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A Computer Program for Calculating the Non-linear Aerodynamic Characteristics of Arbitrary Configurations

USER'S MANUAL

B. Maskew

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Prepared for
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LIST OF CONTENTS

Page No.

LIST OF FIGURES

Fig. No.	Figure	Page No.
21	Body of Revolution Option	41
22	Automatic Patch Generator (A.P.G.)	
	(a) Patch Location	45
	(b) Flat Patch Option (KURV=0)	45
	(c) Semi-Circular and Semi-Ellipse Sections (KURV=1 and 2)	46
	(d) Triangular Sections (KURV=3)	46
23	Panel Geometry	49
24	Panel Neighbor Information	50
25	CARD SET 17-18: Example of Wake-Grid-Plane Input	52
26	Wake Arrangement	54
27	Wake Shedding Parameters	55
28	Separation Line Definition	
	(a) Wing	56
	(b) General Case	57
29	Streamwise Wake Points	59
30	Velocity Scan Volumes	
	(a) Skewed Box	63
	(b) Cylindrical Volume	65
31	Identifying a Set of Panels on a Patch . . .	89
A1	Wing-Body Sample Case	142
A2	Patch Arrangement	143

1.0 INTRODUCTION

VSAERO is a computer program for calculating the non-linear aerodynamic characteristics of arbitrary configurations in subsonic flow. Non-linear effects of Vortex Separation and Vortex-Surface interaction are treated in an iterative wake-shape calculation procedure, while the effects of viscosity are treated in an iterative loop coupling potential flow and integral boundary layer calculations. The program is under continued development (Refs. 1 through 5) in a number of directions outlined in Figure 1. The present document is an interim User's Manual for the basic non-linear capability identified in Figure 1. The program scope covered by this document is given in Section 2.0.

The basis of the computer program is a surface singularity panel method using quadrilateral panels on which doublet and source singularities are distributed in a piecewise constant form. The panel source values are directly determined by the external Neumann boundary condition controlling the normal component of the local resultant flow: the doublet values are solved after imposing the internal Dirichlet boundary condition of zero perturbation potential at the centers (underside) of all the panels simultaneously. Surface perturbation velocities are obtained from the gradient of the doublet solution, while field velocities are obtained by direct summation of all singularity panel contributions. An outline of the mathematical formulation for the basic method is given in Section 3.0.

Details of the configuration modelling are given in Section 4.0, while Section 5.0 shows how the off-body velocity scan volumes are formed. Section 6.0 describes the way the program is run on the C.D.C. Cyber 176.

The program input is described in Section 7.0 in three ways: first, the input variables are listed card by card; secondly, the function of each variable is described in detail on a card by card basis, and finally, a flow chart of the input is given showing in a more visual way the sequence and relationship of cards according to the various input options. This latter form is especially useful when some familiarity with the input variables has been gained.

The program output is described in Section 8.0, while the input and output for an example case of a wing-body configuration is given in the Appendix.

The program is written in standard FORTRAN IV and has been developed on the C.D.C. Cyber 176 computer. Minor changes to the code allow it to run on IBM and Cray computers. There are two versions of the basic code; the first allows up to 1,000 panels (i.e., unknowns) and the second allows up to 3,000 panels. Where limiting values for variables are quoted the 1,000 panel numbers comes first followed by a slash then the 3,000 panel number. For

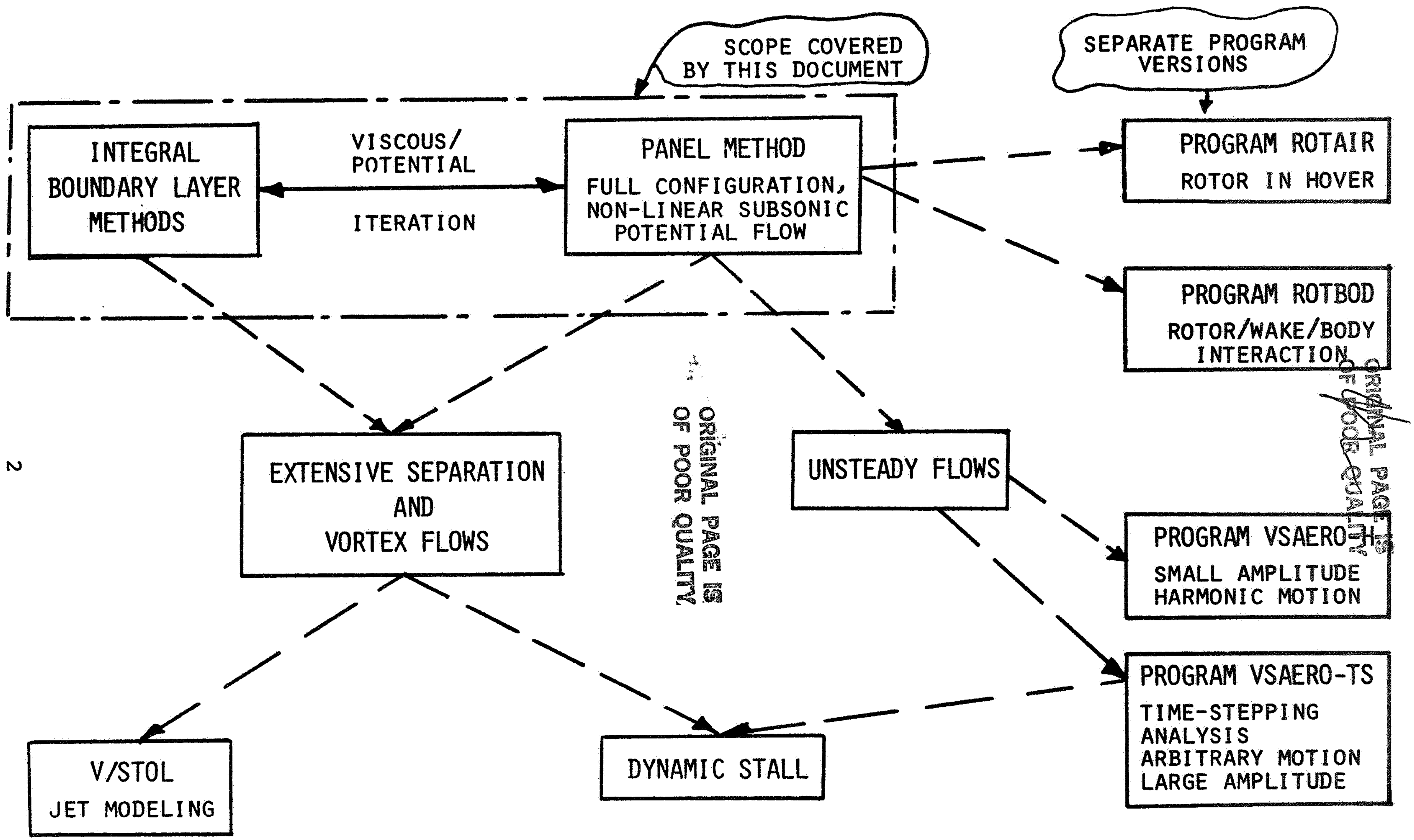

Figure 1. VSAERO Program Development.

example, the core requirement (octal) for the program is 234K-203K in SCM and 0-321K in LCM.

The CPU time required by the program is plotted in Figure 2 against the number of panels (unknowns). The CP seconds are converted to CDC 7600 values. The run times are for cases with symmetry about the x-z plane; i.e., the actual number of panels is double the value shown. The approximate effects of wake complexity and iteration cycles are indicated in Figure 2.

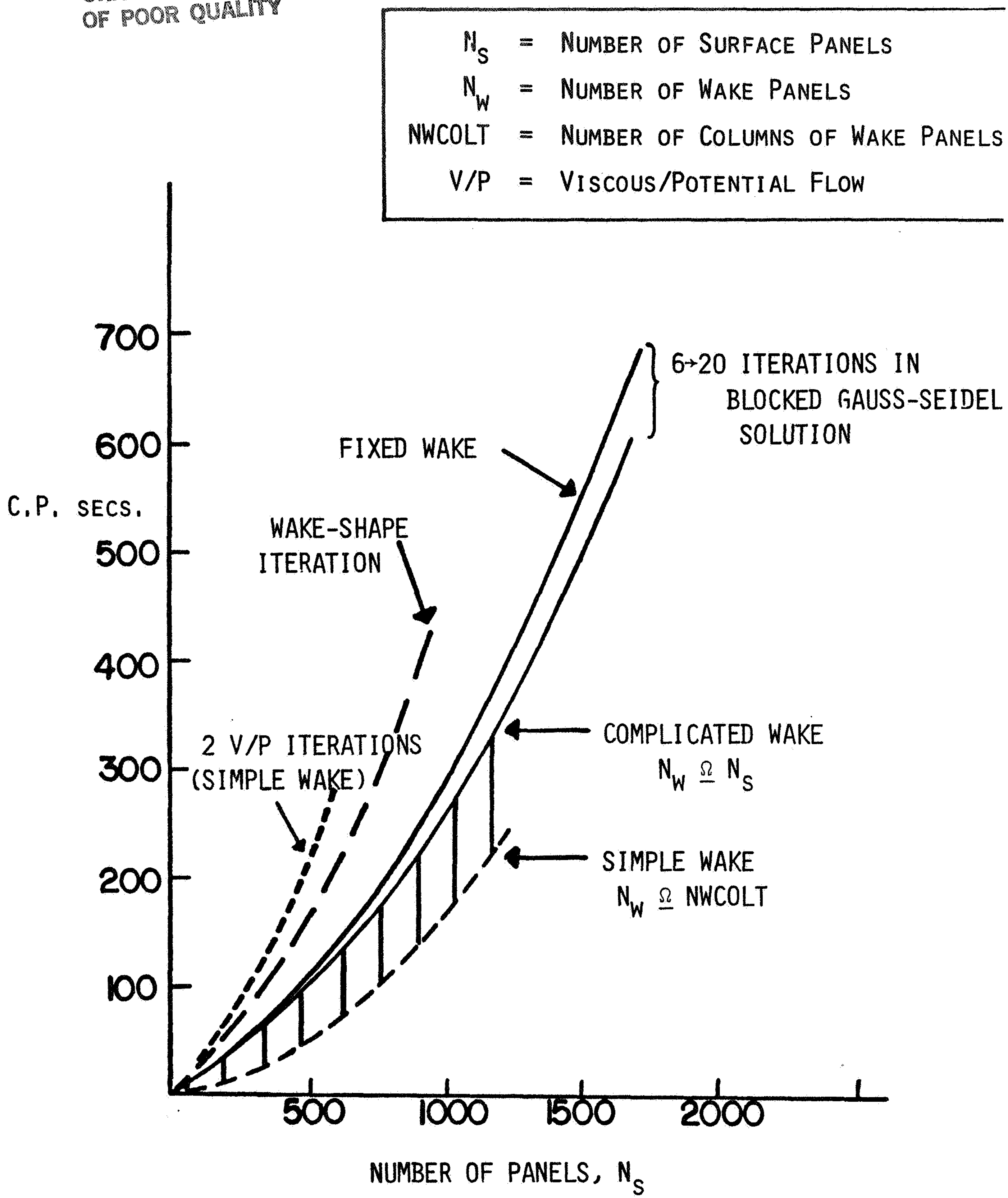

Figure 2. CPU Time (CDC 7600 C.P. secs.)

2.0 PROGRAM SCOPE

This section describes the general capability of the program covered by the present user manual. Other options are in the code--in fact, several of these appear in the input lists here; however, these are still in the process of being checked out or are being developed further.

The program was generated primarily for analyzing high-lift configurations; however, a number of additional features now allow the program to be applied to complete aircraft configurations, including wings, bodies, tailplanes, fins, slats, slotted flaps, powered nacelles, etc. The non-linear wake relaxation routines for the high-lift calculations are applicable also to the full configuration cases.

The analyses are normally performed in 'symmetrical' flight; i.e., only one half of the aircraft geometry is described. Asymmetric conditions can be treated but the complete geometry must be described at this time (i.e., even if the geometry has symmetry).

The configuration can be analysed in ground effect; the ground plane is actually the horizontal x-y plane of the global coordinate system. The components of the configuration can be moved and rotated within the program to set up the required conditions. Non-zero normal velocities can be specified on user-selected sets of panels to represent inflow or outflow; e.g., for powered nacelles. Vortex sheet wakes, representing the shear between outflow (jet) velocity and local external velocity, are then attached to the surface panels to enclose each jet.

Although the program deals primarily with closed surfaces (i.e., thick wings and bodies), provision is made to treat open surfaces also. In such cases only the Neumann boundary condition is satisfied and the singularity model for that part of the surface is identical to that used in the quadrilateral vortex method (Ref. 6). Open and closed surfaces can be mixed in a configuration.

Surface streamline calculations can be requested. Each calculation starts in a panel and proceeds upstream and downstream until either a stagnation region is entered or until the calculation reaches an edge or a cut in panel neighbor relationships (see 3.2). The user supplies a set of 'starting' panels to adequately cover the region(s) of interest.

Two integral boundary layer calculation options are provided in a viscous-potential flow iteration coupling. The user specifies the number of iteration cycles.

At the end of the calculation the user can request off-body velocity surveys and off-body streamlines.

The program generates a plot file of geometric and aerodynamic data. The user must save this in the JCL (see 6.2) for plotting at a later stage. The program can also generate restart files for the purpose of continuing with the calculation at a later stage (see 6.3). Provision is made to change some of the input data on a restart run.

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3.0 MATHEMATICAL MODEL OVERVIEW

3.1 Formulation

The general arrangement of a configuration is shown in Figure 3 and is described in terms of a body-fixed GLOBAL COORDINATE SYSTEM referred to as the G.C.S. The configuration is immersed in a uniform onset flow, $\vec{V}_\infty$ with velocity potential ϕ_∞. Potential flow is assumed to exist both inside and outside the boundaries of the configuration. In the external flow field (i.e., the one of interest) the total velocity potential, Φ, is the sum of the onset flow potential, ϕ_∞, and the perturbation potential, ϕ. Similarly, the total velocity potential inside the configuration is Φ_i. For the present description, the wake surfaces are assumed to have vanishing thickness with zero entrainment.

After applying Green's Theorem to the inner and outer regions and combining the resulting expressions, the velocity potential at a point P on the inside surface can be written

$$
\begin{aligned}
4\pi\Phi_p = & \iint_{S-P} (\Phi - \Phi_i)\vec{n} \cdot \nabla\left(\frac{1}{r}\right) dS - 2\pi(\Phi - \Phi_i)_p \\
& + \iint_{W} (\Phi_U - \Phi_L)\vec{n} \cdot \nabla\left(\frac{1}{r}\right) dW \\
& + \iint_{S} \frac{1}{r}\, n \cdot (\nabla\Phi_i - \nabla\Phi)\, dS + 4\pi\phi_{\infty\, p}
\end{aligned}
\qquad (1)
$$

where r is the length of the vector from the surface element to the point P, and S-P signifies that the point P is excluded from the surface integral. $\Phi_u - \Phi_i$ is the local jump in potential across the wake surface, W. Equation (1) gives the total potential at the interior point, P, as the sum of perturbation potentials due to a normal doublet distribution of strength $(\Phi - \Phi_i)$ on S and $(\Phi_u - \Phi_L)$ on W, respectively, and a source distribution of strength, $\hat{n}(\nabla\Phi_i - \nabla\Phi)$ on S. The potential for the uniform onset flow, ϕ_∞, is also included.

In principle, an infinite number of combinations of doublet and source distribution will give the same external flowfield, but different internal flowfields. To render a unique combination of singularities either one of the singularity distributions must be specified (e.g., $\sigma = 0$ in the doublet-only formulation) or, as in the present case, the internal flow must be specified. There are several reasonable options for the

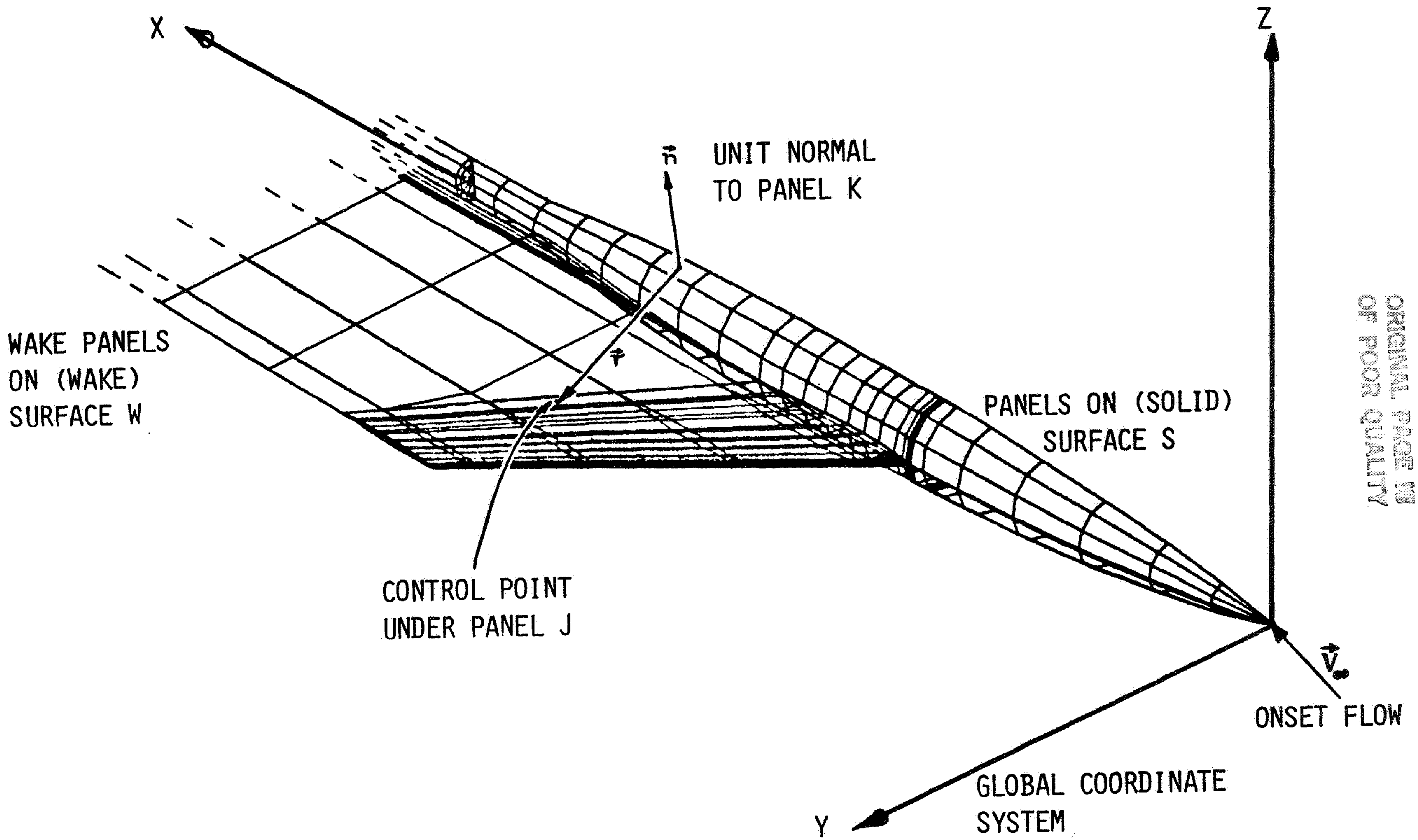


Figure 3. General Arrangement of the Configuration.

internal potential flow. On the of most convenient options is to set $\Phi_i = \phi_\infty$. This internal Dirichlet boundary condition gives zero perturbation to the onset flow inside the configuration. Eqn. (1) becomes:

$$0 = \iint_{S-P} \phi \vec{n} \cdot \nabla \left(\frac{1}{r}\right) dS - 2\pi\phi_p$$
$$+ \iint_{W} (\Phi_U - \Phi_L)\vec{n} \cdot \nabla \left(\frac{1}{r}\right) dW$$
$$+ \iint_{S} \frac{1}{r} \vec{n} \cdot (\nabla\phi_\infty - \nabla\Phi) dS \qquad (2)$$

where ϕ_i, the perturbation potential in the flow field, has been substituted for $\Phi - \Phi_\infty$.

The first two terms in Eqn. (2) give the perturbation potential due to a distribution of normal doublets of strength, ϕ, on the configuration surface, S. Similarly, the third term represents a doublet distribution of strength, $\Phi_U - \Phi_L$, on the wake and the fourth term represents a source distribution of strength $\vec{n} \cdot (\nabla\phi_\infty - \nabla\Phi)$ on the configuration surface.

For the problem of analyzing the flow about a given configuration geometry, the doublet distribution, ϕ, is the unknown while the source distribution is determined directly by the external Neumann boundary condition:

$$n \cdot \nabla\Phi = -V_N$$

where V_N is the local normal velocity component of the external flow relative to the fixed surface. (This component is positive in the direction of $\vec{n}$.).

For solid boundary conditions, V_N is zero; for more general cases, however, V_N can have several parts representing various special effects (Refs. 1 through 5). Two of these effects are considered here:

(i) boundary layer displacement effect using the transpiration technique; and

(ii) inflow/outflow for engine inlet/exhaust representation.

Thus,

$$V_N = \frac{\partial}{\partial s}(U_e \delta^*) + V_{NORM}$$

where the first term represents the rate of 'growth' of the boundary layer and the second term, V_{NORM}, is positive for outflow and negative for inflow. The boundary layer term is usually zero at the start of the calculation and is then updated during each viscous/potential iteration cycle.

Thus the source strengths can be evaluated in Eqn. (2) before each doublet solution:

$$\vec{n} \cdot (\nabla\phi_\infty - \nabla\phi) = 4\pi\sigma = \frac{\partial}{\partial s}(U_e \delta^*) + V_{NORM} - \vec{n} \cdot \vec{V}_\infty$$

The above internal Dirichlet boundary condition is applicable for closed surfaces only. If there are parts of the surface that are extremely thin (e.g., thickness/chord ratio < 5%), or are wing-like and are well away from the area of interest, then these can be represented by open sheets using the Neumann boundary condition only. The treatment of these open surfaces is identical to that in the quadrilateral vortex method (Ref. 6). The thin and thick options may be mixed within the matrix of influence coefficients and so a configuration can include patches of both types.

3.2 Numerical Procedure

Figure 4 shows a flow chart of the numerical procedure for the complete solution. For this purpose the configuration surface and wake are represented by a number of flat quadrilateral panels (Figure 3). (The way the panels are formed will be treated in Section 4.) The surface integrals are performed in a piecewise manner with the assumption of uniform singularity distributions over each panel. Eqn. (2) is then satisfied simultaneously at a control point on each surface panel, i.e., Eqn. (2) becomes

$$\sum_{K=1,K\neq J}^{N_S} (\mu_K C_{JK}) - 2\pi\mu_J + \sum_{K=1}^{N_W} (\mu_{W_K} C_{JK}) + \sum_{K=1}^{N_S} \sigma_K B_{JK} = 0; \qquad J=1,\ NS \tag{3}$$

where N_S, N_W are the number of surface and wake panels, respectively. The panel doublet value (unknown) is $\phi_K/4\pi$. The quantities B_{JK}, C_{JK} are the perturbation velocity influence coefficients for the constant source and doublet distributions, respectively, on panel K acting on the control point on panel J. (The control point is the average point of the panel's four corners.) These coefficients include contributions from 'image'

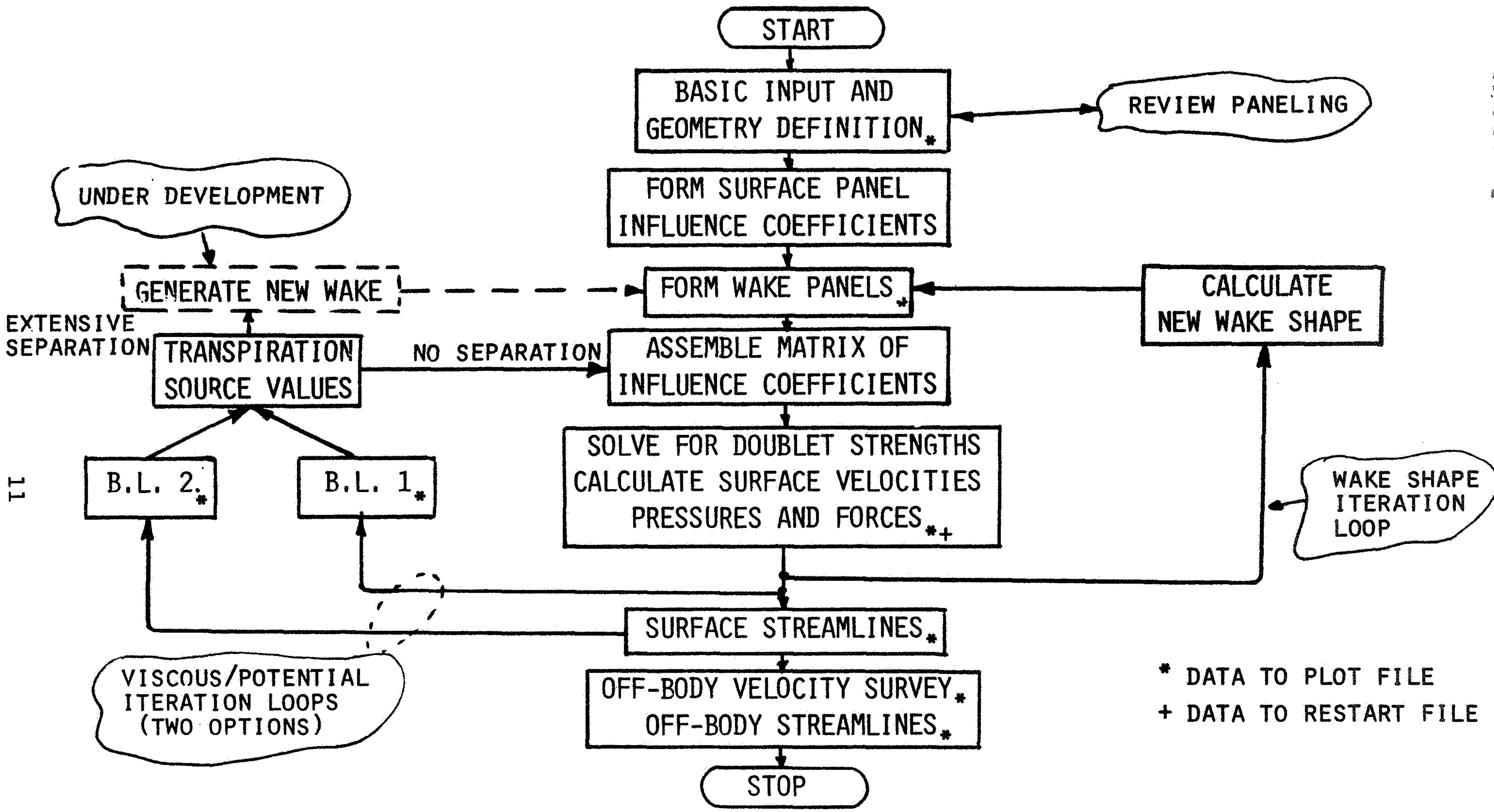


Figure 4. VSAERO Program Outline.

for cases of symmetry and/or ground effect. (For control points on open surfaces the Neumann boundary condition equation has a similar form to Eqn. (3), but the influence coefficients are for the normal component of induced velocity.)

Equation (3) is solved by a direct method when $N_s \leq 320/630$ and by a blocked Gauss-Seidel iterative procedure for N_s values above this.

The surface gradient of μ is evaluated on each panel by differentiating a two-way parabolic curve fit through the doublet values on the panel and its four immediate neighbors. At certain lines on the surface where there is a jump in local conditions, e.g., wake separation lines, edges of inflow/outflow regions, etc., the program 'steps back' and uses information from the 'neighbor of a neighbor' to avoid taking a gradient across such a line. The doublet gradient provides the local tangential velocity perturbation which is combined with the local tangential component of the onset flow to give the total local velocity. This is used to evaluate the pressure coefficient at each panel's center. The integrated force and moment for the configuration and its parts are obtained by summing the pressure force and moment contributions from each panel.

When a solution has been formed, a wake shape iteration loop can be executed. In this loop the wake is repositioned so that the streamwise edges of wake panels are aligned with the local calculated flow directions. The wake panels and their influence coefficients are then reformed prior to a new solution, Figure 4.

When the wake shape iteration is completed the viscous/potential iteration loops can be entered. At this time there are two integral boundary layer options. The first (B.L.1 in Figure 4) is an infinite swept wing stripwise calculation intended primarily for wing-type surfaces. This method is described in Reference 7. It uses calculated pressure and velocity distributions from streamwise strips on the wing. The second option, B.L.2, is a two-dimensional boundary layer calculation along calculated streamlines; local curvature effects are treated as if the surface were part of an axisym-metric body (Ref. 8). Use of the B.L.2 option requires surface streamline calculations to be performed and is applied mainly on body-type surfaces.

Both boundary layer routines return transpiration source values back to the potential flow code. Since the source values only affect the right-hand side of the equations, a new solution can be readily obtained (Figure 4). The boundary layer routines also provide the locations of separation lines; if there is a large amount of separation or if the separation zone has changed markedly from the previous iteration solution, then a new wake must be formed before the next solution. This part of the procedure is still being checked out.

After the last iteration, off-body velocity surveys and off-body streamlines may be executed. These use a general velocity calculation scheme somewhat similar to Eqn. (3) except velocity influence coefficients are used instead of velocity potential coefficients. Special near-field techniques are activated for velocity points that are close to the body surface or wake.

4.0 CONFIGURATION MODELLING

4.1 Overview

This section describes the way the configuration is subdivided to form the set of panels used in the numerical solution. The operation has been designed with a view to both user convenience and to internal efficiency in the program code. First, the panels are organized in a multiple level hierarchy to facilitate treatment of complicated configurations and also to simplify relocating separate pieces of a configuration (e.g., flaps): inside the code the organization simplifies the problem of identifying a panel's immediate neighbors. Secondly, options for automatic paneling are provided so that it is not necessary for the user to provide the actual panel corner points. (He still can do this if he wants to.) These options also provide a powerful capability for changing, in a later run, the emphasis of high panel density from one part of the configuration to another. Such a repaneling is achieved with only minor changes to the input file, the input geometry can remain essentially the same.

4.2 Hierarchy

The description of the mathematical model in 3.1 has already shown the initial breakdown of a CONFIGURATION into two major parts; viz., the (solid) SURFACE and the (flexible) WAKE. In fact, on a complicated configuration, there may be several separate surfaces and several wakes. Each wake is broken down directly into columns of WAKE PANELS while the surface is subdivided into several parts; i.e., COMPONENTS, ASSEMBLIES, PATCHES and PANELS, Figure 5. (Panels are further subdivided into SUBPANELS, but this is an internal automatic feature activated for special treatment of near-field velocity calculations.)

The smallest 'stand-alone' part of a configuration surface is a PATCH. A patch contains a rectangular array of PANELS. Patches are grouped together under two headings (Figure 5): COMPONENTS and ASSEMBLIES. These are at the same level in the hierarchy because they each contain one or more patches, in fact, they overlap. The main difference between the two groupings is that the patches within an assembly are regarded as detached from patches on other assemblies while the patches within a component may or may not be contiguous with patches of other components.

The nature, purpose and treatment of each part of the configuration are described in the following subsections; in the meantime, Figure 6 shows an example of the breakdown of a high-lift wing configuration into assemblies, components and patches. The wing has a leading-edge slat and part-span slotted flap. Thus there are three separate pieces of surface which are identified as separate assemblies. For this example, the wing and slat have been placed under component 1 and the flap is

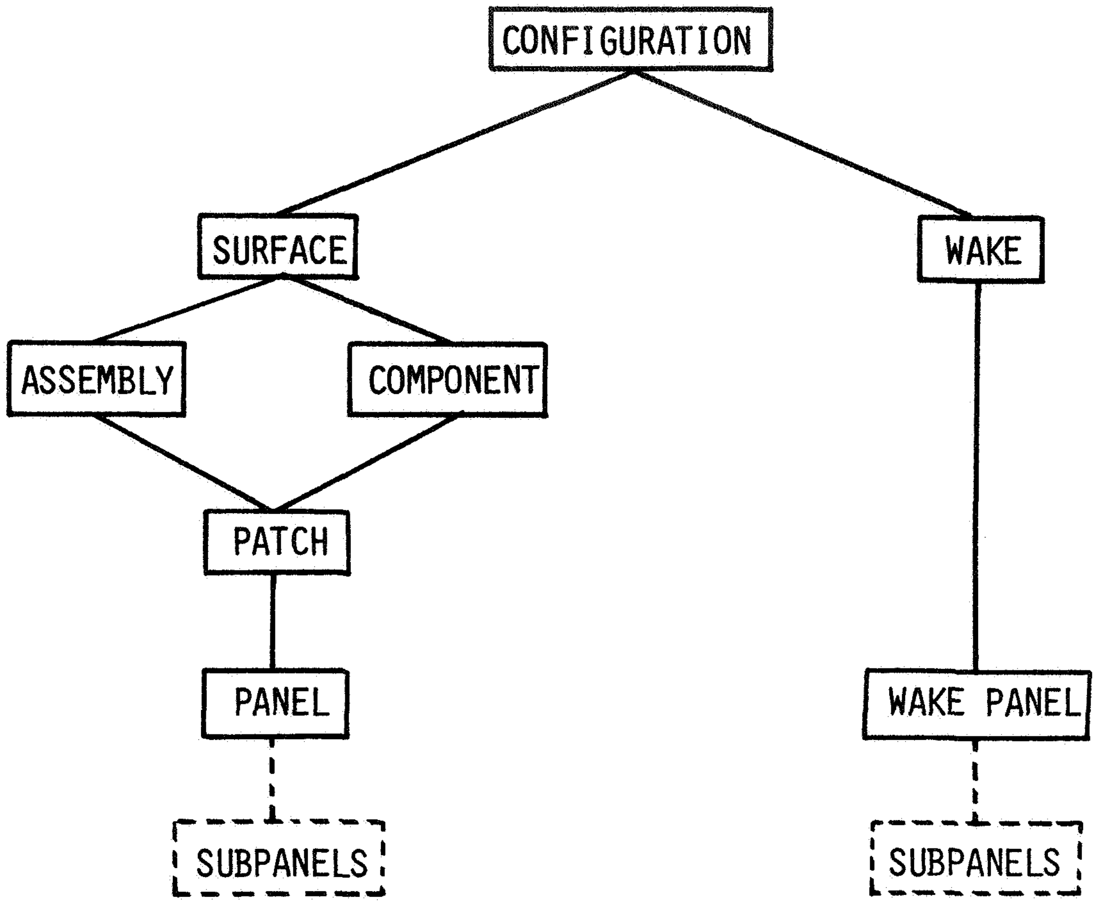


Figure 5. Configuration Hierarchy.

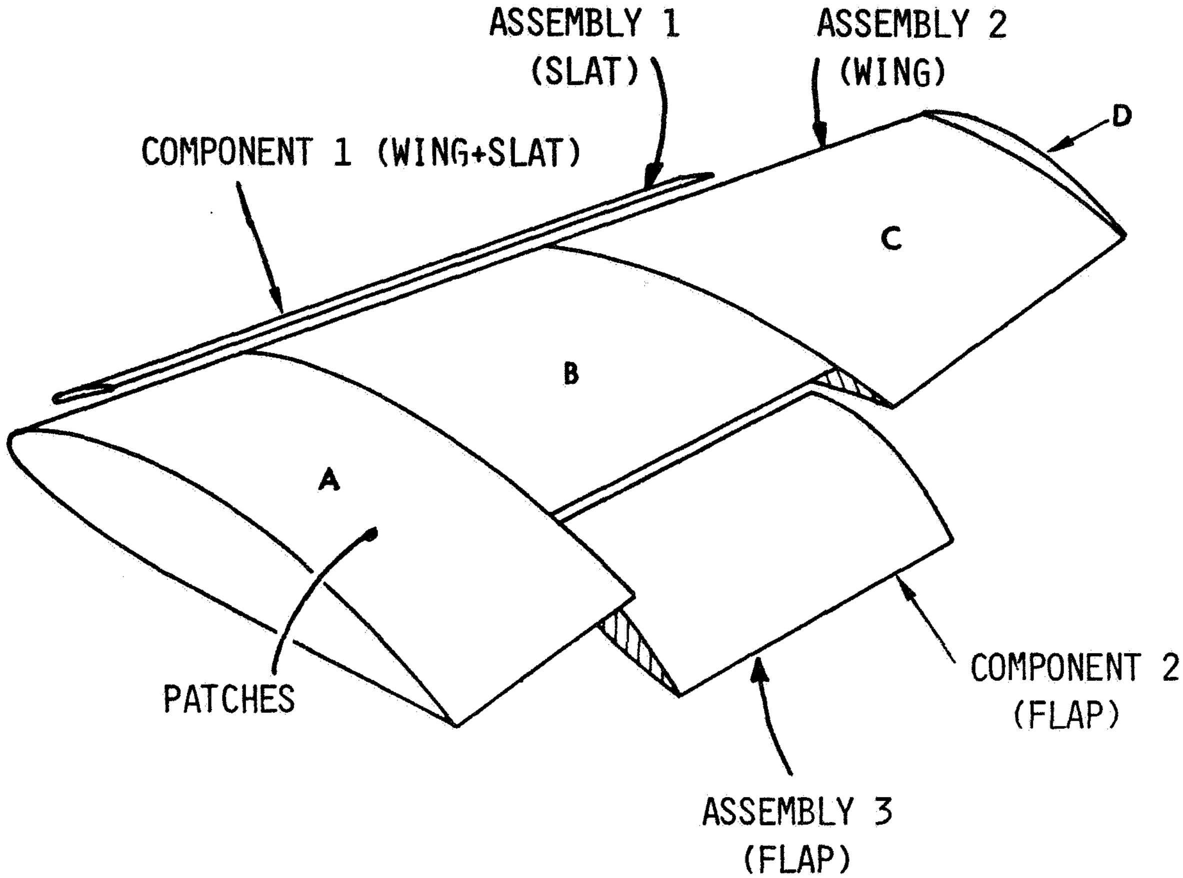


Figure 6. Examples of Assemblies, Components and Patches on a High-Lift Configuration.

called Component 2--this grouping is entirely up to the user. The grouping shown allows the flap to be easily repositioned to a new setting later on (see the component subsection). Typical patches (A, B, C, D) are indicated in Figure 6. As will be described below in 4.5.7.2, automatic procedures can be called on to form the tip-edge patches closing the wing, flap and slat. (A small closing patch can be left off when a detailed solution is not required in that area.)

4.3 Assembly

An assembly is a completely separate piece of the surface. For example, the entire wing, fuselage, fin, tailplane and nacelle of an aircraft configuration would form one assembly, while slotted flaps, slats, etc., would be separate assemblies. (Small attachment structures would not normally be represented in the global treatment of a full configuration.)

The primary function of the assembly status is to prevent panel neighbor relationships being formed across small slots or gaps. Each panel needs to 'know' its four immediate neighbors for the purpose of evaluating the doublet gradient (3.2). Within a patch the neighbor relationships are straightforward, but across patch edges the panel neighbors are identified by an automatic procedure. During its search for possible neighbor candidates, this procedure only considers panels within the same assembly.

A secondary function of an assembly is that it has its own printout of integrated force and moment data.

The assembly number for each patch is identified on the patch card (CARD 10) using the variable KLASS.

4.4 Component

The set of patches forming a component is completely in the hands of the user and the patches need not necessarily be contiguous. The main function of a component is to provide the user with a separate printout of integrated force and moment data for his selected parts of the configuration. The component number for a patch is set by an internal counter. This counter is incremented by one when the user places a value of 4 for NODES on a patch's terminating section card (CARD 11). (Note that a component card (CARD 9) for the new component must then precede the next patch card (CARD 10)).

It should be remembered that the order of patches in the input is dictated more by surface proximity (see 4.5.4) rather than the user's choice of patch sets for a component. For this reason, provision is made to override the current component counter using the variable KOMP on the patch card (CARD 10). This does not change the counter value, it merely identifies the present patch with another component; this facility must not be used on the first patch of a new component. (Why change the counter otherwise?)

Each component can be defined in its own COMPONENT COORDINATE SYSTEM (referred to as the C.C.S.). This facility allows all the patches within a component to be scaled, moved and rotated (in that order) en bloc with one instruction on the component card (CARD 9).

The component card contains the appropriate transformation information which converts the geometry from the C.C.S. to the global coordinate system (referred to as G.C.S.). This information includes (i) the translation vector, (CTX, CTY, CTZ), which is simply the origin of the C.C.S. located in the G.C.S.; (ii) the scaling factor; and (iii) the rotation angle, θ, about a hinge line vector, $\underline{h}$, Figure 7. Provision is made for the user to specify two points on a general hinge line vector (in the C.C.S.), otherwise the y-axis in the C.C.S. is used. Both the scaling and the rotation are applied in the C.C.S. prior to the translation. This component transformation is performed at the end of the geometry input routine; i.e., after the basic geometry of the complete configuration is assembled.

4.5 Patch

4.5.1 Shape

The developed (i.e., 'opened out') shape of a patch should be roughly four-sided to keep panel shapes and distributions reasonably regular. This does not exclude the presence of kinks in any or all of the patch sides, but kink angles should not be large (the upper limit has not been established, but for the time being 60° should be regarded as a large kink angle). One side or two opposite sides of a patch may be reduced to zero length provided the overall patch shape is reasonably regular. Figure 8 gives some basic guidelines for acceptable patch shapes.

Awkwardly shaped surfaces may be represented by several patches, whereas simple shapes may require just one patch. In Figure 6, for example, parts A, B, C and D are typical patches on assembly 2. The main surfaces of assemblies 1 and 3 may be formed by single patches; additional patches may be used to cover the open ends (shaded). Patches that are wrapped around until two opposite sides meet (e.g., patches A, B and C in Figure 6) are referred to as FOLDED PATCHES. It is recommended that folded patches (with sides 2 and 4 meeting) be used to represent all wing-type surfaces.

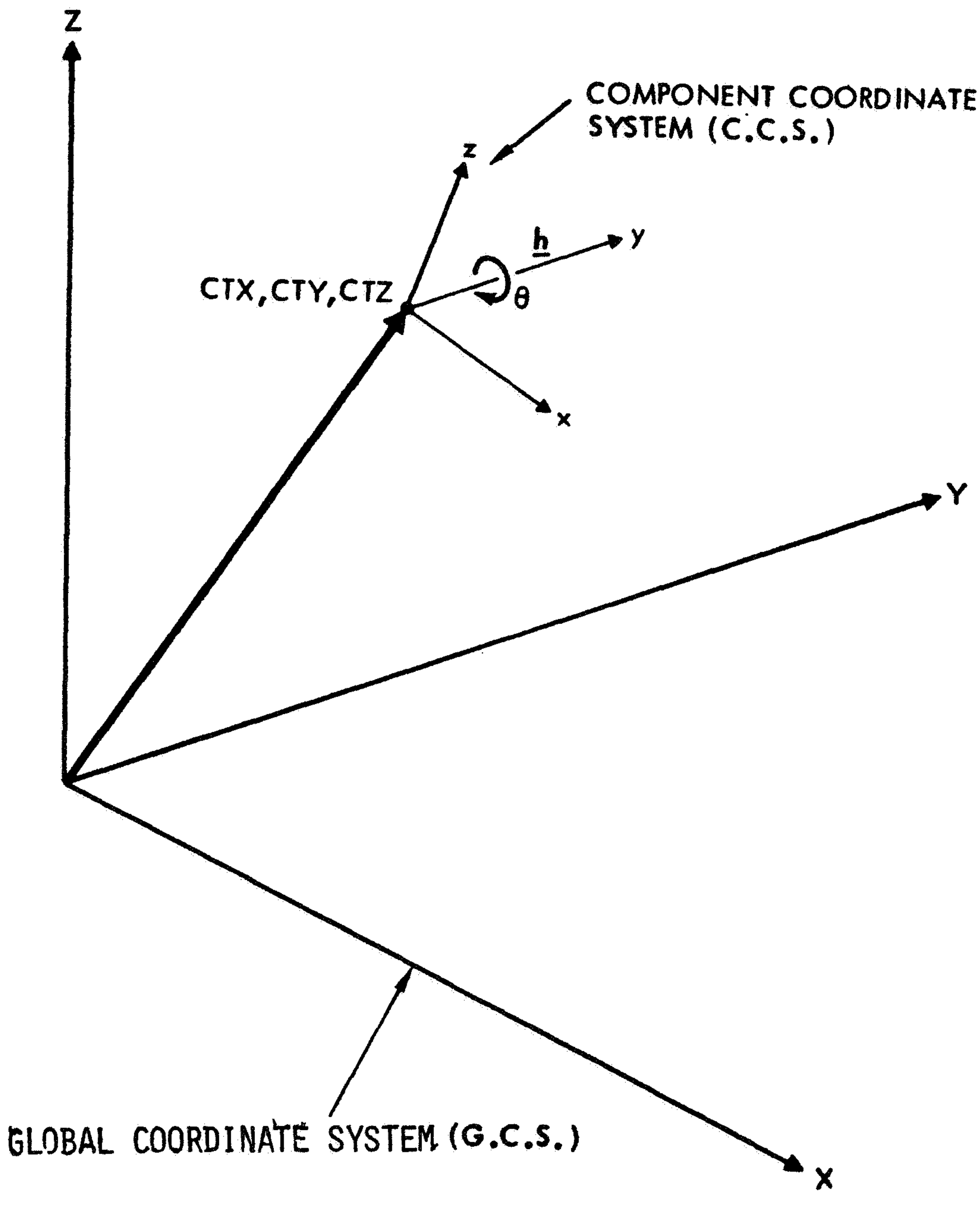


Figure 7 . Component Transformation.

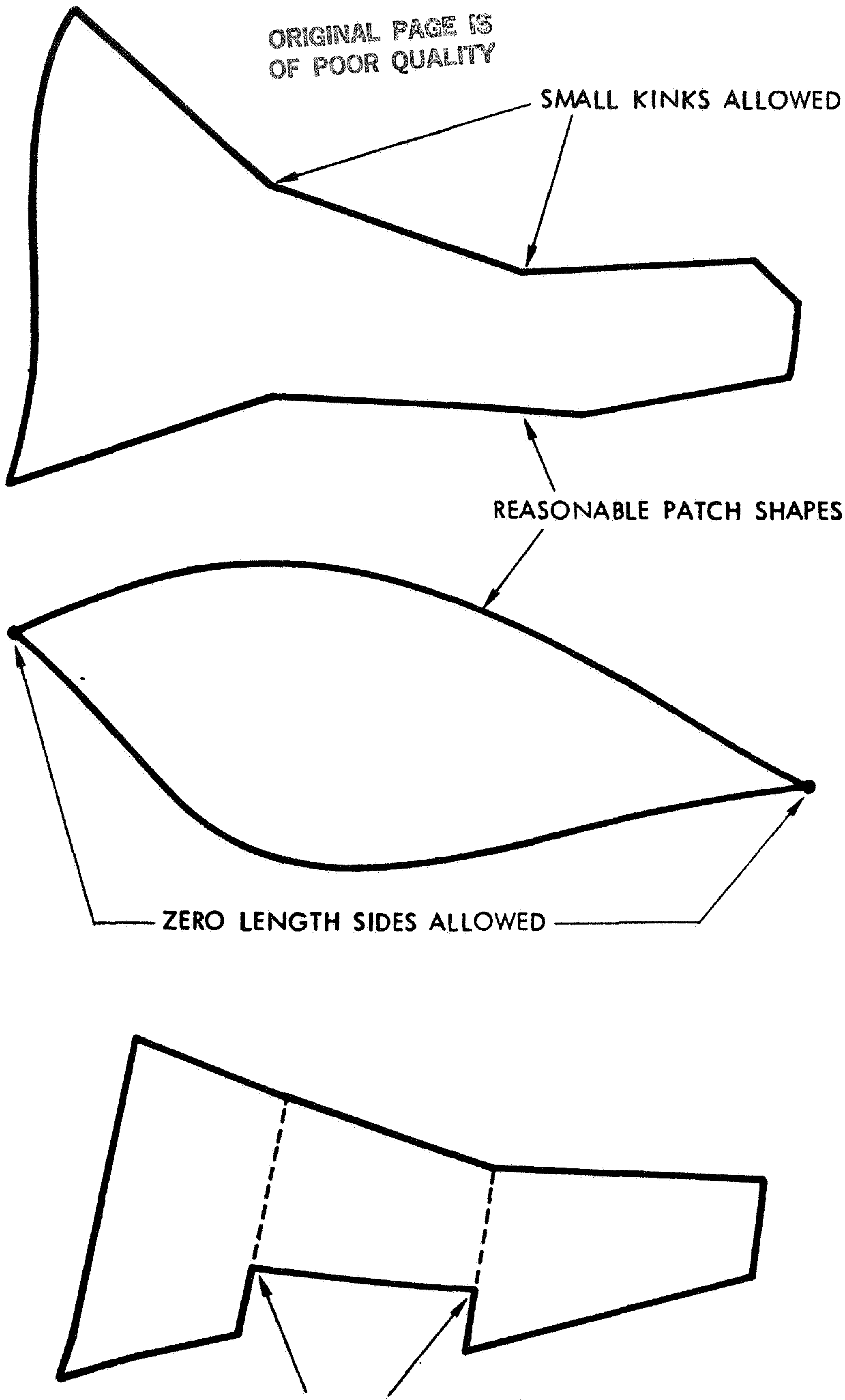


Figure 8. Preliminary Guidelines for Patch Shapes.

4.5.2 Convention

We have seen above that a patch is basically a four-sided shape when developed or 'opened out'. It must always be regarded as such even if one of the sides or two opposite sides are made zero or if some of the sides have kinks. In the following discussions patches will often be regarded as rectangular--this is purely a convenience for discussion relationships and is not a shape restriction. Our view of the patch will always be from the outside; i.e., looking onto the wetted surface from a point in the flow field.

For convenience the terms 'chordwise' and 'spanwise' are used to describe the directions of the panel columns and rows, respectively, Figure 9. These directions are analogous to the conventional wing layout, but, in the patch context, these directions are not restricted to the x and y directions, respectively. For example, on a patch representing the wing tip it is convenient to have the columns of panels vertical and the rows of panels to be parallel to the wing chord; in this case, therefore, the 'chordwise' direction on the patch is actually vertical while its 'spanwise' direction is along the wing chord (see later in Figure 22).

Patch geometry is defined using chordwise lines called SECTIONS. (These are described below.) A set of sections distributed spanwise across a patch defines the patch surface. The convention adopted here is that points defining a section shape proceed from top to bottom, Figure 10. (in the case where a patch represents the main surface of a wing, this convention causes the points defining each section to proceed from the trailing-edge lower surface and finish at the trailing-edge upper surface.) In our view of the patch, the order of the sections proceeds in the positive spanwise direction, Figure 10.

For the purpose of automatically connecting panels from one patch to another, it is important to identify patch sides. The convention adoped here is that the first and last sections defining a patch correspond to sides 1 and 3, respectively. With this convention, the order of the sides is anticlockwise, Figure 9. The order of the corner points follows the same sequence as the sides, starting with 1 at the top of side 1. All the panels within a patch take the same side and corner point convention as for the patch.

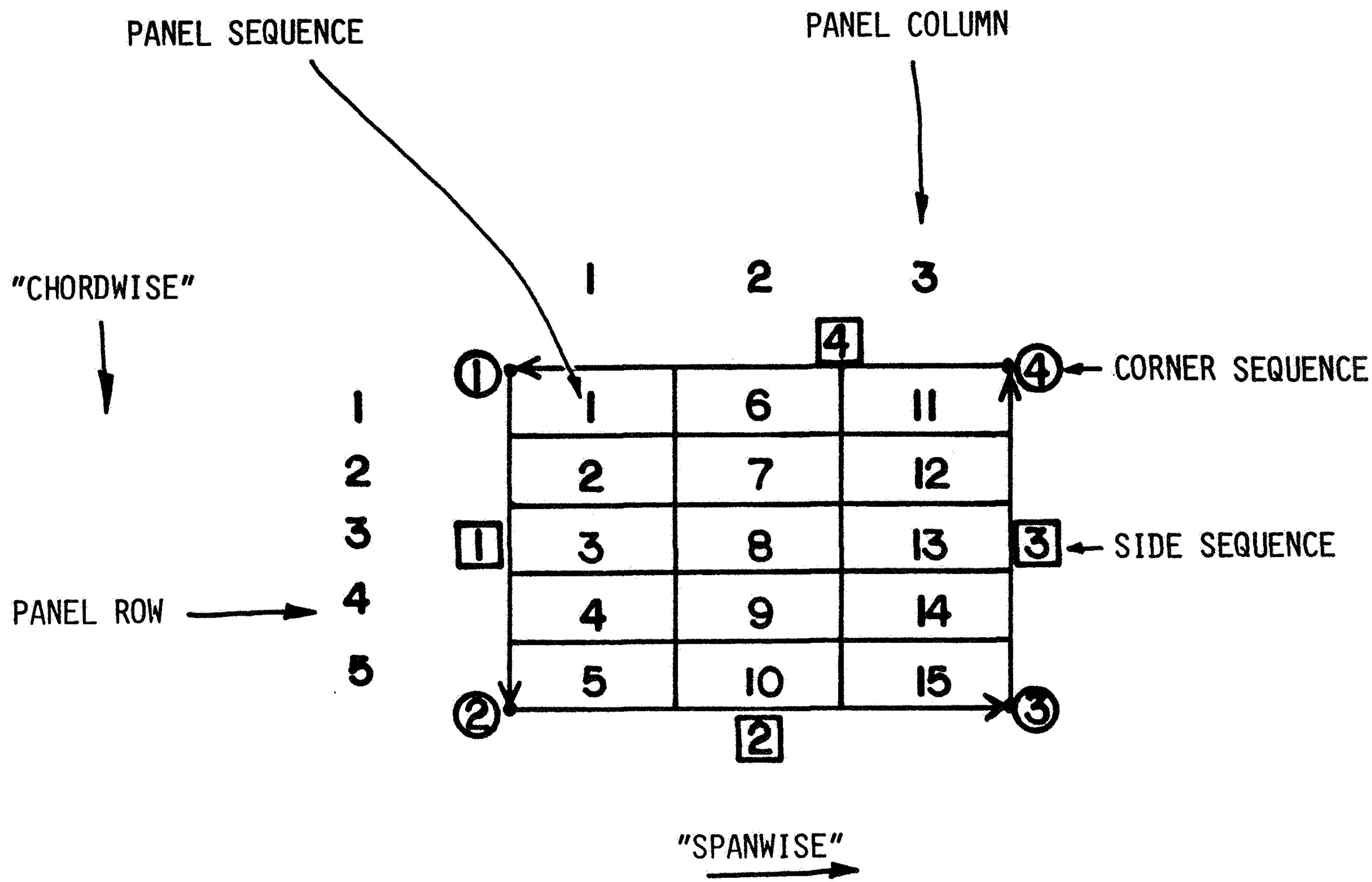


Figure 9. Patch Conventions.

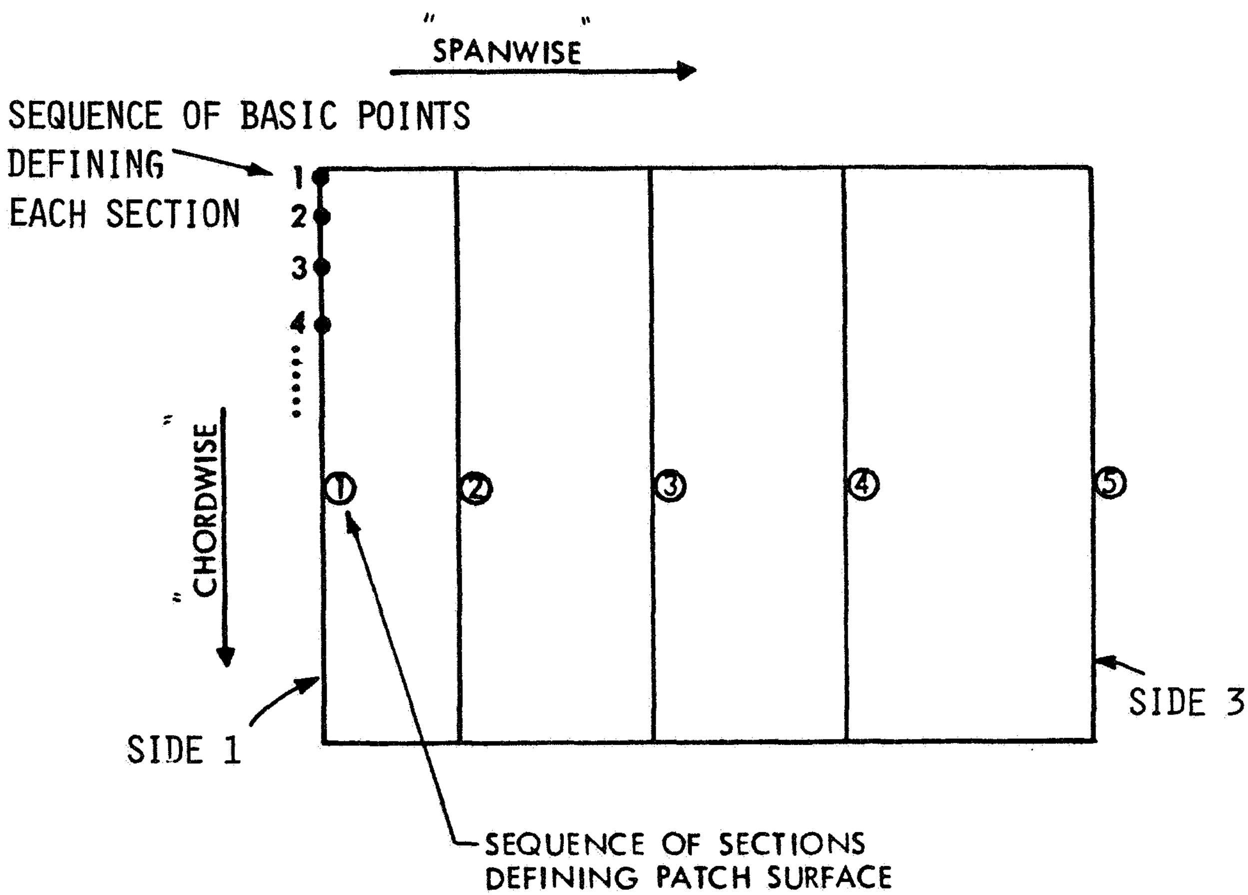


Figure 10. Sections Defining Patch Surface.

4.5.3 Parameters

The main parameters associated with a patch are:

PNAME, IDENT, KLASS, KOMP, NROW, NCOL, IPAN, LPAN, NPAN

PNAME is an optional text description for each patch while IDENT gives the patch type. At this time IDENT = 1 and 2 are used for patches on closed surfaces, 1 for a wing type and 2 for a body type. Both of these use the internal Dirichlet boundary condition. IDENT = 3 is for patches on open surfaces; on these the Neumann boundary condition is used. Different printouts are used for the analysis results depending on the IDENT value.

KLASS and KOMP are the assembly number and component number associated with each patch and NROW, NCOL hold the patch's number of rows and columns of panels, respectively. IPAN and LPAN are the first and last panel subscripts (absolute) on the patch and NPAN is the number of panels on the patch.

4.5.4 Input Order

The order of input patches and their orientation is not very restrictive. The main requirement is that patches with panels 'facing' each other across a small gap (i.e., small in relation to panel size) should be kept together in the input. The upper and lower surfaces of a wing in the trailing-edge region should be part of the same patch to ensure that the upper and lower panels at the trailing edge occur in the same column of the patch; in this way they are sure to fall in the same matrix block in the Gauss-Seidel iterative solution procedure.

Patches adjacent to each other and essentially in the same plane can be separated in the patch sequence--this is because a panel's potential influence coefficient at a point beyond its perimeter is small near the plane of the panel.

4.5.5 Sections

4.5.5.1 Section Coordinate System

Each section of a patch may be defined in its own local coordinate system, referred to as the SECTION COORDINATE SYSTEM, or S.C.S. The user provides the necessary information on the section card to transform from the S.C.S. into the C.C.S. This transformation is performed immediately a section's geometric description is complete. This transformation is separate from the component transformation in which the complete component is converted into the G.C.S. (at which stage the S.C.S. geometry is discarded). This double transformation--both levels of which are optional--offers useful flexibility when preparing the input data. One particular advantage is that the geometric relationships--especially the rotations--are kept reasonably simple without sacrificing generality.

The information required to transform from the S.C.S. into the C.C.S. (see Figure 11) consists of: (i) the translation vector, (STX, STY, STZ), which is the position vector of the S.C.S. origin expressed in the C.C.S. coordinates; (ii) a scaling factor which is applied in the S.C.S.; (iii) the rotation angle (ALF, degrees) about the y-axis of the S.C.S.; and (iv) the angle (THETA, degrees) in the C.C.S. x-y plane, between the projection of the S.C.S. y-axis and the C.C.S. y-axis.

4.5.5.2 Basic Points

The contour line of each section is defined by a set of BASIC POINTS, (BX, BY, BZ). These points may be used directly as panel corner points, i.e., MANUAL PANELING, in which case the user must take care over the <u>number</u> of input points. Alternatively, an AUTOMATIC PANELLLNG ROUTINE, referred to as the A.P.R. may be activated which interpolates through the basic points to form a new set of points corresponding to panel corner points. (Note, this is just a temporary set as the user may opt to use the A.P.R. in the spanwise direction as well, in which case the <u>sections</u> do not necessarily line up with panel edges.)

No matter which paneling option has been selected, basic points should be reasonably dense in regions of high curvature, such as near the wing leading edge.

Several options have been provided for defining the basic points and these, in combination with the two-stage transformation described above, provide great flexibility when preparing the input. The options may be exercised at the section level so the input form may be changed from section to section. The options available at this time are described below and are controlled by the value of INPUT. INPUT takes the value of INMODE on the section CARD 11 for values of 1 through 4; these are illustrated in Figure 12, together with instances for their use.

INPUT values of 1, 2 and 3 are used when a section lies in one of the reference planes of the chosen S.C.S.; in these cases we have a constant coordinate, x, y, or z, respectively. With one coordinate fixed, we need input only two coordinates for each basic point, e.g., y and z when INPUT = 1. Provision is made to specify a third quantity to give a local adjustment to the 'constant' coordinate, e.g., when using INPUT = 2 we may specify x, z and δy. Usually the δ-quantity is left blank (i.e., 0). The basic value for the constant coordinate is zero until the section points are transformed into the C.C.S., so the value of that coordinate in the C.C.S. must be provided in the transformation information on the section CARD 11.

INPUT value of 4, which requires all the components of each basic point position vector, is used when defining a completely arbitrary section shape.

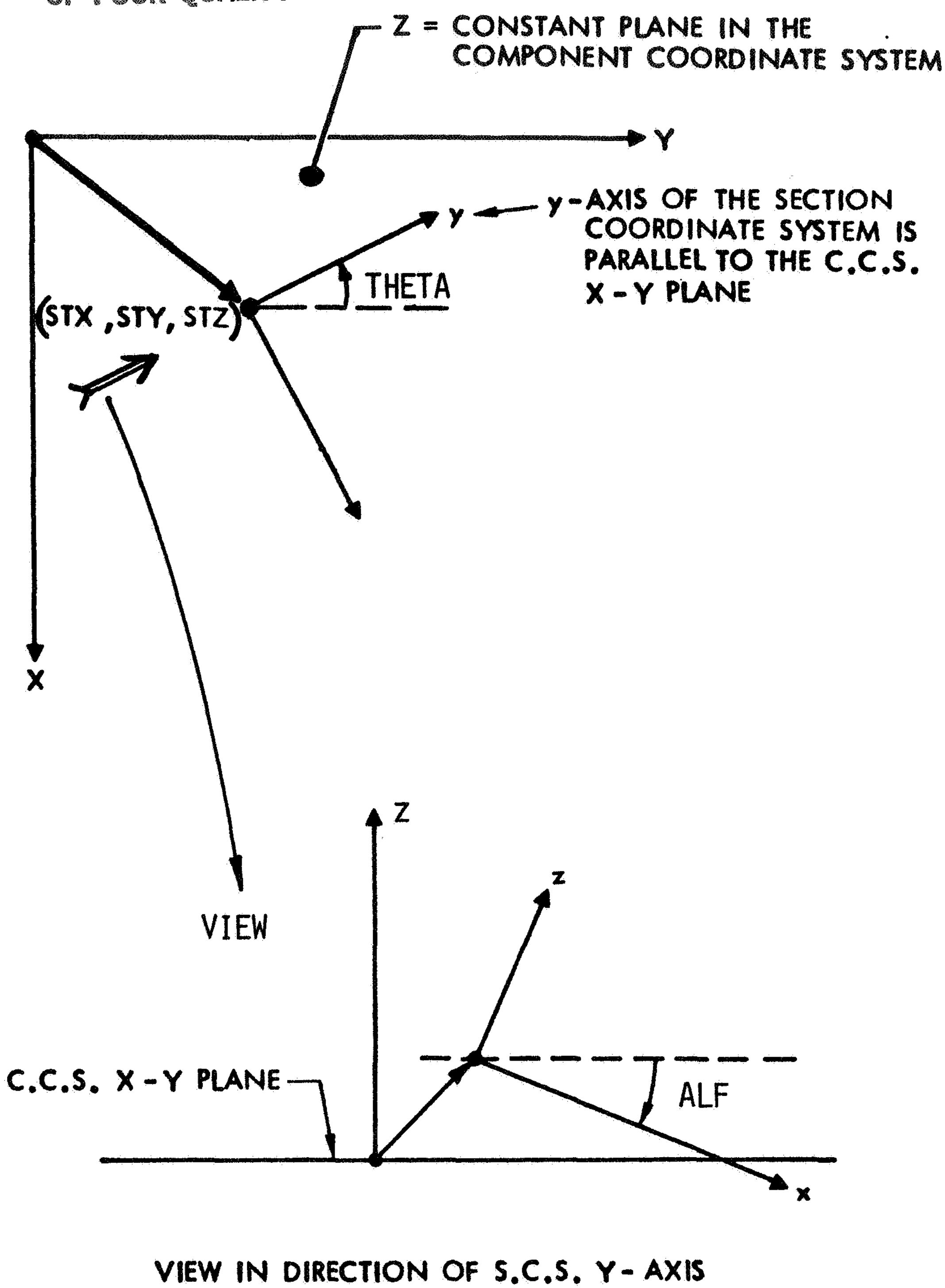


Figure 11. Section Transformation Into C.C.S.

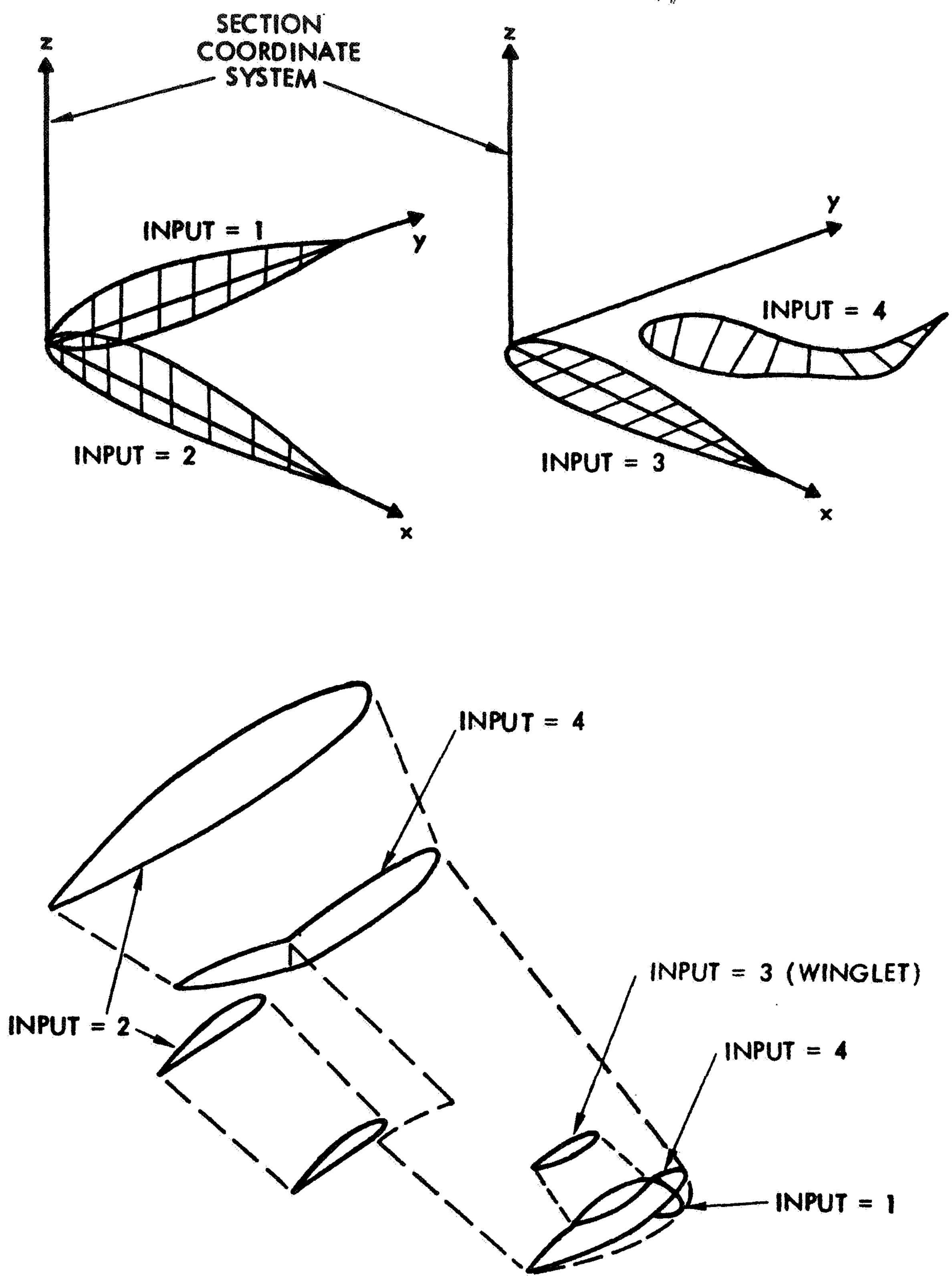


Figure 12. Basic Point Input Options 1 through 4.
Note: INPUT=INMODE on CARD 11 for these cases.

An option to input basic points in polar coordinate format, see Figure 13, has been provided. This requires INMODE = 12 on the section card. Other INMODE options have been provided for automatically generating basic points on certain shapes: these will be described below in 4.5.5.3.

Zero or negative INMODE values allow the present section's basic points to be copied over completely from any previously defined section. The section number is (-INMODE) except when INMODE = 0; the latter copies over the points from the section just completed. The section number specififed is the absolute number from the beginning of the input and includes other copied sections as well as sections which may have been generated automatically. If the section counting becomes complicated, alternative ways of copying are available as described under sspecial routines (4.5.7). The basic points are copied from the S.C.S. set (i.e., as originally specified) and are then transformed to the present C.C.S. according to the new section's transformation information.

4.5.5.3 Chordwise Regions

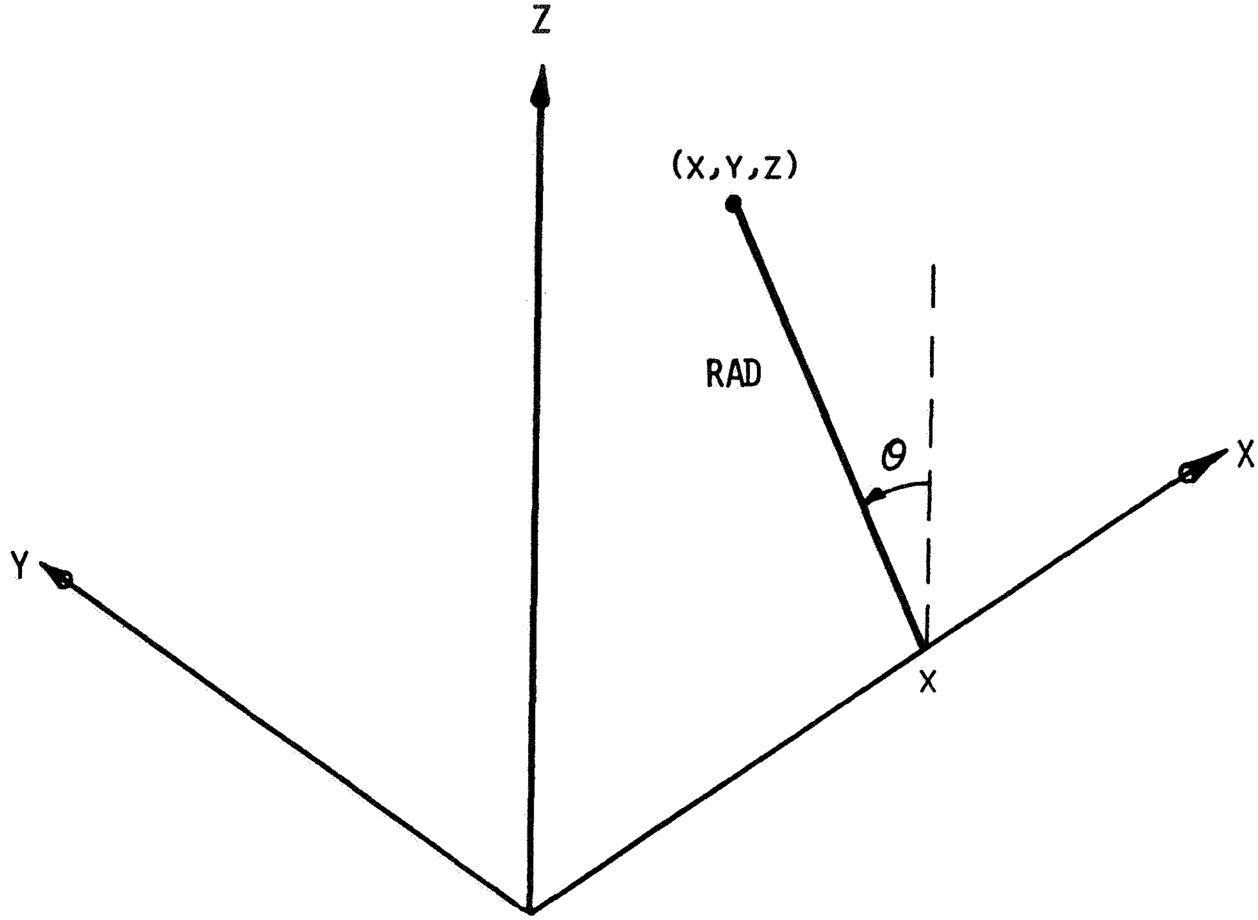
The basic points defining a section may be assembled in a number of CHORDWISE REGIONS for the purpose of controlling the panel density and distribution on that section. In addition, the option on manual or automatic paneling is selected at the chordwise region level, allowing the user to switch from one to the other within each section wherever he chooses. Chordwise regions are used only as an input convenience and are discarded in the program as soon as the surface paneling is complete.

A chordwise region must end on a basic point called a NODE POINT, Figure 14. A NODE CARD, containing the chordwise region paneling information (see below), inserted after a basic point in the input deck identifies that point as the end of a chordwise region. Node points are usually placed at 'problem' areas where large velocity gradients are expected to occur, e.g., flap hinge line, leading edge, close-interference regions, but the user can place them wherever he wishes to change from one panel scheme to another or to ensure panel matching on patches facing each other across small gaps. Four types of node point are provided at this time and are described below.

The information on a NODE CARD consists of just three integers.

(i) NODEC identifies the node point and its type.

(ii) NPC is the number of panels to be generated by the A.P.R. in the chordwise region just completed--a zero value gives manual paneling.



INPUT: X, RAD, THET (DEGREES)

PROGRAM COMPUTES: Y = RAD * SIN (THET)

Z = RAD * COS (THET)

Figure 13. Polar Coordinate Input (INMODE=12).

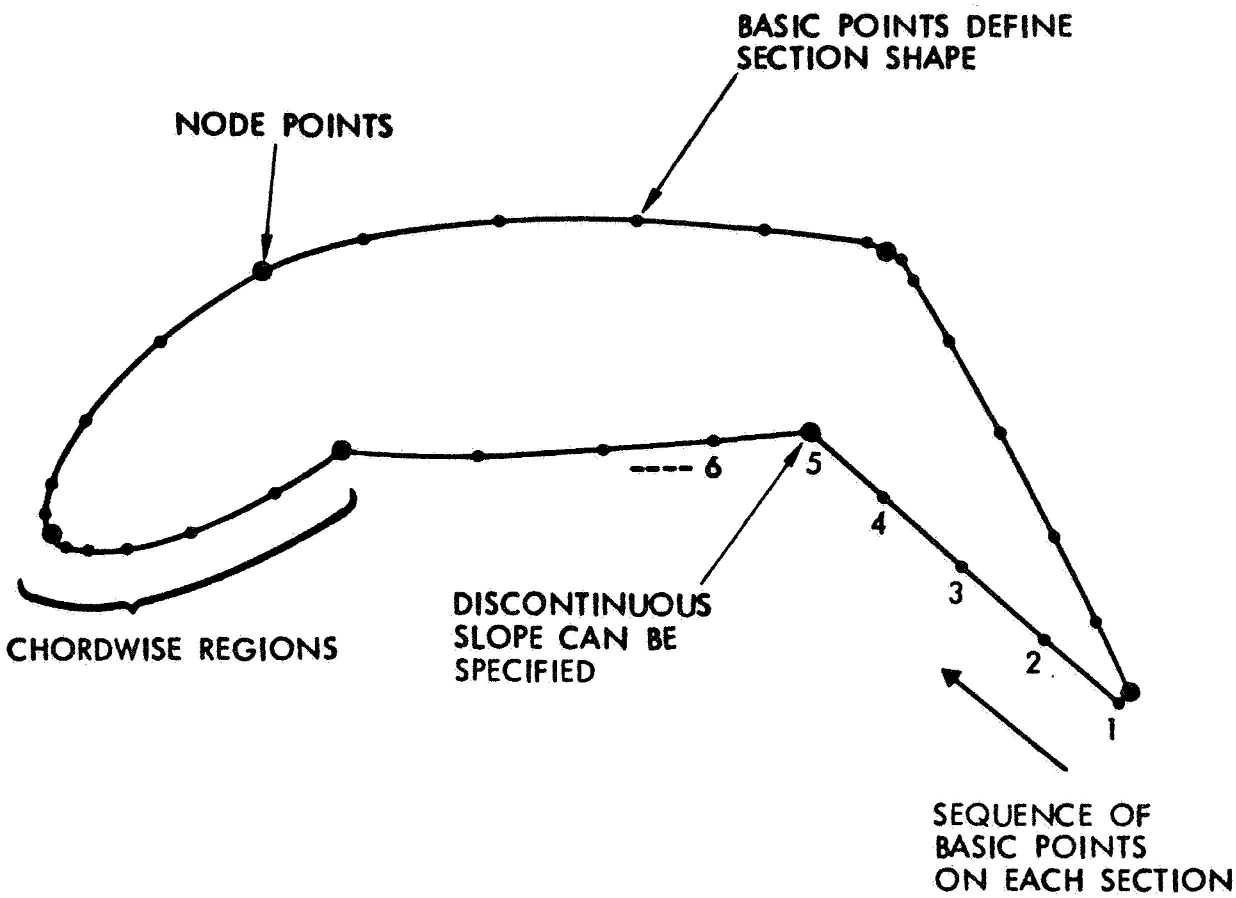


Figure 14. Chordwise Regions on a Section.

(iii) INTC controls the form of the distribution in the automatic paneling mode and is inactive in the manual paneling mode.

(The C on the end of each quantity distinguishes the chordwise from the corresponding spanwise quantities, which end in S, 4.5.6)

NODEC values of 1 or 2 specify the end of a chordwise region with, respectively, continuous or discontinuous surface slope onto the next chordwise region. These values are, therefore, used only on regions ending in the interior of a section. The last point on a section is specified by NODEC = 3 and is the only node point that <u>must</u> always be specified even if manual paneling has been selected. Negative NODEC values are also permitted and initiate a special copying routine described in 4.5.7.1.

Four panel spacing options are provided in the A.P.R. The action of INTC values of 0, 1 and 2 is illustrated in Figure 15, and is based on the cosine distribution giving increased panel density towards, respectively, the beginning and end, the beginning only, or the end only, of the region. Equal spacing throughout the region is provided by INTC = 3. Coupled with the flexibility offered by the choice of chordwise region location, these spacing options have proven adequate so far; however, other options could easily be added should the need arise later, e.g., one based on increments in integrated surface curvature, or on increments in doublet value from a preliminary two-dimensional solution for the section have been considered.

Clearly, node cards provide the user with an extremely versatile paneling tool. With one card deck of basic points defining the configuration geometry, he can, from run to run, change the form of the paneling simply by changing two integer values on each node card. Not only that, he can also move node cards within the deck (but not the node cards at section ends) or remove some or add new ones from run to run. This allows the user to concentrate his paneling in areas of interest, leaving other areas more sparsely panelled. It thereby provides a very effective use of the limited number of panels available, yet, on a subsequent run a few small changes to the node cards allow the emphasis to be switched to another area without having to punch a new basic geometry card deck.

There is just one important ground rule for the use of node cards; the <u>total</u> number of panels (automatic and/or manual) on each section of a patch <u>must be the same</u>. The total is, in fact, the number of panel rows, NROW, for that patch. The program monitors the number of panels on each section and the calculations are terminated with an error message should the user make a mistake. Provided this ground rule is satisfied, it is not necessary for the panel <u>distribution</u> to be the same from section to section--in other words, the number of chordwise regions and their node information can vary from section to section.

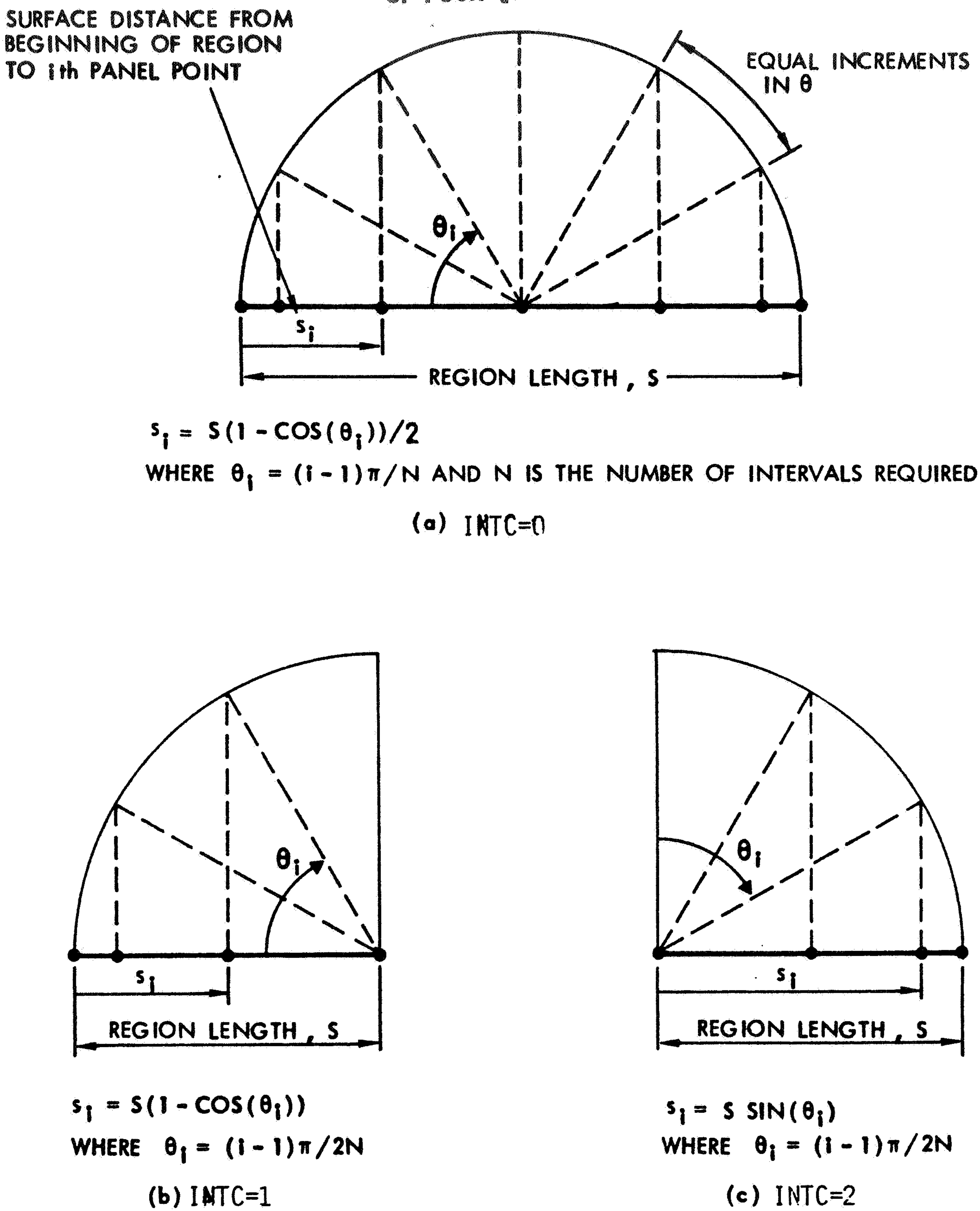


Figure 15. Spacing Options 0, 1 and 2 in the A.P.R.

Figure 16 illustrates the use of NODE CARDS to form chordwise regions on a section for a wing patch. Figure 16(a) is for the case of a simple section with two chordwise regions while Figure 16(b) shows a more complicated case with five chordwise regions. This case includes an illustration of the more general copying capability to be described in 4.5.7.1.

The chordwise region option can also be used on sections generated internally by the code under INMODE values of 5 through 8. For example, INMODE = 5 causes a NACA four-digit equation to generate a symmetrical section. (Note: the four-digit equation has been modified in the quadratic coefficient to give zero thickness at the trailing edge:

$$z_i = \pm TC*(1.4845 \sqrt{x_i} - .63x_i - 1.758x_i^2 + 1.4215x_i^3 - .518x_i^4).$$

The basic points on the section are generated with

$$x_i = 1.0 - \sin\theta_i; \qquad 0 \leq \theta_i \leq \pi.$$

(Note: this determines panel spacing if NPC = 0 on CARD 14.)

$$\theta = (i - 1)\nabla\theta/NINT + \theta_a$$

where $\nabla\theta$ is the interval in θ over the chordwise region and NINT is the number of intervals to be generated in that chordwise region. (Warning: if NPC = 0 on CARD 14, then NINT is the number of panels; default = 70.)

θ_a is the value of θ at the start of the chordwise region. The θ interval, $\nabla\theta$, over the region is evaluated as:

$$\nabla\theta = \sin^{-1}(1 - |XRB|) - \theta_a$$

The user supplies the values for NINT and XRB on CARD 13. XRB is the x-station for the end of the required chordwise region; it takes a negative sign if the region ends on the lower surface.

Figure 17 illustrates the card set required for the INMODE = 5 option using four chordwise regions. It also covers the case for INMODE = 7 which generates a biconvex section.

Figure 18 illustrates the case for INMODE = 6. This generates a semi-ellipse with a unit horizontal semi-axis in the S.C.S. A similar chordwise region option is available as in the INMODE = 5 case and uses the CARD 13/14 information, see Figure 17.

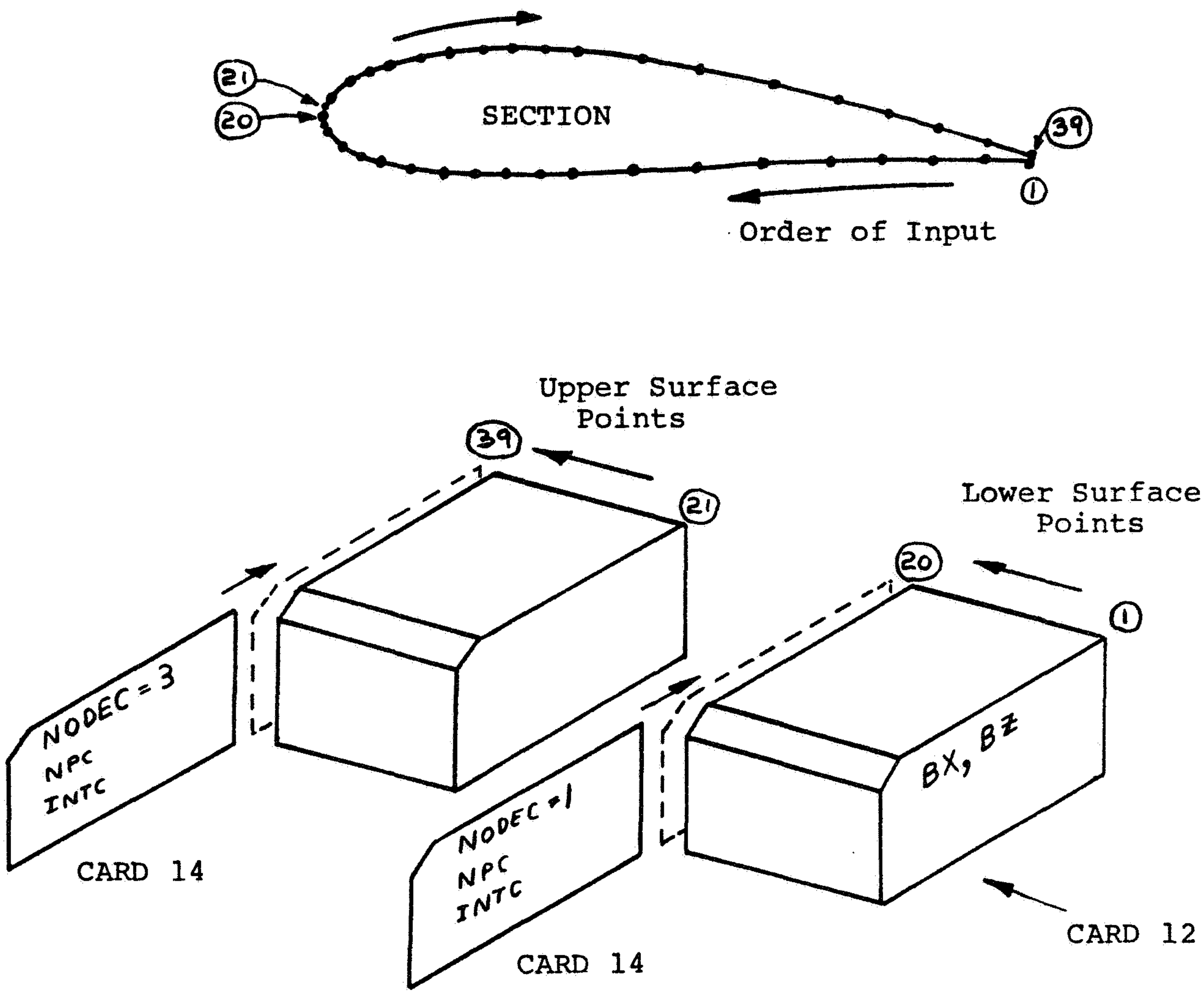


Figure 16. Illustration of CARD SET 12/14 for Section Coordinates.

(a) Simple Section.

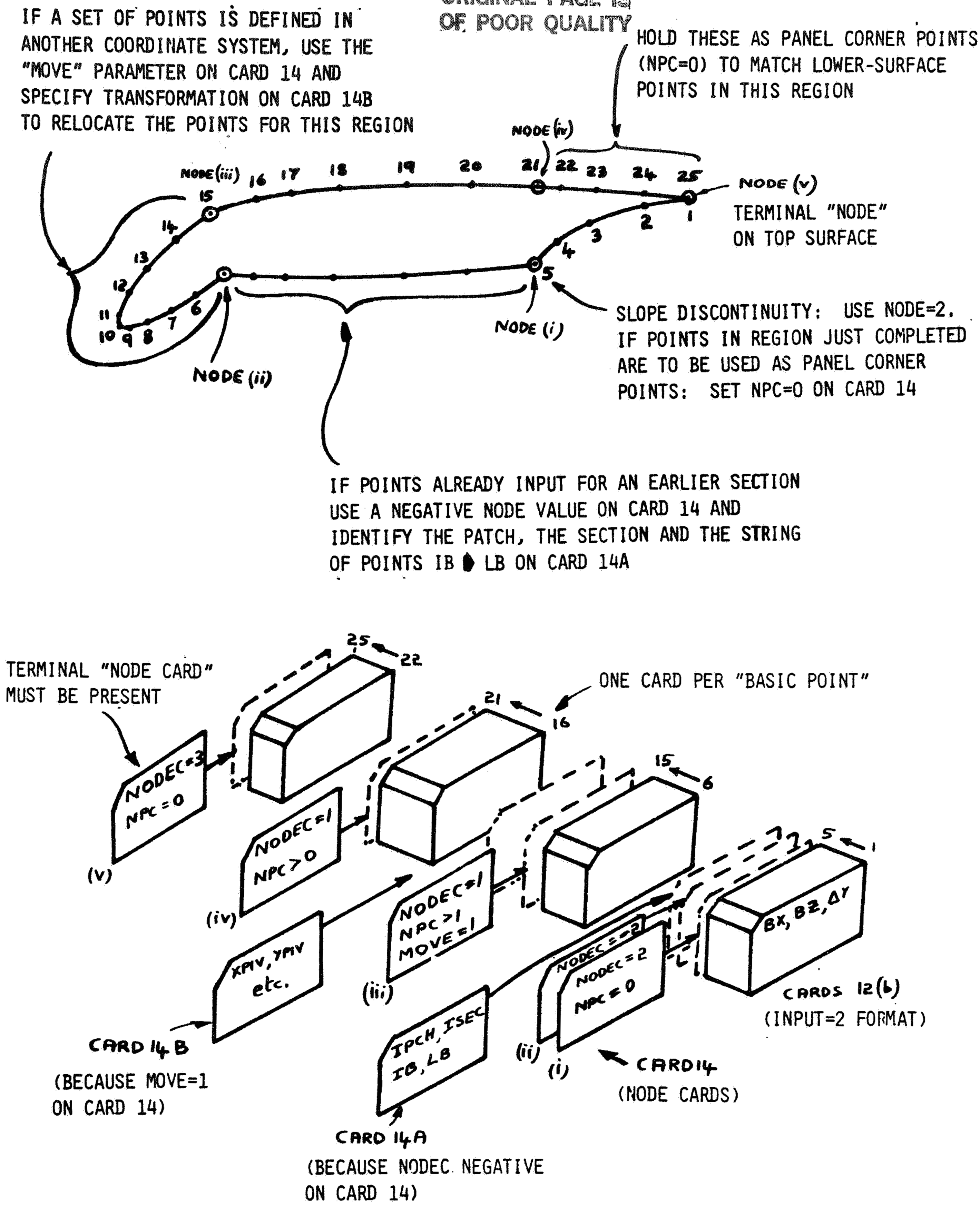


Figure 16. Concluded.

(b) Complicated Section.

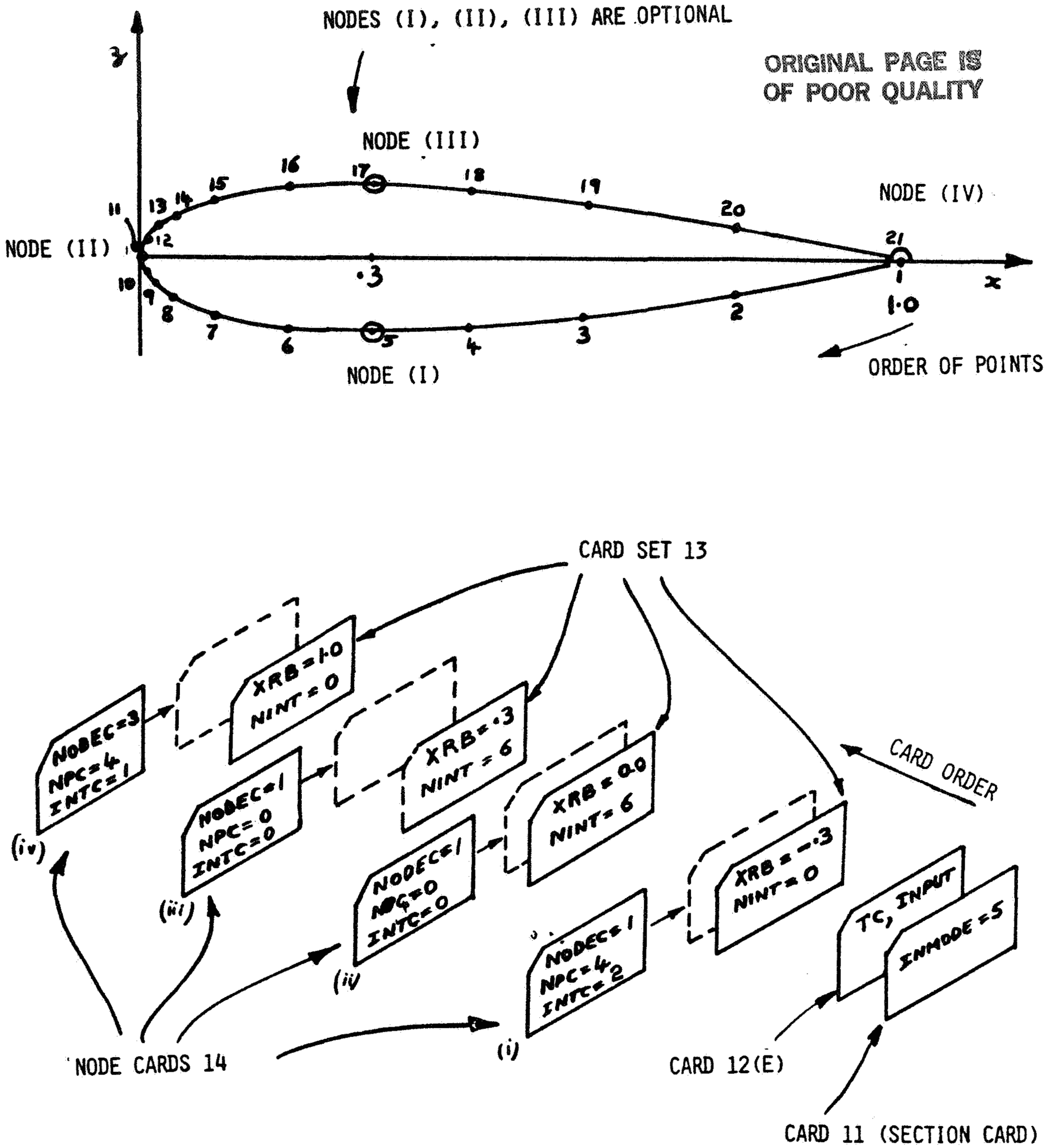
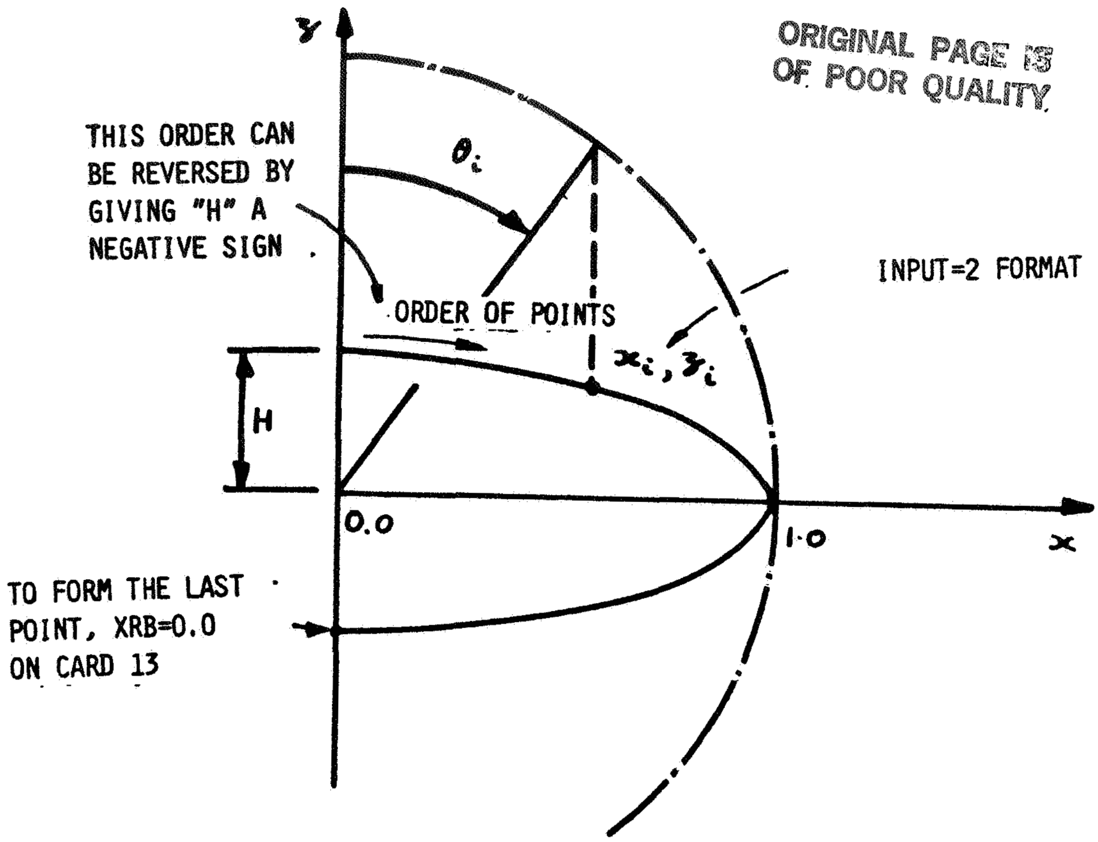


Figure 17. Illustration of NACA Section Option (INMODE=5) (Biconvex Section Option is Similar (INMODE=7)).



HORIZONTAL SEMIAXIS = 1.0
VERTICAL SEMIAXIS = H (INPUT ON CARD 12(F))

$$X_I = \sin \theta_I$$

$$Z_I = H \cos \theta_I$$

$$\theta_I = \theta_A + (I - 1)\Delta\theta$$

$$\left.\begin{aligned} \Delta\theta &= (\theta_B - \theta_A)/\mathrm{NINT} \\ \theta_B &= \sin^{-1} |\mathrm{XRB}| \end{aligned}\right\} \text{NINT AND XRB INPUT ON CARD 13}$$

$$\theta_B = \pi - \theta_B \text{ IF XRB NEGATIVE}$$

θ_A, θ_B ARE THE VALUES OF θ AT THE BEGINNING AND END, RESPECTIVELY, OF A "CHORDWISE" REGION.

Figure 18. Illustration of Semi-Ellipse Option, INMODE=6.

A complete ellipse can be generated as a section using the INMODE = 8 option, Figure 19. In this case the complete horizontal axis stretches from 0 to 1.0 in the S.C.S. The vertical semi-axis, H, is supplied by the user on CARD 12(f). The chordwise region option using CARDS 13-14 is available in a similar form to that shown in Figure 16.

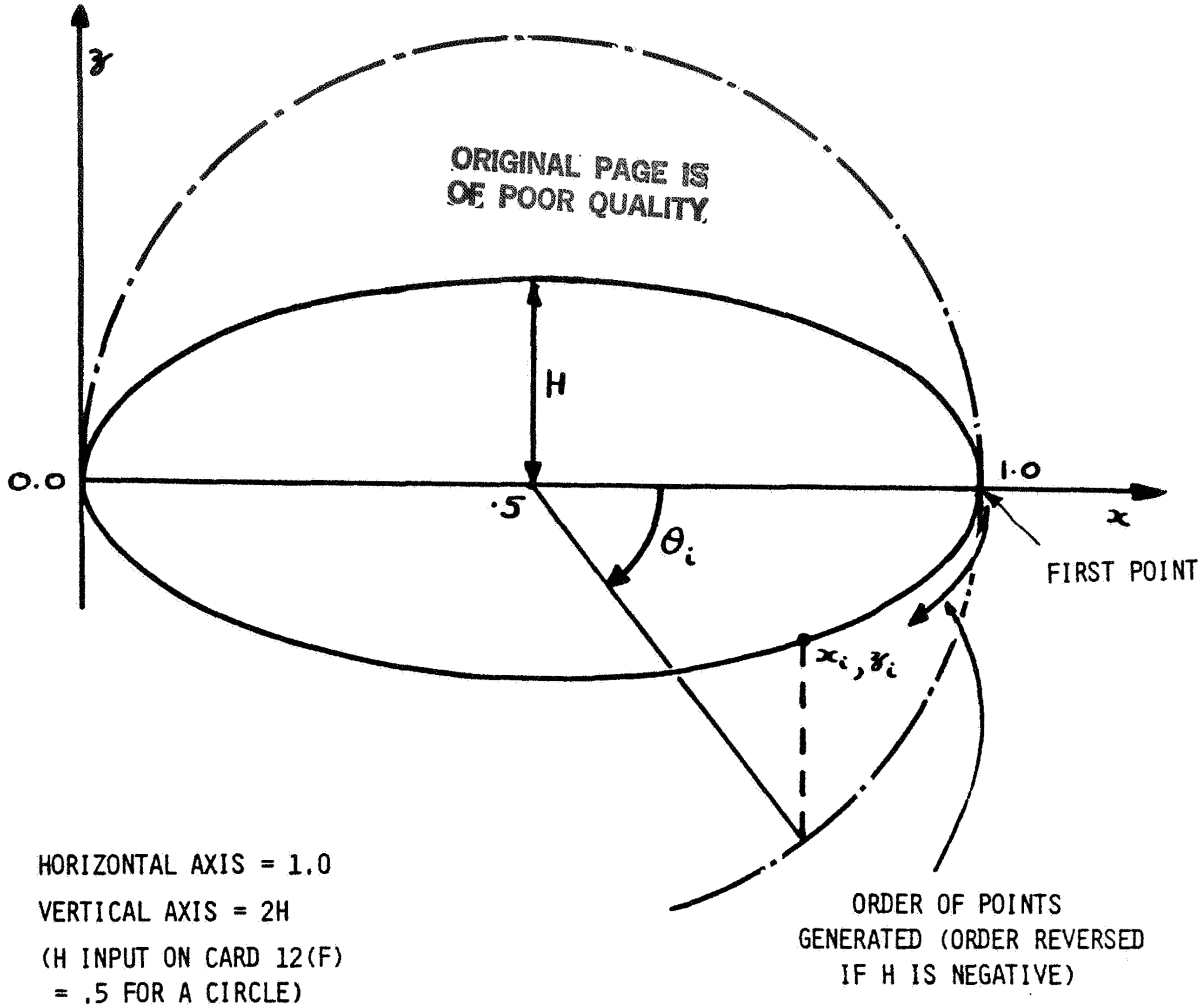
4.5.6 Spanwise Regions

Sections defined within each patch may be assembled in a number of spanwise regions for the purpose of controlling panel density and spacing in the spanwise direction. In forming spanwise regions, sections defined by the user take on a similar role to that of basic points in the chordwise regions. Although the options available for the spanwise regions are essentially the same as described for the chordwise regions in 4.5.5.3, the two are applied completely independently; for example, the user may request automatic paneling in the chordwise direction and manual in the spanwise direction. As in the case of chordwise regions, spanwise regions are used only as an input convenience and are discarded once the paneling is complete.

Spanwise regions must end at user-defined sections, called NODE SECTIONS, Figure 20. These usually coincide with kinks in the spanwise direction on the patch planform, but the user can place one whenever he wishes to change the form of the paneling or to change between manual and automatic paneling in the spanwise direction. For convenience, the spanwise node information is included on the section card (CARD 11) together with the section transformation information (4.5.5.1). The function of the spanwise region node quantities, NODES, NPS, INTS, follows closely the description in 4.5.5.3. NODES, however, must be set to zero (blank) on the first section of a patch and on all intermediate input sections that are not node sections. (NPS and INTS are then inactive.) The last section on a patch is identified by a NODES value of 3, 4 or 5; 4 is used if the patch is the last one on a component and 5 is used if the patch is the one on the configuration, in which case the present section completes the basic description of surface geometry.

An exception to the above occurs in the case of a body of revolution. To execute this option a negative sign is placed on the NODES value on the first section card. The section basic points are then generated in the S.C.S. z,x plane, Figure 21. the section is rotated about the x-axis through an angle given on CARD 15; this generates the 'spanwise' paneling in accordance with the NPS, INTS data on the section card. Multiple spanwise regions may be used, if required, as illustrated in Figure 21.

The total number of panels defined (manually or automatically) across each patch in the spanwise direction is monitored by the program and becomes the number of panel columns, NCOL, for that patch. In view of the ease of generating panels,



$$X_I = 0.5\ (1.0 + \cos\theta_I)$$

$$Z_I = -H \sin\theta_I$$

$$\theta_I = \theta_A + (I - 1)\Delta\theta$$

$$\left.\begin{aligned} \Delta\theta &= (\theta_B - \theta_A)/\mathrm{NINT} \\ \theta_B &= \cos^{-1}((|\mathrm{XRB}| - .5)/.5) \end{aligned}\right\} \text{XRB, NINT INPUT ON CARD 13}$$

$$\theta_B = 2\pi - \theta_B \text{ IF XRB NEGATIVE}$$

Figure 19. Illustration of Full Ellipse Option (INMODE=8).

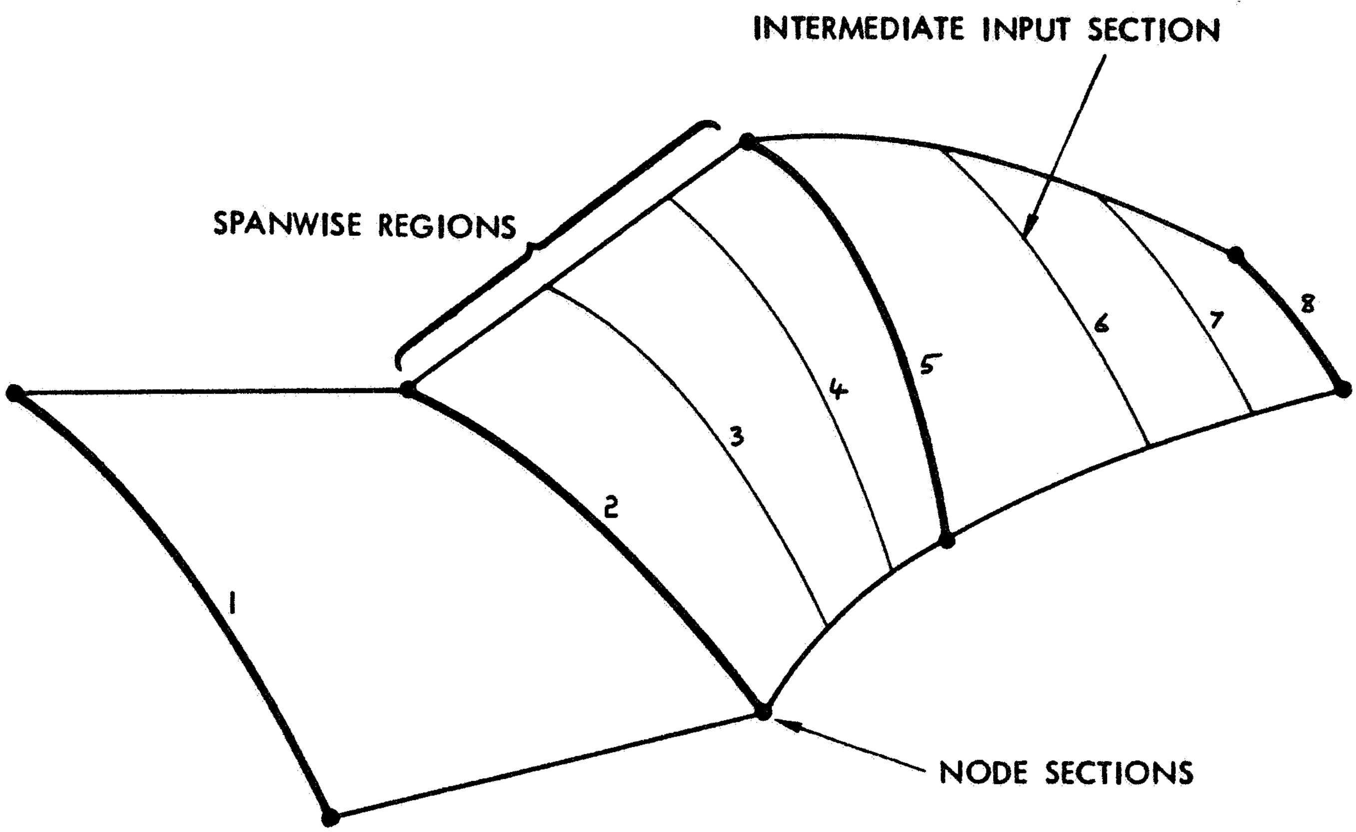


Figure 20. Spanwise Regions on a Patch.

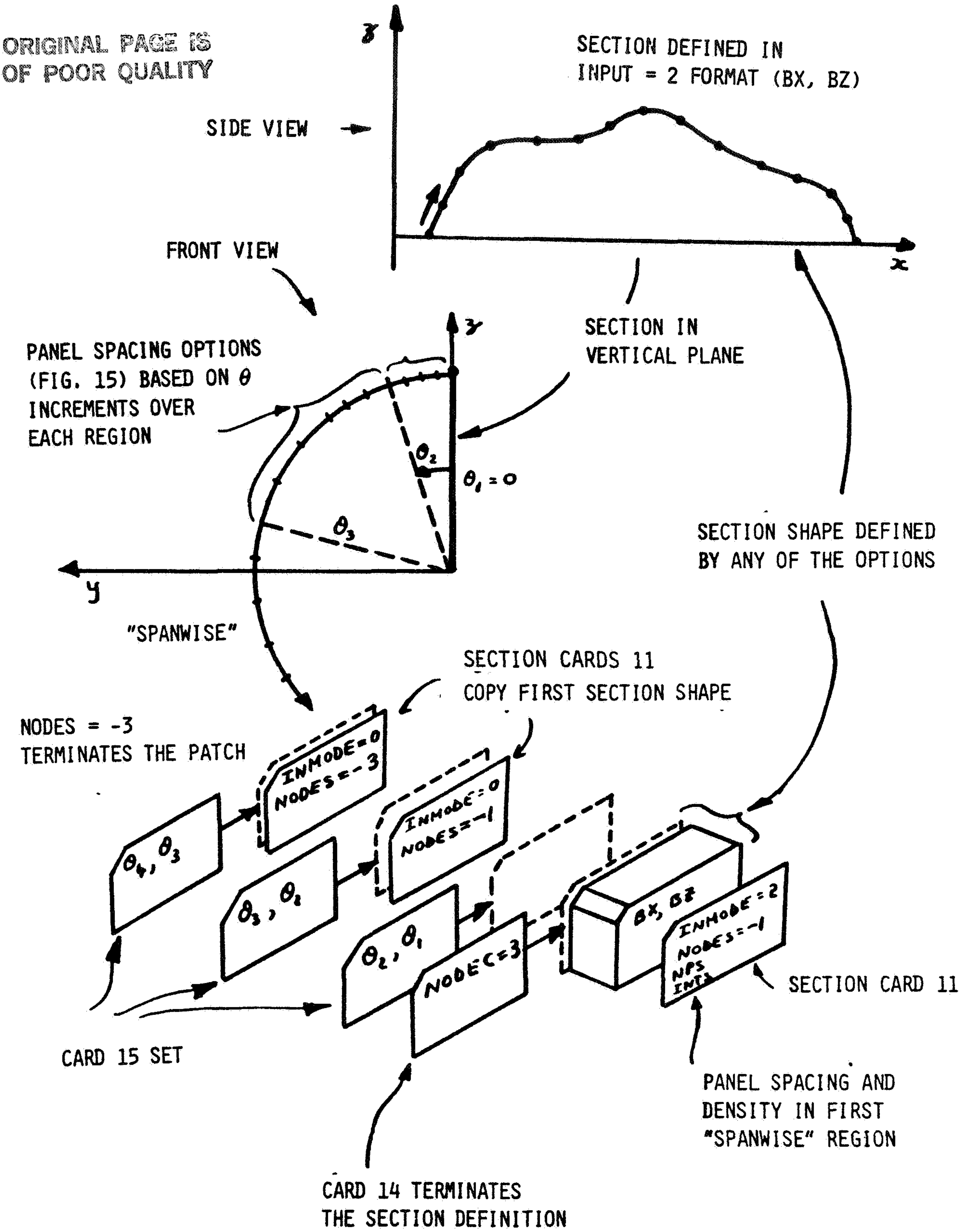


Figure 21. Body of Revolution Option.

the code also monitors the running total of panels, and if a limit is exceeded, the calculation terminates with an appropriate error message. The limit is set internally by the storage capacity, but the user is given the opportunity (with variable NPNMAX on CARD 3) to override that value with his own estimate of the total he intends to use for that case. In the event of an input error, this will avoid the inadvertent and expensive use of, say, 1,000 panels when the user intended using only 100.

4.5.7 Special Routines

The geometry routines described above may be applied for all patches on the configuration surface; however, special routines have been provided to reduce user input and, in particular, to avoid duplicating information already supplied. These routines, which are described below, are optional.

4.5.7.1 Copying Routine

We have already seen (4.5.5.2) a copying facility accessible at the section input level. This copies over a complete section, including the chordwise region information, and has, therefore, a rather limited application. More general copying routines are provided and are activated at the basic point level to copy STRINGS OF BASIC POINTS, rather than complete sections. This capability allows a new section to be assembled from parts of previously defined sections. Several strings of basic points may be assembled from a number of previously defined sections and the points selected need not follow the same direction as originally specified. Furthermore, the copied strings of points may be intermixed with strings of manually input basic points to complete the new section.

For this copying mode, the value of INMODE on the section card 11 must be in the range 1 to 4. The copying is activated by inserting a NODE CARD having a NEGATIVE sign on NODEC. This is regarded as a DUMMY node card because it does not necessarily terminate a chordwise region (see below). The negative value for NODEC determines the action at the end of the copied string of basic points. If NODEC = -1 or -2, then the last copied point becomes the end of a chordwise region on the new section and signifies, respectively, continuous or discontinuous slope onto the next chordwise region. We then continue to specify further basic points, or, by inputting another negative node card, we can copy another string of basic points, and so on. If NODEC = -3, then the last copied point in the string completes the new section.

If the user does not require a chordwise region to end at the last point in a copied string, then he sets NODEC = -4 when he initiates the copy. When the string has been copied over, the program then expects to receive further basic points to complete the chordwise region or another negative node card can be used to copy another string of points, and so on. Clearly, if NODEC = -4, then the NPC and INTC values on that NODE CARD are inactive and may be left blank.

Whenever a negative node card is inserted, it must always be followed by a COPY CARD (CARD 14A) containing the following information (four integers) defining the location of the required string of points, IPCH, ISEC, IB, LB.

IPCH is the patch number containing the required points.

ISEC is the section number <u>relative to the start</u> of that patch.

IB, LB are, respectively, the first and last basic point numbers (inclusive) defining the string. The numbering is <u>relative to the start</u> of the section ISEC.

(Note: these subscripts can be obtained during an MSTOP = 1 run (CARD 2) with IPROGOM print control set on CARD 2A.

Thus, even in a complicated configuration, it is relatively easy to specify a string of basic points.

This option offers not only an alternative to the earlier copying routine, but also a more general capability because the copying is initiated at the basic point input level, rather than at the section input level. For example, the complete copied section need form only a part of the new section, it being possible to have other basic points, both before and after the copied string. In addition to this, the ability to break the copying into strings of points allows a new distribution of chordwise regions and paneling to be selected.

One restriction must be considered when using this copy routine--the new section's value for INPUT must coincide with the INPUT values on sections from which strings of points are to be copied. This restriction has not posed a problem so far, but if it does, it would not be too difficult to remove it.

This copy routine is used in the wing-body sample case in the Appendix. The fuselage lines at the wing-body junction are copied from the first section on the wing patch.

4.5.7.2 <u>Automatic Patch Generator</u>

Patches covering tip edges, flap edge, cutouts, etc. can be input by the user as ordinary patches, but this can get tedious. Optional automatic procedures have ben installed which simplify this input by generating a complete patch within the code. This AUTOMATIC PATCH GENERATOR, or A.P.G., is initiated at the patch input level by inserting a non-zero value for parameter, MAKE, on the patch CARD 10. The value of MAKE identifies the patch number on the edge of which a closing patch is to be generated. The sign of MAKE determines whether the new patch is on side 3 (positive) or side 1 (negative) of the basic patch. The patch referred to should be a folded patch although sides 2 and 4 need not necessarily meet for the A.P.G. More importantly, an equal number of points (or panels if NPS = 0) should have been used on the upper and lower sides of the edge section.

Consider, for example, a tip-edge patch. Here we have already defined the patch representing the main surface. The end section of that patch provides the BASE SECTION from which the A.P.G. creates the new patch, Figure 22(a), according to user instructions. When the A.P.G. has been activated, the next card (CARD 16) must contain the following:

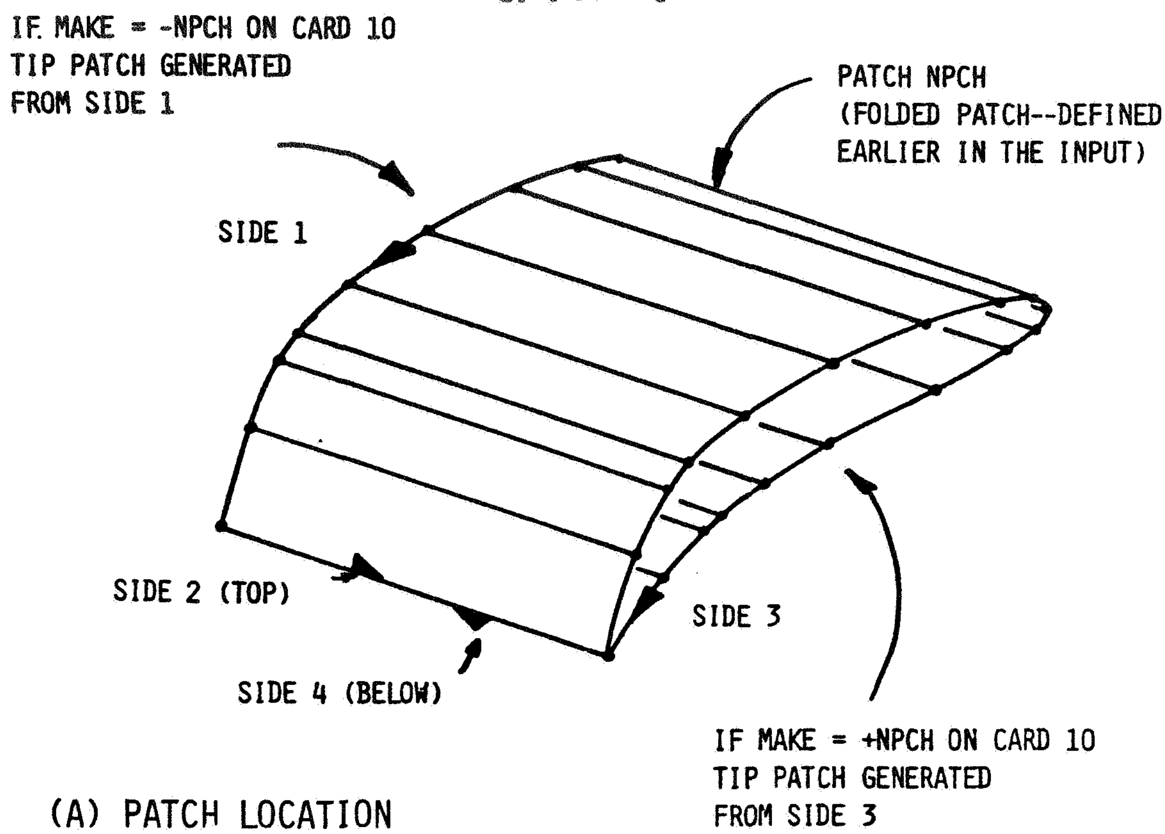
NPC, INTC, KURV, NPTIP, NPS, INTS

Referring to 4.5.5 and 4.5.6, the generated patch has one chordwise region with NPC panels spaced according to the value of INTC. It has one spanwise region with NPS panels spaced according to INTS. In this case, the basic points (in the C.C.S.) defining the base section are brought over. If NPS = 0, then the main program uses the actual panel corner points on the base section; clearly, this gives an exact matching of panels across the patch edge. The values of NODES must be either 3, 4 or 5, depending on the location of the patch in the input. The function of KURV is described below.

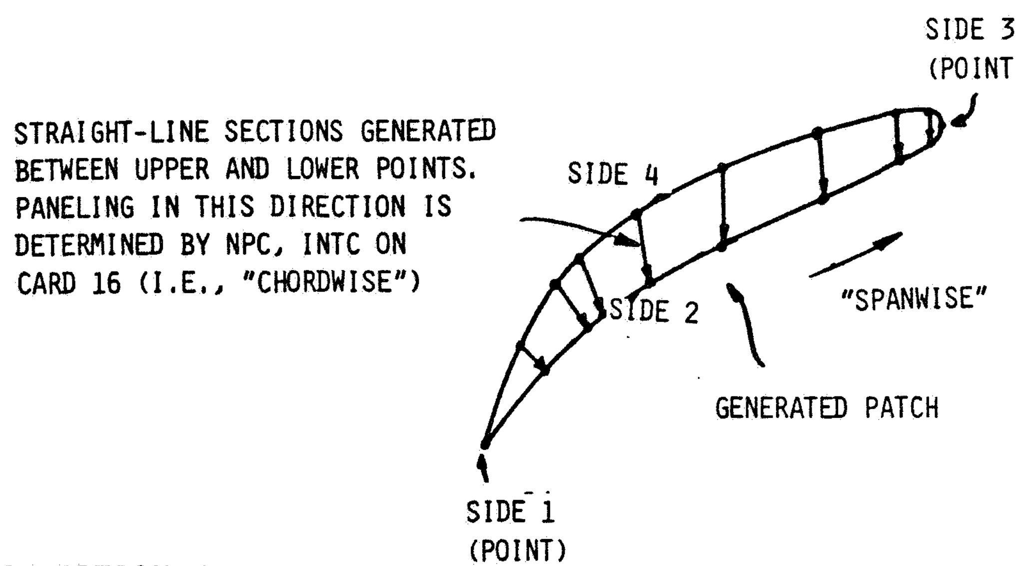
Sections defining the new patch are created automatically from the base section coordinates. The contour of each section generated may be either a straight line ('square-cut' tip) or an ellipse or triangle, depending on the value of the quantity, KURV, supplied by the user. If KURV is 0, sets of basic points are generated on straight lines joining upper and lower points on the base section. The same number of points is created even if the interval across the base section is zero (e.g., at the leading and trailing edges), Figure 22(b).

If KURV is 1, the basic points are created on semicirles having diameter equal to the local 'thickness' of the base section.

If KURV is 2, the basic points are created on semi-ellipses; the base section local thickness provides one axis, while the horizontal semi-axis is derived from additional user input, Figure 22(c). A planform shape is input using a set of coordinates, s^i, y^i, i = 1, NPTIP, defined in a convenient local coordinate system with origin at the trailing edge, Figure 22(d). The scale and point distribution are completely arbitrary, so the points may be conveniently measured from a planform view of the wing. The program scales the shape to fit the length of the basic section and interpolates to find the local semi-axis for each ellipse.



(A) PATCH LOCATION



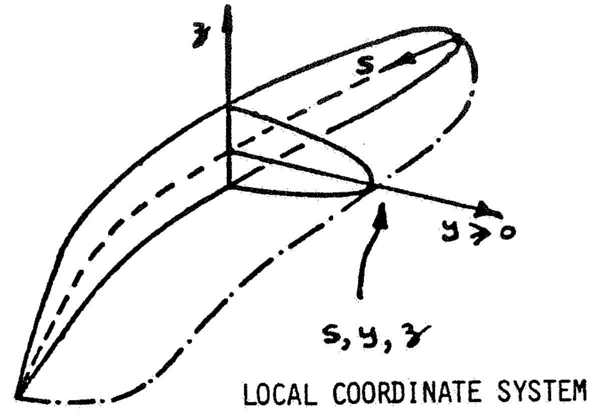
(B) FLAT PATCH OPTION (KURV=0)

Figure 22. Automatic Patch Generator (A.P.G.).

(a) Patch Location.
(b) Flat Patch Option (KURV=0)

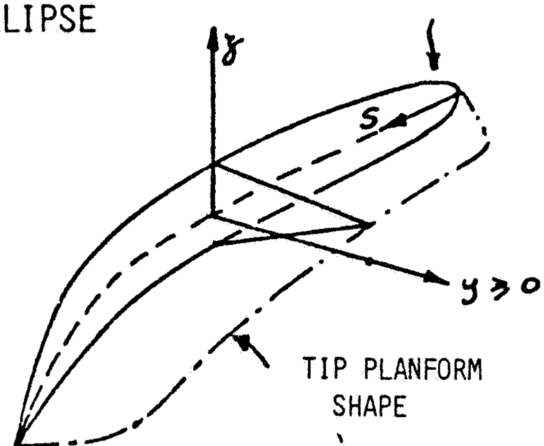
KURV = 1: SEMI-CIRCULAR SECTIONS GENERATED BETWEEN UPPER AND LOWER POINTS

KURV = 2: SEMI-ELLIPTICAL SECTIONS GENERATED. USER MUST SUPPLY PLANFORM SHAPE (s_I, Y_I, I = 1, NPTIP ON CARD 16A)

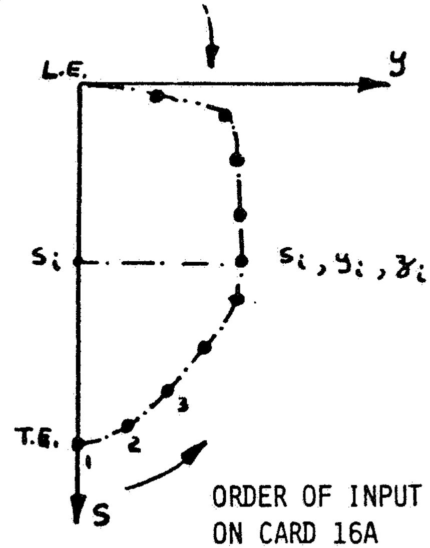


(C) SEMI-CIRCULAR AND SEMI-ELLIPSE SECTIONS (KURV=1 AND 2)

KURV = 3: TRIANGULAR SECTIONS GENERATED. USER MUST SUPPLY PLANFORM SHAPE AND z LOCATION OF APEX (s_I, Y_I, Z_I, I = 1, NPTIP ON CARD 16A)



POINTS DEFINING TIP PLANFORM SHAPE MAY HAVE ARBITRARY SCALE AND ARBITRARY SPACING



(D) TRIANGULAR SECTIONS (KURV=3)

Figure 22. Concluded.

(c) Semi-Circular and Semi-Ellipse Sections (KURV=1 and 2)
(d) Triangular Sections (KURV=3)

A KURV value of 3 is treated in a similar way to the semi-ellipse case, except the tip planform description must now include vertical offsets which locate the apex of each triangular section (see Figure 22(d)).

4.6 Panel

4.6.1 Panel Generation

When the basic geometry has been specified, the panel corner points are assembled, patch by patch. A temporary set of chordwise points corresponding to panel corners is first assembled on each of the defined sections. This is performed in each chordwise region in turn (4.5.5.3) and interpolation is used when the A.P.R. is requested (i.e., when NPC > 0). The form of the interpolation used by the A.P.R. depends on the number of basic points available in the chordwise region, including the two end points. The code augments this number by taking a basic point from a neighboring chordwise region if continuous slope has been specified onto that region (i.e., NODEC = 1 on this or the previous region). The A.P.R. takes the available set of basic points and first eliminates zero length intervals, then, depending on the number of basic points left, i.e., one, two, three or more, it uses, respectively, constant, linear, quadratic or biquadratic interpolation to generate the panel points.

When the temporary set of chordwise points is complete for all sections on a patch, corresponding points on each section are joined by lines called SPANWISE GENERATORS. The panel points along each spanwise generator are then assembled in a similar way to that described for the chordwise direction, but now based on the spanwise region information. The interpolation routine is now applied along each spanwise generator in each spanwise region where the A.P.R. has been selected. The new set of (spanwise) points are actual panel corner points from which the panel geometry is generated.

The fact that we input just one set of spanwise region information for a patch means that the same spanwise interpolation format is used on all the spanwise generators on that patch. Thus the A.P.R. in the spanwise direction has lost generality compared with the chordwise capability; however, this loss is not serious (and to avoid it would require considerably more input).

4.6.2 Panel Geometry

The four corner points, R_i, i = 1, 4, specifying a panel quadrilateral are assembled in the same sequence as the corners on the parent patch, Figure 23. The panel's control point, R_c (where the boundary condition is applied) is the mean of these four points.

The parallelogram formed by joining the mid-points of the sides in sequence provides the mean plane of the panel. The unit vector, $\vec{n}$, normal to this plane and unit vectors, $\vec{l}$ and $\vec{m}$, within the plane form the panel's right-handed orthogonal unit vector system for local coordinates. This system takes the panel control point, R_c, as origin and the vector, $\vec{m}$, passes through the midpoint of side 3.

The four corner points are projected onto the mean plane to form the flat panel used for the velocity potential influence coefficients. The distance between the actual corner points and the mean plane (this is the same for all four corners) is a measure of the amount the panel is skewed. A warning is printed when this value becomes large.

The program forms the half-distance, SMP, SMQ from the control point to the midpoints of sides 2 and 3, respectively (or sides 4 and 1), see Figure 23. These distances are used both as a measure of panel size (SMP + SMQ) and also as a measure of surface distance in the evaluation of doublet gradients. Within a patch the side midpoints of neighboring panels coincide and so linked SMP values and linked SMQ values give a close approximation to surface distances between panel control points.

4.6.3 Panel Neighbors

The program keeps two files on panel neighbor information. This information includes the subscripts NABOR^i; i=1,4 (in the same sequence as the sides) for each panel's set of immediate neighbors and NABSID^i, the sides of those neighbors adjacent to the panel, see Figure 24. Initially, for panels within a patch this information is rather trivial; only the information across patch edges is significant. The latter information is formed by an automatic procedure performing a neighbor search. All this initial information is stored in one file while a second file is formed in which the neighbor information is modified at expected jumps in the doublet distribution. The files are referred to as 'before wake shedding' and 'after wake shedding', respectively. Both sets can be printed using the IPRNAB option on CARD 2A. Temporary cuts in the neighbor relationships are indicated in the second file by a zero NABOR value and a negative NABSID. A panel side on a plane of symmetry has a negative NABSID and its own subscript in the NABOR value in both neighbor files.

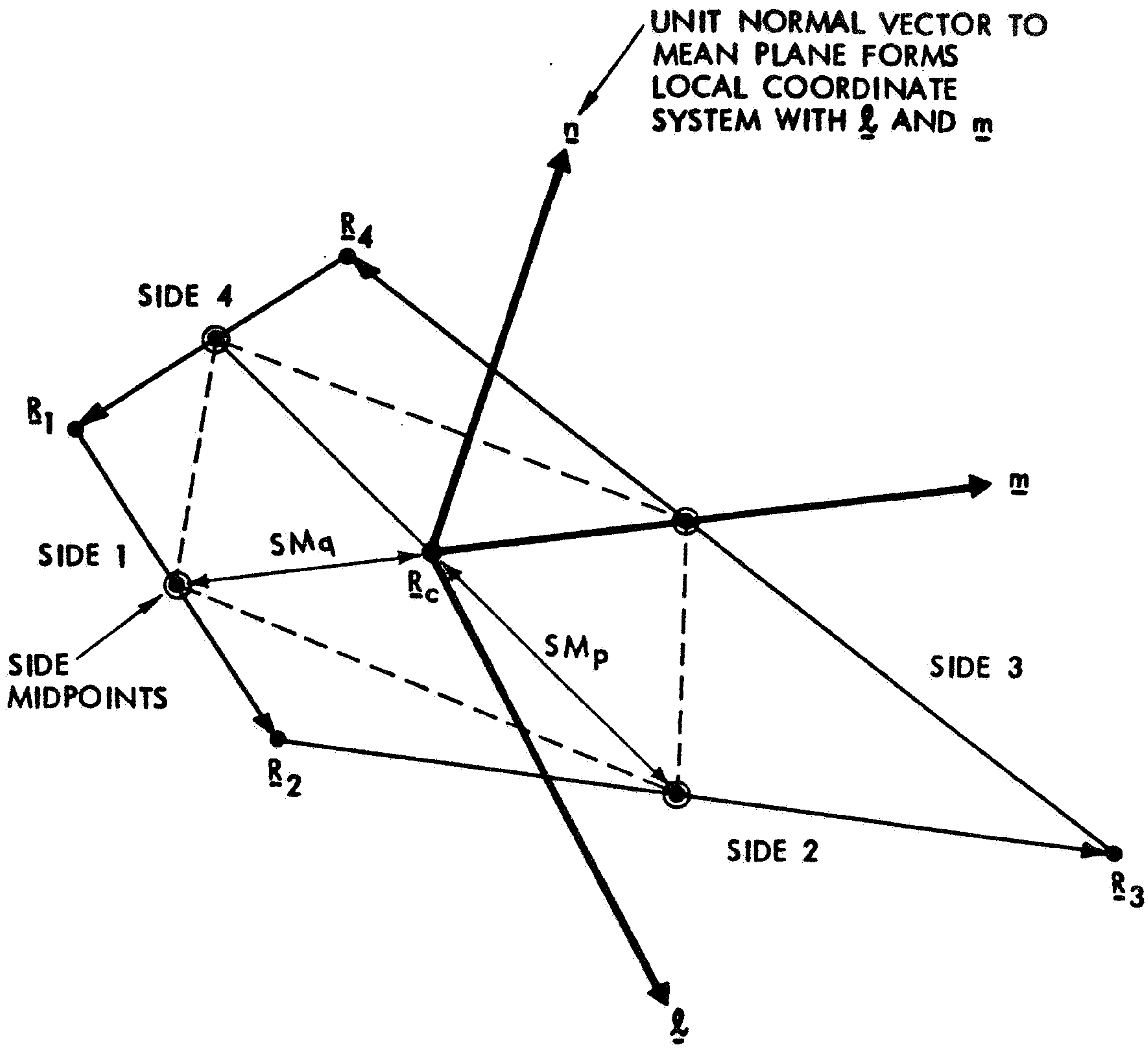


Figure 23. Panel Geometry.

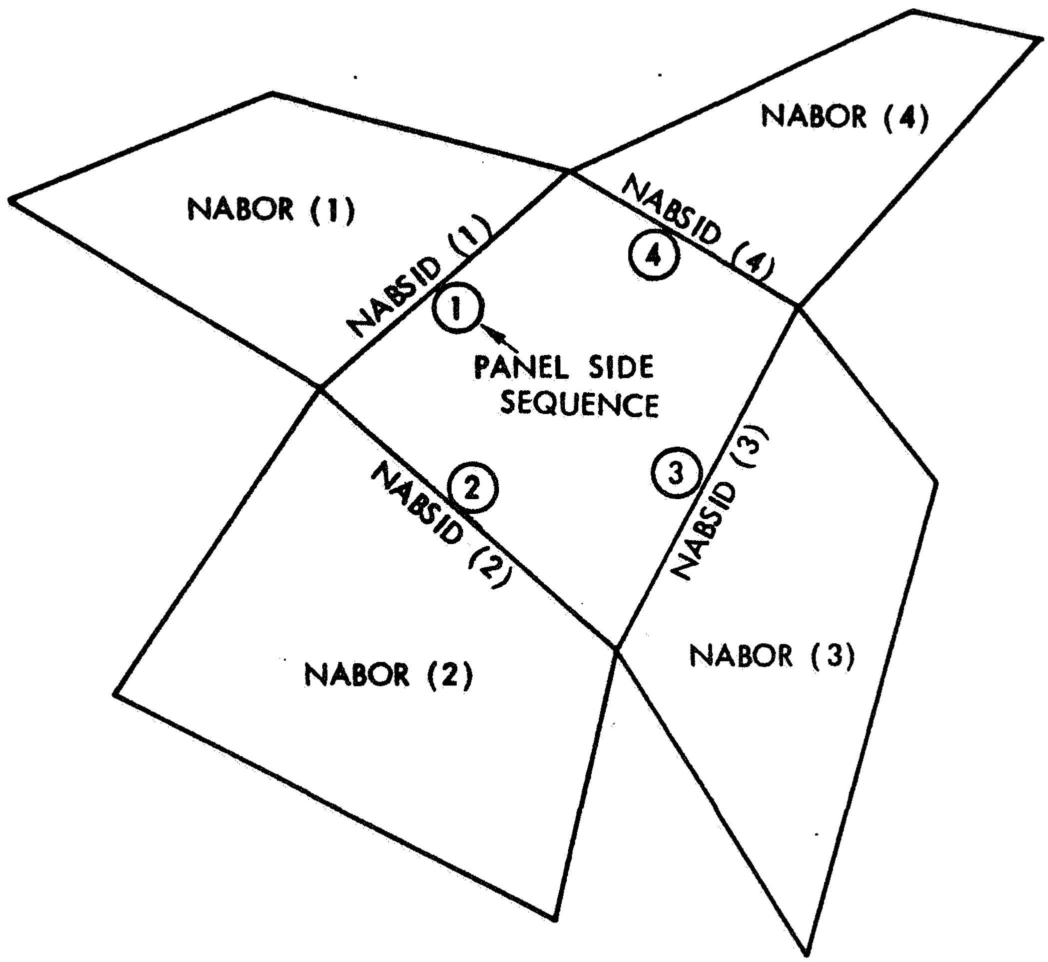


Figure 24. Panel Neighbor Information.

The panel neighbor information can be modified by using the options on CARD 8. The new information overrides the automatic neighbor information. This facility is used to correct errors made by the automatic procedure in awkward patch junctions or to obtain special effects. It should be noted that the panel neighbor information does not normally affect the doublet solution--it mainly affects the doublet gradients evaluated in the analysis procedure. An exception to this would occur if neighbor errors occurred along a wake-shedding line--this could then cause a doublet solution error because wake shedding panel information (see later in Figure 27) would be wrong.

4.7 Wake

4.7.1 Wake-Grid-Planes

The wake is formed after all the surface patches have been panelled and the panel neighbor information stored (before wake shedding). Within the code, the wake geometry is described in a set of cross-flow planes called WAKE-GRID-PLANES, whose x-stations are prescribed by the user, Figure 25. Spacing between wake-grid-planes should be small where intense vortex roll-up and vortex/surface interaction is anticipated. The intervals between wake-grid-planes can be progressively widened with distance downstream beyond the region of interest.

4.7.2 Wake Parameters

At the input stage the wake has the following parameters:

WNAME, IDENTW, IFLEXW, IDEFW

WNAME is a text identification for user convenience, while IDENTW is the wake type. Two 'wake types' are considered in the present document: IDENTW=1 is a regular wing-type wake with constant doublet distribution down each strip in the streamwise direction; and IDENTW=4 is a jet-type wake whose stripwise doublet distributions are linear in the streamwise direction. The doublet gradient is specified as the jump in tangential velocity across the type 4 wake sheet. the IFLEXW parameter is used to specify relaxable (0) or rigid (1) wakes. The IDEFW parameter determines the way the wake FIXED BASELINE is to be defined. IDEFW=0 requires strings of WAKE-SHEDDING PANELS--described below--while IDEFW=1 requires a set of separation points. The latter option is being checked out at this time.

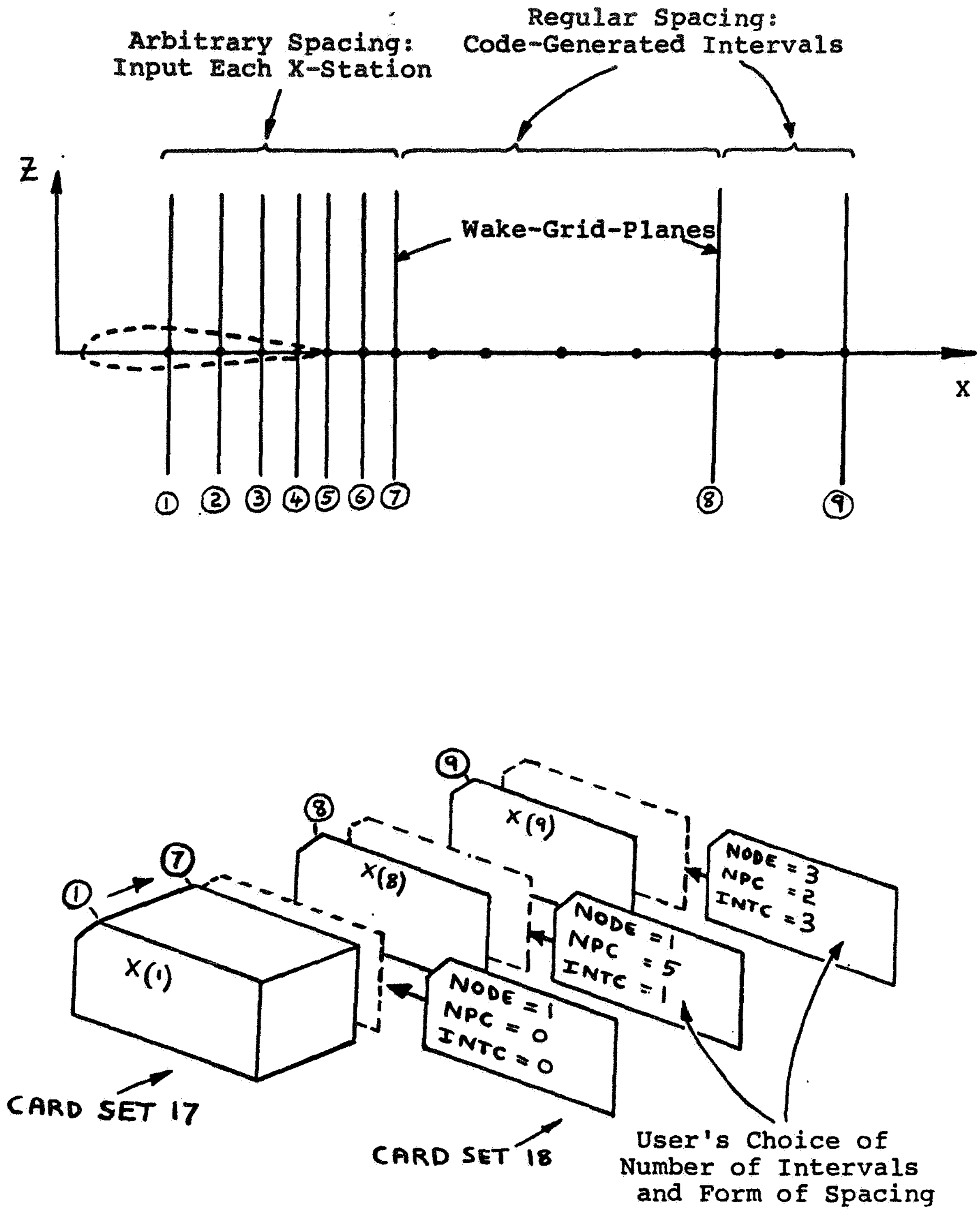


Figure 25. Card Set 17/18. Example of Wake-Grid-Plane Input Using Three Regions.

Inside the program wakes have additional parameters associated primarily with WAKE COLUMNS of WAKE PANELS. Figure 26 shows the arrangement of these in relation to the wake-grid-planes. The view is from <u>above</u>; i.e., wake panel normals are directed towards us. The first wake panel (at the top) on each wake column (NWC) has subscript IWPAN(NWC). The total number of columns on a wake is NWCOL and on the whole configuration, NWCOLT.

Each wake column is associated with a set of four surface panels, two upstream (or Upper) and two downstream (or Lower) of the separation line. These are KWPU, KWPUU, KWPL, KWPLL, Figure 27. The corresponding surface distances between control points and separation line are also stored SU, DSU, SL, DSL. The onset flow potential at these panels are also stored PHIU, PHIUU, PHIL, PHILL.

Each WAKE LINE (along an edge of a wake column) keeps the first wake-grid-plane, IWGP, intersected downstream of the separation point. The array, LSEQU, keeps the subscript sequence of wake lines intersecting the wake-grid-planes. A negative sign is placed on subscripts of wake lines at the edges of each wake.

4.7.3 Wake-Shedding Panels

To locate the initial wake, the user identifies strings of wake-shedding panels, the side geometry of which defines the fixed base line of each wake. The basic information required to define a string of wake-shedding panels is

KWPACH, KWSIDE, KWLINE, KWPAN1, KWPAN2

KWPACH is the patch number and KWSIDE is the side of that patch that is parallel to and has the <u>same direction</u> as the separation line on that patch, Figure 28. KWLINE determines which line of panels (row or column) is providing the separation line within the patch. KWLINE may be left blank (i.e., 0) if separation is from the patch edge, KWSIDE; otherwise it refers to the row number of column number (as defined in Figure 28) of the panels shedding the wake. The wake-shedding panels are regarded as being 'upstream' of the separation line; they are always on the <u>left</u> when looking in the direction of the separation line (Figure 28).

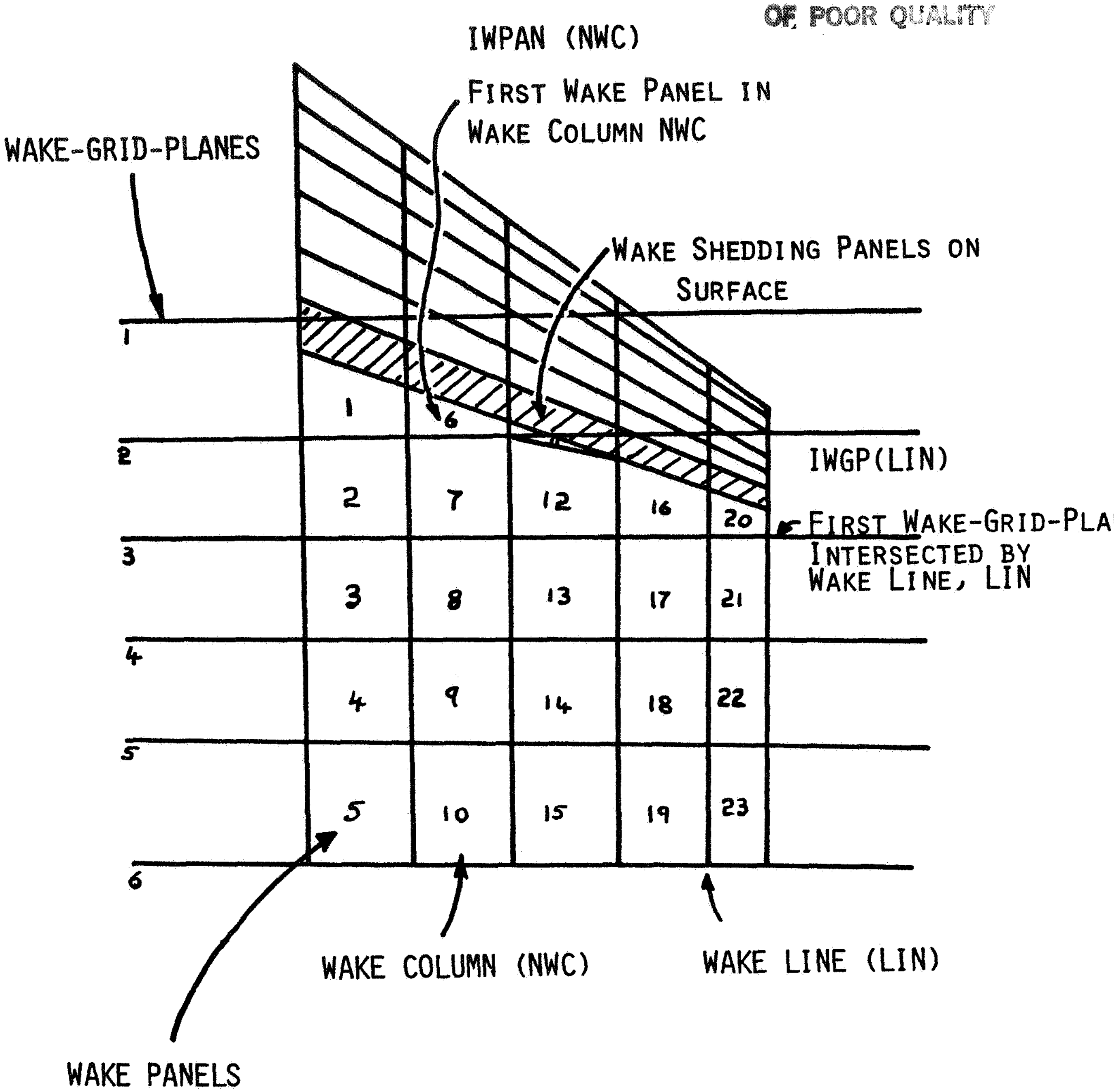


Figure 26. Wake Arrangement.

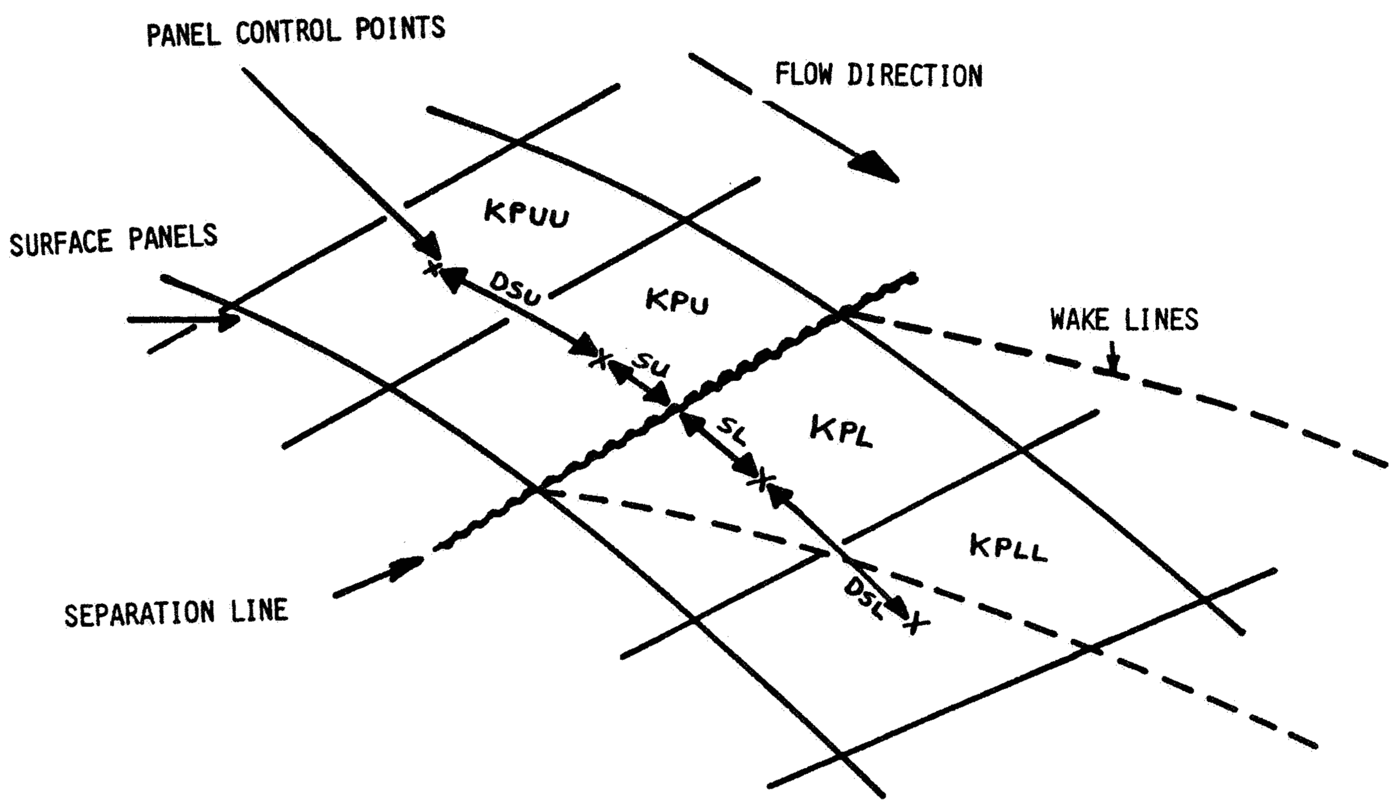
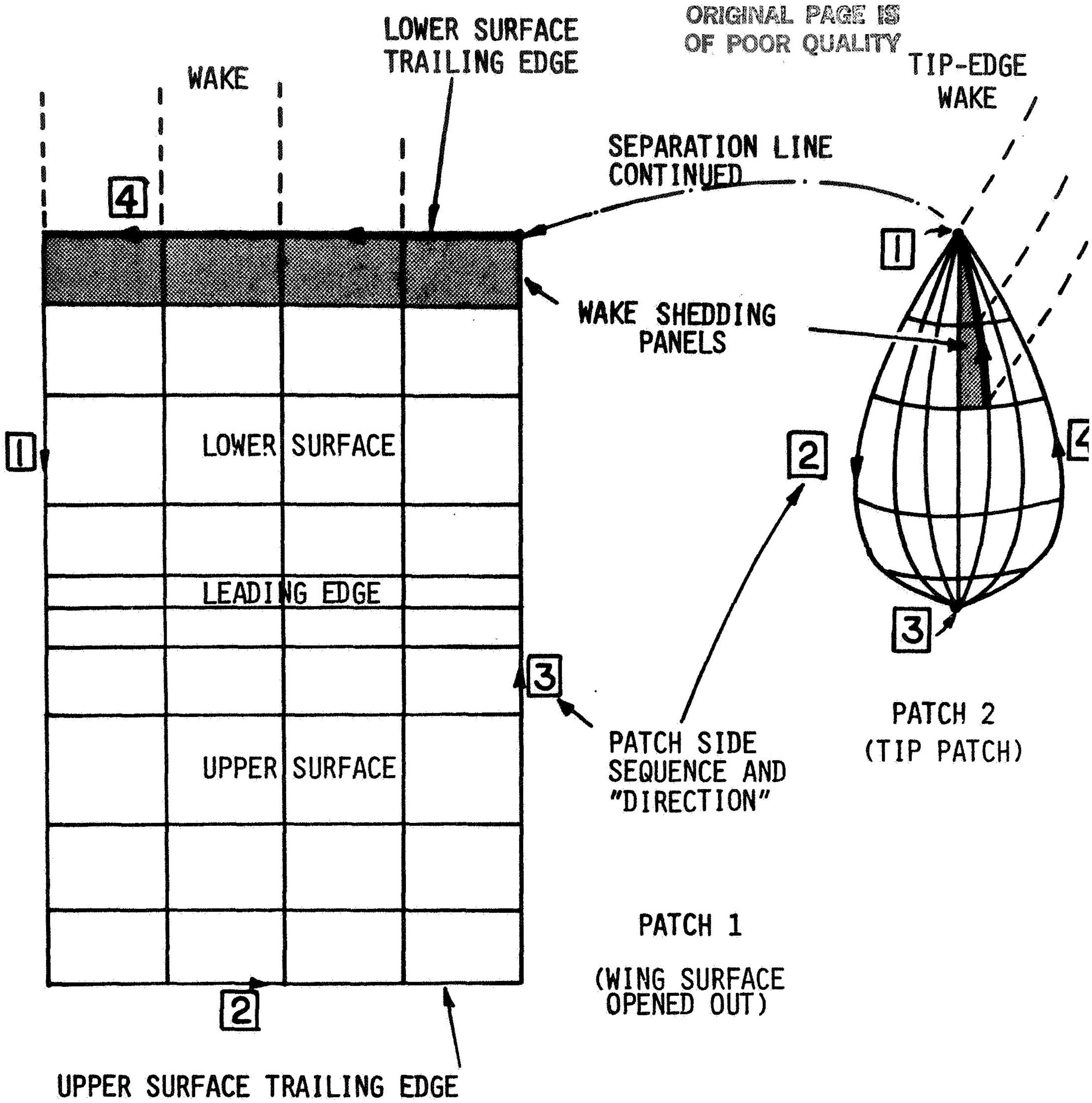


Figure 27. Wake-Shedding Parameters.

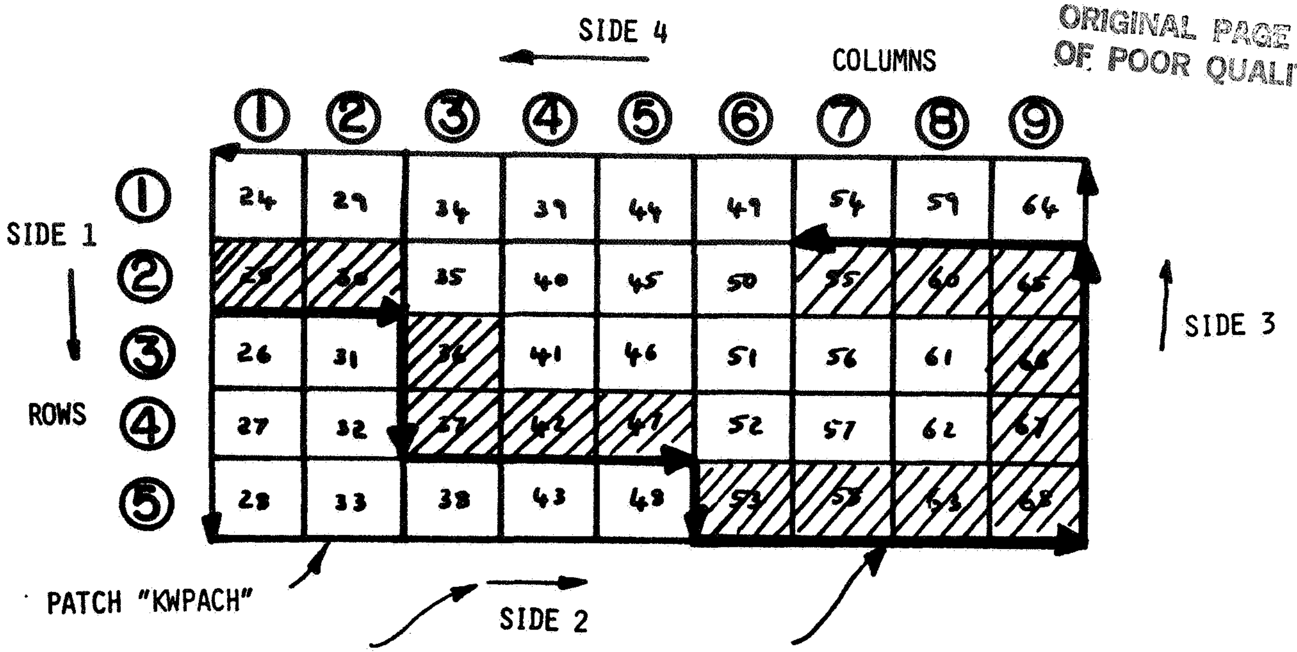


SEPARATION LINE COMPLETELY DEFINED BY:

	KWPACH	KWSIDE	KWLINE	KWPAN1	KWPAN2
(I)	2	4	3	4	5
(II)	1	4	0	1	4

Figure 28. Separation Line Definition.

(a) Wing.



The separation line shown above is described by 7 sets of wake-shedding panels (shaded) as follows:

Set No.	KWPACH	KWSIDE	KWLINE	KWPAN1	KWPAN2	(Remarks)
1	1	2	2 (row)	1	2	(Counting along row 2 in direction of side 2
2	1	1	3 (col)	3	4	(Counting down Col. 3 in direction of side 1)
3	1	2	4 (row)	3	5	
4	1	1	6 (col)	5	5	
5	1	2	5 (row)	6	9	
6	1	3	9 (col)	1	4	(Counting along side 3
7	1	4	2 (row)	1	3	

Local counting, not absolute panel subscripts

Figure 28. Concluded.
(b) General Case.

KWPAN1, KWPAN2 are the first and last panels, respectively, in the present string of wake shedding panels. These are local numbers starting with 1 at the patch edge and proceeding along the row or column in the direction of the line being defined: using local numbers along the line avoids the complicated task of identifying a string of absolute panel numbers which are not necessarily on a continuous sequence. For example, on patch 2 in Figure 28(a), the separation line is along row 3 (KWLINE) parallel to side 4 and so the local panel numbering sequence starts with 1 at side 3 and proceeds to 5 at side 1; in this local sequence, the separation panels, KWPAN1, KWPAN2 are therefore 4 and 5, respectively. (The corresponding absolute panel subscripts are worked out inside the code.) A more general separation line path is shown in Figure 28(b); this illustrates most of the possibilities of this scheme for describing the separation line location.

A separate string of wake-shedding panels must be defined for each patch crossed by the separation line.

4.7.4 Streamwise Wake Lines

At the beginning of each string of wake-shedding panels and at the end of the last string on each wake, the user must specify the geometry of a STREAMWISE WAKE LINE using STREAMWISE WAKE POINTS (SWPX, SWPY, SWPZ), Figure 29. The function of these points is similar to that of basic points defining patch sections (4.5.5.2). NODE cards are used here also and allow the user to augment his input points with interpolated points. As a minimum, one streamwise wake point must be provided at some station beyond the last wake-grid-plane. (The upstream end is taken automatically from the fixed baseline identified by the string of wake-shedding panels.)

The streamwise wake points are defined in a local coordinate system parallel to the global coordinate system but with origin at the local separation point on the fixed baseline. The program relocates the streamwise wake lines into the global coordinate system.

An option is provided to copy and rotate the previous streamwise wake line. The rotation (DTH) is about the x-axis of the local system and is in the same sense as the body of revolution option, Figure 21.

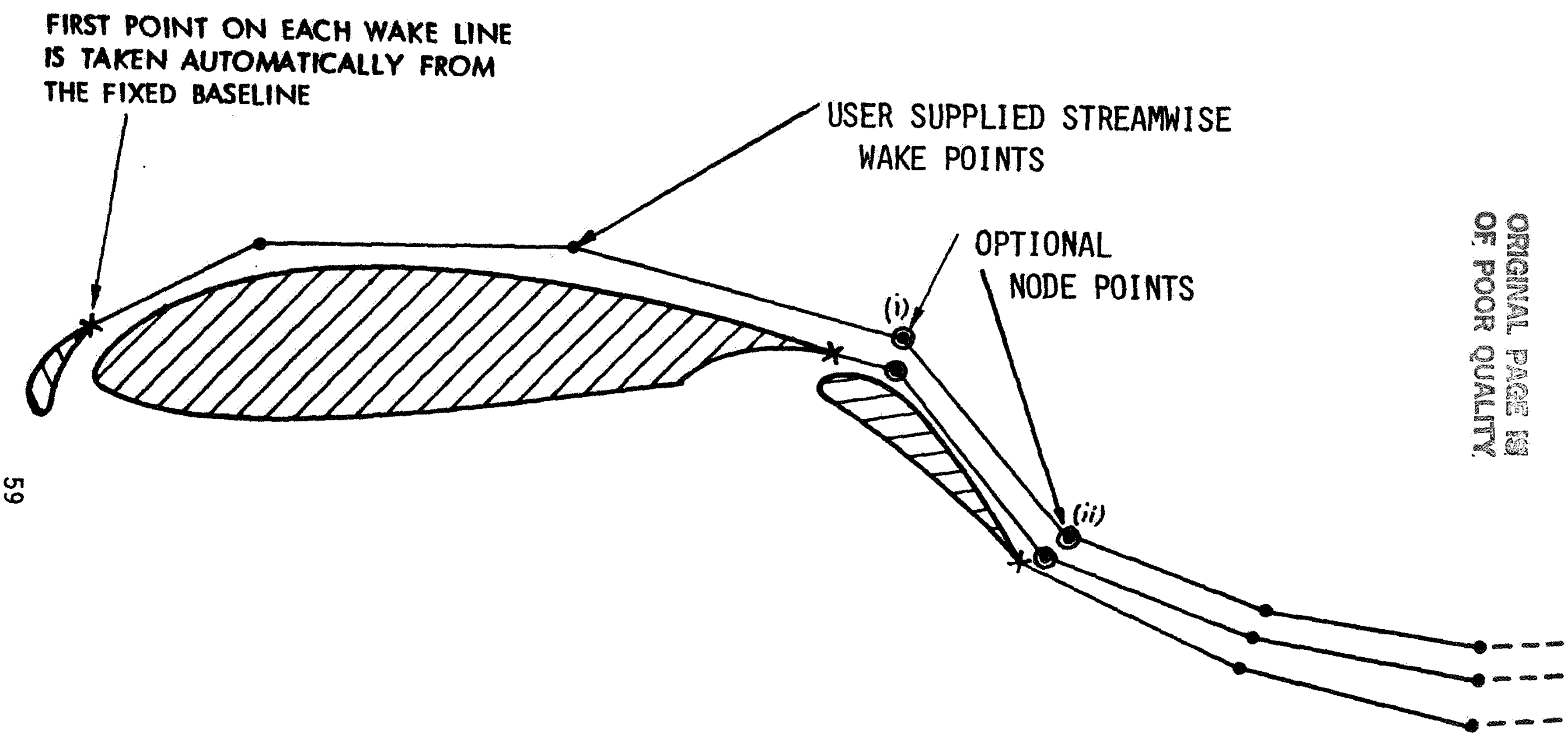


Figure 29. Streamwise Wake Points Define Initial Wake Geometry.

4.7.5 Wake Panel Points

When the basic wake information has been supplied, the program generates streamwise sets of coordinates describing the path of each of the defined wake lines according to the user's instructions on the node cards. Biquadratic interpolation is used to generate these points based on the user supplied coordinates. Linear interpolation is used in the spanwise direction to generate intermediate wake lines between the defined lines. Wake lines are formed corresponding to each of the wake-shedding panels. As each wake line is formed, its intersections with the WAKE GRID PLANES are computed and these intersection points become the wake panel corner points. LINEAR interpolation is used in the computation of these intersection points. The user should bear this in mind when selecting the number and location of both basic points and streamwise lines. It must be emphasized, however, that this information is used only to define the preliminary wake for the purpose of the first solution--thereafter, the wake relaxation routine will redefine the wake geometry at each iteration. In the unsteady mode, this basic wake is transported downstream as new panels are formed at the separation line.

The points generated in the wake-grid-planes are the actual wake panel corner points, Figure 26. These are treated in exactly the same was as surface panels (see Section 4.6).

5.0 OFF-BODY VELOCITY SCANS

5.1 Options

Off-body velocity calculations are performed at user selected points. Normally, the points are assembled along straight scan lines. These lines in turn may be assembled in planes and the planes in volumes. The shape of the scan volume is determined by the parameter MOLD. Two options are currently available:

MOLD=1 Allows a single point, points along a straight line, straight lines within a parallelogram or within a parallelepiped.

MOLD=2 Allows points along radial lines in a cylindrical volume.

A number of scan boxes can be specified, one after the other. A MOLD=0 value terminates the off-body velocity scan.

The location of scan lines within the scan boxes can be controlled in the input. The default option is equal spacing generated along the sides of the box. The location of points along a scan line can be controlled also in the input, but again, the default option is equal spacing.

If a scan line intersects the surface of the configuration, an intersection routine locates the points of entry and exit through the surface paneling. The nearest scan line points to each intersection are then moved to coincide with the surface. Points falling within the configuration volume are identified by the routine to avoid unnecessary velocity computations. These points are flagged in the printout. The input parameter MEET controls the calls to the intersection routine: MEET=0 (default) makes the routine active while MEET=1 switches it off. Clearly, if the velocity scan volume selected is known to be outside the configuration volume then switching the intersection routine off avoids a lot of wasted computation.

The velocity routine VEL computes the velocity vector at each point by summing the contributions from all surface panels, wake panels, image panels (if present), onset flow, etc. The routine includes near-field procedures for dealing with points that are close to the surface panels or wake panels. The near-field routine involves a lot of extra computation, if, therefore, it is known that a scan box is well clear of the configuration surface and wake then it is worthwhile turning off the near-field routine. This is controlled by the input parameter NEAR; NEAR=0 (default) keeps the near-field routine active while NEAR=1 switches it off.

Clearly, because of the MEET and NEAR options, it may be an advantage to divide large scan volumes into a number of smaller boxes, many of which could have the near-field and intersection routines switched off.

The velocity scan data (X, Y, Z, VX, VY, VZ, V, CP) for each point on a scan line is written away to a plot file (TAPE 7) together with other data. Since this provides a ready means of examining the off-body data quickly and since a large amount of printout can be generated by the off-body scan routine, then an option is provided to just print out a sample of the calculated data. The frequency of this print by plane, line or point is specified by the input parameters, INCPRI, INCPRJ, INCPRK, respectively. A zero (default) causes all the appropriate data to be printed while a value of N, say, causes the results to be printed every N^{th} plane, line or point as appropriate.

5.2 MOLD=1, Skewed Box

The MOLD=1 option allows a very general scan volume to be defined. Basically, three edge vectors are input and a parallelepiped is constructed, Figure 30(a). However, the position vectors defining the edge vectors are input one at a time giving the option to stop the input after each point, thus allowing a single point, a straight line or a plane to be considered in addition to the volume option.

Referring to Figure 30(a), the coordinates of the first corner point are input

XO, YO, ZO, NP

NP controls the various options as follows:

NP=1 This is a one-point box and therefore has no further input (but it can be followed by another scan box with any MOLD options)

NP>1 A line ($\vec{S1}$) is generated after inputting the second corner point:

X1, Y1, Z1, NP1

where NP1 is the number of points (equally spaced) along the side $\vec{S1}$

NP=2 This is a line scan only and so there is no further input for this box

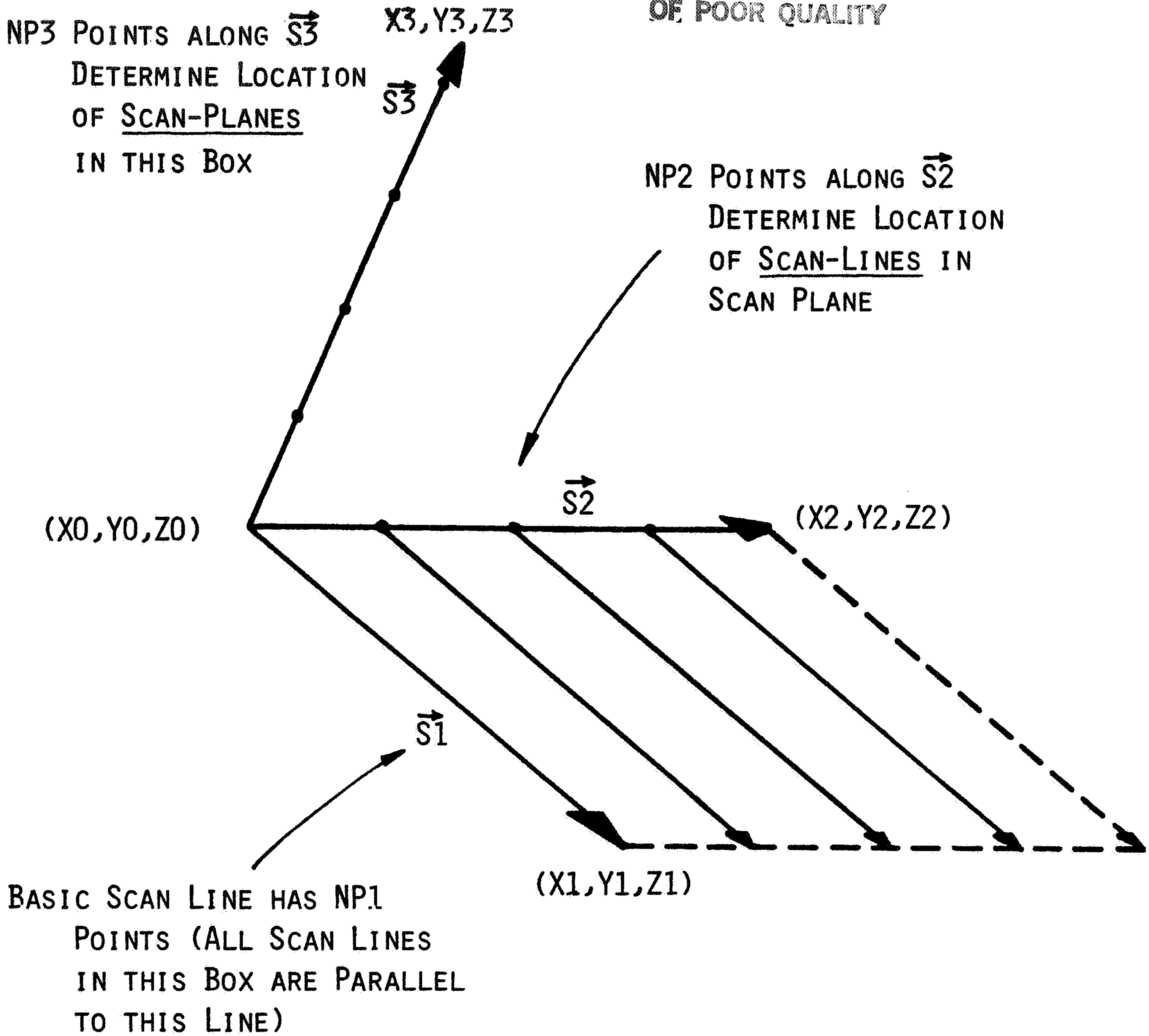


Figure 30. Velocity Scan Volumes.

(a) Skewed Box.

NP>2 The third corner point is input:

X2, Y2, Z2, NP2

This defines side $\vec{S}2$ with NP2 points along it.

NP=3 This is a scan plane only and so there is no further input for this box. The scan plane is the parallelogram generated from the two sides, $\vec{S}1$, $\vec{S}2$. Each scan line within the plane is parallel to side $\vec{S}1$, has the same point distribution as $\vec{S}1$ and is located by one of the points on $\vec{S}2$.

NP=4 The fourth and last corner point is input:

X3, Y3, Z3, NP3

This defines side $\vec{S}3$ with NP3 points along it. These points locate a set of parallelograms with sides parallel to $\vec{S}1$, $\vec{S}2$ and each one having a set of straight scan lines as described for NP=3.

The points along each scan line are, by default, equally spaced. However, negative signs can be placed on NP1, NP2 or NP3 and then the point locations along the corresponding sides(s) must be input; e.g., α_i, i=1, |NP1|, where $0 \leq \alpha_i \leq 1.0$, locates points along vector $\vec{S}1$.

5.3 MOLD=2, Cylindrical Volume

The cylindrical volume scan requires a minimum of three input cards. The first card defines the location of the center of a circle (X1, Y1, Z1); the inner and outer radius there (RI, RO); and the first and last θ values (θ_1, θ_2), measured from the vertical, Figure 30(b).

The second card defines a second circle plane with center at X2, Y2, Z2, respectively, and with inner and outer radii, RI_2, RO_2, respectively. The values of θ_1, θ_2 are assumed the same as on the first card.

The last card specifies the number of points (NAL) along the cylinder axis between X1,Y1,Z1 to X2, Y2, Z2; the number of θ values (NTHETA) between θ_1, θ_2; and the number of points (NRAD) along radial lines between local inner and outer radius. The points are located using equal spacing by default. However, as before, a negative sign placed on the number of points allows these points to be specified in an arbitrary distribution.

A point on a scan line in the cylindrical volume is located as follows (referring to Figure 30(b)).

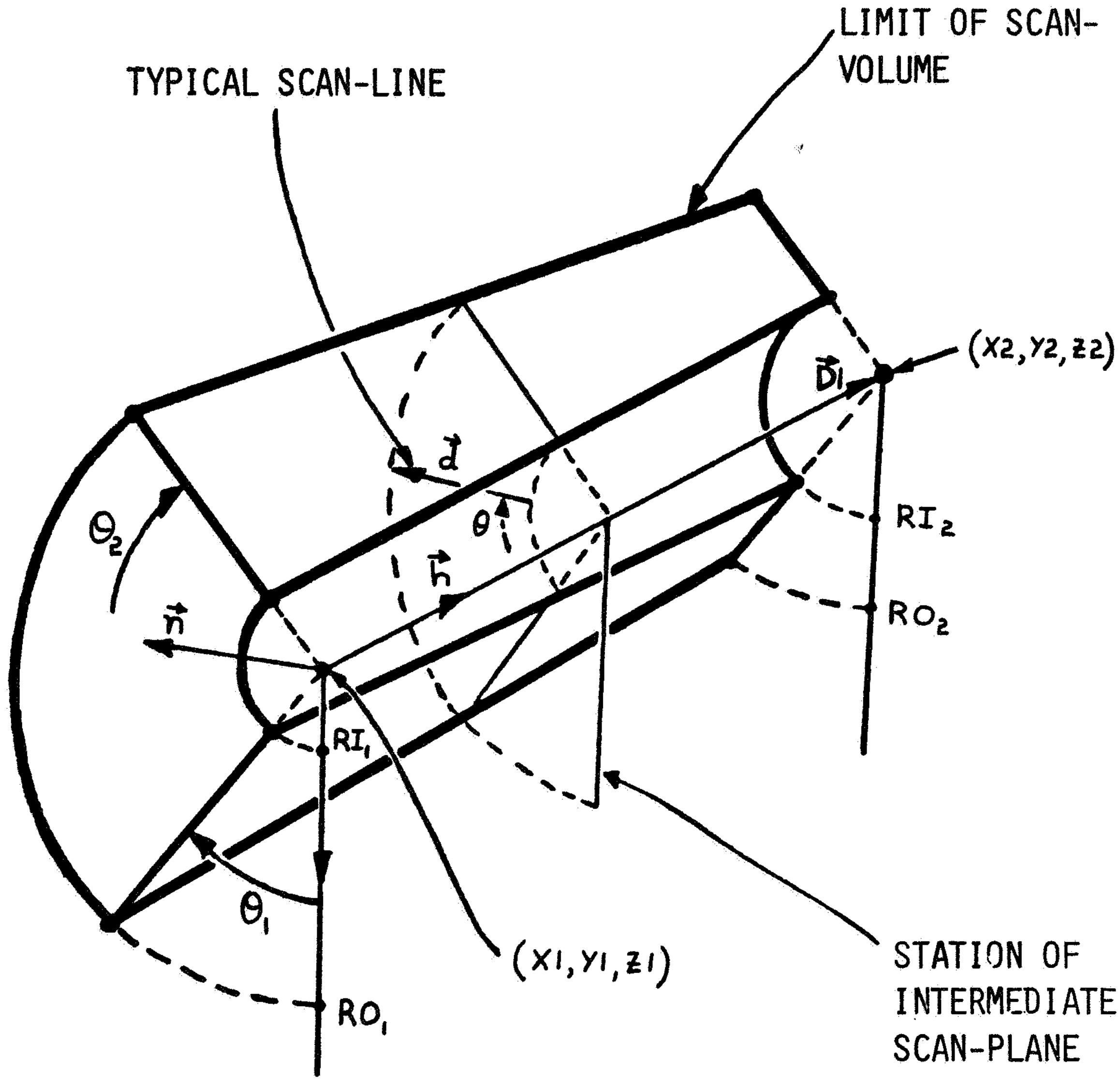


Figure 30. Concluded.

(b) Cylindrical Volume.

First define vector $\vec{D}1$ along the cylinder axis, i.e.,

$$\vec{D}1 = \vec{R}2 - \vec{R}1$$

From this the unit vector, $\vec{h}$, is formed, also the unit vector, $\vec{n}$, which is in the horizontal plane and which is normal to the vertical plane containing h, i.e.,

$$\vec{n} = \frac{\vec{k} \wedge \vec{h}}{|\vec{k} \wedge \vec{h}|}$$

Also, the unit vector, $\vec{g} = \vec{n} \wedge \vec{h}$, is generated forming a local unit orthogonal vector system, $\vec{n}$, $\vec{h}$, $\vec{g}$.

The unit radius vector, $\vec{u}$, at angle θ to the vector $\vec{g}$ is given by:

$$\vec{g} \wedge \vec{u} = \vec{h} \sin\theta$$

or

$$\vec{u} = \vec{g} \cos\theta + \vec{n} \sin\theta$$

Thus, the position vector of the Kth point on the Jth radius vector at the Ith location along the cylinder axis becomes

$$\vec{R} = \vec{P}1 + \alpha_R(K) * d\vec{u}(J) \qquad K=1,\ NRAD.$$

where

$$\vec{P}1 = \vec{R}1 + \alpha(I) * \vec{D}1 + RI(I) * \vec{u}(J) \qquad \begin{array}{l} J=1,\ NTHETA \\ I=1,\ NAL \end{array}$$

$\vec{u}(J)$ is evaluated with

$$\theta(J) = \theta_1 + \alpha_T(J) * (\theta_1 - \theta_2)$$

$$RI(I) = RI_1 + \alpha(I) * (RI_2 - RI_1)$$

and

$$d = RO_1 - RI_1 + \alpha(I) * (RO_2 - RI_2 - RO_1 + RI_1)$$

is the length of the present radial scan line.

6.0 RUNNING THE PROGRAM

6.1 Job Control Cards

A typical JCL file for running the VSAERO program on the CRAY computer at NASA Ames Research Center is listed below:

```
JOHNDOE, MICR.
USER, XXXXX,XXX.
JOB, JN=JOHNDOE, T=200, US=XXXX.
ACCOUNT, AC=XXXXX.
ACCESS, DN=$BLD, PDN=VSLGO, ID=XXXX.
ASSIGN, DN=DATA, A=FT05.
LDR.
REWIND, DN=FT06.
SAVE, DN=FT06, PDN=WINGDO, ID=XXXX.
```

The binary program is stored here as a direct access file called VSLGO. The input data file is called WING and the output file is saved as a direct access file, WINGDO.

6.2 Plotting Data

In order to plot the data interactively the plot file (TAPE 7) must be saved after the run. To do this requires the following additional cards in the JCL:

```
REWIND, DN=FT07.
SAVE, DN=FT07, PDN=WINDDP, ID=XXXXX.
```

This set of cards should be located after the LDR card in the basic JCL, see 6.1. The plot file is then saved as a direct access file called WINGDP, which can be plotted using the routine OMNIPLT.

The OMNIPLT routine steers the user through plots of panel and wake geometry, sections through the surface pressure and velocity distributions, on-body streamlines (if present) and boundary layer data (if present), see 8.2.

A typical day file follows.

ORIGINAL PAGE IS
OF POOR QUALITY

```
SP
SP     ------------------------------------------------------------------------------------------
SP                                         BULLETIN
SP
SP         **** ATTENTION ****
S
SP           CURRENT MACHINE SCHEDULE:
SP
SP                THE CYBER AND CRAY ARE AVAILABLE:
SP
SP                      06:00 TO 24 00 MONDAY, TUESDAY, WEDNESDAY, FRIDAY
SP                      07 00 TO 24 00 THURSDAY
SP
SP
SP     *****************
SP
SP                CRAY USERS MEETING
SP
SP                   JUNE 24, 1982 AT 09:30 AM
SP                        BLDG 233-A RM 172(TRAINING ROOM)
SP
SP     *****************
SP
SP     ------------------------------------------------------------------------------------------
SP
SP            CRAY-1  SERIAL 34 - ADVANCED COMPUTATIONAL FACILITY      06/17/82
SP
SP            CRAY-1  OPERATING SYSTEM        COS 1.10  ASSEMBLY DATE 06/09/82
SP
SP
SP     JOB, JN=BRIAN, T=200, US= XXXXX
       ACCOUNT.
SP     ACCESS, DN=$BLD, PDN=VSLGOMAY, ID=XXXXX
DM     PD001 - ACCESS   VSLGOMAY          ED=0001 COMPLETE
SP     LDR.
SER    LD010 - BEGIN EXECUTION
SER    FT063 -    STOP                  IN MVP
SP     REWIND, DN=FT07.
SP     SAVE, DN=FT07, PDN=WNGPLT, ID= XXXXX
DM     PD001 - SAVE     WNGPLT            ED=0009 COMPLETE
SP     END OF JOB
SP
SP
SP
SP            JOBNAME BRIAN        USER NUMBER XXXXX
SP            TIME EXECUTING IN CPU - 00:02:38.2016
SP            TIME WAITING TO EXECUTE 00:00.45.5733
SP            TIME WAITING FOR I/O -- 00.01:01.3441
SP            MEMORY USAGE ---    57.75944 MWDS-SEC
SP            DISK BLOCKS MOVED -----    32383
SP            PHYSICAL I/O REQUESTS -     7366
SP            TOTAL COST INCURRED -- $      82.29
```

7.0 INPUT DESCRIPTION

7.1 Input Summary

The input is divided into the following parts:

(i) BASIC INPUT
General information, operating mode, onset flow, reference conditions, special options

(ii) PATCH GEOMETRY
Description of configuration surface in components, patches, sections, basic points, etc., for panel generation

(iii) WAKE INPUT
Wake-grid-planes, type of wake, wake separation line, initial streamwise geometry

(iv) SURFACE STREAMLINE INPUT
Location of starting point for each surface streamline

(v) BOUNDARY LAYER INPUT
Reynold's number, etc.

(iv) OFF-BODY STREAMLINE INPUT
Location of starting point and required upstream/downstream distances for each off-body streamline

In the following description, the input variables are first listed in 7.2 for each of the above parts. Then, 7.3 gives a detailed description of the function of each input variable. This is followed in 7.4 by an input flow chart to help with the assembly of the input data file.

7.2 Input Variable List

Basic Input Summary

Card No.	Variables	Format
1	Text	20A4
2	IPRI, IPRLEV, IPRESS, MSTOP, MSTART, MODIFY	6I5
2A	IPRGOM, IPRNAB, IPRWAK, IPRCPV, IPRPPI (only if IPRLEV=5 on CARD 2)	5I5
3	MODE, NPNMAX, NRBMAX, ITGSMX, IMERGE, NSUB, NSPMAX, NPCMAX	8I5
3A	NROWB(I), I=1, |NRBMAX| (only if NRBMAX<0 on CARD 3)	16I5
4(a)	NWIT, NVPI, IBLTYP (if MODE=1 on CARD 3)	3I5
or		
4(b)	NT, NHC (if MODE=2 on CARD 3)	2I5
4A	(only if NVPI>0 and IBLTYP=0 on CARD 4(a)	
(i)	NPSETS	I5
(ii)	NPCHBL, NBCOL, (KOL(I), I=1, NBCOL) (Number of 4A(ii) cards = NPSETS)	16I5
	If MSTART>0 and MODIFY=0; this is the end of the basic data on a restart run.	
5	RSYM, RGPR, RNF, RFF, RCORE, SOLRES, TOL	7F10.0
6	ALDEG, YAWDEG, RMACH, VMOD, COMFAC	5F10.0
6A	ALBAR, RFREQU, HX, HY, HZ (only if MODE=2 on CARD 3)	5F10.0
7	CBAR, SREF, SSPAN, RMPX, RMPY, RMPZ	6F10.0
8	NORSET, NVORT, NPASUM, JETPAN, NBCHGE	5I5
8A	(NORPCH(I), NORF(I), NORL(I), NOCF(I), NOCL(I), VNORM(I), ADUB(I), I=1, NORSET) (only if NORSET>0 on CARD 8)	5I5, 2F10.0
8B(i)	VORT (only if NVORT>0 on CARD 8)	F10.0
(ii)	(RXV(I), RYV(I), RZV(I), I=1, NVORT+1) (only if NVORT>0 on CARD 8)	3F10.0

Card No.	Variables	Format
8C	(NPSPCH(I), NPSRF(I), NPSRL(I), NPSCF(I), NPSCL(I), I=1, NPASUM) (only if NPASUM>0 on CARD 8)	5I5
8D	(JETPCH(I), JETRF(I), JETRL(I), JETCF(I), JETCL(I), VIN(I), VOUT(I), I=1, JETPAN) (only if JETPAN>0 ON CARD 8)	5I5 2F10.0
8E	(KPAN(I), KSIDE(I), NEWNAB(I), NEWSID(I), I=1, NBCHGE) (only if NBCHGE>0 on CARD 8)	4I5

Patch Geometry Input Summary

Card No.	Variable	Format
9	CTX, CTY, CTZ, SCAL, THET (component card)	5F10.0
9A	CPX, CPY, CPZ, CHX, CHY, CHZ (only if SCAL<0 on CARD 9)	6F10.0
10	IDENT, MAKE, KOMP, KLASS, PNAME (patch card) (Note: If MAKE<0, go directly to CARD 16)	4I5, 6A4
11	STX, STY, STZ, SCALE, ALF, THETA, INMODE, NODES, NPS, INTS (section card)	
12(a)	BY, BZ, X (INMODE=1)	
(b)	BX, BZ, Y (INMODE=2)	3F10.0
(c)	BX, BY Z (INMODE=3)	
(d)	BX, BY, BZ (INMODE=4)	
(e)	TC, INPUT (INMODE=5 or 7)	F10.0, I5
(f)	H, INPUT (INMODE=6 or 8)	
(g)	BX, RAD, THET (INMODE=12)	3F10.0
13	XRB, NINT (after options 12(e) and 12(f)	F10.0, I5
14	KODEC, NPC, INTC, MOVE (use with CARD 12 and and 13)	30X, 4I5
14A	NPCH, NSEC, IB, LB (if NODEC<0 on CARD 14)	4I5

Card No.	Variable	Format
14B	XPIV, YPIV, ZPIV, HX, HY, HZ, ROT (if MOVE=1 on CARD 14)	7F10.0
15	THETA2, THETA1 (only if NODES<0 on CARD 11)	2F10.0
16	NPC, INTC, KURV, NPTIP, NODES, NPS, NTS (special tip patch) (only if MAKE≠0 on CARD 10)	35X, 3I5, 10X, 3I5
16A	(S(I), Y(I), Z(I), I=1, NPTIP (only if KURV>1 on CARD 16)	3F10.0

Wake Input Summary

Card No.	Variables	Format
17	X (wake grid plane stations)	F10.0
18	NODE, NPC, INTC, MARK	30X, 4I5
19	IDENTW, IFLEXW, IDEFW, WNAME (wake card)	3I5,5X 6A4
20	KWPACH, KWSIDE, KWLINE, KWPAN1, KWPAN2, INPUT, NODEWS, IDWC, IFLXL, DTHET	9I5, F10.0
21(a)	SWPY, SWPZ, ΔX (if INPUT=1 on CARD 20)	3F10.0
21(b)	SWPX, SWPZ, ΔY (if INPUT=2 ON CARD 20)	
21(c)	SWPX, SWPY, ΔZ (if INPUT=3 on CARD 20)	
21(d)	SWPX, SWPY, SWPZ (if INPUT=4 on CARD 20)	
22	NODEWC, NPC, INTC	30X, 3I5
23	VIN, VOUT ... (if IDENTW=4 on CARD 19)	8F10.0

Surface Streamline Input Summary

Card No.	Variables	Format
24	F, KP, NS (compulsory input if IBLTYP=1) (Place one card no. 24 for each streamline)	F10.4, 2I5
25	F, KP, NS (end of surface streamline data)	2F10.4, 2I5

Boundary Layer Input Summary

Card No.	Variables	Format
26	RNE, TRIPUP, TRIPOP, XPRINT, XSKIP (CARD 26 only present if NVPI>0 on CARD 4(a))	5F10.0

Off-Body Velocity Scan Input Summary

Card No.	Variables	Format
27	MOLD, MEET, NEAR, INCPRI, INCPRJ, INCPRK (Start of each scan box. Finish the set with a blank card)	6I5
28	XO, YO, ZO, NP (if MOLD=1 on CARD 27)	3F10.0, I5
29	X1, Y1, Z1, NP1 (if NP>1 on CARD 28)	
29A	(AL1(I), I=1, |NP1|)(only if NP1<0 on CARD 29)	8F10.0
30	X2, Y2, Z2, NP2 (if NP>2 on CARD 28)	3F10.0, I5
30A	(AL2(I), I=1, |NP2|)(only if NP2<0 on CARD 30)	8F10.0,
31	X3, Y3, Z3, NP3 (if NP=4 on CARD 28)	3F10.0, I5
31A	(AL3(I), I-1, |NP3|)(only if NP3<0 on CARD 31)	8F10.0

Card No.	Variables	Format
32	X1, Y1, Z1, RO1, RI1, THETA1, THETA2 (if MOLD=2 on CARD 27)	7F10.0
33	X2, Y2, Z2, RO2, RI2 (if MOLD=2 on CARD 27)	5F10.0
34	NAL, NTHETA, NRAD (if MOLD=2 on CARD 27)	3I5
34A	(AL1(I), I=1, |NAL|)(if NAL<0 on CARD 34)	8F10.0
34B	(ALTHET(I), I=1, |NTHETA|)(if NTHETA<0 on CARD 34)	8F10.0
34C	(ALRAD(I), I=1, |NRAD|)(if NRAD<0 on CARD 34)	8F10.0

Off-Body Streamline Input Summary

Card No.	Variables	Format
35	RSX, RSY, RSZ, SU, SD, DELS, NEAR (one card per streamline; finish with a blank card)	6F10.0, I5

7.3 Description of Input Variables

Throughout the description below, the following notes apply.

(i) All integers are right adjusted.

(ii) Limits on the value of a variable and default values are quoted for two versions of the VSAERO program: VSAERO-1000/VSAERO-3000 where these differ.

7.3.1 Basic Input

CARD 1: Case Description

Columns	Variable	Description	Format
1-80	TEXT	Alphanumeric text identifying the case	20A4

CARD 2: Control Card

Columns	Variable	Value	Description	Format
1-5	IPRI		Input data print control	6I5
		0	Prints all input data except the PATCH GEOMETRY	
		1	Prints all input data except the detail coordinates of the PATCH GEOMETRY input. (This option is useful for cases with large input decks: it still displays the information on NODE CARDS, SECTION CARDS, etc.)	
		2	Prints all input data. (Warning: a complicated case may give a large amount of printout from the PATCH GEOMETRY. For such cases remember to request a reasonable output line limit; e.g., LGO (PL=7777), or use IPRI=0 or 1 as an alternative)	

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CARD 2: Continued

Columns	Variable	Value	Description	Format1
6-10	IPRLEV		Output print control	
		0	Basic print level (see 8.0) All other options below are additional prints	
		1	Panel corner points are printed (IPRCOM=1); also, the wake print is activated at the level IPRWAK=1 (see CARD 2A	
		2	The doublet solution, $\mu/(4\pi V_\infty REFL)$, is printed (IPRSOL=1). Also, the neighbor information is printed at the level IPRNAB=1 (see CARD 2A)	
		3	The P/P_∞ values are added to the basic printout of panel velocities and pressures (IPRPPI=1, see under CARD 2A)	
		4	Corner point analysis results are printed at the level IPRCPV=1 (see CARD 2A)	
		5	Gives the option to read in the print control variables IPRGOM, IPRNAB, IPRWAK, IPRCPV, IPRPPI. Requires CARD 2A to follow CARD 2	
11-15	IPRESS		Controls frequency of printout in the wake iteration or time-stepping loop	
		0	Prints only at the last step	
		1	Prints at every step (avoid this if using a large number of time steps or wake relaxations)	
		N	Prints at every Nth step (including the first or last steps) according to the IPRLEV option	

CARD 2: Continued

Columns	Variable	Value	Description	Format
16-20	MSTOP	0	Complete run through the code	
		1	Calculations stop after GEOMIN subroutine. This sets IPRGOM=1. (The input file only requires basic data and patch geometry for cases with MSTOP=1 or 2)	
		2	Calculations stop after the SURPAN subroutine. This sets IPRGOM=2. The panel geometry file is formed (TAPE 7) and can be saved for plotting purposes	
		3	Calculations stop after the WAKPAN subroutine. This sets IPRMAB=1 and IPRWAK=2. The matrix of influence coefficients is <u>not</u> formed if MSTOP=3. The geometry file (TAPE 7) now includes the initial wake geometry. (The input file must now include the WAKE INPUT)	
		4	This is a complete run through the code but a RESTART file is formed after subroutine ANALIZ	

Note: The print control values set on IPRGOM, IPRMAB and IPRWAK according to the MSTOP values above, can be overwritten using the IPRLEV options on this card (e.g., see CARD 2A).

Columns	Variable	Value	Description	Format
21-25	MSTART		Restart control (see 6.3)	
		0	Regular first run of a case	
		3	Program restart for further solutions and wake shape iterations and/or boundary layer calculations (IBLTYP=0)	

CARD 2: Continued

Columns	Variable	Value	Description	Format
21-25	MSTART	4	Program restart for more surface streamlines and boundary layer calculations (IBLTYP=1) Future option	
		5	Program restart mainly for off-body velocity scans and off-body streamlines using the earlier solution	
26-30	MODIFY		Controls details of a restart run (i.e., MSTART>0)	
		0	No change in the basic conditions except on CARDS 1 through 4	
		>0	All the BASIC INPUT must be repeated as for the original run but with the required changes for the restart case	
		2	The WAKE INPUT must be included with the required changes	

CARD 2A: Additional Print Control (Only if IPRLEV=5 on CARD 2)

Columns	Variable	Value	Description	Format
1-5	IPRGOM		Controls printout of panel geometry (see 8.0)	4I5
		0	Print off	
		1	Panel corner points printed for all panels	
		200+N	Panel corner points printed for panels on patch N only	
		2	Panel control points and unit normal vectors printed for all panels	
		400+N	As for IPRGOM=2 but for panels on patch N only	

Card 2A Continued

Columns	Variable	Value	Description	Format
1-5	IPRGOM	-1	Prints basic points (input and generated) for defined sections on all patches.	
		-(200+N)	As for IPRGOM=-1 but for patch N only	

Note: Negative IPRGOM values are intended for use in runs with MSTOP=1 (see under CARD 2) for the purpose of identifying strings of basic points for copying into later defined sections.

Columns	Variable	Value	Description	Format
6-10	IPRNAB		Controls printout of panel neighbor information (see 8.0)	
		0	Off	
		1	Information is printed for panels on patch edges, panels at wake-shedding lines and panels which have failed to find one or more of their neighbors	
		2	Prints neighbor information for all panels	
11-15	IPRWAK		Controls printout of wake data (see 8.0)	
		0	Off	
		1	Prints wake-shedding information for each wake column	
		2	As for IPRWAK=1 plus details of wake line geometry	
		3	As for IPRWAK=2 plus wake panel doublet values	
16-20	IPRCPV		Controls printout of panel corner point analysis	
		0	Off	

CARD 2A: Continued

Columns	Variable	Value	Description	Format
16-20	IPRCPV	1	Prints x, y, z, vx, vy, vz V and CP for each panel corner point	
		2	As for 1 plus panel corner point doublet and source values	
21-25	IPRPPI		Controls printout of P/P_∞ values with the velocity and pressure data at panel centers	
		0	Off	
		1	On	

CARD 3: MODE CARD

Columns	Variable	Value	Description	Format
1-5	MODE	1	Steady calculation. Uses option (a) on CARD 4	8I5
		2	Unsteady calculation. Uses option (b) on CARD 4 and requires CARD 6A	
6-10	NPNMAX		Upper limit on number of panels the user expects to be generated (default 1000/3000)	
11-15	NRBMAX		Limit on the block size in the blocked Gauss-Seidel solution iteration. (Default value--also the upper limit--is 140/290)	
		-N	A negative number allows the user to specify the block sizes in N blocks. Requires CARD 3A to follow	
16-20	ITGSMX		Limit on the number of Gauss-Seidel iterations for a solution (default = 20)	

CARD 3: Continued

Columns	Variable	Value	Description	Format
21-25	IMERGE	0	Vortex line merging future option	
26-30	NSUB		Number of subpanel intervals used on a near-field wake panel whose IDENTW>1 during the evaluation of wake influences in PHIMAT subroutine. These subpanels are used only in the streamwise direction here. (Default = 10)	
31-35	NSPMAX		Limit on the number of subpanels per panel used on near-field panels on a wake in the velocity (VEL) routine. (Default = 25)	
36-40	NPCMAX		Limit on the number of Predictor-Corrector cycles in the steady (MODE=1) wake relaxation in subroutine WAKREL. (Default = 2)	

Note: NRBMAX and ITGSMX are only active if the number of panels exceeds 320-635. For a smaller number of panels, a direct solver is used.

CARD 3A: User-Specified Block Sizes in Blocked Gauss-Seidel Routine (DUBSOL)(Only if NRBMAX negative on CARD 3)

Columns	Variable	Value	Description	Format
1-80	NROWB(I), I=1,N		Where N=|NRBMAX| on CARD 3. Number of rows in each block of the matrix	16I5

CARD 4: Number of Steps. Use one of two options depending on the value of MODE on CARD 3.

OPTION (a): (MODE=1)

Columns	Variable	Value	Description	Format
1-5	NWIT	0	One pass through potential flow calculation; i.e., rigid wake	
		N	Number of wake shape iterations per viscous/potential flow iteration	3I5
6-10	NVPI	0	Potential flow solution only	
		>0	Number of viscous/potential flow iterations. CARD 26 must be included in the input deck	
11-15	IBLTYP		Type of boundary layer procedure if NVPI>0	
		0	Stripwise infinite swept wing. Requires CARD SET 4A to input the required strips for this analysis	
		1	Two-dimensional procedure along calculated streamlines. SURFACE STREAMLINE INPUT (CARD SET 24) must be used for this analysis	

OPTION (b): (MODE=2)

Columns	Variable	Value	Description	Format
1-5	NT		Number of time steps	2I5
6-10	NHC	≥3	Number of half cycles	

CARD SET 4A. Specifies patch columns for stripwise boundary layer calculations. Only if NVPI>0 and IBLTYP=0 on CARD 4(a), (MODE=1).

CARD 4A(i): Number of Sets of Columns

Columns	Variable	Value	Description	Format
1-5	NPSETS	1≤NPSETS≤5	Number of sets of patch columns	I5

CARD 4A(ii)

Columns	Variable	Value	Description	Format
1-5	NPCHBL		Patch number (note: the patch should have IDENT=1 on CARD 10)	16I5
6-10	NBCOL	1≤NBCOL≤14	Number of columns on this patch on which the stripwise boundary layer calculation is required. At least two columns should be specified (preferably the first and last). If NBCOL=1, then all the columns on this patch will be analysed	
11-80	(KOL(I),I=1, NBCOL)		Column numbers (numbered relative to the start of this patch) only if NBCOL>1	

Note: Use one card 4A(ii) for each set. If more than 14 columns are required to be analysed on one patch, then an additional set can be used with the same patch number.

If MSTART>0 and MODIFY=0, then proceed to end of BASIC INPUT.

CARD 5: Symmetry Card

Columns	Variable	Value	Description	Format
1-10	RSYM	0.0	Symmetrical case (aerodynamic and geometric symmetry about the y=0 plane)	7F10.0
		1.0	Asymmetrical case	
11-20	RGPR	0.0	Free-air case (no ground plane)	
		1.0	Ground plane present on the z=0 plane	
21-30	RNF		Radius of near-field factor; default = 2.5. (Based on the panel mean width)	
31-40	RFF		Radius of far-field factor; default = 5.0. (Based on the panel mean width)	
41-50	RCORE		Core radius on vortex filaments (based on CBAR/2.0); default = .05	
51-60	SCLRES		Gauss-Seidel Residual Limit as a percentage of the maximum doublet size in the solution; default = .2	
61-70	TOL		Tolerance limit for the test of proximity of a point to a panel edge. (Factor on the panel side length); default = .2	

CARD 6. Onset Conditions

Columns	Variable	Value	Description	Format
1-10	ALDEG		Incidence of x-axis in degrees	4F10.0
11-20	YAWDEG		Yaw of x-axis in degrees	
21-30	RMACH		Mach number	
31-40	VMOD		Onset flow velocity magnitude (default = 1.0 if VMOD<10^{-8}	
41-50	COMFAC		Compressibility algorithm factor (default = 0.0). Second-order correction being checked out	

CARD 6A: (Only Present if MODE=2)

Columns	Variable	Value	Description	Format
1-10	ALBAR		Amplitude of motion (degrees)	5F10.0
11-20	RFREQ		Reduced frequency, $\pi f CBAR/V_\infty$	
21-30	HX HY HZ		Pivot axis unit vector through reference moment point (default 0.0, 1.0, 0.0)	

CARD 7: Reference Condition

Columns	Variable	Value	Description	Format
1-10	CBAR		Reference chord used for normalizing pitching moment. (Note: reference length (REFL) used inside the code for the unsteady mode (MODE=2) and also for normalizing the geometry is CBAR/2.0)	6F10.0

CARD 7: Continued

Columns	Variable	Value	Description	Format
11-20	SREF		Reference area	
21-30	SSPAN		Semispan used for normalizing rolling and yawing moments	
31-40 41-50 51-60	RMPX RMPY RMPZ		Coordinates of the reference moment point. If MODE=2, this is a point on the pivot axis	

CARD 8: Special Options

Columns	Variable	Value	Description	Format
1-5	NORSET		Allows non-zero normal velocities to be set. Requires CARD SET 8A if NORSET>0. NORSET = number of sets of panels (limit = 200/300)	5I5
6-10	NVORT		Allows a free vortex to be specified. NVORT = number of segments on vortex. Requires CARD SET 8B if NVORT>0 (limit = 20). This option is not complete at this time	
11-15	NPASUM		Allows sets of panels to be identified for a separate accumulation of force and moment data. Requires CARD SET 8C if NPASUM>0. NPASUM = number of panels sets (limit = 200/300)	
16-20	JETPAN		Allows panels to be identified inside jet regions of high or low energy to make correction for total head difference in the analysis stage. Requires CARD SET 8D if JETPAN>0. JETPAN = number of panel sets limit = 200/300)	

CARD 8: Continued

Columns	Variable	Value	Description	Format
21-25	NDCHGE		Allows the automatic panel neighbor information to be overwritten. Requires CARD SET 8E. (Note: an initial run with NSTOP=3 and with IPRLEV=2 on CARD 2 gives a quick look at the automatic panel neighbor information. The present option allows that data to be changed on a panel by panel basis)	

Note: The action of NORSET and JETPAN also affects the panel neighbor relationships so that doublet gradients are not attempted across boundaries of different regions.

CARD SET 8A: Only present if NORSET>0 on CARD 8.

Columns	Variable	Value	Description	Format
1-5	NORPCH		Number of patch containing the required panel set	5I5 2F10.0
6-10 11-15	NORF NORL		First and last rows of panels, inclusive, covering the required set of panels, see Figure 31 (default gives full set of rows on this patch)	
16-20 21-25	NOCF NOCL		First and last column of panels, inclusive. (Default gives full set of columns on this patch)	
26-35	VNORM		Specified normal velocity for the set of panels identified above. Positive outwards from the surface	

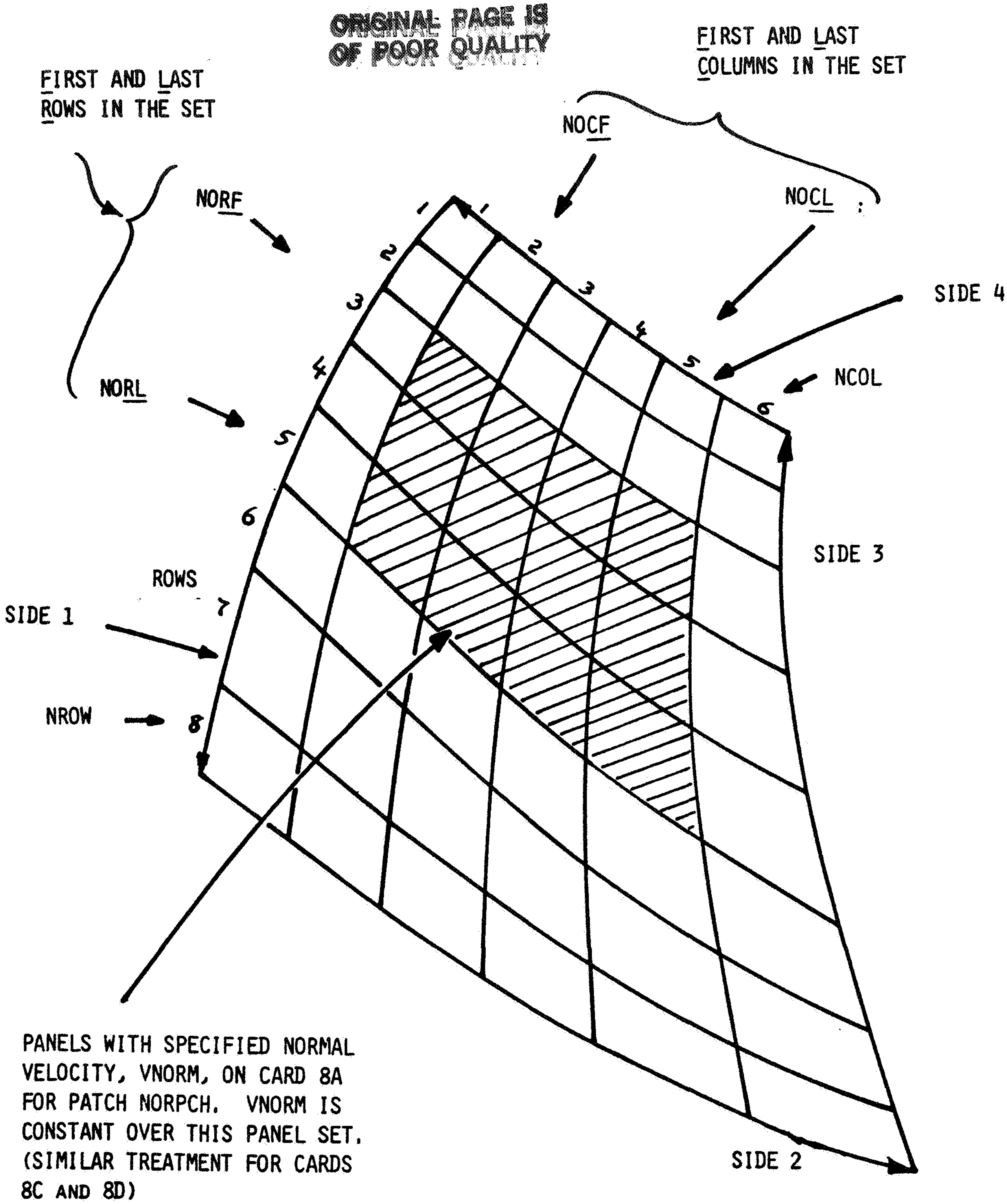

Figure 31. Identifying a Set of Panels on a Patch.

CARD 8A: Continued

Column	Variable	Value	Description	Format
36-45	ADUB		Applied doublet value--allows an initial doublet solution to be applied at the outset	

Note: Use one card per set of panels. Total number of sets = NORSET on CARD 8.

CARD SET 8B: Only Present if NVORT>0 on CARD 8.

CARD 8B(i)

Columns	Variable	Value	Description	Format
1-10	VORT		Vortex Strength	F10.0

CARD 8B(ii)

Columns	Variable	Value	Description	Format
1-10	RXV(I)		Points describing vortex line	3F10.0
11-20	RYV(I)			
21-30	RZV(I)			

I=1, NVORT+1; One card per point.

CARD SET 8C: Only Present if NPASUM>0 on CARD 8.

Columns	Variable	Value	Description	Format
1-5	NPSPCH		Number of patch containing set of panels	5I5
6-15 11-15	NPSRF NPSRL		First and last rows of panels, inclusive, covering the required set of panels, see Figure 31. (Default gives full set of rows on this patch)	
16-20 21-25	NPSCF NPSCL		First and last columns of panels, inclusive, covering the required set of panels. (Default gives full set of columns of this patch)	

Note: One card per set. Number of sets = NPASUM.

CARD SET 8D: Only Present if JETPAN>0 on CARD 8.

Columns	Variable	Value	Description	Format
1-5	JETPCH		Number of patch containing the required panel	5I5, 2F10.0
6-10 11-15	JETRF JETRL		First and last rows of panels, inclusive, covering the required set of panels, see Figure 31. (Default gives full set of rows on this patch)	
16-20 21-25	JETCF JETCL		First and last columns of panels, inclusive, covering the required set of panels. (Default gives full set of columns on this patch)	
26-35 36-45	VIN VOUT		Tangential velocity components in the 'jet-wise' direction on the inside and outside surfaces, respectively, on the jet sheet enclosing region. (Normal vector on jet sheet points outside)	

CARD SET 8E: Only Present if NDCHGE>0 on CARD 8.

Columns	Variable	Value	Description	Format
1-5 6-10	KPAN KSIDE		Panel number and the side of that panel requiring a modified neighbor	4I5
11-25 16-20	NEWNAB NEWSID		New neighbor and the side of that neighbor adjacent to KSIDE of KPAN, see Figure 24	

Note: One card per set; number of sets = NDCHGE.

If NEWNAB = 0 then the program sets NEWSID = -KSIDE. Also, it treats the original neighbor in the same way. Thus, neighbor relationship is cut completely across side KSIDE.

7.3.2 PATCH GEOMETRY INPUT

Repeat the following cards for each component/patch as appropriate.

CARD 9: Component Card.

Columns	Variable	Value	Description	Format
1-10 11-20 21-30	CTX CTY CTZ		Location of component coordinate system origin in the global coordinate system, see Figure 7	5F10.0
31-40	SCAL		Scale factor (|SCAL|) applied to component geometry (default = 1.0). If set negative, include CARD 9A	
41-50	THET		Rotation angle (degrees) for the complete component (default axis = component y-axis). For an arbitrary axis use negative SCAL and use CARD 9A	

Note: Limit on number of components = 10.

C-2

CARD 9A: (Only Present if SCAL<0 on CARD 9).

Columns	Variable	Value	Description	Format
1-10 11-20 21-30	CPX CPY CPZ		Two points on the arbitrary axis about which the component is to be rotated	6F10.0
31-40 41-50 51-60	CHX CHY CHZ		(CPX, CPY, CPZ becomes a point on the axis and CHX, CHY, CHZ is changed to the unit vector along the axis of rotation)	

CARD 10: Patch Card.

Columns	Variable	Value	Description	Format
1-5	IDENT	1	Wing-type patch, analysis includes sectional quantities. Allows IBLTYP=0 boundary layer analysis (see CARD 4(a))	4I5,6A4
		2	Body-type patch, analysis excludes sectional quantities. Only IBLTYP=1 boundary layer analysis allowed on this patch (see CARD 4(a))	
		3	Patch with Neumann boundary condition panels (single sheet). No boundary layer analysis allowed on these patches at this time	
6-10	MAKE		Switch for automatic patch generator	
		0	Regular patch input. Requires CARD 11 and CARDS 12, 13, ... where applicable	
		+M	Automatic patch closing side 3 of folded patch, M; see Figure 22	
		-M	Automatic patch closing side 1 of folded patch, M (Continued)	

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CARD 10: Continued

Note: (i) MAKE$\neq$0 requires CARD SET 16 only to follow CARD 10.

(ii) If MAKE$\neq$0, the upper and lower surfaces of the folded patch, |MAKE|, should have the same number of panels.

Columns	Variable	Value	Description	Format
11-15	KOMP		COMPONENT number to which this patch is assigned (0 or blank automatically assigns the patch to the current component number). Note: the <u>first</u> patch on a new component should not be assigned to a different component. See 4.4	
16-20	KLASS		Assigns an ASSEMBLY number to this patch--these can be in any order (default is 1)	

Note: Patches on different COMPONENTS can be contiguous (but watch the component transformations on the CARD 9 information); whereas patches on different ASSEMBLIES are not allowed to connect in the panel neighbor information.

Columns	Variable	Value	Description	Format
21-80	PNAME		Text for Patch Identification (optional)	

Note: (Limit on Number of Patches = 100;
Limit on Panels/Patch = 500/1000;
Limit on NROW or NCOL for a patch = 100.)

CARD 11: Section Card.

Columns	Variable	Value	Description	Format
1-10 11-20 21-30	STX STY STZ		Location of the section origin in the component reference frame (see Figure 11)	6F10.0, 4I5
31-40	SCALE	≥ 0	Scaling factor	

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CARD 11: Continued.

Columns	Variable	Value	Description	Format
41-50	ALF		Section pitch angle in degrees	See Figure 11
51-60	THETA		Section orientation angle in degrees	See Figure 11
61-65	INMODE		Type of section input	
		0	Copies the previously defined section as originally specified; i.e., basic coordinates before scaling, etc. If the original section was defined using INMODE=4, then new section is located using incremental vector (STX,STY,STZ) relative to the original location	
		-M	Copies the basic coordinates of section M (absolute subscript)	
		1	Input y,z coordinates of SECTION. Requires Option (a) on CARD SET 12	See Figure 12
		2	Input x,z coordinates of SECTION. Requires Option (b) on CARD SET 12	See Figure 12
		3	Input x,y coordinates of SECTION. Requires Option (c) on CARD SET 12	See Figure 12
		4	Input x,y,z coordinates of SECTION. Requires Option (d) on CARD SET 12	See Figure 12
		5	Generates coordinates on a NACA 4-digit section. Requires Option (e) on CARD SET 12, see Figure 17	
		6	Generates coordinates on a semi-ellipse section. Requires Option (f) on CARD SET 12 (See Figure 18)	
		7	Generates coordinates on a biconvex section. Requires Option (e) on CARD SET 12 (see Figure 17)	

CARD 11: Continued.

Columns	Variable	Value	Description	Format
61-65	INMODE (continued)	8	Generates a complete ellipse. Requires Option (f) on CARD SET 12 (see Figure 19)	
		12	Polar coordinate input. Requires Option (g) on CARD SET 12 (see Figure 13)	
66-70	NODES	0	First or interior section on a patch	
		1 2	End of a spanwise region within a patch with continuous (1) or discontinuous (2) slope on the spanwise generators onto the next spanwise region	
		3	This section completes the present PATCH	
		4	This section completes the last patch on the present COMPONENT. (The next patch will start a new component)	
		5	This section completes the last patch in the configuration. This must be present on the last section to terminate the PATCH GEOMETRY INPUT	
		Negative (1 thru 5)	If NODES is set to a negative value, the present section is rotated about the S.C.S. x-axis to form a part or a complete body of revolution. Requires CARd 15 to follow the section coordinates (see Figure 21)	

CARD 11: Continued.

Columns	Variable	Value	Description	Format
71-75	NPS		Only active if NODES$\neq$0	
		0	Manual paneling in spanwise region just completed; defined sections are used as panel edges in this region	
		>0	Number of panels to be generated in the spanwise region just completed	
76-80	INTS		(Only active if NODES$\neq$0 and NPS>0	
			Form of spanwise interval spacing for the generated panels in the spanwise region just completed. See Figure 15	
		0	Full cosine spacing with smaller panels near the beginning and end of the region	
		1	Half-cosine spacing with smaller panels near the beginning of the region	
		2	Half-cosine spacing with smaller panels near the end of the region	
		3	Equal spacing throughout the region	

Note: Limit on the number of defined sections: 500.

CARD SET 12: Section Definition. (Present if INMODE>0 on CARD 11, see 4.5.5). In each set use one card per point. Insert NODE CARD(S) 14 to control paneling and to complete a set. Use one of the options below depending on the value of INMODE. Use one card per point if INMODE=1, 2, 3, 4 or 12; see Figures 12 and 13.

CARD SET 12: Continued.

OPTION (a): (INMODE=1)

Columns	Variable	Value	Description	Format
1-10 11-30 21-30	BY BZ ΔX		y,z coordinates of a point on the section. The x-stations are essentially constant (0.0); however, local deviations in x can be placed in Δx	3F10.0

OPTION (b): (INMODE=2)

Columns	Variable	Value	Description	Format
1-10 11-20 21-30	BX BZ ΔY		x-z coordinates of a point on the section. The y-stations are essentially constant (0.0); however, local deviations in y can be placed in Δy	3F10.0

OPTION (c): (INMODE=3)

Columns	Variable	Value	Description	Format
1-10 11-20 21-30	BX BY ΔZ		x-y coordinates of a point on the section. The z-stations are essentially constant (0.0); however, local deviations in z can be placed in Δz	3F10.0

OPTION (d): (INMODE=4)

Columns	Variable	Value	Description	Format
1-10 11-20 21-30	BX BY BZ		x,y,z coordinates of a point on an arbitrary skewed section	3F10.0

OPTION (e): INMODE=5-NACA 4-DIGIT SECTION or INMODE=7-BICONVEX SECTION

Columns	Variable	Value	Description	Format
1-10	TC		Thickness-chord ratio of section	F10.0, I5
11-15	INPUT	1	Generates y,z coordinates; x = 0.0	
		2	Generates x,z coordinates; y = 0.0	
		3	Generates x,y coordinates; z = 0.0	

Note: The coordinates are generated on a chord of 0.0 to 1.0. They start at the trailing edge on the lower side and finish at the trailing edge on the upper side. (See Figure 17.)

CARD SET 13 must follow this card.

OPTION (f): INMODE=6, SEMI-ELLIPSE or INMODE=8, FULL ELLIPSE.

Columns	Variable	Value	Description	Format
1-10	H		Height of 'vertical' semi-axis; see Figures 18 and 19	F10.0, I5
11-15	INPUT	1	Generates y,z coordinates; x = 0.0	
		2	Generates x,z coordinates; y = 0.0	
		3	Generates x,y coordinates; z = 0.0	

Note: CARD SET 13 must follow this card.

OPTION (g): (INMODE=12) Polar Coordinate Input.

Columns	Variable	Value	Description	Format
1-10	DX		x-station	3F10.0
11-20	RAD		Radius vector	
21-30	THET		Orientation (degrees), see Figure 13	

CARD SET 13: (Used After Option 12(e) or 12(f).

Columns	Variable	Value	Description	Format
1-10	XRD		Chordwise station in the range 0.0 to 1.0 at the end of a chordwise region on a generated section. Place a negative sign on XRD if the region end occurs on the section underside. See Figures 17, 18 and 19. on the last CARD 13 of a set, XRD=1.0 for a complete section except in the case when INMODE=6: in this case, the last region ends with XRD=0.0	F10.0, I5
11-15	NINT		Number of basic point intervals to be generated in the chordwise region just completed. Default value is 70	

Note: A NODE CARD (CARD 14) must be placed after each CARD 13. The TERMINAL NODE CARD (with NODEC=3) must be placed after the last CARD 13 in the set.

CARD 14: Chordwise Node Card.

Columns	Variable	Value	Description	Format
30-35	NODEC	1 2	Terminates a chordwise region having continuous (1) or discontinuous (2) surface slope onto the next chordwise region	30X,4I5

CARD 14: Continued.

Columns	Variable	Value	Description	Format
30-35	NODEC Continued	3	Signifies a TERMINAL NODE CARD. This must be placed after the last point on a section	
		-1, -2, -3	Negative values indicate a copying routine. Use CARD 14A to define a string of points to be copied over to form part or all of present section. The last copied point is the end of a chordwise region with the corresponding action according to the modulus of the NODEC value, see 4.5.7.1	
		-4	As above but the last point copied is not at a chordwise region end. In this case the CARD 14A must be followed either with another negative NODE CARD or with further basic points	
36-40	NPC	0	Manual paneling in the chordwise region just completed (i.e., basic points correspond to panel corners)	
		>0	Number of panels to be generated in the chordwise region just completed	
41-45	INTC	0, 1, 2, 3	Form of chordwise interval spacing for the generated panels. See 4.5.5 and Figure 15. Also under CARD 11	
46-50	MOVE		(Only used for basic point input; i.e., INMODE=1, 2, 3 4 or 12)	
		0	No action	
		1	Chordwise region just completed is to be transformed. CARD 14B must follow	

CARD 14A: ***Copy Card*****.** Defines a string of basic points to be copied over. (Follows CARD 14 if NODEC negative.) See Figure 16(b).

Columns	Variable	Value	Description	Format
1-5	NPCH		Patch number	4I5
6-10	NSEC		Section number within that patch (local sub-script)	
11-15	IB, LB		First and last basic points on that section (local subscript)	

CARD 14B: ***Transformation for a Chordwise Region*****.** (Only if MOVE=1 on CARD 14)

Columns	Variable	Value	Description	Format
1-10	XPIV		Pivot point coordinates	7F10.0
11-20	XPIV			
21-30	ZPIV			
31-40	HX		Pivot axis (unit vector)	
41-50	HY			
51-60	HZ			
61-70	ROT		Rotation angle (degrees) (Positive right-hand rotation)	

CARD 15: ***Body of Revolution*****.** (Only present if NODES negative on CARD 11.)

Columns	Variable	Value	Description	Format
1-10	THETA2		Theta interval for body of revolution. This can be used to build up a body of revolution with varying panel density. See Figure 21	2F10.0
11-20	THETA1			

CARD SET 16: Special Tip Patch. See 4.5.7.2 and Figure 22.
(Only present if MAKE$\cancel{<}$0 on card 10)

Columns	Variable	Value	Description	Format
36-40	NPC		Number of panel 'chord-wise' across patch	35X,4I5 10X,3I5
41-45	INTC		Form of panel spacing 'chordwise' (0, 1, 2 or 3 options as under CARD 11)	
46-50	KURV	0	Flat patch	
		1	Semicircular sections	
		2	Semi-elliptical sections	
		3	Triangular sections	
51-55	NPTIP		Number of points defining the tip-edge contour. Required only for KURV>1, then use CARD 16A	
66-70	NODES	3	More patches to follow this one	
		4	This is the last patch on a component	
		5	This is the last patch in the PATCH GEOMETRY input	
71-75 76-80	NPS INTS	0 0	Same options as given on CARD 11 but not usually needed here (the default paneling matches that of the basic patch)	

CARD SET 16A: Tip Planform Shape. (Only if NPTIP>0 on CARD 16)

Columns	Variable	Value	Description	Format
11-20 11-20 21-30	S Y Z		Coordinates describing the tip-edge shape in a local system. See Figure 22(d). z=0.0 if KURV=2	3F10.0

Note: Use one card per point. Number of cards = NPTIP.

7.3.3 Wake Input

CARD 17: Wake-Grid-Plane.

Columns	Variable	Value	Description	Format
1-10	x		x-station of each wake-grid-plane; one value per card. First station must be upstream of all separation points The set of x-stations must be terminated with a NODE CARD (CARD 18) with NODE=3. Intermediate NODE cards (with NODE=1) may be inserted to generate intermediate stations as described below. (See also Figure 25)	F10.0

Note: Limit on Number of Wake-Grid-Planes = 31.

CARD 18: NODE CARD.

Columns	Variable	Value	Description	Format
30-35	NODE	1	Intermediate node card may be placed after any CARD 17 except the first and the last	30X,4I5
		3	Terminal node card placed after the last CARD 17	
36-40	NPC	0	Manual intervals: the set of x-stations just completed is used directly as a set of wake-grid-plane locations	
		>0	Automatic intervals: NPC intervals are generated in the region between the previous two x-stations	

CARD 18: Continued.

Columns	Variable	Value	Description	Format
41-45	INTC		(Only active is NPC>0.) Controls the spacing of the automatic intervals. Spacing options are the same as described in 4.5.5.3 and Figure 15	
		0	Full cosine spacing with smaller intervals near the beginning and end of the region	
		1	Half-cosine spacing with smaller panels near the beginning of the region	
		2	Half-cosine spacing with smaller panels near the end of the region	
		3	Equal spacing throughout the region	
46-40	MARK	0	Usual	
		1	Use on <u>one</u> x-station to mark downstream end of region of interest. If MARK is not used the default is two stations before last one. (Wake downstream of this point will not be printed or passed to plot file and will not receive detail relaxation calculation.)	

<u>Note</u>: Repeat the following cards (19 through 23) as appropriate for each wake.

CARD 19: Wake Card.

Columns	Variable	Value	Description	Format
1-5	IDENTW		Type of wake	3I5,5X, 6A4
		1	Regular wake. Doublet distribution is constant in streamwise direction	
		2	Unsteady wake (continuously generated and transported streamwise in time-stepping loop)	
		4	Jet model. Doublet distribution is linear in stream-direction with specified gradient. Requires CARD 23	
6-10	IFLEXW	0	Flexible wake--will be relaxed if wake shape iteration specified (NWIT>0 on CARD 4(a))	
		1	Rigid wake--will remain fixed throughout wake shape iteration cycles	
11-15	IDEFW	0	Separation line defined by strings of separation panels. Requires CARDS 20, 21 and 22 where appropriate	
		1	Separation line defined by set of point coordinates on the surface. (Future option)	
21-80	WNAME		Text for wake identification (optional)	

Note: Limit on Number of Wakes = 10/50;
Limit on Number of Wake Columns = 50/200;
Limit on Number of Wake Panels = 1500/4000.

CARD 20: Separation Line Specification along Panel Edges.
(See Figure 28)

Repeat CARD 20 and its CARD SETS 21 and 22 where applicable for each patch crossed by the separation line.

Columns	Variable	Value	Description	Format
1-5	KWPACE		Patch number	7I5
6-10	KWSIDE	1,2,3 or 4	Patch side which is parallel to the direction of the separation line (see 4.7.3 and Note (ii) below	
11-15	KWLINE	0	Separation is from the patch edge	
		>0	Line number (row or column) within the patch where wake is attached	
16-20 21-25	KWPAN1 KWPAN2		First and last wake shedding panels in the present set. The numbering is local along the separation line on patch KWPACE. If the separation line extends across a complete row or column of this patch in the present string, then KWPAN1, KWPAN2 should be set to 0 (default option)	
26-30	INPUT	0	Copies previous wake line geometry	
		1	Wake line geometry specified by y,z coordinates. Requires OPTION (a) on CARD 21	
		2	Wake line geometry specified by x,z coordinates. Requires OPTION (b) on CARD 21	
		3	Wake line geometry specified by x,y coordinates. Requires OPTION (c) on CARD 21	

CARD 20: Continued.

Columns	Variable	Value	Description	Format
26-30	INPUT (continued)	4	Wake line geometry specified by x,y,z coordinates (global reference). Requires OPTION (d) on CARD 21	
31-35	NODEWS	0	First or intermediate string of panels being specified	
		3	Completes a wake. Only INPUT and the following variables are active on this card. If INPUT>0, then the appropriate geometry of the last wake line for this wake (CARD 21) must follow	
		5	As for the NODEWS=3 but this completes the last WAKE in the input data	
36-40	IDWC		Future option to change the type of wake (IDENTW) on a column-by-column basis	
31-45	IFLXL		Future option to change the 'flexible' status (IFLEXW) on a line-by-line basis	
46-55	DTHET		Option to rotate a wake line geometry about the local x-axis	

Notes: (i) If, in a subsequent case the panel density is changed on a patch crossed by the separation line, then KWPAN1, KWPAN2 and possibly KWLINE might need to be changed also.

(ii) The 'direction' of the separation line is such that the wake-shedding panels 'upstream' of the wake separation are on the left when looking along the line.

CARD 21: Streamwise Wake-Line Geometry. (Only if INPUT≠0 on CARD 20)

Use one of four options depending on the value INPUT on CARD 20. OPTIONS (a), (b) and (c) require local coordinates relative to an origin at the separation point with coordinates axes parallel to the global co-ordinate system.

OPTION (d) requires coordinates specified in the global coordinate system.

OPTION (a): (INPUT=1).

Columns	Variable	Value	Description	Format
1-20	SWPY		y,z coordinates of each point on a wake line.	3F10.0
11-20	SWPZ		x values are essentially constant (0.0); however,	
21-30	Δx		local deviations in x can be placed in Δx	

(See notes below.)

OPTION (b): (INPUT=2).

Columns	Variable	Value	Description	Format
1-20	SWPX		x,z coordinates of each point on a line. y values	3F10.0
11-20	SWPZ		are essentially constant (0.0); however, local de-	
21-30	Δy		viations in y can be placed in Δy	

(See notes below.)

OPTION (c): (INPUT=3).

Columns	Variable	Value	Description	Format
1-10	SWPX		x,y coordinates of each point on a wake line.	3F10.0
11-20	SWPY		z values are essentially constant (0.0); however,	
21-30	Δz		local deviations in z can be placed in Δz	

(See notes below.)

OPTION (d): (INPUT=4).

Columns	Variable	Input	Description	Format
1-10	SWPX		x,y,z coordinates of each point on a wake line specified in global coordinates	3F10.0
11-20	SWPY			
21-30	SWPZ			

Notes:

(i) Use one card per point for the above options.

(ii) Exclude the first point on the wake line (i.e., the separation point). This is located by the program using the information on CARD 20.

(iii) Wake node cards, CARD 22, can be inserted in the set of points to generate additional points on curved lines. A terminal node card with NODEWC=3 must be placed after the last point on a wake line. See Figure 29.

(iv) The points input or generated on a wake line are not directly related to the wake panels. The x-stations of the wake panel corner points are determined by linear interpolation at the wake-grid-planes defined on CARD 17.

CARD 22: Wake Node Card.

Columns	Variable	Value	Description	Format
30-35	NODEWC	1 2	Optional intermediate node card placed within a set of wake line points in order to generate additional points along a curved line with continuous (1) or discontinuous (2) slope onto the next region	30X,3I5
		3	Terminal node card. This must be placed at the end of a set of points to finish a wake line	

CARD 22: Continued.

Columns	Variable	Value	Description	Format
36-40	NPC	0	Manual intervals. The input points are taken directly	
		>1	Number of intervals to be generated in the region just completed	
41-45	INTC		Form of spacing if NPC>0 (see Figure 15)	
		0	Full cosine spacing with smaller intervals near the beginning of the region	
		1	Half-cosine spacing with smaller panels near the beginning of the region	
		2	Half-cosine spacing with smaller panels near the end of the region	
		3	Equal spacing throughout the region	

CARD 23: TYPE-4 Wake Velocity Data. (Only if INDENTW=4 on CARD 19)

Columns	Variable	Value	Description	Format
1-10	VIN		Tangential velocity on the underside or inside of the vortex sheet wake	8F10.0
11-20	VOUT		As above but on the top side or outside surface	

Note: (i) If just one pair of values is given as above, then the code will set the same values for all columns on this wake. If different values are required on other columns of this wake, then NWC pairs of values must be input on the 8F10.0 format continuing onto additional cards if necessary. NWC is the total number of columns (i.e., number of wake-shedding panels) on this wake.

Note: (ii) Surface panels immersed in a jet should be identified using JETPAN on CARD 8 and data on CARD 8D. This does not affect the doublet solution--only the analysis of surface velocities and pressures; it changes panel neighbor information and provides the jump in total head for C_p calculations inside the jet.

7.3.4 Input for Surface Streamline Calculation.

One data card is required for each streamline to be calculated and a final card to signify the end of the streamline data. Calculation proceeds upstream and downstream from starting point.

CARD 24: Starting Point of Each Streamline.

Columns	Variable	Value	Description	Format
1-10	F	$0.05 \leq F \leq 0.95$	Location of starting point of streamline as a fraction of the panel side containing it (measured anticlockwise). A value of F=0.5 will cause the starting point to be in the middle of the panel side	F10.0 2I5
11-15	KP		Panel number of the panel through which the streamline is to pass. Caution: this must not be a stagnation panel	
16-20	NS	1,2,3 or 4	Panel side number for streamline entry. Normally to be left blank. Program will select a side. If a side is prescribed ($1 \leq NS \leq 4$), the user must ensure that a streamline would actually enter the panel through that side as opposed to exiting through that side	

CARD 25: Last Card of Streamline Input.

Columns	Variable	Value	Description	Format
1-10	F		Must be set equal to 2.0 if the body is attached to a plane of symmetry	F10.0 2I5
11-15	KP		Must be blank (to signal end of input)	
15-20	NS		Leave blank for normal output: set NS=1 to shut off all output printing (but save the plot file; see 6.2) except listing of input data	

7.3.5 Boundary Layer Input. (Only present if KVPI>0 on CARD 4(a).)

CARD 26: Reynolds Number, Etc.

Columns	Variable	Value	Description	Format
1-10	RNB		Reynolds number based on reference chord and free stream velocity in millions, $V_\infty \bar{c}/\nu \times (10^{-6})$	5F10.0
11-20	TRIPUP		Trip location (x/c). If tripping is not desired, TRIPUP=1	
21-30	TRIPOP		Trip option. TRIPOP=1: this deters the user from specifying a trip location where the boundary layer could not (because of the Reynolds number) become turbulent. If too early a trip location is specified, the location is repositioned to corespond to the point where R_θ exceeds 200	

CARD 26: Continued.

Columns	Variable	Value	Description	Format
31-40	XPRINT		Boundary layer printout	
		0.	No crossflow parameters will be printed	
		1.	Crossflow parameters will be printed	
41-50	XSKIP		Number of integral intervals to be skipped between boundary layer printouts (streamline is divided into 200 intervals, e.g., if XSKIP=10, 20 printouts are produced)	

7.3.6 Off-Body Velocity Scan Input

CARD 27: Scan Box.

Columns	Variable	Value	Description	Format
1-5	MOLD		Shape of velocity scan volume, see Figure 30	6I5
		1	Skewed box option: allows a single point, points along a straight line or straight lines within a parallelogram or within a parallelepiped. Requires CARD SET 28, etc.	
		2	Allows points along radial lines in a cylindrical volume. Requires CARD SET 32, etc.	
		0	Stops the scan	
6-10	MEET		Controls the intersection line routine (see 5.1)	
		0	Active	
		1	Off	

CARD 27: Continued.

Columns	Variable	Value	Description	Format
11-15	NEAR		Controls the near-field routine in the velocity calculation (see 5.1)	
		0	Active	
		1	Active only for surface panels (wake near-field off)	
		-1	Inactive	
16-20 21-25 26-30	INCPRI INCPRJ INCPRK		Print frequency control for planes, lines or points, respectively	
		0	All the velocity scan results are printed	
		N	Prints the results only for every Nth plane, line or point, respectively	

Note: Use one CARD 27 for each scan box. Finish the set with a blank card (i.e., MOLD=0).

CARD 28: First Corner of Skewed Box. (Only if MOLD=1 on CARD 27)

Columns	Variable	Value	Description	Format
1-10 11-20 21-30	XO YO ZO		Coordinates of first corner point of a box	3F10.0. I5
31-35	NP	1	Single point. No further input for this 'box'	
		2	Single line. CARD 29 must follow to complete this 'box'	
		3	Lines within a parallelogram. CARDS 29, 30 must follow to complete this 'box'	
		4	Lines within a parallelepiped CARDS 29, 30 and 31 must follow to complete this 'box'	

CARD 29: Second Corner of Skewed Box. (Only if MOLD=1 on CARD 27 and NP>1 on CARD 28)

Columns	Variable	Value	Description	Format
1-10 11-20 21-30	X1 Y1 Z1		Coordinates of a second corner point of a box	3F10.0, I5
31-35	NP1	N	Number of points (equally spaced) along the straight line (X0, Y0, Z0) (X1, Y1, Z1)	
		-N	A negative sign on the number of points allows the point locations along the line to be specified. Rerequires CARD 29A to follow	

CARD 29A: Specified Point Locations along First Edge of Box. (Only if NP1 negative on CARD 29)

Columns	Variable	Value	Description	Format
1-80	(AL1(I), I=1,|NP1|)	0≤AL1≤1.0	Normalized location of each point along first edge of box	8F10.0

CARD 30: Third Corner Point of Skewed Box. (Only if MOLD=1 on CARD 27 and NP>2 on CARD 28)

Columns	Variable	Value	Description	Format
1-20 11-20 21-30	X2 Y2 Z2		Coordinates of third corner point of a box	3F10.0, I5
31-35	NP2	N	Number of points (equally spaced) along the straight line (X0, Y0, Z0) (X2, Y2, Z2)). These points locate the start of each scan line within a scan plane	
		-N	A negative sign or NP2 allows the point locations along the line to be specified. Requires CARD 30A to follow	

CARD 30A: Specified Locations of Scan Lines. (Only if NP2 negative on CARD 30)

Columns	Variable	Value	Description	Format
1-80	(AL2(I), I=1,|NP2|)	$0 \leq AL2 \leq 1.0$	Normalized location of each point along the second edge of box	8F10.0

CARD 31: Fourth Corner Point of Skewed Box. (Only if MOLD=1 on CARD 27 and NP=4 on CARD 28)

Columns	Variable	Value	Description	Format
1-10 11-20 21-30	X3 Y3 Z3		Coordinates of fourth corner point of a box	3F10.0, I5
31-35	NP3	N	Number of points (equally spaced) along the straight line (X0, Y0, Z0) (X3, Y3, Z3). These points locate the corners of the scan planes along the third edge of the box	
		-N	A negative sign on NP3 allows the point locations to be specified. Requires CARD 31A to follow	

CARD 31A: Specified Locations of Scan Planes. (Only if NP3 negative on CARD 31)

Columns	Variable	Value	Description	Format
1-80	(AL3(I), I=1,|NP3|)	$0 \leq AL3 \leq 1.0$	Normalized location of each point along the third edge of the box	8F10.0

CARD 32: First Point for Cylindrical Volume. (If MOLD=2 on CARD 27)

Columns	Variable	Value	Description	Format
1-30 11-20 21-30	X1 Y1 Z1		Coordinates of first point locating axis of cylindrical volume	7F10.0
31-40 41-50	RO1 RI1		Outer and inner radii, respectively (see Figure 30(b)	
51-60 61-70	THETA1 THETA2		First and last azimuthal stations (degrees) measured from the vertical (see Figure 30(b)	

CARD 33: Second Point for Cylindrical Volume. (If MCLD=2 on CARD 27)

Columns	Variable	Value	Description	Format
1-10 11-20 21-30	X2 Y2 Z2		Coordinates of second point locating the axis of cylindrical volume ((X1, Y1, Z1) (X2, Y2, Z2))	5F10.0
31-40 41-50	RO2 RI2		Outer and inner radii, respectively, at second station	

CARD 34: Point Distribution in Cylindrical Volume. (If MOLD=2 on CARD 27)

Columns	Variable	Value	Description	Format
1-5	NAL	N	Number of stations (equally spaced) along the cylinder axis, defining the location of scan planes (see Figure 30(b)	3I5
		-N	A negative sign allows the stations to be specified. Requires CARD 34A	

CARD 34: Continued.

Columns	Variable	Value	Description	Format
6-10	NTHETA	N	Number of azimuthal stations (equally spread between THETA1 THETA2) locating scan lines within each scan plane	
		-N	A negative sign on NTHETA allows the stations to be specified. Requires CARD 34B	
11-15	NRAD	N	Number of points (equally spaced) along each radial scan line	
		-N	A negative sign on NRAD allows the stations to be specified. Requires CARD 34C	

CARD-34A: Specified Location of Scan Planes in Cylindrical Volume. (If MODE=2 on CARD 27 and NAL<0 on CARD 34)

Columns	Variable	Value	Description	Format
1-80	(AL1(I) I=1,|NAL|)	$0 \leq AL1 \leq 1.0$	Normalized locations along the cylinder axis. (X1, Y1, Z1) (X2, Y2, Z2)	8F1010

CARD 34B: Specified Location of Scan Lines in Cylindrical Volume.(If MODE=2 on CARD 27 and NTHETA<0 onCARD 34)

Columns	Variable	Value	Description	Format
1-80	(ALTHET(I), I=1,|NTHETA|)	$0 \leq ALTHET \leq 1.0$	Normalized azimuthal stations between THETA1 and THETA2	8F10.0

CARD 34C: Specified Point Locations in Cylindrical Volume.
(If MODE=2 on CARD 27 and NRAD<0 on CARD 34)

Columns	Variable	Value	Description	Format
1-80	(ALRAD(I), I=1,|NRAD|)	$0 \leq$ ALRAD ≤ 1.0	Normalized point locations between inner and outer radii on each radial scan line	8F10.0

Note: CARDS 34A, 34B and 34C may all be present (in that order).

7.3.7 Off-Body Streamline Input

CARD 35: Location of a Starting Point For Streamline Calculation.

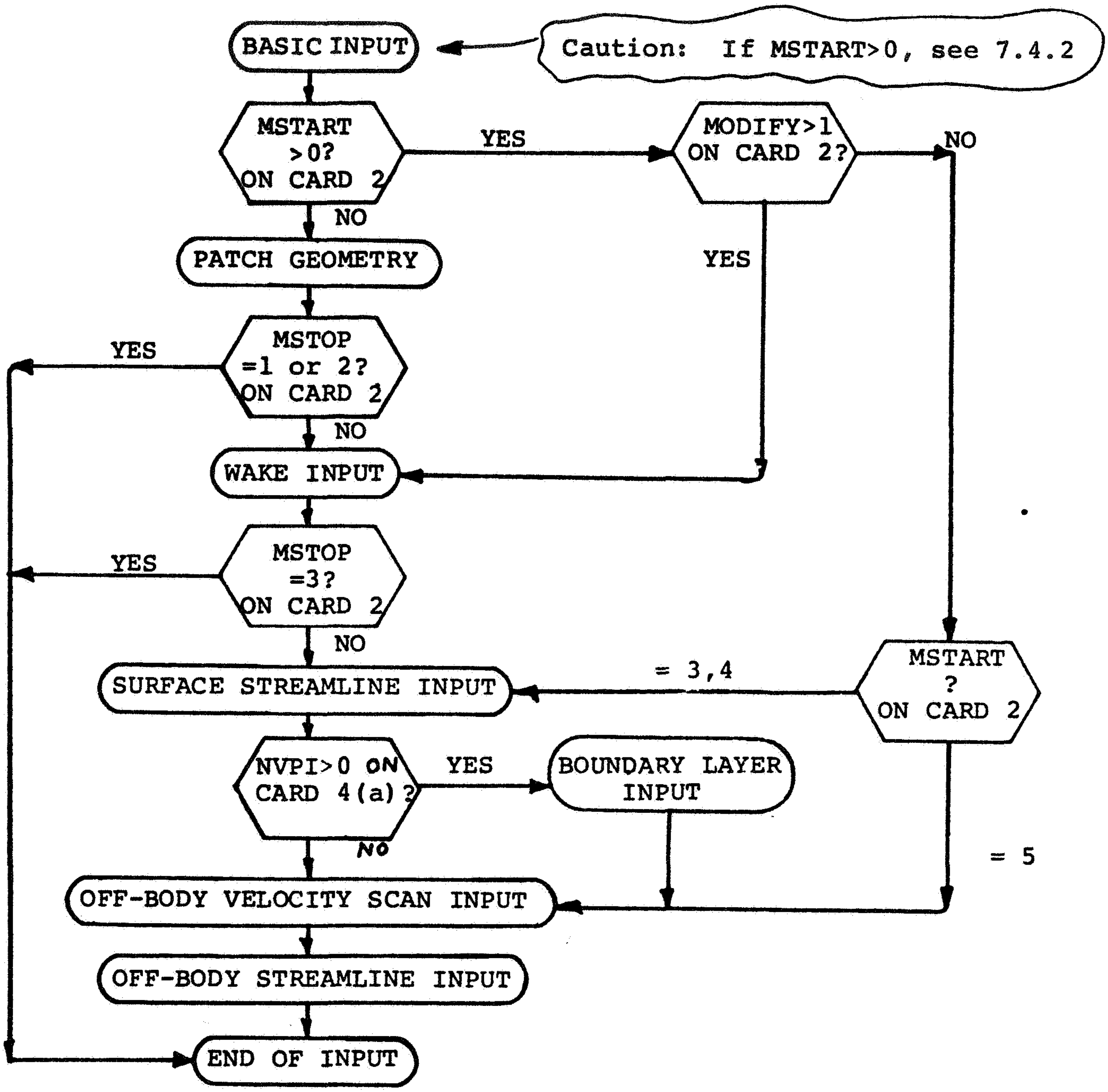
Columns	Variable	Value	Description	Format
1-10 11-20 21-30	RSX RSY RSZ		Coordinates of starting point	6F10.0, I5
31-40 41-50	SU SD		Distances upstream and downstream, respectively, for length of streamline measured from the starting point	
51-60	DELS		Basic length increment for steps along the streamline. This is a factor on CBAR on CARD 7. (The step length is adjusted up and down within the procedure)	
61-65	NEAR		Controls the near-field routine in the velocity calculator	
		0	Active (use if streamline passes close to a surface)	
		1	Active only for surface panels (wake near field off)	
		-1	Off (use if streamline is well clear of the surface and wake)	

Note: (i) Use one card per off-body streamline. Finish the set with a blank card.

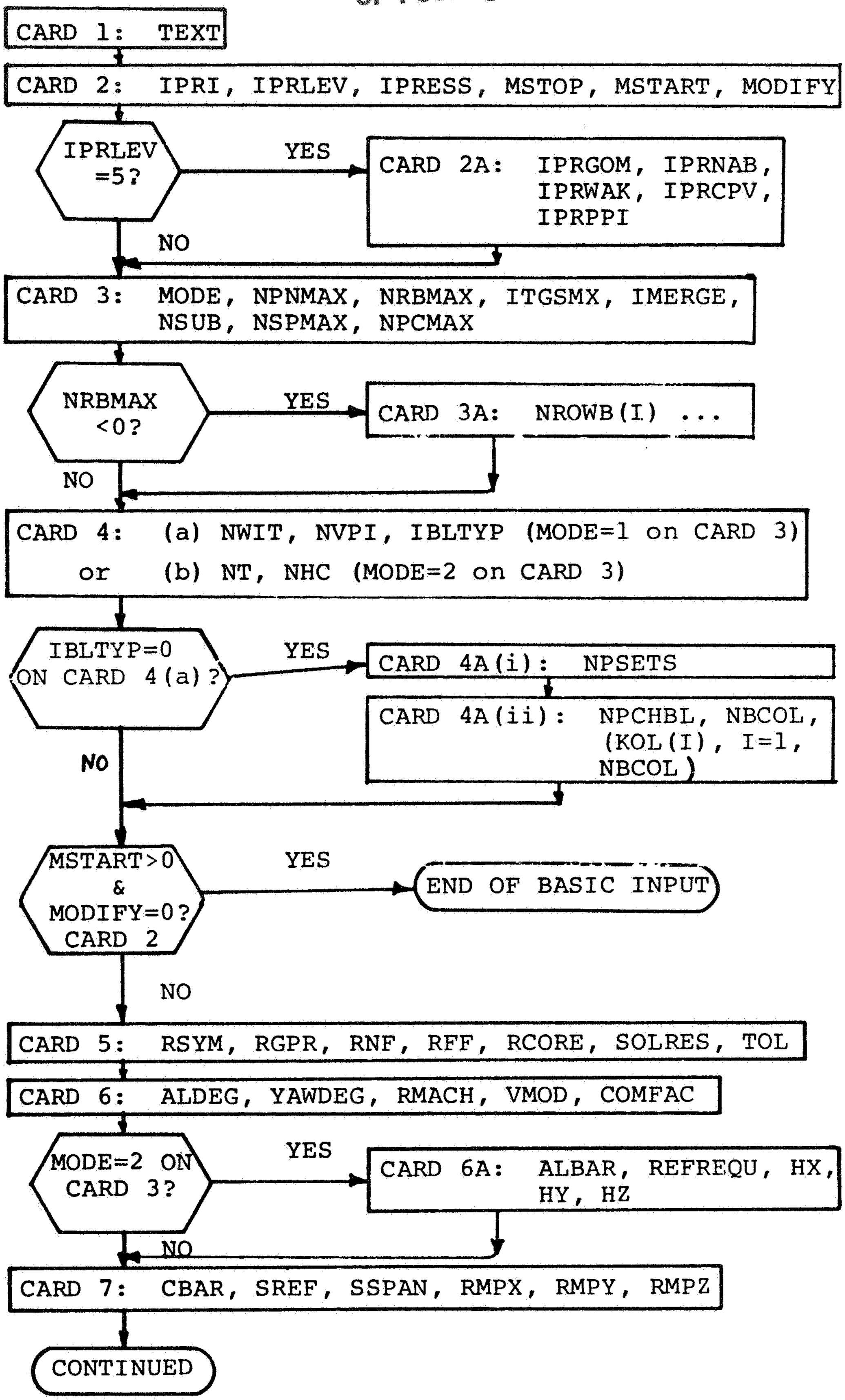
(ii) This procedure is still being checked out.

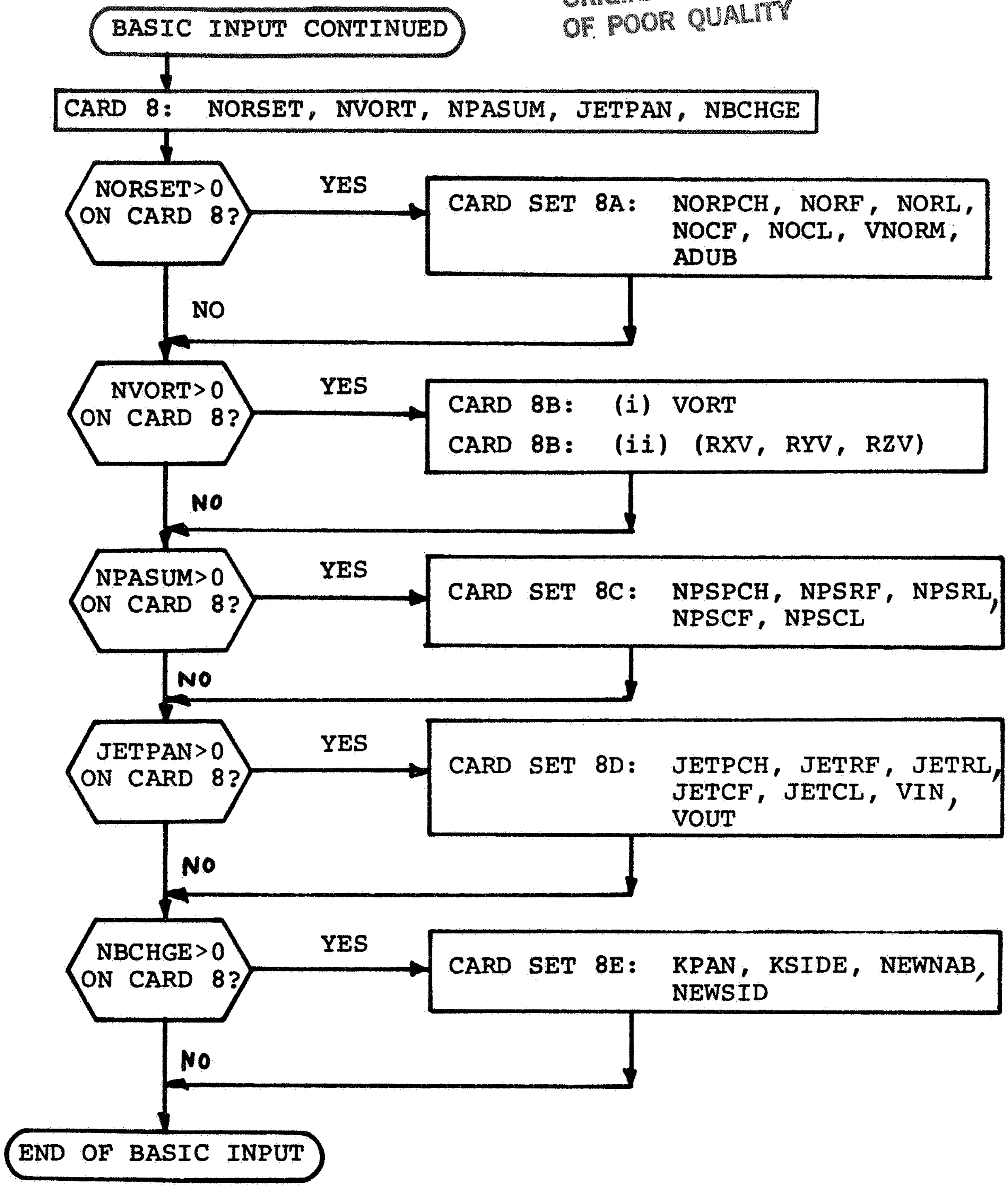
7.4 Input Flow Chart

7.4.1 Overview

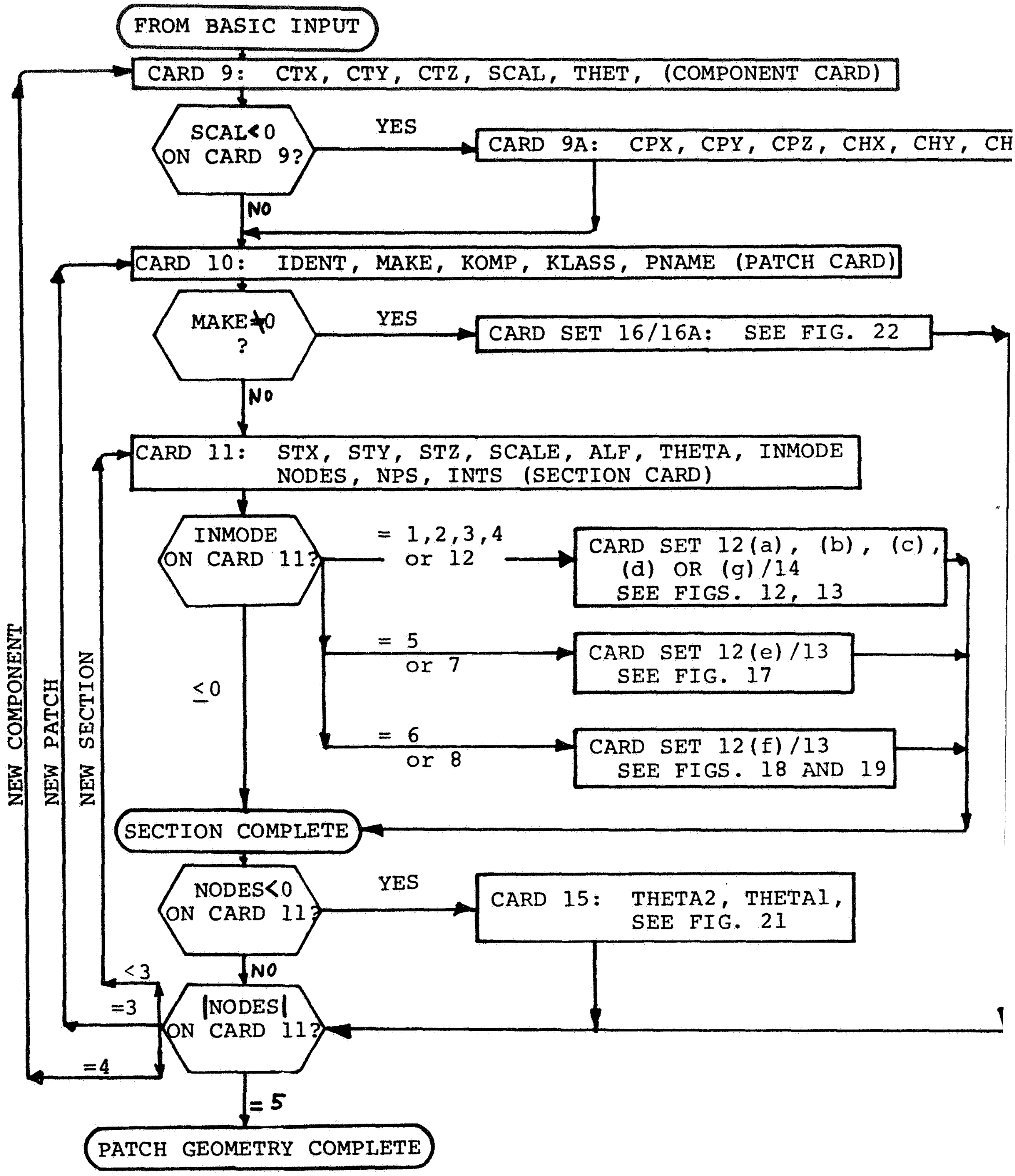


7.4.2 Basic Input




BASIC INPUT CONTINUED
CARD 8: NORSET, NVORT, NPASUM, JETPAN, NBCHGE
NORSET>0 ON CARD 8?
YES
CARD SET 8A: NORPCH, NORF, NORL, NOCF, NOCL, VNORM, ADUB
NO
NVORT>0 ON CARD 8?
YES
CARD 8B: (i) VORT
CARD 8B: (ii) (RXV, RYV, RZV)
NO
NPASUM>0 ON CARD 8?
YES
CARD SET 8C: NPSPCH, NPSRF, NPSRL, NPSCF, NPSCL
NO
JETPAN>0 ON CARD 8?
YES
CARD SET 8D: JETPCH, JETRF, JETRL, JETCF, JETCL, VIN, VOUT
NO
NBCHGE>0 ON CARD 8?
YES
CARD SET 8E: KPAN, KSIDE, NEWNAB, NEWSID
NO
END OF BASIC INPUT

7.4.3 Patch Geometry



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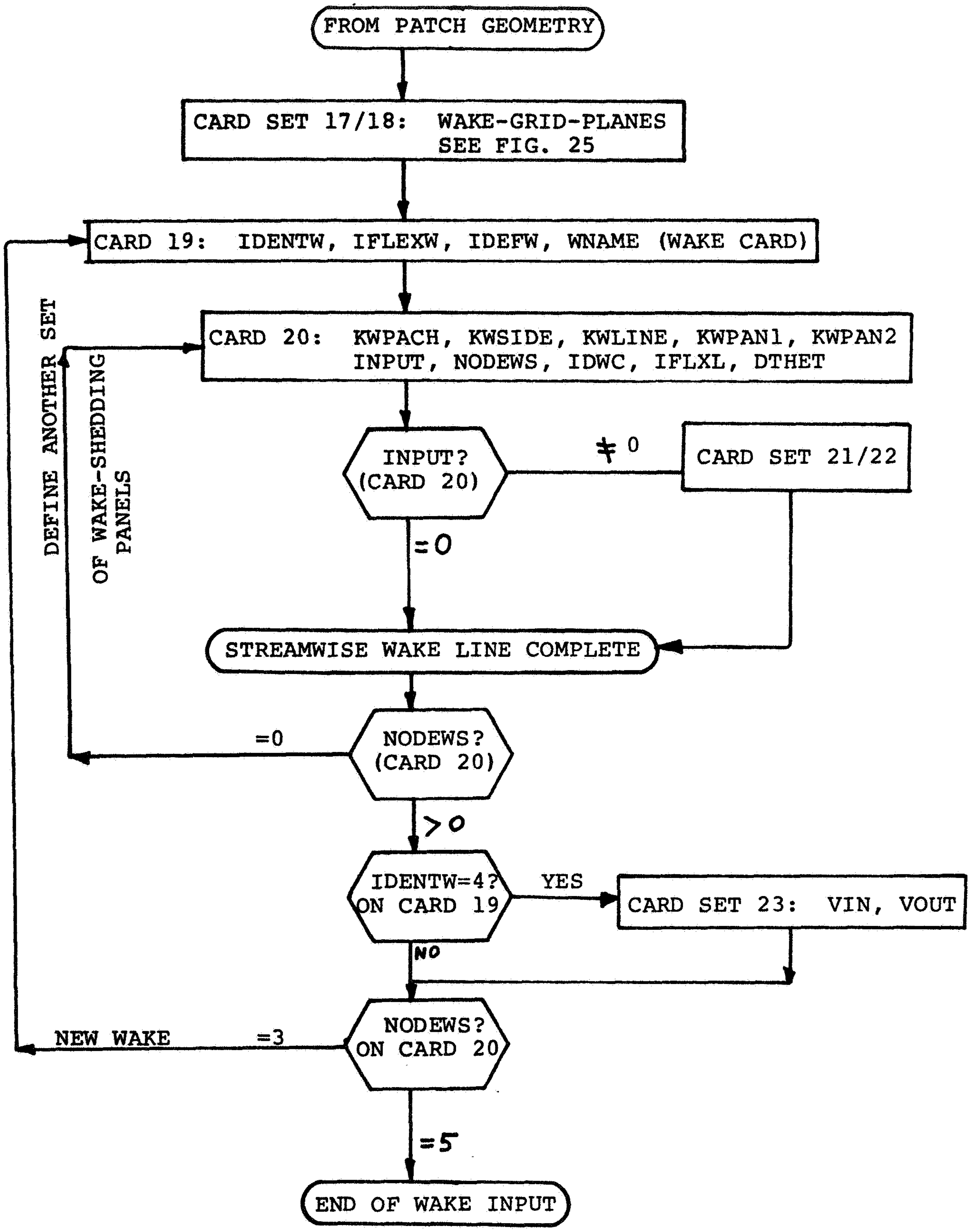
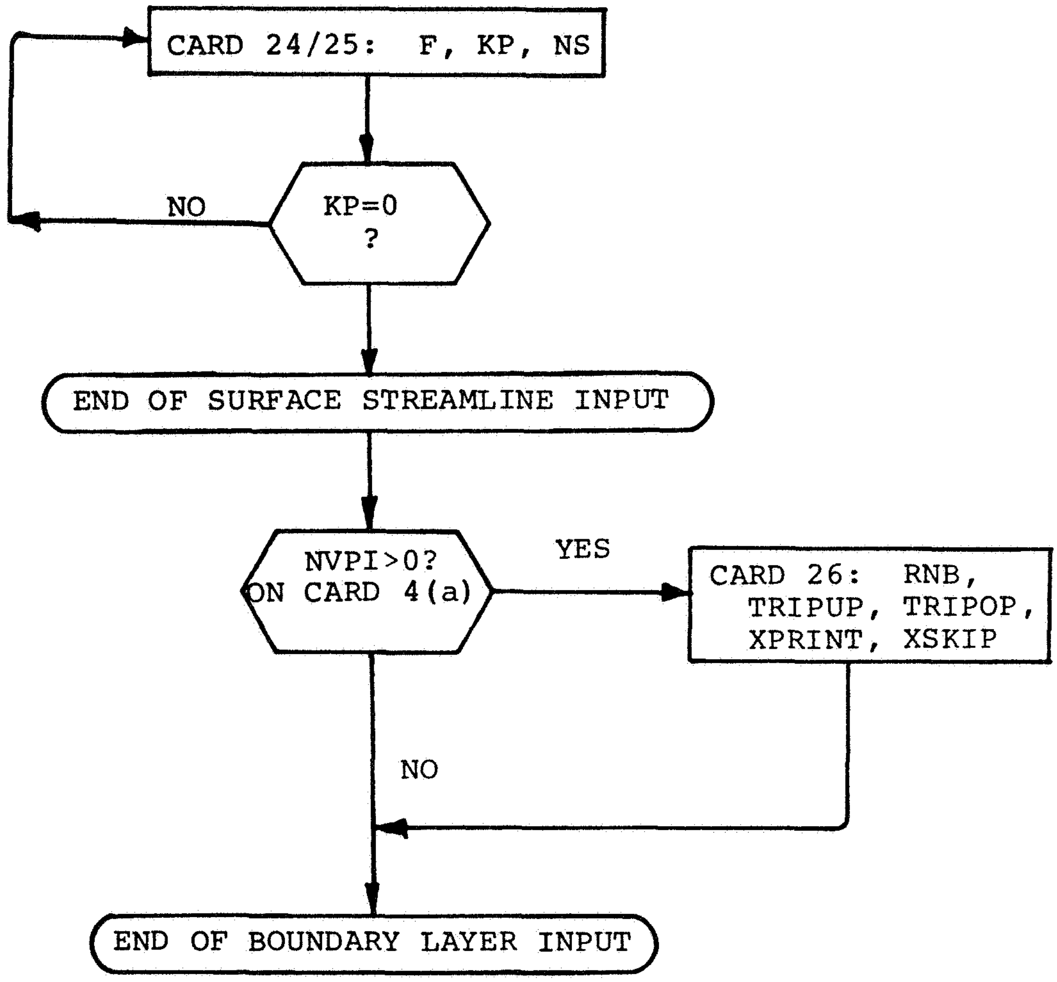
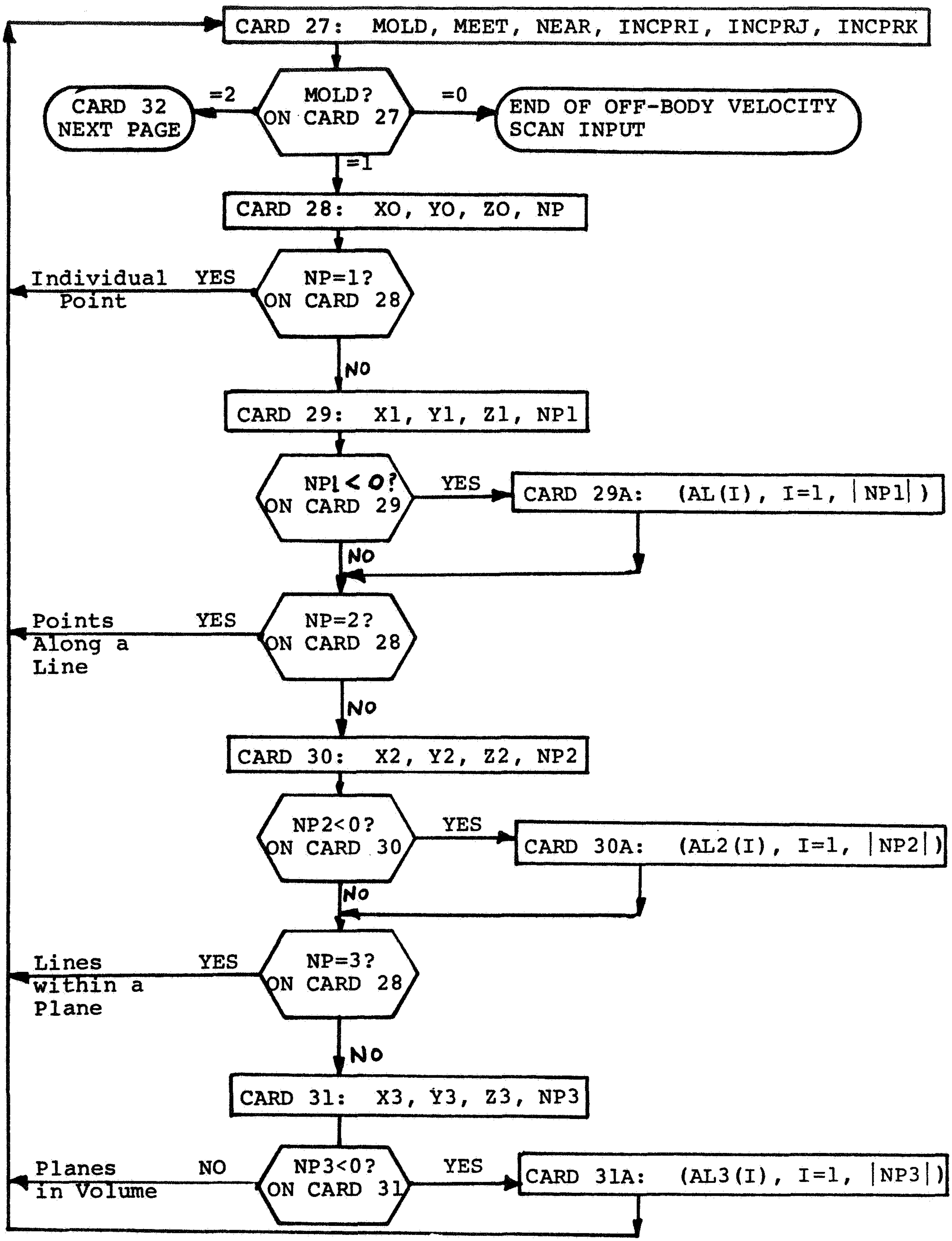
7.4.4 Wake Input



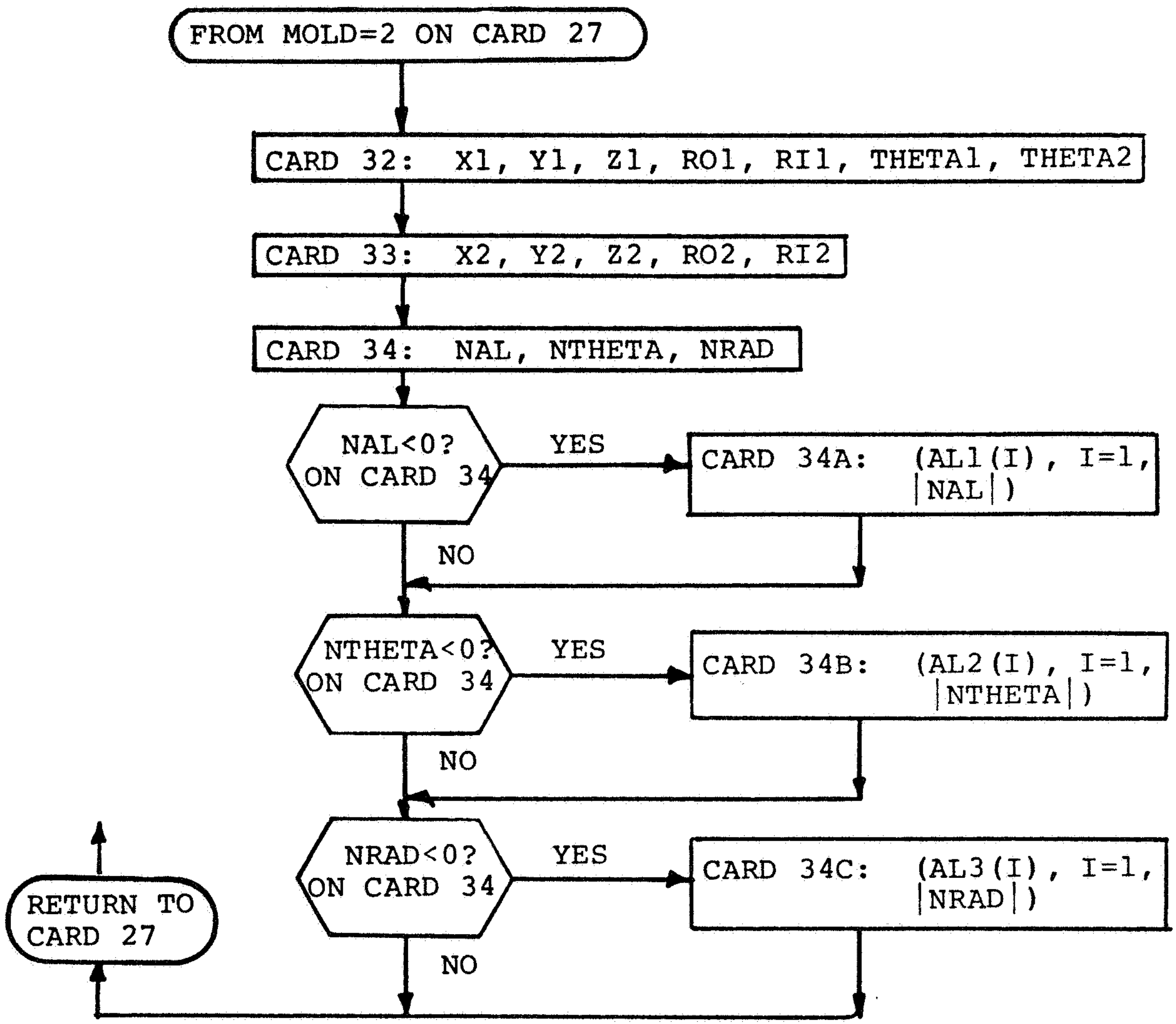
7.4.5 Surface Streamline and Boundary Layer Input



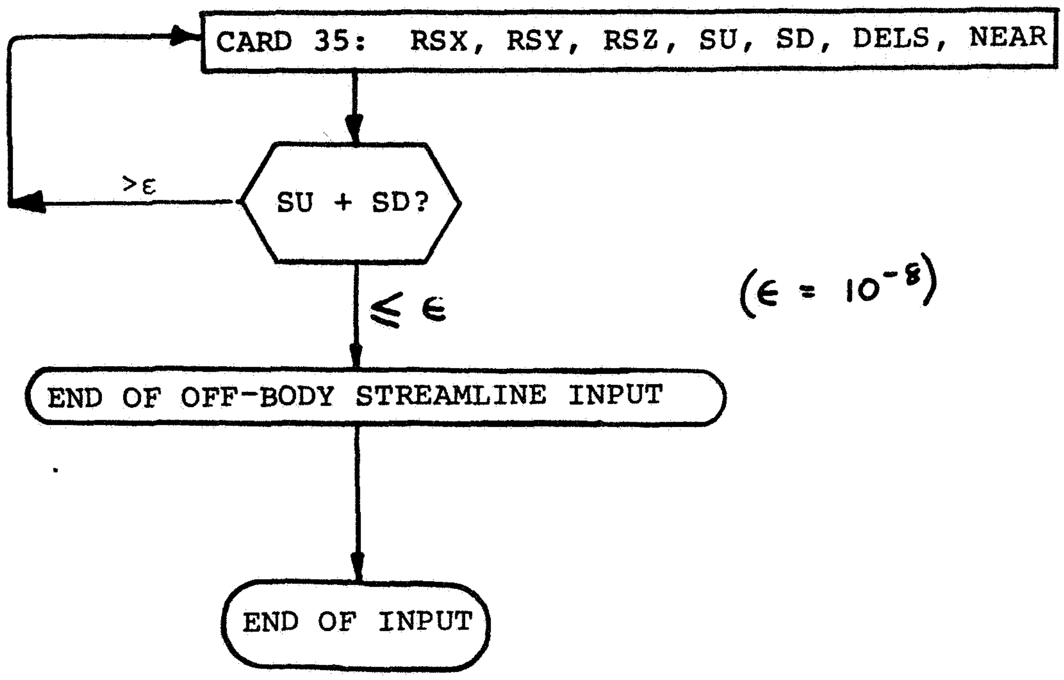
7.4.6 Off-Body Velocity Scan Input



OFF-BODY VELOCITY SCAN INPUT, CONTINUED



7.4.7 Off-Body Streamline Input



8.0 OUTPUT DESCRIPTION

8.1 Print File

The output starts with the program header followed by the user's TEXT identification. The list of BASIC INPUT is printed next, card by card. Each variable is identified in parentheses. The input list for PATCH GEOMETRY is printed next if the IPRI input option has been set >0. If IPRI=1 this input list excludes the basic point coordinates; these can be included in the list by setting IPRI=2, but this can give a large volume of print for complicated configurations.

If the negative IPRGOM option has been used on CARD 2A, then the BASIC POINTS defining patch SECTIONS are printed patch by patch:

LIST OF BASIC POINTS ON SECTION # ON PATCH #

BX	BY	BZ	(NBP)
.	.	.	.
.	.	.	.
.	.	.	.

These basic points include those generated by the code as well as those input by the user. The subscripts NBP identify the basic points for the purpose of copying strings of points over into later sections.

After processing the patch geometry input, the program (subroutine GEOMIN) prints out a summary table of the patch parameters:

M	IDENT	KLASS	KOMP	NROW	NCOL	IPAN	LPAN	NPAN
.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.

where M is the patch number; IDENT is the patch identifier (1, 2 or 3); KLASS is the ASSEMBLY number and KOMP is the component number to which this patch is assigned; NROW and NCOL are the number of panel rows and columns, respectively, on each patch; and IPAN, LPAN are the first and last panel subscripts on each patch. NPAN is the total number of panels within the patch. If a text identification, PNAME, has been given for the patch, this is written to the right of NPAN.

If IPRGOM=1 (see CARDS 2, under IPRLEV, and/or CARD 2A), then the panel corner point coordinates are printed patch by patch:

PANEL CORNER POINTS ON PATCH #

K	X1	Y1	Z1	X2	Y2	Z2	X3	Y3	Z3	X4	Y4	Z4
.	.	.	.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.	.	.	.

where K is the panel subscript, and x_i, y_i, z_i are expressed in the global coordinate system.

If IPRGOM=2 (see CARD 2 under IPRLEV and/or CARD 2A) then the panel control point (XC, YC, ZC) and unit normal vector (XN, YN, ZN) are printed patch by patch:

PANEL CONTROL POINTS AND UNIT NORMAL VECTORS ON PATCH #

K	XC	YC	ZC	XN	YN	ZN
.	.	.	.	.	.	.
.	.	.	.	.	.	.
.	.	.	.	.	.	.

The list for WAKE INPUT follows. Again, the input variables are identified in parentheses. When the wake input has been processed, the wake-grid-plane x-stations are printed in 10F10.4 format.

If IPRNAB>0 (see CARD 2 under IPRLEV and/or CARD 2A), then the panel neighbor information (see Figure 24) is printed patch by patch 'before' and 'after wake shedding'.

PANEL NEIGHBORS ON PATCH #

BEFORE WAKE SHEDDING NABOR (NABSID)					AFTER WAKE SHEDDING NABOR (NABSID)				
KPAN	SIDE 1	SIDE 2	SIDE 3	SIDE 4	KPAN	SIDE 1	SIDE 2	SIDE 3	SIDE 4
.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.

If IPRNAB=1 only those panels with missing neighbors (e.g., at a wake-shedding line) or with special neighbors (e.g., at a plane of symmetry) are included in the list. If IPRNAB=2, all the panel neighbor information is printed.

Each wake shape iteration (MODE=1 on CARD 3) starts with the printout:

WAKE ITERATION #
ALPHA = #

(Unless the print frequency control parameter, IPRESS, (see CARD 2) has suppressed it.)

On subsequent viscous-potential flow iterations, this will be preceded by:

VISCOUS-POTENTIAL FLOW ITERATION #

If MODE=2, the corresponding printout (unless suppressed by the parameter IPRESS) is

IT = #	TAU = #
ALPHA = #	OMEGA = #

where IT is the time-step number; TAU is the normalized time from the start of the final complete cycle (i.e., the cycle being analysed for real and imaginary terms); ALPHA is the instantaneous incidence (degrees) and OMEGA is the instantaneous rotation rate (i.e., $\dot{\alpha}$).

All the following printout in the wake shape iteration loop (MODE=1) or time-step loop (MODE=2) is controlled by the print frequency control parameter, IPRESS (CARD 2); the printout can be suppressed or just printed for every nth step, say.

Details of the wake paneling are printed next depending on the value of IPRWAK (see CARD 2 under IPRLEV or CARD 2A); if IPRWAK>0, the following is printed for each wake:

SUBROUTINE WAKPAN
DATA FOR WAKE #, IT = #

IDEFW	IFLEXW	NWCOL
#	#	#

where IT is the wake shape iteration number (if MODE=1) or time step number (if MODE=2).

IDEFW, IFLEXW are the input quantities (see CARD 19) and NWCOL is the number of wake columns on this wake. The text for the wake identification (if this option was used on CARD 19) is printed to the right of NWCOL.

This is followed by the wake shedding parameters (Figure 27) for each column on the wake:

IDWCOL	KWPU	KWPUU	KWPL	KWPLL	SU	DSU	SL	DSL	PHIU	PHIUU	PHIL	PHILL	DELV
.	.	.	.	.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.	.	.	.	.

where IDWCOL is the wake type (see under CARDS 19, 20); KWPU, KWPUU, KWPL and KWPLL are subscripts for upper and lower surface panels at the wake separation line, see Figure 27; PHIU, PHIUU, PHIL, PHILL are onset flow velocity potential values at the center points of panels KWPU, etc. DELV is the jump in the streamwise tangential velocity across the wake for those columns with IDWCOL=4 (i.e., jet wakes).

If IPRWAK=2, the wake line geometry on this wake is also printed:

WAKE LINE GEOMETRY

(Note: the print excludes the last three points on each line.)

LINE #

N	X	Y	Z
.	.	.	.
.	.	.	.
.	.	.	.

If IPRWAK=3, the wake panel doublet values are printed, column by column.

When all the wakes have been processed, the standard printout (i.e., IPRWAK=0) from WAKPAN follows:

DATA IN WAKPAN

(NWC, IWPAN(NWC), NWC=1, NWCOLT)

These are printed in sets of 10 across the page. NWC is the wake column subscript and IWPAN is the wake panel subscript at the beginning of each column. NWCOLT is the total number of wake columns in the configuration. The wake panel subscripts used in the plotting routine CHNIPLT are obtained by adding 3000 to IWPAN.

The relationships between the wake lines and the wake-grid-planes is printed next:

WAKE LINE SEQUENCE ARRAY IN WAKE-GRID-PLANE SYSTEM

J, (LSEQU(M,J) M=1, NWGP)

NWGP is the number of wake-grid-planes. J is the wake line subscript.

The wake-grid-planes are the columns in the array output with the upstream plane at the left. Each LSEQU value is the subscript of a wake line intersecting each wake-grid-plane. A negative sign is placed on the first and last wake line of each wake.

A summary of the first wake-grid-plane intersected by each wake line is printed next:

FIRST WAKE-GRID-PLANE INTERSECTED BY EACH WAKE LINE

(J, IWGP(J), J=1, LINT)

where LINT is the total number of wake lines.

Output from the doublet solution subroutine DUBSOL follows next. If the number of panels is such that the iterative solution procedure has been used, then the following is printed.

First, the blocking arrangement is given, NFRB is the first row of a block, while NROWB is the number of rows in the block. This is followed by:

SOLUTION HISTORY ON PANEL WITH MAXIMUM RESIDUAL

JMESH, SOL (panel subscript and solution value)
follows in 5(I4, 2X, G12.6) format

If the value of IPRSOL=1 (see under IPRLEV on CARD 2), then the complete doublet solution is printed in 5(I9, F10.5) format (i.e., panel subscript and doublet value).

The surface pressure distribution is printed next:

(a) <u>MODE=1</u>. The pressure distribution is printed according to the type of patch (IDENT). If IDENT=1, the following is printed for each column of panels.

K	X	Y	Z	DUB	VX	VY	VZ	V	C_p	X/C	Z/C
.	.	.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.	.	.

where K is the panel subscript; X, Y, Z is the control point location, and DUB the doublet value; VX, VY, VZ and V are the velocity vector components and magnitude; C_p is the pressure coefficient and X/C, Z/C the location of the point relative to the local chord line.

If IPRPPI=1, then the P/P_∞ values are printed to the right of C_p.

Each column is followed by the integrated section force and moment coefficients defined in the wind axes.

CD CS CL CMX CMY CMZ CIRC CHORD XLE YLE ZLE YLE/SSPAN

where CD, CS and CL are the section force coefficients in the drag, side and lift directions, respectively; CMX, CMY, CMZ the roll, pitch and yaw moment coefficients; CIRC is the circulation value; CHORD is the local chord length with leading edge at XLE, YLE, ZLE. The coordinate are given in the same reference frame as originally specified. YLE/SSPAN is the normalized spanwise location of the section where SSPAN is the reference semispan on CARD 7. SSPAN is used to normalize the rolling and yawing moments while CBAR is used to normalize the pitching moment.

The force and moment coefficients are also given in the body axis system. In this case, CMX and CMZ have been normalized by SSPAN and CMY by CBAR.

For type 2 patches (IDENT=2), the pressure printout is shortened by omitting X/C, Z/C and by omitting the section force and moment summary at each column.

A summary of the patch force and moment coefficients normalized by the reference quantities in the basic data is printed after each patch and the total force and moment coefficients are printed after the last patch for components and assemblies and also for user-selected panel sets specified under the options on CARD 8.

(b) MODE=2. The unsteady pressure distribution is printed out in a similar way to the MODE=1 format. If IDENT=1, the following is printed for each column of panels on the patch.

K	X	Y	Z	CPR	CPI	CPMOD	PHASE	X/C	Z/C
.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.

Here, CPR, CPI and CPMOD are, respectively, the real and imaginary pressure coefficients and the pressure coefficient modulus divided by ; and PHASE is the phase angle in degrees. Each column is followed by a summary of the section real and imaginary lift and pitching moments normalized by local conditions and divided by $\bar{\alpha}$.

CLR	CLI	CMR	CMI
CLMOD	CLPHASE	CMMOD	CMPHASE

The phase angles are in degrees.

This summary and the X/C, Z/C details are omitted if IDENT=2.

The force and moment summary based on overall conditions is printed for each patch and for the total configuration.

If IPRCPV=1 (see under IPRLEV on CARD 2 and/or CARD 2A), then the pressures and velocity results are printed from subroutine PHIDIF.

'Patch No. = ...'	Patch number of array of corner point.
'Column No. = ...'	Column number of array of corner points. When an array is common to two columns, the smaller column number is output.

MAIN OUTPUT OF CORNER POINT VALUES

KP	L	X	Y	Z	PHI	VX	VY	VZ	VT	CP
.	.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.	.

PHI is the panel doublet value (also the surface perturbation potential). KP is the subscript of the panel containing the corner points. When a point is common to two panels the smaller panel number is output. L is the location of the corner point relative to the panel. Numbering is 1 to 4, with 1 denoting the top left-hand corner. Other corners are numbered sequentially in an anticlockwise direction, e.g., see Figure 9.

After the wake shape iteration loop, the output from subroutine STLINE is printed (unless IBLTYP=0 and this is not the last viscous/potential flow solution).

STLN=n   Panel No. = ...   Side No. = ...   F = ...

n is the streamline number which is set sequentially by the order of data cards input. Other information output in the same line reproduces the input information on the data card, n, except for Side No. If NS was set to zero in the input, then Side No. is the value determined by the program.

The main output of points on the streamline are:

KP X Y Z   VX VY VZ   VT CP DS GK

where KP is the panel number; X, Y, Z the point coordinates; VX, VY, VZ, VT is the velocity vector and its magnitude; CP is the pressure coefficient; DS is the distance of the point along the streamline; and GK has the significance of geodesic curvature on a body. On a wing it serves as a measure of convergence or divergence of streamlines.

The output from the boundary layer routine follows if NVPI>0 on CARD 4(a). The calculated boundary layer characteristics are tabulated for each streamline and include the local shape parameter and skin friction coefficient. Each table is preceded by a summary of the streamline geometry and pressure distribution.

Output from the off-body velocity scan routine comes next. For each scan box the input data is printed first, followed by

I NBOX KOUNT

where I is the scan-plane subscript in the box, NBOX; KOUNT is a number written to the plot file (see below) to identify the scan plane. The velocity and pressure data is then printed point by point for each line in the plane.

K	X	Y	Z	VX	VY	VZ	V	C_p
.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.

This data is also written to the plot file (TAPE 7) except that KOUNT is substituted for K.

Output from the off-body streamline routine comes last. The input data for each streamline is followed by the streamline geometry and aerodynamic data.

J	X	Y	Z	VX	VY	VZ	V	C_p	M	S
.	.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.	.

Here, M is the local Mach number and S is the distance measured from the upstream end.

8.2 Plot File

During the execution of the program, an unformatted plot file (TAPE 7) is assembled as follows:

(i) Surface Panel Geometry

For each panel there are four records containing the four corner points.

NP, X1, Y1, Z1
NP, X2, Y2, Z2
NP, X3, Y3, Z3
NP, X4, Y4, Z4

There are N_s sets.

(ii) Wake Panel Geometry

The wake panel corner points are written in the same way as the surface panels except the counter NP starts at 3001. After each pass the wake panel geometry is terminated by

-IT, 0.0, 0.0, 0.0

where IT is the wake shape iteration number (MODE=1) or the time-step number (MODE=2).

For each cycle the aerodynamic data follows this line:

N_s (the total number of panels)

followed by N_s records:

NP, XC, YC, ZC, VX, VY, VZ, V, CP

If MODE=2, the last set of aerodynamic data is followed by the unsteady pressure analysis; i.e., N_s records of

NP, XC, YC, ZC, CP_R, CP_I, CP_{MOD}, PHASE

Off-body velocity data is placed next on the file

KOUNT, X, Y, Z, VX, VY, VZ, V, CP

where KCUNT starts at 6001 and is incremented by 1 for each scan line, 10 for a scan plane and 100 for a box.

-1, 0.0, 0.0, 0.0

The streamline data comes next. The first record is

NLINES

This is the total number of streamlines (i.e., on-body and off-body). This is followed by one record for each streamline.

IMAX, ((ST(J,K), J=1, 12), NPSL(K), K=L, IMAX)

where the quantities in the ST array include

X, Y, Z, VX, VY, VZ, V, CP, S

The NPSL(K) values are surface panel subscripts crossed by the streamline. Off-body streamlines are treated in a similar way but NPSL values are zero in this case. The streamline data is terminated with a -1 for NPSL.

Finally, the boundary layer data is placed on the tape with two records per surface streamline.

JLINE - the streamline number; and

KPOINT, (D(K), K=1, 13)

The records are terminated by setting JLINE=-1.

The boundary layer parameters are:

D(1) = x-coordinate
D(2) = y-coordinate
D(3) = z-coordinate
D(4) = s, distance along streamline
D(5) = v, velocity
D(6) = $\partial u/\partial s$, rate of change of velocity along s direction
D(7) = H, shape factor
D(8) = δ, displacement thickness
D(9) = THT, momentum thickness
D(10) = RTH, Reynolds number based on momentum thickness
D(11) = CFD, skin friction drag
D(12) = CDS, skin friction from Squire and Young formula
D(13) = Displacement thickness divided by y-coordinate

9.0 REFERENCES

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8. Dvorak, F.A., Maskew, B. and Woodward, F.A., 'Investigation of Three-Dimensional Flow Separation on Fuselage Configurations', USAAMRDL-TR-77-4, Eustis Directorate, U.S. Army Air Mobility Research and Development Laboratory, Fort Eustis, VA 23604, March 1977.

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APPENDIX: SAMPLE CASE

In the following pages the input and output are given for the wing-body configuration shown in Figure A1. The way the surface has been broken into seven patches is shown in Figure A2(a). Each patch is illustrated separately in Figures A2(b) through (h), showing the form of input.

The figures are followed by a listing of the complete input deck. Finally, samples from the program output file are given.

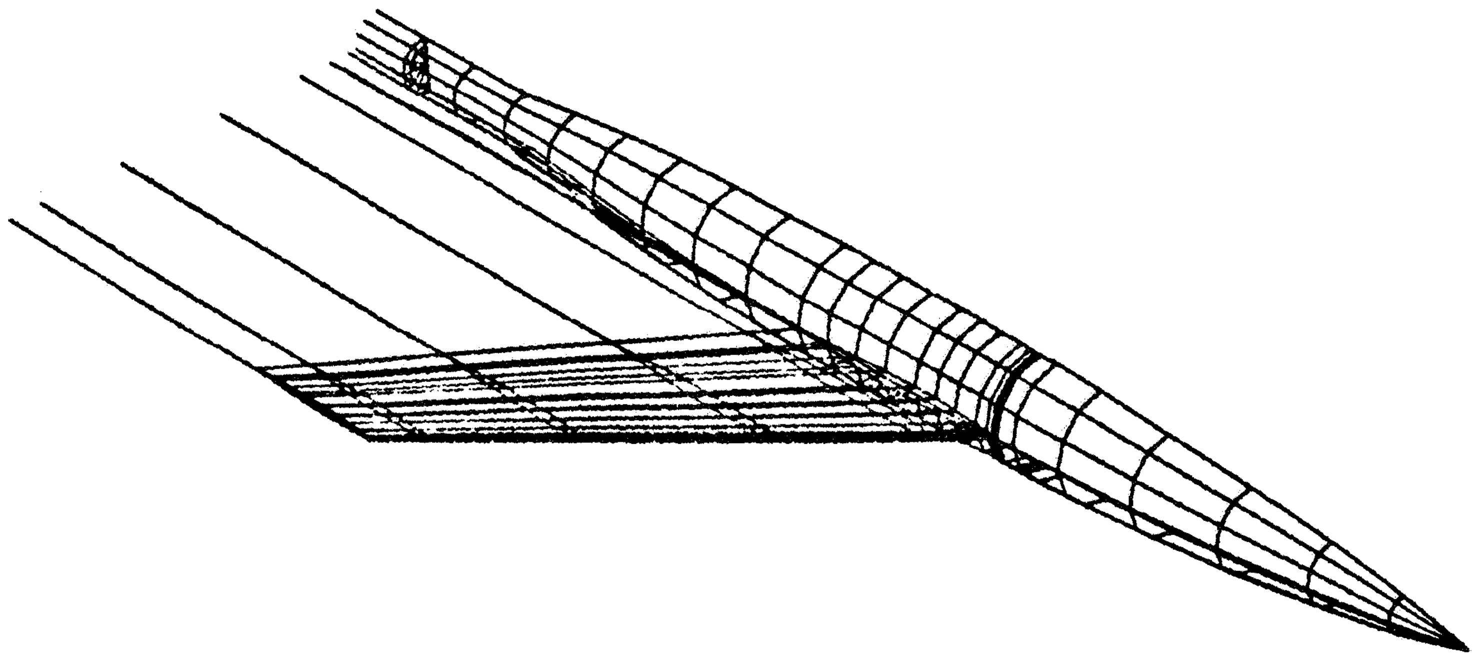


Figure A1. Wing-Body Sample Case

WING-BODY AERODYNAMICS,TEST CASE

XVUE= -100.00 YVUE= 100.00 ZVUE= 100.00

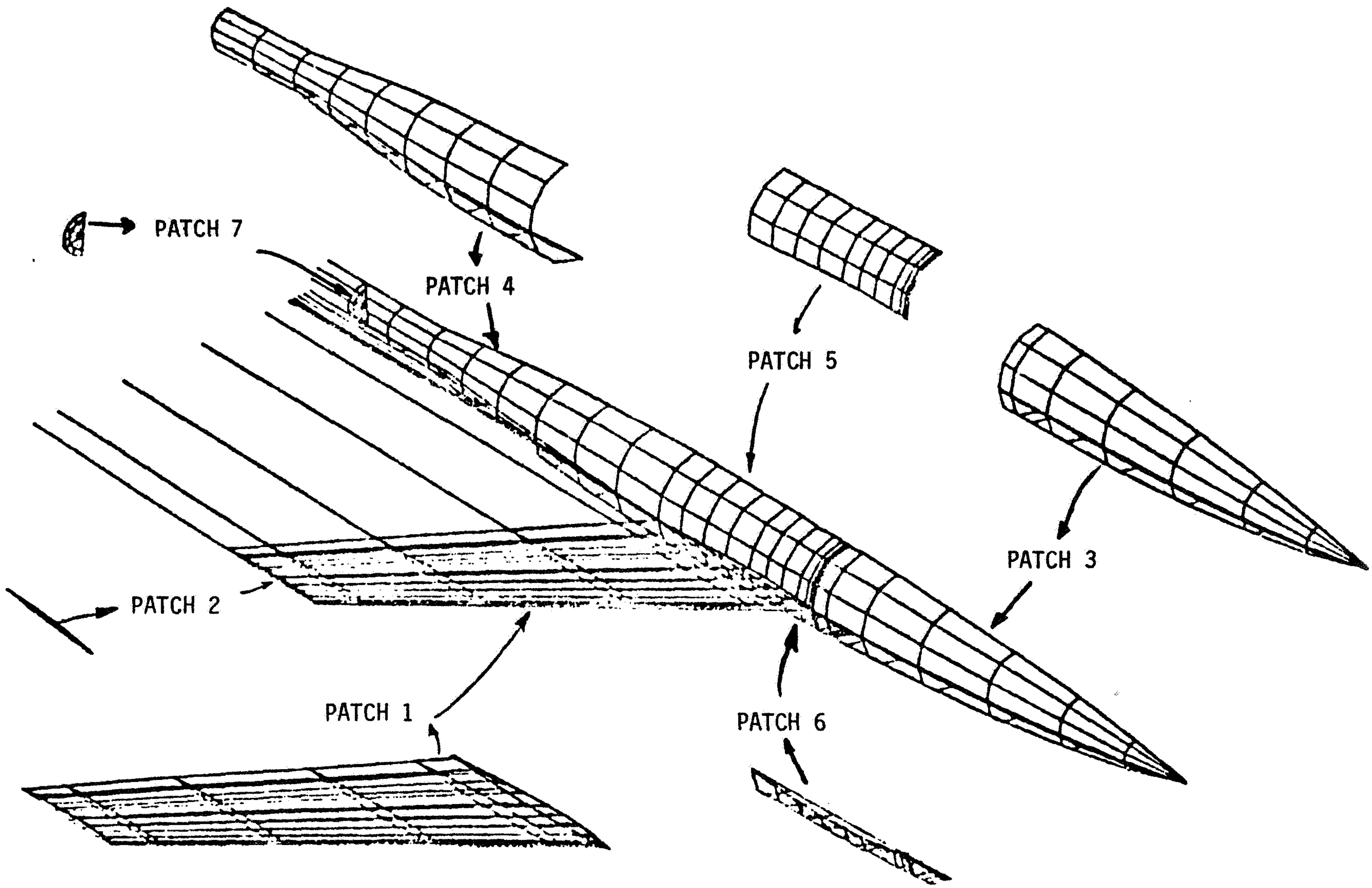
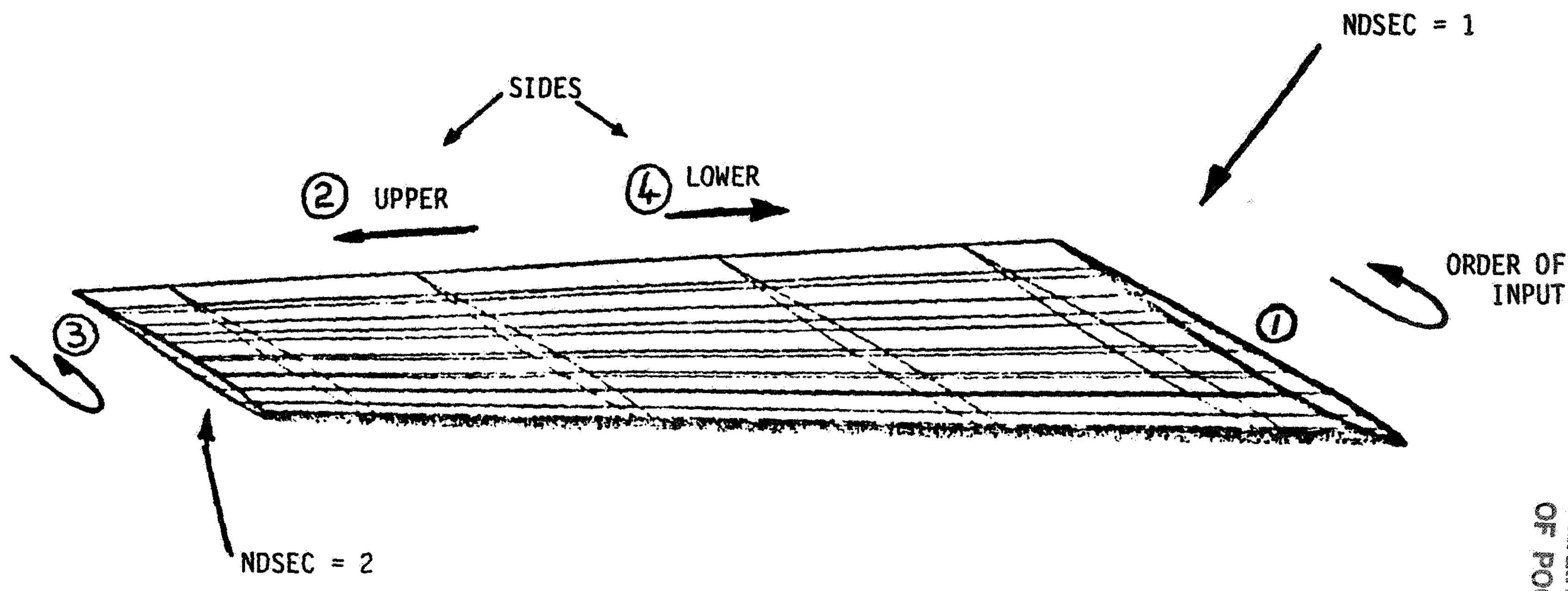


Figure A2 Patch Arrangement. (a) General View

WING-BODY AERODYNAMICS,TEST CASE

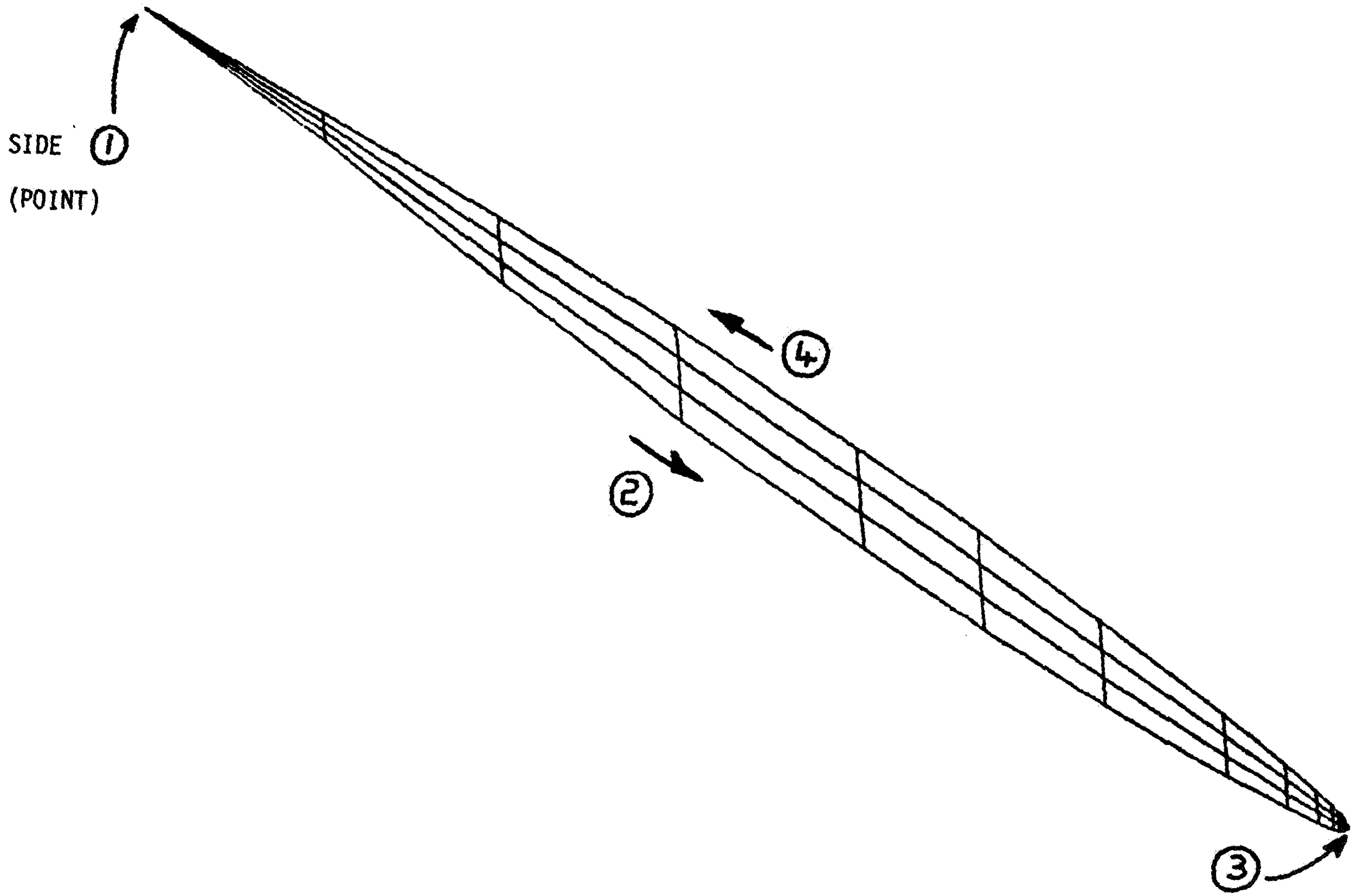
XVUE= -100.00 YVUE= 100.00 ZVUE= 100.00



WING-BODY AERODYNAMICS,TEST CASE

Figure A2(b). Patch 1, Wing.

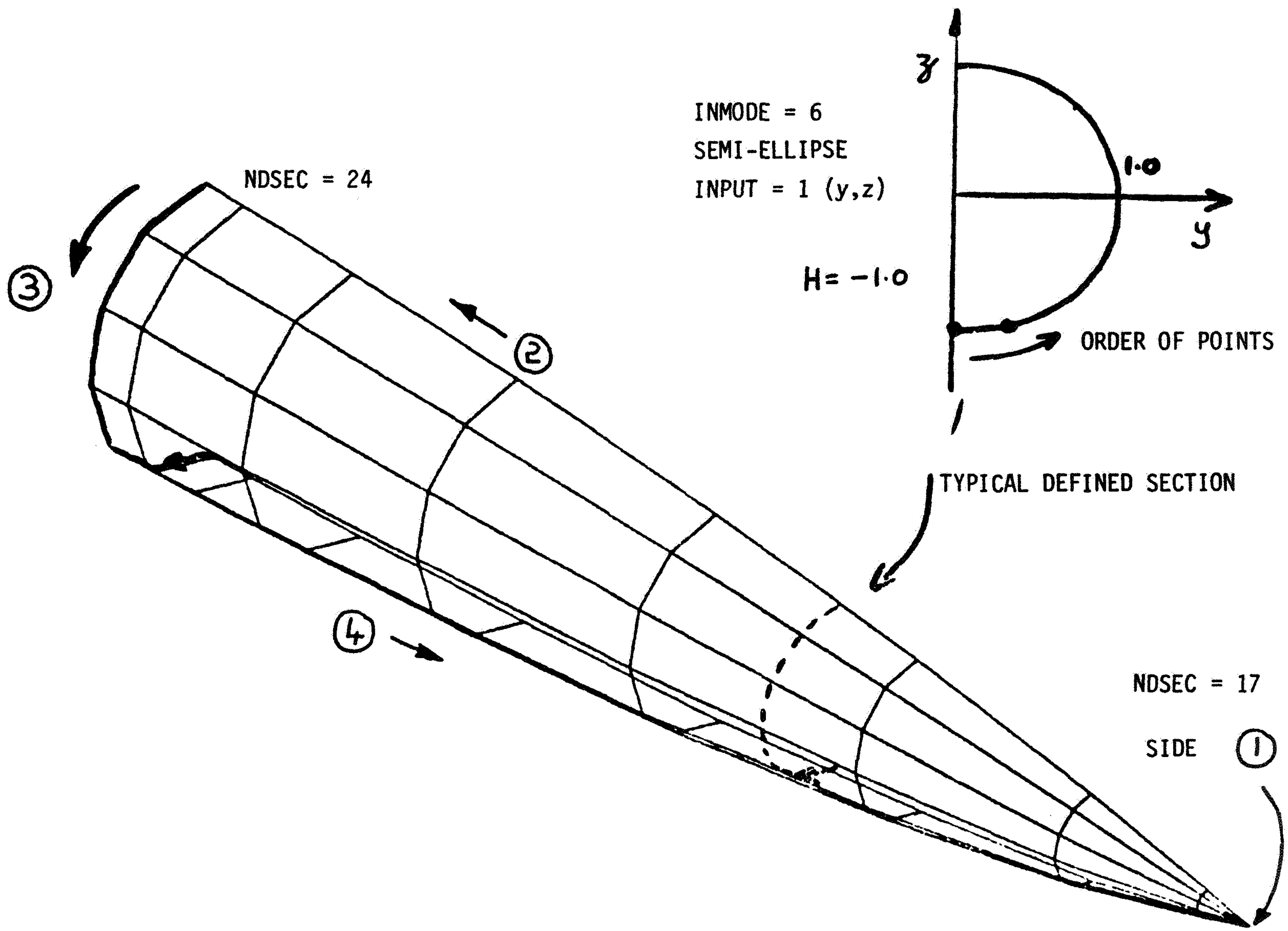
XVUE= -100.00 YVUE= 100.00 ZVUE= 100.00



WING-BODY AERODYNAMICS,TEST CASE

Figure A2(c). Patch 2, Wing Tip.

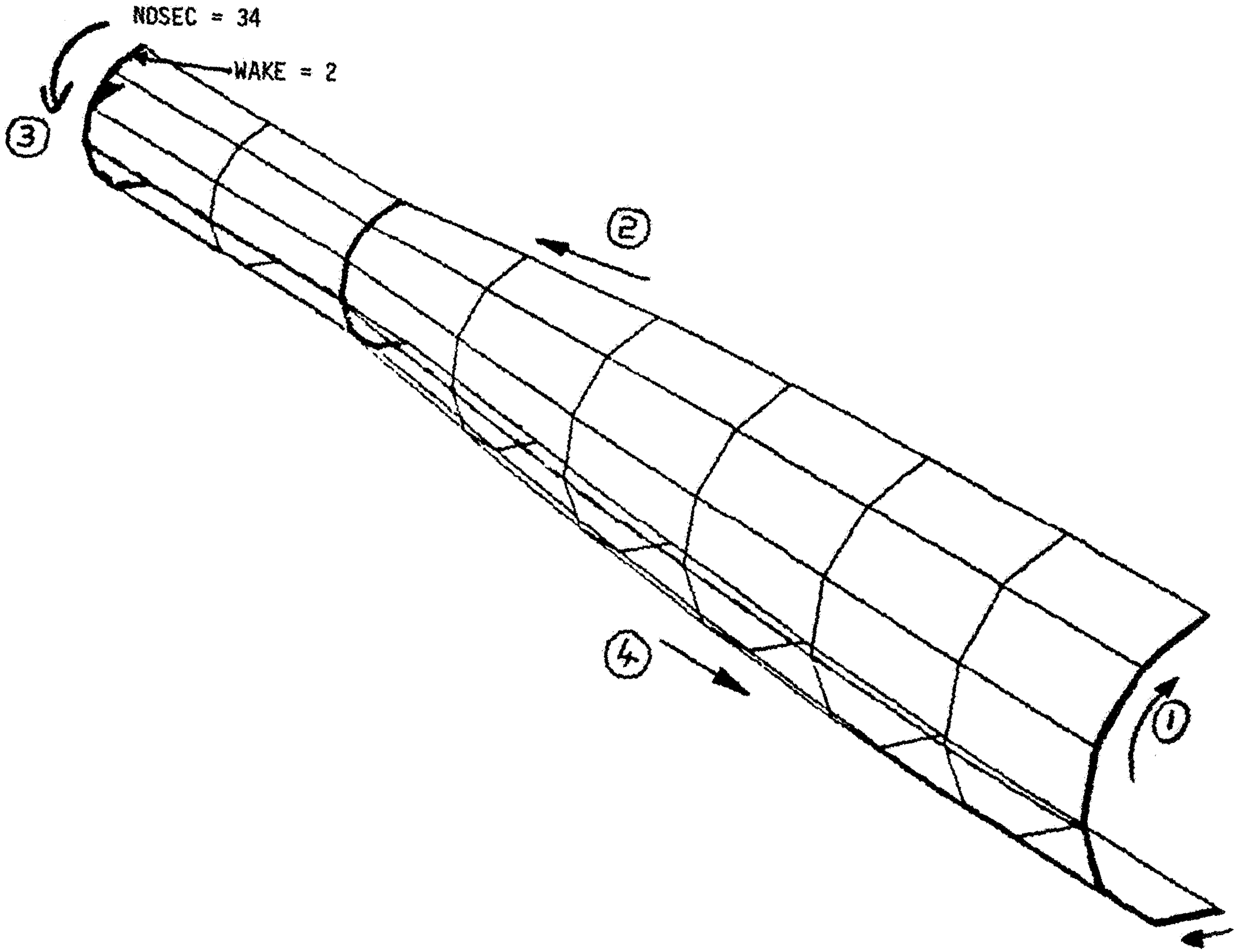
XVUE= -100.00 YVUE= 100.00 ZVUE= 100.00



WING-BODY AERODYNAMICS,TEST CASE

Figure A2(d). Patch 3, Forebody.

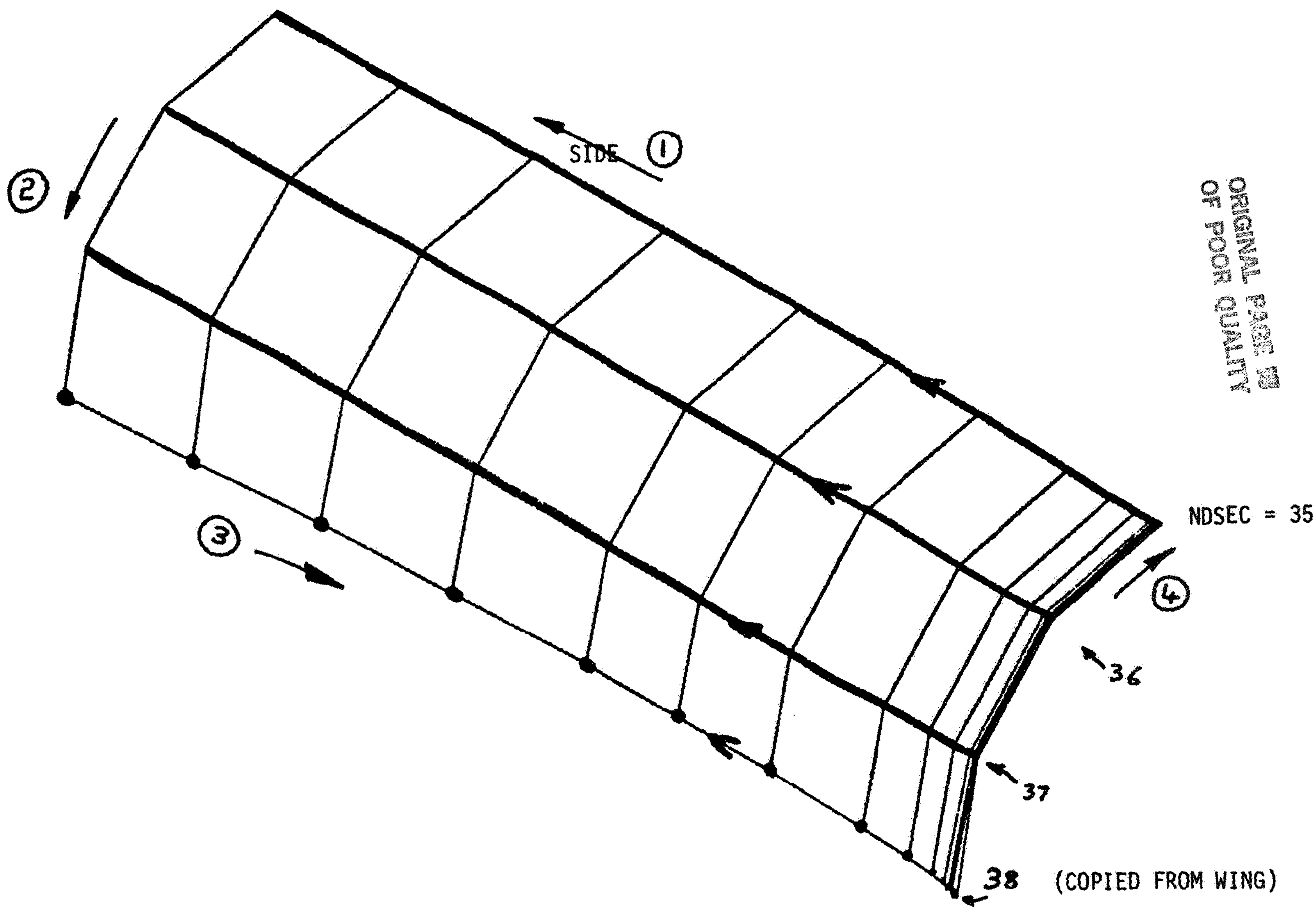
XVUE= -100.00 YVUE= 100.00 ZVUE= 100.00



WING-BODY AERODYNAMICS,TEST CASE

Figure A2(e). Patch 4, Aft Body

XVUE= -100.00 YVUE= 100.00 ZVUE= 100.00



WING-BODY AERODYNAMICS,TEST CASE

Figure 2(f). Patch 5, Mid-Body Upper.

XVUE= -100.00 YVUE= 100.00 ZVUE= 100.00

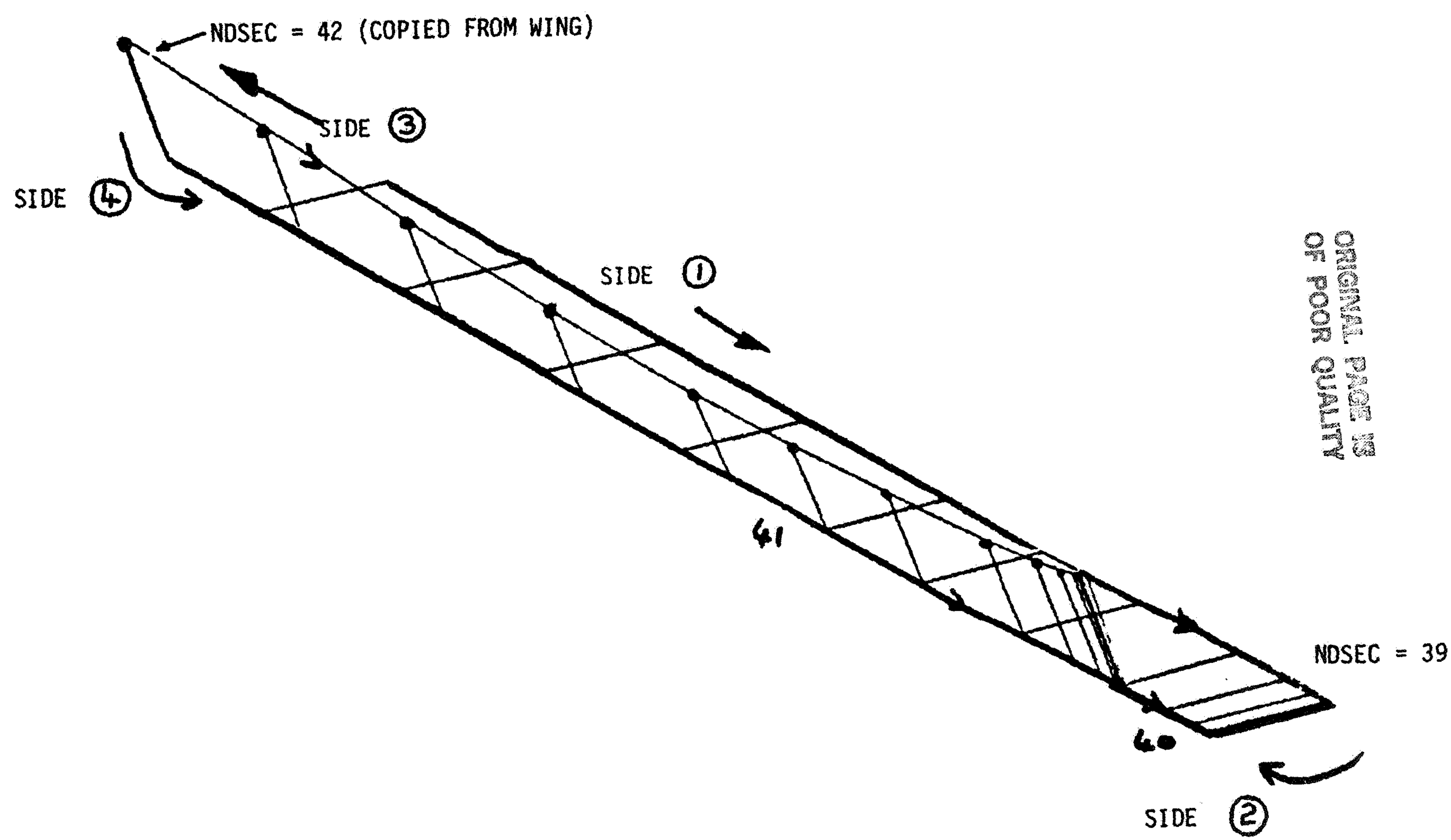
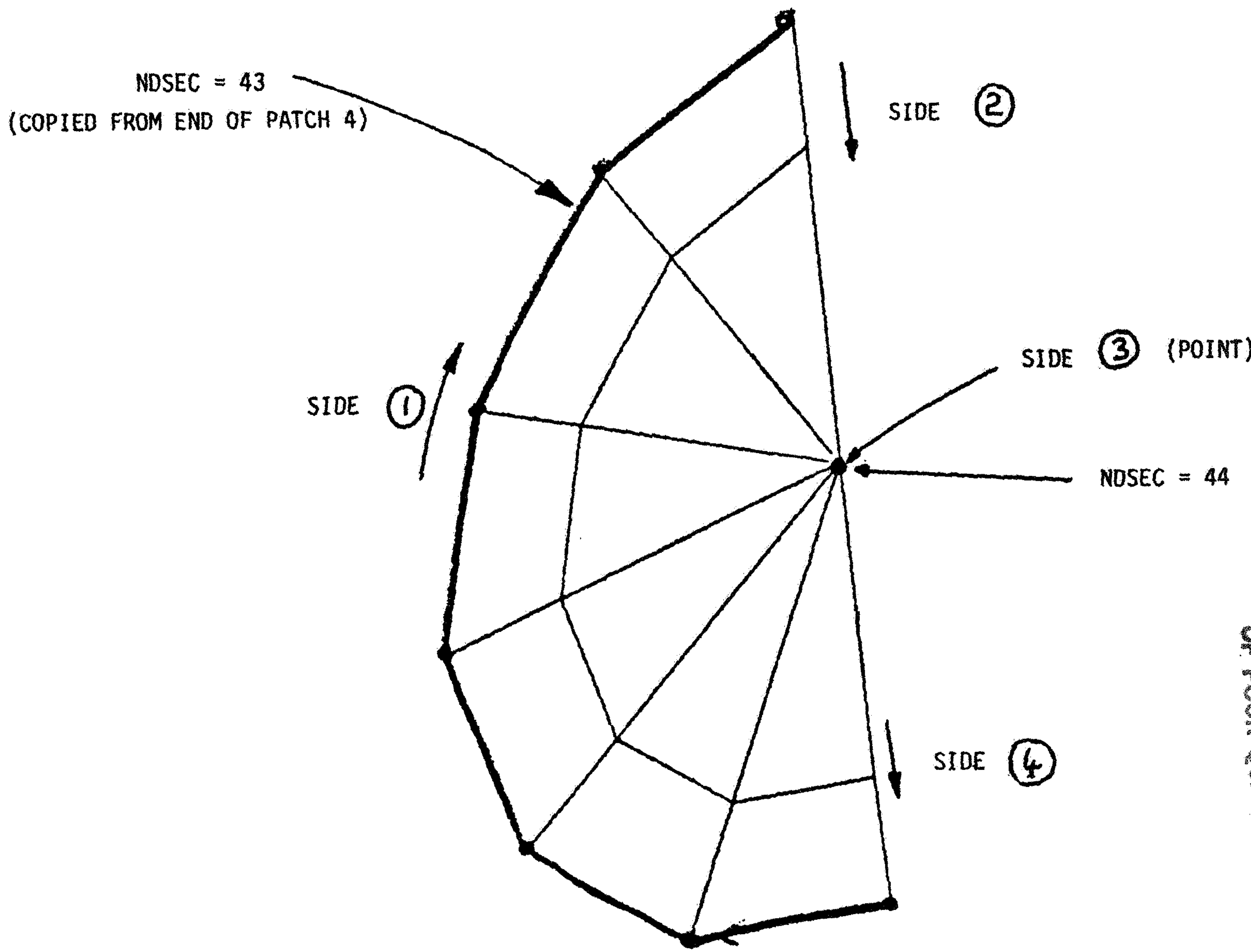


Figure A2(q). Patch 6, Mid-Body Lower

WING-BODY AERODYNAMICS,TEST CASE

XVUE= -100.00 YVUE= 100.00 ZVUE= 100.00



WING-BODY AERODYNAMICS,TEST CASE   Figure A2(h). Patch 7, Body Base.

XVUE= -100.00   YVUE= 100.00   ZVUE= 100.00

INPUT LISTING

ORIGINAL PAGE IS
OF POOR QUALITY

```
 WING/BODY TEST CASE
     1     0     1
     1   500
     0     1     1
0. 0
10. 0
6. 05      145. 2     12. 0      0. 0       0. 0       0. 0
                         2
  304     3    26     1
  331     3     1     1

     1     0     1     1  WING
14. 325    1. 6       0. 0       . 071      0. 0       0. 0              2
100. 0     0. 0       . 8592
85. 0      - 865      . 9718
70. 0      -1. 935    . 9718
55. 0      -2 741     . 9310
40. 0      -2. 998    . 662
30. 0      -2. 852    . 507
20. 0      -2. 482    . 3099
10. 0      -1. 824    . 0634
5. 0       -1 310     -. 0704
2. 5       -. 956     -. 1408
1. 25      -. 717     -. 169
0. 75      -. 574     -. 1972
0. 5       -. 476     -. 2183
0. 0       0. 0       -. 2254
                                    1
   5        . 476     -. 2183
0. 75       . 574     -. 1972
1. 25       . 717     -. 169
2. 5        . 956     -  1408
5. 0        1. 310    -. 0704
10. 0       1. 824    . 0634
20. 0       2. 482    . 3099
30. 0       2. 852    . 507
40. 0       2. 998    . 662
55. 0       2. 741    . 9310
70. 0       1  935    . 9718
85. 0      0. 865     . 9718
100. 0     0. 0       . 8592
                                    3
25. 375    12. 0      0. 0       . 045                                   2     3     5     (
100. 0     0. 0
85. 0      -. 865
70. 0      -1. 935
55. 0      -2. 741
40. 0      -2. 998
30. 0      -2  852
20. 0      -2  482
10. 0      -1. 824
5. 0       -1. 310
2. 5       -. 956
1. 25      -  717
   75      -. 574
0. 5       -. 476
0  0       0  0
                                    1
0  5        476
0  75      . 574
```

```
1.25        .717
2.5         .956
5.0        1.310
10.0       1.824
   0       2.482
30.0       2.852
40.0       2.998
55.0       2.741
70.0       1.935
85.0       0.865
100.0      0.0
                                         3
    2    1    1    1  WING TIP
                                              3     3     0                   3     0
    2    0    1    1  FOREBODY
0.0       0.0      0 0        0.0        0.0        0.0              6
-1.0                1
0.0                 6
                                         3
2.0       0.0       0.0       .4830      0.0        0.0              0
4.0       0.0       0.0       .7900      0.0        0.0              0
6.0       0.0       0.0      1.0775      0.0        0.0              0
8.0        .0       0.0      1.2359      0.0        0.0              0
10.0       0        0.0      1.3880      0.0        0.0              0
12.0      0.0       0.0      1.5000      0.0        0.0              0
14.325    0.0       0.0      1.5840      0.0        0.0              0    3    8
    2    0    1    0  AFT BODY
21.425    0.0       0.0      1.66        0.0        0.0              0
22.0      0.0       0.0      1.655       0.0        0.0              0
   .0     0.0       0.0      1.610       0.0        0.0              0
26.0      0.0       0.0      1.540       0.0        0.0              0
28.0      0.0       0.0      1.428       0.0        0.0              0
30.0      0.0       0.0      1.253       0.0        0.0              0
32.0      0.0       0.0      1.0241      0.0        0.0              0
34.0      0.0       0.0      0.8         0.0        0.0              0
36.0      0.0       0.0      0.8         0.0        0.0              0
38.0      0.0       0.0      0.8         0.0        0.0              0    3    8
    2    0    1    0  MID-BODY UPPER
14.325    0.0       0.0      1.0         0.0       -90.0             1
0.0        1.584
.015       1.585
.035       1.586
.065       1.587
.175       1.59
.365       1.595
.715       1.604
1.435      1.622
2.145      1.638
2.855      1.648
3.925      1.661
4.975      1.669
6.055      1.669
7.10       1.66
                                         3
14.325    0.0       0.0      1.0        -30.0      -90.0             0
 4.325    0.0       0.0      1.0        -60.0      -90.0             0
14.325    1.6       0.0       .071       0 0        0.0              2    3    0
                                        -3     0     0
    1    1   14   27
    2    0    1    0  MID-BODY LOWER
```

```
14 325    0 0       0.0       1 0       0 0       -90.0         1
7.10      -1.66
 .055     -1.669
+975      -1.669
3.925     -1.661
2.855     -1.648
2.145     -1.638
1.435     -1.622
.715      -1.604
.365      -1.595
.175      -1 59
.065      -1.587
.035      -1.586
.015      -1.585
0.0       -1.584
                                    3
14 325    0.0       0 0       1 0       30.0      -90.0         0
14.325    0.0       0.0       1 0       60.0      -90.0         0
14.325    1.6       0.0       .071      0.0       0.0           2    3    0
                                   -3    0    0
    1    1    1    14
    2    0    1    0   BODY BASE
38 0      0.0       0.0       0.8       0.0       0.0           1
                                   -3    0    0
    4   10
38.0      0.0       0.0       1.0       0.0       0.0           1    5    2
0.0       0.0
 .0       0.0
                                    3    6    3

14.0
40.0
                                    1    5    1
60.0
                                    3    3    1
    1    0    0    0   WING WAKE
    1    2    0    0    0  . 2
100.
                                    3    5    1
                                    3
    4    1    0    0   BODY BASE SEPARATION
    4    3    0    1    6    2
100.
                                    3    5    1
                                    5
0.0       1.0
0.5          21
0.5          47
0.5          10
0.5          12
2.0
4.0       1 0       1.0       10.       - 10.
```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****

ANALYTICAL METHODS, INC.

PROGRAM VSAERO-3000

FLOW ANALYSIS METHOD

FOR GENERAL CONFIGURATIONS

CONTACT. BRIAN MASKEW (206) 643 9090

****
WING/BODY TEST CASE

****

```
INPUT LIST FOR BASIC DATA IN SUBROUTINE INDAT/
**********************************************

(VARIABLES ARE IDENTIFIED IN PARENTHESES FOR CONVENIENCE)


  (IPRI IPRLEV IPRESS  MSTOP MSTART MODIFY)
     1      0      1      0      0      0

  (MODE NPNMAX NRBMAX ITGSMX IMERGE   NSUB NSPMAX NPCMAX)
     1    500      0      0      0      0      0      0

  (NWIT   NVPI IBLTYP)
     0      1      1

    (RSYM       RGPR        RNF         RFF         RCORE       SOLRES      TOL)
   0.00000     0.00000     0.00000     0.00000     0.00000     0.00000     0.00000

    (ALDEG      YAWDEG      RMACH       VMOD        COMFAC)
  10.00000     0.00000     0.00000     0.00000     0.00000

    (CBAR       SREF        SSPAN       RMPX        RMPY        RMPZ)
  6.0500     145.2000     12.0000     0.0000      0.0000      0.0000

(NORSET  NVORT NPASUM JETPAN NBCHGE)
     0      0      0      0      2

  (KPAN  KSIDE NEWNAB NEWSID)
    304      3     26      1
    331      3      1      1

(END OF INPUT LIST FOR BASIC DATA)

***********************************
```

```
INPUT LIST FOR PATCH GEOMETRY IN SUBROUTINE GEOMIN/  (AT LEVEL IPRI=    1 )
****************************************************

   (CTX      CTY      CTZ      SCAL      THET)
  0.00000  0.00000  0.00000  0.00000  0.00000                                                        (NCOMP=  1 )

 (IDENT   MAKE   KOMP  KLASS)          ********************
     1      0      1      1              WING                                               (NPATCH=   1 )
                                       ********************

   (STX      STY      STZ      SCALE      ALF       THETA INMODE NODES NPS INTS)
 14.32500  1.60000  0.00000  0.07100  0.00000  0.00000     2     0    0    0         (NDSEC=   1)
   (BX       BZ       DELY        (  NBP  )

                               (NODEC    NPC    INTC)
                                    1      0      0
                                                    (END OF CHORDWISE REGION    1 )


   (BX       BZ       DELY        (  NBP  )

                               (NODEC    NPC    INTC)
                                    3      0      0
                                                    (END OF CHORDWISE REGION    2 )

   (STX      STY      STZ      SCALE      ALF       THETA INMODE NODES NPS INTS)
 25.37500 12.00000  0.00000  0.04500  0.00000  0.00000     2     3    5    0         (NDSEC=   2)
   (BX       BZ       DELY        (  NBP  )

                               (NODEC    NPC    INTC)
                                    1      0      0
                                                    (END OF CHORDWISE REGION    3 )


   (BX       BZ       DELY        (  NBP  )

                               (NODEC    NPC    INTC)
                                    3      0      0
                                                    (END OF CHORDWISE REGION    4 )

 (IDENT   MAKE   KOMP  KLASS)          ********************
     2      1      1      1              WING TIP                                           (NPATCH=   2 )
                                       ********************


                                   (NPC INTC KURV NPTIP           NODES NPS INTS          AUTOMATIC TIP PATCH)
                                     2    2    0    0                 3    0    0
```

```
(IDENT   MAKE   KOMP   KLASS)          ********************
   2       0      1      1               FOREBODY                                        (NPATCH=   3 )
                                        ********************

   (STX       STY       STZ       SCALE      ALF       THETA  INMODE NODES NPS  INTS)
 0.00000   0.00000   0.00000   0.00000   0.00000   0.00000      6      0    0    0        (NDSEC=  17)

   (H       INPUT           SEMI-ELLIPSE GENERATED)
 -1.000       1

  (XRB    NINT)
 0.00000    6

                              (NODEC    NPC    INTC)
                                  3       0      0
                                                     (END OF CHORDWISE REGION    19 )

   (STX       STY       STZ       SCALE      ALF       THETA  INMODE NODES NPS  INTS)
 2.00000   0.00000   0.00000   0.48300   0.00000   0.00000      0      0    0    0        (NDSEC=  18)
   (STX       STY       STZ       SCALE      ALF       THETA  INMODE NODES NPS  INTS)
 4.00000   0.00000   0.00000   0.79000   0.00000   0.00000      0      0    0    0        (NDSEC=  19)
   (STX       STY       STZ       SCALE      ALF       THETA  INMODE NODES NPS  INTS)
 6.00000   0.00000   0.00000   1.07750   0.00000   0.00000      0      0    0    0        (NDSEC=  20)
   (STX       STY       STZ       SCALE      ALF       THETA  INMODE NODES NPS  INTS)
 8.00000   0.00000   0.00000   1.23590   0.00000   0.00000      0      0    0    0        (NDSEC=  21)
   (STX       STY       STZ       SCALE      ALF       THETA  INMODE NODES NPS  INTS)
10.00000   0.00000   0.00000   1.38800   0.00000   0.00000      0      0    0    0        (NDSEC=  22)
   (STX       STY       STZ       SCALE      ALF       THETA  INMODE NODES NPS  INTS)
12.00000   0.00000   0.00000   1.50000   0.00000   0.00000      0      0    0    0        (NDSEC=  23)
   (STX       STY       STZ       SCALE      ALF       THETA  INMODE NODES NPS  INTS)
14.32500   0.00000   0.00000   1.58400   0.00000   0.00000      0      3    8    0        (NDSEC=  24)
```

(IDENT MAKE KOMP KLASS)
2 0 1 0

****
AFT BODY
****

(NPATCH= 4)

(STX	STY	STZ	SCALE	ALF	THETA	INMODE	NODES	NPS	INTS)	
21.42500	0.00000	0.00000	1.66000	0.00000	0.00000	0	0	0	0	(NDSEC= 25)
22.00000	0.00000	0.00000	1.65500	0.00000	0.00000	0	0	0	0	(NDSEC= 26)
24.00000	0.00000	0.00000	1.61000	0.00000	0.00000	0	0	0	0	(NDSEC= 27)
26.00000	0.00000	0.00000	1.54000	0.00000	0.00000	0	0	0	0	(NDSEC= 28)
28.00000	0.00000	0.00000	1.42800	0.00000	0.00000	0	0	0	0	(NDSEC= 29)
30.00000	0.00000	0.00000	1.25300	0.00000	0.00000	0	0	0	0	(NDSEC= 30)
32.00000	0.00000	0.00000	1.02410	0.00000	0.00000	0	0	0	0	(NDSEC= 31)
34.00000	0.00000	0.00000	0.80000	0.00000	0.00000	0	0	0	0	(NDSEC= 32)
36.00000	0.00000	0.00000	0.80000	0.00000	0.00000	0	0	0	0	(NDSEC= 33)
38.00000	0.00000	0.00000	0.80000	0.00000	0.00000	0	3	8	3	(NDSEC= 34)

```
(IDENT   MAKE   KOMP   KLASS)          ********************
    2      0      1       0              MID-BODY UPPER                                                    (NPATCH=    5 )
                                       ********************

   (STX       STY        STZ        SCALE       ALF        THETA INMODE NODES NPS INTS)
 14.32500   0.00000    0.00000    1.00000    0.00000  -90.00000      1     0    0    0           (NDSEC=  35)

   (BY        BZ         DELX          (  NBP  )

                                   (NODEC    NPC    INTC)
                                        3      0       0

                                                         (END OF CHORDWISE REGION   37 )

   (STX       STY        STZ        SCALE       ALF        THETA INMODE NODES NPS INTS)
 14 32500   0 00000    0.00000    1 00000  -30.00000  -90.00000      0     0    0    0           (NDSEC=  36)
   (STX       STY        STZ        SCALE       ALF        THETA INMODE NODES NPS INTS)
 14.32500   0 00000    0.00000    1 00000  -60.00000  -90.00000      0     0    0    0           (NDSEC=  37)
   (STX       STY        STZ        SCALE       ALF        THETA INMODE NODES NPS INTS)
 14 32500   1 60000    0.00000    0.07100    0.00000    0 00000      2     3    0    0           (NDSEC=  38)
   (BX        BZ         DELY          (  NBP  )

                                   (NODEC    NPC    INTC)
                                       -3      0       0

 (IP    IS    IB    LB            COPIED DATA)
   1     1    14    27
```

```
(IDENT   MAKE   KOMP  KLASS)          ********************
    2       0      1      0              MID-BODY LOWER                                                    (NPATCH=    6 )
                                      ********************

   (STX       STY       STZ       SCALE      ALF       THETA INMODE NODES NPS  INTS)
 14.32500   0.00000   0.00000   1.00000   0.00000  -90.00000     1     0    0     0        (NDSEC=  39)

   (BY        BZ        DELX        (  NBP  )

                               (NODEC     NPC    INTC)
                                    3       0       0
                                                   (END OF CHORDWISE REGION   41  )

   (STX       STY       STZ       SCALE      ALF       THETA INMODE NODES NPS  INTS)
 14.32500   0.00000   0.00000   1.00000  30.00000  -90.00000     0     0    0     0        (NDSEC=  40)
   (STX       STY       STZ       SCALE      ALF       THETA INMODE NODES NPS  INTS)
 14.32500   0.00000   0.00000   1.00000  60.00000  -90.00000     0     0    0     0        (NDSEC=  41)
   (STX       STY       STZ       SCALE      ALF       THETA INMODE NODES NPS  INTS)
 14.32500   1.60000   0.00000   0.07100   0.00000    0.00000     2     3    0     0        (NDSEC=  42)

   (BX        BZ        DELY        (  NBP  )

                               (NODEC     NPC    INTC)
                                   -3       0       0

 (IP    IS    IB    LB            COPIED DATA)
   1     1     1    14
```

ORIGINAL PAGE IS
OF POOR QUALITY

```
(IDENT   MAKE   KOMP  KLASS)          ********************
    2      0      1      0              BODY BASE                                    (NPATCH=    7 )
                                      ********************

   (STX       STY        STZ        SCALE      ALF        THETA INMODE NODES NPS INTS)
38.00000   0.00000    0.00000    0.80000    0.00000    0.00000      1     0    0    0        (NDSEC=  43)

     (BY        BZ        DELX          (  NBP  )

                                     (NODEC     NPC     INTC)
                                         -3       0        0

   (IP   IS   IB   LB              COPIED DATA)
     4   10    0    0

     (STX       STY        STZ        SCALE      ALF        THETA INMODE NODES NPS INTS)
  38.00000   0.00000    0.00000    1.00000    0.00000    0.00000      1     5    2    1        (NDSEC=  44)

     (BY        BZ        DELX          (  NBP  )

                                     (NODEC     NPC     INTC)
                                          3       6        3
                                                          (END OF CHORDWISE REGION   46 )


 (END OF INPUT LIST FOR PATCH GEOMETRY)

 ****************************************
```

BASIC PATCH DATA

M	IDENT	KOMP	KLASS	NROW	NCOL	IPAN	LPAN	NPAN	
1	1	1	1	26	5	1	130	130	WING
2	2	1	1	3	13	131	169	39	WING TIP
3	2	1	1	6	8	170	217	48	FOREBODY
4	2	1	1	6	8	218	265	48	AFT BODY
5	2	1	1	13	3	266	304	39	MID-BODY UPPER
6	2	1	1	13	3	305	343	39	MID-BODY LOWER
7	2	1	1	6	2	344	355	12	BODY BASE

```
GEOMIN TIME     0.186

SURPAN TIME     0.332

CONECT TIME     0.220

SURPHI TIME     4.937
```

```
INPUT LIST FOR WAKE DATA IN SUBROUTINE WAKCOM/
*******************************************************

(VARIABLES ARE IDENTIFIED IN PARENTHESES FOR CONVENIENCE)


    (DX      ( NBP ))          (BASIC POINTS FOR WAKE-GRID-PLANE STATIONS IN SUBROUTINE WGRID)
   0.0000    (   1 )
  14.0000    (   2 )
  40.0000    (   3 )

                              (NODE  NPC INTC)
                                  1    5    1
  60.0000    (   4 )

                              (NODE  NPC INTC)
                                  3    3    1

(IDENTW IFLEXW  IDEFW)                ********************
      1      0      0                   WING WAKE                                          (NWAKE=   1 )
                                      ********************

(KWPACH KWSIDE KWLINE KWPAN1 KWPAN2  INPUT NODEWS IDWCOL IFLEXL     DTHET)
      1      2      0      0      0      2      0      0      0   0.00000

    (SWPX       SWPZ      DELY)        ( NSWP )
 100.00000   0.00000   0.00000        (    1 )

                              (NODEWC     NPC     INTC)
                                   3        5        1

(KWPACH KWSIDE KWLINE KWPAN1 KWPAN2  INPUT NODEWS IDWCOL IFLEXL     DTHET)
      0      0      0      0      0      0      3      0      0   0.00000
                                                            (LAST SECTION ON WAKE    1 )
```

```
(IDENTW IFLEXW   IDEFW)                    ********************
      4      1       0                       BODY BASE SEPARATION                                          (NWAKE=    2 )
                                           ********************

(KWPACH KWSIDE KWLINE KWPAN1 KWPAN2  INPUT NODEWS IDWCOL IFLEXL      DTHET)
      4      3      0      1      6      2      0      0      0    0.00000

     (SWPX      SWPZ      DELY)        ( NSWP )
 100.00000   0.00000   0.00000         (    1 )

                                   (NODEWC     NPC    INTC)
                                         3       5       1

(KWPACH KWSIDE KWLINE KWPAN1 KWPAN2  INPUT NODEWS IDWCOL IFLEXL      DTHET)
      0      0      0      0      0      0      5      0      0    0.00000
                                                                          (LAST SECTION ON WAKE    2 )
    (EFFLUX VELOCITIES ON TYPE 4 WAKE      VINNER, VOUTER)

       0.00000   1.00000        0.00000   0.00000       0.00000   0.00000       0.00000   0.00000

(END OF INPUT LIST FOR WAKE DATA)

*******************************************

WAKE-GRID-PLANE STATIONS
     0.0000      1.9577      7.6393      16.4886     27.6393     40.0000     42.6795     50.0000     60.0000

WAKCOM TIME     0.249
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WAKE ITERATION 1

ALPHA= 10.0000

WAKPAN TIME 0.026

PHIMAT TIME 1.665

DUBSOL TIME 4.946

PRESSURE DISTRIBUTION ON PATCH 1 WING

COLUMN 1

K	X	Y	Z	DUB	VX	VY	VZ	V	CP	X/C	Z/C
1	21.30526	2.15845	-0.03017	0.82845	0.96522	-0.01446	0.05601	0.96695	0.06501	0.92500	-0.43250E-02
2	20.25888	2.16226	-0.09766	0.80485	0.97336	-0.01032	0.07004	0.97593	0.04756	0.77500	-0.14000E-01
3	19.21250	2.16088	-0.16310	0.78904	0.97415	-0.01144	0.05295	0.97565	0.04810	0.62500	-0.23380E-01
4	18.16612	2.15041	-0.20017	0.76891	0.95454	-0.00241	0.01653	0.95469	0.08857	0.47500	-0.28695E-01
5	17.29414	2.13607	-0.20404	0.73014	0.91698	0.01978	-0.01326	0.91729	0.15857	0.35000	-0.29250E-01
6	16.59656	2.12417	-0.18605	0.67356	0.87766	0.05357	-0.03083	0.87983	0.22589	0.25000	-0.26670E-01
7	15.89897	2.10918	-0.15019	0.59257	0.81275	0.11585	-0.04627	0.82227	0.32387	0.15000	-0.21530E-01
8	15.37578	2.09632	-0.10931	0.49629	0.69714	0.24638	-0.04557	0.74080	0.45122	0.75000E-01	-0.15670E-01
9	15.11419	2.08942	-0.07904	0.41872	0.55230	0.42727	-0.01376	0.69842	0.51221	0.37500E-01	-0.11330E-01
10	14.98339	2.08608	-0.05835	0.36062	0.37341	0.64835	0.06238	0.75079	0.43632	0.18750E-01	-0.83650E-02
11	14.92235	2.08418	-0.04503	0.32148	0.18460	0.87542	0.22679	0.92297	0.14812	0.10000E-01	-0.64550E-02
12	14.89619	2.08251	-0.03662	0.29982	-0.00336	1.09080	0.49900	1.19953	-0.43886	0.62500E-02	-0.52500E-02
13	14.87003	2.08156	-0.01660	0.26114	0.00665	1.11115	1.13242	1.58653	-1.51708	0.25000E-02	-0.23800E-02
14	14.87003	2.08156	0.01660	0.16512	1.45740	-0.62757	2.05121	2.59332	-5.72533	0.25000E-02	0.23800E-02
15	14.89619	2.08251	0.03662	0.11899	1.86372	-1.02123	1.26594	2.47366	-5.11900	0.62500E-02	0.52500E-02
16	14.92235	2.08418	0.04503	0.09318	1.75653	-0.88854	0.82047	2.13262	-3.54808	0.10000E-01	0.64550E-02
17	14.98339	2.08608	0.05835	0.04781	1.61075	-0.70274	0.46218	1.81714	-2.30199	0.18750E-01	0.83650E-02
18	15.11419	2.08942	0.07904	-0.01875	1.44104	-0.48220	0.28559	1.54618	-1.39068	0.37500E-01	0.11330E-01
19	15.37578	2.09632	0.10931	-0.11324	1.32100	-0.31181	0.17536	1.36858	-0.87302	0.75000E-01	0.15670E-01
20	15.89897	2.10918	0.15019	-0.25096	1.23771	-0.18950	0.09782	1.25595	-0.57742	0.15000	0.21530E-01
21	16.59656	2.12417	0.18605	-0.40246	1.20024	-0.12894	0.05119	1.20823	-0.45983	0.25000	0.26670E-01
22	17.29414	2.13607	0.20404	-0.54185	1.17945	-0.09421	0.01968	1.18337	-0.40037	0.35000	0.29250E-01
23	18.16612	2.15041	0.20017	-0.69882	1.15389	-0.06012	-0.02051	1.15564	-0.33550	0.47500	0.28695E-01
24	19.21250	2.16088	0.16310	-0.86735	1.11389	-0.01641	-0.06069	1.11566	-0.24470	0.62500	0.23380E-01
25	20.25888	2.16226	0.09766	-0.99517	1.05984	0.02651	-0.07404	1.06275	-0.12944	0.77500	0.14000E-01
26	21.30526	2.15845	0.03017	-1.06125	1.00564	0.05494	-0.05507	1.00864	-0.01736	0.92500	0.43250E-02

SECTION	CD	CS	CL	CMX	CMY	CMZ	CIRC	CHORD	XLE	YLE	ZLE	YLE/SSPAN
	0.0413	0.0599	0.5523	0.1101	-1.3585	0.0656	1.8897	6.9762	14.8526	2.0813	0.0000	0.1734

IN BODY AXIS SYSTEM/

CFX	CFY	CFZ	CMX	CMY	CMZ
-0.0552	0.0599	0.5511	0.0970	-1.5221	0.0837

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PRESSURE DISTRIBUTION ON PATCH 4 AFT BODY

K	X	Y	Z	DUB	VX	VY	VZ	V	CP
218	22.46315	0.41050	-1.53200	0.77590	0.98659	0.03962	0.02773	0.98777	0.02430
219	22.46315	1.12150	-1.12150	0.77505	0.98790	0.07332	0.09674	0.99533	0.00932
220	22.46315	1.53200	-0.41050	0.78021	1.00628	0.29556	1.16821	1.56993	-1.46467
221	22.46315	1.53200	0.41050	-0.98805	0.98084	-0.32293	1.14170	1.53942	-1.36981
222	22.46315	1.12150	1.12150	-0.95139	1.01942	-0.07605	0.05189	1.02357	-0.04769
223	22.46315	0.41050	1.53200	-0.93311	1.02579	-0.03747	-0.00776	1.02651	-0.05372
224	24.53911	0.39775	-1.48442	0.76131	1.00415	0.04122	0.04296	1.00592	-0.01187
225	24.53911	1.08667	-1.08667	0.75144	1.00860	0.09364	0.13743	1.02221	-0.04492
226	24.53911	1.48442	-0.39775	0.69443	1.04227	0.28026	1.16959	1.59149	-1.53283
227	24.53911	1.48442	0.39775	-0.95258	0.95517	-0.33793	1.14787	1.53106	-1.34415
228	24.53911	1.08667	1.08667	-0.99961	0.99549	-0.12936	0.08614	1.00755	-0.01515
229	24.53911	0.39775	1.48442	-1.00133	1.00371	-0.05239	-0.01786	1.00524	-0.01050
230	26.61389	0.37623	-1.40410	0.71305	1.02224	0.04586	0.06463	1.02531	-0.05126
231	26.61389	1.02787	-1.02787	0.68800	1.02918	0.12786	0.19985	1.05617	-0.11550
232	26.61389	1.40410	-0.37623	0.54332	1.07019	0.25185	1.14442	1.58696	-1.51843
233	26.61389	1.40410	0.37623	-0.87449	0.93235	-0.34687	1.11637	1.49528	-1.23587
234	26.61389	1.02787	1.02787	-1.01526	0.97538	-0.19464	0.12642	1.00261	-0.00524
235	26.61389	0.37623	1.40410	-1.03688	0.98392	-0.06941	-0.03178	0.98688	0.02606
236	28.68564	0.34157	-1.27477	0.63008	1.03599	0.05474	0.10029	1.04227	-0.08632
237	28.68564	0.93320	-0.93320	0.58214	1.04522	0.17350	0.29151	1.09889	-0.20756
238	28.68564	1.27477	-0.34157	0.33866	1.07786	0.20472	1.09649	1.55112	-1.40597
239	28.68564	1.27477	0.34157	-0.75368	0.91126	-0.35782	1.05433	1.43877	-1.07005
240	28.68564	0.93320	0.93320	-0.99561	0.94469	-0.28431	0.17766	1.00242	-0.00484
241	28.68564	0.34157	1.27477	-1.04206	0.95460	-0.09486	-0.05348	0.96079	0.07688
242	30.75221	0.29121	-1.08681	0.52932	1.03485	0.07711	0.13694	1.04671	-0.09561
243	30.75221	0.79560	-0.79560	0.45096	1.04340	0.23233	0.39248	1.13873	-0.29671
244	30.75221	1.08681	-0.29121	0.14460	1.04866	0.16096	1.04046	1.48599	-1.20817
245	30.75221	1.08681	0.29121	-0.60898	0.89844	-0.36496	0.98528	1.38245	-0.91116
246	30.75221	0.79560	0.79560	-0.91472	0.90403	-0.38107	0.24230	1.01054	-0.02118
247	30.75221	0.29121	1.08681	-0.99246	0.91289	-0.13133	-0.06739	0.92474	0.14485
248	32.81564	0.23233	-0.86707	0.44836	1.00177	0.11861	0.14789	1.01955	-0.03948
249	32.81564	0.63474	-0.63474	0.34455	1.00382	0.30438	0.46331	1.14672	-0.31496
250	32.81564	0.86707	-0.23233	0.04423	0.98735	0.15335	0.99940	1.41321	-0.99718
251	32.81564	0.86707	0.23233	-0.46102	0.89458	-0.35681	0.94466	1.34906	-0.81996
252	32.81564	0.63474	0.63474	-0.76114	0.87824	-0.45306	0.31400	1.03690	-0.07517
253	32.81564	0.23233	0.86707	-0.86473	0.88041	-0.17292	-0.05571	0.89896	0.19187

PRESSURE DISTRIBUTION ON PATCH 5 MID-BODY UPPER

K	X	Y	Z	DUB	VX	VY	VZ	V	CP
266	14.33250	0.39612	1.47836	-0.28758	1.06340	-0.08343	0.09325	1.07074	-0.14648
267	14.35000	0.39637	1.47929	-0.28886	1.06756	-0.08768	0.07687	1.07391	-0.15328
268	14.37500	0.39662	1.48022	-0.29094	1.07059	-0.09183	0.06029	1.07621	-0.15823
269	14.44500	0.39712	1.48209	-0.29632	1.06415	-0.09309	0.05397	1.06958	-0.14399
270	14.59500	0.39813	1.48582	-0.30727	1.06194	-0.09225	0.05266	1.06724	-0.13900
271	14.86500	0.39988	1.49235	-0.32738	1.06504	-0.08972	0.05143	1.07005	-0.14500
272	15.40000	0.40325	1.50495	-0.37080	1.07283	-0.08240	0.04890	1.07710	-0.16014
273	16.11500	0.40750	1.52081	-0.43457	1.08099	-0.07066	0.04329	1.08416	-0.17541
274	16.82500	0.41075	1.53294	-0.50335	1.08311	-0.06086	0.03156	1.08528	-0.17783
275	17.71500	0.41363	1.54367	-0.58826	1.08053	-0.04794	0.02597	1.08190	-0.17051
276	18.77500	0.41625	1.55347	-0.68589	1.07410	-0.03647	0.01795	1.07486	-0.15533
277	19.84000	0.41725	1.55720	-0.77546	1.06247	-0.03044	0.00816	1.06293	-0.12983
278	20.90250	0.41613	1.55300	-0.85114	1.04699	-0.03083	-0.00076	1.04745	-0.09714
279	14.33250	1.08223	1.08223	-0.18952	1.06874	-0.16995	0.26728	1.11469	-0.24253
280	14.35000	1.08292	1.08292	-0.19095	1.07710	-0.18112	0.25469	1.12153	-0.25782
281	14.37500	1.08360	1.08360	-0.19344	1.08329	-0.19235	0.24168	1.12646	-0.26892
282	14.44500	1.08497	1.08497	-0.19938	1.07191	-0.19467	0.23460	1.11442	-0.24193
283	14.59500	1.08770	1.08770	-0.21199	1.07341	-0.19011	0.22869	1.11384	-0.24064
284	14.86500	1.09248	1.09248	-0.23627	1.08176	-0.17694	0.21494	1.11701	-0.24771
285	15.40000	1.10170	1.10170	-0.29181	1.09711	-0.14844	0.18590	1.12261	-0.26025
286	16.11500	1.11331	1.11331	-0.37633	1.10916	-0.11729	0.15144	1.12558	-0.26694
287	16.82500	1.12219	1.12219	-0.46591	1.11055	-0.09568	0.11705	1.12079	-0.25618
288	17.71500	1.13004	1.13004	-0.57442	1.10413	-0.06739	0.08571	1.10950	-0.23100
289	18.77500	1.13722	1.13722	-0.69463	1.09122	-0.04363	0.05499	1.09348	-0.19569
290	19.84000	1.13995	1.13995	-0.79867	1.07079	-0.03454	0.03454	1.07190	-0.14897
291	20.90250	1.13687	1.13687	-0.87761	1.04706	-0.04081	0.02849	1.04825	-0.09882
292	14.33762	1.47823	0.40457	0.01555	1.08005	0.11447	0.41563	1.16291	-0.35237
293	14.35969	1.47917	0.41501	0.00977	1.16123	0.03077	0.38043	1.22235	-0.49413
294	14.38550	1.48047	0.41954	0.00462	1.14984	0.00061	0.36306	1.20580	-0.45395
295	14.45156	1.48234	0.42682	-0.00773	1.15382	-0.03881	0.33363	1.20171	-0.44412
296	14.59312	1.48582	0.43835	-0.03255	1.15766	-0.03601	0.30627	1.19803	-0.43528
297	14.86125	1.49248	0.45550	-0.08466	1.17671	-0.03366	0.26878	1.20749	-0.45802
298	15.39500	1.50508	0.47968	-0.19203	1.17988	-0.02922	0.21644	1.19992	-0.43981
299	16.10750	1.52031	0.50218	-0.32690	1.17101	-0.02561	0.16779	1.18325	-0.40007
300	16.81750	1.53219	0.51459	-0.45602	1.16173	-0.02584	0.13015	1.16928	-0.36722
301	17.70625	1.54470	0.51549	-0.60613	1.14544	-0.02005	0.09487	1.14954	-0.32145
302	18.76875	1.55474	0.49925	-0.76668	1.11809	-0.02541	0.06229	1.12011	-0.25464
303	19.83375	1.55720	0.46695	-0.89531	1.07873	-0.02692	0.05036	1.08024	-0.16692
304	20.89750	1.55325	0.43148	-0.97594	1.02928	-0.03262	0.06042	1.03157	-0.06413

PATCH	CD	CS	CL	CMX	CMY	CMZ
5	0.002	0.017	0.015	0.004	-0.043	0.024

IN BODY AXIS SYSTEM/

CFX	CFY	CFZ	CMX	CMY	CMZ

***** INPUT LISTING OF SUBROUTINE STLINE *****

(F)	(KP)	(NS)
0.50000	21	0
0.50000	47	0
0.50000	10	0
0.50000	12	0
2.00000	0	0

STLN NO. = 1 PANEL NO. = 21 SIDE NO. = 4 F= 0.500

KP	X	Y	Z	VX	VY	VZ	VT	CP	DS	GK
10	15.0832	2.1403	-0.0666	0.5699	0.4741	0.0756	0.7452	0.4447	0.0000	-0.8023
11	15.1422	2.2764	-0.0497	0.3662	0.7444	0.0892	0.8344	0.3038	0.1492	-3.9970
12	15.1400	2.3052	-0.0397	0.1811	0.9830	0.2018	1.0197	-0.0398	0.1797	-16.3502
13	15.1356	2.3160	-0.0329	0.0374	1.1680	0.7484	1.3877	-0.9257	0.1932	-82.0915
14	15.1183	2.3318	0.0000	-1.8508	1.5619	9.1811	9.4952	-89.1585	0.2337	-1.2317
15	15.1355	2.3158	0.0329	1.3774	-0.3046	1.8601	2.3345	-4.4500	0.2741	42.0332
16	15.1454	2.3103	0.0397	1.6495	-0.5986	1.1196	2.0815	-3.3325	0.2873	6.9919
17	15.1671	2.2999	0.0496	1.5810	-0.5776	0.6950	1.8211	-2.3163	0.3133	3.8630
18	15.2278	2.2773	0.0662	1.4307	-0.4425	0.4014	1.5505	-1.4039	0.3802	1.6962
19	15.3597	2.2426	0.0909	1.3213	-0.3064	0.2670	1.3824	-0.9109	0.5188	0.5772
20	15.6434	2.1907	0.1268	1.2430	-0.1976	0.1778	1.2711	-0.6157	0.8095	0.1869
21	16.2478	2.1175	0.1731	1.2015	-0.1305	0.1206	1.2146	-0.4753	1.4200	0.0541
22	16.8787	2.0636	0.1994	1.1827	-0.0981	0.0885	1.1900	-0.4162	2.0537	0.0325
23	17.5271	2.0216	0.2100	1.1612	-0.0704	0.0618	1.1650	-0.3572	2.7036	0.0282
24	18.5217	1.9794	0.1925	1.1366	-0.0463	0.0289	1.1379	-0.2949	3.6992	0.0298
25	19.5564	1.9616	0.1360	1.0956	-0.0223	-0.0021	1.0958	-0.2008	4.7357	0.0419
26	20.6176	1.9701	0.0608	1.0412	-0.0029	-0.0169	1.0413	-0.0843	5.7996	0.0302
26	21.6912	1.9867	0.0000	1.0271	0.0143	-0.0582	1.0288	-0.0584	6.8750	0.0113

STLN NO. = 2 PANEL NO. = 47 SIDE NO. = 4 F= 0.500

KP	X	Y	Z	VX	VY	VZ	VT	CP	DS	GK
36	16.9968	3.9538	-0.0622	0.4500	0.5828	0.0142	0.7364	0.4577	0.0000	-1.1040
37	17.0647	4.0933	-0.0464	0.2217	0.8265	0.1138	0.8632	0.2548	0.1560	-4.1162
38	17.0695	4.1268	-0.0371	0.0307	1.0297	0.3379	1.0842	-0.1755	0.1911	-17.8196
39	17.0690	4.1404	-0.0308	-0.0491	1.1141	1.1062	1.5708	-1.4673	0.2061	-26.1067
40	17.0643	4.1661	0.0000	0.6174	0.4103	3.4959	3.5736	-11.7710	0.2465	-3.7000
41	17.0863	4.1568	0.0307	1.7547	-0.7919	1.8493	2.6694	-6.1258	0.2854	[illegible]

INPUT DATA FOR BOUNDARY LAYER CODE, IBLTYP=1/
****

(RNB	TRIPUP	TRIPOP	XPRINT	XSKIP)
4.000	1.000	1.000	10.000	10.000

STREAMLINE NO. 1 STARTING LOCATION, X Y Z 15.08323 2.14034 -0.06656

SEPARATION POINT, XS= -0.00002 YS= 2.12973 ZS= -0.06788

INCOMPRESSIBLE BOUNDARY LAYER CALCULATIONS, RE= 4.000E+06

WING/BODY TEST CASE

LAMINAR BOUNDARY LAYER DEVELOPMENT

I	X	S	US	DU/DS	H	THETAS	CFS
1	15.0832	0.0000	0.7452E+00	0.5978E+00	0.3311E+01	0.1589E-03	0.0000E+00
9	15.1372	0.2764	0.2291E+01	-0.8976E+02	0.3311E+01	0.1589E-03	0.5065E-02

LAMINAR SEPARATION REATTACHMENT AS TURBULENT BOUNDARY LAYER

TURBULENT BOUNDARY LAYER DEVELOPMENT

I	X	S	US	H	DELTA	THETA	RTHETA	CF	CD-SY	DELTA/R
9	15.1372	0.2764	2.291	0.331E+01	0.218E-03	0.159E-03	0.271E+03	0.506E-02	0.000E+00	0.942E-04
0	0.0002	-0.0000	6.875	0.331E+01	0.192E-01	0.159E-03	0.942E-02	-0.120E-01	0.000E+00	0.883E-03

STREAMLINE NO 2 STARTING LOCATION, X Y Z 16.99683 3.95377 -0.06223

LAMINAR SEPARATION

SEPARATION POINT, XS= 22.89334 YS= 3.45759 ZS= 0.00000

INCOMPRESSIBLE BOUNDARY LAYER CALCULATIONS, RE= 4.000E+06

WING/BODY TEST CASE

LAMINAR BOUNDARY LAYER DEVELOPMENT

I	X	S	US	DU/DS	H	THETAS	CFS
1	16.9968	0.0000	0.7364E+00	0.8130E+00	0.3311E+01	0.1363E-03	0.0000E+00
10	17.0827	0.2790	0.2818E+01	-0.2173E+02	0.1497E+01	0.5593E-04	0.4224E-02

LAMINAR SEPARATION REATTACHMENT AS TURBULENT BOUNDARY LAYER

TURBULENT BOUNDARY LAYER DEVELOPMENT

I	X	S	US	H	DELTA	THETA	RTHETA	CF	CD-SY	DELTA/R
10	17.0827	0.2790	2.818	0.150E+01	0.431E-03	0.559E-04	0.630E+03	0.422E-02	0.000E+00	0.104E-03
20	17.3649	0.5890	1.431	0.156E+01	0.188E-01	0.274E-02	0.157E+05	0.154E-02	0.109E-01	0.463E-02
30	17.6648	0.8990	1.307	0.146E+01	0.336E-01	0.451E-02	0.236E+05	0.168E-02	0.130E-01	0.841E-02
40	17.9678	1.2091	1.262	0.140E+01	0.453E-01	0.567E-02	0.286E+05	0.180E-02	0.142E-01	0.115E-01
50	18.2725	1.5191	1.234	0.137E+01	0.550E-01	0.659E-02	0.325E+05	0.184E-02	0.151E-01	0.142E-01
60	18.5781	1.8291	1.213	0.135E+01	0.636E-01	0.741E-02	0.360E+05	0.186E-02	0.159E-01	0.166E-01
70	18.8848	2.1391	1.194	0.134E+01	0.718E-01	0.823E-02	0.393E+05	0.186E-02	0.166E-01	0.190E-01
80	19.1916	2.4491	1.176	0.134E+01	0.797E-01	0.908E-02	0.427E+05	0.184E-02	0.172E-01	0.213E-01
90	19.4993	2.7591	1.163	0.134E+01	0.872E-01	0.986E-02	0.458E+05	0.183E-02	0.179E-01	0.235E-01
100	19.8070	3.0692	1.149	0.133E+01	0.948E-01	0.107E-01	0.491E+05	0.181E-02	0.185E-01	0.259E-01
110	20.1148	3.3792	1.135	0.133E+01	0.103E+00	0.116E-01	0.525E+05	0.179E-02	0.191E-01	0.283E-01
120	20.4230	3.6892	1.117	0.134E+01	0.111E+00	0.127E-01	0.566E+05	0.175E-02	0.197E-01	0.309E-01
130	20.7311	3.9992	1.099	0.134E+01	0.120E+00	0.139E-01	0.609E+05	0.171E-02	0.203E-01	0.337E-01
140	21.0394	4.3092	1.081	0.135E+01	0.130E+00	0.152E-01	0.656E+05	0.166E-02	0.210E-01	0.366E-01
150	21.3481	4.6192	1.061	0.136E+01	0.140E+00	0.167E-01	0.708E+05	0.161E-02	0.216E-01	0.397E-01
160	21.6568	4.9293	1.041	0.137E+01	0.151E+00	0.183E-01	0.761E+05	0.156E-02	0.222E-01	0.429E-01
170	21.9656	5.2393	1.024	0.138E+01	0.161E+00	0.198E-01	0.811E+05	0.151E-02	0.227E-01	0.461E-01
180	22.2748	5.5493	1.021	0.137E+01	0.168E+00	0.204E-01	0.835E+05	0.153E-02	0.232E-01	0.484E-01
190	22.5841	5.8593	1.018	0.136E+01	0.176E+00	0.210E-01	0.856E+05	0.154E-02	0.235E-01	0.506E-01
200	22.8933	6.1693	1.015	0.135E+01	0.183E+00	0.216E-01	0.876E+05	0.156E-02	0.238E-01	0.528E-01

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16. Abstract

VSAERO is a computer program used to predict the non-linear aerodynamic characteristics of arbitrary three dimensional configurations in subsonic flow. Non-linear effects of Vortex Separation and Vortex/Surface interaction are treated in an iterative wake-shape calculation procedure, while the effects of viscosity are treated in an iterative loop coupling potential-flow and integral boundary-layer calculations. The program employs a surface singularity panel method using quadrilateral panels on which doublet and source singularities are distributed in a piecewise constant form. This User's Manual provides a brief overview of the mathematical model, instructions for configuration modelling and a description of the input and output data. A listing of a sample case is included.

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