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AN EFFICIENT USER-ORIENTED METHOD FOR CALCULATING COMPRESSIBLE FLOW IN AND ABOUT THREE-DIMENSIONAL INLETS

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NOTE

The requirements of NASA Policy Directive NPD 2220.4 (Sept. 14, 1970) regarding the use of SI Units have been waived in accordance with the provisions of paragraph 5D of that Directive by the Director of Lewis Research Center.

1.0 ABSTRACT

This method uses a panel method to calculate incompressible flow about arbitrary three-dimensional inlets with or without centerbodies for four fundamental flow conditions: unit onset flows parallel to each of the coordinate axes plus static operation. The computing time is scarcely longer than for a single solution. A linear superposition of these solutions quite rigorously gives incompressible flow about the inlet for any angle of attack, angle of yaw, and mass flow rate. Compressibility is accounted for by applying a well-proven correction to the incompressible flow. Since the computing times for the combination and the compressibility correction are small, flows at a large number of inlet operating conditions are obtained rather cheaply. Geometric input is aided by an automatic generating program. A number of graphical output features are provided to aid the user, including surface streamline tracing and automatic generation of curves of constant pressure, Mach number, and flow inclination at selected inlet cross sections. This report describes the inlet method, including the use of the program and presents illustrative results.

2.0 TABLE OF CONTENTS

3.0 GENERAL DESCRIPTION OF THE METHOD

The computer program that has been constructed for analyzing flow in and about the forward portions of nonaxisymmetric engine inlets applies to nonround inlets, inlets with curved centerlines, and scoop inlets. The range of operating conditions to which the method is applicable is essentially unrestricted except that the flow at large distances must be subsonic with respect to the inlet. Generally speaking, the present method may be considered a generalization of that of Stockman (Ref. 1), which is restricted to axisymmetric geometries. No attempt has been made to develop new physical or mathematical theories. Instead, well-proven computational techniques have been assembled in a new way. The main criterion used in assembling this method has been numerical efficiency with special emphasis on the case where solutions for a fairly large number of distinct operating conditions for a given geometry are desired. A second major consideration has been to assure maximum utility for users of the procedure. This has been accomplished by providing a geometry generating program to facilitate input and certain graphical output options to display the calculated flow quantities in a manner shown by experience to be useful.

3.1 The Panel Method

The basic calculational tool is a panel method for calculating inviscid incompressible lifting flow about arbitrary configurations (Ref. 2). In recent years the use of panel methods has grown to the point where at least the simpler, older versions are now standard aerodynamic design tools. Moreover, the literature on panel methods has increased in a similar degree. Accordingly, details of the panel method are not given here, but only some aspects that are particularly important for the present application are discussed.

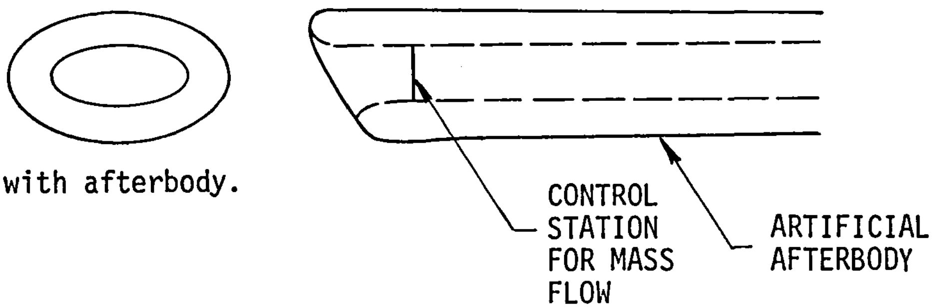
The body about which flow is to be calculated is input to the computer by means of the coordinates of a set of points lying on the body surface. These points are used to form a large number of quadrilateral "panels," which form the discrete representation of the body. An example is shown in Figure 4. On each panel there is a surface source distribution whose strength is initially unknown. The calculational procedure forms a large full matrix that represents the aerodynamic influences of the panel sources on each other. A matrix equation is then solved, which expresses the condition that the total flow about the body must have zero normal velocity at one point of each panel. That is, the source strengths on the panels are adjusted to cancel the normal components of whatever onset flow or flow environment is incident to the body. Each right side of the linear equations corresponds to a particular onset flow, and yields a complete set of panel source strengths and thus a complete flow about the body. The aerodynamic influence matrix depends only on the geometry of the body. If, as in the present program, a direct matrix solution is used, solutions for several flows about the body may be obtained in essentially the same computing time as a single solution.

Because panels are placed on the actual surface of the body, rather than on some interior surface, the method described above is applicable to arbitrary configurations with no restrictions to slender bodies or small flow perturbations. Moreover, the method is numerically exact in the sense that any degree of accuracy may be obtained by using a sufficiently large number of panels. The key calculational efficiency of a panel method, as opposed to, say, a finite-difference method, is that the former need not solve for the entire flow field, but can obtain the flow only on the surface if desired. Flow at off-body locations can then be generated only where it is of interest, e.g., at certain interior cross sections.

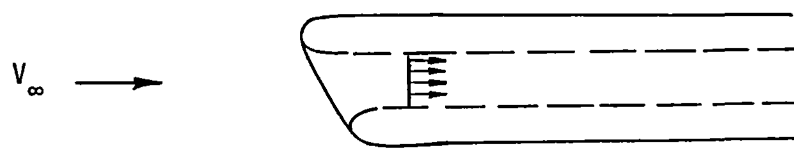
3.2 The Technique of Superposition of Fundamental Solutions

The basic panel-method calculational efficiency as described above is augmented in the inlet application by additional efficiencies arising from use of the technique of superposition of fundamental solutions to obtain flows at various inlet operating conditions. For a simple closed body in incompressible flow the operating condition is defined by the magnitude and direction of the flow at large distances. Thus there are three parameters: angles of attack and yaw, and velocity magnitude. An inlet, however, contains complicated internal machinery that controls the amount of fluid that enters the inlet. It is not possible or even desirable for the panel method to analyze this machinery in detail. Instead, its effect is lumped into a single parameter, mass flow through the inlet. Thus, in incompressible flow the operating condition of an inlet is defined by four parameters. In compressible flow there is a fifth parameter defining compressibility, e.g. sound speed or total temperature.

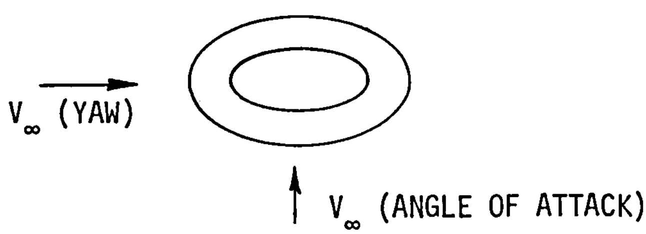
To analyze the flow about the inlet, the forward portion of the inlet, which is the region where the flow is of interest, is artificially extended by means of a long afterbody with constant inner and outer cross sections, as shown in Figure 1(a). The afterbody is open at the downstream end. A forward location is selected by the user and the interior cross section there is designated the control station where mass flow is evaluated. Often the propeller plane or the compressor face is chosen as the control station. Four fundamental flow solutions are calculated. The first three are illustrated in Figure 1. Incompressible flow about the inlet with its extension is calculated by the panel method



(a) Inlet geometry with afterbody.



(b) Zero angle of attack and yaw



(c) Pure angle of attack and pure yaw

Figure 1. Three fundamental flow solutions for three-dimensional inlets.

for three inclinations of the uniform onset flow at large distances: (1) 0^o angle of attack and yaw, (2) 90^o angle of attack with 0^o angle of yaw, and (3) 90^o angle of yaw with 0^o angle of attack. Mass flow for these three fundamental flows are evaluated at the control station. In general, these cannot be predicted in advance, but whatever values are computed simply must be accepted. Usually the mass flows for flows (2) and (3) are near zero. The above three fundamental flows may be linearly combined to give the flow about the inlet at any angle of attack and any angle of yaw, but the mass flow will always be nearly equal to that of flow (1). To control mass flow a fourth fundamental flow is required.

The fourth fundamental flow is the incompressible flow about the extended inlet in static operation, i.e., zero flow at large distance but a finite mass flow at the control station. This is obtained as illustrated in Figure 2 which also shows the N-lines of input points and the lifting strips utilized by the panel method (Ref. 2). A known distribution of vorticity is placed on the panelled inlet surface in such a way that closed vortex lines run around the inlet cross sections — both interior and exterior. (An axisymmetric inlet has ring vorticity oriented exactly on the circular cross sections.) The vorticity strength is constant in the direction parallel to the long afterbody, i.e., in the axial or stream direction. The variation of vorticity strength circumferentially "around" the inlet, i.e., from one lifting strip to another, may be specified by the user if he desires, but the strength is normally taken constant which is definitely the standard option. Possibly better results would be

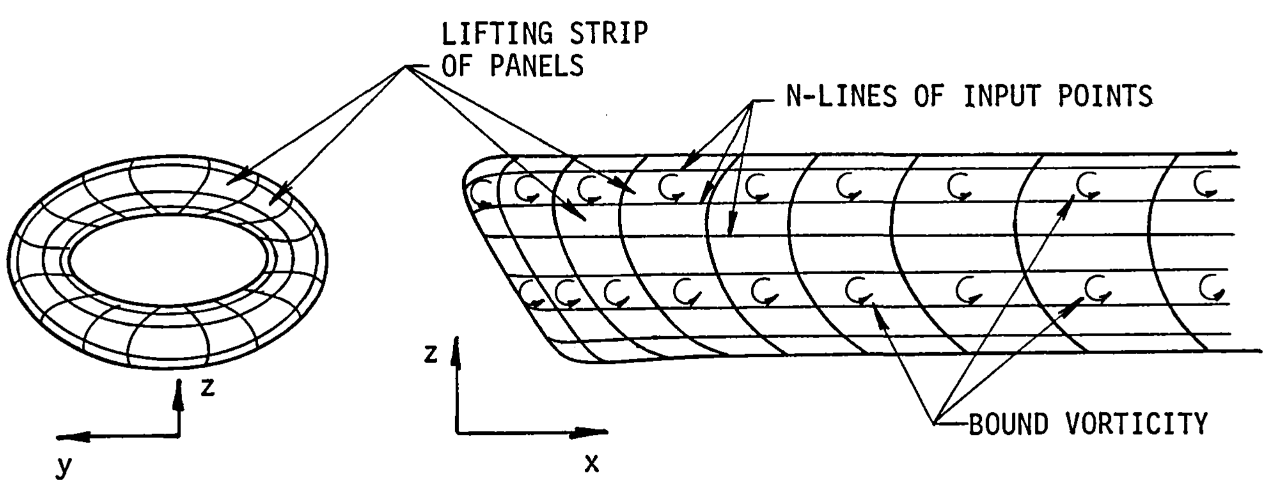


Figure 2. Use of surface vorticity to obtain a solution for a three-dimensional inlet in static operation.

obtained for an unusual inlet geometry using a "circumferentially" varying vorticity strength, but this is up to the user to determine. In any case, the normal velocity on the inlet surface due to the vorticity distribution is not zero, and source distributions on the panels are also required. The vorticity field provides one more onset flow to the inlet and one more right side of the normal-velocity matrix equations. The resulting solution is a fourth flow about the inlet. It can be shown that for a sufficiently long afterbody this flow represents the inlet in static operation. There is a constant uniform flow interior to the inlet at a sufficient distance from the entrance. On the exterior surface the flow velocity falls to zero with increasing distance from the entrance, as indeed it does in all directions in the fluid.

Thus the same mechanism, i.e. vorticity, that is used to produce lift in reference 2 is used here to regulate mass flow. In the lifting application, the vorticity strengths on the lifting strips are determined by the Kutta condition. In the inlet application the distribution of vorticity is prescribed and the total strength is adjusted to give the desired mass flow.

The four fundamental flow solutions may be linearly combined to give the incompressible flow about the inlet at any operating condition. Specifically, the four combination constants are determined so as to yield any prescribed values of: (a) angle of attack, (b) angle of yaw, (c) freestream velocity, and (d) mass flow at the control station. For incompressible potential flow the validity of this superposition is not approximate but is exact. The computational effort required to perform the combination for a particular set of operating conditions is a small fraction of that required for the original panel-method calculation. Thus solutions for large numbers of operating conditions may be obtained quite cheaply. In the inlet program provision has been made for permanent storage of the four fundamental flow solutions, so that additional solutions may be obtained easily at future times. Not only may additional operating conditions be specified, but the location of the control station may be changed, and additional interior cross sections may be designated where it is desired to know the flow field.

Since the computing time for the panel method is much less than that required for a finite-difference solution even for a single operating condition, it is estimated that if several operating conditions are of interest, the present program is faster than a finite-difference method by two orders of magnitude. This numerical efficiency is realized because the main flow calculation of the present program is incompressible. Thus the practicality of this program depends, in an essential way, on the availability of an accurate and general compressibility correction that may be applied a posteriori. That is, it is crucial that a means be available for obtaining compressible flow about an inlet from the incompressible flow about the same inlet, as opposed to, say, a stretched version of the inlet.

3.3 The Compressibility Correction

The compressibility correction used in the present program is that of Leiblein and Stockman (Ref. 3). The mathematical details are contained in the references and will not be repeated here. However, a general description of the procedure appears to warrant inclusion.

The Leiblein-Stockman compressibility correction is a correlation based on empirical observation. The correlation was deduced from a comparison of exact solutions for the compressible and incompressible flows in a turbine stator passage. Strictly, the correction applies to internal flows, but it has been extended to external flows as well.

Physically, the correction consists of one-dimensional compressible flow in the predominant flow direction. Specifically, the compressible total-to-static density ratio is obtained from one-dimensional flow considerations. This requires only the flow passage area, the inlet mass flow, and the total temperature. This one-dimensional density ratio is then modified by the ratio of local incompressible velocity to the average incompressible velocity at that particular axial station. The local incompressible velocity is obtained at each point by combining the four fundamental flow solutions. The average incompressible velocity may be obtained either from the incompressible solution or from one-dimensional incompressible flow. For points in the interior of the inlet, the key quantity in this correlation is the flow passage area, which is automatically calculated by the program from the inlet geometry. At points on the exterior of the inlet an alternate procedure is employed.

Of course the key issue determining the validity of using a compressibility correction of this sort is how well it predicts compressible flow as obtained experimentally. The Leiblein-Stockman correction is exceptionally well verified in this regard (Refs. 1, 3, 4). Indeed it appears to have attained the status of a routine procedure. While all previous work has been done with round inlets, excellent comparisons with experiment have been obtained at large angles of attack — at least 75° — where the flow is essentially three-dimensional in nature. Rather than repeat the comparisons contained in the references, a new comparison is presented here. Figure 3 compares calculated and experimental static-to-total

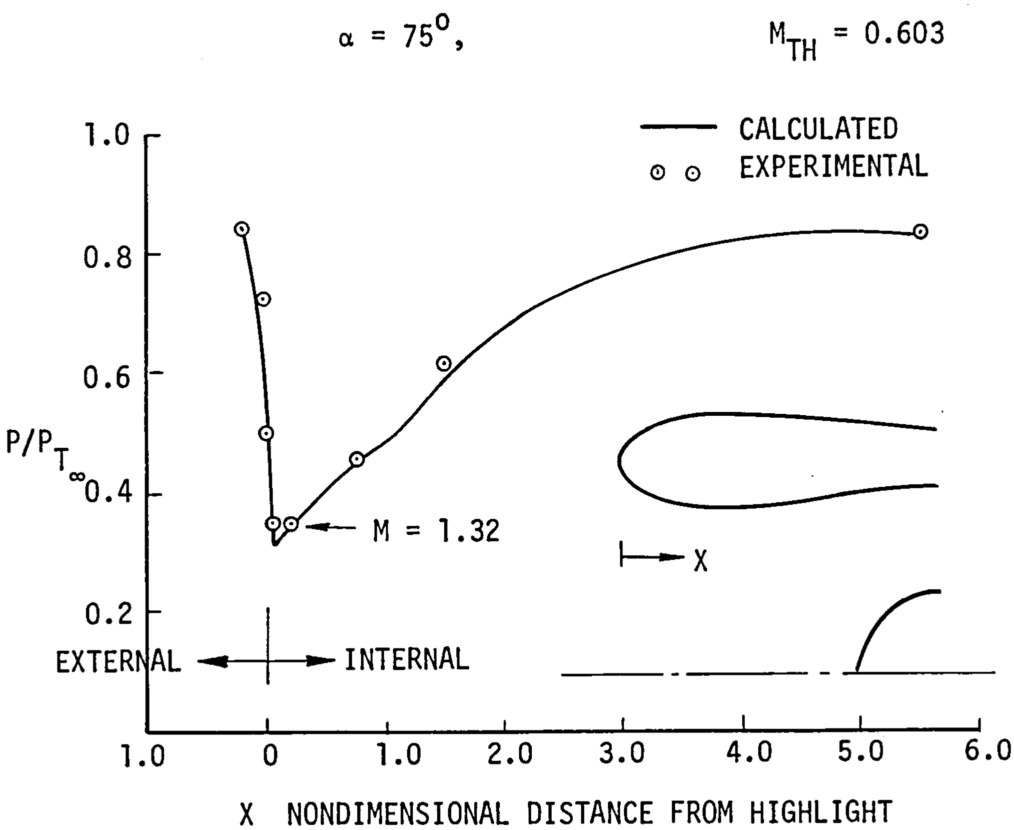


Figure 3. Comparison of calculated and experimental static-to-total pressure ratio distributions on the windward side of an inlet operating condition at which the flow is supercritical.

pressure ratios on the surface of an inlet at 75° angle of attack. The agreement is excellent even at the pressure peak where the local Mach number is 1.32. This illustrates the validity of the compressibility correction for shock-free flows with significant supersonic regions.

3.4 Geometric Specification of the Inlet

For good accuracy the surface of the inlet must be specified by a rather large number of points — larger than is needed for purely external flows. To minimize the effort required of the user of the inlet program, a geometry package has been incorporated into it. This geometry package has a wide range of capabilities and is applicable to a much larger class of problems than inlets (Refs. 6, 7). In the present application the geometry package allows the user to input a relatively small number of points defining the inlet and centerbody. Moreover, extreme care in distributing the points need not be taken. The routine enriches the point number and redistributes the points according to one of a number of algorithms. Graphical output of the points allows the user to approve the distribution before proceeding with the relatively expensive flow calculation. Alternatively, the user may elect to enrich the point number and continue to complete the flow calculation in a single computer run. An example of the use of the geometry package is shown in Figure 4, which presents the input point distribution and the enriched distribution for a typical case.

3.5 Symmetry

It is anticipated that most inlets will have a plane of symmetry. Accordingly, provision has been made to take advantage of this condition to reduce both computing time and the amount of required input data. One half the body is defined by points, and the reflected half is accounted for internally. There are two aerodynamic influence matrices — one matrix for flows where the values of the source densities on symmetrically located panels are equal and another matrix for flows where these values are equal and of opposite sign. Of the four fundamental flow solutions, all use the first matrix except that corresponding to pure yaw, which uses the second. Here pure yaw is defined as a freestream perpendicular to the inlet's symmetry plane.

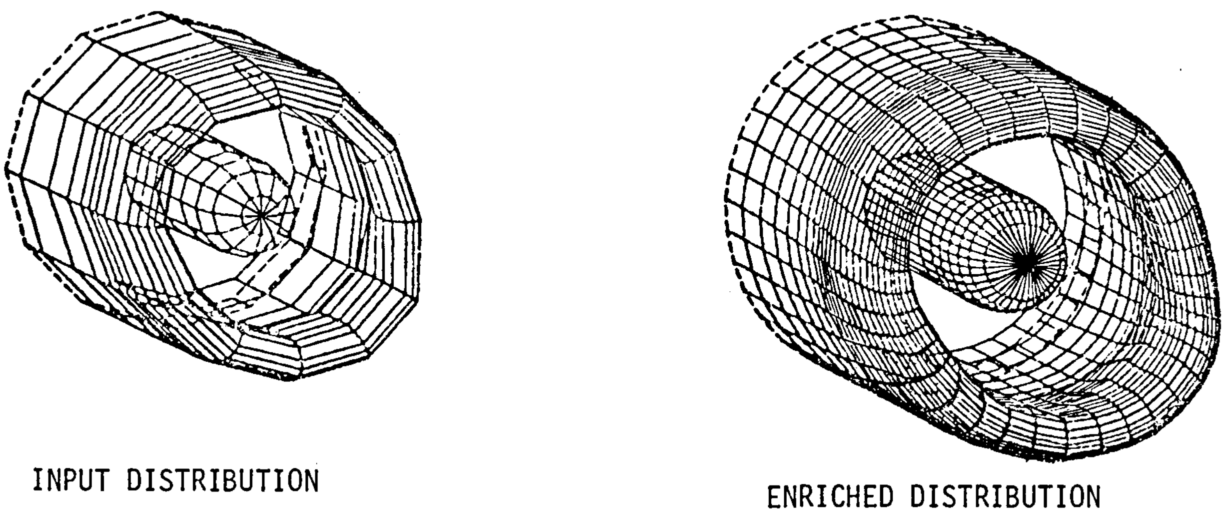


Figure 4. Use of the geometry package to obtain input data for the inlet program.

Even though only half the inlet is input, probably most users prefer graphical output for the complete inlet. Therefore, this has been made the standard option, both for the inlet geometry (Fig. 4) and the calculated flow results. Results for the other half of the inlet are generated internally, including cases with yaw where the combined numerical values are not symmetric.

3.6 Graphical Output Options

The main tabular output of the inlet program consists of local flow properties, e.g., velocity, pressure, Mach number, etc., at one point of each of the panels on the inlet's surface and at points on sections across the interior of the inlet. To aid the user in evaluating this rather formidable amount of data, two graphical output options have been provided. These are the surface streamline option and the cross-section option.

The user may specify a set of points on the surface of the inlet and/or its centerbody through which streamlines are to be constructed. The program calculates these streamlines – in both upstream and downstream directions if desired. It then graphically displays the streamline trajectories against the panel representation of the inlet. Viewing angles may be specified by the user, and a number of angles may be input simultaneously. Either orthographic (parallel) projection or perspective projection may be selected. A second type of graph is also generated by this option, namely conventional two-variable Cartesian plots of pressure, Mach number, and flow angles versus distance along each streamline.

An interior cross section of the inlet is defined by a point and a vector. The program defines a plane through the point whose normal is the given vector, calculates the region of this plane bounded by its intersection with the interior of the inlet and the centerbody, and automatically distributes field points throughout this region. For any inlet operating condition, flow is calculated at the field points, and an interpolation procedure defines curves of constant value of various flow quantities: pressure, Mach number, flow angle. A user may specify several cross sections if he desires. The particular routine used for constructing contours of equal value is quite general. In particular a contour of some particular value may consist of more than one disjoint portion.

4.0 GENERAL REQUIREMENTS OF THE GEOMETRIC INPUT

The present program has been built around that of references 2 and 5, which is designed for lifting wings and wing-fuselages. The geometric input requirements reflect this ancestry. Moreover, to prevent the logic of the Flow Passage Area Calculation from growing too complicated, certain restrictions on the complexity of the inlet calculation have been assumed.

The inlet program is designed for configurations of the type illustrated in Figure 4: a single isolated cowl or inlet either with or without a single disjoint centerbody. Additional surfaces such as slats, vanes, or additional inlets (say an inlet within an inlet) will cause the logic of the Flow Passage Area Calculation and, probably also the Cross Section Calculation, to fail.

In the logical scheme of the lifting panel method the inlet (cowl) is a lifting body on which surface vorticity is placed, and the centerbody is a non-lifting body which has no vorticity. Both bodies are specified to the computer by means of coordinates of a set of points that define their surfaces. These points are organized by means of so-called N-lines, as indicated in Figure 2 and described in reference 2. Basically, an N-line is a curve in the body surface connecting successive input points. Thus points are input N-line by N-line. In the inlet program the N-lines are not cross sections at a given axial station but rather are curves at a given circumferential location that traverse the bodies in the axial or streamwise direction.

Specifically, the first point of each N-line lies at the most aft (downstream) location of the extended afterbody (Figures 2 and 4). Moreover this point is on the interior surface of the inlet. Successive input points on the N-line proceed forward (upstream) along the interior of the inlet, go around the lip, and then proceed aft (downstream) along the exterior surface to the end of the afterbody. The last input on the N-line is a so-called wake point. It is assumed that at the aft end of the afterbody the inlet centerline is straight. The direction from the second-to-last point on an N-line to the last (wake) point should be parallel to the local centerline direction. On the centerbody the first point on each N-line is at the nose and successive points proceed aft (downstream) to the end of the afterbody. Thus, inlet N-lines both begin and end at the end of the afterbody, while centerbody N-lines begin at the front and proceed to the rear. The order of input of N-lines on both the inlet and the centerbody is clockwise as viewed by an observer at upstream infinity.

Every N-line on the inlet must have the same number of points. Every N-line on the centerbody also must have the same number of points, but this number may be different from that of the inlet N-lines. It is required, however, that both the inlet and the centerbody have the same number of N-lines.

If one plane of symmetry is utilized, this must be the $y = 0$ plane, and points must be input in the plane to obtain a closed surface. Thus the first and last N-lines of both the inlet and the centerbody must lie in the $y = 0$ plane.

In all cases the Geometry Package of references 6 and 7, which has been incorporated into the inlet program, is available to aid in preparing geometric input data.

5.0 OVERALL OPERATION OF THE PROGRAM

There are basically two main modes of operation of the inlet program. The first begins with the geometric input data and produces the Fundamental Solutions of Sections 3.2 and 6.0. This is the time-consuming portion of the calculation. Its logical structure is illustrated in Figure 5. Once the fundamental solutions have been generated, they can be saved indefinitely to produce flow solutions at any future time. Thus the expensive part of the calculation need only be done once for each inlet configuration. The second mode of operation begins with values of the physical quantities that define an inlet operating condition and produces a complete flow solution for that condition. It is illustrated in Figure 6, particularly 6c. The first two parts of Figure 6 illustrate the Flow Passage Area and Cross Section Calculations that are performed at the same time. It is possible to run the program all the way through both modes in a single computer run, but this probably will not be the standard mode of operation. In any event several sets of operating conditions may be input simultaneously.

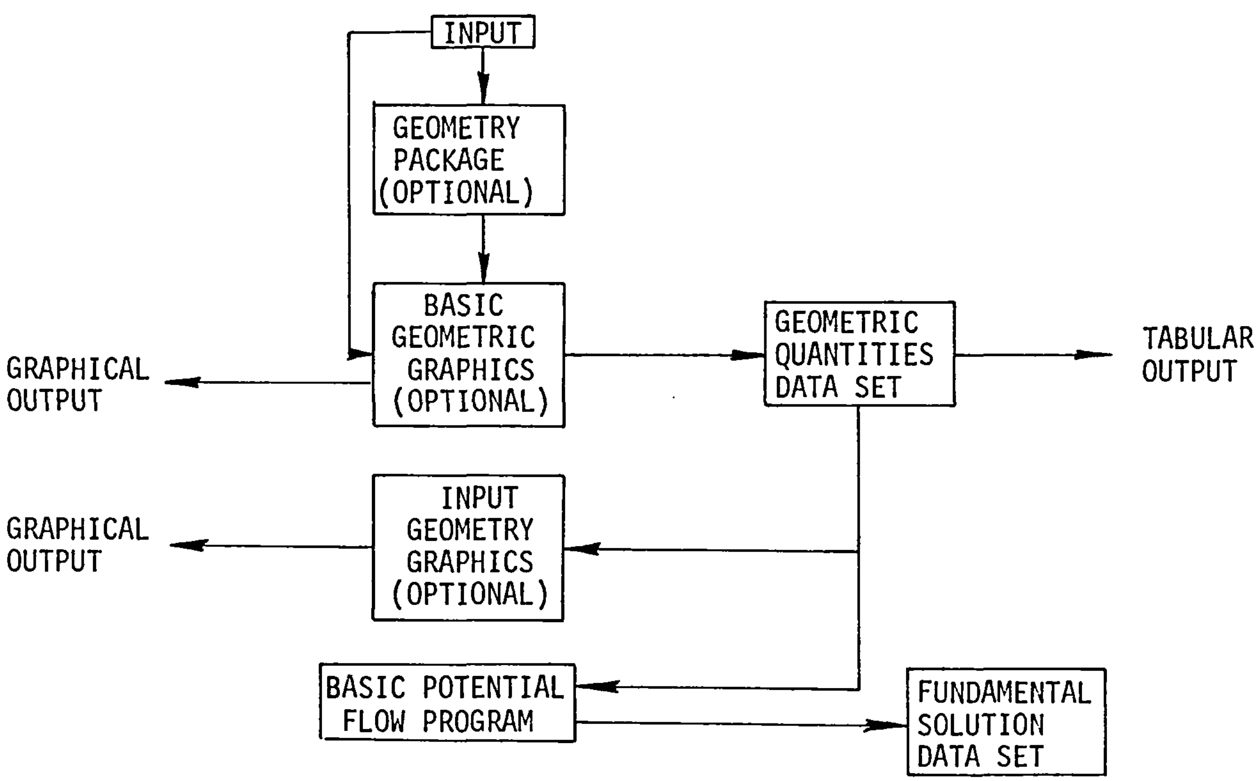
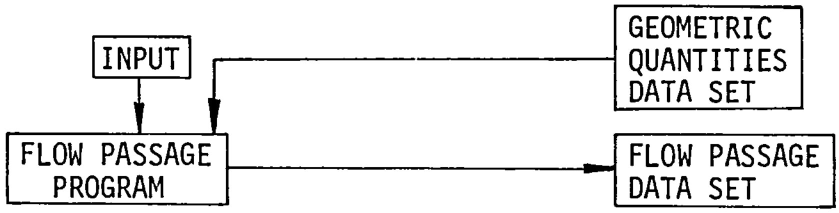
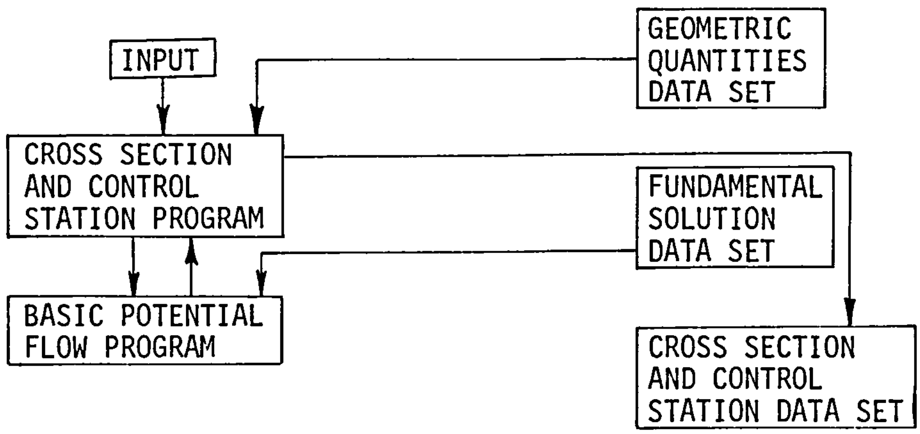


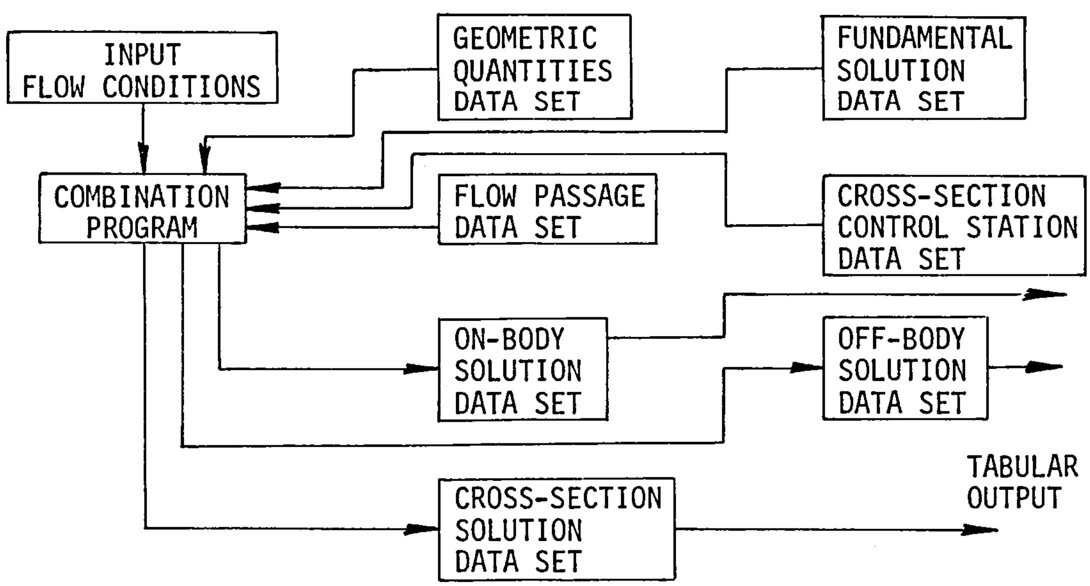
Figure 5. Logic of generating the fundamental flow solutions.



(a) Flow Passage Program



(b) Cross-Section and Control Station Program



(c) Combination Program

Figure 6. Logic of calculating flow at a specified inlet operating condition from the fundamental flow solutions.

6.0 PROCEDURE FOR NONSYMMETRIC CASES

6.1 Basic Potential-Flow Program

This program is very similar to the ordinary lifting panel method of reference 2. It differs: (1) in replacing the Kutta condition by a mass flow condition, (2) in the procedure for cases with symmetry, and (3) in the computation and storage of individual flow solutions.

Solutions are obtained for three uniform onset flows, one parallel to each coordinate axis. Thus the flow components are: (1, 0, 0), (0, 0, 1) and (0, 1, 0). A solution is also obtained corresponding to a uniform vorticity on each lifting strip. If there is no symmetry, all solutions use the same matrices $\vec{V}_{ij}$ and A_{ij}, representing velocity at the ith control point due to a unit source density on the jth panel (see reference 2 for detailed definitions).

Source density solutions are obtained for the three uniform and L nonuniform vorticity onset flows, where L is the number of lifting strips. These last are denoted $\sigma_j^{(k)}$, $j = 1, 2, \ldots, N$, $k = 1, 2, \ldots, L$.

The L sets of source densities for the vorticity solutions are combined into a single set by assigning the relative vorticity strengths $B^{(k)}$, $k = 1, 2, \ldots, L$. There are two options:

1. Constant option: All the vorticity strengths $B^{(k)}$ are simply set equal to unity.
2. Input option: A set of L numbers $B^{(k)}$ are input.

In either case the sets of σ are combined by the formula:

$$\sigma_j^{(s)} = \sum_{k=1}^{L} B^{(k)} \sigma_j^{(k)}, \qquad j = 1, 2, \ldots, N \tag{1}$$

where the subscript j denotes values on the jth panel and N is the total number of panels. This set $\sigma_j^{(s)}$ is denoted the static solution. There are thus four sets of source densities and four onset flow velocities: one for each of the three uniform flows and one for the static solution. The onset flow velocity at the ith control point for the static case is given by

$$\vec{V}_{io}^{(s)} = \sum_{k=1}^{L} B^{(k)} \vec{V}_{io}^{(k)} \tag{2}$$

where the $\vec{V}_{io}^{(k)}$ are the onset flows for the individual strip vorticity solutions.

These source densities and onset flow velocities are used with the influence coefficient matrices in the usual way to obtain on-body and off-body velocities. The new feature is that this is done for all four individual flows. These velocity distributions, and source densities for the individual flows form the fundamental solution data set. After these solutions have been stored, the matrices $\vec{V}_{ij}$ and A_{ij} are destroyed.

6.2 Cross Sections and Control Station

The cross section and control station program furnishes sets of off-body points to the program. Say there are C cross sections specified, each with P points. Moreover, each cross section has its own normal vector. Velocities at each of the CP off-body points are calculated for each of the four onset flows. For each point this involves calculating a new row of the $\vec{V}_{ij}$ matrix including the vorticity onset flows, and then performing summations of the form

$$\vec{V}_{i}^{(f)} = \sum_{j=1}^{N} \vec{V}_{ij} \sigma_{j}^{(f)} + \vec{V}_{io}^{(f)} \tag{3}$$

using the source densities $\sigma_j^{(f)}$ and onset flows $\vec{V}_{io}^{(f)}$ from the fundamental solution data set. The complete set of: off-body points, flow velocities, boundary points (where the cross-section intersects the on-body N-lines), areas, normal vectors and mass flows at each cross section comprise the cross section and control station data set. The areas and mass flows are obtained by numerical integration. One particular cross section is specified as the control station, and data for it are used in the combination program.

6.3 Combination Program (Excluding Mach Number)

To obtain an incompressible combined solution, the basic input consists of: angle of attack α, angle of yaw β, freestream velocity V_∞ and mass flow

Q at the control station. The combined velocity (or source density) formula is

$$\vec{V}_i = V_\infty[\cos\alpha \cos\beta \vec{V}_i^{(100)} + \sin\alpha \vec{V}_i^{(001)} + \cos\alpha \sin\beta \vec{V}_i^{(010)}] + B\vec{V}_i^{(s)} \tag{4}$$

The V_i's on the right are the individual fundamental solutions. The single constant B is evaluated from the mass flow Q at the control station by

$$BQ^{(s)} = Q - V_\infty[\cos\alpha \cos\beta Q^{(100)} + \sin\alpha Q^{(001)} + \cos\alpha \sin\beta Q^{(010)}] \tag{5}$$

where the Q's are the individual mass flows from the control station data set.

After an incompressible combined velocity has been calculated as above, a compressibility correction is applied if a nonzero Mach number has been specified. The flow passage program calculates a flow passage area for every on-body and cross-section point. For each point this area is used together with the incompressible velocity in a compressibility correction program to yield compressible velocity and pressure. A normal output is accomplished for each Mach number. These calculations are discussed in subsequent sections.

7.0 PROCEDURE FOR SYMMETRIC CASES

The symmetry procedure for inlets differs in two important respects from the symmetry procedures for an ordinary lifting case: the use of two flow matrices and the generation of twice the usual amount of output. This section refers to the nonsymmetric description (Section 6.0) for all portions of the calculation that are similar.

7.1 Input and Geometric Output

As is done in the ordinary lifting panel method of reference 2, only the half-body for which $y \geq 0$ is input, and the tabular output of control points, etc., i.e., the basic geometric quantities, is for the half-body. However, the graphical output (if any) is for the complete body, so before entering the graphics program the other half of the body is generated by reflection. Each reflected panel is obtained from a basic (input) panel by changing the signs of five geometric quantities (reference 2). Each input section has its corresponding reflected section. Thus there is twice as much geometry entering the graphics program as was input.

7.2 Basic Potential-Flow Program

The major change here is that two complete $\vec{V}_{ij}$ and A_{ij} are calculated and stored: one calculated by the procedure for a plus symmetry plane and one for a minus symmetry plane. These correspond, respectively, to flows that are symmetric and antisymmetric about the symmetry plane. These are calculated together. After a $\vec{V}_{ij}$ has been calculated for both a panel and its reflection, the two influences are added to get the influence appropriate to a plus symmetry plane and subtracted to obtain the influence appropriate to a minus plane. Both are saved in different places, so that finally the plus and minus $\vec{V}_{ij}$ and A_{ij} matrices are stored separately. All matrices are of order N, where N is the number of input panels (half the body).

The vorticity onset flows are calculated by the procedure appropriate to a plus symmetry plane only. They are summed in the manner of Section 6.1 to obtain a static onset flow.

The fundamental flow solutions, source density and velocity, are obtained in the usual way using the plus matrix for all flows except the uniform onset flow (0, 1, 0) which corresponds to pure yaw and using the minus matrix for that one flow. In particular, the plus matrix is used for the two uniform onset flows (1, 0, 0) and (0, 0, 1) and for the static onset flow. Each flow solution is only for the half-body that was input, i.e. N on-body points and off-body points having $y \geq 0$.

7.3 Cross-Sections and Control Stations

Off-body points, normal vectors and boundary points are calculated as in the nonsymmetric case but only for $y \geq 0$. When calculating velocity influences from the $\vec{V}_{ij}$ matrices both plus and minus influences must be calculated. The minus influences (matrix row) are used with the solution for the flow (0, 1, 0) and the plus influences for all other fundamental solutions. The cross-section and control station data set is generated in the usual way, except the computed areas are doubled, and mass flows Q_k are doubled except for the (0, 1, 0) solution where the mass flow is set equal to zero.

7.4 Combination Program (Excluding Mach Number)

The combination constant B is determined as in the nonsymmetric case, equation (5). The combined incompressible velocity is obtained from the fundamental flow solutions by equation (4) for the control points of the input ($y \geq 0$) panels. Another complete set of output is produced for the control points of the reflected panels. The geometry of the reflected panel is obtained by changing certain signs. In particular the reflected control point coordinates are x_0, $-y_0$, z_0 and the normal vector is n_x, $-n_y$, n_z, where the unsigned quantities are for the input panel.

The velocity components at the reflected control point are obtained from equation (4) using the same fundamental flow components but with certain sign changes. These changes are

	Solution for (010)	All Other Solutions
Sign(s) Changed	x-component z-component	y-component

This holds for off-body points as well.

The flow passage program must be altered to reflect symmetry and to compute flow passage area for both basic (input) and reflected panels. The flow passage area corresponding to the control point of a reflected panel is set equal to the flow passage area corresponding to the associated basic panel. Compressible velocities and pressures are then computed for both basic and reflected panels in the same way as for a nonsymmetric case.

Thus, there is twice as much output as for a nonsymmetric case having the same number of input points.

8.0 FLOW PASSAGE AREA CALCULATION

The compressibility correction of reference 3 requires a flow passage area to be associated with each point where compressible velocities are to be computed. At points interior to an axisymmetric inlet (either on or off the surface), the proper choice of such an area is straightforward. It is the area of the circular cross section of the interior of the inlet at the axial location of the point in question. The area may be constructed geometrically by passing a plane through the point in question normal to the axis of symmetry of the inlet and then finding the intersection of this plane with the interior surface of the inlet. If a centerbody is present, its intersection with the plane is also computed. The flow passage area is then the area contained within the closed curve defining the inlet intersection minus the area contained with the closed curve defining the centerbody intersection.

Determination of the flow passage area for interior points of a three-dimensional inlet is also straightforward and indeed can be accomplished by essentially the above procedure provided: (1) the inlet (and centerbody) has a straight centerline and (2) the inlet highlight lies in a plane perpendicular to the centerline. In such cases the centerline plays the role of the symmetry axis in the construction of the previous paragraph. However, for general three-dimensional inlets, e.g., inlets with curved centerlines or scoop inlets, the proper definition of the flow passage area is not obvious. In constructing the present program it was decided that the program would automatically calculate flow passage areas for all interior points and that this calculation would be entirely geometrical. To accomplish this it was necessary to assume that the inlet highlight lies approximately in a plane, although the orientation of this plane is arbitrary. The centerline of the inlet is defined by the user who inputs a set of centerline points.

At points exterior to the inlet (either on or off the surface) the concept of flow passage area becomes less significant and its definition somewhat arbitrary. Nevertheless, flow passage areas have been defined for points on the surface in a manner that has yielded reasonable compressible velocities in a limited number of preliminary cases. The program automatically calculates these areas. Selection of flow passage areas for exterior off-body points is currently an unsolved problem.

The remaining subsections of Section 8.0 present the details of the flow passage area calculation.

8.1 Organization of the Input

The restrictions on the body geometry and the order of input are set forth in Section 4.0. The result is a configuration as shown in Figure 7. Specifically, there is one inlet (lifting body) and either one or no centerbody (nonlifting body). The N-lines on the inlet are input from lower surface "trailing edge" to leading edge to upper surface "trailing edge." In this context the lower surface is inside the inlet, and the upper surface is outside. Thus, for example, the top of the inlet — both inside and outside — is a single N-line, and the bottom — both inside and outside — is a different N-line, as shown in Figure 7. All N-lines on the centerbody (if any) are assumed to start at a certain "initial point" and to proceed downstream. Thus, in particular, the top and bottom of the centerbody are different N-lines.

The centerline of the inlet is input as a set of points and normal vectors beginning with a certain initial point and continuing downstream (Figure 7). While normally the input centerline corresponds to the physical centerline, it need not. The input centerline is a device for calculating flow passage areas. In particular, the initial centerline point and vector define the inlet lip or highlight.

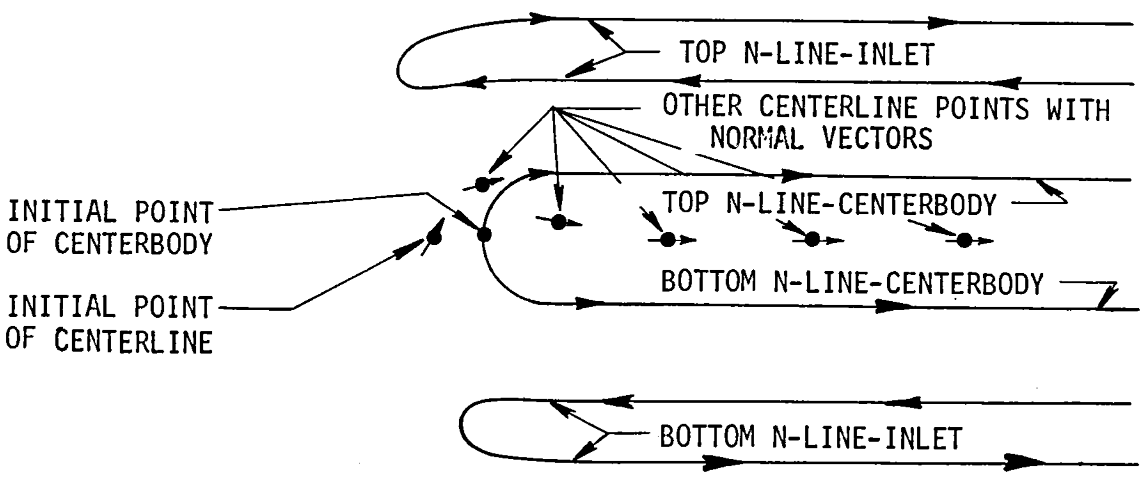


Figure 7. Input to the program including the centerline points used to calculate flow passage areas.

8.2 Intersection Program

The basic calculational unit is a subroutine that takes a segmented line (N-line) and finds the point of intersection with a plane: the coordinates of the intersection and the number of the segment it is on. The plane is defined by a point and a normal vector. The routine also has the capability of computing the area bounded by a set of intersection points obtained for several N-lines.

8.3 Initial Centerline Point

The initial centerline point and its vector are key input quantities. Together they define a plane whose intersection curve with the inlet defines inside and outside. More specifically, this plane should intersect the panels on each side (interior and exterior) of the inlet highlight. This is easy to arrange if the inlet has a highlight that lies in a plane all around the inlet. The plane of the initial centerline point then is parallel and slightly downstream. If the inlet highlight is not plane, the plane of the initial centerline point should be as near the highlight as possible and should intersect the inlet all the way around. More specifically the plane defined by the initial centerline point and its normal vector must have exactly two intersection points on each N-line of the inlet, otherwise the calculation ceases with an error message. For the centerbody there is either one intersection point on each N-line or there are no intersection points on any N-line. The Intersection Program calculates the plane's intersection points with all N-lines.

8.4 Interior and Exterior Points of the Inlet

Points on all N-lines are classified as either interior or exterior and a designation must be added to the data describing each control point. On the inlet for each N-line the one of the two intersection points that is closer to the initial centerline point is designated an interior N-line point. Then, on the strip of panels adjacent (following) the N-line, the control point of the panel adjacent to the segment containing the closer intersection point is designated the "last interior control point." (If the k-th segment of the N-line contains the intersection point, the control point of the k-th element of the strip is the desired one.) It and all preceeding control points of the strip are labelled interior. All succeeding control points of the strip are labelled exterior.

If there are no intersection points with the N-lines of the centerbody, then all control points of the centerbody are labelled interior. If there is an intersection point on one segment of each N-line of the centerbody, the control point of the panel adjacent to that segment is denoted the "first interior control point." It and all succeeding control points of the strip are labelled interior. All preceeding control points are labelled exterior.

8.5 Initial Flow Passage Area

For the inlet, the interior intersection points (interior N-line points) are collected into one list and the exterior intersection points into another list. (These last are the intersection points on each N-line further from the centerline point.) Using the intersection program, areas are computed for both these sets of points: the interior area A_i and the exterior A_e. If there are intersection points of the plane with the centerbody, the area enclosed by these points is called A_c. Define

$$
\begin{aligned}
A_{FP} &= A_i - A_c \\
A^*_{FP} &= A_e - A_c
\end{aligned}
\qquad (6)
$$

If there are no intersection points with the centerbody then

$$
\begin{aligned}
A_{FP} &= A_i \\
A^*_{FP} &= A_e
\end{aligned}
\qquad (7)
$$

Next arc lengths are computed along N-lines from the initial point to the intersection points: the interior and the exterior points on each N-line of the inlet and the point (if any) on each N-line of the centerbody. For a segment containing an intersection, the arc length up to the first point of that segment is given by the method of reference 2. The additional arc length to be added to get the arc length of the intersection point is found by computing the usual straightline distance between the intersection and the first point of the segment.

The area A_{FP}^* is associated with the arc lengths corresponding to the exterior intersection for all N-lines of the inlet. The area A_{FP} is associated with the arc lengths corresponding to the interior intersection for all N-lines of the inlet and also for all N-lines of the centerbody, if any.

8.6 Successive Flow Passage Areas

The procedure of Sections 8.3, 8.4, 8.5 above is repeated for all of the imput centerline points. A plane is passed through each centerline point having its normal vector identical with the centerline tangent vector. Interior and exterior intersection points are found on each N-line of the inlet and a single intersection point on each N-line of the center body (if applicable). The areas A_{FP} and A_{FP}^* are calculated from (6) or (7) and associated with the arc lengths corresponding to the intersections (interior and exterior) on the inlet N-lines and the centerbody N-lines as described in Section 8.5. Thus, tables of area versus arc length are constructed (Section 8.8).

8.7 Possibilities for the Centerbody

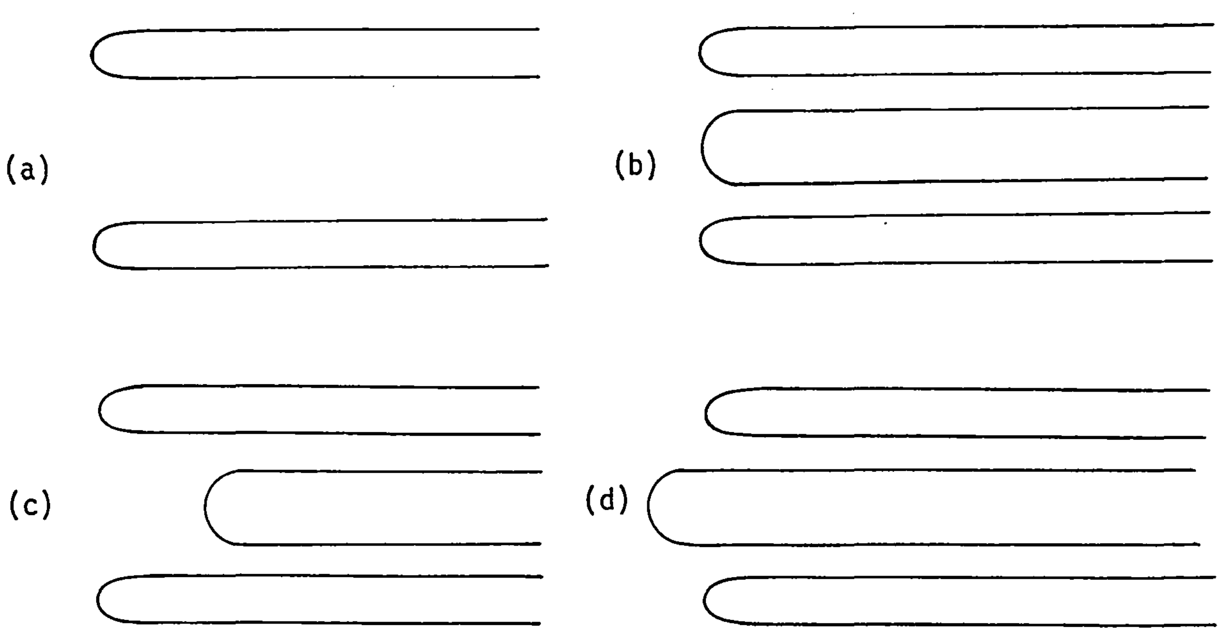


Figure 8. Possibilities of the centerbody.

There are four possibilities for the location of the centerbody, some of which require slightly different logic.

a. No Centerbody: This case is identified by input flag. Equation (7) is used for all points of the inlet, and, of course, no area table is constructed for the centerbody.

b. Centerbody Abreast of Inlet Highlight: This case is identified by the fact that the intersections of the centerbody N-lines with the initial centerline plane occur on the first segments of those N-lines. Equations (6) are used for all intersection points, and a table of area versus arc length is prepared for each N-line of the centerbody using the areas of (6). Tables for the centerbody have the same length as those for the inlet N-lines except for the one additional exterior intersection on each of the latter (Section 8.8).

c. Centerbody Downstream of Inlet Highlight: This case is identified by the fact that there are no intersection points of the initial centerline plane with any of the N-lines of the centerbody, but there is a centerbody. This situation may exist for the first several centerline points. Eventually, a centerline point is reached that is the first whose plane intersects the centerbody. Call this the centerbody point (not necessarily the same as the initial centerbody point where the N-lines start). Equations (7) are used for the intersections corresponding to the centerline points preceeding the centerbody point. Equations (6) are used for the intersections corresponding to the centerbody point and all succeeding points. It is only for the latter cases that there are intersections on the centerbody. Tables of area versus arc length are prepared for all N-lines on the inlet and the centerbody, but the centerbody tables are shorter, because their entries begin with the centerbody point, while those of the inlet begin with the initial centerline point.

d. Centerbody Upstream of Inlet Highlight: This case is characterized by the fact that there are intersections of the N-lines with the initial centerline plane, and these are not on the first segments of the centerbody N-lines. Just as in (b), equation (6) is used to compute areas for all interior intersections on both inlet and centerbody N-lines, but now there are additional expressions to assign values of flow passage area at points of the centerbody upstream of the inlet lip (Section 8.10).

8.8 Arc Length Tables. Interpolation for Flow Passage Areas at Interior Control Points

When the various tasks of Sections 8.3 or 8.7 have been accomplished, flow passage areas A_{FP} have been associated with the arc lengths corresponding to interior intersection points on both inlet and centerbody N-lines. For each N-line a table of area A_{FP} versus arc length can be constructed.

For each inlet N-line, the first entry in the table is the area A^*_{FP} associated with the exterior intersection for the initial centerline point. The second entry is the area A_{FP} associated with the interior intersection for the initial centerline point. Successive entries are the areas A_{FP} for the interior intersections for the successive centerline points, i.e.,

Entry	Associated Arc Length	Area
1	S_1	A^*_{FP} (ext. Initial centerline point)
2	S_2	A_{FP} (int. initial centerline point)
3	S_3	A_{FP} (int. 2nd centerline point)
4	S_4	A_{FP} (int. 3rd centerline point)
.		
.		
.		
Last	S_{LAST}	A_{FP} (int. last centerline point)

Notice this table is in decreasing magnitude of arc length.

For each centerbody N-line the first entry is the area A_{FP} associated with the first intersection point. This is obtained from the initial centerline point in cases b and d of Section 8.7, but from some other centerline point in case c. Successive entries are the areas A_{FP} for successive centerline points. This table is in increasing magnitude of arc length.

Interpolation in arc length is performed in the above tables to obtain flow passage areas at the midpoints of the segments of each N-line.

Once the above has been accomplished, the flow passage areas for the control points must be obtained. This is obtained by averaging the areas for the midpoints on the two segments bounding the panel on which the midpoint is located. Specifically, the area to be associated with the control point of the k-th panel of a strip is obtained by averaging the areas associated with the midpoints of the k-th segments of the two successive N-lines bordering the strip.

The above procedure is used to obtain flow passage areas A_{FP} at the interior control points of the inlet and the centerbody body. The exterior control points require special handling.

8.9 Flow Passage Areas at Exterior Control Points on the Inlet

The area A^*_{FP} defined in Section 8.5 is not really a flow passage area but is merely a geometric area. It is used to obtain flow passage areas at exterior control points. As mentioned above, the definition of such an area is somewhat arbitrary, but the one adopted has given encouraging results. It is important to emphasize that even if the results at exterior points should turn out less accurate than desired, it would not affect the accuracy of interior points, for which the compressibility correction has been thoroughly verified in a large number of cases.

Initially the A^*_{FP} are handled in a manner similar to the internal flow passage areas A_{FP} to obtain a value of A^*_{FP} at each exterior control point. Additionally, however, two special values of A^*_{FP} are needed: an initial value A_0 near the inlet highlight and a final value A_L far downstream on the afterbody.

Key quantities for this computation come from the intersection with the N-lines of the inlet with the plane for the initial centerline point. For each N-line there are the coordinates x_i, y_i, z_i of the intersection point (interior) and the flow passage area A_{FP}. All four of these quantities are averaged between successive N-lines (a two-point average to produce an initial point (x_0, y_0, z_0) and an initial area A_0 for the strip of panels lying between the two N-lines in question). Further, the coordinates of the last intersection on each N-line (from the last centerline point) are averaged between successive N-lines to produce coordinates x_L, y_L, z_L of the last point on the strip lying between the two N-lines, and a similar average of areas A^*_{FP} gives the final area A_L.

Also needed are the exterior geometric areas A^*_{FP} for the exterior control points. These are obtained by interpolation in a manner similar to that described above for interior control points. For each N-line a table of area versus arc length is constructed for the intersection points. The first entry in the table is the area A_{FP} corresponding to the interior intersection for the initial centerline point. The second entry is the area A^*_{FP} associated with the exterior intersection for the initial centerline point. Successive entries are the areas A^*_{FP} for the exterior intersections for successive centerline points, i.e.,

Entry	Arc Length	Area
1	S_1	A_{FP} (int. initial centerline point)
2	S_2	A^*_{FP} (ext. initial centerline point)
3	S_3	A^*_{FP} (ext. 2nd centerline point)
4	S_4	A^*_{FP} (ext. 3rd centerline point)
.		
.		
.		
Last	S_{LAST}	A^*_{FP} (ext. last centerline point)

The table is in increasing magnitude of arc length.

Interpolation in arc length is performed in the above table to obtain areas A^*_{FP} at the midpoints of the segments of each N-line, whose arc length is calculated in the manner described in Section 8.8. These midpoint areas are averaged between successive N-lines to obtain areas A^*_{FP} at the exterior control points.

The geometric area A^*_{FP} associated with each exterior control point, together with the control point coordinates x, y, z, is used to obtain the following linear dimensions needed to compute the exterior flow passage area.

$$y' = \sqrt{(1/\pi)A^*_{FP}}\ , \qquad R = \sqrt{(y')^2 + (x - x_o)^2}, \qquad D = \frac{(y' - y'_o)}{(y'_L - y'_o)} \tag{8}$$

$$y'_o = \sqrt{(1/\pi)A_o}, \qquad y'_L = \sqrt{(1/\pi)A_L}$$

Finally, the flow passage area associated with the control point for use with the compressibility correction is

$$A_{FP} = [1 + D]\pi R[R + x - x_o] \tag{9}$$

Equation (9) gives a flow passage area that varies from a value near the inlet highlight that is approximately equal to the highlight disk area to an area far downstream that equals the surface area of a sphere centered at the highlight minus the final cross section of the inlet. This area distribution is approximately that through which the flow passes in the case of static operation.

8.10 Flow Passage Areas at Exterior Control Points of the Centerbody

The first step is to compute the cross-sectional area of the centerbody at selected "axial" locations. To do this, a set of centerline points upstream of the inlet highlight are input. These are used in the same way as centerline points as far as computing intersections and areas except that: (1) these points are input and used only in case d of Section 8.7, and (2) intersections and areas are found only on the N-lines of the centerbody.

The resulting areas A_c are interpolated in arc length to find areas at the control points in the same manner as in Section 8.8. Finally, the flow passage area to be saved with each exterior control point on the nonlifting centerbody is

$$A_{FP} = A_i - A_c \tag{10}$$

where A_i is the area computed in Section 8.5 for the initial interior intersection. Comparing equation (6) (which applies here rather than (7)) and the definitions in Section 8.9 shows that

$$A_i = A_o + A_c \quad \text{(initial centerline point)} \tag{11}$$

The A_c in (11) is that for the initial centerline point. The A_c in (10) is that for the control point in question. Also, A_o is defined in Section 8.9.

8.11 Flow Passage Areas for Off-Body Points

There are two types of off-body points: ordinary input off-body points and off-body points generated by the cross-section and control station program. The latter are always interior points, and the flow passage area is calculated by that program (Section 9.0). It is anticipated that all interior off-body points will be so generated. Thus, input off-body points will be exterior points. It is not clear at this time how the flow passage areas for such points should be defined, and this decision has been postponed. Thus input off-body points should not be used in compressible cases.

9.0 CROSS-SECTION AND CONTROL STATION PROGRAM

In inlet applications it is not only the flow on the body that is of interest but also the flow at field points off the body, usually in the interior of the inlet. Most commonly, distributions of various flow quantities across some interior cross sections of the inlet are desired. Of course, off-body points could simply be input to the program, but this is tedious for the user. Instead, the program generates the required off-body points at each cross section. The user specifies the location and orientation of each cross section where flow calculation is required, and the program automatically distributes off-body points across the cross section. It is this last calculation that distinguishes a cross-section calculation from the flow passage area calculation of Section 8.0. One cross section is selected as the control station for the combination program and thus at least one cross section is required if a combined flow is to be computed. The remaining subsections of Section 9.0 give the details of the cross-section procedure.

9.1 Input

Each cross section is defined by a cross-section point and normal vector (six numbers) which are used in a manner very similar to the way a centerline point and its normal vector are used in the flow passage program (Figure 7). However, more calculations are required for a cross section. One additional input integer designates which cross section is to be used as the control station in the combination program. Another input integer specifies the number of "radial" segments to be used at each cross section. This latter number is denoted r.

9.2 N-Line Intersections and Flow Passage Area

The intersection program is used to find the intersection points of the N-lines with the plane through the cross-section point whose normal vector is the input cross-section normal vector. On the N-lines of the inlet only the interior intersection points are needed. The exterior intersection points are discarded. If there are intersections with the N-lines of the centerbody, these points are needed. The areas A_i and A_c (if any) are computed as in Section 8.5, and the flow passage area is computed from (6) or (7) as appropriate.

9.3 Cross-Section N-lines

Two situations must be distinguished: the case when there are intersections with the N-lines of the centerbody and the case when there are no such intersections.

9.3.1 No centerbody. — Cross-section N-lines are to be constructed, each of which starts at the cross-section point and ends at an intersection point on an inlet N-line. Clearly one cross-section N-line is constructed for each inlet N-line. For each cross-section N-line the first point is the cross-section point, the last is the intersection point on the inlet N-line, and the interior points are obtained by interpolation (Figure 9).

Let x_{cs}, y_{cs}, z_{cs} be the coordinates of the input cross-section point and $x_i^{(k)}$, $y_i^{(k)}$, $z_i^{(k)}$ be the coordinates of the intersection point on the k-th inlet N-line, k = 1, 2, ..., T, where T is the total number of inlet N-lines. The points on the k-th cross-section N-line have the coordinates

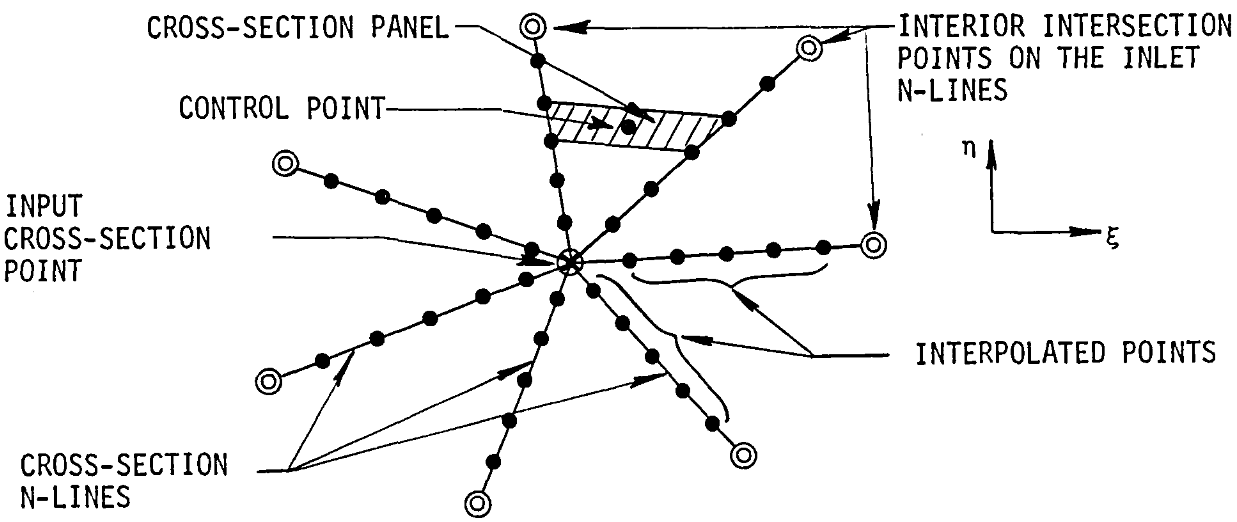


Figure 9. Generation of cross-section points and panels in the absence of a centerbody.

$$x_m^{(k)} = x_{cs} + \left[x_i^{(k)} - x_{cs}\right] \frac{m}{r}$$

$$y_m^{(k)} = y_{cs} + \left[y_i^{(k)} - y_{cs}\right] \frac{m}{r}, \qquad m = 0, 1, \ldots, r \qquad (12)$$

$$z_m^{(k)} = z_{cs} + \left[z_i^{(k)} - z_{cs}\right] \frac{m}{r}, \qquad k = 1, 2, \ldots, T$$

where r is the input integer mentioned in Section 9.1. Each cross-section N-line has $(r + 1)$ points.

9.3.2 With centerbody. — Cross-section N-lines are to be constructed, each of which starts at an intersection point on a centerbody N-line and ends at an intersection point on an inlet N-line. For each cross-section N-line the first point is the centerbody intersection point, the last is the inlet intersection point, and the interior points are obtained by interpolation (Figure 10).

It is assumed that there are the same number of inlet and centerbody N-lines, say T of each; clearly there are T cross-section N-lines.

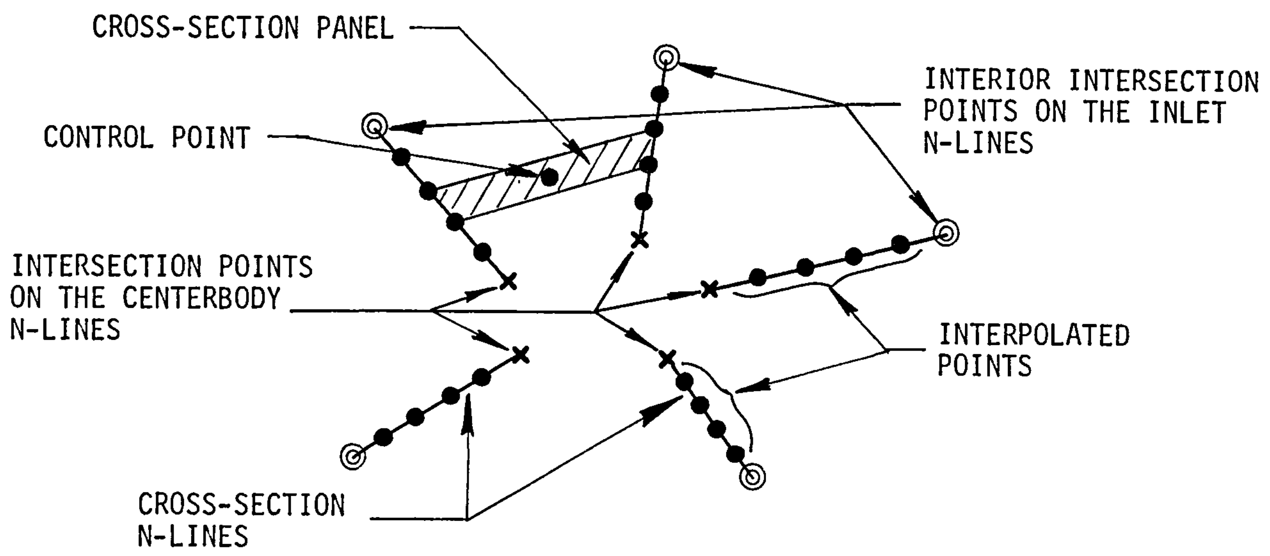


Figure 10. Generation of cross-section points and panels in the presence of a centerbody.

Let $x_c^{(k)}$, $y_c^{(k)}$, $z_c^{(k)}$ be the coordinates of the intersection on the k-th centerbody N-line and, as before, let $x_i^{(k)}$, $y_i^{(k)}$, $z_i^{(k)}$ be the coordinates of the interior intersection point on the k-th inlet N-line where $k = 1, 2, \ldots, T$. The points of the k-th cross-section N-line have the coordinates

$$
\begin{aligned}
x_m^{(k)} &= x_c^{(k)} + \left[x_i^{(k)} - x_c^{(k)}\right]\frac{m}{r}, \\
y_m^{(k)} &= y_c^{(k)} + \left[y_i^{(k)} - y_c^{(k)}\right]\frac{m}{r}, \qquad m = 0, 1, \ldots, r \\
z_m^{(k)} &= z_c^{(k)} + \left[z_i^{(k)} - z_c^{(k)}\right]\frac{m}{r}, \qquad k = 1, 2, \ldots, T
\end{aligned}
\tag{13}
$$

As before, each N-line has $r + 1$ points.

9.4 Cross-Section Panels and Control Points

Cross-section panels are formed from the points of the cross-section N-lines in a manner logically similar to (but using different formulas than) that used to form surface panels from the on-body N-lines. In particular, a panel is formed from four points, which consist of two consecutive points on an N-line and the corresponding two points on the adjacent N-line. Symbolically, the m-th panel of the k-th cross-section strip is formed from the points:

$$
\begin{aligned}
&\left[x_{m-1}^{(k)}, \quad y_{m-1}^{(k)}, \quad z_{m-1}^{(k)}\right] \\
&\left[x_{m}^{(k)}, \quad y_{m}^{(k)}, \quad z_{m}^{(k)}\right] \\
&\left[x_{m-1}^{(k+1)}, \quad y_{m-1}^{(k+1)}, \quad z_{m-1}^{(k+1)}\right] \\
&\left[x_{m}^{(k+1)}, \quad y_{m}^{(k+1)}, \quad z_{m}^{(k+1)}\right]
\end{aligned}
\tag{14}
$$

In parallel to the on-body procedure, first the diagonal vectors

$$
\begin{aligned}
\vec{R}_1 &= \left[x_m^{(k+1)} - x_{m-1}^{(k)}\right]\vec{i} + \left[y_m^{(k+1)} - y_{m-1}^{(k)}\right]\vec{j} + \left[z_m^{(k+1)} - z_{m-1}^{(k)}\right]\vec{k} \\
\vec{R}_2 &= \left[x_{m-1}^{(k+1)} - x_m^{(k)}\right]\vec{i} + \left[y_{m-1}^{(k+1)} - y_m^{(k)}\right]\vec{j} + \left[z_{m-1}^{(k+1)} - z_m^{(k)}\right]\vec{k}
\end{aligned}
\tag{15}
$$

are formed. These are in the cross-section plane.

The unit normal vector is the same for all panels on all strips. It is the input cross-section normal vector divided by its own length, say

$$\vec{n} = n_x\vec{i} + n_y\vec{j} + n_z\vec{k} \tag{16}$$

where

$$n_x = \frac{N_x}{N}, \qquad n_y = \frac{N_y}{N}, \qquad n_z = \frac{N_z}{N}, \qquad N = \sqrt{N_x^2 + N_y^2 + N_z^2} \tag{17}$$

and where N_x, N_y, N_z are the input components. The unit tangent vectors are the same for all panels on all strips. Define

$$\begin{aligned} \vec{T}_2 &= \vec{n} \times \vec{j} = -n_z\vec{i} + 0\vec{j} + n_x\vec{k}, \\ \vec{T}_1 &= \vec{T}_2 \times \vec{n} = -n_x n_y\vec{i} + (n_x^2 + n_z^2)\vec{j} - n_y n_z\vec{k} \end{aligned} \tag{18}$$

These vectors are divided by their own lengths to obtain unit vectors

$$t_{1x} = \frac{T_{1x}}{T_1}, \quad t_{1y} = \frac{T_{1y}}{T_1}, \quad T_{1z} = \frac{T_{1z}}{T_1}, \quad T_1 = \sqrt{T_{1x}^2 + T_{1y}^2 + T_{1z}^2} \tag{19}$$

and the same for t_{2x}, t_{2y}, t_{2z}. These are used as a transformation matrix (just one matrix for all panels)

$$\begin{aligned} a_{11} &= t_{1x}, & a_{12} &= t_{1y}, & a_{13} &= t_{1z} \\ a_{21} &= t_{2x}, & a_{22} &= t_{2y}, & a_{23} &= t_{2z} \\ a_{31} &= n_x, & a_{32} &= n_y, & a_{33} &= n_z \end{aligned} \tag{20}$$

The area of a panel is given by

$$A = \frac{1}{2}\vec{R}_1 \times \vec{R}_2 \cdot \vec{n} = \frac{1}{2}\begin{vmatrix} R_{1x} & R_{1y} & R_{1z} \\ R_{2x} & R_{2y} & R_{2z} \\ n_x & n_y & n_z \end{vmatrix} \quad \text{(a determinant)} \tag{21}$$

The control-point of the panel, which is treated as an off-body point in the flow calculation, has coordinates

$$x_o = \frac{1}{4}\left[x_{m-1}^{(k)} + x_m^{(k)} + x_{m-1}^{(k+1)} + x_m^{(k+1)}\right]$$

$$y_o = \frac{1}{4}\left[y_{m-1}^{(k)} + y_m^{(k)} + y_{m-1}^{(k+1)} + y_m^{(k+1)}\right] \tag{22}$$

$$z_o = \frac{1}{4}\left[z_{m-1}^{(k)} + z_m^{(k)} + z_{m-1}^{(k+1)} + z_m^{(k+1)}\right]$$

Also desired are the cross-section coordinates, ξ, η, of the control point. These are obtained by a transformation using the above transformation matrix and the cross-section point as origin. From formulas (18) - (20) it can be verified that if the cross section is normal to the x-axis, then the ξ axis is parallel to the y-axis and the η-axis to the z-axis. In all cases the η-axis is parallel to the $y = 0$ plane.

The quantities needed for each panel are

$$x_o,\ y_o,\ z_o,\ \xi,\ \eta,\ A \tag{23}$$

These are computed and stored for all panels on the cross-section — a total of $(T - 1)r$ panels.

Quantities needed for the cross section as a whole are

$$x_{cs},\ y_{cs},\ z_{cs} \qquad \begin{matrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{matrix} \qquad A_{FP} \tag{24}$$

Also needed for each cross section are the reference and cross-section coordinates of the boundary points. These are just the intersection points on the inlet N-lines. That is,

$$x_i^{(k)},\ y_i^{(k)},\ z_i^{(k)}, \qquad k = 1, 2, \ldots, T \tag{25}$$

together with the coordinates $\xi_i^{(k)}$, $\eta_i^{(k)}$ obtained by transforming these into cross-section coordinates. The same is done for the centerbody intersection points (if any);

$$x_c^{(k)},\ y_c^{(k)},\ z_c^{(k)} \tag{26}$$

and their transformed cross-section coordinates $\xi_c^{(k)}$, $\eta_c^{(k)}$.

9.5 Flow Calculation

The data generated above are used with: the basic potential-flow program, the geometric quantities data set, and the source densities from the fundamental solution data set. Each cross-section control point is treated as an off-body point, and the flow there is computed.

For each cross-section control point a row of $\vec{V}_{ij}$ matrix is computed by the usual formulas. Also calculated are the vorticity velocities at the off-body points due to each of the individual vorticity flows (one for each lifting strip). These last are combined with the B's in the same manner as for the on-body points to yield the static onset flow velocity in the form of equation (2).

Fundamental flow velocities are computed in a manner analogous to equation (3) for the cross-section control points, i.e.,

$$\begin{aligned}
\vec{V}_i^{(100)} &= \sum_{j=1}^{N} \vec{V}_{ij}\sigma_j^{(100)} + \vec{i} \\
\vec{V}_i^{(010)} &= \sum_{j=1}^{N} \vec{V}_{ij}\sigma^{(010)} + \vec{j} \\
\vec{V}_i^{(001)} &= \sum_{j=1}^{N} \vec{V}_{ij}\ {}^{(001)} + \vec{k} \\
\vec{V}_i(\text{static}) &= \sum_{j=1}^{N} \vec{V}_{ij}\sigma_j^{(s)} + \vec{V}_i^{(s)}
\end{aligned} \tag{27}$$

It is understood that in symmetry cases a different matrix $\vec{V}_{ij}$ is used for the 010 flow.

The above velocities are computed for each cross-section control point to form the cross-section data set. Also in this data set are the vector $\vec{F}$ and scalar F volume fluxes — one set for each fundamental solution. These are given by

$$\vec{F} = \sum_{\substack{\text{cross} \\ \text{section}}} \vec{V}_i A_i \tag{28}$$

and

$$F = \vec{F} \cdot \vec{n} \tag{29}$$

where $\vec{V}_i$ is identified with each of the four velocities above. A_i is the ith panel area. The scalar flux at the control station is needed in the combination program. In symmetry cases the F's calculated from the above equation are doubled and then the F corresponding to the 010 onset flow is set equal to zero.

10.0 COMBINATION PROGRAM INPUT AND PRELIMINARY CALCULATIONS

10.1 Incompressible Option

If the flow is incompressible, this option is selected and only the following quantities are input:

- V_∞ freestream velocity
- V_c average velocity at the control station
- V_{ref} reference velocity used in computing pressure coefficient
- α angle of attack
- β angle of yaw
- k integer denoting that the k-th input cross section is to be used as control station

The volume flux Q at the control station is obtained from

$$Q = V_c \cdot A_{FP}(k) \tag{30}$$

where $A_{FP}(k)$ is the area of the control station. This is used in equation (5) to evaluate the combination constant B. Then velocity is calculated from equation (4).

10.2 Freestream Conditions

For compressible flow the freestream conditions are defined by inputting angle of attack α, angle of yaw β, and three additional quantities:

either velocity V_∞ or Mach number M_∞

either total pressure P_t or static pressure P_s

either total temperature T_t or static temperature T_s

Then the preliminary calculations are as follows.

10.2.1 M_∞ input. –

(a) If P_t is input, P_s is given by

$$P_s = P_t\left(1 + \frac{1}{5} M_\infty^2\right)^{-3.5} \tag{31}$$

If P_s is input, P_t is given by

$$P_t = P_s\left(1 + \frac{1}{5} M_\infty^2\right)^{3.5} \tag{32}$$

If neither is input, the default is

$$P_t = 2116.23 \tag{33}$$

and P_s is as above.

(b) If T_t is input, T_s is given by

$$T_s = T_t\left(1 + \frac{1}{5} M_\infty^2\right)^{-1} \tag{34}$$

If T_s is input, T_t is given by

$$T_t = T_s\left(1 + \frac{1}{5} M_\infty^2\right) \tag{35}$$

If neither is input, the default is

$$T_t = 518.67 \tag{36}$$

and T_s is as above.

In either case stagnation and freestream sound speeds a_t and a_s are calculated from

$$a_t = 49\sqrt{T_t}, \qquad a_s = 49\sqrt{T_s} \tag{37}$$

and V_∞ from

$$V_\infty = a_t M_\infty\left(1 + \frac{1}{5} M_\infty^2\right)^{-1/2} \tag{38}$$

10.2.2 V_∞ Input. —

(a) If T_t is input, a_t is given by

$$a_t = 49\sqrt{T_t} \tag{39}$$

M_∞ is then calculated from

$$M_\infty = \frac{V_\infty}{a_t}\left[1 - \frac{1}{5}\left(\frac{V_\infty}{a_t}\right)^2\right]^{-1/2} \tag{40}$$

The remainder of the calculation proceeds as in 10.2.1 above.

(b) If T_s is input, a_s is given by

$$a_s = 49\sqrt{T_s} \tag{41}$$

and M_∞ by

$$M_\infty = V_\infty/a_s \tag{42}$$

The remainder of the calculation proceeds as in 10.2.1 above.

10.2.3 Additional Freestream Quantities. — Built into the program are constants

$$g = 32.174$$
$$R = 1715.63$$

The following quantities are calculated:

$$\begin{aligned} &\text{Total density:} && \rho_t = \frac{P_t}{RT_t} \\ &\text{Static density:} && \rho_s = \frac{P_s}{RT_s} \\ &\text{Dynamic pressure:} && q_\infty = 0.7P_t\left(\frac{P_s}{P_t}\right)M_\infty^2 \\ &\text{Pressure ratio:} && P_s/P_t \end{aligned} \tag{43}$$

Density ratio: ρ_s/ρ_t

Temperature/sea-level ratio: $\theta = \dfrac{T_t}{518.67}$ (43)

Pressure/sea-level ratio: $\delta = \dfrac{P_t}{2116.23}$

Critical speed: $a_* = a_t/\sqrt{1.2}$

Maximum velocity: $V_{max} = \sqrt{5}\, a_t$

Equivalent Incompressible Freestream velocity: $V'_\infty = V_\infty \left(\dfrac{\rho_s}{\rho_t}\right)$

Equivalent Incompressible Critical velocity: $a'_* = 0.6339a_*$

10.2.4 Summary. — Three freestream conditions are input: V_∞ or M_∞, P_t or P_s, T_t or T_s (or default values). Calculated and saved are

$$V_\infty,\ M_\infty,\ P_t,\ P_s,\ T_t,\ T_s,\ a_t,\ a_s$$

$$\rho_t,\ \rho_s,\ q_\infty,\ P_s/P_t,\ \rho_s/\rho_t,\ \theta,\ \delta \quad (44)$$

$$a_*,\ V_{max},\ V'_\infty,\ a'_*$$

Nineteen quantities altogether.

10.3 Control Station Conditions

Input consists of one of the following three quantities:

$\dot{w}$ inlet mass flow rate

V_c average velocity

M_c average Mach number

The remaining two must be calculated plus some additional quantities.

10.3.1 V_c Input. — ρ_c is given by

$$\rho_c = \rho_t \left[1 - \frac{1}{5}\left(\frac{V_c}{a_t}\right)^2\right]^{2.5} \tag{45}$$

$\dot{w}$ by

$$\dot{w} = g\rho_c V_c \frac{A_{FP}(k)}{144} \tag{46}$$

and M_c by

$$M_c = \frac{V_c}{a_t}\left[1 - \frac{1}{5}\left(\frac{V_c}{a_t}\right)^2\right]^{-1/2} \tag{47}$$

10.3.2 M_c Input. — V_c is given by

$$V_c = a_t M_c \left(1 + \frac{1}{5} M_c^2\right)^{-1/2} \tag{48}$$

Then ρ_c and $\dot{w}$ are obtained as in 10.3.1 above.

10.3.3 $\dot{w}$ Input. — Here V_c must be calculated iteratively by solving the equation

$$V_c = \frac{\dot{w}}{g(A_{FP}(k)/144)\rho_t\left[1 - 1/5(V_c/a_t)^2\right]^{2.5}} \tag{49}$$

starting with $V_c = 0$

Once V_c is known, M_c and ρ_c are obtained as in 10.3.1 above.

10.3.4 Additional Control-Station Quantities. — These are calculated as follows:

Pressure ratio: $(P_c/P_t) = \left[1 - \frac{1}{5}\left(\frac{V_c}{a_t}\right)^2\right]^{3.5}$

Density ratio: ρ_c/ρ_t (50)

$$\text{Dynamic pressure:} \quad q_c = 0.7P_t\left(\frac{P_c}{P_t}\right)M_c^2$$

$$\text{Velocity ratio:} \quad V_\infty/V_c \tag{50}$$

$$\text{Corrected mass flow:} \quad \dot{w}_{cor} = \dot{w}\,\frac{\sqrt{\theta}}{\delta}$$

$$\text{Equivalent Incompressible Average velocity:} \quad V_c' = V_c\left(\frac{\rho_c}{\rho_t}\right)$$

10.3.5 Summary. — One quantity, $\dot{w}$, V_c, or M_c is input. Quantities saved are

$$\dot{w},\ V_c,\ M_c,\ \rho_c,\ (P_c/P_t),\ (\rho_c/\rho_t),\ q_c,\ (V_\infty/V_c),\ \dot{w}_{cor},\ V_c'$$

A total of ten quantities.

10.4 Combination Calculation

The basic combined incompressible velocity at each on-body, off-body and cross-section point is obtained from equations (5) and (4), where

$$Q = V_c'A_{FP}(k) \tag{51}$$

and V_∞' is used instead of V_∞ in these equations. Once the vector $\vec{V}_i$ is calculated from (4), the scalar magnitude V_i is calculated by the usual square root of sum of squares.

For the present discussion the i in V_i denotes incompressible rather than the usual meaning of velocity at i-th control point. However, it is obvious that all calculations must be done for every control point individually, as well as for every off-body point and cross-section point.

10.5 Compressibility Correction

There is a flow passage area A_{FP} associated with every on-body control point, off-body point, and cross-section point (Section 8.0). This is now used in the compressibility correction.

First the average incompressible velocity is calculated from

$$\overline{V}_i = \frac{\dot{w}}{g\rho_t(A_{FP}/144)} \tag{52}$$

If $\overline{V}_i > a_*'$, $\overline{V}_i$ is set equal to a_*' and the average density ratio ε is

$$\varepsilon = \frac{\overline{\rho}}{\rho_t} = 0.6339 \tag{53}$$

If this occurs the point is labelled "choked" on the output.

If $\overline{V}_i < a_*'$, it is used as it stands to compute $(\overline{\rho}/\rho_t)$ by an iterative procedure. The iterative equation is

$$\varepsilon = \left[1 - \frac{1}{5}\left(\frac{\overline{V}_i}{a_t}\right)^2 \frac{1}{\varepsilon^2}\right]^{2.5} \tag{54}$$

with initial value $\varepsilon = 1$.

Finally, the compressible velocity magnitude V is calculated from

$$V = V_i\left(\frac{1}{\varepsilon}\right)^m \qquad m = \frac{V_i}{\overline{V}_i} \tag{55}$$

This is used to calculate all output quantities (Section 11.0). First V is tested. If $V \geq V_{max}$, set $V = V_{max}$ and use $M = \infty$ and $P_s/P_t = 0$ instead of values calculated below, and denote this point as "vacuum." If $V < V_{max}$ use it as it stands in subsequent calculations.

11.0 FINAL COMPUTATION

11.1 Incompressible Option

Once the velocity has been computed as described in Section 10.1, the only remaining calculation is the pressure coefficient

$$C_p = 1 - \left(\frac{V}{V_{ref}}\right)^2 \tag{56}$$

Quantities output are described in Section 14.6.

11.2 Basic Compressible Calculation

Once the calculations of Section 10.5 have been completed the following quantities are known at each on-body point, off-body point and control station point:

Compressible Velocity Magnitude:	V	
Incompressible Velocity Vector:	$\vec{V}_i$	
with components:	V_{ix}, V_{iy}, V_{iz}	
and magnitude:	V_i	(57)
Flow Passage Area:	A_{FP}	
Average Incompressible Velocity:	$\overline{V}_i$	
Average Density Ratio:	$\varepsilon = (\overline{\rho}/\rho_t)$	

These can now be used to compute other quantities

Compressible Velocity Components:

$$V_x = V_{ix}(V/V_i), \qquad V_y = V_{iy}(V/V_i), \qquad V_z = V_{iz}(V/V_i) \tag{58}$$

Mach Number

$$M = \frac{V}{a_t}\left[1 - \frac{1}{5}\left(\frac{V}{a_t}\right)^2\right]^{-1/2} \tag{59}$$

Pressure Ratio

$$\frac{P}{P_t} = \left(1 + \frac{1}{5} M^2\right)^{-3.5} \tag{60}$$

The quantities output at all on-body, off-body, and control station points are described in Section 14.7.

11.3 Additional Output Quantities Pertaining to a Cross Section as a Whole

Additional overall quantities calculated are:

Mass Flow Rate:

$$\dot{w}_{int} = \frac{g\rho_t}{144} \sum \frac{\rho}{\rho_t} (\vec{V} \cdot \vec{n})A \tag{61}$$

where $\vec{V}$ is compressible velocity with components computed in Section 11.2 above, and the density ratio to be used in equation (6a) is

$$\frac{\rho}{\rho_t} = \left[1 - \frac{1}{5}\left(\frac{V}{a_t}\right)^2\right]^{2.5} \tag{62}$$

Corrected Mass Flow Rate:

$$\dot{w}_{cor} = \frac{\dot{w}_{int}\sqrt{\theta}}{\delta} \tag{63}$$

Specific Corrected Mass Flow Rate:

$$\dot{w}_{sp} = \frac{\dot{w}_{cor}}{A_{FP}} \tag{64}$$

Average Mach number $\overline{M}$ is obtained by iteration using

$$\overline{M} = \frac{\dot{w}_{sp}\left[1 + (1/5)\overline{M}^2\right]^3}{85.38} \tag{65}$$

with initial value $\overline{M} = 0$.

11.4 An Example Comparing Calculated Results with Experimental Data

To date only one realistic three-dimensional case has been calculated and the results compared with experimental data. The inlet is the scoop inlet shown in the sketch of Figure 11. Calculated and experimental surface pressures are compared along three curves at different "circumferential" locations around the inlet. Since the freestream is at zero angle of attack and yaw, if the inlet were axisymmetric, all three pressure distributions would be identical. Thus the variation between the three pressure distributions is a measure of the three-dimensionality of the flow. This variation is predicted rather well by the calculations, which also agree quite well with the data. Obviously, a good many more cases must be run to establish the accuracy of the present method, but the results shown in Figure 11 are certainly encouraging.

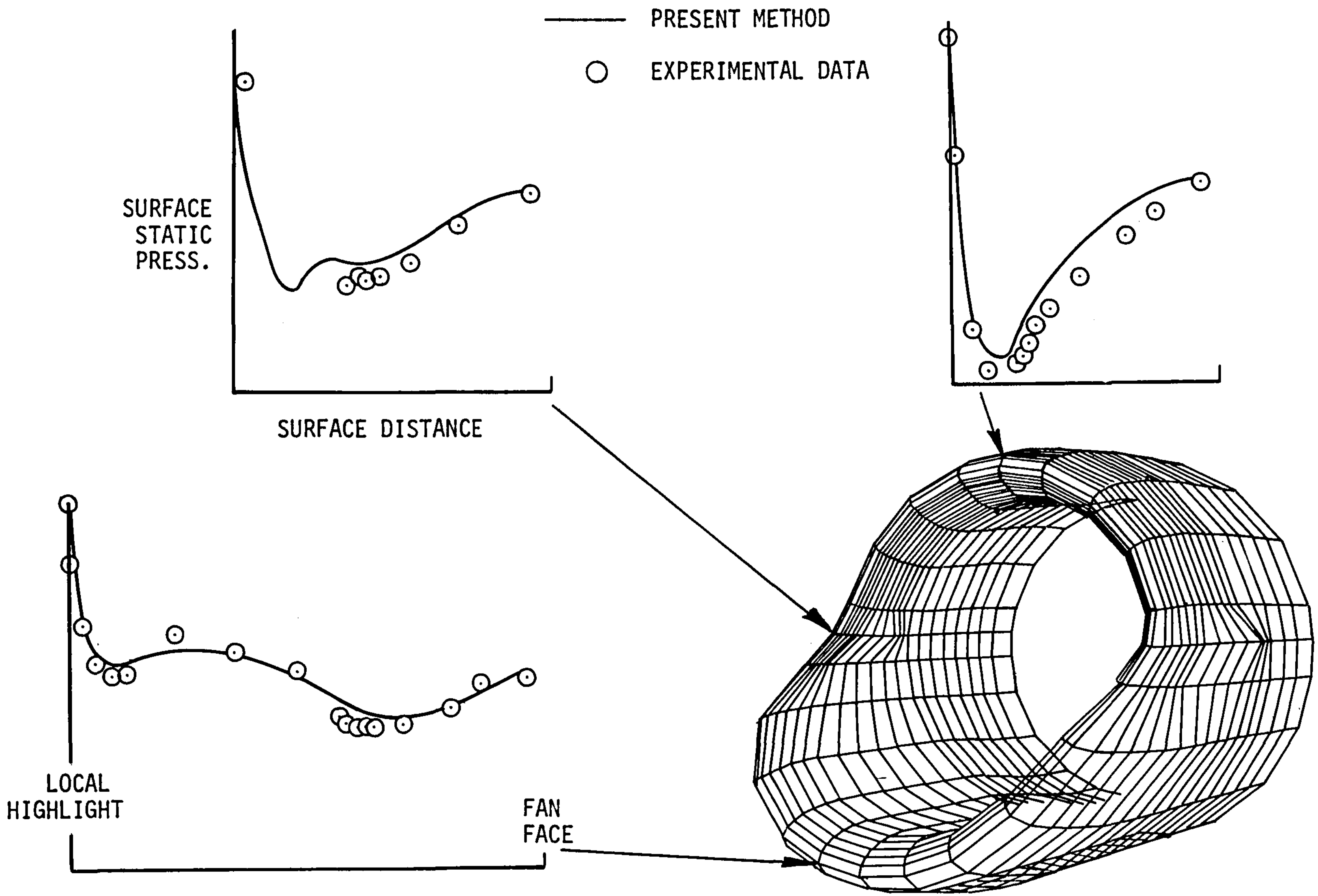


Figure 11. Comparison of calculated and experimental pressure distributions inside a scoop inlet.

12.0 INPUT TO THE PROGRAM

12.1 Types of Execution

There are three modes of operation of the program:

1. Complete Run (Mode 0)
   In this mode the program calculates the fundamental solutions, and continues to produce combined flow for prescribed values of the physical parameters. Input consists of geometric specification of the inlet including cross sections and a control station, and the inlet operating conditions. The fundamental solutions may be stored for future use as in Mode 1 below. It is anticipated that usually interrupted runs will be desired and that this mode will be run infrequently.

2. Fundamental Solution Run (Mode 1)
   In this mode only the fundamental solutions are calculated and stored for future use on external units 4, 22, 23, 29, 32, 33 (see Appendix B). Cross sections, a control station, and operating conditions are not required This is the time-consuming portion of the calculation and is performed only once for each geometry (see Figure 5, Section 5.0).

3. Combination Program Run (Mode 2)
   This is the most common type of run. Obviously either Mode 0 or Mode 1 must have been run previously to produce the Fundamental Solution Data Set. This run starts with this data set and produces combined flow solutions. Input consists of cross sections, a control station, and the inlet operating conditions (see Figure 6, Section 5.0).

12.2 The Various Input Cards

The following are the input cards required by the program:

Card #1: Option card

Card #2: Title card

Card #3:	Control data card
Card #4:	Inlet strips control
Card #5:	Vorticity coefficient card (optional)
Card #6:	On-body coordinates card
Card #7:	Off-body point card (optional)
Card #8:	Viewing angle card
Card #9:	Viewing angle input data
Card #10:	Total cross-section point input
Card #11:	Cross-section point data card
Card #12:	Incompressible combination card
Card #13:	Compressible combination Input card #1
Card #14:	Compressible combination Input card #2
Card #15:	Contour plot card (optional)
Card #16:	Streamline tracing input card (optional)

Obviously either Card 12 or Cards 13 and 14 are used. Cards from 10 on are unnecessary for Mode 1, and Cards 2 through 9 are unnecessary for Mode 2. However, Cards 10 and 11 and either 12 or 13 and 14 are necessary for every Mode 2 run.

12.3 Specific Input Card Formats

Card #1 – Option Card (Generally a nonzero integer calls for the option)

Format (13I5)

Card Columns	Variables		
1-5	IFUND	=0 ≠0	means do not calculate fundamental solutions. means do calculate fundamental solutions. The first is used only for Mode 2 execution
6-10	ICRØS	=0 ≠0	means no cross sections are input. means cross sections are input
11-15	ICMPRS	=N	where N is the number of compressible combinations to be run
16-20	ICØMB	=M	where M is the number of incompressible combinations to be run.
		Note:	Either ICMPRS = 0 or ICØMB = 0 For Mode 1, both are 0.

Card Columns	Variables	
21-25	NCS	= the number of the cross section to be used as the control station
26-30	IPRINT	=0 will print the combination program output =1 will suppress combination and cross-section output =4 will print cross-section geometry as well as combination output
31-35	ISYMPR	=0 means print solution only on input half of the inlet ≠0 means print solution also on the reflected half of the inlet (used with cases having yaw)
36-40	INUNIT	Unit that will read the input data (=5, if input is from cards)
41-45	INSAVE	=0 means fundamental solutions are not saved ≠0 means save fundamental solutions and all other data necessary to restart with Mode 2
46-50	NSL	= number of streamlines to be used in the streamline tracing option
51-55	IPERS	=0 means use orthographic projection to plot streamlines ≠0 means use perspective projection
56-60	ISØPLT	=0 means no cross-section plots ≠0 means plot contours of constant pressure, etc. at each cross section
61-65	IGEØM	=0 means use input points unaltered ≠0 means use geometry package to repanel

Card #2 — TITLE card (Required if IFUND≠0 on card #1)

Format (18A4)

Card Column	Variables	
1-68	TITLE(1) to TITLE(17)	An alphanumeric array which describes the case data to be run. The array should contain no more than 68 characters.
69-72	TITLE(18)	= 'ɃTWØ' means two points per card format is used for inputting body coordinates = blanks means one point per card format is used

Card #3 — Control Data Card (Required if IFUND≠0 on card #1)

Format (A4, 3X, 2I3, 12X, 5I3, 6X, 4L1, 2F10.0)

Card Columns	Variables	
1-4	CASE	Case ID number
8-10	NØFF	=0 means no off-body point is input ≠0 means there is off-body point input
11-13	LIST	=0 program continues after body panels are formed ≠0 program terminates after body panels are formed (i.e. program ends at the completion of INPUT subroutine)
26-28	NSYM	=0 symmetry is not used, entire body is input =1 one plane of symmetry is used. Only half the body, for which $y \geq 0$, is input.
29-31	IB	Input vorticity coefficient option =0 no B-values input. Program sets all B's to 1.0 =1 uses input B's.
32-34	NØRM	=1 lengths will be normalized by an input reference length =2 velocities will be normalized by input reference velocity =3 both lengths and velocities will be normalized
35-37	METIN	=1 means the input is in metric units =0 means the input is in English units
38-40	METØUT	=1 means metric output is desired =0 means the output is in English units
47	TYPEA	=T if there is no centerbody =F if there is a centerbody
48	TYPEB	=T if the front of the centerbody is aligned with the inlet highlight =F otherwise
49	TYPEC	=T if the centerbody is completely inside the inlet downstream of the highlight =F otherwise
50	TYPED	=T if the centerbody protrudes outside the inlet upstream of the highlight =F otherwise

(Note: Exactly one of the previous four flags must be set to T, the other three to F.)

Card Columns	Variables	
51-60	SF	scale factor
61-70	RFLENG	reference length for normalizing the length data. Input only if NØRM=1 or NØRM=3

Card #4 — Inlet Strips Control Card (Required if IFUND≠0 on card #1)

Format (3I4)

Card Columns	Variables	
1-4	NSØRCE	number of on-body source panels in each strip of the inlet (lifting body) section
5-8	NWAKE	number of wake panels in each strip of the inlet. Usually one
9-12	NSTRIP	number of strips of panels on the inlet

Card #5 — Vorticity Coefficient Input Card (This card is input only if IB=1 is input on card #3 and IFUND≠0 on card #1.)

Format (6F12.6)

Card Columns	Variables	
1-12 13-24 25-36 37-48 49-60 61-72	B(I)	values of vorticity coefficient — 6 values per card. Repeat the same format on next card if more than 6B's are input. (Note: The total number of B's input must equal the total number of strips that define the inlet.)

Card #6 — On-Body Coordinates Input Card (Required if IFUND≠0 on card #1.)

Format (3E10.0, 2I1) — For one point per card
Format (2(3E10.0, 2I1)) — For two points per card

The maximum number of on-body panels on inlet and centerbody together is 1000. The maximum number of input points may slightly exceed this.

Card Columns	Variables	
1-10 11-20 21-30	X(I) Y(I) Z(I)	The x,y,z coordinates of an input point on an N-line, either on-body or wake (inches in English units)

Card Columns	Variables	
31	ISTAT	Status flag =2 new section (1st point of inlet and of centerbody) =1 new N-line =0 same N-line =3 end of all input data

(Note: The status flags are somewhat different if the geometry package is used to repanel the body, Section 13.0.)

Card Columns	Variables	
32	LABEL	=1 lifting body — used for the inlet =0 nonlifting body — used for the centerbody

(Note: For two points per card repeat the above sequence from Card Columns 33 - Card Columns 64.)

Card #7 — Off-Body Point Cards (Required if NØFF≠0 on card #2 and IFUND≠0 on card #1)

Format (2(3E10.0, I1))

Card Columns	Variables	
1-10	XØFF(I)	
11-20	YØFF(I)	x,y,z coordinates of an input off-body point
21-30	ZØFF(I)	
31	ISTAT	Status flag =3 indicates end of all off-body point input

(Note: Repeat the above sequence from Card Columns 32 - Card Columns 63.)

Card #8 — Total Number of Viewing Angles Input Card (Required if IFUND≠0)

Format (I5)

Card Columns	Variables	
1-5	NVIEW	number of viewing angles input

Card #9 — Viewing Angle Input Data Card (Required if IFUND≠0)

Format (3F6.0, I2, 15A4) One viewing angle is input per card (required even if graphics is not called for)

Card Columns	Variables	
1-6 7-12 13-18	PSI THETA PHI	angles the viewing direction makes with the x,y,z directions, respectively (degrees) (see Section 15.1)
19-20	LAST	set equal to 1 if this is the last viewing angle card, otherwise, set it to 0
21-80	PLABEL	a 60-character array that describes the viewing angle

<u>Card #10 — Total Number of Cross-Sections Input Card</u> (Required if ICRØS≠0)

Format (I5)

Card Columns	Variables	
1-5	NPLANE	number of cross-section points input

<u>Card #11 — Cross-Section Input Data Card</u> (Required if ICRØS≠0)

Format (6E10.0, I5)

Card Columns	Variables	
1-10 11-20 21-30	XCSP YCSP ZCSP	x,y,z coordinates of the input cross-section point (inches in English units)
31-40 41-50 51-60	UI UJ UK	components of the unit vector of the input cross-section point.
61-65	ICSR	number of panels in each of the strips in the cross-section plane (a maximum of ten)

Repeat this format for another cross-section point until the total number of cards #11 equals NPLANE input in card #10.

<u>Card #12 — Combination (Incompressible) Program Input Card</u> (This card is required if ICØMB≠0 on card #1.)

Format (5F10.6, 2I5)

Card Columns	Variables	
1-10	ALFANG	angle of attack α in degrees
11-20	YAWANG	yaw angle β in degrees

Card Columns	Variables		
21-30	VINF	freestream velocity V_∞	(feet per second in English units)
31-40	VREF	reference velocity V_{ref}	
41-50	VAVG	average velocity V_c	
51-55	ISKIPC	=0 combination program will be called =1 bypass the combination program even though ICØMB≠0, and go directly into the streamline tracing program	
56-60	IDEL	=0 use the program default delta values for cross-section plot =1 input delta values to be used for cross-section plot	

Card #13 — Flow Passage Program Input Cards (Required only if ICMPRS≠0 on card #1.)

(a) Format (I5)

Card Columns	Variables	
1-5	NCPT	number of centerline points input

(b) Format (6E10.0)

Card Columns	Variables	
1-10 11-20 21-30	XCPT YCPT ZCPT	x,y,z coordinates of the centerline point (inches in English units)
31-40 41-50 51-60	UI UJ UK	components of the unit normal vector of the centerline point

Repeat card (b) as many times as specified by NCPT in card (a).

The following set of cards is also needed if the inlet is TYPE D, i.e. the centerbody is upstream of the inlet lip.

(c) Format (I5)

Card Columns	Variables	
1-5	NEGCPT	number of centerline points upstream (outside) of the inlet lip

(d) Format (6E10.0)

Card Columns	Variables	
1-10	XNEG	
11-20	YNEG	x,y,z coordinates of an upstream centerline point
21-30	ZNEG	
31-40	VI	
41-50	VJ	components of the unit vector of an upstream centerline point
51-60	VK	

Repeat card (d) as many times as specified by NEGCPT in card (c).

Card #14a – Combination (Compressible) Program Input Card (This card is required if ICMPRS≠0 on card #1. The format and input variables are the same as in card #12.)

Format (5F10.0, 2I5)

Card Columns	Variables		
1-10	ALFANG	angle of attack α in degrees	
11-20	YAWANG	yaw angle β in degrees	
21-30	VINF	freestream velocity V_∞	(feet per second in English units)
31-40	VREF	reference velocity V_{ref}	(feet per second in English units)
41-50	VAVG	average velocity V_c	(feet per second in English units)
51-55	ISKIPC	same meaning as in card #12	
56-60	IDEL	same meaning as in card #12	

Card #14b – Second Input Card for the Compressible Combination Program

Format (7F10.0)

Card Columns	Variables		
1-10	RMINF	Mach number M_∞	see Section 10.0
11-20	RMAVG	average Mach number $\overline{M}$	see Section 10.0
21-30	PTØTAL	total pressure P_t	see Section 10.0
31-40	PSTATC	freestream static pressure P_s	see Section 10.0

Card Columns	Variables			
41-50	TEMPT	total temperature T_t	(degrees Rankine in English units)	See Section 10.0
51-60	TEMPS	freestream static temperature T_s		
61-70	FRATE	inlet mass flow rate $\dot{w}$	lb mass/sec	

Card #15 — Increment Values for Contour Plots (1 card for each input cross-section point.) (Required if and only if IDEL=1)

Format (4F10.0)

Card Columns	Variables	
1-10	DELCP	isobar increment (default value = 0.1)
11-20	DELTHX	flow angle in the ξ-direction contour plot increment (default value = 1^{o})
21-30	DELTHY	flow angle in the η-direction contour plot increment (default value = 1^{o})
31-40	DELMCH	Mach number increment (omit this for incompressible combination) (default value = 0.1)

Card #16 — Streamline Tracing Input Data Card(s) (One card per streamline)

Format (4I5, F10.0, 2I5, 3I1, 2X, 3I1)

Card Columns	Variables	
1-5	ICFLAG	centerbody or inlet flag: 1 → centerbody; 2 → inlet*
6-10	IPIESL	strip number on the centerbody (or inlet)
11-15	IELNØ	the panel number of this strip**
16-20	IDIREC	the direction of the streamline march: +1 → in local flow direction; -1 → opposite to local flow direction
21-30	XCUTØF	maximum x-value for streamline calculation (cutoff condition)
31-35	NPMAX	maximum number of streamline points to be allowed for this streamline (cutoff condition)

*centerbody (if any) must be input before the inlet if streamlines are to be calculated.

**streamline starts at the control point of this panel.

Card Columns	Variables	
36-40	IPRINT	print flag for streamline tracing calculations: 0= minimum print. (This is the normal option for a production case) 2= maximum print (for batch or TSO debug) 3= medium print (mostly for TSO debug)
41	IMVSS	Flag to generate a plot of Mach No. vs normalized distance along this streamline.
42	IPVSS	Flag to generate a plot of P_s/P_t vs normalized distance along the streamline.
43	IAVSS	Flag to generate a plot of flow inclination angles (rel. to x-axis) vs normalized distance along this streamline.
44-45	(blank)	
46	IMVSX	Flag to generate a plot of Mach No. vs x for this streamline.
47	IPVSX	Flag to generate a plot of P_s/P_t vs x for this streamline
48	IAVSX	Flag to generate a plot of flow inclination angles (rel. to x-axis) vs x for this streamline.

Card no. 16 should be repeated NSL times.

13.0 INPUT TO THE GEOMETRY PACKAGE

Note: If it is desired to use the geometry package (references 6 and 7) to repanel the body, then IGEØM≠0 is specified on card #1. The following instructions pertain to the input cards for the geometry package. The geometry package has been greatly simplified for use in the inlet program, but it is still more general than is needed. For example, many of the spacing options are superfluous. The inlet and centerbody are referred to as body 1 and body 2. Either may be input first*. They should be inserted behind card #5 and card group #6 is not needed if this option is chosen.

Card Type	Required or Optional	Card Columns	Format	Variable	Description
1	Required	1-4	I4	NSEC	Total number of sections
2	Required	1-4	I4	NB(I)	Specified number of on-body points per N-line on body I
		5-8	I4	NW(I)	Specified number of wake points per N-line on body I
		9-12	I4	NS(I)	Specified number of N-lines on body I
		13-16	I4	NALGB(I)	Spacing algorithm for on-body points on N-lines NALGB=0, Input distribution, unaltered NALGB=1, Input distribution, augmented NALGB=2, Constant increments in arc length NALGB=3, Cosine distribution NALGB=4, Curvature-dependent distribution NALGB=5, User-specified distribution
		17-20	I4	NALGW(I)	Spacing algorithm for wake points on N-lines. (Values have same significance as values of NALGB, except that NALGW=3 and NALGW=4 should not be used.) Normally only one wake point is used.

*However, if streamlines are to be calculated, the nonlifting body must be input first.

Card Type	Required or Optional	Card Columns	Format	Variable	Description
2 (cont)	Required	21-24	I4	NALGS(I)	Spacing algorithm for N-lines NALGS=0, Input distribution, unaltered NALGS=1, Input distribution, augmented NALGS=2, Constant increments NALGS=3, User-specified distribution
		29-32	I4	NSEG(I)	Number of segments into which M-lines are broken (Default=1) This is to allow for corners
		33-36	I4	NTR(I)	Component transformation flag. (The value indicates the number of transformations to be performed.)
		37-40	I4	IP1(I)	Punch flag for transformed input coordinates IP1=0, No punch IP1≠0, Punch
		41-44	I4	IP2(I)	Punch flag for coordinates after repaneling bodies IP2=0, No punch IP2≠0, Punch
4	Optional	1-10 11-20 21-30 31-40 41-50 51-60 61-70 71-80	8F10.0	SSB(I,1) SSB(I,2) . . .	Specified arc lengths of on-body points on N-lines on body I $0.0 \leq SSB \leq 1.0$ 8 points per card, NB(I) total This card is required if NALGB(I)=5

Card Type	Required or Optional	Card Columns	Format	Variable	Description
5	Optional	1-10 11-20 21-30 31-40 41-50 51-60 61-70 71-80	8F10.0	SSW(I,1) SSW(I,2) . . .	Specified arc lengths of wake points on N-lines on body I $0.0 \le SSW \le 1.0$ 8 points per card, NW(I) total This card is required if NALGW(I)=5
6	Optional	1-10 11-20 21-30 31-40 41-50 51-60 61-70 71-80	8F10.0	SSS(I,1) SSS(I,2) . . .	Specified distribution of N-lines on body I $0.0 \le SSS \le 1.0$ 8 points per card, NS(I) total This card is required if NALGS(I)=3
7	Optional	1-4 5-8 9-12 13-16 17-20	5I4	IEND(I,1) IEND(I,2) . . .	Point numbers of the ends of the segments on M-lines on body I NSEG(I) total (max.=5 This card is required if NSEG(I)>1
8	Optional	1-4	I4	ITR2(I,J)	Type of Jth transformation to be applied to body I ITR2=1, Scaling ITR2=2, Translation ITR3=3, Rotation
		11-20	F10.0	TR(I,J,1)	First transformation parameter: x multiplication factor if ITR2=1 x translation if ITR2=2 angle of rotation if ITR2=3 (positive clockwise, looking down axis of rotation away from origin)

Card Type	Required or Optional	Card Columns	Format	Variable	Description
8 (cont)	Optional	21-30	F10.0	TR(I,J,2)	Second transformation parameter: y multiplication factor if ITR2=1 y translation if ITR2=2 x direction cosine of axis of rotation if ITR2=3
		31-40	F10.0	TR(I,J,3)	Third transformation parameter: z multiplication factor if ITR2=1 z translation if ITR2=2 y direction cosine of axis of rotation if ITR2=3
		41-50	F10.0	TR(I,J,4)	Fourth transformation parameter: Dummy if ITR2=1 or ITR2=2 z direction cosine of axis of rotation if ITR2=3 Note: The axis of rotation is assumed to pass through the origin. Up to 10 transformations may be performed, in any order. Input this card type NTR(I) times.
9	Required	1-10 11-20 21-30	F10.0 F10.0 F10.0	X Y Z	x,y,z coordinates of a point (all points input N-line by N-line, body by body).
		31	I1	STATUS	STATUS=0 same N-line STATUS=1 new N-line STATUS=2 new body STATUS=3 last point input (exception is #5 below) STATUS=4 first point on wake STATUS=5 first point on wake and also last point input
		32	I1	LABEL	LABEL=0 nonlifting body (center body) LABEL-1 lifting body (inlet)

33-42	F10.0	X	x,y,z coordinates of the next point input
43-52	F10.0	Y	
53-62	F10.0	Z	
63	I1	STATUS	Same meaning as above
64	I1	LABEL	
			Repeat cards to input more points. If TITLE(18)=ØTWØ on card no. 1, input 2 points per card. If TITLE(18) is not equal to "ØTWØ," it implies 1 point per card.

14.0 TABULAR OUTPUT

14.1 Basic Body Geometry

N	Strip number
M	Panel number
X, Y, Z	Coordinates of the four input points used to form the panel
NX, NY, NZ	x,y,z components of the panel normal vector
XO, YO, ZO	Coordinates of the control point
D	For lifting (inlet) panels, it is an average panel length For nonlifting (centerbody) panels, it is the projection distance required to make the input points coplaner
T	Maximum diagonal of the panel
A	Area of the panel

14.2 Fundamental Solution Output

I	Panel number. Here all panels are listed in a single array containing all strips
STATVX STATVY STATVZ	x,y,z components of the velocity at a control point for the static solution
UVX1 UVY1 UVZ1	x,y,z components of the velocity at a control point for the (1,0,0) flow, in which the uniform freestream is parallel to the x-axis
UVX2 UVY2 UVZ2	x,y,z components of the velocity at a control point for the (0,0,1) flow, in which the uniform freestream is parallel to the z-axis
UVX3 UVY3 UVZ3	x,y,z components of the velocity at a control point for the (0,1,0) flow, in which the uniform freestream is parallel to the y-axis

14.3 Cross-Section Control Data

C.S.NØ.	Cross-section number
XCSP YCSP ZCSP	Input coordinates of the cross-section point
UI UJ UK	Input components of the cross-section normal vector
RADIAL PANELS	Number of panels to be formed on each radial strip in the cross-section plane

14.4 Cross-Section Panel Geometry

J	Strip number
I	Panel number
X, Y, Z	Coordinates of the corner points of a panel
XC YC ZC	x,y,z coordinates of the panel control point where flow quantities are to be calculated
XI ETA	Coordinates of the control point in the cross-section coordinate system
AREA	Panel area

14.5 Cross-Section Flux

FLØW	Indicates what type of flow
	FLØW=1 static solution FLØW=2 (1,0,0) flow, uniform freestream parallel to the x-axis FLØW=3 (0,0,1) flow, uniform freestream parallel to the z-axis FLØW=4 (0,1,0) flow, uniform freestream parallel to the y-axis
FLUXX FLUXY FLUXZ	Components of the vector volume flux at the cross-section, equations (28) and (29) plus subsequent discussion
TØTAL FLUX	Normal volume flux through the cross-section plane, equation (29)

14.6 Incompressible Combination Output

N	Strip number
M	Panel number
XC YC ZC	Coordinates of control point
NX NY NZ	Components of normal vector
CØMBVX CØMBVY CØMBVZ	Components of velocity
VN	Normal velocity
V	Total velocity magnitude
CP	Pressure coefficient
DCX DCY DCZ	Components of directional cosines of velocity

The above explanations applied to all elements (i.e. on-body, off-body & cross-sections).

14.7 Compressible Combination Output - On Body

N	Strip number*
M	Panel number
XC, YC, ZC	Control point coordinates
VX, VY, VZ	Velocity components
VMAG	Velocity magnitude $=\sqrt{V_x^2 + V_y^2 + V_z^2}$
MACH	Local Mach number
P/PT	Static-to-total pressure ratio
VBAR	Average incompressible velocity
EPSLØN	ε, Average density ratio, equations(53) and (54)
AREA (FP)	Flow passage area

*If letter R is suffixed to the strip number, it denotes that the strip is on the reflected half of the body.

14.8 Error Messages

(1) Message: **END OF INPUT DATA. NORMAL PROGRAM TERMINATION.

Source: MAIN program

Cause: End of all data.

Action: None

(2) Message: THE MATRIX OF XXXXX ELEMENTS EXCEED XXXXXX.

Source: MAIN program

Cause: The input matrix is too large for the program's allowable computer storage.

Action: Change the working area size in MAIN program.

(3) Message: TOTAL NUMBER OF CENTER-BODY INTERSECTION POINTS DOES NOT EQUAL TO THE NUMBER OF NONLIFTING NLINES INPUT.

Source: Subroutine CSGEØM

Cause: Each cross-section plane (defined by the input cross-section point and its normal vector) should give one intersection point with each line that defines the centerbody. If the total number of intersection points does not equal the number of input nonlifting N-lines, the above message will be printed and the program continues.

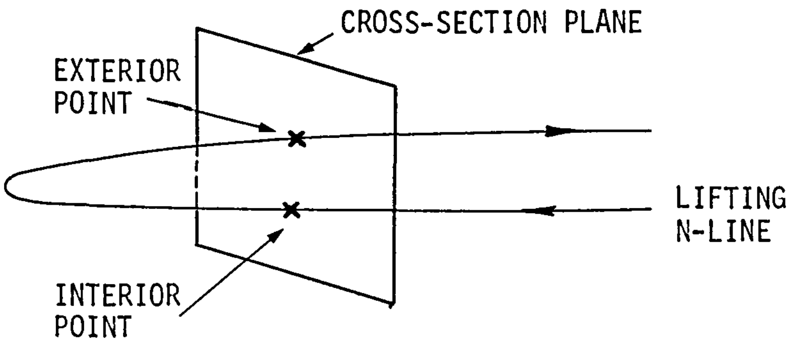
Action: Check the input cross-section point and its normal vector to see if the cross-section plane does cut through each nonlifting N-line.

(4) Message: (a) TOTAL NUMBER OF INTERIOR POINTS DOES NOT EQUAL TO THE LIFTING NLINES INPUT.

(b) TOTAL NUMBER OF EXTERIOR POINTS DOES NOT EQUAL TO THE LIFTING NLINES INPUT.

Source: Subroutine CSGEØM

Cause: Intersection of the cross-section plane and the lifting N-line should generate two intersecting points as illustrated below:



If the number of the interior point or the exterior point does not equal the number of lifting N-lines, the above message will be printed but program continues to execute.

Action: Check the input cross-section point and normal vector to see if the cross-section plane does cut through the lifting N-line.

(5) Message: CURRENTLY EXECUTING SECTION TYPE =, XXX
SECTION TYPE FROM UNIT NO. 4 =, XXX
PROGRAM STOPS

Source: Subroutine FLPASG

Cause: External unit No. 4 stores the geometrical quantities of the input panels for both the inlet and centerbody. If the body type retrieved from unit 4 does not match the body type that the program is currently using, the above message will be printed and execution stops.

Action: Check the contents of the external unit No.4 and see if it matches the case that is used.

(6) Message: NON-LIFTING INTERSECTION POINTS NOT EQUAL TO THE NUMBER OF NLINES INPUT

Source: Subroutine FLPASG

Cause: / Action: See Message No. (3)

(7) Message: INTERIOR POINTS NOT EQUAL TO THE NUMBER OF NLINES INPUT.

Source: Subroutine FLPASG

Cause: / Action: See Message No. (4)

(8) Message: EXTERIOR POINTS NOT EQUAL TO THE NUMBER OF NLINES INPUT.

Source: Subroutine FLPASG

Cause: / Action: See Message No. (4)

(9) Message: ALLOWABLE NUMBER OF POINTS EXCEEDED IN SUBROUTINE PANELS, EXECUTION TERMINATING.

Source: Subroutine GEINPT

Cause: Input total number of panels (for both inlet and centerbody) exceeds 1100.

Action: Change the input geometry and rerun.

(10) Message: MISMATCH OF ELEMENTS IN A LIFTING STRIP IS DETECTED. ELEMENTS FORMED = XXX, ELEMENTS INPUT = XXX. COMPUTATION TERMINATED.

Source: Subroutine INPUT

Cause: Input number of strip and elements for the inlet is not consistent with the input lifting information card.

Action: Check the body coordinates input cards and see if the flags for new line or new section are punched correctly.

(11) Message: NPMAX=XXX HAS BEEN REACHED. COMPUTATIONS TERMINATING FOR THIS STREAMLINE.

Source: Subroutine TRACE

Cause: Generated streamline tracing exceeds the allowable dimension. Program goes to the next streamline.

Action: None

(12) Message: INPUT XX PLANE OF SYMMETRY OPTION IS NOT IN THE PROGRAM. IT IS REPLACED BY 1 PL. SYM.

Source: Subroutine VFMLFT and VFMNLF

Cause: Input number of symmetry plane is more than 1.

Action: User's action none. Program changes the input symmetry to one.

(13) Message: ERROR IN VFORM. THE ELEMENTS FORMED DO NOT CORRESPOND TO THE NO. OF BODY ELEMENTS.

Source: Subroutine VFMLFT and VFMNLF

Cause: On-body panel counter error

Action: Check and see if the variables appeared in the labelled commons "INFORM" and "INLIFT" have been changed.

(14) Message: LABEL ERROR IN LIFTING VFORM

Source: Subroutine VFMLFT

Cause: Data on the external unit No. 4 did not correspond to the type of body at the time of execution.

Action: Check the data on unit No. 4.

(15) Message: LABEL ERROR IN NONLIFTING VFORM.

Source: Subroutine VFMNLF

Cause: Same as in (14)

Action: Same as in (14)

(16) Message: TOTAL NUMBER OF CONTROL POINTS SHOULD BE XXXXX. THE NUMBER OF POINTS STORED ON UNIT NSETV IS XXXXX. EXECUTION STOPS.

Source: Subroutine CØMPRØ, CØMPRS

Cause: The total number of control points (on-body plus off-body) in the variable NØN is not equal to the variable NPØINT stored in the external unit NSETV. (NSETV stores all of the fundamental solutions.)

Action: Check and see if the unit NSETV did store the correct data.

(17) Message: INPUT CONTROL STATION NO. = XXXXX.
READ FROM UNIT NFLUX STATION NO. = XXXXX.
PROGRAM STOPS FOR CHECKING.

Source: Subroutine COMPRO, COMPRES

Cause: Input control station number NCS is not the same as the control station number stored in unit NFLUX.

Action: Check contents of unit NFLUX.

(18) Message: ON-BODY ELEMENT MISSED. JOB STOPS.

Source: Subroutine COMPRO, COMPRS

Cause: Total number of on-body control panels is stored in variable KONTRL. The counter KK is used for counting total number of on-body panels. When these two variables are not equal, the message will be printed.

Action: Check labelled common CONFLG to see if the variable KONTRL has been changed.

(19) Message: CROSS-SECTION PLANE NUMBER CURRENTLY USING XXXXX PLANE NO.
FROM UNIT NV IS XXXX.
PLANE NO. FROM UNIT NOFSAV IS XXXX.
STOP 77.

Source: Subroutine COMPRO, COMPRS

Cause: The three numbers explained in the message should be the same, if they are not, it indicates either the units have different contents or the counter for the cross-section plane number IP is incorrect. Stop code 77, 78 applied to COMPRO and COMPRS, respectively.

Action: Check external units NV and NOFSAV.

(20) Message: STRIP NO. NOW USING IS XXXX.
STRIP NO. FROM UNIT NOFSAV IS XXXX.
PROGRAM HALTS.

Source: Subroutine COMPRO, COMPRS

Cause: Unit NOFSAV is used in retrieving the cross-section geometry data. Strip counter JI is read from NOFSAV and do-loop (2800 in COMPRO, 3800 in COMPRS) counter J is the current strip counter. If these two variables (J1 and J) are not equal, it indicates data read in from NOFSAV is incorrect.

Action: Check contents of the unit NOFSAV.

(21) Message: POINT NUMBER ERROR. ON UNIT NV N = XXXXX.
BUT N IS INCREMENTED = XXXXX.
STOP 59.

Source: Subroutine COMPRO, COMPRS

Cause: In do-loop (2700 in COMPRO, 3700 in COMPRS) counter JS is incremented for each control panel. Unit NV also has a counter N which should be the same as JS. If these two do not agree, message is printed.

Action: Check contents of unit NV.

(22) Message: ********** EPSLON AT 100TH ITERATION IS USED **********.

Source: Subroutine COMPRS

Cause: Iteration for the computation of ε equal to 100. The 100th iterated ε value is used.

Action: None

(23) Message: ********** AVERAGE MACH NO. AT 100TH ITERATION IS USED **********

Source: Subroutine COMPRS

Cause: Iteration for the computation of the average Mach number $\overline{M}$ equal to 100. The 100th iterated $\overline{M}$ is used.

Action: None

(24) Message: AFTER 100 ITERATIONS, COMPUTED VC IS ±XXXXXX.XXXXXXXXX DELTA VC IS ±XXXXXX.XXXXXXXX.
PROGRAM STOPS.

Source: Subroutine COMPRS

Cause: Computed $\delta V_c > 10^{-4}$, program stops.

Action: Reconsider the input data to the combination program (compressible) and make proper change.

(25) Message: NUMBER OF (PRESSURE MACH NO. FLOW ANGLE) ISOLINES EXCEEDS DIMENSION ALLOWED. PROGRAM STOPS.

Source: Subroutine ISOPLN.

Cause: Computed total number of isolines exceeds the dimension allowed in the program.

Action: Change the input delta values for the isoline plot and reinput.

15.0 EXAMPLES OF GRAPHICAL OUTPUT

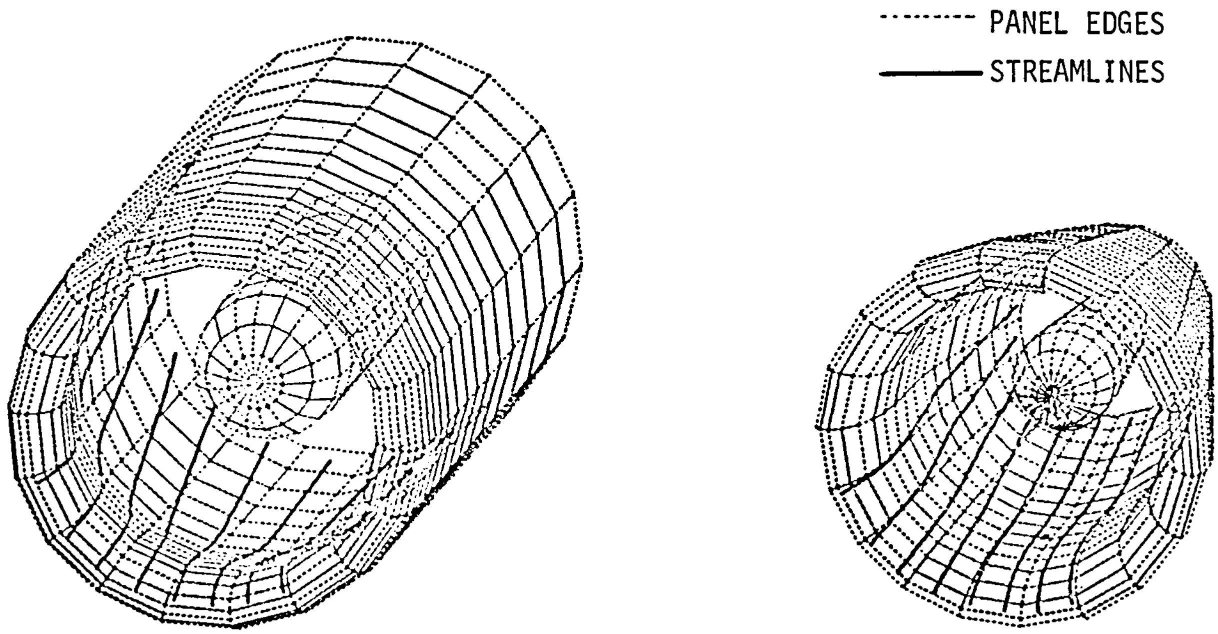
15.1 Surface Streamlines

The user identifies a particular body panel by inputting the number of the strip on which it lies and the number of the panel on that strip. The panel may be on either the inlet or the centerbody. The program then calculates the surface streamline that goes through the control point of that panel in either the upstream or downstream direction. (If both are desired, two inputs are required, since the program regards them as two separate streamlines.) A number of panels may be specified and streamlines calculated through each of their centroids.

To facilitate interpretation of the results, two types of graphical output have been provided. One is rather straightforward. Local values of pressure, Mach number, and flow angle are displayed as functions of arc length (and/or Cartesian x) along the streamline on conventional two-variable Cartesian plots.

The second type of graphical output is more complicated. The program plots the actual streamlines themselves against the panel representation of the inlet configuration. The angles from which the resulting configuration is viewed may be specified by the user. Their choice is quite important. Viewed from an inappropriate direction, the streamline pattern can be quite deceptive. A set of default viewing angles have been built into the program. In complicated cases more than one run may be required to determine the best angles. One complication is the fact that only the panels facing the observer are plotted, while the streamline is plotted regardless. Thus a view of an interior streamline viewed from the exterior is quite misleading.

The plotted view of the inlet with its streamlines may be obtained either by orthographic (parallel) projection or by perspective projection for which a viewing distance has been built into the program. Examples of the output are presented in Figure 12, which shows streamlines on the interior surface of an inlet at angle of attack for both types of projection. The viewing angle is 10 degrees with respect to the inlet centerline, which often has been found to be an effective angle from which to view. While the viewing angle is the same



(a) Orthographic projection. (b) Perspective projection.

Figure 12. Calculated streamlines on the interior surface of an inlet.

for both projections, it appears to be quite different. In this case the perspective view appears more informative, but examples can be found for which orthographic is to be preferred.

The viewing angles input by the user are: a yaw angle PSI, a pitch angle THETA, and a roll angle PHI. They are used both for examining the geometry before performing the flow calculation and for viewing final results as discussed in this section. Since the rotation axes pertinent to the viewing angles remain fixed in the body, it is simpler to imagine that the body and the coordinate system remain fixed while the observer is rotated by the prescribed yaw, pitch, and roll angles about the coordinate axes. In each case rotation about a particular coordinate axes implies that the value of that particular coordinate of the observer remains constant, as does his distance from the axes, and the positive sense of rotation is clockwise. Initially, the observer is assumed to be situated on the positive x-axis and to be looking towards the origin, which he continues to do at all times. He is first rotated about the z-axis by the yaw angle and thus remains in the xy-plane. The observer is then rotated about the y-axis by the pitch angle and finally about the x-axis by the roll angle. This last rotation is rarely used, because the observer can be brought to any desired inclination using only the yaw and pitch angles.

15.2 Equi-Value Contours in a Cross Section

As described in Sections 9.0 and 14.0, plane cross sections are defined at various locations inside the inlet by means of a point and a normal vector. Control points are automatically distributed "spiderweb style" over the cross section from the input point to the inner surface of the inlet if there is no centerbody at that location or from the surface of the centerbody to the inner surface of the inlet if there is a centerbody. Coordinates are defined in the cross-section plane having the input point as origin. Tabular output of various flow quantities at the control points is provided.

The graphical output option for a cross section first plots the geometric shape of the cross section using its own coordinate system, i.e., the intersection of the cross-section plane with the centerbody (if any) and the interior surface of the inlet. It then constructs four separate plots against this geometry consisting of curves of equal value of: nondimensional pressure (pressure coefficient incompressibly and static-to-total pressure ratio compressibly), Mach number, and flow angles with respect to the cross-section normal vector in the planes defined by this vector and the cross-section coordinate axes. Increments of value to be used for these curves may be input by the user, but the same values must be used for all cross sections. Default values for the plotting increments are 0.1 for nondimensional pressure and Mach number and one degree for the two angles. As an aid to interpretation, the equi-value curve having the smallest value of the quantity in question and the curve having a value halfway between the largest and smallest values of the quantity are plotted as heavy and dotted curves, respectively. The values of the quantity corresponding to these two curves and the value increment are printed on the plot.

To illustrate this capability, the example shown in Figure 13 was selected. It is a round inlet but was panelled as a three-dimensional body. The locations of the two cross sections where flow quantities are computed are shown. The forward cross section was designated the control station where the average velocity was specified as three times freestream. The angle of attack was 40°. Figure 14 shows isobar plots at the two cross sections. Figure 15 shows plots of equal values of flow angle. Here the cross-section normal vector is parallel to the x-axis. Thus the flow angle in the xz-plane has the meaning of a pitch angle and has been so designated in Figure 15. In general no such neat designation would be available.

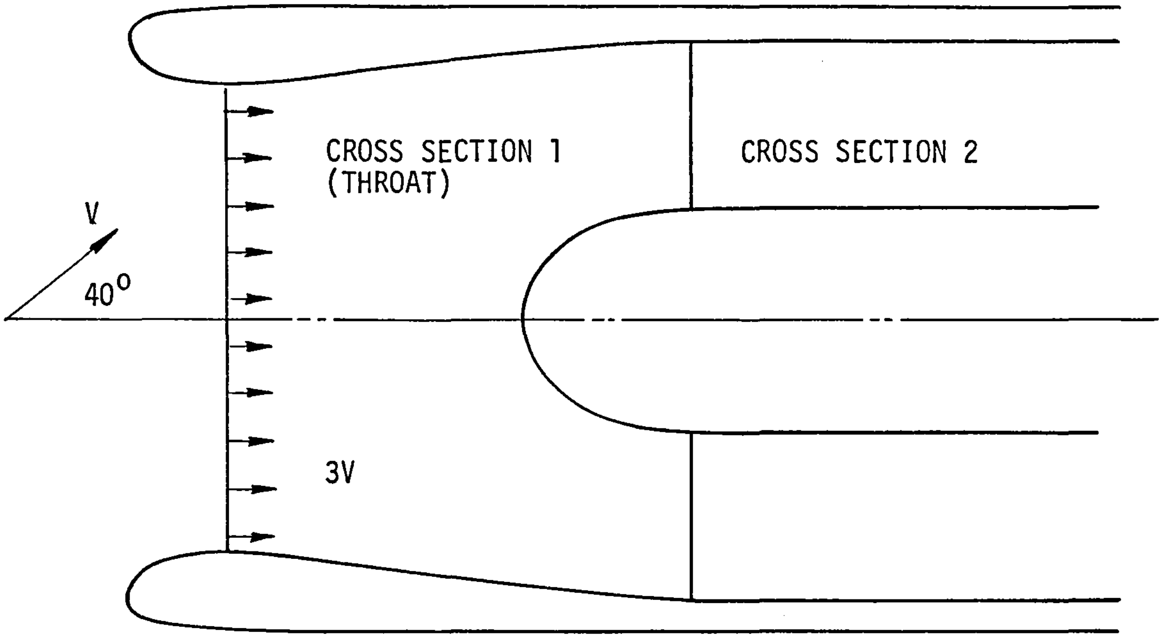


Figure 13. Cross sections selected for output and inlet operating conditions.

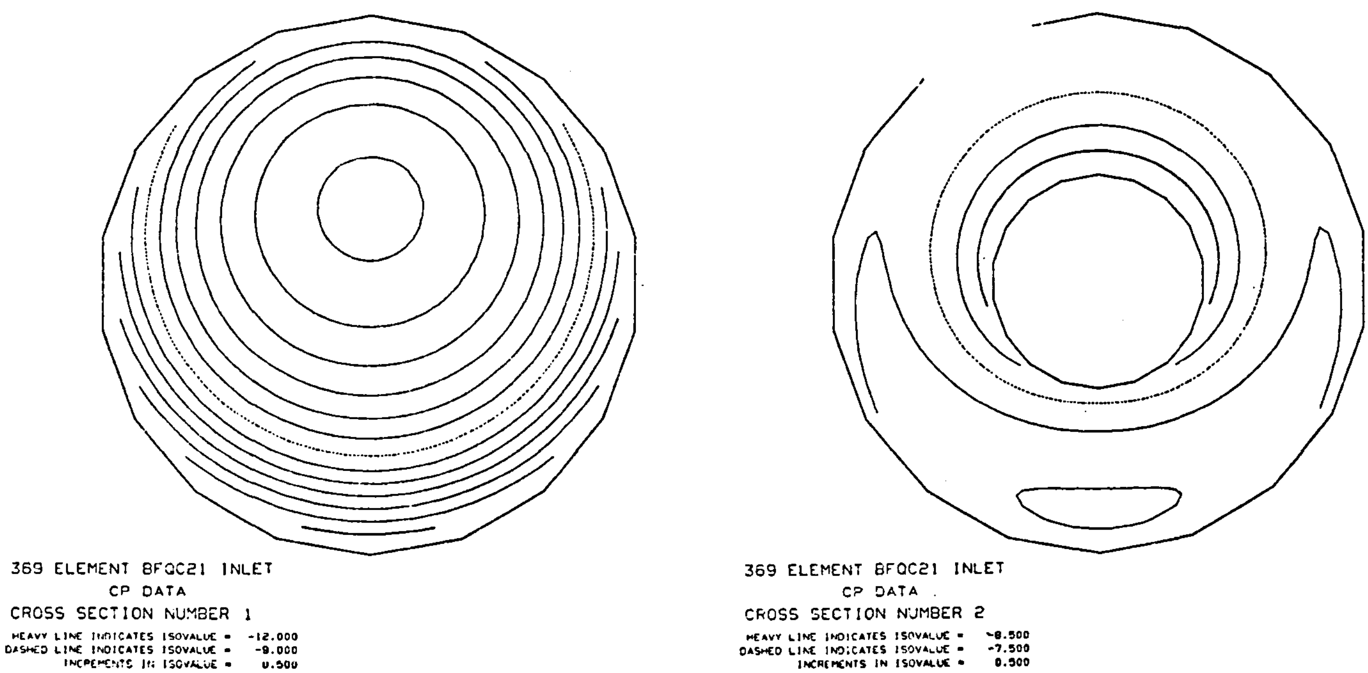


Figure 14. Calculated curves of constant pressure coefficient. (a) Cross section 1. (b) Cross section 2.

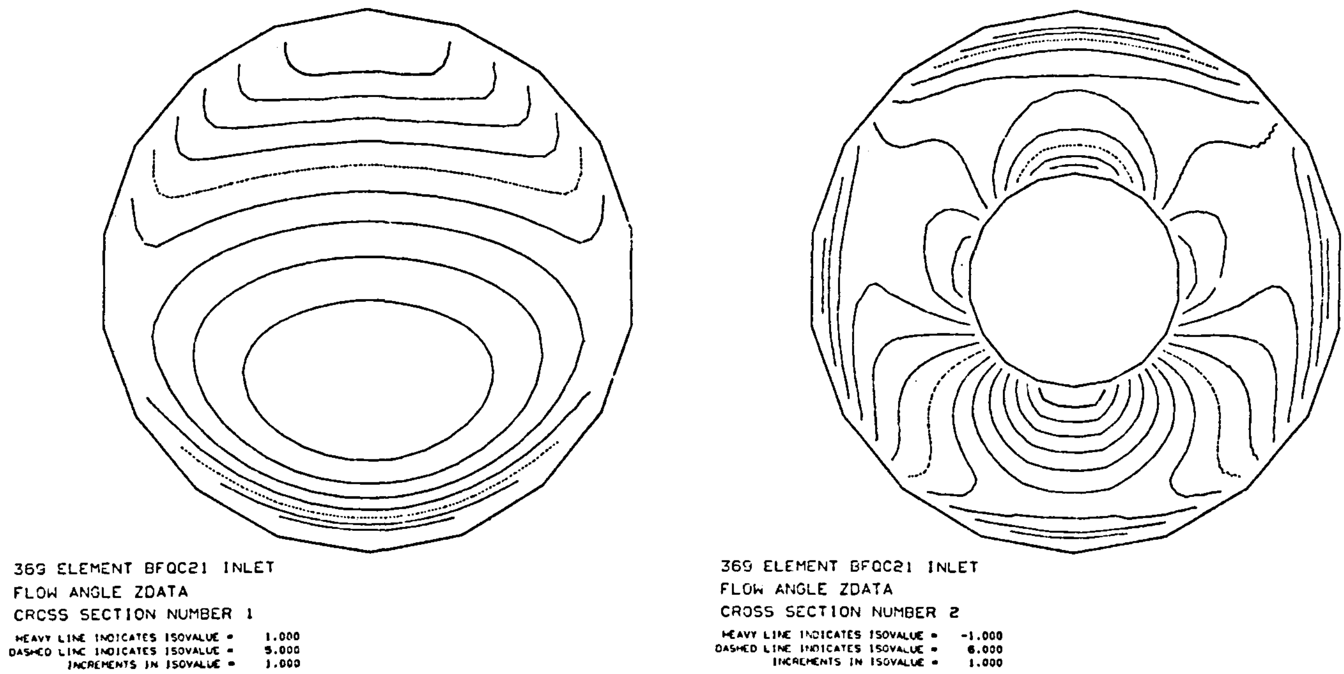


Figure 15. Calculated curves of constant flow pitch angle. (a) Cross section 1. (b) Cross section 2.

16.0 ACKNOWLEDGMENT

While virtually all major computer programs are the result of group efforts, the present work has been especially dependent on the creative contributions of a number of colleagues. Very significant portions of the final program were contributed by Mr. Douglas Halsey and Mr. Douglas Friedman. The running of cases for program checkout and evaluation, together with all manual graphics, was performed by Mrs. Sue Schimke.

17.0 PRINCIPAL NOTATION

A	area of a panel
A_c	area of the intersection of a plane with the centerbody
A_o	area of the intersection of the initial centerline plane with the interior of the inlet
A_{FP}	flow passage area
A^*_{FP}	geometric area associated with exterior points of the inlet's surface
A_{ij}	normal velocity at ith control point due to unit source density on jth panel
a	speed of sound, a_* is critical speed, equation (43)
B	combination constant for static solution, equation (5)
$B^{(k)}$	strength of bound vorticity on the kth strip of the inlet
c	subscript used with $V, \mu, \rho, q,$ and P to denote average conditions over a cross section
$\vec{F}$	vector volume flux through a cross section
j	subscript denoting quantities associated with the jth panel
L	number of lifting strips
M	Mach number
N	total number of panels on both inlet and centerbody
n_x, n_y, n_z	components of unit normal vector
P	pressure
Q	control station mass flow used in combination program, equations (5), (30), and (51)
r	number of control points in radial direction across a cross section
q	dynamic pressure
s	as a subscript denotes freestream static conditions; as a superscript denotes quantities associated with solution to flow about inlet in static operation

T	number of N-lines on the inlet; also denotes temperature
t	a subscript denoting reservoir conditions
V	fluid velocity
$\vec{V}_\infty$	freestream velocity
$\vec{V}_i$	velocity vector at ith control point. Subscript 0 denotes onset flow velocity. Subscript k denotes velocities due to vorticity solution on kth strip. Superscript f denotes velocity of fth fundamental flow solution. Specifically f can be either: s denoting static solution, (100) denoting solution at zero angle of attack and yaw, (010) denoting pure yaw, or (001) denoting 90° angle of attack with no yaw.
x,y,z	Cartesian coordinates
x_{cs},y_{cs},z_{cs}	coordinates of input cross-section point
$x_c^{(k)},y_c^{(k)},z_c^{(k)}$	coordinates of intersection of kth centerbody N-line with cross-section plane
$x_i^{(k)},y_i^{(k)},z_i^{(k)}$	coordinates of intersection of kth inlet N-line with cross-section plane
α	angle of attack
β	angle of yaw
ε	density ratio, equation (53)
ξ,η	Cartesian coordinates in the plane of a cross section. The η-axis is parallel to the $y = 0$ plane, which is the symmetry plane in symmetric cases.
ρ	fluid density
σ	source density

18.0 REFERENCES

1. Stockman, N.O.: Potential and Viscous Flows in VTOL, STOL or CTOL Propulsion System Inlets. AIAA Paper 75-1186, Oct. 1975.

2. Hess, J.L.: Calculation of Potential Flow about Arbitrary Three-Dimensional Lifting Bodies. Final Tech. Report. McDonnell Douglas Rept. No. MDC J5679-01, Oct. 1972. (A somewhat condensed version is contained in Comp. Meth. in Appl. Mech. and Engg., Vol. 4, No. 3, Nov. 1974.)

3. Lieblein, S.; and Stockman, N.O.: Compressibility Correction for Internal Flow Solutions. J. of Aircraft, Vol. 9, No. 4, Apr. 1972.

4. Albers, J.A.: Theoretical and Experimental Internal Flow Characteristics of a 13.97-Centimeter-Diameter Inlet at STOL Takeoff and Approach Conditions. NASA TN D-7185, Mar. 1973.

5. Mack, D.P.: Calculation of Potential Flow about Arbitrary Three-Dimensional Lifting Bodies. Users Manual. McDonnell Douglas Report No. MDC J5679-02, Oct. 1972.

6. Halsey, N.D.; and Hess, J.L.: A Geometry Package for Generation of Input Data for a Three-Dimensional Potential-Flow Program. NASA CR 2962 (McDonnell Douglas Rept. No. MDC J7710), Mar. 1978.

7. Halsey, N.D.: A Three-Dimensional Potential-Flow Program with a Geometry Package for Input Data Generation. NASA CR 145311 (McDonnell Douglas Rept. No. MDC J7733), Mar. 1978.

APPENDIX A. OVERLAY STRUCTURE

(IBM 370)

```
ENTRY MAIN
OVERLAY ALPHA
   INSERT REPAN,GEINPT,PANELC,PANELS
   INSERT TRANSF,SPACEC,SPACES,CBPLN2,CUBPLN
   INSERT ARCLGN,DERV,INTERP,DERV2,INTRP2,NORM,AMAXA
   INSERT FLGS0,FLGS1,FLGS2,PTS1,PTS2,DERC,DERS
   INSERT SSP,SEG,PUNCH,MAXP,PLANE3
OVERLAY ALPHA
   INSERT INPUT
   INSERT POINTS
   INSERT MISC
OVERLAY BETA
   INSERT NOLIFT
OVERLAY BETA
   INSERT LIFT
OVERLAY ALPHA
   INSERT VFORM
   INSERT NEAR
   INSERT WNEAR
   INSERT MOMENT
   INSERT FIELDS
OVERLAY BETA
   INSERT VFMNLF
OVERLAY BETA
   INSERT VFMLFT
OVERLAY ALPHA
   INSERT PSWISE
OVERLAY ALPHA
   INSERT AFORM
OVERLAY ALPHA
   INSERT COLSOL
   INSERT SPACER
OVERLAY ALPHA
   INSERT FSLOIN
OVERLAY ALPHA
   INSERT CSGEOM
OVERLAY ALPHA
   INSERT CROSEC
OVERLAY ALPHA
   INSERT FLPASG
OVERLAY ALPHA
   INSERT COMPRO
OVERLAY ALPHA
INSERT PICTR1
INSERT INTSCT
INSERT ONSCRN,QFIND,SCISSR
   INSERT ACALC,IGS,IGSPLT,PERSPC,PICTR2,ROTATV,SLDRAW,STITL0
   INSERT STITL1
   INSERT ANGBLK,PER,SINCOS
   INSERT CARTES,CHECK,MYMOD,READQ,SLTRAC,TRACE,PVFIND,WRITEQ
   INSERT XINTRP
   INSERT CDATA,SLSTRT
OVERLAY ALPHA
   INSERT COMPRS
```

APPENDIX B. EXTERNAL UNITS USED IN THE INLET PROGRAM

A total of 30 temporary storage external units are used. The unit numbers are: 1, 2, 3, 4, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33. In addition to these units, a SD-4060 unit is also required if graphical plot option is selected.

There are 3 modes of operation in this program:

Mode 0: To obtain the fundamental solution, cross-section and combined solution (incompressible or compressible).

Mode 1: To obtain the fundamental solution. Basic geometry data is input only and unit numbers 4, 22, 23, 24, 29, 30, 32, 33 should be saved so that data may be used for the combination solution.

Mode 2: To obtain the combination solution only. Cross-section data and the combination data should be input but not the basic data that defined the inlet.

Example of the external units set up is illustrated below.

B.1 External Unit Set-Up

(IBM 370)

```
/GO.FT01F001 DD DSNAME=&FT01,UNIT=SYSDA,SPACE=(TRK,(30,5)),
//             DCB=(RECFM=VBS,BLKSIZE=6447,BUFNO=1)
//GO.FT02F001 DD DSNAME=&FT02,UNIT=SYSDA,SPACE=(TRK,(30,5)),
//             DCB=(RECFM=VBS,BLKSIZE=6447,BUFNO=1)
//GO.FT03F001 DD DSNAME=&FT03,UNIT=SYSDA,SPACE=(TRK,(50,5)),
//             DCB=(RECFM=VBS,BLKSIZE=6447,BUFNO=1)
//GO.FT04F001 DD DSNAME=&FT04,UNIT=SYSDA,SPACE=(TRK,(50,5)),
//             DCB=(RECFM=VBS,BLKSIZE=6447,BUFNO=1)
//GO.FT07F001  DD  DUMMY
//GO.FT08F001 DD DSNAME=&FT08,UNIT=SYSDA,SPACE=(TRK,(50,5)),
//             DCB=(RECFM=VBS,BLKSIZE=6447,BUFNO=1)
//GO.FT09F001 DD DSNAME=&FT09,UNIT=SYSDA,SPACE=(TRK,(50,5)),
//             DCB=(RECFM=VBS,BLKSIZE=13030,BUFNO=1)
//GO.FT10F001 DD DSNAME=&FT10,UNIT=SYSDA,SPACE=(TRK,(50,5)),
//             DCB=(RECFM=VBS,BLKSIZE=6447,BUFNO=1)
//GO.FT11F001 DD DSNAME=&FT11,UNIT=SYSDA,SPACE=(TRK,(50,5)),
//             DCB=(RECFM=VBS,BLKSIZE=13030,BUFNO=1)
//GO.FT12F001 DD DSNAME=&FT12,UNIT=SYSDA,SPACE=(TRK,(50,5)),
//             DCB=(RECFM=VBS,BLKSIZE=13030,BUFNO=1)
//GO.FT13F001 DD DSNAME=&FT13,UNIT=SYSDA,SPACE=(TRK,(50,5)),
//             DCB=(RECFM=VBS,BLKSIZE=6447,BUFNO=1)
//GO.FT14F001 DD DSNAME=&FT14,UNIT=SYSDA,SPACE=(TRK,(50,5)),
//             DCB=(RECFM=VBS,BLKSIZE=6447,BUFNO=1)
//GO.FT15F001 DD DSNAME=&FT15,UNIT=SYSDA,SPACE=(TRK,(50,5)),
//             DCB=(RECFM=VBS,BLKSIZE=6447,BUFNO=1)
//GO.FT16F001 DD DSNAME=&FT16,UNIT=SYSDA,SPACE=(TRK,(50,5)),
//             DCB=(RECFM=VBS,BLKSIZE=6447,BUFNO=1)
//GO.FT17F001 DD DSNAME=&FT17,UNIT=SYSDA,SPACE=(TRK,(30,5)),
//             DCB=(RECFM=VBS,BLKSIZE=6447,BUFNO=1)
//GO.FT18F001 DD DSNAME=&FT18,UNIT=SYSDA,SPACE=(TRK,(30,5)),
//             DCB=(RECFM=VBS,BLKSIZE=6447,BUFNO=1)
//GO.FT19F001 DD DSNAME=&FT19,UNIT=SYSDA,SPACE=(TRK,(30,5)),
//             DCB=(RECFM=VBS,BLKSIZE=6447,BUFNO=1)
//GO.FT20F001 DD DSNAME=&FT20,UNIT=SYSDA,SPACE=(TRK,(30,5)),
//             DCB=(RECFM=VBS,BLKSIZE=6447,BUFNO=1)
//GO.FT21F001 DD DSNAME=&FT21,UNIT=SYSDA,SPACE=(TRK,(30,5)),
//             DCB=(RECFM=VBS,BLKSIZE=6447,BUFNO=1)
//GO.FT22F001 DD DSNAME=&FT22,UNIT=SYSDA,SPACE=(TRK,(30,5)),
//             DCB=(RECFM=VBS,BLKSIZE=6447,BUFNO=1)
//GO.FT23F001 DD DSNAME=&FT23,UNIT=SYSDA,SPACE=(TRK,(30,5)),
//             DCB=(RECFM=VBS,BLKSIZE=6447,BUFNO=1)
//GO.FT24F001 DD DSNAME=&FT24,UNIT=SYSDA,SPACE=(TRK,(30,5)),
//             DCB=(RECFM=VBS,BLKSIZE=6447,BUFNO=1)
//GO.FT25F001 DD DSNAME=&FT25,UNIT=SYSDA,SPACE=(TRK,(10,5)),
//             DCB=(RECFM=VBS,BLKSIZE=6447,BUFNO=1)
//GO.FT26F001 DD DSNAME=&FT26,UNIT=SYSDA,SPACE=(TRK,(10,5)),
//             DCB=(RECFM=VBS,BLKSIZE=6447,BUFNO=1)
//GO.FT27F001 DD DSNAME=&FT27,UNIT=SYSDA,SPACE=(TRK,(10,5)),
//             DCB=(RECFM=VBS,BLKSIZE=6447,BUFNO=1)
//GO.FT28F001 DD DSNAME=&FT28,UNIT=SYSDA,SPACE=(TRK,(10,5)),
//             DCB=(RECFM=VBS,BLKSIZE=6447,BUFNO=1)
//GO.FT29F001 DD DSNAME=&FT29,UNIT=SYSDA,SPACE=(TRK,(10,5)),
//             DCB=(RECFM=VBS,BLKSIZE=6447,BUFNO=1)
//GO.FT30F001 DD DSNAME=&FT30,UNIT=SYSDA,SPACE=(TRK,(10,5)),
//             DCB=(RECFM=VBS,BLKSIZE=6447,BUFNO=1)
//GO.FT31F001 DD DSNAME=&FT31,UNIT=SYSDA,SPACE=(TRK,(10,5)),
//             DCB=(RECFM=VBS,BLKSIZE=6447,BUFNO=1)
//GO.FT32F001 DD DSNAME=&FT32,UNIT=SYSDA,SPACE=(TRK,(10,5)),
//             DCB=(RECFM=VBS,BLKSIZE=6447,BUFNO=1)
//GO.FT33F001 DD DSNAME=&FT33,UNIT=SYSDA,SPACE=(TRK,(10,5)),
//             DCB=(RECFM=VBS,BLKSIZE=6447,BUFNO=1)
//GO.SD4000  DD  DSN=&OUTE.CMI.CCMIF.DUN.FL0000.JIHP,DISP=(NEW,KEEP).
//           UNIT=TAPE16,LABEL=RETPD=10,DCB=DEN=3
```

B.2 Data Assignments to External Storage

Unit Variable	Unit Number	Unit Function
	Unit #1 Unit #2	scratch units
NØUT	Unit #3	individual vorticity onset flows
IGEØM	Unit #4	geometric quantities for each input panel (on-body + wake)
NKUTTA	Unit #8	intermediate (left and right) vorticity flows
NAIJ	Unit #9	"plus" A_{ij} matrix
NRSIDE	Unit #10	right-hand sides for "plus" matrix
NT	Unit #11 Unit #12	"plus" on body + off-body $\vec{V}_{ij}$
ND	Unit #13 Unit #14 Unit #15 Unit #16	scratch units to be used in CØLSØL (matrix solutions)
NSIG	Unit #17	source density solutions for each onset flow
NM	Unit #18 Unit #19	"minus" on-body + off-body $\vec{V}_{ij}$
NAMIJ	Unit #20	"minus" A_{ij} matrix
NRM	Unit #21	right-hand side for "minus" matrix
NSETS	Unit #22	static (summed) source densities
NSETV	Unit #23	static velocity distributions
	Unit #24	scratch unit
NØFSAV SCSAVE	Unit #25 Unit #26	generated cross-section data from the input cross-section points
NFLUX	Unit #27	volume flux data
NV	Unit #28	combined velcoities at cross-section control points
KUNIT	Unit #29	important data are saved on this unit for restart capability
IUA IUB	Unit #30 Unit #31	data for streamline tracing program data for streamline plots
IUNITI	Unit #32	viewing angles for the input geometry plots
IUNIT	Unit #33	coordinates of input on-body points

APPENDIX C. SAMPLE INPUT AND OUTPUT FOR A SMALL PANEL NUMBER TEST CASE

C.1 Input for the Test Case

(Card Column)

```
0        1         2         3         4         5         6         7
123456789012345678901234567890123456789012345678901234567890123456789012


   1    1    1    0    1    4    1    5    1    0    0    1    0
INLET TEST CASE WITH CENTERBODY 1 WAKE 1 PL. SYM.  TYPE C              ONE
TEST  1  0  0  0  1  1  0  1  0   FFTF      6.0
  6  1   3
   1.0        0.         0.        2
   1.50       0.         0.2
   2.00       0.         0.35
   4.00       0.         0.35
   1.0        0.         0.        1
   1.50      -0.173205   0.10
   2.00      -0.303109   0.175
   4.00      -0.303109   0.175
   1.0        0.         0.        1
   1.50      -0.173205  -0.10
   2.00      -0.303109  -0.175
   4.00      -0.303109  -0.175
   1.0        0.         0.        1
   1.50       0.        -0.2
   2.00       0.        -0.35
   4.00       0.        -0.35
   4.000000   0.000001   1.00000021
   2.000000   0.000001   1.000000
   0.500000   0.000001   1.200000
   0.0        0.000001   1.700000
   0.500000   0.000001   2.200000
   2.000000   0.000002   2.400000
   4.000000   0.000002   2.400000
   6.000000   0.000002   2.400000
   4.000000  -0.866025   0.5000001
   2.000000  -0.866025   0.500000
   0.500000  -1.039230   0.600000
   0.0       -1.472242   0.850000
   0.500000  -1.905255   1.099999
   2.000000  -2.078461   1.199999
   4.000000  -2.078461   1.199999
   6.000000  -2.078461   1.199999
   4.000000  -0.866025  -0.5000001
   2.000000  -0.866025  -0.500000
   0.500000  -1.039230  -0.600000
   0.0       -1.472242  -0.850000
   0.500000  -1.905255  -1.099999
   2.000000  -2.078461  -1.199999
   4.000000  -2.078461  -1.199999
   6.000000  -2.078461  -1.199999
   4.000000  -0.000000  -1.0000001
   2.000000  -0.000000. -1.000000
   0.500000  -0.000000  -1.200000
   0.0       -0.000001  -1.700000
   0.500000  -0.000001  -2.200000
   2.000000  -0.000001  -2.400000
   4.000000  -0.000001  -2.400000
   6.000000  -0.000001  -2.4000003
   8
    0.0     0.0     0.    0 VIEW OF BODY LOOKING DOWN THE +X AXIS TOWARDS THE ORIGIN
  -90.0     0.0     0.    0 VIEW OF BODY LOOKING DOWN THE +Y AXIS TOWARDS THE ORIGIN
    0.0    90.0     0.    0 VIEW OF BODY LOOKING DOWN THE -Z AXIS TOWARDS THE ORIGIN
    5.0     5.0     0.0   0  5 DEGREE VIEW OF THE BODY FROM THE +X +Y +Z SIDE
   10.0    10.0     0.0   0 10 DEGREE VIEW OF THE BODY FROM THE +X +Y +Z SIDE
   15.0    15.0     0.0   0 15 DEGREE VIEW OF THE BODY FROM THE +X +Y +Z SIDE
   30.0  30.0   0.0       0 30 DEGREE VIEW OF THE BODY FROM THE+X +Y +Z SIDE
  -45.0    45.0     0.    1 45-DEGREE VIEW OF THE BODY FROM THE +X +Y +Z SIDE
   2
   0.25       0.         0.         1.0        0.         0.           5
   3.0        0.         0.         1.0        0.         0.           5
   4
   0.125      0.         0.         1.0        0.         0.
   1.250      0.         0.         1.0        0.         0.
   2.500      0.         0.         1.0        0.         0.
   3.500      0.         0.         1.0        0.         0.
   0.0        0.0        141.6                                  1
                                                                 15.874

   0.02       1.0        1.0        0.02
   0.02       1.0        1.0        0.02
```

```
                         PROGRAM J1HP,      DOUGLAS    AIRCRAFT     COMPANY      PAGE      1
                                                    LONG     BEACH     DIVISION
          CASE NO. TEST                             THURSDAY,    APR 19, 1979

                         INLET TEST CASE WITH CENTERBODY 1 WAKE 1 PL. SYM.  TYPE C              ONE

                                             ------------ * ------------

                                   CASE ID                          ---    TEST
                                   NUMBER OF LIFTING SECTIONS       ---       1
                                   NUMBER OF OFF-BODY POINTS        ---       0
                                   BASIC BODY INPUT CHECKOUT        ---       0
                                   SPECIAL LAST WAKE OPTION         ---       1
                                   PIECEWISE VORTICITY OPTION       ---       0
                                   SYMMETRY INPUT OPTION            ---       1
                                   DIPOLE STRENGTH CONSTANT INPUT             0
                                   FUNDAMENTAL SOLUTION OPTION      --        1
                                   CROSS-SECTION INPUT OPTION       ---       1
                                   FLOW PASSAGE OPTION              ---       1
                                   COMBINATION PROGRAM OPTION       ---       0

                                   INPUT CONTROL STATION NO.  ---             1

                                   INPUT CENTERBODY DOWNSTREAM OF INLET LIP. TYPE C

                                    USER SELECTS TO RUN THE FOLLOWING

                                       FUNDAMENTAL SOLUTION PROGRAM
                                       CROSS-SECTION PROGRAM
                                       FLOW PASSAGE PROGRAM
                                       COMBINATION PROGRAM ( COMPRESSIBLE )

                                 COMPONENTS OF THE UNIFORM ONSET FLOWS

                                 ( 1 )     1.000000,    0.0       ,    0.0

                                 ( 2 )     0.0      ,   0.0       ,    1.000000

                                 ( 3 )     0.0      ,   1.000000,      0.0

                                  INPUT SCALE FACTOR VALUE       6.000000

                                             ------------ * ------------
```

PROGRAM J1HP. DOUGLAS AIRCRAFT COMPANY PAGE 2
LONG BEACH DIVISION
CASE NO. TEST THURSDAY, APR 19, 1979

INLET TEST CASE WITH CENTERBODY 1 WAKE 1 PL. SYM. TYPE C ONE

------------- * -------------

N	M	X Y Z	X Y Z	X Y Z	X Y Z	NX NY NZ	XO YO ZO	D T A	TYPE OF ELEMENT
1	1	6.000000 0.0 0.0	9.000000 0.0 1.200000	9.000000 -1.039229 0.600000	6.000000 0.0 0.0	-0.327327 -0.472456 0.818317	7.999998 -0.346410 0.600000	2.3842E-07 3.2311E+00 1.9049E+00	NLIF
	2	9.000000 0.0 1.200000	12.000000 0.0 2.099999	12.000000 -1.818653 1.049999	9.000000 -1.039229 0.600000	-0.251459 -0.483934 0.838198	10.636363 -0.732185 1.268181	2.0489E-07 3.5114E+00 5.1143E+00	
	3	12.000000 0.0 2.099999	24.000000 0.0 2.099999	24.000000 -1.818653 1.049999	12.000000 -1.818653 1.049999	0.0 -0.500000 0.866025	18.000000 -0.909327 1.574998	5.3644E-07 1.2182E+01 2.5200E+01	
2	1	6.000000 0.0 0.0	9.000000 -1.039229 0.600000	9.000000 -1.039229 -0.600000	6.000000 0.0 0.0	-0.327326 -0.944911 0.0	7.999998 -0.692819 0.000000	1.1921E-07 3.2311E+00 1.9049E+00	NLIF
	2	9.000000 -1.039229 0.600000	12.000000 -1.818653 1.049999	12.000000 -1.818653 -1.049999	9.000000 -1.039229 -0.600000	-0.251460 -0.967868 0.0	10.636362 -1.464368 -0.000000	3.5763E-07 3.5114E+00 5.1143E+00	
	3	12.000000 -1.818653 1.049999	24.000000 -1.818653 1.049999	24.000000 -1.818653 -1.049999	12.000000 -1.818653 -1.049999	0.0 -1.000000 0.0	18.000000 -1.818653 0.0	0.0 1.2182E+01 2.5200E+01	
3	1	6.000000 0.0 0.0	9.000000 -1.039229 -0.600000	9.000000 0.0 -1.200000	6.000000 0.0 0.0	-0.327327 -0.472456 -0.818317	7.999998 -0.346410 -0.600000	2.3842E-07 3.2311E+00 1.9049E+00	NLIF
	2	9.000000 -1.039229 -0.600000	12.000000 -1.818653 -1.049999	12.000000 0.0 -2.099999	9.000000 0.0 -1.200000	-0.251459 -0.483934 -0.838198	10.636363 -0.732185 -1.268180	0.0 3.5114E+00 5.1143E+00	
	3	12.000000 -1.818653 -1.049999	24.000000 -1.818653 -1.049999	24.000000 0.0 -2.099999	12.000000 0.0 -2.099999	0.0 -0.500000 -0.866025	18.000000 -0.909326 -1.574998	2.9802E-07 1.2182E+01 2.5200E+01	
		************			************			************	
1	1	24.000000 0.000006 6.000000	12.000000 0.000006 6.000000	12.000000 -5.196150 3.000000	24.000000 -5.196150 3.000000	0.0 0.500000 -0.866026	18.000000 -2.598071 4.500000	2.4000E+01 1.3416E+01 7.2000E+01	LIFT
	2	12.000000 0.000006 6.000000	3.000000 0.000006 7.199999	3.000000 -6.235382 3.599999	12.000000 -5.196150 3.000000	-0.114708 0.496699 -0.860309	7.500000 -2.857880 4.949999	1.8120E+01 1.1225E+01 5.9926E+01	

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LONG BEACH DIVISION
CASE NO. TEST THURSDAY, APR 19, 1979

INLET TEST CASE WITH CENTERBODY 1 WAKE 1 PL. SYM. TYPE C ONE

------------- * -------------

N	M	X Y Z	X Y Z	X Y Z	X Y Z	NX NY NZ	XO YO ZO	D T A	TYPE OF ELEMENT
1	3	3.000000	0.0	0.0	3.000000	-0.654653	1.500000	7.9373E+00	LIFT
		0.000006	0.000006	-8.833454	-6.235382	0.377964	-3.767204	9.6794E+00	
		7.199999	10.199999	5.099999	3.599999	-0.654654	6.524998	3.6911E+01	
	4	0.0	3.000000	3.000000	0.0	-0.654654	1.500000	7.9373E+00	
		0.000006	0.000006	-11.431532	-8.833454	-0.377965	-5.066241	1.2445E+01	
		10.199999	13.199999	6.599997	5.099999	0.654654	8.774994	4.9639E+01	
	5	3.000000	12.000000	12.000000	3.000000	-0.114707	7.500000	1.8120E+01	
		0.000006	0.000012	-12.470764	-11.431532	-0.496700	-5.975566	1.6519E+01	
		13.199999	14.399998	7.199993	6.599997	0.860309	10.349991	1.2530E+02	
	6	12.000000	24.000000	24.000000	12.000000	0.0	18.000000	2.4000E+01	
		0.000012	0.000012	-12.470764	-12.470764	-0.500000	-6.235375	1.8745E+01	
		14.399998	14.399998	7.199993	7.199993	0.866026	10.799988	1.7280E+02	
	7	24.000000	36.000000	36.000000	24.000000	0.0	30.000000	2.4000E+01	WAKE
		0.000012	0.000012	-12.470764	-12.470764	-0.500000	-6.235375	1.8745E+01	
		14.399998	14.399998	7.199993	7.199993	0.866026	10.799988	1.7280E+02	
2	1	24.000000	12.000000	12.000000	24.000000	0.0	18.000000	2.4000E+01	LIFT
		-5.196150	-5.196150	-5.196150	-5.196150	1.000000	-5.196150	1.3416E+01	
		3.000000	3.000000	-3.000000	-3.000000	0.0	0.0	7.2000E+01	
	2	12.000000	3.000000	3.000000	12.000000	-0.114708	7.500000	1.8120E+01	
		-5.196150	-6.235382	-6.235382	-5.196150	0.993399	-5.715766	1.1225E+01	
		3.000000	3.599999	-3.599999	-3.000000	0.0	0.0	5.9926E+01	
	3	3.000000	0.0	0.0	3.000000	-0.654653	1.500000	7.9372E+00	
		-6.235382	-8.833454	-8.833454	-6.235382	0.755929	-7.534418	9.6794E+00	
		3.599999	5.099999	-5.099999	-3.599999	0.0	0.0	3.6911E+01	
	4	0.0	3.000000	3.000000	0.0	-0.654654	1.500000	7.9373E+00	
		-8.833454	-11.431532	-11.431532	-8.833454	-0.755929	-10.132492	1.2445E+01	
		5.099999	6.599997	-6.599997	-5.099999	0.0	0.0	4.9639E+01	
	5	3.000000	12.000000	12.000000	3.000000	-0.114708	7.500000	1.8120E+01	
		-11.431532	-12.470764	-12.470764	-11.431532	-0.993399	-11.951141	1.6519E+01	
		6.599997	7.199993	-7.199993	-6.599997	0.0	0.0	1.2530E+02	
	6	12.000000	24.000000	24.000000	12.000000	0.0	18.000000	2.4000E+01	
		-12.470764	-12.470764	-12.470764	-12.470764	-1.000000	-12.470764	1.8745E+01	
		7.199993	7.199993	-7.199993	-7.199993	0.0	0.0	1.7280E+02	
	7	24.000000	36.000000	36.000000	24.000000	0.0	30.000000	2.4000E+01	WAKE
		-12.470764	-12.470764	-12.470764	-12.470764	-1.000000	-12.470764	1.8745E+01	
		7.199993	7.199993	-7.199993	-7.199993	0.0	0.0	1.7280E+02	

PROGRAM J1HP, DOUGLAS AIRCRAFT COMPANY PAGE 4
LONG BEACH DIVISION
CASE NO. TEST THURSDAY, APR 19, 1979

INLET TEST CASE WITH CENTERBODY 1 WAKE 1 PL. SYM. TYPE C ONE

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N	M	X Y Z	X Y Z	X Y Z	X Y Z	NX NY NZ	XO YO ZO	D T A	TYPE OF ELEMENT
3	1	24.000000	12.000000	12.000000	24.000000	0.0	18.000000	2.4000E+01	LIFT
		-5.196150	-5.196150	0.0	0.0	0.500000	-2.598075	1.3416E+01	
		-3.000000	-3.000000	-6.000000	-6.000000	0.866025	-4.500000	7.2000E+01	
	2	12.000000	3.000000	3.000000	12.000000	-0.114708	7.500000	1.8120E+01	
		-5.196150	-6.235382	0.0	0.0	0.496700	-2.857382	1.1225E+01	
		-3.000000	-3.599999	-7.199999	-6.000000	0.860309	-4.949999	5.9926E+01	
	3	3.000000	0.0	0.0	3.000000	-0.654654	1.500000	7.9373E+00	
		-6.235382	-8.833454	-0.000006	0.0	0.377964	-3.767209	9.6793E+00	
		-3.599999	-5.099999	-10.199999	-7.199999	0.654654	-6.524998	3.6911E+01	
	4	0.0	3.000000	3.000000	0.0	-0.654654	1.500000	7.9373E+00	
		-8.833454	-11.431532	-0.000006	-0.000006	-0.377965	-5.066248	1.2445E+01	
		-5.099999	-6.599997	-13.199999	-10.199999	-0.654654	-8.774994	4.9639E+01	
	5	3.000000	12.000000	12.000000	3.000000	-0.114708	7.500000	1.8120E+01	
		-11.431532	-12.470764	-0.000006	-0.000006	-0.496700	-5.975574	1.6519E+01	
		-6.599997	-7.199993	-14.399998	-13.199999	-0.860309	-10.349991	1.2530E+02	
	6	12.000000	24.000000	24.000000	12.000000	0.0	18.000000	2.4000E+01	
		-12.470764	-12.470764	-0.000006	-0.000006	-0.500001	-6.235385	1.8745E+01	
		-7.199993	-7.199993	-14.399998	-14.399998	-0.866026	-10.799988	1.7280E+02	
	7	24.000000	36.000000	36.000000	24.000000	0.0	30.000000	2.4000E+01	WAKE
		-12.470764	-12.470764	-0.000006	-0.000006	-0.500001	-6.235385	1.8745E+01	
		-7.199993	-7.199993	-14.399998	-14.399998	-0.866026	-10.799988	1.7280E+02	

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PROGRAM J1HP, DOUGLAS AIRCRAFT COMPANY PAGE 5
LONG BEACH DIVISION
CASE NO. TEST THURSDAY, APR 19, 1979

INLET TEST CASE WITH CENTERBODY 1 WAKE 1 PL. SYM. TYPE C ONE

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TABLE OF INPUT INFORMATION

INPUT SECTION NO.	SECTION TYPE	TOTAL NO. OF ELEMENTS IN EACH SECTION	EXTRA STRIPS	STRIP NO.	SOURCE ELEMENTS IN THE STRIP	WAKE ELEMENTS IN THE STRIP
1	0	9		1	3	0
				2	3	0
				3	3	0
2	1	21		4	6	1
				5	6	1
				6	6	1

PROGRAM J1HP, DOUGLAS AIRCRAFT COMPANY PAGE 8
LONG BEACH DIVISION
CASE NO. TEST THURSDAY, APR 19, 1979

INLET TEST CASE WITH CENTERBODY 1 WAKE 1 PL. SYM. TYPE C ONE

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BODY SECTION NO. = 2 TYPE = 1 TOTAL NO. OF POINTS = 21 NO. OF STRIPS = 3

LIFTING SECTION NO. 1 NO. OF SOURCE ELEMENTS 6

NO. OF WAKE ELEMENTS 1 TOTAL NO. OF ELEMENTS PER STRIP 7

TOTAL NO. OF CONTROL POINTS (INCL. OFF BODY POINTS) = 27

TOTAL NO. OF ELEMENTS IN THE LIFTING SECTION = 21

NO. OF FAR ELEMENTS = 36 NO. OF INTERMEDIATE ELEMENTS = 168 NO. OF NEAR ELEMENTS = 1416

THE 27 X 27 MATRIX WITH 5 RIGHT SIDES WAS SOLVED DIRECTLY IN 0.011MINUTES.

THE 27 X 27 MATRIX WITH 1 RIGHT SIDES WAS SOLVED DIRECTLY IN 0.010MINUTES.

INLET TEST CASE WITH CENTERBODY 1 WAKE 1 PL. SYM. TYPE C ONE

FUNDAMENTAL SOLUTION OUTPUT

I	STATVX	STATVY	STATVZ	UVX1	UVY1	UVZ1	UVX2	UVY2	UVZ2	UVX3	UVY3	UVZ3
1	16.91554	-2.92990	5.07462	0.95474	-0.16537	0.28642	0.21455	0.32402	0.27289	-0.12387	0.64703	0.32402
2	22.12704	-2.87444	4.97854	1.22937	-0.15970	0.27661	0.14612	0.28300	0.20723	-0.08436	0.53402	0.28301
3	22.35988	-0.00003	-0.00001	1.23063	-0.00000	-0.00000	0.02573	0.35573	0.20538	-0.01486	0.61614	0.35573
4	16.91557	-5.85971	-0.00010	0.95474	-0.33073	-0.00000	-0.00000	-0.00000	0.83410	-0.24774	0.08582	-0.00000
5	22.12706	-5.74877	-0.00008	1.22937	-0.31940	0.00000	0.00000	-0.00000	0.69741	-0.16873	0.04384	0.00000
6	22.35986	0.00000	-0.00005	1.23063	0.00000	0.00000	-0.00000	-0.00000	0.82152	-0.02971	0.00000	-0.00000
7	16.91560	-2.92981	-5.07468	0.95474	-0.16536	-0.28642	-0.21454	-0.32401	0.27289	-0.12387	0.64703	-0.32402
8	22.12708	-2.87436	-4.97859	1.22937	-0.15970	-0.27661	-0.14612	-0.28300	0.20723	-0.08436	0.53402	-0.28301
9	22.35986	0.00001	-0.00000	1.23063	-0.00000	0.00000	-0.02573	-0.35573	0.20538	-0.01486	0.61614	-0.35573
10	22.45866	-0.00001	0.00000	1.19751	-0.00000	0.00000	0.02409	0.33969	0.19613	-0.01391	0.58837	0.33969
11	20.20905	1.16665	-2.02096	1.13273	0.06540	-0.11327	-0.14185	0.32269	0.20523	0.08190	0.57784	0.32269
12	8.04817	3.48491	-6.03613	0.33951	0.14701	-0.25463	-1.16699	-0.02911	1.15019	0.67376	1.11658	-0.02910
13	-1.35973	0.58878	-1.01980	0.92633	-0.40111	0.69475	1.32015	-0.01053	1.31408	-0.76219	1.30192	-0.01053
14	-0.35757	0.02065	-0.03576	1.19592	-0.06905	0.11959	0.34165	0.61203	0.39891	-0.19725	1.10562	0.61203
15	-2.29943	-0.00002	0.00011	1.07329	-0.00000	0.00000	-0.18418	0.63284	0.36537	0.10633	1.09611	0.63284
16	22.45863	-0.00002	-0.00003	1.19751	-0.00000	0.00000	0.00000	0.00000	0.78449	-0.02782	0.00000	-0.00000
17	20.20906	2.33352	-0.00002	1.13274	0.13080	0.00000	0.0	0.00000	0.76415	0.16380	0.01892	-0.00000
18	8.04815	6.96990	-0.00003	0.33951	0.29402	0.00000	-0.00000	-0.00000	1.09978	1.34752	1.16699	-0.00000
19	-1.35975	1.17757	-0.00000	0.92633	-0.80222	0.00000	0.00000	-0.00000	1.29584	-1.52437	1.32015	-0.00000
20	-0.35756	0.04129	-0.00001	1.19592	-0.13809	0.00000	0.0	0.00000	1.45398	-0.39450	0.04556	0.00000
21	-2.29944	-0.00014	-0.00003	1.07329	-0.00000	0.00000	-0.00000	0.00000	1.46148	0.21267	0.00000	0.00000
22	22.45863	0.00000	-0.00001	1.19751	-0.00000	-0.00000	-0.02409	-0.33969	0.19612	-0.01391	0.58837	-0.33969
23	20.20901	1.16671	2.02094	1.13273	0.06540	0.11327	0.14185	-0.32269	0.20522	0.08190	0.57784	-0.32269
24	8.04811	3.48491	6.03609	0.33950	0.14701	0.25463	1.16699	0.02911	1.15019	0.67376	1.11658	0.02911
25	-1.35974	0.58879	1.01979	0.92633	-0.40111	-0.69475	-1.32015	0.01053	1.31407	-0.76219	1.30192	0.01053
26	-0.35757	0.02064	0.03577	1.19592	-0.06905	-0.11959	-0.34164	-0.61203	0.39891	-0.19725	1.10562	-0.61203
27	-2.29945	-0.00004	-0.00008	1.07330	-0.00000	-0.00000	0.18418	-0.63284	0.36537	0.10634	1.09611	-0.63284

INLET TEST CASE WITH CENTERBODY 1 WAKE 1 PL. SYM. TYPE C ONE

CROSS SECTION AND CONTROL STATION PROGRAM

C.S. NO.	CROSS SECTION POINT XCSP	YCSP	ZCSP	NORMAL VECTOR UI	UJ	UK	RADIAL ELEMS.
1	0.150000E+01	0.0	0.0	0.100000E+01	0.0	0.0	5
2	0.180000E+02	0.0	0.0	0.100000E+01	0.0	0.0	5

FORMATION OF CROSS SECTION ELEMENTS

CROSS SECTION NO. 1

CROSS SECTION POINT	0.150000E+01	0.0	0.0
ELEMENTS TO BE FORMED PER STRIP	5		
NORMAL VECTOR COMPONENTS	0.100000E+01	0.0	0.0
UNIT NORMAL VECTOR	0.100000E+01	0.0	0.0
A11 A12 A13	0.0	0.100000E+01	0.0
A21 A22 A23	0.0	0.0	0.100000E+01
A31 A32 A33	0.100000E+01	0.0	0.0

INLET TEST CASE WITH CENTERBODY 1 WAKE 1 PL. SYM. TYPE C ONE

CROSS SECTION AND CONTROL STATION PROGRAM

J	I	X Y Z	X Y Z	X Y Z	X Y Z	R1X R1Y R1Z	R2X R2Y R2Z	XC YC ZC	XI ETA AREA	TYPE
1	1	1.50000 0.0 0.0	1.50000 0.00000 1.74000	1.50000 -1.50688 0.87000	1.50000 0.0 0.0	0.0 -1.50688 0.87000	0.0 -0.00000 -1.74000	1.50000 -0.37672 0.65250	-0.37672 0.65250 1.31099	CROS
	2	1.50000 0.00000 1.74000	1.50000 0.00000 3.48000	1.50000 -3.01377 1.74000	1.50000 -1.50688 0.87000	0.0 -3.01377 0.0	0.0 -1.50688 -2.61000	1.50000 -1.13016 1.95750	-1.13016 1.95750 3.93296	CROS
	3	1.50000 0.00000 3.48000	1.50000 0.00000 5.22000	1.50000 -4.52065 2.61000	1.50000 -3.01377 1.74000	0.0 -4.52065 -0.87000	0.0 -3.01377 -3.48000	1.50000 -1.88360 3.26250	-1.88360 3.26250 6.55494	CROS
	4	1.50000 0.00000 5.22000	1.50000 0.00000 6.96000	1.50000 -6.02753 3.48000	1.50000 -4.52065 2.61000	0.0 -6.02754 -1.74000	0.0 -4.52065 -4.35000	1.50000 -2.63704 4.56750	-2.63704 4.56750 9.17691	CROS
	5	1.50000 0.00000 6.96000	1.50000 0.00001 8.70000	1.50000 -7.53442 4.35000	1.50000 -6.02753 3.48000	0.0 -7.53442 -2.61000	0.0 -6.02754 -5.22000	1.50000 -3.39048 5.87250	-3.39048 5.87250 11.79890	CROS
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2	1	1.50000 0.0 0.0	1.50000 -1.50688 0.87000	1.50000 -1.50688 -0.87000	1.50000 0.0 0.0	0.0 -1.50688 -0.87000	0.0 1.50688 -0.87000	1.50000 -0.75344 0.0	-0.75344 0.0 1.31099	CROS
	2	1.50000 -1.50688 0.87000	1.50000 -3.01377 1.74000	1.50000 -3.01377 -1.74000	1.50000 -1.50688 -0.87000	0.0 -1.50688 -2.61000	0.0 1.50688 -2.61000	1.50000 -2.26032 -0.00000	-2.26032 -0.00000 3.93296	CROS
	3	1.50000 -3.01377 1.74000	1.50000 -4.52065 2.61000	1.50000 -4.52065 -2.61000	1.50000 -3.01377 -1.74000	0.0 -1.50688 -4.35000	0.0 1.50688 -4.35000	1.50000 -3.76721 0.0	-3.76721 0.0 6.55494	CROS
	4	1.50000 -4.52065 2.61000	1.50000 -6.02753 3.48000	1.50000 -6.02753 -3.48000	1.50000 -4.52065 -2.61000	0.0 -1.50688 -6.09000	0.0 1.50688 -6.09000	1.50000 -5.27409 0.0	-5.27409 0.0 9.17691	CROS
	5	1.50000 -6.02753 3.48000	1.50000 -7.53442 4.35000	1.50000 -7.53442 -4.35000	1.50000 -6.02753 -3.48000	0.0 -1.50688 -7.83000	0.0 1.50688 -7.83000	1.50000 -6.78097 0.0	-6.78097 0.0 11.79890	CROS
						---------- * ----------				
3		1.50000 0.0 0.0	1.50000 -1.50688 -0.87000	1.50000 -0.00000 -1.74000	50000 0.0 0.0	0.0 -0.00000 -1.74000	0.0 1.50688 0.87000	1.5000 -0.37672 -0.65250	-0.37672 -0.65250 1.31099	CROS

PROGRAM J1HP, DOUGLAS AIRCRAFT COMPANY PAGE 16
LONG BEACH DIVISION
CASE NO. TEST THURSDAY, APR 19, 1979

INLET TEST CASE WITH CENTERBODY 1 WAKE 1 PL. SYM. TYPE C ONE

CROSS SECTION AND CONTROL STATION PROGRAM

J	I	X / Y / Z	X / Y / Z	X / Y / Z	X / Y / Z	R1X / R1Y / R1Z	R2X / R2Y / R2Z	XC / YC / ZC	XI / ETA / AREA	TYPE
3	2	1.50000	1.50000	1.50000	1.50000	0.0	0.0	1.50000	-1.13016	CROS
		-1.50688	-3.01377	-0.00000	-0.00000	1.50688	3.01377	-1.13016	-1.95750	
		-0.87000	-1.74000	-3.48000	-1.74000	-2.61000	0.0	-1.95750	3.93296	
	3	1.50000	1.50000	1.50000	1.50000	0.0	0.0	1.50000	-1.88360	CROS
		-3.01377	-4.52065	-0.00000	-0.00000	3.01376	4.52065	-1.88360	-3.26250	
		-1.74000	-2.61000	-5.22000	-3.48000	-3.48000	-0.87000	-3.26250	6.55494	
	4	1.50000	1.50000	1.50000	1.50000	0.0	0.0	1.50000	-2.63705	CROS
		-4.52065	-6.02753	-0.00000	-0.00000	4.52065	6.02753	-2.63705	-4.56750	
		-2.61000	-3.48000	-6.96000	-5.22000	-4.35000	-1.74000	-4.56750	9.17691	
	5	1.50000	1.50000	1.50000	1.50000	0.0	0.0	1.50000	-3.39049	CROS
		-6.02753	-7.53442	-0.00000	-0.00000	6.02753	7.53442	-3.39049	-5.87249	
		-3.48000	-4.35000	-8.70000	-6.96000	-5.22000	-2.61000	-5.87249	11.79889	

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FINISHED COMPUTATION FOR CROSS SECTION 1

TOTAL NUMBER OF OFF-BODY POINTS GENERATED = 15

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FORMATION OF CROSS SECTION ELEMENTS

CROSS SECTION NO. 2

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CROSS SECTION POINT        0.180000E+02   0.0            0.0
ELEMENTS TO BE FORMED PER STRIP     5
NORMAL VECTOR COMPONENTS      0.100000E+01   0.0            0.0
UNIT NORMAL VECTOR            0.100000E+01   0.0            0.0
A11   A12   A13               0.0            0.100000E+01   0.0
A21   A22   A23               0.0            0.0            0.100000E+01
A31   A32   A33               0.100000E+01   0.0            0.0
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INLET TEST CASE WITH CENTERBODY 1 WAKE 1 PL. SYM. TYPE C ONE

CROSS SECTION AND CONTROL STATION PROGRAM

J	I	X Y Z	X Y Z	X Y Z	X Y Z	R1X R1Y R1Z	R2X R2Y R2Z	XC YC ZC	XI ETA AREA	TYPE
1	1	18.00000	18.00000	18.00000	18.00000	0.0	0.0	18.00000	-1.07820	CROS
		0.0	0.00000	-2.49415	-1.81865	-2.49415	-1.81865	-1.07820	1.86750	
		2.10000	2.88000	1.44000	1.05000	-0.66000	-1.83000	1.86750	1.68199	
	2	18.00000	18.00000	18.00000	18.00000	0.0	0.0	18.00000	-1.41595	CROS
		0.00000	0.00000	-3.16965	-2.49415	-3.16965	-2.49415	-1.41595	2.45250	
		2.88000	3.66000	1.83000	1.44000	-1.05000	-2.22000	2.45250	2.20888	
	3	18.00000	18.00000	18.00000	18.00000	0.0	0.0	18.00000	-1.75370	CROS
		0.00000	0.00000	-3.84515	-3.16965	-3.84515	-3.16965	-1.75370	3.03750	
		3.66000	4.44000	2.22000	1.83000	-1.44000	-2.61000	3.03750	2.73577	
	4	18.00000	18.00000	18.00000	18.00000	0.0	0.0	18.00000	-2.09145	CROS
		0.00000	0.00000	-4.52065	-3.84515	-4.52065	-3.84516	-2.09145	3.62250	
		4.44000	5.22000	2.61000	2.22000	-1.83000	-3.00000	3.62250	3.26266	
	5	18.00000	18.00000	18.00000	18.00000	0.0	0.0	18.00000	-2.42920	CROS
		0.00000	0.00001	-5.19615	-4.52065	-5.19615	-4.52066	-2.42920	4.20750	
		5.22000	6.00000	3.00000	2.61000	-2.22000	-3.39000	4.20750	3.78955	

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J	I	X Y Z	X Y Z	X Y Z	X Y Z	R1X R1Y R1Z	R2X R2Y R2Z	XC YC ZC	XI ETA AREA	TYPE
2	1	18.00000	18.00000	18.00000	18.00000	0.0	0.0	18.00000	-2.15640	CROS
		-1.81865	-2.49415	-2.49415	-1.81865	-0.67550	0.67550	-2.15640	0.0	
		1.05000	1.44000	-1.44000	-1.05000	-2.49000	-2.49000	0.0	1.68199	
	2	18.00000	18.00000	18.00000	18.00000	0.0	0.0	18.00000	-2.83190	CROS
		-2.49415	-3.16965	-3.16965	-2.49415	-0.67550	0.67550	-2.83190	0.0	
		1.44000	1.83000	-1.83000	-1.44000	-3.27000	-3.27000	0.0	2.20888	
	3	18.00000	18.00000	18.00000	18.00000	0.0	0.0	18.00000	-3.50740	CROS
		-3.16965	-3.84515	-3.84515	-3.16965	-0.67550	0.67550	-3.50740	0.0	
		1.83000	2.22000	-2.22000	-1.83000	-4.05000	-4.05000	0.0	2.73577	
	4	18.00000	18.00000	18.00000	18.00000	0.0	0.0	18.00000	-4.18290	CROS
		-3.84515	-4.52065	-4.52065	-3.84515	-0.67550	0.67550	-4.18290	0.0	
		2.22000	2.61000	-2.61000	-2.22000	-4.83000	-4.83000	0.0	3.26266	
	5	18.00000	18.00000	18.00000	18.00000	0.0	0.0	18.00000	-4.85840	CROS
		-4.52065	-5.19615	-5.19615	-4.52065	-0.67550	0.67550	-4.85840	0.0	
		2.61000	3.00000	-3.00000	-2.61000	-5.61000	-5.61000	0.0	3.78955	

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J	I	X Y Z	X Y Z	X Y Z	X Y Z	R1X R1Y R1Z	R2X R2Y R2Z	XC YC ZC	XI ETA AREA	TYPE
3		18.00000	18.00000	18.00000	[illegible] 00000	0.0	0.0	18.0000.	-1.07820	CROS
		-1.81865	-2.49415	0.0	0.0	1.81865	2.49415	-1.07820	-1.86750	
		-1.05000	-1.44000	-2.88000	-2.10000	-1.83000	-0.66000	-1.86750	1.68199	

INLET TEST CASE WITH CENTERBODY 1 WAKE 1 PL. SYM. TYPE C ONE

CROSS SECTION AND CONTROL STATION PROGRAM

J	I	X Y Z	X Y Z	X Y Z	X Y Z	R1X R1Y R1Z	R2X R2Y R2Z	XC YC ZC	XI ETA AREA	TYPE
3	2	18.00000 -2.49415 -1.44000	18.00000 -3.16965 -1.83000	18.00000 0.0 -3.66000	18.00000 0.0 -2.88000	0.0 2.49415 -2.22000	0.0 3.16965 -1.05000	18.00000 -1.41595 -2.45250	-1.41595 -2.45250 2.20880	CROS
	3	18.00000 -3.16965 -1.83000	18.00000 -3.84515 -2.22000	18.00000 0.0 -4.44000	18.00000 0.0 -3.66000	0.0 3.16965 -2.61000	0.0 3.84515 -1.44000	18.00000 -1.75370 -3.03750	-1.75370 -3.03750 2.73577	CROS
	4	18.00000 -3.84515 -2.22000	18.00000 -4.52065 -2.61000	18.00000 0.0 -5.22000	18.00000 0.0 -4.44000	0.0 3.84515 -3.00000	0.0 4.52065 -1.83000	18.00000 -2.09145 -3.62250	-2.09145 -3.62250 3.26266	CROS
	5	18.00000 -4.52065 -2.61000	18.00000 -5.19615 -3.00000	18.00000 0.0 -6.00000	18.00000 0.0 -5.22000	0.0 4.52065 -3.39000	0.0 5.19615 -2.22000	18.00000 -2.42920 -4.20750	-2.42920 -4.20750 3.78955	CROS

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FINISHED COMPUTATION FOR CROSS SECTION 2

TOTAL NUMBER OF OFF-BODY POINTS GENERATED = 15

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INLET TEST CASE WITH CENTERBODY 1 WAKE 1 PL. SYM. TYPE C ONE

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BODY SECTION NO. = 2 TYPE = 1 TOTAL NO. OF POINTS = 21 NO. OF STRIPS = 3

LIFTING SECTION NO. 1 NO. OF SOURCE ELEMENTS 6

NO. OF WAKE ELEMENTS 1 TOTAL NO. OF ELEMENTS PER STRIP 7

TOTAL NO. OF CONTROL POINTS (INCL. OFF BODY POINTS) = 15

TOTAL NO. OF ELEMENTS IN THE LIFTING SECTION = 21

NO. OF FAR ELEMENTS = 0 NO. OF INTERMEDIATE ELEMENTS = 126 NO. OF NEAR ELEMENTS = 774

FLOW	FLUXX	FLUXY	FLUXZ	TOTAL FLUX
1	0.969526E+03	0.0	0.0	0.193905E+04
2	0.596802E+02	0.0	0.0	0.119360E+03
3	-0.429153E-04	0.0	0.0	-0.858307E-04
4	0.460204E+02	0.0	0.0	0.0

CALCULATION OF CROSS SECTION NO. 1HAS BEEN COMPLETED.

INLET TEST CASE WITH CENTERBODY 1 WAKE 1 PL. SYM. TYPE C ONE

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BODY SECTION NO. = 2 TYPE = 1 TOTAL NO. OF POINTS = 21 NO. OF STRIPS = 3

LIFTING SECTION NO. 1 NO. OF SOURCE ELEMENTS 6

NO. OF WAKE ELEMENTS 1 TOTAL NO. OF ELEMENTS PER STRIP 7

TOTAL NO. OF CONTROL POINTS (INCL. OFF BODY POINTS) = 15

TOTAL NO. OF ELEMENTS IN THE LIFTING SECTION = 21

NO. OF FAR ELEMENTS = 0 NO. OF INTERMEDIATE ELEMENTS = 111 NO. OF NEAR ELEMENTS = 789

FLOW	FLUXX	FLUXY	FLUXZ	TOTAL FLUX
1	0.920213E+03	0.0	0.0	0.184043E+04
2	0.498369E+02	0.0	0.0	0.996737E+02
3	0.393391E-05	0.0	0.0	0.786781E-05
4	-0.104613E+01	0.0	0.0	0.0

CALCULATION OF CROSS SECTION NO. 2HAS BEEN COMPLETED.

INLET TEST CASE WITH CENTERBODY 1 WAKE 1 PL. SYM. TYPE C ONE

FLOW PASSAGE CALCULATION PROGRAM

C.P. NO.	CENTERLINE POINT XCP	YCP	ZCP	NORMAL VECTOR UI	UJ	UK
1	0.750000E+00	0.0	0.0	0.100000E+01	0.0	0.0
2	0.750000E+01	0.0	0.0	0.100000E+01	0.0	0.0
3	0.150000E+02	0.0	0.0	0.100000E+01	0.0	0.0
4	0.210000E+02	0.0	0.0	0.100000E+01	0.0	0.0

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LONG BEACH DIVISION
CASE NO. TEST FRIDAY, SEP 28, 1979

INLET TEST CASE WITH CENTERBODY 1 WAKE 1 PL. SYM. TYPE C ONE

FINAL OUTPUT COMPRESSIBLE SOLUTION

COMBINATION SOLUTION NO. 1

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FREESTREAM CONDITIONS ---

ANGLE OF ATTACK	0.0	ANGLE OF YAW	0.0	FREESTREAM VELOCITY	0.141600E+03
FREESTREAM MACH NO.	0.127095E+00	TOTAL PRESSURE	0.211623E+04	STATIC PRESSRE	0.209248E+04
TOTAL TEMPERATURE	0.518670E+03	STATIC TEMPERATURE	0.517000E+03	DYNAMIC PRESSURE	0.236595E+02
TOTAL DENSITY	0.237626E-02	STATIC DENSITY	0.235910E-02	DENSITY RATIO	0.991971E+00
PRESSURE RATIO	0.988777E+00	TEMP/SEA-LEVEL RATIO	0.100000E+01	PRES/SEA-LEVEL RATIO	0.100000E+01
CRITICAL SPEED	0.101871E+04	MAXIMUM VELOCITY	0.249552E+04	FREESTREAM SOUND SPEED	0.111594E+04
EQUIV FREESTREAM VEL.	0.140405E+03	EQUIV CRITICAL VEL.	0.645761E+03	STAGNATION SOUND SPEED	0.111594E+04

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CONTROL STATION CONDITIONS ---

AVERAGE MACH NUMBER	0.137666E+00	INLET MASS FLOW RATE	0.158740E+02	CORR. MASS FLOW RATE	0.158740E+02
EQUIV AVERAGE VEL.	0.151917E+03	PC OVER PT	0.988842E+00	RHOC OVER RHOT	0.990584E+00
DYNAMIC PRESSURE	0.277155E+02	VELOCITY RATIO	0.923312E+00	AVERAGE VELOCITY	0.153361E+03

COMPUTED MASS FLOW --- 0.296712E+05

INLET TEST CASE WITH CENTERBODY 1 WAKE 1 PL. SYM. TYPE C ONE

FINAL OUTPUT COMPRESSIBLE SOLUTION

NON-SYMMETRY PRINT OUTPUT

SOLUTION FOR THE ON-BODY ELEMENTS

N	M	XC YC ZC	VX VY VZ	VMAG MACH P / PT	VBAR EPSLON AREA(FP)
1	1	7.999998 -0.346410 0.600000	255.825241 -44.310364 43.679840	263.282959 0.237253 0.961577	266.170654 C.970045 112.236832
	2	10.636363 -0.732185 1.268181	337.686768 -43.867065 42.717133	343.193115 0.310487 0.935346	321.380371 C.955167 92.955750
	3	18.000000 -0.909327 1.574998	342.087402 -0.000198 2.538933	342.096924 0.309476 0.935750	364.805664 0.940721 81.890594
************			************		************
2	1	7.999998 -0.692819 0.000000	256.037109 -88.693588 -0.000158	270.964355 0.244257 0.959337	266.170654 C.970045 112.236832
	2	10.636362 -1.464368 -0.000000	337.948975 -87.801758 0.000023	349.168701 0.316000 0.933132	321.380371 0.955167 92.955750
	3	18.000000 -1.818653 0.0	342.091553 0.000015 0.000036	342.091797 0.309472 0.935750	364.873535 C.940696 81.875381
************			************		************
3	1	7.999998 -0.346410 -0.600000	255.825653 -44.309662 -43.679916	263.283447 0.237254 0.961577	266.170654 0.970045 112.236832
	2	10.636363 -0.732185 -1.268180	337.686768 -43.866455 -42.717224	343.193115 0.310487 0.935346	321.380371 0.955167 92.955750
	3	18.000000 -0.909326 -1.574998	342.090820 0.000070 -2.538962	342.100342 0.309480 0.935747	364.856445 0.940703 81.879181
************			************		************
4	1	18.000000 -2.598071 4.500000	337.698975 -0.000143 2.423266	337.707764 0.305431 0.937352	365.448975 0.940487 81.746475
	2	7.500000 -2.857880 4.949999	305.916016 17.661087 -14.202209	306.754395 0.276985 0.948100	266.170654 C.970045 112.236816
	3	1.500000 -3.767204 6.524998	102.800751 44.513550 -36.211075	117.731537 0.105617 0.992232	143.946915 C.991560 207.536011
	4	1.500000 -5.066241 8.774994	121.370392 -52.554932 97.876053	164.537415 0.147764 0.984868	56.035858 C.998737 533.125732
	5	7.500000 -5.975566 10.349991	165.750153 -9.569506 20.959061	167.344025 0.150296 0.984348	16.708252 0.999888 1787.98730
	6	18.000000 -6.235375 10.799988	135.253372 -0.000207 4.279458	135.321167 0.121441 0.989747	5.673552 0.999987 5265.51562
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INLET TEST CASE WITH CENTERBODY 1 WAKE 1 PL. SYM. TYPE C ONE

FINAL OUTPUT COMPRESSIBLE SOLUTION

NON-SYMMETRY PRINT OUTPUT

SOLUTION FOR THE ON-BODY ELEMENTS

N	M	XC YC ZC	VX VY VZ	VMAG MACH P / PT	VBAR EPSLON AREA(FP)
5	1	18.000000	337.698486	337.698730	365.448975
		-5.196150	-0.000251	0.305423	0.940487
		0.0	0.000008	0.937355	81.746475
	2	7.500000	305.956543	307.989746	266.170654
		-5.715766	35.328491	0.278117	C.970045
		0.0	0.000058	0.947689	112.236816
	3	1.500000	102.910522	136.137894	143.946915
		-7.534418	89.123047	0.122176	0.991560
		0.0	0.000048	0.989622	207.536011
	4	1.500000	121.359207	160.543488	56.035858
		-10.132492	-105.100464	0.144162	0.998737
		0.0	0.000050	0.985589	533.125732
	5	7.500000	165.749908	166.851410	16.708252
		-11.951141	-19.139160	0.149852	0.999888
		0.0	0.000033	0.984440	1787.98730
	6	18.000000	135.253296	135.253403	5.673552
		-12.470764	-0.000963	0.121379	0.999987
		0.0	0.000012	0.989758	5265.51562
************			************		************
6	1	18.000000	337.698730	337.707764	365.448975
		-2.598075	-0.000025	0.305431	0.940487
		-4.500000	-2.423203	0.937352	81.746475
	2	7.500000	305.916016	306.754395	266.170654
		-2.857882	17.661621	0.276985	0.970045
		-4.949999	14.202299	0.948100	112.236816
	3	1.500000	102.800186	117.731094	143.946915
		-3.767209	44.513626	0.105617	0.991560
		-6.524998	36.211151	0.992232	207.536011
	4	1.500000	121.370255	164.537323	56.035858
		-5.066248	-52.554886	0.147764	0.998737
		-8.774994	-97.876068	0.984868	533.125732
	5	7.500000	165.750320	167.344193	16.708252
		-5.975574	-9.569611	0.150296	0.999888
		-10.349991	-20.959091	0.984348	1787.98730
	6	18.000000	135.253418	135.321228	5.673552
		-6.235385	-0.000322	0.121441	0.999987
		-10.799988	-4.279426	0.989747	5265.51562
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INLET TEST CASE WITH CENTERBODY 1 WAKE 1 PL. SYM. TYPE C ONE

FINAL OUTPUT COMPRESSIBLE SOLUTION

SYMMETRY PRINT OUTPUT -- REFLECTED ELEMENTS

SOLUTION FOR THE ON-BODY ELEMENTS

N	M	XC YC ZC	VX VY VZ	VMAG MACH P / PT	VBAR EPSLON AREA(FP)
1R	1	7.999998 0.346410 0.600000	255.805099 44.306885 39.166000	262.551758 0.236587 0.961787	266.170654 0.970045 112.236832
	2	10.636363 0.732185 1.268181	337.664795 43.864227 38.705170	342.695068 0.310028 0.935529	321.380371 0.955167 92.955750
	3	18.000000 0.909327 1.574998	342.087402 0.000198 -2.538939	342.096924 0.309476 0.935750	364.805664 C.940721 81.890594
************			************		************
2R	1	7.999998 0.692819 0.000000	256.037109 88.693588 -0.000133	270.964355 0.244257 0.959337	266.170654 C.970045 112.236832
	2	10.636362 1.464368 -0.000000	337.948975 87.801758 0.000021	349.168701 0.316000 0.933132	321.380371 0.955167 92.955750
	3	18.000000 1.818653 0.0	342.091553 -0.000015 0.000042	342.091797 0.309472 0.935750	364.873535 C.940696 81.875381
************			************		************
3R	1	7.999998 0.346410 -0.600000	255.805511 44.306168 -39.166046	262.552002 0.236587 0.961787	266.170654 C.970045 112.236832
	2	10.636363 0.732185 -1.268180	337.664795 43.863617 -38.705215	342.694824 0.310028 0.935529	321.380371 0.955167 92.955750
	3	18.000000 0.909326 -1.574998	342.090820 -0.000070 2.538970	342.100342 0.309480 0.935747	364.856445 C.940703 81.879181
************			************		************
4R	1	18.000000 2.598071 4.500000	337.698975 0.000143 -2.423064	337.707764 0.305431 0.937352	365.448975 0.940487 81.746475
	2	7.500000 2.857880 4.949999	305.924072 -17.661560 -18.716019	307.004639 0.277214 0.948016	266.170654 0.970045 112.236816
	3	1.500000 3.767204 6.524998	102.799973 -44.513214 -35.814575	117.609390 0.105507 0.992248	143.946915 0.991560 207.536011
	4	1.500000 5.066241 8.774994	121.370621 52.555023 98.019104	164.622757 0.147841 0.984852	56.035858 0.998737 533.125732
	5	7.500000 5.975566 10.349991	165.749207 9.569451 12.674822	166.508484 0.149542 0.984505	16.708252 0.999888 1787.98730
	6	18.000000 6.235375 10.799988	135.253372 0.000207 -4.279350	135.321167 0.121441 0.989747	5.673552 0.999987 5265.51562
************			************		************

INLET TEST CASE WITH CENTERBODY 1 WAKE 1 PL. SYM. TYPE C ONE

FINAL OUTPUT COMPRESSIBLE SOLUTION

SYMMETRY PRINT OUTPUT -- REFLECTED ELEMENTS

SOLUTION FOR THE ON-BODY ELEMENTS

N	M	XC YC ZC	VX VY VZ	VMAG MACH P / PT	VBAR EPSLON AREA(FP)
5R	1	18.000000 5.196150 0.0	337.698486 0.000251 0.000016	337.698730 0.305423 0.937355	365.448975 0.940487 81.746475
	2	7.500000 5.715766 0.0	305.956543 -35.328491 0.000064	307.989746 0.278117 0.947689	266.170654 C.970045 112.236816
	3	1.500000 7.534418 0.0	102.910522 -89.123047 0.000050	136.137894 0.122176 0.989622	143.946915 0.991560 207.536011
	4	1.500000 10.132492 0.0	121.359207 105.100464 0.000053	160.543488 0.144162 0.985589	56.035858 C.998737 533.125732
	5	7.500000 11.951141 0.0	165.749908 19.139160 0.000030	166.851410 0.149852 0.984440	16.708252 0.999888 1787.98730
	6	18.000000 12.470764 0.0	135.253296 0.000963 0.000008	135.253403 0.121379 0.989758	5.673552 0.999987 5265.51562
************			************		************
6R	1	18.000000 2.598075 -4.500000	337.698730 0.000025 2.423139	337.707764 0.305431 0.937352	365.448975 0.940487 81.746475
	2	7.500000 2.857882 -4.949999	305.924072 -17.662094 18.716110	307.004639 0.277214 0.948016	266.170654 0.970045 112.236816
	3	1.500000 3.767209 -6.524998	102.799408 -44.513290 35.814651	117.608932 0.105507 0.992248	143.946915 0.991560 207.536011
	4	1.500000 5.066248 -8.774994	121.370483 52.554977 -98.019104	164.622650 0.147841 0.984852	56.035858 0.998737 533.125732
	5	7.500000 5.975574 -10.349991	165.749374 9.569556 -12.674834	166.508652 0.149542 0.984505	16.708252 0.999888 1787.98730
	6	18.000000 6.235385 -10.799988	135.253418 0.000322 4.279392	135.321228 0.121441 0.989747	5.673552 0.999987 5265.51562
************			************		************

INLET TEST CASE WITH CENTERBODY 1 WAKE 1 PL. SYM. TYPE C ONE

FINAL OUTPUT COMPRESSIBLE SOLUTION

COMBINATION SOLUTION NO. 1

INPUT ELEMENT PRINT

SOLUTION FOR THE CROSS-SECTION ELEMENTS CROSS - SECTION NO. 1

N	M	XC YC ZC	VX VY VZ	VMAG MACH P / PT	VBAR EPSLON AREA(FP)
1	1	1.500000 -0.376720 0.652499	193.019775 3.648717 -2.111382	193.066055 0.173527 0.979207	303.833252 0.960292 98.324188
	2	1.500000 -1.130161 1.957499	191.280361 11.752361 -6.859131	191.743988 0.172332 0.979427	303.833252 0.960292 98.324188
	3	1.500000 -1.883602 3.262498	183.960125 22.670972 -13.094000	185.871865 0.167028 0.980716	303.833252 0.960292 98.324188
	4	1.500000 -2.637043 4.567497	154.012183 55.944901 -23.995301	166.558727 0.144156 0.985559	303.833252 0.960292 98.324188
	5	1.500000 -3.390485 5.872496	125.511246 57.551422 -32.829239	133.262545 0.119534 0.990083	303.833252 0.960292 98.324188
************			************		************
2	1	1.500000 -0.753441 0.0	193.022384 7.297473 0.000043	193.160416 0.173615 0.979184	303.833252 0.960292 98.324188
	2	1.500000 -2.260324 -0.000000	191.284332 23.507629 0.000040	192.723557 0.173216 0.979278	303.833252 0.960292 98.324188
	3	1.500000 -3.767208 0.0	164.054910 45.765962 0.000036	169.654210 0.170447 0.979929	303.833252 0.960292 98.324188
	4	1.500000 -5.274090 0.0	154.014102 71.983994 0.000043	170.751232 0.155352 0.983714	303.833252 0.960292 98.324188
	5	1.500000 -6.780972 0.0	123.095663 75.215775 0.000046	144.769028 0.129947 0.988270	303.833252 0.960292 98.324188
************			************		************
3	1	1.500000 -0.376721 -0.652499	193.019926 3.648722 2.110464	193.066193 0.173528 0.979207	303.833252 0.960292 98.324188
	2	1.500000 -1.130162 -1.957499	191.280408 11.752379 6.859265	191.744019 0.172332 0.979427	303.833252 0.960292 98.324188
	3	1.500000 -1.883604 -3.262496	183.960171 22.671002 13.094125	185.875946 0.167028 0.980716	303.833252 0.960292 98.324188
	4	1.500000 -2.637046 -4.567497	154.011969 55.945238 23.995408	166.558605 0.144156 0.985569	303.833252 0.960292 98.324188
	5	1.500000 -3.390469 -5.872494	125.511165 57.551775 32.829361	133.262621 0.119534 0.990085	303.833252 0.960292 98.324188
************			************		************

CROSS-SECTION PLANE NO. 1
MASS FLOW RATE 0.249257E+00
CORR.MASS FLOW RATE 0.249257E+00
SPECIFIC C.MASS F.RATE 0.253500E-02
AVERAGE MACH NO. 0.296515E-04
ITERATION 1

INLET TEST CASE WITH CENTERBODY 1 WAKE 1 PL. SYM. TYPE C ONE

FINAL OUTPUT COMPRESSIBLE SOLUTION

COMBINATION SOLUTION NO. 1

SYMMETRY PRINT OUTPUT -- REFLECTED ELEMENTS

SOLUTION FOR THE CROSS-SECTION ELEMENTS CROSS - SECTION NO. 1

N	M	XC YC ZC	VX VY VZ	VMAG MACH P / PT	VBAR EPSLON AREA(FP)
1R	1	1.500000 0.378720 0.652499	193.019775 -5.646717 -2.117768	193.066040 0.173527 0.979207	303.833252 0.960292 98.324188
	2	1.500000 1.130161 1.957499	191.260361 -11.752561 -6.000736	191.744980 0.172333 0.979487	303.833252 0.960292 98.324188
	3	1.500000 1.883002 3.262495	183.966644 -22.871033 -13.767598	185.893555 0.167044 0.980713	303.833252 0.960292 98.324188
	4	1.500000 2.637045 4.567497	154.014059 -35.945545 -24.600247	160.633392 0.144245 0.985572	303.833252 0.960292 98.324188
	5	1.500000 3.390425 5.872498	123.511475 -37.551483 -32.669465	133.217651 0.119547 0.990060	303.833252 0.960292 98.324188
************			************		************
2R	1	1.500000 0.755441 0.0	193.022594 -7.297473 0.000044	193.160416 0.173613 0.979184	303.833252 0.960292 98.324188
	2	1.500000 2.260024 -0.000000	191.284332 -23.507629 0.000053	192.723557 0.173213 0.979278	303.833252 0.960292 98.324188
	3	1.500000 3.767268 0.0	164.054916 -45.765962 0.000042	169.659210 0.170447 0.979929	303.833252 0.960292 98.324188
	4	1.500000 5.274090 0.0	154.014102 -71.963994 0.000044	170.751232 0.153352 0.983714	303.833252 0.960292 98.324188
	5	1.500000 6.780972 0.0	123.695663 -75.215775 0.000048	144.769028 0.129947 0.988270	303.833252 0.960292 98.324188
************			************		************
3R	1	1.500000 0.378721 -0.652499	193.019920 -5.646722 2.117660	193.066193 0.173526 0.979207	303.833252 0.960292 98.324188
	2	1.500000 1.130162 -1.957499	191.260498 -11.752579 6.000036	191.745026 0.172333 0.979487	303.833252 0.960292 98.324188
	3	1.500000 1.883004 -3.262498	183.966696 -22.871163 13.767719	185.893616 0.167044 0.980713	303.833252 0.960292 98.324188
	4	1.500000 2.637040 -4.567497	154.013846 -35.945063 24.600222	160.633276 0.144243 0.985572	303.833252 0.960292 98.324188
	5	1.500000 3.391409 -5.872494	123.511414 -37.551649 32.669527	133.217743 0.119547 0.990060	303.833252 0.960292 98.324188
************			************		************

CROSS-SECTION PLANE NO.	1
MASS FLOW RATE	0.4565151E+00
CORR.MASS FLOW RATE	0.4565151E+00
SPECIFIC C.MASS F.RATE	0.5076211E-02
AVERAGE MACH NO.	0.5936292E-04
ITERATION	1

INLET TEST CASE WITH CENTERBODY 1 WAKE 1 PL. SYM. TYPE C ONE

FINAL OUTPUT COMPRESSIBLE SOLUTION

COMBINATION SOLUTION NO. 1

INPUT ELEMENT PRINT

SOLUTION FOR THE CROSS-SECTION ELEMENTS CROSS - SECTION NO. 2

N	M	XC YC ZC	VX VY VZ	VMAG MACH P / PT	VBAR EPSLON AREA(FP)	
1	1	18.000000 -1.078200 1.867498	407.016846 -0.821428 3.039342	407.029541 0.369692 0.909932	645.760742 0.633900 41.036606	CHOKE
	2	18.000000 -1.415950 2.452498	406.283691 -2.282299 3.501264	406.303711 0.369015 0.910242	645.760742 0.633900 41.036606	CHOKE
	3	18.000000 -1.753698 3.037498	405.269910 -3.069570 3.560026	405.291504 0.368071 0.910674	645.760742 0.633900 41.036606	CHOKE
	4	18.000000 -2.091448 3.622497	403.903839 -2.827495 3.667857	403.930420 0.366801 0.911254	645.760742 0.633900 41.036606	CHOKE
	5	18.000000 -2.429196 4.207497	402.167236 -1.283002 3.220555	402.182861 0.365172 0.911996	645.760742 0.633900 41.036606	CHOKE
************			************		************	
2	1	18.000000 -2.156403 0.0	407.014893 -1.642470 0.000050	407.018311 0.369682 0.909938	645.760742 0.633900 41.036606	CHOKE
	2	18.000000 -2.831902 0.0	406.284912 -4.564244 0.000002	406.310791 0.369022 0.910240	645.760742 0.633900 41.036606	CHOKE
	3	18.000000 -3.507401 0.0	405.267822 -6.159137 0.000011	405.314453 0.368092 0.910666	645.760742 0.633900 41.036606	CHOKE
	4	18.000000 -4.182899 0.0	403.906494 -5.654493 0.000042	403.946289 0.366816 0.911246	645.760742 0.633900 41.036606	CHOKE
	5	18.000000 -4.858398 0.0	402.165527 -2.566099 0.000055	402.173828 0.365164 0.911999	645.760742 0.633900 41.036606	CHOKE
************			************		************	
3	1	18.000000 -1.078201 -1.867498	407.016602 -0.821127 -3.039276	407.029053 0.369692 0.909932	645.760742 0.633900 41.036606	CHOKE
	2	18.000000 -1.415951 -2.452498	406.283447 -2.282155 -3.501214	406.303467 0.369015 0.910242	645.760742 0.633900 41.036606	CHOKE
	3	18.000000 -1.753700 -3.037498	405.268422 -3.069444 -3.565962	405.291016 0.368070 0.910674	645.760742 0.633900 41.036606	CHOKE
	4	18.000000 -2.091450 -3.622499	403.903564 -2.827103 -3.667771	403.930176 0.366801 0.911254	645.760742 0.633900 41.036606	CHOKE
	5	18.000000 -2.429199 -4.207497	402.167725 -1.282800 -3.208406	402.183105 0.365172 0.911996	645.760742 0.633900 41.036606	CHOKE
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CROSS-SECTION PLANE NO. 2
MASS FLOW RATE 0.25064026E+00
UNK.MASS FLOW RATE 0.25064026E+00
SPECIFIC C.MASS F.RATE 0.82495066E-02
AVERAGE MACH NO. 0.7519712E-04
ITERATION 1

INLET TEST CASE WITH CENTERBODY 1 WAKE 1 PL. SYM. TYPE C ONE

FINAL OUTPUT COMPRESSIBLE SOLUTION

COMBINATION SOLUTION NO. 1

SYMMETRY PRINT OUTPUT -- REFLECTED ELEMENTS

SOLUTION FOR THE CROSS-SECTION ELEMENTS CROSS - SECTION NO. 2

N	M	XC YC ZC	VX VY VZ	VMAG MACH P / PT	VBAR EPSLON AREA(FP)	
1R	1	18.000000 1.078260 1.867498	407.015625 0.821425 -2.078607	407.021729 0.369685 0.909935	645.760742 0.633900 41.036606	CHOKE
	2	18.000000 1.415950 2.452496	406.280762 2.282282 -0.486869	406.287354 0.369000 0.910251	645.760742 0.633900 41.036606	CHOKE
	3	18.000000 1.753698 3.037498	405.260010 3.069541 0.226503	405.271973 0.368053 0.910665	645.760742 0.633900 41.036606	CHOKE
	4	18.000000 2.091448 3.622499	403.901146 2.627467 -0.138244	403.910156 0.366782 0.911265	645.760742 0.633900 41.036606	CHOKE
	5	18.000000 2.429196 4.207497	402.164795 1.282994 -1.679596	402.170410 0.365160 0.912001	645.760742 0.633900 41.036606	CHOKE
************			************		************	
2R	1	18.000000 2.156403 0.0	407.014293 1.642478 0.000065	407.018311 0.369682 0.909930	645.760742 0.633900 41.036606	CHOKE
	2	18.000000 2.831902 0.0	406.264912 4.504244 0.000006	406.310791 0.369022 0.910240	645.760742 0.633900 41.036606	CHOKE
	3	18.000000 3.507401 0.0	405.267022 6.159167 0.000015	405.314453 0.368092 0.910606	645.760742 0.633900 41.036606	CHOKE
	4	18.000000 4.182899 0.0	403.906494 5.654493 0.000045	403.946289 0.366816 0.911246	645.760742 0.633900 41.036606	CHOKE
	5	18.000000 4.858396 0.0	402.165527 2.560099 0.000045	402.173828 0.365164 0.911999	645.760742 0.633900 41.036606	CHOKE
************			************		************	
3R	1	18.000000 1.078201 -1.867495	407.014893 0.821124 2.078672	407.021240 0.369684 0.909935	645.760742 0.633900 41.036606	CHOKE
	2	18.000000 1.415951 -2.452496	406.280273 2.282136 0.482947	406.287109 0.368999 0.910251	645.760742 0.633900 41.036606	CHOKE
	3	18.000000 1.753700 -3.037496	405.259766 3.069416 -0.226406	405.271484 0.368052 0.910665	645.760742 0.633900 41.036606	CHOKE
	4	18.000000 2.091450 -3.622499	403.899658 2.627670 0.138552	403.909912 0.366782 0.911265	645.760742 0.633900 41.036606	CHOKE
	5	18.000000 2.429199 -4.207497	402.165527 1.262373 1.679601	402.171387 0.365161 0.912001	645.760742 0.633900 41.036606	CHOKE
************			************		************	

CROSS-SECTION PLANE NO. 2
MASS FLOW RATE 0.312932E+00
CORR.MASS FLOW RATE 0.312923E+00
SPECIFIC C.MASS F.RATE 0.124991E-01
AVERAGE MACH NO. 0.146394E-03
ITERATION 2

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LONG BEACH DIVISION
CASE NO. TEST THURSDAY, APR 19, 1979

INLET TEST CASE WITH CENTERBODY 1 WAKE 1 PL. SYM. TYPE C ONE

TABLE OF RUNTIME BREAKDOWN

SUBROUTINES	CPU TIME AT CALL STATEMENT	CPU TIME AFTER RETURN TO CALL PROG	CPU TIME USED	I/O TIME AT CALL STATEMENT	I/O TIME AFTER RETURN TO CALL PROG	I/O TIME USED
MAIN	0.000	16.590	16.590	0.0	13.244	13.244
REPAN	0.0	0.0	0.0	0.0	0.0	0.0
INPUT	0.035	0.632	0.597	0.068	1.386	1.318
VFORM	0.632	2.194	1.562	1.386	2.286	0.900
PSWISE	0.0	0.0	0.0	0.0	0.0	0.0
AFORM	2.194	2.564	0.370	2.286	2.566	0.280
COLSOL	2.564	3.233	0.668	2.566	3.578	1.012
FSLUTN	4.100	4.824	0.724	3.376	4.066	0.690
CROSEC	4.895	7.853	2.958	4.186	7.488	3.302
FLPASG	7.886	8.501	0.615	7.488	8.804	1.316
COMPRO	0.0	0.0	0.0	0.0	0.0	0.0
ICMPRS	8.501	16.590	8.088	8.804	13.244	4.440

(UNIT IN SECONDS)

*

*** END OF INPUT DATA. NORMAL PROGRAM TERMINATION.

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		6. Performing Organization Code
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15. Supplementary Notes

Final Report. Project Manager: H.C. Kao, Wind Tunnel and Flight Division, NASA-Lewis Research Center Cleveland, Ohio

16. Abstract

This method uses a panel method to calculate incompressible flow about arbitrary three-dimensional inlets with or without centerbodies for four fundamental flow conditions: unit onset flows parallel to each of the coordinate axes plus static operation. The computing time is scarcely longer than for a single solution. A linear superposition of these solutions quite rigorously gives incompressible flow about the inlet for any angle of attack, angle of yaw, and mass flow rate. Compressibility is accounted for by applying a well-proven correction to the incompressible flow. Since the computing times for the combination and the compressibility correction are small, flows at a large number of inlet operating conditions are obtained rather cheaply. Geometric input is aided by an automatic generating program. A number of graphical output features are provided to aid the user, including surface streamline tracing and automatic generation of curves of constant pressure, Mach number, and flow inclination at selected inlet cross sections. This report describes the inlet method, including the use of the program and presents illustrative results.

17. Key Words (Suggested by Author(s))		18. Distribution Statement
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Revision date

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