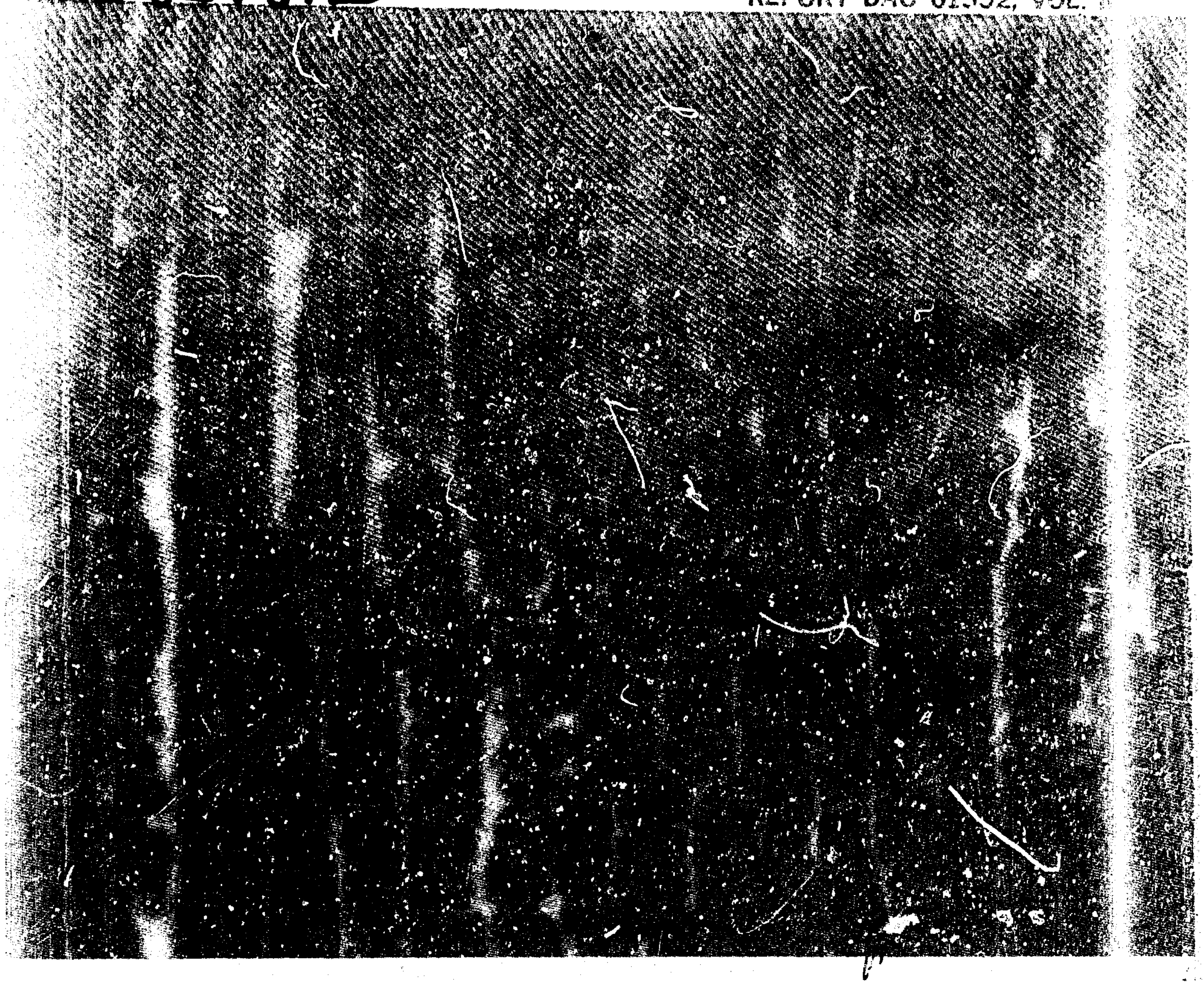

HYPERSONIC ARBITRARY-BODY AERODYNAMIC COMPUTER PROGRAM (MARK III VERSION)

VOLUME II PROGRAM FORMULATION AND LISTINGS

BY

ARVEL E. GENTRY AND DOUGLAS N. SMYTH

APRIL 1968

MCDONNELL DOUGLAS

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MARK III VERSION
VOLUME II - PROGRAM FORMULATION AND LISTINGS

By

Arvel E. Gentry

and

Douglas N. Smyth

Douglas Report DAC 61552

April 1968

This material was prepared under sponsorship of the Douglas Independent Research and Development Program and Air Force Contracts No. F33615 67 C 1008 and F33615 67 C 1602. This report is provided in the interest of information exchange. Responsibility for the contents rests with the author or organization that prepared it.

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FOREWORD

This report describes a computer program developed at the Douglas Aircraft Division of the McDonnell-Douglas Corporation, Long Beach, California. The development of the Douglas Hypersonic Arbitrary-Body Aerodynamic Computer Program was started in 1964 and greatly expanded in subsequent years under sponsorship of the Douglas Independent Research and Development Program (IRAD). From August 1966 to May 1967 the program development was continued under Air Force Contract No. F3361567 C 1008. This contract was administered under the direction of the Aeronautical Systems Division, Directorate of Analysis, Wright-Patterson Air Force Base, Ohio by Mr. R. K. Mills, Project Engineer (ASBED-30). The product of this work was the Mark II version of the program as released for use by government agencies in May 1967. The latest version of the program as presented in this report (the Mark III version) is an extensively revised version of the earlier Mark II program. This version has been prepared as a result of both 1967-68 Douglas IRAD work and another Air Force contract (F33615 67 C 1602). This contract was administered by the Air Force Flight Dynamics Laboratory, Flight Mechanics Division, Gas Dynamics Branch, Mr. Valentine Dahlem, Project Engineer (FDMG).

At the Douglas Aircraft Division this work was conducted under the direction of Mr. A. E. Gentry as Principal Investigator. A number of people contributed to the various phases of this work for which the author is grateful. Mr. D. N. Smyth provided valuable consulting services in many phases of this work and prepared the new skin friction techniques incorporated in the Mark III version. Mr. W. R. Oliver's work in applying the various versions of this program to practical design problems contributed both in program design and in program validation. Others participating in this work include Messrs. G. D. Buell, J. L. Lundry, N. F. Wasson, and B. G. Wilson.

Special appreciation is extended to the various users of the earlier versions of this program for their valuable suggestions in a number of areas and for their efforts in adapting and running earlier versions of the program on the different types of computers. These include Messrs. Fred White, Jr. (Air Force ASBED-30), Don Shereda (Air Force FDMG), Ralph Carmichael and Charles Castolano (NASA Ames), C. L. W. Edwards (NASA Langley), Ralph Grahm (NASA Houston), Ray E. Aley (Lockheed Electronics Co., Houston), and R. E. Finch, A. W. Marziane, and J. H. Kainer (Aerospace Corp.).

This computer program and documentation report were released for general use by the author and by the Guidance and Control Section, ASBED-30, Wright-Patterson Air Force Base, in April 1968. This program and report are provided in the interest of information exchange. Responsibility for the contents rests with the author or organization that prepared it.

The dis ibution of computer program decks for the Mark III version is handled the author.

ABSTRACT

This report describes a digital computer program system that is capable of calculating the hypersonic aerodynamic characteristics of complex three-dimensional shapes. The outstanding features of this program are its flexibility in covering a very wide variety of problems and the multitude of program options available. The program is a combination of techniques and capabilities necessary in performing a complete aerodynamic analysis of hypersonic shapes. These include vehicle geometry generation and description, visual graphics necessary in handling geometry data and in preparing plots of the final aerodynamic data, aerodynamic calculations of surface pressures and skin friction forces, and the integration of these forces to give all aerodynamic coefficients and stability derivatives.

The geometric description techniques in this program provide the capability of handling completely arbitrary three-dimensional shapes. The procedure developed to check the accuracy of the geometric data uses a computer and automatic recorder to draw pictures of the vehicle viewed from any angle.

The pressure calculation methods provided within the program include modified Newtonian, blunt-body Newtonian-Prandtl-Meyer, tangent-wedge, tangent-cone, shock-expansion, Prandtl-Meyer expansion, blast wave, modified tangent-cone, boundary-layer induced pressures, free-molecular flow, and a number of empirical relationships. The pressure calculation method most suitable for each component of the vehicle is specified by the aerodynamicist. Viscous forces are also calculated and include viscous-inviscid interaction effects. Skin friction options include the Reference Temperature and the Reference Enthalpy methods (for both laminar and turbulent flow), the Spalding-Chi method (turbulent), and a special blunt body skin friction method. Control surface deflection pressures, including separation effects that may be caused by the deflected surface, are also calculated.

The program has been used to study a wide variety of hypersonic vehicle shapes including hypersonic cruise aircraft, air-breathing booster aircraft, blunt lifting reentry bodies, high L/D reentry vehicles, blunt reentry capsules, rocket boosters, reentry warheads, and satellite shapes.

The program is documented in two volumes. Volume I is primarily a User's Manual, and Volume II contains the Program Formulation and Listings.

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ILLUSTRATIONS

SECTION I

INTRODUCTION

The objectives of the research work that led to this program were to (1) develop methods for determining the aerodynamic force characteristics of hypersonic vehicles regardless of the vehicle shape or flight condition, (2) program those techniques that required digital computer capability for practical and efficient application, and (3) verify these techniques by comparing the analytical results with test data.

At the start of this research project a list of guiding objectives was established to insure successful completion of the work. Major features desired in the final analysis system would:

1. Provide the ability to analyze completely arbitrary three-dimensional shapes.
2. Provide a component build-up capability where each vehicle component may be of arbitrary shape.
3. Include a number of force analysis methods so that the system would have the widest possible application to various vehicle shapes and flight conditions.
4. Provide the capability to use the best force calculation method for each vehicle component.
5. Provide methods for analyzing simple shapes within a minimum time period.
6. Develop a total analysis system framework that is adaptable to continued improvement and expansion.

The initial phase of this work was started in late 1964 and continued in 1965 as part of a Douglas Independent Research and Development Study. During that time a general arbitrary body force analysis approach was derived for hypersonic vehicles, the important basic components of the computer system were written and checked out, and the system demonstrated by application to several vehicles of completely arbitrary shape. All of this was accomplished under a very modest work effort.

During 1966 this work effort was expanded slightly and new capability added to the program system. This included the incorporation of several new force calculation methods, and the expansion of the force program to calculate vehicle static and dynamic stability derivatives.

In August of 1966, the program development was continued under Air Force Contract F33615 67 C 1008. This work included further expansion of the force calculation methods, the addition of new geometry description features, the incorporation of control surface derivative calculations, the consolidation of all the system components to form one large program, and the preparation of complete program documentation information. The final program resulting from this work was identified as the Mark II version of the Hypersonic Arbitrary-Body Aerodynamic Computer Program.

During 1967 - 1968 the program development was continued under Douglas IRAD and another Air Force Contract (F33615 67 C 1602). During this period a number of major program modifications were accomplished including the addition of a number of new pressure calculation options, extensive revision to the skin friction parts of the program, and conversion of the program to operate on different computers. The program resulting from this work is identified as the Mark III version.

Throughout this report it will be assumed that the reader is familiar with the contents of Volume I, the User's Manual. Discussions of earlier versions of this program are given in References 1 and 2.

Both Volumes I and II of this report are essentially revised editions of the earlier Mark II program report (Reference 2). The differences between the Mark III and Mark II reports reflect the modifications and new capabilities provided by the latest version.

This report contains descriptions of the analysis techniques used within the program. Throughout these discussions an attempt has been made to maintain mathematical notations consistent with the appropriate references involved. This will assist the reader in comparing the approaches with the original reference material at some slight loss in continuity within the present report. This policy has also been used in the selection of many of the program variable names.

The program source language itself has been written in a manner so that the general flow of the program logic is easy to follow, even by the reader unfamiliar with FORTRAN. This has been accomplished by a very liberal use of comment statements throughout the program. This approach, together with the availability of machine-produced program flow charts, and the general widespread knowledge of the basic FORTRAN language, makes it unnecessary to include detailed equation-by-equation descriptions of the program content. Instead, it is only necessary to give a general mathematical description of the approach used.

Appendix A to this report contains the source language listings of the program, machine-produced flow charts, and the definitions of the program symbols. Appendix B contains one complete alphabetical listing of all the program variables and their definitions. Appendix C contains a description of the program subscripted variable arrays.

SECTION II

PROGRAM FORMULATION

PROBLEM FORMULATION

The problem of estimating the aerodynamic characteristics of arbitrary three-dimensional shapes at hypersonic speeds has several salient features. The first problem is to construct an accurate description of the vehicle geometry, as arbitrary and complex as it may be. This difficult geometry problem, together with the extremely wide range of flight conditions, dictates that many different force prediction techniques be available for use. The various approaches used in calculating the aerodynamic forces on three-dimensional shapes differ in that different methods are used to attack these two basic problems — the geometry representation problem, and the force calculation technique problem.

The most ambitious approach presently being attempted uses the method of characteristics. Some of this work is discussed in References 3 and 4. Undoubtedly, this is the eventual ideal approach to the calculation of forces on three-dimensional shapes at high speeds. However, present mathematical techniques and digital computer size and speed capabilities prevent application to typical preliminary design problems. Present applications of the method of characteristics must be reserved for simple bodies of revolution at zero angle of attack or important detail design applications where large computer times of several hours might be acceptable.

Other detailed gas dynamics approaches have been used for very simple shapes such as blunt-nosed bodies of revolution (see References 5 and 6). While this work has considerable value as an aid to understanding the chemical and gas dynamics problems associated with simple blunt shapes, its application to the general three-dimensional shape is restrictive.

Other special techniques, some theoretical and some empirical in nature, have been worked out for simple shapes. Notable examples are the work for hypersonic flow conditions on delta wings by Creager (Reference 7), and McLaughlin (Reference 8).

Another interesting approach to understanding the nature of high-speed flow is to select special shapes that are amenable to exact theory. In Reference 9 a class of delta wings is considered that permits solution using the exact shock wave theory. This work is expanded further in Reference 10 where upper surfaces are included and complete configurations suggested that are derived from simple shock waves and expansions.

Reference 11 contains an approach that uses parts of conical shock waves. This work is also discussed in Reference 12. A typical general approach to these and subsequent similar studies may be described as follows. Several exact methods have been derived for the solution of flow fields about right circular cones at zero angle of attack. The shock wave system formed by this cone is also of a conical shape and the streamlines and flow properties of the air passing through this shock structure may be readily calculated (Reference 13). The first step in deriving a configuration is to define a wing leading edge line that lies on the surface of the shock wave cone. If we then follow the streamlines formed by the original cone from this leading edge line downstream, we find that we have described a surface along which solutions are already available from the exact cone flow calculations. Such an approach has been used in designing and evaluating some high speed airbreathing engine inlet designs. Although this approach again adds to the "storehouse" of knowledge on high speed aerodynamics, it certainly does not give much flexibility either in the design or the analysis process.

A more practical approach to the vehicle analysis problem was presented by Hankey in Reference 14. In this work it was recognized that each general type of vehicle shape (i.e., leading edge, flat surface, cone) required a different method for accurate force prediction. In this approach, solutions were obtained by restricting the vehicle to a few set combinations of simple geometrical shapes and by deriving theoretical and empirical force calculation methods for each shape component. The approach gave good results for the class of vehicles considered (the Dyna-Soar vehcile shape) but was limited in its application because of the restricted set of shapes available. The major contribution, however, was to illustrate that the method of force calculation must be tailored to the vehicle component shape and to the specific flight condition involved.

A similar approach has been in widespread use in both government and industry areas. The general procedure is to break the vehicle into a number of small simple shapes and to estimate the aerodynamic forces on each component by available methods. The widest and most frequently used force method is Newtonian theory. Several reports have been published that give results of Newtonian calculations for simple geometric shapes. References 15 and 16 contain design charts that are useful in evaluating certain geometric components (hemispheres, cylindrical leading edges, cones, cone frustums and flat plates) by Newtonian theory. The difficulty of this approach is that only simple shapes may be analyzed and only elementary force analysis method results such as given by Newtonian theory are available. For complex shapes considerable time and effort is required to define the vehicle in terms of required simple component shapes.

Reference 17 uses a semigraphical method for solving the arbitrary body geometry problem and uses Newtonian theory for the force calculations. The work by Dahlem (of ASD) modifies this procedure to allow computation on a digital computer (Reference 18). The geometric input data consist of coordinates of points on the surface, two angles indicating the surface slope and an angle indicating the orientation of the surface point. The inherent difficulty of preparing these input data for complex configurations from conventional engineering drawings is obvious.

A different approach to the geometry problem is presented by Van Tassell (of AVCO) in Reference 19. In this approach the body is approximated by a series of triangles on the body surface as determined from input coordinate points. In this case the force calculation methods include Newtonian theory and free-molecular flow (completely diffuse reflection). The use of surface coordinate points to form triangular elements still presents a difficult problem in obtaining accurate and correct input data.

A more elaborate technique of surface description has been worked out at MIT by Coons (Reference 20). In this method the surface is divided into a number of large patches and then each patch is mapped into a two-dimensional surface and described by a mathematical surface fit technique. The boundary curves of a patch are described by third order polynomials requiring only the coordinates and surface slopes at the four corner points in the transformed coordinate system. In a practical application the corner point surface slopes must be calculated by the computer since the problem of measuring them directly from engineering drawings would restrict the usefulness of this method. This may be accomplished by using a number of surface points along the boundaries to more completely describe the shape. After the boundary curves are defined in the transformed system the coordinates of a point on the surface may be calculated by using special blending relationships that serve as weighting functions to properly account for the influence of each boundary. Reference 21 contains a brief description of a similar technique used by the Boeing Company.

In most of the references cited above simple Newtonian theory was used to calculate the aerodynamic forces. While this method may give acceptable results for some shapes at very high Mach numbers, other methods must be available before a truly arbitrary body analysis system is available. An equally important problem is the transcription of the geometric description of the vehicle from engineering drawings and the preparation of this information in a form acceptable to the digital computer. Regardless of what surface description method is used, checking of the voluminous and often complex input data poses a difficult problem. Since a single vehicle may be composed of several different classes of general shapes (such as a blunt nose body, together with a thin wing) the arbitrary body analysis system must have the capability of using different force analysis techniques and frequently a different grid work of input surface data on each component of the vehicle.

For hypersonic speeds the most frequently used force analysis method is Newtonian theory. In this theory the pressure on each surface point of the vehicle is only a function of the angle that the surface makes with the free stream flow. Several other methods for calculating inviscid pressure also depend only on the local inclination of the surface. These include tangent-wedge and tangent-cone, and several other empirical methods worked out for special uses such as Newtonian plus Prandtl-Meyer expansion. Another important method for use at high speeds is hypersonic shock-expansion.

With the foregoing discussion as background information we will now proceed with the approach used to solve the general problem that is the subject of this research project — the development of methods for calculating the hypersonic, aerodynamic characteristics of completely arbitrary three-dimensional shapes.

In the following pages we will first present a brief introduction to the program organization. This will be followed by a more detailed derivation of the analysis methods used in each component of the system. The computer program system described in the following pages is capable of calculating the aerodynamic forces on completely arbitrary three-dimensional shapes at high supersonic and hypersonic speeds.

All program components of this system are written in FORTRAN.

PROGRAM COMPONENTS

This program is written on a completely modular basis to facilitate checkout and modification activities. The Mark III program contains five major program components: the Aerodynamic Program, the Picture Drawing Program, the Output Data Plotter Program, the Auxiliary Geometry Generation Program (Slab Delta Program), and the card punch routine.

In the early development phase each of these components was actually a completely separate computer program. The programs could, however, be run back-to-back with the output from one program saved on tape for use by the next. In the Mark III program all of these components are combined under the control of a small executive main program. However, to simplify the discussions in this report, each of these components is still referred to as a program even though it is really just a subroutine in the overall program.

The general activities carried out by the Arbitrary-Body Program System are involved with one of three basic tasks: (1) the preparation of geometry data, (2) the calculation of aerodynamic characteristics, and (3) the preparation of graphic output data. The computations performed in support of each of these system tasks are discussed in the following sections of this report.

GEOMETRY

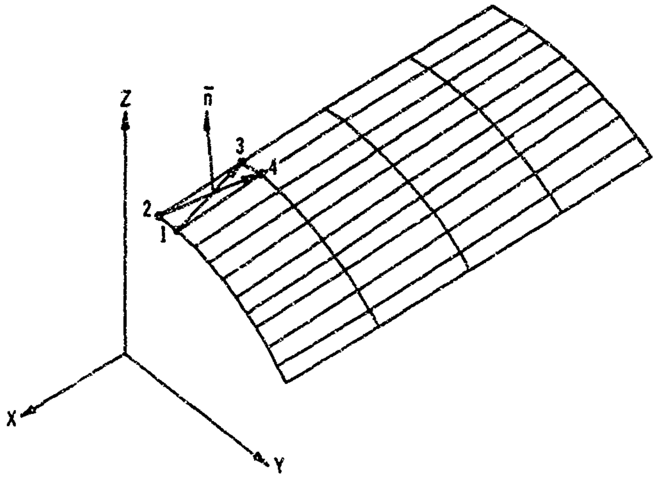
This program contains several different methods for describing three-dimensional geometric shapes. These methods provide the flexibility required to analyze a variety of shapes ranging from very simple surfaces to the most complex forms. The program geometry options provided are (1) the surface element method, (2) the elliptical surface generation method, (3) the parametric cubic method, and (4) the slab delta geometry generation method. If desired, all of these methods could be used in describing a single vehicle shape.

The principles involved in the application of each of these geometry methods are discussed in detail in the User's Manual and need not be covered here. The principal mathematical techniques, however, are important from the programming standpoint and will be discussed on the following pages.

The Surface Element Geometry Method

The basic geometry method used by this program is the surface element or quadrilateral method. This method was developed by J. L. Hess and A. M. O. Smith for the Douglas Three-Dimensional Potential Flow Program (Reference 22). For completeness, certain parts of this report will be included in the following discussions.

The coordinate system used for this analysis is a right-handed Cartesian system as shown in the figure below.



DIAGONAL VECTORS $\bar{T}_1$ and $\bar{T}_2$

$T_{1x} = X_3 - X_1 \quad T_{1y} = Y_3 - Y_1 \quad T_{1z} = Z_3 - Z_1$

$T_{2x} = X_4 - X_2 \quad T_{2y} = Y_4 - Y_2 \quad T_{2z} = Z_4 - Z_2$

UNIT NORMAL $\bar{N} = \bar{T}_2 \times \bar{T}_1$

$N_x = T_{2y}T_{1z} - T_{1y}T_{2z} \qquad n_x = N_x/N$

$N_y = T_{1x}T_{2z} - T_{2x}T_{1z} \qquad n_y = N_y/N$

$N_z = T_{2x}T_{1y} - T_{1x}T_{2y} \qquad n_z = N_z/N$

$$N = \sqrt{N_x^2 + N_y^2 + N_z^2}$$

AVERAGE POINT

$\bar{x} = ¼(X_1 + X_2 + X_3 + X_4)$

$\bar{y} = ¼(Y_1 + Y_2 + Y_3 + Y_4)$

$\bar{z} = ¼(Z_1 + Z_2 + Z_3 + Z_4)$

CORNER POINT PROJECTION DISTANCE

$$d_k = n_x(\bar{x} - X_k) + n_y(\bar{y} - Y_k) + n_z(\bar{z} - Z_k)$$

$$k = 1, 2, 3, 4$$

CORNER POINT COORDINATES

$X'_k = X_k + n_x d_k$

$Y'_k = Y_k + n_y d_k$

$Z'_k = Z_k + n_z d_k$

In the conventional use of this program the vehicle is usually positioned with its nose at the coordinate system origin and with the length of the body stretching in the negative X direction. The slight inconvenience of this negative sign on the body stations has been accepted so that the geometric data will be compatible with the Douglas potential flow program (Neumann Program).

The body surface is represented by a set of points in space. These points are selected on the body surface and are used by the method to obtain an approximation to this surface that is used in subsequent calculations. If the four related points of each set are connected by straight lines we may obtain a picture of how the input surface points are organized to describe a given shape. This has been done in Figure 1. The input scheme has been designed so that each point need only be input once even though it may be a member of as many as four adjacent sets of points. This is accomplished by the use of an additional parameter for each point besides the X, Y, and Z values. This parameter (known as the status flag) indicates whether a point is a continuation of a column of points (STATUS = 0), the beginning of a

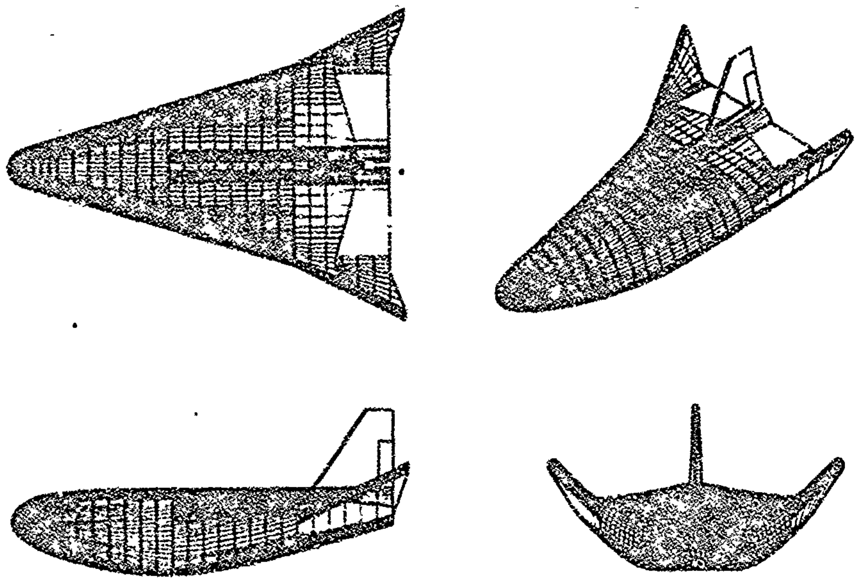


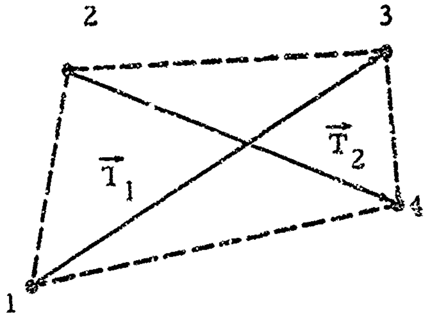
Figure 1. Output from Perspective Drawing Program

new column of points (=1), the first point of a new section of elements (=2), or the last point input for the shape (=3).

As may be seen from the drawings made by the Picture Drawing Program, the different areas of a vehicle may require a different organization and spacing of surface points for accurate representation. Each such area or organization of elements is called a section and each section is independent of all other sections. The division of a vehicle into a given set of sections may also be influenced by another consideration since the force calculation program may be made to calculate the force contributions of each section separately, using different calculation methods.

The input surface points are not sufficient in themselves for the force calculations. Each set of four related points which form an individual element must be converted into quantities useful to the program. This is accomplished by approximating each element area of the vehicle by a plane quadrilateral surface. Since we are using four surface points to form an element, no single surface will contain the points themselves. Also, adjacent plane quadrilateral edges will not necessarily be coincident. With a sufficiently small size of the surface elements this will be of no consequence in the end results.

The mathematical technique used in converting an input set of four points into a plane quadrilateral element is described below. The figure below gives a representation of the input element points with each point identified consecutively around the element by the subscripts 1, 2, 3, and 4, respectively.



The coordinates in the reference coordinate system are as follows:

1	:	x_1^i	y_1^i	z_1^i
2	:	x_2^i	y_2^i	z_2^i
3	:	x_3^i	y_3^i	z_3^i
4	:	x_4^i	y_4^i	z_4^i

The superscript i identifies the coordinates as input coordinates. We next form the two diagonal vectors $\vec{T}_1$ and $\vec{T}_2$. The components of these vectors are

$$T_{1x} = x_3^i - x_1^i \qquad T_{1y} = y_3^i - y_1^i \qquad T_{1z} = z_3^i - z_1^i$$

$$T_{2x} = x_4^i - x_2^i \qquad T_{2y} = y_4^i - y_2^i \qquad T_{2z} = z_4^i - z_2^i$$

We may now obtain a new vector $\vec{N}$ (and its components) by taking the cross product of the diagonal vectors.

$$\bar{N} = \vec{T}_2 \times \vec{T}_1$$

$$N_x = T_{2y} T_{1z} - T_{1y} T_{2z}$$

$$N_y = T_{1x} T_{2z} - T_{2x} T_{1z}$$

$$N_z = T_{2x} T_{1y} - T_{1x} T_{2y}$$

The unit normal vector, $\vec{n}$, to the plane of the element is taken as $\vec{N}$ divided by its own length N (direction cosines of outward unit normal).

$$n_x = \frac{N_x}{N}$$

$$n_y = \frac{N_y}{N}$$

$$n_z = \frac{N_z}{N}$$

where

$$N = \sqrt{N_x^2 + N_y^2 + N_z^2}$$

The plane of the element is now completely determined if a point in this plane is specified. This point is taken as the point whose coordinates, $\bar{x}$, $\bar{y}$, $\bar{z}$ are the averages of the coordinates of the four input points.

$$\bar{x} = \frac{1}{4}\left[x_1^i + x_2^i + x_3^i + x_4^i\right]$$

$$\bar{y} = \frac{1}{4}\left[y_1^i + y_2^i + y_3^i + y_4^i\right]$$

$$\bar{z} = \frac{1}{4}\left[z_1^i + z_2^i + z_3^i + z_4^i\right]$$

Now the input points will be projected into the plane of the element along the normal vector. The resulting points are the corner points of the quadrilateral element. The signed distance of the k-th input points (k = 1, 2, 3, 4) from the plane is

$$d_k = n_x(\bar{x} - x_k^i) + n_y(\bar{y} - y_k^i) + n_z(\bar{z} - z_k^i) \qquad k = 1, 2, 3, 4$$

It turns out that, due to the way in which the plane was generated from the input points, all the d_k's have the same magnitude, those for points 1 and 3 having one sign and those for points 2 and 4 having the opposite sign. Symbolically,

$$d_k = (-1)^{k-1} d_1 \qquad k = 1, 2, 3, 4$$

The magnitude of the common projection distance is called d, i.e.,

$$d = \left| d_1 \right|$$

The coordinates of the corner points in the reference coordinate system are given by

$$x'_k = x^i_k + n_x d_k$$

$$y'_k = y^i_k + n_y d_k \qquad k = 1, 2, 3, 4$$

$$z'_k = z^i_k + n_z d_k$$

Now the element coordinate system must be constructed. This requires the components of three mutually perpendicular unit vectors, one of which points along each of the coordinate axes of the system, and also the coordinates of the origin of the coordinate system. All these quantities must be given in terms of the reference coordinate system. The unit normal vector is taken as one of the unit vectors, so two perpendicular unit vectors in the plane of the element are needed. Denote these unit vectors $\vec{t}_1$ and $\vec{t}_2$. The vector $\vec{t}_1$ is taken as $\vec{T}_1$ divided by its own length T_1, i.e.,

$$t_{1x} = \frac{T_{1x}}{T_1}$$

$$t_{1y} = \frac{T_{1y}}{T_1}$$

$$t_{1z} = \frac{T_{1z}}{T_1}$$

where

$$T_1 = \sqrt{T_{1x}^2 + T_{1y}^2 + T_{1z}^2}$$

The vector $\vec{t}_2$ is defined by $\vec{t}_2 = \vec{n} \times \vec{t}_1$, so that its components are

$$t_{2x} = n_y t_{1z} - n_z t_{1y}$$

$$t_{2y} = n_z t_{1x} - n_x t_{1z}$$

$$t_{2z} = n_x t_{1y} - n_y t_{1x}$$

The vector $\vec{t}_1$ is the unit vector parallel to the x or ξ axis of the element coordinate system, while $\vec{t}_2$ is parallel to the y or η axis, and n is parallel to the z or ζ axis of this coordinate system.

To transform the coordinates of points and the components of vectors between the reference coordinate system and the element coordinate system, the transformation matrix is required. The elements of this matrix are the components of the three basic unit vectors, $\vec{t}_1$, $\vec{t}_2$, and $\vec{n}$. To make the notation uniform define

$$\begin{array}{lll} a_{11} = t_{1x} & a_{12} = t_{1y} & a_{13} = t_{1z} \\ a_{21} = t_{2x} & a_{22} = t_{2y} & a_{23} = t_{2z} \\ a_{31} = n_x & a_{32} = n_y & a_{33} = n_z \end{array}$$

The transformation matrix is thus the array

$$\begin{array}{ccc} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{array}$$

To transform the coordinates of points from one system to the other, the coordinates of the origin of the element coordinate system in the reference coordinate system are required. Let these be denoted x_o, y_o, z_o. Then if a point has coordinates x', y', z' in the reference coordinate system and coordinates x, y, z in the element coordinate system, the transformation from the reference to the element system is

$$x = a_{11}(x' - x_o) + a_{12}(y' - y_o) + a_{13}(z' - z_o)$$

$$y = a_{21}(x' - x_o) + a_{22}(y' - y_o) + a_{23}(z' - z_o)$$

$$z = a_{31}(x' - x_o) + a_{32}(y' - y_o) + a_{33}(z' - z_o)$$

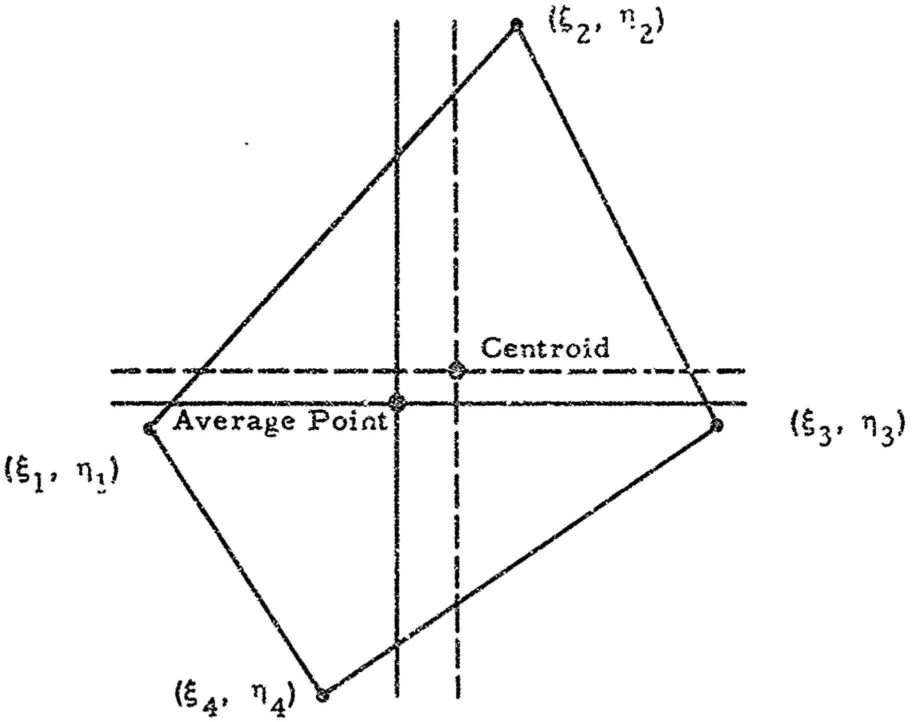
while the transformation from the element to the reference system is

$$x' = x_o + a_{11}x + a_{21}y + a_{31}z$$

$$y' = y_o + a_{12}x + a_{22}y + a_{32}z$$

$$z' = z_o + a_{13}x + a_{23}y + a_{33}z$$

The corner points are now transformed into the element coordinate system based on the average point as origin. These points have coordinates x'_k, y'_k, z'_k in the reference coordinate system. Their coordinates in the element coordinate system with this origin are denoted by ξ^*_k, η^*_k, 0. Because they lie in the plane of the element, they have a zero z or ζ coordinate in the element coordinate system. Also, because the vector $\overrightarrow{t_1}$, which defines the x or ξ axis of the element coordinate system, is a multiple of the "diagonal" vector from point 1 to point 3, the coordinate η^*_1 and the coordinate η^*_3 are equal. This is illustrated in the figure below. Using the above transformation these coordinates are explicitly



$$\xi_k^* = a_{11}(x'_k - \bar{x}) + a_{12}(y'_k - \bar{y}) + a_{13}(z'_k - \bar{z})$$

$$K = 1, 2, 3, 4$$

$$\eta_k^* = a_{21}(x'_k - \bar{x}) + a_{22}(x'_k - \bar{y}) + a_{23}(z'_k - \bar{z})$$

These corner points are taken as the corners of a plane quadrilateral.

The origin of the element coordinate system is now transferred to the centroid of the area of the quadrilateral. With the average point as origin the coordinates of the centroid in the element coordinate system are:

$$\xi_o = \frac{1}{3} \frac{1}{\eta_2^* - \eta_4^*} \left[\xi_4^* (\eta_1^* - \eta_2^*) + \xi_2^* (\eta_4^* - \eta_1^*) \right]$$

$$\eta_o = -\frac{1}{3} \eta_1^*$$

These are subtracted from the coordinates of the corner points in the element coordinate system based on the average point as origin to obtain the coordinates of the corner points in the element coordinate system based on the centroid as origin. Accordingly, these latter coordinates are

$$\xi_k = \xi_k^* - \xi_o \qquad K = 1, 2, 3, 4$$

$$\eta_k = \eta_k^* - \eta_o$$

Since the centroid is to be used as the origin of the element coordinate system, its coordinates in the reference coordinate system are required for use with the transformation matrix. These coordinates are

$$x_o = \bar{x} + a_{11}\,\xi_o + a_{21}\,\eta_o$$

$$y_o = \bar{y} + a_{12}\,\xi_o + a_{22}\,\eta_o$$

$$z_o = \bar{z} + a_{13}\,\xi_o + a_{23}\,\eta_o$$

Since in all subsequent transformations between the reference coordinate system and the element coordinate system the centroid is used as origin of the latter, its coordinates are denoted x_o, y_o, z_o. The coordinates of the average point are no longer needed. The change in origin of the element coordinate system, of course, has no effect on the coordinates of the corner points in the reference coordinate system.

The lengths of the two diagonals of the quadrilateral, t_1 and t_2, are computed from

$$t_1^2 = (\xi_3 - \xi_1)^2$$

$$t_2^2 = (\xi_4 - \xi_2)^2 + (\eta_4 - \eta_2)^2$$

The larger of these is selected and designated the maximum diagonal t.

The body surface area and enclosed volume are determined by summing up the contributions of each element. In terms of the coordinates of the corner points, the area of the quadrilateral is

$$A = \frac{1}{2}\,(\xi_3 - \xi_1)(\eta_2 - \eta_4)$$

The incremental volume is given by the volume of the parallepepiped formed by the element and its projection onto the x - z plane (the x - y or y - z planes would have served equally well).

$$V = y_o\,A\,n_y$$

Summary

The foregoing procedure may be briefly summarized as follows:

Each set of four points is converted into a plane-quadrilateral element by the procedure shown in the sketch on page 7. The normal to the quadrilateral is taken as the cross product of two diagonal vectors formed between opposite element points. The order of the input points and the manner of defining the diagonal vectors is used to ensure that the cross product gives an outward normal to the body surface. The next step is to define the plane of the element by determining the averages of the coordinates of the original four corner points. These points are then projected parallel to the normal vector into the plane of the element to give the corners of the plane quadrilateral. The corner points of the quadrilateral are equidistant from the four points used to form the element. Additional parameters required for subsequent force calculations, quadrilateral area and centroid, may now be calculated.

The spacing and orientation of the elements is varied in such a way that they describe the vehicle shape accurately. Since four points are used to define the plane quadrilateral, the edges of adjacent elements are not coincident. This is not important, since the pressure is calculated only at the quadrilateral centroid. This pressure is then assumed to be constant over the surface of the element.

The plane-quadrilateral surface description method is not as elaborate as some of the other methods. It is important, however, to note that the simplicity of the method permits the use of conventional cross-sectional drawings in data preparation (no surface slopes required) and the use of semiautomatic data-reading techniques. Also, as has been illustrated in Volume I, computer-generated pictures are used in checking the geometric data for errors.

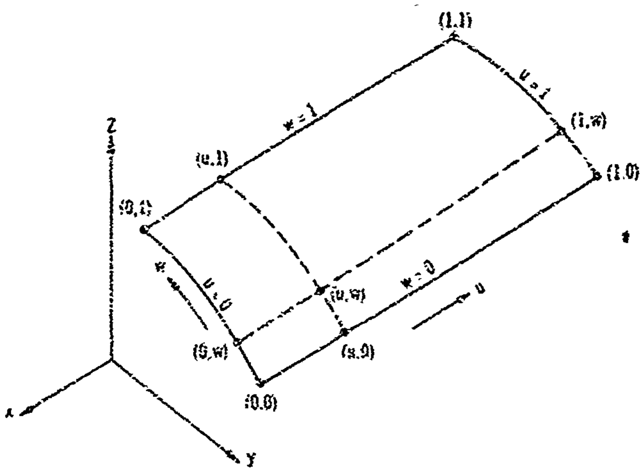
Parametric Cubic

A second technique for describing three-dimensional curved surfaces is also provided within the program. This is a mathematical surface-fit technique and is identified as the Parametric Cubic Method because of the general type of equations used.

Several different mathematical surface-fit techniques are described in the literature. The one used in this program was adopted from the formulation given by Coons of MIT (Reference 20). In this method a vehicle shape is also divided into a number of sections or patches. The size and location of each patch depends upon the shape of the surface.

The basic feature of this method is that only the surface conditions at the patch corner points are required to completely describe the surface enclosed by the boundary curves of the patch. The basic problem, however, is the determination of all the information required at these corner points, i.e., the surface equation requires corner point surface derivatives with respect to the parametric variables rather than the X, Y, Z coordinates. This has been solved by the use of additional points along the boundary curves as will be described later.

In the following discussions we will use the geometrical representation of a surface patch as illustrated in the figure below.



BOUNDARY CURVE (FOR u = 0)

$$X_i(0,w) = Aw^3 + Bw^2 + Cw + D$$

$$A = 2[X_i(0,0) - X_i(0,1)] + \frac{\partial X_i}{\partial w}(0,0) + \frac{\partial X_i}{\partial w}(0,1)$$

$$B = 3[X_i(0,1) - X_i(0,0)] - 2\frac{\partial X_i}{\partial w}(0,0) - \frac{\partial X_i}{\partial w}(0,1)$$

$$C = \frac{\partial X_i}{\partial w}(0,0) \qquad D = X_i(0,0)$$

$$\frac{\partial X_i}{\partial w} = \frac{\partial X_i}{\partial S}\frac{\partial S}{\partial w} \qquad i = 1, 2, 3 \text{ FOR } X, Y, Z$$

BLENDING FUNCTIONS

$$F_1(u) = 3u^2 - 2u^3 \qquad F_1(w) = 3w^2 - 2w^3$$

$$F_0(u) = 1 - F_1(u) \qquad F_0(w) = 1 - F_1(w)$$

SURFACE FORM

$$\begin{aligned} X_i(u,w) = {} & X_i(0,w)F_0(u) + X_i(1,w)F_1(u) + X_i(u,0)F_0(w) \\ & + X_i(u,1)F_1(w) - X_i(0,0)F_0(u)F_0(w) \\ & - X_i(0,1)F_0(u)F_1(w) - X_i(1,0)F_1(u)F_0(w) \\ & - X_i(1,1)F_1(u)F_1(w) \end{aligned}$$

Since the basic surface-fit equations and their derivatives are presented in Reference 20, they need be only reviewed briefly in this report.

The X, Y, Z coordinates of a point on the surface are related to the two parametric variables u and w. Thus, a surface in space is mapped into the u, w unit square. The basic problem is to find the position (X, Y, Z) of a point (u, w) in the interior of the section surface. The general procedure is to first find relationships for the four boundary curves. These are defined as third-order polynomials in terms of the parametric variables. The points on the boundary curves corresponding to u and w (0, w and u, 0, etc.) are then calculated. A general surface equation is used to calculate the properties at the point u, w. This equation uses blending or weighting functions to properly introduce the influence of each of the related boundary-curve points and the four corner points. The blending functions also ensure the continuity of the slopes across the boundaries between adjacent sections.

There are several methods for calculating the direction cosines of the tangent vectors required in the calculation of the corner-point derivatives. Most require the specification of additional surface-boundary points, some of which may lie on the extensions of the boundary curves. The derivatives must be calculated, since it would not be practical to measure them directly from drawings. The method in this program involves the use of circular arcs through three boundary-curve points, the middle one being a corner point.

The first step in the computational procedure is to determine the equations for the cubic boundary curves. The equation used is given by the following relationship for u = 0.

$$X_i(0,w) = Aw^3 + Bw^2 + Cw + D$$

where

$$A = 2\left[X_i(0,0) - X_i(0,1)\right] + \frac{\partial X_i}{\partial w}(0,0) + \frac{\partial X_i}{\partial w}(0,1)$$

$$B = 3\left[X_i(0,1) - X_i(0,0)\right] - 2\frac{\partial X_i}{\partial w}(0,0) - \frac{\partial X_i}{\partial w}(0,1)$$

$$C = \frac{\partial X_i}{\partial w}(0,0)$$

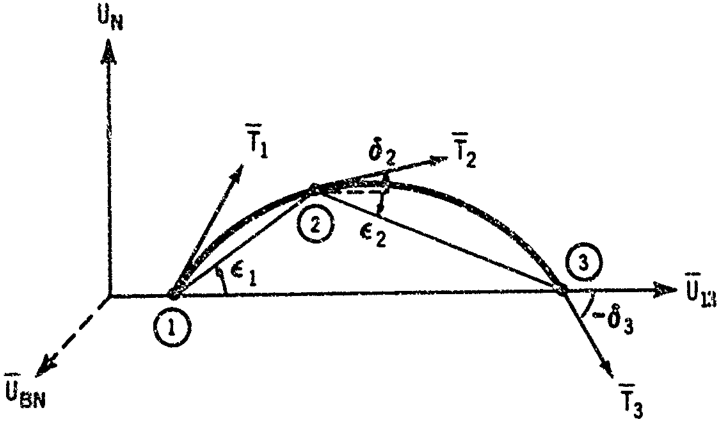
$$D = X_i(0,0)$$

Similar equations are needed for the other three boundary curves with $u = 1$, $w = 0$, and $w = 1$.

The missing items required for the solution of the above equations are the derivatives

$$\frac{\partial X_i}{\partial w}(0,0),\ \frac{\partial X_i}{\partial w}(0,1),\ \text{etc}$$

In the Arbitrary-Body Program these are determined by passing a circular arc through three points, the middle point being the corner point itself. For completeness, the development of this method is presented and the sketch below is useful in following the derivation.



This sketch is a view of the plane of the circle with $\overline{U}_{13}$ as the base coordinate. The vectors $\overline{T}_1$, $\overline{T}_2$, and $\overline{T}_3$ are tangents to the curve at the points 1, 2, and 3.

The tangents make the angles δ_1, δ_2, and δ_3 with respect to $\overline{U}_{13}$. The chord lengths make the angles ϵ_1 and ϵ_2 with respect to the vector $\overline{U}_{13}$.

One of the properties of circular arcs is that the chord angle is the average of the two tangent angles.

$$\epsilon_1 = \frac{\delta_1 + \delta_2}{2} \qquad \epsilon_2 = \frac{\delta_2 + \delta_3}{2} \qquad \epsilon_3 = \frac{\delta_1 + \delta_3}{2}$$

For the coordinate base selected ($\overline{U}_{13}$), $\epsilon_3 = 0$, therefore,

$$\delta_1 = -\delta_3 \quad \text{and} \quad \delta_2 = \epsilon_1 + \epsilon_2$$

The tangent vector at point 2 is then given by

$$\overline{T}_2 = \cos\delta_2\,\overline{U}_{13} + \sin\delta_2\overline{U}_N$$

$$\overline{U}_{13} = \frac{\overline{L}_{13}}{|\overline{L}_{13}|}$$, $\overline{L}_{13}$ is chord vector between points 1 and 3.

To determine $\overline{U}_N$, the binomial $\overline{U}_{BN}$ must first be found

$$\overline{U}_{BN} = \overline{L}_{13} \times \overline{L}_{12}$$

$$\overline{U}_{BN} = \frac{\overline{U}_{BN}}{|\overline{U}_{BN}|} \quad \text{(unit vector)}$$

$$\overline{U}_N = \overline{U}_{BN} \times \overline{U}_{13}$$

The radius vectors (X, Y, Z) for the three points are

$$\overline{r}_1 = X_1\overline{i} + Y_1\overline{j} + Z_1\overline{k}$$

$$\overline{r}_2 = X_2\overline{i} + Y_2\overline{j} + Z_2\overline{k}$$

$$\overline{r}_3 = X_3\overline{i} + Y_3\overline{j} + Z_3\overline{k}$$

The chord vectors between the points are

$$\bar{L}_{12} = \bar{r}_2 - \bar{r}_1 = (X_2 - X_1)\,\bar{i} + (Y_2 - Y_1)\,\bar{j} + (Z_2 + Z_1)\,\bar{k}$$

$$\bar{L}_{23} = \bar{r}_3 - \bar{r}_2 = (X_3 - X_2)\,\bar{i} + (Y_3 - Y_2)\,\bar{j} + (Z_3 - Z_2)\,\bar{k}$$

$$\bar{L}_{13} = \bar{r}_3 - \bar{r}_1 = (X_3 - X_1)\,\bar{i} + (Y_3 - Y_1)\,\bar{j} + (Z_3 - Z_1)\,\bar{k}$$

and the chord angles

$$\cos \epsilon_1 = \frac{\bar{L}_{12} \bullet \bar{L}_{13}}{|\bar{L}_{12}|\ |\bar{L}_{13}|} \qquad \cos \epsilon_2 = \frac{\bar{L}_{23} \bullet \bar{L}_{13}}{|\bar{L}_{23}|\ |\bar{L}_{13}|}$$

For convenience we will use the shortened notation:

$$L_{12} = \left|\bar{L}_{12}\right|, \text{ etc.}$$

$$\bar{U}_{13} = \left(\frac{X_3 - X_1}{L_{13}}\right)\bar{i} + \left(\frac{Y_3 - Y_1}{L_{13}}\right)\bar{j} + \left(\frac{Z_3 - Z_1}{L_{13}}\right)\bar{k}$$

$$= \ell_1\,\bar{i} + m_1\,\bar{j} + n_1\,\bar{k}$$

Similarly

$$\bar{U}_{12} = \ell_2\,\bar{i} + m_2\,\bar{j} + n_2\,\bar{k}$$

$$\bar{U}_{BN} = \frac{\bar{U}_{BN}}{|\bar{U}_{BN}|} = \bar{U}_{13} \times \bar{U}_{12} = \begin{vmatrix} i & j & k \\ \ell_1 & m_1 & n_1 \\ \ell_2 & m_2 & n_2 \end{vmatrix}$$

$$= (m_1\,n_2 - m_2\,n_1)\,\bar{i} - (\ell_1\,n_2 - \ell_2\,n_1)\,\bar{j} + (\ell_1\,m_2 - \ell_2\,m_1)\,\bar{k}$$

$$\bar{U}_N = \bar{U}_{BN} \times \bar{U}_{13} = \begin{vmatrix} i & j & k \\ (\ ) & -(\ ) & (\ ) \\ \ell_1 & m_1 & n_1 \end{vmatrix}$$

$$= \left[- n_i ('_1 n_2 - \ell_2 n_1) - m_1 (\ell_1 m_2 - \ell_2 m_1)\right] i$$

$$- \left[n_1 (m_1 n_2 - m_2 n_1) - \ell_1 (\ell_1 m_2 - \ell_2 m_1)\right] j$$

$$+ \left[m_1 (m_1 v_2 - m_2 n_1) + \ell_1 (\ell_1 n_2 - \ell_2 n_1)\right] k$$

$$\overline{U}_N = \ell_N \, \overline{i} + m_N \, \overline{j} + n_N \, \overline{k}$$

And finally we obtain the tangent vector

$$\overline{T}_2 = (\ell_1 \cos\delta + \ell_N \sin\delta)\, \overline{i} + (m_1 \cos\delta + m_N \sin\delta)\, \overline{j}$$

$$= (n_1 \cos\delta + n_N \sin\delta)\, \overline{k}$$

where

$$\ell_1 = \frac{X_3 - X_1}{L_{13}}, \qquad m_1 = \frac{Y_3 - Y_1}{L_{13}}, \qquad n_1 = \frac{Z_3 - Z_1}{L_{13}}$$

$$L_{13} = \left[(X_2 - X_1)^2 + (Y_3 - Y_1)^2 + (Z_3 - Z_1)^2 \right]^{1/2}$$

$$\ell_N = -\left[n_1 (\ell_1 n_2 - \ell_2 n_1) + m_1 (\ell_1 m_2 - \ell_2 m_1)\right]$$

$$m_N = -\left[n_1 (m_1 n_2 - m_2 n_1) + \ell_1 (\ell_1 m_2 - \ell_2 m_1)\right]$$

$$n_N = \left[m_1 (m_1 n_2 - m_2 n_1) + \ell_1 (\ell_1 n_2 - \ell_2 n_1)\right]$$

and

$$\ell_2 = \frac{X_2 - X_1}{L_{12}}, \qquad m_2 = \frac{Y_2 - Y_1}{L_{12}}, \qquad n_2 = \frac{Z_2 - Z_1}{L_{12}}$$

$$L_{12} = \left[(X_2 - X_1)^2 + (Y_2 - Y_1)^2 + (Z_2 - Z_1)^2 \right]^{1/2}$$

The final end point derivatives are then found from

$$\frac{\partial X_i}{\partial w} = T_i \frac{\partial S}{\partial w}$$

where

$\frac{\partial s}{\partial w}$ = the boundary length since $\Delta w = 1$ on the unit square patch

$$\Delta S = \sum_{I=2}^{I=NB-1} \left[(X_{I+1} - X_I)^2 + (Y_{I+1} - Y_I)^2 + (Z_{I+1} - Z_I)^2 \right]^{1/2}$$

I = 2 at the starting corner point

I = NB - 1 at the final point on the boundary curve

NB = number of points input on the boundary with one point extending off each end of the boundary curve.

Once the boundary curves are found the values required for the general surface equation can be calculated. This equation is given below.

$$\begin{aligned} X_i(u, w) = {} & X_i(0, w)F_o(u) + X_i(1, w)F_i(u) + X_i(u, 0)F_o(w) \\ & + X_i(u, 1)F_1(w) - X_i(0, 0)F_o(u)F_o(w) \\ & - X_i(0, 1)F_o(u)F_1(w) - X_i(1, 0)F_1(u)F_o(w) \\ & - X_i(1, 1)F_1(u)F_1(w) \end{aligned}$$

where the terms F_o and F_1 are blending functions given by

$$F_1(u) = 3u^2 - 2u^3 \qquad F_1(u) = 3w^2 - 2w^3$$

$$F_o(u) = 1 - F_1(u) \qquad F_o(w) = 1 - F_1(w)$$

The program does not use the parametric cubic geometry data directly in the pressure calculations. Instead, the parametric cubic data are used in creating surface elements by a systematic variation of the parametric variables w, and u.

One advantage of the mathematical surface-fit technique over the plane-distributed-element method is the smaller number of surface points required to describe a shape. However, additional points are required on the boundaries to determine the required corner derivatives. This method is not as adaptable to semiautomatic data-reading techniques, since the organization of the required input data is more complex. The accuracy of this method depends upon the distribution and orientation of the surface sections, just as the plane-distributed-element method depends upon the distribution of the elements.

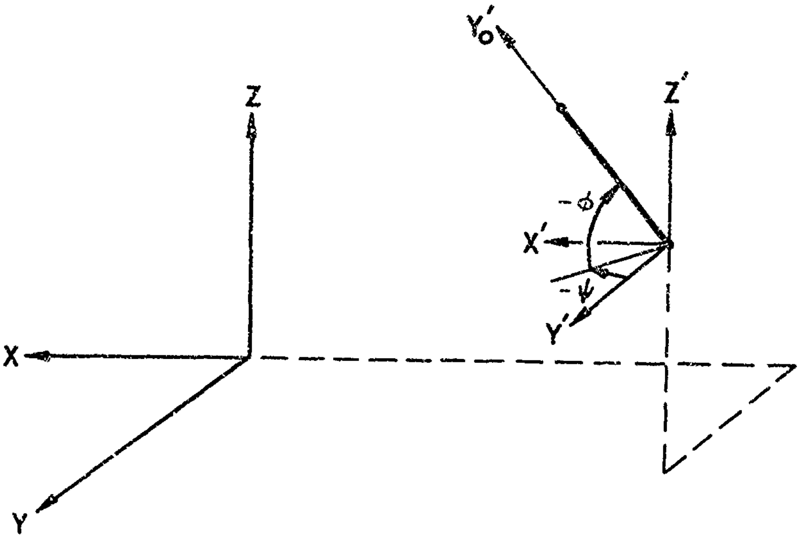
Auxiliary Geometry Methods

The program has two other geometry generation options. These are (1) the ellipse surface generation, and (2) the slab delta geometry generation. In each of these methods the program calculates the necessary Y-Z coordinate data at specified X stations. In the ellipse generation simple ellipse equations are used; in the slab delta geometry generation, similar equations are used along with the necessary equations for the bottom and top parts inboard of the nose and leading edge.

Control Surface Geometry

The geometry data for a control surface flap are input to the program in the undeflected position. The methods used in transforming these data to the required deflected position are outlined in the following discussion.

The coordinate system used in these derivations is shown in the drawing below.



The general procedure involves a coordinate shift and an appropriate rotation to a hinge-line centered coordinate system such that the new Y-axis (Y'_0) lies along the hinge line. For ψ and ϕ equal to zero and with the flap surface normal in the negative z-direction, the hinge-line centered coordinate system has the same directions as the body-axis system. The corner points, centroid, and normal vector (direction cosines) for each element of the flap are transformed into this system. Since the flap is a rigid body this information is independent of flap deflection and the hinge moment factor (moment per unit normal force) need only be determined once. However, the force magnitude is a function of the deflection angle and requires having the geometry of the deflected flap in the vehicle-centered coordinates.

The coordinate system shift is given by

$$X' = X - X_{HL_4}$$

$$Y' = Y - Y_{HL_4}$$

$$Z' = Z - Z_{HL_4}$$

Where

$(\ )_{HL_4}$ is to point 4 on the hinge line

The new coordinates of the flap in the shifted and transformed coordinate system are given by

$$\begin{bmatrix} X'_0 \\ Y'_0 \\ Z'_0 \end{bmatrix} = \begin{bmatrix} E \end{bmatrix} \begin{bmatrix} X' \\ Y' \\ Z' \end{bmatrix}$$

Where

$$\begin{bmatrix} E \end{bmatrix} = \begin{bmatrix} \Phi \end{bmatrix} \begin{bmatrix} \Psi \end{bmatrix}$$

$$\begin{bmatrix} \Psi \end{bmatrix} = \begin{bmatrix} \cos\psi & \sin\psi & 0 \\ -\sin\psi & \cos\psi & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

ψ = rotation about the Z'-axis

$$\begin{bmatrix} \Phi \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos\phi & \sin\phi \\ 0 & -\sin\phi & \cos\phi \end{bmatrix}$$

ϕ = rotation about the X'_o-axis

The final rotation to the deflected position (δ_e is the control surface deflection) is given by

$$\begin{bmatrix} X'_{0\delta_e} \\ Y'_{0\delta_e} \\ Z'_{0\delta_e} \end{bmatrix} = \begin{bmatrix} \delta_e \end{bmatrix} \begin{bmatrix} X'_0 \\ Y'_0 \\ Z'_0 \end{bmatrix} = \begin{bmatrix} \delta_e \end{bmatrix} \begin{bmatrix} E \end{bmatrix} \begin{bmatrix} X' \\ Y' \\ Z \end{bmatrix}$$

where

$$\begin{bmatrix} \delta_e \end{bmatrix} = \begin{bmatrix} \cos \delta_e & 0 & -\sin \delta_e \\ 0 & 1 & 0 \\ \sin \delta_e & 0 & \cos \delta_e \end{bmatrix}$$

The coordinates of the deflected flap are then transformed back to vehicle centered coordinate system, first through the inverse rotation

$$\begin{bmatrix} X'_{\delta_e} \\ Y'_{\delta_e} \\ Z'_{\delta_e} \end{bmatrix} = \begin{bmatrix} E \end{bmatrix}^{-1} \begin{bmatrix} X'_{0\delta_e} \\ Y'_{0\delta_e} \\ Z'_{0\delta_e} \end{bmatrix}$$

and then by the coordinate shift

$$X_{\delta_e} = X'_{\delta_e} + X_{HL_4}$$

$$Y_{\delta_e} = Y'_{\delta_e} + Y_{HL_4}$$

$$Z_{\delta_e} = Z'_{\delta_e} + Z_{HL_4}$$

The rotation angles are defined for a right-handed system and are found from the relationships

$$\psi = \sin^{-1}\left(\frac{X_{HL_1} - X_{HL_4}}{L_{XY}}\right) \text{ and } \phi = -\sin^{-1}\left(\frac{Z_{HL_1} - Z_{HL_4}}{L_{YZ}}\right)$$

where

$$L_{XY} = \left[(X_{HL_1} - X_{HL_4})^2 + (Y_{HL_4})^2\right]^{1/2}$$

and

$$L_{YZ} = \left[L_{XY}^2 + (Z_{HL_1} - Z_{HL_4})^2\right]^{1/2}$$

A check is made in the program and if $Y_{HL_1} < Y_{HL_4}$ then the yaw rotation angle is set to $\psi = \pi - \psi$ to position the hinge line in the proper quadrant.

The third rotation angle δ_e is, of course, specified for a given problem. It should be noted in the present approach, that the coordinate system is rotated through the angle δ_e, positive in the right-handed sense for the system defined. Relative to the physical problem, positive δ_e corresponds to a flap deflection into the flow.

The hinge moment factor (HMFCT) is simply a function of the element geometry and location, and is defined as follows. The total moment of an element is (considering only inviscid forces)

$$\bar{M}'_0 = -(\bar{R}'_0 \times \bar{F}) = P\,(\bar{R}'_0 \times \bar{N}'_0)\,\mathrm{AREA}$$

where

$\bar{R}'_0$ is the radius vector to the element centroid,

P is the net surface pressure,

and AREA is the element area.

The hinge line moment is just the $\bar{Y}'_0$-component of the total moment;

$$M_{HL} = M_{Y'_0} = \bar{j}'_0 \bullet \bar{M}'_0 = P\,(\mathrm{HMFCT})$$

where

$$\mathrm{HMFCT} = (Z'_0\, N_{X'_0} - X'_0\, N_{Z'_0})\,\mathrm{AREA}$$

Once the deflected flap is properly oriented in the vehicle centered coordinates, the force on each element and hinge moment are determined.

Graphics -- Picture Drawing Program

The perspective drawing computer program is an important component of the Arbitrary-Body Hypersonic Force Analysis System. Its use in this system is in providing graphical perspective drawings of the geometric description input to the arbitrary body force program.* The purpose of these drawings is to allow the engineer to detect errors in the geometric input data to the arbitrary body force program.

As explained previously, the body shape is defined by input sets of points in three-dimensional space. A grouping of four surface points is used to describe a surface element. An organization of a large number of related elements forms a body section and a number of sections may be used to give a complete description of the shape. The equations required to produce the perspective pictures are derived in the following paragraphs.

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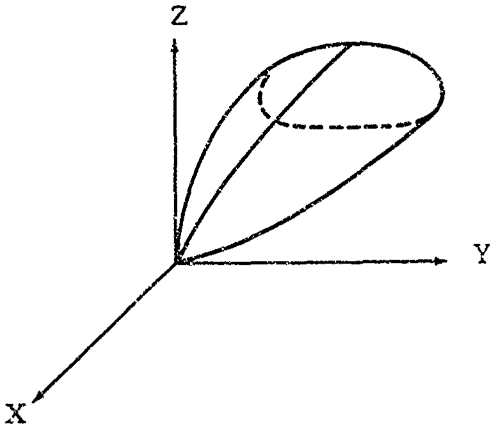
*The drawings made by this program are not true perspective drawings but are a limiting case where the vanishing points have been moved to infinity.

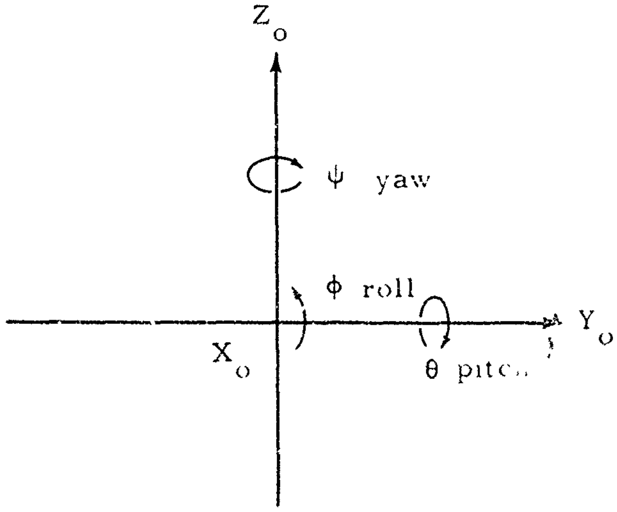
Each point on the surface is described by its coordinates in the body reference coordinate system.

$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix}$$

The body reference coordinate system is assumed to be a conventional right-handed Cartesian system as illustrated below.



To create the perspective drawings illustrated in this report each surface point on the body must be rotated to the desired viewing angle and then transformed into a coordinate system in the plane of the paper. With zero rotation angles the body coordinate system is coincident with the fixed system in the plane of the paper.



The rotations of the body and its coordinate system to give a desired viewing angle are specified by a yaw-pitch-roll sequence (ψ, θ, ϕ). This rotation is given by the following relationship:

$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix} = \begin{bmatrix}\phi\end{bmatrix}\begin{bmatrix}\theta\end{bmatrix}\begin{bmatrix}\psi\end{bmatrix} \begin{bmatrix} X_o \\ Y_o \\ Z_o \end{bmatrix}$$

Where the rotation matrices are

$$\begin{bmatrix}\psi\end{bmatrix} = \begin{bmatrix} \cos\psi & \sin\psi & o \\ -\sin\psi & \cos\psi & o \\ o & o & 1 \end{bmatrix}$$

$$\begin{bmatrix}\theta\end{bmatrix} = \begin{bmatrix} \cos\theta & o & -\sin\theta \\ o & 1 & o \\ \sin\theta & o & \cos\theta \end{bmatrix}$$

$$\begin{bmatrix}\phi\end{bmatrix} = \begin{bmatrix} 1 & o & o \\ o & \cos\phi & \sin\phi \\ o & -\sin\phi & \cos\phi \end{bmatrix}$$

or

$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix} = \begin{bmatrix}E\end{bmatrix} \begin{bmatrix} X_o \\ Y_o \\ Z_o \end{bmatrix}$$

where $\begin{bmatrix}E\end{bmatrix} = \begin{bmatrix}\phi\end{bmatrix}\begin{bmatrix}\theta\end{bmatrix}\begin{bmatrix}\psi\end{bmatrix}$

Since each point on the surface is given by its coordinates in the X, Y, Z system, its position in the fixed coordinate system (X_o, Y_o, Z_o) may be found by reversing the above process.

$$\begin{bmatrix} X_o \\ Y_o \\ Z_o \end{bmatrix} = \begin{bmatrix}E\end{bmatrix}^{-1} \begin{bmatrix} X \\ Y \\ Z \end{bmatrix}$$

If we carry out this operation we obtain

$$\begin{bmatrix} X_o \\ Y_o \\ Z_o \end{bmatrix} = \begin{bmatrix} \cos\theta\cos\psi & -\sin\psi\ \cos\phi+\sin\theta\cos\psi\ \sin\phi & \sin\psi\ \sin\phi+\sin\theta\cos\psi\ \cos\phi \\ \cos\theta\sin\psi & \cos\psi\ \cos\phi+\sin\theta\sin\psi\ \sin\phi & -\cos\psi\ \sin\phi+\sin\theta\sin\psi\ \cos\phi \\ -\sin\theta & \cos\theta\sin\phi & \cos\theta\cos\phi \end{bmatrix} \begin{bmatrix} X \\ Y \\ Z \end{bmatrix}$$

$$X_o = X(\cos\theta\cos\psi) + Y(-\sin\psi\cos\phi+\sin\theta\cos\psi\sin\phi) + Z(\sin\psi\sin\phi+\sin\theta\cos\psi\cos\phi)$$

$$Y_o = X(\cos\theta\sin\psi) + Y(\cos\psi\cos\phi+\sin\theta\sin\psi\sin\phi) + Z(-\cos\psi\sin\phi+\sin\theta\sin\psi\cos\phi)$$

$$Z_o = X(-\sin\theta) + Y(\cos\theta\sin\phi) + Z(\cos\theta\cos\phi)$$

We may now use these last two equations to transform a given point on the body (X, Y, Z) with a specified set of rotation angles (ψ, ϕ, θ) into the plane of the paper (the Y_o, Z_o system). With the SC-4020 library subroutines it now becomes a simple matter to plot these data and to connect the related points with straight lines.

In the surface fit technique used in this program and described in Reference 22, each input element is replaced by a plane quadrilateral surface element whose characteristics are used for all subsequent calculations. These characteristics include the area, centroid, and the direction cosines of the surface unit normal. The surface unit normals may be transformed through the required rotation angles just as was done for the individual points. The resulting value of the component of the unit normal in the X_o direction (out of the plane of the paper) may be found from the following equation.

$$n_{x_o} = n_x(\cos\theta\cos\psi)+n_y(-\sin\psi\cos\phi+\sin\theta\cos\psi\sin\phi)+n_z(\sin\psi\sin\phi+\sin\theta\cos\psi\cos\phi)$$

where n_x, n_y, n_z are the components of the surface unit normal in the vehicle reference system.

If n_{x_o} is positive then the surface element is facing the viewer. If n_{x_o} is negative the element faces away from the plane of the paper. This result is used in the program to provide the capability of deleting most of those elements on a vehicle that normally could not be seen by a viewer. The resulting picture is thus made more realistic and confusing elements which are on the back side of the vehicle do not appear. No criterion is provided, however, for the deletion of those elements that face the viewer but are blocked by other body components. This may be accomplished by a proper selection of viewing angle or by a physical deletion of the offending section from the input data.

COMPUTATION OF VEHICLE FORCES

Calculation of Local Flow Conditions

In the preceding derivations we have converted the input element into a plane quadrilateral element. The quadrilateral is described by its area, the coordinates of the centroid of the element, and by the direction cosines of the surface unit normal. In the force calculation methods we must also know the angle that the element makes with the free-stream velocity vector (the impact angle). This angle changes as the vehicle attitude (angle of attack and yaw angle) changes. The impact angle may be found from the following relationship:

$$\delta = \pi/2 - \theta$$

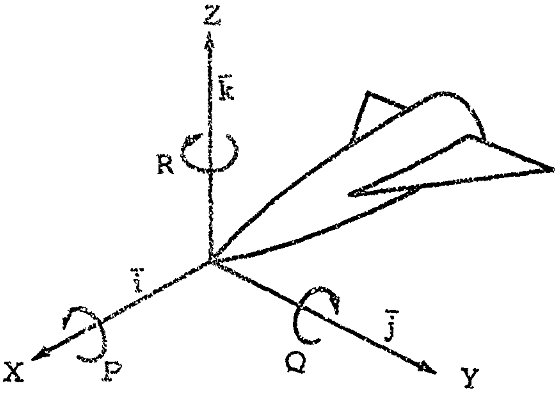
$$\cos\theta = \frac{\bar{n} \cdot \bar{V}}{|\bar{n}|\,|\bar{V}|}$$

where

$\bar{n}$ is the unit normal outward from the surface with direction cosines n_x , n_y, n_z

$\bar{V}$ is the local velocity vector with direction cosines in the vehicle coordinate system given by V_x , V_y , V_z

The direction cosines of the unit surface normal are given by the quadrilateral calculations. The value of the local velocity vector V depends upon the vehicle attitude with respect to the free-stream direction and its angular rotation rates, and is derived in the discussion below. The rotation directions are consistent with the conventional stability body-axis system. The coordinate system, however, is changed to be consistent with the geometric description system discussed previously.



where

P = rolling velocity
Q = pitching velocity
R = yawing velocity
Ω = total angular velocity

The movement of a given element of the vehicle with respect to the free-stream depends upon the vehicle rotation rate and the position of the element relative to the rotation center. The radius vector from an arbitrary reference point on the vehicle to a point on the surface is given by

$$\bar{r} = (x - x_o)\,\bar{i} + (y - y_o)\,\bar{j} + (z - z_o)\,\bar{k}$$

where x_o, y_o, z_o is the moment reference point (center of gravity).

The total angular velocity is given by

$$\bar{\Omega} = P\,\bar{i} - Q\,\bar{j} - R\,\bar{k}$$

The free-stream velocity vector is given by

$$\bar{V}_\infty = V_{\infty_x}\,\bar{i} + V_{\infty_y}\,\bar{j} + V_{\infty_z}\,\bar{k}$$

The free-stream velocity components are given by the following relationships for a conventional yaw-pitch sequence.

$$V_{\infty_x} = -V_\infty \cos\alpha \cos\beta$$

$$V_{\infty_y} = V_\infty \sin\beta$$

$$V_{\infty_z} = V_\infty \cos\beta \sin\alpha$$

where

α = angle of attack
β = sideslip angle

The total velocity vector relative to the surface element is obtained by combining the above relationships as follows:

$$\bar{V} = \bar{V}_\infty - \bar{\Omega} \times \bar{r}$$

The local velocity vector therefore becomes

$$\begin{aligned} \bar{V} &= \left\{ V_{\infty_x} + \left[Q\,(z-z_o) - R\,(y-y_o) \right] \right\} \bar{i} \\ &+ \left\{ V_{\infty_y} + \left[R\,(x-x_o) + P\,(z-z_o) \right] \right\} \bar{j} \\ &+ \left\{ V_{\infty_z} - \left[P\,(y-y_o) + Q\,(x-x_o) \right] \right\} \bar{k} \end{aligned}$$

or $\bar{V} = V_x\,\bar{i} + V_y\,\bar{j} + V_z\,\bar{k}$

where

$$V_x = V_{\infty_x} + \left[Q\,(z-z_o) - R\,(y-y_o) \right]$$

$$V_y = V_{\infty_y} + \left[R\,(x-x_o) + P\,(z-z_o) \right]$$

$$V_z = V_{\infty_z} - \left[P\,(y-y_o) + Q\,(x-x_o) \right]$$

The total local velocity is given by

$$V_{local} = \sqrt{{V_x}^2 + {V_y}^2 + {V_z}^2}$$

The conventional surface impact angle is then given by

$$\delta = \pi/2 - \cos^{-1}\left(\frac{-n_x V_x - n_y V_y - n_z V_z}{V_{local}}\right)$$

where

n_x, n_y, n_z are the outward surface unit normal direction cosines

Vehicle Coefficients and Derivatives

In the program force calculations the pressure on each element is calculated completely independent of all other elements (except the shock-expansion method). If the vehicle is rotating the local pressure coefficient must be corrected back to free stream conditions. This is accomplished by the following relationship.

$$C_p = C_{p_{local}} \left(\frac{V_{local}}{V_\infty}\right)^2$$

In the arbitrary body force calculation program the pressure coefficient on each element is calculated completely independent of all other elements. The contributions of all the elements are then summed to give the total force components. The basic relationships to accomplish this are given below:

axial force $C_A = \frac{1}{S_{ref}} \sum C_p \, n_x \Delta A$

side force $C_Y = \frac{1}{S_{ref}} \sum C_p \, n_y \Delta A$

normal force $C_N = -\frac{1}{S_{ref}} \sum C_p \, n_z \Delta A$

where

ΔA = element area

Note: The minus sign is needed because of the sign convention on Z in the body coordinate system, directed upward.

The moment coefficients are obtained by a summation of the component forces multiplied by the distance from the element centroid to the reference moment center.

rolling moment $C_\ell = \sum(C_Y \frac{z}{b}) + \sum(C_N \frac{y}{b})$

pitching moment $C_m = \sum(C_N \frac{x}{\bar{c}}) + \sum(C_A \frac{z}{\bar{c}})$

yawing moment $C_n = \sum(C_Y \frac{x}{b}) - \sum(C_A \frac{y}{b})$

where

b = reference span (lateral and directional moment coefficient reference length)

$\bar{c}$ = mean aerodynamic chord (for longitudinal moment reference)

x, y, z = distances from the center of gravity

= $x_{centroid} - x_{cg}$, etc.

The conversion of the axial force and normal force coefficients to lift and drag coefficients requires the following rotation matrices.

$$\begin{bmatrix} C_D \\ C_Y' \\ C_L \end{bmatrix} = \left[E\right]^{-1} \begin{bmatrix} C_A \\ C_Y \\ C_N \end{bmatrix}$$

where

$$\left[E\right]^{-1} = \begin{bmatrix} \cos\alpha \cos\beta & -\sin\beta & \sin\alpha \cos\beta \\ \cos\alpha \sin\beta & \cos\beta & \sin\alpha \sin\beta \\ -\sin\alpha & 0 & \cos\alpha \end{bmatrix}$$

α = angle of attack (+ nose up)
β = sideslip angle (+ nose left)

$$C_D = C_A \cos\alpha \cos\beta - C_Y \sin\beta + C_N \sin\alpha \cos\beta$$

$$C_Y' = C_A \cos\alpha \sin\beta + C_Y \cos\beta + C_N \sin\alpha \sin\beta$$

$$C_L = -C_A \sin\alpha + C_N \cos\alpha$$

The vehicle static stability derivatives in angle of attack and sideslip are calculated by the method of small perturbations as indicated below:

$$C_{A_\alpha} = \frac{\left(C_A\right)_{\alpha + \Delta\alpha} - \left(C_A\right)_\alpha}{\Delta\alpha}$$

$$C_{N_\alpha} = \frac{\left(C_N\right)_{\alpha + \Delta\alpha} - \left(C_N\right)_\alpha}{\Delta\alpha}$$

$$C_{m_\alpha} = \frac{\left(C_m\right)_{\alpha + \Delta\alpha} - \left(C_m\right)_\alpha}{\Delta\alpha}$$

$$C_{Y_\beta} = \frac{\left(C_Y\right)_{\beta + \Delta\beta} - \left(C_Y\right)_\beta}{\Delta\beta}$$

$$C_{n_\beta} = \frac{\left(C_n\right)_{\beta + \Delta\beta} - \left(C_n\right)_\beta}{\Delta\beta}$$

The damping derivatives due to vehicle rotation rate are given in a similar manner

$$C_{m_q} = \left[\frac{\left(C_m\right)_{q+\Delta q} - \left(C_m\right)_q}{\Delta q}\right] \Big/ \frac{\bar{c}}{2V}$$

etc.

The control surface derivatives are also calculated by the method of small perturbations.

$$C_{L_\delta} = \frac{\left(C_L\right)_{\delta + \Delta\delta} - \left(C_L\right)_\delta}{\Delta\delta}$$

$$C_{m_\delta} = \frac{\left(C_m\right)_{\delta + \Delta\delta} - \left(C_m\right)_\delta}{\Delta\delta}$$

$$C_{\ell_\delta} = \frac{\left(C_\ell\right)_{\delta + \Delta\delta} - \left(C_\ell\right)_\delta}{\Delta\delta}$$

$$C_{Y_\delta} = \frac{\left(C_Y\right)_{\delta + \Delta\delta} - \left(C_Y\right)_\delta}{\Delta\delta}$$

$$C_{n_\delta} = \frac{\left(C_n\right)_{\delta + \Delta\delta} - \left(C_n\right)_\delta}{\Delta\delta}$$

$$C_{N_\delta} = \frac{\left(C_N\right)_{\delta + \Delta\delta} - \left(C_N\right)_\delta}{\Delta\delta}$$

Inviscid Force Calculation Methods

Many of the pressure calculation methods used in the analysis of high-speed shapes are listed in Figure 2 . An attempt has been made in the preparation of this figure to indicate the interrelationships of the methods (the information can, of course, be organized in many different ways). Some of these methods are more applicable to the arbitrary-body problem than others.

The method of characteristics is the eventual ideal approach for the calculation of forces on three-dimensional shapes at high speeds. It will require starting solutions for three-dimensional blunt bodies of arbitrary shape. The development of a method of calculating three-dimensional boundary layers would permit the use of an iterative process to account for the viscous-inviscid interaction. Although this approach has been used for some very simple shapes, the complete solution for arbitrary shapes is some time away. Significant progress is being made in the solution of the inviscid flow field by the method of characteristics. However, present mathematical techniques and digital-computer size and speed capability prevent application to typical preliminary-design problems. Application must be reserved for simple shapes or important detail design applications where very large computer times might be acceptable.

Many of the other methods shown in Figure 2 would be useful force-calculation methods for inclusion in an arbitrary-body system. The selection of the proper method in a given application depends upon the vehicle-component shape and flight condition and must be selected by the engineer on the basis of his knowledge and experience in the use of each method.

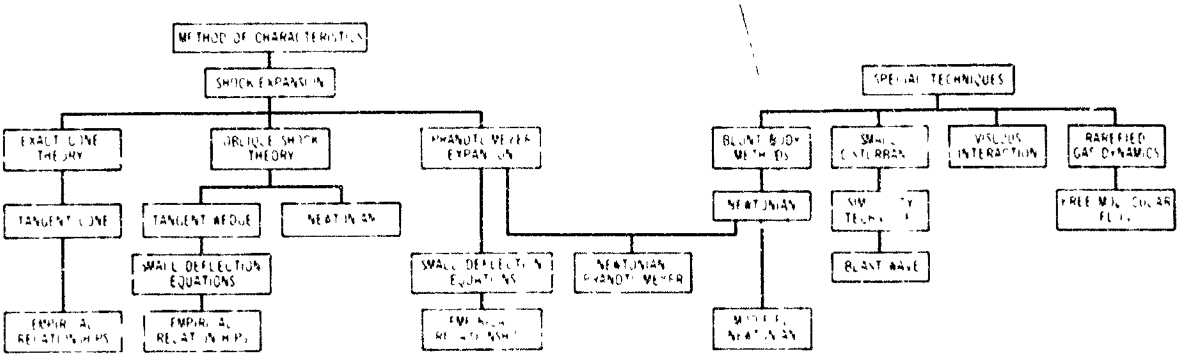


Figure 2. Pressure Calculation Methods

The arbitrary body force computer program contains a number of optional methods for calculating the pressure coefficient. In each method the only geometric parameter required is the element impact angle, δ, or the change in the angle of an element from a previous point.

Before the program calculates the pressure on each surface element, it checks to see if the element is facing the flow (in an impact region) or facing away from the flow (in a shadow region). The methods to be used in calculating the pressure in impact and shadow regions may be specified independently. A summary of the program pressure options is presented below.

PRESSURE CALCULATION METHODS – MARK III MOD 0 PROGRAM

Impact Flow

1. Modified Newtonian
2. Modified Newtonian+Prandtl-Meyer
3. Tangent wedge
4. Tangent-wedge empirical
5. Tangent-cone empirical
6. OSU blunt body empirical
7. Van Dyke Unified
8. Blunt-body shear force
9. Shock-expansion
10. Free molecular flow
11. Input pressure coefficient
12. Hankey flat-surface empirical
13. Delta wing empirical
14. Dahlem-Buck empirical
15. Blast wave
16. Modified tangent-cone
17. Boundary layer induced pressures

Shadow Flow

1. Newtonian ($C_p = 0$)
2. Modified Newtonian+Prandtl-Meyer
3. Prandtl-Meyer from free-stream
4. OSU blunt body empirical
5. Van Dyke Unified
6. High Mach base pressure
7. Shock-expansion
8. Input pressure coefficient
9. Free molecular flow
10. Boundary-layer induced pressures

Since most of these methods are adequately discussed in the literature they will be reviewed only briefly in this document. The blunt-body shear force and the boundary-layer induced pressure methods are discussed in detail in the section describing Viscous Force Methods.

Modified Newtonian

This method is probably the most widely used of all the hypersonic force analysis techniques. The major reason for this is its simplicity. Like all the force calculation methods, however, its validity in any particular application depends upon the flight condition and the shape of the vehicle or component being considered. Its most general application is for blunt shapes at high hypersonic speed. The usual form of the modified Newtonian pressure coefficient is

$$C_p = K \sin^2 \delta$$

In true Newtonian flow ($M = \infty$, $\gamma = 1$) the parameter K is taken as 2. In the various forms of modified Newtonian theory, K is given values other than 2 depending on the type of modified Newtonian theory used. K is frequently taken as being equal to the stagnation pressure coefficient. In other forms it is determined by the following relationship (Reference 23).

$$K = \frac{C_{p_{nose}}}{\sin^2 \delta_{nose}}$$

where

$C_{p_{nose}}$ = the exact value of the pressure coefficient at the nose or leading edge

δ_{nose} = impact angle at the nose or leading edge

In other work K is determined purely on an empirical basis.

$$K = \text{fn}\,(M,\ \alpha,\ \text{shape})$$

When modified Newtonian theory is used, the pressure coefficient in shadow regions (δ is negative) is usually set equal to zero.

Modified Newtonian Plus Prandtl-Meyer

This method, described as the blunt body Newtonian + Prandtl-Meyer technique, is based on the analysis presented by Kaufman in Reference 24. The flow model used in this method assumes a blunt body with a detached shock, followed by an expansion around the body to supersonic conditions. This method uses a combination of modified Newtonian and Prandtl-Meyer expansion theory. Modified Newtonian theory is used along the body until a point is reached where both the pressure and the pressure gradients match those that would be calculated by a continuing Prandtl-Meyer expansion.

The calculation procedure derived for determining the pressure coefficient using the blunt body Newtonian + Prandtl-Meyer technique is outlined below.

1. Calculate free-stream static to stagnation pressure ratio

$$P = \frac{p_\infty}{p_o} = \left[\frac{2}{(\gamma + 1)\, M_\infty^2}\right]^{\frac{\gamma}{\gamma - 1}} \left[\frac{2\gamma M_\infty^2 - (\gamma - 1)}{\gamma + 1}\right]^{\frac{1}{\gamma - 1}}$$

2. Assume a starting value of the matching Mach number, M_q (for $\gamma = 1.4$ assume $M_q = 1.35$)

3. Calculate matching point to free-stream static pressure ratio

$$Q = \frac{p_q}{p_o} = \left[\frac{2}{2 + (\gamma - 1) M_q^2}\right]^{\frac{\gamma}{\gamma - 1}}$$

4. Calculate new free-stream static to stagnation pressure ratio

$$P_c = Q\left[1 - \frac{\gamma^2 M_q^4 Q}{4(M_q^2 - 1)(1 - Q)}\right]$$

5. Assume a new matching point Mach number (1.75) and repeat the above steps to obtain a second set of data.

6. With the above two tries use a linear interpolation equation to estimate a new matching point Mach number. This process is repeated until the solution converges.

7. Calculate the surface slope at the matching point

$$\sin^2 \delta_q = \frac{Q - P}{1 - P}$$

8. Use the Prandtl-Meyer expansion equations to find the Mach number on the surface element, M_δ.

9. Calculate the surface pressure ratio

$$\frac{p_\delta}{p_o} = \eta_c \left[1 + \frac{\gamma - 1}{2} M_\delta^2\right]^{-\frac{\gamma}{\gamma - 1}}$$

where

η_c is provided as an empirical correction factor

p_δ is the pressure on the element of interest

10. Calculate the surface to free-stream pressure ratio

$$\frac{p_\delta}{p_\infty} = \left(\frac{1}{P}\right)\left(\frac{p_\delta}{p_o}\right)$$

11. Calculate the surface pressure coefficient

$$C_{P_\delta} = \frac{2}{\gamma M_\infty^2}\left(\frac{P_\delta}{P_\infty} - 1\right)$$

The results of typical calculations using the above procedure are shown in Figure 3. Note that the calculations give a positive pressure coefficient at a zero impact angle. As pointed out in several references these results correlate well with test data for blunt shapes. However, if the surface curvature changes gradually to zero slope some distance from the blunt stagnation point the pressure calculated by this method will be too high. This is caused by characteristics near the nose intersecting the curved shock system and being reflected back onto the body. If the zero slope is reached near the nose (such as in a hemisphere or a cylinder) this effect has not had time to occur.

Tangent-Wedge

The tangent-wedge and tangent-cone theories are frequently used to calculate the pressures on two-dimensional bodies and bodies of revolution, respectively. These methods are really empirical in nature since they have no firm theoretical basis. They are suggested, however, by the results of more exact theories that show that the pressure on a surface in impact flow is primarily a function of the local impact angle. In this program the tangent-wedge pressures are calculated using the oblique shock relationships of NACA TR-1135 (Reference 25). The basic equation used is the cubic given by

$$\left(\sin^2 \theta_s\right)^3 + b\left(\sin^2 \theta_s\right)^2 + c\left(\sin^2 \theta_s\right) + d = 0 \qquad \text{or}$$

$$R^3 + b\,R^2 + c\,R + d = 0$$

where

θ_s = shock angle

δ = wedge angle

$$b = -\frac{M^2 + 2}{M^2} - \gamma \sin^2 \delta$$

$$c = \frac{2\,M^2 + 1}{M^4} + \left[\frac{(\gamma + 1)^2}{4} + \frac{\gamma - 1}{M^2}\right] \sin^2 \delta$$

$$d = -\frac{\cos^2 \delta}{M^4}$$

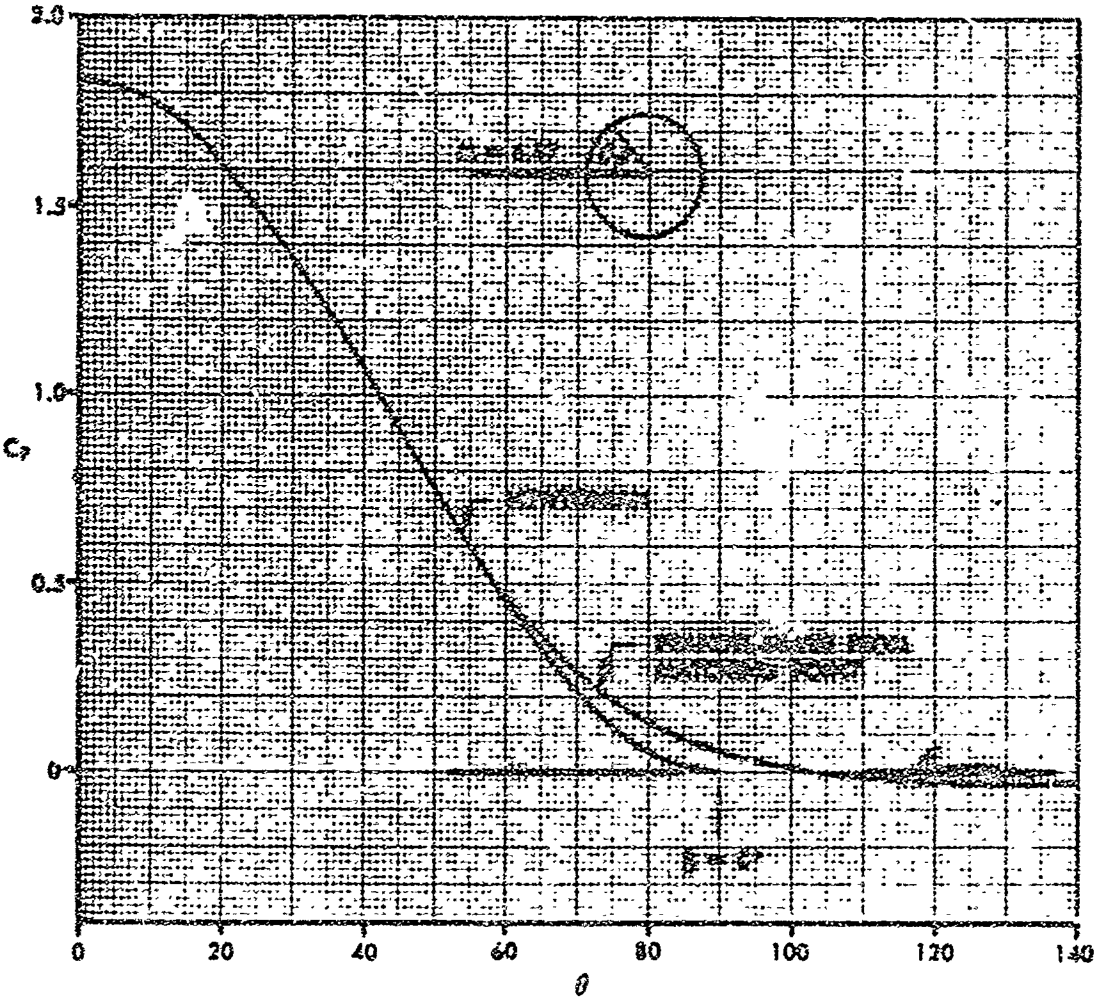


Figure 3. Blunt Body Newtonian + Prandtl-Meyer Pressure Results

The roots of the above cubic equation may be obtained by using the trigonometric solution procedure (see Reference 26) as indicated below.

$$y_1 = 2\sqrt{-p/3}\cos(\omega/3) - b/3$$

$$y_2 = -2\sqrt{-p/3}\cos(\omega/3 + 60°) - b/3$$

$$y_3 = -2\sqrt{-p/3}\cos(\omega/3 - 60°) - b/3$$

$$R_1 = y_1 - b/3$$

$$R_2 = y_2 - b/3$$

$$R_3 = y_3 - b/3$$

where

y_i = roots of the reduced cubic equation

$p = -\frac{b^2}{3} + c$

$q = 2(b/3)^3 - \frac{bc}{3} + d$

$\cos\omega = -\frac{q}{2\sqrt{-(p/3)^3}}$

$R_i = \sin^2\theta_s$ = roots of the cubic equation

The smallest of the three roots corresponds to a decrease in entropy and is disregarded. The largest root is also disregarded since it never appears in physical actuality.

For small deflections, the cubic solution becomes very sensitive to numerical accuracy; that is, to the number of significant digits carried. Since this is dependent on the particular machine employed, an alternate procedure is used.

When the flow deflection angle is equal to or less than 2.0 degrees, the following equation is used instead of the above cubic relationships (Reference 27):

$$\sin^2 \theta_s = \frac{1}{M^2} + \frac{\gamma + 1}{2} \frac{\delta}{\sqrt{M^2 - 1}}$$

Once the shock angle is obtained the remaining flow properties may be found from the relationships of Reference 25.

$$\text{density} = \rho_2 = \rho \left[\frac{6 M^2 \sin^2 \theta_s}{M^2 \sin^2 \theta_s + 5} \right]$$

$$\text{temperature} = T_2 = T \left[\frac{7(M^2 \sin^2 \theta_s - 1)(M^2 \sin^2 \theta_s + 5)}{36 M^2 \sin^2 \theta_s} \right]$$

$$\begin{array}{c}\text{pressure}\\ \text{coefficient}\end{array} = C_p = \frac{\left[\frac{7M^2 \sin^2 \theta_s - 1}{6} \right]}{0.7 M^2}$$

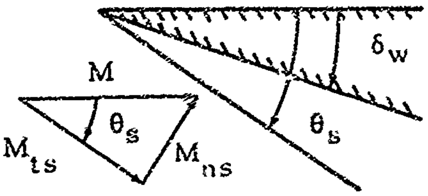
where

$(\ )_2$ = conditions behind the shock

Oblique shock detachment conditions are reached when no solution may be found to the above cubic relationships. Under these conditions the program uses the Newtonian + Prandtl-Meyer method for continued calculations.

Tangent-Wedge, Tangent-Cone, and Delta Wing Newtonian Empirical Method

The tangent-cone and the tangent-wedge Newtonian empirical methods used in this program are based on the empirical relationships derived below.



For wedge flow

$$\sin\theta_s = \frac{\sin\delta_w}{(1-\epsilon)\cos(\theta_s-\delta_w)}$$

where

$$\epsilon = \frac{\rho}{\rho_2} = \frac{\gamma-1}{\gamma+1}\left[1+\frac{2}{(\gamma-1)M_{ns}^2}\right]$$

For cone flow (thin shock layer assumption)

$$\sin\theta_s \cong \frac{\sin\delta_c}{\left(1-\frac{\epsilon}{2}\right)\cos(\theta_s-\delta_c)}$$

In the limit as $M\to\infty$, $\epsilon = \epsilon_{\lim} = \frac{\gamma-1}{\gamma+1}$ and $\cos(\theta_s-\delta) = 1$

Therefore

wedge cone

$$\sin\theta_s = \frac{\gamma+1}{2}\sin {}_w \qquad \sin\theta_s = \frac{2(\gamma+1)}{\gamma+3}\sin\delta_c$$

These limiting expressions for θ may now be compared with the data of TR-1135 (Reference 25) at $\gamma = 7/5$ using the following similarity parameters. The exact equations contain three variables — θ_s, δ, and ϵ. Noting that for γ = constant, $\epsilon = fn(M_{ns})$ only, the preceding equations may be rewritten in the following form:

wedge cone

$$M_{ns} = \frac{M \sin \delta_w}{(1 - \epsilon) \cos (\theta_s - \delta_w)} \qquad M_{ns} = \frac{M \sin \delta_c}{(1 - \frac{\epsilon}{2}) \cos (\theta_s - \delta_c)}$$

The parameter $(\theta - \delta)$ is approximately constant and independent of M except near the shock detachment condition. The equations essentially contain only two variables, M_{ns} and $M \sin \delta$. These are used as coordinates to plot the data for wedge flow shown in Figure 4. A similar plot could be obtained for cone flow. From the figure it is seen that the data are nearly normalized with the use of these coordinates.

For rapid calculations we need relationships for M_{ns} as a function of $M \sin \delta$ that satisfy the following requirements:

1. The effect of shock detachment is neglected
2. At $M \sin \delta = 0$, $M_{ns} = 1$
3. The solution asymptotically approaches the $M = \infty$ line
4. Have the correct slope, $\frac{d\, M_{ns}}{d\, M \sin \delta}$ at $M \sin \delta = 0$

These conditions lead to equations of the following form

$$\text{wedge} \quad M_{ns} = K_w M' + e^{-\frac{K_w}{2} M'}$$

$$K_w = \frac{\gamma + 1}{2}$$

$$\text{cone} \quad M_{ns} = K_c M' + e^{-K_c M'}$$

where

$$M' = M \sin \delta$$

$$K_c = 2 (\gamma + 1)/(\gamma + 3)$$

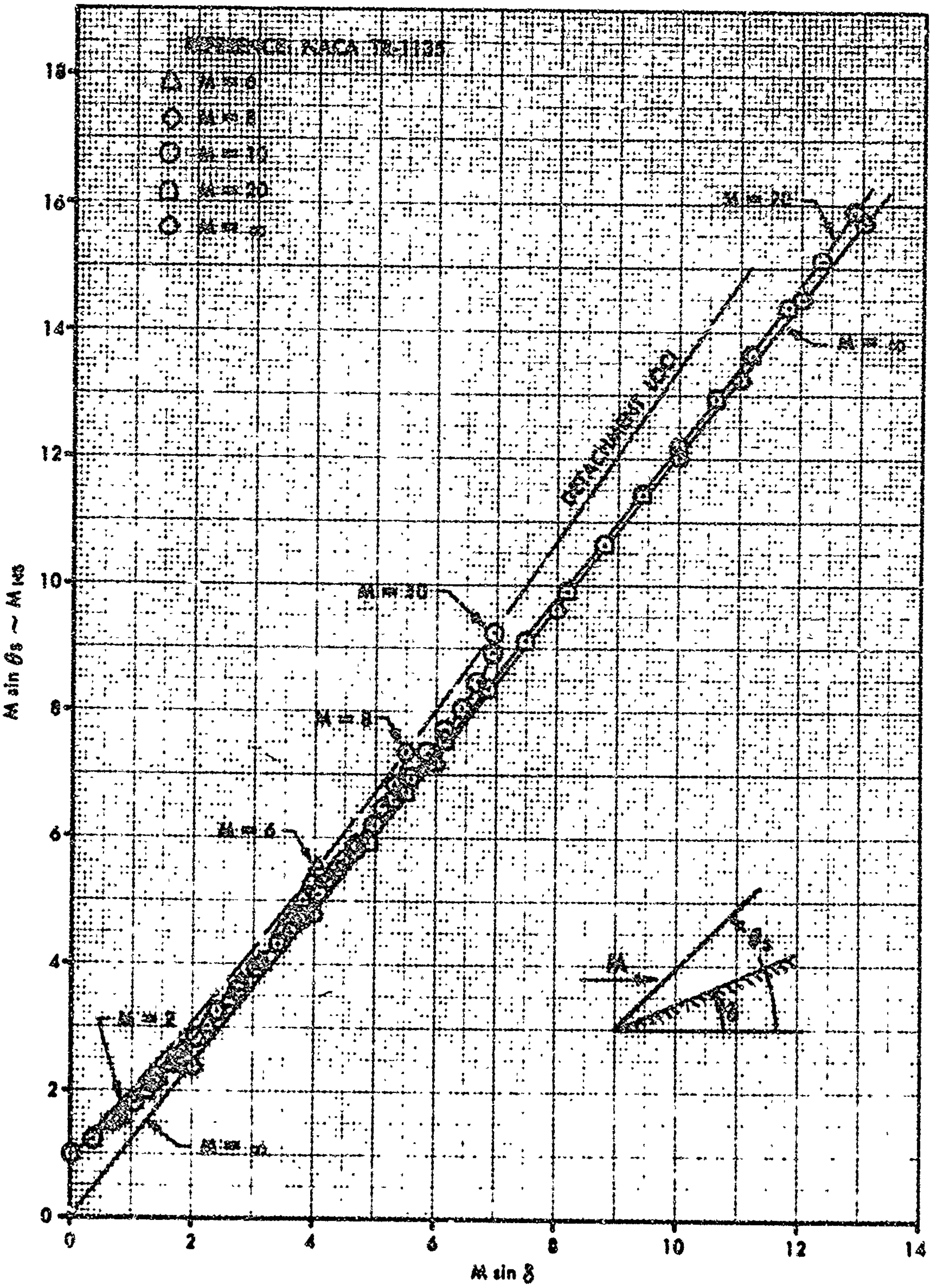


Figure 4. Wedge Flow Shock Angle

These expressions are compared with the data of TR-1135 in Figures 5 and 6. The cone data are also shown in Figure 7 with the same scales as in Figure 4.

The pressure coefficient may now be obtained by the following relationships for a wedge and cone respectively.

$$C_p = \left(\frac{4}{\gamma+1}\right) (M_{ns}^2 - 1) \;/\; M^2$$

$$C_p = 2 \sin^2\delta \left[1 - \frac{(\gamma-1)\, M_{ns}^2 + 2}{4\,(\gamma+1)\, M_{ns}^2}\right]^{-1}$$

Experimental results have shown the pressure on the centerline of a delta wing to be in agreement with two-dimensional theory at small values of the similarity parameter ($M' < 3.0$) and with conical flow theory at higher values. The previous expressions derived for wedge and cone flows have been combined to give these features. The resulting relationships are given below.

$$M_{ns} = K_C M' + e^{-\left(K_C - \frac{K_w}{2}\right) M'}$$

For $\gamma = 7/5$

$$M_{ns} = 1.09\, M \sin\delta + e^{-0.49\, M \sin\delta}$$

The similarity parameter relationship for pressure is

$$M^2 C_p = \left(\frac{4}{\gamma+1}\right) \left(M_{ns}^2 - 1\right)$$

The shock angle and pressure coefficient calculated from the above equations are compared with the experimental results (Reference 28) in Figures 8 and 9, respectively.

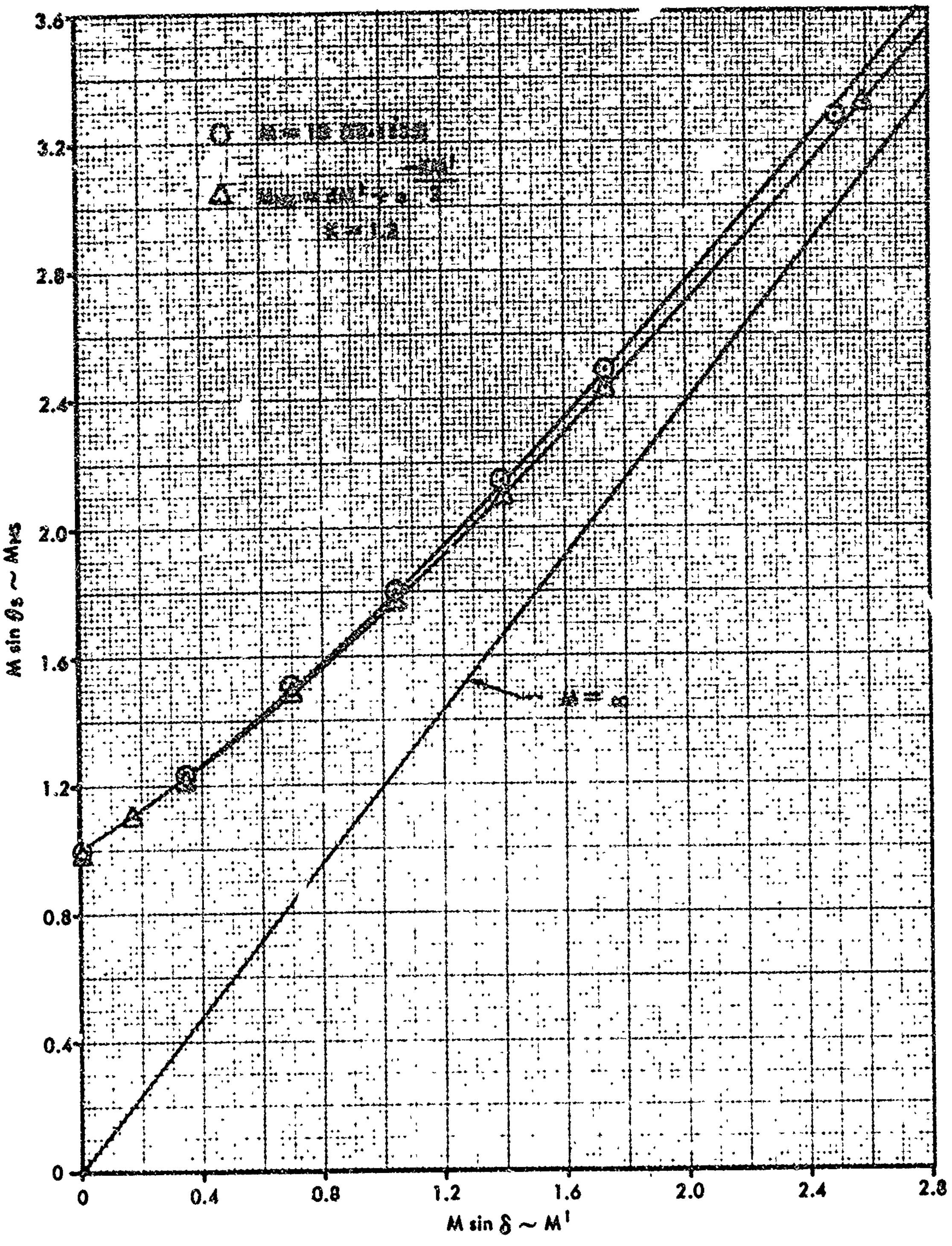


Figure 5. Wedge Flow Shock Angle Empirical Correlation

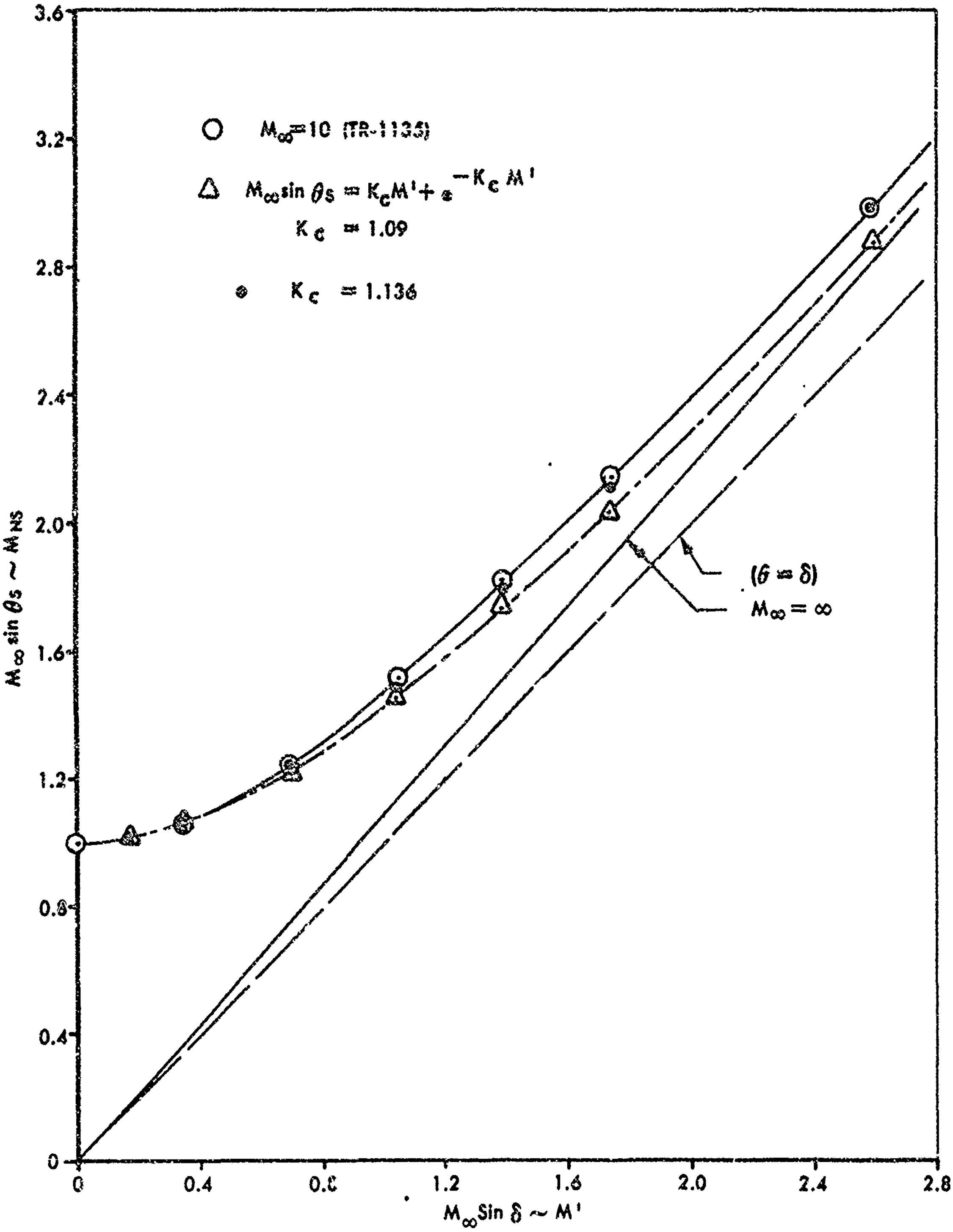


Figure 6. Conical Flow Shock Angle Empirical Correlation

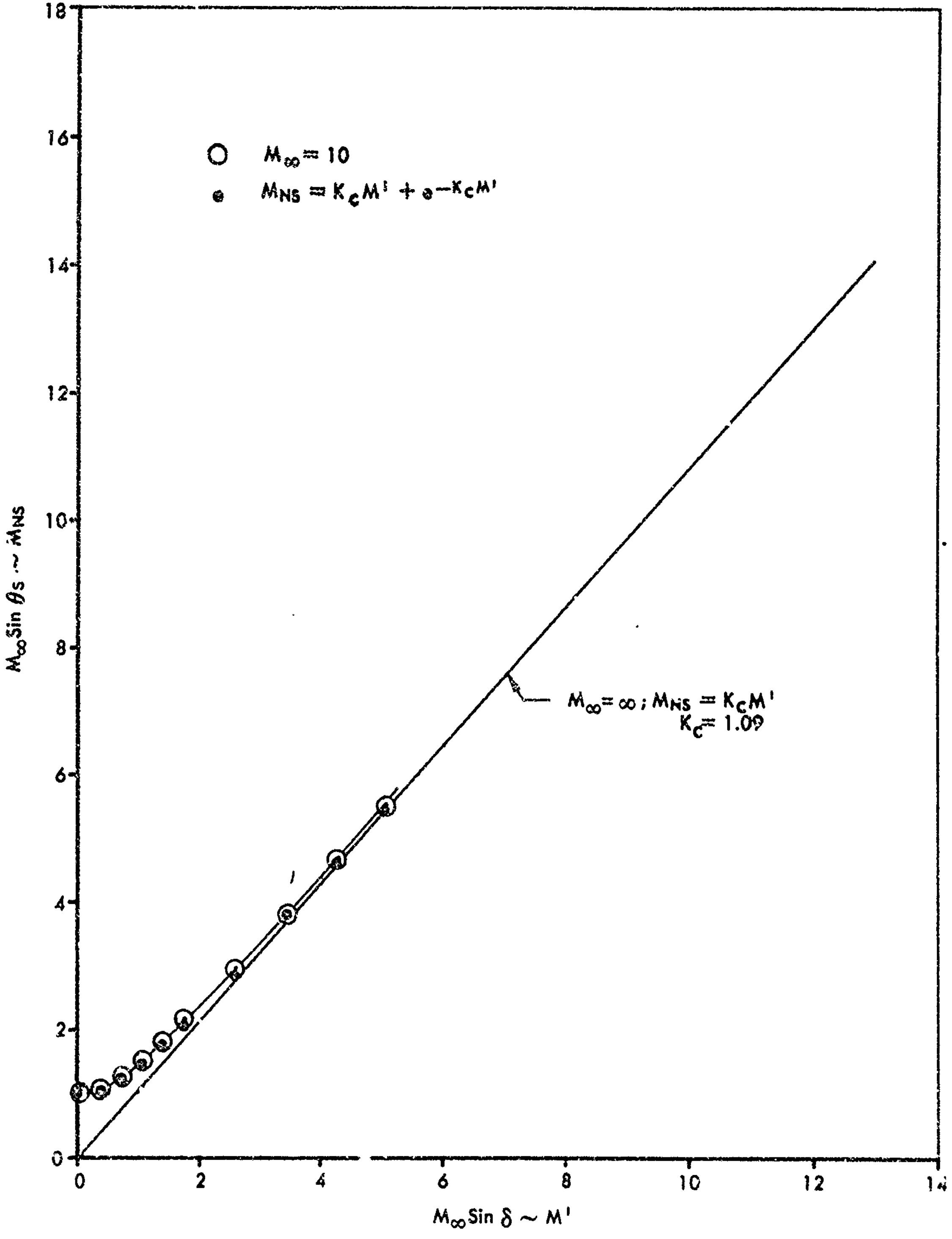


Figure 7. Conical Flow Shock Angle Empirical Correlation

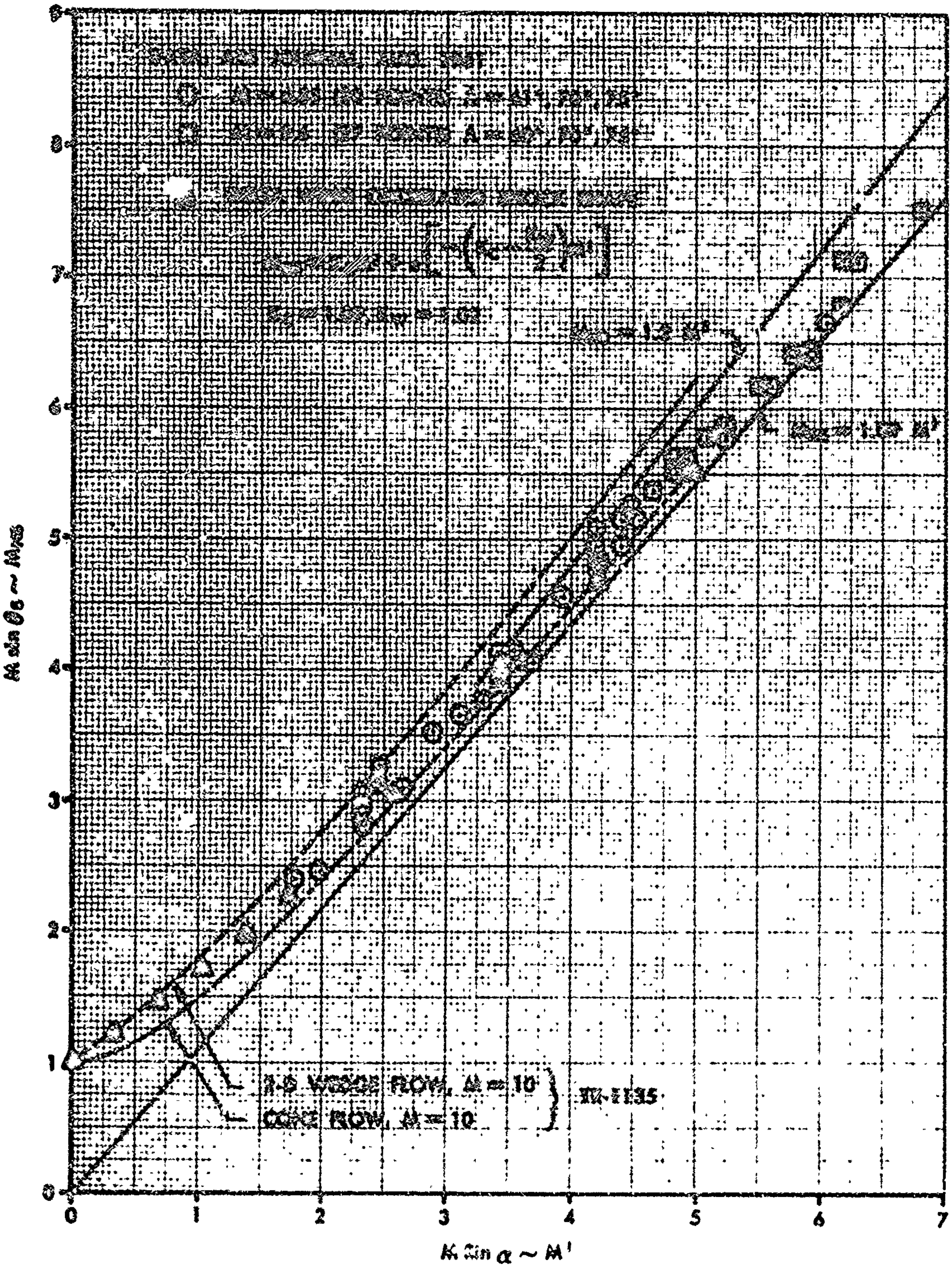


Figure 8. Delta Wing Centerline Shock Angle Correlation

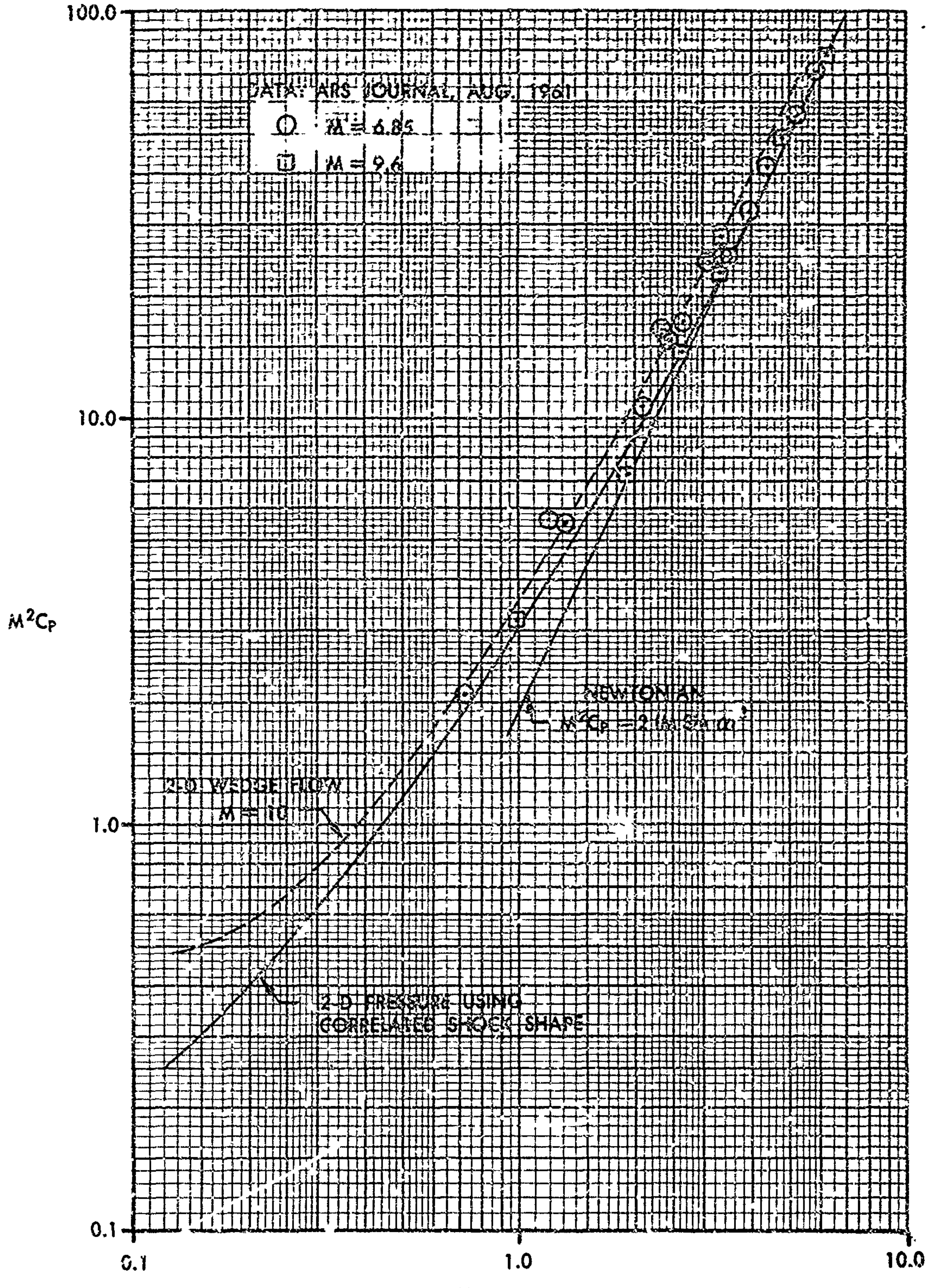


Figure 9. Delta Wing Centerline Pressure Coefficient Correlation

OSU Blunt Body Empirical Method

The OSU (Ohio State University) blunt body empirical equation describes the pressure distribution about cylinders in supersonic flow. The equation was presented in Reference 29 and was stated to match "all the data obtained on the cylinders in the present test series with a maximum deviation of 2.5 percent." The expression used is

$$\frac{p_l}{p_{t_\infty}} = 0.32 + 0.455 \cos\theta + 0.195 \cos 2\theta + 0.035 \cos 3\theta - 0.005 \cos 4\theta$$

where

θ = peripheral angle on a cylinder (= 0 at the stagnation point) = 90° − δ

p_l = surface pressure

p_{t_∞} = total pressure rise through normal shock

The pressure coefficient is calculated from the relationship

$$C_p = \left[\left(\frac{p_l}{p_{t_\infty}}\right)\left(\frac{p_{t_\infty}}{p_\infty}\right) - 1\right] \Big/ \left(\frac{\gamma}{2} M^2\right)$$

where

$$\frac{p_{t_\infty}}{p_\infty} = K \frac{\gamma}{2} M^2 + 1$$

K = stagnation pressure coefficient = $C_{p_{stag}}$

p_∞ = freestream pressure

γ = ratio of specific heats = 1.4

Van Dyke Unified Method

This force calculation method is based on the unified supersonic-hypersonic small disturbance theory proposed by Van Dyke in Reference 30 as applied to basic hypersonic similarity results. The method is useful for thin profile shapes and as the name implies extends down to the supersonic speed region.

The similarity equations that form the basis of this method are derived by manipulating the oblique shock relations for hypersonic flow. The basic derivations are shown on pages 753 and 754 of Reference 31. The result obtained for a compression surface under the assumption of a small deflection angle and large Mach number is (hypersonic similarity equation).

$$C_p = \delta^2 \left[\frac{\gamma - 1}{2} + \sqrt{\left(\frac{\gamma + 1}{2}\right)^2 + \frac{4}{H^2}} \right]$$

where H is the hypersonic similarity parameter given by $M\delta$. The contribution by Van Dyke in Reference 30 suggests that this relationship will also be valid in the realm of supersonic linear theory if the hypersonic similarity parameter $M\delta$ is replaced by the unified supersonic-hypersonic parameter $\left(\sqrt{M^2 - 1}\right)\delta$. This latter parameter is used in the calculations for this force option in the arbitrary body program.

A similar method may also be obtained for a surface in expansion flow with no leading edge shock such as on the upper side of an airfoil. The resulting equation is

$$C_p = \delta^2 \frac{2}{\gamma H^2} \left[\left(1 - \frac{\gamma - 1}{2} H\right)^{\frac{2\gamma}{\gamma - 1}} - 1 \right]$$

where again H is taken to be $\left(\sqrt{M^2 - 1}\right)\delta$ in the unified theory approach.

Shock-Expansion Method

This force calculation method is based on classical shock-expansion theory (see Reference 31). In this method the surface elements are handled in a "strip-theory" manner. The characteristics of the first element of each longitudinal strip of elements may be calculated by oblique shock theory, by conical flow theory, or by a Prandtl-Meyer expansion. Downstream of this initial element the forces are calculated by a Prandtl-Meyer expansion.

By a proper selection of the element orientation the method may be used for both wing-like shapes and for more complex body shapes. In this latter case the method operates in a hypersonic shock-expansion theory mode.

Free Molecular Flow Method

At very high altitudes conventional continuum flow theories fail and one must begin to consider the general macroscopic mass, force, and energy transfer problem at the body surface. This condition occurs when the air is sufficiently rarefied so that the mean free path of the molecules is much greater than a characteristic body dimension. This condition is known as free molecular flow and the method of analysis selected for this program is described in Reference 32. This method was also used in Reference 19. The equations used were taken from these references and are presented below.

Pressure coefficient

$$C_p = \frac{1}{S^2}\left\{\left[\frac{2-f_n}{\sqrt{\pi}} S \sin\delta + \frac{f_n}{2}\sqrt{\frac{T_b}{T_\infty}}\right] e^{-(S\sin\delta)^2} + \left[(2-f_n)\left(S^2 \sin^2\delta + \frac{1}{2}\right) + \frac{f_n}{2}\sqrt{\pi}\sqrt{\frac{T_b}{T_\infty}}\, S\sin\delta\right]\left[1 + \operatorname{erf}(S\sin\delta)\right]\right\}$$

Shear force coefficient

$$C_f = \frac{(\cos\delta) f_t}{\sqrt{\pi} S}\left\{e^{-(S\sin\delta)^2} + \sqrt{\pi} S \sin\delta\left[1 + \operatorname{erf}(S\sin\delta)\right]\right\}$$

where

S = speed ratio = $\sqrt{\gamma/2}\, M_\infty$

f_n = normal momentum accommodation coefficient (= 0. 0 for Newtonian and = 1.0 for completely diffuse reflection)

δ = impact angle

T_b = body temperature, °K

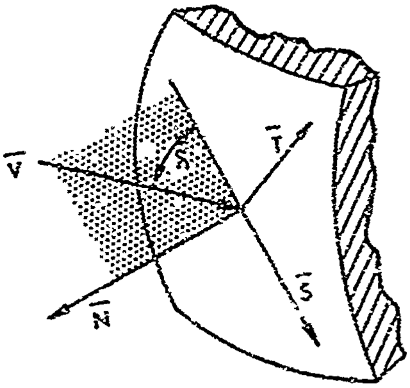
T_∞ = free-stream temperature, °K

erf = error function $\operatorname{erf}(x) = \frac{2}{\sqrt{\pi}}\int_0^x e^{-x^2}\,dx$

f_t = tangential momentum accommodation coefficient (= 0. for Newtonian flow and 1. 0 for completely diffuse reflection)

The pressure force acts perpendicular to the surface and this direction is readily obtained since the element normal has already been determined in the geometry subroutines. The shear force acts in the direction of the tangential velocity component on the surface and this direction is determined by taking successive vector products as follows.

The procedure is illustrated in the accompaning sketch where the incident velocity vector is defined as



$$\bar{V} = V_X \bar{i} + V_Y \bar{j} + V_X \bar{k}$$

and the surface normal as

$$\bar{N} = N_X \bar{i} + N_Y \bar{j} N_Z \bar{k}$$

First, a surface tangent vector $(\bar{T})$ is defined by the cross product of the normal and velocity vectors:

$$\bar{T} = T_X \bar{i} + T_Y \bar{j} - T_Z \bar{k}$$

where

$$T_X = N_Y V_Z - N_Z V_Y$$

$$T_Y = N_Z V_X - N_X V_Z$$

$$T_Z = N_X V_Y - N_Y V_X$$

Then the direction of the shear force $(\bar{S})$ is given by the cross product of the surface tangent and normal vectors;

$$\bar{S} = S_X \bar{i} + S_Y \bar{j} + S_Z \bar{k}$$

where

$$S_X = T_Y N_Z - T_Z N_Y$$

$$S_Y = T_Z N_X - T_X N_Z$$

$$S_Z = T_X N_Y - T_Y N_X$$

The final components of the shear force in the vehicle axis system are given by

$$\text{SHEAR}_X = (\text{SHEAR})\left(S_X\right) / \text{STOTAL}$$

$$\text{SHEAR}_Y = (\text{SHEAR})\left(S_Y\right) / \text{STOTAL}$$

$$\text{SHEAR}_Z = (\text{SHEAR})\left(S_Z\right) / \text{STOTAL}$$

where

SHEAR is the shear force as calculated by the free molecular flow equations,

$$\text{STOTAL} = \left(S_X{}^2 + S_Y{}^2 + S_Z{}^2\right)^{1/2}$$

In using the free molecular flow method the above analysis must be carried out over the entire surface of the shape including the base, shadow regions, etc. When the free molecular flow method is selected, it is used for both impact and shadow region.

This method of determining the shear direction is also used for the continuum viscous forces discussed in the next section. The plane formed by the velocity vector and the surface normal is referred to as the velocity plane (shaded region in the sketch), since both the incident and surface velocity are in this plane. This definition is correct for two-dimensional flow, however, it is only an approximation to the shear direction in the general arbitrary-body case.

Hankey Flat-Surface Emprical Method

This method uses an empirical correlation for lower surface pressures on blunted flat plates. The method, derived in Reference 14, approximates tangent-wedge at low impact angles and approaches Newtonian at high impact angles. The pressure coefficient is given by

$$C_p = 1.95 \sin^2 \delta + 0.21 \cos \delta \sin \delta$$

Dahlem-Buck Empirical Method

This is an impact method that has been derived such that tangent-cone and Newtonian results are approximated, respectively, at low and high values of the impact angle. The empirical relationships presented in Reference 33 are

for $\delta < 22.5^\circ$ $$C_p = \frac{1 + (\sin 4\delta)^{3/4}}{(4 \cos \delta \cos 2\delta)^{3/4}} (\sin \delta)^{5/4}$$

for $\delta \geq 22.5^\circ$ $$C_p = 2.0 \sin^2 \delta$$

Blast Wave Pressure Increments

This method uses conventional blast-wave parameters to calculate the overpressure due to bluntness effects. Force contributions determined by this procedure must be added to the regular inviscid pressure forces (tangent-wedge, tangent-cone, Newtonian, etc.) calculated over the same vehicle geometry. The specific blast wave solutions used in the Program were derived by Lukasiewicz in Reference 34:

$$\frac{P}{P_\infty} = A M_\infty^2 \left\{ \frac{(C_D)^{\frac{1}{1+j}}}{(X_o - X)/d} \right\}^{\frac{2+j}{3}} + B$$

where

C_D is the nose drag coefficient

d is the nose diameter or thickness

X_o is a coordinate reference point

and the coefficients A, B are

Flow	j	A	B
Two-Dimensional	0	0.121	0.56
Axisymmetric	1	0.067	0.44

Modified Tangent-Cone Method

This method. originally developed for use on cones with elliptical cross-sections, modifies the tangent-cone result by an increment representing the deviation from an average pressure divided by an average Mach number. More specifically, the following equations are used (after Jacobs, Reference 35):

$$C_p = C_{p_{tc}} - \frac{C_{p_{tc}} - C_{p_{avg}}}{M_{avg}}$$

where C_p is the surface pressure coefficient

$C_{p_{tc}}$ is the conventional tangent-cone pressure coefficient

$C_{p_{avg}}$ is the average pressure coefficient

$= \sum C_{p_t} A / \sum A$, A is element area

M_{avg} is the average Mach number, defined for an equivalent cone having pressure coefficient $C_{p_{avg}}$.

High Mach Base Pressures

For a body in high speed flow it might be expected that any base regions would experience total vacuum. That is,

$$C_p = -\frac{1}{\frac{\gamma}{2} M_\infty^2}$$

However, the viscosity of real gases causes some pressure to be felt in base region and experimental data have shown this to be roughly 70% vacuum for air. Therefore, the expression

$$C_p = -\frac{1}{M_\infty^2}$$

has been included in the program.

Viscous Force Calculation Methods

The most difficult part in the analysis of an arbitrary shape is the calculation of viscous forces. A detailed knowledge of the local properties and the flow history along surface streamlines is required. This combined with the natural complexity of the boundary-layer equations necessitates considerable simplification of the problem before solutions can be obtained. An engineering approach has been selected that retains the essential characteristics of the hypersonic boundary-layer problem. No attempt is made to calculate the detailed skin friction distribution on the exact arbitrary shape, but rather, the vehicle is represented by a number of flat surfaces on each of which the shear force is determined.

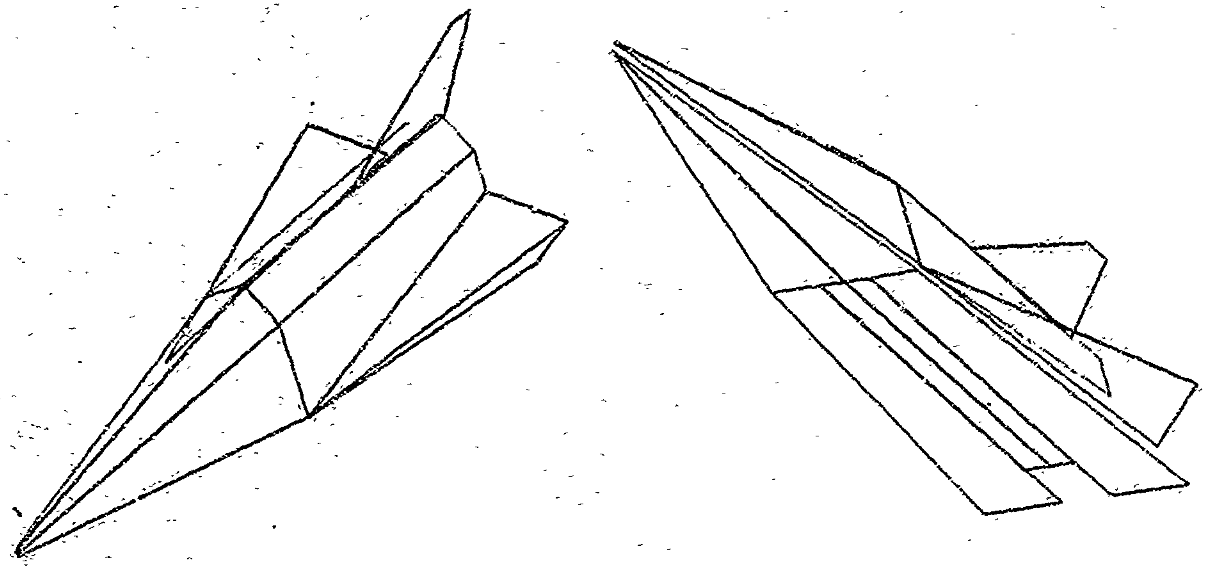
The surface streamlines are assumed in the velocity plane and the flow history is approximated by the inclusion of an initial surface. The shear force is determined for both laminar and turbulent flow and may be summed over the vehicle for either type.

Reference temperature and reference enthalpy methods are available for both laminar and turbulent flows and, in addition, the Spalding-Chi method with either temperature or enthalpy ratios may be selected for turbulent calculations. The surface temperature may be either input or the radiation equilibrium value determined. The effect of planform shape, leading edge viscous-interaction, and the viscous forces on blunt bodies are also considered.

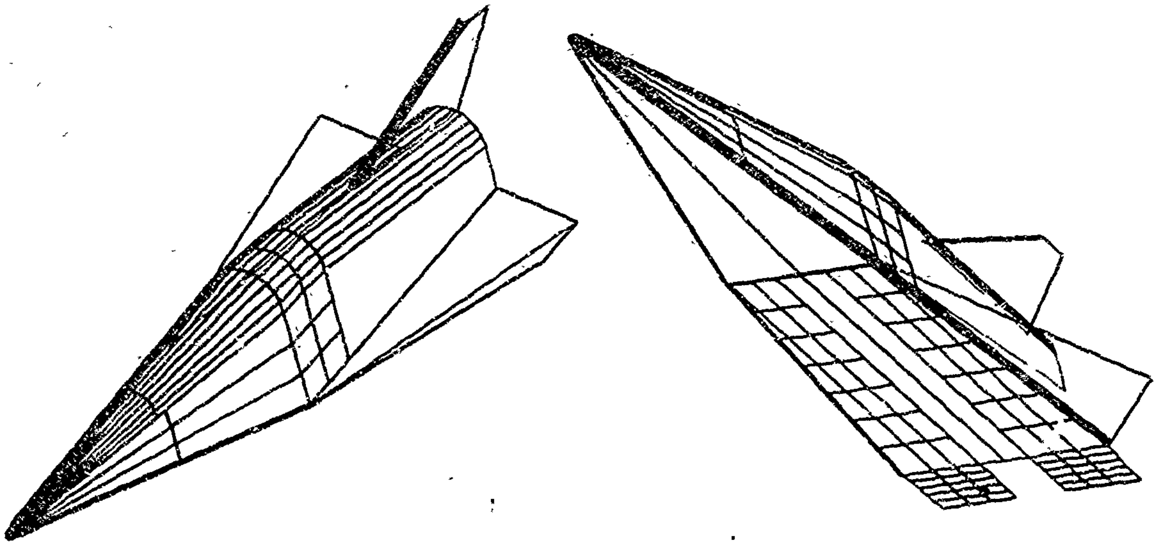
Skin Friction Geometry Model

For the skin friction calculations a geometrically complex vehicle is divided up into a number of plane surfaces in a manner which adequately approximates the true shape. Leading-edge surfaces and local curvatures are omitted. Regions of relatively large curvatures can be represented by using a greater number of plane surfaces. The degree to which this is done will depend upon the complexity of the actual shape and experience of the designer. The geometry data for the skin-friction geometry model is prepared in the same way as the surface element data used for the inviscid pressure calculations and retain their relative location to each other and to the flight path. This skin friction modeling technique is best described by viewing, for example, a typical high L/D vehicle shown in Figure 10. The upper half presents the skin-friction representation of the vehicle which is to be contrasted with the detailed inviscid geometry given in the lower half of the figure. As used in the in the Hypersonic Arbitrary-Body Program the skin friction surfaces are referred to as an approximate representation of the vehicle geometry while, in fact, it has been observed they are as complete as generally used throughout the industry for the inviscid calculations.

From the input element data, the surface normal, area, and area centroid coordinates are calculated. In addition, maximum chord length, taper ratio, and true area are input for each surface. The latter may be different from the calculated area since curvatures have been neglected. The initial surface, specified by its maximum chord length and taper ratio, is assumed to be in the plane of the skin-friction surface and, therefore, the flow history is only approximated. The element planform effect on the average skin friction is



a) Representation for Viscous Calculations



b) Representation for Inviscid Calculations

Figure 10. Geometry Modeling for a Typical High L/D Vehicle

included, however, and is discussed separately for laminar and turbulent flows in later sections. The shear force on each surface is assumed to act through its centroid in a direction on the surface parallel to plane containing the surface normal and the free-stream velocity vector, as described in the section on free-molecular flow.

Local Flow Conditions

The required local properties (pressure, temperature, density, and velocity) are obtained assuming a calorically perfect gas. The pressure on each skin-friction surface may be determined from a choice of several of the inviscid pressure methods — tangent-wedge, tangent-cone, Newtonian+Prandtl-Meyer, and Prandtl-Meyer expansion. At the present time, a continuous strip shock-expansion calculation is not available within the Arbitrary-Body Program and, in this respect, each surface is treated independently of the others.

The skin-friction surfaces and local properties, thus, have been defined in a way that reduces the problem of calculating the viscous forces on a complex shape to one of solving for the skin friction on a number of constant-property flat plates.

Incompressible Flow

The basic philosophy behind both the Spalding-Chi and the reference condition methods is the same. Namely, that the suitably transformed skin-friction coefficient is given by the constant-property or incompressible formulas based on a Reynolds number also suitably transformed. To emphasis the point, this may be stated another way: The compressible skin-friction is given by the incompressible form with appropriate correction factors to account for compressibility effects. That is,

$$C_{f_\delta} = C_{f_i}/F_c$$

$$C_{f_i} = f(Rx_i)\ ,\ Rx_i = F_{Rx} \bullet Rx$$

where

C_f = skin friction coefficient

Rx = Reynolds number

$(\ )_i$ = indicates incompressible

$(\ )_\delta$ = indicates compressible

The incompressible formulas used in the Hypersonic Arbitrary-Body Program are given in Table I and the compressibility factors, F_c and F_{Rx} are discussed below.

Flow	Skin Friction Coefficient, $f(Rx_i)$		Source
	Local	Average	
Laminar	$0.664/\sqrt{Rx_i}$	$1.328/\sqrt{Rx_i}$	Blasius
Turbulent ($Rx_i > R_{Min}$)	$\frac{0.088\,(\log Rx_i - 2.3686)}{[\log Rx_i - 1.5]^3}$	$\frac{0.088}{[\log Rx_i - 1.5]^2}$	Sivells & Payne (Ref. 36)
R_{Min}	2540	6570	

Table I. Incompressible Skin-Friction Coefficient Formulas

The Sivells and Payne formulas have singularities occurring at low Reynolds numbers. However, both occur below the point at which the turbulent values cross the respective Blasius laminar curves. Thus, the turbulent incompressible skin-friction coefficients for Reynolds numbers equal to or less than R_{Min} are given by the corresponding laminar values.

Compressible Flow

Reference Temperature and Reference Enthalpy Method

$$F_c = \rho_\delta / \rho^*$$

$$F_{Rx} = (\mu_\delta / \mu^*) \frac{1}{F_c}$$

where ρ is the density, μ the viscosity, and the superscript "$*$" means evaluated at the reference temperature, T^*, or reference enthalpy, H^*;

$$\frac{T^*}{T_\delta} = (A1)\frac{T_W}{T_\delta} + (A2)\frac{T_{AW}}{T_\delta} + (1 - A1 - A2)$$

$$\frac{H^*}{H_\delta} = (A1)\frac{H_W}{H_\delta} + (A2)\frac{H_{AW}}{H_\delta} + (1 - A1 - A2)$$

The value of the coefficients used are due to Monaghan (Reference 37) for Prandtl number equal to 0.71;

$A1 = 0.5825$

$A2 = 0.1875$

The subscript "W" indicates the wall value and subscript "AW" refers to adiabatic wall conditions given by

$$\frac{T_{AW}}{T_\delta} = \frac{H_{AW}}{H_\delta} = 1 + \left(\frac{\gamma - 1}{2}\right) \; r \; M_\delta^2$$

where

γ = ratio of specific heats (= 1.4)

M = Mach number

r = recovery factor = $(P_r)^{1/n}$

n = 2 for laminar flow

n = 3 for turbulent flow

P_r = Prandtl number (= 0.71)

Spalding-Chi Method (Reference 38):

$$F_c = A \Big/ \left\{ \text{ARSIN}\left(\frac{A-B}{C}\right) + \text{ARSIN}\left(\frac{A+B}{C}\right) \right\}^2$$

where

$$A = \frac{H_{AW}}{H_\delta} - 1$$

$$B = \frac{H_W}{H_\delta} - 1$$

$$C = \left[(A+B)^2 + 4A\right]^{1/2}$$

$$F_{Rx} = \left(\frac{H_{AW}}{H_\delta}\right)^q \Big/ \left[F_c \left(\frac{H_W}{H_\delta}\right)^{p+q}\right], \quad q = 0.772, \; p = 0.702$$

Surface Equilibrium Temperature

In the Arbitrary-Body Program the surface equilibrium temperature is defined as the temperature satisfying the steady-state heat balance between the boundary-layer convection to the surface and the surface radiation to space.

convective heating: $QC(T_c) = C_h \; (H_{AW} - H_W)$

radiation heating: $QR(T_r) = R_K \; T_R^4$

where C_h is the heat transfer coefficient

and $R_K = \epsilon\sigma$, ϵ = emissivity (= 0.8)

σ = Stefan-Boltzman constant

The surface equilibrium temperature is defined when $QC(T_c) = QR(T_R)$ for $T_c = T_R$. The solution is obtained by a simple linear intercept technique illustrated in the sketch and explained briefly as follows.

Linear relations are assumed for both heating rates

$$QC = AC + (BC)T$$

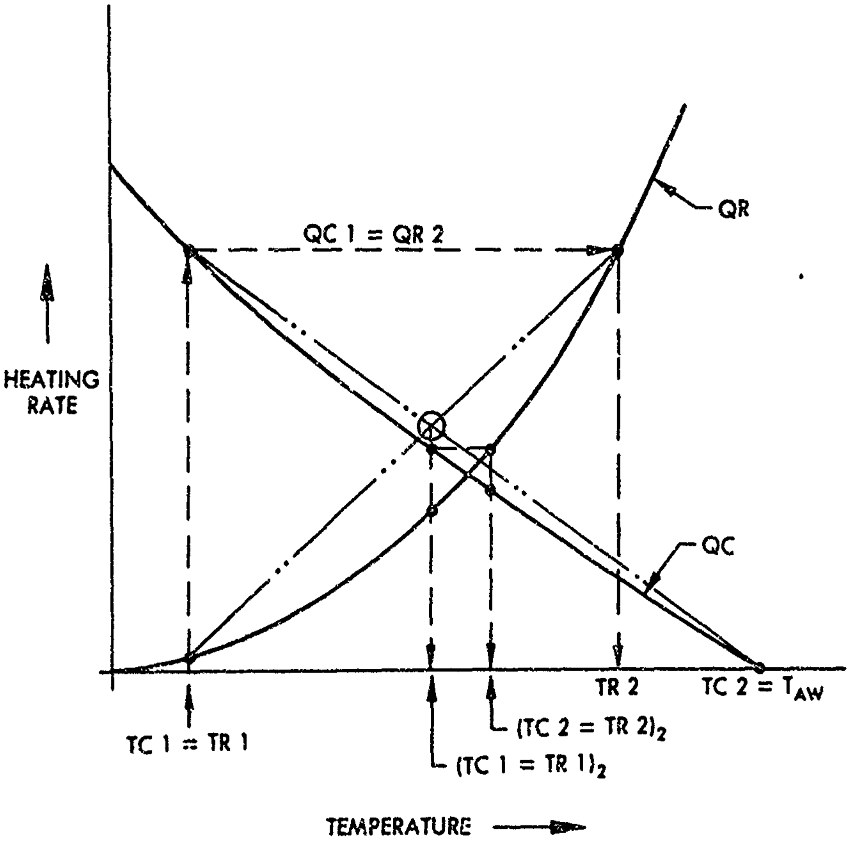
$$QR = AR + (BR)T$$

The four coefficients are initialized as follows.

1. Assume $TC1 = TR1 = 100\ ^{o}R$
2. Calculate QC1 and QR1
3. Let $QR2 = QC1$ and calculate

   $$TR2 = \left(\frac{QR2}{R_K}\right)^{1/4}$$

4. If $TR2 > TC2 = T_{AW}$, then set $TR2 = TC2$ and calculate new QR2



The coefficients may now be readily determined and the result of the linear solution of the heat balance equation is simply

$$T = (AC - AR)/(BR - BC)$$

The convective and radiation heating rates are then calculated at this temperature and checked for convergence:

$$|1 - QC1/QR1| \leq EPST, \text{ where } EPST = 5.0E-4$$

If the criteria is not satisfied the cycle is repeated with TC1 = TR1 = T, QR2 = QC1, and TC2 = TR2. The present technique, while lacking sophistication, is accurate and quite rapid. Normally, two or three cycles are required for ideal gas solutions and one additional cycle for real gas cases.

Real Gas Effects

It is felt that some comments are in order with regard to the overall procedure. Specifically, what is the correctness or justification in using real gas reference enthalpy viscous solutions when the local inviscid flow has been determined only for a calorically perfect or ideal gas? To answer this question, an extensive comparison of laminar boundary-layer methods was undertaken in support of an earlier study and the details are reported in Reference 39. Briefly, the skin friction was determined for the flight conditions of the matrix given in Table II, corresponding to the surface equilibrium temperatures (emissivity = 0.8) at the one-foot station of a flat plate.

Altitude (1000 Ft)	Velocity (1000 fps)					
	8	12	16	20	24	28
100	x	x	x	x	-	-
150	-	x	x	x	x	-
200	-	-	x	x	x	x
250	-	-	x	x	x	x

Table II. Flight Matrix for Skin Friction Calculations

Angle-of-attack variation from 0° to 40° in 10° increments and five boundary-layer calculations were made at each condition. The latter correspond to the combination of three boundary-layer solutions and two shock wave solutions for local properties as shown in Table III.

Boundary Layer Solution	Local Properties	
	Real	Ideal
Exact	1	-
Reference Enthalpy	2	3
Reference Temperature	4	5

Table III. Boundary Layer Calculations

Also, additional calculations were made at the flight condition of 20,000 fps, 200,000 feet altitude, and wall temperature equal to 2000°R.

Methods 1 , 2 , and 5 are self-consistent with respect to the assumptions made and are regarded as normal calculation modes. Methods 3 and 4 are inconsistent in the assumptions made between the inviscid and viscous solutions and are termed mixed calculation modes. The free-stream properties were specified by the 1962 U.S. Standard Atmosphere and Sutherland's viscosity formula. The oblique shock-wave solutions are accurate to 5-significant digits in the inverse density ratio. For the real gas solution, the thermodynamic properties for equilibrium dissociating and ionizing air were obtained by the method in Reference 40. The assumed ideal gas is calorically perfect with ratio of specific heats equal to 1.40.

The real gas variation for the density-viscosity product in the viscous solutions was obtained as a function of enthalpy and pressure using the polynominal equations given in Reference 41. This product is based on the most recent thermodynamic data of Hilsennath (Reference 42) and the viscosity calculations of Hansen (Reference 43). The Prandtl number was assumed equal to 0.71 for all the methods.

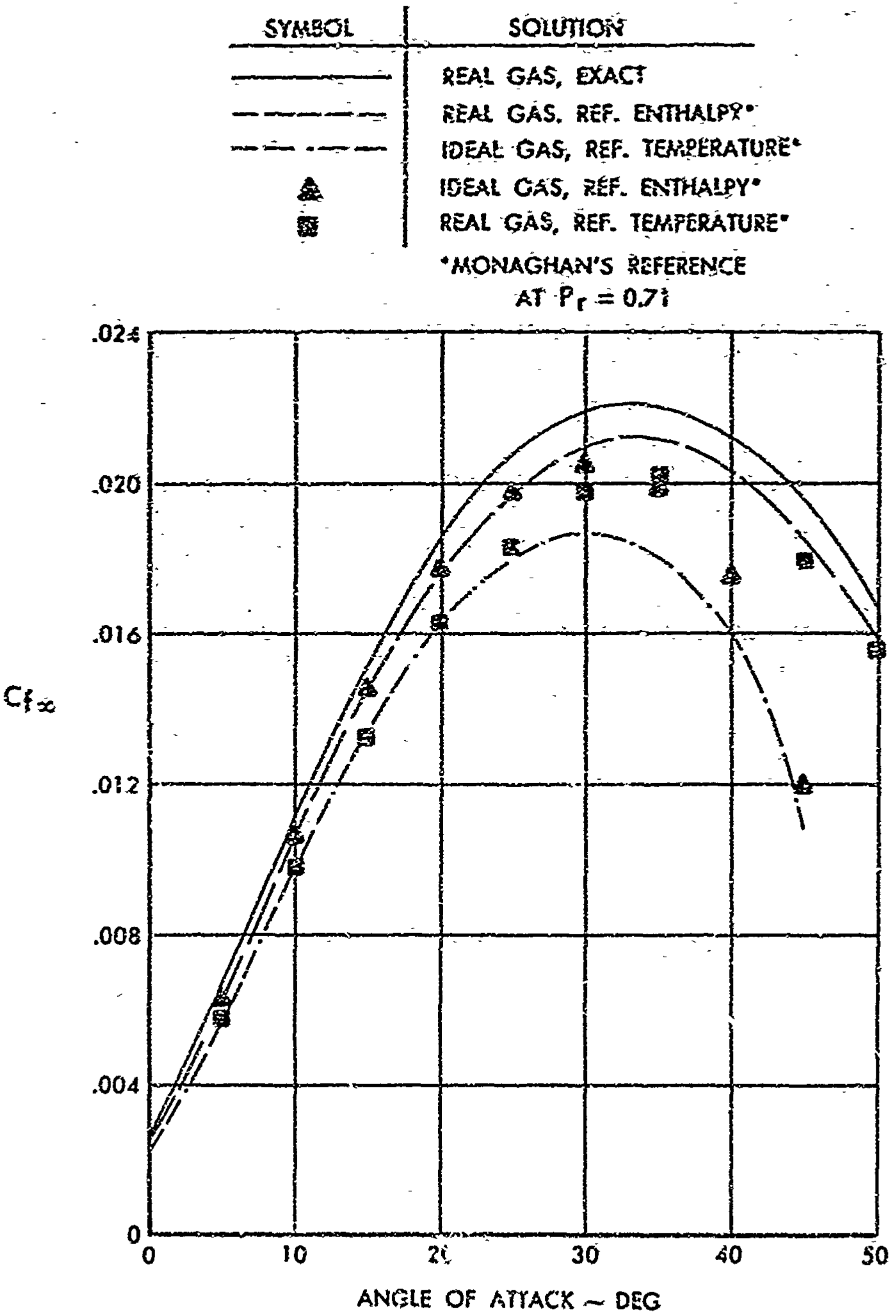


Figure 11. Laminar Skin-Friction Coefficient Comparison
(Altitude = 200,000 Ft., Velocity = 20,000 fps., T_w = 2000°R)

Typical results of the comparison are shown in Figure 11. The exact solutions were obtained using the Douglas General Laminar Compressible Boundary-Layer Program as described in Reference 41. The reference method calculations shown are based on the coefficient values of Monaghan. These were selected since the skin friction calculated consistently gave the best agreement with the exact results. Comparison of the three formulations considered — Monaghan (Reference 37), Michel (Reference 44) and Eckert (Reference 45) are shown in Table IV for the same flight conditions as Figure 11. Major conclusions of the comparison are:

1. With the exception of possibly zero angle-of-attack the reference temperature method, using existing values for the coefficients A1 and A2, is inadequate for predicting skin friction for the complete range of hypersonic flight conditions considered.
2. The real gas, reference enthalpy method using Monaghan's formulation adequately predicts the laminar skin friction over the complete flight range considered. The results, however, are consistently about 3 to 5 percent lower than the exact calculations.
3. The mixed calculation mode, ideal gas inviscid — real gas reference enthalpy is in substantial agreement with the real gas reference enthalpy calculation up to 30° angle-of-attack.

Reference Enthalpy Due to	Angle of Attack in Degrees									
	0	5	10	15	20	25	30	35	45	50
Monaghan	0.247	0.623	1.056	1.445	1.753	1.969	2.096	2.121	1.853	1.590
Michel	0.247	0.628	1.062	1.447	1.747	1.953	2.067	2.075	1.788	1.529
Eckert	0.243	0.613	1.038	1.418	1.717	1.926	2.042	2.058	1.788	1.534

Table IV Comparison of Reference Methods. Values of $C_f \times 10^2$.
(Altitude = 200,000 Ft., Velocity = 20,000 fps, T_W = 2000°R)

On the basis of the results of this study, the mixed-mode ideal gas inviscid-real gas reference enthalpy calculation has been included in the Hypersonic Arbitrary-Body Program. The real gas fluid properties of air are determined by the procedures described in detail in Reference 41. Three different formulas are used to specify the viscosity. At very low temperatures such as might be experienced in a high speed wind tunnel the viscosity is found from the

Bromley-Wilke results (Reference 46). In the Arbitrary-Body Program these are approximated by the following linear relationship;

For $T \leq 225^{\circ}R$

$$\mu = 0.80383436\ T \times 10^{-9}\ \frac{\text{lb sec}}{\text{ft}^2}$$

At higher temperatures and for an ideal gas the Sutherland viscosity formula is used (Reference 25):

For $T > 225^{\circ}R$

$$\mu = 2.270\ \frac{T^{3/2}}{T + 198.6} \times 10^{-8}\ \frac{\text{lb sec}}{\text{ft}^2}$$

For real gas and temperatures greater than about 6000°R Hansen's viscosity values are used (Reference 43).

Viscous - Inviscid Interaction

Under conditions of low Reynolds number and high Mach number, the mutual interaction of the boundary layer and the inviscid flow field can have a large effect on both the laminar skin friction and surface pressure. Boundary-layer displacement effects in hypersonic flow over flat plates have been studied at length (e.g., Reference 47) and the present approach is limited to consideration of these methods. Basically, a pressure is induced from the relatively large outward streamline deflection caused by the thick hypersonic boundary layer. The classical approach is to consider an effective body, made up of the actual body plus the boundary-layer displacement thickness, in an iterative solution with the inviscid flow. This in itself is an approximation and, in addition, the simplifying assumptions of hypersonic viscous similarity are usually employed. This procedure has been adopted for use in the Arbitrary-Body Program and a brief background and development of the final equations follow.

Bertram and Blackstock (Reference 48) presented some simple procedures for estimating the boundary layer induced effects on pressure and skin friction. These involved the use of hypersonic-similarity-boundary-layer theory solutions in an iterative technique with the hypersonic small-disturbance tangent-wedge pressure equation. The analysis showed good correlation with experimental data for surfaces at nearly zero degrees incidence to the free-stream. White (Reference 49) extended the theory of Bertram and Blackstock to include the effect of angle of attack and presented a direct method for solving the problem without requiring iterations. White used hypersonic small disturbance expressions for both compression and expansion flows and introduced a new interaction parameter to correlate the wall temperature effect. Recently, Bertram (Reference 50) has presented more elaborate solutions for the problem employing the techniques of White. Implicit to all these solutions is the assumption of a calorically perfect gas and a Prandtl number of unity.

White's solution has been used in the present analysis because of the relative simplicity in its application. His numerical results showed the local pressure to be nearly a linear function of the iteraction parameter, λ;

$$P = P_o (1 + B)$$

where

$$B = m \frac{\lambda}{P_o} ,$$

and

$$\lambda = \frac{G M_\infty^3}{\sqrt{1 + 2j}} \left(\frac{C}{Rx} \right)^{1/2}$$

The quantity G is a simple function of wall temperature and specific heat, C is the Chapman-Rubesin viscosity coefficient, and j is the Manger transformation parameter: two-dimensional flow, $j = 0$; axially-symmetric flow, $j = 1$.

In the above equations, P is the local pressure to free-stream pressure ratio, and the subscript "o" refers to the inviscid value obtained from the hypersonic small-disturbance relations.

Bertram's (Reference 48) correlation for local skin friction coefficient is

$$C_f = 0.664 \; K_1 \left(\frac{PC}{Rx} \right)^{1/2}$$

where K_1 is a pressure gradient and wall temperature correction factor. The shear on the surface is

$$\tau_W = \int q_\delta C_f \, dA$$

In the present analysis, the approach taken is to determine the effect or factor due to viscous-interaction using White's method and then to modify the previous result without interaction accordingly. This viscous-interaction factor, K_{VI}, is obtained by carrying out the integration of the preceding equation and is defined as follows;

$$K_{VI} = \frac{(\tau_W)_{VI}}{\tau_W} = \sqrt{1 + B_{c_r}} + B_{c_r} \log_e \left| \frac{\sqrt{1 + B_{c_r}} + 1}{\sqrt{B_{c_r}}} \right|$$

where B_{c_r} is based on the root-chord and K_1 has been assumed equal to one. This expression is for a plate with taper ratio one, but the integration could have been done for an arbitrary value (e. g., Reference 51). In the present application the planform effects are included in the shear force without interaction, τ_W. This application results in a slightly lower factor but has the advantage of permitting a step-by-step build up and comparison of the overall viscous forces. The magnitude of the skin-friction correction factor using the above techniques is shown in Figure 12.

The induced pressure on a surface is determined as an increment in pressure coefficient.

$$\Delta C_p = C_p - C_{p_o} = \frac{\bar{P} - P_o}{\frac{\gamma}{2} M^2}$$

The average pressure increment, $\bar{P} - P_o$, is found by summing the local pressure distribution over the surface.

$$\bar{P} - P_o = \frac{1}{A} \int (P - P_o)\, dA$$

Substituting the expression for local pressure and integrating gives

$$\bar{P} - P_o = 2m\lambda c_r$$

The ΔC_p due to induced pressure is determined for the skin-friction geometry representation of the vehicle shape and effects due to the planform shape and due to the initial surface are discussed in the next section.

The basic hypersonic small-disturbance relations for calculating pressure are:

For compression flow $(K \geq 0)$

$$P = 1 + \gamma \left(\frac{\gamma+1}{4}\right) K^2 + \gamma K \left\{ 1 + \left(\frac{\gamma+1}{4} K\right)^2 \right\}^{1/2}$$

For expansion flow $(-2/(\gamma - 1) \leq K \leq 0)$

$$P = \left[1 + \frac{\gamma - 1}{2} K \right]^{2\gamma/(\gamma - 1)}$$

The similarity parameter, K, is given by;

$$K = K_o + \frac{\lambda K_4}{\sqrt{P}} \left[1 + \frac{\lambda}{2P} \frac{dp}{d\lambda} \right]$$

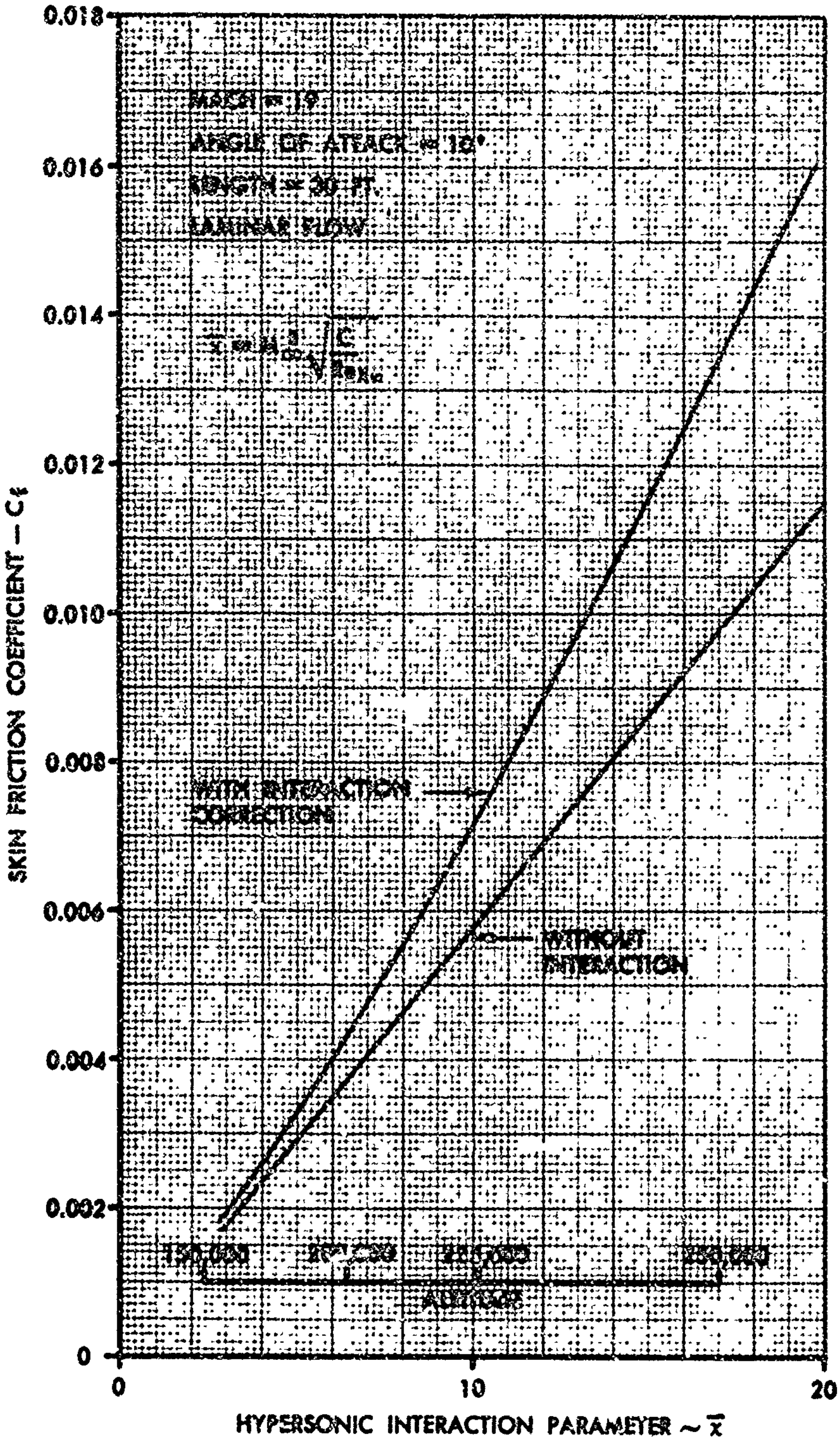


Figure 12. Effect of Viscous Interaction on Skin Friction Coefficient

where $K_o = M_\infty \sin\delta$ (δ is the surface impact angle) and K_4, a boundary-layer growth parameter, is taken equal to 1.0.

White (Reference 49) observed that the pressure equation (either compression or expansion) and the expression for K constituted a first-order nonlinear differential equation in $P(\lambda)$ and obtained numerical solutions directly without iteration. The results are shown in Table V from which White also observed that the pressure could be approximated by the linear relationship

$$P = P_o + m\lambda$$

where P_o and the slope parameter, m, are just functions of K_o. P_o is given by the hypersonic similarity relations as a function of K_o and, in the Arbitrary-Body Program, m is approximated to the data of Table V by the following analytical curves:

For $-2/(\gamma - 1) \leq K < -3.0$,

$$m = 1.424 + 0.219\, K_o$$

For $K \geq -3.0$,

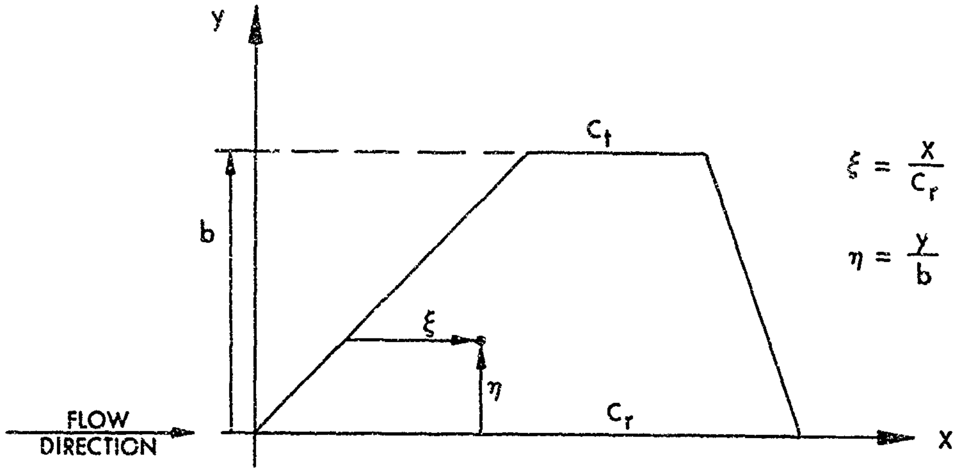
$$m = 1.9156 + 0.41727 K_o - 0.0419101 K_o^2 - 0.010427 K_o^3 + 0.00214381 K_o^4 - 0.000103217 K_o^5$$

λ	Similarity Parameter K_o							
	-3	-2	-1	0	+1	+2	+5	+10
0.0	0.002	0.028	0.210	1.000	3.473	8.734	44.14	170.2
0.5	0.173	0.339	0.748	1.835	4.555	9.930	45.41	171.4
1.0	0.428	0.736	1.379	2.777	5.722	11.18	46.70	172.7
1.5	0.738	1.192	2.059	3.740	6.914	12.47	48.01	174.0
2.0	1.092	1.695	2.770	4.709	8.108	13.76	49.33	175.3
2.5	1.485	2.234	3.506	5.679	9.294	15.07	50.66	176.6
3.0	1.908	2.801	4.260	6.651	10.47	16.37	51.99	177.9
3.5	2.359	3.392	5.029	7.622	11.64	17.67	53.34	179.3
4.0	2.833	4.004	5.810	8.593	12.80	18.96	54.70	180.6
4.5	3.328	4.632	6.601	9.505	13.95	20.25	56.06	181.9
5.0	3.840	5.275	7.400	10.54	15.09	21.52	57.42	183.2

Table V. Numerical Solutions for Pressure Ratio P ($\gamma = 1 - 4$)

Planform Effects

The previous sections have dealt with the determination of the local skin-friction coefficient or the average skin-friction coefficient per unit span. In this section, the determination of the viscous force contribution of a surface element having a planform shape of the type shown in the sketch below is considered. In the derivations that follow it is implicitly assumed that the root and tip chords are parallel to the oncoming flow.



The product of local skin-friction coefficient (C_{f_δ}) and dynamic pressure (q_δ) is integrated over the surface area (A) to obtain the shear force:

$$\tau_W = \int q_\delta \, C_{f_\delta} \, dA$$

(The symbol τ is customarily used to define shear stress, however in the present text it is used consistently as a force. This is done to avoid the unnecessary use of area ratios in the defining equations and at the same time retain the significant connotation associated with the symbol.)

The shear force on each surface is then written as a coefficient with respect to the free-stream dynamic pressure (q_∞) and a specified reference area (S),

$$C_{F_\infty} = \frac{\tau_W}{\frac{1}{2} q_\infty S}$$

and summed over all surfaces to obtain the vehicle characteristics due to viscous forces.

Laminar Shear Force

The local properties are constant on each surface and the above expression becomes

$$\tau_W = q_\delta \quad (C_{f_\delta})_{c_r} \quad c_r \int_0^b \left\{ \int_0^c (x)^{-\frac{1}{2}} dx \right\} dy$$

where the surface has root chord c_r, span b, and $(C_{f_\delta})_{c_r}$ is evaluated at the root chord. The local chord length may be expressed as

$$c = c_r \left[1 - (1 - TR)\eta\right]$$

where TR is the taper ratio ($= c_t/c_r$) and η is the normalized span dimension ($= y/b$). Substituting this expression and completing the integration gives the shear force on the surface as

$$\tau_W = q_\delta \; A\,(C_{F_\delta})_{c_r} \; \frac{4}{3}\left[\frac{1 + TR + \sqrt{TR}}{(1 + TR)(1 + \sqrt{TR})}\right]$$

where $(C_{F_\delta})_{c_r}$ is the local, length-averaged skin-friction coefficient evaluated at the root-chord.

In the Arbitrary-Body Program the shear force is expressed in terms of an average chord length, $\bar{c}$;

$$\tau_W = q_\delta \; A\,(C_{F_\delta})_{\bar{c}}$$

where

$$\bar{c} = c_r \left\{\frac{4}{3} \left[\frac{1 + TR + \sqrt{TR}}{(1 + TR)(1 + \sqrt{TR})}\right]\right\}^2$$

Viscous-Interaction

As was explained in the previous section, the effect of planform on the shear force is not determined directly for flows with viscous-interaction but is included in the calculation of shear force without interaction. This procedure results in a slightly lower force but has the advantage of permitting a step-by-step build-up and comparison of the overall viscous forces. There is, however, an additional effect on the induced pressure due to planform shape which is accounted for.

The average pressure is obtained by integrating the local pressure over the surface:

$$\bar{P}_A = \frac{1}{A}\int P\,dA = \frac{1}{A}\int_0^b \left\{ \int_0^c P\,dx \right\} dy$$

$$= \frac{c_r b}{A}\int_0^1 \left\{ \int^{c/c_r} (P_o + m\lambda c_r \xi^{-\frac{1}{2}})\,d\xi \right\} d\eta$$

where $\xi = x/c_r$, the normalized streamwise coordinate.

Substituting the expressions for

$$A = \frac{c_r b}{2}(1 + TR)$$

and

$$c/c_r = 1 - (1 - TR)\eta$$

the integration is easily completed. The result is

$$\bar{P}_A = P_o \left\{ 1 + \frac{8}{3} B_{c_r} \left[\frac{1 + TR + \sqrt{TR}}{(1 + TR)(1 + \sqrt{TR})} \right] \right\}$$

where

$$B_{c_r} = \frac{m}{P_o}\lambda_{c_r}$$

The average pressure increment for the surface is then

$$\bar{P}_A - P_o = \frac{8}{3} m\lambda_{c_r} \left[\frac{1 + TR + \sqrt{TR}}{(1 + TR)(1 + \sqrt{TR})} \right]$$

which for $TR = 1$ reduces to the value previously given.

Turbulent Shear Force

Because of the nature of the assumed skin-friction formulas, a different approach than used for laminar flow is taken to obtain the turbulent shear force. The end result, however, is an approximate solution which is very similar to the laminar result. The shear force equation is derived as follows.

$$\tau_W = \int q_\delta \, C_{f_\delta} \, dA = q_\delta \int_0^b \left\{ \int_0^c C_{f_\delta} \, dx \right\} dy$$

$$= q_\delta b \int_0^1 c \, C_{F_\delta} \, d\eta$$

The variable of integration is transformed to the local chord-length Reynolds number in two steps. First in terms of the chord length c,

$$\tau_W = q_\delta \, b \int_{c_t}^{c_r} \frac{c \, C_{F_\delta}}{c_r(1 - TR)} \, dc$$

Next, the variable of integration is transformed to the incompressible Reynolds number, $Rc_i = F_{Rx}\left(\frac{\rho U c}{\mu}\right)_\delta$, and normalized with respect to root-chord values;

$$\tau_W = \frac{q_\delta \, b \, c_r \, (C_{F_\delta})_{c_r}}{(1 - TR)} \int_{TR}^{1} \left(\frac{Rc}{Rc_r}\right)_i \left(\frac{C_F}{C_{Fc_r}}\right)_\delta d\left(\frac{Rc}{Rc_r}\right)_i$$

Noting that the surface area is $A = \frac{c_r b}{2}(1 + TR)$, and also that $\left(\frac{C_F}{C_{Fc_r}}\right)_\delta = \left(\frac{C_F}{C_{Fc_r}}\right)_i$, the shear equation becomes

$$\tau_W = q_\delta \, A \, (C_{F_\delta})_{c_r} \left(\frac{2}{1 - TR^2}\right) \int_{TR}^{1} \left(\frac{Rc}{Rc_r}\right)_i \left(\frac{C_F}{C_{Fc_r}}\right)_i d\left(\frac{Rc}{Rc_r}\right)_i$$

With a simple power-law skin-friction formula this equation is easily evaluated;

$$\left(\frac{C_F}{C_{Fc_r}}\right)_i = \left(\frac{Rc}{Rc_r}\right)_i^{-\frac{1}{N}}, \quad \text{where } N \text{ is positive}$$

and

$$\tau_W = q_\delta \, A(C_{F_\delta})_{c_r} \left(\frac{2}{1 - TR^2}\right) \int_{TR}^{1} \left(\frac{Rc}{Rc_r}\right)^{1-\frac{1}{N}} d\left(\frac{Rc}{Rc_r}\right)_i$$

$$= q_\delta \, A(C_{F_\delta})_{c_r} \left(\frac{2}{2 - \frac{1}{N}}\right)\left(\frac{1 - TR^{2-\frac{1}{N}}}{1 - TR^2}\right)$$

For laminar flow $N = 2$ and it is easily verified that this expression is identical to the one previously presented.

In general, the skin-friction coefficient is not given by a simple power-law relationship and this is the reason for deriving the turbulent shear with the Reynolds number as the independent variable.

The use of the Sivells and Payne formula in the shear equation introduces a singlularity in the integrand and the function is nonintegrable. However, this singularity occurs at a Reynolds number much below the laminar cutoff and the shear equation may be integrated numerically. Several examples for the numerically determined integrand are shown in Figure 13. The upper-bound represented by laminar flow and a lower-bound represented by constant skin-friction are also shown. The curves are smooth and the area under each curve times the quantity $2/(1 - TR^2)$ is the factor by which the shear increases due to a tapered planform.

It may be observed from Figure 13, that even with a large variation of Reynolds number on the planform (for example, $Rc_r = 10^9$ to zero at the tip), the major contribution to the integral is obtained over the first decade ($Rc/Rc_r = 1.0$ to 0.1). In the case of the upper-bound (laminar flow) and the lower-bound ($N = \infty$) this contribution is 97 and 99 percent, respectively. This then, suggested the approximate approach of representing the Sivells and Payne formula in the integrand over the entire Reynolds number range by a local power-law fit obtained as the average over the first decade.

Thus, the shear on the surface is obtained from the power-law solution with the exponent parameter, N, given as (for Sivells and Payne);

$$N = \frac{\log Rc_r - 2}{0.8686}$$

Alternately, as was done for laminar flow, the shear force may be expressed in terms of an average chord, $\bar{c}$;

$$\tau_W = q_\delta A (C_{F_\delta})_{\bar{c}}$$

where

$$\bar{c} = c_r \left(\frac{Rc_r}{10^{3/2}} \right)^{Q-1}$$

and

$$Q = \left\{ \left(\frac{1 - TR^2}{1 - TR^{2 - \frac{1}{N}}} \right) \left(\frac{2 - \frac{1}{N}}{2} \right) \right\}^{\frac{1}{2}}$$

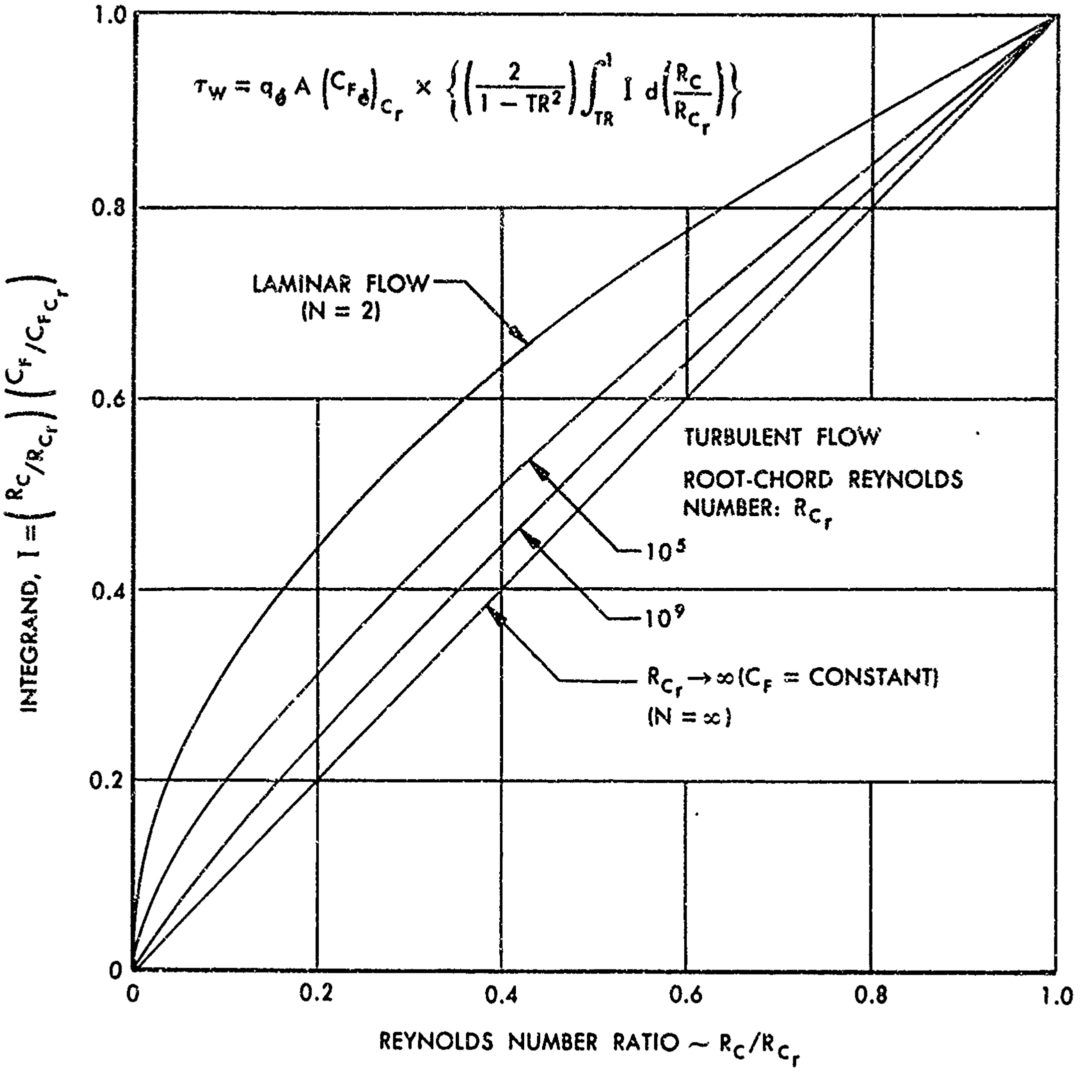


Figure 13. Planform Effect on Shear Force

Initial Surface Correction to Shear Force

When an initial surface is specified, the shear force is determined for the combined surface geometry, for the initial surface, and the difference obtained as the value for the surface of interest. This in effect is dealing with three surfaces which have the following characteristics (see sketch below):

1. Initial surface; Area A_1, maximum chord length L_1, taper ratio TR_1, and shear force τ_{W_1}.
2. Surface of interest; Area A_2, maximum chord length L_2, taper ratio TR_2, and shear force τ_{W_2}.
3. Combined surface; Area $A_3 = A_1 + A_2$, maximum chord length L_3, taper ratio TR_3, and shear force τ_{W_3}.

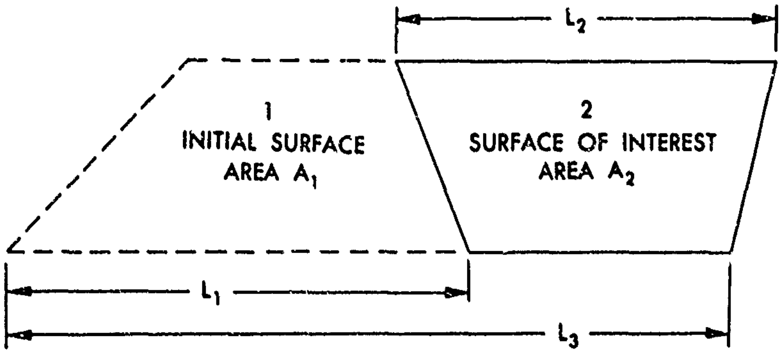
The shear force on surface 2 is

$$\begin{aligned}\tau_{W_2} &= \tau_{W_3} - \tau_{W_1} \\ &= q_\delta A_2 (C_{F_\delta} K_{VI})_3 \left\{ 1 - \frac{A_1}{A_2} \left[\frac{(C_F K_{VI})_1}{(C_F K_{VI})_3} - 1 \right] \right\}\end{aligned}$$

In the Arbitrary-Body Program this is compacted to the form

$$\tau_{W_2} = q_\delta A_2 (C_{F_\delta} K_{VI})_3 \ (1 - FF)$$

where FF has the mnemonic form factor or friction factor. Three possibilities are considered in determining the friction factor: (1) both surfaces laminar, (2) first surface laminar and second surface turbulent, and (3) both surfaces turbulent.



Initial Surface Correction to Induced Pressure

The average pressure on surface 2 is defined as follows:

$$P_2 = \frac{F_2}{A_2} = \frac{F_3 - F_1}{A_2} = \frac{P_3 A_3 - P_1 A_1}{A_2}$$

where F_i is the force on surface i. The average pressures on the initial surface and on the combined surface are given by

$$P_1 = P_o \left\{ 1 + \frac{8}{3} B_1 \left[\frac{1 + TR_1 + \sqrt{TR_1}}{(1 + TR_1)(1 + \sqrt{TR_1})} \right] \right\}$$

$$P_3 = P_o \left\{ 1 + \frac{8}{3} B_3 \left[\frac{1 + TR_3 + \sqrt{TR_3}}{(1 + TR_3)(1 + \sqrt{TR_3})} \right] \right\}$$

and the areas by

$$A_1 = bL_1 (1 + TR_1)/2$$

$$A_2 = bL_2 (1 + TR_2)/2$$

$$A_3 = bL_3 (1 + TR_3)/2$$

Substituting these expressions into the above definition and after some algebraic manipulation the result may be written as

$$\overline{P}_2 - P_o = \frac{8}{3} m\lambda_3 \left(\frac{L_3}{L_2}\right) \left[\frac{1+TR_3 + \sqrt{TR_3}}{(1+TR_2)(1+\sqrt{TR_3})} \right] \left\{ 1 - \left(\frac{L_1}{L_3}\right)^{\frac{1}{2}} \left(\frac{1+TR_1+\sqrt{TR_1}}{1+TR_3+\sqrt{TR_3}} \right) \left(\frac{1+\sqrt{TR_3}}{1+\sqrt{TR_1}} \right) \right\}$$

The length L_3 is defined as the maximum chord length of the combined surface, so as $L_1 \rightarrow 0$ it is readily verified that the pressure reduces to the same expression previously given for a single, tapered plate.

Viscous Force on Blunt Bodies

The earliest space capsules were designed with large spherical nose caps and flew ballistically at zero degrees angle of attack. For such vehicles, it was found that inviscid flow field calculations were adequate to predict the splash point. The later generation capsules were designed to fly at angle of attack to provide lift and it has been shown that viscous forces can have a significant effect on predicting the splash point. The theoretical solution, then, must provide some means for estimating the viscous effect.

The procedure included in the Arbitrary-Body Program is that developed by Goldberg of the General Electric Company (References 52 and 53). This method is given in the form of relatively simple correlation formulas in terms of the shock-layer Reynolds number and inverse density ratio. The method is applicable to the low density conditions associated with high altitude entry and is equally suited to real gas or ideal gas analysis.

The shear force in the stagnation region of a blunt-faced body is given as

$$\tau_W = \tau_{W_o} K_{VI}$$

where the shear without low density or viscous-interation effects is

$$\tau_{W_o} = \frac{q_\infty A \, 2 \cos \delta}{(1 - 0.495\sqrt{\epsilon})\sqrt{R_{e_s}}}$$

and δ is the surface impact angle,

ϵ is the inverse density ratio, $= (\rho_2/\rho_\infty)^{-1}$

R_{e_s} is the shock Reynolds number

$= \rho_2 U_2 R_B/\mu_2$

R_B is the body nose radius.

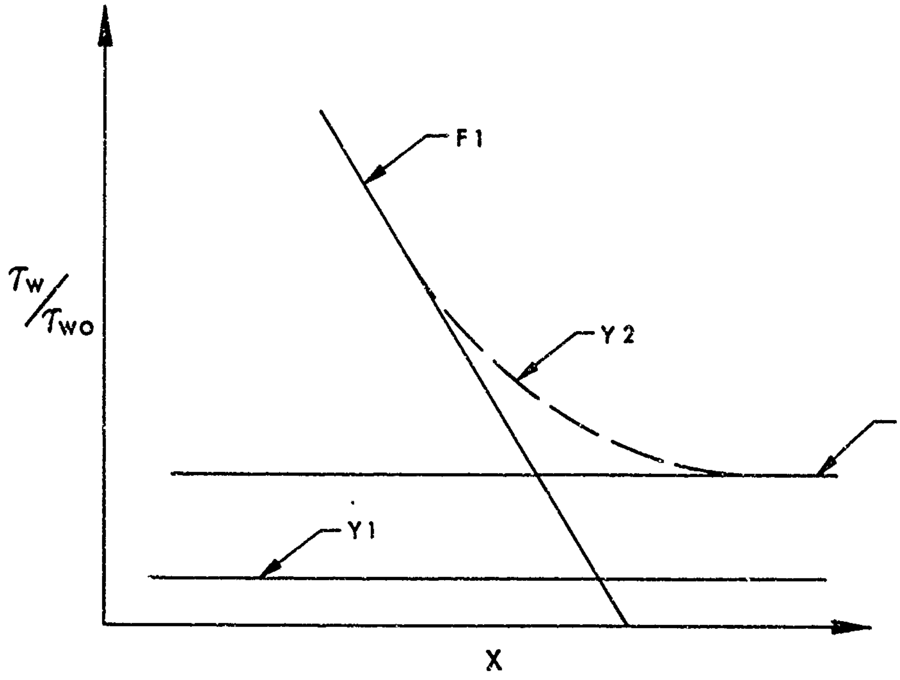
The viscous-interaction correction factor, $K_{VI} = \tau_W/\tau_{W_o}$, was obtained from higher-order analysis of the boundary-layer flow (Reference 52). The present authors have developed a correlation formula to represent these solutions in the Arbitrary-Body Program. This factor, a complicated function of both shock Reynolds number and density ratio, has been approximated by a combination of exponential transition functions of the type described by Grabau (Reference 54). These are

even transition: $y = \dfrac{1}{1 - \exp K(X - X_o)}$

odd transition: $y = \dfrac{1}{1 + \exp K(X - X_o)}$

These functions are essentially the kernels for the Bose-Einstein and for the Fermi-Dirac distribution functions, respectively, for the even and the odd transitions. The notation of transition is used since these functions represent the smooth transition from one asymptote to another; the even case does not have a point of inflection and the odd transition has a point of inflection.

In the present application, a correlation formula for the viscous-interaction parameter has been obtained by a combination of an even and odd transition function. The curve is considered to have three asymptotes (see the sketch below); Y1, F1, and F2. First an even transition is determined for the curve between F1 and F2 and this is designated Y2. Next, an odd transition is established between Y1 and Y2. The curves are adjusted through the values specified for the exponential constants, K, and the origin coordinates, X_o. Details of this procedure are given in Reference 54.



The correlation formulas developed for the present case are as follows.

Independent variable $X = \log (\epsilon^3 R_{e_s})$

$$F1 = A1 + B1(X)$$

$$A1 = 0.667$$

$$B1 = 1.1111$$

$$F2 = 1.0$$

$$Y1 = 0.0$$

$$Y2 = F1 + \frac{(1.0 - F1)}{1.0 - \exp\left[EVK\,(X - XOEV)\right]}$$

$$EVK = -1.80$$

$$XOEV = -0.3$$

$$\tau_W/\tau_{W_b} = \frac{Y2}{1.0 + \exp\left[ODK\,(X - XOOD)\right]}$$

$$ODK = -2.0$$

$$XOOD = AOD + BOD(\log \epsilon)$$

$$AOD = 1.0$$

$$BOD = 3.2907$$

Comparison of this correlation and the boundary-layer solutions are shown in Figure 14. The general shape of the curves is well represented by the correlation, although some accuracy is lost, particularily at the peak of the $\epsilon = 0.04$ curve. It would be possible to tailor-fit each of the ϵ-curves through further variation in F1, the exponential constants and origin coordinates. However, since only three solutions were available, the determination of more accurate fits was not deemed justified. Three additional ϵ-curves are given on the figure to demonstrate the behavior of the correlation formula.

An example of this technique is shown in Figure 15 were the predicted values of lift coefficient for the Gemini space capsule are compared with experimental results (Reference 55). The modified Newtonian calculation has been performed for the entire shape and the viscous calculations (broken lines) made only for the blunt face. The present comparison, due to the limited data used, may not completely justify the method, but it does show the significance of the viscous contributions.

The blunt-body viscous calculations are not limited to entry capsules but may be applied to any blunt portions of a vehicle (e.g., leading edges). The method is primarily dependent on impact angle and, therefore, the detailed inviscid geometry is used. It is for this reason that the method has been included as one of the inviscid force options. Zero contribution is assumed for shadow flow.

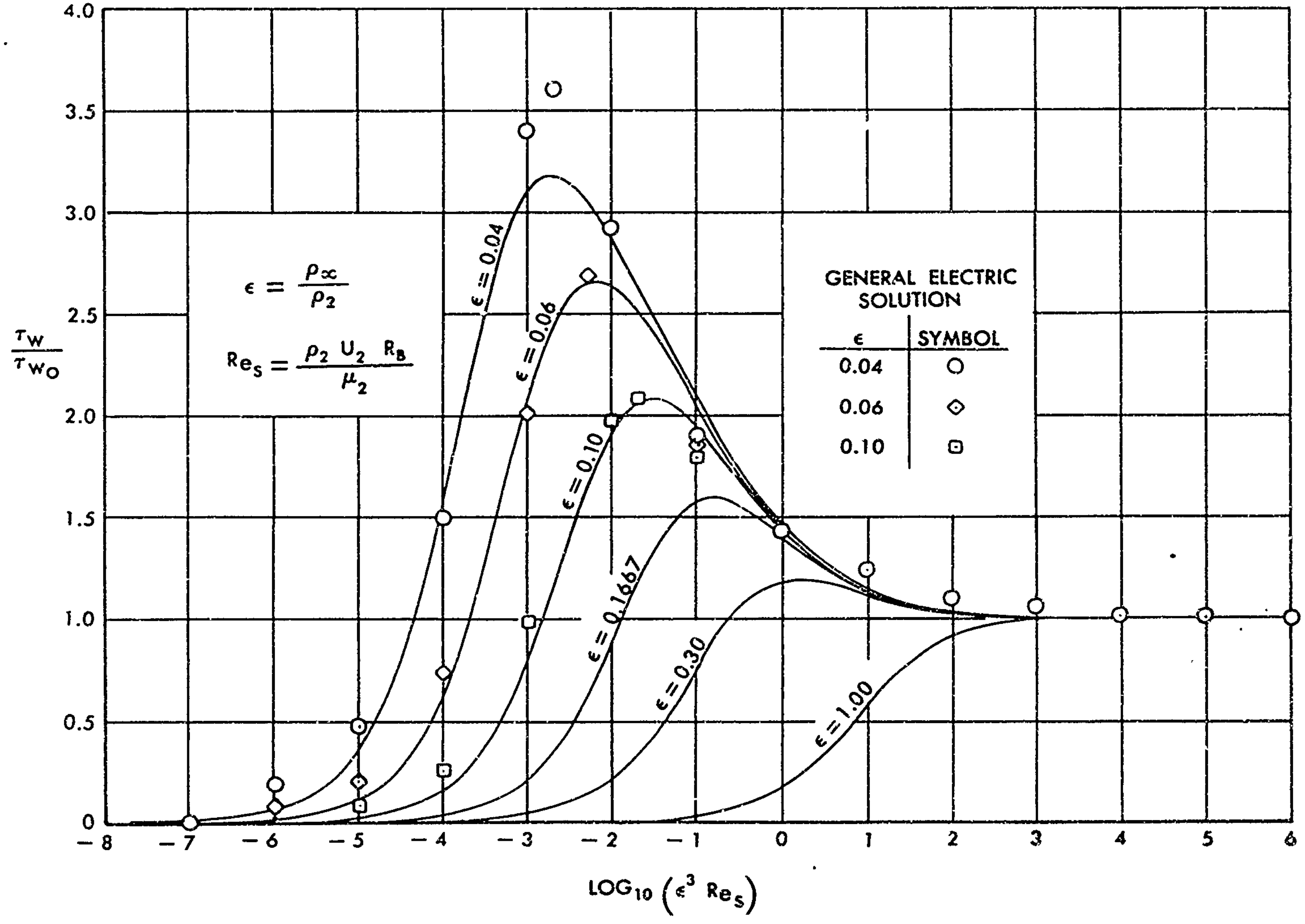


Figure 14. Low Density Correction to Blunt-Body Viscous Forces

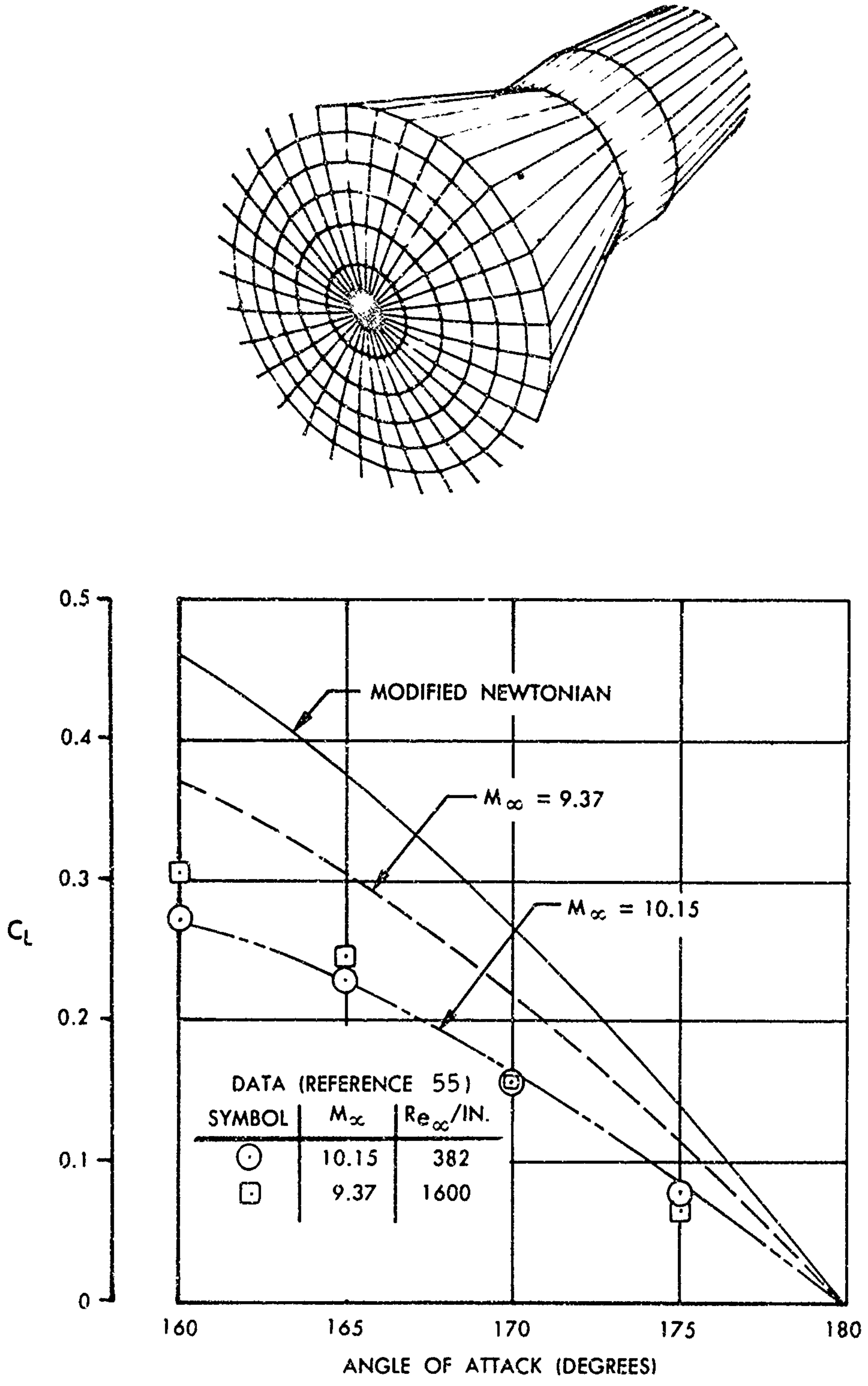


Figure 15. Gemini Lift Coefficient Comparison

Control Surface Forces

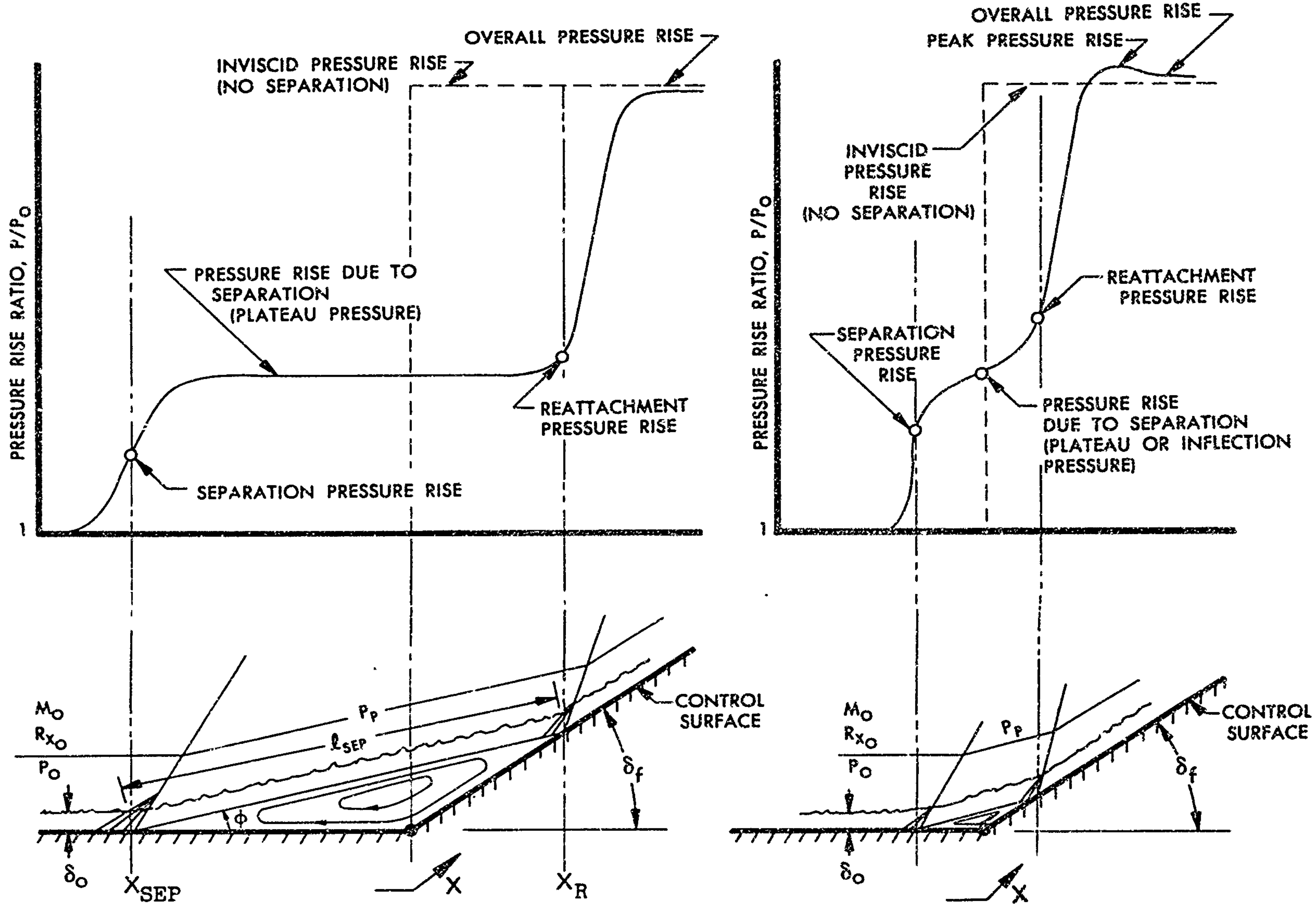
An important feature of the flow about hypersonic control surfaces is the boundary-layer flow separation phenomenon. Flow separation on the control surface and on the surface of the vehicle ahead of the control can have a pronounced influence on control effectiveness. This is a very difficult problem to analyze theoretically with any degree of accuracy. However, the use of a simplified flow model and empirical boundary-layer separation data will allow the solution of this problem with sufficient accuracy for most preliminary design purposes.

The basic factors involved in the control surface flow separation phenomena are illustrated in Figure 16. In these flow models the pressure in the separated region is taken to be the plateau pressure. This region is well defined for laminar flow and may affect a large portion of the vehicle surface on, and ahead of, the control flap. For turbulent flow the separated region is much smaller but, although a true pressure plateau may not exist, a flow model using the inflection pressure will produce useful results for most purposes.

The boundary layer separation at point X_{SEP} is termed a free-separation and the separation angle in this flow model depends only on the local Mach number (M_o) and Reynolds number (R_{x_o}) ahead of the separation region. The extent of the separation region as indicated by the separation length ℓ_{SEP} is determined by the strength of the shock at the flow reattachment point X_R. As the control surface deflection angle $_f$ is increased, the flow turning angle at the reattachment point increases, the final overall pressure rise after the reattachment shock increases, more flow is forced back up the boundary layer and into the separation region, and the length of the separation region increases to accommodate the greater flow in the separated area. The length of the separation region continues to increase until the reattachment point reaches the control surface trailing edge.

Present theoretical methods are completely inadequate for the prediction of separation effects; complete reliance, therefore, must be placed on empirical correlations. The relationships used in this program were taken from the work of Popinski and Ehrlich in Reference 56. The basic approach used in the Arbitrary-Body Program is essentially the same as this reference. There are, however, a few significant differences in the details of the program application. Since the program can perform shock-expansion calculations this capability has been exploited in the flow-separation application. Also, since all of the calculations are carried out by the computer program rather than being done by hand it is possible to use a strip theory approach that permits a rough assessment of the three-dimensional effects. The computations within the program assume an ideal gas.

The application of the flow-separation criteria in this program also has another very significant different from Reference 56. The program uses shock-expansion theory to determine the flow separation pressure changes and then applies these separation corrections to the pressures calculated for the vehicle, using any of the other force methods. This process is illustrated in Figure 17.



LAMINAR FLOW

TURBULENT FLOW

Figure 16. Wall Pressure Distribution in the Vicinity of Separation

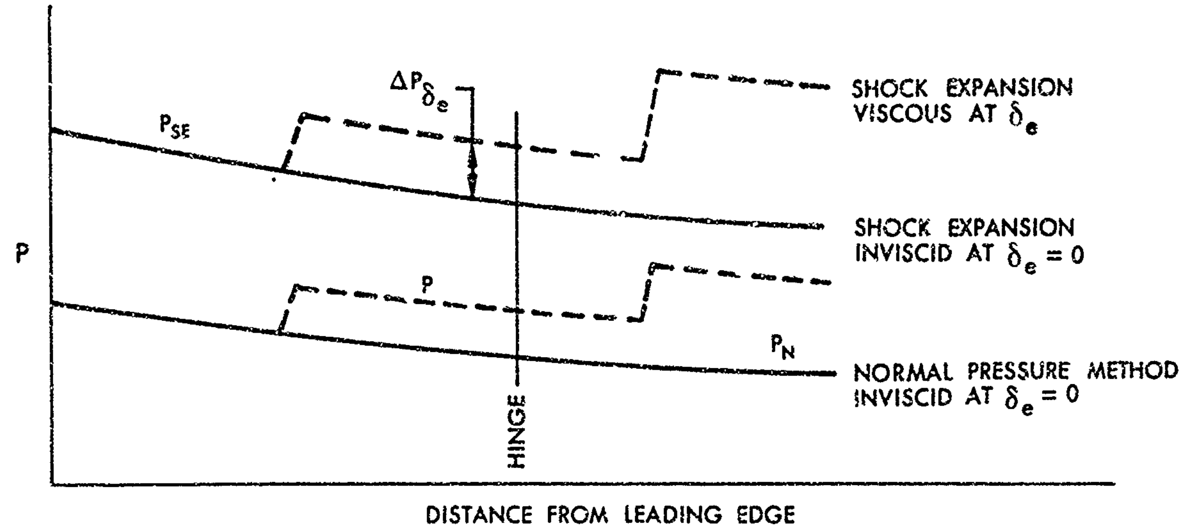


Figure 17. Correction of Normal Pressure Method Results for Separation Effects

The final surface pressure is calculated by the relationship shown below.

$$P = P_N + \left(\frac{\Delta P_{\delta_e}}{P_{SE}}\right) \left(P_N\right)$$

This technique not only gives a smooth trend of data as the deflection angle goes to zero, but also insures that it will match the basic vehicle results using whatever normal force method has been selected.

The essential features of the flow-separation calculations are given below. The notion is maintained consistent with Reference 56.

The calculation of flow-separation effects uses a three-cycle process. On the first cycle a streamwise strip of elements is analyzed using the shock-expansion method to determine local conditions at the hinge point. The inviscid pressure rise onto the flap is calculated also and compared with the incipient separation criteria. The transition Reynolds number is input to the program.

On the next cycle the shock-expansion method is again applied to the same streamwise strip of elements, only this time separation effects are accounted for. This is accomplished by checking at each element to see if the flow separation point has been reached, and by calculating the new pressures. Again, the equations in Reference 56 were used in these computations. For other reviews of the separation problem see References 57, 58, and 59.

On the third cycle of calculations along the streamwise strip of elements the pressures are calculated using the normal input pressure calculation method (IMPACT and ISHAD). At the same time, these pressures are corrected by the flap deflection and flow separation pressure increments.

The above discussion gave a brief outline of the techniques involved in the flow separation calculations. Of course, a thorough study of the listing of the FLOSEP subroutine is necessary to obtain a thorough understanding of the methods used. The following description of the equations used will assist in this study.

The basic purpose of the first flow separation analysis cycle is to determine the local flow properties at the hinge-line element, and with this information, to determine the pressure rise in going from the fore-surface element at the hinge line to the first element on the flap. This pressure rise is then compared with the empirical incipient pressure rise equation to determine if the flow separates.

On the first FLOSEP cycle the flow properties on each element in the streamwise strip are calculated by the shock-expansion method. This gives complete freedom to analyze curved vehicle surfaces in front of a flap (the fore-surface) and also on the flap itself. In many such cases this approach will give useful results even though the empirical separation criteria equations used are derived from tests on flat surfaces only.

When the hinge-line element is reached on the first FLOSEP cycle the program checks for flow separation. The flow turning angle at the hinge line caused by the control deflection is calculated from the following relationship.

$$\delta_f = \sqrt{(N_Y N_{Z_H} - N_Z N_{Y_H})^2 + (N_Z N_{X_H} - N_X N_{Z_H})^2 + (N_X N_{Y_H} - N_Y N_{X_H})^2}$$

where

N_X, N_Y, N_Z = the direction cosines of the first element on the flap.

N_{X_H}, N_{Y_H}, N_{Z_H} = the direction cosines of the hinge-line element.

Note that when the flap is not a plane surface the flow deflection angle calculated by the above equation will be different than the program input control surface deflection angle.

The inviscid pressure rise at the flap is calculated by the shock-expansion method (oblique shock or Prandtl-Meyer expansion as the case may be). This pressure rise is then compared with the incipient pressure rise criteria given in Reference 56.

$$(C_P)_{\alpha\, inc} = \frac{2.03\,(M_\alpha^2 - 1)^{-0.306}}{(R_{e_{\alpha_{HL}}})^{1/4}} \qquad \text{Laminar}$$

$$(C_P)_{\alpha\, inc} = \frac{2.2}{(R_{e_{\alpha_{HL}}})^{1/10}} \qquad \text{Turbulent}$$

where

$(C_{P_{\alpha\,inc}})$ = the pressure rise required to cause incipient separation.

M_α = the local Mach number at the hinge line.

$R_{e_{\alpha_{HL}}}$ = the Reynolds number at the hinge line based on the local hinge-line flow properties and the distance from the leading edge.

Subsequent FLOSEP calculation cycles require a value for the flap chord length (C_{flap}). This length is taken as being the distance from the hinge line to the flap trailing edge as given by the following equation.

$$C_{flap} = \sqrt{(X_{TE} - X_{HL})^2 + (Y_{TE} - Y_{HL})^2 + (Z_{TE} - Z_{HL})^2}$$

where

X_{TE}, Y_{TE}, Z_{TE} = the average values of the X, Y, Z element coordinates at the trailing edge.

Viscous separation effects are calculated on the second FLOSEP calculation cycle. The general procedure used differs from the method of Reference 56 in that no iteration process is used to determine the separation point. Since the vehicle surface is not restricted to flat surfaces this technique is not possible. Instead, as the local flow properties on each stream-wise element are calculated a check is made with the appropriate equations to see if the separation point has been reached. When flow separation is indicated on a given element a linear interpolation of parameters between the last non-separated element and the separated-element is used to determine the exact point and conditions at the separation.

The following calculations are required to provide information for the check for flow separation. The local Reynolds number at the element centroid is given by

$$R_{e_{\alpha X_o'}} = X_{LE}\,(R_{e_\alpha}/\,ft)$$

where

X_{LE} = the distance from the leading edge to the element centroid.

$R_{e_\alpha}/\,ft$ = the Reynolds number per foot based on the local element flow conditions.

The plateau pressure rise due to separation is given by the following equations.

$$(C_{P_\alpha})_P = \frac{1.56\,(M_\alpha^2 - 1)^{-0.262}}{(R_{e_{\alpha X_o'}})^{1/4}} \qquad \text{Laminar flow}$$

$$(C_{P_\alpha})_P = \frac{1.91\,(M_\alpha^2 - 1)^{-0.309}}{(R_{e_{\alpha X_o'}})^{0.1}} \qquad \text{Turbulent flow}$$

The ratio of the plateau pressure to the local element pressure upstream of the separation is given by

$$P_P/P_o = 0.7\,M_\alpha^2\,(C_{P_\alpha})_P + 1.0$$

The ratio of the distance from the start of separation to the hinge line (d_1), and the local boundary layer thickness (δ_o) is given by

$$d_1/\delta_o = 5.69 \times 10^5\,M_\alpha^{-4.1}\,(P_P/P_o - 1)^{3.5} \qquad \text{Laminar flow}$$

$$d_1/\delta_o = 1.1 \times 10^6 \left[M_\alpha^{-1.67}\,(P_P/P_o - 1)\right]^{8.55} \qquad \text{Turbulent flow}$$

The calculation of the boundary layer thickness requires the local surface Reynolds number per unit length based on the reference condition ($R_{e_\alpha}^*/ft$). This parameter is obtained by the temperature subroutine (TEMP) used in the skin friction calculations. The surface wall temperature required to find the Reynolds number may either be determined by the temperature routine or input. The same options used in the viscous force calculations are available to FLOSEP.

The boundary layer thickness is given by the following equations.

$$\frac{\delta_o}{\sqrt{X_{LE}}} = \frac{5.2}{\sqrt{R_{e_\alpha}^*/ft}} \qquad \text{Laminar}$$

$$\frac{\delta_o}{X_{LE}^{6/7}} = \frac{0.154}{(R_{e_\alpha}^*/ft)^{1/7}} \qquad \text{Turbulent}$$

From the above equations for d_1/δ_o and δ_o/X_{LE} we may obtain the distance from the start of separation to the hinge line (d_1). The separation distance parameters are shown in Figure 18 as taken directly from Reference 56.

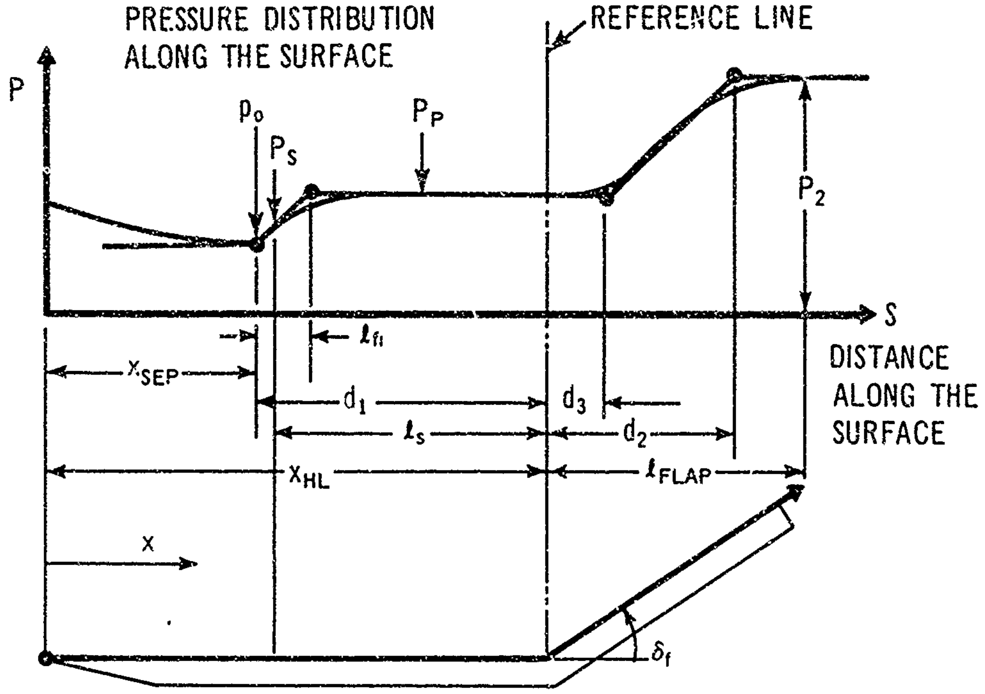


Figure 18. Definition of Interaction Parameters for Separated Flow

The check to see if the flow separation point has been reached is accomplished as follows.

$$X_{SEP} = X_{LE_H} - d_1$$

$$\Delta X_{SEP} = X_{LE} - X_{SEP}$$

If $X_{LE} \geq X_{SEP}$, then the separation point has been reached.

where

X_{LE_H} = the distance from the leading edge to the hinge line.

X_{SEP} = the distance from the leading edge to the separation point.

The exact flow separation point and the attendant flow properties are calculated by a linear interpolation between the data on the element before the separation and the actual separation element.

The procedure used in calculating the other required flow separation geometric parameters and the separation pressures is outlined below.

The ratio of the free interaction length (ℓ_{fi}) to the boundary layer thickness (δ_o) is obtained from the following equation.

$$\frac{\ell_{fi}}{\delta_o} = 2.47 \times 10^5 \; M_\alpha^{-4.2} \; (P_P/P_o - 1)^{3.45} \qquad \text{Laminar}$$

$$\frac{\ell_{fi}}{\delta_o} = 1.84 \times 10^4 \left[\frac{P_P/P_o - 1}{M_\alpha^{1.325}} \right]^{-8.4} \qquad \text{Turbulent}$$

The free interaction length is now calculated.

$$\ell_{fi} = (\ell_{fi}/\delta_o)\; \delta_o$$

If the flow is separated on the first element of a strip the parameter ℓ_{fi} is set equal to 0.0. Also, the parameter $X_{LE_{SEP}}$ is set equal to 0.0.

The ratio of the downstream interaction length to peak pressure (d_2), to the upstream interaction length (d_1) is given by the following equations.

For Laminar Flow

$$\frac{C_{flap}}{d_1} \geq 1 : \frac{d_2}{d_1} = .545 - .04\,(M_\alpha \delta_f)$$

$$\frac{C_{flap}}{d_1} \leq 0.25 : \frac{d_2}{d_1} = .273 - .02\,(M_\alpha \delta_f)$$

$$M_\alpha \delta_f \geq 5 : \frac{d_2/d_1}{\sqrt{\Gamma}} = .344$$

where

$$\Gamma = \begin{cases} \dfrac{C_{flap}}{d_1}, \text{ if } .25 \le \dfrac{C_{flap}}{d_1} \le 1 \\ 1, \text{ if } \dfrac{C_{flap}}{d_1} \ge 1 \\ .25, \text{ if } \dfrac{C_{flap}}{d_1} \le .25 \end{cases}$$

For Turbulent Flow

$$\frac{C_{flap}}{d_1} \ge 1 \; : \; d_2/d_1 = 1.16 - 0.33 \; M_\alpha \delta_f$$

$$\frac{C_{flap}}{d_1} \le 0.25 \; : \; d_2/d_1 = 0.58 - 0.165 \; M_\alpha \delta_f$$

$$M_\alpha \delta_f \ge 2.4 \; : \; d_2/d_1 \; \frac{1}{\sqrt{\Gamma}} = 0.37$$

where

$$\Gamma = \begin{cases} 1, \text{ for } \dfrac{C_{flap}}{d_1} \ge 1 \\ \dfrac{C_{flap}}{d_1}, \text{ for } 1 \ge \dfrac{C_{flap}}{d_1} \ge 0.25 \\ 0.25, \text{ for } \dfrac{C_{flap}}{d_1} \le 0.25 \end{cases}$$

From the above equations the downstream interaction length to the peak pressure (d_2) may now be calculated.

The angles associated with the separation are given by

$$\theta = \sin^{-1} \left[(C_{P_\alpha})_P \frac{\gamma + 1}{4} + \frac{1}{M_\alpha^2} \right]$$

$$\tan \phi = 1 \Big/ \left[\left(\frac{2.0}{(C_{P_\alpha})_P} - 1.0 \right) \frac{\sin \theta}{\cos \theta} \right]$$

where

ϕ = the flow deflection caused by separation.

θ = shock angle for the flow turning angle, ϕ.

If the flow has separated at the leading element the angles are given by

$$\phi = \tan^{-1}\left[\frac{d_2 \sin \delta_f}{d_1 + d_2 \cos \delta_f}\right]$$

The ratio of the downstream interaction length to pressure rise (d_3), to the upstream interaction length (d_1) is given by

$$\frac{d_3}{d_1} = \left(\frac{\tan \phi}{\tan \delta_f - \tan \phi}\right) \frac{1}{\cos \delta_f}$$

and

$$d_3 = (d_3/d_1)\, d_1$$

If the distance d_3 is greater than the flap chord length, C_{flap}, the separated region as determined from the above equation extends beyond the end of the flap. When this condition occurs the distance d_3 is set equal to the flap chord, C_{flap}, and a new value for d_1 calculated based on conditions that existed at the originally calculated separation point.

$$d_1 = d_3/(d_3/d_1)$$

This value for d_1 will be smaller than the original value and will give a new flow geometry model with the same flow turning angle, ϕ, but with the separated region reduced to extend to the exact flap trailing edge point.

The plateau pressure caused by the separation turning angle ϕ, ($C_{P_{I_P}}$), is calculated by the oblique shock compression subroutine.

The flow turning angle in going from the plateau pressure region to the final peak flap pressure area is found from

$$\phi_2 = \delta_f - \phi$$

The resulting peak flap pressure ($C_{P_{I_2}}$) is also calculated by the oblique shock compression subroutine.

The flow separation pressures are distributed on the fore-surface and the flap by using the following equations.

If $X_{LE} \le X_{LE_{SEP}}$ $\qquad C_{P_{SEP}} = C_{P_{I_P}}$

If $X_{LE} \ge X_{LE_{SEP}}$ and $< (X_{LE_{SEP}} + \ell_{fi})$

$$C_{P_{SEP}} = \left(\frac{C_{P_{I_P}} - C_{P_X}}{\ell_{fi}}\right) X_{LE} + C_{P_X} - \left(\frac{C_{P_{I_P}} - C_{P_X}}{\ell_{fi}}\right) X_{LE_{SEP}}$$

where

C_{P_X} = the surface pressure at the separation point.

The following equations are used to distribute the separation pressures on the flap.

If $X_{LE} < (X_{LE_H} + d_2)$ $\qquad C_{P_{SEP}} = C_{P_{I_P}}$

If $X_{LE} > (X_{LE_H} + d_3)$ and $< (X_{LE_H} + d_2)$

$$C_{P_{SEP}} = \left(\frac{C_{P_{I_2}} - C_{P_{I_P}}}{d_2 - d_3}\right) (X_{LE} - X_{LE_H} - d_3) + C_{P_{I_P}}$$

For $d_2 > C_{flap}$ $\qquad C_{P_{SEP}} = C_{P_{I_P}}$

If $d_3 > C_{flap}$ $\qquad C_{P_{SEP}} = C_{P_{I_P}}$

If $X_{LE} \ge (X_{LE_H} + d_2)$ $\qquad C_{P_{SEP}} = C_{P_{I_2}}$

At the end of the second flow separation cycle the above pressure coefficients are converted to pressure with the following equation.

$$P_{SE_{vis}} = \left[C_{P_{SEP}} \frac{\gamma}{2} M_\infty^2 + 1.0\right] P_\infty$$

where

P_∞ = the free stream pressure.

M_∞ = the free stream Mach number.

$P_{SE_{vis}}$ = the pressure on the surface using shock-expansion methods and including viscous separation effects.

The purpose of the third cycle of calculations down a strip of elements is to determine the basic surface pressures using the normal program pressure calculation method (i. e., Newtonian, tangent-cone, etc.), and to determine the final surface pressures including the viscous separation effects. For this cycle the control surface is set to the undeflected position. The final surface pressure is given by

$$P = P_N + \left(\frac{\Delta P_{\delta_e}}{P_{SE}}\right) P_N$$

where

P = the final surface pressure including control surface effects.

P_N = the surface pressure calculated by the normal program input pressure calculation method.

ΔP_{δ_e} = the change in surface pressure due to control surface deflection and including separation effects.

P_{SE} = the surface pressure using shock-expansion methods without the separation effects.

Typical results obtained with the above analysis techniques are shown in Figure 19.

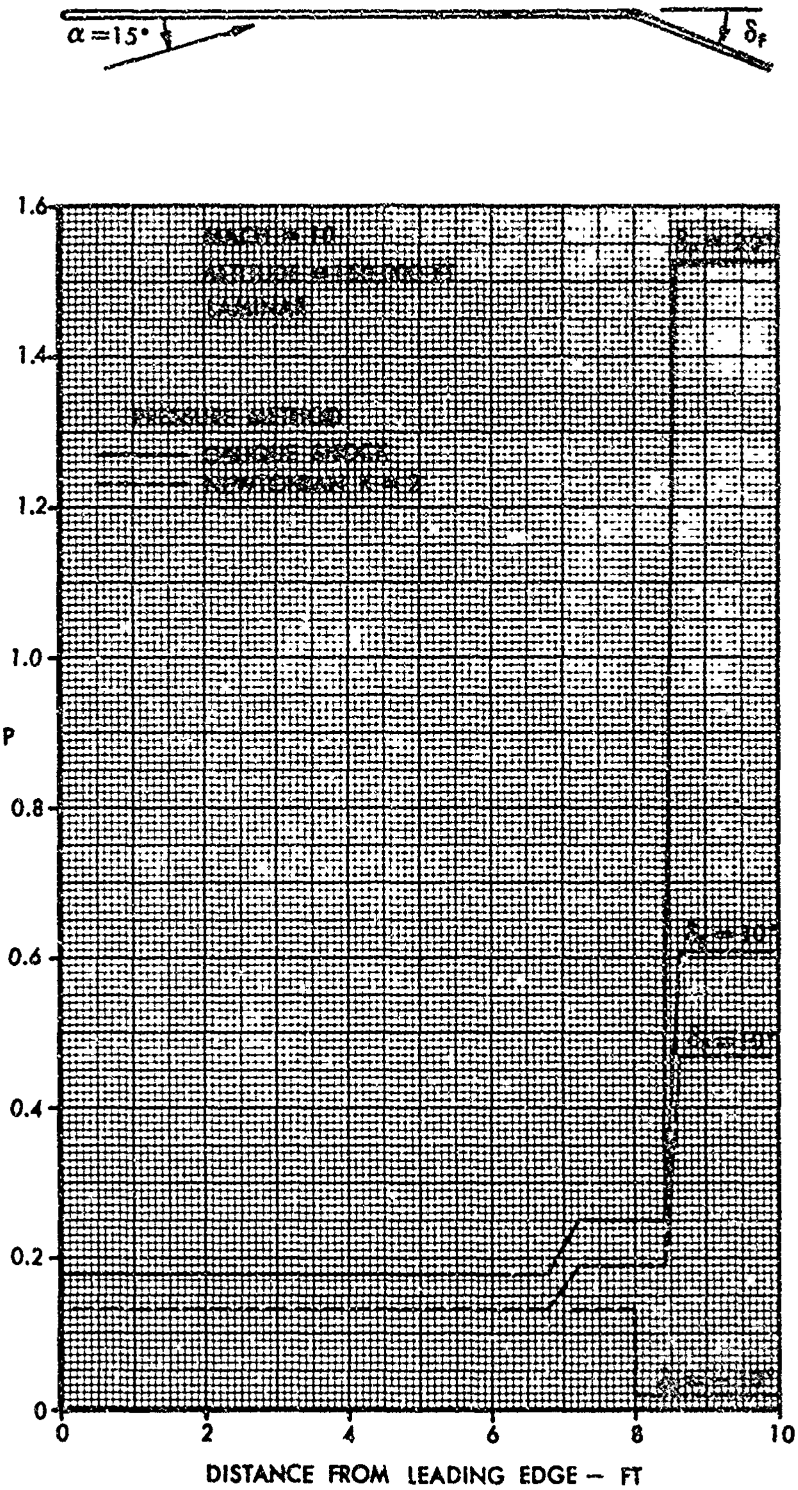


Figure 19. Effect of Flow Separation on Surface Pressure

Propulsion Effects

The operation and design of an air-breathing propulsion system of a hypersonic vehicle can have a strong influence on the vehicle stability and control characteristics. For some aircraft, such as scramjet-powered vehicles, the engine, including the inlet and exhaust systems, may be highly integrated into the vehicle design. For these configurations the bookkeeping system as to what is engine and what is airplane is no longer easy to resolve. A detailed analysis of these problem areas is obviously beyond the scope of this program. These problems must be solved by detailed engine-airframe studies.

It is important, however, that the Arbitrary-Body Program be capable of properly using the results from these propulsion system studies in evaluating a total vehicle's stability characteristics. The approach used is outlined in the following discussion.

In investigating the propulsion effects on hypersonic stability it is usually desirable to examine each of the various components of the engine thrust system. The equations for a general air-breathing propulsion system are given below.

$$T = \dot{m}_a (V_2) + \dot{m}_f V_2 + (p_2 - p_o) A_2$$

$$R = \dot{m}_a (V_1) + (p_1 - p_o) A_1$$

where

T = gross thrust

R = ram drag

$\dot{m}_a$ = mass flow of air through the engine system

$\dot{m}_f$ = mass flow of fuel added to the stream

V_1 = flow velocity at the forward flow control boundary

V_2 = flow velocity at the rearward (exhaust) flow control boundary

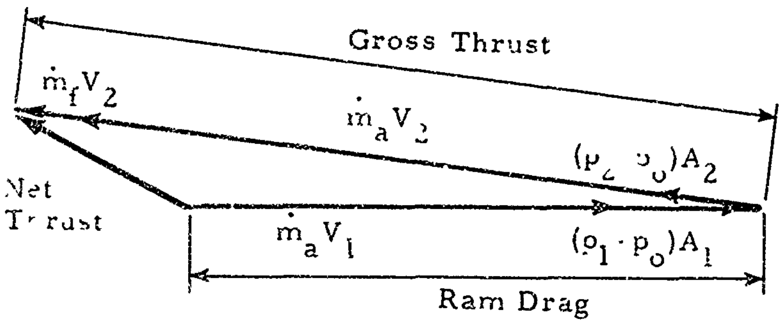
p_o = reference pressure

p_1 = pressure at control boundary 1

p_2 = pressure at control boundary 2

A = area

The vector relationships for a simple engine system are illustrated in the diagram below



The propulsion system has two main influences on a vehicle's stability characteristics. First, the engine ram drag and gross thrust vectors create moments about the vehicle center of gravity. Second, the exhaust jet may at times expand onto the aft surfaces of the vehicle and alter the local pressure distributions. The numerical values of the parameters involved depend upon the engine-airframe bookkeeping system adopted. The final result, however, should be the same under any system. Any given bookkeeping system serves only to insure that all factors are properly included and that no factors are included twice.

The engine related forces are input to the program in the form of vectors positioned in space. The input information includes the magnitude of the force in pounds, its point of action on the vehicle (in the vehicle X, Y, Z coordinate system), and its direction. The direction is given by the force vector direction cosines. Any number of vectors may be used.

The force vectors are converted into vehicle coefficients by the following equations.

$$\Delta C_A = F(-N_X)/(qS_{ref})$$

$$\Delta C_Y = F(-N_Y)/(qS_{ref})$$

$$\Delta C_N \quad F(N_Z)/(qS_{ref})$$

$$\Delta C_\ell \quad \Delta C_Y(Z_{cent} - Z_{cg})/SPAN$$

$$+ \Delta C_N(Y_{cent} - Z_{cg})/SPAN$$

$$\Delta C_M = \Delta C_N (X_{cent} - X_{cg})/MAC$$

$$+\Delta C_A (Z_{cent} - Z_{cg})/MAC$$

$$\Delta C_N = \Delta C_Y (X_{cent} - X_{cg})/SPAN$$

$$-\Delta C_A (Y_{cent} - Y_{cg})/SPAN$$

where

F = force vector in pounds

N_X, N_Y, N_Z are the direction cosines of the force vector

q = free stream dynamic pressure

These coefficients are converted to the lift and drag directions by the standard transformation equations previously discussed.

Dynamic Stability Derivatives

The dynamic stability derivatives due to pitching velocity (C_{m_q}) and vertical acceleration ($C_{m_{\dot{\alpha}}}$) are important in the damping of the short-period stability mode. For flight at hypersonic speeds the derivative C_{m_q} provides the major part of the damping since $C_{m_{\dot{\alpha}}}$ is usually quite small.

The derivative C_{m_q} is the change in pitching moment coefficient with varying pitch velocity and is commonly referred to as the pitch damping derivative. This derivative represents the effect of rotation of the vehicle about a spanwise axis at constant angle of attack such as in a steady pull-up. Because the vehicle is rotating, different parts of the vehicle have different velocities relative to the free-stream depending upon their distance from the center of rotation. This is essentially a steady-state problem and may be solved by the use of steady flow concepts. The common definition for C_{m_q} is

$$C_{m_q} = \frac{\partial C_m}{\partial\left(\frac{q\bar{c}}{2V}\right)} \quad .$$

where

C_m = pitching moment coefficient

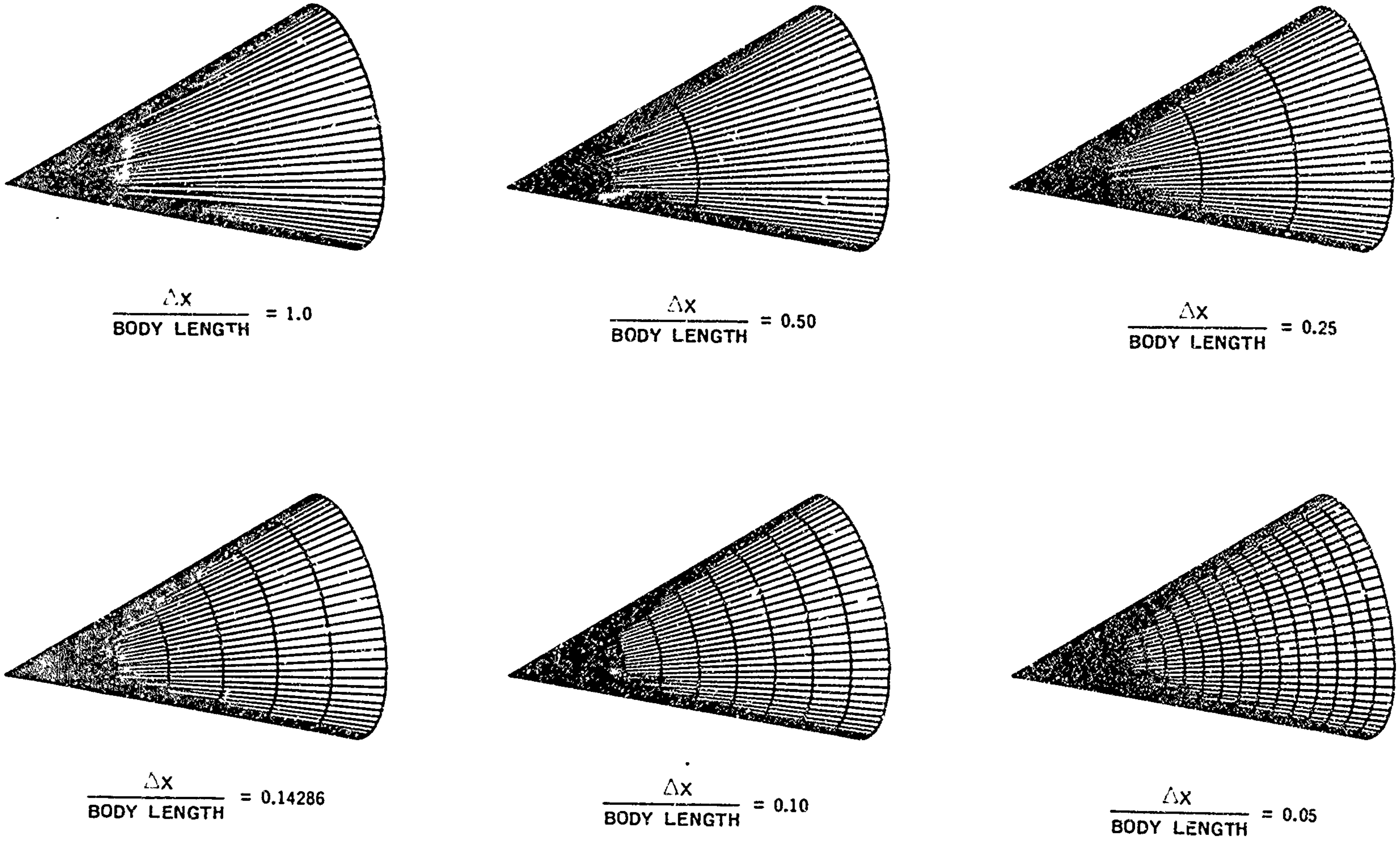
q = pitching rate

$\bar{c}$ = reference chord for moment coefficients (frequently the mean aerodynamic chord)

V = flight velocity

The method used in the Arbitrary Body Program to calculate this derivative has been presented earlier in this report and will not be repeated again in this section. The basic approach used involves the calculation of the local relative flow velocity for each part of the vehicle depending upon its distance from the center of rotation and the rotation rate. Once the local velocity direction is known the surface pressure is calculated using any of the methods available in the progra. as desired (except the shock-expansion method).

The results of the rotational derivative calculations depends upon the amount of detail used in the geometrical description of a shape. This effect is illustrated in Figures 20 through 23. These figures contain the results of the C_{m_q} calculations for a cone and for a wedge. The geometrical representations used are shown in Figures 20 and 21. The results obtained with different amounts of geometry detail in the longitudinal direction (ΔX/body length) are shown in Figures 22 and 23. These figures show that the program calculated values of C_{m_q} are within less than one percent of the exact analytical results when the shape is represented with longitudinal divisions of 10 percent of body length or less. It is evident from these results that the normal definition of a vehicle as used to give accurate static coefficients is also quite adequate for the dynamic derivatives.



$\frac{\Delta x}{\text{BODY LENGTH}} = 1.0$

$\frac{\Delta x}{\text{BODY LENGTH}} = 0.50$

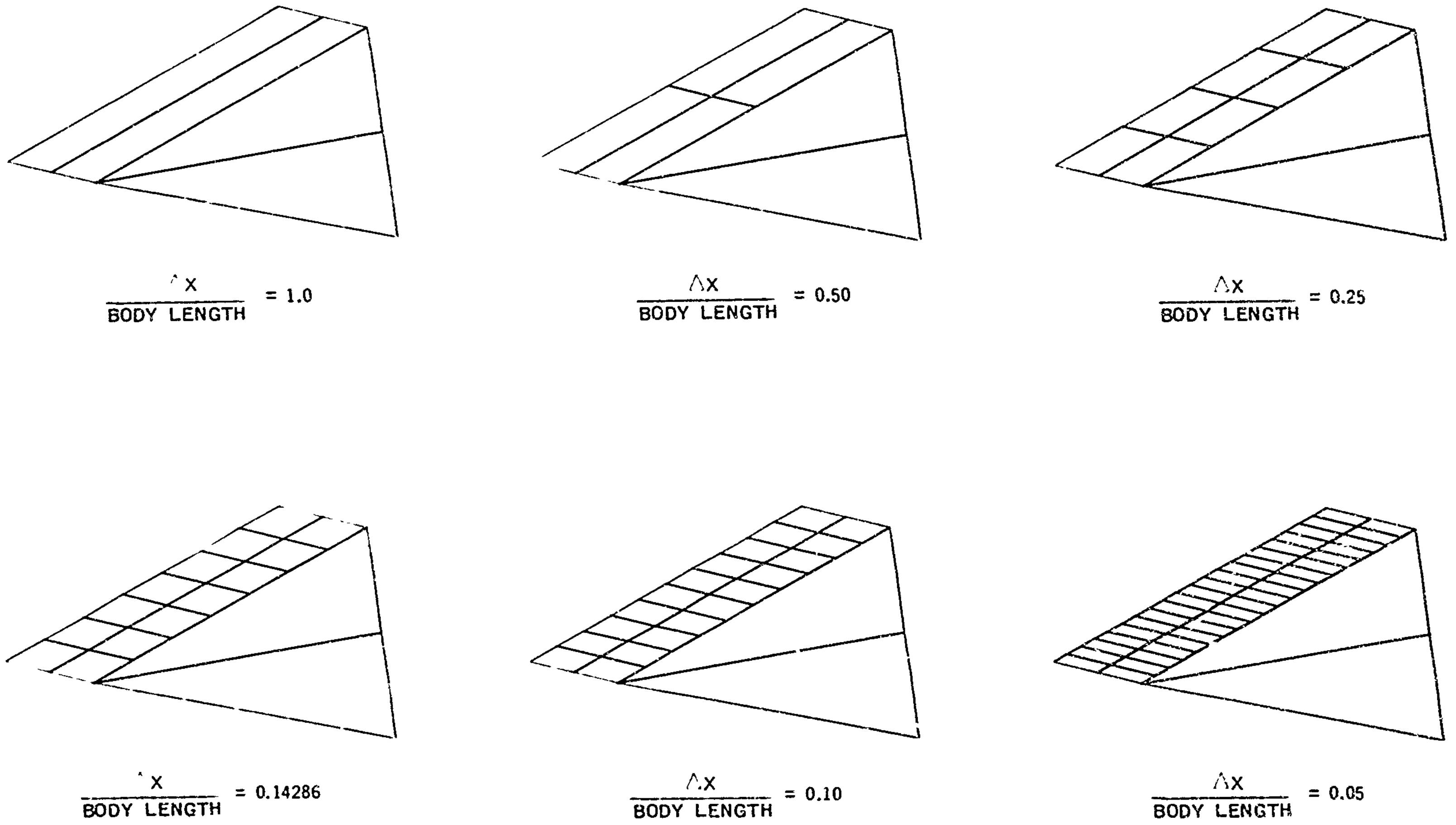
$\frac{\Delta x}{\text{BODY LENGTH}} = 0.25$

$\frac{\Delta x}{\text{BODY LENGTH}} = 0.14286$

$\frac{\Delta x}{\text{BODY LENGTH}} = 0.10$

$\frac{\Delta x}{\text{BODY LENGTH}} = 0.05$

Figure 20. 20° Half Angle Cone. Graphical Representation of Various $\frac{\Delta X}{\text{Body Length}}$ Selections



$\frac{\Delta X}{\text{BODY LENGTH}} = 1.0$

$\frac{\Delta X}{\text{BODY LENGTH}} = 0.50$

$\frac{\Delta X}{\text{BODY LENGTH}} = 0.25$

$\frac{\Delta X}{\text{BODY LENGTH}} = 0.14286$

$\frac{\Delta X}{\text{BODY LENGTH}} = 0.10$

$\frac{\Delta X}{\text{BODY LENGTH}} = 0.05$

Figure 21. 20° Half Angle Wedge. Graphical Representation of Various $\frac{\Delta X}{\text{Body Length}}$ Selections

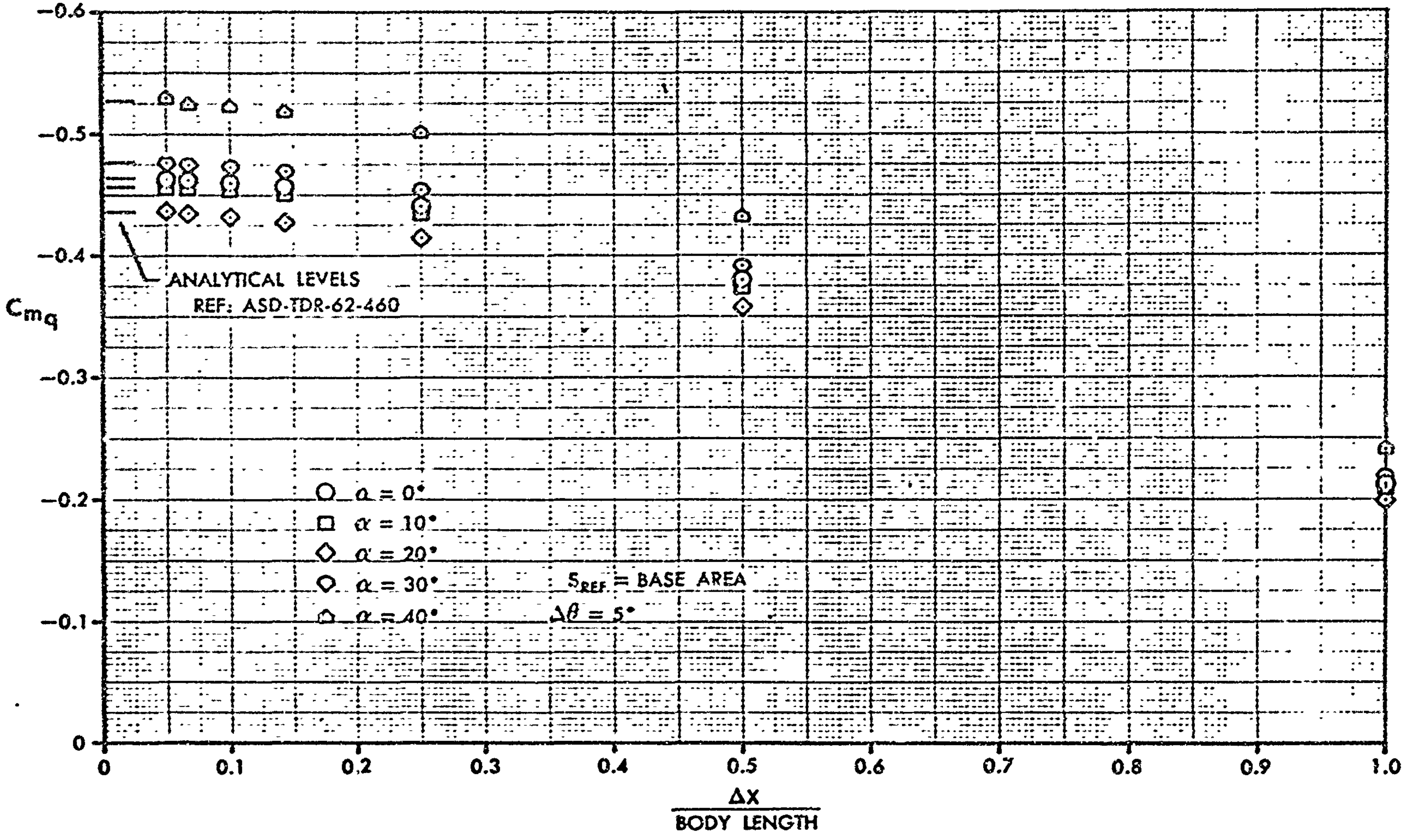


Figure 22. 20° Half Angle Cone. Effect of $\frac{\Delta X}{\text{Body Length}}$ on C_{m_q} Calculation

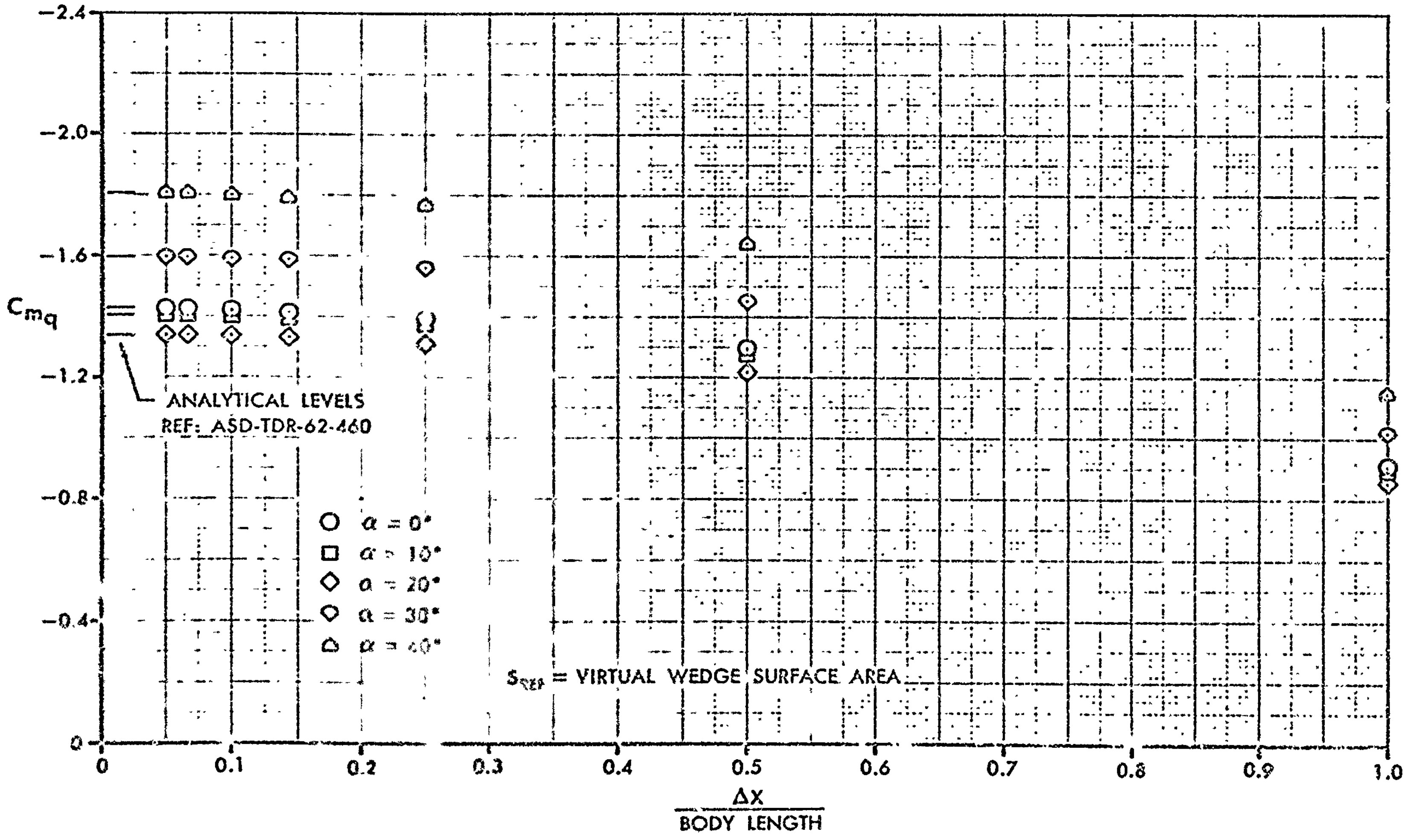


Figure 23. 20° Half Angle Wedge. Effect of $\frac{\Delta X}{\text{Body Length}}$ on C_{m_q} Calculation

The derivative $C_{m_{\dot{\alpha}}}$ is much more difficult to calculate accurately since it is caused by unsteady flow phenomena. Fortunately, this term is quite small for hypersonic vehicles in high-speed flight so approximate methods usually suffice. This stability derivative is the change in pitching moment with rate of change of angle of attack and occurs at constant pitch angle. It is frequently referred to as the "plunge" derivative since it represents the effect of a change in vertical acceleration. The common definition of this derivative is

$$C_{m_{\dot{\alpha}}} = \frac{\partial C_m}{\partial \left(\frac{\dot{\alpha}\bar{c}}{2V}\right)}$$

For a rigid vehicle this derivative arises from an aerodynamic time lag effect since the flow is not able to instantaneously adjust to changes in flight conditions. For low-speed airplanes the major component of this coefficient is caused by the fact that a change in the wing downwash field takes a finite length of time before it arrives at the tail. For tailless aircraft there still is a $C_{m_{\dot{\alpha}}}$ since the vehicle must accelerate the air mass in its path as it accelerates. This parameter is also subject to high-speed aeroelastic effects.

No general theory is currently available for calculating $C_{m_{\dot{\alpha}}}$. The parameter itself is usually difficult to obtain experimentally since it cannot be separated from the total damping coefficient measured $\left(C_{m_{\dot{\alpha}}} + C_{m_q}\right)$. References 60, 61, and 62 contain discussions of the most frequently used procedures for calculating $C_{m_{\dot{\alpha}}}$ for wing-body-tail configurations. Reference 63 discusses the use of the rheoelectric analogy for stability derivative determination.

In the analysis for the damping derivative C_{m_α} it is convenient to divide the vehicle into separate components consisting of the body, wing, and tail surface. The wing contribution may be found from the relationship below.

$$\left(C_{m_{\dot{\alpha}}}\right)_w = \frac{S_w}{S}\left(K_{wB} + K_{Bw}\right)\left(\frac{\bar{c}_w}{\bar{c}}\right)^2\left(C'_{m_{\dot{\alpha}}}\right)_w$$

where

S_w = exposed wing area

S = reference area

K_{wB} = interference factor for effect of wing in presence of body (see Reference 64)

K_{Bw} = interference factor for effect of body in presence of wing

$\bar{c}_w$ = mean aerodynamic chord of exposed wing

$\bar{c}$ = reference chord for moment coefficients

$C'_{m_{\dot{\alpha}_w}}$ = basic wing $\dot{\alpha}$ derivative as obtained from Reference 60.

The body contribution may be obtained by using the relatively simple results derived from slender-body theory. Reference 65 points out that although slender-body theory alone does not accurately predict the characteristics of nonslender configurations, the ratio of slender-body derivatives may be used to obtain reasonably accurate results as indicated below.

$$\left(C_{m_{\dot{\alpha}}}\right)_B = \left(C_{m_\alpha}\right)_B \left(\frac{C_{m_{\dot{\alpha}}}}{C_{m_\alpha}}\right)_{\text{slender body}}$$

where

$\left(C_{m_\alpha}\right)_B$ = body pitching moment derivative as calculated by the arbitrary body program for the actual shape involved

$$\left(\frac{C_{m_{\dot{\alpha}}}}{C_{m_\alpha}}\right)_{\text{slender body}} = \frac{-4\,(L/\bar{c})^2\,\frac{S_B}{S}\,\frac{\text{Volume}}{S_B\,L}\left(\frac{x_o}{L} - \frac{x_c}{L}\right)}{2\,(L/\bar{c})\,\frac{S_B}{S}\left[\frac{\text{Volume}}{S_B\,L} - \left(1 - \frac{x_o}{L}\right)\right]}$$

x_o/L and x_c/L = center-of-gravity and area-centroid locations relative to the overall body length

S_B = body frontal area

The contributions of a horizontal tail to $C_{m_{\dot{\alpha}}}$ are given by the relationship

$$\left(C_{m_{\dot{\alpha}}}\right)_T = \frac{2Q\,S_T}{S} \cos^2 \Gamma_T \left(C_{L_\alpha}\right)_T \left(K_{TB} + K_{BT}\right)\left(\frac{\bar{x}_T}{\bar{c}}\right)^2 \overline{\frac{\partial}{\partial Z}\left(\frac{\Omega_\alpha}{\alpha V}\right)}$$

where

Q = tail effectiveness ratio = $\dfrac{q_1 \left(C_{L_\alpha}\right)_1}{q_\infty \left(C_{L_\alpha}\right)_\infty}$

S_T = tail exposed area

Γ_T = tail dihedral angle

$\left(C_{L_\alpha}\right)_T$ = tail lift curve slope

K_{TB} and K_{BT} = tail lift interference factors

$\bar{x}_T$ = tail length

$\overline{\dfrac{\partial}{\partial Z}\left(\dfrac{\Omega_\alpha}{\alpha V}\right)}$ = average upwash induced by the wing at the tail location (becomes negligible in the hypersonic range)

The accuracy of the above methods for high angle of attack conditions or for very blunt lifting re-entry bodies is not known, although Reference 63 states that slender body theory is useful for such situations.

The use of the above relatively simple approach for the calculation of the $C_{m_{\dot{\alpha}}}$ derivatives would allow the determination of the $\dot{\beta}$ derivatives in a similar manner (see Reference 65).

$$\left(C_{Y_{\dot{\beta}}}\right)_B = \left(C_{Y_\beta}\right)_B \cdot \left(\frac{C_{Y_{\dot{\beta}}}}{C_{Y_\beta}}\right)_{\text{slender body}}$$

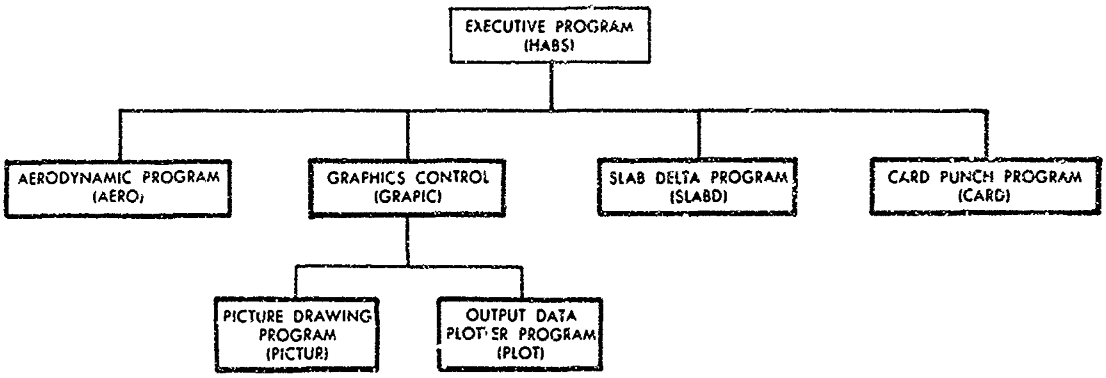
where

$$\left(\frac{C_{Y_{\dot{\beta}}}}{C_{Y_\beta}}\right)_{\text{slender body}} = \frac{4\,\dfrac{\text{Volume}}{Sb}}{-2\,\dfrac{S_B}{S}}$$

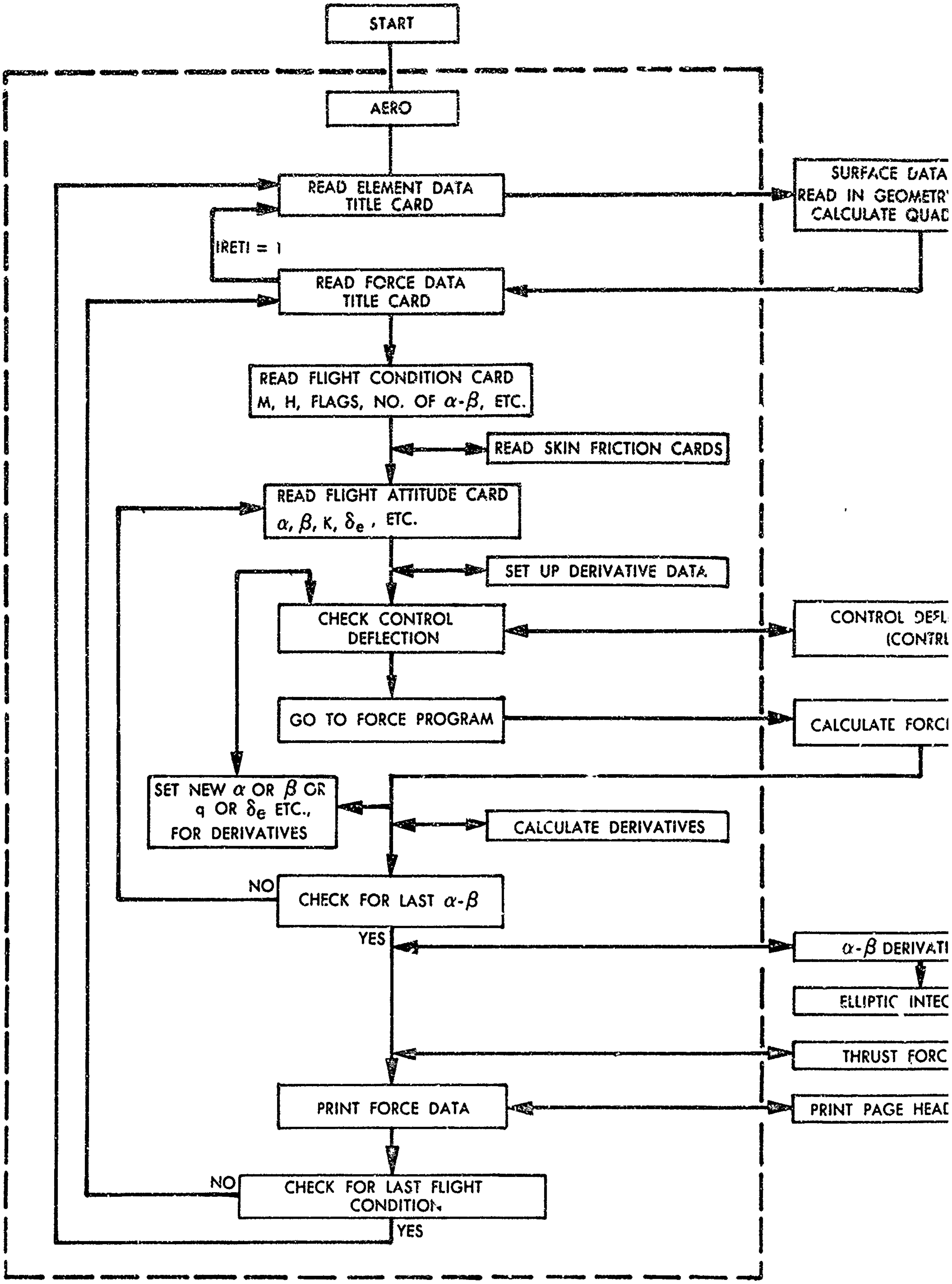
SECTION III

PROGRAM ORGANIZATION

The basic organization of the Mark III version of the Arbitrary-Body Program is shown in the diagram below. Each major part of the program could, with only minor modifications, operate as a completely separate computer program.



The most important component of this system is the Aerodynamic Program (AERO). The general features of the logic flow for this part of the system are shown on Figure 24. Each subroutine is described in more detail in Volume I of this report (pages 16 through 25). The graphics parts of the system are described on pages 25 and 26 of Volume I.


START
AERO
READ ELEMENT DATA TITLE CARD
SURFACE DATA
READ IN GEOMETR
CALCULATE QUAD
IRETI = 1
READ FORCE DATA TITLE CARD
READ FLIGHT CONDITION CARD
M, H, FLAGS, NO. OF α-β, ETC.
READ SKIN FRICTION CARDS
READ FLIGHT ATTITUDE CARD
α, β, K, δ_e , ETC.
SET UP DERIVATIVE DATA
CHECK CONTROL DEFLECTION
CONTROL DEFL
(CONTR
GO TO FORCE PROGRAM
CALCULATE FORC
SET NEW α OR β OR q OR δ_e ETC., FOR DERIVATIVES
CALCULATE DERIVATIVES
NO
CHECK FOR LAST α-β
YES
α-β DERIVAT
ELLIPTIC INTEG
THRUST FORC
PRINT FORCE DATA
PRINT PAGE HEAD
NO
CHECK FOR LAST FLIGHT CONDITION
YES

A

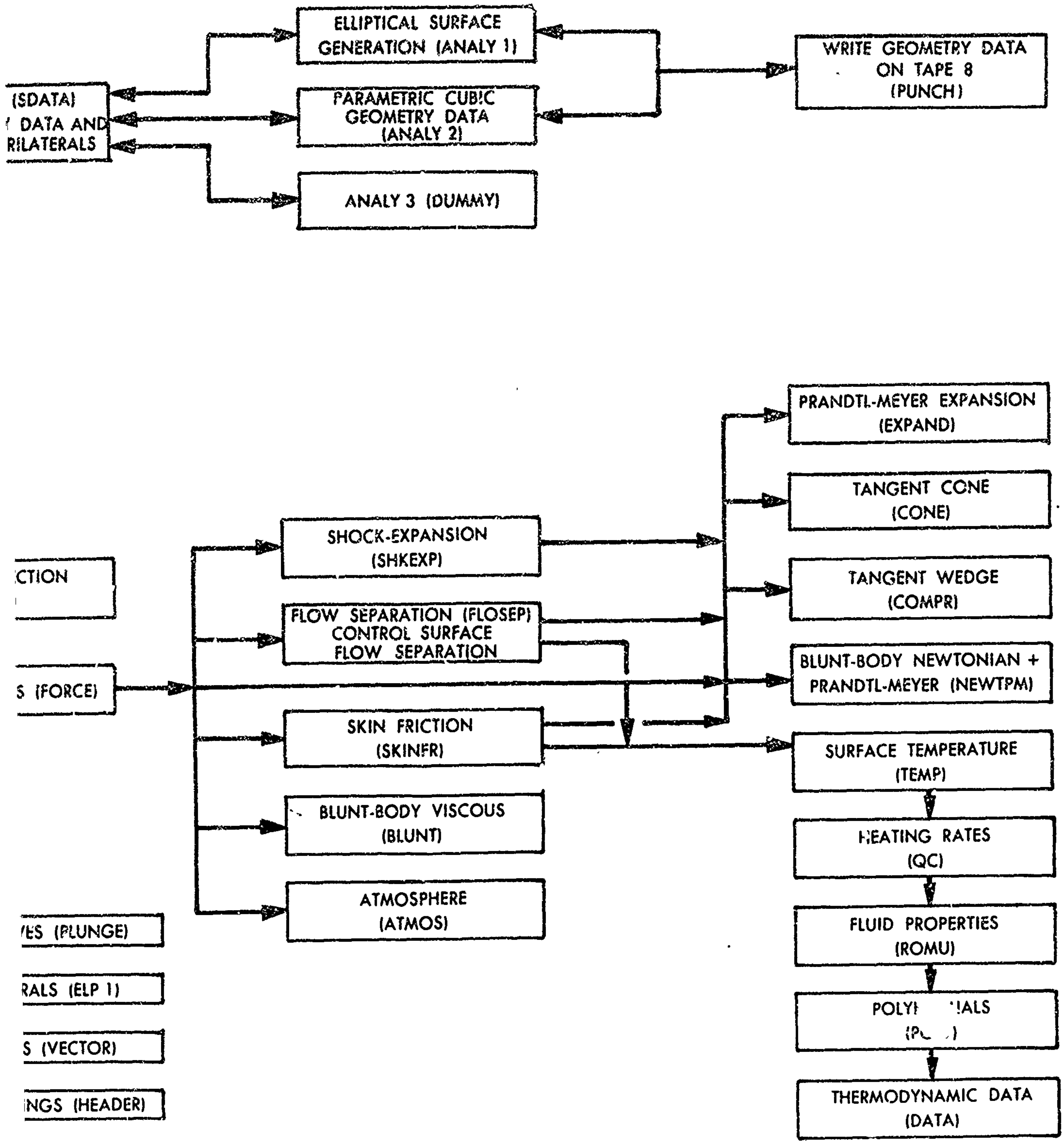


Figure 24. AERO Program Flow Chart

B

SECTION IV

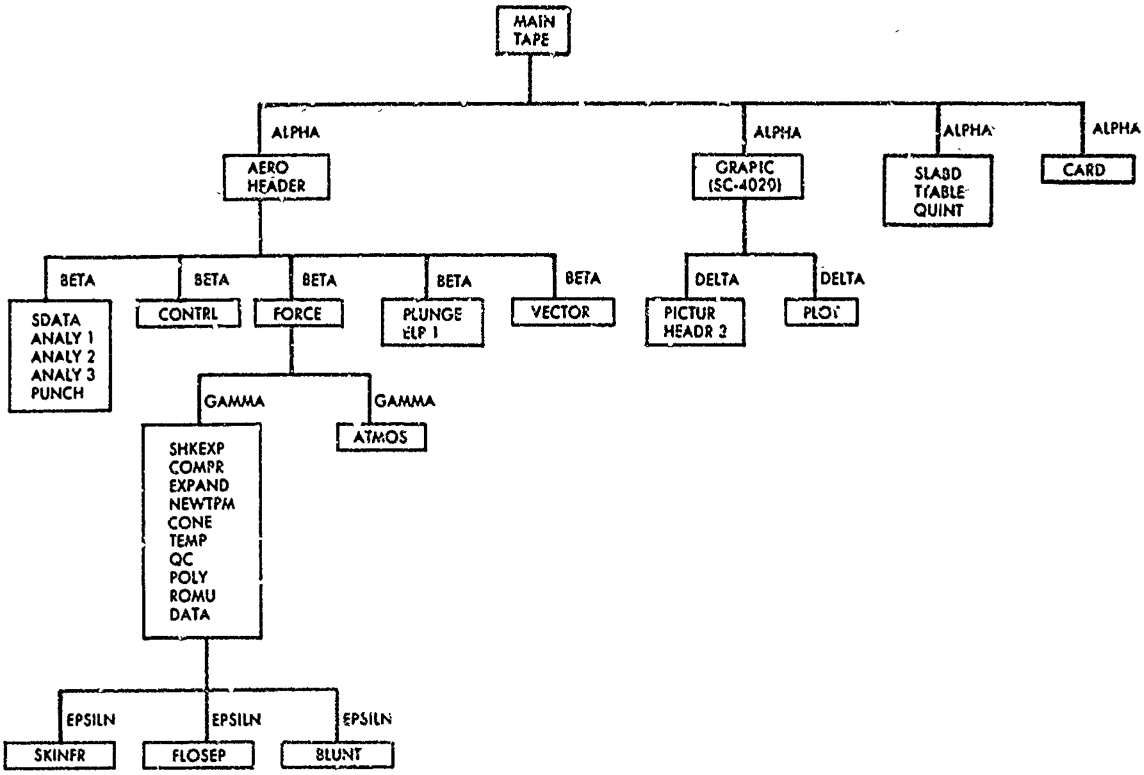
OPERATIONAL CONSIDERATIONS

The Mark III version of the Hypersonic Arbitrary-Body Aerodynamic Computer Program System is written entirely in FORTRAN. Models of the Mark III program are available for use on the IBM 360, the IBM 7094, and the UNIVAC 1108 computers. For the Mark III program the IBM 360 model is considered to be the base-line program. The differences between the programs are of a minor nature and modifications necessary for operation on other similar computers should be easy to accomplish. The program also makes use of the Douglas version of the SC-4020 software system package to generate a plotting tape. This tape is then processed off-line by a Stromberg Carlson SC-4020 Data Recording System. The graphics parts of the program may be converted by the user for operation with on-line graphics equipment such as the IBM 2250.

OVERLAY STRUCTURE

Because of the large size of this program it is necessary to use the overlay feature of FORTRAN. The overlay structure for the Mark III program is shown below. With this structure the program requires approximately 105,000 bytes of storage on the IBM 360 computer. The program will also operate on an IBM 7094 (32K) with the requirement that eleven tape drives be available (including the standard input Tape 5, output Tape 6, and the SC-4020 output tape).

OVERLAY STRUCTURE
MARK III PROGRAM



DECK SET-UP AND OPERATION

The overlay structure cards for the IBM 360 computer are given below.

```
ENTRY MAIN
INSERT MAIN=
OVERLAY ALPHA
INSERT AERO=, HEADER=
OVERLAY BETA
INSERT SDATA=, ANALY1=, ANALY2=, ANALY3=, PUNCH=
OVERLAY BETA
INSERT CONTRL=
OVERLAY BETA
INSERT FORCE=
INSERT IHCSERF
OVERLAY GAMMA
INSERT SHKEXP=, COMPR=, EXPAND=, NEWTPM=, TEMP=, QC=,
        POLY=, ROMU=, CONE=
OVERLAY EPSILN
INSERT FLOSEP=
OVERLAY EPSILN
INSERT SKINFR=
OVERLAY EPSILN
INSERT BLUNT=
OVERLAY GAMMA
INSERT ATMOS=
OVERLAY BETA
INSERT PLUNGE=, ELP1=
OVERLAY BETA
INSERT VECTOR=
OVERLAY ALPHA
INSERT GRAPHIC=
INSERT NXV=, XSCALV=, NHCAWAU, NHCAWAO, NHCAWAP  *
INSERT YMODV=, XMODV=, NHCAWBN  *
INSERT NHCAWFC, VXAXV=, APLOTV=, APRNTV=, BNBCDV=,  *
        BRITEV=, DOTLNV=     *
INSERT ERMRKV=, ERRLNV=, ERRNLV=, GRID1V=, LABLV=, LINEV=,  *
        LINRV=    *
INSERT NOFRV=, NONLNV=, PLOTV=, SETCIV=   *
INSERT SCSETV=, ARGQ=    *
OVERLAY DELTA
INSERT PICTUR=, HEADR2=
OVERLAY DELTA
INSERT PLOT=
OVERLAY ALPHA
INSERT SLABD=, TTABLE =, QINT=
OVERLAY ALPHA
INSERT CARD=
```

Note: Those cards marked with an asterisk (*) contain the SC-4020 routines. The asterisk is not actually punched on the cards but is just used in this report to indicate the SC-4020 insert cards.

The deck set-up for the IBM 7094 model of this program is outlined below.

```
$JOB           as required

$SETUP         as required

$RESTORE       required on Douglas system

$*             as required to give on-line message to machine
               operator (any text in card columns 3-72)

$EXECUTE       IBJOB

$IBJOB

   HABS      Main program

$ORIGIN        ALPHA

   AROA      Subroutine AERO
   AROB                 HEADER

$ORIGIN        BETA

   AROC      Subroutine SDATA
   AROD                 ANALY1
   AROE                 ANALY2
   AROF                 ANALY3
   AROG                 PUNCH

$ORIGIN        BETA

   AROH      Subroutine CONTRL

$ORIGIN        BETA

   AROI      Subroutine FORCE

$INCLUDE       FERF

$ORIGIN        GAMMA

   AROJ      Subroutine SHKEXP
   AROM                 COMPR
   ARON                 EXPAND
   AROO                 NEWTPM
   AROP                 CONE
   AROR                 TEMP
   AROS                 QC
   AROT                 POLY
   AROU                 ROMU
   AROV                 DATA
```

IBM 7094 Deck Set-Up (Continued)

```
$ORIGIN      EPSILN
   AROL      Subroutine  SKINFR

$ORIGIN      EPSILN
   AROK      Subroutine  FLOSEP

$ORIGIN      EPSILN
   AROQ      Subroutine  BLUNT

$ORIGIN      GAMMA
   AROW      Subroutine  ATMOS

$ORIGIN      BETA
   AROX      Subroutine  PLUNGE
   AROY                  ELP1

$ORIGIN      BETA
   AROZ      Subroutine  VECTOR

$ORIGIN      ALPHA
   GRPA      Subroutine  GRAPIC

$INCLUDE     All SC-4020 subroutines required by program except
             those that must be in the main link.

$ORIGIN      DELTA
   GRPB      Subroutine  PICTUR
   GRPC                  HEADER2

$ORIGIN      DELTA
   GRPD      Subroutine  PLOT

$ORIGIN      ALPHA
   SLBA      Subroutine  SLABD
   SLBB                  TTABLE
   SLBC                  QINT

$ORIGIN      ALPHA
   CARD      Subroutine  CARD

$DATA
    All program input data cards
End of File  (7 and 8 punches in card column 1)
$IBSYS
```

TAPE ASSIGNMENTS

The operation of this program requires the availability of 11 logical units (besides the systems units). On the IBM 7094 these will be magnetic tape units. On the IBM 360 computer some or all of these units will be on disk storage. In either case, the logical units are referred to as "Tapes" throughout this discussion. The units required and their use in the program are listed below.

Unit	Mode	Program Usage
1	Binary	Storage of aerodynamic coefficients for summation.
3	Binary	Storage of control fore-surface geometry data.
4	Binary	Storage of excess of quadrilateral element data when number of elements is greater than ISIZE. Also used to store geometry data for control-surface flap.
5	BCD	Standard system input tape unit.
6	BCD	Standard system output tape unit.
7	Binary	Standard system punch tape unit.
8	BCD	Storage of geometry data in surface-element form.
9	Binary	Storage of aerodynamic data to be plotted by PLOT routine.
10	Binary	Storage of counter of aerodynamic data saved for plotting by PLOT routine.
11	Binary	Storage of control-surface geometry in the flap-deflected position.
16	Binary	SC-4020 output tape for the Douglas version of the SC-4020 system.

Tape Assignments (Continued)

For operation on the IBM 360 computer it is recommended that the following units be on magnetic tape: 3, 4, 8, and 11. These tapes may be defined as follows:

```
//GO.FT03F001   DD DSNAME=&FT03,UNIT=TAPEA,DISP=(NEW,DELETE),                X
//                 DCB=(RECFM=V,BLKSIZE=800,DEN=2,TRTCH=C)
//GO.FT04F001   DD DSNAME=&FT04,UNIT=TAPEB,DISP=(NEW,DELETE),                X
//                 DCB=(RECFM=V,BLKSIZE=800,DEN=2,TRTCH=C)
//GO.FT08F001   DD DSNAME=TFT08,UNIT=TAPEB,DISP=(NEW,KEEP),                  X
//                 DCB=(TRTCH=ET,RECFM=F,BLKSIZE=84,DEN=2)
//GO.FT11F001   DD DSNAME=&FT11,UNIT=TAPEB,DISP=(NEW,DELETE),                X
//                 DCB=(RECFM=V,BLKSIZE=800,DEN=2,TRTCH=C)
```

SC-4020 SYSTEM

This program makes use of the Stromberg Carlson SC-4020 Data Recording System. The SC-4020 software system used by this program was originally developed by North American Aviation, Inc. The Douglas version of this system contains a number of revisions. Some of these revisions were made to facilitate the use of the overlay features of FORTRAN.

Because of the large core-storage requirements of the Hypersonic Arbitrary-Body System, it is important that all system subroutines be included in the proper overlay link. On the Douglas version of the SC-4020 system two subprograms must be overlay link 0. Other versions of the SC-4020 system may have similar restrictions. For the IBM 7094 model of the program these subroutines are PLO1 and SCOUTQ. Those subroutines required in the overlay structure for the IBM 360 model of the program are indicated by the asterisk on page 116. All other SC-4020 routines on the IBM 360 must be in the main link. The following cards may be used to include the appropriate SC-4020 subroutines in the proper part of the overlay structure for the IBM 7094 model of the program.

```
$INCLUDE        APLOTV,APRNTV,BUTTV,BNBCDV,BRITEV,CO4020,CH4020

$INCLUDE        DOTLNV,ER4020,ERMRKV,ERRLNV,ERRNLV,FR4020,GRID1V

$INCLUDE        HD4020,HOLDIV,HOLLV,ID4020,INCRV,INTBCD,LABLV

$INCLUDE        LE4020,LINEV,LINRV,NOFRV,NONLNV,PL4020,PLOTV

$INCLUDE        PRINTV,SCBSR,SETCIV,SETMIV,SMXYV,STOPTV,TF4020

$INCLUDE        TI4020,TPNUMV,WP4020,WR4020,XAXISV,XMODQ,XSCALQ
```

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APPENDIX A

PROGRAM LISTINGS AND FLOW CHARTS

This part of the report contains the listings and flow charts for the Mark III Mod O version of the Hypersonic Arbitrary-Body Aerodynamic Computer Program System. Also included are the symbol lists defining the variables used in each subroutine. A combined list of all program variables is included in Appendix B.

The symbol lists are divided into five fields which are described as follows:

(i) The first field contains the symbol

(ii) The second field contains the letters I, L, or R, denoting integer, logical, or real variable respectively.

(iii) The third field contains the letters A, C, D, U, denoting argument list, common, dimensioned, or undimensioned, variable respectively. The hierarchy of the above letters is A, C, D, U.

(iv) The fourth field contains the definition of the symbol.

(v) The fifth field contains the name of the subroutine in which the symbol occurs.

INDEX TO SUBROUTINE LISTINGS AND FLOW CHARTS

1. MAIN PROGRAM (DECK HABS)

a. Algorithm

This routine, the main routine for the Mark III version of the Hypersonic Arbitrary-Body Aerodynamic Computer Program System, acts as the system monitor. It controls and initiates execution of the five principal components of this system. These are the Aerodynamic Force Analysis Program (Program AERO and its associated subroutines), the Graphics Program Options (the Picture Drawing Program and the Output Data Plotter Program), the Auxiliary Geometry Generation Program (Slab Delta Program), and the card punch routine.

The first action of the program is for this Executive routine to read in the System Control Card (Type 0). This card controls the selection of each program option and the order in which the options are to be used. Up to twenty different program phases may be used, and any given option may be used several times.

If an error has been detected in any of the program subroutines control will be returned to the Executive Program with the ERROR flag set to the appropriate value. If the error is of the non-fatal type the Executive Main Program will start reading in data cards until it finds a card with a Type number of 99. The program will then attempt to execute the next phase option.

b. Input/Output

System Control Card (Type 0)
Program Flow monitoring information

c. Error

An error condition occurs when an error is returned by a subroutine, or when the System Control Card contains an illegal value.

d. Subroutines Required

AERO, GRAPIC, SLABD, CARD

e. Argument List

Not applicable

f. Length

2170 bytes

DECK HABS

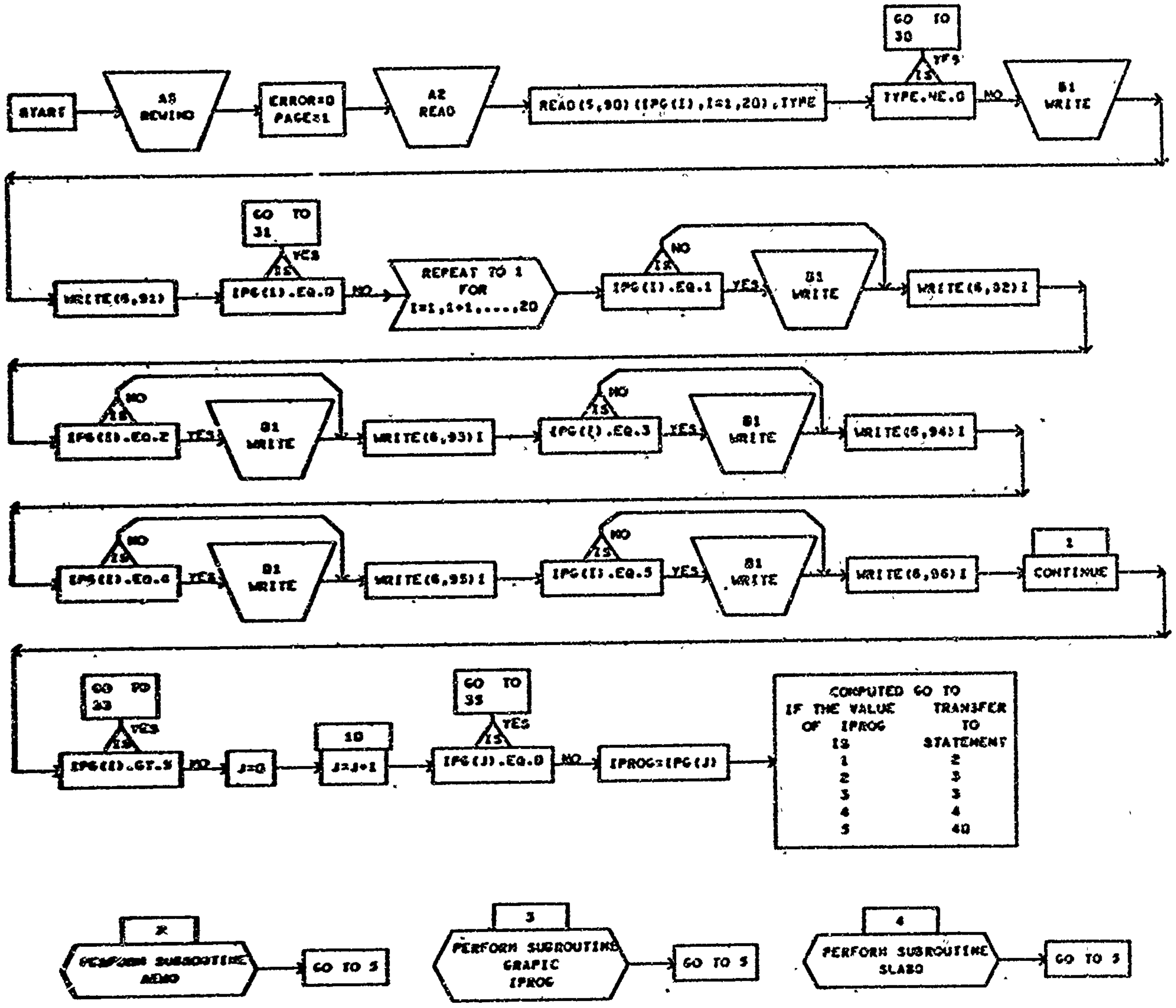
```
C***********************************************************************HABS 0010
C*****                                                             *****HABS 0020
C**** HYPERSONIC ARBITRARY-BODY AERODYNAMIC COMPUTER PROGRAM SYSTEM ****HABS 0030
C*****                          IBM 360 MODEL                      *****HABS 0040
C***********************************************************************HABS 0050
C                                                                       HABS 0060
C     THIS IS THE  MARK III  MOD  0  VERSION OF THE HYPERSONIC          HABS 0070
C     ARBITRARY BODY FORCE ANALYSIS PROGRAM.  THE BASIC PROGRAM         HABS 0080
C     WAS DEVELOPED AT THE DOUGLAS AIRCRAFT COMPANY, AIRCRAFT           HABS 0090
C     DIVISION UNDER SPONSORSHIP OF THE INDEPENDENT RESEARCH AND        HABS 0100
C     DEVELOPMENT PROGRAM.  MODIFICATIONS TO THIS PROGRAM TO            HABS 0110
C     INCORPORATE ADDITIONAL STABILITY AND CONTROL DERIVATIVES          HABS 0120
C     AND PROGRAM DOCUMENTATION WHERE ACCOMPLISHED UNDER                HABS 0130
C     AIR FORCE CONTRACT F 33615 67 C 1008 (SESSG, R.K. MILLS PROJECT   HABS 0140
C     ENGINEER).  THIS VERSION WAS IDENTIFIED AS THE MARK II VERSION    HABS 0150
C     AND WAS RELEASED IN MAY OF 1967 AND DOCUMENTED IN DOUGLAS         HABS 0160
C     REPORT DAC 56080.  THE PRESENT MARK III VERSION IS AN             HABS 0170
C     EXTENSIVELY MODIFIED VERSION OF THE EARLIER PROGRAM.  THESE       HABS 0180
C     MODIFICATIONS WERE ACCOMPLISHED UNDER DOUGLAS IRAD AND ALSO       HABS 0190
C     SUPPORTED IN PART BY AIR FORCE CONTRACT F 33615 67 C 1602         HABS 0200
C     (FDMG, V. DAHLEM  PROJECT ENGINEER).                              HABS 0210
C                                                                       HABS 0220
C     COMPLETE DOCUMENTATION OF THIS PROGRAM IS CONTAINED IN            HABS 0230
C     DOUGLAS REPORT  DAC 61552                                         HABS 0240
C         VOLUME 1  HYPERSONIC ARBITRARY-BODY AERODYNAMIC COMPUTER      HABS 0250
C                   PROGRAM  MARK III VERSION - USERS MANUAL            HABS 0260
C         VOLUME 2  HYPERSONIC ARBITRARY-BODY AERODYNAMIC COMPUTER      HABS 0270
C                   PROGRAM  MARK III VERSION - PROGRAM FORMULATION     HABS 0280
C                   AND LISTINGS                                        HABS 0290
C                                                                       HABS 0300
C************THIS PROGRAM WAS WRITTEN BY ARVEL E. GENTRY****************HABS 0310
C***************SENIOR ENGINEER  AERO-RESEARCH GROUP********************HABS 0320
C*****************REVISED SKIN FRICTION ROUTINES FOR******************  HABS 0330
C*****************THE MARK III PROGRAM BY D.N. SMYTH******************  HABS 0340
C***********************************************************************HABS 0350
```

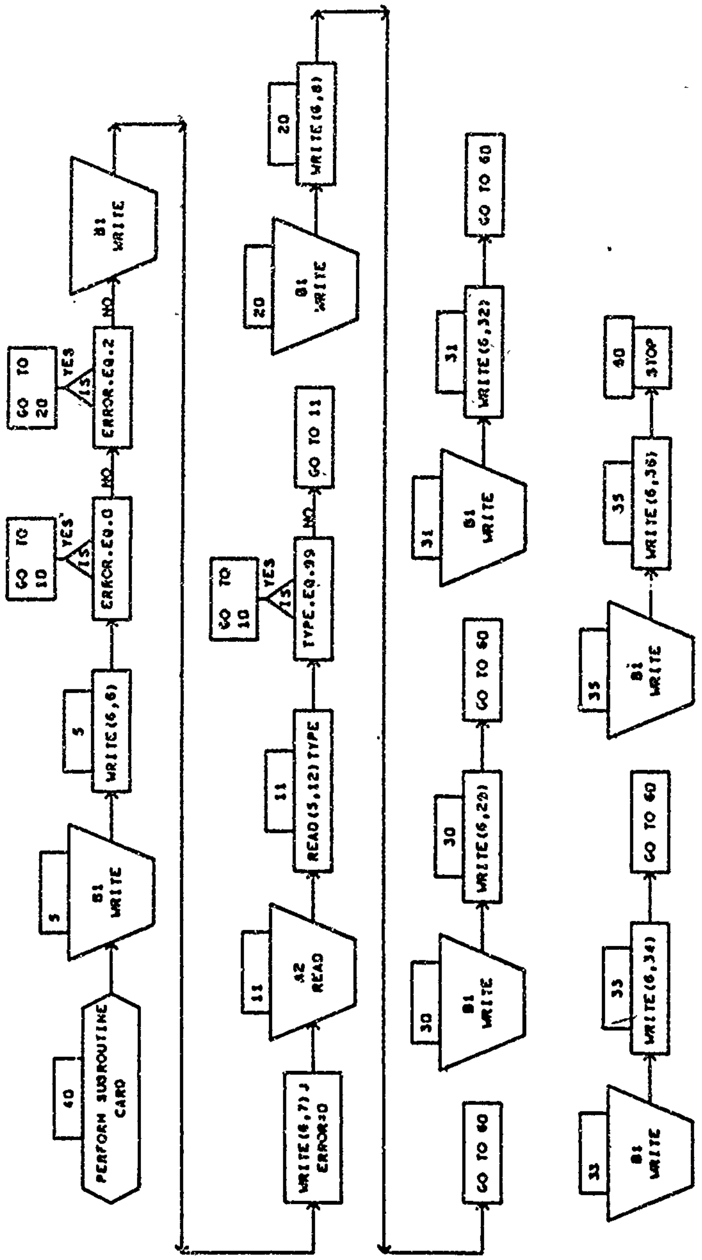
```
DECK HABS

C                                                                         HABS 0360
C                                                                         HABS 0370
C                                                                         HABS 0380
C***** EXECUTIVE MAIN PROGRAM *****                                       HABS 0390
C                                                                         HABS 0400
      DIMENSION  IPG(20),TITLE(15)                                        HABS 0410
      COMMON  CASE,TITLE,PAGE,ERROR                                       HABS 0420
      INTEGER  TYPE,ERROR,CASE,PAGE                                       HABS 0430
      REWIND 8                                                            HABS 0440
      ERROR = 0                                                           HABS 0450
      PAGE = 1                                                            HABS 0460
C                                                                         HABS 0470
C **********************************************************************  HABS 0480
C ***** READ SYSTEM CONTROL CARD TO SELECT PROGRAMS TO BE USED AND ORDER  HABS 0490
C ***** OF USE. A MAXIMUM OF 20 OPTIONS MAY BE USED.  THIS VERSION OF     HABS 0500
C ***** THE PROGRAM WILL ALLOW ONLY CPTIONS  1, 2, 3, 4, 5.               HABS 0510
C***********************************************************************  HABS 0520
C                                                                         HABS 0530
      READ (5,90)  (IPG(I),I=1,20),TYPE                                   HABS 0540
   90 FORMAT (20(2XI1),10X,I2)                                            HABS 0550
      IF (TYPE .NE. 0) GO TO 30                                           HABS 0560
      WRITE (6,91)                                                        HABS 0570
   91 FORMAT (1H1,////,/1H ,39H************* HYPERSONIC ARBITRARY-BODY    HABS 0580
     1 50H AERODYNAMIC COMPUTER PROGRAM SYSTEM ************* ,///,1H ,    HABS 0590
     2 10X,46HPROGRAM OPTIONS ARE IN THE FOLLOWING ORDER....   ,/1H  )    HABS 0600
      IF (IPG(1) .EQ. 0) GO TO 31                                         HABS 0610
C                                                                         HABS 0620
C                                                                         HABS 0630
      DO 1 I=1,20                                                         HABS 0640
      IF (IPG(I) .EQ. 1) WRITE (6,92) I                                   HABS 0650
   92 FORMAT (1H0,15X,I2,40H  AERODYNAMIC FORCE PROGRAM   (OPTION 1) )    HABS 0660
      IF (IPG(I) .EQ. 2) WRITE (6,93) I                                   HABS 0670
   93 FORMAT (1H0,15X,I2,40H  PICTURE DRAWING PROGRAM     (OPTION 2) )    HABS 0680
      IF (IPG(I) .EQ. 3) WRITE (6,94) I                                   HABS 0690
   94 FORMAT (1H0,15X,I2,40H  OUTPUT DATA PLOTTER PROGRAM (OPTION 3) )    HABS 0700
      IF (IPG(I) .EQ. 4) WRITE (6,95) I                                   HABS 0710
```

```
DECK HABS

   95 FORMAT (1HO,15X,I2,40H  SLAB DELTA GEOMETRY PROGRAM (OPTION 4) )   HABS  0720
      IF (IPG(I) .EQ. 5) WRITE (6,96) I                                  HABS  0730
   96 FORMAT (1HO,15X,I2,41H  GEOMETRY DATA PUNCH PROGRAM (OPTION 5)  )  HABS  0740
C                                                                        HABS  0750
    1 IF (IPG(I) .GT. 5) GO TO 33                                        HABS  0760
      J = 0                                                              HABS  0770
C                                                                        HABS  0780
   10 J = J + 1                                                          HABS  0790
      IF (IPG(J) .EQ. 0) GO TO 35                                        HABS  0800
C                                                                        HABS  0810
      IPROG = IPG(J)                                                     HABS  0820
      GO TO (2,3,3,4,40), IPROG                                          HABS  0830
    2 CALL AERO                                                          HABS  0840
      GO TO 5                                                            HABS  0850
C                                                                        HABS  0860
    3 CALL GRAPIC (IPROG)                                                HABS  0870
      GO TO 5                                                            HABS  0880
C                                                                        HABS  0890
    4 CALL SLABD                                                         HABS  0900
      GO TO 5                                                            HABS  0910
C                                                                        HABS  0920
   40 CALL CARD                                                          HABS  0930
C                                                                        HABS  0940
    5 WRITE (6,6)                                                        HABS  0950
    6 FORMAT (1H1,//////,1HO,40H******** MAIN PROGRAM NOW HAS CONTROL OF HABS  0960
     1 16H SYSTEM ******** )                                             HABS  0970
      IF (ERROR .EQ. 0) GO TO 10                                         HABS  0980
      IF (ERROR .EQ. 2) GO TO 20                                         HABS  0990
      WRITE (6,7) J                                                      HABS  1000
    7 FORMAT (1HO,15X,35HA NON-FATAL ERROR OCCURRED IN PHASE ,I3,/15X,   HABS  1010
     1 57H   PROGRAM WILL ATTEMPT TO CONTINUE BY SEARCHING FOR NEXT      HABS  1020
     2 17H TYPE = 99  CARD.)                                             HABS  1030
      ERROR = 0                                                          HABS  1040
   11 READ (5,12) TYPE                                                   HABS  1050
   12 FORMAT (70X,I2)                                                    HABS  1060
      IF (TYPE .EQ. 99) GO TO 10                                         HABS  1070
```

DECK HABS

```
      GO TO 11                                                          HABS  1080
C                                                                       HABS  1090
   20 WRITE (6,8)                                                       HABS  1100
    8 FORMAT (1H ,//,1H ,40H******** FATAL ERROR *** PROGRAM STOPPED )  HABS  1110
      GO TO 60                                                          HABS  1120
C                                                                       HABS  1130
   30 WRITF (6,29)                                                      HABS  1140
   29 FORMAT (1H0,50H ***** MASTER CCNTROL CARD HAD TYPE NOT = 0 ******) HABS  1150
      GO TO 60                                                          HABS  1160
C                                                                       HABS  1170
C                                                                       HABS  1180
   31 WRITE (6,32)                                                      HABS  1190
   32 FORMAT (1H ,//,1H ,38H***** FIRST PHASE OPTION IS ZERO *****      HABS  1200
     1 21H**** FATAL ERROR **** )                                       HABS  1210
      GO TO 60                                                          HABS  1220
C                                                                       HABS  1230
   33 WRITE (6,34)                                                      HABS  1240
   34 FORMAT (1H ,//,1H ,42H***** PROGRAM GPTION IS GREATER THAN 5 ***  HABS  1250
     1 22H***** FATAL FRROR ****  )                                     HABS  1260
      GO TO 60                                                          HABS  1270
C                                                                       HABS  1280
   35 WRITE (6,36)                                                      HABS  1290
   36 FORMAT (1H ,//,1H ,44H***** PROGRAM HAS REACHED NORMAL TERMINATION HABS  1300
     1  7H ******   )                                                   HABS  1310
   60 STOP                                                              HABS  1320
      END                                                               HABS  1330
```


START
A5 REWIND
ERROR=0 PAGE=1
A2 READ
READ(5,90)(IPG(I),I=1,20),TYPE
GO TO 30
YES
IS
TYPE.NE.0
NO
B1 WRITE
WRITE(6,91)
GO TO 31
YES
IS
IPG(1).EQ.0
NO
REPEAT TO 1 FOR I=1,I+1,....,20
IS
NO
IPG(I).EQ.1
YES
B1 WRITE
WRITE(6,92)I
IS
NO
IPG(I).EQ.2
YES
B1 WRITE
WRITE(6,93)I
IS
NO
IPG(I).EQ.3
YES
B1 WRITE
WRITE(6,94)I
IS
NO
IPG(I).EQ.4
YES
B1 WRITE
WRITE(6,95)I
IS
NO
IPG(I).EQ.5
YES
B1 WRITE
WRITE(6,96)I
1
CONTINUE
GO TO 33
YES
IS
IPG(I).GT.5
NO
J=0
10
J=J+1
GO TO 35
YES
IS
IPG(J).EQ.0
NO
IPROG=IPG(J)
COMPUTED GO TO
IF THE VALUE OF IPROG IS
TRANSFER TO STATEMENT
1 2
2 3
3 3
4 4
5 40
2
PERFORM SUBROUTINE AERO
GO TO 5
3
PERFORM SUBROUTINE GRAPIC IPROG
GO TO 5
4
PERFORM SUBROUTINE SLAB0
GO TO 5


40
PERFORM SUBROUTINE CARD
5
B1 WRITE
5
WRITE(6,6)
IS ERROR.EQ.0
YES
GO TO 10
NO
IS ERROR.EQ.2
YES
GO TO 20
NO
B1 WRITE
WRITE(6,7) J ERROR=0
11
A2 READ
11
READ(5,12)TYPE
IS TYPE.EQ.99
YES
GO TO 10
NO
GO TO 11
20
B1 WRITE
20
WRITE(6,8)
GO TO 60
30
B1 WRITE
30
WRITE(6,29)
GO TO 60
31
B1 WRITE
31
WRITE(6,32)
GO TO 60
33
B1 WRITE
33
WRITE(6,34)
GO TO 60
35
B1 WRITE
35
WRITE(6,36)
40
STOP

```
SYMBOLS USED IN SUBROUTINE MAIN

CASE     I  C  PROBLEM CASE NUMBER                                                    MAIN
ERROR    I  C  ERROR FLAG (=0 NO ERRUR, =1 NON-FATAL, =2 FATAL)                       MAIN
I        I  U  DO-LOOP INDEX                                                          MAIN
IPG      I  D  PROGRAM OPTION FLAG ARRAY                                              MAIN
IPROG    I  U  ACTIVE PROGRAM OPTION                                                  MAIN
J        I  U  INDEX UN PROGRAM OPTION                                                MAIN
PAGE     I  C  PAGE NUMBER                                                            MAIN
TITLE    R  C  PROBLEM TITLE                                                          MAIN
TYPE     I  U  CARD TYPE                                                              MAIN
```

2. SUBROUTINE AERO (DECK AROA)

This routine controls the flow of calculations within the Aerodynamic Force Calculation Option.

a. Algorithm

The first operation of this routine is to rewind the necessary program tape units. It then reads the Element Data Title Card (Type 1) and calls the Surface Data routine for the geometry calculations. Upon return from Surface Data (SDATA) the Force Data Title Card (Type 8) is read and if IRET1 is zero the Force Data Title Card will be read next. This is then followed by the Flight Condition Card, the Center of Gravity Data Card, and if required, the Skin Friction Data Cards and Coefficient Increment Data Cards. The program then starts the cycle to calculate force data at each flight attitude. This is initiated by the reading of the Flight Attitude Data Card. The necessary data arrays are initialized, derivative data established, and the Force calculation routine called.

Upon return from the FORCE routine the derivative cycle data is set and control returned to the FORCE routine if required. If the control surface is to be deflected the CONTROL routine will be called before the FORCE routine is called. If required the Plunge Derivative and Thrust Vector routines will also be called.

b. Input/Output

Element Data Title Card (Type 1), Force Data Title Card (Type 8), Flight Condition Card (Type 9), Center of Gravity Data Card (Type 10), Skin Friction Data Cards (Type 11), Flight Attitude Data Cards (Type 12), and Coefficient Increment Data Cards (Type 13). Output data consists of the vehicle summary force data.

c. Error

An error condition occurs when input card Type number is in error.

d. Subroutines Required

SDATA, CONTRL, FORCE, PLUNGE, VECTOR, HEADER

e. Argument List

None

f. Length

15396 bytes

DECK AROA

```
      SUBROUTINE AERO                                                   AROA  0010
C                                                                       AROA  0020
      DIMENSION  TITLE(15),ALP(20),BET(20),CCA(20),CCY(20),CCN(20),     AROA  0030
     1 CCLL(20),CCLM(20),CCLN(20),CCL(20),CCD(20),CLOD(20),CPS(20),     AROA  0040
     2 CF(20),CARD(20),QQINFS(20),IS(10,9),SURF(10,8),FS(8),BS(8),      AROA  0050
     3 CCDS(20),CCLS(20),CCAS(20),CCYS(20),CCNS(20),CCLMS(20),          AROA  0060
     4 CCLLS(20),CCLNS(20),CFS(20),DCAA(20),DCLA(20),DCNA(20),DCMA(20), AROA  0070
     5 DCMQ(20),DCAQ(20),DCNQ(20),DCYB(20),DCNB(20),DCLLB(20),DCYR(20), AROA  0080
     6 DCLNR(20),DCLLR(20),DCAAS(20),DCLAS(20),DCNAS(20),DCMAS(20),     AROA  0090
     7 DCMQS(20),DCAQS(20),DCNQS(20),DCYBS(20),DCNBS(20),DCLLBS(20),    AROA  0100
     8 DCYRS(20),DCLNRS(20),DCLLRS(20),IMP(20),ISH(20),IMPI(20),        AROA  0110
     9 ISHI(20),ETACS(20),ENPMS(20),QRPS(20),DELTES(20),IDERS(20),      AROA  0120
     A IPRINS(20),IPRTS(20),DCLD(20),DCMD(20),DCLLD(20),DCYD(20),       AROA  0130
     B DCLND(20),DCND(20),DCLDS(20),DCMDS(20),DCLLDS(20),               AROA  0140
     C DCYDS(20),DCLNDS(20),DCNDS(20),HMLS(20),HMRS(20),HML(20),        AROA  0150
     D HMR(20),DCMADT(20),DCYBDT(20),DCMADS(20),DCYBDS(20)              AROA  0160
C                                                                       AROA  0170
      DIMENSION NX2( 300),NY2( 300),NZ2( 300),XCENT2( 300),             AROA  0180
     1 YCENT2( 300),ZCENT2( 300),AREA2( 300),IN( 300),IM( 300)          AROA  0190
C                                                                       AROA  0200
C                                                                       AROA  0210
      COMMON  CASE,TITLE,PAGE,ERROR,NX2,NY2,NZ2,XCENT2,YCENT2,ZCENT2,   AROA  0220
     1 AREA2,IN,IM,L,LS,FS,BS,ALP,BET,CCA,CCY,CCN,CCLL,CCLM,CCLN,CCL,   AROA  0230
     2 CCD,CLOD,CF,CPS,QQINFS,IS,SURF                                   AROA  0240
      REAL  NX2,NY2,NZ2                                                 AROA  0250
C                                                                       AROA  0260
      REAL  MACH,MAC                                                    AROA  0270
C                                                                       AROA  0280
      DATA  CCDS,CCLS,CCAS,CCYS,CCNS,CCLMS,                             AROA  0290
     1  CCLLS,CCLNS,CFS/180*0.0/                                        AROA  0300
      DATA  DCAAS,DCLAS,DCNAS,DCMAS,DCMQS,DCAQS,                        AROA  0310
     1   DCNQS,DCYBS,DCNBS,DCLLBS,DCYRS,DCLNRS,                         AROA  0320
     2   DCLLRS,DCLDS,DCMDS,DCLLDS,DCYDS,DCLNDS,                        AROA  0330
     3   DCNDS,HMLS,HMRS,DCMADS,DCYBDS/460*0.0/                         AROA  0340
C                                                                       AROA  0350
```

```
DECK ARDA

      DATA IPL9,IPL10/43,42/                                           ARDA  0360
C                                                                      ARDA  0370
      INTEGER  PAGE,CASE,SYMFCT,ERROR,TYPE,PRINT,PRINTS                ARDA  0380
C                                                                      ARDA  0390
      REWIND 1                                                         ARDA  0400
      REWIND 9                                                         ARDA  0410
      REWIND 10                                                        ARDA  0420
      NSAVE = 0                                                        ARDA  0430
      ISIZ =  300                                                      ARDA  0440
C                                                                      ARDA  0450
C  SET INITIAL CONSTANTS FOR START OF CASE                             ARDA  0460
    1 ERROR = 0                                                        ARDA  0470
      REWIND 3                                                         ARDA  0480
      REWIND 4                                                         ARDA  0490
      REWIND 11                                                        ARDA  0500
      DELTAS = 999.0                                                   ARDA  0510
C                                                                      ARDA  0520
C  READ IN TITLE CARD (CARD COLUMN 1 THROUGH 60)                       ARDA  0530
      READ (5,100) (TITLE(I),I=1,15),ISUM,IREW8,IPS,IABDOT,IVECT,CASE, ARDA  0540
     1     TYPE                                                        ARDA  0550
  100 FORMAT(14A4,A3,2I1,1X3I1,I3,2XI2)                                ARDA  0560
      IF (TYPE .EQ. 99) GO TO 700                                      ARDA  0570
      IF (TYPE.NE.1) GO TO 800                                         ARDA  0580
      IF (IREW8 .NE. 0) REWIND 8                                       ARDA  0590
C                                                                      ARDA  0600
C  CHECK IF PREVIOUSLY CALCULATED DATA IS TO BE SUMMED (IF ISUM= 2 OR 3) ARDA  0610
      IF (ISUM .GT. 1) GO TO 15                                        ARDA  0620
C                                                                      ARDA  0630
C  GO TO SURFACE DATA ROUTINE                                          ARDA  0640
      CALL SDATA (PRINTS,SYMFCT,ISIZ,IORIEN,IGTYPE)                    ARDA  0650
C                                                                      ARDA  0660
C  CHECK CARD TYPE ERROR                                               ARDA  0670
      IF (ERROR.EQ.1) GO TO 800                                        ARDA  0680
      IF (ERROR .EQ. 3) GO TO 806                                      ARDA  0690
C                                                                      ARDA  0700
C  READ IN TITLE CARD (CARD COLUMN 1 THROUGH 60)                       ARDA  0710
```

```
DECK ARDA

   11  READ (5,110) (TITLE(I),I=1,15),IRFT1,CASE,TYPE                    ARDA  0720
  110  FORMAT(14A4,1A3,I1,5XI3,2XI2)                                     ARDA  0730
       IF (TYPE.NE.8) GO TO 800                                          ARDA  0740
       IF (IRET1 .NE. 0) GO TO 1                                         ARDA  0750
C                                                                        ARDA  0760
C  READ IN VEHICLE CONDITION DATA CARDS (2 CARDS)                        ARDA  0770
       READ (5,101) MACH,ALT,SREF,PSTAG,TSTAG,IPS,ITYP13,IABDOT,IVECT,   ARDA  0780
     1      LAST,NAB,NDAB,NS,TYPE                                        ARDA  0790
  101  FORMAT (3F10.0,1X,F5.0,F7.0,1XI1,2XI1,4X,2I1,5XI1,I2,I1,I2,5XI2)  ARDA  0800
       IF (MACH .GT. 1.0) GO TO 702                                      ARDA  0810
       WRITE (6,701)                                                     ARDA  0820
  701  FORMAT (1H0,47H****INPUT MACH NUMBER MUST BE GREATER THAN  1.0  ) ARDA  0830
       ERROR = 1                                                         ARDA  0840
       GO TO 806                                                         ARDA  0850
  702  IFIRST = 0                                                        ARDA  0860
       IF (TYPE.NE.9) GO TO 800                                          ARDA  0870
       READ (5,102) XCG,YCG,ZCG,SPAN,MAC,TYPE                            ARDA  0880
  102  FORMAT (5F10.0,20XI2  )                                           ARDA  0890
       IF (TYPE .NE. 10) GO TO 800                                       ARDA  0900
       NABCT = 1                                                         ARDA  0910
       NABS = NAB                                                        ARDA  0920
       NPRT = 28                                                         ARDA  0930
       IDFLGA = 0                                                        ARDA  0940
       IDFLGB = 0                                                        ARDA  0950
       IDFLGC = 0                                                        ARDA  0960
       IDFLGD = 0                                                        ARDA  0970
       IDFLGE = 0                                                        ARDA  0980
       IDFLGF = 0                                                        ARDA  0990
C                                                                        ARDA  1000
C  CHECK ON NUMBER OF ALPHA-BETA CONDITIONS (MUST BE LESS THAN 21)       ARDA  1010
       IF (NAB.LT.21) GO TO 7                                            ARDA  1020
       WRITE (6,108)                                                     ARDA  1030
  108  FORMAT (1H ,47H***** NUMBER OF ALPHA-BETA CONDITIONS CANNOT BE    ARDA  1040
     1 59H GREATER THAN 20. JOB WILL BE ATTEMPTED WITH NAB = 20 ***** )  ARDA  1050
       NAB = 20                                                          ARDA  1060
C                                                                        ARDA  1070
```

```
DECK AROA

C  READ SKIN FRICTION SURFACE DATA IF REQUIRED                                   AROA  1080
   7 IF (NS .EQ. 0) GO TO 2                                                     AROA  1090
     DO 8 I=1,NS                                                                AROA  1100
     READ (5,103) (IS(I,J), J=1,9), (SURF(I,J), J=1,8), TYPE                    AROA  1110
 103 FORMAT (I2,8I1,2F9.0,3F6.0,2F6.0,F4.0,8XI2 )                               AROA  1120
     IF (TYPE .NE. 11) GO TO 800                                                AROA  1130
   8 CONTINUE                                                                   AROA  1140
C                                                                               AROA  1150
C  START OF CYCLE TO CALCULATE DATA AT EACH ALPHA-BETA COMBINATION              AROA  1160
C  READ ALPHA-BETA-CPSTAG-SKIN DATA CARD                                        AROA  1170
   2 IF (NOAB .EQ. 1) GO TO 34                                                  AROA  1180
     READ (5,104) ALPHA,BETA,CPSTAG,QRP,ETAC,ENPM,QQINF,IMPACT,ISHAD,           AROA  1190
    1  IDERIV,PRINT,IPRINT,NW,IMPACI,ISHADI,DELTAE,RETRAN,TWALL,TYPE            AROA  1200
 104 FORMAT (3F6.0,F7.0,3F5.0,2I2,4I1,2I2,F5.0,2F4.0,5XI2)                      AROA  1210
C  CHECK CARD TYPE ERROR                                                        AROA  1220
     IF (TYPE .NE. 12) GO TO 802                                                AROA  1230
     RETRAN = RETRAN * 1.0E6                                                    AROA  1240
     GO TO 35                                                                   AROA  1250
C  SET FLIGHT CONDITION DATA TO PREVIOUS INPUT DATA                             AROA  1260
  34 ALPHA = ALP(NABCT)                                                         AROA  1270
     BETA  = BET(NABCT)                                                         AROA  1280
     CPSTAG= CPS(NABCT)                                                         AROA  1290
     QRP   = QRPS(NABCT)                                                        AROA  1300
     ETAC  = ETACS(NABCT)                                                       AROA  1310
     ENPM  = ENPMS(NABCT)                                                       AROA  1320
     QQINF = QQINFS(NABCT)                                                      AROA  1330
     IMPACT= IMP(NABCT)                                                         AROA  1340
     ISHAD = ISH(NABCT)                                                         AROA  1350
     IDERIV= IDERS(NABCT)                                                       AROA  1360
     PRINT = IPRINS(NABCT)                                                      AROA  1370
     IPRINT= IPRTS(NABCT)                                                       AROA  1380
     IMPACI= IMPI(NABCT)                                                        AROA  1390
     ISHADI= ISHI(NABCT)                                                        AROA  1400
     DELTAE= DELTES(NABCT)                                                      AROA  1410
     IF (NAB .EQ. 0) NAB = NABS                                                 AROA  1420
C                                                                               AROA  1430
```

```
DECK AROA

   35  IMP(NABCT) = IMPACT                                                   AROA  1440
       ISH(NABCT) = ISHAD                                                    AROA  1450
       ETACS(NABCT) = ETAC                                                   AROA  1460
       ENPMS(NABCT) = ENPM                                                   AROA  1470
       QRPS(NABCT) = QRP                                                     AROA  1480
       IDERS(NABCT) = IDERIV                                                 AROA  1490
       IPRINS(NABCT) = PRINT                                                 AROA  1500
       IPRTS(NABCT) = IPRINT                                                 AROA  1510
C   SET ALL DERIVATIVES TO ZERO                                              AROA  1520
       DCAA(NABCT)  = 0.0                                                    AROA  1530
       DCLA(NABCT)  = 0.0                                                    AROA  1540
       DCNA(NABCT)  = 0.0                                                    AROA  1550
       DCMA(NABCT)  = 0.0                                                    AROA  1560
       DCMQ(NABCT)  = 0.0                                                    AROA  1570
       DCAQ(NABCT)  = 0.0                                                    AROA  1580
       DCNQ(NABCT)  = 0.0                                                    AROA  1590
       DCYB(NABCT)  = 0.0                                                    AROA  1600
       DCNB(NABCT)  = 0.0                                                    AROA  1610
       DCLLB(NABCT) = 0.0                                                    AROA  1620
       DCYR(NABCT)  = 0.0                                                    AROA  1630
       DCLNR(NABCT) = 0.0                                                    AROA  1640
       DCLLR(NABCT) = 0.0                                                    AROA  1650
       DCLD(NABCT)  = 0.0                                                    AROA  1660
       DCMD(NABCT)  = 0.0                                                    AROA  1670
       DCLLD(NABCT) = 0.0                                                    AROA  1680
       DCYD(NABCT)  = 0.0                                                    AROA  1690
       DCLND(NABCT) = 0.0                                                    AROA  1700
       DCND(NABCT)  = 0.0                                                    AROA  1710
       DCMADT(NABCT)= 0.0                                                    AROA  1720
       DCYBDT(NABCT)= 0.0                                                    AROA  1730
C                                                                            AROA  1740
C   CHECK IF DERIVATIVES ARE TO BE CALCULATED                                AROA  1750
       IF (IDERIV .EQ. 0) GO TO 5                                            AROA  1760
C   SET UP STARTING DERIVATIVE DATA                                          AROA  1770
       IDSTAT = 1                                                            AROA  1780
       ALPHAS = ALPHA                                                        AROA  1790
```

DECK AROA

```
      BETAS   = BETA                                                    AROA  1800
      DELTS   = DELTAE                                                  AROA  1810
      QRPSS   = QRP                                                     AROA  1820
      IF (IDERIV.EQ.1 .OR. IDERIV.EQ.5) ALPHA = ALPHA + 1.0             AROA  1830
      IF (IDERIV.EQ.2 .OR. IDERIV.EQ.6) BETA  = BETA  + 1.0             AROA  1840
      IF (IDERIV .EQ. 4) DELTAE= DELTAE+ 1.0                            AROA  1850
C                                                                       AROA  1860
C  READ INPUT FORCE ITFM CONTRIBUTIONS                                   AROA  1870
    5 IF (ITYP13 .EQ. 0) GO TO 6                                        AROA  1880
      READ (5,107) CAI,CNI,CYI,CLLI,CLMI,CLNI,TYPE                      AROA  1890
  107 FORMAT (6F10.0,10XI2 )                                            AROA  1900
      IF(TYPE .NE. 13) GO TO 800                                        AROA  1910
      GO TO 60                                                          AROA  1920
C  RESET INITIAL ZFRO VALUES ON FORCE COEFFICIENTS                      AROA  1930
    6 CAI = 0.0                                                         AROA  1940
      CNI = 0.0                                                         AROA  1950
      CYI = 0.0                                                         AROA  1960
      CLLI= 0.0                                                         AROA  1970
      CLMI= 0.0                                                         AROA  1980
      CLNI= 0.0                                                         AROA  1990
   60 CONTINUE                                                          AROA  2000
C  GO TO CONTROL DEFLECTION SUBROUTINE IF REQUIRFD                      AROA  2010
      IF (IGTYPF .NE. 1 .AND. IGTYPE .NF. 3) GO TO 36                   AROA  2020
      IF (DELTAE .EQ. DELTAS) GO TO 36                                  AROA  2030
      DELTAS = DELTAE                                                   AROA  2040
      CALL CONTRL (DELTAE,ISIZ)                                         AROA  2050
      IF (ERROR .NE. 0) GO TO 806                                       AROA  2060
   36 CONTINUE                                                          AROA  2070
C                                                                       AROA  2080
C  GO TO FORCE CALCULATION ROUTINE                                      AROA  2090
      CALL FORCE (ALPHA,BETA,CPSTAG,SREF,SYMFCT,XCG,YCG,ZCG,MACH,       AROA  2100
     1 SPAN,MAC,NABCT,QRP,ALT,PRINT,CAI,CNI,CYI,CLLI,CLMI,CLNI,ETAC,NS, AROA  2110
     2 IMPACT,IPRINT,IFIRST,PSTAG,TSTAG,RENO,ISIZ,ENPM,QQINF,ISHAD,     AROA  2120
     3 IORIEN,IMPACI,ISHADI,IDERIV,V,IGTYPE,DELTAE,SWEEP,RETRAN,        AROA  2130
     4 HMLT,HMRT,PFS,NW,TWALL)                                          AROA  2140
      IF (FRROR.NE.0) GO TO 806                                         AROA  2150
```

```
DECK AROA
      DELTES(NABCT) = DELTAE                                            AROA  2160
      IMPI(NABCT)= IMPACI                                               AROA  2170
      ISHI(NABCT)= ISHADI                                               AROA  2180
      HML(NABCT) = HMLT                                                 AROA  2190
      HMR(NABCT) = HMRT                                                 AROA  2200
C                                                                       AROA  2210
C                                                                       AROA  2220
      IFLG = IDERIV + 1                                                 AROA  2230
      GO TO (70,30,40,50,61,30,40),IFLG                                 AROA  2240
C                                                                       AROA  2250
C  LONGITUDINAL DERIVATIVES                                             AROA  2260
   30 GO TO (31,32,33),IDSTAT                                           AROA  2270
   31 CASD1= CCA(NABCT)                                                 AROA  2280
      CLSD1= CCL(NABCT)                                                 AROA  2290
      CNSD1= CCN(NABCT)                                                 AROA  2300
      CLMSD1= CCLM(NABCT)                                               AROA  2310
C                                                                       AROA  2320
      IDSTAT = 2                                                        AROA  2330
      ALPHA = ALPHAS                                                    AROA  2340
      IF (IDERIV .EQ. 1) GO TO 120                                      AROA  2350
      DELQRP = V*0.5E-4                                                 AROA  2360
      QRP = QRP + DELQRP                                                AROA  2370
      GO TO 60                                                          AROA  2380
C                                                                       AROA  2390
   32 CLMSD2 = CCLM(NABCT)                                              AROA  2400
      CASD2  =  CCA(NABCT)                                              AROA  2410
      CNSD2  =  CCN(NABCT)                                              AROA  2420
      QRP    = QRPSS                                                    AROA  2430
C                                                                       AROA  2440
  120 IDSTAT = 3                                                        AROA  2450
      GO TO 60                                                          AROA  2460
C  CALCULATE LONGITUDINAL DERIVATIVES (PER DEGREE)                      AROA  2470
   33 DCAA(NABCT)  =  (CASD1 - CCA(NABCT))  /  1.0                      AROA  2480
      DCLA(NABCT)  =  (CLSD1 - CCL(NABCT))  /  1.0                      AROA  2490
      DCNA(NABCT)  =  (CNSD1 - CCN(NABCT))  /  1.0                      AROA  2500
      DCMA(NABCT)  =  (CLMSD1- CCLM(NABCT)) /  1.0                      AROA  2510
```

```
DECK AROA
C                                                                       AROA  2520
      IF (IDERIV .EQ. 1) GO TO 121                                      AROA  2530
      DCMQ(NABCT)   = ((CLMSD2- CCLM(NABCT))/ DELQRP)*2.0*V/MAC         AROA  2540
      DCAQ(NABCT)   = ((CASD2 - CCA(NABCT)) / DELQRP)*2.0*V/MAC         AROA  2550
      DCNQ(NABCT)   = ((CNSD2 - CCN(NABCT)) / DELQRP)*2.0*V/MAC         AROA  2560
      IDFLGE = 1                                                        AROA  2570
  121 IDFLGA = 1                                                        AROA  2580
      GO TO 70                                                          AROA  2590
C                                                                       AROA  2600
C  DIRECTIONAL DERIVATIVES                                              AROA  2610
   40 GO TO (41,42,43),IDSTAT                                           AROA  2620
   41 CYSD1 = CCY(NABCT)                                                AROA  2630
      CLNSD1= CCLN(NABCT)                                               AROA  2640
      CLLSD1= CCLL(NABCT)                                               AROA  2650
C                                                                       AROA  2660
      IDSTAT = 2                                                        AROA  2670
      BETA = BETAS                                                      AROA  2680
      IF (IDERIV .EQ. 2) GO TO 122                                      AROA  2690
      DELQRP = V*0.5E-4                                                 AROA  2700
      QRP = QRP + DELQRP                                                AROA  2710
      GO TO 60                                                          AROA  2720
C                                                                       AROA  2730
   42 CYSD2 = CCY(NABCT)                                                AROA  2740
      CLNSD2= CCLN(NABCT)                                               AROA  2750
      CLLSD2= CCLL(NABCT)                                               AROA  2760
C                                                                       AROA  2770
      QRP    = QRPSS                                                    AROA  2780
  122 IDSTAT = 3                                                        AROA  2790
      GO TO 60                                                          AROA  2800
C  CALCULATE LATERAL-DIRECTIONAL DERIVATIVES (PER DEGREE)               AROA  2810
   43 DCYB(NABCT)   =  (CYSD1 - CCY(NABCT)) / 1.0                       AROA  2820
      DCNB(NABCT)   =  (CLNSD1-CCLN(NABCT)) / 1.0                       AROA  2830
      DCLLB(NABCT)  =  (CLLSD1-CCLL(NABCT)) / 1.0                       AROA  2840
C                                                                       AROA  2850
      IF (IDERIV .EQ. 2) GO TO 123                                      AROA  2860
      DCYR(NABCT)   = ((CYSD2 - CCY(NABCT)) / DELQRP)*2.0*V/MAC         AROA  2870
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DECK ARDA

      DCLNR(NABCT) = ((CLNSD2-CCLN(NABCT)) / DELQRP)*2.0*V/SPAN              ARDA  2880
      DCLLR(NABCT) = ((CLLSD2-CCLL(NABCT)) / DELQRP)*2.0*V/SPAN              ARDA  2890
      IDFLGF = 1                                                             ARDA  2900
  123 IDFLGB = 1                                                             ARDA  2910
      GO TO 70                                                               ARDA  2920
C  ROLL DERIVATIVES                                                          ARDA  2930
   5C WRITE (6,813)                                                          ARDA  2940
  813 FORMAT (1H ,51H***ROLL DERIVATIVE PART OF PROGRAM IS NOT OPERATIVE     ARDA  2950
     1 23H AT THE PRESENT TIME*** )                                          ARDA  2960
      GO TO 806                                                              ARDA  2970
C                                                                            ARDA  2980
C  CONTROL SURFACE DERIVATIVES                                               ARDA  2990
   61 GO TO (62,63), IDSTAT                                                  ARDA  3000
   62 CLSD1 = CCL(NABCT)                                                     ARDA  3010
      CLMSD1= CCLM(NABCT)                                                    ARDA  3020
      CLLSD1=CCLL(NABCT)                                                     ARDA  3030
      CYSD1 = CCY(NABCT)                                                     ARDA  3040
      CLNSD1= CCLN(NABCT)                                                    ARDA  3050
      CNSD1 = CCN(NABCT)                                                     ARDA  3060
C                                                                            ARDA  3070
      IDSTAT = 2                                                             ARDA  3080
      DELTAE = DELTS                                                         ARDA  3090
      GO TO 60                                                               ARDA  3100
C  CALCULATE CONTROL SURFACE DERIVATIVES (PER DEGREE)                        ARDA  3110
   63 DCLD(NABCT)  =  (CLSD1  - CCL(NABCT))  / 1.0                           ARDA  3120
      DCMD(NABCT)  =  (CLMSD1 - CCLM(NABCT)) / 1.0                           ARDA  3130
      DCLLD(NABCT) =  (CLLSD1 - CCLL(NABCT)) / 1.0                           ARDA  3140
      DCYD(NABCT)  =  (CYSD1  - CCY(NABCT))  / 1.0                           ARDA  315
      DCLND(NABCT) =  (CLNSD1 - CCLN(NABCT)) / 1.0                           ARDA  3160
      DCND(NABCT)  =  (CNSD1  - CCN(NABCT))  / 1.0                           ARDA  3170
      IF (ABS(DCLLD(NABCT)).LT.1.0E-10) DCLLD(NABCT) = 0.0                   ARDA  3180
      IF (ABS(DCYD(NABCT)).LT.1.0E-10) DCYD(NABCT) = 0.0                     ARDA  3190
      IF (ABS(DCLND(NABCT)).LT.1.0E-10) DCLND(NABCT) = 0.0                   ARDA  3200
      IDFLGD = 1                                                             ARDA  3210
C                                                                            ARDA  3220
C                                                                            ARDA  3230
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DECK AROA

C  STEP ALPHA-BETA COUNTER BY ONE                                        AROA  3240
  70  NABCT = NABCT + 1                                                  AROA  3250
C                                                                        AROA  3260
C  CHECK ON ALPHA-BETA COUNTER FOR END OF ALPHA-BETA SET                 AROA  3270
      IF (NABCT.LE.NAB) GO TO 2                                          AROA  3280
C                                                                        AROA  3290
C   CALCULATE PLUNGE DERIVATIVES IF REQUIRED                             AROA  3300
  21  IF (IABDOT .EQ. 0) GO TO 125                                       AROA  3310
      DO 124 J=1,NAB                                                     AROA  3320
      IF (IDERIV.NE.5 .AND. IDERIV.NE.6) GO TO 124                       AROA  3330
      CALL PLUNGE (IDERS(NAB),DCMA(NAB),DCYB(NAB),DCMADT(NAB),           AROA  3340
     1  DCYBDT(NAB))                                                     AROA  3350
      IF (ERROR .NE. 0) GO TO 800                                        AROA  3360
 124  CONTINUE                                                           AROA  3370
C                                                                        AROA  3380
C   CALCULATE EFFECT OF INPUT VECTORS IF REQUIRED                        AROA  3390
 125  IF (IVECT .EQ. 0) GO TO 127                                        AROA  3400
      DO 126 J=1,NAB                                                     AROA  3410
      CALL VECTOR (MACH,PFS,SREF,XCG,YCG,ZCG,SPAN,MAC,                   AROA  3420
     1  ALP(J),CCD(J),CCL(J),CCA(J),CCY(J),CCN(J),BET(J),                AROA  3430
     2  CLOD(J),CCLM(J),CCLL(J),CCLN(J))                                 AROA  3440
      IF (ERROR .NE. 0) GO TO 800                                        AROA  3450
 126  CONTINUE                                                           AROA  3460
C  WRITE OUT SUMMARY OF FORCE DATA                                       AROA  3470
 127  DO 14 J=1,NAB                                                      AROA  3480
      IF (NPRT.GE.28) GO TO 3                                            AROA  3490
      NPRT = NPRT + 2                                                    AROA  3500
       GO TO 4                                                           AROA  3510
   3  NPRT = 0                                                           AROA  3520
      CALL HEADER                                                        AROA  3530
      WRITE (6,105) MACH,V,RENO                                          AROA  3540
 105  FORMAT (1H0,7H  MACH=F8.3,6H  VEL=F9.1,16H FT/SEC  RE/FT =E13.5 )  AROA  3550
      IF (PSTAG .LT. 0.00001) WRITE (6,111) ALT                          AROA  3560
 111  FORMAT (1H ,7H  ALT =F8.0 )                                        AROA  3570
      IF (PSTAG .GT. 0.00001) WRITE (6,112) PSTAG,TSTAG                  AROA  3580
 112  FORMAT (1H ,16X7HP STAG=F7.1,16H ATMOS   T STAG=F7.1,6H DEG F )    AROA  3590
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      WRITE (6,113) SREF,SPAN,MAC,XCG,YCG,ZCG                             AROA  3600
 113  FORMAT (1HO,9H   S REF =F9.2,8H  SPAN =F8.2,8H  MAC   =F8.2,/1H ,   AROA  3610
     1  9H   X CG  =F9.2,8H  Y CG =F8.2,8H  Z CG =F8.2 )                   AROA  3620
      WRITE (6,114)                                                        AROA  3630
 114  FORMAT (1HO,10HFORCE DATA,71X12HCONTROL DATA,/1H ,                   AROA  3640
     1 7H  ALPHA,4X3HC D,7X3HC L,7X3HC A,7X3HC Y,7X3HC N,6X3H  K,         AROA  3650
     2 20X29HIMPACT  ETAC  IMPACI  DELTA E,/1H ,                          AROA  3660
     3 6H  BETA,5X3HL/D,7X3HC M,7X4HC LL,6X4HC LN,6X3HC F,6X7HQ/Q INF,    AROA  367C
     4 16X20HISHAD   ENPM  ISHADI  )                                       AROA  3680
C                                                                          AROA  3690
      IF (IDFLGA .EQ. 1) WRITE (6,807)                                     AROA  3700
 8C7  FORMAT (1H ,11X4HCA A,6X4HCL A,6X4HCN A,6X4HCM A)                    AROA  3710
      IF (IDFLGB .EQ. 1) WRITE (6,808)                                     AROA  3720
 8C8  FORMAT (1H ,11X4HCY B,6X5HCLN B,5X5HCLL B)                           AROA  3730
      IF (IDFLGE .EQ. 1) WRITE (6,816)                                     AROA  3740
 816  FORMAT (1H ,11X4HCM Q,6X4HCA Q,6X4HCN Q,6X5HCMA D,39X1HQ )           AROA  3750
      IF (IDFLGF .EQ. 1) WRITE (6,817)                                     AROA  3760
 817  FORMAT (1H ,11X4HCY R,6X5HCLN R,5X5HCLL R,5X5HCYB D,39X1HR )         AROA  3770
      IF (IDFLGD .EQ. 1) WRITE (6,814)                                     AROA  3780
 814  FORMAT (1H ,11X4HCM D,6X5HCLL D,5X4HCY D,6X5HCLN D,5X4HCN D,29X,     AROA  3790
     1  4HHM L,4X4HHM R)                                                   AROA  3800
C                                                                          AROA  3810
   4  WRITE (6,106)ALP(J),CCD(J),CCL(J),CCA(J),CCY(J),CCN(J),CPS(J),       AROA  3820
     1 IMP(J),ETACS(J),IMPI(J),DELTES(J),                                  AROA  3830
     2 BET(J),CLOD(J),CCLM(J),CCLL(J),CCLN(J),CF(J),QQINFS(J),             AROA  3840
     3 ISH(J),ENPMS(J),ISHI(J)                                             AROA  3850
 106  FORMAT (1HO,F7.2,6F10.5,16XI3,F10.4,I5,F10.2,/1H ,F7.2,6F10.5,       AROA  3860
     1 16XI3,F10.4,I5 )                                                    AROA  3870
      IF (IDFLGA .EQ. 1) WRITE (6,809) DCAA(J),DCLA(J),DCNA(J),DCMA(J)     AROA  3880
 809  FORMAT (1H ,7X,4F10.5)                                               AROA  3890
      IF (IDFLGB .EQ. 1) WRITE (6,812) DCYB(J),DCNB(J),DCLLB(J)            AROA  390C
 812  FORMAT (1H ,7X,3F10.5)                                               AROA  3910
      IF (IDFLGE .EQ. 1) WRITE (6,818) DCMQ(J),DCAQ(J),DCNQ(J),            AROA  3920
     1                           DCMADT(J),QRPS(J)                         AROA  3930
 818  FORMAT (1H ,7X,4F10.5,34X,1PE10.3)                                   AROA  3940
      IF (IDFLGF .EQ. 1) WRITE (6,819) DCYR(J),DCLNR(J),DCLLR(J),          AROA  3950
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     1                      DCYBDT(J),QRPS(J)                                  ARDA  3960
 819  FORMAT (1H ,7X,4F10.5,34X,1PE10.3)                                        ARDA  3970
      IF (IDFLGD .EQ. 1) WRITE (6,815) DCMD(J),DCLLD(J),DCYD(J),                ARDA  3980
     1  DCLND(J),DCND(J),HML(J),HMR(J)                                          ARDA  3990
 815  FORMAT (1H ,8X,1PE10.2,4E10.2,22X,2E10.2)                                 ARDA  4000
      IF (IDFLGA.EQ.1) NPRT = NPRT + 1                                          ARDA  4010
      IF (IDFLGB.EQ.1) NPRT = NPRT + 1                                          ARDA  4020
      IF (IDFLGD.EQ.1) NPRT = NPRT + 1                                          ARDA  4030
      IF (IDFLGE.EQ.1) NPRT = NPRT + 1                                          ARDA  4040
      IF (IDFLGF.EQ.1) NPRT = NPRT + 1                                          ARDA  4050
C                                                                               ARDA  4060
      IF (IPS .EQ. 0) GO TO 20                                                  ARDA  4070
      WRITE (9) ALP(J),CCD(J),CCL(J),CCA(J),CCY(J),CCN(J),BET(J),               ARDA  4080
     1          CLOD(J),CCLM(J),CCLL(J),CCLN(J),CF(J),IPL9                      ARDA  4090
C  STORE DATA FOR FUTURE SUMMATION ON TAPE 1 IF REQUIRED                        ARDA  4100
  20  IF (ISUM .NE. 1) GO TO 14                                                 ARDA  4110
      WRITE (1) ALP(J),CCD(J),CCL(J),CCA(J),CCY(J),CCN(J),CPS(J),               ARDA  4120
     1 BET(J),CLOD(J),CCLM(J),CCLL(J),CCLN(J),CF(J),QQINFS(J),                  ARDA  4130
     2 DCAA(J),DCLA(J),DCNA(J),DCMA(J),DCMQ(J),DCAQ(J),DCNQ(J),                 ARDA  4140
     3 DCYB(J),DCNB(J),DCLLB(J),DCYR(J),DCLNR(J),DCLLR(J),DELTES(J),            ARDA  4150
     4 DCLD(J),DCMD(J),DCLLD(J),DCYD(J),DCLND(J),DCND(J),HML(J),HMR(J),         ARDA  4160
     5 DCMADT(J),DCYBDT(J)                                                      ARDA  4170
      NSAVE = NSAVE + 1                                                         ARDA  4180
  14  CONTINUE                                                                  ARDA  4190
      IF (ISUM .EQ. 1) WRITE (6,128)                                            ARDA  4200
 128  FORMAT (1H0,10X,40HTHESE DATA HAVE BEEN SAVED FOR SUMMATION)              ARDA  4210
      IF (ISUM .GE. 2) WRITE (6,130) NSAVE2                                     ARDA  4220
 130  FORMAT (1H0,10X,31HTHESE DATA ARE THE SUMMATION OF,I4,                    ARDA  4230
     1 28H COMPONENTS PREVIOUSLY SAVED )                                        ARDA  4240
C                                                                               ARDA  4250
      IF (IPS .EQ. 0) GO TO 16                                                  ARDA  4260
      WRITE (10) NAB,NAB,NAB,NAB,IPL10                                          ARDA  4270
      WRITE (6,129)                                                             ARDA  4280
 129  FORMAT (1H0,10X,39HTHESE DATA HAVE BEEN SAVED FOR PLOTTING )              ARDA  4290
  16  CONTINUE                                                                  ARDA  4300
C                                                                               ARDA  4310
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DECK AROA

C  CHECK IF LAST MACH-ALT CONDITION HAS BEEN CALCULATED                 AROA  4320
  10  IF (LAST) 11,1,11                                                 AROA  4330
C                                                                       AROA  4340
C  ADD UP PREVIOUSLY SAVED DATA AND PRINT (IF ISUM = 2)                 AROA  4350
  15  REWIND 1                                                          AROA  4360
      NSAVE2 = NSAVE / NAB                                              AROA  4370
      DO 17 I=1,NSAVE2                                                  AROA  4380
       DO 18 J=1,NAB                                                    AROA  4390
        READ (1) ALP(J),CCD(J),CCL(J),CCA(J),CCY(J),CCN(J),CPS(J),      AROA  4400
     1   BET(J),CLOD(J),CCLM(J),CCLL(J),CCLN(J),CF(J),QQINFS(J),       AROA  4410
     2   DCAA(J),DCLA(J),DCNA(J),DCMA(J),DCMQ(J),DCAQ(J),DCNQ(J),      AROA  4420
     3   DCYB(J),DCNB(J),DCLLB(J),DCYR(J),DCLNR(J),DCLLR(J),DELTES(J), AROA  4430
     4   DCLD(J),DCMD(J),DCLLD(J),DCYD(J),DCLND(J),DCND(J),HML(J),     AROA  4440
     5   HMR(J),DCMADT(J),DCYBDT(J)                                    AROA  4450
         CCDS(J)= CCDS(J) + CCD(J)                                      AROA  4460
         CCLS(J)= CCLS(J) + CCL(J)                                      AROA  4470
         CCAS(J)= CCAS(J) + CCA(J)                                      AROA  4480
         CCYS(J)= CCYS(J) + CCY(J)                                      AROA  4490
         CCNS(J)= CCNS(J) + CCN(J)                                      AROA  4500
         CCLMS(J) = CCLMS(J) + CCLM(J)                                  AROA  4510
         CCLLS(J) = CCLLS(J) + CCLL(J)                                  AROA  4520
         CCLNS(J) = CCLNS(J) + CCLN(J)                                  AROA  4530
         CFS(J) = CFS(J) + CF(J)                                        AROA  4540
         DCAAS(J) =  DCAAS(J) + DCAA(J)                                 AROA  4550
         DCLAS(J) =  DCLAS(J) + DCLA(J)                                 AROA  4560
         DCNAS(J) =  DCNAS(J) + DCNA(J)                                 AROA  4570
         DCMAS(J) =  DCMAS(J) + DCMA(J)                                 AROA  4580
         DCMQS(J) =  DCMQS(J) + DCMQ(J)                                 AROA  4590
         DCAQS(J) =  DCAQS(J) + DCAQ(J)                                 AROA  4600
         DCNQS(J) =  DCNQS(J) + DCNQ(J)                                 AROA  4610
         DCYBS(J) =  DCYBS(J) + DCYB(J)                                 AROA  4620
         DCNBS(J) =  DCNBS(J) + DCNB(J)                                 AROA  4630
         DCLLBS(J)=  DCLLBS(J)+ DCLLB(J)                                AROA  4640
         DCYRS(J) =  DCYRS(J) + DCYR(J)                                 AROA  4650
         DCLNRS(J)=  DCLNRS(J)+ DCLNR(J)                                AROA  4660
         DCLLRS(J)=  DCLLRS(J)+ DCLLR(J)                                AROA  4670
```

```
DECK ARDA

            DCLDS(J) =  DCLDS(J) + DCLD(J)                          ARDA  4680
            DCMDS(J) =  DCMDS(J) + DCMD(J)                          ARDA  4690
            DCLLDS(J)=  DCLLDS(J)+ DCLLD(J)                         ARDA  4700
            DCYDS(J) =  DCYDS(J) + DCYD(J)                          ARDA  4710
            DCLNDS(J)=  DCLNDS(J)+ DCLND(J)                         ARDA  4720
            DCNDS(J) =  DCNDS(J) + DCND(J)                          ARDA  4730
            HMLS(J)  =  HMLS(J)  + HML(J)                           ARDA  4740
            HMRS(J)  =  HMRS(J)  + HMR(J)                           ARDA  4750
            DCMADS(J)=  DCMADS(J)+ DCMADT(J)                        ARDA  4760
            DCYBDS(J)=  DCYBDS(J)+ DCYBDT(J)                        ARDA  4770
   18    CONTINUE                                                   ARDA  4780
   17   CONTINUE                                                    ARDA  4790
C                                                                   ARDA  4800
        DO 19 J=1,NAB                                               ARDA  4810
         CCD(J) = CCDS(J)                                           ARDA  4820
         CCL(J) = CCLS(J)                                           ARDA  4830
         CCA(J) = CCAS(J)                                           ARDA  4840
         CCY(J) = CCYS(J)                                           ARDA  4850
         CCN(J) = CCNS(J)                                           ARDA  4860
         CCLM(J) = CCLMS(J)                                         ARDA  4870
         CCLL(J) = CCLLS(J)                                         ARDA  4880
         CCLN(J) = CCLNS(J)                                         ARDA  4890
         CF(J) = CFS(J)                                             ARDA  4900
         DCAA(J) = DCAAS(J)                                         ARDA  4910
         DCLA(J) = DCLAS(J)                                         ARDA  4920
         DCNA(J) = DCNAS(J)                                         ARDA  4930
         DCMA(J) = DCMAS(J)                                         ARDA  4940
         DCMQ(J) = DCMQS(J)                                         ARDA  4950
         DCAQ(J) = DCAQS(J)                                         ARDA  4960
         DCNQ(J) = DCNQS(J)                                         ARDA  4970
         DCYB(J) = DCYBS(J)                                         ARDA  4980
         DCNB(J) = DCNBS(J)                                         ARDA  4990
         DCLLB(J)= DCLLBS(J)                                        ARDA  5000
         DCYR(J) = DCYRS(J)                                         ARDA  5010
         DCLNR(J)= DCLNRS(J)                                        ARDA  5020
         DCLLR(J)= DCLLRS(J)                                        ARDA  5030
```

DECK AROA

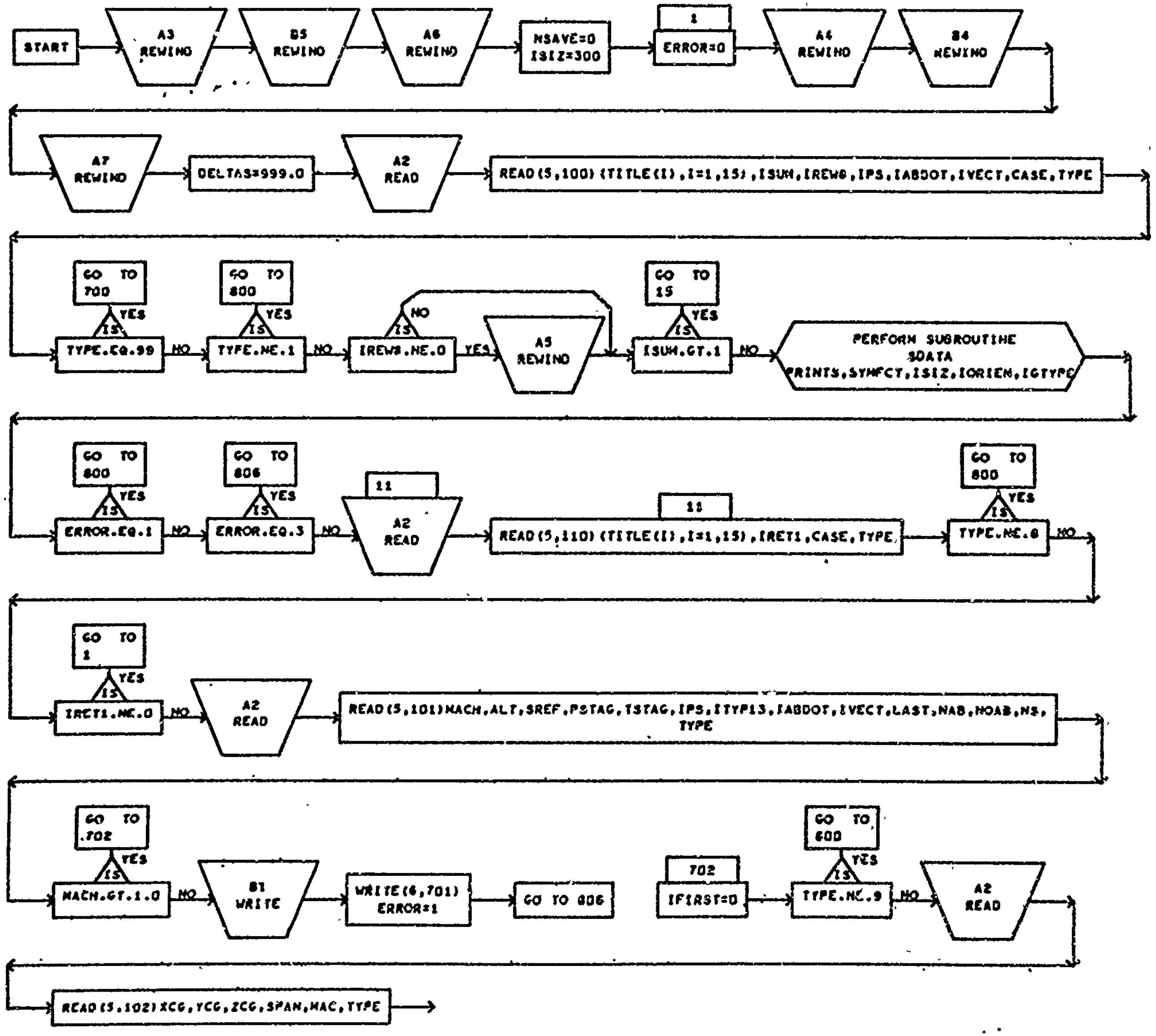
```
        DCLD(J)  = DCLDS(J)                                                     AROA  5040
        DCMD(J)  = DCMDS(J)                                                     AROA  5050
        DCLLD(J)= DCLLDS(J)                                                     AROA  5060
        DCYD(J)  = DCYDS(J)                                                     AROA  5070
        DCLND(J)= DCLNDS(J)                                                     AROA  5080
        DCND(J)  = DCNDS(J)                                                     AROA  5090
        HML(J)   = HMLS(J)                                                      AROA  5100
        HMR(J)   = HMRS(J)                                                      AROA  5110
        DCMADT(J)= DCMADS(J)                                                    AROA  5120
        DCYBDT(J)= DCYBDS(J)                                                    AROA  5130
         CCDS(J)  = 0.0                                                         AROA  5140
         CCLS(J)  = 0.0                                                         AROA  5150
         CCAS(J)  = 0.0                                                         AROA  5160
         CCYS(J)  = 0.0                                                         AROA  5170
         CCNS(J)  = 0.0                                                         AROA  5180
         CCLMS(J)= 0.0                                                          AROA  5190
         CCLLS(J)= 0.0                                                          AROA  5200
         CCLNS(J)= 0.0                                                          AROA  5210
         CFS(J)   = 0.0                                                         AROA  5220
         DCAAS(J)  = 0.0                                                        AROA  5230
         DCLAS(J)  = 0.0                                                        AROA  5240
         DCNAS(J)  = 0.0                                                        AROA  5250
         DCMAS(J)  = 0.0                                                        AROA  5260
         DCMQS(J)  = 0.0                                                        AROA  5270
         DCAQS(J)  = 0.0                                                        AROA  5280
         DCNQS(J)  = 0.0                                                        AROA  5290
         DCYBS(J)  = 0.0                                                        AROA  5300
         DCNBS(J)  = 0.0                                                        AROA  5310
         DCLLBS(J)= 0.0                                                         AROA  5320
         DCYRS(J)  = 0.0                                                        AROA  5330
         DCLNRS(J)= 0.0                                                         AROA  5340
         DCLLRS(J)= 0.0                                                         AROA  5350
         DCLDS(J)  = 0.0                                                        AROA  5360
         DCMDS(J)  = 0.0                                                        AROA  5370
         DCLLDS(J)= 0.0                                                         AROA  5380
         DCYDS(J)  = 0.0                                                        AROA  5390
```

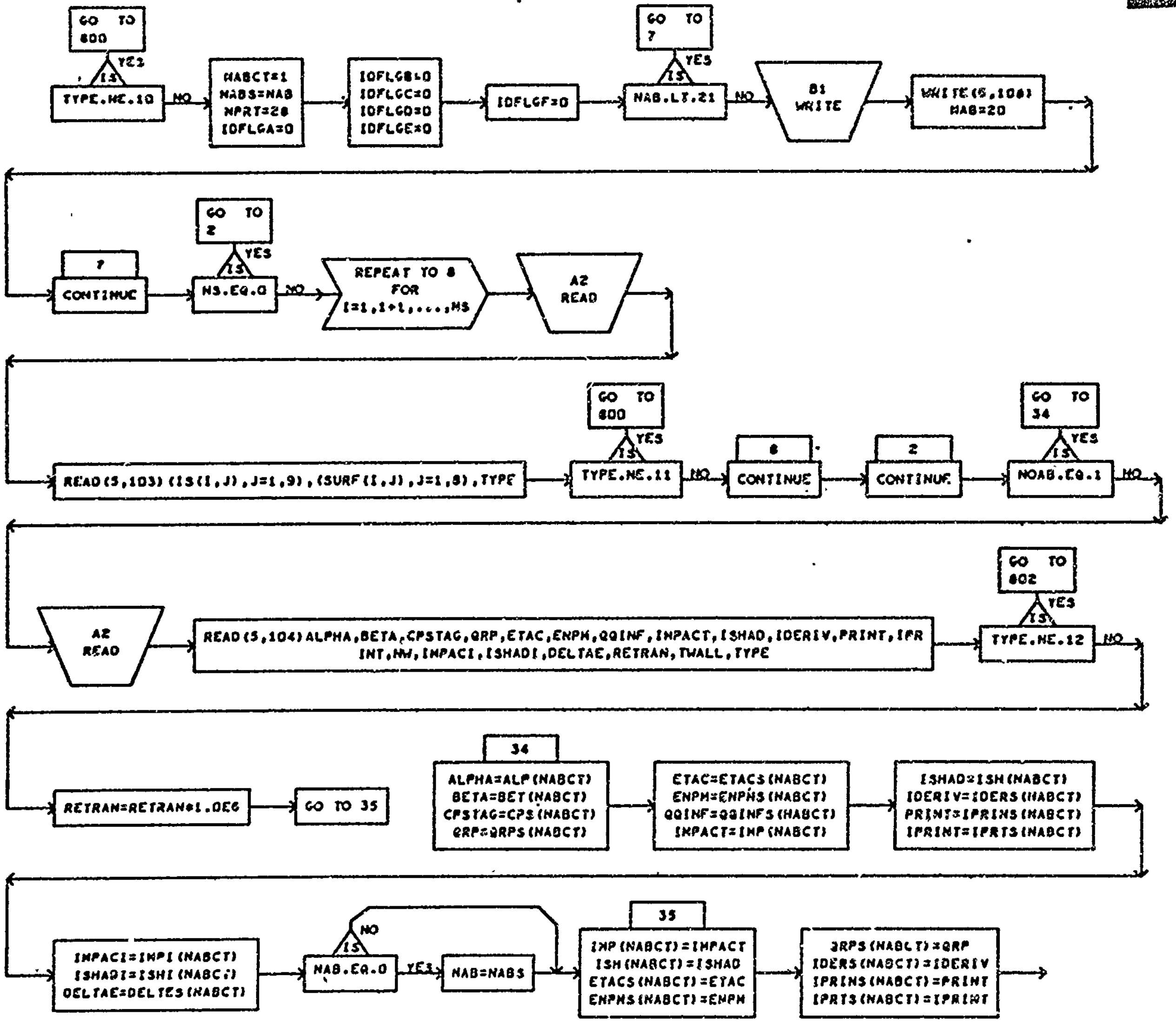
DECK AROA

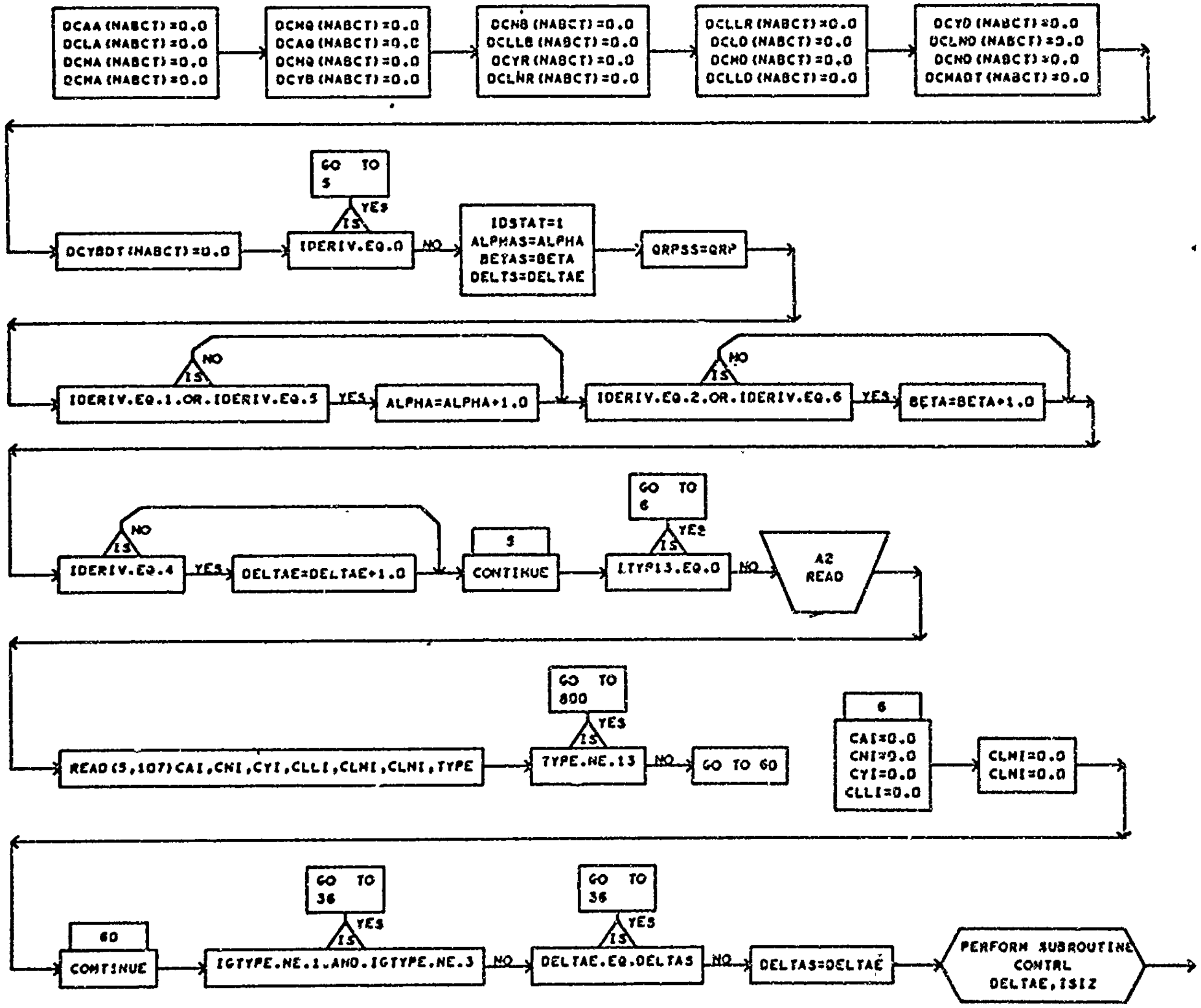
```
        DCLNDS(J)= 0.0                                                  AROA  5400
        DCNDS(J) = 0.0                                                  AROA  5410
       HMLS(J)   = 0.0                                                  AROA  5420
       DCMADS(J) = 0.0                                                  AROA  5430
       DCYBDS(J) = 0.0                                                  AROA  5440
       HMRS(J)   = 0.0                                                  AROA  5450
   19  CLOD(J) = CCL(J) / CCD(J)                                        AROA  5460
C                                                                       AROA  5470
      LAST = 0                                                          AROA  5480
      NPRT = 28                                                         AROA  5490
C  CHECK ISUM FLAG AND SET TAPE 1 TO PROPER POSITION FOR NEXT RUN       AROA  5500
C     IF ISUM = 2 LEAVE TAPE 1 IN ITS PRESENT POSITION FOR NEW DATA     AROA  5510
C     IF ISUM = 3 REWIND TAPE 1 FOR A NEW SET OF SAVED DATA             AROA  5520
C     IF ISUM = 4 BACKSPACE TAPE 1 ONE SET OF SUMMATION DATA            AROA  5530
C     IF ISUM = 5 AFTER PRINTING OF SUMMATION DATA REWIND SUMMATION TAPE AROA  5540
C               AND WRITE THE SUMMATION DATA ONLY ON THE TAPE           AROA  5550
      GO TO (21,21,22,23,25),ISUM                                       AROA  5560
   22 REWIND 1                                                          AROA  5570
      NSAVE = 0                                                         AROA  5580
      GO TO 21                                                          AROA  5590
   23 DO 24 J=1,NAB                                                     AROA  5600
   24 BACKSPACE 1                                                       AROA  5610
      NSAVE = NSAVE - NAB                                               AROA  5620
      GO TO 21                                                          AROA  5630
   25 REWIND 1                                                          AROA  5640
      NSAVE = 0                                                         AROA  5650
      ISUM  = 1                                                         AROA  5660
      GO TO 21                                                          AROA  5670
C                                                                       AROA  5680
C  ERROR CHECK ON READING CARDS                                         AROA  5690
  802 WRITE (6,804)                                                     AROA  5700
  804 FORMAT (1H0,48H***** PROGRAM HAS ATTEMPTED TO READ A ALPHA-BETA   AROA  5710
     147H COMBINATION CARD WITH THE WRONG TYPE CODE***** )              AROA  5720
C                                                                       AROA  5730
C  WRITE OUT CARD TYPE ERROR STATEMENT AND TERMINATE JOB                AROA  5740
  800 WRITE (6,801)                                                     AROA  5750
```

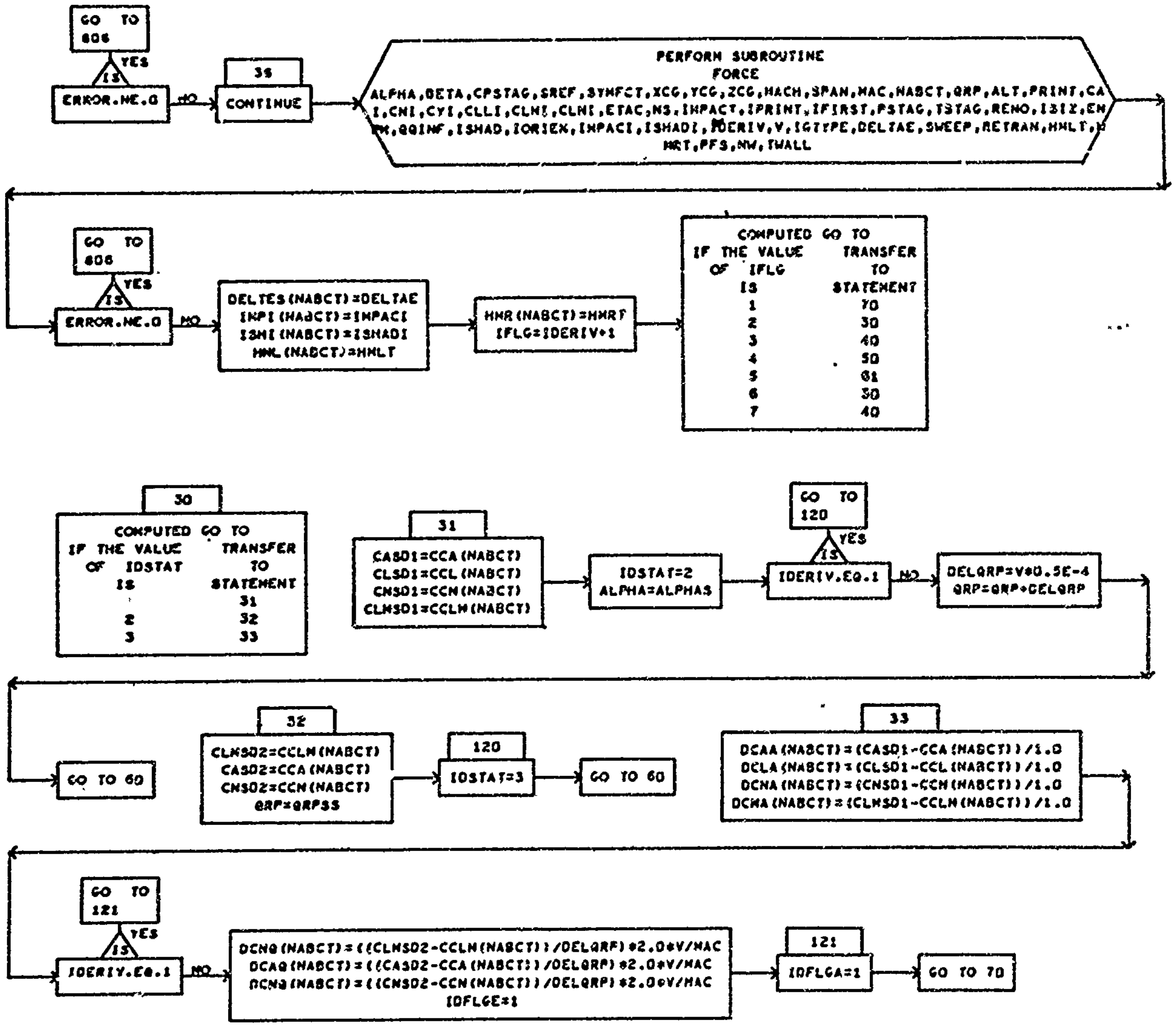
```
CECK AROA

 801  FORMAT (1H0,51H **************************************************  AROA  5760
     163H***************************************************************  AROA  5770
     2 /1H ,  54H*** CONGRATULATIONS - YOU HAVE HIT THE JACKPOT WITH AN   AROA  5780
     3 61H ERROR INVOLVING EITHER CARD ORDER OR CARD TYPE INDICATION***)  AROA  5790
      READ (5,810) (CARD(I),I=1,20)                                       AROA  5800
 810  FORMAT (20A4)                                                       AROA  5810
      WRITE (6,805) (CARD(I),I=1,20)                                      AROA  5820
 805  FORMAT (1H0,45H THE CARD LOCATED JUST BEFORE THE CARD LISTED        AROA  5830
     1 18H BELOW IS IN ERROR,/1H 20A4)                                    AROA  5840
      ERROR = 1                                                           AROA  5850
 806  RETURN                                                              AROA  5860
 700  ERROR = 0                                                           AROA  5870
      RETURN                                                              AROA  5880
C                                                                         AROA  5890
      END                                                                 AROA  5900
```

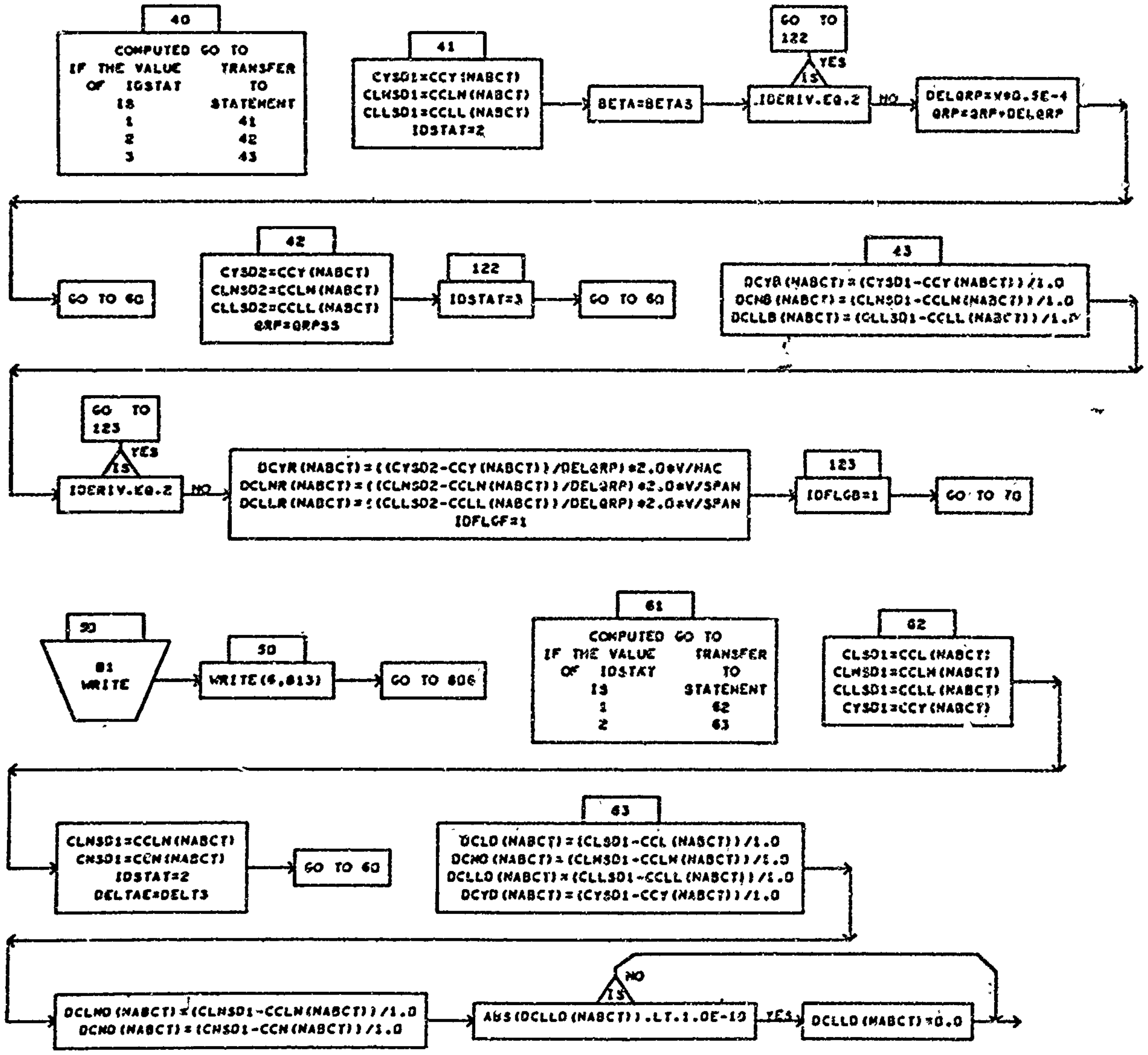
SUBROUTINE AERO

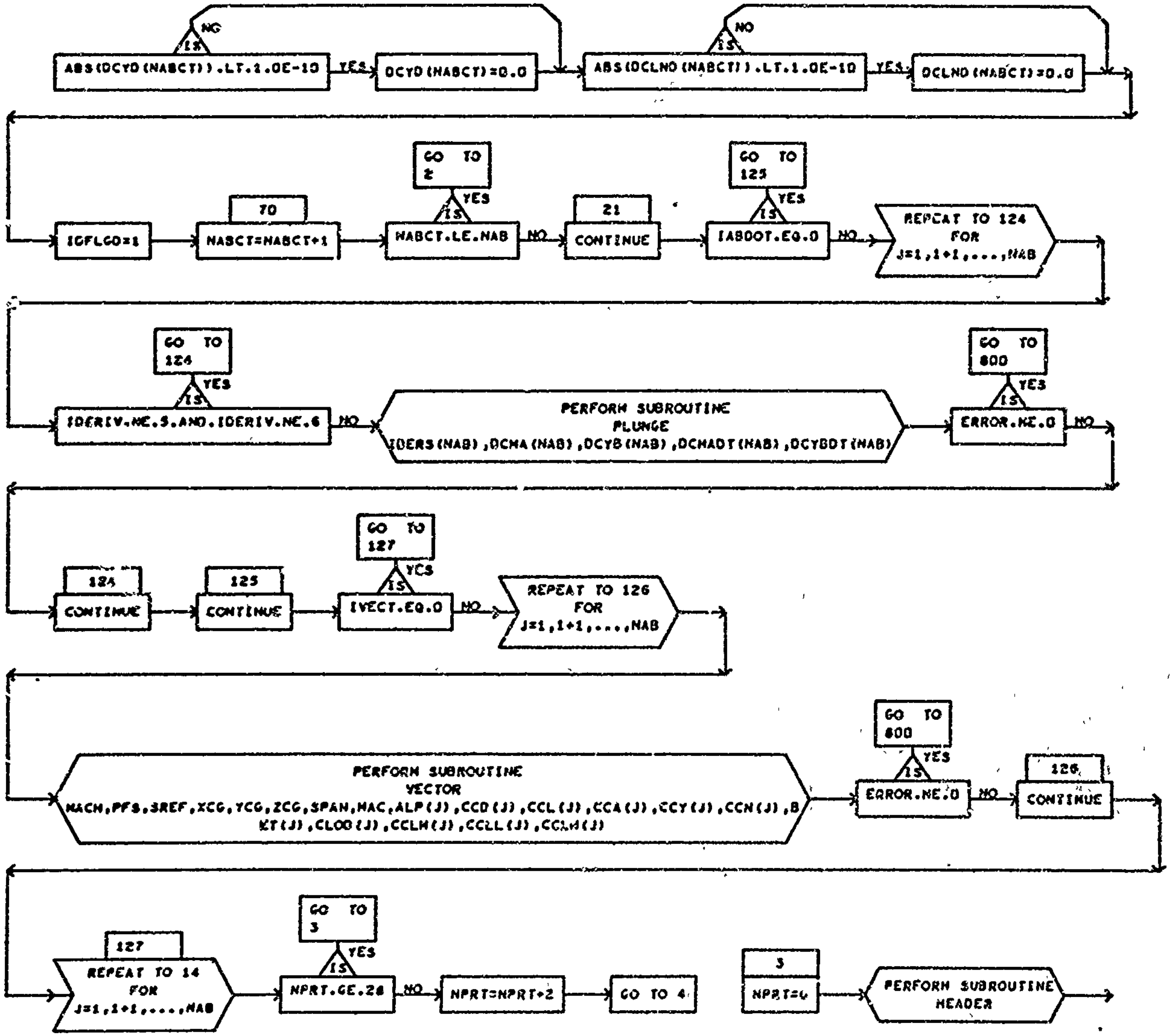


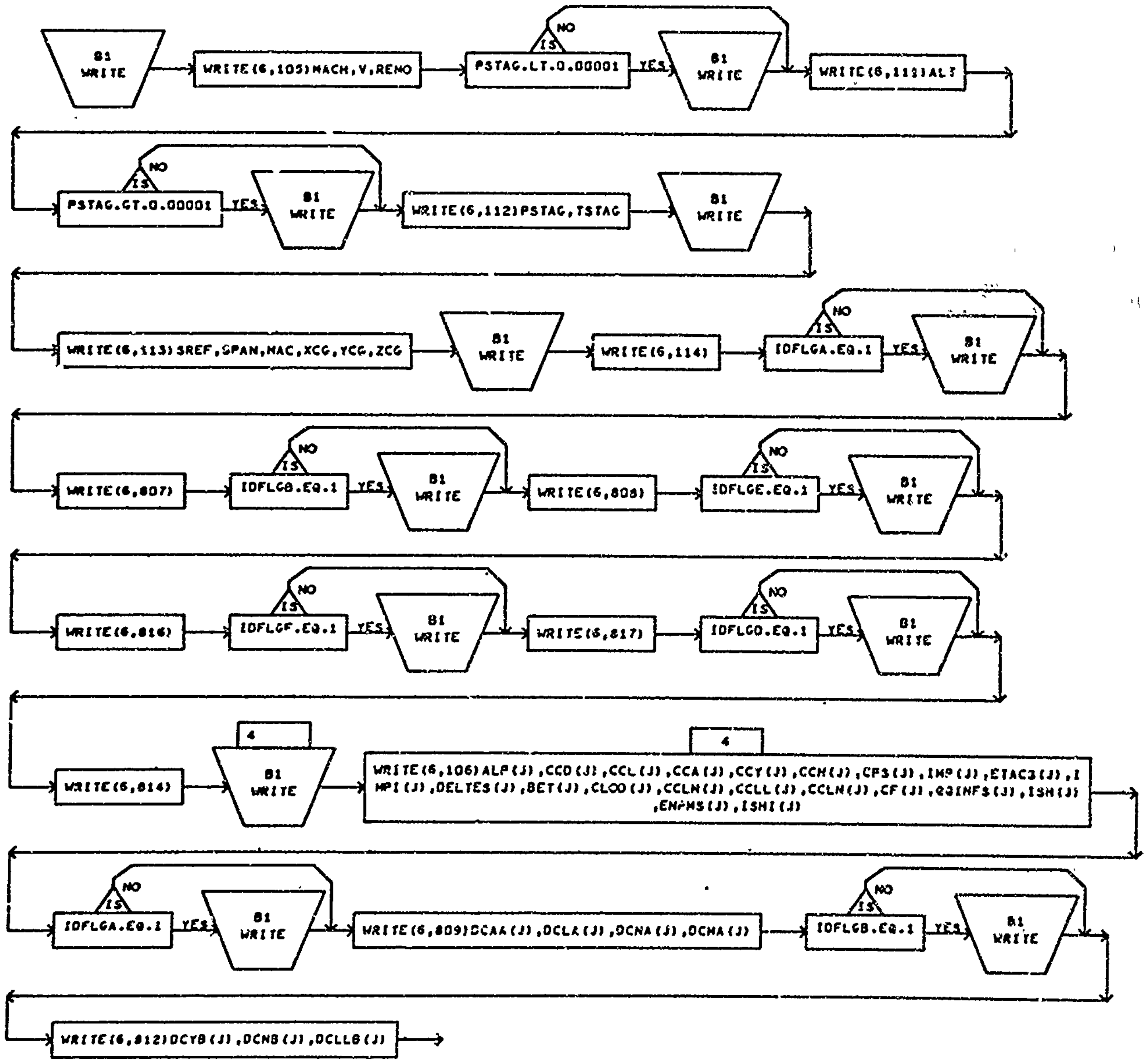

GO TO 800
YES
IS
TYPE.NE.10
NO
NABCT=1
NABS=NAB
NPRT=28
IDFLGA=0
IDFLGB=0
IDFLGC=0
IDFLGD=0
IDFLGE=0
IDFLGF=0
GO TO 7
YES
IS
NAB.LT.21
NO
B1
WRITE
WRITE(6,108)
NAB=20
7
CONTINUE
GO TO 2
YES
IS
NS.EQ.0
NO
REPEAT TO 8
FOR
I=1,1+1,....,NS
A2
READ
READ(5,103) (IS(I,J),J=1,9),(SURF(I,J),J=1,8),TYPE
GO TO 800
YES
IS
TYPE.NE.11
NO
8
CONTINUE
2
CONTINUE
GO TO 34
YES
IS
NOAB.EQ.1
NO
A2
READ
READ(5,104) ALPHA,BETA,CPSTAG,QRP,ETAC,ENPH,QQINF,IMPACT,ISHAD,IDERIV,PRINT,IPR
INT,NW,IMPACI,ISHADI,DELTAE,RETRAN,TWALL,TYPE
GO TO 802
YES
IS
TYPE.NE.12
NO
RETRAN=RETRAN*1.0E6
GO TO 35
34
ALPHA=ALP(NABCT)
BETA=BET(NABCT)
CPSTAG=CPS(NABCT)
QRP=QRPS(NABCT)
ETAC=ETACS(NABCT)
ENPH=ENPHS(NABCT)
QQINF=QQINFS(NABCT)
IMPACT=IMP(NABCT)
ISHAD=ISH(NABCT)
IDERIV=IDERS(NABCT)
PRINT=IPRINS(NABCT)
IPRINT=IPRTS(NABCT)
IMPACI=IMPI(NABCT)
ISHADI=ISHI(NABCT)
DELTAE=DELTES(NABCT)
NO
IS
NAB.EQ.0
YES
NAB=NABS
35
IMP(NABCT)=IMPACT
ISH(NABCT)=ISHAD
ETACS(NABCT)=ETAC
ENPHS(NABCT)=ENPH
QRPS(NABCT)=QRP
IDERS(NABCT)=IDERIV
IPRINS(NABCT)=PRINT
IPRTS(NABCT)=IPRINT

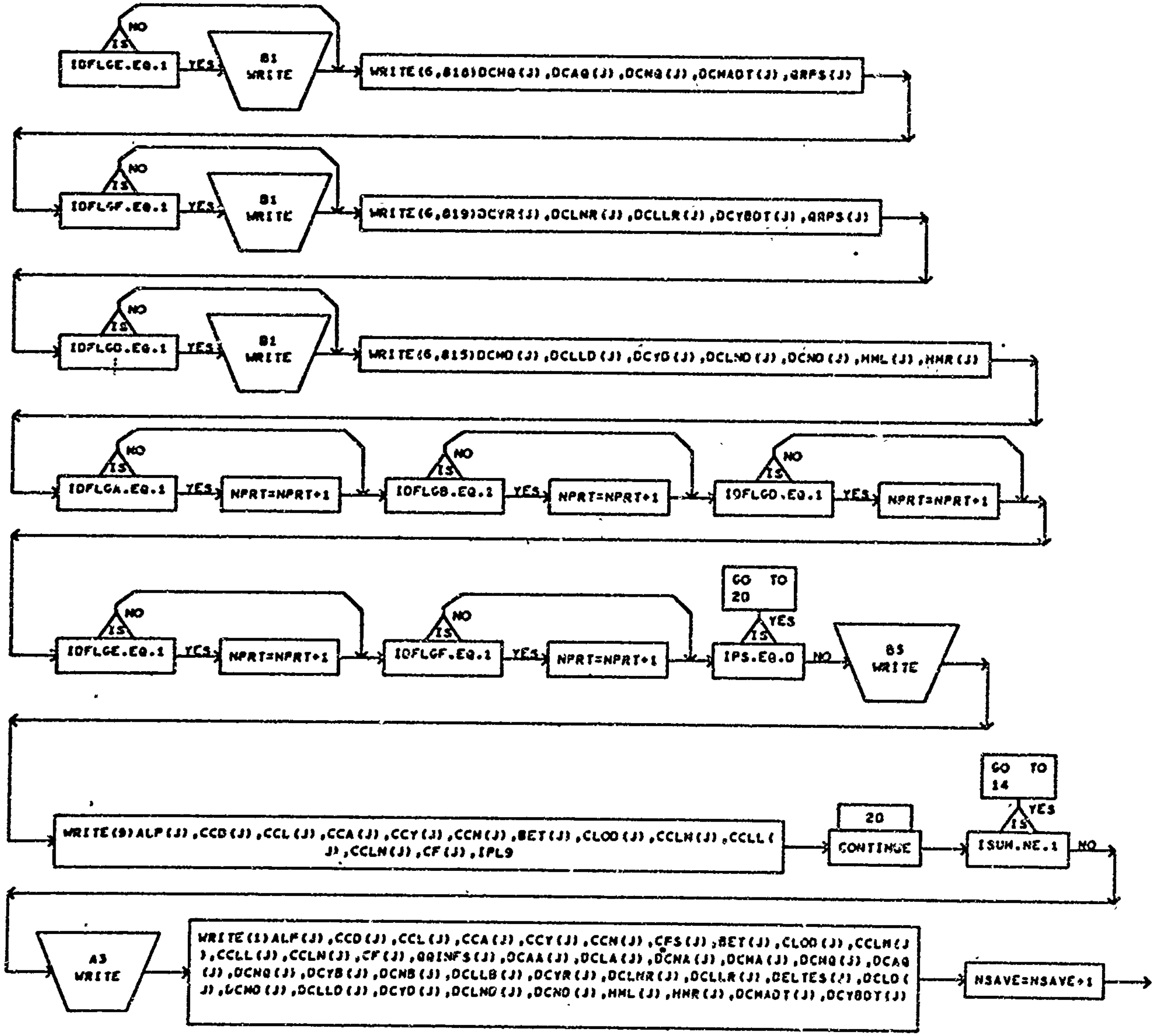

DCAA (NABCT)=0.0
DCLA (NABCT)=0.0
DCNA (NABCT)=0.0
DCMA (NABCT)=0.0
DCMQ (NABCT)=0.0
DCAQ (NABCT)=0.0
DCNQ (NABCT)=0.0
DCYB (NABCT)=0.0
DCNB (NABCT)=0.0
DCLLB (NABCT)=0.0
DCYR (NABCT)=0.0
DCLNR (NABCT)=0.0
DCLLR (NABCT)=0.0
DCLD (NABCT)=0.0
DCMD (NABCT)=0.0
DCLLD (NABCT)=0.0
DCYD (NABCT)=0.0
DCLND (NABCT)=0.0
DCND (NABCT)=0.0
DCMADT (NABCT)=0.0
DCYBDT (NABCT)=0.0
IDERIV.EQ.0
IS
YES
GO TO 5
NO
IDSTAT=1
ALPHAS=ALPHA
BETAS=BETA
DELTS=DELTAE
QRPSS=QRP
IDERIV.EQ.1.OR.IDERIV.EQ.5
IS
NO
YES
ALPHA=ALPHA+1.0
IDERIV.EQ.2.OR.IDERIV.EQ.6
IS
NO
YES
BETA=BETA+1.0
IDERIV.EQ.4
IS
NO
YES
DELTAE=DELTAE+1.0
5
CONTINUE
LTYP13.EQ.0
IS
YES
GO TO 6
NO
A2
READ
READ(5,107)CAI,CNI,CYI,CLLI,CLMI,CLNI,TYPE
TYPE.NE.13
IS
YES
GO TO 800
NO
GO TO 60
6
CAI=0.0
CNI=0.0
CYI=0.0
CLLI=0.0
CLMI=0.0
CLNI=0.0
60
CONTINUE
IGTYPE.NE.1.AND.IGTYPE.NE.3
IS
YES
GO TO 36
NO
DELTAE.EQ.DELTAS
IS
YES
GO TO 36
NO
DELTAS=DELTAE
PERFORM SUBROUTINE
CONTRL
DELTAE,ISIZ

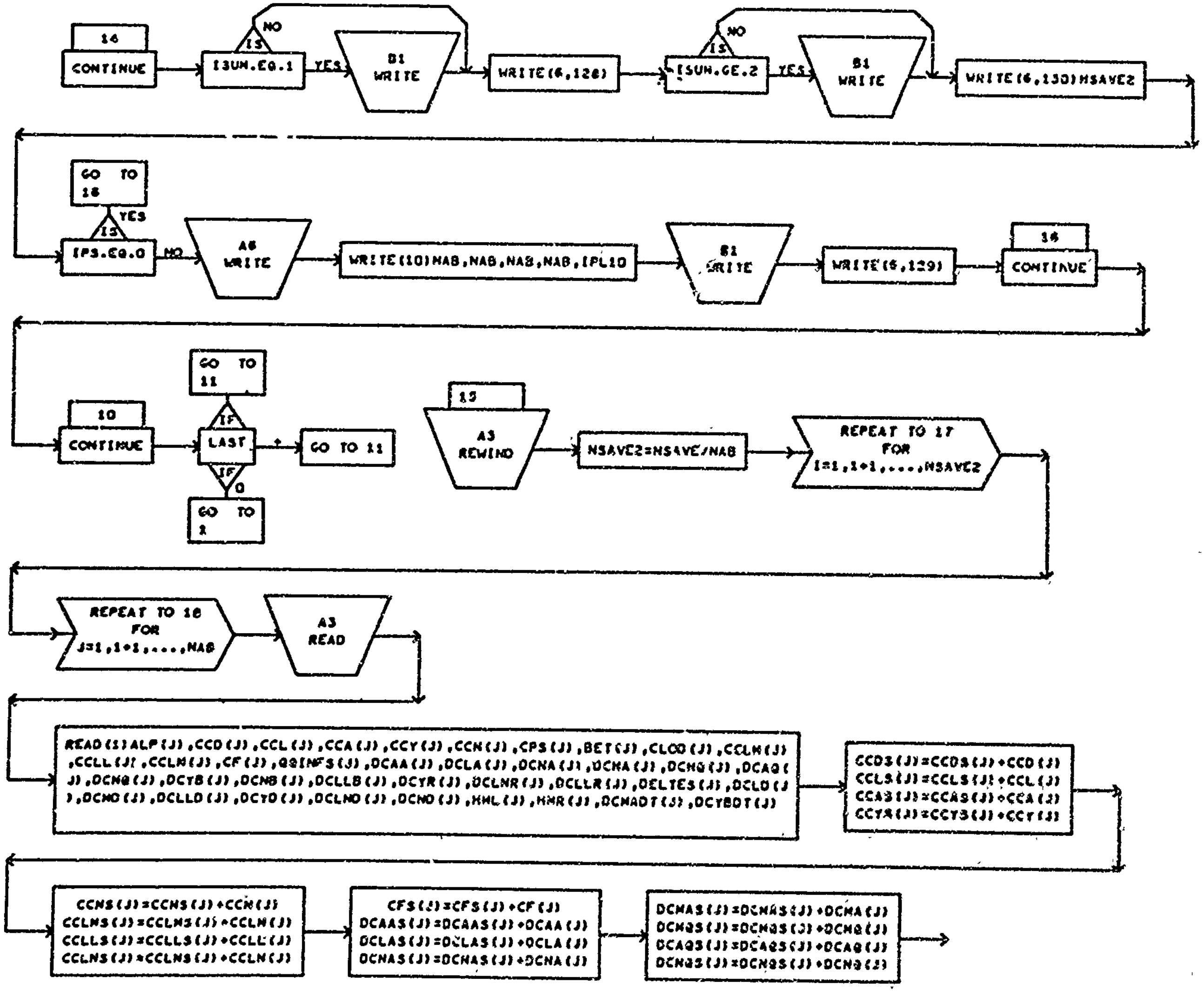

GO TO 806
YES
IS
ERROR.NE.0
NO
35
CONTINUE
PERFORM SUBROUTINE FORCE
ALPHA,BETA,CPSTAG,SREF,SYMFCT,XCG,YCG,ZCG,MACH,SPAN,MAC,NABCT,QRP,ALT,PRINT,CAI,CNI,CYI,CLLI,CLMI,CLNI,ETAC,NS,IMPACT,IPRINT,IFIRST,PSTAG,TSTAG,RENO,ISIZ,EMM,QQINF,ISHAD,IORIEN,IMPACI,ISHADI,IDERIV,V,IGTYPE,DELTAE,SWEEP,RETRAN,HMLT,HMRT,PFS,NW,TWALL
GO TO 806
YES
IS
ERROR.NE.0
NO
DELTES(NABCT)=DELTAE
IMPI(NABCT)=IMPACI
ISHI(NABCT)=ISHADI
HML(NABCT)=HMLT
HMR(NABCT)=HMRT
IFLG=IDERIV+1
COMPUTED GO TO
IF THE VALUE OF IFLG IS / TRANSFER TO STATEMENT
1 70
2 30
3 40
4 50
5 61
6 30
7 40
30
COMPUTED GO TO
IF THE VALUE OF IDSTAT IS / TRANSFER TO STATEMENT
1 31
2 32
3 33
31
CASD1=CCA(NABCT)
CLSD1=CCL(NABCT)
CNSD1=CCN(NABCT)
CLMSD1=CCLM(NABCT)
IDSTAT=2
ALPHA=ALPHAS
GO TO 120
YES
IS
IDERIV.EQ.1
NO
DELQRP=V*0.5E-4
QRP=QRP+DELQRP
GO TO 60
32
CLMSD2=CCLM(NABCT)
CASD2=CCA(NABCT)
CNSD2=CCN(NABCT)
QRP=QRPSS
120
IDSTAT=3
GO TO 60
33
DCAA(NABCT)=(CASD1-CCA(NABCT))/1.0
DCLA(NABCT)=(CLSD1-CCL(NABCT))/1.0
DCNA(NABCT)=(CNSD1-CCN(NABCT))/1.0
DCMA(NABCT)=(CLMSD1-CCLM(NABCT))/1.0
GO TO 121
YES
IS
IDERIV.EQ.1
NO
DCMQ(NABCT)=((CLMSD2-CCLM(NABCT))/DELQRP)*2.0*V/MAC
DCAQ(NABCT)=((CASD2-CCA(NABCT))/DELQRP)*2.0*V/MAC
DCNQ(NABCT)=((CNSD2-CCN(NABCT))/DELQRP)*2.0*V/MAC
IDFLGE=1
121
IDFLGA=1
GO TO 70

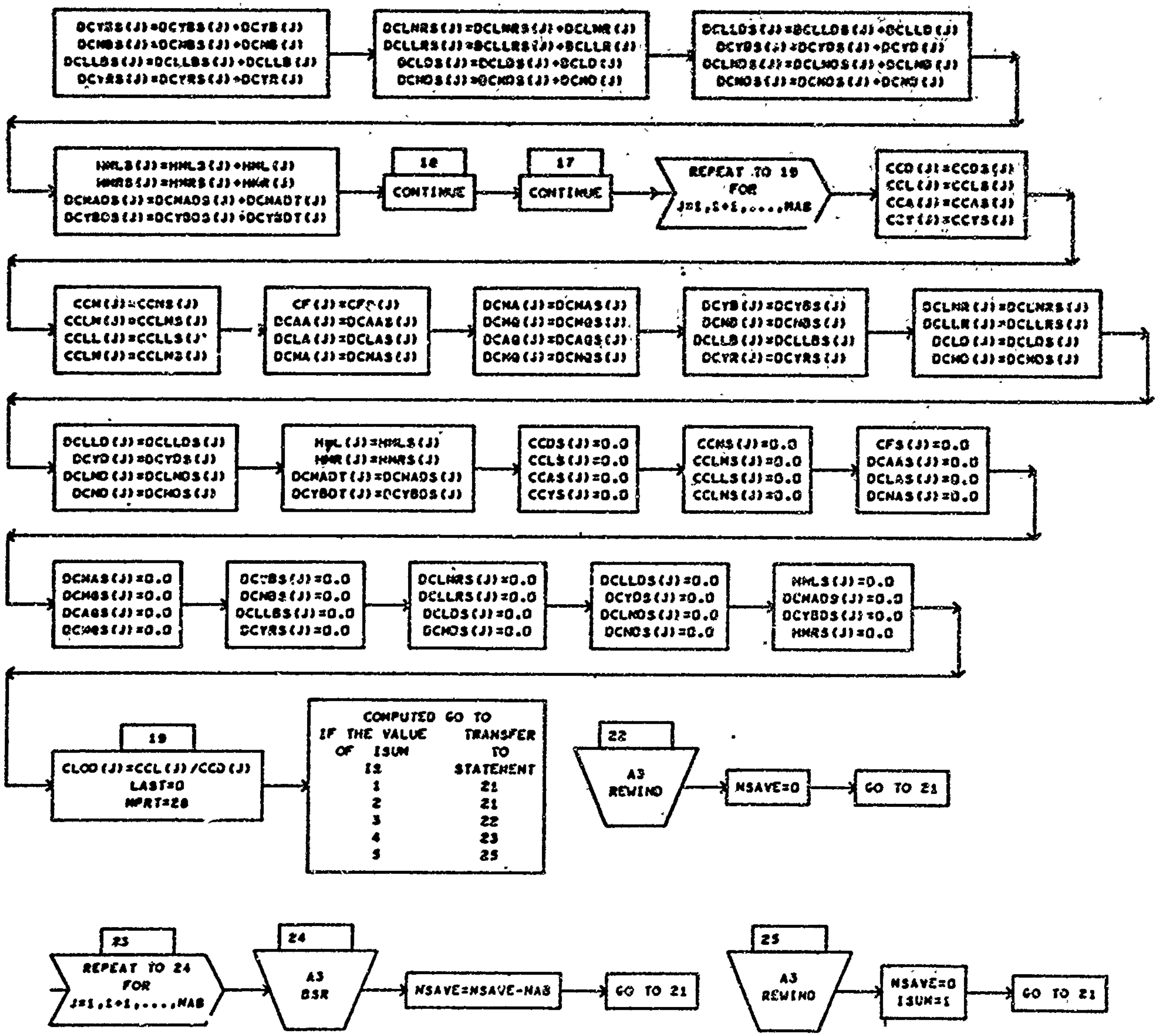

40
COMPUTED GO TO
IF THE VALUE OF IDSTAT IS 1 2 3
TRANSFER TO STATEMENT 41 42 43
41
CYSD1=CCY(NABCT)
CLNSD1=CCLN(NABCT)
CLLSD1=CCLL(NABCT)
IDSTAT=2
BETA=BETA3
IS IDERIV.EQ.2
YES
GO TO 122
NO
DELQRP=V*0.5E-4
QRP=QRP+DELQRP
GO TO 60
42
CYSD2=CCY(NABCT)
CLNSD2=CCLN(NABCT)
CLLSD2=CCLL(NABCT)
QRF=QRPSS
122
IDSTAT=3
GO TO 60
43
DCYB(NABCT)=(CYSD1-CCY(NABCT))/1.0
DCNB(NABCT)=(CLNSD1-CCLN(NABCT))/1.0
DCLLB(NABCT)=(CLLSD1-CCLL(NABCT))/1.0
IS IDERIV.EQ.2
YES
GO TO 123
NO
DCYR(NABCT)=((CYSD2-CCY(NABCT))/DELQRP)*2.0*V/MAC
DCLNR(NABCT)=((CLNSD2-CCLN(NABCT))/DELQRP)*2.0*V/SPAN
DCLLR(NABCT)=((CLLSD2-CCLL(NABCT))/DELQRP)*2.0*V/SPAN
IDFLGF=1
123
IDFLGB=1
GO TO 70
50
81 WRITE
50
WRITE(6,813)
GO TO 806
61
COMPUTED GO TO
IF THE VALUE OF IDSTAY IS 1 2
TRANSFER TO STATEMENT 62 63
62
CLSD1=CCL(NABCT)
CLNSD1=CCLN(NABCT)
CLLSD1=CCLL(NABCT)
CYSD1=CCY(NABCT)
CLNSD1=CCLN(NABCT)
CNSD1=CCN(NABCT)
IDSTAT=2
DELTAE=DELT3
GO TO 60
63
DCLD(NABCT)=(CLSD1-CCL(NABCT))/1.0
DCNO(NABCT)=(CLNSD1-CCLN(NABCT))/1.0
DCLLD(NABCT)=(CLLSD1-CCLL(NABCT))/1.0
DCYD(NABCT)=(CYSD1-CCY(NABCT))/1.0
DCLNO(NABCT)=(CLNSD1-CCLN(NABCT))/1.0
DCNO(NABCT)=(CNSD1-CCN(NABCT))/1.0
IS ABS(DCLLD(NABCT)).LT.1.0E-10
YES
NO
DCLLD(NABCT)=0.0

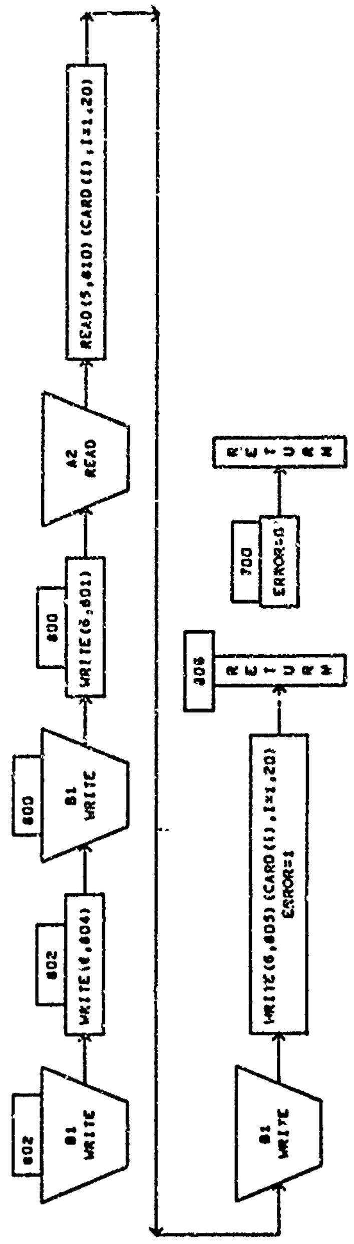

ABS(DCYD(NABCT)).LT.1.0E-10
IS
NO
YES
DCYD(NABCT)=0.0
ABS(DCLNO(NABCT)).LT.1.0E-10
IS
NO
YES
DCLNO(NABCT)=0.0
IGFLGO=1
70
NABCT=NABCT+1
NABCT.LE.NAB
IS
YES
GO TO 2
NO
21
CONTINUE
IABOOT.EQ.0
IS
YES
GO TO 125
NO
REPEAT TO 124 FOR J=1,1+1,...,NAB
IDERIV.NE.5.AND.IDERIV.NE.6
IS
YES
GO TO 124
NO
PERFORM SUBROUTINE PLUNGE
IDERS(NAB),DCHA(NAB),DCYB(NAB),DCHADT(NAB),DCYBDT(NAB)
ERROR.NE.0
IS
YES
GO TO 800
NO
124
CONTINUE
125
CONTINUE
IVECT.EQ.0
IS
YES
GO TO 127
NO
REPEAT TO 126 FOR J=1,1+1,...,NAB
PERFORM SUBROUTINE VECTOR
MACH,PFS,SREF,XCG,YCG,ZCG,SPAN,MAC,ALP(J),CCD(J),CCL(J),CCA(J),CCY(J),CCN(J),BKT(J),CLOO(J),CCLM(J),CCLL(J),CCLM(J)
ERROR.NE.0
IS
YES
GO TO 800
NO
126
CONTINUE
127
REPEAT TO 14 FOR J=1,1+1,...,NAB
NPRT.GE.28
IS
YES
GO TO 3
NO
NPRT=NPRT+2
GO TO 4
3
NPRT=0
PERFORM SUBROUTINE HEADER


B1 WRITE
WRITE(6,105)MACH,V,RENO
PSTAG.LT.0.00001
IS
NO
YES
B1 WRITE
WRITE(6,111)ALT
PSTAG.GT.0.00001
IS
NO
YES
B1 WRITE
WRITE(6,112)PSTAG,TSTAG
B1 WRITE
WRITE(6,113)SREF,SPAN,MAC,XCG,YCG,ZCG
B1 WRITE
WRITE(6,114)
IDFLGA.EQ.1
IS
NO
YES
B1 WRITE
WRITE(6,807)
IDFLGB.EQ.1
IS
NO
YES
B1 WRITE
WRITE(6,808)
IDFLGE.EQ.1
IS
NO
YES
B1 WRITE
WRITE(6,816)
IDFLGF.EQ.1
IS
NO
YES
B1 WRITE
WRITE(6,817)
IDFLGD.EQ.1
IS
NO
YES
B1 WRITE
WRITE(6,814)
4
B1 WRITE
4
WRITE(6,106)ALP(J),CCD(J),CCL(J),CCA(J),CCY(J),CCH(J),CPS(J),IMP(J),ETAC3(J),I
MPI(J),DELTES(J),BET(J),CLOO(J),CCLN(J),CCLL(J),CCLN(J),CF(J),Q3INFS(J),ISH(J)
,ENPMS(J),ISHI(J)
IDFLGA.EQ.1
IS
NO
YES
B1 WRITE
WRITE(6,809)DCAA(J),DCLA(J),DCNA(J),DCHA(J)
IDFLGB.EQ.1
IS
NO
YES
B1 WRITE
WRITE(6,812)DCYB(J),DCNB(J),DCLLB(J)


IS
IDFLGE.EQ.1
NO
YES
B1
WRITE
WRITE(6,818)DCHQ(J),DCAQ(J),DCNQ(J),DCHADT(J),QRPS(J)
IS
IDFLGF.EQ.1
NO
YES
B1
WRITE
WRITE(6,819)DCYR(J),DCLNR(J),DCLLR(J),DCYBDT(J),QRPS(J)
IS
IDFLGD.EQ.1
NO
YES
B1
WRITE
WRITE(6,815)DCMD(J),DCLLD(J),DCYD(J),DCLND(J),DCND(J),HML(J),HMR(J)
IS
IDFLGA.EQ.1
NO
YES
NPRT=NPRT+1
IS
IDFLGB.EQ.1
NO
YES
NPRT=NPRT+1
IS
IDFLGD.EQ.1
NO
YES
NPRT=NPRT+1
IS
IDFLGE.EQ.1
NO
YES
NPRT=NPRT+1
IS
IDFLGF.EQ.1
NO
YES
NPRT=NPRT+1
GO TO 20
YES
IS
IPS.EQ.0
NO
B5
WRITE
WRITE(9)ALP(J),CCD(J),CCL(J),CCA(J),CCY(J),CCN(J),BET(J),CLOD(J),CCLH(J),CCLL(J),CCLN(J),CF(J),IPL9
20
CONTINUE
GO TO 14
YES
IS
ISUM.NE.1
NO
A3
WRITE
WRITE(1)ALF(J),CCD(J),CCL(J),CCA(J),CCY(J),CCN(J),CFS(J),BET(J),CLOD(J),CCLM(J),CCLL(J),CCLN(J),CF(J),QQINFS(J),DCAA(J),DCLA(J),DCNA(J),DCMA(J),DCHQ(J),DCAQ(J),DCNQ(J),DCYB(J),DCNB(J),DCLLB(J),DCYR(J),DCLNR(J),DCLLR(J),DELTES(J),DCLD(J),DCMD(J),DCLLD(J),DCYD(J),DCLND(J),DCND(J),HML(J),HMR(J),DCHADT(J),DCYBDT(J)
NSAVE=NSAVE+1


14
CONTINUE
ISUN.EQ.1
IS
NO
YES
B1
WRITE
WRITE(6,128)
ISUN.GE.2
IS
NO
YES
B1
WRITE
WRITE(6,130)NSAVE2
GO TO
16
YES
IS
IPS.EQ.0
NO
A6
WRITE
WRITE(10)NAB,NAB,NAB,NAB,IPL10
B1
WRITE
WRITE(6,129)
16
CONTINUE
10
CONTINUE
GO TO
11
IF
LAST
+
IF
0
GO TO
2
GO TO 11
15
A3
REWIND
NSAVE2=NSAVE/NAB
REPEAT TO 17
FOR
I=1,1+1,....,NSAVE2
REPEAT TO 18
FOR
J=1,1+1,....,NAB
A3
READ
READ(1)ALP(J),CCD(J),CCL(J),CCA(J),CCY(J),CCN(J),CPS(J),BET(J),CLCD(J),CCLM(J),CCLL(J),CCLN(J),CF(J),QSINFS(J),DCAA(J),DCLA(J),DCNA(J),DCMA(J),DCMQ(J),DCAQ(J),DCNQ(J),DCYB(J),DCNB(J),DCLLB(J),DCYR(J),DCLNR(J),DCLLR(J),DELTES(J),DCLD(J),DCMD(J),DCLLD(J),DCYD(J),DCLND(J),DCND(J),HML(J),HMR(J),DCMADT(J),DCYBDT(J)
CCDS(J)=CCDS(J)+CCD(J)
CCLS(J)=CCLS(J)+CCL(J)
CCAS(J)=CCAS(J)+CCA(J)
CCYS(J)=CCYS(J)+CCY(J)
CCNS(J)=CCNS(J)+CCN(J)
CCLMS(J)=CCLMS(J)+CCLM(J)
CCLLS(J)=CCLLS(J)+CCLL(J)
CCLNS(J)=CCLNS(J)+CCLN(J)
CFS(J)=CFS(J)+CF(J)
DCAAS(J)=DCAAS(J)+DCAA(J)
DCLAS(J)=DCLAS(J)+DCLA(J)
DCNAS(J)=DCNAS(J)+DCNA(J)
DCMAS(J)=DCMAS(J)+DCMA(J)
DCMQS(J)=DCMQS(J)+DCMQ(J)
DCAQS(J)=DCAQS(J)+DCAQ(J)
DCNQS(J)=DCNQS(J)+DCNQ(J)


DCYBS(J)=DCYBS(J)+DCYB(J)
DCNBS(J)=DCNBS(J)+DCNB(J)
DCLLBS(J)=DCLLBS(J)+DCLLB(J)
DCYRS(J)=DCYRS(J)+DCYR(J)
DCLNRS(J)=DCLNRS(J)+DCLNR(J)
DCLLRS(J)=DCLLRS(J)+DCLLR(J)
DCLDS(J)=DCLDS(J)+DCLD(J)
DCNDS(J)=DCNDS(J)+DCND(J)
DCLLDS(J)=DCLLDS(J)+DCLLD(J)
DCYDS(J)=DCYDS(J)+DCYD(J)
DCLNDS(J)=DCLNDS(J)+DCLND(J)
DCNDS(J)=DCNDS(J)+DCND(J)
HMLS(J)=HMLS(J)+HML(J)
HMRS(J)=HMRS(J)+HMR(J)
DCNADS(J)=DCNADS(J)+DCNADT(J)
DCYBDS(J)=DCYBDS(J)+DCYBDT(J)
16
CONTINUE
17
CONTINUE
REPEAT TO 19
FOR
J=1,1+1,...,NAB
CCD(J)=CCDS(J)
CCL(J)=CCLS(J)
CCA(J)=CCAS(J)
CCY(J)=CCYS(J)
CCN(J)=CCNS(J)
CCLN(J)=CCLNS(J)
CCLL(J)=CCLLS(J)
CCLN(J)=CCLNS(J)
CF(J)=CFS(J)
DCAA(J)=DCAAS(J)
DCLA(J)=DCLAS(J)
DCNA(J)=DCNAS(J)
DCNA(J)=DCNAS(J)
DCNQ(J)=DCNQS(J)
DCAQ(J)=DCAQS(J)
DCNQ(J)=DCNQS(J)
DCYB(J)=DCYBS(J)
DCNB(J)=DCNBS(J)
DCLLB(J)=DCLLBS(J)
DCYR(J)=DCYRS(J)
DCLNR(J)=DCLNRS(J)
DCLLR(J)=DCLLRS(J)
DCLD(J)=DCLDS(J)
DCND(J)=DCNDS(J)
DCLLD(J)=DCLLDS(J)
DCYD(J)=DCYDS(J)
DCLND(J)=DCLNDS(J)
DCND(J)=DCNDS(J)
HML(J)=HMLS(J)
HMR(J)=HMRS(J)
DCNADT(J)=DCNADS(J)
DCYBDT(J)=DCYBDS(J)
CCDS(J)=0.0
CCLS(J)=0.0
CCAS(J)=0.0
CCYS(J)=0.0
CCNS(J)=0.0
CCLNS(J)=0.0
CCLLS(J)=0.0
CCLNS(J)=0.0
CFS(J)=0.0
DCAAS(J)=0.0
DCLAS(J)=0.0
DCNAS(J)=0.0
DCNAS(J)=0.0
DCNQS(J)=0.0
DCAQS(J)=0.0
DCNQS(J)=0.0
DCYBS(J)=0.0
DCNBS(J)=0.0
DCLLBS(J)=0.0
DCYRS(J)=0.0
DCLNRS(J)=0.0
DCLLRS(J)=0.0
DCLDS(J)=0.0
DCNDS(J)=0.0
DCLLDS(J)=0.0
DCYDS(J)=0.0
DCLNDS(J)=0.0
DCNDS(J)=0.0
HMLS(J)=0.0
DCNADS(J)=0.0
DCYBDS(J)=0.0
HMRS(J)=0.0
19
CLOD(J)=CCL(J)/CCD(J)
LAST=0
NPRT=28
COMPUTED GO TO
IF THE VALUE OF ISUM IS
TRANSFER TO STATEMENT
1 21
2 21
3 22
4 23
5 25
22
A3
REWIND
NSAVE=0
GO TO 21
23
REPEAT TO 24
FOR
J=1,1+1,...,NAB
24
A3
BSR
NSAVE=NSAVE-NAB
GO TO 21
25
A3
REWIND
NSAVE=0
ISUM=1
GO TO 21


802
B1
WRITE
802
WRITE(6,804)
800
B1
WRITE
800
WRITE(6,801)
A2
READ
READ(5,810)(CARD(I),I=1,20)
B1
WRITE
WRITE(6,805)(CARD(I),I=1,20)
ERROR=1
806
RETURN
700
ERROR=0
RETURN

```
SYMBOLS USED IN SUBROUTINE AERO

ALP      R  C  ANGLE OF ATTACK ARRAY                                                  AERO
ALPHA    R  U  ANGLE OF ATTACK, DEGREES                                               AERO
ALPHAS   R  U  SAVED VALUE OF ANGLE OF ATTACK                                         AERO
ALT      R  U  ALTITUDE, FEET                                                         AERO
AREA2    R  C  SURFACE AREA OF QUADRILATERALS                                         AERO
BET      R  C  YAW ANGLE ARRAY                                                        AERO
BETA     R  U  YAW ANGLE, DEGREES                                                     AERO
BETAS    R  U  SAVED VALUE OF YAW ANGLE                                               AERO
BS       R  C  FLOW CONDITIONS BEHIND SHOCK OR EXPANSION                              AERO
CAI      R  U  AXIAL FORCE INCREMENT                                                  AERO
CARD     R  D  ARRAY FOR READING IN 80 COLUMN CARD                                    AERO
CASD1    R  U  FIRST VALUE OF AXIAL FORCE FOR DERIVATIVE CALCULATIONS                 AERO
CASD2    R  U  SECOND VALUE OF AXIAL FORCE FOR DERIVATIVE CALCULATIONS                AERO
CASE     I  C  CASE NUMBER                                                            AERO
CCA      R  C  AXIAL FORCE COEFFICIENT ARRAY                                          AERO
CCAS     R  D  SAVED VALUES OF AXIAL FORCE COEFFICIENT                                AERO
CCD      R  C  DRAG COEFFICIENT ARRAY                                                 AERO
CCDS     R  D  SAVED VALUES OF DRAG COEFFICIENT                                       AERO
CCL      R  C  LIFT COEFFICIENT ARRAY                                                 AERO
CCLL     R  C  ROLLING MOMENT COEFFICIENT ARRAY                                       AERO
CCLLS    R  D  SAVED VALUES OF ROLLING MOMENT COEFFICIENT                             AERO
CCLM     R  C  PITCHING MOMENT COEFFICIENT ARRAY                                      AERO
CCLMS    R  D  SAVED VALUES OF PITCHING MOMENT COEFFICIENT                            AERO
CCLN     R  C  YAWING MOMENT COEFFICIENT ARRAY                                        AERO
CCLNS    R  D  SAVED VALUES OF YAWING MOMENT COEFFICIENT                              AERO
CCLS     R  D  SAVED VALUES OF LIFT COEFFICIENT                                       AERO
CCN      R  C  NORMAL FORCE COEFFICIENT ARRAY                                         AERO
CCNS     R  D  SAVED VALUES OF NORMAL FORCE COEFFICIENT                               AERO
CCY      R  C  SIDE FORCE COEFFICIENT ARRAY                                           AERO
CCYS     R  D  SAVED VALUES OF SIDE FORCE COEFFICIENT                                 AERO
CF       R  C  SKIN FRICTION TOTAL AXIAL FORCE CONTRIBUTION                           AERO
CFS      R  D  SAVED VALUES OF SKIN FRICTION TOTAL AXIAL FORCE CONTRIBUTION           AERO
CLLI     R  U  ROLLING MOMENT COEFFICIENT INCREMENT                                   AERO
CLLSD1   R  U  FIRST VALUE OF ROLLING MOMENT FOR DERIVATIVE                           AERO
CLLSD2   R  U  SECOND VALUE OF ROLLING MOMENT FOR DERIVATIVE                          AERO
CLMI     R  U  PITCHING MOMENT COEFFICIENT INCREMENT                                  AERO
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SYMBOLS USED IN SUBROUTINE AERO

CLMSD1  R  U  FIRST VALUE OF PITCHING MOMENT FOR DERIVATIVE                 AERO
CLMSD2  R  U  SECOND VALUE OF PITCHING MOMENT FOR DERIVATIVE                AERO
CLNI    R  U  YAWING MOMENT COEFFICIENT INCREMENT                           AERO
CLNSD1  R  U  FIRST VALUE OF YAWING MOMENT FOR DERIVATIVE                   AERO
CLNSD2  R  U  SECOND VALUE OF YAWING MOMENT FOR DERIVATIVE                  AERO
CLOD    R  C  LIFT TO DRAG RATIO ARRAY                                      AERO
CLSD1   R  U  FIRST VALUE OF LIFT COEFFICIENT FOR DERIVATIVE                AERO
CNI     R  U  NORMAL FORCE COEFFICIENT INCREMENT                            AERO
CNSD1   R  U  FIRST VALUE OF NORMAL FORCE FOR DERIVATIVE                    AERO
CNSD2   R  U  SECOND VALUE OF NORMAL FORCE FOR DERIVATIVE                   AERO
CPS     R  C  ARRAY FOR NEWTONIAN CORRELATION FACTOR, K                     AERO
CPSTAG  R  U  MODIFIED NEWTONIAN CORRELATION FACTOR, K                      AERO
CYI     R  U  SIDE FORCE COEFFICIENT INCREMENT                              AERO
CYSD1   R  U  FIRST VALUE OF SIDE FORCE COEFFICIENT FOR DERIVATIVE          AERO
CYSD2   R  U  SECOND VALUE OF SIDE FORCE COEFFICIENT FOR DERIVATIVE         AERO
DCAA    R  D  DERIVATIVE OF AXIAL FORCE WITH ANGLE OF ATTACK                AERO
DCAAS   R  D  SAVED VALUES OF AXIAL FORCE-ANGLE OF ATTACK DERIVATIVE        AERO
DCAQ    R  D  DERIVATIVE OF AXIAL FORCE WITH PITCH RATE                     AERO
DCAQS   R  D  SAVED VALUES OF AXIAL FORCE DERIVATIVE WITH PITCH RATE        AERO
DCLA    R  D  DERIVATIVE OF LIFT COEFFICIENT WITH ANGLE OF ATTACK           AERO
DCLAS   R  D  SAVED LIFT COEFFICIENT DERIVATIVE WITH ANGLE OF ATTACK        AERO
DCLD    R  D  DERIVATIVE OF CL WITH CONTROL SURFACE DEFLECTION              AERO
DCLDS   R  D  SAVED VALUES OF CL DERIVATIVE WITH CONTROL DEFLECTION         AERO
DCLLB   R  D  DERIVATIVE OF ROLLING MOMENT WITH YAW ANGLE                   AERO
DCLLBS  R  D  SAVED VALUES OF ROLLING MOMENT DERIVATIVE WITH YAW            AERO
DCLLD   R  D  DERIVATIVE OF ROLLING MOMENT WITH CONTROL DEFLECTION          AERO
DCLLDS  R  D  SAVED VALUES OF ROLLING MOMENT-CONTROL DERIVATIVE             AERO
DCLLR   R  D  DERIVATIVE OF ROLLING MOMENT WITH YAW RATE                    AERO
DCLLRS  R  D  SAVED VALUES OF ROLLING MOMENT DERIVATIVE WITH YAW            AERO
DCLND   R  D  DERIVATIVE OF YAWING MOMENT WITH CONTROL DEFLECTION           AERO
DCLNDS  R  D  SAVED VALUES OF YAWING MOMENT-CONTROL DERIVATIVE              AERO
DCLNR   R  D  DERIVATIVE OF YAWING MOMENT WITH YAW RATE                     AERO
DCLNRS  R  D  SAVED VALUES OF YAWING MOMENT-YAW RATE DERIVATIVE             AERO
DCMA    R  D  DERIVATIVE OF PITCHING MOMENT WITH ANGLE OF ATTACK            AERO
DCMADS  R  D  SAVED VALUES OF PITCHING MOMENT-ALPHA DOT DERIVATIVE          AERO
DCMADT  R  D  PITCHING MOMENT-ALPHA DOT DERIVATIVE                          AERO
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SYMBOLS USED IN SUBROUTINE AERO

DCMAS    R  D  SAVED VALUE OF PITCHING MOMENT-ALPHA DERIVATIVE                     AERO
DCMD     R  D  PITCHING MOMENT-CONTROL DEFLECTION DERIVATIVE                       AERO
DCMDS    R  D  SAVED VALUES OF PITCHING MOMENT-CONTROL DERIVATIVE                  AERO
DCMQ     R  D  DERIVATIVE OF PITCHING MOMENT WITH PITCH RATE                       AERO
DCMQS    R  D  SAVED VALUES OF PITCHING MOMENT-PITCH RATE DERIVATIVE               AERO
DCNA     R  D  DERIVATIVE OF NORMAL FORCE WITH ANGLE OF ATTACK                     AERO
DCNAS    R  D  SAVED VALUE OF NORMAL FORCE-ALPHA DERIVATIVE                        AERO
DCNB     R  D  DERIVATIVE OF YAWING MOMENT WITH YAW ANGLE                          AERO
DCNBS    R  D  SAVED VALUE OF NORMAL FORCE-YAW DERIVATIVE                          AERO
DCND     R  D  DERIVATIVE OF NORMAL FORCE WITH CONTROL DEFLECTION                  AERO
DCNDS    R  D  SAVED VALUE OF NORMAL FORCE-CONTROL DERIVATIVE                      AERO
DCNQ     R  D  DERIVATIVE OF NORMAL FORCE WITH PITCH RATE                          AERO
DCNQS    R  D  SAVED VALUES OF NORMAL FORCE-PITCH RATE DERIVATIVES                 AERO
DCYB     R  D  DERIVATIVE OF SIDE FORCE WITH YAW ANGLE                             AERO
DCYBDS   R  D  SAVED VALUE OF CY-BETA DATA DERIVATIVE                              AERO
DCYBDT   R  D  DERIVATIVE OF SIDE FORCE WITH BETA DOT                              AERO
DCYBS    R  D  SAVED VALUE OF SIDE FORCE-YAW DERIVATIVE                            AERO
DCYD     R  D  DERIVATIVE OF SIDE FORCE WITH CONTROL DEFLECTION                    AERO
DCYDS    R  D  SAVED VALUES OF SIDE FORCE-CONTROL DERIVATIVE                       AERO
DCYR     R  D  DERIVATIVE OF SIDE FORCE WITH YAW RATE                              AERO
DCYRS    R  D  SAVED VALUES OF SIDE FORCE-YAW RATE DERIVATIVES                     AERO
DELQRP   R  U  INCREMENT IN ROTATION RATE FOR ROTATION DERIVATIVES                 AERO
DELTAE   R  U  CONTROL SURFACE DEFLECTION                                          AERO
DELTAS   R  U  SAVED VALUE OF CONTROL SURFACE DEFLECTION                           AERO
DELTES   R  D  SAVED VALUE OF CONTROL SURFACE DEFLECTION                           AERO
DELTS    R  U  SAVED VALUES OF CONTROL DEFLECTION                                  AERO
ENPM     R  U  SURFACE SLOPE MODIFICATION FACTOR                                   AERO
ENPMS    R  D  SAVED VALUES OF SURFACE SLOPE MODIFICATION FACTOR                   AERO
ERROR    I  C  ERROR FLAG                                                          AERO
ETAC     R  U  PRANDTL-MEYER-EXPANSION CORRECTION FACTOR                           AERO
ETACS    R  D  SAVED VALUES OF PRANDTL-MEYER CORRECTION FACTOR                     AERO
FS       R  C  FLOW PROPERTIES BEFORE SHOCK OR EXPANSION                           AERO
HML      R  D  HINGE MOMENT (+Y SIDE OF VEHICLE)                                   AERO
HMLS     R  D  SAVED VALUES OF HINGE MOMENT (+Y)                                   AERO
HMLT     R  U  HINGE MOMENT (+Y)                                                   AERO
HMR      R  D  HINGE MOMENT (-Y)                                                   AERO
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SYMBOLS USED IN SUBROUTINE AERO

HMRS     R  D  SAVED VALUES OF HINGE MOMENT (-Y)                              AERO
HMRT     R  U  HINGE MOMENT (-Y)                                              AERO
I        I  U  DO-LOOP INDEX                                                  AERO
IABDOT   I  U  ALPHA-DOT BETA-DOT DERIVATIVE FLAG                             AERO
IDERIV   I  U  DERIVATIVE OPTION FLAG                                         AERO
IDERS    I  D  SAVED VALUES OF DERIVATIVE OPTION FLAG                         AERO
IDFLGA   I  U  ALPHA DERIVATIVE PRINT FLAG                                    AERO
IDFLGB   I  U  BETA DERIVATIVE PRINT FLAG                                     AERO
IDFLGC   I  U  ROLL DERIVATIVE PRINT FLAG (NOT USED BY MARK II)               AERO
IDFLGD   I  U  CONTROL DERIVATIVE PRINT FLAG                                  AERO
IDFLGE   I  U  PITCH RATE DERIVATIVE PRINT FLAG                               AERO
IDFLGF   I  U  YAW RATE DERIVATIVE PRINT FLAG                                 AERO
IDSTAT   I  U  DERIVATIVE CYCLE FLAG                                          AERO
IFIRST   I  U  FIRST POINT FLAG FOR USE IN NEWTPM                             AERO
IFLG     I  U  DERIVATIVE FLAG                                                AERO
IGTYPE   I  U  COMPONENT TYPE (=1 FOR CONTROL)                                AERO
IM       I  C  ELEMENT ROW NUMBER ARRAY                                       AERO
IMP      I  D  IMPACT METHOD ARRAY                                            AERO
IMPACI   I  U  STARTING ELEMENT IMPACT METHOD                                 AERO
IMPACT   I  U  IMPACT FORCE CALCULATION METHOD                                AERO
IMPI     I  D  STARTING IMPACT METHOD ARRAY                                   AERO
IN       I  C  ELEMENT COLUMN NUMBER ARRAY                                    AERO
IORIEN   I  U  ELEMENT ORIENTATION                                            AERO
IPL10    I  U  TYPE NUMBER FOR TAPE 10 DATA = 42                              AERO
IPL9     I  U  TYPE NUMBER FOR TAPE 9 DATA =43                                AERO
IPRINS   I  D  SAVED VALUES OF PRINT FLAG                                     AERO
IPRINT   I  U  PRINT FLAG FOR SHOCK-EXPANSION CALCULATIONS                    AERO
IPRTS    I  D  SAVED VALUES OF IPRINT FLAG                                    AERO
IPS      I  U  SC-4020 AERO-DATA SAVE FLAG                                    AERO
IRET1    I  U  RETURN TO TYPE 1 CARD CONTROL FLAG                             AERO
IREW8    I  U  REWIND TAPE 8 FLAG                                             AERO
IS       I  C  SKIN FRICTION CONTROL FLAG ARRAY                               AERO
ISH      I  D  SHADOW METHOD ARRAY                                            AERO
ISHAD    I  U  SHADOW FORCE CALCULATION METHOD                                AERO
ISHADI   I  U  STARTING ELEMENT METHOD IN SHADOW REGION                       AERO
ISHI     I  D  SHADOW STARTING ELEMENT ARRAY                                  AERO
```

SYMBOLS USED IN SUBROUTINE AERO

ISIZ	I	U	NUMBER OF ELEMENTS TO BE STORED IN CORE	AERO
ISUM	I	U	COMPONENT SUMMATION AND SAVE FLAG	AERO
ITYP13	I	U	TYPE 13 CARD READ FLAG	AERO
IVECT	I	U	FORCE VECTOR METHOD FLAG	AERO
J	I	U	DO-LOOP INDEX	AERO
L	I	C	NUMBER OF ELEMENTS	AERO
LAST	I	U	LAST FLIGHT CONDITION FLAG	AERO
LS	I	C	NUMBER OF ELEMENTS	AERO
MAC	R	U	REFERENCE LENGTH FOR MOMENT COEFFICIENTS	AERO
MACH	R	U	MACH NUMBER	AERO
NAB	I	U	NUMBER OF ALPHA-BETA COMBINATIONS	AERO
NABCT	I	U	ALPHA-BETA COUNTER	AERO
NABS	I	U	SAVED VALUE FOR NUMBER OF ALPHA-BETA COMBINATIONS	AERO
NOAB	I	U	NO ALPHA-BETA CARD FLAG	AERO
NPRT	I	U	LINE COUNTER	AERO
NS	I	U	NUMBER OF SKIN FRICTION SURFACES	AERO
NSAVE	I	U	NUMBER OF SETS OF DATA SAVED FOR SUMMATION	AERO
NSAVE2	I	U	DO-LOOP INDEX FOR DATA SUMMATION	AERO
NW	R	U	WALL TEMPERATURE CALCULATION FLAG FOR FLOSEP	AERO
NX2	R	C	ELEMENT DIRECTION COSINE ARRAY-X	AERO
NY2	R	C	ELEMENT DIRECTION COSINE ARRAY-Y	AERO
NZ2	R	C	ELEMENT DIRECTION COSINE ARRAY-Z	AERO
PAGE	I	C	PAGE NUMBER	AERO
PFS	R	U	FREE-STREAM PRESSURE-LBS/SQUARE FOOT	AERO
PRINT	I	U	DETAIL FORCE CONTRIBUTION PRINT FLAG	AERO
PRINTS	I	U	PRINT FLAG FOR ELEMENT DATA	AERO
PSTAG	R	U	WIND TUNNEL STAGNATION PRESSURE, ATMOSPHERES	AERO
QQINF	R	U	DYNAMIC PRESSURE RATIO CORRECTION FACTOR	AERO
QQINFS	R	C	SAVED VALUES OF DYNAMIC PRESSURE CORRECTION	AERO
QRP	R	U	INPUT VEHICLE ROTATION RATE, RADIANS/SECOND	AERO
QRPS	R	D	SAVED VALUES OF ROTATION RATE	AERO
QRPSS	R	U	SAVED VALUE OF INPUT ROTATION RATE	AERO
RENO	R	U	FREE STREAM REYNOLDS NUMBER	AERO
RETRAN	R	U	TRANSITION REYNOLDS NUMBER FOR CONTROL SURFACE	AERO
SPAN	R	U	REFERENCE LENGTH FOR ROLLING, YAWING COEFFICIENTS	AERO
SREF	R	U	VEHICLE REFERENCE AREA (WING AREA)	AERO

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SYMBOLS USED IN SUBROUTINE AERO

SURF     R  C  SKIN FRICTION DATA ARRAY                                  AERO
SWEEP    R  U  LEADING EDGE SWEEP (NOT USED BY MARK II)                  AERO
SYMFCT   I  U  SYMMETRY FLAG                                             AERO
TITLE    R  C  TITLE ARRAY                                               AERO
TSTAG    R  U  WIND TUNNEL STAGNATION TEMPERATURE-DEGREES F              AERO
TWALL    R  U  WALL TEMPERATURE FOR FLOSEP                               AERO
TYPE     I  U  CARD TYPE                                                 AERO
V        R  U  FREE-STREAM VELOCITY-FEET/SECOND                          AERO
XCENT2   R  C  ELEMENT CENTROID COORDINATE ARRAY-X                       AERO
XCG      R  U  X-CENTER FOR MOMENT CALCULATIONS                          AERO
YCENT2   R  C  ELEMENT CENTROID COORDINATE ARRAY-Y                       AERO
YCG      R  U  Y-CENTER FOR MOMENT CALCULATIONS                          AERO
ZCENT2   R  C  ELEMENT CENTROID COORDINATE ARRAY-Z                       AERO
ZCG      R  U  Z-CENTER FOR MOMENT CALCULATIONS                          AERO
```

3. SUBROUTINE HEADER (DECK AROB)

a. Algorithm

This routine provides the title at the top of each page of the output and advances the page counter.

b. Input/Output

Program header is printed at top of page on output Tape 6.

c. Error

None

d. Subroutines Required

None

e. Argument List

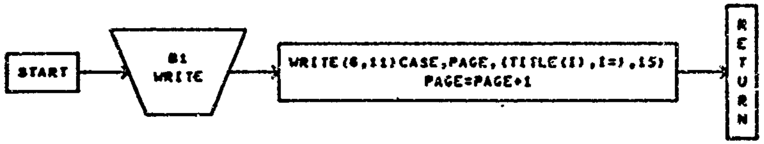
None

f. Length

342 bytes

```
DECK AROB

      SUBROUTINE HEADER                                                 AROB  0010
C                                                                       AROB  0020
      DIMENSION  TITLE(15)                                              AROB  0030
C                                                                       AROB  0040
      COMMON CASE,TITLE,PAGE                                            AROB  0050
C                                                                       AROB  0060
      INTEGER  PAGE, CASE                                               AROB  0070
C                                                                       AROB  0080
C  PRINT OUT HEADER AT TOP OF EACH PAGE OF OUTPUT                       AROB  0090
      WRITE (6,11) CASE,PAGE,(TITLE(I),I=1,15)                          AROB  0100
   11 FORMAT (1H1,49HHYPERSONIC ARBITRARY-BODY PROGRAM, MARK III MOD 0, AROB  0110
     1/,1H0,6H  CASE,I5,85X,5HPAGE I4,/1H0,14A4,1A3)                    AROB  0120
C                                                                       AROB  0130
C  STEP PAGE NUMBER BY ONF                                              AROB  0140
      PAGE = PAGE + 1                                                   AROB  0150
C                                                                       AROB  0160
      RETURN                                                            AROB  0170
      END                                                               AROB  0180
```


START
B1
WRITE
WRITE(6,11)CASE,PAGE,(TITLE(I),I=),15)
PAGE=PAGE+1
RETURN

```
SYMBOLS USED IN SUBROUTINE HEADER                                                        

CASE     I  C  CASE NUMBER                                                               HEADER
PAGE     I  C  PAGE NUMBER                                                               HEADER
TITLE    R  C  TITLE                                                                     HEADER
```

4. SUBROUTINE SDATA (DECK AROC)

This subroutine prepares geometry data for use by the rest of the program.

a. Algorithm

The Element Data Control Card (Type 2) is read and control passed to one of the other geometry routines (ANALY1, ANALY2, ANALY3) if required. The surface element data is then read (either from input Tape 5 or from the geometry storage Tape 8) and converted to quadrilaterals. These data are stored in core for the first 300 elements and on Tape 4 thereafter. All geometry data for control surface components are stored on Tapes 3 and 4.

b. Input/Output

Element Data Control Card (Type 2), Element Data Input Cards (Type 3).
When PRINTS is equal to 1 the Input Surface Element Data along with the direction cosines and centroid coordinates of each quadrilateral element are printed on output Tape 6.

c. Error

An error condition occurs when an input card type number is wrong.

d. Subroutines Required

ANALY1, ANALY2, ANALY3, HEADER

e. Argument List

(PRINTS, SYMFCT, ISIZ, IORIEN, IGTYPE)

f. Length

13264 bytes

```
DECK AROC

      SUBROUTINE SDATA (PRINTS,SYMFCT,ISIZ,IORIEN,IGTYPE)                 AROC  0010
C                                                                         AROC  0020
C  THIS SUBROUTINE DETERMINES THE DIRECTION COSINES, CENTROID, AND AREA   AROC  0030
C  OF THE INPUT SURFACE ELEMENTS.                                         AROC  0040
C                                                                         AROC  0050
      DIMENSION  XA(250),XB(250),YA(250),YB(250),ZA(250),ZB(250),         AROC  0060
     1 XI(4),ETA(4),XIN(4),YIN(4),ZIN(4),TITLE(15),XPA(4),YPA(4),ZPA(4)   AROC  0070
      DIMENSION NX2( 300),NY2( 300),NZ2( 300),XCENT2( 300),               AROC  0080
     1  YCENT2( 300),ZCENT2( 300),AREA2( 300),IN( 300),IM( 300)           AROC  0090
C                                                                         AROC  0100
      COMMON  CASE,TITLE,PAGE,ERROR,NX2,NY2,NZ2,XCENT2,YCENT2,ZCENT2,     AROC  0110
     1  AREA2,IN,IM,L,LS                                                  AROC  0120
C                                                                         AROC  0130
      REAL  NX,NY,NZ,LEFCT                                                AROC  0140
      REAL  NX2,NY2,NZ2                                                   AROC  0150
      LOGICAL  RFLAG, AFLAG, BFLAG                                        AROC  0160
      INTEGER  STAT, STATT, PAGE, CASE, TYPE, ERROR, PRINTS, SYMFCT, SEQ  AROC  0170
    1 FORMAT (3F10.4,I1,3F10.4,I1,3X,I3,1A2,I2,4X,I4)                     AROC  0180
    2 FORMAT (3F10.4,I1,3F10.4,I1,3X,I3,1A2,I2,4HAERO,I4)                 AROC  0190
C                                                                         AROC  0200
C     SET UP STARTING CONSTANTS                                           AROC  0210
       N = -1                                                             AROC  0220
      NN = -1                                                             AROC  0230
       KLCT = 0                                                           AROC  0240
       NPRT = 10                                                          AROC  0250
       L = 0                                                              AROC  0260
       IGT = 0                                                            AROC  0270
       AREAT = 0.0                                                        AROC  0280
       VOL = 0.0                                                          AROC  0290
      WRITE (6,4016)                                                      AROC  0300
C  READ ELEMENT DATA CONTROL CARD                                         AROC  0310
      READ (5,3) PRINTS,SYMFCT,IORIEN,IFACT,XSC,YSC,ZSC,DELX,DELY,DELZ,   AROC  0320
     1  LEFCT,XLEO,IGEOM,ITAPE,IGTYPE,ZELOV,TYPE                          AROC  0330
    3 FORMAT (I1,1XI1,2I1,1X3F6.0,1X3F6.0,1X,F5.0,F7.0,3X,4I1,7X,I2)      AROC  0340
      IF (TYPE.EQ.2) GO TO 7                                              AROC  0350
```

```
DECK AROC

      WRITE (6,5)                                                       AROC  0360
    5 FORMAT(1HO,46H***** ELEMENT DATA CONTROL CARD IS NOT PRESENT,    AROC  0370
     1 35H OR HAS THE WRONG TYPE NUMBER *****  )                        AROC  0380
       GO TO 301                                                        AROC  0390
    7 IF (SYMFCT .EQ. 0) SYMFCT = 2                                     AROC  0400
      IF((IGTYPE.EQ.1.OR.IGTYPE.EQ.3).AND.IORIEN.EQ.0)WRITE(6,290)IORIEN AROC  0410
  290 FORMAT (1H ,49H**** ON CONTROL SURFACE, ORIENTATION WAS INPUT AS  AROC  0420
     1  2H =I2,49H  PROGRAM CONTINUED WITH ORIENTATION SET = 1 ****  )  AROC  0430
      IF ((IGTYPE.EQ.1.OR.IGTYPE.EQ.3).AND.IORIEN.EQ.0) IORIEN = 1      AROC  0440
      IA = 0                                                            AROC  0450
      IB = 0                                                            AROC  0460
      IF (IORIEN .EQ. 2) IB = 1                                         AROC  0470
      IF (IORIEN .EQ. 3) IA = 1                                         AROC  0480
      IF (IORIEN .GT. 1) IORIEN = 1                                     AROC  0490
      IF (IGTYPE .GT. 0) IGT = 1                                        AROC  0500
      IF (IGEOM .EQ. 0) GO TO 4                                         AROC  0510
C  GEOMETRY IS TO BE CALCULATED BY ONE OF THE ANALYTICAL SHAPE ROUTINES AROC  0520
      GO TO (11,12,13),IGEOM                                            AROC  0530
   11 CALL ANALY1                                                       AROC  0540
      GO TO 4                                                           AROC  0550
   12 CALL ANALY2                                                       AROC  0560
      GO TO 4                                                           AROC  0570
   13 CALL ANALY3                                                       AROC  0580
    4 IF (ERROR .NE. 0) GO TO 6                                         AROC  0590
      IF (ITAPE.EQ.1 .OR. ITAPE.EQ.3) REWIND 8                          AROC  0600
      IF (ITAPE .EQ. 5) GO TO 6                                         AROC  0610
C                                                                       AROC  0620
C     READ IN ALL SURFACE DATA                                          AROC  0630
   29 IF (ITAPE.EQ.0 .OR. ITAPE.EQ.3 .OR. ITAPE.EQ.4) READ (5,1) X,Y,Z, AROC  0640
     1    STAT, XX,YY,ZZ, STATT, CASE, SECT, TYPE, SEQ                  AROC  0650
      IF (ITAPE.EQ.1 .OR. ITAPE.EQ.2) READ (8,1) X,Y,Z,STAT, XX,YY,ZZ,  AROC  0660
     1     STATT, CASE, SECT, TYPE, SEQ                                 AROC  0670
      STAT =IABS(STAT)                                                  AROC  0680
      STATT =IABS(STATT)                                                AROC  0690
      IF (ITAPE.EQ.3 .OR. ITAPE.EQ.4) WRITE (8,2) X,Y,Z,STAT, XX,YY,ZZ, AROC  0700
     1     STATT, CASE, SECT, TYPE, SEQ                                 AROC  0710
```

```
DECK AROC

      IF (TYPE.NE.3) GO TO 300                                          AROC  0720
      IF ((STAT.EQ.0.OR.STATT.EQ.0).AND.(STAT.NE.2.AND.STATT.NE.2))     AROC  0730
     1     SECTS = SECT                                                 AROC  0740
      RFLAG = .FALSE.                                                   AROC  0750
      GO TO 80                                                          AROC  0760
   30 IF (RFLAG) GO TO 50                                               AROC  0770
      RFLAG = .TRUE.                                                    AROC  0780
      X = XX                                                            AROC  0790
      Y = YY                                                            AROC  0800
      Z = ZZ                                                            AROC  0810
      STAT = STATT                                                      AROC  0820
      GO TO 60                                                          AROC  0830
   50 RFLAG = .FALSE.                                                   AROC  0840
      IF (ITAPE.FQ.0 .OR. ITAPE.EQ.3 .OR. ITAPE.EQ.4) READ (5,1) X,Y,Z, AROC  0850
     1   STAT, XX,YY,ZZ, STAIT, CASE, SECT, TYPE, SEQ                   AROC  0860
      IF (ITAPE.EQ.1 .OR. ITAPE.EQ.2) READ (8,1) X,Y,Z,STAT, XX,YY,ZZ,  AROC  0870
     1    STATT, CASE, SECT, TYPE, SEQ                                  AROC  0880
      STAT =IABS(STAT)                                                  AROC  0890
      STATT =IABS(STATT)                                                AROC  0900
      IF (ITAPE.EQ.3 .OR. ITAPE.EQ.4) WRITE (8,2) X,Y,Z,STAT, XX,YY,ZZ, AROC  0910
     1    STATT, CASE, SECT, TYPE, SEQ                                  AROC  0920
      IF (TYPE.NE.3) GO TO 300                                          AROC  0930
      IF ((STAT.EQ.0.OR.STATT.EQ.0).AND.(STAT.NE.2.AND.STATT.NE.2))     AROC  0940
     1     SECTS = SECT                                                 AROC  0950
   60 IF (STAT .EQ. 0 .OR. STAT .EQ. 3) GO TO 180                       AROC  0960
      IF (STAT .EQ. 2) GO TO 200                                        AROC  0970
   70 IF (.NOT. AFLAG) GO TO 200                                        AROC  0980
      MC = M                                                            AROC  0990
   80 M = 1                                                             AROC  1000
       IF (STAT .EQ. 2) GO TO 150                                       AROC  1010
       IF (.NOT. BFLAG) GO TO 84                                        AROC  1020
   75 DO 81 J =1,MC                                                     AROC  1030
        XA(J) = XB(J)                                                   AROC  1040
        YA(J) = YB(J)                                                   AROC  1050
   81   ZA(J) = ZB(J)                                                   AROC  1060
   83 XB(1) = X                                                         AROC  1070
```

```
      YB(1) = Y                                                         AROC  1080
      ZB(1) = Z                                                         AROC  1090
      GO TO 30                                                          AROC  1100
   84 IF (AFLAG) GO TO 85                                               AROC  1110
       BFLAG = .TRUE.                                                   AROC  1120
       GO TO 75                                                         AROC  1130
   85 AFLAG = .FALSE.                                                   AROC  1140
       GO TO 83                                                         AROC  1150
  150 AFLAG = .TRUE.                                                    AROC  1160
       BFLAG = .FALSE.                                                  AROC  1170
       N = N+1                                                          AROC  1180
      NN = NN + 1                                                       AROC  1190
  160 XA(M) = X                                                         AROC  1200
      YA(M) = Y                                                         AROC  1210
      ZA(M) = Z                                                         AROC  1220
      GO TO 30                                                          AROC  1230
  180 M = M + 1                                                         AROC  1240
      IF (AFLAG) GO TO 160                                              AROC  1250
       XB(M) = X                                                        AROC  1260
       YB(M) = Y                                                        AROC  1270
       ZB(M) = Z                                                        AROC  1280
      IF (STAT .NE. 3) GO TO 30                                         AROC  1290
  200 MMIN = MIN0 (M,MC) - 1                                            AROC  1300
       NN2 = 1                                                          AROC  1310
       MC = M                                                           AROC  1320
  250 N = N + 1                                                         AROC  1330
      NN = NN + 1                                                       AROC  1340
       KLCT = KLCT + 1                                                  AROC  1350
       JJ = 0                                                           AROC  1360
C                                                                       AROC  1370
C  BEGIN COMPUTATION OF SURFACE ELEMENT CHARACTERISTICS                 AROC  1380
  450 IF (IELOV .EQ. 1) GO TO 2001                                      AROC  1390
      DO 2000 I= 1,MMIN                                                 AROC  1400
      IIA = I + IA                                                      AROC  1410
      IIB = I + IB                                                      AROC  1420
      IF (IFACT.EQ.1) GO TO 460                                         AROC  1430
```

```
DECK AROC
          XIN(1) = XA(IIA )                          AROC  1440
          XIN(2) = XA(IIA +1)                        AROC  1450
          XIN(3) = XB(IIB +1)                        AROC  1460
          XIN(4) = XB(IIB )                          AROC  1470
          YIN(1) = YA(IIA )                          AROC  1480
          YIN(2) = YA(IIA +1)                        AROC  1490
          YIN(3) = YB(IIB +1)                        AROC  1500
          YIN(4) = YB(IIB )                          AROC  1510
          ZIN(1) = ZA(IIA )                          AROC  1520
          ZIN(2) = ZA(IIA +1)                        AROC  1530
          ZIN(3) = ZB(IIB +1)                        AROC  1540
          ZIN(4) = ZB(IIB )                          AROC  1550
        GO TO 201                                    AROC  1560
C                                                    AROC  1570
 460      XIN(1) = XA(IIA )    * XSC + DELX          AROC  1580
          XIN(2) = XA(IIA +1) * XSC + DELX           AROC  1590
          XIN(3) = XB(IIB +1) * XSC + DELX           AROC  1600
          XIN(4) = XB(IIB )    * XSC + DELX          AROC  1610
          YIN(1) = YA(IIA )    * YSC + DELY          AROC  1620
          YIN(2) = YA(IIA +1) * YSC + DELY           AROC  1630
          YIN(3) = YB(IIB +1) * YSC + DELY           AROC  1640
          YIN(4) = YB(IIB )    * YSC + DELY          AROC  1650
          ZIN(1) = ZA(IIA )    * ZSC + DELZ          AROC  1660
          ZIN(2) = ZA(IIA +1) * ZSC + DELZ           AROC  1670
          ZIN(3) = ZB(IIB +1) * ZSC + DELZ           AROC  1680
          ZIN(4) = ZB(IIB )    * ZSC + DELZ          AROC  1690
C  FORM DIAGONAL VECTORS                             AROC  1700
 201     T1X = XIN(3) - XIN(1)                       AROC  1710
         T2X = XIN(4) - XIN(2)                       AROC  1720
         T1Y = YIN(3) - YIN(1)                       AROC  1730
         T2Y = YIN(4) - YIN(2)                       AROC  1740
         T1Z = ZIN(3) - ZIN(1)                       AROC  1750
         T2Z = ZIN(4) - ZIN(2)                       AROC  1760
C                                                    AROC  1770
C  FORM CROSS PRODUCT  N=T2 X T1                     AROC  1780
         NX = T2Y*T1Z - T1Y*T2Z                      AROC  1790
```

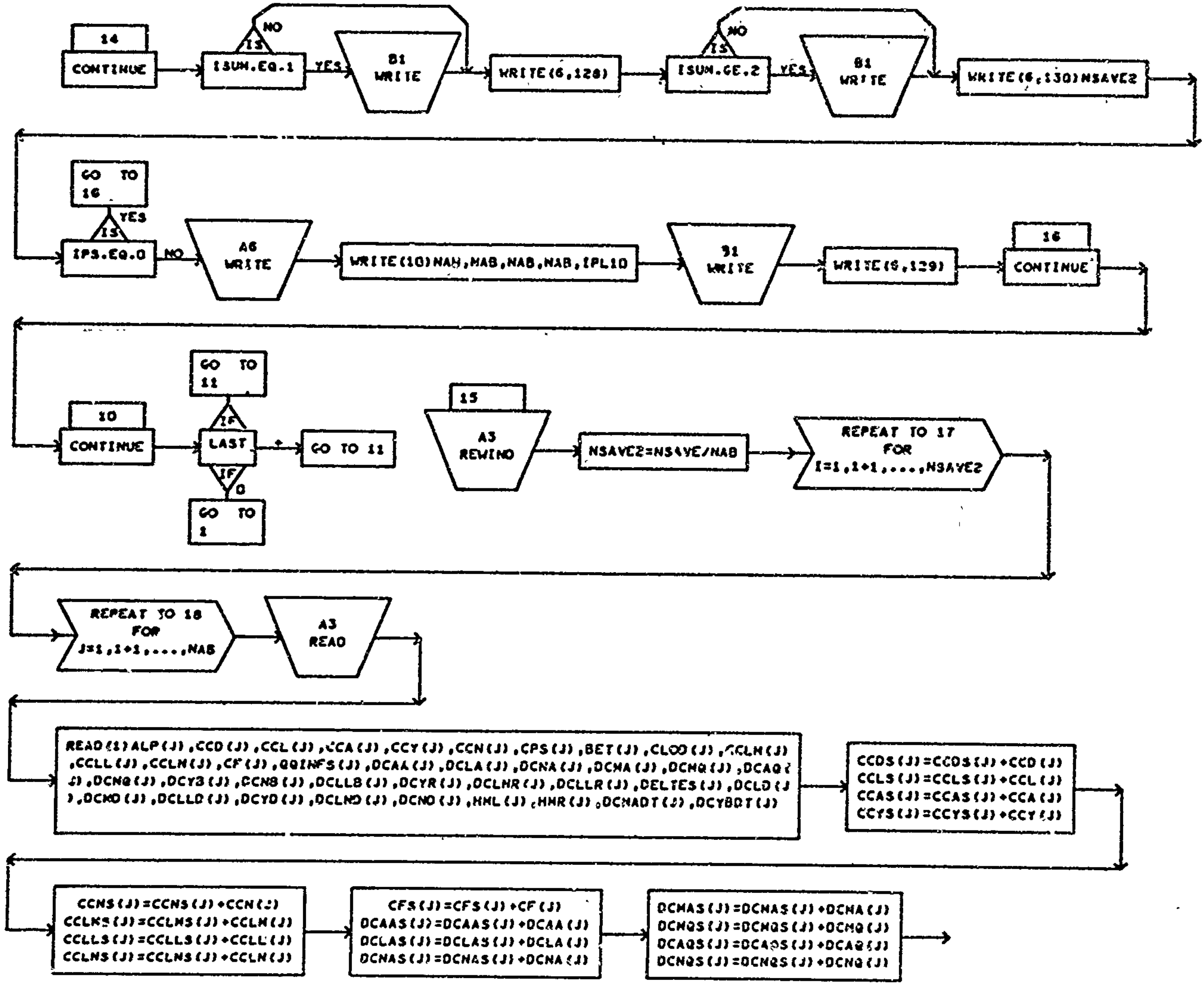
DECK AROC

```
      NY = T1X*T2Z - T2X*T1Z
      NZ = T2X*T1Y - T1X*T2Y
      VN = SQRT ( NX*NX + NY*NY + NZ*NZ )
     IF (VN .EQ. 0.0) GO TO 601
C
C  FORM UNIT NORMAL VECTOR
      NX = NX / VN
      NY = NY / VN
      NZ = NZ / VN
C
C  COMPUTE AVERAGE POINT
 601 AVX = 0.25 * (XIN(1) + XIN(2) + XIN(3) +  XIN(4) )
      AVY = 0.25 * (YIN(1) + YIN(2) + YIN(3) + YIN(4) )
      AVZ = 0.25 * (ZIN(1) + ZIN(2) + ZIN(3) + ZIN(4) )
C
C  COMPUTE PROJECTION DISTANCE
      D = NX*(AVX - XIN(1)) + NY*(AVY - YIN(1)) + NZ*(AVZ-ZIN(1))
      PD = ABS(D)
C
      T = SQRT (T1X*T1X + T1Y*T1Y + T1Z*T1Z)
     IF (T .EQ. 0.0) GO TO 603
     T1X = T1X / T
      T1Y = T1Y / T
      T1Z = T1Z / T
C
 603 T2X = NY*T1Z - NZ*T1Y
      T2Y = NZ*T1X - NX*T1Z
      T2Z = NX*T1Y - NY*T1X
C
C  COMPUTE COORDINATES OF CORNER POINTS IN REFERENCE COORD. SYSTEM
     DO 1000 J = 1,4
      XPA(J) = XIN(J) + NX*D
      YPA(J) = YIN(J) + NY*D
      ZPA(J) = ZIN(J) + NZ*D
      D = - D
      XDIF = XPA(J) - AVX
```

```
DECK AROC
      YDIF = YPA(J) - AVY                                               AROC  2160
      ZDIF = ZPA(J) - AVZ                                               AROC  2170
C                                                                       AROC  2180
C  TRANSFORM CORNER POINTS TO ELEMENT COORDINATE SYSTEM (XI,ETA) WITH   AROC  2190
C   AVERAGE POINT AS ORIGIN                                             AROC  2200
      XI(J) = T1X*XDIF + T1Y*YDIF + T1Z*ZDIF                            AROC  2210
 1000 ETA(J)= T2X*XDIF + T2Y*YDIF + T2Z*ZDIF                            AROC  2220
     ETACK = ETA(2) - ETA(4)                                            AROC  2230
     IF (ETACK .NE.0.0) GO TO 312                                       AROC  2240
      XI0 = 0.0                                                         AROC  2250
      GO TO 313                                                         AROC  2260
C                                                                       AROC  2270
C  COMPUTE CENTROID                                                     AROC  2280
 312 XI0 = .333333333 * (XI(4) * (ETA(1)-ETA(2)) + XI(2)                AROC  2290
    1      * (ETA(4)-ETA(1))) / (ETA(2)-ETA(4))                         AROC  2300
 313 ETA0 = -.333333333 * ETA(1)                                        AROC  2310
C                                                                       AROC  2320
C  OBTAIN CORNER POINTS IN SYSTEM WITH CENTROID AS ORIGIN               AROC  2330
      DO 1020 J = 1,4                                                   AROC  2340
       XI(J) = XI(J) - XI0                                              AROC  2350
 1020  ETA(J) = ETA(J) - ETA0                                           AROC  2360
C                                                                       AROC  2370
C  TRANSFORM CENTROID TO REFERENCE COORDINATE SYSTEM                    AROC  2380
      XCENT = AVX + T1X*XI0 + T2X*ETA0                                  AROC  2390
      YCENT = AVY + T1Y*XI0 + T2Y*ETA0                                  AROC  2400
      ZCENT = AVZ + T1Z*XI0 + T2Z*ETA0                                  AROC  2410
C                                                                       AROC  2420
C  CONSTANTS FOR USE IN COMPUTING AREA OF ELEMENT                       AROC  2430
      XI3M1 = XI(3) - XI(1)                                             AROC  2440
      ETA2M4 = ETA(2) - ETA(4)                                          AROC  2450
C                                                                       AROC  2460
C  COMPUTE AREA AND VOLUME OF ELEMENTS                                  AROC  2470
      AREA = 0.5 * XI3M1 * ETA2M4                                       AROC  2480
     AREAT = AREAT + AREA                                               AROC  2490
      DELVOL = AREA * NY * YCENT                                        AROC  2500
     VOL = VOL + DELVOL                                                 AROC  2510
```

```
DECK AROC

      L = L + 1                                                         AROC  2520
      II = I                                                            AROC  2530
      IF (PRINTS.EQ.0) GO TO 1770                                       AROC  2540
C                                                                       AROC  2550
C                                                                       AROC  2560
C  PRINT RESULTS OF CALCULATICNS TO DETERMINE ELEMENT CHARACTERISTICS   AROC  2570
 1700 IF (NPRT .GE.9)  GO TO 1750                                       AROC  2580
       NPRT = NPRT + 1                                                  AROC  2590
      IF  (I .EQ. 1) GO TO 1760                                         AROC  2600
       WRITE (6,4005) I, XIN, NX, XCENT, AREA,L,YIN,NY,YCENT,DELVOL,ZIN,AROC  2610
     1  NZ,ZCENT,VOL                                                    AROC  2620
      GO TO 1770                                                        AROC  2630
 1750 NPRT = 0                                                          AROC  2640
      CALL HEADER                                                       AROC  2650
      WRITE (6, 4002)                                                   AROC  2660
 1760 WRITE (6, 4010) N, I, XIN, NX, XCENT, AREA,L,YIN,NY,YCENT,DELVOL, AROC  2670
     1 ZIN,NZ,ZCENT,VOL                                                 AROC  2680
C                                                                       AROC  2690
C  SET UP DATA TO BE SAVED AND USED IN FORCE CALCULATIONS              AROC  2700
 1770 IF (IGT .GT. 0) GO TO 1772                                        AROC  2710
      IF (L .LE. ISIZ) GO TO 1771                                       AROC  2720
      WRITE (4) L,N,I,NX,NY,NZ,XCENT,YCENT,ZCENT,AREA                   AROC  2730
      GO TO 2000                                                        AROC  2740
 1771  NX2(L) = NX                                                      AROC  2750
       NY2(L) = NY                                                      AROC  2760
       NZ2(L) = NZ                                                      AROC  2770
       XCENT2(L) = XCENT                                                AROC  2780
       YCENT2(L) = YCENT                                                AROC  2790
       ZCENT2(L)  = ZCENT                                               AROC  2800
       AREA2(L)  = AREA                                                 AROC  2810
       IN(L)     = N                                                    AROC  2820
       IM(L)     = I                                                    AROC  2830
      GO TO 2000                                                        AROC  2840
C  SAVE GEOMETRY DATA FOR CONTROL SURFACE USE                           AROC  2850
 1772  IF (L.GT. 1) GO TO 1600                                          AROC  2860
      XLEP1 = XPA(1)                                                    AROC  2870
```


14
CONTINUE
ISUM.EQ.1
IS
NO
YES
B1
WRITE
WRITE(6,128)
ISUM.GE.2
IS
NO
YES
B1
WRITE
WRITE(6,130)NSAVE2
GO TO
16
YES
IS
IPS.EQ.0
NO
A6
WRITE
WRITE(10)NAB,NAB,NAB,NAB,IPL10
B1
WRITE
WRITE(6,129)
16
CONTINUE
10
CONTINUE
GO TO
11
IF
LAST
+
GO TO 11
IF
0
GO TO
1
15
A3
REWIND
NSAVE2=NSAVE/NAB
REPEAT TO 17
FOR
I=1,1+1,....,NSAVE2
REPEAT TO 18
FOR
J=1,1+1,....,NAB
A3
READ
READ(1)ALP(J),CCD(J),CCL(J),CCA(J),CCY(J),CCN(J),CPS(J),BET(J),CLOO(J),CCLM(J)
,CCLL(J),CCLN(J),CF(J),QQINFS(J),DCAA(J),DCLA(J),DCNA(J),DCMA(J),DCMQ(J),DCAQ(
J),DCNQ(J),DCYB(J),DCNB(J),DCLLB(J),DCYR(J),DCLNR(J),DCLLR(J),DELTES(J),DCLD(J
),DCMD(J),DCLLD(J),DCYD(J),DCLND(J),DCND(J),HML(J),HMR(J),DCMADT(J),DCYBDT(J)
CCDS(J)=CCDS(J)+CCD(J)
CCLS(J)=CCLS(J)+CCL(J)
CCAS(J)=CCAS(J)+CCA(J)
CCYS(J)=CCYS(J)+CCY(J)
CCNS(J)=CCNS(J)+CCN(J)
CCLMS(J)=CCLMS(J)+CCLM(J)
CCLLS(J)=CCLLS(J)+CCLL(J)
CCLNS(J)=CCLNS(J)+CCLN(J)
CFS(J)=CFS(J)+CF(J)
DCAAS(J)=DCAAS(J)+DCAA(J)
DCLAS(J)=DCLAS(J)+DCLA(J)
DCNAS(J)=DCNAS(J)+DCNA(J)
DCMAS(J)=DCMAS(J)+DCMA(J)
DCMQS(J)=DCMQS(J)+DCMQ(J)
DCAQS(J)=DCAQS(J)+DCAQ(J)
DCNQS(J)=DCNQS(J)+DCNQ(J)

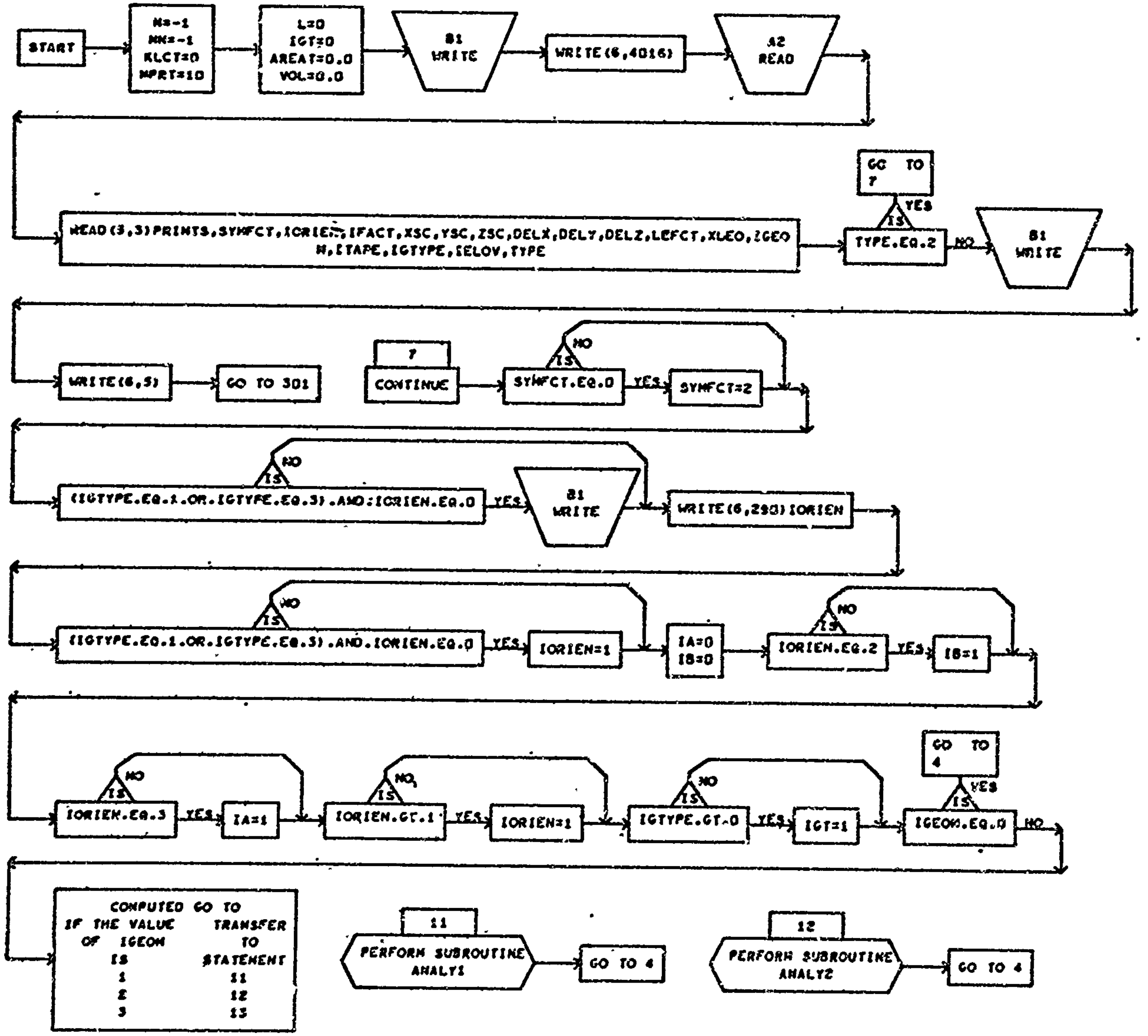
```
DECK AROC

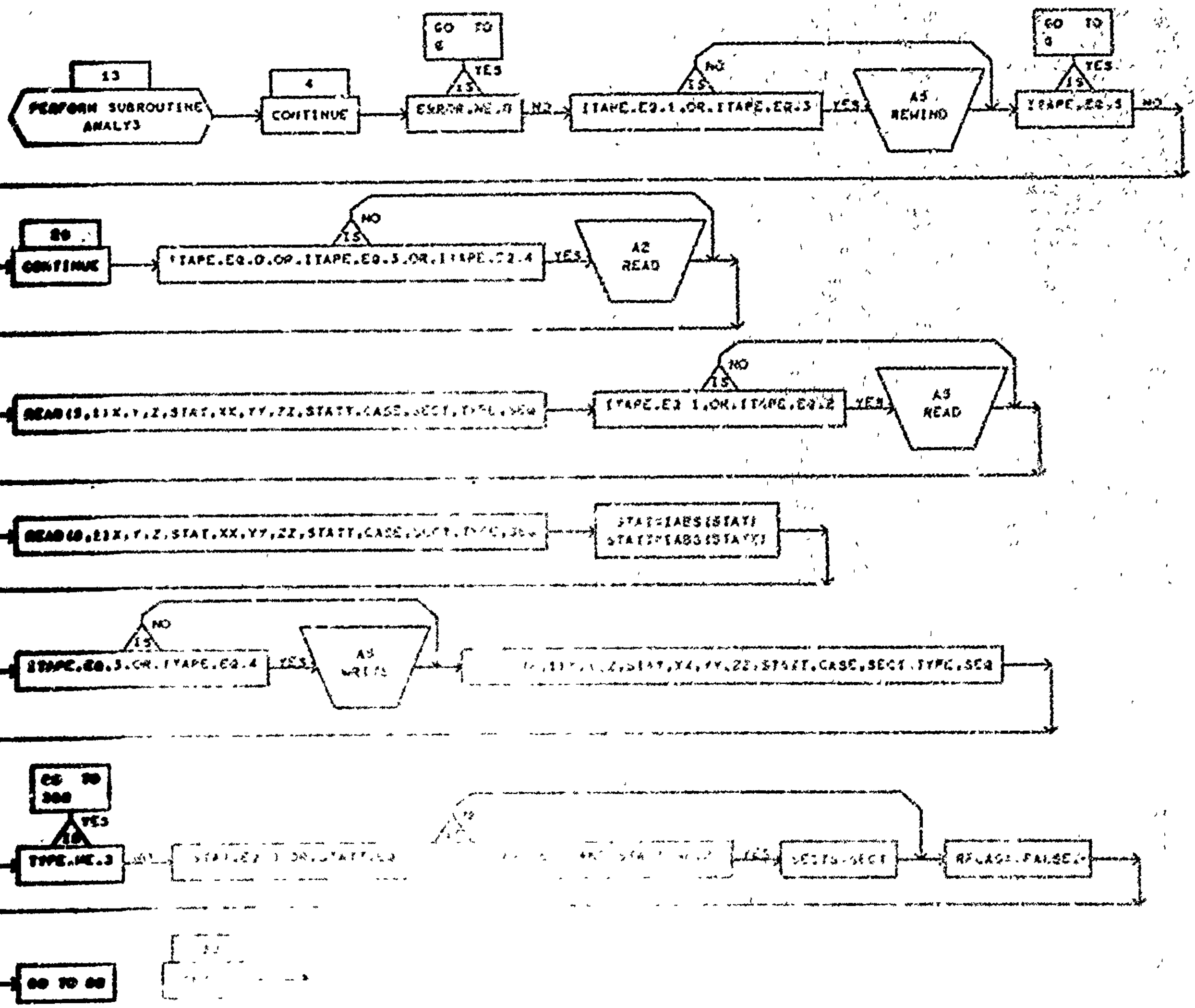
      IF (IGT .FQ. 2) GO TO 1650                                         AROC  3240
      NX2(2) = XIN(3)                                                    AROC  3250
      NY2(2) = YIN(3)                                                    AROC  3260
      NZ2(2) = ZIN(3)                                                    AROC  3270
      IN(1) = L                                                          AROC  3280
      NFS = N                                                            AROC  3290
      IA = 0                                                             AROC  3300
      IB = 0                                                             AROC  3310
      IGT = 2                                                            AROC  3320
      GO TO 2020                                                         AROC  3330
 1650 IN(2) = L - IN(1)                                                  AROC  3340
      IN(4) = II                                                         AROC  3350
      IF (N .EQ. NFS) GO TO 2020                                         AROC  3360
      WRITE (6,1651)                                                     AROC  3370
 1651 FORMAT (1H ,49H***** NUMBER OF STREAMWISE STRIPS ON FORE-SURFACE   AROC  3380
     1  55H AND FLAP MUST BE THE SAME.  CHANGE GFCMETRY DATA ***** )     AROC  3390
      ERROR = 3                                                          AROC  3400
      GO TO 6                                                            AROC  3410
C                                                                        AROC  3420
C  TEST FOR END OF CASE                                                  AROC  3430
 2020 IF (STAT .NE. 3) GO TO 80                                          AROC  3440
      GO TO 302                                                          AROC  3450
C                                                                        AROC  3460
C  ERROR CHECK ON READING CARDS                                          AROC  3470
 300  WRITE (6,4003)                                                     AROC  3480
C                                                                        AROC  3490
 4003 FORMAT (1H0,50H***** SURFACE DATA ROUTINE HAS ATTEMPYED TO READ A  AROC  3500
     142H NON SURFACE CARD - CHECK YOUR CARDS *****  )                   AROC  3510
 301  ERROR = 1                                                          AROC  3520
      RETURN                                                             AROC  3530
C                                                                        AROC  3540
 302  LS = L                                                             AROC  3550
      WRITE (6,4016)                                                     AROC  3560
 4016 FORMAT (1H1 )                                                      AROC  3570
      REWIND 3                                                           AROC  3580
      REWIND 4                                                           AROC  3590
```

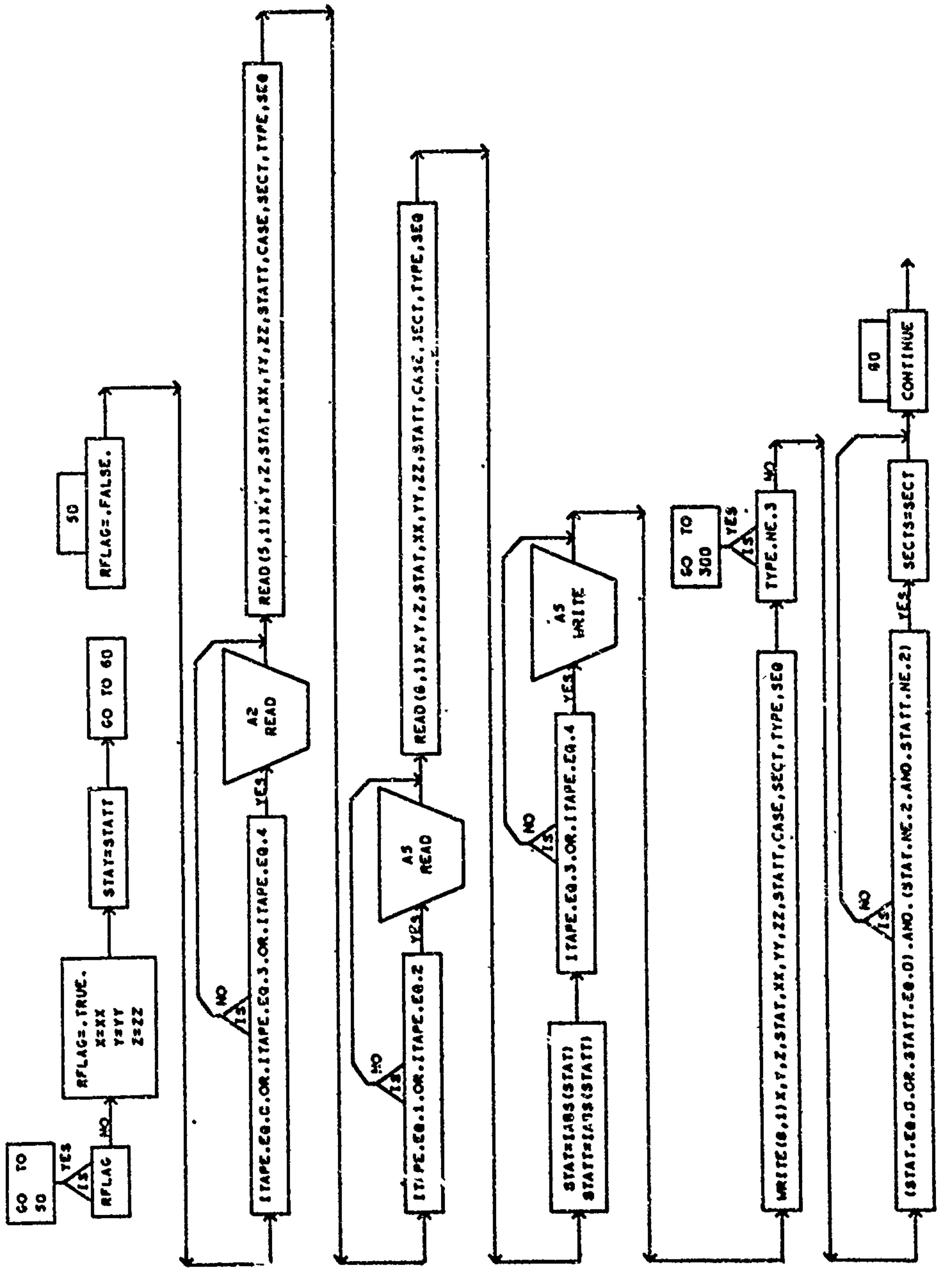
```
DECK AROC

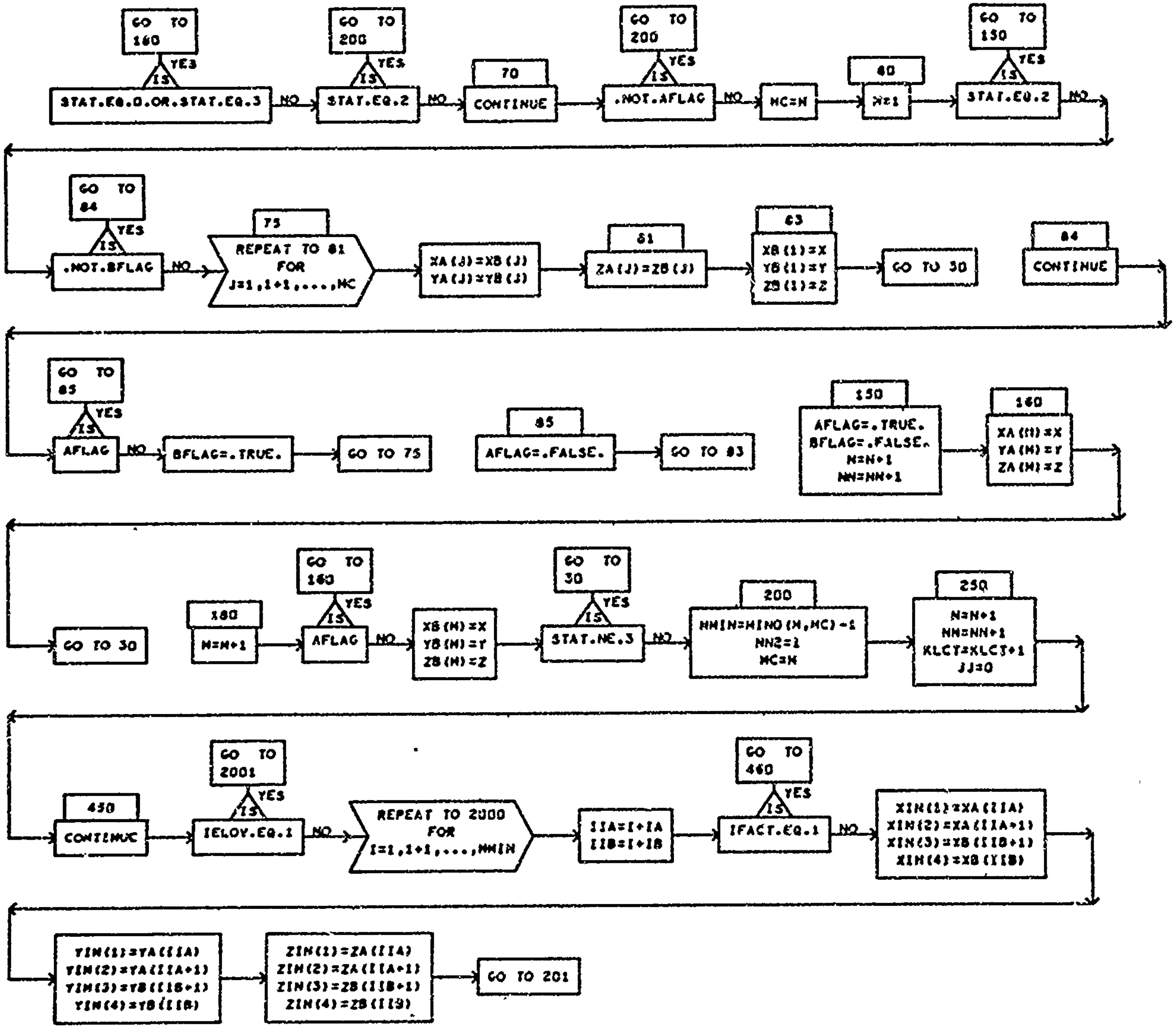
   6  RETURN                                                          AROC  3600
C                                                                     AROC  3610
 4005 FORMAT (1H0,7X, I4, 1P4E14.5,0PF10.6,1P2E14.5,I6,2(/12X,4E14.5, AROC  3620
     1 0PF10.6,1P2E14.5)  )                                           AROC  3630
C                                                                     AROC  3640
 4010 FORMAT (1H0,3X, 2I4,1P4E14.5,0PF10.6,1P2E14.5,I6,2(/12X,4E14.5, AROC  3650
     1 0PF10.6,1P2E14.5)  )                                           AROC  3660
C                                                                     AROC  3670
 4015 FORMAT (1H0,10H SECTION =1A2,33H   TOTAL AREA OF INPUT ELEMENTS = AROC  3680
     1 F12.3,6X26HTOTAL NUMBER OF ELEMENTS = I5/1H ,12X,              AROC  3690
     2 33H TOTAL VOLUME OF INPUT ELEMENTS =F12.3,/1H0,3(20X,          AROC  3700
     3 9H*********))                                                  AROC  3710
C                                                                     AROC  3720
 4002 FORMAT (1H0,28H  INPUT SURFACE ELEMENT DATA/1H0,6X1HN3X1HM7X1HX, AROC  3730
     1 3(13X,1HX),11X2HNX9X5HXCENT9X4HAREA8X1HL ,/1H ,5X, 4(13X,1HY), AROC  3740
     2 11X2HNY9X5HYCENT ,7X,7HDELTA V,/1H ,5X,4(13X,1HZ),11X2HNZ,     AROC  3750
     3 9X,5HZCENT ,7X,6HVOLUME,/1H  )                                 AROC  3760
C                                                                     AROC  3770
      END                                                             AROC  3780
```

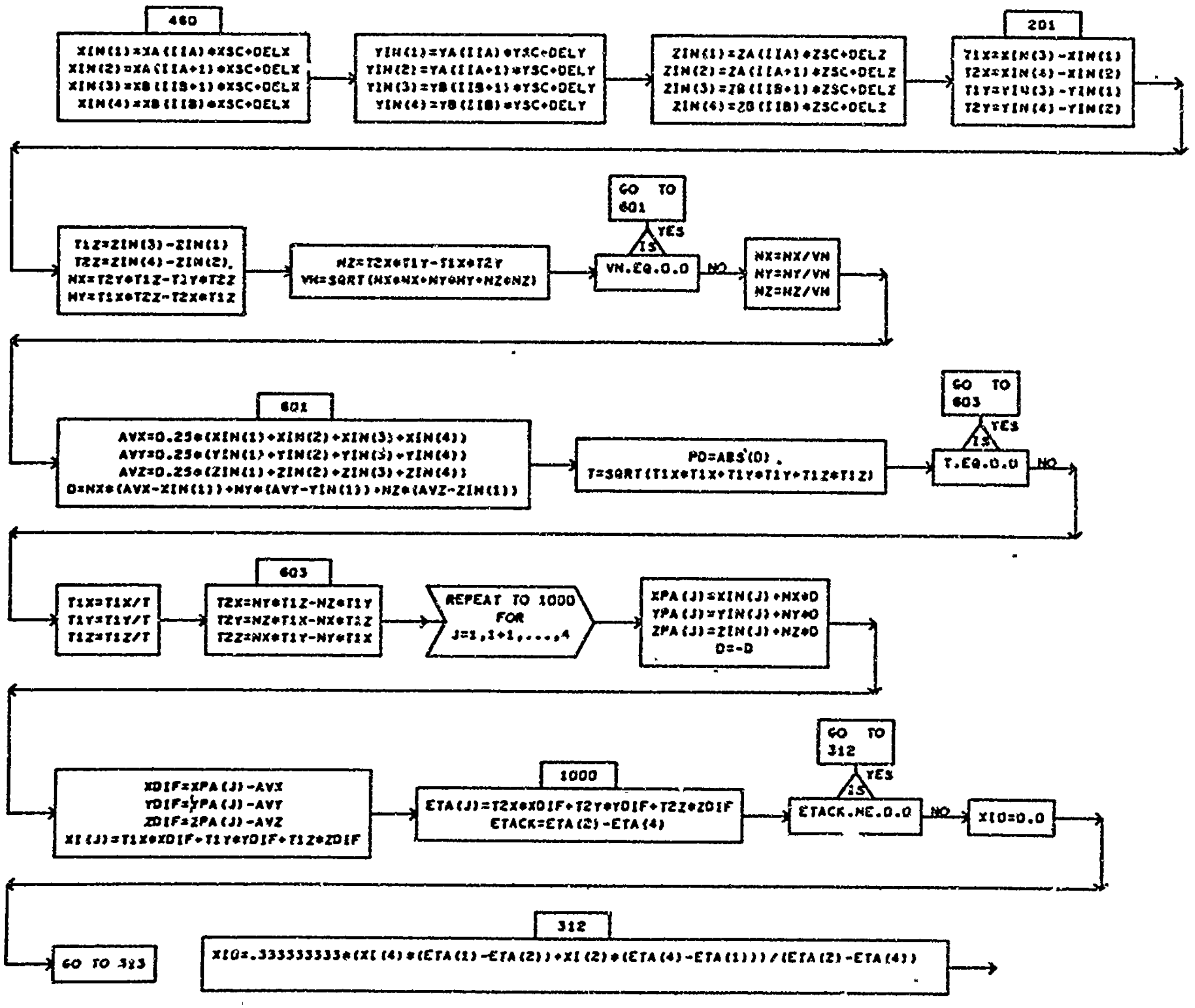
SUBROUTINE SDATA

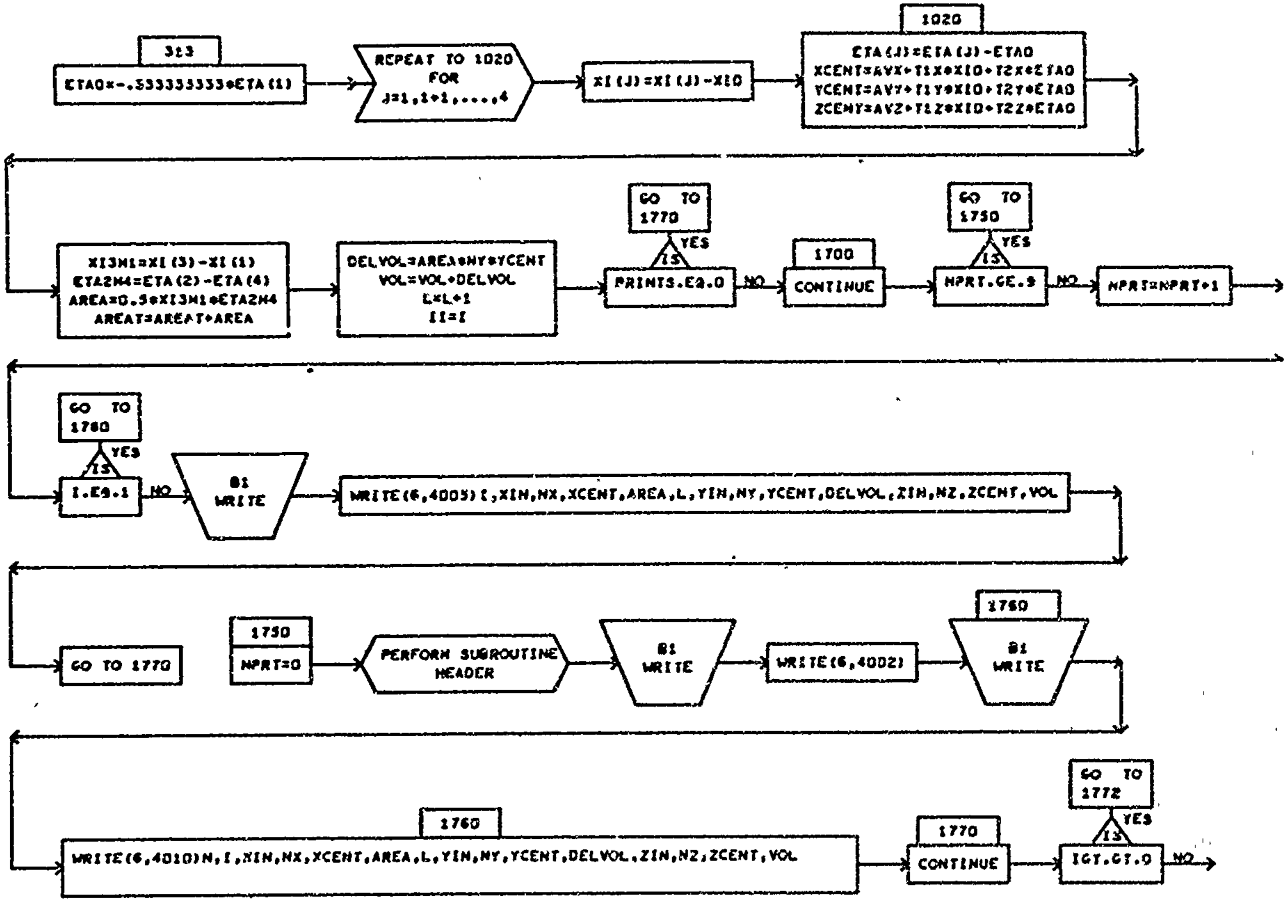


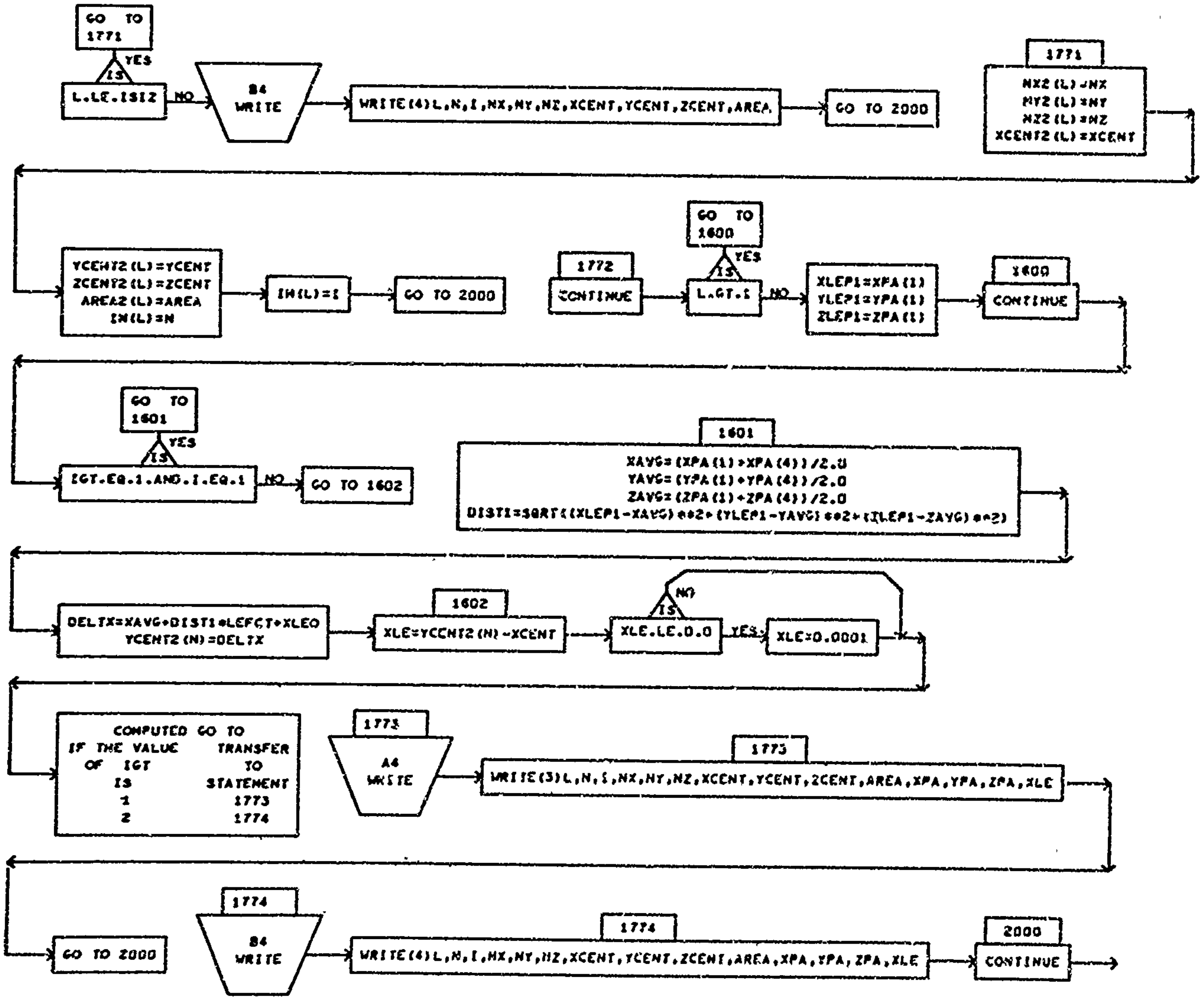

13
PERFORM SUBROUTINE ANALYS
4
CONTINUE
ERROR.NE.0
IS
YES
GO TO 6
NO
ITAPE.EQ.1.OR.ITAPE.EQ.3
A5 REWIND
ITAPE.EQ.3
GO TO 6
20
CONTINUE
ITAPE.EQ.0.OR.ITAPE.EQ.3.OR.ITAPE.EQ.4
A2 READ
READ(3,1)X,Y,Z,STAT,XX,YY,ZZ,STATT,CASE,SECT,TYPE,SEQ
ITAPE.EQ.1.OR.ITAPE.EQ.2
A3 READ
READ(4,1)X,Y,Z,STAT,XX,YY,ZZ,STATT,CASE,SECT,TYPE,SEQ
STAT=IABS(STAT)
STATT=IABS(STATT)
ITAPE.EQ.3.OR.ITAPE.EQ.4
A5 WRITE
X,Y,Z,STAT,XX,YY,ZZ,STATT,CASE,SECT,TYPE,SEQ
TYPE.NE.3
GO TO 300
STAT.EQ.0.OR.STATT.EQ
SECTS=SECT
RFLAG=.FALSE.
GO TO 20

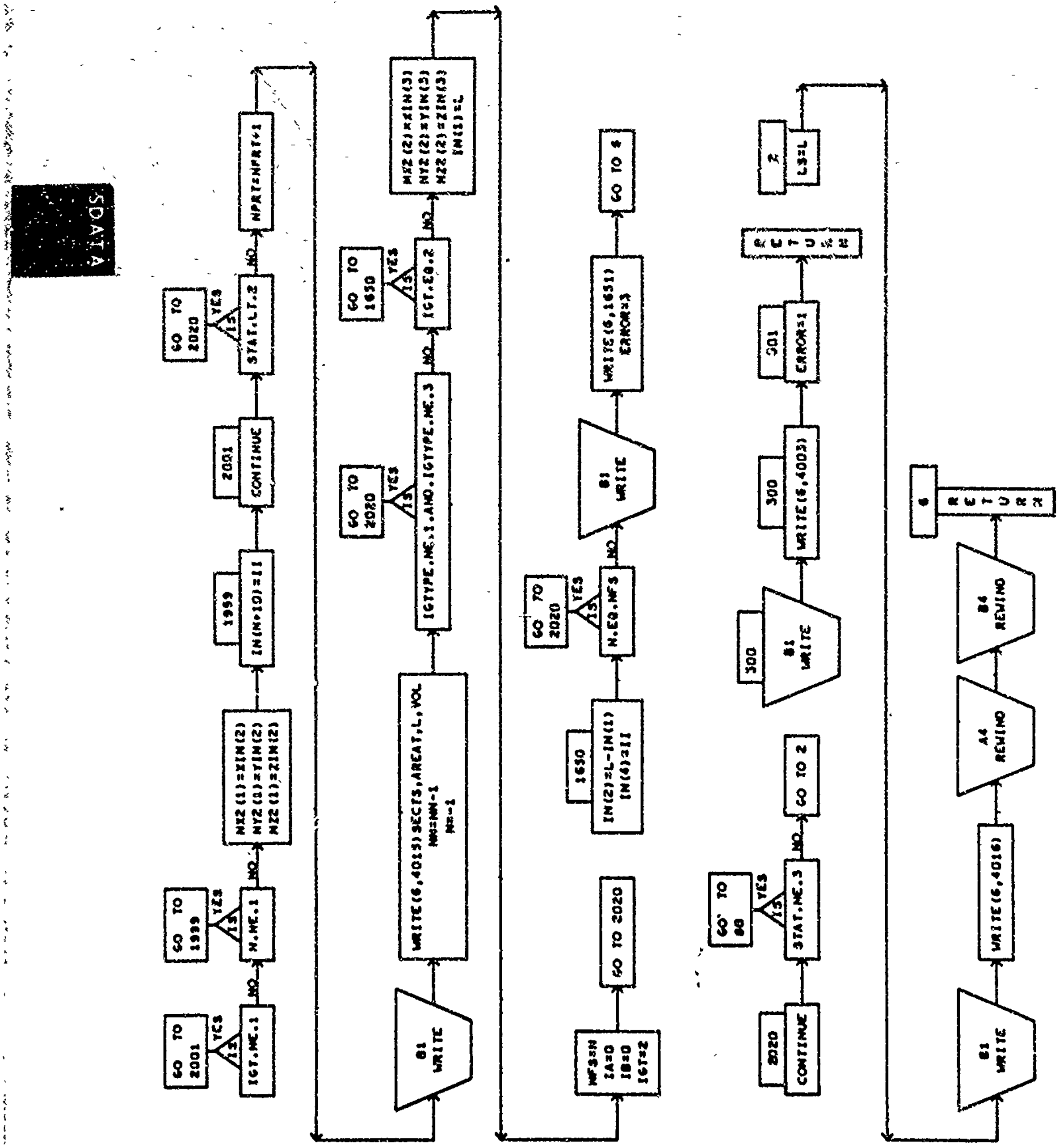

GO TO 50
RFLAG
IS
YES
NO
RFLAG=.TRUE.
X=XX
Y=YY
Z=ZZ
STAY=STATT
GO TO 60
50
RFLAG=.FALSE.
ITAPE.EQ.0.OR.ITAPE.EQ.3.OR.ITAPE.EQ.4
IS
NO
YES
A2
READ
READ(5,1)X,Y,Z,STAT,XX,YY,ZZ,STATT,CASE,SECT,TYPE,SEQ
ITAPE.EQ.1.OR.ITAPE.EQ.2
IS
NO
YES
A5
READ
READ(6,1)X,Y,Z,STAT,XX,YY,ZZ,STATT,CASE,SECT,TYPE,SEQ
STAT=IABS(STAT)
STATT=IABS(STATT)
ITAPE.EQ.3.OR.ITAPE.EQ.4
IS
NO
YES
A5
WRITE
WRITE(8,1)X,Y,Z,STAT,XX,YY,ZZ,STATT,CASE,SECT,TYPE,SEQ
TYPE.NE.3
IS
YES
GO TO 300
NO
(STAT.EQ.0.OR.STATT.EQ.0).AND.(STAT.NE.2.AND.STATT.NE.2)
IS
NO
YES
SECTS=SECT
60
CONTINUE


GO TO 160
IS
YES
STAT.EQ.0.OR.STAT.EQ.3
NO
GO TO 200
IS
YES
STAT.EQ.2
NO
70
CONTINUE
GO TO 200
IS
YES
.NOT.AFLAG
NO
MC=N
40
N=1
GO TO 150
IS
YES
STAT.EQ.2
NO
GO TO 84
IS
YES
.NOT.BFLAG
NO
75
REPEAT TO 81 FOR J=1,1+1,....,MC
XA(J)=XB(J)
YA(J)=YB(J)
81
ZA(J)=ZB(J)
83
XB(1)=X
YB(1)=Y
ZB(1)=Z
GO TO 30
84
CONTINUE
GO TO 85
IS
YES
AFLAG
NO
BFLAG=.TRUE.
GO TO 75
85
AFLAG=.FALSE.
GO TO 83
150
AFLAG=.TRUE.
BFLAG=.FALSE.
N=N+1
NN=NN+1
160
XA(N)=X
YA(N)=Y
ZA(N)=Z
GO TO 30
180
N=N+1
GO TO 160
IS
YES
AFLAG
NO
XB(N)=X
YB(N)=Y
ZB(N)=Z
GO TO 30
IS
YES
STAT.NE.3
NO
200
NMIN=MINO(N,MC)-1
NN2=1
MC=N
250
N=N+1
NN=NN+1
KLCT=KLCT+1
JJ=0
450
CONTINUE
GO TO 2001
IS
YES
IELOV.EQ.1
NO
REPEAT TO 2000 FOR I=1,1+1,....,NMIN
IIA=I+IA
IIB=I+IB
GO TO 460
IS
YES
IFACT.EQ.1
NO
XIN(1)=XA(IIA)
XIN(2)=XA(IIA+1)
XIN(3)=XB(IIB+1)
XIN(4)=XB(IIB)
YIN(1)=YA(IIA)
YIN(2)=YA(IIA+1)
YIN(3)=YB(IIB+1)
YIN(4)=YB(IIB)
ZIN(1)=ZA(IIA)
ZIN(2)=ZA(IIA+1)
ZIN(3)=ZB(IIB+1)
ZIN(4)=ZB(IIB)
GO TO 201


460
XIN(1)=XA(IIA)*XSC+DELX
XIN(2)=XA(IIA+1)*XSC+DELX
XIN(3)=XB(IIB+1)*XSC+DELX
XIN(4)=XB(IIB)*XSC+DELX
YIN(1)=YA(IIA)*YSC+DELY
YIN(2)=YA(IIA+1)*YSC+DELY
YIN(3)=YB(IIB+1)*YSC+DELY
YIN(4)=YB(IIB)*YSC+DELY
ZIN(1)=ZA(IIA)*ZSC+DELZ
ZIN(2)=ZA(IIA+1)*ZSC+DELZ
ZIN(3)=ZB(IIB+1)*ZSC+DELZ
ZIN(4)=ZB(IIB)*ZSC+DELZ
201
T1X=XIN(3)-XIN(1)
T2X=XIN(4)-XIN(2)
T1Y=YIN(3)-YIN(1)
T2Y=YIN(4)-YIN(2)
T1Z=ZIN(3)-ZIN(1)
T2Z=ZIN(4)-ZIN(2),
NX=T2Y*T1Z-T1Y*T2Z
NY=T1X*T2Z-T2X*T1Z
NZ=T2X*T1Y-T1X*T2Y
VN=SQRT(NX*NX+NY*NY+NZ*NZ)
GO TO 601
YES
IS
VN.EQ.0.0
NO
NX=NX/VN
NY=NY/VN
NZ=NZ/VN
601
AVX=0.25*(XIN(1)+XIN(2)+XIN(3)+XIN(4))
AVY=0.25*(YIN(1)+YIN(2)+YIN(3)+YIN(4))
AVZ=0.25*(ZIN(1)+ZIN(2)+ZIN(3)+ZIN(4))
D=NX*(AVX-XIN(1))+NY*(AVY-YIN(1))+NZ*(AVZ-ZIN(1))
PD=ABS(D) ,
T=SQRT(T1X*T1X+T1Y*T1Y+T1Z*T1Z)
GO TO 603
YES
IS
T.EQ.0.0
NO
T1X=T1X/T
T1Y=T1Y/T
T1Z=T1Z/T
603
T2X=NY*T1Z-NZ*T1Y
T2Y=NZ*T1X-NX*T1Z
T2Z=NX*T1Y-NY*T1X
REPEAT TO 1000
FOR
J=1,1+1,....,4
XPA(J)=XIN(J)+NX*D
YPA(J)=YIN(J)+NY*D
ZPA(J)=ZIN(J)+NZ*D
D=-D
XDIF=XPA(J)-AVX
YDIF=YPA(J)-AVY
ZDIF=ZPA(J)-AVZ
XI(J)=T1X*XDIF+T1Y*YDIF+T1Z*ZDIF
1000
ETA(J)=T2X*XDIF+T2Y*YDIF+T2Z*ZDIF
ETACK=ETA(2)-ETA(4)
GO TO 312
YES
IS
ETACK.NE.0.0
NO
XI0=0.0
GO TO 323
312
XI0=.333333333*(XI(4)*(ETA(1)-ETA(2))+XI(2)*(ETA(4)-ETA(1)))/(ETA(2)-ETA(4))


313
ETAO=-.333333333*ETA(1)
REPEAT TO 1020 FOR J=1,1+1,....,4
XI(J)=XI(J)-XIO
1020
ETA(J)=ETA(J)-ETAO
XCENT=AVX+T1X*XIO+T2X*ETAO
YCENT=AVY+T1Y*XIO+T2Y*ETAO
ZCENT=AVZ+T1Z*XIO+T2Z*ETAO
XI3M1=XI(3)-XI(1)
ETA2M4=ETA(2)-ETA(4)
AREA=0.5*XI3M1*ETA2M4
AREAT=AREAT+AREA
DELVOL=AREA*NY*YCENT
VOL=VOL+DELVOL
L=L+1
II=I
GO TO 1770
YES
IS
PRINTS.EQ.0
NO
1700
CONTINUE
GO TO 1750
YES
IS
NPRT.GE.9
NO
NPRT=NPRT+1
GO TO 1760
YES
IS
I.EQ.1
NO
B1
WRITE
WRITE(6,4005)I,XIN,NX,XCENT,AREA,L,YIN,NY,YCENT,DELVOL,ZIN,NZ,ZCENT,VOL
GO TO 1770
1750
NPRT=0
PERFORM SUBROUTINE HEADER
B1
WRITE
WRITE(6,4002)
1760
B1
WRITE
1760
WRITE(6,4010)N,I,XIN,NX,XCENT,AREA,L,YIN,NY,YCENT,DELVOL,ZIN,NZ,ZCENT,VOL
1770
CONTINUE
GO TO 1772
YES
IS
IGT.GT.0
NO


GO TO 1771
YES
IS
L.LE.ISI2
NO
B4 WRITE
WRITE(4)L,N,I,NX,NY,NZ,XCENT,YCENT,ZCENT,AREA
GO TO 2000
1771
NX2(L)=NX
NY2(L)=NY
NZ2(L)=NZ
XCENT2(L)=XCENT
YCENT2(L)=YCENT
ZCENT2(L)=ZCENT
AREA2(L)=AREA
IN(L)=N
IN(L)=I
GO TO 2000
1772
CONTINUE
GO TO 1600
YES
IS
L.GT.1
NO
XLEP1=XPA(1)
YLEP1=YPA(1)
ZLEP1=ZPA(1)
1600
CONTINUE
GO TO 1601
YES
IS
IGT.EQ.1.AND.I.EQ.1
NO
GO TO 1602
1601
XAVG=(XPA(1)+XPA(4))/2.0
YAVG=(YPA(1)+YPA(4))/2.0
ZAVG=(ZPA(1)+ZPA(4))/2.0
DISTI=SQRT((XLEP1-XAVG)**2+(YLEP1-YAVG)**2+(ZLEP1-ZAVG)**2)
DELTX=XAVG+DISTI*LEFCT+XLEO
YCENT2(N)=DELTX
1602
XLE=YCENT2(N)-XCENT
NO
IS
XLE.LE.0.0
YES
XLE=0.0001
COMPUTED GO TO
IF THE VALUE OF IGT IS
TRANSFER TO STATEMENT
1 1773
2 1774
1773
A4 WRITE
1773
WRITE(3)L,N,I,NX,NY,NZ,XCENT,YCENT,ZCENT,AREA,XPA,YPA,ZPA,XLE
GO TO 2000
1774
B4 WRITE
1774
WRITE(4)L,N,I,NX,NY,NZ,XCENT,YCENT,ZCENT,AREA,XPA,YPA,ZPA,XLE
2000
CONTINUE


SDATA
GO TO 2001
YES
IS
IGT.NE.1
NO
GO TO 1999
YES
IS
N.NE.1
NO
NX2(1)=XIN(2)
NY2(1)=YIN(2)
NZ2(1)=ZIN(2)
1999
IN(N+10)=II
2001
CONTINUE
GO TO 2020
YES
IS
STAT.LT.2
NO
NPRT=NPRT+1
B1
WRITE
WRITE(6,4015)SECTS,AREAT,L,VOL
NN=NN-1
NX=-1
GO TO 2020
YES
IS
IGTYPE.NE.1.AND.IGTYPE.NE.3
NO
GO TO 1650
YES
IS
IGT.EQ.2
NO
NX2(2)=XIN(3)
NY2(2)=YIN(3)
NZ2(2)=ZIN(3)
IN(1)=L
NFS=N
IA=0
IB=0
IGT=2
GO TO 2020
1650
IN(2)=L-IN(1)
IN(4)=II
GO TO 2020
YES
IS
N.EQ.NFS
NO
B1
WRITE
WRITE(6,1651)
ERROR=1
GO TO 4
2020
CONTINUE
GO TO 86
YES
IS
STAT.NE.3
NO
GO TO 2
300
B1
WRITE
300
WRITE(6,4003)
301
ERROR=1
RETURN
2
LS=L
B1
WRITE
WRITE(6,4016)
A4
REWIND
B4
REWIND
6
RETURN

```
SYMBOLS USED IN SUBROUTINE SDATA

AFLAG     L  U  INPUT DATA READ CONTROL FLAG                                            SDATA
AREA      R  U  ELEMENT AREA                                                            SDATA
AREAT     R  U  TOTAL AREA                                                              SDATA
AREA2     R  C  QUADRILATERAL ELEMENT AREA ARRAY                                        SDATA
AVX       R  U  AVERAGE POINT COORDINATE-X                                              SDATA
AVY       R  U  AVERAGE POINT COORDINATE-Y                                              SDATA
AVZ       R  U  AVERAGE POINT COORDINATE-Z                                              SDATA
BFLAG     L  U  INPUT DATA READ CONTROL FLAG                                            SDATA
CASE      I  C  CASE NUMBER                                                             SDATA
D         R  U  CORNER POINT PROJECTION DISTANCE                                        SDATA
DELTX     R  U  DISTANCE FROM LEADING EDGE TO CENTROID                                  SDATA
DELVOL    R  U  ELEMENT VOLUME CONTRIBUTION                                             SDATA
DELX      R  U  GEOMETRY DATA X-INCREMENT                                               SDATA
DELY      R  U  GEOMETRY DATA Y-INCREMENT                                               SDATA
DELZ      R  U  GEOMETRY DATA Z-INCREMENT                                               SDATA
DIST1     R  U  LEADING EDGE DISTANCE VALUE                                             SDATA
ERROR     I  C  ERROR FLAG                                                              SDATA
ETA       R  U  COORDINATE IN ELEMENT COORDINATE SYSTEM                                 SDATA
ETACK     R  U  ETA CHECK PARAMETER                                                     SDATA
ETAO      R  U  CENTROID IN ELEMENT COORDINATE SYSTEM                                   SDATA
ETA2M4    R  U  CONSTANT IN AREA EQUATION                                               SDATA
I         I  U  ELEMENT NUMBER IN COLUMN                                                SDATA
IA        I  U  FLAG TO CONTROL SHIFTING OF COLUMN DATA POINTS FOR IORIEN=3             SDATA
IB        I  U  FLAG TO CONTROL SHIFTING OF COLUMN DATA POINTS FOR IORIEN=2             SDATA
IELOV     I  U  ELEMENT CHARACTERISTIC OVERRIDE FLAG                                    SDATA
IFACT     I  U  SCALE FACTOR FLAG                                                       SDATA
IGEOM     I  U  GEOMETRY SOURCE FLAG                                                    SDATA
IGT       I  U  CONTROL SURFACE FLAG                                                    SDATA
IGTYPE    I  A  COMPONENT TYPE FLAG                                                     SDATA
II        I  U  NUMBER OF ELEMENTS IN COLUMN                                            SDATA
IIA       I  U  DATA SHIFTING CONTROL PARAMETER (IORIEN=3)                              SDATA
IIB       I  U  DATA SHIFTING CONTROL PARAMETER (IORIEN=2)                              SDATA
IM        I  C  ELEMENT ROW NUMBER ARRAY                                                SDATA
IN        I  C  ELEMENT COLUMN NUMBER ARRAY                                             SDATA
IORIEN    I  A  ELEMENT ORIENTATION FLAG                                                SDATA
ISIZ      I  A  NUMBER OF ELEMENTS TO BE STORED IN CORE                                 SDATA
```

```
SYMBOLS USED IN SUBROUTINE SDATA

ITAPE    I  U  GEOMETRY TAPE CONTROL FLAG                                SDATA
JJ       I  U  COUNTER                                                   SDATA
KLCT     I  U  COUNTER                                                   SDATA
L        I  C  NUMBER OF ELEMENTS                                        SDATA
LEFCT    R  U  LEADING EDGE FACTOR                                       SDATA
LS       I  C  NUMBER OF ELEMENTS                                        SDATA
M        I  U  DATA READ IN CONTROL FLAG                                 SDATA
MC       I  U  DATA READ IN CONTROL NUMBER                               SDATA
MMIN     I  U  NUMBER OF ELEMENTS IN A COLUMN                            SDATA
N        I  U  COLUMN NUMBER                                             SDATA
NFS      I  U  ELEMENT COUNTER                                           SDATA
NN       I  U  ELEMENT COUNTER                                           SDATA
NN2      I  U  ELEMENT COUNTER                                           SDATA
NPRT     I  U  LINE COUNTER                                              SDATA
NX       R  U  ELEMENT DIRECTION COSINE-X                                SDATA
NX2      R  C  ELEMENT DIRECTION COSINE ARRAY-X                          SDATA
NY       R  U  ELEMENT DIRECTION COSINE-Y                                SDATA
NY2      R  C  ELEMENT DIRECTION COSINE ARRAY-Y                          SDATA
NZ       R  U  ELEMENT DIRECTION COSINE-Z                                SDATA
NZ2      R  C  ELEMENT DIRECTION COSINE ARRAY-Z                          SDATA
PAGE     I  C  PAGE NUMBER                                               SDATA
PD       R  U  CORNER POINT PROJECTION DISTANCE                          SDATA
PRINTS   I  A  ELEMENT DATA PRINT FLAG                                   SDATA
RFLAG    L  U  INPUT DATA READ CONTROL FLAG                              SDATA
SECT     R  U  SECTION IDENTIFICATION                                    SDATA
SECTS    R  U  SECTION IDENTIFICATION                                    SDATA
SEQ      I  U  CARD SEQUENCE NUMBER                                      SDATA
STAT     I  U  COORDINATE POINT STATUS FLAG                              SDATA
STATT    I  U  COORDINATE POINT STATUS FLAG                              SDATA
SYMFCT   I  A  SYMMETRY FLAG                                             SDATA
T        R  U  UNIT VECTOR                                               SDATA
TITLE    R  C  TITLE                                                     SDATA
TYPE     I  U  CARD TYPE NUMBER                                          SDATA
T1X      R  U  X-COMPONENT OF VECTOR T1                                  SDATA
T1Y      R  U  Y-COMPONENT OF VECTOR T1                                  SDATA
T1Z      R  U  Z-COMPONENT OF VECTOR T1                                  SDATA
```

```
SYMBOLS USED IN SUBROUTINE SDATA

T2X      R  U  X-COMPONENT OF VECTOR T2                                  SDATA
T2Y      R  U  Y-COMPONENT OF VECTOR T2                                  SDATA
T2Z      R  U  Z-COMPONENT OF VECTOR T2                                  SDATA
VN       R  U  VECTOR LENGTH                                             SDATA
VOL      R  U  TOTAL VOLUME                                              SDATA
X        R  U  X-COORDINATE                                              SDATA
XA       R  D  X-COORDINATE                                              SDATA
XAVG     R  U  AVERAGE X-COORDINATE                                      SDATA
XB       R  D  X-COORDINATE                                              SDATA
XCENT    R  U  ELEMENT CENTROID COORDINATE-X                             SDATA
XCENT2   R  C  ELEMENT CENTROID COORDINATE ARRAY-X                       SDATA
XDIF     R  U  COORDINATE DIFFERENCE-X                                   SDATA
XI       R  D  COORDINATE IN ELEMENT COORDINATE SYSTEM                   SDATA
XIN      R  D  ELEMENT COORDINATES-X                                     SDATA
XIO      R  U  CENTROID IN ELEMENT COORDINATE SYSTEM                     SDATA
XI3M1    R  U  CONSTANT FOR AREA EQUATION                                SDATA
XLE      R  U  DISTANCE FROM LEADING EDGE TO ELEMENT CENTROID            SDATA
XLEO     R  U  LEADING EDGE X INCREMENT                                  SDATA
XLEP1    R  U  SAVED X-COORDINATE                                        SDATA
XPA      R  D  COORDINATES OF ELEMENT CORNER POINTS, X                   SDATA
XSC      R  U  X SCALE FACTOR                                            SDATA
XX       R  U  X-COORDINATE                                              SDATA
Y        R  U  Y-COORDINATE                                              SDATA
YA       R  D  Y-COORDINATE                                              SDATA
YAVG     R  U  AVERAGE Y COORDINATE                                      SDATA
YB       R  D  Y-COORDINATE                                              SDATA
YCENT    R  U  ELEMENT CENTROID COORDINATE-Y                             SDATA
YCENT2   R  C  ELEMENT CENTROID COORDINATE ARRAY-Y                       SDATA
YDIF     R  U  COORDINATE DIFFERENCE-Y                                   SDATA
YIN      R  D  ELEMENT COORDINATE-Y                                      SDATA
YLEP1    R  U  SAVED Y-COORDINATE                                        SDATA
YPA      R  D  COORDINATES OF ELEMENT CORNER POINTS-Y                    SDATA
YSC      R  U  Y-SCALE FACTOR                                            SDATA
YY       R  U  Y-COORDINATE                                              SDATA
Z        R  U  Z-COORDINATE                                              SDATA
ZA       R  D  Z-COORDINATE                                              SDATA
```

```
SYMBOLS USED IN SUBROUTINE SDATA

ZAVG     R  U  AVERAGE Z COORDINATE                                        SDATA
ZB       R  D  Z-COORDINATE                                                SDATA
ZCENT    R  U  ELEMENT CENTROID COORDINATE-Z                               SDATA
ZCENT2   R  C  ELEMENT CENTROID COORDINATE ARRAY-Z                         SDATA
ZDIF     R  U  COORDINATE DIFFERENCE Z                                     SDATA
ZIN      R  D  ELEMENT COORDINATE-Z                                        SDATA
ZLEP1    R  U  SAVED Z-COORDINATE                                          SDATA
ZPA      R  D  COORDINATES OF ELEMENT CORNER POINTS-Z                      SDATA
ZSC      R  U  Z-SCALE FACTOR                                              SDATA
ZZ       R  U  Z-COORDINATE                                                SDATA
```

5. SUBROUTINE ANALY1 (DECK AROD)

This subprogram prepares surface-element data points for circular or elliptical cross-sections.

a. Algorithm

The Ellipse Generation Control Card (Type 4) is read as are all the Cross-Section Data Cards (Type 5). The input cross-section data are stored in the appropriate arrays. The program then takes each cross-section and calculates the surface element data as directed by the input parameters. This information is stored on Tape 11 and at the appropriate time is transmitted to the PUNCH routine, recording onto the geometry storage tape.

b. Input/Output

Ellipse Generation Control Card (Type 4), and Cross-Section Data Cards (Type 5).
No output data are produced.

c. Error

An error condition occurs when input card type numbers are wrong.

d. Subroutines Required

PUNCH

e. Argument List

None

f. Length

8552 bytes

DECK AROD

```
      SUBROUTINE ANALY1                                                 AROD  0010
C     THIS SUBROUTINE PREPARES THE REQUIRED SURFACE ELEMENTS FOR        AROD  0020
C     CIRCULAR OR ELLIPTICAL ARC SECTIONS.  EACH CROSS-SECTION          AROD  0030
C     IS CONSIDERED SEPARATELY. DUMMY POINTS ARE COMPUTED SO THAT EACH  AROD  0040
C     SECTION IS FORCED TO HAVE AN EVEN NUMBER OF POINTS AND SO THAT    AROD  0050
C     POINTS IN A ROW ARE CORRECTLY MATCHED WITH POINTS IN AN ADJACENT  AROD  0060
C     ROW WHEN THESE ROWS CONTAIN AN UNEQUAL NUMBER OF POINTS.          AROD  0070
C                                                                       AROD  0080
C  THE PARAMETER DISCON WHICH IS SPECIFIED BY THE PROGRAMMER IS VALUED  AROD  0090
C     DEPENDING ON HOW THE POINTS ARE TO BE MATCHED                     AROD  0100
C         DISCON= 1  ALL THETAO AND THETAL ARE THE SAME. DELTHE MUST    AROD  0110
C                    DIVIDE THE ANGULAR INCREMENT THETAL - THETAO       AROD  0120
C                    EVENLY.                                            AROD  0130
C               = 2  ALL THETAL ARE EQUAL BUT THETAO VARIES             AROD  0140
C               = 3  ALL THETAO ARE EQUAL BUT THETAL VARIES             AROD  0150
      DIMENSION TITLE(15),AX(100),THETOX(100),THETLX(100),DELTHX( 100), AROD  0160
     1   NN(100),SECT(1),DELZX(100),DELYX(100),AA(100),BB(100)          AROD  0170
      COMMON CASE,TITLE,PAGE,ERROR                                      AROD  C180
      INTEGER  STAT,STATT,STATD,STATC,ERROR                             AROD  0190
      INTEGER  STATA, STATB,PAGE,SEQ,TYPE,CASE,DISCON                   AROD  0200
      RADD(BBI,AAI,THP) = SQRT(BBI*BBI*COS(THP)*COS(THP) +              AROD  0210
     1                    AAI*AAI*SIN(THP)*SIN(THP) )                   AROD  0220
      WRITE (6,603)                                                     AROD  0230
  603 FORMAT (1H1,/////,1H0,33HELLIPTICAL GEOMETRY DATA IS BEING        AROD  0240
     1 21H GENERATED **********  )                                      AROD  0250
C     SET COUNTERS                                                      AROD  0260
      TYPE = 3                                                          AROD  C270
      NREC = 0                                                          AROD  0280
C  READ IN TITLE CARD                                                   AROD  0290
    1 READ (5,600) (TITLE(L),L=1,12),DISCON,IPRINT,CASE,(SECT(L),L=1,1), AROD  0300
     1          ITYPE                                                   AROD  0310
  600 FORMAT(12A4,11X,2I1,4XI3,1A2,I2)                                  AROD  0320
      IF (ITYPE .NE. 4) GO TO 700                                       AROD  0330
      LINE = 100                                                        AROD  0340
      SEQ  = 1                                                          AROD  0350
```

```
DECK AROD

C  READ IN ALL DATA CARDS FOR THE SECTION                                 AROD  0360
      REWIND 11                                                           AROD  0370
      I = 1                                                               AROD  0380
    4 READ (5,602) X,THETO,THETL,NN(I),A,B,DFLZ,DELY,LAST,ITYPE           AROD  0390
  602 FORMAT (F10.0,2F6.0,I3,2F10.0,2F7.0,I1,10XI2)                       AROD  0400
      IF (ITYPE .NE. 5) GC TO 700                                         AROD  C410
      DELTH = (THETL-THETO)/FLOAT(NN(I))                                  AROD  0420
      THETO  = THETO /57.2957795                                          AROD  0430
      THETL  = THETL /57.2957795                                          AROD  0440
      DELTH  = DELTH /57.2957795                                          AROD  0450
      AX(I) = X                                                           AROD  0460
      THETOX(I) = THETO                                                   AROD  0470
      THETLX(I) = THETL                                                   AROD  0480
      DFLTHX(I) = DELTH                                                   AROD  0490
      AA(I) = A                                                           AROD  0500
      BB(I) = B                                                           AROD  0510
      DELYX(I) = DELY                                                     AROD  0520
      DELZX(I) = DELZ                                                     AROD  0530
      IF (LAST .EQ. 0)  GO TO 2                                           AROD  C540
      N = I                                                               AROD  0550
      GO TO 3                                                             AROD  0560
    2 I = I + 1                                                           AROD  0570
      GO TO 4                                                             AROD  0580
    3 I = 1                                                               AROD  0590
      M = C                                                               AROD  0600
    8 IF (I .GT. N)  GO TO 5                                              AROD  0610
C                                                                         AROD  0620
      IF (NN(I)-M)  6,6,7                                                 AROD  0630
    7 M =NN(I)                                                            AROD  0640
    6 I = I + 1                                                           AROD  0650
      GO TO 8                                                             AROD  0660
C                                                                         AROD  0670
    5 GO TO (10C,2C0,3C0), DISCCN                                         AROD  0680
C                                                                         AROD  C690
  100 M = M + 1                                                           AROD  0700
C                                                                         AROD  0710
```

```
DECK AROD

      DO 101 I=1,N                                                      AROD  0720
C                                                                       AROD  0730
      DO 102 J=1,M                                                      AROD  0740
C                                                                       AROD  0750
      XA = AX(I)                                                        AROD  0760
      THETA = THETOX(I) + (FLOAT(J-1)) * DELTHX(I)                      AROD  0770
      THETAP = ABS(THETA - 1.57079633)                                  AROD  0780
      RAD = RADD(BB(I),AA(I),THETAP)                                    AROD  0790
      IF (RAD .NE. 0.0)  RAD = AA(I)*BB(I) / RAD                        AROD  0800
      YA = RAD * SIN(THETA)                                             AROD  0810
      ZA =-RAD * COS(THETA)                                             AROD  0820
      YA = YA + DELYX(I)                                                AROD  0830
      ZA = ZA + DELZX(I)                                                AROD  0840
C                                                                       AROD  0850
      IF (J .EQ. 1) GO TO 103                                           AROD  0860
      STATA = 0                                                         AROD  0870
      GO TO 105                                                         AROD  0880
C                                                                       AROD  0890
  103 IF (I .EQ. 1) GO TO 104                                           AROD  0900
      STATA = 1                                                         AROD  0910
      GO TO 105                                                         AROD  0920
C                                                                       AROD  0930
  104 STATA = 2                                                         AROD  0940
  105 WRITE (11)XA,YA,ZA,STATA,STATA                                    AROD  0950
  102 CONTINUE                                                          AROD  0960
  101 CONTINUE                                                          AROD  0970
C                                                                       AROD  0980
      GO TO 10                                                          AROD  0990
C                                                                       AROD  1000
C                                                                       AROD  1010
  200 DO 201 I=1,N                                                      AROD  1020
C                                                                       AROD  1030
      LIM = M+1-NN(I)                                                   AROD  1040
C                                                                       AROD  1050
      DO 202 J=1,LIM                                                    AROD  1060
      XA = AX(I)                                                        AROD  1070
```

```
DECK AROD

      THETA = THETDX(I)                                                 AROD  1080
      THETAP = ABS(THETA - 1.57079633)                                  AROD  1090
      RAD = RADD(BB(I),AA(I),THETAP)                                    AROD  1100
      IF (RAD .NE. 0.0)  RAD = AA(I)*BB(I) / RAD                        AROD  1110
      YA = RAD * SIN(THETA)                                             AROD  1120
      ZA =-RAD * COS(THETA)                                             AROD  1130
      YA = YA + DELYX(I)                                                AROD  1140
      ZA = ZA + DELZX(I)                                                AROD  1150
      IF ( J .EQ. 1)  GO TO 203                                         AROD  1160
      STATA = 0                                                         AROD  1170
      GO TO 205                                                         AROD  1180
C                                                                       AROD  1190
  203 IF (I .EQ. 1)  GO TO 204                                          AROD  1200
      STATA = 1                                                         AROD  1210
      GO TO 205                                                         AROD  1220
C                                                                       AROD  1230
  204 STATA = 2                                                         AROD  1240
  205 WRITE (11)XA,YA,ZA,STATA,STATA                                    AROD  1250
C                                                                       AROD  1260
  202 CONTINUE                                                          AROD  1270
      K=0                                                               AROD  1280
      LIM = LIM +1                                                      AROD  1290
      NM =M * 2                                                         AROD  1300
      DO 206  J = LIM,NM                                                AROD  1310
      XA = AX(I)                                                        AROD  1320
      THETA = THETLX(I)-(FLOAT(NN(I)-K))*DELTHX(I)                      AROD  1330
      THETAP = ABS(THETA - 1.57079633)                                  AROD  1340
      RAD = RADD(BB(I),AA(I),THETAP)                                    AROD  1350
      IF (RAD .NE. 0.0)  RAD = AA(I)*BB(I) / RAD                        AROD  1360
      YA = RAD * SIN(THETA)                                             AROD  1370
      ZA =-RAD * COS(THETA)                                             AROD  1380
      YA = YA + DELYX(I)                                                AROD  1390
      ZA = ZA + DELZX(I)                                                AROD  1400
C                                                                       AROD  1410
      IF (J.EQ. 1)  GO TO 207                                           AROD  1420
      STATA = 0                                                         AROD  1430
```

DECK AROD

```
      GO TO 208
C
  207 STATA = 1
C
 208  WRITE (11)XA,YA,ZA,STATA,STATA
      K = K + 1
  206 CONTINUE
C
  201 CONTINUE
      M = M + 2
      GO TO 10
C
  300 M = M +2
      DO 301 I = 1,N
      NM =NN(I) +1
C
      DO 302 J = 1,NM
      XA = AX(I)
      THETA = THETOX(I) + (FLCAT(J-1))*DELTHX(I)
      THETAP = ABS(THETA - 1.57079633)
      RAD = RADD(BB(I),AA(I),THETAP)
      IF (RAD .NE. 0.0)  RAD = AA(I)*BB(I) / RAD
      YA = RAD * SIN(THETA)
      ZA =-RAD * COS(THETA)
      YA = YA + DELYX(I)
      ZA = ZA + DELZX(I)
      IF (J.EQ.1) GO TO 303
      STATA = 0
      GO TO 305
C
  303 IF (I.EQ.1) GO TO 304
      STATA = 1
      GO TO 305
C
  304 STATA = 2
  305 WRITE (11)XA,YA,ZA,STATA,STATA
```

```
DECK AROD
C                                                                       AROD  1800
  302 CONTINUE                                                          AROD  1810
      NM =NM+1                                                          AROD  1820
C                                                                       AROD  1830
      DO 306  J = NM,M                                                  AROD  1840
      XA = AX(I)                                                        AROD  1850
      THETA = THETLX(I)                                                 AROD  1860
      THETAP = ABS(THETA - 1.57079633)                                  AROD  1870
      RAD = RADD(BB(I),AA(I),THETAP)                                    AROD  1880
      IF (RAD .NE. 0.0)  RAD = AA(I)*BB(I) / RAD                        AROD  1890
      YA = RAD * SIN(THETA)                                             AROD  1900
      ZA =-RAD * COS(THETA)                                             AROD  1910
      YA = YA + DELYX(I)                                                AROD  1920
      ZA = ZA + DELZX(I)                                                AROD  1930
      IF (J.EQ.1) GO TO 307                                             AROD  1940
      STATA = 0                                                         AROD  1950
      GO TO 308                                                         AROD  1960
C                                                                       AROD  1970
  307 STATA = 1                                                         AROD  1980
  308 WRITE (11)XA,YA,ZA,STATA,STATA                                    AROD  1990
C                                                                       AROD  2000
  306 CONTINUE                                                          AROD  2010
C                                                                       AROD  2020
  301 CONTINUE                                                          AROD  2030
C                                                                       AROD  2040
C                                                                       AROD  2050
   10 STATA = 3                                                         AROD  2060
      IF (LAST.EQ.0 .OR. LAST.EQ.2) STATA = 4                           AROD  2070
C                                                                       AROD  2080
      BACKSPACE 11                                                      AROD  2090
      READ (11)XA, YA, ZA, STAT,STAT                                    AROD  2100
      BACKSPACE 11                                                      AROD  2110
      WRITE (11)XA, YA, ZA, STATA ,STATA                                AROD  2120
C                                                                       AROD  2130
      REWIND 11                                                         AROD  2140
      K = 1                                                             AROD  2150
```

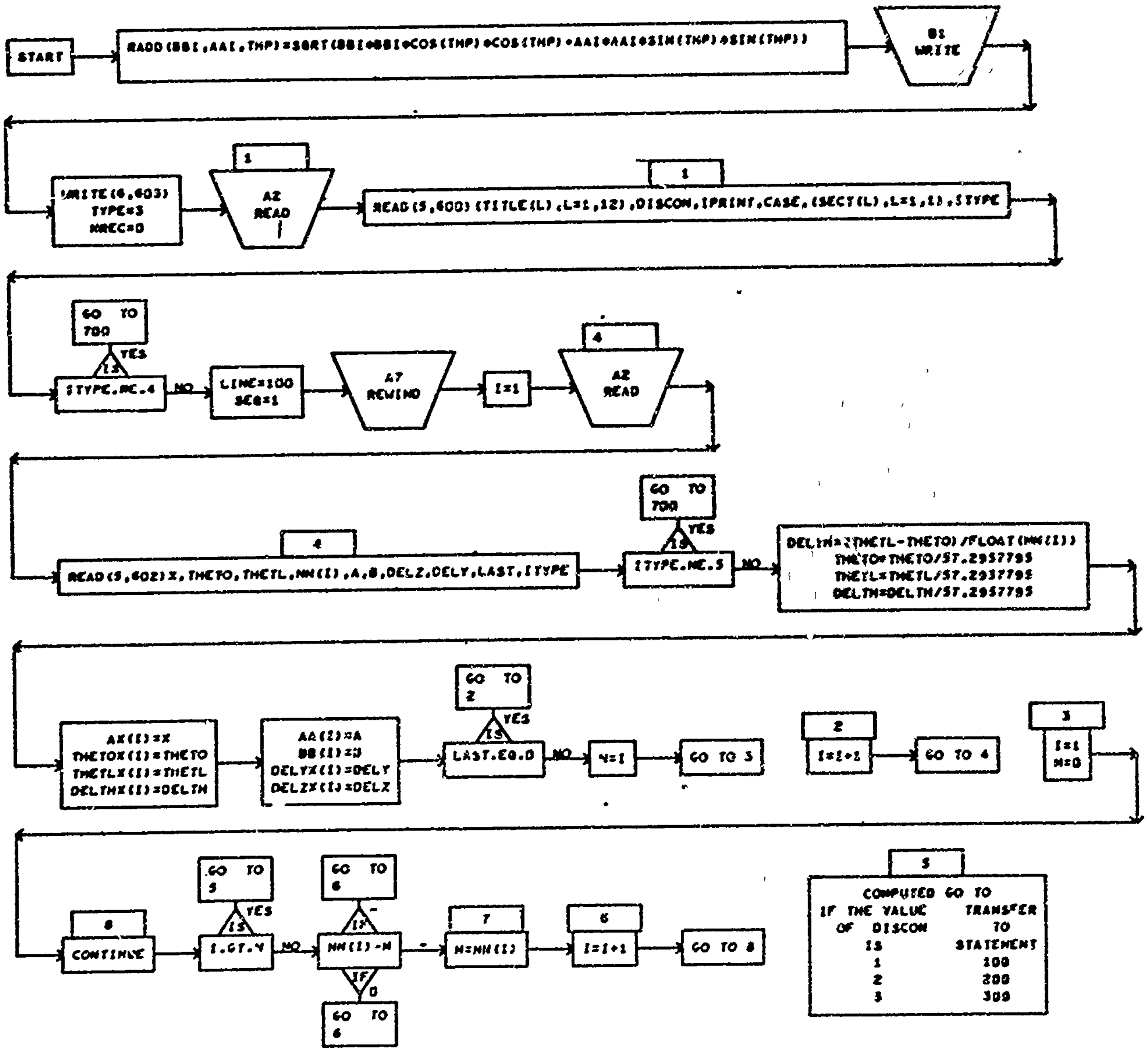
[redacted]

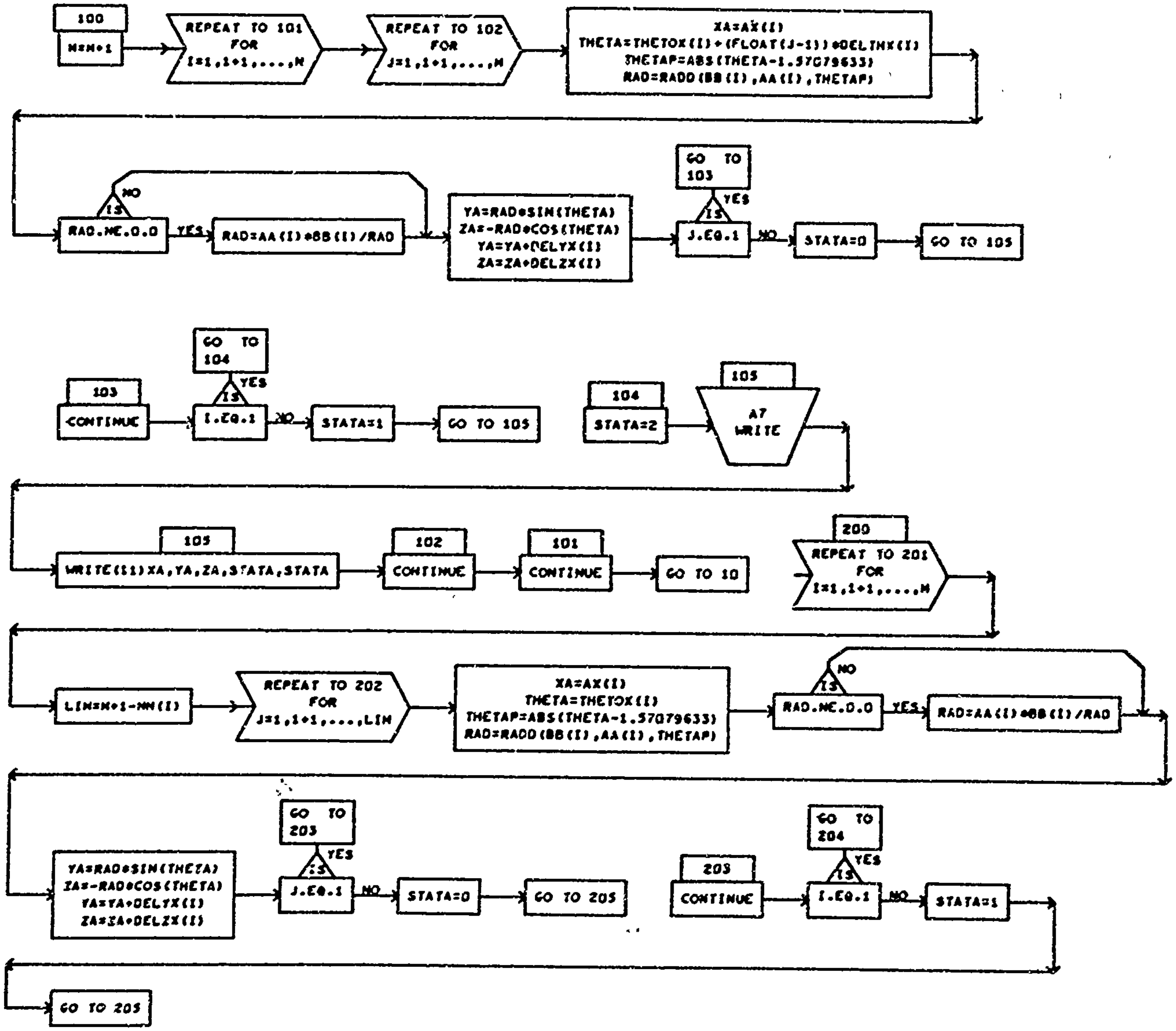
```
DECK AROD
C                                                                        AROD   2160
   15 READ (11) X,Y,Z,STAT,STAT                                          AROD   2170
C                                                                        AROD   2180
      IF ( STAT .GT. 2)     GO TO 13                                     AROD   2190
      READ (11) XX,YY,ZZ,STATT,STATT                                     AROD   2200
C                                                                        AROD   2210
      IF ( STATT .GT. 2)    GO TO 14                                     AROD   2220
C                                                                        AROD   2230
  17  CALL PUNCH (X,Y,Z,STAT,XX,YY,ZZ,STATT,SECT,TYPE,LINE,SEQ,          AROD   2240
     1  LAST,IPRINT,NREC)                                                AROD   2250
C                                                                        AROD   2260
      GO TO (15,1,18), K                                                 AROD   2270
C                                                                        AROD   2280
C                                                                        AROD   2290
   14  IF (STATT.EQ. 3) GO TO 16                                         AROD   2300
      STATT = 0                                                          AROD   2310
      K = 2                                                              AROD   2320
      GO TO 17                                                           AROD   2330
C                                                                        AROD   2340
   16 K = 3                                                              AROD   2350
      GO TO 17                                                           AROD   2360
C                                                                        AROD   2370
C                                                                        AROD   2380
   13 XB = X                                                             AROD   2390
      YB = Y                                                             AROD   2400
      ZB = Z                                                             AROD   2410
      STATB = STAT                                                       AROD   2420
      GO TO 21                                                           AROD   2430
  20  BACKSPACE 11                                                       AROD   2440
   21 BACKSPACE 11                                                       AROD   2450
      READ (11)XA,YA,ZA,STATA ,STATA                                     AROD   2460
      IF (STATA.EQ.1 .OR. STATA.EQ.2) GO TO 22                           AROD   2470
      GO TO 20                                                           AROD   2480
  22  STATC = 0                                                          AROD   2490
      CALL PUNCH (XB,YB,ZB,STATC,XA,YA,ZA,STATA,SECT,TYPE,LINE,SEQ,      AROD   2500
     1     LAST,IPRINT,NREC)                                             AROD   2510
```

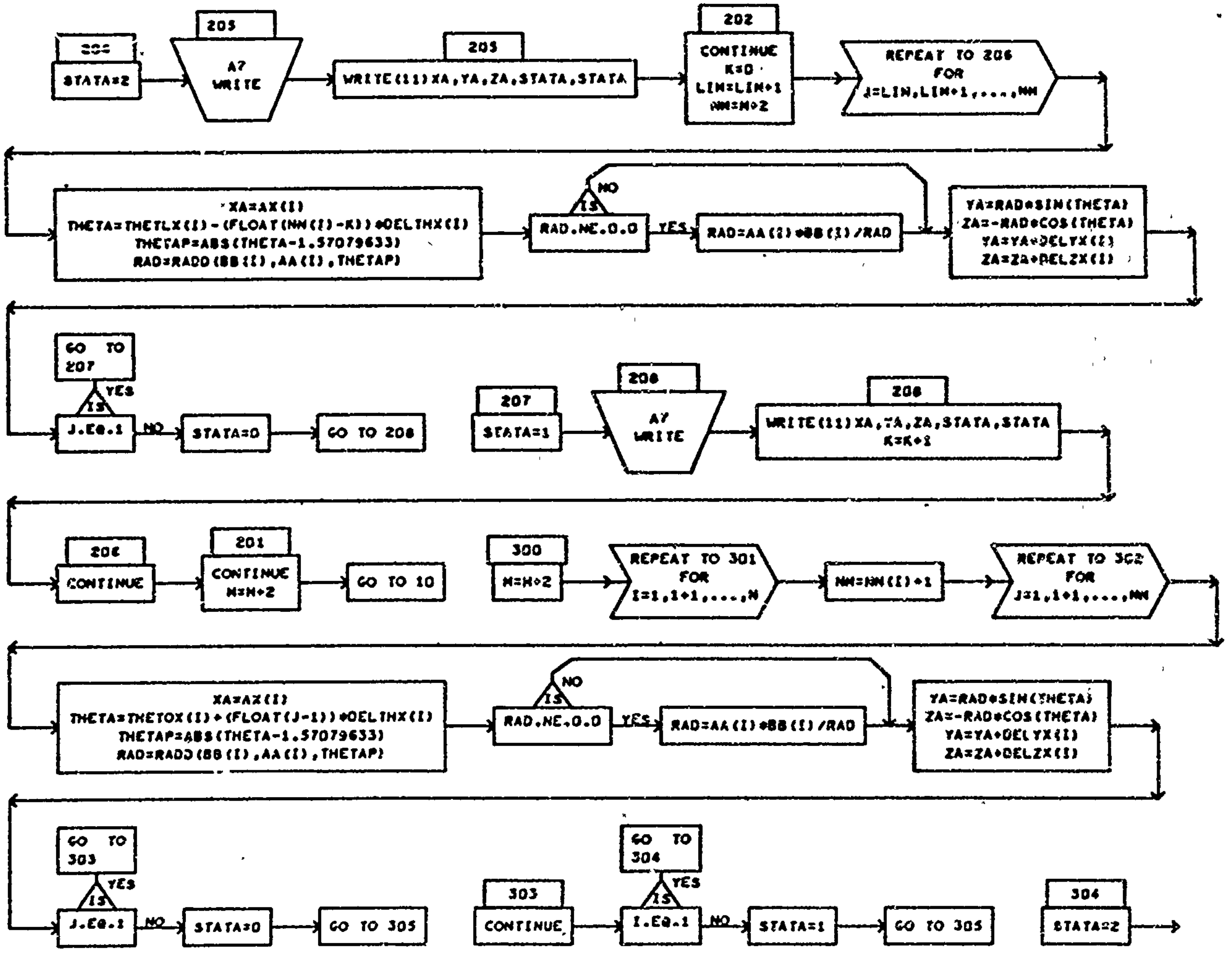
```
DECK AROD

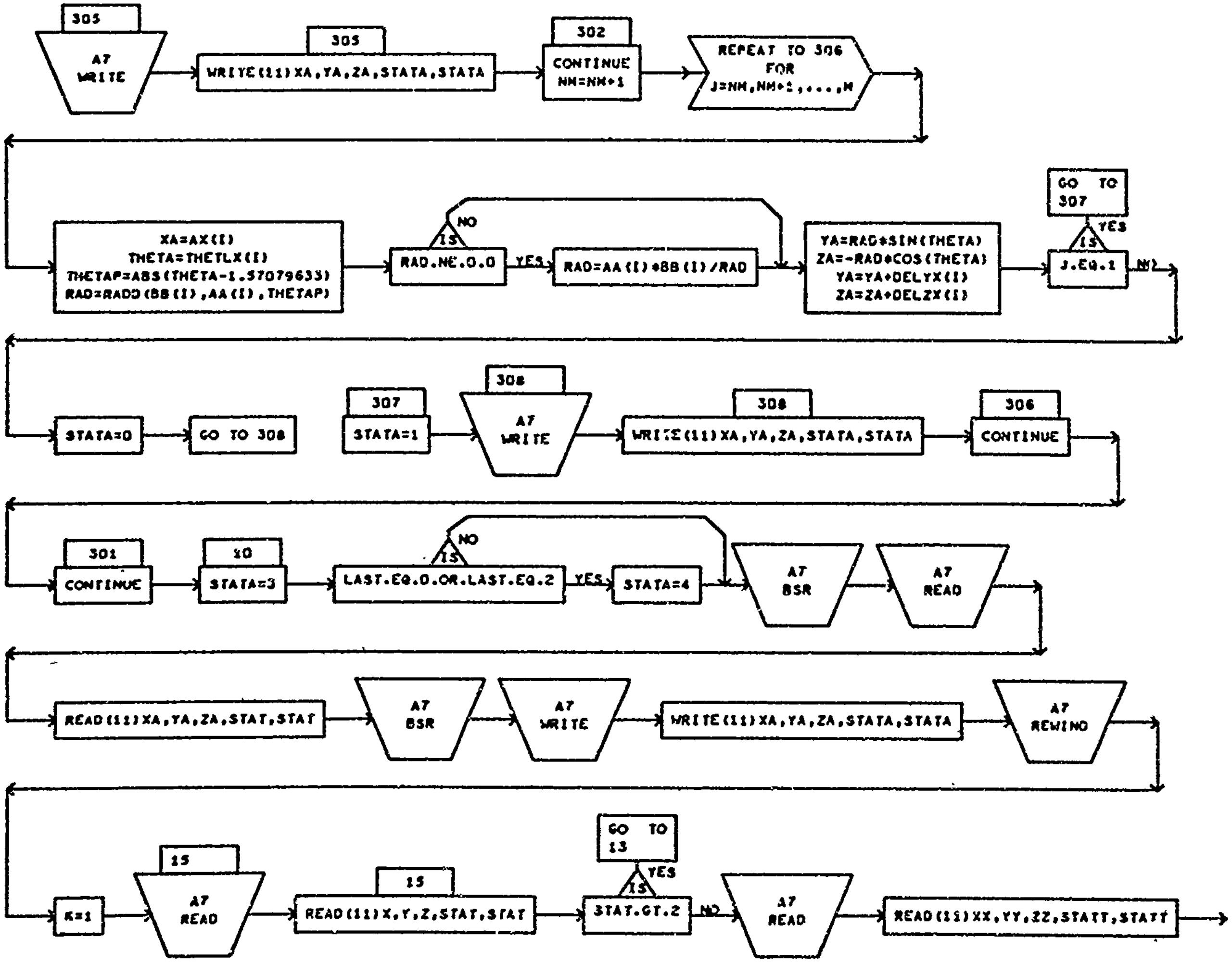
      STATD = 0                                                         AROD  2520
      IF (STAT .EQ. 3)  STATD = 3                                       AROD  2530
      READ (11)XC, YC, ZC, STATT ,STATT                                 AROD  2540
      READ (11) XD, YD, ZD, STATT ,STATT                                AROD  2550
      CALL PUNCH (XC,YC,ZC,STATC,XD,YD,ZD,STATD,SECT,TYPE,LINE,SEQ,     AROD  2560
     1     LAST,IPRINT,NREC)                                            AROD  2570
                                                                        AROD  2580
      IF (STAT .NE. 3)  GO TO 1                                         AROD  2590
C                                                                       AROD  2600
C                                                                       AROD  2610
   18 CONTINUE                                                          AROD  2620
      WRITE (8,500)                                                     AROD  2630
  500 FORMAT (12H**BLANK CARD,68X)                                      AROD  2640
      END FILE 8                                                        AROD  2650
      BACKSPACE 8                                                       AROD  2660
      BACKSPACE 8                                                       AROD  2670
      IF (LAST .NE. 3) GO TO 1000                                       AROD  2680
      DO 23 I=1,NREC                                                    AROD  2690
   23 BACKSPACE 8                                                       AROD  2700
 1000 RETURN                                                            AROD  2710
  700 ERROR = 1                                                         AROD  2720
      RETURN                                                            AROD  2730
      END                                                               AROD  2740
```

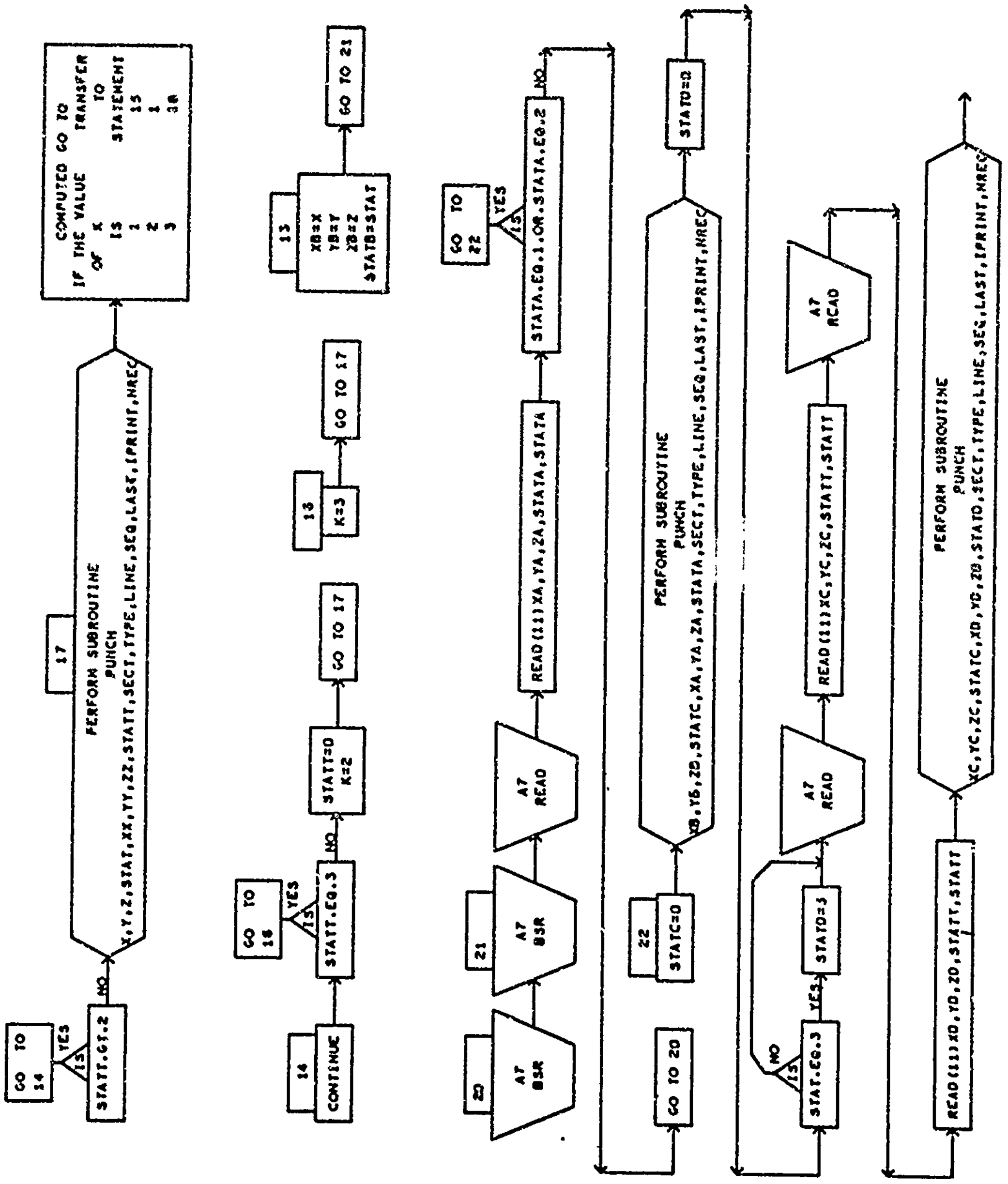
SUBROUTINE ANALYS

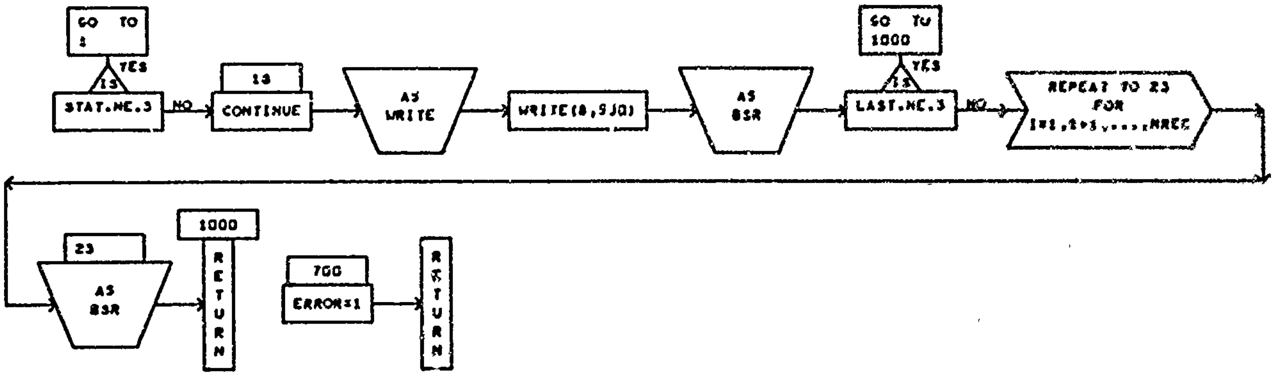



100
N=N+1
REPEAT TO 101 FOR I=1,1+1,...,M
REPEAT TO 102 FOR J=1,1+1,...,M
XA=AX(I)
THETA=THETOX(I)+(FLOAT(J-1))*DELTHX(I)
THETAP=ABS(THETA-1.57079633)
RAD=RADD(BB(I),AA(I),THETAP)
RAD.NE.0.0
IS
NO
YES
RAD=AA(I)*BB(I)/RAD
YA=RAD*SIN(THETA)
ZA=-RAD*COS(THETA)
YA=YA+DELYX(I)
ZA=ZA+DELZX(I)
J.EQ.1
IS
YES
GO TO 103
NO
STATA=0
GO TO 105
103
CONTINUE
I.EQ.1
IS
YES
GO TO 104
NO
STATA=1
GO TO 105
104
STATA=2
105
A7 WRITE
105
WRITE(11)XA,YA,ZA,STATA,STATA
102
CONTINUE
101
CONTINUE
GO TO 10
200
REPEAT TO 201 FOR I=1,1+1,...,M
LIN=N+1-NN(I)
REPEAT TO 202 FOR J=1,1+1,...,LIN
XA=AX(I)
THETA=THETOX(I)
THETAP=ABS(THETA-1.57079633)
RAD=RADD(BB(I),AA(I),THETAP)
RAD.NE.0.0
IS
NO
YES
RAD=AA(I)*BB(I)/RAD
YA=RAD*SIN(THETA)
ZA=-RAD*COS(THETA)
YA=YA+DELYX(I)
ZA=ZA+DELZX(I)
J.EQ.1
IS
YES
GO TO 203
NO
STATA=0
GO TO 205
203
CONTINUE
I.EQ.1
IS
YES
GO TO 204
NO
STATA=1
GO TO 205


STATA=2
205
A7
WRITE
205
WRITE(11)XA,YA,ZA,STATA,STATA
202
CONTINUE
K=0
LIN=LIN+1
NN=N+2
REPEAT TO 206
FOR
J=LIN,LIN+1,....,NN
XA=AX(I)
THETA=THETLX(I)-(FLOAT(NN(I)-K))*DELTHX(I)
THETAP=ABS(THETA-1.57079633)
RAD=RADD(BB(I),AA(I),THETAP)
IS
RAD.NE.0.0
NO
YES
RAD=AA(I)*BB(I)/RAD
YA=RAD*SIN(THETA)
ZA=-RAD*COS(THETA)
YA=YA+DELTX(I)
ZA=ZA+DELZX(I)
GO TO
207
YES
IS
J.EQ.1
NO
STATA=0
GO TO 208
207
STATA=1
208
A7
WRITE
208
WRITE(11)XA,YA,ZA,STATA,STATA
K=K+1
206
CONTINUE
201
CONTINUE
N=N+2
GO TO 10
300
N=N+2
REPEAT TO 301
FOR
I=1,1+1,....,N
NN=NN(I)+1
REPEAT TO 302
FOR
J=1,1+1,....,NN
XA=AX(I)
THETA=THETOX(I)+(FLOAT(J-1))*DELTHX(I)
THETAP=ABS(THETA-1.57079633)
RAD=RADD(BB(I),AA(I),THETAP)
IS
RAD.NE.0.0
NO
YES
RAD=AA(I)*BB(I)/RAD
YA=RAD*SIN(THETA)
ZA=-RAD*COS(THETA)
YA=YA+DELTX(I)
ZA=ZA+DELZX(I)
GO TO
303
YES
IS
J.EQ.1
NO
STATA=0
GO TO 305
303
CONTINUE
GO TO
304
YES
IS
I.EQ.1
NO
STATA=1
GO TO 305
304
STATA=2


305
A7 WRITE
305
WRITE(11)XA,YA,ZA,STATA,STATA
302
CONTINUE NM=NM+1
REPEAT TO 306 FOR J=NM,NM+1,....,M
XA=AX(I)
THETA=THETLX(I)
THETAP=ABS(THETA-1.57079633)
RAD=RADD(BB(I),AA(I),THETAP)
IS RAD.NE.0.0
NO
YES
RAD=AA(I)*BB(I)/RAD
YA=RAD*SIN(THETA)
ZA=-RAD*COS(THETA)
YA=YA+DELYX(I)
ZA=ZA+DELZX(I)
IS J.EQ.1
YES
GO TO 307
NO
STATA=0
GO TO 308
307
STATA=1
308
A7 WRITE
308
WRITE(11)XA,YA,ZA,STATA,STATA
306
CONTINUE
301
CONTINUE
10
STATA=3
IS LAST.EQ.0.OR.LAST.EQ.2
NO
YES
STATA=4
A7 BSR
A7 READ
READ(11)XA,YA,ZA,STAT,STAT
A7 BSR
A7 WRITE
WRITE(11)XA,YA,ZA,STATA,STATA
A7 REWIND
K=1
15
A7 READ
15
READ(11)X,Y,Z,STAT,STAT
IS STAT.GT.2
YES
GO TO 13
NO
A7 READ
READ(11)XX,YY,ZZ,STATT,STATT


GO TO 14
15
YES
STATT.GT.2
NO
17
PERFORM SUBROUTINE PUNCH
X,Y,Z,STAT,XX,YY,ZZ,STATT,SECT,TYPE,LINE,SEQ,LAST,IPRINT,NREC
COMPUTED GO TO
IF THE VALUE OF K IS
1
2
3
TRANSFER TO STATEMENT
13
1
18
14
CONTINUE
GO TO 18
15
YES
STATT.EQ.3
NO
STATT=0
K=2
GO TO 17
18
K=3
GO TO 17
13
XB=X
YB=Y
ZB=Z
STATB=STAT
GO TO 21
20
A7 BSR
21
A7 BSR
A7 READ
READ (11) XA,YA,ZA,STATA,STATA
GO TO 22
15
YES
STATA.EQ.1.OR.STATA.EQ.2
NO
GO TO 20
22
STATC=0
PERFORM SUBROUTINE PUNCH
XB,YB,ZB,STATC,XA,YA,ZA,STATA,SECT,TYPE,LINE,SEQ,LAST,IPRINT,NREC
STATD=0
NO
15
STAT.EQ.3
YES
STATD=3
A7 READ
READ (11) XC,YC,ZC,STATT,STATT
A7 READ
READ (11) XD,YD,ZD,STATT,STATT
PERFORM SUBROUTINE PUNCH
XC,YC,ZC,STATC,XD,YD,ZD,STATD,SECT,TYPE,LINE,SEQ,LAST,IPRINT,NREC


GO TO 1
YES
IS
STAT.NE.3
NO
13
CONTINUE
AS WRITE
WRITE(8,SJ0)
AS BSR
GO TO 1000
YES
IS
LAST.NE.3
NO
REPEAT TO 23 FOR I=1,2,3,...,NREC
23
AS BSR
1000
RETURN
700
ERROR=1
RETURN

```
SYMBOLS USED IN SUBROUTINE ANALY1

A        R  U  ELLIPSE RADIUS IN Y-DIRECTION                                   ANALY1
AA       R  D  Y-DIRECTION ELLIPSE RADIUS ARRAY                                ANALY1
AX       R  D  X-STATION ARRAY                                                 ANALY1
B        R  U  ELLIPSE RADIUS IN Z-DIRECTION                                   ANALY1
BB       R  D  Z-DIRECTION ELLIPSE RADIUS ARRAY                                ANALY1
CASE     I  C  CASE NUMBER                                                     ANALY1
DELTH    R  U  THETA ANGULAR INCREMENT                                         ANALY1
DELTHX   R  D  THETA ANGULAR INCREMENT ARRAY                                   ANALY1
DELY     R  U  Y-SHIFT INCREMENT FOR ELLIPSE DATA                              ANALY1
DELYX    R  D  Y-SHIFT INCREMENT ARRAY                                         ANALY1
DELZ     R  U  Z-SHIFT INCREMENT FOR ELLIPSE DATA                              ANALY1
DELZX    R  D  Z-SHIFT INCREMENT ARRAY                                         ANALY1
DISCON   I  U  ANGULAR MODE CONTROL FLAG                                       ANALY1
ERROR    I  C  ERROR FLAG                                                      ANALY1
I        I  U  SECTION INDEX NUMBER                                            ANALY1
IPRINT   I  U  PRINT FLAG                                                      ANALY1
ITYPE    I  U  CARD TYPE                                                       ANALY1
J        I  U  ANGULAR INCREMENT COUNTER                                       ANALY1
K        I  U  CARD WRITE CYCLE FLAG                                           ANALY1
LAST     I  U  LAST CROSS-SECTION FLAG                                         ANALY1
LIM      I  U  ANGULAR LIMIT FLAG                                              ANALY1
LINE     I  U  LINE COUNTER                                                    ANALY1
M        I  U  COUNTER                                                         ANALY1
N        I  U  COUNTER                                                         ANALY1
NM       I  U  COUNTER                                                         ANALY1
NN       I  D  COUNTER                                                         ANALY1
NREC     I  U  TAPE 8 RECORD COUNTER                                           ANALY1
PAGE     I  C  PAGE NUMBER                                                     ANALY1
RAD      R  U  ELLIPSE RADIUS                                                  ANALY1
SECT     R  D  SECTION IDENTIFICATION                                          ANALY1
SEQ      I  U  CARD SEQUENCE NUMBER                                            ANALY1
STAT     I  U  POINT STATUS FLAG                                               ANALY1
STATA    I  U  POINT STATUS FLAG                                               ANALY1
STATB    I  U  POINT STATUS FLAG                                               ANALY1
STATC    I  U  POINT STATUS FLAG                                               ANALY1
STATD    I  U  POINT STATUS FLAG                                               ANALY1
```

```
SYMBOLS USED IN SUBROUTINE ANALY1

STATT    I  U  POINT STATUS FLAG                                      ANALY1
THETA    R  U  ANGULAR POSITION                                       ANALY1
THETAP   R  U  ANGULAR POSITION                                       ANALY1
THETL    R  U  LAST THETA ANGLE                                       ANALY1
THETLX   R  D  LAST THETA ANGLE ARRAY                                 ANALY1
THETO    R  U  INITIAL THETA                                          ANALY1
THETOX   R  D  INITIAL THETA ANGLE ARRAY                              ANALY1
TITLE    R  C  TITLE                                                  ANALY1
TYPE     I  U  CARD TYPE FOR GEOMETRY DATA =3                         ANALY1
X        R  U  X-COORDINATE                                           ANALY1
XA       R  U  X-COORDINATE                                           ANALY1
XB       R  U  X-COORDINATE                                           ANALY1
XC       R  U  X-COORDINATE                                           ANALY1
XD       R  U  X-COORDINATE                                           ANALY1
XX       R  U  X-COORDINATE                                           ANALY1
Y        R  U  Y-COORDINATE                                           ANALY1
YA       R  U  Y-COORDINATE                                           ANALY1
YB       R  U  Y-COORDINATE                                           ANALY1
YC       R  U  Y-COORDINATE                                           ANALY1
YD       R  U  Y-COORDINATE                                           ANALY1
YY       R  U  Y-COORDINATE                                           ANALY1
Z        R  U  Z-COORDINATE                                           ANALY1
ZA       R  U  Z-COORDINATE                                           ANALY1
ZB       R  U  Z-COORDINATE                                           ANALY1
ZC       R  U  Z-COORDINATE                                           ANALY1
ZD       R  U  Z-COORDINATE                                           ANALY1
ZZ       R  U  Z-COORDINATE                                           ANALY1
```

6. SUBROUTINE ANALY2 (DECK AROE)

This routine prepares surface element data from parametric cubic boundary patch data.

a. Algorithm

The routine first reads in the Parametric Cubic Title Card (Type 6). The boundary curve data for a patch is then read in (Type 7 cards). A maximum of 20 points per boundary are permitted. The boundary curve coordinate arrays are set up and the arc length along each boundary calculated. The tangent vectors at the corner points and the related end-point derivatives are calculated. The constants for the boundary curve equations are then determined. The routine then starts a cycle to generate element data points on the surface of the patch. This requires the determination of the blending functions, the related points on the boundary curves, and finally, the solution of the surface equation. The element data are transmitted to the PUNCH routine where they are recorded onto Tape 8.

b. Input/Output

Parametric Cubic Title Card (Type 6), Parametric Cubic Boundary Data Cards (Type 7).
No output data are produced.

c. Error

An error condition occurs when input card type numbers are wrong.

d. Subroutines Required

PUNCH

e. Argument List

None

f. Length

6688 bytes

```
DECK AROE

      SUBROUTINE ANALY2                                                 AROE  0010
C THIS SUBPROGRAM CALCULATES THE QUADRILATERAL DATA FOR A SURFACE GIVFN AROE  0020
C BY THE COONS MIT SURFACE FIT TECHNIQUE.                               AROE  0030
C                                                                       AROE  0040
      DIMENSION XA(20),XB(20),YA(20),YB(20),ZA(20),ZB(20),XB1(4,20),YB1(AROE  0050
     14,20),ZB1(4,20),NPTS(4),D(4,9),TITLE(15),SECT(1)                  AROE  0060
      COMMON CASE,TITLE,PAGE,ERROR                                      AROE  0070
      REAL L21,L31,L32,L1,M1,N1,L2,M2,N2,LN,MN,NN                       AROE  0080
      INTEGER STAT,STATT,TYPE,SEQ,CASE,PAGF,ERROR                       AROE  0090
      WRITE (6,200)                                                     AROE  0100
  200 FORMAT (1H1,///////,1H0,33HPARAMETRIC CUBIC GEOMETRY DATA IS      AROE  0110
     1     24H BEING GENERATED *******  )                               AROE  0120
C                                                                       AROE  0130
C                                                                       AROE  0140
      TYPE=3                                                            AROE  0150
      SEQ=1                                                             AROE  0160
      LINE=100                                                          AROE  0170
      NREC=0                                                            AROE  0180
C                                                                       AROE  0190
C *******RFAD IN BOUNDARY CURVE DATA                                    AROE  0200
C     SET UP STARTING CONSTANTS                                         AROE  0210
C                                                                       AROE  0220
  100 CONTINUE                                                          AROE  0230
      N=-1                                                              AROE  0240
      L=C                                                               AROE  0250
    1 II=1                                                              AROE  0260
      ITRUE=0                                                           AROE  0270
      IFALSE=1                                                          AROE  0280
      READ (5,96)(TITLE(K),K=1,12),NCU,NOW,LAST,ISOVR,IPRINT,CASE,      AROE  0290
     1     (SECT(K),K=1,1),ITYPE                                        AROE  0300
   96 FORMAT(12A4,1X,I3,1X,I3,3X,3I1,3XI3,1A2,I2)                       AROE  0310
      IF (ITYPE .NE. 6) GC TO 51                                        AROE  0320
C                                                                       AROE  0330
C     READ IN BOUNDARY CURVE DATA                                       AROE  0340
C                                                                       AROE  0350
```

DECK AROE

```
   29 CONTINUE                                                     AROE 0360
      READ (5,61)X,Y,Z,ISTAT,XX,YY,ZZ,ISTATT,ITYPE                 AROE 0370
   61 FORMAT(3F10.4,I1,3F10.4,I1,8XI2)                             AROE 0380
      IF (ITYPE .NE. 7) GO TO 51                                   AROE 0390
      IRFLAG=IFALSE                                                AROE 0400
      GO TO 80                                                     AROE 0410
   30 IF(IRFLAG)10,50,10                                           AROE 0420
   10 IRFLAG=ITRUE                                                 AROE 0430
      X=XX                                                         AROE 0440
      Y=YY                                                         AROE 0450
      Z=ZZ                                                         AROE 0460
      ISTAT=ISTATT                                                 AROE 0470
      GO TO 60                                                     AROE 0480
   50 IRFLAG=IFALSE                                                AROE 0490
      READ (5,61)X,Y,Z,ISTAT,XX,YY,ZZ,ISTATT,ITYPE                 AROE 0500
      IF (ITYPE .NE. 7) GO TO 51                                   AROE 0510
   60 IF(ISTAT)11,180,11                                           AROE 0520
   11 IF(ISTAT-3)12,180,12                                         AROE 0530
   12 IF(ISTAT-2)70,199,70                                         AROE 0540
   70 IF(IAFLAG-1)13,199,13                                        AROE 0550
   13 MC=M                                                         AROE 0560
   80 M=1                                                          AROE 0570
      IF(ISTAT-2)14,150,14                                         AROE 0580
   14 IF(IBFLAG-1)75,84,75                                         AROE 0590
   75 DO 81 J=1,MC                                                 AROE 0600
      XA(J)=XB(J)                                                  AROE 0610
      YA(J)=YB(J)                                                  AROE 0620
   81 ZA(J)=ZB(J)                                                  AROE 0630
   83 XB(1)=X                                                      AROE 0640
      YB(1)=Y                                                      AROE 0650
      ZB(1)=Z                                                      AROE 0660
      GO TO 30                                                     AROE 0670
   84 IF(IAFLAG)15,85,15                                           AROE 0680
   15 IBFLAG=0                                                     AROE 0690
      GO TO 75                                                     AROE 0700
   85 IAFLAG=1                                                     AROE 0710
```

```
DECK AROE

      GO TO 83                                                          AROE 0720
  150 IAFLAG=0                                                          AROE 0730
      IBFLAG=1                                                          AROE 0740
      N=N+1                                                             AROE 0750
  160 XA(M)=X                                                           AROE 0760
      YA(M)=Y                                                           AROE 0770
      ZA(M)=Z                                                           AROE 0780
      GO TO 30                                                          AROE 0790
  180 M=M+1                                                             AROE 0800
      IF(IAFLAG)16,160,16                                               AROE 0810
   16 XB(M)=X                                                           AROE 0820
      YB(M)=Y                                                           AROE 0830
      ZB(M)=Z                                                           AROE 0840
      IF(ISTAT-3)30,199,30                                              AROE 0850
 199  ML=MC                                                             AROE 0860
      MC=M                                                              AROE 0870
  198 N=N+1                                                             AROE 0880
C                                                                       AROE 0890
C  SET UP BOUNDARY CURVE COORDINATE ARRAYS                              AROE 0900
  157 CONTINUE                                                          AROE 0910
      IF(II-1)40,40,41                                                  AROE 0920
   40 DO 42 I=1,ML                                                      AROE 0930
      XB1(II,I)=XA(I)                                                   AROE 0940
      YB1(II,I)=YA(I)                                                   AROE 0950
   42 ZB1(II,I)=ZA(I)                                                   AROE 0960
      NPTS(II)=ML                                                       AROE 0970
   41 II=II+1                                                           AROE 0980
      DO 43 I=1,MC                                                      AROE 0990
      XB1(II,I)=XB(I)                                                   AROE 1000
      YB1(II,I)=YB(I)                                                   AROE 1010
   43 ZB1(II,I)=ZB(I)                                                   AROE 1020
      NPTS(II)=MC                                                       AROE 1030
      IF(II-4)80,18,18                                                  AROE 1040
   18 CONTINUE                                                          AROE 1050
      IF(ISTAT-3)1,19,19                                                AROE 1060
   19 CONTINUE                                                          AROE 1070
```

```
DECK AROE

C                                                                       AROE  1080
C                                                                       AROE  1090
C *******CALCULATE BOUNDARY CURVE CONSTANTS                              AROE  1100
C  CALCULATE ARC LENGTH S ON BOUNDARY                                   AROE  1110
      NB=1                                                              AROE  1120
   22 S=0.0                                                             AROE  1130
      K=NPTS(NB)-2                                                      AROE  1140
      DO 6 I=2,K                                                        AROE  1150
    6 0S=S+SQRT((XB1(NB,I+1)-XB1(NB,I))**2+(YB1(NB,I+1)-YB1(NB,I))**2+(ZB AROE  1160
     41(NB,I+1)-ZB1(NB,I))**2)                                          AROE  1170
C  CALCULATE TANGENT VECTORS AT THE START OF THE BOUNDARY              AROE  1180
      IFLAG1=0                                                          AROE  1190
      J1=1                                                              AROE  1200
      J2=2                                                              AROE  1210
      J3=3                                                              AROE  1220
   25 X2X1=XB1(NB,J2)-XB1(NB,J1)                                        AROE  1230
      X3X1=XB1(NB,J3)-XB1(NB,J1)                                        AROE  1240
      X3X2=XB1(NB,J3)-XB1(NB,J2)                                        AROE  1250
      Y2Y1=YB1(NB,J2)-YB1(NB,J1)                                        AROE  1260
      Y3Y1=YB1(NB,J3)-YB1(NB,J1)                                        AROE  1270
      Y3Y2=YB1(NB,J3)-YB1(NB,J2)                                        AROE  1280
      Z2Z1=ZB1(NB,J2)-ZB1(NB,J1)                                        AROE  1290
      Z3Z1=ZB1(NB,J3)-ZB1(NB,J1)                                        AROE  1300
      Z3Z2=ZB1(NB,J3)-ZB1(NB,J2)                                        AROE  1310
      L21=SQRT(X2X1*X2X1+Y2Y1*Y2Y1+Z2Z1*Z2Z1)                           AROE  1320
      L31=SQRT(X3X1*X3X1+Y3Y1*Y3Y1+Z3Z1*Z3Z1)                           AROE  1330
      L32=SQRT(X3X2*X3X2+Y3Y2*Y3Y2+Z3Z2*Z3Z2)                           AROE  1340
      L1=X3X1/L31                                                       AROE  1350
      M1=Y3Y1/L31                                                       AROE  1360
      N1=Z3Z1/L31                                                       AROE  1370
      L2=X2X1/L21                                                       AROE  1380
      M2=Y2Y1/L21                                                       AROE  1390
      N2=Z2Z1/L21                                                       AROE  1400
      LN=-(N1*(L1*N2-L2*N1)+M1*(L1*M2-L2*M1))                           AROE  1410
      MN=-(N1*(M1*N2-M2*N1)+L1*(L1*M2-L2*M1))                           AROE  1420
      NN=M1*(M1*N2-M2*N1)+L1*(L1*N2-L2*N1)                              AROE  1430
```

DECK AROE

```
      COSEP1=(X2X1*X3X1+Y2Y1*Y3Y1+Z2Z1*Z3Z1)/(L21*L31)
      IF(COSEP1-0.999999)32,32,31
   31 EPS1=0.0
      GO TO 35
   32 IF(COSEP1+0.999999)33,34,34
   33 EPS1=0.0
      GO TO 35
   34 EPS1=ARCOS(COSEP1)
   35 COSEP2=(X3X2*X3X1+Y3Y2*Y3Y1+Z3Z2*Z3Z1)/(L32*L31)
      IF(COSEP2-0.999999)37,37,36
   36 EPS2=0.0
      GO TO 44
   37 IF(COSEP2+0.999999)38,39,39
   38 EPS2=0.0
      GO TO 44
   39 EPS2=ARCOS(COSEP2)
   44 DELTA=EPS1+EPS2
      TX=L1*COS(DELTA)+LN*SIN(DELTA)
      TY=M1*COS(DELTA)+MN*SIN(DELTA)
      TZ=N1*COS(DELTA)+MN*SIN(DELTA)
C
C  CALCULATE END POINT DERIVATIVES
      IF(IFLAG1)23,23,24
   23 X1V00=TX*S
      Y1V00=TY*S
      Z1V00=TZ*S
      J1=NPTS(NB)-2
      J2=NPTS(NB)-1
      J3=NPTS(NB)
      IFLAG1=1
      GO TO 25
   24 X1V01=TX*S
      Y1V01=TY*S
      Z1V01=TZ*S
C
C
```

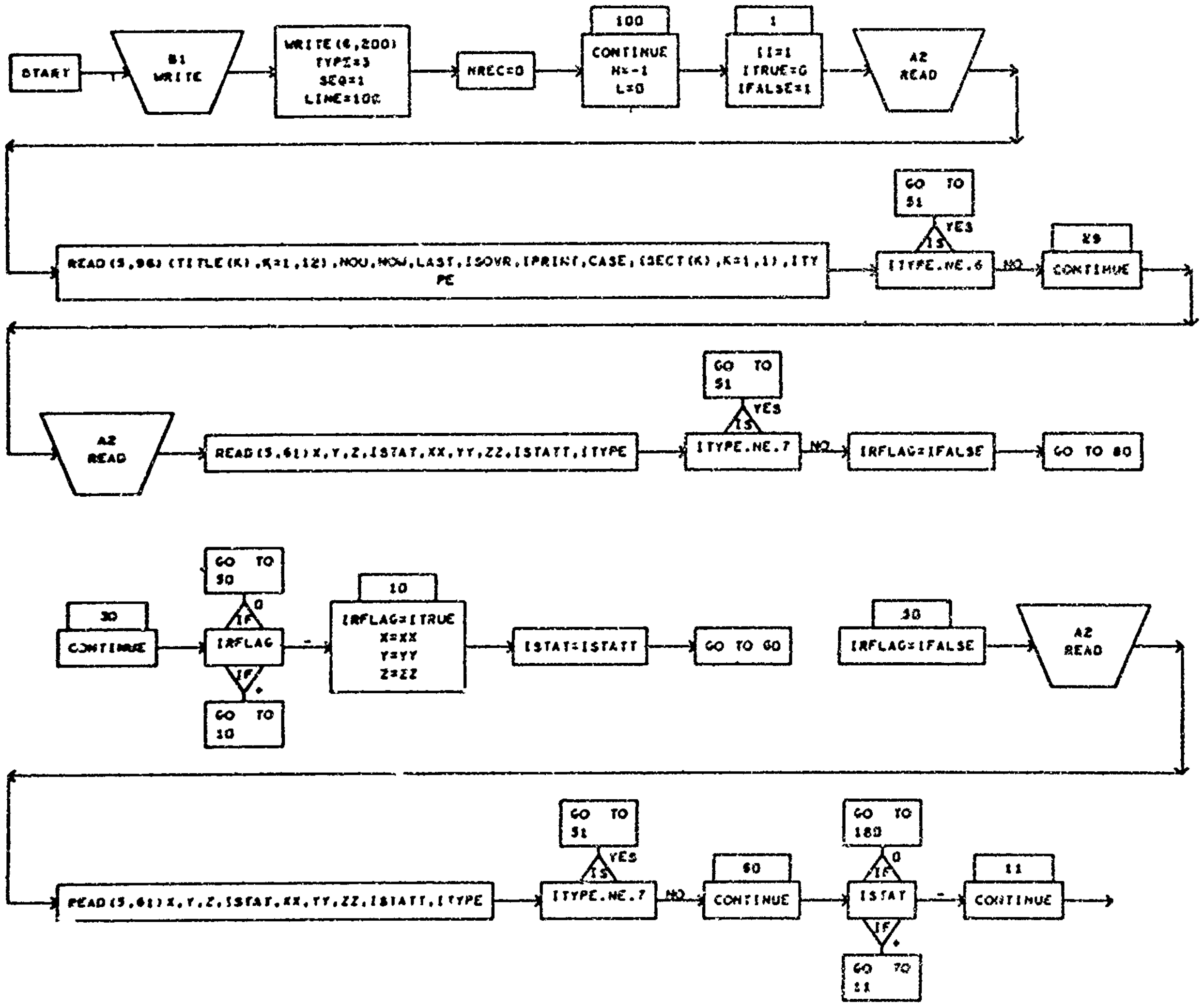
```
DECK AROE
C *********CALCULATE CONSTANTS FOR BCUNDARY CURVE                       AROE  1800
      D(NB,1)=2.0*(XB1(NB,2)-XB1(NB,J2))+X1V00+X1V01                    AROE  1810
      D(NB,2)=3.0*(XB1(NB,J2)-XB1(NB,2))-2.0*X1V00-X1V01                AROE  1820
      D(NB,3)=X1V00                                                     AROE  1830
      D(NB,4)=2.0*(YB1(NB,2)-YB1(NB,J2))+Y1V00+Y1V01                    AROE  1840
      D(NB,5)=3.0*(YB1(NB,J2)-YB1(NB,2))-2.0*Y1V00-Y1V01                AROE  1850
      D(NB,6)=Y1V00                                                     AROE  1860
      D(NB,7)=2.0*(ZB1(NB,2)-ZB1(NB,J2))+Z1V00+Z1V01                    AROE  1870
      D(NB,8)=3.0*(ZB1(NB,J2)-ZB1(NB,2))-2.0*Z1V00-Z1V01                AROE  1880
      D(NB,9)=Z1V00                                                     AROE  1890
      NB=NB+1                                                           AROE  1900
      IF(NB-4)22,22,26                                                  AROE  1910
C                                                                       AROE  1920
C *********CALCULATE PATCH DATA                                         AROE  1930
   26 NOW=NOW/2*2+1                                                     AROE  1940
      DELU=1.0/FLOAT(NOU)                                               AROE  1950
      DELW=1.0/FLOAT(NOW)                                               AROE  1960
      NOU=NOU+1                                                         AROE  1970
      NOW=NOW+1                                                         AROE  1980
      STATT=0                                                           AROE  1990
      U=0.0                                                             AROE  2000
C                                                                       AROE  2010
      DO 95 I=1,NOU                                                     AROE  2020
      STAT=1                                                            AROE  2030
      INU=0                                                             AROE  2040
      W=0.0                                                             AROE  2050
C                                                                       AROE  2060
      DO 93 K=1,NOW                                                     AROE  2070
C                                                                       AROE  2080
C                                                                       AROE  2090
      W3=W**3                                                           AROE  2100
      W2=W**2                                                           AROE  2110
      U3=U**3                                                           AROE  2120
      U2=U**2                                                           AROE  2130
C  CALCULATE BLENDING FUNCTIONS                                         AROE  2140
      F1U=3.0*U2-2.0*U3                                                 AROE  2150
```

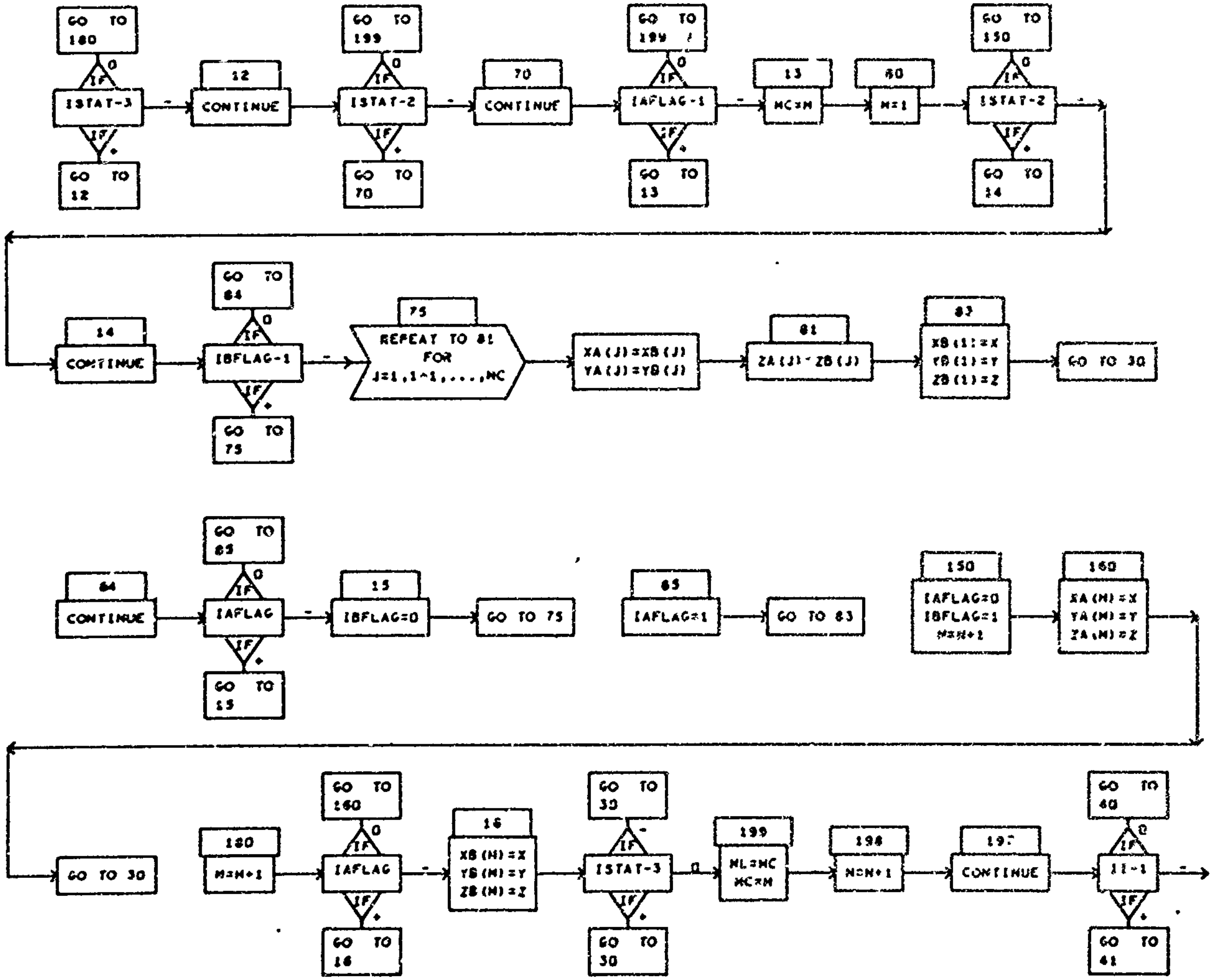
```
DECK AROE
      FOU=1.0-3.0*U2+2.0*U3                                             AROE  2160
      F1W=3.0*W2-2.0*W3                                                 AROE  2170
      FOW=1.0-3.0*W2+2.0*W3                                             AROE  2180
C                                                                       AROE  2190
C  CALCULATE POINTS ON BOUNDARY CURVES                                  AROE  2200
      XOW=D(1,1)*W3+D(1,2)*W2+D(1,3)*W+XB1(1,2)                         AROE  2210
      YOW=D(1,4)*W3+D(1,5)*W2+D(1,6)*W+YB1(1,2)                         AROE  2220
      ZOW=D(1,7)*W3+D(1,8)*W2+D(1,9)*W+ZB1(1,2)                         AROE  2230
      X1W=D(2,1)*W3+D(2,2)*W2+D(2,3)*W+XB1(2,2)                         AROE  2240
      Y1W=D(2,4)*W3+D(2,5)*W2+D(2,6)*W+YB1(2,2)                         AROE  2250
      Z1W=D(2,7)*W3+D(2,8)*W2+D(2,9)*W+ZB1(2,2)                         AROE  2260
      XUO=D(3,1)*U3+D(3,2)*U2+D(3,3)*U+XB1(3,2)                         AROE  2270
      YUO=D(3,4)*U3+D(3,5)*U2+D(3,6)*U+YB1(3,2)                         AROE  2280
      ZUO=D(3,7)*U3+D(3,8)*U2+D(3,9)*U+ZB1(3,2)                         AROE  2290
      XU1=D(4,1)*U3+D(4,2)*U2+D(4,3)*U+XB1(4,2)                         AROE  2300
      YU1=D(4,4)*U3+D(4,5)*U2+D(4,6)*U+YB1(4,2)                         AROE  2310
      ZU1=D(4,7)*U3+D(4,8)*U2+D(4,9)*U+ZB1(4,2)                         AROE  2320
      NPT1=NPTS(1)-1                                                    AROE  2330
      NPT2=NPTS(2)-1                                                    AROE  2340
C                                                                       AROE  2350
C  CALCULATE POSITION OF A POINT ON THE SURFACE                         AROE  2360
     OXS = XOW*FOU+X1W*F1U+XUO*FOW+XU1*F1W-XB1(1,2)*FOU*FOW-XB1(1,NPT1)* AROE  2370
     4  FOU*F1W-XB1(2,2)*F1U*FOW-XB1(2,NPT2)*F1U*F1W                    AROE  2380
     OYS = YOW*FOU+Y1W*F1U+YUO*FOW+YU1*F1W-YB1(1,2)*FOU*FOW-YB1(1,NPT1)* AROE  2390
     4  FOU*F1W-YB1(2,2)*F1U*FOW-YB1(2,NPT2)*F1U*F1W                    AROE  2400
     OZS = ZOW*FOU+Z1W*F1U+ZUO*FOW+ZU1*F1W-ZB1(1,2)*FOU*FOW-ZB1(1,NPT1)* AROE  2410
     4  FOU*F1W-ZB1(2,2)*F1U*FOW-ZB1(2,NPT2)*F1U*F1W                    AROE  2420
C                                                                       AROE  2430
      IF(INU-1)97,94,94                                                 AROE  2440
   97 XXS = XS                                                          AROE  2450
      YYS = YS                                                          AROE  2460
      ZZS = ZS                                                          AROE  2470
      INU=1                                                             AROE  2480
      GO TO 89                                                          AROE  2490
   94 IF (I.EQ.NOU .AND. K.EQ.NOW .AND. LAST.EQ.1) STATT = 3            AROE  2500
      IF (I.EQ.NOU .AND. K.EQ.NOW .AND. LAST.EQ.3) STATT = 3            AROE  2510
```

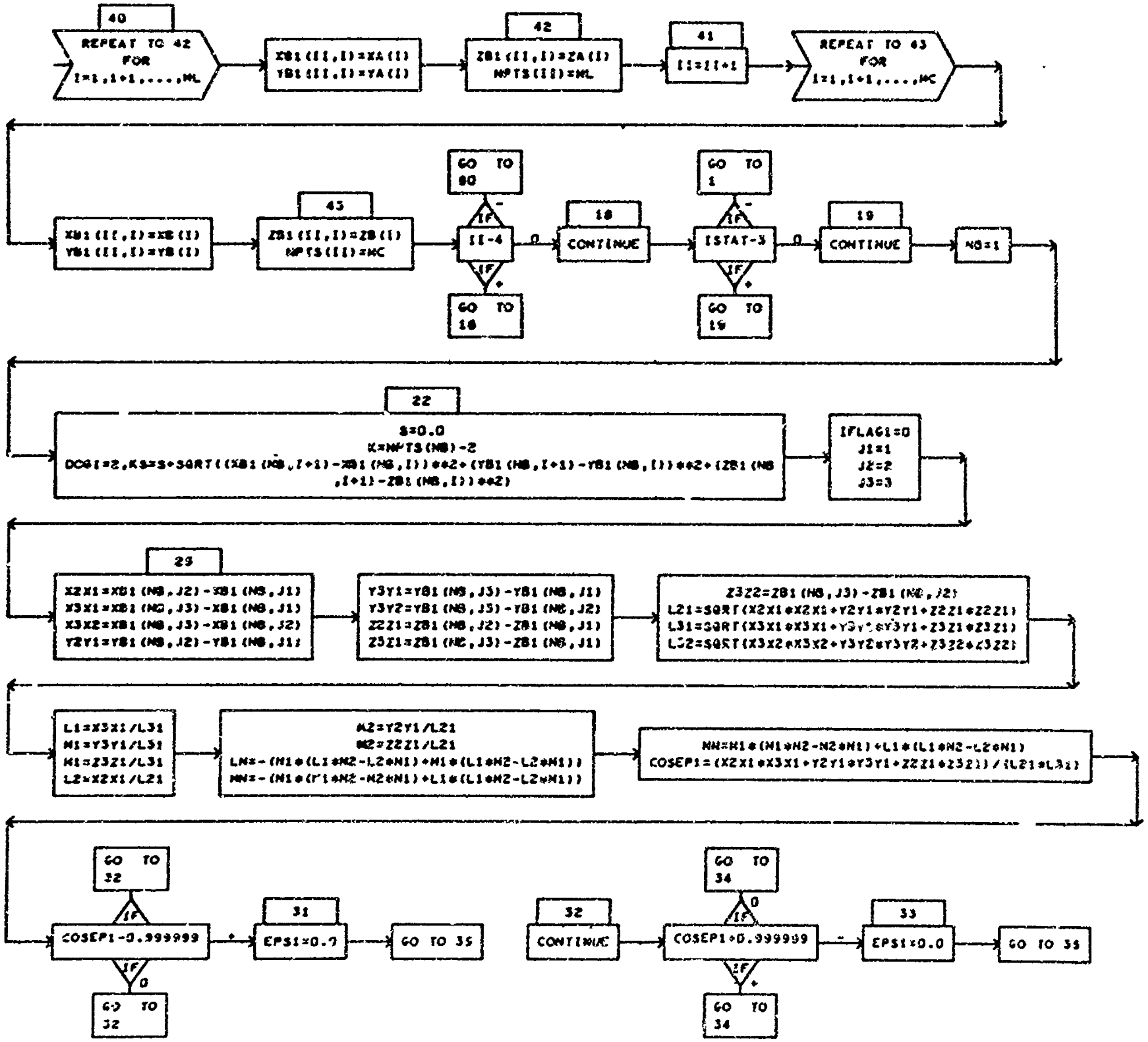
```
DECK AROE

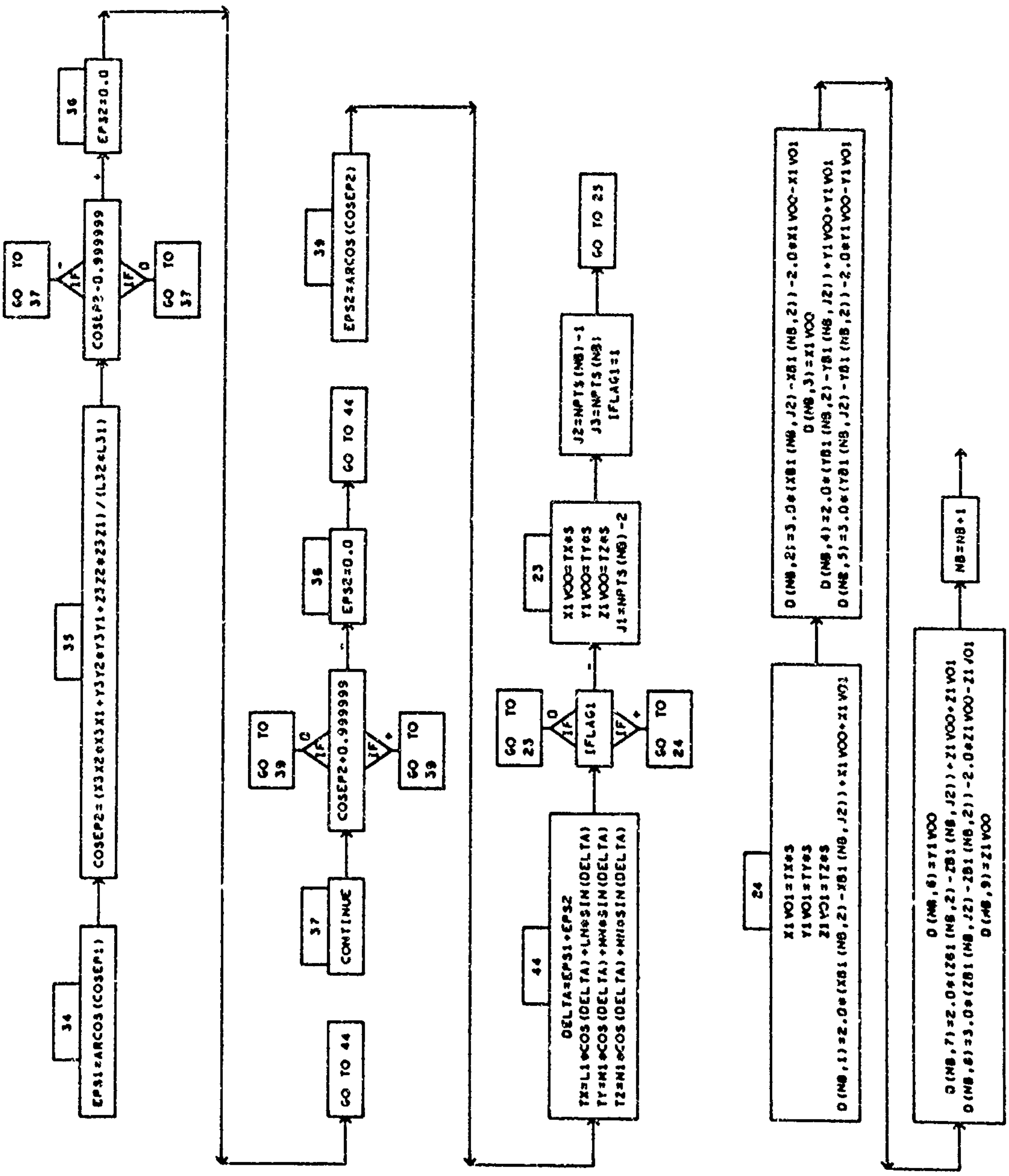
      IF (I.EQ.NOU .AND. K.EQ.NOW .AND. LAST.EQ.4) STATT = 3            AROE  2520
      IF (I.EQ.1 .AND. K.EQ.2 .AND. ISOVR.EQ.0) STAT = 2                AROE  2530
      CALL PUNCH (XXS,YYS,ZZS,STAT,XS,YS,ZS,STATT,SECT,TYPE,LINE,SEQ,   AROE  2540
     1    LAST,IPRINT,NREC)                                             AROE  2550
      INU=0                                                             AROE  2560
      STAT=0                                                            AROE  2570
   89 W=W+DELW                                                          AROE  2580
   93 CONTINUE                                                          AROE  2590
      U=U+DELU                                                          AROE  2600
   95 CONTINUE                                                          AROE  2610
C                                                                       AROE  2620
      IF (STATT .NE. 3) GO TO 100                                       AROE  2630
      WRITE (8,500)                                                     AROE  2640
  500 FORMAT (12H**BLANK CARD,68X)                                      AROE  2650
      END FILE 8                                                        AROE  2660
      BACKSPACE 8                                                       AROE  2670
      BACKSPACE 8                                                       AROE  2680
      IF (LAST .NE. 3) GO TO 1000                                       AROE  2690
      DO 99 I=1,NREC                                                    AROE  2700
   99 BACKSPACE 8                                                       AROE  2710
 1000 RETURN                                                            AROE  2720
   91 ERROR = 1                                                         AROE  2730
      RETURN                                                            AROE  2740
      END                                                               AROE  2750
```

SUBROUTINE ANALY2

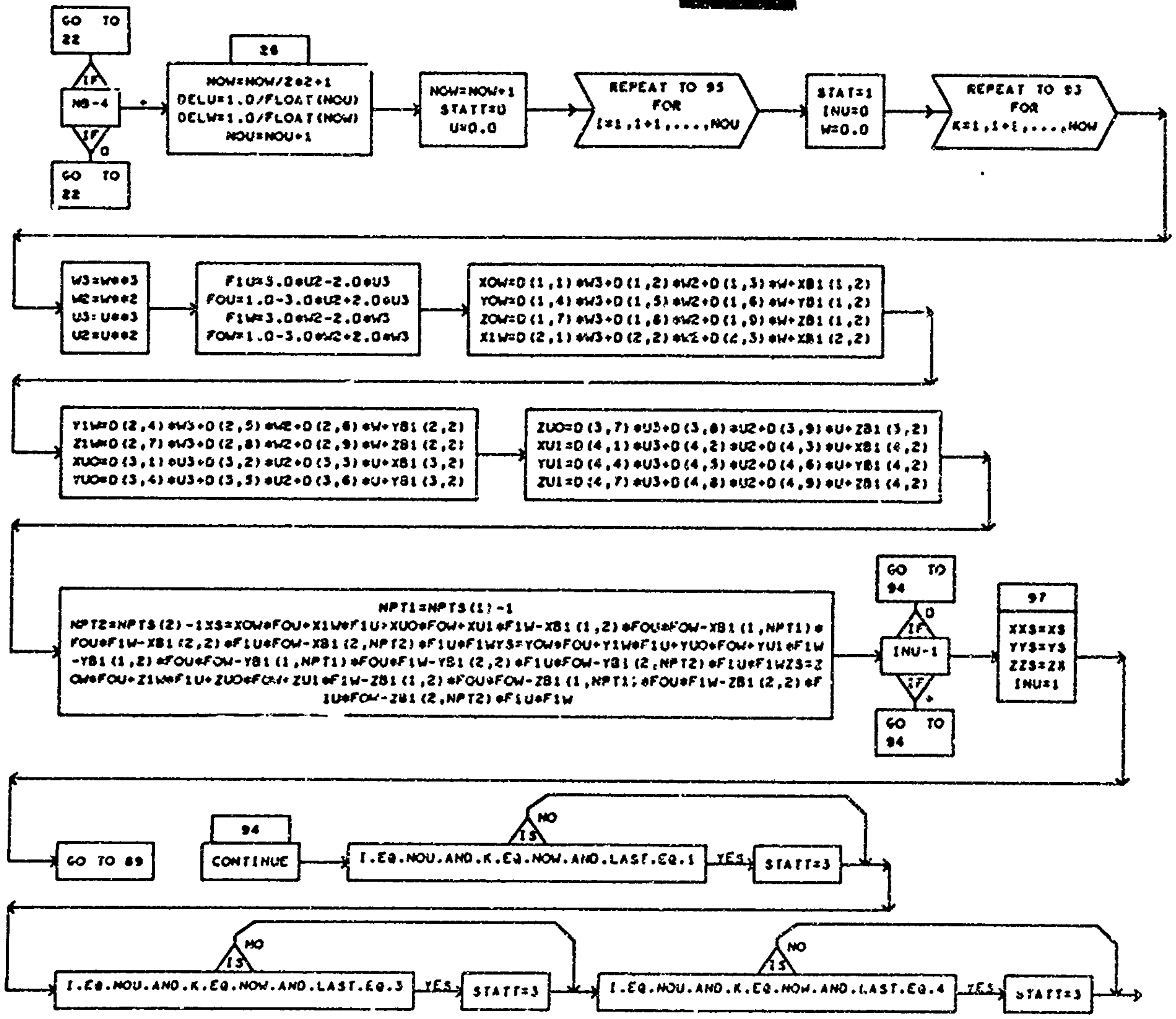


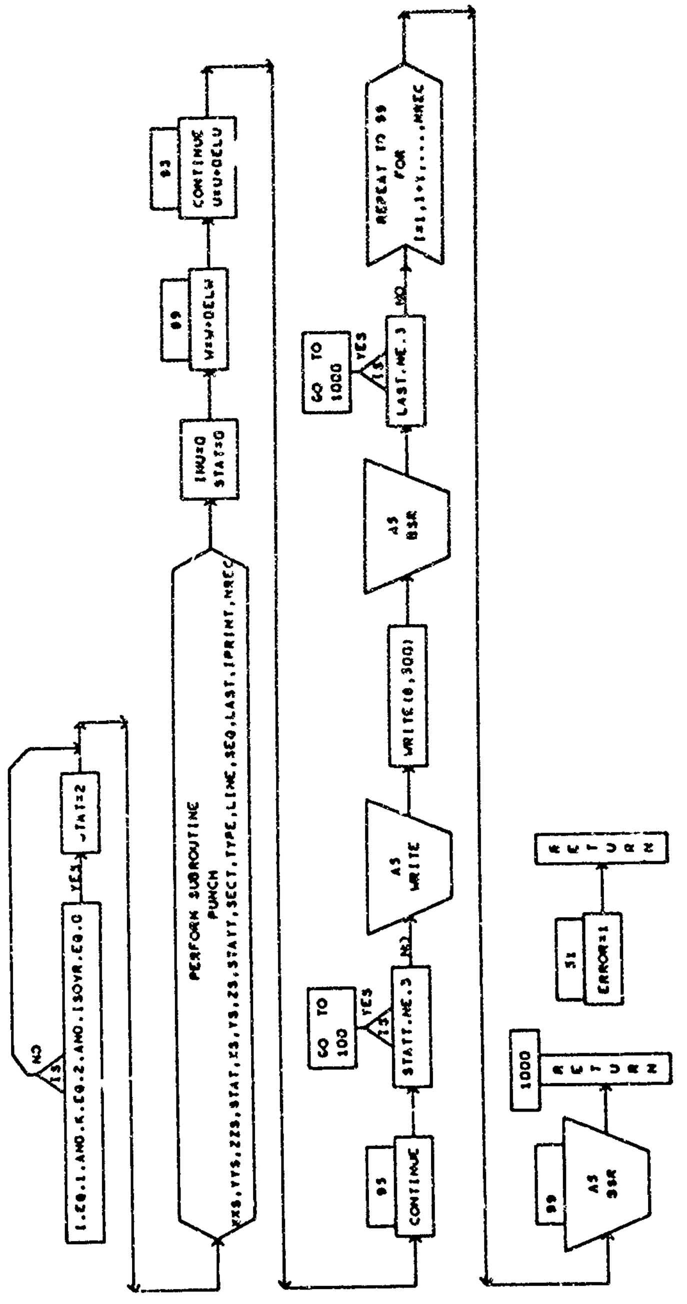

GO TO 180
ISTAT-3
IF
0
+
-
GO TO 12
12
CONTINUE
GO TO 199
ISTAT-2
GO TO 70
70
CONTINUE
GO TO 199
IAFLAG-1
GO TO 13
13
NC=N
80
N=1
GO TO 150
ISTAT-2
GO TO 14
14
CONTINUE
GO TO 84
IBFLAG-1
GO TO 75
75
REPEAT TO 81 FOR J=1,1-1,...,NC
XA(J)=XB(J)
YA(J)=YB(J)
81
ZA(J)=ZB(J)
83
XB(1)=X
YB(1)=Y
ZB(1)=Z
GO TO 30
84
CONTINUE
GO TO 85
IAFLAG
GO TO 15
15
IBFLAG=0
GO TO 75
85
IAFLAG=1
GO TO 83
150
IAFLAG=0
IBFLAG=1
N=N+1
160
XA(N)=X
YA(N)=Y
ZA(N)=Z
GO TO 30
180
N=N+1
GO TO 160
IAFLAG
GO TO 16
16
XB(N)=X
YB(N)=Y
ZB(N)=Z
GO TO 30
ISTAT-3
GO TO 30
199
NL=NC
NC=N
198
N=N+1
197
CONTINUE
GO TO 40
II-1
GO TO 41


40
REPEAT TO 42 FOR I=1,I+1,....,ML
XB1(II,I)=XA(I)
YB1(II,I)=YA(I)
42
ZB1(II,I)=ZA(I)
NPTS(II)=ML
41
II=II+1
REPEAT TO 43 FOR I=1,I+1,....,MC
XB1(II,I)=XB(I)
YB1(II,I)=YB(I)
43
ZB1(II,I)=ZB(I)
NPTS(II)=MC
II-4
IF
-
GO TO 80
+
GO TO 18
0
18
CONTINUE
ISTAT-3
IF
-
GO TO 1
+
GO TO 19
0
19
CONTINUE
NB=1
22
S=0.0
K=NPTS(NB)-2
DO9I=2,KS=S+SQRT((XB1(NB,I+1)-XB1(NB,I))**2+(YB1(NB,I+1)-YB1(NB,I))**2+(ZB1(NB,I+1)-ZB1(NB,I))**2)
IFLAG1=0
J1=1
J2=2
J3=3
25
X2X1=XB1(NB,J2)-XB1(NB,J1)
X3X1=XB1(NB,J3)-XB1(NB,J1)
X3X2=XB1(NB,J3)-XB1(NB,J2)
Y2Y1=YB1(NB,J2)-YB1(NB,J1)
Y3Y1=YB1(NB,J3)-YB1(NB,J1)
Y3Y2=YB1(NB,J3)-YB1(NB,J2)
Z2Z1=ZB1(NB,J2)-ZB1(NB,J1)
Z3Z1=ZB1(NB,J3)-ZB1(NB,J1)
Z3Z2=ZB1(NB,J3)-ZB1(NB,J2)
L21=SQRT(X2X1*X2X1+Y2Y1*Y2Y1+Z2Z1*Z2Z1)
L31=SQRT(X3X1*X3X1+Y3Y1*Y3Y1+Z3Z1*Z3Z1)
L32=SQRT(X3X2*X3X2+Y3Y2*Y3Y2+Z3Z2*Z3Z2)
L1=X3X1/L31
M1=Y3Y1/L31
N1=Z3Z1/L31
L2=X2X1/L21
M2=Y2Y1/L21
N2=Z2Z1/L21
LN=-(M1*(L1*M2-L2*M1)+N1*(L1*N2-L2*N1))
MN=-(N1*(M1*N2-M2*N1)+L1*(L1*M2-L2*M1))
NN=M1*(M1*N2-N2*M1)+L1*(L1*N2-L2*N1)
COSEP1=(X2X1*X3X1+Y2Y1*Y3Y1+Z2Z1*Z3Z1)/(L21*L31)
COSEP1-0.999999
IF
GO TO 32
IF
0
GO TO 32
+
31
EPS1=0.7
GO TO 35
32
CONTINUE
COSEP1+0.999999
IF
0
GO TO 34
IF
+
GO TO 34
-
33
EPS1=0.0
GO TO 35


34
EPS1=ARCOS(COSEP1)
35
COSEP2=(X3X2*X3X1+Y3Y2*Y3Y1+Z3Z2*Z3Z1)/(L32*L31)
IF
COSEP2-0.999999
-
GO TO 37
0
GO TO 37
+
36
EPS2=0.0
37
CONTINUE
IF
COSEP2+0.999999
0
GO TO 39
+
GO TO 39
-
38
EPS2=0.0
GO TO 44
39
EPS2=ARCOS(COSEP2)
GO TO 44
44
DELTA=EPS1+EPS2
TX=L1*COS(DELTA)+LM*SIN(DELTA)
TY=M1*COS(DELTA)+MM*SIN(DELTA)
TZ=N1*COS(DELTA)+NM*SIN(DELTA)
IF
IFLAG1
0
GO TO 23
+
GO TO 24
-
23
X1VOO=TX*S
Y1VOO=TY*S
Z1VOO=TZ*S
J1=NPTS(NB)-2
J2=NPTS(NB)-1
J3=NPTS(NB)
IFLAG1=1
GO TO 25
24
X1VO1=TX*S
Y1VO1=TY*S
Z1VO1=TZ*S
D(NB,1)=2.0*(XB1(NB,2)-XB1(NB,J2))+X1VOO+X1VO1
D(NB,2)=3.0*(XB1(NB,J2)-XB1(NB,2))-2.0*X1VOO-X1VO1
D(NB,3)=X1VOO
D(NB,4)=2.0*(YB1(NB,2)-YB1(NB,J2))+Y1VOO+Y1VO1
D(NB,5)=3.0*(YB1(NB,J2)-YB1(NB,2))-2.0*Y1VOO-Y1VO1
D(NB,6)=Y1VOO
D(NB,7)=2.0*(ZB1(NB,2)-ZB1(NB,J2))+Z1VOO+Z1VO1
D(NB,8)=3.0*(ZB1(NB,J2)-ZB1(NB,2))-2.0*Z1VOO-Z1VO1
D(NB,9)=Z1VOO
NB=NB+1

ANALY


GO TO 22
IF
NB-4
IF
0
GO TO 22
+
26
NOW=NOW/2*2+1
DELU=1.0/FLOAT(NOU)
DELW=1.0/FLOAT(NOW)
NOU=NOU+1
NOW=NOW+1
STATT=0
U=0.0
REPEAT TO 95 FOR I=1,1+1,....,NOU
STAT=1
INU=0
W=0.0
REPEAT TO 93 FOR K=1,1+1,....,NOW
W3=W**3
WE=W**2
U3: U**3
U2=U**2
F1U=3.0*U2-2.0*U3
FOU=1.0-3.0*U2+2.0*U3
F1W=3.0*W2-2.0*W3
FOW=1.0-3.0*W2+2.0*W3
XOW=D(1,1)*W3+D(1,2)*W2+D(1,3)*W+XB1(1,2)
YOW=D(1,4)*W3+D(1,5)*W2+D(1,6)*W+YB1(1,2)
ZOW=D(1,7)*W3+D(1,8)*W2+D(1,9)*W+ZB1(1,2)
X1W=D(2,1)*W3+D(2,2)*W2+D(2,3)*W+XB1(2,2)
Y1W=D(2,4)*W3+D(2,5)*W2+D(2,6)*W+YB1(2,2)
Z1W=D(2,7)*W3+D(2,8)*W2+D(2,9)*W+ZB1(2,2)
XUO=D(3,1)*U3+D(3,2)*U2+D(3,3)*U+XB1(3,2)
YUO=D(3,4)*U3+D(3,5)*U2+D(3,6)*U+YB1(3,2)
ZUO=D(3,7)*U3+D(3,8)*U2+D(3,9)*U+ZB1(3,2)
XU1=D(4,1)*U3+D(4,2)*U2+D(4,3)*U+XB1(4,2)
YU1=D(4,4)*U3+D(4,5)*U2+D(4,6)*U+YB1(4,2)
ZU1=D(4,7)*U3+D(4,8)*U2+D(4,9)*U+ZB1(4,2)
NPT1=NPTS(1)-1
NPT2=NPTS(2)-1XS=XOW*FOU+X1W*F1U+XUO*FOW+XU1*F1W-XB1(1,2)*FOU*FOW-XB1(1,NPT1)*FOU*F1W-XB1(2,2)*F1U*FOW-XB1(2,NPT2)*F1U*F1WYS=YOW*FOU+Y1W*F1U+YUO*FOW+YU1*F1W-YB1(1,2)*FOU*FOW-YB1(1,NPT1)*FOU*F1W-YB1(2,2)*F1U*FOW-YB1(2,NPT2)*F1U*F1WZS=ZOW*FOU+Z1W*F1U+ZUO*FOW+ZU1*F1W-ZB1(1,2)*FOU*FOW-ZB1(1,NPT1)*FOU*F1W-ZB1(2,2)*F1U*FOW-ZB1(2,NPT2)*F1U*F1W
GO TO 94
0
IF
INU-1
IF
+
GO TO 94
97
XXS=XS
YYS=YS
ZZS=ZS
INU=1
GO TO 89
94
CONTINUE
I.EQ.NOU.AND.K.EQ.NOW.AND.LAST.EQ.1
IS
NO
YES
STATT=3
I.EQ.NOU.AND.K.EQ.NOW.AND.LAST.EQ.3
IS
NO
YES
STATT=3
I.EQ.NOU.AND.K.EQ.NOW.AND.LAST.EQ.4
IS
NO
YES
STATT=3


I.EQ.1.AND.K.EQ.2.AND.ISOVR.EQ.0
IS
NO
YES
JTAT=2
PERFORM SUBROUTINE
PUNCH
XXS,YYS,ZZS,STAT,XS,YS,ZS,STATT,SECT,TYPE,LINE,SEQ,LAST,IPRINT,NREC
IHU=0
STAT=0
99
W=W+DELW
93
CONTINUE
U=U+DELU
95
CONTINUE
GO TO
100
IS
YES
STATT.NE.3
NO
AS
WRITE
WRITE(6,300)
AS
BSR
GO TO
1000
YES
IS
LAST.NE.3
NO
REPEAT TO 99
FOR
I=1,I+1,...,NREC
99
AS
BSR
1000
RETURN
31
ERROR=1
RETURN

```
SYMBOLS USED IN SUBROUTINE ANALY2

CASE     I  C  CASE NUMBER                                    ANALY2
COSEP1   R  U  COSINE OF EPSILON 1                            ANALY2
COSEP2   R  U  COSINE OF EPSILON 2                            ANALY2
D        R  D  CONSTANTS FOR BOUNDARY CURVES                  ANALY2
DELTA    R  U  EPSILON 1 + EPSILON 2                          ANALY2
DELU     R  U  DELTA INCREMENT FOR U                          ANALY2
DELW     R  U  DELTA INCREMENT FOR W                          ANALY2
EPS1     R  U  EPSILON 1                                      ANALY2
EPS2     R  U  EPSILON 2                                      ANALY2
ERROR    I  C  ERROR FLAG                                     ANALY2
FOU      R  U  BLENDING FUNCTION VALUE                        ANALY2
FOW      R  U  BLENDING FUNCTION VALUE                        ANALY2
F1U      R  U  BLENDING FUNCTION VALUE                        ANALY2
F1W      R  U  BLENDING FUNCTION VALUE                        ANALY2
I        I  U  DO-LOOP INDEX                                  ANALY2
IAFLAG   I  U  INPUT DATA READ CONTROL FLAG                   ANALY2
IBFLAG   I  U  INPUT DATA READ CONTROL FLAG                   ANALY2
IFALSE   I  U  INPUT DATA READ CONTROL FLAG                   ANALY2
IFLAG1   I  U  INPUT DATA READ CONTROL FLAG                   ANALY2
II       I  U  BOUNDARY NUMBER                                ANALY2
INU      I  U  FLAG                                           ANALY2
IPRINT   I  U  PRINT FLAG                                     ANALY2
IRFLAG   I  U  INPUT DATA READ CONTROL FLAG                   ANALY2
ISOVR    I  U  FIRST POINT STATUS OVERRIDE FLAG               ANALY2
ISTAT    I  U  SURFACE POINT STATUS FLAG                      ANALY2
ISTATT   I  U  SURFACE POINT STATUS FLAG                      ANALY2
ITRUE    I  U  INPUT DATA CONTROL FLAG                        ANALY2
ITYPE    I  U  CARD TYPE NUMBER                               ANALY2
J1       I  U  POINT INDEX                                    ANALY2
J2       I  U  POINT INDEX                                    ANALY2
J3       I  U  POINT INDEX                                    ANALY2
K        I  U  DO-LOOP INDEX                                  ANALY2
L        I  U  INDEX                                          ANALY2
LAST     I  U  LAST FLAG                                      ANALY2
LINE     I  U  LINE COUNTER                                   ANALY2
LN       R  U  VARIABLE IN TANGENT VECTOR EQUATIONS           ANALY2
```

```
SYMBOLS USED IN SUBROUTINE ANALY2

L1       R  U  VARIABLE IN TANGENT VECTOR EQUATIONS                          ANALY2
L2       R  U  VARIABLE IN TANGENT VECTOR EQUATIONS                          ANALY2
L21      R  U  VARIABLE IN TANGENT VECTOR EQUATIONS                          ANALY2
L31      R  U  VARIABLE IN TANGENT VECTOR EQUATIONS                          ANALY2
L32      R  U  VARIABLE IN TANGENT VECTOR EQUATIONS                          ANALY2
M        I  U  DATA READ IN CONTROL FLAG                                     ANALY2
MC       I  U  DATA READ IN CONTROL NUMBER                                   ANALY2
ML       I  U  DATA READ IN CONTROL NUMBER                                   ANALY2
MN       R  U  VARIABLE IN TANGENT VECTOR EQUATIONS                          ANALY2
M1       R  U  VARIABLE IN TANGENT VECTOR EQUATIONS                          ANALY2
M2       R  U  VARIABLE IN TANGENT VECTOR EQUATIONS                          ANALY2
N        I  U  DATA READ IN COUNTER                                          ANALY2
NB       I  U  BOUNDARY CURVE NUMBER                                         ANALY2
NN       R  U  VARIABLE IN TANGENT VECTOR EQUATIONS                          ANALY2
NOU      I  U  NUMBER OF U INCREMENTS                                        ANALY2
NOW      I  U  NUMBER OF W INCREMENTS                                        ANALY2
NPTS     I  D  NUMBER OF BOUNDARY POINTS                                     ANALY2
NPT1     I  U  BOUNDARY POINT COUNTER                                        ANALY2
NPT2     I  U  BOUNDARY POINT COUNTER                                        ANALY2
NREC     I  U  NUMBER OF CARDS WRITTEN ON TAPE 8                             ANALY2
N1       R  U  VARIABLE IN TANGENT VECTOR EQUATIONS                          ANALY2
N2       R  U  VARIABLE IN TANGENT VECTOR EQUATIONS                          ANALY2
PAGE     I  C  PAGE NUMBER                                                   ANALY2
S        R  U  BOUNDARY LENGTH                                               ANALY2
SECT     R  D  SECTION IDENTIFICATION                                        ANALY2
SEQ      I  U  CARD SEQUENCE NUMBER                                          ANALY2
STAT     I  U  SURFACE POINT STATUS FLAG                                     ANALY2
STATT    I  U  SURFACE POINT STATUS FLAG                                     ANALY2
TITLE    R  C  TITLE                                                         ANALY2
TX       R  U  TANGENT VECTOR X-COMPONENT                                    ANALY2
TY       R  U  TANGENT VECTOR Y-COMPONENT                                    ANALY2
TYPE     I  U  CARD TYPE NUMBER                                              ANALY2
TZ       R  U  TANGENT VECTOR Z-COMPONENT                                    ANALY2
U        R  U  PARAMETRIC VARIABLE, U                                        ANALY2
U2       R  U  PARAMETRIC VARIABLE U SQUARED                                 ANALY2
U3       R  U  PARAMETRIC VARIABLE U CUBED                                   ANALY2
```

```
SYMBOLS USED IN SUBROUTINE ANALY2

W        R  U  PARAMETRIC VARIABLE, W                                          ANALY2
W2       R  U  PARAMETRIC VARIABLE W SQUARED                                   ANALY2
W3       R  U  PARAMETRIC VARIABLE W CUBED                                     ANALY2
X        R  U  X-COORDINATE                                                    ANALY2
XA       R  D  X-COORDINATE                                                    ANALY2
XB       R  D  X-COORDINATE                                                    ANALY2
XB1      R  D  BOUNDARY CURVE X-COORDINATE ARRAY                               ANALY2
X0W      R  U  BOUNDARY CURVE POINT, X(0,W)                                    ANALY2
XS       R  U  SURFACE X-COORDINATE POINT                                      ANALY2
XU0      R  U  BOUNDARY CURVE POINT, X(U,0)                                    ANALY2
XU1      R  U  BOUNDARY CURVE POINT, X(U,1)                                    ANALY2
XX       R  U  X-COORDINATE                                                    ANALY2
XXS      R  U  X-COORDINATE                                                    ANALY2
X1V00    R  U  END POINT DERIVATIVE                                            ANALY2
X1V01    R  U  END POINT DERIVATIVE                                            ANALY2
X1W      R  U  BOUNDARY CURVE POINT, X(1,W)                                    ANALY2
X2X1     R  U  VARIABLE IN TANGENT VECTOR EQUATIONS                            ANALY2
X3X1     R  U  VARIABLE IN TANGENT VECTOR EQUATIONS                            ANALY2
X3X2     R  U  VARIABLE IN TANGENT VECTOR EQUATIONS                            ANALY2
Y        R  U  Y-COORDINATE                                                    ANALY2
YA       R  D  Y-COORDINATE                                                    ANALY2
YB       R  D  Y-COORDINATE                                                    ANALY2
YB1      R  D  BOUNDARY CURVE Y-COORDINATE ARRAY                               ANALY2
Y0W      R  U  BOUNDARY CURVE POINT, Y(0,W)                                    ANALY2
YS       R  U  SURFACE Y-COORDINATE POINT                                      ANALY2
YU0      R  U  BOUNDARY CURVE POINT, Y(U,0)                                    ANALY2
YU1      R  U  BOUNDARY CURVE POINT, Y(U,1)                                    ANALY2
YY       R  U  Y-COORDINATE                                                    ANALY2
YYS      R  U  Y-COORDINATE                                                    ANALY2
Y1V00    R  U  END POINT DERIVATIVE                                            ANALY2
Y1V01    R  U  END POINT DERIVATIVE                                            ANALY2
Y1W      R  U  BOUNDARY CURVE POINT, Y(1,W)                                    ANALY2
Y2Y1     R  U  VARIABLE IN TANGENT VECTOR EQUATIONS                            ANALY2
Y3Y1     R  U  VARIABLE IN TANGENT VECTOR EQUATIONS                            ANALY2
Y3Y2     R  U  VARIABLE IN TANGENT VECTOR EQUATIONS                            ANALY2
Z        R  U  Z-COORDINATE                                                    ANALY2
```

```
SYMBOLS USED IN SUBROUTINE ANALY2

ZA       R  D  Z-COORDINATE                                              ANALY2
ZB       R  D  Z-COORDINATE                                              ANALY2
ZB1      R  D  BOUNDARY CURVE Z-COORDINATE ARRAY                         ANALY2
Z0W      R  U  BOUNDARY CURVE POINT, Z(0,W)                              ANALY2
ZS       R  U  SURFACE Z-COORDINATE POINT                                ANALY2
ZU0      R  U  BOUNDARY CURVE POINT, Z(U,0)                              ANALY2
ZU1      R  U  BOUNDARY CURVE POINT, Z(U,1)                              ANALY2
ZZ       R  U  Z-COORDINATE                                              ANALY2
ZZS      R  U  Z-COORDINATE                                              ANALY2
Z1V00    R  U  END POINT DERIVATIVE                                      ANALY2
Z1V01    R  U  END POINT DERIVATIVE                                      ANALY2
Z1W      R  U  BOUNDARY CURVE COORDINATE, Z(1,W)                         ANALY2
Z2Z1     R  U  VARIABLE IN TANGENT VECTOR EQUATIONS                      ANALY2
Z3Z1     R  U  VARIABLE IN TANGENT VECTOR EQUATIONS                      ANALY2
Z3Z2     R  U  VARIABLE IN TANGENT VECTOR EQUATIONS                      ANALY2
```

7. SUBROUTINE ANALY3 (DECK AROF)

This is a dummy subroutine provided for future use. This routine may be replaced with a routine similar to either the Ellipse Generation routine or the Parametric Cubic routine.

a. Algorithm

b. Input/Output

c. Error

d. Subroutines Required

e. Argument List

None

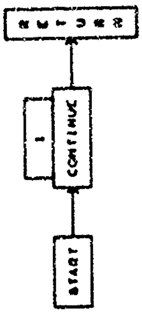
f. Length

124 bytes

```
DECK AROF

      SUBROUTINE ANALY3                                                 AROF  0010
    1 CONTINUE                                                          AROF  0020
      RETURN                                                            AROF  0030
      END                                                               AROF  0040
```

SUBROUTINE ANALYS



8. SUBROUTINE PUNCH (DECK AROG)

This routine writes element data card images on Tape 8.

a. Algorithm

If IPRINT is equal to 1, each card image will be written on output Tape 6. The element data are recorded on Tape 8 in exactly the same form as normal input surface element data (Type 3). Each card is given a sequence number and the number of records written on Tape 8 is furnished to the calling routines.

b. Input/Output

Element data are recorded on Tape 8 and also on the standard output tape if required.

c. Error

None

d. Subroutines Required

None

e. Argument List

(X1. Y1, Z1, NSTAT1, X2, Y2, Z2, NSTAT3, SECT, TYPE, LINE, SEQ, LAST, IPRINT, NREC)

f. Length

1276 bytes

DECK AROG

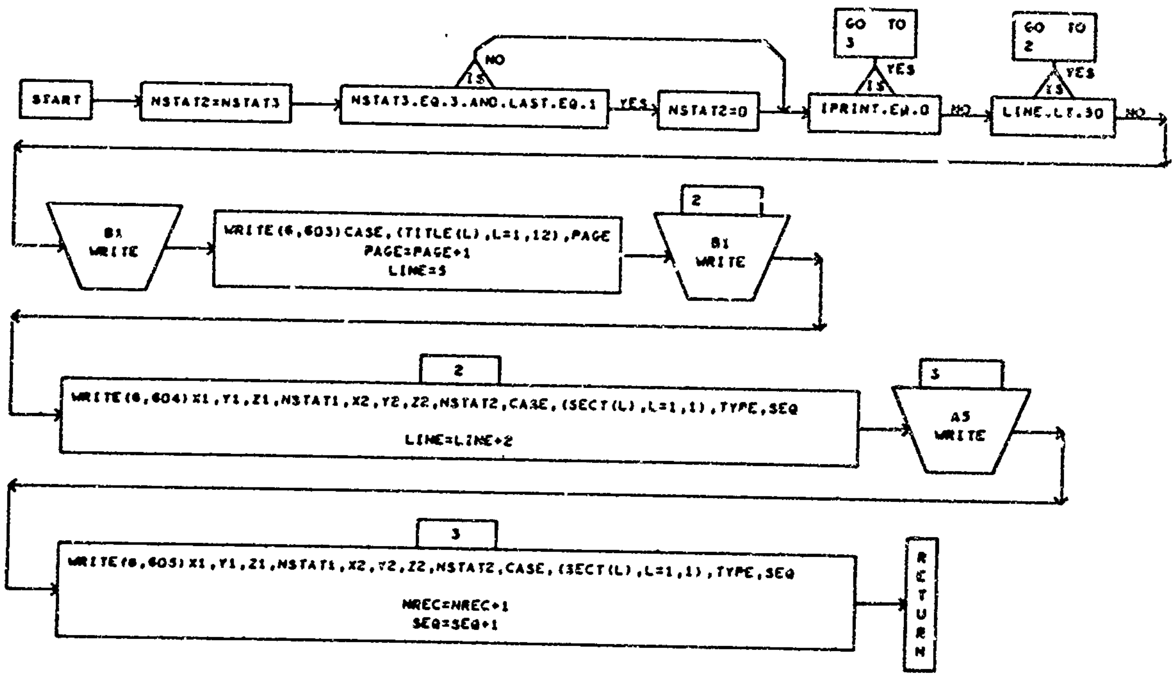
```
      SUBROUTINF PUNCH (X1,Y1,Z1,NSTAT1,X2,Y2,Z2,NSTAT3,SECT,TYPE,
     1     LINE,SEQ,LAST,IPRINT,NREC)
C
C  THIS SUBROUTINE PREPARES VEHICLE GEOMETRY DATA IN THE PROPER FORM
C   FOR USE BY SDATA ROUTINE
C
      DIMENSION  TITLE(15),SECT(1)
C
      COMMON CASE,TITLE,PAGE
      INTEGER  PAGE, SEQ, TYPE
C
      NSTAT2 = NSTAT3
C
C  CHECK IF THIS IS THE LAST POINT OF THE ENTIRE VEHICLE
      IF (NSTAT3.EQ.3 .AND. LAST.EQ.1) NSTAT2 = 0
      IF (IPRINT .EQ. 0) GO TO 3
C
      IF  (LINE .LT. 50 )  GO TO 2
C
C  WRITE PAGE HEADFR FOR STANDARD OUTPUT TAPE
      WRITE (6,603) CASE, (TITLE(L),L=1,12),PAGE
  603 FORMAT (1H1,5X,36HANALYTICALLY GENFRATED ELEMENT DATA ,/
     1 1H0,6H  CASE,I5,17X,12A4,17X,5HPAGE ,I4,/
     2 1H0,5X1HX9X1HY9X1HZ4X1HS5X1HX9X1HY8X1HZ5X1HS10H CASE SECT,
     3 6X3HSEQ )
C
      PAGE = PAGE + 1
      LINE = 5
C
C  WRITE GEOMETRY CARDS ON STANDARD OUTPUT TAPE
    2 WRITE (6,604) X1,Y1,Z1,NSTAT1,X2,Y2,Z2,NSTAT2,CASE,(SECT(L),L=1,1)
     1      ,TYPE,SEQ
  604 FORMAT (1H0,3F10.4,I1,3F10.4,I1,I6,  1A2,1XI1,4HAERO,I4   )
C
      LINE = LINE + 2
```

```
DECK AROG

C                                                                                 AROG  0360
C  WRITE GEOMETRY DATA ON GECMETRY TAPE                                           AROG  0370
   3  WRITE (8,605) X1,Y1,Z1,NSTAT1,X2,Y2,Z2,NSTAT2,CASE,(SECT(L),L=1,1)          AROG  0380
     1        ,TYPE,SEQ                                                           AROG  0390
  605 FORMAT (3F10.4, I1,3F10.4,I1,I6,  1A2,1XI1,4HAERO,I4  )                     AROG  0400
C                                                                                 AROG  0410
      NREC = NREC + 1                                                             AROG  0420
      SEQ = SEQ + 1                                                               AROG  0430
C                                                                                 AROG  0440
      RETURN                                                                      AROG  0450
      END                                                                         AROG  0460
```

RUNCH

SUBROUTINE PUNCH



```
SYMBOLS USED IN SUBROUTINE PUNCH

CASE     R  C  CASE NUMBER                                              PUNCH
IPRINT   I  A  PRINT FLAG                                               PUNCH
LAST     I  A  LAST FLAG                                                PUNCH
LINE     I  A  LINE COUNTER                                             PUNCH
NREC     I  A  NUMBER OF RECORDS ON TAPE 8                              PUNCH
NSTAT1   I  A  POINT STATUS FLAG                                        PUNCH
NSTAT2   I  U  POINT STATUS FLAG                                        PUNCH
NSTAT3   I  A  POINT STATUS FLAG                                        PUNCH
PAGE     I  C  PAGE NUMBER                                              PUNCH
SECT     R  A  SECTION IDENTIFICATION                                   PUNCH
SEQ      I  A  CARD SEQUENCE NUMBER                                     PUNCH
TITLE    R  C  TITLE                                                    PUNCH
TYPE     I  A  CARD TYPE NUMBER                                         PUNCH
X1       R  A  X-COORDINATE                                             PUNCH
X2       R  A  X-COORDINATE                                             PUNCH
Y1       R  A  Y-COORDINATE                                             PUNCH
Y2       R  A  Y-COORDINATE                                             PUNCH
Z1       R  A  Z-COORDINATE                                             PUNCH
Z2       R  A  Z-COORDINATE                                             PUNCH
```

9. SUBROUTINE CONTRL (DECK AROH)

This routine changes the geometry data for control surfaces to the proper deflected position.

a. Algorithm

The hinge-line coordinate data are determined from the first two items in the NX2 data array. The required transformation angles are then calculated. The element data for the control flap in the undeflected position are read from Tape 4. The rotation matrix and the control deflection matrix are then applied to the geometry data. These data are then rotated back to the original hinge-line centered coordinate system. Hinge moment factor data are calculated and stored in the XCENT2 data array. The new geometry data for the deflected flap are stored on Tape 11.

b. Input/Output

None

c. Error

An error condition occurs when the total number of elements on the control surface is greater than ISIZ (300 for the Mark II program).

d. Subroutines Required

None

e. Argument List

(DELTAE, ISIZ)

f. Length

2376 bytes

DECK AROH

```
      SUBROUTINE CONTRL (DELTAE,ISIZ)                                   AROH  0010
C                                                                       AROH  0020
C  THIS SUBROUTINE READS CONTROL SURFACE GEOMETRY DATA,                 AROH  0030
C  ROTATES THE CONTROL SURFACE TO THE REQUIRED NEW POSITION,            AROH  0040
C  AND STORES THE NEW GEOMETRY DATA FOR USE BY THE FORCE PROGRAM.       AROH  0050
C                                                                       AROH  0060
      DIMENSION NX2( 300),NY2( 300),NZ2( 300),XCENT2( 300),             AROH  0070
     1  YCENT2( 300),ZCENT2( 300),AREA2( 300),IN( 300),IM( 300)         AROH  0080
      DIMENSION XPA(4),YPA(4),ZPA(4),XPAD(4),YPAD(4),ZPAD(4),TITLE(15)  AROH  0090
C                                                                       AROH  0100
      COMMON  CASE,TITLE,PAGE,ERROR,NX2,NY2,NZ2,XCENT2,YCENT2,ZCENT2,   AROH  0110
     1  AREA2,IN,IM,L,LS                                                AROH  0120
C                                                                       AROH  0130
      REAL  NX2,NY2,NZ2,NX,NY,NZ,NXD,NYD,NZD,NN,LXY,LYZ                 AROH  0140
      INTEGER  PAGE,CASE,ERROR                                          AROH  0150
C                                                                       AROH  0160
      REWIND 4                                                          AROH  0170
      REWIND 11                                                         AROH  0180
C  SET UP HINGE LINE COORDINATE DATA                                    AROH  0190
      IL = IN(2)                                                        AROH  0200
      XHL1 = NX2(1)                                                     AROH  0210
      YHL1 = NY2(1)                                                     AROH  0220
      ZHL1 = NZ2(1)                                                     AROH  0230
      XHL4 = NX2(2)                                                     AROH  0240
      YHL4 = NY2(2)                                                     AROH  0250
      ZHL4 = NZ2(2)                                                     AROH  0260
C                                                                       AROH  0270
C  CALCULATE TRANSFORMATION ANGLES                                      AROH  0280
C                                                                       AROH  0290
      LXY=SQRT((XHL1-XHL4)**2+(YHL1-YHL4)**2)                           AROH  0300
      LYZ=SQRT((XHL1-XHL4)**2+(YHL1-YHL4)**2+(ZHL1-ZHL4)**2)            AROH  0310
      IF (LXY .NE. 0.0) GO TO 51                                        AROH  0320
      PSIR = 0.0                                                        AROH  0330
      SINPSI = 0.0                                                      AROH  0340
      GO TO 56                                                          AROH  0350
```

```
DECK AROH
C
   51   SINPSI = -(XHL1-XHL4)/LXY
        IF (ABS(SINPSI) .GT. 1.0) SINPSI = SINPSI / ABS(SINPSI)
        PSIR = ARSIN(SINPSI)
        IF ((YHL1-YHL4) .GE. 0.0) GO TO 56
        PSIR = 3.141593 - PSIR
   56   SINPHI = (ZHL1-ZHL4)/LYZ
        IF (ABS(SINPHI) .GT. 1.0) SINPHI = SINPHI / ABS(SINPHI)
        PHIR = ARSIN(SINPHI)
        PSI = PSIR*.5729578E2
        PHI = PHIR*.5729578E2
        COSPSI = COS(PSIR)
        COSPHI = COS(PHIR)
        COSDE = COS(DELTAE/.5729578E2)
        SINDE = SIN(DELTAE/.5729578E2)
C
C  READ ELEMENT DATA FROM TAPE 4 AND AFTER DEFLECTING THE SURFACE
C  SAVE THE FINAL GEOMETRY ON TAPE 11 FOR USE BY THE FORCE PROGRAM.
C
        DO 11 J=1,IL
C
        READ (4)LL,N,M,NX,NY,NZ,XCENT,YCENT,ZCENT,AREA,XPA,YPA,ZPA,XLE
C
        IFLAG=1
        XP=XCENT-XHL4
        YP=YCENT-YHL4
        ZP=ZCENT-ZHL4
C
      4 CONTINUE
C  APPLY ROTATION MATRIX  E  TO XP, YP, AND ZP
        XOP=XP*COSPSI+YP*SINPSI
        YOP=-XP*COSPHI*SINPSI+YP*COSPHI*COSPSI+ZP*SINPHI
        ZOP=XP*SINPHI*SINPSI-YP*SINPHI*COSPSI+ZP*COSPHI-
C
C  APPLY CONTROL DEFLECTION MATRIX
        XOPDE=XOP*COSDE-ZOP*SINDE
```

CONTRL

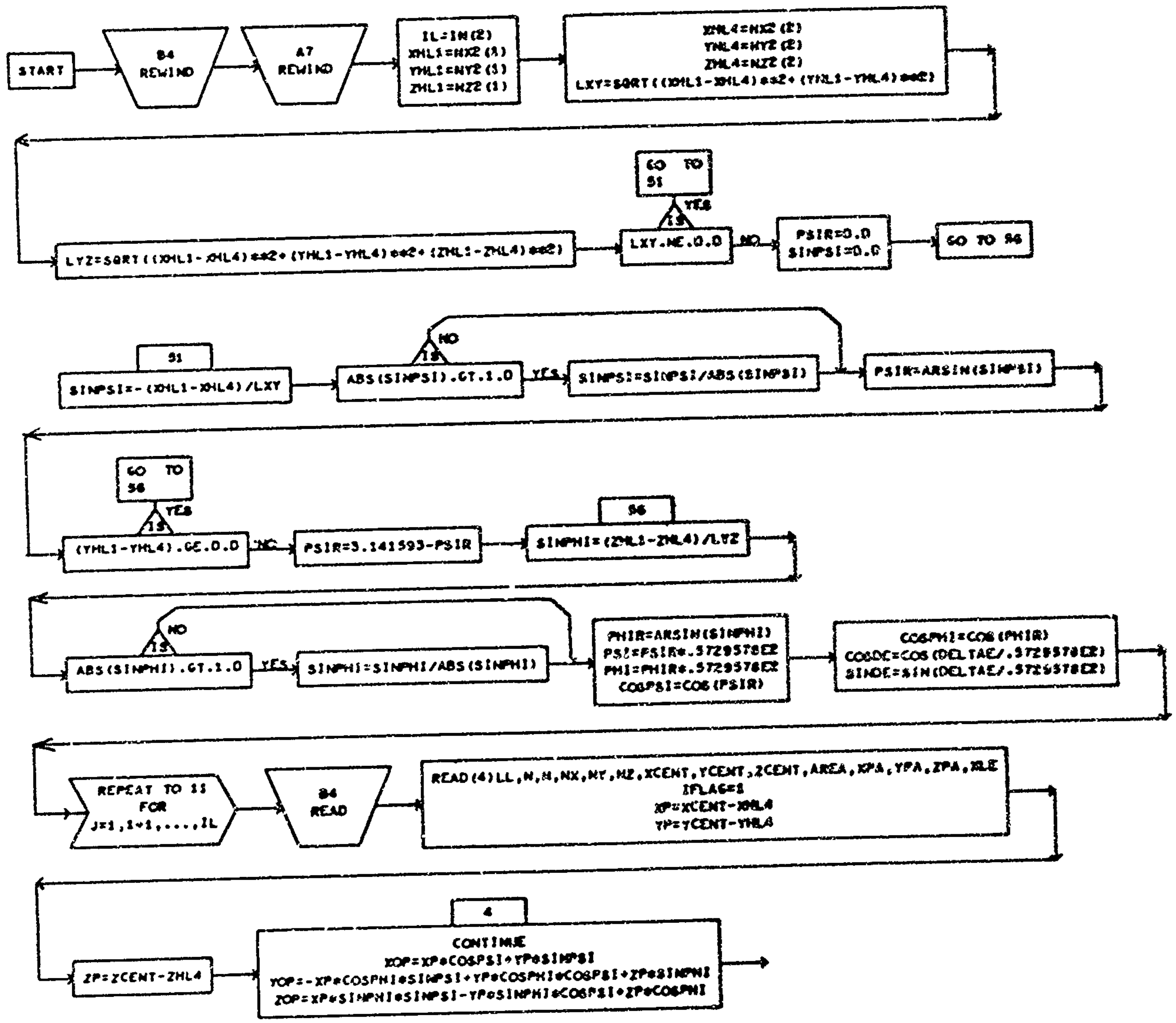
```
DECK AROH

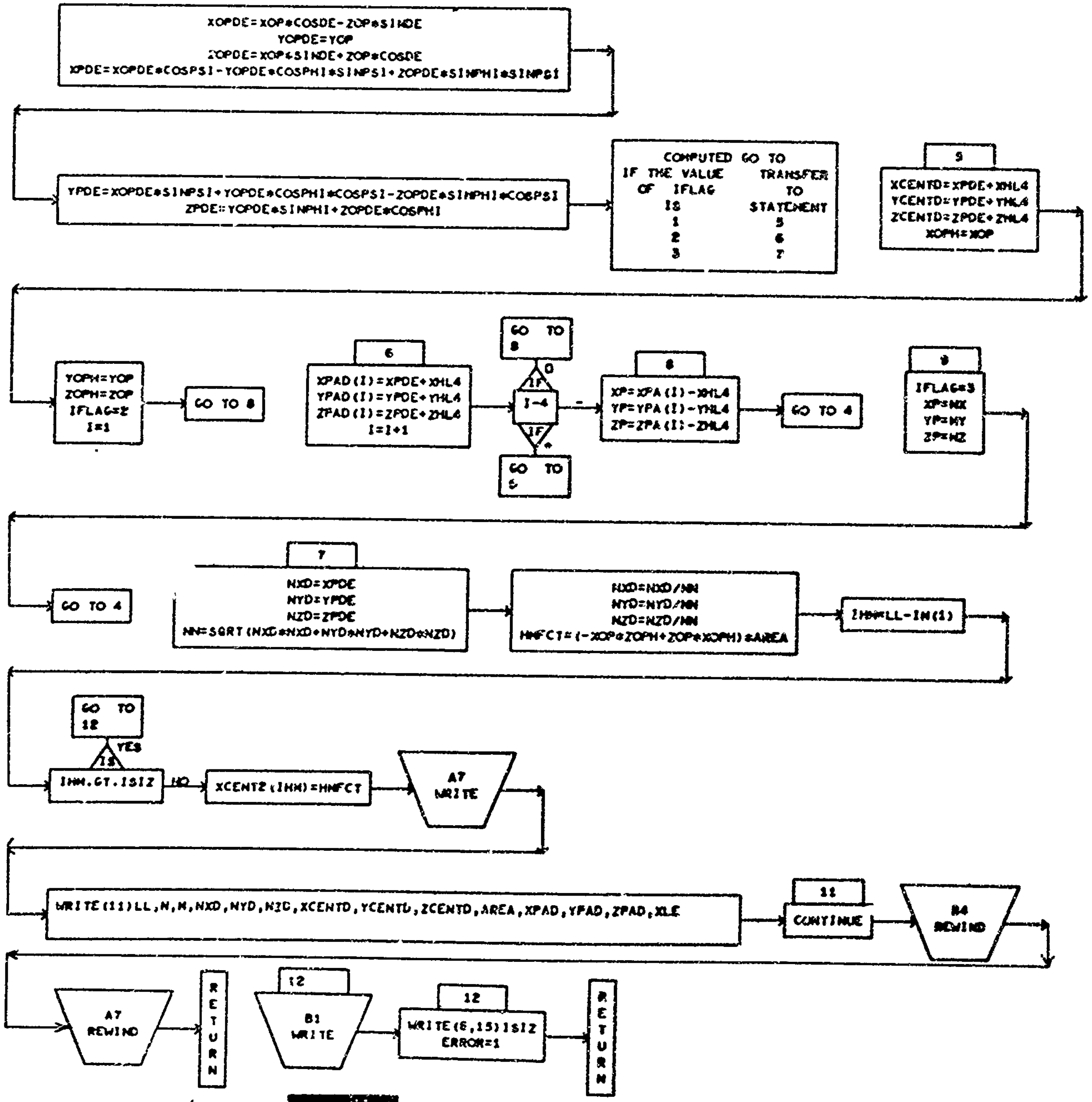
      YOPDE=YOP                                                         AROH 0720
      ZOPDE=XOP*SINDE+ZOP*COSDE                                         AROH 0730
C                                                                       AROH 0740
C                                                                       AROH 0750
C  ROTATE POINT BACK TO ORIGINAL HINGE LINE CENTERED COORDINATE         AROH 0760
C  SYSTEM.                                                              AROH 0770
C                                                                       AROH 0780
      XPDE=XOPDE*COSPSI-YOPDE*COSPHI*SINPSI+ZOPDE*SINPHI*SINPSI         AROH 0790
      YPDE=XOPDE*SINPSI+YOPDE*COSPHI*COSPSI-ZOPDE*SINPHI*COSPSI         AROH 0800
      ZPDE=YOPDE*SINPHI+ZOPDE*COSPHI                                    AROH 0810
C                                                                       AROH 0820
      GO TO (5,6,7),IFLAG                                               AROH 0830
    5 XCENTD = XPDE + XHL4                                              AROH 0840
      YCENTD = YPDE + YHL4                                              AROH 0850
      ZCENTD = ZPDE + ZHL4                                              AROH 0860
      XOPH=XOP                                                          AROH 0870
      ZOPH=ZOP                                                          AROH 0880
      IFLAG=2                                                           AROH 0890
      I=1                                                               AROH 0900
      GO TO 8                                                           AROH 0910
C                                                                       AROH 0920
    6 XPAD(I) = XPDE + XHL4                                             AROH 0930
      YPAD(I) = YPDE + YHL4                                             AROH 0940
      ZPAD(I) = ZPDE + ZHL4                                             AROH 0950
      I=I+1                                                             AROH 0960
      IF(I-4)8,8,9                                                      AROH 0970
C                                                                       AROH 0980
    8 XP=XPA(I)-XHL4                                                    AROH 0990
      YP=YPA(I)-YHL4                                                    AROH 1000
      ZP=ZPA(I)-ZHL4                                                    AROH 1010
      GO TO 4                                                           AROH 1020
C                                                                       AROH 1030
    9 IFLAG=3                                                           AROH 1040
      XP = NX                                                           AROH 1050
      YP = NY                                                           AROH 1060
      ZP = NZ                                                           AROH 1070
```

```
DECK AROH
      GO TO 4                                                           AROH  1080
C                                                                       AROH  1090
    7 NXD = XPDE                                                        AROH  1100
      NYD = YPDE                                                        AROH  1110
      NZD = ZPDE                                                        AROH  1120
      NN = SQRT(NXD*NXD + NYD*NYD + NZD*NZD)                            AROH  1130
      NXD = NXD/NN                                                      AROH  1140
      NYD = NYD/NN                                                      AROH  1150
      NZD = NZD/NN                                                      AROH  1160
C                                                                       AROH  1170
C  CALCULATE HINGE MOMENT FACTOR                                        AROH  1180
      HMFCT = (-XOP*ZOPH + ZOP*XL H) * AREA                             AROH  1190
      IHM = LL - IN(1)                                                  AROH  1200
      IF (IHM .GT. ISIZ) GO TO 12                                       AROH  1210
      XCENT2(IHM) = HMFCT                                               AROH  1220
C                                                                       AROH  1230
C  SAVE NEW GEOMETRY DATA FOR FORCE PROGRAM                             AROH  1240
      WRITE (11) LL,N,M,NXD,NYD,NZD,XCENTD,YCENTD,ZCENTD,AREA,XPAD,     AROH  1250
     1           YPAD,ZPAD,XLE                                          AROH  1260
C                                                                       AROH  1270
C                                                                       AROH  1280
C  END OF ELEMENT DATA READ DO LOOP                                     AROH  1290
   11 CONTINUE                                                          AROH  1300
C                                                                       AROH  1310
      REWIND 4                                                          AROH  1320
      REWIND 11                                                         AROH  1330
      RETURN                                                            AROH  1340
C                                                                       AROH  1350
   12 WRITE (6,15) ISIZ                                                 AROH  1360
   15 FORMAT (1H ,49H***** TOTAL NUMBER OF ELEMENTS ON CONTROL SURFACE  AROH  1370
     1 14H CANNOT EXCEED,I4,6H ***** )                                  AROH  1380
      ERROR = 1                                                         AROH  1390
      RETURN                                                            AROH  1400
      END                                                               AROH  1410
```

CONTRL

CONTRL


START
B4
REWIND
A7
REWIND
IL=IN(2)
XHL1=NX2(1)
YHL1=NY2(1)
ZHL1=NZ2(1)
XHL4=NX2(2)
YHL4=NY2(2)
ZHL4=NZ2(2)
LXY=SQRT((XHL1-XHL4)**2+(YHL1-YHL4)**2)
LYZ=SQRT((XHL1-XHL4)**2+(YHL1-YHL4)**2+(ZHL1-ZHL4)**2)
LXY.NE.0.0
IS
YES
GO TO 51
NO
PSIR=0.0
SINPSI=0.0
GO TO 56
51
SINPSI=-(XHL1-XHL4)/LXY
ABS(SINPSI).GT.1.0
IS
NO
YES
SINPSI=SINPSI/ABS(SINPSI)
PSIR=ARSIN(SINPSI)
(YHL1-YHL4).GE.0.0
IS
YES
GO TO 56
NO
PSIR=3.141593-PSIR
56
SINPHI=(ZHL1-ZHL4)/LYZ
ABS(SINPHI).GT.1.0
IS
NO
YES
SINPHI=SINPHI/ABS(SINPHI)
PHIR=ARSIN(SINPHI)
PSI=PSIR*.5729578E2
PHI=PHIR*.5729578E2
COSPSI=COS(PSIR)
COSPHI=COS(PHIR)
COSDC=COS(DELTAE/.5729578E2)
SINDE=SIN(DELTAE/.5729578E2)
REPEAT TO 11
FOR
J=1,1+1,....,IL
B4
READ
READ(4)LL,N,M,NX,NY,NZ,XCENT,YCENT,ZCENT,AREA,XPA,YPA,ZPA,XLE
IFLAG=1
XP=XCENT-XHL4
YP=YCENT-YHL4
ZP=ZCENT-ZHL4
4
CONTINUE
XOP=XP*COSPSI+YP*SINPSI
YOP=-XP*COSPHI*SINPSI+YP*COSPHI*COSPSI+ZP*SINPHI
ZOP=XP*SINPHI*SINPSI-YP*SINPHI*COSPSI+ZP*COSPHI


XOPDE=XOP*COSDE-ZOP*SINDE
YOPDE=YOP
ZOPDE=XOP*SINDE+ZOP*COSDE
XPDE=XOPDE*COSPSI-YOPDE*COSPHI*SINPSI+ZOPDE*SINPHI*SINPSI
YPDE=XOPDE*SINPSI+YOPDE*COSPHI*COSPSI-ZOPDE*SINPHI*COSPSI
ZPDE=YOPDE*SINPHI+ZOPDE*COSPHI
COMPUTED GO TO
IF THE VALUE OF IFLAG IS
TRANSFER TO STATEMENT
1 5
2 6
3 7
5
XCENTD=XPDE+XHL4
YCENTD=YPDE+YHL4
ZCENTD=ZPDE+ZHL4
XOPH=XOP
YOPH=YOP
ZOPH=ZOP
IFLAG=2
I=1
GO TO 8
6
XPAD(I)=XPDE+XHL4
YPAD(I)=YPDE+YHL4
ZPAD(I)=ZPDE+ZHL4
I=I+1
GO TO 8
IF
I-4
0
-
+
IF
GO TO 5
8
XP=XPA(I)-XHL4
YP=YPA(I)-YHL4
ZP=ZPA(I)-ZHL4
GO TO 4
9
IFLAG=3
XP=NX
YP=NY
ZP=NZ
GO TO 4
7
NXD=XPDE
NYD=YPDE
NZD=ZPDE
NN=SQRT(NXD*NXD+NYD*NYD+NZD*NZD)
NXD=NXD/NN
NYD=NYD/NN
NZD=NZD/NN
HMFCT=(-XOP*ZOPH+ZOP*XOPH)*AREA
IHH=LL-IN(1)
GO TO 12
YES
IS
IHH.GT.ISIZ
NO
XCENT2(IHH)=HMFCT
A7
WRITE
WRITE(11)LL,M,M,NXD,NYD,NZD,XCENTD,YCENTD,ZCENTD,AREA,XPAD,YPAD,ZPAD,XLE
11
CONTINUE
B4
REWIND
A7
REWIND
RETURN
12
B1
WRITE
12
WRITE(6,15)ISIZ
ERROR=1
RETURN

CONTRL

SYMBOLS USED IN SUBROUTINE CONTRL

AREA	R	U	ELEMENT AREA	CONTRL
AREA2	R	C	QUADRILATERAL ELEMENT AREA ARRAY	CONTRL
CASE	I	C	CASE NUMBER	CONTRL
COSDE	R	U	COSINE OF CONTROL DEFLECTION ANGLE	CONTRL
COSPHI	R	U	COSINE OF TRANSFORMATION ANGLE, PHI	CONTRL
COSPSI	R	U	COSINE OF TRANSFORMATION ANGLE, PSI	CONTRL
DELTAE	R	A	CONTROL SURFACE DEFLECTION	CONTRL
ERROR	I	C	ERROR FLAG	CONTRL
HMFCT	R	U	HINGE MOMENT FACTOR	CONTRL
I	I	U	INDEX	CONTRL
IFLAG	I	U	CYCLE FLAG	CONTRL
IHM	I	U	ELEMENT NUMBER INDEX	CONTRL
IL	I	U	NUMBER OF ELEMENTS ON THE FORE SURFACE	CONTRL
IM	I	C	ELEMENT ROW NUMBER ARRAY	CONTRL
IN	I	C	ELEMENT COLUMN NUMBER ARRAY	CONTRL
ISIZ	I	A	NUMBER OF ELEMENTS STORED IN CORE	CONTRL
J	I	U	DO-LOOP INDEX	CONTRL
L	I	C	NUMBER OF ELEMENTS	CONTRL
LL	I	U	ELEMENT NUMBER	CONTRL
LS	I	C	NUMBER OF ELEMENTS	CONTRL
LXY	R	U	HINGE LINE LENGTH IN X-Y PLANE	CONTRL
LYZ	R	U	HINGE LINE LENGTH IN Y-Z PLANE	CONTRL
M	I	U	ELEMENT ROW NUMBER	CONTRL
N	I	U	ELEMENT COLUMN NUMBER	CONTRL
NN	R	U	SURFACE NORMAL LENGTH	CONTRL
NX	R	U	ELEMENT DIRECTION COSINE-X	CONTRL
NXD	R	U	ELEMENT DIRECTION COSINE-X (CONTROL DEFLECTED)	CONTRL
NX2	R	C	ELEMENT DIRECTION COSINE ARRAY-X	CONTRL
NY	R	U	ELEMENT DIRECTION COSINE-Y	CONTRL
NYD	R	U	ELEMENT DIRECTION COSINE-Y (CONTROL DEFLECTED)	CONTRL
NY2	R	C	ELEMENT DIRECTION COSINE ARRAY-Y	CONTRL
NZ	R	U	ELEMENT DIRECTION COSINE-Z	CONTRL

```
SYMBOLS USED IN SUBROUTINE CONTRL

NZD      R  U  ELEMENT DIRECTION COSINE-Z (CONTROL DEFLECTED)                 CONTRL
NZ2      R  C  ELEMENT DIRECTION COSINE ARRAY-Z                               CONTRL
PAGE     I  C  PAGE NUMBER                                                    CONTRL
PHI      R  U  COORDINATE TRANSFORMATION ANGLE, DEGREES                       CONTRL
PHIR     R  U  COORDINATE TRANSFORMATION ANGLE, RADIANS                       CONTRL
PSI      R  U  COORDINATE TRANSFORMATION ANGLE, DEGREES                       CONTRL
PSIR     R  U  COORDINATE TRANSFORMATION ANGLE, RADIANS                       CONTRL
SINDE    R  U  SINE OF CONTROL DEFLECTION ANGLE                               CONTRL
SINPHI   R  U  SINE OF PHI                                                    CONTRL
SINPSI   R  U  SINE OF PSI                                                    CONTRL
TITLE    R  C  TITLE                                                          CONTRL
XCENT    R  U  QUADRILATERAL ELEMENT CENTROID-X                               CONTRL
XCENTD   R  U  QUADRILATERAL ELEMENT CENTROID-X (CONTROL DEFLECEDD)           CONTRL
XCENT2   R  C  HINGE MOMENT FACTOR                                            CONTRL
XHL1     R  U  HINGE LINE X-COORDINATE OF POINT 1                             CONTRL
XHL4     R  U  HINGE LINE X-COORDINATE OF POINT 4                             CONTRL
XLE      R  U  DISTANCE FROM LEADING EDGE TO ELEMENT CENTROID                 CONTRL
XOP      R  U  X IN TRANSFORMED SYSTEM                                        CONTRL
XOPDE    R  U  X IN TRANSFORMED SYSTEM (CONTROL DEFLECTED)                    CONTRL
XOPH     R  U  X-COORDINATE                                                   CONTRL
XP       R  U  X-COORDINATE                                                   CONTRL
XPA      R  D  COORDINATES OF ELEMENT CORNER POINTS, X                        CONTRL
XPAD     R  D  COORDINATES OF ELEMENT CORNER POINTS (DEFLECTED)               CONTRL
XPDE     R  U  X-COORDINATE (DEFLECTED)                                       CONTRL
YCENT    R  U  QUADRILATERAL ELEMENT CENTROID-Y                               CONTRL
YCENTD   R  U  QUADRILATERAL ELEMENT CENTROID-Y (CONTROL DEFLECTED)           CONTRL
YCENT2   R  C  QUADRILATERAL ELEMENT CENTROID ARRAY-Y                         CONTRL
YHL1     R  U  HINGE LINE Y-COORDINATE OF POINT 1                             CONTRL
YHL4     R  U  HINGE LINE Y-COORDINATE OF POINT 4                             CONTRL
YOP      R  U  Y IN TRANSFORMED SYSTEM                                        CONTRL
YOPDE    R  U  Y IN TRANSFORMED SYSTEM (CONTROL DEFLECTED)                    CONTRL
YOPH     R  U  Y-COORDINATE                                                   CONTRL
YP       R  U  Y-COORDINATE                                                   CONTRL
YPA      R  D  COORDINATES OF ELEMENT CORNER POINTS, Y                        CONTRL
YPAD     R  D  COORDINATES OF ELEMENT CORNER POINTS (DEFLECTED)               CONTRL
```

```
SYMBOLS USED IN SUBROUTINE CONTRL

YPDE     R  U  Y-COORDINATE (DEFLECTED)                                          CONTRL
ZCENT    R  U  QUADRILATERAL ELEMENT CENTROID-Z                                  CONTRL
ZCENTD   R  U  QUADRILATERAL ELEMENT CENTROID-Z (CONTROL DEFLECTED)              CONTRL
ZCENT2   R  C  QUADRILATERAL ELEMENT CENTROID ARRAY, Z                           CONTRL
ZHL1     R  U  HINGE LINE Z-COORDINATE OF POINT 1                                CONTRL
ZHL4     R  U  HINGE LINE Z-COORDINATE OF POINT 4                                CONTRL
ZCP      R  U  Z IN TRANSFORMED SYSTEM                                           CONTRL
ZOPDE    R  U  Z IN TRANSFORMED SYSTEM (CONTROL DEFLECTED)                       CONTRL
ZOPH     R  U  Z-COORDINATE                                                      CONTRL
ZP       R  U  Z-COORDINATE                                                      CONTRL
ZPA      R  D  COORDINATES OF ELEMENT CORNER POINTS, Z                           CONTRL
ZPAD     R  D  COORDINATES OF ELEMENT CORNER POINTS (DEFLECTED)                  CONTRL
ZPDE     R  U  Z-COORDINATE (DEFLECTED)                                          CONTRL
```

10. SUBROUTINE FORCE (DECK AROI)

This routine determines the pressure coefficients on each quadrilateral element, resolves the force in the required body axis system, and sums the contributions of each element to give the vehicle's six aerodynamic coefficients.

a. Algorithm

First the necessary starting constants and conditions are set up. The free-stream properties are then determined either from the Atmosphere subprogram or from the ideal gas equation of NASA TR 1135. The loop for calculating and summing up the forces on each element is then started. The direction cosines of the velocity vector are calculated and the quadrilateral element data are read from core or from tape. Symmetry requirements are then checked and the signs changed if required. The velocity components with vehicle rotation and the impact angle are calculated. If the impact angle is less than zero then the element is in a shadow region; if not, it is in an impact region. The proper force calculation method is then used to determine the pressure coefficient. The force summation method to meet symmetry requirements is selected, the six aerodynamic coefficients calculated, and summation of the coefficients is accomplished. If required, the Skin Friction Subprogram is called for the viscous calculations.

b. Input/Output

If PRINT is equal to 1 the detailed force contributions of each element will be printed.

c. Error

An error will occur when the arccosine of the angle between the velocity vector and the unit normal is greater than 1.

d. Subroutines Required

ATMOS, NEWTPM, COMPR, SHKEXP, EXPAND, FLOSEP, HEADER, SKINFR, BLUNT, CONE

e. Argument List

(ALPHA, BETA, CPSTAG, SREF, SYMFCT, XCG, YCG, ZCG, MACH, SPAN, MAC, J, QRP, ALT, PRINT, CAI, CNI, CYI, CLLI, CLMI, CLNI, ETAC, NS, IMPACT, IPRINT, IFIRST, PSTAG, TSTAG, RENO, ISIZ, ENPM, QQINF, ISHAD, IORIEN, IMPACI, ISHADI, IDERIV, V, IGTYPE, DELTAE, SWEEP, RETRAN, HML, HMR, PFS)

f. Length

13156 bytes

DECK AR01

```
      SUBROUTINE FORCE (ALPHA,BETA,CPSTAG,SREF,SYMFCT,XCG,YCG,ZCG,MACH,   AR01  0010
     1  SPAN,MAC,J,QRP,ALT,PRINT,CAI,CNI,CYI,CLLI,CLMI,CLNI,ETAC,NS,      AR01  0020
     2   IMPACT,IPRINT,IFIRST,PSTAG,TSTAG,RENO,ISIZ,ENPM,QQINF,ISHAD,     AR01  0030
     3  IORIEN,IMPACI,ISHADI,IDERIV,V,IGTYPE,DELTAE,SWEEP,RETRAN,         AR01  0040
     4  HML,HMR,PFS,NW,TWALL)                                             AR01  0050
C                                                                         AR01  0060
C************************************************************************ AR01  0070
C**THIS SUBROUTINE CALCULATES THE PRESSURE COEFFICIENT ON EACH SURFACE**  AR01  0080
C**ELEMENT, RESOLVES IT INTO THE REQUIRED DIRECTIONS, AND ADDS UP THE **  AR01  0090
C**CONTRIBUTIONS TO FIND THE TOTAL VEHICLE COEFFICIENTS.              **  AR01  0100
C************************************************************************ AR01  0110
C                                                                         AR01  0120
      DIMENSION  TITLE(15),ALP(20),BET(20),CCA(20),CCY(20),CCN(20),       AR01  0130
     1  CCLL(20),CCLM(20),CCLN(20),CCL(20),CCD(20),CLOD(20),CF(20),       AR01  0140
     2  CPS(20),QQINFS(20),IS(10, 9),SURF(10, 8),ANGLE(3),FS(8),BS(8),    AR01  0150
     3 XPA(4),YPA(4),ZPA(4)                                               AR01  0160
      DIMENSION NX2( 300),NY2( 300),NZ2( 300),XCENT2( 300),               AR01  0170
     1  YCENT2( 300),ZCENT2( 300),AREA2( 300),IN( 300),IM( 300)           AR01  0180
C                                                                         AR01  0190
      COMMON  CASE,TITLE,PAGE,ERROR,NX2,NY2,NZ2,XCENT2,YCENT2,ZCENT2,     AR01  0200
     1  AREA2,IN,IM,K,LS,FS,BS,ALP,BET,CCA,CCY,CCN,CCLL,CCLM,CCLN,CCL,    AR01  0210
     2  CCD,CLOD,CF,CPS,QQINFS,IS,SURF,NPRT                               AR01  0220
C                                                                         AR01  0230
      INTEGER  CASE,PAGE,ERROR,SYMFCT,PRINT,SYMFCO                        AR01  0240
C                                                                         AR01  0250
      REAL  MAC,LOVERD,MACH,NX,NY,NZ                                      AR01  0260
      REAL  NX2,NY2,NZ2                                                   AR01  0270
C                                                                         AR01  0280
      RAD(A) = A /.572957795E+02                                          AR01  0290
C  SET UP NECESSARY STARTING CONSTANTS AND CONDITIONS                     AR01  0300
      REWIND 3                                                            AR01  0310
      REWIND 4                                                            AR01  0320
      REWIND 11                                                           AR01  0330
      AREAT = 0.0                                                         AR01  0340
      NPRT = 14                                                           AR01  0350
```

```
DECK AROI

      NPCK = 13                                                         AROI  0360
      IPRCK = 0                                                         AROI  0370
      SYMFCO = 1                                                        AROI  0380
      ISBP = 0                                                          AROI  0390
      IFSCY = 1                                                         AROI  0400
      DELCPC = 0.0                                                      AROI  0410
      CPNIN = 0.0                                                       AROI  0420
      IMPS = IMPACT                                                     AROI  0430
      ISHS = ISHAD                                                      AROI  0440
      ISPNT = 0                                                         AROI  0450
      DELTAS = DELTAE                                                   AROI  0460
      IREDII = 0                                                        AROI  0470
      CF(J) = 0.0                                                       AROI  0480
      SKIN = 0.0                                                        AROI  0490
      IF (IGTYPE.EQ.1 .AND. DELTAE.NE.0.0) IMPACT = 9                   AROI  0500
      IF (IGTYPE.EQ.1 .AND. DELTAE.NE.0.0) ISHAD = 7                    AROI  0510
      IF (IGTYPE.EQ.1 .AND. IMPACI.EQ.0) IMPACI=3                       AROI  0520
      IF (IGTYPE.EQ.1 .AND. ISHADI.EQ.0) ISHADI = 3                     AROI  0530
      IF (DELTAE .EQ. 0.0) IFSCY = 3                                    AROI  0540
      CA  = 0.0                                                         AROI  0550
      CY  = 0.0                                                         AROI  0560
      CN  = 0.0                                                         AROI  0570
      CLL = 0.0                                                         AROI  0580
      CLM = 0.0                                                         AROI  0590
      HML = 0.0                                                         AROI  0600
      HMR = 0.0                                                         AROI  0610
      CLN = 0.0                                                         AROI  0620
      G = 1.4                                                           AROI  0630
      Q = 0.0                                                           AROI  0640
      R = 0.0                                                           AROI  0650
      P = 0.0                                                           AROI  0660
      ROLL = 0.0                                                        AROI  0670
C   SET UP VEHICLE ROTATION RATES IF REQUIRED                           AROI  0680
      IF (IDERIV.EQ.0.OR.IDERIV.EQ.1.OR.IDERIV.EQ.5) Q = QRP            AROI  0690
      IF (IDERIV.EQ.2.OR.IDERIV.EQ.6) R = QRP                           AROI  0700
      IF (IDERIV .EQ. 3) P = QRP                                        AROI  0710
```

FORCE

```
DECK AROI

C                                                                       AROI 0720
C  DETERMINE FREE STREAM PROPERTIES                                     AROI 0730
      IF (PSTAG .GT. 0.0) GO TO 15                                      AROI 0740
C  USE U S 1962 ATMOSPHERE                                              AROI 0750
      CALL ATMOS (ALT,TFS,PFS,AFS,RHOFS)                                AROI 0760
      GO TO 16                                                          AROI 0770
C  USE WIND TUNNEL CONDITIONS  (GAMMA = 1.4) EQ.44,43,29C,26 OF TR 1135 AROI 0780
   15 PFS = PSTAG * (1.0 + (G-1.0)*MACH*MACH/2.)**(-G/(G-1.0))*2116.217 AROI 0790
      TFS = (TSTAG + 459.6) / (1.0 + (G-1.0)*MACH*MACH/2.0)             AROI 0800
      AFS = 49.021177 * SQRT(TFS)                                       AROI 0810
      RHOFS = PFS / (1716.0 * TFS)                                      AROI 0820
   16 IF(TFS.GE.225.0) VIS =2.27*TFS**1.5/((TFS+198.6)*10.0**8)         AROI 0830
      IF(TFS.LT.225.0) VIS =0.80382436E-9 * TFS                         AROI 0840
      V = MACH * AFS                                                    AROI 0850
      RENO = RHOFS * V / VIS                                            AROI 0860
C                                                                       AROI 0870
C                                                                       AROI 0880
C                                                                       AROI 0890
C                                                                       AROI 0900
C*********************************************************************** AROI 0910
C***** START OF LOOP FOR SUMMING UP FORCES ON ELEMENTS            ***** AROI 0920
C*********************************************************************** AROI 0930
   30 L = 0                                                             AROI 0940
   36 L = L + 1                                                         AROI 0950
      IF (L.NE.1)GO TO 2                                                AROI 0960
C                                                                       AROI 0970
C  CALCULATE DIRECTION COSINES OF VELOCITY VECTOR                       AROI 0980
      ALPHAR = RAD(ALPHA)                                               AROI 0990
      BETAR  = RAD(BETA)                                                AROI 1000
      ROLLR = RAD(ROLL)                                                 AROI 1010
      PHIR = 0.0                                                        AROI 1020
      VXI =-V*COS(ALPHAR)*COS(BETAR)                                    AROI 1030
      VYI = V*SIN(BETAR)                                                AROI 1040
      VZI = V*COS(BETAR)*SIN(ALPHAR)                                    AROI 1050
      VX  = VXI                                                         AROI 1060
      VY  = VYI                                                         AROI 1070
```

```
DECK AROI

      VZ  = VZI                                                         AROI  1080
      I4CT = 0                                                          AROI  1090
      IGT = 1                                                           AROI  1100
      CPAVG = 0.0                                                       AROI  1110
      AREAS = 0.0                                                       AROI  1120
C                                                                       AROI  1130
C  SET UP SURFACE ELEMENT DATA                                          AROI  1140
   2  IF (IGTYPE .GT. 0) GO TO 35                                       AROI  1150
      IF (L .GT. ISIZ) GO TO 17                                         AROI  1160
      IF (IMPACT .NE. 16) GO TO 305                                     AROI  1170
      M = IM(L)                                                         AROI  1180
      IF (L .GT. LS) M = 1                                              AROI  1190
      IF (L.EQ.1 .OR. M.GT.1) GO TO 305                                 AROI  1200
C  CALCULATE DATA FOR IMPACT METHOD NUMBER 16                           AROI  1210
      IF (IGT .EQ. 4) GO TO 306                                         AROI  1220
       CPAVG = CPAVG / AREAS                                            AROI  1230
      DELTAR = 0.35                                                     AROI  1240
      L = 0                                                             AROI  1250
 310  L = L + 1                                                         AROI  1260
      EMNS = 1.090909*MACH*SIN(DELTAR) + EXP(-1.090909*MACH*SIN(DELTAR)) AROI  1270
      CP = 2.0*SIN(DELTAR)*SIN(DELTAR) / (1.0-0.25*((EMNS*EMNS+5.0)/    AROI  1280
     1     (6.0*EMNS*EMNS)))                                            AROI  1290
      IF (L .GT. 1) GO TO 312                                           AROI  1300
      DEL1 = DELTAR                                                     AROI  1310
      CP1 = CP                                                          AROI  1320
      DELTAR = DELTAR + 0.05                                            AROI  1330
      GO TO 310                                                         AROI  1340
 312  IF ((ABS(CP-CPAVG).LT.0.0001 ) .OR. L.GT.25) GO TO 313            AROI  1350
      DELT2  = DELTAR - (CP-CPAVG)*(DELTAR-DEL1)/(CP-CP1)               AROI  1360
      IF (DELT2 .GT. 1.5708) DELT2 = 1.57                               AROI  1370
      CP1 = CP                                                          AROI  1380
      DEL1 = DELTAR                                                     AROI  1390
      DELTAR = DELT2                                                    AROI  1400
      GO TO 310                                                         AROI  1410
 313  FINT2 = ((G+1.0)**2 *EMNS*EMNS)/((2.0*G*EMNS*EMNS-(G-1.0))*       AROI  1420
     1          ((G-1.0)*EMNS*EMNS + 2.0))                              AROI  1430
```

```
DECK AROI

      EMCONE=SQRT((2.0/(G-1.0))*(TINT2*(1.0+((G-1.)/2.)*MACH*MACH)-1.0))  AROI  1440
      L = LSAVE                                                           AROI  1450
      IGT = 4                                                             AROI  1460
      M = IM(L)                                                           AROI  1470
      GO TO 305                                                           AROI  1480
  306 IGT = 1                                                             AROI  1490
      CPAVG = 0.0                                                         AROI  1500
      AREAS = 0.0                                                         AROI  1510
  305  NX = NX2(L)                                                        AROI  1520
       NY = NY2(L)                                                        AROI  1530
       NZ = NZ2(L)                                                        AROI  1540
       XCENT = XCENT2(L)                                                  AROI  1550
       YCENT = YCENT2(L)                                                  AROI  1560
       ZCENT = ZCENT2(L)                                                  AROI  1570
       AREA = AREA2(L)                                                    AROI  1580
       N = IN(L)                                                          AROI  1590
       M = IM(L)                                                          AROI  1600
      LL = L                                                              AROI  1610
      GO TO 18                                                            AROI  1620
C                                                                         AROI  1630
   17 IF (IMPACT .NE. 16) GO TO 307                                       AROI  1640
      WRITE (6,308) ISIZ                                                  AROI  1650
  308 FORMAT (1H0,49H****NUMBER OF ELEMENTS FOR IMPACT PRESSURE METHOD    AROI  1660
     1 26H IS CANNOT BE GREATER THEN,I5)                                  AROI  1670
       ERROR = 1                                                          AROI  1680
       GO TO 10                                                           AROI  1690
  307 READ (4) LL,N,M,NX,NY,NZ,XCENT,YCENT,ZCENT,AREA                     AROI  1700
      I4CT = I4CT + 1                                                     AROI  1710
      GO TO 18                                                            AROI  1720
C                                                                         AROI  1730
C  READ CONTROL SURFACE GEOMETRY DATA                                     AROI  1740
   35 IF (IGT .EQ. 1)                                                     AROI  1750
     1READ ( 3)  LL,N,M,NX,NY,NZ,XCENT,YCENT,ZCENT,AREA,XPA,YPA,ZPA,XLE   AROI  1760
      IREDI1 = 0                                                          AROI  1770
      IF (IGTYPE .EQ. 2) GO TO 18                                         AROI  1780
      IF (IGT.EQ.2 .AND. DELTAE.EQ.0.0)                                   AROI  1790
```

```
DECK AROI

      IREAD ( 4)  LL,N,M,NX,NY,NZ,XCENT,YCENT,ZCENT,AREA,XPA,YPA,ZPA,XLE   AROI  1800
       IF (IGT.EQ.2 .AND. DELTAE.NE.0.0)                                     AROI  1810
      IREAD (11)  LL,N,M,NX,NY,NZ,XCENT,YCENT,ZCENT,AREA,XPA,YPA,ZPA,XLE   AROI  1820
       I4CT = I4CT + 1                                                       AROI  1830
       IGTS = IGT                                                            AROI  1840
       IF(IGTS.EQ.1 .AND. I4CT.EQ.IN(N+10)) IGT = 2                          AROI  1850
       IF(IGTS.EQ.2 .AND. I4CT.EQ.IN(4)) IGT = 1                             AROI  1860
       IF (IGT .NE. IGTS) I4CT = 0                                           AROI  1870
C                                                                            AROI  1880
C  CHECK ON SYMMETRY REQUIREMENTS (CHANGE SIGNS IF REQUIRED)                 AROI  1890
  18   IF (SYMFCT.EQ.2 .AND. SYMFCO.EQ.2) GO TO 26                           AROI  1900
       IF (SYMFCT.NE.3) GO TO 27                                             AROI  1910
       GO TO (27,25,26,25), SYMFCO                                           AROI  1920
  25    NZ = -NZ                                                             AROI  1930
        ZCENT = -ZCENT                                                       AROI  1940
       IF (IGTYPE .EQ. 0) GO TO 22                                           AROI  1950
        DO 21 I=1,4                                                          AROI  1960
  21    ZPA(I) = -ZPA(I)                                                     AROI  1970
  22   IF (SYMFCO .NE. 4) GO TO 27                                           AROI  1980
  26    NY = -NY                                                             AROI  1990
        YCENT = -YCENT                                                       AROI  2000
       IF (IGTYPE .EQ. 0) GO TO 27                                           AROI  2010
        DO 29 I=1,4                                                          AROI  2020
  29    YPA(I) =-YPA(I)                                                      AROI  2030
  27   IF (Q.EQ.0.0 .AND. R.EQ.0.0 .AND. P.EQ.0.0) GO TO 19                  AROI  2040
C  CALCULATE VELOCITY COMPONENTS WITH VEHICLE ROTATION                       AROI  2050
       VX = VXI+ (Q*(+ZCENT-ZCG)-R*(+YCENT-YCG))                             AROI  2060
       VY = VYI+ (R*(+XCENT-XCG)+P*(+ZCENT-ZCG))                             AROI  2070
       VZ = VZI- (P*(+YCENT-YCG)+Q*(+XCENT-XCG))                             AROI  2080
C                                                                            AROI  2090
  19   VLOCAL = SQRT(VX*VX + VY*VY + VZ*VZ)                                  AROI  2100
       IF (IRED11 .EQ. 1) GO TO 37                                           AROI  2110
C                                                                            AROI  2120
C  COMPUTE COSINE OF ANGLE BETWEEN UNIT VECTORS                              AROI  2130
       COSDEL =(-NX*VX - NY*VY - NZ*VZ) / VLOCAL                             AROI  2140
       IF (COSDEL.GT.-1.0001 .AND. COSDEL.LT.-1.0   ) COSDEL = -1.0          AROI  2150
```

```
DECK ARO1
      IF (COSDEL.GT. 1.0    .AND. COSDEL.LT. 1.0001) COSDEL =  1.0
      IF (COSDEL.GE.-1.0 .AND. COSDEL.LE.1.0) GO TO 20
      WRITE (6,9)
    9 FORMAT (1H0,44H***** FORCE ROUTINE WILL ATTEMPT TO FIND THE
     162H ARCCOSINE OF AN ARGUMENT WHOSE ABSOLUTE VALUE IS GREATER THAN
     210H ONE *****,/1H ,15X30H*** JOB WILL BE TERMINATED ***  )
      ERROR = 1
      GO TO 10
C
C  COMPUTE ANGLE BETWEEN UNIT VECTORS
   20 THETA = ARCOS(COSDEL)
C
C
C
C  COMPUTE NEWTONIAN IMPACT ANGLE
    8 IF (IMPACT.NE.10 .AND. ENPM.NE.0.0) THETA = THETA / ENPM
      DELTAR = 1.57079627 - THETA
      IF (DELTAR.GT.-0.000001 .AND. DELTAR.LT.0.000001) DELTAR = 0.0
C
C  CALCULATE NEWTONIAN IMPACT ANGLE IN DEGREES
      DELTA = DELTAR * .572957795E+02
      IF (IMPACT.EQ.17 .OR. ISHAD.EQ.10) GO TO 314
      IF (IGTYPE .EQ. 2) GO TO 204
C  CHECK TO SEE IF SURFACE IS IN A SHADOW REGION
  314 IF (DELTAR .LT. 0.0) GO TO 5
C
C
C
C
C***********************************************************************
C*********** SELECT IMPACT PRESSURE METHOD      ************************
C***********************************************************************
      GO TO (41,42,43,44,45,46,47,48,49,50,51,52,53,54,55,45,315),IMPACT
C
C  CALCULATE PRESSURE USING MODIFIED NEWTONIAN THEORY
   41 CP = CPSTAG * COSDEL * COSDEL
```

DECK AROI

```
      GO TO 11                                                          AROI  2520
C                                                                       AROI  2530
C  CALCULATE PRESSURE USING NEWTONIAN - PRANDTL-MEYER METHOD            AROI  2540
   42 IF (PRINT.EQ.1 .AND. IPRINT.EQ.1) IPRCK = 1                       AROI  2550
       ANGLE(2) = DELTA                                                 AROI  2560
       DO 13 I=1,8                                                      AROI  2570
   13   FS(I) = 1.0                                                     AROI  2580
        FS(2) = PFS                                                     AROI  2590
        FS(6) = MACH                                                    AROI  2600
        ISE   = 1                                                       AROI  2610
      CALL NEWTPM (ANGLE,EMN,CP,ETAC,IPRCK,MER,CPSTAG,TFS,              AROI  2620
     1  PFS,ISE,IFIRST)                                                 AROI  2630
      GO TO 11                                                          AROI  2640
C                                                                       AROI  2650
C  CALCULATE PRESSURE USING TANGENT WEDGE                               AROI  2660
   43 IF (PRINT.EQ.1 .AND. IPRINT.EQ.1) IPRCK= 1                        AROI  2670
       ANGLE(2) = DELTA                                                 AROI  2680
       DO 14 I=1,8                                                      AROI  2690
   14   FS(I) = 1.0                                                     AROI  2700
        FS(2) = PFS                                                     AROI  2710
        FS(6) = MACH                                                    AROI  2720
        ISDET = 2                                                       AROI  2730
      CALL COMPR (ANGLE,MER,IPRCK,CPSTAG,TFS,PFS,ISDET,IFIRST,CP)       AROI  2740
      GO TO 11                                                          AROI  2750
C                                                                       AROI  2760
C  CALCULATE PRESSURE USING TANGENT WEDGE - INFINITE MACH METHOD        AROI  2770
   44 EMNS = 1.2*MACH*SIN(DELTAR) + EXP(-0.6 *MACH*SIN(DELTAR))         AROI  2780
      CP = 1.6666667 *(EMNS*EMNS - 1.0)/(MACH*MACH)                     AROI  2790
      GO TO 11                                                          AROI  2800
C                                                                       AROI  2810
C  CALCULATE PRESSURE USING TANGENT CONE EMPIRICAL METHOD               AROI  2820
   45 FS(6) = MACH                                                      AROI  2830
      ANGLE(1) = DELTA                                                  AROI  2840
      CALL CONE (ANGLE,CP,2)                                            AROI  2850
C                                                                       AROI  2860
      IF (IMPACT .NE. 16) GO TO 11                                      AROI  2870
```

FORCE

DECK AROI

```
      IF (IGT .EQ. 1) LSAVE = L                                         AROI  2880
      IF (IGT .EQ. 1) IGT = 3                                           AROI  2890
      IF (IGT .EQ. 4) GO TO 309                                         AROI  2900
      CPAVG = CPAVG + CP*AREA                                           AROI  2910
      AREAS = AREAS + AREA                                              AROI  2920
      GO TO 36                                                          AROI  2930
C  CALCULATE PRESSURE USING MODIFIED TANGENT CONE METHOD                AROI  2940
  309 CP = CP - (CP-CPAVG)/EMCONE                                       AROI  2950
      GO TO 11                                                          AROI  2960
C                                                                       AROI  2970
C  CALCULATE PRESSURE USING OSU EMPIRICAL EQUATION (FDL-TDR-64-102)     AROI  2980
   46 PPT2 = 0.32 + 0.455*COS(THETA) + 0.195*COS(2.0*THETA) +           AROI  2990
     1       0.035*COS(3.0*THETA) - 0.005*COS(4.0*THETA)                AROI  3000
      PT2PO = CPSTAG * 0.7*MACH*MACH + 1.0                              AROI  3010
      CP = (PPT2*PT2PO - 1.0) / (0.7*MACH*MACH)                         AROI  3020
      GO TO 11                                                          AROI  3030
C                                                                       AROI  3040
C  CALCULATE PRESSURE USING VAN DYKE UNIFIED THEORY                     AROI  3050
   47 CP = 1.2*DELTAR*DELTAR + SQRT(1.44*DELTAR**4 + 4.0*DELTAR*DELTAR  AROI  3060
     1    /(MACH*MACH-1.0))                                             AROI  3070
      GO TO 11                                                          AROI  3080
C                                                                       AROI  3090
C  CALCULATE BLUNT BODY VISCOUS EFFECTS                                 AROI  3100
   48 CP = 0.0                                                          AROI  3110
      IVISIN = 1                                                        AROI  3120
C                                                                       AROI  3130
C  THE VISCOUS FORCE COEFFICIENT TAU IS CALCULATED IN                   AROI  3140
C  SUBROUTINE BLUNT, WHICH ONLY NEEDS TO BE CALLED ONCE                 AROI  3150
C  FOR EACH SECTION.                                                    AROI  3160
C                                                                       AROI  3170
      IF (L.EQ.1)CALL BLUNT(PFS,MACH,TFS,VIS,RHOFS,ETAC,RENO,TAU,IVISIN) AROI  3180
      SHEAR = TAU*COS(DELTAR)                                           AROI  3190
      GO TO 203                                                         AROI  3200
C                                                                       AROI  3210
C  CALCULATE PRESSURE USING SHOCK-EXPANSION METHOD                      AROI  3220
   49 CALL SHKEXP (IORIEN,N,M,IPRCK,NX,NY,NZ,DELTA,PFS,MACH,IGTS,       AROI  3230
```

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DECK AROI

     1  DELTAR,IMPACI,CPSTAG,TFS,CP,G,ISHADI,IFIRST,LL,IPRINT,IGTYPE,     AROI  3240
     2  RHOFS,AFS,VIS,V,RENO,O)                                            AROI  3250
      IF (ERROR .EQ. 3) GO TO 10                                           AROI  3260
      GO TO 11                                                             AROI  3270
C                                                                          AROI  3280
C  CALCULATE PRESSURE USING FREE MOLECULAR FLOW                            AROI  3290
  50  FN = CPSTAG                                                          AROI  3300
      FT = ENPM                                                            AROI  3310
      TBTIN = ETAC                                                         AROI  3320
      S = SQRT(G/2.0)*MACH                                                 AROI  3330
      SSIND = S * SIN(DELTAR)                                              AROI  3340
      ERFS = ERF(SSIND)                                                    AROI  3350
      CP =(1.0/(S*S))*(((2.0-FN)/1.7724539*SSIND+FN/2.0*SQRT(TBTIN))*      AROI  3360
     1    EXP(-SSIND*SSIND)) + (((2.0-FN)*(SSIND*SSIND+0.5)+FN/2.0*        AROI  3370
     2    1.7724539*SQRT(TBTIN)*SSIND) * (1.0+ERFS) ))                     AROI  3380
C  CALCULATE SHEAR FORCE COEFFICIENT FOR FREE MOLECULAR FLOW               AROI  3390
      SHEAR = COS(DELTAR)*FT/(1.7724539*S)* (EXP(-SSIND*SSIND)             AROI  3400
     1        +1.7724539*SSIND*(1.0+ERFS))                                 AROI  3410
      SKIN = SHEAR                                                         AROI  3420
 203  TX = NY*VZ - NZ*VY                                                   AROI  3430
      TY = NZ*VX - NX*VZ                                                   AROI  3440
      TZ = NX*VY - NY*VX                                                   AROI  3450
      SX = TY*NZ - TZ*NY                                                   AROI  3460
      SY = TZ*NX - TX*NZ                                                   AROI  3470
      SZ = TX*NY - TY*NX                                                   AROI  3480
      STOTAL = SQRT(SX*SX + SY*SY + SZ*SZ)                                 AROI  3490
      IF (STOTAL .NE. 0.0) GO TO 200                                       AROI  3500
       SHEARX = 0.0                                                        AROI  3510
       SHEARY = 0.0                                                        AROI  3520
       SHEARZ = 0.0                                                        AROI  3530
      IF (IGTYPE .EQ. 2) GO TO 201                                         AROI  3540
       GO TO 11                                                            AROI  3550
 200  SHEARX = SHEAR * SX / STOTAL                                         AROI  3560
      SHEARY = SHEAR * SY / STOTAL                                         AROI  3570
      SHEARZ = SHEAR * SZ / STOTAL                                         AROI  3580
      IF (IGTYPE .EQ. 2) GO TO 201                                         AROI  3590
```

FORCE

DECK AROI

```
      GO TO 11
C
C  SET PRESSURE COEFFICIENT TO INPUT VALUE
   51 CP = CPSTAG
      GO TO 11
C
C
C  CALCULATE PRESSURE USING HANKEY FLAT SURFACE EMPIRICAL CORRELATION
   52 IF (DELTA .GE. 10.0) GO TO 56
      HANKEY= (0.195+0.222594/MACH**0.3-0.4)*DELTA + 4.0
      GO TO 57
   56 HANKEY= 1.95 + 0.3925/(MACH**0.3*TAN(DELTAR))
   57 CP = HANKEY* COSDEL*COSDEL
      GO TO 11
C
C  CALCULATE PRESSURE USING DELTA WING CORRELATION (SMYTH)
   53 DELDLW = DELTAR
      IF (DELDLW .LT. 0.01745) DELDLW = 0.01745
      EMNS = MACH * SIN(DELDLW)
      EMNS = 1.09*EMNS + EXP(-0.49 *EMNS)
      CP = 1.0/(MACH*MACH) * 1.66667*(EMNS*EMNS-1.0)
      GO TO 11
C
C  CALCULATE PRESSURE USING DAHLEM-BUCK RELATIONSHIP
   54 IF (DELTAR .EQ. 0.0) DELTAR = 0.00001
      CP = 1.0 / (ABS(SIN(4.0*DELTAR)))**0.75 + 1.0
      IF (CP .GT. 5.0) CP = 5.0
      IF (CP.LT.2.0 .OR. (DELTA.GT.22.5)) CP = 2.0
      CP = CP * COSDEL*COSDEL
      GO TO 11
C
C  CALCULATE PRESSURE USING BLAST WAVE ANALYSIS
   55 IF (CPSTAG .GT. 0.5) GO TO 300
      CP = (0.067*MACH*MACH*ETAC/(ENPM-XCENT) + 0.44 )
     1    / (G/2.0*MACH*MACH)
      GO TO 11
```

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DECK AROI

 300  CP = (0.121*MACH*MACH*ETAC/(ENPM-XCENT)**.667 + 0.56 )              AROI  3960
     1    /(G/2.0*MACH*MACH)                                              AROI  3970
      GO TO 11                                                            AROI  3980
C                                                                         AROI  3990
C*********************************************************************** AROI  4000
C****************   SELECT SHADOW PRESSURE METHOD   ******************** AROI  4010
C*********************************************************************** AROI  4020
   5  GO TO (61,62,63,64,65,66,49,67,50,315),ISHAD                        AROI  4030
C                                                                         AROI  4040
C  CALCULATE PRESSURE IN SHADOW REGIONS                                   AROI  4050
C                                                                         AROI  4060
C  CALCULATE PRESSURE USING CP=0 IN SHADOW REGIONS                        AROI  4070
  61  CP = 0.0                                                            AROI  4080
      GO TO 11                                                            AROI  4090
C                                                                         AROI  4100
C  CALCULATE PRESSURE USING NEWTONIAN - PRANDTL-MEYER                     AROI  4110
  62  IF (PRINT.EQ.1 .AND. IPRINT.EQ.1) IPRCK = 1                         AROI  4120
      ANGLE(2) = DELTA                                                    AROI  4130
      DO 23 I=1,8                                                         AROI  4140
  23   FS(I) = 1.0                                                        AROI  4150
       FS(2) = PFS                                                        AROI  4160
       FS(6) = MACH                                                       AROI  4170
       ISE   = 1                                                          AROI  4180
      CALL NEWTPM (ANGLE,EMN,CP,ETAC,IPRCK,MER,CPSTAG,TFS,                AROI  4190
     1   PFS,ISE,IFIRST )                                                 AROI  4200
      GO TO 11                                                            AROI  4210
C                                                                         AROI  4220
C  CALCULATE PRESSURE USING PRANDTL-MEYER EXPANSION FROM FREE STREAM      AROI  4230
  63  ANGLE(2) = ABS(DELTA)                                               AROI  4240
      DO 24 I=1,8                                                         AROI  4250
  24   FS(I) = 1.0                                                        AROI  4260
       FS(2) = PFS                                                        AROI  4270
       FS(6) = MACH                                                       AROI  4280
       ISDET = 2                                                          AROI  4290
      CALL EXPAND (ANGLE,MER,IPRCK,ISDET,CP)                              AROI  4300
       GO TO 11                                                           AROI  4310
```

FORCE

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DECK AROI

C                                                                         AROI   4320
C   CALCULATE PRESSURE USING OSU EMPIRICAL EQUATION                       AROI   4330
  64  PPT2 = 0.32 + 0.455*COS(THETA) + 0.195*COS(2.0*THETA) +             AROI   4340
     1        0.035*COS(3.0*THETA) - 0.005*COS(4.0*THETA)                 AROI   4350
      PT2PO = CPSTAG * 0.7*MACH*MACH + 1.0                                AROI   4360
      CP = (PPT2*PT2PO - 1.0) / (0.7*MACH*MACH)                           AROI   4370
      GO TO 11                                                            AROI   4380
C                                                                         AROI   4390
C   CALCULATE PRESSURE USING VAN DYKE UNIFIED THEORY                      AROI   4400
  65  CP =(1.42857/(MACH*MACH-1.0))* ((1.0-0.2*SQRT(MACH*MACH-1.0)*       AROI   4410
     1    ABS(DELTAR))**7 - 1.0)                                          AROI   4420
      IF (CP.LT. (-1./(MACH*MACH))) CP = -1.0/(MACH*MACH)                 AROI   4430
      GO TO 11                                                            AROI   4440
C                                                                         AROI   4450
C   CALCULATE PRESSURE USING BASE PRESSURE RELATIONSHIP (CP --1/M**2)     AROI   4460
  66  CP = - 1.0 / (MACH*MACH)                                            AROI   4470
      GO TO 11                                                            AROI   4480
C                                                                         AROI   4490
C   SET PRESSURE COEFFICIENT TO INPUT VALUE                               AROI   4500
  67  CP = ETAC                                                           AROI   4510
      GO TO 11                                                            AROI   4520
C                                                                         AROI   4530
C   DETERMINE INDUCED PRESSURE INCREMENT                                  AROI   4540
 315  NS = L                                                              AROI   4550
      IGTYPE = 17                                                         AROI   4560
      CALL SKINFR (ALPHA,CA,SREF,SHEAR,NS,ALT,MACH,CPSTAG,TFS,PFS,AFS,    AROI   4570
     1  RHOFS,IFIRST,VIS,ISIZ,CN,IGTYPE,DELTA)                            AROI   4580
      IF (SURF(NS,1) .GT. 0.00001) AREA = SURF(NS,1)                      AROI   4590
      CP = SHEAR / (G/2.0 * MACH*MACH) * QQINF                            AROI   4600
      GO TO 201                                                           AROI   4610
  11  CONTINUE                                                            AROI   4620
      IF (IMPACT.EQ.16 .AND. IGT.EQ.3) GO TO 36                           AROI   4630
C                                                                         AROI   4640
C ***  GO TO FLOW SEPARATION SUBROUTINE IF REQUIRED  ****                 AROI   4650
      IF (IGTYPE.EQ.1 .AND. DELTAS.NE.0.0)                                AROI   4660
     1 CALL FLOSEP (IGT,LL,N,M,NX,NY,NZ,XCENT,YCENT,ZCENT,AREA,XPA,       AROI   4670
```

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DECK AROI

      2     YPA,ZPA,IGTYPE,IORIEN,IPRCK,DELTA,PFS,MACH,DELTAR,IMPACI,
      3    CPSTAG,TFS,CP,G,ISHADI,IFIRST,ISBP,IFSCY,IGTS,IMPS,
      4    ISHS,L,XLE,DELTAE,SWEEP,CPNIN,DELCPC,XATACH,XSEPP,ISPNT,
      5    IMPACT,ISHAD,RETRAN,NW,TWALL,IREDI1)
       IF (ERROR .NE. 0) GO TO 10
       IF (IREDI1 .EQ. 1) GO TO 18
C
C  CORRECT CP FOR LOCAL Q
  37  CP = CP * QQINF * VLOCAL*VLOCAL / (V*V)
C
C  CALCULATE SKIN FRICTION IF REQUIRED
 204  IF (IGTYPE .NE. 2) GO TO 201
      NS = L
      CALL SKINFR (ALPHA,CA,SREF,SHEAR,NS,ALT,MACH,CPSTAG,TFS,PFS,AFS,
     1  RHOFS,IFIRST,VIS,ISIZ,CN,IGTYPE,DELTA)
      IF (SURF(NS,1) .GT. 0.00001) AREA = SURF(NS,1)
      SHEAR = SHEAR * QQINF
      CP = 0.0
      GO TO 203
C
C**********************************************************************
C******* PRESSURE CALCULATION PART OF PROGRAM HAS BEEN COMPLETED *******
C**********************************************************************
C
 201  IF (ISBP .EQ. 1) GO TO 4
C
C
C  SELECT FORCE METHOD TO MEET SYMMETRY REQUIREMENTS
      IF (SYMFCT .EQ. 1) GO TO 6
      IF (R.NE.0.0 .OR. P.NE.0.0) GO TO 6
      IF (BETA.EQ.0.0 .AND. ROLL.EQ.0.0) GO TO 28
C
C  CALCULATE SIX-COMPONENT FORCE CONTRIBUTIONS OF ELEMENT
   6  DELCA = NX    * (CP*AREA/SREF)
      DELCY = NY    * (CP*AREA/SREF)
      DELCN =-NZ    * (CP*AREA/SREF)
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DECK AROI

      IF (IMPACT.EQ.17 .OR. ISHAD.EQ.10) GO TO 110                      AROI  5040
      IF (IGTYPE .EQ. 2) GO TO 113                                      AROI  5050
      IF (IMPACT.EQ.8 .AND. DELTAR.GE.0.0) GO TO 113                    AROI  5060
      IF ((IMPACT.EQ.10.AND.DELTAR.GE.0.0) .OR.                         AROI  5070
     1    (ISHAD.EQ.9.AND.DELTAR.LT.0.0)) GO TO 113                     AROI  5080
      GO TO 110                                                         AROI  5090
  113 DELCA = DELCA - SHEARX *(AREA/SREF)                               AROI  5100
      DELCY = DELCY - SHEARY *(AREA/SREF)                               AROI  5110
      DELCN = DELCN + SHEARZ *(AREA/SREF)                               AROI  5120
 110  DELCLL= DELCY * (ZCENT - ZCG)/SPAN                                AROI  5130
     1        +DELCN * (YCENT - YCG)/SPAN                               AROI  5140
      DELCLM= DELCN * (XCENT - XCG)/MAC                                 AROI  5150
     1        +DELCA * (ZCENT - ZCG)/MAC                                AROI  5160
      DELCLN= DELCY * (XCENT - XCG)/SPAN                                AROI  5170
     1        -DELCA * (YCENT - YCG)/SPAN                               AROI  5180
      GO TO 7                                                           AROI  5190
  28  DELCA = NX    * (CP*AREA/SREF) * 2.0                              AROI  5200
      DELCY =  0.0                                                      AROI  5210
      DELCN =-NZ    * (CP*AREA/SREF) * 2.0                              AROI  5220
      IF (IMPACT.EQ.17 .OR.ISHAD.EQ.10) GO TO 111                       AROI  5230
      IF (IGTYPE .EQ. 2) GO TO 114                                      AROI  5240
      IF (IMPACT.EQ.8 .AND. DELTAR.GE.0.0) GO TO 114                    AROI  5250
      IF ((IMPACT.EQ.10.AND.DELTAR.GE.0.0) .OR.                         AROI  5260
     1    (ISHAD.EQ.9.AND.DELTAR.LT.0.0)) GO TO 114                     AROI  5270
       GO TO 111                                                        AROI  5280
 114  DELCA = DELCA - SHEARX * 2.0*(AREA/SREF)                          AROI  5290
      DELCN = DELCN + SHEARZ * 2.0*(AREA/SREF)                          AROI  5300
 111  DELCLL = 0.0                                                      AROI  5310
      DELCLM=(DELCN * (XCENT - XCG) / MAC                               AROI  5320
     1        +DELCA * (ZCENT - ZCG) / MAC )                            AROI  5330
      DELCLN=  0.0                                                      AROI  5340
C                                                                       AROI  5350
C  SUM UP SIX-COMPONENT FORCE CONTRIBUTIONS                             AROI  5360
    7 CA = CA + DELCA                                                   AROI  5370
      CY = CY + DELCY                                                   AROI  5380
      CN = CN + DELCN                                                   AROI  5390
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DECK AROI

      CLL = CLL + DELCLL                                                AROI  5400
      CLM = CLM + DELCLM                                                AROI  5410
      CLN = CLN + DELCLN                                                AROI  5420
      AREAT = AREAT + AREA                                              AROI  5430
      IF ((IGTYPE.NE.1 .AND. IGTYPE.NE.3) .OR. ((IGTYPE.EQ.1 .OR.       AROI  5440
     1 IGTYPE.EQ.3) .AND. (IGTS.EQ.1))) GO TO 70                        AROI  5450
      IHM = LL - IN(1)                                                  AROI  5460
      HMFCT = XCENT2(IHM)                                               AROI  5470
      DELTHM = HMFCT * CP * G/2.0 *MACH*MACH * PF5                      AROI  5480
      IF (SYMFCO .EQ. 1) HML = HML + DELTHM                             AROI  5490
      IF (SYMFCO .EQ. 2) HMR = HMR + DELTHM                             AROI  5500
   70 IF (PRINT .EQ. 0) GO TO 4                                         AROI  5510
C                                                                       AROI  5520
C  CHECK IF THIS IS A SKIN FRICTION SURFACE.                            AROI  5530
      IF (NS.EQ.0 .OR. IMPACT.EQ.17 .OR. ISHAD.EQ.10) GO TO 71          AROI  5540
C                                                                       AROI  5550
C  SKIN FRICTION SURFACE.  CHECK IF TEMP. ITERATIONS TO BE PRINTED.     AROI  5560
      IF (IS(L,9).EQ.1) GO TO 72                                        AROI  5570
C                                                                       AROI  5580
C  CHECK IF DETAIL AND/OR LOCAL CF DATA TO BE PRINTED.                  AROI  5590
      IF ((IS(L,7).EQ.0).AND.(IS(L,9).EQ.0)) GO TO 71                   AROI  5600
C                                                                       AROI  5610
C  DETAIL AND/OR LOCAL CF DATA TO BE PRINTED.  WRITE ELEMENT DATA       AROI  5620
C  HEADING FOR FIRST SURFACE PER PAGE ONLY.                             AROI  5630
      IF (NPRT - 26) 72,72,73                                           AROI  5640
   72 NPRT = NPRT + 11                                                  AROI  5650
      GO TO 74                                                          AROI  5660
   73 NPRT = NPRT + 3                                                   AROI  5670
      GO TO 12                                                          AROI  5680
C                                                                       AROI  5690
C  CHECK TO PRINT HEADER AT TOP OF PAGE                                 AROI  5700
   71 IF (NPRT.GE.NPCK) GO TO 3                                         AROI  5710
       NPRT = NPRT + 1                                                  AROI  5720
       GO TO 12                                                         AROI  5730
    3 NPRT = 0                                                          AROI  5740
      CALL HEADER                                                       AROI  5750
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DECK ARO1

   74 CONTINUE                                                                 ARO1  5760
      WRITE (6,102) MACH,ALT,SREF,SPAN,IMPACT,IMPACI,                          ARO1  5770
     1  XCG,YCG,ZCG,MAC,ISHAD,ISHADI                                           ARO1  5780
  102 FORMAT (1H0,20HELEMENT DATA   MACH=F7.3,7H  ALT =F8.0,9H  S REF =        ARO1  5790
     1 F8.1,8H  SPAN =F7.1,10H  IMPACT =I3,10H  IMPACI =I3,/1H ,               ARO1  5800
     2 15X5HXCG =F7.1,7H  YCG =F7.1,10H    ZCG  =F7.1,4X9HMAC =F7.1,           ARO1  5810
     3 10H   ISHAD =I3,10H  ISHADI =I3)                                        ARO1  5820
      WRITE (6,100) ALPHA,BETA,CPSTAG,ETAC,DELTAS,IDERIV,Q,R,P                 ARO1  5830
  100 FORMAT (1H ,5X17HANGLE OF ATTACK =F6.2,3X11HYAW ANGLE =F6.2,             ARO1  5840
     1  3X3HK =      F8.5,3X6HETAC =F8.4,3X,9HDELTA E =F6.2,/1H ,              ARO1  5850
     2  5X8HIDERIV =I3,3X3HQ =E12.5,3X,3HR =E12.5,3X3HP =E12.5,/               ARO1  5860
     3  1H0,2X,1HL,6X,6HDEL CA,8X                                              ARO1  5870
     4  6HDEL CY,8X6HDEL CN,7X7HDEL CLL,7X7HDEL CLM,7X7HDEL CLN,7X2HCF,        ARO1  5880
     5  13X4HAREA,/1H ,11X2HCA,12X2HCY,12X2HCN,11X3HCLL,11X3HCLM,              ARO1  5890
     6  12X3HCLN,8X5HDELTA )                                                   ARO1  5900
                                                                               ARO1  5910
C  PRINT ELEMENT DATA                                                          ARO1  5920
   12 WRITE (6,101)LL,DELCA,DELCY,DELCN,DELCLL,DELCLM,DELCLN,CP,AREA,          ARO1  5930
     1  CA,CY,CN,CLL,CLM,CLN,DELTA                                             ARO1  5940
  101 FORMAT (1H0,I4,8E14.5,/1H ,4X7E14.5  )                                   ARO1  5950
      IF (IGTYPE .NE. 1 .AND. IGTYPE .NE. 3) GO TO 4                           ARO1  5960
      WRITE (6,103) DELCPC,CPNIN,HML,HMR                                       ARO1  5970
  103 FORMAT (1H ,7X,18HDELTA CP CONTROL =F12.5,19H  FORCE METHOD CP =         ARO1  5980
     1  E12.5,13H  H.M. (+Y) =E12.5,13H  H.M. (-Y) =E12.5)                     ARO1  5990
      IF (ISPNT .EQ. 1) WRITE (6,104) XSEPP                                    ARO1  6000
  104 FORMAT (1H ,4X,34H******* FLOW HAS SEPARATED AT  X =E12.5)               ARO1  6010
      IF (ISPNT .EQ. 2) WRITE (6,105) XATACH                                   ARO1  6020
  105 FORMAT (1H ,4X,34H******* FLOW HAS ATTACHED AT   X =E12.5)               ARO1  6030
      NPCK = 9                                                                 ARO1  6040
C                                                                              ARO1  6050
C  END OF MAJOR LOOP TO SUM UP ELEMENT FORCES                                  ARO1  6060
    4 IF (L .LT. LS) GO TO 36                                                  ARO1  6070
      IF (IGTYPE.EQ.1 .AND. IFSCY.NE.3) GO TO 30                               ARO1  6080
C                                                                              ARO1  6090
C  SYMMETRY RE-CYCLE CONTROL                                                   ARO1  6100
      IF (SYMFCT.EQ.1) GO TO 33                                                ARO1  6110
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DECK AROI

      IF (SYMFCT.EQ.3 .AND. SYMFCO.EQ.1) GO TO 31                       AROI  6120
      IF (R.NE.0.0 .OR. P.NE.0.0) GO TO 31                              AROI  6130
      IF (BETA.EQ.0.0 .AND. ROLL.EQ.0.0) GO TO 33                       AROI  6140
   31 IF (SYMFCT.EQ.2 .AND. SYMFCO.EQ.2) GO TO 33                       AROI  6150
      IF (SYMFCO.EQ.4) GO TO 33                                         AROI  6160
C  SET UP FOR RE-CYCLE                                                  AROI  6170
      SYMFCO = SYMFCO + 1                                               AROI  6180
      IF (IGTYPE .EQ. 0) GO TO 39                                       AROI  6190
      IF (IGTYPE .NE. 1) GO TO 40                                       AROI  6200
      IF (DELTAS .NE. 0.0) IFSCY = 1                                    AROI  6210
       IMPACT = 9                                                       AROI  6220
       ISHAD  = 7                                                       AROI  6230
   40 REWIND 3                                                          AROI  6240
      REWIND 4                                                          AROI  6250
      REWIND 11                                                         AROI  6260
      GO TO 30                                                          AROI  6270
   39 IF (LS.LE.ISIZ) GO TO 30                                          AROI  6280
      DO 32 L=1,14CT                                                    AROI  6290
   32 BACKSPACE 4                                                       AROI  6300
      GO TO 30                                                          AROI  6310
   33 CONTINUE                                                          AROI  6320
C                                                                       AROI  6330
C  CALL SKIN FRICTION ROUTINE                                           AROI  6340
      IF (NS.EQ.0 .OR. IGTYPE.EQ.2) GO TO 112                           AROI  6350
      CALL SKINFR (ALPHA,CA,SREF,SKIN,NS,ALT,MACH,CPSTAG,TFS,PFS,AFS,   AROI  6360
     1  RHOFS,IFIRST,VIS,ISIZ,CN,IGTYPE,DELTA)                          AROI  6370
C                                                                       AROI  6380
C                                                                       AROI  6390
C                                                                       AROI  6400
C  SET UP ARRAYS OF DATA TO BE PRINTED                                  AROI  6410
  112 ALP(J)   = ALPHA                                                  AROI  6420
      BET(J)   = BETA                                                   AROI  6430
      CCA(J)    = CA + CAI                                              AROI  6440
      CCY(J)    = CY + CYI                                              AROI  6450
      CCN(J)    = CN + CNI                                              AROI  6460
      CCLL(J)   = CLL+ CLLI                                             AROI  6470
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FORCE

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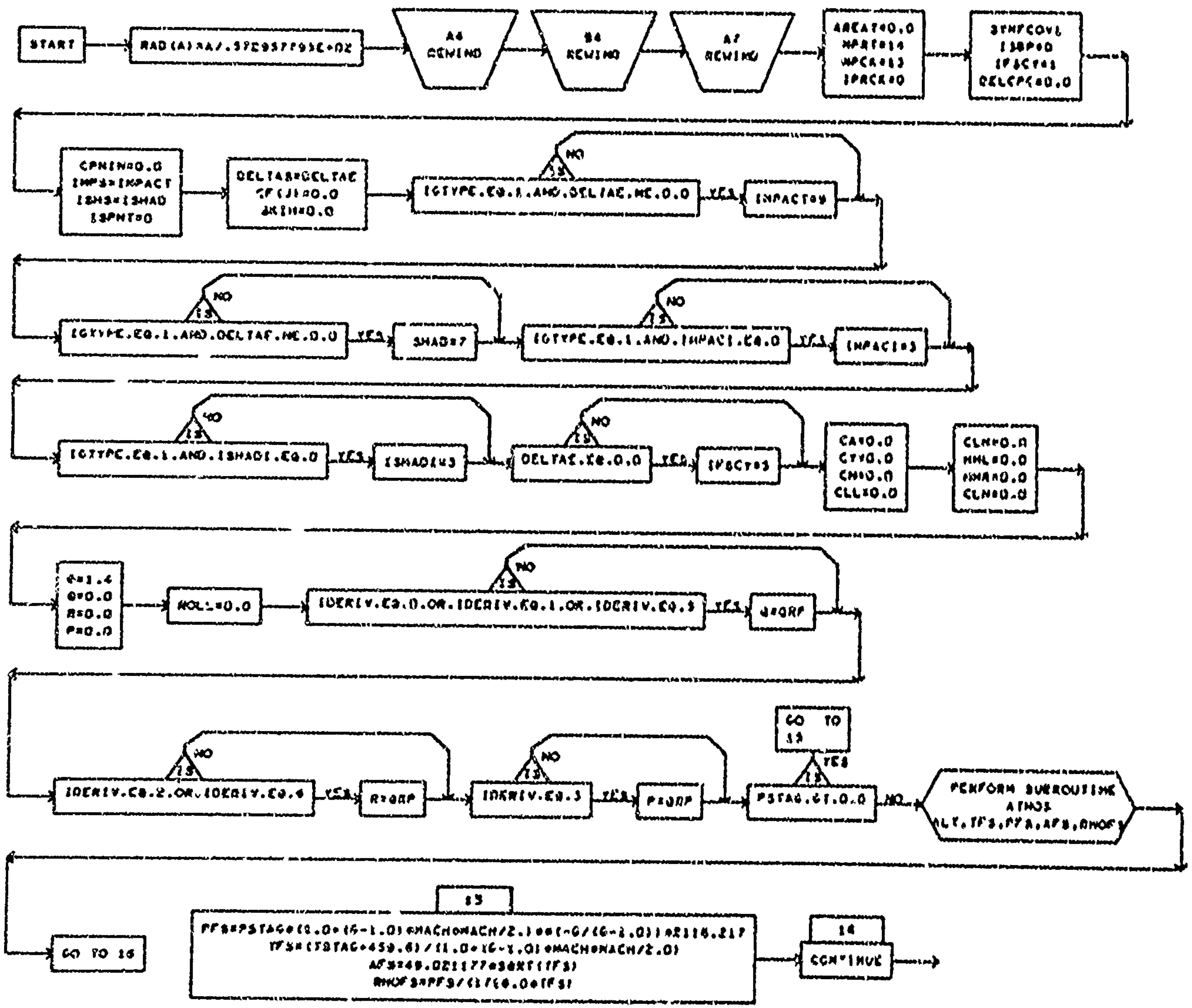
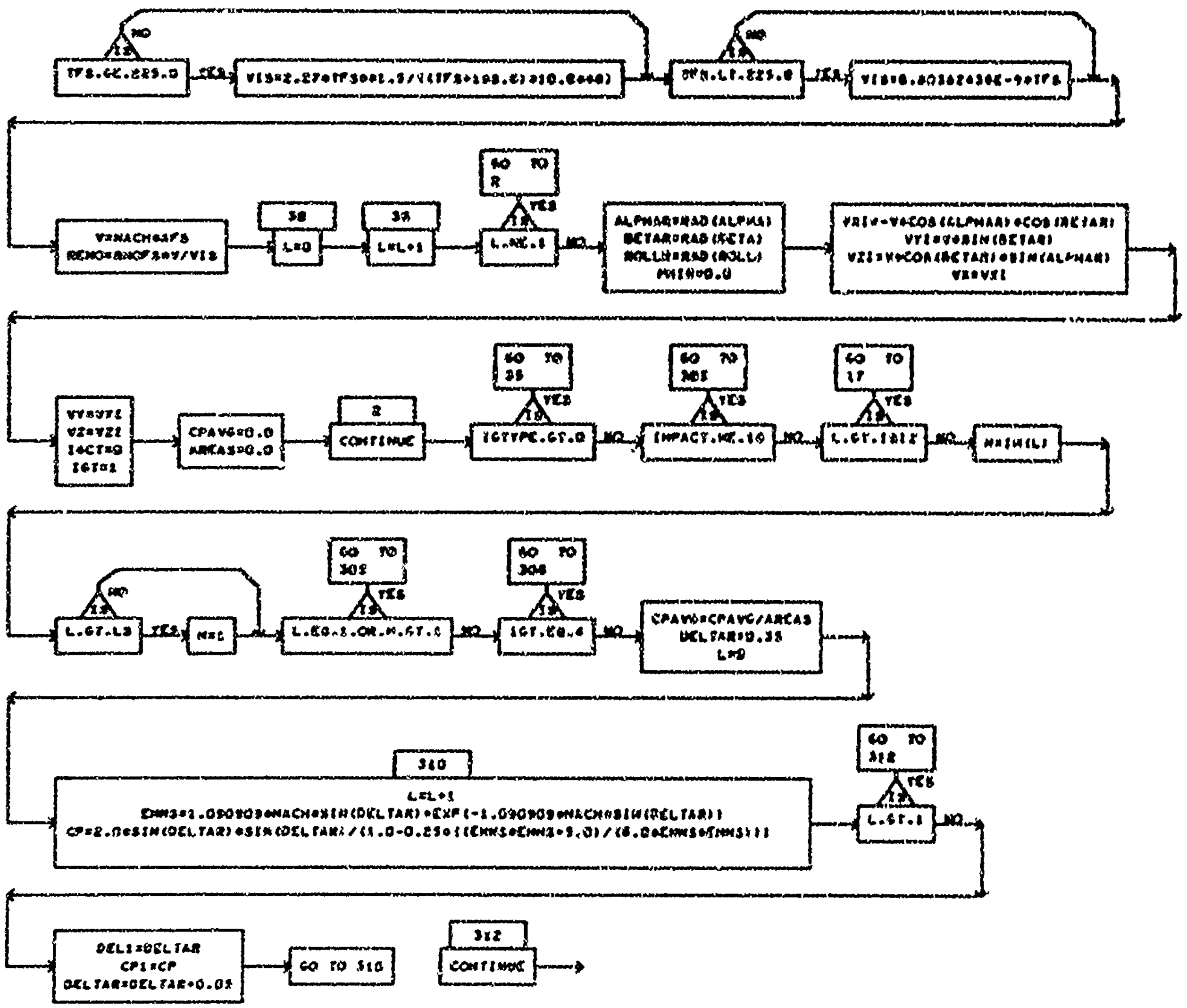
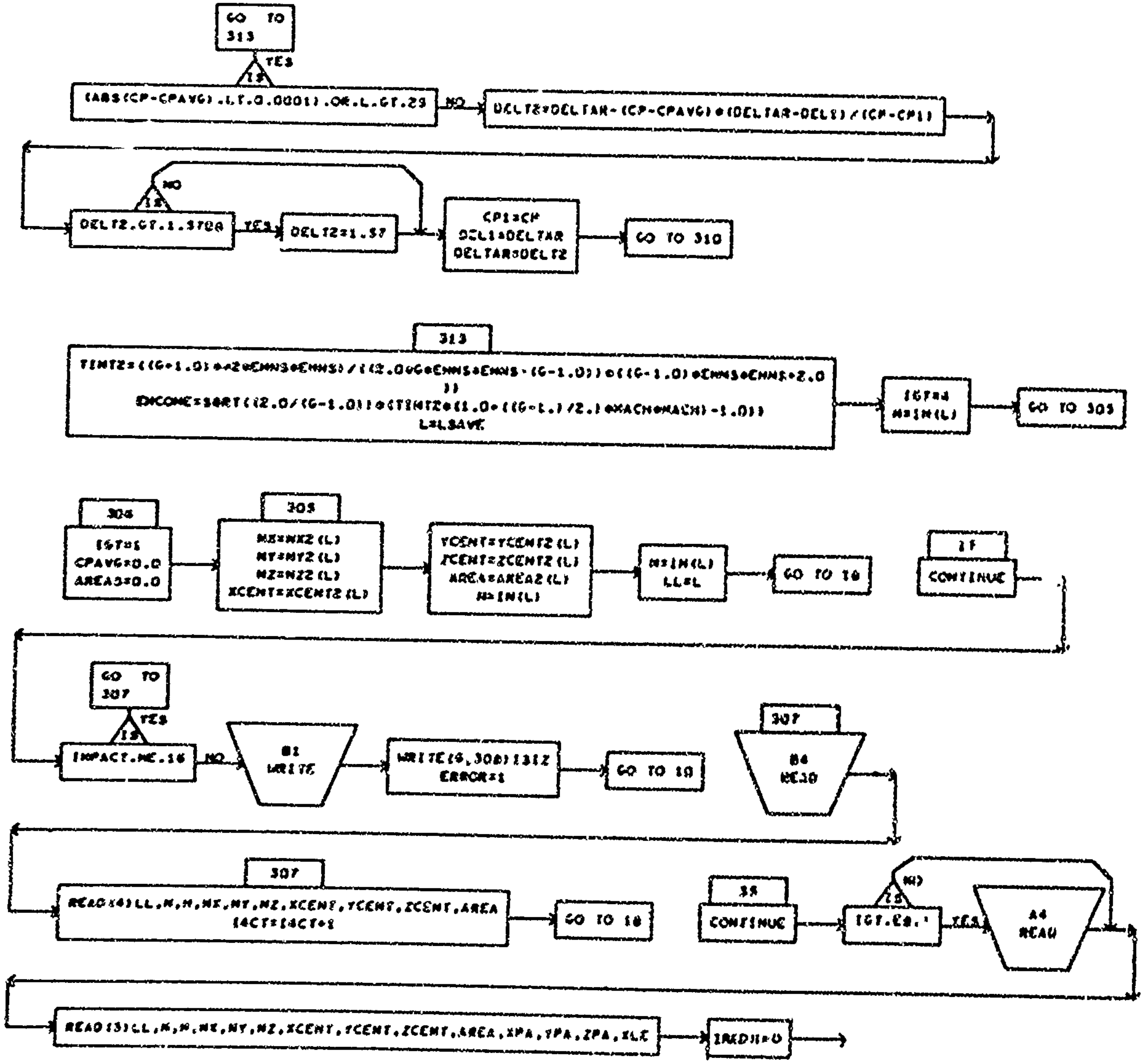
DFCK AROI

      CCLM(J)   = CLM+ CLMI                                          AROI  6480
      CCLN(J)   = CLN+ CLNI                                          AROI  6490
C  RESOLVE NORMAL AND AXIAL FORCES IN LIFT AND DRAG DIRECTION         AROI  6500
      CD = CCA(J)*COS(ALPHAR)*COS(BETAR) - CCY(J)*SIN(BETAR)         AROI  6510
     1    +CCN(J)*SIN(ALPHAR)*COS(BETAR)                             AROI  6520
      CYPRIM = CCA(J)*COS(ALPHAR)*SIN(BETAR) + CCY(J)*COS(BETAR)     AROI  6530
     1         +CCN(J)*SIN(ALPHAR)*SIN(BETAR)                        AROI  6540
      CL = -CCA(J)*SIN(ALPHAR) + CCN(J)*COS(ALPHAR)                  AROI  6550
C  CALCULATE LIFT-DRAG RATIO                                         AROI  6560
      IF (CD .EQ. 0.0) CD = 0.000001                                 AROI  6570
      LOVERD = CL/CD                                                 AROI  6580
      CCL(J)   = CL                                                  AROI  6590
      CCD(J)   = CD                                                  AROI  6600
      CLOD(J)  = LOVERD                                              AROI  6610
      CPS(J)   = CPSTAG                                              AROI  6620
      QQINFS(J)=QQINF                                                AROI  6630
C                                                                    AROI  6640
C                                                                    AROI  6650
   10 RETURN                                                         AROI  6660
      END                                                            AROI  6670
```

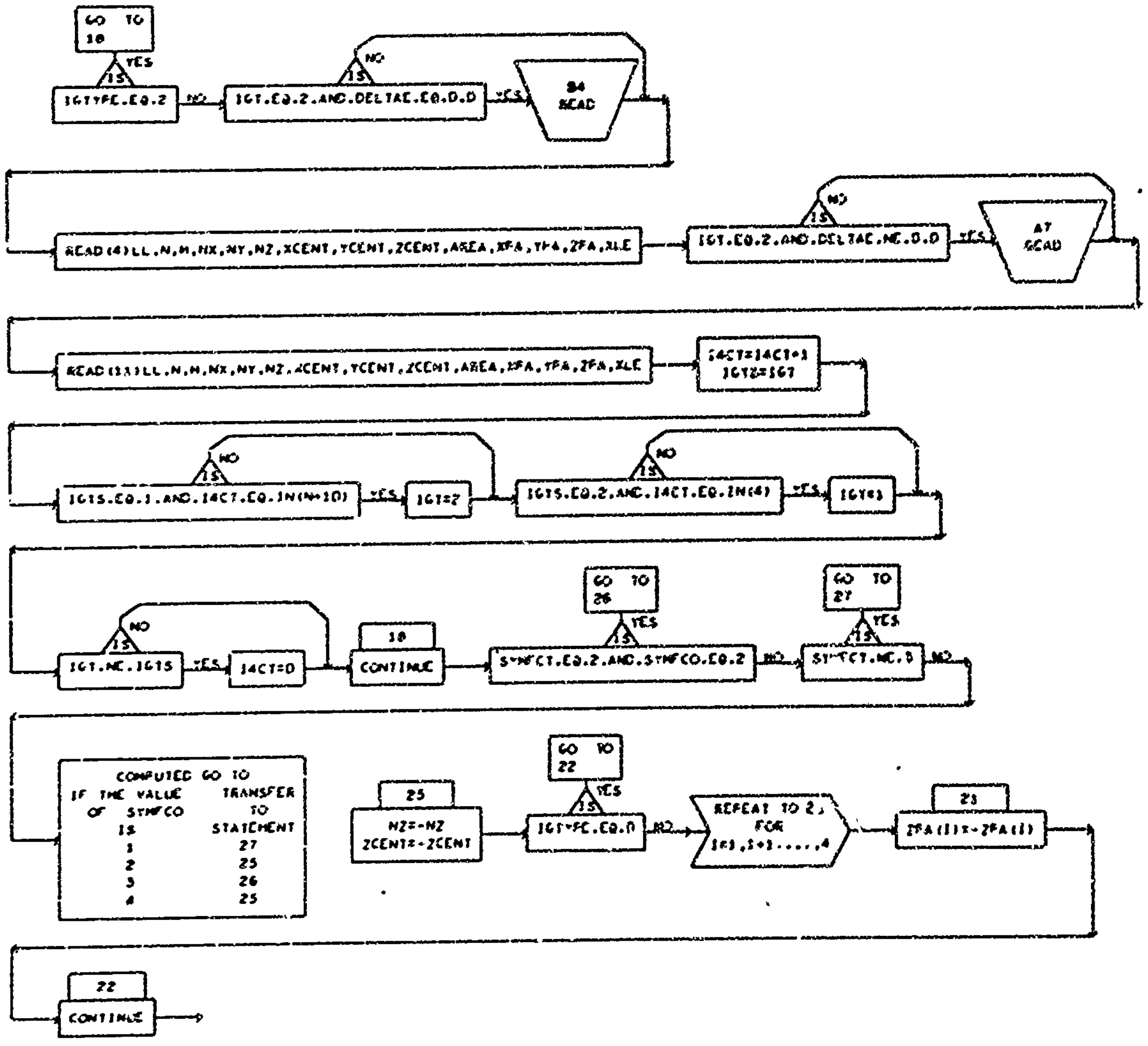
SUBROUTINE FORCE

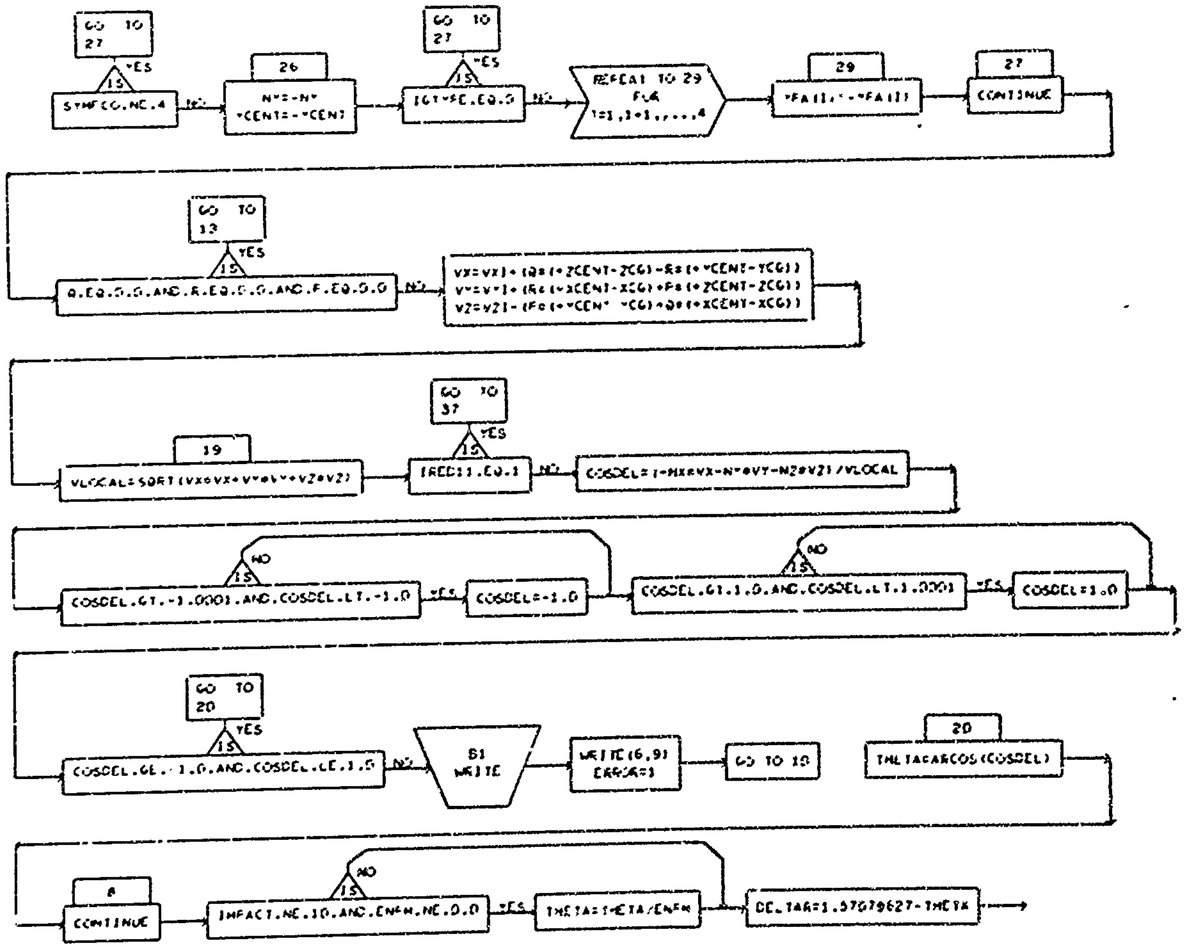


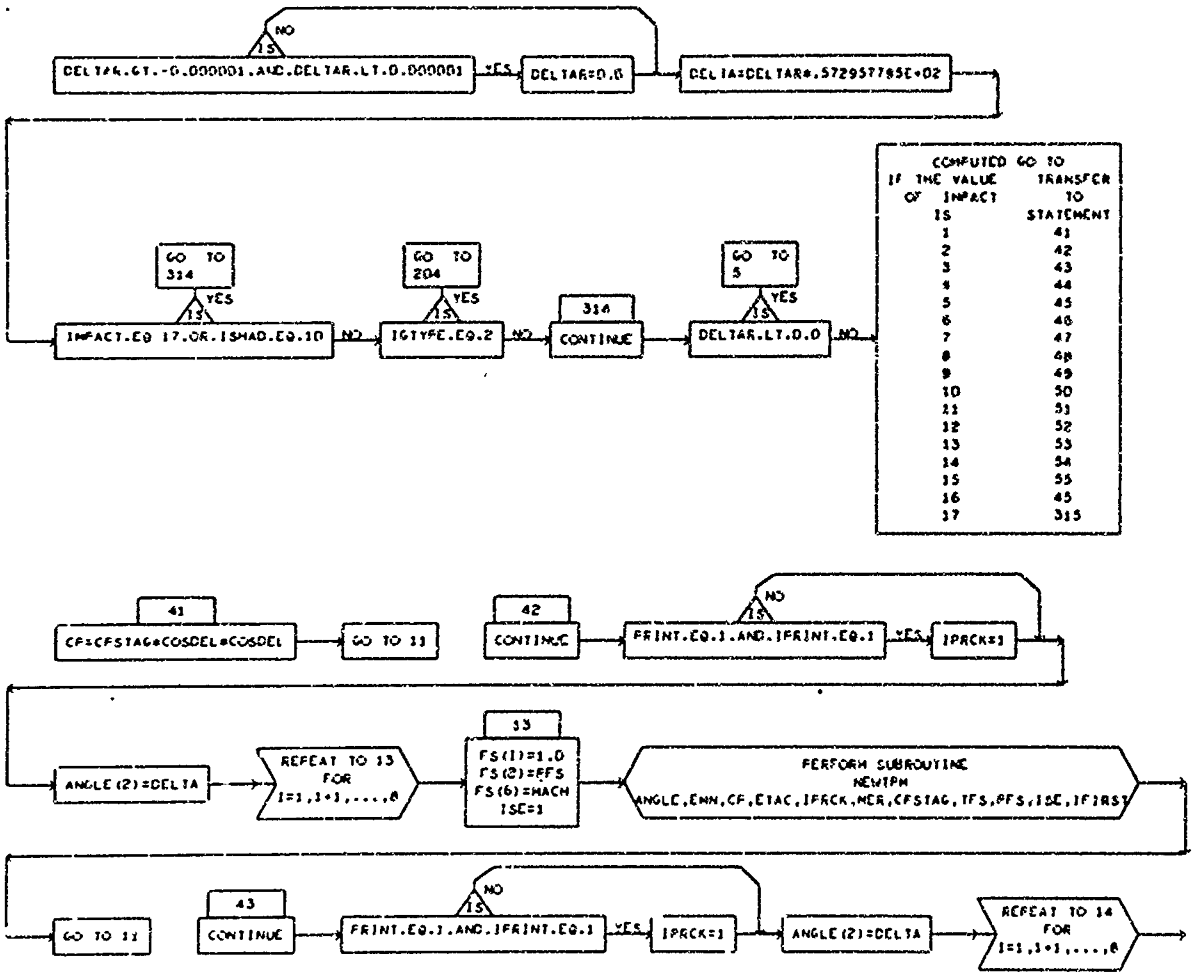

TFS.GE.225.0
IS
NO
YES
VIS=2.27*TFS**1.5/((TFS+198.6)*10.0**8)
TFS.LT.225.0
IS
NO
YES
VIS=8.0382436E-9*TFS
V=MACH*AFS
RENO=RHOFS*V/VIS
38
L=0
39
L=L+1
L.NE.1
IS
YES
GO TO 2
NO
ALPHAR=RAD(ALPHA)
BETAR=RAD(BETA)
ROLLR=RAD(ROLL)
PHI=0.0
VXI=-V*COS(ALPHAR)*COS(BETAR)
VYI=V*SIN(BETAR)
VZI=V*COS(BETAR)*SIN(ALPHAR)
VX=VXI
VY=VYI
VZ=VZI
ICT=0
IGT=1
CPAVG=0.0
AREAS=0.0
2
CONTINUE
IGTYPE.GT.0
IS
YES
GO TO 35
NO
IMPACT.NE.10
IS
YES
GO TO 305
NO
L.GT.IBIZ
IS
YES
GO TO 17
NO
M=IM(L)
L.GT.L3
IS
NO
YES
M=1
L.EQ.1.OR.M.GT.0
IS
YES
GO TO 305
NO
IGT.EQ.4
IS
YES
GO TO 306
NO
CPAVG=CPAVG/AREAS
DELTAR=0.35
L=0
310
L=L+1
EMNS=1.090909*MACH*SIN(DELTAR)+EXP(-1.090909*MACH*SIN(DELTAR))
CP=2.0*SIN(DELTAR)*SIN(DELTAR)/(1.0-0.25*((EMNS*EMNS+3.0)/(8.0*EMNS*EMNS)))
L.GT.1
IS
YES
GO TO 312
NO
DEL1=DELTAR
CP1=CP
DELTAR=DELTAR+0.05
GO TO 310
312
CONTINUE

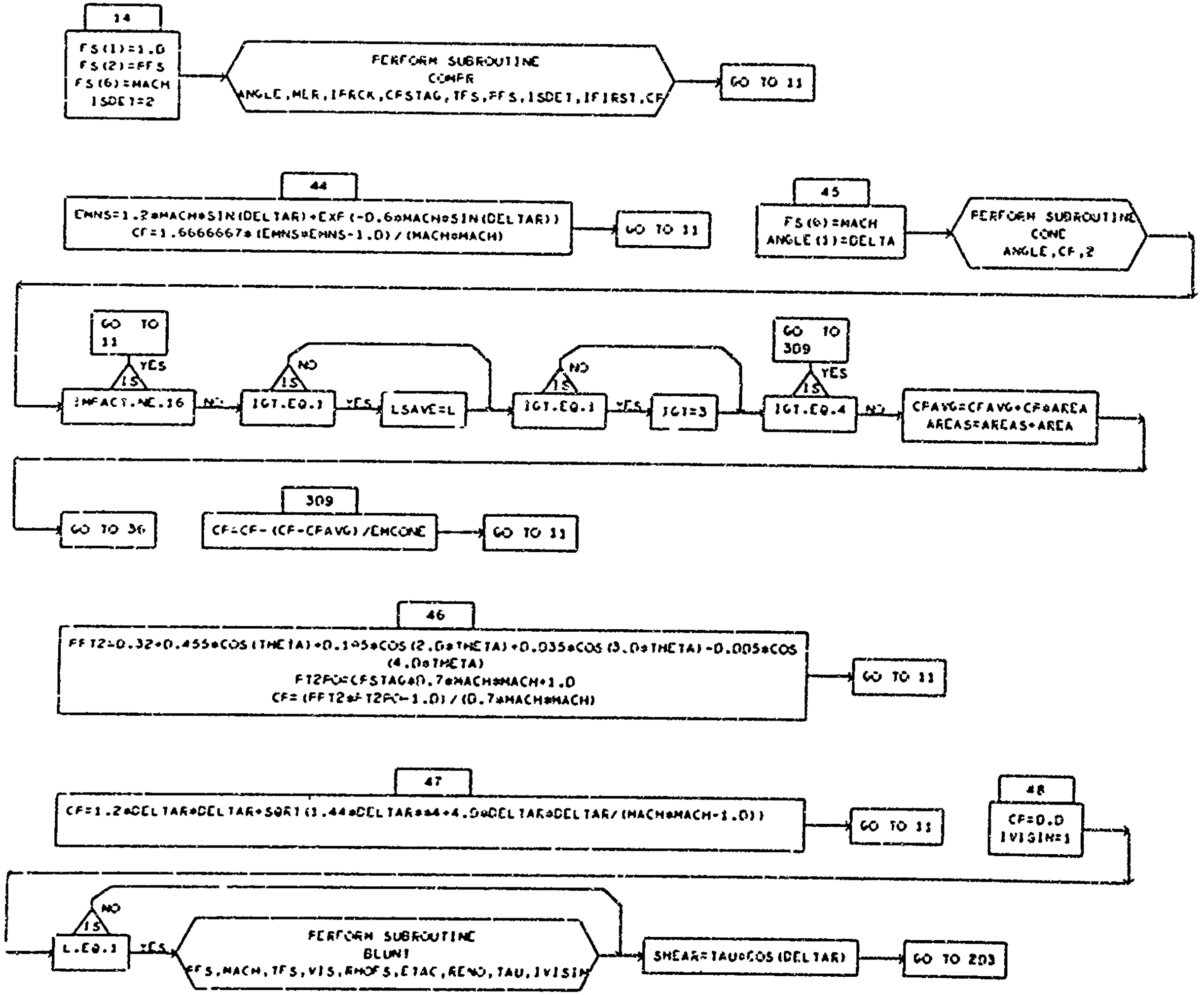

GO TO 313
YES
IS
(ABS(CP-CPAVG).LT.0.0001).OR.L.GT.25
NO
DELTZ=DELTAR-(CP-CPAVG)*(DELTAR-DEL1)/(CP-CP1)
DELTZ.GT.1.5708
NO
IS
YES
DELTZ=1.57
CP1=CP
DEL1=DELTAR
DELTAR=DELTZ
GO TO 310
313
TINTZ=((G+1.0)**2*EMNS*EMNS)/((2.0*G*EMNS*EMNS-(G-1.0))*((G-1.0)*EMNS*EMNS+2.0))
EMCONE=SQRT((2.0/(G-1.0))*(TINTZ*(1.0+((G-1.)/2.)*MACH*MACH)-1.0))
L=LSAVE
IST=4
N=IN(L)
GO TO 305
304
IST=1
CPAVG=0.0
AREA3=0.0
305
NX=NX2(L)
NY=NY2(L)
NZ=NZ2(L)
XCENT=XCENT2(L)
YCENT=YCENT2(L)
ZCENT=ZCENT2(L)
AREA=AREA2(L)
N=IN(L)
N=IN(L)
LL=L
GO TO 18
17
CONTINUE
GO TO 307
YES
IS
IMPACT.NE.16
NO
B1
WRITE
WRITE(6,308)I31Z
ERROR=1
GO TO 10
307
B4
READ
307
READ(4)LL,K,N,NX,NY,NZ,XCENT,YCENT,ZCENT,AREA
I4CT=I4CT+1
GO TO 18
35
CONTINUE
IS
NO
IGT.EQ.1
YES
A4
READ
READ(3)LL,K,N,NX,NY,NZ,XCENT,YCENT,ZCENT,AREA,XPA,YPA,ZPA,XLC
IREDII=0

FORCE

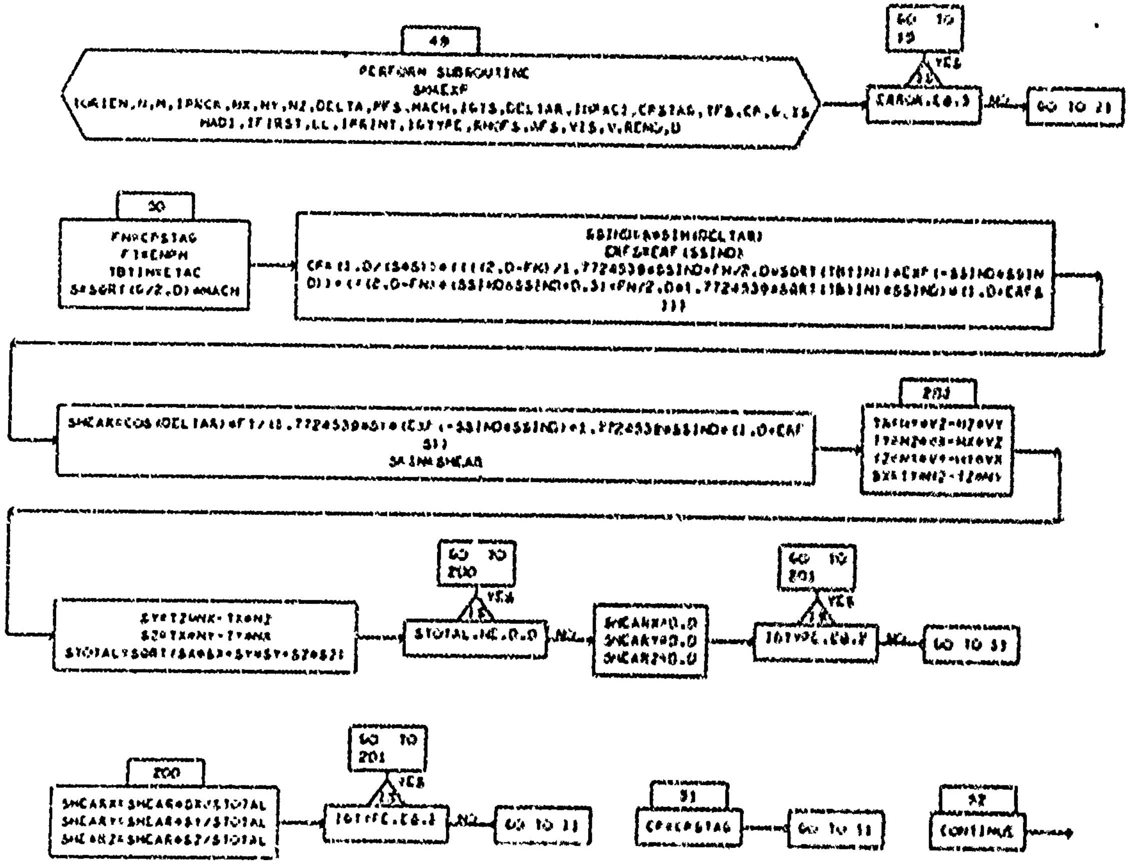

GO TO 10
YES
IS
IGTYPE.EQ.2
NO
IGT.EQ.2.AND.DELTAE.EQ.0.0
NO
YES
84 READ
READ(4)LL,N,M,NX,NY,NZ,XCENT,YCENT,ZCENT,AREA,XFA,YFA,ZFA,XLE
IGT.EQ.2.AND.DELTAE.NE.0.0
NO
YES
87 READ
READ(33)LL,N,M,NX,NY,NZ,XCENT,YCENT,ZCENT,AREA,XFA,YFA,ZFA,XLE
IACT=IACT+1
IGTS=IGT
IGTS.EQ.1.AND.IACT.EQ.IN(N+10)
NO
YES
IGT=2
IGTS.EQ.2.AND.IACT.EQ.IN(4)
NO
YES
IGT=1
IGT.NE.IGTS
NO
YES
IACT=0
10
CONTINUE
SYMFCT.EQ.2.AND.SYMFCO.EQ.2
GO TO 26
YES
NO
SYMFCT.NE.0
GO TO 27
YES
NO
COMPUTED GO TO
IF THE VALUE OF SYMFCO IS
TRANSFER TO STATEMENT
1 27
2 25
3 26
4 25
25
NZ=-NZ
ZCENT=-ZCENT
GO TO 22
YES
IGTYPE.EQ.0
NO
REPEAT TO 23, FOR I=1,I+1,...,4
23
ZFA(I)=-ZFA(I)
22
CONTINUE

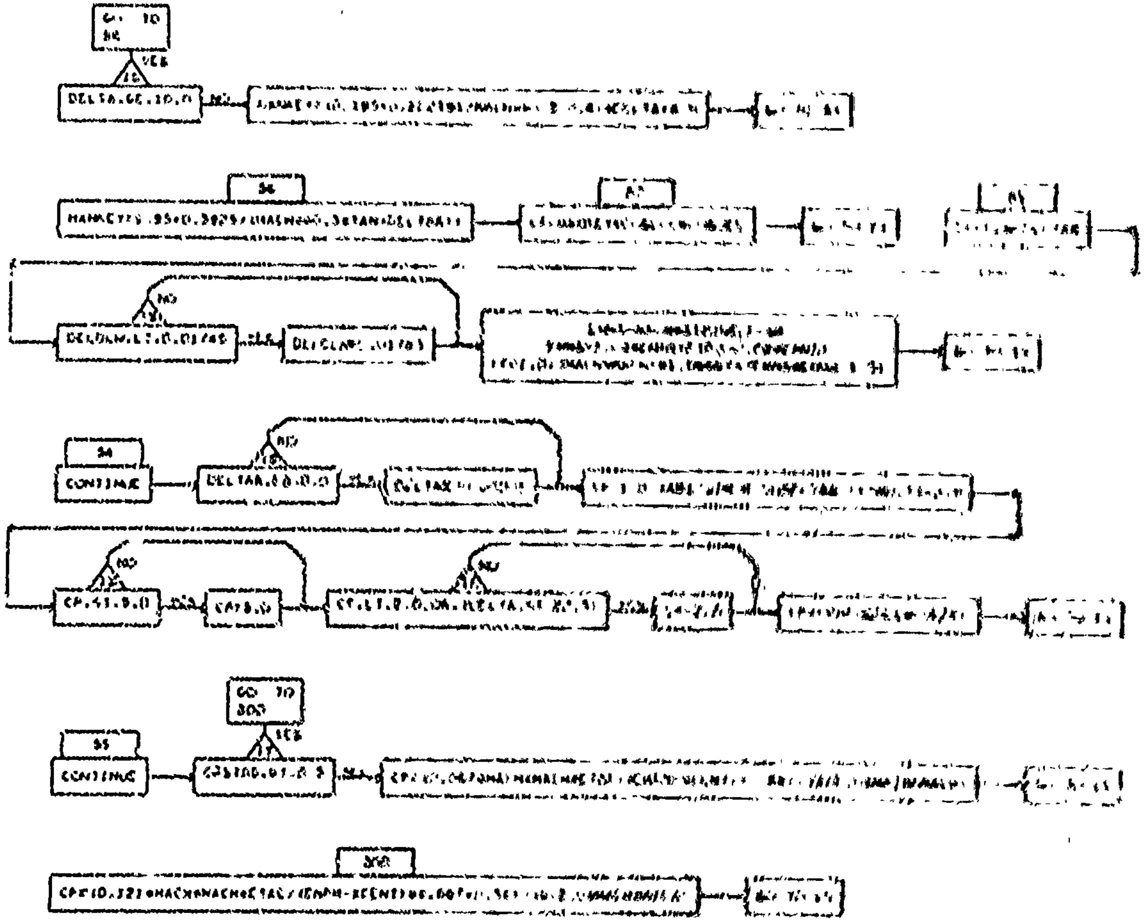

GO TO 27
IS
YES
SYMF(I).NE.4
NO
26
NY=-NY
YCENT=-YCENT
GO TO 27
IS
YES
IGT=FE.EQ.0
NO
REPEAT TO 29
FOR
I=1,I+1,...,4
29
YFA(I)=-YFA(I)
27
CONTINUE
GO TO 13
IS
YES
Q.EQ.0.0.AND.R.EQ.0.0.AND.P.EQ.0.0
NO
VX=VX1+(Q*(+ZCENT-ZCG)-R*(+YCENT-YCG))
VY=VY1+(R*(+XCENT-XCG)+P*(+ZCENT-ZCG))
VZ=VZ1-(P*(+YCENT-YCG)+Q*(+XCENT-XCG))
19
VLOCAL=SQRT(VX*VX+VY*VY+VZ*VZ)
GO TO 37
IS
YES
IRED(I).EQ.1
NO
COSDEL=(-NX*VX-NY*VY-NZ*VZ)/VLOCAL
IS
NO
COSDEL.GT.-1.0001.AND.COSDEL.LT.-1.0
YES
COSDEL=-1.0
IS
NO
COSDEL.GT.1.0.AND.COSDEL.LT.1.0001
YES
COSDEL=1.0
GO TO 20
IS
YES
COSDEL.GE.-1.0.AND.COSDEL.LE.1.0
NO
81
WRITE
WRITE(6,9)
ERROR=1
GO TO 10
20
THETA=ARCOS(COSDEL)
8
CONTINUE
IS
NO
IMPACT.NE.10.AND.ENFM.NE.0.0
YES
THETA=THETA/ENFM
DELTAR=1.57079627-THETA

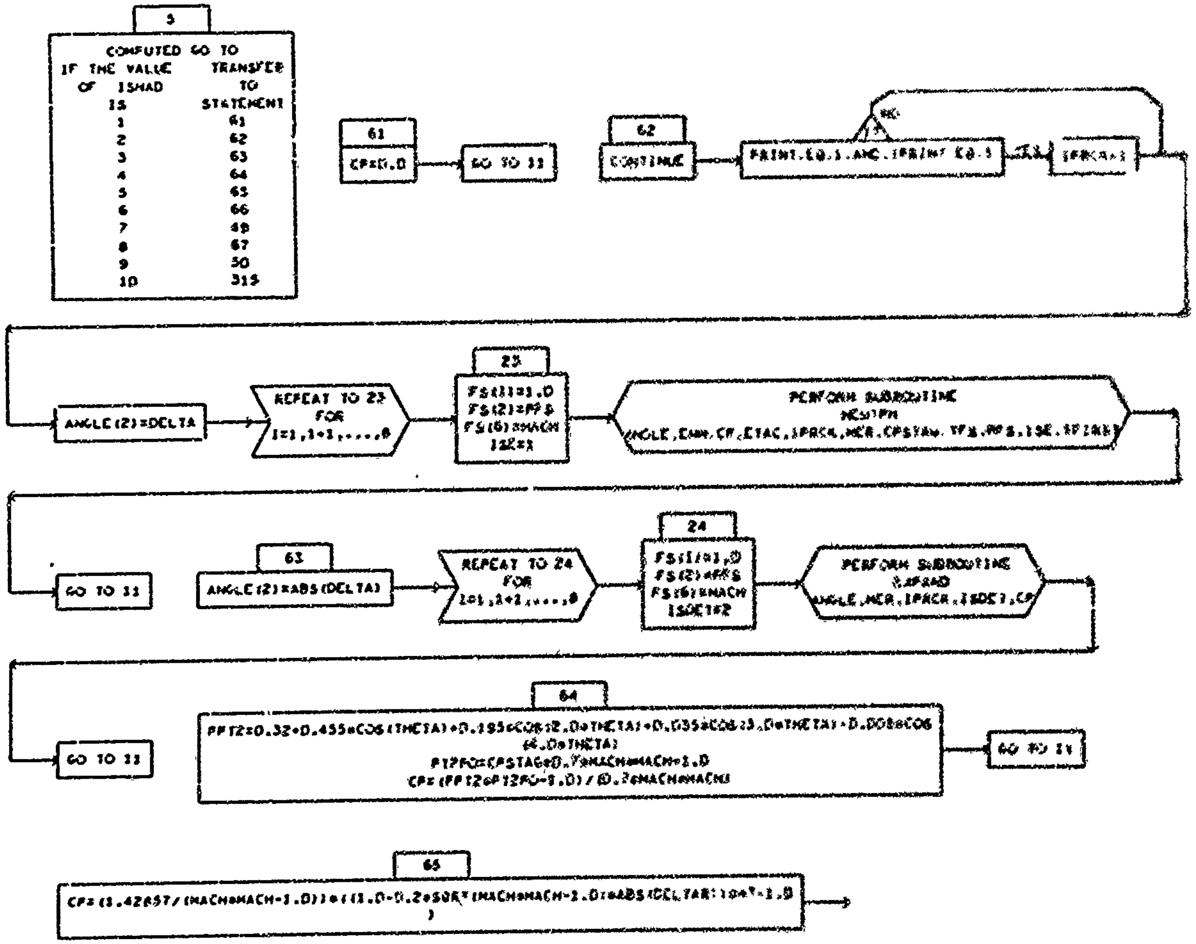

DELTAR.GT.-0.000001.AND.DELTAR.LT.0.000001
IS
NO
YES
DELTAR=0.0
DELTA=DELTAR*.572957795E+02
IMPACT.EQ 17.OR.ISHAD.EQ.10
IS
YES
GO TO 314
NO
IGTYPE.EQ.2
IS
YES
GO TO 204
NO
314
CONTINUE
DELTAR.LT.0.0
IS
YES
GO TO 5
NO
COMPUTED GO TO
IF THE VALUE OF IMPACT IS
TRANSFER TO STATEMENT
1 41
2 42
3 43
4 44
5 45
6 46
7 47
8 48
9 49
10 50
11 51
12 52
13 53
14 54
15 55
16 45
17 315
41
CF=CFSTAG*COSDEL*COSDEL
GO TO 11
42
CONTINUE
PRINT.EQ.1.AND.IPRINT.EQ.1
IS
NO
YES
IPRCK=1
ANGLE(2)=DELTA
REPEAT TO 13 FOR I=1,1+1,...,8
13
FS(1)=1.0
FS(2)=PFS
FS(6)=MACH
ISE=1
PERFORM SUBROUTINE NEWTPH
ANGLE,EMN,CF,ETAC,IPRCK,MER,CFSTAG,TFS,PFS,ISE,IFIRST
GO TO 11
43
CONTINUE
PRINT.EQ.1.AND.IPRINT.EQ.1
IS
NO
YES
IPRCK=1
ANGLE(2)=DELTA
REPEAT TO 14 FOR I=1,1+1,...,8

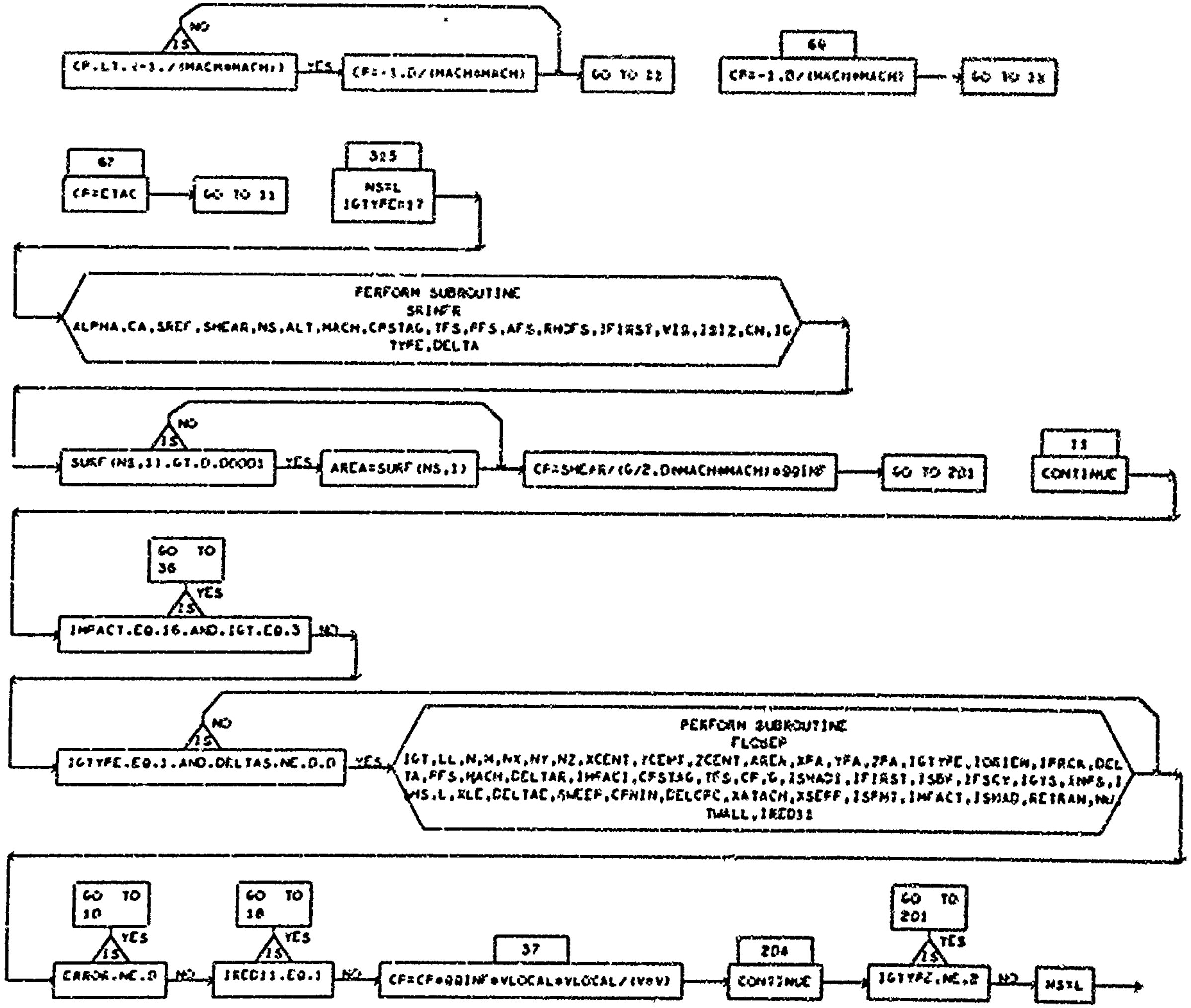

14
FS(1)=1.0
FS(2)=FFS
FS(6)=MACH
ISDET=2
PERFORM SUBROUTINE
COMPR
ANGLE,MER,IFRCK,CFSTAG,TFS,FFS,ISDET,IFIRST,CF
GO TO 11
44
EMNS=1.2*MACH*SIN(DELTAR)+EXF(-0.6*MACH*SIN(DELTAR))
CF=1.6666667*(EMNS*EMNS-1.0)/(MACH*MACH)
GO TO 11
45
FS(6)=MACH
ANGLE(1)=DELTA
PERFORM SUBROUTINE
CONE
ANGLE,CF,2
IS
INFACT.NE.16
YES
GO TO 11
NO
IS
IGT.EQ.1
NO
YES
LSAVE=L
IS
IGT.EQ.1
NO
YES
IGT=3
IS
IGT.EQ.4
YES
GO TO 309
NO
CFAVG=CFAVG+CF*AREA
AREAS=AREAS+AREA
GO TO 36
309
CF=CF-(CF-CFAVG)/EMCONE
GO TO 11
46
FFT2=0.32+0.455*COS(THETA)+0.195*COS(2.0*THETA)+0.035*COS(3.0*THETA)-0.005*COS
(4.0*THETA)
FT2FO=CFSTAG*0.7*MACH*MACH+1.0
CF=(FFT2*FT2FO-1.0)/(0.7*MACH*MACH)
GO TO 11
47
CF=1.2*DELTAR*DELTAR+SQRT(1.44*DELTAR**4+4.0*DELTAR*DELTAR/(MACH*MACH-1.0))
GO TO 11
48
CF=0.0
IVISIN=1
IS
L.EQ.1
NO
YES
PERFORM SUBROUTINE
BLUNT
FFS,MACH,TFS,VIS,RHOFS,ETAC,RENO,TAU,IVISIN
SHEAR=TAU*COS(DELTAR)
GO TO 203

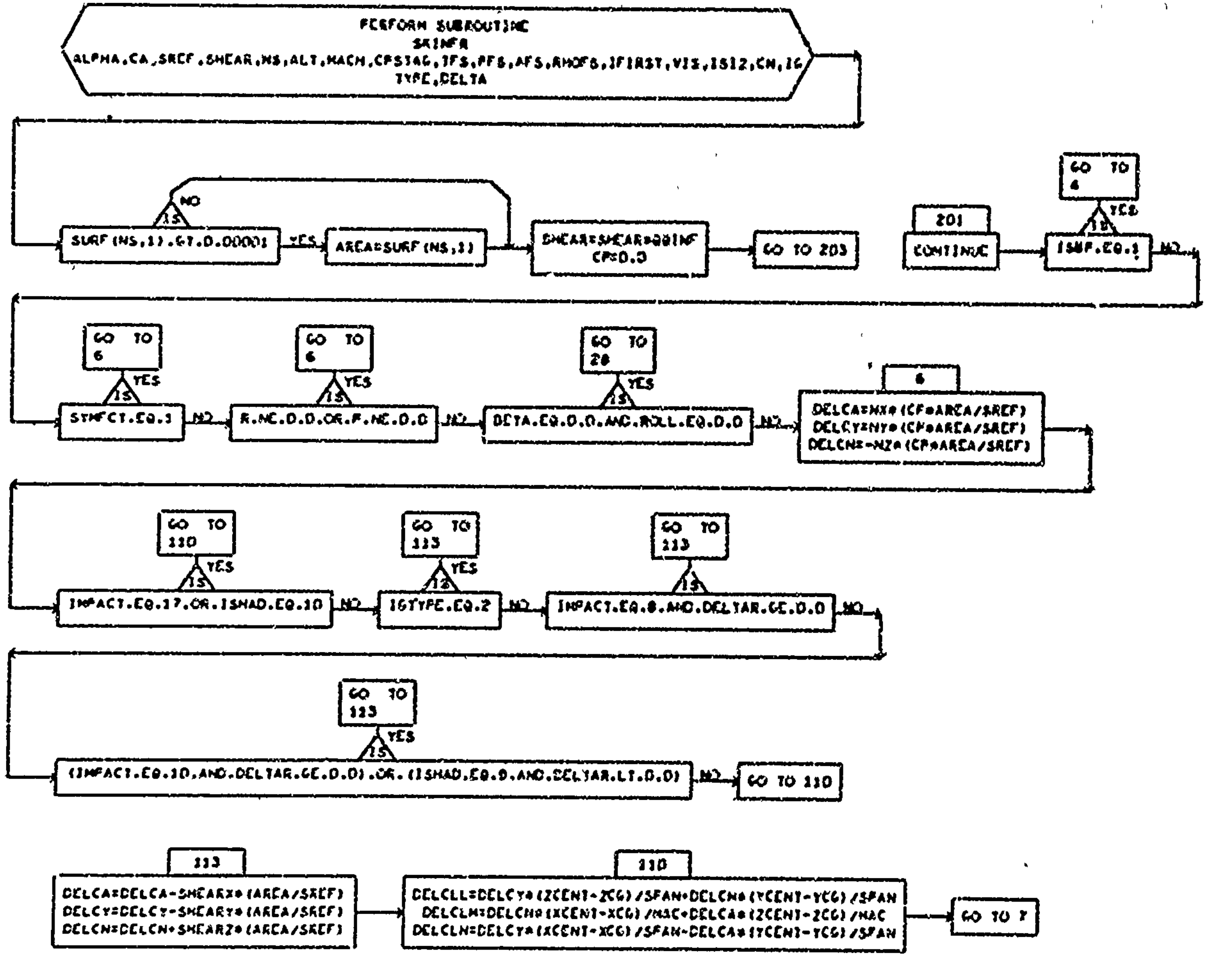
FORCE

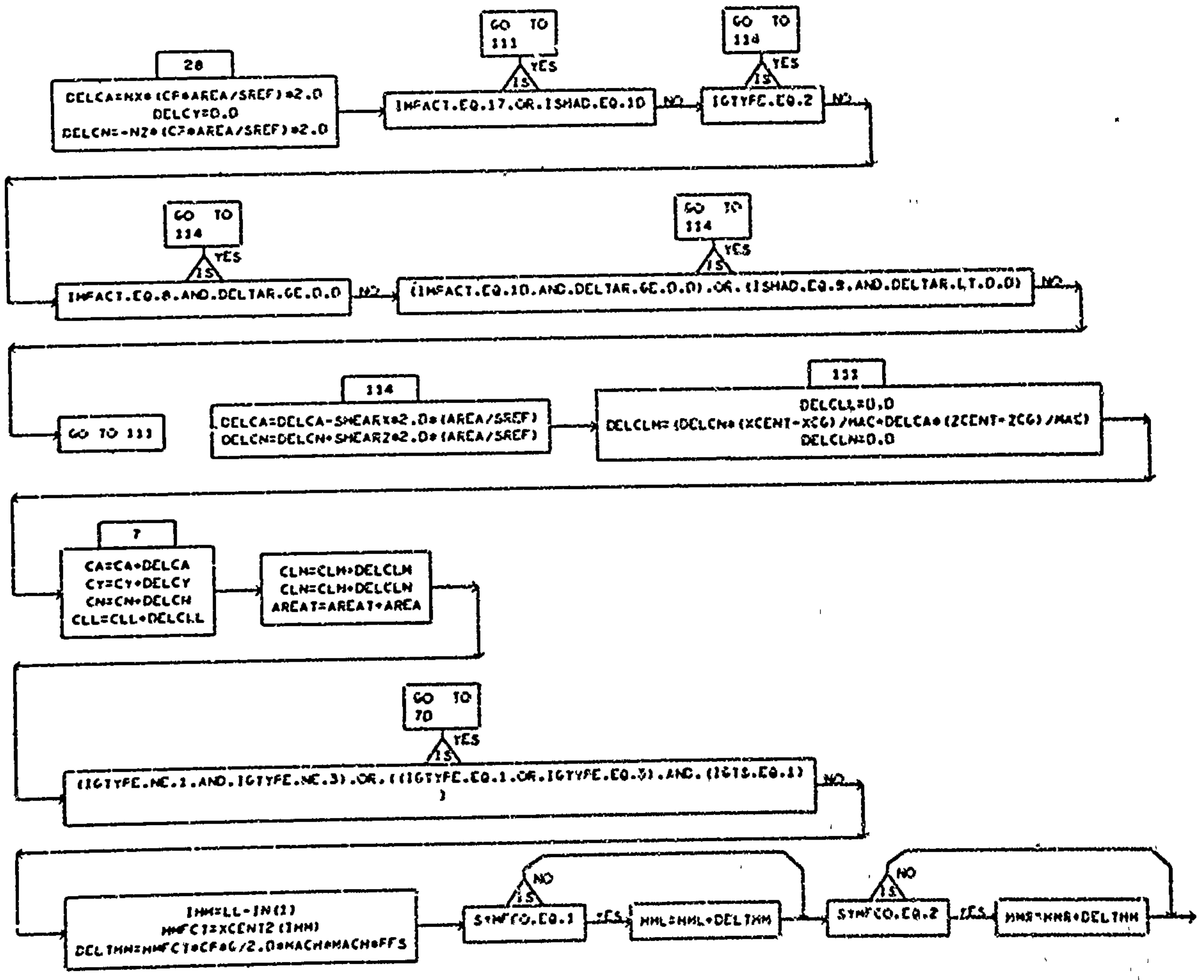

49
PERFORM SUBROUTINE
SHEXP
(ORIEN,N,M,IPACK,NX,NY,NZ,DELTA,PFS,MACH,IGTS,DELTAR,IIPAC1,CPSTAG,TFS,CA,G,IS,
MADJ,IFIRST,LL,IPRINT,IGTYPE,RHOFS,UFS,VIS,V,RENO,D)
ERROR.EQ.3
YES
GO TO 19
NO
GO TO 21
30
FN=CPSTAG
FT=ENPH
TB1IN=ETAC
S=SQRT(G/2.D)*MACH
SSINO=S*SIN(DELTAR)
ERF=ERF(SSINO)
CP=(1.D/(S*S))*(((2.D-FN)/1.7724539*SSINO+FN/2.D*SQRT(TB1IN))*EXP(-SSINO*SSIN
O))+((2.D-FN)*(SSINO*SSINO+0.5)+FN/2.D*1.7724539*SQRT(TB1IN)*SSINO)*(1.D+ERF)
)))
SHEAR=COS(DELTAR)*FT/(1.7724539*S)*(EXP(-SSINO*SSINO)+1.7724539*SSINO*(1.D+ERF
S))
SA=AN*SHEAR
203
TX=(NY*VZ-NZ*VY
TY=NZ*VX-NX*VZ
TZ=NX*VY-NY*VX
SX=TY*NZ-TZ*NY
SY=TZ*NX-TX*NZ
SZ=TX*NY-TY*NX
STOTAL=SQRT(SX*SX+SY*SY+SZ*SZ)
STOTAL.NE.0.D
YES
GO TO 200
NO
SHEARX=0.D
SHEARY=0.D
SHEARZ=0.D
IGTYPE.EQ.?
YES
GO TO 201
NO
GO TO 31
200
SHEARX=SHEAR*SX/STOTAL
SHEARY=SHEAR*SY/STOTAL
SHEARZ=SHEAR*SZ/STOTAL
IGTYPE.EQ.1
YES
GO TO 201
NO
GO TO 31
31
CP=CPSTAG
GO TO 31
32
CONTINUE

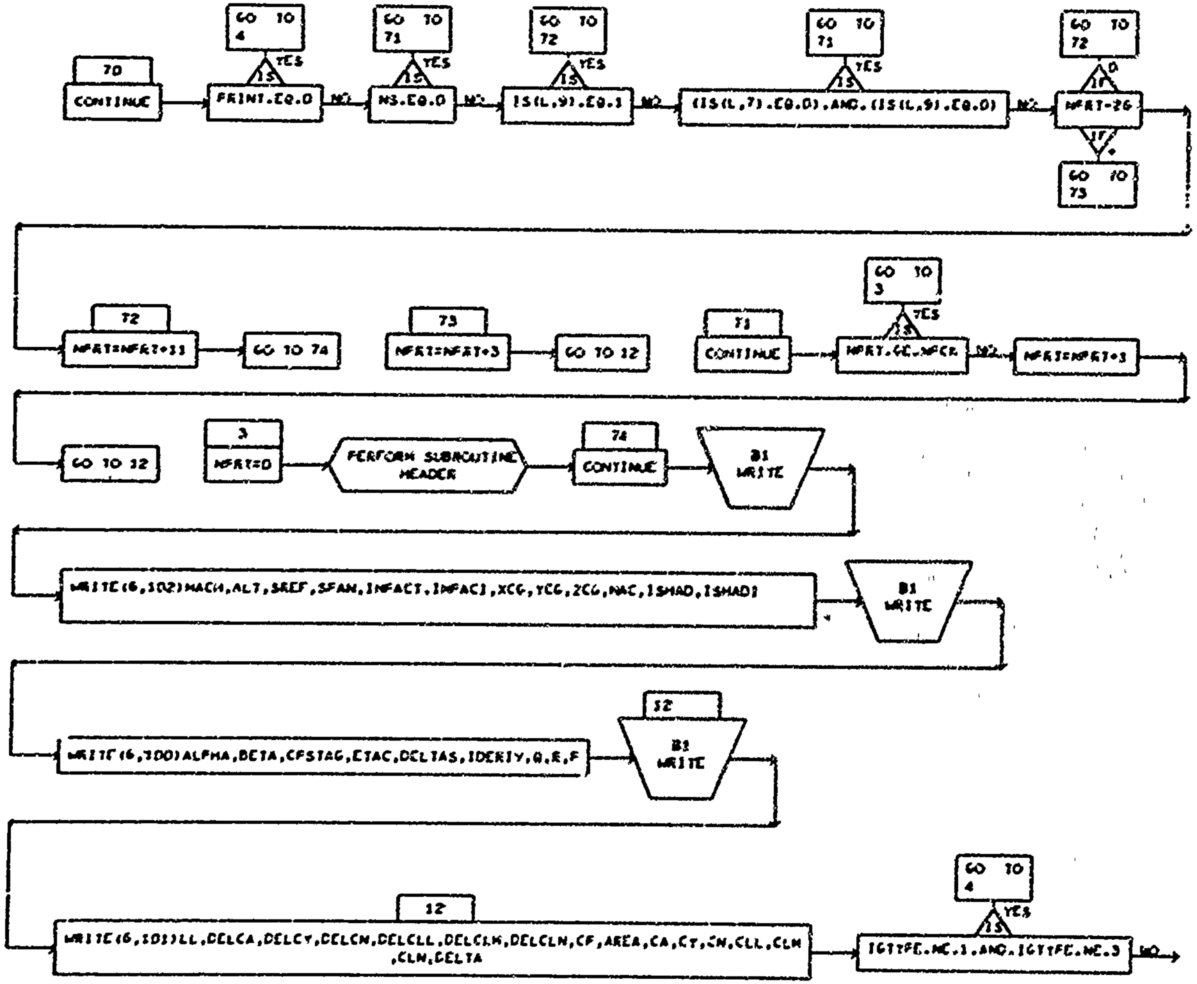

YES
NO
36
34
CONTINUE
CONTINUE
35
GO TO 308
308


5
COMPUTED GO TO
IF THE VALUE OF ISHAD IS
TRANSFER TO STATEMENT
1 61
2 62
3 63
4 64
5 65
6 66
7 49
8 67
9 50
10 315
61
CP=0.0
GO TO 11
62
CONTINUE
PRINT.EQ.1.AND.IPRINT.EQ.1
NO
YES
IPRCR=1
ANGLE(2)=DELTA
REPEAT TO 23 FOR I=1,1+1,...,8
23
FS(1)=1.0
FS(2)=PPS
FS(6)=MACH
ISE=1
PERFORM SUBROUTINE
NEWTPH
(ANGLE,EMH,CP,ETAC,IPRCR,MCR,CPSTAG,TFS,PPS,ISE,IPINK)
GO TO 11
63
ANGLE(2)=ABS(DELTA)
REPEAT TO 24 FOR I=1,1+1,...,8
24
FS(1)=1.0
FS(2)=PPS
FS(6)=MACH
ISDET=2
PERFORM SUBROUTINE
SHPAND
ANGLE,MCR,IPRCR,ISDET,CP
GO TO 11
64
PPT2=0.32+0.455*COS(THETA)+0.195*COS(2.0*THETA)+0.035*COS(3.0*THETA)-0.008*COS(4.0*THETA)
PT2PO=CPSTAG*0.7*MACH*MACH+1.0
CP=(PPT2*PT2PO-1.0)/0.7*MACH*MACH
GO TO 11
65
CP=(1.42857/(MACH*MACH-1.0))*((1.0-0.2*SQRT(MACH*MACH-1.0)*ABS(DELTA))**(-3.5)-1.0)

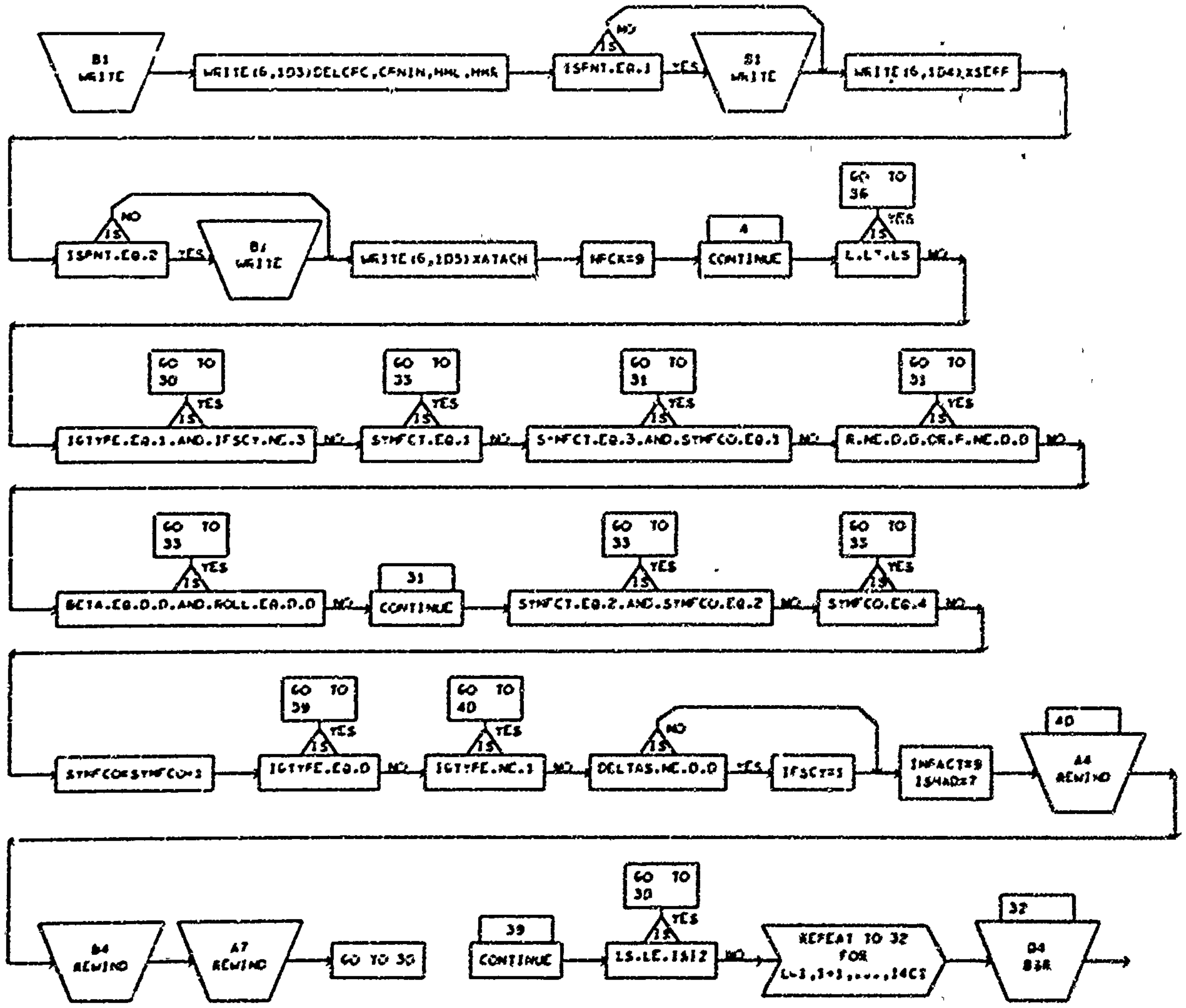

CP.LT.(-1./(MACH*MACH))
IS
NO
YES
CP=-1.D/(MACH*MACH)
GO TO 22
64
CP=-1.D/(MACH*MACH)
GO TO 28
67
CP=CTAC
GO TO 11
325
NSFL
IGTYPE=17
PERFORM SUBROUTINE
SRINFR
ALPHA,CA,SREF,SHEAR,NS,ALT,MACH,CPSTAG,TFS,PFS,AFS,RHOFS,IFIRST,VIO,I812,CN,IG
TYPE,DELTA
SURF(NS,1).GT.0.00001
IS
NO
YES
AREA=SURF(NS,1)
CF=SHEAR/(G/2.D*MACH*MACH)*QQINF
GO TO 201
11
CONTINUE
GO TO
36
YES
IS
IMPACT.EQ.16.AND.IGT.EQ.3
NO
IGTYPE.EQ.1.AND.DELTAS.NE.0.0
IS
NO
YES
PERFORM SUBROUTINE
FLOSEP
IGT,LL,N,M,NX,NY,NZ,XCENT,YCENT,ZCENT,AREA,XFA,YFA,ZFA,IGTYPE,IORIEN,IFRCR,DEL
TA,PFS,MACH,DELTAR,IMPACI,CPSTAG,TFS,CF,G,ISHADI,IFIRST,ISBF,IFSCY,IGYS,INFS,I
MS,L,XLE,DELTAC,SWEEP,CPMIN,DELCPC,XATACH,XSEFF,ISPHT,IMPACT,ISHAD,RETRAN,NU
TWALL,IREDII
GO TO
10
YES
IS
ERROR.NE.0
NO
GO TO
18
YES
IS
IREDII.EQ.1
NO
37
CF=CF*QQINF*VLOCAL*VLOCAL/(V*V)
204
CONTINUE
GO TO
201
YES
IS
IGTYPE.NE.2
NO
NSFL

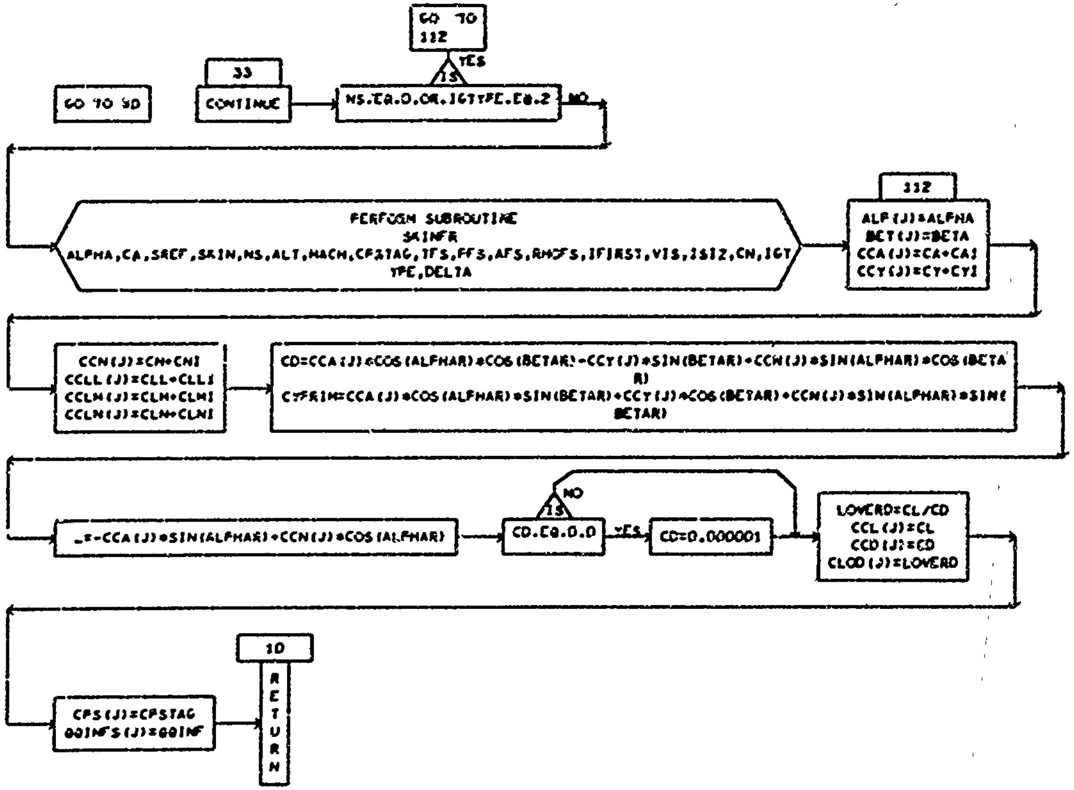

PERFORM SUBROUTINE
SKINFR
ALPHA,CA,SREF,SHEAR,NS,ALT,MACH,CPSTAG,TFS,PFS,AFS,RHOFS,IFIRST,VIS,IS12,CN,IG
TYPE,DELTA
SURF(NS,1).GT.0.00001
IS
NO
YES
AREA=SURF(NS,1)
SHEAR=SHEAR*QINF
CP=0.0
GO TO 203
201
CONTINUE
ISMF.EQ.1
IS
YES
GO TO 6
NO
SYMFCT.EQ.1
IS
YES
GO TO 6
NO
R.NE.0.0.OR.F.NE.0.0
IS
YES
GO TO 6
NO
DETA.EQ.0.0.AND.ROLL.EQ.0.0
IS
YES
GO TO 28
NO
6
DELCA=NX*(CP*AREA/SREF)
DELCY=NY*(CP*AREA/SREF)
DELCN=-NZ*(CP*AREA/SREF)
IMPACT.EQ.17.OR.ISHAD.EQ.10
IS
YES
GO TO 110
NO
IGTYPE.EQ.2
IS
YES
GO TO 113
NO
IMPACT.EQ.8.AND.DELTAR.GE.0.0
IS
GO TO 113
NO
(IMPACT.EQ.10.AND.DELTAR.GE.0.0).OR.(ISHAD.EQ.0.AND.DELTAR.LT.0.0)
IS
YES
GO TO 113
NO
GO TO 110
113
DELCA=DELCA-SHEARX*(AREA/SREF)
DELCY=DELCY-SHEARY*(AREA/SREF)
DELCN=DELCN+SHEARZ*(AREA/SREF)
110
DELCLL=DELCY*(ZCENT-ZCG)/SPAN+DELCN*(YCENT-YCG)/SPAN
DELCLM=DELCN*(XCENT-XCG)/MAC+DELCA*(ZCENT-ZCG)/MAC
DELCLN=DELCY*(XCENT-XCG)/SPAN-DELCA*(YCENT-YCG)/SPAN
GO TO 7


28
DELCA=NX*(CF*AREA/SREF)*2.0
DELCY=0.0
DELCN=-NZ*(CF*AREA/SREF)*2.0
GO TO 111
YES
IS
IMPACT.EQ.17.OR.ISHAD.EQ.10
NO
GO TO 114
YES
IS
IGTYPE.EQ.2
NO
GO TO 114
YES
IS
IMPACT.EQ.8.AND.DELTAR.GE.0.0
NO
GO TO 114
YES
IS
(IMPACT.EQ.10.AND.DELTAR.GE.0.0).OR.(ISHAD.EQ.9.AND.DELTAR.LT.0.0)
NO
GO TO 111
114
DELCA=DELCA-SHEARX*2.0*(AREA/SREF)
DELCN=DELCN+SHEARZ*2.0*(AREA/SREF)
111
DELCLL=0.0
DELCLM=(DELCN*(XCENT-XCG)/MAC+DELCA*(ZCENT-ZCG)/MAC)
DELCLN=0.0
7
CA=CA+DELCA
CY=CY+DELCY
CN=CN+DELCN
CLL=CLL+DELCLL
CLM=CLM+DELCLM
CLN=CLN+DELCLN
AREAT=AREAT+AREA
GO TO 70
YES
IS
(IGTYPE.NE.2.AND.IGTYPE.NE.3).OR.((IGTYPE.EQ.1.OR.IGTYPE.EQ.3).AND.(IGTS.EQ.1)
)
NO
IHM=LL-IN(1)
HMFCT=XCENT2(IHM)
DELTHM=HMFCT*CF*G/2.0*MACH*MACH*FFS
IS
NO
SYMFCO.EQ.1
YES
HML=HML+DELTHM
IS
NO
SYMFCO.EQ.2
YES
HMR=HMR+DELTHM



70
CONTINUE
PRINT.EQ.0
IS
YES
GO TO 4
NO
NS.EQ.0
IS
YES
GO TO 71
NO
IS(L,9).EQ.1
IS
YES
GO TO 72
NO
(IS(L,7).EQ.0).AND.(IS(L,9).EQ.0)
IS
YES
GO TO 71
NO
NFRT-26
IF
0
GO TO 72
IF
+
GO TO 73
72
NFRT=NFRT+11
GO TO 74
73
NFRT=NFRT+3
GO TO 12
71
CONTINUE
NFRT.GE.NFCR
IS
YES
GO TO 3
NO
NFRT=NFRT+3
GO TO 12
3
NFRT=0
PERFORM SUBROUTINE HEADER
74
CONTINUE
B1
WRITE
WRITE(6,102)MACH,ALT,SREF,SFAN,INFACT,INFAC1,XCG,YCG,ZCG,NAC,ISHAD,ISHAD1
B1
WRITE
WRITE(6,100)ALPHA,BETA,CFSTAG,ETAC,DELTAS,IDERIY,Q,R,F
12
B1
WRITE
12
WRITE(6,101)LL,DELCA,DELCY,DELCN,DELCLL,DELCLM,DELCLN,CF,AREA,CA,CY,CN,CLL,CLM,CLN,DELTA
IGTYPE.NE.1.AND.IGTYPE.NE.3
IS
YES
GO TO 4
NO


B1
WRITE
WRITE(6,103)DELCFC,CFNIN,HHL,HHR
ISFNT.EQ.1
IS
YES
NO
B1
WRITE
WRITE(6,104)XSEFF
ISFNT.EQ.2
IS
NO
YES
B1
WRITE
WRITE(6,105)XATACH
NFCK=9
4
CONTINUE
L.LT.LS
IS
YES
GO TO 36
NO
IGTYPE.EQ.1.AND.IFSCY.NE.3
IS
YES
GO TO 30
NO
STMFCT.EQ.1
IS
YES
GO TO 33
NO
S+NFCT.EQ.3.AND.STMFCO.EQ.1
IS
YES
GO TO 31
NO
R.NE.0.0.OR.F.NE.0.0
IS
YES
GO TO 33
NO
BETA.EQ.0.0.AND.ROLL.EQ.0.0
IS
YES
GO TO 33
NO
31
CONTINUE
STMFCT.EQ.2.AND.STMFCO.EQ.2
IS
YES
GO TO 33
NO
STMFCO.EQ.4
IS
YES
GO TO 33
NO
STMFCO=STMFCO+1
IGTYPE.EQ.0
IS
YES
GO TO 39
NO
IGTYPE.NE.1
IS
YES
GO TO 40
NO
DELTAS.NE.0.0
IS
NO
YES
IFSCY=1
INFACT=9
ISHAD=7
40
A4
REWIND
B4
REWIND
A7
REWIND
GO TO 30
39
CONTINUE
LS.LE.ISI2
IS
YES
GO TO 30
NO
REPEAT TO 32
FOR
L=1,1+1,...,14CS
32
B4
BSR


GO TO 30
33
CONTINUE
NS.EQ.0.OR.IGTYPE.EQ.2
IS
YES
NO
GO TO
112
PERFORM SUBROUTINE
SKINFR
ALPHA,CA,SREF,SKIN,NS,ALT,MACH,CPSTAG,TFS,FFS,AFS,RHOFS,IFIRST,VIS,ISIZ,CN,IGT
YPE,DELTA
112
ALF(J)=ALPHA
BET(J)=BETA
CCA(J)=CA+CAI
CCY(J)=CY+CYI
CCN(J)=CN+CNI
CCLL(J)=CLL+CLLI
CCLM(J)=CLM+CLMI
CCLN(J)=CLN+CLNI
CD=CCA(J)*COS(ALPHAR)*COS(BETAR)-CCY(J)*SIN(BETAR)+CCN(J)*SIN(ALPHAR)*COS(BETA
R)
CYFRIM=CCA(J)*COS(ALPHAR)*SIN(BETAR)+CCY(J)*COS(BETAR)+CCN(J)*SIN(ALPHAR)*SIN(
BETAR)
CL=-CCA(J)*SIN(ALPHAR)+CCN(J)*COS(ALPHAR)
CD.EQ.0.0
IS
NO
YES
CD=0.000001
LOVERD=CL/CD
CCL(J)=CL
CCD(J)=CD
CLOD(J)=LOVERD
CPS(J)=CPSTAG
QQINFS(J)=QQINF
10
RETURN

```
SYMBOLS USED IN SUBROUTINE FORCE

AFS      R  U  FREE-STREAM SPEED OF SOUND                                      FORCE
ALP      R  C  ANGLE OF ATTACK ARRAY                                           FORCE
ALPHA    R  A  ANGLE OF ATTACK, DEGREES                                        FORCE
ALPHAR   R  U  ANGLE OF ATTACK, RADIANS                                        FORCE
ALT      R  A  ALTITUDE, FEET                                                  FORCE
ANGLE    R  D  FLOW ANGLE ARRAY                                                FORCE
AREA     R  U  ELEMENT AREA                                                    FORCE
AREAS    R  U  TOTAL AREA OF A COLUMN OF ELEMENTS                              FORCE
AREAT    R  U  TOTAL AREA                                                      FORCE
AREA2    R  C  QUADRILATERAL ELEMENT AREA ARRAY                                FORCE
BET      R  C  YAW ANGLE ARRAY                                                 FORCE
BETA     R  A  YAW ANGLE, DEGREES                                              FORCE
BETAR    R  U  YAW ANGLE, RADIANS                                              FORCE
BS       R  C  FLOW CONDITIONS BEHIND SHOCK OR EXPANSION                       FORCE
CA       R  U  AXIAL FORCE COEFFICIENT                                         FORCE
CAI      R  A  AXIAL FORCE INCREMENT                                           FORCE
CASE     I  C  CASE NUMBER                                                     FORCE
CCA      R  C  AXIAL FORCE COEFFICIENT ARRAY                                   FORCE
CCD      R  C  DRAG COEFFICIENT ARRAY                                          FORCE
CCL      R  C  LIFT COEFFICIENT ARRAY                                          FORCE
CCLL     R  C  ROLLING MOMENT COEFFICIENT ARRAY                                FORCE
CCLM     R  C  PITCHING MOMENT COEFFICIENT ARRAY                               FORCE
CCLN     R  C  YAWING MOMENT COEFFICIENT ARRAY                                 FORCE
CCN      R  C  NORMAL FORCE COEFFICIENT ARRAY                                  FORCE
CCY      R  C  SIDE FORCE COEFFICIENT ARRAY                                    FORCE
CD       R  U  DRAG COEFFICIENT                                                FORCE
CF       R  C  SKIN FRICTION CONTRIBUTION TO AXIAL FORCE ARRAY                 FORCE
CL       R  U  LIFT COEFFICIENT ARRAY                                          FORCE
CLL      R  U  ROLLING MOMENT COEFFICIENT                                      FORCE
CLLI     R  A  ROLLING MOMENT COEFFICIENT INCREMENT                            FORCE
CLM      R  U  PITCHING MOMENT COEFFICIENT                                     FORCE
CLMI     R  A  PITCHING MOMENT COEFFICIENT INCREMENT                           FORCE
CLN      R  U  YAWING MOMENT COEFFICIENT                                       FORCE
CLNI     R  A  YAWING MOMENT COEFFICIENT MOMENT                                FORCE
CLOD     R  C  LIFT TO DRAG RATIO ARRAY                                        FORCE
CN       R  U  NORMAL FORCE COEFFICIENT                                        FORCE
```

```
SYMBOLS USED IN SUBROUTINE FORCE

CNI      R  A  NORMAL FORCE COEFFICIENT INCREMENT                                FORCE
COSDEL   R  U  COSINE OF ANGLE NORMAL AND VELOCITY VECTORS                       FORCE
CP       R  U  PRESSURE COEFFICIENT                                              FORCE
CPAVG    R  U  AVERAGE PRESSURE COEFFICIENT TIMES AREA FOR EQUIVALENT CONE       FORCE
CPMIN    R  U  MINIMUN PRESSURE COEFFICIENT                                      FORCE
CPS      R  C  ARRAY FOR NEWTONIAN CORRELATION FACTOR, K                         FORCE
CPSTAG   R  A  MODIFIED NEWTONIAN CORRELATION FACTOR, K                          FORCE
CP1      R  U  ITERATION PRESSURE COEFFICIENT                                    FORCE
CY       R  U  SIDE FORCE COEFFICIENT                                            FORCE
CYI      R  A  SIDE FORCE COEFFICIENT INCREMENT                                  FORCE
CYPRIM   R  U  SIDE FORCE COEFFICIENT-WIND AXIS                                  FORCE
DELCA    R  U  ELEMENT CONTRIBUTION TO AXIAL FORCE                               FORCE
DELCLL   R  U  ELEMENT CONTRIBUTION TO ROLLING MOMENT                            FORCE
DELCLM   R  U  ELEMENT CONTRIBUTION TO PITCHING MOMENT                           FORCE
DELCLN   R  U  ELEMENT CONTRIBUTION TO YAWING MOMENT                             FORCE
DELCN    R  U  ELEMENT CONTRIBUTION TO NORMAL FORCE                              FORCE
DELCPC   R  U  DELTA CP DUE TO CONTROL SURFACE DEFLECTION                        FORCE
DELCY    R  U  ELEMENT CONTRIBUTION TO SIDE FORCE                                FORCE
DELDLW   R  U  IMPACT ANGLE FOR DELTA WING                                       FORCE
DELTA    R  U  IMPACT ANGLE, DEGREES                                             FORCE
DELTAE   R  A  CONTROL SURFACE DEFLECTION                                        FORCE
DELTAR   R  U  IMPACT ANGLE, RADIANS                                             FORCE
DELTAS   R  U  IMPACT CONTROL SURFACE DEFLECTION ANGLE                           FORCE
DELTHM   R  U  HINGE MOMENT INCREMENT                                            FORCE
DELT2    R  U  ITERATION VALUE FOR EQUIVALENT CONE ANGLE (2)                     FORCE
DEL1     R  U  ITERATION VALUE FOR EQUIVALENT CONE ANGLE (1)                     FORCE
EMCONE   R  U  MACH NUMBER ON SURFACE OF EQUIVALENT CONE                         FORCE
EMN      R  U  MACH NUMBER TIMES SHOCK ANGLE SQUARED                             FORCE
EMNS     R  U  MACH NUMBER NORMAL TO SHOCK                                       FORCE
ENPM     R  A  SURFACE SLOPE MODIFICATION FACTOR                                 FORCE
ERFS     R  U  ERROR FUNCTION PARAMETER                                          FORCE
ERROR    I  C  ERROR FLAG                                                        FORCE
ETAC     R  A  PRANDTL-MEYER EXPANSION CORRECTION FACTOR                         FORCE
FN       R  U  NORMAL MOMENTUM ACCOMODATION COEFFICIENT                          FORCE
FS       R  C  FLOW CONDITIONS BEFORE SHOCK OR EXPANSION                         FORCE
FT       R  U  TANGENTIAL MOMENTUM ACCOMODATION COEFFICIENT                      FORCE
```

```
SYMBOLS USED IN SUBROUTINE FORCE

G         R  U  RATIO OF SPECIFIC HEATS = 1.4                                  FORCE
HANKEY    R  U  NEWTONIAN CORRELATION FACTOR IN HANKEY EQUATION                FORCE
HMFCT     R  U  HINGE MOMENT FACTOR                                            FORCE
HML       R  A  HINGE MOMENT (+Y)                                              FORCE
HMR       R  A  HINGE MOMENT (-Y)                                              FORCE
HSIMP     R  U  HYPERSONIC INTERACTION PARAMETER                               FORCE
IDERIV    I  A  DERIVATIVE CONTROL FLAG                                        FORCE
IFIRST    I  A  INITIAL PRINT FLAG FOR NEWTPM                                  FORCE
IFSCY     I  U  CONTROL SURFACE FLOW SEPARATION CALCULATION CYCLE NUMBER       FORCE
IGT       I  U  CONTROL SURFACE FLAG (=1 FORE-SURFACE, =2 CONTROL SURFACE)     FORCE
IGTS      I  U  CONTROL SURFACE FLAG FOR PRESENT ELEMENT                       FORCE
IGTYPE    I  A  GEOMETRY TYPE (=1 FOR CONTROL SURFACE COMPOMENT)               FORCE
IHM       I  U  HINGE MOMENT ELEMENT INDEX                                     FORCE
IM        I  C  ELEMENT ROW NUMBER ARRAY                                       FORCE
IMPACI    I  A  STARTING ELEMENT IMPACT METHOD                                 FORCE
IMPACT    I  A  IMPACT FORCE CALCULATION METHOD                                FORCE
IMPS      I  U  SAVED VALUE OF IMPACT FORCE METHOD                             FORCE
IN        I  C  ELEMENT COLUMN NUMBER ARRAY                                    FORCE
IORIEN    I  A  ELEMENT ORIENTATION                                            FORCE
IPRCK     I  U  PRINT FLAG                                                     FORCE
IPRINT    I  A  PRINT FLAG                                                     FORCE
IRFD11    I  U  TAPE 11 READ FLAG INDICATOR                                    FORCE
IS        I  C  SKIN FRICTION FLAG DATA ARRAY                                  FORCE
ISBP      I  U  FORCE SUMMATION BY PASS FLAG (=1 TO BY PASS SUMMATION)         FORCE
ISDET     I  U  DATA GENERATION CONTROL FLAG                                   FORCE
ISE       I  U  DATA GENERATION CONTROL FLAG                                   FORCE
ISHAD     I  A  SHADOW FORCE CALCULATION METHOD                                FORCE
ISHADI    I  A  STARTING ELEMENT METHOD IN SHADOW REGION                       FORCE
ISHS      I  U  SAVED VALUE OF SHADOW FORCE METHOD                             FORCE
ISIZ      I  A  NUMBER OF ELEMENTS TO BE STORED IN CORE                        FORCE
ISPNT     I  U  SEPARATION AND ATTACHMENT PRINT FLAG                           FORCE
IVISIN    I  U  VISCOUS-INTERACTION CONTROL FLAG                               FORCE
I4CT      I  U  COUNTER FOR READING CONTROL SURFACE GEOMETRY DATA              FORCE
J         I  A  ALPHA-BETA COUNTER FLAG                                        FORCE
K         I  C  NUMBER OF ELEMENTS                                             FORCE
L         I  U  ELEMENT FORCE CALCULATION LOOP COUNTER                         FORCE
LL        I  U  ELEMENT NUMBER                                                 FORCE
```

```
SYMBOLS USED IN SUBROUTINE FORCE

LOVERD   R  U  LIFT TO DRAG RATIO                                           FORCE
LS       I  C  NUMBER OF ELEMENTS                                           FORCE
LSAVE    I  U  SAVEL ELEMENT NUMBER (ALSO ITERATION COUNTER)                FORCE
M        I  U  ELEMENT ROW NUMBER                                           FORCE
MAC      R  A  REFERENCE LENGTH FOR MOMENT COEFFICIENTS                     FORCE
MACH     R  A  MACH NUMBER                                                  FORCE
MER      I  U  ERROR FLAG                                                   FORCE
N        I  U  ELEMENT COLUMN NUMBER                                        FORCE
NPCK     I  U  HEADER PRINT CHECK FLAG                                      FORCE
NPRT     I  U  PRINT COUNTER                                                FORCE
NS       I  A  NUMBER OF SKIN FRICTION SURFACES                             FORCE
NW       R  A  WALL TEMPERATURE CALCULATION FLAG FOR FLOSEP                 FORCE
NX       R  U  ELEMENT DIRECTION COSINE-X                                   FORCE
NX2      R  C  ELEMENT DIRECTION COSINE ARRAY-X                             FORCE
NY       R  U  ELEMENT DIRECTION COSINE-Y                                   FORCE
NY2      R  C  ELEMENT DIRECTION COSINE ARRAY-Y                             FORCE
NZ       R  U  ELEMENT DIRECTION COSINE-Z                                   FORCE
NZ2      R  C  ELEMENT DIRECTION COSINE ARRAY-Z                             FORCE
P        R  U  ROLL RATE                                                    FORCE
PAGE     I  C  PAGE NUMBER                                                  FORCE
PFS      R  A  FREE-STREAM PRESSURE-LBS / SQUARE FOOT                       FORCE
PHIR     R  U  ROLL ANGLE, RADIANS                                          FORCE
PPT2     R  U  OSU METHOD PRESSURE RATIO                                    FORCE
PRINT    I  A  PRINT FLAG                                                   FORCE
PSTAG    R  A  WIND TUNNEL STAGNATION PRESSURE-LBS / SQUARE FOOT            FORCE
PT2PO    R  U  OSU METHOD PRESSURE RATIO BEHIND NORMAL SHOCK                FORCE
Q        R  U  PITCH RATE, RADIANS / SECOND                                 FORCE
QQINF    R  A  DYNAMIC PRESSURE RATIO CORRECTION FACTOR                     FORCE
QQINFS   R  C  SAVED VALUES OF DYNAMIC PRESSURE CORRECTION                  FORCE
QRP      R  A  INPUT VEHICLE ROTATION RATE, RADIANS / SECOND                FORCE
R        R  U  YAW RATE, RADIANS / SECOND                                   FORCE
RENO     R  A  FREE STREAM REYNOLDS NUMBER                                  FORCE
RETRAN   R  A  TRANSITION REYNOLDS NUMBER FOR CONTROL SURFACE               FORCE
RHOFS    R  U  FREE STREAM DENSITY                                          FORCE
ROLL     R  U  ROLL ANGLE, DEGREES                                          FORCE
ROLLR    R  U  ROLL ANGLE, RADIANS                                          FORCE
```

```
SYMBOLS USED IN SUBROUTINE FORCE

S         R  U  FREE MOLECULAR FLOW SPEED RATIO                                        FORCE
SHEAR     R  U  FREE MOLECULAR FLOW SHEAR FORCE                                        FORCE
SHEARX    R  U  X-COMPONENT OF FREE MOLECULAR FLOW SHEAR FORCE                         FORCE
SHEARY    R  U  Y-COMPONENT OF FREE MOLECULAR FLOW SHEAR FORCE                         FORCE
SHEARZ    R  U  Z-COMPONENT OF FREE MOLECULAR FLOW SHEAR FORCE                         FORCE
SKIN      R  U  TOTAL AXIAL FORCE SKIN FRICTION CONTRIBUTION                           FORCE
SPAN      R  A  REFERENCE LENGTH FOR ROLLING, YAWING COEFFICIENTS                      FORCE
SREF      R  A  VEHICLE REFERENCE AREA (WING AREA)                                     FORCE
SSIND     R  U  SPEED RATIO TIMES SINE OF IMPACT ANGLE                                 FORCE
STOTAL    R  U  TOTAL VALUE OF SHEAR FORCE VECTOR                                      FORCE
SURF      R  C  SKIN FRICTION DATA ARRAY                                               FORCE
SWEEP     R  A  LEADING EDGE SWEEP (NOT USED BY MARK II)                               FORCE
SX        R  U  SHEAR FORCE VECTOR COMPONENT-X                                         FORCE
SY        R  U  SHEAR FORCE VECTOR COMPONENT-Y                                         FORCE
SYMFCO    I  U  SYMMETRY FACTOR                                                        FORCE
SYMFCT    I  A  SYMMETRY FACTOR                                                        FORCE
SZ        R  U  SHEAR FORCE VECTOR COMPONENT-Z                                         FORCE
TBTIN     R  U  RATIO OF BODY TEMPERATURE TO FREE-STREAM TEMPERATURE                   FORCE
TFS       R  U  FREE-STREAM TEMPERATURE                                                FORCE
THETA     R  U  SURFACE SLOPE                                                          FORCE
TINT2     R  U  TEMPERATURE PARAMETER FOR CONE MACH NUMBER EQUATION                    FORCE
TITLE     R  C  TITLE                                                                  FORCE
TSTAG     R  A  WIND TUNNEL STAGNATION TEMPERATURE, DEGREES F                          FORCE
TWALL     R  A  WALL TEMPERATURE FOR FLOSEP                                            FORCE
TX        R  U  FREE MOLECULAR FLOW VECTOR COMPONENT-X                                 FORCE
TY        R  U  FREE MOLECULAR FLOW VECTOR COMPONENT-Y                                 FORCE
TZ        R  U  FREE MOLECULAR FLOW VECTOR COMPONENT-Z                                 FORCE
V         R  A  FREE-STREAM VELOCITY, FEET / SECOND                                    FORCE
VIS       R  U  FREE-STREAM VISCOSITY                                                  FORCE
VLOCAL    R  U  TOTAL LOCAL VELOCITY                                                   FORCE
VX        R  U  LOCAL VELOCITY COMPONENT-X                                             FORCE
VXI       R  U  FREE-STREAM VELOCITY COMPONENT-X                                       FORCE
VY        R  U  LOCAL VELOCITY COMPONENT-Y                                             FORCE
VYI       R  U  FREE-STREAM VELOCITY COMPONENT-Y                                       FORCE
VZ        R  U  LOCAL VELOCITY COMPONENT-Z                                             FORCE
VZI       R  U  FREE STREAM VELOCITY COMPONENT-Z                                       FORCE
```

FORCE

```
SYMBULS USED IN SUBROUTINE FORCE

XATACH   R  U  X-COORDINATE AT FLOW ATTACHMENT POINT                              FORCE
XCENT    R  U  QUADRILATERAL ELEMENT CENTROID-X                                   FORCE
XCENT2   R  C  QUADRILATERAL ELEMENT CENTROID ARRAY-X                             FORCE
XCG      R  A  X-CENTER FOR MOMENT CALCULATIONS                                   FORCE
XLE      R  U  X-DISTANCE FROM CENTRAID OF ELEMENT TO LEADING EDGE LINE           FORCE
XPA      R  D  X-COORDINATES OF QUADRILATERAL ELEMENT                             FORCE
XSEPP    R  U  X-COORDINATE AT FLOW SEPARATION POINT                              FORCE
YCENT    R  U  QUADRILATERAL ELEMENT CENTROID-Y                                   FORCE
YCENT2   R  C  QUADRILATERAL ELEMENT CENTROID ARRAY-Y                             FORCE
YCG      R  A  Y-CENTER FOR MOMENT CALCULATIONS                                   FORCE
YPA      R  D  Y-COORDINATES OF QUADRILATERAL ELEMENT                             FORCE
ZCENT    R  U  QUADRILATERAL ELEMENT CENTRAID-Z                                   FORCE
ZCENT2   R  C  QUADRILATERAL ELEMENT CENTRAID ARRAY-Z                             FORCE
ZCG      R  A  Z-CENTER FOR MOMENT CALCULATIONS                                   FORCE
ZPA      R  D  Z-COORDINATES OF QUADRILATERAL ELEMENT                             FORCE
```

11. SUBROUTINE SHKEXP (DECK AROJ)

This subroutine performs a shock expansion analysis along a streamwise strip of elements.

a. Algorithm

The element is first checked to see if it is the first element in a strip. If it is, the local properties on it are calculated by the appropriate method and saved for use on the next element. For the next element in the strip the turning angle is calculated and either the compression or the expansion routine is used to determine its local properties (pressure coefficient, Mach number, and temperature).

b. Input/Output

None

c. Error

An error condition occurs when the number of initial strip elements is greater than 100, and when the wrong initial element method has been input.

d. Subroutines Required

COMPR, EXPAND, CONE

e. Argument List

(IORIEN, N, M, IPRCK, NX, NY, NZ, DELTA, PFS, MACH, IGTS, DELTAR, IMPACI, CPSTAG, TFS, CP, G, ISHADI, IFIRST, LL, IPRINT, IGTYPE, RHOFS, AFS, VIS, V, RENO, ISMODE)

f. Length

4472 bytes

DECK AROJ

```
      SUBROUTINE SHKEXP (IORIEN,N,M,IPRCK,NX,NY,NZ,DELTA,PFS,MACH,IGTS,
     1  DELTAR,IMPACI,CPSTAG,TFS,CP,G,ISHADI,IFIRST,LL,IPRINT,IGTYPE,
     2  RHOFS,AFS,VIS,V,RENO,ISMODE)
C
C*********************************************************************
C*** THIS SUBROUTINE CALCULATES LOCAL CONDITIONS ON AN ELEMENT USING ***
C*** SHOCK EXPANSION THEORY.                                        ***
C*********************************************************************
C
      DIMENSION  TITLE(15),ANGLE(3),FS(8),BS(8),NXI( 30),NYI( 30),
     1  NZI( 30),MACHI( 30),PI( 30),TI( 30)
      DIMENSION NX2( 300),NY2( 300),NZ2( 300),XCENT2( 300),
     1  YCENT2( 300),ZCENT2( 300),AREA2( 300),IN( 300),IM( 300)
C
      COMMON  CASE,TITLE,PAGE,ERROR,NX2,NY2,NZ2,XCENT2,YCENT2,ZCENT2,
     1  AREA2,IN,IM,K,LS,FS,BS
C
      INTEGER  CASE,PAGE,ERROR
C
      REAL  MACH,NX,NY,NZ,NXI,NYI,NZI,MACHI,NU
      REAL  NX2,NY2,NZ2
C
C
C  CHECK IF THIS ELEMENT IS THE FIRST ELEMENT IN A COLUMN OF ELEMENTS
      IF (IGTYPE .EQ. 1) GO TO 50
      IF( IORIEN.EQ.0.AND.N.EQ.1 .OR. IORIEN.EQ.1.AND.M.EQ.1 ) GO TO 80
      GO TO 51
   50 IF (IGTS.EQ.1 .AND. M.EQ.1) GO TO 80
C
C*********************************************************************
C******  CALCULATIONS FOR ELEMENTS THAT ARE NOT INITIAL ROW ELEMENTS ***
C*********************************************************************
   51 IF (IORIEN .EQ. 0) II = M
      IF (IORIEN.EQ.0 .AND. M.GT.MMAX) GO TO 80
      IF (IORIEN .EQ. 1) II=N
```

```
DECK AROJ

      SINNU =SQRT((NY*NZI(II)-NZ*NYI(II))**2+(NZ*NXI(II)-NX*NZI(II))**2    AROJ  0360
     1      +(NX*NYI(II)-NY*NXI(II))**2)                                    AROJ  0370
      NU = ARSIN(SINNU) * 0.5729578E02                                      AROJ  0380
      NU = ABS(NU)                                                          AROJ  0390
      IF (NX .LT. NXI(II)) NU = -NU                                         AROJ  0400
      ANGLE(2) = ABS(NU)                                                    AROJ  0410
C                                                                           AROJ  0420
C  SET UP DATA FOR COMPR OR EXPAND                                          AROJ  0430
      DO 82 I=1,8                                                           AROJ  0440
   82 FS(I) = BS(I)                                                         AROJ  0450
       FS(2) = PI(II)                                                       AROJ  0460
       FS(3) = TI(II)                                                       AROJ  0470
       FS(6) = MACHI(II)                                                    AROJ  0480
       ISDET = 0                                                            AROJ  0490
      IF (NU.GT.-0.00001 .AND. NU.LT.0.00001) GO TO 61                      AROJ  0500
      IF (NU .LT. 0.0) GO TO 81                                             AROJ  0510
      CALL COMPR (ANGLE,MER,IPRCK,CPSTAG,TFS,PFS,ISDET,IFIRST,CP)           AROJ  0520
      GO TO 60                                                              AROJ  0530
   81 CALL EXPAND (ANGLE,MER,IPRCK,ISDET,CP)                                AROJ  0540
      GO TO 60                                                              AROJ  0550
C                                                                           AROJ  0560
   61 DO 62 I=1,8                                                           AROJ  0570
   62 BS(I) = FS(I)                                                         AROJ  0580
   60 GO TO 97                                                              AROJ  0590
C                                                                           AROJ  0600
C*********************************************************************      AROJ  0610
C************  CALCULATION FOR INITIAL ELEMENT OF EACH ROW  ************      AROJ  0620
C*********************************************************************      AROJ  0630
C                                                                           AROJ  0640
C  CHECK IF THERE ARE TOO MANY INITIAL ELEMENTS (MAXIMUM OF 100)            AROJ  0650
   80 IF ((IORIEN.EQ.0 .AND. M.GT. 30).OR.(IORIEN.EQ.1.AND.N.GT. 30))       AROJ  0660
     1   GO TO 83                                                           AROJ  0670
C                                                                           AROJ  0680
      MMAX = M                                                              AROJ  0690
      IF (IORIEN.EQ.0) II=M                                                 AROJ  0700
      IF (IORIEN.EQ.1) II=N                                                 AROJ  0710
```

DECK AROJ

```
      IF (ISMODE .EQ. 1) GO TO 97
C
      ANGLE(2) = ABS(DELTA)
      NU = DELTA
      FS(1) = RHOFS
      FS(2) = PFS
      FS(3) = TFS
      FS(4) = AFS
      FS(5) = VIS
      FS(6) = MACH
      FS(7) = V
      FS(8) = RENO
      ISDET = 0
C
C  CHECK IF IMPACT OR SHADOW
      IF (DELTAR .LE. 0.0) GO TO 85
C
C  IMPACT FLOW  *****************
      GO TO (86,86,88,86,90,86,86,86,86,86,86,86,91), IMPACI
C
C  TANGENT WEDGE
   88 CALL COMPR (ANGLE,MER,IPRCK,CPSTAG,TFS,PFS,ISDET,IFIRST,CP)
      GO TO 97
C
C  TANGENT CONE EMPIRICAL
   90 ANGLE(1) = DELTA
      CALL CONE (ANGLE,CP,0)
      PI(II) = BS(2)
      MACHI(II) = BS(6)
      TI(II) = BS(3)
      GO TO 105
C  DELTA WING EMPIRICAL FOR SHOCK-EXPANSION CALCS.
   91 DELDLW = DELTAR
      IF (DELDLW .LT. 0.01745) DELDLW = 0.01745
      EMNS = MACH * SIN(DELDLW)
      EMNS = 1.09*EMNS + EXP(-0.49 *EMNS)
```

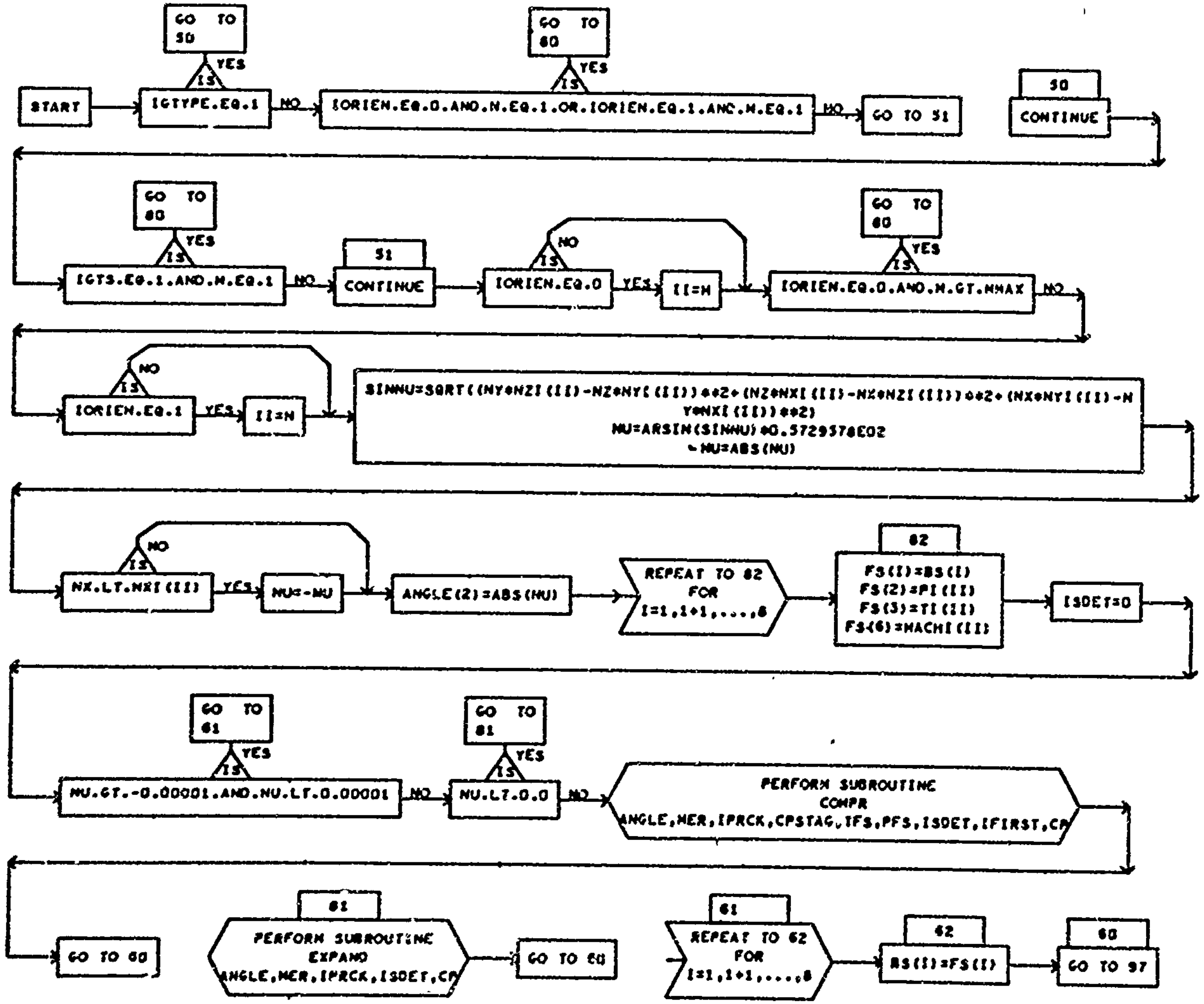
```
DECK AROJ
      CP = 1.0/(MACH*MACH) * 1.66667*(EMNS*EMNS-1.0)                   AROJ  1080
      P2PII = 0.7*MACH*MACH*CP + 1.0                                   AROJ  1090
      PI(II) = P2PII * FS(2)                                           AROJ  1100
      TINT2 = ((G+1.0)**2 *EMNS*EMNS)/((2.0*G*EMNS*EMNS-(G-1.0))*      AROJ  1110
     1         ((G-1.0)*EMNS*EMNS + 2.0))                              AROJ  1120
      MACHI(II) = SQRT((MACH*MACH-(4.0*(EMNS-1.0)*(G*EMNS+1.0))/       AROJ  1130
     1              ((G+1.0)**2*EMNS))*TINT2)                          AROJ  1140
      TI(II) = FS(3) / TINT2                                           AROJ  1150
  105 BS(3) = TI(II)                                                   AROJ  1160
      BS(2) = PI(II)                                                   AROJ  1170
      BS(6) = MACHI(II)                                                AROJ  1180
      BS(1) = RHOFS * (BS(2)/PFS) * (TFS/BS(3))                        AROJ  1190
      BS(4) = 49.021177 * SQRT(BS(3))                                  AROJ  1200
      IF (BS(3).GE.225.0) BS(5)=2.27*BS(3)**1.5/((BS(3)+198.6)*10.**8) AROJ  1210
      IF (BS(3).LT.225.0) BS(5) = 0.80382436E-9 * BS(3)                AROJ  1220
      BS(7) = BS(4) * BS(6)                                            AROJ  1230
      BS(8) = BS(1) * BS(7) / BS(5)                                    AROJ  1240
      GO TO 99                                                         AROJ  1250
C  SHADOW FLOW *************************                               AROJ  1260
   85 GO TO (70,70,72,70,70,70,70),ISHADI                              AROJ  1270
   70 GO TO 86                                                         AROJ  1280
C  EXPANSION FROM FREESTREAM                                           AROJ  1290
   72 ISDET = 0                                                        AROJ  1300
      CALL EXPAND (ANGLE,MER,IPRCK,ISDET,CP)                           AROJ  1310
C                                                                      AROJ  1320
   97 MACHI(II) = BS(6)                                                AROJ  1330
      PI(II)    = BS(2)                                                AROJ  1340
      TI(II)    = BS(3)                                                AROJ  1350
      CP =  (BS(2)/PFS - 1.0) / (0.7*MACH*MACH)                        AROJ  1360
   99 NXI(II) = NX                                                     AROJ  1370
      NYI(II) = NY                                                     AROJ  1380
      NZI(II) = NZ                                                     AROJ  1390
C                                                                      AROJ  1400
C                                                                      AROJ  1410
   11 CONTINUE                                                         AROJ  1420
      IF (IPRINT .EQ. 1) WRITE (6,100) LL,N,M,BS(2),BS(3),BS(6),CP,    AROJ  1430
```

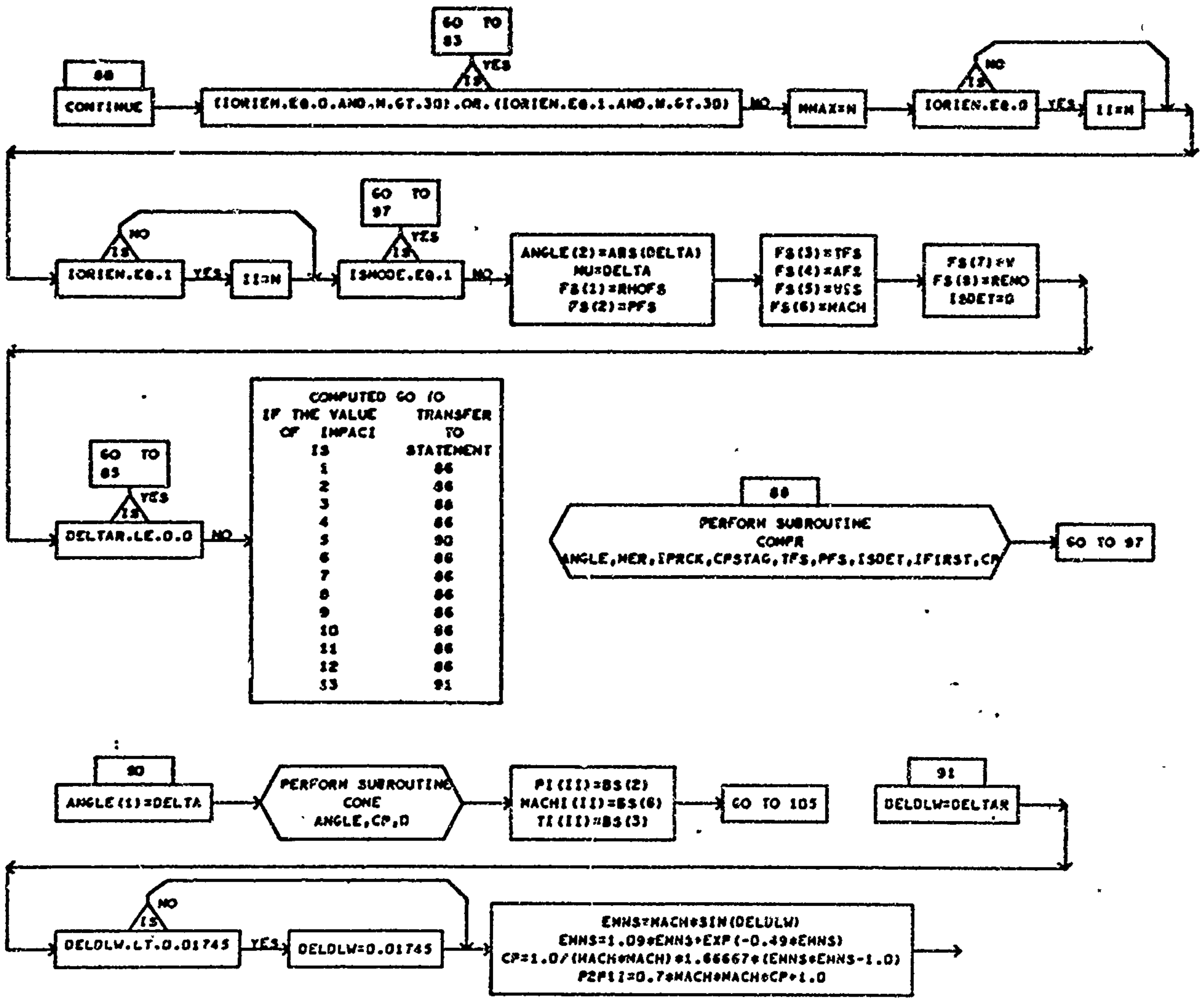
SHKEXP

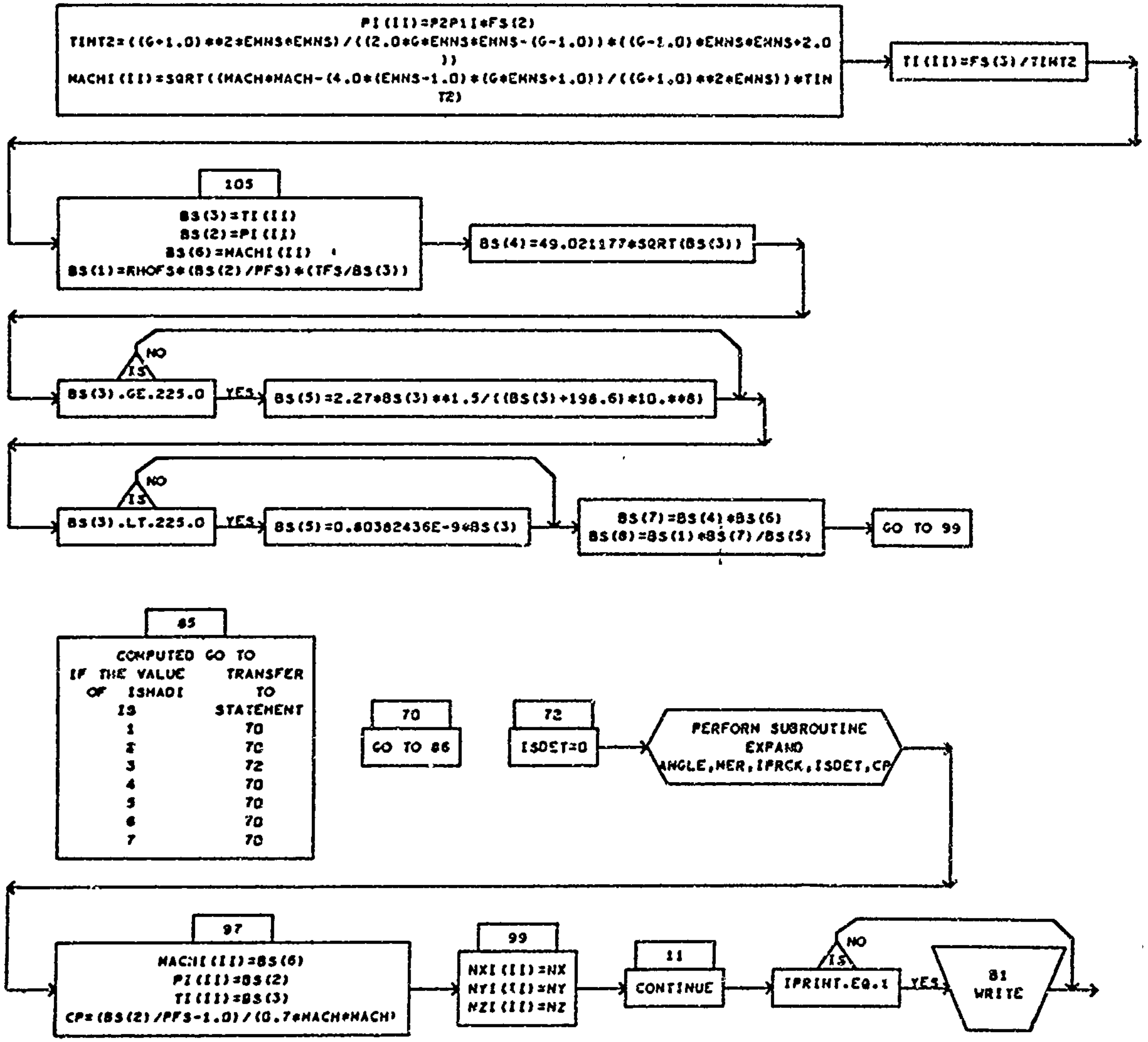
```
DECK AROJ

      1  NU,FS(2),FS(3),FS(6)                                                AROJ  1440
 100  FORMAT (1H0,32H   SHK-EXP. LOCAL CONDITIONS   LL=I5,4H   N=I4,        AROJ  1450
      1  4H   M=I4,4H   P=E12.5,4H   T=E12.5,7H   MACH=F7.3,5H   CP=E12.5,/  AROJ  1460
      2  1H ,28X,13HTURN ANGLE   =F9.4,4X,3HPI=E12.5,4H TI=E12.5,            AROJ  1470
      3  7H MACHI=F7.3 )                                                     AROJ  1480
       RETURN                                                                AROJ  1490
C                                                                            AROJ  1500
C                                                                            AROJ  1510
  83   WRITE (6,98)                                                          AROJ  1520
  98   FORMAT (1H ,48H****NUMBER OF INITIAL ELEMENTS CANNOT EXCEED 100       AROJ  1530
      1 57H FOR SHOCK-EXPANSION CALCULATIONS.  CHANGE INPUT DATA**** )       AROJ  1540
       WRITE (6,101) IORIEN,IGTYPE,IGTS,LL,N,M                               AROJ  1550
 101   FORMAT (1H ,10X,8HIORIEN =I2,5X,8HIGTYPE =I2,5X,6HIGTS =I2,           AROJ  1560
      1  5X,4HLL =I5,5X,3HN =I5,5X,3HM =I5)                                  AROJ  1570
       ERROR  = 3                                                            AROJ  1580
       RETURN                                                                AROJ  1590
  86   WRITE(6,96)                                                           AROJ  1600
  96   FORMAT (1H ,47H****DURING SHOCK-EXPANSION CALCULATIONS PROGRAM        AROJ  1610
      1 59H TRIED TO USE WRONG INITIAL ELEMENT METHOD--CHECK INPUT****)      AROJ  1620
       ERROR  = 3                                                            AROJ  1630
       RETURN                                                                AROJ  1640
C                                                                            AROJ  1650
       END                                                                   AROJ  1660
```

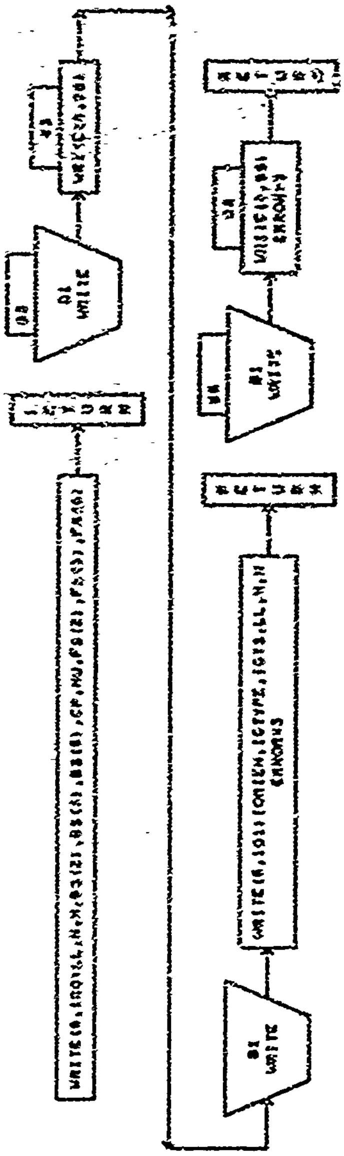
SUBROUTINE SHKEXP




80
CONTINUE
((IORIEN.EQ.0.AND.N.GT.30).OR.(IORIEN.EQ.1.AND.N.GT.30))
IS
YES
GO TO 83
NO
NMAX=N
IORIEN.EQ.0
IS
NO
YES
II=N
IORIEN.EQ.1
IS
NO
YES
II=N
ISMODE.EQ.1
IS
YES
GO TO 97
NO
ANGLE(2)=ABS(DELTA)
MU=DELTA
FS(1)=RHOFS
FS(2)=PFS
FS(3)=TFS
FS(4)=AFS
FS(5)=VSS
FS(6)=MACH
FS(7)=V
FS(8)=RENO
ISDET=0
DELTAR.LE.0.0
IS
YES
GO TO 85
NO
COMPUTED GO TO
IF THE VALUE OF IMPACI IS
TRANSFER TO STATEMENT
1 86
2 86
3 86
4 86
5 90
6 86
7 86
8 86
9 86
10 86
11 86
12 86
13 91
86
PERFORM SUBROUTINE
COMPR
ANGLE,MER,IPRCK,CPSTAG,TFS,PFS,ISDET,IFIRST,CP
GO TO 97
90
ANGLE(1)=DELTA
PERFORM SUBROUTINE
CONE
ANGLE,CP,D
PI(II)=BS(2)
MACHI(II)=BS(6)
TI(II)=BS(3)
GO TO 105
91
DELDLW=DELTAR
DELDLW.LT.0.01745
IS
NO
YES
DELDLW=0.01745
EMNS=MACH*SIN(DELDLW)
EMNS=1.09*EMNS+EXP(-0.49*EMNS)
CP=1.0/(MACH*MACH)*1.66667*(EMNS*EMNS-1.0)
P2P1I=0.7*MACH*MACH*CP+1.0


PI(II)=P2P1I*FS(2)
TINT2=((G+1.0)**2*EHNS*EHNS)/((2.0*G*EHNS*EHNS-(G-1.0))*((G-1.0)*EHNS*EHNS+2.0
))
MACHI(II)=SQRT((MACH*MACH-(4.0*(EHNS-1.0)*(G*EHNS+1.0))/((G+1.0)**2*EHNS))*TIN
T2)
TI(II)=FS(3)/TINT2
105
BS(3)=TI(II)
BS(2)=PI(II)
BS(6)=MACHI(II)
BS(1)=RHOFS*(BS(2)/PFS)*(TFS/BS(3))
BS(4)=49.021177*SQRT(BS(3))
BS(3).GE.225.0
IS
NO
YES
BS(5)=2.27*BS(3)**1.5/((BS(3)+198.6)*10.**8)
BS(3).LT.225.0
IS
NO
YES
BS(5)=0.80382436E-9*BS(3)
BS(7)=BS(4)*BS(6)
BS(8)=BS(1)*BS(7)/BS(5)
GO TO 99
85
COMPUTED GO TO
IF THE VALUE OF ISHADI IS
TRANSFER TO STATEMENT
1 70
2 70
3 72
4 70
5 70
6 70
7 70
70
GO TO 86
72
ISDET=0
PERFORM SUBROUTINE
EXPAND
ANGLE,MER,IPRCK,ISDET,CP
97
MACHI(II)=BS(6)
PI(II)=BS(2)
TI(II)=BS(3)
CP=(BS(2)/PFS-1.0)/(0.7*MACH*MACH)
99
NXI(II)=NX
NYI(II)=NY
NZI(II)=NZ
11
CONTINUE
IPRINT.EQ.1
IS
NO
YES
81
WRITE

SHKEXP


WRITE(6,100)LL,N,K,BS(2),BS(3),BS(5),CP,HU,FS(2),FS(3),FA(6)
RETURN
D1
WRITE
B1
WRITE
WRITE(6,103)(OMIEN,ICTYPE,ICYS,LL,N,N
ERRORS
RETURN
B1
WRITE
RETURN

```
SYMBOLS USED IN SUBROUTINE SHKEXP

AFS      R  A  FREE-STREAM SPEED OF SOUND                                    SHKEXP
ANGLE    R  D  FLOW ANGLE ARRAY                                              SHKEXP
AREA2    R  C  QUADRILATERAL ELEMENT AREA ARRAY                              SHKEXP
BS       R  C  FLOW CONDITIONS BEHIND SHOCK OR EXPANSION                     SHKEXP
CASE     I  C  CASE NUMBER                                                   SHKEXP
CP       R  A  PRESSURE COEFFICIENT                                          SHKEXP
CPSTAG   R  A  MODIFIED NEWTONIAN CORRELATION FACTOR, K                      SHKEXP
DELDLW   R  U  IMPACT ANGLE FOR DELTA-WING OPTION, RADIANS                   SHKEXP
DELTA    R  A  IMPACT ANGLE, DEGREES                                         SHKEXP
DELTAR   R  A  IMPACT ANGLE, RADIANS                                         SHKEXP
EMNS     R  U  MACH NORMAL TO THE SHOCK                                      SHKEXP
ERROR    I  C  ERROR FLAG                                                    SHKEXP
FS       R  C  FLOW CONDITIONS BEFORE SHOCK OR EXPANSION                     SHKEXP
G        R  A  RATIO OF SPECIFIC HEATS                                       SHKEXP
IFIRST   I  A  FIRST POINT FLAG FOR USE IN NEWTPM                            SHKEXP
IGTS     I  A  CONTROL SURFACE FLAG FOR PRESENT ELEMENT                      SHKEXP
IGTYPE   I  A  GEOMETRY TYPE (=1 FOR CONTROL SURFACE COMPONENT)              SHKEXP
II       I  U  LEADING ELEMENT INDEX                                         SHKEXP
IM       I  C  ELEMENT ROW NUMBER ARRAY                                      SHKEXP
IMPACI   I  A  STARTING ELEMENT IMPACT METHOD                                SHKEXP
IN       I  C  ELEMENT COLUMN NUMBER ARRAY                                   SHKEXP
IORIEN   I  A  ELEMENT ORIENTATION                                           SHKEXP
IPRCK    I  A  PRINT FLAG                                                    SHKEXP
IPRINT   I  A  PRINT FLAG                                                    SHKEXP
ISDEF    I  U  DATA GENERATION CONTROL FLAG                                  SHKEXP
ISHADI   I  A  STARTING ELEMENT METHOD IN SHADOW REGION                      SHKEXP
ISMODE   I  A  SHOCK-EXPANSION MODE FLAG (USED IN FLOSEP)                    SHKEXP
K        I  C  NUMBER OF ELEMENTS                                            SHKEXP
LL       I  A  ELEMENT NUMBER                                                SHKEXP
LS       I  C  NUMBER OF ELEMENTS                                            SHKEXP
M        I  A  ELEMENT ROW NUMBER                                            SHKEXP
MACH     R  A  MACH NUMBER                                                   SHKEXP
MACHI    R  D  STARTING OR PREVIOUS ELEMENT MACH NUMBER                      SHKEXP
MER      I  U  ERROR FLAG                                                    SHKEXP
MMAX     I  U  MAXIMUM VALUE FOR PARAMETER M                                 SHKEXP
N        I  A  ELEMENT COLUMN NUMBER                                         SHKEXP
```

[redacted]

```
SYMBOLS USED IN SUBROUTINE SHKEXP

NU       R  U   FLOW TURNING ANGLE                                                  SHKEXP
NX       R  A   ELEMENT DIRECTION COSINE-X                                          SHKEXP
NXI      R  D   ELEMENT DIRECTION COSINE-X                                          SHKEXP
NX2      R  C   ELEMENT DIRECTION COSINE ARRAY-X                                    SHKEXP
NY       R  A   ELEMENT DIRECTION COSINE-Y                                          SHKEXP
NYI      R  D   ELEMENT DIRECTION COSINE-Y                                          SHKEXP
NY2      R  C   ELEMENT DIRECTION COSINE ARRAY-Y                                    SHKEXP
NZ       R  A   ELEMENT DIRECTION COSINE-Z                                          SHKEXP
NZI      R  D   ELEMENT DIRECTION COSINE-Z                                          SHKEXP
NZ2      R  C   ELEMENT DIRECTION COSINE ARRAY-Z                                    SHKEXP
PAGE     I  C   PAGE NUMBER                                                         SHKEXP
PFS      R  A   FREE-STREAM PRESSURE, LBS/SQUARE FOOT                               SHKEXP
PI       R  D   PRESSURE                                                            SHKEXP
P2PI1    R  U   PRESSURE RATIO                                                      SHKEXP
RENO     R  A   FREE-STREAM REYNOLDS NUMBER                                         SHKEXP
RHOFS    R  A   FREE-STREAM DENSITY                                                 SHKEXP
SINNU    R  U   SINE OF FLOW TURNING ANGLE                                          SHKEXP
TFS      R  A   FREE STREAM TEMPERATURE                                             SHKEXP
TI       R  D   LOCAL TEMPERATURE                                                   SHKEXP
TINT2    R  U   TEMPERATURE RATIO                                                   SHKEXP
TITLE    R  C   TITLE                                                               SHKEXP
V        R  A   FREE STREAM VELOCITY, FEET/SECOND                                   SHKEXP
VIS      R  A   FREE-STREAM VISCOSITY                                               SHKEXP
XCENT2   R  C   QUADRILATERAL ELEMENT CENTROID ARRAY-X                              SHKEXP
YCENT2   R  C   QUADRILATERAL ELEMENT CENTROID ARRAY-Y                              SHKEXP
ZCENT2   R  C   QUADRILATERAL ELEMENT CENTROID ARRAY-Z                              SHKEXP
```

12. SUBROUTINE FLOSEP (DECK AROK)

This subroutine has the task of determining the effect of flow separation caused by the deflection of a control surface.

a. Algorithm

The flow separation calculations are performed in three cycles. The first cycle is with the control deflected and determines if separation will occur. The second cycle determines where the separation occurs and the pressure changes due to separation. The third cycle calculated the final pressure, using the normal program input method in combination with the flow separation increments.

b. Input/Output

None

c. Error

An error condition occurs when the number of streamwise elements for the control fore-surface and flap is greater than 125.

d. Subroutines Required

TEMP, COMPR, SHKEXP

e. Argument List

(IGT, LL, N, M, NX, NY, NZ, XCENT, YCENT, ZCENT, AREA, XPA, YPA, ZPA, IGTYPE, IORIEN, IPRCK, DELTA, PFS, MACH, DELTAR, IMPACI, CPSTAG, TFS, CP, G, ISHADI, IFIRST, ISBP, IFSCY, IGTS, IMPS, ISHS, L, XLE, DELTAE, SWEEP, CPNIN, DELCPC, XATACH, XSEPP, ISPNT, IMPACT, ISHAD, RETRAN)

f. Length

10208 bytes

DECK AROK

```
      SUBROUTINE FLOSEP (IGT,LL,N,M,NX,NY,NZ,XCENT,YCENT,ZCENT,AREA,XPA,
     1        YPA,ZPA,IGTYPE,IORIEN,IPRCK,DELTA,PFS,MACH,DELTAR,IMPACI,
     2        CPSTAG,TFS,CP,G,ISHADI,IFIRST,    ISBP,IFSCY,IGTS,IMPS,
     3        ISHS,L,XLE,DELTAE,SWEEP,CPNIN,DELCPC,XATACH,XSEPP,ISPNT,
     4        IMPACT,ISHAD,RETRAN,NW,TWALL,IRED11)
C
C***********************************************************************
C******  THIS SUBROUTINE DETERMINES THE EFFECT OF VISCOUS FLOW  ********
C******  SEPARATION ON SURFACE PRESSURES                         ********
C***********************************************************************
C
      DIMENSION  TITLE(15),ANGLE(3),FS(8),BS(8),XPA(4),YPA(4),ZPA(4),
     1  TR(10),RE(2),TS(2),PSEVIS(125),PSEIN(125)
      DIMENSION NX2( 300),NY2( 300),NZ2( 300),XCENT2( 300),
     1  YCENT2( 300),ZCENT2( 300),AREA2( 300),IN( 300),IM( 300)
C
      COMMON  CASE,TITLE,PAGE,ERROR,NX2,NY2,NZ2,XCENT2,YCENT2,ZCENT2,
     1  AREA2,IN,IM,K,LS,FS,BS
C
      INTEGER  CASE,PAGE,ERROR
C
      REAL  MACH,NX,NY,NZ,NX2,NY2,NZ2,NXH,NYH,NZH,MACHH,MACHX,MACHX1,MA,
     1 NXS,NYS,NZS,NXF,NYF,NZF,NXFS,NYFS,NZFS
C
C ***** THE FOLLOWING CARD SHOULD BE ICHECK = 1 FOR CHECKOUT ONLY
      ICHECK = 0
      IF (IGTS.EQ.1 .AND. M.EQ.1) ISCT = 0
      ISCT = ISCT + 1
      IF (ISCT .GT. 125) GO TO 150
      IF (ICHECK .EQ. 1)
     1WRITE (6,900) IGTS,IGT,L,LL,N,M,IFSCY,CP,ISCT
  900 FORMAT (1H0,5X,5HIGTS=I2,5H IGT=I2,3H L=I3,4H LL=I3,3H N=I3,
     1  3H M=I3,7H IFSCY=I2,4H CP=E12.5,7H  ISCT=I4)
C
C ***** CHECK FLOSEP CYCLE NUMBER  *****
```

```
DECK AROK

      GO TO (1,20,40), IFSCY                                                  AROK  0360
C                                                                             AROK  0370
C ****************************************************************************  AROK  0380
C ***** FIRST FLOSEP CYCLE WITH SHOCK EXPANSION AND FLAP DEFLECTED *****      AROK  0390
C ****************************************************************************  AROK  0400
C                                                                             AROK  0410
C  ***** CHECK IF THIS IS HINGE LINE ELEMENT, THE FIRST ELEMENT OF A          AROK  0420
C  ***** STRIP, OR THE FIRST FLAP ELEMENT                                     AROK  0430
    1 IF (IGTS.EQ.1 .AND. IGT.EQ.2 .AND. M.NE.1) GO TO 2                      AROK  0440
      IF (IGTS.EQ.1 .AND. M.EQ.1) LSS = L - 1                                 AROK  0450
      IF (IGTS.EQ.1 .AND. IGT.EQ.2 .AND. M.EQ.1) GO TO 2                      AROK  0460
      IF (IGTS.EQ.2 .AND. M.EQ.1) GO TO 9                                     AROK  0470
      GU TO 10                                                                AROK  0480
C                                                                             AROK  0490
C  CHECK IF FLOW SEPARATES                                                    AROK  0500
    9 CPA2IN = (BS(2)/PH - 1.0)/(G/2.0 *MACHH*MACHH)                          AROK  0510
C                                                                             AROK  0520
      IF (ITRANS .EQ. 0) CPAINC = 2.03*(MACHH**2-1.0)**(-0.306)               AROK  0530
     1                            /REAHL**0.25                                AROK  0540
      IF (ITRANS .EQ. 1) CPAINC = 2.2 / REAHL**0.1                            AROK  0550
C  SET FLOW SEPARATION FLAG ON OR OFF (KFLSP = 1 OR 0)                        AROK  0560
      KFLSP = 0                                                               AROK  0570
      IF (CPA2IN .GT. CPAINC) KFLSP = 1                                       AROK  0580
      IF (RETRAN .LT. 0.0) KFLSP = 0                                          AROK  0590
      DELTER=SQRT((NY*NZH-NZ*NYH)**2+(NZ*NXH-NX*NZH)**2+(NX*NYH-NY*NXH)       AROK  0600
     1   **2)                                                                 AROK  0610
      IF (ABS(DELTER) .GT. 1.0) DELTER = 1.0                                  AROK  0620
      DELTER = ABS(ARSIN(DELTER))                                             AROK  0630
      IF (NX .LT. NXH) DELTER = -DELTER                                       AROK  0640
      IF (ICHECK .EQ. 1)                                                      AROK  0650
     1WRITE (6,901) BS(2),MACHH,CPA2IN,REAFT,REAHL,CPAINC,ITRANS,KFLSP         AROK  0660
  901 FORMAT (1H ,6E14.5,2I2)                                                 AROK  0670
C                                                                             AROK  0680
      GO TO 10                                                                AROK  0690
C                                                                             AROK  0700
C  SAVE HINGE LINE ELEMENT GEOMETRY DATA                                      AROK  0710
```

FLOSEP

```
DECK AROK

    2  PH = BS(2)                                                         AROK  0720
       TH = BS(3)                                                         AROK  0730
       MACHH = BS(6)                                                      AROK  0740
       NXH = NX                                                           AROK  0750
       NYH = NY                                                           AROK  0760
       NZH = NZ                                                           AROK  0770
       LSEP = 0                                                           AROK  0780
       LATT = 0                                                           AROK  0790
       XHL = (XPA(2) + XPA(3)) / 2.0                                      AROK  0800
       YHL = (YPA(2) + YPA(3)) / 2.0                                      AROK  0810
       ZHL = (ZPA(2) + ZPA(3)) / 2.0                                      AROK  0820
       XSEPP = XHL                                                        AROK  0830
       XATACH = XSEPP                                                     AROK  0840
C   CALCULATE REYNOLDS NUMBER AT THE HINGE LINE                           AROK  0850
       XLEH = XLE -((XPA(2)+XPA(3))/2.0) + XCENT                          AROK  0860
       REAHL = XLEH * BS(8)                                               AROK  0870
       REAFT = BS(8)                                                      AROK  0880
       ITRANS = 0                                                         AROK  0890
       IF (REAHL .GE. RETRAN) ITRANS = 1                                  AROK  0900
C                                                                         AROK  0910
C                                                                         AROK  0920
   10  PSEIN(ISCT) = BS(2)                                                AROK  0930
       PSEVIS(ISCT) = BS(2)                                               AROK  0940
       ISBP = 1                                                           AROK  0950
C                                                                         AROK  0960
C   IS THIS THE LAST ELEMENT IN THE STRIP                                 AROK  0970
       IF (IGTS.EQ.2 .AND. IGY.EQ.1) GO TO 14                             AROK  0980
       GO TO 100                                                          AROK  0990
   14  J = IN(N+10)                                                       AROK  1000
       DO 11 I=1,J                                                        AROK  1010
   11  BACKSPACE 3                                                        AROK  1020
       J = IN(4)                                                          AROK  1030
       DO 12 I=1,J                                                        AROK  1040
   12  BACKSPACE 11                                                       AROK  1050
       L = LSS                                                            AROK  1060
       XTE = (XPA(2) + XPA(3)) / 2.0                                      AROK  1070
```

DECK AROK

```
      YTE = (YPA(2) + YPA(3)) / 2.0
      ZTE = (ZPA(2) + ZPA(3)) / 2.0
      CFLAP = SQRT ((XTE-XHL)**2 + (YTE-YHL)**2 + (ZTE-ZHL)**2)
      IF (ICHECK .EQ. 1)
     1WRITE (6,903)
  903 FORMAT (1H ,21HLAST ELEMENT ON STRIP  )
C
C  IS FLOW SEPARATION FLAG ON
      IF (KFLSP .EQ. 1) GO TO 13
      IFSCY = 3
      IMPACT = IMPS
      ISHAD = ISHS
      DELTAS = DELTAE
      DELTAE = 0.0
      GO TO 100
C
   13 IFSCY = 2
      ISEP = 0
      GO TO 100
C
C
C ***************************************************************************
C ***** SECOND FLOSEP CYCLE.  VISCOUS CALCULATION CYCLE  ***************
C ***************************************************************************
C
C  IS THIS ELEMENT ON FORE SURFACE OR ON FLAP
   20 IF (IGTS .EQ. 2) GO TO 30
C
      IF (ISEP .EQ. 1) GO TO 29
C *****CALCULATE REQUIRED DATA TO CHECK FOR FLOW SEPARATION POINT
      TR(5) = TWALL
      TR(6) = TWALL
      CALL TEMP (XLE,TR,RE,TS,NW,MER,0,RT)
      IF (ITRANS.EQ.0) REASFT = RE(1) / XLE
      IF (ITRANS.EQ.1) REASFT = RE(2) / XLE
      IF (ITRANS.EQ.0) DSQXP = 5.2 / SQRT(REASFT)
```

FLOSEP

DECK AROK

```
      IF (ITRANS.EQ.1) DSQXP = 0.154 / REASFT**0.1428*XLE**0.357
      DO = DSQXP * SQRT(XLE)
      IF (ISEP .EQ. 0) GO TO 202
      DXSEP = XLE - XSEP
      IF (XLE .LT. XSEP) GO TO 201
      GO TO 22
C
 202  MA = BS(6)
      REAXOP = XLE * BS(8)
      IF (ITRANS.EQ.0) CPAP=1.56*(MA*MA-1.0)**(-0.262)/REAXOP**0.25
      IF (ITRANS.EQ.1) CPAP=1.91*(MA*MA-1.0)**(-0.309)/REAXOP**0.1
      PPPO = 0.7*MA*MA*CPAP + 1.0
      IF (ITRANS.EQ.0) D1DO =5.69E5*MA**(-4.1)*(PPPO-1.0)**3.5
      IF (ITRANS.EQ.1) D1DO =1.1E6*(MA**(-1.67)*(PPPO-1.0))**8.55
      D1 = D1DO * DO
      XSEP = XLEH - D1
      DXSEP = XLE - XSEP
C
      IF (ICHECK .EQ. 1)
     1WRITE (6,904)
 904  FORMAT (1H0,31HCHECK FOR SEPARATION ON ELEMENT  )
      IF (ICHECK .EQ. 1)
     1WRITE (6,950) REAXOP,CPAP,PPPO,D1DO,REASFT,DSQXP,DO,D1,XSEP,XLE
 950  FORMAT (1H ,5E14.5,/1H ,5E14.5)
C
C ***** CHECK IF SEPARATION POINT HAS BEEN REACHED
      IF (XLE .GE. XSEP) GO TO 22
C     SEPARATION POINT HAS NOT BEEN REACHED
      ISEP = 0
 201  DXSEP1 = DXSEP
      XLE1 = XLE
      MACHX1 = BS(6)
      PX1 = BS(2)
      TX1 = BS(3)
      PPPO1 = PPPO
      DO1 = DO
```

DECK AROK

```
      CPSEP = CP                                                        AROK  1800
      GO TO 21                                                          AROK  1810
C                                                                       AROK  1820
C     SEPARATION POINT HAS BEEN REACHED                                 AROK  1830
   22 LSEP = ISCT                                                       AROK  1840
C                                                                       AROK  1850
C ***** CALCULATE CONDITIONS AT EXACT SEPARATION POINT                  AROK  1860
      IF (IGTS.EQ.1 .AND. M.EQ.1) GO TO 31                              AROK  1870
      XLESEP = XLE1 - DXSEP1*(XLE-XLE1)/(DXSEP-DXSEP1)                  AROK  1880
      IF (ICHECK .EQ. 1) WRITE (6,909) XLESEP,XLE1,DXSEP1,XLE,XLE1,     AROK  1890
     1  DXSEP,DXSEP1                                                    AROK  1900
  909 FORMAT (1H ,7E14.5)                                               AROK  1910
      IF (ISEP .EQ. 0) D1 = XLEH - XLESEP                               AROK  1920
      XSEPP = XSEPP + D1                                                AROK  1930
      MACHX = (MA-MACHX1)/(XLE-XLE1)*(XLESEP-XLE1) + MACHX1             AROK  1940
      PPPOX = (PPPO-PPPO1)/(XLE-XLE1)*(XLESEP-XLE1) + PPPO1             AROK  1950
      PX = (BS(2) - PX1)/(XLE-XLE1)*(XLESEP-XLE1)+PX1                   AROK  1960
      CPX = (PX/PFS-1.0)/(G/2.0*MACH*MACH)                              AROK  1970
      GO TO 19                                                          AROK  1980
C  SET UP DATA  FLOW SEPARATED AT LEADING EDGE                          AROK  1990
   31 D1 = XLEH                                                         AROK  2000
      ELFI = 0.0                                                        AROK  2010
      PX = BS(2)                                                        AROK  2020
      MACHX = BS(6)                                                     AROK  2030
      XLESEP = 0.0                                                      AROK  2040
      XSEPP = (XPA(1) + XPA(4)) / 2.0                                   AROK  2050
   19 CFD1 = CFLAP / D1                                                 AROK  2060
      EMADF = MACHX * DELTER                                            AROK  2070
      IF (ITRANS .EQ. 0) D2D1 = (0.545 - 0.04*EMADF) * SQRT(CFD1)       AROK  2080
      IF (ITRANS .EQ. 1) D2D1 = (1.16  - 0.33*EMADF) * SQRT(CFD1)       AROK  2090
      IF (CFD1 .GE. 1.0) GO TO 24                                       AROK  2100
      IF (CFD1 .GT. 0.25) GO TO 23                                      AROK  2110
      IF (ITRANS .EQ. 0) D2D1 = 0.273 - 0.02*EMADF                      AROK  2120
      IF (ITRANS .EQ. 1) D2D1 = 0.58 - 0.165*EMADF                      AROK  2130
      ELAM = 0.25                                                       AROK  2140
      GO TO 25                                                          AROK  2150
```

FLOSEP

```
DECK AROK

   23 ELAM = CFD1                                                        AROK  2160
      GO TO 25                                                           AROK  2170
   24 IF (ITRANS .EQ. 0) D2D1 = 0.545 - 0.04*EMADF                       AROK  2180
      IF (ITRANS .EQ. 1) D2D1 = 1.16 - 0.33*EMADF                        AROK  2190
      ELAM = 1.0                                                         AROK  2200
   25 IF ((ITRANS.EQ.0 .AND. EMADF.LT.5.0) .OR.                          AROK  2210
     1    (ITRANS.EQ.1 .AND. EMADF.LT.2.4)) GO TO 26                     AROK  2220
      IF (ITRANS .EQ. 0) D2D1 = 0.344 * SQRT(ELAM)                       AROK  2230
      IF (ITRANS .EQ. 1) D2D1 = 0.37 * SQRT(ELAM)                        AROK  2240
   26 D2 = D2D1 * D1                                                     AROK  2250
      IF (ISEP .EQ. 2) D2 = D3                                           AROK  2260
      XATACH = XATACH - D2                                               AROK  2270
C                                                                        AROK  2280
C                                                                        AROK  2290
C    CALCULATE DOWNSTREAM INTERACTION LENGTH TO PRESSURE RISE            AROK  2300
      IF (IGTS.EQ.1 .AND. M.EQ.1) GO TO 17                               AROK  2310
      IF (ISEP .EQ. 2) GO TO 200                                         AROK  2320
      SINTH = SQRT(CPAP*(G+1.0)/4.0+1.0/(MACHX*MACHX))                   AROK  2330
      THETA = ARSIN(SINTH)                                               AROK  2340
      TANPHI = 1.0 / ((2.0/CPAP-1.0)*SINTH/COS(THETA))                   AROK  2350
      GO TO 18                                                           AROK  2360
   17 TANPHI = D2*SIN(DELTER) / (D1 + D2*COS(DELTER))                    AROK  2370
   18 PHI = ATAN(TANPHI) * 57.29578                                      AROK  2380
      D3D1 = (TANPHI/(SIN(DELTER)/COS(DELTER)-TANPHI))/COS(DELTER)       AROK  2390
      D3 = D3D1 * D1                                                     AROK  2400
      IF (D3 .GT. D2) D3 = D2                                            AROK  2410
      IF (D3 .LE. CFLAP) GO TO 200                                       AROK  2420
      D3 = CFLAP                                                         AROK  2430
      D1 = D3 / D3D1                                                     AROK  2440
      XSEPP = XHL                                                        AROK  2450
      XSEP = XLEH - D1                                                   AROK  2460
      DXSEP = XLE1 - XLE                                                 AROK  2470
      ISEP = 2                                                           AROK  2480
      LSEP = 0                                                           AROK  2490
      GO TO 201                                                          AROK  2500
C                                                                        AROK  2510
```

```
DECK AROK

C   CALCULATE PLATEAU PRESSURE AND PEAK FLAP PRESSURE                   AROK  2520
 200  ISEP = 1                                                          AROK  2530
      FS2 = FS(2)                                                       AROK  2540
      FS6 = FS(6)                                                       AROK  2550
      FS(2) = PX                                                        AROK  2560
      FS(6) = MACHX                                                     AROK  2570
      ANGLE(2) = PHI                                                    AROK  2580
      ISDET = 0                                                         AROK  2590
      IPRCK = 0                                                         AROK  260C
      IFIRST = 0                                                        AROK  2610
      CALL COMPR (ANGLE,MER,IPRCK,CPSTAG,TFS,PFS,ISDET,IFIRST,DUMMY)    AROK  2620
      IF (IGTS.EQ.1 .AND. M.EQ.1) GO TO 203                             AROK  2630
C                                                                       AROK  2640
C  CALCULATE FREE INTERACTION LENGTH                                    AROK  2650
      PPPOX = BS(2) / FS(2)                                             AROK  266C
      IF (ITRANS.EQ.0) ELFIDO = 2.47E5*MACHX**(-4.2)*(PPPOX-1.0)**3.45  AROK  2670
      IF (ITRANS.EQ.1) ELFIDO = 1.84E4*((PPPOX-1.0)/MACHX**1.325)       AROK  2680
     1                          **(-8.4)                                AROK  2690
      DOX = (DO-DO1)/(XLE-XLE1)*(XLESEP-XLE1) + DO1                     AROK  270C
C                                                                       AROK  2710
C   CALCULATE DOWNSTREAM INTERACTION LENGTH TO PEAK PRESSURE            AROK  272C
      ELFI = ELFIDO * DOX                                               AROK  2730
C                                                                       AROK  274C
C ***** PLATEAU PRESSURE *************                                  AROK  2750
 203  CPIP = (BS(2)/PFS - 1.0) / (G/2.0*MACH*MACH)                      AROK  2760
      FS(2) = BS(2)                                                     AROK  2770
      FS(6) = BS(6)                                                     AROK  278C
      ANGLE(2) = DELTER*57.29578 - PHI                                  AROK  2790
      CALL COMPR (ANGLE,MER,IPRCK,CPSTAG,TFS,PFS,ISDET,IFIRST,DUMMY)    AROK  2800
C                                                                       AROK  2810
C ***** PEAK FLAP PRESSURE *****                                        AROK  282C
      CPI2 = (BS(2)/PFS - 1.0) / (G/2.0 *MACH*MACH)                     AROK  2830
      FS(2) = FS2                                                       AROK  2840
      FS(6) = FS6                                                       AROK  2850
C                                                                       AROK  2860
C                                                                       AROK  2870
```

ELOSEP

```
DECK AROK.

C   CALCULATE VISCOUS PRESSURE COEFFICIENT WITH SEPARATION               AROK  2880
 29  CPSEP = CPIP                                                        AROK  2890
     IF (XLE.GE.XLESEP .AND. XLE.LT.(XLESEP+ELFI))                       AROK  2900
    1  CPSEP = ((CPIP-CPX)/ELFI)*XLE + CPX - (CPIP-CPX)/ELFI * XLESEP    AROK  2910
     IF (ICHECK .EQ. 1)                                                  AROK  2920
    1WRITE (6,960) XSEP,D1,D2,D3,ELFI,CPIP,CPI2                          AROK  2930
 960 FORMAT (1H ,21HSEPARATION CONDITIONS,/1H ,6H XSEP=F8.3,4H D1=F8.3,  AROK  2940
    1 4H D2=F8.3,4H D3=F8.3,6H ELFI=F8.3,6H CPIP=E12.5,6H CPI2=E12.5 )   AROK  2950
     IF (ICHECK .EQ. 1)                                                  AROK  2960
    1WRITE (6,951) D2D1,EMADF,CFD1,ELFI,DOX,ELFIDO,PPPDX,XLESEP,         AROK  2970
    2  DXSEP,XSEP,D2,PHI,D3D1,D3                                         AROK  2980
 951 FORMAT (1H ,8E14.5,/1H ,6E14.5)                                     AROK  2990
     GO TO 21                                                            AROK  3000
C                                                                        AROK  3010
C                                                                        AROK  3020
C  CALCULATE CP VISCOUS ON THE FLAP                                      AROK  3030
 30  IF (ISEP .EQ. 1) GO TO 32                                           AROK  3040
     CPSEP = CP                                                          AROK  3050
     GO TO 28                                                            AROK  3060
 32  IF ((XLE.GT.(XLEH+D3)) .AND. (XLE.LT.(XLEH+D2))) GO TO 33           AROK  3070
     IF (XLE .GE. (XLEH+D2)) GO TO 27                                    AROK  3080
     CPSEP = CPIP                                                        AROK  3090
     GO TO 28                                                            AROK  3100
 27  CPSEP = CPI2                                                        AROK  3110
     IF (LATT .EQ. 0) LATT = ISCT                                        AROK  3120
     GO TO 28                                                            AROK  3130
 33  CPSEP = (CPI2-CPIP)/(D2-D3)*(XLE-XLEH-D3) + CPIP                    AROK  3140
     IF (D2 .GT. CFLAP) CPSEP = CPIP                                     AROK  3150
C                                                                        AROK  3160
CC  IS THIS THE LAST STRIP ELEMENT                                       AROK  3170
 28  IF (IGTS.EQ.2 .AND. IGT.EQ.1) GO TO 34                              AROK  3180
     GO TO 21                                                            AROK  3190
C                                                                        AROK  3200
 34  J = IN(N+10)                                                        AROK  3210
     DO 35 I=1,J                                                         AROK  3220
 35  BACKSPACE 3                                                         AROK  3230
```

```
DECK AROK
      J = IN(4)                                                         AROK  3240
      DO 36 I=1,J                                                       AROK  3250
   36 BACKSPACE 11                                                      AROK  3260
C                                                                       AROK  3270
      IF (ICHECK .EQ. 1)                                                AROK  3280
     1WRITE (6,906)                                                     AROK  3290
  906 FORMAT (1H ,34HLAST STRIP ELEMENT ON SECOND CYCLE  )              AROK  3300
      L = LSS                                                           AROK  3310
      IFSCY = 3                                                         AROK  3320
      IMPACT = IMPS                                                     AROK  3330
      ISHAD = ISHS                                                      AROK  3340
      DELTAS = DELTAE                                                   AROK  3350
      DELTAE = 0.0                                                      AROK  3360
C                                                                       AROK  3370
C                                                                       AROK  3380
C ***** CALCULATE PRESSURE COEFFICIENT INCREMENT DUE TO SEPARATION      AROK  3390
   21 PSEVIS(ISCT) = (CPSEP*G/2.0 * MACH*MACH + 1.0) * PFS              AROK  3400
      IF (ICHECK .EQ. 1)                                                AROK  3410
     1WRITE (6,970) CPSEP,PSEVIS(ISCT),ISCT                             AROK  3420
  970 FORMAT (1H ,5X,2E14.5,I5)                                         AROK  3430
      GO TO 100                                                         AROK  3440
C                                                                       AROK  3450
C                                                                       AROK  3460
C***** THIRD FLOSEP CYCLE  *****                                        AROK  3470
C                                                                       AROK  3480
   40 ISPNT = 0                                                         AROK  3490
      PNIN = (CP*G/2.0 * MACH*MACH + 1.0) * PFS                         AROK  3500
C  IS THIS ELEMENT ON FORE  SURFACE OR ON THE FLAP                      AROK  3510
      IF (IGTS .EQ. 2) GO TO 50                                         AROK  3520
      IF (ISCT .EQ. LSEP) ISPNT = 1                                     AROK  3530
      BS2F = PSEIN(ISCT)                                                AROK  3540
      IF (ICHECK .EQ. 1)                                                AROK  3550
     1WRITE (6,907)                                                     AROK  3560
  907 FORMAT (1H0,25H3RD CYCLE ON FORE-SURFACE  )                       AROK  3570
      GO TO 80                                                          AROK  3580
   50 BS2 = BS(2)                                                       AROK  3590
```

```
DECK AROK
      BS3 = BS(3)                                                      AROK  3600
      BS6 = BS(6)                                                      AROK  3610
      NXS = NX                                                         AROK  3620
      NYS = NY                                                         AROK  3630
      NZS = NZ                                                         AROK  3640
      IF (IGTS.EQ.2 .AND. M.EQ.1) GO TO 60                             AROK  3650
      BS(2) = BS2F                                                     AROK  3660
      BS(3) = BS3F                                                     AROK  3670
      BS(6) = BS6F                                                     AROK  3680
      NXF = NXFS                                                       AROK  3690
      NYF = NYFS                                                       AROK  3700
      NZF = NZFS                                                       AROK  3710
      GO TO 61                                                         AROK  3720
C                                                                      AROK  3730
   60 BS(2) = PH                                                       AROK  3740
      BS(3) = TH                                                       AROK  3750
      BS(6) = MACHH                                                    AROK  3760
      NXF = NXH                                                        AROK  3770
      NYF = NYH                                                        AROK  3780
      NZF = NZH                                                        AROK  3790
C                                                                      AROK  3800
C                                                                      AROK  3810
   61 CALL SHKEXP (1,1,1,0,NXF,NYF,NZF,0.0,PFS,MACH,1,                 AROK  3820
     1 0.0,1,0.0,0.0,CPF,0.0,1,0,0,0,1,0.0,0.0,0.0,0.0,0.0,1)          AROK  3830
      CALL SHKEXP (1,N,M,0,NX,NY,NZ,DELTA,PFS,MACH,IGTS,               AROK  3840
     1 DELTAR,IMPACI,CPSTAG,TFS,CPF,G,ISHADI,0,LL,0,IGTYPE,            AROK  3850
     2 1.0,1.0,1.0,1.0,1.0,0)                                          AROK  3860
C                                                                      AROK  3870
      BS2F = BS(2)                                                     AROK  3880
      BS3F = BS(3)                                                     AROK  3890
      BS6F = BS(6)                                                     AROK  3900
      NXFS = NX                                                        AROK  3910
      NYFS = NY                                                        AROK  3920
      NZFS = NZ                                                        AROK  3930
C  SET SHOCK EXPANSION DATA BACK TO THE ORIGINAL CONDITIONS            AROK  3940
      BS(2) = BS2                                                      AROK  3950
```

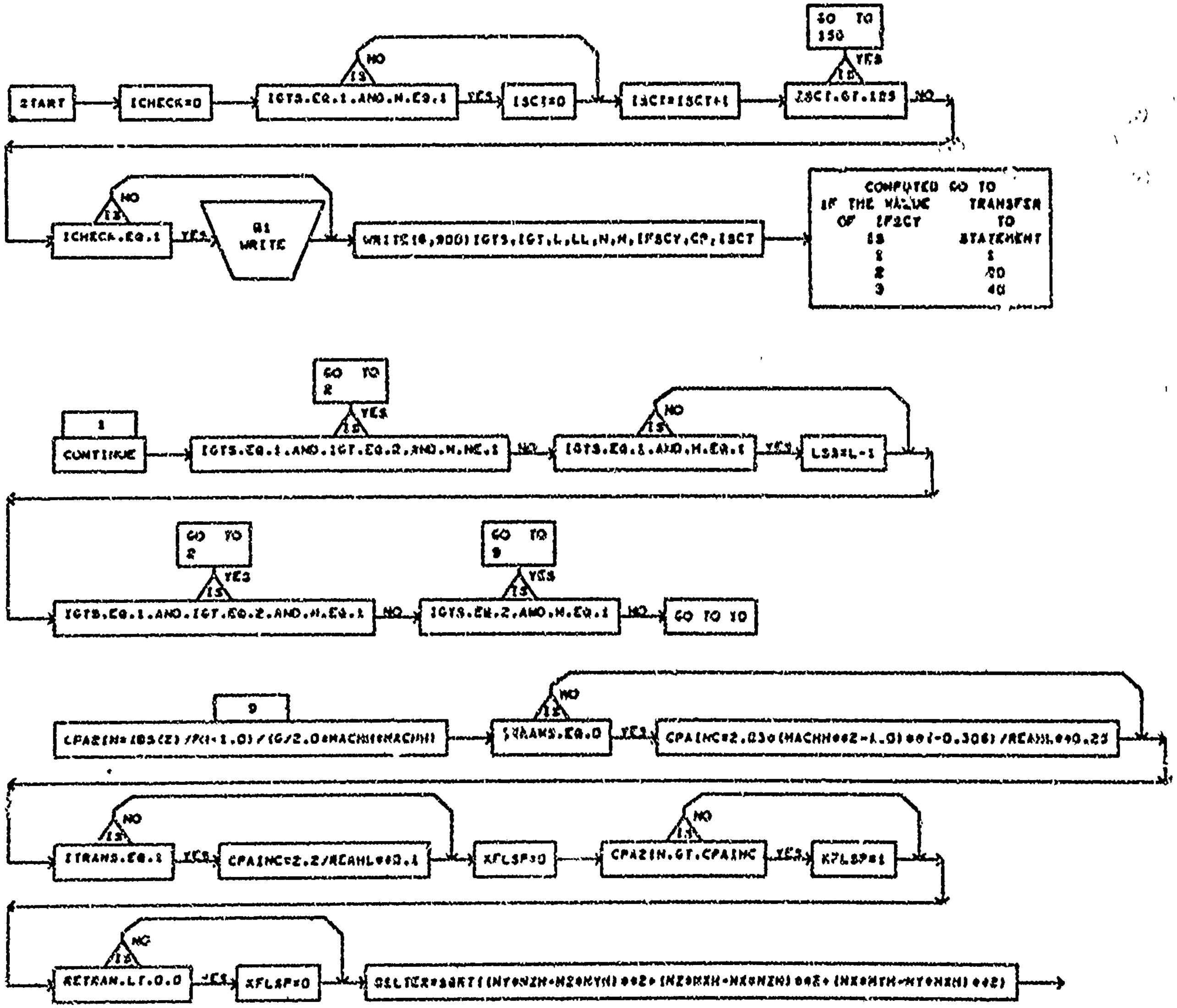
```
DECK AROK

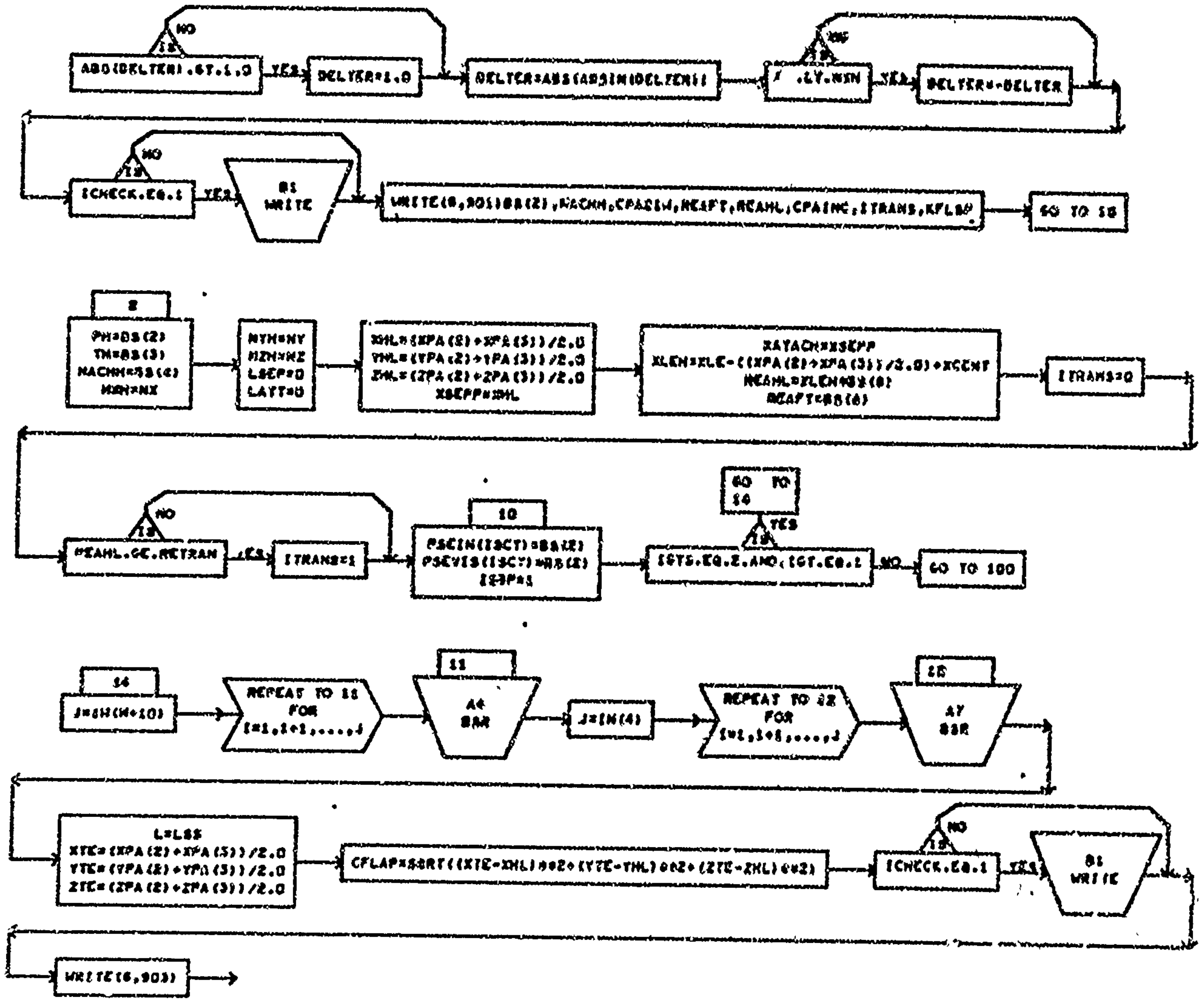
      BS(3) = BS3
      BS(6) = BS6
      NX = NXS
      NY = NYS
      NZ = NZS
      CALL SHKEXP (1,1,1,0,NX ,NY ,NZ ,0.0,PFS,MACH,1,
     1  0.0,1,0.0,0.0,CPF,0.0,1,0,0,0,1,0.0,0.0,0.0,0.0,0.0,1)
      READ (11)  LL,N,M,NX,NY,NZ,XCENT,YCENT,ZCENT,AREA,XPA,YPA,ZPA,XLE
      IRED11 = 1
      IF (ISCT .EQ. LATT) ISPNT = 2
C
C
C ***** CALCULATE FINAL DELTA PRESSURE TO BE APPLIED TO NORMAL CP
   80 DELP = (PSEVIS(ISCT) - BS2F) / BS2F*PNIN
      P = PNIN + DELP
      CPNIN = (PNIN/PFS - 1.0) / (G/2.0 * MACH*MACH)
      CP = (P/PFS - 1.0) / (G/2.0 * MACH*MACH)
      DELCPC = CP - CPNIN
      IF (ABS(DELCPC) .LT. 1.0E-06) DELCPC = 0.0
      IF (ICHECK .EQ. 1)
     1WRITE (6,800) ISCT,CP,P,DELP,PSEVIS(ISCT),BS2F,PNIN
  800 FORMAT (1H ,12HFINAL RESULT, 6H ISCT=I3,4H CP=E12.5,3H P=E12.5,
     1 6H DELP=E12.5,8H PSEVIS=E12.5,6H BS2F=E12.5,6H PNIN=E12.5)
C
      ISBP = 0
C
      IF (IGTS.EQ.2 .AND. IGT.EQ.1) GO TO 81
      GO TO 100
   81 DELTAE = DELTAS
      IF (L .EQ. LL) GO TO 100
      IFSCY = 1
      IMPACT = 9
      ISHAD = 7
  100 RETURN
  150 WRITE (6,151)
  151 FORMAT (1H ,46H**** NUMBER OF STREAMWISE ELEMENTS FOR CONTROL
```

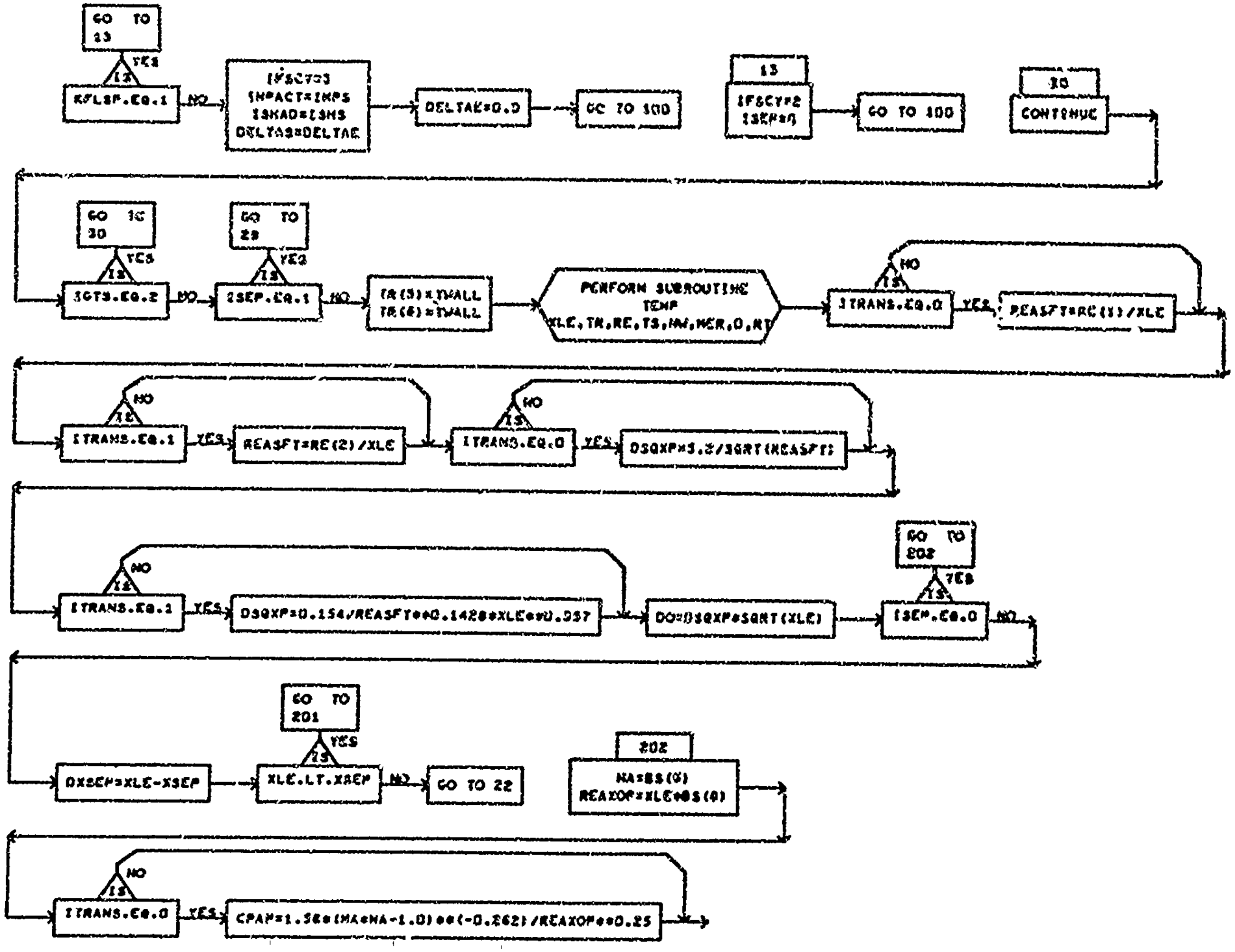
```
DECK AROK

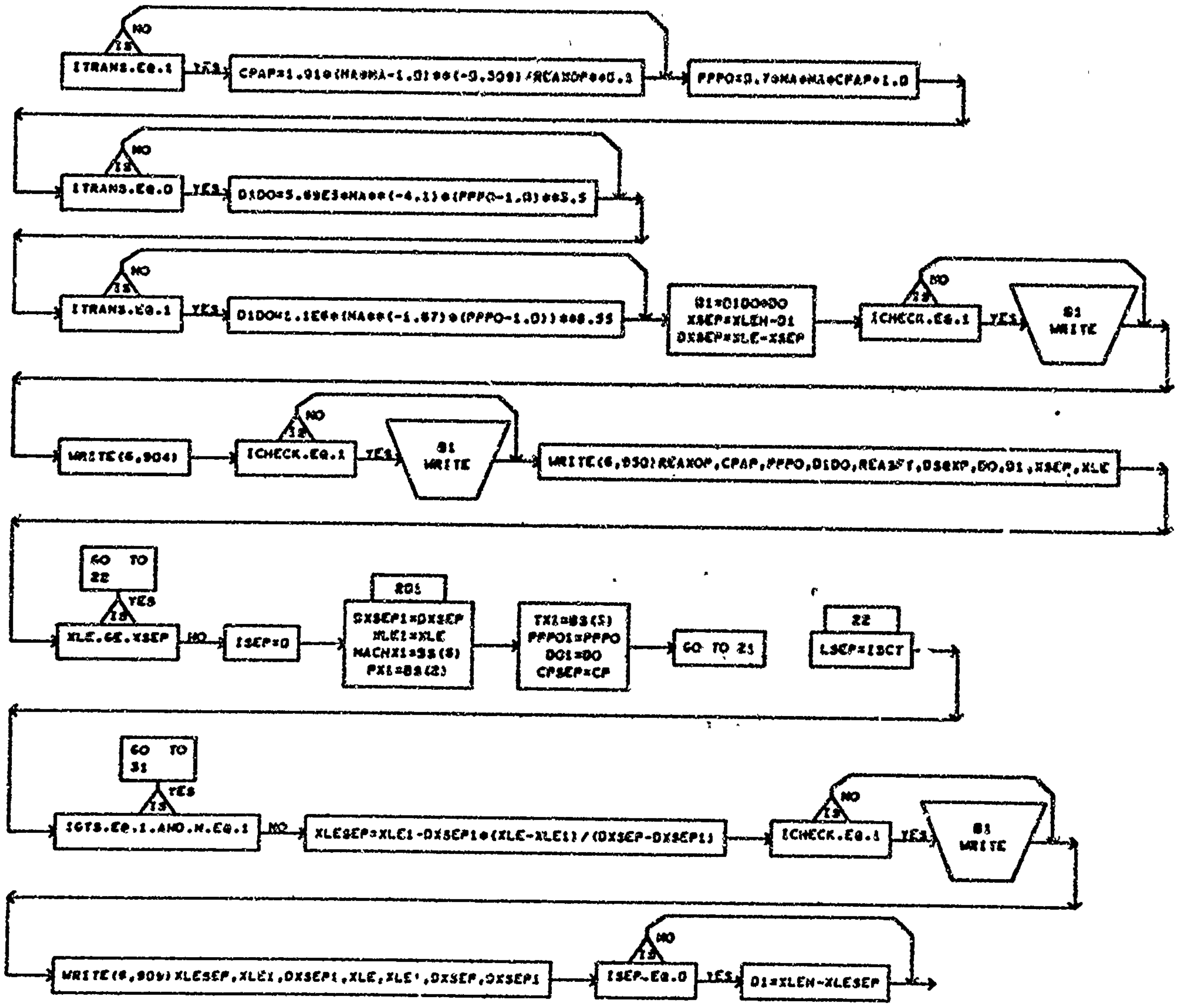
      1 45H FORE-SURFACE AND FLAP CANNOT EXCEED 12% ****)                  AROK  4320
       ERROR = 1                                                           AROK  4330
       RETURN                                                              AROK  4340
       END                                                                 AROK  4350
```

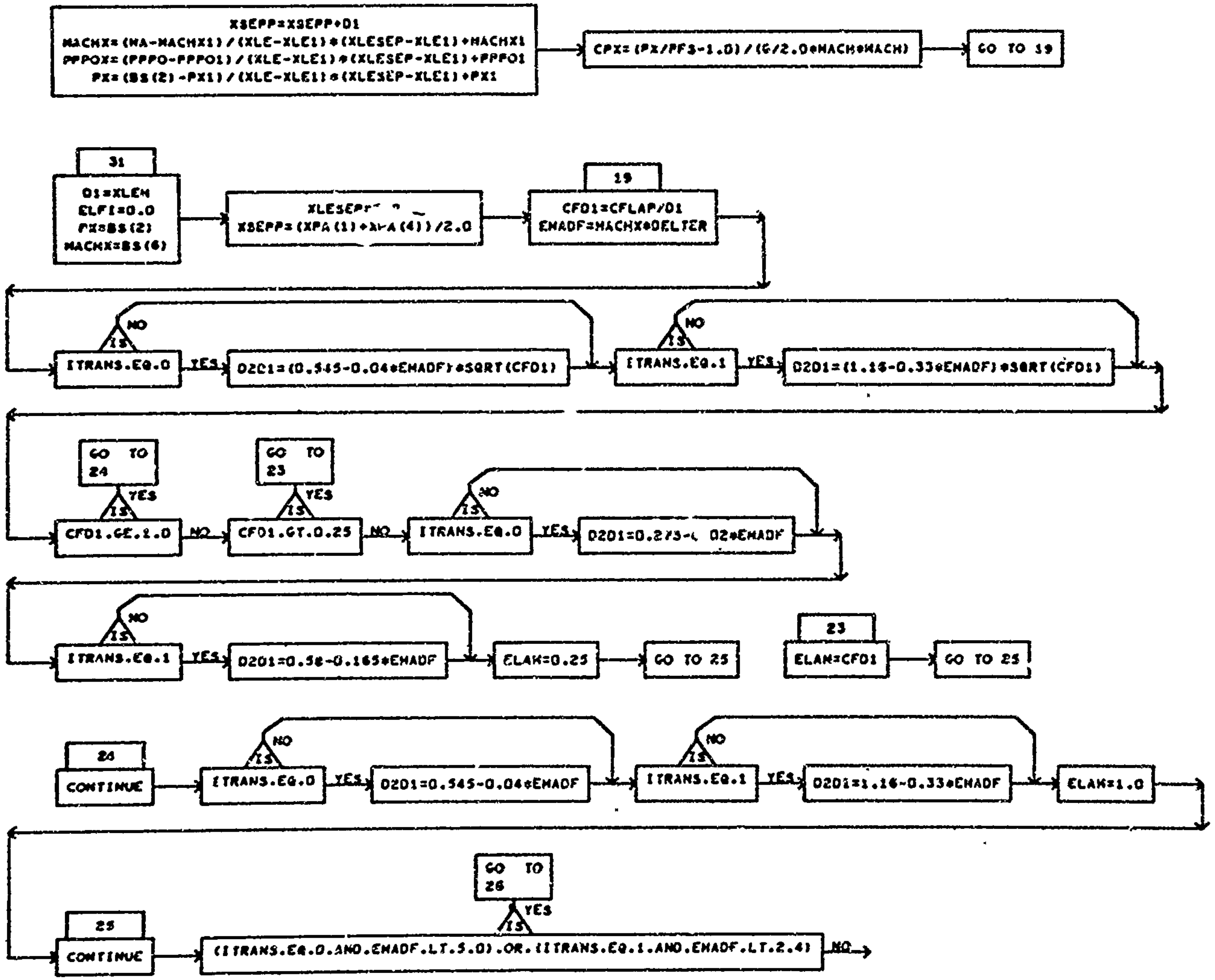
SUBROUTINE FLOSEP

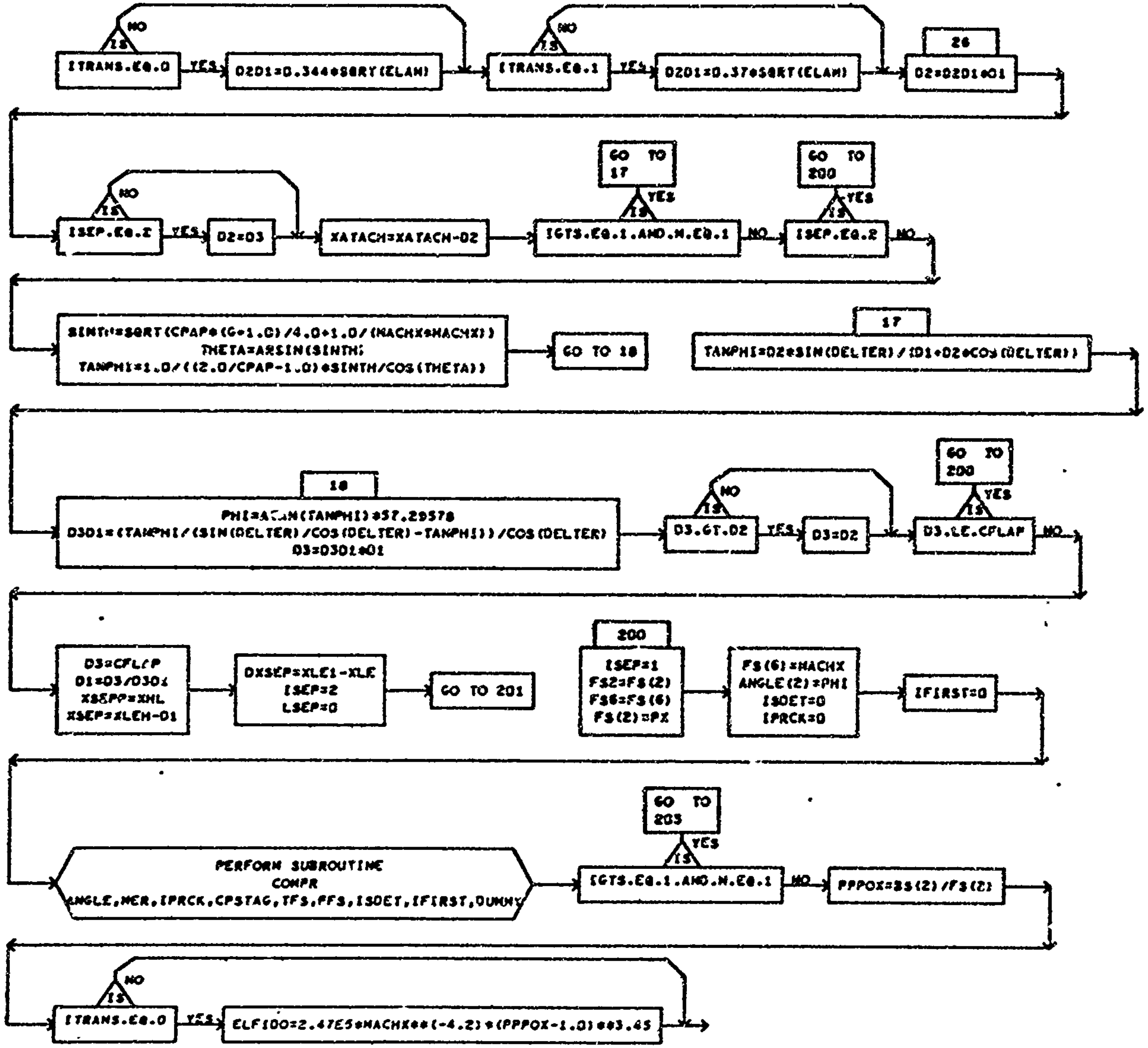


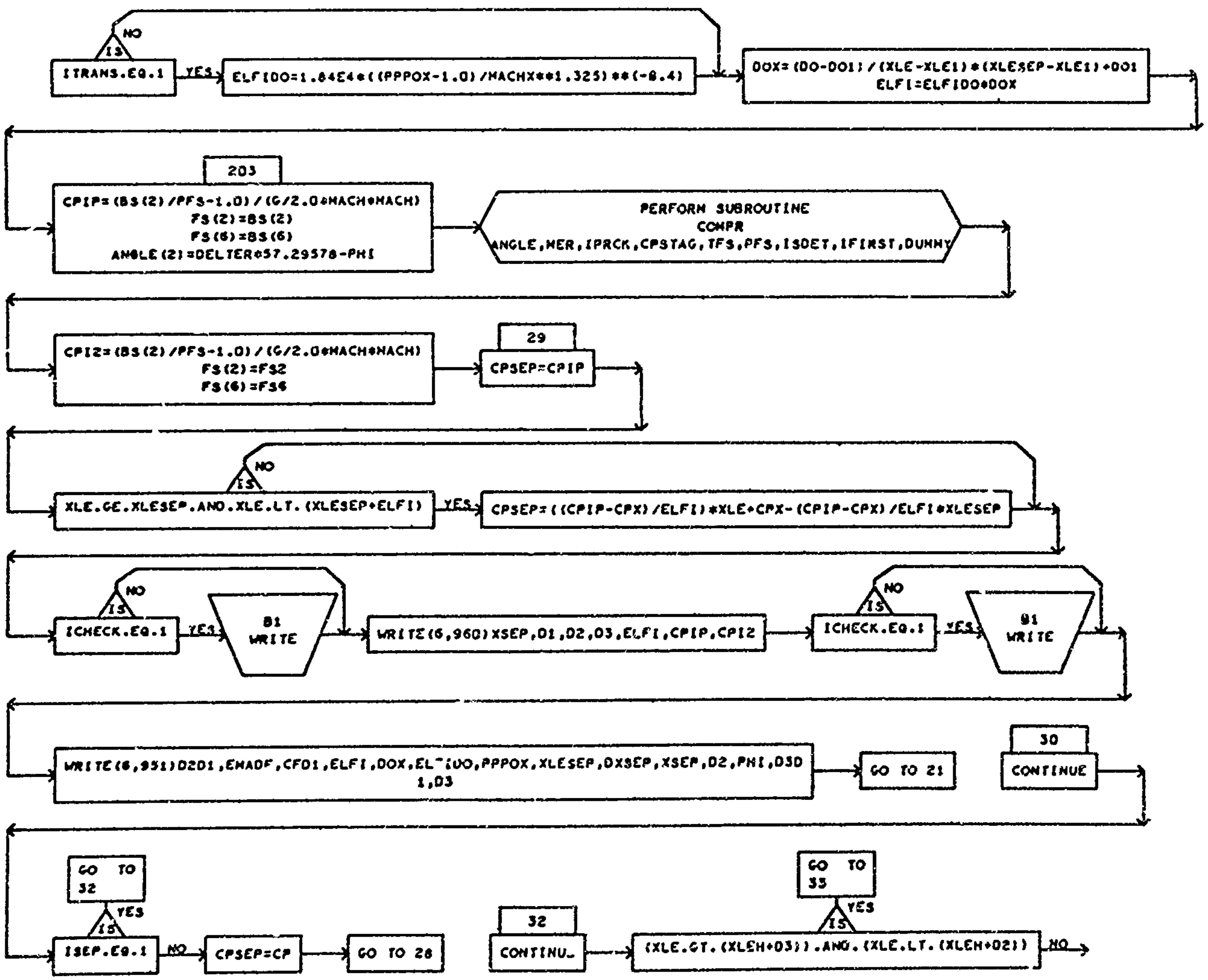

ABS(DELTER).GT.1.0
13
NO
YES
DELTER=1.0
DELTER=ABS(ARSIN(DELTER))
.LT.NXN
13
NO
YES
DELTER=-DELTER
ICHECK.EQ.1
13
NO
YES
B1
WRITE
WRITE(6,905)BB(2),MACHN,CPASIW,NEAFT,NEAHL,CPAINC,ITRANS,KFLAG
GO TO 18
8
PH=BS(2)
TH=BS(3)
MACHN=BS(4)
NXN=NX
NYN=NY
NZN=NZ
LSEP=0
LAYT=0
XHL=(XPA(2)+XPA(3))/2.0
YHL=(YPA(2)+YPA(3))/2.0
ZHL=(ZPA(2)+ZPA(3))/2.0
XSEPP=XHL
XATACH=XSEPP
XLEN=XLE-((XPA(2)+XPA(3))/2.0)+XCENT
NEAHL=XLEN*BB(8)
NEAFT=BB(8)
ITRANS=0
NEAHL.GE.NETRAN
13
NO
YES
ITRANS=1
10
PSCIN(ISCT)=BA(2)
PSCVIS(ISCT)=BB(2)
ISBP=1
ISTS.EQ.2.AND.ICT.EQ.1
13
YES
NO
GO TO 14
GO TO 100
14
J=8H(N+10)
REPEAT TO 11 FOR I=1,I+1,....,J
11
A4
BAR
J=IN(4)
REPEAT TO 12 FOR I=1,I+8,....,J
12
A7
BSR
L=LSS
XTE=(XPA(2)+XPA(3))/2.0
YTE=(YPA(2)+YPA(3))/2.0
ZTE=(ZPA(2)+ZPA(3))/2.0
CFLAP=SQRT((XTE-XHL)**2+(YTE-YHL)**2+(ZTE-ZHL)**2)
ICHECK.EQ.1
13
NO
YES
B1
WRITE
WRITE(6,903)


GO TO 13
YES
IS
KFLSP.EQ.1
NO
IFSCY=3
IMPACT=IMPS
ISHAD=ISHS
DELTAS=DELTAE
DELTAE=0.0
GO TO 100
13
IFSCY=2
ISEP=0
GO TO 100
30
CONTINUE
GO TO 30
YES
IS
IGTS.EQ.2
NO
GO TO 29
YES
IS
ISEP.EQ.1
NO
TR(5)=TWALL
TR(6)=TWALL
PERFORM SUBROUTINE
TEMP
XLE,TR,RE,TS,HW,HER,D,RT
NO
IS
ITRANS.EQ.0
YES
REASFT=RE(1)/XLE
NO
IS
ITRANS.EQ.1
YES
REASFT=RE(2)/XLE
NO
IS
ITRANS.EQ.0
YES
DSQXP=3.2/SQRT(REASFT)
NO
IS
ITRANS.EQ.1
YES
DSQXP=0.154/REASFT**0.1428*XLE**0.357
DO=DSQXP*SQRT(XLE)
GO TO 202
YES
IS
ISEP.EQ.0
NO
DXSEP=XLE-XSEP
GO TO 201
YES
IS
XLE.LT.XSEP
NO
GO TO 22
202
MA=BS(9)
REAXOP=XLE*BS(8)
NO
IS
ITRANS.EQ.0
YES
CPAP=1.58*(MA*MA-1.0)**(-0.262)/REAXOP**0.25

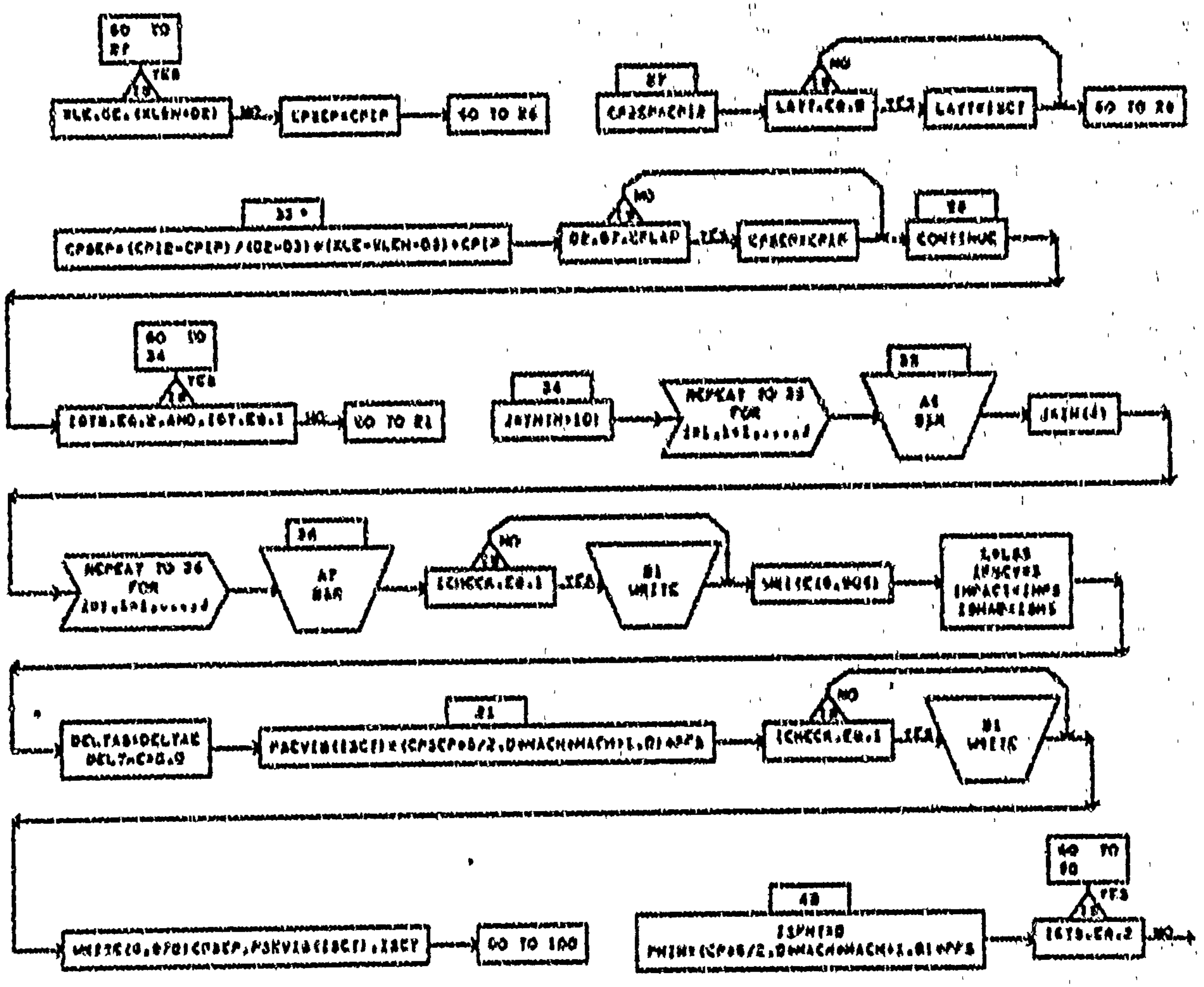

ITRANS.EQ.1
IS
NO
YES
CPAP=1.91*(MA*MA-1.0)**(-0.309)/REAXOP**0.1
PPPO=0.7*MA*MA*CPAP+1.0
ITRANS.EQ.0
IS
NO
YES
DIDO=5.89E3*MA**(-4.1)*(PPPO-1.0)**5.5
ITRANS.EQ.1
IS
NO
YES
DIDO=2.1E4*(MA**(-1.87)*(PPPO-1.0))**0.55
D1=DIDO*DO
XSEP=XLEN-D1
DXSEP=XLE-XSEP
ICHECK.EQ.1
IS
NO
YES
81
WRITE
WRITE(6,904)
ICHECK.EQ.1
IS
NO
YES
81
WRITE
WRITE(6,950)REAXOP,CPAP,PPPO,DIDO,REASFT,DSEXP,DO,D1,XSEP,XLE
GO TO
22
YES
IS
XLE.GE.XSEP
NO
ISEP=0
201
DXSEP1=DXSEP
XLE1=XLE
MACHX1=SS(5)
PX1=BS(2)
TX1=BS(5)
PPPO1=PPPO
DO1=DO
CPSEP=CP
GO TO 21
22
LSEP=ISCT
GO TO
31
YES
IS
IGTS.EQ.1.AND.N.EQ.1
NO
XLESEP=XLE1-DXSEP1*(XLE-XLE1)/(DXSEP-DXSEP1)
ICHECK.EQ.1
IS
NO
YES
81
WRITE
WRITE(6,909)XLESEP,XLE1,DXSEP1,XLE,XLE1,DXSEP,DXSEP1
ISEP.EQ.0
IS
NO
YES
D1=XLEN-XLESEP

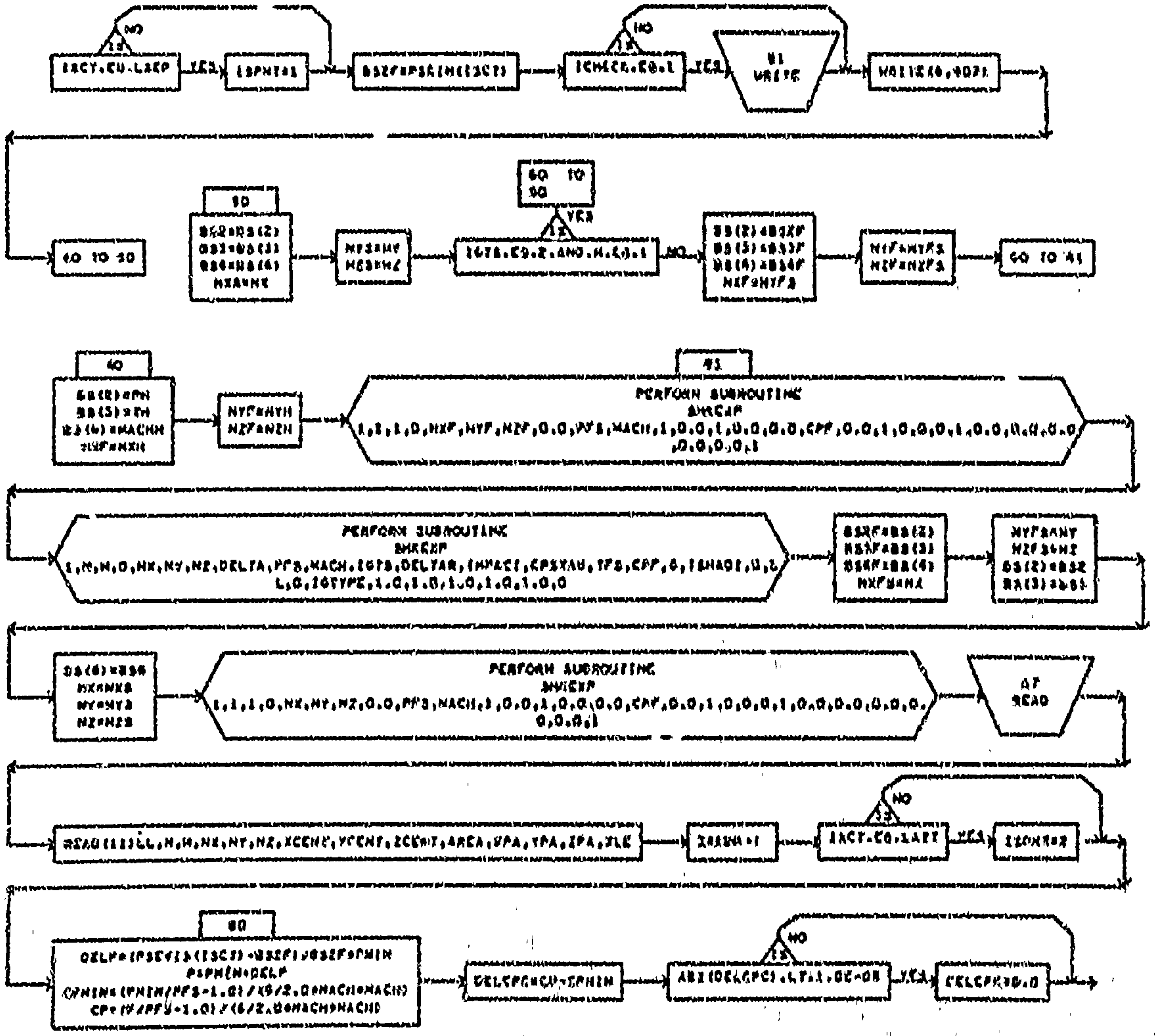

XSEPP=XSEPP+D1
MACHX=(MA-MACHX1)/(XLE-XLE1)*(XLESEP-XLE1)+MACHX1
PPPOX=(PPPO-PPPO1)/(XLE-XLE1)*(XLESEP-XLE1)+PPPO1
PX=(BS(2)-PX1)/(XLE-XLE1)*(XLESEP-XLE1)+PX1
CPX=(PX/PFS-1.0)/(G/2.0*MACH*MACH)
GO TO 19
31
D1=XLEM
ELFI=0.0
PX=BS(2)
MACHX=BS(6)
XLESEP
XSEPP=(XPA(1)+XPA(4))/2.0
19
CFD1=CFLAP/D1
EMADF=MACHX*DELTER
IS
NO
ITRANS.EQ.0
YES
D2C1=(0.545-0.04*EMADF)*SQRT(CFD1)
IS
NO
ITRANS.EQ.1
YES
D2D1=(1.16-0.33*EMADF)*SQRT(CFD1)
GO TO 24
YES
IS
CFD1.GE.2.0
NO
GO TO 23
YES
IS
CFD1.GT.0.25
NO
IS
NO
ITRANS.EQ.0
YES
D2D1=0.275-0.02*EMADF
IS
NO
ITRANS.EQ.1
YES
D2D1=0.58-0.165*EMADF
ELAM=0.25
GO TO 25
23
ELAM=CFD1
GO TO 25
24
CONTINUE
IS
NO
ITRANS.EQ.0
YES
D2D1=0.545-0.04*EMADF
IS
NO
ITRANS.EQ.1
YES
D2D1=1.16-0.33*EMADF
ELAM=1.0
GO TO 26
YES
IS
25
CONTINUE
(ITRANS.EQ.0.AND.EMADF.LT.5.0).OR.(ITRANS.EQ.1.AND.EMADF.LT.2.4)
NO

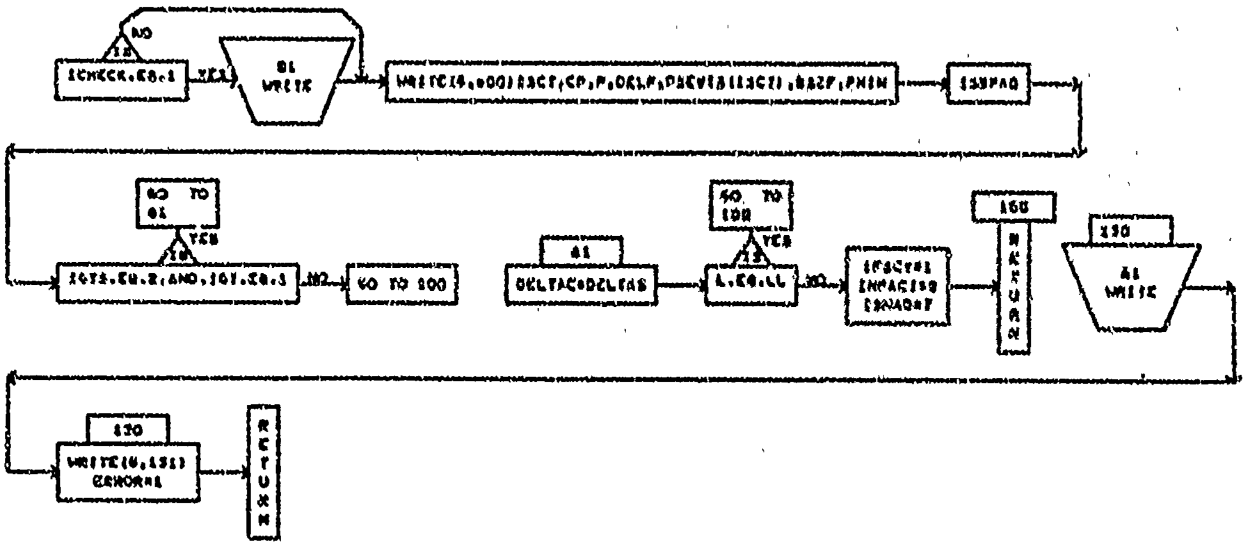

ITRANS.EQ.0
IS
NO
YES
D2D1=0.344*SQRT(ELAM)
ITRANS.EQ.1
IS
NO
YES
D2D1=0.37*SQRT(ELAM)
26
D2=D2D1*D1
ISEP.EQ.2
IS
NO
YES
D2=D3
XATACH=XATACH-D2
IGTS.EQ.1.AND.M.EQ.1
IS
YES
GO TO 17
NO
ISEP.EQ.2
IS
YES
GO TO 200
NO
SINTH=SQRT(CPAP*(G+1.0)/4.0+1.0/(MACHX*MACHX))
THETA=ARSIN(SINTH)
TANPHI=1.0/((2.0/CPAP-1.0)*SINTH/COS(THETA))
GO TO 18
17
TANPHI=D2*SIN(DELTER)/(D1+D2*COS(DELTER))
18
PHI=ATAN(TANPHI)*57.29578
D3D1=(TANPHI/(SIN(DELTER)/COS(DELTER)-TANPHI))/COS(DELTER)
D3=D3D1*D1
D3.GT.D2
IS
NO
YES
D3=D2
D3.LE.CFLAP
IS
YES
GO TO 200
NO
D3=CFLAP
D1=D3/D3D1
XSEPP=XHL
XSEP=XLEH-D1
DXSEP=XLE1-XLE
ISEP=2
LSEP=0
GO TO 201
200
ISEP=1
FS2=FS(2)
FS6=FS(6)
FS(2)=PX
FS(6)=MACHX
ANGLE(2)=PHI
ISDET=0
IPRCK=0
IFIRST=0
PERFORM SUBROUTINE
COMPR
ANGLE,MER,IPRCK,CPSTAG,TFS,FFS,ISDET,IFIRST,DUMMY
IGTS.EQ.1.AND.M.EQ.1
IS
YES
GO TO 203
NO
PPPOX=SS(2)/FS(2)
ITRANS.EQ.0
IS
NO
YES
ELF100=2.47E5*MACHX**(-4.2)*(PPPOX-1.0)**3.45


ITRANS.EQ.1
IS
NO
YES
ELFIDO=1.84E4*((PPPOX-1.0)/MACHX**1.325)**(-8.4)
DOX=(DO-DO1)/(XLE-XLE1)*(XLESEP-XLE1)+DO1
ELFI=ELFIDO*DOX
203
CPIP=(BS(2)/PFS-1.0)/(G/2.0*MACH*MACH)
FS(2)=BS(2)
FS(6)=BS(6)
ANGLE(2)=DELTER*57.29578-PHI
PERFORM SUBROUTINE
COMPR
ANGLE,MER,IPRCK,CPSTAG,TFS,PFS,ISDET,IFIRST,DUMMY
CPI2=(BS(2)/PFS-1.0)/(G/2.0*MACH*MACH)
FS(2)=FS2
FS(6)=FS6
29
CPSEP=CPIP
XLE.GE.XLESEP.AND.XLE.LT.(XLESEP+ELFI)
IS
NO
YES
CPSEP=((CPIP-CPX)/ELFI)*XLE+CPX-(CPIP-CPX)/ELFI*XLESEP
ICHECK.EQ.1
IS
NO
YES
81
WRITE
WRITE(6,960)XSEP,D1,D2,D3,ELFI,CPIP,CPI2
ICHECK.EQ.1
IS
NO
YES
81
WRITE
WRITE(6,951)D2D1,EMADF,CFD1,ELFI,DOX,EL⁻IDO,PPPOX,XLESEP,DXSEP,XSEP,D2,PHI,D3D
1,D3
GO TO 21
30
CONTINUE
ISEP.EQ.1
IS
YES
GO TO
32
NO
CPSEP=CP
GO TO 28
32
CONTINU
(XLE.GT.(XLEH+D3)).AND.(XLE.LT.(XLEH+D2))
IS
YES
GO TO
33
NO

LDSEP


GO TO
YES
NO
GO TO
NO
YES
CONTINUE
GO TO
34
YES
NO
34
REPEAT TO 33 FOR
33
REPEAT TO 36 FOR
36
ICHECK.EQ.1
NO
YES
WRITE
DELTAB=DELTAE
DELTA=C20.0
ICHECK.EQ.1
NO
YES
WRITE
WRITE
GO TO 100
GO TO
YES
NO


NO
IACT.EQ.LAEP
YES
ISPHI=1
DSZF=PSEIH(ISCT)
NO
ICHECK.EQ.1
YES
81
WRITE
WRITE(6,407)
GO TO 20
90
DS2=DS(2)
DS3=DS(3)
DS4=DS(4)
NX=NX
NY=NY
NZ=NZ
YES
GO TO 90
IGTS.EQ.2.AND.N.EQ.1
NO
DS(2)=DS2F
DS(3)=DS3F
DS(4)=DS4F
NXF=NXFS
NYF=NYFS
NZF=NZFS
GO TO 41
40
DS(2)=PH
DS(3)=TH
DS(4)=MACHH
NXF=NXH
NYF=NYH
NZF=NZH
41
PERFORM SUBROUTINE
SHKCAP
1,1,1,0,NXF,NYF,NZF,0.0,PFS,MACH,1,0.0,1,0.0,0.0,CPF,0.0,1,0.0,0,1,0.0,0.0,0.0,0.0,0.0,1
PERFORM SUBROUTINE
SHKEXP
1,N,N,0,NX,NY,NZ,DELTA,PFS,MACH,IGTS,DELTAR,IMPACT,CPSTAU,TFS,CPF,0,ISHADE,0,2,L,0,IGTYPE,1.0,1.0,1.0,1.0,1.0,0
DS2F=DS(2)
DS3F=DS(3)
DS4F=DS(4)
NXF=NX
NYF=NY
NZF=NZ
DS(2)=DS2
DS(3)=DS3
DS(4)=DS4
NX=NXS
NY=NYS
NZ=NZS
PERFORM SUBROUTINE
SHVEXP
1,1,1,0,NX,NY,NZ,0.0,PFS,MACH,1,0.0,1,0.0,0.0,CPF,0.0,1,0,0,0,1,0.0,0.0,0.0,0.0,0.0,0.0,1
47
READ
READ(11)LL,N,M,NX,NY,NZ,XCENT,YCENT,ZCENT,AREA,XPA,YPA,ZPA,XLE
IASN=1
IACT.EQ.LAST
YES
ICONT=2
NO
80
DELP=(PSEIS(ISCT)-DSZF)/DSZF*PHIN
P=PH(N)+DELP
CPHIN=(PHIN/PFS-1.0)/(G/2.0*MACH*MACH)
CP=(P/PFS-1.0)/(G/2.0*MACH*MACH)
DELCPC=CP-CPHIN
ABS(DELCPC).LT.1.0E-05
YES
DELCPC=0.0
NO


ICHECK.EQ.1
IS
NO
YES
81
WRITE
WRITE(6,800)IACT,CP,P,DELP,PSEVIS(ICT),BASF,PHIN
GO TO
81
IS
YES
ICYS.EQ.2.AND.ICT.EQ.3
NO
GO TO 200
41
DELTAC=DELTAS
GO TO
100
IS
YES
L.EQ.LL
NO
160
RETURN
130
41
WRITE
130
WRITE(6,131)
RETURN

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SYMBOLS USED IN SUBROUTINE FLOSEP

ANGLE    R  D  FLOW ANGLE ARRAY                                              FLOSEP
AREA     R  A  ELEMENT AREA                                                  FLOSEP
AREA2    R  C  (NOT USED)                                                    FLOSEP
BS       R  C  FLOW CONDITIONS BEHIND SHOCK OR EXPANSION                     FLOSEP
BS2      R  U  PRESSURE TO BE SAVED                                          FLOSEP
BS2F     R  U  INVISCID SHOCK-EXPANSION PRESSURE                             FLOSEP
BS3      R  U  TEMPERATURE TO BE SAVED                                       FLOSEP
BS3F     R  U  TEMPERATURE TO BE SAVED                                       FLOSEP
BS6      R  U  MACH NUMBER TO BE SAVED                                       FLOSEP
BS6F     R  U  MACH NUMBER ON FLAP TO BE SAVED                               FLOSEP
CASE     I  C  CASE NUMBER                                                   FLOSEP
CFD1     R  U  FLAP CHORD/UPSTREAM INTERACTION LENGTH                        FLOSEP
CFLAP    R  U  FLAP CHORD                                                    FLOSEP
CP       R  A  PRESSURE COEFFICIENT                                          FLOSEP
CPAINC   R  U  PRESSURE RISE TO CAUSE INCIPIENT SEPARATION                   FLOSEP
CPAP     R  U  PLATEAU PRESSURE COEFFICIENT                                  FLOSEP
CPA2IN   R  U  INVISCID PRESSURE RISE COEFFICIENT ON TO CONTROL SURFACE      FLOSEP
CPF      R  U  PRESSURE COEFFICIENT ON FLAP (DUMMY-NOT USED)                 FLOSEP
CPIP     R  U  PLATEAU PRESSURE COEFFICIENT                                  FLOSEP
CPI2     R  U  PEAK PRESSURE COEFFICIENT ON FLAP                             FLOSEP
CPNIN    R  A  PRESSURE COEFFICIENT (INPUT FORCE METHOD, INVISCID)           FLOSEP
CPSEP    R  U  VISCOUS PRESSURE COEFFICIENT WITH SEPARATION                  FLOSEP
CPSTAG   R  A  NEWTONIAN CORRELATION FACTOR, K (STAGNATION PRESSURE COEFF)   FLOSEP
CPX      R  U  PRESSURE COEFFICIENT AT SEPARATION POINT                      FLOSEP
DELCPC   R  A  PRESSURE COEFFICIENT INCREMENT DUE TO CONTROL SURFACE         FLOSEP
DELP     R  U  PRESSURE INCREMENT DUE TO FLAP AND SEPARATION                 FLOSEP
DELTA    R  A  ELEMENT IMPACT ANGLE (DEGREES)                                FLOSEP
DELTAE   R  A  CONTROL SURFACE DEFLECTION                                    FLOSEP
DELTAR   R  A  ELEMENT IMPACT ANGLE (RADIANS)                                FLOSEP
DELTAS   R  U  SAVED INITIAL CONTROL SURFACE DEFLECTION                      FLOSEP
DELTER   R  U  FLAP DEFLECTION ANGLE (RADIANS)                               FLOSEP
DD       R  U  BOUNDARY LAYER THICKNESS                                      FLOSEP
DDX      R  U  BOUNDARY LAYER THICKNESS AT EXACT SEPARATION POINT            FLOSEP
DD1      R  U  BOUNDARY LAYER THICKNESS ON ELEMENT BEFORE SEPARATION POINT   FLOSEP
DSQXP    R  U  SQUARE ROOT OF X-PRIME                                        FLOSEP
DUMMY    R  U  DUMMY ARGUMENT                                                FLOSEP
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SYMBOLS USED IN SUBROUTINE FLOSEP

DXSEP    R  U  DIFFERENCE BETWEEN LEADING EDGE AND SEPARATION X-DISTANCE        FLOSEP
DXSEP1   R  U  XLE-XSEP ON ELEMENT JUST BEFORE SEPARATION ELEMENT               FLOSEP
D1       R  U  UPSTREAM INTERACTION LENGTH                                      FLOSEP
D1DO     R  U  UPSTREAM INTERACTION LENGTH/BOUNDARY LAYER THICKNESS             FLOSEP
D2       R  U  DOWNSTREAM INTERACTION LENGTH TO PEAK PRESSURE                   FLOSEP
D2D1     R  U  RATIO OF DOWNSTREAM TO UPSTREAM INTERACTION LENGTHS              FLOSEP
D3       R  U  DOWNSTREAM INTERACTION LENGTH TO PRESSURE RISE                   FLOSEP
D3D1     R  U  DOWNSTREAM INTERACTION LENGTH/UPSTREAM INTERACTION LENGTH        FLOSEP
ELAM     R  U  A FUNCTION OF RELATIVE FLAP CHORD LENGTH                         FLOSEP
ELFI     R  U  FREE INTERACTION LENGTH                                          FLOSEP
ELFIDO   R  U  FREE INTERACTION LENGTH / BOUNDARY LAYER THICKNESS               FLOSEP
EMADF    R  U  PRODUCT OF MACH NUMBER AND FLAP DEFLECTION                       FLOSEP
ERROR    I  C  ERROR FLAG                                                       FLOSEP
FS       R  C  FLOW CONDITIONS BEFORE SHOCK OR EXPANSION                        FLOSEP
FS2      R  U  PRESSURE TO BE SAVED                                             FLOSEP
FS6      R  U  MACH NUMBER TO BE SAVED                                          FLOSEP
G        R  A  SPECIFIC HEAT RATIO (GAMMA)                                      FLOSEP
I        I  U  DO LOOP COUNTER                                                  FLOSEP
ICHECK   I  U  PRINT FLAG FOR CHECKOUT PURPOSES                                 FLOSEP
IFIRST   I  A  FLAG FOR FIRST TIME INTO NEWTONIAN-PRANDTL-MEYER ROUTINE         FLOSEP
IFSCY    I  A  FLOW SEPARATION CYCLE FLAG                                       FLOSEP
IGT      I  A  CONTROL SURFACE FLAG (=1 FORESURFACE, = 2 CONTROL SURFACE)       FLOSEP
IGTS     I  A  CONTROL SURFACE FLAG FOR THE PRESENT ELEMENT                     FLOSEP
IGTYPE   I  A  GEOMETRY TYPE (=1 FOR CONTROL SURFACE COMPONENT)                 FLOSEP
IM       I  C  (NOT USED)                                                       FLOSEP
IMPACI   I  A  INITIAL STRIP ELEMENT IMPACT FORCE METHOD                        FLOSEP
IMPACT   I  A  IMPACT FORCE CALCULATION METHOD FLAG                             FLOSEP
IMPS     I  A  INPUT IMPACT FORCE CALCULATION METHOD                            FLOSEP
IN       I  C  IN(1) AND IN(2) NUMBER OF ELEMENTS IN FORE-SURFACE AND FLAP      FLOSEP
IORIEN   I  A  ELEMENT ORIENTATION (=1 FOR STREAMWISE STRIP)                    FLOSEP
IPRCK    I  A  DETAILED DATA PRINT CONTROL FLAG                                 FLOSEP
IRFD11   I  A  TAPE 11 READ FLAG INDICATOR                                      FLOSEP
ISBP     I  A  FORCE SUMMATION BYPASS FLAG (=1 TO BYPASS SUMMATION)             FLOSEP
ISCT     I  U  ELEMENT COUNTER                                                  FLOSEP
ISDET    I  U  CALCULATION CONTROL FLAG FOR COMPRESSION ROUTINE                 FLOSEP
ISEP     I  U  SEPARATION INDICATOR FLAG                                        FLOSEP
ISHAD    I  A  SHADOW FORCE CALCULATION METHOD FLAG                             FLOSEP
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SYMBOLS USED IN SUBROUTINE FLOSEP

ISHADI   I  A  INITIAL STRIP ELEMENT SHADOW FORCE METHOD                      FLOSEP
ISHS     I  A  INPUT SHADOW FORCE CALCULATION METHOD                          FLOSEP
ISPNT    I  A  SEPARATION AND ATTACHMENT PRINT FLAG                           FLOSEP
ITRANS   I  U  FLOW TRANSITION FLAG (=0 LAMINAR, =1 TURBULENT)                FLOSEP
J        I  U  DO LOOP INDEX                                                  FLOSEP
K        I  C  NUMBER OF ELEMENTS IN COMPONENT                                FLOSEP
KFLSP    I  U  FLOW SEPARATION FLAG (=0 NO SEPARATION, =1 FLOW SEPARATED)     FLOSEP
L        I  A  NUMBER OF ELEMENT IN FORCE CALCULATION LOOP                    FLOSEP
LATT     I  U  ELEMENT NUMBER AT FLOW ATTACHMENT POINT                        FLOSEP
LL       I  A  ELEMENT NUMBER                                                 FLOSEP
LS       I  C  NUMBER OF ELEMENTS IN COMPONENT                                FLOSEP
LSEP     I  U  ELEMENT NUMBER AT SEPARATION                                   FLOSEP
LSS      I  U  NUMBER OF ELEMENTS IN COMPONENT                                FLOSEP
M        I  A  ELEMENT NUMBER IN STRIP                                        FLOSEP
MA       R  U  LOCAL MACH NUMBER ON ELEMENT                                   FLOSEP
MACH     R  A  FREE-STREAM MACH NUMBER                                        FLOSEP
MACHH    R  U  SHOCK-EXPANSION MACH NUMBER AT HINGE LINE ELEMENT              FLOSEP
MACHX    R  U  MACH NUMBER AT SEPARATION                                      FLOSEP
MACHX1   R  U  MACH NUMBER ON ELEMENT JUST BEFORE SEPARATION                  FLOSEP
MER      I  U  COMPRESSION ROUTINE ERROR FLAG                                 FLOSEP
N        I  A  STREAMWISE ELEMENT STRIP NUMBER                                FLOSEP
NW       R  A  WALL TEMPERATURE CALCULATION FLAG FOR FLOSEP                   FLOSEP
NX       R  A  X-COMPONENT OF OUTWARD NORMAL                                  FLOSEP
NXF      R  U  X-COMPONENT OF FLAP SURFACE NORMAL                             FLOSEP
NXFS     R  U  X-COMPONENT OF FLAP OUTWARD NORMAL TO BE SAVED                 FLOSEP
NXH      R  U  X-COMPONENT OF OUTWARD NORMAL AT HINGE LINE ELEMENT            FLOSEP
NXS      R  U  X-COMPONENT OF SURFACE NORMAL TO BE SAVED                      FLOSEP
NX2      R  C  NX2(1) AND NX2(2) ARE HINGE LINE X-COORDINATE DATA             FLOSEP
NY       R  A  Y-COMPONENT OF OUTWARD NORMAL                                  FLOSEP
NYF      R  U  Y-COMPONENT OF FLAP OUTWARD NORMAL                             FLOSEP
NYFS     R  U  Y-COMPONENT OF FLAP OUTWARD NORMAL TO BE SAVED                 FLOSEP
NYH      R  U  Y-COMPONENT OF OUTWARD NORMAL AT HINGE LINE ELEMENT            FLOSEP
NYS      R  U  Y-COMPONENT OF OUTWARD NORMAL TO BE SAVED                      FLOSEP
NY2      R  C  NY2(1) AND NY2(2) ARE HINGE LINE Y-COORDINATE DATA             FLOSEP
NZ       R  A  Z-COMPONENT OF OUTWARD NORMAL                                  FLOSEP
NZF      R  U  Z-COMPONENT OF FLAP SURFACE NORMAL (UNDEFLECTED)               FLOSEP
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SYMBOLS USED IN SUBROUTINE FLOSEP

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NZFS     R  U  Z-COMPONENT OF FLAP SURFACE NORMAL TO BE SAVED (UNDEFLECTED)    FLOSEP
NZH      R  U  Z-COMPONENT OF OUTWARD NORMAL AT HINGE LINE ELEMENT             FLOSEP
NZS      R  U  Z-COMPONENT OF SURFACE NORMAL TO BE SAVED                       FLOSEP
NZ2      R  C  (NOT USED)                                                      FLOSEP
P        R  U  FINAL PRESSURE ON ELEMENT WITH SEPARATION                       FLOSEP
PAGE     I  C  PAGE NUMBER                                                     FLOSEP
PFS      R  A  FREE-STREAM PRESSURE                                            FLOSEP
PH       R  U  HINGE LINE INVISCID SHOCK-EXPANSION PRESSURE                    FLOSEP
PHI      R  U  ANGLE ASSOCIATED WITH GEOMETRY OF SEPARATION                    FLOSEP
PNIN     R  U  INVISCID PRESSURE USING NORMAL FORCE METHOD                     FLOSEP
PPPO     R  U  RATIO OF PLATEAU PRESSURE TO FREE-STREAM PRESSURE               FLOSEP
PPPOX    R  U  PLATEAU PRESSURE/STREAM PRESSURE AT SEPARATION POINT            FLOSEP
PPPO1    R  U  PLATEAU PRESS/FREE-STREAM PRESS ON ELEMENT BEFORE SEPARATION    FLOSEP
PSEIN    R  D  INVISCID SHOCK-EXPANSION PRESSURE                               FLOSEP
PSEVIS   R  D  SHOCK-EXPANSION PRESSURE WITH VISCOUS SEPARATION                FLOSEP
PX       R  U  LOCAL PRESSURE AT EXACT SEPARATION POINT                        FLOSEP
PX1      R  U  PRESSURE ON ELEMENT JUST BEFORE SEPARATION POINT                FLOSEP
RE       R  D  REFERENCE REYNOLDS NUMBER                                       FLOSEP
REAFT    R  U  LOCAL SURFACE REYNOLDS NUMBER PER FOOT                          FLOSEP
REAHL    R  U  REYNOLDS NUMBER AT HINGE LINE ELEMENT                           FLOSEP
REASFT   R  U  REFERENCE REYNOLDS NUMBER PER FOOT                              FLOSEP
REAXOP   R  U  REYNOLDS NUMBER ON LOCAL ELEMENT                                FLOSEP
RETRAN   R  A  INPUT FLOW TRANSITION REYNOLD'S NUMBER                          FLOSEP
RT       R  U  RECOVERY TEMPERATURE                                            FLOSEP
SINTH    R  U  SINE OF SHOCK ANGLE                                             FLOSEP
SWEEP    R  A  LEADING EDGE SWEEP ANGLE                                        FLOSEP
TANPHI   R  U  TANGENT OF FLOW SEPARATION ANGLE                                FLOSEP
TFS      R  A  FREE-STREAM TEMPERATURE                                         FLOSEP
TH       R  U  FLOW TEMPERATURE AT HINGE LINE ELEMENT                          FLOSEP
THETA    R  U  SHOCK ANGLE                                                     FLOSEP
TITLE    R  C  TITLE ARRAY                                                     FLOSEP
TR       R  D  TEMPERATURE DATA ARRAY                                          FLOSEP
TS       R  D  REFERENCE TEMPERATURE (DEGREE R)                                FLOSEP
TWALL    R  A  WALL TEMPERATURE FOR FLOSEP                                     FLOSEP
TX1      R  U  FLOW TEMPERATURE ON ELEMENT JUST BEFORE SEPARATION ELEMENT      FLOSEP
XATACH   R  A  X-COORDINATE AT FLOW ATTACHMENT POINT                           FLOSEP
```

```
SYMBOLS USED IN SUBROUTINE FLOSEP

XCENT    R  A  HINGE MOMENT FACTOR FOR CONTROL SURFACE ELEMENT                  FLOSEP
XCENT2   R  C  HINGE MOMENT FACTOR ARRAY FOR CONTROL SURFACE ELEMENTS           FLOSEP
XHL      R  U  ELEMENT AVERAGE X-COORDINATE AT HINGE LINE                       FLOSEP
XLE      R  A  X-DISTANCE FROM CENTROID OF ELEMENT TO LEADING EDGE LINE         FLOSEP
XLEH     R  U  X-DISTANCE FROM LEADING EDGE TO HINGE LINE                       FLOSEP
XLESEP   R  U  DISTANCE FROM LEADING EDGE TO SEPARATION POINT                   FLOSEP
XLE1     R  U  ELEMENT CENTROID DISTANCE FROM L. E. BEFORE SEPARATION           FLOSEP
XPA      R  A  X-COORDINATES OF QUADRILATERAL ELEMENT                           FLOSEP
XSEP     R  U  DISTANCE FROM LEADING EDGE MINUS UPSTREAM INTERACTION LENGTH     FLOSEP
XSEPP    R  A  X-COORDINATE AT FLOW SEPARATION POINT                            FLOSEP
XTE      R  U  AVERAGE X-COORDINATE AT TRAILING EDGE                            FLOSEP
YCENT    R  A  (NOT USED)                                                       FLOSEP
YCENT2   R  C  (NOT USED)                                                       FLOSEP
YHL      R  U  ELEMENT AVERAGE Y-COORDINATE AT HINGE LINE                       FLOSEP
YPA      R  A  Y-COORDINATES OF QUADRILATERAL ELEMENT                           FLOSEP
YTE      R  U  AVERAGE Y-COORDINATE AT TRAILING EDGE                            FLOSEP
ZCENT    R  A  (NOT USED)                                                       FLOSEP
ZCENT2   R  C  (NOT USED)                                                       FLOSEP
ZHL      R  U  ELEMENT AVERAGE Z-COORDINATE AT HINGE LINE                       FLOSEP
ZPA      R  A  Z-COORDINATES OF QUADRILATERAL ELEMENT                           FLOSEP
ZTE      R  U  ELEMENT AVERAGE Z-COORDINATE AT TRAILING EDGE                    FLOSEP
```

13. SUBROUTINE SKINFR (DECK AROL)

This routine calculates viscous forces for both laminar and turbulent flows including viscous-interaction and planform effects. Also, the viscous induced pressures are determined.

a. Algorithm

The basic program constants and control flags are first established. The routine then starts a major DO-loop to calculate the viscous forces on each of the skin-friction surfaces. This involves the following steps: Calculate the surface planform geometry, local flow conditions, surface temperature, viscous-interaction effects, laminar and turbulent viscous forces, and summation of forces for either laminar or turbulent as specified. If desired, the induced pressure increment due to viscous-interaction is also calculated. At the user's option, the skin friction may be calculated by the reference temperature, reference enthalpy, or theSpalding-Chi methods.

b. Input/Output

If IS(I, 7) = 1, skin friction data for each surface will be printed.

c. Error

An error condition will occur if the input Mach number is subsonic.

d. Subroutines Required

TEMP. CONE, COMPR, EXPAND, NEWTPM, HEADER

e. Argument List

(ALPHA, CA, SREF, SKIN, NS, ALT, MACH, CPSTAG, TFS, PFS, AFS, RHOFS, IFIRST, VIS, ISIZ, CN, IGTYPE, DELTA)

f. Length

10,030 bytes

```
DECK AROL

      SUBROUTINE SKINFR (ALPHA,CA,SREF,SKIN,NS,ALT,MACH,CPSTAG,TFS,         AROL  0010
     1  PFS,AFS,RHOFS,IFIRST,VIS,ISIZ,CN,IGTYPE,DELTA)                      AROL  0020
C                                                                           AROL  0030
C                                                                           AROL  0040
C                                                                           AROL  0050
C   THIS SUBROUTINE CALCULATES SKIN FRICTION FOR BOTH LAMINAR               AROL  0060
C   AND TURBULENT FLOWS.  REFERENCE TEMPERATURE, REFERENCE                  AROL  0070
C   ENTHALPY, AND SPALDING-CHI CALCULATION PROCEDURES MAY BE SELECTED.      AROL  0080
C   ALSO, THE INDUCED PRESSURES DUE TO VISCOUS-INTERACTION ARE              AROL  0090
C   DETERMINED IN THIS SUBROUTINE.                                          AROL  0100
C                                                                           AROL  0110
C                                                                           AROL  0120
C                                                                           AROL  0130
      DIMENSION  ANGLE(3),BS(8),CFT(6),CFL(6),FS(8),RE(2),SCF(4),TR(10),    AROL  0140
     1  TS(2),          SCFA(2),TITLE(15),SURF(10,8),IS(10,9),RT(2),        AROL  0150
     2  CCA(20),CCY(20),CCN(20),CCLL(20),CCLM(20),CCLN(20),CCL(20),         AROL  0160
     3  CCD(20),CLOD(20),CF(20),CPS(20),ETACS(20),ALP(20),BET(20)           AROL  0170
      DIMENSION NX2( 300),NY2( 300),NZ2( 300),XCENT2( 300),                 AROL  0180
     1  YCENT2( 300),ZCENT2( 300),AREA2( 300),IN( 300),IM( 300)             AROL  0190
C                                                                           AROL  0200
C                                                                           AROL  0210
      COMMON  CASE,TITLE,PAGE,ERROR,NX2,NY2,NZ2,XCENT2,YCENT2,ZCENT2,       AROL  0220
     1  AREA2,IN,IM,L,LS,FS,BS,ALP,BET,CCA,CCY,CCN,CCLL,CCLM,CCLN,CCL,      AROL  0230
     2  CCD,CLOD,CF,CPS,ETACS,IS,SURF,NPRT                                  AROL  0240
      COMMON /TEMPOC/HAW,H2,H1,HW,CKU,FC,FRX,RET,ELLOC,CCP,   YST1,ROMURA   AROL  0250
      INTEGER  CASE,PAGE,ERROR                                              AROL  0260
      REAL  MACH, NX2, NY2, NZ2, KO, M, LAMBDA                              AROL  0270
C                                                                           AROL  0280
C                                                                           AROL  0290
C   CHECK IF FLOW IS SUPERSONIC                                             AROL  0300
    2  IF (MACH .GT.1.0) GO TO 7                                            AROL  0310
      WRITE (6,9)                                                           AROL  0320
    9  FORMAT (1H0,47H**** INPUT MACH NUMBER IS NOT SUPERSONIC.  SKIN       AROL  0330
     1 49H FRICTION ANALYSIS FOR THIS POINT IS STOPPED ****  )              AROL  0340
      SKIN = 0.0                                                            AROL  0350
```

DECK AROL

```
      GO TO 1                                                           AROL  0360
C                                                                       AROL  0370
C   SET STARTING CONSTANTS                                              AROL  0380
    7 MER   = 1                                                         AROL  0390
      SCFA(1) = 0.0                                                     AROL  0400
      SCFA(2) = 0.0                                                     AROL  0410
      IF (IGTYPE.NE.2 .OR. (IGTYPE.EQ.2 .AND. NS.EQ.1)) NPRY = 0        AROL  0420
      IGTY = 0                                                          AROL  0430
      IF (IGTYPE .EQ. 17) IGTY = 1                                      AROL  0440
      IF (IGTYPE .EQ. 17) IGTYPE = 2                                    AROL  0450
      MEREXP= 0                                                         AROL  0460
      NC    = 0                                                         AROL  0470
      SCF(1) = 0.0                                                      AROL  0480
      SCF(2) = 0.0                                                      AROL  0490
      SCF(3) = 0.0                                                      AROL  0500
      SCF(4) = 0.0                                                      AROL  0510
      FS(1) = RHOFS                                                     AROL  0520
      FS(2) = PFS                                                       AROL  0530
      FS(3) = TFS                                                       AROL  0540
      FS(4) = AFS                                                       AROL  0550
C                                                                       AROL  0560
C   VISCOSITY EQUATION                                                  AROL  0570
      FS(5) = VIS                                                       AROL  0580
C                                                                       AROL  0590
      TR(1) = ALT                                                       AROL  0600
      TR(2) = MACH                                                      AROL  0610
      TR(3) = MACH * FS(4)                                              AROL  0620
      TR(4) = ALPHA + 0.000001                                          AROL  0630
      IF (IGTYPE .EQ. 2) TR(4) = 0.0                                    AROL  0640
      FS(6) = TR(2)                                                     AROL  0650
      FS(7) = TR(3)                                                     AROL  0660
      FS(8) = FS(1)*FS(7)/FS(5)                                         AROL  0670
      II = 1                                                            AROL  0680
      IF (IGTYPE .EQ. 2) II = NS                                        AROL  0690
C                                                                       AROL  0700
C                                                                       AROL  0710
```

```
DECK AROL

C  CALCULATE SKIN FRICTION FOR EACH SURFACE                                   AROL  0720
      DO 1000 I=II,NS                                                         AROL  0730
      ELO = 0.0                                                               AROL  0740
      EL  = SURF(I,2)                                                         AROL  0750
C                                                                             AROL  0760
C  CHECK IF INITIAL SURFACE SPECIFIED (IGTYPE = 2).  IF SO,                   AROL  0770
C  DETERMINE APPROPRIATE LENGTHS AND TAPER RATIOS.                            AROL  0780
      IF (IGTYPE.NE.2) GO TO 110                                              AROL  0790
      ELO = SURF(I,3)                                                         AROL  0800
      TAPER1 = SURF(I,4)                                                      AROL  0810
      TAPER2 = SURF(I,5)                                                      AROL  0820
      IF (TAPER1 .LT. 0.0) GO TO 130                                          AROL  0830
      SURF(I,5) = (EL*TAPER2 + ELO*TAPER1)/(EL + ELO)                         AROL  0840
      EL = EL + ELO                                                           AROL  0850
      GO TO 133                                                               AROL  0860
  130 TAPER1 = -TAPER1                                                        AROL  0870
      SURF(I,5) = 1.0                                                         AROL  0880
      EL1 = ELO + EL*TAPER2                                                   AROL  0890
      EL = EL + ELO*TAPER1                                                    AROL  0900
      IF (EL-EL1) 131,133,132                                                 AROL  0910
  131 SURF(I,5) = EL/EL1                                                      AROL  0920
      EL = EL1                                                                AROL  0930
      GO TO 133                                                               AROL  0940
  132 SURF(I,5) = EL1/EL                                                      AROL  0950
  133 IF (TAPER1 .EQ. 0.0) TAPER1 = 0.0001                                    AROL  0960
  110 IF (SURF(I,5) .EQ. 0.0) SURF(I,5) = 0.0001                              AROL  0970
      TR(5) = SURF(I,6)                                                       AROL  0980
       TR(6) = SURF(I,7)                                                      AROL  0990
C                                                                             AROL  1000
      IF (SURF(I,5) .LT. 0.8) GO TO 77                                        AROL  1010
      ELL    = EL * 4.0 * ((1.0 + SURF(I,5)) / (3.0+SURF(I,5)))**2            AROL  1020
      GO TO 79                                                                AROL  1030
C                                                                             AROL  1040
   77 ELL    = EL * (0.75*(1.0-SURF(I,5)**2) /(1.0-SURF(I,5)**1.5))**2        AROL  1050
   79 REND = FS(8) * ELL                                                      AROL  1060
      IS3 = IS(I,3)                                                           AROL  1070
```

```
DECK AROL
C                                                                       AROL  1080
C  DETERMINE ANGLE OF ATTACK USE                                        AROL  1090
      IF (IS(I,5) .NE. 1) GO TO 14                                      AROL  1100
C                                                                       AROL  1110
C  ANGLE OF ATTACK IS NOT USED                                          AROL  1120
      ANGLE(1) = SURF(I,4)                                              AROL  1130
      GO TO 90                                                          AROL  1140
C                                                                       AROL  1150
C  ANGLE OF ATTACK IS USED. CHECK CALCULATION TYPE REQUIRED             AROL  1160
   14 GO TO (21,16,21,16,21,16), IS3                                    AROL  1170
C                                                                       AROL  1180
C  UPPER SURFACE                                                        AROL  1190
   21 ANGLE(1) = SURF(I,3) + TR(4) - SURF(I,4)                          AROL  1200
      IF (IGTYPE .EQ. 2) ANGLE(1) = -DELTA                              AROL  1210
C  CHECK FLOW TYPE                                                      AROL  1220
      IF (ANGLE(1)) 18,19,17                                            AROL  1230
C                                                                       AROL  1240
C  LOWER SURFACE                                                        AROL  1250
   16 ANGLE(1) = SURF(I,3) + TR(4) + SURF(I,4)                          AROL  1260
      IF (IGTYPE .EQ. 2) ANGLE(1) = DELTA                               AROL  1270
C  CHECK FLOW TYPE                                                      AROL  1280
   90 IF (ANGLE(1)) 17,19,18                                            AROL  1290
C                                                                       AROL  1300
C                                                                       AROL  1310
C  COMPRESSION                                                          AROL  1320
   18 KF = 2                                                            AROL  1330
C  FLAT PLATE OR DELTA WING CHECK                                       AROL  1340
      IF (IS(I,2) .NE. 1) GO TO 86                                      AROL  1350
      CALL CONE (ANGLE,CP,0)                                            AROL  1360
      GO TO 24                                                          AROL  1370
C                                                                       AROL  1380
   86 ANGLE(2) = ABS(ANGLE(1))                                          AROL  1390
C  CHECK USE OF SHOCK-EXPANSION                                         AROL  1400
      IF (IS(I,3) .LT. 5) GO TO 23                                      AROL  1410
       KF = 5                                                           AROL  1420
       GO TO 85                                                         AROL  1430
```

DECK AROL

```
C                                                                       AROL  1440
   23 ISE = 0                                                           AROL  1450
      ISDET = 0                                                         AROL  1460
      CALL COMPR (ANGLE,MER,IS(I,9),CPSTAG,TFS,PFS,ISDET,IFIRST,CP)     AROL  1470
       GO TO 67                                                         AROL  1480
C                                                                       AROL  1490
C                                                                       AROL  1500
C  EXPANSION                                                            AROL  1510
   17 ANGLE(2) = ABS(ANGLE(1))                                          AROL  1520
C  CHECK USE OF SHOCK-EXPANSION                                         AROL  1530
      IF (IS(I,3) .LT. 3) GO TO 22                                      AROL  1540
       KF = 4                                                           AROL  1550
       ANGLE(2) = -ANGLE(2)                                             AROL  1560
       GO TO 85                                                         AROL  1570
C                                                                       AROL  1580
   22 KF = 1                                                            AROL  1590
      ISDET = 0                                                         AROL  1600
      CALL EXPAND (ANGLE,MER,IS(I,9),ISDET,CP)                          AROL  1610
      IF (IGTY.EQ.0 .OR. MER.LE.1) GO TO 67                             AROL  1620
      SKIN = 0.0                                                        AROL  1630
      GO TO 1                                                           AROL  1640
C                                                                       AROL  1650
C                                                                       AROL  1660
C  NEITHER EXPANSION OR COMPRESSION                                     AROL  1670
   19 ANGLE(2) = 0.0                                                    AROL  1680
C  CHECK USE OF SHOCK-EXPANSION                                         AROL  1690
      IF (IS(I,3).LT. 5) GO TO 84                                       AROL  1700
       KF = 6                                                           AROL  1710
       GO TO 85                                                         AROL  1720
C                                                                       AROL  1730
   84 KF = 3                                                            AROL  1740
      DO 20 K=1,8                                                       AROL  1750
   20  BS(K) = FS(K)                                                    AROL  1760
       ONEOM = 1.0 / BS(6)                                              AROL  1770
      ANGLE(3) = ARSIN(ONEOM) * 0.5729578E02                            AROL  1780
       GO TO 24                                                         AROL  1790
```

```
DECK AROL

C
C
C  SHOCK-EXPANSION CALCULATION
 85  ISE = 0
     CALL NEWTPM (ANGLE,EMN,CP,SURF(I,8),IS(I,9),MER,CPSTAG,
    1  TFS, PFS,ISE,IFIRST)
     IF (MER .EQ. 0) GO TO 67
     ISDET = 1
     CALL COMPR (ANGLE,MER,IPRINT,CPSTAG,TFS,PFS,ISDET,IFIRST,CP)
C
C  CHECK ERROR FLAG
 67  IF (MER .LE. 1) GO TO 24
      MEREXP = 1
  5   MER = 1
      GO TO 65
C
C  CALCULATE REFERENCE TEMPERATURE, REYNOLDS NO., AND WALL
C  TEMPERATURE (IF REQUIRED).  FIRST CHECK IF TEMPERATURE
C  ITERATIONS AND/OR LOCAL CF DATA TO BE PRINTED.
  24 IF (IS(I,9).EQ.0) GO TO 26
C
C  LOCAL DATA TO BE PRINTED.  IF TEMPERATURE ITERATIONS START
C  NEW PAGE FOR EACH SURFACE.  OTERWISE TEST IF HEADER REQUIRED.
     IF (IS(I,9).EQ.1) GO TO 25
     IF ((NPRT.LT.52).AND.(NS.NE.1))GO TO 26
C
  25 CALL HEADER
     WRITE(6,31) ALPHA,MACH,TR(3),ALT,FS(8),SREF
     NPRT = 8
  26 CALL TEMP(EL,TR,RE,TS,IS(I,6),MER,IS(I,9),RT)
C  CHECK ERROR FLAG
     IF (MER - 1) 83,83,5
C
C  CALCULATE VISCOUS-INVISCID INTERACTION EFFECT ON SKIN FRICTION
 83  KO = MACH * SIN(ANGLE(1) / 57.295779)
     IF (IS3.EQ.1.OR.IS3.EQ.3.OR.IS3.EQ.5) KO = - KO
```

```
DECK AROL
      IF (KO.LT.-C.0001 .OR. KO.GT.0.0001) GO TO 91                     AROL  2160
      PO = 1.0                                                          AROL  2170
       M = 1.9156                                                       AROL  2180
       GO TO 92                                                         AROL  2190
   91 GA = 1.4                                                          AROL  2200
      IF (KO.GE.0.0) GO TO 93                                           AROL  2210
C  EXPANSION SURFACE.                                                   AROL  2220
      PO = 0.00001                                                      AROL  2230
      M = 0.00001                                                       AROL  2240
      IF (KO.LE.(-2/(GA-1.))) GO TO 92                                  AROL  2250
      PO = (1.0 + 0.5*(GA-1.)*KO)**(2.*GA/(GA-1.))                      AROL  2260
      IF (KO.GE.-3.0) GO TO 94                                          AROL  2270
      M = 1.424 + C.219*KO                                              AROL  2280
      GO TO 92                                                          AROL  2290
C  COMPRESSION SURFACE.                                                 AROL  2300
   93 PO = 1.0 + 0.25*GA*(GA + 1.0)*KO*KO +                             AROL  2310
     1         GA*KO*SQRT(1.0 + (0.25*(GA + 1.0)*KO)**2)                AROL  2320
   94 M = 1.9156 + KO*(0.41727 - KO*(0.0419101 + KO*(0.010427           AROL  2330
     1           - KO*(0.00214381 - KO*1.03217E-4))))                   AROL  2340
  92  TWTRL  = TR(5) / RT(1)                                            AROL  2350
      G = 0.34416 * (TWTRL + 0.3859)                                    AROL  2360
      A =  G / 2.0                                                      AROL  2370
      IF (TR(5).GE.225.0) VISWL =2.27*TR(5)**1.5/((TR(5)+198.6)*10.**8) AROL  2380
      IF (TR(6).GE.225.0) VISWT =2.27*TR(6)**1.5/((TR(6)+198.6)*10.**8) AROL  2390
      IF (TR(5).LT.225.0) VISWL = 0.80382436E-9 * TR(5)                 AROL  2400
      IF (TR(6).LT.225.0) VISWT = 0.80382436E-9 * TR(6)                 AROL  2410
      RELOC = BS(8) * SURF(I,2)                                         AROL  2420
      CLAM = VISWL * TFS / (VIS*TR(5))                                  AROL  2430
      CTURB= VISWT * TFS / (VIS*TR(6))                                  AROL  2440
      CHIBAR = MACH**3*SQRT(CLAM) / SQRT(RENO*EL/ELL)                   AROL  2450
      VBAR = CHIBAR /(MACH*MACH)                                        AROL  2460
      IF (TS(1).GE.225.0) VISTAR =2.27*TS(1)**1.5/((TS(1)+198.6)*10.**8) AROL  2470
      IF (TS(1).LT.225.0) VISTAR = 0.803824E-9 * TS(1)                  AROL  2480
      CSTAR = VISTAR * TFS / (VIS*TS(1))                                AROL  2490
      VSTAR = MACH * SQRT(CSTAR) / SQRT(RENO*EL/ELL)                    AROL  2500
      FJ = IS(I,2)                                                      AROL  2510
```

```
DECK AROL

      LAMBDA = A * CHIBAR /SQRT(1. + 2.*FJ)                             AROL  2520
      IF (IGTY .EQ. 1) GO TO 500                                        AROL  2530
      B = M * LAMBDA / PO * SQRT(EL/ELL)                                AROL  2540
      CFCFOL = SQRT(1.0+B) + 0.5*B*ALOG(ABS((SQRT(1.0+B)+1.0)/          AROL  2550
     1                (SQRT(1.0+B)-1.0)))                               AROL  2560
      IF (CFCFOL .LT. 1.0) CFCFOL = 1.0                                 AROL  2570
      CFCFOT = 1.0                                                      AROL  2580
                                                                        AROL  2590
C                                                                       AROL  2600
C   START TURBULENT FLOW CALCULATIONS                                   AROL  2610
      IF (RE(2) .LE. 6570.) GO TO 100                                   AROL  2620
      EN = 0.8686 / (ALOG10(RE(2)) - 2.0)                               AROL  2630
C  CHECK TAPER RATIO AND CHARACTERISTIC LENGTH TERMS                    AROL  2640
      IF (SURF(I,5) .LT. 0.8) GO TO 72                                  AROL  2650
      Q = SQRT ((1.0 + SURF(I,5)) / (1.0 + EN + SURF(I,5) * (1.0-EN)))  AROL  2660
      GO TO 73                                                          AROL  2670
C                                                                       AROL  2680
   72 Q = SQRT ((1.0 - SURF(I,5)**2) *(1.0- 0.5 *EN) /                  AROL  2690
     1   (1.0 - SURF(I,5)**(2.0-EN)))                                   AROL  2700
C                                                                       AROL  2710
   73 ELT = EL * (RE(2)/10.0**1.5) ** (Q - 1.0)                         AROL  2720
      ESIN = SIN((ANGLE(1)-TR(4))/57.295779)                            AROL  2730
      ECOS = COS((ANGLE(1)-TR(4))/57.295779)                            AROL  2740
      RE(2)  = RE(2) * ELT/EL                                           AROL  2750
      CFT(1) = 0.088 / (0.43429448 * ALOG(RE(2)) - 1.5)**2              AROL  2760
      FF = ELO      /SURF(I,2)*(1.0 + TAPER1)/(1.0 + TAPER2)            AROL  2770
      IF (ELO.LT. 0.0001) GO TO 112                                     AROL  2780
      IF ((RE(2)*ELO/ELT).GT. 6570.0) GO TO 111                         AROL  2790
      IF (TAPER1.LT. 0.8) GO TO 113                                     AROL  2800
      EL1 = ELO*4.0*((1.+TAPER1)/(3.0+TAPER1))**2                       AROL  2810
      GO TO  114                                                        AROL  2820
  113 EL1 = ELO*(0.75*(1.-TAPER1**2)/(1.-TAPER1**1.5))**2               AROL  2830
  114 CFL(1) = 1.328/SQRT(RE(2)*EL1/ELT)                                AROL  2840
      FF = FF*(CFL(1)/CFT(1) - 1.0)                                     AROL  2850
      GO TO 112                                                         AROL  2860
  111 EN = 0.8686/(ALOG10(RE(2)*ELO/ELT) - 2.0)                         AROL  2870
```

```
DECK AROL
      IF (TAPER1.LT. 0.8) GO TO 115                                     AROL  2880
      Q = SQRT((1.0+TAPER1)/(1.0+EN+TAPER1*(1.-EN)))                    AROL  2890
      GO TO 116                                                         AROL  2900
  115 Q = SQRT((1.0-TAPER1**2)*(1.0-0.5*EN)/(1.0-TAPER1**(2.0-EN)))     AROL  2910
  116 EL1 = ELO*(RE(2)*ELO/ELT/10.**1.5)**(Q-1.0)                       AROL  2920
      FF = FF*(((ALOG10(RE(2))-1.5)/(ALOG10(RE(2)*EL1/ELT)              AROL  2930
     1               -1.5))**2 - 1.0)                                   AROL  2940
  112 CFT(1) = CFT(1)*(1.0-FF)                                          AROL  2950
      CFT(2) = CFT(1) /FC                                               AROL  2960
      CFT(3) = CFT(2) * (BS(7)/FS(7))**2 * BS(1) / FS(1) * CFCFOT       AROL  2970
      CFT(4) = CFT(3) * SURF(I,1) / SREF                                AROL  2980
      IF (IGTYPE .EQ. 2) GO TO 100                                      AROL  2990
      IF (IS(I,5).EQ.0) CFT(5) = -ESIN * CFT(4)                         AROL  3000
      IF (IS(I,5).EQ.0) CFT(6) =  ECOS * CFT(4)                         AROL  3010
      IF (IS(I,5).EQ.1) CFT(5) =  0.0                                   AROL  3020
      IF (IS(I,5).EQ.1) CFT(6) = CFT(4) * COS(SURF(I,4)/57.295779)      AROL  3030
C                                                                       AROL  3040
C  START LAMINAR FLOW CALCULATIONS                                      AROL  3050
 100  RE(1)  = RE(1) * ELL/EL                                           AROL  3060
      ESIN = SIN((ANGLE(1)-TR(4))/57.295779)                            AROL  3070
      ECOS = COS((ANGLE(1)-TR(4))/57.295779)                            AROL  3080
      FF = ELO      /SURF(I,2)*(1.0 + TAPER1)/(1.0 + TAPER2)            AROL  3090
      IF (ELO.LT. 0.0001) GO TO 122                                     AROL  3100
      IF (TAPER1.LT. 0.8) GO TO 120                                     AROL  3110
      EL1 = ELO*4.0*((1.0 + TAPER1)/(3.0 + TAPER1))**2                  AROL  3120
      GO TO 121                                                         AROL  3130
  120 EL1 = ELO*(0.75*(1.0-TAPER1**2)/(1.0-TAPER1**1.5))**2             AROL  3140
  121 B = B*SQRT(ELL/EL1)                                               AROL  3150
      CFCFO1 = SQRT(1.0+B) + 0.5*B*ALOG(ABS((SQRT(1.0+B)+1.0)/          AROL  3160
     1               (SQRT(1.0+B)-1.0)))                                AROL  3170
      FF = FF*(SQRT(ELL/EL1)*CFCFO1/CFCFOL - 1.0)                       AROL  3180
  122 CFL(1) = 1.328/SQRT(RE(1))*(1.0-FF)                               AROL  3190
      CFL(2) = CFL(1) * BS(3)/TS(1)                                     AROL  3200
      CFL(3) = CFL(2) * (BS(7)/FS(7))**2 * BS(1) / FS(1) * CFCFOL       AROL  3210
      CFL(4) = CFL(3) * SURF(I,1) / SREF                                AROL  3220
      IF (IGTYPE .EQ. 2) GO TO 101                                      AROL  3230
```

```
      IF (IS(I,5).EQ.0) CFL(5) = -ESIN * CFL(4)                         AROL  3240
      IF (IS(I,5).EQ.0) CFL(6) =  ECOS * CFL(4)                         AROL  3250
      IF (IS(I,5).EQ.1) CFL(5) =  0.0                                   AROL  3260
      IF (IS(I,5).EQ.1) CFL(6) = CFL(4) * COS(SURF(I,4)/57.295779)      AROL  3270
C                                                                       AROL  3280
C  CALCULATE TOTALS USING LAMINAR FLOW                                  AROL  3290
      SCF(1) = SCF(1) + CFL(5)                                          AROL  3300
      SCF(2) = SCF(2) + CFL(6)                                          AROL  3310
C  TOTAL SKIN FRICTION FORCE COEFF. AND SURFACE                         AROL  3320
      SCFA(1) = SCFA(1) + CFL(4)                                        AROL  3330
C                                                                       AROL  3340
C  CHECK IF RE(2) IS LOWER THAN THE CUTOFF POINT (USE LAMINAR PROP.)    AROL  3350
      IF (RE(2) .GT. 6570.0) GO TO 82                                   AROL  3360
      SCF(3) = SCF(3) + CFL(5)                                          AROL  3370
      SCF(4) = SCF(4) + CFL(6)                                          AROL  3380
      SCFA(2) = SCFA(2) + CFL(4)                                        AROL  3390
      CFT(3) = CFL(3)                                                   AROL  3400
      CFT(5) = CFL(5)                                                   AROL  3410
      CFT(6) = CFL(6)                                                   AROL  3420
      GO TO 28                                                          AROL  3430
C  CALCULATE TOTALS USING TURBULENT FLOW                                AROL  3440
   82 SCF(3) = SCF(3) + CFT(5)                                          AROL  3450
      SCF(4) = SCF(4) + CFT(6)                                          AROL  3460
C  TOTAL SKIN FRICTION FORCE COEFF. AND SURFACE                         AROL  3470
      SCFA(2) = SCFA(2) + CFT(4)                                        AROL  3480
      GO TO 28                                                          AROL  3490
  101 CFL(6) = 0.0                                                      AROL  3500
      CFL(5) = 0.0                                                      AROL  3510
      SCF(2) = 0.0                                                      AROL  3520
      SCF(1) = 0.0                                                      AROL  3530
      CDL = 0.0                                                         AROL  3540
      CFT(6) = 0.0                                                      AROL  3550
      CFT(5) = 0.0                                                      AROL  3560
      SCF(4) = 0.0                                                      AROL  3570
      SCF(3) = 0.0                                                      AROL  3580
      CDT = 0.0                                                         AROL  3590
```

DECK AROL

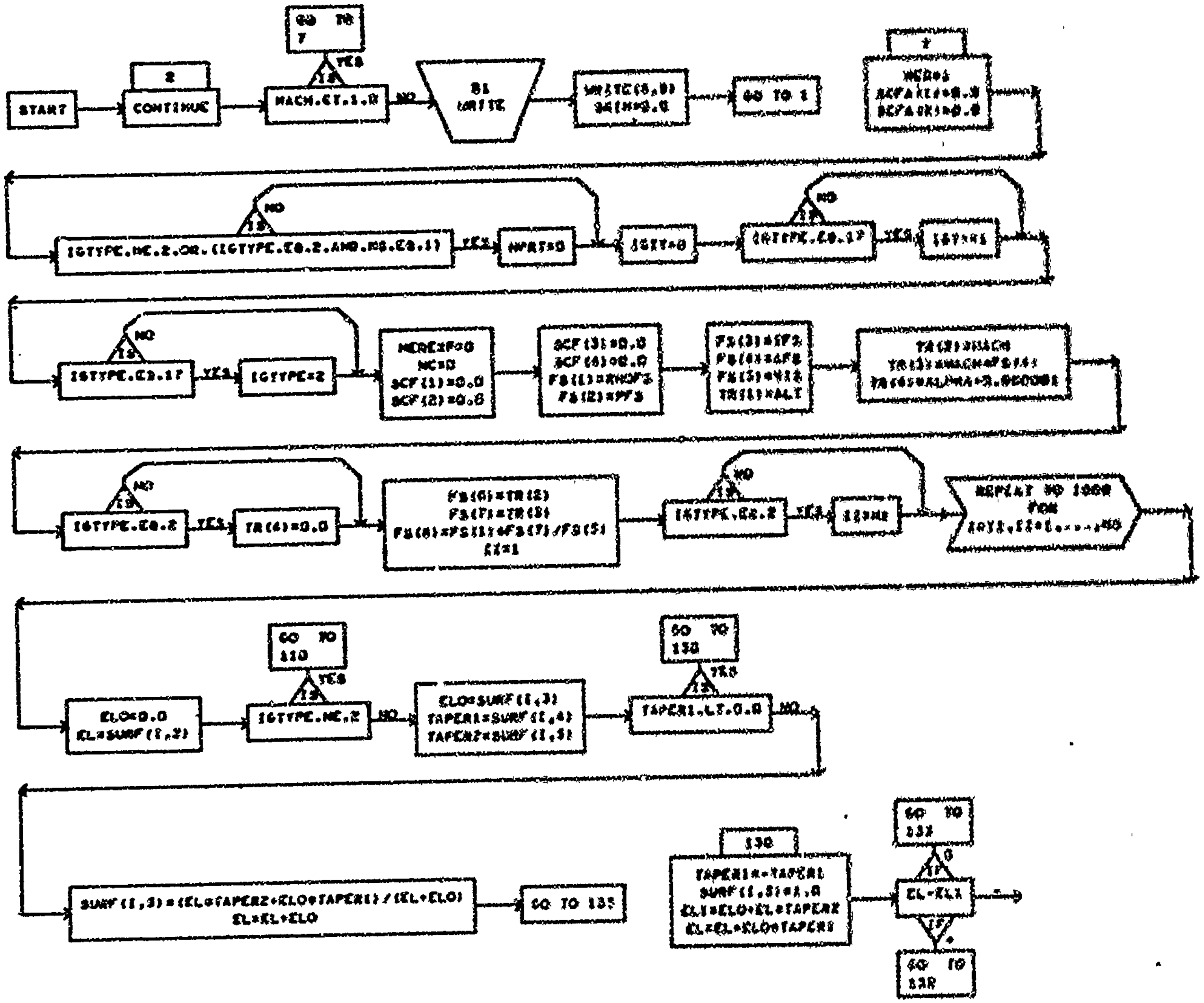
```
      IF (RE(2) .LE. 6570.0) CFT(3) = CFL(3)                                   AROL  3600
C                                                                              AROL  3610
C  CALCULATE RE*/FT                                                            AROL  3620
   28 RE1 = RE(1) / ELL                                                        AROL  3630
      IF (RE(2) .LE. 6570.0) ELT = EL                                          AROL  3640
      RE2 = RE(2) / ELT                                                        AROL  3650
      TWTL = TR(5) / FS(3)                                                     AROL  3660
      TWTT = TR(6) / FS(3)                                                     AROL  3670
      TWTRL = TR(5) / RT(1)                                                    AROL  3680
      TWTRT = TR(6) / RT(2)                                                    AROL  3690
      IF (IGTYPE .EQ. 2) GO TO 65                                              AROL  3700
      ALPHAR = ALPHA / 57.295779                                               AROL  3710
      CDT = CFT(5)*SIN(ALPHAR) + CFT(6)*COS(ALPHAR)                            AROL  3720
      CDL = CFL(5)*SIN(ALPHAR) + CFL(6)*COS(ALPHAR)                            AROL  3730
C                                                                              AROL  3740
C  CHECK IF DATA IS TO BE PRINTED                                              AROL  3750
   65 IF (IS(I,7 ) .EQ. 0) GO TO 1000                                          AROL  3760
C                                                                              AROL  3770
C  PRINT SKIN FRICTION DATA                                                    AROL  3780
C                                                                              AROL  3790
      IF (IS(I,9).EQ.0) GO TO 32                                               AROL  3800
      IF (IS(I,9).EQ.1) GO TO 33                                               AROL  3810
      IF ((NS.NE.1).AND.(NPRT.GT.23)) GO TO 60                                 AROL  3820
      GO TO 33                                                                 AROL  3830
C                                                                              AROL  3840
C  CHECK IF HEADER IS REQUIRED                                                 AROL  3850
   32 IF ((NS.NE.1).AND.(NPRT.LT.52)) GO TO 60                                 AROL  3860
      CALL HEADER                                                              AROL  3870
      NPRT = 4                                                                 AROL  3880
C                                                                              AROL  3890
      WRITE (6,31) ALPHA,MACH,TR(3),ALT,FS(8),SREF                             AROL  3900
   31 FORMAT (1H0,                                                             AROL  3910
     1 23H FREE STREAM CONDITIONS,/1H ,9X7HALPHA =F7.2,6X9HMACH    =           AROL  3920
     2 F6.2,3X10HVELOCITY =F9.1,3X10HALTITUDE =F9.1,/1H ,9X7HRE/FT =           AROL  3930
     3 1PE10.3,3X9HS REF    =0PF9.1)                                           AROL  3940
      NPRT = NPRT + 4                                                          AROL  3950
```

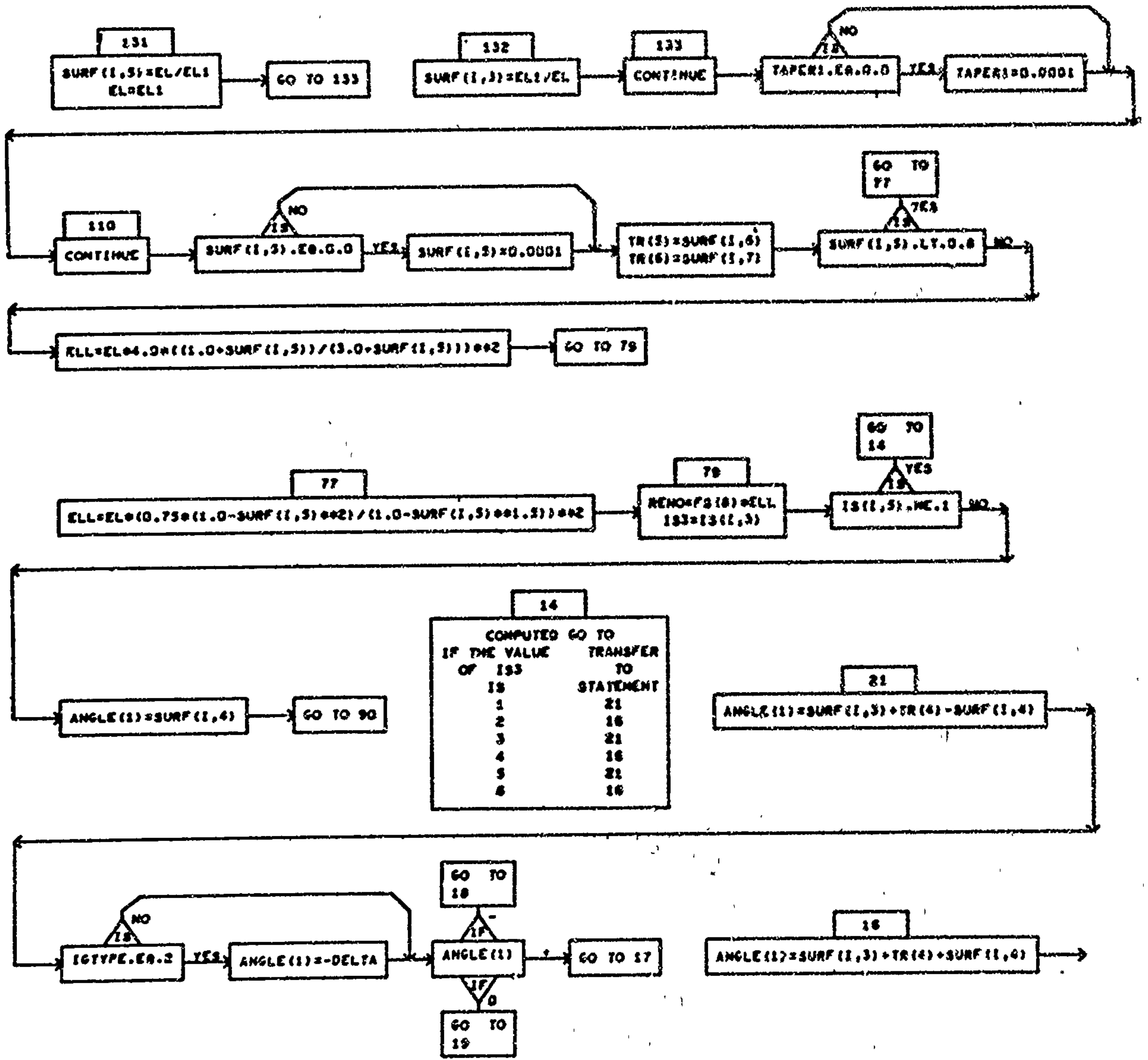
```
DECK AROL

C                                                                         AROL  3960
   33 WRITE(6,58)                                                         AROL  3970
      NPRT = NPRT + 5                                                     AROL  3980
   58 FORMAT (1H0,19H SKIN FRICTION DATA,/1H ,9X8HSURF NO.,3X4HTYPE,      AROL  3990
     1 4X6HMETHOD,4X5HS WET,3X6HLENGTH,3X7HALPHA 0,3X5HWEDGE,             AROL  4000
     2 4X8HANGLE(2),2X6HRE LOC,4X7HCHI BAR,2X5HV BAR,/                    AROL  4010
     3 1H ,2X3HLAM,7X2HCF,7X2HCA,7X2HCN,5X6HSUM CA,3X6HSUM CN,5X2HTW,     AROL  4020
     4 7X4HTW/T,6X5HTW/TR,3X6HRE*/FT,4X7H   CD  ,2X6HCF/CFO,/             AROL  4030
     5 1H ,2X4HTURB,6X2HCF,7X2HCA,7X2HCN,5X6HSUM CA,3X6HSUM CN,5X2HTW,    AROL  4040
     6 7X4HTW/T,6X5HTW/TR,3X6HRE*/FT,4X7H   CD  ,2X6HCF/CFO )             AROL  4050
C                                                                         AROL  4060
      IF (IS(I,8) .EQ. 0) GO TO 60                                        AROL  4070
      WRITE (6,4)                                                         AROL  4080
      NPRT = NPRT + 1                                                     AROL  4090
    4 FORMAT (1H ,10X4HMACH,8X1HV,5X7HV SCUND,3X5HP-PSF,3X6HTEMP-R,       AROL  4100
     1 3X9HRHO*10**4,1X9HVIS*10**7,3X5HRE/FT,2X,6HC STAR,7X,1HC,5X,       AROL  4110
     2 6HV STAR)                                                          AROL  4120
C                                                                         AROL  4130
   60 WRITE (6,39) (IS(I,J),J=1,3),(SURF(I,J),J=1,4),ANGLE(2),RELOC       AROL  4140
     1             ,CHIBAR,VBAR                                           AROL  4150
      NPRT = NPRT + 2                                                     AROL  4160
   39 FORMAT (1H0,11XI2,9XI1,7XI2,4XF8.0,2XF6.1,4XF5.1,3XF5.1,6XF6.2,     AROL  4170
     1 1X1PE10.3,2X0PF7.3,1XF7.4 )                                        AROL  4180
C                                                                         AROL  4190
      IF (MEREXP.NE.0) GO TO 59                                           AROL  4200
C                                                                         AROL  4210
      WRITE (6,37)  CFL(3),CFL(6),CFL(5),SCF(2),SCF(1),TR(5),TWTL,        AROL  4220
     1  TWTRL,RE1,CDL     ,CFCFOL,                                        AROL  4230
     2              CFT(3),CFT(6),CFT(5),SCF(4),SCF(3),TR(6),TWTT,        AROL  4240
     3  TWTRT,RE2,CDT     ,CFCFOT                                         AROL. 4250
      NPRT = NPRT + 2                                                     AROL  4260
   37 FORMAT (1H ,2X3HLAM,4XF8.5,F9.5,F9.5,F9.5,F9.5,F9.1,F10.4,          AROL  4270
     1 F10.4,1PE10.3,0PF9.5,1XF7.4,/                                      AROL  4280
     2 1H ,2X4HTURB,3XF8.5,F9.5,F9.5,F9.5,F9.5,F9.1,F10.4,F10.4,          AROL  4290
     3 1PE10.3,0PF9.5,1XF7.4 )                                            AROL  4300
C                                                                         AROL  4310
```

```
DECK AROL

  66  IF (IS(I,8) .EQ. 0) GO TO 63                                    AROL  4320
      WRITE (6,44) FS(6),FS(7),FS(4),FS(2),FS(3),FS(1),FS(5),FS(8),   AROL  4330
     1 CSTAR,CLAM,VSTAR,BS(6),BS(7),BS(4),BS(2),BS(3),BS(1),BS(5),BS(8) AROL  4340
      NPRT = NPRT + 2                                                 AROL  4350
  44  FORMAT (1H ,2X6HSTREAM,F9.5,F9.1,F9.2,F9.4,F9.2,4PF10.7,7PF10.6, AROL  4360
     11PE10.3,2E10.3,0PF7.4,/1H ,2X6HLOCAL ,0PF9.5,F9.1,F9.2,F9.4,    AROL  4370
     2  F9.2,4PF10.7,7PF10.6,1PF10.3)                                 AROL  4380
      GO TO 63                                                        AROL  4390
C                                                                     AROL  4400
  59  WRITE (6,64)                                                    AROL  4410
      NPRT = NPRT + 1                                                 AROL  4420
  64  FORMAT (1H ,10X43HFLOW EXPANDED TO A VACUUM - SURFACE DELFTED ) AROL  4430
      MEREXP = 0                                                      AROL  4440
      CFL(3) = 0.0                                                    AROL  4450
      CFT(3) = 0.0                                                    AROL  4460
      GO TO 66                                                        AROL  4470
C  STEP PRINT FLAG                                                    AROL  4480
   63 CONTINUE                                                        AROL  4490
C                                                                     AROL  4500
C  END OF DO LOOP CALCULATING SKIN FRICTION FOR EACH SURFACE           AROL  4510
 1000 IJ = I                                                          AROL  4520
C                                                                     AROL  4530
C                                                                     AROL  4540
C  ADD SKIN FRICTION DRAG TO AXIAL FORCE COEFFICIENT                  AROL  4550
      IF (IGTYPE .EQ. 2) GO TO 102                                    AROL  4560
      IF (IS(I,4) .EQ. 0) GO TO 27                                    AROL  4570
      CA = CA + SCF(2)                                                AROL  4580
      CN = CN + SCF(1)                                                AROL  4590
      SKIN = SCF(2)                                                   AROL  4600
      GO TO 1                                                         AROL  4610
  27  CA = CA + SCF(4)                                                AROL  4620
      CN = CN + SCF(3)                                                AROL  4630
      SKIN = SCF(4)                                                   AROL  4640
      GO TO 1                                                         AROL  4650
 102  IF (IS(IJ,4) .EQ. 0) SKIN = CFT(3)                              AROL  4660
      IF (IS(IJ,4) .NE. 0) SKIN = CFL(3)                              AROL  4670
```

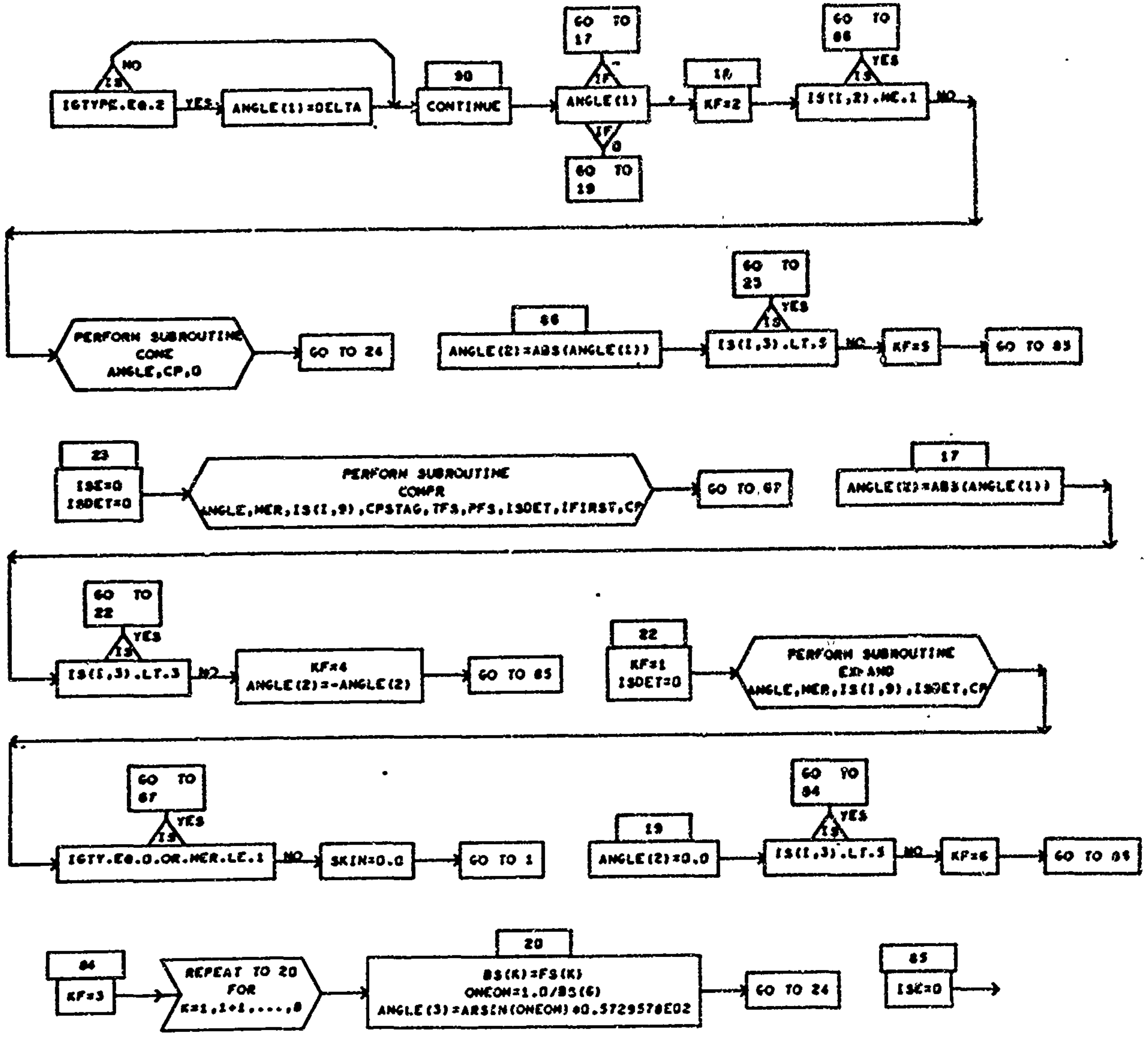
```
DECK AROL

      GO TO 1                                                           AROL  4680
C                                                                       AROL  4690
C  CALCULATE INDUCED PRESSURE INCREMENT                                 AROL  4700
 500  SKIN  =8./3.*M*LAMBDA*EL/SURF(I,2)*((1.+SURF(I,5)+SQRT(SURF(I,5)))AROL  4710
     1 /((1.+SQRT(SURF(I,5)))*(1.+TAPER2))-(1.+TAPER1+SQRT(TAPER1))/    AROL  4720
     2 ((1.+SQRT(TAPER1))*(1.+TAPER2))*SQRT(ELO/EL))                    AROL  4730
C                                                                       AROL  4740
    1 RETURN                                                            AROL  4750
C                                                                       AROL  4760
      END                                                               AROL  4770
```

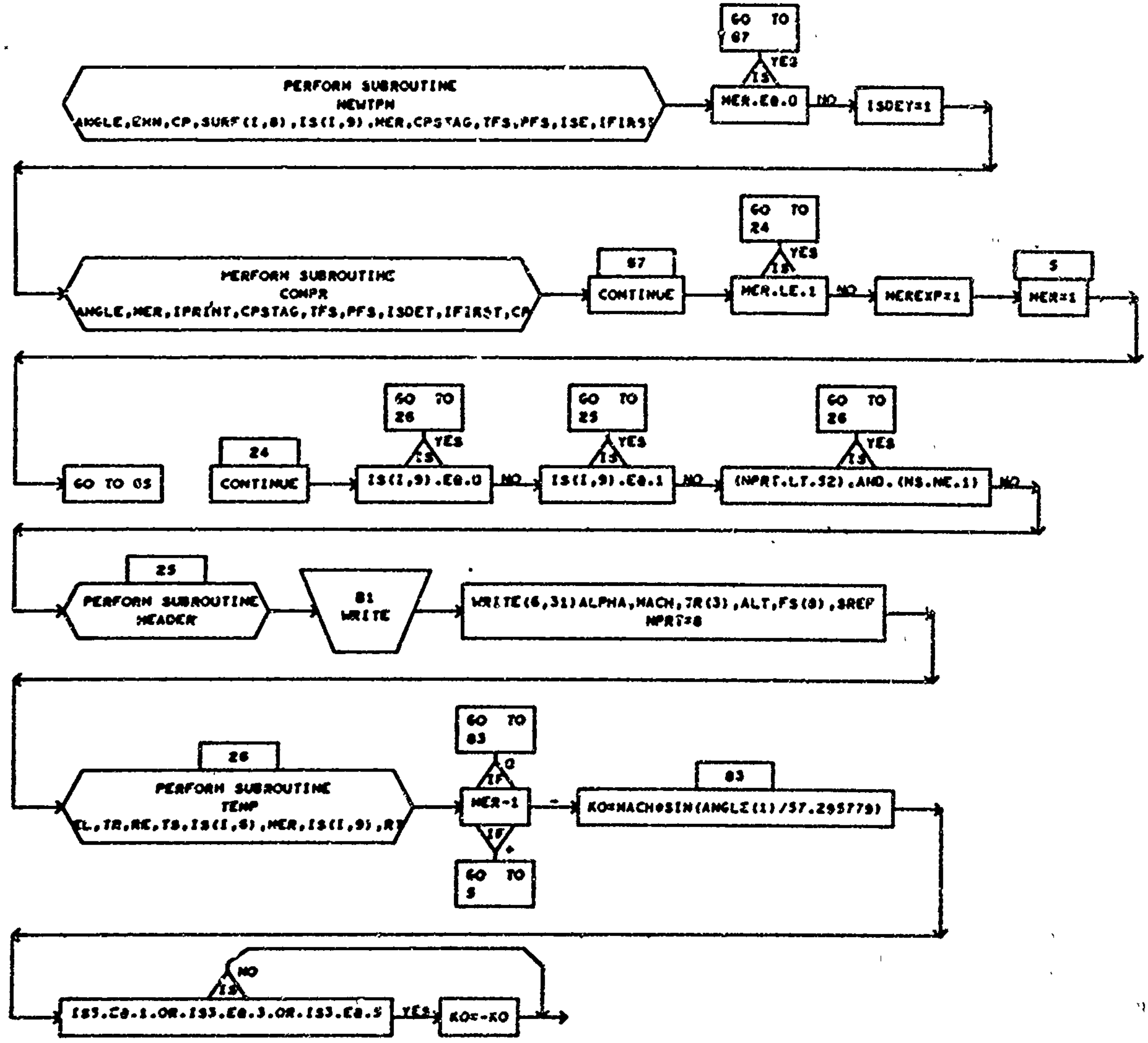
SUBROUTINE SKINFR

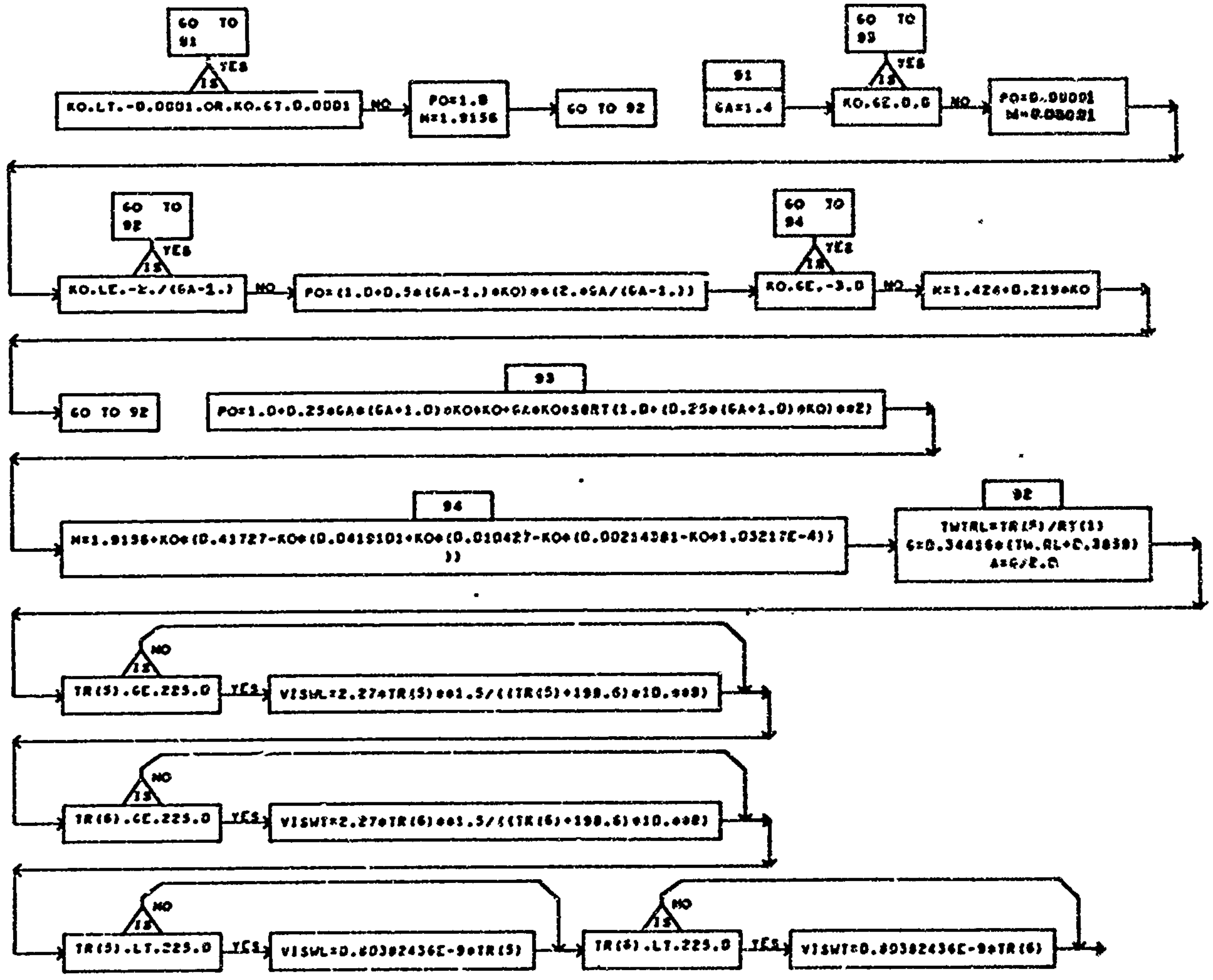


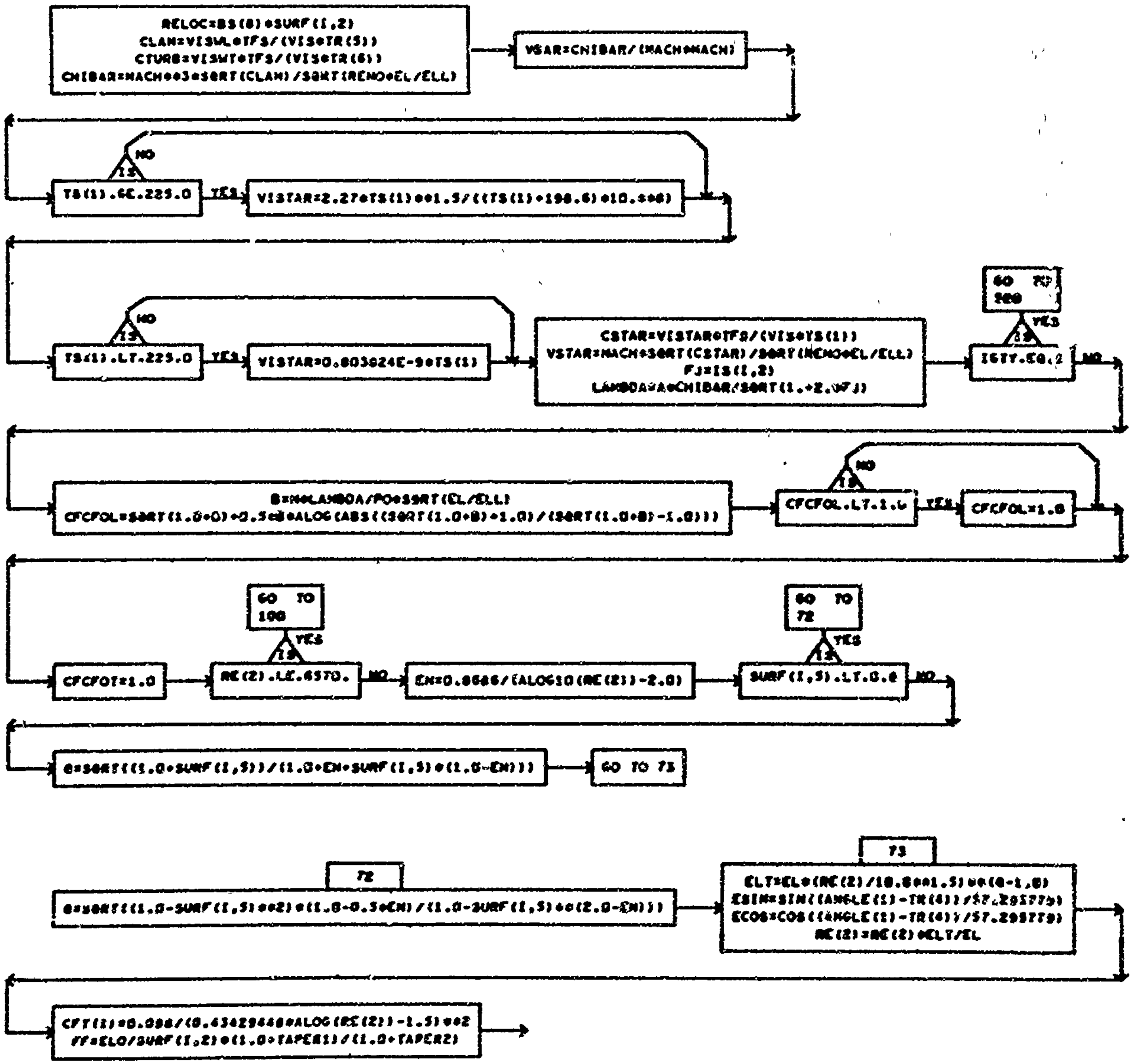

131
SURF(I,5)=EL/EL1
EL=EL1
GO TO 133
132
SURF(I,5)=EL1/EL
133
CONTINUE
IS
TAPER1.EQ.0.0
NO
YES
TAPER1=0.0001
110
CONTINUE
IS
SURF(I,5).EQ.0.0
NO
YES
SURF(I,5)=0.0001
TR(5)=SURF(I,6)
TR(6)=SURF(I,7)
IS
SURF(I,5).LT.0.8
YES
GO TO 77
NO
ELL=EL*4.0*((1.0+SURF(I,5))/(3.0+SURF(I,5)))**2
GO TO 79
77
ELL=EL*(0.75*(1.0-SURF(I,5)**2)/(1.0-SURF(I,5)**1.5))**2
79
RENO=FS(8)*ELL
IS3=IS(I,3)
IS
IS(I,5).NE.1
YES
GO TO 14
NO
ANGLE(1)=SURF(I,4)
GO TO 90
14
COMPUTED GO TO
IF THE VALUE OF IS3 IS
TRANSFER TO STATEMENT
1 21
2 16
3 21
4 16
5 21
6 16
21
ANGLE(1)=SURF(I,3)+TR(4)-SURF(I,4)
IS
IGTYPE.EQ.2
NO
YES
ANGLE(1)=-DELTA
ANGLE(1)
IF
-
GO TO 18
+
GO TO 17
IF
0
GO TO 19
16
ANGLE(1)=SURF(I,3)+TR(4)+SURF(I,4)

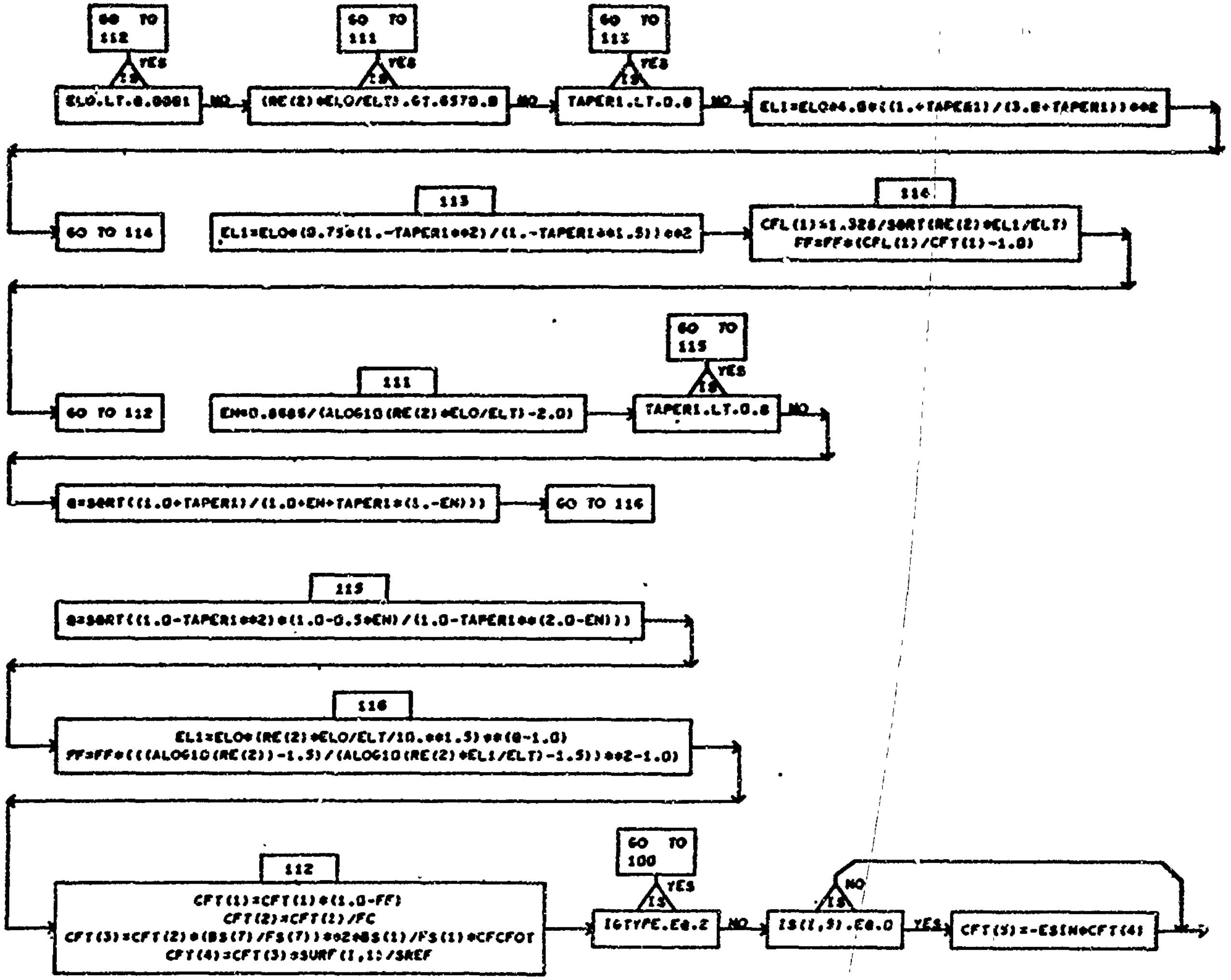
SKINFR

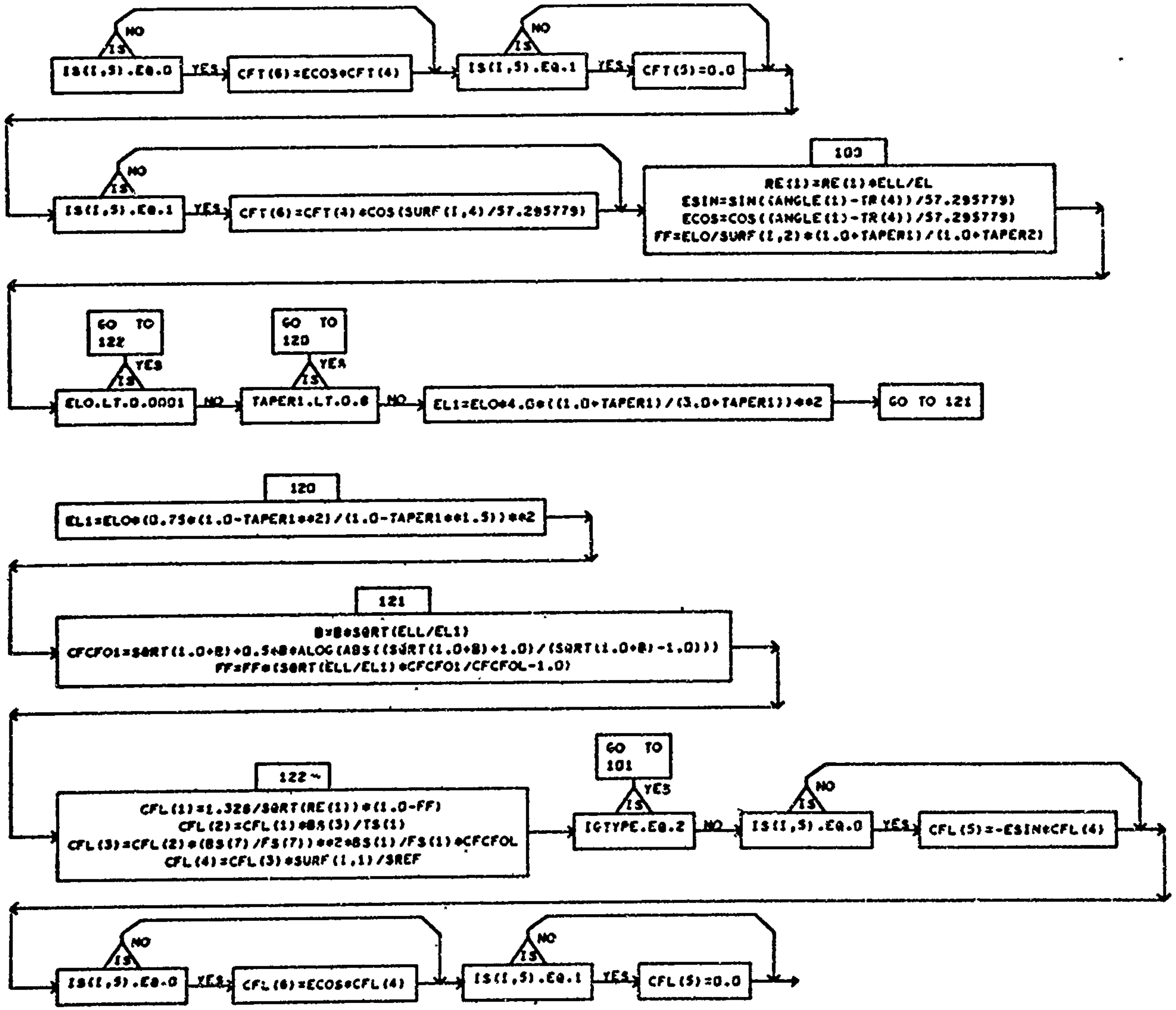

IGTYPE.EQ.2
IS
NO
YES
ANGLE(1)=DELTA
30
CONTINUE
ANGLE(1)
IF
-
+
0
GO TO 17
GO TO 19
18
KF=2
IS(I,2).NE.1
IS
YES
GO TO 86
NO
PERFORM SUBROUTINE
CONE
ANGLE,CP,0
GO TO 24
86
ANGLE(2)=ABS(ANGLE(1))
IS(I,3).LT.5
IS
YES
GO TO 23
NO
KF=5
GO TO 85
23
ISE=0
ISDET=0
PERFORM SUBROUTINE
COMPR
ANGLE,MER,IS(I,9),CPSTAG,TFS,PFS,ISDET,IFIRST,CP
GO TO 87
17
ANGLE(2)=ABS(ANGLE(1))
IS(I,3).LT.3
IS
YES
GO TO 22
NO
KF=4
ANGLE(2)=-ANGLE(2)
GO TO 85
22
KF=1
ISDET=0
PERFORM SUBROUTINE
EXPAND
ANGLE,MER,IS(I,9),ISDET,CP
IGTY.EQ.0.OR.MER.LE.1
IS
YES
GO TO 87
NO
SKIN=0.0
GO TO 1
19
ANGLE(2)=0.0
IS(I,3).LT.5
IS
YES
GO TO 84
NO
KF=6
GO TO 85
84
KF=3
REPEAT TO 20
FOR
K=1,1+1,....,8
20
BS(K)=FS(K)
ONEOM=1.0/BS(6)
ANGLE(3)=ARSIN(ONEOM)*0.5729578E02
GO TO 24
85
ISE=0

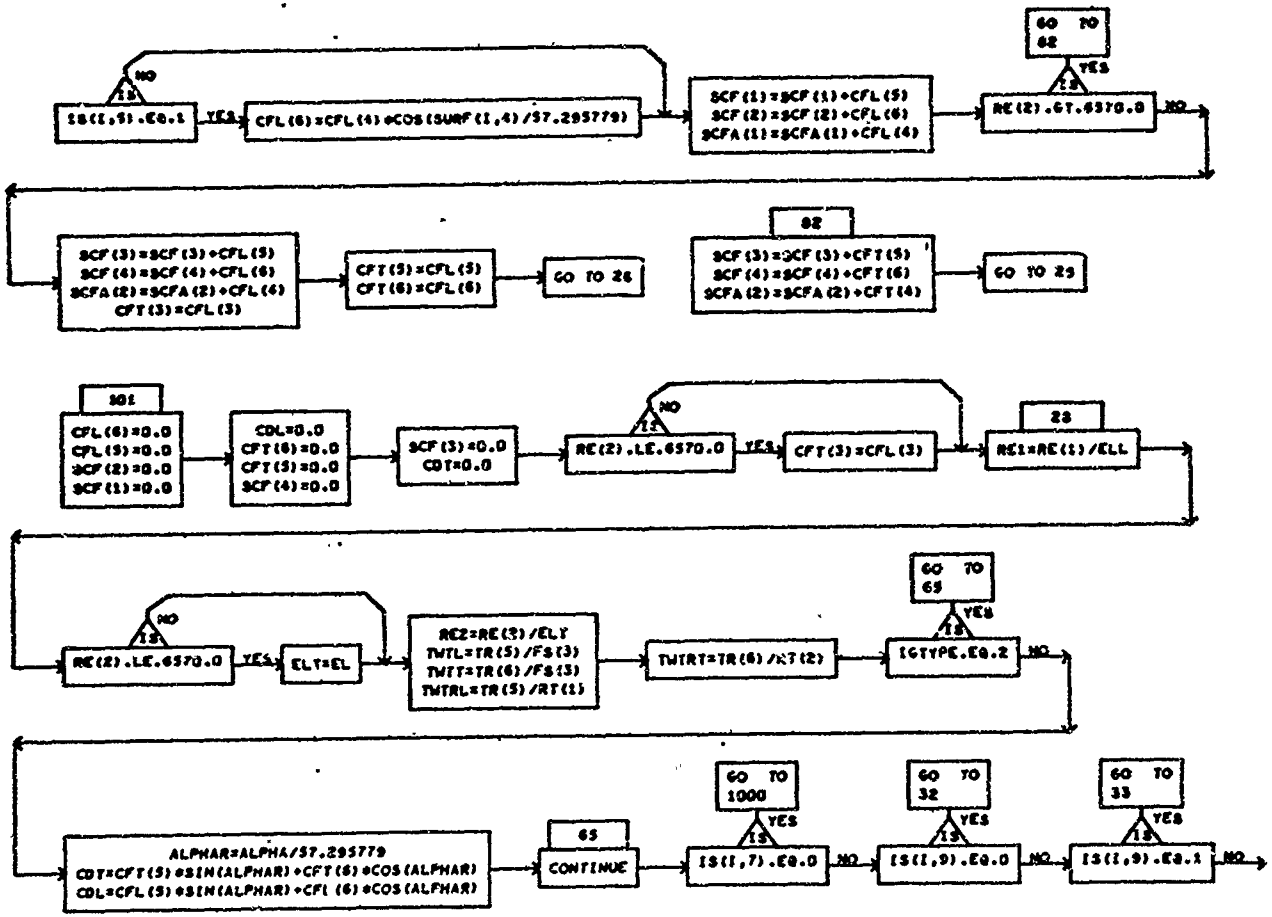

GO TO 67
YES
IS
PERFORM SUBROUTINE
NEWTPN
ANGLE,EMN,CP,SURF(I,8),IS(I,9),MER,CPSTAG,TFS,PFS,ISE,IFIRST
MER.EQ.0
NO
ISDEY=1
GO TO 24
YES
IS
67
PERFORM SUBROUTINE
COMPR
ANGLE,MER,IPRINT,CPSTAG,TFS,PFS,ISDET,IFIRST,CP
CONTINUE
MER.LE.1
NO
MEREXP=1
5
MER=1
GO TO 26
YES
IS
GO TO 25
YES
IS
GO TO 26
YES
IS
GO TO 05
24
CONTINUE
IS(I,9).EQ.0
NO
IS(I,9).EQ.1
NO
(NPRT.LT.52).AND.(NS.NE.1)
NO
25
PERFORM SUBROUTINE
HEADER
81
WRITE
WRITE(6,31)ALPHA,MACH,TR(3),ALT,FS(8),SREF
NPRT=8
GO TO 83
0
IF
26
PERFORM SUBROUTINE
TEMP
L,TR,RE,TS,IS(I,6),MER,IS(I,9),R
MER-1
-
83
KO=MACH*SIN(ANGLE(1)/57.295779)
IF
+
GO TO 5
NO
IS
IS3.EQ.1.OR.IS3.EQ.3.OR.IS3.EQ.5
YES
KO=-KO

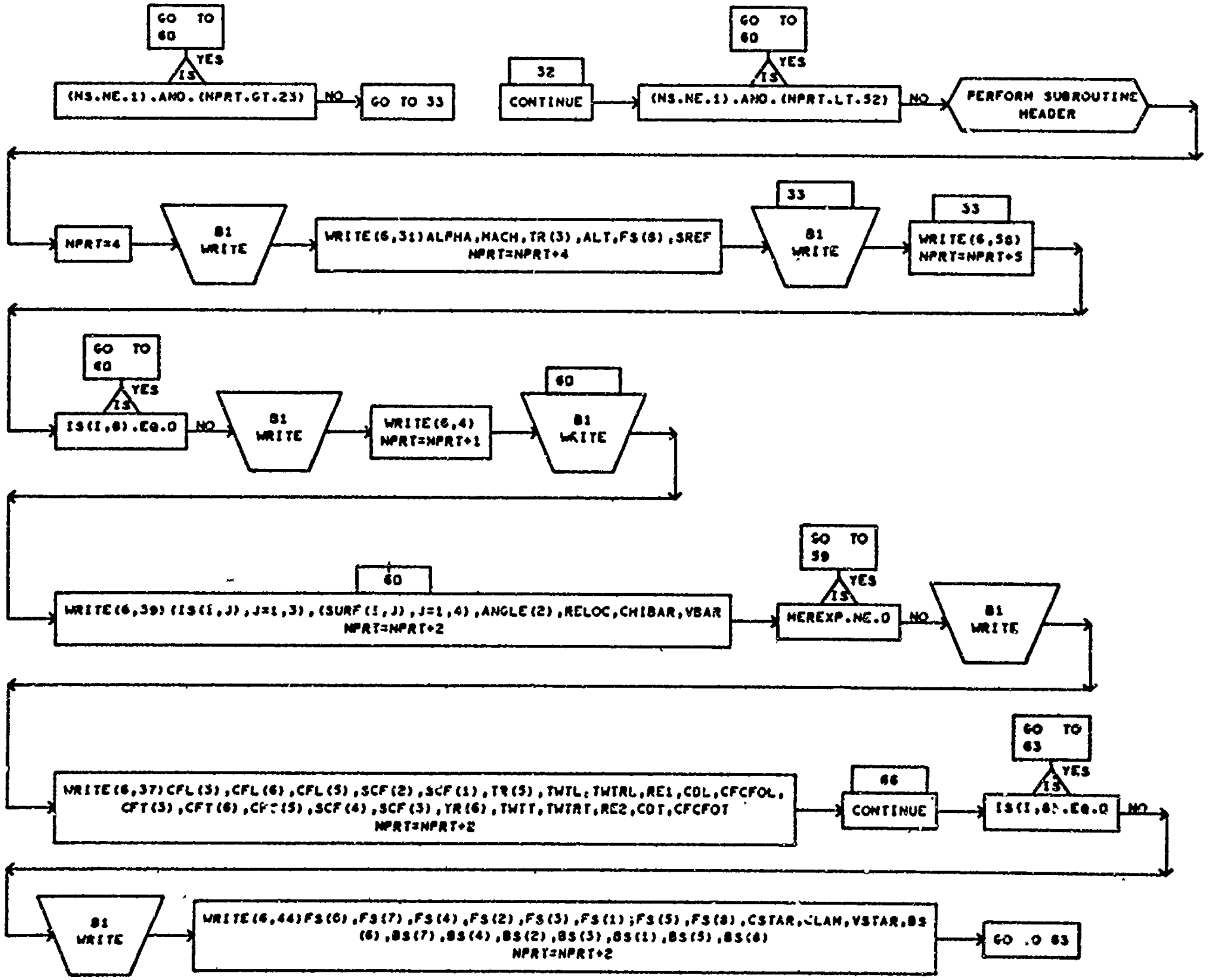

GO TO 91
YES
IS
KO.LT.-0.0001.OR.KO.GT.0.0001
NO
PO=1.0
N=1.9156
GO TO 92
91
GA=1.4
GO TO 93
YES
IS
KO.GE.0.0
NO
PO=0.00001
N=0.00001
GO TO 92
YES
IS
KO.LE.-2./(GA-1.)
NO
PO=(1.0+0.5*(GA-1.)*KO)**(2.*GA/(GA-1.))
GO TO 94
YES
IS
KO.GE.-3.0
NO
N=1.424+0.219*KO
GO TO 92
93
PO=1.0+0.25*GA*(GA+1.0)*KO*KO+GA*KO*SQRT(1.0+(0.25*(GA+1.0)*KO)**2)
94
N=1.9156+KO*(0.41727-KO*(0.0419101+KO*(0.010427-KO*(0.00214381-KO*1.03217E-4)))
))
92
TWTRL=TR(5)/RT(1)
G=0.34456*(TW.RL+0.3838)
A=G/2.0
IS
NO
TR(5).GE.225.0
YES
VISWL=2.27*TR(5)**1.5/((TR(5)+198.6)*10.**8)
IS
NO
TR(6).GE.225.0
YES
VISWT=2.27*TR(6)**1.5/((TR(6)+198.6)*10.**8)
IS
NO
TR(5).LT.225.0
YES
VISWL=0.60382436E-9*TR(5)
IS
NO
TR(6).LT.225.0
YES
VISWT=0.60382436E-9*TR(6)

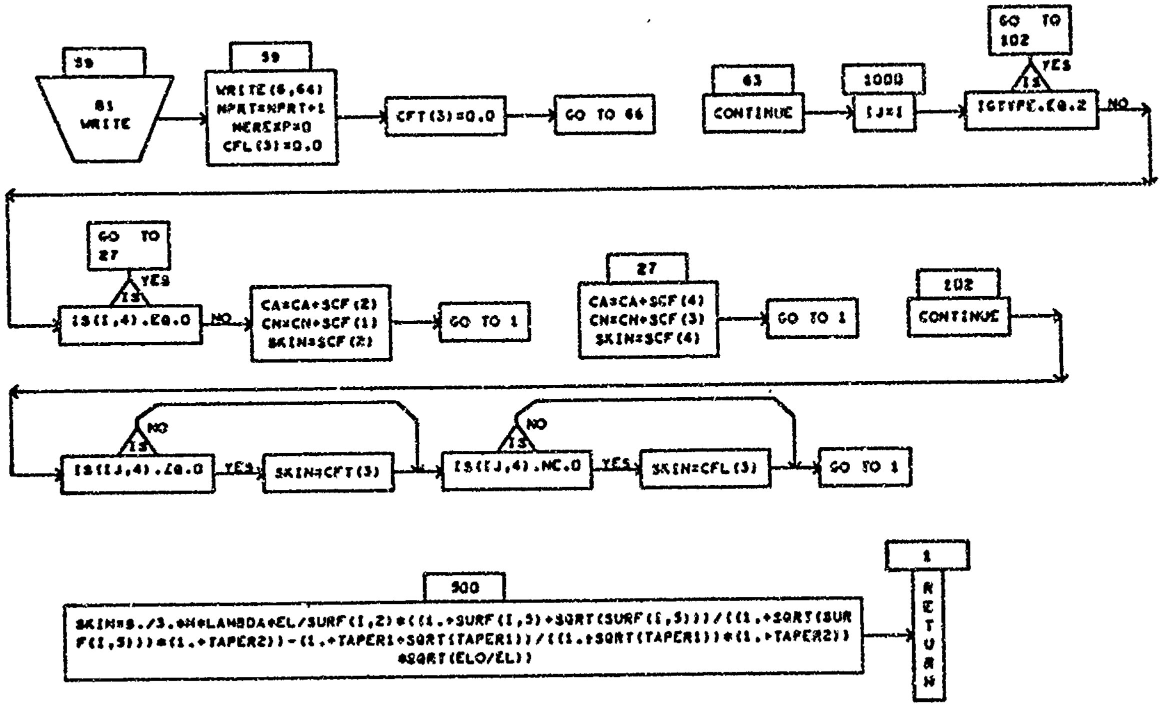

RELOC=BS(8)*SURF(I,2)
CLAM=VISML*TFS/(VIS*TR(5))
CTURB=VISMT*TFS/(VIS*TR(6))
CHIBAR=MACH**3*SQRT(CLAM)/SQRT(RENO*EL/ELL)
VSAR=CHIBAR/(MACH*MACH)
IS
NO
TS(1).GE.225.0
YES
VISTAR=2.27*TS(1)**1.5/((TS(1)+198.6)*10.**8)
IS
NO
TS(1).LT.225.0
YES
VISTAR=0.803024E-9*TS(1)
CSTAR=VISTAR*TFS/(VIS*TS(1))
VSTAR=MACH*SQRT(CSTAR)/SQRT(RENO*EL/ELL)
FJ=IS(I,2)
LAMBDA=A*CHIBAR/SQRT(1.+2.*FJ)
GO TO 200
YES
IS
ISTY.EQ.2
NO
B=N*LAMBDA/FO*SQRT(EL/ELL)
CFCFOL=SQRT(1.0+B)+0.5*B*ALOG(ABS((SQRT(1.0+B)+1.0)/(SQRT(1.0+B)-1.0)))
IS
NO
CFCFOL.LT.1.0
YES
CFCFOL=1.0
CFCFOT=1.0
GO TO 100
YES
IS
RE(2).LE.6570.
NO
EN=0.8686/(ALOG10(RE(2))-2.0)
GO TO 72
YES
IS
SURF(I,5).LT.0.0
NO
Q=SQRT((1.0+SURF(I,5))/(1.0+EN*SURF(I,5)*(1.0-EN)))
GO TO 73
72
Q=SQRT((1.0-SURF(I,5)**2)*(1.0-0.5*EN)/(1.0-SURF(I,5)**(2.0-EN)))
73
ELT=EL*(RE(2)/10.8**1.5)**(Q-1.0)
ESIN=SIN((ANGLE(I)-TR(4))/57.295779)
ECOS=COS((ANGLE(I)-TR(4))/57.295779)
RE(2)=RE(2)*ELT/EL
CFT(I)=0.088/(0.43429448*ALOG(RE(2))-1.5)**2
FF=ELO/SURF(I,2)*(1.0+TAPER1)/(1.0+TAPER2)


GO TO 112
YES
IS
ELO.LT.0.0001
NO
GO TO 111
YES
IS
(RE(2)*ELO/ELT).GT.6570.0
NO
GO TO 113
YES
IS
TAPER1.LT.0.8
NO
EL1=ELO*4.0*((1.+TAPER1)/(3.0+TAPER1))**2
GO TO 114
113
EL1=ELO*(0.75*(1.-TAPER1**2)/(1.-TAPER1**1.5))**2
114
CFL(1)=1.328/SQRT(RE(2)*EL1/ELT)
FF=FF*(CFL(1)/CFT(1)-1.0)
GO TO 112
111
EN=0.8686/(ALOG10(RE(2)*ELO/ELT)-2.0)
GO TO 115
YES
IS
TAPER1.LT.0.8
NO
Q=SQRT((1.0+TAPER1)/(1.0+EN+TAPER1*(1.-EN)))
GO TO 116
115
Q=SQRT((1.0-TAPER1**2)*(1.0-0.5*EN)/(1.0-TAPER1**(2.0-EN)))
116
EL1=ELO*(RE(2)*ELO/ELT/10.**1.5)**(Q-1.0)
FF=FF*(((ALOG10(RE(2))-1.5)/(ALOG10(RE(2)*EL1/ELT)-1.5))**2-1.0)
112
CFT(1)=CFT(1)*(1.0-FF)
CFT(2)=CFT(1)/FC
CFT(3)=CFT(2)*(BS(7)/FS(7))**2*BS(1)/FS(1)*CFCFOT
CFT(4)=CFT(3)*SURF(1,1)/SREF
GO TO 100
YES
IS
IGTYPE.EQ.2
NO
NO
IS
IS(1,5).EQ.0
YES
CFT(5)=-ESIN*CFT(4)


IS(I,5).EQ.0
IS
NO
YES
CFT(6)=ECOS*CFT(4)
IS(I,5).EQ.1
IS
NO
YES
CFT(5)=0.0
IS(I,5).EQ.1
IS
NO
YES
CFT(6)=CFT(4)*COS(SURF(I,4)/57.295779)
103
RE(1)=RE(1)*ELL/EL
ESIN=SIN((ANGLE(1)-TR(4))/57.295779)
ECOS=COS((ANGLE(1)-TR(4))/57.295779)
FF=ELO/SURF(1,2)*(1.0+TAPER1)/(1.0+TAPER2)
GO TO 122
IS
YES
ELO.LT.0.0001
NO
GO TO 120
IS
YES
TAPER1.LT.0.6
NO
EL1=ELO*4.0*((1.0+TAPER1)/(3.0+TAPER1))**2
GO TO 121
120
EL1=ELO*(0.75*(1.0-TAPER1**2)/(1.0-TAPER1**1.5))**2
121
B=B*SQRT(ELL/EL1)
CFCFO1=SQRT(1.0+B)+0.5*B*ALOG(ABS((SQRT(1.0+B)+1.0)/(SQRT(1.0+B)-1.0)))
FF=FF*(SQRT(ELL/EL1)*CFCFO1/CFCFOL-1.0)
122
CFL(1)=1.328/SQRT(RE(1))*(1.0-FF)
CFL(2)=CFL(1)*BS(3)/TS(1)
CFL(3)=CFL(2)*(BS(7)/FS(7))**2*BS(1)/FS(1)*CFCFOL
CFL(4)=CFL(3)*SURF(1,1)/SREF
GO TO 101
IS
YES
IGTYPE.EQ.2
NO
IS(I,5).EQ.0
IS
NO
YES
CFL(5)=-ESIN*CFL(4)
IS(I,5).EQ.0
IS
NO
YES
CFL(6)=ECOS*CFL(4)
IS(I,5).EQ.1
IS
NO
YES
CFL(5)=0.0


IS(I,5).EQ.1
IS
NO
YES
CFL(6)=CFL(4)*COS(SURF(I,4)/57.295779)
SCF(1)=SCF(1)+CFL(5)
SCF(2)=SCF(2)+CFL(6)
SCFA(1)=SCFA(1)+CFL(4)
RE(2).GT.6570.0
IS
YES
GO TO 82
NO
SCF(3)=SCF(3)+CFL(5)
SCF(4)=SCF(4)+CFL(6)
SCFA(2)=SCFA(2)+CFL(4)
CFT(3)=CFL(3)
CFT(5)=CFL(5)
CFT(6)=CFL(6)
GO TO 26
82
SCF(3)=SCF(3)+CFT(5)
SCF(4)=SCF(4)+CFT(6)
SCFA(2)=SCFA(2)+CFT(4)
GO TO 25
101
CFL(6)=0.0
CFL(5)=0.0
SCF(2)=0.0
SCF(1)=0.0
CDL=0.0
CFT(6)=0.0
CFT(5)=0.0
SCF(4)=0.0
SCF(3)=0.0
CDT=0.0
RE(2).LE.6570.0
IS
NO
YES
CFT(3)=CFL(3)
23
RE1=RE(1)/ELL
RE(2).LE.6570.0
IS
NO
YES
ELT=EL
RE2=RE(3)/ELY
TWTL=TR(5)/FS(3)
TWTT=TR(6)/FS(3)
TWTRL=TR(5)/RT(1)
TWTRT=TR(6)/RT(2)
IGTYPE.EQ.2
IS
YES
GO TO 65
NO
ALPHAR=ALPHA/57.295779
CDT=CFT(5)*SIN(ALPHAR)+CFT(6)*COS(ALPHAR)
CDL=CFL(5)*SIN(ALPHAR)+CFL(6)*COS(ALPHAR)
65
CONTINUE
IS(I,7).EQ.0
IS
YES
GO TO 1000
NO
IS(I,9).EQ.0
IS
YES
GO TO 32
NO
IS(I,9).EQ.1
IS
YES
GO TO 33
NO


GO TO 60
YES
IS
(NS.NE.1).AND.(NPRT.GT.23)
NO
GO TO 33
32
CONTINUE
GO TO 60
YES
IS
(NS.NE.1).AND.(NPRT.LT.52)
NO
PERFORM SUBROUTINE HEADER
NPRT=4
B1 WRITE
WRITE(6,31)ALPHA,MACH,TR(3),ALT,FS(8),SREF NPRT=NPRT+4
33
B1 WRITE
33
WRITE(6,58) NPRT=NPRT+5
GO TO 60
YES
IS
IS(I,8).EQ.0
NO
B1 WRITE
WRITE(6,4) NPRT=NPRT+1
60
B1 WRITE
60
WRITE(6,39)(IS(I,J),J=1,3),(SURF(I,J),J=1,4),ANGLE(2),RELOC,CHIBAR,VBAR NPRT=NPRT+2
GO TO 59
YES
IS
MEREXP.NE.0
NO
B1 WRITE
WRITE(6,37)CFL(3),CFL(6),CFL(5),SCF(2),SCF(1),TR(5),TWTL,TWTRL,RE1,CDL,CFCFOL, CFT(3),CFT(6),CFT(5),SCF(4),SCF(3),TR(6),TWTT,TWTRT,RE2,CDT,CFCFOT NPRT=NPRT+2
66
CONTINUE
GO TO 63
YES
IS
IS(I,8).EQ.0
NO
B1 WRITE
WRITE(6,44)FS(6),FS(7),FS(4),FS(2),FS(3),FS(1);FS(5),FS(8),CSTAR,CLAM,VSTAR,BS (6),BS(7),BS(4),BS(2),BS(3),BS(1),BS(5),BS(8) NPRT=NPRT+2
GO TO 63


39
81
WRITE
39
WRITE(6,64)
NPRT=NPRT+1
NERSXP=0
CFL(3)=0.0
CFT(3)=0.0
GO TO 66
63
CONTINUE
1008
IJ=1
GO TO
102
YES
IS
IGTYPE.EQ.2
NO
GO TO
27
YES
IS
IS(I,4).EQ.0
NO
CA=CA+SCF(2)
CN=CN+SCF(1)
SKIN=SCF(2)
GO TO 1
27
CA=CA+SCF(4)
CN=CN+SCF(3)
SKIN=SCF(4)
GO TO 1
202
CONTINUE
NO
IS
IS(IJ,4).EQ.0
YES
SKIN=CFT(3)
NO
IS
IS(IJ,4).NE.0
YES
SKIN=CFL(3)
GO TO 1
300
SKIN=8./3.*H*LAMBDA*EL/SURF(I,2)*((1.+SURF(I,3)+SQRT(SURF(I,3)))/((1.+SQRT(SURF(I,3)))*(1.+TAPER2))-(1.+TAPER1+SQRT(TAPER1))/((1.+SQRT(TAPER1))*(1.+TAPER2))
*SQRT(ELO/EL))
1
RETURN

```
SYMBOLS USED IN SUBROUTINE SKINFR

A        R  U  SPEED OF SOUND                                                    SKINFR
AFS      R  A  FREE-STREAM SPEED OF SOUND                                        SKINFR
ALP      R  C  ANGLE OF ATTACK ARRAY                                             SKINFR
ALPHA    R  A  ANGLE OF ATTACK, DEGREES                                          SKINFR
ALT      R  A  ALTITUDE, FEET                                                    SKINFR
ANGLE    R  D  FLOW ANGLE ARRAY                                                  SKINFR
AREA2    R  C  QUADRILATERAL ELEMENT AREA ARRAY                                  SKINFR
B        R  U  LAMINAR VISCOUS INTERACTION PARAMETER                             SKINFR
BET      R  C  YAW ANGLE ARRAY                                                   SKINFR
BS       R  C  FLOW CONDITIONS BEHIND SHOCK OR EXPANSION                         SKINFR
CA       R  A  AXIAL FORCE COEFFICIENT                                           SKINFR
CASE     I  C  CASE NUMBER                                                       SKINFR
CCA      R  C  AXIAL FORCE COEFFICIENT ARRAY                                     SKINFR
CCD      R  C  DRAG COEFFICIENT ARRAY                                            SKINFR
CCL      R  C  LIFT COEFFICIENT ARRAY                                            SKINFR
CCLL     R  C  ROLLING MOMENT COEFFICIENT ARRAY                                  SKINFR
CCLM     R  C  PITCHING MOMENT COEFFICIENT ARRAY                                 SKINFR
CCLN     R  C  YAWING MOMENT COEFFICIENT ARRAY                                   SKINFR
CCN      R  C  NORMAL FORCE COEFFICIENT ARRAY                                    SKINFR
CCY      R  C  SIDE FORCE COEFFICIENT ARRAY                                      SKINFR
CDL      R  U  LAMINAR FLOW DRAG COEFFICIENT                                     SKINFR
CDT      R  U  TURBULENT FLOW DRAG COEFFICIENT                                   SKINFR
CF       R  C  SKIN FRICTION CONTRIBUTION TO AXIAL FORCE ARRAY                   SKINFR
CFCFOL   R  U  LAMINAR RATIO OF SKIN FRACTION, INTERACTION/NO INTERACTION        SKINFR
CFCFOT   R  U  TURBULENT RATIO OF SKIN FRICTION = 1.0                            SKINFR
CFCFOI   R  U  INITIAL SURFACE SKIN FRICTION RATIO                               SKINFR
CFL      R  D  LAMINAR SKIN FRICTION COEFFICIENTS                                SKINFR
CFT      R  D  TURBULENT SKIN FRICTION COEFFICIENTS                              SKINFR
CHIBAR   R  U  HYPERSONIC INTERACTION PARAMETER                                  SKINFR
CKU      R  C  LAMINAR FLOW FLIGHT CONDITION CONSTANT                            SKINFR
CLAM     R  U  CHAPMAN-RUBESIN VISCOSITY COEFFICIENT, LAMINAR                    SKINFR
CLOD     R  C  LIFT TO DRAG RATIO ARRAY                                          SKINFR
CN       R  A  NORMAL FORCE COEFFICIENT                                          SKINFR
CP       R  U  PRESSURE COEFFICIENT                                              SKINFR
CPS      R  C  ARRAY FOR NEWTONIAN CORRELATION FACTOR, K                         SKINFR
CPSTAG   R  A  MODIFIED NEWTONIAN CORRELATION FACTOR, K                          SKINFR
```

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SYMBOLS USED IN SUBROUTINE SKINFR

CSTAR    R  U  LINEAR VISCOSITY COEFFICIENT AT REFERENCE CONDITION     SKINFR
CTURB    R  U  CHAPMAN-RUBESIN VISCOSITY COEFFICIENT, TURBULENT        SKINFR
DELTA    R  A  IMPACT ANGLE, DEGREES                                   SKINFR
ECOS     R  U  COSINE OF FLOW TURNING ANGLE                            SKINFR
EL       R  U  SURFACE REFERENCE LENTH, INPUT                          SKINFR
ELL      R  U  EFFECTIVE SURFACE LENGTH, LAMINAR                       SKINFR
ELLOC    R  C  REFERENCE LENGTH (=EL)                                  SKINFR
ELO      R  U  LENGTH OF INITIAL SURFACE                               SKINFR
ELT      R  U  EFFECTIVE SURFACE LENGTH, TURBULENT                     SKINFR
EL1      R  U  EFFECTIVE LENGTH OF INITIAL SURFACE                     SKINFR
EMN      R  U  MACH NUMBER TIMES SHOCK ANGLE SQUARED                   SKINFR
EN       R  U  PARAMETER IN CHARACTERISTIC LENGTH EQUATION             SKINFR
ERROR    I  C  ERROR FLAG                                              SKINFR
ESIN     R  U  SINE OF FLOW TURNING ANGLE                              SKINFR
ETACS    R  C  SAVED VALUES OF PRANDTL-MEYER CORRECTION FACTOR         SKINFR
FC       R  C  TURBULENT FLOW, SKIN FRICTION COMPRESSIBILITY FACTOR    SKINFR
FF       R  U  FRICTION FACTOR                                         SKINFR
FJ       R  U  MANGLER TRANSFORMATION PARAMETER                        SKINFR
FRX      R  C  TURBULENT FLOW, REYNOLDS NUMBER COMPRESSIBILITY FACTOR  SKINFR
FS       R  C  FLOW CONDITIONS BEFORE SHOCK OR EXPANSION               SKINFR
G        R  U  RATIO OF SPECIFIC HEATS                                 SKINFR
GCP      R  C  GAS SPECIFIC HEAT AT CONSTANT PRESSURE                  SKINFR
HAW      R  C  ADIABATIC-WALL ENTHALPY                                 SKINFR
HW       R  C  WALL ENTHALPY                                           SKINFR
H1       R  C  FREE-STREAM ENTHALPY                                    SKINFR
H2       R  C  LOCAL ENTHALPY                                          SKINFR
I        I  U  DO-LOOP INDEX (SKIN FRICTION SURFACE NUMBER)            SKINFR
IFIRST   I  A  INITIAL POINT FLAG FOR NEWTPM                           SKINFR
IGTY     I  U  INDUCED PRESSURE FLAG                                   SKINFR
IGTYPE   I  A  GEOMETRY TYPE                                           SKINFR
II       I  U  DO-LOOP INDEX (SKIN FRICTION SURFACE NUMBER)            SKINFR
IM       I  C  ELEMENT ROW NUMBER ARRAY                                SKINFR
IN       I  C  ELEMENT COLUMN NUMBER ARRAY                             SKINFR
IPRINT   I  U  PRINT FLAG                                              SKINFR
IS       I  C  SKIN FRICTION FLAG DATA ARRAY                           SKINFR
ISDET    I  U  DATA GENERATION CONTROL FLAG                            SKINFR
```

```
SYMBOLS USED IN SUBROUTINE SKINFR

ISE      I  U  DATA GENERATION CONTROL FLAG                                        SKINFR
ISIZ     I  A  NUMBER OF ELEMENTS STORED IN CORE                                   SKINFR
IS3      I  U  PRESSURE CALCULATION METHOD FLAG                                    SKINFR
KF       I  U  METHOD-SURFACE TYPE FLAG                                            SKINFR
KO       R  U  SIMILARITY PARAMETER                                                SKINFR
L        I  C  NUMBER OF ELEMENTS                                                  SKINFR
LAMBDA   R  U  MODIFIED HYPERSONIC INTERACTION PARAMETER                           SKINFR
LS       I  C  NUMBER OF ELEMENTS                                                  SKINFR
M        R  U  SLOPE OF PRESSURE RATIO VERSUS LAMBDA                               SKINFR
MACH     R  A  MACH NUMBER                                                         SKINFR
MER      I  U  ERROR FLAG                                                          SKINFR
MEREXP   I  U  VACUUM EXPANSION FLAG                                               SKINFR
NC       I  U  NOT USED                                                            SKINFR
NPRT     I  C  PRINT COUNTER                                                       SKINFR
NS       I  A  NUMBER OF SKIN FRICTION SURFACES                                    SKINFR
NX2      R  C  ELEMENT DIRECTION COSINE ARRAY-X                                    SKINFR
NY2      R  C  ELEMENT DIRECTION COSINE ARRAY-Y                                    SKINFR
NZ2      R  C  ELEMENT DIRECTION COSINE ARRAY-Z                                    SKINFR
ONEOM    R  U  1.0 DIVIDED BY MACH NUMBER                                          SKINFR
PAGE     I  C  PAGE NUMBER                                                         SKINFR
PFS      R  A  FREE-STREAM PRESSURE-LBS/SQUARE FOOT                                SKINFR
PO       R  U  PRESSURE RATIO AT LAMBDA = 0.0                                      SKINFR
Q        R  U  TAPER RATIO CORRECTION EQUATION EXPONENT                            SKINFR
RE       R  D  REFERENCE REYNOLDS NUMBER                                           SKINFR
RELOC    R  U  LOCAL REYNOLDS NUMBER                                               SKINFR
RENO     R  U  FREE-STREAM REYNOLDS NUMBER                                         SKINFR
RET      R  C  TURBULENT FLOW REYNOLDS NUMBER AT REFERENCE CONDITION               SKINFR
RHOFS    R  A  FREE STREAM DENSITY                                                 SKINFR
ROMURA   R  C  SQUARE-ROOT OF REFERENCE DENSITY-VISCOSITY RATIO                    SKINFR
RT       R  D  RECOVERY TEMPERATURE                                                SKINFR
SCF      R  D  TOTAL SKIN FRICTION                                                 SKINFR
SCFA     R  D  TOTAL SKIN FRICTION                                                 SKINFR
SKIN     R  A  TOTAL AXIAL SKIN FRICTION CONTRIBUTION                              SKINFR
SREF     R  A  VEHICLE REFERENCE AREA (WING AREA)                                  SKINFR
SURF     R  C  SKIN FRICTION DATA ARRAY                                            SKINFR
TAPER1   R  U  TAPER RATIO OF INITIAL SURFACE                                      SKINFR
```

```
SYMBOLS USED IN SUBROUTINE SKINFR

TAPER2   R  U  TAPER RATIO OF SURFACE                                          SKINFR
TFS      R  A  FREE-STREAM TEMPERATURE                                         SKINFR
TITLE    R  C  TITLE                                                           SKINFR
TR       R  D  FLIGHT CONDITION AND SKIN FRICTION DATA ARRAY                   SKINFR
TS       R  D  REFERENCE TEMPERATURE (T STAR)                                  SKINFR
TST1     R  C  REFERENCE TO FREE-STREAM TEMPERATURE (OR ENTHALPY) RATIO        SKINFR
TWTL     R  U  WALL TO FREE-STREAM TEMPERATURE RATIO, LAMINAR                  SKINFR
TWTRL    R  U  WALL TO RECOVERY TEMPERATURE RATIO, LAMINAR                     SKINFR
VBAR     R  U  HYPERSONIC VISCOUS PARAMETER                                    SKINFR
VIS      R  A  FREE STREAM VISCOSITY                                           SKINFR
VISTAR   R  U  VICOSITY AT REFERENCE CONDITION                                 SKINFR
VISWL    R  U  VISCOSITY AT WALL TEMPERATURE, LAMINAR                          SKINFR
VISWT    R  U  VISCOSITY AT WALL TEMPERATURE, TURBULENT                        SKINFR
VSTAR    R  U  VICOUS-INTERACTION PARAMETER                                    SKINFR
XCENT2   R  C  QUADRILATERAL ELEMENT CENTROID ARRAY-X                          SKINFR
YCENT2   R  C  QUADRILATERAL ELEMENT CENTROID ARRAY-Y                          SKINFR
ZCENT2   R  C  QUADRILATERAL ELEMENT CENTROID ARRAY-Z                          SKINFR
```

14. SUBROUTINE COMPR (DECK AROM)

This routine calculates the local flow properties using conventional oblique-shock relationships (NACA TR 1135).

a. Algorithm

First the constants in the oblique equation are calculated. A check is made for shock detachment, and if the shock is not detached the three real roots for the cubic are found. If the shock has detached, the conditions will be calculated by the NEWTPM routine. The proper root is selected and local flow conditions are calculated.

b. Input/Output

None

c. Error

An error condition will occur if a negative value is found for sine theta squared. Set it to 0 and the program will continue.

d. Subroutines Required

NEWTPM

e. Argument List

(ANGLE, MER, IPRINT, CPSTAG, TFS, PFS, ISDET, IFIRST, CP)

f. Length

2794 bytes

DECK AROM

```
      SUBROUTINE COMPR (ANGLE,MER,IPRINT,CPSTAG,TFS,PFS,ISDET,IFIRST,CP)  AROM  0010
C                                                                         AROM  0020
C  USING THE FREE STREAM MACH NUMBER AND THE EQUIVALENT WEDGE ANGLE,      AROM  0030
C  THIS ROUTINE COMPUTES THE CONDITIONS BEHIND THE SHOCK                  AROM  0040
C                                                                         AROM  0050
      DIMENSION  FS(8),ANGLE(3),BS(8),R(3)                                AROM  0060
      DIMENSION   TITLE(15)                                               AROM  0070
      DIMENSION NX2( 300),NY2( 300),NZ2( 300),XCENT2( 300),               AROM  0080
     1  YCENT2( 300),ZCENT2( 300),AREA2( 300),IN( 300),IM( 300)           AROM  0090
      COMMON  CASE,TITLE,PAGE,ERROR,NX2,NY2,NZ2,XCENT2,YCENT2,ZCENT2,     AROM  0100
     1  AREA2,IN,IM,K,LS,FS,BS                                            AROM  0110
C                                                                         AROM  0120
      INTEGER  CASE,PAGE,ERROR                                            AROM  0130
      REAL  NX2, NY2, NZ2                                                 AROM  0140
      REAL        MACHSQ, MACHO, MACH1                                    AROM  0150
      MER = 0                                                             AROM  0160
      IF (ISDET .EQ. 1) GO TO 24                                          AROM  0170
      IF (ABS(ANGLE(2)) .LT. 0.00001) GO TO 35                            AROM  0180
      IF (ANGLE(2) .GT. 55.0) GO TO 1                                     AROM  0190
      IF (ABS(ANGLE(2)) .LE. 2.0) GO TO 37                                AROM  0200
C                                                                         AROM  0210
C  SET UP CUBIC TO BE SOLVED FOR SIN**2 THETA (SHOCK ANGLE) - CONSTANTS   AROM  0220
C  DEFINED IN EQUATION 1508 OF TR 1135                                    AROM  0230
      B = -(FS(6)**2 + 2.0)/FS(6)**2 - 1.4*SIN(ANGLE(2)/57.295779)**2     AROM  0240
      C =   (2.0*FS(6)**2 + 1.0)/FS(6)**4 + (1.44 + 0.4/FS(6)**2)*        AROM  0250
     1      SIN(ANGLE(2)/57.295779)**2                                    AROM  0260
      D = -COS(ANGLE(2)/57.295779)**2/FS(6)**4                            AROM  0270
                                                                          AROM  0280
C     CHECK FOR SHOCK DETACHMENT                                          AROM  0290
      IF (((-B**2/9. + C/3.)**3 + ((B/3.)**3 - (B*C - 3.*D)/6.)**2)       AROM  0300
     1        .GE. 0.0) GO TO 1                                           AROM  0310
                                                                          AROM  0320
C     SHOCK NOT DETACHED, COMPUTE THREE REAL ROOTS                        AROM  0330
                                                                          AROM  0340
      Y      = B**2 - 3.*C                                                AROM  0350
```

DECK AROM

```
      Z       = (9.*B*C - 2.*B**3 - 27.*D)/(2.*Y**1.5)                   AROM  0360
      W       = ARCOS(Z)                                                 AROM  0370
      Z       = W/3.                                                     AROM  0380
      Y       = 2.*SQRT(Y)                                               AROM  0390
      R(1)    = (Y*COS(Z) - B)/3.                                        AROM  0400
      R(2)    = -(Y*COS(Z + 60./57.295779) + B)/3.                       AROM  0410
      R(3)    = -(Y*COS(Z - 60./57.295779) + B)/3.                       AROM  0420
      GO TO 3                                                            AROM  0430
                                                                         AROM  0440
C  CUBIC SOLUTION WAS NOT FOUND BECAUSE THE SHOCK HAS DETACHED. FLOW     AROM  0450
C  PROPERTIES WILL BE CALCULATED BY THE METHOD OF KAUFMAN                AROM  0460
    1 ETAC    = 1.0                                                      AROM  0470
      ISE = 0                                                            AROM  0480
      CALL NEWTPM (ANGLE,EMN,CP,ETAC,IPRINT,MER,CPSTAG,                  AROM  0490
     1  TFS,PFS,ISE,IFIRST)                                              AROM  0500
      IF (MER - 1) 17,24,24                                              AROM  0510
C                                                                        AROM  0520
C  A SOLUTION TO THE CUBIC WAS FOUND. CHECK FOR DESIRED SOLUTION.        APOM  0530
C  SMALLEST ROOT REQUIRES A DECREASE IN ENTROPY WHICH IS NOT ALLOWED.    AROM  0540
C  LARGEST ROOT IS NOT ATTAINED IN PRACTICAL CASES. THEREFORE PICK       AROM  0550
C  MIDDLE ANSWER.                                                        AROM  0560
    3 IF (R(1) - R(2)) 4,13,5                                            AROM  0570
    4 K = 1                                                              AROM  0580
      GO TO 6                                                            AROM  0590
    5 K = 2                                                              AROM  0600
    6 IF (R(2) - R(3)) 7,14,8                                            AROM  0610
    7 L = 1                                                              AROM  0620
      GO TO 9                                                            AROM  0630
    8 L = 2                                                              AROM  0640
    9 IF (K .EQ. L) GO TO 14                                             AROM  0650
      IF (R(1) - R(3)) 11,15,12                                          AROM  0660
   11 GO TO (15,13), K                                                   AROM  0670
   12 GO TO (13,15), K                                                   AROM  0680
   13 ANGLE(3) = R(1)                                                    AROM  0690
       GO TO 16                                                          AROM  0700
   14 ANGLE(3) = R(2)                                                    AROM  0710
```

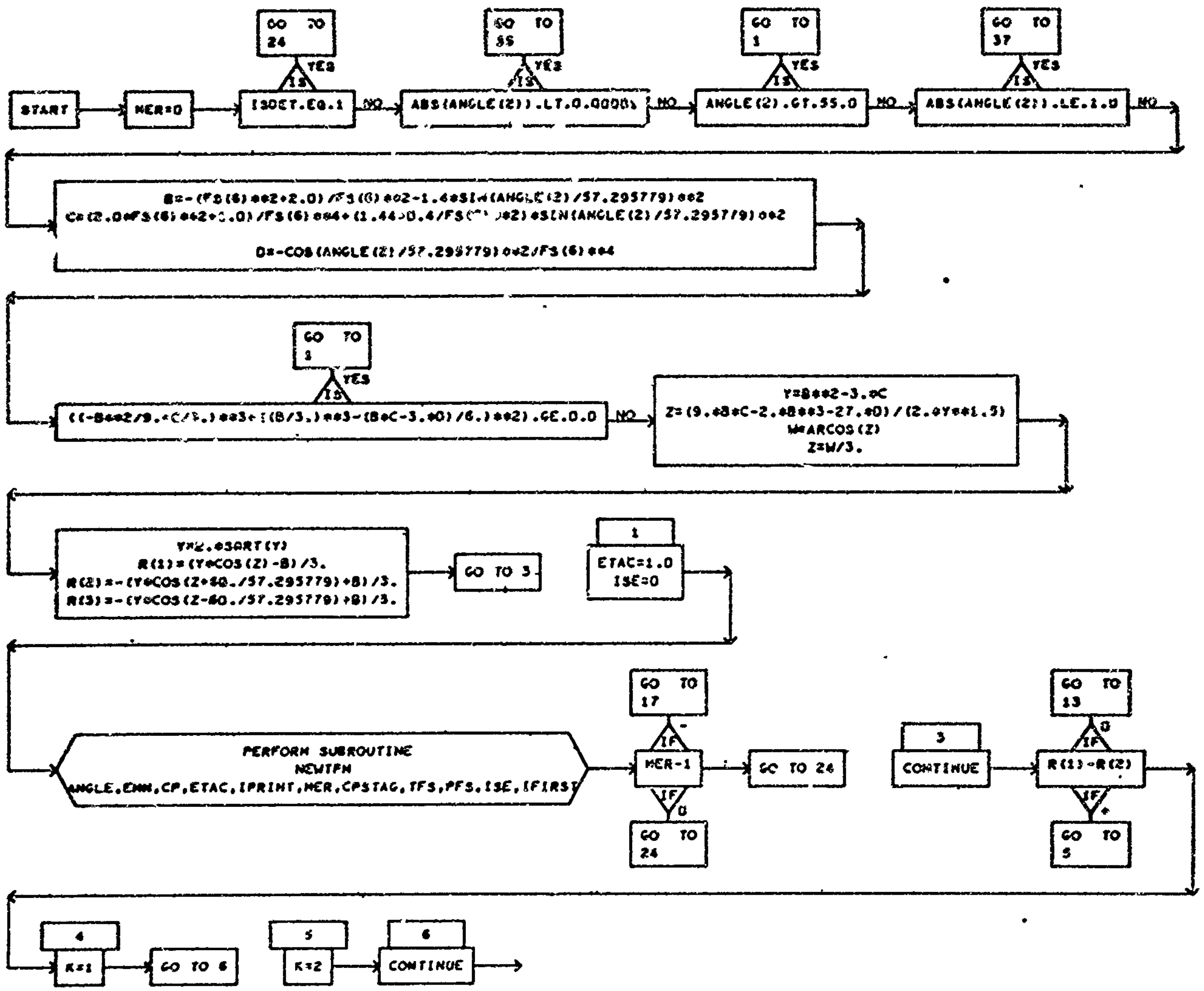
DECK AROM

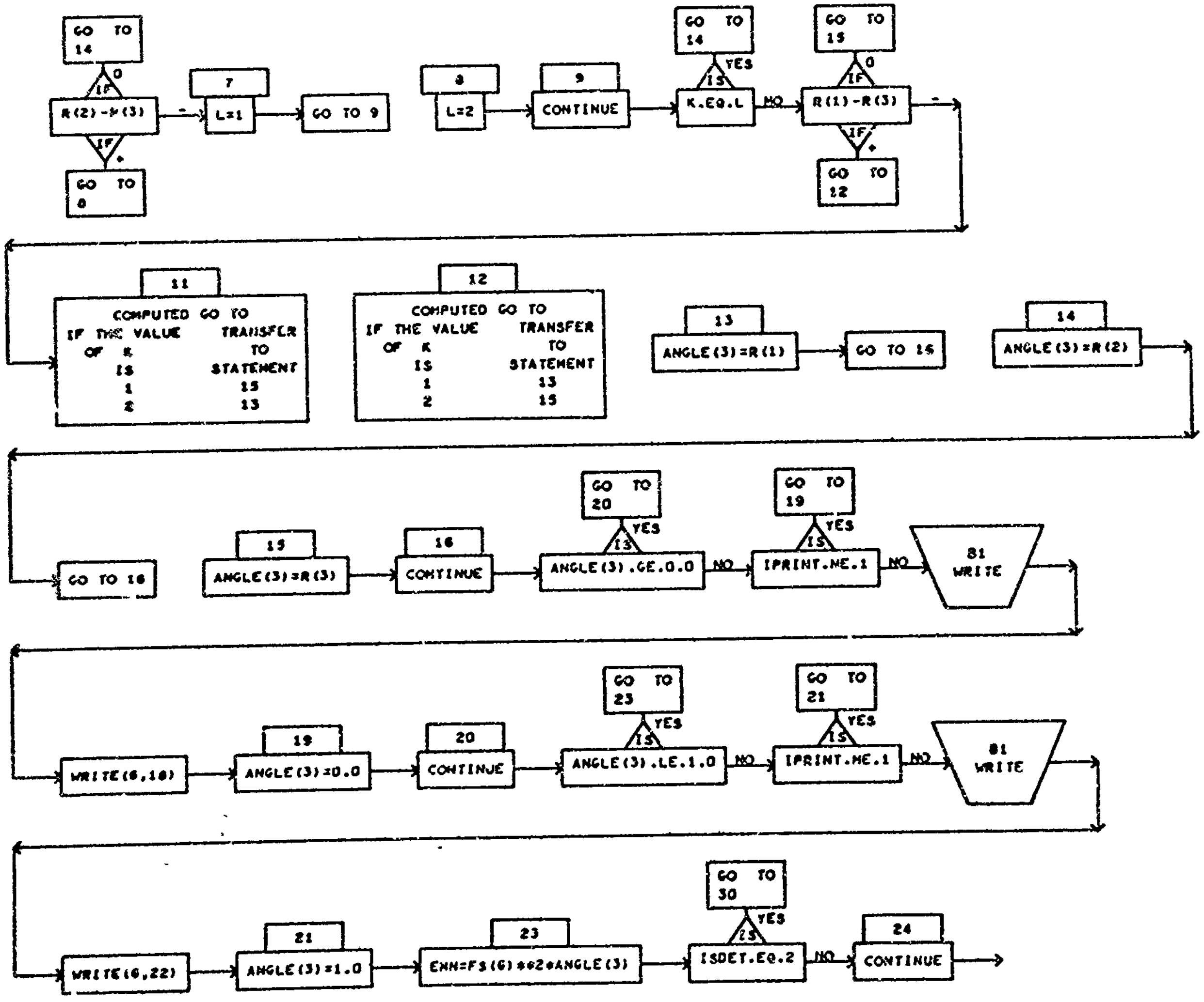
```
      GO TO 16
   15 ANGLE(3) = R(3)
C
C  CHECK IF ANGLE IS NEGATIVE AND PRINT ERROR NOTE IF REQUIRED
   16 IF (ANGLE(3) .GE. 0.0) GO TO 20
      IF (IPRINT .NE. 1) GO TO 19
      WRITE (6,18)
   18 FORMAT (1H0,39H NEGATIVE VALUE FOUND FOR SIN**2 THETA
     1  41HIN CUBIC. TO CONTINUE, IT IS SET TO ZERO.  )
   19 ANGLE(3) = 0.0
   20 IF (ANGLE(3) .LE. 1.0) GO TO 23
      IF (IPRINT .NE. 1) GO TO 21
      WRITE (6,22)
   22 FORMAT (1H0,41H IN CUBIC, SIN**2 THETA GREATER THAN ONE.
     1 31H TO CONTINUE, IT IS SET TO ONE.  )
   21 ANGLE(3) = 1.0
C
C  CALCULATE CONDITIONS BEHIND THE SHOCK USING THE SELECTED SIN**2 THETA
   23 EMN    = FS(6)**2 * ANGLE(3)
      IF (ISDET .EQ. 2) GO TO 30
C  DENSITY       EQ. 129 OF TR 1135
   24 IF (EMN .LT. 1.01) EMN = 1.01
      BS(1) = FS(1)*6.0 * EMN / (EMN + 5.0)
C  PRESSURE      EQ. 128
      BS(2) = FS(2) * (7.0*EMN - 1.0)/6.0
C  TEMPERATURE   EQ. 130
         R(3) = (7.0*EMN - 1.0)*(EMN + 5.0) / (36.0*EMN)
      BS(3) = FS(3) * R(3)
C  SPEED OF SOUND
      BS(4) = FS(4) * SQRT(R(3))
C  VISCOSITY
      IF(BS(3).GE.225.0) BS(5)=2.27*BS(3)**1.5/((BS(3)+198.6)*10.0**8)
      IF(BS(3).LT.225.0) BS(5)=0.80382436E-9 * BS(3)
C  MACH NUMBER   EQ. 132
      BS6SQ = (36.0*FS(6)**2*EMN - 5.0*(EMN - 1.0)*
     1          (7.0*EMN + 5.0)) / ((7.0*EMN - 1.0) * (EMN + 5.0))
```

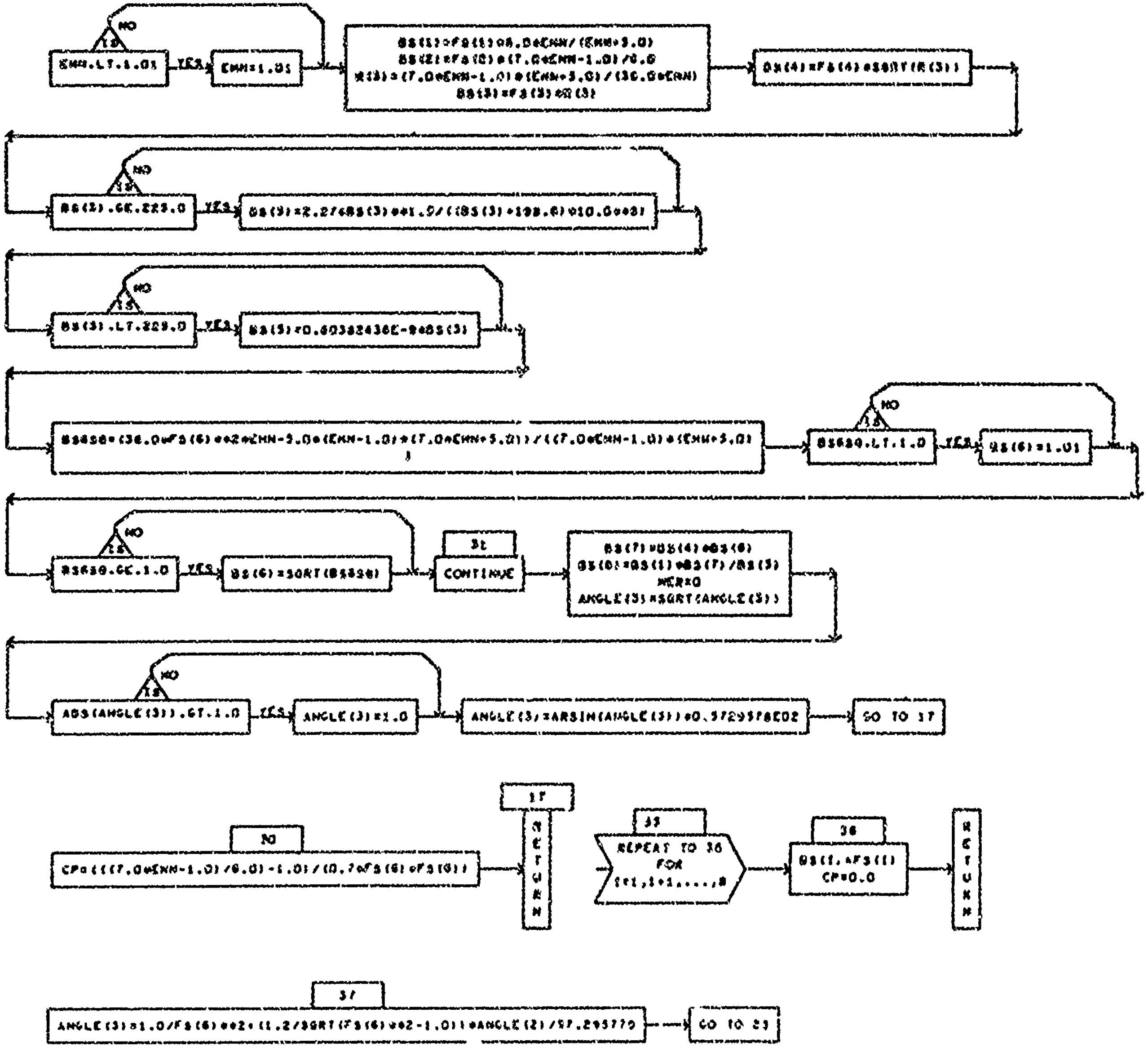
```
DECK AROM

      IF (BS6SQ .LT. 1.0) BS(6) = 1.01                                  AROM  1080
      IF (BS6SQ .GE. 1.0) BS(6) = SQRT(BS6SQ)                           AROM  1090
   31 CONTINUE                                                          AROM  1100
C  VELOCITY                                                             AROM  1110
      BS(7) = BS(4) * BS(6)                                             AROM  1120
C  REYNOLDS NUMBER PER FOOT                                             AROM  1130
      BS(8) = BS(1) * BS(7)/BS(5)                                       AROM  1140
      MER = 0                                                           AROM  1150
C  SHOCK ANGLE                                                          AROM  1160
      ANGLE(3) = SQRT(ANGLE(3))                                         AROM  1170
      IF (ABS(ANGLE(3)) .GT. 1.0) ANGLE(3) = 1.0                        AROM  1180
      ANGLE(3) = ARSIN(ANGLE(3)) * 0.5729578E02                         AROM  1190
      GO TO 17                                                          AROM  1200
C                                                                       AROM  1210
   30 CP = (((7.0*EMN - 1.0)/6.0) - 1.0) / (0.7*FS(6)*FS(6))            AROM  1220
C                                                                       AROM  1230
   17 RETURN                                                            AROM  1240
C                                                                       AROM  1250
C     ANGLE(2) IS ZERO, SET BS(I) = FS(I), CP = 0.0, AND EXIT           AROM  1260
                                                                        AROM  1270
   35 DO 36 I= 1,8                                                      AROM  1280
   36 BS(I)  = FS(I)                                                    AROM  1290
      CP     = 0.0                                                      AROM  1300
      RETURN                                                            AROM  1310
C  USE WEAK OBLIQUE SHOCK RELATIONSHIP (LIEPMAN AND ROSHKO, P.92)       AROM  1320
   37 ANGLE(3) = 1.0/FS(6)**2 + (1.2/SQRT(FS(6)**2-1.0))*ANGLE(2)/      AROM  1330
     1           57.295779                                              AROM  1340
      GO TO 23                                                          AROM  1350
      END                                                               AROM  1360
```

SUBROUTINE COMPR




GO TO 14
0
IF
R(2)-R(3)
IF
+
GO TO 8
-
7
L=1
GO TO 9
8
L=2
9
CONTINUE
GO TO 14
YES
IS
K.EQ.L
NO
GO TO 15
0
IF
R(1)-R(3)
IF
+
GO TO 12
-
11
COMPUTED GO TO
IF THE VALUE OF K IS
TRANSFER TO STATEMENT
1
15
2
13
12
COMPUTED GO TO
IF THE VALUE OF K IS
TRANSFER TO STATEMENT
1
13
2
15
13
ANGLE(3)=R(1)
GO TO 15
14
ANGLE(3)=R(2)
GO TO 16
15
ANGLE(3)=R(3)
16
CONTINUE
GO TO 20
YES
IS
ANGLE(3).GE.0.0
NO
GO TO 19
YES
IS
IPRINT.NE.1
NO
81
WRITE
WRITE(6,18)
19
ANGLE(3)=0.0
20
CONTINUE
GO TO 23
YES
IS
ANGLE(3).LE.1.0
NO
GO TO 21
YES
IS
IPRINT.NE.1
NO
81
WRITE
WRITE(6,22)
21
ANGLE(3)=1.0
23
EMN=FS(6)**2*ANGLE(3)
GO TO 30
YES
IS
ISDET.EQ.2
NO
24
CONTINUE


EMN.LT.1.01
YES
NO
EMN=1.01
BS(1)=FS(1)*8.0*EMN/(EMN+3.0)
BS(2)=FS(2)*(7.0*EMN-1.0)/6.0
R(3)=(7.0*EMN-1.0)*(EMN+3.0)/(36.0*EMN)
BS(3)=FS(3)*R(3)
BS(4)=FS(4)*SQRT(R(3))
BS(3).GE.225.0
YES
NO
BS(3)=2.27*BS(3)**1.5/((BS(3)+198.6)*10.0**3)
BS(3).LT.225.0
YES
NO
BS(5)=0.60382436E-9*BS(3)
BSQ36=(36.0*FS(6)**2*EMN-3.0*(EMN-1.0)*(7.0*EMN+5.0))/((7.0*EMN-1.0)*(EMN+3.0)
)
BSQ36.LT.1.0
YES
NO
BS(6)=1.01
BSQ36.GE.1.0
YES
NO
BS(6)=SQRT(BSQ36)
31
CONTINUE
BS(7)=BS(4)*BS(6)
BS(8)=BS(1)*BS(7)/BS(3)
NER=0
ANGLE(3)=SQRT(ANGLE(3))
ABS(ANGLE(3)).GT.1.0
YES
NO
ANGLE(3)=1.0
ANGLE(3)=ARSIN(ANGLE(3))*0.5729578E02
GO TO 17
30
CP=(((7.0*EMN-1.0)/6.0)-1.0)/(0.7*FS(6)*FS(6))
17
RETURN
35
REPEAT TO 36
FOR
I=1,I+1,....,8
36
BS(I)=FS(I)
CP=0.0
RETURN
37
ANGLE(3)=1.0/FS(6)**2+(1.2/SQRT(FS(6)**2-1.0))*ANGLE(2)/57.295779
GO TO 23

```
SYMBOLS USED IN SUBROUTINE COMPR

ANGLE    R  A  FLOW ANGLE ARRAY                                      COMPR
AREA2    R  C  QUADRILATERAL ELEMENT AREA ARRAY                      COMPR
B        R  U  VARIABLE IN CUBIC EQUATION                            COMPR
BS       R  C  FLOW CONDITIONS BEHIND SHOCK OR EXPANSION             COMPR
BS6SQ    R  U  MACH NUMBER SQUARED                                   COMPR
C        R  U  VARIABLE IN CUBIC EQUATION                            COMPR
CASE     I  C  CASE NUMBER                                           COMPR
CP       R  A  PRESSURE COEFFICIENT                                  COMPR
CPSTAG   R  A  MODIFIED NEWTONIAN CORRELATION FACTOR, K              COMPR
D        R  U  VARIABLE IN CUBIC EQUATION                            COMPR
EMN      R  U  MACH NUMBER TIMES SINE THETA SQUARED                  COMPR
ERROR    I  C  ERROR FLAG                                            COMPR
ETAC     R  U  PRANDTL-MEYER EXPANSION CORRECTION FACTOR             COMPR
FS       R  C  FLOW CONDITIONS BEFORE SHOCK OR EXPANSION             COMPR
IFIRST   I  A  FIRST POINT FLAG FOR NEWTPM                           COMPR
IM       I  C  ELEMENT ROW NUMBER ARRAY                              COMPR
IN       I  C  ELEMENT COLUMN NUMBER ARRAY                           COMPR
IPRINT   I  A  PRINT FLAG                                            COMPR
ISDET    I  A  DATA GENERATION CONTROL FLAG                          COMPR
ISE      I  U  DATA GENERATION CONTROL FLAG                          COMPR
K        I  C  NUMBER OF ELEMENTS                                    COMPR
L        I  U  FLAG                                                  COMPR
LS       I  C  NUMBER OF ELEMENTS                                    COMPR
MACHO    R  U  MACH NUMBER                                           COMPR
MACHSQ   R  U  MACH NUMBER SQUARED                                   COMPR
MACH1    R  U  MACH NUMBER                                           COMPR
MER      I  A  ERROR FLAG                                            COMPR
NX2      R  C  ELEMENT DIRECTION COSINE ARRAY -X                     COMPR
NY2      R  C  ELEMENT DIRECTION COSINE ARRAY-Y                      COMPR
NZ2      R  C  ELEMENT DIRECTION COSINE ARRAY-Z                      COMPR
PAGE     I  C  PAGE NUMBER                                           COMPR
PFS      R  A  FREE-STREAM PRESSURE-LB/FT SQUARED                    COMPR
R        R  D  ROOTS OF CUBIC EQUATION                               COMPR
TFS      R  A  FREE-STREAM TEMPERATURE-DEGREE R                      COMPR
TITLE    R  C  TITLE                                                 COMPR
W        R  U  PARAMETER IN CUBIC EQUATION                           COMPR
```

```
SYMBOLS USED IN SUBROUTINE COMPR

XCENT2  R  C  ELEMENT CENTROID ARRAY-X                                    COMPR
Y       R  U  PARAMETER IN CUBIC EQUATION                                 COMPR
YCENT2  R  C  ELEMENT CENTROID ARRAY-Y                                    COMPR
Z       R  U  PARAMETER IN CUBIC EQUATION                                 COMPR
ZCENT2  R  C  ELEMENT CENTROID ARRAY-Z                                    COMPR
```

15. SUBROUTINE EXPAND (DECK ARON)

This routine calculates the local flow conditions on a surface by using conventional Prandtl-Meyer relationships (NACA TR 1135).

a. Algorithm

Calculate the Prandtl-Meyer angle after the expansion. Check if the flow is to be compressed to subsonic conditions or if it has expanded to an infinite Mach number (100). An iterative procedure is used to determine the flow conditions after the expansion fan.

b. Input/Output

None

c. Error

None

d. Subroutines Required

None

e. Argument List

(ANGLE, MER, IPRINT, ISDET, CP)

f. Length

2104 bytes

DECK ARON

```
      SUBROUTINE EXPAND (ANGLE,MER,IPRINT,ISDET,CP)                     ARON 0010
C                                                                       ARON 0020
C  GIVEN THE FREE STREAM CONDITIONS (FS) AND THE  TURNING  ANGLE IN     ARON 0030
C  DEGREES (ANGLE(2)), THIS SUBROUTINE PERFORMS AN ISENTROPIC PRANDTL-  ARON 0040
C  MEYER EXPANSION(ANGLE(2).GT.0.) OR COMPRESSION(ANGLE(2).LT.0.)       ARON 0050
C                                                                       ARON 0060
      DIMENSION  FS(8),ANGLE(3),BS(8),A(2),C(2)                         ARON 0070
      DIMENSION  TITLE(15)                                              ARON 0080
      DIMENSION NX2( 300),NY2( 300),NZ2( 300),XCENT2( 300),             ARON 0090
     1  YCENT2( 300),ZCENT2( 300),AREA2( 300),IN( 300),IM( 300)         ARON 0100
      COMMON  CASE,TITLE,PAGE,ERROR,NX2,NY2,NZ2,XCENT2,YCENT2,ZCENT2,   ARON 0110
     1  AREA2,IN,IM,K,LS,FS,BS                                          ARON 0120
C                                                                       ARON 0130
      REAL  NX2, NY2, NZ2                                               ARON 0140
      INTEGER  CASE,PAGE,ERROR                                          ARON 0150
      REAL  NU1, NU2, NU1D, NU2D                                        ARON 0160
C                                                                       ARON 0170
C  CHECK IF FREE STREAM MACH NO. .GE. 1.0                               ARON 0180
      IF (FS(6).GE.1.0) GO TO 1                                         ARON 0190
C  INPUT MACH NO. SUBSONIC. FOR PROGRAM CONTINUITY SET = 1.0 AND GO ON  ARON 0200
      EMSQ = 1.0                                                        ARON 0210
      GO TO 2                                                           ARON 0220
C                                                                       ARON 0230
C  SQUARE FREE STREAM MACH NO.                                          ARON 0240
   1  EMSQ = FS(6)**2                                                   ARON 0250
C   DEFINE GAMMA RATIO FUNCTION, GR = SQRT((G+1)/(G-1)). FOR G=1.4      ARON 0260
   2  GR = SQRT(6.0)                                                    ARON 0270
C  CALCULATE PRANDTL-MEYER ANGLE FOR FREE STREAM CONDITIONS USING       ARON 0280
C  EQUATION 171C OF TR 1135  (RADIANS)                                  ARON 0290
      NU1 = GR*ATAN(SQRT (EMSQ-1.)/GR ) - ATAN(SQRT(EMSQ-1.))           ARON 0300
C                                                                       ARON 0310
C  CALCULATE PRANDTL-MEYER ANGLE AFTER THE EXPANSION (RADIANS)          ARON 0320
      NU1D = NU1 * 57.295779                                            ARON 0330
      NU2D = NU1D + ANGLE(2)                                            ARON 0340
      NU2 = NU2D/57.295779                                              ARON 0350
```

```
DECK ARON
C
C  CHECK IF FLOW COMPRESSED TC SUBSONIC.
C
      IF (NU2D.GT.0.) GO TO 21
C  NU2D .LE. 0.0, RETURN SONIC CONDITIONS
C
      BS(6) = 1.0
      MER = 2
      GO TO 13
C
C  CHECK IF FLOW HAS EXPANDED TO AN INFINITE MACH NUMBER (TAKEN
C  AS 100. FOR ALL PRACTICAL PURPOSES).  IF SO, RETURN ZERO PRESSURE.
   21 IF (NU2D.LT. 127.6) GO TO 22
      MER = 2
      BS(6) = 100.0
      GO TO 13
C
C
C  START OF ITERATION TO FIND MACH NC. DOWNSTREAM
C  SET INITIAL CONDITIONS AND TOLERANCE
   22 I = 0
      A(2) = 0.0
      C(2) = 0.0
      EPS = 1.E-4
      JPATH = 1
C  JPATH CONTROLS THE LOGICAL PATH DURING THE ITERATION CYCLE.
C  CALCULATE APPROXIMATE DOWNSTREAM MACH NO.
      BS(6) = FS(6)*(1. + (NU2-NU1)*(1.+0.2*EMSQ)/SQRT(EMSQ-1.))
      IF (BS(6).GT.1.0) GO TO 3
      BS(6) = 1.01
C  SET ITERATION COUNTER AND CHECK FOR MAXIMUM
    3 I     = I + 1
C
C  CHECK NUMBER OF ITERATIONS COUNTER
    6 IF (I .LE. 20) GO TO 9
      WRITE (6,8) I
```

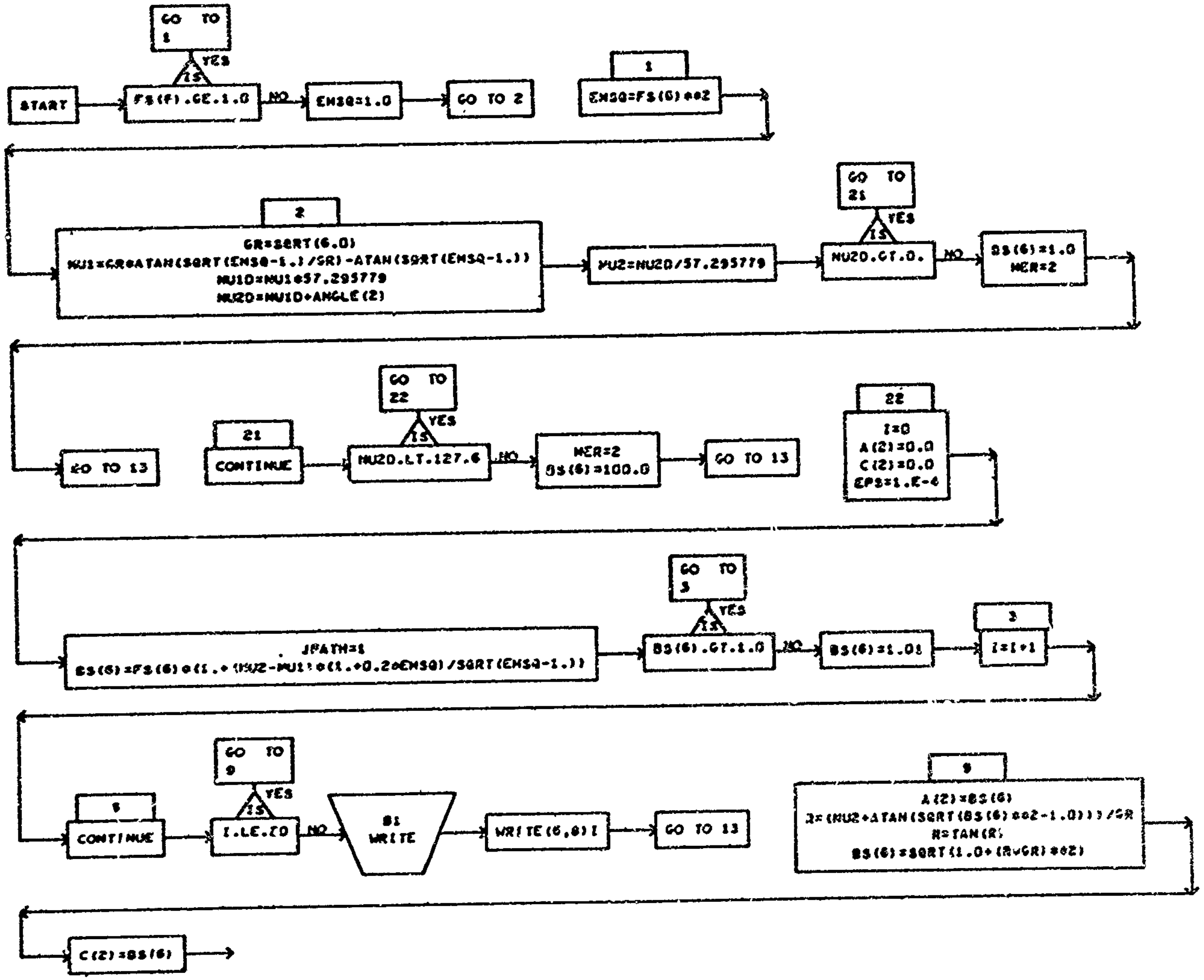
DECK ARON

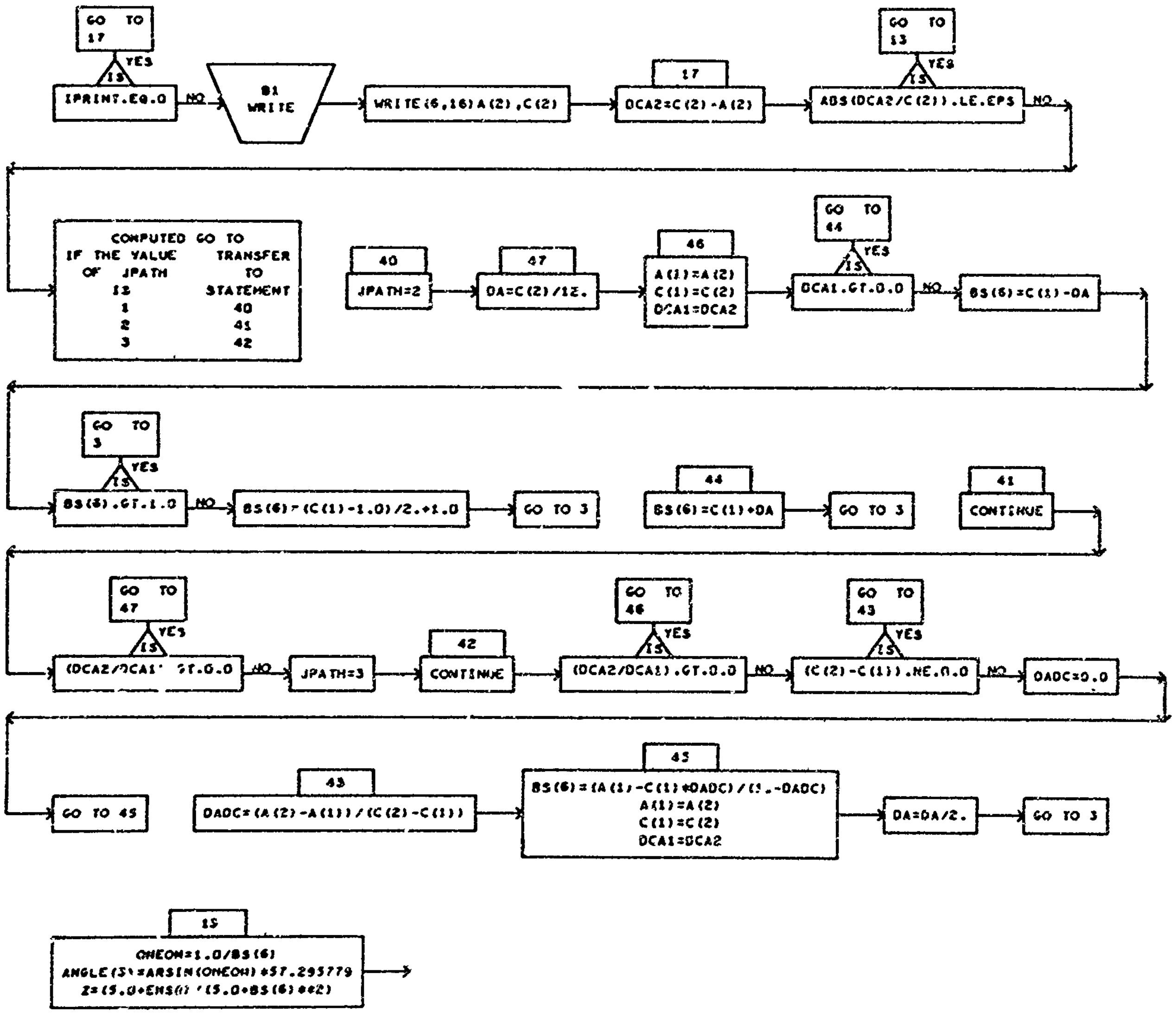
```
    8  FORMAT (1H0,I4,42H ITERATIONS IN EXPANSION ROUTINE. THE LAST           ARON  0720
      1 25H VALUE HAS BEEN ACCEPTED. )                                        ARON  0730
       GO TO 13                                                               ARON  0740
C                                                                             ARON  0750
    9  A(2) = BS(6)                                                           ARON  0760
C                                                                             ARON  0770
       R =  (NU2     + ATAN(SQRT(BS(6)**2 - 1.0)))/GR                         ARON  0780
       R = TAN(R)                                                             ARON  0790
       BS(6) = SQRT(1.0 + (R*GR)**2)                                          ARON  0800
C                                                                             ARON  0810
       C(2) = BS(6)                                                           ARON  0820
C                                                                             ARON  0830
C  CHECK IF FLOW ITERATION IS TO BE PRINTED OUT                               ARON  0840
       IF (IPRINT .EQ. 0) GO TO 17                                            ARON  0850
       WRITE (6,16) A(2), C(2)                                                ARON  0860
   16   FORMAT (1H ,17X3HMA=F8.4,4X3HMC=F8.4 )                                ARON  0870
C                                                                             ARON  0880
C  CHECK IF ITERATION ACCURACY HAS BEEN REACHED                               ARON  0890
   17  DCA2 = C(2)-A(2)                                                       ARON  0900
       IF (ABS(DCA2/C(2)).LE.EPS) GO TO 13                                    ARON  0910
C                                                                             ARON  0920
       GO TO (40,41,42), JPATH                                                ARON  0930
   40  JPATH = 2                                                              ARON  0940
C  STEP ASSUMED VALUE BY AN ARBITRARY INCREMENT                               ARON  0950
C  EXPERIENCE HAS SHOWN THAT ONE-12TH OF C(2) TO BE A GOOD VALUE.             ARON  0960
   47  DA = C(2)/12.                                                          ARON  0970
   46  A(1) = A(2)                                                            ARON  0980
       C(1) = C(2)                                                            ARON  0990
       DCA1 = DCA2                                                            ARON  1000
       IF (DCA1.GT.0.0) GO TO 44                                              ARON  1010
       BS(6)= C(1) - DA                                                       ARON  1020
C  MAKE SURE THAT 2ND GUESS IS NOT OUT OF RANGE.                              ARON  1030
       IF(BS(6).GT.1.0) GO TO 3                                               ARON  1040
       BS(6)= (C(1)-1.0)/2. + 1.0                                             ARON  1050
       GO TO 3                                                                ARON  1060
   44  BS(6)= C(1) + DA                                                       ARON  1070
```

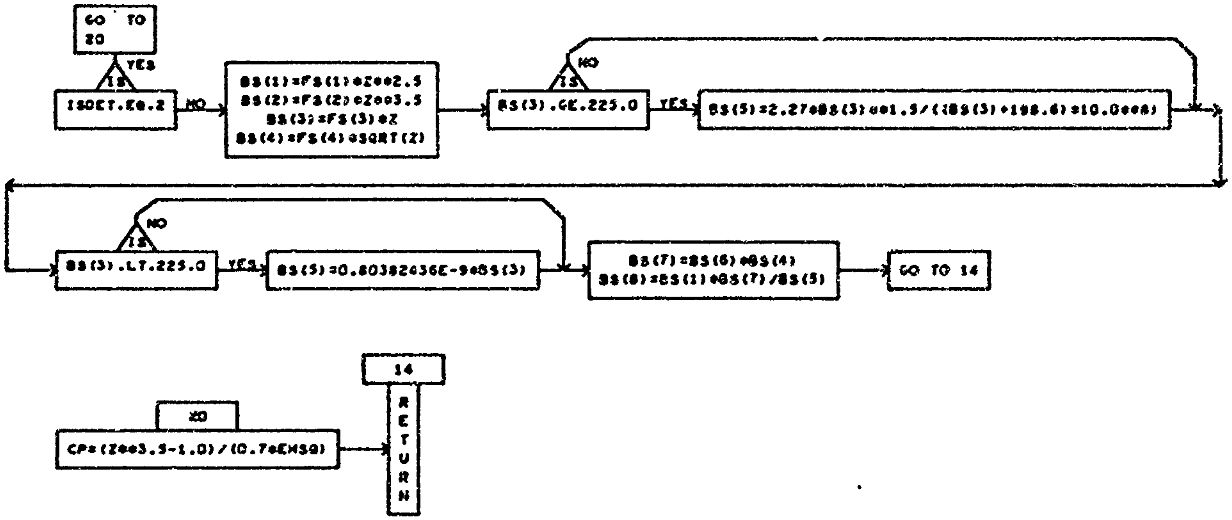
```
DECK ARON
      GO TO 3
   41 IF ((DCA2/DCA1).GT.0.0) GO TO 47
      JPATH = 3
   42 IF ((DCA2/DCA1).GT.0.0) GO TO 46
C  CALCULATE MACH NUMBER AFTER EXPANSION USING 2 PREVIOUS ESTIMATES
      IF ((C(2)-C(1)) .NE. 0.0) GO TO 43
      DADC = 0.0
      GO TO 45
   43 DADC = (A(2)-A(1))/(C(2)-C(1))
   45 BS(6) = (A(1)-C(1)*DADC)/(1.-DADC)
      A(1) = A(2)
      C(1) = C(2)
      DCA1 = DCA2
      DA = DA/2.
      GO TO 3
C
C
C  CALCULATE FINAL CHARACTERISTICS BEHIND EXPANSION FAN
   13  ONEOM = 1.0 / BS(6)
      ANGLE(3) = ARSIN(ONEOM)*57.295779
      Z      = (5.0 + EMSQ)      / (5.0 + BS(6)**2)
      IF (ISDET .EQ. 2) GO TO 20
      BS(1) = FS(1) *Z**2.5
      BS(2) = FS(2) *Z**3.5
      BS(3) = FS(3) *Z
      BS(4) = FS(4) *SQRT(Z)
      IF(BS(3).GE.225.0) BS(5)=2.27*BS(3)**1.5/((BS(3)+198.6)*10.0**8)
      IF(BS(3).LT.225.0) BS(5)=0.80382436E-9 * BS(3)
      BS(7) = BS(6) * BS(4)
      BS(8) = BS(1) * BS(7)/BS(5)
      GO TO 14
C
   20 CP = (Z**3.5 - 1.0) / (0.7*EMSQ)

   14 RETURN
C
      END
```

SUBROUTINE EXPAND




GO TO 17
YES
IS
IPRINT.EQ.0
NO
81 WRITE
WRITE(6,16)A(2),C(2)
17
DCA2=C(2)-A(2)
GO TO 13
YES
IS
ABS(DCA2/C(2)).LE.EPS
NO
COMPUTED GO TO
IF THE VALUE OF JPATH IS 1 2 3
TRANSFER TO STATEMENT 40 41 42
40
JPATH=2
47
DA=C(2)/12.
46
A(1)=A(2)
C(1)=C(2)
DCA1=DCA2
GO TO 44
YES
IS
DCA1.GT.0.0
NO
BS(6)=C(1)-DA
GO TO 3
YES
IS
BS(6).GT.1.0
NO
BS(6)=(C(1)-1.0)/2.+1.0
GO TO 3
44
BS(6)=C(1)+DA
GO TO 3
41
CONTINUE
GO TO 47
YES
IS
(DCA2/DCA1).GT.0.0
NO
JPATH=3
42
CONTINUE
GO TO 46
YES
IS
(DCA2/DCA1).GT.0.0
NO
GO TO 43
YES
IS
(C(2)-C(1)).NE.0.0
NO
DADC=0.0
GO TO 45
43
DADC=(A(2)-A(1))/(C(2)-C(1))
45
BS(6)=(A(1)-C(1)*DADC)/(1.-DADC)
A(1)=A(2)
C(1)=C(2)
DCA1=DCA2
DA=DA/2.
GO TO 3
15
ONEOM=1.0/BS(6)
ANGLE(3)=ARSIN(ONEOM)*57.295779
Z=(5.0+ENS(I))*(5.0+BS(6)**2)


ISDET.EQ.2
IS
YES
GO TO 20
NO
BS(1)=FS(1)*Z**2.5
BS(2)=FS(2)*Z**3.5
BS(3)=FS(3)*Z
BS(4)=FS(4)*SQRT(Z)
BS(3).GE.225.0
IS
NO
YES
BS(5)=2.27*BS(3)**1.5/((BS(3)+198.6)*10.0**8)
BS(3).LT.225.0
IS
NO
YES
BS(5)=0.80382436E-9*BS(3)
BS(7)=BS(6)*BS(4)
BS(8)=BS(1)*BS(7)/BS(5)
GO TO 14
20
CP=(Z**3.5-1.0)/(0.7*EMSQ)
14
RETURN

```
SYMBOLS USED IN SUBROUTINE EXPAND

A         R  D  ITERATION VARIABLE ARRAY                                    EXPAND
ANGLE     R  A  FLOW ANGLE ARRAY                                            EXPAND
AREA2     R  C  QNADRILATERAL ELEMENT AREA ARRAY                            EXPAND
BS        R  C  FLOW CONDITIONS BEHIND SHOCK OR EXPANSION                   EXPAND
C         R  D  ITERATION VARIABLE ARRAY                                    EXPAND
CASE      I  C  CASE NUMBER                                                 EXPAND
CP        R  A  PRESSURE COEFFICIENT                                        EXPAND
DA        R  U  ITERATION INCREMENT                                         EXPAND
DADC      R  U  EXPANSION ITERATION PARAMETER                               EXPAND
DCA1      R  U  EXPANSION ITERATION PARAMETER                               EXPAND
DCA2      R  U  EXPANSION ITERATION PARAMETER                               EXPAND
EMSQ      R  U  MACH NUMBER SQUARED                                         EXPAND
EPS       R  U  ITERATION ACCURACY PARAMETER                                EXPAND
ERROR     I  C  ERROR FLAG                                                  EXPAND
FS        R  C  FLOW CONDITIONS BEFORE SHOCK OR EXPANSION                   EXPAND
GR        R  U  GAMMA RATIO FUNCTION                                        EXPAND
I         I  U  ITERATION COUNTER                                           EXPAND
IM        I  C  ELEMENT ROW NUMBER ARRAY                                    EXPAND
IN        I  C  ELEMENT COLUMN NUMBER ARRAY                                 EXPAND
IPRINT    I  A  PRINT FLAG                                                  EXPAND
ISDET     I  A  DATA GENERATION CONTROL FLAG                                EXPAND
JPATH     I  U  CONTROL FLAG FOR ITERATION PATH                             EXPAND
K         I  C  NUMBER OF ELEMENTS                                          EXPAND
LS        I  C  NUMBER OF ELEMENTS                                          EXPAND
MER       I  A  ERROR FLAG                                                  EXPAND
NU1       R  U  INITIAL PRANDTL-MEYER ANGLE, RADIANS                        EXPAND
NU1D      R  U  INITIAL PRANDTL-MEYER ANGLE, DEGREES                        EXPAND
NU2       R  U  FINAL PRANDTL-MEYER ANGLE, RADIANS                          EXPAND
NU2D      R  U  FINAL PRANDTL-MEYER ANGLE, DEGREES                          EXPAND
NX2       R  C  ELEMENT DIRECTION COSINE ARRAY-X                            EXPAND
NY2       R  C  ELEMENT DIRECTION COSINE ARRAY-Y                            EXPAND
NZ2       R  C  ELEMENT DIRECTION COSINE ARRAY-Z                            EXPAND
ONEOM     R  U  SINE OF ANGLE 3                                             EXPAND
PAGE      I  C  PAGE NUMBER                                                 EXPAND
R         R  U  VARIABLE IN MACH NUMBER EQUATION                            EXPAND
TITLE     R  C  TITLE                                                       EXPAND
```

```
SYMBOLS USED IN SUBROUTINE EXPAND

XCENT2   R  C  ELEMENT CENTROID ARRAY-X                                          EXPAND
YCENT2   R  C  ELEMENT CENTROID ARRAY-Y                                          EXPAND
Z        R  U  FLOW CHARACTERISTIC PARAMETERS                                    EXPAND
ZCENT2   R  C  ELEMENT CENTROID ARRAY-Z                                          EXPAND
```

16. SUBROUTINE NEWTPM (DECK AROO)

This subroutine calculates the pressure coefficients on a surface by the blunt-body Newtonian + Prandtl-Meyer method.

a. Algorithm

This first section of this routine performs an iteration to find the matching point Mach number. A Prandtl-Meyer expansion is then calculated from the matching point condition to the local element slope using the EXPAND routine. Finally, the pressure coefficient and the local flow properties are calculated.

b. Input/Output

None

c. Error

None

d. Subroutines Required

EXPAND

e. Argument List

(ANGLE, EMN, CP, ETAC, IPRINT, MER, CPSTAG, TFS, PFS, ISE, IFIRST)

f. Length

2862 bytes

DECK AROD

```
      SUBROUTINE NEWTPM (ANGLE,EMN,CP,ETAC,IPRINT,MER,CPSTAG,           AROD  0010
     1  TFS,PFS,ISE,IFIRST )                                            AROD  0020
C                                                                       AROD  0030
C  THIS SUBROUTINE CALCULATES THE SURFACE CONDITIONS USING THE BLUNT   AROD  0040
C  BODY SHOCK-EXPANSION TECHNIQUE OF KAUFMAN, JOURNAL OF THE           AROD  0050
C  ASTRONAUTICAL SCIENCES, VOL X, NO.2 SUMMER 1963.                    AROD  0060
C                                                                       AROD  0070
      DIMENSION FS(8),BS(8),ANGLE(3)                                    AROD  0080
      DIMENSION  TITLE(15)                                              AROD  0090
      DIMENSION NX2( 300),NY2( 300),NZ2( 300),XCENT2( 300),             AROD  0100
     1  YCENT2( 300),ZCENT2( 300),AREA2( 300),IN( 300),IM( 300)         AROD  0110
      COMMON  CASE,TITLE,PAGE,ERROR,NX2,NY2,NZ2,XCENT2,YCENT2,ZCENT2,   AROD  0120
     1  AREA2,IN,IM,K,LS,FS,BS                                          AROD  0130
      REAL  NX2, NY2, NZ2                                               AROD  0140
      INTEGER  CASE,PAGE,ERROR                                          AROD  0150
C                                                                       AROD  0160
      REAL MACHO, MACH, MSUBQ, MU, MACHSQ, M1, M2                       AROD  0170
C                                                                       AROD  0180
C                                                                       AROD  0190
      IF (CPSTAG .LE. 0.01) CPSTAG = 2.0                                AROD  0200
      IF (ETAC .LE. 0.01) ETAC = 1.0                                    AROD  0210
      MER = 0                                                           AROD  0220
      IF (IFIRST .EQ. 1) GO TO 11                                       AROD  0230
      IFIRST = 1                                                        AROD  0240
      MACHO = FS(6)                                                     AROD  0250
C                                                                       AROD  0260
C                                                                       AROD  0270
C  THE FOLLOWING SECTION PERFORMS AN ITERATION TO FIND THE MATCHING    AROD  0280
C  POINT MACH NUMBER. IT ONLY WORKS FOR GAMMA = 1.4.                   AROD  0290
C                                                                       AROD  0300
C  SET GAMMA = G = 1.4                                                 AROD  0310
      G = 1.4                                                           AROD  0320
      J = 0                                                             AROD  0330
C  SOLVE FOR PRESSURE RATIO  (1.0/ EQ. 100 OF TR 1135)                 AROD  0340
      PCAP= (2./((G+1.0)*MACHO*MACHO))**(G/(G-1.0))   *                 AROD  0350
```

```
DECK AROO

     1    ((2.*G*MACHO*MACHO-(G-1.0))/(G+1.0))**(1.0/(G-1.0))                AROO  0360
C                                                                            AROO  0370
C  ASSUME MACH SUB Q = 1.35                                                  AROO  0380
      MSUBQ = 1.35                                                           AROO  0390
C                                                                            AROO  0400
C  CALCULATE  Q  (SEE KAUFMAN)                                               AROO  0410
   9  Q =  (2.0/(2.0+ (G-1.0)*MSUBQ*MSUBQ))**(G/(G-1.0))                    AROO  0420
C                                                                            AROO  0430
C  CALCULATE P SUB C  (EQ 9 OF KAUFMAN)                                      AROO  0440
      PC = Q * (1.0 - (G*G*MSUBQ**4*Q)/ (4.0*(MSUBQ*MSUBQ-1.0)*(1.-Q)))      AROO  0450
      CPQ = (2.0 / (G*MACHO*MACHO)) * (Q/PC - 1.0)                           AROO  0460
      IF (IPRINT .EQ. 0) GO TO 12                                            AROO  0470
      WRITE (6,10) MSUBQ,PC,CPQ                                              AROO  0480
  10  FORMAT (1H ,17X7HMSUBQ =F9.6,6H  PC =1PE11.4,7H  CPQ =E11.4 )          AROO  0490
C                                                                           .AROO  0500
C  CHECK ITERATION ACCURACY                                                  AROO  0510
  12  IF (ABS(PCAP-PC) .LT. 0.0000001) GO TO 7                               AROO  0520
C                                                                            AROO  0530
C  SET UP ITERATION TERMS                                                    AROO  0540
      P1 = P2                                                                AROO  0550
      P2 = PC                                                                AROO  0560
      M1 = M2                                                                AROO  0570
      M2 = MSUP                                                              AROO  0580
C                                                                            AROO  0590
C  STEP ITERATION COUNTER AND CHECK CYCLE                                    AROO  0600
      J = J + 1                                                              AROO  0610
      IF (J .GT. 1) GO TO 8                                                  AROO  0620
       MSUBQ= 1.7                                                            AROO  0630
       GO TO 9                                                               AROO  0640
   8  IF (J.GT. 20) GO TO 7                                                  AROO  0650
C  ESTIMATE NEW M                                                            AROO  0660
      MSUBQ = M1 + (PCAP-P1)*(M2-M1)/(P2-P1)                                 AROO  0670
C  CHECK NEW ESTIMATE FOR M                                                  AROO  0680
      IF (MSUBQ .GT. 1.75) MSUBQ = 1.75                                      AROO  0690
      IF (MSUBQ .LT. 1.35) MSUBQ = 1.35                                      AROO  0700
      IF (MSUBQ.EQ.M1 .OR. MSUBQ.EQ.M2) MSUBQ = MSUBQ + 0.0001               AROO  0710
```

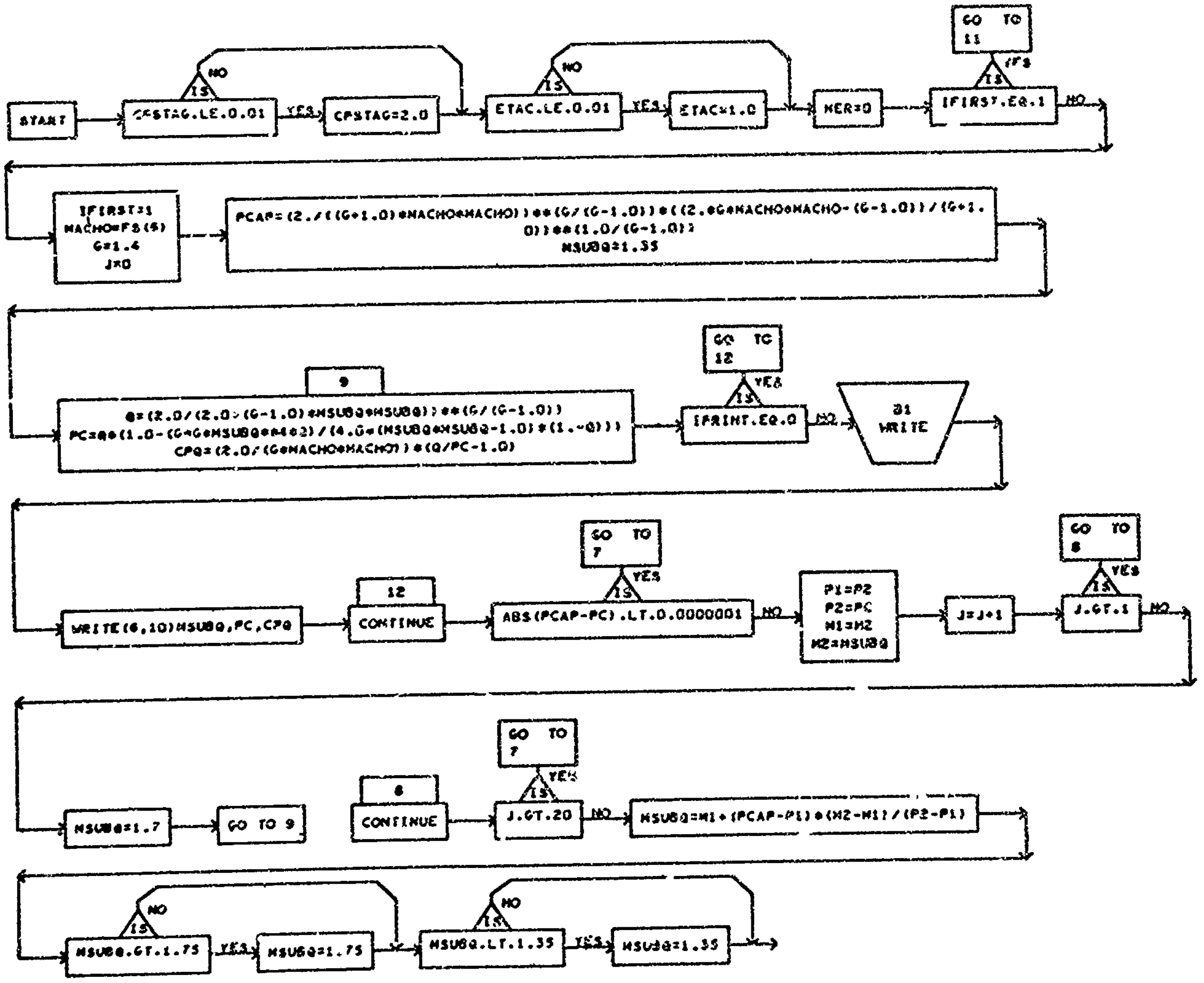
```
      GO TO 9                                                           AROO 0720
C                                                                       AROO 0730
C  CALCULATE MATCHING POINT IMPACT ANGLE                                AROO 0740
    7 SDELTQ = SQRT((Q-PCAP)/(1.0-PCAP))                                AROO 0750
      DELTQ = ARSIN(SDELTQ) * 0.5729578E02                              AROO 0760
C                                                                       AROO 0770
C  CALCULATE EXPANSION ANGLE FROM MATCHING POINT                        AROO 0780
   11 DLTMU = DELTQ - ANGLE(2)                                          AROO 0790
C                                                                       AROO 0800
C  CHECK IF FLOW WILL EXPAND AT LEAST TO MATCHING POINT                 AROO 0810
      IF (DLTMU .LT. 0.0) GO TO 2                                       AROO 0820
C                                                                       AROO 0830
C  DETERMINE MACH NUMBER ON SURFACE                                     AROO 0840
      FS(6) = MSUBQ                                                     AROO 0850
      ANGLE(2) = DLTMU                                                  AROO 0860
C                                                                       AROO 0870
      ISDET = 0                                                         AROO 0880
      CALL EXPAND (ANGLE,MER,IPRINT,ISDET,CP)                           AROO 0890
      FS(6) = MACHO                                                     AROO 0900
C  SET UP SURFACE MACH NUMBER                                           AROO 0910
      MACH = BS(6)                                                      AROO 0920
C                                                                       AROO 0930
C  CALCULATE SURFACE PRESSURE RATIO (EQ. 44 OF TR 1135)                 AROO 0940
      PPO = ETAC * (1.0 + (G-1.0)*MACH*MACH/2.0)**(-G/(G-1.0))          AROO 0950
C                                                                       AROO 0960
C  CALCULATE  P / P FREE STREAM                                         AROO 0970
      PPFS = (1.0/PCAP)*PPO                                             AROO 0980
C  CALCULATE PRESSURE COEFFICIENT ON SURFACE                            AROO 0990
      CP =  (2.0/(G*MACHO*MACHO))* (PPFS - 1.0)                         AROO 1000
      IF (IPRINT .EQ. 0) GO TO 3                                        AROO 1010
      WRITE (6,5) MSUBQ,PCAP,Q,PPO,MACH,DELTQ,PC,DLTMU,PPFS,CP          AROO 1020
    5 FORMAT (1H ,17X23HSHOCK-EXPANSION  M Q  =F7.5,8H  P CAP=1PE11.4,  AROO 1030
     1  8H  Q     =E11.4,8H  P/PO =F11.4,7H  MACH=0PF7.3,/1H ,17X       AROO 1040
     2 23HCALCULATIONS      DELTQ=F7.3,8H  P C  =1PE11.4, 8H  DLTMU=    AROO 1050
     3  E11.4,8H  P/PFS=E11.4,5H  CP=0PF9.5 )                           AROO 1060
C  CHECK IF FLOW CONDITIONS ARE NEEDED                                  AROO 1070
```

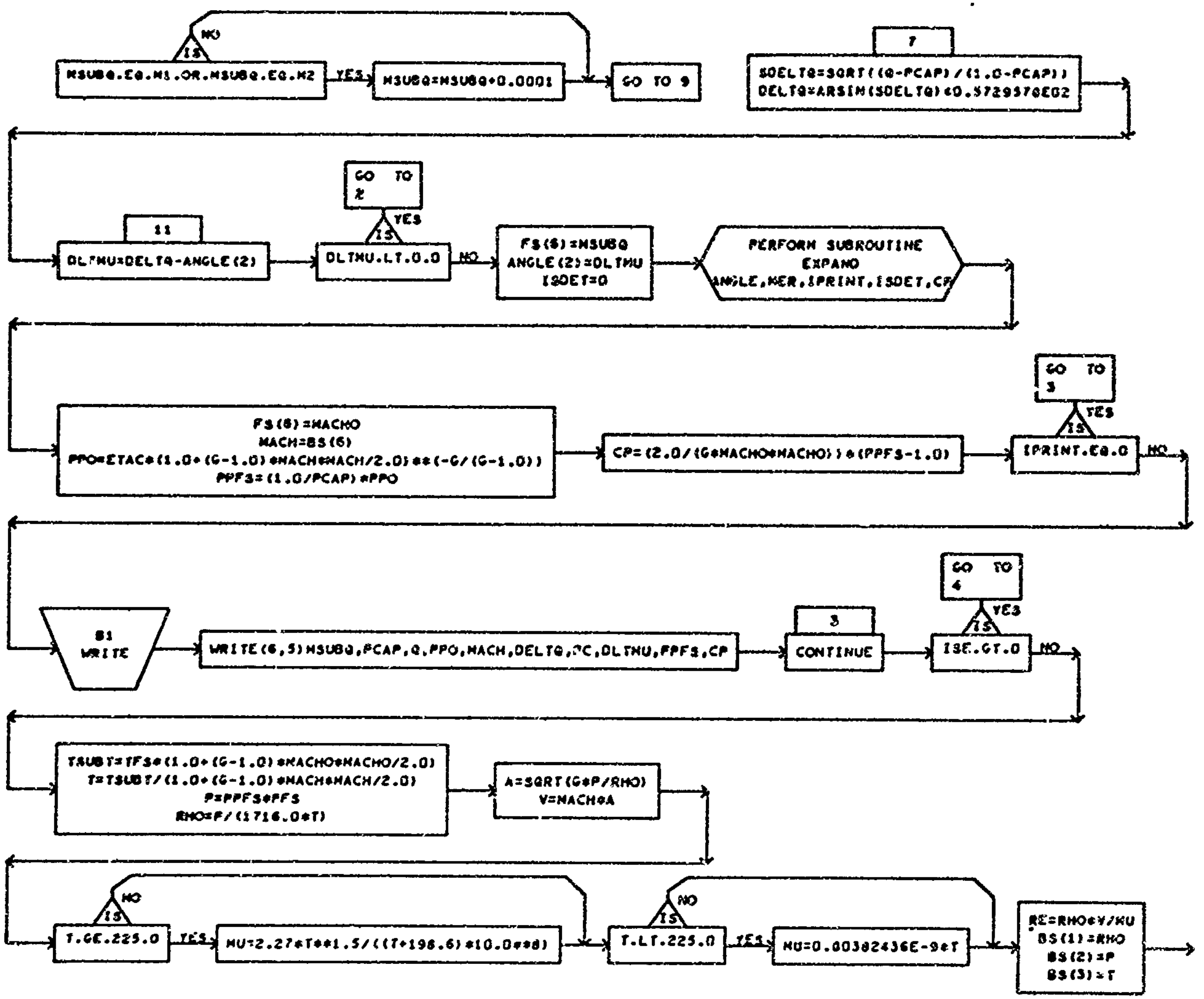
```
DECK AROO

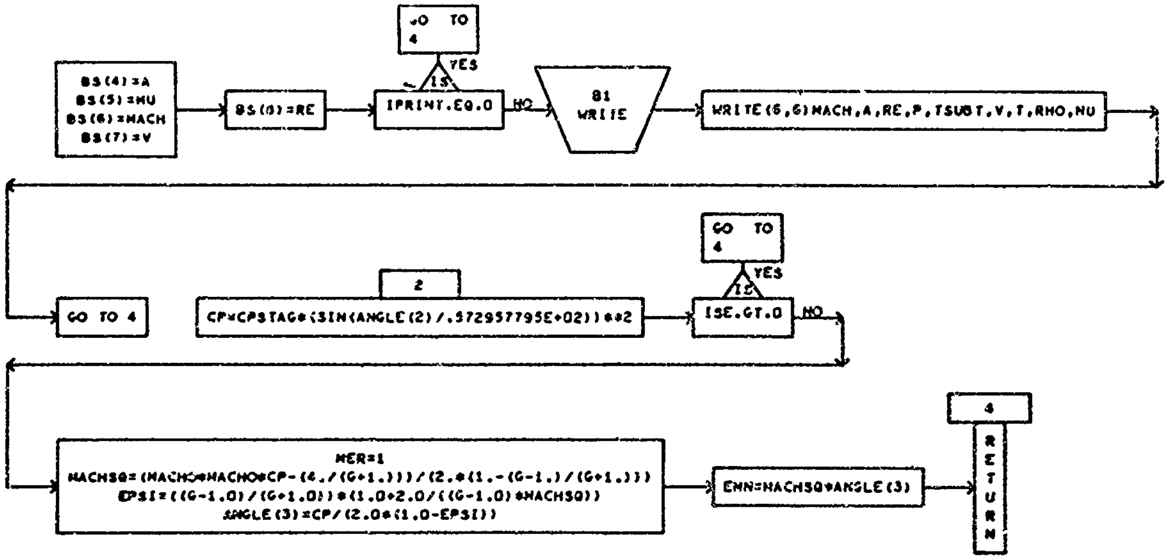
   3  IF (ISE .GT. 0) GO TO 4                                    AROO 1080
C                                                                AROO 1090
C  CALCULATE FREE STREAM TOTAL TEMPERATURE (EQ. 43 OF TR 1135)   AROO 1100
      TSUBT = TFS * (1.0 +  (G-1.0)*MACHO*MACHO/2.0)             AROO 1110
C                                                                AROO 1120
C  CALCULATE TEMPERATURE AFTER EXPANSION (IN RANKINE)            AROO 1130
      T  = TSUBT /  (1.0 + (G-1.0)*MACH*MACH / 2.0)              AROO 1140
C                                                                AROO 1150
C  CALCULATE SURFACE PRESSURE                                    AROO 1160
      P  = PPFS * PFS                                            AROO 1170
C                                                                AROO 1180
C  CALCULATE DENSITY (FQ. 26 OF TR 1135)                         AROO 1190
      RHO  = P / (1716.0*T)                                      AROO 1200
C                                                                AROO 1210
C  CALCULATE LOCAL SPEED CF SCUND                                AROO 1220
      A =  SQRT(G*P/RHO)                                         AROO 1230
C                                                                AROO 1240
C  CALCULATE LOCAL VELOCITY                                      AROO 1250
      V = MACH * A                                               AROO 1260
C                                                                AROO 1270
C  CALCULATE VISCOSITY                                           AROO 1280
      IF(T.GE.225.0) MU = 2.27*T**1.5/((T+198.6)*10.0**8)        AROO 1290
      IF(T.LT.225.0) MU = 0.8C382436E-9 * T                      AROO 1300
C                                                                AROO 1310
C  CALCULATE REYNOLDS NUMBER PER FOOT (EQ) B1 TR1135)            AROO 1320
      RE  = RHO * V / MU                                         AROO 1330
C                                                                AROO 1340
C  SET UP DATA FOR USE BACK IN OTHER SUBROUTINES                 AROO 1350
      BS(1) = RHO                                                AROO 1360
      BS(2) = P                                                  AROO 1370
      BS(3) = T                                                  AROO 1380
      BS(4) = A                                                  AROO 1390
      BS(5) = MU                                                 AROO 1400
      BS(6) = MACH                                               AROO 1410
      BS(7) = V                                                  AROO 1420
      BS(8) = RE                                                 AROO 1430
```

```
DECK AROO
      IF (IPRINT .EQ. 0) GO TO 4                                          AROO  1440
      WRITE (6,6) MACH,A,RE,P,TSUBT,V,T,RHO,MU                            AROO  1450
    6 FORMAT (1H ,34X6HMACH =F7.5,8H  A    =1PE11.4,8H  RE   =E11.4,      AROO  1460
     1  8H  P    =E11.4,7H  TTOT=0PF7.1,/1H ,34X6HV    =F7.1,8H  T    =   AROO  1470
     2  1PE11.4,8H  RHO  =E11.4,8H  MU   =E11.4  )                        AROO  1480
C                                                                         AROO  1490
C                                                                         AROO  1500
      GO TO 4                                                             AROO  1510
C                                                                         AROO  1520
C                                                                         AROO  1530
C   FLOW HAS NOT REACHED THE MATCHING POINT. USE NEWTONIAN CALCULATIONS   AROO  1540
C   AND SHOCK DETACHED METHOD SUGGESTED BY SMYTH.                         AROO  1550
    2 CP = CPSTAG * (SIN(ANGLE(2)/.572957795E+02))**2                     AROO  1560
C                                                                         AROO  1570
C   CHECK IF FLOW CONDITIONS ARE NEEDED                                   AROO  1580
      IF (ISE .GT. 0) GO TO 4                                             AROO  1590
      MER = 1                                                             AROO  1600
C                                                                         AROO  1610
C   CALCULATE FLOW DATA FOR DETACHED CONDITIONS                           AROO  1620
C   CALCULATE SQUARE OF MACH NUMBER NORMAL TO EFFECTIVE SHOCK             AROO  1630
      MACHSQ=(MACHO*MACHO*CP-(4./(G+1.)))/(2.*(1.-(G-1.)/(G+1.)))         AROO  1640
C   CALCULATE EFFECTIVE DENSITY RATIO                                     AROO  1650
      EPSI = ((G-1.0)/(G+1.0))* (1.0 + 2.0/((G-1.0)*MACHSQ))              AROO  1660
C   CALCULATE THE EFFECTIVE SHOCK ANGLE SQUARED                           AROO  1670
      ANGLE(3) = CP / (2.0*(1.0-EPSI))                                    AROO  1680
C   CALCULATE NORMAL MACH SQUARED TIMES SQUARE OF SHOCK ANGLE             AROO  1690
      EMN = MACHSQ * ANGLE(3)                                             AROO  1700
C                                                                         AROO  1710
    4 RETURN                                                              AROO  1720
C                                                                         AROO  1730
      END                                                                 AROO  1740
```

SUBROUTINE NEWTPN




MSUBQ.EQ.M1.OR.MSUBQ.EQ.M2
IS
NO
YES
MSUBQ=MSUBQ+0.0001
GO TO 9
7
SDELTQ=SQRT((Q-PCAP)/(1.0-PCAP))
DELTQ=ARSIN(SDELTQ)*0.5729570E02
11
DLTMU=DELTQ-ANGLE(2)
DLTMU.LT.0.0
IS
YES
GO TO 2
NO
FS(6)=MSUBQ
ANGLE(2)=DLTMU
ISDET=0
PERFORM SUBROUTINE
EXPANO
ANGLE,MER,IPRINT,ISDET,CP
FS(6)=MACHO
MACH=BS(6)
PPO=ETAC*(1.0+(G-1.0)*MACH*MACH/2.0)**(-G/(G-1.0))
PPFS=(1.0/PCAP)*PPO
CP=(2.0/(G*MACHO*MACHO))*(PPFS-1.0)
IPRINT.EQ.0
IS
YES
GO TO 3
NO
81
WRITE
WRITE(6,5)MSUBQ,PCAP,Q,PPO,MACH,DELTQ,?C,DLTMU,PPFS,CP
3
CONTINUE
ISE.GT.0
IS
YES
GO TO 4
NO
TSUBT=TFS*(1.0+(G-1.0)*MACHO*MACHO/2.0)
T=TSUBT/(1.0+(G-1.0)*MACH*MACH/2.0)
P=PPFS*PFS
RHO=P/(1716.0*T)
A=SQRT(G*P/RHO)
V=MACH*A
T.GE.225.0
IS
NO
YES
MU=2.27*T**1.5/((T+198.6)*10.0**8)
T.LT.225.0
IS
NO
YES
MU=0.00382436E-9*T
RE=RHO*V/MU
BS(1)=RHO
BS(2)=P
BS(3)=T


BS(4)=A
BS(5)=NU
BS(6)=MACH
BS(7)=V
BS(8)=RE
IPRINT.EQ.0
IS
YES
GO TO 4
NO
81
WRITE
WRITE(6,6)MACH,A,RE,P,TSUBT,V,T,RHO,NU
GO TO 4
2
CP=CPSTAG*(SIN(ANGLE(2)/.572957795E+02))**2
ISE.GT.0
IS
YES
GO TO 4
NO
NER=1
MACHSQ=(MACH0*MACH0*CP-(4./(G+1.)))/(2.*(1.-(G-1.)/(G+1.)))
EPSI=((G-1.0)/(G+1.0))*(1.0+2.0/((G-1.0)*MACHSQ))
ANGLE(3)=CP/(2.0*(1.0-EPSI))
ENN=MACHSQ*ANGLE(3)
4
RETURN

```
SYMBOLS USED IN SUBROUTINE NEWTPM

A        R  U  SPEED OF SOUND                                             NEWTPM
ANGLE    R  A  FLOW ANGLE ARRAY                                           NEWTPM
AREA2    R  C  QUADRILATERAL ELEMENT AREA ARRAY                           NEWTPM
BS       R  C  FLOW CONDITIONS BEHIND SHOCK OR EXPANSION                  NEWTPM
CASE     I  C  CASE NUMBER                                                NEWTPM
CP       R  A  PRESSURE COEFFICIENT                                       NEWTPM
CPQ      R  U  PRESSURE COEFFICIENT AT MATCHING POINT                     NEWTPM
CPSTAG   R  A  MODIFIED NEWTONIAN CORRELATION FACTOR, K                   NEWTPM
DELTQ    R  U  IMPACT ANGLE AT MATCHING POINT                             NEWTPM
DLTMU    R  U  EXPANSION ANGLE FROM MATCHING MOMENT                       NEWTPM
EMN      R  A  MACH NUMBER TIMES SHOCK ANGLE SQUARED                      NEWTPM
EPSI     R  U  EFFECTIVE DENSITY RATIO                                    NEWTPM
ERROR    I  C  ERROR FLAG                                                 NEWTPM
ETAC     R  A  PRANDTL-MEYER EXPANSION CORRECTION FACTOR                  NEWTPM
FS       R  C  FLOW CONDITIONS BEFORE SHOCK OR EXPANSION                  NEWTPM
G        R  U  RATIO OF SPECIFIC HEATS = 1.4                              NEWTPM
IFIRST   I  A  FIRST POINT FLAG FOR USE IN NEWTPM                         NEWTPM
IM       I  C  ELEMENT ROW NUMBER ARRAY                                   NEWTPM
IN       I  C  ELEMENT COLUMN NUMBER ARRAY                                NEWTPM
IPRINT   I  A  PRINT FLAG                                                 NEWTPM
ISDET    I  U  DATA GENERATION CONTROL FLAG                               NEWTPM
ISE      I  A  DATA GENERATION CONTROL FLAG                               NEWTPM
J        I  U  ITERATION COUNTER                                          NEWTPM
K        I  C  NUMBER OF ELEMENTS                                         NEWTPM
LS       I  C  NUMBER OF ELEMENTS                                         NEWTPM
MACH     R  U  MACH NUMBER                                                NEWTPM
MACHO    R  U  INITIAL MACH NUMBER                                        NEWTPM
MACHSQ   R  U  SQUARE OF MACH NUMBER NORMAL TO EFFECIVE SHOCK             NEWTPM
MER      I  A  ERROR FLAG                                                 NEWTPM
MSUBQ    R  U  MACH NUMBER AT MATCHING POINT                              NEWTPM
MU       R  U  VISCOSITY                                                  NEWTPM
M1       R  U  FIRST ITERATION MACH NUMBER                                NEWTPM
M2       R  U  SECOND ITERATION MACH NUMBER                               NEWTPM
NX2      R  C  ELEMENT DIRECTION COSINE ARRAY-X                           NEWTPM
NY2      R  C  ELEMENT DIRECTION COSINE ARRAY-Y                           NEWTPM
NZ2      R  C  ELEMENT DIRECTION COSINE ARRAY-Z                           NEWTPM
```

```
SYMBOLS USED IN SUBROUTINE NEWTPM

P        R  U  PRESSURE                                                   NEWTPM
PAGE     I  C  PAGE NUMBER                                                NEWTPM
PC       R  U  FREE-STREAM STATIC TO STAGNATION PRESSURE RATIO            NEWTPM
PCAP     R  U  FREE-STREAM STATIC TO STAGNATION PRESSURE RATIO            NEWTPM
PFS      R  A  FREE-STREAM PRESSURE, LBS / SQUARE FOOT                    NEWTPM
PPFS     R  U  LOCAL TO FREE-STREAM PRESSURE RATIO                        NEWTPM
PPO      R  U  SURFACE PRESSURE RATIO                                     NEWTPM
P1       R  U  FIRST ITERATION PRESSURE                                   NEWTPM
P2       R  U  SECOND ITERATION PRESSURE                                  NEWTPM
Q        R  U  MATCHING POINT TO FREE-STREAM STATIC PRESSURE RATIO        NEWTPM
RE       R  U  REYNOLDS NUMBER                                            NEWTPM
RHO      R  U  DENSITY                                                    NEWTPM
SDELTQ   R  U  SINE OF MATCHING POINT IMPACT ANGLE                        NEWTPM
T        R  U  TEMPERATURE                                                NEWTPM
TFS      R  A  FREE STREAM TEMPERATURE                                    NEWTPM
TITLE    R  C  TITLE                                                      NEWTPM
TSUBT    R  U  FREE STREAM TOTAL TEMPERATURE                              NEWTPM
V        R  U  VELOCITY                                                   NEWTPM
XCENT2   R  C  ELEMENT CENTROID COORDINATE-X                              NEWTPM
YCENT2   R  C  ELEMENT CENTROID COORDINATE-Y                              NEWTPM
ZCENT2   R  C  ELEMENT CENTROID COORDINATE-Z                              NEWTPM
```

```
SYMBOLS USED IN SUBROUTINE NEWTPM

P         R  U  PRESSURE                                                    NEWTPM
PAGE      I  C  PAGE NUMBER                                                 NEWTPM
PC        R  U  FREE-STREAM STATIC TO STAGNATION PRESSURE RATIO             NEWTPM
PCAP      R  U  FREE-STREAM STATIC TO STAGNATION PRESSURE RATIO             NEWTPM
PFS       R  A  FREE-STREAM PRESSURE, LBS / SQUARE FOOT                     NEWTPM
PPFS      R  U  LOCAL TO FREE-STREAM PRESSURE RATIO                         NEWTPM
PPO       R  U  SURFACE PRESSURE RATIO                                      NEWTPM
P1        R  U  FIRST ITERATION PRESSURE                                    NEWTPM
P2        R  U  SECOND ITERATION PRESSURE                                   NEWTPM
Q         R  U  MATCHING POINT TO FREE-STREAM STATIC PRESSURE RATIO         NEWTPM
RE        R  U  REYNOLDS NUMBER                                             NEWTPM
RHO       R  U  DENSITY                                                     NEWTPM
SDELTQ    R  U  SINE OF MATCHING POINT IMPACT ANGLE                         NEWTPM
T         R  U  TEMPERATURE                                                 NEWTPM
TFS       R  A  FREE STREAM TEMPERATURE                                     NEWTPM
TITLE     R  C  TITLE                                                       NEWTPM
TSUBT     R  U  FREE STREAM TOTAL TEMPERATURE                               NEWTPM
V         R  U  VELOCITY                                                    NEWTPM
XCENT2    R  C  ELEMENT CENTROID COORDINATE-X                               NEWTPM
YCENT2    R  C  ELEMENT CENTROID COORDINATE-Y                               NEWTPM
ZCENT2    R  C  ELEMENT CENTROID COORDINATE-Z                               NEWTPM
```

17. SUBROUTINE CONE (DECK AROP)

This subroutine solves for the local properties about a cone in supersonic flow using empirically derived equations.

a. Algorithm

Calculates the shock normal Mach number, surface pressure coefficient and, at the user's option the following local flow properties on the cone surface: pressure, density, temperature, velocity, speed of sound, Mach number, viscosity, and Reynolds number per foot. Solutions are empirically derived for a calorically perfect gas with ratio of specific heats equal to 1.40.

b. Input/Output

None

c. Error

None

d. Subroutines Required

None

e. Argument List

(ANGLE, CP, ISDT)

f. Length

1256 bytes

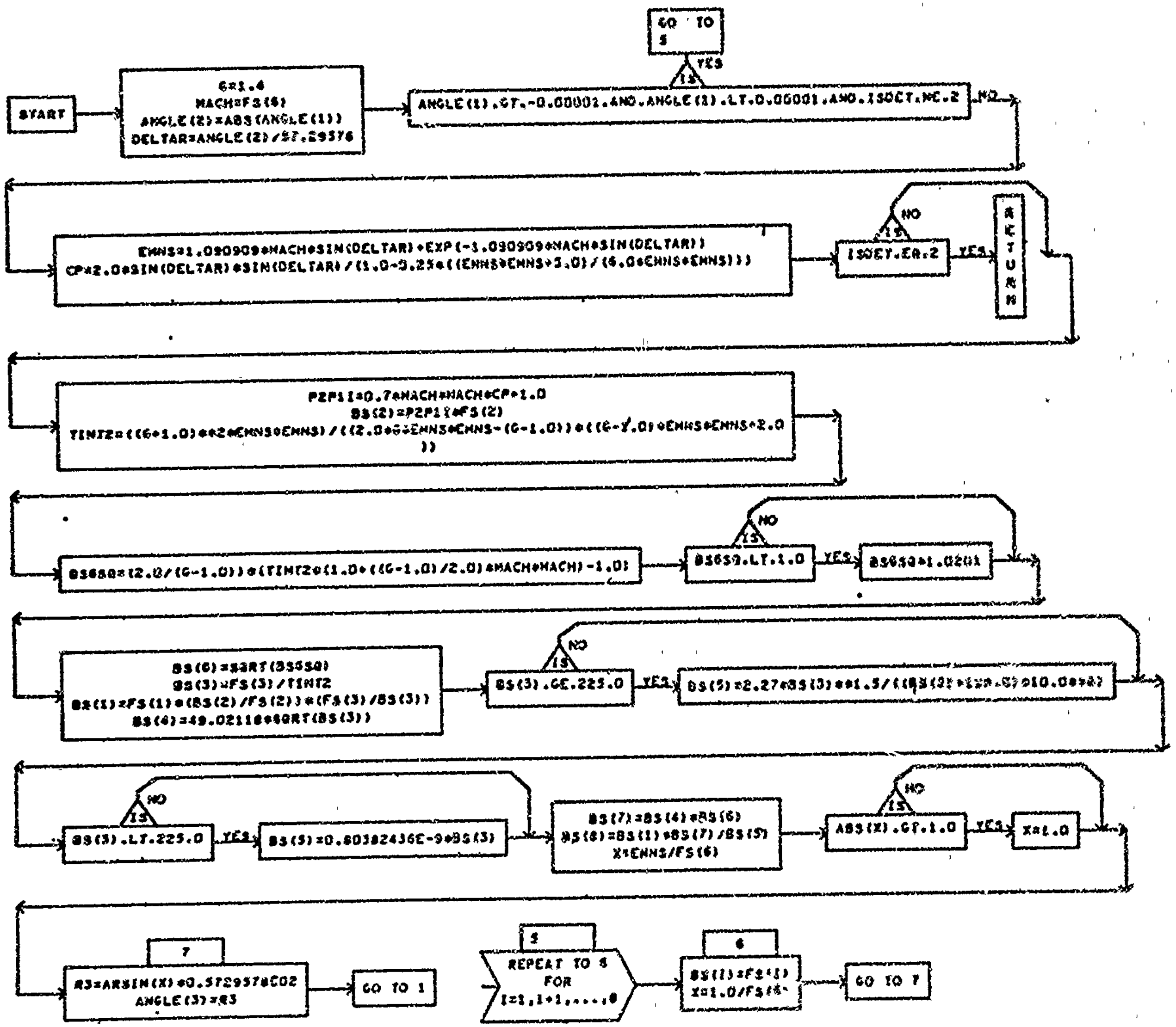
DECK AROP

```
      SUBROUTINE CONE (ANGLE,CP,ISDET)                                  AROP 0010
C  THIS ROUTINE SOLVES FOR THE FLOW PROPERTIES ABOUT A CONE             AROP 0020
C  USING EMPIRICAL EQUATIONS.                                           AROP 0030
      DIMENSION ANGLE(3),FS(8),BS(8)                                    AROP 0040
      DIMENSION  TITLE(15)                                              AROP 0050
      DIMENSION NX2( 300),NY2( 300),NZ2( 300),XCENT2( 300),             AROP 0060
     1 YCENT2( 300),ZCENT2( 300),AREA2( 300),IN( 300),IM( 300)          AROP 0070
      COMMON  CASE,TITLE,PAGE,ERROR,NX2,NY2,NZ2,XCENT2,YCENT2,ZCENT2,   AROP 0080
     1 AREA2,IN,IM,K,LS,FS,BS                                           AROP 0090
      REAL  NX2,NY2,NZ2,MACH                                            AROP 0100
      INTEGER  CASE,PAGE,ERROR                                          AROP 0110
      G = 1.4                                                           AROP 0120
      MACH = FS(6)                                                      AROP 0130
      ANGLE(2) =  ABS(ANGLE(1))                                         AROP 0140
      DELTAR = ANGLE(2)/57.29578                                        AROP 0150
      IF (ANGLE(1).GT.-0.00001.AND.ANGLE(1).LT.0.00001.AND.ISDET.NE.2)  AROP 0160
     1 GO TO 5                                                          AROP 0170
      EMNS = 1.090909*MACH*SIN(DELTAR) + EXP(-1.090909*MACH*SIN(DELTAR))AROP 0180
      CP = 2.0*SIN(DELTAR)*SIN(DELTAR)/(1.0-0.25*((EMNS*EMNS+5.0)/      AROP 0190
     1     (6.0*EMNS*EMNS)))                                            AROP 0200
      IF (ISDET .EQ. 2) RETURN                                          AROP 0210
      P2P1I = 0.7*MACH*MACH*CP + 1.0                                    AROP 0220
      BS(2) = P2P1I * FS(2)                                             AROP 0230
      TINT2 = ((G+1.0)**2 *EMNS*EMNS)/((2.0*G*EMNS*EMNS-(G-1.0))*       AROP 0240
     1        ((G-1.0)*EMNS*EMNS + 2.0))                                AROP 0250
      BS6SQ = (2.0/(G-1.0))*(TINT2*(1.0+((G-1.0)/2.0)*MACH*MACH)-1.0)   AROP 0260
      IF (BS6SQ .LT. 1.0) BS6SQ = 1.0201                                AROP 0270
      BS(6) = SQRT(BS6SQ)                                               AROP 0280
      BS(3) = FS(3) / TINT2                                             AROP 0290
      BS(1) = FS(1)*(BS(2)/FS(2))*(FS(3)/BS(3))                         AROP 0300
      BS(4) = 49.02118 * SQRT(BS(3))                                    AROP 0310
      IF(BS(3).GE.225.0) BS(5)=2.27*BS(3)**1.5/((BS(3)+198.6)*10.0**8)  AROP 0320
      IF(BS(3).LT.225.0) BS(5)=0.80382436E-9 * BS(3)                    AROP 0330
      BS(7) = BS(4)*BS(6)                                               AROP 0340
      BS(8) = BS(1)*BS(7)/BS(5)                                         AROP 0350
```

```
DECK AROP

C      CALCULATE SHOCK ANGLE                                         AROP  0360
       X = EMNS / FS(6)                                              AROP  0370
       IF (ABS(X) .GT. 1.0) X = 1.0                                  AROP  0380
    7  R3 = ARSIN(X) * 0.5729578E02                                  AROP  0390
       ANGLE(3) = R3                                                 AROP  0400
       GO TO 1                                                       AROP  0410
    5  DO 6 I=1,8                                                    AROP  0420
    6    BS(I) = FS(I)                                               AROP  0430
         X = 1.0 / FS(6)                                             AROP  0440
         GO TO 7                                                     AROP  0450
     1 RETURN                                                        AROP  0460
       END                                                           AROP  0470
```

SUBROUTINE CONE




1
RETURN

SYMBOLS USED IN SUBROUTINE CONE

```
ANGLE    R  A  FLOW ANGLE ARRAY                                  CONE
AREA2    R  C  QUADRILATERAL ELEMENT AREA ARRAY                  CONE
BS       R  C  FLOW CONDITIONS BEHIND COMPRESSION                CONE
BS6SQ    R  U  MACH NUMBER SQUARED                               CONE
CASE     I  C  CASE NUMBER                                       CONE
CP       R  U  PRESSURE COEFFICIENT                              CONE
CP       R  A  PRESSURE COEFFICIENT                              CONE
DELTAR   R  U  SURFACE IMPACT ANGLE IN RADIANS                   CONE
EMNS     R  U  MACH NUMBER NORMAL TO SHOCK                       CONE
ERROR    I  C  ERROR FLAG                                        CONE
FS       R  C  FLOW CONDITIONS BEFORE COMPRESSION                CONE
G        R  U  RATIO OF SPECIFIC HEATS =1.4                      CONE
IM       I  C  ELEMENT ROW NUMBER ARRAY                          CONE
IN       I  C  ELEMENT COLUMN NUMBER ARRAY                       CONE
ISDET    I  A  DATA GENERATION CONTROL FLAG                      CONE
K        I  C  NUMBER OF ELEMENTS                                CONE
LS       I  C  NUMBER OF ELEMENTS                                CONE
MACH     R  U  MACH NUMBER                                       CONE
NX2      R  C  ELEMENT DIRECTION COSINE ARRAY-X                  CONE
NY2      R  C  ELEMENT DIRECTION COSINE ARRAY-Y                  CONE
NZ2      R  C  ELEMENT DIRECTION COSINF ARRAY-Z                  CONE
PAGE     I  C  PAGE NUMBER                                       CONE
P2P1I    R  U  PRESSURE RATIO ACROSS COMPRESSION                 CONE
R3       R  U  SHOCK ANGLE PARAMETER                             CONE
TINT2    R  U  TEMPERATURE RATIO                                 CONE
TITLE    R  C  TITLE                                             CONE
X        R  U  SHOCK ANGLE PARAMETER                             CONE
XCENT2   R  C  ELEMENT CENTROID ARRAY-X                          CONE
YCENT2   R  C  ELEMENT CENTROID ARRAY-Y                          CONE
ZCENT2   R  C  ELEMENT CENTROID ARRAY-Z                          CONE
```

18. SUBROUTINE BLUNT (DECK AROQ)

This routine calculates the viscous forces on a blunt body including low density effects.

a. Algorithm

Checks for ideal or real gas option, then calculates local properties behind normal shock. Determines local viscous forces and calculates low density viscous-interaction effects.

b. Input/Output

IPRINT = 1, pertinent local and free-stream properties and viscous force coefficients will be printed. (This is intended for checkout only and IPRINT must be set within the program.)

c. Error

None

d. Subroutines Required

None

e. Argument List

(PFS, MACH, TFS, VIS, RHOFS, RB, RENO, TAU, IVISIN)

f. Length

1596 bytes

```
DECK AROQ

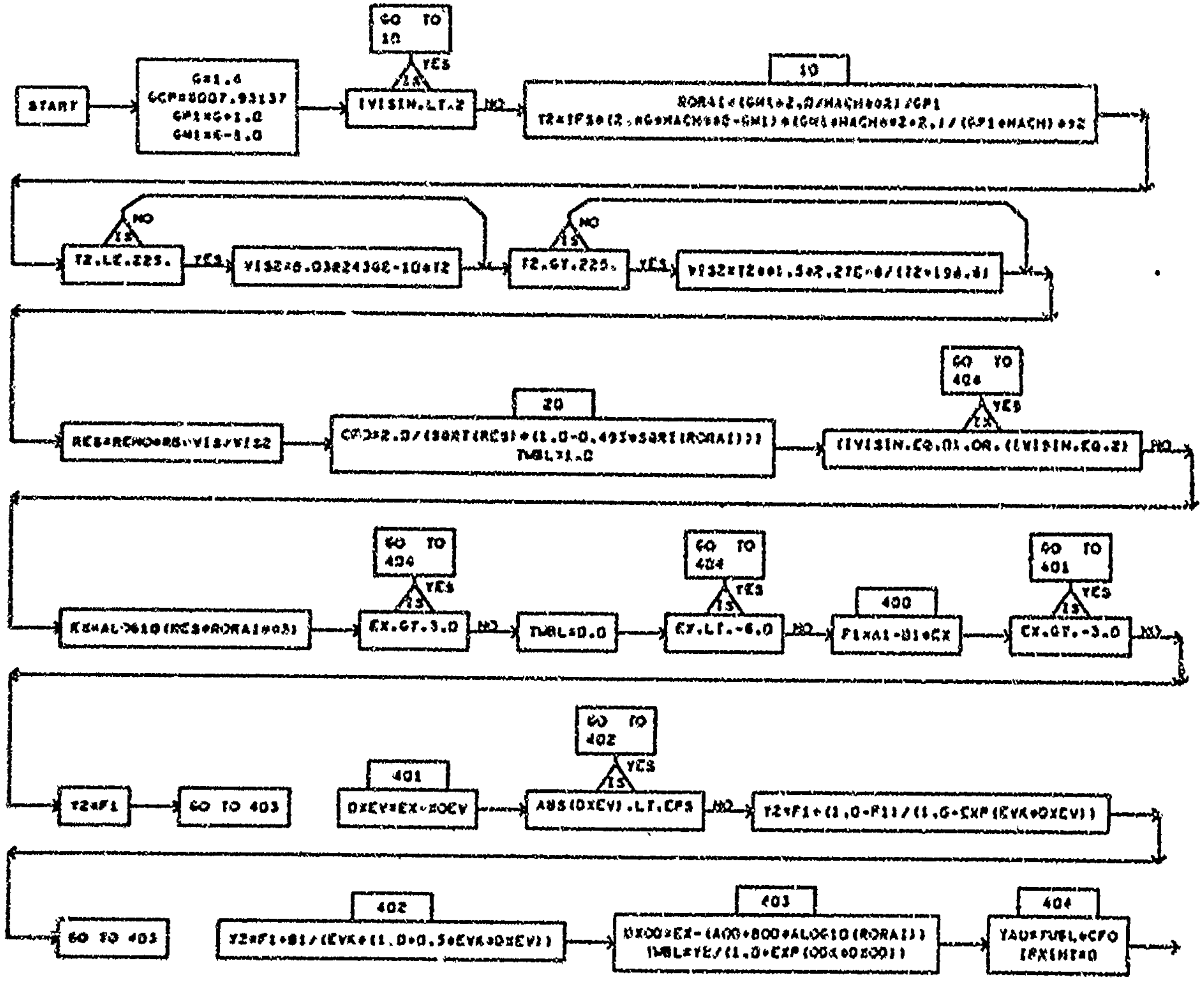
      SUBROUTINE BLUNT(PFS,MACH,TFS,VIS,RHOFS,RB,RENO,TAU,IVISIN)        AROQ  0010
C                                                                         AROQ  0020
C                                                                         AROQ  0030
C  THIS SUBROUTINE CALCULATES THE VISCOUS FORCES ON A BLUNT               AROQ  0040
C  FACED BODY FOLLOWING THE APPROACH SUGGESTED BY L. GOLDBERG IN          AROQ  0050
C  G. E. REPORT R66SD21 (SEE ALSO R65SD50).  THE STRAIGHT VISCOUS         AROQ  0060
C  FORCES ARE CALCULATED USING A SIMPLE CORRELATION FORMULA BASED ON      AROQ  0070
C  THE RESULTS OF SCALA AND GILBERT.  THE LOW DENSITY OR VISCOUS          AROQ  0080
C  INTERACTION EFFECTS ARE BASED ON NUMERICAL RESULTS OF HIGHER           AROQ  0090
C  ORDER BOUNDARY-LAYER SOLUTIONS.  THE SHEAR EFFECTS ARE A COMPLICATED   AROQ  0100
C  FUNCTION OF THE INVERSE DENSITY RATIO AND THE SHOCK REYNOLDS           AROQ  0110
C  NUMBER.  IN THE PRESENT CALCULATIONS THESE LOW DENSITY                 AROQ  0120
C  EFFECTS ARE DETERMINED FROM A SET OF EXPONENTIAL FUNCTION              AROQ  0130
C  CURVES WHICH HAVE BEEN MATCHED TO THE NUMERICAL RESULTS.               AROQ  0140
C  CALCULATION OPTIONS ARE CONTROLLED BY THE FLAG IVISIN.                 AROQ  0150
C                                                                         AROQ  0160
C        IVISIN      GAS      VISCOUS-INTERACTION                         AROQ  0170
C           0        IDEAL         NO                                     AROQ  0180
C           1        IDEAL         YES                                    AROQ  0190
C           2        REAL          NO                                     AROQ  0200
C           3        REAL          YES                                    AROQ  0210
C                                                                         AROQ  0220
C  THE LAST TWO OPTIONS ARE NOT YET AVAILABLE.                            AROQ  0230
C******M*******D. N. SMYTH PROGRAM AUTHOR*****************************    AROQ  0240
C                                                                         AROQ  0250
C                                                                         AROQ  0260
C                                                                         AROQ  0270
C                                                                         AROQ  0280
C                                                                         AROQ  0290
      DATA  AOD,   BOD,     A1,     B1,     ODK,  XOEV,   EVK,    EPS  /  AROQ  0300
     1      1.0, 3.2907,  0.667,  1.1111, -2.0,  -0.3,  -1.80,  0.01  /   AROQ  0310
      REAL MACH                                                           AROQ  0320
      G = 1.4                                                             AROQ  0330
      GCP = 6007.93137                                                    AROQ  0340
      GP1 = G + 1.0                                                       AROQ  0350
```

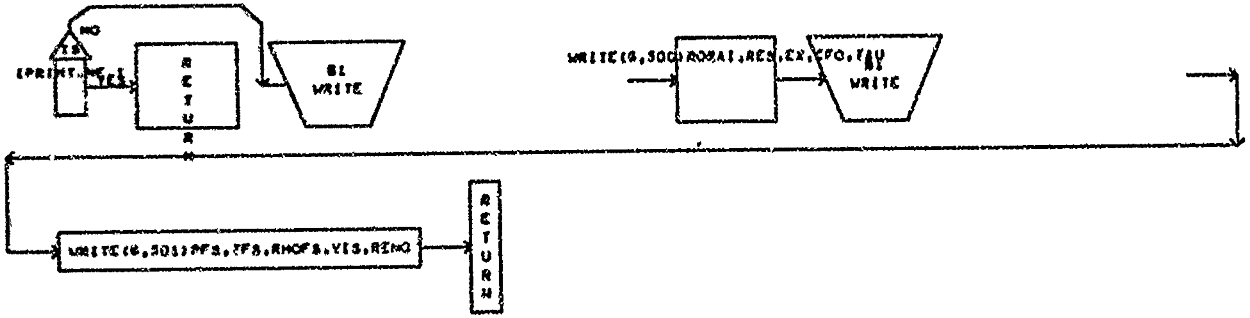
```
DECK AROQ
      GM1 = G - 1.0                                                     AROQ  0360
C                                                                       AROQ  0370
      IF (IVISIN.LT.2) GO TO 10                                         AROQ  0380
C                                                                       AROQ  0390
C  REAL GAS SOLUTION (TO BE ADDED).                                     AROQ  0400
C                                                                       AROQ  0410
C  IDEAL GAS SOLUTION.  ALL EQUATIONS FROM NACA TR-1135.                AROQ  0420
C  INVERSE DENSITY RATIO ACROSS NORMAL SHOCK.                           AROQ  0430
   10 RORAI = (GM1 + 2.0/MACH**2)/GP1                                   AROQ  0440
C                                                                       AROQ  0450
C  TEMPERATURE BEHIND NORMAL SHOCK.                                     AROQ  0460
      T2 = TFS*(2.*G*MACH**2-GM1)*(GM1*MACH**2+2.)/(GP1*MACH)**2        AROQ  0470
C                                                                       AROQ  0480
C  CALCULATE VISCOSITY.                                                 AROQ  0490
      IF (T2.LE.225.) VIS2 = 8.0382436E-10*T2                           AROQ  0500
      IF (T2.GT.225.) VIS2 = T2**1.5*2.27E-8/(T2+198.6)                 AROQ  0510
C                                                                       AROQ  0520
C  REYNOLDS NUMBER BEHIND NORMAL SHOCK.                                 AROQ  0530
      RES = RENO*RB*VIS/VIS2                                            AROQ  0540
C                                                                       AROQ  0550
C  CALCULATE SHEAR COEFFICIENT.                                         AROQ  0560
   20 CFO = 2.0/(SQRT(RES)*(1.0 - 0.495*SQRT(RORAI)))                   AROQ  0570
C                                                                       AROQ  0580
C  CHECK IF LOW DENSITY VISCOUS-INTERACTION EFFECTS DESIRED.            AROQ  0590
      TWBL = 1.0                                                        AROQ  0600
      IF((IVISIN.EQ.0).OR.(IVISIN.EQ.2))GO TO 404                       AROQ  0610
C                                                                       AROQ  0620
C  DETERMINE LOW DENSITY EFFECTS.  CALCULATE INDEPENDENT VARIABLE, EX.  AROQ  0630
      EX = ALOG10(RES*RORAI**3)                                         AROQ  0640
C                                                                       AROQ  0650
C  CHECK BOUNDARIES                                                     AROQ  0660
      IF (EX.GT.3.0) GO TO 404                                          AROQ  0670
      TWBL = 0.0                                                        AROQ  0680
      IF (EX.LT.-6.0) GO TO 404                                         AROQ  0690
C                                                                       AROQ  0700
C                                                                       AROQ  0710
```

```
DECK AROQ

  400 F1 = A1 - B1*EX                                                          AROQ  0720
      IF  (EX.GT.-3.0) GO TO 401                                               AROQ  0730
      Y2 = F1                                                                  AROQ  0740
      GO TO 403                                                                AROQ  0750
C                                                                              AROQ  0760
C                                                                              AROQ  0770
  401 DXEV = EX - XOEV                                                         AROQ  0780
      IF  (ABS(DXEV).LT.EPS)GO TO 402                                          AROQ  0790
      Y2 = F1 + (1.0 - F1)/(1.0 - EXP(EVK*DXEV))                               AROQ  0800
      GO TO 403                                                                AROQ  0810
C                                                                              AROQ  0820
C                                                                              AROQ  0830
  402 Y2 = F1 + B1/(EVK*(1.0 + 0.5*EVK*DXEV))                                  AROQ  0840
  403 DXOD = EX - (AOD + BOD*ALOG10(RORAI))                                    AROQ  0850
      TWBL = Y2/(1.0 + EXP(ODK*DXOD))                                          AROQ  0860
C                                                                              AROQ  0870
C                                                                              AROQ  0880
  404 TAU = TWBL*CFO                                                           AROQ  0890
C                                                                              AROQ  0900
C                                                                              AROQ  0910
C  THE FOLLOWING CARDS ARE FOR CHECKOUT ONLY (SET IPRINT = 1).                 AROQ  0920
C                                                                              AROQ  0930
      IPRINT = 0                                                               AROQ  0940
C                                                                              AROQ  0950
      IF (IPRINT.NE.1) RETURN                                                  AROQ  0960
      WRITE(6,500) RORAI,RES,EX,CFO,TAU                                        AROQ  0970
  500 FORMAT(1H1, 2X7HRORAI =,E13.6,5X5HRES =,E13.6,5X11H(E**3)RES =,          AROQ  0980
     1      E13.6,5X5HCFO =,E13.6, 5X5HTAU =,E13.6)                            AROQ  0990
      WRITE(6,501) PFS,TFS,RHOFS,VIS,RENO                                      AROQ  1000
  501 FORMAT(1H0,2X7H  PFS =,E13.6,5X5HTFS =,E13.6,5X11H    RHOFS =,           AROQ  1010
     1           E13.6,5X5HVIS =,E13.6, 4X6HRENO =,E13.6)                      AROQ  1020
      RETURN                                                                   AROQ  1030
      END                                                                      AROQ  1040
```

SUBROUTINE BLUNT




IPRINT.NE.1
IS
NO
YES
RETURN
81
WRITE
WRITE(6,500)ROMAI,RES,EX,EPO,TAU
82
WRITE
WRITE(6,501)PFS,ZFS,RHOFS,VIS,RINO
RETURN

```
SYMBOLS USED IN SUBROUTINE BLUNT

AOD      R  U  COEFFICIENT IN DEFINITION OF ODD ORIGIN                    BLUNT
A1       R  U  COEFFICIENT IN DEFINITION OF FIRST FUNCTION                BLUNT
BOD      R  U  COEFFICIENT IN DEFINITION OF ODD ORIGIN                    BLUNT
B1       R  U  COEFFICIENT IN DEFINITION OF FIRST FUNCTION                BLUNT
CFO      R  U  SKIN-FRICTION COEFFICIENT WITHOUT INTERACTION              BLUNT
DXEV     R  U  INCREMENT FROM ORIGIN, EVEN EXPONENTIAL                    BLUNT
EPS      R  U  TOLERANCE FOR EVEN EXPONENTIAL                             BLUNT
EVK      R  U  EVEN EXPONENTIAL CONSTANT                                  BLUNT
EX       R  U  INDEPENDENT VARIABLE                                       BLUNT
F1       R  U  FIRST FUNCTION OF EVEN EXPONENTIAL                         BLUNT
G        R  U  RATIO OF SPECIFIC HEATS                                    BLUNT
GCP      R  U  GAS SPECIFIC HEAT AT CONSTANT PRESSURE                     BLUNT
GM1      R  U  RATIO OF SPECIFIC HEATS MINUS ONE                          BLUNT
GP1      R  U  RATIO OF SPECIFIC HEATS PLUS ONE                           BLUNT
IVISIN   I  A  VISCOUS-INTERACTION CONTROL FLAG                           BLUNT
MACH     R  A  MACH NUMBER                                                BLUNT
ODK      R  U  ODD EXPONENTIAL CONSTANT                                   BLUNT
PFS      R  A  FREE-STREAM PRESSURE                                       BLUNT
PXOD     R  U  INCREMENT FROM ORIGIN, ODD EXPONENTIAL                     BLUNT
RB       R  A  BODY NOSE RADIUS (FEET)                                    BLUNT
RENO     R  A  FREE-STREAM REYNOLDS NUMBER PER FOOT                       BLUNT
RES      R  U  SHOCK REYNOLDS NUMBER                                      BLUNT
RHOFS    R  A  FREE-STREAM DENSITY                                        BLUNT
RORAI    R  U  INVERSE DENSITY RATIO ACROSS NORMAL SHOCK                  BLUNT
TAU      R  A  SHEAR FORCE                                                BLUNT
TFS      R  A  FREE-STREAM TEMPERATURE                                    BLUNT
TWBL     R  U  RATIO OF SHEAR FORCE WITH INTERACTION TO THAT WITHOUT      BLUNT
T2       R  U  TEMPERATURE BEHIND NORMAL SHOCK                            BLUNT
VIS      R  A  FREE-STREAM VISCOSITY                                      BLUNT
VIS2     R  U  VISCOSITY BEHIND NORMAL SHOCK                              BLUNT
XOEV     R  U  ORIGIN FOR EVEN EXPONENTIAL                                BLUNT
Y2       R  U  SECOND FUNCTION OF ODD EXPONENTIAL                         BLUNT
```

19. SUBROUTINE TEMP (DECK AROR)

This routine uses an iterative procedure to calculate the surface equilibrium temperature for either an ideal gas or a real gas.

a. Algorithm

Calculate local and recovery enthalpy and general constants. Check for type of calculation desired (ideal or real gas, temperature input or calculate), proceed with iteration and determine local convective heating rate, reference Reynolds number and compressibility factors. Print local skin friction data and temperature iterations if required.

b. Input/Output

IPRINT = 1, temperature iterations and local skin friction data will be printed.

IPRINT = 2, only local skin friction data will be printed.

c. Error

None

d. Subroutines Required

QC

e. Argument List

(EL, TR, RE, TS, NW, MER, IPRINT, RT)

f. Length

3620 bytes

```
DECK AROR

      SUBROUTINE TEMP(EL,TR,RE,TS,NW,MER,IPRINT,RT)                     AROR  0010
C                                                                       AROR  0020
C                                                                       AROR  0030
C  CALCULATES WALL TEMPERATURE AND OTHER QUANTITIES NECESSARY           AROR  0040
C  FOR SKIN FRICTION AND BOUNDARY LAYER CALCULATIONS.                   AROR  0050
C  NW IS CONTROL FLAG WITH OPTIONS GIVEN BY FOLLOWING MATRIX.           AROR  0060
C                                                                       AROR  0070
C        GAS        WALL TEMP. TYPE            METHOD FOR               AROR  0080
C        TYPE     EQUIL    TAW   INPUT      LAMINAR    TURBULENT        AROR  0090
C                                                                       AROR  0100
C        IDEAL      0       1      2         REF. T       S-C           AROR  0110
C                                                                       AROR  0120
C        REAL       3       4      5         REF. H       S-C           AROR  0130
C                                                                       AROR  0140
C        IDEAL      6      ---     7         REF. T      REF. T         AROR  0150
C                                                                       AROR  0160
C        REAL       8      ---     9         REF. H      REF. H         AROR  0170
C                                                                       AROR  0180
C                                                                       AROR  0190
C                                                                       AROR  0200
C  BOTH LAMINAR (K = 1) AND TURBULENT (K = 2) DETERMINED.               AROR  0210
C***************D. N. SMYTH PROGRAM AUTHOR******************************AROR  0220
C                                                                       AROR  0230
C                                                                       AROR  0240
C                                                                       AROR  0250
      DIMENSION TITLE(15),BS(8),FS(8),RE(2),TR(10),TS(2),RT(2),RF(2)    AROR  0260
     1         ,ALP(20),BET(20),CCA(20),CCY(20),CCN(20),CCLL( 20),      AROR  0270
     2          CCLM(20),CCLN(20),CCL(20),CCD(20),CLOD( 20),CF( 20),    AROR  0280
     3          CPS(20),ETACS(20),IS(10, 9),SURF(10, 8)                 AROR  0290
      DIMENSION NX2( 300),NY2( 300),NZ2( 300),XCENT2( 300),YCENT2( 300),AROR  0300
     1          ZCENT2( 300),AREA2( 300),IN( 300),IM( 300)              AROR  0310
      COMMON CASE,TITLE,PAGE,ERROR,NX2,NY2,NZ2,XCENT2,YCENT2,ZCENT2,    AROR  0320
     1  AREA2,IN,IM,L,LS,FS,BS,ALP,BET,CCA,CCY,CCN,CCLL,CCLM,CCLN,CCL,  AROR  0330
     2  CCD,CLOD,CF,CPS,ETACS,IS,SURF,NPRT                              AROR  0340
      COMMON /TEMPQC/HAW,H2,H1,HW,CKU,FC,FRX,RET,ELLOC,GCP,  TST1,ROMURA AROR  0350
```

```
DECK AROR
      COMMON /FLAG2/ITW,IHW,IFLOW,ITURB,CFTLOC                          AROR 0360
      REAL NX2,NY2,NZ2                                                  AROR 0370
      INTEGER CASE,PAGE,ERROR                                           AROR 0380
      DATA EPST,KTMAX,EMISS,PRAN,G                                      AROR 0390
     1    /5.E-4, 10, 0.8,  0.71 ,1.40                                  AROR 0400
     2    /                                                             AROR 0410
C                                                                       AROR 0420
C   SET UP GENERAL QUANTIES (GCP CONSISTENT WITH ATMOS).                AROR 0430
      GCP =  6007.93137                                                 AROR 0440
      H1 = GCP*FS(3)                                                    AROR 0450
      HTOT =          H1*(1. + 0.5*(G-1.)*FS(6)**2)                     AROR 0460
      H2 = HTOT - 0.5*BS(7)**2                                          AROR 0470
      ELLOC = EL                                                        AROR 0480
      RF(1) = SQRT(PRAN)                                                AROR 0490
      RF(2) = PRAN**(1./3.)                                             AROR 0500
      CKU = 0.332*FS(5)*SQRT(FS(8)/EL)/PRAN**(2./3.)*SQRT(BS(7)/FS(7))  AROR 0510
      RADK = 0.480E-12*EMISS*778.0                                      AROR 0520
C                                                                       AROR 0530
C   SET UP CONTROL FLAGS                                                AROR 0540
      ITURB = 1                                                         AROR 0550
      IF (NW.GT.5) ITURB = 2                                            AROR 0560
      NWI = NW                                                          AROR 0570
      ITW = 1                                                           AROR 0580
      IF (NWI.LT.3) GO TO 6                                             AROR 0590
      ITW = 2                                                           AROR 0600
      NWI = NWI - 3                                                     AROR 0610
      IF (NWI.LT.3) GO TO 6                                             AROR 0620
      IF (NWI.LT.5) GO TO 4                                             AROR 0630
      NWI = NWI - 5                                                     AROR 0640
      GO TO 5                                                           AROR 0650
    4 ITW = 1                                                           AROR 0660
      NWI = NWI - 3                                                     AROR 0670
    5 IF (NWI.NE.0) NWI = 2                                             AROR 0680
C                                                                       AROR 0690
C   MAJOR LOOP FOR CALCULATING LAMINAR (K=1) AND TURBULENT (K=2) FLOW.  AROR 0700
    6 DO 1000 K = 1,2                                                   AROR 0710
```

```
DECK AROR

      IF (IPRINT.NE.1) GO TO 302                                        AROR  0720
      WRITE(6,301)                                                      AROR  0730
      NPRT = NPRT + 1                                                   AROR  0740
  301 FORMAT(1H )                                                       AROR  0750
  302 KT = 0                                                            AROR  0760
      IFLOW = K                                                         AROR  0770
      IHW = 0                                                           AROR  0780
      HAW = H2 + RF(K)*(HTOT - H2)                                      AROR  0790
      TC1 = 100.                                                        AROR  0800
      IF (NWI - 1) 9,7,8                                                AROR  0810
    7 HW = HAW                                                          AROR  0820
      IHW = 1                                                           AROR  0830
      GO TO 21                                                          AROR  0840
    8 TC1 = TR(K+4)                                                     AROR  0850
      IF (TC1.GT.7000.) TC1 = 7000.                                     AROR  0860
      GO TO 21                                                          AROR  0870
    9 ITW = 1                                                           AROR  0880
C  NOTE, FOR REAL GAS EQUILIBRIUM TW IDEAL GAS DONE FIRST.              AROR  0890
      TR1 = TC1                                                         AROR  0900
      QC1 = QC(TC1)                                                     AROR  0910
      QR1 = RADK*1.E+8                                                  AROR  0920
      QR2 = QC1                                                         AROR  0930
      TR2 = (QR2/RADK)**0.25                                            AROR  0940
      TC2 = HAW/GCP                                                     AROR  0950
      IF (TR2 .LT.TC2) GO TO 3                                          AROR  0960
      QC2 = 0.0                                                         AROR  0970
      TR2 = TC2                                                         AROR  0980
      QR2 = RADK*TR2**4                                                 AROR  0990
      GO TO 10                                                          AROR  1000
    3 TC2 = TR2                                                         AROR  1010
      QC2 = QC(TC2)                                                     AROR  1020
C                                                                       AROR  1030
C  ITERATION CYCLE FOR TW                                               AROR  1040
   10 KT = KT + 1                                                       AROR  1050
C**CHECK IF TEMPERATURE ITERATIONS TO BE PRINTED.                       AROR  1060
      IF (IPRINT.EQ.1)                                                  AROR  1070
```

```
DECK AROR

      1WRITE(6,300) KT,TC1,TR1,TC2,TR2,ITW,QC1,QR1,QC2,QR2                AROR  1080
  300 FORMAT(1H ,2X4HKT =,I4,5X5HTC1 =,E13.6,5X5HTR1 =,E13.6,             AROR  1090
     1         5X5HTC2 =,E13.6,5X5HTR2 =,E13.6, /3X4HITW=,I4,             AROR  1100
     2         5X5HQC1 =,E13.6,5X5HQR1 =,E13.6,5X5HQC2 =,E13.6,           AROR  1110
     3         5X5HQR2 =,E13.6)                                           AROR  1120
C                                                                         AROR  1130
C  CHECK IF ALLOWABLE NUMBER OF ITERATIONS EXCEEDED.                      AROR  1140
      IF (KT.GT.KTMAX) GO TO 22                                           AROR  1150
      DQC = QC1-QC2                                                       AROR  1160
      DQR = QR2-QR1                                                       AROR  1170
      DTC = TC1-TC2                                                       AROR  1180
      DTR = TR2-TR1                                                       AROR  1190
C  LINEAR SOLUTION (OR INTERCEPT FOR NEXT GUESS.                          AROR  1200
      TC1 = ((QR1*TR2 - QR2*TR1)*DTC + (QC1*TC2 - QC2*TC1)*DTR)/          AROR  1210
     1      (DQC*DTR - DQR*DTC)                                           AROR  1720
C                                                                         AROR  1230
C  CALCULATE HEATING RATES AND CHECK CONVERGENCE.                         AROR  1240
      IF (TC1.LT.0.0) GO TO 81                                            AROR  1250
   11 TR1 = TC1                                                           AROR  1260
      QR1 = RADK*TR1**4                                                   AROR  1270
      QC1 = QC(TC1)                                                       AROR  1280
      IF (ABS(1. - QC1/QR1).LE.EPST) GO TO 12                             AROR  1290
C  NO SOLUTION, INITIATE NEXT CYCLE.                                      AROR  1300
      IF (QC1.GT.0.0) GO TO 83                                            AROR  1310
C                                                                         AROR  1320
C  QC1 NEQATIVE, SPECIAL INITIALIZATION USED.                             AROR  1330
   81 KSUB = 1                                                            AROR  1340
   82 QC2 = 0.0                                                           AROR  1350
      TC2 = HAW/GCP                                                       AROR  1360
      TR2 = TC2                                                           AROR  1370
      QR2 = RADK*TR2**4                                                   AROR  1380
      IF (KSUB.NE.1) GO TO 10                                             AROR  1390
      TC1 = TC2                                                           AROR  1400
   80 TC1 = 0.5*TC1                                                       AROR  1410
      QC1 = QC(TC1)                                                       AROR  1420
      TR1 = TC1                                                           AROR  1430
```

TEMP

```
DECK AROR

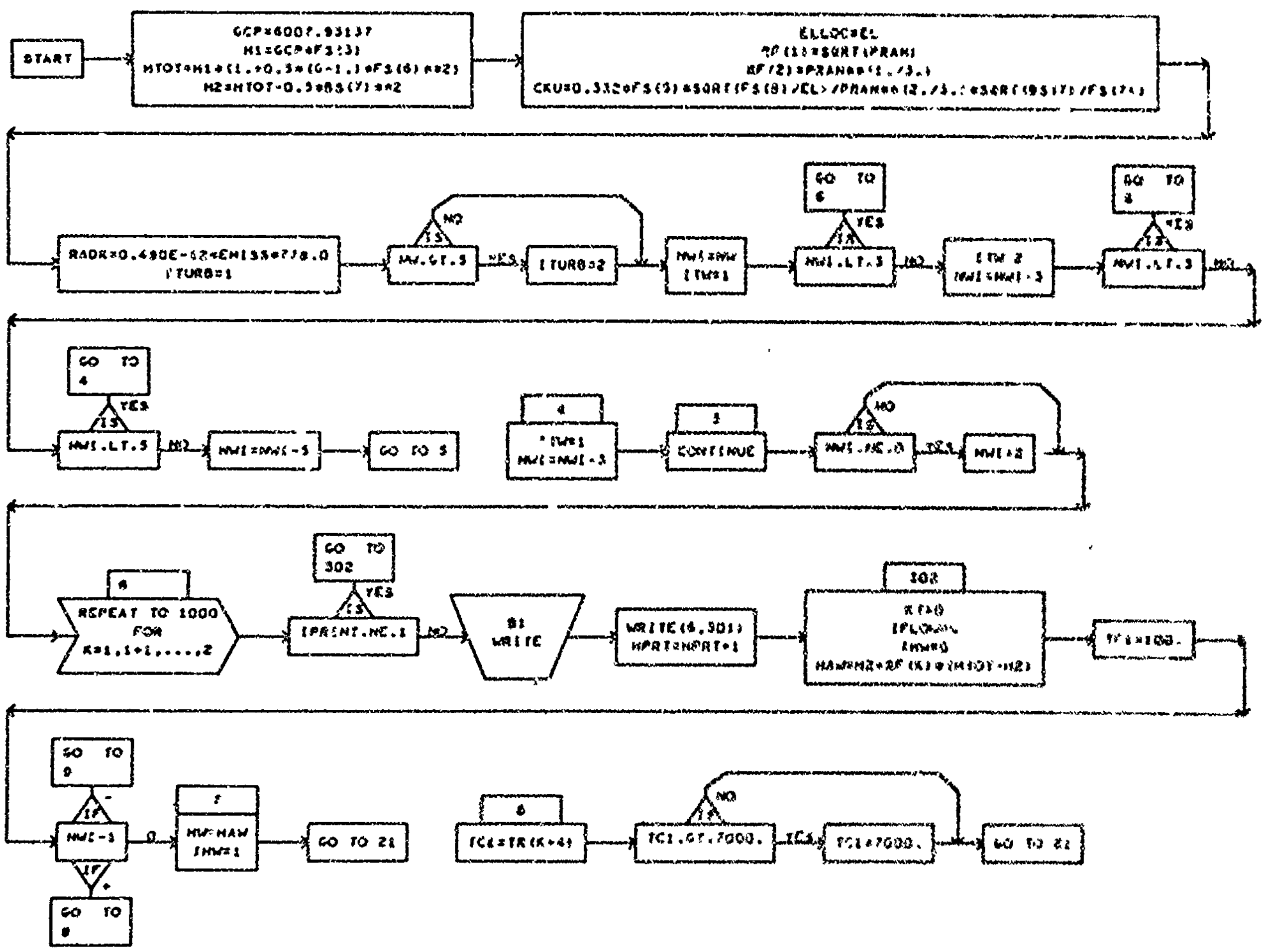
      QR1 = RADK*TR1**4                                                 AROR  1440
      IF (QC1.GT.QR1) GO TO 10                                          AROR  1450
      IF (KSUB.EQ.5) GO TO 10                                           AROR  1460
      KSUB = KSUB + 1                                                   AROR  1470
      GO TO 80                                                          AROR  1480
C                                                                       AROR  1490
C  QC1 POSITIVE, CONTINUE INITIALIZATION OF NEXT CYCLE.                 AROR  1500
   83 QR2 = QC1                                                         AROR  1510
      TR2 = (QR2/RADK)**0.25                                            AROR  1520
      TC2 = TR2                                                         AROR  1530
      QC2 = QC(TC2)                                                     AROR  1540
      IF (ABS(1. - QC2/QR2).LE.EPST) GO TO 84                           AROR  1550
      IF (QC2.GT.0.0) GO TO 10                                          AROR  1560
      KSUB = 2                                                          AROR  1570
      GO TO 82                                                          AROR  1580
C                                                                       AROR  1590
C  SOLUTION OBTAINED                                                    AROR  1600
   84 TC1 = TC2                                                         AROR  1610
C                                                                       AROR  1620
C  CHECK IF REAL GAS SOLUTION DESIRED.                                  AROR  1630
   12 IF ((ITW.EQ.2).OR.(NW.LT.3)) GO TO 21                             AROR  1640
      IF ((NW.EQ.6).OR.(NW.EQ.7)) GO TO 21                              AROR  1650
C                                                                       AROR  1660
C  DETERMINE REAL GAS SOLUTION                                          AROR  1670
      ITW = 2                                                           AROR  1680
      KT = 0                                                            AROR  1690
      GO TO 11                                                          AROR  1700
C                                                                       AROR  1710
C  EXCEEDED ALLOWABLE ITERATIONS (KTMAX), AVERAGE LAST TWO VALUES       AROR  1720
   22 CONTINUE                                                          AROR  1730
      TC1 = (TC1 + TC2)*0.5                                             AROR  1740
      GO TO 12                                                          AROR  1750
C                                                                       AROR  1760
C  CALCULATE QC AT FINAL TW VALUE TO SET QUANTITIES IN COMMON.          AROR  1770
   21 QC1 = QC(TC1)                                                     AROR  1780
   30 TR(K+4) = TC1                                                     AROR  1790
```

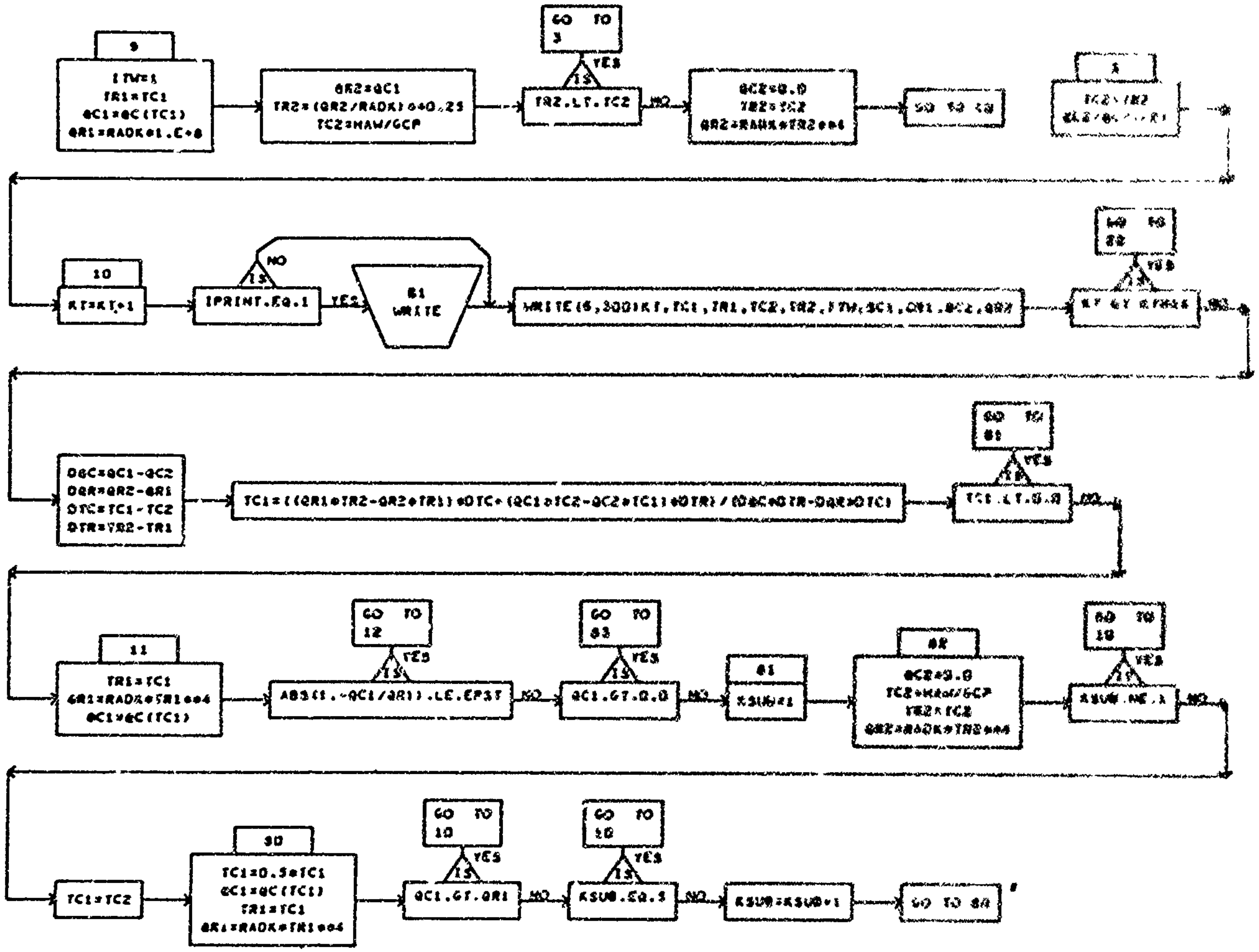
```
DECK AROR
      RT(K) = HAW/GCP                                                   AROR 1800
      TR(K+6) = HW                                                      AROR 1810
      TR(K+8) = HAW                                                     AROR 1820
      TS(K) = TST1*FS(3)                                                AROR 1830
C  RT AND TS ARE CORRECT ONLY FOR AN IDEAL GAS.                         AROR 1840
      GO TO (23,24),K                                                   AROR 1850
   23 CFLLOC = CKU*ROMURA*2.0*PRAN**(2./3.)/(BS(1)*BS(7))               AROR 1860
      RE(K) = (0.664*BS(3)/(TS(K)*CFLLOC))**2                           AROR 1870
      NW1 = 0                                                           AROR 1880
C                                                                       AROR 1890
C  CHECK IF PRINTOUT OF LOCAL SKIN FRICTION CHARACTERISTICS DESIRED.    AROR 1900
      IF  ((IPRINT.LT.1).OR.(IPRINT.GT.2)) GO TO 1000                   AROR 1910
C                                                                       AROR 1920
C  THE FOLLOWING CARDS ARE FOR LOCAL CF PRINTOUT ONLY.                  AROR 1930
C  LAMINAR FLOW                                                         AROR 1940
      CF1RE1 = 0.664*SQRT((BS(7)/FS(7))**3)*ROMURA                      AROR 1950
      CF1 = CF1RE1/SQRT(FS(8)*ELLOC)                                    AROR 1960
      RORA = ROMURA**2                                                  AROR 1970
      HAWH1 = HAW/H1                                                    AROR 1980
      NW1 = NW + 1                                                      AROR 1990
   39 NPRT = NPRT + 2                                                   AROR 2000
      GO TO (40,40,40,41,41,41,42,42,43,43),NW1                         AROR 2010
   40 WRITE(6,50) NW                                                    AROR 2020
   50 FORMAT(1H0,2X3HNW=,I2,3X32HIDEAL GAS, REF. T/S-C  SOLUTION.)      AROR 2030
      GO TO 44                                                          AROR 2040
   41 WRITE(6,51) NW                                                    AROR 2050
   51 FORMAT(1H0,2X3HNW=,I2,3X32HREAL  GAS, REF. H/S-C  SOLUTION.)      AROR 2060
      GO TO 44                                                          AROR 2070
   42 WRITE(6,52) NW                                                    AROR 2080
   52 FORMAT(1H0,2X3HNW=,I2,3X35HIDEAL GAS, REF. T/REF. T  SOLUTION.)   AROR 2090
      GO TO 44                                                          AROR 2100
   43 WRITE(6,53) NW                                                    AROR 2110
   53 FORMAT(1H0,2X3HNW=,I2,3X35HREAL  GAS, REF. H/REF. H  SOLUTION.)   AROR 2120
   44 WRITE(6,217) KT,TC1,CF1,CF1RE1,RORA,TST1,HAWH1                    AROR 2130
      NPRT = NPRT + 1                                                   AROR 2140
  217 FORMAT(1H , 2X3HKT=, I2, 3X6HTWEQ =,F7.1,1HR, 3X5HCF1 =,E13.6,    AROR 2150
```

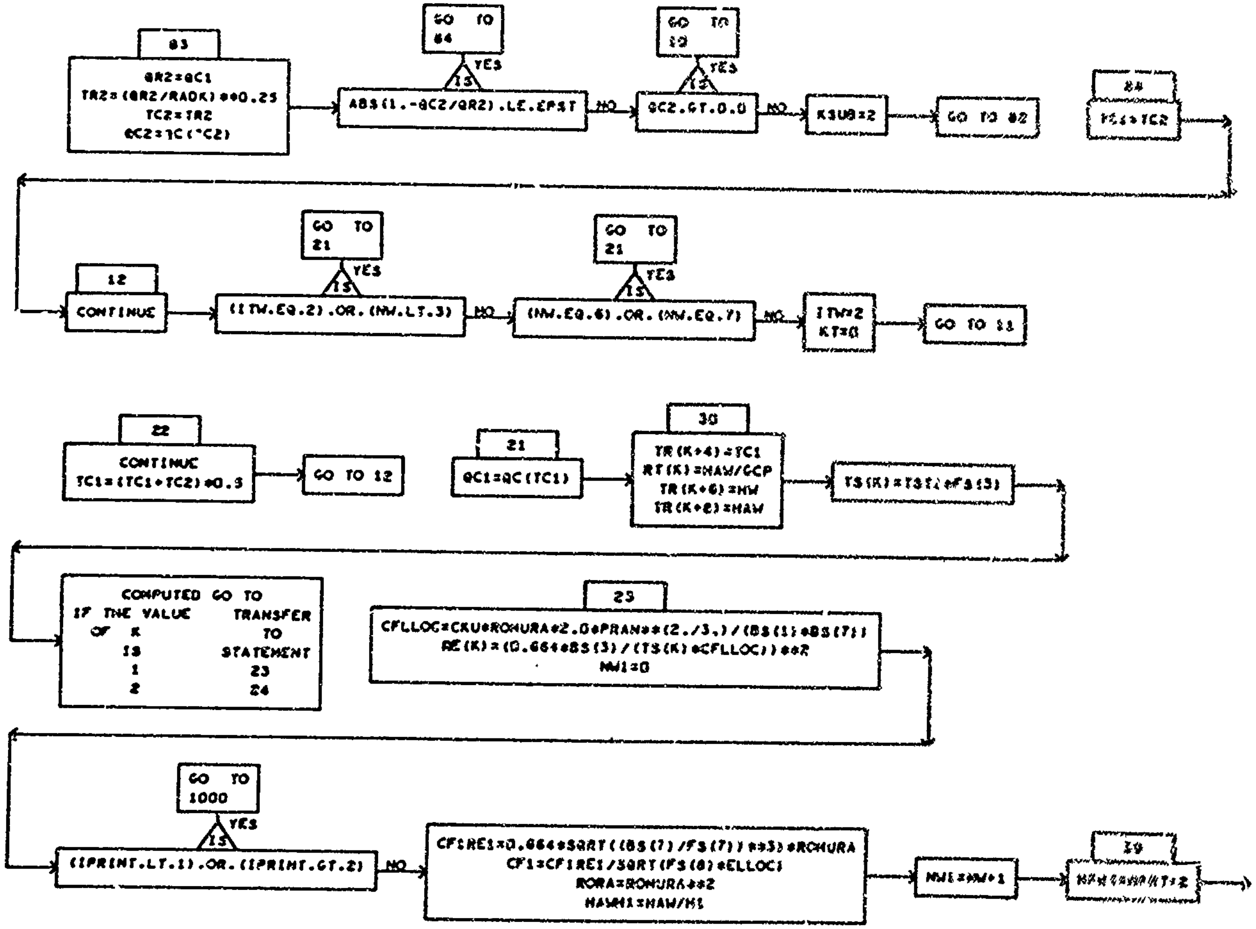
```
DECK AROR

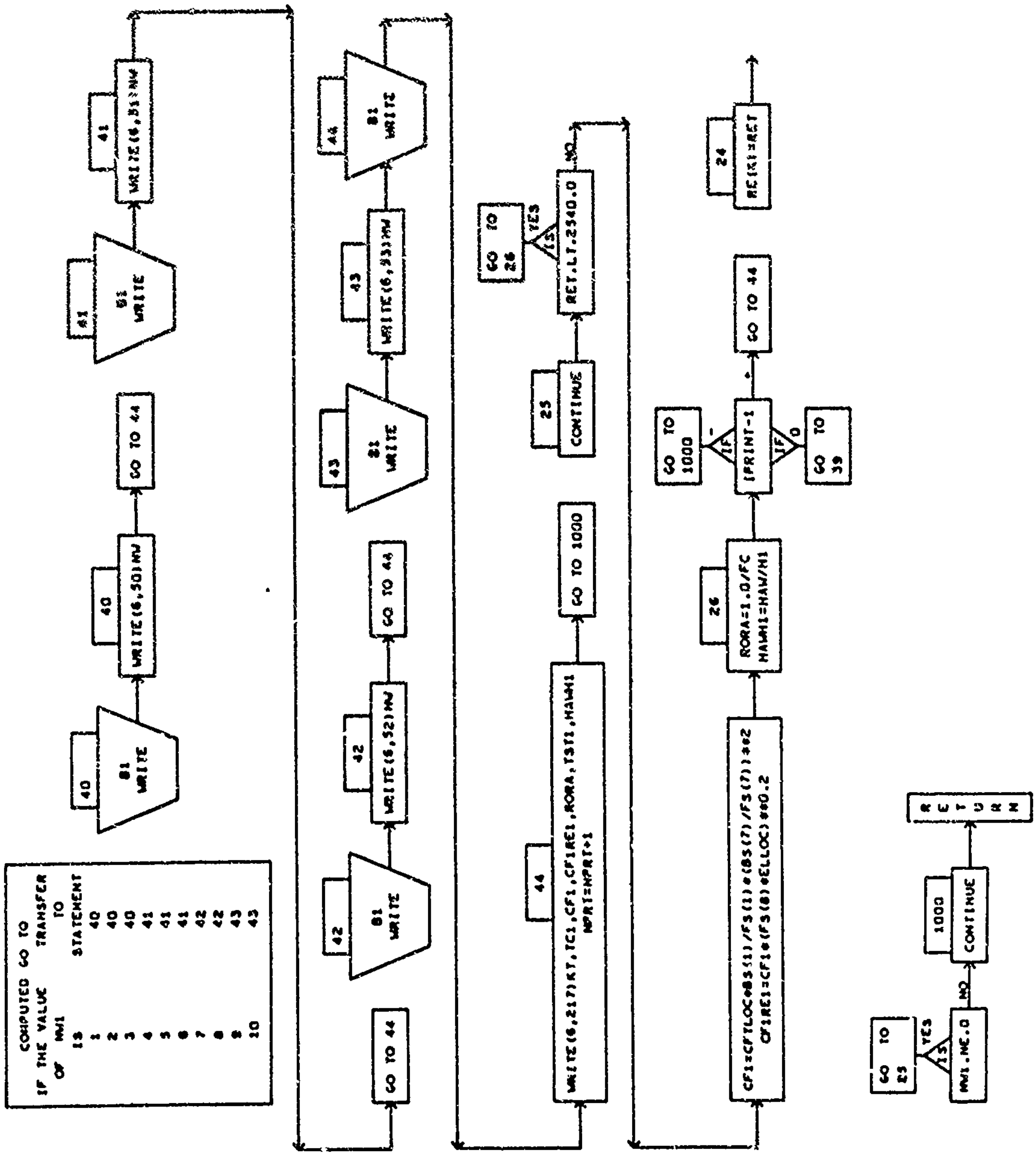
      1        3X10HCF1(RE1) =,F9.6,3X9H ROMURA =,F9.5, 3X7HH*/H1 =,F9.4,     AROR  2160
      2         3X8HHAW/H1 =,F9.4)                                             AROR  2170
       GO TO 1000                                                              AROR  2180
C                                                                              AROR  2190
C   TURBULENT FLOW                                                             AROR  2200
   25 IF (RET.LT.2540.0) GO TO 26                                              AROR  2210
      CF1 = CFTLOC*BS(1)/FS(1)*(BS(7)/FS(7))**2                                AROR  2220
      CF1RE1 = CF1*(FS(8)*ELLOC)**0.2                                          AROR  2230
   26 RORA = 1.0/FC                                                            AROR  2240
      HAWH1 = HAW/H1                                                           AROR  2250
      IF (IPRINT - 1) 1000,39,44                                               AROR  2260
C                                                                              AROR  2270
C   THIS ENDS PRINTOUT CARDS.                                                  AROR  2280
   24 RE(K) = RET                                                              AROR  2290
      IF (NW1.NE.0) GO TO 25                                                   AROR  2300
 1000 CONTINUE                                                                 AROR  2310
      RETURN                                                                   AROR  2320
      END                                                                      AROR  2330
```

SUBROUTINE TEMP




9
ITW=1
TR1=TC1
QC1=QC(TC1)
QR1=RADK*1.E+8
QR2=QC1
TR2=(QR2/RADK)**0.25
TC2=HAW/GCP
TR2.LT.TC2
IS
YES
GO TO 3
NO
QC2=0.0
TR2=TC2
QR2=RADK*TR2**4
GO TO 10
3
TC2=TR2
10
KT=KT+1
IPRINT.EQ.1
IS
NO
YES
81
WRITE
WRITE(6,300)KT,TC1,TR1,TC2,TR2,ITW,QC1,QR1,QC2,QR2
KT.GT.KTMAX
IS
YES
GO TO 22
NO
DQC=QC1-QC2
DQR=QR2-QR1
DTC=TC1-TC2
DTR=TR2-TR1
TC1=((QR1*TR2-QR2*TR1)*DTC+(QC1*TC2-QC2*TC1)*DTR)/(DQC*DTR-DQR*DTC)
TC1.LT.0.0
IS
YES
GO TO 80
NO
11
TR1=TC1
QR1=RADK*TR1**4
QC1=QC(TC1)
ABS(1.-QC1/QR1).LE.EPST
IS
YES
GO TO 12
NO
QC1.GT.0.0
IS
YES
GO TO 83
NO
81
KSUB=1
82
QC2=0.0
TC2=HAW/GCP
TR2=TC2
QR2=RADK*TR2**4
KSUB.NE.1
IS
YES
GO TO 10
NO
TC1=TC2
80
TC1=0.5*TC1
QC1=QC(TC1)
TR1=TC1
QR1=RADK*TR1**4
QC1.GT.QR1
IS
YES
GO TO 10
NO
KSUB.EQ.5
IS
YES
GO TO 10
NO
KSUB=KSUB+1
GO TO 82


83
QR2=QC1
TR2=(QR2/RADK)**0.25
TC2=TR2
QC2=TC(*C2)
ABS(1.-QC2/QR2).LE.EPST
IS
YES
GO TO 84
NO
QC2.GT.0.0
IS
YES
GO TO 19
NO
KSUB=2
GO TO 82
84
TC1=TC2
12
CONTINUE
(ITW.EQ.2).OR.(NW.LT.3)
IS
YES
GO TO 21
NO
(NW.EQ.6).OR.(NW.EQ.7)
IS
YES
GO TO 21
NO
ITW=2
KT=0
GO TO 11
22
CONTINUE
TC1=(TC1+TC2)*0.5
GO TO 12
21
QC1=QC(TC1)
30
TR(K+4)=TC1
RT(K)=HAW/GCP
TR(K+6)=HW
TR(K+8)=HAW
TS(K)=TS1(*FS(3)
COMPUTED GO TO
IF THE VALUE OF K IS
TRANSFER TO STATEMENT
1
23
2
24
23
CFLLOC=CKU*ROHURA*2.0*PRAN**(2./3.)/(BS(1)*BS(7))
RE(K)=(0.664*BS(3)/(TS(K)*CFLLOC))**2
NW1=0
(IPRINT.LT.1).OR.(IPRINT.GT.2)
IS
YES
GO TO 1000
NO
CF1RE1=0.664*SQRT((BS(7)/FS(7))**3)*ROHURA
CF1=CF1RE1/SQRT(FS(8)*ELLOC)
RORA=ROHURA**2
HAWH1=HAW/H1
NW1=NW+1
19


COMPUTED GO TO
IF THE VALUE OF NW1 IS — TRANSFER TO STATEMENT
1 — 40
2 — 40
3 — 40
4 — 41
5 — 41
6 — 41
7 — 42
8 — 42
9 — 43
10 — 43
40
B1 WRITE
40
WRITE(6,50)NW
GO TO 44
41
B1 WRITE
41
WRITE(6,51)NW
42
B1 WRITE
GO TO 44
42
WRITE(6,52)NW
GO TO 44
43
B1 WRITE
43
WRITE(6,53)NW
44
B1 WRITE
44
WRITE(6,217)KT,TC1,CF1,CF1RE1,RORA,TST1,HAWM1
NPRT=NPRT+1
GO TO 1000
25
CONTINUE
RET.LT.2540.0
IS
YES
GO TO 26
NO
CF1=CF1LOC*BS(1)/FS(1)*(BS(7)/FS(7))**2
CF1RE1=CF1*(FS(8)*ELLOC)**0.2
26
RORA=1.0/FC
HAWM1=HAW/H1
IPRINT-1
IF
-
GO TO 1000
IF
0
GO TO 39
+
GO TO 44
24
RET(K)=RET
NW1.NE.0
IS
YES
GO TO 25
NO
1000
CONTINUE
RETURN

```
SYMBOLS USED IN SUBROUTINE TEMP

ALP      R  C  ANGLE OF ATTACK ARRAY                                      TEMP
AREA2    R  C  QUADRILATERAL ELEMENT AREA ARRAY                           TEMP
BET      R  C  YAW ANGLE ARRAY                                            TEMP
BS       R  C  FLOW CONDITIONS BEHIND THE SHOCK OR EXPANSION              TEMP
CASE     I  C  CASE NUMBER                                                TEMP
CCA      R  C  AXIAL FORCE COEFFICIENT ARRAY                              TEMP
CCD      R  C  DRAG COEFFICIENT ARRAY                                     TEMP
CCL      R  C  LIFT COEFFICIENT ARRAY                                     TEMP
CCLL     R  C  ROLLING MOMENT COEFFICIENT ARRAY                           TEMP
CCLM     R  C  PITCHING MOMENT COEFFICIENT ARRAY                          TEMP
CCLN     R  C  YAWING MOMENT COEFFICIENT ARRAY                            TEMP
CCN      R  C  NORMAL FORCE COEFFICIENT ARRAY                             TEMP
CCY      R  C  SIDE FORCE COEFFICIENT ARRAY                               TEMP
CF       R  C  SKIN FRICTION CONTRIBUTION TO AXIAL FORCE ARRAY            TEMP
CFLLOC   R  U  LOCAL LAMINAR SKIN-FRICTION COEFFICIENT                    TEMP
CFTLOC   R  C  LOCAL TURBULENT SKIN-FRICTION COEFFICIENT                  TEMP
CF1      R  U  SKIN FRICTION COEFFICIENT REFERENCED TO FREE-STREAM        TEMP
CF1RE1   R  U  SKIN FRICTION PARAMETER                                    TEMP
CKU      R  C  LAMINAR FLOW FLIGHT CONDITION CONSTANT                     TEMP
CLOD     R  C  LIFT TO DRAG RATIO ARRAY                                   TEMP
CPS      R  C  ARRAY FOR NEWTONIAN CORRECTION FACTOR, K                   TEMP
DQC      R  U  DIFFERENCE IN CONVECTIVE HEATING RATES                     TEMP
DQR      R  U  DIFFERENCE IN RADIATION HEATING RATES                      TEMP
DTC      R  U  DIFFERENCE IN CONVECTIVE TEMPERATURES                      TEMP
DYR      R  U  DIFFERENCE IN RADIATION TEMPERATURES                       TEMP
EL       R  A  REFERENCE LENGTH                                           TEMP
ELLOC    R  C  REFERENCE LENGTH (=EL)                                     TEMP
EMISS    R  U  EMISSIVITY                                                 TEMP
EPST     R  U  TOLERANCE OF TEMPERATURE ITERATIONS                        TEMP
ERROR    I  C  ERROR FLAG                                                 TEMP
ETACS    R  C  SAVED VALUES OF PRANDTL-MEYER CORRECTION FACTOR            TEMP
FC       R  C  TURBULENT FLOW, SKIN-FRICTION COMPRESSIBILITY FACTOR       TEMP
FRX      R  C  TURBULENT FLOW, REYNOLDS NUMBER COMPRESSIBILITY FACTOR     TEMP
FS       R  C  FLOW CONDITIONS BEFORE THE SHOCK OR EXPANSION              TEMP
G        R  U  RATIO OF SPECIFIC HEATS                                    TEMP
GCP      R  C  GAS SPECIFIC HEAT AT CONSTANT PRESSURE                     TEMP
```

```
SYMBOLS USED IN SUBROUTINE TEMP

HAW      R  C  ADIABATIC-WALL FNTHALPY                                    TEMP
HAWH1    R  U  ADIABATIC-WALL TO FREE-STREAM ENTHALPY RATIO               TEMP
HTOT     R  U  TOTAL ENTHALPY                                             TEMP
HW       R  C  WALL ENTHALPY                                              TEMP
H1       R  C  FREE-STREAM ENTHALPY                                       TEMP
H2       R  C  LOCAL FNTHALPY                                             TEMP
IFLOW    I  C  LAMINAR (=1) OR TURBULENT (=2) FLOW FLAG                   TEMP
IHW      I  C  WALL ENTHALPY FLAG                                         TEMP
IM       I  C  ELEMENT ROW NUMBER ARRAY                                   TEMP
IN       I  C  ELEMENT COLUMN NUMBER ARRAY                                TEMP
IPRINT   I  A  PRINT FLAG                                                 TEMP
IS       I  C  SKIN FRICTION FLAG DATA ARRAY                              TEMP
ITURB    I  C  TURBULENT FLOW FLAG                                        TEMP
ITW      I  C  IDEAL GAS (=1) OR REAL GAS(=2) FLAG                        TEMP
K        I  U  FLAG (=1 LAMINAR, =2 TURBULENT)                            TEMP
KSUB     I  U  SECONDARY COUNTER IN TEMPERATURE ITERATIONS                TEMP
KT       I  U  TEMPERATURE ITERATION COUNTER                              TEMP
KTMAX    I  U  MAXIMUM NUMBER OF TEMPERATURE ITERATIONS                   TEMP
L        I  C  NUMBER OF FLEMENTS                                         TEMP
LS       I  C  NUMBER OF ELEMENTS                                         TEMP
MER      I  A  ERROR FLAG                                                 TEMP
NPRT     I  C  PRINT COUNTER                                              TEMP
NW       I  A  TEMPERATURE CALCULATION CONTROL FLAG                       TEMP
NWI      I  U  TEMPERATURE CALCULATION CONTROL FLAG                       TEMP
NW1      I  U  TEMPERATURE CALCULATION PRINT CONTROL FLAG                 TEMP
NX2      R  C  ELEMENT DIRECTION COSINE ARRAY-X                           TEMP
NY2      R  C  ELEMENT DIRECTION COSINE ARRAY-Y                           TEMP
NZ2      R  C  ELEMENT DIRECTION COSINE ARRAY-Z                           TEMP
PAGE     I  C  PAGF NUMBER                                                TEMP
PRAN     R  U  PRANDTL NUMBER                                             TEMP
QC1      R  U  CONVECTIVE HEATING RATE AT TC1                             TEMP
QC2      R  U  CONVECTIVE HEATING RATE AT TC2                             TEMP
QR1      R  U  RADIATION HEATING RATE AT TR1                              TEMP
QR2      R  U  RADIATION HEATING RATE AT TR1                              TEMP
RADK     R  U  RADIATION CONSTANT                                         TEMP
RE       T  A  REFERENCE REYNOLDS NUMBER                                  TEMP
```

```
SYMBOLS USED IN SUBROUTINE TEMP

RET      R  C  TURBULENT FLOW REYNOLDS NUMBER AT REFERENCE CONDITION         TEMP
RF       R  D  RECOVERY FACTOR                                               TEMP
RCMURA   R  C  SQUARE-ROOT OF REFERENCE DENSITY-VISCOSITY RATIO              TEMP
RORA     R  U  REFERENCE TO FREE-STREAM DENSITY-VISCOSITY RATIO              TEMP
RT       R  A  RECOVERY TEMPERATURE                                          TEMP
SURF     R  C  SKIN FRICTION DATA ARRAY                                      TEMP
TC1      R  U  FIRST VALUE OF CONVECTIVE TEMPERATURE                         TEMP
TC2      R  U  SECOND VALUE OF CONVECTIVE TEMPERATURE                        TEMP
TITLE    R  C  TITLE                                                         TEMP
TR       R  A  FLIGHT CONDITION AND SKIN FRICTION DATA ARRAY                 TEMP
TR1      R  U  FIRST VALUE OF RADIATION TEMPERATURE                          TEMP
TR2      R  U  SECOND VALUE OF RADIATION TEMPERATURE                         TEMP
TS       R  A  REFERENCE TEMPERATURE (T STAR)                                TEMP
TST1     R  C  REFERENCE TO FREE-STREAM TEMPERATURE (OR ENTHALPY) RATIO      TEMP
XCENT2   R  C  QUADRILATERAL CENTROID ARRAY-X                                TEMP
YCENT2   R  C  QUADRILATERAL CENTROID ARRAY-Y                                TEMP
ZCENT2   R  C  QUADRILATERAL CENTROID ARRAY-Z                                TEMP
```

```
SYMBOLS USED IN SUBROUTINE TEMP

RET       R  C  TURBULENT FLOW REYNOLDS NUMBER AT REFERENCE CONDITION           TEMP
RF        R  D  RECOVERY FACTOR                                                 TEMP
RCMURA    R  C  SQUARE-ROOT OF REFERENCE DENSITY-VISCOSITY RATIO                TEMP
RORA      R  J  REFERENCE TO FREE-STREAM DENSITY-VISCOSITY RATIO                TEMP
RT        R  A  RECOVERY TEMPERATURE                                            TEMP
SURF      R  C  SKIN FRICTION DATA ARRAY                                        TEMP
TC1       R  U  FIRST VALUE OF CONVECTIVE TEMPERATURE                           TEMP
TC2       R  U  SECOND VALUE OF CONVECTIVE TEMPERATURE                          TEMP
TITLE     R  C  TITLE                                                           TEMP
TR        R  A  FLIGHT CONDITION AND SKIN FRICTION DATA ARRAY                   TEMP
TR1       R  U  FIRST VALUE OF RADIATION TEMPERATURE                            TEMP
TR2       R  U  SECOND VALUE OF RADIATION TEMPERATURE                           TEMP
TS        R  A  REFERENCE TEMPERATURE (T STAR)                                  TEMP
TST1      R  C  REFERENCE TO FREE-STREAM TEMPERATURE (OR ENTHALPY) RATIO        TEMP
XCENT2    R  C  QUADRILATERAL CENTROID ARRAY-X                                  TEMP
YCENT2    R  C  QUADRILATERAL CENTROID ARRAY-Y                                  TEMP
ZCENT2    R  C  QUADRILATERAL CENTROID ARRAY-Z                                  TEMP
```

20. FUNCTION QC (DECK AROS)

This routine calculates the aerodynamic heating at the given wall temperature.

a. Algorithm

Tests for laminar or turbulent flow, for reference method or Spalding-Chi, and for ideal or real gas. Calculates convective heating rate and sets certain quantities in common.

b. Input/Output

None

c. Error

None

d. Subroutines Required

ROMU (three entries, ROMU, ROW, ENTHAL)

e. Argument List

(TW)

f. Length

2132 bytes

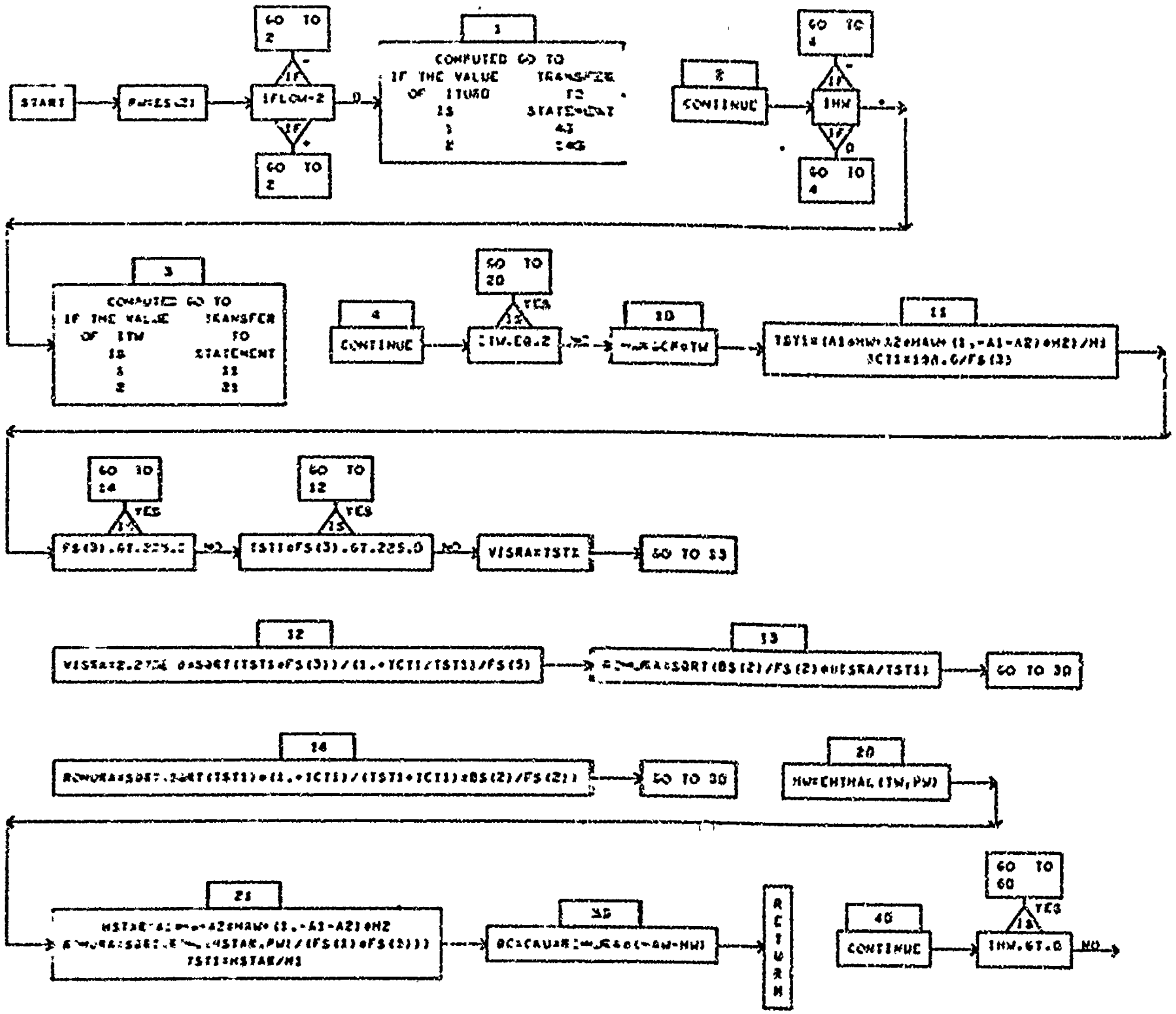
DECK AROS

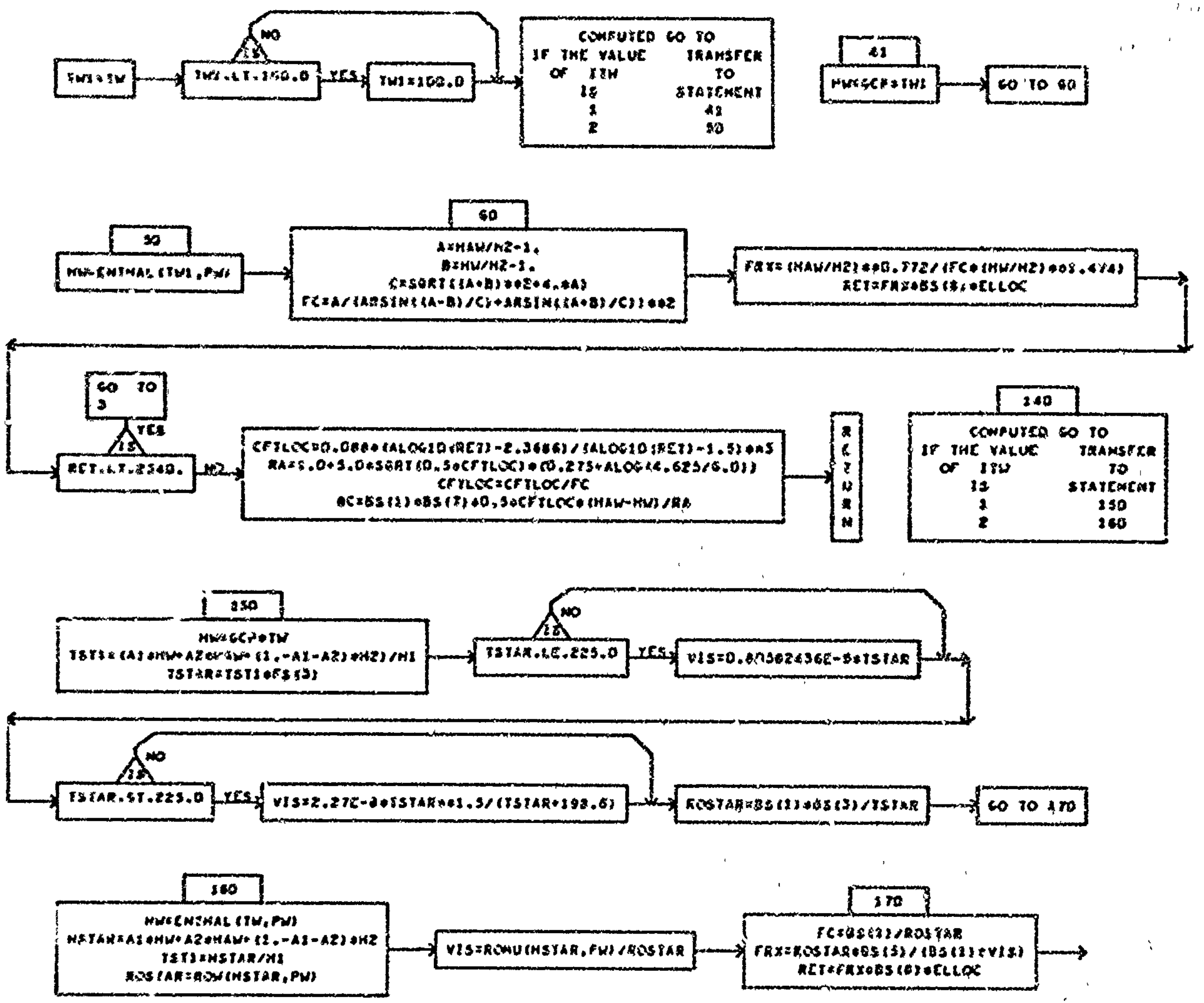
```
      FUNCTION  QC(TW)
C
C
C  CALCULATES THE AERODYNAMIC HEATING AT THE GIVEN
C  WALL TEMP.(TW) IN LAMINAR (IFLOW = 1) AND TURBULENT
C  (IFLOW = 2) FLOW OF EITHER AN IDEAL GAS (ITW = 1)
C  OR A REAL GAS (ITW = 2).  REFERENCE TEMPERATURE OR
C REFERENCE ENTHALPY USED FOR LAMINAR FLOW.  SPALDING-CHI (ITURB = 1)
C  OR REFERENCE TEMPERATURE/REFERENCE ENTHALPY (ITURB = 2) USED
C  FOR TURBULENT FLOW.
C***************D. N. SMYTH PROGRAM AUTHOR******************************
C
C
C
      DIMENSION TITLE(15),BS(8),FS(8)
      DIMENSION NX2( 300),NY2( 300),NZ2( 300),XCENT2( 300),YCENT2( 300),
     1          ZCENT2( 300),AREA2( 300),IN( 300),IM(300)
      COMMON CASE,TITLE,PAGE,ERROR,NX2,NY2,NZ2,XCENT2,YCENT2,ZCENT2,
     1      AREA2,IN,IM,L,LS,FS,BS
      COMMON /TEMPQC/HAW,H2,H1,HW,CKU,FC,FRX,RET,ELLOC,GCP,  TST1,ROMURA
      COMMON /FLAG2/ITW,IHW,IFLOW,ITURB,CFTLOC
      REAL NX2,NY2,NZ2
      INTEGER CASE,PAGE,ERROR
C
C  MONAGHAN REFERENCE CONDITION COEFFICIENTS (PR = 0.71)
      DATA A1,A2/0.5825,0.1875/
      PW = BS(2)
C
C  CHECK FOR LAMINAR OR TURBULENT.
      IF (IFLOW.EQ.2) GO TO (40,140), ITURB
C
C
C  LAMINAR FLOW.  CHECK IF ENTHALPY INPUT.
      IF (IHW.GT.0) GO TO (11,21), ITW
      GO TO (10,20), ITW
```

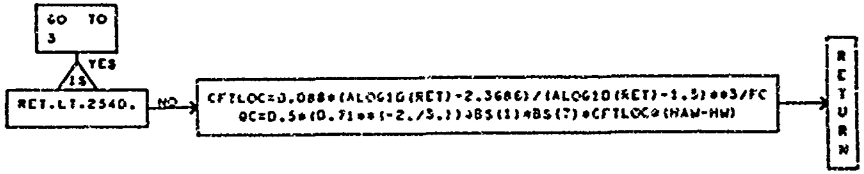
DECK AROS

```
C                                                                       AROS  0360
C  REFERENCE TEMP. SOLUTION.                                            AROS  0370
   10 HW = GCP*TW                                                       AROS  0380
   11 TST1 = (A1*HW + A2*HAW + (1.-A1-A2)*H2)/H1                        AROS  0390
      TCT1 = 198.6/FS(3)                                                AROS  0400
      IF (FS(3).GT.225.0) GO TO 14                                      AROS  0410
      IF (TST1*FS(3).GT.225.0) GO TC 12                                 AROS  0420
      VISRA = TST1                                                      AROS  0430
      GO TO 13                                                          AROS  0440
   12 VISRA = 2.270E-8*SQRT(TST1*FS(3))/(1.+ TCT1/TST1)/ FS(5)          AROS  0450
   13 ROMURA = SQRT(BS(2)/FS(2)*VISRA/TST1)                             AROS  0460
      GO TO 30                                                          AROS  0470
   14 ROMURA = SQRT(SQRT(TST1)*(1.+TCT1)/(TST1+TCT1)*BS(2)/FS(2))       AROS  0480
      GO TO 30                                                          AROS  0490
C                                                                       AROS  0500
C  REFERENCE ENTHALPY SOLUTION.                                         AROS  0510
   20 HW = ENTHAL(TW,PW)                                                AROS  0520
   21 HSTAR = A1*HW + A2*HAW + (1.-A1-A2)*H2                            AROS  0530
      ROMURA = SQRT(ROMU(HSTAR,PW)/(FS(1)*FS(5)))                       AROS  0540
      TST1 = HSTAR/H1                                                   AROS  0550
   30 QC = CKU*ROMURA*(HAW - HW)                                        AROS  0560
      RETURN                                                            AROS  0570
C                                                                       AROS  0580
C                                                                       AROS  0590
C  TURBULENT FLOW,  SPALDING-CHI METHOD                                 AROS  0600
   40 IF (IHW.GT.0) GO TO 60                                            AROS  0610
      TW1 = TW                                                          AROS  0620
      IF(TW1.LT.100.0) TW1= 100.0                                       AROS  0630
      GO TO (41,50),ITW                                                 AROS  0640
C  IDEAL GAS SOLUTION                                                   AROS  0650
   41 HW = GCP*TW1                                                      AROS  0660
      GO TO 60                                                          AROS  0670
C  REAL GAS SOLUTION                                                    AROS  0680
   50 HW = ENTHAL(TW1,PW)                                               AROS  0690
   60 A = HAW/H2 - 1.                                                   AROS  0700
      B = HW/H2 - 1.                                                    AROS  0710
```

```
DECK AROS
      C = SQRT((A+B)**2 + 4.*A)                                              AROS  0720
      FC = A/(ARSIN((A-B)/C) + ARSIN((A+B)/C))**2                            AROS  0730
      FRX = (HAW/H2)**0.772/(FC*(HW/H2)**1.474)                              AROS  0740
      RET = FRX*BS(8)*ELLOC                                                  AROS  0750
      IF (RET.LT.2540.) GO TO (11,21), ITW                                   AROS  0760
      CFTLOC = 0.088*(ALOG10(RET) - 2.3686)/(ALOG10(RET)-1.5)**3             AROS  0770
      RA = 1.0 + 5.0*SQRT(0.5*CFTLOC)*(0.275 + ALOG(4.625/6.0))              AROS  0780
      CFTLOC = CFTLOC/FC                                                     AROS  0790
      QC = BS(1)*BS(7)*0.5*CFTLOC*(HAW - HW)/RA                              AROS  0800
      RETURN                                                                 AROS  0810
C                                                                            AROS  0820
C  TURBULENT FLOW,  REFERENCE METHOD                                         AROS  0830
  140 GO TO (150,160), ITW                                                   AROS  0840
C  IDEAL GAS - REFERENCE TEMPERATURE                                         AROS  0850
  150 HW = GCP*TW                                                            AROS  0860
      TST1 = (A1*HW + A2*HAW + (1.-A1-A2)*H2)/H1                             AROS  0870
      TSTAR = TST1*FS(3)                                                     AROS  0880
      IF (TSTAR.LE.225.0) VIS = 0.80382436E-9*TSTAR                          AROS  0890
      IF (TSTAR.GT.225.0) VIS = 2.27E-8*TSTAR**1.5/(TSTAR + 198.6)           AROS  0900
      ROSTAR = BS(1)*BS(3)/TSTAR                                             AROS  0910
      GO TO 170                                                              AROS  0920
C  REAL GAS - REFERENCE ENTHALPY                                             AROS  0930
  160 HW = ENTHAL(TW,PW)                                                     AROS  0940
      HSTAR = A1*HW + A2*HAW + (1.-A1-A2)*H2                                 AROS  0950
      TST1 = HSTAR/H1                                                        AROS  0960
      ROSTAR = ROW(HSTAR,PW)                                                 AROS  0970
      VIS = ROMU(HSTAR,PW)/ROSTAR                                            AROS  0980
  170 FC = BS(1)/ROSTAR                                                      AROS  0990
      FRX  =      ROSTAR*BS(5)/(BS(1)*VIS)                                   AROS  1000
      RET  = FRX*BS(8)*ELLOC                                                 AROS  1010
      IF (RET.LT.2540.0) GO TO (11,21), ITW                                  AROS  1020
      CFTLOC = 0.088*(ALOG10(RET) - 2.3686)/(ALOG10(RET) - 1.5)**3/FC        AROS  1030
      QC = 0.5*(0.71**(-2./3.))*BS(1)*BS(7)*CFTLOC*(HAW - HW)                AROS  1040
      RETURN                                                                 AROS  1050
      END                                                                    AROS  1060
```


START
PW=ES(2)
IFLOW-2
IF
GO TO 2
GO TO 2
-
+
0
1
COMPUTED GO TO
IF THE VALUE OF ITURB
TRANSFER TO STATEMENT
1 3
2 43
3 40
2
CONTINUE
IHW
GO TO 4
GO TO 4
3
COMPUTED GO TO
IF THE VALUE OF ITW
TRANSFER TO STATEMENT
1 11
2 21
4
CONTINUE
ITW.EQ.2
YES
NO
GO TO 20
10
HW=ICF*TW
11
TSTI=(A1*HW+A2*HAW+(1.-A1-A2)*H2)/H1
TCTI=190.0/FS(3)
FS(3).GT.225.0
YES
NO
GO TO 14
TSTI*FS(3).GT.225.0
GO TO 12
VISRA=TSTI
GO TO 13
12
VISRA=2.27E-8*SQRT(TSTI*FS(3))/(1.+TCTI/TSTI)/FS(5)
13
RE=RA*SQRT(BS(2)/FS(2)*UESRA/TSTI)
GO TO 30
14
RENURA=SQRT(TSTI)*(1.+TCTI)/(TSTI+TCTI)*BS(2)/FS(2)
GO TO 30
20
HW=ENTHAL(TW,PW)
21
HSTAR=A1*HW+A2*HAW+(1.-A1-A2)*H2
RENURA=SQRT(HSTAR,PW)/(FS(1)*FS(2)))
TSTI=HSTAR/H1
30
RETURN
40
CONTINUE
IHW.GT.0
YES
NO
GO TO 60


TW1=TW
TW1.LT.100.0
IS
NO
YES
TW1=100.0
COMPUTED GO TO
IF THE VALUE TRANSFER
OF ITW TO
IS STATEMENT
1 41
2 50
41
HW=GCP*TW1
GO TO 60
50
HW=ENTHAL(TW1,PW)
60
A=HAW/H2-1.
B=HW/H2-1.
C=SQRT((A+B)**2+4.*A)
FC=A/(ARSIN((A-B)/C)+ARSIN((A+B)/C))**2
FRX=(HAW/H2)**0.772/(FC*(HW/H2)**0.474)
RET=FRX*BS(8)*ELLOC
GO TO 3
YES
IS
RET.LT.2340.
NO
CFTLOC=0.088*(ALOG10(RET)-2.3686)/(ALOG10(RET)-1.5)**3
RA=5.0+5.0*SQRT(0.5*CFTLOC)*(0.275+ALOG(4.625/6.0))
CFTLOC=CFTLOC/FC
QC=BS(1)*BS(7)*0.5*CFTLOC*(HAW-HW)/RA
RETURN
140
COMPUTED GO TO
IF THE VALUE TRANSFER
OF ITW TO
IS STATEMENT
1 150
2 160
150
HW=GCP*TW
TST1=(A1*HW+A2*HAW+(1.-A1-A2)*H2)/H1
TSTAR=TST1*FS(3)
NO
IS
TSTAR.LE.225.0
YES
VIS=0.87502436E-5*TSTAR
NO
IS
TSTAR.GT.225.0
YES
VIS=2.27E-8*TSTAR**1.5/(TSTAR+198.6)
ROSTAR=BS(1)*BS(3)/TSTAR
GO TO 170
160
HW=ENTHAL(TW,PW)
HSTAR=A1*HW+A2*HAW+(1.-A1-A2)*H2
TST1=HSTAR/H1
ROSTAR=ROW(HSTAR,PW)
VIS=ROMU(HSTAR,PW)/ROSTAR
170
FC=BS(3)/ROSTAR
FRX=ROSTAR*BS(5)/(BS(1)*VIS)
RET=FRX*BS(8)*ELLOC


GO TO
3
YES
15
RET.LT.2540.
NO
CFILOC=0.088*(ALOG10(RET)-2.3686)/(ALOG10(RET)-1.5)**3/FC
QC=0.5*(0.71**(-2./3.))*BS(1)*BS(7)*CFILOC*(HAW-HW)
RETURN

```
SYMBOLS USED IN SUBROUTINE QC

A         R  U  COEFFICIENT USED IN SPALDING-CHI METHOD                  QC
AREA2     R  C  QUADRILATERAL ELEMENT AREA ARRAY                         QC
A1        R  U  COEFFICENT IN THE DEFINITION OF REFERENCE CONDITION      QC
A2        R  U  COEFFICIENT IN THE DEFINITION OF REFERENCE CONDITION     QC
B         R  U  COEFFICIENT USED IN SPALDING-CHI METHOD                  QC
BS        R  C  FLOW CONDITION ARRAY BEHIND SHOCK OR EXPANSION           QC
C         R  U  COEFFICIENT USED IN SPALDING-CHI METHOD                  QC
CASE      I  C  CASE NUMBER                                              QC
CFTLOC    R  C  LOCAL TURBULENT SKIN-FRICTION COEFFICIENT                QC
CKU       R  C  LAMINAR FLOW FLIGHT CONDITION CONSTANT                   QC
ELLOC     R  C  REFERENCE LENGTH                                         QC
ERROR     I  C  ERROR FLAG                                               QC
FC        R  C  TURBULENT FLOW, SKIN FRICTION COMPRESSIBILITY FACTOR     QC
FRX       R  C  TURBULENT FLOW, REYNOLDS NUMBER COMPRESSIBILITY FACTOR   QC
FS        R  C  FREE-STREAM FLOW CONDITION ARRAY                         QC
GCP       R  C  GAS SPECIFIC HEAT AT CONSTANT PRESSURE                   QC
HAW       R  C  ADIABATIC-WALL ENTHALPY                                  QC
HSTAR     R  U  REFERENCE ENTHALPY                                       QC
HW        R  C  WALL ENTHALPY                                            QC
H1        R  C  FREE-STREAM ENTHALPY                                     QC
H2        R  C  LOCAL ENTHALPY                                           QC
IFLOW     I  C  LAMINAR (=1) OR TURBULENT (=2) FLOW FLAG                 QC
IHW       I  C  WALL ENTHALPY FLAG                                       QC
IM        I  C  ELEMENT ROW NUMBER ARRAY                                 QC
IN        I  C  ELEMENT COLUMN NUMBER ARRAY                              QC
ITURB     I  C  TURBULENT FLOW FLAG                                      QC
ITW       I  C  IDEAL GAS (=1) OR REAL GAS (=2) FLAG                     QC
L         I  C  NUMBER OF ELEMENTS                                       QC
LS        I  C  NUMBER OF ELEMENTS                                       QC
NX2       R  C  ELEMENT DIRECTION COSINE ARRAY-X                         QC
NY2       R  C  ELEMENT DIRECTION COSINE ARRAY-Y                         QC
NZ2       R  C  ELEMENT DIRECTION COSINE ARRAY-Z                         QC
PAGE      I  C  PAGE NUMBER                                              QC
PW        R  U  PRESSURE                                                 QC
QC        R  U  CONVECTIVE HEATING RATE                                  QC
RA        R  U  REYNOLDS ANALOGY FACTOR                                  QC
```

```
SYMBOLS USED IN SUBROUTINE QC

RET      R  C  TURBULENT FLOW REYNOLDS NUMBER AT REFERENCE CONDITION          QC
RUMURA   R  C  SQUARE-ROOT OF REFERENCE DENSITY-VISCOSITY RATIO               QC
ROSTAR   R  U  DENSITY AT REFERENCE CONDITION                                 QC
TCT1     R  U  SUTHERLAND CONSTANT TO FREE-STREAM TEMPERATURE RATIO           QC
TITLE    R  C  TITLE                                                          QC
TSTAR    R  U  REFERENCE TEMPERATURE                                          QC
TST1     R  C  REFERENCE TO FREE-STREAM TEMPERATURE (OR ENTHALPY) RATIO       QC
TW       R  A  WALL TEMPERATURE                                               QC
TW1      R  U  WALL TEMPERATURE                                               QC
VIS      R  U  VICOSITY AT REFERENCE CONDITION                                QC
VISRA    R  U  REFERENCE TO FREE-STREAM VISCOSITY RATIO                       QC
XCENT2   R  C  QUADRILATERAL ELEMENT CENTROID ARRAY-X                         QC
YCENT2   R  C  QUADRILATERAL ELEMENT CENTROID ARRAY-Y                         QC
ZCENT2   R  C  QUADRILATERAL ELEMENT CENTROID ARRAY-Z                         QC
```

21. FUNCTION POLY (DECK AROT)

This routine generates an N-th order polynomial.

a. Algorithm

Polynomial is evaluated for the input order and coefficient array at a specified starting value.

b. Input/Output

None

c. Error

None

d. Subroutines Required

None

e. Argument List

(A, I, HX, N)

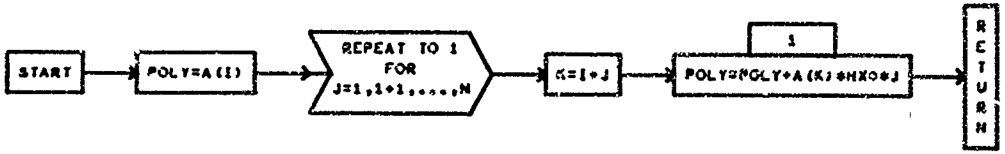
f. Length

444 bytes

```
DECK AROT

      FUNCTION POLY(A,I,HX,N)                                           AROT  0010
      DIMENSION A(135)                                                  AROT  0020
C                                                                       AROT  0030
C  THIS FUNCTION GENERATES AN N-TH ORDER POLYNOMIAL                     AROT  0040
C  IN HX WITH COEFFICIENTS A(K) STARTING WITH K=I.                      AROT  0050
C                                                                       AROT  0060
      POLY = A(I)                                                       AROT  0070
      DO  1 J = 1,N                                                     AROT  0080
      K = I + J                                                         AROT  0090
    1 POLY = POLY + A(K)*HX**J                                          AROT  0100
      RETURN                                                            AROT  0110
      END                                                               AROT  0120
```

FUNCTION POLY



```
SYMBOLS USED IN SUBROUTINE POLY

A         R  A  POLYNOMIAL COEFFICIENT ARRAY                                           POLY
HX        R  A  INDEPENDENT VARIABLE                                                   POLY
I         I  A  INDEX NUMBER OF INITIAL COEFFICIENT                                    POLY
J         I  U  DO-LOOP INDEX                                                          POLY
K         I  U  COEFFICIENT NUMBER                                                     POLY
N         I  A  ORDER OF POLYNOMIAL                                                    POLY
POLY      R  U  VALUE OF POLYNOMIAL                                                    POLY
```

22. FUNCTION ROMU (DECK AROU)

This routine calculates various equilibrium air real gas properties. Has three entries; ROMU, ENTHAL, and ROW.

a. Algorithm

ROMU determines the density-viscosity product as a function of the input enthalpy and pressure.

ENTHAL determines the enthalpy as a function of the input temperature and pressure.

ROW calculates the density as a function of the input enthalpy and pressure.

b. Input/Output

None

c. Error

None

d. Subroutines Required

POLY

e. Argument List

ROMU (HS, P2), ENTHAL (TW, PW), ROW (HS, P2)

f. Length

2478 bytes

DECK AROU

```
      FUNCTION ROMU(HS,P2)                                              AROU  0010
C                                                                       AROU  0020
C                                                                       AROU  0030
C  THIS FUNCTION HAS THREE ENTRIES.  THE FIRST, ROMU(HS,P2), CALCULATES AROU  0040
C  THE DENSITY-VISCOSITY PRODUCT FOR EQUILIBRIUM AIR AT THE INPUT       AROU  0050
C  ENTHALPY (HS) AND PRESSURE (P2).                                     AROU  0060
C           RANGE,  HS TO ABOUT 4.E+8 (FT/SEC)**2 AND P2 .GT. 1.E-4     AROU  0070
C                    AND .LT. 10.  EXTRAPOLATION FOR P2 OUTSIDE THIS.   AROU  0080
C  THE SECOND, ENTHAL(TW,PW), CALCULATES THE ENTHALPY CORRESPONDING     AROU  0090
C  TO THE INPUT TEMPERATURE (TW) AND PRESSURE (PW).                     AROU  0100
C           RANGE,  TW TO ABOUT 8000.OR (PROGRAM HAS CUTOFF AT          AROU  0110
C                    7000.OR)  AND PW SAME AS P2 ABOVE.                 AROU  0120
C  THE  THIRD, ROW(HS,P2), CALCULATES THE DENSITY (SLUGS/FT**3)         AROU  0130
C  FOR EQUILIBRIUM AIR AT THE INPUT ENTHALPY (HS) AND PRESSURE (P2).    AROU  0140
C           RANGE,  SAME AS FOR ROMU ABOVE.                             AROU  0150
C  ALL ENTRIES REQUIRE BLOCK DATA FOR COMMON/PROP/ AND FUNCTION         AROU  0160
C  POLY.  THE PROPERTIES BASED ON AEDC TR-65-58 AND HANSENS VISCOSITY.  AROU  0170
C  DETAILS OF THE PROPERTY FITS ARE GIVEN IN DOUGLAS REPORT LB-32706.   AROU  0180
C**************D. N. SMYTH PROGRAM AUTHOR*******************************AROU  0190
C                                                                       AROU  0200
C                                                                       AROU  0210
C                                                                       AROU  0220
      COMMON /PROP/ FH(135), FR(135)                                    AROU  0230
      DIMENSION IH(3)                                                   AROU  0240
      DATA PREF/2117.36/                                                AROU  0250
      H1 = HS*1.0E-8                                                    AROU  0260
C                                                                       AROU  0270
C  DETERMINE ENTHALPY RANGE AT 10.0ATM                                  AROU  0280
      IRM1 = 1                                                          AROU  0290
      IF (H1.LT.0.042) GO TO 1                                          AROU  0300
      IRM1 = 10                                                         AROU  0310
      IF (H1.LT.0.1768) GO TO 1                                         AROU  0320
      IRM1 = 46                                                         AROU  0330
      IF (H1.LT.0.650) GO TO 2                                          AROU  0340
      IRM1 = 55                                                         AROU  0350
```

```
DECK AROU
      IF (H1.GT.1.10) IRM1 = 64                                        AROU  0360
C                                                                      AROU  0370
C  DETERMINE ENTHALPY RANGE AT 10.0**-4 ATM                            AROU  0380
    1 IF (H1.GT.0.1768) GO TO 2                                        AROU  0390
      IRM2 = IRM1                                                      AROU  0400
      H1 = H1*10.0                                                     AROU  0410
      GO TO 3                                                          AROU  0420
    2 IRM2 = 19                                                        AROU  0430
      IF (H1.LT.0.580) GO TO 3                                         AROU  0440
      IRM2 = 28                                                        AROU  0450
      IF (H1.GT.0.980) IRM2 = 37                                       AROU  0460
    3 N = 6                                                            AROU  0470
      PBAR = P2/PREF                                                   AROU  0480
      PBARLG = ALOG10(PBAR)                                            AROU  0490
      ROMU =-0.2*((PBARLG-1.0)*POLY(FR,IRM2,H1,N) - (PBARLG+4.0)*      AROU  0500
     1             POLY(FR,IRM1,H1,N))                                 AROU  0510
      ROMU = ROMU*PBAR*1.0E-9                                          AROU  0520
      RETURN                                                           AROU  0530
C                                                                      AROU  0540
C                                                                      AROU  0550
C  DETERMINE ENTHALPY FOR GIVEN TEMPERATURE (MAXIMUM 7000.0R)          AROU  0560
      ENTRY ENTHAL(TW,PW)                                              AROU  0570
      N = 8                                                            AROU  0580
      IF (TW.GT.7000.0) TW = 7000.0                                    AROU  0590
      THX = TW*1.0E-4                                                  AROU  0600
      J = 1                                                            AROU  0610
      IF (TW.GT.2700.) GO TO 10                                        AROU  0620
      IH1 = 1                                                          AROU  0630
      ROMU = POLY(FH,IH1,THX,N)*1.0E+8                                 AROU  0640
      RETURN                                                           AROU  0650
C                                                                      AROU  0660
   10 PBAR = PW/PREF                                                   AROU  0670
      PBARLG = ALOG10(PBAR)                                            AROU  0680
C                                                                      AROU  0690
C  DETERMINE THREE PBARLG VALVES TO USE IN QUADRATIC INTERPOLATION     AROU  0700
      IF (PBARLG.GT.-3.0) GO TO 20                                     AROU  0710
```

DECK AROU

```
      PBAR1 = -4.0                                                      AROU  0720
      PBAR2 = -3.0                                                      AROU  0730
      PBAR3 = -2.0                                                      AROU  0740
      GO TO 12                                                          AROU  0750
   20 IF (PBARLG.GT.-2.0) GO TO 30                                      AROU  0760
      PBAR1 = -3.0                                                      AROU  0770
      PBAR2 = -2.0                                                      AROU  0780
      PBAR3 = -1.0                                                      AROU  0790
      GO TO 14                                                          AROU  0800
   30 IF (PBARLG.GT.-1.0) GO TO 40                                      AROU  0810
      PBAR1 = -2.0                                                      AROU  0820
      PBAR2 = -1.C                                                      AROU  0830
      PBAR3 =  0.0                                                      AROU  0840
      GO TO 16                                                          AROU  0850
   40 PBAR1 = -1.0                                                      AROU  0860
      PBAR2 =  C.0                                                      AROU  0870
      PBAR3 =  1.C                                                      AROU  0880
      GO TO 18                                                          AROU  0890
C                                                                       AROU  0900
C   DETERMINE TFMP. RANGE AT PBARLG = -4                                AROU  0910
   12 IH(J) = 10                                                        AROU  0920
      IF (Tk.LT.4200.) GO TO 13                                         AROU  0930
      IH(J) = 19                                                        AROU  0940
      IF (Tk.GT.5500.) IH(J) = 28                                       AROU  0950
   13 J = J + 1                                                         AROU  0960
C                                                                       AROU  0970
C   DETERMINE TEMP. RANGE AT PBARLG = -3                                AROU  0980
   14 IH(J) = 37                                                        AROU  0990
      IF (Tk.LT.4540.) GO TC 15                                         AROU  1000
      IH(J) = 46                                                        AROU  1010
      IF (Tk.GT.6120.) IH(J) = 55                                       AROU  1020
   15 J = J + 1                                                         AROU  1030
C                                                                       AROU  1040
C   DETERMINE TFMP. RANGE AT PBARLG = -2                                AROU  1050
   16 IH(J) = 64                                                        AROU  1060
      IF (Tk.LT.5220.) GO TO 17                                         AROU  1070
```

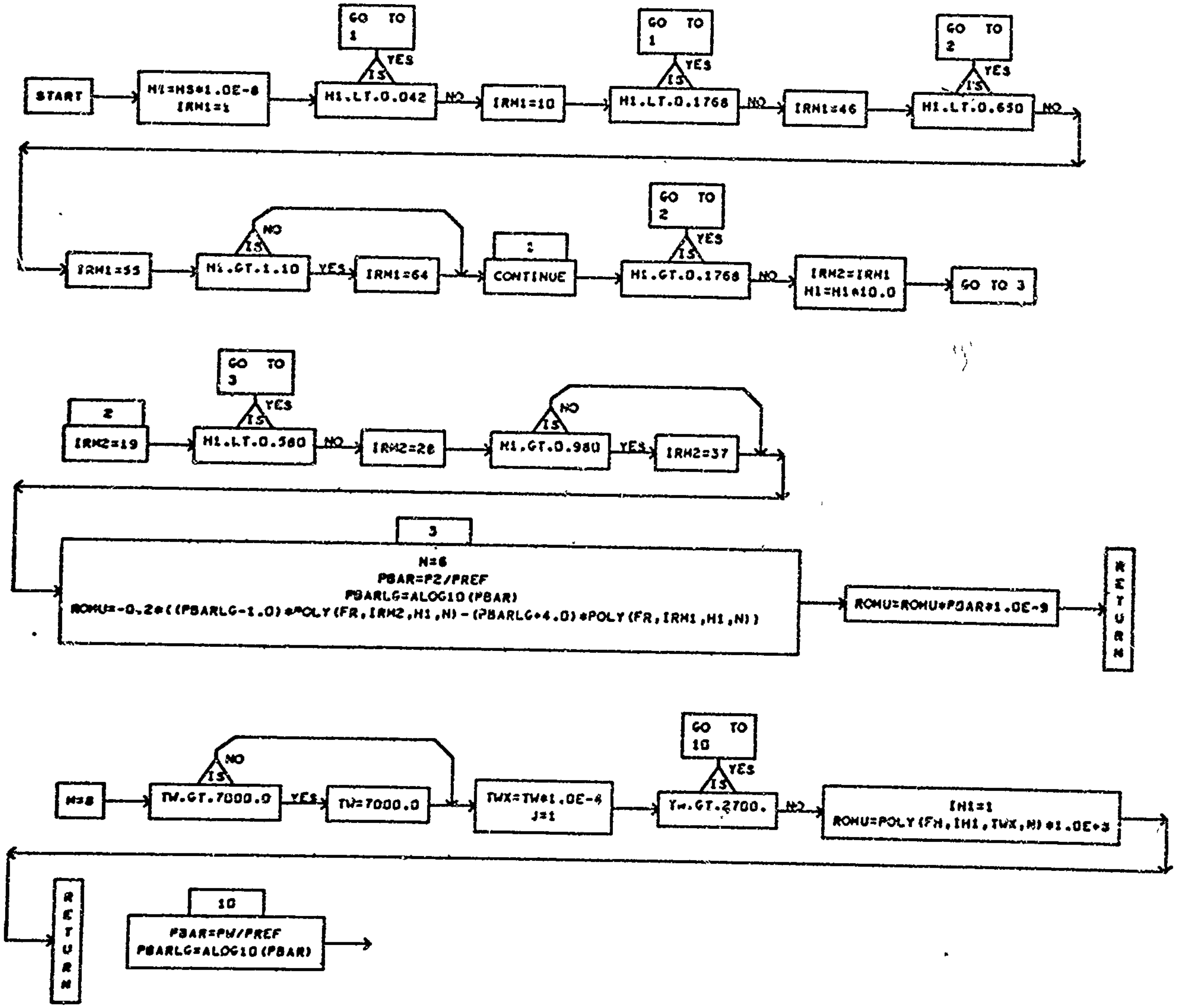
DECK AROU

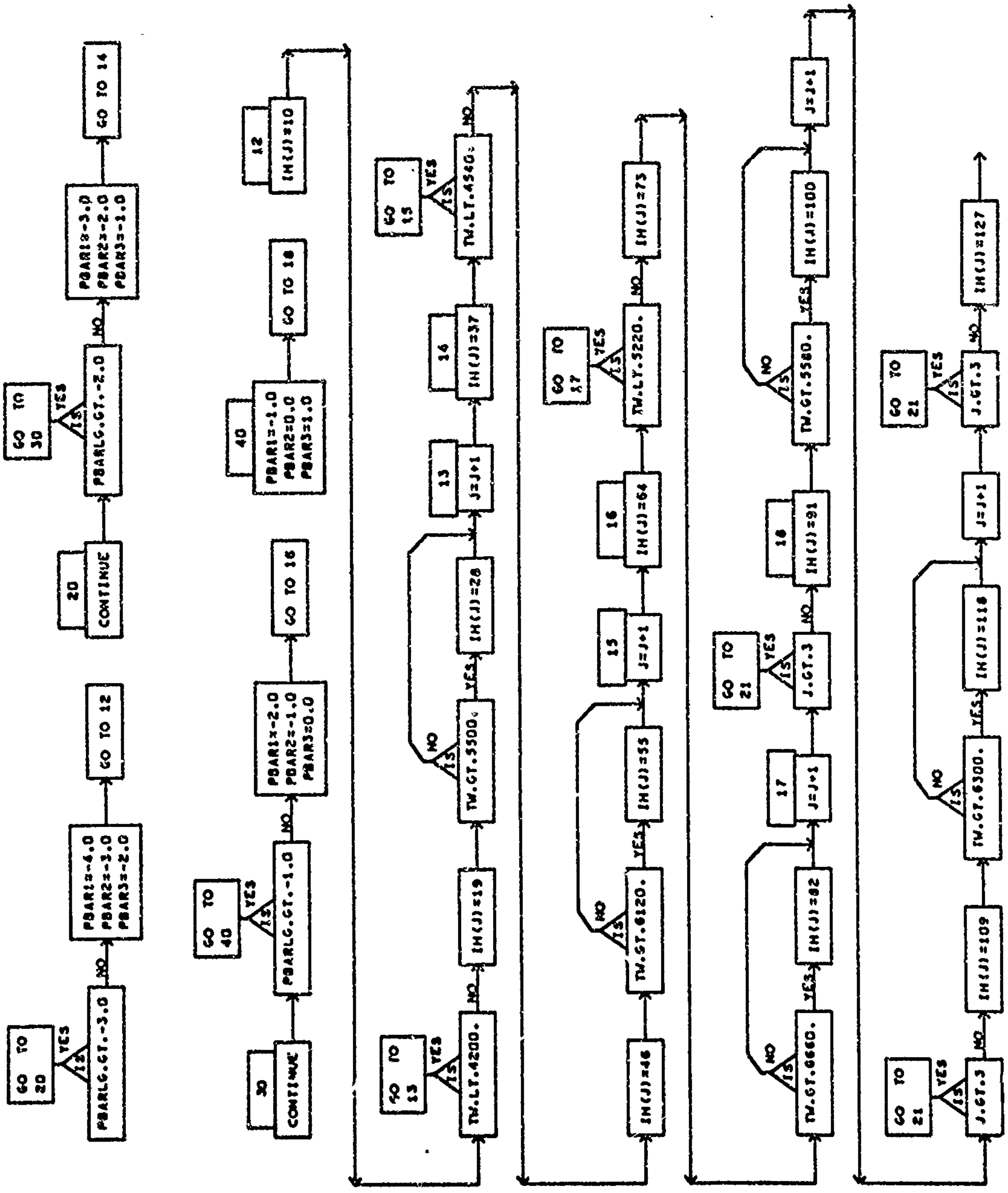
```
      IH(J) = 73                                                        AROU  1080
      IF (TW.GT.6660.) IH(J) = 82                                       AROU  1090
   17 J = J + 1                                                         AROU  1100
      IF (J.GT.3) GO TO 21                                              AROU  1110
C                                                                       AROU  1120
C  DETERMINE TEMP. RANGE AT PBARLG = -1                                 AROU  1130
   18 IH(J) = 91                                                        AROU  1140
      IF (TW.GT.5580.) IH(J) = 100                                      AROU  1150
      J = J + 1                                                         AROU  1160
      IF (J.GT.3) GO TO 21                                              AROU  1170
C  DETERMINE TEMP. RANGE AT PBARLG = 0                                  AROU  1180
      IH(J) = 109                                                       AROU  1190
      IF (TW.GT.6300.) IH(J) = 118                                      AROU  1200
      J = J + 1                                                         AROU  1210
      IF (J.GT.3) GO TO 21                                              AROU  1220
C                                                                       AROU  1230
C  DETERMINE TEMP. RANGE AT PBARLG = 1                                  AROU  1240
      IH(J) = 127                                                       AROU  1250
C                                                                       AROU  1260
C  CALCULATE ENTHALPY                                                   AROU  1270
   21 IH1 = IH(1)                                                       AROU  1280
      IH2 = IH(2)                                                       AROU  1290
      IH3 = IH(3)                                                       AROU  1300
      HC1 = (PBARLG - PBAR2)*(PBARLG - PBAR3)*0.5                       AROU  1310
      HC2 = (PBARLG - PBAR1)*(PBARLG - PBAR3)                           AROU  1320
      HC3 = (PBARLG - PBAR1)*(PBARLG - PBAR2)*0.5                       AROU  1330
      ROMU =(HC1*POLY(FH,IH1,TWX,N) - HC2*POLY(FH,IH2,TWX,N)            AROU  1340
     1          + HC3*POLY(FH,IH3,TWX,N))*1.0E+8                        AROU  1350
      RETURN                                                            AROU  1360
C                                                                       AROU  1370
C                                                                       AROU  1380
C  DETERMINE DENSITY FOR GIVEN ENTHALPY AND PRESSURE.                   AROU  1390
      ENTRY  ROW(HS,P2)                                                 AROU  1400
      H1 = HS*1.0E-8                                                    AROU  1410
      N = 9                                                             AROU  1420
C                                                                       AROU  1430
```

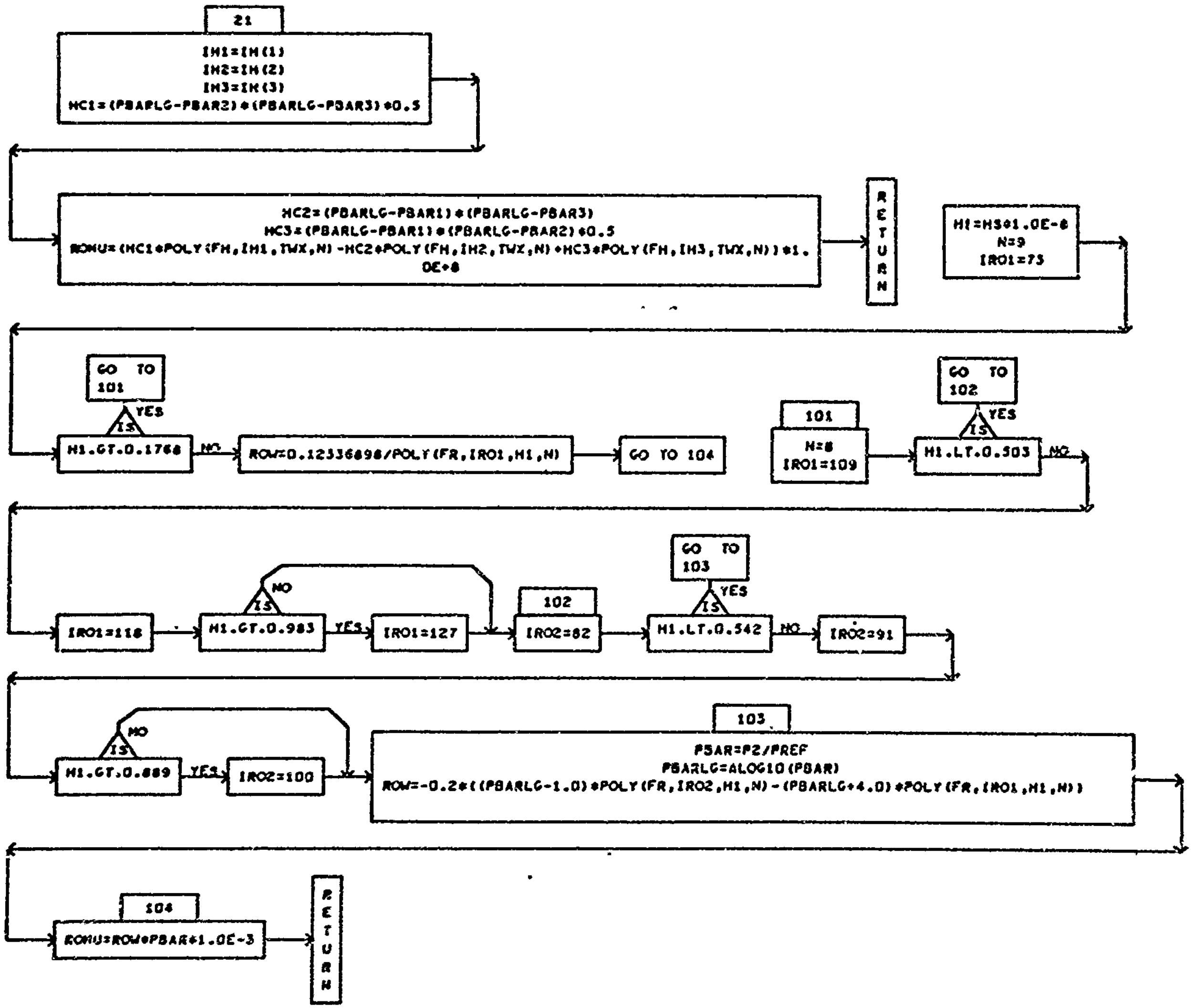
```
DECK AROU

C DETERMINE ENTHALPY RANGE AT 10.0 ATM.                                 AROU  1440
      IRO1  = 73                                                        AROU  1450
      IF (H1.GT.0.1768) GO TO 101                                       AROU  1460
      ROW = 0.12336898/POLY(FR,IRO1, H1,N)                              AROU  1470
      GO TO 104                                                         AROU  1480
  101 N = 8                                                             AROU  1490
      IRO1  = 109                                                       AROU  1500
      IF (H1.LT.0.503) GO TO 102                                        AROU  1510
      IRO1  = 118                                                       AROU  1520
      IF (H1.GT.0.983) IRO1  = 127                                      AROU  1530
C                                                                       AROU  1540
C  DETERMINE ENTHALPY RANGE AT 10.0**-4 ATM.                            AROU  1550
  102 IRO2 = 82                                                         AROU  1560
      IF (H1.LT.0.542) GO TO 103                                        AROU  1570
      IRO2 = 91                                                         AROU  1580
      IF (H1.GT.0.889) IRO2 = 100                                       AROU  1590
  103 PBAR = P2/PREF                                                    AROU  1600
      PBARLG = ALOG10(PBAR)                                             AROU  1610
      ROW = -0.2*((PBARLG - 1.0)*POLY(FR,IRO2,H1,N) -                   AROU  1620
     1            (PBARLG + 4.0)*POLY(FR,IRO1,H1,N))                    AROU  1630
  104 ROHU = ROW*PBAR*1.0E-3                                            AROU  1640
      RETURN                                                            AROU  1650
      END                                                               AROU  1660
```

FUNCTION ROMU




PBARLG.GT.-3.0
IS
YES
GO TO 20
NO
PBAR1=-4.0
PBAR2=-3.0
PBAR3=-2.0
GO TO 12
20
CONTINUE
PBARLG.GT.-2.0
GO TO 30
PBAR1=-3.0
PBAR2=-2.0
PBAR3=-1.0
GO TO 14
30
CONTINUE
PBARLG.GT.-1.0
GO TO 40
PBAR1=-2.0
PBAR2=-1.0
PBAR3=0.0
GO TO 16
40
PBAR1=-1.0
PBAR2=0.0
PBAR3=1.0
GO TO 18
12
IH(J)=10
TW.LT.4200.
GO TO 13
IH(J)=19
TW.GT.5500.
IH(J)=28
13
J=J+1
14
IH(J)=37
TW.LT.4540.
GO TO 15
IH(J)=46
TW.GT.6120.
IH(J)=55
15
J=J+1
16
IH(J)=64
TW.LT.5220.
GO TO 17
IH(J)=73
TW.GT.6660.
IH(J)=82
17
J=J+1
J.GT.3
GO TO 21
18
IH(J)=91
TW.GT.5580.
IH(J)=100
J=J+1
J.GT.3
GO TO 21
IH(J)=109
TW.GT.6300.
IH(J)=118
J=J+1
J.GT.3
GO TO 21
IH(J)=127


21
IH1=IH(1)
IH2=IH(2)
IH3=IH(3)
HC1=(PBARLG-PBAR2)*(PBARLG-PBAR3)*0.5
HC2=(PBARLG-PBAR1)*(PBARLG-PBAR3)
HC3=(PBARLG-PBAR1)*(PBARLG-PBAR2)*0.5
ROMU=(HC1*POLY(FH,IH1,TWX,N)-HC2*POLY(FH,IH2,TWX,N)+HC3*POLY(FH,IH3,TWX,N))*1.0E+8
RETURN
HI=HS*1.0E-8
N=9
IRO1=75
GO TO 101
YES
IS
H1.GT.0.1768
NO
ROW=0.12336898/POLY(FR,IRO1,H1,N)
GO TO 104
101
N=8
IRO1=109
GO TO 102
YES
IS
H1.LT.0.503
NO
IRO1=118
NO
IS
H1.GT.0.983
YES
IRO1=127
102
IRO2=82
GO TO 103
YES
IS
H1.LT.0.542
NO
IRO2=91
NO
IS
H1.GT.0.889
YES
IRO2=100
103
PBAR=P2/PREF
PBARLG=ALOG10(PBAR)
ROW=-0.2*((PBARLG-1.0)*POLY(FR,IRO2,H1,N)-(PBARLG+4.0)*POLY(FR,IRO1,H1,N))
104
ROMU=ROW*PBAR*1.0E-3
RETURN

```
SYMBOLS USED IN SUBROUTINE ROMU

ENTHAL   R  U  ENTRY TO DETERMINE ENTHALPY                                      ROMU
FH       R  C  ENTHALPY ARRAY                                                   ROMU
FR       R  C  DENSITY-VISCOSITY PRODUCT AND DENSITY ARRAYS                     ROMU
HC1      R  U  FIRST ENTHALPY COEFFICIENT                                       ROMU
HC2      R  U  SECOND ENTHALPY COEFFICIENT                                      ROMU
HC3      R  U  THIRD ENTHALPY COEFFICIENT                                       ROMU
HS       R  A  ENTHALPY (FT/SEC)**2                                             ROMU
H1       R  U  REDUCED ENTHALPY (HS*1.0E-8)                                     ROMU
IH       I  D  ENTHALPY ARRAY INDEX                                             ROMU
IH1      I  U  ENTHALPY ARRAY INDEX AT FIRST PRESSURE                           ROMU
IH2      I  U  ENTHALPY ARRAY INDEX AT SECOND PRESSURE                          ROMU
IH3      I  U  ENTHALPY ARRAY INDEX AT THIRD PRESSURE                           ROMU
IRM1     I  U  DENSITY-VISCOSITY ARRAY INDEX AT 10.0 ATM.                       ROMU
IRM2     I  U  DENSITY-VISCOSITY ARRAY INDEX AT 10.0**-4 ATM.                   ROMU
IRO1     I  U  DENSITY ARRAY INDEX AT 10.0 ATM.                                 ROMU
IRO2     I  U  DENSITY ARRAY INDEX AT 10.0**-4 ATM.                             ROMU
J        I  U  ENTHALPY INDEX COUNTER                                           ROMU
N        I  U  ORDER OF POLYNOMIAL                                              ROMU
PBAR     R  U  PRESSURE RATIO (PW/PREF)                                         ROMU
PBARLG   R  U  LOG10 OF PBAR                                                    ROMU
PBAR1    R  U  LOG10 OF FIRST REFERENCE PRESSURE RATIO                          ROMU
PBAR2    R  U  LOG10 OF SECOND REFERENCE PRESSURE RATIO                         ROMU
PBAR3    R  U  LOG10 OF THIRD REFERENCE PRESSURE RATIO                          ROMU
PREF     R  U  REFERENCE PRESSURE (2117.36 LB/SQ.FT.)                           ROMU
PW       R  A  LOCAL PRESSURE (LB/SQ.FT.)                                       ROMU
P2       R  A  LOCAL PRESSURE (LB/SQ.FT.)                                       ROMU
ROMU     R  U  DENSITY-VISCOSITY PRODUCT                                        ROMU
ROW      R  U  ENTRY TO DETERMINE DENSITY (ALSO DENSITY PARAMETER)              ROMU
TW       R  A  TEMPERATURE (RANKINE)                                            ROMU
TWX      R  U  REDUCED TEMPERATURE (TW*1.0E-4)                                  ROMU
```

23. BLOCK DATA (DECK AROV)

This routine initializes data arrays into common required in calculating equilibrium air real gas properties.

a. Algorithm

Data arrays are initialized at time of compilation into labelled common /PROP/.

b. Input/Output

None

c. Error

None

d. Subroutines Required

None

e. Argument List

None

f. Length

1080 bytes

```
DECK AROV

      BLOCK DATA
C
C
C  THIS SUBROUTINE INITIALIZES INTO CCMMON/PROP/  THE COEFFICIENT
C  ARRAYS REQUIRED BY FUNCTION ROMU (ARO3)  TO DETERMINE THE
C  REAL EQUILIBRIUM AIR PROPERTIES.
C
C
C
         DIMENSION FH(135),FR(135),FH1(108),FH2(27),FR1(72),FR2(63)
      COMMON /PROP/ FH,FR
      EQUIVALENCE  (FH(1),FH1(1)),(FH(109),FH2(1)),
     1              (FR(1),FR1(1)), (FR(73),FR2(1))
C
C
      DATA                  FH1  / 0.0, .60181771, -.22228717, 2.5953429,
     1 -2.7853922, -9.7092052, 23.289510, -12.199244, -2.5817427,
     2 -.12935540, -2.9966848, 48.010840, -184.77242, 249.48974,
     3 -51.244932, 0.0, 0.0, 0.0,   -6.5939838, 19.010757, 19.992531,
     4 -39.975681, -112.89466, 156.16378, 0.0, 0.0, 0.0,   2.2022949,
     5 -14.101200, 23.004509, 52.890407, -165.08756, 113.04871, 0.0,
     6 0.0, 0.0,   -.20293060, .71240021, 11.699213, -47.629621,
     7 42.913642, 30.631199, 0.0, 0.0, 0.0,    1.8692814, -22.097879,
     8 56.153394, -16.042275, 36.738951, -263.49237, 239.87072, 0.0,
     9 0.0,    -.15686170, 1.1830883, -2.0213376, 19.029276, -26.810587,
     A -9.9053574, 24.334188, 0.0 , 0.0,    .92262030, -8.5032999,
     B 20.492311, 45.587738, -119.90206, -509.58200, 1721.3813,
     C -1337.6228, 0.0,    -2.6782862, 1.2865940, 22.104893, -12.395676,
     D -26.121859, -12.897718, 38.794573, 0.0, 0.0,    -1.6135321,
     E 5.3650713, 2.4832548, -9.7412082, 1.2468173, .39646271, 4.5573527
     F,0.0, 0.0,    .44553169, -3.0252481, 2.6196596, 50.144314,
     G -151.34585, 133.67463, -154.12089, 535.69899, -494.43566,
     H -3.0416265, 12.560193, -20.33612, 17.381598, 23.843668,
     I -64.498613, 36.134646, 0.0, 0.0/
C
```

```
DECK AROV
C                                                                       AROV  0360
      DATA                   FH2  / .1199213, -.65116698, 3.8928011,    AROV  0370
     1 -.45545770, -5.3407127, -21.592914, 33.774256, 58.270657,        AROV  0380
     2 -78.177197,    .34683226, -.79201527, -.79886544, 5.2064374,     AROV  0390
     3 -1.2818503, 4.3016173, -6.9417639, 0.0, 0.0,   .11764422,        AROV  0400
     4 -.62580124, 3.5461409, 4.8925829, -39.857784, 71.680475,         AROV  0410
     5 -48.794024, 9.9564413, 0.0 /,                                    AROV  0420
     6               FR1 / 1.0490322, -.31228101,.90103854E-1,-6.7117799, AROV  0430
     7 18.184363, -13.551560, 0.0, 0.0, 0.0,   1.1329366, -.94702472,   AROV  0440
     8 .55849455,-.92146834E-1,-.50705935E-1,.17519852E-1,0.0,0.0,0.0,  AROV  0450
     9 .88808527, -3.9763502, 14.251132, -27.521840, 26.791510,         AROV  0460
     A -10.436079, 0.0, 0.0, 0.0,    -.14569908, 3.0171600, -5.9999473, AROV  0470
     8 4.6748398, -1.2742339, 0.0, 0.0, 0.0, 0.0, .37102156, -.13586302, AROV  0480
     C.44261289E-1,-.78199161E-2,.52479786E-3,0.0, 0.0, 0.0, 0.0,       AROV  0490
     D .77497574, -2.1673001, 4.0652322, -2.7726303, -1.1814257,        AROV  0500
     E 1.6918670, 0.0, 0.0, 0.0,   .52865913, -.58894771, .58988212,    AROV  0510
     F -.42483488, .19163722,-.38356068E-1,0.0, 0.0, 0.0,    .48598990, AROV  0520
     G -.41125640, .25298705, -.82910932F-1,.13654598E-1, -.89113877E-3, AROV  0530
     H 0.0, 0.0, 0.0/                                                   AROV  0540
C                                                                       AROV  0550
C                                                                       AROV  0560
      DATA                   FR2  / 0.0, 1.6627798, 1.1792685,          AROV  0570
     1 -28.017959, 155.77436, -439.43620, 709.71808, -671.23004,        AROV  0580
     2 317.22690,   1.5380637, -11.161238, 32.383428, 2.5847158,        AROV  0590
     3 -196.69668, 370.82431, -218.12898, 0.0, 0.0,   1.3507331,        AROV  0600
     4 -5.0193304, 6.0404391, 4.1730680, -13.136917, 6.7913235, 0.0,    AROV  0610
     5 0.0, 0.0,   .42795709, -.56949512, .40404761, -.11638753,        AROV  0620
     6 -.74634946E-2, .12505798E-1,-.27304295E-2, .19434979E-3, 0.0,    AROV  0630
     71.3644197, -9.5027751, 34.791129, -68.553220, 69.547355,          AROV  0640
     8 -28.523442, 0.0, 0.0, 0.0,   .48102262, -.91625506, .62421014,   AROV  0650
     9 .57730033, -1.0682441, .42044702, 0.0, 0.0, 0.0,   .42220834,    AROV  0660
     A -.61202419, .44184292, -.15420936,  .18083084E-1,.36418043E-2,   AROV  0670
     B  -.12611833E-2, .10222056E-3, 0.0 /                              AROV  0680
C                                                                       AROV  0690
C                                                                       AROV  0700
      END                                                               AROV  0710
```

```
SYMBOLS USED IN SUBROUTINE DATA

FH       R  C  ENTHALPY ARRAY                                                        DATA
FH1      R  D  FIRST 108 ELEMENTS OF ENTHALPY ARRAY                                  DATA
FH2      R  D  FINAL 27 ELEMENTS OF ENTHALPY ARRAY                                   DATA
FR       R  C  DENSITY-VISCOSITY PRODUCT AND DENSITY ARRAYS                          DATA
FR1      R  D  DENSITY-VISCOSITY PRODUCT ARRAY                                       DATA
FR2      R  D  DENSITY ARRAY                                                         DATA
```

24. SUBROUTINE ATMOS (DECK AROW)

This routine calculates the atmospheric properties using the 1962 U. S. Atmosphere.

a. Algorithm

Set up arrays and constant values. Calculate atmospheric properties assuming an inverse square gravitational field.

b. Input/Output

c. Error

None

d. Subroutines Required

None

e. Argument List

(A3, A8, A4, A1, A6)

f. Length

1792 bytes

DECK AROW

```
      SUBROUTINE ATMOS (A3,A8,A4,A1,A6)

C     THIS ROUTINE CALCULATES ATMOSPHERIC PROPERTIES OF THE
C     US STANDARD ATMOSPHERE,1962,ASSUMING AN INVERSE SQUARE
C     GRAVITATIONAL FIELD. THIS ASSUMPTION YIELDS DATA THAT
C     AGREES WITH THE COESA DOCUMENT WITHIN 1 PER CENT AT
C     ALL ALTITUDES UP TO 700 KILOMETERS (2296588 FEET). THE
C     DATA IS ARRANGED IN THE ATMOSPHERE ARRAY, A, AS
C     FOLLOWS
C     A(1)  = CS, SPEED OF SOUND, FT/SEC
C     A(2)  = (1/CS)(DCS/DZ), SOUND DERIVATIVE, 1/FT
C     A(3)  = Z, GEOMETRIC ALTITUDE, FT (GIVEN)
C     A(4)  = P, PRESSURE, LB/FT2
C     A(5)  = DP/DZ, PRESSURE DERIVATIVE, LB/FT3
C     A(6)  = RHO, DENSITY, SLUGS/FT3
C     A(7)  = (1/RHO)(DRHO/DZ), DENSITY DERIVATIVE, 1/FT
C     A(8)  = T, TEMPERATURE, DEG RANKINE
C     A(9)  = DT/DZ, TEMPERATURE DERIVATIVE, DEG RANKINE/FT

C     VARIOUS CONSTANTS USED
C      EARTH RADIUS                  = 20890855 FT
C      SPECIFIC HEAT RATIO FOR AIR = 1.4
C     SEA LEVEL VALUES
C      GRAVITATIONAL ACCELERATION   = 32.1740484 FT/SEC2
C      MOLECULAR WEIGHT              = 28.9644
C      GO*MO/R*                      = 0.018743418 DEG RANK/FT

      DIMENSION  A( 9),HG(10),ZM(14),WM(14),TM(23),PM(22)

C     SET ARRAYS AND CONSTANT VALUES
      DATA GO,WMO,RO,GMRS/32.1740484,28.9644,20890855.0,
     1     0.018743418/,HG/-16404.,0.0
     2     ,36089.,65617.,104987.,154199.,170604.,200131.,
     3     259186.,291160./,ZM/295276.,328084.,
     4     360892.,393701.,492126.,524934.,557743.,623360.,
```

```
DECK AROW

     5       754593.,984252.,1312336.,1640420.,1968504.,                          AROW  0360
     6       2296588./,WM/28.9644,28.88,28.56,                                    AROW  0370
     7       28.07,26.92,26.66,26.4,25.85,24.7,22.66,19.94,                       AROW  0380
     8       17.94,16.84,16.17/                                                   AROW  0390
                                                                                  AROW  0400
      DATA   TM/577.17,518.67,389.97,389.97,411.57                                AROW  0410
     1       ,487.17,487.17,454.77,325.17,325.17,379.17,469.17                    AROW  0420
     2       ,649.17,1729.17,1999.17,2179.17,2431.17,2791.17                      AROW  0430
     3       ,3295.17,3889.17,4357.17,4663.17,4861.17/,PM/                        AROW  0440
     4       3711.0839,2116.2165,472.67563,114.34314,                             AROW  0450
     5       18.128355,2.3162178,1.2321972,3.8030279E-01,                         AROW  0460
     6       2.1671352E-02,3.4313478E-03,6.2773411E-04,1.53490                    AROW  0470
     7       91E-04,5.2624212E-05,1.0561806E-05,7.7083076E-06,                    AROW  0480
     8       5.8267151E-06,3.9159854E-06,1.4520255E-06,3.92905                    AROW  0490
     9       63E-07,8.4030242E-08,2.2835256E-08,7.1875452E-09/                    AROW  0500
                                                                                  AROW  0510
      A(3) = A3                                                                   AROW  0520
                                                                                  AROW  0530
C     CALCULATE G, Z, AND CHECK                                                   AROW  0540
    2 Z = A(3)                                                                    AROW  0550
      G = G0*(RO/(RO+Z))**2                                                       AROW  0560
      IF (Z .GT. 295276.0) GO TO 6                                                AROW  0570
                                                                                  AROW  0580
C     TMS LINEAR WITH GEOPOTENTIAL. CALCULATE H AND SEARCH                        AROW  0590
      H        = RO*Z/(RO+Z)                                                      AROW  0600
      DO 3 I = 2,10                                                               AROW  0610
      J        = I - 1                                                            AROW  0620
      IF (HG(I) .GE. H) GO TO 4                                                   AROW  0630
    3 CONTINUE                                                                    AROW  0640
                                                                                  AROW  0650
C     CALCULATE TMS SLOPE,TMS, AND SET MOL WT STUFF                               AROW  0660
    4 ELH      = (TM(J+1) - TM(J))/(HG(J+1) - HG(J))                              AROW  0670
      TMS      = TM(J) +  ELH*(H - HG(J))                                         AROW  0680
      ELZ      = ELH*G/G0                                                         AROW  0690
      DMDZ     = 0.0                                                              AROW  0700
      EM       = WMO                                                              AROW  0710
```

DECK AROW

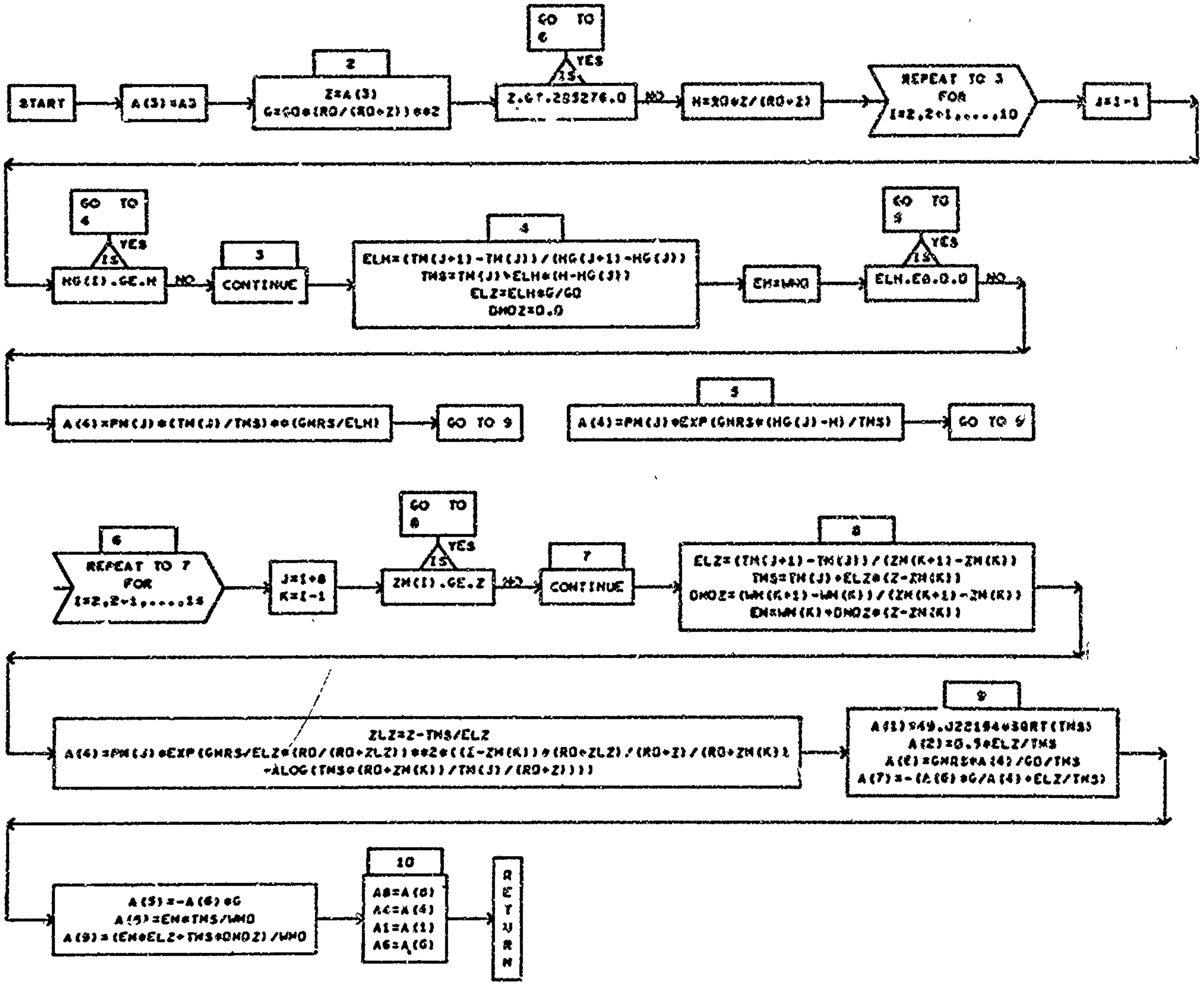
```
                                                                        AROW  0720
C     CHECK TMS SLOPE AND CALCULATE PRESSURE                            AROW  0730
      IF (ELH .EQ. 0.0) GO TO 5                                         AROW  0740
                                                                        AROW  0750
C     NON - ZERO SLOPE PRESSURE EQUATION                                AROW  0760
      A(4) = PM(J)*(TM(J)/TMS)**(GMRS/ELH)                              AROW  0770
      GO TO 9                                                           AROW  0780
                                                                        AROW  0790
C     ZERO SLOPE PRESSURE EQUATION                                      AROW  0800
    5 A(4) = PM(J)*EXP(GMRS*(HG(J)-H)/TMS)                              AROW  0810
      GO TO 9                                                           AROW  0820
                                                                        AROW  0830
C     TMS LINEAR WITH Z. SEARCH MATRIX                                  AROW  0840
    6 DO 7 I = 2,14                                                     AROW  0850
      J      = I + 8                                                    AROW  0860
      K      = I - 1                                                    AROW  0870
      IF (ZM(I) .GE. Z) GO TO 8                                         AROW  0880
    7 CONTINUE                                                          AROW  0890
                                                                        AROW  0900
C     CALCULATE TMS, SLOPE, AND STUFF                                   AROW  0910
    8 ELZ  = (TM(J+1) - TM(J))/(ZM(K+1) - ZM(K))                        AROW  0920
      TMS  = TM(J) + ELZ*(Z - ZM(K))                                    AROW  0930
      DMDZ = (WM(K+1) - WM(K))/(ZM(K+1) - ZM(K))                        AROW  0940
      EM   = WM(K) + DMDZ*(Z - ZM(K))                                   AROW  0950
      ZLZ  = Z - TMS/ELZ                                                AROW  0960
                                                                        AROW  0970
C     PRESSURE EQUATION FOR TMS LINEAR WITH Z                           AROW  0980
      A(4) = PM(J)*EXP(GMRS/ELZ*(RO/(RO+ZLZ))**2*((Z-ZM(K))*            AROW  0990
     1        (RO+ZLZ)/(RO+Z)/(RO+ZM(K)) - ALOG(TMS*(RO+ZM(K)           AROW  1000
     2        )/TM(J)/(RO+Z))))                                         AROW  1010
                                                                        AROW  1020
C     CALCULATE SOUND SPEED AND DERIVATIVE                              AROW  1030
    9 A(1) = 49.022164*SQRT(TMS)                                        AROW  1040
      A(2) = 0.5*ELZ/TMS                                                AROW  1050
                                                                        AROW  1060
C     CALCULATE DENSITY, DERIVATIVE, AND PRESSURE DERIVATIVE            AROW  1070
```

```
DECK AROW

      A(6) = GMRS*A(4)/GO/TMS                                           AROW  1080
      A(7) = - (A(6)*G/A(4) + ELZ/TMS)                                  AROW  1090
      A(5) = - A(6)*G                                                   AROW  1100
                                                                        AROW  1110
C     CALCULATE TEMPERATURE, DERIVATIVE, AND LEAVE                      AROW  1120
      A(8) = EM*TMS/WMO                                                 AROW  1130
      A(9) = (EM*ELZ + TMS*DMDZ)/WMO                                    AROW  1140
   10 A8 = A(8)                                                         AROW  1150
      A4 = A(4)                                                         AROW  1160
      A1 = A(1)                                                         AROW  1170
      A6 = A(6)                                                         AROW  1180
      RETURN                                                            AROW  1190
      END                                                               AROW  1200
```

[redacted]

SUBROUTINE ATMOS



```
SYMBOLS USED IN SUBROUTINE ATMOS

A         R  D  MATRIX OF ATMOSPHERIC PROPERTIES                                       ATMOS
A1        R  A  ATMOSPHERIC SPEED OF SOUND, FEET/SECOND                                ATMOS
A3        R  A  GEOMETRIC ALTITUDE, FEET                                               ATMOS
A4        R  A  ATMOSPHERIC PRESSURE, POUNDS PER SQUARE FOOT                           ATMOS
A6        R  A  ATMOSPHERIC DENSITY, SLUGS PER CUBIC FOOT                              ATMOS
A8        R  A  ATMOSPHERIC TEMPERATURE, DEGREE RANKINE                                ATMOS
DMDZ      R  U  DERIVATIVE OF MOLECULAR WEIGHT OF AIR                                  ATMOS
ELH       R  U  MOLECULAR SCALE TEMPERATURE DERIVATIVE, DEGREE RANKINE/FOOT            ATMOS
ELZ       R  U  MOLECULAR SCALE TEMPERATURE DERIVATIVE, DEGREE RANKINE/FOOT            ATMOS
EM        R  U  MOLECULAR WEIGHT OF AIR                                                ATMOS
G         R  U  GRAVITATIONAL ACCELERATION, FEET PER SECOND SQUARED                    ATMOS
GMRS      R  U  COMBINATION OF GEODETIC AND GAS CONSTANTS, DEG RANKINE/FOOT            ATMOS
GO        R  U  GRAVITATIONAL ACCELERATION AT SEA LEVEL, FT/SEC SQUARED                ATMOS
H         R  U  GEOPOTENTIAL ALTITUDE, FEET                                            ATMOS
HG        R  D  MATRIX OF GEOPOTENTIAL ALTITUDES, FT                                   ATMOS
I         I  U  DO LOOP INDEX WHEN DETERMINING APPROPRIATE ATMOSPHERE LAYER            ATMOS
J         I  U  COUNTER IN VARIOUS DO LOOPS                                            ATMOS
K         I  U  COUNTER IN DO LOOP DETERMINING APPROPRIATE ATMOSPHERE LAYER            ATMOS
PM        R  D  MATRIX OF ATMOSPHERIC PRESSURES                                        ATMOS
RO        R  U  EARTH RADIUS = 20890855 FEET                                           ATMOS
TM        R  D  MATRIX OF MOLECULAR SCALE TEMPERATURES, DEG RANKINE                    ATMOS
TMS       R  U  MOLECULAR SCALE TEMPERATURE, DEGREE RANKINE                            ATMOS
WM        R  D  MATRIX OF MOLECULAR WEIGHTS OF AIR                                     ATMOS
WMO       R  U  MOLECULAR WEIGHT OF AIR AT SEA LEVEL = 28.9644                         ATMOS
Z         R  U  GEOMETRIC ALTITUDE, FEET                                               ATMOS
ZLZ       R  U  INTERIM CALCULATION FOR PRESSURE EQUATION.                             ATMOS
ZM        R  D  MATRIX OF GEOMETRIC ALTITUDES, FEET, ABOVE 245276 FEET                 ATMOS
```

ATMOS

```
SYMBOLS USED IN SUBROUTINE ATMOS

A        R  D  MATRIX OF ATMOSPHERIC PROPERTIES                                 ATMOS
A1       R  A  ATMOSPHERIC SPEED OF SOUND, FEET/SECOND                          ATMOS
A3       R  A  GEOMETRIC ALTITUDE, FEET                                         ATMOS
A4       R  A  ATMOSPHERIC PRESSURE, POUNDS PER SQUARE FOOT                     ATMOS
A6       R  A  ATMOSPHERIC DENSITY, SLUGS PER CUBIC FOOT                        ATMOS
A8       R  A  ATMOSPHERIC TEMPERATURE, DEGREE RANKINE                          ATMOS
DMDZ     R  U  DERIVATIVE OF MOLECULAR WEIGHT OF AIR                            ATMOS
ELH      R  U  MOLECULAR SCALE TEMPERATURE DERIVATIVE, DEGREE RANKINE/FOOT      ATMOS
ELZ      R  U  MOLECULAR SCALE TEMPERATURE DERIVATIVE, DEGREE RANKINE/FOOT      ATMOS
EM       R  U  MOLECULAR WEIGHT OF AIR                                          ATMOS
G        R  U  GRAVITATIONAL ACCELERATION, FEET PER SECOND SQUARED              ATMOS
GMRS     R  U  COMBINATION OF GEODETIC AND GAS CONSTANTS, DEG RANKINE/FOOT      ATMOS
GO       R  U  GRAVITATIONAL ACCELERATION AT SEA LEVEL, FT/SEC SQUARED          ATMOS
H        R  U  GEOPOTENTIAL ALTITUDE, FEET                                      ATMOS
HG       R  D  MATRIX OF GEOPOTENTIAL ALTITUDES, FT                             ATMOS
I        I  U  DO LOOP INDEX WHEN DETERMINING APPROPRIATE ATMOSPHERE LAYER      ATMOS
J        I  U  COUNTER IN VARIOUS DO LOOPS                                      ATMOS
K        I  U  COUNTER IN DO LOOP DETERMINING APPROPRIATE ATMOSPHERE LAYER      ATMOS
PM       R  D  MATRIX OF ATMOSPHERIC PRESSURES                                  ATMOS
RO       R  U  EARTH RADIUS = 20890855 FEET                                     ATMOS
TM       R  D  MATRIX OF MOLECULAR SCALE TEMPERATURES, DEG RANKINE              ATMOS
TMS      R  U  MOLECULAR SCALE TEMPERATURE, DEGREE RANKINE                      ATMOS
WM       R  D  MATRIX OF MOLECULAR WEIGHTS OF AIR                               ATMOS
WMO      R  U  MOLECULAR WEIGHT OF AIR AT SEA LEVEL = 28.9644                   ATMOS
Z        R  U  GEOMETRIC ALTITUDE, FEET                                         ATMOS
ZLZ      R  U  INTERIM CALCULATION FOR PRESSURE EQUATION.                       ATMOS
ZM       R  D  MATRIX OF GEOMETRIC ALTITUDES, FEET, ABOVE 245276 FEET           ATMOS
```

25. SUBROUTINE PLUNGE (DECK AROX)

This routine calculates $C_{m_{\dot{\alpha}}}$ and $C_{Y_{\dot{\beta}}}$ for wings, bodies, and tails.

a. Algorithm

Read the Plunge Derivative Control Card (Type 14). Check correctness of input data flags. Read in plunge derivative data (Card Types 15, 16, 17, 18, 19, 20, 21) as required. Select proper calculation method, determine KBW if required, and calculate final derivatives.

b. Input/Output

Card Types 14, 15, 16, 17, 18, 19, 20, and 21

c. Error

An error condition occurs if the input flags are wrong, or if the card types are in error.

d. Subroutines Required

ELP1

e. Argument List

(IDERIV, CMA, CYB, CMADT, CYBDT)

f. Length

5540 bytes

DECK AROX

```
      SUBROUTINE PLUNGE (IDERIV,CMA,CYB,CMADT,CYBDT)
C
C***********************************************************************
C**** THIS ROUTINE COMPUTES C-SUB-M-SUB-ALPHA-DOT AND C-SUB-Y-SUB-BETA-
C**** DOT FOR WINGS, BODIES, OR TAILS
C***********************************************************************
C                THIS SUBROUTINE WRITTEN BY J. LUNDRY
C
C
C     THE MAJOR CONTROL FLAGS FOR THIS SUBROUTINE ARE GIVEN BELOW
C         IPART = 1    CALCULATION FOR WING
C         IPART = 2    CALCULATION FOR BODY
C         IPART = 3    CALCULATION FOR TAIL
C
C         ICALC = 1    CALCULATION OF C-SUB-M-SUB-ALPHA-DOT
C         ICALC = 2    CALCULATION OF C-SUB-Y-SUB-BETA-DOT
C
C         K   IS FLAG CONTROLLING EQUATION FOR KBW.
C         COEF IS THE DESIRED COEFFICIENT DERIVATIVE
C
      DIMENSION  TITLE(15)
      COMMON  CASE,TITLE,PAGE,ERROR
      REAL KWB , KBW , M , LAMBDA, LENGTH
      INTEGER  TYPE,ERROR,CASE,PAGE
C
C     ARITHMETIC STATEMENT FUNCTIONS ARC-COSH, ARC-TANH
      ACOSH(X) = ALOG (X + SQRT(X**2 - 1.0))
      ATANH(X) = 0.5 * ALOG ( (1.0 + X) / (1.0 - X) )
C
      ERROR = 0
      IF (IDERIV .EQ. 5) ICALC = 1
      IF (IDERIV .EQ. 6) ICALC = 2
      PI = 3.1415926
C
C
```

DECK AROX

```
C ***** READ IN INPUT DATA *********************************************  AROX  0360
C                                                                         AROX  0370
C                                                                         AROX  0380
      READ (5,101) IPART , TYPE                                           AROX  0390
  101 FORMAT (I1, 69X, I2)                                                AROX  0400
      IF (TYPE .NE. 14) GO TO 1000                                        AROX  0410
C                                                                         AROX  0420
C     CHECK IPART AND ICALC                                               AROX  0430
C                                                                         AROX  0440
      IF (IPART .GT. 0 .AND. IPART .LE. 3 .AND.                           AROX  0450
     A    ICALC .GT. 0 .AND. ICALC .LE. 2                                 AROX  0460
     B    ) GO TO 61                                                      AROX  0470
      WRITE (6,102) IPART , ICALC                                         AROX  0480
  102 FORMAT (1H , 73H**** BASIC INPUT FLAG ERRORS - SUBROUTINE PLUNGE    AROX  0490
     A   IPART AND ICALC ARE  , 2I6 //22H **** TO ERR IS HUMAN  //)       AROX  0500
      GO TO 1000                                                          AROX  0510
   61 IF (IPART .EQ. 2) GO TO (63,64) , ICALC                             AROX  0520
      IF (ICALC .EQ. 1) GO TO 62                                          AROX  0530
      COEF = 0.0                                                          AROX  0540
      GO TO 90                                                            AROX  0550
   62 CONTINUE                                                            AROX  0560
      IF (IPART .EQ. 3) GO TO 105                                         AROX  0570
C                                                                         AROX  0580
C     READ WING DATA FOR C-SUB-M-SUB-ALPHA-DOT                            AROX  0590
C                                                                         AROX  0600
      READ (5,103) AR , LAMBDA , M , SWBYS , CWBYC , S , K , TYPE         AROX  0610
  103 FORMAT (6F10.0 , I1, 9X, I2)                                        AROX  0620
      IF (TYPE .NE. 15) GO TO 1000                                        AROX  0630
      READ (5,104) CR , R , BETA , CLALW , CMWPR , KBW , TYPE             AROX  0640
  104 FORMAT (6F10.0 , 10X, I2)                                           AROX  0650
      IF (TYPE .NE. 16) GO TO 1000                                        AROX  0660
      GO TO 107                                                           AROX  0670
  105 CONTINUE                                                            AROX  0680
C                                                                         AROX  0690
C     READ TAIL DATA FOR C-SUB-M-SUB-ALPHA-DOT                            AROX  0700
C                                                                         AROX  0710
```

PLUNGE

```
DECK AROX
      READ (5,103) AR , LAMBDA , M , SWBYS , GAMMAT , S , K , TYPE
      IF (TYPE .NE. 17) GO TO 1000
      READ (5,104) CR , R , BETA , CLALW , UPWASH , XBTBYC , TYPE
      IF (TYPE .NE. 18) GO TO 1000
      READ (5,106) KBW , Q, TYPE
  106 FORMAT (2F10.0, 50X, I2)
      IF (TYPE .NE. 19) GO TO 1000
  107 CONTINUE
C
C ***********************************************************************
C ***** WING OR TAIL CONTRIBUTION
C     THE SLENDER BODY THEORY IS USED TO DETERMINE KWB.  THE EXPRESSION
C     IS EQ. (14) OF NACA REPORT 1307.
C
      D = 2.0 * R
      RS = R / S
      SR = S / R
      KWB = 2.0 / PI * (    (1.0 + RS ** 4) * (0.5 * ATAN (0.5 * (SR - RS
     A       )) + PI / 4.0) - RS ** 2 * (SR - RS + 2.0 * ATAN (RS))    )
     B       / (1.0 - RS) ** 2
C
C ****CALCULATE KBW ******************************************************
C     SEVERAL EXPRESSIONS ARE TAKEN FROM NACA REPORT 1307 FOR KBW.
C     THIS ROUTINE GIVES THE FOLLOWING OPTIONS AS A FUNCTION OF THE
C     INTEGER ITYPE (IF EQ. (22) OF REPORT 1307 IS NOT SATISFIED,
C     SLENDER BODY THEORY IS AUTOMATICALLY USED UNLESS KBW IS INPUT
C     BY THE USER).
C
C ITYPE  REFERENCE FOR KBW
C   0      USER LOADS A VALUE OF KBW
C   1      NACA REPT. 1307 EQ. (21)  (SLENDER BODY THEORY)
C   2      NACA REPT. 1307 EQ. (24)    SUPERSONIC LEADING EDGE
C                              (26)    SUBSONIC LEADING EDGE
C               HALF-PLANFORM IS A TRAPEZOID.  WING/TAIL ON LONG BODY.
C   3      NACA REPT. 1307 EQ. (27)
C               RECTANGULAR PLANFORM.  WING/TAIL ON LONG BODY.
```

```
DECK AROX

C   4      NACA REPT. 1307 EQ. (28)    SUBSONIC LEADING EDGE
C                          EQ. (29)    SUPERSONIC LEADING EDGE
C               TRIANGULAR PLANFORM.  WING/TAIL ON LONG BODY.
C   5      NACA REPT. 1307 EQ. (30)    SUPERSONIC LEADING EDGE
C                          EQ. (31)    SUBSONIC LEADING EDGE
C               HALF-PLANFORM IS A TRAPEZOID.  NO AFTER-BODY FOR WING.
      ITYPE = K
C
C     TEST ITYPE FOR VALID RANGE
C
      IF (ITYPE .GE. 0 .AND. ITYPE .LE. 5) GO TO 72
      WRITE (6,71) ITYPE
   71 FORMAT(1H ,107H**** SUBROUTINE PLUNGE - THE FLAG ITYPE (WHICH CONT
     2ROLS EQUATION USED TO CALCULATE KBW) IS INCORRECT AND =   ,I7 //)
      GO TO 1000
   72 CONTINUE
C
C
C     TEST FOR EQ. (22) FOLLOWS.  IF TEST FAILS, SLENDER-BODY THEORY
C     WILL BE USED AUTOMATICALLY.
C
      IF (ITYPE .GT. 1 .AND. (BETA * AR * (1.0 + LAMBDA) * (1.0 /
     A    (BETA * M) + 1.0)) .LT. 4.0) ITYPE = 1
      I = ITYPE + 1
      GO TO (30, 2, 3, 5, 6, 8) , I
C
C     EQ. (21)
C
    2 KBW = (    (1.0 - RS ** 2) ** 2 - 2.0 / PI * ( (1.0 + RS ** 4) *
     A        (0.5 * ATAN (0.5 * (SR - RS)) + PI / 4.0) - RS ** 2 *
     B        (SR - RS + 2.0 * ATAN (RS)) )    ) / (1.0 - RS) ** 2
      GO TO 30
C
C     EQ. (24)
C
    3 BM1 = BETA * M
```

PLUNGE

DECK AROX

```
      IF (BM1 .LT. 1.0) GO TO 4                                         AROX 1440
      BM2 = BM1 ** 2                                                    AROX 1450
      BMR2 = SQRT (BM2 - 1.0)                                           AROX 1460
      T1 = (    1.0 + (1.0 + BM1) * BETA * D / CR   )                   AROX 1470
     A     / (    BM1 + (BM1 + 1.0) * BETA * D / CR    )                AROX 1480
      T2 = 1.0 / BM1                                                    AROX 1490
      T1 = ARCOS (T1)                                                   AROX 1500
      T2 = ARCOS (T2)                                                   AROX 1510
      KBW = 8.0 * BM1 / (PI * BMR2 * (1.0 + LAMBDA) * BETA * D / CR *   AROX 1520
     A        (SR - 1.0) * BETA * CLALW)                                AROX 1530
     B        * (    (BM1 / (1.0 + BM1)) * (((BM1 + 1.0) * BETA * D / CR AROX 1540
     C        + BM1) / BM1) ** 2 * T1                                   AROX 1550
     D        + BMR2 / (BM1 + 1.0) * (SQRT(1.0 + 2.0 * BETA * D / CR)   AROX 1560
     E        - 1.0)                                                    AROX 1570
     F        - BMR2 / BM1 * (BETA * D / CR) ** 2 * ACOSH(1.0 + CR/BETA/D) AROX 1580
     G        - BM1 / (1.0 + BM1) * T2    )                             AROX 1590
      GO TO 30                                                          AROX 1600
C                                                                       AROX 1610
C     EQ. (26)                                                          AROX 1620
C                                                                       AROX 1630
    4 BM = BM1                                                          AROX 1640
      T1 = SQRT ( (BM + (1.0 + BM) * BETA * D / CR) / BM )              AROX 1650
      KBW = 16.0 * (BM / (1.0 + BM)) ** 2                               AROX 1660
     A        / (PI * (1.0 + LAMBDA) * BETA * D / CR * (SR - 1.0) * BETA AROX 1670
     B        * CLALW)                                                  AROX 1680
     C        * (    T1 ** 3 + T1 - 2.0 - (((1.0 + BM) * BETA * C / CR) AROX 1690
     D        / BM) ** 2 * ATANH (1.0 / T1)    )                        AROX 1700
      GO TO 30                                                          AROX 1710
C                                                                       AROX 1720
C     EQ. (27)                                                          AROX 1730
C                                                                       AROX 1740
    5 BA = BETA * AR                                                    AROX 1750
      BARS = BA * RS                                                    AROX 1760
      T1 = BA / (BA + SR - 1.0)                                         AROX 1770
      T1 = ARCOS (T1)                                                   AROX 1780
      KBW = 2.0 / (PI * (BA - 0.5)) *                                   AROX 1790
```

```
DECK AROX
     A     (   0.5 * (1.0 + BARS / (1.0 - RS)) ** 2 * T1                      AROX  1800
     B     - 0.5 * (BARS / (1.0 - RS)) ** 2 * ACOSH (1.0 + (1.0 - RS)         AROX  1810
     C     / BARS) - 0.5 - PI / 4.0 + 0.5 * SQRT (1.0 + 2.0 * BARS            AROX  1820
     D     / (1.0 - RS))    )                                                 AROX  1830
      GO TO 30                                                                AROX  1840
C                                                                             AROX  1850
C     EQ. (28)                                                                AROX  1860
C                                                                             AROX  1870
    6 BA = BETA * AR                                                          AROX  1880
      BA4 = BA / 4.0                                                          AROX  1890
      IF (BA4 .GE. 1.0) GO TO 7                                               AROX  1900
      T1 = SQRT (1.0 - BA4 ** 2)                                              AROX  1910
      CALL ELPI (T1, DUMMY, T1, NER1)                                         AROX  1920
C     ERROR TEST 3                                                            AROX  1930
      IF (NER1.NE.0) WRITE (6,22)                                             AROX  1940
   22 FORMAT (1H ,46H**** ELLIPTICAL INTEGRAL ERROR. T1 FROM PLUNGE           AROX  1950
     1  55H IS NOT LESS THAN ONE AND GREATER THAN OR EQUAL TO ZERO )          AROX  1960
      T2 = (BA4 / (BA4 + 1.0)) ** 2 / 2.0                                     AROX  1970
      T3 = SQRT (1.0 + 2.0 * (1.0 + BA4) * RS / (1.0 - RS))                   AROX  1980
      KBW = 8.0 * T1 / (PI * BA4) ** 2 *                                      AROX  1990
     A    (   T2 * T3 ** 3 - (BA / (BA + 4.0)) ** 2 + T2 * T3                 AROX  2000
     B      - 2.0 * (BA4 * RS / (1.0 - RS)) ** 2 * ATANH (1.0 / T3)    )      AROX  2010
      GO TO 30                                                                AROX  2020
C                                                                             AROX  2030
C     EQ. (29)                                                                AROX  2040
C                                                                             AROX  2050
    7 T1 = 2.0 * (1.0 + BA4) * RS / (1.0 - RS)                                AROX  2060
      T2 = (1.0 + BA4 * T1) / (BA4 + BA4 * T1)                                AROX  2070
      T3 = 1.0 / BA4                                                          AROX  2080
      T2 = ARCOS (T2)                                                         AROX  2090
      T3 = ARCOS (T3)                                                         AROX  2100
      KBW = 1.0 / (PI * SQRT (BA4 ** 2 - 1.0)) *                              AROX  2110
     A     (   (BA / (BA + 4.0)) * (1.0 + T1) ** 2 * T2                       AROX  2120
     B     + SQRT ( (BA4 ** 2 - 1.0) * (1.0 + BA * RS / (1.0 - RS)) )         AROX  2130
     C     / (1.0 + BA4)  - BA4 * T3 / (1.0 + BA4)                            AROX  2140
     D     - SQRT (BA4 ** 2 - 1.0) * BA * (RS / (1.0 - RS)) ** 2              AROX  2150
```

```
DECK AROX

     E      * ACOSH (1.0 + 2.0 * (1.0 - RS) / BA / RS)               AROX  2160
     F      - SQRT (BA4 ** 2 - 1.0) / (BA4 + 1.0)   )                AROX  2170
      GO TO 30                                                        AROX  2180
C                                                                     AROX  2190
C     EQNS. (30) AND (31)                                             AROX  2200
C                                                                     AROX  2210
    8 BDCR = BETA * D / CR                                            AROX  2220
C                                                                     AROX  2230
C     TEST BDCR.  IF BDCR GT 1.0, SET BDCR = 1.0 TO GET PROPER RESULT. AROX  2240
C     SEE PARAGRAPH FOLLOWING EQ. (31) OF NACA REPORT 1307.           AROX  2250
C                                                                     AROX  2260
      IF (BDCR .GT. 1.0) BDCR = 1.0                                   AROX  2270
      BM    = BETA * M                                                AROX  2280
      IF (BM .LT. 1.0) GO TO 9                                        AROX  2290
C                                                                     AROX  2300
C     EQ. (30)                                                        AROX  2310
C                                                                     AROX  2320
      T1 = (BM + 1.0 / BDCR) / (1.0 + BM / BDCR)                      AROX  2330
      T2 = 1.0 / BM                                                   AROX  2340
      T3 = BDCR                                                       AROX  2350
      T4 = SQRT (BM ** 2 - 1.0)                                       AROX  2360
      T1 = ARCOS (T1)                                                 AROX  2370
      T2 = ARCOS (T2)                                                 AROX  2380
      T3 = ARSIN (T3)                                                 AROX  2390
      KBW = 8.0 * BDCR / (PI * T4 * BETA * CLALW * (1.0 + LAMBDA) *   AROX  2400
     A      (SR - 1.0)) *                                             AROX  2410
     B      (   (1.0 + BM / BDCR ) ** 2 * T1                          AROX  2420
     C      - (BM / BDCR) ** 2 * T2                                   AROX  2430
     D      + BM / BDCR ** 2 * T4 * T3                                AROX  2440
     E      - T4 * ACOSH (1.0 / BDCR)                                 AROX  2450
      GO TO 30                                                        AROX  2460
    9 CRBD = 1.0 / BDCR                                               AROX  2470
      CRBD2 = CRBD ** 2                                               AROX  2480
C                                                                     AROX  2490
C     EQ. (31)                                                        AROX  2500
C                                                                     AROX  2510
```

```
DECK AROX

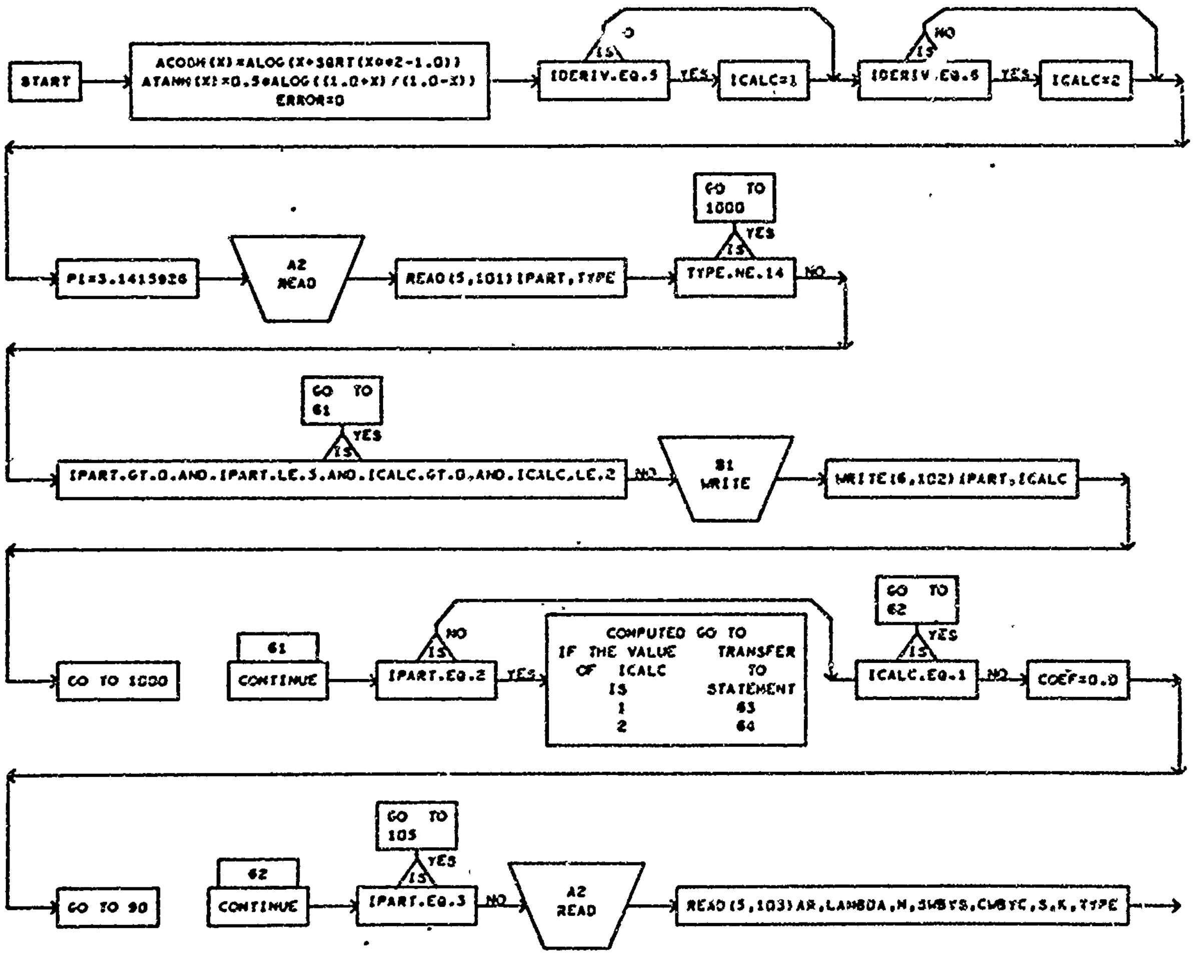
       KBW = 16.0 * SQRT (BM) * BDCR / (PI * (BM + 1.0) * BETA * CLALW     AROX  2520
      A        * (1.0 + LAMBDA) * (SR - 1.0)) *                              AROX  2530
      B        (   (1.0 + M * CR / D) * SQRT ((CRBD - 1.0)*(M*CR/D + 1.0))   AROX  2540
      C        - CRBD2 * BM ** 1.5                                           AROX  2550
      D        + BM * CRBD2 * (BM + 1.0) * (ATAN (SQRT(1.0 / BM))            AROX  2560
      E        - ATAN (SQRT((CRBD - 1.0) / (M * CR / D + 1.0))))             AROX  2570
      F        - (BM + 1.0) / SQRT (BM) * ATANH (SQRT(BM * (CRBD - 1.0) /    AROX  2580
      G          (M * CR / D + 1.0)))    )                                   AROX  2590
       GO TO 30                                                              AROX  2600
C                                                                            AROX  2610
C      HOPEFULLY, BY THIS TIME, KBW HAS BEEN CALCULATED.                     AROX  2620
C                                                                            AROX  2630
   30 CONTINUE                                                               AROX  2640
      IF (IPART .EQ. 3) GO TO 32                                             AROX  2650
C                                                                            AROX  2660
C***** CALCULATE WING CM ALPHA DOT ************************************      AROX  2670
      COEF = SWBYS * (KWB + KBW) * CWBYC ** 2 * CMWPR                        AROX  2680
      GO TO 90                                                               AROX  2690
C                                                                            AROX  2700
C                                                                            AROX  2710
C***** CALCULATE TAIL CONTRIBUTION TO C-SUB-M-SUB-BETA-DOTA                  AROX  2720
   32 CONTINUE                                                               AROX  2730
      COEF = 2.0 * Q * SWBYS * ( COS (0.017453292 * GAMMAT) ) ** 2           AROX  2740
     A       * CLALW * (KWB + KBW) * XBTBYC ** 2 * UPWASH                    AROX  2750
      GO TO 90                                                               AROX  2760
C                                                                            AROX  2770
C                                                                            AROX  2780
C***** CONTRIBUTION OF BODY TO C-SUB-M-SUB-ALPHA-DOT   ******************    AROX  2790
   63 CONTINUE                                                               AROX  2800
C                                                                            AROX  2810
C      READ BODY DATA                                                        AROX  2820
C                                                                            AROX  2830
      READ (5,104) VOLUME , SFRONT , LENGTH , XO , XC , C , TYPE             AROX  2840
      IF (TYPE .NE. 20) GO TO 1000                                           AROX  2850
      RATIO = (-2.0 * VOLUME / C / SFRONT) * (XO - XC) / LENGTH              AROX  2860
     A         / (VOLUME / SFRONT / LENGTH - 1.0 + XO / LENGTH)              AROX  2870
```

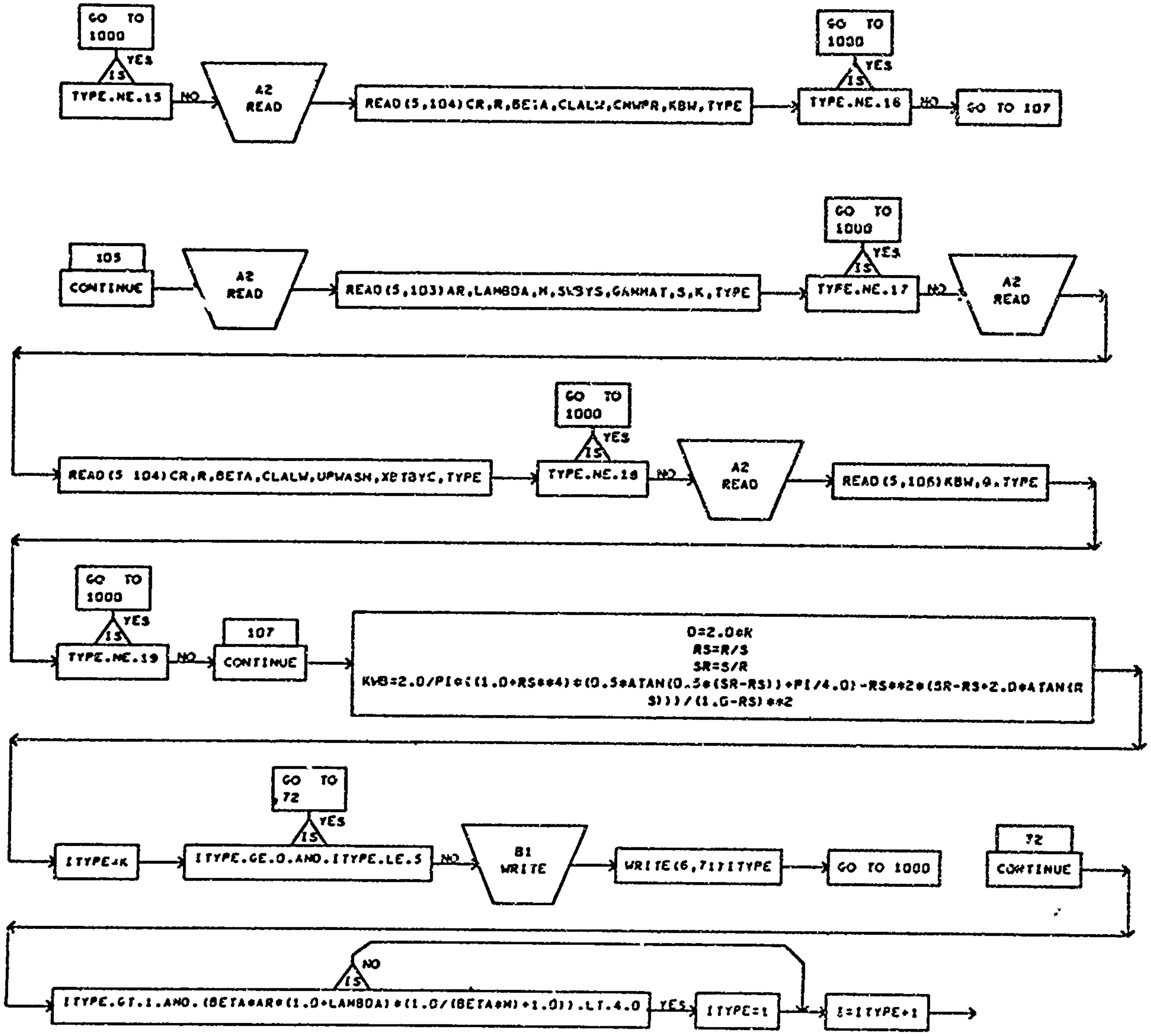
PLUNGE

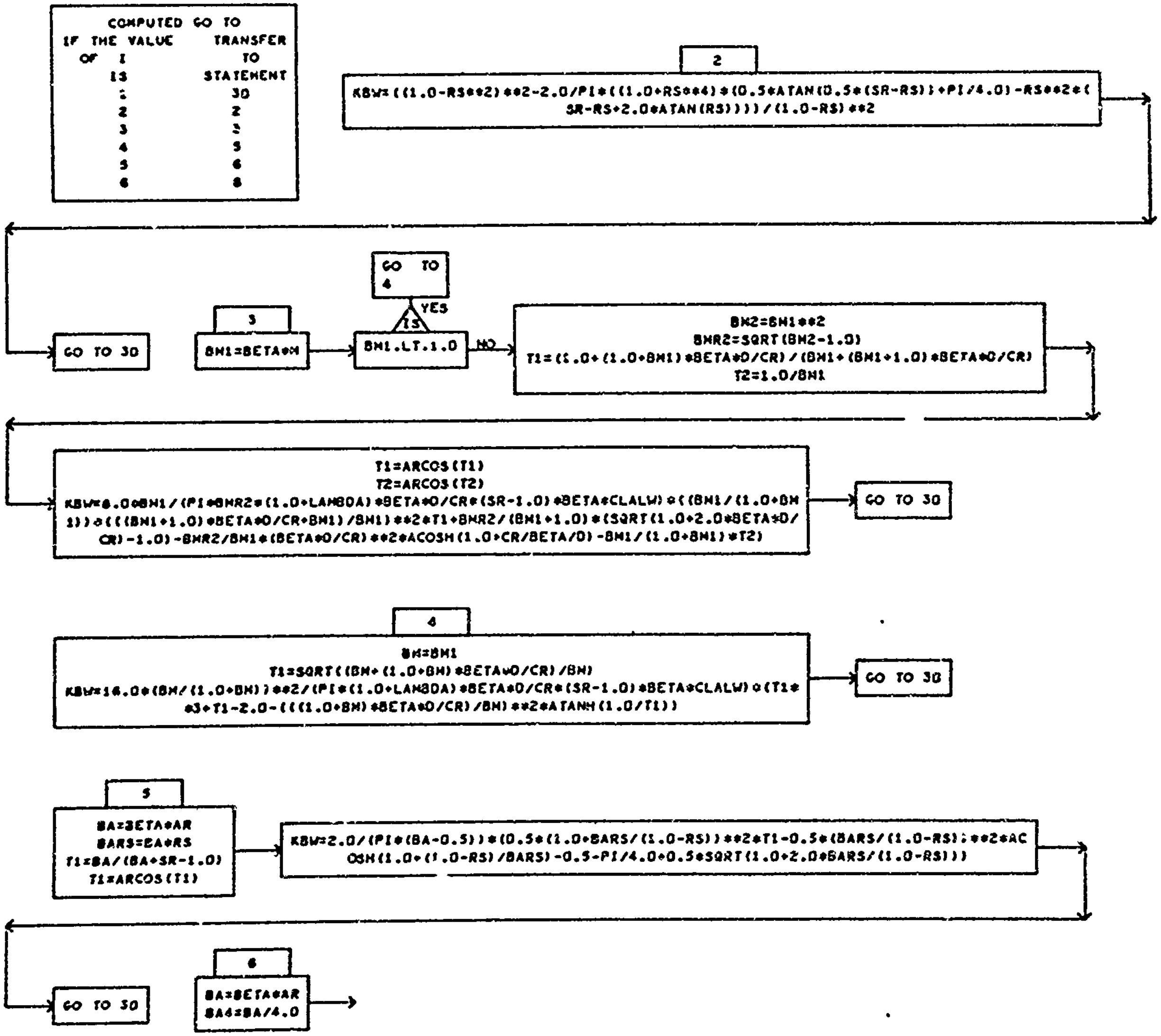
DECK AROX

```
      COEF = RATIO * CMA
      GO TO 90
C
C***** BODY CY BETA DOT ************************************************
   64 CONTINUE
C     THIS PART OF THE ROUTINE COMPUTES C-SUB-Y-SUB-BETA DOT
C     THE BASIC REFERENCE IS NASA TMX-287.
C     THE REFERENCE SHOWS THAT WING AND TAIL CONTRIBUTIONS.CAN BE
C     NEGLECTED, AND THAT THE FUSELAGE TERM CAN BE OBTAINED BY A
C     SLENDER-BODY-THEORY RATIO MULTIPLIED BY C-SUB-Y-SUB-BETA.
C
C
C     READ BODY DATA
C
      READ (5,108) VOLUME , SFRONT , B , TYPE
  108 FORMAT (3F10.0 , 40X, I2)
      IF (TYPE .NE. 21) GO TO 1000
      COEF = (-2.0) * VOLUME / SFRONT * CYB / B
   90 IF (IDERIV .EQ. 5) CMADT = COEF
      IF (IDERIV .EQ. 6) CYBDT = COEF
      RETURN
 1000 ERROR = 1
      WRITE (6,1001)
 1001 FORMAT (1H , 39H**** SUBROUTINE PLUNGE SETS ERROR FLAG ///)
      RETURN
      END
```

SUBROUTINE PLUNGE




GO TO 1000
YES
IS
TYPE.NE.15
NO
A2 READ
READ(5,104)CR,R,BETA,CLALW,CNWPR,KBW,TYPE
GO TO 1000
YES
IS
TYPE.NE.16
NO
GO TO 107
105
CONTINUE
A2 READ
READ(5,103)AR,LAMBDA,M,SWSYS,GAMMAT,S,K,TYPE
GO TO 1000
YES
IS
TYPE.NE.17
NO
A2 READ
READ(5 104)CR,R,BETA,CLALW,UPWASH,XBTBYC,TYPE
GO TO 1000
YES
IS
TYPE.NE.18
NO
A2 READ
READ(5,106)KBW,Q,TYPE
GO TO 1000
YES
IS
TYPE.NE.19
NO
107
CONTINUE
D=2.0*K
RS=R/S
SR=S/R
KWB=2.0/PI*((1.0+RS**4)*(0.5*ATAN(0.5*(SR-RS))+PI/4.0)-RS**2*(SR-RS+2.0*ATAN(R
S)))/(1.0-RS)**2
ITYPE=K
GO TO 72
YES
IS
ITYPE.GE.0.AND.ITYPE.LE.5
NO
B1 WRITE
WRITE(6,71)ITYPE
GO TO 1000
72
CONTINUE
ITYPE.GT.1.AND.(BETA*AR*(1.0+LAMBDA)*(1.0/(BETA*M)+1.0)).LT.4.0
IS
NO
YES
ITYPE=1
I=ITYPE+1



COMPUTED GO TO

IF THE VALUE OF I IS	TRANSFER TO STATEMENT
1	30
2	2
3	3
4	5
5	6
6	8

```
2
KBW=((1.0-RS**2)**2-2.0/PI*((1.0+RS**4)*(0.5*ATAN(0.5*(SR-RS))+PI/4.0)-RS**2*(
SR-RS+2.0*ATAN(RS))))/(1.0-RS)**2
```

```
GO TO 30
```

```
3
BH1=BETA*M
BH1.LT.1.0  IS  YES: GO TO 4  NO:
BH2=BH1**2
BHR2=SQRT(BH2-1.0)
T1=(1.0+(1.0+BH1)*BETA*D/CR)/(BH1+(BH1+1.0)*BETA*D/CR)
T2=1.0/BH1
```

```
T1=ARCOS(T1)
T2=ARCOS(T2)
KBW=8.0*BH1/(PI*BHR2*(1.0+LAMBDA)*BETA*D/CR*(SR-1.0)*BETA*CLALW)*((BH1/(1.0+BH
1))*(((BH1+1.0)*BETA*D/CR+BH1)/BH1)**2*T1+BHR2/(BH1+1.0)*(SQRT(1.0+2.0*BETA*D/
CR)-1.0)-BHR2/BH1*(BETA*D/CR)**2*ACOSH(1.0+CR/BETA/D)-BH1/(1.0+BH1)*T2)
GO TO 30
```

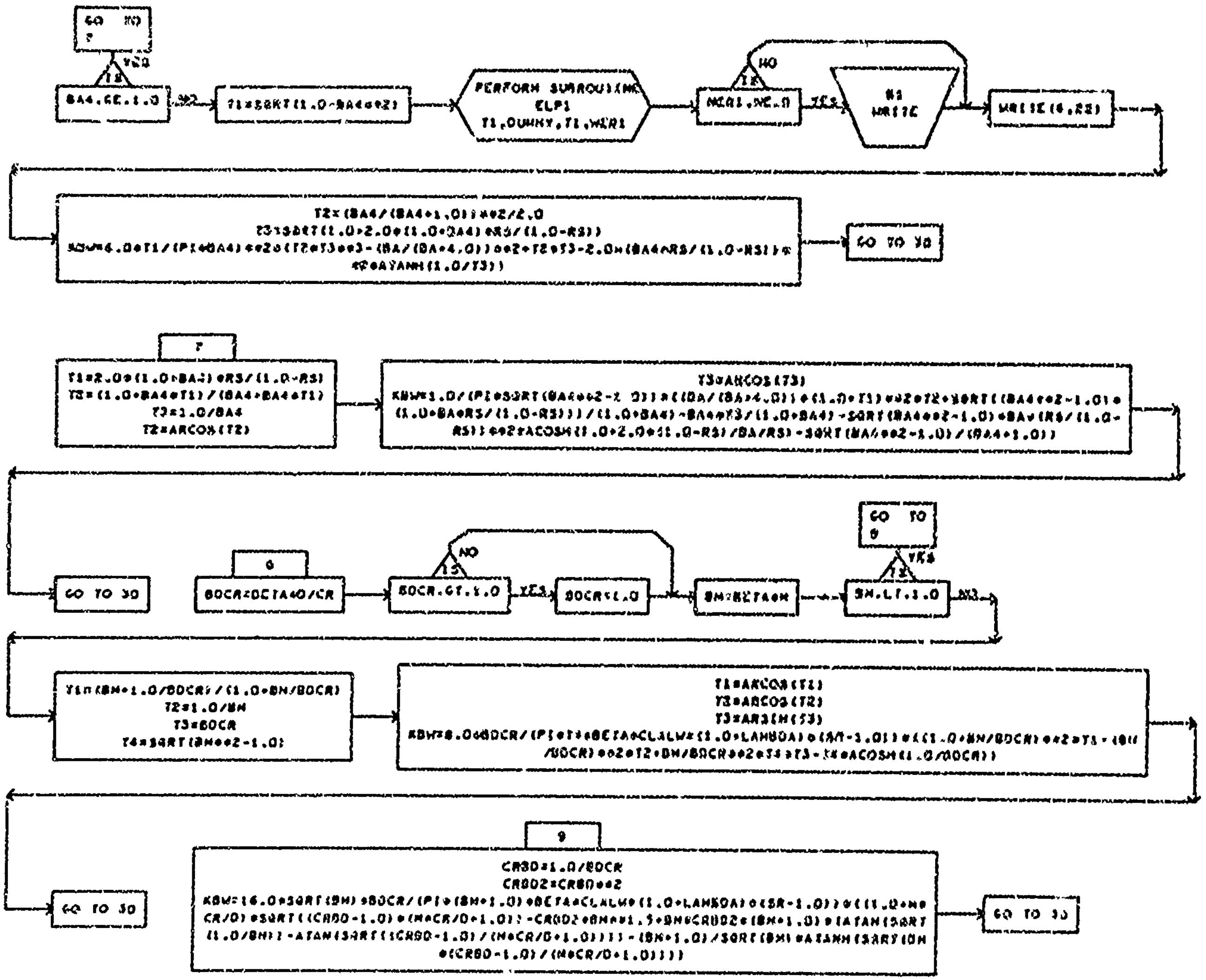
```
4
BH=BH1
T1=SQRT((BH+(1.0+BH)*BETA*D/CR)/BH)
KBW=16.0*(BH/(1.0+BH))**2/(PI*(1.0+LAMBDA)*BETA*D/CR*(SR-1.0)*BETA*CLALW)*(T1*
*3+T1-2.0-(((1.0+BH)*BETA*D/CR)/BH)**2*ATANH(1.0/T1))
GO TO 30
```

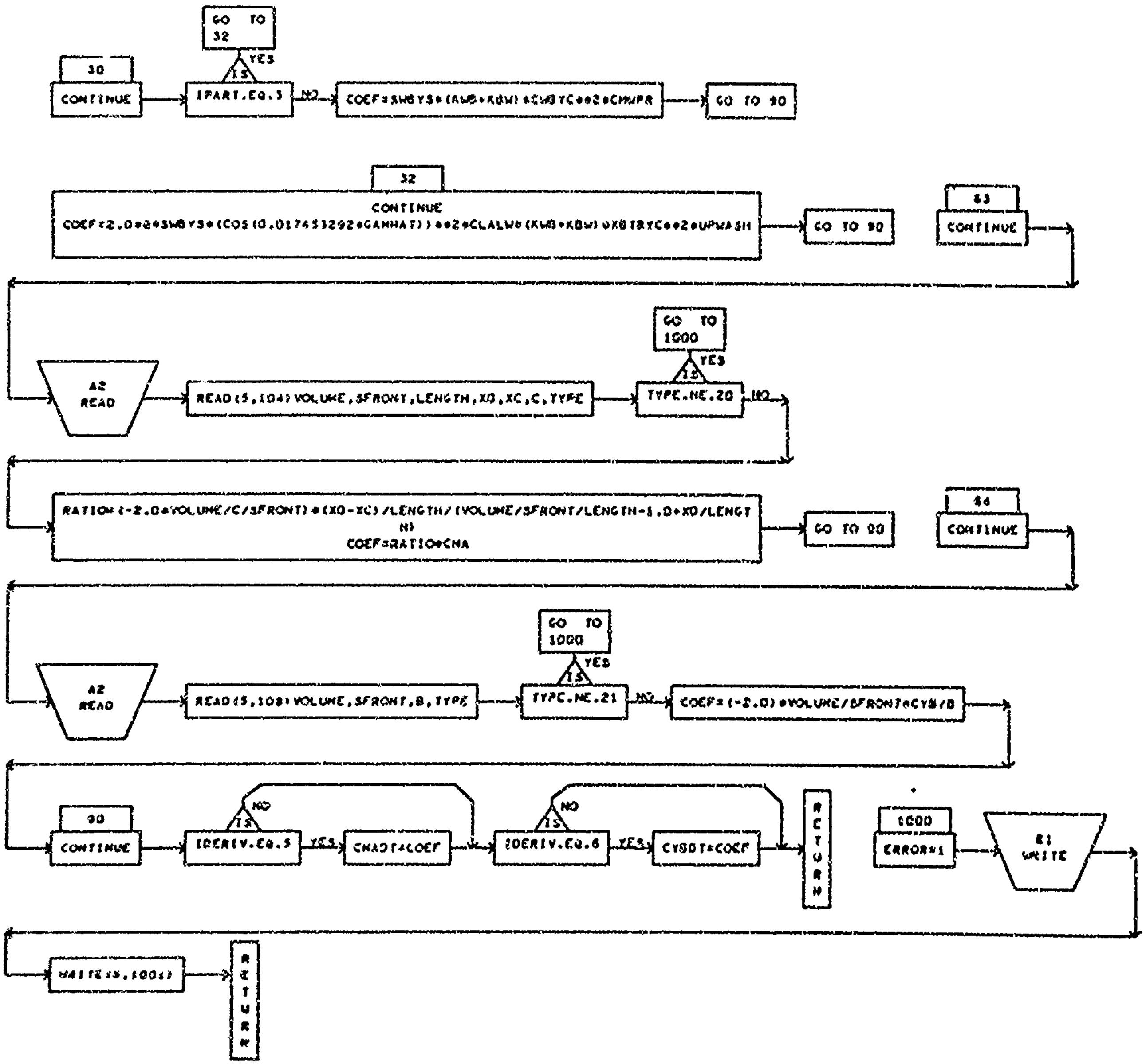
```
5
BA=BETA*AR
BARS=BA*RS
T1=BA/(BA+SR-1.0)
T1=ARCOS(T1)
KBW=2.0/(PI*(BA-0.5))*(0.5*(1.0+BARS/(1.0-RS))**2*T1-0.5*(BARS/(1.0-RS))**2*AC
OSH(1.0+(1.0-RS)/BARS)-0.5-PI/4.0+0.5*SQRT(1.0+2.0*BARS/(1.0-RS)))
```

```
GO TO 30
```

```
6
BA=BETA*AR
BA4=BA/4.0
```

PLUNGE


GO TO 7
YES
IS
BA4.GE.1.0
NO
T1=SQRT(1.0-BA4**2)
PERFORM SUBROUTINE ELP1 T1,DUMMY,T1,NER1
IS
NER1.NE.0
NO
YES
N1 WRITE
WRITE(6,22)
T2=(BA4/(BA4+1.0))**2/2.0
T3=SQRT(1.0+2.0*(1.0+BA4)*RS/(1.0-RS))
KBW=6.0*T1/(PI*BA4)**2*(T2*T3**3-(BA/(BA+4.0))**2+T2*T3-2.0*(BA4*RS/(1.0-RS))*
*2*ATANH(1.0/T3))
GO TO 30
7
T1=2.0*(1.0+BA4)*RS/(1.0-RS)
T2=(1.0+BA4*T1)/(BA4+BA4*T1)
T3=1.0/BA4
T2=ARCOS(T2)
T3=ARCOS(T3)
KBW=1.0/(PI*SQRT(BA4**2-1.0))*((BA/(BA+4.0))*(1.0+T1)**2*T2+SQRT((BA4**2-1.0)*
(1.0+BA*RS/(1.0-RS)))/(1.0+BA4)-BA4*T3/(1.0+BA4)-SQRT(BA4**2-1.0)*BA*(RS/(1.0-
RS))**2*ACOSH(1.0+2.0*(1.0-RS)/BA/RS)-SQRT(BA4**2-1.0)/(BA4+1.0))
GO TO 30
6
BOCR=BETA*D/CR
IS
BOCR.GT.1.0
NO
YES
BOCR=1.0
BM=BETA*M
IS
BM.LT.1.0
YES
GO TO 9
NO
T1=(BM+1.0/BOCR)/(1.0+BM/BOCR)
T2=1.0/BM
T3=BOCR
T4=SQRT(BM**2-1.0)
T1=ARCOS(T1)
T2=ARCOS(T2)
T3=ARSIN(T3)
KBW=8.0*BOCR/(PI*T4*BETA*CLALW*(1.0+LAMBDA)*(BM-1.0))*((1.0+BM/BOCR)**2*T1-(BM
/BOCR)**2*T2+BM/BOCR**2*T4*T3-T4*ACOSH(1.0/BOCR))
GO TO 30
9
CRBD=1.0/BOCR
CRBD2=CRBD**2
KBW=16.0*SQRT(BM)*BOCR/(PI*(BM+1.0)*BETA*CLALW*(1.0+LAMBDA)*(SR-1.0))*((1.0+M*
CR/D)*SQRT((CRBD-1.0)*(M*CR/D+1.0))-CRBD2*BM**1.5+BM*CRBD2*(BM+1.0)*(ATAN(SQRT
(1.0/BM))-ATAN(SQRT((CRBD-1.0)/(M*CR/D+1.0))))-(BM+1.0)/SQRT(BM)*ATANH(SQRT(BM
*(CRBD-1.0)/(M*CR/D+1.0))))
GO TO 30


30
CONTINUE
IPART.EQ.3
IS
YES
GO TO 32
NO
COEF=SWBYS*(KWB+KBW)*CWBYC**2*CMWPR
GO TO 90
32
CONTINUE
COEF=2.0*2*SWBYS*(COS(0.01745329*GAMMAT))**2*CLALW*(KWB+KBW)*XBTRYC**2*UPWASH
GO TO 90
83
CONTINUE
A2
READ
READ(5,104)VOLUME,SFRONT,LENGTH,XO,XC,C,TYPE
TYPE.NE.20
IS
YES
GO TO 1000
NO
RATIO=(-2.0*VOLUME/C/SFRONT)*(XO-XC)/LENGTH/(VOLUME/SFRONT/LENGTH-1.0+XO/LENGTH)
COEF=RATIO*CNA
GO TO 90
84
CONTINUE
A2
READ
READ(5,108)VOLUME,SFRONT,B,TYPE
TYPE.NE.21
IS
YES
GO TO 1000
NO
COEF=(-2.0)*VOLUME/SFRONT*CYB/B
90
CONTINUE
IDERIV.EQ.5
IS
NO
YES
CNADT=COEF
IDERIV.EQ.6
IS
NO
YES
CYBDT=COEF
RETURN
1000
ERROR=1
E1
WRITE
WRITE(6,1001)
RETURN

```
SYMBOLS USED IN SUBROUTINE PLUNGE

AR       R  U  ASPECT RATIO OF WING/TAIL                                       PLUNGE
B        R  U  WING/TAIL SPAN                                                  PLUNGE
BA       R  U  PRODUCT OF BETA AND ASPECT RATIO                                PLUNGE
BARS     R  U  PRODUCT OF BA AND RS                                            PLUNGE
BA4      R  U  BA DIVIDED BY 4                                                 PLUNGE
BDCR     R  U  PRODUCT OF BETA AND D DIVIDED BY CR                             PLUNGE
BETA     R  U  PRANDTL-GLAUERT FACTOR                                          PLUNGE
BM       R  U  PRODUCT OF BETA AND M                                           PLUNGE
BMR2     R  U  SQUARE ROOT OF DIFFERENCE OF BM2 AND 1.0                        PLUNGE
BM1      R  U  PRODUCT OF BETA AND M                                           PLUNGE
BM2      R  U  SQUARE OF PRODUCT OF BETA AND M                                 PLUNGE
C        R  U  REFERENCE CHORD FOR BODY                                        PLUNGE
CASE     I  C  CASE NUMBER                                                     PLUNGE
CLALW    R  U  LIFT-CURVE SLOPE FOR WING/TAIL (PER. RADIAN)                    PLUNGE
CMA      R  A  DERIVATIVE OF PITCHING MOMENT WITH ANGLE OF ATTACK              PLUNGE
CMADT    R  A  PITCHING MOMENT-ALPHA DOT DERIVATIVE                            PLUNGE
CMWPR    R  U  WING-ALONE/TAIL-ALONE PITCHING MOMENT DERIVATIVE                PLUNGE
COEF     R  U  COEFFICIENT DERIVATIVE                                          PLUNGE
CR       R  U  WING/TAIL CHORD AT WING/TAIL-BODY JUNCTURE                      PLUNGE
CRBD     R  U  RICIPROCAL OF BDCR                                              PLUNGE
CRBD2    R  U  SQUARE OF CRBD                                                  PLUNGE
CWBYC    R  U  MEAN AERODYNAMIC CHORD OF EXPOSED WING/TAIL                     PLUNGE
CYB      R  A  DERIVATIVE OF SIDE FORCE WITH YAW ANGLE                         PLUNGE
CYBDT    R  A  DERIVATIVE OF SIDE FORCE WITH BETA DOT                          PLUNGE
D        R  U  BODY DIAMETER AT WING OR TAIL                                   PLUNGE
DUMMY    R  U  DUMMY VARIABLE                                                  PLUNGE
ERROR    I  C  ERROR FLAG                                                      PLUNGE
GAMMAT   R  U  TAIL DIHEDRAL ANGLE (DEGREES)                                   PLUNGE
I        I  U  INDEX                                                           PLUNGE
ICALC    I  U  CALCULATION OPTION FLAG                                         PLUNGE
IDERIV   I  A  DERIVATIVE OPTION FLAG                                          PLUNGE
IPART    I  U  CONTROL FLAG FOR COMPONENT TYPE (BODY,WING,TAIL)                PLUNGE
ITYPE    I  U  FLAG TO CONTROL EQUATION TO BE USED IN CALCULATING KBW          PLUNGE
K        I  U  FLAG TO CONTROL SELECTION OF KBW EQUATION                       PLUNGE
KBW      R  U  INTERFERENCE ON BODY IN PRESENCE OF WING/TAIL                   PLUNGE
KWB      R  U  INTERFERENCE ON WING/TAIL IN PRESENCE OF BODY                   PLUNGE
```

```
SYMBOLS USED IN SUBROUTINE PLUNGE

LAMBDA  R  U  WING/TAIL TAPER RATIO (TIP CHORD/ROOT CHORD)          PLUNGE
LENGTH  R  U  BODY LENGTH                                           PLUNGE
K       R  U  COTANGENT OF WING/TAIL LEADING EDGE SWEEP ANGLE       PLUNGE
NER1    I  U  ERROR FLAG                                            PLUNGE
PAGE    I  C  PAGE NUMBER                                           PLUNGE
PI      R  U  RATIO OF CIRCUMFERENCE OF A CIRCLE TO ITS DIAMETER    PLUNGE
Q       R  U  TAIL EFFECTIVENESS RATIO                              PLUNGE
R       R  U  BODY RADIUS AT WING OR TAIL                           PLUNGE
RATIO   R  U  DUMMY VARIABLE                                        PLUNGE
RS      R  U  R DIVIDED BY S                                        PLUNGE
S       R  U  WING/TAIL SEMI-SPAN                                   PLUNGE
SFRONT  R  U  BODY FRONTAL AREA                                     PLUNGE
SR      R  U  S DIVIDED BY R                                        PLUNGE
SWBYS   R  U  WING/TAIL AREA DIVIDED BY REFERENCE AREA              PLUNGE
TITLE   R  C  TITLE                                                 PLUNGE
TYPE    I  U  CARD TYPE                                             PLUNGE
T1      R  U  DUMMY VARIABLE                                        PLUNGE
T2      R  U  DUMMY VARIABLE                                        PLUNGE
T3      R  U  DUMMY VARIABLE                                        PLUNGE
T4      R  U  DUMMY VARIABLE                                        PLUNGE
UPWASH  R  U  TAIL UPWASH DERIVATIVE CAUSED BY WING                 PLUNGE
VOLUME  R  U  BODY VOLUME                                           PLUNGE
XBTBYC  R  U  TAIL LENGTH DIVIDED BY REFERENCE CHORD                PLUNGE
XC      R  U  AREA CENTROID LOCATION OF BODY                        PLUNGE
XO      R  U  CENTER OF GRAVITY LOCATION                            PLUNGE
```

26. SUBROUTINE ELP1 (DECK AROY)

This routine approximates the values of the elliptical integrals of the first and second kinds.

a. Algorithm

The approximation to a value of the elliptical integral of the first kind is given by

$$K(k) = (a_o + a_1\eta + \ldots + a_4\eta^4) + (b_o + b_1\eta + \ldots + b_4\eta^4) \ln \frac{1}{\eta}$$

where $\eta = 1 - k^2$

$a_o = 1.386294361$	$b_o = 0.5$
$a_1 = 0.0966634426$	$b_1 = 0.124985936$
$a_2 = 0.0359009238$	$b_2 = 0.0688024857$
$a_3 = 0.0374256371$	$b_3 = 0.0332835534$
$a_4 = 0.0145119621$	$b_4 = 0.0044178701$

The approximation to the value of the elliptical integral of the second kind is given by

$$E(k) = (a_o + a_1\eta + \ldots + a_4\eta^4) + (b_o + b_1\eta + \ldots + b_4\eta^4) \ln \frac{1}{\eta}$$

where $\eta = 1 - k^2$

$a_o = 1.0$	$b_o = 0.0$
$a_1 = 0.4432514146$	$b_1 = 0.2499836831$
$a_2 = 0.0626060122$	$b_2 = 0.0920018004$
$a_3 = 0.0475738355$	$b_3 = 0.0406969753$
$a_4 = 0.0173650645$	$b_4 = 0.0052644964$

b. Input/Output

None

c. Error

None

d. Subroutines Required

None

e. Argument List

(AK, AKK, E, NERROR)

f. Length

828 bytes

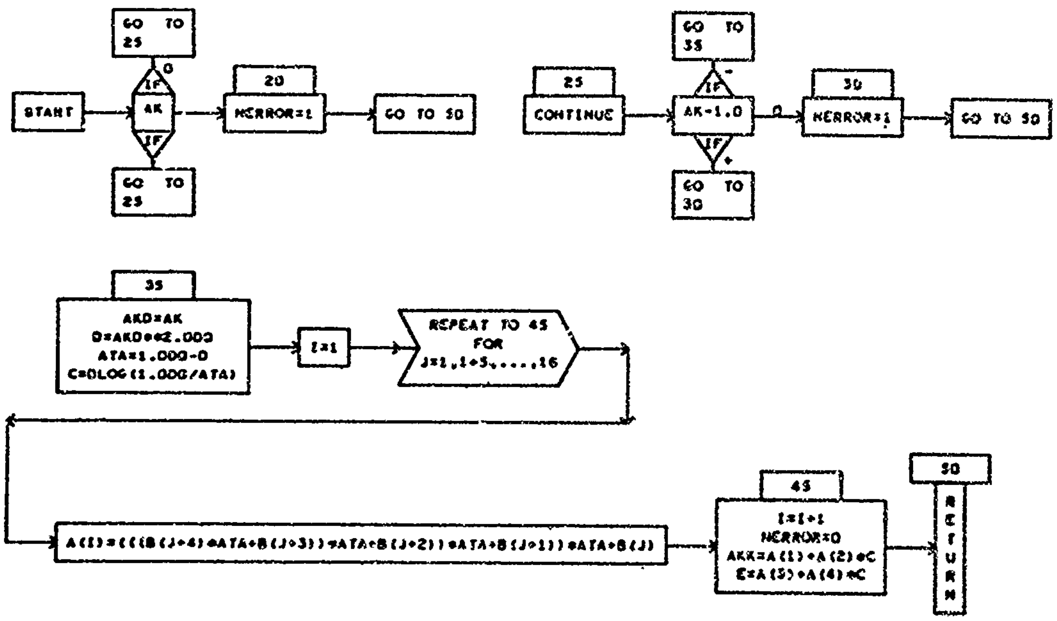
DECK ARDY

```
      SUBROUTINE ELP1(AK, AKK, E, NERROR)                                ARDY  0010
CELP1  ELP1 IS A ROUTINE TO APPROXIMATE THE VALUE OF THE ELLIPTICAL      ARDY  0020
C      INTEGRALS E(K) AND K(K) BY A METHOD OF NUMERICAL ANALYSIS.        ARDY  0030
C      ARGUMENTS OF THE ROUTINE ARE AS FOLLOWS                           ARDY  0040
C      AK     = INPUT VALUE OF K                                         ARDY  0050
C      AKK    = OUTPUT VALUE OF K(K) ELLIPTICAL INTEGRAL                 ARDY  0060
C      E      = OUTPUT VALUE OF E(K) ELLIPTICAL INTEGRAL                 ARDY  0070
C      NERROR = ERROR CODE                                               ARDY  0080
C                   0 = K IS IN ALLOWABLE RANGE                          ARDY  0090
C                   1 = K OUT OF ALLOWABLE RANGE, I.E. EQUAL TO OR GREATER ARDY  0100
C                        THAN ONE OR LESS THAN ZERO.                     ARDY  0110
C                                                                        ARDY  0120
      DIMENSION B(20), A(4)                                              ARDY  0130
      DOUBLE PRECISION A, B, ATA, C, D, AKD                              ARDY  0140
      DATA                B/1.38629436112, 0.09666344259, 0.03590092383, ARDY  0150
     1                                                                   ARDY  0160
     2 .03742563713, .01451196212, .5D0, .12498593597, .06880248576,     ARDY  0170
     3                                                                   ARDY  0180
     4 .03328355346, .004178701200, 1.0D0, .44325141463, .06260601220,   ARDY  0190
     5                                                                   ARDY  0200
     6 .04757383546, .01736506451, .0D0, .29499836831, .09200180037,     ARDY  0210
     7                                                                   ARDY  0220
     8 .04069657526, .00526449639D0/                                     ARDY  0230
C                                                                        ARDY  0240
      IF(AK) 20,25,25                                                    ARDY  0250
   20 NERROR = 1                                                         ARDY  0260
      GO TO 50                                                           ARDY  0270
   25 IF(AK-1.0) 35,30,30                                                ARDY  0280
   30 NERROR = 1                                                         ARDY  0290
      GO TO 50                                                           ARDY  0300
   35 AKD = AK                                                           ARDY  0310
      D = AKD ** 2.0D0                                                   ARDY  0320
      ATA = 1.0D0 - D                                                    ARDY  0330
      C = DLOG(1.0D0 / ATA)                                              ARDY  0340
      I = 1                                                              ARDY  0350
```

```
DECK ARDY

      DO 45 J = 1,16,5                                                   ARDY  0360
      A(I) = (((B(J+4)*ATA + B(J+3))*ATA + B(J+2))*ATA + B(J+1))*ATA +   ARDY  0370
     1        B(J)                                                       ARDY  0380
   45 I = I + 1                                                          ARDY  0390
      NERROR = 0                                                         ARDY  0400
      AKK = A(1) + A(2)*C                                                ARDY  0410
      E   = A(3) + A(4)*C                                                ARDY  0420
   50 RETURN                                                             ARDY  0430
      END                                                                ARDY  0440
```

SUBROUTINE ELP1



```
SYMBOLS USED IN SUBROUTINE ELP1

A         D  D  ELLIPTICAL INTEGRAL PARAMETER                           ELP1
AK        R  A  THE MODULUS                                             ELP1
AKD       D  U  MODULUS                                                 ELP1
AKK       R  A  ELLIPTICAL INTEGRAL OF THE FIRST KIND                   ELP1
ATA       D  U  ELLIPTICAL INTEGRAL PARAMETER                           ELP1
B         D  D  ELLIPTICAL INTEGRAL CONSTANT ARRAY                      ELP1
C         D  U  ELLIPTICAL INTEGRAL PARAMETER                           ELP1
D         D  U  ELLIPTICAL INTEGRAL PARAMETER                           ELP1
E         R  A  ELLIPTICAL INTEGRAL OF THE SECOND KIND                  ELP1
I         I  U  INDEX                                                   ELP1
J         I  U  DO-LOOP INDEX                                           ELP1
NERROR    I  A  ERROR FLAG                                              ELP1
```

27. SUBROUTINE VECTOR (DECK AROZ)

This routine converts input thrust vector data to coefficients and adds the results to the vehicle aerodynamic coefficients.

a. Algorithm

Set up initial conditions and constants. Read in a force vector and convert to force coefficients. Print the results if required. Continue to read in force vector data until LAST equals one.

b. Input/Output

Thrust Vector Data Cards (Type 22)
Thrust Vector coefficient contributions are printed if IPRINT = 1.

c. Error

An error condition occurs if the card type number is wrong.

d. Subroutines Required

HEADER

e. Argument List

(MACH, PFS, SREF, XCG, YCG, ZCG, SPAN, MAC, ALPHA, CD, CL, CA, CY, CN, BETA, LOD, CLM, CLL, CLN)

f. Length

2304 bytes

DECK AROZ

```
      SUBROUTINE VECTOR (MACH,PFS,SREF,XCG,YCG,ZCG,SPAN,MAC,
     1 ALPHA,CD,CL,CA,CY,CN,BETA,LOD,CLM,CLL,CLN)
C
C************************************************************************
C**** THIS SUBROUTINE CONVERTS THRUST VECTORS INTO AERODYNAMIC
C**** COEFFICIENTS.  ANY NUMBER OF VECTORS MAY BE INPUT.
C************************************************************************
C
      DIMENSION  TITLE(15)
      COMMON  CASE,TITLE,PAGE,ERROR
      REAL  MACH,MAC,LOD,NX,NY,NZ
      INTEGER  ERROR,CASE,PAGE,TYPE
C
C   SET UP INITIAL CONDITIONS
      Q = 0.5 * PFS * MACH*MACH
      NPRT = 4
      IVCTNO = 0
      ALPHAR = ALPHA / 0.5729578E02
      BETAR  = BETA  / 0.5729578E02
      ROLLR = 0.0
C
C   READ IN FORCE VECTOR DATA AND CONVERT TO FORCE COEFFICIENTS
    1 READ (5,2) F,XCENT,YCENT,ZCENT,NX,NY,NZ,LAST,IPRINT,TYPE
    2 FORMAT (F10.0,6F6.0,13X,I1,1XI1,8X,I2)
      IF (TYPE .NE. 22) GO TO 100
      IVCTNO = IVCTNO + 1
      DELCA = F *(-NX)/ (Q * SREF)
      DELCY = F *(-NY)/ (C * SREF)
      DELCN = F *  NZ / (Q * SREF)
      DELCLL= DELCY * (ZCENT - ZCG)/SPAN
     1       +DELCN * (YCENT - YCG)/SPAN
      DELCLM= DELCN * (XCENT - XCG)/MAC
     1       +DELCA * (ZCENT - ZCG)/MAC
      DELCLN= DELCY * (XCENT - XCG)/SPAN
     1       -DELCA * (YCENT - YCG)/SPAN
```

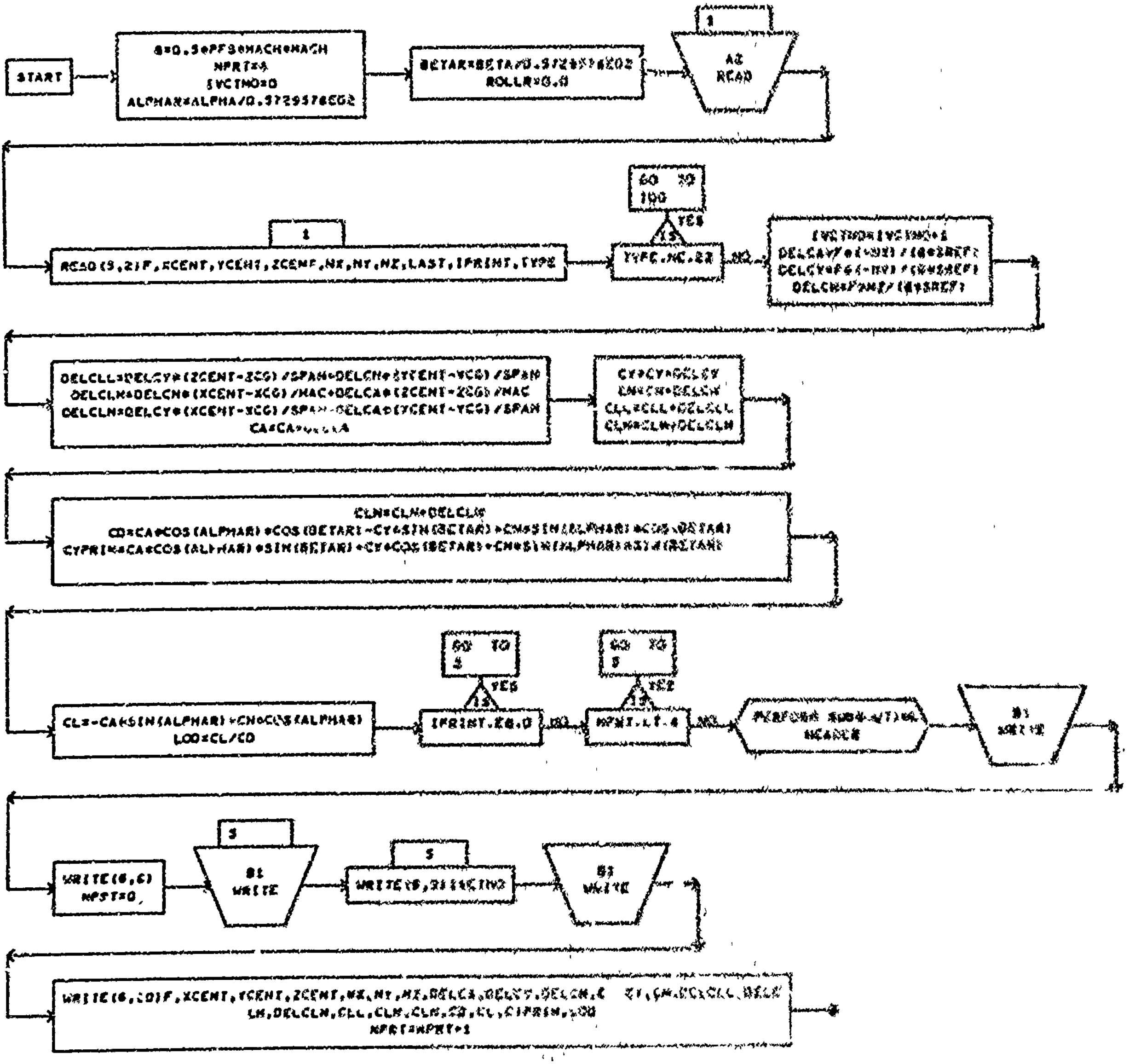
```
DECK AROZ

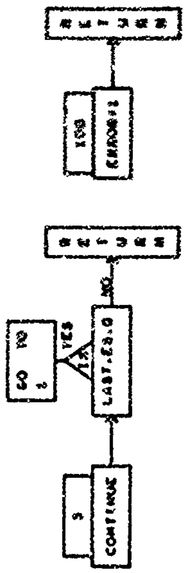
      CA   = CA  + DELCA                                                AROZ  0360
      CY   = CY  + DELCY                                                AROZ  0370
      CN   = CN  + DELCN                                                AROZ  0380
      CLL  = CLL + DELCLL                                               AROZ  0390
      CLM  = CLM + DELCLM                                               AROZ  0400
      CLN  = CLN + DELCLN                                               AROZ  0410
      CD = CA*COS(ALPHAR)*COS(BETAR) - CY*SIN(BETAR)                    AROZ  0420
     1    +CN*SIN(ALPHAR)*COS(BETAR)                                    AROZ  0430
      CYPRIM = CA*COS(ALPHAR)*SIN(BETAR) + CY*COS(BETAR)                AROZ  0440
     1        +CN*SIN(ALPHAR)*SIN(BETAR)                                AROZ  0450
C                                                                       AROZ  0460
C                                                                       AROZ  0470
      CL  = -CA*SIN(ALPHAR) + CN*COS(ALPHAR)                            AROZ  0480
C                                                                       AROZ  0490
C                                                                       AROZ  0500
C                                                                       AROZ  0510
      LOD = CL / CD                                                     AROZ  0520
C                                                                       AROZ  0530
C   PRINT RESULTS IF REQUIRED                                           AROZ  0540
      IF (IPRINT .EQ. 0) GO TO 3                                        AROZ  0550
      IF (NPRT .LT. 4) GO TO 5                                          AROZ  0560
      CALL HEADER                                                       AROZ  0570
      WRITE (6,8)                                                       AROZ  0580
    8 FORMAT (1H0,50HRFSULTS OF VECTOR CONVERSION TO FORCE COEFFICIENTS) AROZ  0590
      NPRT = 0                                                          AROZ  0600
    5 WRITE (6,9) IVCTNO                                                AROZ  0610
    9 FORMAT (1H0,13HVECTOR NUMBER,I3)                                  AROZ  0620
      WRITE (6,10) F,XCENT,YCENT,ZCENT,NX,NY,NZ,DELCA,DELCY,DELCN,      AROZ  0630
     1  CA,CY,CN,DELCLL,DELCLM,DELCLN,CLL,CLM,CLN,CD,CL,CYPRIM,LOD      AROZ  0640
   10 FORMAT (1H ,3X,3HF =F12.1,2X6HXCENT=F7.1,2X6HYCENT=F7.1,          AROZ  0650
     1  2X6HZCENT=F7.1,/1H ,23X3HNX=F7.4,5X3HNX=F7.4,5X3HNX=F7.4,/      AROZ  0660
     2  1H ,3X8HDEL CA =E12.5,2X8HDEL CY =E12.5,2X8HDEL CN =E12.5,/     AROZ  0670
     3  1H ,3X8HTOT CA =E12.5,2X8HTOT CY =E12.5,2X8HTOT CN =E12.5,/     AROZ  0680
     4  1H0,3X8HDEL CLL=E12.5,2X8HDEL CLM=E12.5,2X8HDEL CLN=E12.5,/     AROZ  0690
     5  1H ,3X8HTOT CLL=E12.5,2X8HTOT CLM=E12.5,2X8HTOT CLN=E12.5,/     AROZ  0700
     6  1H0,6X5HC D =F9.5,8X5HC L =F9.5,7X,5HC Y =F9.5,/                AROZ  0710
```

```
DECK AROZ

   7  1H ,6X,5HL/D =F9.5)                                              AROZ  0720
      NPRT = NPRT + 1                                                  AROZ  0730
   3  IF (LAST .EQ. 0) GO TO 1                                         AROZ  0740
      RETURN                                                           AROZ  0750
 100  ERROR = 1                                                        AROZ  0760
      RETURN                                                           AROZ  0770
      END                                                              AROZ  0780
```

SUBROUTINE VECTOR




9
CONTINUE
LAST.EQ.0
IF
YES
GO TO 2
NO
RETURN
1000
ERROR#1
RETURN

```
SYMBOLS USED IN SUBROUTINE VECTOR

ALPHA    R  A  ANGLE OF ATTACK, DEGREES                                          VECTOR
ALPHAR   R  U  ANGLE OF ATTACK, RADIANS                                          VECTOR
BETA     R  A  YAW ANGLE, DEGREES                                                VECTOR
BETAR    R  U  YAW ANGLE, RADIANS                                                VECTOR
CA       R  A  AXIAL FORCE COEFFICIENT                                           VECTOR
CASE     I  C  CASE NUMBER                                                       VECTOR
CD       R  A  DRAG COEFFICIENT                                                  VECTOR
CL       R  A  LIFT COEFFICIENT                                                  VECTOR
CLL      R  A  ROLLING MOMENT COEFFICIENT                                        VECTOR
CLM      R  A  PITCHING MOMENT COEFFICIENT                                       VECTUR
CLN      R  A  YAWING MOMENT COEFFICIENT                                         VECTOR
CN       R  A  NORMAL FURCE COEFFICIENT                                          VECTOR
CY       R  A  SIDE FORCE COEFFICIENT                                            VECTOR
CYPRIM   R  U  SIDE FORCE COEFFICIENT (WIND AXIS)                                VECTOR
DELCA    R  U  DRAG COEFFICIENT INCREMENT                                        VECTOR
DELCLL   R  U  ROLLING MOMENT COEFFICIENT INCREMENT                              VECTOR
DELCLM   R  U  PITCHING MOMENT COEFFICIENT INCREMENT                             VECTOR
DELCLN   R  U  YAWING MOMENT COEFFICIENT INCREMENT                               VECTOR
DELCN    R  U  NORMAL FORCE COEFFICIENT INCREMENT                                VECTOR
DELCY    R  U  SIDE FORCE COEFFICIENT INCREMENT                                  VECTOR
ERROR    I  C  ERROR FLAG                                                        VECTOR
F        R  U  FORCE MAGNITUDE, POUNDS                                           VECTOR
IPRINT   I  U  PRINT FLAG                                                        VECTOR
IVCTNO   I  U  VECTOR NUMBER                                                     VECTOR
LAST     I  U  LAST VECTOR FLAG                                                  VECTOR
LOD      R  A  LIFT-TO-DRAG RATIO                                                VECTOR
MAC      R  A  REFERENCE LENGTH FOR MOMENT COEFFICIENTS                          VECTOR
MACH     R  A  MACH NUMBER                                                       VECTOR
NPRT     I  U  PRINT LINE COUNTER                                                VECTOR
NX       R  U  FORCE VECTOR DIRECTION COSINE IN X-DIRECTION                      VECTOR
NY       R  U  FORCE VECTOR DIRECTION COSINE IN Y-DIRECTION                      VECTOR
NZ       R  U  FORCE VECTOR DIRECTION COSINE IN Z-DIRECTION                      VECTOR
PAGE     I  C  PAGE NUMBER                                                       VECTOR
PFS      R  A  FREE-STREAM PRESSURE, LBS/SQUARE FOOT                             VECTOR
Q        R  U  DYNAMIC PRESSURE                                                  VECTOR
ROLLR    R  U  ROLL ANGLE IN RADIANS                                             VECTOR
```

```
SYMBOLS USED IN SUBROUTINE VECTOR

SPAN     R  A  REFERENCE LENGTH FOR ROLLING, YAWING COEFFICIENTS        VECTOR
SREF     R  A  VEHICLE REFERENCE AREA (WING AREA)                       VECTOR
TITLE    R  C  TITLE                                                    VECTOR
TYPE     I  U  CARD TYPE NUMBER                                         VECTOR
XCENT    R  U  ACTION POINT FOR FORCE VECTOR-X                          VECTOR
XCG      R  A  X-CENTER FOR MOMENT CALCULATIONS                         VECTOR
YCENT    R  U  ACTION POINT FOR FORCE VECTOR-Y                          VECTOR
YCG      R  A  Y-CENTER FOR MOMENT CALCULATIONS                         VECTOR
ZCENT    R  U  ACTION POINT FOR FORCE VECTOR-Z                          VECTOR
ZCG      R  A  Z-CENTER FOR MOMENT CALCULATIONS                         VECTOR
```

28. SUBROUTINE GRAPIC (DECK GRPA)

This is the Executive routine for the graphics part of the program.

a. Algorithm

Print that GRAPHIC OPTION HAS CONTROL and select the proper graphic routine depending upon the value of IPROG.

b. Input/Output

None

c. Error

None

d. Subroutines Required

PICTUR, PLOT

e. Argument List

(IPROG)

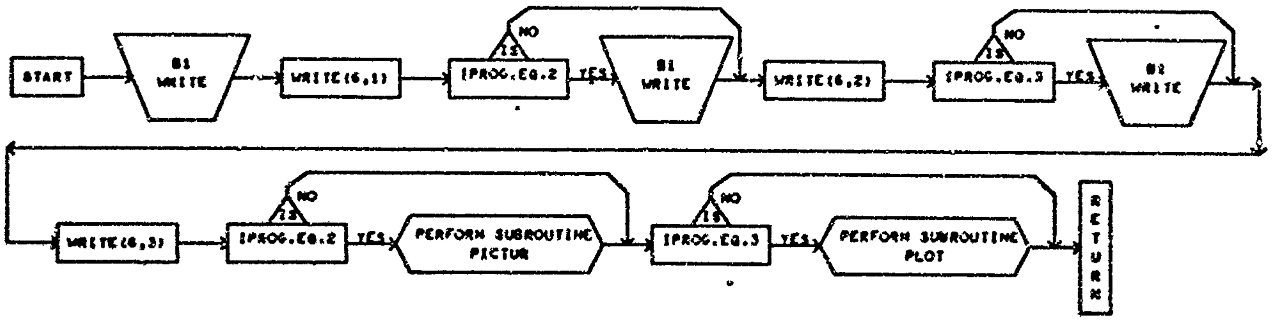
f. Length

536 bytes

```
DECK GRPA

      SUBROUTINE GRAPIC (IPROG)                                         GRPA  0010
C                                                                       GRPA  0020
      COMMON CASE,TITLE,PAGE,ERROR                                      GRPA  0030
      DIMENSION  TITLE(15)                                              GRPA  0040
      INTEGER  ERROR,CASE,PAGE                                          GRPA  0050
C                                                                       GRPA  0060
C***** GRAPHIC OUTPUT DATA CONTROL PROGRAM ******************            GRPA  0070
C                                                                       GRPA  0080
C                                                                       GRPA  0090
      WRITE (6,1)                                                       GRPA  0100
    1 FORMAT (1H ,///,1H ,38H***** GRAPHIC OPTION HAS CONTROL ***** )   GRPA  0110
      IF (IPROG .EQ. 2) WRITE (6,2)                                     GRPA  0120
    2 FORMAT (1H0,10X,40HPICTURE DRAWING PROGRAM WILL BE EXECUTED  )    GRPA  0130
      IF (IPROG .EQ. 3) WRITE (6,3)                                     GRPA  0140
    3 FORMAT (1H0,10X,44HOUTPUT DATA PLOTTER PROGRAM WILL BE EXECUTED ) GRPA  0150
C                                                                       GRPA  0160
      IF (IPROG.EQ. 2) CALL PICTUR                                      GRPA  0170
C                                                                       GRPA  0180
      IF (IPROG .EQ. 3) CALL PLOT                                       GRPA  0190
C                                                                       GRPA  0200
      RETURN                                                            GRPA  0210
      END                                                               GRPA  0220
```

SUBROUTINE GRAPIC



```
SYMBOLS USED IN SUBROUTINE GRAPIC

CASE     I  C  CASE NUMBER                                                                  GRAPIC
ERROR    I  C  ERROR FLAG                                                                   GRAPIC
IPROG    I  A  PROGRAM OPTION NUMBER                                                        GRAPIC
PAGE     I  C  PAGE NUMBER                                                                  GRAPIC
TITLE    R  C  TITLE                                                                        GRAPIC
```

29. SUBROUTINE PICTUR (DECK GRPB)

This routine prepares an output tape for procession on the SC-4020. The result will be pictures of the vehicle with the selected viewing angles.

a. Algorithm

Read the Picture Drawing Program Element Data Title Card (Type 31) and the Element Data Control Card (Type 32). Read the surface element data either from Tape 5 or from Tape 8 as directed. Read plotting instruction data (Card Types 34, 35, 36, and 37). Set up starting constants for pictures. Read element data from Tape 3 using the same techniques as for SDATA and convert to quadrilaterals. Generate scale grids if required. Plot points and draw lines between the points as directed by the input data. Print the detailed element characteristics if PRINTS is equal to 1.

b. Input/Output

Element Data Title Card (Type 31), Element Data Control Card (Type 32), Element Data Cards from Tape 5 or Tape 8 (Type 3), Picture Control Data Card (Type 34), Grid Data Card (Type 35), Scale Label Card (Type 36), and Plot Title Card(s) (Type 37). If PRINTS is equal to 1 the detailed element characteristics will be printed on Tape 6 (just as is the case for SDATA).

c. Error

An error condition occurs if a card type number is wrong.

d. Subroutines Required

HEADR2, SC-4020 routines

e. Argument List

None

f. Length

16180 bytes

DECK GRPB

```
      SUBROUTINE PICTUR                                                 GRPB  0010
C       SC-4020 PLOTTER PROGRAM FOR PLOTTING SURFACE DATA               GRPB  0020
C                                                                       GRPB  0030
C                                                                       GRPB  0040
      DIMENSION  XA(250),XB(250),YA(250),YB(250),ZA(250),ZB(250),       GRPB  0050
     1 XI(4),ETA(4),XIN(4),YIN(4),ZIN(4),VTITLE(8),HTITLE(8),HLABEL(15),GRPB  0060
     2 YIN2(4),ZIN2(4),CARD(20),TITLE(15)                               GRPB  0070
C                                                                       GRPB  0080
      COMMON  CASE,TITLE,PAGE,ERROR                                     GRPB  0090
C                                                                       GRPB  0100
      REAL  NX,NY,NZ,NXO                                                GRPB  0110
      LOGICAL  RFLAG, AFLAG, BFLAG                                      GRPB  0120
      INTEGER  STAT,STATT,TYPE,PRINTS,SYMFCT,CASE,PAGE,ERROR            GRPB  0130
C                                                                       GRPB  0140
C                                                                       GRPB  0150
      FIRST(QX,QY,QZ,Q1,Q2,Q3) = QX*Q1 + QY*Q2 + QZ*Q3                  GRPB  0160
C                                                                       GRPB  0170
      THIRD(QX,QY,QZ,QPSI,QTHETA,QPHI) = QX*(COS(QTHETA)*COS(QPSI)) +   GRPB  0180
     1  QY*(-SIN(QPSI)*COS(QPHI)+SIN(QTHETA)*COS(QPSI)*SIN(QPHI)) +     GRPB  0190
     2  QZ*(SIN(QPSI)*SIN(QPHI)+SIN(QTHETA)*COS(QPSI)*COS(QPHI))        GRPB  0200
C                                                                       GRPB  0210
      CALL CAMRAV (9)                                                   GRPB  0220
      IDUM = -1                                                         GRPB  0230
      REWIND 2                                                          GRPB  0240
      CALL INCRV (6,3)                                                  GRPB  0250
      IPIC = 1                                                          GRPB  0260
    2 REWIND 3                                                          GRPB  0270
C  READ ALL INPUT DATA AND STCRE ON TAPE 3 FOR FUTURE USE               GRPB  0280
      READ(5,10C) (TITLE(I),I=1,15),CASE,TYPE                           GRPB  0290
  100 FORMAT(14A4,A3,6X,I3,2XI2)                                        GRPB  0300
      IF (TYPE .NE. 99) GO TO 301                                       GRPB  0310
      ERROR = 0                                                         GRPB  0320
      RETURN                                                            GRPB  0330
  301 IF (TYPE .NE. 31) GO TO 300                                       GRPB  0340
      READ(5,101) PRINTS,SYMFCT,IORIEN,IFACT,XSC,YSC,ZSC,DELX,DELY,DELZ,GRPB  0350
```

DECK GRPB

```
    1      ISTAT3,ITAPE,IREW8,TYPE
 101  FORMAT (I1,1XI1,2I1,1X3F6.0,1X3F6.0,16XI2,2I1,7XI2)
      IF (TYPE .NE. 32) GO TO 300
      IF (IREW8 .EQ. 0) REWIND 8
      IF (SYMFCT .EQ. 0) SYMFCT = 2
      IA = 0
      IB = 0
      IF (IORIEN .EQ. 2) IB = 1
      IF (IORIEN .EQ. 3) IA = 1
    3 IF (ITAPE.EQ.0) READ (5,1) X,Y,Z,STAT,XX,YY,ZZ,STATT,TYPE
      IF (ITAPE.NE.0) READ (8,1) X,Y,Z,STAT,XX,YY,ZZ,STATT,TYPE
    1 FORMAT (2(3F10.0,I1),8XI2 )
      IF (TYPE.NE.3 .AND. ITAPE.EQ.0) GO TO 300
      IF (TYPE.NE.3 .AND. ITAPE.NE.0) GO TO 806
C
      IF (IFACT.EQ.0) GO TO 10
        X = X * XSC + DELX
        XX= XX* XSC + DELX
        Y = Y * YSC + DELY
        YY= YY* YSC + DELY
        Z = Z * ZSC + DELZ
        ZZ= ZZ* ZSC + DELZ
   10 IF (STAT.EQ.3 .OR. STATT.EQ.3 .AND. ISTAT3.GT.0) ISTAT3 = ISTAT3-1
      IF (STAT.EQ.3 .AND. ISTAT3.GT.0) STAT = 0
      IF (STATT.EQ.3 .AND. ISTAT3.GT.0) STATT = 0
      WRITE (3) X,Y,Z,STAT,XX,YY,ZZ,STATT
      IF (STAT.EQ.3 .OR. STATT.EQ.3) GO TO 4
      GO TO 3
    4 WRITE (6,4016) IPIC
 4016 FORMAT (1H1,////,1H0,34HPICTURE DRAWING PROGRAM    PICTURE
    1      7H NUMBER ,I4)
      IPIC = IPIC + 1
C
C  READ PLOTTING INSTRUCTIONS
      READ (5,5) PSI,THETA,PHI,ICS,IREFL,ISHAD,IAREA,IQUAD,IFRAME,NCAM,
     1  MARKPT,NG,MG,IG,JG,NXG,NYG,LAST,TYPE
```

```
      DECK GRPB

    5 FORMAT (F6.0,1XF6.0,1XF6.0,6(1XI1),2(1XI2),2X2I3,1X2I3,1X2I2,         GRPB  0720
     1  1XI1,10XI2 )                                                          GRPB  0730
      IF (TYPE .NE. 34) GO TO 300                                             GRPB  0740
      READ (5,6) XLG,XRG,YBG,YTG,DXG,DYG,NOSCAL,TYPE                         GRPB  0750
    6 FORMAT (5F10.0,F9.0,I1,10XI2)                                           GRPB  0760
      IF (TYPE .NE. 35) GO TO 300                                             GRPB  0770
      IF (NOSCAL .EQ. 1) GO TO 8                                              GRPB  0780
      READ (5,7) (VTITLE(I),I=1,8),(HTITLE(I),I=1,8),TYPE                     GRPB  0790
    7 FORMAT (7A4,A2,7A4,A1,11XI2)                                            GRPB  0800
      IF (TYPE .NE. 36) GO TO 300                                             GRPB  0810
C                                                                             GRPB  0820
    8 CALL CAMRAV (NCAM)                                                      GRPB  0830
      CALL FRAMEV (0)                                                         GRPB  0840
C                                                                             GRPB  0850
C     SET UP STARTING CONSTANTS                                               GRPB  0860
      IFADV = 1                                                               GRPB  0870
      ISTART = 0                                                              GRPB  0880
      PSI   =  PSI   / 57.2957795                                             GRPB  0890
      THETA = THETA / 57.2957795                                              GRPB  0900
      PHI   =  PHI   / 57.2957795                                             GRPB  0910
      SINTH = SIN(THETA)                                                      GRPB  0920
      COSTH = COS(THETA)                                                      GRPB  0930
      SINPSI= SIN(PSI)                                                        GRPB  0940
      COSPSI= COS(PSI)                                                        GRPB  0950
      SINPHI= SIN(PHI)                                                        GRPB  0960
      COSPHI= COS(PHI)                                                        GRPB  0970
      A1  = COSTH * SINPSI                                                    GRPB  0980
      A2  = COSPSI*COSPHI + SINTH*SINPSI*SINPHI                               GRPB  0990
      A3  =-COSPSI*SINPHI + SINTH*SINPSI*COSPHI                               GRPB  1000
      A4  =-SINTH                                                             GRPB  1010
      A5  = COSTH*SINPHI                                                      GRPB  1020
      A6  = COSTH*COSPHI                                                      GRPB  1030
      A7  = COSTH*COSPSI                                                      GRPB  1040
      A8  =-SINPSI*COSPHI + SINTH*COSPSI*SINPHI                               GRPB  1050
      A9  = SINPSI*SINPHI + SINTH*COSPSI*COSPHI                               GRPB  1060
       N  = -1                                                                GRPB  1070
```

```
DECK GRPB
      NN = - 1                                                          GRPB 1080
      KLCT = 0                                                          GRPB 1090
      L = 0                                                             GRPB 1100
      NPRT = 10                                                         GRPB 1110
      AREAT = 0.0                                                       GRPB 1120
      VOL = 0.0                                                         GRPB 1130
      REWIND 3                                                          GRPB 1140
C                                                                       GRPB 1150
C                                                                       GRPB 1160
C     READ IN ALL SURFACE DATA                                          GRPB 1170
   29 READ (3) X,Y,Z,STAT, XX,YY,ZZ,STATT                               GRPB 1180
      RFLAG = .FALSE.                                                   GRPB 1190
      GO TO 80                                                          GRPB 1200
   30 IF (RFLAG) GO TO 50                                               GRPB 1210
      RFLAG = .TRUE.                                                    GRPB 1220
      X = XX                                                            GRPB 1230
      Y = YY                                                            GRPB 1240
      Z = ZZ                                                            GRPB 1250
      STAT = STATT                                                      GRPB 1260
      GO TO 60                                                          GRPB 1270
   50 RFLAG = .FALSE.                                                   GRPB 1280
      READ (3) X,Y,Z,STAT, XX,YY,ZZ,STATT                               GRPB 1290
   60 IF (STAT .EQ. 0 .OR. STAT .EQ. 3) GO TO 180                       GRPB 1300
      IF (STAT .EQ. 2) GO TO 200                                        GRPB 1310
   70 IF (.NOT. AFLAG) GO TO 200                                        GRPB 1320
      MC = M                                                            GRPB 1330
   80 M = 1                                                             GRPB 1340
       IF (STAT .EQ. 2) GO TO 150                                       GRPB 1350
       IF (.NOT. BFLAG) GO TO 84                                        GRPB 1360
   75 DO 81 J =1,MC                                                     GRPB 1370
        XA(J) = XB(J)                                                   GRPB 1380
        YA(J) = YB(J)                                                   GRPB 1390
   81   ZA(J) = ZB(J)                                                   GRPB 1400
   83 XB(1) = X                                                         GRPB 1410
      YB(1) = Y                                                         GRPB 1420
      ZB(1) = Z                                                         GRPB 1430
```

```
DECK GRPB

      GO TO 30                                                          GRPB  1440
   84 IF (AFLAG) GO TO 85                                               GRPB  1450
       BFLAG = .TRUE.                                                   GRPB  1460
       GO TO 75                                                         GRPB  1470
   85 AFLAG = .FALSE.                                                   GRPB  1480
       GO TO 83                                                         GRPB  1490
  150 AFLAG = .TRUE.                                                    GRPB  1500
       BFLAG = .FALSE.                                                  GRPB  1510
       N = N+1                                                          GRPB  1520
  140 XA(M) = X                                                         GRPB  1530
      YA(M) = Y                                                         GRPB  1540
      ZA(M) = Z                                                         GRPB  1550
      GO TO 30                                                          GRPB  1560
  180 M = M + 1                                                         GRPB  1570
      IF (AFLAG) GO TO 160                                              GRPB  1580
       XB(M) = X                                                        GRPB  1590
       YB(M) = Y                                                        GRPB  1600
       ZB(M) = Z                                                        GRPB  1610
      IF (STAT .NE. 3) GO TO 30                                         GRPB  1620
  200 MMIN = MIN0 (M,MC) - 1                                            GRPB  1630
       NN2 = 1                                                          GRPB  1640
       MC = M                                                           GRPB  1650
  250 N = N + 1                                                         GRPB  1660
      NN = NN + 1                                                       GRPB  1670
       KLCT = KLCT + 1                                                  GRPB  1680
C                                                                       GRPB  1690
C                                                                       GRPB  1700
C  BEGIN COMPUTATION OF SURFACE ELEMENT CHARACTERISTICS                 GRPB  1710
C                                                                       GRPB  1720
  450 DO 2000 I= 1,MMIN                                                 GRPB  1730
      IIA = I + IA                                                      GRPB  1740
      IIB = I + IB                                                      GRPB  1750
        XIN(1) = XA(IIA )                                               GRPB  1760
        XIN(2) = XA(IIA +1)                                             GRPB  1770
        XIN(3) = XB(IIB +1)                                             GRPB  1780
        XIN(4) = XB(IIB )                                               GRPB  1790
```

```
DECK GRPB
          YIN(1) = YA(IIA )                                                GRPB  1800
          YIN(2) = YA(IIA +1)                                              GRPB  1810
          YIN(3) = YB(IIB +1)                                              GRPB  1820
          YIN(4) = YB(IIB )                                                GRPB  1830
          ZIN(1) = ZA(IIA )                                                GRPB  1840
          ZIN(2) = ZA(IIA +1)                                              GRPB  1850
          ZIN(3) = ZB(IIB +1)                                              GRPB  1860
          ZIN(4) = ZB(IIB )                                                GRPB  1870
          IRFLG = 0                                                        GRPB  1880
C                                                                          GRPB  1890
C   FORM DIAGONAL VECTORS                                                  GRPB  1900
         T1X = XIN(3) - XIN(1)                                             GRPB  1910
         T2X = XIN(4) - XIN(2)                                             GRPB  1920
         T1Y = YIN(3) - YIN(1)                                             GRPB  1930
         T2Y = YIN(4) - YIN(2)                                             GRPB  1940
         T1Z = ZIN(3) - ZIN(1)                                             GRPB  1950
         T2Z = ZIN(4) - ZIN(2)                                             GRPB  1960
C                                                                          GRPB  1970
C   FORM CROSS PRODUCT  N=T2 X T1                                          GRPB  1980
         NX = T2Y*T1Z - T1Y*T2Z                                            GRPB  1990
         NY = T1X*T2Z - T2X*T1Z                                            GRPB  2000
         NZ = T2X*T1Y - T1X*T2Y                                            GRPB  2010
         VN = SQRT ( NX*NX + NY*NY + NZ*NZ )                               GRPB  2020
C                                                                          GRPB  2030
C   FORM UNIT NORMAL VECTOR                                                GRPB  2040
        IF (VN .EQ. 0.0) GO TO 421                                         GRPB  2050
        NX = NX / VN                                                       GRPB  2060
         NY = NY / VN                                                      GRPB  2070
         NZ = NZ / VN                                                      GRPB  2080
C                                                                          GRPB  2090
C   COMPUTE AVERAGE POINT                                                  GRPB  2100
 421    AVX = 0.25 * (XIN(1) + XIN(2) + XIN(3) + XIN(4) )                  GRPB  2110
         AVY = 0.25 * (YIN(1) + YIN(2) + YIN(3) + YIN(4) )                 GRPB  2120
         AVZ = 0.25 * (ZIN(1) + ZIN(2) + ZIN(3) + ZIN(4) )                 GRPB  2130
C                                                                          GRPB  2140
C   COMPUTE PROJECTION DISTANCE                                            GRPB  2150
```

DECK GRPB

```
      D = NX*(AVX - XIN(1)) + NY*(AVY - YIN(1)) + NZ*(AVZ-ZIN(1))          GRPB  2160
      PD = ABS(D)                                                          GRPB  2170
C                                                                          GRPB  2180
C                                                                          GRPB  2190
      T = SQRT (T1X*T1X + T1Y*T1Y + T1Z*T1Z)                               GRPB  2200
     IF (T .EQ. 0.0) GO TO 431                                             GRPB  2210
     T1X = T1X / T                                                         GRPB  2220
      T1Y = T1Y / T                                                        GRPB  2230
      T1Z = T1Z / T                                                        GRPB  2240
C                                                                          GRPB  2250
C                                                                          GRPB  2260
 431 T2X = NY*T1Z - NZ*T1Y                                                 GRPB  2270
      T2Y = NZ*T1X - NX*T1Z                                                GRPB  2280
      T2Z = NX*T1Y - NY*T1X                                                GRPB  2290
C                                                                          GRPB  2300
C  COMPUTE COORDINATES OF CORNER POINTS IN REFERENCE COORD. SYSTEM         GRPB  2310
C                                                                          GRPB  2320
     DO 1000 J = 1,4                                                       GRPB  2330
      XPA= XIN(J) + NX*D                                                   GRPB  2340
      YPA= YIN(J) + NY*D                                                   GRPB  2350
      ZPA= ZIN(J) + NZ*D                                                   GRPB  2360
C                                                                          GRPB  2370
     IF (IQUAD .EQ. 0) GO TO 470                                           GRPB  2380
       XIN(J) = XPA                                                        GRPB  2390
       YIN(J) = YPA                                                        GRPB  2400
       ZIN(J) = ZPA                                                        GRPB  2410
C                                                                          GRPB  2420
 470  D = - D                                                              GRPB  2430
      XDIF = XPA- AVX                                                      GRPB  2440
      YDIF = YPA- AVY                                                      GRPB  2450
      ZDIF = ZPA- AVZ                                                      GRPB  2460
C                                                                          GRPB  2470
C  TRANSFORM CORNER POINTS TO ELEMENT COORDINATE SYSTEM (XI,ETA) WITH      GRPB  2480
C   AVERAGE POINT AS ORIGIN                                                GRPB  2490
      XI(J) = T1X*XDIF + T1Y*YDIF + T1Z*ZDIF                               GRPB  2500
 1000 ETA(J)= T2X*XDIF + T2Y*YDIF + T2Z*ZDIF                               GRPB  2510
```

```
DECK GRPB

C                                                                         GRPB  2520
C  COMPUTE CENTROID                                                       GRPB  2530
      ETACK = ETA(2) - ETA(4)                                             GRPB  2540
      IF (ETACK .NE. 0.0) GO TO 432                                       GRPB  2550
       XIO = 0.0                                                          GRPB  2560
       GO TO 433                                                          GRPB  2570
 432  XIO = .333333333 * (XI(4) * (ETA(1)-ETA(2)) + XI(2)                 GRPB  2580
     1       * (ETA(4)-ETA(1))) / (ETA(2)-ETA(4))                         GRPB  2590
 433  ETAO = -.333333333 * ETA(1)                                         GRPB  2600
C                                                                         GRPB  2610
C  OBTAIN CORNER POINTS IN SYSTEM WITH CENTROID AS ORIGIN                 GRPB  2620
       DO 1020 J = 1,4                                                    GRPB  2630
        XI(J) = XI(J) - XIO                                               GRPB  2640
 1020   ETA(J) = ETA(J) - ETAO                                            GRPB  2650
C                                                                         GRPB  2660
C  TRANSFORM CENTROID TO REFERENCE COORDINATE SYSTEM                      GRPB  2670
       XCENT = AVX + T1X*XIO + T2X*ETAO                                   GRPB  2680
       YCENT = AVY + T1Y*XIO + T2Y*ETAO                                   GRPB  2690
       ZCENT = AVZ + T1Z*XIO + T2Z*ETAO                                   GRPB  2700
C                                                                         GRPB  2710
C  CONSTANTS                                                              GRPB  2720
       XI3M1 = XI(3) - XI(1)                                              GRPB  2730
       ETA2M4 = ETA(2) - ETA(4)                                           GRPB  2740
C                                                                         GRPB  2750
C  COMPUTE AREA AND VOLUME OF ELEMENTS                                    GRPB  2760
       AREA = 0.5 * XI3M1 * ETA2M4                                        GRPB  2770
      AREAT = AREAT + AREA                                                GRPB  2780
       DELVOL = AREA * NY * YCENT                                         GRPB  2790
      VOL = VOL + DELVOL                                                  GRPB  2800
      L = L + 1                                                           GRPB  2810
      IF (PRINTS.EQ.0) GO TO 1770                                         GRPB  2820
C  PRINT RESULTS OF CALCULATIONS TO DETERMINE ELEMENT CHARACTERISTICS     GRPB  2830
 1700 IF (NPRT.GE.9) GO TO 1750                                           GRPB  2840
       NPRT = NPRT + 1                                                    GRPB  2850
      IF (I .EQ. 1) GO TO 1760                                            GRPB  2860
       WRITE (6,4005) I, XIN, NX, XCENT, AREA,L,YIN,NY,YCENT,DELVOL,ZIN,  GRPB  2870
```

```
     1  NZ,ZCENT,VOL                                                     GRPB  2880
        GO TO 1770                                                       GRPB  2890
 1750 NPRT = 0                                                           GRPB  2900
        CALL HEADR2                                                      GRPB  2910
        WRITE (6,4002)                                                   GRPB  2920
 1760 WRITE (6, 4010) N, I, XIN, NX, XCENT, AREA,L,YIN,NY,YCENT,DELVOL,  GRPB  2930
     1 ZIN,NZ,ZCENT,VOL                                                  GRPB  2940
 1770 IF (AREA .LT. 0.1E-09) GO TO 2000                                  GRPB  2950
C                                                                        GRPB  2960
C  CHECK IF NEW GRID IS REQUIRED AND PREPARE GRID                        GRPB  2970
        IF (IFADV .EQ. 0) GO TO 471                                      GRPB  2980
C                                                                        GRPB  2990
        IF (NOSCAL .EQ. 0) GO TO 505                                     GRPB  3000
         CALL STOPTV                                                     GRPB  3010
         CALL BRITEV                                                     GRPB  3020
         CALL XSCALV (XLG,XRG,24,0)                                      GRPB  3030
         CALL YSCALV (YBG,YTG,0,24)                                      GRPB  3040
         GO TO 511                                                       GRPB  3050
 505    CALL GRID1V (2,XLG,XRG,YBG,YTG,DXG,DYG,NG,MG,IG,JG,NXG,NYG)      GRPB  3060
        DO 510 II=1,3                                                    GRPB  3070
 510    CALL APRNTV (0,-12,30,VTITLE,8,689)                              GRPB  3080
        DO 520 II=1,3                                                    GRPB  3090
 520    CALL PRINTV (29,HTITLE,391,8)                                    GRPB  3100
 511    IF (IFRAME.EQ.1 .AND. ISTART.EQ.1) GO TO 521                     GRPB  3110
        READ (5,522) (HLABEL(II),II=1,15),TYPE                           GRPB  3120
 522    FORMAT(14A4,1A3,11XI2)                                           GRPB  3130
        IF (TYPE .NE. 37) GO TO 300                                      GRPB  3140
        ISTART = 1                                                       GRPB  3150
 521    DO 523 II=1,3                                                    GRPB  3160
        CALL PRINTV (-45,45HHYPERSONIC ARBITRARY-BODY AERODYNAMIC PROGRAM,  GRPB  3170
     1  330,1023)                                                        GRPB  3180
 523    CALL PRINTV (59,HLABEL,248,1007)                                 GRPB  3190
        IF (IFRAME .NE. 1) GO TO 525                                     GRPB  3200
        CALL SCSETV (4)                                                  GRPB  3210
        WRITE (16,524) XIN(1),XIN(4)                                     GRPB  3220
 524    FORMAT (1H ,10X11HSTATIONS  =F9.3,8H   AND =F9.3 )               GRPB  3230
```

```
DECK GRPB
 525  IFADV = 0                                                        GRPB 3240
C                                                                      GRPB 3250
 471  NXO = THIRD(NX,NY,NZ,PSI,THETA,PHI)                              GRPB 3260
      IF (NXO.LE.0.0 .AND. ISHAD.EQ.0) GO TO 571                       GRPB 3270
C                                                                      GRPB 3280
C                                                                      GRPB 3290
C  CALCULATE POINTS TO BE PLOTTED                                      GRPB 3300
 530  YO1 = FIRST(XIN(1),YIN(1),ZIN(1),A1,A2,A3)                       GRPB 3310
      YO2 = FIRST(XIN(2),YIN(2),ZIN(2),A1,A2,A3)                       GRPB 3320
      YO3 = FIRST(XIN(3),YIN(3),ZIN(3),A1,A2,A3)                       GRPB 3330
      YO4 = FIRST(XIN(4),YIN(4),ZIN(4),A1,A2,A3)                       GRPB 3340
      ZO1 = FIRST(XIN(1),YIN(1),ZIN(1),A4,A5,A6)                       GRPB 3350
      ZO2 = FIRST(XIN(2),YIN(2),ZIN(2),A4,A5,A6)                       GRPB 3360
      ZO3 = FIRST(XIN(3),YIN(3),ZIN(3),A4,A5,A6)                       GRPB 3370
      ZO4 = FIRST(XIN(4),YIN(4),ZIN(4),A4,A5,A6)                       GRPB 3380
C                                                                      GRPB 3390
      YIN2(1)  = YO1                                                   GRPB 3400
      YIN2(2)  = YO2                                                   GRPB 3410
      YIN2(3)  = YO3                                                   GRPB 3420
      YIN2(4)  = YO4                                                   GRPB 3430
      ZIN2(1)  = ZO1                                                   GRPB 3440
      ZIN2(2)  = ZO2                                                   GRPB 3450
      ZIN2(3)  = ZO3                                                   GRPB 3460
      ZIN2(4)  = ZO4                                                   GRPB 3470
C                                                                      GRPB 3480
      CALL APLOTV (4,YIN2,ZIN2,1,1,1,MARKPT,IERR)                      GRPB 3490
C                                                                      GRPB 3500
      IF (ICS .EQ. 3) GO TO 571                                        GRPB 3510
C                                                                      GRPB 3520
      IF (ICS.EQ.0 .OR. ICS.EQ.1) GO TO 540                            GRPB 3530
       GO TO 541                                                       GRPB 3540
 540   IX1 = NXV(YO1)                                                  GRPB 3550
       IY1 = NYV(ZO1)                                                  GRPB 3560
      CALL SCERRV (KX,KY)                                              GRPB 3570
       IX2 = NXV(YO2)                                                  GRPB 3580
       IY2 = NYV(ZO2)                                                  GRPB 3590
```

```
DECK GRPB
      CALL  SCERRV (KX1,KY1)                                          GRPB  3600
      KKXY = KX+KY+KX1+KY1                                            GRPB  3610
      IF (KKXY.NE.0) GO TO 541                                        GRPB  3620
      IF (NXO.GT.0.0) CALL LINEV (IX1,IY1,IX2,IY2)                    GRPB  3630
      IF (NXO.LE.0.0) CALL DOTLNV(IX1,IY1,IX2,IY2)                    GRPB  3640
C                                                                     GRPB  3650
  541 IF (ICS.EQ.0 .OR. ICS.EQ.2 .OR. ICS.EQ.4) GO TO 550             GRPB  3660
       GO TO 551                                                      GRPB  3670
  550  IX1 = NXV(YO2)                                                 GRPB  3680
       IY1 = NYV(ZO2)                                                 GRPB  3690
      CALL  SCERRV (KX,KY)                                            GRPB  3700
       IX2 = NXV(YO3)                                                 GRPB  3710
       IY2 = NYV(ZO3)                                                 GRPB  3720
      CALL  SCERRV (KX1,KY1)                                          GRPB  3730
      KKXY = KX+KY+KX1+KY1                                            GRPB  3740
      IF (KKXY.NE.0) GO TO 551                                        GRPB  3750
      IF (NXO.GT.0.0) CALL LINEV (IX1,IY1,IX2,IY2)                    GRPB  3760
      IF (NXO.LE.0.0) CALL DOTLNV(IX1,IY1,IX2,IY2)                    GRPB  3770
C                                                                     GRPB  3780
  551 IF (ICS.EQ.0 .OR. ICS.EQ.1 .OR. ICS.EQ.4) GO TO 560             GRPB  3790
       GO TO 561                                                      GRPB  3800
  560  IX1 = NXV(YO3)                                                 GRPB  3810
       IY1 = NYV(ZO3)                                                 GRPB  3820
      CALL  SCERRV (KX,KY)                                            GRPB  3830
       IX2 = NXV(YO4)                                                 GRPB  3840
       IY2 = NYV(ZO4)                                                 GRPB  3850
      CALL  SCERRV (KX1,KY1)                                          GRPB  3860
      KKXY = KX+KY+KX1+KY1                                            GRPB  3870
      IF (KKXY.NE.0) GO TO 561                                        GRPB  3880
      IF (NXO.GT.0.0) CALL LINEV (IX1,IY1,IX2,IY2)                    GRPB  3890
      IF (NXO.LE.0.0) CALL DOTLNV(IX1,IY1,IX2,IY2)                    GRPB  3900
C                                                                     GRPB  3910
  561 IF (ICS.EQ.0 .OR. ICS.EQ.2) GO TO 570                           GRPB  3920
       GO TO 571                                                      GRPB  3930
  570  IX1 = NXV(YO1)                                                 GRPB  3940
       IY1 = NYV(ZO1)                                                 GRPB  3950
```

DECK GRPB

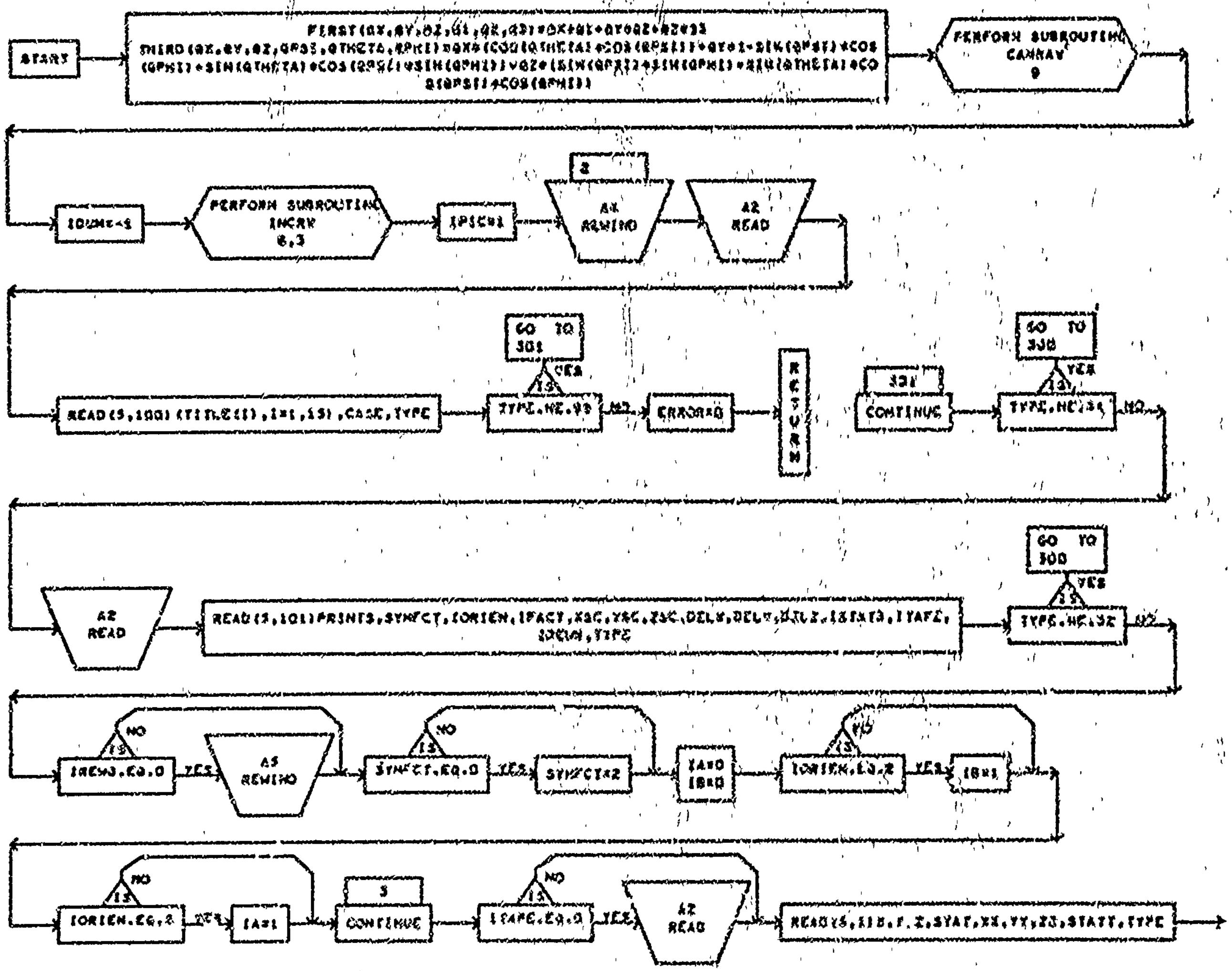
```
      CALL SCERRV (KX,KY)                                                GRPB  3960
       IX2 = NXV(Y04)                                                    GRPB  3970
       IY2 = NYV(Z04)                                                    GRPB  3980
      CALL SCERRV (KX1,KY1)                                              GRPB  3990
      KKXY = KX+KY+KX1+KY1                                               GRPB  4000
      IF (KKXY.NE.0) GO TO 571                                           GRPB  4010
      IF (NXO.GT.0.0) CALL LINEV (IX1,IY1,IX2,IY2)                       GRPB  4020
      IF (NXO.LE.0.0) CALL DOTLNV(IX1,IY1,IX2,IY2)                       GRPB  4030
C                                                                        GRPB  4040
  571 IF (IREFL .EQ. 0 .OR. IRFLG .EQ. 3) GO TO 2000                     GRPB  4050
      IF (IREFL .EQ. 2 .AND. IRFLG .EQ. 1) GO TO 600                     GRPB  4060
      IF (IREFL .EQ. 2 .AND. IRFLG .EQ. 2) GO TO 602                     GRPB  4070
C                                                                        GRPB  4080
C     REFLECT QUADRANT I ELEMENTS TO QUADRANT II                         GRPB  4090
      DO 580 II = 1,4                                                    GRPB  4100
  580  YIN(II) = -YIN(II)                                                GRPB  4110
       NY = -NY                                                          GRPB  4120
       GO TO 604                                                         GRPB  4130
C                                                                        GRPB  4140
C     REFLECT QUADRANT II ELEMENTS TO QUADRANT IV                        GRPB  4150
  600 DO 601 II = 1,4                                                    GRPB  4160
       YIN(II) = -YIN(II)                                                GRPB  4170
  601  ZIN(II) = -ZIN(II)                                                GRPB  4180
       NY = -NY                                                          GRPB  4190
       NZ = -NZ                                                          GRPB  4200
       GO TO 604                                                         GRPB  4210
C                                                                        GRPB  4220
C     REFLECT QUADRANT IV ELEMENTS TO QUADRANT III                       GRPB  4230
  602 DO 603 II = 1,4                                                    GRPB  4240
  603  YIN(II) = -YIN(II)                                                GRPB  4250
       NY = -NY                                                          GRPB  4260
C                                                                        GRPB  4270
C                                                                        GRPB  4280
  604 IRFLG = IRFLG + 1                                                  GRPB  4290
      IF (IREFL .EQ. 1) IRFLG = 3                                        GRPB  4300
      GO TO 471                                                          GRPB  4310
```

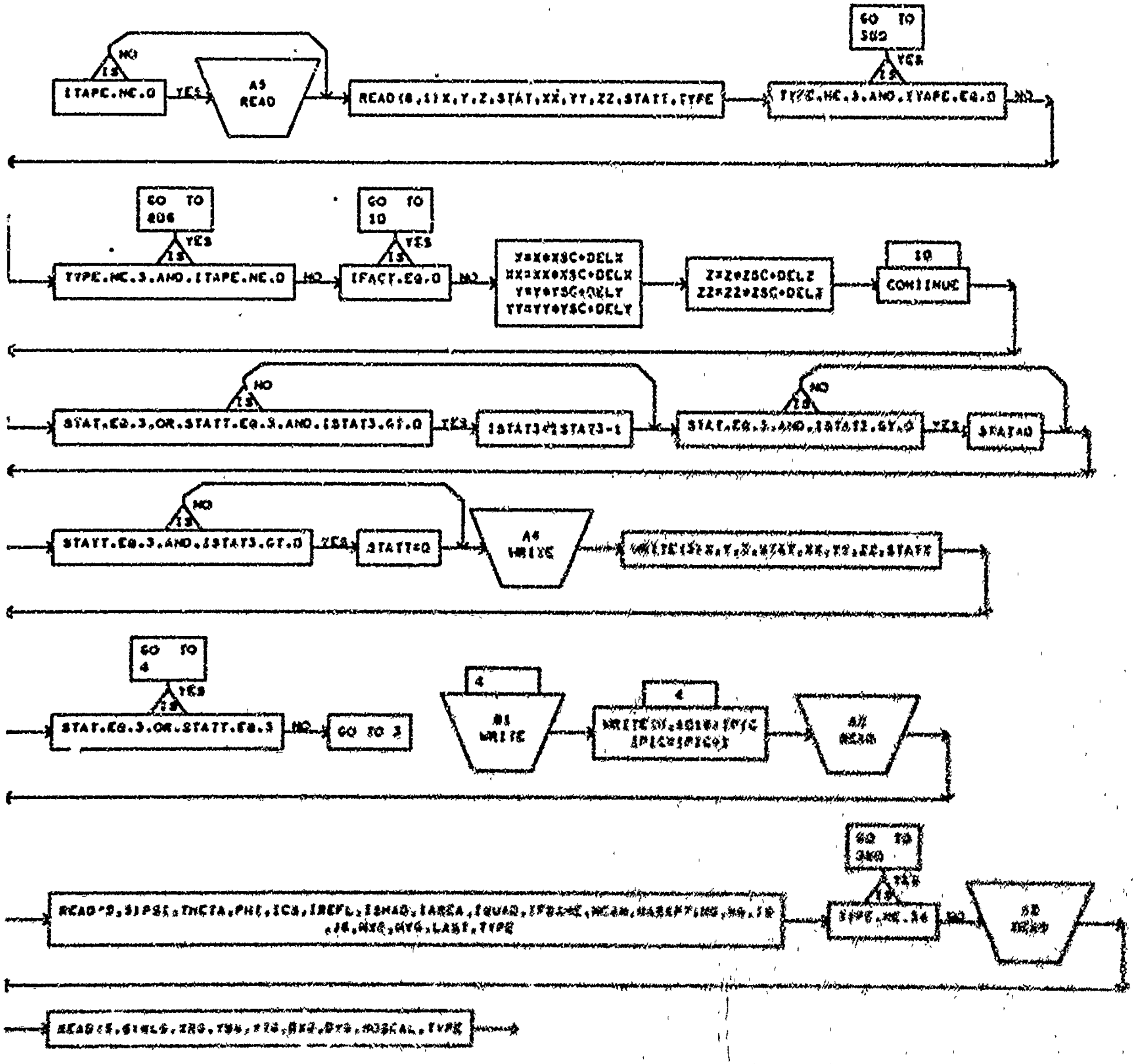
```
DECK GRPB
C
C
 2000 CONTINUE
 2001 IF (STAT .LT. 2) GO TO 480
       NPRT = NPRT + 1
      WRITE (6,472) AREAT,L,VOL
      NN = NN - 1
      N = - 1
       IF (IAREA .EQ. 0) GO TO 475
       CALL SCSETV (3)
       WRITE (16,472) AREAT,L
 472   FORMAT( 1H ,25X31HTOTAL AREA OF INPUT ELEMENTS   = F14.4,
     1       6X26HTOTAL NUMBER OF ELEMENTS = I5/1H ,23X,
     2 33H TOTAL VOLUME OF INPUT ELEMENTS =F12.3)
 475  IF (IFRAME .EQ. 2) IFADV = 1
 480  IF (IFRAME .EQ. 1) IFADV = 1
 485  IF (IFADV .EQ. 1) CALL FRAMEV (0)
C
C
C  TEST FOR END OF CASE
 2020 IF (STAT .NE. 3) GO TO 80
      IF (LAST .EQ. 1) GO TO 2
      PRINTS=0
      GO TO 4
C
C
C  ERROR CHECK ON READING CARDS
 300  WRITE (6,4003)
C
 4003 FORMAT (1H0,47H*****YOU HAVE MADE AN ERROR EITHER IN CARD TYPE
     1 49H INDICATION OR CARD ORDER - CHECK YOUR CARDS*****  )
      READ (5,810) (CARD(II),II=1,20)
 810  FORMAT (20A4)
      WRITE (6,805) (CARD(II),II=1,20)
 805  FORMAT (1H0,45H THE CARD LOCATED JUST BEFORE THE CARD LISTED
     1 18H BELOW IS IN ERROR,/1H ,10X,20A4)
```

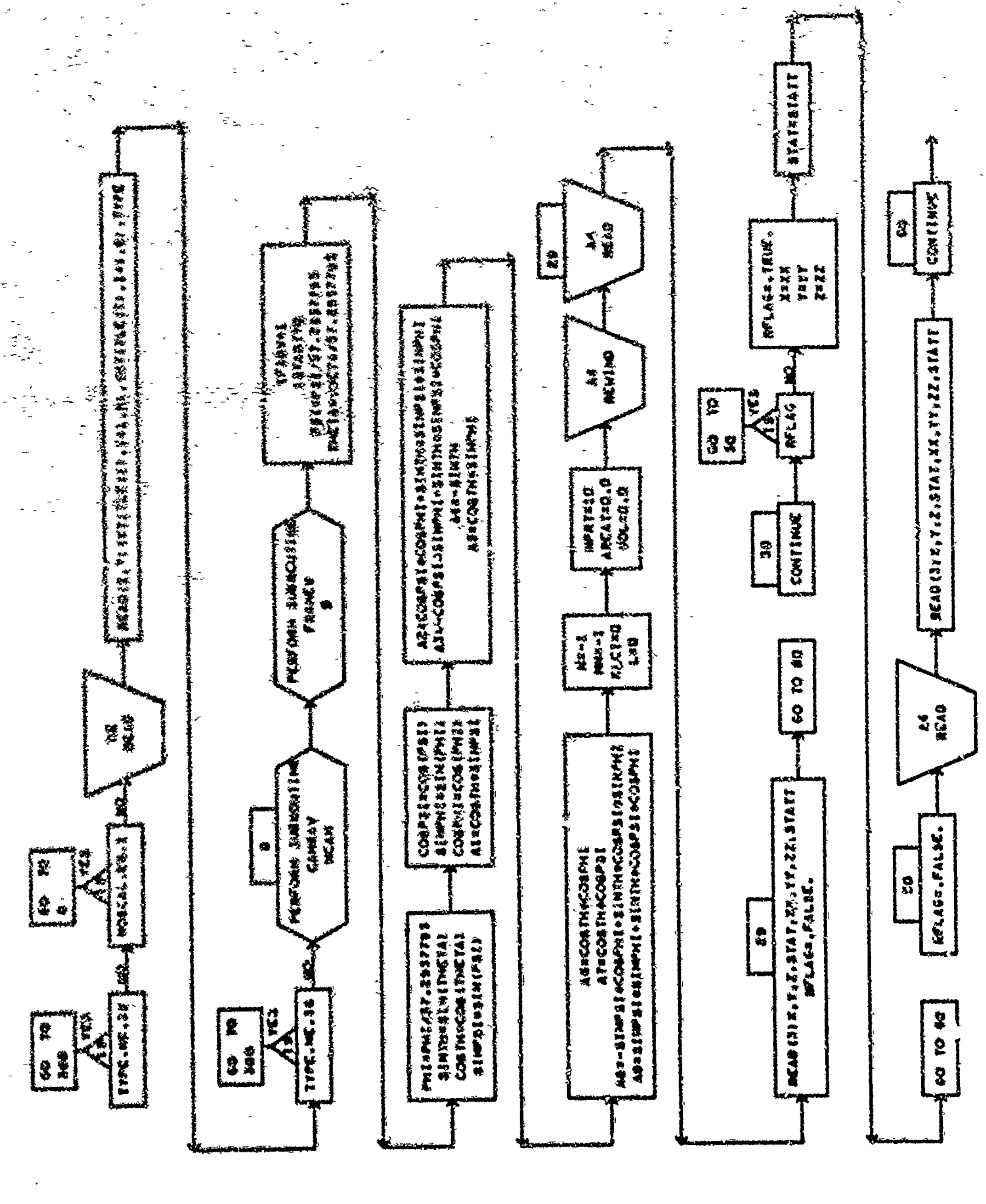
DECK GRPB

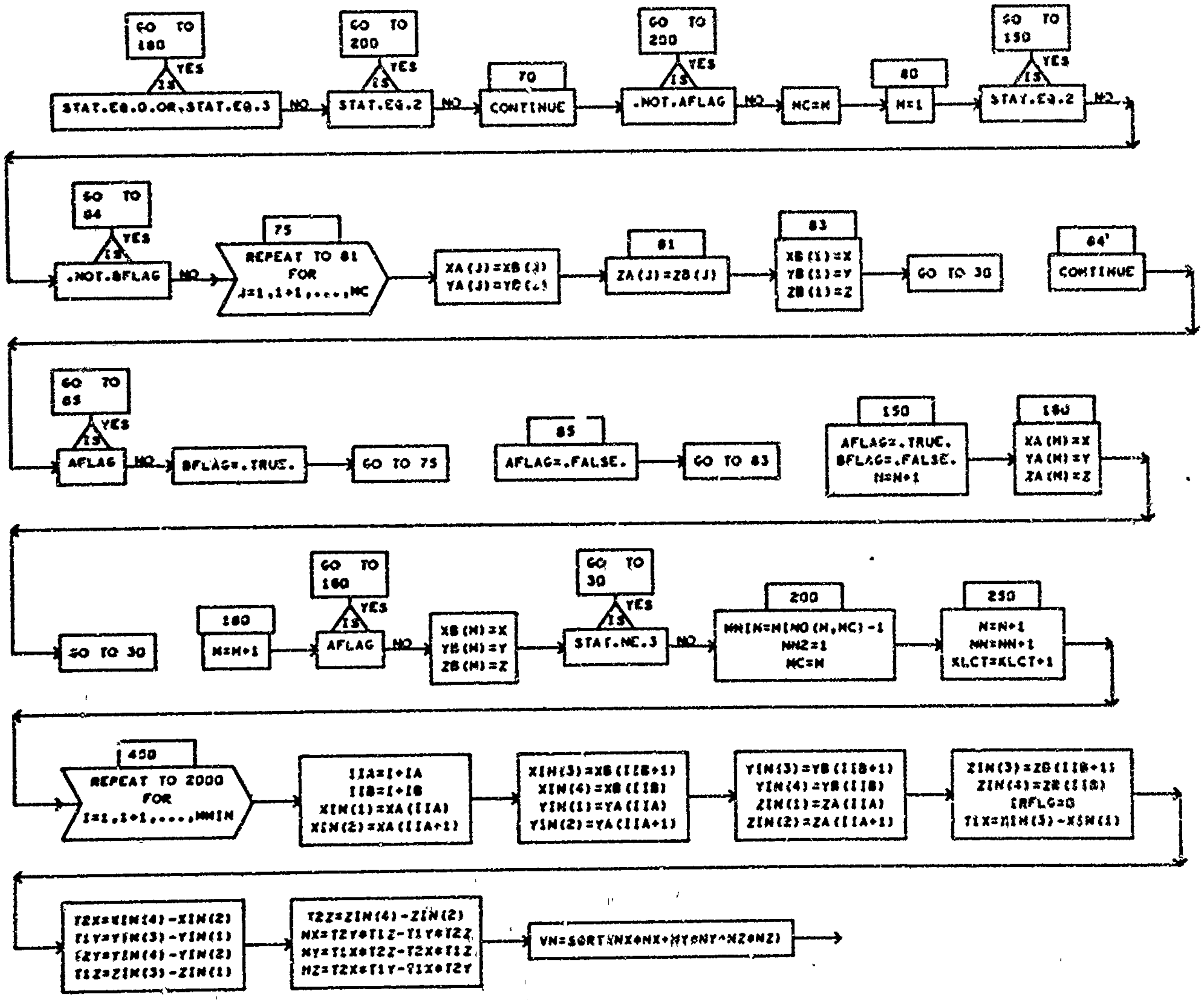
```
      GO TO 807                                                         GRPB  4680
  806 BACKSPACE 8                                                       GRPB  4690
      READ (8,810) (CARD(II),II=1,20)                                   GRPB  4700
      WRITE (6,808) (CARD(II),II=1,20)                                  GRPB  4710
  8C8 FORMAT (1H0,46H***THE FOLLOWING CARD ON TAPE 8 IS IN ERROR***,/   GRPB  4720
     1 1H ,10X,20A4)                                                    GRPB  4730
  807 CALL FRAMEV (0)                                                   GRPB  4740
      CALL SCSETV (4)                                                   GRPB  4750
      WRITE (16,4004)                                                   GRPB  4760
 4004 FORMAT (1H ,45HNO MORE SC-4020 DATA IS PLOTTED BECAUSE OF AN      GRPB  4770
     126H ERROR IN YOUR INPUT CARDS )                                   GRPB  4780
      ERROR = 1                                                         GRPB  4790
      RETURN                                                            GRPB  4800
C                                                                       GRPB  4810
 4002 FORMAT (1H0,28H  INPUT SURFACE ELEMENT DATA/1H0,6X1HN3X1HM7X1HX,  GRPB  4820
     1 3(13X,1HX),11X2HNX9X5HXCENT9X4HAREA8X1HL ,/1H ,5X, 4(13X,1HY),   GRPB  4830
     2 11X2HNY9X5HYCENT ,7X,7HDELTA V,/1H ,5X,4(13X,1HZ),11X2HNZ,       GRPB  4840
     3 9X,5HZCENT ,7X,6HVOLUME,/1H  )                                   GRPB  4850
 4005 FORMAT (1H0,7X, I4, 1P4E14.5,0PF10.6,1P2E14.5,I6,2(/12X,4E14.5,   GRPB  4860
     1 0PF10.6,1P2E14.5)  )                                             GRPB  4870
 4010 FORMAT (1H0,3X, 2I4,1P4E14.5,0PF10.6,1P2E14.5,I6,2(/12X,4E14.5,   GRPB  4880
     1 0PF10.6,1P2E14.5)  )                                             GRPB  4890
C                                                                       GRPB  4900
      END                                                               GRPB  4910
```

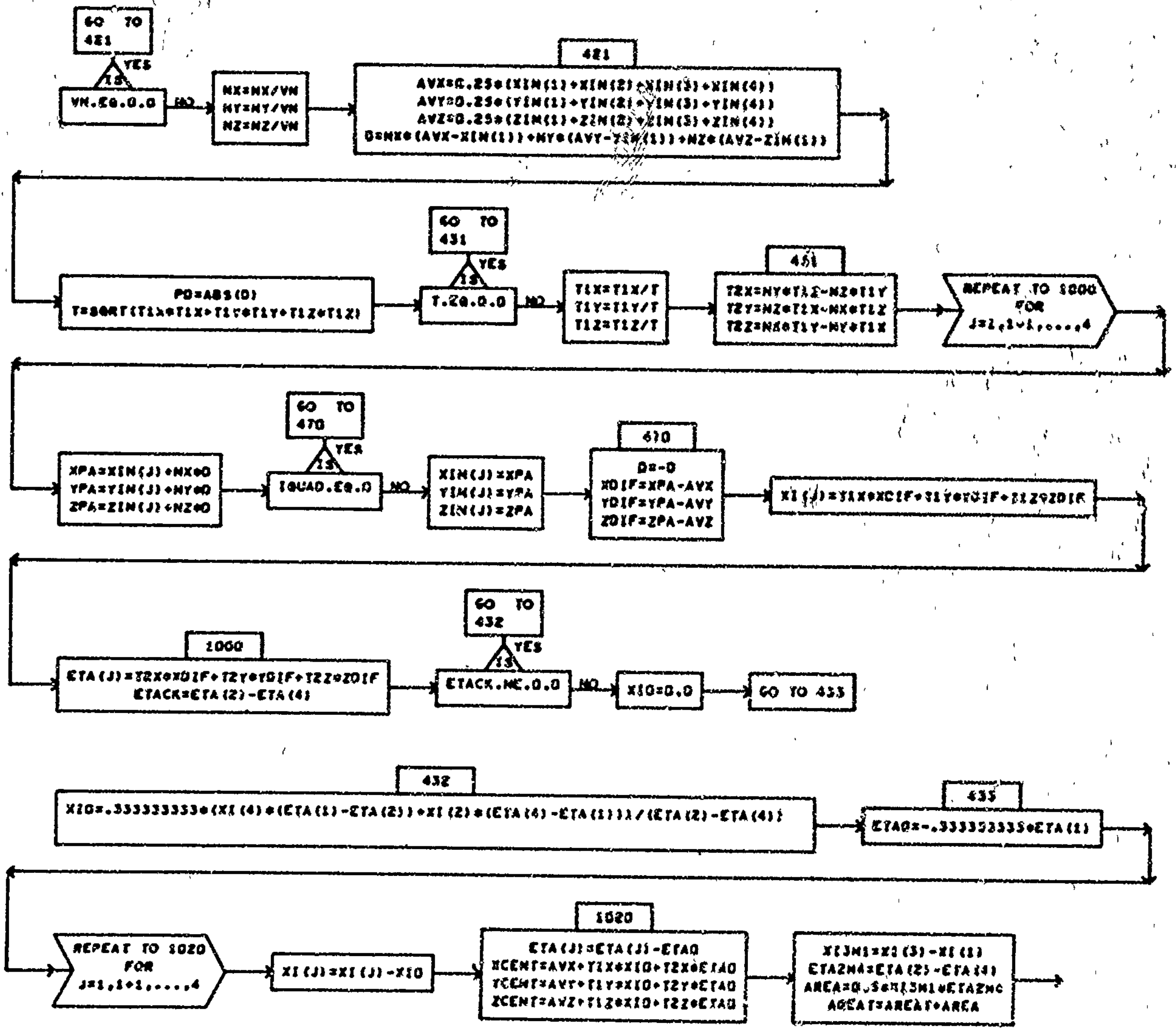
SUBROUTINE PICTUR

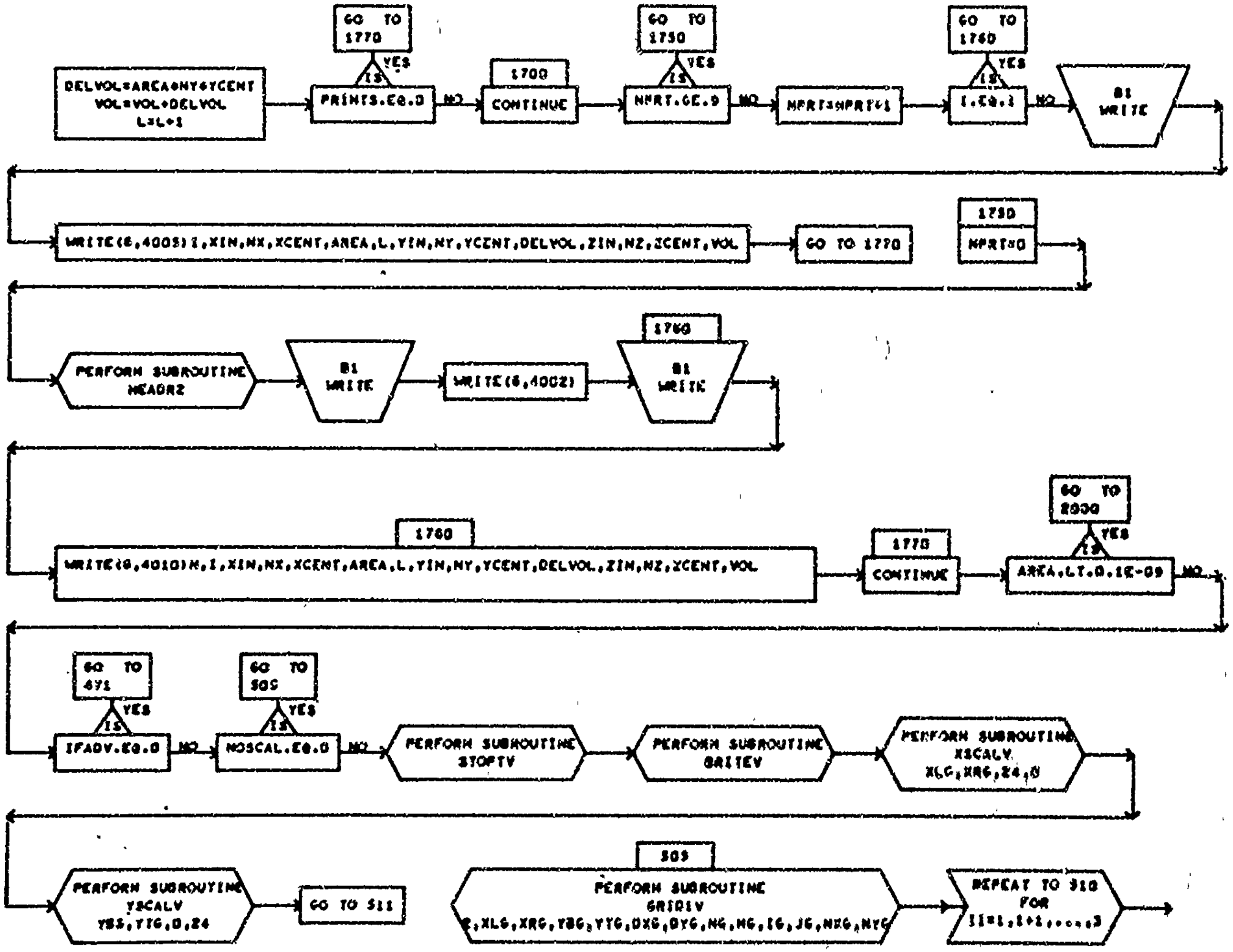


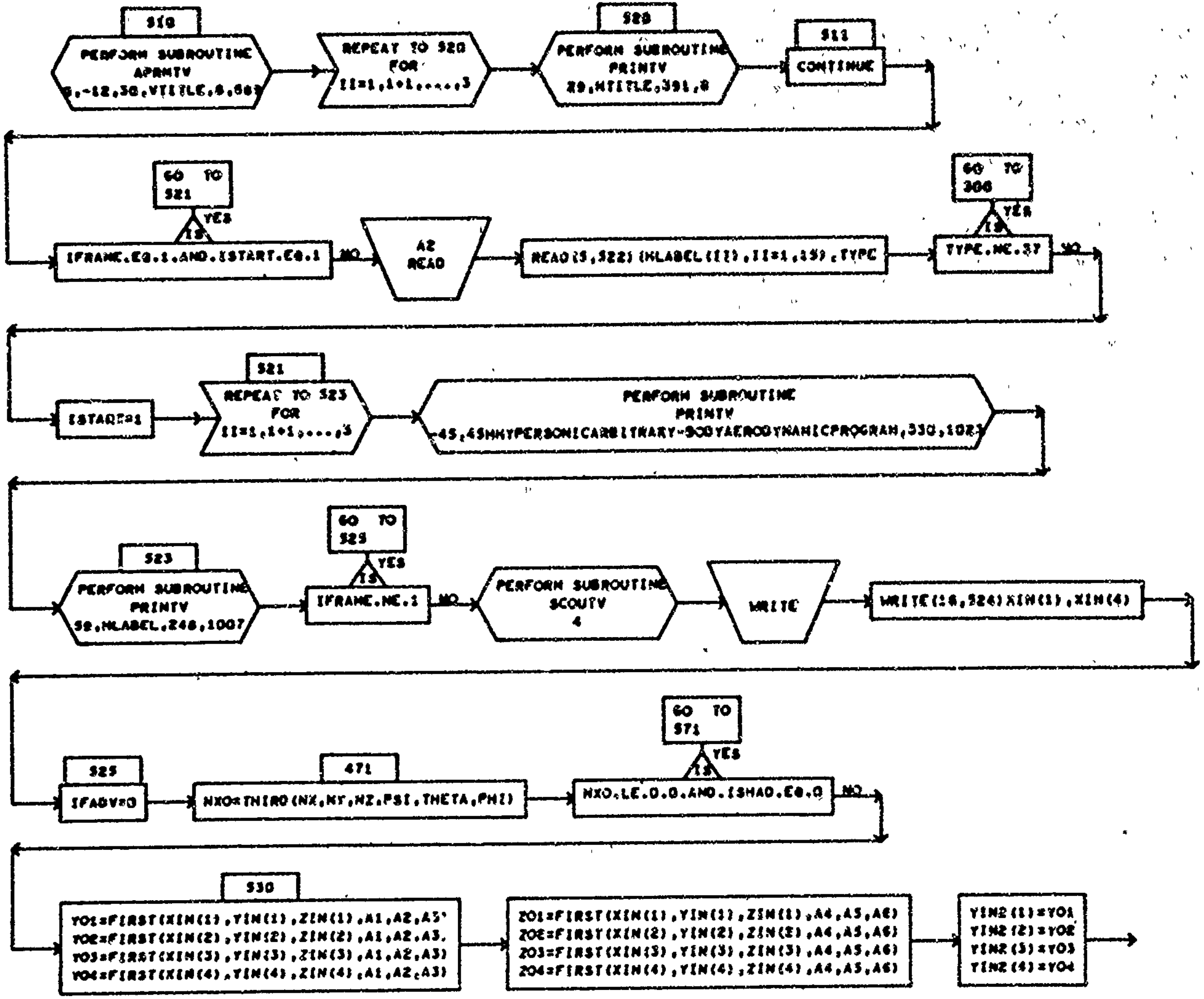

ITAPE.NE.0
IS
NO
YES
A5
READ
READ(8,1)X,Y,Z,STAT,XX,YY,ZZ,STATT,TYPE
TYPE.NE.3.AND.ITAPE.EQ.0
GO TO 500
GO TO 206
TYPE.NE.3.AND.ITAPE.NE.0
GO TO 10
IFACT.EQ.0
X=X*XSC+DELX
XX=XX*XSC+DELX
Y=Y*YSC+DELY
YY=YY*YSC+DELY
Z=Z*ZSC+DELZ
ZZ=ZZ*ZSC+DELZ
10
CONTINUE
STAT.EQ.3.OR.STATT.EQ.3.AND.ISTAT3.GT.0
ISTAT3=ISTAT3-1
STAT.EQ.3.AND.ISTAT2.GT.0
STAT=0
STATT.EQ.3.AND.ISTAT3.GT.0
STATT=0
A6
WRITE
WRITE(3)X,Y,Z,STAT,XX,YY,ZZ,STATT
GO TO 4
STAT.EQ.3.OR.STATT.EQ.3
GO TO 3
4
B1
WRITE
4
READ
GO TO 3
TYPE.NE.14
B2
READ

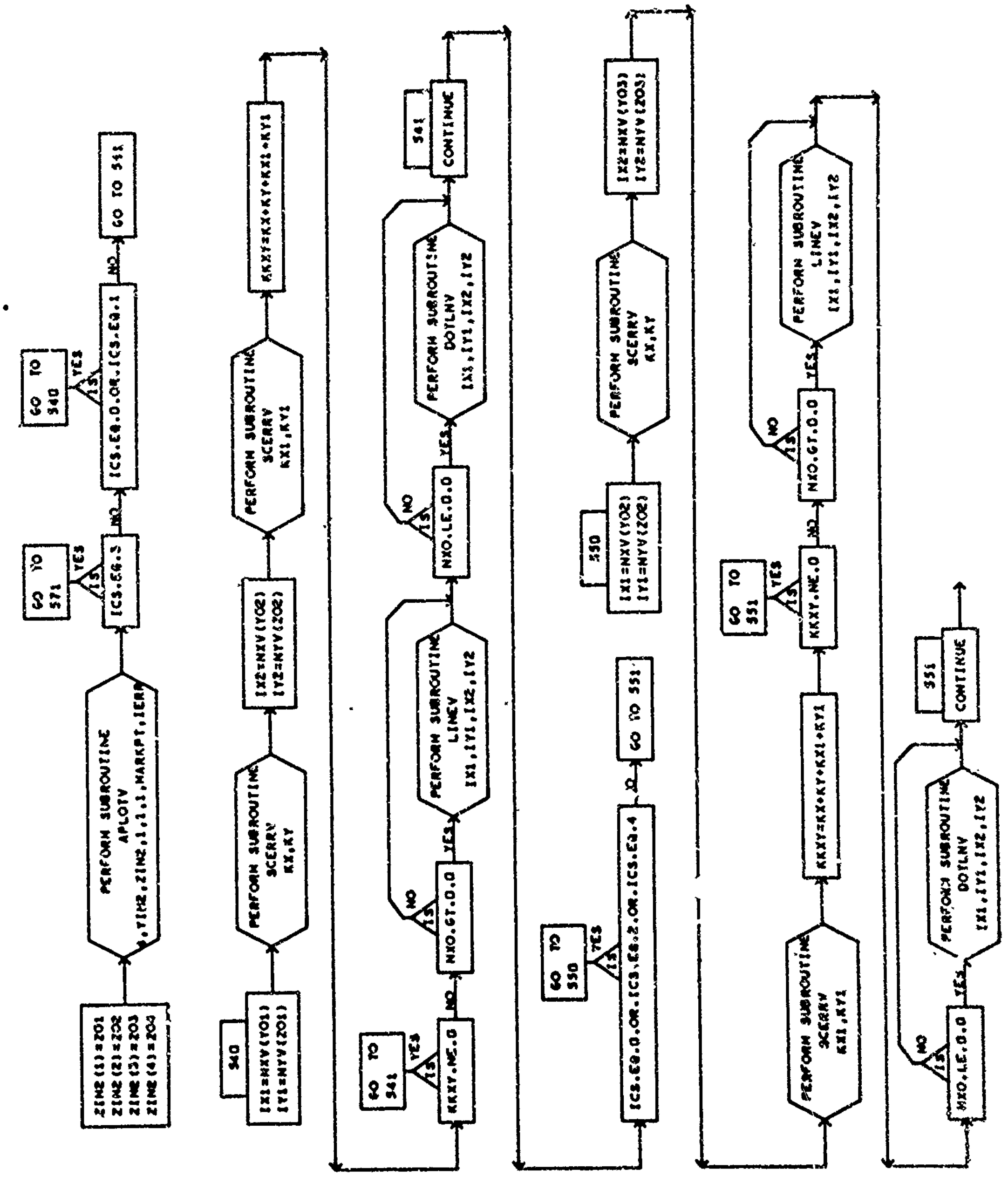

YES
NO
PERFORM SUBROUTINE CAMRAY SCAN
PERFORM SUBROUTINE FRAMEV
REWIND
READ
CONTINUE
GO TO 60
RFLAG=.TRUE.
X=XX
Y=YY
Z=ZZ
STAT=STATT
RFLAG=.FALSE.
READ(3)X,Y,Z,STAT,XX,YY,ZZ,STATT

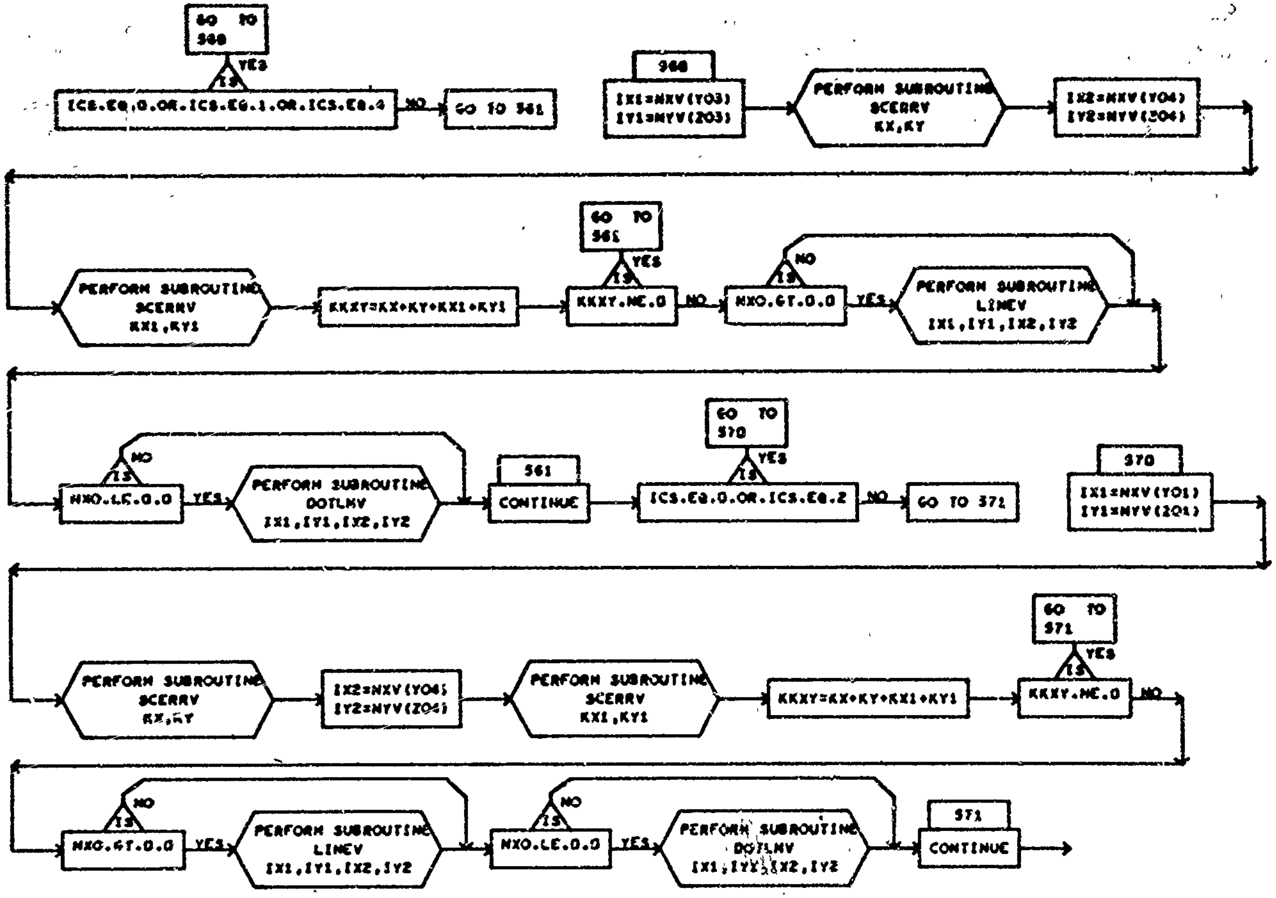

GO TO 180
YES
IS
STAT.EQ.0.OR.STAT.EQ.3
NO
GO TO 200
YES
IS
STAT.EQ.2
NO
70
CONTINUE
GO TO 200
YES
IS
.NOT.AFLAG
NO
NC=N
80
N=1
GO TO 150
YES
IS
STAT.EQ.2
NO
GO TO 84
YES
IS
.NOT.BFLAG
NO
75
REPEAT TO 81 FOR J=1,1+1,....,NC
XA(J)=XB(J)
YA(J)=YB(J)
81
ZA(J)=ZB(J)
83
XB(1)=X
YB(1)=Y
ZB(1)=Z
GO TO 30
84'
CONTINUE
GO TO 85
YES
IS
AFLAG
NO
BFLAG=.TRUE.
GO TO 75
85
AFLAG=.FALSE.
GO TO 83
150
AFLAG=.TRUE.
BFLAG=.FALSE.
N=N+1
180
XA(N)=X
YA(N)=Y
ZA(N)=Z
GO TO 30
180
N=N+1
GO TO 160
YES
IS
AFLAG
NO
XB(N)=X
YB(N)=Y
ZB(N)=Z
GO TO 30
YES
IS
STAT.NE.3
NO
200
NNIN=MINO(N,NC)-1
NN2=1
NC=N
250
N=N+1
NN=NN+1
KLCT=KLCT+1
450
REPEAT TO 2000 FOR I=1,1+1,....,NNIN
IIA=I+IA
IIB=I+IB
XIN(1)=XA(IIA)
XIN(2)=XA(IIA+1)
XIN(3)=XB(IIB+1)
XIN(4)=XB(IIB)
YIN(1)=YA(IIA)
YIN(2)=YA(IIA+1)
YIN(3)=YB(IIB+1)
YIN(4)=YB(IIB)
ZIN(1)=ZA(IIA)
ZIN(2)=ZA(IIA+1)
ZIN(3)=ZB(IIB+1)
ZIN(4)=ZB(IIB)
IRFLG=0
T1X=XIN(3)-XIN(1)
T2X=XIN(4)-XIN(2)
T1Y=YIN(3)-YIN(1)
T2Y=YIN(4)-YIN(2)
T1Z=ZIN(3)-ZIN(1)
T2Z=ZIN(4)-ZIN(2)
NX=T2Y*T1Z-T1Y*T2Z
NY=T1X*T2Z-T2X*T1Z
NZ=T2X*T1Y-T1X*T2Y
VN=SQRT(NX*NX+NY*NY+NZ*NZ)

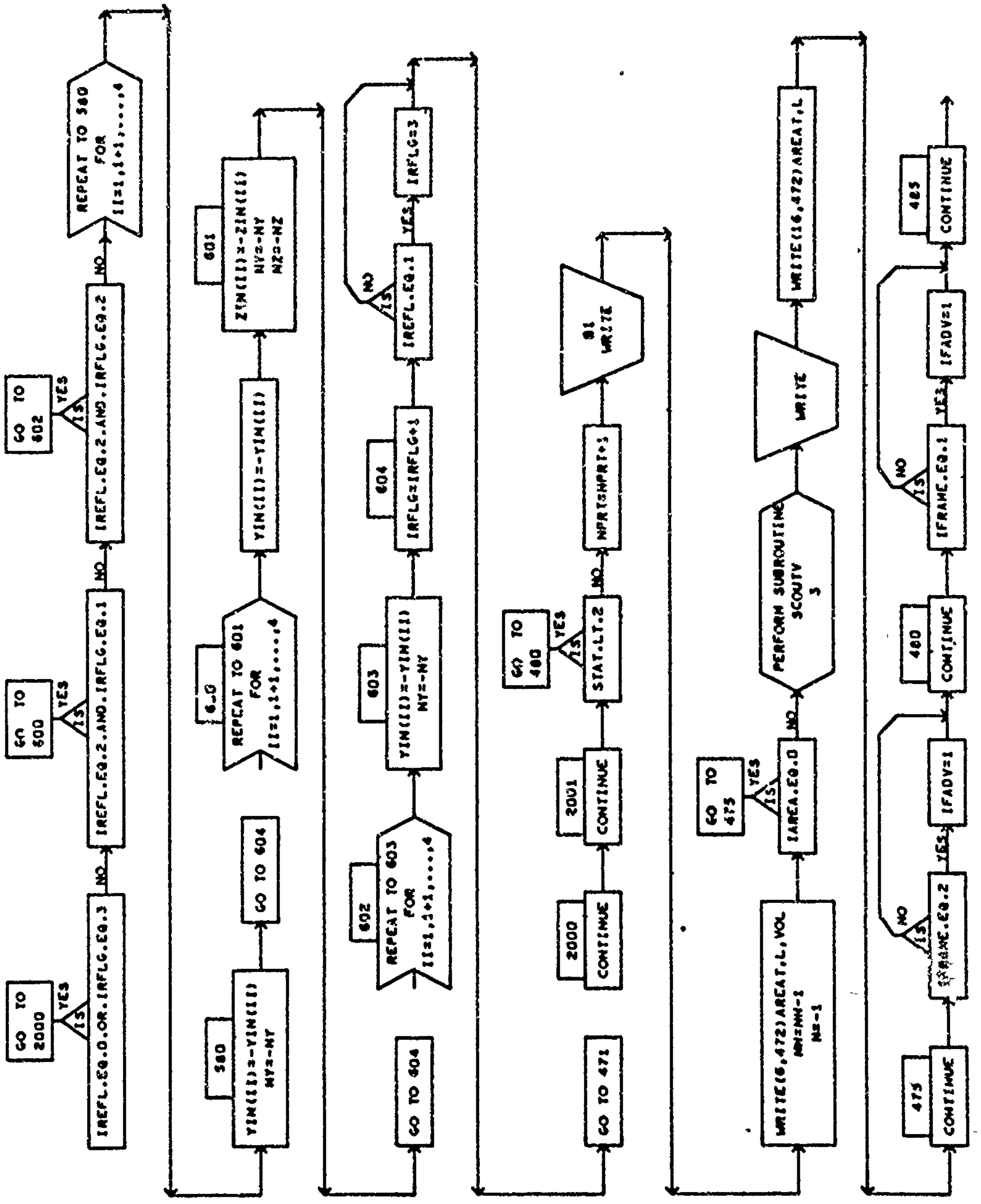

GO TO 421
YES
IS
VN.EQ.0.0
NO
NX=NX/VN
NY=NY/VN
NZ=NZ/VN
421
AVX=0.25*(XIN(1)+XIN(2)+XIN(3)+XIN(4))
AVY=0.25*(YIN(1)+YIN(2)+YIN(3)+YIN(4))
AVZ=0.25*(ZIN(1)+ZIN(2)+ZIN(3)+ZIN(4))
D=NX*(AVX-XIN(1))+NY*(AVY-YIN(1))+NZ*(AVZ-ZIN(1))
PD=ABS(D)
T=SQRT(T1X*T1X+T1Y*T1Y+T1Z*T1Z)
GO TO 431
YES
IS
T.EQ.0.0
NO
T1X=T1X/T
T1Y=T1Y/T
T1Z=T1Z/T
431
T2X=NY*T1Z-NZ*T1Y
T2Y=NZ*T1X-NX*T1Z
T2Z=NX*T1Y-NY*T1X
REPEAT TO 1000 FOR J=1,1+1,....,4
XPA=XIN(J)+NX*D
YPA=YIN(J)+NY*D
ZPA=ZIN(J)+NZ*D
GO TO 470
YES
IS
IQUAD.EQ.0
NO
XIN(J)=XPA
YIN(J)=YPA
ZIN(J)=ZPA
410
D=-D
XDIF=XPA-AVX
YDIF=YPA-AVY
ZDIF=ZPA-AVZ
XI(J)=T1X*XDIF+T1Y*YDIF+T1Z*ZDIF
1000
ETA(J)=T2X*XDIF+T2Y*YDIF+T2Z*ZDIF
ETACK=ETA(2)-ETA(4)
GO TO 432
YES
IS
ETACK.NE.0.0
NO
XI0=0.0
GO TO 433
432
XI0=.333333333*(XI(4)*(ETA(1)-ETA(2))+XI(2)*(ETA(4)-ETA(1)))/(ETA(2)-ETA(4))
433
ETA0=-.333333333*ETA(1)
REPEAT TO 1020 FOR J=1,1+1,....,4
XI(J)=XI(J)-XI0
1020
ETA(J)=ETA(J)-ETA0
XCENT=AVX+T1X*XI0+T2X*ETA0
YCENT=AVY+T1Y*XI0+T2Y*ETA0
ZCENT=AVZ+T1Z*XI0+T2Z*ETA0
XI3M1=XI(3)-XI(1)
ETA2M4=ETA(2)-ETA(4)
AREA=0.5*XI3M1*ETA2M4
AREAT=AREAT+AREA

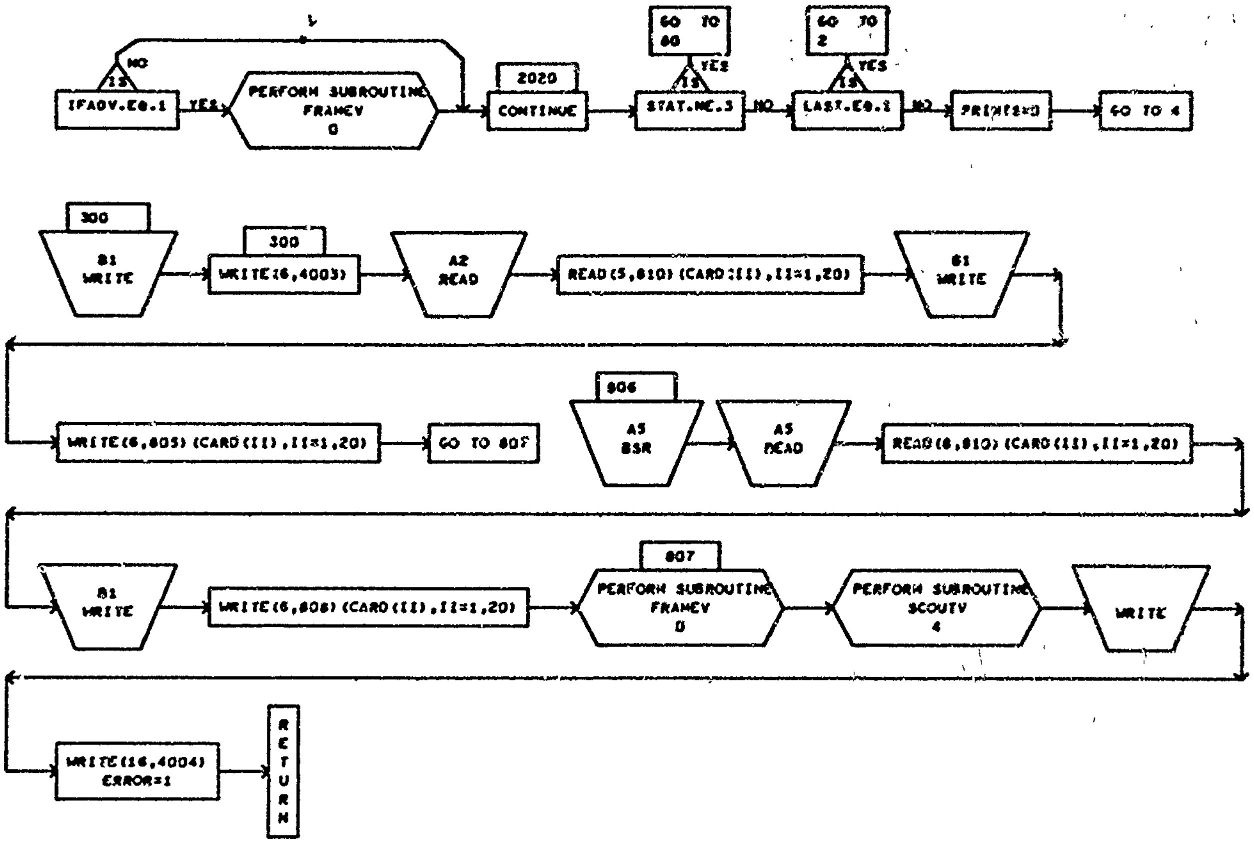

DELVOL=AREA*NY*YCENT
VOL=VOL+DELVOL
L=L+1
GO TO 1770
YES
IS
PRINTS.EQ.0
NO
1700
CONTINUE
GO TO 1750
YES
IS
NPRT.GE.9
NO
NPRT=NPRT+1
GO TO 1760
YES
IS
I.EQ.1
NO
B1
WRITE
WRITE(6,4005)I,XIN,NX,XCENT,AREA,L,YIN,NY,YCENT,DELVOL,ZIN,NZ,ZCENT,VOL
GO TO 1770
1750
NPRT=0
PERFORM SUBROUTINE
HEADR2
B1
WRITE
WRITE(6,4002)
1760
B1
WRITE
1760
WRITE(6,4010)M,I,XIN,NX,XCENT,AREA,L,YIN,NY,YCENT,DELVOL,ZIN,NZ,ZCENT,VOL
1770
CONTINUE
GO TO 2000
YES
IS
AREA.LT.0.1E-09
NO
GO TO 471
YES
IS
IFADV.EQ.0
NO
GO TO 505
YES
IS
NOSCAL.EQ.0
NO
PERFORM SUBROUTINE
STOPTV
PERFORM SUBROUTINE
GRITEV
PERFORM SUBROUTINE
XSCALV
XLG,XRG,24,0
PERFORM SUBROUTINE
YSCALV
YBS,YTG,0,24
GO TO 511
505
PERFORM SUBROUTINE
GRIDIV
2,XLG,XRG,YBG,YTG,DXG,DYG,NG,NG,IG,JG,NXG,NYG
REPEAT TO 310
FOR
II=1,I+1,....,3


519
PERFORM SUBROUTINE
APRNTV
5,-12,30,VTITLE,6,66)
REPEAT TO 520
FOR
II=1,1+1,....,3
520
PERFORM SUBROUTINE
PRINTV
29,HTITLE,391,8
511
CONTINUE
GO TO
521
YES
IS
IFRAME.EQ.1.AND.ISTART.EQ.1
NO
A2
READ
READ(5,522)(HLABEL(II),II=1,15),TYPE
GO TO
306
YES
IS
TYPE.NE.37
NO
ISTART=1
521
REPEAT TO 523
FOR
II=1,1+1,....,3
PERFORM SUBROUTINE
PRINTV
-45,45HHYPERSONICARBITRARY-BODYAERODYNAMICPROGRAM,330,102)
523
PERFORM SUBROUTINE
PRINTV
52,HLABEL,248,1007
GO TO
525
YES
IS
IFRAME.NE.1
NO
PERFORM SUBROUTINE
SCOUTV
4
WRITE
WRITE(16,524)XIN(1),XIN(4)
525
IFADV=0
471
NXO=THIRD(NX,NY,NZ,PSI,THETA,PHI)
GO TO
571
YES
IS
NXO.LE.0.0.AND.ISHAD.EQ.0
NO
530
YO1=FIRST(XIN(1),YIN(1),ZIN(1),A1,A2,A3'
YO2=FIRST(XIN(2),YIN(2),ZIN(2),A1,A2,A3.
YO3=FIRST(XIN(3),YIN(3),ZIN(3),A1,A2,A3)
YO4=FIRST(XIN(4),YIN(4),ZIN(4),A1,A2,A3)
ZO1=FIRST(XIN(1),YIN(1),ZIN(1),A4,A5,A6)
ZO2=FIRST(XIN(2),YIN(2),ZIN(2),A4,A5,A6)
ZO3=FIRST(XIN(3),YIN(3),ZIN(3),A4,A5,A6)
ZO4=FIRST(XIN(4),YIN(4),ZIN(4),A4,A5,A6)
YIN2(1)=YO1
YIN2(2)=YO2
YIN2(3)=YO3
YIN2(4)=YO4


ZINZ(1)=Z01
ZINZ(2)=Z02
ZINZ(3)=Z03
ZINZ(4)=Z04
PERFORM SUBROUTINE APLOTV
X,YINZ,ZINZ,1,1,1,MARKPT,IERR
ICS.EQ.3
IS
YES
GO TO 571
NO
ICS.EQ.0.OR.ICS.EQ.1
IS
YES
GO TO 540
NO
GO TO 511
540
IX1=NXV(Y01)
IY1=NYV(Z01)
PERFORM SUBROUTINE SCERRV KX,KY
IX2=NXV(Y02)
IY2=NYV(Z02)
PERFORM SUBROUTINE SCERRV KX1,KY1
KKXY=KX*KY+KX1*KY1
KKXY.NE.0
IS
YES
GO TO 541
NO
NXO.GT.0.0
IS
YES
NO
PERFORM SUBROUTINE LINEV IX1,IY1,IX2,IY2
NXO.LE.0.0
IS
YES
NO
PERFORM SUBROUTINE DOTLNV IX1,IY1,IX2,IY2
541
CONTINUE
ICS.EQ.0.OR.ICS.EQ.2.OR.ICS.EQ.4
IS
YES
GO TO 550
NO
GO TO 551
550
IX1=NXV(Y02)
IY1=NYV(Z02)
PERFORM SUBROUTINE SCERRV KX,KY
IX2=NXV(Y03)
IY2=NYV(Z03)
PERFORM SUBROUTINE SCERRV KX1,KY1
KKXY=KX*KY+KX1*KY1
KKXY.NE.0
IS
YES
GO TO 551
NO
NXO.GT.0.0
IS
YES
NO
PERFORM SUBROUTINE LINEV IX1,IY1,IX2,IY2
NXO.LE.0.0
IS
YES
NO
PERFORM SUBROUTINE DOTLNV IX1,IY1,IX2,IY2
551
CONTINUE


GO TO 360
YES
IS
ICS.EQ.0.OR.ICS.EQ.1.OR.ICS.EQ.4
NO
GO TO 361
360
IX1=NXV(Y03)
IY1=NYV(Z03)
PERFORM SUBROUTINE SCERRV KX,KY
IX2=NXV(Y04)
IY2=NYV(Z04)
PERFORM SUBROUTINE SCERRV KX1,KY1
KKXY=KX+KY+KX1+KY1
GO TO 361
YES
IS
KKXY.NE.0
NO
NO
IS
NXO.GT.0.0
YES
PERFORM SUBROUTINE LINEV IX1,IY1,IX2,IY2
NO
IS
NXO.LE.0.0
YES
PERFORM SUBROUTINE DOTLNV IX1,IY1,IX2,IY2
361
CONTINUE
GO TO 370
YES
IS
ICS.EQ.0.OR.ICS.EQ.2
NO
GO TO 371
370
IX1=NXV(Y01)
IY1=NYV(Z01)
PERFORM SUBROUTINE SCERRV KX,KY
IX2=NXV(Y04)
IY2=NYV(Z04)
PERFORM SUBROUTINE SCERRV KX1,KY1
KKXY=KX+KY+KX1+KY1
GO TO 371
YES
IS
KKXY.NE.0
NO
NO
IS
NXO.GT.0.0
YES
PERFORM SUBROUTINE LINEV IX1,IY1,IX2,IY2
NO
IS
NXO.LE.0.0
YES
PERFORM SUBROUTINE DOTLNV IX1,IY1,IX2,IY2
371
CONTINUE


GO TO 2000
YES
IS
IREFL.EQ.0.OR.IRFLG.EQ.3
NO
GO TO 500
YES
IS
IREFL.EQ.2.AND.IRFLG.EQ.1
NO
GO TO 602
YES
IS
IREFL.EQ.2.AND.IRFLG.EQ.2
NO
REPEAT TO 580 FOR II=1,1+1,....,4
580
YIN(II)=-YIN(II) NY=-NY
GO TO 604
600
REPEAT TO 601 FOR II=1,1+1,....,4
YIN(II)=-YIN(II)
601
ZIN(II)=-ZIN(II) NY=-NY NZ=-NZ
GO TO 604
602
REPEAT TO 603 FOR II=1,1+1,....,4
603
YIN(II)=-YIN(II) NY=-NY
604
IRFLG=IRFLG+1
IREFL.EQ.1
IS
NO
YES
IRFLG=3
GO TO 471
2000
CONTINUE
2001
CONTINUE
STAT.LT.2
IS
YES
GO TO 480
NO
NPRTS=NPRTS+1
81 WRITE
WRITE(6,472)AREAT,L,VOL NN=NN-1 NX=-1
IAREA.EQ.0
IS
YES
GO TO 475
NO
PERFORM SUBROUTINE SCOUTV 3
WRITE
WRITE(16,472)AREAT,L
475
CONTINUE
IFRAME.EQ.2
IS
NO
YES
IFADV=1
480
CONTINUE
IFRAME.EQ.1
IS
NO
YES
IFADV=1
485
CONTINUE


IFADV.EQ.1
IS
NO
YES
PERFORM SUBROUTINE
FRAMEV
0
2020
CONTINUE
STAT.NE.3
IS
YES
GO TO
80
NO
LAST.EQ.1
IS
YES
GO TO
2
NO
PRINT=0
GO TO 4
300
B1
WRITE
300
WRITE(6,4003)
A2
READ
READ(5,810) (CARD(II),II=1,20)
B1
WRITE
WRITE(6,805) (CARD(II),II=1,20)
GO TO 807
806
A5
BSR
A5
READ
READ(8,810) (CARD(II),II=1,20)
B1
WRITE
WRITE(6,806) (CARD(II),II=1,20)
807
PERFORM SUBROUTINE
FRAMEV
0
PERFORM SUBROUTINE
SCOUTV
4
WRITE
WRITE(16,4004)
ERROR=1
RETURN

```
SYMBOLS USED IN SUBROUTINE PICTUR

AFLAG    L  U  IMPUT DATA READ CONTROL FLAG                              PICTUR
AREA     R  U  ELEMENT AREA                                              PICTUR
AREAT    R  U  TOTAL AREA                                                PICTUR
AVX      R  U  AVERAGE POINT COORDINATE-X                                PICTUR
AVY      R  U  AVERAGE POINT COORDINATE-Y                                PICTUR
AVZ      R  U  AVERAGE POINT COORDINATE-Z                                PICTUR
A1       R  U  ROTATION MATRIX CONSTANT                                  PICTUR
A2       R  U  ROTATION MATRIX CONSTANT                                  PICTUR
A3       R  U  ROTATION MATRIX CONSTANT                                  PICTUR
A4       R  U  ROTATION MATRIX CONSTANT                                  PICTUR
A5       R  U  ROTATION MATRIX CONSTANT                                  PICTUR
A6       R  U  ROTATION MATRIX CONSTANT                                  PICTUR
A7       R  U  ROTATION MATRIX CONSTANT                                  PICTUR
A8       R  U  ROTATION MATRIX CONSTANT                                  PICTUR
A9       R  U  ROTATION MATRIX CONSTANT                                  PICTUR
BFLAG    L  U  IMPUT DATA READ CONTROL FLAG                              PICTUR
CARD     R  D  ARRAY FOR READING IN 80 COLUMN CARD                       PICTUR
CASE     I  C  CASE NUMBER                                               PICTUR
COSPHI   R  U  COSINE OF PHI                                             PICTUR
COSPSI   R  U  COSINE OF PSI                                             PICTUR
COSTH    R  U  COSINE OF THETA                                           PICTUR
D        R  U  CORNER POINT PROJECTION DISTANCE                          PICTUR
DELVOL   R  U  ELEMENT VOLUME CONTRIBUTION                               PICTUR
DELX     R  U  GEOMETRY DATA X-INCREMENT                                 PICTUR
DELY     R  U  GEOMETRY DATA Y-INCREMENT                                 PICTUR
DELZ     R  U  GEOMETRY DATA Z-INCREMENT                                 PICTUR
DXG      R  U  GRID DELTA-X INCREMENT                                    PICTUR
DYG      R  U  GRID DELTA-Y INCREMENT                                    PICTUR
ERROR    I  C  ERROR FLAG                                                PICTUR
ETA      R  D  COORDINATE IN ELEMENT COORDINATE SYSTEM                   PICTUR
ETACK    R  U  ETA CHECK PARAMETER                                       PICTUR
ETAO     R  U  COORDINATE IN ELEMENT COORDINATE SYSTEM                   PICTUR
ETA2M4   R  U  CONSTANT IN AREA EQUATION                                 PICTUR
HLABEL   R  D  HORIZONTAL LABEL                                          PICTUR
HTITLE   R  D  VERTICAL LABEL                                            PICTUR
I        I  U  ELEMENT NUMBER IN COLUMN                                  PICTUR
```

```
SYMBOLS USED IN SUBROUTINE PICTUR

IA        I  U  FLAG TO CONTROL SHIFTING OF COLUMN DATA POINTS FOR IORIEN=3     PICTUR
IAREA     I  U  SURFACE AREA PRINT FLAG                                          PICTUR
IB        I  U  FLAG TO CONTROL SHIFTING OF COLUMN DATA POINTS FOR IORIEN=2     PICTUR
ICS       I  U  POINT CORRECT FLAG                                               PICTUR
IDUM      I  U  DUMMY VARIABLE                                                   PICTUR
IERR      I  U  ERROR FLAG                                                       PICTUR
IFACT     I  U  SCALE FACTOR FLAG                                                PICTUR
IFADV     I  U  FRAME FLAG                                                       PICTUR
IFRAME    I  U  FRAME ADVANCE FLAG                                               PICTUR
IG        I  U  VERTICAL GRID LINE LABEL CONTROL FLAG                            PICTUR
IIA       I  U  DATA SHIFTING CONTROL PARAMETER (IORIEN=3)                       PICTUR
IIB       I  U  DATA SHIFTING CONTROL PARAMETER (IORIEN=2)                       PICTUR
IORIEN    I  U  ELEMENT ORIENTATION (NOT USED)                                   PICTUR
IPIC      I  U  FRAME NUMBER                                                     PICTUR
IQUAD     I  U  QUADRILATERAL PLOT FLAG                                          PICTUR
IREFL     I  U  REFLECTION ELEMENTS CONTROL FLAG                                 PICTUR
IREW8     I  U  TAPE 8 REWIND FLAG                                               PICTUR
IRFLG     I  U  REFLECTION CONTROL FLAG                                          PICTUR
ISHAD     I  U  SHADOW ELEMENT FLAG                                              PICTUR
ISTART    I  U  CONTROL FLAG                                                     PICTUR
ISTAT3    I  U  NUMBER OF STATUS = 3 POINTS IN DECK                              PICTUR
ITAPE     I  U  GEOMETRY SOURCE FLAG                                             PICTUR
IX1       I  U  X-RASTER COORDIVATE OF FIRST POINT                               PICTUR
IX2       I  U  X-RASTER COORDINATE OF SECOND POINT                              PICTUR
IY1       I  U  Y-RASTER COORDINATE OF FIRST POINT                               PICTUR
IY2       I  U  Y-RASTER COORDINATE OF SECOND POINT                              PICTUR
JG        I  U  HORIZONTAL GRID LINE LABEL CONTROL FLAG                          PICTUR
KKXY      I  U  OFF-SCALE DETECTION FLAG                                         PICTUR
KLCT      I  U  COUNTER                                                          PICTUR
KX        I  U  OFF-SCALE DETECTION FLAG                                         PICTUR
KX1       I  U  OFF-SCALE DETECTION FLAG                                         PICTUR
KY        I  U  OFF-SCALE DETECTION FLAG                                         PICTUR
KY1       I  U  OFF-SCALE DETECTION FLAG                                         PICTUR
L         I  U  ELEMENT NUMBER                                                   PICTUR
LAST      I  U  LAST PLOT CONTROL FLAG                                           PICTUR
M         I  U  DATA READ IN CONTROL FLAG                                        PICTUR
```

```
SYMBOLS USED IN SUBROUTINE PICTUR

MARKPT   I  U  PLOTTING SYMBOL CODE                                       PICTUR
MC       I  U  DATA READ IN CONTROL NUMBER                                PICTUR
MG       I  U  HORZONTAL LINE EMPHASIZE FLAG                              PICTUR
MMIN     I  U  NUMBER OF ELEMENTS IN A COLUMN                             PICTUR
N        I  U  COLUMN NUMBER                                              PICTUR
NCAM     I  U  CAMERA SELECTION FLAG                                      PICTUR
NG       I  U  VERTICAL LINE EMPHASIZE FLAG                               PICTUR
NN       I  U  COLUMN ELEMENT COUNTER                                     PICTUR
NN2      I  U  COUNTER                                                    PICTUR
NOSCAL   I  U  NO GRID FLAG                                               PICTUR
NPRT     I  U  LINE COUNTER                                               PICTUR
NX       R  U  ELEMENT DIRECTION COSINE-X                                 PICTUR
NXG      I  U  NUMBER OF CHARACTERS IN X-SCALE NUMBER LABELS              PICTUR
NXO      R  U  DIRECTION COSINE OUT OF PLANE OF PAPER                     PICTUR
NY       R  U  ELEMENT DIRECTION COSINE-Y                                 PICTUR
NYG      I  U  NUMBER OF CHARACTERS IN Y-SCALE NUMBER LABELS              PICTUR
NZ       R  U  ELEMENT DIRECTION COSINE-Z                                 PICTUR
PAGE     I  C  PAGE NUMBER                                                PICTUR
PD       R  U  CORNER POINT PROJECTION DISTANCE                           PICTUR
PHI      R  U  ROLL ANGLE, DEGREES                                        PICTUR
PRINTS   I  U  ELEMENT DATA PRINT FLAG                                    PICTUR
PSI      R  U  YAW ANGLE                                                  PICTUR
RFLAG    L  U  INPUT DATA READ CONTROL FLAG                               PICTUR
SINPHI   R  U  SIN OF PHI                                                 PICTUR
SINPSI   R  U  SIN OF PSI                                                 PICTUR
SINTH    R  U  SIN OF THETA                                               PICTUR
STAT     I  U  COORDINATE POINT STATUS FLAG                               PICTUR
STATT    I  U  COORDINATE POINT STATUS FLAG                               PICTUR
SYMFCT   I  U  SYMMETRY FLAG                                              PICTUR
T        R  U  UNIT VECTOR                                                PICTUR
THETA    R  U  PITCH ANGLE                                                PICTUR
TITLE    R  C  TITLE                                                      PICTUR
TYPE     I  U  CARD TYPE NUMBER                                           PICTUR
T1X      R  U  X-COMPONENT OF VECTOR T1                                   PICTUR
T1Y      R  U  Y-COMPONENT OF VECTOR T1                                   PICTUR
T1Z      R  U  Z-COMPONENT OF VECTOR T1                                   PICTUR
```

```
SYMBOLS USED IN SUBROUTINE PICTUR

T2X     R  U  X-COMPONENT OF VECTOR T2                                PICTUR
T2Y     R  U  Y-COMPONENT OF VECTOR T2                                PICTUR
T2Z     R  U  Z-COMPONENT OF VECTOR T2                                PICTUR
VN      R  U  VECTOR LENGTH                                           PICTUR
VOL     R  U  TOTAL VOLUME                                            PICTUR
VTITLE  R  D  VERTICAL SCALE TITLE                                    PICTUR
X       R  U  X-COORDINATE                                            PICTUR
XA      R  D  X-COORDINATE                                            PICTUR
XB      R  D  X-COORDINATE                                            PICTUR
XCENT   R  U  ELEMENT CENTROID COORDINATE-X                           PICTUR
XDIF    R  U  COORDINATE DIFFERENCE-X                                 PICTUR
XI      R  D  COORDINATE IN ELEMENT COORDINATE SYSTEM                 PICTUR
XIN     R  D  ELEMENT COORDINATES-X                                   PICTUR
XIO     R  U  CENTROID IN ELEMENT COORDINATE SYSTEM                   PICTUR
XI3M1   R  U  CONSTANT FOR AREA EQUATION                              PICTUR
XLG     R  U  VALUE OF LEFT SIDE OF HORIZONTAL SCALE                  PICTUR
XPA     R  U  COORDINATE OF ELEMENT CORNER POINT                      PICTUR
XRG     R  U  VALUE OF RIGHT SIDE OF HORIZONTAL SCALE                 PICTUR
XSC     R  U  X SCA'E FACTOR                                          PICTUR
XX      R  U  X-COORDINATE                                            PICTUR
Y       R  U  Y-COORDINATE                                            PICTUR
YA      R  D  Y-COORDINATE                                            PICTUR
YB      R  D  Y-COORDINATE                                            PICTUR
YBG     R  U  VALUE OF BOTTOM OF VERTICAL SCALE                       PICTUR
YCENT   R  U  ELEMENT CENTROID COORDINATE-Y                           PICTUR
YDIF    R  U  COORDINATE DIFFERENCE-Y                                 PICTUR
YIN     R  D  ELEMENT COORDINATES-Y                                   PICTUR
YIN2    R  D  Y-COORDINATE FOR PLOT                                   PICTUR
YO1     R  U  Y-COORDINATE FOR PLOT-POINT 1                           PICTUR
YO2     R  U  Y-COORDINATE FOR PLOT-POINT 2                           PICTUR
YO3     R  U  Y-COORDINATE FOR PLOT-POINT 3                           PICTUR
YO4     R  U  Y-COORDINATE FOR PLOT-POINT 4                           PICTUR
YPA     R  U  COORDINATE OF ELEMENT CORNER POINT                      PICTUR
YSC     R  U  Y-SCALE FACTOR                                          PICTUR
YTG     R  U  VALUE OF TOP OF VERTICAL SCALE                          PICTUR
YY      R  U  Y-COORDINATE                                            PICTUR
```

```
SYMBOLS USED IN SUBROUTINE PICTUR

Z         R  U  Z-COORDINATE                                                    PICTUR
ZA        R  D  Z-COORDINATE                                                    PICTUR
ZB        R  D  Z-COORDINATE                                                    PICTUR
ZCENT     R  U  ELEMENT CENTROID COORDINATE-Z                                   PICTUR
ZDIF      R  U  COORDINATE DIFFERENCE-Z                                         PICTUR
ZIN       R  D  ELEMENT COORDINATES-Z                                           PICTUR
ZIN2      R  D  Z-COORDINATE FOR PLOT                                           PICTUR
Z01       R  U  Z-COORDINATE FOR PLOT-POINT 1                                   PICTUR
Z02       R  U  Z-COORDINATE FOR PLOT-POINT 2                                   PICTUR
Z03       R  U  Z-COORDINATE FOR PLOT-POINT 3                                   PICTUR
Z04       R  U  Z-COORDINATE FOR PLOT-POINT 4                                   PICTUR
ZPA       R  U  COORDINATE OF ELEMENT CORNER POINT                              PICTUR
ZSC       R  U  Z-SCALE FACTOR                                                  PICTUR
ZZ        R  U  Z-COORDINATE                                                    PICTUR
```

30. SUBROUTINE HEADR2 (DECK GRPC)

a. Algorithm

This routine provides the title at the top of each page of the output and advances the page counter. This routine is very similar to the HEADER routine.

b. Input/Output

Program header is printed at top of page on output Tape 6.

c. Error

None

d. Subroutines Required

None

e. Argument List

None

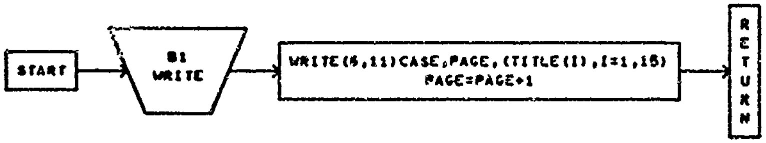
f. Length

350 bytes

DECK GRPC

```
      SUBROUTINE HEADR2
C
      DIMENSION  TITLE(15)
C
      COMMON CASE,TITLE,PAGE
C
      INTEGER  PAGE, CASE
C
C  PRINT OUT HEADER AT TOP OF EACH PAGE OF OUTPUT
      WRITE (6,11) CASE,PAGE,(TITLE(I),I=1,15)
   11 FORMAT (1H1,5X,39HQUADRILATERAL CHARACTERISTICS - PICTURE
     1 16H DRAWING PROGRAM ,/1H0,5X,6H  CASE,I5,80X,5HPAGE I4,/
     2 1H0,14A4,A3)
C
C  STEP PAGE NUMBER BY ONE
      PAGE = PAGE + 1
C
      RETURN
      END
```

SUBROUTINE HEADR2



```
SYMBOLS USED IN SUBROUTINE HEADR2

CASE      I  C  CASE NUMBER                                                                             HEADR2
PAGE      I  C  PAGE NUMBER                                                                             HEADR2
TITLE     R  C  TITLE                                                                                   HEADR2
```

31. SUBROUTINE PLOT (DECK GRPD)

This routine is used to produce graphically plotted data as obtained from the aerodynamics part of the program.

a. Algorithm

Read in plotter control cards. As directed, read aerodynamic data from Tape 9. Prepare plot scales and grids. Plot data and connect data points as directed.

b. Input/Output

Data Source Control Card (Type 41), Vertical-Title Card (Type 44), Horizontal-Title Card (Type 45), Plotting-Grid Data Card (Type 45), Plot Control Array Card (Type 47), and Horizontal-Lable Card(s) Type 48).
Output plots are on the SC-4020 tape.

c. Error

An error condition occurs when the card type number is wrong.

d. Subroutines Required

None

e. Argument List

None

f. Length

10772 bytes

DECK GRPD

```
      SUBROUTINE PLOT                                                   GRPD  0010
C      POINT PLOTTER PROGRAM. UP TO 12 ARRAYS CAN BE INPUT              GRPD  0020
C      AND ANY ONE OF THEM PLOTTED AGAINST ANY OTHER                    GRPD  0030
C                                                                       GRPD  0040
      DIMENSION A(20),B(20),C(20),D(20),E(20),F(20),AA(20),BB(20),      GRPD  0050
     1 CC(20),DD(20),EE(20),FF(20),X(20),Y(20),I(100),TITLE(900),W(10), GRPD  0060
     3 PRINT(18),TITLE2(15)                                             GRPD  0070
      COMMON  CASE,TITLE2,PAGE,ERROR                                    GRPD  0080
      INTEGER  ERROR,TYPE,PAGE,CASE                                     GRPD  0090
C                                                                       GRPD  0100
      CALL CAMRAV (9)                                                   GRPD  0110
      REWIND 1                                                          GRPD  0120
      REWIND 10                                                         GRPD  0130
      REWIND 9                                                          GRPD  0140
C     READ FIRST CONTROL CARD                                           GRPD  0150
    1 READ (5,2) NC,IT                                                  GRPD  0160
    2  FORMAT (I4,66XI2)                                                GRPD  0170
C     CHECK TYPE OF CARD                                                GRPD  0180
      IF (IT .EQ. 41) GO TO 5                                           GRPD  0190
C                                                                       GRPD  0200
C     TYPE CARD GOOFY. PRINT ERROR HEADER AND LEAVE                     GRPD  0210
      IT = 41                                                           GRPD  0220
    3 CALL CAMRAV(9)                                                    GRPD  0230
      CALL FRAMEV (0)                                                   GRPD  0240
      CALL SCOUTV                                                       GRPD  0250
      CALL SCSETV (4)                                                   GRPD  0260
      WRITE (16,4) IT,IT                                                GRPD  0270
    4 FORMAT (1H4,15X30HFOR SOME ODD REASON, TYPE CARDI3,1X             GRPD  0280
     1  15HDOES NOT HAVE AI3,31H IN COLUMN 71-72. BETTER LUCK N         GRPD  0290
     2  9HEXT TIME. )                                                   GRPD  0300
      WRITE (6,48) IT,IT                                                GRPD  0310
   48 FORMAT (1H0,15X30HFOR SOME ODD REASON, TYPE CARDI3,1X             GRPD  0320
     1  15HDOES NOT HAVE AI3,31H IN COLUMN 71-72. BETTER LUCK N         GRPD  0330
     2  9HEXT TIME. )                                                   GRPD  0340
      READ (5,49) (TITLE(J),J=1,20)                                     GRPD  0350
```

```
DECK GRPD

   49 FORMAT (20A4)                                                    GRPD  0360
      WRITE (6,50) (TITLE(J),J=1,20)                                   GRPD  0370
   50 FORMAT (1H0,26X36HWRITTEN BELOW IS THE IMAGE OF THE CA           GRPD  0380
     1  30HRD FOLLOWING THE INCORRECT ONE//20X,20A4)                   GRPD  0390
      ERROR = 1                                                        GRPD  0400
      GO TO 101                                                        GRPD  0410
C                                                                      GRPD  0420
C     CHECK FOR INPUT TAPE, IF ANY                                     GRPD  0430
    5  I(20) = 0                                                       GRPD  0440
      ICNT  = 0                                                        GRPD  0450
      IF (NC) 28,33,7                                                  GRPD  0460
   33 READ(10)NC,NC,NC,NC,IT                                           GRPD  0470
      WRITE (6,44) NC                                                  GRPD  0480
   44 FORMAT (1H0,31X34HTAPE 10 JUST INSTRUCTED ME TO READI4           GRPD  0490
     1  ,18H CARDS FROM TAPE 9 )                                       GRPD  0500
C                                                                      GRPD  0510
C     CHECK TYPE                                                       GRPD  0520
      IF (IT .EQ. 42) GO TO 43                                         GRPD  0530
C                                                                      GRPD  0540
C     TYPE ERROR                                                       GRPD  0550
      IT = 42                                                          GRPD  0560
      GO TO 3                                                          GRPD  0570
   43 DO 34 J = 1,NC                                                   GRPD  0580
   34  READ (9) A(J),B(J),C(J),D(J),E(J),F(J),AA(J),BB(J),             GRPD  0590
     1  CC(J),DD(J),EE(J),FF(J),IT                                     GRPD  0600
C                                                                      GRPD  0610
C      CHECK TYPE (IT) OF CARD JUST READ                               GRPD  0620
      IF (IT .EQ. 43) GO TO 71                                         GRPD  0630
C                                                                      GRPD  0640
C      TYPE ERROR                                                      GRPD  0650
      IT = 43                                                          GRPD  0660
       GO TO 3                                                         GRPD  0670
   71  CONTINUE                                                        GRPD  0680
       WRITE (6,45) NC                                                 GRPD  0690
   45  FORMAT (1H0,42X11HI JUST READI4,18H CARDS FROM TAPE 9)          GRPD  0700
      IF (I(20) .NE. 0) GO TO 78                                       GRPD  0710
```

```
DECK AROX

      READ (5,103) AR , LAMBDA , M , SWBYS , GAMMAT , S , K , TYPE      AROX  0720
      IF (TYPE .NE. 17) GO TO 1000                                      AROX  0730
      READ (5,104) CR , R , BETA , CLALB , UPWASH , XBTBYC , TYPE       AROX  0740
      IF (TYPE .NE. 18) GO TO 1000                                      AROX  0750
      READ (5,106) KBW , Q, TYPE                                        AROX  0760
  106 FORMAT (2F10.0, 50X, I2)                                          AROX  0770
      IF (TYPE .NE. 19) GO TO 1000                                      AROX  0780
  107 CONTINUE                                                          AROX  0790
C                                                                       AROX  0800
C **********************************************************************AROX  0810
C ***** WING OR TAIL CONTRIBUTION                                       AROX  0820
C     THE SLENDER BODY THEORY IS USED TO DETERMINE KWB.  THE EXPRESSION AROX  0830
C     IS EQ. (14) OF NACA REPORT 1307.                                  AROX  0840
C                                                                       AROX  0850
      D = 2.0 * R                                                       AROX  0860
      RS = R / S                                                        AROX  0870
      SR = S / R                                                        AROX  0880
      KWB = 2.0 / PI * (    (1.0 + RS ** 4) * (0.5 * ATAN (0.5 * (SR - RS AROX  0890
     A      )) + PI / 4.0) - RS ** 2 * (SR - RS + 2.0 * ATAN (RS))    )   AROX  0900
     B      / (1.0 - RS) ** 2                                           AROX  0910
C                                                                       AROX  0920
C ****CALCULATE KBW ****************************************************AROX  0930
C     SEVERAL EXPRESSIONS ARE TAKEN FROM NACA REPORT 1307 FOR KBW.      AROX  0940
C     THIS ROUTINE GIVES THE FOLLOWING OPTIONS AS A FUNCTION OF THE     AROX  0950
C     INTEGER ITYPE (IF EQ. (22) OF REPORT 1307 IS NOT SATISFIED,       AROX  0960
C     SLENDER BODY THEORY IS AUTOMATICALLY USED UNLESS KBW IS INPUT     AROX  0970
C     BY THE USER).                                                     AROX  0980
C                                                                       AROX  0990
C ITYPE  REFERENCE FOR KBW                                              AROX  1000
C   0      USER LOADS A VALUE OF KBW                                    AROX  1010
C   1      NACA REPT. 1307 EQ. (21)  (SLENDER BODY THEORY)              AROX  1020
C   2      NACA REPT. 1307 EQ. (24)    SUPERSONIC LEADING EDGE          AROX  1030
C                              (26)    SUBSONIC LEADING EDGE            AROX  1040
C               HALF-PLANFORM IS A TRAPEZOID.  WING/TAIL ON LONG BODY.  AROX  1050
C   3      NACA REPT. 1307 EQ. (27)                                     AROX  1060
C               RECTANGULAR PLANFORM.  WING/TAIL ON LONG BODY.          AROX  1070
```

DECK AROX

```
C    4      NACA REPT. 1307 EQ. (28)    SUBSONIC LEADING EDGE               AROX  1080
C                           EQ. (29)    SUPERSONIC LEADING EDGE             AROX  1090
C                 TRIANGULAR PLANFORM.  WING/TAIL ON LONG BODY.             AROX  1100
C    5      NACA REPT. 1307 EQ. (30)    SUPERSONIC LEADING EDGE             AROX  1110
C                           EQ. (31)    SUBSONIC LEADING EDGE               AROX  1120
C                 HALF-PLANFORM IS A TRAPEZOID.  NO AFTER-BODY FOR WING.    AROX  1130
      ITYPE = K                                                             AROX  1140
C                                                                           AROX  1150
C     TEST ITYPE FOR VALID RANGE                                            AROX  1160
C                                                                           AROX  1170
      IF (ITYPE .GE. 0 .AND. ITYPE .LE. 5) GO TO 72                         AROX  1180
      WRITE (6,71) ITYPE                                                    AROX  1190
   71 FORMAT(1H ,107H**** SUBROUTINE PLUNGE - THE FLAG ITYPE (WHICH CONT    AROX  1200
     2ROLS EQUATION USED TO CALCULATE KBW) IS INCORRECT AND =   ,I7 //)     AROX  1210
      GO TO 1000                                                            AROX  1220
   72 CONTINUE                                                              AROX  1230
C                                                                           AROX  1240
C                                                                           AROX  1250
C     TEST FOR EQ. (22) FOLLOWS.  IF TEST FAILS, SLENDER-BODY THEORY        AROX  1260
C     WILL BE USED AUTOMATICALLY.                                           AROX  1270
C                                                                           AROX  1280
      IF (ITYPE .GT. 1 .AND. (BETA * AR * (1.0 + LAMBDA) * (1.0 /           AROX  1290
     A    (BETA * M) + 1.0)) .LT. 4.0) ITYPE = 1                            AROX  1300
      I = ITYPE + 1                                                         AROX  1310
      GO TO (30, 2, 3, 5, 6, 8) , I                                         AROX  1320
C                                                                           AROX  1330
C     EQ. (21)                                                              AROX  1340
C                                                                           AROX  1350
    2 KBW = (    (1.0 - RS ** 2) ** 2 - 2.0 / PI * ( (1.0 + RS ** 4) *      AROX  1360
     A       (0.5 * ATAN (0.5 * (SR - RS)) + PI / 4.0) - RS ** 2 *          AROX  1370
     B       (SR - RS + 2.0 * ATAN (RS)) )    ) / (1.0 - RS) ** 2           AROX  1380
      GO TO 30                                                              AROX  1390
C                                                                           AROX  1400
C     EQ. (24)                                                              AROX  1410
C                                                                           AROX  1420
    3 BM1 = BETA * M                                                        AROX  1430
```

[redacted]

DECK AROX

```
      IF (BM1 .LT. 1.0) GO TO 4                                         AROX  1440
      BM2 = BM1 ** 2                                                    AROX  1450
      BMR2 = SQRT (BM2 - 1.0)                                           AROX  1460
      T1 = (    1.0 + (1.0 + BM1) * BETA * D / CR    )                  AROX  1470
     A     / (    BM1 + (BM1 + 1.0) * BETA * D / CR    )                AROX  1480
      T2 = 1.0 / BM1                                                    AROX  1490
      T1 = ARCOS (T1)                                                   AROX  1500
      T2 = ARCOS (T2)                                                   AROX  1510
      KBW = 8.0 * BM1 / (PI * BMR2 * (1.0 + LAMBDA) * BETA * D / CR *   AROX  1520
     A       (SR - 1.0) * BETA * CLALW)                                 AROX  1530
     B       * (    (BM1 / (1.0 + BM1)) * (((BM1 + 1.0) * BETA * D / CR AROX  1540
     C       + BM1) / BM1) ** 2 * T1                                    AROX  1550
     D       + BMR2 / (BM1 + 1.0) * (SQRT(1.0 + 2.0 * BETA * D / CR)    AROX  1560
     E       - 1.0)                                                     AROX  1570
     F       - BMR2 / BM1 * (BETA * D / CR) ** 2 * ACOSH(1.0 + CR/BETA/D) AROX  1580
     G       - BM1 / (1.0 + BM1) * T2    )                              AROX  1590
      GO TO 30                                                          AROX  1600
C                                                                       AROX  1610
C     EQ. (26)                                                          AROX  1620
C                                                                       AROX  1630
    4 BM = BM1                                                          AROX  1640
      T1 = SQRT ( (BM + (1.0 + BM) * BETA * D / CR) / BM )              AROX  1650
      KBW = 16.0 * (BM / (1.0 + BM)) ** 2                               AROX  1660
     A       / (PI * (1.0 + LAMBDA) * BETA * D / CR * (SR - 1.0) * BETA AROX  1670
     B       * CLALW)                                                   AROX  1680
     C       * (    T1 ** 3 + T1 - 2.0 - (((1.0 + BM) * BETA * C / CR)  AROX  1690
     D       / BM) ** 2 * ATANH (1.0 / T1)    )                         AROX  1700
      GO TO 30                                                          AROX  1710
C                                                                       AROX  1720
C     EQ. (27)                                                          AROX  1730
C                                                                       AROX  1740
    5 BA = BETA * AR                                                    AROX  1750
      BARS = BA * RS                                                    AROX  1760
      T1 = BA / (BA + SR - 1.0)                                         AROX  1770
      T1 = ARCOS (T1)                                                   AROX  1780
      KBW = 2.0 / (PI * (CA - 0.5)) *                                   AROX  1790
```

```
DECK AROX
     A       (   0.5 * (1.0 + BARS / (1.0 - RS)) ** 2 * T1                  AROX  1800
     B       - 0.5 * (BARS / (1.0 - RS)) ** 2 * ACOSH (1.0 + (1.0 - RS)      AROX  1810
     C       / BARS) - 0.5 - PI / 4.0 + 0.5 * SQRT (1.0 + 2.0 * BARS         AROX  1820
     D       / (1.0 - RS))   )                                               AROX  1830
      GO TO 30                                                               AROX  1840
C                                                                            AROX  1850
C     EQ. (28)                                                               AROX  1860
C                                                                            AROX  1870
    6 BA = BETA * AR                                                         AROX  1880
      BA4 = BA / 4.0                                                         AROX  1890
      IF (BA4 .GE. 1.0) GO TO 7                                              AROX  1900
      T1 = SQRT (1.0 - BA4 ** 2)                                             AROX  1910
      CALL ELP1 (T1, DUMMY, T1, NER1)                                        AROX  1920
C     ERROR TEST 3                                                           AROX  1930
      IF (NER1.NE.0) WRITE (6,22)                                            AROX  1940
   22 FORMAT (1H ,46H**** ELLIPTICAL INTEGRAL ERROR. T1 FROM PLUNGE          AROX  1950
     1  55H IS NOT LESS THAN ONE AND GREATER THAN OR EQUAL TO ZERO )         AROX  1960
      T2 = (BA4 / (BA4 + 1.0)) ** 2 / 2.0                                    AROX  1970
      T3 = SQRT (1.0 + 2.0 * (1.0 + BA4) * RS / (1.0 - RS))                  AROX  1980
      KBW = 8.0 * T1 / (PI * BA4) ** 2 *                                     AROX  1990
     A      (    T2 * T3 ** 3 - (BA / (BA + 4.0)) ** 2 + T2 * T3             AROX  2000
     B       - 2.0 * (BA4 * RS / (1.0 - RS)) ** 2 * ATANH (1.0 / T3)    )    AROX  2010
      GO TO 30                                                               AROX  2020
C                                                                            AROX  2030
C     EQ. (29)                                                               AROX  2040
C                                                                            AROX  2050
    7 T1 = 2.0 * (1.0 + BA4) * RS / (1.0 - RS)                               AROX  2060
      T2 = (1.0 + BA4 * T1) / (BA4 + BA4 * T1)                               AROX  2070
      T3 = 1.0 / BA4                                                         AROX  2080
      T2 = ARCOS (T2)                                                        AROX  2090
      T3 = ARCOS (T3)                                                        AROX  2100
      KBW = 1.0 / (PI * SQRT (BA4 ** 2 - 1.0)) *                             AROX  2110
     A       (    (BA / (BA + 4.0)) * (1.0 + T1) ** 2 * T2                   AROX  2120
     B       + SQRT ( (BA4 ** 2 - 1.0) * (1.0 + BA * RS / (1.0 - RS)) )      AROX  2130
     C       / (1.0 + BA4)   - BA4 * T3 / (1.0 + BA4)                        AROX  2140
     D       - SQRT (BA4 ** 2 - 1.0) * BA * (RS / (1.0 - RS)) ** 2           AROX  2150
```

[redacted]

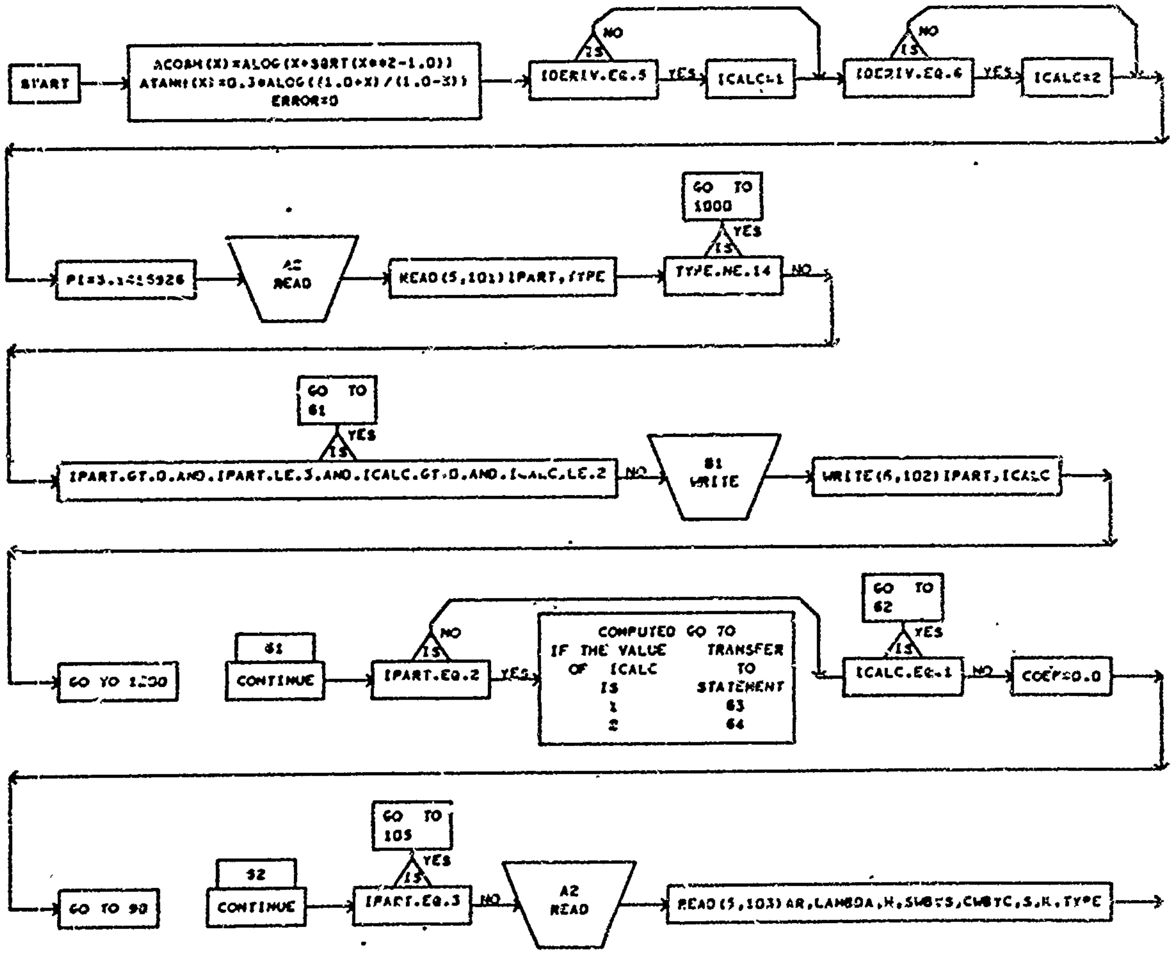
```
     E       * ACOSH (1.0 + 2.0 * (1.0 - RS) / BA / RS)                       AROX  2160
     F       - SQRT (BA4 ** 2 - 1.0) / (BA4 + 1.0)    )                       AROX  2170
      GO TO 30                                                                AROX  2180
C                                                                             AROX  2190
C     EQNS. (30) AND (31)                                                     AROX  2200
C                                                                             AROX  2210
    8 BDCR = BETA * D / CR                                                    AROX  2220
C                                                                             AROX  2230
C     TEST BDCR.  IF BDCR GT 1.0, SET BDCR = 1.0 TO GET PROPER RESULT.        AROX  2240
C     SEE PARAGRAPH FOLLOWING EQ. (31) OF NACA REPORT 1307.                   AROX  2250
C                                                                             AROX  2260
      IF (BDCR .GT. 1.0) BDCR = 1.0                                           AROX  2270
      BM   = BETA * M                                                         AROX  2280
      IF (BM .LT. 1.0) GO TO 9                                                AROX  2290
C                                                                             AROX  2300
C     EQ. (30)                                                                AROX  2310
C                                                                             AROX  2320
      T1 = (BM + 1.0 / BDCR) / (1.0 + BM / BDCR)                              AROX  2330
      T2 = 1.0 / BM                                                           AROX  2340
      T3 = BDCR                                                               AROX  2350
      T4 = SQRT (BM ** 2 - 1.0)                                               AROX  2360
      T1 = ARCOS (T1)                                                         AROX  2370
      T2 = ARCOS (T2                                                          AROX  2380
      T3 = ARSIN (T3)                                                         AROX  2390
      KBW = 8.0 * BDCR / (PI * T4 * BETA * CLALW * (1.0 + LAMBDA) *           AROX  2400
     A       (SR - 1.0)) *                                                    AROX  2410
     B       (    (1.0 + BM / BDCR ) ** 2 * T1                                AROX  2420
     C       - (BM / BDCR) ** 2 * T2                                          AROX  2430
     D       + BM / BDCR ** 2 * T4 * T3                                       AROX  2440
     E       - T4 * ACOSH (1.0 / BDCR)                                        AROX  2450
      GO TO 30                                                                AROX  2460
    9 CRBD = 1.0 / BDCR                                                       AROX  2470
      CRBD2 = CRBD ** 2                                                       AROX  2480
C                                                                             AROX  2490
C     FQ. (31)                                                                AROX  2500
C                                                                             AROX  2510
```

```
DECK AROX
      KBW = 16.0 * SQRT (BM) * BDCR / (PI * (BM + 1.0) * BETA * CLALW      AROX  2520
     A        * (1.0 + LAMBDA) * (SR - 1.0)) *                             AROX  2530
     B        (    (1.0 + M * CR / D) * SQRT ((CRBD - 1.0)*(M*CR/D + 1.0))  AROX  2540
     C        - CRBD2 * BM ** 1.5                                          AROX  2550
     D        + BM * CRBD2 * (BM + 1.0) * (ATAN (SQRT(1.0 / BM))           AROX  2560
     E        - ATAN (SQRT((CRBD - 1.0) / (M * CR / D + 1.0))))            AROX  2570
     F        - (BM + 1.0) / SQRT (BM) * ATANH (SQRT(BM * (CRBD - 1.0) /   AROX  2580
     G          (M * CR / D + 1.0)))    )                                  AROX  2590
      GO TO 30                                                             AROX  2600
C                                                                          AROX  2610
C     HOPEFULLY, BY THIS TIME, KBW HAS BEEN CALCULATED.                    AROX  2620
C                                                                          AROX  2630
   30 CONTINUE                                                             AROX  2640
      IF (IPART .EQ. 3) GO TO 32                                           AROX  2650
C                                                                          AROX  2660
C***** CALCULATE WING CM ALPHA DOT ***************************************  AROX  2670
      COEF = SWBYS * (KWB + KBW) * CWBYC ** 2 * CMWPR                      AROX  2680
      GO TO 90                                                             AROX  2690
C                                                                          AROX  2700
C                                                                          AROX  2710
C***** CALCULATE TAIL CONTRIBUTION TO C-SUB-M-SUB-BETA-DOTA                 AROX  2720
   32 CONTINUE                                                             AROX  2730
      COEF = 2.0 * Q * SWBYS * ( COS (0.017453292 * GAMMAT) ) ** 2         AROX  2740
     A        * CLALW * (KWB + KBW) * XBTBYC ** 2 * UPWASH                 AROX  2750
      GO TO 90                                                             AROX  2760
C                                                                          AROX  2770
C                                                                          AROX  2780
C***** CONTRIBUTION OF BODY TO C-SUB-M-SUB-ALPHA-DOT   ******************  AROX  2790
   63 CONTINUE                                                             AROX  2800
C                                                                          AROX  2810
C     READ BODY DATA                                                       AROX  2820
C                                                                          AROX  2830
      READ (5,104) VOLUME , SFRONT , LENGTH , XO , XC , C , TYPE           AROX  2840
      IF (TYPE .NE. 20) GO TO 1000                                         AROX  2850
      RATIO = (-2.0 * VOLUME / C / SFRONT) * (XO - XC) / LENGTH            AROX  2860
     A        / (VOLUME / SFRONT / LENGTH - 1.0 + XO / LENGTH)             AROX  2870
```

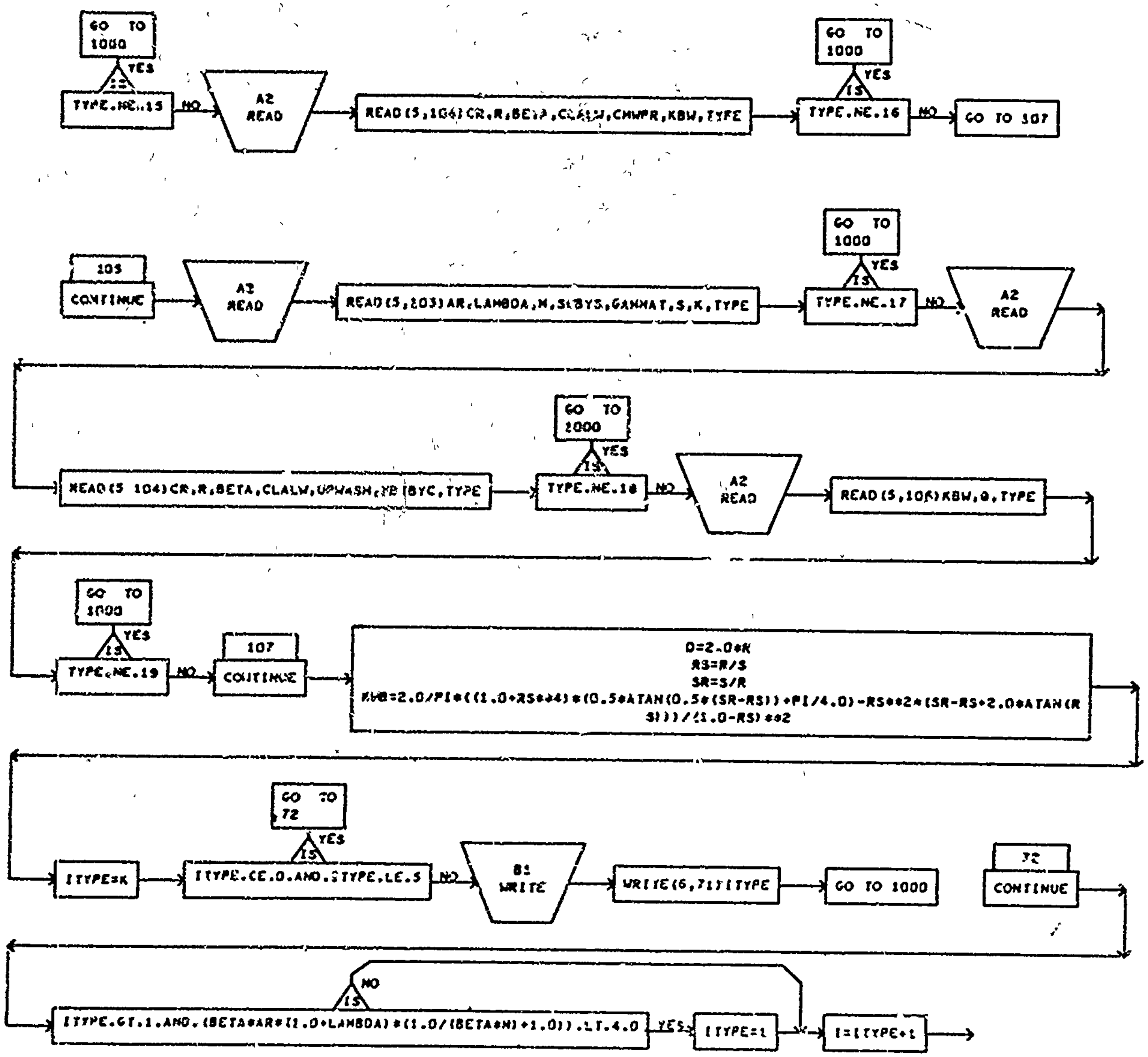
PLUNGE

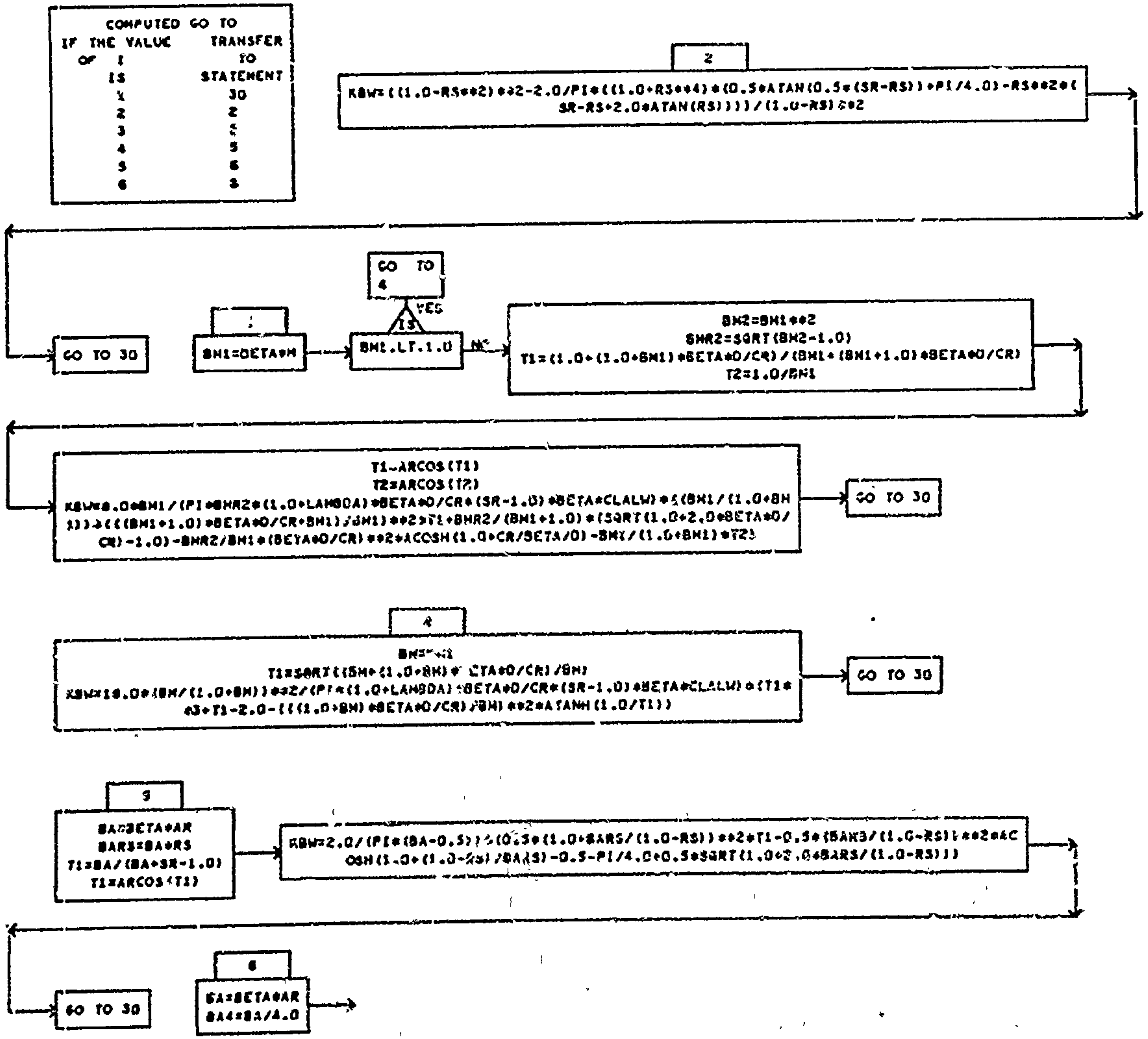
```
DECK AROX
      COEF = RATIO * CMA                                                AROX  2880
      GO TO 90                                                          AROX  2890
C                                                                       AROX  2900
C***** BODY CY BETA DOT ************************************************AROX  2910
   64 CONTINUE                                                          AROX  2920
C     THIS PART OF THE ROUTINE COMPUTES C-SUB-Y-SUB-BETA DOT            AROX  2930
C     THE BASIC REFERENCE IS NASA TMX-287.                              AROX  2940
C     THE REFERENCE SHOWS THAT WING AND TAIL CONTRIBUTIONS.CAN BE       AROX  2950
C     NEGLECTED, AND THAT THE FUSELAGE TERM CAN BE OBTAINED BY A        AROX  2960
C     SLENDER-BODY-THEORY RATIO MULTIPLIED BY C-SUB-Y-SUB-BETA.         AROX  2970
C                                                                       AROX  2980
C                                                                       AROX  2990
C     READ BODY DATA                                                    AROX  3000
C                                                                       AROX  3010
      READ (5,108) VOLUME , SFRONT , B , TYPE                           AROX  3020
  108 FORMAT (3F10.0 , 40X, I2)                                         AROX  3030
      IF (TYPE .NE. 21) GO TO 1000                                      AROX  3040
      COEF = (-2.0) * VOLUME / SFRONT * CYB / B                         AROX  3050
   90 IF (IDERIV .EQ. 5) CMADT = COEF                                   AROX  3060
      IF (IDERIV .EQ. 6) CYBDT = COEF                                   AROX  3070
      RETURN                                                            AROX  3080
 1000 ERROR = 1                                                         AROX  3090
      WRITE (6,1001)                                                    AROX  3100
 1001 FORMAT (1H , 39H**** SUBROUTINE PLUNGE SETS ERROR FLAG ///)       AROX  3110
      RETURN                                                            AROX  3120
      END                                                               AROX  3130
```

SUBROUTINE PLUNGE



PLUNGE


GO TO 1000
YES
IS
TYPE.NE.15
NO
A2 READ
READ(5,106)CR,R,BETA,CLALW,CHWPR,KBW,TYPE
GO TO 1000
YES
IS
TYPE.NE.16
NO
GO TO 107
105
CONTINUE
A2 READ
READ(5,103)AR,LAMBDA,M,SLBYS,GAMMAT,S,K,TYPE
GO TO 1000
YES
IS
TYPE.NE.17
NO
A2 READ
READ(5 104)CR,R,BETA,CLALW,UPWASH,YB(BYC,TYPE
GO TO 1000
YES
IS
TYPE.NE.18
NO
A2 READ
READ(5,105)KBW,0,TYPE
GO TO 1000
YES
IS
TYPE.NE.19
NO
107
CONTINUE
D=2.0*K
RS=R/S
SR=S/R
KWB=2.0/PI*((1.0+RS**4)*(0.5*ATAN(0.5*(SR-RS))+PI/4.0)-RS**2*(SR-RS+2.0*ATAN(RS)))/(1.0-RS)**2
GO TO 72
YES
IS
ITYPE=K
ITYPE.GE.0.AND.ITYPE.LE.5
NO
B1 WRITE
WRITE(6,71)ITYPE
GO TO 1000
72
CONTINUE
NO
IS
ITYPE.GT.1.AND.(BETA*AR*(1.0+LAMBDA)*(1.0/(BETA*N)+1.0)).LT.4.0
YES
ITYPE=1
I=ITYPE+1



COMPUTED GO TO

IF THE VALUE OF I IS	TRANSFER TO STATEMENT
1	30
2	2
3	4
4	5
5	6
6	3

```
2
KBW=((1.0-RS**2)**2-2.0/PI*((1.0+RS**4)*(0.5*ATAN(0.5*(SR-RS))+PI/4.0)-RS**2*(
SR-RS+2.0*ATAN(RS))))/(1.0-RS)**2

GO TO 30

1
BH1=BETA*H
IS BH1.LT.1.0   YES: GO TO 4
NO:
BH2=BH1**2
BHR2=SQRT(BH2-1.0)
T1=(1.0+(1.0+BH1)*BETA*D/CR)/(BH1+(BH1+1.0)*BETA*D/CR)
T2=1.0/BH1

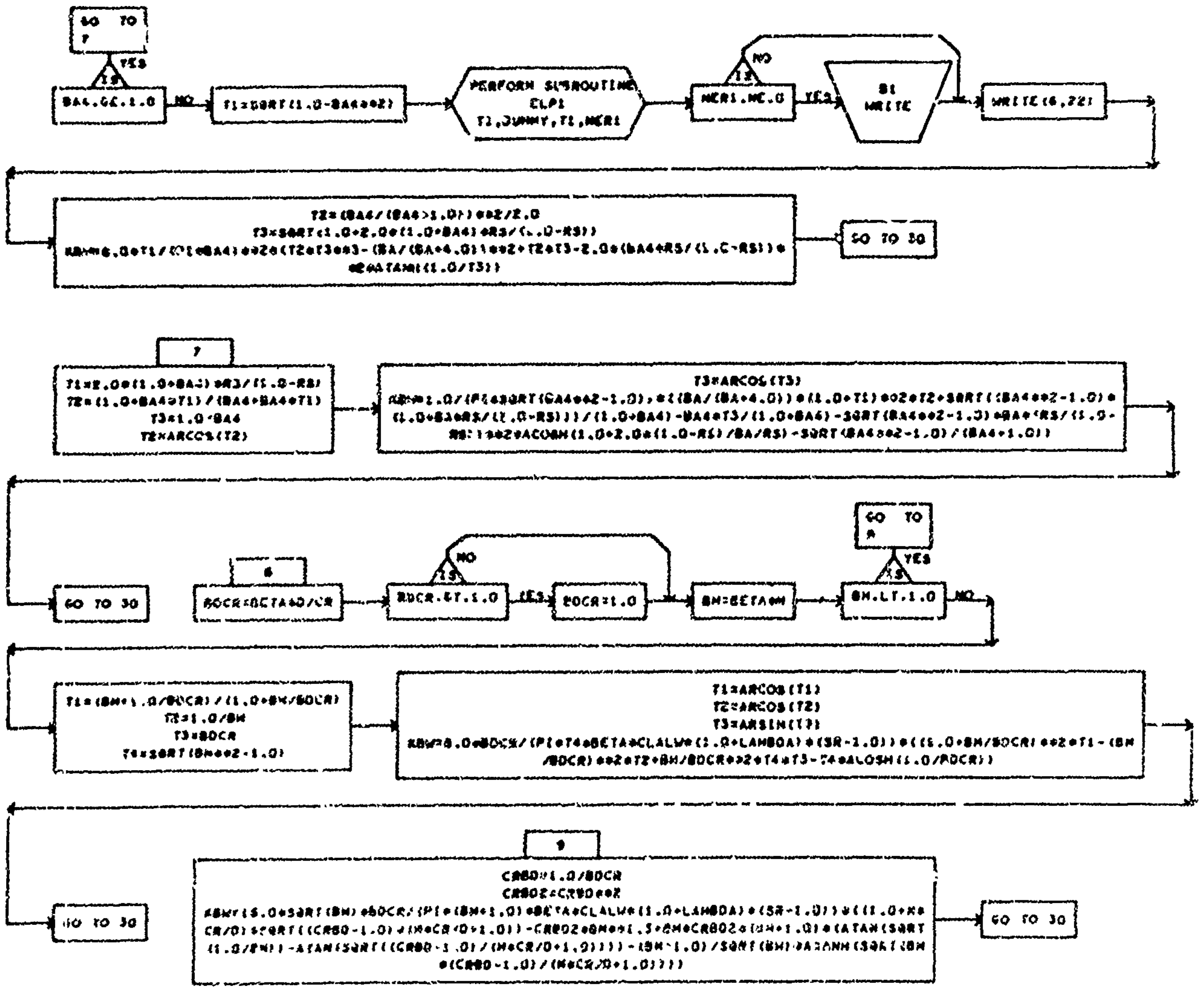
T1=ARCOS(T1)
T2=ARCOS(T2)
KBW=8.0*BH1/(PI*BHR2*(1.0+LAMBDA)*BETA*D/CR*(SR-1.0)*BETA*CLALW)*((BH1/(1.0+BH
1))**2*(((BH1+1.0)*BETA*D/CR+BH1)/BH1)**2*T1+BHR2/(BH1+1.0)*(SQRT(1.0+2.0*BETA*D/
CR)-1.0)-BHR2/BH1*(BETA*D/CR)**2*ACOSH(1.0+CR/BETA/D)-BH1/(1.0+BH1)*T2)
GO TO 30

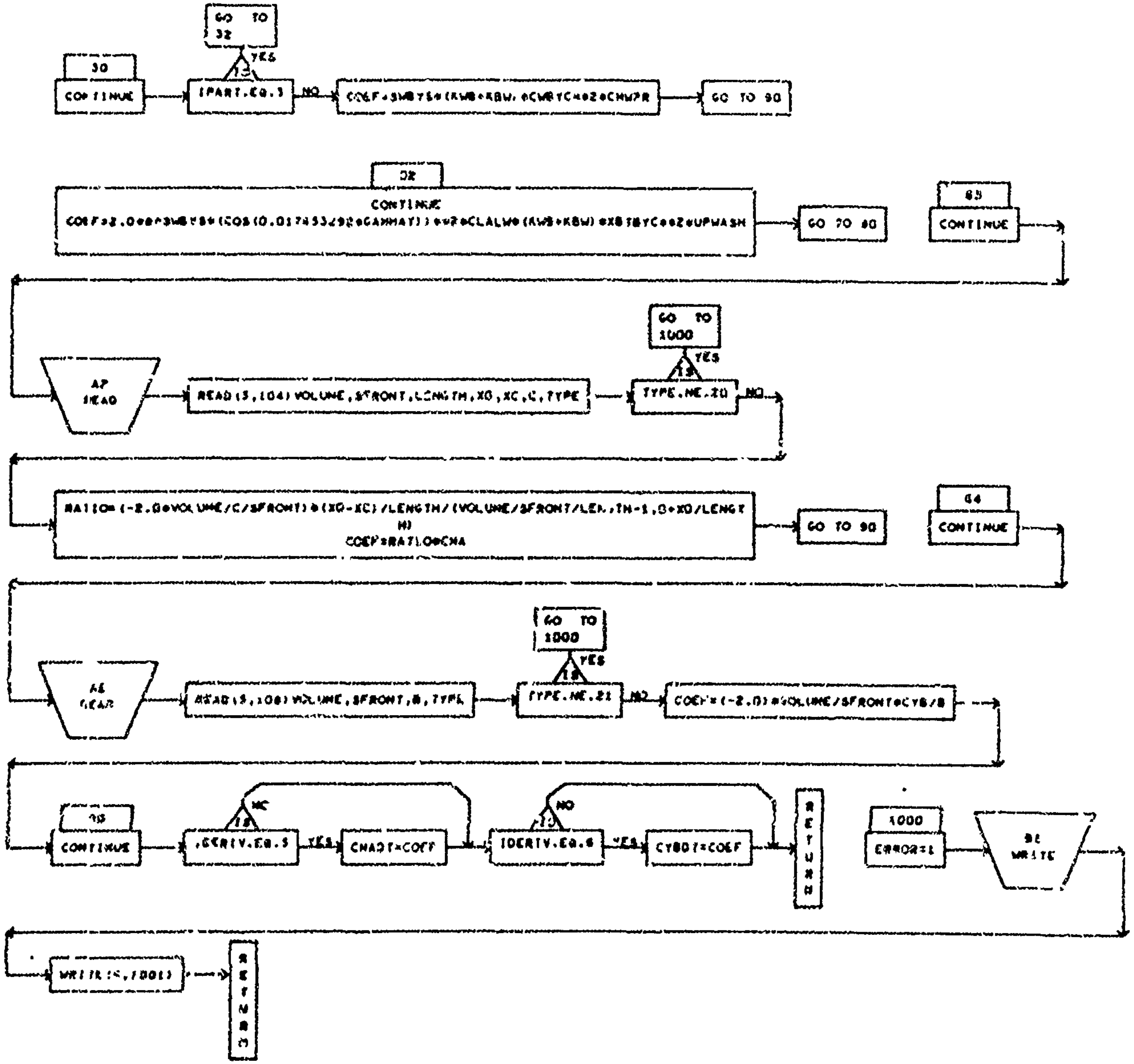
4
BH=*1
T1=SQRT((BH+(1.0+BH)* ETA*D/CR)/BH)
KBW=16.0*(BH/(1.0+BH))**2/(PI*(1.0+LAMBDA)*BETA*D/CR*(SR-1.0)*BETA*CLALW)*(T1*
*3+T1-2.0-(((1.0+BH)*BETA*D/CR)/BH)**2*ATANH(1.0/T1))
GO TO 30

3
BA=BETA*AR
BARS=BA*RS
T1=BA/(BA+SR-1.0)
T1=ARCOS(T1)
KBW=2.0/(PI*(BA-0.5))*(0.5*(1.0+BARS/(1.0-RS))**2*T1-0.5*(BARS/(1.0-RS))**2*AC
OSH(1.0+(1.0-RS)/BARS)-0.5-PI/4.0+0.5*SQRT(1.0+2.0*BARS/(1.0-RS)))
GO TO 30

6
BA=BETA*AR
BA=BA/4.0
```

PLUNGE


GO TO 7
YES
IS
BA4.GE.1.0
NO
T1=SQRT(1.0-BA4**2)
PERFORM SUBROUTINE ELP1 T1,DUMMY,T1,NER1
NER1.NE.0
IS
NO
YES
B1 WRITE
WRITE(6,22)
T2=(BA4/(BA4+1.0))**2/2.0
T3=SQRT(1.0+2.0*(1.0+BA4)*RS/(1.0-RS))
KBW=6.0*T1/(PI*BA4)**2*(T2*T3**3-(BA/(BA+4.0))**2+T2*T3-2.0*(BA4*RS/(1.0-RS))*
*2*ATANH(1.0/T3))
GO TO 30
7
T1=2.0*(1.0+BA4)*RS/(1.0-RS)
T2=(1.0+BA4*T1)/(BA4+BA4*T1)
T3=1.0+BA4
T2=ARCOS(T2)
T3=ARCOS(T3)
KBW=1.0/(PI*SQRT(BA4**2-1.0))*((BA/(BA+4.0))*(1.0+T1)**2*T2+SQRT((BA4**2-1.0)*
(1.0+BA4*RS/(1.0-RS)))/(1.0+BA4)-BA4*T3/(1.0+BA4)-SQRT(BA4**2-1.0)*BA*(RS/(1.0-
RS))**2*ACOSH(1.0+2.0*(1.0-RS)/BA/RS)-SQRT(BA4**2-1.0)/(BA4+1.0))
GO TO 30
6
BOCR=BETA*D/CR
BOCR.GT.1.0
IS
NO
YES
BOCR=1.0
BM=BETA*M
BM.LT.1.0
IS
YES
GO TO 8
NO
T1=(BM+1.0/BOCR)/(1.0+BM/BOCR)
T2=1.0/BM
T3=BOCR
T4=SQRT(BM**2-1.0)
T1=ARCOS(T1)
T2=ARCOS(T2)
T3=ARSIN(T3)
KBW=8.0*BOCR/(PI*T4*BETA*CLALW*(1.0+LAMBDA)*(SR-1.0))*((1.0+BM/BOCR)**2*T1-(BM
/BOCR)**2*T2+BM/BOCR**2*T4*T3-T4*ACOSH(1.0/BOCR))
GO TO 30
9
CRBD=1.0/BOCR
CRBD2=CRBD**2
KBW=(5.0*SQRT(BM)*BOCR/(PI*(BM+1.0)*BETA*CLALW*(1.0+LAMBDA)*(SR-1.0)))*((1.0+M*
CR/D)*SQRT((CRBD-1.0)*(M*CR/D+1.0))-CRBD2*BM**1.5+BM*CRBD2*(BM+1.0)*(ATAN(SQRT
(1.0/BM))-ATAN(SQRT((CRBD-1.0)/(M*CR/D+1.0))))-(BM-1.0)/SQRT(BM)*ATANH(SQRT(BM
*(CRBD-1.0)/(M*CR/D+1.0))))
GO TO 30


30
CONTINUE
IPART.EQ.3
YES
13
GO TO 32
NO
COEF=SWBYS*(KWB+KBW)*CWBYC**2*CHWPR
GO TO 90
32
CONTINUE
COEF=2.0*PI*SWBYS*(COS(0.01745329*GAMMAT))**2*CLALW*(KWB+KBW)*XBTBYC**2*UPWASH
GO TO 90
83
CONTINUE
AP
READ
READ(5,104)VOLUME,SFRONT,LENGTH,XO,XC,C,TYPE
TYPE.NE.20
13
YES
GO TO 1000
NO
RATIO=(-2.0*VOLUME/C/SFRONT)*(XO-XC)/LENGTH/(VOLUME/SFRONT/LENGTH-1.0+XO/LENGTH)
COEF=RATIO*CNA
GO TO 90
84
CONTINUE
AE
READ
READ(5,108)VOLUME,SFRONT,B,TYPE
TYPE.NE.21
13
YES
GO TO 1000
NO
COEF=(-2.0)*VOLUME/SFRONT*CYB/B
95
CONTINUE
IDERIV.EQ.5
13
NO
YES
CHADT=COEF
IDERIV.EQ.6
13
NO
YES
CYBDT=COEF
RETURN
1000
ERROR=1
BE
WRITE
WRITE(6,1001)
RETURN

```
SYMBOLS USED IN SUBROUTINE PLUNGE

AR        R  U  ASPECT RATIO OF WING/TAIL                                     PLUNGE
B         R  U  WING/TAIL SPAN                                                PLUNGE
BA        R  U  PRODUCT OF BETA AND ASPECT RATIO                              PLUNGE
BARS      R  U  PRODUCT OF BA AND RS                                          PLUNGE
BA4       R  U  BA DIVIDED BY 4                                               PLUNGE
BDCR      R  U  PRODUCT OF BETA AND D DIVIDED BY CR                           PLUNGE
BETA      R  U  PRANDTL-GLAUERT FACTOR                                        PLUNGE
BM        R  U  PRODUCT OF BETA AND M                                         PLUNGE
BMR2      R  U  SQUARE ROOT OF DIFFERENCE OF BM2 AND 1.0                      PLUNGE
BM1       R  U  PRODUCT OF BETA AND M                                         PLUNGE
BM2       R  U  SQUARE OF PRODUCT OF BETA AND M                               PLUNGE
C         R  U  REFERENCE CHORD FOR BODY                                      PLUNGE
CASE      I  C  CASE NUMBER                                                   PLUNGE
CLALW     R  U  LIFT-CURVE SLOPE FOR WING/TAIL (PER. RADIAN)                  PLUNGE
CMA       R  A  DERIVATIVE OF PITCHING MOMENT WITH ANGLE OF ATTACK            PLUNGE
CMADT     R  A  PITCHING MOMENT-ALPHA DOT DERIVATIVE                          PLUNGE
CMWPR     R  U  WING-ALONE/TAIL-ALONE PITCHING MOMENT DERIVATIVE              PLUNGE
COEF      R  U  COEFFICIENT DERIVATIVE                                        PLUNGE
CR        R  U  WING/TAIL CHORD AT WING/TAIL-BODY JUNCTURE                    PLUNGE
CRBD      R  U  RICIPROCAL OF BDCR                                            PLUNGE
CRBD2     R  U  SQUARE OF CRBD                                                PLUNGE
CWBYC     R  U  MEAN AERODYNAMIC CHORD OF EXPOSED WING/TAIL                   PLUNGE
CYB       R  A  DERIVATIVE OF SIDE FORCE WITH YAW ANGLE                       PLUNGE
CYBDT     R  A  DERIVATIVE OF SIDE FORCE WITH BETA DOT                        PLUNGE
D         R  U  BODY DIAMETER AT WING OR TAIL                                 PLUNGE
DUMMY     R  U  DUMMY VARIABLE                                                PLUNGE
ERROR     I  C  ERROR FLAG                                                    PLUNGE
GAMMAT    R  U  TAIL DIHEDRAL ANGLE (DEGREES)                                 PLUNGE
I         I  U  INDEX                                                         PLUNGE
ICALC     I  U  CALCULATION OPTION FLAG                                       PLUNGE
IDERIV    I  A  DERIVATIVE OPTION FLAG                                        PLUNGE
IPART     I  U  CONTROL FLAG FOR COMPONENT TYPE (BODY,WING,TAIL)              PLUNGE
ITYPE     I  U  FLAG TO CONTROL EQUATION TO BE USED IN CALCULATING KBW        PLUNGE
K         I  U  FLAG TO CONTROL SELECTION OF KBW EQUATION                     PLUNGE
KBW       R  U  INTERFERENCE ON BODY IN PRESENCE OF WING/TAIL                 PLUNGE
KWB       R  U  INTERFERENCE ON WING/TAIL IN PRESENCE OF BODY                 PLUNGE
```

```
SYMBOLS USED IN SUBROUTINE PLUNGE

LAMBDA   R  U  WING/TAIL TAPER RATIO (TIP CHORD/ROOT CHORD)                        PLUNGE
LENGTH   R  U  BODY LENGTH                                                        PLUNGE
M        R  U  COTANGENT OF WING/TAIL LEADING EDGE SWEEP ANGLE                    PLUNGE
NER1     I  U  ERROR FLAG                                                         PLUNGE
PAGE     I  C  PAGE NUMBER                                                        PLUNGE
PI       R  U  RATIO OF CIRCUMFERENCE OF A CIRCLE TO ITS DIAMETER                 PLUNGE
Q        R  U  TAIL EFFECTIVENESS RATIO                                           PLUNGE
R        R  U  BODY RADIUS AT WING OR TAIL                                        PLUNGE
RATIO    R  U  DUMMY VARIABLE                                                     PLUNGE
RS       R  U  R DIVIDED BY S                                                     PLUNGE
S        R  U  WING/TAIL SEMI-SPAN                                                PLUNGE
SFRONT   R  U  BODY FRONTAL AREA                                                  PLUNGE
SR       R  U  S DIVIDED BY R                                                     PLUNGE
SWBYS    R  U  WING/TAIL AREA DIVIDED BY REFERENCE AREA                           PLUNGE
TITLE    R  C  TITLE                                                              PLUNGE
TYPE     I  U  CARD TYPE                                                          PLUNGE
T1       R  U  DUMMY VARIABLE                                                     PLUNGE
T2       R  U  DUMMY VARIABLE                                                     PLUNGE
T3       R  U  DUMMY VARIABLE                                                     PLUNGE
T4       R  U  DUMMY VARIABLE                                                     PLUNGE
UPWASH   R  U  TAIL UPWASH DERIVATIVE CAUSED BY WING                              PLUNGE
VOLUME   R  U  BODY VOLUME                                                        PLUNGE
XBTBYC   R  U  TAIL LENGTH DIVIDED BY REFERENCE CHORD                             PLUNGE
XC       R  U  AREA CENTROID LOCATION OF BODY                                     PLUNGE
XO       R  U  CENTER OF GRAVITY LOCATION                                         PLUNGE
```

26. SUBROUTINE ELP1 (DECK AROY)

This routine approximates the values of the elliptical integrals of the first and second kinds.

a. Algorithm

The approximation to a value of the elliptical integral of the first kind is given by

$$K(k) = (a_o + a_1\eta + \ldots + a_4\eta^4) + (b_o + b_1\eta + \ldots + b_4\eta^4) \ln \frac{1}{\eta}$$

where $\eta = 1 - k^2$

$a_o = 1.386294361$ $b_o = 0.5$
$a_1 = 0.0966634426$ $b_1 = 0.124985936$
$a_2 = 0.0359009238$ $b_2 = 0.0688024857$
$a_3 = 0.0374256371$ $b_3 = 0.0332835534$
$a_4 = 0.0145119621$ $b_4 = 0.0044178701$

The approximation to the value of the elliptical integral of the second kind is given by

$$E(k) = (a_o + a_1\eta + \ldots + a_4\eta^4) + (b_o + b_1\eta + \ldots + b_4\eta^4) \ln \frac{1}{\eta}$$

where $\eta = 1 - k^2$

$a_o = 1.0$ $b_o = 0.0$
$a_1 = 0.4432514146$ $b_1 = 0.2499836831$
$a_2 = 0.0626060122$ $b_2 = 0.0920018004$
$a_3 = 0.0475738355$ $b_3 = 0.0406969753$
$a_4 = 0.0173650645$ $b_4 = 0.0052644964$

b. Input/Output

None

c. Error

None

d. Subroutines Required

None

e. Argument List

(AK, AKK, E, NERROR)

f. Length

828 bytes

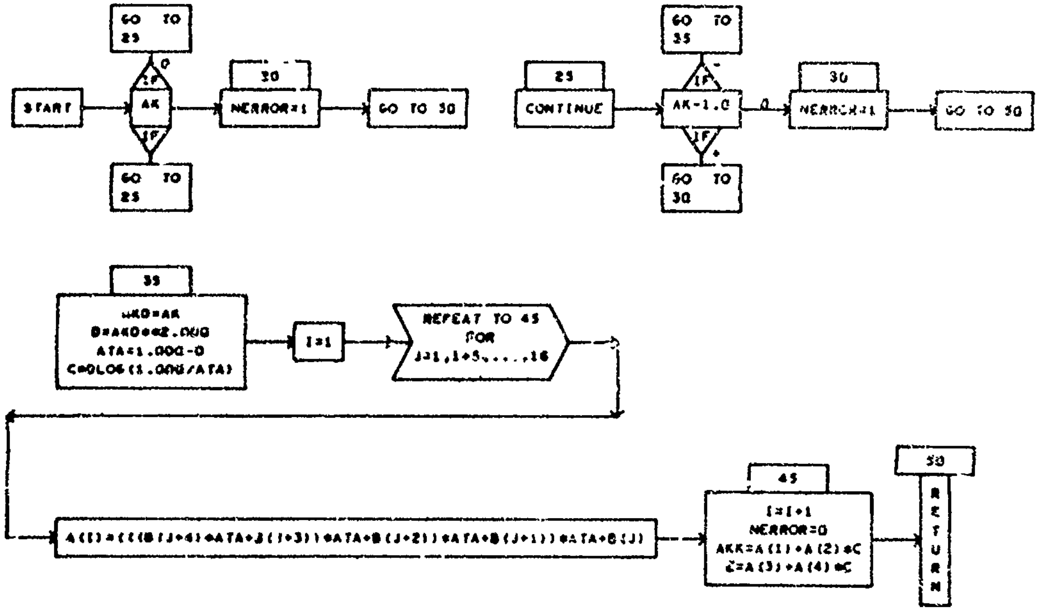
```
DECK AROY

      SUBROUTINE ELP1(AK, AKK, E, NERROR)                               AROY  0010
CELP1  ELP1 IS A ROUTINE TO APPROXIMATE THE VALUE OF THE ELLIPTICAL     AROY  0020
C     INTEGRALS E(K) AND K(K) BY A METHOD OF NUMERICAL ANALYSIS.        AROY  0030
C     ARGUMENTS OF THE ROUTINE ARE AS FOLLOWS                           AROY  0040
C     AK    = INPUT VALUE OF K                                          AROY  0050
C     AKK   = OUTPUT VALUE OF K(K) ELLIPTICAL INTEGRAL                  AROY  0060
C     F     = OUTPUT VALUE OF E(K) ELLIPTICAL INTEGRAL                  AROY  0070
C     NERROR = ERROR CODE                                               AROY  0080
C             0 = K IS IN ALLOWABLE RANGE                               AROY  0090
C             1 = K OUT OF ALLOWABLE RANGE, I.E. EQUAL TO OR GREATER    AROY  0100
C                 THAN ONE OR LESS THAN ZERO.                           AROY  0110
C                                                                       AROY  0120
      DIMENSION B(20), A(4)                                             AROY  0130
      DOUBLE PRECISION A, B, ATA, C, D, AKD                             AROY  0140
      DATA                 B/1.38629436112, 0.09666344259, 0.03590092383, AROY  0150
     1                                                                  AROY  0160
     2 .03742563713, .01451196212, .5D0, .12498593597, .06880248576,    AROY  0170
     3                                                                  AROY  0180
     4 .03328355346, .0041787012D0, 1.000, .44325141463, .06260601220,  AROY  0190
     5                                                                  AROY  0200
     6 .04757383546, .01736506451, .000, .29499836831, .09200180037,    AROY  0210
     7                                                                  AROY  0220
     8 .04069697526, .00526449639D0/                                    AROY  0230
C                                                                       AROY  0240
      IF(AK) 20,25,25                                                   AROY  0250
   20 NERROR = 1                                                        AROY  0260
      GO TO 50                                                          AROY  0270
   25 IF(AK-1.0) 35,30,30                                               AROY  0280
   30 NERROR = 1                                                        AROY  0290
      GO TO 50                                                          AROY  0300
   35 AKD = AK                                                          AROY  0310
      D = AKD ** 2.0D0                                                  AROY  0320
      ATA = 1.0D0 - D                                                   AROY  0330
      C = DLOG(1.0D0 / ATA)                                             AROY  0340
      I = 1                                                             AROY  0350
```

```
DECK AROY

      DO 45 J = 1,16,5                                                  AROY  0360
      A(I) = (((B(J+4)*ATA + B(J+3))*ATA + B(J+2))*ATA + B(J+1))*ATA +  AROY  0370
     1         B(J)                                                     AROY  0380
   45 I = I + 1                                                         AROY  0390
      NERROR = 0                                                        AROY  0400
      AKK = A(1) + A(2)*C                                               AROY  0410
      F   = A(3) + A(4)*C                                               AROY  0420
   50 RETURN                                                            AROY  0430
      END                                                               AROY  0440
```

SUBROUTINE ELP1



```
SYMBOLS USED IN SUBROUTINE ELP1

A         D  D  ELLIPTICAL INTEGRAL PARAMETER                     ELP1
AK        R  A  THE MODULUS                                       ELP1
AKO       D  U  MODULUS                                           ELP1
AKK       R  A  ELLIPTICAL INTEGRAL OF THE FIRST KIND             ELP1
ATA       D  U  ELLIPTICAL INTEGRAL PARAMETER                     ELP1
B         D  D  ELLIPTICAL INTEGRAL CONSTANT ARRAY                ELP1
C         D  U  ELLIPTICAL INTEGRAL PARAMETER                     ELP1
D         D  U  ELLIPTICAL INTEGRAL PARAMETER                     ELP1
E         R  A  ELLIPTICAL INTEGRAL OF THE SECOND KIND            ELP1
I         I  U  INDEX                                             ELP1
J         I  U  DO-LOOP INDEX                                     ELP1
NERROR    I  A  ERROR FLAG                                        ELP1
```

27. SUBROUTINE VECTOR (DECK AROZ)

This routine converts input thrust vector data to coefficients and adds the results to the vehicle aerodynamic coefficients.

a. Algorithm

Set up initial conditions and constants. Read in a force vector and convert to force coefficients. Print the results if required. Continue to read in force vector data until LAST equals one.

b. Input/Output

Thrust Vector Data Cards (Type 22)
Thrust Vector coefficient contributions are printed if IPRINT = 1.

c. Error

An error condition occurs if the card type number is wrong.

d. Subroutines Required

HEADER

e. Argument List

(MACH, PFS, SREF, XCG, YCG, ZCG, SPAN, MAC, ALPHA, CD, CL, CA, CY, CN, BETA, LOD, CLM, CLL, CLN)

f. Length

2304 bytes

DECK AROZ

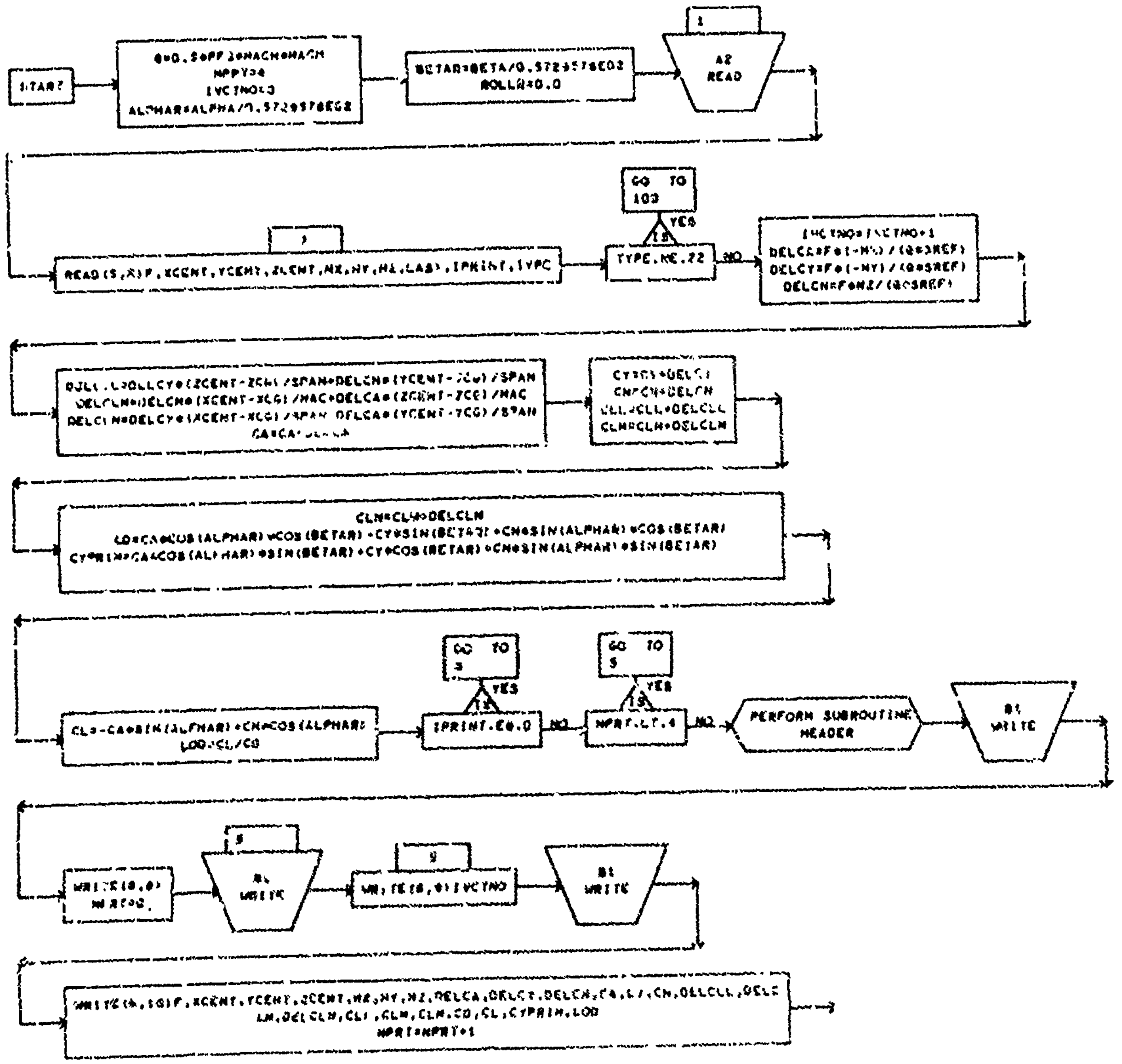
```
      SUBROUTINE VECTOR (MACH,PFS,SREF,XCG,YCG,ZCG,SPAN,MAC,
     1 ALPHA,CD,CL,CA,CY,CN,BETA,LOD,CLM,CLL,CLN)
C
C***********************************************************************
C**** THIS SUBROUTINE CONVERTS THRUST VECTORS INTO AERODYNAMIC
C**** COEFFICIENTS.  ANY NUMBER OF VECTORS MAY BE INPUT.
C***********************************************************************
C
      DIMENSION  TITLE(15)
      COMMON  CASE,TITLE,PAGE,ERROR
      REAL  MACH,MAC,LOD,NX,NY,NZ
      INTEGER  ERROR,CASE,PAGE,TYPE
C
C  SET UP INITIAL CONDITIONS
      Q = 0.5 * PFS * MACH*MACH
      NPRT = 4
      IVCTNO = 0
      ALPHAR = ALPHA / 0.5729578E02
      BETAR  = BETA  / 0.5729578E02
      ROLLR = 0.0
C
C  READ IN FORCE VECTOR DATA AND CONVERT TO FORCE COEFFICIENTS
    1 READ (5,2) F,XCENT,YCENT,ZCENT,NX,NY,NZ,LAST,IPRINT,TYPE
    2 FORMAT (F10.0,6F6.0,13X,I1,1XI1,8X,I2)
      IF (TYPE .NE. 22) GO TO 100
      IVCTNO = IVCTNO + 1
      DELCA = F *(-NX)/ (Q * SREF)
      DELCY = F *(-NY)/ (Q * SREF)
      DELCN = F *  NZ / (Q * SREF)
      DELCLL= DELCY * (ZCENT - ZCG)/SPAN
     1        +DELCN * (YCENT - YCG)/SPAN
      DELCLM= DELCN * (XCENT - XCG)/MAC
     1        +DELCA * (ZCENT - ZCG)/MAC
      DELCLN= DELCY * (XCENT - XCG)/SPAN
     1        -DELCA * (YCENT - YCG)/SPAN
```

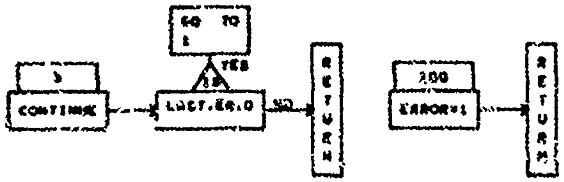
```
DECK AROZ
      CA   = CA   + DELCA                                                AROZ  0360
      CY   = CY   + DELCY                                                AROZ  0370
      CN   = CN   + DELCN                                                AROZ  0380
      CLL  = CLL  + DELCLL                                               AROZ  0390
      CLM  = CLM  + DELCLM                                               AROZ  0400
      CLN  = CLN  + DELCLN                                               AROZ  0410
      CD = CA*COS(ALPHAR)*COS(BETAR) - CY*SIN(BETAR)                     AROZ  0420
     1    +CN*SIN(ALPHAR)*COS(BETAR)                                     AROZ  0430
      CYPRIM = CA*COS(ALPHAR)*SIN(BETAR) + CY*COS(BETAR)                 AROZ  0440
     1         +CN*SIN(ALPHAR)*SIN(BETAR)                                AROZ  0450
C                                                                        AROZ  0460
C                                                                        AROZ  0470
      CL = -CA*SIN(ALPHAR) + CN*COS(ALPHAR)                              AROZ  0480
C                                                                        AROZ  0490
C                                                                        AROZ  0500
C                                                                        AROZ  0510
      LOD = CL / CD                                                      AROZ  0520
C                                                                        AROZ  0530
C    PRINT RESULTS IF REQUIRED                                           AROZ  0540
      IF (IPRINT .EQ. 0) GO TO 3                                         AROZ  0550
      IF (NPRT .LT. 4) GO TO 5                                           AROZ  0560
      CALL HEADER                                                        AROZ  0570
      WRITE (6,8)                                                        AROZ  0580
    8 FORMAT (1H0,50HRESULTS OF VECTOR CONVERSION TO FORCE COEFFICIENTS) AROZ  0590
      NPRT = 0                                                           AROZ  0600
    5 WRITE (6,9) IVCTNO                                                 AROZ  0610
    9 FORMAT (1H0,13HVECTOR NUMBER,I3)                                   AROZ  0620
      WRITE (6,10) F,XCENT,YCENT,ZCENT,NX,NY,NZ,DELCA,DELCY,DELCN,       AROZ  0630
     1  CA,CY,CN,DELCLL,DELCLM,DELCLN,CLL,CLM,CLN,CD,CL,CYPRIM,LOD       AROZ  0640
   10 FORMAT (1H ,5X,3HF =F12.1,2X6HXCENT=F7.1,2X6HYCENT=F7.1,           AROZ  0650
     1  2X6HZCENT=F7.1,/1H ,23X3HNX=F7.4,5X3HNX=F7.4,5X3HNX=F7.4,/       AROZ  0660
     2  1H ,3X8HDEL CA =E12.5,2X8HDEL CY =E12.5,2X8HDEL CN =E12.5,/      AROZ  0670
     3  1H ,3X8HTOT CA =E12.5,2X8HTOT CY =E12.5,2X8HTOT CN =E12.5,/      AROZ  0680
     4  1H0,3X8HDEL CLL=E12.5,2X8HDEL CLM=E12.5,2X8HDEL CLN=E12.5,/      AROZ  0690
     5  1H ,3X8HTOT CLL=E12.5,2X8HTOT CLM=E12.5,2X8HTOT CLN=E12.5,/      AROZ  0700
     6  1H0,6X5HC D =F9.5,8X5HC L =F9.5,7X,5HC Y =F9.5,/                 AROZ  0710
```

```
DECK AROZ

     7  1H ,6X,5HL/D =F9.3)                                         AROZ  0720
        NPRT = NPRT + 1                                              AROZ  0730
   3    IF (LAST .EQ. 0) GO TO 1                                     AROZ  0740
        RETURN                                                       AROZ  0750
 100    ERROR = 1                                                    AROZ  0760
        RETURN                                                       AROZ  0770
        END                                                          AROZ  0780
```

SUBROUTINE VECTOR




3
CONTINUE
GO TO
1
YES
IF
LACT.EQ.0
NO
RETURN
200
IERROR=1
RETURN

```
SYMBOLS USED IN SUBROUTINE VECTOR

ALPHA    R  A  ANGLE OF ATTACK, DEGREES                                   VECTOR
ALPHAR   R  U  ANGLE OF ATTACK, RADIANS                                   VECTOR
BETA     R  A  YAW ANGLE, DEGREES                                         VECTOR
BETAR    R  U  YAW ANGLE, RADIANS                                         VECTOR
CA       R  A  AXIAL FORCE COEFFICIENT                                    VECTOR
CASE     I  C  CASE NUMBER                                                VECTOR
CD       R  A  DRAG COEFFICIENT                                           VECTOR
CL       R  A  LIFT COEFFICIENT                                           VECTOR
CLL      R  A  ROLLING MOMENT COEFFICIENT                                 VECTOR
CLM      R  A  PITCHING MOMENT COEFFICIENT                                VECTOR
CLN      R  A  YAWING MOMENT COEFFICIENT                                  VECTOR
CN       R  A  NORMAL FORCE COEFFICIENT                                   VECTOR
CY       R  A  SIDE FORCE COEFFICIENT                                     VECTOR
CYPRIM   R  U  SIDE FORCE COEFFICIENT (WIND AXIS)                         VECTOR
DELCD    R  U  DRAG COEFFICIENT INCREMENT                                 VECTOR
DELCLL   R  U  ROLLING MOMENT COEFFICIENT INCREMENT                       VECTOR
DELCLM   R  U  PITCHING MOMENT COEFFICIENT INCREMENT                      VECTOR
DELCLN   R  U  YAWING MOMENT COEFFICIENT INCREMENT                        VECTOR
DELCN    R  U  NORMAL FORCE COEFFICIENT INCREMENT                         VECTOR
DELCY    R  U  SIDE FORCE COEFFICIENT INCREMENT                           VECTOR
ERROR    I  C  ERROR FLAG                                                 VECTOR
F        R  U  FORCE MAGNITUDE, POUNDS                                    VECTOR
IPRINT   I  U  PRINT FLAG                                                 VECTOR
IVCTNU   I  U  VECTOR NUMBER                                              VECTOR
LAST     I  U  LAST VECTOR FLAG                                           VECTOR
LOD      R  A  LIFT-TO-DRAG RATIO                                         VECTOR
MAC      R  A  REFERENCE LENGTH FOR MOMENT COEFFICIENTS                   VECTOR
MACH     R  A  MACH NUMBER                                                VECTOR
NPRT     I  U  PRINT LINE COUNTER                                         VECTOR
NX       R  U  FORCE VECTOR DIRECTION COSINE IN X-DIRECTION               VECTOR
NY       R  U  FORCE VECTOR DIRECTION COSINE IN Y-DIRECTION               VECTOR
NZ       R  U  FORCE VECTOR DIRECTION COSINE IN Z-DIRECTION               VECTOR
PAGE     I  C  PAGE NUMBER                                                VECTOR
PFS      R  A  FREE-STREAM PRESSURE, LBS/SQUARE FOOT                      VECTOR
Q        R  U  DYNAMIC PRESSURE                                           VECTOR
ROLLR    R  U  ROLL ANGLE IN RADIANS                                      VECTOR
```

```
SYMBOLS USED IN SUBROUTINE VECTOR

SPAN     R  A  REFERENCE LENGTH FOR ROLLING & YAWING COEFFICIENTS             VECTOR
SREF     R  A  VEHICLE REFERENCE AREA (WING AREA)                             VECTOR
TITLE    R  C  TITLE                                                          VECTOR
TYPE     I  U  CARD TYPE NUMBER                                               VECTOR
XCENT    R  U  ACTION POINT FOR FORCE VECTOR-X                                VECTOR
XCG      R  A  X-CENTER FOR MOMENT CALCULATIONS                               VECTOR
YCENT    R  U  ACTION POINT FOR FORCE VECTOR-Y                                VECTOR
YCG      R  A  Y-CENTER FOR MOMENT CALCULATIONS                               VECTOR
ZCENT    R  U  ACTION POINT FOR FORCE VECTOR-Z                                VECTOR
ZCG      R  A  Z-CENTER FOR MOMENT CALCULATIONS                               VECTOR
```

28. SUBROUTINE GRAPIC (DECK GRPA)

This is the Executive routine for the graphics part of the program.

a. Algorithm

Print that GRAPHIC OPTION HAS CONTROL and select the proper graphic routine depending upon the value of IPROG.

b. Input/Output

None

c. Error

None

d. Subroutines Required

PICTUR, PLOT

e. Argument List

(IPROG)

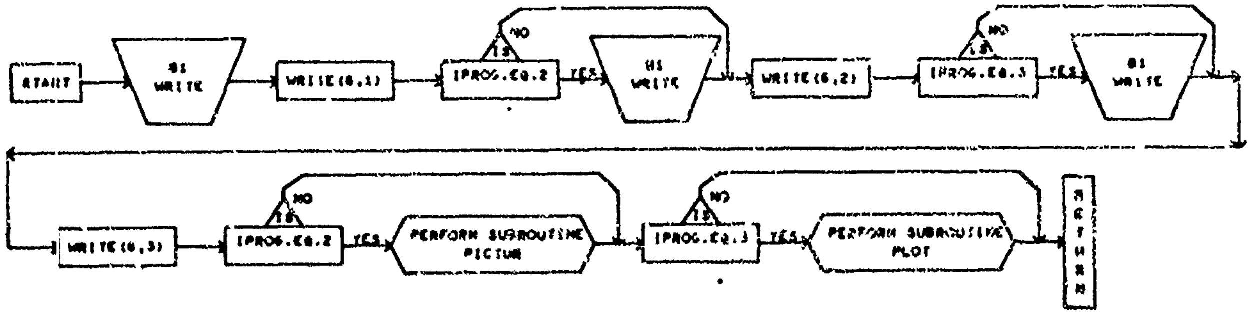
f. Length

536 bytes

```
DECK GRPA

      SUBROUTINE GRAPIC (IPROG)                                                GRPA  0010
C                                                                              GRPA  0020
      COMMON CASE,TITLE,PAGE,ERROR                                             GRPA  0030
      DIMENSION  TITLE(15)                                                     GRPA  0040
      INTEGER  ERROR,CASE,PAGE                                                 GRPA  0050
C                                                                              GRPA  0060
C***** GRAPHIC OUTPUT DATA CONTROL PROGRAM ******************                  GRPA  0070
C                                                                              GRPA  0080
C                                                                              GRPA  0090
      WRITE (6,1)                                                              GRPA  0100
    1 FORMAT (1H ,///,1H ,38H***** GRAPHIC OPTION HAS CONTROL ***** )          GRPA  0110
      IF (IPROG .EQ. 2) WRITE (6,2)                                            GRPA  0120
    2 FORMAT (1H0,10X,40HPICTURE DRAWING PROGRAM WILL BE EXECUTED  )           GRPA  0130
      IF (IPROG .EQ. 3) WRITE (6,3)                                            GRPA  0140
    3 FORMAT (1H0,10X,44HOUTPUT DATA PLOTTER PROGRAM WILL BE EXECUTED )        GRPA  0150
C                                                                              GRPA  0160
      IF (IPROG.EQ. 2) CALL PICTUR                                             GRPA  0170
C                                                                              GRPA  0180
      IF (IPROG .EQ. 3) CALL PLOT                                              GRPA  0190
C                                                                              GRPA  0200
      RETURN                                                                   GRPA  0210
      END                                                                      GRPA  0220
```

SUBROUTINE GRAPIC



```
SYMBOLS USED IN SUBROUTINE GRAPIC

CASE     I  C   CASE NUMBER                                                                          GRAPIC
ERROR    I  C   ERROR FLAG                                                                           GRAPIC
IPROG    I  A   PROGRAM OPTION NUMBER                                                                GRAPIC
PAGE     I  C   PAGE NUMBER                                                                          GRAPIC
TITLE    R  C   TITLE                                                                                GRAPIC
```

29. SUBROUTINE PICTUR (DECK GRPB)

This routine prepares an output tape for procession on the SC-4020. The result will be pictures of the vehicle with the selected viewing angles.

a. Algorithm

Read the Picture Drawing Program Element Data Title Card (Type 31) and the Element Data Control Card (Type 32). Read the surface element data either from Tape 5 or from Tape 8 as directed. Read plotting instruction data (Card Types 34, 35, 36, and 37). Set up starting constants for pictures. Read element data from Tape 3 using the same techniques as for SDATA and convert to quadrilaterals. Generate scale grids if required. Plot points and draw lines between the points as directed by the input data. Print the detailed element characteristics if PRINTS is equal to 1.

b. Input/Output

Element Data Title Card (Type 31), Element Data Control Card (Type 32), Element Data Cards from Tape 5 or Tape 8 (Type 3), Picture Control Data Card (Type 34), Grid Data Card (Type 35), Scale Label Card (Type 36), and Plot Title Card(s) (Type 37). If PRINTS is equal to 1 the detailed element characteristics will be printed on Tape 6 (just as is the case for SDATA).

c. Error

An error condition occurs if a card type number is wrong.

d. Subroutines Required

HEADR2, SC-4020 routines

e. Argument List

None

f. Length

16180 bytes

```
DECK GRPB

      SUBROUTINE PICTUR                                                 GRPB  0010
C      SC-4020 PLOTTER PROGRAM FOR PLOTTING SURFACE DATA                GRPB  0020
C                                                                       GRPB  0030
C                                                                       GRPB  0040
       DIMENSION  XA(250),XB(250),YA(250),YB(250),ZA(250),ZB(250),      GRPB  0050
      1 XI(4),ETA(4),XIN(4),YIN(4),ZIN(4),VTITLE(8),HTITLE(8),HLABEL(15), GRPB  0060
      2 YIN2(4),ZIN2(4),CARD(20),TITLE(15)                              GRPB  0070
C                                                                       GRPB  0080
       COMMON  CASE,TITLE,PAGE,ERROR                                    GRPB  0090
C                                                                       GRPB  0100
       REAL  NX,NY,NZ,NXO                                               GRPB  0110
       LOGICAL  RFLAG, AFLAG, BFLAG                                     GRPB  0120
       INTEGER  STAT,STATT,TYPE,PRINTS,SYMFCT,CASE,PAGE,ERROR           GRPB  0130
C                                                                       GRPB  0140
C                                                                       GRPB  0150
       FIRST(QX,QY,QZ,Q1,Q2,Q3) = QX*Q1 + QY*Q2 + QZ*Q3                 GRPB  0160
C                                                                       GRPB  0170
      THIRD(QX,QY,QZ,QPSI,QTHETA,QPHI) = QX*(COS(QTHETA)*COS(QPSI)) +   GRPB  0180
      1  QY*(-SIN(QPSI)*COS(QPHI)+SIN(QTHETA)*COS(QPSI)*SIN(QPHI)) +    GRPB  0190
      2  QZ*(SIN(QPSI)*SIN(QPHI)+SIN(QTHETA)*COS(QPSI)*COS(QPHI))       GRPB  0200
C                                                                       GRPB  0210
      CALL CAMRAV (9)                                                   GRPB  0220
      IDUN = -1                                                         GRPB  0230
      REWIND 2                                                          GRPB  0240
      CALL INCRV (6,3)                                                  GRPB  0250
      IPIC = 1                                                          GRPB  0260
    2 REWIND 3                                                          GRPB  0270
C  READ ALL INPUT DATA AND STORE ON TAPE 3 FOR FUTURE USE               GRPB  0280
      READ(5,100) (TITLE(I),I=1,15),CASE,TYPE                           GRPB  0290
  100 FORMAT(14A4,A3,6X,I3,2XI2)                                        GRPB  0300
      IF (TYPE .NE. 99) GO TO 301                                       GRPB  0310
      ERROR = 0                                                         GRPB  0320
      RETURN                                                            GRPB  0330
  301 IF (TYPE .NE. 51) GO TO 300                                       GRPB  0340
      READ(5,101) PRINTS,SYMFCT,IORIEN,IFACT,XSC,YSC,ZSC,DELX,DELY,DELZ, GRPB  0350
```

```
DECK GRPB

     1      ISTAT3,ITAPE,IREW8,TYPE                                       GRPB  0360
 101  FORMAT (I1,1XI1,2I1,1X3F6.0,1X3F6.0,16XI2,2I1,7XI2)                 GRPB  0370
      IF (TYPE .NE. 32) GO TO 300                                         GRPB  0380
      IF (IREW8 .EQ. 0) REWIND 8                                          GRPB  0390
      IF (SYMFCT .EQ. 0) SYMFCT = 2                                       GRPB  0400
      IA = 0                                                              GRPB  0410
      IB = 0                                                              GRPB  0420
      IF (IORIEN .EQ. 2) IB = 1                                           GRPB  0430
      IF (IORIEN .EQ. 3) IA = 1                                           GRPB  0440
    3 IF (ITAPE.EQ.0) READ (5,1) X,Y,Z,STAT,XX,YY,ZZ,STATT,TYPE           GRPB  0450
      IF (ITAPE.NE.0) READ (8,1) X,Y,Z,STAT,XX,YY,ZZ,STATT,TYPE           GRPB  0460
    1 FORMAT (2(3F10.0,I1),8XI2 )                                         GRPB  0470
      IF (TYPE.NE.3 .AND. ITAPE.EQ.0) GO TO 300                           GRPB  0480
      IF (TYPE.NE.3 .AND. ITAPE.NE.0) GO TO 806                           GRPB  0490
C                                                                         GRPB  0500
      IF (IFACT.EQ.0) GO TO 10                                            GRPB  0510
        X = X * XSC + DELX                                                GRPB  0520
        XX= XX* XSC + DELX                                                GRPB  0530
        Y = Y * YSC + DELY                                                GRPB  0540
        YY= YY* YSC + DELY                                                GRPB  0550
        Z = Z * ZSC + DELZ                                                GRPB  0560
        ZZ= ZZ* ZSC + DELZ                                                GRPB  0570
   10 IF (STAT.EQ.3 .OR. STATT.EQ.3 .AND. ISTAT3.GT.0) ISTAT3 = ISTAT3-1  GRPB  0580
      IF (STAT.EQ.3 .AND. ISTAT3.GT.0) STAT = 0                           GRPB  0590
      IF (STATT.EQ.3 .AND. ISTAT3.GT.0) STATT = 0                         GRPB  0600
      WRITE (3) X,Y,Z,STAT,XX,YY,ZZ,STATT                                 GRPB  0610
      IF (STAT.EQ.3 .OR. STATT.EQ.3) GO TO 4                              GRPB  0620
      GO TO 3                                                             GRPB  0630
    4 WRITE (6,4016) IPIC                                                 GRPB  0640
 4016 FORMAT (1H1,////,1H0,34HPICTURE DRAWING PROGRAM    PICTURE          GRPB  0650
     1     7H NUMBER ,I4)                                                 GRPB  0660
      IPIC = IPIC + 1                                                     GRPB  0670
C                                                                         GRPB  0680
C  READ PLOTTING INSTRUCTIONS                                             GRPB  0690
      READ (5,5) PSI,THETA,PHI,ICS,IREFL,ISHAD,IAREA,IQUAD,IFRAME,NCAM,   GRPB  0700
     1  MARKPT,NG,MG,IG,JG,NXG,NYG,LAST,TYPE                              GRPB  0710
```

```
DECK GRPB
    5  FORMAT (F6.0,1XF6.0,1XF6.0,6(1XI1),2(1XI2),2X2I3,1X2I3,1X2I2,        GRPB  0720
     1  1XI1,10XI2 )                                                           GRPB  0730
       IF (TYPE .NE. 34) GO TO 300                                             GRPB  0740
       READ (5,6) XLG,XRG,YBG,YTG,DXG,DYG,NOSCAL,TYPE                          GRPB  0750
    6  FORMAT (5F10.0,F9.0,I1,10XI2)                                           GRPB  0760
       IF (TYPE .NE. 35) GO TO 300                                             GRPB  0770
       IF (NOSCAL .EQ. 1) GO TO 8                                              GRPB  0780
       READ (5,7) (VTITLE(I),I=1,8),(HTITLE(I),I=1,8),TYPE                     GRPB  0790
    7  FORMAT (7A4,A2,7A4,A1,11XI2)                                            GRPB  0800
       IF (TYPE .NE. 36) GO TO 300                                             GRPB  0810
C                                                                              GRPB  0820
    8  CALL CAMRAV (NCAM)                                                      GRPB  0830
       CALL FRAMEV (0)                                                         GRPB  0840
C                                                                              GRPB  0850
C      SET UP STARTING CONSTANTS                                               GRPB  0860
       IFADV = 1                                                               GRPB  0870
       ISTART = 0                                                              GRPB  0880
       PSI   =  PSI   / 57.2957795                                             GRPB  0890
       THETA =  THETA / 57.2957795                                             GRPB  0900
       PHI   =  PHI   / 57.2957795                                             GRPB  0910
       SINTH = SIN(THETA)                                                      GRPB  0920
       COSTH = COS(THETA)                                                      GRPB  0930
       SINPSI= SIN(PSI)                                                        GRPB  0940
       COSPSI= COS(PSI)                                                        GRPB  0950
       SINPHI= SIN(PHI)                                                        GRPB  0960
       COSPHI= COS(PHI)                                                        GRPB  0970
       A1 = COSTH * SINPSI                                                     GRPB  0980
       A2 = COSPSI*COSPHI + SINTH*SINPSI*SINPHI                                GRPB  0990
       A3 =-COSPSI*SINPHI + SINTH*SINPSI*COSPHI                                GRPB  1000
       A4 =-SINTH                                                              GRPB  1010
       A5 = COSTH*SINPHI                                                       GRPB  1020
       A6 = COSTH*COSPHI                                                       GRPB  1030
       A7 = COSTH*COSPSI                                                       GRPB  1040
       A8 =-SINPSI*COSPHI + SINTH*COSPSI*SINPHI                                GRPB  1050
       A9 = SINPSI*SINPHI + SINTH*COSPSI*COSPHI                                GRPB  1060
        N = -1                                                                 GRPB  1070
```

```
DECK GRPB
      NN = - 1                                                          GRPB  1080
       KLCT = 0                                                         GRPB  1090
       L = 0                                                            GRPB  1100
       NPRT = 10                                                        GRPB  1110
       AREAT = 0.0                                                      GRPB  1120
       VOL = 0.0                                                        GRPB  1130
      REWIND 3                                                          GRPB  1140
C                                                                       GRPB  1150
C                                                                       GRPB  1160
C     READ IN ALL SURFACE DATA                                          GRPB  1170
   29 READ (3) X,Y,Z,STAT, XX,YY,ZZ,STATT                               GRPB  1180
       RFLAG = .FALSE.                                                  GRPB  1190
       GO TO 80                                                         GRPB  1200
   30 IF (RFLAG) GO TO 50                                               GRPB  1210
       RFLAG = .TRUE.                                                   GRPB  1220
       X = XX                                                           GRPB  1230
       Y = YY                                                           GRPB  1240
       Z = ZZ                                                           GRPB  1250
       STAT = STATT                                                     GRPB  1260
       GO TO 60                                                         GRPB  1270
   50 RFLAG = .FALSE.                                                   GRPB  1280
      READ (3) X,Y,Z,STAT, XX,YY,ZZ,STATT                               GRPB  1290
   60 IF (STAT .EQ. 0 .OR. STAT .EQ. 3) GO TO 180                       GRPB  1300
      IF (STAT .EQ. 2) GO TO 200                                        GRPB  1310
   70 IF (.NOT. AFLAG) GO TO 200                                        GRPB  1320
       MC = M                                                           GRPB  1330
   80 K = 1                                                             GRPB  1340
       IF (STAT .EQ. 2) GO TO 150                                       GRPB  1350
       IF (.NOT. BFLAG) GO TO 84                                        GRPB  1360
   75 DO 81 J =1,MC                                                     GRPB  1370
         XA(J) = XB(J)                                                  GRPB  1380
         YA(J) = YB(J)                                                  GRPB  1390
   81    ZA(J) = ZB(J)                                                  GRPB  1400
   83 XB(1) = X                                                         GRPB  1410
      YB(1) = Y                                                         GRPB  1420
      ZB(1) = Z                                                         GRPB  1430
```

```
DECK GRPB

      GO TO 30                                                          GRPB  1440
   34 IF (AFLAG) GO TO 85                                               GRPB  1450
       BFLAG = .TRUE.                                                   GRPB  1460
       GO TO 75                                                         GRPB  1470
   85 AFLAG = .FALSE.                                                   GRPB  1480
       GO TO 83                                                         GRPB  1490
  150 AFLAG = .TRUE.                                                    GRPB  1500
       BFLAG = .FALSE.                                                  GRPB  1510
       N = N+1                                                          GRPB  1520
  160 XA(M) = X                                                         GRPB  1530
      YA(M) = Y                                                         GRPB  1540
      ZA(M) = Z                                                         GRPB  1550
      GO TO 30                                                          GRPB  1560
  180 M = M + 1                                                         GRPB  1570
      IF (AFLAG) GO TO 160                                              GRPB  1580
       XB(M) = X                                                        GRPB  1590
       YB(M) = Y                                                        GRPB  1600
       ZB(M) = Z                                                        GRPB  1610
      IF (STAT .NE. 3) GO TO 30                                         GRPB  1620
  200 MMIN = MINO (M,MC) - 1                                            GRPB  1630
       NN2 = 1                                                          GRPB  1640
       MC = M                                                           GRPB  1650
  250 N = N + 1                                                         GRPB  1660
      NN = NN + 1                                                       GRPB  1670
       KLCT = KLCT + 1                                                  GRPB  1680
C                                                                       GRPB  1690
C                                                                       GRPB  1700
C  BEGIN COMPUTATION OF SURFACE ELEMENT CHARACTERISTICS                 GRPB  1710
C                                                                       GRPB  1720
  450 DO 2000 I= 1,MMIN                                                 GRPB  1730
      IIA = I + IA                                                      GRPB  1740
      IIB = I + IB                                                      GRPB  1750
        XIN(1) = XA(IIA )                                               GRPB  1760
        XIN(2) = XA(IIA +1)                                             GRPB  1770
        XIN(3) = XB(IIB +1)                                             GRPB  1780
        XIN(4) = XB(IIB )                                               GRPB  1790
```

DECK GRPB

```
         YIN(1) = YA(IIA )                                             GRPB  1800
         YIN(2) = YA(IIA +1)                                           GRPB  1810
         YIN(3) = YB(IIB +1)                                           GRPB  1820
         YIN(4) = YB(IIB )                                             GRPB  1830
         ZIN(1) = ZA(IIA )                                             GRPB  1840
         ZIN(2) = ZA(IIA +1)                                           GRPB  1850
         ZIN(3) = ZB(IIB +1)                                           GRPB  1860
         ZIN(4) = ZB(IIB )                                             GRPB  1870
         IRFLG = 0                                                     GRPB  1880
C                                                                      GRPB  1890
C  FORM DIAGONAL VECTORS                                               GRPB  1900
        T1X = XIN(3) - XIN(1)                                          GRPB  1910
        T2X = XIN(4) - XIN(2)                                          GRPB  1920
        T1Y = YIN(3) - YIN(1)                                          GRPB  1930
        T2Y = YIN(4) - YIN(2)                                          GRPB  1940
        T1Z = ZIN(3) - ZIN(1)                                          GRPB  1950
        T2Z = ZIN(4) - ZIN(2)                                          GRPB  1960
C                                                                      GRPB  1970
C  FORM CROSS PRODUCT  N=T2 X T1                                       GRPB  1980
        NX = T2Y*T1Z - T1Y*T2Z                                         GRPB  1990
        NY = T1X*T2Z - T2X*T1Z                                         GRPB  2000
        NZ = T2X*T1Y - T1X*T2Y                                         GRPB  2010
        VN = SQRT ( NX*NX + NY*NY + NZ*NZ )                            GRPB  2020
C                                                                      GRPB  2030
C  FORM UNIT NORMAL VECTOR                                             GRPB  2040
       IF (VN .EQ. 0.0) GO TO 421                                      GRPB  2050
       NX = NX / VN                                                    GRPB  2060
        NY = NY / VN                                                   GRPB  2070
        NZ = NZ / VN                                                   GRPB  2080
C                                                                      GRPB  2090
C  COMPUTE AVERAGE POINT                                               GRPB  2100
 421  AVX = 0.25 * (XIN(1) + XIN(2) + XIN(3) + XIN(4) )                GRPB  2110
        AVY = 0.25 * (YIN(1) + YIN(2) + YIN(3) + YIN(4) )              GRPB  2120
        AVZ = 0.25 * (ZIN(1) + ZIN(2) + ZIN(3) + ZIN(4) )              GRPB  2130
C                                                                      GRPB  2140
C  COMPUTE PROJECTION DISTANCE                                         GRPB  2150
```

```
DECK  GRPB

      D = NX*(AVX - XIN(1)) + NY*(AVY - YIN(1)) + NZ*(AVZ-ZIN(1))          GRPB  2160
      PD = ABS(D)                                                          GRPB  2170
C                                                                          GRPB  2180
C                                                                          GRPB  2190
      T = SQRT (T1X*T1X + T1Y*T1Y + T1Z*T1Z)                               GRPB  2200
     IF (T .EQ. 0.0) GO TO 431                                             GRPB  2210
     T1X = T1X / T                                                         GRPB  2220
      T1Y = T1Y / T                                                        GRPB  2230
      T1Z = T1Z / T                                                        GRPB  2240
C                                                                          GRPB  2250
C                                                                          GRPB  2260
 431 T2X = NY*T1Z - NZ*T1Y                                                 GRPB  2270
      T2Y = NZ*T1X - NX*T1Z                                                GRPB  2280
      T2Z = NX*T1Y - NY*T1X                                                GRPB  2290
C                                                                          GRPB  2300
C  COMPUTE COORDINATES OF CORNER POINTS IN REFERENCE COORD. SYSTEM         GRPB  2310
C                                                                          GRPB  2320
     DO 1000 J = 1,4                                                       GRPB  2330
      XPA= XIN(J) + NX*D                                                   GRPB  2340
      YPA= YIN(J) + NY*D                                                   GRPB  2350
      ZPA= ZIN(J) + NZ*D                                                   GRPB  2360
C                                                                          GRPB  2370
     IF (IQUAD .EQ. 0) GO TO 470                                           GRPB  2380
       XIN(J) = XPA                                                        GRPB  2390
       YIN(J) = YPA                                                        GRPB  2400
       ZIN(J) = ZPA                                                        GRPB  2410
C                                                                          GRPB  2420
 470  D = - D                                                              GRPB  2430
      XDIF = XPA- AVX                                                      GRPB  2440
      YDIF = YPA- AVY                                                      GRPB  2450
      ZDIF = ZPA- AVZ                                                      GRPB  2460
C                                                                          GRPB  2470
C  TRANSFORM CORNER POINTS TO ELEMENT COORDINATE SYSTEM (XI,ETA) WITH      GRPB  2480
C   AVERAGE POINT AS ORIGIN                                                GRPB  2490
      XI(J) = T1X*XDIF + T1Y*YDIF + T1Z*ZDIF                               GRPB  2500
 1000 ETA(J)= T2X*XDIF + T2Y*YDIF + T2Z*ZDIF                               GRPB  2510
```

```
DECK GRPB
C                                                                       GRPB  2520
C  COMPUTE CENTROID                                                     GRPB  2530
      ETACK = ETA(2) - ETA(4)                                           GRPB  2540
      IF (ETACK .NE. 0.0) GO TO 432                                     GRPB  2550
       XIO = 0.0                                                        GRPB  2560
       GO TO 433                                                        GRPB  2570
 432  XIO = .333333333 * (XI(4) * (ETA(1)-ETA(2)) + XI(2)               GRPB  2580
     1      * (ETA(4)-ETA(1))) / (ETA(2)-ETA(4))                        GRPB  2590
 433  ETAO = -.333333333 * ETA(1)                                       GRPB  2600
C                                                                       GRPB  2610
C  OBTAIN CORNER POINTS IN SYSTEM WITH CENTROID AS ORIGIN               GRPB  2620
       DO 1020 J = 1,4                                                  GRPB  2630
        XI(J) = XI(J) - XIO                                             GRPB  2640
 1020   ETA(J) = ETA(J) - ETAO                                          GRPB  2650
C                                                                       GRPB  2660
C  TRANSFORM CENTROID TO REFERENCE COORDINATE SYSTEM                    GRPB  2670
       XCENT = AVX + T1X*XIO + T2X*ETAO                                 GRPB  2680
       YCENT = AVY + T1Y*XIO + T2Y*ETAO                                 GRPB  2690
       ZCENT = AVZ + T1Z*XIO + T2Z*ETAO                                 GRPB  2700
C                                                                       GRPB  2710
C  CONSTANTS                                                            GRPB  2720
       XI3M1 = XI(3) - XI(1)                                            GRPB  2730
       ETA2M4 = ETA(2) - ETA(4)                                         GRPB  2740
C                                                                       GRPB  2750
C  COMPUTE AREA AND VOLUME OF ELEMENTS                                  GRPB  2760
       AREA = 0.5 * XI3M1 * ETA2M4                                      GRPB  2770
      AREAT = AREAT + AREA                                              GRPB  2780
       DELVOL = AREA * NY * YCENT                                       GRPB  2790
      VOL = VOL + DELVOL                                                GRPB  2800
      L = L + 1                                                         GRPB  2810
      IF (PRINTS.EQ.0) GO TO 1770                                       GRPB  2820
C  PRINT RESULTS OF CALCULATIONS TO DETERMINE ELEMENT CHARACTERISTICS   GRPB  2830
 1700 IF (NPRT.GE.9) GO TO 1750                                         GRPB  2840
       NPRT = NPRT + 1                                                  GRPB  2850
      IF (I .EQ. 1) GO TO 1760                                          GRPB  2860
       WRITE (6,4005) I, XIN, NX, XCENT, AREA,L,YIN,NY,YCENT,DELVOL,ZIN, GRPB  2870
```

DECK GRPB

```
      1  NZ,ZCENT,VOL                                                    GRPB  2880
       GO TO 1770                                                        GRPB  2890
 1750 NPRT = 0                                                           GRPB  2900
       CALL HEADR2                                                       GRPB  2910
       WRITE (6,4002)                                                    GRPB  2920
 1760 WRITE (6, 4010) N, I, XIN, NX, XCENT, AREA,L,YIN,NY,YCENT,DELVOL,  GRPB  2930
      1 ZIN,NZ,ZCENT,VOL                                                 GRPB  2940
 1770 IF (AREA .LT. 0.1E-09) GO TO 2000                                  GRPB  2950
C                                                                        GRPB  2960
C  CHECK IF NEW GRID IS REQUIRED AND PREPARE GRID                        GRPB  2970
       IF (IFADV .EQ. 0) GO TO 471                                       GRPB  2980
C                                                                        GRPB  2990
       IF (NOSCAL .EQ. 0) GO TO 505                                      GRPB  3000
        CALL STOPTV                                                      GRPB  3010
        CALL BRITEV                                                      GRPB  3020
        CALL XSCALV (XLG,XRG,24,0)                                       GRPB  3030
        CALL YSCALV (YBG,YTG,0,24)                                       GRPB  3040
        GO TO 511                                                        GRPB  3050
 505   CALL GRIDIV (2,XLG,XRG,YBG,YTG,DXG,DYG,NG,MG,IG,JG,NXG,NYG)       GRPB  3060
       DO 510 II=1,3                                                     GRPB  3070
 510   CALL APRNTV (0,-12,30,VTITLE,8,689)                               GRPB  3080
       DO 520 II=1,3                                                     GRP3  3090
 520   CALL PRINTV (29,HTITLE,391,8)                                     GRPB  3100
 511   IF (IFRAME.EQ.1 .AND. ISTART.EQ.1) GO TO 521                      GRPB  3110
       READ (5,522) (HLABEL(II),II=1,15),TYPE                            GRPB  3120
 522   FORMAT(14A4,1A3,11XI2)                                            GRPB  3130
       IF (TYPE .NE. 37) GO TO 300                                       GRPB  3140
       ISTART = 1                                                        GRPB  3150
 521   DO 523 II=1,3                                                     GRPB  3160
       CALL PRINTV (-45,45HHYPERSONIC ARBITRARY-BODY AERODYNAMIC PROGRAM, GRPB  3170
      1  330,1023)                                                       GRPB  3180
 523   CALL PRINTV (59,HLABEL,249,1007)                                  GRPB  3190
       IF (IFRAME .NE. 1) GO TO 525                                      GRPB  3200
       CALL SCSETV (4)                                                   GRPB  3210
       WRITE (16,524) XIN(1),XIN(4)                                      GRPB  3220
 524   FORMAT (1H ,10X11HSTATIONS  =F9.3,8H   AND =F9.3 )                GRPB  3230
```

```
DECK GRPB

 525  IFADV = 0                                                     GRPB  3240
C                                                                   GRPB  3250
 471  NXO = THIRD(NX,NY,NZ,PSI,THETA,PHI)                           GRPB  3260
      IF (NXO.LE.0.0 .AND. ISHAD.EQ.0) GO TO 571                    GRPB  3270
C                                                                   GRPB  3280
C                                                                   GRPB  3290
C  CALCULATE POINTS TO BE PLOTTED                                   GRPB  3300
 530  YO1 = FIRST(XIN(1),YIN(1),ZIN(1),A1,A2,A3)                    GRPB  3310
      YO2 = FIRST(XIN(2),YIN(2),ZIN(2),A1,A2,A3)                    GRPB  3320
      YO3 = FIRST(XIN(3),YIN(3),ZIN(3),A1,A2,A3)                    GRPB  3330
      YO4 = FIRST(XIN(4),YIN(4),ZIN(4),A1,A2,A3)                    GRPB  3340
      ZO1 = FIRST(XIN(1),YIN(1),ZIN(1),A4,A5,A6)                    GRPB  3350
      ZO2 = FIRST(XIN(2),YIN(2),ZIN(2),A4,A5,A6)                    GRPB  3360
      ZO3 = FIRST(XIN(3),YIN(3),ZIN(3),A4,A5,A6)                    GRPB  3370
      ZO4 = FIRST(XIN(4),YIN(4),ZIN(4),A4,A5,A6)                    GRPB  3380
C                                                                   GRPB  3390
      YIN2(1) = YO1                                                 GRPB  3400
      YIN2(2) = YO2                                                 GRPB  3410
      YIN2(3) = YO3                                                 GRPB  3420
      YIN2(4) = YO4                                                 GRPB  3430
      ZIN2(1) = ZO1                                                 GRPB  3440
      ZIN2(2) = ZO2                                                 GRPB  3450
      ZIN2(3) = ZO3                                                 GRPB  3460
      ZIN2(4) = ZO4                                                 GRPB  3470
C                                                                   GRPB  3480
      CALL APLOTV (4,YIN2,ZIN2,1,1,1,MARKPT,IERR)                   GRPB  3490
C                                                                   GRPB  3500
      IF (ICS .EQ. 3) GO TO 571                                     GRPB  3510
C                                                                   GRPB  3520
      IF (ICS.EQ.0 .OR. ICS.EQ.1) GO TO 540                         GRPB  3530
       GO TO 541                                                    GRPB  3540
 540   IX1 = NXV(YO1)                                               GRPB  3550
       IY1 = NYV(ZO1)                                               GRPB  3560
      CALL SCERRV (KX,KY)                                           GRPB  3570
       IX2 = NXV(YO2)                                               GRPB  3580
       IY2 = NYV(ZO2)                                               GRPB  3590
```

```
DECK GRPB
      CALL SCERRV (KX1,KY1)                                            GRPB  3600
      KKXY = KX+KY+KX1+KY1                                             GRPB  3610
      IF (KKXY.NE.0) GO TO 541                                         GRPB  3620
      IF (NXO.GT.0.0) CALL LINEV (IX1,IY1,IX2,IY2)                     GRPB  3630
      IF (NXO.LE.0.0) CALL DOTLNV(IX1,IY1,IX2,IY2)                     GRPB  3640
C                                                                      GRPB  3650
  541 IF (ICS.EQ.0 .OR. ICS.EQ.2 .OR. ICS.EQ.4) GO TO 550              GRPB  3660
       GO TO 551                                                       GRPB  3670
  550  IX1 = NXV(YO2)                                                  GRPB  3680
       IY1 = NYV(ZO2)                                                  GRPB  3690
      CALL SCERRV (KX,KY)                                              GRPB  3700
       IX2 = NXV(YO3)                                                  GRPB  3710
       IY2 = NYV(ZO3)                                                  GRPB  3720
      CALL SCERRV (KX1,KY1)                                            GRPB  3730
      KKXY = KX+KY+KX1+KY1                                             GRPB  3740
      IF (KKXY.NE.0) GO TO 551                                         GRPB  3750
      IF (NXO.GT.0.0) CALL LINEV (IX1,IY1,IX2,IY2)                     GRPB  3760
      IF (NXO.LE.0.0) CALL DOTLNV(IX1,IY1,IX2,IY2)                     GRPB  3770
C                                                                      GRPB  3780
  551 IF (ICS.EQ.0 .OR. ICS.EQ.1 .OR. ICS.EQ.4) GO TO 560              GRPB  3790
       GO TO 561                                                       GRPB  3800
  560  IX1 = NXV(YO3)                                                  GRPB  3810
       IY1 = NYV(ZO3)                                                  GRPB  3820
      CALL SCERRV (KX,KY)                                              GRPB  3830
       IX2 = NXV(YO4)                                                  GRPB  3840
       IY2 = NYV(ZO4)                                                  GRPB  3850
      CALL SCERRV (KX1,KY1)                                            GRPB  3860
      KKXY = KX+KY+KX1+KY1                                             GRPB  3870
      IF (KKXY.NE.0) GO TO 561                                         GRPB  3880
      IF (NXO.GT.0.0) CALL LINEV (IX1,IY1,IX2,IY2)                     GRPB  3890
      IF (NXO.LE.0.0) CALL DOTLNV(IX1,IY1,IX2,IY2)                     GRPB  3900
C                                                                      GRPB  3910
  561 IF (ICS.EQ.0 .OR. ICS.EQ.2) GO TO 570                            GRPB  3920
       GO TO 571                                                       GRPB  3930
  570  IX1 = NXV(YO1)                                                  GRPB  3940
       IY1 = NYV(ZO1)                                                  GRPB  3950
```

```
DECK GRPB

      CALL SCERRV (KX,KY)                                          GRPB  3960
       IX2 = NXV(Y04)                                              GRPB  3970
       IY2 = NYV(Z04)                                              GRPB  3980
      CALL SCERRV (KX1,KY1)                                        GRPB  3990
      KKXY = KX+KY+KX1+KY1                                         GRPB  4000
      IF (KKXY.NE.0) GO TO 571                                     GRPB  4010
      IF (NXO.GT.0.0) CALL LINEV (IX1,IY1,IX2,IY2)                 GRPB  4020
      IF (NXO.LE.0.0) CALL DOTLNV(IX1 IY1,IX2,IY2)                 GRPB  4030
C                                                                  GRPB  4040
 571  IF (IREFL .EQ. 0 .OR. IRFLG .EQ. 3) GO TO 2000               GRPB  4050
      IF (IREFL .EQ. 2 .AND. IRFLG .EQ. 1) GO TO 600               GRPB  4060
      IF (IREFL .EQ. 2 .AND. IRFLG .EQ. 2) GO TO 602               GRPB  4070
C                                                                  GRPB  4080
C     REFLECT QUADRANT I ELEMENTS TO QUADRANT II                   GRPB  4090
      DO 580 II = 1,4                                              GRPB  4100
 580   YIN(II) = -YIN(II)                                          GRPB  4110
       NY = -NY                                                    GRPB  4120
       GO TO 604                                                   GRPB  4130
C                                                                  GRPB  4140
C     REFLECT QUADRANT II ELEMENTS TO QUADRANT IV                  GRPB  4150
 600  DO 601 II = 1,4                                              GRPB  4160
       YIN(II) = -YIN(II)                                          GRPB  4170
 601   ZIN(II) = -ZIN(II)                                          GRPB  4180
       NY = -NY                                                    GRPB  4190
       NZ = -NZ                                                    GRPB  4200
       GO TO 604                                                   GRPB  4210
C                                                                  GRPB  4220
C     REFLECT QUADRANT IV ELEMENTS TO QUADRANT III                 GRPB  4230
 602  DO 603 II = 1,4                                              GRPB  4240
 603   YIN(II) = -YIN(II)                                          GRPB  4250
       NY = -NY                                                    GRPB  4260
C                                                                  GRPB  4270
C                                                                  GRPB  4280
 604  IRFLG = IRFLG + 1                                            GRPB  4290
      IF (IREFL .EQ. 1) IRFLG = 3                                  GRPB  4300
      GO TO 471                                                    GRPB  4310
```

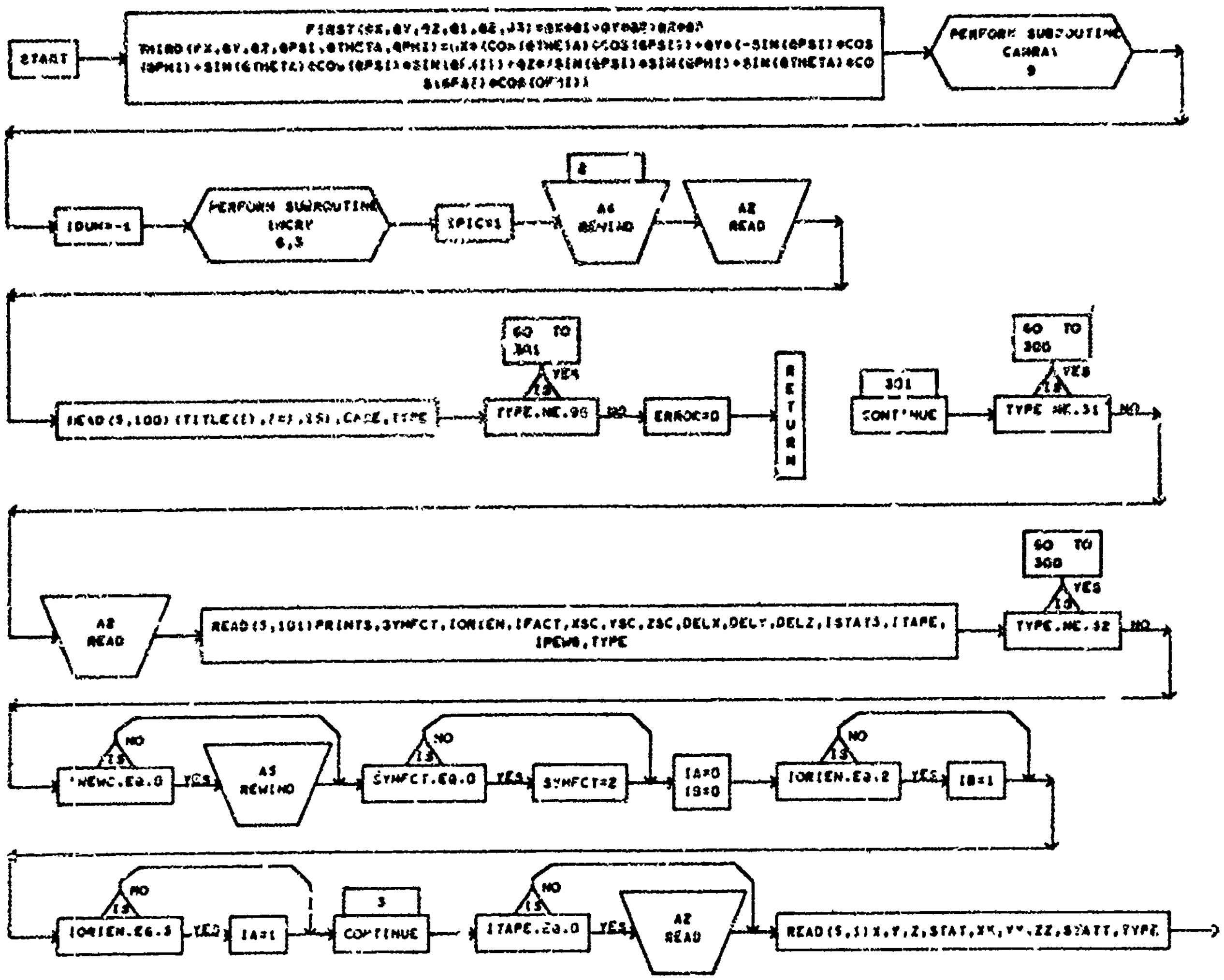
```
DECK GRPB

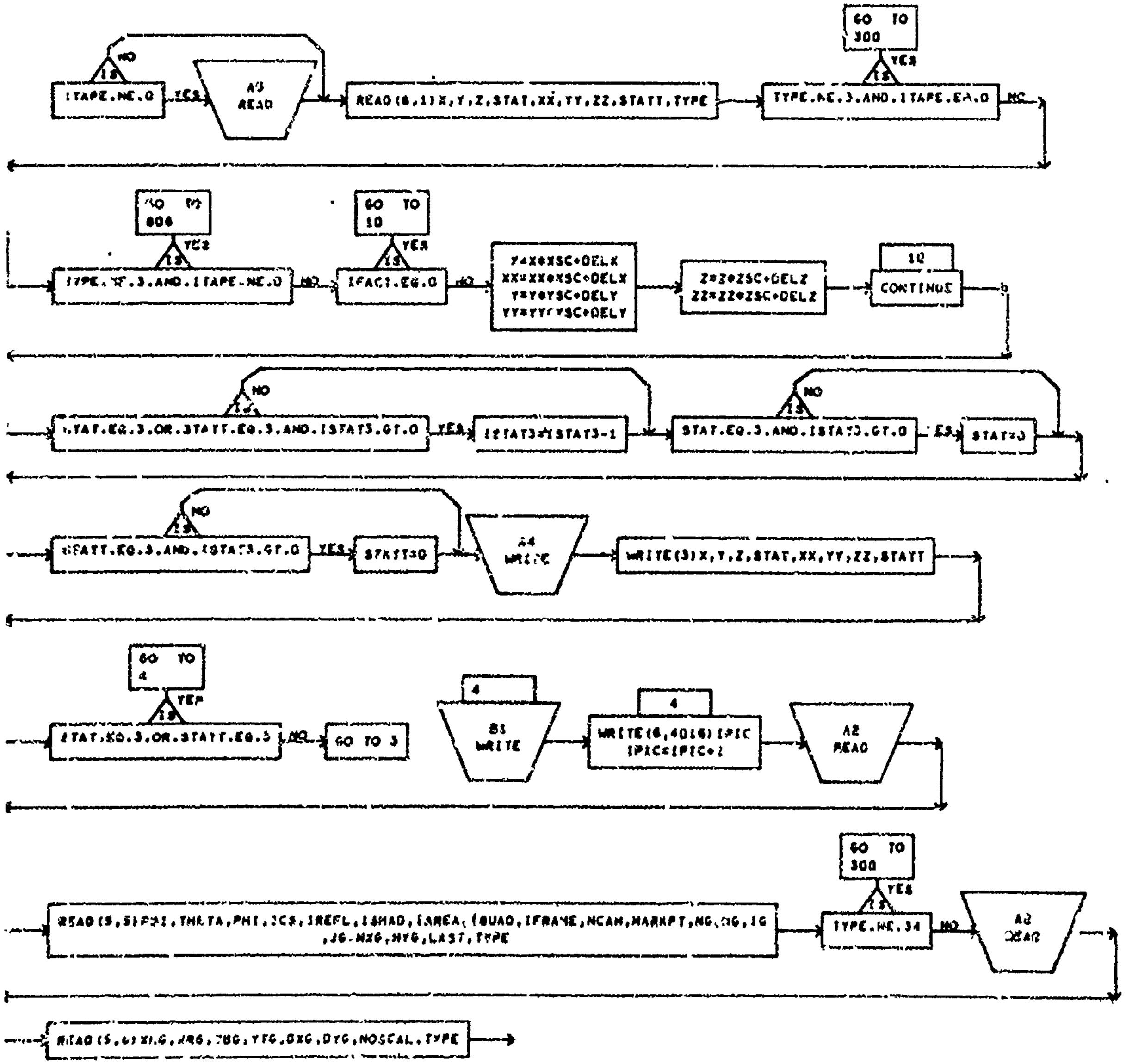
C                                                                        GRPB  4320
C                                                                        GRPB  4330
 2000 CONTINUE                                                           GRPB  4340
 2001 IF (STAT .LT. 2) GO TO 480                                         GRPB  4350
       NPRT = NPRT + 1                                                   GRPB  4360
      WRITE (6,472) AREAT,L,VOL                                          GRPB  4370
      NN = NN - 1                                                        GRPB  4380
      N = - 1                                                            GRPB  4390
      IF (IAREA .EQ. 0) GO TO 475                                        GRPB  4400
       CALL SCSETV (3)                                                   GRPB  4410
       WRITE (16,472) AREAT,L                                            GRPB  4420
 472   FORMAT(1H ,25X31HTOTAL AREA OF INPUT ELEMENTS  = F14.4,          GRPB  4430
     1        6X26HTOTAL NUMBER OF ELEMENTS = I5/1H ,23X,               GRPB  4440
     2 33H TOTAL VOLUME OF INPUT ELEMENTS =F12.3)                        GRPB  4450
 475  IF (IFRAME .EQ. 2) IFADV = 1                                       GRPB  4460
 480  IF (IFRAME .EQ. 1) IFADV = 1                                       GRPB  4470
 485  IF (IFADV .EQ. 1) CALL FRAMEV (0)                                  GRPB  4480
C                                                                        GRPB  4490
C                                                                        GRPB  4500
C  TEST FOR END OF CASE                                                  GRPB  4510
 2020 IF (STAT .NE. 3) GO TO 80                                          GRPB  4520
      IF (ILAST .EQ. 1) GO TO 2                                          GRPB  4530
      PRINTS=0                                                           GRPB  4540
      GO TO 4                                                            GRPB  4550
C                                                                        GRPB  4560
C                                                                        GRPB  4570
C  ERROR CHECK ON READING CARDS                                          GRPB  4580
 300  WRITE (6,4003)                                                     GRPB  4590
C                                                                        GRPB  4600
 4003 FORMAT (1H0,47H*****YOU HAVE MADE AN ERROR EITHER IN CARD TYPE    GRPB  4610
     1 49H INDICATION OR CARD ORDER - CHECK YOUR CARDS*****  )           GRPB  4620
      READ (5,810) (CARD(II),II=1,20)                                    GRPB  4630
 810  FORMAT (20A4)                                                      GRPB  4640
      WRITE (6,805) (CARD(II),II=1,20)                                   GRPB  4650
 805  FORMAT (1H0,45H THE CARD LOCATED JUST BEFORE THE CARD LISTED      GRPB  4660
     1 18H BELOW IS IN ERROR,/1H ,10X,20A4)                              GRPB  4670
```

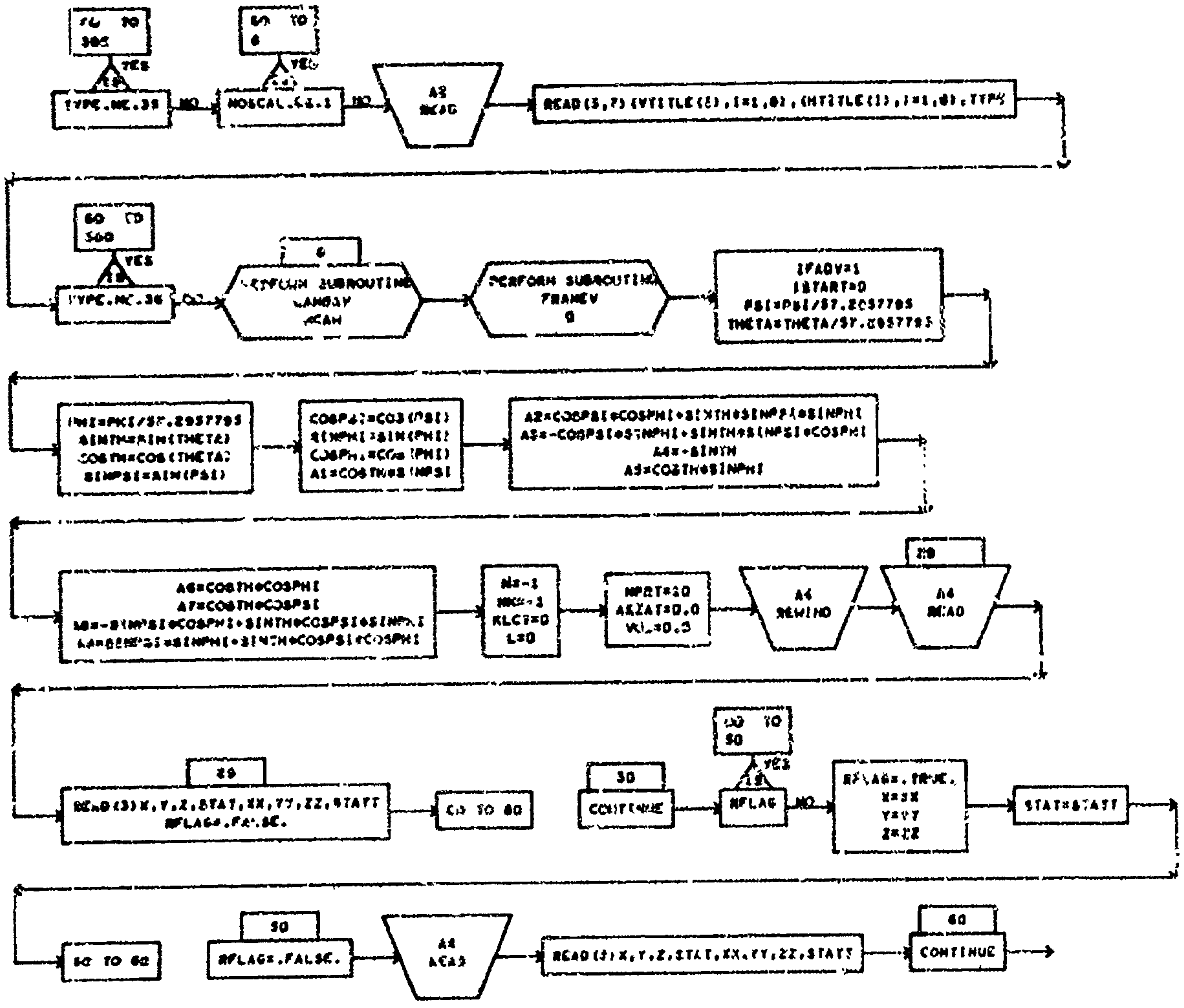
```
DECK GRPB

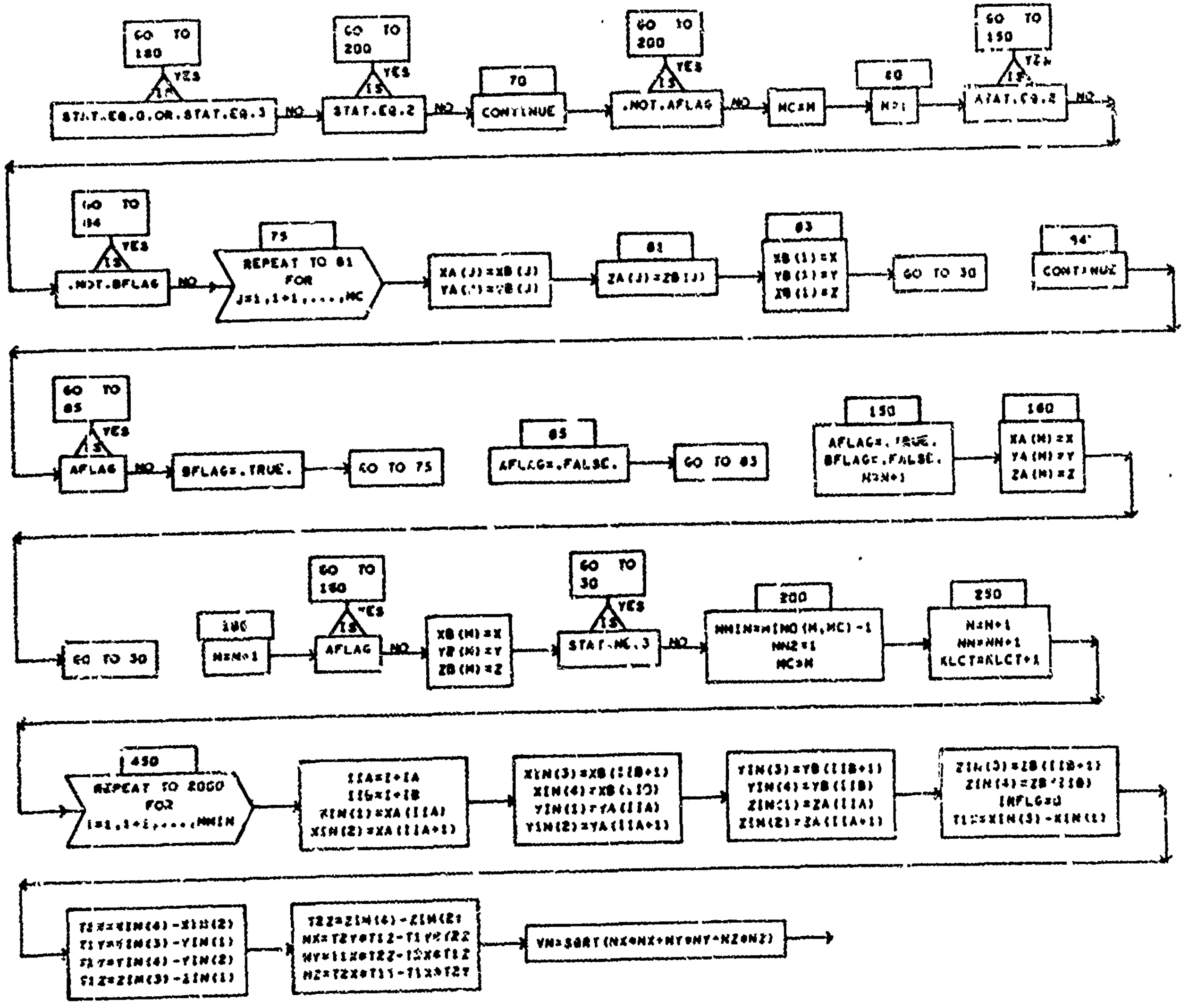
      GO TO 807                                                         GRPB  4680
  306 BACKSPACE 8                                                       GRPB  4690
      READ (8,810) (CARD(II),II=1,20)                                   GRPB  4700
      WRITE (6,808) (CARD(II),II=1,20)                                  GRPB  4710
  808 FORMAT (1H0,46H***THE FOLLOWING CARD ON TAPE 8 IS IN ERROR***,/   GRPB  4720
     1 1H ,10X,20A4)                                                    GRPB  4730
  807 CALL FRAMEV (0)                                                   GRPB  4740
      CALL SCSETV (4)                                                   GRPB  4750
      WRITE (16,4004)                                                   GRPB  4760
 4004 FORMAT (1H ,45HNO MORE SC-4020 DATA IS PLOTTED BECAUSE OF AN      GRPB  4770
     126H ERROR IN YOUR INPUT CARDS )                                   GRPB  4780
      ERROR = 1                                                         GRPB  4790
      RETURN                                                            GRPB  4800
C                                                                       GRPB  4810
 4002 FORMAT (1H0,28H  INPUT SURFACE ELEMENT DATA/1H0,6X1HN3X1HM7X1HX,  GRPB  4820
     1 3(13X,1HX),11X2HNX9X5HXCENT9X4HAREA8X1HL ,/1H ,5X, 4(13X,1HY),   GRPB  4830
     2 11X2HNY9X5HYCENT ,7X,7HDELTA V,/1H ,5X,4(13X,1HZ),11X2HNZ,       GRPB  4840
     3 9X,5HZCENT ,7X,6HVOLUME,/1H  )                                   GRPB  4850
 4005 FORMAT (1H0,7X, I4, 1P4E14.5,0PF10.6,1P2E14.5,I6,2(/12X,4E14.5,   GRPB  4860
     1 0PF10.6,1P2E14.5)  )                                             GRPB  4870
 4010 FORMAT (1H0,3X, 2I4,1P4E14.5,0PF10.6,1P2E14.5,I6,2(/12X,4E14.5,   GRPB  4880
     1 0PF10.6,1P2E14.5)  )                                             GRPB  4890
C                                                                       GRPB  4900
      END                                                               GRPB  4910
```

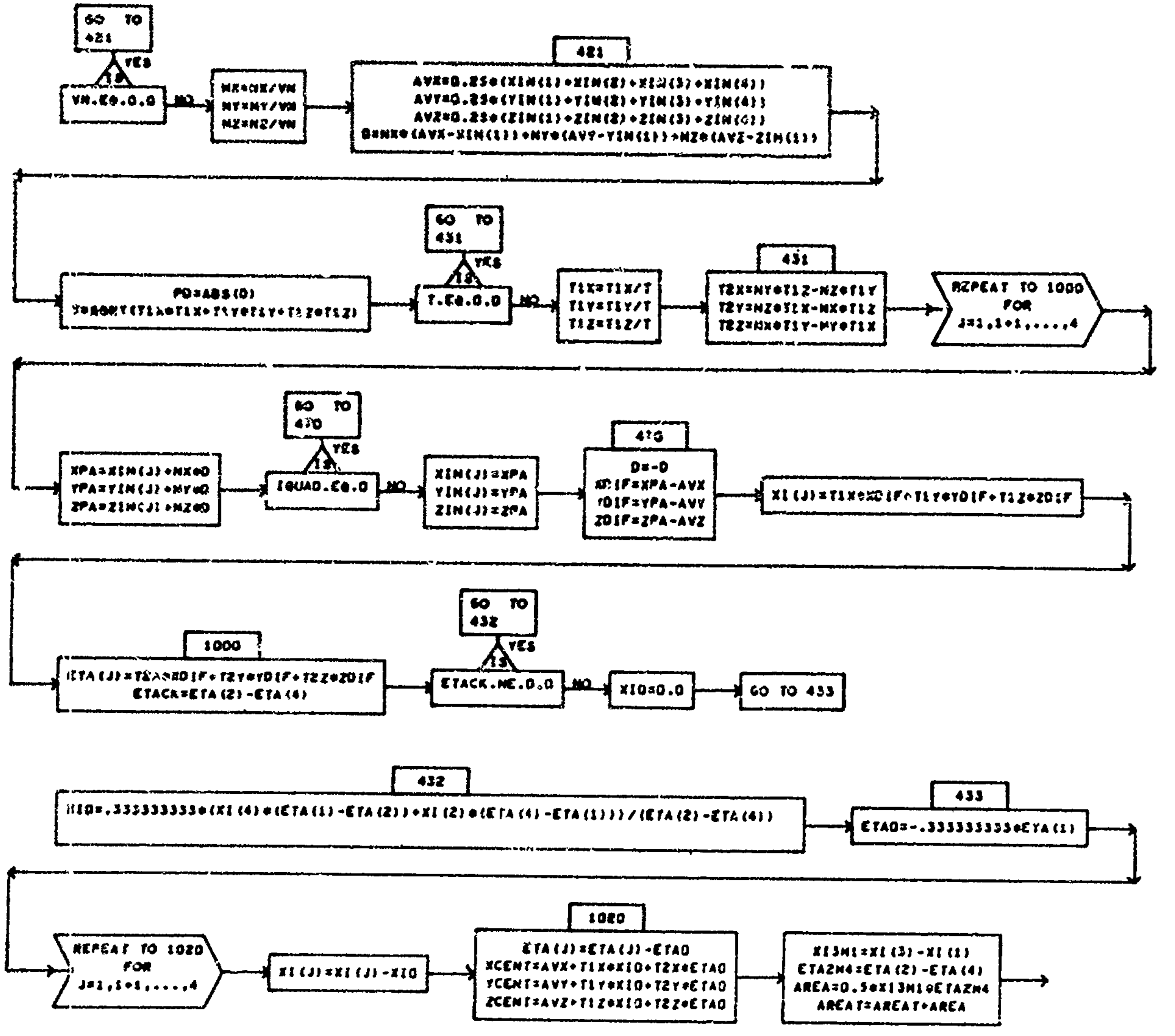
SUBROUTINE PICTUR

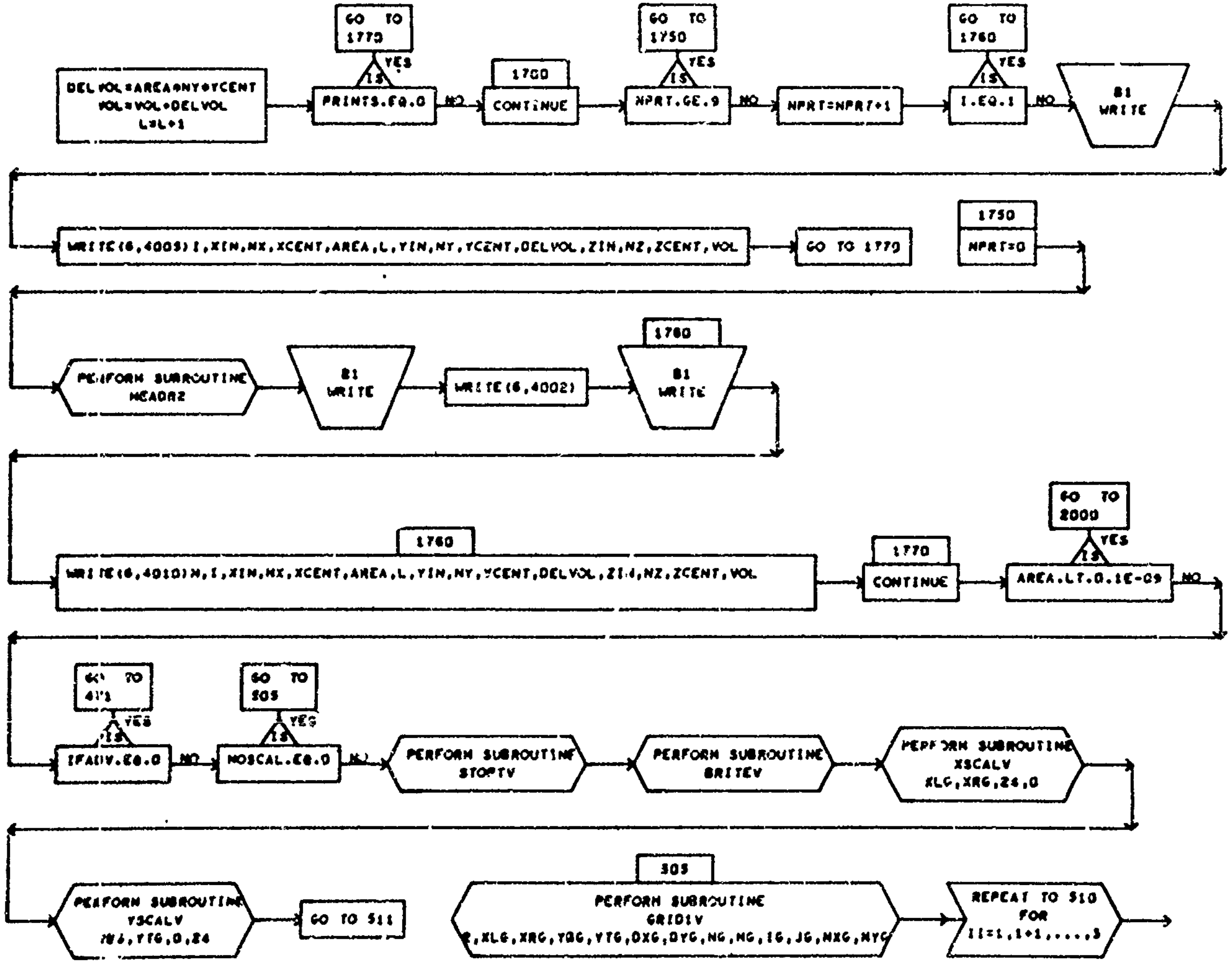


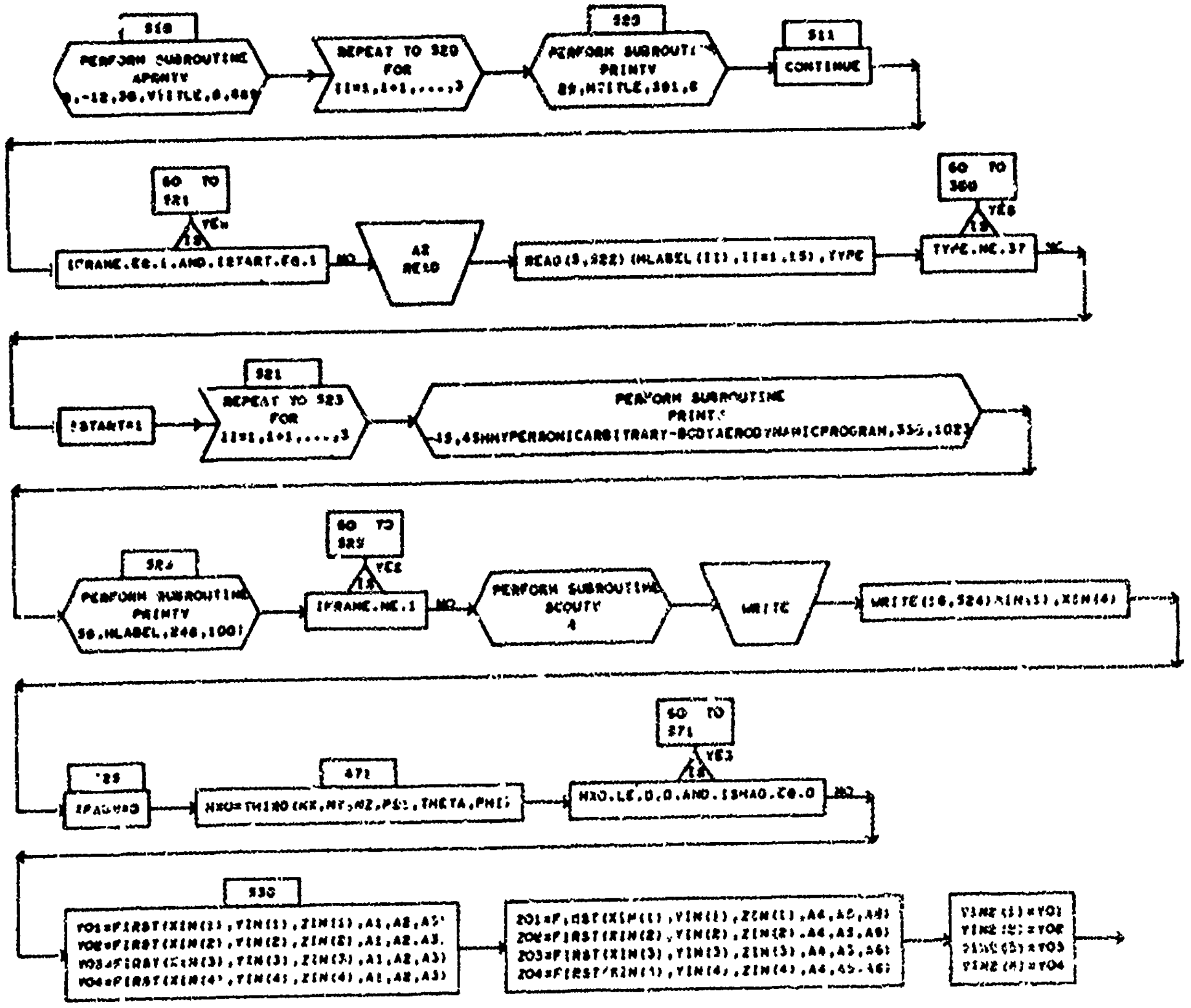

ITAPE.NE.0
IS
NO
YES
A3
READ
READ(6,1)X,Y,Z,STAT,XX,YY,ZZ,STATT,TYPE
TYPE.NE.3.AND.ITAPE.EQ.0
IS
YES
GO TO 300
NO
TYPE.GT.3.AND.ITAPE.NE.0
IS
YES
GO TO 606
NO
IFAC1.EQ.0
IS
YES
GO TO 10
NO
X=X*XSC+DELX
XX=XX*XSC+DELX
Y=Y*YSC+DELY
YY=YY*YSC+DELY
Z=Z*ZSC+DELZ
ZZ=ZZ*ZSC+DELZ
10
CONTINUE
STAT.EQ.3.OR.STATT.EQ.3.AND.ISTAT3.GT.0
IS
NO
YES
ISTAT3=ISTAT3-1
STAT.EQ.3.AND.ISTAT3.GT.0
IS
NO
YES
STAT=0
STATT.EQ.3.AND.ISTAT3.GT.0
IS
NO
YES
STATT=0
A4
WRITE
WRITE(3)X,Y,Z,STAT,XX,YY,ZZ,STATT
STAT.EQ.3.OR.STATT.EQ.3
IS
YES
GO TO 4
NO
GO TO 3
4
B1
WRITE
4
WRITE(6,4016)IPIC
IPIC=IPIC+1
A2
READ
READ(5,5)PSI,THETA,PHI,ICS,IREFL,ISHAD,IAREA,(QUAD,IFRAME,NCAM,MARKPT,NG,IG
,JG,NXG,NYG,LAST,TYPE
TYPE.NE.34
IS
YES
GO TO 300
NO
A2
READ
READ(5,6)XLG,XRG,YBG,YTG,DXG,DYG,NOSCAL,TYPE

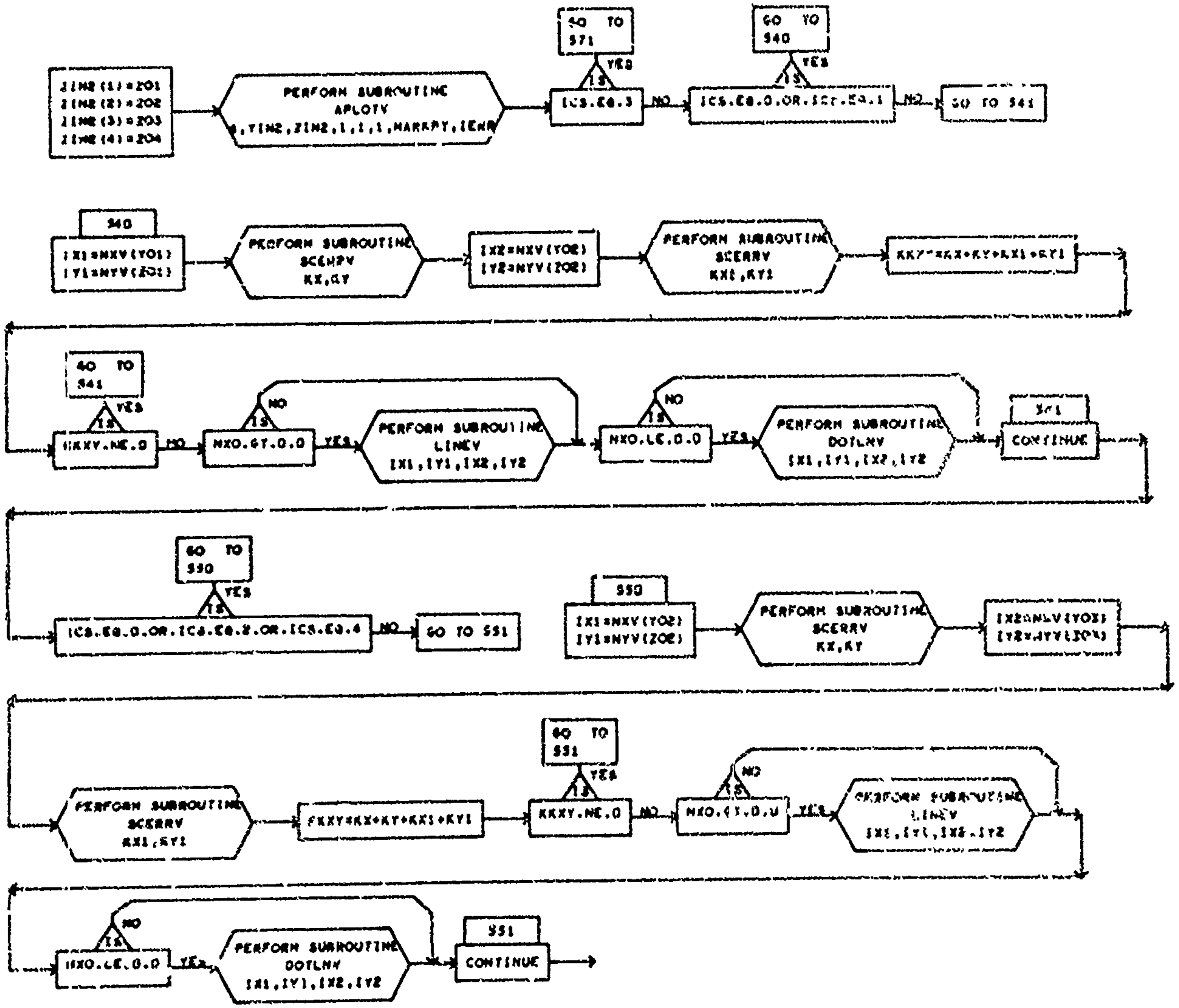

GO TO 300
YES
IF
TYPE.NE.35
NO
GO TO 6
YES
IF
NOSCAL.EQ.1
NO
A3
READ
READ(5,7)(VTITLE(I),I=1,8),(HTITLE(I),I=1,8),TYPE
GO TO 500
YES
IF
TYPE.NE.36
NO
6
PERFORM SUBROUTINE LANDAY ACAH
PERFORM SUBROUTINE FRAMEV 9
IFADV=1
ISTART=0
PSI=PSI/57.2957795
THETA=THETA/57.2957795
PHI=PHI/57.2957795
SINTH=SIN(THETA)
COSTH=COS(THETA)
SINPSI=SIN(PSI)
COSPSI=COS(PSI)
SINPHI=SIN(PHI)
COSPHI=COS(PHI)
A1=COSTH*SINPSI
A2=COSPSI*COSPHI+SINTH*SINPSI*SINPHI
A3=-COSPSI*SINPHI+SINTH*SINPSI*COSPHI
A4=-SINTH
A5=COSTH*SINPHI
A6=COSTH*COSPHI
A7=COSTH*COSPSI
A8=-SINPSI*COSPHI+SINTH*COSPSI*SINPHI
A9=SINPSI*SINPHI+SINTH*COSPSI*COSPHI
N=-1
NK=-1
KLCT=0
L=0
NPRT=10
AKZAT=0.0
VKL=0.5
A4
REWIND
20
A4
READ
25
READ(3)X,Y,Z,STAT,XX,YY,ZZ,STATT
NFLAG=.FALSE.
GO TO 60
30
CONTINUE
GO TO 50
YES
IF
NFLAG
NO
NFLAG=.TRUE.
X=XX
Y=YY
Z=ZZ
STAT=STATT
GO TO 60
50
NFLAG=.FALSE.
A4
READ
READ(3)X,Y,Z,STAT,XX,YY,ZZ,STATT
60
CONTINUE


GO TO 180
YES
IS
STAT.EQ.0.OR.STAT.EQ.3
NO
GO TO 200
YES
IS
STAT.EQ.2
NO
70
CONTINUE
GO TO 200
YES
IS
.NOT.AFLAG
NO
MC=M
60
N=1
GO TO 150
YES
IS
STAT.EQ.2
NO
GO TO 134
YES
IS
.NOT.BFLAG
NO
75
REPEAT TO 81 FOR J=1,1+1,...,MC
XA(J)=XB(J)
YA(J)=YB(J)
81
ZA(J)=ZB(J)
83
XB(1)=X
YB(1)=Y
ZB(1)=Z
GO TO 30
94
CONTINUE
GO TO 85
YES
IS
AFLAG
NO
BFLAG=.TRUE.
GO TO 75
85
AFLAG=.FALSE.
GO TO 83
150
AFLAG=.TRUE.
BFLAG=.FALSE.
N=N+1
160
XA(N)=X
YA(N)=Y
ZA(N)=Z
GO TO 30
180
N=N+1
GO TO 160
YES
IS
AFLAG
NO
XB(M)=X
YB(M)=Y
ZB(M)=Z
GO TO 30
YES
IS
STAT.NE.3
NO
200
MMIN=MIN0(M,MC)-1
MN2=1
MC=M
250
N=N+1
NN=NN+1
KLCT=KLCT+1
450
REPEAT TO 2000 FOR I=1,1+1,...,MMIN
IIA=I+IA
IIB=I+IB
XIN(1)=XA(IIA)
XIN(2)=XA(IIA+1)
XIN(3)=XB(IIB+1)
XIN(4)=XB(IIB)
YIN(1)=YA(IIA)
YIN(2)=YA(IIA+1)
YIN(3)=YB(IIB+1)
YIN(4)=YB(IIB)
ZIN(1)=ZA(IIA)
ZIN(2)=ZA(IIA+1)
ZIN(3)=ZB(IIB+1)
ZIN(4)=ZB(IIB)
INFLG=0
T1X=XIN(3)-XIN(1)
T2X=XIN(4)-XIN(2)
T1Y=YIN(3)-YIN(1)
T2Y=YIN(4)-YIN(2)
T1Z=ZIN(3)-ZIN(1)
T2Z=ZIN(4)-ZIN(2)
NX=T2Y*T1Z-T1Y*T2Z
NY=T1X*T2Z-T2X*T1Z
NZ=T2X*T1Y-T1X*T2Y
VN=SQRT(NX*NX+NY*NY+NZ*NZ)

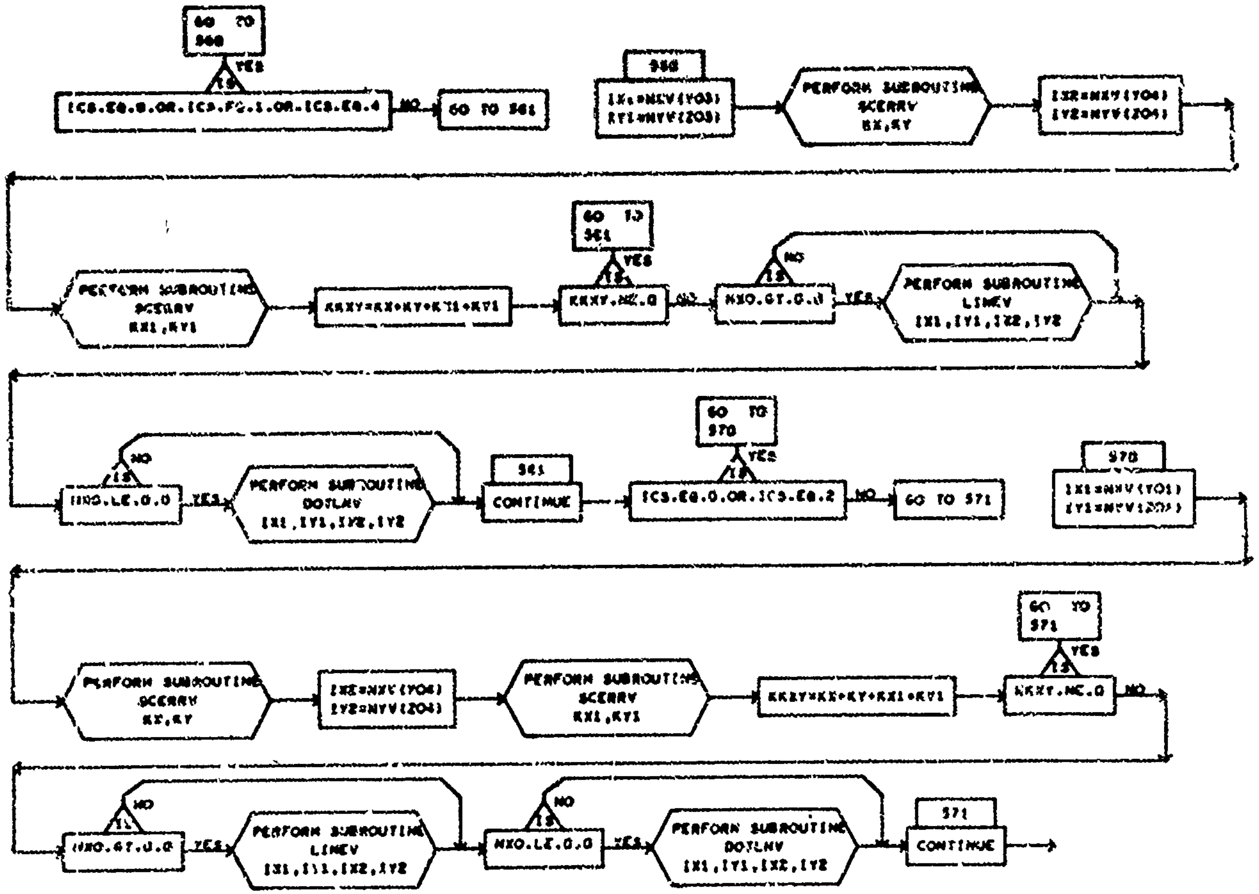

GO TO 421
YES
13
VN.EQ.0.0
NO
NX=NX/VN
NY=NY/VN
NZ=NZ/VN
421
AVX=0.25*(XIN(1)+XIN(2)+XIN(3)+XIN(4))
AVY=0.25*(YIN(1)+YIN(2)+YIN(3)+YIN(4))
AVZ=0.25*(ZIN(1)+ZIN(2)+ZIN(3)+ZIN(4))
D=NX*(AVX-XIN(1))+NY*(AVY-YIN(1))+NZ*(AVZ-ZIN(1))
PD=ABS(D)
T=SQRT(T1X*T1X+T1Y*T1Y+T1Z*T1Z)
GO TO 431
YES
13
T.EQ.0.0
NO
T1X=T1X/T
T1Y=T1Y/T
T1Z=T1Z/T
431
T2X=NY*T1Z-NZ*T1Y
T2Y=NZ*T1X-NX*T1Z
T2Z=NX*T1Y-NY*T1X
REPEAT TO 1000
FOR
J=1,1+1,...,4
XPA=XIN(J)+NX*D
YPA=YIN(J)+NY*D
ZPA=ZIN(J)+NZ*D
GO TO 470
YES
13
IQUAD.EQ.0
NO
XIN(J)=XPA
YIN(J)=YPA
ZIN(J)=ZPA
470
D=-D
XDIF=XPA-AVX
YDIF=YPA-AVY
ZDIF=ZPA-AVZ
XI(J)=T1X*XDIF+T1Y*YDIF+T1Z*ZDIF
1000
ETA(J)=T2X*XDIF+T2Y*YDIF+T2Z*ZDIF
ETACK=ETA(2)-ETA(4)
GO TO 432
YES
13
ETACK.NE.0.0
NO
XI0=0.0
GO TO 433
432
XI0=.333333333*(XI(4)*(ETA(1)-ETA(2))+XI(2)*(ETA(4)-ETA(1)))/(ETA(2)-ETA(4))
433
ETA0=-.333333333*ETA(1)
REPEAT TO 1020
FOR
J=1,1+1,...,4
XI(J)=XI(J)-XI0
1020
ETA(J)=ETA(J)-ETA0
XCENT=AVX+T1X*XI0+T2X*ETA0
YCENT=AVY+T1Y*XI0+T2Y*ETA0
ZCENT=AVZ+T1Z*XI0+T2Z*ETA0
XI3M1=XI(3)-XI(1)
ETA2M4=ETA(2)-ETA(4)
AREA=0.5*XI3M1*ETA2M4
AREAT=AREAT+AREA

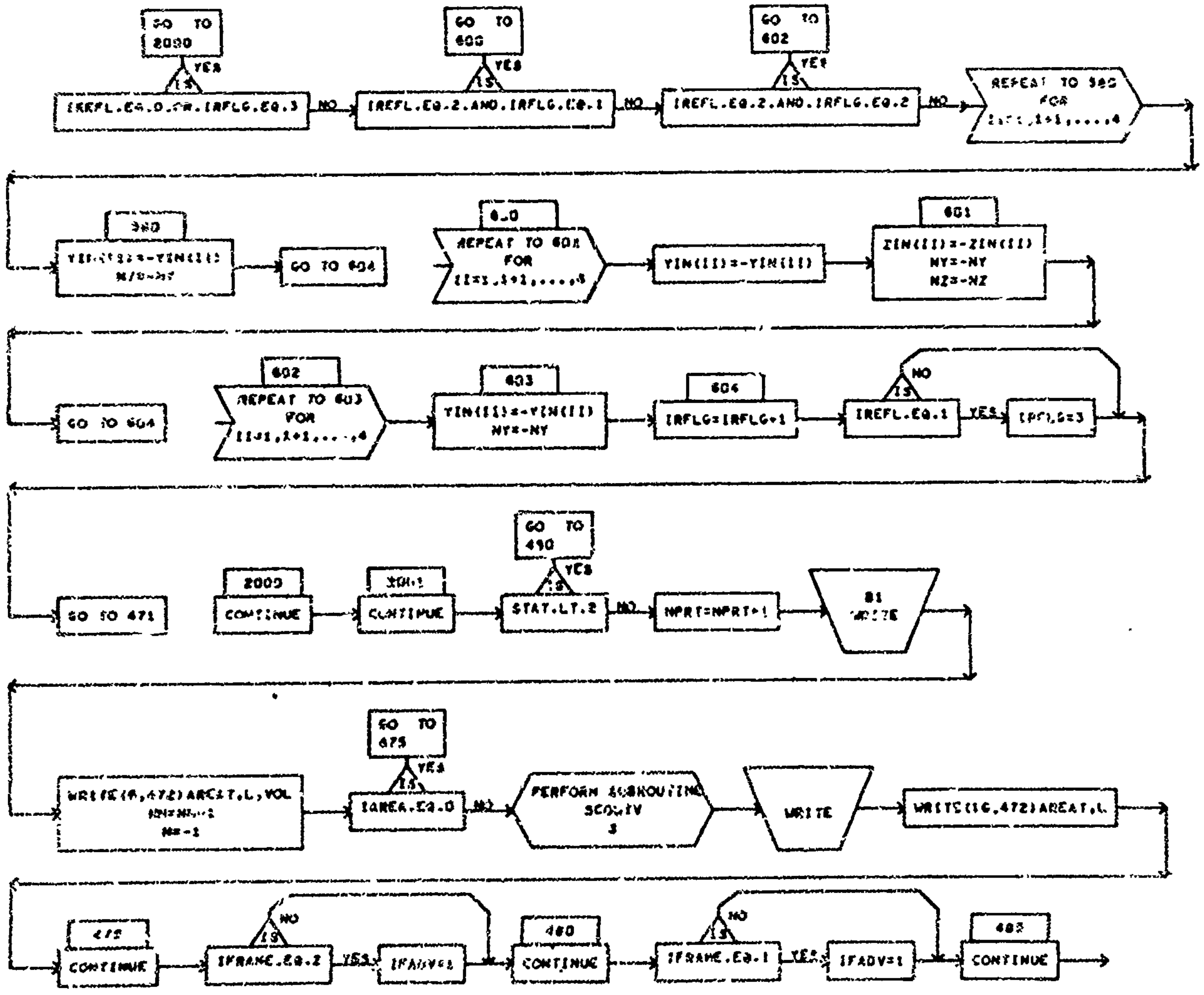

DELVOL=AREA*NY*YCENT
VOL=VOL+DELVOL
L=L+1
GO TO 1770
YES
IS
PRINTS.EQ.0
NO
1700
CONTINUE
GO TO 1750
YES
IS
NPRT.GE.9
NO
NPRT=NPRT+1
GO TO 1760
YES
IS
I.EQ.1
NO
B1
WRITE
WRITE(6,4005)I,XIN,NX,XCENT,AREA,L,YIN,NY,YCENT,DELVOL,ZIN,NZ,ZCENT,VOL
GO TO 1770
1750
NPRT=0
PERFORM SUBROUTINE
HEADR2
B1
WRITE
WRITE(6,4002)
1760
B1
WRITE
1760
WRITE(6,4010)N,I,XIN,NX,XCENT,AREA,L,YIN,NY,YCENT,DELVOL,ZIN,NZ,ZCENT,VOL
1770
CONTINUE
GO TO 2000
YES
IS
AREA.LT.0.1E-09
NO
GO TO 411
YES
IS
IFAUV.EQ.0
NO
GO TO 505
YES
IS
NOSCAL.EQ.0
NO
PERFORM SUBROUTINE
STOPTV
PERFORM SUBROUTINE
BRITEV
PERFORM SUBROUTINE
XSCALV
XLG,XRG,24,0
PERFORM SUBROUTINE
YSCALV
YBG,YTG,0,24
GO TO 511
505
PERFORM SUBROUTINE
GRIDIV
2,XLG,XRG,YBG,YTG,DXG,DYG,NG,NG,IG,JG,NXG,NYG
REPEAT TO 510
FOR
II=1,1+1,...,3

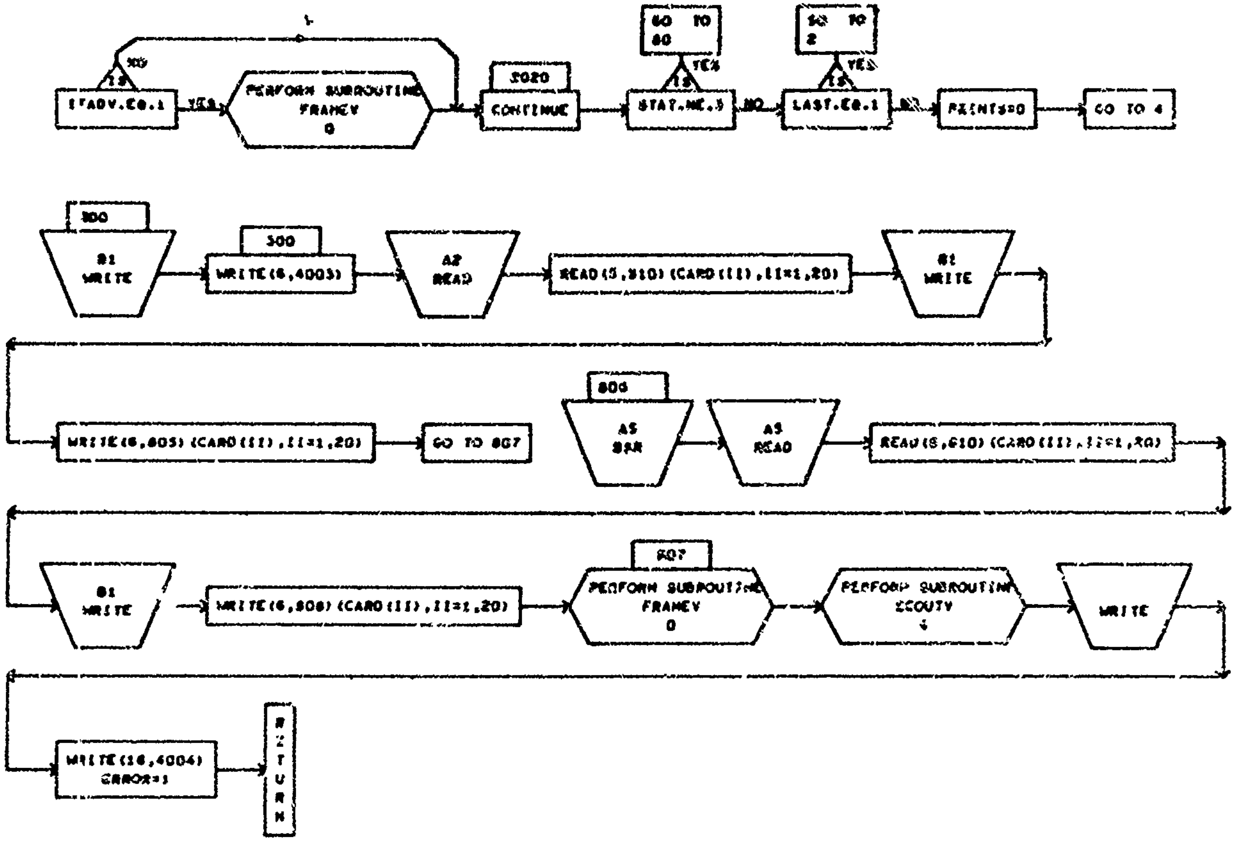

518
PERFORM SUBROUTINE
APRNTV
9,-12,30,VTITLE,6,66
REPEAT TO 520
FOR
II=1,1+1,...,3
520
PERFORM SUBROUTINE
PRINTV
29,HTITLE,301,6
511
CONTINUE
GO TO
521
YES
IS
IFRAME.EQ.1.AND.ISTART.EQ.1
NO
A2
READ
READ(5,522) (HLABEL(II),II=1,15),TYPE
GO TO
300
YES
IS
TYPE.NE.37
NO
ISTART=1
521
REPEAT TO 523
FOR
II=1,1+1,...,3
PERFORM SUBROUTINE
PRINTV
15,45HHYPERSONICARBITRARY-BODYAERODYNAMICPROGRAM,355,102
524
PERFORM SUBROUTINE
PRINTV
56,HLABEL,246,100
GO TO
525
YES
IS
IFRAME.NE.1
NO
PERFORM SUBROUTINE
SCOUTV
4
WRITE
WRITE(16,524)XIN(1),XIN(4)
'25
IPAUSE=0
471
NXO=THIRD(NX,NY,NZ,PSI,THETA,PHI)
GO TO
271
YES
IS
NXO.LE.0.0.AND.ISHAD.EQ.0
NO
530
YO1=FIRST(XIN(1),YIN(1),ZIN(1),A1,A2,A3)
YO2=FIRST(XIN(2),YIN(2),ZIN(2),A1,A2,A3)
YO3=FIRST(XIN(3),YIN(3),ZIN(3),A1,A2,A3)
YO4=FIRST(XIN(4),YIN(4),ZIN(4),A1,A2,A3)
ZO1=FIRST(XIN(1),YIN(1),ZIN(1),A4,A5,A6)
ZO2=FIRST(XIN(2),YIN(2),ZIN(2),A4,A5,A6)
ZO3=FIRST(XIN(3),YIN(3),ZIN(3),A4,A5,A6)
ZO4=FIRST(XIN(4),YIN(4),ZIN(4),A4,A5,A6)
YIN2(1)=YO1
YIN2(2)=YO2
YIN2(3)=YO3
YIN2(4)=YO4


ZINE(1)=201
ZINE(2)=202
ZINE(3)=203
ZINE(4)=204
PERFORM SUBROUTINE
APLOTV
X,YINE,ZINE,1,1,1,MARKPT,IERR
GO TO
571
YES
IS
ICS.EQ.3
NO
GO TO
540
YES
IS
ICS.EQ.0.OR.ICS.EQ.1
NO
GO TO 541
540
IX1=NXV(YO1)
IY1=NYV(ZO1)
PERFORM SUBROUTINE
SCERRV
KX,KY
IX2=NXV(YO2)
IY2=NYV(ZO2)
PERFORM SUBROUTINE
SCERRV
KX1,KY1
KKXY=KX+KY+KX1+KY1
GO TO
541
YES
IS
KKXY.NE.0
NO
IS
NO
NXO.GT.0.0
YES
PERFORM SUBROUTINE
LINEV
IX1,IY1,IX2,IY2
IS
NO
NXO.LE.0.0
YES
PERFORM SUBROUTINE
DOTLNV
IX1,IY1,IX2,IY2
571
CONTINUE
GO TO
550
YES
IS
ICS.EQ.0.OR.ICS.EQ.2.OR.ICS.EQ.4
NO
GO TO 551
550
IX1=NXV(YO2)
IY1=NYV(ZO2)
PERFORM SUBROUTINE
SCERRV
KX,KY
IX2=NXV(YO3)
IY2=NYV(ZO3)
PERFORM SUBROUTINE
SCERRV
KX1,KY1
KKXY=KX+KY+KX1+KY1
GO TO
551
YES
IS
KKXY.NE.0
NO
IS
NO
NXO.GT.0.0
YES
PERFORM SUBROUTINE
LINEV
IX1,IY1,IX2,IY2
IS
NO
NXO.LE.0.0
YES
PERFORM SUBROUTINE
DOTLNV
IX1,IY1,IX2,IY2
551
CONTINUE

]


GO TO 560
YES
IS
ICS.EQ.0.OR.ICS.EQ.1.OR.ICS.EQ.4
NO
GO TO 561
560
IX1=NXV(YO3)
IY1=NYV(ZO3)
PERFORM SUBROUTINE
SCERRV
KX,KY
IX2=NXV(YO4)
IY2=NYV(ZO4)
PERFORM SUBROUTINE
SCERRV
KX1,KY1
KKXY=KX+KY+KX1+KY1
GO TO 561
YES
IS
KKXY.NE.0
NO
NO
IS
NXO.GT.0.0
YES
PERFORM SUBROUTINE
LINEV
IX1,IY1,IX2,IY2
NO
IS
NXO.LE.0.0
YES
PERFORM SUBROUTINE
DOTLNV
IX1,IY1,IX2,IY2
561
CONTINUE
GO TO 570
YES
IS
ICS.EQ.0.OR.ICS.EQ.2
NO
GO TO 571
570
IX1=NXV(YO1)
IY1=NYV(ZO1)
PERFORM SUBROUTINE
SCERRV
KX,KY
IX2=NXV(YO4)
IY2=NYV(ZO4)
PERFORM SUBROUTINE
SCERRV
KX1,KY1
KKXY=KX+KY+KX1+KY1
GO TO 571
YES
IS
KKXY.NE.0
NO
NO
IS
NXO.GT.0.0
YES
PERFORM SUBROUTINE
LINEV
IX1,IY1,IX2,IY2
NO
IS
NXO.LE.0.0
YES
PERFORM SUBROUTINE
DOTLNV
IX1,IY1,IX2,IY2
571
CONTINUE


GO TO 2090
YES
IS
IREFL.EQ.0.OR.IRFLG.EQ.3
NO
GO TO 600
YES
IS
IREFL.EQ.2.AND.IRFLG.EQ.1
NO
GO TO 602
YES
IS
IREFL.EQ.2.AND.IRFLG.EQ.2
NO
REPEAT TO 590
FOR
I=1,I+1,....4
590
YIN(I)=-YIN(I)
NY=-NY
GO TO 604
600
REPEAT TO 601
FOR
II=1,1+1,....4
YIN(II)=-YIN(II)
601
ZIN(II)=-ZIN(II)
NY=-NY
NZ=-NZ
GO TO 604
602
REPEAT TO 603
FOR
II=1,1+1,....4
603
YIN(II)=-YIN(II)
NY=-NY
604
IRFLG=IRFLG+1
IS
IREFL.EQ.1
NO
YES
IRFLG=3
GO TO 471
2000
CONTINUE
CONTINUE
GO TO 490
YES
IS
STAT.LT.2
NO
NPRT=NPRT+1
81
WRITE
WRITE(6,472)AREAT,L,VOL
NN=NN+1
NN=1
GO TO 475
YES
IS
IAREA.EQ.0
NO
PERFORM SUBROUTINE
SCOWIV
3
WRITE
WRITE(16,472)AREAT,L
475
CONTINUE
IS
IFRAME.EQ.2
NO
YES
IFADV=1
480
CONTINUE
IS
IFRAME.EQ.1
NO
YES
IFADV=1
482
CONTINUE


IFADV.EQ.1
IS
NO
YES
PERFORM SUBROUTINE
FRAMEV
0
3020
CONTINUE
GO TO
80
IS
YES
STAT.NE.3
NO
GO TO
2
IS
YES
LAST.EQ.1
NO
PRINTS=0
GO TO 4
300
B1
WRITE
300
WRITE(6,4003)
A2
READ
READ(5,810)(CARD(II),II=1,20)
B1
WRITE
WRITE(6,805)(CARD(II),II=1,20)
GO TO 807
806
A5
BSR
A5
READ
READ(5,810)(CARD(II),II=1,20)
B1
WRITE
WRITE(6,808)(CARD(II),II=1,20)
807
PERFORM SUBROUTINE
FRAMEV
0
PERFORM SUBROUTINE
ECOUTV
4
WRITE
WRITE(16,4004)
ERROR=1
RETURN

SYMBOLS USED IN SUBROUTINE PICTUR

AFLAG	L	U	INPUT DATA READ CONTROL FLAG	PICTUR
AREA	R	U	ELEMENT AREA	PICTUR
AREAT	R	U	TOTAL AREA	PICTUR
AVX	R	U	AVERAGE POINT COORDINATE-X	PICTUR
AVY	R	U	AVERAGE POINT COORDINATE-Y	PICTUR
AVZ	R	U	AVERAGE POINT COORDINATE-Z	PICTUR
A1	R	U	ROTATION MATRIX CONSTANT	PICTUR
A2	R	U	ROTATION MATRIX CONSTANT	PICTUR
A3	R	U	ROTATION MATRIX CONSTANT	PICTUR
A4	R	U	ROTATION MATRIX CONSTANT	PICTUR
A5	R	U	ROTATION MATRIX CONSTANT	PICTUR
A6	R	U	ROTATION MATRIX CONSTANT	PICTUR
A7	R	U	ROTATION MATRIX CONSTANT	PICTUR
A8	R	U	ROTATION MATRIX CONSTANT	PICTUR
A9	R	U	ROTATION MATRIX CONSTANT	PICTUR
BFLAG	L	U	INPUT DATA READ CONTROL FLAG	PICTUR
CARD	R	D	ARRAY FOR READING IN 80 COLUMN CARD	PICTUR
CASE	I	C	CASE NUMBER	PICTUR
COSPHI	R	U	COSINE OF PHI	PICTUR
COSPSI	R	U	COSINE OF PSI	PICTUR
COSTH	R	U	COSINE OF THETA	PICTUR
D	R	U	CORNER POINT PROJECTION DISTANCE	PICTUR
DELVOL	R	U	ELEMENT VOLUME CONTRIBUTION	PICTUR
DELX	R	U	GEOMETRY DATA X-INCREMENT	PICTUR
DELY	R	U	GEOMETRY DATA Y-INCREMENT	PICTUR
DELZ	R	U	GEOMETRY DATA Z-INCREMENT	PICTUR
DXG	R	U	GRID DELTA-X INCREMENT	PICTUR
DYG	R	U	GRID DELTA-Y INCREMENT	PICTUR
ERROR	I	C	ERROR FLAG	PICTUR
ETA	R	D	COORDINATE IN ELEMENT COORDINATE SYSTEM	PICTUR
ETACK	R	U	ETA CHECK PARAMETER	PICTUR
ETAO	R	U	COORDINATE IN ELEMENT COORDINATE SYSTEM	PICTUR
ETA2M4	R	U	CONSTANT IN AREA EQUATION	PICTUR
HLABEL	R	D	HORIZONTAL LABEL	PICTUR
HTITLE	R	D	VERTICAL LABEL	PICTUR
I	I	U	ELEMENT NUMBER IN COLUMN	PICTUR

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SYMBOLS USED IN SUBROUTINE PICTUR

IA       I  U  FLAG TO CONTROL SHIFTING OF COLUMN DATA POINTS FOR IORIEN=3     PICTUR
IAREA    I  U  SURFACE AREA PRINT FLAG                                         PICTUR
IB       I  U  FLAG TO CONTROL SHIFTING OF COLUMN DATA POINTS FOR IORIEN=2     PICTUR
ICS      I  U  POINT CORRECT FLAG                                              PICTUR
IDUM     I  U  DUMMY VARIABLE                                                  PICTUR
IERR     I  U  ERROR FLAG                                                      PICTUR
IFACT    I  U  SCALE FACTOR FLAG                                               PICTUR
IFADV    I  U  FRAME FLAG                                                      PICTUR
IFRAME   I  U  FRAME ADVANCE FLAG                                              PICTUR
IG       I  U  VERTICAL GRID LINE LABEL CONTROL FLAG                           PICTUR
IIA      I  U  DATA SHIFTING CONTROL PARAMETER (IORIEN=3)                      PICTUR
IIB      I  U  DATA SHIFTING CONTROL PARAMETER (IORIEN=2)                      PICTUR
IORIEN   I  U  ELEMENT ORIENTATION (NOT USED)                                  PICTUR
IPIC     I  U  FRAME NUMBER                                                    PICTUR
IQUAD    I  U  QUADRILATERAL PLOT FLAG                                         PICTUR
IREFL    I  U  REFLECTION ELEMENTS CONTROL FLAG                                PICTUR
IREWB    I  U  TAPE 8 REWIND FLAG                                              PICTUR
IRFLG    I  U  REFLECTION CONTROL FLAG                                         PICTUR
ISHAD    I  U  SHADOW ELEMENT FLAG                                             PICTUR
ISTART   I  U  CONTROL FLAG                                                    PICTUR
ISTAT3   I  U  NUMBER OF STATUS = 3 POINTS IN DECK                             PICTUR
ITAPE    I  U  GEOMETRY SOURCE FLAG                                            PICTUR
IX1      I  U  X-RASTER COORDIVATE OF FIRST POINT                              PICTUR
IX2      I  U  X-RASTER COORDINATE OF SECOND POINT                             PICTUR
IY1      I  U  Y-RASTER COORDINATE OF FIRST POINT                              PICTUR
IY2      I  U  Y-RASTER COORDINATE OF SECOND POINT                             PICTUR
JG       I  U  HORIZONTAL GRID LINE LABEL CONTROL FLAG                         PICTUR
KKXY     I  U  OFF-SCALE DETECTION FLAG                                        PICTUR
KLCT     I  U  COUNTER                                                         PICTUR
KX       I  U  OFF-SCALE DETECTION FLAG                                        PICTUR
KX1      I  U  OFF-SCALE DETECTION FLAG                                        PICTUR
KY       I  U  OFF-SCALE DETECTION FLAG                                        PICTUR
KY1      I  U  OFF-SCALE DETECTION FLAG                                        PICTUR
L        I  U  ELEMENT NUMBER                                                  PICTUR
LAST     I  U  LAST PLOT CONTROL FLAG                                          PICTUR
M        I  U  DATA READ IN CONTROL FLAG                                       PICTUR
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SYMBOLS USED IN SUBROUTINE PICTUR

MARKPT   I  U  PLOTTING SYMBOL CODE                                    PICTUR
MC       I  U  DATA READ IN CONTROL NUMBER                             PICTUR
MG       I  U  HORIZONTAL LINE EMPHASIZE FLAG                          PICTUR
MMIN     I  U  NUMBER OF ELEMENTS IN A COLUMN                          PICTUR
N        I  U  COLUMN NUMBER                                           PICTUR
NCAM     I  U  CAMERA SELECTION FLAG                                   PICTUR
NG       I  U  VERTICAL LINE EMPHASIZE FLAG                            PICTUR
NN       I  U  COLUMN ELEMENT COUNTER                                  PICTUR
NN2      I  U  COUNTER                                                 PICTUR
NOSCAL   I  U  NO GRID FLAG                                            PICTUR
NPRT     I  U  LINE COUNTER                                            PICTUR
NX       R  U  ELEMENT DIRECTION COSINE-X                              PICTUR
NXG      I  U  NUMBER OF CHARACTERS IN X-SCALE NUMBER LABELS           PICTUR
NXO      R  U  DIRECTION COSINE OUT OF PLANE OF PAPER                  PICTUR
NY       R  U  ELEMENT DIRECTION COSINE-Y                              PICTUR
NYG      I  U  NUMBER OF CHARACTERS IN Y-SCALE NUMBER LABELS           PICTUR
NZ       R  U  ELEMENT DIRECTION COSINE-Z                              PICTUR
PAGE     I  C  PAGE NUMBER                                             PICTUR
PD       R  U  CORNER POINT PROJECTION DISTANCE                        PICTUR
PHI      R  U  ROLL ANGLE, DEGREES                                     PICTUR
PRINTS   I  U  ELEMENT DATA PRINT FLAG                                 PICTUR
PSI      R  U  YAW ANGLE                                               PICTUR
RFLAG    L  U  INPUT DATA READ CONTROL FLAG                            PICTUR
SINPHI   R  U  SIN OF PHI                                              PICTUR
SINPSI   R  U  SIN OF PSI                                              PICTUR
SINTH    R  U  SIN OF THETA                                            PICTUR
STAY     I  U  COORDINATE POINT STATUS FLAG                            PICTUR
START    I  U  COORDINATE POINT STATUS FLAG                            PICTUR
SYMFCT   I  U  SYMMETRY FLAG                                           PICTUR
T        R  U  UNIT VECTOR                                             PICTUR
THETA    R  U  PITCH ANGLE                                             PICTUR
TITLE    R  C  TITLE                                                   PICTUR
TYPE     I  U  CARD TYPE NUMBER                                        PICTUR
T1X      R  U  X-COMPONENT OF VECTOR T1                                PICTUR
T1Y      R  U  Y-COMPONENT OF VECTOR T1                                PICTUR
T1Z      R  U  Z-COMPONENT OF VECTOR T1                                PICTUR
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SYMBOLS USED IN SUBROUTINE PICTUR

T2X     R  U  X-COMPONENT OF VECTOR T2                                      PICTUR
T2Y     R  U  Y-COMPONENT OF VECTOR T2                                      PICTUR
T2Z     R  U  Z-COMPONENT OF VECTOR T2                                      PICTUR
VN      R  U  VECTOR LENGTH                                                 PICTUR
VOL     R  U  TOTAL VOLUME                                                  PICTUR
VTITLE  R  D  VERTICAL SCALE TITLE                                          PICTUR
X       R  U  X-COORDINATE                                                  PICTUR
XA      R  D  X-COORDINATE                                                  PICTUR
XB      R  D  X-COORDINATE                                                  PICTUR
XCENT   R  U  ELEMENT CENTROID COORDINATE-X                                 PICTUR
XDIF    R  U  COORDINATE DIFFERENCE-X                                       PICTUR
XI      R  D  COORDINATE IN ELEMENT COORDINATE SYSTEM                       PICTUR
XIN     R  D  ELEMENT COORDINATES-X                                         PICTUR
XIO     R  U  CENTROID IN ELEMENT COORDINATE SYSTEM                         PICTUR
XI3M1   R  U  CONSTANT FOR AREA EQUATION                                    PICTUR
XLG     R  U  VALUE OF LEFT SIDE OF HORIZONTAL SCALE                        PICTUR
XPA     R  U  COORDINATE OF ELEMENT CORNER POINT                            PICTUR
XRG     R  U  VALUE OF RIGHT SIDE OF HORIZONTAL SCALE                       PICTUR
XSC     R  U  X SCALE FACTOR                                                PICTUR
XX      R  U  X-COORDINATE                                                  PICTUR
Y       R  U  Y-COORDINATE                                                  PICTUR
YA      R  D  Y-COORDINATE                                                  PICTUR
YB      R  D  Y-COORDINATE                                                  PICTUR
YBG     R  U  VALUE OF BOTTOM OF VERTICAL SCALE                             PICTUR
YCENT   R  U  ELEMENT CENTROID COORDINATE-Y                                 PICTUR
YDIF    R  U  COORDINATE DIFFERENCE-Y                                       PICTUR
YIN     R  D  ELEMENT COORDINATES-Y                                         PICTUR
YIN2    R  D  Y-COORDINATE FOR PLOT                                         PICTUR
YO1     R  U  Y-COORDINATE FOR PLOT-POINT 1                                 PICTUR
YO2     R  U  Y-COORDINATE FOR PLOT-POINT 2                                 PICTUR
YO3     R  U  Y-COORDINATE FOR PLOT-POINT 3                                 PICTUR
YO4     R  U  Y-COORDINATE FOR PLOT-POINT 4                                 PICTUR
YPA     R  U  COORDINATE OF ELEMENT CORNER POINT                            PICTUR
YSC     R  U  Y-SCALE FACTOR                                                PICTUR
YTG     R  U  VALUE OF TOP OF VERTICAL SCALE                                PICTUR
YY      R  U  Y-COORDINATE                                                  PICTUR
```

```
SYMBOLS USED IN SUBROUTINE PICTUR

Z        R  U  Z-COORDINATE                                              PICTUR
ZA       R  D  Z-COORDINATE                                              PICTUR
ZB       R  D  Z-COORDINATE                                              PICTUR
ZCENT    R  U  ELEMENT CENTROID COORDINATE-Z                             PICTUR
ZDIF     R  U  COORDINATE DIFFERENCE-Z                                   PICTUR
ZIN      R  D  ELEMENT COORDINATES-Z                                     PICTUR
ZIN2     R  D  Z-COORDINATE FOR PLOT                                     PICTUR
ZO1      R  U  Z-COORDINATE FOR PLOT-POINT 1                             PICTUR
ZO2      R  U  Z-COORDINATE FOR PLOT-POINT 2                             PICTUR
ZO3      R  U  Z-COORDINATE FOR PLOT-POINT 3                             PICTUR
ZO4      R  U  Z-COORDINATE FOR PLOT-POINT 4                             PICTUR
ZPA      R  U  COORDINATE OF ELEMENT CORNER POINT                        PICTUR
ZSC      R  U  Z-SCALE FACTOR                                            PICTUR
ZZ       R  U  Z-COORDINATE                                              PICTUR
```

30. SUBROUTINE HEADR2 (DECK GRPC)

a. Algorithm

This routine provides the title at the top of each page of the output and advances the page counter. This routine is very similar to the HEADER routine.

b. Input/Output

Program header is printed at top of page on output Tape 6.

c. Error

None

d. Subroutines Required

None

e. Argument List

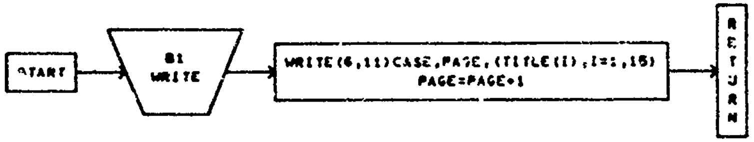
None

f. Length

350 bytes

```
DECK GRPC

      SUBROUTINE HEADR2                                                 GRPC  0010
C                                                                       GRPC  0020
      DIMENSION  TITLE(15)                                              GRPC  0030
C                                                                       GRPC  0040
      COMMON CASE,TITLE,PAGE                                            GRPC  0050
C                                                                       GRPC  0060
      INTEGER  PAGE, CASE                                               GRPC  0070
C                                                                       GRPC  0080
C  PRINT OUT HEADER AT TOP OF EACH PAGE OF OUTPUT                       GRPC  0090
      WRITE (6,11) CASE,PAGE,(TITLE(I),I=1,15)                          GRPC  0100
   11 FORMAT (1H1,5X,35HQUADRILATERAL CHARACTERISTICS - PICTURE         GRPC  0110
     1 16H DRAWING PROGRAM ,/1H0,5X,6H  CASE,I5,80X,5HPAGE I4,/         GRPC  0120
     2 1H0,14A4,A3)                                                     GRPC  0130
C                                                                       GRPC  0140
C  STEP PAGE NUMBER BY ONE                                              GRPC  0150
      PAGE = PAGE + 1                                                   GRPC  0160
C                                                                       GRPC  0170
      RETURN                                                            GRPC  0180
      END                                                               GRPC  0190
```

SUBROUTINE HEADR2



```
SYMBOLS USED IN SUBROUTINE HEADR2

CASE     I  C  CASE NUMBER                                                                              HEADR2
PAGE     I  C  PAGE NUMBER                                                                              HEADR2
TITLE    R  C  TITLE                                                                                    HEADR2
```

31. SUBROUTINE PLOT (DECK GRPD)

This routine is used to produce graphically plotted data as obtained from the aerodynamics part of the program.

a. Algorithm

Read in plotter control cards. As directed, read aerodynamic data from Tape 9. Prepare plot scales and grids. Plot data and connect data points as directed.

b. Input/Output

Data Source Control Card (Type 41), Vertical-Title Card (Type 44), Horizontal-Title Card (Type 45), Plotting-Grid Data Card (Type 45), Plot Control Array Card (Type 47), and Horizontal-Lable Card(s) Type 48).
Output plots are on the SC-4020 tape.

c. Error

An error condition occurs when the card type number is wrong.

d, Subroutines Required

None

e. Argument List

None

f. Length

10772 bytes

```
DECK GRPD

      SUBROUTINE PLOT                                                   GRPD 0010
C      POINT PLOTTER PROGRAM. UP TO 12 ARRAYS CAN BE INPUT              GRPD 0020
C      AND ANY ONE OF THEM PLOTTED AGAINST ANY OTHER                    GRPD 0030
C                                                                       GRPD 0040
      DIMENSION A(20),B(20),C(20),D(20),E(20),F(20),AA(20),BB(20),      GRPD 0050
     1 CC(20),DD(20),EE(20),FF(20),X(20),Y(20),I(100),TITLE(900),W(10), GRPD 0060
     3 PRINT(10),TITLE2(15)                                             GRPD 0070
      COMMON  CASE,TITLE2,PAGE,ERROR                                    GRPD 0080
      INTEGER  ERROR,TYPE,PAGE,CASE                                     GRPD 0090
C                                                                       GRPD 0100
      CALL CAMRAV (9)                                                   GRPD 0110
      REWIND 1                                                          GRPD 0120
      REWIND 10                                                         GRPD 0130
      REWIND 9                                                          GRPD 0140
C     READ FIRST CONTROL CARD                                           GRPD 0150
    1 READ (5,2) NC,IT                                                  GRPD 0160
    2  FORMAT (I4,65XI2)                                                GRPD 0170
C     CHECK TYPE OF CARD                                                GRPD 0180
      IF (IT .EQ. 41) GO TO 5                                           GRPD 0190
C                                                                       GRPD 0200
C     TYPE CARD GOOFY. PRINT ERROR HEADER AND LEAVE                     GRPD 0210
      IT = 41                                                           GRPD 0220
    3 CALL CAMRAV(9)                                                    GRPD 0230
      CALL FRAMEV (0)                                                   GRPD 0240
      CALL SCOUTV                                                       GRPD 0250
      CALL SCSETV (4)                                                   GRPD 0260
      WRITE (16,4) IT,IT                                                GRPD 0270
    4 FORMAT (1H4,15X30HFOR SOME ODD REASON, TYPE CARDI3,1X             GRPD 0280
     1  15HDOES NOT HAVE AI3,31H IN COLUMN 71-72. BETTER LUCK N         GRPD 0290
     2  9HEXT TIME. )                                                   GRPD 0300
      WRITE (6,48) IT,IT                                                GRPD 0310
   48 FORMAT (1H0,15X30HFOR SOME ODD REASON, TYPE CARDI3,1X             GRPD 0320
     1  15HDOES NOT HAVE AI3,31H IN COLUMN 71-72. BETTER LUCK N         GRPD 0330
     2  9HEXT TIME. )                                                   GRPD 0340
      READ (5,49) (TITLE(J),J=1,20)                                     GRPD 0350
```

```
DECK GRPD

   49 FORMAT (20A4)                                                    GRPD  0360
      WRITE (6,50) (TITLE(J),J=1,20)                                   GRPD  0370
   50 FORMAT (1H0,25X36HWRITTEN BELOW IS THE IMAGE OF THE CA          GRPD  0380
     1  30HRD FOLLOWING THE INCORRECT ONE//20X,20A4)                   GRPD  0390
      ERROR = 1                                                        GRPD  0400
      GO TO 101                                                        GRPD  0410
C                                                                      GRPD  0420
C     CHECK FOR INPUT TAPE, IF ANY                                     GRPD  0430
    5 I(20) = 0                                                        GRPD  0440
      ICNT  = 0                                                        GRPD  0450
      IF (NC) 28,33,7                                                  GRPD  0460
   33 READ(10)NC,NC,NC,NC,IT                                           GRPD  0470
      WRITE (6,44) NC                                                  GRPD  0480
   44 FORMAT (1H0,31X34HTAPE 10 JUST INSTRUCTED ME TO READI4          GRPD  0490
     1  ,18H CARDS FROM TAPE 9 )                                       GRPD  0500
C                                                                      GRPD  0510
C     CHECK TYPE                                                       GRPD  0520
      IF (IT .EQ. 42) GO TO 43                                         GRPD  0530
C                                                                      GRPD  0540
C     TYPE ERROR                                                       GRPD  0550
      IT = 42                                                          GRPD  0560
      GO TO 3                                                          GRPD  0570
   43 DO 34 J = 1,NC                                                   GRPD  0580
   34  READ (9) A(J),B(J),C(J),D(J),E(J),F(J),AA(J),BB(J),             GRPD  0590
     1  CC(J),DD(J),EE(J),FF(J),IT                                     GRPD  0600
C                                                                      GRPD  0610
C      CHECK TYPE (IT) OF CARD JUST READ                               GRPD  0620
      IF (IT .EQ. 43) GO TO 71                                         GRPD  0630
C                                                                      GRPD  0640
C      TYPE ERROR                                                      GRPD  0650
      IT = 43                                                          GRPD  0660
       GO TO 3                                                         GRPD  0670
   71  CONTINUE                                                        GRPD  0680
       WRITE (6,45) NC                                                 GRPD  0690
   45  FORMAT (1H0,42X11HI JUST READI4,18H CARDS FROM TAPE 9)          GRPD  0700
      IF (I(20) .NE. 0) GO TO 78                                       GRPD  0710
```

```
DECK GRPD

      GO TO 28                                                          GRPD 0720
    7 DO 6 K = 1, NC                                                    GRPD 0730
      DO 6 J = 1, 2                                                     GRPD 0740
      IF (J .EQ. 2) GO TO 69                                            GRPD 0750
      READ(5,8)  A(K),B(K),C(K),D(K),E(K),F(K),AA(K),IT                 GRPD 0760
    8 FORMAT (7F10.0,I2)                                                GRPD 0770
C                                                                       GRPD 0780
C     CHECK TYPE (IT) OF CARD JUST READ                                 GRPD 0790
    9 IF(IT .EQ. 43) GO TO 6                                            GRPD 0800
C                                                                       GRPD 0810
C     TYPE SCREWED UP. ERROR                                            GRPD 0820
      IT = 43                                                           GRPD 0830
      GO TO 3                                                           GRPD 0840
   69 READ(5,70)  BB(K),CC(K),DD(K),EE(K),FF(K),IT                      GRPD 0850
   70 FORMAT(5F10.0,20XI2)                                              GRPD 0860
      GO TO 9                                                           GRPD 0870
    6 CONTINUE                                                          GRPD 0880
      WRITE (6,46) NC                                                   GRPD 0890
   46 FORMAT (1H0,24X33HTAPE 5 JUST INSTRUCTED ME TO READI4,            GRPD 0900
     1   34H RECORDS FROM TAPE 5, WHICH I DID. )                        GRPD 0910
     GO TO 28                                                           GRPD 0920
C                                                                       GRPD 0930
C    READ STUFF FROM TAPE 1                                             GRPD 0940
   51 READ (1) NC,NC,NC,NC,NC                                           GRPD 0950
     DO 52 J = 1,NC                                                     GRPD 0960
   52 READ (1) A(J),B(J),C(J),D(J),E(J),F(J),AA(J),                     GRPD 0970
     1 BB(J),CC(J),DD(J),EE(J),FF(J)                                    GRPD 0980
     REWIND 1                                                           GRPD 0990
     WRITE (6,53) NC                                                    GRPD 1000
   53 FORMAT (1H0,24X33HTAPE 1 JUST INSTRUCTED ME TO READI4,            GRPD 1010
     1  32H CARDS FROM TAPE 1, WHICH I DID. )                           GRPD 1020
C                                                                       GRPD 1030
C    READ IN PLOTTING INFORMATION CARDS                                 GRPD 1040
   28 READ (5,10) (TITLE(J), J=1, 18), IT                               GRPD 1050
   10 FORMAT (17A4,A2,I2)                                               GRPD 1060
      IF (IT .EQ. 44) GO TO 72                                          GRPD 1070
```

DECK GRPD

```
      IT = 44                                                           GRPD  1080
      GO TO 3                                                           GRPD  1090
   72 READ (5,10) (TITLE(J), J=19,36), IT                               GRPD  1100
      IF (IT .EQ. 45) GO TO 74                                          GRPD  1110
      IT = 45                                                           GRPD  1120
      GO TO 3                                                           GRPD  1130
   74 READ (5,75) (W(J), J=1, 6), IT                                    GRPD  1140
   75 FORMAT (6F10.0,10XI2)                                             GRPD  1150
      IF (IT .EQ. 46) GO TO 76                                          GRPD  1160
      IT =6                                                             GRPD  1170
      GO TO 3                                                           GRPD  1180
  76 READ (5,77) (I(J), J=1,21), IT                                     GRPD  1190
   77 FORMAT (3I2,I4,I3,I4,I3,I5,I4,I3,I4,I3,I2,I3,I2,I3,I2,            GRPD  1200
     1   I3,I2,I3,I2,9XI2)                                              GRPD  1210
      IF (IT .EQ. 47) GO TO 78                                          GRPD  1220
      IT = 47                                                           GRPD  1230
      GO TO 3                                                           GRPD  1240
C                                                                       GRPD  1250
C     SET UP DATA FOR GRIDIV                                            GRPD  1260
   78 L  =I(3)                                                          GRPD  1270
     ICNT = ICNT + 1                                                    GRPD  1280
     XL  = W(1)                                                         GRPD  1290
     XR  = W(2)                                                         GRPD  1300
     YB  = W(3)                                                         GRPD  1310
     YT  = W(4)                                                         GRPD  1320
     DX  = W(5)                                                         GRPD  1330
     DY  = W(6)                                                         GRPD  1340
     N   = I(4)                                                         GRPD  1350
     M   = I(5)                                                         GRPD  1360
     IV  = I(6)                                                         GRPD  1370
     IH  = I(7)                                                         GRPD  1380
     NX  = I(16)                                                        GRPD  1390
     NY  = I(17)                                                        GRPD  1400
     IC  = I(18)                                                        GRPD  1410
     CALL CAMRAV(IC)                                                    GRPD  1420
     CALL GRIDIV (L,XL,XR,YB,YT,DX,DY,N,M,IV,IH,NX,NY)                  GRPD  1430
```

```
      DECK GRPD
C                                                                      GRPD  1440
C     CHECK TO SEE IF DATA HAS BEEN CALLED IN                          GRPD  1450
      IF (NC .LT. 1) GO TO 30                                          GRPD  1460
C                                                                      GRPD  1470
C     TRANSFER DATA TO PLOTTING ARRAYS                                 GRPD  1480
      NX = I(1)                                                        GRPD  1490
      NY = I(2)                                                        GRPD  1500
      DO 24 J = 1,NC                                                   GRPD  1510
      GO TO (11,12,13,14,15,16,57,58,59,60,61,62),NX                   GRPD  1520
   11 X(J)     = A(J)                                                  GRPD  1530
      GO TO 17                                                         GRPD  1540
   12 X(J)     = B(J)                                                  GRPD  1550
      GO TO 17                                                         GRPD  1560
   13 X(J)     = C(J)                                                  GRPD  1570
      GO TO 17                                                         GRPD  1580
   14 X(J)     = D(J)                                                  GRPD  1590
      GO TO 17                                                         GRPD  1600
   15 X(J)     = E(J)                                                  GRPD  1610
      GO TO 17                                                         GRPD  1620
   16 X(J)     = F(J)                                                  GRPD  1630
      GO TO 17                                                         GRPD  1640
   57 X(J)     = AA(J)                                                 GRPD  1650
      GO TO 17                                                         GRPD  1660
   58 X(J)     = BB(J)                                                 GRPD  1670
      GO TO 17                                                         GRPD  1680
   59 X(J)     = CC(J)                                                 GRPD  1690
      GO TO 17                                                         GRPD  1700
   60 X(J)     = DD(J)                                                 GRPD  1710
      GO TO 17                                                         GRPD  1720
   61 X(J)     = EE(J)                                                 GRPD  1730
      GO TO 17                                                         GRPD  1740
   62 X(J)     = FF(J)                                                 GRPD  1750
   17 GO TO  (18,19,20,21,22,23,63,64,65,66,67,68),NY                  GRPD  1760
   18 Y(J)     = A(J)                                                  GRPD  1770
      GO TO 24                                                         GRPD  1780
   19 Y(J)     = B(J)                                                  GRPD  1790
```

DECK GRPD

```
      GO TO 24                                                          GRPD  1800
   20 Y(J)     = C(J)                                                   GRPD  1810
      GO TO 24                                                          GRPD  1820
   21 Y(J)     = D(J)                                                   GRPD  1830
      GO TO 24                                                          GRPD  1840
   22 Y(J)     = E(J)                                                   GRPD  1850
      GO TO 24                                                          GRPD  1860
   23 Y(J)     = F(J)                                                   GRPD  1870
      GO TO 24                                                          GRPD  1880
   63 Y(J)     = AA(J)                                                  GRPD  1890
      GO TO 24                                                          GRPD  1900
   64 Y(J)     = BB(J)                                                  GRPD  1910
      GO TO 24                                                          GRPD  1920
   65 Y(J)     = CC(J)                                                  GRPD  1930
      GO TO 24                                                          GRPD  1940
   66 Y(J)     = DD(J)                                                  GRPD  1950
      GO TO 24                                                          GRPD  1960
   67 Y(J)     = EE(J)                                                  GRPD  1970
      GO TO 24                                                          GRPD  1980
   68 Y(J)     = FF(J)                                                  GRPD  1990
   24 CONTINUE                                                          GRPD  2000
C                                                                       GRPD  2010
C     SET UP DATA FOR PLOTTING ALL POINTS THREE TIMES                   GRPD  2020
C     CHECK FOR INPUT NUMBER OF POINTS TO BE PLOTTED                    GRPD  2030
      IF (I(8) .GT. 0) GO TO 35                                         GRPD  2040
      I(8) = NC                                                         GRPD  2050
   35 NP = I(8)                                                         GRPD  2060
      NX = I(9)                                                         GRPD  2070
      NY = I(10)                                                        GRPD  2080
      IP = I(11)                                                        GRPD  2090
      IS = I(12)                                                        GRPD  2100
      DO 25 J = 1,3                                                     GRPD  2110
   25 CALL APLOTV (NP,X,Y,NX,NY,IP,IS,IERR)                             GRPD  2120
C                                                                       GRPD  2130
C     DUMMY CHECK TO SEE IF ANY POINTS OUTSIDE GRID                     GRPD  2140
      IF (IERR .EQ. 0) GO TO 31                                         GRPD  2150
```

DECK GRPD

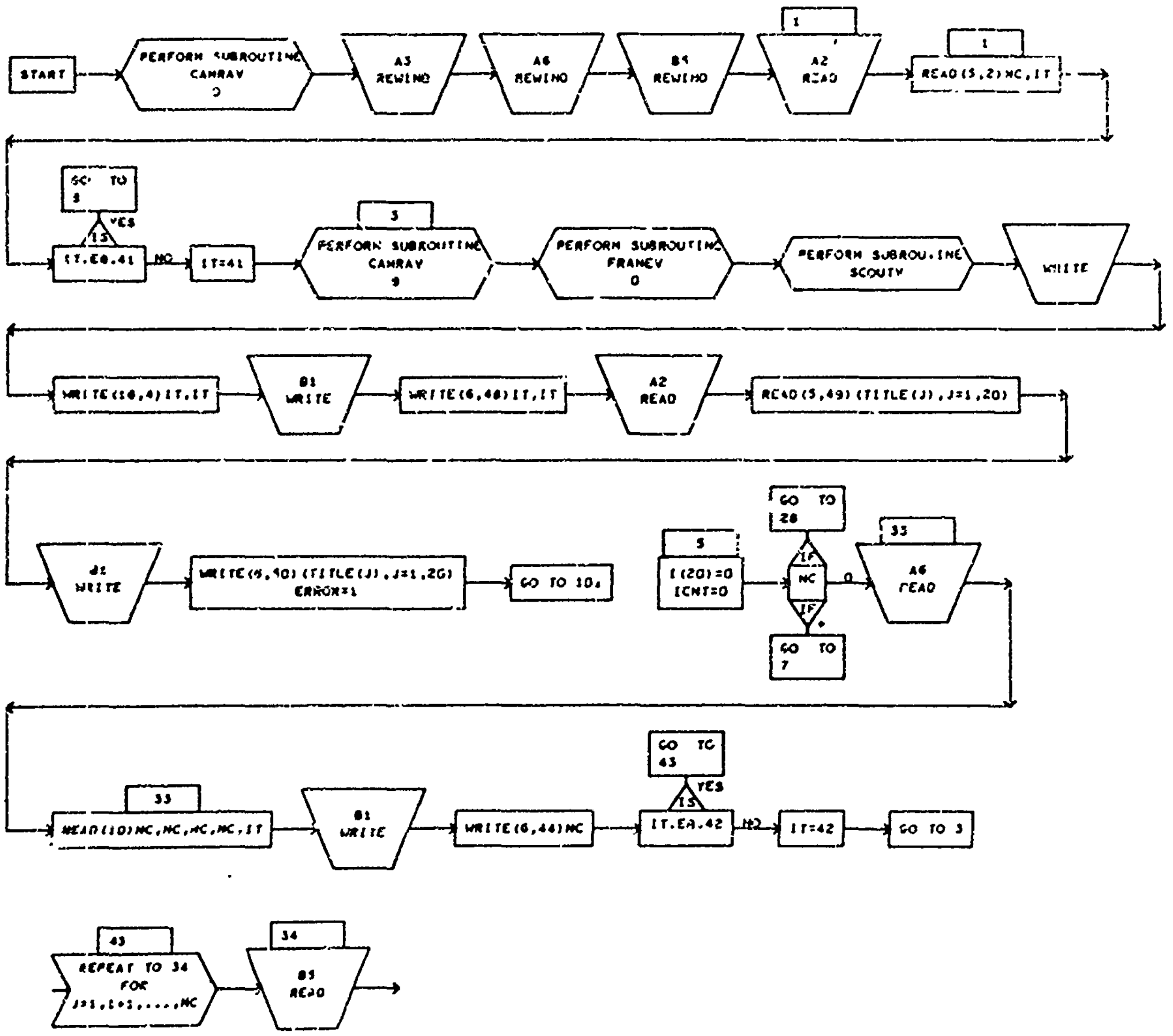
```
      IERR = 0
C
C     CHECK TO SEE IF POINTS ARE TO BE CONNECTED
   31 IF (I(13) .LT.1) GO TO 30
C
C     SET UP TO CONNECT DATA POINTS (3 TIMES)
      DO 26 J = 1,3
      DO 26 K = 1,NC,NX
      G1       = G2
      H1       = H2
      IX1      = IX2
      IY1      = IY2
      G2       = X(K)
      H2       = Y(K)
      IX2      = NXV(G2)
      IY2      = NYV(H2)
      IF (K .EQ. 1) GO TO 26
C
C     TEST FOR OFF SCALE POINTS
      IF (IX1*IY1 .EQ. 0) GO TO 26
      IF (IX2*IY2 .EQ. 0) GO TO 26
      CALL LINEV (IX1,IY1,IX2,IY2)
   26 CONTINUE
C
C     PRINT VERTICAL AND HORIZONTAL TITLES 3 TIMES
   30 DO 36 J = 1,3
   36 CALL APRNTV (0,-12,70,TITLE,8,943)
C
C     SET UP FOR HORIZONTAL TITLE
      DO 27 J = 1,18
   27 PRINT(J) = TITLE(J+18)
      DO 37 J = 1,3
   37 CALL PRINTV (70,PRINT,224,8)
C
C     CHECK FOR HORIZONTAL LABEL CARDS
      IF (I(18) .LE. 0) GO TO 42
```

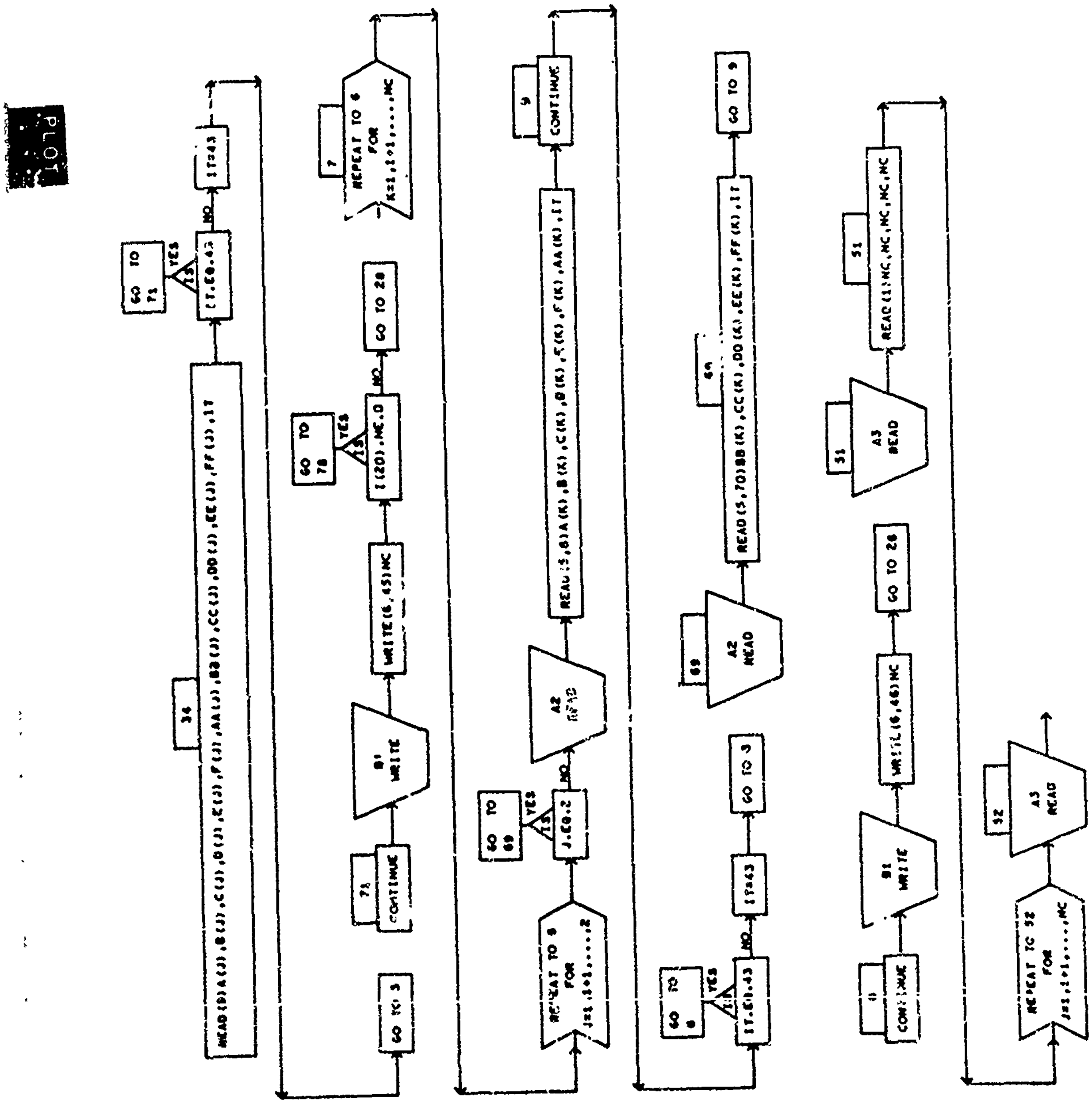
DECK GRPD

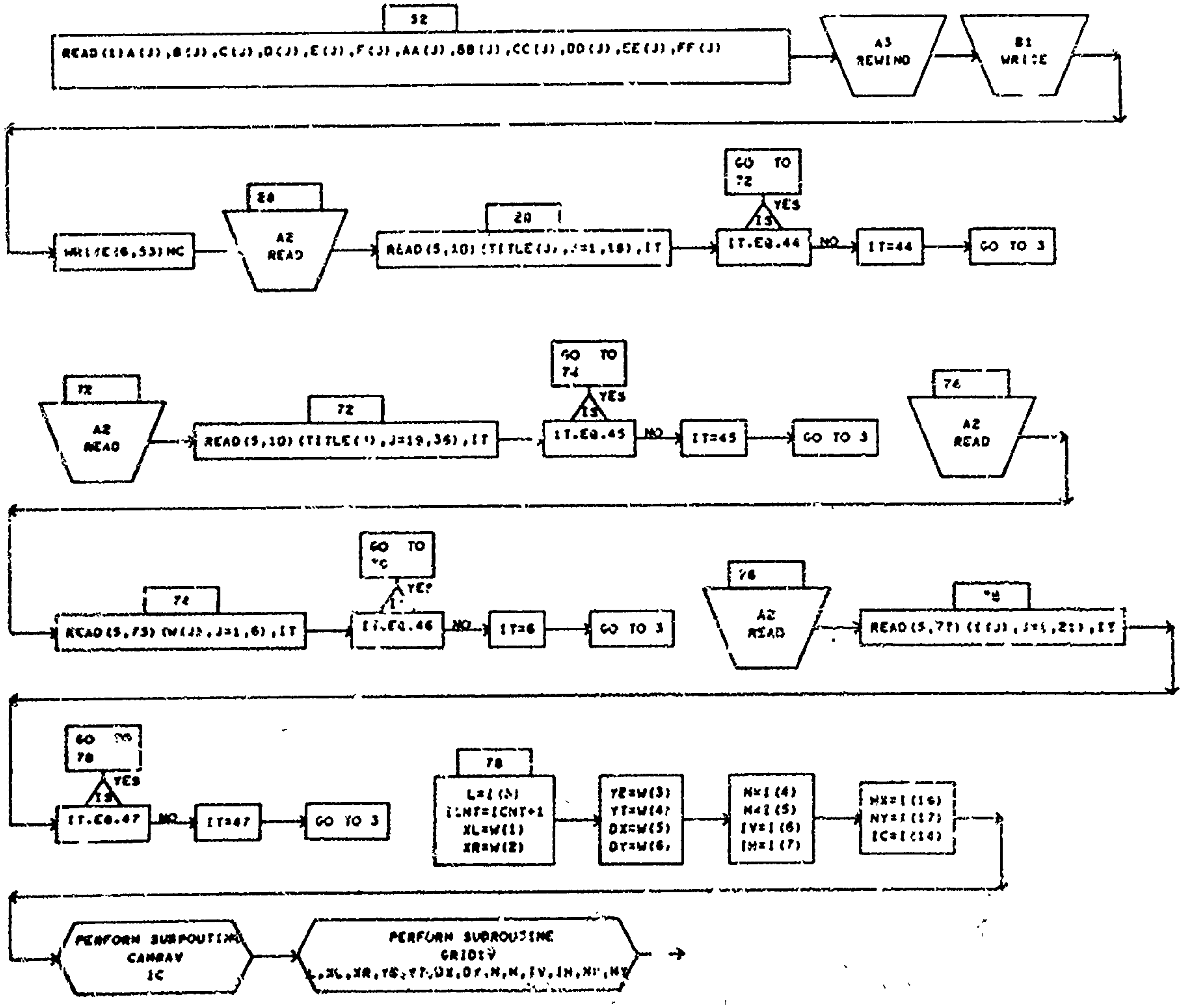
```
C                                                                       GRPD  2520
C     READ AND CHECK TYPE OF HORIZONTAL LABEL CARDS                     GRPD  2530
      J         = I(18)                                                 GRPD  2540
      DO 39 K = 1,J                                                     GRPD  2550
      M         = 18*(K+2)                                              GRPD  2560
      L         = M - 17                                                GRPD  2570
      READ (5,38) (TITLE(N),N=L,M),IT                                   GRPD  2580
   38 FORMAT (17A4,A2,I2)                                               GRPD  2590
       IF (IT .EQ. 48) GO TO 39                                         GRPD  2600
C                                                                       GRPD  2610
C     TYPE ERROR                                                        GRPD  2620
      IT = 48                                                           GRPD  2630
      GO TO 3                                                           GRPD  2640
   39 CONTINUE                                                          GRPD  2650
C                                                                       GRPD  2660
      PRINT ALL HORIZONTAL LABELS 3 TIMES                               GRPD  2670
      DO 41 K = 1,3                                                     GRPD  2680
      DO 41 L = 1,J                                                     GRPD  2690
      IY        = 1039 - 16*L                                           GRPD  2700
      M         = 18*(L+1)                                              GRPD  2710
      DO 40 N = 1,18                                                    GRPD  2720
      II        = M + N                                                 GRPD  2730
   40 PRINT(N)= TITLE(II)                                               GRPD  2740
   41 CALL PRINTV (70,PRINT,224,IY)                                     GRPD  2750
C                                                                       GRPD  2760
C     CHECK FOR WRITING ARRAYS ON TAPE 1                                GRPD  2770
   42 IF (I(19) .NE. 1) GO TO 56                                        GRPD  2780
C                                                                       GRPD  2790
C     TRANSFER ARRAYS TO TAPE 1                                         GRPD  2800
      WRITE (1) NC,NC,NC,NC,NC                                          GRPD  2810
      DO 54 J = 1,NC                                                    GRPD  2820
   54 WRITE (1) A(J),B(J),C(J),D(J),E(J),F(J),AA(J),BB(J),              GRPD  2830
     1CC(J),DD(J),EE(J),FF(J)                                           GRPD  2840
      REWIND 1                                                          GRPD  2850
      WRITE (6,55) NC                                                   GRPD  2860
   55 FORMAT (1H0,43X12HI JUST WROTEI4,16H CARDS ON TAPE 1 )            GRPD  2870
```

```
DECK GRPD

C
C       CHECK RETURNS OR FINISH OF PROGRAM
   56  IF (ICNT .EQ. I(20))I(15) = I(21)
       IR = I(15) + 1
       GO TO (29,28,1,33,51), IR
    29 WRITE (6,47)
    47 FORMAT (1H0,    36HJUST FINISHED PLOTTING ALL SORTS OF
      1  49HGOODIES ON TAPE 16. IF ALL GOES WELL, YOU SHOULD
      2  34HGET SOME RESULTS FROM THE SC-4020. )
       ERROR = 1
       READ (5,100) TYPE
  100  FORMAT (70X,I2)
       IF (TYPE .EQ. 99) ERROR = 0
  101  RETURN
       END
```

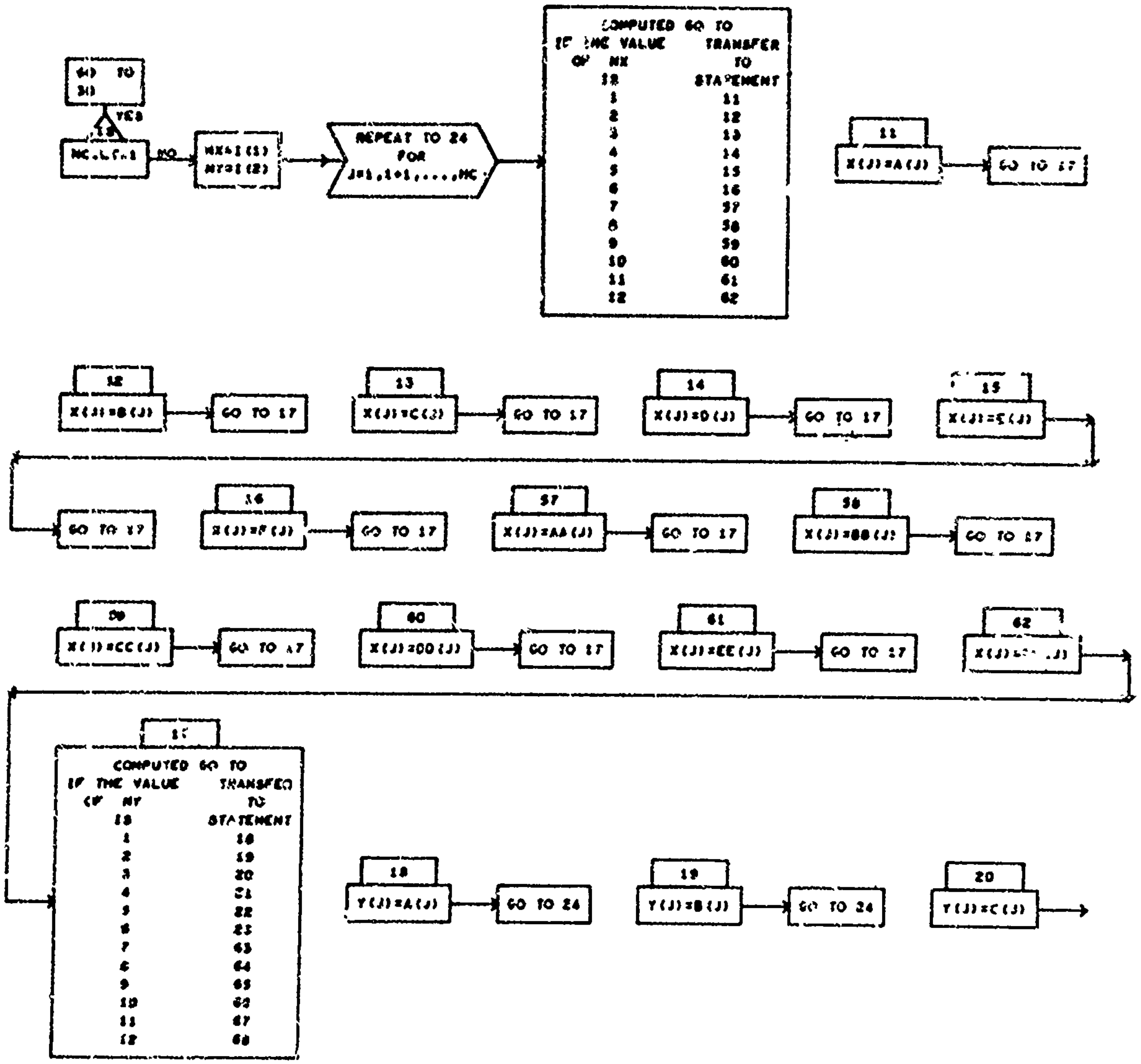
SUBROUTINE PLOT

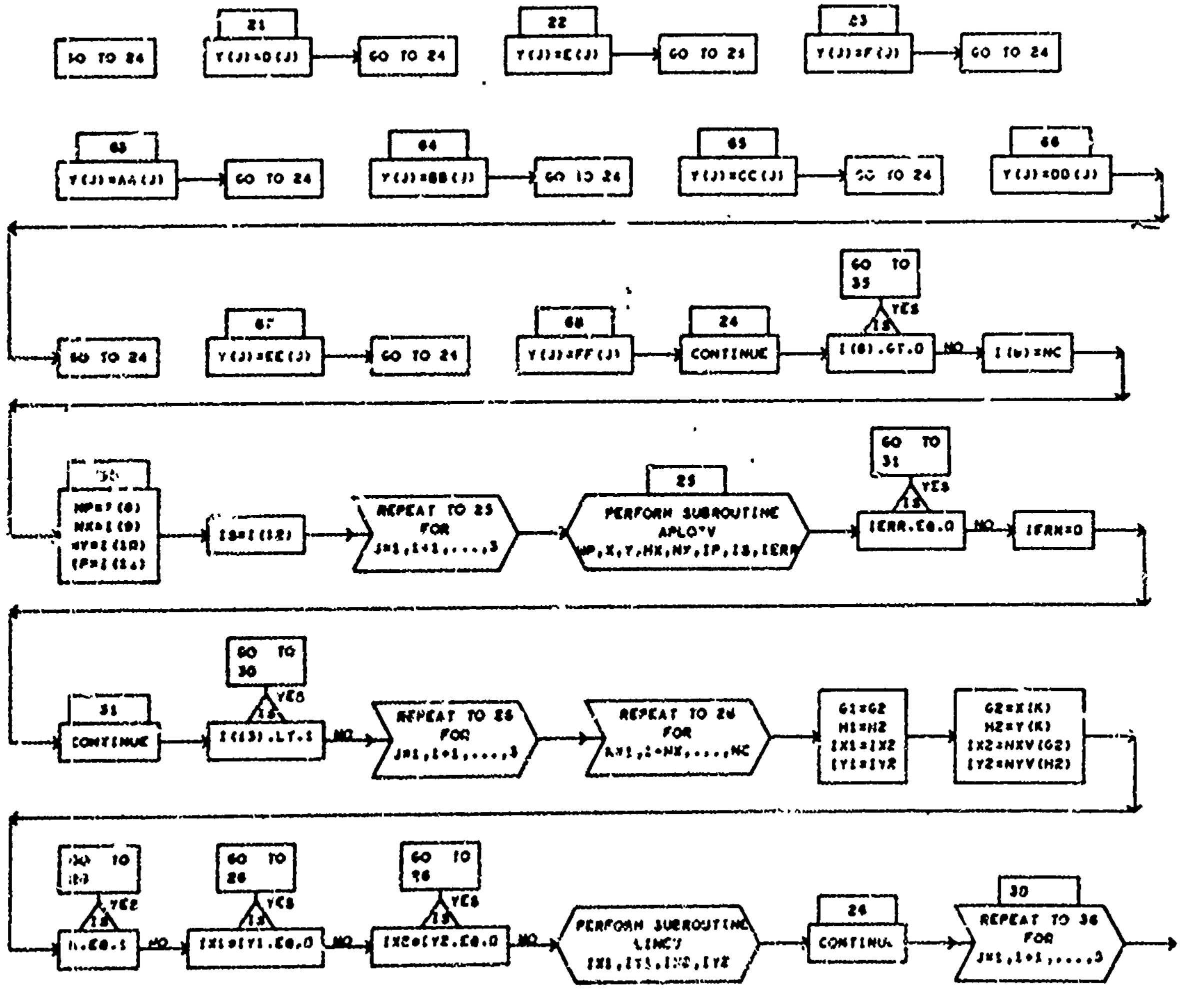


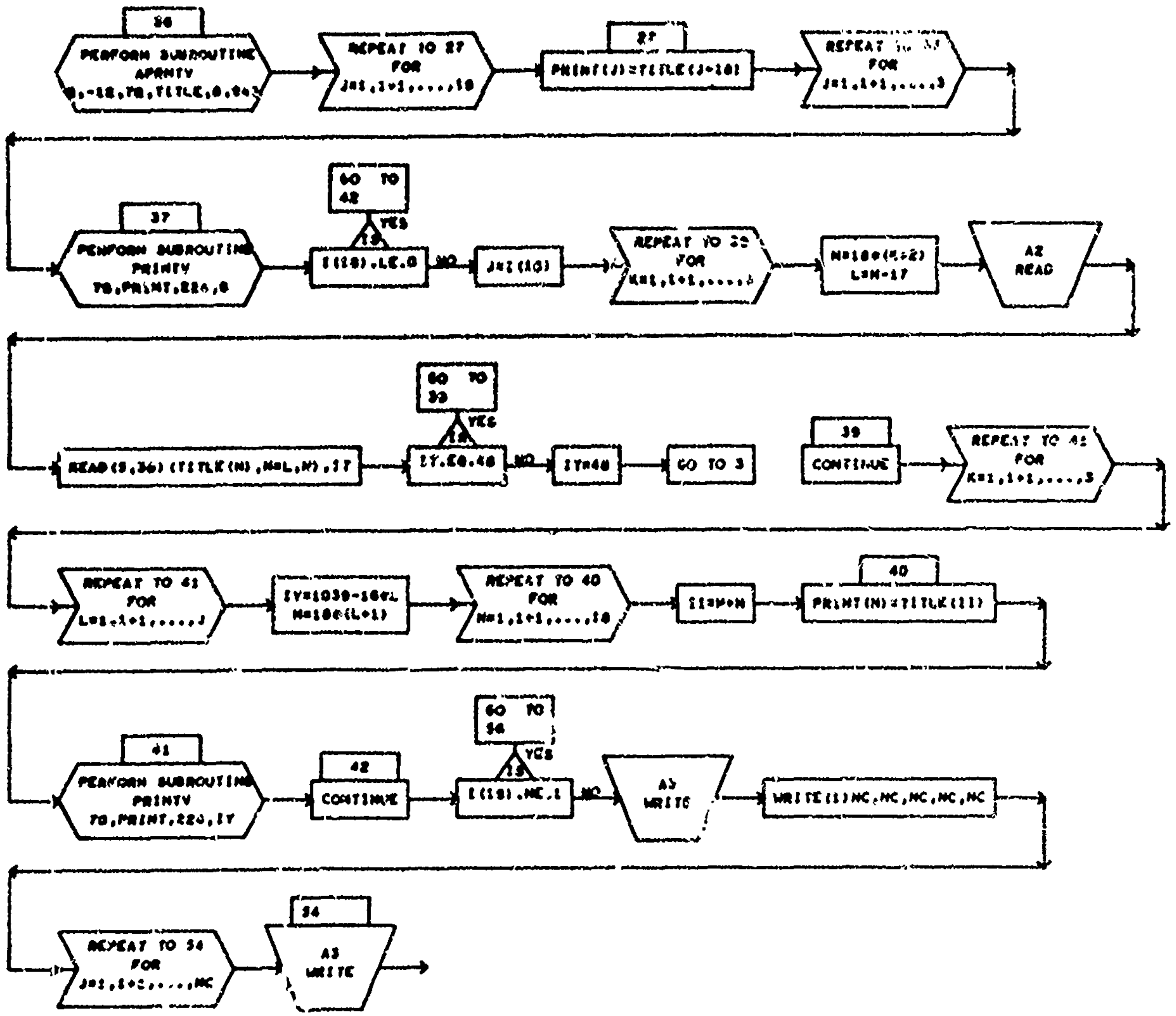

PLOT
34
READ(5,...)A(J),B(J),C(J),D(J),E(J),F(J),AA(J),BB(J),CC(J),DD(J),EE(J),FF(J),IT
IS
IT.EQ.43
YES
GO TO 71
NO
IT=43
GO TO 3
78
CONTINUE
B1
WRITE
WRITE(6,45)NC
IS
I(20).NE.0
YES
GO TO 78
NO
GO TO 28
7
REPEAT TO 6 FOR K=1,1+1,...,NC
REPEAT TO 8 FOR J=1,1+1,...,2
IS
J.EQ.2
YES
GO TO 69
NO
A2
READ
READ(5,61)A(K),B(K),C(K),D(K),E(K),F(K),AA(K),IT
9
CONTINUE
IS
IT.EQ.43
YES
GO TO 8
NO
IT=43
GO TO 3
69
A2
READ
64
READ(5,70)BB(K),CC(K),DD(K),EE(K),FF(K),IT
GO TO 9
11
CONTINUE
B1
WRITE
WRITE(6,46)NC
GO TO 26
51
A3
READ
51
READ(1)NC,NC,NC,NC
REPEAT TO 52 FOR J=1,1+1,...,NC
52
A3
READ

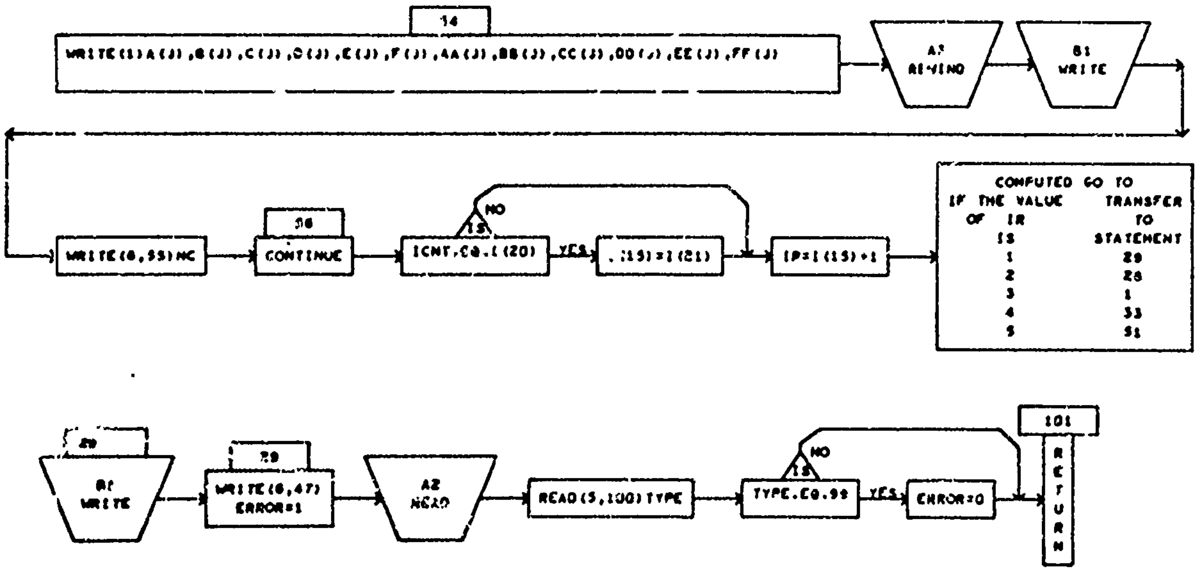


52
READ(1)A(J),B(J),C(J),D(J),E(J),F(J),AA(J),BB(J),CC(J),DD(J),EE(J),FF(J)
A3
REWIND
B1
WRITE
WRITE(6,53)NC
28
A2
READ
28
READ(5,10)(TITLE(J),J=1,18),IT
GO TO
72
YES
IS
IT.EQ.44
NO
IT=44
GO TO 3
72
A2
READ
72
READ(5,10)(TITLE(J),J=19,36),IT
GO TO
74
YES
IS
IT.EQ.45
NO
IT=45
GO TO 3
74
A2
READ
74
READ(5,73)(W(J),J=1,6),IT
GO TO
76
YES
IT.EQ.46
NO
IT=6
GO TO 3
76
A2
READ
READ(5,77)(I(J),J=1,21),IT
GO TO
78
YES
IS
IT.EQ.47
NO
IT=47
GO TO 3
78
L=I(3)
ICNT=ICNT+1
XL=W(1)
XR=W(2)
YB=W(3)
YT=W(4)
DX=W(5)
DY=W(6)
N=I(4)
M=I(5)
IV=I(6)
IH=I(7)
NX=I(16)
NY=I(17)
IC=I(14)
PERFORM SUBROUTINE
CAMRAV
IC
PERFORM SUBROUTINE
GRIDIV
L,XL,XR,YB,YT,DX,DY,N,M,IV,IH,NX,NY


GO TO
30
YES
13
NC.LT.1
NO
NX=I(1)
NY=I(2)
REPEAT TO 24
FOR
J=1,1+1,....,NC
COMPUTED GO TO
IF THE VALUE OF NX
TRANSFER TO STATEMENT
12
1 11
2 12
3 13
4 14
5 15
6 16
7 57
8 58
9 59
10 60
11 61
12 62
11
X(J)=A(J)
GO TO 17
12
X(J)=B(J)
GO TO 17
13
X(J)=C(J)
GO TO 17
14
X(J)=D(J)
GO TO 17
15
X(J)=E(J)
GO TO 17
16
X(J)=F(J)
GO TO 17
57
X(J)=AA(J)
GO TO 17
58
X(J)=BB(J)
GO TO 17
59
X(J)=CC(J)
GO TO 17
60
X(J)=DD(J)
GO TO 17
61
X(J)=EE(J)
GO TO 17
62
17
COMPUTED GO TO
IF THE VALUE OF NY
TRANSFER TO STATEMENT
18
1 18
2 19
3 20
4 21
5 22
6 23
7 63
8 64
9 65
10 66
11 67
12 68
18
Y(J)=A(J)
GO TO 24
19
Y(J)=B(J)
GO TO 24
20
Y(J)=C(J)


GO TO 24
21
Y(J)=D(J)
GO TO 24
22
Y(J)=E(J)
GO TO 24
23
Y(J)=F(J)
GO TO 24
63
Y(J)=AA(J)
GO TO 24
64
Y(J)=BB(J)
GO TO 24
65
Y(J)=CC(J)
GO TO 24
66
Y(J)=DD(J)
GO TO 24
67
Y(J)=EE(J)
GO TO 24
68
Y(J)=FF(J)
24
CONTINUE
I(8).GT.0
IS
YES
GO TO 35
NO
I(8)=NC
35
NP=I(8)
NX=I(9)
NY=I(10)
IP=I(14)
IS=I(12)
REPEAT TO 25 FOR J=1,1+1,...,3
25
PERFORM SUBROUTINE APLOTV NP,X,Y,NX,NY,IP,IS,IERR
IERR.EQ.0
IS
YES
GO TO 31
NO
IERR=0
31
CONTINUE
I(13).LT.1
IS
YES
GO TO 30
NO
REPEAT TO 26 FOR J=1,1+1,...,3
REPEAT TO 26 FOR K=1,1+NX,...,NC
G1=G2
H1=H2
IX1=IX2
IY1=IY2
G2=X(K)
H2=Y(K)
IX2=NXV(G2)
IY2=NYV(H2)
K.EQ.1
IS
YES
GO TO 26
NO
IX1=IY1.EQ.0
IS
YES
GO TO 26
NO
IX2=IY2.EQ.0
IS
YES
GO TO 26
NO
PERFORM SUBROUTINE LINCV IX1,IY1,IX2,IY2
26
CONTINUE
30
REPEAT TO 36 FOR J=1,1+1,...,3


36
PERFORM SUBROUTINE
APRNTV
0,-18,TB,TITLE,0,0
REPEAT TO 27
FOR
J=1,1+1,...,18
27
PRINT(J)=TITLE(J+18)
REPEAT TO 37
FOR
J=1,1+1,...,3
37
PERFORM SUBROUTINE
PRINTV
TB,PRINT,224,0
GO TO
42
YES
IS
I(18).LE.0
NO
J=I(10)
REPEAT TO 39
FOR
K=1,1+1,...,3
N=18*(K+2)
L=N-17
A2
READ
READ(5,36)(TITLE(N),N=L,N),IT
GO TO
39
YES
IS
IT.EQ.48
NO
IT=48
GO TO 3
39
CONTINUE
REPEAT TO 41
FOR
K=1,1+1,...,3
REPEAT TO 41
FOR
L=1,1+1,...,J
IY=1039-18*L
M=18*(L+1)
REPEAT TO 40
FOR
N=1,1+1,...,18
II=M+N
40
PRINT(N)=TITLE(II)
41
PERFORM SUBROUTINE
PRINTV
TB,PRINT,224,IY
42
CONTINUE
GO TO
54
YES
IS
I(18).NE.1
NO
A3
WRITE
WRITE(1)NC,NC,NC,NC,NC
REPEAT TO 54
FOR
J=1,1+1,...,NC
54
A3
WRITE


14
WRITE(1)A(J),B(J),C(J),D(J),E(J),F(J),AA(J),BB(J),CC(J),DD(J),EE(J),FF(J)
A? REWIND
B1 WRITE
WRITE(6,55)NC
36
CONTINUE
ICNT.EQ.I(20)
IS
NO
YES
.I(15)=I(21)
IP=I(15)+1
COMPUTED GO TO
IF THE VALUE OF IR IS
TRANSFER TO STATEMENT
1 29
2 28
3 1
4 33
5 51
28
B1 WRITE
29
WRITE(6,47) ERROR=1
A2 READ
READ(5,100)TYPE
TYPE.EQ.99
IS
NO
YES
ERROR=0
101
RETURN

```
SYMBOLS USED IN SUBROUTINE PLOT

A        R  D  FIRST DATA ARRAY                                         PLOT
AA       R  D  SEVENTH DATA ARRAY                                       PLOT
B        R  D  SECOND DATA ARRAY                                        PLOT
BB       R  D  EIGHT DATA ARRAY                                         PLOT
C        R  D  THIRD DATA ARRAY                                         PLOT
CASE     I  C  CARD NUMBER                                              PLOT
CC       R  D  NINTH DATA ARRAY                                         PLOT
D        R  D  FOURTH DATA ARRAY                                        PLOT
DD       R  D  TENTH DATA ARRAY                                         PLOT
DX       R  U  INCREMENT BETWEEN VERTICAL GRID LINES                    PLOT
DY       R  U  INCREMENT BETWEEN HORIZONAL GRID LINES                   PLOT
E        R  D  FIFTH DATA ARRAY                                         PLOT
EE       R  D  ELEVENTH DATA ARRAY                                      PLOT
ERROR    I  C  ERROR FLAG                                               PLOT
F        R  D  SIXTH DATA ARRAY                                         PLOT
FF       R  D  TWELVETH DATA ARRAY                                      PLOT
G1       R  U  ACTUAL LOCATION ALONG X-AXIS FIRST PLOTTED POINT         PLOT
G2       R  U  ACTUAL LOCATION ALONG X-AXIS OF SECOND PLOTTED POINT     PLOT
H1       R  U  ACTUAL LOCATION ALONG Y-AXIS OF FIRST PLOTTED POINT      PLOT
H2       R  U  ACTUAL LOCATION ALONG Y-AXIS SECOND PLOTTED POINT        PLOT
I        I  D  PROGRAM CONTROL ARRAY                                    PLOT
IC       I  U  CAMERA SELECTION FLAG                                    PLOT
ICNT     I  U  PICTURE COUNTER                                          PLOT
IERR     I  U  NAME OF AN ERROR LOCATION.                               PLOT
IH       I  U  TERM CAUSES LABEL OF EVERY IHTH HORIZONTAL GRID LINE     PLOT
II       I  U  HORIZONTAL TITLE ARRAY SUBSCRIPT                         PLOT
IP       I  U  NUMBER OF CHARACTERS TO BE USED AS PLOTTING SYMBOLS      PLOT
IR       I  U  CONTROL FLAG VALUE OF WHICH DETERMINES NEXT OPERATION    PLOT
IS       I  U  PLOTTING SYMBOL CODE                                     PLOT
IT       I  U  TYPE OF INPUT DATA CARD                                  PLOT
IV       I  U  TERM CAUSES LABEL OF EVERY IVTH VERTICAL GRID LINE       PLOT
IX1      I  U  RASTER LOCATION ALONG X-AXIS OF FIRST PLOTTED POINT      PLOT
IX2      I  U  RASTER LOCATION ALONG X-AXIS OF SECOND PLOTTED POINT     PLOT
IY       I  U  VERTICAL RASTER LOCATION OF HORIZONTAL TITLES            PLOT
IY1      I  U  RASTER LOCATION ALONG Y-AXIS SECOND PLOTTED POINT        PLOT
IY2      I  U  RASTER LOCATION ALONG Y-AXIS OF SECOND PLOTTED POINT     PLOT
```

```
SYMBOLS USED IN SUBROUTINE PLOT

J        I  U  MULTI-PURPOSE INDEX                                                 PLOT
K        I  U  MULTI-PURPOSE INDEX                                                 PLOT
L        I  U  MULTI-PURPOSE INDEX AND FILM ADVANCE FLAG                           PLOT
M        I  U  MULTI-PURPOSE INDEX AND EMPHASIS FLAG FOR HORIZ. GRID LINES         PLOT
N        I  U  MULTI-PURPOSE INDEX AND EMPHASIS FLAG FOR VERT. GRID LINES          PLOT
NC       I  U  NUMBER OF DATA POINTS                                               PLOT
NP       I  U  NUMBER OF POINTS TO BE PLOTTED                                      PLOT
NX       I  U  SUBSCRIPT INCREMENT OF X-ARRAY DATA TO BE PLOTTED                   PLOT
NY       I  U  SUBSCRIPT INCREMENT OF X-ARRAY DATA TO BE PLOTTED.                  PLOT
PAGE     I  C  PAGE NUMBER                                                         PLOT
PRINT    R  D  PRINTING ARRAY                                                      PLOT
TITLE    R  D  ABSISSA AND ORDINATE TITLES, AND HORIZONTAL TITLE ARRAY             PLOT
TITLE2   R  C  DUMMY TITLE ARRAY                                                   PLOT
TYPE     I  U  CARD TYPE                                                           PLOT
W        R  D  GRID INFORMATION ARRAY                                              PLOT
X        R  D  PLOTTING ARRAY, LOCATION ALONG X-AXIS                               PLOT
XL       R  U  LEFT-MOST LIMIT OF THE GRID ON X-AXIS                               PLOT
XR       R  U  RIGHT-MOST LIMIT OF THE GRID ON X-AXIS                              PLOT
Y        R  D  PLOTTING ARRAY, LOCATION ALONG Y-AXIS                               PLOT
YB       R  U  BOTTOM MOST LIMIT OF THE GRID ON Y-AXIS                             PLOT
YT       R  U  TOP MOST LIMIT OF THE GRID ON Y-AXIS                                PLOT
```

```
SYMBOLS USED IN SUBROUTINE PLOT

J        I  U  MULTI-PURPOSE INDEX                                             PLOT
K        I  U  MULTI-PURPOSE INDEX                                             PLOT
L        I  U  MULTI-PURPOSE INDEX AND FILM ADVANCE FLAG                       PLOT
M        I  U  MULTI-PURPOSE INDEX AND EMPHASIS FLAG FOR HORIZ. GRID LINES     PLOT
N        I  U  MULTI-PURPOSE INDEX AND EMPHASIS FLAG FOR VERT. GRID LINES      PLOT
NC       I  U  NUMBER OF DATA POINTS                                           PLOT
NP       I  U  NUMBER OF POINTS TO BE PLOTTED                                  PLOT
NX       I  U  SUBSCRIPT INCREMENT OF X-ARRAY DATA TO BE PLOTTED               PLOT
NY       I  U  SUBSCRIPT INCREMENT OF X-ARRAY DATA TO BE PLOTTED.              PLOT
PAGE     I  C  PAGE NUMBER                                                     PLOT
PRINT    R  D  PRINTING ARRAY                                                  PLOT
TITLE    R  D  ABSISSA AND ORDINATE TITLES, AND HORIZONTAL TITLE ARRAY         PLOT
TITLE2   R  C  DUMMY TITLE ARRAY                                               PLOT
TYPE     I  U  CARD TYPE                                                       PLOT
W        R  D  GRID INFORMATION ARRAY                                          PLOT
X        R  D  PLOTTING ARRAY, LOCATION ALONG X-AXIS                           PLOT
XL       R  U  LEFT-MOST LIMIT OF THE GRID ON X-AXIS                           PLOT
XR       R  U  RIGHT-MOST LIMIT OF THE GRID ON X-AXIS                          PLOT
Y        R  D  PLOTTING ARRAY, LOCATION ALONG Y-AXIS                           PLOT
YB       R  U  BOTTOM MOST LIMIT OF THE GRID ON Y-AXIS                         PLOT
YT       R  U  TOP MOST LIMIT OF THE GRID ON Y-AXIS                            PLOT
```

32. SUBROUTINE SLABD (DECK SLBA)

This routine generates the element data for a simple slab delta vehicle.

a. Algorithm

Read in Slab Delta Title Card (Type 50), and the Configuration Control Card (Type 51). If required read in the Thickness Correction Cards (Type 52 and 53). Read in a Cross-Section Data Card (Type 54) and calculate the element data for this X-station. Write the card images on the regular output Tape 6 if required and also on the geometry storage Tape 8. Continue until all the X-station cards have been read.

b. Input/Output

Slab Delta Title Card (Type 50), Slab Delta Sweep Card (Type 51), and the Slab Delta Station Data Card (Type 54). If ITOC is equal to 1 the Thickness Correction Cards (Type 52 and 53) are also input.
The card images of the element data are written on the normal output Tape 6 if IPRINT equals 1, and also on the geometry storage Tape 8.

c. Error

An error condition occurs when a card type number is wrong.

d. Subroutines Required

TTABLE

e. Argument List

None

f. Length

7584 bytes

DECK SLBA

```
      SUBROUTINE SLABD
C
C*************************************************************************
C **** THIS PROGRAM PREPARES SURFACE ELEMENT DATA OF ANALYTICAL SHAPES
C***** FOR USE IN THE FORCE PROGRAM.  THIS PROGRAM GENERATES THE
C***** SURFACE DATA CARDS AND STORES THEM ON TAPE 8.
C*************************************************************************
C
      DIMENSION  TITLE(15),ZT(300),ZB(300),CARD(20)
C
      COMMON  CASE,TITLE,PAGE,ERROR
      INTEGER  STAT,STATT,CASE,TYPE,SEQ,PAGE,ROWS,THETAB,THETAT,STATA,
     1  LAST,LAST2,LAST3,PAGE,ERROR
C
C  SET COUNTERS
    1 LINE = 100
      SEQ = 1
      IP = 1
      STATA= 2
      TYPE = 3
C
C  READ IN TITLE CARD
      READ (5,100) (TITLE(L),L=1,15),LAST,CASE,ITYPE
  100 FORMAT(14A4,1A3,I1,5XI3,2XI2)
      IF (ITYPE .NE. 50) GO TO 300
C
C
C  THE FOLLOWING STATEMENTS TO STATEMENT 5 MAY BE ALTERED OR
C  REPLACED FOR OTHER ANALYTICAL SHAPES
C
C  BLUNT SLAB DELTA WING SURFACE DATA GENERATION
C  READ INPUT CASE DATA CARD
      READ (5,106) SWEEP,RNOSE,THETAB,THETAT,NOSPAN,ITOC,MODE,
     1  IREW8,IOBSP,IPRINT,ITYPE
  106 FORMAT (2F10.0,3I3,2I1,4XI1,5XI1,5X,I1,22XI2)
```

```
DECK SLBA

      IF (ITYPE .NE. 51) GO TO 300                                      SLBA  0360
      IF (IREW8 .EQ. 0) REWIND 8                                        SLBA  0370
      WRITE (6,60) SWEEP,RNOSE                                          SLBA  0380
   60 FORMAT (1H1,15X,42HSLAB DELTA GEOMETRY DATA WILL BE GENERATED ,/  SLBA  0390
     1 1H ,20X7HSWEEP =F6.2,5X,7HRNOSE =F9.3)                           SLBA  0400
C                                                                       SLBA  0410
C  CHECK IF SPANWISE Z FACTOR DATA IS INPUT                             SLBA  0420
      IF (ITOC .EQ. 0) GO TO 21                                         SLBA  0430
C                                                                       SLBA  0440
C  READ IN Z FACTOR DATA                                                SLBA  0450
      I = -4                                                            SLBA  0460
   30 I = I + 5                                                         SLBA  0470
      READ (5,107) ZT(I),ZT(I+1),ZT(I+2),ZT(I+3),ZT(I+4),LAST2,ITYPE    SLBA  0480
  107 FORMAT (5F10.0,9XI1.10XI2)                                        SLBA  0490
      IF (ITYPE .NE. 52) GO TO 300                                      SLBA  0500
      IF (LAST2 .EQ. 0) GO TO 30                                        SLBA  0510
      I = -4                                                            SLBA  0520
   31 I = I + 5                                                         SLBA  0530
      READ (5,107) ZB(I),ZB(I+1),ZB(I+2),ZB(I+3),ZB(I+4),LAST2,ITYPE    SLBA  0540
      IF (ITYPE .NE. 53) GO TO 300                                      SLBA  0550
      IF (LAST2 .EQ. 0) GO TO 31                                        SLBA  0560
C  SET UP INITIAL DATA                                                  SLBA  0570
   21 DELTHB = (90.0 / FLOAT(THETAB)) / 57.2957795                      SLBA  0580
C                                                                       SLBA  0590
      DELTHT = (90.0 / FLOAT(THETAT)) / 57.2957795                      SLBA  0600
      THETAO = - DELTHB * FLOAT(NOSPAN)                                 SLBA  0610
      THEMAX = 180.0/57.2957795 + DELTHT * FLOAT(NOSPAN)                SLBA  0620
      N = 2                                                             SLBA  0630
      I = 1                                                             SLBA  0640
      SWEEP = SWEEP / 57.2957795                                        SLBA  0650
C                                                                       SLBA  0660
C  READ IN SECTION DATA CARD                                            SLBA  0670
   13 READ (5,108) XB,DELZ,TOPTC,BOTTC,ITOP,LAST3,ITYPE                 SLBA  0680
  108 FORMAT (4F10.0,1XI1,17XI1,10XI2)                                  SLBA  0690
      IF (ITYPE .NE. 54) GO TO 300                                      SLBA  0700
C                                                                       SLBA  0710
```

```
DECK SLBA

      IF (LAST3 .EQ. 1) I = N                                           SLBA  0720
      XB = - XB                                                         SLBA  0730
C                                                                       SLBA  0740
      YLECL =  (XB - RNOSE)*COS(SWEEP)/SIN(SWEEP)                       SLBA  0750
C                                                                       SLBA  0760
C  START OF ANGULAR LOOP                                                SLBA  0770
      J = 0                                                             SLBA  0780
      ISIDE = 0                                                         SLBA  0790
   14 J = J + 1                                                         SLBA  0800
C                                                                       SLBA  0810
C   CHECK IF THIS POINT IS A TOP OR A BOTTOM POINT AND SET FLAG         SLBA  0820
   42 IF (ISIDE .EQ. 1) GO TO 53                                        SLBA  0830
      THETA = THETAO + DELTHB * (FLOAT(J)-1.0)                          SLBA  0840
      IF (THETA .GT. 1.5708    ) GO TO 44                               SLBA  0850
      GO TO 43                                                          SLBA  0860
C                                                                       SLBA  0870
   44 ISIDE = 1                                                         SLBA  0880
      THETA = THETAO + DELTHB * (FLOAT(J)-2.0)                          SLBA  0890
      THESID = (90.0/57.2957795 + DELTHT) - DELTHT * FLOAT(J)           SLBA  0900
      GO TO 43                                                          SLBA  0910
   53 THETA = THESID + DELTHT * (FLOAT(J)-1.0)                          SLBA  0920
C                                                                       SLBA  0930
C  CHECK IF SECTION HAS BEEN COMPLETED                                  SLBA  0940
   43 IF (THETA .GT. (THEMAX+0.01)) GO TO 2                             SLBA  0950
C                                                                       SLBA  0960
      IF (THETA.GT.-0.0001 .AND. THETA.LT. 3.1416   ) GO TO 16          SLBA  0970
C                                                                       SLBA  0980
      IF (YLECL .GT. 0.0) GO TO 15                                      SLBA  0990
C  SPHERE FLAT SECTIONS                                                 SLBA  1000
      YA = 0.0                                                          SLBA  1010
      RADIUS = SQRT(2.0*RNOSE*XB - XB*XB)                               SLBA  1020
      ZA = RADIUS                                                       SLBA  1030
      IF (THETA .LT. 0.0) ZA = -RADIUS                                  SLBA  1040
      GO TO 19                                                          SLBA  1050
C  FLAT SECTIONS                                                        SLBA  1060
   15 ZA = RNOSE                                                        SLBA  1070
```

```
DECK SLBA
      IF (THETA .LT. 0.0) ZA = -RNOSE                                   SLBA 1080
      IF (THETA .GT. 1.5708     ) GO TO 17                              SLBA 1090
C  BOTTOM FLAT                                                          SLBA 1100
      YA = (FLOAT(J-1) / (FLOAT(NOSPAN)))* YLECL                        SLBA 1110
      GO TO 19                                                          SLBA 1120
C  TOP FLAT                                                             SLBA 1130
   17 YA = ((THEMAX - THETA) / (THEMAX - 3.14159265) ) * YLECL          SLBA 1140
      IF (ITOP .EQ. 1) YA = YLECL                                       SLBA 1150
      GO TO 19                                                          SLBA 1160
C                                                                       SLBA 1170
C  SPHERE OR LEADING EDGE                                               SLBA 1180
   16 IF (MODE.EQ.3 .AND. ISIDE.EQ.1) GO TO 19                          SLBA 1190
      IF (XB .GE. RNOSE) GO TO 18                                       SLBA 1200
      C = (RNOSE-XB) *SIN(SWEEP) / COS(SWEEP)                           SLBA 1210
      RADIUS = SQRT(2.0*RNOSE*XB - XB*XB)                               SLBA 1220
      YA = RADIUS * SIN(THETA)                                          SLBA 1230
      IF (YA .GT. C) GO TO 18                                           SLBA 1240
      ZA = -RADIUS * COS(THETA)                                         SLBA 1250
      GO TO 19                                                          SLBA 1260
C                                                                       SLBA 1270
   18 YA = YLECL + (RNOSE*SIN(THETA) / SIN(SWEEP))                      SLBA 1280
      ZA = -RNOSE * COS(THETA)                                          SLBA 1290
C                                                                       SLBA 1300
C                                                                       SLBA 1310
   19 A =RNOSE * (1.0 - COS(SWEEP))                                     SLBA 1320
      IF (XB .LT.A) YLE = SQRT(2.0*RNOSE*XB - XB*XB)                    SLBA 1330
      IF (XB .GE.A) YLE = YLECL +(RNOSE/SIN(SWEEP))                     SLBA 1340
      IF (ISIDE .EQ. 0) ZA = ZA*BOTTC                                   SLBA 1350
      IF (MODE .GT. 1) GO TO 45                                         SLBA 1360
      IF (ISIDE .EQ. 1) ZA = ZA*TOPTC                                   SLBA 1370
       GO TO 46                                                         SLBA 1380
C  CHECK TOP OR BOTTOM FOR MODES 2 AND 3                                SLBA 1390
   45 IF (ISIDE .EQ. 1) GO TO 47                                        SLBA 1400
      ZA = ZA + DELZ                                                    SLBA 1410
      GO TO 46                                                          SLBA 1420
   47 IF (MODE .EQ. 3) GO TO 48                                         SLBA 1430
```

DECK SLBA

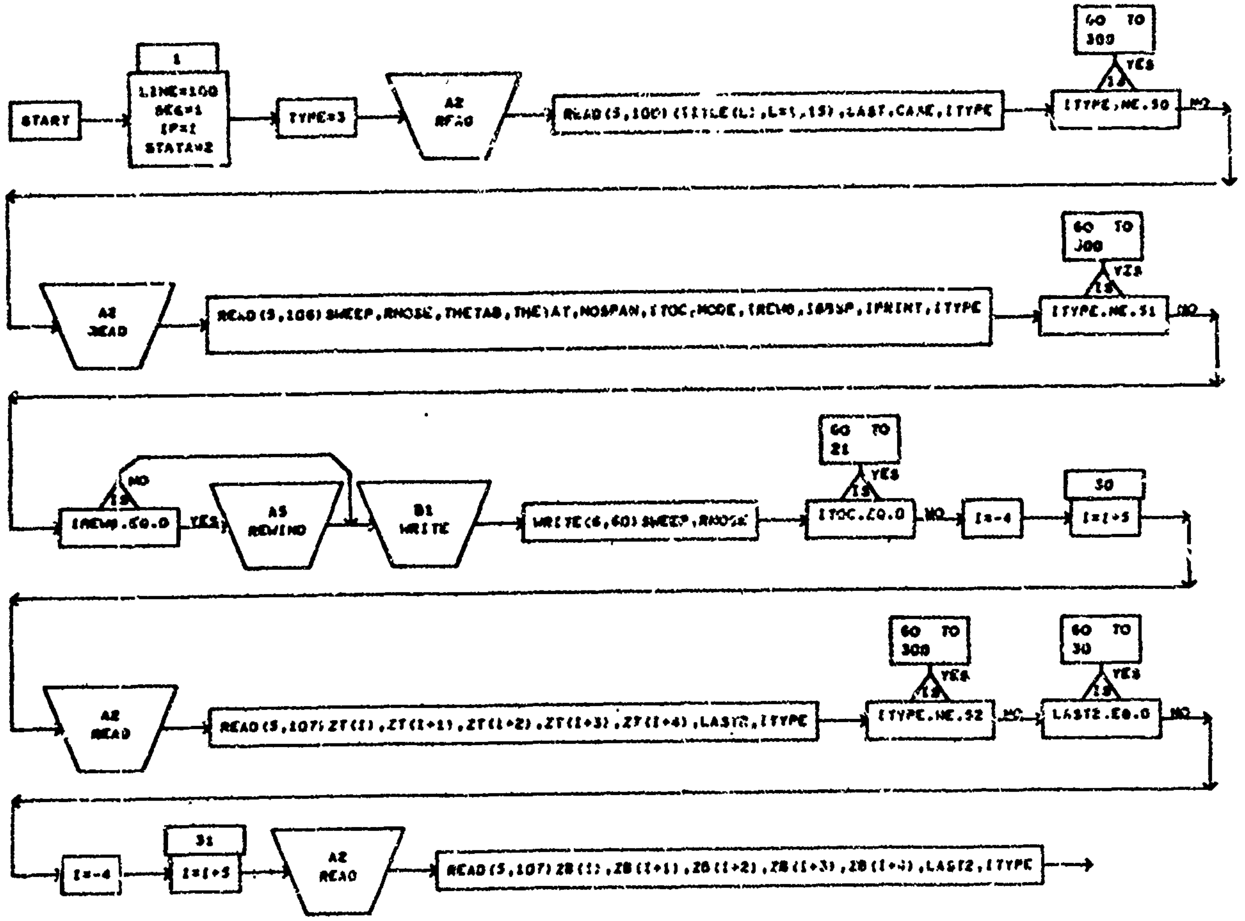
```
      ZA = ZA * TOPTC                                                   SLBA  1440
      GO TO 46                                                          SLBA  1450
   48 THETA2 = THETA - 1.57079633                                       SLBA  1460
      IF (THETA .GT. 3.1416    ) THETA2 = 1.57079633                    SLBA  1470
       AA = YLE                                                         SLBA  1480
      IF (XB .LE. RNOSE) BB = TOPTC*SQRT(2.0*RNOSE*XB - XB*XB) - DELZ   SLBA  1490
      IF (XB .GT. RNOSE) BB = RNOSE * TOPTC - DELZ                      SLBA  1500
       R = AA*BB / SQRT(BB*BB*COS(THETA2)*COS(THETA2)                   SLBA  1510
     1      + AA*AA*SIN(THETA2)*SIN(THETA2))                            SLBA  1520
      YA = R * COS(THETA2)                                              SLBA  1530
      ZA = R * SIN(THETA2) + DELZ                                       SLBA  1540
C                                                                       SLBA  1550
C  CHECK IF SPAN CORRECTION IS TO BE MADE                               SLBA  1560
   46 IF (ITOC .EQ. 0) GO TO 50                                         SLBA  1570
C  CORRECT THICKNESS                                                    SLBA  1580
      PSPAN = YA / YLE                                                  SLBA  1590
      DUMMY = 0.0                                                       SLBA  1600
      IF (THETA .GT. 1.5708    ) GO TO 40                               SLBA  1610
      CALL TTABLE (PSPAN,ZFACT,DUMMY,XB,ZB,BDOT,BDOT2)                  SLBA  1620
      GO TO 41                                                          SLBA  1630
   40 CALL TTABLE (PSPAN,ZFACT,DUMMY,ZB,ZT,BDOT,BDOT2)                  SLBA  1640
   41 ZA = ZA * ZFACT                                                   SLBA  1650
C                                                                       SLBA  1660
C                                                                       SLBA  1670
C  CORRECT FOR LEADING EDGE CENTER LINE SHIFT AND CHANGE SIGN ON XA     SLBA  1680
   50 IF (MODE .EQ. 1) ZA = ZA + DELZ                                   SLBA  1690
      XA = -XB                                                          SLBA  1700
      THCHK = THEMAX - 0.01                                             SLBA  1710
      IF (I.EQ.N .AND. THETA.GT.THCHK) M = J                            SLBA  1720
C                                                                       SLBA  1730
C  CHECK IF LAST POINT OF CASE HAS BEEN REACHED (I=N AND J=M)           SLBA  1740
      IF (I.EQ.N .AND. J.EQ.M)  STATA = 3                               SLBA  1750
C                                                                       SLBA  1760
C  CHECK ON LEFT OR RIGHT DATA POINT POSITION                           SLBA  1770
    5 GO TO (7,9), IP                                                   SLBA  1780
C                                                                       SLBA  1790
```

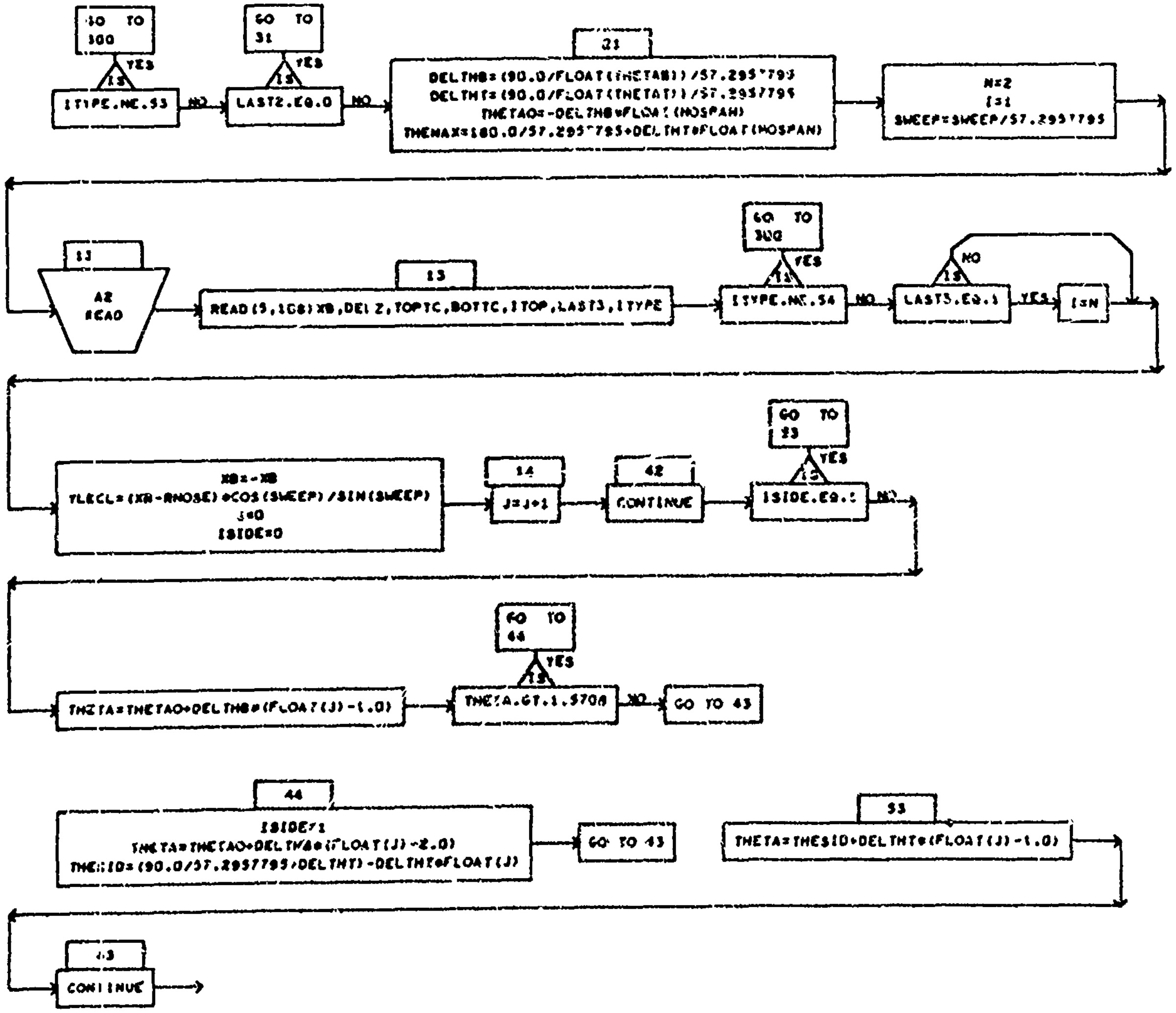
```
      DECK SLBA
C     SET UP DATA FOR LEFT SIDE PRINTING AND PUNCHING                   SLBA  1800
    7 X     = XA                                                        SLBA  1810
      Y     = YA                                                        SLBA  1820
      Z     = ZA                                                        SLBA  1830
      STAT  = STATA                                                     SLBA  1840
C                                                                       SLBA  1850
C     CHANGE PRINT POSITION FLAG TO RIGHT SIDE PRINT                    SLBA  1860
      IP = 2                                                            SLBA  1870
      IF (STATA.EQ.3) GO TO 12                                          SLBA  1880
      GO TO 3                                                           SLBA  1890
C                                                                       SLBA  1900
C     SET UP DATA FOR RIGHT SIDE PRINTING AND PUNCHING                  SLBA  1910
    8 XX    = XA                                                        SLBA  1920
      YY    = YA                                                        SLBA  1930
      ZZ    = ZA                                                        SLBA  1940
      STATT= STATA                                                      SLBA  1950
C                                                                       SLBA  1960
C     CHANGE PRINT POSITION FLAG TO LEFT SIDE PRINT                     SLBA  1970
      IP = 1                                                            SLBA  1980
C                                                                       SLBA  1990
C     CHECK LINE COUNT AND HEADER REQUIREMENT                           SLBA  2000
   12 IF (IPRINT .EQ. 0) GO TO 11                                       SLBA  2010
      IF (LINE.LT.50) GO TO 11                                          SLBA  2020
C                                                                       SLBA  2030
C     PRINT HEADER AT TOP OF PAGE                                       SLBA  2040
      WRITE (6,101) CASE, (TITLE(L) ,L=1,15), PAGE                      SLBA  2050
  101 FORMAT (1H1,5X,24HSLAB DELTA GEOMETRY DATA,/                      SLBA  2060
     1 1H0,5X,6H  CASE,I5,19X,14A4,1A3,5X,5HPAGE I4,/1H0,5X             SLBA  2070
     2 1HX9X1HY9X1HZ4X1HS5X1HX9X1HY8X1HZ5X1HS18H CASE  TYPE    SEQ  )    SLBA  2080
C                                                                       SLBA  2090
C     STEP PAGE NUMBER                                                  SLBA  2100
      PAGE = PAGE + 1                                                   SLBA  2110
      LINE = 5                                                          SLBA  2120
C                                                                       SLBA  2130
C     CHECK IF THIS IS A PARTIAL CARD CONDITION                         SLBA  2140
   11 IF (STAT.EQ.3.AND.IP.EQ.2) GO TO 9                                SLBA  2150
```

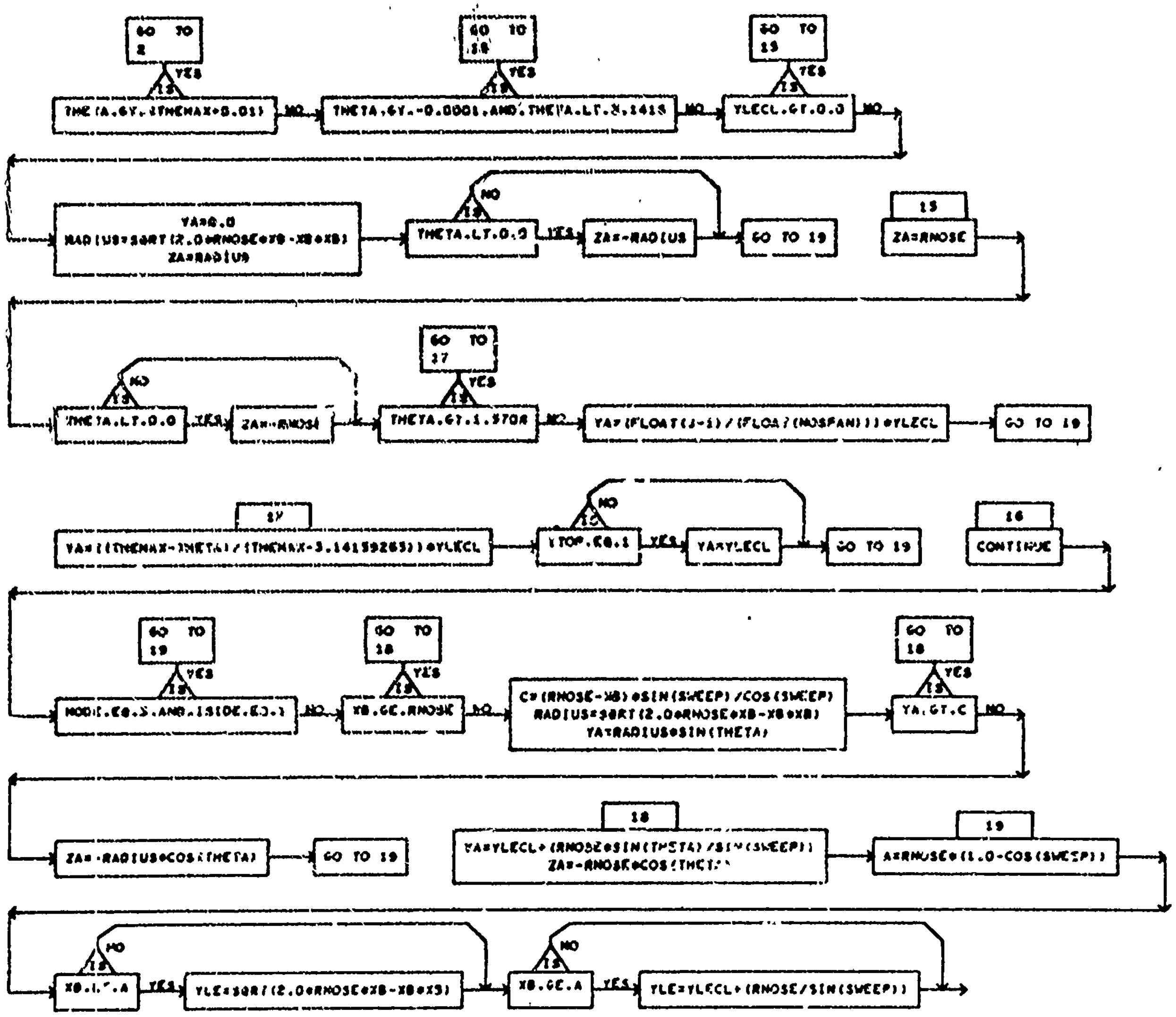
```
DECK SLBA

      IF (IPRINT .EQ. 0) GO TO 61                                       SLBA  2160
C                                                                       SLBA  2170
C  PRINT OUTPUT DATA FOR ONE CARD (BOTH LEFT AND RIGHT SIDE)            SLBA  2180
      WRITE (6,102) X,Y,Z,STAT,XX,YY,ZZ,STATT,CASE,TYPE,SEQ             SLBA  2190
  102 FORMAT (1H0,3F10.4,I1,3F10.4,I1,I6,3X,I1,4HAERO,I4)               SLBA  2200
      LINE = LINE + 2                                                   SLBA  2210
C                                                                       SLBA  2220
C  WRITE DATA ON PUNCH TAPE 8 (FULL CARD)                               SLBA  2230
   61 WRITE (8,103) X,Y,Z,STAT,XX,YY,ZZ,STATT,CASE,TYPE,SEQ             SLBA  2240
  103 FORMAT (3F10.4,I1,3F10.4,I1,I6,3X,I1,4HAERO,I4)                   SLBA  2250
      GO TO 10                                                          SLBA  2260
C                                                                       SLBA  2270
C  PRINT OUTPUT FOR ONE CARD (LEFT SIDE ONLY)                           SLBA  2280
    9 IF (IPRINT .EQ. 0) GO TO 62                                       SLBA  2290
      WRITE (6,104) X,Y,Z,STAT,CASE,TYPE,SEQ                            SLBA  2300
  104 FORMAT (1H0,3F10.4,I1,31X,I6,3X,I1,4HAERO,I4)                     SLBA  2310
C                                                                       SLBA  2320
C  WRITE DATA ON PUNCH TAPE 8  (LEFT PART OF CARD ONLY)                 SLBA  2330
   62 WRITE (8,105) X,Y,Z,STAT,CASE,TYPE,SEQ                            SLBA  2340
  105 FORMAT (3F10.4,I1,31X,I6,3X,I1,4HAERO,I4)                         SLBA  2350
C                                                                       SLBA  2360
C  STEP SEQUENCE COUNTER                                                SLBA  2370
   10 SEQ = SEQ + 1                                                     SLBA  2380
C                                                                       SLBA  2390
C                                                                       SLBA  2400
C  END OF THETA DO LOOP - CHANGE STATUS TO 0 FOR NEXT POINT             SLBA  2410
    3 IF (STATA .EQ. 3) GO TO 52                                        SLBA  2420
      STATA = 0                                                         SLBA  2430
      GO TO 14                                                          SLBA  2440
C                                                                       SLBA  2450
C                                                                       SLBA  2460
C  END OF CROSS SECTION ROW DO LOOP - CHANGE STATUS TO 1 FOR NEXT ROW   SLBA  2470
    2 STATA = 1                                                         SLBA  2480
      GO TO 13                                                          SLBA  2490
C                                                                       SLBA  2500
C                                                                       SLBA  2510
```

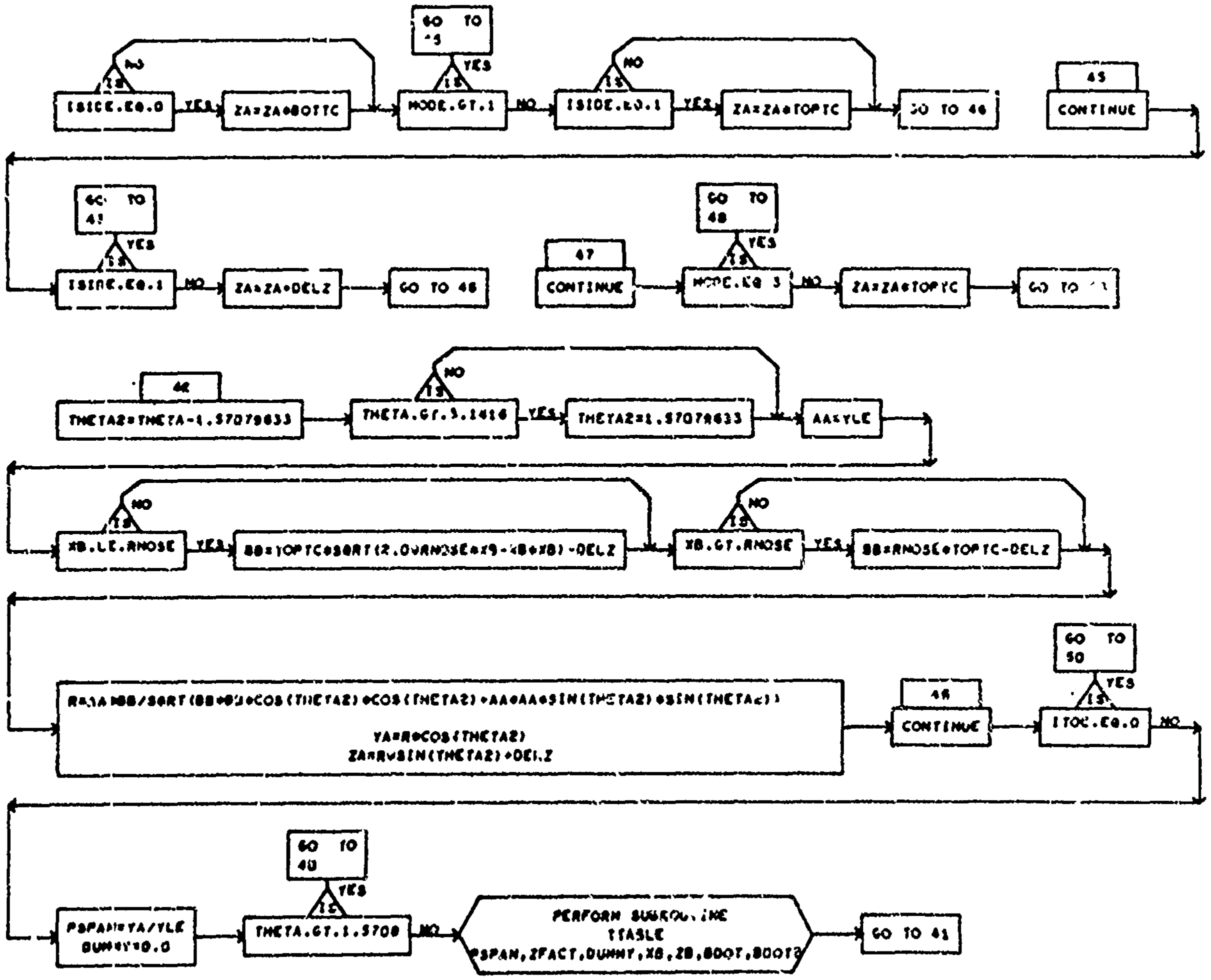
```
DECK SLBA

C  CHECK IF LAST CASE HAS BEEN REACHED                                  SLBA  2520
  52  IF (LAST .NE. 1) GO TO 1                                          SLBA  2530
C                                                                       SLBA  2540
C  LAST CASE HAS BEEN COMPLETED SO WRITE END OF FILE ON PUNCH TAPE 8    SLBA  2550
      WRITE (8,500)                                                     SLBA  2560
 500  FORMAT (12H**BLANK CARD,68X)                                      SLBA  2570
      END FILE 8                                                        SLBA  2580
      BACKSPACE 8                                                       SLBA  2590
      BACKSPACE 8                                                       SLBA  2600
      IF (I8BSP .EQ. 0) GO TO 501                                       SLBA  2610
      SEQ = SEQ - 1                                                     SLBA  2620
      DO 502 III=1,SEQ                                                  SLBA  2630
 502  BACKSPACE 8                                                       SLBA  2640
 501  ERROR = 1                                                         SLBA  2650
      READ (5,200) TYPE                                                 SLBA  2660
 200  FORMAT (70X,I2)                                                   SLBA  2670
      IF (TYPE .EQ. 99) ERROR = 0                                       SLBA  2680
      RETURN                                                            SLBA  2690
 300  ERROR = 1                                                         SLBA  2700
      WRITE (6,301)                                                     SLBA  2710
 301  FORMAT (1H0,47H*****YOU HAVE MADE AN ERROR EITHER IN CARD TYPE    SLBA  2720
     1 49H INDICATION OR CARD ORDER - CHECK YOUR CARDS*****  )          SLBA  2730
      READ (5,302) (CARD(II),II=1,20)                                   SLBA  2740
 302  FORMAT (20A4)                                                     SLBA  2750
      WRITE (6,803) (CARD(II),II=1,20)                                  SLBA  2760
 803  FORMAT (1H0,45H THE CARD LOCATED JUST BEFORE THE CARD LISTED      SLBA  2770
     1 18H BELOW IS IN ERROR,/1H ,10X,20A4)                             SLBA  2780
      RETURN                                                            SLBA  2790
      END                                                               SLBA  2800
```

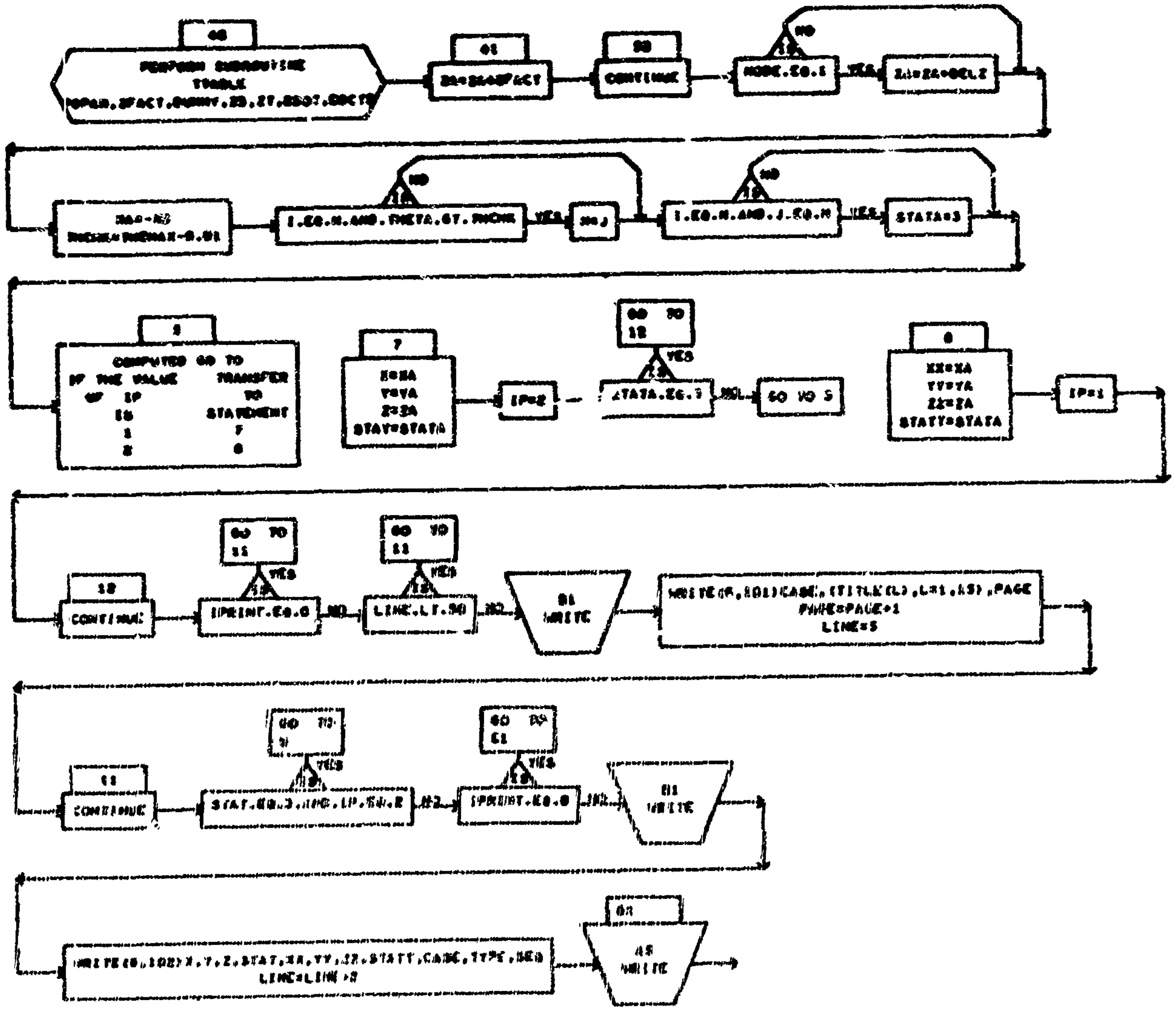
SUBROUTINE SLAG3

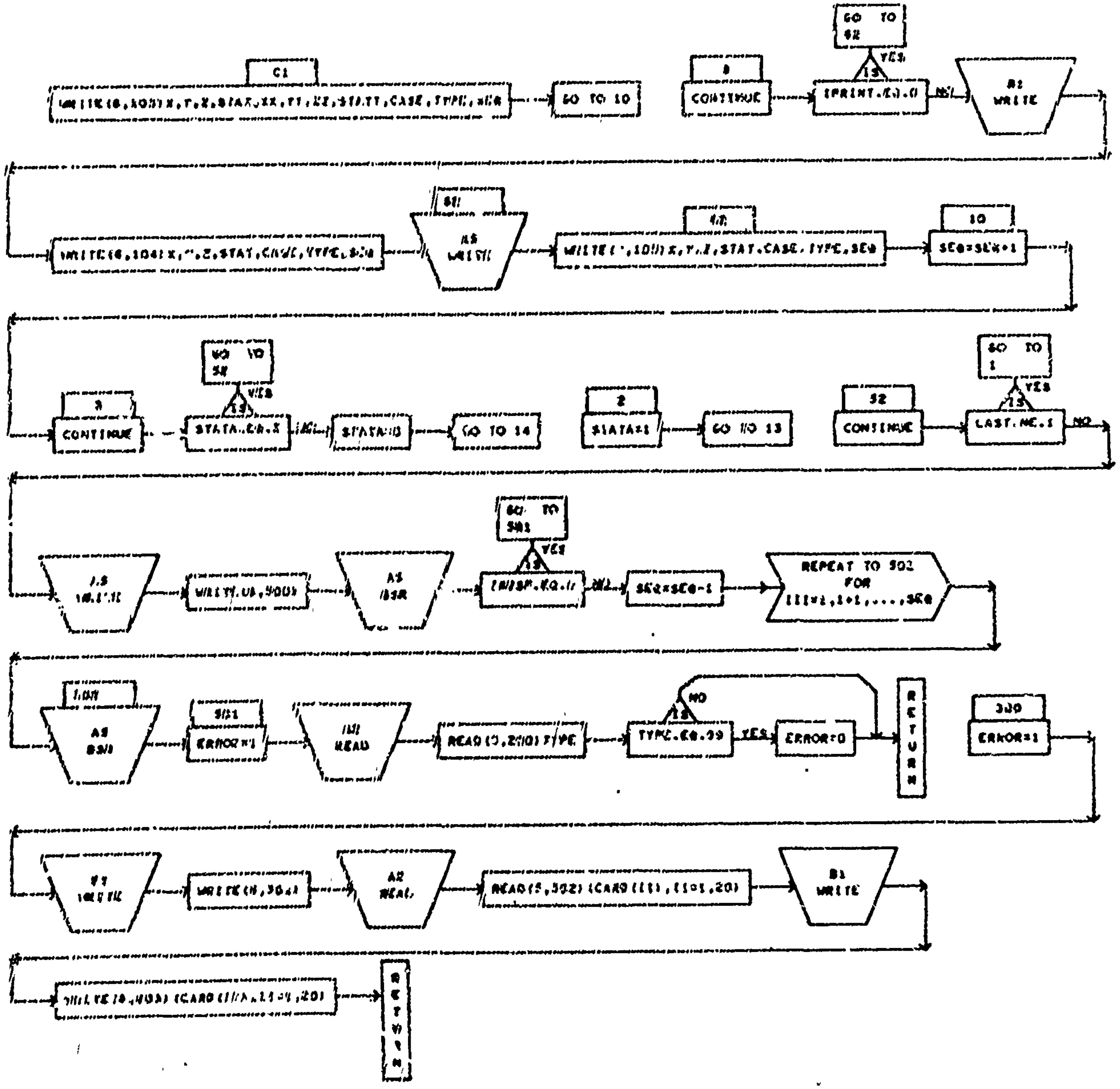



GO TO 300
YES
IS
ITYPE.NE.53
NO
GO TO 31
YES
IS
LAST2.EQ.0
NO
21
DELTHB=(90.0/FLOAT(THETAB))/57.2957795
DELTHT=(90.0/FLOAT(THETAT))/57.2957795
THETAO=-DELTHB*FLOAT(NOSPAN)
THEMAX=180.0/57.2957795+DELTHT*FLOAT(NOSPAN)
N=2
I=1
SWEEP=SWEEP/57.2957795
11
A2
READ
13
READ(5,108)XB,DELZ,TOPTC,BOTTC,ITOP,LAST3,ITYPE
GO TO 300
YES
IS
ITYPE.NE.54
NO
NO
IS
LAST3.EQ.1
YES
I=N
XB=-XB
TLECL=(XB-RNOSE)*COS(SWEEP)/SIN(SWEEP)
J=0
ISIDE=0
14
J=J+1
42
CONTINUE
GO TO 53
YES
IS
ISIDE.EQ.1
NO
THETA=THETAO+DELTHB*(FLOAT(J)-1.0)
GO TO 44
YES
IS
THETA.GT.1.5708
NO
GO TO 43
44
ISIDE=1
THETA=THETAO+DELTHB*(FLOAT(J)-2.0)
THESID=(90.0/57.2957795+DELTHT)-DELTHT*FLOAT(J)
GO TO 43
53
THETA=THESID+DELTHT*(FLOAT(J)-1.0)
43
CONTINUE


GO TO 2
YES
IS
THETA.GT.(THEMAX+0.01)
NO
GO TO 16
YES
IS
THETA.GT.-0.0001.AND.THETA.LT.3.1415
NO
GO TO 15
YES
IS
YLECL.GT.0.0
NO
YA=0.0
RADIUS=SQRT(2.0*RNOSE*XB-XB*XB)
ZA=RADIUS
IS
NO
THETA.LT.0.5
YES
ZA=-RADIUS
GO TO 19
15
ZA=RNOSE
IS
NO
THETA.LT.0.0
YES
ZA=-RNOSE
GO TO 17
YES
IS
THETA.GT.1.5708
NO
YA=(FLOAT(J-1)/(FLOAT(NOSFAN)))*YLECL
GO TO 19
17
YA=((THEMAX-THETA)/(THEMAX-3.14159265))*YLECL
IS
NO
ITOP.EQ.1
YES
YA=YLECL
GO TO 19
16
CONTINUE
GO TO 19
YES
IS
MODE.EQ.3.AND.ISIDE.EQ.1
NO
GO TO 18
YES
IS
XB.GE.RNOSE
NO
C=(RNOSE-XB)*SIN(SWEEP)/COS(SWEEP)
RADIUS=SQRT(2.0*RNOSE*XB-XB*XB)
YA=RADIUS*SIN(THETA)
GO TO 18
YES
IS
YA.GT.C
NO
ZA=-RADIUS*COS(THETA)
GO TO 19
18
YA=YLECL+(RNOSE*SIN(THETA)/SIN(SWEEP))
ZA=-RNOSE*COS(THETA)
19
A=RNOSE*(1.0-COS(SWEEP))
IS
NO
XB.LT.A
YES
YLE=SQRT(2.0*RNOSE*XB-XB*XB)
IS
NO
XB.GE.A
YES
YLE=YLECL+(RNOSE/SIN(SWEEP))


ISIDE.EQ.0
IS
NO
YES
ZA=ZA+BOTTC
GO TO 45
IS
YES
MODE.GT.1
NO
ISIDE.EQ.1
IS
NO
YES
ZA=ZA+TOPTC
GO TO 46
45
CONTINUE
GO TO 41
IS
YES
ISIDE.EQ.1
NO
ZA=ZA+DELZ
GO TO 46
47
CONTINUE
GO TO 48
IS
YES
MODE.EQ 3
NO
ZA=ZA+TOPTC
GO TO
46
THETA2=THETA-1.57079633
THETA.GT.3.1416
IS
NO
YES
THETA2=1.57079633
AA=YLE
XB.LE.RNOSE
IS
NO
YES
BB=TOPTC*SQRT(2.0*RNOSE*XB-XB*XB)-DELZ
XB.GT.RNOSE
IS
NO
YES
BB=RNOSE+TOPTC-DELZ
R=AA*BB/SQRT(BB*BB*COS(THETA2)*COS(THETA2)+AA*AA*SIN(THETA2)*SIN(THETA2))
YA=R*COS(THETA2)
ZA=R*SIN(THETA2)+DELZ
48
CONTINUE
GO TO 50
IS
YES
ITOC.EQ.0
NO
PSPAN=YA/YLE
DUMMY=0.0
GO TO 40
IS
YES
THETA.GT.1.5708
NO
PERFORM SUBROUTINE
TTABLE
PSPAN,ZFACT,DUMMY,XB,ZB,BOOT,BOOT2
GO TO 41


40
PERFORM SUBROUTINE
TABLE
(OPAR,ZFACT,DUMMY,ZD,ZT,ZDOT,DDCT)
41
ZA=ZA*ZFACT
50
CONTINUE
MODE.EQ.1
YES
NO
ZA=ZA+DELZ
I.EQ.N.AND.THETA.GT.THCHK
YES
NO
N=J
I.EQ.N.AND.J.EQ.M
YES
NO
STATA=3
5
COMPUTED GO TO
IF THE VALUE OF IP IS
1
2
TRANSFER TO STATEMENT
7
8
7
X=XA
Y=YA
Z=ZA
STAT=STATA
IP=2
STATA.EQ.3
YES
GO TO 12
NO
GO TO 5
8
XX=XA
YY=YA
ZZ=ZA
STATT=STATA
IP=1
12
CONTINUE
IPRINT.EQ.0
YES
GO TO 11
NO
LINE.LT.50
YES
GO TO 11
NO
81
WRITE
WRITE(6,101)CASE,(TITLE(L),L=1,15),PAGE
PAGE=PAGE+1
LINE=5
11
CONTINUE
STAT.EQ.3.AND.IP.EQ.2
YES
NO
IPRINT.EQ.0
YES
GO TO 61
NO
81
WRITE
62
WRITE(6,102)X,Y,Z,STAT,XX,YY,ZZ,STATT,CASE,TYPE,SEQ
LINE=LINE+2
WRITE


C1
WRITE(6,103)X,Y,Z,STAT,XX,YY,ZZ,STATT,CASE,TYPE,SEQ
GO TO 10
8
CONTINUE
GO TO 52
YES
IS
IPRINT.EQ.0
NO
A1 WRITE
WRITE(6,104)X,Y,Z,STAT,CASE,TYPE,SEQ
A5 WRITE
WRITE(',105)X,Y,Z,STAT,CASE,TYPE,SEQ
10
SEQ=SEQ+1
3
CONTINUE
GO TO 52
STATA.EQ.X
NO
STATA=0
GO TO 14
2
STATA=1
GO TO 13
52
CONTINUE
GO TO 1
LAST.NE.1
NO
WRITE(11,500)
A5 BSR
GO TO 501
IS
YES
NDISP.EQ.1
NO
SEQ=SEQ-1
REPEAT TO 502 FOR III=1,1+1,...,SEQ
A5 BSR
ERROR=1
READ
READ(5,200) TYPE
IS
NO
TYPE.EQ.99
YES
ERROR=0
RETURN
300
ERROR=1
WRITE
WRITE(6,304)
A2 READ
READ(5,302)(CARD(II),II=1,20)
B1 WRITE
WRITE(6,403)(CARD(II),II=1,20)
RETURN

```
SYMBOLS USED IN SUBROUTINE SLABD

A         R  U  DISTANCE TO TRANSITION BETWEEN NOSE AND LEADING EDGE            SLABD
AA        R  U  SEMI-SPAN DISTANCE PARAMETER                                    SLABD
BB        R  U  SEMI-SPAN DISTANCE PARAMETER                                    SLABD
BDCT2     R  U  DUMMY VARIABLE                                                  SLABD
BDOT      R  U  DUMMY VARIABLE                                                  SLABD
BDOT2     R  U  DUMMY VARIABLE                                                  SLABD
BOTTC     R  U  BOTTOM THICKNESS CORRECTION PARAMETER                           SLABD
C         R  U  SEMI-SPAN DISTANCE PARAMETER                                    SLABD
CARD      R  D  ARRAY FOR READING CARD                                          SLABD
CASE      I  C  CASE NUMBER                                                     SLABD
DELTHB    R  U  BOTTOM SURFACE DELTA-THETA INCREMENT                            SLABD
DELTHT    R  U  TOP SURFACE DELTA THETA INCREMENT                               SLABD
DELZ      R  U  GEOMETRY DATA DISPLACEMENT PARAMETER IN Z-DIRECTION             SLABD
DUMMY     R  U  DUMMY VARIABLE                                                  SLABD
ERROR     I  C  ERROR FLAG                                                      SLABD
I         I  U  INDEX COUNTER                                                   SLABD
IP        I  U  CARD PRINT POSITION FLAG                                        SLABD
IPRINT    I  U  PRINT FLAG                                                      SLABD
IREW8     I  U  TAPE 8 REWIND FLAG                                              SLABD
ISIDE     I  U  GEOMETRY ANGULAR POSITION INDICATOR                             SLABD
ITOC      I  U  THICKNESS CORRECTION TABLE FLAG                                 SLABD
ITOP      I  U  TOP GEOMETRY CONTROL FLAG                                       SLABD
ITYPE     I  U  CARD TYPE                                                       SLABD
I8BSP     I  U  TAPE 8 BACKSPACE CONTROL FLAG                                   SLABD
J         I  U  ANGULAR LOOP INDEX                                              SLABD
LAST      I  U  SLAB DELTA OPTION TERMINATION FLAG                              SLABD
LAST2     I  U  FLAG TO INDICATE LAST CARD OF T/C TABLE                         SLABD
LAST3     I  U  FLAG TO INDICATE LAST CROSS-SECTION CARD                        SLABD
LINE      I  U  OUTPUT LINE COUNTER                                             SLABD
M         I  U  COUNTER                                                         SLABD
MODE      I  U  GEOMETRY MODE FLAG                                              SLABD
N         I  U  COUNTER                                                         SLABD
NOSPAN    I  U  NUMBER OF ELEMENT DIVISIONS FOR TOP OR BOTTOM                   SLABD
PAGE      I  C  PAGE NUMBER                                                     SLABD
PSPAN     R  U  PER CENT SEMI-SPAN                                              SLABD
R         R  U  LOCAL RADIUS                                                    SLABD
```

```
SYMBOLS USED IN SUBROUTINE SLABD

RADIUS   R  U  RADIUS                                                          SLABD
RNOSE    R  U  RADIUS OF NOSE AND LEADING EDGE                                 SLABD
RONS     I  U  NOT USED                                                        SLABD
SEQ      I  U  CARD SEQUENCE NUMBER                                            SLABD
STAT     I  U  COORDINATE POINT STATUS FLAG                                    SLABD
STATA    I  U  COORDINATE POINT STATUS FLAG                                    SLABD
STATT    I  U  COORDINATE POINT STATUS FLAG                                    SLABD
SWEEP    R  U  LEADING EDGE SWEEP ANGLE                                        SLABD
THCHK    R  U  ANGULAR CHECK PARAMETER                                         SLABD
THEMAX   R  U  MAXIMUM VALUE OF THETA                                          SLABD
THESID   R  U  THETA AT THE SIDE                                               SLABD
THETA    R  U  ANGULAR POSITION IN Z-Y PLANE (FROM BOTTOM)                     SLABD
THETAB   I  U  NUMBER OF ANGULAR DIVISIONS ON THE BOTTOM                       SLABD
THETAO   R  U  STARTING VALUE OF THETA                                         SLABD
THETAT   I  U  NUMBER OF ANGULAR DIVISIONS ON THE TOP                          SLABD
THETA2   R  U  ANGULAR POSITION                                                SLABD
TITLE    R  C  TITLE                                                           SLABD
TOPTC    R  U  TOP THICKNESS CORRECTION FACTOR                                 SLABD
TYPE     I  U  CARD TYPE NUMBER                                                SLABD
X        R  U  X-COORDINATE                                                    SLABD
XA       R  U  X-COORDINATE                                                    SLABD
XB       R  U  INPUT X-COORDINATE STATION                                      SLABD
XX       R  U  X-COORDINATE                                                    SLABD
Y        R  U  Y-COORDINATE                                                    SLABD
YA       R  U  Y-COORDINATE                                                    SLABD
YLE      R  U  Y-DISTANCE TO THE LEADING EDGE                                  SLABD
YLECL    R  U  Y-DISTANCE TO LEADING EDGE CENTER LINE                          SLABD
YY       R  U  Y-COORDINATE                                                    SLABD
Z        R  U  Z-COORDINATE                                                    SLABD
ZA       R  U  Z-COORDINATE                                                    SLABD
ZB       R  D  Z-COORDINATE                                                    SLABD
ZFACT    R  U  THICKNESS CORRECTION FACTOR FROM TABLES                         SLABD
ZT       R  D  THICKNESS CORRECTION TABLE ARRAY                                SLABD
ZZ       R  U  Z-COORDINATE                                                    SLABD
```

```
SYMBOLS USED IN SUBROUTINE SLABD

RADIUS   R  U  RADIUS                                                  SLABD
RNOSE    R  U  RADIUS OF NOSE AND LEADING EDGE                         SLABD
ROWS     I  U  NOT USED                                                SLABD
SEQ      I  U  CARD SEQUENCE NUMBER                                    SLABD
STAT     I  U  COORDINATE POINT STATUS FLAG                            SLABD
STATA    I  U  COORDINATE POINT STATUS FLAG                            SLABD
STATT    I  U  COORDINATE POINT STATUS FLAG                            SLABD
SWEEP    R  U  LEADING EDGE SWEEP ANGLE                                SLABD
THCHK    R  U  ANGULAR CHECK PARAMETER                                 SLABD
THEMAX   R  U  MAXIMUM VALUE OF THETA                                  SLABD
THESID   R  U  THETA AT THE SIDE                                       SLABD
THETA    R  U  ANGULAR POSITION IN Z-Y PLANE (FROM BOTTOM)             SLABD
THETAB   I  U  NUMBER OF ANGULAR DIVISIONS ON THE BOTTOM               SLABD
THETAO   R  U  STARTING VALUE OF THETA                                 SLABD
THETAT   I  U  NUMBER OF ANGULAR DIVISIONS ON THE TOP                  SLABD
THETA2   R  U  ANGULAR POSITION                                        SLABD
TITLE    R  C  TITLE                                                   SLABD
TOPTC    R  U  TOP THICKNESS CORRECTION FACTOR                         SLABD
TYPE     I  U  CARD TYPE NUMBER                                        SLABD
X        R  U  X-COORDINATE                                            SLABD
XA       R  U  X-COORDINATE                                            SLABD
XB       R  U  INPUT X-COORDINATE STATION                              SLABD
XX       R  U  X-COORDINATE                                            SLABD
Y        R  U  Y-COORDINATE                                            SLABD
YA       R  U  Y-COORDINATE                                            SLABD
YLE      R  U  Y-DISTANCE TO THE LEADING EDGE                          SLABD
YLECL    R  U  Y-DISTANCE TO LEADING EDGE CENTER LINE                  SLABD
YY       R  U  Y-COORDINATE                                            SLABD
Z        R  U  Z-COORDINATE                                            SLABD
ZA       R  U  Z-COORDINATE                                            SLABD
ZB       R  D  Z-COORDINATE                                            SLABD
ZFACT    R  U  THICKNESS CORRECTION FACTOR FROM TABLES                 SLABD
ZT       R  D  THICKNESS CORRECTION TABLE ARRAY                        SLABD
ZZ       R  U  Z-COORDINATE                                            SLABD
```

33. SUBROUTINE TTABLE (DECK SLBB)

This routine performs the interpolation to find the thickness correction factors for the Slab Delta Routine.

a. Algorithm

Search for the proper points in the data table to be used in the interpolation. Call on the quadratic interpolation routine, QINT, to obtain the interpolated value.

b. Input/Output

None

c. Error

None

d. Subroutines Required

QINT

e. Argument List

(A, B, C, D, R, G, G1)

f. Length

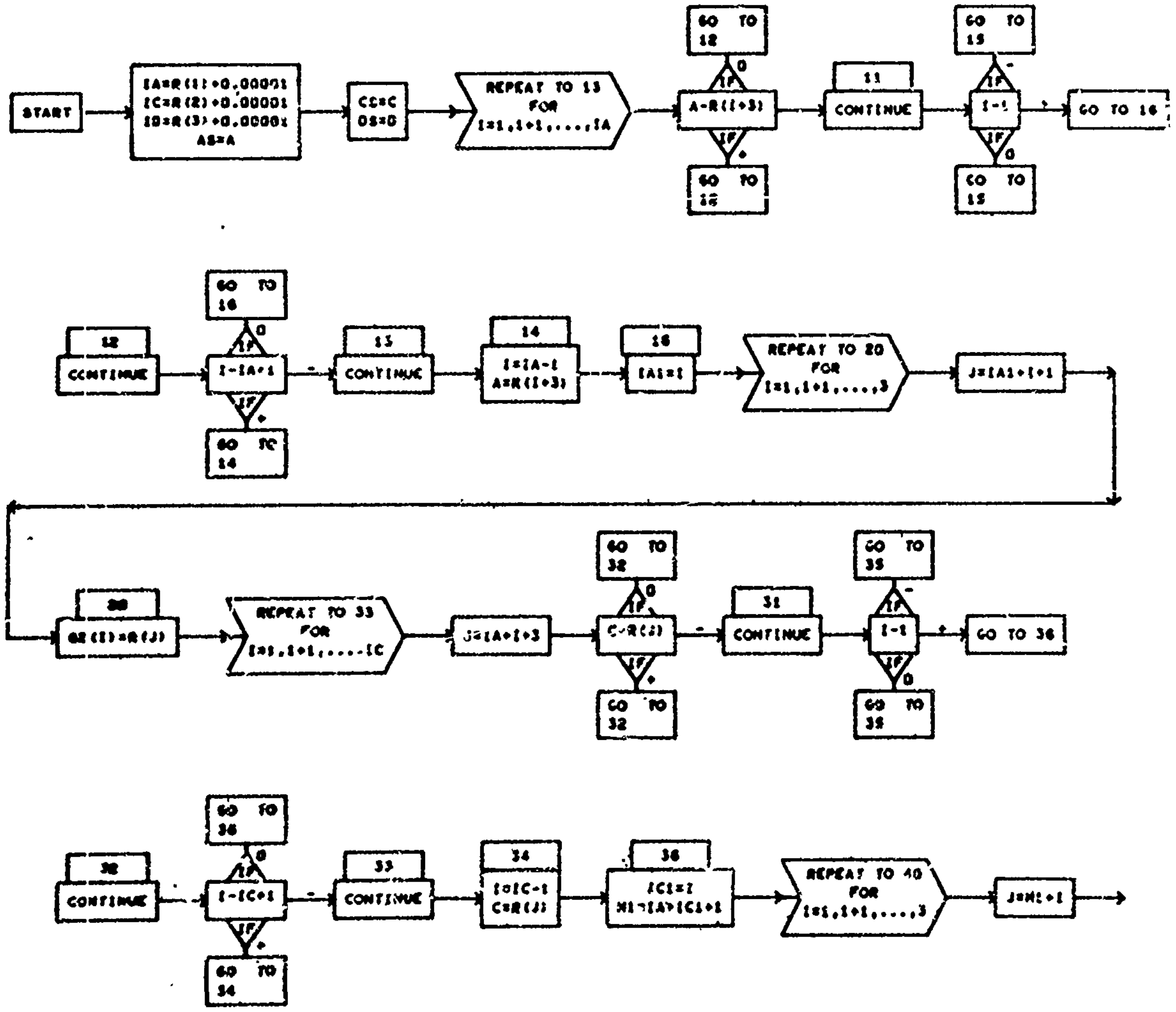
1888 bytes

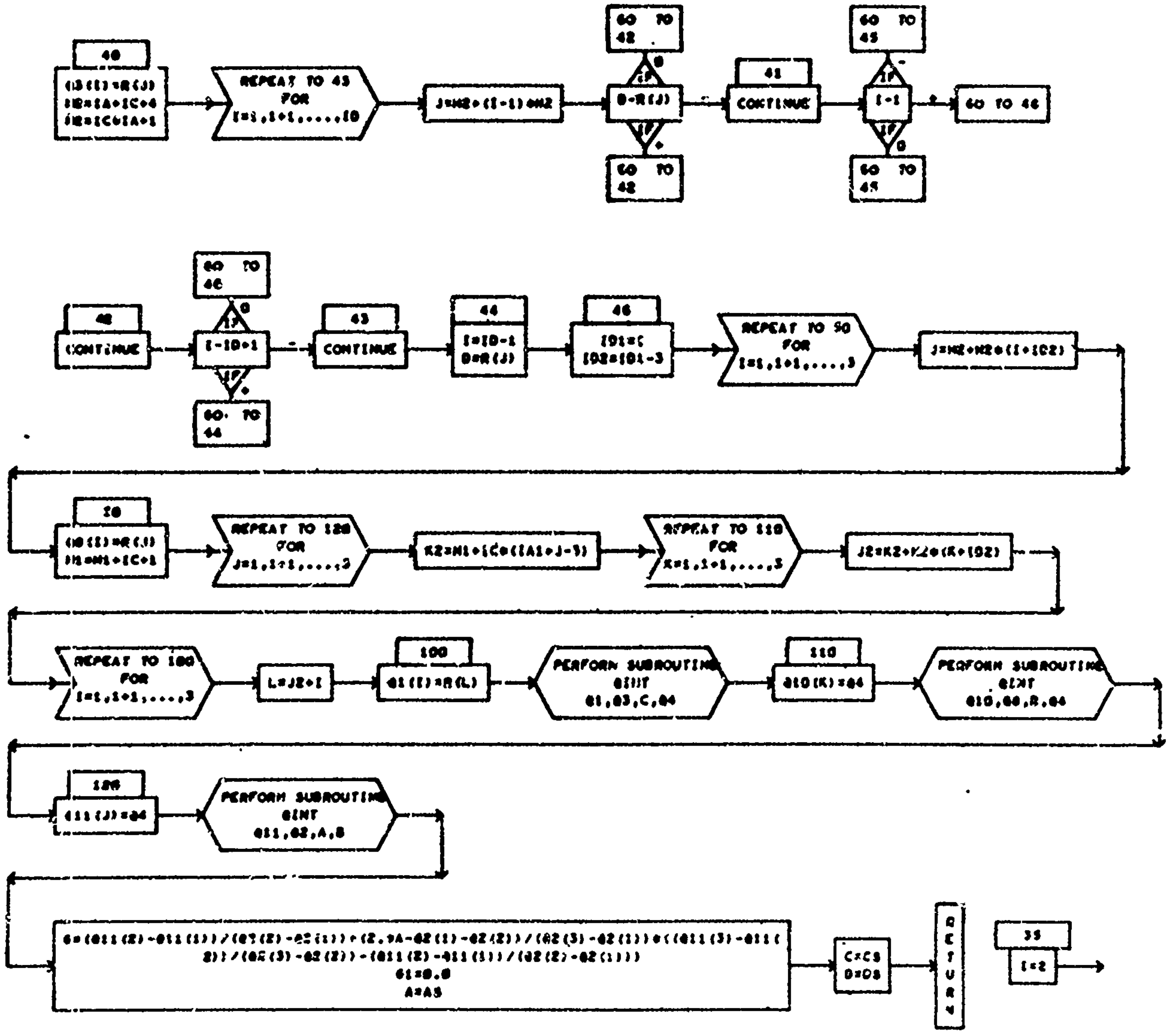
```
DECK SLBB

      SUBROUTINE TTABLE (A,B,C,D,R,G,G1)                                        SLBB  0010
C           TRIPLE  INTERPOLATION  ROUTINE                                      SLBB  0020
      DIMENSION R(300),Q1(3),Q2(3),Q3(3),Q8(3),Q10(3),Q11(3)                    SLBB  0030
C     DIMENSION R(300),Q1(3),Q2(3),Q3(3),Q8(3),Q10(3),Q11(3)                    SLBB  0040
          IA = R(1) + 0.00001                                                   SLBB  0050
          IC = R(2) + 0.00001                                                   SLBB  0060
          ID = R(3) + 0.00001                                                   SLBB  0070
        AS = A                                                                  SLBB  0080
        CS = C                                                                  SLBB  0090
        DS = D                                                                  SLBB  0100
         DO 13 I = 1,IA                                                         SLBB  0110
        IF(A-R(I+3))11,12,12                                                    SLBB  0120
   11   IF(I-1) 15,15,16                                                        SLBB  0130
   12   IF(I-IA+1) 13,16,14                                                     SLBB  0140
   13 CONTINUE                                                                  SLBB  0150
   14     I = IA-1                                                              SLBB  0160
          A = R(I+3)                                                            SLBB  0170
   16     IA1 = I                                                               SLBB  0180
         DO 20 I =1,3                                                           SLBB  0190
          J = IA1+I+1                                                           SLBB  0200
   20     Q2(I)= R(J)                                                           SLBB  0210
C      C ARGUMENT CHECK                                                         SLBB  0220
         DO 33 I = 1, IC                                                        SLBB  0230
          J = IA+I+3                                                            SLBB  0240
        IF(C-R(J)) 31,32,32                                                     SLBB  0250
   31   IF(I-1) 35,35,36                                                        SLBB  0260
   32   IF(I-IC+1) 33,36,34                                                     SLBB  0270
   33 CONTINUE                                                                  SLBB  0280
   34     I = IC-1                                                              SLBB  0290
          C = R(J)                                                              SLBB  0300
   36     IC1 = I                                                               SLBB  0310
C      C ARGUMENT ARRAY                                                         SLBB  0320
           M1 = IA+IC1+1                                                        SLBB  0330
         DO 40 I = 1,3                                                          SLBB  0340
          J = M1+I                                                              SLBB  0350
```

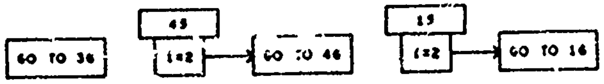
```
DECK  SLBB
  40       Q3(I) = R(J)                                                       SLBB  0360
C        D ARGUMENT CHECK                                                     SLBB  0370
           M2 = IA+IC+4                                                       SLBB  0380
           N2 = IC*IA+1                                                       SLBB  0390
          DO 43 I = 1,ID                                                      SLBB  0400
           J = M2+(I-1)*N2                                                    SLBB  0410
         IF(D-R(J)) 41,42,42                                                  SLBB  0420
  41     IF(I-1) 45,45,45                                                     SLBB  0430
  42     IF(I-ID+1) 43,46,44                                                  SLBB  0440
  43 CONTINUE                                                                 SLBB  0450
  44       I = ID-1                                                           SLBB  0460
           D  = R(J)                                                          SLBB  0470
  46       ID1 = I                                                            SLBB  0480
C        D ARGUMENT ARRAY                                                     SLBB  0490
           ID2 = ID1-3                                                        SLBB  0500
     DO 50 I=1,3                                                              SLBB  0510
           J = M2+N2*(I+ID2)                                                  SLBB  0520
  50       Q8(I) = R(J)                                                       SLBB  0530
           N1 = M1+IC+1                                                       SLBB  0540
     DO 120 J=1,3                                                             SLBB  0550
     K2 = N1 + IC*(IA1+J-3)                                                   SLBB  0560
     DO 110 K=1,3                                                             SLBB  0570
     J2 = K2 + N2*(K+ID2)                                                     SLBB  0580
     DO 100 I=1,3                                                             SLBB  0590
     L = J2 + I                                                               SLBB  0600
 100 Q1(I) = R(L)                                                             SLBB  0610
     CALL QINT (Q1,Q3,C,Q4)                                                   SLBB  0620
 110 Q10(K) = Q4                                                              SLBB  0630
     CALL QINT (Q10,Q8,D,Q4)                                                  SLBB  0640
 120 Q11(J) = Q4                                                              SLBB  0650
     CALL QINT (Q11,Q2,A,B)                                                   SLBB  0660
     G = (Q11(2)-Q11(1))/(Q2(2)-Q2(1))+(2.*A-Q2(1)-Q2(2))/(Q2(3)-Q2(1))       SLBB  0670
    1  *((Q11(3)-Q11(2))/(Q2(3)-Q2(2))-(Q11(2)-Q11(1))/(Q2(2)-Q2(1)))         SLBB  0680
     G1= 0.0                                                                  SLBB  0690
      A = AS                                                                  SLBB  0700
      C = CS                                                                  SLBB  0710
```

```
DECK  SLBB

       D = DS                                                             SLBB  0720
      RETURN                                                              SLBB  0730
   35    I = 2                                                            SLBB  0740
         GO TO 36                                                         SLBB  0750
   45    I = 2                                                            SLBB  0760
      GO TO 46                                                            SLBB  0770
   15    I = 2                                                            SLBB  0780
         GO TO 16                                                         SLBB  0790
      END                                                                 SLBB  0800
```

SUBROUTINE FTABLE




40
G3(I)=R(J)
IB=IA+IC+4
IE=IC+IA+1
REPEAT TO 45
FOR
I=1,1+1,....,10
J=M2+(I-1)*M2
GO TO 42
IF
0
B-R(J)
IF
+
GO TO 42
-
41
CONTINUE
GO TO 45
IF
-
I-1
IF
0
GO TO 45
+
GO TO 46
42
CONTINUE
GO TO 46
IF
0
I-ID+1
IF
+
GO TO 44
-
43
CONTINUE
44
I=ID-1
B=R(J)
46
ID1=C
ID2=ID1-3
REPEAT TO 50
FOR
I=1,1+1,....,3
J=M2+M2*(I+ID2)
50
G6(I)=R(J)
M1=M1+IC+1
REPEAT TO 120
FOR
J=1,1+1,....,3
K2=M1+IC*(IA1+J-3)
REPEAT TO 110
FOR
K=1,1+1,....,3
J2=K2+K2*(K+ID2)
REPEAT TO 100
FOR
I=1,1+1,....,3
L=J2+I
100
G1(I)=R(L)
PERFORM SUBROUTINE
GINT
G1,G3,C,G4
110
G10(K)=G4
PERFORM SUBROUTINE
GINT
G10,G6,B,G4
120
G11(J)=G4
PERFORM SUBROUTINE
GINT
G11,G2,A,B
G=(G11(2)-G11(1))/(G2(2)-G2(1))+(2.*A-G2(1)-G2(2))/(G2(3)-G2(1))*((G11(3)-G11(
2))/(G2(3)-G2(2))-(G11(2)-G11(1))/(G2(2)-G2(1)))
G1=0.0
A=AS
C=CS
D=DS
RETURN
35
I=2


GO TO 36
45
I=2
GO TO 46
15
I=2
GO TO 16

```
SYMBOLS USED IN SUBROUTINE TTABLE

A         R  A  FIRST INDEPENDENT VARIABLE (PER CENT SEMI-SPAN)                TTABLE
AS        R  U  SAVED VALUE OF FIRST INDEPENDENT VARIABLE                      TTABLE
B         R  A  DEPENDENT VARIABLE (ZFACT)                                     TTABLE
C         R  A  DUMMY VARIABLE                                                 TTABLE
CS        R  U  SAVED VALUE OF DUMMY VARIABLE                                  TTABLE
D         R  A  SECOND INDEPENDENT VARIABLE (STATION)                          TTABLE
DS        R  U  SAVED VALUE OF SECOND INDEPENDENT VARIABLE                     TTABLE
G         R  A  FIRST DERIVATIVE (NOT USED)                                    TTABLE
G1        R  A  SECOND DERIVATIVE (NOT USED)                                   TTABLE
I         I  U  DO-LOOP INDEX                                                  TTABLE
IA        I  U  INDEX                                                          TTABLE
IA1       I  U  INDEX                                                          TTABLE
IC        I  U  INDEX                                                          TTABLE
IC1       I  U  INDEX                                                          TTABLE
ID        I  U  INDEX                                                          TTABLE
ID1       I  U  INDEX                                                          TTABLE
ID2       I  U  INDEX                                                          TTABLE
J         I  U  INDEX                                                          TTABLE
J2        I  U  INDEX                                                          TTABLE
K         I  U  DO-LOOP INDEX                                                  TTABLE
K2        I  U  INDEX                                                          TTABLE
L         I  U  INDEX                                                          TTABLE
M1        I  U  INDEX                                                          TTABLE
M2        I  U  INDEX                                                          TTABLE
N1        I  U  INDEX                                                          TTABLE
N2        I  U  INDEX                                                          TTABLE
Q1        R  D  QUADRATIC INTERPOLATION VARIABLE                               TTABLE
Q10       R  D  QUADRATIC INTERPOLATION VARIABLE                               TTABLE
Q11       R  D  QUADRATIC INTERPOLATION VARIABLE                               TTABLE
Q2        R  D  QUADRATIC INTERPOLATION VARIABLE                               TTABLE
Q3        R  D  QUADRATIC INTERPOLATION VARIABLE                               TTABLE
Q4        R  U  QUADRATIC INTERPOLATION VARIABLE                               TTABLE
Q8        R  D  QUADRATIC INTERPOLATION VARIABLE                               TTABLE
R         R  A  DATA ARRAY                                                     TTABLE
```

34. SUBROUTINE QINT (DECK SLBC)

a. Algorithm

Perform a quadratic interpolation with the given values.

b. Input/Output

None

c. Error

None

d. Subroutines Required

None

e. Argument List

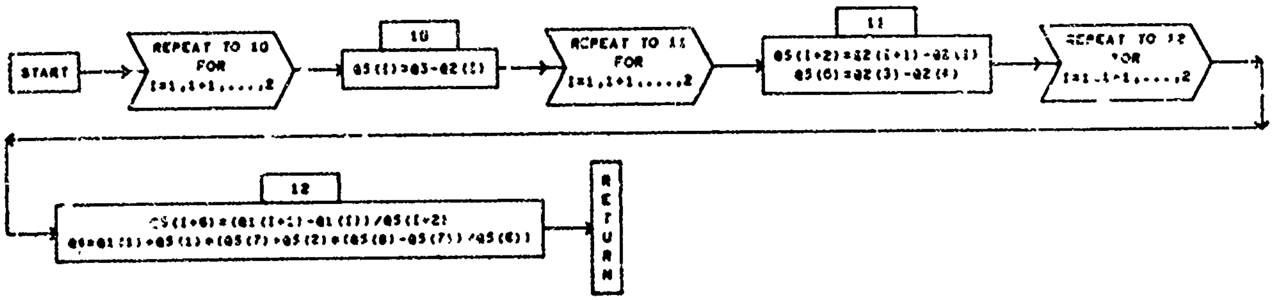
(Q1, Q2, Q3, Q4)

f. Length

490 bytes

```
DECK SLBC

      SUBROUTINE QINT(Q1,Q2,Q3,Q4)                                         SLBC  0010
      DIMENSION   Q1(3),Q2(3),Q5(8)                                        SLBC  0020
C     DIMENSION   Q1(3),Q2(3),Q5(8)                                        SLBC  0030
        DO 10 I = 1,2                                                      SLBC  0040
   10     Q5(I) = Q3 - Q2(I)                                               SLBC  0050
        DO 11 I = 1,2                                                      SLBC  0060
   11     Q5(I+2) = Q2(I+1) -Q2(I)                                         SLBC  0070
          Q5(6) = Q2(3) -Q2(1)                                             SLBC  0080
        DO 12 I = 1,2                                                      SLBC  0090
   12     Q5(I+6) =(Q1(I+1)-Q1(I))/Q5(I+2)                                 SLBC  0100
          Q4 = Q1(1) + Q5(1)*(Q5(7)+Q5(2)*(Q5(8)-Q5(7))  /Q5(6)    )       SLBC  0110
      RETURN                                                               SLBC  0120
      END                                                                  SLBC  0130
```

SUBROUTINE QINT



```
SYMBOLS USED IN SUBROUTINE QINT

Q1        R  A  QUADRATIC INTERPOLATION DATA ARRAY                              QINT
Q2        R  A  QUADRATIC INTERPOLATION DATA ARRAY                              QINT
Q3        R  A  QUADRATIC INTERPOLATION DATA ARRAY                              QINT
Q4        R  A  QUADRATIC INTERPOLATION DATA ARRAY                              QINT
Q5        R  D  QUADRATIC INTERPOLATION DATA ARRAY                              QINT
```

35. SUBROUTINE CARD (DECK CARD)

This routine reads geometry data from a tape unit and punches the information on cards.

a. Algorithm

The version for use with the IBM 360 reads the data from Tape 8 and writes the same information on the punch unit (Unit 7).

b. Input/Output

Reads geometry data from Tape 8 and writes the same information on the punch unit (Unit 7)

c. Error

None

d. Subroutines Required

None

e. Argument List

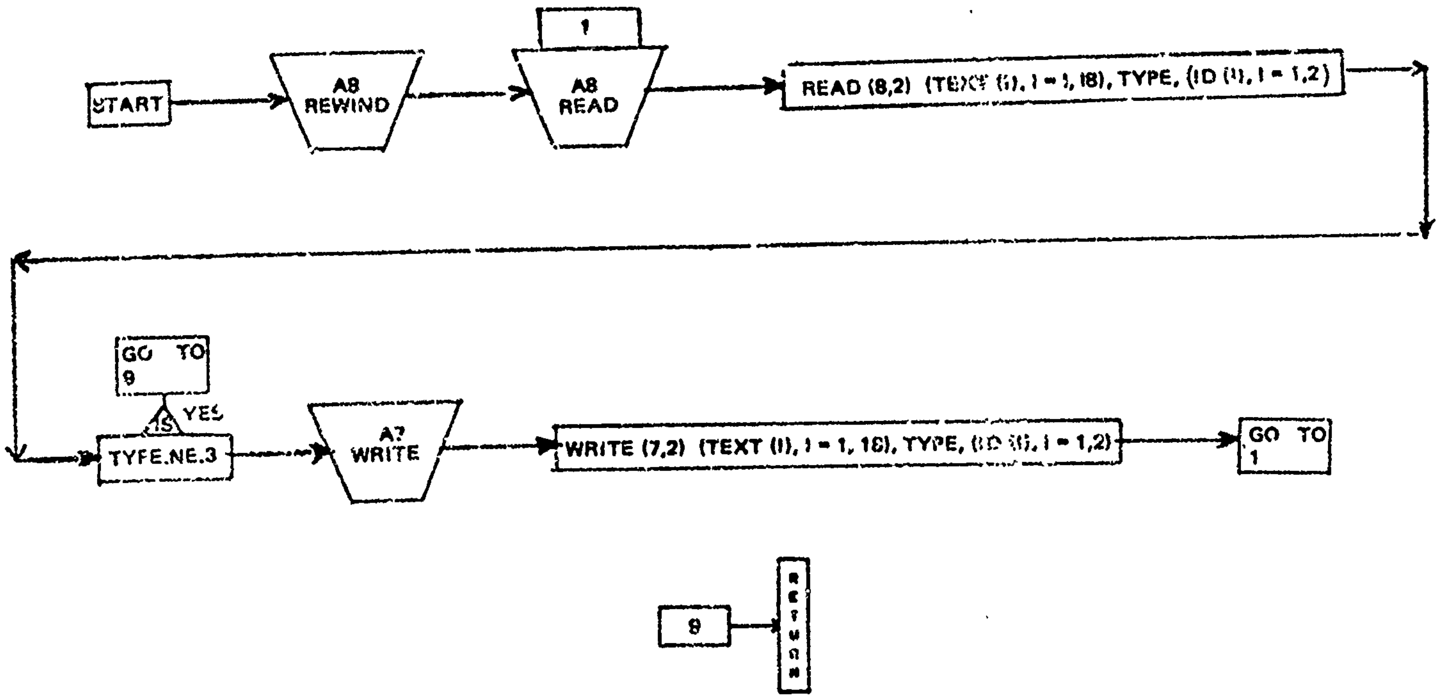
None

f. Length

460 bytes

```
DECK CARD

      SUBROUTINE CARD                                                   CARD  0010
C   IBM 360 VERSION OF SUBROUTINE CARD                                  CARD  0020
C   THIS SUBROUTINE (OPTION 5) READS DATA FROM TAPE 8 AND WRITES THE    CARD  0030
C   SAME INFORMATION ON THE PUNCH UNIT (UNIT 7).                        CARD  0040
C                                                                       CARD  0050
      DIMENSION  TEXT(18),ID(2)                                         CARD  0060
      INTEGER TYPE                                                      CARD  0070
C                                                                       CARD  0080
      REWIND 8                                                          CARD  0090
    1 READ (8,2) (TEXT(I),I=1,18),TYPE,(ID(I),I=1,2)                    CARD  0100
    2 FORMAT (17A4,1A3,I1,2A4)                                          CARD  0110
      IF (TYPE.NE.3) GO TO 9                                            CARD  0120
C                                                                       CARD  0130
      WRITE (7,2) (TEXT(I),I=1,18),TYPE,(ID(I),I=1,2)                   CARD  0140
      GO TO 1                                                           CARD  0150
C                                                                       CARD  0160
    9 RETURN                                                            CARD  0170
      END                                                               CARD  0180
```

SUBROUTINE CARD



```
SYMBOLS USED IN SUBROUTINE CARD

ID       I  D  INFORMATION ON TYPE 3 CARD FROM CC 73 TO CC 80                 CARD
TEXT     I  D  INFORMATION ON TYPE 3 CARD FROM CC 1 TO CC 71                  CARD
TYPE     I  U  CARD TYPE                                                      CARD
```

APPENDIX B

PROGRAM MNEMONIC LIST

This appendix contains an alphabetic list of all symbols used in the Mark III Mod 0 program. The list is divided into five fields which are described as follows:

(i) The first field contains the symbol

(ii) The second field contains the letters I, L, or R, denoting integer, logical, or real variable respectively.

(iii) The third field contains the letters A, C, D, U, denoting argument list. common, dimensioned, or undimensioned, variable respectively. The hierarchy of the above letters is A, C, D, U.

(iv) The fourth field contains the definition of the symbol.

(v) The fifth field contains the name of the subroutine in which the symbol occurs.

SYMBOL	TYPE	DEFINITION	ROUTINE
A	R U	ELLIPSE RADIUS IN Y-DIRECTION	ANALY1
A	R D	MATRIX OF ATMOSPHERIC PROPERTIES	ATMOS
A	D D	ELLIPTICAL INTEGRAL PARAMETER	ELP1
A	R D	ITERATION VARIABLE ARRAY	EXPAND
A	R U	SPEED OF SOUND	NEWTPM
A	R D	FIRST DATA ARRAY	PLOT
A	R A	POLYNOMIAL COEFFICIENT ARRAY	POLY
A	R U	COEFFICIENT USED IN SPALDING-CHI METHOD	QC
A	R U	SPEED OF SOUND	SKINFR
A	R U	DISTANCE TO TRANSITION BETWEEN NOSE AND LEADING EDGE	SLABD
A	R A	FIRST INDEPENDENT VARIABLE (PER CENT SEMI-SPAN)	TTABLE
AA	R D	Y-DIRECTION ELLIPSE RADIUS ARRAY	ANALY1
AA	R D	SEVENTH DATA ARRAY	PLOT
AA	R U	SEMI-SPAN DISTANCE PARAMETER	SLABD
AFLAG	L U	INPUT DATA READ CONTROL FLAG	PICTUR
AFLAG	L U	INPUT DATA READ CONTROL FLAG	SDATA
AFS	R U	FREE-STREAM SPEED OF SOUND	FORCE
AFS	R A	FREE-STREAM SPEED OF SOUND	SHKEXP
AFS	R A	FREE-STREAM SPEED OF SOUND	SKINFR
AK	R A	THE MODULUS	ELP1
AKD	D U	MODULUS	ELP1
AKK	R A	ELLIPTICAL INTEGRAL OF THE FIRST KIND	ELP1
ALP	R C	ANGLE OF ATTACK ARRAY	AERO
ALP	R C	ANGLE OF ATTACK ARRAY	FORCE
ALP	R C	ANGLE OF ATTACK ARRAY	SKINFR
ALP	R C	ANGLE OF ATTACK ARRAY	TEMP
ALPHA	R U	ANGLE OF ATTACK, DEGREES	AERO
ALPHA	R A	ANGLE OF ATTACK, DEGREES	FORCE
ALPHA	R A	ANGLE OF ATTACK, DEGREES	SKINFR
ALPHA	R A	ANGLE OF ATTACK, DEGREES	VECTOR
ALPHAR	R U	ANGLE OF ATTACK, RADIANS	FORCE
ALPHAR	R U	ANGLE OF ATTACK, RADIANS	VECTOR
ALPHAS	R U	SAVED VALUE OF ANGLE OF ATTACK	AERO
ALT	R U	ALTITUDE, FEET	AERO
ALT	R A	ALTITUDE, FEET	FORCE
ALT	R A	ALTITUDE, FEET	SKINFR

SYMBOL	TYPE	DEFINITION	ROUTINE
ANGLE	R A	FLOW ANGLE ARRAY	COMPR
ANGLE	R A	FLOW ANGLE ARRAY	CONE
ANGLE	R A	FLOW ANGLE ARRAY	DELWNG
ANGLE	R A	FLOW ANGLE ARRAY	EXPAND
ANGLE	R D	FLOW ANGLE ARRAY	FLOSEP
ANGLE	R D	FLOW ANGLE ARRAY	FORCE
ANGLE	R A	FLOW ANGLE ARRAY	NEWTPM
ANGLE	R D	FLOW ANGLE ARRAY	SHKEXP
ANGLE	R D	FLOW ANGLE ARRAY	SKINFR
AOD	R U	COEFFICIENT IN DEFINITION OF ODD ORIGIN	BLUNT
AR	R U	ASPECT RATIO OF WING/TAIL	PLUNGE
AREA	R U	ELEMENT AREA	CONTRL
AREA	R A	ELEMENT AREA	FLOSEP
AREA	R U	ELEMENT AREA	FORCE
AREA	R U	ELEMENT AREA	PICTUR
AREA	R U	ELEMENT AREA	SDATA
AREAS	R U	TOTAL AREA OF A COLUMN OF ELEMENTS	FORCE
AREAT	R U	TOTAL AREA	FORCE
AREAT	R U	TOTAL AREA	PICTUR
AREAT	R U	TOTAL AREA	SDATA
AREA2	R C	SURFACE AREA OF QUADRILATERALS	AERO
AREA2	R C	QUADRILATERAL ELEMENT AREA ARRAY	COMPR
AREA2	R C	QUADRILATERAL ELEMENT AREA ARRAY	CONE
AREA2	R C	QUADRILATERAL ELEMENT AREA ARRAY	CONTRL
AREA2	R C	QUADRILATERAL ELEMENT AREA ARRAY	DELWNG
AREA2	R C	QUADRILATERAL ELEMENT AREA ARRAY	EXPAND
AREA2	R C	(NOT USED)	FLOSEP
AREA2	R C	QUADRILATERAL ELEMENT AREA ARRAY	FORCE
AREA2	R C	QUADRILATERAL ELEMENT AREA ARRAY	NEWTPM
AREA2	R C	QUADRILATERAL ELEMENT AREA ARRAY	QC
AREA2	R C	QUADRILATERAL ELEMENT AREA ARRAY	SDATA
AREA2	R C	QUADRILATERAL ELEMENT AREA ARRAY	SHKEXP
AREA2	R C	QUADRILATERAL ELEMENT AREA ARRAY	SKINFR
AREA2	R C	QUADRILATERAL ELEMENT AREA ARRAY	TEMP
AS	R U	SAVED VALUE OF FIRST INDEPENDENT VARIABLE	TTABLE
ATA	D U	ELLIPTICAL INTEGRAL PARAMETER	ELP1

SYMBOL	TYPE		DEFINITION	ROUTINE
AVX	R	U	AVERAGE POINT COORDINATE-X	PICTUR
AVX	R	U	AVERAGE POINT COORDINATE-X	SDATA
AVY	R	U	AVERAGE POINT COORDINATE-Y	PICTUR
AVY	R	U	AVERAGE POINT COORDINATE-Y	SDATA
AVZ	R	U	AVERAGE POINT COORDINATE-Z	PICTUR
AVZ	R	U	AVERAGE POINT COORDINATE-Z	SDATA
AX	R	D	X-STATION ARRAY	ANALY1
A1	R	A	ATMOSPHERIC SPEED OF SOUND, FEET/SECOND	ATMOS
A1	R	U	COEFFICIENT IN DEFINITION OF FIRST FUNCTION	BLUNT
A1	R	U	ROTATION MATRIX CONSTANT	PICTUR
A1	R	U	COEFFICENT IN THE DEFINITION OF REFERENCE CONDITION	QC
A2	R	U	ROTATION MATRIX CONSTANT	PICTUR
A2	R	U	COEFFICIENT IN THE DEFINITION OF REFERENCE CONDITION	QC
A3	R	A	GEOMETRIC ALTITUDE, FEET	ATMOS
A3	R	U	ROTATION MATRIX CONSTANT	PICTUR
A4	R	A	ATMOSPHERIC PRESSURE, POUNDS PER SQUARE FOOT	ATMOS
A4	R	U	ROTATION MATRIX CONSTANT	PICTUR
A5	R	U	ROTATION MATRIX CONSTANT	PICTUR
A6	R	A	ATMOSPHERIC DENSITY, SLUGS PER CUBIC FOOT	ATMOS
A6	R	U	ROTATION MATRIX CONSTANT	PICTUR
A7	R	U	ROTATION MATRIX CONSTANT	PICTUR
A8	R	A	ATMOSPHERIC TEMPERATURE, DEGREE RANKINE	ATMOS
A8	R	U	ROTATION MATRIX CONSTANT	PICTUR
A9	R	U	ROTATION MATRIX CONSTANT	PICTUR
B	R	U	ELLIPSE RADIUS IN Z-DIRECTION	ANALY1
B	R	U	VARIABLE IN CUBIC EQUATION	COMPR
B	D	D	ELLIPTICAL INTEGRAL CONSTANT ARRAY	ELP1
B	R	D	SECOND DATA ARRAY	PLOT
B	R	U	WING/TAIL SPAN	PLUNGE
B	R	U	COEFFICIENT USED IN SPALDING-CHI METHOD	QC
B	R	U	LAMINAR VISCOUS INTERACTION PARAMETER	SKINFR
B	R	A	DEPENDENT VARIABLE (ZFACT)	TTABLE
BA	R	U	PRODUCT OF BETA AND ASPECT RATIO	PLUNGE
BARS	R	U	PRODUCT OF BA AND RS	PLUNGE
BA4	R	U	BA DIVIDED BY 4	PLUNGE
BB	R	D	Z-DIRECTION ELLIPSE RADIUS ARRAY	ANALY1

SYMBOL	TYPE	DEFINITION	ROUTINE
BB	R D	EIGHT DATA ARRAY	PLOT
BB	R U	SEMI-SPAN DISTANCE PARAMETER	SLABD
BDCK	R U	PRODUCT OF BETA AND D DIVIDED BY CR	PLUNGE
BDCT2	R U	DUMMY VARIABLE	SLABD
BDOT	R U	DUMMY VARIABLE	SLABD
BDOT2	R U	DUMMY VARIABLE	SLABD
BET	R C	YAW ANGLE ARRAY	AERO
BET	R C	YAW ANGLE ARRAY	FORCE
BET	R C	YAW ANGLE ARRAY	SKINFR
BET	R C	YAW ANGLE ARRAY	TEMP
BETA	R U	YAW ANGLE, DEGREES	AERO
BETA	R A	YAW ANGLE, DEGREES	FORCE
BETA	R U	PRANDTL-GLAUERT FACTOR	PLUNGE
BETA	R A	YAW ANGLE, DEGREES	VECTOR
BETAR	R U	YAW ANGLE, RADIANS	FORCE
BETAR	R U	YAW ANGLE, RADIANS	VECTOR
BETAS	R U	SAVED VALUE OF YAW ANGLE	AERO
BFLAG	L U	INPUT DATA READ CONTROL FLAG	PICTUR
BFLAG	L U	INPUT DATA READ CONTROL FLAG	SDATA
BM	R U	PRODUCT OF BETA AND M	PLUNGE
BMR2	R U	SQUARE ROOT OF DIFFERENCE OF BM2 AND 1.0	PLUNGE
BM1	R U	PRODUCT OF BETA AND M	PLUNGE
BM2	R U	SQUARE OF PRODUCT OF BETA AND M	PLUNGE
BOD	R U	COEFFICIENT IN DEFINITION OF ODD ORIGIN	BLUNT
BOTTC	R U	BOTTOM THICKNESS CORRECTION PARAMETER	SLABD
BS	R C	FLOW CONDITIONS BEHIND SHOCK OR EXPANSION	AERO
BS	R C	FLOW CONDITIONS BEHIND SHOCK OR EXPANSION	COMPR
BS	R C	FLOW CONDITIONS BEHIND COMPRESSION	CONE
BS	R C	FLOW CONDITIONS BEHIND SHOCK OR EXPANSION	DELWNG
BS	R C	FLOW CONDITIONS BEHIND SHOCK OR EXPANSION	EXPAND
BS	R C	FLOW CONDITIONS BEHIND SHOCK OR EXPANSION	FLOSEP
BS	R C	FLOW CONDITIONS BEHIND SHOCK OR EXPANSION	FORCE
BS	R C	FLOW CONDITIONS BEHIND SHOCK OR EXPANSION	NEWTPM
BS	R C	FLOW CONDITION ARRAY BEHIND SHOCK OR EXPANSION	QC
BS	R C	FLOW CONDITIONS BEHIND SHOCK OR EXPANSION	SHKEXP
BS	R C	FLOW CONDITIONS BEHIND SHOCK OR EXPANSION	SKINFR

SYMBOL	TYPE	DEFINITION	ROUTINE
BS	R C	FLOW CONDITIONS BEHIND THE SHOCK OR EXPANSION	TEMP
BS2	R U	PRESSURE TO BE SAVED	FLOSEP
BS2F	R U	INVISCID SHOCK-EXPANSION PRESSURE	FLOSEP
BS3	R U	TEMPERATURE TO BE SAVED	FLOSEP
BS3F	R U	TEMPERATURE TO BE SAVED	FLOSEP
BS6	R U	MACH NUMBER TO BE SAVED	FLOSEP
BS6F	R U	MACH NUMBER ON FLAP TO BE SAVED	FLOSEP
BS6SQ	R U	MACH NUMBER SQUARED	COMPR
BS6SQ	R U	MACH NUMBER SQUARED	CONE
BS6SQ	R U	MACH NUMBER SQUARED	DELWNG
B1	R U	COEFFICIENT IN DEFINITION OF FIRST FUNCTION	BLUNT
C	R U	VARIABLE IN CUBIC EQUATION	COMPR
C	D U	ELLIPTICAL INTEGRAL PARAMETER	ELP1
C	R D	ITERATION VARIABLE ARRAY	EXPAND
C	R D	THIRD DATA ARRAY	PLOT
C	R U	REFERENCE CHORD FOR BODY	PLUNGE
C	R U	COEFFICIENT USED IN SPALDING-CHI METHOD	QC
C	R U	SEMI-SPAN DISTANCE PARAMETER	SLABD
C	R A	DUMMY VARIABLE	TTABLE
CA	R U	AXIAL FORCE COEFFICIENT	FORCE
CA	R A	AXIAL FORCE COEFFICIENT	SKINF
CA	R A	AXIAL FORCE COEFFICIENT	VECTOR
CAI	R U	AXIAL FORCE INCREMENT	AERO
CAI	R A	AXIAL FORCE INCREMENT	FORCE
CARD	R D	ARRAY FOR READING IN 80 COLUMN CARD	AERO
CARD	R D	ARRAY FOR READING IN 80 COLUMN CARD	PICTUR
CARD	R D	ARRAY FOR READING CARD	SLABD
CASD1	R U	FIRST VALUE OF AXIAL FORCE FOR DERIVATIVE CALCULATIONS	AERO
CASD2	R U	SECOND VALUE OF AXIAL FORCE FOR DERIVATIVE CALCULATIONS	AERO
CASE	I C	CASE NUMBER	AERO
CASE	I C	CASE NUMBER	ANALY1
CASE	I C	CASE NUMBER	ANALY2
CASE	I C	CASE NUMBER	COMPR
CASE	I C	CASE NUMBER	CONE
CASE	I C	CASE NUMBER	CONTRL
CASE	I C	CASE NUMBER	DELWNG

SYMBOL	TYPE		DEFINITION	ROUTINE
CASE	I	C	CASE NUMBER	EXPAND
CASE	I	C	CASE NUMBER	FLOSEP
CASE	I	C	CASE NUMBER	FORCE
CASE	I	C	CASE NUMBER	GRAPIC
CASE	I	C	CASE NUMBER	HEADER
CASE	I	C	CASE NUMBER	HEADR2
CASE	I	C	PROBLEM CASE NUMBER	MAIN
CASE	I	C	CASE NUMBER	NEWTPM
CASE	I	C	CASE NUMBER	PICTUR
CASE	I	C	CARD NUMBER	PLOT
CASE	I	C	CASE NUMBER	PLUNGE
CASE	R	C	CASE NUMBER	PUNCH
CASE	I	C	CASE NUMBER	QC
CASE	I	C	CASE NUMBER	SDATA
CASE	I	C	CASE NUMBER	SHKEXP
CASE	I	C	CASE NUMBER	SKINFR
CASE	I	C	CASE NUMBER	SLABO
CASE	I	C	CASE NUMBER	TEMP
CASE	I	C	CASE NUMBER	VECTOR
CC	R	D	NINTH DATA ARRAY	PLOT
CCA	R	C	AXIAL FORCE COEFFICIENT ARRAY	AERO
CCA	R	C	AXIAL FORCE COEFFICIENT ARRAY	FORCE
CCA	R	C	AXIAL FORCE COEFFICIENT ARRAY	SKINFR
CCA	R	C	AXIAL FORCE COEFFICIENT ARRAY	TEMP
CCAS	R	D	SAVED VALUES OF AXIAL FORCE COEFFICIENT	AERO
CCD	R	C	DRAG COEFFICIENT ARRAY	AERO
CCD	R	C	DRAG COEFFICIENT ARRAY	FORCE
CCD	R	C	DRAG COEFFICIENT ARRAY	SKINFR
CCD	R	C	DRAG COEFFICIENT ARRAY	TEMP
CCDS	R	D	SAVED VALUES OF DRAG COEFFICIENT	AERO
CCL	R	C	LIFT COEFFICIENT ARRAY	AERO
CCL	R	C	LIFT COEFFICIENT ARRAY	FORCE
CCL	R	C	LIFT COEFFICIENT ARRAY	SKINFR
CCL	R	C	LIFT COEFFICIENT ARRAY	TEMP
CCLL	R	C	ROLLING MOMENT COEFFICIENT ARRAY	AERO
CCLL	R	C	ROLLING MOMENT COEFFICIENT ARRAY	FORCE

SYMBOL	TYPE	DEFINITION	ROUTINE
CCLL	R C	ROLLING MOMENT COEFFICIENT ARRAY	SKINFR
CCLL	R C	ROLLING MOMENT COEFFICIENT ARRAY	TEMP
CCLLS	R D	SAVED VALUES OF ROLLING MOMENT COEFFICIENT	AERO
CCLM	R C	PITCHING MOMENT COEFFICIENT ARRAY	AERO
CCLM	R C	PITCHING MOMENT COEFFICIENT ARRAY	FORCE
CCLM	R C	PITCHING MOMENT COEFFICIENT ARRAY	SKINFR
CCLM	R C	PITCHING MOMENT COEFFICIENT ARRAY	TEMP
CCLMS	R D	SAVED VALUES OF PITCHING MOMENT COEFFICIENT	AERO
CCLN	R C	YAWING MOMENT COEFFICIENT ARRAY	AERO
CCLN	R C	YAWING MOMENT COEFFICIENT ARRAY	FORCE
CCLN	R C	YAWING MOMENT COEFFICIENT ARRAY	SKINFR
CCLM	R C	YAWING MOMENT COEFFICIENT ARRAY	TEMP
CCLNS	R D	SAVED VALUES OF YAWING MOMENT COEFFICIENT	AERO
CCLS	R D	SAVED VALUES OF LIFT COEFFICIENT	AERO
CCN	R C	NORMAL FORCE COEFFICIENT ARRAY	AERO
CCN	R C	NORMAL FORCE COEFFICIENT ARRAY	FORCE
CCN	R C	NORMAL FORCE COEFFICIENT ARRAY	SKINFR
CCN	R C	NORMAL FORCE COEFFICIENT ARRAY	TEMP
CCNS	R D	SAVED VALUES OF NORMAL FORCE COEFFICIENT	AERO
CCY	R C	SIDE FORCE COEFFICIENT ARRAY	AERO
CCY	R C	SIDE FORCE COEFFICIENT ARRAY	FORCE
CCY	R C	SIDE FORCE COEFFICIENT ARRAY	SKINFR
CCY	R C	SIDE FORCE COEFFICIENT ARRAY	TEMP
CCYS	R D	SAVED VALUES OF SIDE FORCE COEFFICIENT	AERO
CD	R U	DRAG COEFFICIENT	FORCE
CD	R A	DRAG COEFFICIENT	VECTOR
CDL	R U	LAMINAR FLOW DRAG COEFFICIENT	SKINFR
CDT	R U	TURBULENT FLOW DRAG COEFFICIENT	SKINFR
CF	R C	SKIN FRICTION TOTAL AXIAL FORCE CONTRIBUTION	AERO
CF	R C	SKIN FRICTION CONTRIBUTION TO AXIAL FORCE ARRAY	FORCE
CF	R C	SKIN FRICTION CONTRIBUTION TO AXIAL FORCE ARRAY	SKINFR
CF	R C	SKIN FRICTION CONTRIBUTION TO AXIAL FORCE ARRAY	TEMP
CFCFOL	R U	LAMINAR RATIO OF SKIN FRACTION, INTERACTION/NO INTERACTION	SKINFR
CFCFOT	R U	TURBULENT RATIO OF SKIN FRICTION = 1.0	SKINFR
CFCFO1	R U	INITIAL SURFACE SKIN FRICTION RATIO	SKINFR
CFDI	R U	FLAP CHORD/UPSTREAM INTERACTION LENGTH	FLOSEP

SYMBOL	TYPE	DEFINITION	ROUTINE
CFL	R D	LAMINAR SKIN FRICTION COEFFICIENTS	SKINFR
CFLAP	R U	FLAP CHORD	FLOSEP
CFLLOC	R U	LOCAL LAMINAR SKIN-FRICTION COEFFICIENT	TEMP
CFO	R U	SKIN-FRICTION COEFFICIENT WITHOUT INTERACTION	BLUNT
CFS	R D	SAVED VALUES OF SKIN FRICTION TOTAL AXIAL FORCE CONTRIBUTION	AERO
CFT	R D	TURBULENT SKIN FRICTION COEFFICIENTS	SKINFR
CFTLOC	R C	LOCAL TURBULENT SKIN-FRICTION COEFFICIENT	QC
CFTLOC	R C	LOCAL TURBULENT SKIN FRICTION COEFFICIENT	TEMP
CFI	R U	SKIN FRICTION COEFFICIENT REFERENCED TO FREE-STREAM	TEMP
CFIRE1	R U	SKIN FRICTION PARAMETER	TEMP
CHIBAR	R U	HYPERSONIC INTERACTION PARAMETER	SKINFR
CKU	R C	LAMINAR FLOW FLIGHT CONDITION CONSTANT	QC
CKU	R C	LAMINAR FLOW FLIGHT CONDITION CONSTANT	SKINFR
CKU	R C	LAMINAR FLOW FLIGHT CONDITION CONSTANT	TEMP
CL	R U	LIFT COEFFICIENT ARRAY	FORCE
CL	R A	LIFT COEFFICIENT	VECTOR
CLALW	R U	LIFT-CURVE SLOPE FOR WING/TAIL (PER. RADIAN)	PLUNGE
CLAM	R U	CHAPMAN-RUBESIN VISCOSITY COEFFICIENT, LAMINAR	SKINFR
CLL	R U	ROLLING MOMENT COEFFICIENT	FORCE
CLL	R A	ROLLING MOMENT COEFFICIENT	VECTOR
CLLI	R U	ROLLING MOMENT COEFFICIENT INCREMENT	AERO
CLLI	R A	ROLLING MOMENT COEFFICIENT INCREMENT	FORCE
CLLSD1	R U	FIRST VALUE OF ROLLING MOMENT FOR DERIVATIVE	AERO
CLLSD2	R U	SECOND VALUE OF ROLLING MOMENT FOR DERIVATIVE	AERO
CLM	R U	PITCHING MOMENT COEFFICIENT	FORCE
CLM	R A	PITCHING MOMENT COEFFICIENT	VECTOR
CLMI	R U	PITCHING MOMENT COEFFICIENT INCREMENT	AERO
CLMI	R A	PITCHING MOMENT COEFFICIENT INCREMENT	FORCE
CLMSD1	R U	FIRST VALUE OF PITCHING MOMENT FOR DERIVATIVE	AERO
CLMSD2	R U	SECOND VALUE OF PITCHING MOMENT FOR DERIVATIVE	AERO
CLN	R U	YAWING MOMENT COEFFICIENT	FORCE
CLN	R A	YAWING MOMENT COEFFICIENT	VECTOR
CLNI	R U	YAWING MOMENT COEFFICIENT INCREMENT	AERO
CLNI	R A	YAWING MOMENT COEFFICIENT MOMENT	FORCE
CLNSD1	R U	FIRST VALUE OF YAWING MOMENT FOR DERIVATIVE	AERO
CLNSD2	R U	SECOND VALUE OF YAWING MOMENT FOR DERIVATIVE	AERO

SYMBOL	TYPE	DEFINITION	ROUTINE
CLOD	R C	LIFT TO DRAG RATIO ARRAY	AERO
CLOD	R C	LIFT TO DRAG RATIO ARRAY	FORCE
CLOD	R C	LIFT TO DRAG RATIO ARRAY	SKINFR
CLOD	R C	LIFT TO DRAG RATIO ARRAY	TEMP
CLSD1	R U	FIRST VALUE OF LIFT COEFFICIENT FOR DERIVATIVE	AERO
CMA	R A	DERIVATIVE OF PITCHING MOMENT WITH ANGLE OF ATTACK	PLUNGE
CMADT	R A	PITCHING MOMENT-ALPHA DOT DERIVATIVE	PLUNGE
CMWPR	R U	WING-ALONE/TAIL-ALONE PITCHING MOMENT DERIVATIVE	PLUNGE
CN	R U	NORMAL FORCE COEFFICIENT	FORCE
CN	R A	NORMAL FORCE COEFFICIENT	SKINFR
CN	R A	NORMAL FORCE COEFFICIENT	VECTOR
CNI	R U	NORMAL FORCE COEFFICIENT INCREMENT	AERO
CNI	R A	NORMAL FORCE COEFFICIENT INCREMENT	FORCE
CNSD1	R U	FIRST VALUE OF NORMAL FORCE FOR DERIVATIVE	AERO
CNSD2	R U	SECOND VALUE OF NORMAL FORCE FOR DERIVATIVE	AERO
COEF	R U	COEFFICIENT DERIVATIVE	PLUNGE
COSDE	R U	COSINE OF CONTROL DEFLECTION ANGLE	CONTRL
COSDEL	R U	COSINE OF ANGLE NORMAL AND VELOCITY VECTORS	FORCE
COSEP1	R U	COSINE OF EPSILON 1	ANALY2
COSEP2	R U	COSINE OF EPSILON 2	ANALY2
COSPHI	R U	COSINE OF TRANSFORMATION ANGLE, PHI	CONTRL
COSPHI	R U	COSINE OF PHI	PICTUR
COSPSI	R U	COSINE OF TRANSFORMATION ANGLE, PSI	CONTRL
COSPSI	R U	COSINE OF PSI	PICTUR
COSTH	R U	COSINE OF THETA	PICTUR
CP	R A	PRESSURE COEFFICIENT	COMPR
CP	R U	PRESSURE COEFFICIENT	CONE
CP	R A	PRESSURE COEFFICIENT	CONE
CP	R A	PRESSURE COEFFICIENT	EXPAND
CP	R A	PRESSURE COEFFICIENT	FLOSEP
CP	R U	PRESSURE COEFFICIENT	FORCE
CP	R A	PRESSURE COEFFICIENT	NEWTPM
CP	R A	PRESSURE COEFFICIENT	SHKEXP
CP	R U	PRESSURE COEFFICIENT	SKINFR
CPAINC	R U	PRESSURE RISE TO CAUSE INCIPIENT SEPARATION	FLOSEP

SYMBOL	TYPE	DEFINITION	ROUTINE
CPAP	R U	PLATEAU PRESSURE COEFFICIENT	FLOSEP
CPAVG	R U	AVERAGE PRESSURE COEFFICIENT TIMES AREA FOR EQUIVALENT CONE	FORCE
CPA2IN	R U	INVISCID PRESSURE RISE COEFFICIENT ON TO CONTROL SURFACE	FLOSEP
CPF	R U	PRESSURE COEFFICIENT ON FLAP (DUMMY-NOT USED)	FLOSEP
CPIP	R U	PLATEAU PRESSURE COEFFICIENT	FLOSEP
CPI2	R U	PEAK PRESSURE COEFFICIENT ON FLAP	FLOSEP
CPNIN	R A	PRESSURE COEFFICIENT (INPUT FORCE METHOD, INVISCID)	FLOSEP
CPNIN	R U	MINIMUN PRESSURE COEFFICIENT	FORCE
CPQ	R U	PRESSURE COEFFICIENT AT MATCHING POINT	NEWTPM
CPS	R C	ARRAY FOR NEWTONIAN CORRELATION FACTOR, K	AERO
CPS	R C	ARRAY FOR NEWTONIAN CORRELATION FACTOR, K	FORCE
CPS	R C	ARRAY FOR NEWTONIAN CORRELATION FACTOR, K	SKINFR
CPS	R C	ARRAY FOR NEWTONIAN CORRECTION FACTOR, K	TEMP
CPSEP	R U	VISCOUS PRESSURE COEFFICIENT WITH SEPARATION	FLOSEP
CPSTAG	R U	MODIFIED NEWTONIAN CORRELATION FACTOR, K	AERO
CPSTAG	R A	MODIFIED NEWTONIAN CORRELATION FACTOR, K	COMPR
CPSTAG	R A	NEWTONIAN CORRELATION FACTOR, K (STAGNATION PRESSURE COEFF)	FLOSEP
CPSTAG	R A	MODIFIED NEWTONIAN CORRELATION FACTOR, K	FORCE
CPSTAG	R A	MODIFIED NEWTONIAN CORRELATION FACTOR, K	NEWTPM
CPSTAG	R A	MODIFIED NEWTONIAN CORRELATION FACTOR, K	SHKEXP
CPSTAG	R A	MODIFIED NEWTONIAN CORRELATION FACTOR, K	SKINFR
CPX	R U	PRESSURE COEFFICIENT AT SEPARATION POINT	FLOSEP
CP1	R U	ITERATION PRESSURE COEFFICIENT	FORCE
CR	R U	WING/TAIL CHORD AT WING/TAIL-BODY JUNCTURE	PLUNGE
CRBD	R U	RICIPROCAL OF BDCR	PLUNGE
CRBD2	R U	SQUARE OF CRBD	PLUNGE
CS	R U	SAVED VALUE OF DUMMY VARIABLE	TTABLE
CSTAR	R U	LINEAR VISCOSITY COEFFICIENT AT REFERENCE CONDITION	SKINFR
CTURB	R U	CHAPMAN-RUBESIN VISCOSITY COEFFICIENT, TURBULENT	SKINFR
CWBYC	R U	MEAN AERODYNAMIC CHORD OF EXPOSED WING/TAIL	PLUNGE
CY	R U	SIDE FORCE COEFFICIENT	FORCE
CY	R A	SIDE FORCE COEFFICIENT	VECTOR
CYB	R [illegible]	DERIVATIVE OF SIDE FORCE WITH YAW ANGLE	PLUNGE
CYBDT	R A	DERIVATIVE OF SIDE FORCE WITH BETA DOT	PLUNGE
CYI	R U	SIDE FORCE COEFFICIENT INCREMENT	AERO
CYI	R A	SIDE FORCE COEFFICIENT INCREMENT	FORCE

SYMBOL	TYPE		DEFINITION	ROUTINE
CYPRIM	R	U	SIDE FORCE COEFFICIENT-WIND AXIS	FORCE
CYPRIM	R	U	SIDE FORCE COEFFICIENT (WIND AXIS)	VECTOR
CYSD1	R	U	FIRST VALUE OF SIDE FORCE COEFFICIENT FOR DERIVATIVE	AERO
CYSD2	R	U	SECOND VALUE OF SIDE FORCE COEFFICIENT FOR DERIVATIVE	AERO
D	R	D	CONSTANTS FOR BOUNDARY CURVES	ANALY2
D	R	U	VARIABLE IN CUBIC EQUATION	COMPR
D	D	U	ELLIPTICAL INTEGRAL PARAMETER	ELP1
D	R	U	CORNER POINT PROJECTION DISTANCE	PICTUR
D	R	D	FOURTH DATA ARRAY	PLOT
D	R	U	BODY DIAMETER AT WING OR TAIL	PLUNGE
D	R	U	CORNER POINT PROJECTION DISTANCE	SDATA
D	R	A	SECOND INDEPENDENT VARIABLE (STATION)	TTABLE
DA	R	U	ITERATION INCREMENT	EXPAND
DADC	R	U	EXPANSION ITERATION PARAMETER	EXPAND
DCAA	R	D	DERIVATIVE OF AXIAL FORCE WITH ANGLE OF ATTACK	AERO
DCAAS	R	D	SAVED VALUES OF AXIAL FORCE-ANGLE OF ATTACK DERIVATIVE	AERO
DCAQ	R	D	DERIVATIVE OF AXIAL FORCE WITH PITCH RATE	AERO
DCAQS	R	D	SAVED VALUES OF AXIAL FORCE DERIVATIVE WITH PITCH RATE	AERO
DCA1	R	U	EXPANSION ITERATION PARAMETER	EXPAND
DCA2	R	U	EXPANSION ITERATION PARAMETER	EXPAND
DCLA	R	D	DERIVATIVE OF LIFT COEFFICIENT WITH ANGLE OF ATTACK	AERO
DCLAS	R	D	SAVED LIFT COEFFICIENT DERIVATIVE WITH ANGLE OF ATTACK	AERO
DCLD	R	D	DERIVATIVE OF CL WITH CONTROL SURFACE DEFLECTION	AERO
DCLDS	R	D	SAVED VALUES OF CL DERIVATIVE WITH CONTROL DEFLECTION	AERO
DCLLB	R	D	DERIVATIVE OF ROLLING MOMENT WITH YAW ANGLE	AERO
DCLLBS	R	D	SAVED VALUES OF ROLLING MOMENT DERIVATIVE WITH YAW	AERO
DCLLD	R	D	DERIVATIVE OF ROLLING MOMENT WITH CONTROL DEFLECTION	AERO
DCLLDS	R	D	SAVED VALUES OF ROLLING MOMENT-CONTROL DERIVATIVE	AERO
DCLLR	R	D	DERIVATIVE OF ROLLING MOMENT WITH YAW RATE	AERO
DCLLRS	R	D	SAVED VALUES OF ROLLING MOMENT DERIVATIVE WITH YAW	AERO
DCLND	R	D	DERIVATIVE OF YAWING MOMENT WITH CONTROL DEFLECTION	AERO
DCLNDS	R	D	SAVED VALUES OF YAWING MOMENT-CONTROL DERIVATIVE	AERO
DCLNR	R	D	DERIVATIVE OF YAWING MOMENT WITH YAW RATE	AERO
DCLNRS	R	D	SAVED VALUES OF YAWING MOMENT-YAW RATE DERIVATIVE	AERO
DCMA	R	D	DERIVATIVE OF PITCHING MOMENT WITH ANGLE OF ATTACK	AERO
DCMADS	R	D	SAVED VALUES OF PITCHING MOMENT-ALPHA DOT DERIVATIVE	AERO

SYMBOL	TYPE	DEFINITION	ROUTINE
DCMADT	R D	PITCHING MOMENT-ALPHA DOT DERIVATIVE	AERO
DCMAS	R D	SAVED VALUE OF PITCHING MOMENT-ALPHA DERIVATIVE	AERO
DCMD	R D	PITCHING MOMENT-CONTROL DEFLECTION DERIVATIVE	AERO
DCMDS	R D	SAVED VALUES OF PITCHING MOMENT-CONTROL DERIVATIVE	AERO
DCMQ	R D	DERIVATIVE OF PITCHING MOMENT WITH PITCH RATE	AERO
DCMQS	R D	SAVED VALUES OF PITCHING MOMENT-PITCH RATE DERIVATIVE	AERO
DCNA	R D	DERIVATIVE OF NORMAL FORCE WITH ANGLE OF ATTACK	AERO
DCNAS	R D	SAVED VALUE OF NORMAL FORCE-ALPHA DERIVATIVE	AERO
DCNB	R D	DERIVATIVE OF YAWING MOMENT WITH YAW ANGLE	AERO
DCNBS	R D	SAVED VALUE OF NORMAL FORCE-YAW DERIVATIVE	AERO
DCND	R D	DERIVATIVE OF NORMAL FORCE WITH CONTROL DEFLECTION	AERO
DCNDS	R D	SAVED VALUE OF NORMAL FORCE-CONTROL DERIVATIVE	AERO
DCNQ	R D	DERIVATIVE OF NORMAL FORCE WITH PITCH RATE	AERO
DCNQS	R D	SAVED VALUES OF NORMAL FORCE-PITCH RATE DERIVATIVES	AERO
DCYB	R D	DERIVATIVE OF SIDE FORCE WITH YAW ANGLE	AERO
DCYBDS	R D	SAVED VALUE OF CY-BETA DATA DERIVATIVE	AERO
DCYBDT	R D	DERIVATIVE OF SIDE FORCE WITH BETA DOT	AERO
DCYBS	R D	SAVED VALUE OF SIDE FORCE-YAW DERIVATIVE	AERO
DCYD	R D	DERIVATIVE OF SIDE FORCE WITH CONTROL DEFLECTION	AERO
DCYDS	R D	SAVED VALUES OF SIDE FORCE-CONTROL DERIVATIVE	AERO
DCYR	R D	DERIVATIVE OF SIDE FORCE WITH YAW RATE	AERO
DCYRS	R D	SAVED VALUES OF SIDE FORCE-YAW RATE DERIVATIVES	AERO
DD	R D	TENTH DATA ARRAY	PLOT
DELCA	R U	ELEMENT CONTRIBUTION TO AXIAL FORCE	FORCE
DELCA	R U	DRAG COEFFICIENT INCREMENT	VECTOR
DELCLL	R U	ELEMENT CONTRIBUTION TO ROLLING MOMENT	FORCE
DELCLL	R U	ROLLING MOMENT COEFFICIENT INCREMENT	VECTOR
DELCLM	R U	ELEMENT CONTRIBUTION TO PITCHING MOMENT	FORCE
DELCLM	R U	PITCHING MOMENT COEFFICIENT INCREMENT	VECTOR
DELCLN	R U	ELEMENT CONTRIBUTION TO YAWING MOMENT	FORCE
DELCLN	R U	YAWING MOMENT COEFFICIENT INCREMENT	VECTOR
DELCN	R U	ELEMENT CONTRIBUTION TO NORMAL FORCE	FORCE
DELCN	R U	NORMAL FORCE COEFFICIENT INCREMENT	VECTOR
DELCPC	R A	PRESSURE COEFFICIENT INCREMENT DUE TO CONTROL SURFACE	FLOSEP
DELCPC	R U	DELTA CP DUE TO CONTROL SURFACE DEFLECTION	FORCE
DELCY	R U	ELEMENT CONTRIBUTION TO SIDE FORCE	FORCE

SYMBOL	TYPE	DEFINITION	ROUTINE
DELCY	R U	SIDE FORCE COEFFICIENT INCREMENT	VECTOR
DELDLW	R U	IMPACT ANGLE FOR DELTA WING	FORCE
DELDLW	R U	IMPACT ANGLE FOR DELTA-WING OPTION, RADIANS	SHKEXP
DELP	R U	PRESSURE INCREMENT DUE TO FLAP AND SEPARATION	FLOSEP
DELQRP	R U	INCREMENT IN ROTATION RATE FOR ROTATION DERIVATIVES	AERO
DELTA	R U	EPSILON 1 + EPSILON 2	ANALY2
DELTA	R A	ELEMENT IMPACT ANGLE (DEGREES)	FLOSEP
DELTA	R U	IMPACT ANGLE, DEGREES	FORCE
DELTA	R A	IMPACT ANGLE, DEGREES	SHKEXP
DELTA	R A	IMPACT ANGLE, DEGREES	SKINFR
DELTAE	R U	CONTROL SURFACE DEFLECTION	AERO
DELTAE	R A	CONTROL SURFACE DEFLECTION	CONTRL
DELTAE	R A	CONTROL SURFACE DEFLECTION	FLOSEP
DELTAE	R A	CONTROL SURFACE DEFLECTION	FORCE
DELTAR	R U	SURFACE IMPACT ANGLE IN RADIANS	CONE
DELTAR	R A	ELEMENT IMPACT ANGLE (RADIANS)	FLOSEP
DELTAR	R U	IMPACT ANGLE, RADIANS	FORCE
DELTAR	R A	IMPACT ANGLE, RADIANS	SHKEXP
DELTAS	R U	SAVED VALUE OF CONTROL SURFACE DEFLECTION	AERO
DELTAS	R U	SAVED INITIAL CONTROL SURFACE DEFLECTION	FLOSEP
DELTAS	R U	IMPACT CONTROL SURFACE DEFLECTION ANGLE	FORCE
DELTER	R U	FLAP DEFLECTION ANGLE (RADIANS)	FLOSEP
DELTES	R D	SAVED VALUE OF CONTROL SURFACE DEFLECTION	AERO
DELTH	R U	THETA ANGULAR INCREMENT	ANALY1
DELTHB	R U	BOTTOM SURFACE DELTA-THETA INCREMENT	SLABD
DELTHM	R U	HINGE MOMENT INCREMENT	FORCE
DELTHT	R U	TOP SURFACE DELTA THETA INCREMENT	SLABD
DELTHX	R D	THETA ANGULAR INCREMENT ARRAY	ANALY1
DELTQ	R U	IMPACT ANGLE AT MATCHING POINT	NEWTPM
DELTS	R U	SAVED VALUES OF CONTROL DEFLECTION	AERO
DELTX	R U	DISTANCE FROM LEADING EDGE TO CENTROID	SDATA
DELT2	R U	ITERATION VALUE FOR EQUIVALENT CONE ANGLE (2)	FORCE
DELU	R U	DELTA INCREMENT FOR U	ANALY2
DELVOL	R U	ELEMENT VOLUME CONTRIBUTION	PICTUR
DELVOL	R U	ELEMENT VOLUME CONTRIBUTION	SDATA
DELW	R U	DELTA INCREMENT FOR W	ANALY2

SYMBOL	TYPE	DEFINITION	ROUTINE
DELX	R U	GEOMETRY DATA X-INCREMENT	PICTUR
DELX	R U	GEOMETRY DATA X-INCREMENT	SDATA
DELY	R U	Y-SHIFT INCREMENT FOR ELLIPSE DATA	ANALY1
DELY	R U	GEOMETRY DATA Y-INCREMENT	PICTUR
DELY	R U	GEOMETRY DATA Y-INCREMENT	SDATA
DELYX	R D	Y-SHIFT INCREMENT ARRAY	ANALY1
DELZ	R U	Z-SHIFT INCREMENT FOR ELLIPSE DATA	ANALY1
DELZ	R U	GEOMETRY DATA Z-INCREMENT	PICTUR
DELZ	R U	GEOMETRY DATA Z-INCREMENT	SDATA
DELZ	R U	GEOMETRY DATA DISPLACEMENT PARAMETER IN Z-DIRECTION	SLABD
DELZX	R D	Z-SHIFT INCREMENT ARRAY	ANALY1
DEL1	R U	ITERATION VALUE FOR EQUIVALENT CONE ANGLE (1)	FORCE
DISCON	I U	ANGULAR MODE CONTROL FLAG	ANALY1
DIST1	R U	LEADING EDGE DISTANCE VALUE	SDATA
DLTMU	R U	EXPANSION ANGLE FROM MATCHING MOMENT	NEWTPM
DMDZ	R U	DERIVATIVE OF MOLECULAR WEIGHT OF AIR	ATMOS
DO	R U	BOUNDARY LAYER THICKNESS	FLOSEP
DOX	R U	BOUNDARY LAYER THICKNESS AT EXACT SEPARATION POINT	FLOSEP
DO1	R U	BOUNDARY LAYER THICKNESS ON ELEMENT BEFORE SEPARATION POINT	FLOSEP
DQC	R U	DIFFERENCE IN CONVECTIVE HEATING RATES	TEMP
DQR	R U	DIFFERENCE IN RADIATION HEATING RATES	TEMP
DS	R U	SAVED VALUE OF SECOND INDEPENDENT VARIABLE	TTABLE
DSQXP	R U	SQUARE ROOT OF X-PRIME	FLOSEP
DTC	R U	DIFFERENCE IN CONVECTIVE TEMPERATURES	TEMP
DTR	R U	DIFFERENCE IN RADIATION TEMPERATURES	TEMP
DUMMY	R U	DUMMY ARGUMENT	FLOSEP
DUMMY	R U	DUMMY VARIABLE	PLUNGE
DUMMY	R U	DUMMY VARIABLE	SLABD
DX	R U	INCREMENT BETWEEN VERTICAL GRID LINES	PLOT
DXEV	R U	INCREMENT FROM ORIGIN, EVEN EXPONENTIAL	BLUNT
DXG	R U	GRID DELTA-X INCREMENT	PICTUR
DXSEP	R U	DIFFERENCE BETWEEN LEADING EDGE AND SEPARATION X-DISTANCE	FLOSEP
DXSEP1	R U	XLE-XSEP ON ELEMENT JUST BEFORE SEPARATION ELEMENT	FLOSEP
DY	R U	INCREMENT BETWEEN HORIZONAL GRID LINES	PLOT
DYG	R U	GRID DELTA-Y INCREMENT	PICTUR
D1	R U	UPSTREAM INTERACTION LENGTH	FLOSEP

SYMBOL	TYPE		DEFINITION	ROUTINE
D1DO	R	U	UPSTREAM INTERACTION LENGTH/BOUNDARY LAYER THICKNESS	FLOSEP
D2	R	U	DOWNSTREAM INTERACTION LENGTH TO PEAK PRESSURE	FLOSEP
D2D1	R	U	RATIO OF DOWNSTREAM TO UPSTREAM INTERACTION LENGTHS	FLOSEP
D3	R	U	DOWNSTREAM INTERACTION LENGTH TO PRESSURE RISE	FLOSEP
D3D1	R	U	DOWNSTREAM INTERACTION LENGTH/UPSTREAM INTERACTION LENGTH	FLOSEP
E	R	A	ELLIPTICAL INTEGRAL OF THE SECOND KIND	ELP1
E	R	D	FIFTH DATA ARRAY	PLOT
ECOS	R	U	COSINE OF FLOW TURNING ANGLE	SKINFR
EE	R	D	ELEVENTH DATA ARRAY	PLOT
EL	R	U	SURFACE REFERENCE LENTH, INPUT	SKINFR
EL	R	A	REFERENCE LENGTH	TEMP
ELAM	R	U	A FUNCTION OF RELATIVE FLAP CHORD LENGTH	FLOSEP
ELFI	R	U	FREE INTERACTION LENGTH	FLOSEP
ELFIDO	R	U	FREE INTERACTION LENGTH / BOUNDARY LAYER THICKNESS	FLOSEP
ELH	R	U	MOLECULAR SCALE TEMPERATURE DERIVATIVE, DEGREE RANKINE/FOOT	ATMOS
ELL	R	U	EFFECTIVE SURFACE LENGTH, LAMINAR	SKINFR
ELLOC	R	C	REFERENCE LENGTH	QC
ELLOC	R	C	REFERENCE LENGTH (=EL)	SKINFR
ELLOC	R	C	REFERENCE LENGTH (=EL)	TEMP
ELO	R	U	LENGTH OF INITIAL SURFACE	SKINFR
ELT	R	U	EFFECTIVE SURFACE LENGTH, TURBULENT	SKINFR
ELZ	R	U	MOLECULAR SCALE TEMPERATURE DERIVATIVE, DEGREE RANKINE/FOOT	ATMOS
EL1	R	U	EFFECTIVE LENGTH OF INITIAL SURFACE	SKINFR
EM	R	U	MOLECULAR WEIGHT OF AIR	ATMOS
EMADF	R	U	PRODUCT OF MACH NUMBER AND FLAP DEFLECTION	FLOSEP
EMCONE	R	U	MACH NUMBER ON SURFACE OF EQUIVALENT CONE	FORCE
EMISS	R	U	EMISSIVITY	TEMP
EMN	R	U	MACH NUMBER TIMES SINE THETA SQUARED	COMPR
EMN	R	U	MACH NUMBER NORMAL TO THE SHOCK	DELWNG
EMN	R	U	MACH NUMBER TIMES SHOCK ANGLE SQUARED	FORCE
EMN	R	A	MACH NUMBER TIMES SHOCK ANGLE SQUARED	NEWTPM
EMN	R	U	MACH NUMBER TIMES SHOCK ANGLE SQUARED	SKINFR
EMNS	R	U	MACH NUMBER NORMAL TO SHOCK	CONE
EMNS	R	U	MACH NUMBER NORMAL TO SHOCK	FORCE
EMNS	R	U	MACH NORMAL TO THE SHOCK	SHKEXP
EMSQ	R	U	MACH NUMBER SQUARED	EXPAND

SYMBOL	TYPE	DEFINITION	ROUTINE
EN	R U	PARAMETER IN CHARACTERISTIC LENGTH EQUATION	SKINFR
ENPM	R U	SURFACE SLOPE MODIFICATION FACTOR	AERO
ENPM	R A	SURFACE SLOPE MODIFICATION FACTOR	FORCE
ENPMS	R D	SAVED VALUES OF SURFACE SLOPE MODIFICATION FACTOR	AERO
ENTHAL	R U	ENTRY TO DETERMINE FNTHALPY	ROMU
EPS	R U	TOLERANCE FOR EVEN EXPONENTIAL	BLUNT
EPS	R U	ITERATION ACCURACY PARAMETER	EXPAND
EPSI	R U	EFFECTIVE DENSITY RATIO	NEWTPM
EPST	R U	TOLERANCE OF TEMPERATURE ITERATIONS	TEMP
EPS1	R U	EPSILON 1	ANALY2
EPS2	R U	EPSILON 2	ANALY2
ERFS	R U	ERROR FUNCTION PARAMETER	FORCE
ERROR	I C	ERROR FLAG	AERO
ERROR	I C	ERROR FLAG	ANALY1
ERROR	I C	ERROR FLAG	ANALY2
ERROR	I C	ERROR FLAG	COMPR
ERROR	I C	ERROR FLAG	CONE
ERROR	I C	ERROR FLAG	CONTRL
ERROR	I C	ERROR FLAG	DELWNG
ERROR	I C	ERROR FLAG	EXPAND
ERROR	I C	ERROR FLAG	FLOSEP
ERROR	I C	ERROR FLAG	FORCE
ERROR	I C	ERROR FLAG	GRAPIC
ERROR	I C	ERROR FLAG (=0 NO ERROR, =1 NON-FATAL, =2 FATAL)	MAIN
ERROR	I C	ERROR FLAG	NEWTPM
ERROR	I C	ERROR FLAG	PICTUR
ERROR	I C	ERROR FLAG	PLOT
ERROR	I C	ERROR FLAG	PLUNGE
ERROR	I C	ERROR FLAG	QC
ERROR	I C	ERROR FLAG	SDATA
ERROR	I C	ERROR FLAG	SHKEXP
ERROR	I C	ERROR FLAG	SKINFR
ERROR	I C	ERROR FLAG	SLABD
ERROR	I C	ERROR FLAG	TEMP
ERROR	I C	ERROR FLAG	VECTOR

SYMBOL	TYPE	DEFINITION	ROUTINE
ESIN	R U	SINE OF FLOW TURNING ANGLE	SKINFR
ETA	R D	COORDINATE IN ELEMENT COORDINATE SYSTEM	PICTUR
ETA	R D	COORDINATE IN ELEMENT COORDINATE SYSTEM	SDATA
ETAC	R U	PRANDTL-MEYER-EXPANSION CORRECTION FACTOR	AERO
ETAC	R U	PRANDTL-MEYER EXPANSION CORRECTION FACTOR	COMPR
ETAC	R A	PRANDTL-MEYER EXPANSION CORRECTION FACTOR	FORCE
ETAC	R A	PRANDTL-MEYER EXPANSION CORRECTION FACTOR	NEW1PM
ETACK	R U	ETA CHECK PARAMETER	PICTUR
ETACK	R U	ETA CHECK PARAMETER	SDATA
ETACS	R D	SAVED VALUES OF PRANDTL-MEYER CORRECTION FACTOR	AERO
ETACS	R C	SAVED VALUES OF PRANDTL-MEYER CORRECTION FACTOR	SKINFR
ETACS	R C	SAVED VALUES OF PRANDTL-MEYER CORRECTION FACTOR	TEMP
ETAO	R U	COORDINATE IN ELEMENT COORDINATE SYSTEM	PICTUR
ETAO	R U	CENTROID IN ELEMENT COORDINATE SYSTEM	SDATA
ETA2M4	R U	CONSTANT IN AREA EQUATION	PICTUR
ETA2M4	R U	CONSTANT IN AREA EQUATION	SDATA
EVK	R U	EVEN EXPONENTIAL CONSTANT	BLUNT
EX	R U	INDEPENDENT VARIABLE	BLUNT
F	R D	SIXTH DATA ARRAY	PLOT
F	R U	FORCE MAGNITUDE, POUNDS	VECTOR
FC	R C	TURBULENT FLOW, SKIN FRICTION COMPRESSIBILITY FACTOR	QC
FC	R C	TURBULENT FLOW, SKIN FRICTION COMPRESSIBILITY FACTOR	SKINFR
FC	R C	TURBULENT FLOW, SKIN-FRICTION COMPRESSIBILITY FACTOR	TEMP
FF	R D	TWELVETH DATA ARRAY	PLOT
FF	R U	FRICTION FACTOR	SKINFR
FH	R C	ENTHALPY ARRAY	DATA
FH	R C	ENTHALPY ARRAY	ROMU
FH1	R D	FIRST 108 ELEMENTS OF ENTHALPY ARRAY	DATA
FH2	R D	FINAL 27 ELEMENTS OF ENTHALPY ARRAY	DATA
FJ	R U	MANGLER TRANSFORMATION PARAMETER	SKINFR
FN	R U	NORMAL MOMENTUM ACCOMODATION COEFFICIENT	FORCE
FOU	R U	BLENDING FUNCTION VALUE	ANALY2
FOW	R U	BLENDING FUNCTION VALUE	ANALY2
FR	R C	DENSITY-VISCOSITY PRODUCT AND DENSITY ARRAYS	DATA
FR	R C	DENSITY-VISCOSITY PRODUCT AND DENSITY ARRAYS	ROMU
FRX	R C	TURBULENT FLOW, REYNOLDS NUMBER COMPRESSIBILITY FACTOR	QC

SYMBOL	TYPE	DEFINITION	ROUTINE
FRX	R C	TURBULENT FLOW, REYNOLDS NUMBER COMPRESSIBILITY FACTOR	SKINFR
FRX	R C	TURBULENT FLOW, REYNOLDS NUMBER COMPRESSIBILITY FACTOR	TEMP
FR1	R D	DENSITY-VISCOSITY PRODUCT ARRAY	DATA
FR2	R D	DENSITY ARRAY	DATA
FS	R C	FLOW PROPERTIES BEFORE SHOCK OR EXPANSION	AERO
FS	R C	FLOW CONDITIONS BEFORE SHOCK OR EXPANSION	COMPR
FS	R C	FLOW CONDITIONS BEFORE COMPRESSION	CONE
FS	R C	FLOW CONDITIONS BEFORE SHOCK OR EXPANSION	DELWNG
FS	R C	FLOW CONDITIONS BEFORE SHOCK OR EXPANSION	EXPAND
FS	R C	FLOW CONDITIONS BEFORE SHOCK OR EXPANSION	FLOSEP
FS	R C	FLOW CONDITIONS BEFORE SHOCK OR EXPANSION	FORCE
FS	R C	FLOW CONDITIONS BEFORE SHOCK OR EXPANSION	NEWTPM
FS	R C	FREE-STREAM FLOW CONDITION ARRAY	QC
FS	R C	FLOW CONDITIONS BEFORE SHOCK OR EXPANSION	SHKEXP
FS	R C	FLOW CONDITIONS BEFORE SHOCK OR EXPANSION	SKINFR
FS	R C	FLOW CONDITIONS BEFORE THE SHOCK OR EXPANSION	TEMP
FS2	R U	PRESSURE TO BE SAVED	FLOSEP
FS6	R U	MACH NUMBER TO BE SAVED	FLOSEP
FT	R U	TANGENTIAL MOMENTUM ACCOMODATION COEFFICIENT	FORCE
F1	R U	FIRST FUNCTION OF EVEN EXPONENTIAL	BLUNT
F1U	R U	BLENDING FUNCTION VALUE	ANALY2
F1W	R U	BLENDING FUNCTION VALUE	ANALY2
G	R U	GRAVITATIONAL ACCELERATION, FEET PER SECOND SQUARED	ATMOS
G	R U	RATIO OF SPECIFIC HEATS	BLUNT
G	R U	RATIO OF SPECIFIC HEATS =1.4	CONE
G	R A	SPECIFIC HEAT RATIO (GAMMA)	FLOSEP
G	R U	RATIO OF SPECIFIC HEATS = 1.4	FORCE
G	R U	RATIO OF SPECIFIC HEATS = 1.4	NEWTPM
G	R A	RATIO OF SPECIFIC HEATS	SHKEXP
G	R U	RATIO OF SPECIFIC HEATS	SKINFR
G	R U	RATIO OF SPECIFIC HEATS	TEMP
G	R A	FIRST DERIVATIVE (NOT USED)	TTABLE
GAMMAT	R U	TAIL DIHEDRAL ANGLE (DEGREES)	PLUNGE
GCP	R U	GAS SPECIFIC HEAT AT CONSTANT PRESSURE	BLUNT
GCP	R C	GAS SPECIFIC HEAT AT CONSTANT PRESSURE	QC
GCP	R C	GAS SPECIFIC HEAT AT CONSTANT PRESSURE	SKINFR

SYMBOL	TYPE	DEFINITION	ROUTINE
GCP	R C	GAS SPECIFIC HEAT AT CONSTANT PRESSURE	TEMP
GMRS	R U	COMBINATION OF GEODETIC AND GAS CONSTANTS, DEG RANKINE/FOOT	ATMOS
GM1	R U	RATIO OF SPECIFIC HEATS MINUS ONE	BLUNT
GP1	R U	RATIO OF SPECIFIC HEATS PLUS ONE	BLUNT
GR	R U	GAMMA RATIO FUNCTION	EXPAND
G0	R U	GRAVITATIONAL ACCELERATION AT SEA LEVEL, FT/SEC SQUARED	ATMOS
G1	R U	ACTUAL LOCATION ALONG X-AXIS FIRST PLOTTED POINT	PLOT
G1	R A	SECOND DERIVATIVE (NOT USED)	TTABLE
G2	R U	ACTUAL LOCATION ALONG X-AXIS OF SECOND PLOTTED POINT	PLOT
H	R U	GEOPOTENTIAL ALTITUDE, FEET	ATMOS
HANKEY	R U	NEWTONIAN CORRELATION FACTOR IN HANKEY EQUATION	FORCE
HAW	R C	ADIABATIC-WALL ENTHALPY	QC
HAW	R C	ADIABATIC-WALL ENTHALPY	SKINFR
HAW	R C	ADIABATIC-WALL ENTHALPY	TEMP
HAWH1	R U	ADIABATIC-WALL TO FREE-STREAM ENTHALPY RATIO	TEMP
HC1	R U	FIRST ENTHALPY COEFFICIENT	ROMU
HC2	R U	SECOND ENTHALPY COEFFICIENT	ROMU
HC3	R U	THIRD ENTHALPY COEFFICIENT	ROMU
HG	R D	MATRIX OF GEOPOTENTIAL ALTITUDES, FT	ATMOS
HLABEL	R D	HORIZONTAL LABEL	PICTUR
HMFCT	R U	HINGE MOMENT FACTOR	CONTRL
HMFCT	R U	HINGE MOMENT FACTOR	FORCE
HML	R D	HINGE MOMENT (+Y SIDE OF VEHICLE)	AERO
HML	R A	HINGE MOMENT (+Y)	FORCE
HMLS	R D	SAVED VALUES OF HINGE MOMENT (+Y)	AERO
HMLT	R U	HINGE MOMENT (+Y)	AERO
HMR	R D	HINGE MOMENT (-Y)	AERO
HMR	R A	HINGE MOMENT (-Y)	FORCE
HMRS	R D	SAVED VALUES OF HINGE MOMENT (-Y)	AERO
HMRT	R U	HINGE MOMENT (-Y)	AERO
HS	R A	ENTHALPY (FT/SEC)**2	ROMU
HSIMP	R U	HYPERSONIC INTERACTION PARAMETER	FORCE
HSTAR	R U	REFERENCE ENTHALPY	QC
HTITLE	R D	VERTICAL LABEL	PICTUR

SYMBOL	TYPE	DEFINITION	ROUTINE
HTOT	R U	TOTAL ENTHALPY	TEMP
HW	R C	WALL ENTHALPY	QC
HW	R C	WALL ENTHALPY	SKINFR
HW	R C	WALL ENTHALPY	TEMP
HX	R A	INDEPENDENT VARIABLE	POLY
H1	R U	ACTUAL LOCATION ALONG Y-AXIS OF FIRST PLOTTED POINT	PLOT
H1	R C	FREE-STREAM ENTHALPY	QC
H1	R U	REDUCED ENTHALPY (HS*1.0E-8)	ROMU
H1	R C	FREE-STREAM ENTHALPY	SKINFR
H1	R C	FREE-STREAM ENTHALPY	TEMP
H2	R U	ACTUAL LOCATION ALONG Y-AXIS SECOND PLOTTED POINT	PLOT
H2	R C	LOCAL ENTHALPY	QC
H2	R C	LOCAL ENTHALPY	SKINFR
H2	R C	LOCAL ENTHALPY	TEMP
I	I U	DO-LOOP INDEX	AERO
I	I U	SECTION INDEX NUMBER	ANALY1
I	I U	DO-LOOP INDEX	ANALY2
I	I U	DO LOOP INDEX WHEN DETERMINING APPROPRIATE ATMOSPHERE LAYER	ATMOS
I	I U	INDEX	CONTRL
I	I U	INDEX	ELP1
I	I U	ITERATION COUNTER	EXPAND
I	I U	DO LOOP COUNTER	FLOSEP
I	I U	DO-LOOP INDEX	MAIN
I	I U	ELEMENT NUMBER IN COLUMN	PICTUR
I	I D	PROGRAM CONTROL ARRAY	PLOT
I	I U	INDEX	PLUNGE
I	I A	INDEX NUMBER OF INITIAL COEFFICIENT	POLY
I	I U	ELEMENT NUMBER IN COLUMN	SDATA
I	I U	DO-LOOP INDEX (SKIN FRICTION SURFACE NUMBER)	SKINFR
I	I U	INDEX COUNTER	SLABD
I	I U	DO-LOOP INDEX	TTABLE
IA	I U	FLAG TO CONTROL SHIFTING OF COLUMN DATA POINTS FOR IORIEN=3	PICTUR
IA	I U	FLAG TO CONTROL SHIFTING OF COLUMN DATA POINTS FOR IORIEN=3	SDATA
IA	I U	INDEX	TTABLE
IABDOT	I U	ALPHA-DOT BETA-DOT DERIVATIVE FLAG	AERO
IAFLAG	I U	INPUT DATA READ CONTROL FLAG	ANALY2

SYMBOL	TYPE	DEFINITION	ROUTINE
IAREA	I U	SURFACE AREA PRINT FLAG	PICTUR
IA1	I U	INDEX	TTABLE
IB	I U	FLAG TO CONTROL SHIFTING OF COLUMN DATA POINTS FOR IORIEN=2	PICTUR
IB	I U	FLAG TO CONTROL SHIFTING OF COLUMN DATA POINTS FOR IORIEN=2	SDATA
IBFLAG	I U	INPUT DATA READ CONTROL FLAG	ANALY2
IC	I U	CAMERA SELECTION FLAG	PLOT
IC	I U	INDEX	TTABLE
ICALC	I U	CALCULATION OPTION FLAG	PLUNGE
ICHECK	I U	PRINT FLAG FOR CHECKOUT PURPOSES	FLOSEP
ICNT	I U	PICTURE COUNTER	PLOT
ICS	I U	POINT CORRECT FLAG	PICTUR
IC1	I U	INDEX	TTABLE
ID	I D	INFORMATION ON TYPE 3 CARD FROM CC 73 TO CC 80	CARD
ID	I U	INDEX	TTABLE
IDERIV	I U	DERIVATIVE OPTION FLAG	AERO
IDERIV	I A	DERIVATIVE CONTROL FLAG	FORCE
IDERIV	I A	DERIVATIVE OPTION FLAG	PLUNGE
IDERS	I D	SAVED VALUES OF DERIVATIVE OPTION FLAG	AERO
IDFLGA	I U	ALPHA DERIVATIVE PRINT FLAG	AERO
IDFLGB	I U	BETA DERIVATIVE PRINT FLAG	AERO
IDFLGC	I U	ROLL DERIVATIVE PRINT FLAG (NOT USED BY MARK II)	AERO
IDFLGD	I U	CONTROL DERIVATIVE PRINT FLAG	AERO
IDFLGE	I U	PITCH RATE DERIVATIVE PRINT FLAG	AERO
IDFLGF	I U	YAW RATE DERIVATIVE PRINT FLAG	AERO
IDSTAT	I U	DERIVATIVE CYCLE FLAG	AERO
IDUM	I U	DUMMY VARIABLE	PICTUR
ID1	I U	INDEX	TTABLE
ID2	I U	INDEX	TTABLE
IELOV	I U	ELEMENT CHARACTERISTIC OVERRIDE FLAG	SDATA
IERR	I U	ERROR FLAG	PICTUR
IERR	I U	NAME OF AN ERROR LOCATION.	PLOT
IFACT	I U	SCALE FACTOR FLAG	PICTUR
IFACT	I U	SCALE FACTOR FLAG	SDATA
IFADV	I U	FRAME FLAG	PICTUR
IFALSE	I U	INPUT DATA READ CONTROL FLAG	ANALY2
IFIRST	I U	FIRST POINT FLAG FOR USE IN NEWTPM	AERO
IFIRST	I A	FIRST POINT FLAG FOR NEWTPM	COMPR

SYMBOL	TYPE	DEFINITION	ROUTINE
IFIRST	I A	FLAG FOR FIRST TIME INTO NEWTONIAN-PRANDTL-MEYER ROUTINE	FLOSEP
IFIRST	I A	INITIAL PRINT FLAG FOR NEWTPM	FORCE
IFIRST	I A	FIRST POINT FLAG FOR USE IN NEWTPM	NEWTPM
IFIRST	I A	FIRST POINT FLAG FOR USE IN NEWTPM	SHKEXP
IFIRST	I A	INITIAL POINT FLAG FOR NEWTPM	SKINFR
IFLAG	I U	CYCLE FLAG	CONTRL
IFLAG1	I U	INPUT DATA READ CONTROL FLAG	ANALY2
IFLG	I U	DERIVATIVE FLAG	AERO
IFLOW	I C	LAMINAR (=1) OR TURBULENT (=2) FLOW FLAG	QC
IFLOW	I C	LAMINAR (=1) OR TURBULENT (=2) FLOW FLAG	TEMP
IFRAME	I U	FRAME ADVANCE FLAG	PICTUR
IFSCY	I A	FLOW SEPARATION CYCLE FLAG	FLOSEP
IFSCY	I U	CONTROL SURFACE FLOW SEPARATION CALCULATION CYCLE NUMBER	FORCE
IG	I U	VERTICAL GRID LINE LABEL CONTROL FLAG	PICTUR
IGEOM	I U	GEOMETRY SOURCE FLAG	SDATA
IGT	I A	CONTROL SURFACE FLAG (=1 FORESURFACE, = 2 CONTROL SURFACE)	FLOSEP
IGT	I U	CONTROL SURFACE FLAG (=1 FORE-SURFACE, =2 CONTROL SURFACE)	FORCE
IGT	I U	CONTROL SURFACE FLAG	SDATA
IGTS	I A	CONTROL SURFACE FLAG FOR THE PRESENT ELEMENT	FLOSEP
IGTS	I U	CONTROL SURFACE FLAG FOR PRESENT ELEMENT	FORCE
IGTS	I A	CONTROL SURFACE FLAG FOR PRESENT ELEMENT	SHKEXP
IGTY	I U	INDUCED PRESSURE FLAG	SKINFR
IGTYPE	I U	COMPONENT TYPE (=1 FOR CONTROL)	AERO
IGTYPE	I A	GEOMETRY TYPE (=1 FOR CONTROL SURFACE COMPONENT)	FLOSEP
IGTYPE	I A	GEOMETRY TYPE (=1 FOR CONTROL SURFACE COMPONENT)	FORCE
IGTYPE	I A	COMPONENT TYPE FLAG	SDATA
IGTYPE	I A	GEOMETRY TYPE (=1 FOR CONTROL SURFACE COMPONENT)	SHKEXP
IGTYPE	I A	GEOMETRY TYPE	SKINFR
IH	I U	TERM CAUSES LABEL OF EVERY IHTH HORIZONTAL GRID LINE	PLOT
IH	I O	ENTHALPY ARRAY INDEX	ROMU
IHM	I U	ELEMENT NUMBER INDEX	CONTRL
IHM	I U	HINGE MOMENT ELEMENT INDEX	FORCE
IHW	I C	WALL ENTHALPY FLAG	QC
IHW	I C	WALL ENTHALPY FLAG	TEMP
IH1	I U	ENTHALPY ARRAY INDEX AT FIRST PRESSURE	ROMU
IH2	I U	ENTHALPY ARRAY INDEX AT SECOND PRESSURE	ROMU

SYMBOL	TYPE	DEFINITION	ROUTINE
IH3	I U	ENTHALPY ARRAY INDEX AT THIRD PRESSURE	ROHU
II	I U	BOUNDARY NUMBER	ANALY2
II	I U	HORIZONTAL TITLE ARRAY SUBSCRIPT	PLOT
II	I U	NUMBER OF ELEMENTS IN COLUMN	SDATA
II	I U	LEADING ELEMENT INDEX	SHKEXP
II	I U	DO-LOOP INDEX (SKIN FRICTION SURFACE NUMBER)	SKINFR
IIA	I U	DATA SHIFTING CONTROL PARAMETER (IORIEN=3)	PICTUR
IIA	I U	DATA SHIFTING CONTROL PARAMETER (IORIEN=3)	SDATA
IIB	I U	DATA SHIFTING CONTROL PARAMETER (IORIEN=2)	PICTUR
IIB	I U	DATA SHIFTING CONTROL PARAMETER (IORIEN=2)	SDATA
IL	I U	NUMBER OF ELEMENTS ON THE FORE SURFACE	CONTRL
IM	I C	ELEMENT ROW NUMBER ARRAY	AERO
IM	I C	ELEMENT ROW NUMBER ARRAY	COMPR
IM	I C	ELEMENT ROW NUMBER ARRAY	CONE
IM	I C	ELEMENT ROW NUMBER ARRAY	CONTRL
IM	I C	ELEMENT ROW NUMBER ARRAY	DELWNG
IM	I C	ELEMENT ROW NUMBER ARRAY	EXPAND
IM	I C	(NOT USED)	FLOSEP
IM	I C	ELEMENT ROW NUMBER ARRAY	FORCE
IM	I C	ELEMENT ROW NUMBER ARRAY	NEWTPM
IM	I C	ELEMENT ROW NUMBER ARRAY	QC
IM	I C	ELEMENT ROW NUMBER ARRAY	SDATA
IM	I C	ELEMENT ROW NUMBER ARRAY	SHKEXP
IM	I C	ELEMENT ROW NUMBER ARRAY	SKINFR
IM	I C	ELEMENT ROW NUMBER ARRAY	TEMP
IMP	I D	IMPACT METHOD ARRAY	AERO
IMPACI	I U	STARTING ELEMENT IMPACT METHOD	AERO
IMPACI	I A	INITIAL STRIP ELEMENT IMPACT FORCE METHOD	FLOSEP
IMPACI	I A	STARTING ELEMENT IMPACT METHOD	FORCE
IMPACI	I A	STARTING ELEMENT IMPACT METHOD	SHKEXP
IMPACT	I U	IMPACT FORCE CALCULATION METHOD	AERO
IMPACT	I A	IMPACT FORCE CALCULATION METHOD FLAG	FLOSEP
IMPACT	I A	IMPACT FORCE CALCULATION METHOD	FORCE
IMPI	I D	STARTING IMPACT METHOD ARRAY	AERO
IMPS	I A	INPUT IMPACT FORCE CALCULATION METHOD	FLOSEP
IMPS	I U	SAVED VALUE OF IMPACT FORCE METHOD	FORCE

SYMBOL	TYPE	DEFINITION	ROUTINE
IN	I C	ELEMENT COLUMN NUMBER ARRAY	AERO
IN	I C	ELEMENT COLUMN NUMBER ARRAY	COMPR
IN	I C	ELEMENT COLUMN NUMBER ARRAY	CONE
IN	I C	ELEMENT COLUMN NUMBER ARRAY	CONTRL
IN	I C	ELEMENT COLUMN NUMBER ARRAY	DELWNG
IN	I C	ELEMENT COLUMN NUMBER ARRAY	EXPAND
IN	I C	IN(1) AND IN(2) NUMBER OF ELEMENTS IN FORE-SURFACE AND FLAP	FLOSEP
IN	I C	ELEMENT COLUMN NUMBER ARRAY	FORCE
IN	I C	ELEMENT COLUMN NUMBER ARRAY	NEWTPN
IN	I C	ELEMENT COLUMN NUMBER ARRAY	QC
IN	I C	ELEMENT COLUMN NUMBER ARRAY	SDATA
IN	I C	ELEMENT COLUMN NUMBER ARRAY	SHKEXP
IN	I C	ELEMENT COLUMN NUMBER ARRAY	SKINFR
IN	I C	ELEMENT COLUMN NUMBER ARRAY	TEMP
INU	I U	FLAG	ANALY2
IORIEN	I U	ELEMENT ORIENTATION	AERO
IORIEN	I A	ELEMENT ORIENTATION (=1 FOR STREAMWISE STRIP)	FLOSEP
IORIEN	I A	ELEMENT ORIENTATION	FORCE
IORIEN	I U	ELEMENT ORIENTATION (NOT USED)	PICTUR
IORIEN	I A	ELEMENT ORIENTATION FLAG	SDATA
IORIEN	I A	ELEMENT ORIENTATION	SHKEXP
IP	I U	NUMBER OF CHARACTERS TO BE USED AS PLOTTING SYMBOLS	PLOT
IP	I U	CARD PRINT POSITION FLAG	SLABD
IPART	I U	CONTROL FLAG FOR COMPONENT TYPE (BODY,WING,TAIL)	PLUNGE
IPG	I O	PROGRAM OPTION FLAG ARRAY	MAIN
IPIC	I U	FRAME NUMBER	PICTUR
IPL10	I U	TYPE NUMBER FOR TAPE 10 DATA = 42	AERO
IPL9	I U	TYPE NUMBER FOR TAPE 9 DATA =43	AERO
IPRCK	I A	DETAILED DATA PRINT CONTROL FLAG	FLOSEP
IPRCK	I U	PRINT FLAG	FORCE
IPRCK	I A	PRINT FLAG	SHKEXP
IPRINS	I O	SAVED VALUES OF PRINT FLAG	AERO
IPRINT	I U	PRINT FLAG FOR SHOCK-EXPANSION CALCULATIONS	AERO
IPRINT	I U	PRINT FLAG	ANALY1
IPRINT	I U	PRINT FLAG	ANALY2
IPRINT	I A	PRINT FLAG	COMPR

SYMBOL	TYPE	DEFINITION	ROUTINE
IPRINT	I A	PRINT FLAG	EXPAND
IPRINT	I A	PRINT FLAG	FORCE
IPRINT	I A	PRINT FLAG	MEMTPM
IPRINT	I A	PRINT FLAG	PUNCH
IPRINT	I A	PRINT FLAG	SHKEXP
IPRINT	I U	PRINT FLAG	SKINFR
IPRINT	I U	PRINT FLAG	SLABD
IPRINT	I A	PRINT FLAG	TEMP
IPRINT	I U	PRINT FLAG	VECTOR
IPROG	I A	PROGRAM OPTION NUMBER	GRAPIC
IPROG	I U	ACTIVE PROGRAM OPTION	MAIN
IPRTS	I D	SAVED VALUES OF IPRINT FLAG	AERO
IPS	I U	SC-4020 AERO-DATA SAVE FLAG	AERO
IQUAD	I U	QUADRILATERAL PLOT FLAG	PICTUR
IR	I U	CONTROL FLAG VALUE OF WHICH DETERMINES NEXT OPERATION	PLOT
IRFD11	I U	TAPE 11 READ FLAG INDICATOR	FORCE
IRFD11	I A	TAPE 11 READ FLAG INDICATOR	FLOSEP
IREFL	I U	REFLECTION ELEMENTS CONTROL FLAG	PICTUR
IRET1	I U	RETURN TO TYPE 1 CARD CONTROL FLAG	AERO
IREW8	I U	REWIND TAPE 8 FLAG	AERO
IREW8	I U	TAPE 8 REWIND FLAG	PICTUR
IREW8	I U	TAPE 8 REWIND FLAG	SLABD
IRFLAG	I U	INPUT DATA READ CONTROL FLAG	ANALY2
IRFLG	I U	REFLECTION CONTROL FLAG	PICTUR
IRM1	I U	DENSITY-VISCOSITY ARRAY INDEX AT 10.0 ATM.	ROMU
IRM2	I U	DENSITY-VISCOSITY ARRAY INDEX AT 10.0**-4 ATM.	ROMU
IRO1	I U	DENSITY ARRAY INDEX AT 10.0 ATM.	ROMU
IRO2	I U	DENSITY ARRAY INDEX AT 10.0**-4 ATM.	ROMU
IS	I C	SKIN FRICTION CONTROL FLAG ARRAY	AERO
IS	I C	SKIN FRICTION FLAG DATA ARRAY	FORCE
IS	I U	PLOTTING SYMBOL CODE	PLOT
IS	I C	SKIN FRICTION FLAG DATA ARRAY	SKINFR
IS	I C	SKIN FRICTION FLAG DATA ARRAY	TEMP
ISBP	I A	FORCE SUMMATION BYPASS FLAG (=1 TO BYPASS SUMMATION)	FLOSEP
ISBP	I U	FORCE SUMMATION BY PASS FLAG (=1 TO BY PASS SUMMATION)	FORCE
ISCT	I U	ELEMENT COUNTER	FLOSEP
ISDET	I A	DATA GENERATION CONTROL FLAG	COMPR
ISDET	I A	DATA GENERATION CONTROL FLAG	CONE

SYMBOL	TYPE		DEFINITION	ROUTINE
ISDET	I	A	DATA GENERATION CONTROL FLAG	EXPAND
ISDET	I	U	CALCULATION CONTROL FLAG FOR COMPRESSION ROUTINE	FLOSEP
ISDET	I	U	DATA GENERATION CONTROL FLAG	FORCE
ISDET	I	U	DATA GENERATION CONTROL FLAG	NEWTPM
ISDET	I	U	DATA GENERATION CONTROL FLAG	SHKEXP
ISDET	I	U	DATA GENERATION CONTROL FLAG	SKINFR
ISE	I	U	DATA GENERATION CONTROL FLAG	COMPR
ISE	I	U	DATA GENERATION CONTROL FLAG	FORCE
ISE	I	A	DATA GENERATION CONTROL FLAG	NEWTPM
ISE	I	U	DATA GENERATION CONTROL FLAG	SKINFR
ISEP	I	U	SEPARATION INDICATOR FLAG	FLOSEP
ISH	I	D	SHADOW METHOD ARRAY	AERO
ISHAD	I	U	SHADOW FORCE CALCULATION METHOD	AERO
ISHAD	I	A	SHADOW FORCE CALCULATION METHOD FLAG	FLOSEP
ISHAD	I	A	SHADOW FORCE CALCULATION METHOD	FORCE
ISHAD	I	U	SHADOW ELEMENT FLAG	PICTUR
ISHADI	I	U	STARTING ELEMENT METHOD IN SHADOW REGION	AERO
ISHADI	I	A	INITIAL STRIP ELEMENT SHADOW FORCE METHOD	FLOSEP
ISHADI	I	A	STARTING ELEMENT METHOD IN SHADOW REGION	FORCE
ISHADI	I	A	STARTING ELEMENT METHOD IN SHADOW REGION	SHKEXP
ISHI	I	D	SHADOW STARTING ELEMENT ARRAY	AERO
ISHS	I	A	INPUT SHADOW FORCE CALCULATION METHOD	FLOSEP
ISHS	I	U	SAVED VALUE OF SHADOW FORCE METHOD	FORCE
ISIDE	I	U	GEOMETRY ANGULAR POSITION INDICATOR	SLABO
ISIZ	I	U	NUMBER OF ELEMENTS TO BE STORED IN CORE	AERO
ISIZ	I	A	NUMBER OF ELEMENTS STORED IN CORE	CONTRL
ISIZ	I	A	NUMBER OF ELEMENTS TO BE STORED IN CORE	FORCE
ISIZ	I	A	NUMBER OF ELEMENTS TO BE STORED IN CORE	SDATA
ISIZ	I	A	NUMBER OF ELEMENTS STORED IN CORE	SKINFR
ISMODE	I	A	SHOCK-EXPANSION MODE FLAG (USED IN FLOSEP)	SHKEXP
ISOVR	I	U	FIRST POINT STATUS OVERRIDE FLAG	ANALY2
ISPNT	I	A	SEPARATION AND ATTACHMENT PRINT FLAG	FLOSEP
ISPNT	I	U	SEPARATION AND ATTACHMENT PRINT FLAG	FORCE
ISTART	I	U	CONTROL FLAG	PICTUR
ISTAT	I	U	SURFACE POINT STATUS FLAG	ANALY2
ISTATT	I	U	SURFACE POINT STATUS FLAG	ANALY2

SYMBOL	TYPE	DEFINITION	ROUTINE
ISTAT3	I U	NUMBER OF STATUS = 3 POINTS IN DECK	PICTUR
ISUM	I U	COMPONENT SUMMATION AND SAVE FLAG	AERO
IS3	I U	PRESSURE CALCULATION METHOD FLAG	SKINFR
IT	I U	TYPE OF INPUT DATA CARD	PLOT
ITAPE	I U	GEOMETRY SOURCE FLAG	PICTUR
ITAPE	I U	GEOMETRY TAPE CONTROL FLAG	SDATA
ITOC	I U	THICKNESS CORRECTION TABLE FLAG	SLABD
ITOP	I U	TOP GEOMETRY CONTROL FLAG	SLABD
ITRANS	I U	FLOW TRANSITION FLAG (=0 LAMINAR, =1 TURBULENT)	FLOSEP
ITRUE	I U	INPUT DATA CONTROL FLAG	ANALY2
ITURB	I C	TURBULENT FLOW FLAG	QC
ITURB	I C	TURBULENT FLOW FLAG	TEMP
ITW	I C	IDEAL GAS (=1) OR REAL GAS (=2) FLAG	QC
ITW	I C	IDEAL GAS (=1) OR REAL GAS(=2) FLAG	TEMP
ITYPE	I U	CARD TYPE	ANALY1
ITYPE	I U	CARD TYPE NUMBER	ANALY2
ITYPE	I U	FLAG TO CONTROL EQUATION TO BE USED IN CALCULATING KBW	PLUNGE
ITYPE	I U	CARD TYPE	SLABD
ITYP13	I U	TYPE 13 CARD READ FLAG	AERO
IV	I U	TERM CAUSES LABEL OF EVERY IVTH VERTICAL GRID LINE	PLOT
IVCTNO	I U	VECTOR NUMBER	VECTOR
IVECT	I U	FORCE VECTOR METHOD FLAG	AERO
IVISIN	I A	VISCOUS-INTERACTION CONTROL FLAG	BLUNT
IVISIN	I U	VISCOUS-INTERACTION CONTROL FLAG	FORCE
IX1	I U	X-RASTER COORDINATE OF FIRST POINT	PICTUR
IX1	I U	RASTER LOCATION ALONG X-AXIS OF FIRST PLOTTED POINT	PLOT
IX2	I U	X-RASTER COORDINATE OF SECOND POINT	PICTUR
IX2	I U	RASTER LOCATION ALONG X-AXIS OF SECOND PLOTTED POINT	PLOT
IY	I U	VERTICAL RASTER LOCATION OF HORIZONTAL TITLES	PLOT
IY1	I U	Y-RASTER COORDINATE OF FIRST POINT	PICTUR
IY1	I U	RASTER LOCATION ALONG Y-AXIS SECOND PLOTTED POINT	PLOT
IY2	I U	Y-RASTER COORDINATE OF SECOND POINT	PICTUR
IY2	I U	RASTER LOCATION ALONG Y-AXIS OF SECOND PLOTTED POINT	PLOT
I4CT	I U	COUNTER FOR READING CONTROL SURFACE GEOMETRY DATA	FORCE
I8BSP	I U	TAPE 8 BACKSPACE CONTROL FLAG	SLABD
J	I U	DO-LOOP INDEX	AERO

SYMBOL	TYPE	DEFINITION	ROUTINE
J	I U	ANGULAR INCREMENT COUNTER	ANALY1
J	I U	COUNTER IN VARIOUS DO LOOPS	ATMOS
J	I U	DO-LOOP INDEX	CONTRL
J	I U	DO-LOOP INDEX	ELP1
J	I U	DO LOOP INDEX	FLOSEP
J	I A	ALPHA-BETA COUNTER FLAG	FORCE
J	I U	INDEX ON PROGRAM OPTION	MAIN
J	I U	ITERATION COUNTER	NEWTPM
J	I U	MULTI-PURPOSE INDEX	PLOT
J	I U	DO-LOOP INDEX	POLY
J	I U	ENTHALPY INDEX COUNTER	ROMU
J	I U	ANGULAR LOOP INDEX	SLABD
J	I U	INDEX	TTABLE
JG	I U	HORIZONTAL GRID LINE LABEL CONTROL FLAG	PICTUR
JJ	I U	COUNTER	SDATA
JPATH	I U	CONTROL FLAG FOR ITERATION PATH	EXPAND
J1	I U	POINT INDEX	ANALY2
J2	I U	POINT INDEX	ANALY2
J2	I U	INDEX	TTABLE
J3	I U	POINT INDEX	ANALY2
K	I U	CARD WRITE CYCLE FLAG	ANALY1
K	I U	DO-LOOP INDEX	ANALY2
K	I U	COUNTER IN DO LOOP DETERMINING APPROPRIATE ATMOSPHERE LAYER	ATMOS
K	I C	NUMBER OF ELEMENTS	COMPR
K	I C	NUMBER OF ELEMENTS	CONE
K	I C	NUMBER OF ELEMENTS	DELWNG
K	I C	NUMBER OF ELEMENTS	EXPAND
K	I C	NUMBER OF ELEMENTS IN COMPONENT	FLOSEP
K	I C	NUMBER OF ELEMENTS	FORCE
K	I C	NUMBER OF ELEMENTS	NEWTPM
K	I U	MULTI-PURPOSE INDEX	PLOT
K	I U	FLAG TO CONTROL SELECTION OF KBW EQUATION	PLUNGE
K	I U	COEFFICIENT NUMBER	POLY
K	I C	NUMBER OF ELEMENTS	SHKEXP
K	I U	FLAG (=1 LAMINAR, =2 TURBULENT)	TEMP
K	I U	DO-LOOP INDEX	TTABLE

SYMBOL	TYPE	DEFINITION	ROUTINE
KBW	R U	INTERFERENCE ON BODY IN PRESENCE OF WING/TAIL	PLUNGE
KF	I U	METHOD-SURFACE TYPE FLAG	SKINFR
KFLSP	I U	FLOW SEPARATION FLAG (=0 NO SEPARATION, =1 FLOW SEPARATED)	FLOSEP
KKXY	I U	OFF-SCALE DETECTION FLAG	PICTUR
KLCT	I U	COUNTER	PICTUR
KLCT	I U	COUNTER	SDATA
KQ	R U	SIMILARITY PARAMETER	SKINFR
KSUB	I U	SECONDARY COUNTER IN TEMPERATURE ITERATIONS	TEMP
KT	I U	TEMPERATURE ITERATION COUNTER	TEMP
KTMAX	I U	MAXIMUM NUMBER OF TEMPERATURE ITERATIONS	TEMP
KWB	R U	INTERFERENCE ON WING/TAIL IN PRESENCE OF BODY	PLUNGE
KX	I U	OFF-SCALE DETECTION FLAG	PICTUR
KX1	I U	OFF-SCALE DETECTION FLAG	PICTUR
KY	I U	OFF-SCALE DETECTION FLAG	PICTUR
KY1	I U	OFF-SCALE DETECTION FLAG	PICTUR
K2	I U	INDEX	TTABLE
L	I C	NUMBER OF ELEMENTS	AERO
L	I U	INDEX	ANALY2
L	I U	FLAG	COMPR
L	I C	NUMBER OF ELEMENTS	CONTRL
L	I A	NUMBER OF ELEMENT IN FORCE CALCULATION LOOP	FLOSEP
L	I U	ELEMENT FORCE CALCULATION LOOP COUNTER	FORCE
L	I U	ELEMENT NUMBER	PICTUR
L	I U	MULTI-PURPOSE INDEX AND FILM ADVANCE FLAG	PLOT
L	I C	NUMBER OF ELEMENTS	QC
L	I C	NUMBER OF ELEMENTS	SDATA
L	I C	NUMBER OF ELEMENTS	SKINFR
L	I C	NUMBER OF ELEMENTS	TEMP
L	I U	INDEX	TTABLE
LAMBDA	R U	WING/TAIL TAPER RATIO (TIP CHORD/ROOT CHORD)	PLUNGE
LAMBDA	R U	MODIFIED HYPERSONIC INTERACTION PARAMETER	SKINFR
LAST	I U	LAST FLIGHT CONDITION FLAG	AERO
LAST	I U	LAST CROSS-SECTION FLAG	ANALY1
LAST	I U	LAST FLAG	ANALY2
LAST	I U	LAST PLOT CONTROL FLAG	PICTUR
LAST	I A	LAST FLAG	PUNCH

SYMBOL	TYPE		DEFINITION	ROUTINE
LAST	I	U	SLAB DELTA OPTION TERMINATION FLAG	SLABD
LAST	I	U	LAST VECTOR FLAG	VECTOR
LAST2	I	U	FLAG TO INDICATE LAST CARD OF T/C TABLE	SLABD
LAST3	I	U	FLAG TO INDICATE LAST CROSS-SECTION CARD	SLABD
LATT	I	U	ELEMENT NUMBER AT FLOW ATTACHMENT POINT	FLOSEP
LEFCT	R	U	LEADING EDGE FACTOR	SDATA
LENGTH	R	U	BODY LENGTH	PLUNGE
LIM	I	U	ANGULAR LIMIT FLAG	ANALY1
LINE	I	U	LINE COUNTER	ANALY1
LINE	I	U	LINE COUNTER	ANALY2
LINE	I	A	LINE COUNTER	PUNCH
LINE	I	U	OUTPUT LINE COUNTER	SLABD
LL	I	U	ELEMENT NUMBER	CONTRL
LL	I	A	ELEMENT NUMBER	FLOSEP
LL	I	U	ELEMENT NUMBER	FORCE
LL	I	A	ELEMENT NUMBER	SHKEXP
LN	R	U	VARIABLE IN TANGENT VECTOR EQUATIONS	ANALY2
LOD	R	A	LIFT-TO-DRAG RATIO	VECTOR
LOVERD	R	U	LIFT TO DRAG RATIO	FORCE
LS	I	C	NUMBER OF ELEMENTS	AERO
LS	I	C	NUMBER OF ELEMENTS	COMPR
LS	I	C	NUMBER OF ELEMENTS	CONE
LS	I	C	NUMBER OF ELEMENTS	CONTRL
LS	I	C	NUMBER OF ELEMENTS	DELWNG
LS	I	C	NUMBER OF ELEMENTS	EXPAND
LS	I	C	NUMBER OF ELEMENTS IN COMPONENT	FLOSEP
LS	I	C	NUMBER OF ELEMENTS	FORCE
LS	I	C	NUMBER OF ELEMENTS	NEWTPH
LS	I	C	NUMBER OF ELEMENTS	QC
LS	I	C	NUMBER OF ELEMENTS	SDATA
LS	I	C	NUMBER OF ELEMENTS	SHKEXP
LS	I	C	NUMBER OF ELEMENTS	SKINFR
LS	I	C	NUMBER OF ELEMENTS	TEMP
LSAVE	I	U	SAVEL ELEMENT NUMBER (ALSO ITERATION COUNTER)	FORCE
LSEP	I	U	ELEMENT NUMBER AT SEPARATION	FLOSEP
LSS	I	U	NUMBER OF ELEMENTS IN COMPONENT	FLOSEP

SYMBOL	TYPE	DEFINITION	ROUTINE
LXY	R U	HINGE LINE LENGTH IN X-Y PLANE	CONTRL
LYZ	R U	HINGE LINE LENGTH IN Y-Z PLANE	CONTRL
L1	R U	VARIABLE IN TANGENT VECTOR EQUATIONS	ANALY2
L2	R U	VARIABLE IN TANGENT VECTOR EQUATIONS	ANALY2
L21	R U	VARIABLE IN TANGENT VECTOR EQUATIONS	ANALY2
L31	R U	VARIABLE IN TANGENT VECTOR EQUATIONS	ANALY2
L32	R U	VARIABLE IN TANGENT VECTOR EQUATIONS	ANALY2
M	I U	COUNTER	ANALY1
M	I U	DATA READ IN CONTROL FLAG	ANALY2
M	I U	ELEMENT ROW NUMBER	CONTRL
M	I A	ELEMENT NUMBER IN STRIP	FLOSEP
M	I U	ELEMENT ROW NUMBER	FORCE
M	I U	DATA READ IN CONTROL FLAG	PICTUR
M	I U	MULTI-PURPOSE INDEX AND EMPHASIS FLAG FOR HORIZ. GRID LINES	PLOT
M	R U	COTANGENT OF WING/TAIL LEADING EDGE SWEEP ANGLE	PLUNGE
M	I U	DATA READ IN CONTROL FLAG	SDATA
M	I A	ELEMENT ROW NUMBER	SHKEXP
M	R U	SLOPE OF PRESSURE RATIO VERSUS LAMBDA	SKINFR
M	I U	COUNTER	SLABD
MA	R U	LOCAL MACH NUMBER ON ELEMENT	FLOSEP
MAC	R U	REFERENCE LENGTH FOR MOMENT COEFFICIENTS	AERO
MAC	R A	REFERENCE LENGTH FOR MOMENT COEFFICIENTS	FORCE
MAC	R A	REFERENCE LENGTH FOR MOMENT COEFFICIENTS	VECTOR
MACH	R U	MACH NUMBER	AERO
MACH	R A	MACH NUMBER	BLUNT
MACH	R U	MACH NUMBER	CONE
MACH	R A	FREE-STREAM MACH NUMBER	FLOSEP
MACH	R A	MACH NUMBER	FORCE
MACH	R U	MACH NUMBER	NEWTPM
MACH	R A	MACH NUMBER	SHKEXP
MACH	R A	MACH NUMBER	SKINFR
MACH	R A	MACH NUMBER	VECTOR
MACHH	R U	SHOCK-EXPANSION MACH NUMBER AT HINGE LINE ELEMENT	FLOSEP
MACHI	R D	STARTING OR PREVIOUS ELEMENT MACH NUMBER	SHKEXP
MACHO	R U	MACH NUMBER	COMPR
MACHO	R U	INITIAL MACH NUMBER	NEWTPM

SYMBOL	TYPE		DEFINITION	ROUTINE
MACHSQ	R	U	MACH NUMBER SQUARED	COMPR
MACHSQ	R	U	SQUARE OF MACH NUMBER NORMAL TO EFFECIVE SHOCK	NEWTPM
MACHX	R	U	MACH NUMBER AT SEPARATION	FLOSEP
MACHX1	R	U	MACH NUMBER ON ELEMENT JUST BEFORE SEPARATION	FLOSEP
MACH1	R	U	MACH NUMBER	COMPR
MARKPT	I	U	PLOTTING SYMBOL CODE	PICTUR
MC	I	U	DATA READ IN CONTROL NUMBER	ANALY2
MC	I	U	DATA READ IN CONTROL NUMBER	PICTUR
MC	I	U	DATA READ IN CONTROL NUMBER	SDATA
MER	I	A	ERROR FLAG	COMPR
MER	I	A	ERROR FLAG	EXPAND
MER	I	U	COMPRESSION ROUTINE ERROR FLAG	FLOSEP
MER	I	U	ERROR FLAG	FORCE
MER	I	A	ERROR FLAG	NEWTPM
MER	I	U	ERROR FLAG	SHKEXP
MER	I	U	ERROR FLAG	SKINFR
MER	I	A	ERROR FLAG	TEMP
MEREXP	I	U	VACUUM EXPANSION FLAG	SKINFR
MG	I	U	HORZONTAL LINE EMPHASIZE FLAG	PICTUR
ML	I	U	DATA READ IN CONTROL NUMBER	ANALY2
MMAX	I	U	MAXIMUM VALUE FOR PARAMETER M	SHKEXP
MMIN	I	U	NUMBER OF ELEMENTS IN A COLUMN	PICTUR
MMIN	I	U	NUMBER OF ELEMENTS IN A COLUMN	SDATA
MN	R	U	VARIABLE IN TANGENT VECTOR EQUATIONS	ANALY2
MODE	I	U	GEOMETRY MODE FLAG	SLABD
MSUBO	R	U	MACH NUMBER AT MATCHING POINT	NEWTPM
MU	R	U	VISCOSITY	NEWTPM
M1	R	U	VARIABLE IN TANGENT VECTOR EQUATIONS	ANALY2
M1	R	U	FIRST ITERATION MACH NUMBER	NEWTPM
M1	I	U	INDEX	TTABLE
M2	R	U	VARIABLE IN TANGENT VECTOR EQUATIONS	ANALY2
M2	R	U	SECOND ITERATION MACH NUMBER	NEWTPM
M2	I	U	INDEX	TTABLE
N	I	U	COUNTER	ANALY1
N	I	U	DATA READ IN COUNTER	ANALY2
N	I	U	ELEMENT COLUMN NUMBER	CONTRL

SYMBOL	TYPE		DEFINITION	ROUTINE
N	I	A	STREAMWISE ELEMENT STRIP NUMBER	FLOSEP
N	I	U	ELEMENT COLUMN NUMBER	FORCE
N	I	U	COLUMN NUMBER	PICTUR
N	I	U	MULTI-PURPOSE INDEX AND EMPHASIS FLAG FOR VERT. GRID LINES	PLOT
N	I	A	ORDER OF POLYNOMIAL	POLY
N	I	U	ORDER OF POLYNOMIAL	ROMU
N	I	U	COLUMN NUMBER	SDATA
N	I	A	ELEMENT COLUMN NUMBER	SHKEXP
N	I	U	COUNTER	SLABD
NAB	I	U	NUMBER OF ALPHA-BETA COMBINATIONS	AERO
NABCT	I	U	ALPHA-BETA COUNTER	AERO
NABS	I	U	SAVED VALUE FOR NUMBER OF ALPHA-BETA COMBINATIONS	AERO
NB	I	U	BOUNDARY CURVE NUMBER	ANALY2
NC	I	U	NUMBER OF DATA POINTS	PLOT
NC	I	U	NOT USED	SKINFR
NCAM	I	U	CAMERA SELECTION FLAG	PICTUR
NERROR	I	A	ERROR FLAG	ELP1
NER1	I	U	ERROR FLAG	PLUNGE
NFS	I	U	ELEMENT COUNTER	SDATA
NG	I	U	VERTICAL LINE EMPHASIZE FLAG	PICTUR
NM	I	U	COUNTER	ANALY1
NN	I	D	COUNTER	ANALY1
NN	R	U	VARIABLE IN TANGENT VECTOR EQUATIONS	ANALY2
NN	R	U	SURFACE NORMAL LENGTH	CONTRL
NN	I	U	COLUMN ELEMENT COUNTER	PICTUR
NN	I	U	ELEMENT COUNTER	SDATA
NN2	I	U	COUNTER	PICTUR
NN2	I	U	ELEMENT COUNTER	SDATA
NOAB	I	U	NO ALPHA-BETA CARD FLAG	AERO
NOSCAL	I	U	NO GRID FLAG	PICTUR
NOSPAN	I	U	NUMBER OF ELEMENT DIVISIONS FOR TOP OR BOTTOM	SLABD
NOU	I	U	NUMBER OF U INCREMENTS	ANALY2
NOW	I	U	NUMBER OF W INCREMENTS	ANALY2
NP	I	U	NUMBER OF POINTS TO BE PLOTTED	PLOT
NPCK	I	U	HEADER PRINT CHECK FLAG	FORCE
NPRT	I	U	LINE COUNTER	AERO

SYMBOL	TYPE	DEFINITION	ROUTINE
NPRT	I U	PRINT COUNTER	FORCE
NPRT	I U	LINE COUNTER	PICTUR
NPRT	I U	LINE COUNTER	SDATA
NPRT	I C	PRINT COUNTER	SKINFR
NPRT	I C	PRINT COUNTER	TEMP
NPRT	I U	PRINT LINE COUNTER	VECTOR
NPTS	I D	NUMBER OF BOUNDARY POINTS	ANALY2
NPT1	I U	BOUNDARY POINT COUNTER	ANALY2
NPT2	I U	BOUNDARY POINT COUNTER	ANALY2
NREC	I U	TAPE 8 RECORD COUNTER	ANALY1
NREC	I U	NUMBER OF CARDS WRITTEN ON TAPE 8	ANALY2
NREC	I A	NUMBER OF RECORDS ON TAPE 8	PUNCH
NS	I U	NUMBER OF SKIN FRICTION SURFACES	AERO
NS	I A	NUMBER OF SKIN FRICTION SURFACES	FORCE
NS	I A	NUMBER OF SKIN FRICTION SURFACES	SKINFR
NSAVE	I U	NUMBER OF SETS OF DATA SAVED FOR SUMMATION	AERO
NSAVE2	I U	DO-LOOP INDEX FOR DATA SUMMATION	AERO
NSTAT1	I A	POINT STATUS FLAG	PUNCH
NSTAT2	I U	POINT STATUS FLAG	PUNCH
NSTAT3	I A	POINT STATUS FLAG	PUNCH
NU	R U	FLOW TURNING ANGLE	SHKEXP
NU1	R U	INITIAL PRANDTL-MEYER ANGLE, RADIANS	EXPAND
NU1D	R U	INITIAL PRANDTL-MEYER ANGLE, DEGREES	EXPAND
NU2	R U	FINAL PRANDTL-MEYER ANGLE, RADIANS	EXPAND
NU2D	R U	FINAL PRANDTL-MEYER ANGLE, DEGREES	EXPAND
NW	R U	WALL TEMPERATURE CALCULATION FLAG FOR FLOSEP	AERO
NW	R A	WALL TEMPERATURE CALCULATION FLAG FOR FLOSEP	FLOSEP
NW	R A	WALL TEMPERATURE CALCULATION FLAG FOR FLOSEP	FORCE
NW	I A	TEMPERATURE CALCULATION CONTROL FLAG	TEMP
NWI	I U	TEMPERATURE CALCULATION CONTROL FLAG	TEMP
NW1	I U	TEMPERATURE CALCULATION PRINT CONTROL FLAG	TEMP
NX	R U	ELEMENT DIRECTION COSINE-X	CONTRL
NX	R A	X-COMPONENT OF OUTWARD NORMAL	FLOSEP
NX	R U	ELEMENT DIRECTION COSINE-X	FORCE
NX	R U	ELEMENT DIRECTION COSINE-X	PICTUR
NX	I U	SUBSCRIPT INCREMENT OF X-ARRAY DATA TO BE PLOTTED	PLOT

SYMBOL	TYPE	DEFINITION	ROUTINE
NX	R U	ELEMENT DIRECTION COSINE-X	SDATA
NX	R A	ELEMENT DIRECTION COSINE-X	SHKEXP
NX	R U	FORCE VECTOR DIRECTION COSINE IN X-DIRECTION	VECTOR
NXD	R U	ELEMENT DIRECTION COSINE-X (CONTROL DEFLECTED)	CONTRL
NXF	R U	X-COMPONENT OF FLAP SURFACE NORMAL	FLOSEP
NXFS	R U	X-COMPONENT OF FLAP OUTWARD NORMAL TO BE SAVED	FLOSEP
NXG	I U	NUMBER OF CHARACTERS IN X-SCALE NUMBER LABELS	PICTUR
NXH	R U	X-COMPONENT OF OUTWARD NORMAL AT HINGE LINE ELEMENT	FLOSEP
NXI	R D	ELEMENT DIRECTION COSINE-X	SHKEXP
NXO	R U	DIRECTION COSINE OUT OF PLANE OF PAPER	PICTUR
NXS	R U	X-COMPONENT OF SURFACE NORMAL TO BE SAVED	FLOSEP
NX2	R C	ELEMENT DIRECTION COSINE ARRAY-X	AERO
NX2	R C	ELEMENT DIRECTION COSINE ARRAY -X	COMPR
NX2	R C	ELEMENT DIRECTION COSINE ARRAY-X	CONE
NX2	R C	ELEMENT DIRECTION COSINE ARRAY-X	CONTRL
NX2	R C	ELEMENT DIRECTION COSINE ARRAY-X	DELWNG
NX2	R C	ELEMENT DIRECTION COSINE ARRAY-X	EXPAND
NX2	R C	NX2(1) AND NX2(2) ARE HINGE LINE X-COORDINATE DATA	FLOSEP
NX2	R C	ELEMENT DIRECTION COSINE ARRAY-X	FORCE
NX2	R C	ELEMENT DIRECTION COSINE ARRAY-X	NEWTPM
NX2	R C	ELEMENT DIRECTION COSINE ARRAY-X	QC
NX2	R C	ELEMENT DIRECTION COSINE ARRAY-X	SDATA
NX2	R C	ELEMENT DIRECTION COSINE ARRAY-X	SHKEXP
NX2	R C	ELEMENT DIRECTION COSINE ARRAY-X	SKINFR
NX2	R C	ELEMENT DIRECTION COSINE ARRAY-X	TEMP
NY	R U	ELEMENT DIRECTION COSINE-Y	CONTRL
NY	R A	Y-COMPONENT OF OUTWARD NORMAL	FLOSEP
NY	R U	ELEMENT DIRECTION COSINE-Y	FORCE
NY	R U	ELEMENT DIRECTION COSINE-Y	PICTUR
NY	I U	SUBSCRIPT INCREMENT OF X-ARRAY DATA TO BE PLOTTED.	PLOT
NY	R U	ELEMENT DIRECTION COSINE-Y	SDATA
NY	R A	ELEMENT DIRECTION COSINE-Y	SHKEXP
NY	R U	FORCE VECTOR DIRECTION COSINE IN Y-DIRECTION	VECTOR
NYD	R U	ELEMENT DIRECTION COSINE-Y (CONTROL DEFLECTED)	CONTRL
NYF	R U	Y-COMPONENT OF FLAP OUTWARD NORMAL	FLOSEP
NYFS	R U	Y-COMPONENT OF FLAP OUTWARD NORMAL TO BE SAVED	FLOSEP

SYMBOL	TYPE		DEFINITION	ROUTINE
NYG	I	U	NUMBER OF CHARACTERS IN Y-SCALE NUMBER LABELS	PICTUR
NYH	R	U	Y-COMPONENT OF OUTWARD NORMAL AT HINGE LINE ELEMENT	FLOSEP
NYI	R	D	ELEMENT DIRECTION COSINE-Y	SHKEXP
NYS	R	U	Y-COMPONENT OF OUTWARD NORMAL TO BE SAVED	FLOSEP
NY2	R	C	ELEMENT DIRECTION COSINE ARRAY-Y	AERO
NY2	R	C	ELEMENT DIRECTION COSINE ARRAY-Y	COMPR
NY2	R	C	ELEMENT DIRECTION COSINE ARRAY-Y	CONE
NY2	R	C	ELEMENT DIRECTION COSINE ARRAY-Y	CONTRL
NY2	R	C	ELEMENT DIRECTION COSINE ARRAY-Y	DELWNG
NY2	R	C	ELEMENT DIRECTION COSINE ARRAY-Y	EXPAND
NY2	R	C	NY2(1) AND NY2(2) ARE HINGE LINE Y-COORDINATE DATA	FLOSEP
NY2	R	C	ELEMENT DIRECTION COSINE ARRAY-Y	FORCE
NY2	R	C	ELEMENT DIRECTION COSINE ARRAY-Y	NEWTPM
NY2	R	C	ELEMENT DIRECTION COSINE ARRAY-Y	QC
NY2	R	C	ELEMENT DIRECTION COSINE ARRAY-Y	SDATA
NY2	R	C	ELEMENT DIRECTION COSINE ARRAY-Y	SHKEXP
NY2	R	C	ELEMENT DIRECTION COSINE ARRAY-Y	SKINFR
NY2	R	C	ELEMENT DIRECTION COSINE ARRAY-Y	TEMP
NZ	R	U	ELEMENT DIRECTION COSINE-Z	CONTRL
NZ	R	A	Z-COMPONENT OF OUTWARD NORMAL	FLOSEP
NZ	R	U	ELEMENT DIRECTION COSINE-Z	FORCE
NZ	R	U	ELEMENT DIRECTION COSINE-Z	PICTUR
NZ	R	U	ELEMENT DIRECTION COSINE-Z	SDATA
NZ	R	A	ELEMENT DIRECTION COSINE-Z	SHKEXP
NZ	R	U	FORCE VECTOR DIRECTION COSINE IN Z-DIRECTION	VECTOR
NZD	R	U	ELEMENT DIRECTION COSINE-Z (CONTROL DEFLECTED)	CONTRL
NZF	R	U	Z-COMPONENT OF FLAP SURFACE NORMAL (UNDEFLECTED)	FLOSEP
NZFS	R	U	Z-COMPONENT OF FLAP SURFACE NORMAL TO BE SAVED (UNDEFLECTED)	FLOSEP
NZH	R	U	Z-COMPONENT OF OUTWARD NORMAL AT HINGE LINE ELEMENT	FLOSEP
NZI	R	D	ELEMENT DIRECTION COSINE-Z	SHKEXP
NZS	R	U	Z-COMPONENT OF SURFACE NORMAL TO BE SAVED	FLOSEP
NZ2	R	C	ELEMENT DIRECTION COSINE ARRAY-Z	AERO
NZ2	R	C	ELEMENT DIRECTION COSINE ARRAY-Z	COMPR
NZ2	R	C	ELEMENT DIRECTION COSINE ARRAY-Z	CONE
NZ2	R	C	ELEMENT DIRECTION COSINE ARRAY-Z	CONTRL
NZ2	R	C	ELEMENT DIRECTION COSINE ARRAY-Z	DELWNG

SYMBOL	TYPE		DEFINITION	ROUTINE
NZ2	R	C	ELEMENT DIRECTION COSINE ARRAY-Z	EXPAND
NZ2	R	C	(NOT USED)	FLOSEP
NZ2	R	C	ELEMENT DIRECTION COSINE ARRAY-Z	FORCE
NZ2	R	C	ELEMENT DIRECTION COSINE ARRAY-Z	NEWTPM
NZ2	R	C	ELEMENT DIRECTION COSINE ARRAY-Z	QC
NZ2	R	C	ELEMENT DIRECTION COSINE ARRAY-Z	SDATA
NZ2	R	C	ELEMENT DIRECTION COSINE ARRAY-Z	SHKEXP
NZ2	R	C	ELEMENT DIRECTION COSINE ARRAY-Z	SKINFR
NZ2	R	C	ELEMENT DIRECTION COSINE ARRAY-Z	TEMP
N1	R	U	VARIABLE IN TANGENT VECTOR EQUATIONS	ANALY2
N1	I	U	INDEX	TTABLE
N2	R	U	VARIABLE IN TANGENT VECTOR EQUATIONS	ANALY2
N2	I	U	INDEX	TTABLE
ODK	R	U	ODD EXPONENTIAL CONSTANT	BLUNT
ONEOM	R	U	SINE OF ANGLE 3	EXPAND
ONEOM	R	U	1.0 DIVIDED BY MACH NUMBER	SKINFR
P	R	U	FINAL PRESSURE ON ELEMENT WITH SEPARATION	FLOSEP
P	R	U	ROLL RATE	FORCE
P	R	U	PRESSURE	NEWTPM
PAGE	I	C	PAGE NUMBER	AERO
PAGE	I	C	PAGE NUMBER	ANALY1
PAGE	I	C	PAGE NUMBER	ANALY2
PAGE	I	C	PAGE NUMBER	COMPR
PAGE	I	C	PAGE NUMBER	CONE
PAGE	I	C	PAGE NUMBER	CONTRL
PAGE	I	C	PAGE NUMBER	DELWNG
PAGE	I	C	PAGE NUMBER	EXPAND
PAGE	I	C	PAGE NUMBER	FLOSEP
PAGE	I	C	PAGE NUMBER	FORCE
PAGE	I	C	PAGE NUMBER	GRAPIC
PAGE	I	C	PAGE NUMBER	HEADER
PAGE	I	C	PAGE NUMBER	HEADR2
PAGE	I	C	PAGE NUMBER	MAIN
PAGE	I	C	PAGE NUMBER	NEWTPM
PAGE	I	C	PAGE NUMBER	PICTUR
PAGE	I	C	PAGE NUMBER	PLOT

SYMBOL	TYPE		DEFINITION	ROUTINE
PAGE	I	C	PAGE NUMBER	PLUNGE
PAGE	I	C	PAGE NUMBER	PUNCH
PAGE	I	C	PAGE NUMBER	QC
PAGE	I	C	PAGE NUMBER	SDATA
PAGE	I	C	PAGE NUMBER	SHKEXP
PAGE	I	C	PAGE NUMBER	SKINFR
PAGE	I	C	PAGE NUMBER	SLABD
PAGE	I	C	PAGE NUMBER	TEMP
PAGE	I	C	PAGE NUMBER	VECTOR
PBAR	R	U	PRESSURE RATIO (PW/PREF)	ROMU
PBARLG	R	U	LOG10 OF PBAR	ROMU
PBAR1	R	U	LOG10 OF FIRST REFERENCE PRESSURE RATIO	ROMU
PBAR2	R	U	LOG10 OF SECOND REFERENCE PRESSURE RATIO	ROMU
PBAR3	R	U	LOG10 OF THIRD REFERENCE PRESSURE RATIO	ROMU
PC	R	U	FREE-STREAM STATIC TO STAGNATION PRESSURE RATIO	NEWTPM
PCAP	R	U	FREE-STREAM STATIC TO STAGNATION PRESSURE RATIO	NEWTPM
PD	R	U	CORNER POINT PROJECTION DISTANCE	PICTUR
PD	R	U	CORNER POINT PROJECTION DISTANCE	SDATA
PFS	R	U	FREE-STREAM PRESSURE-LBS/SQUARE FOOT	AERO
PFS	R	A	FREE-STREAM PRESSURE	BLUNT
PFS	R	A	FREE-STREAM PRESSURE-LB/FT SQUARED	COMPR
PFS	R	A	FREE-STREAM PRESSURE	FLOSEP
PFS	R	A	FREE-STREAM PRESSURE-LBS / SQUARE FOOT	FORCE
PFS	R	A	FREE-STREAM PRESSURE, LBS / SQUARE FOOT	NEWTPM
PFS	R	A	FREE-STREAM PRESSURE, LBS/SQUARE FOOT	SHKEXP
PFS	R	A	FREE-STREAM PRESSURE-LBS/SQUARE FOOT	SKINFR
PFS	R	A	FREE-STREAM PRESSURE, LBS/SQUARE FOOT	VECTOR
PH	R	U	HINGE LINE INVISCID SHOCK-EXPANSION PRESSURE	FLOSEP
PHI	R	U	COORDINATE TRANSFORMATION ANGLE, DEGREES	CONTRL
PHI	R	U	ANGLE ASSOCIATED WITH GEOMETRY OF SEPARATION	FLOSEP
PHI	R	U	ROLL ANGLE, DEGREES	PICTUR
PHIR	R	U	COORDINATE TRANSFORMATION ANGLE, RADIANS	CONTRL
PHIR	R	U	ROLL ANGLE, RADIANS	FORCE
PI	R	U	RATIO OF CIRCUMFERENCE OF A CIRCLE TO ITS DIAMETER	PLUNGE
PI	R	D	PRESSURE	SHKEXP
PM	R	D	MATRIX OF ATMOSPHERIC PRESSURES	ATMOS

SYMBOL	TYPE	DEFINITION	ROUTINE
PNIN	R U	INVISCID PRESSURE USING NORMAL FORCE METHOD	FLOSEP
PO	R U	PRESSURE RATIO AT LAMBDA = 0.0	SKINFR
POLY	R U	VALUE OF POLYNOMIAL	POLY
PPFS	R U	LOCAL TO FREE-STREAM PRESSURE RATIO	NEWTPM
PPO	R U	SURFACE PRESSURE RATIO	NEWTPM
PPPO	R U	RATIO OF PLATEAU PRESSURE TO FREE-STREAM PRESSURE	FLOSEP
PPPOX	R U	PLATEAU PRESSURE/STREAM PRESSURE AT SEPARATION POINT	FLOSEP
PPPO1	R U	PLATEAU PRESS/FREE-STREAM PRESS ON ELEMENT BEFORE SEPARATION	FLOSEP
PPT2	R U	OSU METHOD PRESSURE RATIO	FORCE
PRAN	R U	PRANDTL NUMBER	TEMP
PREF	R U	REFERENCE PRESSURE (2117.36 LB/SQ.FT.)	ROMU
PRINT	I U	DETAIL FORCE CONTRIBUTION PRINT FLAG	AERO
PRINT	I A	PRINT FLAG	FORCE
PRINT	R D	PRINTING ARRAY	PLOT
PRINTS	I U	PRINT FLAG FOR ELEMENT DATA	AERO
PRINTS	I U	ELEMENT DATA PRINT FLAG	PICTUR
PRINTS	I A	ELEMENT DATA PRINT FLAG	SDATA
PSEIN	R D	INVISCID SHOCK-EXPANSION PRESSURE	FLOSEP
PSEVIS	R D	SHOCK-EXPANSION PRESSURE WITH VISCOUS SEPARATION	FLOSEP
PSI	R U	COORDINATE TRANSFORMATION ANGLE, DEGREES	CONTRL
PSI	R U	YAW ANGLE	PICTUR
PSIR	R U	COORDINATE TRANSFORMATION ANGLE, RADIANS	CONTRL
PSPAN	R U	PER CENT SEMI-SPAN	SLABD
PSTAG	R U	WIND TUNNEL STAGNATION PRESSURE, ATMOSPHERES	AERO
PSTAG	R A	WIND TUNNEL STAGNATION PRESSURE-LBS / SQUARE FOOT	FORCE
PT2PO	R U	OSU METHOD PRESSURE RATIO BEHIND NORMAL SHOCK	FORCE
PW	R U	PRESSURE	QC
PW	R A	LOCAL PRESSURE (LB/SQ.FT.)	ROMU
PX	R U	LOCAL PRESSURE AT EXACT SEPARATION POINT	FLOSEP
PXOD	R U	INCREMENT FROM ORIGIN, ODD EXPONENTIAL	BLUNT
PX1	R U	PRESSURE ON ELEMENT JUST BEFORE SEPARATION POINT	FLOSEP
P1	R U	FIRST ITERATION PRESSURE	NEWTPM
P2	R U	SECOND ITERATION PRESSURE	NEWTPM
P2	R A	LOCAL PRESSURE (LB/SQ.FT.)	ROMU
P2P11	R U	PRESSURE RATIO ACROSS COMPRESSION	CONE
P2P11	R U	PRESSURE RATIO	SHKEXP

SYMBOL	TYPE		DEFINITION	ROUTINE
Q	R	U	PITCH RATE, RADIANS / SECOND	FORCE
Q	R	U	MATCHING POINT TO FREE-STREAM STATIC PRESSURE RATIO	NEWTPM
Q	R	U	TAIL EFFECTIVENESS RATIO	PLUNGE
Q	R	U	TAPER RATIO CORRECTION EQUATION EXPONENT	SKINFR
Q	R	U	DYNAMIC PRESSURE	VECTOR
QC	R	U	CONVECTIVE HEATING RATE	QC
QC1	R	U	CONVECTIVE HEATING RATE AT TC1	TEMP
QC2	R	U	CONVECTIVE HEATING RATE AT TC2	TEMP
QQINF	R	U	DYNAMIC PRESSURE RATIO CORRECTION FACTOR	AERO
QQINF	R	A	DYNAMIC PRESSURE RATIO CORRECTION FACTOR	FORCE
QQINFS	R	C	SAVED VALUES OF DYNAMIC PRESSURE CORRECTION	AERO
QQINFS	R	C	SAVED VALUES OF DYNAMIC PRESSURE CORRECTION	FORCE
QRP	R	U	INPUT VEHICLE ROTATION RATE, RADIANS/SECOND	AERO
QRP	R	A	INPUT VEHICLE ROTATION RATE, RADIANS / SECOND	FORCE
QRPS	R	D	SAVED VALUES OF ROTATION RATE	AERO
QRPSS	R	U	SAVED VALUE OF INPUT ROTATION RATE	AERO
QR1	R	U	RADIATION HEATING RATE AT TR1	TEMP
QR2	R	U	RADIATION HEATING RATE AT TR1	TEMP
Q1	R	A	QUADRATIC INTERPOLATION DATA ARRAY	QINT
Q1	R	D	QUADRATIC INTERPOLATION VARIABLE	TTABLE
Q10	R	D	QUADRATIC INTERPOLATION VARIABLE	TTABLE
Q11	R	D	QUADRATIC INTERPOLATION VARIABLE	TTABLE
Q2	R	A	QUADRATIC INTERPOLATION DATA ARRAY	QINT
Q2	R	D	QUADRATIC INTERPOLATION VARIABLE	TTABLE
Q3	R	A	QUADRATIC INTERPOLATION DATA ARRAY	QINT
Q3	R	U	QUADRATIC INTERPOLATION VARIABLE	TTABLE
Q4	R	A	QUADRATIC INTERPOLATION DATA ARRAY	QINT
Q4	R	U	QUADRATIC INTERPOLATION VARIABLE	TTABLE
Q5	R	D	QUADRATIC INTERPOLATION DATA ARRAY	QINT
Q8	R	D	QUADRATIC INTERPOLATION VARIABLE	TTABLE
R	R	D	ROOTS OF CUBIC EQUATION	COMPR
R	R	U	VARIABLE IN MACH NUMBER EQUATION	EXPAND
R	R	U	YAW RATE, RADIANS / SECOND	FORCE
R	R	U	BODY RADIUS AT WING OR TAIL	PLUNGE
R	R	U	LOCAL RADIUS	SLABD
R	R	A	DATA ARRAY	TTABLE

SYMBOL	TYPE	DEFINITION	ROUTINE
RA	R U	REYNOLDS ANALOGY FACTOR	QC
RAD	R U	ELLIPSE RADIUS	ANALY1
RADIUS	R U	RADIUS	SLABD
RADK	R U	RADIATION CONSTANT	TEMP
RATIO	R U	DUMMY VARIABLE	PLUNGE
RB	R A	BODY NOSE RADIUS (FEET)	BLUNT
RE	R D	REFERENCE REYNOLDS NUMBER	FLOSEP
RE	R U	REYNOLDS NUMBER	NEWTPM
RE	R D	REFERENCE REYNOLDS NUMBER	SKINFR
RE	T A	REFERENCE REYNOLDS NUMBER	TEMP
REAFT	R U	LOCAL SURFACE REYNOLDS NUMBER PER FOOT	FLOSEP
REAHL	R U	REYNOLDS NUMBER AT HINGE LINE ELEMENT	FLOSEP
REASFT	R U	REFERENCE REYNOLDS NUMBER PER FOOT	FLOSEP
REAXOP	R U	REYNOLDS NUMBER ON LOCAL ELEMENT	FLOSEP
RELOC	R U	LOCAL REYNOLDS NUMBER	SKINFR
RENO	R U	FREE STREAM REYNOLDS NUMBER	AERO
RENO	R A	FREE-STREAM REYNOLDS NUMBER PER FOOT	BLUNT
RENO	R A	FREE STREAM REYNOLDS NUMBER	FORCE
RENO	R A	FREE-STREAM REYNOLDS NUMBER	SHKEXP
RENO	R U	FREE-STREAM REYNOLDS NUMBER	SKINFR
RES	R U	SHOCK REYNOLDS NUMBER	BLUNT
RET	R C	TURBULENT FLOW REYNOLDS NUMBER AT REFERENCE CONDITION	QC
RET	R C	TURBULENT FLOW REYNOLDS NUMBER AT REFERENCE CONDITION	SKINFR
RET	R C	TURBULENT FLOW REYNOLDS NUMBER AT REFERENCE CONDITION	TEMP
RETRAN	R U	TRANSITION REYNOLDS NUMBER FOR CONTROL SURFACE	AERO
RETRAN	R A	INPUT FLOW TRANSITION REYNOLD'S NUMBER	FLOSEP
RETRAN	R A	TRANSITION REYNOLDS NUMBER FOR CONTROL SURFACE	FORCE
RF	R D	RECOVERY FACTOR	TEMP
RFLAG	L U	INPUT DATA READ CONTROL FLAG	PICTUR
RFLAG	L U	INPUT DATA READ CONTROL FLAG	SDATA
RHO	R U	DENSITY	NEWTPM
RHOFS	R A	FREE-STREAM DENSITY	BLUNT
RHOFS	R U	FREE STREAM DENSITY	FORCE
RHOFS	R A	FREE-STREAM DENSITY	SHKEXP
RHOFS	R A	FREE STREAM DENSITY	SKINFR
RNOSE	R U	RADIUS OF NOSE AND LEADING EDGE	SLABD

SYMBOL	TYPE	DEFINITION	ROUTINE
ROLL	R U	ROLL ANGLE, DEGREES	FORCE
ROLLR	R U	ROLL ANGLE, RADIANS	FORCF
ROLLR	R U	ROLL ANGLE IN RADIANS	VECTOR
ROMU	R U	DENSITY-VISCOSITY PRODUCT	ROMU
ROMURA	R C	SQUARE-ROOT OF REFERENCE DENSITY-VISCOSITY RATIO	QC
ROMURA	R C	SQUARE-ROOT OF REFERENCE DENSITY-VISCOSITY RATIO	SKINFR
ROMURA	R C	SQUARE-ROOT OF REFERENCE DENSITY-VISCOSITY RATIO	TEMP
RORA	R U	REFERENCE TO FREE-STREAM DENSITY-VISCOSITY RATIO	TEMP
RORAI	R U	INVERSE DENSITY RATIO ACROSS NORMAL SHOCK	BLUNT
ROSTAR	R U	DENSITY AT REFERENCE CONDITION	QC
ROW	R U	ENTRY TO DETERMINE DENSITY (ALSO DENSITY PARAMETER)	ROMU
ROWS	I U	NOT USED	SLABD
RS	R U	R DIVIDED BY S	PLUNGE
RT	R U	RECOVERY TEMPERATURE	FLOSEP
RT	R D	RECOVERY TEMPERATURE	SKINFR
RT	R A	RECOVERY TEMPERATURE	TEMP
RO	R U	EARTH RADIUS = 20890855 FEET	ATMOS
R3	R U	SHOCK ANGLE PARAMETER	CONE
R3	R U	PARAMETER IN TEMPERATURE EQUATION	DELWNG
S	R U	BOUNDARY-LENGTH	ANALY2
S	R U	FREE MOLECULAR FLOW SPEED RATIO	FORCE
S	R U	WING/TAIL SEMI-SPAN	PLUNGE
SCF	R D	TOTAL SKIN FRICTION	SKINFR
SCFA	R D	TOTAL SKIN FRICTION	SKINFR
SDELTQ	R U	SINE OF MATCHING POINT IMPACT ANGLE	NEWTPM
SECT	R D	SECTION IDENTIFICATION	ANALY1
SECT	R D	SECTION IDENTIFICATION	ANALY2
SECT	R A	SECTION IDENTIFICATION	PUNCH
SECT	R U	SECTION IDENTIFICATION	SDATA
SECTS	R U	SECTION IDENTIFICATION	SDATA
SEQ	I U	CARD SEQUENCE NUMBER	ANALY1
SEQ	I U	CARD SEQUENCE NUMBER	ANALY2
SEQ	I A	CARD SEQUENCE NUMBER	PUNCH
SEQ	I U	CARD SEQUENCE NUMBER	SDATA
SEQ	I U	CARD SEQUENCE NUMBER	SLABD
SFRON	R U	BODY FRONTAL AREA	PLUNGE

SYMBOL	TYPE	DEFINITION	ROUTINE
SHEAR	R U	FREE MOLECULAR FLOW SHEAR FORCE	FORCE
SHEARX	R U	X-COMPONENT OF FREE MOLECULAR FLOW SHEAR FORCE	FORCE
SHEARY	R U	Y-COMPONENT OF FREE MOLECULAR FLOW SHEAR FORCE	FORCE
SHEARZ	R U	Z-COMPONENT OF FREE MOLECULAR FLOW SHEAR FORCE	FORCE
SINDE	R U	SINE OF CONTROL DEFLECTION ANGLE	CONTRL
SINNU	R U	SINE OF FLOW TURNING ANGLE	SHKEXP
SINPHI	R U	SINE OF PHI	CONTRL
SINPHI	R U	SIN OF PHI	PICTUR
SINPSI	R U	SINE OF PSI	CONTRL
SINPSI	R U	SIN OF PSI	PICTUR
SINTH	R U	SINE OF SHOCK ANGLE	FLOSEP
SINTH	R U	SIN OF THETA	PICTUR
SKIN	R U	TOTAL AXIAL FORCE SKIN FRICTION CONTRIBUTION	FORCE
SKIN	R A	TOTAL AXIAL SKIN FRICTION CONTRIBUTION	SKINFR
SPAN	R U	REFERENCE LENGTH FOR ROLLING, YAWING COEFFICIENTS	AERO
SPAN	R A	REFERENCE LENGTH FOR ROLLING, YAWING COEFFICIENTS	FORCE
SPAN	R A	REFERENCE LENGTH FOR ROLLING, YAWING COEFFICIENTS	VECTOR
SR	R U	S DIVIDED BY R	PLUNGE
SREF	R U	VEHICLE REFERENCE AREA (WING AREA)	AERO
SREF	R A	VEHICLE REFERENCE AREA (WING AREA)	FORCE
SREF	R A	VEHICLE REFERENCE AREA (WING AREA)	SKINFR
SREF	R A	VEHICLE REFERENCE AREA (WING AREA)	VECTOR
SSIND	R U	SPEED RATIO TIMES SINE OF IMPACT ANGLE	FORCE
STAT	I U	POINT STATUS FLAG	ANALY1
STAT	I U	SURFACE POINT STATUS FLAG	ANALY2
STAT	I U	COORDINATE POINT STATUS FLAG	PICTUR
STAT	I U	COORDINATE POINT STATUS FLAG	SDATA
STAT	I U	COORDINATE POINT STATUS FLAG	SLABD
STATA	I U	POINT STATUS FLAG	ANALY1
STATA	I U	COORDINATE POINT STATUS FLAG	SLABD
STATB	I U	POINT STATUS FLAG	ANALY1
STATC	I U	POINT STATUS FLAG	ANALY1
STATD	I U	POINT STATUS FLAG	ANALY1
STATT	I U	POINT STATUS FLAG	ANALY1
STATT	I U	SURFACE POINT STATUS FLAG	ANALY2

SYMBOL	TYPE		DEFINITION	ROUTINE
STATZ	I	U	COORDINATE POINT STATUS FLAG	PICTUR
STATT	I	U	COORDINATE POINT STATUS FLAG	SDATA
STATY	I	U	COORDINATE POINT STATUS FLAG	SLABD
STOTAL	R	U	TOTAL VALUE OF SHEAR FORCE VECTOR	FORCE
SURF	R	C	SKIN FRICTION DATA ARRAY	AERO
SURF	R	C	SKIN FRICTION DATA ARRAY	FORCE
SURF	R	C	SKIN FRICTION DATA ARRAY	SKINFR
SURF	R	C	SKIN FRICTION DATA ARRAY	TEMP
SWBYS	R	U	WING/TAIL AREA DIVIDED BY REFERENCE AREA	PLUNGE
SWEEP	R	U	LEADING EDGE SWEEP (NOT USED BY MARK II)	AERO
SWEEP	R	A	LEADING EDGE SWEEP ANGLE	FLOSEP
SWEEP	R	A	LEADING EDGE SWEEP (NOT USED BY MARK II)	FORCE
SWEEP	R	U	LEADING EDGE SWEEP ANGLE	SLABD
SX	R	U	SHEAR FORCE VECTOR COMPONENT-X	FORCE
SY	R	U	SHEAR FORCE VECTOR COMPONENT-Y	FORCE
SYMFCO	I	U	SYMMETRY FACTOR	FORCE
SYMFCT	I	U	SYMMETRY FLAG	AERO
SYMFCT	I	A	SYMMETRY FACTOR	FORCE
SYMFCT	I	U	SYMMETRY FLAG	PICTUR
SYMFCT	I	A	SYMMETRY FLAG	SDATA
SZ	R	U	SHEAR FORCE VECTOR COMPONENT-Z	FORCE
T	R	U	TEMPERATURE	NEWTPM
T	R	U	UNIT VECTOR	PICTUR
T	R	U	UNIT VECTOR	SDATA
TANPHI	R	U	TANGENT OF FLOW SEPARATION ANGLE	FLOSEP
TAPER1	R	U	TAPER RATIO OF INITIAL SURFACE	SKINFR
TAPER2	R	U	TAPER RATIO OF SURFACE	SKINFR
TAU	R	A	SHEAR FORCE	BLUNT
TBTIN	R	U	RATIO OF BODY TEMPERATURE TO FREE-STREAM TEMPERATURE	FORCE
TCT1	R	U	SUTHERLAND CONSTANT TO FREE-STREAM TEMPERATURE RATIO	QC
TC1	R	U	FIRST VALUE OF CONVECTIVE TEMPERATURE	TEMP
TC2	R	U	SECOND VALUE OF CONVECTIVE TEMPERATURE	TEMP
TEXT	I	D	INFORMATION ON TYPE 3 CARD FROM CC 1 TO CC 71	CARD
TFS	R	A	FREE-STREAM TEMPERATURE	BLUNT
TFS	R	A	FREE-STREAM TEMPERATURE-DEGREE R	COMPR
TFS	R	A	FREE-STREAM TEMPERATURE	FLOSEP
TFS	R	U	FREE-STREAM TEMPERATURE	FORCE

SYMBOL	TYPE	DEFINITION	ROUTINE
TFS	R A	FREE STREAM TEMPERATURE	NEWTPH
TFS	R A	FREE STREAM TEMPERATURE	SHKEXP
TFS	R A	FREE-STREAM TEMPERATURE	SKINFR
TH	R U	FLOW TEMPERATURE AT HINGE LINE ELEMENT	FLOSEP
THCHK	R U	ANGULAR CHECK PARAMETER	SLABD
THEMAX	R U	MAXIMUM VALUE OF THETA	SLABD
THESID	R U	THETA AT THE SIDE	SLABD
THETA	R U	ANGULAR POSITION	ANALY1
THETA	R U	SHOCK ANGLE	FLOSEP
THETA	R U	SURFACE SLOPE	FORCE
THETA	R U	PITCH ANGLE	PICTUR
THETA	R U	ANGULAR POSITION IN Z-Y PLANE (FROM BOTTOM)	SLABD
THETAB	I U	NUMBER OF ANGULAR DIVISIONS ON THE BOTTOM	SLABD
THETA0	R U	STARTING VALUE OF THETA	SLABD
THETAP	R U	ANGULAR POSITION	ANALY1
THETAT	I U	NUMBER OF ANGULAR DIVISIONS ON THE TOP	SLABD
THETA2	R U	ANGULAR POSITION	SLABD
THETL	R U	LAST THETA ANGLE	ANALY1
THETLX	R D	LAST THETA ANGLE ARRAY	ANALY1
THET0	R U	INITIAL THETA	ANALY1
THET0X	R D	INITIAL THETA ANGLE ARRAY	ANALY1
TI	R U	LOCAL TEMPERATURE	SHKEXP
TINT2	R U	TEMPERATURE RATIO	CONE
TINT2	R U	TEMPERATURE PARAMETER FOR CONE MACH NUMBER EQUATION	FORCE
TINT2	R U	TEMPERATURE RATIO	SHKEXP
TITLE	R C	TITLE ARRAY	AERO
TITLE	R C	TITLE	ANALY1
TITLE	R C	TITLE	ANALY2
TITLE	R C	TITLE	COMPR
TITLE	R C	TITLE	CONE
TITLE	R C	TITLE	CONTRL
TITLE	R C	TITLE	DELWNG
TITLE	R C	TITLE	EXPAND
TITLE	R C	TITLE ARRAY	FLOSEP
TITLE	R C	TITLE	FORCE
TITLE	R C	TITLE	GRAPIC

SYMBOL	TYPE	DEFINITION	ROUTINE
TITLE	R C	TITLE	HEADER
TITLE	R C	TITLE	HEADR2
TITLE	R C	PROBLEM TITLE	MAIN
TITLE	R C	TITLE	NEWTPM
TITLE	R C	TITLE	PICTUR
TITLE	R D	ABSISSA AND ORDINATE TITLES, AND HORIZONTAL TITLE ARRAY	PLOT
TITLE	R C	TITLE	PLUNGE
TITLE	R C	TITLE	PUNCH
TITLE	R C	TITLE	QC
TITLE	R C	TITLE	SDATA
TITLE	R C	TITLE	SHKEXP
TITLE	R C	TITLE	SKINFR
TITLE	R C	TITLE	SLABD
TITLE	R C	TITLE	TEMP
TITLE	R C	TITLE	VECTOR
TITLE2	R C	DUMMY TITLE ARRAY	PLOT
TM	R D	MATRIX OF MOLECULAR SCALE TEMPERATURES, DEG RANKINE	ATMOS
TMS	R U	MOLECULAR SCALE TEMPERATURE, DEGREE RANKINE	ATMOS
TOPTC	R U	TOP THICKNESS CORRECTION FACTOR	SLABD
TR	R D	TEMPERATURE DATA ARRAY	FLOSEP
TR	R D	FLIGHT CONDITION AND SKIN FRICTION DATA ARRAY	SKINFR
TR	R A	FLIGHT CONDITION AND SKIN FRICTION DATA ARRAY	TEMP
TR1	R U	FIRST VALUE OF RADIATION TEMPERATURE	TEMP
TR2	R U	SECOND VALUE OF RADIATION TEMPERATURE	TEMP
TS	R D	REFERENCE TEMPERATURE (DEGREE R)	FLOSEP
TS	R D	REFERENCE TEMPERATURE (T STAR)	SKINFR
TS	R A	REFERENCE TEMPERATURE (T STAR)	TEMP
TSTAG	R U	WIND TUNNEL STAGNATION TEMPERATURE-DEGREES F	AERO
TSTAG	R A	WIND TUNNEL STAGNATION TEMPERATURE, DEGREES F	FORCE
TSTAR	R U	REFERENCE TEMPERATURE	QC
TST1	R C	REFERENCE TO FREE-STREAM TEMPERATURE (OR ENTHALPY) RATIO	QC
TST1	R C	REFERENCE TO FREE-STREAM TEMPERATURE (OR ENTHALPY) RATIO	SKINFR
TST1	R C	REFERENCE TO FREE-STREAM TEMPERATURE (OR ENTHALPY) RATIO	TEMP
TSUBT	R U	FREE STREAM TOTAL TEMPERATURE	NEWTPM
TW	R A	WALL TEMPERATURE	QC
TW	R A	TEMPERATURE (RANKINE)	ROMU

SYMBOL	TYPE		DEFINITION	ROUTINE
TWALL	R	U	WALL TEMPERATURE FOR FLOSEP	AERO
TWALL	R	A	WALL TEMPERATURE FOR FLOSEP	FLOSEP
TWALL	R	A	WALL TEMPERATURE FOR FLOSEP	FORCE
TWBL	R	U	RATIO OF SHEAR FORCE WITH INTERACTION TO THAT WITHOUT	BLUNT
TWTL	R	U	WALL TO FREE-STREAM TEMPERATURE RATIO, LAMINAR	SKINFR
TWTRL	R	U	WALL TO RECOVERY TEMPERATURE RATIO, LAMINAR	SKINFR
TWX	R	U	REDUCED TEMPERATURE (TW*1.0E-4)	ROMU
TW1	R	U	WALL TEMPERATURE	QC
TX	R	U	TANGENT VECTOR X-COMPONENT	ANALY2
TX	R	U	FREE MOLECULAR FLOW VECTOR COMPONENT-X	FORCE
TX1	R	U	FLOW TEMPERATURE ON ELEMENT JUST BEFORE SEPARATION ELEMENT	FLOSEP
TY	R	U	TANGENT VECTOR Y-COMPONENT	ANALY2
TY	R	U	FREE MOLECULAR FLOW VECTOR COMPONENT-Y	FORCE
TYPE	I	U	CARD TYPE	AERO
TYPE	I	U	CARD TYPE FOR GEOMETRY DATA =3	ANALY1
TYPE	I	U	CARD TYPE NUMBER	ANALY2
TYPE	I	U	CARD TYPE	CARD
TYPE	I	U	CARD TYPE	MAIN
TYPE	I	U	CARD TYPE NUMBER	PICTUR
TYPE	I	U	CARD TYPE	PLOT
TYPE	I	U	CARD TYPE	PLUNGE
TYPE	I	A	CARD TYPE NUMBER	PUNCH
TYPE	I	U	CARD TYPE NUMBER	SDATA
TYPE	I	U	CARD TYPE NUMBER	SLABD
TYPE	I	U	CARD TYPE NUMBER	VECTOR
TZ	R	U	TANGENT VECTOR Z-COMPONENT	ANALY2
TZ	R	U	FREE MOLECULAR FLOW VECTOR COMPONENT-Z	FORCE
T1	R	U	DUMMY VARIABLE	PLUNGE
T1X	R	U	X-COMPONENT OF VECTOR T1	PICTUR
T1X	R	U	X-COMPONENT OF VECTOR T1	SDATA
T1Y	R	U	Y-COMPONENT OF VECTOR T1	PICTUR
T1Y	R	U	Y-COMPONENT OF VECTOR T1	SDATA
T1Z	R	U	Z-COMPONENT OF VECTOR T1	PICTUR
T1Z	R	U	Z-COMPONENT OF VECTOR T1	SDATA
T2	R	U	TEMPERATURE BEHIND NORMAL SHOCK	BLUNT
T2	R	U	DUMMY VARIABLE	PLUNGE
T2X	R	U	X-COMPONENT OF VECTOR T2	PICTUR

SYMBOL	TYPE	DEFINITION	ROUTINE
T2X	R U	X-COMPONENT OF VECTOR T2	SDATA
T2Y	R U	Y-COMPONENT OF VECTOR T2	PICTUR
T2Y	R U	Y-COMPONENT OF VECTOR T2	SDATA
T2Z	R U	Z-COMPONENT OF VECTOR T2	PICTUR
T2Z	R U	Z-COMPONENT OF VECTOR T2	SDATA
T3	R U	DUMMY VARIABLE	PLUNGE
T4	R U	DUMMY VARIABLE	PLUNGE
U	R U	PARAMETRIC VARIABLE, U	ANALY2
UPWASH	R U	TAIL UPWASH DERIVATIVE CAUSED BY WING	PLUNGE
U2	R U	PARAMETRIC VARIABLE U SQUARED	ANALY2
U3	R U	PARAMETRIC VARIABLE U CUBED	ANALY2
V	R U	FREE-STREAM VELOCITY-FEET/SECOND	AERO
V	R A	FREE-STREAM VELOCITY, FEET / SECOND	FORCE
V	R U	VELOCITY	NEWTPM
V	R A	FREE STREAM VELOCITY, FEET/SECOND	SHKEXP
VBAR	R U	HYPERSONIC VISCOUS PARAMETER	SKINFR
VIS	R A	FREE-STREAM VISCOSITY	BLUNT
VIS	R U	FREE-STREAM VISCOSITY	FORCE
VIS	R U	VICOSITY AT REFERENCE CONDITION	QC
VIS	R A	FREE-STREAM VISCOSITY	SHKEXP
VIS	R A	FREE STREAM VISCOSITY	SKINFR
VISRA	R U	REFERENCE TO FREE-STREAM VISCOSITY RATIO	QC
VISTAR	R U	VICOSITY AT REFERENCE CONDITION	SKINFR
VISWL	R U	VISCOSITY AT WALL TEMPERATURE, LAMINAR	SKINFR
VISWT	R U	VISCOSITY AT WALL TEMPERATURE, TURBULENT	SKINFR
VIS2	R U	VISCOSITY BEHIND NORMAL SHOCK	BLUNT
VLOCAL	R U	TOTAL LOCAL VELOCITY	FORCE
VN	R U	VECTOR LENGTH	PICTUR
VN	R U	VECTOR LENGTH	SDATA
VOL	R U	TOTAL VOLUME	PICTUR
VOL	R U	TOTAL VOLUME	SDATA
VOLUME	R U	BODY VOLUME	PLUNGE
VSTAR	R U	VICOUS-INTERACTION PARAMETER	SKINFR
VTITLE	R D	VERTICAL SCALE TITLE	PICTUR
VX	R U	LOCAL VELOCITY COMPONENT-X	FORCE
VXI	R U	FREE-STREAM VELOCITY COMPONENT-X	FORCE

SYMBOL	TYPE	DEFINITION	ROUTINE
VY	R U	LOCAL VELOCITY COMPONENT-Y	FORCE
VYI	R U	FREE-STREAM VELOCITY COMPONENT-Y	FORCE
VZ	R U	LOCAL VELOCITY COMPONENT-Z	FORCE
VZI	R U	FREE STREAM VELOCITY COMPONENT-Z	FORCE
W	R U	PARAMETRIC VARIABLE, W	ANALY2
W	R U	PARAMETER IN CUBIC EQUATION	COMPR
W	R D	GRID INFORMATION ARRAY	PLOT
WM	R D	MATRIX OF MOLECULAR WEIGHTS OF AIR	ATMOS
WMO	R U	MOLECULAR WEIGHT OF AIR AT SEA LEVEL = 28.9644	ATMOS
W2	R U	PARAMETRIC VARIABLE W SQUARED	ANALY2
W3	R U	PARAMETRIC VARIABLE W CUBED	ANALY2
X	R U	X-COORDINATE	ANALY1
X	R U	X-COORDINATE	ANALY2
X	R U	SHOCK ANGLE PARAMETER	CONE
X	R U	SHOCK ANGLE PARAMETER	DELWNG
X	R U	X-COORDINATE	PICTUR
X	R D	PLOTTING ARRAY, LOCATION ALONG X-AXIS	PLOT
X	R U	X-COORDINATE	SDATA
X	P U	X-COORDINATE	SLABD
XA	R U	X-COORDINATE	ANALY1
XA	R D	X-COORDINATE	ANALY2
XA	R D	X-COORDINATE	PICTUR
XA	R D	X-COORDINATE	SDATA
XA	R U	X-COORDINATE	SLABD
XATACH	R A	X-COORDINATE AT FLOW ATTACHMENT POINT	FLOSEP
XATACH	R U	X-COORDINATE AT FLOW ATTACHMENT POINT	FORCE
XAVG	R U	AVERAGE X-COORDINATE	SDATA
XB	R U	X-COORDINATE	ANALY1
XB	R D	X-COORDINATE	ANALY2
XB	R D	X-COORDINATE	PICTUR
XB	R D	X-COORDINATE	SDATA
XB	R U	INPUT X-COORDINATE STATION	SLABD
XBTBYC	R U	TAIL LENGTH DIVIDED BY REFERENCE CHORD	PLUNGE
XB1	R D	BOUNDARY CURVE X-COORDINATE ARRAY	ANALY2
XC	R U	X-COORDINATE	ANALY1
XC	R U	AREA CENTROID LOCATION OF BODY	PLUNGE

SYMBOL	TYPE	DEFINITION	ROUTINE
XCENT	R U	QUADRILATERAL ELEMENT CENTROID-X	CONTRL
XCENT	R A	HINGE MOMENT FACTOR FOR CONTROL SURFACE ELEMENT	FLOSEP
XCENT	R U	QUADRILATERAL ELEMENT CENTROID-X	FORCE
XCENT	R U	ELEMENT CENTROID COORDINATE-X	PICTUR
XCENT	R U	ELEMENT CENTROID COORDINATE-X	SDATA
XCENT	R U	ACTION POINT FOR FORCE VECTOR-X	VECTOR
XCENTD	R U	QUADRILATERAL ELEMENT CENTROID-X (CONTROL DEFLECEDD)	CONTRL
XCENT2	R C	ELEMENT CENTROID COORDINATE ARRAY-X	AERO
XCENT2	R C	ELEMENT CENTROID ARRAY-X	COMPR
XCENT2	R C	ELEMENT CENTROID ARRAY-X	CONE
XCENT2	R C	HINGE MOMENT FACTOR	CONTRL
XCENT2	R C	ELEMENT CENTROID COORDINATE-X	DELWNG
XCENT2	R C	ELEMENT CENTROID ARRAY-X	EXPAND
XCENT2	R C	HINGE MOMENT FACTOR ARRAY FOR CONTROL SURFACE ELEMENTS	FLOSEP
XCENT2	R C	QUADRILATERAL ELEMENT CENTROID ARRAY-X	FORCE
XCENT2	R C	ELEMENT CENTROID COORDINATE-X	NEWTPM
XCENT2	R C	QUADRILATERAL ELEMENT CENTROID ARRAY-X	QC
XCENT2	R C	ELEMENT CENTROID COORDINATE ARRAY-X	SDATA
XCENT2	R C	QUADRILATERAL ELEMENT CENTROID ARRAY-X	SHKEXP
XCENT2	R C	QUADRILATERAL ELEMENT CENTROID ARRAY-X	SKINFR
XCENT2	R C	QUADRILATERAL CENTROID ARRAY-X	TEMP
XCG	R U	X-CENTER FOR MOMENT CALCULATIONS	AERO
XCG	R A	X-CENTER FOR MOMENT CALCULATIONS	FORCE
XCG	R A	X-CENTER FOR MOMENT CALCULATIONS	VECTOR
XD	R U	X-COORDINATE	ANALYI
XDIF	R U	COORDINATE DIFFERENCE-X	PICTUR
XDIF	R U	COORDINATE DIFFERENCE-X	SDATA
XHL	R U	ELEMENT AVERAGE X-COORDINATE AT HINGE LINE	FLOSEP
XHL1	R U	HINGE LINE X-COORDINATE OF POINT 1	CONTRL
XHL4	R U	HINGE LINE X-COORDINATE OF POINT 4	CONTRL
XI	R D	COORDINATE IN ELEMENT COORDINATE SYSTEM	PICTUR
XI	R D	COORDINATE IN ELEMENT COORDINATE SYSTEM	SDATA
XIN	R D	ELEMENT COORDINATES-X	PICTUR
XIN	R D	ELEMENT COORDINATES-X	SDATA
XIO	R U	CENTROID IN ELEMENT COORDINATE SYSTEM	PICTUR
XIO	R U	CENTROID IN ELEMENT COORDINATE SYSTEM	SDATA

SYMBOL	TYPE	DEFINITION	ROUTINE
XI3M1	R U	CONSTANT FOR AREA EQUATION	PICTUR
XI3M1	R U	CONSTANT FOR AREA EQUATION	SDATA
XL	R U	LEFT-MOST LIMIT OF THE GRID ON X-AXIS	PLOT
XLE	R U	DISTANCE FROM LEADING EDGE TO ELEMENT CENTROID	CONTRL
XLE	R A	X-DISTANCE FROM CENTROID OF ELEMENT TO LEADING EDGE LINE	FLOSEP
XLE	R U	X-DISTANCE FROM CENTRAID OF ELEMENT TO LEADING EDGE LINE	FORCE
XLE	R U	DISTANCE FROM LEADING EDGE TO ELEMENT CENTROID	SDATA
XLEH	R U	X-DISTANCE FROM LEADING EDGE TO HINGE LINE	FLOSEP
XLEO	R U	LEADING EDGE X INCREMENT	SDATA
XLEP1	R U	SAVED X-COORDINATE	SDATA
XLESEP	R U	DISTANCE FROM LEADING EDGE TO SEPARATION POINT	FLOSEP
XLE1	R U	ELEMENT CENTROID DISTANCE FROM L. E. BEFORE SEPARATION	FLOSEP
XLG	R U	VALUE OF LEFT SIDE OF HORIZONTAL SCALE	PICTUR
XOEV	R U	ORIGIN FOR EVEN EXPONENTIAL	BLUNT
XOP	R U	X IN TRANSFORMED SYSTEM	CONTRL
XOPDE	R U	X IN TRANSFORMED SYSTEM (CONTROL DEFLECTED)	CONTRL
XOPH	R U	X-COORDINATE	CONTRL
XOW	R U	BOUNDARY CURVE POINT, X(O,W)	ANALY2
XP	R U	X-COORDINATE	CONTRL
XPA	R D	COORDINATES OF ELEMENT CORNER POINTS, X	CONTRL
XPA	R A	X-COORDINATES OF QUADRILATERAL ELEMENT	FLOSEP
XPA	R D	X-COORDINATES OF QUADRILATERAL ELEMENT	FORCE
XPA	R U	COORDINATE OF ELEMENT CORNER POINT	PICTUR
XPA	R D	COORDINATES OF ELEMENT CORNER POINTS, X	SDATA
XPAD	R D	COORDINATES OF ELEMENT CORNER POINTS (DEFLECTED)	CONTRL
XPDE	R U	X-COORDINATE (DEFLECTED)	CONTRL
XR	R U	RIGHT-MOST LIMIT OF THE GRID ON X-AXIS	PLOT
XRG	R U	VALUE OF RIGHT SIDE OF HORIZONTAL SCALE	PICTUR
XS	R U	SURFACE X-COORDINATE POINT	ANALY2
XSC	R U	X SCALE FACTOR	PICTUR
XSC	R U	X SCALE FACTOR	SDATA
XSEP	R U	DISTANCE FROM LEADING EDGE MINUS UPSTREAM INTERACTION LENGTH	FLOSEP
XSEPP	R A	X-COORDINATE AT FLOW SEPARATION POINT	FLOSEP
XSEPP	R U	X-COORDINATE AT FLOW SEPARATION POINT	FORCE
XTE	R U	AVERAGE X-COORDINATE AT TRAILING EDGE	FLOSEP
XUO	R U	BOUNDARY CURVE POINT, X(U,O)	ANALY2

SYMBOL	TYPE	DEFINITION	ROUTINE
XU1	R U	BOUNDARY CURVE POINT, X(U,1)	ANALY2
XX	R U	X-COORDINATE	ANALY1
XX	R U	X-COORDINATE	ANALY2
XX	R U	X-COORDINATE	PICTUR
XX	R U	X-COORDINATE	SDATA
XX	R U	X-COORDINATE	SLABD
XXS	R U	X-COORDINATE	ANALY2
X0	R U	CENTER OF GRAVITY LOCATION	PLUNGE
X1	R A	X-COORDINATE	PUNCH
X1V00	R U	END POINT DERIVATIVE	ANALY2
X1V01	R U	END POINT DERIVATIVE	ANALY2
X1W	R U	BOUNDARY CURVE POINT, X(1,W)	ANALY2
X2	R A	X-COORDINATE	PUNCH
X2X1	R U	VARIABLE IN TANGENT VECTOR EQUATIONS	ANALY2
X3X1	R U	VARIABLE IN TANGENT VECTOR EQUATIONS	ANALY2
X3X2	R U	VARIABLE IN TANGENT VECTOR EQUATIONS	ANALY2
Y	R U	Y-COORDINATE	ANALY1
Y	R U	Y-COORDINATE	ANALY2
Y	R U	PARAMETER IN CUBIC EQUATION	COMPR
Y	R U	Y-COORDINATE	PICTUR
Y	R D	PLOTTING ARRAY, LOCATION ALONG Y-AXIS	PLOT
Y	R U	Y-COORDINATE	SDATA
Y	R U	Y-COORDINATE	SLABD
YA	R U	Y-COORDINATE	ANALY1
YA	R D	Y-COORDINATE	ANALY2
YA	R D	Y-COORDINATE	PICTUR
YA	R D	Y-COORDINATE	SDATA
YA	R U	Y-COORDINATE	SLABD
YAVG	R U	AVERAGE Y COORDINATE	SDATA
YB	R U	Y-COORDINATE	ANALY1
YB	R D	Y-COORDINATE	ANALY2
YB	R D	Y-COORDINATE	PICTUR
YB	R U	BOTTOM MOST LIMIT OF THE GRID ON Y-AXIS	PLOT
YB	R D	Y-COORDINATE	SDATA
YBG	R U	VALUE OF BOTTOM OF VERTICAL SCALE	PICTUR
YB1	R D	BOUNDARY CURVE Y-COORDINATE ARRAY	ANALY2

SYMBOL	TYPE	DEFINITION	ROUTINE
YC	R U	Y-COORDINATE	ANALY1
YCENT	R U	QUADRILATERAL ELEMENT CENTROID-Y	CONTRL
YCENT	R A	(NOT USED)	FLOSEP
YCENT	R U	QUADRILATERAL ELEMENT CENTROID-Y	FORCE
YCENT	R U	ELEMENT CENTROID COORDINATE-Y	PICTUR
YCENT	R U	ELEMENT CENTROID COORDINATE-Y	SDATA
YCENT	R U	ACTION POINT FOR FORCE VECTOR-Y	VECTOR
YCENTD	R U	QUADRILATERAL ELEMENT CENTROID-Y (CONTROL DEFLECTED)	CONTRL
YCENT2	R C	ELEMENT CENTROID COORDINATE ARRAY-Y	AERO
YCENT2	R C	ELEMENT CENTROID ARRAY-Y	COMPR
YCENT2	R C	ELEMENT CENTROID ARRAY-Y	CONE
YCENT2	R C	QUADRILATERAL ELEMENT CENTROID ARRAY-Y	CONTRL
YCENT2	R C	ELEMENT CENTROID COORDINATE-Y	DELWNG
YCENT2	R C	ELEMENT CENTROID ARRAY-Y	EXPAND
YCENT2	R C	(NOT USED)	FLOSEP
YCENT2	R C	QUADRILATERAL ELEMENT CENTROID ARRAY-Y	FORCE
YCENT2	R C	ELEMENT CENTROID COORDINATE-Y	NEWTPM
YCENT2	R C	QUADRILATERAL ELEMENT CENTROID ARRAY-Y	QC
YCENT2	R C	ELEMENT CENTROID COORDINATE ARRAY-Y	SDATA
YCENT2	R C	QUADRILATERAL ELEMENT CENTROID ARRAY-Y	SHKEXP
YCENT2	R C	QUADRILATERAL ELEMENT CENTROID ARRAY-Y	SKINFR
YCENT2	R C	QUADRILATERAL CENTROID ARRAY-Y	TEMP
YCG	R U	Y-CENTER FOR MOMENT CALCULATIONS	AERO
YCG	R A	Y-CENTER FOR MOMENT CALCULATIONS	FORCE
YCG	R A	Y-CENTER FOR MOMENT CALCULATIONS	VECTOR
YD	R U	Y-COORDINATE	ANALY1
YDIF	R U	COORDINATE DIFFERENCE-Y	PICTUR
YDIF	R U	COORDINATE DIFFERENCE-Y	SDATA
YHL	R U	ELEMENT AVERAGE Y-COORDINATE AT HINGE LINE	FLOSEP
YHL1	R U	HINGE LINE Y-COORDINATE OF POINT 1	CONTRL
YHL4	R U	HINGE LINE Y-COORDINATE OF POINT 4	CONTRL
YIN	R D	ELEMENT COORDINATES-Y	PICTUR
YIN	R D	ELEMENT COORDINATE-Y	SDATA
YIN2	R D	Y-COORDINATE FOR PLOT	PICTUR
YLE	R U	Y-DISTANCE TO THE LEADING EDGE	SLABD
YLECL	R U	Y-DISTANCE TO LEADING EDGE CENTER LINE	SLABD

SYMBOL	TYPE	DEFINITION	ROUTINE
YLEP1	R U	SAVED Y-COORDINATE	SDATA
YOP	R U	Y IN TRANSFORMED SYSTEM	CONTRL
YOPDE	R U	Y IN TRANSFORMED SYSTEM (CONTROL DEFLECTED)	CONTRL
YOPH	R U	Y-COORDINATE	CONTRL
YOW	R U	BOUNDARY CURVE POINT, Y(O,W)	ANALY2
YO1	R U	Y-COORDINATE FOR PLOT-POINT 1	PICTUR
YO2	R U	Y-COORDINATE FOR PLOT-POINT 2	PICTUR
YO3	R U	Y-COORDINATE FOR PLOT-POINT 3	PICTUR
YO4	R U	Y-COORDINATE FOR PLOT-POINT 4	PICTUR
YP	R U	Y-COORDINATE	CONTRL
YPA	R D	COORDINATES OF ELEMENT CORNER POINTS, Y	CONTRL
YPA	R A	Y-COORDINATES OF QUADRILATERAL ELEMENT	FLOSEP
YPA	R D	Y-COORDINATES OF QUADRILATERAL ELEMENT	FORCE
YPA	R U	COORDINATE OF ELEMENT CORNER POINT	PICTUR
YPA	R D	COORDINATES OF ELEMENT CORNER POINTS-Y	SDATA
YPAD	R D	COORDINATES OF ELEMENT CORNER POINTS (DEFLECTED)	CONTRL
YPDE	R U	Y-COORDINATE (DEFLECTED)	CONTRL
YS	R U	SURFACE Y-COORDINATE POINT	ANALY2
YSC	R U	Y-SCALE FACTOR	PICTUR
YSC	R U	Y-SCALE FACTOR	SDATA
YT	R U	TOP MOST LIMIT OF THE GRID ON Y-AXIS	PLOT
YTE	R U	AVERAGE Y-COORDINATE AT TRAILING EDGE	FLOSEP
YTG	R U	VALUE OF TOP OF VERTICAL SCALE	PICTUR
YUO	R U	BOUNDARY CURVE POINT, Y(U,O)	ANALY2
YU1	R U	BOUNDARY CURVE POINT, Y(U,1)	ANALY2
YY	R U	Y-COORDINATE	ANALY1
YY	R U	Y-COORDINATE	ANALY2
YY	R U	Y-COORDINATE	PICTUR
YY	R U	Y-COORDINATE	SDATA
YY	R U	Y-COORDINATE	SLABD
YYS	R U	Y-COORDINATE	ANALY2
Y1	R A	Y-COORDINATE	PUNCH
Y1VOO	R U	END POINT DERIVATIVE	ANALY2
Y1VO1	R U	END POINT DERIVATIVE	ANALY2
Y1W	R U	BOUNDARY CURVE POINT, Y(1,W)	ANALY2
Y2	R U	SECOND FUNCTION OF ODD EXPONENTIAL	BLUNT

SYMBOL	TYPE		DEFINITION	ROUTINE
Y2	R	A	Y-COORDINATE	PUNCH
Y2Y1	R	U	VARIABLE IN TANGENT VECTOR EQUATIONS	ANALY2
Y3Y1	R	U	VARIABLE IN TANGENT VECTOR EQUATIONS	ANALY2
Y3Y2	R	U	VARIABLE IN TANGENT VECTOR EQUATIONS	ANALY2
Z	R	U	Z-COORDINATE	ANALY1
Z	R	U	Z-COORDINATE	ANALY2
Z	R	U	GEOMETRIC ALTITUDE, FEET	ATMOS
Z	R	U	PARAMETER IN CUBIC EQUATION	COMPR
Z	R	U	FLOW CHARACTERISTIC PARAMETERS	EXPAND
Z	R	U	Z-COORDINATE	PICTUR
Z	R	U	Z-COORDINATE	SDATA
Z	R	U	Z-COORDINATE	SLABD
ZA	R	U	Z-COORDINATE	ANALY1
ZA	R	D	Z-COORDINATE	ANALY2
ZA	R	D	Z-COORDINATE	PICTUR
ZA	R	D	Z-COORDINATE	SDATA
ZA	R	U	Z-COORDINATE	SLABD
ZAVG	R	U	AVERAGE Z COORDINATE	SDATA
ZB	R	U	Z-COORDINATE	ANALY1
ZB	R	D	Z-COORDINATE	ANALY2
ZB	R	D	Z-COORDINATE	PICTUR
ZB	R	D	Z-COORDINATE	SDATA
ZB	R	D	Z-COORDINATE	SLABD
ZB1	R	D	BOUNDARY CURVE Z-COORDINATE ARRAY	ANALY2
ZC	R	U	Z-COORDINATE	ANALY1
ZCENT	R	U	QUADRILATERAL ELEMENT CENTROID-Z	CONTRL
ZCENT	R	A	(NOT USED)	FLOSEP
ZCENT	R	U	QUADRILATERAL ELEMENT CENTRAID-Z	FORCE
ZCENT	R	U	ELEMENT CENTROID COORDINATE-Z	PICTUR
ZCENT	R	U	ELEMENT CENTROID COORDINATE-Z	SDATA
ZCENT	R	U	ACTION POINT FOR FORCE VECTOR-Z	VECTOR
ZCENTD	R	U	QUADRILATERAL ELEMENT CENTROID-Z (CONTROL DEFLECTED)	CONTRL
ZCENT2	R	C	ELEMENT CENTROID COORDINATE ARRAY-Z	AERO
ZCENT2	R	C	ELEMENT CENTROID ARRAY-Z	COMPR
ZCENT2	R	C	ELEMENT CENTROID ARRAY-Z	CONE
ZCENT2	R	C	QUADRILATERAL ELEMENT CENTROID ARRAY, Z	CONTRL

SYMBOL	TYPE		DEFINITION	ROUTINE
ZCENT2	R	C	ELEMENT CENTROID COORDINATE-Z	DELWNG
ZCENT2	R	C	ELEMENT CENTROID ARRAY-Z	EXPAND
ZCENT2	R	C	(NOT USED)	FLOSEP
ZCENT2	R	C	QUADRILATERAL ELEMENT CENTRAID ARRAY-Z	FORCE
ZCENT2	R	C	ELEMENT CENTROID COORDINATE-Z	NEWTPM
ZCENT2	R	C	QUADRILATERAL ELEMENT CENTROID ARRAY-Z	QC
ZCENT2	R	C	ELEMENT CENTROID COORDINATE ARRAY-Z	SDATA
ZCENT2	R	C	QUADRILATERAL ELEMENT CENTROID ARRAY-Z	SHKEXP
ZCENT2	R	C	QUADRILATERAL ELEMENT CENTROID ARRAY-Z	SKINFR
ZCENT2	R	C	QUADRILATERAL CENTROID ARRAY-Z	TEMP
ZCG	R	U	Z-CENTER FOR MOMENT CALCULATIONS	AERO
ZCG	R	A	Z-CENTER FOR MOMENT CALCULATIONS	FORCE
ZCG	R	A	Z-CENTER FOR MOMENT CALCULATIONS	VECTOR
ZD	R	U	Z-COORDINATE	ANALY1
ZDIF	R	U	COORDINATE DIFFERENCE-Z	PICTUR
ZDIF	R	U	COORDINATE DIFFERENCE Z	SDATA
ZFACT	R	U	THICKNESS CORRECTION FACTOR FROM TABLES	SLABD
ZHL	R	U	ELEMENT AVERAGE Z-COORDINATE AT HINGE LINE	FLOSEP
ZHL1	R	U	HINGE LINE Z-COORDINATE OF POINT 1	CONTRL
ZHL4	R	U	HINGE LINE Z-COORDINATE OF POINT 4	CONTRL
ZIN	R	D	ELEMENT COORDINATES-Z	PICTUR
ZIN	R	D	ELEMENT COORDINATE-Z	SDATA
ZIN2	R	D	Z-COORDINATE FOR PLOT	PICTUR
ZLEP1	R	U	SAVED Z-COORDINATE	SDATA
ZLZ	R	U	INTERIM CALCULATION FOR PRESSURE EQUATION.	ATMOS
ZM	R	D	MATRIX OF GEOMETRIC ALTITUDES, FEET, ABOVE 245276 FEET	ATMOS
ZOP	R	U	Z IN TRANSFORMED SYSTEM	CONTRL
ZOPDE	R	U	Z IN TRANSFORMED SYSTEM (CONTROL DEFLECTED)	CONTRL
ZOPH	R	U	Z-COORDINATE	CONTRL
ZOW	R	U	BOUNDARY CURVE POINT, Z(O,W)	ANALY1
ZO1	R	U	Z-COORDINATE FOR PLOT-POINT 1	PICTUR
ZO2	R	U	Z-COORDINATE FOR PLOT-POINT 2	PICTUR
ZO3	R	U	Z-COORDINATE FOR PLOT-POINT 3	PICTUR
ZO4	R	U	Z-COORDINATE FOR PLOT-POINT 4	PICTUR
ZP	R	U	Z-COORDINATE	CONTRL
ZPA	R	D	COORDINATES OF ELEMENT CORNER POINTS, Z	CONTRL

SYMBOL	TYPE		DEFINITION	ROUTINE
ZPA	R	A	Z-COORDINATES OF QUADRILATERAL ELEMENT	FLOSEP
ZPA	R	D	Z-COORDINATES OF QUADRILATERAL ELEMENT	FORCE
ZPA	R	U	COORDINATE OF ELEMENT CORNER POINT	PICTUR
ZPA	R	D	COORDINATES OF ELEMENT CORNER POINTS-Z	SDATA
ZPAD	R	D	COORDINATES OF ELEMENT CORNER POINTS (DEFLECTED)	CONTRL
ZPDE	R	U	Z-COORDINATE (DEFLECTED)	CONTRL
ZS	R	U	SURFACE Z-COORDINATE POINT	ANALY2
ZSC	R	U	Z-SCALE FACTOR	PICTUR
ZSC	R	U	Z-SCALE FACTOR	SDATA
ZT	R	D	THICKNESS CORRECTION TABLE ARRAY	SLABD
ZTE	R	U	ELEMENT AVERAGE Z-COORDINATE AT TRAILING EDGE	FLOSEP
ZU0	R	U	BOUNDARY CURVE POINT, Z(U,0)	ANALY2
ZU1	R	U	BOUNDARY CURVE POINT, Z(U,1)	ANALY2
ZZ	R	U	Z-COORDINATE	ANALY1
ZZ	R	U	Z-COORDINATE	ANALY2
ZZ	R	U	Z-COORDINATE	PICTUR
ZZ	R	U	Z-COORDINATE	SDATA
ZZ	R	U	Z-COORDINATE	SLABD
ZZS	R	U	Z-COORDINATE	ANALY2
Z1	R	A	Z-COORDINATE	PUNCH
Z1V00	R	U	END POINT DERIVATIVE	ANALY2
Z1V01	R	U	END POINT DERIVATIVE	ANALY2
Z1W	R	U	BOUNDARY CURVE COORDINATE, Z(1,W)	ANALY2
Z2	R	A	Z-COORDINATE	PUNCH
Z221	R	U	VARIABLE IN TANGENT VECTOR EQUATIONS	ANALY2
Z321	R	U	VARIABLE IN TANGENT VECTOR EQUATIONS	ANALY2
Z322	R	U	VARIABLE IN TANGENT VECTOR EQUATIONS	ANALY2

APPENDIX C

PROGRAM ARRAYS

This program contains a number of subscripted variable arrays. Most of these are single parameter arrays and are described in Appendix B. However, some of the arrays are used to represent several different program parameters. The most important of these are listed below. All of these arrays are used in the skin friction calculations.

Array Item	Description
ANGLE(1)	Angle through which flow is compressed or expanded. For an upper surface, + for expansion - for compression For a lower surface, + for compression - for expansion
ANGLE(2)	Compression or expansion angle (absolute value of ANGLE(1))
ANGLE(3)	Shock angle for compression and Mach angle for expansion
TR(1)	Altitude
TR(2)	Mach number
TR(3)	Velocity
TR(4)	Angle of attack of flight reference plane
TR(5)	Wall temperature, degrees Rankine, laminar
TR(6)	Wall temperature, degrees Rankine, turbulent
TR(7)	Wall enthalpy, laminar
TR(8)	Wall enthalpy, turbulent
TR(9)	Adiabatic wall enthalpy, laminar
TR(10)	Adiabatic wall enthalpy, turbulent
FS(I)	Flow conditions before shock or expansion
FS(1)	Density, slugs/ft^3
FS(2)	Pressure, pounds/ft^2
FS(3)	Temperature, degrees Rankine
FS(4)	Speed of sound, feet/sec
FS(5)	Viscosity, slugs/ft-sec

Array Item	Description
FS(6)	Mach number
FS(7)	Velocity, feet/sec
FS(8)	Reynolds number per foot
BS(I)	Flow conditions behind shock or expansion. See FS above for individual parameters.
SCF(1)	Total skin friction coefficient based on free stream properties and reference area. This is the sum of the proper combination of laminar and turbulent coefficients. Value in the lift direction.
SCF(2)	Total skin friction coefficient, value in the drag direction.
CFL(I)	Laminar skin friction values.
CFL(1)	Local average coefficient based on incompressible relations.
CFL(2)	Local average coefficient based on local flow conditions.
CFL(3)	Free stream skin friction coefficient based on local length.
CFL(4)	Total skin friction coefficient based on vehicle reference area.
CFL(5)	Total skin friction coefficient in the lift direction.
CFL(6)	Total skin friction coefficient in the drag direction.
CFT(I)	Turbulent skin friction values (see CFL above).
TS(1)	Reference temperature, degrees Rankine, laminar.
TS(2)	Reference temperature, degrees Rankine, turbulent.
RE(1)	Reference Reynolds number based on local length, laminar.
RE(2)	Reference Reynolds number based on local length, turbulent.
RF(1)	Recovery factor, laminar.
RF(2)	Recovery factor, turbulent.
RT(1)	Recovery temperature, laminar.
RT(2)	Recovery temperature, turbulent.

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13. ABSTRACT

This report describes a digital computer program system that is capable of calculating the hypersonic aerodynamic characteristics of complex three-dimensional shapes. The outstanding features of this program are its flexibility in covering a very wide variety of problems and the multitude of program options available. The program is a combination of techniques and capabilities necessary in performing a complete aerodynamic analysis of hypersonic shapes. These include vehicle geometry generation and description, visual graphics necessary in handling geometry data and in preparing plots of the final aerodynamic data, aerodynamic calculations of surface pressures and skin friction forces, and the integration of these forces to give all aerodynamic coefficients and stability derivatives.

The geometric description techniques in this program provide the capability of handling completely arbitrary three-dimensional shapes. The procedure developed to check the accuracy of the geometric data uses a computer and automatic recorder to draw pictures of the vehicle viewed from any angle.

The pressure calculation methods provided within the program include modified Newtonian, blunt-body Newtonian-Prandtl-Meyer, tangent-wedge, tangent-cone, shock-expansion, Prandtl-Meyer expansion, blast wave, modified tangent-cone, boundary-layer induced pressures, free-molecular flow, and a number of empirical relationships. The pressure calculation method most suitable for each component of the vehicle is specified by the aerodynamicist. Viscous forces are also calculated and include viscous-inviscid interaction effects. Skin friction options include the Reference Temperature and the Reference Enthalpy methods (for both laminar and turbulent flow), the Spalding-Chi method (turbulent), and a special blunt body skin friction method. Control surface deflection pressures, including separation effects that may be caused by the deflected surface, are also calculated.

The program has been used to study a wide variety of hypersonic vehicle shapes including hypersonic cruise aircraft, air-breathing booster aircraft, blunt lifting reentry bodies, high L/D reentry vehicles, blunt reentry capsules, rocket boosters, reentry warheads, and satellite shapes.

The program is documented in two volumes. Volume I is primarily a User's Manual, and Volume II contains the Program Formulation and Listings.

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