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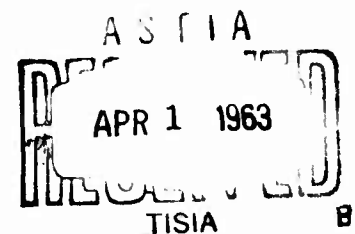
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**NWL Report No. 1840****STAGNATION AND WAKE FLOWS  
NORMAL TO A FLAT SURFACE**

by

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U. S. Naval Weapons Laboratory  
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ABSTRACT

Complete numerical results of axisymmetric and plane stagnation and wake flows, which are produced by homogeneous motions with finite initial velocities normal to a flat surface, are presented for a variety of Reynolds numbers. The results have been obtained on the basis of an extension of Prandtl's boundary layer theory. Characteristic flow properties are pointed out and discussed. Critical Reynolds numbers for nonexistent laminar attached flows are computed.

FOREWORD

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Technical Director

## 1. Introduction

Axisymmetric and plane stagnation and wake flows "normal" to a flat surface have been investigated in [4] on the basis of the extended boundary layer theory which was introduced in [3]. In contrast to the classical stagnation flows "past" a flat surface, which are produced by nonhomogeneous motions of infinite initial velocities (see [1, 2]), the new stagnation flows are generated by homogeneous motions of finite initial velocities (see Fig. 1). While the classical stagnation flows represent significant models for real flows past blunt bodies, the new flows are of interest in the design of piston machines.

In [4] the Navier-Stokes equations have been reduced to a single ordinary differential equation which has been solved by the Runge-Kutta method. Complete numerical results of axisymmetric and plane stagnation and wake flows are displayed in the present paper for a selected variety of Reynolds numbers. Characteristic properties of these flows are pointed out and discussed.

## 2. The Reduced Navier-Stokes Equations

In a plane or axisymmetric stagnation or wake flow normal to a flat solid surface let  $(r, z)$  be an orthogonal coordinate system in which  $z = 0$  denotes the solid surface and  $r = 0$  the axis of symmetry of the flow (see [4] and Fig. 1). The corresponding velocity  $(u, w)$  of the flow with the variable pressure  $p$  and the constant density and kinematic viscosity  $\rho$  and  $\nu$  is determined by the Navier-Stokes equations

$$uu_r + wu_z = -\frac{1}{\rho} p_r + \nu \left[ u_{rr} + n \left( \frac{u}{r} \right)_r + u_{zz} \right] \quad (1)$$

$$uw_r + ww_z = -\frac{1}{\rho} p_z + \nu \left[ w_{rr} + \frac{n}{r} w_r + w_{zz} \right] \quad (2)$$

$$u_r + \frac{n}{r} u + w_z = 0 \quad (3)$$

The unifying parameter  $n$  assumes the value  $n = 0$  for plane flows and  $n = 1$  for axisymmetric motions.

The stagnation and wake flows normal to the flat solid surface at  $z = 0$  are determined by the following set of regular and singular boundary data:

$$\left. \begin{array}{l} -\infty < r < +\infty \\ z = 0 \end{array} \right\} u = 0, \quad w = 0 \quad (4)$$

$$\left. \begin{array}{l} -\infty \leq r \leq +\infty \\ z \rightarrow \infty \end{array} \right\} u \rightarrow 0, \quad w \rightarrow w_\infty \quad (5)$$

$$\left. \begin{array}{l} r \rightarrow \pm \infty \\ z > 0 \end{array} \right\} u \rightarrow 0, \quad w \rightarrow w_\infty \quad (6)$$

The constant  $w_\infty$  is at one's disposal. The motions may be called "stagnation" or "wake" flows according as  $w_\infty$  is negative or positive. It may be noted that no boundary data are prescribed at the two singular points ( $r = \pm\infty$ ,  $z = 0$ ) (see Fig. 1).

On the basis of the extended boundary layer theory, which was introduced in [3], the problem under consideration has been reduced to an ordinary boundary value problem in [4]. Its significance for the design of piston machines follows directly from the characterizing boundary data (4), (5), and (6) and Figure 1.

The first order reduction of the Navier-Stokes equations, which is valid for small values of  $r$ , was achieved with the aid of the limiting line of the boundary layer along the surface at  $z = 0$ . In accordance with the extended boundary layer theory (see [3]) this limiting line  $z = \delta(r)$  was defined as the solution of the  $\epsilon$ -equation

$$w(r, z) = w_\infty(1 - \epsilon) \quad . \quad (7)$$

Because of the analyticity and symmetry of the motions  $\delta(r)$  must yield an expansion of the form

$$z = \delta(r) = a - br^2 \dots \quad (8)$$

around  $r = 0$ . Furthermore, it must decrease monotonically to zero as  $r$  tends to infinity, i. e., the limiting line of the boundary layer connects the two singular points at  $(r = \pm\infty, z = 0)$ .

While the product

$$ab = \sigma^2 \quad (9)$$

depends on the accuracy parameter  $\epsilon$ , the ratio

$$\frac{a}{b} = \left(\frac{D}{2}\right)^2 \quad (10)$$

remains as an additional parameter at one's disposal. The value  $D$  was roughly identified as the diameter of a flat plate which represents the solid surface of an approximate finite flow model (see Fig. 1). The first order approximation around  $r = 0$  was obtained by separation of variables after applying the following similarity transformation:

$$r = r, \quad \zeta = \frac{z}{\delta(r)}, \quad R = \frac{w_\infty}{\nu} \sqrt{\frac{a}{b}} \quad (11)$$

$$u = w_\infty \sqrt{\frac{b}{a}} r U(\zeta), \quad w = w_\infty W(\zeta), \quad \frac{p}{\rho} = -\frac{w_\infty^2}{2} P(\zeta) \quad (12)$$

$$U(\zeta) = -\dot{G}(\zeta), \quad W(\zeta) = 2^n \sigma G(\zeta), \quad P(\zeta) = 4^n \sigma^2 H(\zeta) \quad (13)$$

The constant parameter  $|R|$  was found to be the Reynolds number of the flow, which determines the motion uniquely in the  $(r, \zeta)$  plane.

With the transformation (11), (12), and (13) one arrives easily at the following ordinary differential equation for the dimensionless stream function  $G(\zeta)$  of the flow (see [4]):

$$\ddot{G} + \sigma^2[(2+n)4\zeta - (n+1)RG]\ddot{G} + 2(n+1)^2\sigma^4\zeta[2\dot{\zeta} - RG]\dot{G} + \sigma^2R\dot{G}^2 = 0 \quad (14)$$

This differential equation remained to be integrated under the boundary conditions

$$\zeta = 0: \quad G = 0, \quad \dot{G} = 0, \quad (15)$$

$$\zeta = \infty: \quad G = \frac{1}{\sigma(n+1)} = G_\infty \quad (16)$$

The pressure function  $H(\zeta)$  was then found to be

$$H = 2^{n-1}G^2 - \frac{\dot{G}}{\sigma^2 R} + \frac{2(n+1)}{R} \int_{\zeta}^{\infty} t\dot{G}(t)dt \quad (17)$$

For a numerical integration of the nonlinear differential equation (14) it is convenient to introduce the following new scales for all variables concerned:

$$\eta = \sigma\zeta, \quad g = \sigma RG, \quad h = \sigma^2 R^2 H \quad (18)$$

This leads to the new equation

$$\ddot{g} + [(2+n)4\eta - (n+1)g]\ddot{g} + 2(n+1)^2\eta[2\dot{\eta} - g]\dot{g} + \dot{g}^2 = 0, \quad (19)$$

which must be integrated under the boundary conditions

$$\eta = 0: \quad g = 0, \quad \dot{g} = 0 \quad (20)$$

$$\eta = \infty: \quad g = g_{\infty} = \frac{R}{n+1} \quad (21)$$

The pressure function  $h(\zeta)$  is determined by

$$h = 2^{n-1}g^2 - \dot{g} + 2(n+1) \int_{\eta}^{\infty} t \dot{g}(t) dt \quad (22)$$

The advantage of the transformation (18) is evident, as the differential equation (19) may be integrated from a complete set of initial data at  $\eta = 0$ . The corresponding Reynolds number of the flow is then determined by the boundary condition (21), provided the limiting value  $g_{\infty}$  exists. The remaining initial value problem has been solved by the Runge-Kutta method for a variety of Reynolds numbers. The numerical results will be discussed in the following section.

Since the approximations applied are valid as long as the flow remains laminar and attached to the surface at  $z = 0$  at least in the vicinity of the axis of symmetry  $r = 0$ , it is possible to deal with slow and fast laminar attached motions with stagnation ( $w_{\infty} < 0$ ) and wake ( $w_{\infty} > 0$ ) character. This indicates the possibility of detecting those critical Reynolds numbers for which the corresponding laminar flows separate from the surface.

According to physical arguments points of separation may occur in stagnation type flows, but only at some distance from the stagnation point. Thus the extended boundary layer theory can be expected to yield proper results for any finite Reynolds number in the case of stagnation flows. However, points of separation, which may occur farther downstream in stagnation flows, should manifest themselves as points of instability through inflection points in the velocity components parallel to the surface (see, for instance, [1, 2] ). In wake type flows the motions are always separated at the wake center provided separation occurs at all. Hence, separation of wake flows should lead to nonexistence of proper solutions to the remaining ordinary boundary value problems, because such flows violate any boundary layer assumption.

The following numerical results will verify the foregoing heuristic observations and, thus, demonstrate probably the most significant justification of the extended boundary layer theory. Indeed, the new boundary layer approximation resolves an old paradox of the classical boundary layer theory. Prandtl's boundary layer assumptions are believed to be best for flows with large Reynolds numbers, that is, for those flows for which in most cases no laminar everywhere attached boundary layer exists. The existence of finite or infinite critical Reynolds numbers contradicts a modern attempt to justify Prandtl's boundary layer approximation

which is considered as the leading term of an assumed expansion with respect to the reciprocal Reynolds number (see, e. g., [1]).

### 3. Properties of Stagnation Flows

The ordinary boundary value problem, which is defined by the equations (19) through (22), has been integrated as an initial value problem by the Runge-Kutta method. Numerical results for axisymmetric ( $n = 1$ ) and plane ( $n = 0$ ) stagnation flows ( $w_\infty < 0$ ) are presented in the tables 1 through 6 for a selected variety of Reynolds numbers. Characteristic examples have been selected and plotted in the figures 2 through 7. These figures display the dimensionless velocity components and the pressure  $U$ ,  $W$ , and  $P$  as functions of the dimensionless variable  $\eta$ .

It may be emphasized that the numerical calculations of all stagnation flows computed indicated no symptoms of divergence in the Runge-Kutta method for any Reynolds number. Examples with very large Reynolds numbers have been omitted only because of the very long computing time which such solutions require. Consequently, axisymmetric and plane stagnation flows normal to a flat surface remain laminar and attached at least in the vicinity of their stagnation points at the surface no matter how large the Reynolds number may be chosen. The boundary layer thickness at the stagnation point, which is measured by  $\sigma$  in the  $(r, \eta)$ -plane (see Fig. 2 through 7 and 14), is a decreasing function of the Reynolds number  $R$  as long as the flow remains attached to the entire surface.

A basic difference between axisymmetric and plane stagnation flows can be observed by comparing the corresponding radial velocities plotted in Figures 2 and 3. The radial velocities of axisymmetric stagnation flows remain free of inflection points within the boundary layer even for very large Reynolds numbers. Hence axisymmetric stagnation flows normal to a flat surface are stable for all finite Reynolds numbers.

In contrast to axisymmetric motions plane stagnation flows normal to a flat surface become unstable as the Reynolds number increases beyond a "critical" value  $R_c$ , which has been found to be (see Fig. 5)

$$R_c \approx 54 . \quad (23)$$

Hence, in plane stagnation flows separation is to be expected somewhere downstream of the stagnation point, if the Reynolds number passes the critical value (23). Indeed, when the Reynolds number of a plane stagnation flow approaches the critical value (23) one double inflection point occurs in the radial velocity in the lower portion of the boundary layer. As the Reynolds number increases the double inflection point splits into two single inflection points such that the lower point descends to the surface.

The occurrence of two inflection points in the radial velocity of plane stagnation flows contradicts the common description of the phenomenon of flow separation which is based on the classical

boundary layer theory (see, e. g., [1, 2]). This reveals a significant deficiency of Prandtl's boundary layer theory which destroys intrinsic properties of flows along surfaces. In fact any flow, which satisfies the Navier-Stokes equations (1) through (3) and the nonslip condition (4), can be divided into three different strips:

(I) A "slow motion layer" exists directly at the surface  $z = 0$  where any regular flow is essentially governed by the so-called Stokes equations, which neglect all inertial forces as terms of second and higher order in  $z$ .

(II) A "fast motion layer" exists at large distances from the surface, where the flow is essentially determined by the Euler equations, which ignore all friction forces (boundary layer assumption).

(III) A "transition layer" joins the slow motion layer with the fast motion region, where the flow is governed by the complete Navier-Stokes equations.

As generally acknowledged the classical boundary layer theory is not applicable to slow motions and, hence, presents itself as inadequate to describe the phenomenon of flow separation which originates in the lower part of the transition layer. If the fast motion at some distance from the surface tends to surpass the slow motion at the surface, an instability develops in the

transition layer which spreads gradually across the slow motion layer and causes the flow separation when the surface is reached.

#### 4. Properties of Wake Flows

Axisymmetric and plane wake ( $w_\infty > 0$ ) flows normal to a flat surface have been computed and tabulated for various Reynolds numbers (see Tables 7 through 12). Characteristic examples have been selected and plotted in the figures 8 through 13.

As anticipated in section 2 solutions were only computable for relatively small Reynolds numbers. If the Reynolds number approaches a "critical" value, which has been found to be

$$R_a \approx 6.6 \text{ for axisymmetric flows} \quad (24)$$

and

$$\hat{R}_p \approx 4.8 \text{ for plane flow,} \quad (25)$$

one double inflection point occurs in the radial velocity (see Fig. 8 and 11) in the upper portion of the boundary layer. If the Reynolds number increases beyond its critical value the double inflection point splits into two single inflection points where the upper point ascends very rapidly to infinity and a proper solution ceases to exist.

In contrast to plane stagnation flows separation originates in wake flows in the upper portion of the boundary layer. An instability occurs in the transition layer and spreads very rapidly across the fast motion region. At the same time the

boundary layer thickness grows beyond any limits (see Fig. 8 through 13 and 15) and the existence of a laminar boundary layer is no longer possible.

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**APPENDIX A**

TABLE 1

## RADIAL VELOCITY U OF AXISYMMETRIC STAGNATION FLOWS

| $R$                  | .6982 | 6.028 | 46.84 | 412.4   | 3974    |
|----------------------|-------|-------|-------|---------|---------|
| $R \frac{dU}{d\eta}$ | -1    | -10   | -100  | $-10^3$ | $-10^4$ |
| $\sigma$             | 2.15  | 1.85  | 1.50  | 1.41    | 1.40    |
| $\eta$               |       |       |       |         |         |
| 0                    | .0000 | .0000 | .0000 | .0000   | .0000   |
| .1                   | .1404 | .1626 | .2093 | .2376   | .2461   |
| .2                   | .2648 | .3066 | .3943 | .4450   | .4562   |
| .3                   | .3611 | .4179 | .5344 | .5917   | .6007   |
| .4                   | .4239 | .4895 | .6157 | .6622   | .6673   |
| .5                   | .4539 | .5211 | .6341 | .6598   | .6608   |
| .6                   | .4562 | .5174 | .5971 | .6009   | .5986   |
| .7                   | .4377 | .4862 | .5222 | .5075   | .5030   |
| .8                   | .4053 | .4361 | .4280 | .4013   | .3958   |
| .9                   | .3648 | .3757 | .3315 | .2995   | .2939   |
| 1.0                  | .3204 | .3122 | .2440 | .2118   | .2068   |
| 1.1                  | .2754 | .2512 | .1714 | .1427   | .1385   |
| 1.2                  | .2322 | .1961 | .1155 | .0917   | .0885   |
| 1.3                  | .1922 | .1491 | .0748 | .0565   | .0541   |
| 1.4                  | .1561 | .1106 | .0467 | .0333   | .0317   |
| 1.5                  | .1247 | .0802 | .0281 | .0189   | .0178   |
| 1.6                  | .0980 | .0569 | .0164 | .0103   | .0096   |
| 1.7                  | .0756 | .0395 | .0092 | .0054   | .0050   |
| 1.8                  | .0575 | .0270 | .0051 | .0027   | .0025   |
| 1.9                  | .0430 | .0180 | .0027 | .0013   | .0012   |
| 2.0                  | .0316 | .0119 | .0014 | .0006   | .0005   |
| 2.2                  | .0163 | .0049 | .0003 |         |         |
| 2.4                  | .0079 | .0019 | .0007 |         |         |
| 2.6                  | .0036 | .0007 |       |         |         |
| 2.8                  | .0015 | .0002 |       |         |         |
| 3.0                  | .0006 | .0001 |       |         |         |
| 3.4                  | .0001 |       |       |         |         |

TABLE 2

## AXIAL VELOCITY W OF AXISYMMETRIC STAGNATION FLOWS

| $ R $                | .6982  | 6.028  | 46.84  | 412.4   | 3974    |
|----------------------|--------|--------|--------|---------|---------|
| $R \frac{dU}{d\eta}$ | -1     | -10    | -100   | $-10^3$ | $-10^4$ |
| $\sigma$             | 2.15   | 1.85   | 1.50   | 1.41    | 1.40    |
| $\eta$               |        |        |        |         |         |
| 0                    | .0000  | .0000  | .0000  | .0000   | .0000   |
| .1                   | .0142  | .0164  | .0211  | .0240   | .0249   |
| .2                   | .0551  | .0638  | .0821  | .0931   | .0960   |
| .3                   | .1182  | .1369  | .1758  | .1979   | .2030   |
| .4                   | .1973  | .2283  | .2919  | .3249   | .3311   |
| .5                   | .2856  | .3300  | .4179  | .4579   | .4650   |
| .6                   | .3770  | .4343  | .5418  | .5849   | .5918   |
| .7                   | .4660  | .5352  | .6541  | .6959   | .7021   |
| .8                   | .5511  | .6277  | .7494  | .7871   | .7921   |
| .9                   | .6282  | .7090  | .8254  | .8569   | .8611   |
| 1.0                  | .6969  | .7777  | .8826  | .9079   | .9109   |
| 1.1                  | .7565  | .8338  | .9240  | .9428   | .9451   |
| 1.2                  | .8072  | .8786  | .9522  | .9661   | .9673   |
| 1.3                  | .8496  | .9131  | .9710  | .9806   | .9814   |
| 1.4                  | .8843  | .9386  | .9829  | .9893   | .9899   |
| 1.5                  | .9123  | .9579  | .9902  | .9942   | .9946   |
| 1.6                  | .9344  | .9711  | .9949  | .9971   | .9974   |
| 1.7                  | .9519  | .9808  | .9974  | .9988   | .9990   |
| 1.8                  | .9651  | .9874  | .9987  | .9995   | .9996   |
| 1.9                  | .9751  | .9920  | .9996  | 1.0000  | 1.0000  |
| 2.0                  | .9822  | .9947  | .9996  |         |         |
| 2.2                  | .9917  | .9980  | 1.0000 |         |         |
| 2.4                  | .9963  | .9993  |        |         |         |
| 2.6                  | .9986  | .9997  |        |         |         |
| 2.8                  | .9994  | 1.0000 |        |         |         |
| 3.0                  | 1.0000 |        |        |         |         |

TABLE 3

## PRESSURE DISTRIBUTION P OF AXISYMMETRIC STAGNATION FLOWS

| $ R $                | .6982  | 6.028  | 46.84  | 412.4   | 3974    |
|----------------------|--------|--------|--------|---------|---------|
| $R \frac{dU}{d\eta}$ | -1     | -10    | -100   | $-10^3$ | $-10^4$ |
| $\sigma$             | 2.5    | 1.85   | 1.50   | 1.41    | 1.40    |
| $\eta$               |        |        |        |         |         |
| 0                    | -9.388 | -.9559 | -.1033 | -.0111  | -.0011  |
| .1                   | -8.567 | -.8463 | -.0848 | -.0082  | -.0003  |
| .2                   | -7.774 | -.7371 | -.0611 | +.0002  | +.0086  |
| .3                   | -7.022 | -.6240 | -.0209 | .0346   | .0408   |
| .4                   | -6.314 | -.5004 | +.0473 | .1023   | .1093   |
| .5                   | -5.639 | -.3619 | .1480  | .2077   | .2161   |
| .6                   | -4.984 | -.2083 | .2753  | .3407   | .3500   |
| .7                   | -4.343 | -.0444 | .4158  | .4837   | .4931   |
| .8                   | -3.712 | +.1219 | .5534  | .6189   | .6276   |
| .9                   | -3.099 | .2819  | .6757  | .7338   | .7414   |
| 1.0                  | -2.513 | .4284  | .7754  | .8237   | .8295   |
| 1.1                  | -1.964 | .5573  | .8511  | .8885   | .8931   |
| 1.2                  | -1.462 | .6652  | .9052  | .9438   | .9359   |
| 1.3                  | -1.008 | .7522  | .9419  | .9612   | .9633   |
| 1.4                  | -.6198 | .8216  | .9655  | .9786   | .9800   |
| 1.5                  | -.2810 | .8733  | .9803  | .9887   | .9894   |
| 1.6                  | .0000  | .9119  | .9891  | .9944   | .9947   |
| 1.7                  | +.2397 | .9405  | .9942  | .9974   | .9990   |
| 1.8                  | .4215  | .9604  | .9969  | .9988   | .9997   |
| 1.9                  | .5702  | .9736  | .9996  | .9998   | 1.0000  |
| 2.0                  | .6860  | .9835  | .9996  | 1.0000  |         |
| 2.2                  | .8430  | .9934  | 1.0000 |         |         |
| 2.4                  | .9256  | .9978  |        |         |         |
| 2.6                  | .9669  | 1.0000 |        |         |         |
| 2.8                  | .9917  |        |        |         |         |
| 3.0                  | 1.0000 |        |        |         |         |

TABLE 4

## HORIZONTAL VELOCITY U OF PLANE STAGNATION FLOWS

| $ R $                | .7127 | 6.697 | 53.59 | 100.2 | 11700  |
|----------------------|-------|-------|-------|-------|--------|
| $R \frac{dU}{d\eta}$ | -1    | -10   | -64   | -100  | -1000  |
| $\sigma$             |       |       |       |       |        |
| $\eta$               | 3.51  | 2.85  | 2.27  | 2.22  | 2.27   |
| 0                    | .0000 | .0000 | .0000 | .0000 | .0000  |
| .1                   | .1385 | .1474 | .1182 | .0989 | .0088  |
| .2                   | .2663 | .2843 | .2314 | .1955 | .0213  |
| .3                   | .3752 | .4030 | .3402 | .2941 | .0454  |
| .4                   | .4602 | .4999 | .4480 | .4006 | .0909  |
| .5                   | .5201 | .5740 | .5551 | .5159 | .1683  |
| .6                   | .5566 | .6263 | .6568 | .6333 | .2862  |
| .7                   | .5736 | .6581 | .7442 | .7040 | .4441  |
| .8                   | .5751 | .6715 | .8067 | .8233 | .6274  |
| .9                   | .5653 | .6684 | .8365 | .8695 | .8079  |
| 1.0                  | .5475 | .6504 | .8300 | .8728 | .9513  |
| 1.1                  | .5238 | .6200 | .7886 | .8343 | 1.0300 |
| 1.2                  | .4964 | .5798 | .7190 | .7613 | 1.0320 |
| 1.3                  | .4664 | .5323 | .6307 | .6654 | .9658  |
| 1.4                  | .4348 | .4805 | .5339 | .5589 | .8491  |
| 1.5                  | .4024 | .4269 | .4374 | .4529 | .7071  |
| 1.6                  | .3699 | .3736 | .3476 | .3529 | .5615  |
| 1.7                  | .3376 | .3224 | .2689 | .2701 | .4276  |
| 1.8                  | .3062 | .2747 | .2030 | .2001 | .3140  |
| 1.9                  | .2759 | .2313 | .1498 | .1446 | .2232  |
| 2.0                  | .2469 | .1926 | .1082 | .1022 | .1542  |
| 2.2                  | .1943 | .1295 | .0534 | .0479 | .0681  |
| 2.4                  | .1493 | .0839 | .0246 | .0208 | .0274  |
| 2.6                  | .1120 | .0527 | .0107 | .0084 | .0101  |
| 2.8                  | .0821 | .0321 | .0044 | .0032 | .0034  |
| 3.0                  | .0588 | .0190 | .0017 | .0011 | .0011  |
| 3.4                  | .0283 | .0062 | .0002 | .0001 |        |
| 3.8                  | .0124 | .0018 |       |       |        |
| 4.2                  | .0050 | .0050 |       |       |        |
| 4.6                  | .0019 | .0001 |       |       |        |
| 5.0                  | .0006 |       |       |       |        |

TABLE 5

## VERTICAL VELOCITY W OF PLANE STAGNATION FLOWS

| $ R $                | .7127  | 6.697  | 53.59  | 100.2  | 11700  |
|----------------------|--------|--------|--------|--------|--------|
| $R \frac{dU}{d\eta}$ | -1     | -10    | -64    | -100   | -1000  |
| $\sigma$             | 3.51   | 2.85   | 2.27   | 2.22   | 2.27   |
| $\eta$               |        |        |        |        |        |
| 0                    | .0000  | .0000  | .0000  | .0000  | .0000  |
| .1                   | .0070  | .0074  | .0059  | .0050  | .0004  |
| .2                   | .0273  | .0291  | .0235  | .0197  | .0019  |
| .3                   | .0596  | .0637  | .0521  | .0441  | .0051  |
| .4                   | .1016  | .1090  | .0915  | .0788  | .0117  |
| .5                   | .1508  | .1629  | .1416  | .1246  | .0243  |
| .6                   | .2049  | .2231  | .2023  | .1820  | .0467  |
| .7                   | .2615  | .2874  | .2724  | .2509  | .0829  |
| .8                   | .3191  | .3540  | .3503  | .3293  | .1364  |
| .9                   | .3762  | .4212  | .4327  | .4143  | .2083  |
| 1.0                  | .4319  | .4872  | .5163  | .5018  | .2968  |
| 1.1                  | .4855  | .5508  | .5975  | .5874  | .3964  |
| 1.2                  | .5364  | .6109  | .6733  | .6675  | .5002  |
| 1.3                  | .5847  | .6666  | .7408  | .7389  | .6006  |
| 1.4                  | .6297  | .7172  | .7990  | .8002  | .6916  |
| 1.5                  | .6715  | .7626  | .8475  | .8507  | .7696  |
| 1.6                  | .7101  | .8026  | .8867  | .8910  | .8330  |
| 1.7                  | .7455  | .8374  | .9175  | .9222  | .8821  |
| 1.8                  | .7777  | .8673  | .9410  | .9455  | .9188  |
| 1.9                  | .8068  | .8925  | .9586  | .9627  | .9462  |
| 2.0                  | .8329  | .9137  | .9713  | .9749  | .9650  |
| 2.2                  | .8769  | .9455  | .9869  | .9893  | .9855  |
| 2.4                  | .9112  | .9667  | .9944  | .9959  | .9949  |
| 2.6                  | .9371  | .9801  | .9978  | .9990  | .9983  |
| 2.8                  | .9564  | .9884  | .9993  | 1.0000 | .9991  |
| 3.0                  | .9704  | .9934  | .9998  |        | 1.0000 |
| 3.4                  | .9872  | .9981  | 1.0000 |        |        |
| 3.8                  | .9949  | .9994  |        |        |        |
| 4.2                  | .9983  | .9999  |        |        |        |
| 4.6                  | .9996  | 1.0000 |        |        |        |
| 5.0                  | 1.0000 |        |        |        |        |

TABLE 6

## PRESSURE DISTRIBUTION P OF PLANE STAGNATION FLOWS

| $R$                  | .7127  | 6.697  | 53.59  | 100.2  | 11700  |
|----------------------|--------|--------|--------|--------|--------|
| $R \frac{dU}{d\eta}$ | -1     | -10    | -64    | -100   | -1000  |
| $\sigma$             | 3.51   | 2.85   | 2.27   | 2.22   | 2.27   |
| $\eta$               |        |        |        |        |        |
| 0                    | -7.075 | -.6589 | -.0756 | -.0409 | -.0004 |
| .1                   | -6.685 | -.6146 | -.0711 | -.0389 | -.0004 |
| .2                   | -6.309 | -.5709 | -.0662 | -.0365 | -.0004 |
| .3                   | -5.957 | -.5270 | -.0594 | -.0328 | -.0004 |
| .4                   | -5.629 | -.4807 | -.0487 | -.0259 | -.0003 |
| .5                   | -5.326 | -.4295 | -.0313 | -.0135 | +.0002 |
| .6                   | -5.038 | -.3708 | -.0042 | +.0078 | .0018  |
| .7                   | -4.758 | -.3035 | +.0358 | .0415  | .0065  |
| .8                   | -4.480 | -.2269 | .0909  | .0910  | .0183  |
| .9                   | -4.196 | -.1418 | .1618  | .1580  | .0432  |
| 1.0                  | -3.906 | -.0495 | .2469  | .2415  | .0879  |
| 1.1                  | -3.608 | +.0473 | .3421  | .3376  | .1569  |
| 1.2                  | -3.305 | .1462  | .4420  | .4402  | .2500  |
| 1.3                  | -3.000 | .2448  | .5406  | .5424  | .3606  |
| 1.4                  | -2.694 | .3402  | .6324  | .6378  | .4784  |
| 1.5                  | -2.388 | .4302  | .7139  | .7220  | .5922  |
| 1.6                  | -2.094 | .5140  | .7828  | .7927  | .6939  |
| 1.7                  | -1.808 | .5903  | .8392  | .8494  | .7785  |
| 1.8                  | -1.529 | .6580  | .8837  | .8933  | .8450  |
| 1.9                  | -1.271 | .7173  | .9172  | .9261  | .8947  |
| 2.0                  | -1.024 | .7686  | .9422  | .9500  | .9305  |
| 2.2                  | -.5804 | .8489  | .9735  | .9783  | .9718  |
| 2.4                  | -.2039 | .9046  | .9882  | .9914  | .9896  |
| 2.6                  | +.1020 | .9412  | .9951  | .9970  | .9966  |
| 2.8                  | +.3451 | .9648  | .9979  | .9992  | .9991  |
| 3.0                  | .5333  | .9795  | .9993  | 1.0000 | 1.0000 |
| 3.4                  | .7804  | .9933  | 1.0000 |        |        |
| 3.8                  | .9059  | .9982  |        |        |        |
| 4.2                  | .9647  | .9996  |        |        |        |
| 4.6                  | .9882  | 1.0000 |        |        |        |
| 5.0                  | 1.0000 |        |        |        |        |

TABLE 7

## RADIAL VELOCITY U OF AXISYMMETRIC WAKE FLOWS

| $ R $                | .0720 | .7412 | 1.539 | 3.414 | 6.554 | 8.692 |
|----------------------|-------|-------|-------|-------|-------|-------|
| $R \frac{dU}{d\eta}$ | .1    | 1     | 2     | 4     | 6.2   | 7     |
| $\sigma$             | 2.23  | 2.29  | 2.38  | 2.62  | 3.14  | 3.55  |
| $\eta$               |       |       |       |       |       |       |
| 0                    | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 |
| .1                   | .1362 | .1323 | .1274 | .1149 | .0927 | .0790 |
| .2                   | .2568 | .2495 | .2402 | .2166 | .1749 | .1489 |
| .3                   | .3503 | .3403 | .3277 | .2955 | .2386 | .2032 |
| .4                   | .4112 | .3996 | .3850 | .3474 | .2807 | .2391 |
| .5                   | .4407 | .4285 | .4131 | .3735 | .3023 | .2575 |
| .6                   | .4436 | .4320 | .4171 | .3781 | .3073 | .2622 |
| .7                   | .4269 | .4168 | .4035 | .3682 | .3012 | .2578 |
| .8                   | .3972 | .3894 | .3787 | .3489 | .2890 | .2485 |
| .9                   | .3599 | .3548 | .3475 | .3248 | .2740 | .2373 |
| 1.0                  | .3189 | .3169 | .3133 | .2991 | .2586 | .2262 |
| 1.1                  | .2774 | .2782 | .2782 | .2723 | .2435 | .2158 |
| 1.2                  | .2368 | .2403 | .2437 | .2460 | .2289 | .2063 |
| 1.3                  | .1989 | .2044 | .2105 | .2203 | .2148 | .1975 |
| 1.4                  | .1643 | .1713 | .1795 | .1954 | .2013 | .1893 |
| 1.5                  | .1335 | .1414 | .1510 | .1716 | .1877 | .1811 |
| 1.6                  | .1067 | .1149 | .1252 | .1491 | .1742 | .1731 |
| 1.7                  | .0840 | .0920 | .1023 | .1281 | .1607 | .1650 |
| 1.8                  | .0651 | .0725 | .0824 | .1086 | .1472 | .1566 |
| 1.9                  | .0496 | .0563 | .0654 | .0910 | .1337 | .1481 |
| 2.0                  | .0372 | .0430 | .0511 | .0752 | .1204 | .1392 |
| 2.2                  | .0200 | .0240 | .0299 | .0492 | .0948 | .1206 |
| 2.4                  | .0101 | .0126 | .0164 | .0304 | .0713 | .1013 |
| 2.6                  | .0048 | .0062 | .0085 | .0177 | .0510 | .0819 |
| 2.8                  | .0021 | .0029 | .0041 | .0096 | .0345 | .0635 |
| 3.0                  | .0009 | .0012 | .0019 | .0050 | .0220 | .0468 |
| 3.4                  | .0001 | .0002 | .0003 | .0011 | .0074 | .0215 |
| 3.8                  |       |       |       | .0002 | .0019 | .0077 |
| 4.2                  |       |       |       |       | .0004 | .0021 |
| 4.6                  |       |       |       |       | .0001 | .0005 |
| 5.0                  |       |       |       |       |       | .0001 |

TABLE 8

## AXIAL VELOCITY W OF AXISYMMETRIC WAKE FLOWS

| $R$                  | .0720  | .7412  | 1.539  | 3.414  | 6.554  | 8.692  |
|----------------------|--------|--------|--------|--------|--------|--------|
| $R \frac{dU}{d\eta}$ | .1     | 1      | 2      | 4      | 6.2    | 7      |
| $\sigma$             | 2.23   | 2.29   | 2.38   | 2.62   | 3.14   | 3.55   |
| $\eta$               |        |        |        |        |        |        |
| 0                    | .0000  | .0000  | .0000  | .0000  | .0000  | .0000  |
| .1                   | .0138  | .0134  | .0129  | .0116  | .0094  | .0080  |
| .2                   | .0534  | .0519  | .0500  | .0451  | .0364  | .0310  |
| .3                   | .1146  | .1114  | .1072  | .0967  | .0781  | .0665  |
| .4                   | .1913  | .1859  | .1790  | .1615  | .1304  | .1110  |
| .5                   | .2770  | .2692  | .2593  | .2339  | .1890  | .1609  |
| .6                   | .3658  | .3556  | .3426  | .3094  | .2502  | .2131  |
| .7                   | .4531  | .4406  | .4250  | .3842  | .3113  | .2653  |
| .8                   | .5358  | .5216  | .5033  | .4561  | .3702  | .3159  |
| .9                   | .6117  | .5961  | .5761  | .5235  | .4266  | .3645  |
| 1.0                  | .6794  | .6632  | .6421  | .5858  | .4800  | .4107  |
| 1.1                  | .7392  | .7226  | .7013  | .6432  | .5301  | .4549  |
| 1.2                  | .7906  | .7744  | .7534  | .6948  | .5774  | .4972  |
| 1.3                  | .8339  | .8189  | .7989  | .7417  | .6216  | .5375  |
| 1.4                  | .8703  | .8564  | .8377  | .7832  | .6634  | .5762  |
| 1.5                  | .9000  | .8877  | .8707  | .8196  | .7022  | .6132  |
| 1.6                  | .9239  | .9131  | .8984  | .8518  | .7385  | .6486  |
| 1.7                  | .9428  | .9339  | .9210  | .8793  | .7717  | .6825  |
| 1.8                  | .9578  | .9504  | .9395  | .9033  | .8026  | .7147  |
| 1.9                  | .9692  | .9630  | .9541  | .9233  | .8306  | .7451  |
| 2.0                  | .9778  | .9730  | .9658  | .9397  | .8560  | .7738  |
| 2.2                  | .9889  | .9860  | .9817  | .9643  | .8990  | .8258  |
| 2.4                  | .9947  | .9933  | .9908  | .9801  | .9323  | .8702  |
| 2.6                  | .9975  | .9968  | .9956  | .9895  | .9567  | .9068  |
| 2.8                  | .9989  | .9987  | .9981  | .9947  | .9735  | .9358  |
| 3.0                  | .9994  | .9995  | .9991  | .9977  | .9847  | .9579  |
| 3.4                  | .9997  | .9997  | .9999  | .9994  | .9957  | .9844  |
| 3.8                  | 1.0000 | 1.0000 | 1.0000 | 1.0000 | .9991  | .9954  |
| 4.2                  |        |        |        |        | .9997  | .9988  |
| 4.6                  |        |        |        |        | 1.0000 | .9998  |
| 5.0                  |        |        |        |        |        | 1.0000 |

TABLE 9

## PRESSURE DISTRIBUTION P OF AXISYMMETRIC WAKE FLOWS

| $ R $                | .0720 | .7412  | 1.539 | 3.414 | 6.554 | 8.692 |
|----------------------|-------|--------|-------|-------|-------|-------|
| $R \frac{dU}{d\eta}$ | .1    | 1      | 2     | 4     | 6.2   | 7     |
| $\sigma$             | 2.23  | 2.29   | 2.38  | 2.62  | 3.14  | 3.55  |
| $\eta$               |       |        |       |       |       |       |
| 0                    | 92.46 | 9.196  | 4.594 | 2.271 | 1.432 | 1.246 |
| .1                   | 84.82 | 8.4759 | 4.259 | 2.135 | 1.375 | 1.210 |
| .2                   | 77.46 | 7.7848 | 3.938 | 2.006 | 1.321 | 1.175 |
| .3                   | 70.58 | 7.146  | 3.645 | 1.890 | 1.274 | 1.145 |
| .4                   | 64.24 | 6.567  | 3.386 | 1.793 | 1.236 | 1.122 |
| .5                   | 58.37 | 6.047  | 3.160 | 1.714 | 1.210 | 1.107 |
| .6                   | 52.85 | 5.571  | 2.962 | 1.652 | 1.192 | 1.098 |
| .7                   | 47.57 | 5.126  | 2.782 | 1.602 | 1.182 | 1.093 |
| .8                   | 42.44 | 4.701  | 2.616 | 1.559 | 1.176 | 1.092 |
| .9                   | 37.46 | 4.290  | 2.454 | 1.519 | 1.171 | 1.092 |
| 1.0                  | 32.68 | 3.892  | 2.297 | 1.480 | 1.167 | 1.093 |
| 1.1                  | 28.15 | 3.512  | 2.145 | 1.441 | 1.163 | 1.093 |
| 1.2                  | 23.92 | 3.153  | 2.000 | 1.401 | 1.158 | 1.093 |
| 1.3                  | 20.08 | 2.820  | 1.862 | 1.362 | 1.152 | 1.092 |
| 1.4                  | 16.65 | 2.517  | 1.734 | 1.323 | 1.145 | 1.091 |
| 1.5                  | 13.62 | 2.246  | 1.616 | 1.285 | 1.138 | 1.090 |
| 1.6                  | 11.08 | 2.009  | 1.509 | 1.249 | 1.130 | 1.088 |
| 1.7                  | 8.846 | 1.804  | 1.417 | 1.214 | 1.121 | 1.085 |
| 1.8                  | 7.077 | 1.630  | 1.334 | 1.183 | 1.112 | 1.082 |
| 1.9                  | 5.615 | 1.486  | 1.265 | 1.153 | 1.103 | 1.078 |
| 2.0                  | 4.462 | 1.370  | 1.207 | 1.127 | 1.093 | 1.075 |
| 2.2                  | 2.846 | 1.203  | 1.121 | 1.083 | 1.057 | 1.066 |
| 2.4                  | 1.923 | 1.109  | 1.066 | 1.052 | 1.041 | 1.056 |
| 2.6                  | 1.462 | 1.051  | 1.034 | 1.030 | 1.028 | 1.046 |
| 2.8                  | 1.231 | 1.022  | 1.017 | 1.016 | 1.018 | 1.036 |
| 3.0                  | 1.077 | 1.007  | 1.007 | 1.009 | 1.006 | 1.027 |
| 3.4                  | 1.000 | 1.000  | 1.002 | 1.002 | 1.002 | 1.013 |
| 3.8                  |       |        | 1.000 | 1.000 | 1.000 | 1.005 |
| 4.2                  |       |        |       |       |       | 1.001 |
| 4.6                  |       |        |       |       |       | 1.000 |
| 5.0                  |       |        |       |       |       |       |

TABLE 10

## HORIZONTAL VELOCITY U OF PLANE WAKE FLOWS

| $ R $                | .0728 | .7443 | 1.536 | 3.378 | 4.831 | 6.139 |
|----------------------|-------|-------|-------|-------|-------|-------|
| $R \frac{dU}{d\eta}$ | .1    | 1     | 2     | 4     | 5.2   | 6     |
| $\sigma$             | 3.659 | 3.785 | 3.965 | 4.37  | 4.62  | 4.78  |
| $\eta$               |       |       |       |       |       |       |
| 0                    | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 |
| .1                   | .1355 | .1326 | .1285 | .1168 | .1062 | .0964 |
| .2                   | .2607 | .2549 | .2469 | .2244 | .2039 | .1850 |
| .3                   | .3668 | .3586 | .3471 | .3150 | .2861 | .2595 |
| .4                   | .4494 | .4387 | .4241 | .3840 | .3480 | .3154 |
| .5                   | .5068 | .4939 | .4766 | .4298 | .3887 | .3517 |
| .6                   | .5410 | .5261 | .5066 | .4547 | .4101 | .3703 |
| .7                   | .5560 | .5396 | .5182 | .4627 | .4159 | .3747 |
| .8                   | .5562 | .5386 | .5161 | .4586 | .4109 | .3694 |
| .9                   | .5457 | .5276 | .5047 | .4467 | .3993 | .3584 |
| 1.0                  | .5279 | .5101 | .4876 | .4307 | .3846 | .3450 |
| 1.1                  | .5056 | .4886 | .4673 | .4133 | .3691 | .3312 |
| 1.2                  | .4800 | .4647 | .4452 | .3952 | .3540 | .3181 |
| 1.3                  | .4525 | .4395 | .4223 | .3777 | .3397 | .3062 |
| 1.4                  | .4238 | .4134 | .3992 | .3606 | .3264 | .2957 |
| 1.5                  | .3947 | .3869 | .3760 | .3443 | .3142 | .2862 |
| 1.6                  | .3655 | .3606 | .3530 | .3283 | .3026 | .2777 |
| 1.7                  | .3365 | .3344 | .3302 | .3126 | .2917 | .2698 |
| 1.8                  | .3081 | .3087 | .3077 | .2972 | .2811 | .2623 |
| 1.9                  | .2805 | .2836 | .2857 | .2823 | .2708 | .2553 |
| 2.0                  | .2539 | .2593 | .2641 | .2674 | .2606 | .2482 |
| 2.2                  | .2048 | .2136 | .2230 | .2382 | .2403 | .2349 |
| 2.4                  | .1617 | .1725 | .1850 | .2098 | .2202 | .2214 |
| 2.6                  | .1247 | .1365 | .1507 | .1824 | .2001 | .2077 |
| 2.8                  | .0942 | .1058 | .1205 | .1563 | .1800 | .1935 |
| 3.0                  | .0696 | .0803 | .0945 | .1319 | .1600 | .1789 |
| 3.4                  | .0356 | .0434 | .0546 | .0892 | .1214 | .1485 |
| 3.8                  | .0167 | .0216 | .0291 | .0560 | .0866 | .1177 |
| 4.2                  | .0072 | .0098 | .0142 | .0325 | .0576 | .0880 |
| 4.6                  | .0028 | .0041 | .0064 | .0173 | .0355 | .0616 |
| 5.0                  | .0010 | .0016 | .0026 | .0085 | .0201 | .0401 |

TABLE 11

## VERTICAL VELOCITY W OF PLANE WAKE FLOWS

| R                    | .0728  | .7443  | 1.536  | 3.378  | 4.831  | 6.139  |
|----------------------|--------|--------|--------|--------|--------|--------|
| $R \frac{dU}{d\eta}$ | .1     | 1      | 2      | 4      | 5.2    | 6      |
| $\sigma$             | 3.659  | 3.785  | 3.965  | 4.37   | 4.62   | 4.78   |
| $\eta$               |        |        |        |        |        |        |
| 0                    | .0000  | .0000  | .0000  | .0000  | .0000  | .0000  |
| .1                   | .0068  | .0067  | .0065  | .0059  | .0053  | .0049  |
| .2                   | .0268  | .0262  | .0254  | .0231  | .0209  | .0190  |
| .3                   | .0583  | .0570  | .0552  | .0502  | .0456  | .0414  |
| .4                   | .0993  | .0971  | .0940  | .0854  | .0775  | .0703  |
| .5                   | .1474  | .1439  | .1393  | .1262  | .1145  | .1038  |
| .6                   | .2000  | .1951  | .1886  | .1706  | .1546  | .1400  |
| .7                   | .2549  | .2486  | .2400  | .2166  | .1960  | .1774  |
| .8                   | .3107  | .3026  | .2917  | .2627  | .2374  | .2147  |
| .9                   | .3657  | .3559  | .3428  | .3079  | .2780  | .2510  |
| 1.0                  | .4196  | .4079  | .3925  | .3520  | .3171  | .2862  |
| 1.1                  | .4712  | .4579  | .4403  | .3940  | .3548  | .3201  |
| 1.2                  | .5205  | .5054  | .4859  | .4346  | .3910  | .3525  |
| 1.3                  | .5672  | .5507  | .5293  | .4731  | .4256  | .3838  |
| 1.4                  | .6110  | .5933  | .5704  | .5101  | .4589  | .4137  |
| 1.5                  | .6520  | .6333  | .6091  | .5453  | .4910  | .4429  |
| 1.6                  | .6899  | .6707  | .6456  | .5790  | .5218  | .4711  |
| 1.7                  | .7250  | .7055  | .6797  | .6110  | .5514  | .4985  |
| 1.8                  | .7573  | .7376  | .7116  | .6415  | .5802  | .5250  |
| 1.9                  | .7867  | .7673  | .7415  | .6705  | .6077  | .5509  |
| 2.0                  | .8133  | .7944  | .7689  | .6980  | .6342  | .5762  |
| 2.2                  | .8592  | .8416  | .8177  | .7484  | .6843  | .6244  |
| 2.4                  | .8958  | .8802  | .8581  | .7934  | .7305  | .6700  |
| 2.6                  | .9242  | .9109  | .8919  | .8324  | .7725  | .7130  |
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| 5.0                  | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 |

TABLE 12

## PRESSURE DISTRIBUTION P OF PLANE WAKE FLOWS

| $R$                  | .0728 | .7443 | 1.536 | 3.378 | 4.831 | 6.139 |
|----------------------|-------|-------|-------|-------|-------|-------|
| $R \frac{dU}{d\eta}$ | .1    | 1     | 2     | 4     | 5.2   | 5     |
| $\sigma$             | 3.659 | 3.785 | 3.965 | 4.37  | 4.62  | 4.73  |
| $\eta$               |       |       |       |       |       |       |
| 0                    | 73.19 | 7.272 | 3.674 | 1.876 | 1.458 | 1.266 |
| .1                   | 69.37 | 6.912 | 3.505 | 1.806 | 1.413 | 1.234 |
| .2                   | 65.70 | 6.566 | 3.343 | 1.739 | 1.371 | 1.204 |
| .3                   | 62.28 | 6.247 | 3.195 | 1.679 | 1.333 | 1.177 |
| .4                   | 59.17 | 5.962 | 3.064 | 1.628 | 1.302 | 1.155 |
| .5                   | 56.36 | 5.710 | 2.953 | 1.588 | 1.278 | 1.139 |
| .6                   | 53.80 | 5.488 | 2.859 | 1.557 | 1.262 | 1.129 |
| .7                   | 51.40 | 5.289 | 2.779 | 1.535 | 1.251 | 1.123 |
| .8                   | 49.08 | 5.103 | 2.707 | 1.518 | 1.246 | 1.121 |
| .9                   | 46.79 | 4.923 | 2.642 | 1.505 | 1.243 | 1.122 |
| 1.0                  | 44.47 | 4.744 | 2.577 | 1.494 | 1.241 | 1.123 |
| 1.1                  | 42.11 | 4.562 | 2.512 | 1.484 | 1.240 | 1.125 |
| 1.2                  | 39.70 | 4.377 | 2.447 | 1.473 | 1.239 | 1.127 |
| 1.3                  | 37.26 | 4.189 | 2.379 | 1.461 | 1.237 | 1.128 |
| 1.4                  | 34.80 | 3.998 | 2.310 | 1.448 | 1.235 | 1.129 |
| 1.5                  | 32.35 | 3.805 | 2.239 | 1.434 | 1.232 | 1.130 |
| 1.6                  | 29.29 | 3.612 | 2.168 | 1.420 | 1.228 | 1.130 |
| 1.7                  | 27.54 | 3.424 | 2.095 | 1.405 | 1.224 | 1.130 |
| 1.8                  | 25.23 | 3.236 | 2.023 | 1.389 | 1.220 | 1.129 |
| 1.9                  | 23.00 | 3.051 | 1.953 | 1.372 | 1.214 | 1.128 |
| 2.0                  | 20.85 | 2.873 | 1.882 | 1.355 | 1.209 | 1.127 |
| 2.2                  | 16.96 | 2.540 | 1.746 | 1.320 | 1.196 | 1.123 |
| 2.4                  | 13.54 | 2.243 | 1.620 | 1.284 | 1.182 | 1.118 |
| 2.6                  | 10.62 | 1.978 | 1.505 | 1.247 | 1.166 | 1.112 |
| 2.8                  | 8.231 | 1.757 | 1.402 | 1.212 | 1.149 | 1.105 |
| 3.0                  | 6.308 | 1.572 | 1.314 | 1.178 | 1.132 | 1.096 |
| 3.4                  | 3.654 | 1.304 | 1.179 | 1.118 | 1.098 | 1.077 |
| 3.8                  | 2.192 | 1.145 | 1.092 | 1.070 | 1.065 | 1.057 |
| 4.2                  | 1.462 | 1.058 | 1.041 | 1.036 | 1.037 | 1.035 |
| 4.6                  | 1.115 | 1.018 | 1.014 | 1.014 | 1.015 | 1.016 |
| 5.0                  | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 |

**APPENDIX B**

$$w(z = \infty) = \text{finite}$$

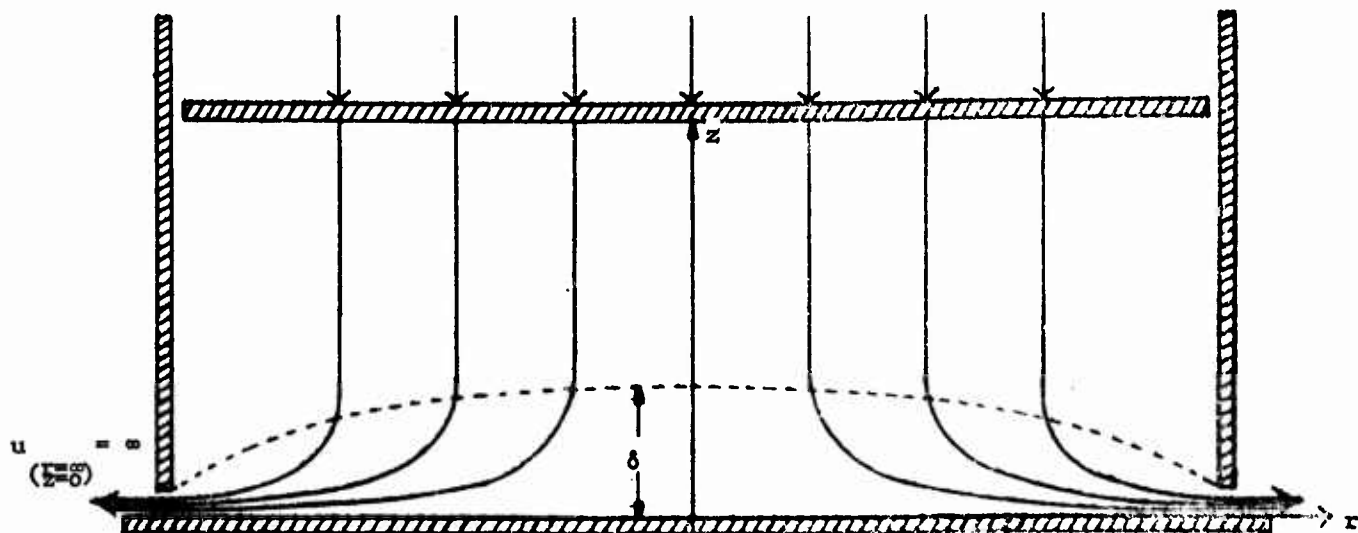


FIGURE 1a: Model of the stagnation flow "normal" to a plate.

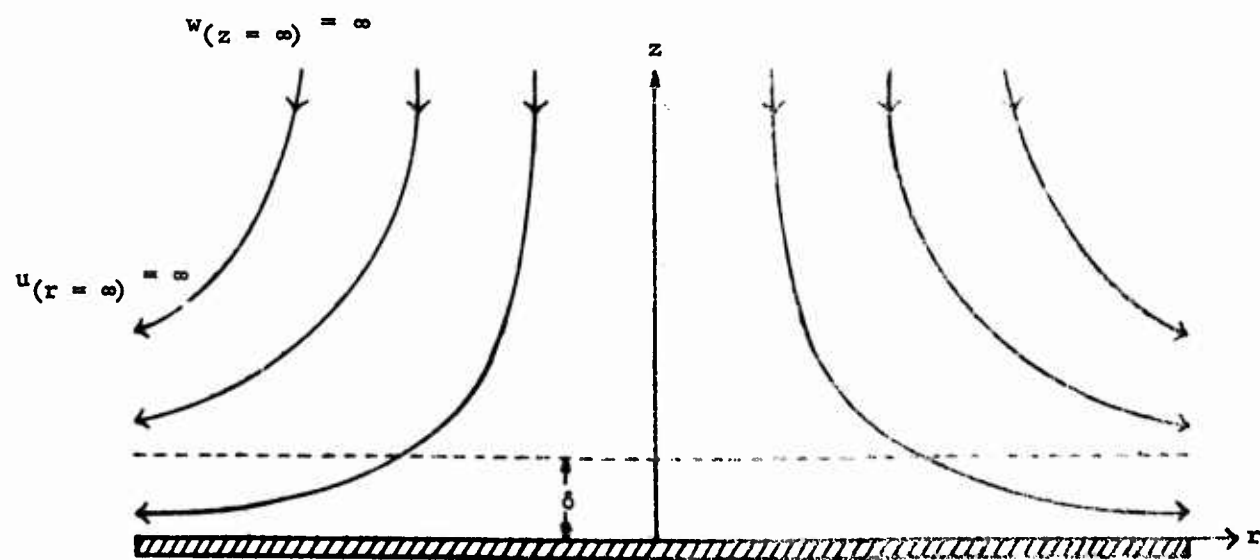


FIGURE 1b: Model of the classical stagnation flow "past" a plate.

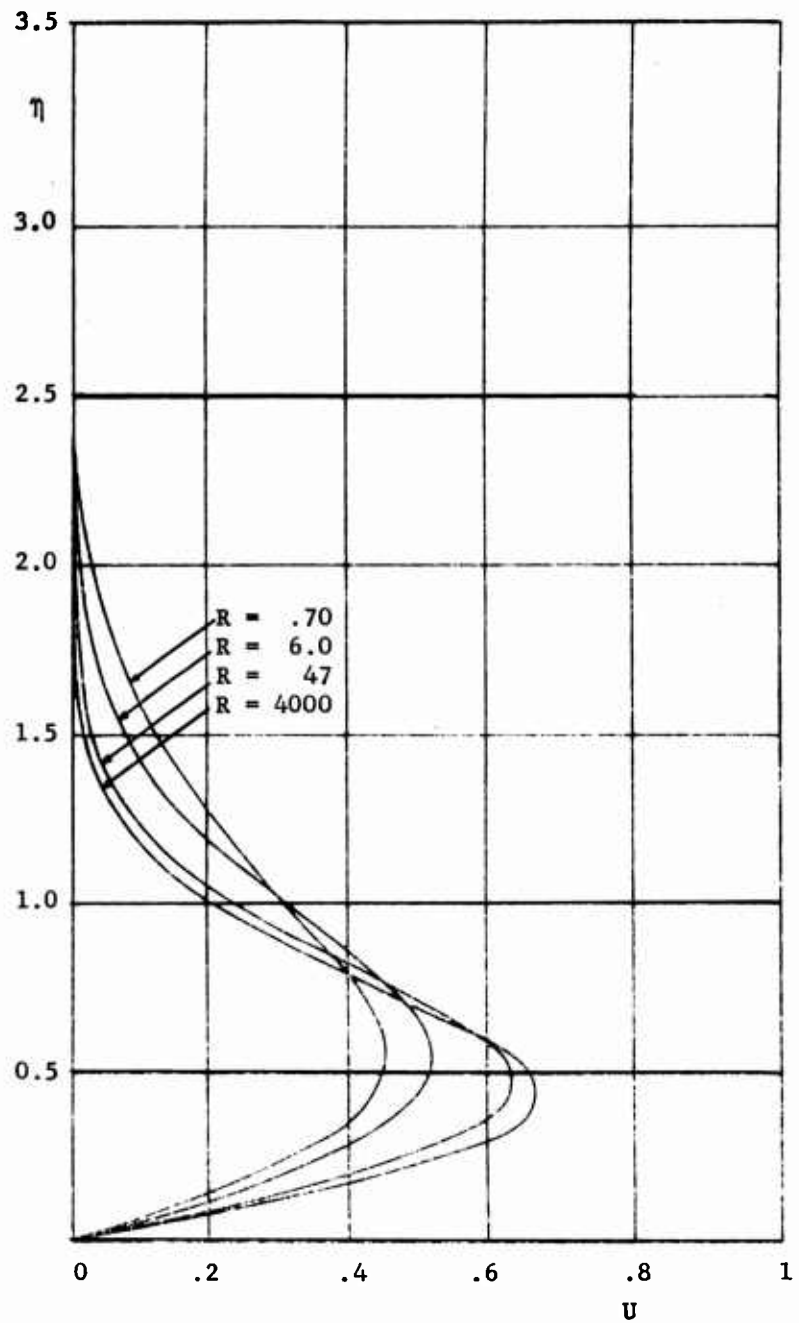
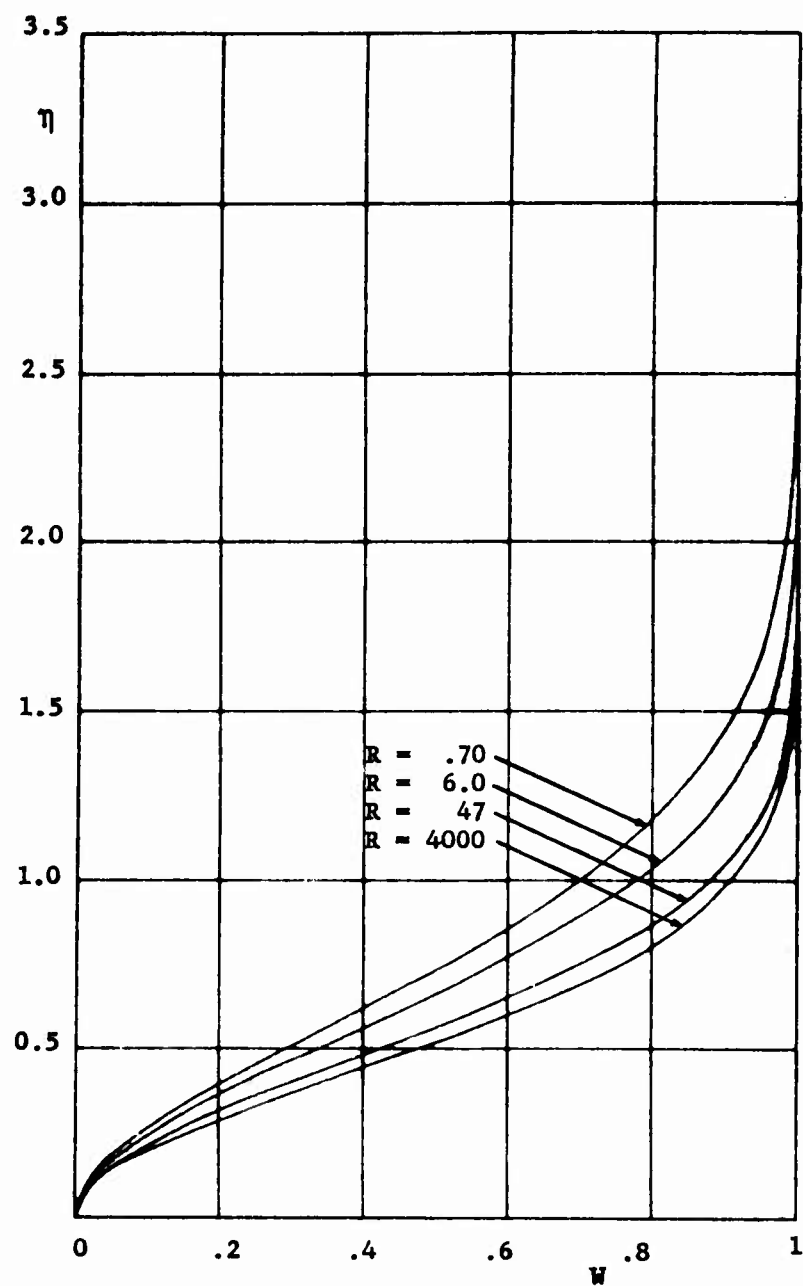


FIGURE 2: The radial velocity  $U$  of axisymmetric stagnation flows vs. the dimensionless variable  $\eta$  for four different Reynolds numbers  $R$ .



**FIGURE 3:** The axial velocity  $W$  of axisymmetric stagnation flows vs the dimensionless variable  $\eta$  for four different Reynolds numbers  $R$ .

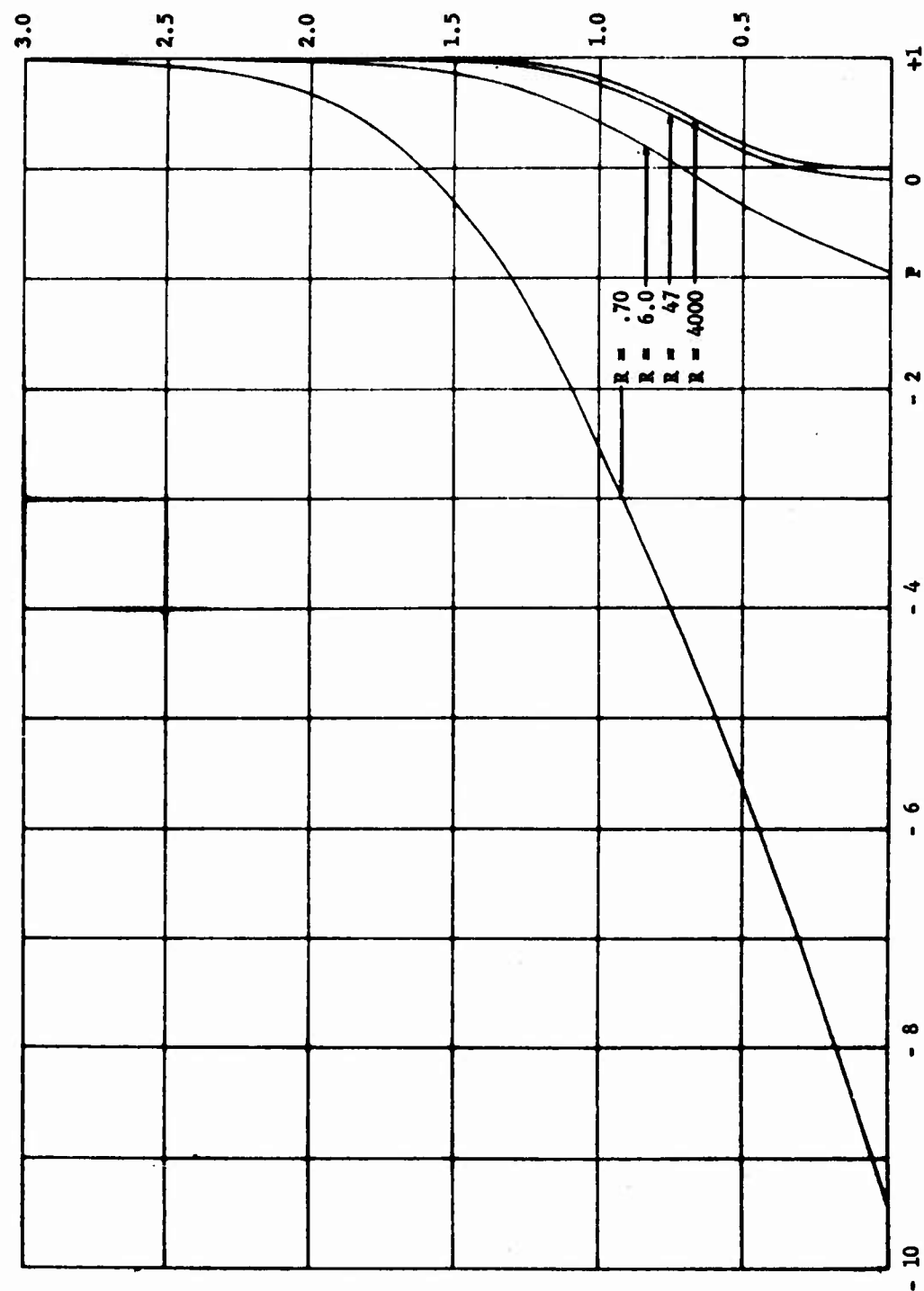


FIGURE 4: Pressure distribution  $P$  of axisymmetric stagnation flows vs. the dimensionless variable  $\eta$  for four different Reynolds numbers  $R$ .

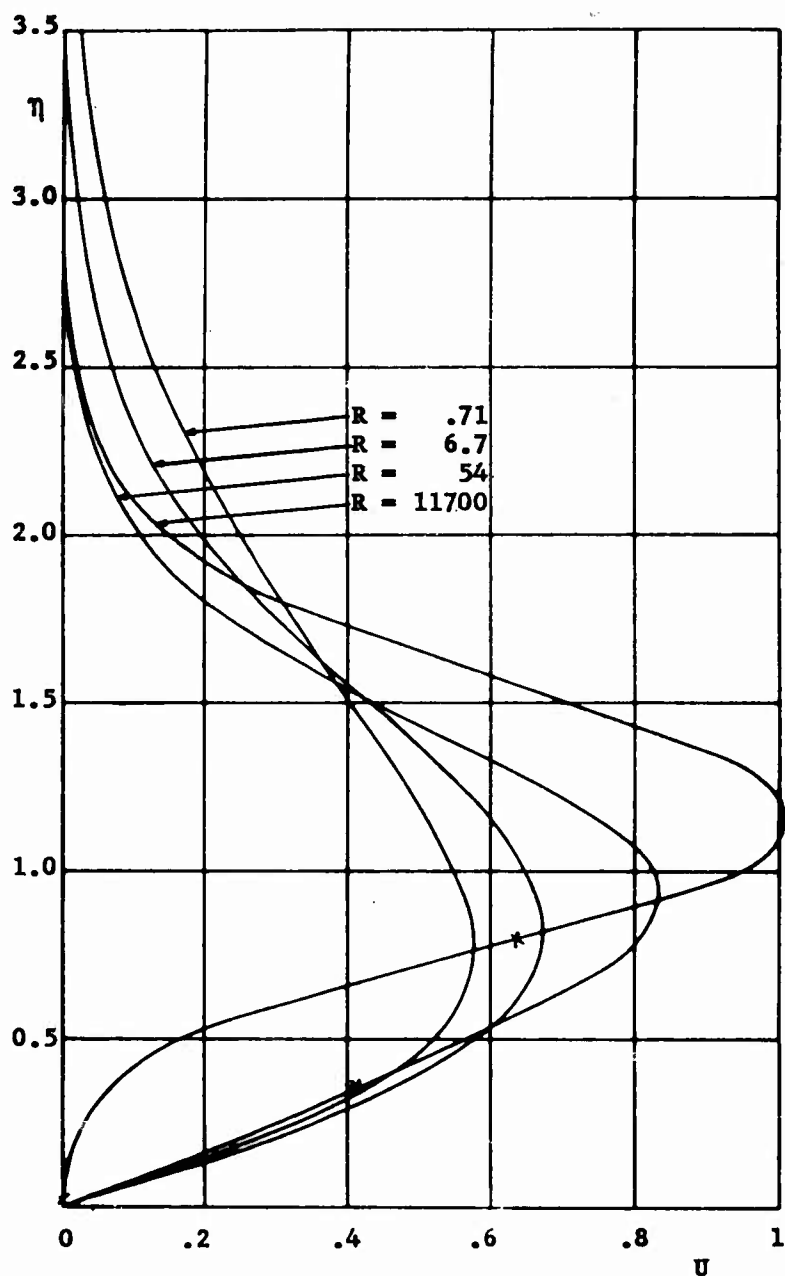


FIGURE 5: The horizontal velocity  $U$  of plane stagnation flows vs. the dimensionless variable  $\eta$  for four different Reynolds numbers  $R$ . (\*Inflection point of instability)

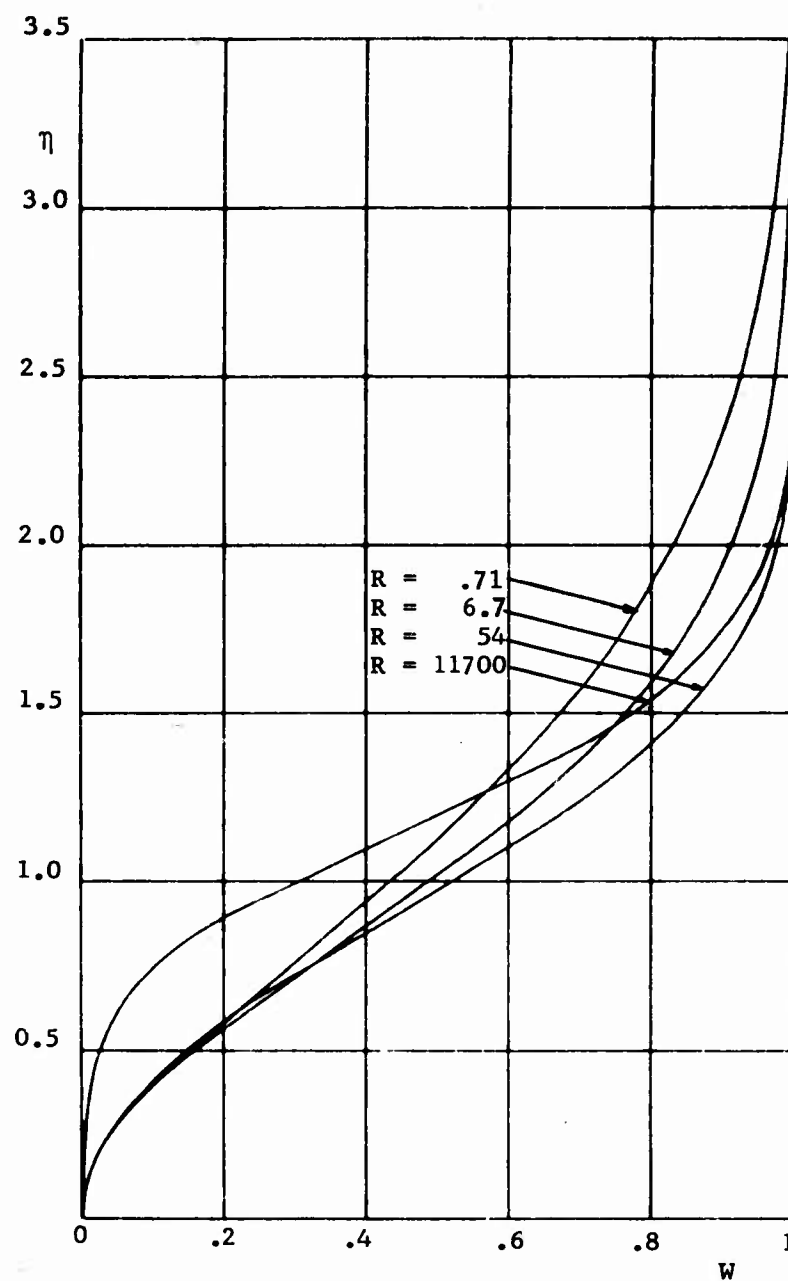


FIGURE 6: The vertical velocity  $W$  of plane stagnation flows vs. the dimensionless variable  $\eta$  for four different Reynolds numbers  $R$ .

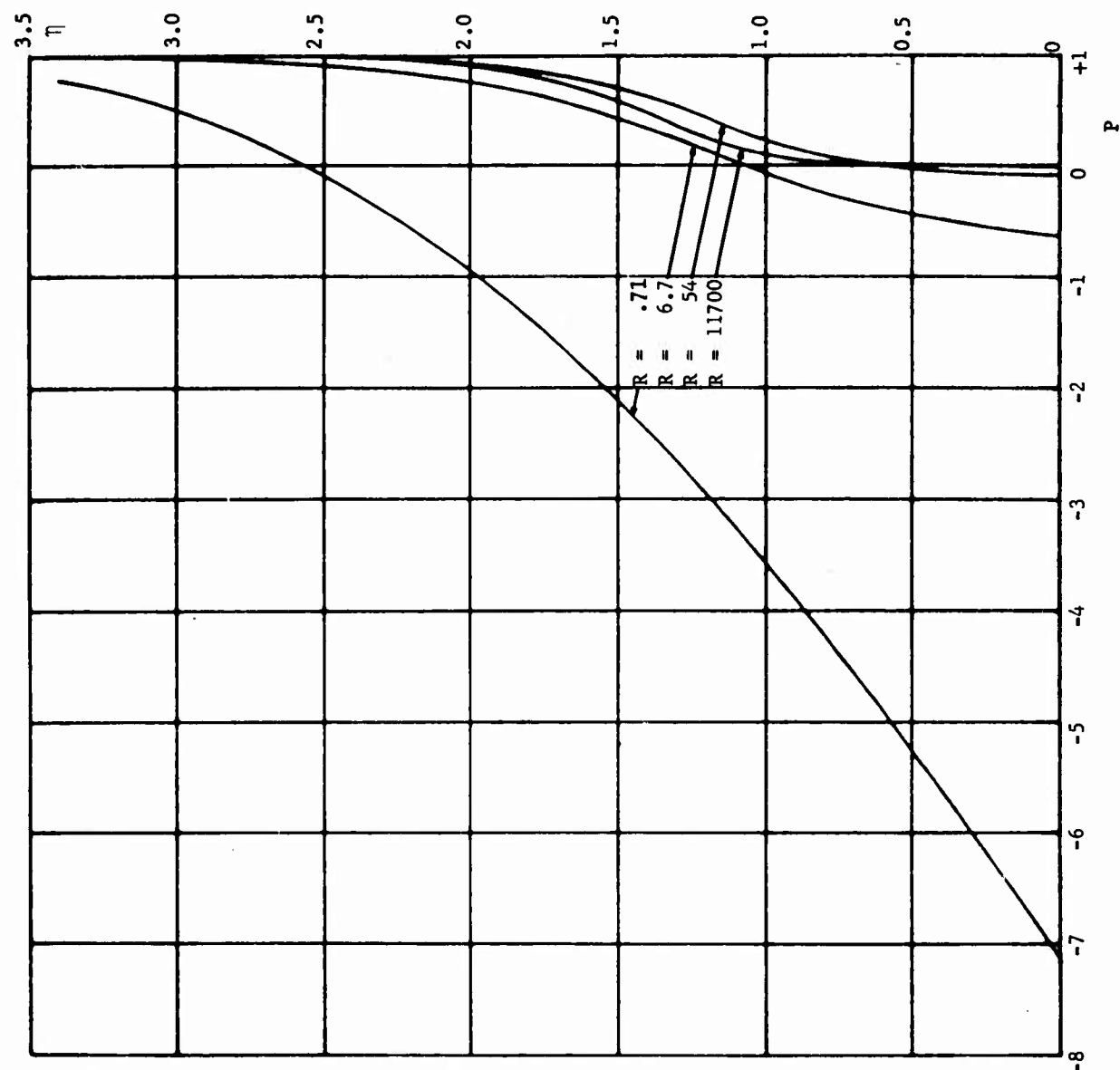
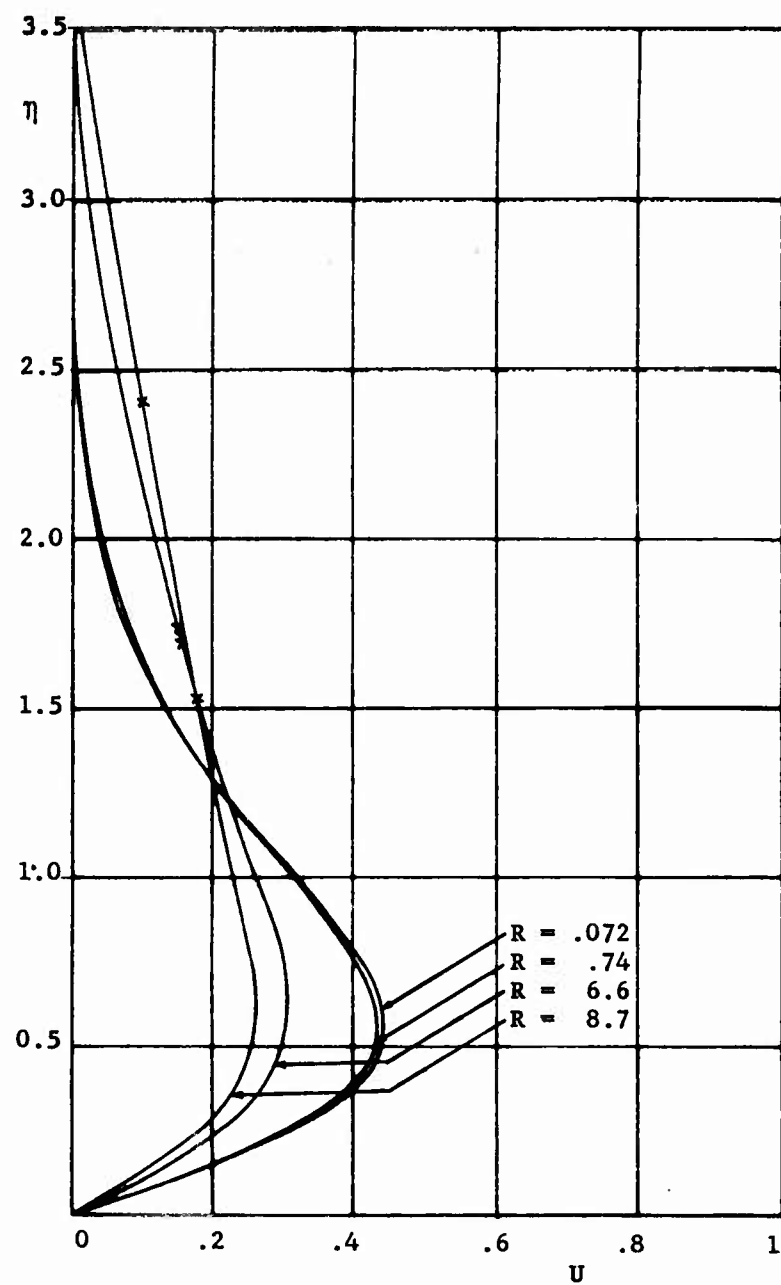


FIGURE 7: Pressure distribution  $P$  of plane stagnation flows vs. the dimensionless variable  $\eta$  for four different Reynolds numbers  $R$ .



**FIGURE 8:** The radial velocity  $U$  of axisymmetric wake flows vs. the dimensionless variable  $\eta$  for four different Reynolds numbers  $R$ . (\*Inflection point of instability)

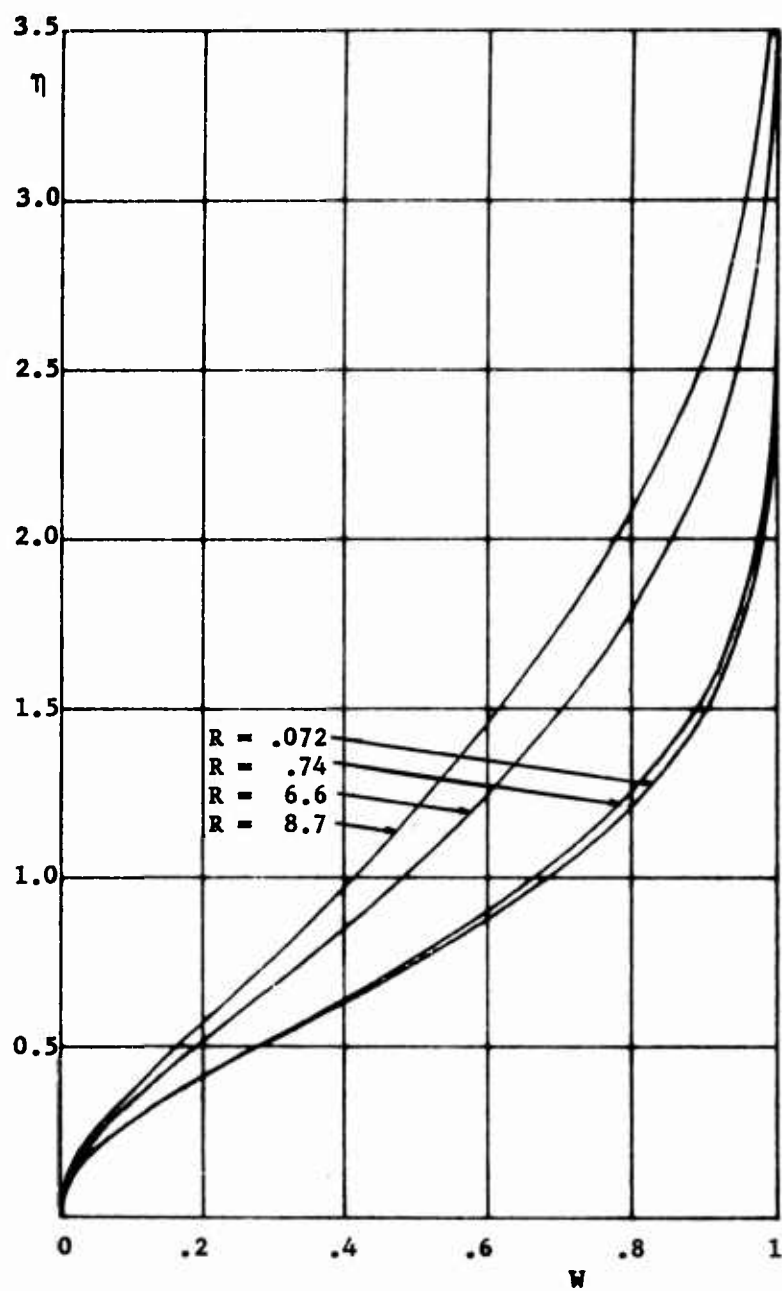


FIGURE 9: The axial velocity  $W$  of axisymmetric wake flows vs. the dimensionless variable  $\eta$  for four different Reynolds numbers  $R$ .

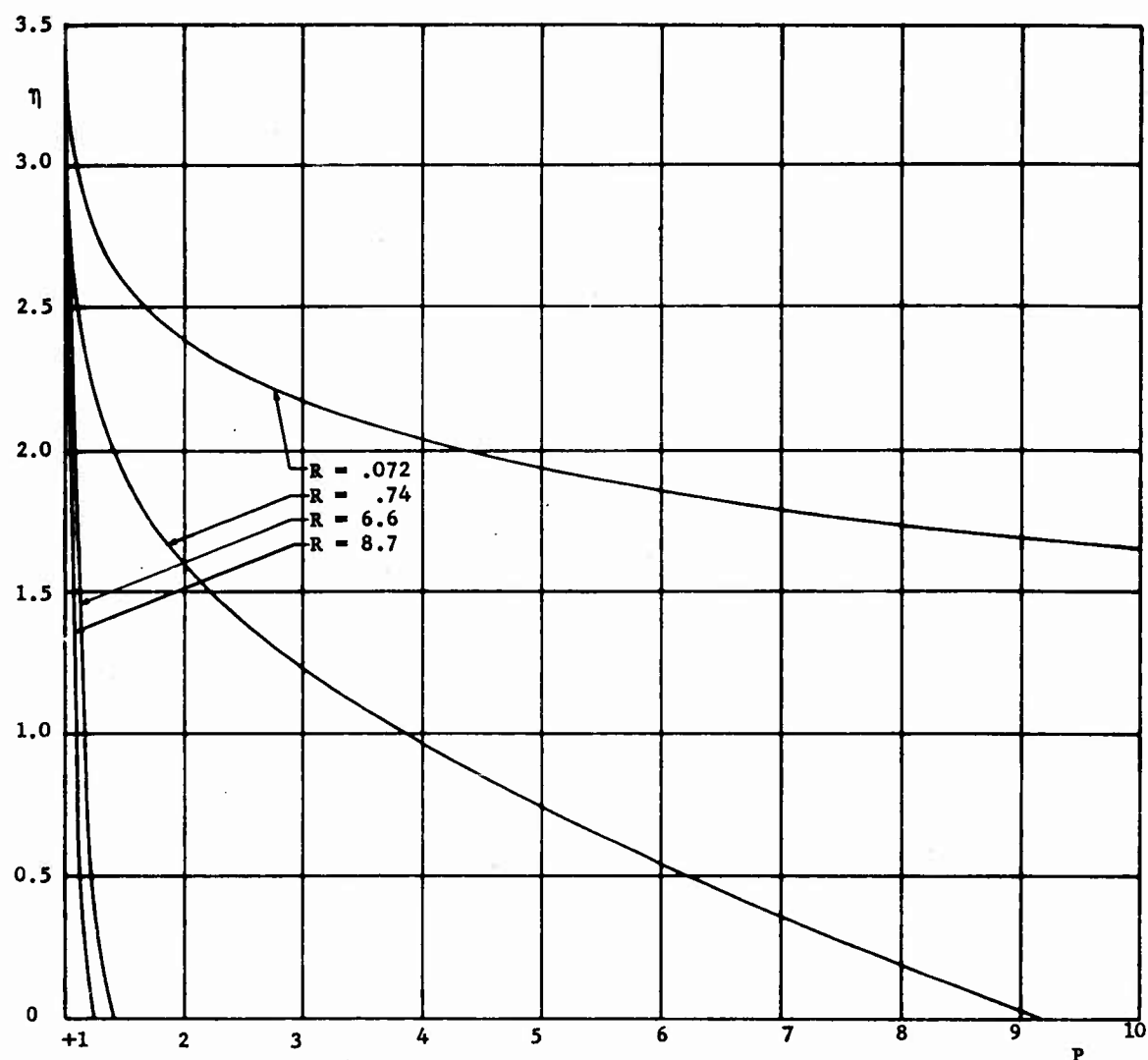


FIGURE 10: The pressure distribution  $P$  of axisymmetric wake flows vs. the dimensionless variable  $\eta$  for four different Reynolds numbers  $R$ .

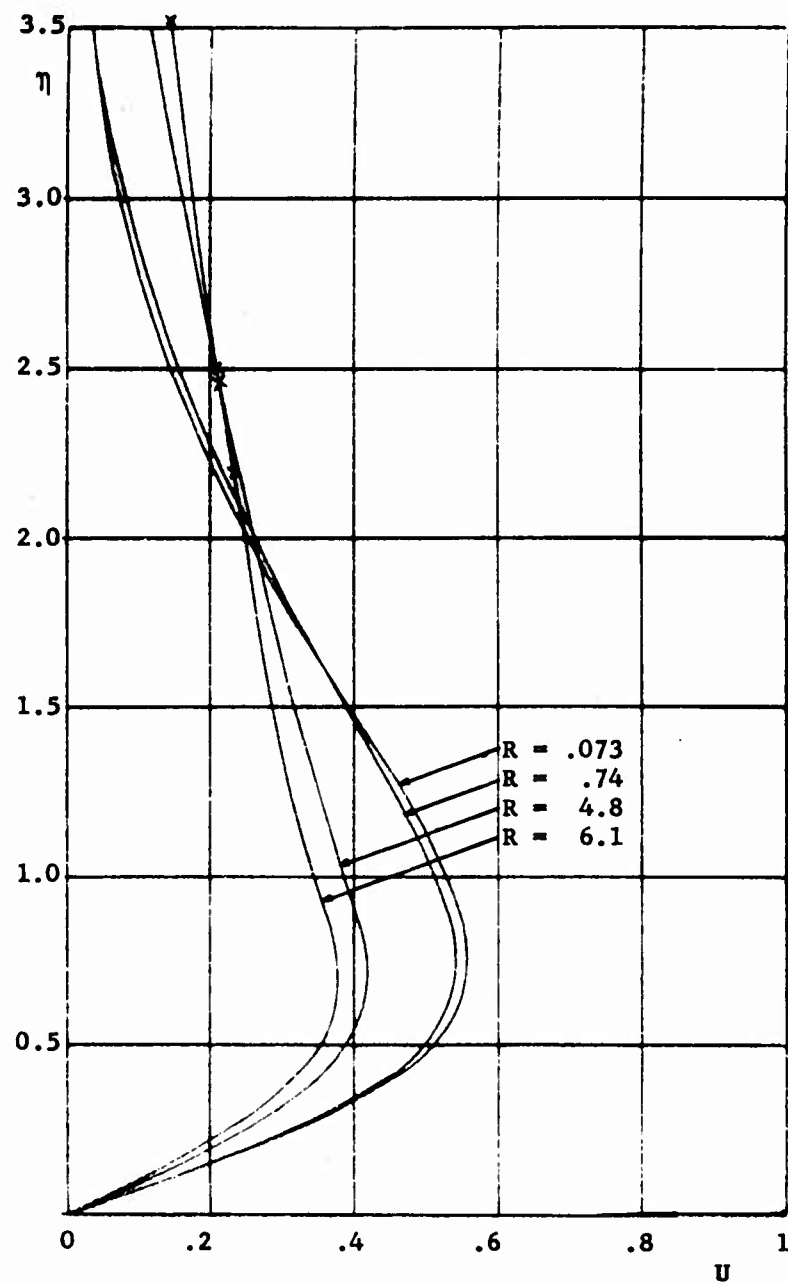


FIGURE 11: The horizontal velocity  $U$  of plane wake flows vs. the dimensionless variable  $\eta$  for four different Reynolds numbers  $R$ . (\*Inflection point of instability)

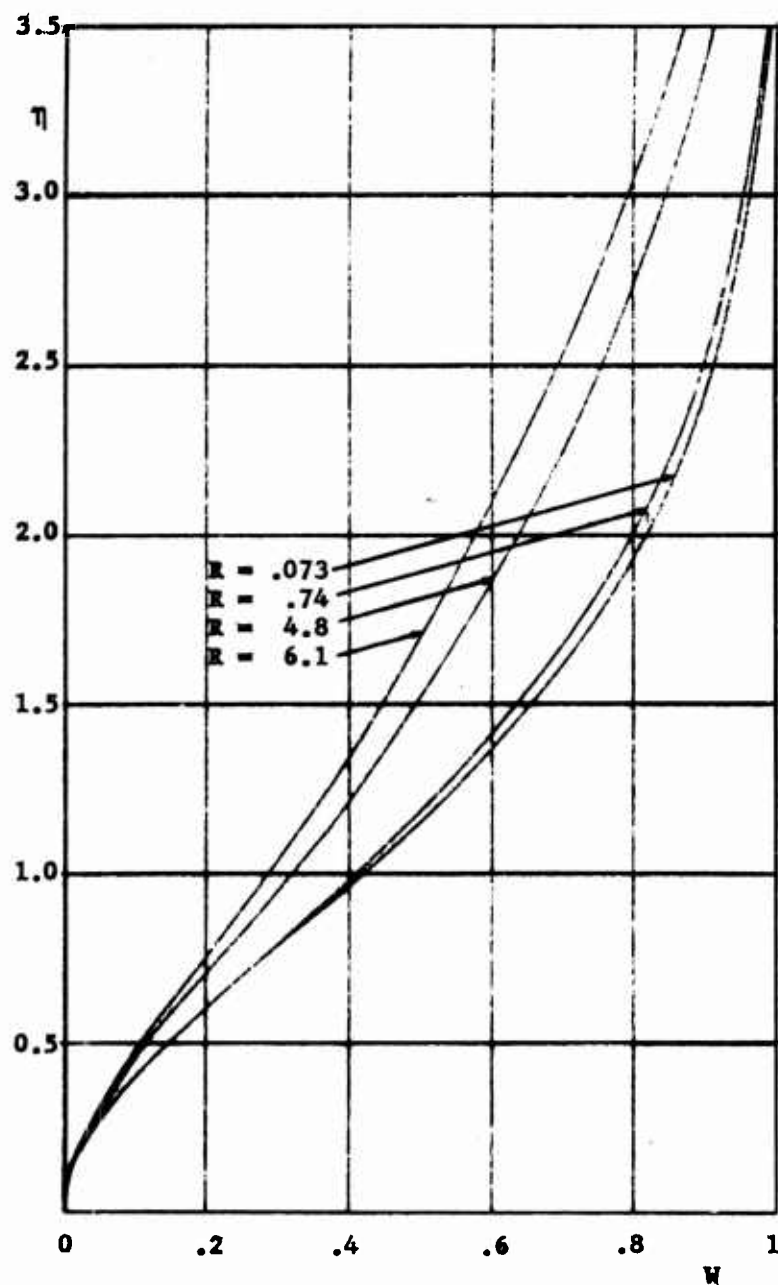


FIGURE 12: The vertical velocity  $W$  of plane wake flows vs. the dimensionless variable  $\eta$  for four different Reynolds numbers  $R$ .

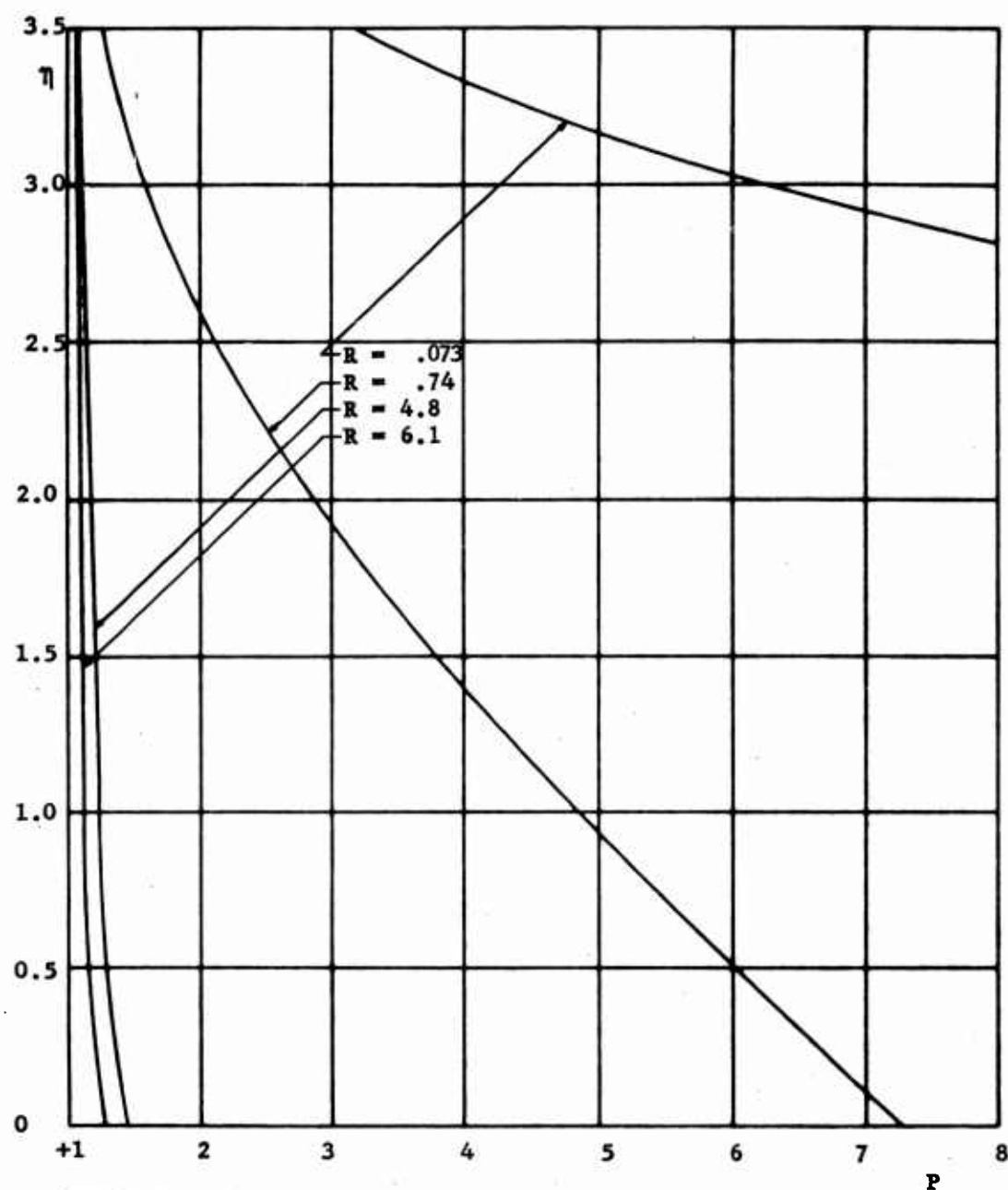


FIGURE 13: The pressure distribution  $P$  of plane wake flows vs. the dimensionless variable  $\eta$  for four different Reynolds numbers  $R$ .

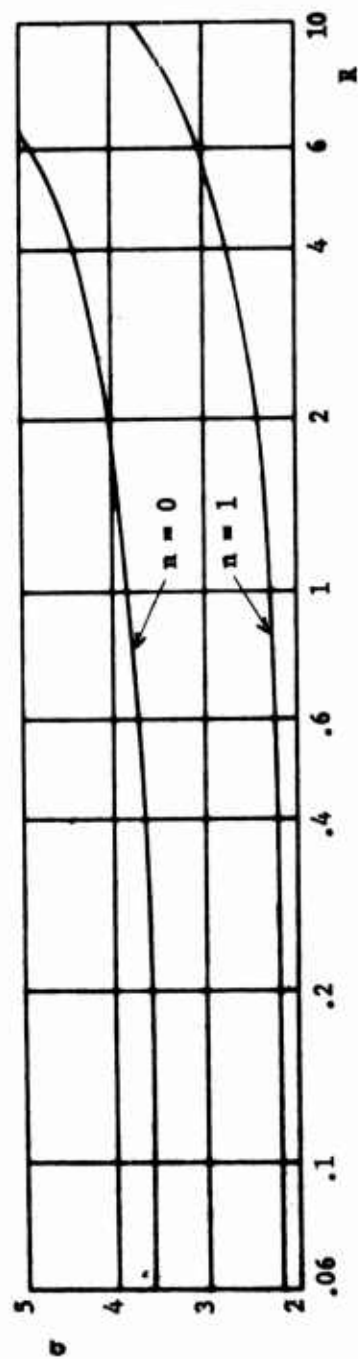


FIGURE 15: The characteristic number  $\sigma$  of axisymmetric ( $n = 1$ ) and plane ( $n = 0$ ) wake flows for an accuracy of 1% vs. the Reynolds number  $R$ .

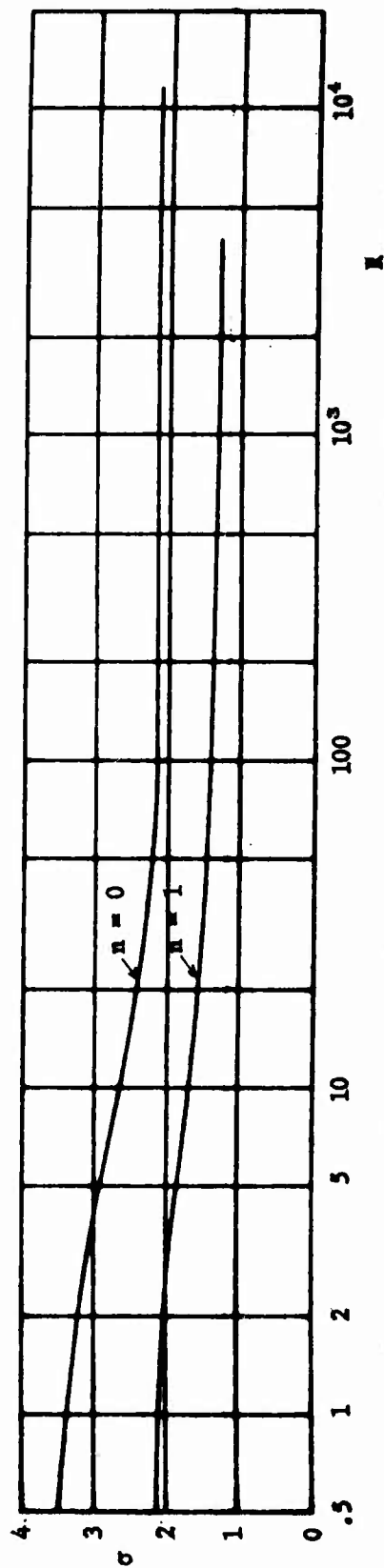


FIGURE 14: The characteristic number  $\sigma$  of axisymmetric ( $n = 1$ ) and plane ( $n = 0$ ) stagnation flows for an accuracy of 1% vs. the Reynolds number  $R$ .

**APPENDIX C**

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