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TECHNICAL NOTE 3322

AN ACCURATE AND RAPID METHOD FOR THE DESIGN OF SUPERSONIC NOZZLES

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SUMMARY

A procedure is given for designing two-dimensional nozzles in which the streamline coordinates are computed directly from tabulated flow parameters and appropriate equations. The method of characteristics is used to obtain the first part of the flow, which consists of a continuous expansion from a uniform sonic flow to a radial flow. The Foelsch equations are then used for the transition from radial flow to the final uniform flow. Information is presented which enables the designer to select and compute rapidly the wall contour for any nozzle or series of nozzles for a wide range of length-to-height ratio, Mach number, and wall angle at the inflection point. In general, a nozzle is determined by specifying any two of these three parameters.

INTRODUCTION

Recent experience obtained at the Langley Gas Dynamics Branch of the National Advisory Committee for Aeronautics with the aerodynamic design and flow calibration of two-dimensional supersonic nozzles for wind tunnels has indicated that a need exists for a more accurate and rapid design method than the graphical and computational methods in common use. The analytic equations derived independently by Foelsch and Atkin (refs. 1 and 2) partially fulfill this need since they are an exact solution to the problem of generating uniform parallel flow from a supersonic divergent radial flow. These equations give the required streamline coordinates directly in terms of the assumed radial flow. The Foelsch-Atkin method, however, has not been widely used because of the difficulties associated with generating a divergent radial flow from a parallel sonic flow.

Atkin (ref. 2) reduced these difficulties to some extent by deriving analogous expressions for expanding a uniform supersonic stream to a divergent radial flow at a larger Mach number. Pinkel (ref. 3) has suggested several convenient procedures for obtaining the transition from a parallel sonic flow to a uniform flow at a slightly higher Mach number, which is required in the Atkin solution, either by adaptations of the

Prandtl-Meyer solution or by the use of a minimum-length "subnozzle" to be computed by graphical methods. Although the procedures of reference 3 are in theory satisfactory, the peculiar shape of the resulting streamlines will ordinarily introduce practical construction difficulties or other problems connected with boundary-layer development.

This report presents a computational procedure which provides for the rapid and accurate calculation of any streamline in a series of special flows. These flows were computed by the method of characteristics and are designed to form continuous expansions from a uniform sonic flow to divergent radial flows. The coordinates of any streamline through these flows may be obtained from the tables included in this report by linear interpolation. The nozzle contour is then completed by using the Foelsch equations to obtain the transition streamline between the divergent radial flow and a uniform supersonic stream. Information is presented in the form of tables and graphs which enables the designer to select and compute the wall contour for any nozzle or series of nozzles for a wide range of length-to-height ratio, Mach number, and wall angle at the inflection point.

Detailed information is given on the boundary conditions and equations used for computing the characteristic nets and stream function. Expressions relating the stream function to certain nozzle parameters such as Mach number and length-to-height ratio are also derived. The section entitled "Nozzle Design and Computing Procedure" is intended to supply computing instructions for the reader interested only in the practical application of the tables and formulas to a specific nozzle design.

SYMBOLS

a	speed of sound
h	one-half the test-section height of symmetrical nozzle (fig. 1(a))
h_{cr}	one-half the minimum-throat height of symmetrical nozzle (fig. 1(a))
l	total length of nozzle (fig. 1(a))
M	Mach number
r	radial distance from source point in radial flow
r_{cr}	radial distance from source point to sonic arc in radial flow (fig. 1(b))

s	distance along Mach line
x,y	two-dimensional Cartesian coordinates
y_{cr}	length of sonic line AA' (fig. 1(a))
γ	ratio of specific heats; 1.400 used throughout
ζ	constant of integration for right Mach lines
η	constant of integration for left Mach lines
θ	flow angle with respect to x-axis
θ_{max}	maximum wall angle; also, scale factor, y_{cr}/r_{cr}
μ	Mach angle, $\sin^{-1} \frac{1}{M}$
ν	total expansion angle integrated from $M = 1$ (eq. (5))
ρ	mass density
ψ	stream function (eq. (17))
Ψ	dimensionless stream function

The following symbols are used to represent points in the flow fields and also as subscripts to denote the value of a flow variable at a particular point:

A,A'	end points of sonic line (fig. 1(a))
B,C,D,E	intersection points of certain right and left Mach lines, (figs. 1 and 2)
S,S'	end points of sonic arc in radial flow (fig. 1(b))
R',R	upstream and downstream end points, respectively, on radial-flow streamline (fig. 1(a) or 1(b))
P',P	any points on left and right Mach lines, respectively, in radial flow
O	source point in radial flow (fig. 1(b))

Subscripts:

m arithmetic mean value

o conditions after isentropic deceleration to zero velocity

ANALYSIS OF PROBLEM

General Description of Method

The primary objective of this report is to provide a rapid method for computing wall contours (that is, streamlines) which will generate true radial flows from a known sonic flow. The Foelsch equations (ref. 1) are then used to compute streamlines which provide the transition between the radial flow and the final parallel uniform flow.

Some typical streamlines and the associated flow fields are shown in figure 1(a). The solid lines represent streamlines, with arrows indicating the flow direction, and the dashed lines are used to represent certain Mach lines which conveniently divide the flow into various regions. These regions are defined in figure 1(a) as follows: Region I is the subsonic approach upstream of the sonic line AA'; region II is the initial expansion bounded by the sonic line AA' and the Mach line AB; region III is the secondary expansion bounded by the Mach lines AB and BC; region IV is the radial flow bounded by the Mach lines BC and CD; and region V is the final transition flow bounded by Mach lines CD and DE. Since the flow is symmetrical about the x-axis, only the flow above this axis is considered.

The flow within regions II and III has been computed by the method of characteristics with the initial conditions chosen so as to result in a smooth, continuous expansion from the straight sonic line AA', coincident with the y-axis, to the first radial-flow Mach line BC. This calculation was done by first computing the flow within region II, which is based on a Prandtl-Meyer expansion at point A, and then selecting the scale of the radial flow relative to region II so that the Mach number gradient along the x-axis is continuous at point B. The flow within region III was computed next by using as initial conditions the previous results along Mach line AB and the radial-flow Mach line BC. The latter Mach line, as well as the flow anywhere within region IV, may be computed directly from the radial-flow equations or the tables included in this report.

Clearly, *any* streamline passing through regions II and III may be used as a portion of a nozzle with the final design Mach number determined by the total expansion angle ν_D at point D. Variation of the expansion angle ν_B at point B for a given value of ν_D changes the amount of curvature obtained along the streamlines through regions II and III. The final length-to-height ratio l/h of any particular nozzle depends not only on ν_D (which may be varied independently of ν_B) and ν_B but also on the wall angle θ_R within the radial flow. This angle is also the wall angle at the inflection point and hence is always the maximum wall angle for any given nozzle. In general, a nozzle is uniquely determined by fixing any three of the four parameters, M_D, ν_B, l/h, and θ_R. However, ν_B should not be regarded as a completely arbitrary parameter since only four values of ν_B are used in this report. The coordinates and the value of the stream function Ψ have been computed and tabulated for each point in the various characteristic nets required for regions II and III. Any streamline through these regions may then be obtained by simple linear interpolation between the tabulated points since each streamline corresponds to a constant value of Ψ.

Application of the Method of Characteristics

The method of characteristics is a numerical procedure for solving the hyperbolic partial-differential equations of motion by means of ordinary differential equations which relate the dependent variables along certain curves known as characteristics. Prandtl and Busemann were the first to apply this method to problems of supersonic flow (ref. 4) when they developed the well-known graphical procedure for the construction of steady, two-dimensional, isentropic flow. In the graphical method the convenient concept was used that a discrete change in the flow occurs across the Mach lines or characteristic lines, as described in detail by Puckett (ref. 5). Others (for example, refs. 6 and 7) have indicated that a flow field can be obtained just as easily and probably more accurately by computing directly the change in flow variables along the characteristic lines. One of the principal advantages of such a computing procedure is that the flow properties are specified at a definite point rather than within a finite region so that, for example, the coordinates of a streamline through a completed flow field can be obtained more accurately and with less work. Improved control of mesh size and distribution is another advantage which results from computing the flow variables along the Mach lines rather than across them.

The characteristic lines for steady flow are given by the following equations (from ref. 7):

Right line

$$\frac{dy}{dx} = \tan(\theta - \mu) \tag{1}$$

Left line

$$\frac{dy}{dx} = \tan(\theta + \mu) \tag{2}$$

where, for the case of plane, irrotational, isentropic flow, the dependent variables along the characteristic lines are related by the equations:

Right line

$$\nu + \theta = \zeta = \text{Constant} \tag{3}$$

Left line

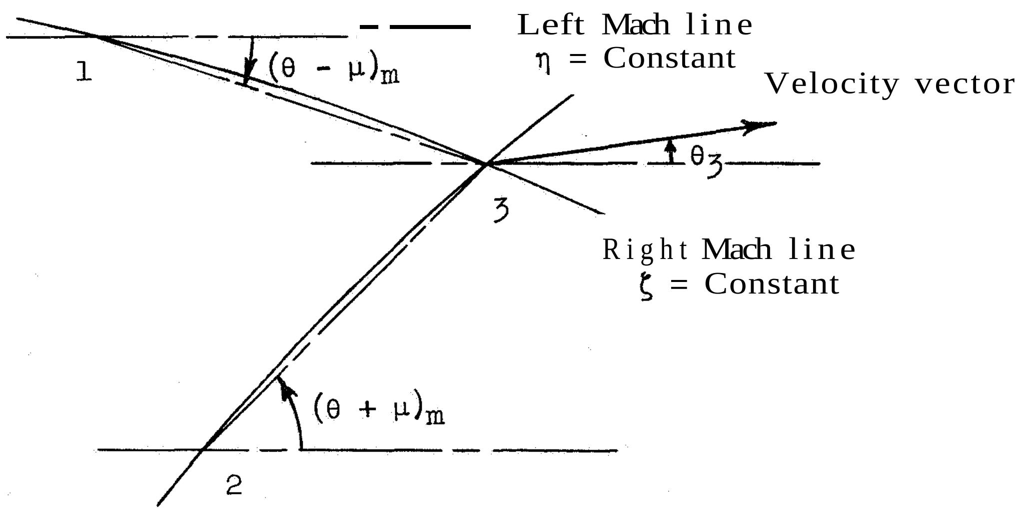
$$\nu - \theta = \eta = \text{Constant} \tag{4}$$

The right and left families of characteristic lines as used in this report are defined in figure 2(a). The relation between ν and μ is given by the equation

$$\nu = \sqrt{\frac{\gamma + 1}{\gamma - 1}} \tan^{-1}\left(\sqrt{\frac{\gamma - 1}{\gamma + 1}} \cot \mu\right) + \mu - \frac{\pi}{2} \tag{5}$$

Values of μ are tabulated as a function of ν for a large range of values in table I. Thus, θ and μ are used as the dependent variables in computing the characteristic net. The Mach number may then be obtained from table I, and any other desired flow variable, such as pressure or velocity, may be obtained from standard supersonic-flow tables.

The procedure used herein for computing the characteristic nets is illustrated by the following sketch:



Assume that the coordinates and flow properties are known at points 1 and 2 and that the coordinates and flow properties are desired at point 3 where the right and left characteristic lines through points 1 and 2, respectively, intersect. From equations (3) and (4),

$$\left.\begin{aligned} \zeta_3 &= \zeta_1 \\ \eta_3 &= \eta_2 \end{aligned}\right\} \tag{6}$$

and, by addition and subtraction of equations (6),

$$\nu_3 = \frac{\theta_1 - \theta_2}{2} + \frac{\nu_1 + \nu_2}{2}$$

$$\theta_3 = \frac{\theta_1 + \theta_2}{2} + \frac{\nu_1 - \nu_2}{2}$$

From table I μ_3 is obtained as a function of ν_3; then x_3 and y_3 are computed by assuming that the small curved segments between points 1 and 3 and between points 2 and 3 may be replaced by straight lines with the slopes

$$\tan(\theta - \mu)_m = \tan \frac{(\theta - \mu)_1 + (\theta - \mu)_3}{2}$$

$$\tan(\theta + \mu)_m = \tan \frac{(\theta + \mu)_2 + (\theta + \mu)_3}{2}$$

Boundary Conditions and Equations for the Flow Fields

The subsonic approach (region I).- The calculation of the supersonic portion of a nozzle is simplified by the assumption of a straight sonic line; however, the question naturally arises as to whether a subsonic approach which will insure a reasonably straight sonic line can be calculated. According to a general theorem proved by Görtler in reference 8, a straight sonic line normal to the axis is always obtained when the velocity gradient along the x-axis vanishes at the sonic point. Furthermore, Görtler shows that, under these conditions, the curvature of the streamlines and the velocity gradient along them must be zero at the throat. Görtler gives the equation for the streamlines in the simplest example of this type of flow as

$$y = c(1 + 0.1924x^6)$$

where c is a constant for any given streamline. Unfortunately, no direct experimental evidence confirming this theorem appears to exist at present; however, practical experience has indicated that a relatively long, smooth curve which approaches zero curvature at the throat gives satisfactory results.

The initial expansion (region II).- The computation for region II is based on the boundary conditions of a uniform parallel flow along the sonic line AA' coincident with the y-axis, a Prandtl-Meyer expansion at point A, and zero flow angle along the x-axis.

The flow in this region, which is bounded by the straight sonic line AA' and the Mach line AB as shown in figure 1(a), has been computed up to $\nu_B = 42^\circ$, corresponding to $M_B = 2.626$. The values of ν, x/y_{cr}, y/y_{cr}, and Ψ for each point in this flow are tabulated in table II(a). The corresponding values of θ may be obtained from the tabulated values of η and ν and equation (4).

For convenience in discussion and tabulation, each left Mach line is designated by a lowercase letter and each right Mach line is designated by a number. Then a point in the flow field is designated by a lowercase letter and a number which indicate the intersection point of those particular right and left Mach lines, as illustrated in figure 2. As an example, point B in figure 2(a) would be designated by the notation (m,13).

The radial flow (region IV).- A plane radial flow (or source flow) is defined as one in which all dependent variables are a function only of the distance r from a fixed point in the plane. This leads to the expression (ref. 1, for example)

$$\frac{r}{r_{cr}} = \frac{1}{M}\left[\frac{2}{\gamma + 1}\left(1 + \frac{\gamma - 1}{2} M^2\right)\right]^{\frac{\gamma+1}{2(\gamma-1)}} \tag{7}$$

which is the same as the well-known area-ratio equation in a one-dimensional flow. The length r_{cr} is the radial distance from the origin to the sonic arc SS', as shown in figure 1(b). The streamlines within the radial flow are straight lines which, if extended, would emanate from the origin of the radial flow, say, point O in figure 1(b).

With the aid of equation (7) and this property of radial flow, the exact coordinates of *any* point on a Mach line may be computed without recourse to a step-by-step calculation. As an example, the coordinates of any point P' along the Mach line BC in figure 1(a) or 1(b) are computed as follows: The flow angle $\theta_{P'}$ is used as a parameter, and by making all lengths dimensionless in terms of y_{cr}, there are obtained from the geometry of the flow as shown in figure 1(b) the relations

$$\left(\frac{x}{y_{cr}}\right)_{P'} = \frac{r_{cr}}{y_{cr}}\left(\frac{r}{r_{cr}}\right)_{P'} \cos\theta_{P'} + \left[\left(\frac{x}{y_{cr}}\right)_B - \frac{r_{cr}}{y_{cr}}\left(\frac{r}{r_{cr}}\right)_B\right] \tag{8}$$

and

$$\left(\frac{y}{y_{cr}}\right)_{P'} = \frac{r_{cr}}{y_{cr}}\left(\frac{r}{r_{cr}}\right)_{P'} \sin\theta_{P'} \tag{9}$$

The terms within the brackets in equation (8) locate the origin of the radial flow at point 0. The value of $\left(r/r_{cr}\right)_{P'}$ is obtained from equations (5) and (7) or table I as a function of $\nu_{P'}$, which is written as

$$\nu_{P'} = \nu_B + \theta_{P'} \tag{10}$$

from equation (4) with $\theta_B = 0$. The coordinates of a point P along a right Mach line CD are computed from equations (8) and (9) (with subscript P' replaced by P) where again $\left(r/r_{cr}\right)_P$ is obtained from table I as a function of ν_P which is given by equation (3) as

$$\nu_P = \nu_D - \theta_P \tag{11}$$

The values of ν_B and ν_D are fixed by the design Mach number M_D and other properties of the complete nozzle, as discussed later.

<u>The secondary expansion (region III).</u> - The flow in region III, which is bounded by the Mach lines AB and BC (fig. 1(a)), was computed by the method of characteristics by using initial conditions which result in a continuous curvature and velocity gradient along all streamlines between the sonic line and the Mach line BC. These conditions are obtained (as

can be proved by reasoning similar to that of ref. 9) by specifying a continuous Mach number gradient along the x-axis through point B where the computation for the secondary expansion begins. The Mach number gradient along the x-axis within the radial flow is

$$\left[\frac{dM}{d\left(\frac{x}{r_{cr}}\right)}\right]_{y=0} = \frac{dM}{d\left(\frac{r}{r_{cr}}\right)} = \frac{M\left(1 + \frac{\gamma - 1}{2} M^2\right)}{\frac{r}{r_{cr}}\left(M^2 - 1\right)} \tag{12}$$

by differentiation of equation (7). The Mach number gradient along A'B was obtained from a large plot of $M_{y=0}$ against x/y_{cr} resulting from the solution for the initial-expansion flow. Equating these two slopes at point B gives

$$\left[\frac{dM}{d\left(\frac{x}{y_{cr}}\right)}\right]_B = \left[\frac{M\left(1 + \frac{\gamma - 1}{2} M^2\right)}{\frac{r}{r_{cr}}\left(M^2 - 1\right)}\right]_B \frac{y_{cr}}{r_{cr}}$$

where equation (12) has been multiplied by the ratio y_{cr}/r_{cr} so that all lengths are made dimensionless in terms of y_{cr}. Thus the Mach number gradient in the radial flow is matched to the gradient in region II along the axis of symmetry by multiplying the conventional coordinate of the radial flow by the scale factor

$$\frac{r_{cr}}{y_{cr}} = \frac{1}{\left[\frac{dM}{d\left(\frac{x}{y_{cr}}\right)}\right]_B} \left[\frac{M\left(1 + \frac{\gamma - 1}{2} M^2\right)}{\frac{r}{r_{cr}}\left(M^2 - 1\right)}\right]_B \tag{13}$$

as obtained from the previous equation. The reciprocal of this scale factor is the maximum wall angle θ_{max}, as can be shown by the following considerations: The streamline through point A (fig. 1(a)) forms the physical limit to the flow considered herein and intersects the Mach line BC in the point C. If a straight line is extended upstream from point C with the same inclination as the local flow angle at this point, it will pass through point 0 (fig. 1(b)) since radial flow is attained all along the Mach line BC. Then, from mass-flow considerations, the length of the sonic line y_{cr} must be the same as the length of the sonic arc SS' in a hypothetical radial flow with the origin at 0 as shown in figure 1(b). Hence

$$\frac{y_{cr}}{r_{cr}} = \theta_{max} \tag{14}$$

where θ_{max} is in radians. The numerical values of θ_{max}, $\frac{dM}{d\left(x/y_{cr}\right)_{y=0}}$, and $\left(x/y_{cr}\right)_{y=0}$ are listed in table II(b) as functions of ν_B.

In order to provide for a wide choice of l/h and θ_R, four different flows for region III have been computed. These flows are started along four different Mach lines taken from the flow in region II corresponding to values of ν_B of 6°, 12°, 22°, and 40°. The information needed to obtain any streamline in these flows is listed in tables III(a) to III(d).

<u>The final transition flow (region V)</u>.- Region V is bounded by the radial-flow Mach line CD and the straight Mach line DE as shown in figure 1(a). The coordinates for any streamline within this flow are given by the Foelsch equations (ref. 1). In the present notation, these equations may be written as

$$\frac{x}{y_{cr}} = \frac{\left(\frac{r}{r_{cr}}\right)_P}{\theta_{max}}\left[\cos\theta_P + \left(\theta_R - \theta_P\right)\left(\frac{\cos\theta_P}{\tan\mu_P} - \sin\theta_P\right)\right] + \left[\left(\frac{x}{y_{cr}}\right)_B - \frac{\left(\frac{r}{r_{cr}}\right)_B}{\theta_{max}}\right] \tag{15}$$

$$\frac{Y}{y_{cr}} = \frac{\left(\frac{r}{r_{cr}}\right)_P}{\theta_{max}}\left[\sin\theta_P + \left(\theta_R - \theta_P\right)\left(\frac{\sin\theta_P}{\tan\mu_P} + \cos\theta_P\right)\right] \tag{16}$$

where the scale factor θ_{max} is used to make all lengths dimensionless in terms of y_{cr}; θ_{max} and the difference $\theta_R - \theta_P$ are entered in radians. The terms within the last brackets in equation (15) locate the origin of the original Foelsch coordinates at the point 0. Equations (15) and (16) are used by first selecting the values of ν_D (or

M_D), θ_R, and ν_B. Then, with θ_P as the parameter, the corresponding values of ν_P are obtained from equation (11), which, in turn, determine the values of M_P and $\left(r/r_{cr}\right)_P$ from table I. The values of θ_{max} and $\left(x/y_{cr}\right)_B$ are given as functions of ν_B in table II(b).

A property of the Foelsch nozzles, in common with most conventional supersonic nozzles, is the discontinuity in curvature occurring on the streamlines at the Mach line CD. For applications where this discontinuity is undesirable, as for flexible-wall nozzles, certain modifications which eliminate the discontinuity may be introduced into the boundary conditions for this transition flow (see ref. 9). In order to utilize the tabulated flows in this report, such a modification would consist of fairing the finite slope of the Mach number distribution curve in the radial flow at point D into a smooth curve with zero slope and $M > M_D$ at a point downstream of D. The transition flow must then be recalculated by the method of characteristics by using this extended center-line distribution and the Mach line CD as the initial conditions.

It may be noted that a Foelsch streamline can be used as an exact solution for the design of a variable Mach number nozzle with a rigid contour, that is, nonflexible walls. This application of the Foelsch equations is discussed in detail in the appendix.

Streamlines in Regions II, III, and IV

Calculation of the value of a stream function at each point in a characteristic net provides an easy way to obtain streamlines through the flow, since by definition the stream function is constant along a streamline. Integration along a Mach line of the mass flow normal to the Mach line gives the stream function

$$\psi = \int_0^s \rho a \, ds \tag{17}$$

where ρ is the mass density, a is the speed of sound, and s is the distance along a Mach line. The lower limit of integration is taken as the x-axis. Introducing the isentropic-flow relations for ρ/ρ_o and a/a_o and using y_{cr} as a reference length in equation (17) results in

$$\frac{\psi}{\rho_o a_o y_{cr}} = \int_0^{s/y_{cr}} \left(1 + \frac{\gamma - 1}{2} M^2\right)^{\frac{\gamma+1}{2(1-\gamma)}} d\left(\frac{s}{y_{cr}}\right)$$

For convenience in computation, this equation may be written in the form

$$\Psi = \left(\frac{\gamma + 1}{2}\right)^{\frac{\gamma+1}{2(\gamma-1)}} \frac{\psi}{\rho_o a_o y_{cr}} = \int_0^{y/y_{cr}} \frac{1}{M \frac{r}{r_{cr}} \sin(\theta + \mu)} d\left(\frac{y}{y_{cr}}\right) \tag{18}$$

by the use of equation (7) and the general relation $ds = \frac{dy}{\sin(\theta + \mu)}$. The integration is still carried out along a Mach line.

The value of ψ within the radial flow is obtained by integration along the arc of radius r. The result is

$$\frac{\psi}{\rho_o a_o y_{cr}} = \frac{\rho}{\rho_o} \frac{a}{a_o} M \frac{r}{r_{cr}} \frac{r_{cr}}{y_{cr}} \theta$$

since ρ, M, and a are constant along the arc. Introducing the isentropic-flow relations as before then gives

$$\Psi = \frac{\theta}{\theta_{max}} \tag{19}$$

where the value of θ_{max} depends on ν_B, according to equations (13) and (14) or table II(b).

Equation (18) was integrated numerically along the left Mach lines for the different flows by using a trapezoidal rule of the form

$$\Psi_n = \sum_{i=1}^{n} \frac{1}{2}\left[\frac{1}{\left(\frac{r}{r_{cr}} M\right)_{i-1}} + \frac{1}{\left(\frac{r}{r_{cr}} M\right)_i}\right] \frac{y_{i-1} - y_i}{\sin \frac{(\theta + \mu)_{i-1} + (\theta + \mu)_i}{2}}$$

The values of Ψ have been computed and tabulated for each point in the initial-expansion flow of region II (table II(a)) and the four secondary-expansion flows for region III (tables III(a) to III(d)).

The coordinates of any given streamline corresponding to a fixed value of Ψ in a particular flow field are then determined by linear interpolation along the Mach lines. The local flow angle θ along the streamline is obtained from equation (4), where the value of ν is obtained by linear interpolation in the tables. Plots of the variation of $\tan\theta$ with x along typical streamlines indicate that the maximum deviation of any particular point from a smooth curve is less than $\tan\theta = 0.0005$ which corresponds to an error in local flow angle of less than 0.03°. Thus, the streamline coordinates obtained from the tables as just described may be used directly for nonviscous-flow nozzle design without further corrections or refinements.

Relations Between Length-to-Height Ratio, Design Mach Number, and Wall Angle at the Inflection Point

The length l of any nozzle (see fig. 1(a)) is written in terms of y_{cr} as

$$\frac{l}{y_{cr}} = \frac{A'D}{y_{cr}} + \frac{h}{y_{cr}} \cot \mu_D$$

or

$$\frac{l}{y_{cr}} = \frac{\left(\frac{r}{r_{cr}}\right)_D}{\theta_{max}} + \left[\left(\frac{x}{y_{cr}}\right)_B - \frac{\left(\frac{r}{r_{cr}}\right)_B}{\theta_{max}}\right] + \frac{h}{y_{cr}} \cot \mu_D$$

since $\frac{y_{cr}}{r_{cr}} = \theta_{max}$ from equation (14). Division by $\frac{h}{y_{cr}} = \frac{h}{h_{cr}} \frac{h_{cr}}{y_{cr}} = \left(\frac{r}{r_{cr}}\right)_D \frac{\theta_{R'}}{\theta_{max}}$ gives the length-to-height ratio as

$$\frac{l}{h} = \frac{1}{\theta_{R'}} + \frac{\left(\frac{x}{y_{cr}}\right)_B - \frac{1}{\theta_{max}}\left(\frac{r}{r_{cr}}\right)_B}{\left(\frac{r}{r_{cr}}\right)_D \frac{\theta_{R'}}{\theta_{max}}} + \cot \mu_D \tag{20}$$

For the case where $\nu_R = \nu_{R'}$, combining equations (3) and (4) applied to the Mach lines bounding region IV gives

$$2\theta_{R'} = \nu_D - \nu_B \tag{21}$$

so that equation (20) can be written as

$$\frac{l}{h} = \frac{2}{\nu_D - \nu_B} + \frac{\left(\frac{x}{y_{cr}}\right)_B - \frac{1}{\theta_{max}}\left(\frac{r}{r_{cr}}\right)_B}{\left(\frac{r}{r_{cr}}\right)_D \frac{\nu_D - \nu_B}{2\theta_{max}}} + \cot \mu_D \tag{22}$$

where θ_{max}, $\theta_{R'}$, and $\nu_D - \nu_B$ must be entered in radians.

NOZZLE DESIGN AND COMPUTING PROCEDURE

The purpose of this section is to supply sufficient information so that the design parameters and streamline or contour coordinates for any complete nozzle may be calculated without referring to the previous discussion; however, useful background material is given in the section entitled "General Description of Method."

Selection of Nozzle Parameters

The number of independent parameters available for any particular design depends on whether the streamline forming the nozzle contour may consist in part of a straight line or whether it is to be continuously curving. For the former case, which is considered as example I, the choice of any three of the four parameters M_D, ν_B, l/h, and θ_R determines from equations (20) and (19) all that is required to compute the complete streamline, since $\theta_R = \theta_{R'}$. For the other case, considered as example II, fixing any two of these four parameters determines the nozzle from equations (21), (22), and (19). Of course, ν_B would not ordinarily be considered as a completely independent parameter since there are only four values used in this report.

The ratio l/h from equation (22) has been plotted as a function of M_D in figure 3 for the four secondary-expansion flows computed herein. Thus, if a nozzle of the type in which the wall streamline intersects the radial flow at only one point is desired, equation (22) or the corresponding curves in figure 3 determine the value of l/h for given values of ν_D (or M_D from table I) and ν_B. The value of $\theta_{R'}$ is found from equation (21). The three curves for $\nu_B = 6^\circ$, 12°, and 22° are terminated at the point where $\theta_{R'} = \theta_{max}$.

For some applications, values of l/h or θ_R that do not satisfy equations (21) and (22) may be required. In this case, the desired combinations of M_D, l/h, and θ_R may be obtained by utilizing a streamline that passes through the radial-flow region with the inclination θ_R. The portion of the streamline within the radial flow is then a straight line with its end-point coordinates given by equations (8), (9), and (14). The length-to-height ratio for this type of nozzle is obtained from equation (20). Then, for given values of ν_D and ν_B, this length-to-height ratio is greater than that of a nozzle with $\nu_R = \nu_{R'}$ since θ_R is larger for the latter type of nozzle. Consequently, for fixed values of l/h and M_D corresponding to a certain point in figure 3, the possible choices for ν_B are restricted to those curves lying to the left of or below this point. The associated value of θ_R is obtained from equation (20) as

$$\theta_R = \frac{\left(\frac{r}{r_{cr}}\right)_D - \left(\frac{r}{r_{cr}}\right)_B + \theta_{max}\left(\frac{x}{y_{cr}}\right)_B}{\left(\frac{r}{r_{cr}}\right)_D\left(\frac{l}{h} - \cot \mu_D\right)} \tag{23}$$

where θ_{max} and θ_R are in radians $\left(\theta_{max}\right.$ is listed in table II(b)$\left.\right)$.

Also plotted in figure 3 for comparison is a curve of l/h against Mach number for minimum-length nozzles. A minimum-length nozzle of final Mach number M_B is obtained from the initial-expansion flow with a streamline through point A (see fig. 1(a)). The length-to-height ratio for this type of nozzle is written as

$$\frac{l}{h} = \left(\frac{x}{y_{cr}}\right)_B \frac{1}{\left(\frac{r}{r_{cr}}\right)_B} + \cot \mu_B$$

The present computation of the initial-expansion flow has been carried out only to $M_B = 2.63$; hence, the results of reference 10 are used to extend this curve for a minimum-length nozzle up to $M_B = 10$.

Example I.- Compute the required parameters for three nozzles of the same length-to-height ratio but with final design Mach numbers of 2, 3, and 4.

Examination of figure 3 shows that a nozzle with $M_D = 4$ may be obtained on either the $\nu_B = 22^\circ$ or 40° curve. At $\nu_B = 22^\circ$, $\frac{l}{h} = 6.37$ and $\theta_R' = \frac{66 - 22}{2} = 22^\circ$ (from eq. (21)), and on the $\nu_B = 40^\circ$ curve, $\frac{l}{h} = 8.32$ and $\theta_R' = \frac{66 - 40}{2} = 13^\circ$. Thus, an intermediate value of θ_R can be obtained with $8.3 > \frac{l}{h} > 6.4$. Choosing $\frac{l}{h} = 7.0$ then fixes the values of θ_R from equation (23) for given values of ν_B and M_D as follows:

ν_B, deg	$M_D = 4.0$		$M_D = 3.0$		$M_D = 2.0$	
	θ_R, deg	Ψ	θ_R, deg	Ψ	θ_R, deg	Ψ
22	17.52	0.482	12.22	0.336		
12	17.09	.680	11.40	.454	6.23	0.248
6	16.83 $(> \theta_{max})$		10.91	.713	5.26	.344

where $\Psi = \theta_R/\theta_{max}$ from equation (19). Note that, for a given point in figure 3, values of ν_B are used only from the curves which are to the left of or below the point considered. Obvious exceptions to this statement occur when $\theta_R > \theta_{max}$, as for the case in which $M_D = 4.0$ and $\nu_B = 6^\circ$. Also of interest is the fact that Ψ increases as ν_B decreases for a given value of M_D. Since Ψ at point A is always unity (from eq. (19) with $\theta = \theta_{max}$), the value of Ψ for *any* particular nozzle is a rough measure of the curvature of the streamline; that is, a large value of Ψ indicates a high curvature.

Example II.- Compute the required parameters for a Mach number 5 nozzle with minimum length-to-height ratio using the available values of ν_B.

All the nozzles in example I utilize streamlines that pass through the radial flow so that this portion of the contour is a straight line. If this straight-line section is undesirable in a particular application, the nozzle parameters are obtained directly from the curves of figure 3.

Thus, for a nozzle with $M_D = 5.0$, the minimum value of l/h is 6.95 for $\nu_B = 22^\circ$. The corresponding value of θ_R' is $\frac{77 - 22}{2} = 27.5^\circ$ from equation (21), and $\Psi = 27.5/36.320 = 0.757$ from equation (19).

Calculation of Streamline Coordinates

Value of the stream function.- If the final design Mach number M_D, initial-expansion angle ν_B, length-to-height ratio l/h, and wall angle at the inflection point θ_R have already been selected or are available, the first step is to compute the stream function Ψ from equation (19)

$$\Psi = \frac{\theta_R}{\theta_{max}}$$

where θ_{max} depends on ν_B as listed in table II(b).

Streamlines in regions II and III.- A complete layout of the characteristic net for regions II and III with $\nu_B = 6^\circ$ is shown in figure 2(a). The Mach lines are represented by the solid lines and the long-and-short-dash line represents the limiting streamline for $\Psi = 1.00$ (that is, no streamline is possible for Ψ greater than 1.00). Region II is bounded by the sonic line AA', the right Mach line AB (line 13 in fig. 2(a)) and a portion of the center line A'B. Region III is bounded by Mach lines AB and BC and the limiting streamline. Figures 2(b), 2(c), and 2(d) show the general outlines only of regions II and III for $\nu_B = 12^\circ$, 22°, and 40°, respectively. Note that $\Psi = 0.698$ on the limiting streamline for $\nu_B = 40^\circ$. The computations were arbitrarily stopped when this value of Ψ was reached because larger values of Ψ with $\nu_B = 40^\circ$ would result in Mach numbers too high to be practical for two-dimensional nozzles.

The dimensionless Cartesian coordinates x/y_{cr} and y/y_{cr} of any streamline (corresponding to particular values of θ_R and Ψ) in region II are determined by linear interpolation in table II(a) with Ψ used as the argument. Starting at the sonic line AA', the first point on the streamline is always $x/y_{cr} = 0$ and $y/y_{cr} = \Psi$. The next point is obtained at the intersection of the streamline with the right Mach line 1 (see fig. 2(a)). The coordinates of this point are found by linear interpolation, according to the given value of Ψ, between the point (a,1) ($x/y_{cr} = 0.14243$, $y/y_{cr} = 0$, $\Psi = 0$) and the point A ($x/y_{cr} = 0$, $y/y_{cr} = 1.00$, $\Psi = 1.00$). Similarly, the next point is found by interpolation along the right Mach line 2 between the points (a,2) $\left(x/y_{cr} = 0.15675,\ \ y/y_{cr} = 0.08423,\ \ \Psi = 0.08420\right)$ and point A. This procedure is continued until the point on the left Mach line a ((a,3), (a,4), etc.) is reached where the tabulated value of Ψ is greater than the given value of Ψ. This indicates that the streamline has crossed the first left Mach line a. A sample streamline for $\Psi = 0.344$, shown in figure 2(a) as a short-dash line, crosses Mach line a between points (a,5) and (a,6) since $\Psi = 0.31023$ at (a,5) and $\Psi = 0.34507$ at (a,6). However, depending on the values of Ψ and ν_B, a streamline may pass completely through region II without crossing the left Mach line a. As can be seen by inspection of figures 2(a) to 2(c), this occurs when $\Psi > 0.5507$ for $\nu_B = 6^o$, $\$ > 0.6300$ for $\nu_B = 12^o$, and $\Psi > 0.7039$ for $\nu_B = 22^o$. For $\nu_B = 40^o$ the maximum value available is $\Psi = 0.698$.

When the given value of Ψ is less than these limits, the streamline enters that portion of region II which is downstream of the Mach line a, and the interpolation process is continued in table II(a). In general, a sufficient number of points may be obtained by interpolating along the left Mach lines only. In any case, this is the most convenient procedure since the points along the left Mach lines are always tabulated successively. Interpolation is continued in table II(a) until the streamline crosses the last right Mach line in region 11. Again, as is obvious from inspectidn of figures 2(a) to 2(d), this limiting right Mach line is different for the four different values of ν_B. Table II(a) cannot be used beyond this limiting right Mach line, which is line 13 for $\nu_B = 6^o$, line 17 for $\nu_B = 12^o$, line 22 for $\nu_B = 22^o$, and line 31 for $\nu_B = 40^o$.

After the streamline enters region 111, table III(a) is used for $\nu_B = 6^o$, table III(b) for $\nu_B = 12^o$, table III(c) for $\nu_B = 22^o$, and table III(d) for $\nu_B = 40^o$ as indicated in figures 2(a) to 2(d). A sufficient number of points in region III may also be determined by interpolation along the left Mach lines only. The local values of θ along the streamlines in both regions II and III may be determined by interpolation between the values of θ at the tabulated points as computed from the tabulated values of ν and η by using equation (4), which is $\theta = \nu - \eta$. Similarly, any other flow variable may be determined by interpolating for ν according to the desired value of Ψ and using table I to find the corresponding Mach number.

<u>Streamlines in region IV</u>.- The flow within region IV is always radial flow; that is, the streamlines are straight lines which, if extended upstream, would all emanate from a common point. The streamline forming the wall contour of a nozzle may or may not enter the radial-flow region. On the one hand, the streamline may contact the radial flow at only one point $\left(\nu_R = \nu_R'\right)$, which will then be the inflection point of the nozzle.

On the other hand, if the streamline passes through the radial flow $\left(\nu_R \neq \nu_{R'}\right)$, this portion of the nozzle will be a straight line. The coordinates of the first point on this straight line are computed from equations (8) and (9), which, by the use of equation (14), are written as

$$\left(\frac{x}{y_{cr}}\right)_{R'} = \frac{1}{\theta_{max}}\left(\frac{r}{r_{cr}}\right)_{R'} \cos \theta_{R'} + \left[\left(\frac{x}{y_{cr}}\right)_B - \frac{1}{\theta_{max}}\left(\frac{r}{r_{cr}}\right)_B\right] \tag{24}$$

$$\left(\frac{y}{y_{cr}}\right)_{R'} = \frac{1}{\theta_{max}}\left(\frac{r}{r_{cr}}\right)_{R'} \sin \theta_{R'} \tag{25}$$

where θ_{max} is entered in radians. The value of $\left(r/r_{cr}\right)_{R'}$ is found from table I as a function of $\nu_{R'}$, which is given by equation (10) as

$$\nu_{R'} = \nu_B + \theta_R$$

since $\theta_R = \theta_{R'}$. The values of $\left(x/y_{cr}\right)_B$, θ_{max}, and $\left(r/r_{cr}\right)_B$ needed in equations (24) and (25) are all obtained from table II(b) as functions of ν_B.

Note that $\nu_{R'} = \nu_R$ when the streamline has no straight-line section, and for this particular situation there is obtained from equation (11) the relation

$$\nu_{R'} = \nu_R = \nu_D - \theta_R$$

Streamlines in region V.- Region V is bounded by Mach lines CD and DE as shown in figure 1(a). Parallel and uniform flow at the design Mach number M_D is attained along the straight Mach line DE. The streamlines within this region are computed from the Foelsch equations (ref. 1) which in the present notation may be written as

$$\frac{x}{y_{cr}} = \frac{\left(\frac{r}{r_{cr}}\right)_P}{\theta_{max}}\left[\cos\theta_P + \left(\theta_R - \theta_P\right)\left(\frac{\cos\theta_P}{\tan\mu_P} - \sin\theta_P\right)\right] + \left[\left(\frac{x}{y_{cr}}\right)_B - \frac{\left(\frac{r}{r_{cr}}\right)_B}{\theta_{max}}\right]$$

$$\frac{y}{y_{cr}} = \frac{\left(\frac{r}{r_{cr}}\right)_P}{\theta_{max}}\left[\sin\theta_P + \left(\theta_R - \theta_P\right)\left(\frac{\sin\theta_P}{\tan\mu_P} + \cos\theta_P\right)\right]$$

where θ_{max} and the term $\theta_R - \theta_P$ must be entered in radians. The computing parameter in these equations is θ_P, which may vary from $\theta_P = 0$ to $\theta_P = \theta_R$. The corresponding values of $\left(r/r_{cr}\right)_P$ and μ_P are obtained from table I as functions of ν_P, which is given by equation (11) as

$$\nu_P = \nu_D - \theta_P$$

The value of ν_D is also determined from table I from the given value of M_D. The values of θ_{max}, $\left(x/y_{cr}\right)_B$, and $\left(r/r_{cr}\right)_B$ are given in table II(b) as functions of ν_B. Note that the first point on the Foelsch streamline is obtained with $\theta_P = \theta_R$ and corresponds to the end point of the straight-line section for the case of $\nu_R \neq \nu_{R'}$ or to the inflection point for $\nu_R = \nu_{R'}$.

The final nozzle coordinates are obtained to the desired scale by multiplying all dimensionless coordinates by a suitable factor.

CONCLUDING REMARKS

A method is presented for computing flows which generate supersonic radial flows from a parallel and uniform sonic flow. The coordinates of each point in the characteristic nets and corresponding values of the stream function have been computed and tabulated for several flows of this type. The coordinates of any streamline in these flows may be obtained to a high degree of accuracy by simple linear interpolation between the tabulated points for the required value of the stream function. The local flow angles along the streamlines may be obtained in the same way. The supersonic nozzle design is then completed by matching one of these streamlines to a streamline computed from the Foelsch equations for the transition from radial flow to the final uniform parallel flow. Graphs and formulas are included to aid in the selection of nozzle parameters for a wide range of Mach number, length-to-height ratio, and wall angle at the inflection point. In general, a nozzle is determined by specifying *any* two of these three parameters.

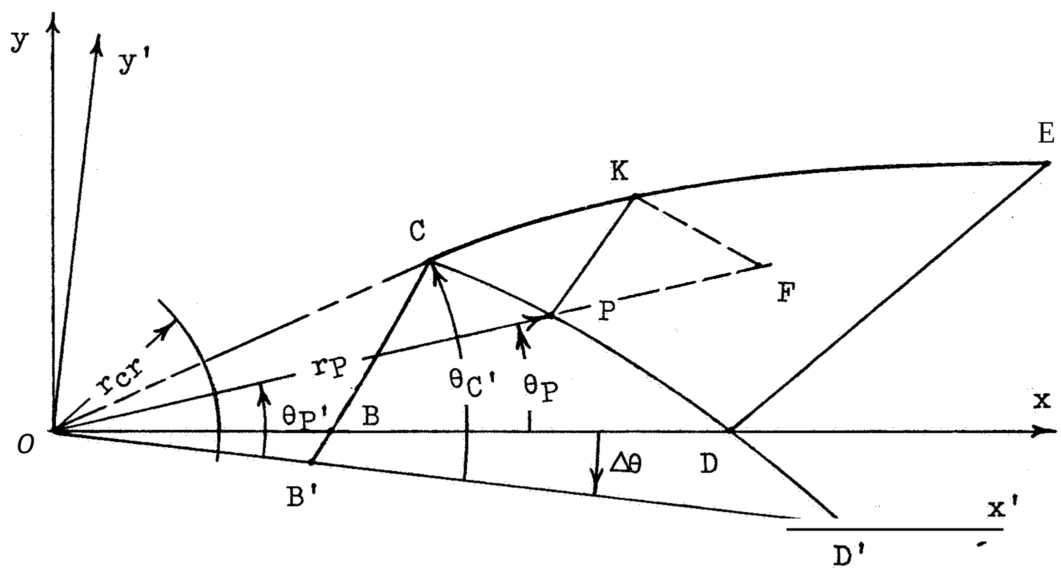
Langley Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., October 4, 1954.

APPENDIX

APPLICATION OF THE FOELSCH EQUATIONS TO THE DESIGN OF VARIABLE MACH NUMBER NOZZLES

Analytic expressions derived by Foelsch (ref. 1) give the coordinates of streamlines in a transition flow which generates a uniform parallel supersonic stream from two-dimensional supersonic radial flow. Rotation as a unit of any single streamline about the radial-flow origin results in a continuous variation of the Mach number and relative location of the uniform-flow portion, as can be shown by rotating the x- and y-axes through an angle $\Delta\theta$ (where $\Delta\theta$ may be either positive or negative) and applying the resulting transformation of coordinates to the Foelsch equations.

The coordinates of any point K along the streamline CE in the following sketch



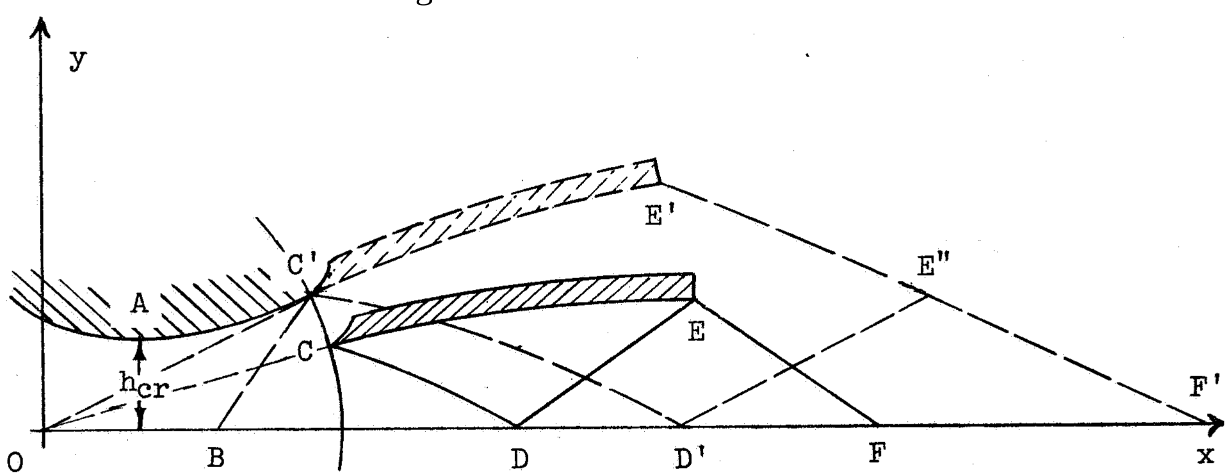
are given by the Foelsch equations as

$$\left(\frac{x}{r_{cr}}\right)_K = \left(\frac{r}{r_{cr}}\right)_P\left[\cos\theta_P + \left(\theta_C - \theta_P\right)\left(\sqrt{M_P^2 - 1}\,\cos\theta_P - \sin\theta_P\right)\right] \tag{A1}$$

$$\left(\frac{y}{r_{cr}}\right)_K = \left(\frac{r}{r_{cr}}\right)_P\left[\sin\theta_P + \left(\theta_C - \theta_P\right)\left(\sqrt{M_P^2 - 1}\,\sin\theta_P + \cos\theta_P\right)\right] \tag{A2}$$

where the origin of the radial flow coincides with the origin of the Cartesian coordinates. Two-dimensional radial flow is assumed to exist within the region bounded by the Mach lines BC and CD. Uniform flow, parallel to the x-axis, exists downstream from the straight Mach line DE. Although details of the mathematics are not included herein, it is easy to verify that rotation of the x- and y-axes, through the angle $\Delta\theta$ to the new axes x' and y', and application of the coordinate transformation to equations (A1) and (A2) results in equations for x' and y' which are exactly the same as equations (A1) and (A2) except that θ_P and θ_C are replaced by $\theta_{P'}$ and $\theta_{C'}$ where $\theta_{C'} = \theta_C - \Delta\theta$. This shows that the streamline CE is also a portion of a streamline required to produce a uniform flow at a Mach number of $M_{D'}$ from a radial flow bounded by the Mach lines B'C and CD'. That is, the streamline CE forms a portion of a new nozzle with the final Mach number of $M_{D'} > M_D$ for negative values of $\Delta\theta$, and $M_{D'} < M_D$ for positive values of $\Delta\theta$, where the x'-axis forms the new line of symmetry. The same conclusions may be obtained, perhaps in a more straightforward manner, by inspection of the geometrical relations between the radial flow and transition flow as indicated in the above sketch. Thus, any streamline OP within the radial flow can serve as a line of symmetry; then, since all left Mach lines such as PK within the transition flow are straight lines, the normal expansion along Mach line CD (or its extension) is in effect cut off by the new line of symmetry resulting in a uniform-flow region PKF.

These results can be applied to the design of a variable Mach number nozzle by constructing the section of the nozzle contour CE as an adjustable scoop designed to utilize only a part of the radial flow as indicated in the following sketch:



Radial flow is produced within the entire region BC'D' by the throat section AC'. This throat section is designed according to the method discussed in this report. Thus, at the lower position CE, a uniform-flow test rhombus is produced within the region DEF (since the x-axis is a line of symmetry, only the upper part of the nozzle is shown), and that part of the radial flow passing through the arc CC' is discarded. To obtain a larger Mach number, the solid section is rotated outward about the origin of the radial flow to C'E' or any intermediate position. At the position C'E' a uniform-flow test rhombus is produced within the region D'E"F' and all the radial flow is utilized. The line E'E"F' is a Mach line originating at point E'.

The actual construction and operation of a variable or adjustable Mach number nozzle of this type would naturally be limited by various physical considerations. The lower limit of operation, corresponding to positive values of $\Delta\theta$ and $M_D' < M_D$ would be determined by the onset of choking as the height y_E is reduced. The upper limit of operation would probably depend on the diffuser design. Certain mechanical design problems, such as the relatively large longitudinal displacement of the test region, would also limit the range of operation.

In order to indicate the possible range of Mach numbers and general utility of the above scheme, the quantities M_D, M_D', y_E/h_{cr}, y_E'/h_{cr}, y_E''/h_{cr}, x_E/h_{cr}, and x_E''/h_{cr} have been computed for various arbitrary values of θ_C and θ_C'. The four values of ν_B corresponding to the four different secondary-expansion flows as shown in tables III(a) to III(d) have been used in this computation.

ν_B, deg	θ_C, deg	M_D	$\frac{x_E}{h_{cr}}$	$\frac{y_E}{h_{cr}}$	θ_C', deg	M_D'	$\frac{x_E''}{h_{cr}}$	$\frac{y_E''}{h_{cr}}$	$\frac{y_E'}{h_{cr}}$
6	2.0	1.89	6.10	0.202	15.30	2.39	9.39	0.202	1.61
12	3.0	2.54	7.03	.328	25.13	3.74	21.0	.433	2.95
22	5.0	3.82	19.0	1.25	36.32	7.76	289	3.48	10.9
40	8.0	5.53	114	9.02	33.50	12.06	2,660	34.7	56.9

For the convenience of the designer the formulas needed to compute the parameters are as follows: For given values of ν_B, θ_C, and θ_C',

$$\nu_D' = 2\theta_C' + \nu_B$$

$$\nu_D = \nu_B + \theta_C' + \theta_C$$

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$$\frac{L}{r_{cr}} = \frac{r_D}{r_{cr}} M_D\theta_C\left(\frac{M_D^2 - 1}{M_D'^2 - 1}\right)^{1/4}\left(\frac{1 + \frac{\gamma - 1}{2} M_D'^2}{1 + \frac{\gamma - 1}{2} M_D^2}\right)^{\frac{\gamma}{2(\gamma-1)}}$$

This equation may be derived from considerations analogous to those used in reference 1 to obtain the length of a left Mach line in the transition flow.

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TABLE I.- SUPERSONIC-FLOW VARIABLES FOR $\gamma = 1.400$

ν, deg	M	μ, deg	r/r_{cr}	ν, deg	M	μ, deg	r/r_{cr}	ν, deg	M	μ, deg	r/r_{cr}
0	1.0000	90.000	1.00000	2.37500	1.1497	60.432	1.01739	4.75000	1.2469	53.318	1.04566
.03125	1.0079	82.837	1.00005	2.40625	1.1511	60.310	1.01771	4.78125	1.2481	53.242	1.04609
.06250	1.0125	80.983	1.00013	2.43750	1.1525	60.189	1.01803	4.81250	1.2493	53.171	1.04651
.09375	1.0164	79.686	1.00022	2.46875	1.1539	60.069	1.01835	4.84375	1.2505	53.098	1.04694
.12500	1.0199	78.655	1.00033	2.50000	1.1553	59.950	1.01867	4.87500	1.2517	53.025	1.04737
.15625	1.0232	77.787	1.00044	2.53125	1.1567	59.832	1.01899	4.90625	1.2529	52.953	1.04780
.18750	1.0262	77.029	1.00056	2.56250	1.1580	59.715	1.01931	4.93750	1.2541	52.881	1.04823
.21875	1.0291	76.353	1.00069	2.59375	1.1594	59.600	1.01964	4.96875	1.2553	52.810	1.04867
.25000	1.0318	75.740	1.00083	2.62500	1.1608	59.485	1.01996	5.000	1.2565	52.738	1.04910
.28125	1.0344	75.176	1.00097	2.65625	1.1621	59.371	1.02029	5.125	1.2612	52.457	1.05086
.31250	1.0370	74.654	1.00112	2.68750	1.1635	59.259	1.02062	5.250	1.2659	52.180	1.05263
.34375	1.0394	74.166	1.00127	2.71875	1.1648	59.147	1.02095	5.375	1.2706	51.909	1.05442
.37500	1.0418	73.708	1.00142	2.75000	1.1662	59.036	1.02129	5.500	1.2753	51.642	1.05623
.40625	1.0442	73.274	1.00159	2.78125	1.1675	58.926	1.02162	5.625	1.2799	51.380	1.05807
.43750	1.0465	72.864	1.00176	2.81250	1.1689	58.817	1.02196	5.750	1.2846	51.122	1.05992
.46875	1.0487	72.473	1.00192	2.84375	1.1702	58.709	1.02230	5.875	1.2892	50.868	1.06180
.50000	1.0509	72.099	1.00210	2.87500	1.1716	58.601	1.02264	6.000	1.2938	50.619	1.06369
.53125	1.0530	71.741	1.00228	2.90625	1.1729	58.495	1.02298	6.125	1.2983	50.373	1.06560
.56250	1.0551	71.397	1.00246	2.93750	1.1742	58.390	1.02332	6.250	1.3029	50.131	1.06754
.59375	1.0572	71.066	1.00265	2.96875	1.1755	58.284	1.02367	6.375	1.3075	49.893	1.06950
.62500	1.0592	70.747	1.00284	3.00000	1.1769	58.180	1.02401	6.500	1.3120	49.658	1.07147
.65625	1.0613	70.438	1.00303	3.03125	1.1782	58.077	1.02436	6.625	1.3165	49.427	1.07347
.68750	1.0632	70.140	1.00322	3.06250	1.1795	57.975	1.02470	6.750	1.3210	49.199	1.07548
.71875	1.0652	69.851	1.00342	3.09375	1.1808	57.873	1.02506	6.875	1.3255	48.974	1.07752
.75000	1.0671	69.570	1.00363	3.12500	1.1821	57.772	1.02541	7.000	1.3300	48.753	1.07957
.78125	1.0690	69.298	1.00383	3.15625	1.1834	57.672	1.02576	7.125	1.3345	48.534	1.08165
.81250	1.0709	69.032	1.00404	3.18750	1.1847	57.572	1.02612	7.250	1.3390	48.318	1.08374
.84375	1.0728	68.774	1.00425	3.21875	1.1860	57.473	1.02648	7.375	1.3434	48.106	1.08586
.87500	1.0746	68.522	1.00447	3.25000	1.1873	57.375	1.02683	7.500	1.3478	47.8%	1.08799
.90625	1.0764	68.277	1.00468	3.28125	1.1886	57.278	1.02719	7.625	1.3523	47.688	1.09015
.93750	1.0783	68.037	1.00490	3.31250	1.1899	57.181	1.02755	7.750	1.3567	47.484	1.09232
.96875	1.0800	67.803	1.00512	3.34375	1.1912	57.085	1.02791	7.875	1.3611	47.281	1.09452
1.00000	1.0818	67.574	1.00535	3.37500	1.1925	56.990	1.02828	8.000	1.3655	47.082	1.09673
1.03125	1.0836	67.350	1.00558	3.40625	1.1938	56.895	1.02864	8.125	1.3699	46.884	1.09897
1.06250	1.0853	67.131	1.00581	3.43750	1.1951	56.801	1.02901	8.250	1.3743	46.689	1.10122
1.09375	1.0870	66.916	1.00604	3.46875	1.1964	56.707	1.02938	8.375	1.3785	46.497	1.10350
1.12500	1.0888	66.705	1.00628	3.50000	1.1976	56.614	1.02975	8.500	1.3830	46.306	1.10579
1.15625	1.0905	66.499	1.00651	3.53125	1.1989	56.522	1.03012	8.625	1.3874	46.118	1.10811
1.18750	1.0921	66.2%	1.00675	3.56250	1.2002	56.430	1.03049	8.750	1.3918	45.932	1.11044
1.21875	1.0938	66.097	1.00699	3.59375	1.2014	56.339	1.03086	8.875	1.3961	45.748	1.11280
1.25000	1.0955	65.902	1.00724	3.62500	1.2027	56.249	1.03124	9.000	1.4005	45.566	1.11517
1.28125	1.0971	65.710	1.00749	3.65625	1.2040	56.159	1.03162	9.125	1.4048	45.386	1.11757
1.31250	1.0988	65.521	1.00773	3.68750	1.2052	56.069	1.03199	9.250	1.4091	45.208	1.11998
1.34375	1.1004	65.335	1.00799	3.71875	1.2065	55.980	1.03237	9.375	1.4134	45.031	1.12242
1.37500	1.1020	65.153	1.00824	3.75000	1.2078	55.892	1.03275	9.500	1.4178	44.857	1.12488
1.40625	1.1036	64.973	1.00850	3.78125	1.2090	55.804	1.03314	9.625	1.4221	44.684	1.12735
1.43750	1.1052	64.796	1.00875	3.81250	1.2103	55.717	1.03352	9.750	1.4264	44.514	1.12985
1.46875	1.1068	64.622	1.00901	3.84375		55.631	1.03390	9.875	1.4307	44.344	1.13237
1.50000	1.1084	64.450	1.00928	3.87500	1.2128	55.544	1.03429	10.000	1.4350	44.177	1.13491
1.53125	1.1100	64.281	1.00954	3.90625	1.2140	55.459	1.03468	10.125	1.4393	44.011	1.13746
1.56250	1.1115	64.115	1.00981	3.93750	1.2153	55.374	1.03507	10.250	1.4436	43.847	1.14004
1.59375	1.1131	63.950	1.01007	3.96875	1.2165	55.289	1.03546	10.375	1.4478	43.684	1.14264
1.62500	1.1146	63.788	1.01034	4.00000	1.2177	55.205	1.03585	10.500	1.4521	43.523	1.14526
1.65625	1.1162	63.628	1.01062	4.03125	1.2190	55.121	1.03624	10.625	1.4564	43.364	1.14791
1.68750	1.1177	63.471	1.01089	4.06250	1.2202	55.038	1.03664	10.750	1.4607	43.206	1.15057
1.71875	1.1192	63.315	1.01117	4.09375	1.2214	54.955	1.03703	10.875	1.4649	43.049	1.15325
1.75000	1.1207	63.161	1.01144	4.12500	1.2227	54.873	1.03743	11.000	1.4692	42.894	1.15595
1.78125	1.1222	63.009	1.01173	4.15625	1.2239	54.791	1.03783	11.125	1.4735	42.740	1.15868
1.81250	1.1237	62.860	1.01201	4.18750	1.2251	54.710	1.03823	11.250	1.4777	42.588	1.16142
1.84375	1.1252	62.712	1.01229	4.21875	1.2264	54.629	1.03863	11.375	1.4820	42.437	1.16419
1.87500	1.1267	62.565	1.01258	4.25000	1.2276	54.549	1.03903	11.500	1.4862	42.287	1.16698
1.90625	1.1282	62.421	1.01286	4.28125	1.2288	54.469	1.03944	11.625	1.4905	42.138	1.16979
1.93750	1.1297	62.278	1.01315	4.31250	1.2300	54.389	1.03985	11.750	1.4947	41.991	1.17262
1.96875	1.1311	62.137	1.01344	4.34375	1.2313	54.310	1.04025	11.875	1.4990	41.845	1.17548
2.00000	1.1326	61.997	1.01374	4.37500	1.2325	54.231	1.04066	12.000	1.5032	41.701	1.17835
2.03125	1.1341	61.859	1.01403	4.40625	1.2337	54.153	1.04107	12.125	1.5075	41.557	1.18124
2.06250	1.1355	61.722	1.01433	4.43750	1.2349	54.075	1.04148	12.250	1.5117	41.415	1.18416
2.09375	1.1370	61.587	1.01463	4.46875	1.2361	53.997	1.04189	12.375	1.5159	41.274	1.18710
2.12500	1.1384	61.454	1.01493	4.50000	1.2373	53.920	1.04231	12.500	1.5202	41.134	1.19006
2.15625	1.1398	61.321	1.01523	4.53125	1.2385	53.844	1.04272	12.625	1.5244	40.995	1.19305
2.18750	1.1413	61.190	1.01553	4.56250	1.2397	53.767	1.04314	12.750	1.5286	40.857	1.19605
2.21875	1.1427	61.061	1.01584	4.59375	1.2409	53.691	1.04356	12.875	1.5329	40.721	1.19908
2.25000	1.1441	60.933	1.01615	4.62500	1.2421	53,616	1.04397	13.000	1.5371	40.585	1.20213
2.28125	1.1455	60.806	1.01646	4.65625	1.2433	53.541	1.04439	13.125	1.5413	40.450	1.20521
2.31250	1.1469	60.680	1.01677	4.68750	1.2445	53.466	1.04481	13.250	1.5456	40.317	1.20830
2.34375	1.1483	60.555	1.01708	4.71875	1.2457	53.392	1.04524	13.375	1.5498	40.184	1.21142

TABLE I.- SUPERSONIC-FLOW VARIABLES FOR γ = 1.400 - Continued

ν, deg	M	μ, deg	r/r_{cr}	ν, deg	M	μ, deg	r/r_{cr}	ν, deg	M	μ, deg	r/r_{cr}
13.500	1.5540	40.053	1.21456	21.000	1.8095	33.548	1.44939	28.500	2.0778	28.769	1.80217
13.625	1.5582	39.922	1.21772	21.125	1.8139	33.457	1.45418	28.625	2.0824	28.699	1.80936
13.750	1.5625	39.793	1.22091	21.250	1.8182	33.367	1.45899	28.750	2.0871	28.629	1.81659
13.875	1.5667	39.664	1.22412	21.375	1.8225	33.277	1.46384	28.875	2.0917	28.560	1.82388
14.000	1.5709	39.536	1.22735	21.500	1.8269	33.188	1.46873	29.000	2.0964	28.491	1.83121
14.125	1.5751	39.410	1.23060	21.625	1.8312	33.099	1.47364	29.125	2.1010	28.421	1.83860
14.250	1.5794	39.284	1.23388	21.750	1.8356	33.010	1.47859	29.250	2.1057	28.353	1.84604
14.375	1.5836	39.159	1.23719	21.875	1.8399	32.922	1.48357	29.375	2.1104	28.284	1.85353
14.500	1.5878	39.035	1.24051	22.000	1.8443	32.834	1.48859	29.500	2.1151	28.216	1.86107
14.625	1.5920	38.912	1.24386	22.125	1.8487	32.747	1.49364	29.625	2.1198	28.148	1.86866
14.750	1.5963	38.789	1.24724	22.250	1.8530	32.660	1.49872	29.750	2.1245	28.080	1.87631
14.875	1.6005	38.668	1.25063	22.375	1.8574	32.574	1.50384	29.875	2.1292	28.012	1.88401
15.000	1.6047	38.547	1.25406	22.500	1.8618	32.488	1.50900	30.000	2.1339	27.945	1.89176
15.125	1.6089	38.428	1.25750	22.625	1.8662	32.402	1.51418	30.125	2.1386	27.878	1.89957
15.250	1.6132	38.309	1.26097	22.750	1.8705	32.317	1.51940	30.250	2.1434	27.811	1.90743
15.375	1.6174	38.190	1.26447	22.875	1.8749	32.232	1.52466	30.375	2.1481	27.744	1.91534
15.500	1.6216	38.073	1.26799	23.000	1.8793	32.148	1.52995	30.500	2.1528	27.678	1.92331
15.625	1.6259	37.956	1.27153	23.125	1.8837	32.064	1.53528	30.625	2.1576	27.612	1.93134
15.750	1.6301	37.840	1.27510	23.250	1.8881	31.980	1.54065	30.750	2.1623	27.546	1.93943
15.875	1.6343	37.725	1.27869	23.375	1.8925	31.897	1.54605	30.875	2.1671	27.480	1.94757
16.000	1.6386	37.611	1.28231	23.500	1.8970	31.814	1.55149	31.000	2.1719	27.415	1.95577
16.125	1.6428	37.497	1.28595	23.625	1.9014	31.731	1.55696	31.125	2.1767	27.350	1.96402
16.250	1.6470	37.384	1.28962	23.750	1.9058	31.649	1.56248	31.250	2.1815	27.250	1.97234
16.375	1.6513	37.272	1.29332	23.875	1.9102	31.567	1.56802	31.375	2.1862	27.220	1.98070
16.500	1.6555	37.160	1.29704	24.000	1.9147	31.486	1.57361	31.500	2.1910	27.155	1.98913
16.625	1.6597	37.050	1.30079	24.125	1.9191	31.405	1.57923	31.625	2.1959	27.091	1.99763
16.750	1.6640	36.939	1.30456	24.250	1.9235	31.324	1.58490	31.750	2.2007	27.027	2.00618
16.875	1.6682	36.830	1.30835	24.375	1.9280	31.244	1.59060	31.875	2.2055	26.963	2.01479
17.000	1.6725	36.721	1.31218	24.500	1.9324	31.164	1.59634	32.000	2.2103	26.899	2.02346
17.125	1.6767	36.613	1.31603	24.625	1.9369	31.084	1.60211	32.125	2.2152	26.836	2.03219
17.250	1.6810	36.506	1.31991	24.750	1.9413	31.005	1.60793	32.250	2.2200	26.772	2.04098
17.375	1.6852	36.399	1.32381	24.875	1.9458	30.926	1.61379	32.375	2.2249	26.709	2.04984
17.500	1.6895	36.293	1.32774	25.000	1.9503	30.847	1.61969	32.500	2.2297	26.646	2.05876
17.625	1.6937	36.187	1.33170	25.125	1.9548	30.769	1.62563	32.625	2.2346	26.584	2.06775
17.750	1.6980	36.082	1.33569	25.250	1.9592	30.691	1.63160	32.750	2.2395	26.521	2.07679
17.875	1.7022	35.978	1.33970	25.375	1.9637	30.613	1.63762	32.875	2.2444	26.459	2.08590
18.000	1.7065	35.874	1.34374	25.500	1.9682	30.536	1.64368	33.000	2.2493	26.397	2.09508
18.125	1.7107	35.771	1.34781	25.625	1.9727	30.458	1.64978	33.125	2.2542	26.335	2.10432
18.250	1.7150	35.668	1.35190	25.750	1.9772	30.382	1.65592	33.250	2.2591	26.273	2.11363
18.375	1.7193	35.566	1.35603	25.875	1.9817	30.305	1.66210	33.375	2.2640	26.212	2.12300
18.500	1.7235	35.465	1.36018	26.000	1.9863	30.229	1.66833	33.500	2.2689	26.151	2.13244
18.625	1.7278	35.364	1.36436	26.125	1.9908	30.153	1.67459	33.625	2.2739	26.090	2.14195
18.750	1.7321	35.264	1.36857	26.250	1.9953	30.078	1.68091	33.750	2.2788	26.029	2.15153
18.875	1.7364	35.164	1.37280	26.375	1.9998	30.003	1.68726	33.875	2.2838	25.968	2.16118
19.000	1.7406	35.065	1.37707	26.500	2.0044	29.928	1.69365	34.000	2.2887	25.908	2.17089
19.125	1.7449	34.966	1.38136	26.625	2.0089	29.853	1.70009	34.125	2.2937	25.847	2.18068
19.250	1.7492	34.868	1.38569	26.750	2.0135	29.779	1.70658	34.250	2.2987	25.787	2.19053
19.375	1.7535	34.770	1.39004	26.875	2.0180	29.705	1.71311	34.375	2.3037	25.727	2.20046
19.500	1.7578	34.673			2.0226	29.632	1.71968	34.500	2.3087	25.668	2.21046
19.625	1.7621	34.577			2.0271	29.558	1.72630	34.625	2.3137	25.608	2.22053
19.750	1.7664	34.481			2.0317	29.485	1.73297	34.750	2.3187	25.549	2.23068
19.875	1.7707	34.385	1.40775	27.375	2.0363	29.412	1.73967	34.875	2.3237	25.490	2.24089
20.000	1.7750	34.290	1.41225	27.500	2.0409	29.340	1.74643	35.000	2.3288	25.431	2.25118
20.125	1.7793	34.196	1.41679	27.625	2.0455	29.267	1.75323	35.125	2.3338	25.372	2.26155
20.250	1.7836	34.102	1.42135	27.750	2.0501	29.195	1.76008	35.250	2.3388	25.313	2.27199
20.375	1.7879	34.008	1.42595	27.875	2.0547	29.124	1.76697	35.375	2.3439	25.255	2.28251
20.500	1.7922	33.915	1.43057	28.000	2.0593	29.052	1.77392	35.500	2.3490	25.196	2.29310
20.625	1.7965	33.823	1.43523	28.125	2.0639	28.981	1.78091	35.625	2.3540	25.138	2.30378
20.750	1.8009	33.731	1.43992	28.250	2.068[illegible]	28.910	1.78795	35.750	2.3591	25.080	2.31453
20.875	1.8052	33.639	1.44464	28.375	2.0731	28.840	1.79503	35.875	2.3642	25.02[illegible]	2.32535

TABLE I.- SUPERSONIC-FLOW VARIABLES FOR $\gamma = 1.400$ - Continued

ν, deg	M	μ, deg	r/r_{cr}	ν, [redacted]	M	μ, deg	r/r_{cr}	ν, deg	M	μ, deg	r/r_{cr}
36.000	2.3693	24.965	2.33626	43.500	2.6944	21.786	3.16616	51.000	3.0652	19.041	4.50581
36.125	2.3744	24.907	2.34725	43.625	2.7002	21.737	3.18350	51.125	3.0719	18.998	4.53443
36.250	2.3796	24.850	2.35832	43.750	2.7059	21.688	3.20099	51.250	3.0786	18.955	4.56329
36.375	2.3847	24.793	2.36947	43.875	2.7117	21.640	3.21863	51.375	3.0852	18.913	4.59241
36.500	2.3898	24.736	2.38071	44.000	2.7175	21.591	3.23639	51.500	3.0920	18.870	4.62179
36.625	2.3950	24.679	2.39202	44.125	2.7234	21.543	3.25431	51.625	3.0987	18.827	4.65141
36.750	2.4001	24.623	2.40342	44.250	2.7292	21.494	3.27237	51.750	3.1054	18.785	4.68131
36.875	2.4053	24.566	2.41490	44.375	2.7350	21.446	3.29057	51.875	3.1122	18.743	4.71148
37.000	2.4105	24.510	2.42646	44.500	2.7409	21.398	3.30890	52.000	3.1189	18.701	4.74189
37.125	2.4157	24.454	2.43812	44.625	2.7468	21.350	3.32740	52.125	3.1257	18.659	4.77259
37.250	2.4209	24.398	2.44986	44.750	2.7526	21.302	3.34606	52.250	3.1325	18.616	4.80358
37.375	2.4261	24.342	2.46169	44.875	2.7585	21.254	3.36485	52.375	3.1394	18.574	4.83481
37.500	2.4313	24.287	2.47360	45.000	2.7645	21.207	3.38381	52.500	3.1462	18.532	4.86634
37.625	2.4365	24.231	2.48561	45.125	2.7704	21.159	3.40289	52.625	3.1531	18.491	4.89815
37.750	2.4418	24.176	2.49770	45.250	2.7763	21.112	3.42216	52.750	3.1600	18.449	4.93027
37.875	2.4470	24.121	2.50989	45.375	2.7823	21.065	3.44159	52.875	3.1669	18.407	4.96263
38.000	2.4523	24.066	2.52216	45.500	2.7882	21.017	3.46116	53.000	3.1738	18.366	4.99531
38.125	2.4575	24.011	2.53452	45.625	2.7942	20.970	3.48088	53.125	3.1807	18.324	5.02830
38.250	2.4628	23.956	2.54699	45.750	2.8002	20.923	3.50077	53.250	3.1877	18.283	5.06156
38.375	2.4681	23.902	2.55954	45.875	2.8062	20.876	3.52083	53.375	3.1947	18.241	5.09515
38.500	2.4734	23.847	2.57218	46.000	2.8122	20.830	3.54107	53.500	3.2017	18.200	5.12904
38.625	2.4787	23.793	2.58493	46.125	2.8183	20.783	3.56144	53.625	3.2087	18.159	5.16320
38.750	2.4840	23.739	2.59777	46.250	2.8243	20.736	3.58200	53.750	3.2158	18.118	5.19770
38.875	2.4894	23.685	2.61070	46.375	2.8304	20.690	3.60273	53.875	3.2228	18.078	5.23252
39.000	2.4947	23.631	2.62374	46.500	2.8364	20.644	3.62362	54.000	3.2298	18.036	5.26766
39.125	2.5001	23.578	2.63687	46.625	2.8425	20.597	3.64470	54.125	3.2369	17.995	5.30312
39.250	2.5054	23.524	2.65010	46.750	2.8486	20.551	3.66594	54.250	3.2440	17.954	5.33891
39.375	2.5108	23.471	2.66343	46.875	2.8548	20.505	3.68736	54.375	3.2512	17.914	5.37501
39.500	2.5162	23.418	2.67686	47.000	2.8609	20.459	3.70896	54.500	3.2583	17.873	5.41145
39.625	2.5216	23.364	2.69040	47.125	2.8670	20.413	3.73074	54.625	3.2655	17.832	5.44823
39.750	2.5270	23.312	2.70404	47.250	2.8732	20.368	3.75270	54.750	3.2727	17.792	5.48537
39.875	2.5324	23.259	2.71778	47.375	2.8794	20.322	3.77485	54.875	3.2799	17.751	5.52282
40.000	2.5378	23.206	2.73163	47.500	2.8856	20.277	3.79718	55.000	3.2871	17.711	5.56063
40.125	2.5433	23.154	2.74559	47.625	2.8918	20.231	3.81971	55.125	3.2944	17.671	5.59878
40.250	2.5487	23.101	2.75964	47.750	2.8980	20.186	3.84240	55.250	3.3016	17.630	5.63731
40.375	2.5542	23.049	2.77381	47.875	2.9042	20.141	3.86529	55.375	3.3089	17.591	5.67617
40.500	2.5596	22.997	2.78808	48.000	2.9105	20.096	3.88838	55.500	3.3162	17.551	5.71543
40.625	2.5651	22.945	2.80248	48.125	2.9167	20.051	3.91167	55.625	3.3236	17.511	5.75505
40.750	2.5706	22.893	2.81698	48.250	2.9230	20.006	3.93515	55.750	3.3309	17.471	5.79503
40.875	2.5761	22.841	2.83159	48.375	2.9293	19.961	3.95883	55.875	3.3383	17.431	5.83538
41.000	2.5816	22.790	2.84631	48.500	2.9356	19.916	3.98272	56.000	3.3457	17.391	5.87612
41.125	2.5871	22.739	2.86114	48.625	2.9420	19.871	4.00680	56.125	3.3531	17.351	5.91725
41.250	2.5927	22.687	2.87609	48.750	2.9483	19.827	4.03108	56.250	3.3605	17.312	5.95876
41.375	2.5982	22.636	2.89116	48.875	2.9547	19.782	4.05559	56.375	3.3680	17.272	6.00065
41.500	2.6038	22.585	2.90635	49.000	2.9610	19.738	4.08029	56.500	3.3755	17.233	6.04296
41.625	2.6094	22.534	2.92165	49.125	2.9674	19.694	4.10521	56.625	3.3830	17.193	6.08568
41.750	2.6150	22.483	2.93707	49.250	2.9738	19.650	4.13032	56.750	3.3905	17.154	6.12878
41.875	2.6205	22.433	2.95262	49.375	2.9803	19.605	4.15569	56.875	3.3980	17.115	6.17233
42.000	2.6262	22.382	2.96828	49.500	2.9867	19.561	4.18125	57.000	3.4056	17.076	6.21625
42.125	2.6318	22.332	2.98407	49.625	2.9931	19.518	4.20703	57.125	3.4132	17.037	6.26059
42.250	2.6374	22.282	2.99998	49.750	2.9996	19.474	4.23302	57.250	3.4208	16.997	6.30540
42.375	2.6431	22.232	3.01602	49.875	3.0061	19.430	4.25927	57.375	3.4284	16.959	6.35061
42.500	2.6487	22.182	3.03217	50.000	3.0126	19.386	4.28573	57.500	3.4361	16.920	6.39628
42.625	2.6544	22.132	3.04847	50.125	3.0191	19.343	4.31241	57.625	3.4438	16.881	6.44237
42.750	2.6601	22.082	3.06488	50.250	3.0257	19.300	4.33932	57.750	3.4515	16.842	6.48890
42.875	2.6657	22.032	3.08142	50.375	3.0322	19.256	4.36648	57.875	3.4592	16.803	6.53588
43.000	2.6715	21.983	3.09810	50.500	3.0388	19.213	4.39386	58.000	3.4669	16.765	6.58335
43.125	2.6772	21.933	3.11491	50.625	3.0454	19.170	4.42149	58.125	3.4747	16.726	6.63126
43.250	2.6829	21.884	3.13186	50.750	3.0520	19.127	4.44934	58.250	3.4825	16.687	6.67965
43.375	2.6886	21.835	3.14893	50.875	3.0586	19.084	4.47746	58.375	3.4903	16.649	6.72848

TABLE I.- SUPERSONIC-FLOW VARIABLES FOR $\gamma = 1.400$ - Continued

ν, deg	M	μ, deg	r/r_{cr}	ν, deg	M	μ, deg	r/r_{cr}	ν, deg	M	μ, deg	r/r_{cr}
58.500	3.4981	16.611	6.77782	66.000	4.0163	14.417	10.87615	73.500	4.6548	12.406	18.86223
58.625	3.5060	16.572	6.82762	66.125	4.0259	14.382	10.96894	73.625	4.6668	12.373	19.05047
58.750	3.5139	16.534	6.87789	66.250	4.0354	14.348	11.06278	73.750	4.6788	12.341	19.24120
58.875	3.5218	16.496	6.92871	66.375	4.0451	14.313	11.15769	73.875	4.6908	12.309	19.43417
59.000	3.5297	16.458	6.97998	66.500	4.0547	14.278	11.25360	74.000	4.7029	12.277	19.62976
59.125	3.5377	16.420	7.03181	66.625	4.0644	14.243	11.35065	74.125	4.7150	12.245	19.82788
59.250	3.5457	16.382	7.08413	66.750	4.0741	14.209	11.44873	74.250	4.7272	12.213	20.02846
59.375	3.5537	16.344	7.13697	66.875	4.0838	14.174	11.54793	74.375	4.7394	12.181	20.23153
59.500	3.5617	16.304	7.19031	67.000	4.0936	14.140	11.64821	74.500	4.7517	12.149	20.43744
59.625	3.5697	16.268	7.24421	67.125	4.1034	14.105	11.74966	74.625	4.7641	12.117	20.64588
59.750	3.5778	16.230	7.29862	67.250	4.1132	14.071	11.85224	74.750	4.7764	12.085	20.85704
59.875	3.5859	16.193	7.35361	67.375	4.1231	14.036	11.95599	74.875	4.7889	12.053	21.07088
50.000	3.5940	16.155	7.40911	67.500	4.1330	14.002	12.06096	75.000	4.8014	12.021	21.28760
60.125	3.6022	16.118	7.46521	67.625	4.1430	13.968	12.16707	75.125	4.8139	11.989	21.50722
60.250	3.6104	16.080	7.52186	67.750	4.1529	13.933	12.27435	75.250	4.8265	11.958	21.72957
60.375	3.6186	16.043	7.57906	67.875	4.1630	13.899	12.38294	75.375	4.8392	11.926	21.95494
60.500	3.6268	16.005	7.63687	68.000	4.1730	13.865	12.49279	75.500	4.8519	11.894	22.18310
60.625	3.6351	15.968	7.69526	68.125	4.1831	13.831	12.60383	75.625	4.8646	11.863	22.41435
60.750	3.6433	15.931	7.75421	68.250	4.1932	13.797	12.71608	75.750	4.8774	11.831	22.64874
60.875	3.6516	15.894	7.81378	68.375	4.2034	13.763	12.82979	75.875	4.8903	11.800	22.88618
61.000	3.6600	15.856	7.87397	68.500	4.2136	13.729	12.94469	76.000	4.9032	11.768	23.12678
61.125	3.6683	15.819	7.93473	68.625	4.2238	13.695	13.06092	76.125	4.9162	11.736	23.37051
61.250	3.6767	15.782	7.99616	68.750	4.2341	13.661	13.17856	76.250	4.9292	11.705	23.61759
61.375	3.6851	15.745	8.05819	68.875	4.2444	13.627	13.29751	76.375	4.9423	11.674	23.86801
61.500	3.6936	15.708	8.12087	69.000	4.2548	13.593	13.41791	76.500	4.9554	11.642	24.12164
61.625	3.7020	15.672	8.18420	69.125	4.2652	13.560	13.53968	76.625	4.9686	11.611	24.37885
61.750	3.7105	15.635	8.24814	69.250	4.2756	13.526	13.66282	76.750	4.9819	11.580	24.63941
61.875	3.7190	15.598	8.31279	69.375	4.2861	13.492	13.78747	76.875	4.9952	11.548	24.90358
62.000	3.7276	15.561	8.37809	69.500	4.2966	13.459	13.91360	77.000	5.0085	11.517	25.17128
62.125	3.7361	15.525	8.44405	69.625	4.3071	13.425	14.04120	77.125	5.0220	11.486	25.44264
62.250	3.7447	15.488	8.51070	69.750	4.3177	13.392	14.17029	77.250	5.0354	11.455	25.71762
62.375	2.7534	15.452	8.57809	69.875	4.3283	13.358	14.30086	77.375	5.0490	11.424	25.99634
62.500	3.7620	15.415	8.64612	70.000	4.3390	13.325	14.43303	77.500	5.0626	11.392	26.27909
62.625	3.7707	15.379	8.71487	70.125	4.3497	13.291	14.56682	77.625	5.0763	11.361	26.56552
62.750	3.7794	15.343	8.78437	70.250	4.3604	13.258	14.70209	77.750	5.0900	11.330	26.85598
62.875	3.7882	15.306	8.85459	70.375	4.3712	13.225	14.83900	77.875	5.1038	11.299	27.15027
63.000	3.7969	15.270	8.92551	70.500	4.3820	13.191	14.97760	78.000	5.1176	11.268	27.44894
63.125	3.8057	15.234	8.99725	70.625	4.3929	13.158	15.11790	78.125	5.1315	11.237	27.75152
63.250	3.8145	15.198	9.06971	70.750	4.4038	13.125	15.25981	78.250	5.1455	11.206	28.05833
63.375	3.8234	15.162	9.14292	70.875	4.4148	13.092	15.40346	78.375	5.1595	11.176	28.36945
63.500	3.8323	15.126	9.21690	71.000	4.4258	13.059	15.54882	78.500	5.1736	11.145	28.68493
63.625	3.8412	15.090	9.29174	71.125	4.4368	13.026	15.69588	78.625	5.1878	11.114	29.00490
63.750	3.8501	15.054	9.36730	71.250	4.4479	12.993	15.84489	78.750	5.2020	11.083	29.32921
63.875	3.8591	15.018	9.44367	71.375	4.4590	12.960	15.99561	78.875	5.2163	11.052	29.65806
64.000	3.8681	14.983	9.52086	71.500	4.4702	12.927	16.14818	79.000	5.2306	11.022	29.99164
64.125	3.8771	14.947	9.59890	71.625	4.4814	12.894	16.30264	79.125	5.2451	10.991	30.32998
64.250	3.8862	14.911	9.67779	71.750	4.4926	12.861	16.45896	79.250	5.2595	10.960	30.67312
64.375	3.8953	14.876	9.75750	71.875	4.5039	12.828	16.61720	79.375	5.2741	10.930	31.02097
64.500	3.9044	14.840	9.83809	72.000	4.5152	12.796	16.77732	79.500	5.2887	10.899	31.37418
64.625	3.9136	14.804	9.91952	72.125	4.5266	12.763	16.93944	79.625	5.3034	10.869	31.73197
64.750	3.9228	14.769	10.00182	72.250	4.5381	12.730	17.10364	79.750	5.3181	10.838	32.09531
64.875	3.9320	14.734	10.08506	72.375	4.5495	12.697	17.26983	79.875	5.3330	10.808	32.46344
65.000	3.9412	14.698	10.16919	72.500	4.5610	12.665	17.43805	80.000	5.3479	10.777	32.83728
65.125	3.9505	14.663	10.25422	72.625	4.5726	12.632	17.60844	80.125	5.3628	10.747	33.21646
65.250	3.9598	14.628	10.34020	72.750	4.5842	12.600	17.78090	80.250	5.3778	10.716	33.60104
65.375	3.9691	14.593	10.42708	72.875	4.5959	12.567	17.95554	80.375	5.3929	10.686	33.99112
65.500	3.9785	14.557	10.51490	73.000	4.6076	12.535	18.13247	80.500	5.4081	10.656	34.38684
65.625	3.9879	14.522	10.60381	73.125	4.6193	12.503	18.31142	80.625	5.4234	10.625	34.78857
65.750	3.9974	14.487	10.69358	73.250	4.6311	12.470	18.49267	80.750	5.4387	10.595	35.19612
65.875	4.0068	14.452	10.78433	73.375	4.6430	12.438	18.67633	80.875	5.4541	10.565	35.60957

TABLE I.- SUPERSONIC-FLOW VARIABLES FOR γ = 1.400 - Concluded

ν, deg	M	μ, deg	r/r_{cr}	ν, deg	M	μ, deg	r/r_{cr}	ν, deg	M	μ, deg	r/r_{cr}
81.000	5.4695	10.535	36.02916	90.000	6.8190	8.433	92.73120	99.000	8.9049	6.448	311.42070
81.125	5.4850	10.505	36.45499	90.125	6.8418	8.404	94.10800	99.125	8.9420	6.421	317.50420
81.250	5.5007	10.474	36.88714	90.250	6.8647	8.376	95.51025	99.250	8.9795	6.394	323.73250
81.375	5.5163	10.444	37.32561	90.375	6.8878	8.348	96.93840	99.375	9.0172	6.367	330.11050
81.500	5.5321	10.414	37.77064	90.500	6.9110	8.320	98.39276	99.500	9.0553	6.340	336.64170
81.625	5.5479	10.384	38.22236	90.625	6.9743	8.292	99.87450	99.625	9.0936	6.313	343.33300
81.750	5.5638	10.354	38.68081	90.750	6.9578	8.263	101.38360	99.750	9.1323	6.287	350.18450
81.875	5.5798	10.324	39.14621	90.875	6.9814	8.235	102.92080	99.875	9.1712	6.260	357.20310
82.000	5.5959	10.294	39.61844	31.000	7.0052	8.207	104.48670	100.000	9.2105	6.233	364.39530
82.125	5.6120	10.264	40.09795	31.125	7.0291	8.179	106.08170	100.125	9.2501	6.206	371.76350
82.250	5.6282	10.234	40.58471	91.250	7.0532	8.151	107.70710	100.250	9.2900	6.179	379.31290
82.375	5.6446	10.204	41.07886	91.375	7.0774	8.123	109.36340	100.375	9.3302	6.153	387.04870
82.500	5.6609	10.175	41.58048	91.500	7.1017	8.095	111.05070	100.500	9.3708	6.126	394.98340
82.625	5.6774	10.145	42.08975	91.625	7.1262	8.067	112.77040	100.625	9.4117	6.099	403.10910
82.750	5.6939	10.115	42.60691	91.750	7.1509	8.039	114.52280	100.750	9.4529	6.073	411.44590
82.875	5.7106	10.085	43.13191	91.875	7.1757	8.011	116.30900	100.875	9.4945	6.046	419.98620
83.000	5.7273	10.056	43.66506	92.000	7.2007	7.983	118.12920	101.000	9.5364	6.019	428.75070
83.125	5.7441	10.026	44.20643	92.125	7.2258	7.955	119.98500	101.125	9.5787	5.993	437.73160
83.250	5.7610	9.9%	44.75619	92.250	7.2511	7.927	121.87600	101.250	9.6213	5.966	446.94930
83.375	5.7779	9.967	45.31443	92.375	7.2765	7.899	123.80430	101.375	9.6643	5.939	456.39870
83.500	5.7950	9.937	45.88137	92.500	7.3021	7.871	125.76980	101.500	9.7076	5.913	466.09250
83.625	5.8121	9.907	46.45713	92.625	7.3279	7.843	127.77410	101.625	9.7514	5.886	476.04030
83.750	5.8293	9.878	47.04193	92.750	7.3539	7.815	129.81740	101.750	9.7954	5.859	486.24030
83.875	5.8466	9.848	47.63599	P.875	7.3800	7.788	131.90140	101.875	9.8399	5.833	496.71200
84m	5.8640	9.819	48.23930	93.000	7.4062	7.760	134.02580	102.000	9.8848	5.806	507.45890
84.125	5.8815	9.789	48.85227	93.125	7.4327	7-732	136.19250	102.125	9.9300	5.778	518.48750
84.250	5.8991	9.760	49.47485	93.250	7.4593	7.704	138.40270	M2.250	9.9756	5.753	529.81140
84.375	5.9168	9.730	50.10733	33.375	7.4861	7.677	140.65730	102.375	10.0217	5.727	541.43420
84.500	5.9345	9.701	543.74996	93.500	7.5130	7.649	142.95660	102.500	10.0681	5.700	553.37370
84.625	5.9524	9.672	51.40273	93.625	7.5402	7.621	145.30240	102.625	10.1150	5.674	565.62910
84.750	5-9703	9.642	52.06608	93.750	7.5675	7.594	147.69500	102.750	10.1622	5.647	578.22190
84.875	5.9883	9.613	52.74006	A.875	7.5950	7.566	150.13620	102.875	10.2099	5.621	591.14960
85.000	6.0065	9.584	53.42484	94.000	7.6227	7.538	152.62780	103.000	10.2580	5.594	604.43220
85.125	6.0247	9.554	54.12066	94.125	7.6505	7.511	155.16970	103.125	io.3066	5.568	618.07490
85.250	6.0430	9.525	54.82784	94.250	7.6786	7.483	157.76350	103.250	10.3556	5.541	632.09980
85.375	6.0614	9.4%	55.54660	94.375	7.7068	7.455	160.41030	103.375	10.4050	5.515	646.51690
85.500	6.0799	9.467	56.27693	34.500	7.7333	7.428	163.11270	103.500	10.4549	5.489	661.32560
85.625	6.0986	9.438	57.01925	94.625	7.7639	7.400	165.86990	103.625	10.5052	5.462	676.54500
85.750	6.1173	9.408	57.77371	94.750	7.7927	7.373	168.68530	103.750	10.5560	5-4%	692.20000
85.875	6.1361	9.379	58.54064	94.875	7.8217	7.345	171.55940	103.875	10.6073	5.410	708.29250
86.000	6.1550	9.350	59.32020	95.000	7.8510	7.318	174.49370	104.000	10.6590	5.383	724.83630
86.125	6.1740	9.321	60.11265	95.125	7.8801	7.290	177.48810	104.125	10.7112	5.357	741.85110
86.250	6.1931	9.292	60.91833	95.250	7.9100	7.263	180.54710	104.250	10.7640	5.331	759.36460
86.375	6.2123	9.263	61.73718	95.375	7.9398	7-235	183.67020	104.375	10.8172	5.304	777.37820
86.500	6.2317	9.234	62.56999	95.500	7.9698	7.208	186.86000	104.500	10.8709	5.278	795.90880
86.625	6.2511	9.205	63.41655	95.625	8.0001	7.181	190.11810	104.625	10.9251	5.252	814.97620
86.750	6.2706	9.176	64.27738	95.750	8.0305	7.153	193.44500	104.750	10.9799	5.225	834.59760
86.875	6.2903	9.147	65.15283	95.875	8.0612	7.126	196.84360	104.875	11.0351	5.199	854.78950
87.000	6.3100	9.119	66.04308	96.000	8.0921	7.099	200.31580	105.000	11.0909	5.173	875.58140
87.125	6.3299	9.090	66.94830	96.125	8.1232	7.071	203.86270	105.125	11.1473	5.147	897.00930
87.250	6.3499	9.061	67.86899	96.250	8.1545	7.044	207.48760	105.250	11.2042	5.121	919.04920
87.375	6.3699	9.032	68.80544	96.375	8.1860	7.017	211.19070	105.375	11.2617	5.094	941.76360
87.500	6.3901	9.003	69.75768	96.500	8.2178	6.989	214.97480	105.500	11.3197	5.068	965.15190
87.625	6.4104	8.975	70.72664	96.625	8.2498	6.962	218.84310	105.625	11.3783	5.042	989.24790
87.750	6.4309	8.946	71.71197	96.750	8.2820	6.935	222.79500	105.750	11.4375	5.016	1014.08300
87.875	6.4514	8.917	72.71436	96.875	8.3145	6.908	226.83560	105.875	11.4973	4.990	1039.66600
88.000	6.4720	8.888	73.73427	97.000	8.3472	6.881	230.96570	106.000	11.5577	4.964	1066.04400
88.125	6.4928	8.860	74.77167	97.125	8.3802	6.853	235.18770	106.125	11.6187	4.937	1093.24500
88.250	6.5137	8.831	75.82738	97.250	8.4133	6.826	239.50500	106.250	11.6803	4.911	1121.28100
88.375	6.5347	8.803	76.90129	97.375	8.4468	6.799	243.91870	106.375	11.7426	4.885	1150.19400
88.500	6.5558	8.774	77.99423	97.500	8.4804	6.772	248.43220	106.500	11.8055	4.859	1180.01400
88.625	6.5770	8.745	79.10629	97.625	8.5144	6.745	253.04860	106.625	11.8690	4.833	1210.77400
88.750	6.5984	8.717	80.23824	97.750	8.5485	6.718	257.76880	106.750	11.9332	4.307	1242.49900
88.875	6.6199	8.688	81.39006	97.875	8.5830	6.691	262.59720	106.875	11.9981	4.781	1275.25300
89.000	6.6415	8.660	82.56221	98.000	8.6177	6.664	267.53720	107.000	12.0637	4.755	1309.05500
89.125	6.6633	8.631	83.75567	98.125	8.6526	6.637	272.59060				
89.250	6.6851	8.603	84.97016	98.250	8.6878	6.610	277.76090				
89.375	6.7071	8.575	86.20645	98.375	8.7233	6.583	283.05150				
89.500	6.7292	8.546	87.46479	98.500	8.7591	6.556	288.46420				
89.625	6.7515	8.518	88.74594	98.625	8.7951	6.529	294.00550				
89.750	6.7739	8.489	90-05047	98.750	8.8314	6.502	299.67500				
89.875	6.7964	8.461	91.37843	98.875	8.8680	6.475	305.47970				

TABLE II.- INITIAL-EXPANSION FLOW

(a) Characteristic nets

Point A	ν or θ, deg
1	0.03125
2	.0625
3	.125
4	.250
5	.375
6	.500
7	.750
8	1.00
9	1.25
10	1.50
11	2.00
12	2.50
13	3.00
14	3.50
15	4.25
16	5.00
17	6.00
18	7.00
19	8.00
20	9.00
21	10.00
22	11.00
23	12.00
24	13.00
25	14.00
26	15.00
27	16.00
28	17.00
29	18.00
30	19.00
31	20.00
32	21.00

Point	ν, deg	$\frac{x}{y_{cr}}$	$\frac{y}{y_{cr}}$	ψ	Point	ν, deg	$\frac{x}{y_{cr}}$	$\frac{y}{y_{cr}}$	ψ
η = 0.0625°					η = 0.250°				
(a,1)	0.06250	0.14243	0	0	(c,3)	0.250	0.21462	0	0
(a,2)	.09375	.15675	.08423	.08420	(c,4)	.375	.24094	.09678	.09663
(a,3)	.15625	.17422	.17243	.17234	(c,5)	.500	.25845	.15438	.15406
(a,4)	.28125	.19510	.26033	.26010	(c,6)	.625	.27194	.19524	.19475
(a,5)	.40625	.20903	.31061	.31023	(c,7)	.875	.29264	.25255	.25165
(a,6)	.53125	.21979	.34559	.34507	(c,8)	1.125	.30869	.29301	.29168
(a,7)	.78125	.23632	.39391	.39305	(c,9)	1.375	.32204	.32434	.32255
(a,8)	1.03125	.24914	.42761	.42640	(c,10)	1.625	.33359	.34996	.34767
(a,9)	1.28125	.25982	.45354	.45195	(c,11)	2.125	.35318	.39056	.38720
(a,10)	1.53125	.26906	.47464	.47265	(c,12)	2.625	.36970	.42243	.41789
(a,11)	2.03125	.28474	.50794	.50507	(c,13)	3.125	.38420	.44887	.44306
(a,12)	2.53125	.29796	.53397	.53015	(c,14)	3.625		.47161	.46445
(a,13)	3.03125	.30957	.55551	.55067	(c,15)	4.375	.41492	.50099	.49163
(a,14)	3.53125	.32003	.57401	.56808	(c,16)	5.125	.43089	.52639	.51465
(a,15)	4.28125	.33417	.59786	.59016	(c,17)	6.125	.45030	.55605	.54083
(a,16)	5.03125	.34696	.61845	.60883	(c,18)	7.125	.46818	.58238	.56336
(a,17)	6.03125	.36251	.64247	.63005	(c,19)	8.125	.48493	.60638	.58321
(a,18)	7.03125	.37683	.66378	.64829	(c,20)	9.125	.50083	.62867	.60103
(a,19)	8.03125	.39024	.68317	.66435	(c,21)	10.125	.51607	.64970	.61723
(a,20)	9.03125	.40297	.70118	.67876	(c,22)	11.125	.53079	.66978	.63212
(a,21)	10.03125	.41517	.71815	.69185	(c,23)	12.125	.54510	.68913	.64593
(a,22)	11.03125	.42695	.73435	.70388	(c,24)	13.125	.55907	.70793	.65882
(a,23)	12.03125	.43840	.74996	.71503	(c,25)	14.125	.57280	.72635	.67093
(a,24)	13.03125	.44959	.76512	.72543	(c,26)	15.125	.58631	.74448	.68235
(a,25)	14.03125	.46058	.77996	.73520	(c,27)	16.125	.59967	.76242	.69317
(a,26)	15.03125	.47139	.79456	.74441	(c,28)	17.125	.61290	.78025	.70346
(a,27)	16.03125	.48208	.80902	.75314	(c,29)	18.125	.62604	.79805	.71327
(a,28)	17.03125	.49266	.82338	.76144	(c,30)	19.125	.63912	.81588	.72265
(a,29)	18.03125	.50317	.83770	.76935	(c,31)	20.125	.65216	.83381	.73164
(a,30)	19.03125	.51363	.85206	.77692	(c,32)	21.125	.66518	851%	.74027
(a,31)	20.03125	.52406	.86648	.78417					
(a,32)	21.03125	.53447	.88100	.79113					
η = 0.125°					η = 0.5000				
(b,2)	0.1250	0.17288	0	0	(d,4)	0.500	0.27082	0	0
(b,3)	.1875	.19248	.09119	.09113	(d,5)	.625	.29072	.05940	.05923
(b,4)	.3125	.21581	.18455	.18434	(d,6)	.750	.30604	.10232	.10195
(b,5)	.4375	.23135	.23877	.23841	(d,7)	1.000	.32957	.16344	.16264
(b,6)	.5625	.24333	.27677	.27625	(d,8)	1.250	.34781	.20719	.20591
(b,7)	.8125	.26173	.32953	.32865	(d,9)	1.500	.36298	.24135	.23955
(b,8)	1.0625	.27599	.36649	.36522	(d,10)	1.750	.37612	.26942	.26708
(b,9)	1.3125	.28786	.39498	.39330	(d,11)	2.250	.39839	.31418	.31063
(b,10)	1.5625	.29813	.41820	.41608	(d,12)	2.750	.41717	.34948	.34461
(b,11)	2.0625	.31556	.45490	.45181	(d,13)	3.250	.43366	.37887	.37257
(b,12)	2.5625	.33025	.48363	.47949	(d,14)	3.750	.44850	.40421	.39639
(b,13)	3.0625	.34315	.50742	.50215	(d,15)	4.500	.46858	.43701	.42671
(b,14)	3.5625	.35477	.52786	.52138	(d,16)	5.250	.48674	.46543	.45244
(b,15)	4.3125	.37048	.55424	.54579	(d,17)	6.250	.50882	.49867	.48176
(b,16)	5.0625	.38469	.57702	.56644	(d,18)	7.250	.52915	.52823	.50702
(b,17)	6.0625	.40196	.60360	.58992	(d,19)	8.250	.54820	.55519	.52930
(b,18)	7.0625	.41786	.62719	.61011	(d,20)	9.250	.56629	.58026	.54931
(b,19)	8.0625	.43276	.64866	.62789	(d,21)	10.250		.60393	.56752
(b,20)	9.0625	.44690	.66861	.64384	(d,22)	11.250	.60038	.62654	.58427
(b,21)	10.0625	.46045	.68742	.65834	(d,23)	12.250	.61666	.64835	.59980
(b,22)	11.0625	.47354	.70537	.67167	(d,24)	13.250	.63257	.66956	.61430
(b,23)	12.0625	.48627	.72266	.68402	(d,25)	14.250	.64820	.69033	.62793
(b,24)	13.0625	.49870	.73947	.69555	(d,26)	15.250	.66359	.71078	.64079
(b,25)	14.0625	.51090	.75592	.70637	(d,27)	16.250	.67880	.73104	.65298
(b,26)	15.0625	.52292	.77211	.71658	(d,28)	17.250	.693437	.75119	.66457
(b,27)	16.0625	.53479	.78813	.72625	(d,29)	18.250	.70884	.77130	.67563
(b,28)	17.0625	.54655	.80405	.73545	(d,30)	19.250	.72374	.79145	.68621
(b,29)	18.0625	.55823	.81994	.74422	(d,31)	20.250	.73861	.81171	.69635
(b,30)	19.0625	.56986	.83586	.75261	(d,32)	21.250	.75345	.83213	.70609
(b,31)	20.0625	.58144	.85185	.76065					
(b,32)	21.0625	.59302	.86796	.76837					

TABLE II.- INITIAL-EXPANSION FLOW - Continued

(a) Characteristic nets - Continued

Point	ν, deg	$\frac{x}{y_{cr}}$	$\frac{y}{y_{cr}}$	ψ	Point	ν, deg	$\frac{x}{y_{cr}}$	$\frac{y}{y_{cr}}$	ψ
		$\eta = 0.750^{\circ}$					$\eta = 1.500$		
(e,5)	0.750	0.31222	0	0	(g,7)	1.50	0.40278	0	0
(e,6)	.875	.32880	.04345	.04325	(g,8)	1.75	.42563	.04672	.04619
(e,7)	1.125	.35428	.10607	.10542	(g,9)	2.00	.44467	.08401	.08290
(e,8)	1.375	.37404	.15136	.15020	(g,10)	2.25	.46118	.11517	.11342
(e,9)	1.625	.39048	.18697	.18526	(g,11)	2.75	.48920	.16570	.16252
(e,10)	1.875	.40471	.21638	.21409	(g,12)	3.25	.51287	.20620	.20145
(e,11)	2.375	.42885	.26350	.25992	(g,13)	3.75	.53366	.24031	.23385
(e,12)	2.875	.44921	.30083	.29585	(g,14)	4.25	.55240	.26998	.26167
(e,13)	3.375	.46709	.33201	.32550	(g,15)	5.00	.57775	.30868	.29736
(e,14)	3.875	.48319	.35896	.35081	(g,16)	5.75	.60070	.34245	.32784
(e,15)	4.625	.50496	.39391	.38310	(g,17)	6.75	.62864	.38221	.36278
(e,16)	5.375	.52466	.42425	.41055	(g,18)	7.75	.65438	.41776	.39304
(e,17)	6.375	.54861	.45980	.44188	(g,19)	8.75	.67852	.45033	.41983
(e,18)	7.375	.57068	.49146	.46890	(g,20)	9.75	.70144	.48073	.44396
(e,19)	8.375	.59135	.52036	.49276	(g,21)	10.75	.72344	.50951	.46597
(e,20)	9.375	.61098	.54727	.51421	(g,22)	11.75	.74471	.53708	.48626
(e,21)	10.375	.62980	.57269	.53373	(g,23)	12.75	.76540	.56372	.50511
(e,22)	11.375	.64799	.59799	.55170	(g,24)	13.75	.78563	.58969	.52274
(e,23)	12.375	.66568	.62044	.56837	(g,25)	14.75	.80551	.61518	.53933
(e,24)	13.375	.68296	.64326	.58395	(g,26)	15.75	.82511	.64031	.55500
(e,25)	14.375	.69993	.66562	.59859	(g,27)	16.75	.84449	.66524	.56987
(e,26)	15.375	.71665	.68764	.61241	(g,28)	17.75	.86371	.69008	.58403
(e,27)	16.375	.73318	.70946	.62551	(g,29)	18.75	.88281	.71490	.59754
(e,28)	17.375	.74956	.73117	.63797	(g,30)	19.75	.90184	.73982	.61048
(e,29)	18.375	.76584	.75285	.64986	(g,31)	20.75	.92084	.76489	.62289
(e,30)	19.375	.78204	.77459	.66124	(g,32)	21.75	.93982	.79020	.63482
(e,31)	20.375	.79821	.79644	.67215					
(e,32)	21.375	.81435	.81848	.68263					
		$\eta = 1.00^{\circ}$					$\eta = 2.00^{\circ}$		
(f,6)	1.00	0.34637	0	0	(h,8)	2.00	0.45000	0	0
(f,7)	1.25	.37338	.06320	.06274	(h,9)	2.25	.47032	.03757	.03697
(f,8)	1.50	.39434	.10930	.10832	(h,10)	2.50	.48795	.06914	.06788
(f,9)	1.75	.41178	.14576	.14421	(h,11)	3.00	.51792	.12065	.11792
(f,10)	2.00	.42689	.17600	.17385	(h,12)	3.50	.54324	.16222	.15785
(f,11)	2.50	.45252	.22466	.22117	(h,13)	4.00	.56551	.19739	.19123
(f,12)	3.00	.47415	.26339	.25842	(h,14)	4.50	.58559	.22809	.21999
(f,13)	3.50	.49314	.29582	.28925	(h,15)	5.25	.61277	.26827	.25700
(f,14)	4.00	.51026	.32392	.31563	(h,16)	6.00	.63739	.30346	.28872
(f,15)	4.75	.53340	.36044	.34934	(h,17)	7.00	.66737	.34500	.32517
(f,16)	5.50	.55433	.39219	.37804	(h,18)	8.00	.69501	.38224	.35680
(f,17)	6.50	.57980	.42946	.41085	(h,19)	9.00	.72094	.41644	.38487
(f,18)	7.50	.60326	.46269	.43919	(h,20)	10.00	.74558	.44840	.41019
(f,19)	8.50	.62525	.49307	.46424	(h,21)	11.00	.76923	.47871	.43331
(f,20)	9.50	.64614	.52138	.48677	(h,22)	12.00	.79211	.50778	.45464
(f,21)	10.50	.66616	.54813	.50729	(h,23)	13.00	.81437	.53591	.47447
(f,22)	11.50	.68551	.57373	.52619	(h,24)	14.00	.83615	.56335	.49303
(f,23)	12.50	.70434	.59844	.54373	(h,25)	15.00	.85755	.59030	.51051
(f,24)	13.50	.72273	.62250	.56012	(h,26)	16.00	.87866	.61692	.52703
(f,25)	14.50	.74080	.64609	.57553	(h,27)	17.00	.89955	.64333	.54272
(f,26)	15.50	.75861	.66934	.59008	(h,28)	18.00	.92026	.66966	.55766
(f,27)	16.50	.77622	.69238	.60388	(h,29)	19.00	.94086	.69600	.57193
(f,28)	17.50	.79367	.71531	.61701	(h,30)	20.00	.96140	.72244	.58559
(f,29)	18.50	.81100	.73822	.62954	(h,31)	21.00	.98190	.74908	.59870
(f,30)	19.50	.82827	.76119	.64153	(h,32)	22.00	1.00240	.77598	.61131
(f,31)	20.50	.84550	.78430	.65303					
(f,32)	21.50	.86272	.80761	.66408					

TABLE II.- INITIAL-EXPANSION FLOW - Continued

(a) Characteristic nets - continued

Point	ν, deg	$\frac{x}{y_{cr}}$	$\frac{y}{y_{cr}}$	ψ
		η = 2.50°		
(i,9)	2.50	0.49174	0	0
(i,10)	2.75	.51033	.03172	.03106
(i,11)	3.25	.54197	.08376	.08160
(i,12)	3.75	.56873	.12598	.12214
(i,13)	4.25	.59228	.16186	.15617
(i,14)	4.75	.61353	.19329	.18559
(i,15)	5-50	.64231	.23455	.22356
(i,16)	6.25	.66839	.27080	.25619
(i,17)	7.25	.70017	.31370	.29378
(i,18)	8.25	.72948	.35226	.32648
(i,19)	9.25	.75700	.38774	.35554
(i,20)	10.25	.78317	.42096	.38179
(i,21)	11.25	.80829	.45250	.40579
(i,22)	12.25	.83260	.48279	.42795
(i,23)	13.25	.85626	.51214	.44857
(i,24)	14.25	.87942	.54079	.46789
(i,25)	15.25	.90220	.56896	.48609
(i,26)	16.25	.92466	.59680	-50330
(i,27)	17.25	.94690	.62445	.51965
(i,28)	18.25	.96897	.65203	.53523
(i,29)	19.25	.99092	.67964	.55011
(i,30)	20.25	1.01280	.70739	.56437
(i,31)	21.25	1.03467	.73536	.57806
(i,32)	22.25	1.05653	.76361	.59123
		η = 3.00		
(j,10)	3.00	0.52978	0	0
(j,11)	3.50	.56290	.05228	.05077
(j,12)	4.00	.59095	.09492	.09169
(j,13)	4.50	.61565	.13128	.12616
(j,14)	5.00	.63795	.16322	.15604
(j,15)	5.75	.66818	.20530	.19472
(j,16)	6.50	.69559	.24236	.22804
(j,17)	7-50	.72901	.28635	.26652
(j,18)	8.50	.75986	.32598	.30006
(j,19)	9.50	.78883	.36251	.32992
(j,20)	10.50	.81639	.39677	.35693
(j,21)	11.50	.84286	.42935	.38165
(j,22)	12.50	.86848	.46067	.40450
(j,23)	13.50	.89344	.49105	.42578
(j,24)	14.50	.91788	.52074	.44573
(j,25)	15.50	.94192	.54996	.46453
(j,26)	16.50	.96564	.57885	.48233
(j,27)	17.50	.98913	.60758	.49924
(j,28)	18.50	1.01245	.63626	.51536
(j,29)	19.50	1.03566	.66498	.53077
(j,30)	20.50	1.05880	.69387	.54554
(j,31)	21.50	1.08194	.72300	.55973
(j,32)	22.50	1.10508	.75245	.57338
		η = 4.00°		
(k,11)	4.00	0.59862	0	0
(k,12)	4.50	.62894	.04300	.04125
(k,13)	5.00	.65568	.07991	.07621
(k,14)	5.50	-67985	.11251	.10667
(k,15)	6.25	.71266	.15568	.14629
(k,16)	7.00	.74246	.19390	.18059
(k,17)	8.00	.77883	.23950	.22037
(k,18)	9.00	.81246	.28076	.25518
(k,19)	10.00	.84407	.31893	.28627
(k,20)	11.00	.87417	.35485	.31446
(k,21)	12.00	.90311	.38909	.34031
(k,22)	13.00	.93116	.42210	.36425
(k,23)	14.00	.95850	.45418	.38659
(k,24)	15.00	.98529	.48559	.40755
(k,25)	16.00	1.01166	.51656	.42733
(k,26)	17.00	1.03771	.54723	.44608
(k,27)	18.00	1.06352	.57778	.46391
(k,28)	19.00	1.08917	.60831	.48092
(k,29)	20.00	1.11471	.63894	.49719
(k,30)	21.00	1.14021	.66978	.51280
(k,31)	22.00	1.16571	.70093	.52780
(k,32)	23.00	1.19124	.73245	.54224
		η = 5.08		
(l,12)	5.00	0.66124	0	0
(l,13)	5.50	.68978	.03712	.03514
(l,14)	6.00	.71563	.07005	.06589
(l,15)	6.75	.75075	.11387	.10606
(l,16)	7.50	.78269	.15286	.14098
(l,17)	8.50	.82174	.19956	.18164
(l,18)	9.50	.85789	.24201	.21735
(l,19)	10.50	.89192	.28141	.24933
(l,20)	11.50	.92436	.31860	.27839
(l,21)	12.50	.95557	.35415	.30510
(l,22)	13.50	.98585	.38849	.32988
(l,23)	14.50	1.01540	.42194	.35303
(l,24)	15.50	1.04438	.45475	.37479
(l,25)	16.50	1.07293	.48715	.39535
(l,26)	17.50	1.10119	.51935	.41488
(l,27)	18.50	1.12914	.55137	.43342
(l,28)	19.50	1.15698	.58347	.45115
(l,29)	20.50	1.18472	.61572	.46812
(l,30)	21.50	1.21243	.64823	.48441
(l,31)	22.50	1.24018	.68110	.50008
(l,32)	23.50	1.26798	.71441	.51517
		η = 6.00°		
(m,13)	6.00	0.71997	0	0
(m,14)	6.50	.74734	.03307	.03086
(m,15)	7.25	.78459	.07725	.07133
(m,16)	8.00	.81852	.11673	.10664
(m,17)	9.00	.86006	.16422	.14791
(m,18)	10.00	.89857	.20755	.18427
(m,19)	11.00	.93486	.24791	.a692
(m,20)	12.00	.96950	.28611	.24666
(m,21)	13.00	1.00288	.32271	.27404
(m,22)	14.00	1.03528	.35815	.29948
(m,23)	15.00	1.06692	.39274	32329
(m,24)	16.00	1.09799	.42673	.34569
(m,25)	17.00	1.12862	.46036	.36688
(m,26)	18.00	1.15897	.49383	.38703
(m,27)	19.00	I. 18902	.52716	.40618
(m,28)	20.00	1.21896	.56062	.42450
(m,29)	21.00	1.24883	.59429	.44206
(m,30)	22.00	1.27869	.62827	.45892
(m,31)	23.00	1.30861	.66267	.47515
(m,32)	24.00	1.33862	.69758	.49079
		η = 7.00		
(n,14)	7.00	0.77613	0	0
(n,15)	7.75	.81538	.04435	.04060
(n,16)	8.50	.85118	.08414	.07615
(n,17)	9.50	.89507	.13218	.11783
(n,18)	10.50	.93583	.17617	.15466
(n,19)	11.50	.97429	.21728	.18782
(n,20)	12.50	1.01104	.25630	.21809
(n,21)	13.50	1.04649	.29377	.24601
(n,22)	14.50	1.08094	.33013	.27199
(n,23)	15.50	1.11462	.36569	
(n,24)	16.50	1.14771	.40070	.31926
(n,25)	17.50	1.18037	.43539	.34098
(n,26)	18.50	1.21276	.46997	.36165
(n,27)	19.50	1.24485	.50447	.38131
(n,28)	20.50	1.27685	.53915	.40014
(n,29)	21.50	1.30881	.57408	.41820
(n,30)	22.50	1.34078	.60939	.43556
(n,31)	23.50	1.37284	.64519	.45227
(n,32)	24.50	1.40502	.68155	.46839
		η = 8.50°		
(o,15)	8.50	0.85744	0	0
(o,16)	9.25	.89588	.04000	.03571
(o,17)	10.25	.94312	.08855	.07776
(o,18)	11.25	.98711	.13325	.11508
(o,19)	12.25	1.02870	.17520	.14879

TABLE II.- INITIAL-EXPANSION FLOW - Continued

(a) Characteristic nets - Continued

Point	ν, deg	$\frac{x}{Y_{cr}}$	$\frac{y}{Y_{cr}}$	Ψ
$\eta = 8.50^\circ$ - Concluded				
(o,20)	13.25	1.06850	0.21516	0.17965
(o,21)	14.25	1.10696	.25368	.20819
(o,22)	15.25	1.14439	.29118	.23481
(o,23)	16.25	1.18104	.32795	.25979
(o,24)	17.25	1.21710	.36426	.28337
(o,25)	18.25	1.25274	.40032	.30573
(o,26)	19.25	1.28813	.43635	.32704
(o,27)	20.25	1.32324	.47238	.34734
(o,28)	21.25	1.35830	.50867	.36680
(o,29)	22.25	1.39335	.54530	.38548
(o,30)	23.25	1.42847	.58240	.40346
(o,31)	24.25	1.46373	.62008	.42079
(o,32)	25.25	1.49916	.65842	.43752
$\eta = 10.00^\circ$				
(p,16)	10.00	0.93685	0	0
(p,17)	11.00	.98731	.04879	.04222
(p,18)	12.00	1.03437	.09392	.07982
(p,19)	13.00	1.07896	.13645	.11389
(p,20)	14.00	1.12173	.17712	.14516
(p,21)	15.00	1.16312	.21645	.17415
(p,22)	16.00	1.20347	.25485	.20124
(p,23)	17.00	1.24304	.29262	.22672
(p,24)	18.00	1.28203	.33000	.25081
(p,25)	19.00	1.32062	.36723	.27369
(p,26)	20.00	1.35898	.40450	.29552
(p,27)	21.00	1.39710	.44186	.31634
(p,28)	22.00	1.43522	.47957	.33633
(p,29)	23.00	1.47336	.51771	.35554
(p,30)	24.00	1.51164	.55640	.37404
(p,31)	25.00	1.55011	.59578	.39189
(p,32)	26.00	1.58882	.63592	.40913
$\eta = 12.00^\circ$				
(q,17)	12.00	1.04188	0	0
(q,18)	13.00	1.09294	.04540	.03777
(q,19)	14.00	1.14144	.08840	.07212
(q,20)	15.00	1.18808	.12972	.10376
(q,21)	16.00	1.23331	.16985	.13317
(q,22)	17.00	1.27751	.20918	.16073
(q,23)	18.00	1.32093	.24801	.18670
(q,24)	19.00	1.36381	.28657	.21131
(q,25)	20.00	1.40633	.32509	.23472
(q,26)	21.00	1.44867	.36378	.25709

Point	ν, deg	$\frac{x}{Y_{cr}}$	$\frac{y}{Y_{cr}}$	Ψ
$\eta = 12.00^\circ$ - Concluded				
(q,27)	22.00	1.49082	0.40267	0.27847
(q,28)	23.00	1.53305	.44203	.29902
(q,29)	24.00	1.57538	.48195	.31879
(q,30)	25.00	1.61792	.52256	.33786
(q,31)	26.00	1.66076	.56397	.35628
(q,32)	27.00	1.70394	.60630	.37410
$\eta = 14.00^\circ$				
(r,18)	14.00	1.14788	0	0
(r,19)	15.00	1.20024	.04332	.03447
(r,20)	16.00	1.25069	.08493	.06631
(r,21)	17.00	1.29974	.12560	.09599
(r,22)	18.00	1.34777	.16562	.12386
(r,23)	19.00	1.39507	.20526	.15019
(r,24)	20.00	1.44185	.24477	.17518
(r,25)	21.00	1.48833	.28435	.19900
(r,26)	22.00	1.53471	.32422	.22180
(r,27)	23.00	1.58097	.36442	.24362
(r,28)	24.00	1.62738	.40522	.26462
(r,29)	25.00	1.67399	.44670	.28485
(r,30)	26.00	1.72092	.48901	.30439
(r,31)	27.00	1.76825	.53228	.32328
(r,32)	28.00	1.81604	.57660	.34157
$\eta = 16.00^\circ$				
(s,19)	16.00	1.25640	0	0
(s,20)	17.00	1.31066	.04189	.03193
(s,21)	18.00	1.36354	.08290	.06177
(s,22)	19.00	1.41543	.12340	.08985
(s,23)	20.00	1.46662	.16365	.11643
(s,24)	21.00	1.51737	.20390	.14170
(s,25)	22.00	1.56788	.24436	.16582
(s,26)	23.00	1.61837	.28523	.18895
(s,27)	24.00	1.66883	.32655	.21112
(s,28)	25.00	1.71954	.36861	.23248
(s,29)	26.00	1.77057	.41148	.25309
(s,30)	27.00	1.82203	.45532	.27301
(s,31)	28.00	1.87401	.50026	.29229
(s,32)	29.00	1.92660	.54641	.31098

TABLE II.- INITIAL-EXPANSION FLOW - Continued

(a) Characteristic nets - Concluded

Point	ν, deg	$\frac{x}{y_{cr}}$	$\frac{y}{y_{cr}}$	ψ
η = 18.00°				
(t,20)	18.00	1.36875	0	0
(t,21)	19.00	1.42548	.04117	.02991
(t,22)	20.00	1.48127	.08197	.05811
(t,23)	21.00	1.53643	.12266	.08485
(t,24)	22.00	1.59121	.16349	.11032
(t,25)	23.00	1.64585	.20465	.13467
(t,26)	24.00	1.70056	.24635	.15805
(t,27)	25.00	1.75534	.28864	.18049
(t,28)	26.00	1.81050	.33179	.20214
(t,29)	27.00	1.86609	.37590	.22305
(t,30)	28.00	1.92225	.42112	.24328
(t,31)	29.00	1.97908	.46759	.26289
(t,32)	30.00	2.03668	.51543	.28192
η = 20.00°				
(u,21)	20.00	1.48611	0	0
(u,22)	21.00	1.54586	.04094	.02826
(u,23)	22.00	1.60507	.08192	.05510
(u,24)	23.00	1.66398	.12317	.08070
(u,25)	24.00	1.72285	.16487	.10522
(u,26)	25.00	1.78191	.20726	.12879
(u,27)	26.00	1.84116	.25036	.15144
(u,28)	27.00	1.90091	.29447	.17332
(u,29)	28.00	1.96125	.33967	.19448
(u,30)	29.00	2.02231	.38614	.21498
(u,31)	30.00	2.08420	.43401	.23486
(u,32)	31.00	2.14703	.48341	.25417
η = 22.00°				
(v,22)	22.00	1.60966	0	0
(v,23)	23.00	1.67300	.04112	.02688
(v,24)	24.00	1.73616	.08263	.05257
(v,25)	25.00	1.79939	.12475	.07720
(v,26)	26.00	1.86294	.16767	.10091
(v,27)	27.00	1.92681	.21145	.12373
(v,28)	28.00	1.99134	.25638	.14580
(v,29)	29.00	2.05662	.30254	.16716
(v,30)	30.00	2.12279	.35012	.18787
(v,31)	31.00	2.18998	.39927	.20798
(v,32)	32.00	2.25831	.45012	.22753
η = 24.00°				
(w,23)	24.00	1.74058	0	0
(w,24)	25.00	1.80811	.04165	.02573
(w,25)	26.00	1.87584	.08404	.05043
(w,26)	27.00	1.94403	.12736	.07424
(w,27)	28.00	2.01270	.17169	.09718
(w,28)	29.00	2.08221	.21730	.11939
(w,29)	30.00	2.15264	.26430	.14091
(w,30)	31.00	2.22416	.31287	.16179
(w,31)	32.00	2.29691	.36316	.18209
(w,32)	33.00	2.37102	.41534	.20184
(x,24)	26.00	1.88014	0	0
(x,25)	27.00	1.95253	.04252	.02473
(x,26)	28.00	2.02554	.08612	.04859
(x,27)	29.00	2.09920	.13085	.07161
(x,28)	30.00	2.17390	.17702	.09392
η = 26.00° - Concluded				
(x,29)	31.00	2.24971	0.22472	0.11556
(x,30)	32.00	2.32684	.27416	.13658
(x,31)	33.00	2.40543	.32548	.15703
(x,32)	34.00	2.48563	.37887	.17695
η = 28.00°				
(y,25)	28.00	2.02973	0	0
(y,26)	29.00	2.10776	.04373	.02389
(y,27)	30.00	2.18662	.08875	.04696
(y,28)	31.00	2.26673	.13533	.06935
(y,29)	32.00	2.34819	.18362	.09108
(y,30)	33.00	2.43120	.23379	.11221
(y,31)	34.00	2.51593	.28602	.13279
(y,32)	35.00	2.60255	.34050	.15285
η = 30.00°				
(z,26)	30.00	2.19099	0	0
(z,27)	31.00	2.27528	.04516	.02310
(z,28)	32.00	2.36105	.09204	.04553
(z,29)	33.00	2.44843	.14076	.06733
(z,30)	34.00	2.53762	.19154	.08855
(z,31)	35.00	2.62882	.24456	.10923
(z,32)	36.00	2.72221	.30000	.12940
η = 32.00°				
(a',27)	32.00	2.36524	0	0
(a',28)	33.00	2.45694	.04702	.02245
(a',29)	34.00	2.55052	.09605	.04429
(a',30)	35.00	2.64621	.14729	.06557
(a',31)	36.00	2.74423	.20095	.08632
(a',32)	37.00	2.84477	.25723	.10658
η = 34.00°				
(b',28)	34.00	2.55485	0	0
(b',29)	35.00	2.65495	.04918	.02186
(b',30)	36.00	2.75748	.10075	.04317
(b',31)	37.00	2.86270	.15491	.06398
(b',32)	38.00	2.97081	.21188	.08431
η = 36.00°				
(c',29)	36.00	2.76189	0	0
(c',30)	37.00	2.87165	.05173	.02133
(c',31)	38.00	2.98446	.10624	.04217
(c',32)	39.00	3.10059	.16376	.06254
η = 38.00°				
(d',30)	38.00	2.98901	0	0
(d',31)	39.00	3.10986	.05469	.02086
(d',32)	40.00	3.23447	.11258	.04127
η = 40.00°				
(e',31)	40.00	3.23921	0	0
(e',32)	41.00	3.37282	.05809	.02042
η = 42.00°				
(f',32)	42.00	3.51597	0	0

TABU II.- INITIAL-EXPANSION FLOW - Concluded

(b) Flow parameters at $y = 0$

Point	ν_B, deg	$\frac{r}{r_{cr}}$	$\frac{x}{y_{cr}}$	$\frac{dM}{d\left(\frac{x}{y_{cr}}\right)}$	θ_{max}, deg
(a,1)	0.0625	1.000129	0.14243	0.208	0.246
(b,2)	.125	1.000328	.17288	.258	.483
(c,3)	.250	1.000828	.21462	.310	.917
(d,4)	.500	1.002099	.27082	.367	1.714
(e,5)	.750	i.003625	.31222	.409	2.491
(f,6)	1.00	1.005349	.34637	.445	3.270
(g,7)	1.50	1.009275	.40278	.498	4.771
(h,8)	2.00	1.013737	.45000	.533	6.154
(i,9)	2.50	1.018665	.49174	555	7.414
(j,10)	3.00	1.024010	.52978	.575	8.640
(k,11)	4.0	1.035851	.59862	.607	11.018
(l,12)	5.0	1.049103	.66124	.629	13.247
(m,13)	6.0	1.063689	.71997	.643	15.304
(n,14)	7.0	1.079571	.77613	.651	17.194
(o,15)	8.5	1.105792	.85744	.655	19.813
(p,16)	10.0	1.134906	.93685	.653	22.196
(q,17)	12	1.178347	1.0419	.645	25.136
(r,18)	14	1.227349	1.1479	.631	27.783
(s,19)	16	1.282311	1.2564	.614	30.206
(t,20)	18	1.343740	1.3687	.594	32.412
(u,21)	20	1.412254	1.4861	.572	34.429
(v,22)	22	1.488589	1.6097	.549	36.320
(w,23)	24	1.573611	1.7406	.526	38.102
(x,24)	26	1.668326	1.8801	.501	39.695
(y,25)	28	1.773918	2.0297	.476	41.196
(z,26)	30	1.891760	2.1910	.452	42.697
(a',27)	32	2.023455	2.3652	.427	44.066
(b',28)	34	2.170891	2.5548	.403	45.332
(c',29)	36	2.336262	2.7619	.379	46.599
(d',30)	38	2.522160	2.9890	.355	47.682
(e',31)	40	2.731631	3.2392	.332	48.684
(f',32)	42	2.968278	3.5160	.308	49.515

TABLE III.- SECONDARY-EXPANSION FLOW

(a) $\nu_B = 6^\circ$

Point	ν, deg	$\frac{x}{y_{cr}}$	$\frac{y}{y_{cr}}$	Ψ
		$\eta = 0.0625^\circ$		
(a,13)	3.03125	0.30957	0.55551	0.55067
(a,14)	3.53125	.32134	.57632	.57025
(a,15)	4.28125	.34104	.61106	.60241
(a,16)	5.03125	.36564	.64923	.63702
(a,17)	6.03125	.40138	.70443	.68579
(a,18)	7.03125	.44140	.76399	.73678
(a,19)	8.03125	.48535	.82754	.78941
(a,20)	9.03125	.53296	.89489	.84328
(a,21)	10.03125	.58410	.96605	.89817
(a,22)	11.03125	.63866	1.04105	.95388
(a,23)	12.03125	.69660	1.12001	1.01029
		$\eta = 0.125^\circ$		
(b,13)	3.0625	0.34315	0.50742	0.50215
(b,14)	3.5625	.35608	.53017	.52356
(b,15)	4.3125	.37827	.56742	.55803
(b,16)	5.0625	.40342	.60775	.59459
(b,17)	6.0625	.44092	.66547	.64557
(b,18)	7.0625	.48259	.72727	.69846
(b,19)	8.0625	.52809	.79286	.75276
(b,20)	9.0625	.57718	.86210	.80813
(b,21)	10.0625	.62976	.93506	.86438
(b,22)	11.0625	.68572	1.01178	.92134
(b,23)	12.0625	.74503	1.09240	.97891
(b,24)	13.0625	.80764	1.17705	1.03697
		$\eta = 0.250^\circ$		
(c,13)	3.125	0.38420	0.44887	0.44306
(c,14)	3.625	.39858	.47391	.46661
(c,15)	4.375	.42275	.51412	.50381
(c,16)	5.125	.44971	.55701	.54267
(c,17)	6.125	.48946	.61772	.59627
(c,18)	7.125	.53322	.68219	.65142
(c,19)	8.125	.58070	.75021	.70771
(c,20)	9.125	.63170	.82173	.76486
(c,21)	10.125	.68612	.89684	.82273
(c,22)	11.125	.74388	.97561	.88117
(c,23)	12.125	.80496	1.05823	.94011
(c,24)	13.125	.86933	1.14483	.99945
(c,25)	14.125	.93701	1.23565	1.05915
		$\eta = 0.500^\circ$		
(d,13)	3.250	0.43366	0.37887	0.37257
(d,14)	3.750	.44984	.40649	.39853
(d,15)	4.500	.47650	.45004	.43879
(d,16)	5.250	.50576	.49584	.48025
(d,17)	6.250	.54836	.55997	.53682
(d,18)	7.250	.59480	.62749	.59452
(d,19)	8.250	.64485	.69831	.65306
(d,20)	9.250	.69833	.77246	.71222
(d,21)	10.250	.75517	.85006	.77192
(d,22)	11.250	.81531	.93124	.83205
(d,23)	12.250	.87875	1.01619	.89255
(d,24)	13.250	.94545	1.10509	.95335
(d,25)	14.250	1.01547	1.19817	1.01442
		= 0.750°		
(e,13)	3.375	0.46709	0.33201	0.32550
(e,14)	3.875	.48454	.36122	.35294
(e,15)	4.625	.51296	.40684	.39509
(e,16)	5.375	.54386	.45446	.43816
(e,17)	6.375	.58853	.52074	.49657
(e,18)	7.375	.63693	.59018	.55585
(e,19)	8.375	.68886	.66279	.61579
(e,20)	9.375	.74417	.73861	.67621
(e,21)	10.375	.80282	.81782	.73706
(e,22)	11.375	.86475	.90056	.79824
(e,23)	12.375	.92996	.98703	.85972
(e,24)	13.375	.99844	1.07743	.92143
(e,25)	14.375	1.07024	1.17200	.98336
(e,26)	15.375	1.14540	1.27102	1.04548
		$\eta = 1.000$		
(f,13)	3.50	0.49314	0.29582	0.28925
(f,14)	4.00	.51162	.32616	.31773
(f,15)	4.75	.54148	.37327	.36122
(f,16)	5.50	.57373	.42219	.40544
(f,17)	6.50	.62009	.49003	.46517
(f,18)	7.50	.67012	.56089	.52559
(f,19)	8.50	.72362	.63481	.58654
(f,20)	9.50	.78048	.71187	.64787
(f,21)	10.50	.84065	.79227	.70955
(f,22)	11.50	.90408	.87616	.77149
(f,23)	12.50	.97081	.96378	.83368
(f,24)	13.50	1.04081	1.05532	.89605
(f,25)	14.50	1.11414	1.15103	.95860
(f,26)	15.50	1.19085	1.25120	1.02130
		$\eta = 1.50^\circ$		
(g,13)	3.75	0.53366	0.24031	0.23385
(g,14)	4.25	.55379	.27218	.26374
(g,15)	5.00	.58599	.32133	.30906
(g,16)	5.75	.62046	.37206	.35485
(g,17)	6.75	.66965	.44208	.41639
(g,18)	7.75	.72240	.51493	.47839
(g,19)	8.75	.77857	.59072	.54074
(g,20)	9.75	.83804	.66956	.60333
(g,21)	10.75	.90082	.75170	.66616
(g,22)	11.75	.96686	.83730	.72917
(g,23)	12.75	1.03620	.92661	.79235
(g,24)	13.75	1.10884	1.01983	.85565
(g,25)	14.75	1.18484	1.11725	.91907
(g,26)	15.75	1.26427	1.21915	.98259
(g,27)	16.75	1.34717	1.32579	1.04619
		$\eta = 2.00^\circ$		
(h,13)	4.00	0.56551	0.19739	0.19123
(h,14)	4.50	.58701	.23026	.22203
(h,15)	5.25	.62116	.28075	.26853
(h,16)	6.00	.65750	.33270	.31535
(h,17)	7.00	.70909	.40419	.37808

TABLE III.- SECONDARY-EXPANSION FLOW - Continued

(a) $\nu_B = 6^{\circ}$ - Concluded

Point	ν, deg	$\frac{x}{y_{cr}}$	$\frac{y}{y_{cr}}$	Ψ
η = 2.00° - Concluded				
(h,18)	8.00	0.76418	0.47841	0.44113
(h,19)	9.00	.82264	.55550	.50441
(h,20)	10.00	.88440	.63561	.56785
(h,21)	11.00	.94946	.71898	.63145
(h,22)	12.00	1.01779	.80581	.69517
(h,23)	13.00	1.08945	.89636	.75901
(h,24)	14.00	1.16444	.99084	.82293
(h,25)	15.00	1.24283	1.08954	.88693
(h,26)	16.00	1.32469	1.19275	.95101
(h,27)	17.00	1.41009	1.30074	1.01514
= 2.50°				
(i,13)	4.25	0.59228	0.16186	0.15617
(i,14)	4.75	.61497	.19542	.18759
(i,15)	5.50	.65084	.24686	.23491
(i,16)	6.25	.68884	.29967	.28245
(i,17)	7.25	.74258	.37223	.34602
(i,18)	8.25	.79978	.44745	.40980
(i,19)	9.25	.86033	.52551	.47374
(i,20)	10.25	.92417	.60657	.53778
(i,21)	11.25	.99132	.69089	.60193
(i,22)	12.25	1.06177	.77867	.66616
(i,23)	13.25	1.13557	.87019	.73047
(i,24)	14.25	1.21275	.96566	.79483
(i,25)	15.25	1.29337	1.06538	.85925
(i,26)	16.25	1.37751	1.16965	.92372
(i,27)	17.25	1.46525	1.27875	.98823
(i,28)	18.25	1.55669	1.39304	1.05278
η = 3.00°				
(j,13)	4.50	0.61565	0.13128	0.12616
(j,14)	5.00	.63942	.16533	.15801
(j,15)	5.75	.67686	.21744	.20591
(j,16)	6.50	.71638	.27088	.25396
(j,17)	7.50	.77211	.34423	.31813
(j,18)	8.50	.83126	.42021	.38244
(j,19)	9.50	.89375	.49901	.44686
(j,20)	10.50	.95954	.58081	.51133
(j,21)	11.50	1.02866	.66588	.57588
(j,22)	12.50	1.10111	.75442	.64048

Point	ν, deg	$\frac{x}{y_{cr}}$	$\frac{y}{y_{cr}}$	Ψ
η = 3.00° - Concluded				
(j,23)	13.50	1.17695	0.84672	0.70514
(j,24)	14.50	1.25619	.94301	.76983
(j,25)	15.50	1.33894	1.04358	.83456
(j,26)	16.50	1.42527	1.14874	.89933
(j,27)	17.50	1.51525	1.25878	.96411
(j,28)	18.50	1.60901	1.37406	1.02892
η = 4.00°				
(k,13)	5.00	0.65568	0.07991	0.07621
(k,14)	5.50	.68137	.11456	.10858
(k,15)	6.25	.72162	.16751	.15718
(k,16)	7.00	.76390	.22175	.20585
(k,17)	8.00	.82324	.29614	.27076
(k,18)	9.00	.88600	.37315	.33573
(k,19)	10.00	.95211	.45298	.40074
(k,20)	11.00	1.02154	.53584	.46575
(k,21)	12.00	1.09436	.62199	.53080
(k,22)	13.00	1.17057	.71168	.59587
(k,23)	14.00	1.25025	.80517	.66097
(k,24)	15.00	1.33344	.90272	.72607
(k,25)	16.00	1.42024	1.00464	.79119
(k,26)	17.00	1.51075	1.11123	.85633
(k,27)	18.00	1.60504	1.22280	.92146
(k,28)	19.00	1.70326	1.33972	.98661
(k,29)	20.00	1.80553	1.46238	1.05178
η = 5.00°				
(l,13)	5.50	0.68978	0.03712	0.03514
(l,14)	6.00	.71719	.07205	.06775
(l,15)	6.75	.75997	.12542	.11667
(l,16)	7.50	.80475	.18007	.16563
(l,17)	8.50	.86742	.25503	.23088
(l,18)	9.50	.93351	.33263	.29616
(l,19)	10.50	1.00299	.41309	.36145
(l,20)	11.50	1.07584	.49662	.42672
(l,21)	12.50	1.15214	.58350	.49202
(l,22)	13.50	1.23193	.67398	.55731
(l,23)	14.50	1.31527	.76833	.62262
(l,24)	15.50	1.40224	.86682	.68792
(l,25)	16.50	1.49294	.96975	.75323
(l,26)	17.50	1.58747	1.07746	.81855
(l,27)	18.50	1.68594	1.19025	.88386
(l,28)	19.50	1.78849	1.30850	.94917
(l,29)	20.50	1.89526	1.43261	1.01449

TABLE III.- SECONDARY-EXPANSION FLOW - Continued

(b) $\nu_B = 12^\circ$

Point	ν, deg	$\frac{x}{y_{cr}}$	$\frac{y}{y_{cr}}$	ψ
$\eta = 0.0625^\circ$				
(a,17)	6.03125	0.36251	0.64247	0.63005
(a,18)	7.03125	.37887	.66681	.65089
(a,19)	8.03125	.39801	.69449	.67382
(a,20)	9.03125	.41972	.72521	.69839
(a,21)	10.03125	.44382	.75875	.72426
(a,22)	11.03125	.47021	.79501	.75120
(a,23)	12.03125	.49881	.83399	.77905
(a,24)	13.03125	.52956	.87566	.80764
(a,25)	14.03125	.56246	.92012	.83691
(a,26)	15.03125	.59749	.96742	.86675
(a,27)	16.03125	.63463	1.01765	.89709
(a,28)	17.03125	.67393	1.07097	.92791
(a,29)	18.03125	.71540	1.12750	.95913
(a,30)	19.03125	.75907	1.18742	.99072
(a,31)	20.03125	.80499	1.25090	1.02265
$\eta = 0.125^\circ$				
(b,17)	6.0625	0.40196	0.60360	0.58992
(b,18)	7.0625	.41991	.63022	.61270
(b,19)	8.0625	.44055	.65998	.63734
(b,20)	9.0625	.46369	.69262	.66344
(b,21)	10.0625	.48917	.72797	.69070
(b,22)	11.0625	.51688	.76597	.71891
(b,23)	12.0625	.54680	.80663	.74794
(b,24)	13.0625	.57882	.84993	.77764
(b,25)	14.0625	.61299	.89599	.80795
(b,26)	15.0625	.64926	.94486	.83877
(b,27)	16.0625	.68764	.99664	.87004
(b,28)	17.0625	.72817	1.05152	.90173
(b,29)	18.0625	.77086	1.10960	.93378
(b,30)	19.0625	.81577	1.17109	.96617
(b,31)	20.0625	.86292	1.23614	.99886
(b,32)	21.0625	.91238	1.30501	1.03185
$\eta = 0.250^\circ$				
(c,17)	6.125	0.45030	0.55605	0.54083
(c,18)	7.125	.47024	.58540	.56595
(c,19)	8.125	.49276	.61766	.59264
(c,20)	9.125	.51769	.65263	.62058
(c,21)	10.125	.54490	.69018	.64951
(c,22)	11.125	.57430	.73028	.67926
(c,23)	12.125	.60585	.77296	.70971
(c,24)	13.125	.63950	.81824	.74073
(c,25)	14.125	.67527	.86623	.77228
(c,26)	15.125	.71313	.91702	.80427
(c,27)	16.125	.75309	.97070	.83665
(c,28)	17.125	.79521	1.02748	.86940
(c,29)	18.125	.83948	1.08745	.90246
(c,30)	19.125	.88597	1.15084	.93581
(c,31)	20.125	.93471	1.21782	.96942
(c,32)	21.125	.98578	1.28863	1.00329
$\eta = 0.500^\circ$				
(d,17)	6.250	0.50882	0.49867	0.48176
(d,18)	7.250	.53122	.53124	.50959
(d,19)	8.250	.55609	.56643	.53867
(d,20)	9.250	.58328	.60412	.56875
(d,21)	10.250	.61268	.64426	.59963
(d,22)	11.250	.64422	.68684	.63117
(d,23)	12.250	.67788	.73192	.66328
(d,24)	13.250	.71362	.77954	.69585
(d,25)	14.250	.75145	.82984	.72885
(d,26)	15.250	.79138	.88291	.76221
(d,27)	16.250	.83340	.93886	.79588
(d,28)	17.250	.87758	.99791	.82986
(d,29)	18.250	.92392	1.06017	.86409
(d,30)	19.250	.97250	1.12586	.89856
(d,31)	20.250	1.02334	1.19517	.93325
(d,32)	21.250	1.07654	1.26835	.96815
(d,33)	22.250	1.13213	1.34560	1.00322
$\eta = 0.750^\circ$				
(e,17)	6.375	0.54861	0.45980	0.44188
(e,18)	7.375	.57276	.49445	.47146
(e,19)	8.375	.59930	.53155	.50209
(e,20)	9.375	.62810	.57104	.53356
(e,21)	10.375	.65908	.61287	.56570
(e,22)	11.375	.69217	.65708	.59839
(e,23)	12.375	.72736	.70375	.63157
(e,24)	13.375	.76461	.75292	.66514
(e,25)	14.375	.80396	.80476	.69908
(e,26)	15.375	.84540	.85935	.73333
(e,27)	16.375	.88894	.91683	.76784
(e,28)	17.375	.93465	.97740	.80261
(e,29)	18.375	.98254	1.04120	.83760
(e,30)	19.375	1.03268	1.10845	.87280
(e,31)	20.375	1.08511	1.17934	.90818
(e,32)	21.375	1.13992	1.25414	.94374
(e,33)	22.375	1.19714	1.33304	.97945
(e,34)	23.375	1.25685	1.41632	1.01530
$\eta = 1.000^\circ$				
(f,17)	6.50	0.57980	0.42946	0.41085
(f,18)	7.50	.60536	.46567	.44173
(f,19)	8.50	.63326	.50421	.47351
(f,20)	9.50	.66338	.54504	.50601
(f,21)	10.50	.69565	.58816	.53909
(f,22)	11.50	.73002	.63361	.57265
(f,23)	12.50	.76648	.68149	.60663
(f,24)	13.50	.80500	.73185	.64095
(f,25)	14.50	.84561	.78486	.67559
(f,26)	15.50	.88831	.84062	.71050
(f,27)	16.50	.93313	.89928	.74564
(f,28)	17.50	.98014	.96104	.78101
(f,29)	18.50	1.02933	1.02604	.81657
(f,30)	19.50	1.08080	1.09451	.85231
(f,31)	20.50	1.13458	1.16665	.88821
(f,32)	21.50	1.19076	1.24271	.92427
(f,33)	22.50	1.24938	1.32292	.96046
(f,34)	23.50	1.31052	1.40754	.99677
(f,35)	24.50	1.37430	1.49692	1.03322
$\eta = 1.50^\circ$				
(g,17)	6.75	0.62864	0.38221	0.36278
(g,18)	7.75	.65651	.42071	.39554
(g,19)	8.75	.68665	.46137	.42899
(g,20)	9.75	.71896	.50420	.46299
(g,21)	10.75	.75338	.54924	.49744
(g,22)	11.75	.78988	.59655	.53226
(g,23)	12.75	.82846	.64625	.56742
(g,24)	13.75	.86911	.69841	.60283
(g,25)	14.75	.91186	.75321	.63850
(g,26)	15.75	.95672	.81076	.67438
(g,27)	16.75	1.00372	.87123	.71044
(g,28)	17.75	1.05294	.93481	.74669
(g,29)	18.75	1.10438	1.00167	.78308
(g,30)	19.75	1.15814	1.07204	.81962
(g,31)	20.75	1.21426	1.14612	.85629
(g,32)	21.75	1.27283	1.22418	.89309
(g,33)	22.75	1.33389	1.30645	.92999
(g,34)	23.75	1.39754	1.39320	.96698
(g,35)	24.75	1.46390	1.48479	1.00409
$\eta = 2.00^\circ$				
(h,17)	7.00	0.66737	0.34500	0.32507
(h,18)	8.00	.69718	.38516	.35919
(h,19)	9.00	.72919	.42738	.39384
(h,20)	10.00	.76335	.47169	.42893
(h,21)	11.00	.79960	.51815	.46437

TABLE III.- SECONDARY-EXPANSION FLOW - Continued

(b) $\nu_B = 12^\circ$ - Continued

Point	ν, deg	$\frac{x}{y_{cr}}$	$\frac{y}{y_{cr}}$	Ψ
$\eta = 2.00^\circ$ - Concluded				
(h,22)	12.00	0.83793	0.56685	0.50011
(h,23)	13.00	.87834	.61792	.53612
(h,24)	14.00	.92082	.67144	.57233
(h,25)	15.00	.96543	.72761	.60875
(h,26)	16.00	1.01217	.78654	.64534
(h,27)	17.00	1.06108	.84839	.68207
(h,28)	18.00	1.11224	.91340	.71895
(h,29)	19.00	1.16567	.98171	.75595
(h,30)	20.00	1.22146	1.05357	.79307
(h,31)	21.00	1.27965	1.12919	.83029
(h,32)	22.00	1.34035	1.20884	.86762
(h,33)	23.00	1.40361	1.29276	.90503
(h,34)	24.00	1.46951	1.38123	.94252
(h,35)	25.00	1.53819	1.47461	.98011
(h,36)	26.00	1.60969	1.57316	1.01775
$\eta = 2.50^\circ$				
(i,17)	7.25	0.70017	0.31370	0.29378
(i,18)	8.25	.73168	.35516	.32893
(i,19)	9.25	.76537	.39858	.36450
(i,20)	10.25	.80119	.44406	.40043
(i,21)	11.25	.83909	.49165	.43664
(i,22)	12.25	.87906	.$146	.47309
(i,23)	13.25	.92114	.59363	.50975
(i,24)	14.25	.96529	.64826	.54658
(i,25)	15.25	1.01160	.70554	.58358
(i,26)	16.25	1.06006	-76559	.62072
(i,27)	17.25	1.11073	.82860	.65797
(i,28)	18.25	1.16369	.89478	.69535
(i,29)	19.25	1.21895	.96431	.73283
(i,30)	20.25	1.27662	1.03742	.77040
(i,31)	21.25	1.33675	1.11433	.80806
(i,32)	22.25	1.39944	1.19534	.84581
(i,33)	23.25	1.46475	1.28067	.88362
(i,34)	24.25	1.53277	1.37061	.92150
(i,35)	25.25	1.60364	1.46554	.95946
(i,36)	26.25	1.67740	1.56571	.99746
(i,37)	27.25	1.75421	1.67156	1.03553
$\eta = 3.00^\circ$				
(j,17)	7.50	0.72901	0.28635	0.26652
(j,18)	8.50	.76209	.32884	.30249
(j,19)	9.50	.79732	.37326	.33880
(j,20)	10.50	.83466	.41969	.37539
(j,21)	11.50	.87408	.46821	.41221
(j,22)	12.50	.91559	.51894	.44922
(j,23)	13.50	.95921	.57204	.48641
(j,24)	14.50	1.00498	.62759	.52373
(j,25)	15.50	1.05284	.68581	.56120
(j,26)	16.50	1.10292	.74682	.59878
(j,27)	17.50	1.15525	.81082	.63645
(j,28)	18.50	1.20990	.87801	.67423
(j,29)	19.50	1.26691	.94859	.71209
(j,30)	20.50	1.32637	1.02279	.75003
(j,31)	21.50	1.38835	1.10084	.78804
(j,32)	22.50	1.45294	1.18304	.82613
(j,33)	23.50	1.52021	1.26961	.86427
(j,34)	24.50	1.59026	1.36086	.90246
(j,35)	25.50	1.66323	1.45718	.94072
(j,36)	26.50	1.73917	1.55881	.97901
(j,37)	27.50	1.81825	1.66620	1.01736

Point	ν, deg	$\frac{x}{y_{cr}}$	$\frac{y}{y_{cr}}$	Ψ
$\eta = 4.00^\circ$				
(k,17)	8.00	0.77883	0.23950	0.22037
(k,18)	9.00	.81475	.28357	.25755
(k,19)	10.00	.85279	.32950	.29495
(k,20)	11.00	.89293	.37741	.33254
(k,21)	12.00	.93518	.42740	.37028
(k,22)	13.00	.97953	.47959	.40815
(k,23)	14.00	1.02604	.53416	.44614
(k,24)	15.00	1.07469	.59121	.48421
(k,25)	16.00	1.12558	.65096	.52239
(k,26)	17.00	1.17873	.71356	.56064
(k,27)	18.00	1.23420	.77919	.59895
(k,28)	19.00	1.29207	.84808	.63734
(k,29)	20.00	1.35239	.92043	.67578
(k,30)	21.00	1.41527	.99649	.71428
(k,31)	22.00	1.48077	1.07649	.75282
(k,32)	23.00	1.$902	1.16074	.79142
(k,33)	24.00	1.62007	1.24948	.83005
(k,34)	25.00	1.69404	1.34302	.86872
(k,35)	26.00	1.77108	1.44177	.90744
(k,36)	27.00	1.85124	1.54598	.94618
(k,37)	28.00	1.93472	1.65612	.98496
(k,38)	29.00	2.02162	1.77258	1.02377
$\eta = 5.00^\circ$				
(l,17)	8.50	0.82174	0.19956	0.18164
(l,18)	9.50	.86024	.24477	.21967
(l,19)	10.50	.90086	.29181	.25784
(l,20)	11.50	.94360	.34081	.29614
(l,21)	12.50	.98847	.39190	.33453
(l,22)	13.50	1.03548	.44522	.37300
(l,23)	14.50	1.08469	.50092	.41156
(l,24)	15.50	1.13611	.55915	.45017
(l,25)	16.50	1.18984	.62013	.48886
(l,26)	17.50	1.24590	.68400	.52759
(l,27)	18.50	1.30435	.75096	.56636
(l,28)	19.50	1.36531	.82125	.60518
(l,29)	20.50	1.42882	.89508	.64404
(l,30)	21.50	1.49500	.97269	.68294
(l,31)	22.50	1.56391	1.05435	.72187
(l,32)	23.50	1.63569	1.14036	.76084
(l,33)	24.50	1.71042	1.23097	.79983
(l,34)	25.50	1.78821	1.32652	.83884
(l,35)	26.50	1.86922	1.42740	.87789
(l,36)	27.50	1.95353	1.53390	-91695
(l,37)	28.50	2.04133	1.64649	.95605
(l,38)	29.50	2.13273	1.76559	.99517
(l,39)	30.50	2.22790		1.03431
$\eta = 6.00^\circ$				
(m,17)	9.00	0.86006	0.16422	0.14791
(m,18)	10.00	.90098	.21026	.18654
(m,19)	11.00	.94403	.25813	.22526
(m,20)	12.00	.98923	.30798	.26406
(m,21)	13.00	1.03659	.35992	.30292
(m,22)	14.00	1.08614	.41412	.34183
(m,23)	15.00	1.13795	.47074	.38080
(m,24)	16.00	1.19204	.52993	.41980
(m,25)	17.00	1.24850	.59191	.45886
(m,26)	18.00	1.30738	.65684	.49794

TABLE III.- SECONDARY-EXPANSION FLOW - Continued

(b) $\nu_B = 12^\circ$ - Concluded

Point	ν, deg	$\frac{x}{y_{cr}}$	$\frac{y}{y_{cr}}$	Ψ
$\eta = 6.00^\circ$ - Concluded				
(m,27)	19.00	1.36875	0.72492	0.53705
(m,28)	20.00	1.43272	.79641	.57619
(m,29)	21.00	1.49934	.87150	.61535
(m,30)	22.00	1.56875	.95048	.65454
(m,31)	23.00	1.64102	1.03359	.69375
(m,32)	24.00	1.71629	1.12116	.73299
(m,33)	25.00	1.79465	1.21345	.77224
(m,34)	26.00	1.87622	1.31079	.81151
(m,35)	27.00	1.96119	1.41360	.85081
(m,36)	28.00	2.04962	1.52219	.89011
(m,37)	29.00	2.14172	1.63704	.92944
(m,38)	30.00	2.23763	1.75856	.96878
(m,39)	31.00	2.33752	1.88724	1.00813
$\eta = 7.00^\circ$				
(n,17)	9.50	0.89507	0.13218	0.11783
(n,18)	10.50	.93830	.17884	.15689
(n,19)	11.50	.98367	.22734	.19601
(n,20)	12.50	1.03124	.27783	.23518
(n,21)	13.50	1.08101	.33044	.27438
(n,22)	14.50	1.13302	.38535	.31361
(n,23)	15.50	1.18736	.44272	.35288
(n,24)	16.50	1.24405	.50270	.39216
(n,25)	17.50	1.30320	.56552	.43149
(n,26)	18.50	1.36484	.63135	.47083
(n,27)	19.50	1.42908	.70040	.51018
(n,28)	20.50	1.49602	.77293	.54956
(n,29)	21.50	1.56573	.84914	.58895
(n,30)	22.50	1.63834	.92932	.62836
(n,31)	23.50	1.71394	1.01374	.66778
(n,32)	24.50	1.79269	1.10271	.70722
(n,33)	25.50	1.87468	1.19652	.74667
(n,34)	26.50	1.96003	1.29552	.78612
(n,35)	27.50	2.04895	1.40012	.82560
(n,36)	28.50	2.14151	1.51065	.86507
(n,37)	29.50	2.23794	1.62760	.90457
(n,38)	30.50	2.33839	1.75141	.94407
(n,39)	31.50	2.44304	1.88257	.98358
(n,40)	32.50	2.55208	2.02164	1.02310
$\eta = 8.50^\circ$				
	10.25	0.94314	0.08855	0.07776
(o,18)	11.25	.98966	.13584	.11724
(o,19)	12.25	1.03840	.18500	.15674
(o,20)	13.25	1.08938	.23620	.19627
(o,21)	14.25	1.14266	.28957	.23581
(o,22)	15.25	1.19828	.34528	.27536
(o,23)	16.25	1.25634	.40353	.31493
(o,24)	17.25	1.31686	.46446	.35450
(o,25)	18.25	1.37997	.52832	.39410
(o,26)	19.25	1.44572	.59527	.43370

Point	ν, deg	$\frac{x}{y_{cr}}$	$\frac{y}{y_{cr}}$	Ψ
$\eta = 8.50^\circ$ - Concluded				
(o,27)	20.25	1.51422	0.66555	0.47330
(o,28)	21.25	1.58559	.73941	.51292
(o,29)	22.25	1.65990	.81708	.55254
(o,30)	23.25	1.73731	.89886	.59217
(o,31)	24.25	1.81793	.98501	.63180
(o,32)	25.25	1.90191	1.07588	.67145
(o,33)	26.25	1.98936	1.17176	.71110
(o,34)	27.25	2.08043	1.27302	.75074
(o,35)	28.25	2.17534	1.38010	.79040
(o,36)	29.25	2.27418	1.49333	.83005
(o,37)	30.25	2.37720	1.61324	.86972
(o,38)	31.25	2.48456	1.74028	.90939
(o,39)	32.25	2.59647	1.87496	.94906
(o,40)	33.25	2.71315	2.01789	.98874
(o,41)	34.25	2.83480	2.16963	1.02842
$\eta = 10.00^\circ$				
(p,17)	11.00	0.98731	0.04879	0.04222
(p,18)	12.00	1.03700	.09644	.08193
(p,19)	13.00	1.08898	.14601	.12164
(p,20)	14.00	1.14330	.19767	.16136
(p,21)	15.00	1.20000	.25156	.20108
(p,22)	16.00	1.25916	.30785	.24080
(p,23)	17.00	1.32087	.36675	.29054
(p,24)	18.00	1.38518	.42841	.32027
(p,25)	19.00	1.45222	.49309	.36001
(p,26)	20.00	1.52207	.56096	.39975
(p,27)	21.00	1.59482	.63224	.43948
(p,28)	22.00	1.67062	.70724	.47923
(p,29)	23.00	1.74957	.78616	.51897
(p,30)	24.00	1.83181	.86932	.55872
(p,31)	25.00	1.91749	.95701	.59847
(p,32)	26.00	2.00676	1.04957	.63823
(p,33)	27.00	2.09975	[illegible]	.67798
(p,34)	28.00	2.19664		.71773
(p,35)	29.00	2.29766	1.36002	.75750
(p,36)	30.00	2.40291	1.47576	.79725
(p,37)	31.00	2.51267	1.59843	.83701
(p,38)	32.00	2.62712	1.72851	.87677
(p,39)	33.00	2,74649	1.86655	.91653
(p,40)	34.00	2.87103	2.01316	.95630
(p,41)	35.00	3.00098	2.16895	.99606
(p,42)	36.00	3.13663	2.33468	1.03583

TABLE III.- SECONDARY-EXPANSION FLOW - Continued

(c) $\nu_B = 22^o$

mint	ν, deg	$\frac{x}{y_{cr}}$	$\frac{y}{y_{cr}}$	ψ
				0.70388
				.71598
				.72905
				74296
				.75761
				.77291
				.78879
				.80520
				.82208
				.83941
				.85713
				.87523
				.89366
				.91243
				.93149
				.95083
				.97045
				.99032
				1.01042
		$\eta = 0.125^o$		
(b,22)	11.0625	0.47354	0.70537	0.67167
(b,23)	12.0625	.48725	.72399	.68497
(b,24)	13.0625	.50255	.74468	.69916
(b,25)	14.0625	.51941	.76741	.71411
(b,26)	15.0625	.53781	.79220	.72975
(b,27)	16.0625	.55773	.81908	.74598
(b,28)	17.0625	.57918	.84812	.76275
(b,29)	18.0625	.60216	.87939	.78001
(b,30)	19.0625	.62669	.91297	.79770
(b,31)	20.0625	.65280	.94899	.81580
(b,32)	21.0625	.68049	.98755	.83427
(b,33)	22.0625	.70983	1.02880	.85309
(b,34)	23.0625	.74081	1.07287	.87221
(b,35)	24.0625	.77353	1.11997	.89164
(b,36)	25.0625	.80800	1.17024	.91134
(b,37)	26.0625	.84427	1.22389	.93130
(b,38)	27.0625	.88243	1.28117	.95152
(b,39)	28.0625	.92251	1.34229	.97197
(b,40)	29.0625	.96458	1.40751	.99264
(b,41)	30.0625	1.00873	1.47712	1.01352
		$\eta = 0.250^o$		
(c,22)	11.125	0.53079	0.66978	0.63212
(c,23)	12.125	.54608	.69046	.64687
(c,24)	13.125	.56294	.71314	.66241
(c,25)	14.125	.58133	.73782	.67864
(c,26)	15.125	.60125	.76454	.69547
(c,27)	16.125	.62269	.79334	.71284
(c,28)	17.125	.64564	.82428	.73069
(c,29)	18.125	.67012	.85745	.74897
(c,30)	19.125	.69615	.89294	.76764
(c,31)	20.125	.72376	.93088	.78668
(c,32)	a.125	.75297	.97138	.80605
(c,33)	22.125	.78383	1.01460	.82573
(c,34)	23.125	.81634	1.06066	.84569
(c,35)	24.125	.85061	1.10980	.86593
(c,36)	25.125	.88663	1.16213	.88641
(c,37)	26.125	.92448	1.21790	.90712
(c,38)	27.125	.96423	1.27736	.92806
(c,39)	28.125	1.00593	1.34070	.94921
(c,40)	29.125	1.04964	1.40820	.97056
(c,41)	30.125	1.09544	1.48017	.99210
(c,42)	31.125	1.14340	1.55689	1.01382
		$\eta = 0.500^o$		
(d,22)	11.25	0.60038	0.62654	0.58427
(d,23)	12.25	.61765	.64968	.60074
(d,24)	13.25	.63646	.67475	.61789
(d,25)	14.25	.65679	.70178	.63562
(d,26)	15.25	.67863	.73081	.65387
		η = .500° - Concluded		
(d,27)	16.25	0.70198	0.76190	0.67258
(d,28)	17.25	.72684	.79513	.69170
(d,29)	18.25	.75324	.83059	.71120
(d,30)	19.25	.78119	.86839	.73103
(d,31)	20.25	.81074	.90866	.75118
(d,32)	21.25	.84189	.95151	.77161
(d,33)	22.25	.87470		
(d,34)	23.25	.90920	1.99712	[illegible]
(d,35)	24.25	.94547	1.09722	.83445
(d,36)	25.25	.98353	1.15209	.85585
(d,37)	26.25	1.02344	1.21046	.87745
(d,38)	27.25	1.06529	1.27257	.89925
(d,39)	28.25	1.10912	1.33866	.92123
(d,40)	29.25	1.15499	1.40898	.94338
(d,41)	30.25	1.20301	1.48387	.96570
(d,42)	31.25	1.25322	1.56360	.98817
(d,43)	32.25	1.30574	1.64856	1.01080
		$\eta = 0.750^o$		
(e,22)	11.375	0.64799	0.59699	0.55170
(e,23)	12.375	.66667	.62176	.56931
(e,24)	13.375	.68688	.64844	.58752
(e,25)	14.375	.70859	.67703	.60625
(e,26)	15.375	.73180	.70762	.62544
(e,27)	16.375	.75653	.74026	.64504
(e,28)	17.375	.78277	.77503	.66500
(e,29)	18.375	.81055	.81205	.68530
(e,30)	19.375	.83990	.85141	.70590
(e,31)	20.375	.87085	.89326	.72679
(e,32)	21.375	.90343	.93771	.74793
(e,33)	22.375	.93769	.98495	.76931
(e,34)	23.375	.97365	1.03511	.79090
(e,35)	24.375	1.01141	1.08843	.81272
(e,36)	25.375	1.05097	1.14504	.83472
(e,37)	26.375	1.09242	1.20521	.85691
(e,38)	27.375	1.13584	1.26917	.87928
(e,39)	28.375	1.18127	1.33716	.90181
(e,40)	29.375	1.22878	1.40946	.92449
(e,41)	30.375	1.27847	1.48638	.94733
(e,42)	31.375	1.33040	1.56823	.97030
(e,43)	32.375	1.38467	1.65539	.99341
(e,44)	33.375	1.44136	1.74822	1.01665
		$\eta = 1.00^o$		
(f,22)	11.50	0.68551	0.57373	0.52619
(f,23)	12.50	.70534	.59976	.54467
(f,24)	13.50	.72668	.62766	.56369
(f,25)	14.50	.74952	.65748	.58317
(f,26)	15.50	.77387	.68927	.60307
(f,27)	16.50	.79972	.72311	.62334
(f,28)	17.50	.82710	.75908	.64394
(f,29)	18.50	.85603	.79731	.66485
(f,30)	19.50	.88654	.83789	.68603
(f,31)	20.50	.91866	.88098	.70748
(f,32)	21.50	.95243	.92670	.72915
(f,33)	22.50	.98789	.97522	.75105
(f,34)	23.50	1.02508	1.02670	.77314
(f,35)	24.50	1.06409	1.08136	.79543
(f,36)	25.50	1.10493	1.13936	.81789
(f,37)	26.50	1.14769	1.20095	.84052
(f,38)	27.50	1.19244	1.26639	.86332
(f,39)	28.50	1.23923	1.33591	.88626
(f,40)	29.50	1.28814	1.40978	.90934
(f,41)	30.50	1.33926	1.48835	.93257
(f,42)	31.50	1.39266	1.57190	.95592
(f,43)	32.50	1.44845	1.66084	.97940
(f,44)	33.50	1.50670	1.75552	1.00300

TABLE III.- SECONDARY-EXPANSION FLOW - Continued

(c) $\nu_B = 22^\circ$ - continued

Point	ν, deg	$\frac{x}{y_{cr}}$	$\frac{y}{y_{cr}}$	Ψ
$\eta = 1.50^\circ$				
(g,22)	11.75	0.74471	0.53708	0.48626
(g,23)	12.75	.76642	.56503	.50604
(g,24)	13.75	.78963	.59483	.52627
(g,25)	14.75	.81435	.62651	.54689
(g,26)	15.75	.84057	.66015	.56787
(g,27)	16.75	.86832	.69585	.58916
(g,28)	17.75	.89761	.73368	.61073
(g,29)	18.75	.92847	.77379	.63256
(g,30)	19.75	.96092	.81628	.65462
(g,31)	20.75	.99503	.86131	.67691
(g,32)	21.75	1.03081	.90900	.69939
(g,33)	22.75	1.06834	.95955	.72206
(g,34)	23.75	1.10763	1.01310	.74490
(g,35)	24.75	1.14878	1.06990	.76791
(g,36)	25.75	1.19181	1.13010	.79106
(g,37)	26.75	1.23681	1.19397	.81436
(g,38)	27.75	1.28387	1.26177	.83781
(g,39)	28.75	1.33304	1.33374	.86138
(g,40)	29.75	1.38438	1.41016	.88507
(g,41)	30.75	1.43802	1.49139	.90888
(g,42)	31.75	1.49400	1.57772	.93280
(g,43)	32.75	1.55246	1.66956	.95683
(g,44)	33.75	1.61346	1.76728	.98096
(g,45)	34.75	1.67714	1.87136	1.00520
$\eta = 2.00^\circ$				
(h,22)	12.00	0.79211	0.50778	0.45464
(h,23)	13.00	.81540	.53721	.47539
(h,24)	14.00	.84020	.56846	.49653
(h,25)	15.00	.86650	.60158	.51801
(h,26)	16.00	.89433	.63666	.53979
(h,27)	17.00	.92370	.67380	.56184
(h,28)	18.00	.95462	.71310	.58414
(h,29)	19.00	.98715	.75468	.60666
(h,30)	20.00	1.02130	.79867	.62938
(h,31)	21.00	1.05713	.84523	.65230
(h,32)	22.00	1.09467	.89449	.67539
(h,33)	23.00	1.13399	.94666	.69865
(h,34)	24.00	1.17512	1.00187	.72205
(h,35)	25.00	1.21816	1.06039	.74560
(h,36)	26.00	1.26313	1.12238	.76928
(h,37)	27.00	1.31013	1.18810	.79309
(h,38)	28.00	1.35924	1.25782	.81702
(h,39)	29.00	1.41052	1.33180	.84106
(h,40)	30.00	1.46404	1.41032	.86521
(h,41)	31.00	1.51993	1.49374	.88947
(h,42)	32.00	1.57825	1.58237	.91382
(h,43)	33.00	1.63912	1.67663	.93827
(h,44)	34.00	1.70262	1.77690	.96281
(h,45)	35.00	1.76889	1.88366	.98744
(h,46)	36.00	1.83803	1.99736	1.01215
$\eta = 2.50^\circ$				
(i,22)	12.25	0.83260	0.48279	0.42795
(i,23)	13.25	.85731	.51343	.44948
(i,24)	14.25	.88353	.54587	.47135
(i,25)	15.25	.91127	.58018	.49351
(i,26)	16.25	.94054	.61646	.51594
(i,27)	17.25	.97137	.65479	.53861
(i,28)	18.25	1.00378	.69531	.56149
(i,29)	19.25	1.03782	.73813	.58457
(i,30)	20.25	1.07352	.78338	.60783
(i,31)	21.25	1.11093	.83124	.63126
(i,32)	22.25	1.15008	.88131	.65484
(i,33)	23.25	1.19106	.93537	.67857
(i,34)	24.25	1.23389	.99201	.70242
(i,35)	25.25	1.27868	1.05200	.72641
(i,36)	26.25	1.32545	1.11552	.75051
$\eta = 2.50^\circ$ - Concluded				
(i,37)	27.25	1.37430	1.18284	0.77472
(i,38)	28.25	1.42533	1.25424	.79905
(i,39)	29.25	1.47858	1.32996	.82347
(i,40)	30.25	1.53416	1.41032	.84799
(i,41)	31.25	1.59217	1.49566	.87260
(i,42)	32.25	1.65268	1.58632	.89729
(i,43)	33.25	1.71582	1.68272	.92207
(i,44)	34.25	1.78170	1.78525	.94693
(i,45)	35.25	1.85043	1.89440	.97188
(i,46)	36.25	1.92213	2.01063	.99690
(i,47)	37.25	1.99692	2.13448	1.02199
$\eta = 3.00^\circ$				
(j,22)	12.50	0.86848	0.46067	0.40450
(j,23)	13.50	.89450	.49234	.42668
(j,24)	14.50	.92204	.52579	.44916
(j,25)	15.50	.95110	.56112	.47190
(j,26)	16.50	.98173	.59842	.49487
(j,27)	17.50	1.01392	.63780	.51805
(j,28)	18.50	1.04773	.67936	.54142
(j,29)	19.50	1.08319	.72326	.56497
(j,30)	20.50	1.12033	.76961	.58867
(j,31)	21.50	1.15923	.81861	.61253
(j,32)	22.50	1.19991	.87037	.63652
(j,33)	23.50	1.24246	.92513	.66064
(j,34)	24.50	1.28690	.98302	.68487
(j,35)	25.50	1.33335	1.04433	.70922
(j,36)	26.50	1.38184	1.10922	.73367
(j,37)	27.50	1.43246	1.17797	.75822
(j,38)	28.50	1.48532	1.25087	.78287
(j,39)	29.50	1.54047	1.32817	.80761
(j,40)	30.50	1.59801	1.41018	.83243
(j,41)	31.50	1.65806	1.49728	.85734
(j,42)	32.50	1.72069	1.58979	.88232
(j,43)	33.50	1.78604	1.68814	.90738
(j,44)	34.50	1.85420	1.79274	.93251
(j,45)	35.50	1.92532	1.90409	.95772
(j,46)	36.50	1.99951	2.02265	.98299
(j,47)	37.50	2.07689	2.14899	1.00833
$\eta = 4.00^\circ$				
(k,22)	13.00	0.93116	0.42210	0.36425
(k,23)	14.00	.95958	.45545	.38747
(k,24)	15.00	.98955	.49059	.41092
(k,25)	16.00	1.02108	.52761	.43457
(k,26)	17.00	1.05420	.56662	.45841
(k,27)	18.00	1.08895	.60774	.48241
(k,28)	19.00	1.12536	.65108	.50656
(k,29)	20.00	1.16349	.69681	.53085
(k,30)	21.00	1.20337	.74505	.55527
(k,31)	22.00	1.24508	.79599	.57981
(k,32)	23.00	1.28865	.84978	.60445
(k,33)	24.00	1.33417	.90663	.62920
(k,34)	25.00	1.38169	.96673	.65404
(k,35)	26.00	1.43131	1.03033	.67898
(k,36)	27.00	1.48308	1.09763	.70400
(k,37)	28.00	1.53711	1.16891	.72910
(k,38)	29.00	1.59349	1.24448	.75428
(k,39)	30.00	1.65231	1.32460	.77953
(k,40)	31.00	1.71365	1.40958	.80485
(k,41)	32.00	1.77765	1.49983	.83024
(k,42)	33.00	1.84439	1.59568	.85569
(k,43)	34.00	1.91403	1.69759	.88121
(k,44)	35.00	1.98667	1.80596	.90678
(k,45)	36.00	2.06246	1.92134	.93241
(k,46)	37.00	2.14153	2.04420	.95810
(k,47)	38.00	2.22402	2.17513	.98384
(k,48)	39.00	2.31010	2.31477	1.00963

TABLE III.- SECONDARY-EXPANSION FLOW - continued

(c) $\nu_B = 22^{\circ}$ - Continued

Point	ν, deg	$\frac{x}{y_{cr}}$	$\frac{Y}{y_{cr}}$	Ψ
		η = 5.00		
(l,22)	13.50	0.98585	0.38849	0.32988
(l,23)	14.50	1.01651	.42319	.35390
(l,24)	15.50	1.04874	.45970	.37810
(l,25)	16.50	1.08258	.49810	.40246
(l,26)	17.50	1.11805	.53852	.42697
(l,27)	18.50	1.15521	.58108	.45161
(l,28)	19.50	1.19409	.62591	.47637
(l,29)	20.50	1.23475	.67317	.50125
(l,30)	21.50	1.27723	.72300	.52622
(l,31)	22.50	1.32162	.77560	.55130
(l,32)	23.50	1.36796	.83113	.57646
(l,33)	24.50	1.41635	.88980	.60171
(l,34)	25.50	1.46683	.95180	.62703
(l,35)	26.50	1.51952	1.01742	.65243
(l,36)	27.50	1.57448	1.08684	.67789
(l,37)	28.50	1.63181	1.16036	.70342
(l,38)	29.50	1.69163	1.23830	.72902
(l,39)	30.50	1.75402	1.32093	.75468
(l,40)	31.50	1.81908	1.40860	.78039
(l,41)	32.50	1.88697	1.50170	.80616
(l,42)	33.50	1.95776	1.60058	.83197
(l,43)	34.50	2.03164	1.70573	.85784
(l,44)	35.50	2.10871	1.81758	.88376
(l,45)	36.50	2.18914	1.93667	.90973
(l,46)	37.50	2.27305	2.06351	.93574
(l,47)	38.50	2.36063	2.19871	.96179
(l,48)	39-50	2.45205	2.34294	.98789
(l,49)	40.50	2.54748	2.49689	1.01403
		η = 6.00		
(m,22)	14.00	1.03528	0.35815	0.29948
(m,23)	15.00	1.06806	.39398	.32414
(m,24)	16.00	1.10246	.43162	.34895
(m,25)	17.00	1.13851	.57119	.37388
(m,26)	18.00	1.17625	.51281	.39893
(m,27)	19.00	1.21573	.55661	.42409
(m,28)	20.00	1.25699	.60272	.44934
(m,29)	21.00	1.30011	.65132	.47468
(m,30)	22.00	1.34513	.70255	.50010
(m,31)	23.00	1.39214	.75662	.52561
(m,32)	24.00	1.44120	.81368	.55118
(m,33)	25.00	1.49239	.87398	.57683
(m,34)	26.00	1.54579	.93770	.60253
(m,35)	27.00	1.60151	1.00512	.62830
(m,36)	28.00	1.65961	1.07646	.65412
(m,37)	29.00	1.72022	1.15204	.68000
(m,38)	30.00	1.78345	1.23215	.70593
(m,39)	31.00	1.84939	1.31711	.73191
(m,40)	32.00	1.91817	1.40726	.75793
(m,41)	33.00	1.98994	1.50301	.78400
(m,42)	34.00	2.06480	1.60473	.81011
(m,43)	35.00	2.14292	1.71293	.83627
(m,44)	36.00	2.22444	1.82805	.86247
(m,45)	37.00	2.30953	1.95066	.88871
(m,46)	38.00	2.39834	2.08128	.91498
(m,47)	39.00	2.49107	2.22056	.94129
(m,48)	40.00	2.58789	2.36919	.96763
(m,49)	41.00	2.68900	2.52789	.99401
(m,50)	42.00	2.79464	2.69752	1.02043
		η = 7.00		
(n,22)	14.50	1.08094	0.33013	0.27199
(n,23)	15.50	1.11578	.36691	.29717
(n,24)	16.50	1.15228	.40554	.32247
(n,25)	17.50	1.19048	.44611	.34787
(n,26)	18.50	1.23044	.48878	.37337
(n,27)	19.50	1.27219	.53366	.39895
(n,28)	20.50	1.31580	.58091	.42461
(n,29)	21.50	1.36134	.63069	.45034
(n,30)	22.50	1.40886	.68318	.47613
(n,31)	23.50	1.45847	.73856	.50199

Point	ν, deg	$\frac{x}{y_{cr}}$	$\frac{Y}{y_{cr}}$	Ψ
		η = 7.00 - Concluded		
(n,32)	24.50	1.51020	0.79702	0.52791
(n,33)	25.50	1.56419	.85879	.55389
(n,34)	26.50	1.62048	.92408	.57991
(n,35)	27.50	1.67922	.99318	.60599
(n,36)	28.50	1.74046	1.06631	.63211
(n,37)	29.50	1.80434	1.14378	.65827
(n,38)	30.50	1.87099	1.22593	.68448
(n,39)	31.50	1.94051	1.31308	.71073
(n,40)	32.50	2.01303	1.40556	.73701
(n,41)	33.50	2.08871	1.50383	.76334
(n,42)	34.50	2.16766	1.60826	.78970
(n,43)	35.50	2.25008	1.71937	.81610
(n,44)	36.50	2.33611	1.83762	.84253
(n,45)	37.50	2.42594	1.96361	.86899
(n,46)	38.50	2.51973	2.09789	.89548
(n,47)	39.50	2.61769	2.24113	.92200
(n,48)	40.50	2.72002	2.39404	.94855
(n,49)	41.50	2.82694	2.55737	.97513
(n,50)	42.50	2.93873.	2.73203	1.00174
		η = 8.50		
(o,22)	15.25	1.14439	0.29118	0.23481
(o,23)	16.25	1.18224	.32915	.26061
(o,24)	17.25	1.22183	.36901	.28649
(o,25)	18.25	1.26320	.41087	.31245
(o,26)	19.25	1.30642	.45488	.33848
(o,27)	20.25	1.35154	.50118	.36457
(o,28)	21.25	1.39863	.54991	.39071
(o,29)	22.25	1.44777	.60127	.41691
(o,30)	23.25	1.49903	.65542	.44315
(o,31)	24.25	1.55251	.71258	.46944
(o,32)	25.25	1.60828	.77292	.49577
(o,33)	26.25	1.66646	.83672	.52215
(o,34)	27.25	1.72712	.90416	.54855
(o,35)	28.25	1.79041	.97557	.57500
(o,36)	29-25	1.85641	1.05117	.60148
(o,37)	30.25	1.92526	1.13131	.62799
(o,38)	31.25	1.99711	1.a633	.65454
(o,39)	32.25	2.07207	1.30655	.68112
(o,40)	33.25	2.15029	1.40236	.70772
(o,41)	34.25	2.23195	1.50422	.73435
(o,42)	35.25	2.31718	1.61252	.76100
(o,43)	36.25	2.40619	1.72783	.78768
(o,44)	37.25	2.49915	1.85062	.81439
(o,45)	38.25	2.59627	1.98153	.84112
(o,46)	39.25	2.69774	2.12114	.86787
(o,47)	40.25	2.80379	2.27016	.89465
(o,48)	41.25	2.91466	2.42935	.92145
(o,49)	42.25	3.03060	2.59952	.94827
(o,50)	43.25	3.15188	2.78160	.97511
(o,51)	44.25	3.27874	2.97650	1.00197
		η = 10.00		
(p,22)	16.00	1.20347	0.25485	0.20124
(p,23)	17.00	1.24428	.29380	.22752
(p,24)	18.00	1.28691	.33468	.25386
(p,25)	19.00	1.33142	.37761	.28025
(p,26)	20.00	1.37788	.42276	.30669
(p,27)	21.00	1.42635	.47026	.33317
(p,28)	22.00	1.47692	.52029	.35969
(p,29)	23.00	1.52967	.57302	.38625
(p,30)	24.00	1.58468	.62865	.41284
(p,31)	25.00	1.64208	.68739	.43947
(p,32)	26.00	1.70191	.74943	.46612
(p,33)	27.00	1.76434	.81505	.49281
(p,34)	28.00	1.82943	.88447	.51952
(p,35)	29.00	1.897%	.95801	.54626
(p,36)	30.00	1.96820	1.03591	.57302

TABLE III.- SECONDARY-EXPANSION FLOW - Continued

(c) $\nu_B = 22^\circ$ - continued

Point	ν, deg	$\frac{x}{y_{cr}}$	$\frac{y}{y_{cr}}$	Ψ
		$\eta = 10.00^\circ$ - Concluded		
(p,37)	31.00	2.04213	1.11854	0.59980
(p,38)	32.00	2.11930	1.20624	.62661
(p,39)	33.00	2.19984	1.29938	.65344
(p,40)	34.00	2.28392	1.39836	.68029
(p,41)	35.00	2.37174	1.50365	.70716
(p,42)	36.00	2.46344	1.61568	.76096
(p,43)	37.00	2.55928	1.73503	
(p,44)	38.00	2.65942	1.86223	.78789
(p,45)	39.00	2.76411	1.99793	.81484
(p,46)	40.00	2.87357	2.14276	.84180
(p,47)	41.00	2.98806	2.29747	.86878
(p,48)	42.00	3.10784	2.46286	.89577
(p,49)	43.00	3.23320	2.63979	.92278
(p,50)	44.00	3.36446	2.82926	.94981
(p,51)	45.00	3.50189	3.03224	.97685
(p,52)	46.00	3.64588	3.24993	1.00391
		$\eta = 12.00^\circ$		
(q,22)	17.00	1.27751	0.20918	0.16073
(q,23)	18.00	1.32222	.24916	.18747
(q,24)	19.00	1.36890	.29114	.21425
(q,25)	20.00	1.41759	.33525	.24106
(q,26)	21.00	1.46838	.38167	.26790
(q,27)	22.00	1.52136	.43054	.29477
(q,28)	23.00	1.57660	.48204	.32166
(q,29)	24.00	1.63423	.53637	.34858
(q,30)	25.00	1.69432	.59373	.37551
(q,31)	26.00	1.75701	.65435	.40247
(q,32)	27.00	1.82238	.71843	.42944
(q,33)	28.00	1.89059	.78627	.45644
(q,34)	29.00	1.96175	.85810	.48345
(q,35)	30.00	2.05602	.93426	.51048
(q,36)	31.00	2.11352	1.01502	.53752
(q,37)	32.00	2.19444	1.10076	.56458
(q,38)	33.00	2.27896	1.19186	.59166
(q,39)	34.00	2.36722	1.28870	.61875
(q,40)	35.00	2.45942	1.39171	.64585
(q,41)	36.00	2.55580	1.50140	.67297
(q,42)	37.00	2.65653	1.61825	.70009
(q,43)	38.00	2.76187	1.74286	.72723
(q,44)	39.00	2.87206	1.87580	.75438
(q,45)	40.00	2.98736	2.01778	.78154
(q,46)	41.00	3.10803	2.16948	.80871
(q,47)	42.00	3.23439	2.33171	.83589
(q,48)	43.00	3.36674	2.50533	.86308
(q,49)	44.00	3.50541	2.69129	.89028
(q,50)	45.00	3.65080	2.89065	.91750
(q,51)	46.00	3.80321	3.10448	.94472
(q,52)	47.00	3.96312	3.33408	.97195
(q,53)	48.00	4.13094	3.58080	.99919
(q,54)	49.00	4.30710	3.84612	1.02644
		$\eta = 14.00^\circ$		
(r,22)	18.00	1.34777	0.16562	0.12386
(r,23)	19.00	1.39641	.20638	.15093
(r,24)	20.00	1.44714	.24922	.17803
(r,25)	21.00	1.50005	.29428	.20514
(r,26)	22.00	1.55524	.34174	.23227
(r,27)	23.00	1.61279	.39175	.25941
(r,28)	24.00	1.67280	.44450	.28657
(r,29)	25.00	1.73541	.50022	.31374
(r,30)	26.00	1.80070	.55908	.34092
(r,31)	27.00	1.86884	.62137	.36812
(r,32)	28.00	1.93992	.68729	.39532
(r,33)	29.00	2.01412	.75714	.42254
(r,34)	30.00	2.0955	.83118	.44976
(r,35)	31.00	2.17242	.90977	.47700
(r,36)	32.00	2.25686	.99320	.50424
		$\eta = 14.00^\circ$ - Concluded		
(r,37)	33.00	2.34507	1.08187	0.53149
(r,38)	34.00	2.43727	1.17619	.55876
(r,39)	35.00	2.53363	1.27657	.58603
(r,40)	36.00	2.63438	1.38347	.61331
(r,41)	37.00	2.73977	1.49743	.64060
(r,42)	38.00		1.61897	.66789
(r,43)	39.00		1.74873	.69519
(r,44)	40.00	3.08627	1.88733	.72250
(r,45)	41.00	3.21285	2.03553	.74982
(r,46)	42.00	3.34548	2.19407	.77714
(r,47)	43.00	3.48450	2.36382	.80447
(r,48)	44.00	3.63030	2.54572	.83181
(r,49)	45.00	3.78325	2.74078	.85915
(r,50)	46.00	3.94381	2.95017	.88650
(r,51)	47.00	4.11238	3.17504	.91385
(r,52)	48.00	4.28947	3.41680	.94121
(r,53)	49.00	4.47557	3.67691	.96858
(r,54)	50.00	4.67126	3.95702	.99595
(r,55)	51.00	4.87710	4.25893	1.02333
		$\eta = 16.00^\circ$		
(s,22)	19.00	1.41543	0.12340	0.08985
(s,23)	20.00	1.46801	.16474	.11715
(s,24)	21.00	1.52286	.20825	.14446
(s,25)	22.00	1.58006	.25406	.17178
(s,26)	23.00	1.63972	.30236	.19911
(s,27)	24.00	1.70195	.35332	.22644
(s,28)	25.00	1.76686	.40714	.25378
(s,29)	26.00	1.83458	.46404	.28113
(s,30)	27.00	1.90525	.52425	.30848
(s,31)	28.00	1.97902	.58802	.33584
(s,32)	29.00	2.05601	.65559	.36320
(s,33)	30.00	2.13642	.72728	.39057
(s,34)	31.00	2.22039	.80337	.41794
(s,35)	32.00	2.30815	.88423	.44533
(s,36)	33.00	2.39984	.97017	.47271
(s,37)	34.00	2.49571	1.06163	.50010
(s,38)	35.00	2.59598	1.15904	.52750
(s,39)	36.00	2.70087	1.26283	.55490
(s,40)	37.00	2.81063	1.37350	.58230
(s,41)	38.00	2.92556	1.49163	.60971
(s,42)	39.00	3.04590	1.61778	.63712
(s,43)	40.00	3.17201	1.75263	.66454
(s,44)	41.00	3.30418	1.89685	.69196
(s,45)	42.00	3.44279	2.05126	.71939
(s,46)	43.00	3.58818	2.21666	.74682
(s,47)	44.00	3.74078	2.39399	.77425
(s,48)	45.00	3.90100	2.58425	.80169
(s,49)	46.00	4.06931	2.78856	.82913
(s,50)	47.00	4.24623	3.00817	.85658
(s,51)	48.00	4.43222	3.24432	.88403
(s,52)	49.00	4.62709	3.49856	.91148
(s,53)	50.00	4.83385	3.77249	.93894
(s,54)	51.00	5.05072	4.06700	.96640
(s,55)	52.00	5.27923	4.38672	.99386
(s,56)	53.00	5.52011	4.73116	1.02132
		$\eta = 18.00^\circ$		
(t,22)	20.00	1.48127	0.08197	0.05811
(t,23)	21.00	1.53787	.12373	.08555
(t,24)	22.00	1.59691	.16772	.11300
(t,25)	23.00	1.65849	.21411	.14045
(t,26)	24.00	1.72274	.26308	.16790
(t,27)	25.00	1.78977	.31483	.19536
(t,28)	26.00	1.85971	.36955	.22282
(t,29)	27.00	1.93273	.42748	.25028
(t,30)	28.00	2.00895	.48886	.27774
(t,31)	29.00	2.08856	.55396	.30521

TABLE III.- SECONDARY-EXPANSION FLOW - Continued

(c) $\nu_B = 22^o$ - Concluded

Point	ν, deg	$\frac{x}{y_{cr}}$	$\frac{y}{y_{cr}}$	ψ
		$\eta = 18.00^o$ - concluded		
(t,32)	30.00	2.17171	0.62303	0.33268
(t,33)	31.00	2.25860	.69641	.36015
(t,34)	32.00	2.34941	.77439	.38762
(t,35)	33.00	2.44438	.85738	.41510
(t,36)	34.00	2.54368	.94571	.44258
(t,37)	35.00	2.64760	1.03983	.47006
(t,38)	36.00	2.75638	1.14020	.49755
(t,39)	37.00	2.87028	1.24730	.52504
(t,40)	38.00	2.98957	1.36165	.55253
(t,41)	39.00	3.11461	1.48388	.58002
(t,42)	40.00	3.24568	1.61457	.60751
(t,43)	41.00	3.38317	1.75448	.63501
(t,44)	42.00	3.52743	1.90432	.66250
(t,45)	43.00	3.67890	2.06495	.69000
(t,46)	44.00	3.83797	2.23725	.71750
(t,47)	45.00	4.00512	2.42224	.74500
(t,48)	46.00	4.18086	2.62101	.77250
(t,49)	47.00	4.36572	2.83475	.80000
(t,50)	48.00	4.56030	3.06481	.82751
(t,51)	49.00	4.76513	3.31256	.85502
(t,52)	50.00	4.98096	3.57967	.88253
(t,53)	51.00	5.20846	3.86788	.91004
(t,54)	52.00	5.44841	4.17914	.93755
(t,55)	53.00	5.70165	4.51560	.96507
(t,56)	54.00	5.96903	4.87961	.99259
(t,57)	55.00	6.25152	5.27381	1.02011
		$\eta = 20.00^o$		
(u,22)	21.00	1.54586	0.04094	0.02826
(u,23)	22.00	1.60656	.08296	.05578
(u,24)	23.00	1.66989	.12729	.08330
(u,25)	24.00	1.73596	.17410	.11082
(u,26)	25.00	1.80492	.22359	.13834
(u,27)	26.00	1.87691	.27596	.16586
(u,28)	27.00	1.95206	.33143	.19338
(u,29)	28.00	2.03055	.39024	.22090
(u,30)	29.00	2.11255	.45264	.24842
(u,31)	30.00	2.19824	.51892	.27595
(u,32)	31.00	2.28781	.58934	.30347
(u,33)	32.00	2.38148	.66427	.33100
(u,34)	33.00	2.47944	.74402	.35852
(u,35)	34.00	2.58198	.82900	.38605
(u,36)	35.00	2.68929	.91959	.41358
(u,37)	36.00	2.80168	1.01626	.44111
(u,38)	37.00	2.91946	1.11949	.46865
(u,39)	38.00	3.04289	1.22980	.49618
(u,40)	39.00	3.17230	1.34776	.52371
(u,41)	40.00	3.30808	1.47401	.55125
(u,42)	41.00	3.45056	1.60922	.57878
(u,43)	42.00	3.60019	1.75415	.60632
(u,44)	43.00	3.75737	1.90960	.63386
(u,45)	44.00	3.92260	2.07650	.66140
(u,46)	45.00	4.09635	2.25578	.68894
(u,47)	46.00	4.27916	2.44854	.71648
(u,48)	47.00	4.47161	2.65597	.74402
(u,49)	48.00	4.67432	2.87934	.77156
(u,50)	49.00	4.88797	3.12013	.79910
(u,51)	50.00	5.11323	3.37983	.82664
(u,52)	51.00	5.35092	3.66024	.85418
(u,53)	52.00	5.60187	3.96327	.88172
(u,54)	53.00	5.86697	4.29103	.90927
(u,55)	54.00	6.14721	4.64588	.93682
(u,56)	55.00	6.44359	5.03039	.96437
(u,57)	56.00	6.75729	5.44746	.99192
(u,58)	57.00	7.08957	5.90034	1.01947

TABLE III.- SECONDARY-EXPANSION FLOW - Continued

(d) $\nu_B = 40^\circ$

Point	ν, deg	$\frac{x}{y_{cr}}$	$\frac{y}{y_{cr}}$	Ψ
		$\eta = 0.500^\circ$		
(d,31)	20.250	0.73861	0.81171	0.69635
		$\eta = 0.750^\circ$		
(e,31)	20.375	0.79821	0.79644	0.67215
(e,32)	21.375	.81474	.81901	.68288
(e,33)	22.375	.83250	.84350	.69397
		$\eta = 1.00^\circ$		
(f,31)	20.500	0.84550	0.78430	0.65303
(f,32)	21.500	.86311	.80814	.66433
(f,33)	22.500	.88195	.83392	.67597
(f,34)	23.500	.90210	.86180	.68793
		$\eta = 1.50^\circ$		
(g,31)	20.75	0.92084	0.76489	0.62289
(g,32)	21.75	.94022	.79072	.63507
(g,33)	22.75	.96087	.81854	.64755
(g,34)	23.75	.98284	.84850	.66032
(g,35)	24.75	1.00619	.88072	.67338
(g,36)	25.75	1.03093	.91533	.68669
		$\eta = 2.00^\circ$		
(h,31)	21.00	0.98190	0.74908	0.59870
(h,32)	22.00	1.00280	.77651	.61155
(h,33)	23.00	1.02499	.80595	.62468
(h,34)	24.00	1.04854	.83757	.63808
(h,35)	25.00	1.07350	.87150	.65174
(h,36)	26.00	1.09988	.90787	.66563
(h,37)	27.00	1.12774	.94683	.67974
(h,38)	28.00	1.15716	.98858	.69407
		$\eta = 2.50^\circ$		
(i,31)	21.25	1.03467	0.73536	0.57806
(i,32)	22.25	1.05694	.76414	.59147
(i,33)	23.25	1.08053	.79496	.60513
(i,34)	24.25	1.10552	.82800	.61904
(i,35)	25.25	1.13194	.86340	.63319
(i,36)	26.25	1.15983	.90127	.64756
(i,37)	27.25	1.18924	.94179	.66213
(i,38)	28.25	1.22023	.98516	.67691
(i,39)	29.25	1.25286	1.03156	.69188
		$\eta = 3.00^\circ$		
(j,31)	21.50	1.08194	0.72700	0.55973
(j,32)	22.50	1.10549	.75297	.57362
(j,33)	23.50	1.13040	.78503	.58774
(j,34)	24.50	1.15673	.81933	.60209
(j,35)	25.50	1.18452	.85602	.61667
(j,36)	26.50	1.21383	.89524	.63145
(j,37)	27.50	1.24469	.93715	.64642
(j,38)	28.50	1.27719	.98196	.66158
(j,39)	29.50	1.31137	1.02987	.67691
(j,40)	30.50	1.34729	1.08107	.69241
		$\eta = 4.00^\circ$		
(k,31)	22.00	1.16571	0.70093	0.52780
(k,32)		1.19166	.73297	.54248
(k,33)		1.21904	.76715	.55736
(k,34)	25.00	1.24789	.80365	.57245
(k,35)	26.00	1.27830	.84262	.58773
(k,36)	27.00	1.31028	.88420	.60319
(k,37)	28.00	1.34390	.92856	.61881
(k,38)	29.00	1.37925	.97593	.63460
(k,39)	30.00	1.41638	1.02651	.65054
(k,40)	31.00	1.45535	1.08051	.66663
(k,41)	32.00	1.49626	1.13820	.68286
		$\eta = 5.00^\circ$		
(l,31)	22.50	1.24018	0.68110	0.50008
(l,32)	23.50	1.26841	.71493	.51541
(l,33)	24.50	1.29812	.75096	.53091
(l,34)	25.50	1.32939	.78937	.54659
(l,35)	26.50	1.36228	.83032	.56244
		$\eta = 5.00^\circ$ - Concluded		
(l,36)	27.50	1.39684	0.87397	0.57845
(l,37)	28.50	1.43312	.92050	.59461
(l,38)	29.50	1.47122	.97014	.61091
(l,39)	30.50	1.51120	1.02310	.62735
(l,40)	31.50	1.55313	1.07960	.64392
(l,41)	32.50	1.59712	1.13992	.66062
(l,42)	33.50	1.64323	1.20432	.67743
(l,43)	34.50	1.69158	1.27314	.69436
		$\eta = 6.00^\circ$		
(m,31)	23.00	1.30861	0.66267	0.47515
(m,32)	24.00	1.33906	.69810	.49102
(m,33)	25.00	1.37106	.73578	.50705
(m,34)	26.00	1.40469	.77591	.52324
(m,35)	27.00	1.44001	.81866	.53958
(m,36)	28.00	1.47709	.86420	.55606
(m,37)	29.00	1.51599	.91270	.57267
(m,38)	30.00	1.55681	.96441	.58941
(m,39)	31.00	1.59961	1.01955	.60627
(m,40)	32.00	1.64447	1.07836	.62325
(m,41)	33.00	1.69151	1.14112	.64034
(m,42)	34.00	1.74081	1.20811	.65754
(m,43)	35.00	1.79248	1.27967	.67484
(m,44)	36.00	1.84664	1.35616	.69225
		$\eta = 7.00^\circ$		
(n,31)	23.50	1.37284	0.64519	0.45227
(n,32)	24.50	1.40547	.68206	.46862
(n,33)	25.50	1.43973	.72126	.48510
(n,34)	26.50	1.47570	.76297	.50173
(n,35)	27.50	1.51344	.80738	.51849
(n,36)	28.50	1.55304	.85465	.53537
(n,37)	29.50	1.59454	.90499	.55237
(n,38)	30.50	1.63807	.95864	.56949
(n,39)	31.50	1.68369	1.01583	.58672
(n,40)	32.50	1.73150	1.07680	.60405
(n,41)	33.50	1.78161	1.14186	.62148
(n,42)	34.50	1.83411	1.21130	.63901
(n,43)	35.50	1.88913	1.28548	.65663
(n,44)	36.50	1.94679	1.36475	.67434
(n,45)	37.50	2.00721	1.44949	.69214
		$\eta = 8.50^\circ$		
(o,31)	24.25	1.46373	0.62008	0.42079
(o,32)	25.25	1.49963	.65893	.43774
(o,33)	26.25	1.53727	.70020	.45480
(o,34)	27.25	1.57675	.74409	.47198
(o,35)	28.25	1.61815	.79080	.48928
(o,36)	29.25	1.66153	.84049	.50668
(o,37)	30.25	1.70698	.89340	.52418
(o,38)	31.25	1.75462	.94976	.54178
(o,39)	32.25	1.80453	1.00984	.55948
(o,40)	33.25	1.85682	1.07388	.57726
(o,41)	34.25	1.91160	1.14222	.59513
(o,42)	35.25	1.96900	1.21516	.61308
(o,43)	36.25	2.02914	1.29306	.63111
(o,44)	37.25	2.09218	1.37634	.64922
(o,45)	38.25	2.15824	1.46537	.66740
(o,46)	39.25	2.22748	1.56065	.68566
		$\eta = 10.00^\circ$		
(p,31)	25.00	1.55011	0.59578	0.39189
(p,32)	26.00	1.58931	.63643	.40935
(p,33)	27.00	1.63037	[illegible]	[illegible]
(p,34)	28.00	1.67341	.72959	.44696
(p,35)	29.00	1.71851	.77432	.46232
(p,36)	30.00	1.76575	.82626	.48016
(p,37)	31.00	1.81523	.88156	.49808
(p,38)	32.00	1.86707	.94048	.51609
(p,39)	33.00	1.92138	1.00328	.53418
(p,40)	34.00	1.97826	1.07024	.55234

TABLE III.- SECONDARY-EXPANSION FLOW - Continued

(a) $\nu_B = 40^\circ$ - Continued

Point	ν, deg	$\frac{x}{y_{cr}}$	$\frac{y}{y_{cr}}$	ψ
η = 10.00° - Concluded				
(p,41)	35.00	2.03786	1.14170	0.57058
(p,42)	36.00	2.10031	1.21799	.58889
(p,43)	37.00	2.16575	1.29949	.60727
(p,44)	38.00	2.23436	1.38664	.62572
(p,45)	39.00	2.30627	1.47984	.64423
(p,46)	40.00	2.38167	1.57961	.66280
(p,47)	41.00	2.46073	1.68645	.68143
η = 12.00°				
(q,31)	26.00	1.66076	0.56397	0.35628
(q,32)	27.00	1.70445	.60680	.37431
(q,33)	28.00	1.75018	.65228	.39241
(q,34)	29.00	1.79808	.70064	.41059
(q,35)	30.00	1.84826	.75209	.42885
(q,36)	31.00	1.90081	.80685	.44718
(q,37)	32.00	1.95583	.86515	.46558
(q,38)	33.00	2.01348	.92730	.48405
(q,39)	34.00	2.07387	.99355	.50258
(q,40)	35.00	2.13713	1.06423	.52117
	36.00	2.20343	1.13969	.53982
	37.00	2.27291	1.22029	.55853
(q,43)	38.00	2.34575	1.30645	.57730
(q,44)	39.00	2.42215	1.39862	.59612
(q,45)	40.00	2.50226	1.49726	.61499
(q,46)	41.00	2.58631	1.60293	.63392
(q,47)	42.00	2.67451	1.71617	.65289
(q,48)	43.00	2.76708	1.83761	.67191
(q,49)	44.00	2.86429	1.96796	.69098
η = 14.00°				
(r,31)	27.00	1.76825	0.53228	0.32328
(r,32)	28.00	1.81657	.57709	.34177
(r,33)	29.00	1.86714	.62470	.36032
(r,34)	30.00	1.92010	.67533	.37894
(r,35)	31.00	1.97556	.72924	.39762
(r,36)	32.00	2.03364	.78663	.41636
(r,37)	33.00	2.09447	.84777	.43515
(r,38)	34.00	2.15821	.91297	.45400
(r,39)	35.00	2.22499	.98254	.47290
(r,40)	36.00	2.29497	1.05679	.49185
(r,41)	37.00	2.36834	1.13612	.51085
(r,42)	38.00	2.44526	1.22092	.52989
(r,43)	39.00	2.52595	1.31164	.54898
(r,44)	40.00	2.61062	1.40877	.56812
(r,45)	41.00	2.69948	1.51279	.58730
(r,46)	42.00	2.79277	1.62432	.60652
(r,47)	43.00	2.89073	1.74393	.62578
(r,48)	44.00	2.99365	1.87233	.64508
(r,49)	45.00	3.10181	2.01027	.66441
(r,50)	46.00	3.21553	2.15857	.68378
η = 16.00°				
(s,31)	28.00	1.87401	0.50026	0.29229
(s,32)	29.00	1.92715	.54690	.31118
(s,33)	30.00	1.98276	.59647	.33011
(s,34)	31.00	2.04100	.64924	.34909
(s,35)	32.00	2.10200	.70544	.36813
(s,36)	33.00	2.16588	.76533	.38721
(s,37)	34.00	2.23281	.82918	.40633
(s,38)	35.00	2.30296	.89733	.42550
(s,39)	36.00	2.37649	.97009	.44471
(s,40)	37.00	2.45358	1.04782	.46396
(s,41)	38.00	2.53445	1.13094	.48325
(s,42)	39.00	2.61929	1.21987	.50257
(s,43)	40.00	2.70833	1.31508	.52193
(s,44)	41.00	2.80184	1.41712	.54133
(s,45)	42.00	2.90004	1.52651	.56076
η = 16.00° - Concluded				
(s,46)	43.00	3.00323	1.64390	0.58023
(s,47)	44.00	3.11169	1.76994	.59973
(s,48)	45.00	3.22573	1.90537	.61926
(s,49)	46.00	3.34572	2.05101	.63882
(s,50)	47.00	3.47199	2.20775	.65841
(s,51)	48.00	3.60494	2.37657	.67803
(s,52)	49.00	3.74501	2.55856	.69768
η = 18.00°				
(t,31)	29.00	1.97908	0.46759	0.26289
(t,32)	30.00	2.03725	.51591	.28211
(t,33)	31.00	2.09813	.56732	.30136
(t,34)	32.00	2.16190	.62209	.32065
(t,35)	33.00	2.22871	.68047	.33998
(t,36)	34.00	2.29872	.74274	.35935
(t,37)	35.00	2.37208	.80919	.37875
(t,38)	36.00	2.44901	.88017	.39819
(t,39)	37.00	2.52970	.95604	.41766
(t,40)	38.00	2.61434	1.03717	.43716
(t,41)	39.00	2.70318	1.12402	.45669
(t,42)	40.00	2.79645	1.21703	.47625
(t,43)	41.00	2.89442	1.31672	.49584
(t,44)	42.00	2.99739	1.42366	.51546
(t,45)	43.00	3.10560	1.53843	.53511
(t,46)	44.00	3.21943	1.66173	.55479
(t,47)	45.00	3.33918	1.79425	.57449
(t,48)	46.00	3.46524	1.93682	.59422
(t,49)	47.00	3.59799	2.09032	.61397
(t,50)	48.00	3.73786	2.25570	.63375
(t,51)	49.00	3.88530	2.43403	.65355
(t,52)	50.00	4.04083	2.62652	.67337
(t,53)	51.00	4.20494	2.83442	.69322
η = 20.00°				
(u,31)	30.00	2.08420	0.43401	0.23486
(u,32)	31.00	2.14763	.48388	.25435
(u,33)	32.00	2.21404	.53700	.27387
(u,34)	33.00	2.28363	.59365	.29342
(u,35)	34.00	2.35657	.65411	.31301
(u,36)	35.00	2.43303	.71865	.33262
(u,37)	36.00	2.51320	.78760	.35226
(u,38)	37.00	2.59732	.86134	.37193
(u,39)	38.00	2.68560	.94024	.39162
(u,40)	39.00	2.77828	1.02471	.41134
(u,41)	40.00	2.87562	1.11523	.43108
(u,42)	41.00	2.97790	1.21228	.45084
(u,43)	42.00	3.08543	1.31643	.47063
(u,44)	43.00	3.19852	1.42828	.49044
(u,45)	44.00	3.31751	1.54847	.51027
(u,46)	45.00	3.44279	1.67774	.53013
(u,47)	46.00	3.57472	1.81686	.55001
(u,48)	47.00	3.71375	1.96670	.56991
(u,49)	48.00	3.86033	2.12823	.58982
(u,50)	49.00	4.01495	2.30248	.60975
(u,51)	50.00	4.17814	2.49062	.62970
(u,52)	51.00	4.35050	2.69396	.64967
(u,53)	52.00	4.53261	2.91387	.66966
(u,54)	53.00	4.72515	3.15192	.68967
η = 22.00°				
(v,31)	31.00	2.18998	0.39927	0.20798
(v,32)	32.00	2.25894	.45058	.22771
(v,33)	33.00	2.33116	.50530	.24745
(v,34)	34.00	2.40688	.56372	.26722
(v,35)	35.00	2.48628	.62614	.28702

TABLE 111.- SECONDARY-SEPARATION FLOW - Continued

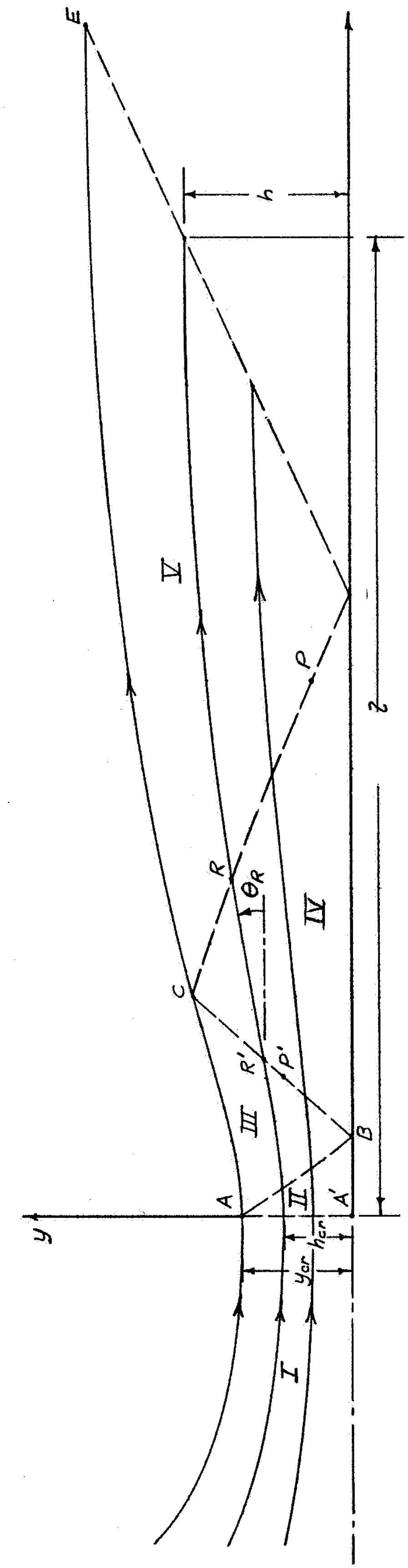
(d) ν_B = 40° - Continued

Point	ν, deg	$\frac{x}{y_{cr}}$	$\frac{y}{y_{cr}}$	Ψ
η = 22.00° - concluded				
(v,36)	36.00	2.56957	0.69285	0.30684
(v,37)	37.00	2.656%	.76422	.32668
(v,38)	38.00	2.74871	.84064	.34654
(v,39)	39.00	2.84508	.92250	.36642
(v,40)	40.00	2.94631	1.01025	.38632
(v,41)	41.00	3.05274	1.10440	.40624
(v,42)	42.00	3.16466	1.20548	.42617
(v,43)	43.00	3.28242	1.31408	.44612
(v,44)	44.00	3.40640	1.43087	.46609
(v,45)	45.00	3.53698	1.55652	.48608
(v,46)	46.00	3.67460	1.69184	.so609
(v,47)	47.00	3.81970	1.83767	.52611
(v,48)	48.00	3.97276	1.99494	.54615
(v,49)	49.00	4.13432	2.16470	.56620
(v,50)	50.00	4.304%	2.34809	.58627
(v,51)	51.00	4.48529	2.54636	.60635
(v,52)	52.00	4.67600	2.76094	.62645
(v,53)	53.00	4.87779	2.99335	.64656
(v,54)	54.00	5.09143	3.24527	.66668
(v,55)	55.00	5.31777	3.51862	.68682
η = 24.00°				
(w,31)	32.00	2.29691	0.36316	0.18209
(w,32)	33.00	2.37167	.41580	.20201
(w,33)	34.00	2.45002	.47200	.22194
(w,34)	35.00	2.53220	.53208	.24189
(w,35)	36.00	2.61845	.59636	.26186
(w,36)	37.00	2.70897	.66516	.28185
(w,37)	38.00	2.80402	.73885	.30185
(w,38)	39.00	2.90389	.81786	.32187
(w,39)	40.00	3.00886	.90262	.34191
(w,40)	41.00	3.11924		.36196
(w,41)	42.00	3.23538	1.09135	.38203
(w,42)	43.00	3.35762	1.19644	.40211
(w,43)	44.00	3.48638	1.30950	.42220
(w,44)	45.00	3.62208	1.43125	.44231
(w,45)	46.00	3.76514	1.56242	.46243
(w,46)	47.00	3.91608	1.70389	.48257
(w,47)	48.00	4.07540	1.85655	.50272
(w,48)	49.00	4.24367	2.02143	.52288
(w,49)	50.00	4.42150	2.19965	.54305
(w,50)	51.00	4.60956	2.39245	.56323
(w,51)	52.00	4.80856	2.60121	.58342
(w,52)	53.00	5-01931	2.82747	.60363
(w,53)	54.00	5.24261	3.07289	.62385
(w,54)	55.00	5.47937	3.33931	.64407
(w,55)	56.00	5.73061	3.62884	.66431
(w,56)	57.00	5.99743	3.94384	.68456
η = 26.000				
(x,31)	33.00	2.40543	0.32548	0.15703
(x,32)	34.00	2.48630	.37932	.17711
(x,33)	35.00	2.57111	.43689	.19720
(x,34)	36.00	2.66013	.49852	.21731
(x,35)	37.00	2.75361	.56456	.23743
	38.00	2.85181	.63535	.25756
	39.00	2.95500	.71128	.27770
(x,38)	40.00	3.06351	.79281	.29786
(x,39)	41.00	3.17767	.88041	.31803
(x,40)	42.00	3.29782	.97456	.33821
(x,41)	43.00	1.42435	1.07587	.35840
(x,42)	44.00	3.55767	1.18495	.37860
(x,43)	45.00	3.69824	1.30248	.39881
(x,44)	46.00	3.84654	1.42922	.41903
(x,45)	47.00	4.00307	1.56598	.43926
(x,46)	48.00	4.16841	1.71369	.45950
(x,47)	49.00	4.34312	1.87332	.47975
(x,48)	50.00	4.52788	2.04598	.50001
(x,49)	51.00	4.72339	2.23290	.52028
(x,50)	52.00	4.93041	2.43543	.54056
η = 26.000 - concluded				
		5.14978	2.65505	0.56084
		5.38242	2.89345	.58113
		5.62928	3.15244	.60143
		5.89141	3.43405	.62174
		6.17000	3.74058	.64206
		6.46634	4.07458	.66239
		6.78174	4.43883	.68272
η = 28.000				
(y,31)	34.00	2.51593	0.28602	0.13279
(y,32)	35.00	2.60325	.34094	.15301
(y,33)	36.00	2.69487	.39976	.17323
(y,34)	37.00	2.79113	.46284	.19346
(y,35)	38.00	2.89229	.53053	.21370
(y,36)	39.00	2.99864	.60321	.23395
(y,37)	40.00	3.11048	.68129	.25421
(y,38)	41.00	3.22822	.76526	.27448
(y,39)	42.00	3.35219	.85561	.29476
(y,40)	43.00	3.48278	.95289	.31504
(y,41)	44.00	3.62046	1.05773	.33533
(y,42)	45.00	3.76567	1.17077	.35563
(y,43)	46.00	3.91895	1.29277	.37594
(y,44)	47.00	4.08084	1.42454	.39626
(y,45)	48.00	4.25190	1.56695	.41658
(y,46)	49.00	4.43280	1.72099	.43691
(y,47)	50.00	4.62420	1.88774	.45725
(y,48)	51.00	4.82685	2.06839	.47759
(y,49)	52.00	5.04158	2.26427	.49794
(y,50)	53.00	5.26927	2.47684	.51829
(y,51)	54.00	5.51087	2.70772	.53865
(y,52)	55.00	5.76746	2.95876	.55902
(y,53)	56.00	6.04014	3.23193	.57939
(y,54)	57.00	6.33014	3.52945	.59977
(y,55)	58.00	6.63882	3.85382	.62016
(y,56)	59.00	6.96772	4.20789	.64055
(y,57)	60.00	7.31835	4.59467	.66095
(y,58)	61.00	7.69252	5.01767	.68135
η = 30.00°				
(z,31)	35.00	2.62882	0.24456	0.10923
(z,32)	36.00	2.72294	.30043	.12956
(z,33)	37.00	2.82179	.36038	.14989
(z,34)	38.00	2.92571	.42479	.17022
(z,35)	39.00	3.03502	.49402	.19056
(z,36)	40.00	3.15003	.56848	.21091
(z,37)	41.00	3.27111	.64861	.23126
(z,38)	42.00	3.39868	.73494	.25162
(z,39)	43.00	3.53313	.82798	.27199
(z,40)	44.00	3.67492	.92832	.29236
(z,41)	45.00	3.82456	1.03664	.31274
(z,42)	46.00	3.98256	1.15363	.33312
(z,43)	47.00	4.14952	1.28010	.35351
(z,44)	48.00	4.32607	1.41693	.37390
(z,45)	49.00	4.51283	1.56505	.39430
(z,46)	50.00	4.71058	1.72554	.41470
(z,47)	51.00	4.92008	1.89955	.43511
(z,48)	52.00	5.14218	2.08839	.45552
(z,49)	53.00	5.37786	2.29349	.47594
(z,50)	54.00	5.62808	2.51644	.49636
(z,51)	55.00	5.89397	2.75901	.51678
(z,52)	56.00	6.17679	3.02322	.53721
(z,53)	57.00	6.47781	3.31120	.55764
(z,54)	58.00	6.79843	3.62540	.57808
(z,55)	59.00	7.14027	3.96857	.59852
(z,56)	60.00	7.50509	4.34380	.61897
(z,57)	61.00	7.89468	4.75443	.63942
(z,58)	62.00	8.31118	5.20435	.65987
(z,59)	63.00	8.75691	5.69793	.68033

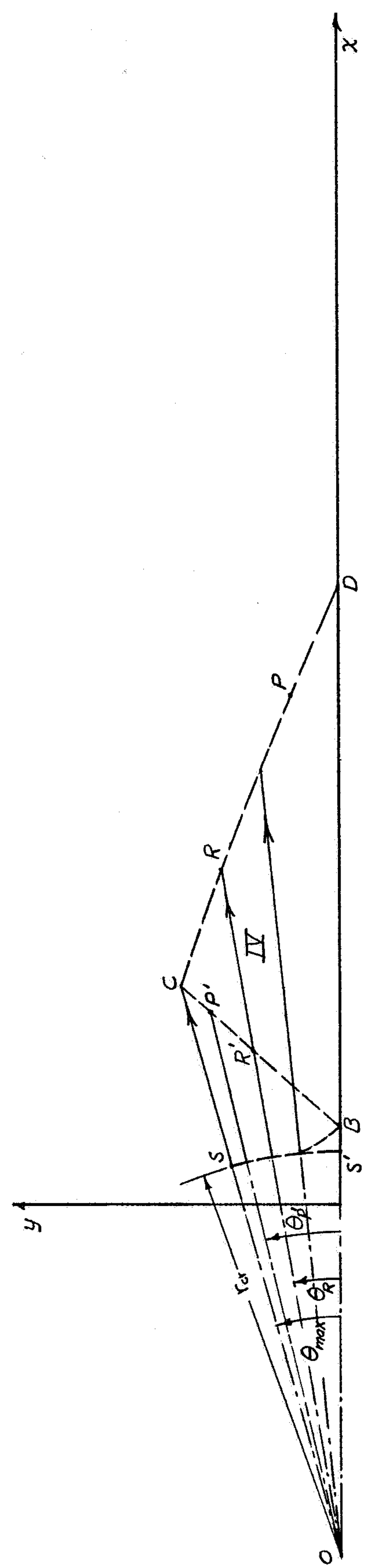
TABLE III.- SECONDARY-EXPANSION FLOW - Concluded

(d) $\nu_B = 40^o$ - Concluded

Point	ν, deg	$\frac{x}{y_{cr}}$	$\frac{y}{y_{cr}}$	ψ
		$\eta = 32.00^o$		
(a',31)	36.00	2.74423	0.20095	0.08632
(a',32)	37.00	2.84552	.25765	.10673
(a',33)	38.00	2.95200	.31861	.12714
(a',34)	39.00	3.06405	.38421	.14755
(a',35)	40.00	3.18201	.45486	.16797
(a',36)	41.00	3.30624	.53098	.18839
(a',37)	42.00	3.43716	.61306	.20881
(a',38)	43.00	3.57522	.70163	.22924
(a',39)	44.00	3.72089	.79728	.24967
(a',40)	45.00	3.87467	.90061	.27011
(a',41)	46.00	4.03714	1.01235	.29055
(a',42)	47.00	4.20890	1.13326	.31099
(a',43)	48.00	4.39060	1.26419	.33144
(a',44)	49.00	4.58295	1.40609	.35189
(a',45)	50.00	4.78669	1.55997	.37234
(a',46)	51.00	5.00270	1.72700	.39280
(a',47)	52.00	5.23183	1.90842	.41326
(a',48)	53.00	5.47509	2.10564	.43372
(a',49)	54.00	5.73356	2.32023	.45419
(a',50)	55.00	6.00837	2.55390	.47466
(a',51)	56.00	6.30085	2.80860	.49513
(a',52)	57.00	6.61240	3.08651	.51561
(a',53)	58.00	6.94450	3.38997	.53609
(a',54)	59.00	7.29882	3.72166	.55657
(a',55)	60.00	7.67920	4.08460	.57706
(a',56)	61.00	8.08169	4.48217	.59755
(a',57)	62.00	8.51442	4.91807	.61804
(a',58)	63.00	8.97787	5.39658	.63853
(a',59)	64.00	9.47480	5.92255	.65903
(a',60)	65.00	10.00797	6.50115	.67953
		$\eta = 34.00^o$		
(b',31)	37.00	2.86270	0.15491	0.06398
(b',32)	38.00	2.97160	.21230	.08445
(b',33)	39.00	3.08617	.27411	.10492
(b',34)	40.00	3.20683	.34077	.12539
(b',35)	41.00	3.33400	.41271	.14587
(b',36)	42.00	3.46806	.49038	.16635
(b',37)	43.00	3.60946	.57428	.18683
(b',38)	44.00	3.75875	.66500	.20732
(b',39)	45.00	3.91643	.76315	.22781
(b',40)	46.00	4.08308	.86939	.24830
(b',41)	47.00	4.25936	.98450	.26879
(b',42)	48.00	4.44592	1.10928	.28928
(b',43)	49.00	4.64350	1.24465	.30977
(b',44)	50.00	4.85295	1.39165	.33027
(b',45)	51.00	5.07507	1.55134	.35077
(b',46)	52.00	5.31087	1.72500	.37127
(b',47)	53.00	5.56135	1.91398	.39177
(b',48)	54.00	5.82763	2.11979	.41227
(b',49)	55.00	6.11096	2.34415	.43278
(b',50)	56.00	6.41267	2.58891	.45329
(b',51)	57.00	6.73424	2.85620	.47380
(b',52)	58.00	7.07730	3.14837	.49431
(b',53)	59.00	7.44359	3.46803	.51483
(b',54)	60.00	7.83502	3.81808	.53535
(b',55)	61.00	8.25371	4.20183	.55587
(b',56)	62.00	8.70210	4.62302	.57639
(b',57)	63.00	9.18264	5.08572	.59691
(b',58)	64.00	9.69827	5.59466	.61744
(b',59)	65.00	10.25218	6.15518	.63797
(b',60)	66.00	10.84762	6.77303	.65850
(b',61)	67.00	11.48871	7.45519	.67903
		$\eta = 36.00^o$		
(c',31)	38.00	2.98446	0.10624	0.04217
(c',32)	39.00	3.10140	.16416	.06269
(c',33)	40.00	3.22454	.22668	.08320
(c',34)	41.00	3.35437	.29426	.10372
(c',35)	42.00	3.49132	.36734	.12424
		$\eta = 36.00^o$ - concluded		
(c',36)	43.00	3.63585	0.44641	0.14476
(c',37)	44.00	3.78846	.53201	.16528
(c',38)	45.00	3.94976	.62476	.18580
(c',39)	46.00	4.12032	.72530	.20632
(c',40)	47.00	4.30078	.83435	.22684
(c',41)	48.00	4.49190	.95274	.24737
(c',42)	49.00	4.69440	1.08133	.26790
(c',43)	50.00	4.90915	1.22112	.28843
(c',44)	51.00	5.13706	1.37320	.30896
(c',45)	52.00	5.37910	1.53875	.32949
(c',46)	53.00	5.63640	1.71914	.35002
(c',47)	54.00	5.91008	1.91580	.37055
(c',48)	55.00	6.20144	2.13040	.39108
(c',49)	56.00	6.51192	2.36480	.41162
(c',50)	57.00	6.84304	2.62102	.43216
(c',51)	58.00	7.19648	2.90136	.45270
(c',52)	59.00	7.57415	3.20840	.47324
(c',53)	60.00	7.97804	3.54499	.49378
(c',54)	61.00	8.41036	3.91430	.51432
(c',55)	62.00	8.87362	4.31998	.53486
(c',56)	63.00	9.37059	4.76614	.55541
(c',57)	64.00	9.90421	5.25727	.57596
(c',58)	65.00	10.47784	5.79860	.59651
(c',59)	66.00	11.09522	6.39599	.61706
(c',60)	67.00	11.76029	7.05593	.63761
(c',61)	68.00	12.47775	7.78608	.65816
(c',62)	69.00	13.25276	8.59506	.67872
		$\eta = 38.00^o$		
(d',31)	39.00	3.10986	0.05469	0.02086
(d',32)	40.00	3.23531	.11297	.04140
(d',33)	41.00	3.36756	.17604	.06194
(d',34)	42.00	3.50712	.24438	.08248
(d',35)	43.00	3.65450	.31844	.10302
(d',36)	44.00	3.81020	.39876	.12356
(d',37)	45.00	3.97479	.48590	.14410
(d',38)	46.00	4.14894	.58053	.16465
(d',39)	47.00	4.33332	.68334	.18520
(d',40)	48.00	4.52862	.79509	.20574
(d',41)	49.00	4.73570	.91666	.22629
(d',42)	50.00	4.95540	1.04900	124684
(d',43)	51.00	5.18868	1.19315	.26739
(d',44)	52.00	5.43660	1.35031	.28794
(d',45)	53.00	5.70024	1.52174	.30849
(d',46)	54.00	5.98088	1.708%	.32904
(d',47)	55.00	6.27981	1.91339	.34959
(d',48)	56.00	6.59853	2.13698	.37014
(d',49)	57.00	6.93867	2.38170	.39069
(d',50)	58.00	7.30197	2.64974	.41124
(d',51)	59.00	7.69038	2.94360	.43179
(d',52)	60.00	8.10608	3.26613	.45235
(d',53)	61.00	8.55138	3.62041	.47291
(d',54)	62.00	9.02884	4.00995	.49347
(d',55)	63.00	9.54137	4.43873	.51403
(d',56)	64.00	10.09223	4.91130	.53459
(d',57)	65.00	10.68478	5.43261	.55515
(d',58)	66.00	11.32296	6.00840	.57571
(d',59)	67.00	12.01122	6.64524	.59628
(d',60)	68.00	12.75412	7.35028	.61684
(d',61)	69.00	13.55723	8.13206	.63741
(d',62)	70.00	14.42660	9.00019	.65798
(d',63)	71.00	15.36874	9.96536	.67855

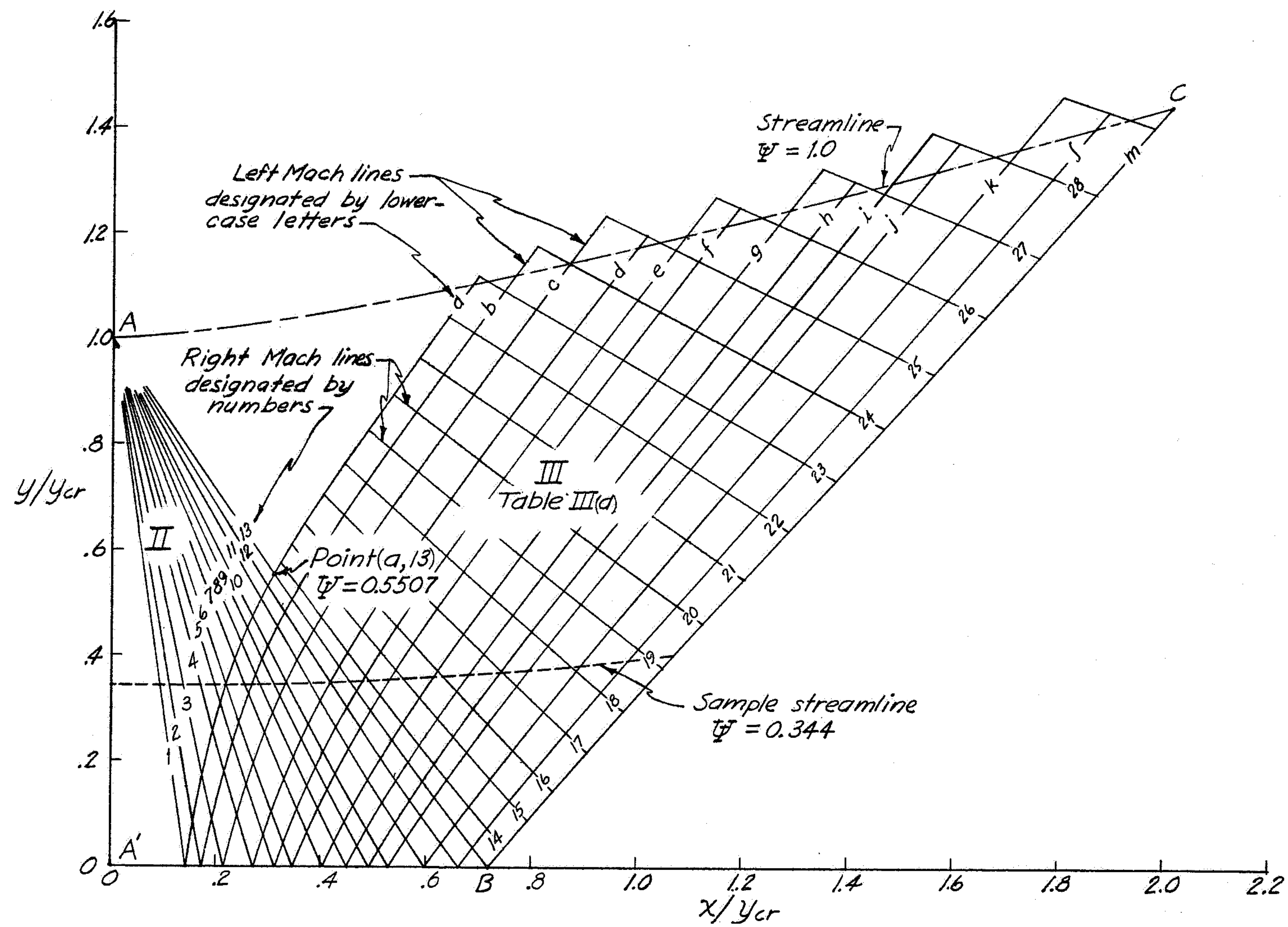


(a) Streamlines and flow regions for some typical nozzles.



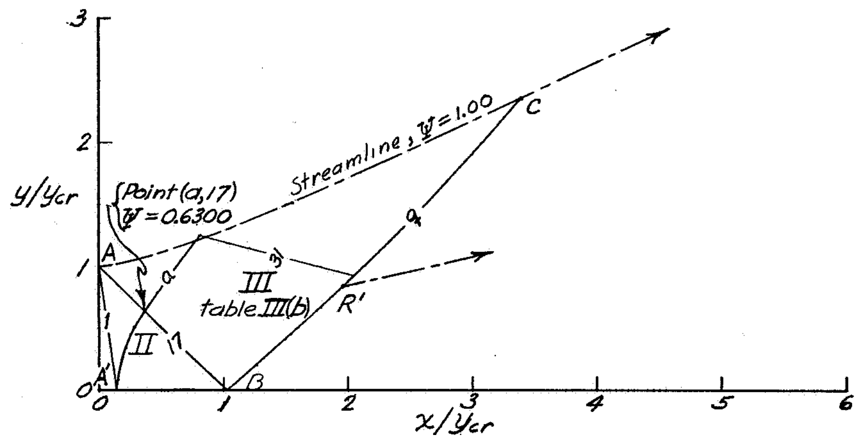
(b) Sonic arc and other radial-flow parameters, shown to the same scale as that of figure 1(a).

Figure 1.- Schematic representation of flow fields.

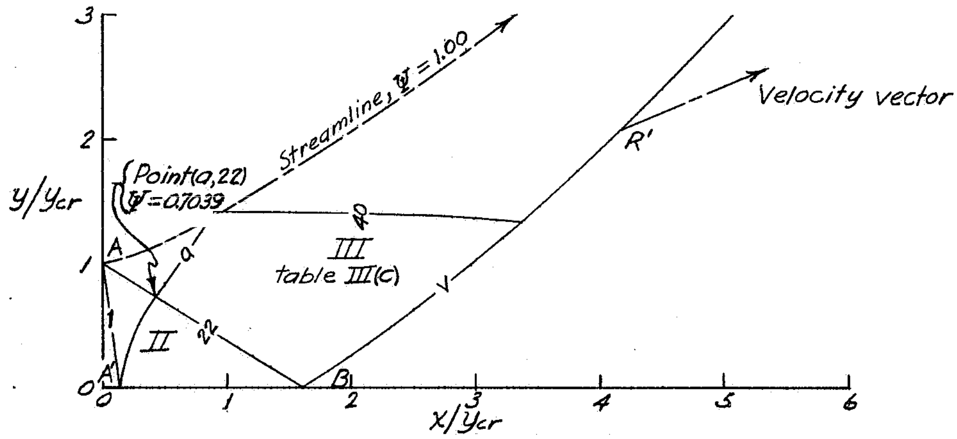


(a) $\nu_B = 6^{\circ}$.

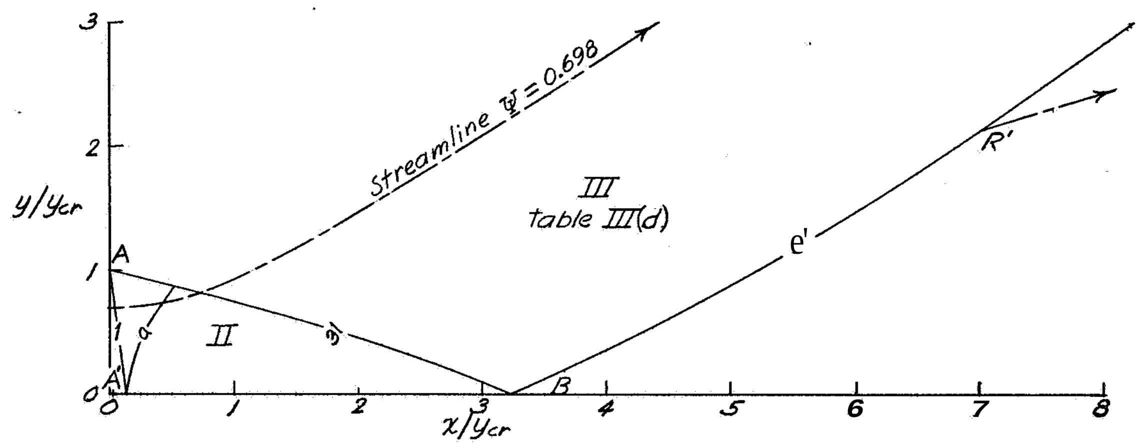
Figure 2.- Layout of Mach lines and streamlines in the initial- and secondary-expansion regions (regions II and III, respectively).



(b) $\nu_B = 12^\circ$.



(c) $\nu_B = 22^\circ$.



(d) $\nu_B = 40^\circ$.

Figure 2.- Concluded.

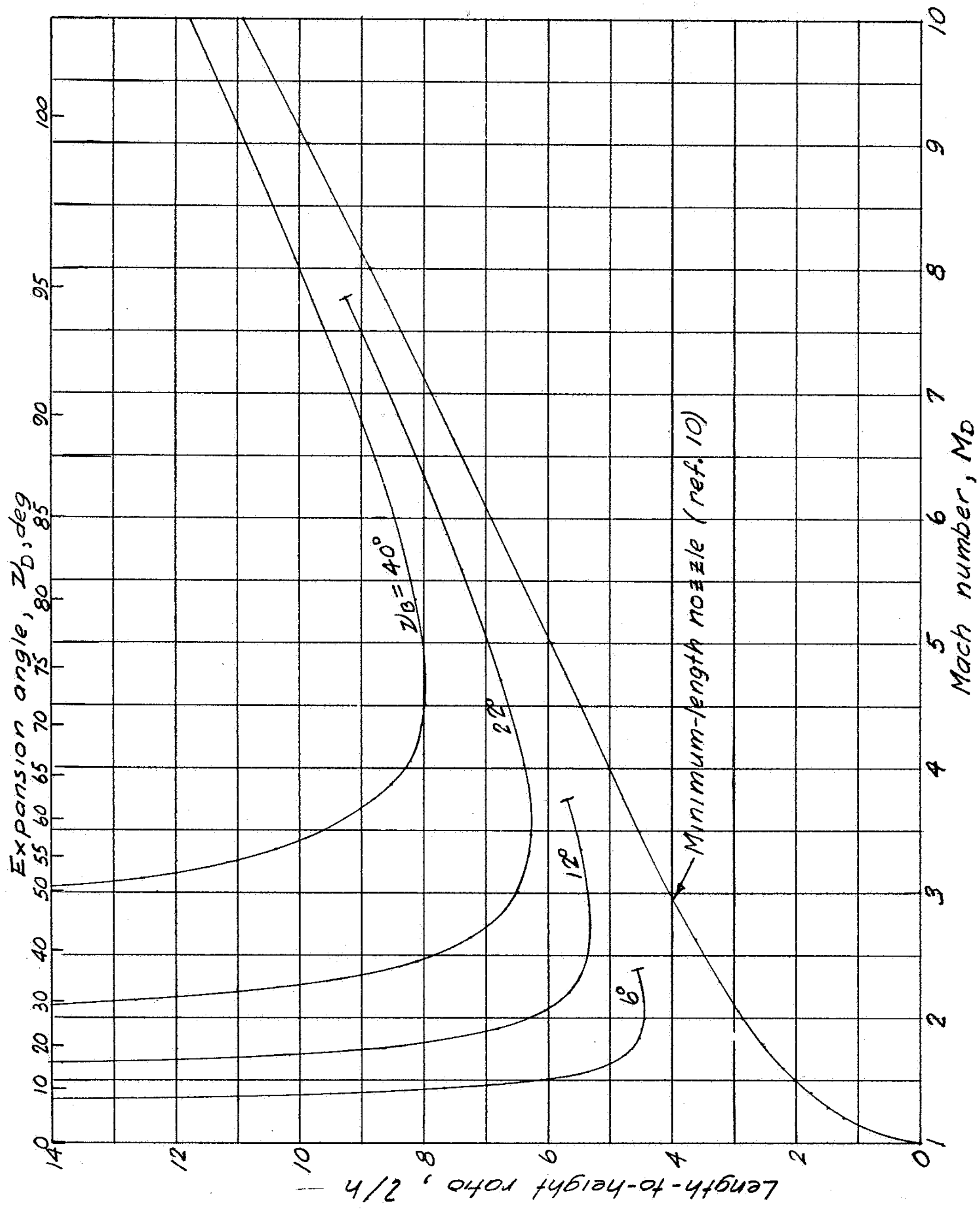


Figure 3.- Nozzle design parameters, where for given values of M_D and ν_B the four upper curves give the shortest possible nozzle by the present method.