

A NEW SLOTTED-WALL METHOD
FOR PRODUCING
LOW BOUNDARY CORRECTIONS IN
TWO-DIMENSIONAL AIRFOIL TESTING

by

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ABSTRACT

This thesis deals with a new approach to reducing windtunnel wall corrections in airfoil testing, by employing a transversely-slotted wall opposite the suction side of the airfoil, and a solid wall opposite the pressure side. The solid elements of the slotted wall are symmetrical airfoils at zero incidence. This geometry permits the flow to assume closely the streamline pattern for unconfined flow, without degrading the flow quality through shear layer mixing near the test airfoil. The theory uses the potential flow surface source-element method, with Kutta conditions satisfied on the test airfoil and the wall slats. In experiments using a range of sizes of airfoils of three different profiles, good agreement with the predictions of the theory has been obtained. It appears that uncorrected lift coefficients and pressure distributions, accurate to within one percent, can be obtained for a wide range of airfoil shapes, sizes, and lift coefficients, using a slotted wall of open-area ratio between 60 and 70 percent.

RÉSUMÉ

Cette thèse décrit une nouvelle méthode en vue de diminuer les corrections de parois en soufflerie aux essais des ailes. Cette méthode emploie un mur à fente transversale, en face du flanc de dépression de l'aile d'essai; et un mur solide, en face du flanc de pression. Les éléments solides du mur à fente sont de profils aérodynamiques et symétriques à l'angle d'incidence zéro. Cette figure géométrique permet l'écoulement d'air, suivie de près par les lignes de courant, de l'écoulement libre; ce résultat est obtenu sans diminuer la qualité de l'écoulement par le mélange de la couche de discontinuité, près de l'aile d'essai. La théorie demande d'utiliser l'écoulement à potentiel des éléments de la source de surface, satisfaisant les conditions Kutta à l'aile d'essai et aux ailes murales. Les expériences ont été faites en employant des ailes de corde de trois profils différents. Les théories obtenues respectent assez bien les hypothèses préétablies. Les coefficients portances non vérifiés, et les distributions de pressions sont exacts à un pourcent près; et ils peuvent être obtenus pour une grande variété de profils, de dimensions et de coefficients portances; en utilisant un mur à fente, de quotient entre la paroi et la surface totale, de soixante à soixante-dix pourcent.

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Notation

A_{ji}, B_{ji}, C_{ji}	matrices of disturbance velocities.
c	airfoil chord
c_{ji}	element of the matrix C_{ji}
$C_D = D/qc$	drag coefficient
$C_L = L/qc$	lift coefficient
$C_{M_0} = M_0/qc^2$	midchord pitching moment
$C_{\frac{M_c}{4}} = \frac{M_c}{4qc^2}$	quarterchord pitching moment
$C_p = \frac{p-p_\infty}{q}$	measured pressure coefficient
$\bar{C}_p$	average pressure coefficient on streamline
$C_{p_i} = 1 - (v_{t_i}/U)^2$	calculated pressure coefficient
d_i	element of column vector of approach flow boundary conditions
ds_j, dx_j, dy_j	surface element length differentials
H	windtunnel testsection height (or total head)
$K(s)$	porosity parameter for longitudinally slotted walls
$m = \frac{dC_L}{d\alpha}$	lift-curve slope
$\vec{n}$	outward surface normal
OAR	transversely-slotted wall open area ratio
p	local static pressure
$P(s)$	porosity parameter for porous or perforated walls
$q = \frac{1}{2}\rho U^2$	dynamic pressure
$r_{ij}, r(PQ)$	distance between surface elements
Re	Reynolds number

s	distance along the surface
Δs_j	length of surface element
U	magnitude of approach flow velocity
$V_i, V_{n_i}, V_{t_i}, V_{x_i}, V_{y_i}$	velocity induced by a surface element
$\vec{V}_\infty$	approach flow velocity, magnitude U
x_j, y_j	Cartesian axes fixed to the j -th surface element
X, Y	wind axes, with X -axis in the flow direction
x_{ac}	aerodynamic center distance
x_0	midchord distance
α	airfoil incidence
Γ	circulation
$\gamma_j, v_j,$	surface vortex element strength density
$\sigma_j, \mu_j,$	surface source element strength density
ϕ	disturbance velocity potential
θ_j	inclination of surface element w.r.t. X -axis
ρ	fluid density
$\tau = \frac{dC}{d\alpha} M_0$	midchord pitching moment curve slope
ψ	stream function

Subscripts:

F	free air value	S	solid wall value
L	lower surface	t	tangential direction
n	normal direction	T	windtunnel value
s	streamwise direction	U	upper surface
∞	upstream undisturbed flow condition		

1. Introduction.

In the subsonic windtunnel testing of airfoil sections, the existing theory for corrections to the measured data for the effects of windtunnel wall constraints is satisfactory for windtunnels with solid walls in which the test airfoils are small relative to the testsection crosssections, and develop relatively small lift coefficients.

However, current research on high-lift airfoil sections requires testing at very high lift coefficients, and the use of relatively large models to give sufficiently high Reynolds numbers. Under these conditions, the wall corrections in windtunnels with solid walls may become unacceptably large, unless windtunnels with very large test crosssections are available. Such windtunnels are expensive to build and operate, so a method of modification of existing smaller windtunnels, that would reduce or eliminate these large wall corrections, would be most desirable.

Since the major corrections to measured data in windtunnels with solid walls are of opposite sign from those for windtunnels with open jets, an obvious possibility to explore is the use of partly solid-partly open walls, to produce cancelling effects. Two such forms of windtunnel wall have been considered in recent years for this purpose, walls with narrow longitudinal slots, and walls with a pattern of small holes. Theories have been presented for prediction of the corresponding wall corrections.

Unfortunately, experiments have shown that the existing

theory for walls with longitudinal slots is useless for the present purposes, and the theory for porous walls is impractical to apply. An empirical porosity factor is needed, which depends on the wall geometry and on the test model.

In the present thesis, a two-dimensional potential flow theory is developed for a different partly solid-partly open wall system, and the results of experiments designed to test the theory are presented.

2. Survey of Windtunnel Wall Correction Methods.

2.1 Conventional Linear Theories.

In windtunnel testing of two-dimensional airfoil sections at subsonic speeds, the windtunnel wall constraint influences the measured forces, moments, and pressure distributions. The current theories for the corrections to be applied to the measured values to account for wall effects are satisfactory only when the test airfoils are small relative to the windtunnel crosssection, and develop small lift coefficients. Current practice for such cases is well summarized in a report by Garner et al [1].

The essential feature of current wall correction theories is the selection of an appropriate system of source, vortex and doublet singularities, together with images of the singularities in the windtunnel boundaries, such that the flow conditions at the boundaries are satisfied. The lift-producing characteristics of the airfoil (incidence, camber), the airfoil thickness, and the airfoil wake, are associated with distributions of vortices, doublets and sources respectively. The characteristics of the windtunnel walls are then simulated by associating an appropriate set of images with each singularity in the field. For example, a solid wall boundary condition requires zero disturbance velocity normal to the boundary. This condition may be simulated by an infinite set of images in the windtunnel walls; sources, and doublets oriented in the streamwise direction, have images of the same sign; vortices have images of alternating sign. For further details, see Allen and Vincenti

[2], and Goldstein [3].

When the net effect of the systems of singularities and images has been calculated, the velocities thereby induced at the airfoil may be determined. For simplicity both in interpretation and application, it is useful if the net effect of all the systems is the direct sum of the induced effects of each of the individual systems. In terms of the corresponding field equations, a superposition is possible if the exact boundary conditions may be linearized. The linear approximations in turn are valid only for small induced velocities, which implies a small, thin, slightly cambered airfoil at low incidence.

An alternative to the images technique, which yields similar results, is the conformal mapping technique developed by Woods [4]. The problem of finding velocity potentials in a complex domain bounded by an airfoil and windtunnel walls is transformed, by conformal mappings, to an equivalent, but geometrically simpler, boundary value problem. The problem is thus reduced to the determination of an analytic function on a transformed domain whose real and/or imaginary parts are prescribed on the boundary. Woods' technique results in integral equations for the mapping functions, and usually numerical methods are required for their solution. A linearized form of his theory agrees with the results to be found in Garner et al [1].

For the case of a thin flat plate between parallel boundaries, the solutions of Havelock [5] and Tomotika [6] are

available. Havelock uses the method of images while Tomotika uses that of conformal transformations. The results are similar.

In recent publications, de Jager and van de Vooren [7], and de Vries and Schipholt [8], use image methods for thin airfoils with hinged flaps, between solid windtunnel walls.

For porous or perforated windtunnel walls, Baldwin et al [9] propose an "equivalent homogeneous wall boundary condition". This homogeneous boundary condition is a combination of the boundary conditions for solid walls and for an open jet.

These wall boundary conditions are expressed in terms of a disturbance flow velocity potential ϕ , which for incompressible flow satisfies Laplace's equation. The general linear wall boundary condition may be written:

$$a(s)\frac{\partial\phi}{\partial n} + b(s)\frac{\partial\phi}{\partial s} + c(s)\frac{\partial^2\phi}{\partial s\partial n} = 0. \quad (2.1)$$

For a solid boundary where there is zero disturbance flow normal to the boundary, equation (2.1) has the form

$$\frac{\partial\phi}{\partial n} = 0. \quad (2.2)$$

For an open jet boundary it is assumed that the disturbance from the test airfoil at the jet boundary is small. The linearized condition of constant pressure can be interpreted, using Bernoulli's equation, as requiring zero streamwise disturbance velocity. Hence for an open jet boundary, condition (2.1) becomes

$$\frac{\partial \phi}{\partial s} = 0. \quad (2.3)$$

For porous or perforated walls the pressure drop across the wall due to the cross-flow is assumed to be proportional to the normal disturbance velocity at the wall. The resulting linear relation between the cross-flow and streamwise disturbance velocity components requires

$$\frac{\partial \phi}{\partial n} + P(s) \frac{\partial \phi}{\partial s} = 0. \quad (2.4)$$

A similar expression, but with a different value of $P(s)$, is used for a wall where the porosity consists of transverse slats. For an infinite length testsection wall of closely spaced transverse slats, Maeder and Wood [10], and Woods [4] deduce a constant value for $P(s)$:

$$P = \tan\left(\frac{\pi a}{2d}\right). \quad (2.5)$$

In equation (2.5), 'a' is the slot width and 'd' is the slat spacing; a/d is the open area ratio (OAR).

For walls with longitudinal slots, a potential flow model of the cross-flow through the slots requires the disturbance potential to vanish and the pressure to be constant, in the slots. Hence

$$\frac{\partial \phi}{\partial s} + K(s) \frac{\partial^2 \phi}{\partial s \partial n} = 0 . \quad (2.6)$$

Maeder and Wood [10] give, for an infinite length testsection wall of uniformly spaced longitudinal slots, the value

$$K = \frac{d}{\pi} \log \csc\left(\frac{\pi a}{2d}\right) , \quad (2.7)$$

where a/d is again the OAR.

2.2 Results of Conventional Linear Theories.

In the theoretical determination of homogeneous boundary conditions, the details of the slot or hole geometry can be used to construct an exact boundary condition by, for example, the application of Kutta conditions to the edges of slots or holes. Then by examining the flow through the wall from a point many slot(hole) widths away from the walls the flow details due to the wall geometry are not felt, but only some "averaged" flow field is detected. The exact boundary condition is thus replaced by a linearized, averaged boundary condition. In applying this boundary condition, the wall is regarded as being geometrically homogeneous. The advantage is that a single averaged boundary condition can be applied uniformly over the plane of the wall so that it is not necessary to have separate boundary conditions applied in slots (holes) and on solid sections. This averaging effect explains why the wall boundary condition for porous, perforated and transverse slotted walls are similar. For details see Maeder and Wood [10].

The same "averaging" effect, if applied to longitudinal slots, leads to erroneous predictions. In fact, the longitudinal slots render the flow three-dimensional by imposing spanwise variations on the basic two-dimensional flow conditions. On the assumption that the flow is quasi-plane, that is the spanwise variations are only a small perturbation of the basic two-dimensional flow, an averaged boundary condition for the basic two-dimensional flow can be deduced. For details see Woods [4].

In the use of such geometrically homogeneous linear

boundary conditions, all details of slot or perforation geometry are lost, in particular, their orientation (longitudinal or transverse). Only the effects of bulk properties such as the porosity or OAR are retained. Wood [11] shows, for example that the OAR for longitudinal slots would need to be less than 1%, to achieve a boundary condition appreciably different from the open jet case. In practice, at such a small OAR, real fluid effects would be important, so a potential flow model for the cross-flow would not be valid. Moreover, Wood's analysis of this boundary condition indicates that only cross-flow velocities of less than 0.5% of the mean flow would be in keeping with the arguments for the linearization of terms involved in the derivation of this boundary condition.

Investigations by Parkinson and Lim [12], and Mokry [13] have found that the "porosity parameter" $P(s)$ is not simply an empirical function of wall OAR, but must be determined empirically for each airfoil under test. The usual procedure is to choose a value of $P(s)$ to match lift or pressure data taken at a particular incidence and for a particular size of airfoil and then to try to use this same value of $P(s)$ to calculate the wall effect at other incidences and for other sizes of airfoil. Generally, the results are that $P(s)$ depends on the wall OAR and the particular airfoil under test, an impossible situation for the practical use of such linear porous wall boundary conditions. Figure 2.1 from [12], for example, shows that for two different airfoil profiles tested, there are two completely different variations of "porosity parameter" with OAR, and neither agrees with the theoretical variation of relation (2.5).

Other results by Parkinson and Lim [12], Parker [14], and Tsen [15], have shown that the theory for the longitudinal wall slot parameter $K(s)$ is not useable. Figure 2.2, from [12], for example, shows that for four airfoils of different size, of the same profile, the theoretical wall interference curves corresponding to the values of wall OAR tested, are closely grouped as though all of the wall configurations were effectively open.

Catherall [16] states that "the usefulness of the method is limited by the doubts about this (linear homogenous wall boundary) condition". This is clearly the case for measurements on high lift devices where the predicted wall corrections are of the same order as the measured values themselves.

The great disadvantage of more physically appropriate nonlinear wall boundary conditions is that the mathematical solutions for most boundary problems depend on such boundary conditions being linear as, for example, in complex variable theory. Wood [11] has developed a nonlinear boundary condition for a two-dimensional Helmholtz jet issuing from longitudinal slots, where the "porosity" is a function of the cross-flow velocity. His analysis is for a nonlifting airfoil; the extension to the case of a lifting airfoil does not appear to have been made.

Sears [17] comments that: "Even in those (flow) regimes where the flow perturbations due to tunnel boundaries can be estimated, there is a basic flaw in the idea of "correcting"

measured aerodynamic data, because such correction requires that the effects of such perturbations be known. If the field of extraneous velocities is other than a uniform change of incidence, then in some of the most important technical cases these effects are not known and cannot be calculated".

Figure 2.2, from [12], also shows that the theory for solid walls gives excellent agreement with the data. Therefore in the absence of improvements to the theory for slotted- or perforated-wall corrections, it seems advisable to carry out low-speed two-dimensional airfoil tests, even for large models developing high lift coefficients, in conventional windtunnels with solid walls.

2.3 Low Correction Test Configurations.

An alternative approach is to modify the walls of the windtunnel to provide flow conditions as close as possible to a free-air (unconfined) test environment. Thus the wall corrections would automatically be small.

One approach is that of the "self-correcting" windtunnel [17] whereby an array of sensors (located on a convenient "control surface" inside the tunnel but not in the wall boundary layers) measure, say, the flow speed and inclination there. A calculation is performed to determine if these measured values are compatible with previously calculated values of the same variables for an imaginary infinite inviscid flow field about the test airfoil. If not, adjustments are made, iteratively, until such conditions are met. This could be achieved through the use of flexible walls, and/or wall sections of variable porosity. Obvious disadvantages are the cost of "on-line" computing facilities plus the large number of pressure transducers required to extract and process the flow measurements.

Whatever type of testsection is chosen, the "porosity" variation must produce results like those of Figure 2.3, in order to simulate correctly the free-air flow field. How this is accomplished mechanically is up to the windtunnel designer.

3. A New Slotted-Wall Theory.

3.1 A Physical Basis for the New Theory.

One reason for the lack of success of the longitudinal-slot and porous-wall theories is the occurrence experimentally of separated flows in the slots and holes. Such flows are not accounted for in the theories, primarily as they add undesirable nonlinearities to the theories. In addition, these flow separations seriously degrade the main flow in the vicinity of the walls.

The approach here (see Figure 3.1), uses transverse wall slots, with symmetrical airfoil-shaped solid slats. The flow inclinations near the wall will be small even for a nearly unconfined flow field. Hence all the wall slats will operate within their unstalled incidence range, so that flows near the wall will be free of separated wakes.

Moreover, only the wall opposite the negative pressure side of the test airfoil is slotted. One reason for this choice can be seen from Figure 3.2 which compares theoretical pressure distributions (calculated by the methods of section 3.2) between solid walls and in free air, for a 14% Clark-Y airfoil. The ratio of airfoil chord ' c ' to windtunnel testsection size ' H ' is large at 0.72, and the incidence ' α ' is extreme at 20 degrees, to create a large wall effect. These pressure distributions show that almost all of the wall effect is to increase the magnitude of the negative pressure on the upper surface of the airfoil. The effect on the underside pressure is so small as to be negligible, even in this rather extreme case.

Another reason for using only one slotted wall is to simplify the flow field opposite the pressure side of the test airfoil. A slotted lower wall would allow an inflow of low energy air from within a plenum chamber (surrounding the slotted wall) to enter the testsection upstream of the airfoil. This inflow would consist of a shear layer and its associated turbulent mixing and would degrade the quality of the main flow in the vicinity of the airfoil lower surface. There will be a corresponding outflow from the test section back into the plenum downstream of the test airfoil.

On the other hand, on the wall opposite the negative pressure side, upstream of the test airfoil, there will be an outflow from the testsection into the plenum. The shear layer so formed and its associated turbulent mixing will be shielded from the test airfoil by the presence of the airfoil-shaped wall slats with their boundary conditions impressed on the flow. If this shear layer were idealized as a constant-pressure free streamline, any incorrectness in pressure or location in such a representation of this streamline should have only secondary effects on the test airfoil. The plenum air will enter the testsection downstream of the test airfoil; however, its effect on the test airfoil by entering there will be much smaller than for any air entering the testsection upstream of the test airfoil.

As with most windtunnel wall correction theories, irrotational flow is assumed, and, since the method is designed for low-speed high-lift testing, an incompressible potential

flow method can be used. The test airfoil (and its component flaps) and the airfoil-shaped wall slats are all treated as lifting airfoils. Hence the flow satisfies the usual tangent-velocity and trailing-edge Kutta conditions. The flow past the solid wall sections satisfies the tangent-velocity boundary condition.

3.2 Formulation of an Exact Numerical Theory.

The formulation here is a two-dimensional potential flow theory, based on the surface singularity distribution method of A.M.O. Smith and his colleagues [18].

In this method, the surfaces of the solid walls, the airfoil-shaped slats in the slotted wall, and the test airfoil with its component flaps, are represented by a distribution of source and vortex elements. A normal-velocity boundary condition will prescribe either zero normal velocity, on solid surfaces, or non-zero normal velocity, for suction or blowing there. Source elements are therefore distributed over any surface on which a normal-velocity boundary condition is specified. Vortex elements are used to set the net circulation about a closed lifting body. Therefore vortex elements are distributed over any surface on which a tangent-velocity boundary condition is specified. Hence source elements only are distributed over the solid wall sections, while both source and vortex elements are distributed over the surfaces of the airfoil-shaped wall slats and the test airfoil and its flaps.

The velocities at any point in the flow field due to all such sources and vortices are calculated directly. The usual flow boundary condition of zero normal velocity is applied at all solid surfaces. In addition, a finite-velocity Kutta condition is applied at the trailing edges of the wall slats and test airfoil, including flaps.

Again ϕ is the disturbance velocity potential, which

satisfies Laplace's equation, vanishes at infinity, and satisfies the above boundary conditions.

The potential at a point P due to a single three-dimensional point source singularity at a point Q is

$$\phi(P) = - \frac{m}{4\pi} \frac{1}{r(PQ)}, \quad (3.1)$$

where m is the volume flow rate of fluid emitted by the source and $r(PQ)$ is the distance between the points P and Q . The total potential due to all such sources distributed over a single surface S is

$$\phi(P) = - \iint_S \frac{\sigma(Q)}{r(PQ)} dS, \quad (3.2)$$

where $\sigma(Q)$ is the source strength density, including the factor $1/4\pi$, of the source element at Q .

Since the disturbance velocity is the gradient of the velocity potential, the normal-velocity boundary condition at a surface can be expressed as

$$\frac{\partial \phi}{\partial n} = - \vec{V}_\infty \cdot \vec{n} + F, \quad (3.3)$$

where $\vec{n}$ is the outward surface normal, and $\vec{V}_\infty$ the undisturbed flow at upstream infinity. The function F denotes the value the normal velocity must take at the airfoil surface. F is zero for a solid (impermeable) surface, but non-zero for suction or blowing there.

Analysis (Hess and Smith [18]) shows that the normal velocity at a point P on a surface S, due to a source strength density distribution $\sigma(Q)$ on S, consists of two parts. The "local" contribution is $2\pi\sigma(P)$ due to the source element $\sigma(P)$ at P. The "far field" contribution is

$$- \iint_S \frac{\partial}{\partial n} \left(\frac{1}{r(PQ)} \right) \sigma(Q) \, dS \quad (3.4)$$

due to the summation of the effects of all other source elements $\sigma(Q)$ at points Q on S. The resulting expression of this boundary condition

$$2\pi\sigma(P) - \iint_S \frac{\partial}{\partial n} \left(\frac{1}{r(PQ)} \right) \sigma(Q) \, dS = -\vec{V}_\infty \cdot \vec{n} + F \quad (3.5)$$

produces an integral equation for the unknown source strength density distribution function $\sigma(Q)$. This equation is a Fredholm integral equation of the second kind. Existence and uniqueness theorems for such equations are well known. The surface S may be disjoint, but the outward normal vector must be a continuous function of position. For a discussion of difficulties associated with functional singularities in such source distributions at edges or corners, such as at an airfoil trailing-edge or an unfaired wing-body junction, see Craggs et al [19].

In practice, the surfaces of the solid wall, the airfoil-shaped slats, and the test airfoil and flaps, are replaced by polygonal elements. The continuous distribution of sources

thereby becomes a succession of finite distributed-source elements. In the original method of Smith and his colleagues, each of these finite elements was flat and of constant uniform strength. Successful refinements of the method have used higher-order polynomial curves fitted to sections of the body surface with the source strength density varying in a linear or parabolic way along these curved elements. For examples see Henshaw [20,21], or Hess [22]. The higher-order element shapes are needed for internal flow calculations such as in ducts, but for external flow problems the flat elements give accurate results provided a large enough number of elements is used and their disposition on the body shape is chosen carefully.

Each velocity boundary condition is applied at a single "control point" on each element. For flat elements a convenient choice is the center of each element.

Thus the exact integral equation for a continuous distribution function may be reduced to a set of N simultaneous linear algebraic equations whose N unknowns are the strengths of the finite surface elements.

The above approximations become exact in the limit as $N \rightarrow \infty$. The method is described as numerically exact in the sense that any degree of accuracy may be obtained.

By defining the linear operator

$$A_{ji} = - \iint_{S_j} \frac{\partial}{\partial n_j} \left(\frac{1}{r_{ij}} \right) ds_j, \quad (3.6)$$

the boundary condition (3.5) applied at the i -th control point becomes

$$\sum_{j=1}^N A_{ji} \sigma_j = -\vec{V}_{\infty} \cdot \vec{n}_i + F_i. \quad (3.7)$$

This indicates that A_{ji} is the normal velocity induced at a control point ' i ' by a unit strength source element located at another point ' j '. Hence the "local" normal velocity, A_{ii} , is 2π for all $i=1,2,3,\dots,N$.

For the purposes of this problem, the three-dimensional point source of equation (3.1) must be integrated into a flat two-dimensional distributed-source element; for the details see Appendix 1. The units of $\sigma(Q)$ are therefore: volume flow rate per unit arc length along the contour per unit length in the spanwise direction.

With respect to Cartesian axes x_j and y_j fixed to the j -th element (Figure 3.3), the velocity components induced at a point ' i ' by a source element at point ' j ' are

$$V_{x_j} = \log \left(\frac{(x_j + \frac{\Delta s_j}{2})^2 + y_j^2}{(x_j - \frac{\Delta s_j}{2})^2 + y_j^2} \right) = 2 \log \left(\frac{R_2}{R_1} \right) \quad (3.8)$$

and

$$V_{y_j} = 2 \left\{ \tan^{-1} \left(\frac{x_j + \frac{\Delta s_j}{2}}{y_j} \right) - \tan^{-1} \left(\frac{x_j - \frac{\Delta s_j}{2}}{y_j} \right) \right\} = 2\Omega, \quad (3.9)$$

where x_j and y_j are the distances from the j -th to the i -th element; the j -th element has length Δs_j . The velocity fields

about a single source element are shown in Figure 3.4. The directions of V_{x_j} and V_{y_j} at 'i' are parallel and normal to the direction of the element at 'j', respectively.

The inverse tangents in (3.9) are to be evaluated in the range $(-\pi/2, +\pi/2)$. The two inverse tangents may be combined by means of the tangent law into the alternative expression

$$V_{y_j} = 2 \tan^{-1} \left(\frac{y_j \Delta s_j}{x_j^2 + y_j^2 - (\frac{\Delta s_j}{2})^2} \right), \quad (3.10)$$

where this single inverse tangent is to be evaluated in the range $(-\pi, +\pi)$ by taking into account the individual signs of the numerator and denominator of its argument. When calculating flow quantities at off-surface points which are closer to the origin of the element than $\Delta s/2$, the first expression must be used.

With respect to Cartesian "wind axes" X and Y, (X is in the wind direction), the j-th source element is inclined at an angle θ_j to the X-axis. Thus,

$$A_{ji} = V_{y_j} \cos(\theta_i - \theta_j) - V_{x_j} \sin(\theta_i - \theta_j) \quad (3.11)$$

and

$$B_{ji} = V_{x_j} \cos(\theta_i - \theta_j) + V_{y_j} \sin(\theta_i - \theta_j) \quad (3.12)$$

are the normal and tangential velocities respectively induced at element 'i' due to a unit strength density source element at a point 'j'. The "local" normal velocity A_{ii} is 2π ; the "local"

tangential velocity B_{ii} is zero.

The directions of A_{ji} and B_{ji} at 'i' are normal (positive outward) and parallel (positive clockwise) respectively to the direction of the element at 'i'. Hence for the exterior flow about a single closed contour, the source and vortex elements are labelled for computations in a clockwise order about the contour.

In order to fix the circulation about a lifting body, the usual equal-velocity Kutta condition is applied. This is accomplished by adding finite distributed vortex elements to the body surface, all of the same vortex strength density. The Kutta condition then implies that the tangential velocities established at the control points on the upper and lower surfaces, adjacent to the trailing edge, must be equal in magnitude, and both directed toward the trailing edge.

Since the velocity due to a vortex is simply that due to a source, but rotated 90 degrees, expressions for the velocity components for distributed-vortex elements of circulation strength density $\gamma(\theta)$ can be written, corresponding to those of (3.8,3.9). For a distributed vortex element of unit strength density at point 'j' the corresponding normal and tangential velocities induced at element 'i' are found to be $-B_{ji}$ and A_{ji} respectively. The number and size of vortex elements is arbitrary, since they all have the same strength density. It is convenient to use the same number of vortex as source elements and to have source and vortex elements located to coincide exactly. The velocities A_{ji} and B_{ji} computed for the source

elements are then immediately useable for the vortex elements.

Hence the normal and tangential velocities induced at the control point on element 'i' due to a system of N coincident source and vortex elements immersed in an infinite uniform approach flow U (parallel to the X-direction), are

$$V_{n_i} = \sum_{j=1}^N A_{ji} \sigma_j - \sum_{k=1}^N B_{ki} \gamma_k - U \sin \theta_i \quad (3.13)$$

and

$$V_{t_i} = \sum_{j=1}^N B_{ji} \sigma_j + \sum_{k=1}^N A_{ki} \gamma_k + U \cos \theta_i. \quad (3.14)$$

Since all the vortex elements on a single closed lifting body are of equal strength γ , the description of the flow field about an N-sided polygonal body is complete when the N+1 quantities $\sigma_1, \sigma_2, \dots, \sigma_N$, and γ are known. For zero F_i , the normal-flow boundary conditions at each of the N elements provides N equations

$$V_{n_i} = 0. \quad (3.15)$$

while the finite-velocity Kutta condition at the two control points adjacent to the trailing edge provides the single (N+1)st equation

$$V_{t_U} = - V_{t_L}. \quad (3.16)$$

For the configuration of airfoil-shaped wall slats, solid walls and test airfoil plus flaps of Figure 3.1, with a total of N source elements and M lifting bodies, there are N source and M vortex strength densities to be determined. The zero normal-velocity condition applied on each element on the airfoil, flaps, solid walls and wall slats, yields the N equations

$$\sum_{j=1}^N A_{ji} \sigma_j - \sum_{k=1}^M \gamma_k \sum_{m=1}^{R(k)} B_{mi} = U \sin \theta_i, \quad i=1,2,\dots,N. \quad (3.17)$$

A Kutta condition applied to each of the M bodies (airfoil, flaps, wall slats) yields the M equations

$$\sum_{j=1}^N (B_{jU_r} + B_{jL_r}) \sigma_j + \sum_{k=1}^M \gamma_k \sum_{m=1}^{R(k)} (A_{mU_r} + A_{mL_r}) = -U(\cos \theta_{U_r} + \cos \theta_{L_r}), \quad (3.18)$$

$r=1,2,\dots,M.$

The subscripts U and L indicate the control points adjacent to the trailing edge on the upper and lower surfaces respectively of the r -th lifting body; $R(k)$ is the number of source (and vortex) elements on this body.

In summary there are:

- a total of N source elements distributed over the test airfoil, its flaps, the airfoil-shaped wall slats, and the solid wall sections.

- a total of M bodies requiring Kutta conditions.

- a total of $\sum_{k=1}^M R(k)$ vortex elements distributed over the lifting bodies; there are $R(k)$ source elements and $R(k)$ equal-strength density vortex elements distributed over the k -th body.

- N unknown source strength densities σ_j

- M unknown vortex strength densities γ_k
- M+N equations in the M+N unknowns $\sigma_1, \sigma_2, \dots, \sigma_N, \gamma_1, \gamma_2, \dots, \gamma_M$.

3.3 Other Airfoil-Wall Configurations Examined.

Obvious simplifications of the above general equations (3.17,3.18) are for a test airfoil (a) in an unbounded stream (free air), (b) in the proximity of a single solid lower surface (ground effect), (c) between two solid walls, and (d) between a solid lower boundary and an upper boundary consisting of single-sided transverse slats with no Kutta conditions applied.

In each of the cases (a)-(d) a total of N source elements are distributed over the test airfoil, its flaps, the transverse wall slats, and the solid wall sections. In addition there is an unknown vortex strength density on the test airfoil and on each of its flaps.

For example, for a single test airfoil (no flaps), in free air, equations (3.17,3.18) reduce to, respectively:

$$\sum_{j=1}^N A_{ji} \sigma_j - \gamma \sum_{k=1}^N B_{ki} = U \sin \theta_i, \quad i=1,2,\dots,N, \quad (3.19)$$

and

$$\sum_{j=1}^N (B_{jU} + B_{jL}) \sigma_j + \gamma \sum_{k=1}^N (A_{kU} + A_{kL}) = -U(\cos \theta_U + \cos \theta_L). \quad (3.20)$$

For a single test airfoil in (b), (c), or (d) above, the equations (3.17,3.18) reduce to, respectively:

$$\sum_{j=1}^N A_{ji} \sigma_j - \gamma \sum_{k=1}^{NA} B_{ki} = U \sin \theta_i, \quad i=1,2,\dots,N \quad (3.21)$$

and

$$\sum_{j=1}^N (B_{jU} + B_{jL}) \sigma_j + \gamma \sum_{k=1}^{NA} (A_{kU} + A_{kL}) = -U(\cos\theta_U + \cos\theta_L). \quad (3.22)$$

Here there are NA source (and vortex) elements on the test airfoil and (N-NA) source elements on the appropriate solid wall sections. The subscripts U and L indicate the control points adjacent to the trailing edge on the upper and lower surfaces respectively of the single test airfoil.

The representation of an airfoil in ground effect is different here than in the method used by others, for example Jacob and Steinbach [23] and Mavriplis [24]. Their approach is to use a second airfoil in the "image" position so that the lower straight solid boundary is a "reflection plane". Hence the boundary condition of zero flow normal to this straight solid boundary is represented exactly. If there are N source and N vortex elements distributed over the test airfoil and its flaps, the number of equations to be solved is exactly twice the number to be solved for the same airfoil/flap configuration in an unbounded stream (free air). Hence there is a saving by the present method where the solid lower boundary can be represented by less than N source elements. The shape of the solid lower boundary is arbitrary in the present method; there is no inherent requirement that the boundary be straight as is the case for a "reflection plane".

4. Methods of Numerical Solution.

4.1 Assembling the Equations.

A computer program is used to construct the matrices A and B. This program is written in FORTRAN for the UBC IBM 370/168 system. The program inputs are the coordinates, lengths and orientations of the source and vortex elements on the airfoil, its flaps, the airfoil-shaped wall slats, and the solid wall sections. These matrices A and B are then used to assemble the coefficients c_{ji} of unknowns in the $N+M$ equations (3.17, 3.18). Typically $N+M$ is about 400, hence the matrices A and B each contain more than 150,000 non-zero nonsymmetric entries. In fact the matrices A and B are used to assemble a third matrix C such that the system of equations to be solved is written $C(\sigma, \gamma) = d$; thus all three matrices (or parts thereof) must reside in memory simultaneously.

The actual computational capacity (useable memory) is about 250,000 entries, hence such large matrices must be partitioned for computation in blocks and temporary storage on peripheral devices such as magnetic discs. The matrices A and B describe the relative geometry of the source and vortex elements, that is, their relative position and orientation. These matrices must be recalculated completely for each change in relative geometry, for example, a change in airfoil incidence, size or wall OAR.

In the original method of Hess and Smith [18] and in similar methods in present use (Jacob and Steinbach [23], Mavriplis [24], Labrujere [25], Henshaw [20, 21]), the solution of (3.17, 3.18) uses numerical superposition of three "basic

flow" solutions. This is possible for isolated airfoils, as there is no change in relative geometry when the airfoil incidence is changed. This is also possible for an airfoil with flaps as long as the airfoil-flaps combination changes its attitude as a whole, that is, without a change in relative geometry.

The three "basic flow" solutions are as follows. The first is due to a uniform stream onset flow parallel to the airfoil chord. The second is due to a uniform stream onset flow perpendicular to the airfoil chord. The third is due to a pure circulatory onset flow that corresponds to pure circulation about the airfoil. If more than one airfoil is present (i.e. a flap), there is more than one independent circulatory onset flow. The three "basic flows" for each airfoil are then linearly combined to satisfy the Kutta condition at the trailing edge and to give a prescribed incidence or lift coefficient.

Henshaw [20,21], for example, linearly combines the second and third solutions to yield a fourth solution whereby a Kutta condition is satisfied at the airfoil trailing edge. Linear combinations of the first and fourth solutions yield the flow at any incidence with a Kutta condition automatically satisfied.

This procedure is not possible with an airfoil between solid walls. Since the solid walls are not closed lifting bodies, they do not have vortex elements distributed over their surfaces. Hence there is no circulatory flow associated with the solid walls. For a change in airfoil incidence, size or wall OAR, the matrices A and B must be calculated afresh.

Referring to equations (3.17,3.18), the system of equations to be solved is written below. The subscripts 'j,i' of the matrix elements of A, B, and C are not of standard notation, but are reversed. This is deliberate, as increased efficiency of storage and summation of matrix elements is then possible under the FORTRAN compilers.

With FORTRAN compilers, in conventional form, the elements of a matrix are stored column by column. That is, the elements of a matrix are assigned sequentially to storage beginning with element (1,1) and proceeding through all values of the (left-most) first subscript, then increasing the second subscript by 1, and repeating. If A, B and C are small matrices, they may all reside simultaneously in real memory. In this situation, row-wise access of the elements of a matrix entails accessing elements which are already in memory. However, if the matrices are large, only a portion of each matrix will reside in real memory at any one instant. This is due to the IBM virtual memory operating system which employs some kind of paging system for dynamic storage allocation. For more details, see Moler [26]. Thus accessing of elements in a row requires a transfer in and out of real memory of blocks of each matrix, block by block, until the accessing is completed. This is not efficient. Hence a matrix must be stored row by row. This is accomplished by reversing the subscripts of the elements of a matrix so for example, the elements of the first row are then (1,1), (2,1), (3,1), ..., (N,1). This subscripting is evident in equations (4.1).

The PL/1 compilers store matrices row by row, so this problem does not arise when accessing elements in the same row of a matrix, but would if it were necessary to access elements in the same column.

The system of equations to be solved is written:

$$c_{1,1}\sigma_1 + c_{2,1}\sigma_2 + \dots + c_{N,1}\sigma_N + c_{N+1,1}\gamma_1 + \dots + c_{N+M,1}\gamma_M = d_1$$

$$c_{1,2}\sigma_1 + c_{2,2}\sigma_2 + \dots + c_{N,2}\sigma_N + c_{N+1,2}\gamma_1 + \dots + c_{N+M,2}\gamma_M = d_2$$

$$\begin{array}{ccccccc} \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot \end{array}$$

$$c_{1,N}\sigma_1 + c_{2,N}\sigma_2 + \dots + c_{N,N}\sigma_N + c_{N+1,N}\gamma_1 + \dots + c_{N+M,N}\gamma_M = d_N \quad (4.1)$$

$$c_{1,N+1}\sigma_1 + c_{2,N+1}\sigma_2 + \dots + c_{N,N+1}\sigma_N + c_{N+1,N+1}\gamma_1 + \dots + c_{N+M,N+1}\gamma_M = d_{N+1}$$

$$\begin{array}{ccccccc} \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot \end{array}$$

$$c_{1,N+M}\sigma_1 + c_{2,N+M}\sigma_2 + \dots + c_{N,N+M}\sigma_N + c_{N+1,N+M}\gamma_1 + \dots + c_{N+M,N+M}\gamma_M = d_{N+M}$$

where the matrix C and the column vector d in the system $C(\sigma, \gamma) = d$ are assembled from the matrices A and B by means of equations (3.17, 3.18), that is,

$$c_{ji} = \begin{cases} A_{ji} & j=1, 2, \dots, N; i=1, 2, \dots, N \\ - \sum_{m=1}^{R(k)} B_{mi} & k=1, 2, \dots, M; j=N+k; i=1, 2, \dots, N \end{cases}$$

$$c_{ji} = \begin{cases} B_{jU_r} + B_{jL_r} & j=1,2,\dots,N; r=1,2,\dots,M; i=N+r \quad (4.2) \\ \sum_{m=1}^{R(k)} (A_{mU_r} + A_{mL_r}) & k=1,2,\dots,M; j=N+k; r=1,2,\dots,M; i=N+r \end{cases}$$

and

$$d_i = \begin{cases} U \sin \theta_i & i=1,2,\dots,N \\ -U \cos \theta_{U_r} - U \cos \theta_{L_r} & r=1,2,\dots,M; i=N+r \end{cases} \quad (4.3)$$

Thus the computation of the matrix C requires access to both matrices A and B. When these matrices are large, C must be assembled in blocks. For details see the FORTRAN program in Appendix 2. The alternative is: calculate A and B, write B into peripheral storage, de-allocate the memory assigned to B, allocate memory for C, calculate all parts of C that involve A, de-allocate the memory assigned to A, allocate memory for B, read B into memory from peripheral storage and calculate all parts of C that involve B. This alternative is simpler to program and appears in Appendix 10. The large number of summations of matrix elements in the same row is evident in equations (4.2); this is the main source of inefficiencies under the present paging system.

4.2 Solving the Equations.

Usually the solution of the complete system of $N+M$ equations is obtained directly by Gauss-elimination methods. For a FORTRAN Gauss-elimination subroutine that takes account of the above mentioned paging system, see Moler [26] or Appendix 3.

Another direct method, used by Hess and Smith [18] is the successive row vector orthogonalization process of Purcell [27]. In this method an augmented matrix is treated row by row such that a series of vectors orthogonal to each row vector of the augmented matrix is constructed. The right-hand side vector 'd' is used to construct a set of $N+M$ vectors in $(N+M+1)$ -dimensional space,

$$(c_{1i}, c_{2i}, c_{3i}, \dots, c_{N+M,i}, -d_i) \quad i=1,2,\dots,N+M. \quad (4.4)$$

The solution vector (σ, γ) of equations (4.1) is such that the vector

$$(\sigma_1, \sigma_2, \sigma_3, \dots, \sigma_N, \gamma_1, \gamma_2, \dots, \gamma_M, 1) \quad (4.5)$$

is orthogonal to all the vectors of (4.4). The process of solving equations (4.1) is equivalent to determining an $(N+M+1)$ -dimensional vector orthogonal to the $N+M$ vectors of (4.4) with unity as its $(N+M+1)$ -th component.

Each row of the coefficient matrix C is used at only one stage of the process, and is not needed before or after that

stage. Thus C is transferred from virtual to real memory a row at a time, with each row occupying the same storage location as that of the previous row. Thus an insignificant amount of storage is required for storage of a single row. However, the components of all the orthogonal vectors will tend to be in real memory, since they are used repetitively. The maximum total number of components occurs when the process is about half-finished; the total number of memory locations required is approximately $(N+M)^2/4$. Thus the number of equations which can be solved by this process (for a given computational capacity) is about twice that for a Gauss-elimination process. For a FORTRAN subroutine based on this procedure, see Appendix 3.

Indirect iterative methods such as successive-over-relaxation (SOR) are also possible. For a discussion of such methods, see Hess and Smith [18]. Unsuccessful attempts were made to use SOR; the method was abandoned.

In general, the matrix C is diagonally dominant, that is, the diagonal elements, 2π , are the largest in the matrix. However, by examining the relations (4.2), it is seen that the summations over B_{mi} , A_{mU} and A_{mL} provide large elements in the (last) $(N+M)$ -th column of C . In general, the sum of all the diagonal entries is approximately equal to the sum of all the off-diagonal entries. In essentially all cases, the matrix is non-singular except for very thin bodies, such as cusped trailing edges. Here the source and vortex elements on the two surfaces are almost coincident so matrix singularities (rows linearly dependent) can creep in. For a discussion of such

problems, see Hess and Smith [18].

The summations

$$V_{n_i} = \sum_{j=1}^N A_{ji} \sigma_j - \sum_{k=1}^M \gamma_k \sum_{m=1}^{R(k)} B_{mi} - U \sin \theta_i \quad (4.6)$$

and

$$V_{t_i} = \sum_{j=1}^N B_{ji} \sigma_j + \sum_{k=1}^M \gamma_k \sum_{m=1}^{R(k)} A_{mi} + U \cos \theta_i \quad (4.7)$$

provide the net normal and tangential velocities at control points 'i' due to all source and vortex elements 'j' and 'm' respectively, and the uniform onset flow U. The solution to the set of equations (4.1) is checked by computing the velocities V_{n_i}, V_{t_i} at each point of application of the zero normal-velocity or Kutta boundary conditions. At all control points on solid surfaces, V_{n_i} is zero, and the local pressure coefficient C_{p_i} is calculated from V_{t_i} :

$$C_{p_i} = 1 - \left(\frac{V_{t_i}}{U} \right)^2 \quad (4.8)$$

The resulting values of C_p are integrated numerically (by trapezoidal rule or the fitting of cubic splines) around the test airfoil and flap contours to determine the lift, drag and nose-up midchord and quarterchord pitching moment coefficients, from the expressions

$$C_{L_T} = -\frac{1}{c} \oint C_{p_j} dx_j ; \quad C_{D_T} = \frac{1}{c} \oint C_{p_j} dy_j ;$$

$$C_{M_0 T} = \frac{1}{c^2} \oint C_{P_j} (x_j dx_j + y_j dy_j) , \quad (4.9)$$

$$\text{where } dx_j = ds_j \cos \theta_j \quad \text{and} \quad dy_j = ds_j \sin \theta_j \quad (4.10)$$

and integrations are performed clockwise around the polygonal contours.

From a calculation of the net circulation about a lifting body, represented by NA source and vortex elements,

$$\Gamma = \oint \vec{V} \cdot d\vec{\ell} = \oint v_{t_i} ds_i = \sum_{i=1}^{NA} v_{t_i} \Delta s_i , \quad (4.11)$$

and since the lift coefficient C_L is related to the total circulation Γ by

$$C_L = \frac{2\Gamma}{Uc} , \quad (4.12)$$

C_L is given by

$$C_L = \frac{2}{Uc} \sum_{i=1}^{NA} v_{t_i} \Delta s_i . \quad (4.13)$$

By substitution of (4.7), it can be shown that (4.13) reduces to

$$C_L = \frac{8\pi\gamma}{Uc} (\text{perimeter of the body}) , \quad (4.14)$$

where γ is the vortex strength density for the body under consideration.

The C_L values calculated from (4.9) and (4.13) are equivalent only for an isolated airfoil. If a second body or a

boundary is present the two values are not equal. The calculation of the circulation about a particular body then depends on the size of the contour of integration. The integral (4.11) reduces to the correct value only as the contour size shrinks to zero.

In the following pages, all C_L values quoted are calculated from expression (4.9).

It must be emphasized that on the body surface elements, the flow field solution is valid only at the control points; for "off-center" points any calculated surface velocities are meaningless. Figure 3.4 shows how velocities vary with position, on a surface element. On a given surface element, if the normal velocity is prescribed as zero, it is in general non-zero at all points of the element except the control point. At the edges of the surface elements the tangential velocity approaches infinity because of the singularity in the expression (3.8) and/or the discontinuity in surface slope.

However, the flow field solution is uniformly valid at all off-surface points. Hence at a field point 'i' the velocity components parallel and perpendicular to the streamwise direction can be computed. The local flow direction can be calculated and, by stepping from point to point, a particular streamline can be tracked. The algorithm is given in Appendix 4. Alternatively the expression for the stream function given in Appendix 1 can be solved iteratively for say the y-coordinate, at a given x-coordinate, to locate points on a particular streamline, that is, a locus of points (x,y) can be found along

which the computed value of the stream function is a constant.

5. Results of the New Theory.

The use of this type of two-dimensional surface singularity distribution method, to calculate pressure distributions on isolated bodies, is well established. For a comparison of pressure distributions obtained from this method, with pressure distributions derived from experiments and other two-dimensional potential flow theories, see Hess and Smith [18].

For purposes of comparison here, the slope of the curve of lift coefficient C_L as a function of airfoil incidence will be used. As an example of the present theoretical method, free-air loadings were calculated for the NACA-0015 airfoil, using 50 control points to represent the profile of the airfoil. The coordinates of the 50 control points used are given in Table 1. The values of the lift coefficients so obtained are listed in Table 3, as a function of the incidence α . By exact curve-fitting a polynomial of order 5 through the 6 points at 0, 2, 3, 5, 8, and 10 degrees incidence, the lift-curve slope at zero degrees was found to be 0.1193. The corresponding value at +3 degrees is 0.1229. These values would be slightly higher if a larger number of control points was used.

From thin airfoil theory (see Pope [28]) this lift-curve slope m for symmetrical airfoils is given by (per radian)

$$m = 2\pi \left(\frac{1 + .773 \frac{t}{c}}{1 + (.773 \frac{t}{c})^2} \right) , \quad (5.1)$$

where t/c is the maximum-thickness to chord ratio. For the NACA-0015 airfoil, the value of m is 6.919 per radian or 0.1208 per

degree. The agreement between the two theories is good. Strictly the expression (5.1) gives the theoretical lift-curve slope only at zero degrees, since an underlying assumption is that m is independent of incidence.

The present theory represents a uniform flow of infinite extent, past a set of multiple airfoils, and flat surfaces aligned with the direction of the undisturbed flow. With this configuration (Figure 3.1), loadings were calculated for different test airfoils developing high lift coefficients in the presence of the above mentioned wall configuration. It consists of a solid lower wall in conjunction with a transversely-slotted upper wall, with various upper wall OARs. This configuration will be referred to by the abbreviation TSUSL, meaning transversely-slotted upper, solid lower. By comparing the lift coefficient in the windtunnel, C_{L_T} , to the free-air value, C_{L_F} , the results indicated that a transversely-slotted wall of about 70%OAR gave very small lift corrections ($C_{L_T} - C_{L_F}$) for all the airfoils considered, at all lift coefficients, and up to airfoil sizes, c/H , as large as unity.

Figure 5.1 shows the calculated ratio of lift coefficients as a function of airfoil size, c/H , for three airfoils. The first airfoil is a 14% thick, 4.6% camber Clark-Y (represented by 50 control points) at zero and 20 degrees incidence (the fact that the actual airfoil would be stalled at this incidence is of no consequence for the present purpose). The second airfoil is an NACA-23012 at 8 degrees incidence, with a 25.6% (overall chord length) slotted flap deflected 20 degrees (represented by

46 control points on the main airfoil and 35 on the flap). The third airfoil is an NACA-0015 at 3 degrees incidence.

This ratio of lift coefficients is shown for two wall configurations. One is with two solid walls, and the second is a 70%OAR TSUSL wall configuration. It is seen that whereas the lift correction for an airfoil tested between solid walls could be more than 50% of the true, free-air value, the present theory for one solid wall and one slotted wall of OAR near 70% predicts lift corrections of less than 7%, for airfoil size c/H less than 1.0. Indeed, it appears that a slightly lower value of OAR would shift the curves up slightly, and give lift corrections of less than about 4% for c/H less than 0.8.

For the details of the number of wall slats, number of control points used, slat size and spacings, for any airfoil-wall configuration tested theoretically, and referred to herein, see Table 3.

A principal reason for two-dimensional airfoil testing is to obtain pressure distributions for use in subsequent aerodynamic analysis. Figure 5.2 shows a comparison of the pressure distributions calculated by the present theoretical method on the Clark-Y airfoil at 20 degrees incidence in the presence of a 70%OAR TSUSL wall configuration, and in free air. The lift coefficients are the same, that is, there is zero lift-correction. The figure is plotted in terms of the usual non-dimensional pressure coefficient C_p . The figure shows that the distortion of the pressure distribution on the airfoil in the presence of this TSUSL wall configuration is small, even at the

high C_{L_F} of 3.09. The pressure distribution for free air shows larger negative pressures over the forward section of the airfoil and a lower negative pressure over the after section, than in the pressure distribution for the TSUSL wall configuration. The resulting midchord nose-up pitching moment coefficient for free air is 0.603, which is therefore larger than the corresponding value of 0.573 for the TSUSL wall configuration. The ratio of midchord pitching moment coefficients in the tunnel, $C_{M_0_T}$, to the free-air value $C_{M_0_F}$, is 0.95 here, which suggests that this zero-lift-correction TSUSL wall configuration might also find use as a low moment-correction test configuration.

A flow field comparison of a TSUSL wall configuration and free air was made as follows. The flow speed and direction were computed at points on flat surfaces parallel to the plane of the testsection walls, and slightly inside the walls. A similar computation was performed for the free-air case, for two flat surfaces with the same corresponding positions relative to the test airfoil. The results are shown in Figure 5.3, for the same zero lift-correction case described above, in terms of the variation of C_p along these surfaces. Qualitatively the flow fields are similar in that a detailed calculation using pressures and momentum fluxes for a rectangular control volume about the test airfoil confirms the value of the airfoil lift coefficient within 5%.

6. Experiments to Verify the New Theory.

6.1 Testsection Design.

The success of the proposed transversely-slotted upper and solid lower wall (TSUSL) test configuration depends on the experimental verification of the present theory.

Initial experiments were performed in the octagonal testsection of an existing low-speed closed-circuit windtunnel (Figure 6.1, Plate 1). This tunnel has a testsection 915mm wide by 686mm deep, over a length of 2.59m, and produces a very uniform flow, with a turbulence level less than 0.1%, over a windspeed range of zero to 50m/s. The testsection has 152 by 152mm corner fillets (actually tapered downstream to compensate for boundary layer growth), so that the octagonal crosssection area is 0.582m².

As these initial experiments were encouraging, the existing testsection was modified to accept a two-dimensional testsection insert. This insert is 915mm wide by 388mm deep in crosssection, and 2.59m long. Test airfoils are mounted vertically on the yaw-turntable of a six-component windtunnel balance, at the midpoint of the testsection, and spanned the 388mm depth. One side-wall was surrounded by a 0.39 by 0.30 by 2.44m plenum, and could be fitted with airfoil-shaped slats of NACA-0015 section (Plates 2,3) and chords of 46 or 92mm, at zero incidence. A full range of wall open area ratios (OAR) could be tested, as the slats were fitted with metal sliders which in turn were separated by wooden spacers in an aluminum channel recessed in the side-wall frame.

Modifications to the existing windtunnel consisted of an inserted nozzle and diffuser section (2.6m length) in addition to the 388 by 915mm testsection. The design of the theoretical shape of converging sections of circular crosssection to produce spatially uniform flow conditions at exit is well established; for example, see Smith and Wang [29]. The approach here was to use the same crosssectional area variation (in the streamwise direction) for an equivalent rectangular crosssection as for the theoretical circular crosssection. For the details of the design, see Appendix 5.

The testsection floor and ceiling are parallel and solid; no structural or mechanical compensation for boundary layer growth is attempted. Pitotstatic tube traverses in the empty testsection (with two solid walls) where a test airfoil would be mounted, indicate that the testsection windspeed is spatially uniform to within 0.3% in the central "core" flow, outside the wall boundary layers. Figure 6.2 shows a typical "core" flow pitotstatic tube windspeed traverse. Boundary layer pitotstatic tube measurements in the empty testsection, again where the test airfoil would be mounted, indicate a displacement thickness of the order of 12mm, over a range of windspeeds covering the range of Reynolds numbers required for various test airfoils. Figure 6.3 shows a typical boundary layer pitotstatic tube windspeed traverse.

Initial experiments without the plenum gave inconsistent trends in the data taken as functions of the wall OAR, with a slotted-wall of OAR 70% or greater. The flow exiting from the

testsection through the slotted wall, upstream of the test model, at large OAR was not constrained to re-enter the testsection through the slotted wall downstream of the test airfoil. Conservation of mass flow was preserved by a large influx of air into the diffuser section through a breather slot between the testsection exit and diffuser section entrance. This problem was cured by using a plenum surrounding the transversely-slotted wall. Consistent trends in data taken as functions of wall OAR are now achievable with any OAR whatsoever.

6.2 Airfoil Models Tested.

Altogether nine different airfoils were tested, with lift, drag and pitching moment data taken for each airfoil. In addition, surface pressure measurements were made on two of the airfoils.

Four airfoils of NACA-0015 section, 383mm span and 153, 307, 462, and 616mm chord (model size c/H of 0.17, 0.34, 0.51 and 0.67 respectively), were machined from solid aluminum billets to close tolerances, on a numerically-controlled milling machine. Each airfoil was mounted on a circular spar which passed through a circular hole in the testsection floor with 3mm clearance all around between the circular hole and the mounting spar (Plate 4). The gaps between the tip of the test airfoil and the floor or ceiling were less than 2.5mm on all tests.

Four laminated wood airfoils of 14% thickness, 4.6% camber Clark-Y section, 683mm span and 227, 354, 481 and 608mm chord (airfoil sizes c/H of 0.25, 0.39, 0.53 and 0.66 respectively) were also tested. Since these airfoils extended outside the testsection, they were fitted with large (716mm diameter) circular aluminum endplates 3mm thick (Plate 5). The endplates fit flush with the testsection floor and ceiling into circular stepped recesses, of 724mm diameter and 6mm depth. Thus the test airfoil incidence could be varied by rotating the test airfoil-endplate combination about the vertical axis, without allowing the endplates to touch the testsection floor or ceiling.

A single laminated wood airfoil of 11% thickness, 2.3%

camber Joukowski section, 683mm span and 307mm chord (airfoil size c/H of 0.34) was also tested. It was similarly fitted with circular endplates. The trailing edge region was thickened to 3.8mm to allow pressure taps to be located there. Table 1 contains the theoretical and modified profile coordinates for this airfoil.

For the five airfoils fitted with endplates, it was necessary to measure the loadings on the endplates themselves. While under test, depending on the test airfoil incidence, flow could be detected out of the test section through the gap between the circular endplates and the circular recesses in the testsection floor and ceiling. This flow would certainly affect the loadings on the test airfoil-endplate combination, particularly the loading on an endplate. Thus there would be a loading on an endplate due to the outflow through the gap in addition to the expected skin-friction drag force in the streamwise direction.

The loading on a single endplate was therefore determined by mounting the endplate on the windtunnel balance with the upper surface flush with the testsection floor. Each of the five airfoils was then suspended vertically above the endplate to establish the correct flow field over the endplate at all airfoil incidences. The gap between the tip of the test airfoil and the endplate was adjusted by raising or lowering the airfoil. Measurements of the loading on the endplate were made for each airfoil over a complete range of test airfoil incidence and for varying tip-endplate gaps. The results were extrapolated

to zero gap to deduce that portion of the loadings on the test airfoil/endplate combination which was due to the two endplates. The net effect on test airfoil lift and midchord pitching moment was typically less than 2%; the effect on test airfoil drag was large, typically 30%. Table 4 and Figure 6.4 show typical endplate loadings and the corresponding uncorrected and corrected airfoil loadings for the Joukowski airfoil.

The fact that the loading on the endplate did not vary markedly for a gap less than that corresponding to a gap to chord ratio of about 0.005, supports the claim that the loading on a two-dimensional test airfoil should not be too sensitive to the tip-wall gap, provided the gap is less than a certain minimum value.

The 0.67-NACA-0015 airfoil was fitted with 65 center-span pressure taps (Plate 6). The Joukowski airfoil has a 75mm wide aluminum center-span section housing 37 pressure taps. All pressure taps are surface flush and have 0.5mm diameter orifices in metal. Plastic tubes of 1.6mm inside diameter and approximately 1.0m length transmit the surface pressures via the mounting spar to a location external to the testsection. Pressures were measured using a 48 port "Scanivalve" manual-scan pressure transducer. The tubes were disconnected from the pressure transducer and tied to the windtunnel balance turntable during balance measurements to eliminate any effect of tension in the plastic tubes.

6.3 Test Procedures.

The testsection windspeed was deduced from a pitotstatic tube mounted on the flow centerline in the tunnel nozzle midway between the settling chamber exit and the testsection entrance. Located thus, the pitotstatic tube would be far enough upstream to be relatively unaffected by test model "blockage" effects. Also the pitotstatic tube would be sufficiently far downstream in the nozzle that the flow speed would produce numerically large pitotstatic tube readings (mm of water). Thus a sufficiently accurate reading, either on a "Betz" micromanometer scale or as a "Barocel" output voltage, could be obtained.

The nozzle pitotstatic tube was calibrated against a second pitotstatic tube mounted in the empty solid walled testsection, on the flow centerline, where the test airfoils would be located. The pitotstatic tubes were connected to "Barocel" pressure transducers. During tests, the nozzle pitot reading is simultaneously monitored on a "Betz" micromanometer. During pressure tests, the total head in the nozzle is measured (with the same pitotstatic tube), and used as a calibration pressure for the "Scanivalve" pressure transducer.

The reference windspeed and static pressure used to reduce balance and pressure measurements are determined as follows. Since the total head at the nozzle pitotstatic tube (when there is a test airfoil in place, at incidence) is essentially the same as the total head in the testsection in the vicinity of the test airfoil, the reference windspeed and static pressure can be deduced from the nozzle pitotstatic tube measurements of total

head and dynamic pressure (q). This equality of total heads can only be verified in the empty testsection (solid walls) with no test airfoil in place; such measurements indicated that the testsection total head was lower than the nozzle total head by 1 part in 200.

Let H , p and q be the total head, static pressure and dynamic pressure respectively, and let the subscripts 1 and 2 refer to the nozzle and testsection respectively. In the empty testsection (solid walls), according to the above,

$$H_1 = p_1 + q_1 = H_2 = p_2 + q_2 . \quad (6.1)$$

If k is the empty test section (solid walls) calibrated ratio of q_1 to q_2 , then since only H_1 and q_1 are measured while under test, the equivalent empty testsection (solid walls) dynamic pressure and static pressure are kq_1 and $(H_1 - kq_1)$ respectively. Thus the reference windspeed and static pressure used to reduce data taken for any test airfoil, at any incidence, in the presence of any slotted-wall OAR, are the equivalent values in the undisturbed uniform stream conditions that would actually occur in the empty (solid walls) testsection corresponding to that measured H_1 and q_1 in the nozzle. Hence the reference windspeed so deduced is not the actual flow speed past the test airfoil nor is the reference static pressure the actual static pressure in the testsection, while under test. Figure 6.5 shows a typical nozzle-testsection windspeed calibration curve using the two pitotstatic tubes. The ratio k

is determined from a straight line least-squares curve fitted through the origin.

The six-component windtunnel balance has six independent four-arm strain gauge load cells so that in principle, three forces and three moments can be measured and read independently and simultaneously. In practice, only two strain gauge amplifiers, nulling and readout units are available simultaneously. As these amplifiers are of the vacuum tube type, they are left switched 'ON' at all times to minimize the drift in the zero readings on the readout units. The standard procedure for windtunnel balance readings is to shut off the windspeed every 20 to 30 minutes and record the drifts in the zero readings. These zero drifts are then applied to each reading in a proportion, assuming that these zero drifts are linear in time and that the time between readings is the same.

All pressure transducer and strain gauge voltages are amplified and time-averaged to produce essentially steady 3 or 4 significant digit readings on digital voltmeter displays.

The relative accuracy on a single windtunnel balance measurement is indicated as follows. Typical values and maximum possible errors are, for example, for the Joukowsky airfoil at +3 degrees incidence (including endplate effects), Reynolds number (Re) $0.5(10^6)$:

$$C_L = 0.713 \pm 0.004 (0.6\%); \quad C_{\frac{M_c}{4}} = -0.0625 \pm 0.0005 (0.8\%);$$

$$\text{and} \quad C_D = 0.0286 \pm 0.0004 (1.4\%) \quad (6.2)$$

At this incidence and Re the net lift, quarterchord pitching

moment, drag and windspeed can be measured to within 0.2, 0.4, 1.0 and 0.2%, respectively. Similarly a value of lift coefficient determined by integration of a measured pressure distribution has

$$C_L = 0.709 \pm 0.006 (0.9\%). \quad (6.3)$$

In comparing coefficient values taken at different angles of incidence there is a maximum possible error of ± 0.005 degrees in the measured incidence due to slack in the turntable worm gear mechanism. Care was taken to always rotate the turntable in the same direction to minimize the effect of backlash in the worm gear mechanism. This possible error in α is the largest of the possible errors which arise in computing the slope of the $C_L(\alpha)$ curves.

Figure 6.6 shows a typical $C_L(\alpha)$ curve, with error bars. The vertical error bars indicate the maximum possible cumulative error obtainable on a single measurement as described above. The horizontal error bars indicate the maximum possible error in the measured incidence. The accuracy obtainable on a single measurement is good for the type of measurements made here.

Figure 6.7 shows three $C_L(\alpha)$ curves and indicates the repeatability obtainable in measurements taken in three consecutive runs under identical test conditions and procedures. The degree of repeatability obtainable gives confidence in measurements taken on a single run (which is not repeated), for the type of measurements made here.

The level of turbulence in the two-dimensional testsection

insert was not measured. It is assumed that this level might be as high as in the unmodified octagonal crosssection, that is 0.1%. It is probably less due to the expected reduction in any streamwise fluctuations due to the increased contraction ratio, now 11.8 versus 7 for the octagonal crosssection.

7. Experimental Results.

The results of the experiments using the nine airfoils are listed in Tables 5, 6 and 7. The results are tabulated as coefficients of lift, drag, midchord and quarterchord pitching moments, according to test airfoil size (c/H) and test Reynolds number (Re), as functions of test airfoil incidence (α). The lift-curve slope $dC_L/d\alpha$ is calculated from a least-square fit straight line on an interval of 10 degrees incidence, for measurements in 1 degree increments from 2 degrees below the angle of zero lift to 8 degrees above the zero lift angle. For the NACA-0015 airfoils with a zero-lift angle of 0° , m is calculated on $(-2^\circ, 8^\circ)$. For the Clark-Y airfoils with a zero-lift angle of about -6.3 degrees, m is calculated on $(-8^\circ, 2^\circ)$. For the Joukowsky airfoil with a zero-lift angle of about -3.8 degrees, m is calculated on $(-6^\circ, 4^\circ)$. From the fitted straight line the zero-lift angle can be determined as the α -intercept when C_L is zero. In a similar manner the slope of the midchord pitching moment curve, $dC_{M_0}/d\alpha$, can be determined. The position of the aerodynamic center x_{ac}/c with respect to the airfoil leading edge is

$$\frac{x_{ac}}{c} = \frac{x_0}{c} - \frac{\tau}{m} \quad (7.1)$$

where x_0 , m , c , and τ are the distance from the leading edge to the axis of measurement of the moment coefficient C_{M_0} , the lift-curve slope, the chord and the midchord pitching moment-curve slope, respectively. Table 8 contains values of the lift-curve slope, the zero-lift angle and the position of the aerodynamic

center for the nine airfoils and the various wall configurations tested.

Figure 7.1 shows a typical variation of $C_L(\alpha)$ with upper wall open-area ratio (OAR). The straight line plotted corresponds to established experimental free-air lift-curve slopes (Jacobs and Sherman [31], Riegels [32]). The zero-correction OAR appears to lie between zero and 40%; this fact is also apparent in Figure 7.5 and will be discussed there.

The resulting values of the lift-curve slopes, m , for any of the airfoils are, to the degree of accuracy required here, quite sensitive to the choice of range of incidence over which the least-squares straight line curve fitting is done. For example, for the 0.67-NACA-0015 airfoil between two solid walls, the value of m computed on $(-2^\circ, 8^\circ)$ is 0.1114, while the value on $(0^\circ, 10^\circ)$ is 0.1156 and the value on $(0^\circ, 12^\circ)$ is 0.1138. This is particularly noticeable for this airfoil as there is a pronounced jog in the $C_L(\alpha)$ curve in this range of Reynolds numbers. This jog is attributed to (see Tani [30]) the formation of a laminar separation bubble by the separation of the laminar boundary layer near the leading edge and subsequent reattachment downstream. As the Re is increased, the jog becomes progressively less pronounced.

Figure 7.2 shows a comparison of two sets of measured values of lift-curve slope m , with the corresponding slopes from the present theory, for a 14% 0.53-Clark-Y airfoil, as a function of the upper wall OAR. The large wall slats (92mm) were used for one set of measured values, and the small slats (46mm)

for the other set. The ordinates are normalized by the value of the lift-curve slope, m_s , in the presence of two solid walls (zero OAR). The test Re in both sets of measurements was $0.5(10^6)$, based on the test airfoil chord. The theoretical values of lift-curve slope m are determined from a least-squares straight line fit through three values of lift coefficient C_L , computed at -8 , -3 and $+2$ degrees incidence.

Figure 7.3 shows similar results for the 0.67-NACA-0015 airfoil tested at a Re of $1.0(10^6)$. The measured lift-curve slopes are shown for tests with both the large and small wall slats. The theoretical values of lift-curve slope m are determined from a least-squares straight line fit through three values of lift coefficient C_L , computed at -2 , $+3$ and $+8$ degrees incidence. Figures 7.2 and 7.3 show that the theoretical values of m/m_s are higher than the experimental values, for both airfoils, and for all OARs. This difference is about 2.8%, at 70%OAR, and will be accounted for by two extensions to the present theory in §§8.1 and 8.2.

Figure 7.4 shows experimental values of lift-curve slope, m , (per degree) for four sizes of NACA-0015 airfoil in the presence of walls of different OAR, 0, 60, 70, and 80%, using the large slats. All tests for the three larger airfoils (c/H of 0.67, 0.51, and 0.34) were run at a Re of $0.5(10^6)$. This Re could not be reached for the smallest airfoil (c/H of 0.17), which was tested at a Re of $0.3(10^6)$. The data for this airfoil were then adjusted to correspond to the $0.5(10^6)$ Re , using published $m(Re)$ data for the NACA-0015 airfoil (see Jacobs and

Sherman [31]). The adjusted data are the flagged points in Figure 7.4. The results show a convergence toward a free air (zero c/H) lift-curve slope value of 0.093, in good agreement with [31]. The results indicate zero lift-corrections for an upper wall OAR between 60 and 70%, in agreement with the predictions of the present theory.

Figure 7.5 shows the corresponding experimental values of m for four sizes of Clark-Y airfoil in the presence of walls of different OAR, using the large slats. All tests for the three larger airfoils (c/H of 0.66, 0.53, and 0.39) were run at a Re of $0.5(10^6)$. This Re could not be reached for the smallest (c/H of 0.25) airfoil, which was tested at a Re of $0.45(10^6)$. The data for this airfoil were not adjusted to the $0.5(10^6)$ Re as $m(Re)$ information for the 14% thick Clark-Y section is scarce. The results show a convergence toward a free air (zero c/H) lift-curve slope value of 0.096, which agrees favourably with the information that is available (Silverstein [33]). An extrapolation of the curve of $m(Re)$ of Figure 11 of [33], for an 11.7% thick Clark-Y section of aspect ratio 6 gives a value of m 0.071 at a Re of $0.5(10^6)$. By using the theoretical relation (5.1) to estimate an equivalent value for 14% thickness, then correcting to infinite aspect ratio, the estimated value of m for the 14% thickness at a Re of $0.5(10^6)$ is 0.096. Here zero lift-corrections are indicated for an upper wall OAR less than 60%.

Experimentally, from both Figure 7.1 and 7.5, the zero-correction OAR appears to be somewhat less than 60%, based on a

free air lift-curve slope of 0.096. If a lower value such as 0.092 were chosen, the zero-correction OAR would be about 60%. The m -values for the smallest airfoil should be lowered due to the difference in the test Re . Previous tests [36] with the smallest airfoil have been unreliable. It appears that this airfoil has a relatively smaller nose radius than the larger airfoils, which might account for the higher m -values.

Figure 7.6 gives a comparison of experimental pressure distributions on the Joukowski airfoil, at +3 degrees incidence in the presence of two solid walls, and the 70%OAR, TSUSL wall configuration, using the large wall slats. The comparison supports the theoretical prediction that the chief effect of the slotted wall is to lower the negative pressures over the upper surface of the airfoil, without appreciably modifying the positive pressures on the undersurface, or generally distorting the distribution. The close agreement of C_L values from balance measurements with those obtained by integration of the pressure coefficient, C_p , indicates satisfactory two-dimensional flow conditions. Cubic-spline polynomials are used to curve-fit the distribution of C_p for integration.

In Figure 7.7, the pressure data from Figure 7.6 for two solid walls are corrected to equivalent free-air conditions by conventional wall-correction theory (Pankhurst and Holder [34]). The actual correction formulae used are recorded in Appendix 7. These corrected data are compared with the 70% OAR pressure data as taken. The 70%OAR data are seen to agree quite closely with the corrected solid wall data. The corrected solid wall value of

C_L is 0.675, while the 70%OAR value of C_L is 0.651; this again indicates that zero lift-correction test conditions will occur at an upper wall OAR between 60 and 70%. The hump in the pressure distributions toward the rear upper surface is caused by the thicker trailing edge of the experimental airfoil replacing the theoretical trailing edge cusp.

For completeness, to show how the use of such a TSUSL wall configuration affects other aerodynamic data, some typical curves of pitching moment and drag coefficients are shown, as functions of airfoil incidence.

Figures 7.8 and 7.9 show the midchord pitching moment coefficient C_{M_0} and drag coefficient C_D respectively for the 0.53-Clark-Y airfoil, as a function of airfoil incidence, and upper wall OAR. The values at 70%OAR (near free-air conditions) for $C_{D_{\min}}$ and C_{M_0} agree well with corresponding values from Figure 68 of Pinkerton and Greenberg [35], and Lim [36]. The values of C_D at a given incidence initially increase and then decrease, with increasing OAR. This same behaviour of C_D was observed for the other airfoils tested, both with and without endplates, and appears to be a property of this particular test configuration.

8. Extensions to the New Theory.

What is available at present is a potential flow theory for a transversely-slotted upper and solid lower wall configuration (TSUSL), that, for an upper wall OAR of between 60 and 70% predicts low lift-corrections for a variety of airfoils, sizes and incidences. However, experimentally, the OAR at which zero lift-correction occurs is less than the OAR predicted theoretically. Thus the slotted wall behaves experimentally as if it were operating at a larger OAR.

The result, at a given OAR, is that the ratios of the theoretical values of lift-curve slope m or lift coefficient C_L , normalized by their corresponding theoretical free-air values, are too high. This is because the TSUSL wall configuration theory is a potential flow representation of a viscous flow field.

For example, because of viscosity, the wall slats are not developing their full circulations predicted by the potential flow theory since they are operating in a Re range of 37,500 to 180,000 (with respect to their chord lengths). Thus the net circulation on the slotted wall is less than the circulation predicted theoretically. Hence that portion of the measured lift at a given OAR which is due to the circulation on the wall slats, will be much less than that portion of the lift predicted theoretically.

In other words, in order to predict theoretically the lift that would actually be measured experimentally on an airfoil in

this TSUSL wall configuration, there are two viscous flow fields to be accounted for. The first is the usual free air viscous flow field about the isolated airfoil. Now a second viscous flow field has been introduced, that of the flow through the TSUSL wall configuration. Thus a complete solution would require the application of viscous theory to the test airfoil, the wall slats and any shear layers which develop in the plenum.

Let $C_L(;E)$ and $C_L(;T)$ denote lift coefficients obtained from experiment and theory respectively, and let $C_L(OAR;)$ and $C_L(F;)$ denote lift coefficients from OAR and free air test configurations respectively. For a particular OAR, it is reasonable to assume that the ratio $C_L(OAR;E):C_L(OAR;T)$ will be equal to the ratio $C_L(F;E):C_L(F;T)$, particularly in a low-correction test environment. In this case the viscous effects on each ratio will be the same. Thus the ratio of $C_L(E)$ to $C_L(T)$ will be the same for free-air tests or for tests at whatever OAR produces near free-air test conditions. Therefore it is still useful to compare the ratio of $C_L(OAR;E):C_L(F;E)$, with the ratio of $C_L(OAR;T):C_L(F;T)$.

What is then desired is a potential flow calculation that will account for the viscous effects present experimentally which are due only to the TSUSL wall configuration. That is, the usual viscous flow analysis for the test airfoil will still be required.

8.1 Potential Flow Considerations of Viscous Effects.

There are two ways to extend the present theory toward such a potential flow calculation. One way is to account for the effect of viscosity on the test airfoil and wall slats, through the formation of viscous boundary layers on these streamlined shapes. The second way is to make the geometry of the flow representation more like that which actually occurs experimentally in the testsection, with the plenum surrounding the slotted wall.

The following discussion applies to both the test airfoil and the airfoil-shaped wall slats. For boundary layer effects, only completely attached flows are considered, that is, boundary layer flows which separate from an airfoil surface are not considered. Thus, since the flow leaving the airfoil trailing edge is attached, the velocities and pressures at the upper and lower surfaces adjacent to the trailing edge, must be equal. This statement is true on a time-average, since the formation of a vortex street in the airfoil wake requires the shedding of consecutive trailing vortices of alternate sign. For a given airfoil shape and incidence, there is a unique circulation that will set equal the trailing edge velocities on the upper and lower surfaces. This is the physical reasoning behind the theoretical relation known as the Kutta condition, that is, that the velocities at the upper and lower surfaces adjacent to the trailing edge (of any body which possesses a sharp trailing edge) must be equal.

Experimentally the measured value of lift (which is

proportional to the circulation) is always lower than the lift predicted by the usual potential flow theories; the ratio of these lifts might be, for example, k . What then is required is a procedure to reduce the usual theoretical value of the circulation Γ to a fraction k of Γ .

From the uniqueness of the value of the circulation for a given airfoil shape and incidence, the only possibility of reducing the circulation, if the Kutta condition is retained, is to reduce the incidence, and/or alter the shape of the profile.

The reduction of incidence approach is often used in the comparison of the theoretical and experimental pressure distributions. The theoretical pressures are calculated at a reduced incidence, such that the theoretical lift (determined by integration of the pressure distributions) at the reduced incidence is the same as the measured lift at the measured incidence. This procedure is not completely satisfactory as the magnitude of the negative pressure peaks in the theoretical pressure distributions (near the airfoil leading edge on the upper surface) may not equal the magnitude of the peaks actually measured. Physically the thin laminar boundary layer, which forms beginning at the forward stagnation point on the underside of the airfoil, grows in thickness as it rounds the leading edge and passes through the negative pressure peaks. The effect of this thin boundary layer is to increase the radius of curvature of the airfoil leading edge so that the flow velocities there are much lower than those predicted by theory. Thus the effect of the thin boundary layer over the leading edge is to reduce

the magnitude of the negative pressure peaks below the magnitudes predicted theoretically. Reducing the airfoil incidence for purposes of the theoretical calculation will reduce the magnitude of these negative pressure peaks, but not to the same degree as actually occurs due to the presence of the boundary layer.

However, if the circulation is not fixed by the Kutta condition, it is possible to specify the circulation otherwise. The circulation may be determined for the theoretical calculation from the measured lift. The theoretical pressures are then calculated at the measured incidence. The velocities at the trailing edge will no longer be equal, but the theoretical lift obtained from the integration of the pressure distribution can be made to equal the experimentally measured lift. The procedure for this calculation is presented in Appendix 8. Figure 8.1 compares the resulting theoretical and measured pressure distributions for the 0.67-NACA-0015 airfoil at 10 degrees incidence in the presence of two solid walls. The theoretical results by this method are physically unsatisfactory in the vicinity of the airfoil trailing edge as such large negative pressures are in practice not found there.

It is possible to lower the circulation developed by altering the shape of the airfoil profile. This procedure is justifiable physically if the alterations are in keeping with those which occur when the boundary layer effectively modifies the profile shape.

Recall that for an airfoil, the effects of viscosity are

confined to the thin boundary layer adjacent to the airfoil surface, and the flow outside the boundary layer can be considered as irrotational. Thus the boundary layer modifies the profile shape and the potential flow is calculated about this modified shape, using the usual equal-velocity Kutta condition.

The following procedure follows and extends that of Pinkerton [37] whose analysis is for two-dimensional airfoil sections to be mapped conformally onto a modified circle by means of the classical Theodorsen method. Figure 8.2 shows the original profile of the NACA-0015 airfoil and the resulting modified profile which results from the present procedure when this airfoil is at 10 degrees incidence between two solid walls. This is the modified profile used in the calculation of the theoretical pressure distribution in Figure 8.3. With respect to the direction of the approach flow, the modified profile is effectively at a slightly lower incidence and has slightly less camber than the original profile. The actual profile (original profile swollen by the addition of the boundary layer displacement thickness) about which a potential flow calculation might be considered, would be blunt at the trailing edge and would have the thickness of the wake at that point. The thickness of the boundary layer on the upper surface is greater than the thickness on the lower surface, except for a symmetrical airfoil in free air or between two solid walls, at zero lift. Therefore if the trailing edge was imagined to be taken (vertically) as the midpoint of the wake, and the after portion of the profile were faired to that point, the resulting shape would be similar to the effective profile of Figure 8.2.

The airfoil is supposed to be at incidence α . Points on the profile are to be rotated about the profile leading edge in proportion to their distance from the profile leading edge. The direction of rotation is such to reduce the effective incidence of the profile. As not all points are rotated by the same amount, this is not a rigid body rotation about the profile leading edge. Thus the effective camber of the profile is reduced as the trailing edge is "raised" more than other points on the profile.

The details of this "raised" trailing edge procedure are presented in Appendix 9. Figure 8.3 shows a comparison of the resulting theoretical and measured pressure distributions for the 0.67-NACA-0015 airfoil at 10 degrees incidence in the presence of two solid walls. The theoretical results by this procedure are quite satisfactory except for the negative pressure peak near the airfoil leading edge. The magnitude of the theoretical peaks is still larger than the magnitude actually measured, and will always be so for any procedure that does not increase the radius of curvature of the airfoil leading edge to the same degree that actually occurs due to the boundary layer there.

The above procedure was applied to the airfoil-shaped wall slats to see what the effect would be of reducing the circulations there while maintaining the full Kutta circulation on the test airfoil. For the case of the 0.66-Clark-Y airfoil at 20 degrees incidence in the presence of a 70%OAR TSUSL wall configuration, the test airfoil lift coefficient was reduced

from 3.010 to 2.935, that is, by about 2.5%. This calculation used a value of k of 0.80 on all the wall slats. Thus the effect on the test airfoil of the neglect of viscous effects on the wall slats alone is small in comparison with the neglect of viscous effects on the test airfoil itself.

A complete accounting for the boundary layer effects even for completely attached flows must involve the calculations of the laminar boundary layer growth, transition to a turbulent boundary layer, and the growth of the wake. Seebohm [38] has performed such calculations and found good agreement with experiments. His procedure is as follows. The usual potential flow calculations are performed for the airfoil profile, the growth of the boundary layer and wake are calculated. The airfoil profile is swollen by the boundary layer displacement thickness and is extended downstream to represent the wake. Seebohm develops a condition to fix the circulation (which reduces to the equal-velocity Kutta condition for no boundary layer and no wake) based on the pressure difference across the wake, calculated at two points (vertically) above and below the airfoil trailing edge, at the outer edges of the boundary layers. The last two steps are iterated on until the pressure difference across the wake no longer changes on iteration. Such calculations could be included in the present theory, on the wall slats.

A method of handling the separated flow region over the upper surface of an airfoil at high incidence, approaching maximum lift, has been developed by Jacob and Steinbach [23].

The separating streamline departs tangentially from the upper surface since the observed pressures correspond to a smooth non-zero velocity distribution around the separation point. The separating streamline has an approximately constant pressure variation along its length, near the airfoil, to represent the approximately constant pressure in the real dead air region in the separated wake. This is accomplished by requiring equal pressures at a point at the trailing edge, and at a second point above the trailing edge, on the separating streamline. The circulation is thus fixed, and the method is seen to be similar to the procedure of Seebohm. Again the boundary layer calculations must be performed to calculate the position of the separation point, and the pressure on the separating streamline. Again such a procedure could be incorporated into the present method, for the wall slats, if desired.

8.2 The Flow in the Plenum: The Bounding Shear Layer.

The second extension of the present theory is to make the geometry of the flow representation more like that which actually occurs experimentally in the testsection, with the plenum surrounding the slotted wall. Figure 8.4 compares the flow representation of the present theory with the physical flow which actually occurs in the testsection. The present theory represents a uniform flow of infinite extent, past a set of multiple airfoils, and flat surfaces aligned with the direction of the undisturbed flow. Hence the energy levels of the flows inside and outside the testsection are the same.

Figure 8.5 shows a shear layer formed inside the plenum chamber surrounding the upper slotted wall. This shear layer is formed as the outflowing air from the testsection, upstream of the test airfoil, mixes with and entrains the otherwise stagnant air in the plenum. This shear layer therefore divides the two flows, the high-energy flow which exists in the testsection, and the zero-energy stagnant flow of the plenum. In a potential flow theory, this shearlayer could be idealized as a constant-pressure free streamline which leaves the test section at the upstream end of the slotted wall, enters the plenum and reattaches to the solid wall section at the downstream end of the slotted wall. The position of, and the pressure variation along such a streamline are initially unknown. The initial and terminal positions, inclinations and pressures could be estimated from a flow field calculation which omits representation of this streamline entirely.

An iterative procedure could be developed to calculate the position of this streamline in a segmented step-by-step approach. The position of a segment would be assumed. The resulting flow inclinations would be calculated in the vicinity of the supposed streamline and compared with the direction the streamline is taking there. These steps could be iterated on until a satisfactory streamline position was found. Such procedures are used for locating streamlines in vortex wakes, but are computationally time-consuming.

As the approach to a zero lift-correction wall configuration is made, the overall flow field will approach closely that of the test airfoil in a free-air test environment. An obvious position to take for such a streamline is therefore the position that the particular streamline in the free-air case occupies which passes through the two points defined by the ends of the solid wall sections at the beginning and end of the slotted wall.

In order to investigate the effect of including a constant-pressure free streamline in the present theory, an analytic two-dimensional potential flow representation was developed. The test airfoil was represented by a single vortex, and the wall slats by a set of vortices near the constant pressure boundary. Figure A6.2 shows the multiply-infinite set of vortex images required to satisfy the boundary conditions. On the solid lower wall, the boundary condition is zero disturbance velocity normal to the wall. On the constant pressure boundary, the linearized condition of constant pressure can be expressed via Bernouilli's

equation as requiring zero disturbance velocity in the streamwise direction. Thus in solid boundaries, the appropriate image of a vortex is a vortex of equal but opposite circulation; the image in a constant pressure boundary has identical circulation.

The details of the image system and the equations involved are in Appendix 6. The results shown in Figure 8.6 compare the present analytic image representation with the analysis of Havelock [5], for a flat plate (a) between two solid walls, (b) in ground effect, (c) between a solid lower boundary and a constant pressure upper boundary, and (d) between two constant pressure boundaries (open jet). The image representation is unsatisfactory as it predicts a lower lift than for either the ground effect or the open jet case; the experiments indicate lifts above the ground effect values.

That the lift is so low is a result of the constant pressure boundary condition which requires the tangential disturbance velocity to be zero there. The corresponding value of the pressure coefficient, C_p , is zero. By tracking a streamline (in the TSUSL wall configuration theory) which leaves the testsection through the slotted wall upstream of the test airfoil, and re-enters the testsection downstream of the test airfoil, the theoretical variation of pressure along such a streamline is known. Figure 8.7 shows such a pressure variation, and, excluding the large negative pressure excursions as the flow accelerates when in the vicinity of the wall slats, the average value of the pressure coefficient on this streamline is

about -0.25. Hence any representation which uses a zero C_p value is incorrect. The TSUSL wall configuration theory indicates that the wall slats collectively have a net counter-clockwise circulation, since there are a larger number of slats immersed in the re-entering flow than in the exiting flow. However the image representation correctly predicts the effect on the airfoil lift of including the circulation on the wall slats via the set of vortices adjacent to the constant pressure boundary. For example, for a flat plate at 26.3° incidence (see Appendix 6 and Figure 8.6), the image representation predicts that the lift is depressed 25% below the free air value; the contribution from the wall slat vortices is 2% and that from the constant pressure boundary is 23%. The comparison would be better for the flat plate at 20° incidence, but the calculations use wall slat circulation values from a Clark-Y airfoil at 20° incidence and 70%OAR.

However, any single potential flow free-streamline representation cannot model the division of the two flows of very different energy level, that is, total head, correctly. Suppose that the position of the streamline representing this shear layer is known. The flow along this streamline satisfies the tangent-velocity boundary condition. In addition, the pressure variation along this streamline must reflect the fact that the flow energy level on one side of this streamline (in the plenum) is zero. On the other side (in the testsection) the flow energy level is that of the uniform undisturbed approach flow. This shear layer could be modelled analytically by a vortex sheet, but this modelling was not attempted here.

Physically the pressure variation in the shear layer or on a representative streamline is a result of the manner in which the high energy testsection flow leaves the solid wall section, and of the low pressure region of recirculating flow so formed in the plenum.

To represent the shear layer by the present theoretical method, coincident source and vortex elements are distributed along a representative streamline. Source elements are used in the usual manner to ensure that the flow is tangential to the surface. Vortex elements, all of different strength densities, are used to set prescribed values of the tangential velocity at each control point on the surface. Thus if the shear layer is represented by, say, S control points, there are an additional unknown S source and S vortex strength densities. Thus there are S additional zero normal-velocity equations, and S additional prescribed-tangential-velocity equations to be solved. Since it is usual to prescribe the pressure variation C_{p_i} on the surface rather than the tangential velocity variation, the tangential velocity boundary condition equations have the form, from (3.14, 3.18):

$$\sum_{j=1}^N B_{ji} \sigma_j + \sum_{k=1}^M \gamma_k \sum_{m=1}^{R(k)} A_{mi} \sum_{r=1}^S (B_{ri} \mu_r + A_{ri} \nu_r) = -U \cos \theta_i \pm \sqrt{(1 - C_{p_i})}, \quad i=1, 2, \dots, S. \quad (8.1)$$

Here μ and ν are the source and vortex strength densities respectively on the streamline representing the shear layer. For

calculations in the same sense as the flow direction, the squareroot term is positive if the source and vortex elements are distributed sequentially.

The initial and terminal positions of this streamline are known, and the corresponding inclinations and pressures could be estimated from the flow conditions on the solid wall sections. It remains only to specify the variation of pressure (between two known end values) along the streamline.

Values of spreading coefficients for unbounded shear layers are to be found in the literature, (for example, [40]) and if estimates could be made of the effect of confinement which occurs here in the plenum, such estimates could then be used to specify the position of a streamline representing the shear layer.

It is proposed that the pressure variation along the streamline representing the shear layer is a free parameter in the analysis here. That is, several pressure variations were assumed and specified, and the computations performed. The streamline tracking procedure of Appendix 4 was used to compute the variation of pressure along the streamlines of similar position and shape as are required for specification of the position of the shear layer.

This pressure variation is shown on Figure 8.7. This streamline leaves the upstream upper solid wall section and re-enters the testsection downstream of the test airfoil, thus apparantly "entraining" some of the exterior flow. It would be

expected, from continuity, that this streamline should end on the downstream upper solid wall section. Hess [22] experienced similar "leakage" flows in the calculation of the interior flow in a right angle bend.

At first it appeared that there were too few source elements on the solid wall sections, and that the solid wall sections were too short. These sections were lengthened from two test airfoil chord lengths to ten, and the number of source elements on a section was increased from 20 to 50. The "entrainment" effect was still present. This apparently is a common problem for interior flow calculations using flat distributed source elements with constant uniform source strength densities; the problem is eliminated by using curved source elements with linear or parabolic variations of source strength densities over the elements. The "entrainment" flow rate here is about 5% of the net flow rate; in Hess's example the "leakage" flow rate was 12%.

With the end values of pressure specified, several pressure variations were tried such that the average pressure along the streamline representing the shear layer was similar to the average pressure on the tracked streamlines. The results in Figure 8.8 show how the airfoil lift coefficient varies with the assumed value of $\bar{C}_p$. This representation of the shear layer is used in the following section to compare the theoretical and measured values of lift-curve slope for two airfoils.

8.3 Summary.

A comparison of the curves of Figures 7.2 and 7.3 indicates that at an upper wall OAR of 70%, the experimental value of the ratio of the lift-curve slopes m/m_s is about 2.8% lower than the theoretical value, for both the Clark-Y and the NACA-0015 airfoils. Thus there is a small residual difference of 2.8% to be accounted for by the extensions to the theory outlined in §8.1 and 8.2.

Assuming that there are curves similar to the curves of Figure 8.8 of the ratio of lift coefficients C_{L_T}/C_{L_F} for the present case, the residual 2.8% could be accounted for by an increase in $\bar{C}_p$ of about +6%, for example from -0.33 to -0.31. A value of $\bar{C}_p$ of -0.31 corresponds to the pressure level established by the recirculating flow in the plenum.

Recall that an adjustment of the same order could be accounted for with the procedure of §8.1, that is, by reducing the circulations on the wall slats.

Thus the difference between the theoretical and experimental curves of Figures 7.2 and 7.3 at any OAR can be accounted for in the theory by a combination of (i) the reduction of the circulations on the wall slats by modifying their effective profiles, and (ii) by the representation of the shear layer in the plenum by a single streamline of assumed position and streamwise pressure variation. These extensions are preliminary; further work is required to establish a satisfactory theory.

9. Conclusions.

A two-dimensional theory which predicts a satisfactorily correction-free windtunnel test configuration has been developed. The theory is an extension of the two-dimensional potential flow theory based on the method of distributed surface singularities. The extended theory takes into consideration not only a wide range of airfoil sizes and shapes, but also the effect on the airfoil loadings of different windtunnel wall configurations.

The results of the theoretical study indicate that for two-dimensional airfoil testing, a windtunnel consisting of a solid wall opposite the pressure side of the airfoil, and a transversely slotted wall, the solid portions of which are symmetrical airfoil-shaped slats at zero incidence, with open area ratio between 60 and 70 percent, opposite the suction side of the airfoil, will yield uncorrected pressure distributions and lift coefficients which are within a few percent of the free air values. The theory predicts that this low-correction wall configuration will remain relatively correction-free for a wide range of airfoil sizes and angles of incidence.

Experiments carried out on a number of airfoils for a Reynolds number range of 300,000 to 1 million (based on the airfoil chord), in a two-dimensional test configuration support the predictions of the theory. Experimental work showed that the correction-free test configuration could be achieved with a slotted wall consisting of symmetric airfoil shaped slats at zero incidence, when the slotted section was surrounded by a

plenum chamber.

The above theory was then extended to account for viscous effects on the wall slats, and the effect of the shear layer which forms in the plenum chamber.

Measurements taken with the correction-free wall configuration of the lift, drag and pitching moments for nine different airfoils which ranged in size (chord to height ratio) from 0.17 to 0.67, showed good agreement with established free air values. Furthermore, measurements of the pressure distribution on two airfoils, with the correction-free wall configuration, showed good agreement with pressure distributions measured in solid wall configurations and corrected by standard methods.

The low-correction test configuration theory which has been tested and verified in the work reported in this thesis can be developed to provide a reliable means of testing high lift airfoils in existing windtunnels which can be modified to achieve the low-correction wall configuration. Such tests would otherwise require elaborate test facilities or complex correction procedures.

Appendix 1.

The Integration of a Three Dimensional Point Source to a Two Dimensional Flat Distributed Source Element

The potential ϕ at a point P due to a source strength density distribution $\sigma(Q)$ over a surface S is, from (3.2),

$$\phi(P) = - \iint_S \frac{\sigma(Q)}{r(PQ)} dS, \quad (A1.1)$$

where $r(PQ)$ is the distance from the point P to the point Q.

From Figure A1.1, the potential at $P(x,y,0)$, for unit strength density σ , is

$$\phi(x,y,0) = - \int_{-\frac{\Delta s}{2}}^{\frac{\Delta s}{2}} \left(\int_{-\infty}^{\infty} \frac{d\zeta}{\sqrt{(x-\xi)^2 + y^2 + \zeta^2}} \right) d\xi. \quad (A1.2)$$

The inner integration sums over all infinitesimal source elements $d\zeta d\xi$ to produce that part of the potential at P due to a line source element of width $d\xi$. The outer integration sums over all such line source elements to produce the potential at P due to a flat distributed source element of width Δs , and of constant uniform strength density.

The velocity components in the x and y directions respectively, induced at P by a source element of width Δs , are:

$$V_x = \frac{\partial \phi}{\partial x} = + \int_{-\frac{\Delta s}{2}}^{\frac{\Delta s}{2}} (x-\xi) I(x, \xi, y) d\xi, \quad (A1.3)$$

$$V_y = \frac{\partial \phi}{\partial y} = + \int_{-\frac{\Delta s}{2}}^{\frac{\Delta s}{2}} y I(x, \xi, y) d\xi, \quad (A1.4)$$

where

$$I(x, \xi, y) = \int_{-\infty}^{\infty} \frac{d\zeta}{((x-\xi)^2 + y^2 + \zeta^2)^{3/2}}. \quad (A1.5)$$

Now

$$\frac{\partial}{\partial \zeta} \left(\frac{\zeta}{((x-\xi)^2 + y^2) \sqrt{((x-\xi)^2 + y^2 + \zeta^2)}} \right) = \frac{1}{((x-\xi)^2 + y^2 + \zeta^2)^{3/2}}, \quad (A1.6)$$

therefore

$$I(x, \xi, y) = \frac{\zeta}{((x-\xi)^2 + y^2) \sqrt{((x-\xi)^2 + y^2 + \zeta^2)}} \Big|_{-\infty}^{\infty} = \frac{2}{(x-\xi)^2 + y^2}. \quad (A1.7)$$

Also

$$\frac{\partial}{\partial \xi} (-\log((x-\xi)^2 + y^2)) = \frac{+2(x-\xi)}{(x-\xi)^2 + y^2}, \quad (A1.8)$$

$$\frac{\partial}{\partial \xi} \left(\tan^{-1} \left(\frac{\xi-x}{y} \right) \right) = \frac{y}{(\xi-x)^2 + y^2}. \quad (A1.9)$$

Therefore

$$V_x = -\log((x-\xi)^2 + y^2) \Big|_{-\frac{\Delta s}{2}}^{\frac{\Delta s}{2}} = +\log \left(\frac{(x+\frac{\Delta s}{2})^2 + y^2}{(x-\frac{\Delta s}{2})^2 + y^2} \right), \quad (A1.10)$$

$$v_y = 2 \tan^{-1} \left(\frac{\xi - x}{y} \right) \frac{\frac{\Delta s}{2}}{-\frac{\Delta s}{2}} = 2 \left(\tan^{-1} \left(\frac{x + \frac{\Delta s}{2}}{y} \right) - \tan^{-1} \left(\frac{x - \frac{\Delta s}{2}}{y} \right) \right). \quad (\text{A1.11})$$

In a two dimensional incompressible, irrotational flow, the stream function ψ and the potential ϕ are conjugate harmonic functions. Thus the Cauchy-Riemann equations require

$$\frac{\partial \psi}{\partial y} = \frac{\partial \phi}{\partial x}, \quad \frac{\partial \psi}{\partial x} = - \frac{\partial \phi}{\partial y}. \quad (\text{A1.12})$$

Hence ψ may be expressed as

$$\psi(x, y) - \psi_0 = \int \left(\frac{\partial \phi}{\partial x} \right) dy + f(x) = - \int \left(\frac{\partial \phi}{\partial y} \right) dx + g(y), \quad (\text{A1.13})$$

where f and g are arbitrary functions and ψ_0 is an arbitrary constant.

Some useful identities are:

$$\log(y^2 + a^2) = \frac{\partial}{\partial y} \left(y \log(y^2 + a^2) - 2y + 2a \tan^{-1} \left(\frac{y}{a} \right) \right), \quad (\text{A1.14})$$

$$\tan^{-1} \left(\frac{x}{a} \right) = \frac{\partial}{\partial x} \left(x \tan^{-1} \left(\frac{x}{a} \right) - \frac{a}{2} \log(x^2 + a^2) \right), \quad (\text{A1.15})$$

$$\tan^{-1} A \pm \tan^{-1} B = \tan^{-1} \left(\frac{A \pm B}{1 \mp AB} \right). \quad (\text{A1.16})$$

Therefore, from A1.10,

$$\frac{\partial \phi}{\partial x} = \frac{\partial}{\partial y}(yA - xB + C), \quad \frac{\partial \phi}{\partial y} = \frac{\partial}{\partial x}(-yA + xB + C), \quad (\text{A1.17})$$

where

$$A = \log \left(\frac{(x + \frac{\Delta S}{2})^2 + y^2}{(x - \frac{\Delta S}{2})^2 + y^2} \right), \quad B = 2 \tan^{-1} \left(\frac{y \Delta S}{x^2 + y^2 - (\frac{\Delta S}{2})^2} \right), \quad (\text{A1.18})$$

$$C = \Delta S \tan^{-1} \left(\frac{2xy}{x^2 - y^2 - (\frac{\Delta S}{2})^2} \right).$$

According to equations (A1.13) and (A1.17), the stream function for a flat distributed source element of width Δs and unit strength density is

$$\psi(x, y) = \psi_0 + A - B + C. \quad (\text{A1.19})$$

As in equation (A1.13), the potential ϕ may be expressed as

$$\phi(x, y) - \phi_0 = - \int \left(\frac{\partial \psi}{\partial x} \right) dy + f(x) = \int \left(\frac{\partial \psi}{\partial y} \right) dx + g(y), \quad (\text{A1.20})$$

where f and g are arbitrary functions, and ϕ_0 is an arbitrary constant.

The application of the three relations (A1.14), (A1.15), and (A1.16) to (A1.19) results in

$$-\frac{\partial \psi}{\partial x} = \frac{\partial}{\partial y}(yB + xA + D), \quad \frac{\partial \psi}{\partial y} = \frac{\partial}{\partial x}(yB + xA + D - 2\Delta s), \quad (\text{A1.21})$$

$$D = \frac{\Delta s}{2} \log \left(\left(x + \frac{\Delta s}{2}\right)^2 + y^2 \right) \left(\left(x - \frac{\Delta s}{2}\right)^2 + y^2 \right).$$

Therefore the potential function for a flat distributed source element of width Δs and unit strength density is

$$\phi(x, y) = \phi_0 + xA + yB + D - 2\Delta s. \quad (\text{A1.22})$$

The corresponding results for a unit strength density flat vortex element can be written immediately since in a two-dimensional incompressible irrotational flow

$$\phi(\text{vortex}) = -\psi(\text{source}), \quad \psi(\text{vortex}) = +\phi(\text{source}). \quad (\text{A1.23})$$

Appendix 2.

A Procedure for Block Computation of Matrices A, B and C.

When the matrices A, B and C are large, C might be assembled from A and B by partitioning C into blocks as follows. Memory is allocated for A, B and C according to the size of the largest block.

	*j=1,2,...N*j=N+1,N+2,..N+M*		
i=1,2,...NL4	A_{ji}	$R(k) - \sum_{m=1} B_{mi}$	test airfoil, flaps and solid walls
i=NSU1,NSU2	A_{ji}	$R(k) - \sum_{m=1} B_{mi}$	slats
i=NK1,NK2	$B_{jU_r} + B_{jL_r}$	$R(k) \sum_{m=1} (A_{mU_r} + A_{mL_r})$	r-th slat
i=NKA,M	$B_{jU_r} + B_{jL_r}$	$R(k) \sum_{m=1} (A_{mU_r} + A_{mL_r})$	r-th airfoil or flap

The subscript 'i' refers to the row number in the matrix C. The meanings for the variables NL4, NSU1, NSU2, NK1, NK2 and NKA are given in the programs which follow.

Subroutine SUB1 calculates A and B in blocks as needed to assemble the blocks of C. SUB1 is called twice to set up the zero normal-velocity boundary condition equations on all solid surfaces. It is called first for the test airfoil and flaps, and all solid wall sections and a second time for the wall slats.

Subroutine SUB2 uses A and B to set up the Kutta condition

equations on the wall slats. Subroutine SUB3 does the same for the test airfoil and flaps.

The FORTRAN coded versions of SUB1, SUB2 and SUB3 follow. The subroutines READER (and WRITER) read (write) a matrix from (onto) a peripheral storage device, such as a magnetic disc.

```

1      C  SUB1 CALCULATES A & B IN BLOCKS & SETS UP EQN'S ZERO NORM VEL ON ALL SOLID
2      C  SURFACES
3      SUBROUTINE SUB1(A,B,C,XX,YY,DS,CS,SI,N,L,M,NA,NAF2,L1,L2,NSPS,
4      1 NSLAT,NSU1,NK1)
5      C  A,B - MATRICES OF INFLUENCE COEFFS FOR SOURCE & VORTEX ELEMENTS
6      C  C- MATRIX FOR SYSTEM OF EQN'S C*SIG=D
7      C  SIG(M) - UNKNOWN IN SYSTEM C*SIG=D - PART IS GAM
8      C  GAM(NAF+NSLAT) - VORTEX STRENGTHS ON KUTTA BODY.
9      C  M - TOTAL # UNKNOWN = TOTAL # EQUATIONS
10     C  NAF=#TEST AIRFOILS & FLAPS WITH KUTTA CONDITIONS APPLIED
11     C  NSU1,NSU2 - SET OF EQN'S FOR ZERO NORMAL VELOCITY ON SLATS.
12     C  NK1,NK2 - SET OF EQN'S FOR KUTTA CONDITIONS ON WALL SLATS.
13     C  XX,YY - CONTROL POINT COORDINATES; DS - ELEMENT LENGTH
14     C  NSLAT - # OF SLATS WITH KUTTA CONDITIONS; NSPS - # ELEM'S PER SLAT
15     C  CS SI - SIN,CCS OF ELEMENT INCLINATION
16     C  NA(K) - RANGE OF CONTROL POINT #'S FOR K-TH TEST AIRFOIL OR FLAP I.E. 1,50
17     C  N - TOTAL # CONTROL PTS WHERE NORM VEL IS ZERO ON ALL SOLID SURFACES
18     C  L - BLOCK SIZE
19     C  L1,L2 - RANGE OF CONTROL PT #'S FOR BLOCK - SET OF EQN #S ALSO
20     REAL A(N,L),B(N,L),C(M,L),XX(N),YY(N),DS(N),CS(N),SI(N)
21     INTEGER NA(NAF2)
22     NSU2=NSU1+NSPS*NSLAT-1
23     NK2=NSU2=NSLAT
24     NAF=NAF2/2
25     C  CALCULATE A AND B.
26     DO 1 I=L1,L2
27     K=I-L1+1
28     DO 1 J=1,N
29     IF(J.NE.1) GO TO 2
30     A(J,K)=6.2831927
31     B(J,K)=0.
32     GO TO 1
33     2  DXJ=XX(I)-XX(J)
34     DYJ=YY(I)-YY(J)
35     XJ=DXJ*CS(J)+DYJ*SI(J)
36     YJ=DYJ*CS(J)-DXJ*SI(J)
37     DSJ2=DS(J)/2.
38     YJS=YJ*YJ
39     S=XJ+DSJ2
40     T=XJ-DSJ2

```

```

41 PHIX=ALOG((S*S+YJS)/(T*T+YJS))
42 PHIV=2.*ATAN2((DS(J)*YJ),(XJ*XJ+YJS-DSJ2*DSJ2))
43 SIJ=SI(I)*CS(J)-CS(I)*SI(J)
44 COJ=CS(I)*CS(J)+SI(I)*SI(J)
45 A(J,K)=PHIV*COJ-PHIX*SIJ
46 B(J,K)=PHIX*COJ+PHIV*SIJ
47 C WRITE THIS PART OF A & B INTO FILES.
48 CALL WRITER(A,N,L)
49 CALL WRITER(B,N,L)
50 DO 3 I=1,L
51 C SET UP EQN'S FOR ZERO NORM VELS ON ALL SOLID SURFACES
52 DO 4 J=1,N
53 4 C(J,I)=A(J,I)
54 IF(NSLAT.EQ.0) GO TO 7
55 C SET UP EQN'S FOR NORM VELS ZERO ON WALL SLATS
56 DO 5 KS=1,NSLAT
57 J=NK1+KS-1
58 KK=NSU1+NSPS*(KS-1)
59 KL=KK+NSPS-1
60 SB=0.
61 DO 6 K=KK,KL
62 SB=SB-B(K,I)
63 C(J,I)=SB
64 C SET UP EQN'S FOR ZERO NORM VELS ON AIRFOILS & FLAPS
65 7 DO 8 KN=1,NAF
66 K3=2*(NAF+1-KN)-1
67 K1=NA(K3)
68 K2=NA(K3+1)
69 J=M-NAF+KN
70 SB=0.
71 DO 9 K=K1,K2
72 SB=SB-B(K,I)
73 C(J,I)=SB
74 3 CONTINUE
75 C WRITE THIS PART OF C INTO A FILE.
76 CALL WRITER(C,M,L)
77 RETURN
78 END

```

```

79      C      SUB2 SETS UP KUTTA EQN'S ON WALL SLATS.
80      SUBROUTINE SUB2(A,B,C,NA,N,L,M,NAF2,NSLAT,NSPS,NSU1,NK1)
81      REAL A(N,L),B(N,L),C(M,NSLAT)
82      INTEGER P,Q,NA(NAF2)
83      C      A,B - MATRICES OF INFLUENCE COEFFS FOR SOURCE & VORTEX ELEMENTS
84      C      C- MATRIX FOR SYSTEM OF EQN'S C*SIG=D
85      C      M - TOTAL # UNKNOWS= TOTAL # EQUATIONS
86      C      NAF=#TEST AIRFOILS & FLAPS WITH KUTTA CONDITIONS APPLIED
87      C      NSU1,NSU2 - SET OF EQN'S FOR ZERO NORMAL VELOCITY ON SLATS.
88      C      NK1,NK2 - SET OF EQN'S FOR KUTTA CONDITIONS ON WALL SLATS.
89      C      NSLAT - # OF SLATS WITH KUTTA CONDITIONS; NSPS - # ELEM'S PER SLAT
90      C      NA(K) - RANGE OF CONTROL POINT #'S FOR K-TH TEST AIRFOIL OR FLAP I.E. 1,50
91      C      N - TOTAL # CONTROL PTS WHERE NORM VEL IS ZERO ON ALL SOLID SURFACES
92      C      L=NSPS*NSLAT - BLOCK SIZE
93      NAF=NAF2/2
94      NSU2=NSU1+NSPS*NSLAT-1
95      NK1=NSU2+1
96      NK2=NSU2+NSLAT
97      C      READ IN THAT PART OF A & B WHICH CONTAINS THE INFLUENCE COEFFS FOR VELOCITIES
98      C      INDUCED AT THE CONTROL POINTS ON THE WALL SLATS.
99      CALL READER(A,N,L)
100     CALL READER(B,N,L)
101     C      SET UP EQNS FOR KUTTA ON WALL SLATS
102     DO 1 I=1,NSLAT
103     P=1+NSPS*(I-1)
104     Q=P+NSPS-1
105     C      P,Q - T.E. CONTROL PT #S FOR SLATS
106     C      2 LOOP - TANG'L VELS DUE TO ALL SOURCE ELEM'S.
107     DO 2 J=1,N
108     C(J,I)=B(J,P)+B(J,Q)
109     C      4 LOOP - TANG'L VELS DUE TO VORTEX ELEM'S ON SLATS
110     DO 4 KS=1,NSLAT
111     J=NK1+KS-1
112     KK=NSU1+NSPS*(KS-1)
113     KL=KK+NSPS-1
114     SA=0.
115     DO 3 K=KK,KL
116     SA=SA+A(K,P)+A(K,Q)
117     C(J,I)=SA
118     C      6 LOOP - TANG'L VELS DUE TO VORTEX ELEM'S ON AIRFOILS & FLAPS.

```

```

119      10      DO 6 KN=1,NAF
120          K3=2*(NAF+1-KN)-1
121          K1=NA(K3)
122          K2=NA(K3+1)
123          J=M-NAF+KN
124          SA=0.
125          DO 5 K=K1,K2
126      5      SA=SA+A(K,P)+A(K,Q)
127      6      C(J,I)=SA
128      1      CONTINUE
129      C      WRITE THIS PORTION OF C INTO A FILE.
130          CALL WRITER(C,M,NSLAT)
131          RETURN
132          END
133      C      SUB3 SETS UP KUTTA EQN'S ON TEST AIRFOILS & FLAPS.
134          SUBROUTINE SUB3(A,B,C,NA,NTE,N,M,NL4,NAF,NAF2,NSPS,NSLAT,NSU1,NK1)
135          REAL A(N,NL4),B(N,NL4),C(M,NAF)
136          INTEGER NA(NAF2),NTE(NAF)
137      C      A,B - MATRICES OF INFLUENCE COEFFS FOR SOURCE & VORTEX ELEMENTS
138      C      C- MATRIX FOR SYSTEM OF EQN'S C*SIG=D
139      C      SIG(M) - UNKNOWN IN SYSTEM C*SIG=D - PART IS GAM
140      C      GAM(NAF+NSLAT) - VORTEX STRENGTHS ON KUTTA BODY.
141      C      NL4 - # OF CONTROL POINTS ON TEST AIRFOIL, FLAPS & SOLID WALL SECTIONS
142      C      M - TOTAL # UNKNOWN= TOTAL # EQUATIONS
143      C      NAF=#TEST AIRFOILS & FLAPS WITH KUTTA CONDITIONS APPLIED
144      C      NSLAT - # OF SLATS WITH KUTTA CONDITIONS; NSPS - # ELEM'S PER SLAT
145      C      NA(K) - RANGE OF CONTROL POINT #'S FOR K-TH TEST AIRFOIL OR FLAP I.E. 1,50
146      C      N - TOTAL # CONTROL PTS WHERE NORM VEL IS ZERO ON ALL SOLID SURFACES
147      C      NTE(K) - CONTROL PT # FOR UPPER T.E. ON K-TH TEST AIRFOIL OR FLAP
148          NSU2=NSU1+NSPS*NSLAT-1
149          NK1=NSU2+1
150      C      READ IN THAT PART OF A & B WHICH CONTAINS THE INFLUENCE COEFFS FOR THE
151      C      CONTROL POINTS ON THE TEST AIRFOILS & FLAPS.
152          CALL READER(A,N,NL4)
153          CALL READER(B,N,NL4)
154      C      SET UP EQN'S FOR KUTTA ON AIRFOILS AND FLAPS
155          DO 1 KN=1,NAF
156          I=KN
157          MT=NTE(NAF+1-KN)
158          MTE=MT+1

```

```

159      C      MT,MTE ARE #S FOR T.E. CONTROL PTS. ON TEST AIRFOILS & FLAPS.
160      C      2 LOOP - TANG'L VELS DUE TO ALL SOURCE ELEM'S.
161          DO 2 J=1,N
162      2      C(J,I)=B(J,MT)+B(J,MTE)
163          IF(NSLAT.EQ.0) GO TO 5
164      C      4 LOOP - TANG'L VELS DUE TO VORTEX ELEM'S ON WALL SLATS.
165          DO 4 KS=1,NSLAT
166          J=NK1+KS-1
167          KK=NSU1+NSPS*(KS-1)
168          KL=KK+NSPS-1
169          SA=/.
170          DO 3 K=KK,KL
171      3      SA=SA+A(K,MT)+A(K,MTE)
172      4      C(J,I)=SA
173      C      9 LOOP - TANG'L VELS DUE TO VORTEX ELEM'S ON TEST AIRFOILS & FLAPS.
174      5      DO 9 KM=1,NAF
175          K3=(NAF+1-KM)-1
176          K1=NA(K3)
177          K2=NA(K3+1)
178          J=M-NAF+KM
179          SA=0.
180          DO 8 K=K1,K2
181      8      SA=SA+A(K,MT)+A(K,MTE)
182      9      C(J,I)=SA
183      1      CONTINUE
184      C      WRITE THIS LAST PART OF C INTO A FILE.
185          CALL WRITER(C,M,NAF)
186          RETURN
187          END

```


Appendix 3.

Two Methods of Solving the Systems of Simultaneous Linear Algebraic Equations.

3.1 Gaussian Elimination.

This FORTRAN coded subroutine provides for significant savings when solving a large number of equations under a virtual memory operating system which employs some kind of paging system for dynamic storage allocation. To illustrate the reversed subscript notation, the system of equations is written:

$$\begin{aligned} C_{11}\sigma_1 + C_{21}\sigma_2 + C_{31}\sigma_3 &= d_1 \\ C_{12}\sigma_1 + C_{22}\sigma_2 + C_{32}\sigma_3 &= d_2 \\ C_{13}\sigma_1 + C_{23}\sigma_2 + C_{33}\sigma_3 &= d_3 \end{aligned} \quad (A3.1)$$

The printout of the subroutine ATXB follows.

3.2 Successive Row Vector Orthogonalization Process.

The matrix C for the system $C(\sigma, \gamma) = d$ is augmented by the right hand side vector 'd' to form the equations

$$\begin{aligned} C_{11}\sigma_1 + C_{21}\sigma_2 + C_{31}\sigma_3 - d_1t &= 0 \\ C_{12}\sigma_1 + C_{22}\sigma_2 + C_{32}\sigma_3 - d_2t &= 0 \\ C_{13}\sigma_1 + C_{23}\sigma_2 + C_{33}\sigma_3 - d_3t &= 0 \end{aligned} \quad (A3.2)$$

A set of N vectors in $(N+1)$ -dimensional space is formed:

$$(C_{1i}, C_{2i}, C_{3i}, \dots, C_{Ni}, -d_i) \quad i=1, 2, \dots, N \quad (A3.3)$$

The solution vector of equations (A3.3) is such that the vector

$$(\sigma_1, \sigma_2, \sigma_3, \dots, \sigma_N, 1) \quad (A3.4)$$

is orthogonal to all the vectors of (A3.3). The process of solving equations (A3.2) is equivalent to determining an $(N+1)$ -dimensional vector orthogonal to the N vectors of (A3.3) and having unity as its $(N+1)$ st component.

Let U_j denote the j -th row of the augmented matrix. At each stage j , ($j=1, 2, \dots, N+1$), a set of vectors V_j^i for $i=1, 2, \dots, N+2-j$ is constructed. All $(N+2-j)$ vectors in this j -th set are constructed to be orthogonal to the $(j-1)$ th row of the augmented matrix, that is, U_{j-1} . In fact, all $(N+2-j)$ vectors in this j -th set are orthogonal to all of the first $(j-1)$ rows of the augmented matrix, that is, the vectors $U_1, U_2, \dots, U_{j-1}$.

Thus V_{N+2-j}^j (the last member of the (present) j -th set of vectors V_j^i), is a vector which is orthogonal (by construction) to all of the first $(j-1)$ vectors $U_1, U_2, \dots, U_{j-1}$, and thus is

orthogonal to all of the first $(j-1)$ rows of the augmented matrix.

Ultimately there is a single vector V_1^{N+1} which is orthogonal to all N rows of the augmented matrix. This is the solution to the system of equations, as the $(N+1)$ th (last) component of V_1^{N+1} will be unity. In fact, at each stage 'j' the last component of V_{N+2-j}^j is unity.

To actually construct the set of vectors V_i^j at the j -th stage, scalar multipliers c_i^{j-1} must be calculated such that the set of vectors

$$V_i^j = c_i^{j-1} V_1^{j-1} + V_{i+1}^{j-1} \quad (\text{A3.5})$$

is orthogonal to the $(j-1)$ th row of the augmented matrix, that is U_{j-1} . Thus c_i^{j-1} is defined by the scalar product

$$V_i^j * U_{j-1} = 0. \quad (\text{A3.6})$$

Hence c_i^{j-1} is calculated from

$$c_i^{j-1} = -(V_{i+1}^{j-1} * U_{j-1}) / (V_1^{j-1} * U_{j-1}) \quad (\text{A3.7})$$

To initiate the process, the set of vectors V_i^1 is chosen to be the set of "unit" vectors $(0, 0, \dots, 1, \dots, 0, 0)$, where 1 is the i -th component.

This procedure is best illustrated by an example. For the system of equations

$$\begin{aligned} x+y-z &= 2 \\ 2x+y+z &= 1 \\ x+y+2z &= -1 \end{aligned} \quad (\text{A3.8})$$

The augmented matrix is

$$\begin{bmatrix} 1 & 1 & -1 & -2 \\ 2 & 1 & 1 & -1 \\ 1 & 1 & 2 & 1 \end{bmatrix} \quad (\text{A3.9})$$

and $U_1 = (1, 1, -1, -2)$, $U_2 = (2, 1, 1, -1)$ and $U_3 = (1, 1, 2, 1)$. (A3.10)

For $j=1$, $N+2-j$ is 4, so there are 4 "unit" vectors v_i^1 , so
 $v_1^1 = (1, 0, 0, 0)$, $v_2^1 = (0, 1, 0, 0)$, $v_3^1 = (0, 0, 1, 0)$, $v_4^1 = (0, 0, 0, 1)$. (A3.11)

For $j=2$, $N+2-j$ is 3, so there are 3 vectors v_i^2 and 3 multipliers c_i^1 . Using the reversed subscript notation,

$$v_1^1 * U_{11} = a_{11} \quad \text{and} \quad v_{i+1}^1 * U_{1, i+1, 1} = a_{i+1, 1, 1} \quad (\text{A3.12})$$

therefore

$$c_i^1 = -(a_{i+1, 1, 1}) / a_{11} \quad (\text{A3.13})$$

and $c_1^1 = -1$, $c_2^1 = 1$, $c_3^1 = 2$. (A3.14)

Therefore $v_i^2 = c_i^1 v_{i1}^1 + v_{i+1}^1$ (A3.15)

so $v_1^2 = (-1, 1, 0, 0)$, $v_2^2 = (1, 0, 1, 0)$ and $v_3^2 = (2, 0, 0, 1)$. (A3.16)

All three v_i^2 are seen to be orthogonal to U_1 .

For $j=3$, $N+2-j$ is 2, so there are 2 vectors v_i^3 and multipliers c_i^2 . Here

$$v_1^2 * U_2 = -1 \quad \text{and} \quad c_i^2 = v_{i+1}^2 * U_2 \quad (\text{A3.17})$$

therefore $c_1^2 = 3$ and $c_2^2 = 3$. (A3.18)

Therefore $v_i^3 = c_i^2 v_{i1}^2 + v_{i+1}^2$ (A3.19)

so $v_1^3 = (-2, 3, 1, 0)$ and $v_2^3 = (-1, 3, 0, 1)$. (A3.20)

Both v_i^3 are seen to be orthogonal to U_1 and U_2 .

For $j=4$, $N+2-j$ is 1, so there is a single multiplier c_1^3 and vector v_1^4 . Here

$$v_1^3 * U_3 = 3, \quad v_2^3 * U_3 = 3, \quad \text{so } c_1^3 = 1. \quad (\text{A3.21})$$

Therefore $V_1^4 = (1, 0, -1, 1)$ is the solution vector for the system (A3.8) as $x=1$, $y=0$, and $z=-1$.

The FORTRAN programs for reading and writing matrices onto peripheral storage devices are highly system-dependent, so the program for this vector method is not given here.

Appendix 4.

A Streamline Tracking Algorithm

This algorithm is used to track streamlines from a specified starting point, given an increment in the x-direction. The method uses the subroutine THETA to calculate the flow direction, velocity components, velocity magnitude, and pressure coefficient at each point.

From a starting point (x_1, y_1) , the flow direction θ_1 is calculated, and used to locate the next point $(x_1 + \Delta x, y_1 + \Delta x \tan \theta_1)$. The flow direction θ_2 is calculated there. The two flow directions are averaged to give $\bar{\theta}$, and the y-coordinate is changed so that the next point is now $(x_1 + \Delta x, y_1 + \Delta x \tan \bar{\theta})$. The flow direction θ_2 is calculated there, and so on.

An outline of the FORTRAN coded subroutine THETA follows.

```

SUBROUTINE ATXB(N,A,X,B,LUNIT)
  REAL A(N,N),X(N),B(N)
  NM=N-1
  NP=N+1
  IF(N.EQ.1) GO TO 9
  DO 4 K=1,NM
    S=A(K,K)
    IF(S.EQ.0) GO TO 12
    R=B(K)
    KP=K+1
    DO 4 I=KP,N
      T=A(K,I)/S
      DO 3 J=KP,N
        A(J,I)=A(J,I)-T*A(J,K)
        B(I)=B(I)-T*R
      CONTINUE
      X(N)=B(N)/A(N,N)
      DO 8 II=1,NM
        I=N-II
        X(I)=B(I)
        DO 10 JJ=1,II
          J=NP-JJ
          X(I)=X(I)-A(J,I)*X(J)
          X(I)=X(I)/A(I,I)
        GO TO 11
      WRITE(LUNIT,13) K
      FORMAT(1X,I4,K) ZERO K=1,13,
      1 'MATRIX IS SINGULAR!'
      GO TO 11
    X(I)=B(I)/A(I,I)
    RETURN
  END

```

```

188      SUBROUTINE THETA (X,Y,THE,CP,XX,YY,DS,CS,SI,N,VNT,VTT,VM,A,B,SIG,
189      1 GAM,NA,GAMM,M)
190      REAL XX(N), YY(N), DS(N), CS(N), SI(N), A(N),B(N),SIG(N),GAM(N)
191      INTEGER P, Q
192      COMMON/OAC NA,NL4,NSLAT,NSPS
193      C (X,Y) - CALCULATING FLOW PARAM'S HERE.
194      C XX,YY - CONTROL POINT COORDS FOR ALL SOURCE & VORTEX ELEMS: DS IS ELEM LENGT
195      C SI,CS - SIN,COS ELEM INCLINATION
196      C N - TOTAL @ CONTROL POINTS
197      C A,B - INFLUENCE COEFFS FOR VELOCITIES INDUCED @ (X,Y) DUE TO ALL SOURCE &
198      C VORTEX ELEM'S.
199      DO 1 J=1,N
200      DXJ = X - XX(J)
201      DYJ = Y - YY(J)
202      XJ = DXJ*CS(J) + DYJ*SI(J)
203      YJ=DYJ*CS(J)-DXJ*SI(J)
204      DSJ2=DS(J)/2.
205      YJS=YJ*YJ
206      S=XJ+DSJ2
207      T=XJ-DSJ2
208      PHIX=ALOG((S*S+YJS)/(T*T+YJS))
209      PHIY=2.*ATAN2((DS(J)*YJ),(XJ*XJ+YJS-DSJ2*DSJ2))
210      A(J) = PHIY*CS(J) + PHIX*SI(J)
211      1 B(J) = PHIX*CS(J) - PHIY*SI(J)
212      C SIG - SOURCE & VORTEX STRENGTHS
213      C GAM - VORTEX STRENGTHS FOR TEST AIRFOIL & SLATS
214      C GAMM - TEST AIRFOIL VORTEX STRENGTH
215      C VNST,VTST - TOTAL NORMAL & TANG'L VELs @ (X,Y) DUE TO SOURCE ELEMS.
216      VNST = 0
217      VTST = 0
218      DO 2 J=1,N
219      VNST = VNST + A(J)*SIG(J)
220      2 VTST = VTST + B(J)*SIG(J)
221      AS=0.
222      BS=0.
223      C NSALT,NSPS - # SLATS,# SOURCE ELEMS PER SLAT
224      IF(NSLAT.EQ.0) GO TO 3
225      DO 4 J=1,NSLAT
226      C NL4 - # OF CONTROL POINTS ON TEST AIRFOIL, FLAPS & SOLID WALL SECTIONS
227      P=NL4+NSPS*J

```

```

228      G=P-NSPS+1
229      C    P,Q - 1ST & LAST CONTROL PTS ON A SLAT.
230      C    AP,BP - NORM & TANG VELS @ (X,Y) DUE TO VORTEX ELEMS ON SLATS
231      AP=0.
232      BP=0.
233      DO 5 M=P,Q
234      AP=AP+A(M)
235      5    BP=BP+B(M)
236      AP=AP*GAM(J)
237      BP=BP*GAM(J)
238      AS=AS+AP
239      4    BS=BS+BP
240      C    AT,BT - NORM & TANG VELS @ (X,Y) DUE TO VORTEX ELEMS ON TEST AIRFOIL.
241      AT=0.
242      BT=0.
243      C    NA - # CONTROL PTS ON TEST AIRFOIL.
244      DO 6 J=1,NA
245      AT=AT+A(J)
246      6    BT=BT+B(J)
247      AT=AT*GAMM
248      BT=BT*GAMM
249      C    VNVT,VTVT - TOTAL NORM & TANG VEL @ (X,Y) DUE TO VORTEX ELEMS.
250      VNVT=-BS-BT
251      VTVT=AS+AT
252      C    VNOT,VTVT - NORM & TANG UNIFORM ONSET FLOW VELS.
253      VNOT=0.
254      VTOT=U
255      C    VNT,VTT - TOTAL NORM & TANG VEL @ (X,Y).
256      VNT=VNOT+VNVT+VNST
257      VTT=VTOT+VTVT+VTST
258      VS=VTT*VTT+VNT*VNT
259      C    THE,CP,VM - FLOW DIRECTION,PRESSURE, MAG(VELOC)
260      CP=1.-VS
261      VM=SQRT(VS)
262      THE=ATAN2(VNT,VTT)
263      RETURN
264      END

```


Appendix 5.

Design of the Two-Dimensional Nozzle Insert.

The design of the rectangular contracting section insert was based on the method of Smith and Wang [29]. The solution given makes use of the exact analogy between the magnetic field that is created by two circular coaxial and parallel coils carrying an electric current, and the velocity field that is created by two analogous ring vortices. Experimentally, the high uniformity of the magnetic field over a core area (when the coils are suitably arranged) is well known. Essentially the same uniformity in throat speed will occur in the case of real airflows, provided the normally favourable pressure gradient along the contracting surface is not disturbed. A precise application would require that the contracting surfaces be swollen by the boundary layer displacement thickness. In practice, such boundary layers are quite thin and the thickness increases slowly. Normally, no appreciable error is made in neglecting the boundary layer displacement thickness.

Let Γ be the strength of a ring vortex of ring radius 'a', with the plane of the vortex ring normal to the z-axis (Figure A5.1). The vortex ring is centered on the z-axis, a distance 'b' from the origin. The (axisymmetric) stream function is then

$$\psi(r, z) = \frac{\Gamma a}{4\pi} \int_0^{2\pi} \frac{\cos\theta}{PQ} d\theta, \quad (\text{A5.1})$$

where

$$\overline{PQ}^2 = (z-b)^2 + a^2 + r^2 - 2ar \cos \theta \quad (\text{A5.2})$$

$$= \left((z-b)^2 + (a+r)^2 \right) \left(1 - k^2 \cos^2 \left(\frac{\theta}{2} \right) \right),$$

$$k^2 = \frac{4ar}{\left((z-b)^2 + (a+r)^2 \right)} . \quad (\text{A5.3})$$

Then

$$\begin{aligned} \psi(r, z) = \frac{\Gamma}{4\pi} \frac{ar}{\sqrt{\left((z-b)^2 + (a+r)^2 \right)}} & \left(\frac{-4}{k^2} \int_0^\pi \sqrt{1 - k^2 \cos^2 \alpha} \, d\alpha \right. \\ & \left. + \left(\frac{4}{k^2} - 2 \right) \int_0^{2\pi} \frac{d\alpha}{\sqrt{1 - k^2 \cos^2 \alpha}} \right) = \frac{a\Gamma\sqrt{r}}{\pi k\sqrt{a}} \left(\left(1 - \frac{k^2}{2} \right) K - E \right), \end{aligned} \quad (\text{A5.4})$$

where

$$\alpha = \frac{\theta}{2} . \quad (\text{A5.5})$$

Non-dimensionalizing, let

$$Z = \frac{z}{a}, \quad R = \frac{r}{a}, \quad B = \frac{b}{a}, \quad \hat{\psi} = \frac{\pi\psi}{a\Gamma}, \quad (\text{A5.6})$$

and let

$$F(k) = \frac{1}{k} \left(\left(1 - \frac{k^2}{2} \right) K - E \right), \quad (\text{A5.7})$$

with

$$k^2 = \frac{4R}{(Z-B)^2 + (1+R)^2} . \quad (A5.8)$$

Then

$$\hat{\psi}(R,Z) = \sqrt{R} F(k) , \quad (A5.9)$$

where K and E are the complete elliptic integrals of the first and second kind, respectively.

To generate the uniform flow at the exit of the contracting section, the streamlines must be parallel there. Hence an identical ring vortex must be centered at $(0,0,-b)$.

The resulting stream function is therefore

$$\hat{\psi}(R,Z) = \sqrt{R} \{F(k_1) + F(k_2)\} , \quad (A5.10)$$

where

$$k_1^2 = \frac{4R}{(Z-B)^2 + (1+R)^2}, \quad k_2^2 = \frac{4R}{(Z+B)^2 + (1+R)^2} . \quad (A5.11)$$

Reference [29] states that when b is $0.46936a$ the velocity distribution over a flow core area of radius $0.42241a$ in the median plane between the vortex rings will be uniform to within 1 part in 500.

The elliptic integrals can be evaluated simply from polynomial approximations 17.3.34 and 17.3.36 of [41]. A program was written to search for the value of R which, for a given

value of Z gives the same value of $\hat{\psi}$ as through a starting point (R_0, Z_0) . In this way the coordinates (R, Z) of the stream surface were generated, using a value of $\hat{\psi}$ of 0.10510.

R_0 is chosen to be 0.30 (see Figure 6 of [40]) to obtain a throat flow uniformity within 0.2%. Thus r_0 is 0.30a. The required testsection entrance area is 0.348m^2 . Hence πr_0^2 is 0.348m^2 . Therefore r_0 is 333mm and 'a' is 1110mm. The nozzle length is chosen to be 1.52m, due to physical restrictions in the existing converging section, hence the nozzle entrance area πr_1^2 is fixed at 1.068m^2 . Hence r_1 is 583mm, or $1.751r_0$ or $0.525a$. Therefore R_1 is 0.525, z_1 is $4.58r_0$ or $1.37a$. Hence Z_1 is 1.37.

The table of nozzle coordinates follows. Z, z, R, r are as above, and w and h are the existing width of the contracting section and height of the new nozzle insert respectively.

Z	z	R	r	$A = \pi r^2$ $= wh$	w	h
0.0	0mm	.300	333mm	0.3484m ²	914mm	381mm
0.1	111	.300	333	.3484	915	381
0.2	222	.300	333	.3484	916	381
0.3	333	.301	334	.3507	917	383
0.4	444	.304	337	.3575	920	389
0.5	555	.309	343	.3706	927	400
0.6	666	.318	353	.3924	934	421
0.7	777	.331	367	.4248	942	452
0.8	888	.348	386	.4700	952	496
0.9	999	.370	411	.5298	962	554
1.0	1100	.396	440	.6065	979	626
1.1	1221	.426	473	.7023	1002	710
1.2	1332	.460	511	.8199	1036	803
1.3	1443	.498	553	.9617	1082	902
1.37	1524	.525	583	1.068	1123	951

Appendix 6.

An Analytic Representation of a Lifting Vortex between a Solid a Transversely-Slotted and a Constant Pressure Boundary.

The following describes an analytic two-dimensional potential flow "method of images" model for a lifting airfoil between a solid lower boundary and a transversely-slotted upper boundary consisting of airfoil-shaped slats. A constant pressure boundary outside the slotted wall represents a free streamline that divides the testsection flow from the plenum flow. The airfoil and the wall slats are represented by point vortices which are "imaged" appropriately. The image of a vortex in a solid boundary is a vortex of equal but opposite circulation; the image in a constant pressure boundary is a vortex of identical circulation.

From [41], the complex potential for an infinite vertical row of point vortices of the same sign, spaced a distance 'd' apart, is

$$F(z) = K \log \sinh \frac{\pi}{d}(z-z_0) \quad (\text{A6.1})$$

where the "central" vortex is at z_0 , and the strength K is related to the circulation Γ (positive clockwise) by

$$K = \frac{i\Gamma}{2\pi} \quad (\text{A6.2})$$

With reference to Figures A6.1, A6.2, the image system for a single vortex between the solid and constant pressure

boundaries is the sum of four sets of images. Using the notation of Figure A6.2, two sets are of positive circulation, "centered" with z_0 values of ai and $(a+2b)i$. The other two sets are of negative circulation, "centered" at $-ai$ and $-(a+2b)i$. All four sets have the same spacing, $4(a+b)$. The complete system of images for the single vortex immersed in a uniform flow U (from left to right) has the complex potential

$$F(z) = Uz + K \log \sinh A(z-ai) + K \log \sinh A\{z-(a+2b)i\} \\ - K \log \sinh A(z+ai) - K \log \sinh A\{z+(a+2b)i\}. \quad (A6.3)$$

where

$$A = \frac{\pi}{4(a+b)}. \quad (A6.4)$$

The complex velocity $w(z)$ is the derivative of $F(z)$ with respect to z . Hence for the single vortex,

$$w(z) = U + KA\{\coth A(z-ia) + \coth A\{z-i(a+2b)\} \\ - \coth A(z+ia) - \coth A\{z+i(a+2b)\}\}. \quad (A6.5)$$

To calculate the force on the vortex representing the airfoil, due to the effect of the two boundaries, the Blasius relation ([41]) is used,

$$D - iL = \frac{i\rho}{2} \oint_C w^2(z) dz, \quad (A6.6)$$

where D and L are the forces in the X and Y directions, respectively. Integration is performed about a contour enclosing only the airfoil vortex.

To evaluate this integral using residues, with the airfoil vortex at ih , the coefficient in the Laurent series expansion of $w^2(z)$ of the term in $1/(z-ih)$ is required. The Laurent series expansion for the coth function about ih is

$$\coth(z-ih) = \frac{1}{z-ih} + \frac{(z-ih)}{3} - \frac{(z-ih)^3}{45} + \dots \quad (A6.7)$$

The required coefficient is

$$2UK + 2K^2A[\coth A(z-i(a+2b)) - \coth A(z+ia) - \coth A(z+i(a+2b))]. \quad (A6.8)$$

The residue at ih is

$$2UK + 2K^2Ai\{+\cot(2Ab) + \cot(2Aa) + \cot(2A(a+b))\}, \quad (A6.9)$$

$$\text{since } \coth(iz) = -i\cot(z). \quad (A6.10)$$

Therefore

$$D - iL = \left(\frac{i\rho}{2}\right) 2\pi i (\text{Residue}(ih)) \quad (A6.11)$$

Substituting for K in terms of Γ , D is zero, and

$$L = L_0 \left(1 - \frac{k\Gamma}{4\pi U} \csc(ka) \csc(kb) \right), \quad (\text{A6.12})$$

where

$$k = \frac{\pi}{2(a+b)}, \quad (\text{A6.13})$$

and

$$L_0 = \rho U \Gamma \quad (\text{A6.14})$$

is the tunnel lift.

This is the expression for the reduction in lift experienced by a single point vortex between a solid lower boundary and a constant pressure upper boundary. If the vortex is midway between the two boundaries,

$$\frac{L}{L_0} = 1 - \frac{\Gamma}{4UH}. \quad (\text{A6.15})$$

Using (A6.14) and

$$C_{L_0} = \frac{L_0}{\frac{1}{2}\rho U^2 c}, \quad (\text{A6.16})$$

where 'c' is the airfoil chord,

$$\frac{\Delta L}{L_0} = \frac{L - L_0}{L_0} = -\frac{1}{8} \left(\frac{c}{H} \right) C_{L_0}. \quad (\text{A6.17})$$

Now consider the vortices γ_n representing the airfoil-

shaped wall slats. From equations (A6.4), (A6.5) using the notation of Figure A6.1,

$$w(z) = \sum_{n=-\infty}^{\infty} k_n B_n \left(\coth B_n (z-2ih-nr) + \coth B_n (z-2i(h+\epsilon_n)-nr) \right. \\ \left. - \coth B_n (z+2ih-nr) - \coth B_n (z+2i(h+\epsilon_n)-nr) \right) \quad (A6.18)$$

is the additional complex velocity due to the four sets of images corresponding to 'n' infinite vertical rows of point vortices γ spaced a horizontal distance 'r' apart. Here

$$k_n = \frac{i\gamma}{2\pi} n, \quad B_n = \frac{\pi}{4(2h+\epsilon_n)}. \quad (A6.19)$$

and 'r' is related to the slotted wall open-area ratio.

Hence the complete complex velocity field for the vortex Γ representing the test airfoil, the vortices γ_n representing the wall slats, and the uniform flow U , is

$$w(z) = U + KA \left(\coth A (z-ih) + \coth A (z-i(3h+2\delta)) \right. \\ \left. - \coth A (z+ih) - \coth A (z+i(3h+2\delta)) \right) \\ + \sum_{n=-\infty}^{\infty} k_n B_n \left(\coth B_n (z-2ih-nr) + \coth B_n (z-2i(h+\epsilon_n)-nr) \right. \\ \left. - \coth B_n (z+2ih-nr) - \coth B_n (z+2i(h+\epsilon_n)-nr) \right) \quad (A6.20)$$

where δ and ϵ are the distance of Γ and γ respectively from

the constant pressure boundary.

Following the previous procedure to calculate the coefficient of $1/(z-ih)$ in the Laurent series expansion for $w^2(z)$, the required coefficient is, using (A6.9),

$$\begin{aligned}
 & 2UK + 2K^2 Ai(\cot(2A(h+\delta)) + \cot(2Ah) + \cot(2A(2h+\delta))) \\
 & + 2K \sum_{n=-\infty}^{\infty} k_n B_n (\coth B_n (-ih-nr) + \coth B_n (-i(h+2\epsilon_n)-nr) \\
 & \quad - \coth B_n (+3ih-nr) - \coth B_n (+i(3h+2\epsilon_n)-nr)), \quad (A6.21)
 \end{aligned}$$

where

$$A = \frac{\pi}{4(2h+\delta)}. \quad (A6.22)$$

Now using

$$\coth(x+iy) = \frac{\coth(x) \csc^2(y) - i \operatorname{csch}^2(x) \cot(y)}{\coth^2(x) + \cot^2(y)} \quad (A6.23)$$

to calculate the residue of $w^2(z)$ at ih , and using (A6.12) and (A6.10),

$$\begin{aligned}
 L = \rho U \Gamma - \frac{\rho \beta \Gamma^2}{4\pi} & (\cot(\beta h) + \cot(\beta(h+\delta))) \\
 & - \frac{\rho \Gamma}{2\pi} \sum_{n=-\infty}^{\infty} \gamma_n B_n \operatorname{csch}^2(B_n nr) F(B_n, h, \epsilon_n, n, r), \quad (A6.24)
 \end{aligned}$$

and

$$D = - \frac{\rho \Gamma}{2\pi} \sum_{n=-\infty}^{\infty} \gamma_n B_n \coth(B_n n r) E(B_n, h, \epsilon_n, n, r), \quad (\text{A6.25})$$

where

$$\beta = \frac{\pi}{2(2h+\delta)}, \quad B_n = \frac{\pi}{4(2h+\epsilon_n)}, \quad (\text{A6.26})$$

$$\begin{aligned} E(B_n, h, \epsilon_n, n, r) = & G(B_n h) + G(B_n (h+2\epsilon_n)) \\ & + G(3B_n h) + G(B_n (3h+2\epsilon_n)), \end{aligned} \quad (\text{A6.27})$$

$$\begin{aligned} F(B_n, h, \epsilon_n, n, r) = & H(B_n h) + H(B_n (h+2\epsilon_n)) \\ & - H(3B_n h) - H(B_n (3h+2\epsilon_n)). \end{aligned} \quad (\text{A6.28})$$

In the above expressions

$$G(u) = \frac{\csc^2(u)}{\coth^2(B_n n r) + \cot^2(u)}, \quad (\text{A6.29})$$

and

$$H(u) = \frac{\cot(u)}{\coth^2(B_n n r) + \cot^2(u)}. \quad (\text{A6.30})$$

When all of the γ_n are of identical strength, and all of the ϵ_n (distance of γ_n from the constant pressure boundary) are

equal, the drag force D is zero, since $\coth(B_n nr)$ is an odd function of n .

Numerically it is satisfactory to take n greater than 10, that is, 21 or more vortices γ_n . For the case of a flat plate at 26.3° incidence, and average values of γ and ϵ taken from streamline calculations for a 0.66-Clark-Y airfoil at 20° incidence in the presence of a 70%CAR TSUSL wall configuration, the values of the expressions are

$$\frac{\Gamma}{U_C} = 1.40, \quad \frac{\gamma}{U_{Cs}} = -0.0625, \quad \frac{\epsilon}{h} = 0.1, \quad \frac{r}{h} = 0.67, \quad \frac{c}{h} = 0.67. \quad (A6.31)$$

Hence

$$\begin{aligned} \frac{L}{L_0} &= 1 - (0.168) \left(\frac{\Gamma}{U_C} \right) - (-0.317) \left(\frac{\gamma}{U_{Cs}} \right) \\ &= 1 - 0.235 - 0.020 = 0.745, \end{aligned} \quad (A6.32)$$

and the drag force D is zero.

Hence the effect of the wall slat circulation γ on the test airfoil is small compared to the effect of the constant pressure boundary on the test airfoil.

Another possible analytic representation of the bounding shear layer is a vortex sheet, across which there is a jump in tangential velocity and total head. This was not attempted here.

Appendix 7.

Standard Solid Wall Corrections

The following seven expressions are reproduced from page 382 of [34], and are the expressions used for the calculations herein. They are written for the incidence correction applied as an equivalent change in lift. The corrections are to be applied at the measured incidence. The subscripts T and F imply measured and equivalent free-air values respectively.

The first five expressions are, respectively, the corrections to be added (regardless of sign) to the measured values of windspeed, incidence and lift, quarterchord pitching moment, and drag coefficients.

$$\Delta U = U_F - U_T = \epsilon U_T \quad (A7.1)$$

$$\Delta \alpha = \alpha_F - \alpha_T = 0. \quad (A7.2)$$

$$\Delta C_L = C_{L_F} - C_{L_T} = -2\epsilon C_{L_T} - K C_{L_T} - \frac{K}{2\pi} (C_{L_T} + 4C_{\frac{M_c}{4T}}) \frac{\partial C_L}{\partial \alpha}, \quad (A7.3)$$

$$\Delta C_{\frac{M_c}{4}} = C_{\frac{M_c}{4F}} - C_{\frac{M_c}{4T}} = -2\epsilon C_{\frac{M_c}{4T}} + \frac{K}{4} C_{L_T} - \frac{K}{2\pi} (C_{L_T} + 4C_{\frac{M_c}{4T}}) \frac{\partial C_{\frac{M_c}{4}}}{\partial \alpha}, \quad (A7.4)$$

$$\Delta C_D = C_{D_F} - C_{D_T} = -2\epsilon C_{D_T} + \frac{K}{2\pi} (C_{L_T} + 4C_{\frac{M_c}{4T}}) (C_{L_T} - \frac{\partial C_D}{\partial \alpha}), \quad (A7.5)$$

In the above equations, ϵ is composed of the corrections

for wake and solid blockage, and is given by

$$\varepsilon = \frac{1}{4} \left(\frac{c}{H} \right) C_{D_T} + \Lambda K, \quad (\text{A7.6})$$

where

$$K = \frac{\pi^2}{48} \left(\frac{c}{H} \right)^2, \quad (\text{A7.7})$$

and c/H is the model size. The quantity Λ is obtained from Fig.6.8 of [39].

In practice, the α -derivative values are determined graphically. Otherwise the following values may be used:

$$\frac{\partial C}{\partial \alpha} L = 2\pi, \quad \frac{\partial C}{\partial \alpha} D = 0, \quad \frac{\partial C}{\partial \alpha} M_{\frac{c}{4}} = 0, \quad \frac{\partial C}{\partial \alpha} M_0 = \frac{\pi}{2}. \quad (\text{A7.8})$$

The following correction is applied to the measured pressure distributions (at the measured incidence α_T):

$$C_{p_F} = 1 - \frac{C_{L_F}}{C_{L_T}} (1 - C_{p_T}). \quad (\text{A7.9})$$

Appendix 8.

A Reduced Airfoil Circulation Determined from the Measured Lift.

In this method, the usual Kutta condition of equal velocities on the upper and lower surfaces of a lifting body, adjacent to the trailing edge is abandoned. The circulation is to be determined from the measured lift.

To simplify the equations, consider a single test airfoil between solid walls. The airfoil is represented by N control points, and the two plane solid walls by $M-N$ additional control points. Thus the total number of control points is M . There are therefore M unknown source strength densities σ and a single unknown vortex strength density γ on the airfoil. Thus $M+1$ equations are required to determine the $M+1$ unknowns. There are M control points at which the normal-velocity boundary condition must be satisfied; these yield M equations.

In the notation of §3.2, the tangential velocity at a point 'i' is

$$V_{t_i} = \sum_{j=1}^M B_{ji} \sigma_j + \gamma \sum_{k=1}^N A_{ki} + U \cos \theta_i. \quad (A8.1)$$

The $(M+1)$ st equation usually contains the Kutta condition at the airfoil trailing edge. The usual Kutta condition is expressed as

$$V_{t_i} = -V_{t_{i+1}} \quad (A8.2)$$

which results in the equation

$$\sum_{j=1}^M (B_{ji} + B_{ji+1}) \sigma_j + \gamma \sum_{k=1}^N (A_{ki} + A_{ki+1}) = -U(\cos\theta_i + \cos\theta_{i+1}) \quad (\text{A8.3})$$

for the control points 'i' and 'i+1' adjacent to the trailing edge.

The resulting full Kutta circulation Γ_0 about the airfoil can be calculated from the definition

$$\Gamma_0 = \oint_C \vec{V} \cdot d\vec{\ell} = \sum_{i=1}^N V_{t_i} \Delta s_i. \quad (\text{A8.4})$$

To determine the circulation Γ from the measured lift, the Kutta-Joukowski law expresses the measured lift force, L , on the airfoil as

$$L = \rho U \Gamma. \quad (\text{A8.5})$$

The measured lift coefficient C_L is defined as

$$C_L = \frac{L}{\frac{1}{2} \rho U^2 c}, \quad (\text{A8.6})$$

where 'c' is the airfoil chord. Therefore

$$\Gamma = \frac{1}{2} U c C_L. \quad (\text{A8.7})$$

The left side of equation (A8.7) is therefore written

$$\sum_{i=1}^N V_{t_i} \Delta s_i = \sum_{i=1}^N \left(\sum_{j=1}^M B_{ji} \sigma_j + \gamma \sum_{k=1}^N A_{ki} + U \cos \theta_i \right) \Delta s_i, \quad (A8.8)$$

and (A8.7) becomes

$$\begin{aligned} \sum_{j=1}^M \left(\sum_{i=1}^N B_{ji} \Delta s_i \right) \sigma_j + \sum_{i=1}^N \left(\sum_{k=1}^N A_{ki} \right) \Delta s_i \gamma \\ = -U \left(\sum_{i=1}^N \cos \theta_i \Delta s_i \right) + \frac{1}{2} U c C_L. \end{aligned} \quad (A8.9)$$

The last row of the matrix C in the system of equations $C(\sigma, \gamma) = d$, will now be

$$c_{j, M+1} = \sum_{i=1}^N B_{ji} \Delta s_i, \quad j=1, 2, \dots, M, \quad (A8.10)$$

$$c_{M+1, M+1} = \sum_{i=1}^N \left(\sum_{k=1}^N A_{ki} \right) \Delta s_i = \text{constant}, \quad (A8.11)$$

and the last component of the right hand side vector will be

$$d_{M+1} = -U \left(\sum_{i=1}^N \cos \theta_i \Delta s_i \right) + \frac{1}{2} U c C_L. \quad (A8.12)$$

The expressions (A8.10), (A8.11) and (A8.12) replace the corresponding expressions in (4.2) and (4.3).

Appendix 9.

A Reduced Airfoil Circulation Determined by Modifying the Profile

For a two-dimensional airfoil profile which can be mapped conformally onto a circle of radius R , the full Kutta circulation Γ_0 is [37]

$$\Gamma_0 = 4\pi RU \sin(\alpha - \alpha_0), \quad (\text{A9.1})$$

where U , α and α_0 are the flowspeed, incidence, and zero-lift angle respectively. If the circulation is reduced to a value $k\Gamma_0$, then

$$\Gamma = k\Gamma_0 = 4\pi RU k \sin(\alpha - \alpha_0) = 4\pi RU \sin(\alpha - \alpha_0 - \Delta\alpha). \quad (\text{A9.2})$$

Hence

$$\Delta\alpha = (\alpha - \alpha_0) - \arcsin(k \sin(\alpha - \alpha_0)) \quad (\text{A9.3})$$

is the effective reduction in incidence required to reduce the circulation (and hence the lift) to the fraction 'k' of the full Kutta value.

In order to achieve a reduction in the effective camber, the profile shape is modified by "raising" the trailing edge. Points on the profile are rotated about the profile leading edge through an angle which is proportional to the distance from the leading edge. The direction of rotation is such to reduce the

effective incidence of the profile. For an origin of profile coordinates (x,y) at mid-chord, and flow from left to right, the expression

$$\theta(x) = \frac{\Delta\alpha}{2} \left(1 + \frac{2x}{c}\right), \quad (\text{A9.4})$$

where 'c' is the airfoil chord, will assign a zero rotation to the point at the leading edge and the full rotation $\Delta\alpha$ to the point at the trailing edge. The modified profile coordinates are thus

$$x' = x\cos\theta(x) - y\sin\theta(x) \quad (\text{A9.5})$$

$$y' = y\cos\theta(x) + x\sin\theta(x).$$

The effective reduction in camber is roughly proportional to the amount of lift (or circulation) being developed. The zero-lift angle α_0 for the profile will not change, since when α equals α_0 , $\Delta\alpha$ will be zero.

Appendix 10.

The Computer Program for the Exact Numerical Theory

The program contains a subroutine MAIN1, which calls all of the following subroutines: CALCAB, ASSEMA, ASSEMB, ASSEMD, CPS, FORCES, and MODPRO. In addition, subroutines RE, WR, and WRD are required for reading and writing matrices from/into peripheral storage. The system of equations is solved by the subroutine ATXB, described in Appendix 3. The U.B.C. (system dependent) subroutines GSPACE and FSPACE allocate and deallocate, respectively, blocks of real memory required for the matrices A, B, and C. The U.B.C. subroutine CALLER is used to call subroutines which use matrices that have memory allocated by GSPACE.

A subroutine WALLCO is used to create the control point coordinates for all test airfoils, flaps, solid wall sections and wall slats. The control point coordinates XX and YY, along with DX, DY, DS, CS, and SI, are written into peripheral storage so that all coordinates may be checked before further calculation.

The definitions of the variables used are described by comment statements within the subroutines.

The control points (XSOLSL,YSOLSL) for an arbitrary solid surface such as the plenum boundary are read in at execution

time by the program which calls WALLCO.

The control point coordinates (XM,YM), and the velocity VTI, on the streamline representing the shear layer are read in by the program which calls MAIN1. This program also reads in the coordinates of the slat leading edges (XLE), centers ((XCENT,YCENT)), and trailing edges (XTE), the flow angle that each slat sees (ALF), and the fraction of the full circulation (K1) required.

As shown, this program handles only a single test airfoil; a similar program is used for a flapped airfoil.

The notation for the enumeration of the control points is shown in Figure A10.1. The layout of the system of equations to be solved is shown in Table A10.1; the numbers in parentheses indicate the particular DO-loop in the program which assembles the corresponding coefficients for the unknowns in the equations. The equation numbers (rows in the matrix C) are indicated by 'E'. Across the bottom of Table A10.1, the range of the index of summation (j, k, p or q) for each column of the matrix C is specified.

A complete sample run with the required calling programs follows.

The sample is shown for the Clark-Y airfoil at 20°

incidence, in a 70% OAR TSUSL wall configuration. The shear layer is modelled by a streamline which is represented by 20 control points, that is 20 source and 20 vortex elements. The airfoil is represented by 50, the upper solid end-wall sections each by 20, and the solid lower wall by 80 control points. There are 8 airfoil-shaped slats, each represented by 9 control points. Thus there are 262 control points where the zero normal-velocity boundary condition is specified, and 20 control points where the tangential velocities are prescribed. This leads to 262 unknown source strength densities and 29 unknown vortex strength densities. The result is 291 equations in 291 unknowns.

The velocity distribution on this streamline representing the shear layer is specified, and corresponds to a pressure coefficient with the average value of -0.35 , and is similar to the mean variation of pressure shown in Figure 8.7.

The profiles of the wall slats are modified to reduce their circulation to 0.8 times their full circulation.

The output from the program includes the pressure distributions on the walls, the wall slats, and the airfoil. Also printed are the lift, drag, and pitching moment coefficients for the airfoil and the wall slats.

0001	REAL XX(262),YY(262),DX(262),DY(262),DS(262),CS(262),SI(262)	1,000
0002	REAL SIG(291),VTT(262),CP(262),GAM(9),MU(20),GNU(20)	2,000
0003	REAL VTI(20),XM(21),YM(21)	3,000
0004	REAL AXX(242),AYY(242),ADX(242),ADY(242),ADS(242),ACS(242)	4,000
0005	REAL ASI(242)	5,000
	C XM,YM = PROFILE COORDS FOR STREAMLINE REPRESENTING SHEAR LAYER	6,000
	C XX,YY = CONTROL POINT COORDS; DX,DY,DS = ELEMENT LENGTHS	7,000
	C SIG = SOURCE STRENGTH DENSITIES (ALSO USED AS SOLUTION VECTOR IN	8,000
	C SYSTEM)	8,000
	C (GAM,MU,GNU ARE PART OF SIG)	9,000
	C VTT,CP = TANG VEL, PRESSURE COEFF.	10,000
0006	REAL XQ(10),YQ(10),XR(10),YR(10)	11,000
	C XQ,YQ,XR,YR = MODIFIED SLAT PROFILE COORDS	12,000
0007	REAL XCENT(8),XLE(8),XTE(8),ALF(8),KI(8)	13,000
0008	REAL YCENT(8),DTHICK(8)	14,000
	C AXX,AYY ETC = CONTROL PTS TO BE READ IN FROM FILE (PUT THERE BY	15,000
	C WALLCO)	15,000
0009	EQUIVALENCE (AXX,XX),(AYY,YY),(ADX,DX),(ADY,DY),(ADS,DS)	16,000
0010	EQUIVALENCE (ACS,CS),(ASI,SI)	17,000
0011	INTEGER CALAB,CALCD,WRAB,WRCD,SOLV,GAUSS,ITER,CALCP,CALCL,HSIG	18,000
0012	COMMON/B1/ NWS,NSLAT,NSUI,NKA,NM2,MSV,NA,NSPS,NTEU,NTEL	19,000
0013	COMMON/B2/ U,CH	20,000
0014	COMMON/B3/NU1,NWU1,NU3,NWU2,NL1,NWL1,NL3,NWL2,NSOL1,NSOLSL,NP1,	21,000
	1 NPLAT,NSPF,NL1	22,000
0015	COMMON/B4/CALAB,CALCD,WRAB,WRCD,SOLV,GAUSS,ITER,CALCP,CALCL,HSIG	23,000
0016	COMMON/B5/ NP1,NP2,NL4	24,000
0017	REAL TITLE(20)	25,000
0018	READ(5,303) TITLE	26,000
0019	303 FORMAT(20A4)	27,000
0020	WRITE(6,304)	28,000
0021	304 FORMAT(1H1)	29,000
0022	WRITE(6,305) TITLE	30,000
0023	305 FORMAT(1X,20A4)	31,000
0024	READ(5,25) CALAB,CALCD,WRAB,WRCD,SOLV,GAUSS,ITER,CALCP,CALCL,HSIG	32,000
0025	25 FORMAT(20I4)	33,000
0026	WRITE(6,1) CALAB,CALCD,WRAB,WRCD,SOLV,GAUSS,ITER,CALCP,CALCL,HSIG	34,000
0027	1 FORMAT('CALAB=',I2,2X,'CALCD=',I2,2X,'WRAB=',I2,2X,'WRCD=',I2,2X,	35,000
	1 'SOLV=',I2,2X,'GAUSS=',I2,2X,'ITER=',I2,2X,'CALCP=',I2,2X,	36,000
	2 'CALCL=',I2,2X,'HSIG=',I2)	37,000
0028	READ(5,30) NA,NWU1,NWU2,NWL1,NWL2,NSOLSL,NPLAT,NSPF,NSLAT,NSPS,	38,000
	1 MSV	39,000
0029	30 FORMAT(20I4)	40,000
0030	WRITE(6,31) NA,NWU1,NWU2,NWL1,NWL2,NSOLSL,NPLAT,NSPF,NSLAT,NSPS,	41,000
	1 MSV	42,000
0031	31 FORMAT('NA=',I3,2X,'NWU1=',I3,2X,'NWU2=',I3,2X,'NWL1=',I3,2X,	43,000
	1 'NWL2=',I3,2X,'NSOLSL=',I3,2X,'NPLAT=',I3,2X,'NSPF=',I3,2X,	44,000
	2 'NSLAT=',I3,2X,'NSPS=',I3,2X,'MSV=',I3)	45,000
0032	READ(5,32) NTEU,NTEL,CH,U	46,000
0033	32 FORMAT(2I4,2F8,3)	47,000
0034	WRITE(6,400) NTEU,NTEL,CH,U	48,000
0035	400 FORMAT('NTEU=',I3,2X,'NTEL=',I3,2X,'CH=',F8,3,2X,'U=',F6,1)	49,000
	C READ COORDS FOR AIRFOIL, WALL & WALL SLATS FROM WALLCO FILE (WALLS &	50,000
	C SLATS HAVE YY=0.)	51,000
0036	READ(2) AXX,AYY,ADX,ADY,ADS,ACS,ASI	52,000
0037	YW=18.	53,000

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0038      NU1=NA+1                      54.000
0039      NU3=NU1+NWU1                  55.000
0040      NU4=NU3+NWU2=1                56.000
0041      NL1=NU3+NWU2                  57.000
0042      NL3=NL1+NWL1                  58.000
0043      NL4=NL3+NWL2=1                59.000
0044      NSOL1=NL4+1                   60.000
0045      IF(NSOLSL.EQ.0) NSOL1=NL4     61.000
0046      NF1=NL4+NSOLSL+1              62.000
0047      IF(NFLAT.EQ.0) NF1=NL4+NSOLSL 63.000
C      NF1 = 1ST CON PT ON 1ST FLAT SLAT 64.000
0048      NSU1=NL4+NSOLSL+NFLAT*NSPF+1 65.000
0049      IF(NSLAT.EQ.0) NSU1=NL4+NSOLSL+NFLAT*NSPF 66.000
0050      NSU2=NSU1+NSLAT*NSPS+1         67.000
0051      IF(NSLAT.EQ.0) NSU2=NSU1       68.000
C      NSU2 = LAST CON PT ON LAST SLAT 69.000
C      NI1 = 1ST CONTROL PT ON STREAMLINE FOR SHEAR LAYER 70.000
0052      NI1=NSU2+1                   71.000
0053      IF(MSV.EQ.0) NI1=NSU2         72.000
0054      WRITE(6,401) NU1,NU3,NL1,NL3,NSOL1,NF1,NSU1,NSU2,NI1 73.000
0055      401  FORMAT('NU1=',I3,2X,'NU3=',I3,2X,'NL1=',I3,2X,'NL3=',I3,2X, 74.000
          1  'NSOL1=',I3,2X,'NF1=',I3,2X,'NSU1=',I3,2X,'NSU2=',I3,2X,'NI1=', 75.000
          2  'I3) 76.000
C      NWALL = TOTAL # OF CON PTS ON ALL FLAT SOLID WALL SECTIONS 77.000
0056      NWALL=NU1+NWU2+NWL1+NWL2      78.000
C      NWS = TOTAL # CONTROL POINTS ON AIRFOIL SOLID WALL SECTIONS & SLATS 79.000
0057      NWS=NA+NWALL+NSPS*NSLAT+NSOLSL+NSPF*NFLAT 80.000
C      NKA = # OF EQN FOR KUTTA ON TEST AIRFOIL 81.000
0058      NKA=NSU2+NSLAT+1              82.000
C      NSVT = TOTAL # SOURCE & VORTEX ELEM 83.000
0059      NSVT=NWS+MSV                  84.000
C      NM2 = # OF LAST EQN FOR ZERO NORM VEL ON INNER EDGE OF S,L. 85.000
0060      NM2=NKA+MSV                  86.000
C      NUN = TOTAL # UNKNOWN 87.000
0061      NUN=NWS+2*MSV+NSLAT+1         88.000
C      NFL = TOTAL # CON PTS ON FLAT SLATS (NO KUTTA) 89.000
0062      NFL=NSPF*NFLAT                90.000
C      NSL = TOTAL # CON PTS ON ALL AIRFOILSHAPED SLATS 91.000
0063      NSL=NSPS*NSLAT                92.000
0064      WRITE(6,33) NA,NWALL,NSOLSL,NFL,NSL,NWS 93.000
0065      33  FORMAT('NA=',I3,2X,'NWall=',I3,2X,'NSOLSL=',I3,2X,'NFL=',I3,2X, 94.000
          1  'NSL=',I3,2X,'NWS=',I3) 95.000
0066      WRITE(6,34) MSV,NSVT          96.000
0067      34  FORMAT('MSV=',I3,2X,'NSVT=',I3) 97.000
0068      WRITE(6,35) NKA,NM2,NUN        98.000
0069      35  FORMAT('NKA=',I3,2X,'NM2=',I3,2X,'NUN=',I3) 99.000
C      NA = # CON PTS ON SINGLE TEST AIRFOIL 100.000
0070      N1=NA+1                      101.000
0071      N2=NA+NWU1+NWU2              102.000
C      SET TESTSECTION WALL HEIGHT 103.000
0072      DO 2 I=N1,N2                104.000
C      YW = Y-COORD FOR UPPER AND LOWER WALLS 105.000
0073      2  YY(I)=YW                  106.000
0074      N3=N2+1                      107.000
0075      N4=N2+NWL1+NWL2              108.000

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0076      DO 3 I=NS,N4                      109,000
0077      3  YY(I)=-YH                      110,000
0078      IF(NSLAT.EQ.0) GO TO 500          111,000
0079      DO 4 I=NSU1,NSU2                  112,000
0080      4  YY(I)=YY(I)+YH                  113,000
0081      500 CONTINUE                      114,000
0082      IF(NSLAT.EQ.0) GO TO 45           115,000
0083      C XCEN,YCENT = CENTER OF SLATS    116,000
0084      READ(5,46) (XCEN(K), K=1,NSLAT)  117,000
0085      WRITE(6,308)                       118,000
0086      308 FORMAT('XCEN')                 119,000
0087      WRITE(6,48) (XCEN(K), K=1,NSLAT)  120,000
0088      READ(5,46) (YCENT(K), K=1,NSLAT)  121,000
0089      WRITE(6,309)                       122,000
0090      309 FORMAT('YCENT')                 123,000
0091      WRITE(6,48) (YCENT(K), K=1,NSLAT)  124,000
0092      C MODIFY SLAT PROFILES FOR REDUCED CIRCULATION 125,000
0093      READ(5,50) MOD                     126,000
0094      50  FORMAT(I2)                     127,000
0095      WRITE(6,51) MOD                    128,000
0096      51  FORMAT('MODPRO=',I2)           129,000
0097      C MODIFY PROFILES IF 'MOD' NOT ZERO 130,000
0098      IF(MOD.EQ.0) GO TO 45              131,000
0099      C XLE,XTE = X-COORDS OF SLAT LEADING & TRAILING EDGES 132,000
0100      READ(5,46) (XLE(K), K=1,NSLAT)    133,000
0101      46  FORMAT(13F6.1)                134,000
0102      WRITE(6,306)                       135,000
0103      306 FORMAT('XLE')                  136,000
0104      WRITE(6,48) (XLE(K), K=1,NSLAT)    137,000
0105      48  FORMAT(1X,13F6.1)              138,000
0106      READ(5,46) (XTE(K), K=1,NSLAT)    139,000
0107      WRITE(6,307)                       140,000
0108      307 FORMAT('XTE')                  141,000
0109      WRITE(6,48) (XTE(K), K=1,NSLAT)    142,000
0110      C ALF = FLOW ANGLE AT EACH SLAT    143,000
0111      READ(5,46) (ALF(KS), KS=1,NSLAT)  144,000
0112      WRITE(6,310)                       145,000
0113      310 FORMAT('ALF')                  146,000
0114      WRITE(6,48) (ALF(K), K=1,NSLAT)    147,000
0115      C KI = FRACTION OF CIRCULATION     148,000
0116      READ(5,47) (KI(K), K=1,NSLAT)     149,000
0117      47  FORMAT(16F5.3)                 150,000
0118      WRITE(6,311)                       151,000
0119      311 FORMAT('KI')                   152,000
0120      WRITE(6,49) (KI(K), K=1,NSLAT)     153,000
0121      49  FORMAT(1X,16F5.3)              154,000
0122      C DTHICK = SYMMETRIC DISPLACEMENT THICKNESS 155,000
0123      READ(5,47) (DTHICK(K), K=1,NSLAT) 156,000
0124      WRITE(6,312)                       157,000
0125      312 FORMAT('DTHICK')               158,000
0126      WRITE(6,49) (DTHICK(K), K=1,NSLAT) 159,000
0127      NPS=((NSPS-1)/2)-1                 160,000
0128      NSP=NSPS-1                         161,000
0129      MP=NSPS+1                         162,000
0130      DO 44 KS=1,NSLAT                   163,000

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0124      NT=NSU1+NPS*(KS=1) 164.000
0125      MT=NT+NPS 165.000
0126      ML=MT+NPS 166.000
0127      NL=NT+NPS 167.000
C      ALZ = ZERO LIFT ANGLE FOR SLATS (0015) 168.000
0128      ALZ=0 169.000
0129      CALL MODPRO(XX,YY,DX,DY,DS,CS,SI,NSVT,XR,YR,MP,NT,MT,ALF(KS),ALZ,
1      K1(KS),DTHICK(KS),XCENT(KS),YCENT(KS),ML,MT,NL,NT,XO,YO,XLE(KS),
2      XTE(KS)) 170.000
0130      44 CONTINUE 171.000
0131      45 CONTINUE 172.000
0132      MVS=MSV+1 173.000
0133      IF(MSV,EQ,0) GO TO 36 174.000
C      READ COORDS FOR STREAMLINE FOR SHEAR LAYER 175.000
0134      READ(5,16) XM 176.000
0135      READ(5,16) YM 177.000
0136      16 FORMAT(12F6,1) 178.000
0137      WRITE(6,17) XM 179.000
0138      WRITE(6,18) YM 180.000
0139      17 FORMAT('XM',10F7,2) 181.000
0140      18 FORMAT('YM',10F7,2) 182.000
0141      DO 15 K=1,MSV 183.000
0142      I=NWS+K 184.000
0143      J=K+1 185.000
0144      XX(I)=(XM(K)+XM(J))/2 186.000
0145      YY(I)=(YM(K)+YM(J))/2 187.000
0146      DX(I)=XM(J)-XM(K) 188.000
0147      DY(I)=YM(J)-YM(K) 189.000
0148      DS(I)=SQRT(DX(I)*DX(I)+DY(I)*DY(I)) 190.000
0149      CS(I)=DX(I)/DS(I) 191.000
0150      15 SI(I)=DY(I)/DS(I) 192.000
C      M1,M2 = RANGE OF CONTROL PTS #15 ON SHEAR LAYER 193.000
0151      M1=NWS+1 194.000
0152      M2=NWS+MSV 195.000
0153      WRITE(6,7) 196.000
0154      7 FORMAT('STREAMLINE FOR SHEAR LAYER') 197.000
0155      WRITE(6,6) 198.000
0156      6 FORMAT(7X,'XX',6X,'YY',6X,'DX',6X,'DY',6X,'DS',6X,'CS',6X,'SI') 199.000
0157      WRITE(6,5) (XX(I),YY(I),DX(I),DY(I),DS(I),CS(I),SI(I), I=M1,M2) 200.000
0158      5 FORMAT(1X,7F8,3) 201.000
C      READ VELOCITY DISTRIBUTION ON STREAMLINE FOR S.L. 202.000
0159      READ(5,22) (VTI(I), I=1,MSV) 203.000
0160      22 FORMAT(10F8,3) 204.000
0161      WRITE(6,23) VTI 205.000
0162      23 FORMAT('VTI',10F8,3) 206.000
0163      36 CONTINUE 207.000
0164      N=NSVT 208.000
0165      M=NUN 209.000
C      NG = # VORTEX STRENGTH DEN'S ON SLATS & TEST AIRFOIL 210.000
0166      NG=NSLAT+1 211.000
0167      NM=MSV 212.000
0168      NLS=NSLAT 213.000
0169      CALL MAIN1(XX,YY,DX,DY,DS,CS,SI,N,SIG,M,VTT,CP,GAM,NG,MU,GNU,NM,
1      VTI,XCENT,YCENT,NLS) 214.000
0170      STOP 215.000

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MICHIGAN TERMINAL SYSTEM FORTRAN G(41336)

MAIN

10-22-75

12:59:13

PAGE P005

0171

END

219,000

OPTIONS IN EFFECT ID,EBCDIC,SOURCE,NOLIST,NODECK,LOAD,NOMAP

OPTIONS IN EFFECT NAME = MAIN , LINECNT = 57

STATISTICS SOURCE STATEMENTS = 171, PROGRAM SIZE = 17260

STATISTICS NO DIAGNOSTICS GENERATED

NO ERRORS IN MAIN

NO STATEMENTS FLAGGED IN THE ABOVE COMPILATIONS,
EXECUTION TERMINATED

\$R *LOAD+OBJBSL3+ATXR 2=FILE447 3=-A 4=-R 9=ADUMMY*
EXECUTION BEGINS

*** CY A=20 N=50 70XTSUSL C/H=.66 MSV=20 ***
 CALAB=1 CALCD=1 WRAB=0 WRCD=0 SOLV=1 GAUSS=1 ITER=0 CALCP=1 CALCL=1 MSIG=0
 NA=50 NWU1=20 NWU2=20 NWL1=40 NWL2=40 NSOLSL=0 NPLAT=0 NSPF=0 NSLAT=8 NSPS=9 MSV=20
 NTFU=25 NTELE=26 CH=23.940 U=1.0
 NU1=51 NU3=71 NL1=91 NL3=131 NSOL1=170 NF1=170 NSU1=171 NSU2=242 NI1=243
 NA=50 NWALL=120 NSOLSL=0 NFL=0 NSL=72 NWS=242
 MSV=20 NSVT=262
 NKA=251 NM2=271 NUN=291

XCENY
 40.2 34.2 22.2 10.2 -1.8 -13.8 -25.8 -37.8

YCENY
 18.0 18.0 18.0 18.0 18.0 18.0 18.0 18.0

MODPRN=1

XLE
 44.4 32.4 20.4 8.4 -3.6 -15.6 -27.6 -39.6

XTE
 48.0 36.0 24.0 12.0 0.0 -12.0 -24.0 -36.0

ALF
 -3.7 -4.8 -8.8 -15.2 -15.0 5.5 11.0 10.7

KI
 0.8000,8000,8000,8000,8000,8000,8000,8000

DTHICK
 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
 DELCPST=-0.00943(RAD) -0.54(DEG) K=0.80000 BLDISPLTHICK=0.0
 DELCPST=-0.01678(RAD) -0.96(DEG) K=0.80000 BLDISPLTHICK=0.0
 DELCPST=-0.03089(RAD) -1.77(DEG) K=0.80000 BLDISPLTHICK=0.0
 DELCPST=-0.05397(RAD) -3.09(DEG) K=0.80000 BLDISPLTHICK=0.0
 DELCPST=-0.05324(RAD) -3.05(DEG) K=0.80000 BLDISPLTHICK=0.0
 DELCPST=0.01924(RAD) 1.10(DEG) K=0.80000 BLDISPLTHICK=0.0
 DELCPST=0.03874(RAD) 2.22(DEG) K=0.80000 BLDISPLTHICK=0.0
 DELCPST=0.03767(RAD) 2.16(DEG) K=0.80000 BLDISPLTHICK=0.0

XM 52.00 47.00 42.00 37.00 32.00 27.00 22.00 17.00 12.00 7.00
 XM 2.00 -3.00 -8.00 -13.00 -18.00 -23.00 -28.00 -33.00 -38.00 -43.00

XM -48.00
 YM 18.00 18.20 18.40 18.70 19.10 19.50 20.10 20.70 21.40 22.10

YM 22.60 22.90 22.90 22.60 22.10 21.40 20.70 19.70 19.20 18.50
 YM 18.00

STREAMLINE FOR SHEAR LAYER

XX	YY	DX	DY	DS	CS	SI
49.500	18.100	-5.000	0.200	5.004	-0.999	0.040
44.500	18.300	-5.000	0.200	5.004	-0.999	0.040
39.500	18.550	-5.000	0.300	5.009	-0.998	0.060
34.500	18.900	-5.000	0.400	5.016	-0.997	0.080
29.500	19.300	-5.000	0.400	5.016	-0.997	0.080
24.500	19.800	-5.000	0.600	5.036	-0.993	0.119
19.500	20.400	-5.000	0.600	5.036	-0.993	0.119
14.500	21.050	-5.000	0.700	5.049	-0.990	0.139
9.500	21.750	-5.000	0.700	5.049	-0.990	0.139
4.500	22.350	-5.000	0.500	5.025	-0.995	0.100
-0.500	22.750	-5.000	0.300	5.009	-0.998	0.060
-5.500	22.900	-5.000	0.0	5.000	-1.000	0.0
-10.500	22.750	-5.000	-0.300	5.009	-0.998	-0.060
-15.500	22.350	-5.000	-0.500	5.025	-0.995	-0.100
-20.500	21.750	-5.000	-0.700	5.049	-0.990	-0.139
-25.500	21.050	-5.000	-0.700	5.049	-0.990	-0.139
-30.500	20.200	-5.000	-1.000	5.099	-0.981	-0.196
-35.500	19.450	-5.000	-0.500	5.025	-0.995	-0.100
-40.500	18.850	-5.000	-0.700	5.049	-0.990	-0.139
-45.500	18.250	-5.000	-0.500	5.025	-0.995	-0.100

VTI -1.015 -1.020 -1.026 -1.054 -1.084 -1.109 -1.145 -1.183 -1.217 -1.241
 VTI -1.249 -1.255 -1.255 -1.251 -1.241 -1.225 -1.200 -1.166 -1.136 -1.095
 SIG (291)
 -0.8775E-01 -0.13321 -0.14765 -0.16013 -0.19031 -0.21232 -0.21859 -0.22661 -0.23296 -0.23849
 -0.24558 -0.25749 -0.26838 -0.27204 -0.27668 -0.28200 -0.28765 -0.29661 -0.30188 -0.31116
 -0.32113 -0.33464 -0.34686 -0.36750 -0.40178 -0.38256 -0.34765 -0.32869 -0.31651 -0.30628
 -0.29866 -0.29302 -0.28878 -0.28544 -0.28286 -0.28083 -0.27683 -0.27883 -0.27476 -0.27410
 -0.27547 -0.27837 -0.28281 -0.28594 -0.28889 -0.29332 -0.29716 -0.28940 -0.24204 -0.13887
 -0.16086E-02 -0.17288E-02 -0.18369E-02 -0.19272E-02 -0.19930E-02 -0.20355E-02 -0.20131E-02 -0.19398E-02 -0.17839E-02 -0.15113E-02
 -0.10752E-01 -0.39834E-03 -0.64410E-03 -0.22720E-03 -0.79029E-02 -0.94359E-02 -0.18226E-01 -0.40470E-01 -0.11023 -0.17339E-02
 -0.31725E-01 -0.23248E-01 -0.18870E-01 -0.15926E-01 -0.13741E-01 -0.12043E-01 -0.10682E-01 -0.93708E-02 -0.86494E-02 -0.78776E-02
 -0.72266E-02 -0.60748E-02 -0.62056E-02 -0.58054E-02 -0.54639E-02 -0.51719E-02 -0.49228E-02 -0.47099E-02 -0.45279E-02 -0.43719E-02
 -0.70984E-02 -0.57013E-02 -0.58721E-02 -0.56592E-02 -0.52645E-02 -0.64903E-02 -0.67382E-02 -0.70102E-02 -0.73082E-02 -0.76337E-02
 -0.55451E-02 -0.83739E-02 -0.8713E-02 -0.82407E-02 -0.7223E-02 -0.10237E-01 -0.10782E-01 -0.11356E-01 -0.11955E-01 -0.12574E-01
 -0.13206E-01 -0.13644E-01 -0.14746E-01 -0.15083E-01 -0.15648E-01 -0.16145E-01 -0.16342E-01 -0.16795E-01 -0.16852E-01 -0.16650E-01
 -0.16119E-01 -0.15189E-01 -0.13796E-01 -0.11905E-01 -0.10955E-01 -0.20061E-01 -0.21352E-01 -0.22149E-01 -0.22502E-01 -0.22491E-01
 -0.10263E-01 -0.13304E-01 -0.15940E-01 -0.18266E-01 -0.18266E-01 -0.18818E-01 -0.18818E-01 -0.18818E-01 -0.18818E-01 -0.18818E-01
 -0.21708E-01 -0.21981E-01 -0.20368E-01 -0.19603E-01 -0.18603E-01 -0.18603E-01 -0.18603E-01 -0.18603E-01 -0.18603E-01 -0.18603E-01
 -0.14218E-01 -0.1323E-01 -0.12855E-01 -0.12217E-01 -0.11609E-01 -0.11031E-01 -0.10484E-01 -0.94668E-02 -0.94780E-02 -0.90169E-02
 -0.85920E-02 -0.8119E-02 -0.77848E-02 -0.74196E-02 -0.70749E-02 -0.67491E-02 -0.64414E-02 -0.61504E-02 -0.58756E-02 -0.56160E-02
 -0.4407 -0.60801E-01 -0.16710 -0.10318 -0.13798 -0.25218 -0.19426 -0.12814E-01 -1.4436 -0.37790
 -0.76004E-01 -0.45738E-01 -0.75118E-02 -0.11039 -0.99673E-01 -0.52503E-01 -0.48323E-01 -0.37554 -0.61241 -0.12425
 -0.91808E-01 -0.37740E-01 -0.12188 -0.15525 -0.98633E-01 -0.93948E-01 -0.60982 -0.96813 -0.19467 -0.15099
 -0.96644E-01 -0.13281 -0.22147 -0.10208 -0.16147 -0.96532 -0.56543 -0.12058 -0.86102E-01 -0.19955E-01
 -0.14531 -0.15955 -0.94616E-01 -0.84019E-01 -0.56233 -0.59912 -0.99135E-01 -0.10990 -0.17174 -0.13375
 -0.39240E-01 -0.10018 -0.13422 -0.60219 -0.10677 -0.17216 -0.16420 -0.21817 -0.12395 -0.99256E-01
 -0.15677 -0.20375 -1.0704 -0.68615 -0.95006E-01 -0.66090E-01 -0.13834 -0.12059 -0.18711E-01 -0.76482E-01
 -0.12760 -0.68886 -0.23810E-01 -0.62611E-02 -0.10156E-01 -0.16088E-01 -0.93665E-02 -0.99941E-02 -0.17789E-01 -0.11430E-01
 -0.61145E-01 -0.19266E-01 -0.19665 -0.80495E-01 -0.66359E-01 -0.58728E-01 -0.49724E-01 -0.27915E-01 -0.53738E-02 -0.19208E-01
 -0.52432E-01 -0.67746E-01 -0.77598E-01 -0.80920E-01 -0.66748E-01 -0.61388E-01 -0.55368E-01 -0.37517E-01 -0.18379E-01 -0.14381E-01
 -0.13929E-01 -0.14229 -0.14505E-01 -0.37529E-01 -0.36276E-01 -0.59035E-01 -0.75559E-01 -0.94387E-01 -0.97046E-01 -0.10117
 -0.86410E-01 -0.60707E-01 -0.39609E-01 -0.14600E-01 -0.49259E-02 -0.69955E-02 -0.27499E-01 -0.29153E-01 -0.34972E-01 -0.34119E-01
 -0.20026E-01

-0.020	0.020	-0.0	0.000	-0.048	-0.019	-1.000	-1.066	2.591	-8.564	18.00	82.80	-0.137	0.002
-0.022	0.022	-0.0	0.000	-0.047	-0.020	-1.000	-1.067	2.467	-8.131	18.00	80.40	-0.139	0.002
-0.023	0.023	-0.0	0.000	-0.047	-0.021	-1.000	-1.068	2.347	-7.741	18.00	78.00	-0.141	0.002
-0.026	0.026	-0.0	0.000	-0.047	-0.023	-1.000	-1.069	2.231	-7.380	18.00	75.60	-0.143	0.002
-0.028	0.028	-0.0	0.000	-0.046	-0.024	-1.000	-1.071	2.120	-7.043	18.00	73.20	-0.146	0.002
-0.032	0.032	-0.0	0.000	-0.046	-0.026	-1.000	-1.072	2.013	-6.723	18.00	70.80	-0.150	0.001
-0.038	0.038	-0.0	0.000	-0.046	-0.028	-1.000	-1.074	1.910	-6.418	18.00	68.40	-0.154	0.000
-0.045	0.045	-0.0	0.000	-0.047	-0.030	-1.000	-1.077	1.809	-6.125	18.00	66.00	-0.160	-0.001
-0.056	0.056	-0.0	0.000	-0.048	-0.032	-1.000	-1.080	1.712	-5.843	18.00	63.60	-0.167	-0.002
-0.072	0.072	-0.0	0.000	-0.050	-0.035	-1.000	-1.085	1.616	-5.571	18.00	61.20	-0.178	-0.005
-0.100	0.100	-0.0	0.000	-0.055	-0.038	-1.000	-1.093	1.522	-5.312	18.00	58.80	-0.195	-0.009
-0.153	0.153	-0.0	0.000	-0.068	-0.040	-1.000	-1.108	1.428	-5.073	18.00	56.40	-0.228	-0.018
-0.289	0.289	-0.0	0.000	-0.127	-0.041	-1.000	-1.169	1.333	-4.880	18.00	54.00	-0.366	-0.040
-0.591	0.591	-0.0	0.000	-0.565	0.855	-1.000	-0.709	1.235	-4.828	18.00	51.60	0.497	-0.110
0.138	-0.138	-0.0	-0.000	-0.816	0.803	-1.000	-1.013	1.119	-5.576	18.00	49.20	-0.026	0.002
UPPER LEFT SOLID WALL													
VNST	VHVT	VNOT	VNT	VTST	VTVT	VTOT	VTT	ASUM	BSUM	YY	XX	CP	SIG
0.197	-0.197	-0.0	-0.000	-0.130	-0.032	-1.000	-1.162	1.165	0.610	18.00	-49.20	-0.350	0.032
0.147	-0.147	-0.0	-0.000	-0.060	-0.033	-1.000	-1.093	1.261	2.566	18.00	-51.60	-0.196	0.023
0.122	-0.122	-0.0	-0.000	-0.037	-0.032	-1.000	-1.069	1.356	3.444	18.00	-54.00	-0.143	0.019
0.106	-0.106	-0.0	-0.000	-0.024	-0.030	-1.000	-1.055	1.440	4.039	18.00	-56.40	-0.113	0.016
0.094	-0.094	-0.0	-0.000	-0.016	-0.029	-1.000	-1.045	1.541	4.514	18.00	-58.80	-0.092	0.014
0.085	-0.085	-0.0	-0.000	-0.011	-0.027	-1.000	-1.038	1.634	4.927	18.00	-61.20	-0.077	0.012
0.078	-0.078	-0.0	-0.000	-0.007	-0.025	-1.000	-1.032	1.728	5.307	18.00	-63.60	-0.066	0.011
0.072	-0.072	-0.0	-0.000	-0.004	-0.024	-1.000	-1.028	1.824	5.669	18.00	-66.00	-0.057	0.010
0.066	-0.066	-0.0	-0.000	-0.002	-0.023	-1.000	-1.025	1.923	6.023	18.00	-68.40	-0.050	0.009
0.062	-0.062	-0.0	-0.000	-0.001	-0.021	-1.000	-1.022	2.026	6.376	18.00	-70.80	-0.044	0.008
0.058	-0.058	-0.0	-0.000	0.000	-0.020	-1.000	-1.020	2.132	6.735	18.00	-73.20	-0.040	0.007
0.055	-0.055	-0.0	-0.000	0.001	-0.019	-1.000	-1.017	2.242	7.104	18.00	-75.60	-0.035	0.007
0.052	-0.052	-0.0	-0.000	0.002	-0.018	-1.000	-1.015	2.357	7.491	18.00	-78.00	-0.031	0.006
0.049	-0.049	-0.0	-0.000	0.003	-0.017	-1.000	-1.014	2.476	7.904	18.00	-80.40	-0.027	0.006
0.047	-0.047	-0.0	-0.000	0.004	-0.016	-1.000	-1.012	2.600	8.356	18.00	-82.80	-0.023	0.005
0.044	-0.044	-0.0	-0.000	0.006	-0.015	-1.000	-1.010	2.727	8.865	18.00	-85.20	-0.019	0.005
0.043	-0.043	-0.0	-0.000	0.007	-0.014	-1.000	-1.007	2.858	9.465	18.00	-87.60	-0.014	0.005
0.041	-0.041	-0.0	-0.000	0.010	-0.014	-1.000	-1.004	2.992	10.226	18.00	-90.00	-0.008	0.005
0.039	-0.039	-0.0	-0.000	0.013	-0.013	-1.000	-1.000	3.129	11.324	18.00	-92.40	0.001	0.005
0.037	-0.037	-0.0	-0.000	0.022	-0.012	-1.000	-0.990	3.266	13.588	18.00	-94.80	0.020	0.004
LOWER LEFT SOLID WALL													
VNST	VHVT	VNOT	VNT	VTST	VTVT	VTOT	VTT	ASUM	BSUM	YY	XX	CP	SIG
-0.035	0.035	-0.0	0.000	0.049	-0.008	1.000	1.041	3.603	-13.770	-18.00	-94.80	-0.084	-0.006
-0.036	0.036	-0.0	0.000	0.038	-0.009	1.000	1.030	3.484	-11.525	-18.00	-92.40	-0.060	-0.006
-0.037	0.037	-0.0	0.000	0.034	-0.009	1.000	1.025	3.368	-10.448	-18.00	-90.00	-0.050	-0.006
-0.038	0.038	-0.0	0.000	0.031	-0.010	1.000	1.021	3.255	-9.712	-18.00	-87.60	-0.043	-0.006
-0.039	0.039	-0.0	0.000	0.030	-0.011	1.000	1.019	3.147	-9.139	-18.00	-85.20	-0.037	-0.006
-0.040	0.040	-0.0	0.000	0.029	-0.012	1.000	1.016	3.045	-8.662	-18.00	-82.80	-0.033	-0.006
-0.041	0.041	-0.0	0.000	0.028	-0.013	1.000	1.014	2.948	-8.248	-18.00	-80.40	-0.029	-0.007
-0.043	0.043	-0.0	0.000	0.027	-0.015	1.000	1.013	2.858	-7.878	-18.00	-78.00	-0.025	-0.007
-0.044	0.044	-0.0	0.000	0.027	-0.016	1.000	1.011	2.773	-7.541	-18.00	-75.60	-0.022	-0.007
-0.045	0.045	-0.0	0.000	0.026	-0.018	1.000	1.009	2.696	-7.232	-18.00	-73.20	-0.018	-0.008
-0.046	0.046	-0.0	0.000	0.026	-0.019	1.000	1.007	2.624	-6.945	-18.00	-70.80	-0.014	-0.008
-0.047	0.047	-0.0	0.000	0.026	-0.021	1.000	1.005	2.559	-6.677	-18.00	-68.40	-0.009	-0.008
-0.048	0.048	-0.0	0.000	0.025	-0.023	1.000	1.002	2.498	-6.427	-18.00	-66.00	-0.004	-0.009
-0.049	0.049	-0.0	0.000	0.024	-0.025	1.000	0.999	2.442	-6.193	-18.00	-63.60	0.002	-0.009
-0.050	0.050	-0.0	0.000	0.023	-0.027	1.000	0.996	2.389	-5.974	-18.00	-61.20	0.009	-0.010
-0.051	0.051	-0.0	0.000	0.021	-0.029	1.000	0.991	2.339	-5.769	-18.00	-58.80	0.017	-0.010
-0.052	0.052	-0.0	0.000	0.018	-0.032	1.000	0.987	2.290	-5.579	-18.00	-56.40	0.027	-0.011
-0.053	0.053	-0.0	0.000	0.015	-0.034	1.000	0.981	2.241	-5.402	-18.00	-54.00	0.038	-0.011
-0.053	0.053	-0.0	0.000	0.011	-0.037	1.000	0.974	2.190	-5.239	-18.00	-51.60	0.050	-0.012
-0.054	0.054	-0.0	0.000	0.007	-0.040	1.000	0.967	2.136	-5.088	-18.00	-49.20	0.065	-0.013
-0.055	0.055	-0.0	0.000	0.001	-0.043	1.000	0.958	2.076	-4.948	-18.00	-46.80	0.082	-0.013

LOWER RIGHT SOLID WALL													
VNST	VINY	VNOT	VNT	VTST	VVIT	VTOT	VTT	ASUM	BSUM	YY	XX	CP	STG
-0.055	-0.055	-0.0	0.000	-0.007	-0.046	1.000	0.948	2.009	-41.820	18.000	-44.440	0.102	-0.010
-0.056	-0.056	-0.0	0.000	-0.016	-0.049	1.000	0.936	1.933	-41.702	18.000	-42.000	0.124	-0.010
-0.056	-0.056	-0.0	0.000	-0.026	-0.052	1.000	0.922	1.866	-41.593	18.000	-39.600	0.150	-0.010
-0.057	-0.057	-0.0	0.000	-0.038	-0.056	1.000	0.907	1.746	-41.492	18.000	-37.420	0.178	-0.016
-0.058	-0.058	-0.0	0.000	-0.052	-0.059	1.000	0.889	1.629	-41.395	18.000	-34.800	0.210	-0.016
-0.059	-0.059	-0.0	0.000	-0.067	-0.064	1.000	0.869	1.494	-41.302	18.000	-32.400	0.245	-0.017
-0.060	-0.060	-0.0	0.000	-0.085	-0.069	1.000	0.847	1.359	-41.208	18.000	-30.000	0.283	-0.017
-0.060	-0.060	-0.0	0.000	-0.104	-0.075	1.000	0.822	1.160	-41.111	18.000	-27.600	0.325	-0.017
-0.061	-0.061	-0.0	0.000	-0.124	-0.081	1.000	0.795	0.956	-41.004	18.000	-25.200	0.368	-0.017
-0.061	-0.061	-0.0	0.000	-0.145	-0.089	1.000	0.766	0.725	-33.882	18.000	-22.800	0.413	-0.016
-0.060	-0.060	-0.0	0.000	-0.166	-0.098	1.000	0.736	0.487	-33.737	18.000	-20.400	0.458	-0.015
-0.058	-0.058	-0.0	0.000	-0.186	-0.108	1.000	0.706	0.193	-33.561	18.000	-18.000	0.502	-0.014
-0.054	-0.054	-0.0	0.000	-0.204	-0.119	1.000	0.677	-0.122	-33.344	18.000	-15.600	0.542	-0.012
-0.047	-0.047	-0.0	0.000	-0.218	-0.130	1.000	0.651	-0.441	-33.077	18.000	-13.200	0.576	-0.010
-0.038	-0.038	-0.0	0.000	-0.228	-0.142	1.000	0.630	-0.765	-22.753	18.000	-10.800	0.603	-0.007
-0.027	-0.027	-0.0	0.000	-0.232	-0.154	1.000	0.606	-1.080	-22.567	18.000	-8.400	0.622	-0.003
-0.012	-0.012	-0.0	0.000	-0.230	-0.164	1.000	0.606	-1.373	-1.915	18.000	-6.000	0.633	-0.000
-0.006	-0.006	-0.0	0.000	-0.223	-0.172	1.000	0.605	-1.627	-1.398	18.000	-3.600	0.634	0.003
-0.027	-0.027	-0.0	0.000	-0.212	-0.177	1.000	0.611	-1.824	-0.821	18.000	-1.200	0.627	0.007
-0.050	-0.050	-0.0	0.000	-0.133	-0.178	1.000	0.624	-1.946	-0.193	18.000	1.200	0.610	0.010
-0.075	-0.075	-0.0	-0.000	-0.183	-0.174	1.000	0.643	-1.976	0.469	18.000	3.600	0.586	0.013
-0.099	-0.099	-0.0	-0.000	-0.168	-0.164	1.000	0.668	-1.696	1.141	18.000	6.000	0.554	0.016
-0.121	-0.121	-0.0	-0.000	-0.156	-0.148	1.000	0.696	-1.703	1.788	18.000	8.400	0.515	0.018
-0.139	-0.139	-0.0	-0.000	-0.146	-0.126	1.000	0.728	-1.406	2.370	18.000	10.800	0.470	0.020
-0.150	-0.150	-0.0	-0.000	-0.137	-0.102	1.000	0.761	-1.037	2.957	18.000	13.200	0.421	0.021
-0.155	-0.155	-0.0	-0.000	-0.130	-0.076	1.000	0.794	-0.655	3.236	18.000	15.600	0.369	0.022
-0.154	-0.154	-0.0	-0.000	-0.122	-0.052	1.000	0.826	-0.239	3.515	18.000	18.000	0.317	0.023
-0.147	-0.147	-0.0	-0.000	-0.114	-0.030	1.000	0.856	-0.125	3.715	18.000	20.400	0.267	0.022
-0.138	-0.138	-0.0	-0.000	-0.104	-0.013	1.000	0.883	0.445	3.859	18.000	22.800	0.220	0.022
-0.127	-0.127	-0.0	-0.000	-0.094	0.001	1.000	0.907	0.719	3.699	18.000	25.200	0.177	0.022
-0.115	-0.115	-0.0	-0.000	-0.083	0.012	1.000	0.929	0.949	3.059	18.000	27.600	0.138	0.021
-0.102	-0.102	-0.0	-0.000	-0.072	0.019	1.000	0.947	1.141	4.142	18.000	30.000	0.103	0.020
-0.091	-0.091	-0.0	-0.000	-0.060	0.024	1.000	0.964	1.300	4.424	18.000	32.400	0.071	0.020
-0.080	-0.080	-0.0	-0.000	-0.049	0.027	1.000	0.978	1.433	4.310	18.000	34.800	0.043	0.019
-0.071	-0.071	-0.0	-0.000	-0.037	0.028	1.000	0.991	1.544	4.405	18.000	37.200	0.019	0.018
-0.062	-0.062	-0.0	-0.000	-0.026	0.027	1.000	1.001	1.638	4.509	18.000	39.600	-0.003	0.017
-0.055	-0.055	-0.0	-0.000	-0.015	0.026	1.000	1.011	1.718	4.624	18.000	42.000	-0.022	0.016
-0.049	-0.049	-0.0	-0.000	-0.005	0.024	1.000	1.019	1.788	4.752	18.000	44.400	-0.039	0.016
-0.044	-0.044	-0.0	-0.000	0.004	0.022	1.000	1.026	1.850	4.892	18.000	46.800	-0.054	0.015
-0.040	-0.040	-0.0	-0.000	0.013	0.020	1.000	1.033	1.908	5.045	18.000	49.200	-0.067	0.014
-0.037	-0.037	-0.0	-0.000	0.021	0.017	1.000	1.038	1.962	5.211	18.000	51.600	-0.078	0.014
-0.034	-0.034	-0.0	-0.000	0.027	0.015	1.000	1.043	2.016	5.389	18.000	54.000	-0.087	0.013
-0.032	-0.032	-0.0	-0.000	0.033	0.013	1.000	1.047	2.066	5.580	18.000	56.400	-0.095	0.012
-0.031	-0.031	-0.0	-0.000	0.038	0.012	1.000	1.050	2.125	5.784	18.000	58.800	-0.102	0.012
-0.030	-0.030	-0.0	-0.000	0.042	0.010	1.000	1.053	2.183	6.001	18.000	61.200	-0.108	0.011
-0.029	-0.029	-0.0	-0.000	0.046	0.009	1.000	1.055	2.245	6.231	18.000	63.600	-0.114	0.010
-0.028	-0.028	-0.0	-0.000	0.049	0.008	1.000	1.057	2.311	6.474	18.000	66.000	-0.118	0.010
-0.025	-0.025	-0.0	-0.000	0.057	0.006	1.000	1.063	2.628	7.612	18.000	75.600	-0.130	0.008
-0.025	-0.025	-0.0	-0.000	0.058	0.006	1.000	1.064	2.722	7.951	18.000	78.000	-0.133	0.008
-0.024	-0.024	-0.0	-0.000	0.059	0.006	1.000	1.065	2.821	8.322	18.000	80.400	-0.135	0.007
-0.024	-0.024	-0.0	-0.000	0.061	0.006	1.000	1.066	2.927	8.738	18.000	82.800	-0.137	0.007
-0.023	-0.023	-0.0	-0.000	0.062	0.006	1.000	1.068	3.036	9.215	18.000	85.200	-0.140	0.007
-0.022	-0.022	-0.0	-0.000	0.064	0.006	1.000	1.070	3.133	9.788	18.000	87.600	-0.144	0.006
-0.022	-0.022	-0.0	-0.000	0.067	0.005	1.000	1.072	3.223	10.323	18.000	90.000	-0.150	0.006
-0.021	-0.021	-0.0	-0.000	0.071	0.005	1.000	1.076	3.296	11.000	18.000	92.400	-0.159	0.006

0.097	-0.279	0.183	0.000	-0.078	0.560	0.983	1.465	21.983	-1.173	18.10	-1.26	-1.146	0.084
0.156	-0.247	0.091	0.000	-0.333	0.544	0.996	1.207	22.870	10.022	17.92	-0.18	-0.456	0.562

SLAT #216	224	VNST	VNVT	VNOT	VNT	VTST	VTVT	VTOT	VTT	ASUM	BSUM	YY	XX	CP	SIG
-0.441	0.397	0.044	-0.000	0.001	-0.203	-0.999	-1.201	3.572	-8.002	18.03	-12.18	-0.442	0.599		
-0.463	0.307	0.156	-0.000	-0.315	-0.150	-0.988	-1.452	2.862	1.149	17.88	-13.26	-1.108	0.099		
-0.136	0.183	-0.047	-0.000	-0.175	-0.170	-0.999	-1.343	3.358	7.307	17.76	-14.69	-0.804	0.110		
0.430	0.024	-0.454	-0.000	0.369	-0.190	-0.891	-0.712	8.175	12.894	17.88	-15.40	0.493	0.172		
1.251	-0.251	-1.000	-0.000	1.441	-0.010	0.002	1.433	24.983	8.348	18.00	-15.58	-1.054	0.134		
0.703	-0.259	-0.444	0.000	0.825	0.265	0.896	1.986	23.049	-5.410	18.12	-15.40	-2.945	-0.039		
0.268	-0.221	-0.047	0.000	0.331	0.375	0.999	1.704	20.332	-6.441	18.23	-14.69	-1.905	-0.100		
0.101	-0.228	0.126	0.000	-0.136	0.462	0.992	1.318	20.432	-3.587	18.14	-13.27	-0.737	-0.134		
0.397	-0.386	-0.010	0.000	-0.265	0.466	1.000	1.201	21.680	7.701	18.03	-12.18	-0.442	-0.602		

SLAT #225	233	VNST	VNVT	VNOT	VNT	VTST	VTVT	VTOT	VTT	ASUM	BSUM	YY	XX	CP	SIG
-0.414	0.343	0.071	-0.000	-0.255	0.188	-0.997	-1.065	5.666	-7.097	18.06	-24.18	-0.133	1.068		
-0.319	0.148	0.171	-0.000	-0.540	0.209	-0.985	-1.317	4.791	2.175	17.89	-25.26	-0.734	0.172		
-0.004	0.050	-0.047	-0.000	-0.252	0.199	-0.999	-1.052	5.430	7.784	17.76	-26.69	-0.107	0.164		
0.468	-0.009	-0.459	-0.000	0.452	0.209	-0.889	-0.228	10.191	12.464	17.87	-27.40	0.948	0.218		
0.989	0.010	-1.000	-0.000	1.910	0.277	0.002	2.190	25.486	6.486	18.00	-27.58	-3.794	0.124		
0.424	0.015	-0.439	0.000	1.129	0.192	0.899	2.219	21.553	-6.815	18.12	-27.40	-3.925	-0.099		
0.104	-0.057	-0.047	0.000	0.484	0.201	0.999	1.684	18.379	-7.185	18.23	-26.69	-1.835	-0.157		
0.036	-0.147	0.111	0.000	-0.099	0.256	0.994	1.151	18.335	-4.044	18.16	-25.27	-0.325	-0.204		
0.379	-0.342	-0.038	0.000	-0.203	0.268	0.999	1.065	19.559	6.869	18.06	-24.18	-0.133	-1.070		

SLAT #234	242	VNST	VNVT	VNOT	VNT	VTST	VTVT	VTOT	VTT	ASUM	BSUM	YY	XX	CP	SIG
-0.163	0.094	0.069	-0.000	-0.326	0.267	-0.998	-1.057	6.772	-6.934	18.06	-36.18	-0.117	0.686		
-0.120	-0.051	0.171	-0.000	-0.558	0.255	-0.985	-1.289	5.808	2.417	17.89	-37.26	-0.661	0.095		
0.141	-0.094	-0.047	-0.000	-0.454	0.266	-0.999	-1.187	6.381	7.799	17.76	-38.69	-0.409	0.086		
0.529	-0.071	-0.458	-0.000	-0.113	0.313	-0.889	-0.688	11.032	12.113	17.87	-39.40	0.526	0.138		
0.863	0.137	-1.000	-0.000	0.793	0.320	0.002	1.116	25.567	5.579	18.00	-39.58	-0.245	0.121		
0.245	0.194	-0.439	0.000	0.777	0.067	0.898	1.742	20.770	-7.291	18.12	-39.40	-2.033	-0.019		
0.057	0.105	-0.047	0.000	0.597	-0.000	0.999	1.595	17.431	-7.315	18.23	-38.69	-1.545	-0.076		
-0.126	0.014	0.112	0.000	0.224	0.006	0.994	1.224	17.290	-4.009	18.16	-37.27	-0.499	-0.128		
0.134	-0.098	-0.036	-0.000	0.035	0.022	0.999	1.057	18.449	6.742	18.06	-36.18	-0.117	-0.689		

STREAMLINE FOR SHEAR LAYER	VNST	VNVT	VNOT	VNT	VTST	VTVT	VTOT	VTT	ASUM	BSUM	YY	XX	CP	SIG
0.089	-0.049	-0.040	-0.000	-0.849	0.833	-0.999	-1.015	-11.696	-4.866	18.10	49.50	-0.030	0.024	
0.830	-0.790	0.040	0.000	0.298	-0.319	-0.999	-1.020	-12.560	8.277	18.30	44.50	-0.040	-0.006	
0.476	-0.416	-0.060	-0.000	0.281	-0.309	-0.998	-1.026	-8.478	-3.238	18.55	39.50	-0.053	-0.010	
0.307	-0.317	-0.080	-0.000	0.204	-0.261	-0.997	-1.054	-15.433	-3.127	18.90	34.50	-0.111	-0.016	
0.342	-0.262	-0.080	-0.000	0.392	-0.479	-0.997	-1.084	-7.946	-1.312	19.30	29.50	-0.175	-0.009	
0.328	-0.209	-0.119	-0.000	0.457	-0.573	-0.993	-1.109	-11.563	-4.578	19.80	24.50	-0.230	0.010	
0.156	-0.037	-0.119	-0.000	0.580	-0.732	-0.993	-1.145	-11.110	0.351	20.40	19.50	-0.311	0.018	
0.074	0.064	-0.139	-0.000	0.588	-0.781	-0.990	-1.183	-11.112	-1.842	21.05	14.50	-0.399	0.011	
-0.096	0.235	-0.139	-0.000	0.582	-0.808	-0.990	-1.217	-13.140	0.351	21.75	9.50	-0.481	0.061	
-0.274	0.373	-0.100	0.000	0.513	-0.759	-0.995	-1.241	-11.917	0.326	22.35	4.50	-0.540	0.020	
-0.375	0.435	-0.060	0.000	0.349	-0.600	-0.998	-1.249	-13.110	0.467	22.75	-0.50	-0.560	0.197	
-0.460	0.460	-0.0	0.000	0.215	-0.470	-1.000	-1.255	-12.416	1.591	22.90	-5.50	-0.575	0.080	
-0.487	0.427	0.060	0.000	0.059	-0.316	-0.998	-1.255	-12.223	0.869	22.75	-10.50	-0.575	0.066	
-0.421	0.322	0.100	0.000	-0.071	-0.185	-0.995	-1.251	-12.423	2.284	22.35	-15.50	-0.565	0.059	
-0.407	0.268	0.139	0.000	-0.115	-0.136	-0.990	-1.241	-10.616	1.748	21.75	-20.50	-0.540	0.050	
-0.331	0.192	0.139	0.000	-0.202	-0.033	-0.990	-1.225	-12.381	1.846	21.05	-25.50	-0.501	0.028	
-0.262	0.066	0.196	0.000	-0.273	0.054	-0.981	-1.200	-9.316	3.213	20.20	-30.50	-0.440	0.005	
-0.130	0.031	0.100	-0.000	-0.269	0.098	-0.995	-1.166	-10.026	-0.417	19.45	-35.50	-0.360	-0.019	
0.019	-0.158	0.139	-0.000	-0.256	0.111	-0.990	-1.136	-9.276	7.470	18.85	-40.50	-0.291	-0.052	
0.087	-0.186	0.100	-0.000	-0.171	0.072	-0.995	-1.095	-5.801	2.238	18.25	-45.50	-0.199	-0.068	


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0001      SUBROUTINE MAIN1(XX,YY,DX,DY,DS,CS,SI,N,SIG,M,VTT,CP,GAM,NG,MU,
          1 GNU,NM,VTI,XC,YC,NLS)
0002      REAL XX(N),YY(N),DX(N),DY(N),DS(N),CS(N),SI(N)
          C XX,YY = CONTROL POINT COORDS; DX,DY,DS = ELEMENT LENGTHS
          C CS,SI = COS,SIN OF ELEMENT INCLINATION
0003      REAL XC(NLS),YC(NLS)
          C XC,YC = CENTERS OF WALL SLATS
          C N = TOTLA # CONTROL POINTS
0004      REAL SIG(M),VTT(N),CP(N),GAM(NG),MU(NM),GNU(NM)
          C SIG = SOURCE STRENGTH DENSITIES (ALSO USED AS SOLUTION VECTOR IN
          C SYSTEM )
          C (GAM,MU,GNU, ARE PART OF SIG)
          C M= TOTAL # UNKNOWNNS IN SYSTEM C*SIG=D
          C VTT,CP = TANG VEL, PRESSURE COEFF.
          C GAM = VORTEX STRENGTH DENSITIES ON TEST AIRFOIL & SLATS
          C MU,GNU = SOURCE & VORTEX STRENGTH DEN'S ON STREAMLINE REPRESENTING
          C S.L.
0005      REAL VTI(NM)
          C VTI = PRESCRIBED TANG'L VEL ON SHEAR LAYER STREAMLINE
          C CALAB,CALCD,CALCP,CALCL = IF NONZERO CALCULATE A,B,C,D,CP,CL
          C WRAB,WRCD = IF NONZERO WRITE A,B,C,D INTO FILES
          C SOLV = IF NONZERO SOLVE SYSTEM OF EQNS C*SIG=D
          C GAUSS = IF NONZERO USE GAUSS-ELIMINATION
          C ITER = IF NONZERO USE ITERATIVE METHOD
          C HSG = IF NONZERO ALREADY HAVE SIG IN FILE FROM PREVIOUS RUN
0006      INTEGER CALAB,CALCD,WRAB,WRCD,SOLV,GAUSS,ITER,CALCP,CALCL,HSG
0007      COMMON/B1/ NWS,NSLAT,NSUI,NKA,NM2,MSV,NA,NSPS,NTEU,NTEL
          C NWS = TOTAL # CONTROL POINTS ON AIRFOIL SOLID WALL SECTIONS & SLATS
          C NSLAT,NSPS = #SLATS,#CONTROL PTS /SLAT
          C NSUI = 1ST CONTROL ON 1ST SLAT
          C NKA = EQN # FOR KUTTA COND'N ON TEST AIRFOIL
          C MSV = # CONTROL PTS ON STREAMLINE FOR SHEAR LAYER (MU,GNU)
          C NA = #CONTROL PTS ON SINGLE TEST AIRFOIL
          C NTEU,NTEL = CONTROL PT # 0 TEST AIRFOIL T.E. (U.L)
          C NM2 = # OF LAST EQN FOR ZERO NORM VEL ON INNER EDGE OF S.L.
0008      COMMON/B2/ U,CH
          C U = UNIFORM ONSET STREAM SPEED
          C CH = SINGLE TEST AIRFOIL CHORD
0009      COMMON/B3/ NU1,NW1,NU3,NW2,NL1,NWL1,NL3,NWL2,NSOL1,NSOLSL,NF1,
          1 NPLAT,NSPF,NII
          C NU1,NU3,NL1,NL3 = 1ST CON PT ON EACH FLAT SOLID WALL SECTION
          C NW1,NW2,NWL1,NWL2 = # CON PTS ON EACH FLAT SOLID WALL SECTION
          C NSOLSL = # CON PTS ON ARBITRARY SHAPED SOLID SURFACE E.G. PLENUM
          C BOUNDARY
          C NSOL1 = 1ST CON PT ON ARBITRARY SOLID SURFACE
          C NPLAT,NSPF = # FLAT SLATS, # CON PTS OFLAT SLAT = NO KUTTA APPLIED
          C NF1 = 1ST CON PT ON 1ST FLAT SLAT
          C NII = 1ST CON PT ON SHEAR LAYER
0010      COMMON/B4/ CALAB,CALCD,WRAB,WRCD,SOLV,GAUSS,ITER,CALCP,CALCL,HSG
0011      EXTERNAL CALCAR,ASSEMA,ASSEMB,ASSEM,RE,WR,WRD,ATXB,CPS,FORCES
0012      NSVT=N
0013      NUN=N
0014      NDA=4*NSVT*NSVT
0015      NDB=NDA
0016      NDC=4*NUN*NUN

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0017	CALL GSPACE(A,NDA,0,&301)	53.000
0018	CALL GSPACE(B,NDR,0,&302)	54.000
0019	IF(CALAB.NE.0) GO TO 200	55.000
0020	LA=3	56.000
0021	M=NSVT	57.000
0022	M=NSVT	58.000
0023	CALL CALLER(RE,A,IPTR(N),IPTR(M),IPTR(LA))	59.000
0024	LB=4	60.000
0025	M=NSVT	61.000
0026	M=NSVT	62.000
0027	CALL CALLER(RE,B,IPTR(N),IPTR(M),IPTR(LB))	63.000
0028	GO TO 201	64.000
0029	200 M=NSVT	65.000
0030	M=NSVT	66.000
0031	CALL CALLER(CALCAB,A,B,IPTR(N),IPTR(M),IPTR(XX),IPTR(YY),IPTR(OX), IPTR(DY),IPTR(DS),IPTR(CS),IPTR(SI))	67.000
0032	IF(NSIG.NE.0) GO TO 201	68.000
0033	IF(WRAR.NE.0) GO TO 202	69.000
0034	IF(CALCD.EQ.0) GO TO 203	70.000
0035	GO TO 204	71.000
0036	202 M=NSVT	72.000
0037	M=NSVT	73.000
0038	LA=3	74.000
0039	CALL CALLER(WR,A,IPTR(N),IPTR(M),IPTR(LA))	75.000
0040	M=NSVT	76.000
0041	M=NSVT	77.000
0042	LB=4	78.000
0043	CALL CALLER(WR,B,IPTR(N),IPTR(M),IPTR(LB))	79.000
0044	IF(CALCD.EQ.0) GO TO 205	80.000
0045	204 IF(WRAR.NE.0) GO TO 206	81.000
0046	M=NSVT	82.000
0047	M=NSVT	83.000
0048	LB=4	84.000
0049	CALL CALLER(WR,B,IPTR(N),IPTR(M),IPTR(LB))	85.000
0050	206 CALL FSPACE(B,&303)	86.000
0051	CALL GSPACE(C,NDC,0,&304)	87.000
0052	M=NSVT	88.000
0053	M=NUN	89.000
0054	CALL CALLER(ASSEMA,A,C,IPTR(N),IPTR(M))	90.000
0055	IF(WRAR.NE.0) GO TO 207	91.000
0056	LA=3	92.000
0057	M=NSVT	93.000
0058	M=NSVT	94.000
0059	CALL CALLER(WR,A,IPTR(N),IPTR(M),IPTR(LA))	95.000
0060	CALL FSPACE(A,&305)	96.000
0061	NDB=4*NSVT*NSVT	97.000
0062	CALL GSPACE(B,NDB,0,&306)	98.000
0063	LB=4	99.000
0064	M=NSVT	100.000
0065	M=NSVT	101.000
0066	CALL CALLER(RE,B,IPTR(N),IPTR(M),IPTR(LB))	102.000
0067	207 M=NSVT	103.000
0068	M=NUN	104.000
0069	CALL CALLER(ASSEMB,B,C,IPTR(N),IPTR(M))	105.000
0070	NDD=4*NUN	106.000
		107.000

0071		CALL GSPACE(0,NDD,0,&307)	108.000
0072		N=NSVT	109.000
0073		M=NUN	110.000
0074		N1=NSV	111.000
0075		IF(NSV.EQ.0) N1=1	112.000
0076		N2=NXE	113.000
0077		IF(NXE.EQ.0) N2=1	114.000
0078		CALL CALLER(ASSEM,D,IPTR(M),IPTR(CS),IPTR(SI),IPTR(N),IPTR(VTI),	115.000
		1 IPTR(N1),IPTR(VT0),IPTR(N2))	116.000
0079		IF(SOLV.LQ.0) GO TO 208	117.000
0080		IF(GAUSS.NE.0) GO TO 209	118.000
0081		IF(ITER.NE.0) GO TO 210	119.000
0082	208	IF(WRCD.EQ.0) GO TO 211	120.000
0083	210	LC=7	121.000
0084		N=NHIN	122.000
0085		M=NHIN	123.000
0086		CALL CALLER(WR,C,IPTR(N),IPTR(M),IPTR(LC))	124.000
0087		LD=8	125.000
0088		N=NHIN	126.000
0089		CALL CALLER(WR,D,IPTR(N),IPTR(LD))	127.000
0090		IF(GAUSS.EQ.0) GO TO 212	128.000
0091	209	LU=6	129.000
0092		M=NHIN	130.000
0093		CALL CALLER(ATXB,IPTR(M),C,IPTR(SIG),D,IPTR(LU))	131.000
0094		WRITE(9) SIG	132.000
0095		WRITE(6,900) M	133.000
0096	900	FORMAT('SIG(',I3,')')	134.000
0097		WRITE(6,3) SIG	135.000
0098		CALL FSPACE(C,&308)	136.000
0099		IF(CALCP.EQ.0) GO TO 216	137.000
0100	201	IF(NSIG.EQ.0) GO TO 214	138.000
0101		READ(9) SIG	139.000
0102		WRITE(6,3) SIG	140.000
0103	3	FORMAT('X,10G12.5')	141.000
0104	214	IF(NSIG.NE.0) GO TO 215	142.000
0105		NDA=4*NSVT*NSVT	143.000
0106		CALL GSPACE(A,NDA,0,&309)	144.000
0107		LA=3	145.000
0108		N=NSVT	146.000
0109		M=NSVT	147.000
0110		CALL CALLER(RE,A,IPTR(N),IPTR(M),IPTR(LA))	148.000
0111	215	N=NSVT	149.000
0112		M=NUN	150.000
0113		K=NSLAT	151.000
0114		IF(NSLAT.EQ.0) K=1	152.000
0115		L=MSV	153.000
0116		IF(MSV.EQ.0) L=1	154.000
0117		CALL CALLER(CPS,IPTR(CP),IPTR(VTT),IPTR(XX),IPTR(VY),IPTR(CS),	155.000
		1 IPTR(SI),IPTR(N),IPTR(SIG),IPTR(M),IPTR(GAM),IPTR(K),IPTR(MU),	156.000
		2 IPTR(GNU),IPTR(L),A,B)	157.000
0118	213	IF(CALCL.EQ.0) GO TO 216	158.000
0119		CALL FSPACE(A,&310)	159.000
0120		CALL FSPACE(B,&311)	160.000
0121		N=NSVT	161.000
0122		N1=1	162.000

0123	N2=NA	163.000
0124	XA=0.	164.000
0125	YA=0.	165.000
0126	CALL CALLER(FORCES,IPTR(CP),IPTR(XX),IPTR(YY),IPTR(DX),IPTR(DY),	166.000
	1 IPTR(DS),IPTR(VTT),IPTR(N),IPTR(U),IPTR(CH),IPTR(N1),IPTR(N2),	167.000
	2 IPTR(XA),IPTR(YA))	168.000
0127	IF(NSLAT.EQ.0) GO TO 2	169.000
0128	DO 1 K=1,NSLAT	170.000
0129	N1=NSU1+NSPS*(K-1)	171.000
0130	N2=N1+NSPS	172.000
0131	CH=3.6	173.000
0132	XS=XC(K)	174.000
0133	YS=18.	175.000
0134	1 CALL CALLER(FORCES,IPTR(CP),IPTR(XX),IPTR(YY),IPTR(DX),IPTR(DY),	176.000
	1 IPTR(DS),IPTR(VTT),IPTR(N),IPTR(U),IPTR(CH),IPTR(N1),IPTR(N2),	177.000
	2 IPTR(XS),IPTR(YS))	178.000
0135	2 CONTINUE	179.000
0136	IF(HSIG.NE.0) GO TO 217	180.000
0137	216 CONTINUE	181.000
0138	GO TO 99	182.000
0139	203 STOP 203	183.000
0140	205 STOP 205	184.000
0141	211 STOP 211	185.000
0142	212 STOP 212	186.000
0143	217 STOP 217	187.000
0144	301 STOP 301	188.000
0145	302 STOP 302	189.000
0146	303 STOP 303	190.000
0147	304 STOP 304	191.000
0148	305 STOP 305	192.000
0149	306 STOP 306	193.000
0150	307 STOP 307	194.000
0151	308 STOP 308	195.000
0152	309 STOP 309	196.000
0153	310 STOP 310	197.000
0154	311 STOP 311	198.000
0155	99 RETURN	199.000
0156	END	200.000

OPTIONS IN EFFECT IO,EBODIC,SOURCE,NOLIST,NODECK,LOAD,NOHAP

OPTIONS IN EFFECT NAME = MAIN1 , LINECNT = 57

STATISTICS SOURCE STATEMENTS = 156,PROGRAM SIZE = 6932

STATISTICS NO DIAGNOSTICS GENERATED

NO ERRORS IN MAIN1

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0001      SUBROUTINE CALCAB(A,B,N,M,XX,YY,DX,DY,DS,CS,SI)      201.000
C      CALCAB CALCULATES MATRICES A, B OF INFLUENCE COEFFICIENTS 202.000
      REAL XX(N),YY(N),DX(N),DY(N),DS(N),CS(N),SI(N)          203.000
0003      REAL A(N,M),B(N,M)                                  204.000
0004      COMMON/BI/ NWS,NSLAT,NSUI,NKA,NM2,MSV,NA,NSPS,NTEU,NTEL 205.000
0005      DO 2 I=1,M                                           206.000
0006      DO 2 J=1,N                                           207.000
0007      IF(I.EQ.J) GO TO 3                                   208.000
0008      DXJ=XX(I)-XX(J)                                       209.000
0009      DYJ=YY(I)-YY(J)                                       210.000
C      XJ,YJ = DIST. BCE OF 'I' TO 'J' IN 'J' COORD. SYSTEM 211.000
      XJ=DXJ*CS(J)+DYJ*SI(J)                                   212.000
      YJ=DYJ*CS(J)-DXJ*SI(J)                                   213.000
0012      DSJ2=DS(J)/2.                                         214.000
0013      DSJ4=DSJ2*DSJ2                                         215.000
0014      XJS=XJ*XJ                                             216.000
0015      YJS=YJ*YJ                                             217.000
0016      XP=XJ+DSJ2                                             218.000
0017      XM=XJ-DSJ2                                             219.000
0018      XPS=XP*XP                                             220.000
0019      XMS=XM*XM                                             221.000
C      XJ IS ZERO IF ELEMENTS VERTICALLY ABOVE EACH OTHER 222.000
      IF(XJ.EQ.0.) GO TO 140                                   223.000
0020      PHIX IS VELOCITY IN WIND DIRECTION                    224.000
C      PHIX=ALOG((XPS+YJS)/(XMS+YJS))                          225.000
      GO TO 141                                                 226.000
0023      140 PHIX=0.                                           227.000
C      YJ IS ZERO IF ELEMENTS ARE ON SAME FLAT WALL SECTION 228.000
      IF(YJ.EQ.0.) GO TO 142                                   229.000
0024      141 PHIX IS VELOCITY PERP. TO WIND RIRN              230.000
C      PHIX=2.*ATAN2((DS(J)*YJ),(XJS+YJS-DSJ4))                231.000
      GO TO 143                                                 232.000
0027      142 PHIX=0.                                           233.000
0028      143 IF(SI(J).EQ.0.) GO TO 144                        234.000
0029      SIJ=SI(I)*CS(J)-CS(I)*SI(J)                          235.000
0030      COJ=CS(I)*CS(J)+SI(I)*SI(J)                          236.000
C      A IS NORMAL VEL IN 'I' COORD SYSTEM                    237.000
C      B IS TANG'L VEL IN 'I' COORD SYSTEM                    238.000
      A(J,I)=PHIX*COJ-PHIX*SIJ                                  239.000
      B(J,I)=PHIX*COJ+PHIX*SIJ                                  240.000
0033      GO TO 2                                               241.000
0034      3 A(J,I)=6.283185                                       242.000
0035      R(J,I)=0.                                             243.000
0036      GO TO 2                                               244.000
0037      144 SIJ=SI(I)*CS(J)                                    245.000
      COJ=CS(I)*CS(J)                                    246.000
0039      A(J,I)=PHIX*COJ-PHIX*SIJ                                247.000
0040      B(J,I)=PHIX*COJ+PHIX*SIJ                                248.000
0041      2 CONTINUE                                           249.000
0042      RETURN                                               250.000
0043      END                                                 251.000

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OPTIONS IN EFFECT ID,CBCDIC,SOURCE,NOLIST,NODECK,LOAD,NOMAP

OPTIONS IN EFFECT NAME = CALCAB, LINECNT = 57

STATISTICS SOURCE STATEMENTS = 43, PROGRAM SIZE = 1700

STATISTICS NO DIAGNOSTICS GENERATED

NO ERRORS IN CALCAB


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0001      SUBROUTINE ASSEMA(A,C,N,M)                252,000
      C IS MATRIX FOR SYSTEM C*SIG=D              253,000
      C ASSEMA ASSEMBLES THOSE PARTS OF C THAT DEPEND ON A. 254,000
0002      REAL A(N,N),C(M,M)                        255,000
0003      INTEGER I,P,Q                              256,000
0004      COMMON/B1/ NWS,NSLAT,NSUI,NKA,NM2,MSV,NA,NSPS,NTEU,NTEL 257,000
0005      COMMON/B2/ U,CH                            258,000
0006      NSP=NSPS-1                                  259,000
0007      NM2=NM2+MSV                                 260,000
0008      NWSV=NWS+MSV                                261,000
      C***** LOOP 1 - ASSEMBLE NORMAL VEL EQNS FOR ALL NWS CONTROL PTS ***** 262,000
0009      DO 49 I=1,NWS                               263,000
      C E IS EQUATION #                             264,000
0010      E=I                                          265,000
      C LOOP2 - NORM VELS AT ALL NWS C, P. DUE TO ALL NWS SOURCE ELEMS 266,000
0011      DO 2 J=1,NWS                                267,000
0012      2 C(J,E)=A(J,I)                             268,000
0013      IF(MSV.EQ.0) GO TO 49                       269,000
      C LOOP 8 - NORM VELS AT ALL NWS CON PTS DUE TO SOURCE ELEMS (MU) ON 270,000
      C S.L                                          270,000
0014      DO 8 K=1,MSV                                271,000
0015      J=NKA+K                                       272,000
0016      M=NWS+K                                       273,000
0017      8 C(J,E)=A(M,I)                             274,000
0018      49 CONTINUE                                275,000
0019      IF(NSLAT.EQ.0) GO TO 12                     276,000
      C***** LOOP 10 - ASSEMBLE KUTTA EQNS FOR AIRFOIL-SHAPED SLATS ***** 277,000
0020      DO 52 KS=1,NSLAT                             278,000
0021      KL=NSUI+NSPS*(KS-1)                         279,000
0022      KU=KL+NSP                                    280,000
0023      E=NWS+KS                                     281,000
      C LOOP 13 - TANG VELS AT T.E. OF SLATS DUE TO VORTEX ELEMS ON SLATS 282,000
0024      DO 13 K=1,NSLAT                             283,000
0025      J=NWS+K                                       284,000
0026      P=NSUI+NSPS*(K-1)                           285,000
0027      Q=P+NSP                                       286,000
0028      SA=0.                                         287,000
0029      DO 14 M=P,Q                                   288,000
0030      14 SA=SA+A(M,KL)+A(M,KU)                   289,000
0031      13 C(J,E)=SA                                 290,000
0032      SA=0.                                         291,000
      C LOOP 15 - TANG VELS AT T.E. OF SLATS DUE TO VORTEX ELEMS ON TEST 292,000
      C AIRFOIL                                     292,000
0033      DO 15 K=1,NA                                 293,000
0034      15 SA=SA+A(K,KL)+A(K,KU)                   294,000
0035      C(NKA,E)=SA                                  295,000
0036      IF(MSV.EQ.0) GO TO 52                       296,000
      C LOOP 18 - TANG VELS AT T.E. OF SLATS DUE TO VORTEX ELEMS ON (GNU) 297,000
      C S.L                                          297,000
0037      DO 18 K=1,MSV                                298,000
0038      J=NM2+K                                       299,000
0039      M=NWS+K                                       300,000
0040      18 C(J,E)=A(M,KL)+A(M,KU)                  301,000
0041      52 CONTINUE                                302,000
0042      12 IF(NSLAT.EQ.0) GO TO 20                  303,000

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C*****ASSEMBLE KUTTA EQNS FOR TEST AIRFOIL *****
C   LOOP 21 = TANG VELS AT TEST AIRFOIL T.E. D.T. VORTEX ELEMS ON SLATS
0043   DO 21 K=1,NSLAT
0044   P=NSUI+NSPS*(K-1)
0045   Q=P+NSP
0046   J=NWS+K
0047   SA=0.
0048   DO 22 M=P,Q
0049   22   SA=SA+A(M,NTEU)+A(M,NTEL)
0050   21   C(J,NKA)=SA
0051   20   SA=0.
C   LOOP 23 = TANG VELS AT TEST AIRFOIL T.E. D.T. VORTEX ELEMS ON TEST
C   AIRFOIL
0052   DO 23 K=1,NA
0053   23   SA=SA+A(K,NTEU)+A(K,NTEL)
0054   C(NKA,NKA)=SA
0055   IF(MSV.EQ.0) GO TO 24
C   LOOP 26 = TANG VELS AT TEST AIRFOIL T.E. D.T. VORTEX ELEMS (GNU) ON
0056   DO 26 K=1,MSV
0057   J=NM2+K
0058   M=NWS+K
0059   26   C(J,NKA)=A(M,NTEU)+A(M,NTEL)
0060   24   IF(MSV.EQ.0) GO TO 61
C*****ASSEMBLE NORMAL VELOCITY EQNS FOR MSV CON PTS ON S.L.
0061   DO 27 KM=1,MSV
0062   I=NWS+KM
0063   E=NKA+KM
C   LOOP 28 = NORM VELS AT MSV CON PTS D.T. ALL NWS SOURCE ELEMS
0064   DO 28 J=1,NWS
0065   28   C(J,E)=A(J,I)
C   LOOP 33 = NORM VELS AT MSV CON PTS D.T. ALL MSV SOURCE ELEMS (MU)
C   ON INNER
0066   DO 33 K=1,MSV
0067   J=NKA+K
0068   M=NWS+K
0069   33   C(J,E)=A(M,I)
0070   27   CONTINUE
C *****ASSEMBLE TANG'L VEL EQNS FOR MSV CONTROL POINTS ON INNER EDGE OF
C   S.L.*****
0071   DO 35 KM=1,MSV
0072   I=NWS+KM
0073   E=NM2+KM
0074   IF(NSLAT.EQ.0) GO TO 37
C   LOOP 38 = TANG VELS AT MSV CON PTS D.T. ALL VORTEX ELEMS ON SLATS
0075   DO 38 K=1,NSLAT
0076   P=NSUI+NSPS*(K-1)
0077   Q=P+NSP
0078   J=NWS+K
0079   SA=0.
0080   DO 39 M=P,Q
0081   39   SA=SA+A(M,I)
0082   38   C(J,E)=SA
0083   37   SA=0.
C   LOOP 40 = TANG VELS AT MSV CON PTS D.T. ALL VORTEX ELEMS ON TEST
C   AIRFOIL

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0084      DO 40 K=1,NA                      355,000
0085      40      SA=SA+A(K,I)                356,000
0086      C(NKA,E)=SA                        357,000
      C      LOOP 42 = TANG VELS AT MSV CON PTS D,T,ALL VORTEX ELEMS (GNU) ON 358,000
      C S.L.                                358,000
0087      DO 42 K=1,MSV                      359,000
0088      J=NM2+K                            360,000
0089      M=NWS+K                            361,000
0090      42      C(J,E)=A(M,I)                362,000
0091      35      CONTINUE                    362,500
0092      61      CONTINUE                    363,000
0093      RETURN                             364,000
0094      END                                365,000

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OPTIONS IN EFFECT ID,EBDCIC,SOURCE,NOLIST,NODECK,LOAD,NOMAP

OPTIONS IN EFFECT NAME = ASSEMA , LINECNT = 57

STATISTICS SOURCE STATEMENTS = 94, PROGRAM SIZE = 2980

STATISTICS NO DIAGNOSTICS GENERATED

NO ERRORS IN ASSEMA

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0001      SURROUTINE ASSEMB(R,C,N,M)                                366,000
C      ASSEMB ASSEMBLES THOSE PARTS OF C THAT DEPEND ON B.        367,000
0002      REAL B(N,N),C(M,M)                                       368,000
0003      INTEGER L,P,Q                                              369,000
0004      COMMON/B1/ NWS,NSLAT,NSUI,NKA,NM2,MSV,NA,NSPS,NTEU,NTEL  370,000
0005      COMMON/R2/ U,CH                                           371,000
0006      NSP=NSPS-1                                                372,000
0007      NM2=NM2+MSV                                               373,000
0008      NWSV=NWS+MSV                                              374,000
C*****ASSEMBLE NORMAL VEL EGNS FOR ALL NWS CON PTS *****    375,000
0009      DO 49 I=1,NWS                                           376,000
0010      L=I                                                       377,000
0011      IF(NSLAT.EQ.0) GO TO 3                                     378,000
C      LOOP 4 - NORM VELS * ALL NWS CON PTS D.T. VORTEX ELEMS ON SLATS 379,000
0012      DO 4 K=1,NSLAT                                           380,000
0013      J=NWS+K                                                    381,000
0014      P=NSUI+NSPS*(K-1)                                         382,000
0015      Q=P+NSP                                                    383,000
0016      SB=0.                                                     384,000
0017      DO 5 M=P,Q                                                385,000
0018      SB=SB-R(M,I)                                              386,000
0019      C(J,E)=SB                                                 387,000
0020      SB=0.                                                     388,000
C      LOOP 6 - NORM VELS * ALL NWS CON PTS D.T. VORTEX ELEMS ON TEST 389,000
C AIRFOIL                                                         389,000
0021      DO 6 K=1,NA                                              390,000
0022      SB=SB-R(K,I)                                              391,000
0023      C(NKA,E)=SB                                              392,000
0024      IF(MSV.EQ.0) GO TO 49                                     393,000
C      LOOP 9 - NORM VELS * ALL NWS CON PTS D.T. VORTEX ELEMS(GNU) ON 394,000
C S.L.                                                            394,000
0025      DO 9 K=1,MSV                                             395,000
0026      J=NM2+K                                                  396,000
0027      M=NWS+K                                                  397,000
0028      C(J,E)=-B(M,I)                                           398,000
0029      CONTINUE                                                 399,000
0030      IF(NSLAT.EQ.0) GO TO 12                                   400,000
C*****ASSEMBLE KUTTA EGNS FO AIRFOIL-SHAPED SLATS *****    401,000
0031      DO 52 KS=1,NSLAT                                         402,000
0032      KL=NSUI+NSPS*(KS-1)                                       403,000
0033      KU=KL+NSP                                                 404,000
0034      E=NWS+KS                                                 405,000
C      LOOP 11 - TANG VELS * T.E. OF SLATS D.T. ALL NWS SOURCE ELEMS . 406,000
0035      DO 11 J=1,NWS                                           407,000
0036      C(J,E)=B(J,KL)+B(J,KU)                                    408,000
0037      IF(MSV.EQ.0) GO TO 52                                     409,000
C      LOOP 17 - TANG VELS * T.E. OF SLATS D.T. MSV SOURCE ELEMS (MU) ON 410,000
C S.L.                                                            410,000
0038      DO 17 K=1,MSV                                           411,000
0039      J=NKA+K                                                  412,000
0040      M=NWS+K                                                  413,000
0041      C(J,E)=B(M,KL)+B(M,KU)                                    414,000
0042      CONTINUE                                                 415,000
C      LOOP 19 - TANG VELS * TEST AIRFOIL T.E. D.T. ALL NWS SOURCE ELEMS 416,000
0043      DO 19 J=1,NWS                                           417,000

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0044      19      C(J,NKA)=R(J,NTEU)+R(J,NTEL)      418.000
0045      IF(MSV.EQ.0) GO TO 24      419.000
C      LOOP 25 = TANG VELS * TEST AIRFOIL T.E. D.T. MSV SOURCE ELEMS(MU)      420.000
C ON INNER      420.000
      DO 25 K=1,MSV      421.000
      J=NKA+K      422.000
      M=NWS+K      423.000
0046      25      C(J,NKA)=R(M,NTEU)+R(M,NTEL)      424.000
0047      24      IF(MSV.EQ.0) GO TO 61      425.000
0048      C*****ASSEMBLE NORMAL VEL EQNS FOR MSV CON PTS ON      SHEAR LAYER*****      426.000
0049      DO 27 KM=1,MSV      427.000
0050      I=NWS+KM      428.000
      E=NKA+KM      429.000
0051      IF(NSLAT.EQ.0) GO TO 29      430.000
0052      C      - LOOP 30 = NORM VELS * MSV CON PTS D.T. VORTEX ELEMS ON SLATS      431.000
0053      DO 30 K=1,NSLAT      432.000
0054      J=NWS+K      433.000
      P=NSUI+NSPS*(K-1)      434.000
0055      Q=P+NSP      435.000
0056      SR=0.      436.000
0057      DO 31 M=P,Q      437.000
0058      31      SB=SR-R(M,I)      438.000
0059      30      C(J,E)=SB      439.000
0060      29      SR=0.      440.000
0061      C      - LOOP 32 = NORM VELS * MSV CON PTS D.T. VORTEX ELEMS ON TEST      441.000
0062      C AIRFOIL      441.000
      DO 32 K=1,NA      442.000
0063      32      SB=SR-R(K,I)      443.000
      C(NKA,E)=SB      444.000
0064      C      - LOOP 34 = NORM VELS * MSV CON PTS D.T. MSV VORTEX ELEMS (GNU) ON      445.000
0065      C S.L.      445.000
      DO 34 K=1,MSV      446.000
0066      J=NKA+K      447.000
      M=NWS+K      448.000
0067      34      C(J,E)=-R(M,I)      449.000
0068      27      CONTINUE      450.000
0069      C*****ASSEMBLE TANGIL VEL EQNS FOR MSV CON PTS ON      SHEAR LAYER*****      451.000
0070      DO 35 KM=1,MSV      452.000
0071      I=NWS+KM      453.000
      E=NKA+KM      454.000
0072      C      LOOP 36 = TANG VELS * MSV CON PTS D.T. ALL NWS SOURCE ELEMS      455.000
0073      DO 36 J=1,NWS      456.000
0074      36      C(J,E)=R(J,I)      457.000
0075      C      LOOP 41 = TANG VELS * MSV CON PTS D.T. MSV SOURCE ELEMS (MU) ON      458.000
0076      C S.L.      458.000
      DO 41 K=1,MSV      459.000
0077      J=NKA+K      460.000
      M=NWS+K      461.000
0078      41      C(J,E)=R(M,I)      462.000
0079      35      CONTINUE      462.500
0080      61      CONTINUE      463.000
0081      64      CONTINUE      464.000
0082      RETURN      465.000
0083      END      466.000
0084
0085

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OPTIONS IN EFFECT ID,EBCDIC,SOURCE,NOLIST,NODECK,LOAD,NOMAP

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0001      SUBROUTINE ASSEMB(D,M,CS,SI,N,VTI,N1,VTO,N2)      467.000
      C      ASSEMB ASSEMBLES R.M.S. VECTOR FOR SYSTEM C*SIG=D  468.000
      REAL D(M),CS(N),SI(N),VTI(N1),VTO(N2)      469.000
      INTEGER P,Q      470.000
      COMMON/H1/ NWS,NSLAT,NSUI,NKA,NM2,MSV,NA,NSPS,NTEU,NTEL  471.000
      COMMON/R2/ U,CH      472.000
      NSP=NSPS-1      473.000
      NWSV=NWS+MSV      474.000
      NM2=NM2+MSV      475.000
      C      LOOP 43 - NORMAL ONSET FLOW VEL AT ALL NWS CON PTS  476.000
      DO 43 I=1,NWS      477.000
      D(I)=U*SI(I)      478.000
      IF(NSLAT.EQ.0) GO TO 44      479.000
      C      LOOP 45 - TANG'L ONSET FLOW VELS * T.E. OF SLATS  480.000
      DO 45 K=1,NSLAT      481.000
      I=NWS+K      482.000
      P=NSUI+NSPS*(K-1)      483.000
      Q=P+NSP      484.000
      D(I)=-U*(CS(P)+CS(Q))      485.000
      C      LOOP 44 - TANG'L ONSET FLOW VELS * T.E. OF TEST AIRFOIL  486.000
      D(NKA)=-U*(CS(NTEU)+CS(NTEL))      487.000
      IF(MSV.EQ.0) GO TO 46      488.000
      C      LOOP 47 - NORMAL ONSET FLOW VEL * ALL MSV CON PTS ON SHEAR L.  489.000
      DO 47 K=1,MSV      490.000
      J=NWS+K      491.000
      I=NKA+K      492.000
      D(I)=U*SI(J)      493.000
      C      LOOP 48 - TANG'L ONSET FLOW VEL * ALL MSV CON PTS ON SHEAR L.  494.000
      C      * PRESCRIBED TAN'L VEL THERE.  495.000
      DO 48 K=1,MSV      496.000
      J=NWS+K      497.000
      I=NM2+K      498.000
      D(I)=-U*CS(J)+VTI(K)      499.000
      46      CONTINUE      500.000
      46      RETURN      501.000
      46      END      502.000

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OPTIONS IN EFFECT ID,CBCDIC,SOURCE,NOLIST,NODECK,LOAD,NOMAP

OPTIONS IN EFFECT NAME = ASSEMB , LINECNT = 57

STATISTICS SOURCE STATEMENTS = 29, PROGRAM SIZE = 1194

STATISTICS NO DIAGNOSTICS GENERATED

NO ERRORS IN ASSEMB

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0001 SUBROUTINE CPS(CP,VTT,XX,YY,CS,SI,N1,STG,N2,GAM,N3,MU,GNU,N4,A,B) 503.000
      C CPS CALCULATES VEL, PRESSURE & ALL CON PTS. 504.000
0002 REAL A(N1,N1),R(N1,N1) 505.000
0003 REAL SIG(N2),GAM(N3),MU(N4),GNU(N4) 506.000
0004 REAL VTT(N1),CP(N1),XX(N1),YY(N1),CS(N1),SI(N1) 507.000
0005 INTEGER P,0 508.000
0006 COMMON/B1/ NWS,NSLAT,NSU1,NKA,NM2,MSV,NA,NSPS,NTEU,NTEL 509.000
0007 COMMON/B2/ H,CH 510.000
0008 COMMON/B3/NU1,NWU1,MU3,NWU2,NL1,NWL1,NL3,NWL2,NSOL1,NSOL9L,NF1, 511.000
      1 NPLAT,NSPF,N11 512.000
0009 NM2=NM2+MSV 513.000
0010 NWSV=NWS+MSV 514.000
0011 NVN=NWS+MSV 515.000
0012 NSU2=NSU1+NSPS*NSLAT-1 516.000
0013 NSP=NSPS-1 517.000
0014 IF(NSLAT.EQ.0) GO TO 2 518.000
0015 DO 1 K=1,NSLAT 519.000
0016 I=NWS+K 520.000
      C GAM = SLAT VORTEX STRENGTH DENSITIES 521.000
0017 1 GAM(K)=SIG(I) 522.000
      C GAMM = TEST AIRFOIL VORTEX STRENGTH DENSITY 523.000
0018 2 GAMM=SIG(NKA) 524.000
0019 IF(MSV.EQ.0) GO TO 4 525.000
0020 DO 3 K=1,MSV 526.000
0021 I=NKA+K 527.000
0022 J=NM2+K 528.000
      C MU = S.L. SOURCE STRENGTH DENSITIES 529.000
0023 MU(K)=SIG(I) 530.000
      C GNU = VORTEX STRENGTH DENSITIES FOR SHEAR LAYER 531.000
0024 3 GNU(K)=SIG(J) 532.000
0025 4 LL=0 533.000
0026 DO 5 I=1,NVN 534.000
0027 II=I+NSP 535.000
0028 LK=NSU1+LL*NSPS 536.000
0029 IF(I.EQ.1) WRITE(6,52) 537.000
0030 52 FORMAT(1H1) 538.000
      C VNST,VTST = TOTAL NORMAL & TANG'L VELS DUE TO SOURCE ELEMS 539.000
0031 VNST=0. 540.000
0032 VTST=0. 541.000
0033 ASM=0. 542.000
0034 BSM=0. 543.000
0035 DO 5 J=1,NWS 544.000
0036 VNST=VNST+A(J,I)*SIG(J) 545.000
0037 VTST=VTST+B(J,I)*SIG(J) 546.000
0038 ASM=ASM+A(J,I) 547.000
0039 5 BSM=BSM+B(J,I) 548.000
0040 AS=0. 549.000
0041 RS=0. 550.000
0042 IF(NSLAT.EQ.0) GO TO 8 551.000
0043 DO 6 K=1,NSLAT 552.000
0044 P=NSU1+NSPS*(K-1) 553.000
0045 Q=P+NSP 554.000
      C P,0 = 1ST & LAST CON PTS ON A SLAT 555.000
      C AP,BP = NORM & TANG VELS DUE TO VORTEX ELEMS ON SLATS 556.000
0046 AP=0. 557.000

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0047      BP=0.      558.000
0048      DO 7 M=P,0  559.000
0049      AP=AP+A(M,I) 560.000
0050      7 BP=BP+B(M,I) 561.000
0051      AP=AP*GAM(K) 562.000
0052      BP=BP*GAM(K) 563.000
0053      AS=AS+AP 564.000
0054      6 BS=BS+BP 565.000
0055      C AT,BT - NORM & TANG VELS DUE TO VORTEX ELEMS ON TEST AIRFOIL 566.000
0056      8 AT=0. 567.000
0057      BT=0. 568.000
0058      DO 9 J=1,NA 569.000
0059      AT=AT+A(J,I) 570.000
0060      9 BT=BT+B(J,I) 571.000
0061      AT=AT*GAMH 572.000
0062      BT=BT*GAMH 573.000
0063      C AM,BM - NORM & TANG VELS DUE TO MSV SOURCE ELEMS ON INNER EDGE OF 574.000
0064      C S.L. 574.000
0065      AM=0. 575.000
0066      BM=0. 576.000
0067      C AG,BG - NORM & TANG VELS DUE TO MSV VORTEX ELEMS GNU ON INNER 577.000
0068      C EDGE OF S.L. 577.000
0069      AG=0. 578.000
0070      BG=0. 579.000
0071      IF(MSV.EQ.0) GO TO 11 580.000
0072      DO 10 K=1,MSV 581.000
0073      J=NWS+K 582.000
0074      AG=AG+A(J,I)*GNU(K) 583.000
0075      BG=BG+B(J,I)*GNU(K) 584.000
0076      AM=AM+A(J,I)*AMU(K) 585.000
0077      10 BM=BM+B(J,I)*AMU(K) 586.000
0078      11 VNST=VNST+AM 587.000
0079      VTST=VTST+BM 588.000
0080      C VNV,VTVT - TOTAL NORM & TANG VEL DUE TO ALL VORTEX ELEMS 589.000
0081      VNV=-BS-RT-RG 590.000
0082      VTVT=AS+AT+AG 591.000
0083      C VNOT,VTOT - NORM & TANG VEL DUE TO UNIFORM STREAM U 592.000
0084      VNOT=-U*SI(I) 593.000
0085      VTOT=U*CS(I) 594.000
0086      VNT=VNST+VNV+VNOT 595.000
0087      VTT(I)=VTST+VTVT+VTOT 596.000
0088      C VKL,VKU - TEST AIRFOIL T.E. KUTTA VELS 597.000
0089      IF(I.EQ.NTEU) VKU=VTT(I) 598.000
0090      IF(I.EQ.NTEL) VKL=VTT(I) 599.000
0091      CP(I)=1.-VTT(I)*VTT(I) 600.000
0092      IF(I.EQ.1) GO TO 41 601.000
0093      IF((I.EQ.NU1).AND.(NWU1.NE.0)) GO TO 42 602.000
0094      IF((I.EQ.NU3).AND.(NWU2.NE.0)) GO TO 43 603.000
0095      IF((I.EQ.NL1).AND.(NWL1.NE.0)) GO TO 44 604.000
0096      IF((I.EQ.NL3).AND.(NWL2.NE.0)) GO TO 45 605.000
0097      IF((I.EQ.NSOL1).AND.(NSOLSL.NE.0)) GO TO 46 606.000
0098      IF((I.EQ.NF1).AND.(NFLAT.NE.0)) GO TO 47 607.000
0099      IF((NSLAT.EQ.0).OR.(I.GE.NSU2)) GO TO 70 608.000
0100      IF((I.EQ.LK).AND.(LL.LE.NSLAT)) GO TO 48 609.000
0101      70 CONTINUE 610.000

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0094      IF((I.EQ.NII).AND.(MSV.NE.0)) GO TO 49      611.000
0095      GO TO 12      612.000
0096      40      FORMAT(4X,'VNST',4X,'VNVT',4X,'VNOT',4X,'VNT',5X,'VTST',4X,'VTVT',
1      4X,'VTOT',4X,'VTT',5X,'ASUM',4X,'BSUM',5X,'YY',5X,'XX',5X,'CP',
2      6X,'SIG')      613.000
0097      41      WRITE(6,30)      614.000
0098      30      FORMAT('MAIN AIRFOIL')      615.000
0099      GO TO 51      616.000
0100      42      WRITE(6,31)      617.000
0101      31      FORMAT('UPPER RIGHT SOLID WALL')      618.000
0102      GO TO 51      619.000
0103      43      WRITE(6,32)      620.000
0104      32      FORMAT('UPPER LEFT SOLID WALL')      621.000
0105      GO TO 51      622.000
0106      44      WRITE(6,33)      623.000
0107      33      FORMAT('LOWER LEFT SOLID WALL')      624.000
0108      GO TO 51      625.000
0109      45      WRITE(6,34)      626.000
0110      34      FORMAT('LOWER RIGHT SOLID WALL')      627.000
0111      GO TO 51      628.000
0112      46      WRITE(6,35)      629.000
0113      35      FORMAT('SOLID STREAMLINE WALL')      630.000
0114      GO TO 51      631.000
0115      47      WRITE(6,36)      632.000
0116      36      FORMAT('FLAT SLATS/NO KUTTA')      633.000
0117      GO TO 51      634.000
0118      48      IF(I.NE.NSUI) GO TO 67      635.000
0119      WRITE(6,37)      636.000
0120      37      FORMAT('UPPER SLATS')      637.000
0121      67      LL=LL+1      638.000
0122      69      IF(LL.GT.NSLAT) GO TO 12      639.000
0123      WRITE(6,68) I,II      640.000
0124      68      FORMAT(/,'SLAT #',I3,2X,I3)      641.000
0125      GO TO 51      642.000
0126      49      WRITE(6,38)      643.000
0127      38      FORMAT('STREAMLINE FOR SHEAR LAYER')      644.000
0128      51      WRITE(6,40)      645.000
0129      12      WRITE(6,13) VNST,VNVT,VNOT,VNT,VTST,VTVT,VTOT,VTT(I),ASM,BSM,
1      YY(I),XX(I),CP(I),SIG(I)      646.000
0130      13      FORMAT(1X,10F8.3,2F7.2,2F8.3)      647.000
0131      IF(NSLAT.EQ.0) GO TO 20      648.000
0132      WRITE(6,14) GAM      649.000
0133      20      WRITE(6,18) GAMM      650.000
0134      18      FORMAT('GAMM=',G12.5)      651.000
0135      IF(MSV.EQ.0) GO TO 19      652.000
0136      WRITE(6,15) MU      653.000
0137      WRITE(6,16) GNU      654.000
0138      14      FORMAT('GAM=',10G12.5)      655.000
0139      15      FORMAT('MU=',10G12.5)      656.000
0140      16      FORMAT('GNU=',10G12.5)      657.000
0141      19      WRITE(6,17) VKU,VKL      658.000
0142      17      FORMAT('VKU=',G12.5,2X,'VKL=',G12.5)      659.000
0143      RETURN      660.000
0144      END      661.000

```

OPTIONS IN EFFECT ID,LRCDIC,SOURCE,NOLIST,NODECK,LOAD,NOMAP

```

0001      SUBROUTINE FORCES(CP,XX,YY,DX,DY,DS,VTT,N,U,CH,N1,N2,XC,YC)
0002      REAL CP(N),XX(N),YY(N),DX(N),DY(N),DS(N),VTT(N)
          XC,YC = CENTER OF BODY
0003      WRITE(6,5) N1,N2,XC,YC
0004      5  FORMAT('FORCES ON BODY #1,I3,'F7.2, 'CENTER AT (I,F7.2, '
          'I,F7.2, '))
0005      CLT=0
0006      CDT=0
0007      CM0=0
0008      CIRC=0
0009      PER=0
0010      DO 1 I=N1,N2
0011      CLT=CLT-CP(I)*DX(I)
0012      CDT=CDT+CP(I)*DY(I)
0013      CIRC=CIRC+VTT(I)*DS(I)
          C  PER = BODY PERIMETER
0014      PER=PER+DS(I)
0015      1  CM0=CM0+CP(I)*((XX(I)-XC)*DX(I)+(YY(I)-YC)*DY(I))
          C  CLT = TUNNEL LIFT COEFF.
0016      CLT=CLT/CH
          C  CDT = TUNNEL DRAG COEFF.(THEORY ZERO)
0017      CDT=CDT/CH
          C  CM0 = TUNNEL MIDCHORD PITCHING MOM. COEFF.
0018      CM0=CM0/CH/CH
          C  CM4 = TUNNEL QUARTERCHORD PITCHING MOM. COEFF.
0019      CM4=CM0-CLT/4
          C  CIRC = CIRCULATION ABOUT BODY
          C  CLC= LIFT COEFF. FROM CIRCULATION
0020      CLC=2.*CIRC/CH/U
0021      WRITE(6,2) CLT,CDT,CM0,CM4
0022      2  FORMAT('CLT='F10.5,2X,'CDT='F10.5,2X,'CM0='F10.5,2X,'CM4='
          'F10.5)
0023      WRITE(6,3) CIRC,CLC,PER
0024      3  FORMAT('CIRC='F10.5,2X,'CLC='F10.5,2X,'PERIM='G12.5)
0025      RETURN
0026      END

```

OPTIONS IN EFFECT IO,ERCDC, SOURCE, NOLIST, NODECK, LOAD, NOMAP

OPTIONS IN EFFECT NAME = FORCES , LINECNT = 57

STATISTICS SOURCE STATEMENTS = 26, PROGRAM SIZE = 1276

STATISTICS NO DIAGNOSTICS GENERATED

NO ERRORS IN FORCES

```

MICHIGAN TERMINAL SYSTEM FORTRAN G(41336)      M00PRO      10-22-75      10119140
0001 SUBROUTINE M00PRO(X,Y,XD,YD,DS,CS,SI,N,X,Y,MP,L1,L2,ALF,ALZ,K,
0002 1 DTHICK,XCENT,YCENT,NTEU,NTEL,NLEL,NTEL,XM,YM,XLE,XTE)
0003 REAL XX(N),YY(N),DX(N),DY(N),DS(N),CS(N),SI(N)
0004 REAL X(MP),Y(MP),XM(MP),YM(MP)
0005 REAL K
0006 F=57.29578
0007 K = FRACTION OF FULL KUTTA CIRCIN
0008 IF(K.LT.1.0) GO TO 6
0009 C ALF = INCIDENCE
0010 C ALZ = 7/800 LIFT ANGLE
0011 AR=(ALF-ALZ)/2
0012 DET = FULL ROTATION
0013 DET=(AR-ARSIN(KASIN(AR)))
0014 TED=DET*F
0015 GO TO 7
0016 DET=0
0017 TED=0
0018 WRITE(6,1) DET, TED, K, DTHICK
0019 1 FORMAT('DELEST=',F8.5,'(RAD)',2X,F6.2,'(DEG)',2X,'K=',F7.5,2X,
1 'RLOISPLTHICK=',F8.5)
0020 X0=XCENT
0021 Y0=YCENT
0022 D1=(XTE-XLE)/2
0023 D2=D1-(XTE-X0)
0024 DTHICK = DISPL THICK FOR SYMM B.L.
0025 XX,YY = CONTROL POINT COORDINATES
0026 X,Y = PROFILE COORDINATES
0027 DO 2 I=L1,L2
0028 J=I-L1+1
0029 X(J)=XX(I)-DX(I)/2
0030 Y(J)=YY(I)-DY(I)/2
0031 X(MP)=XX(L2)+DX(L2)/2
0032 Y(MP)=YY(L2)+DY(L2)/2
0033 DO 3 I=1,MP
0034 XC=X(I)-X0
0035 YC=Y(I)-Y0
0036 XF=.5*(1+(XC+D2)/D1)
0037 IF(K.LT.1.0) GO TO 8
0038 AE=DET*XF
0039 CO=COS(AE)
0040 SINESIN(AL)
0041 IF(DTHICK.EQ.0.) GO TO 4
0042 YD=D12*XF
0043 IF((I.LE.NLEU).AND.(I.LE.NTEU)) Y(I)=Y(I)+YD
0044 IF((I.LE.NTEL).AND.(I.LE.NLEL)) Y(I)=Y(I)-YD
0045 IF(K.EQ.1.0) GO TO 9
0046 XM,YM = MODIFIED PROFILE COORDINATES
0047 XM(I)=X0+XC+CO-XCASN
0048 YM(I)=Y0+YC+CO-XCASN
0049 GO TO 3
0050 XM(I)=X(I)
0051 YM(I)=Y(I)
0052 CONTINUE
0053 3

```

```

0045      M=MP-1
0046      C    XX,YY = NOW MODIFIED CONTROL POINT COORDS.
0047      DO 5 I=L1,L2
0048      J=I-L1+1
0049      K=J+1
0049      XX(I)=(XM(J)+XM(K))/2.
0050      YY(I)=(YM(J)+YM(K))/2.
0051      DX(I)=XM(K)-XM(J)
0052      DY(I)=YM(K)-YM(J)
0053      DS(I)=SQRT(DX(I)*DX(I)+DY(I)*DY(I))
0054      CS(I)=DX(I)/DS(I)
0055      S(I)=DY(I)/DS(I)
0056      RETURN
0057      END

```

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OPTIONS IN EFFECT IN,ERCDIC,SOURCE,NOLIST,NODECK,LOAD,NOMAP

OPTIONS IN EFFECT NAME = MODPRO , LINECNT = 57

STATISTICS SOURCE STATEMENTS = 57,PROGRAM SIZE = 2700

STATISTICS NO DIAGNOSTICS GENERATED

NO ERRORS IN MODPRO

MICHIGAN TERMINAL SYSTEM FORTRAN G(41336)

RE

10-22-75

10:19:41

PAGE P001

```

0001      SUBROUTINE RE(A,N,M,LA)
0002      REAL A(N,M)
0003      READ(LA) A
0004      RETURN
0005      END
*OPTIONS IN EFFECT* ID,EBCDIC,SOURCE,NOLIST,NODECK,LOAD,NOMAP
*OPTIONS IN EFFECT* NAME = RE , LINECNT = 57
*STATISTICS* SOURCE STATEMENTS = 5,PROGRAM SIZE = 440
*STATISTICS* NO DIAGNOSTICS GENERATED
NO ERRORS IN RE

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771.000
772.000
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MICHIGAN TERMINAL SYSTEM FORTRAN G(41336)

WR

10-22-75

10:19:41

PAGE P001

```

0001      SUBROUTINE WR(A,N,M,LA)
0002      REAL A(N,M)
0003      WRITE(LA) A
0004      RETURN
0005      END
*OPTIONS IN EFFECT* ID,EBCDIC,SOURCE,NOLIST,NODECK,LOAD,NOMAP
*OPTIONS IN EFFECT* NAME = WR , LINECNT = 57
*STATISTICS* SOURCE STATEMENTS = 5,PROGRAM SIZE = 440
*STATISTICS* NO DIAGNOSTICS GENERATED
NO ERRORS IN WR

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776.000
777.000
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MICHIGAN TERMINAL SYSTEM FORTRAN G(41336)

WRD

10-22-75

10:19:41

PAGE P001

```

0001      SUBROUTINE WRD(D,M,LD)
0002      REAL D(M)
0003      WRITE(LD) D
0004      RETURN
0005      END
*OPTIONS IN EFFECT* ID,EBCDIC,SOURCE,NOLIST,NODECK,LOAD,NOMAP
*OPTIONS IN EFFECT* NAME = WRD , LINECNT = 57
*STATISTICS* SOURCE STATEMENTS = 5,PROGRAM SIZE = 388
*STATISTICS* NO DIAGNOSTICS GENERATED
NO ERRORS IN WRD

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784.000

NO STATEMENTS FLAGGED IN THE ABOVE COMPILATIONS.
EXECUTION TERMINATED

3316

151

Appendix 11.List of Equipment Used

<u>Instrument</u>	<u>Description</u>
Barocel Pressure Sensor Type 511 (10mm Hg = 10 Volts)	pressure transducer for pitotstatic tube measurements
Barocel Electronic Manometer Type 1018B	4-1/2 digit voltmeter for windspeed from pitotstatic tube.
Barocel Signal Conditioner Type 1015	amplifier for Barocel pressure transducers.
Disa Digital Voltmeter Type 55D31	3-1/2 digit voltmeter for windtunnel balance measure- ments.
Digitec Digital Voltmeter Model 2780	4-1/2 digit voltmeter for windtunnel balance measure- ments and Scanivalve pressure measurements.
Leeds & Northrup Microvolt Indicating Amplifier Model 9835-B	strain gauge amplifier for Aerolab windtunnel balance.
Druck pressure transducer Model PDCR-22	for Scanivalve airfoil surface pressure measurements

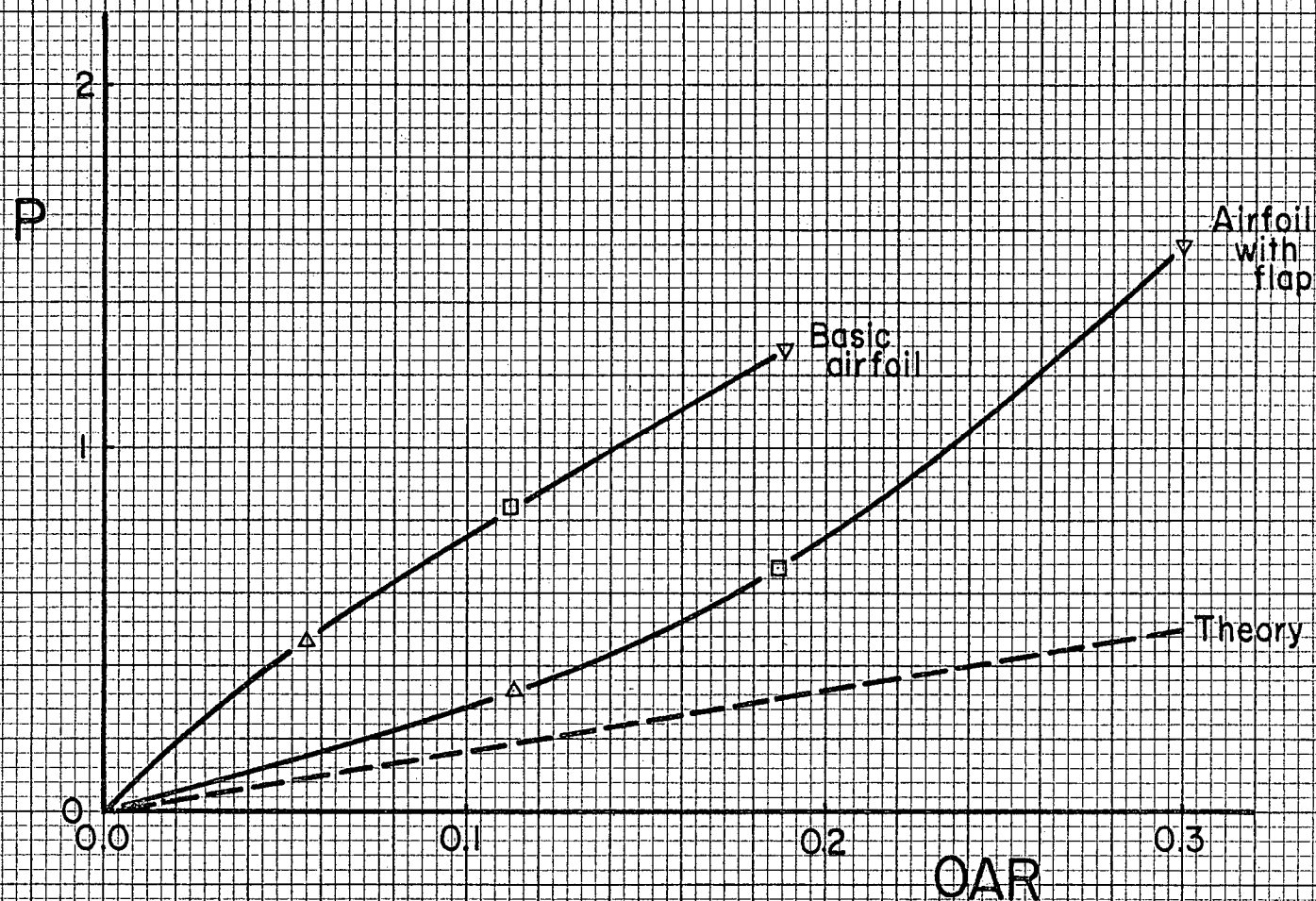


Figure 2.1 Porosity parameter as a function of wall open-area ratio for longitudinal slots [12].

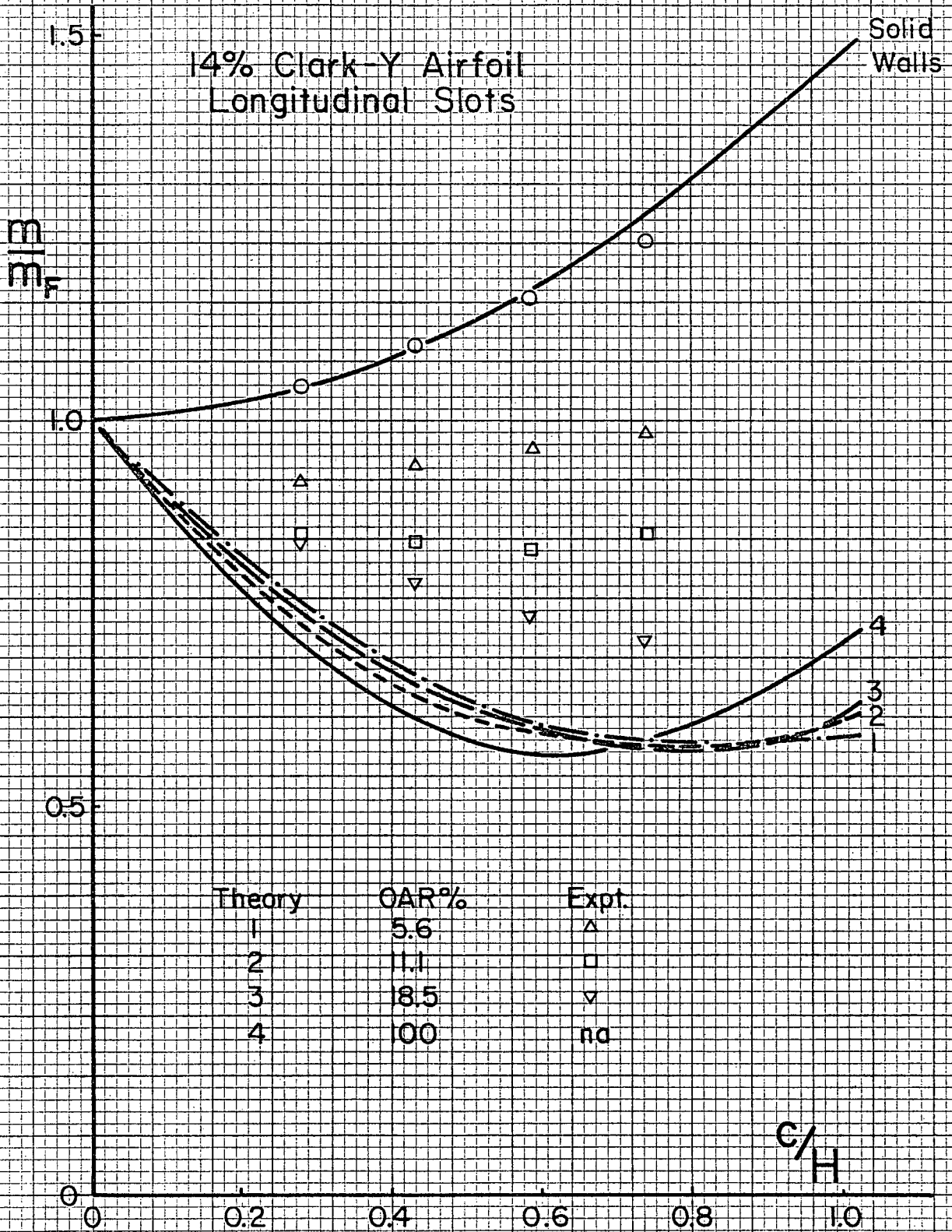


Figure 2.2 Ratio of airfoil lift-curve slopes for longitudinally slotted walls: Experiment [12]

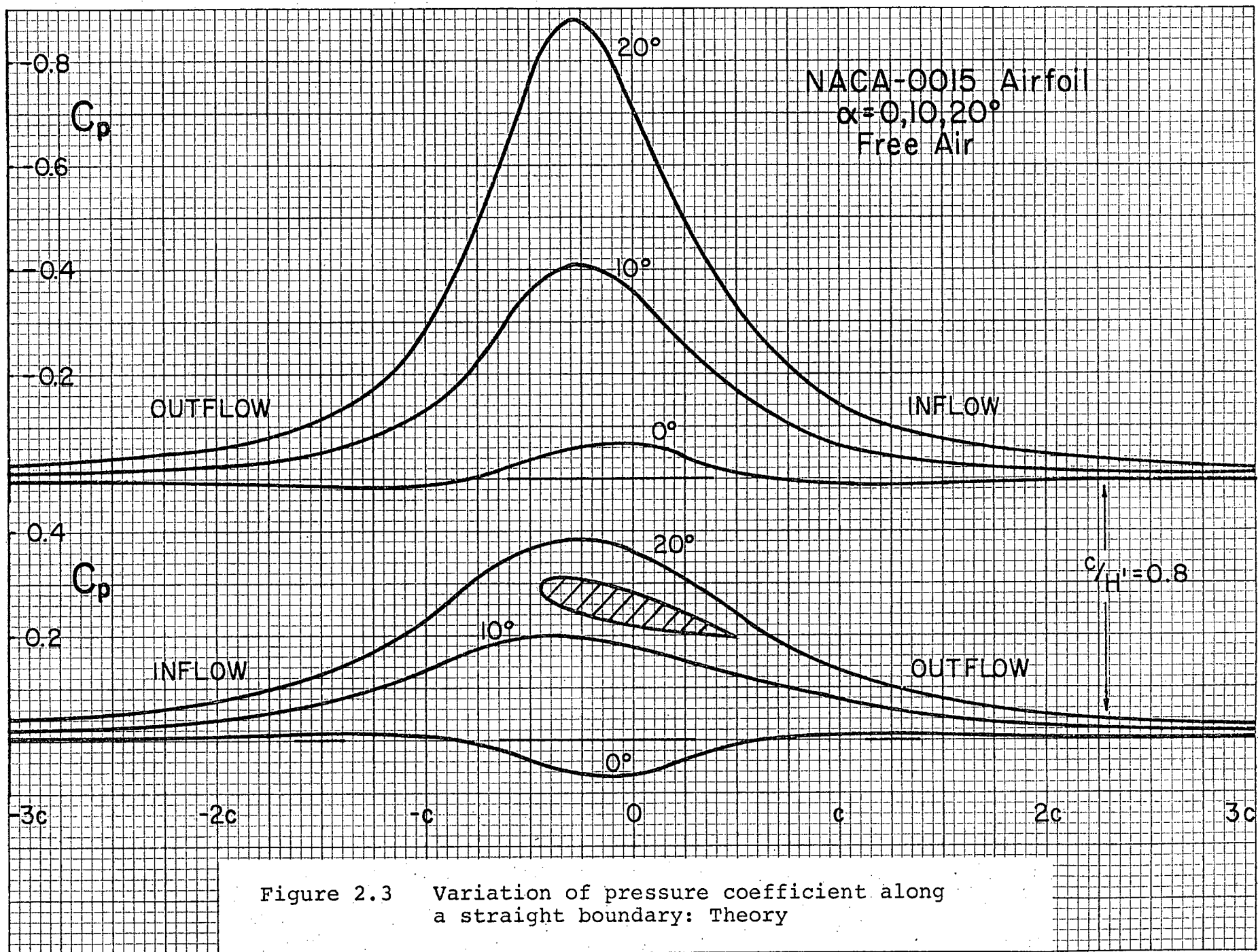


Figure 2.3 Variation of pressure coefficient along a straight boundary: Theory

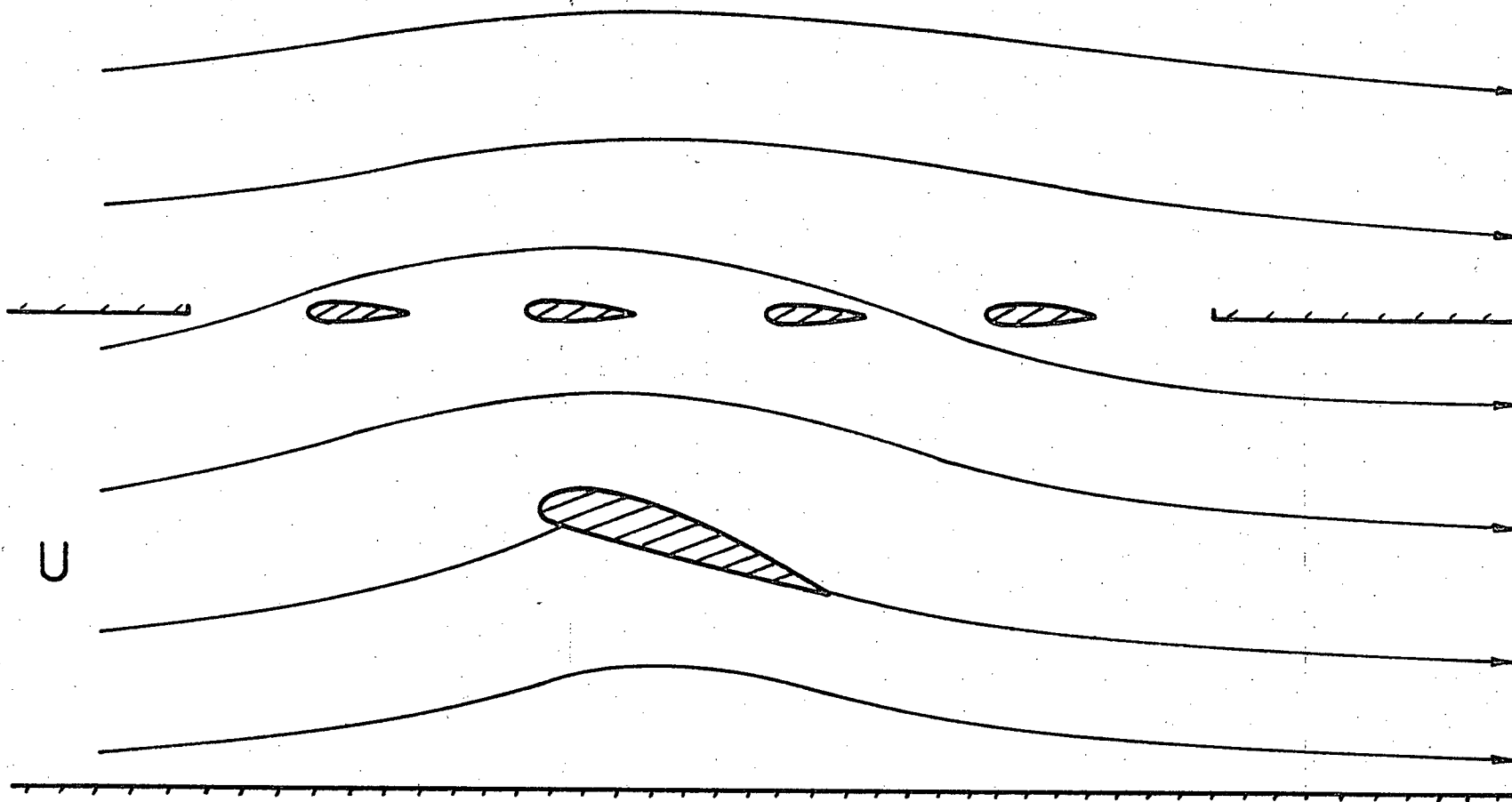
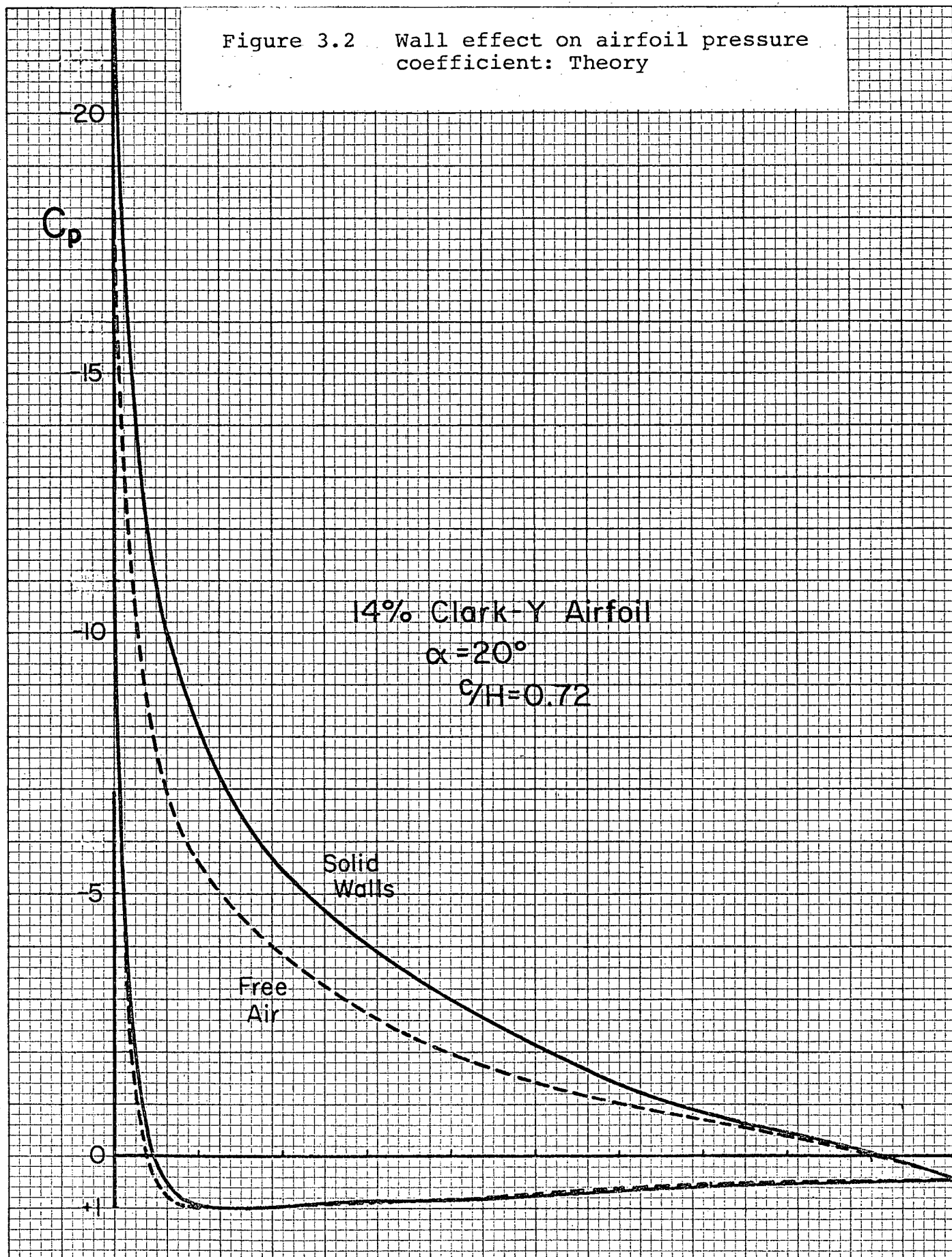


Figure 3.1 An airfoil between transversely-slotted upper and solid lower walls: Theory

Figure 3.2 Wall effect on airfoil pressure coefficient: Theory



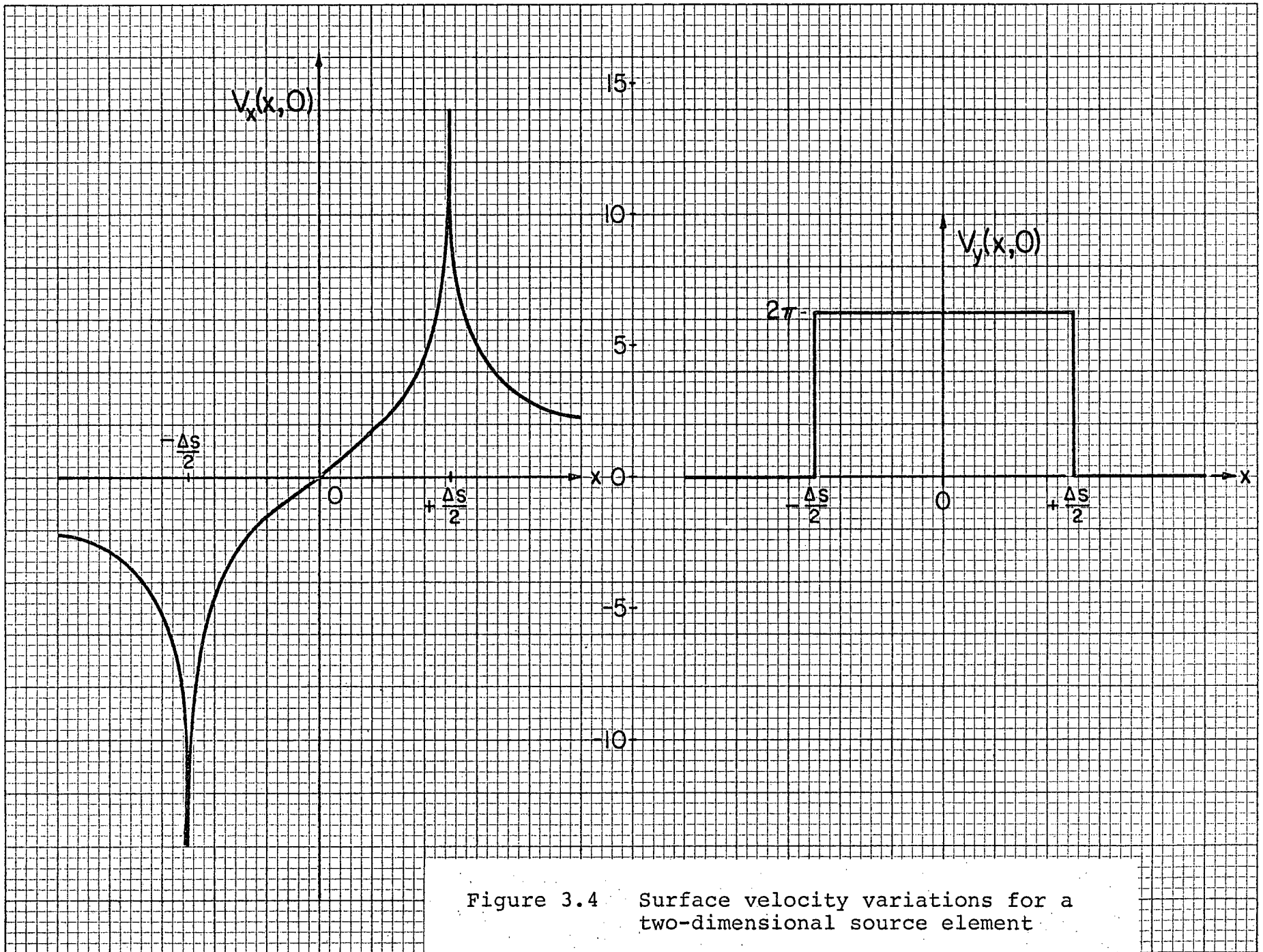


Figure 3.4 Surface velocity variations for a two-dimensional source element

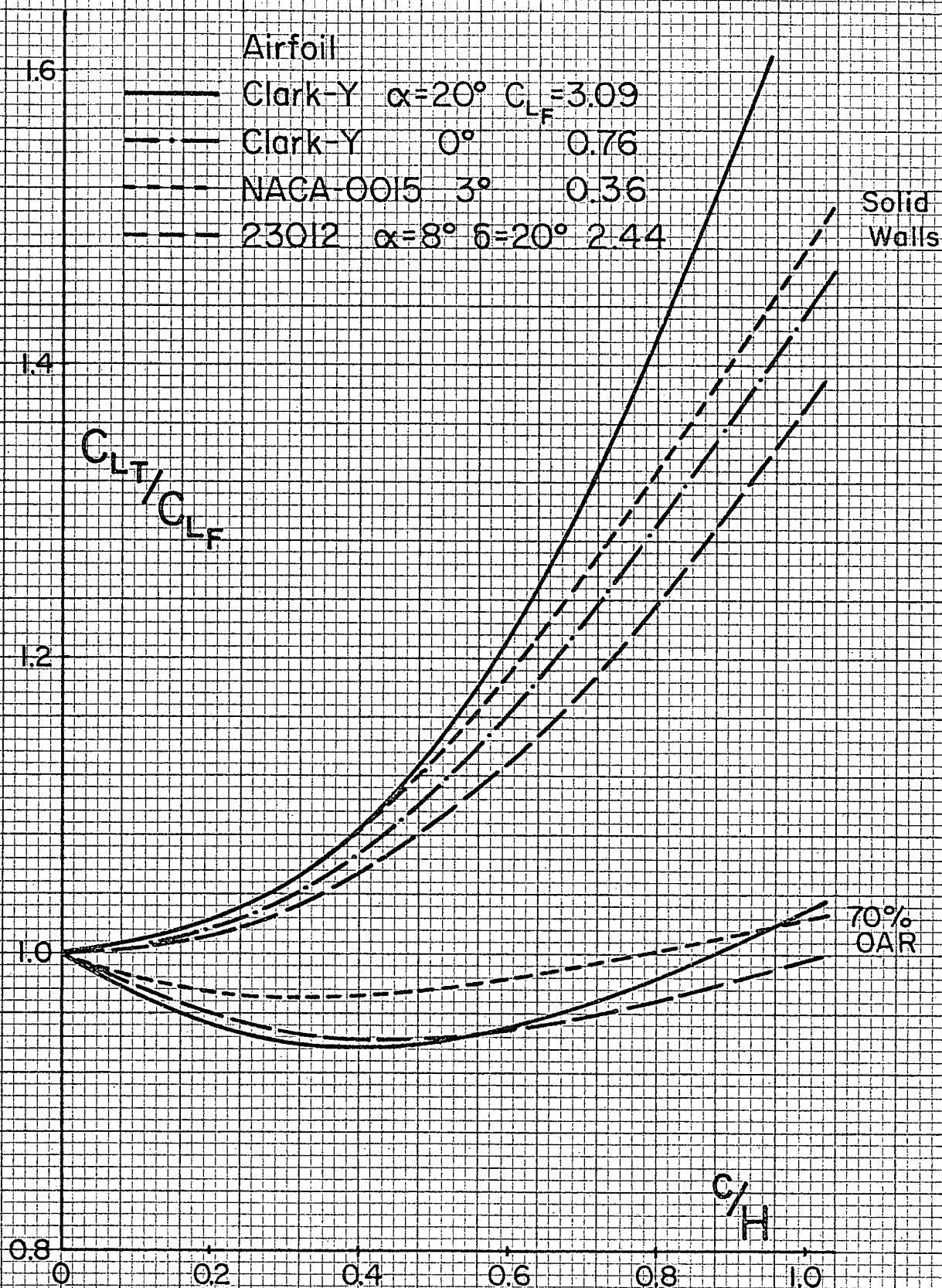
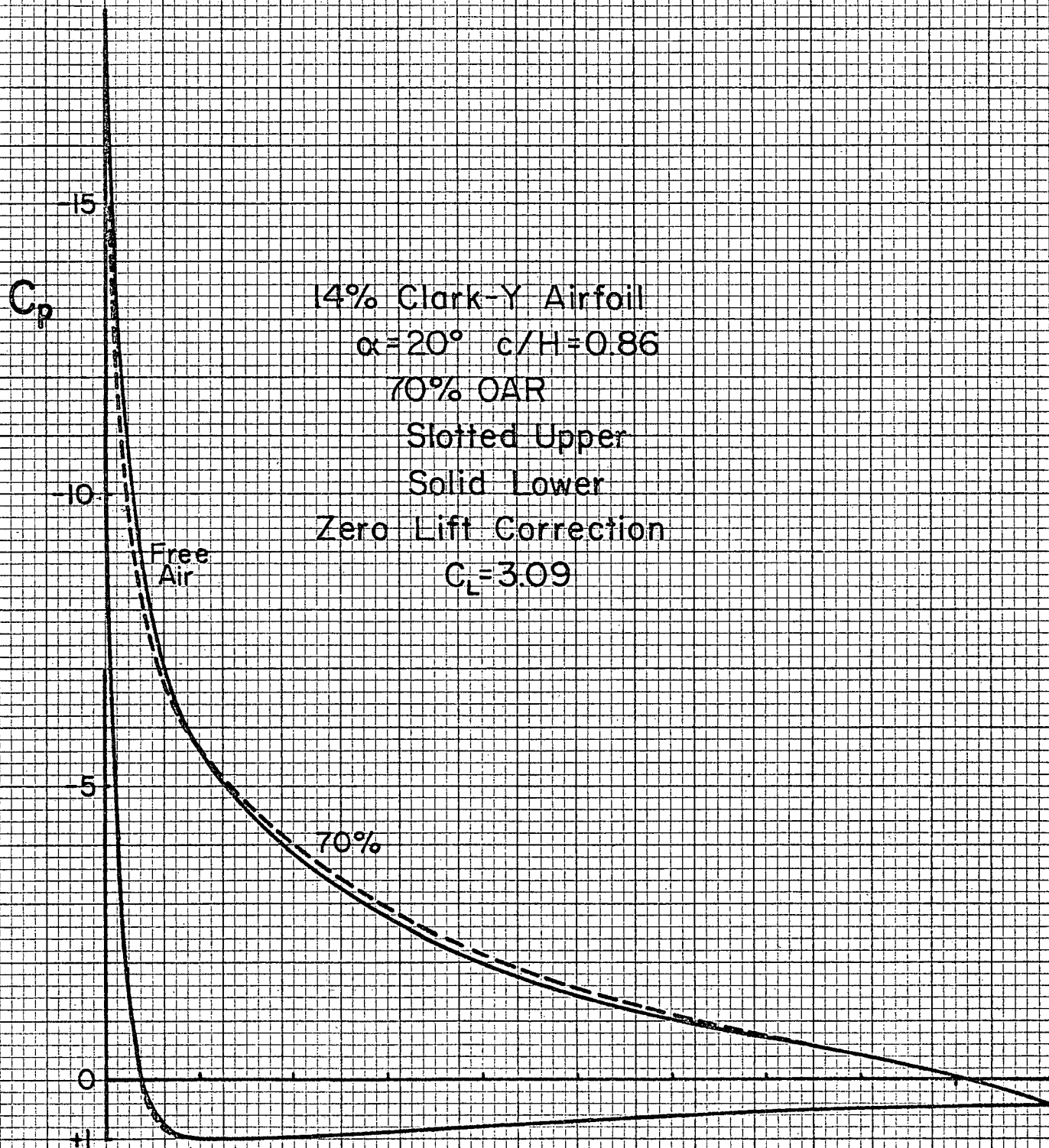
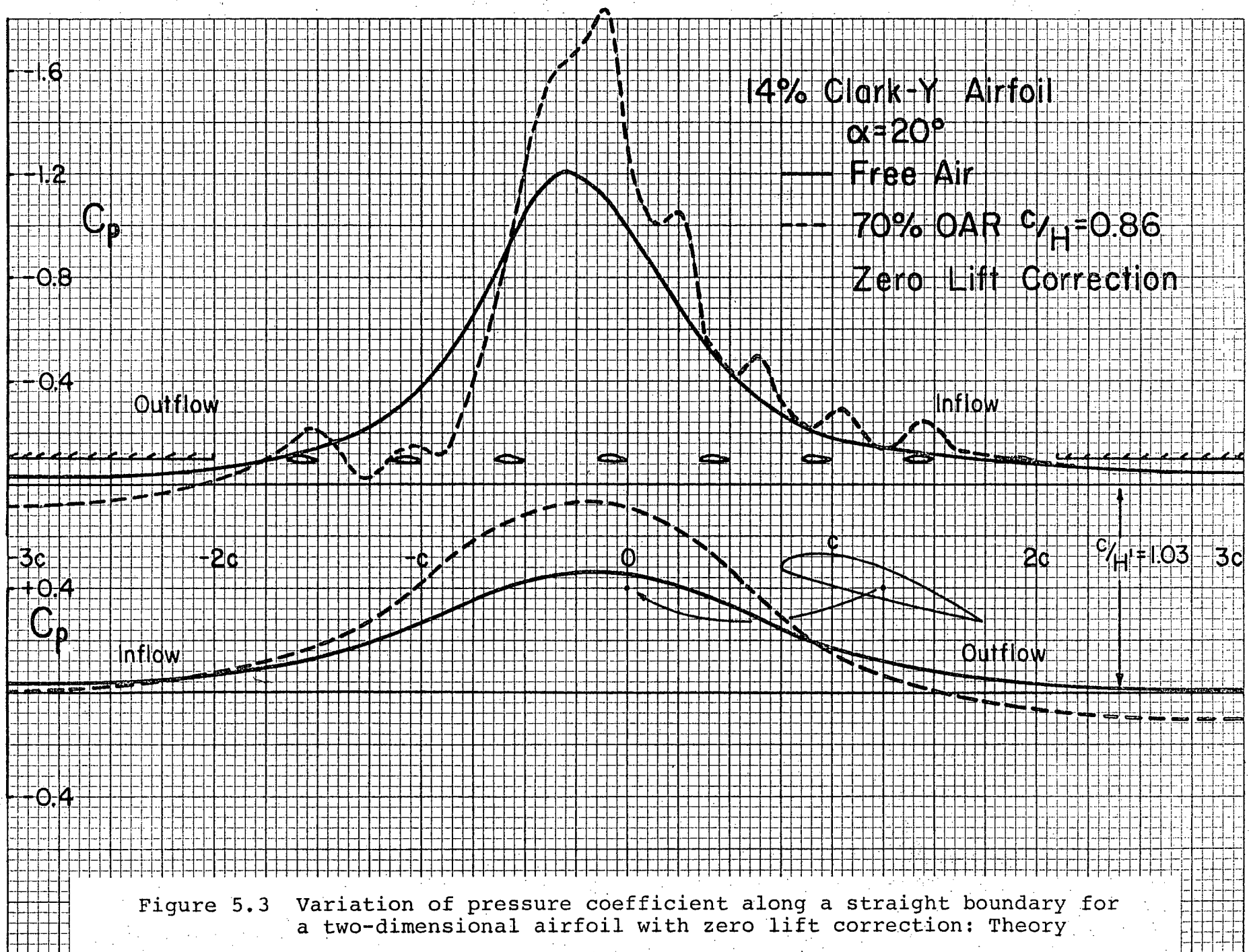


Figure 5.1 Effect of airfoil size on ratio of lift coefficients: Theory

Figure 5.2 Comparison of airfoil pressure coefficients: Theory





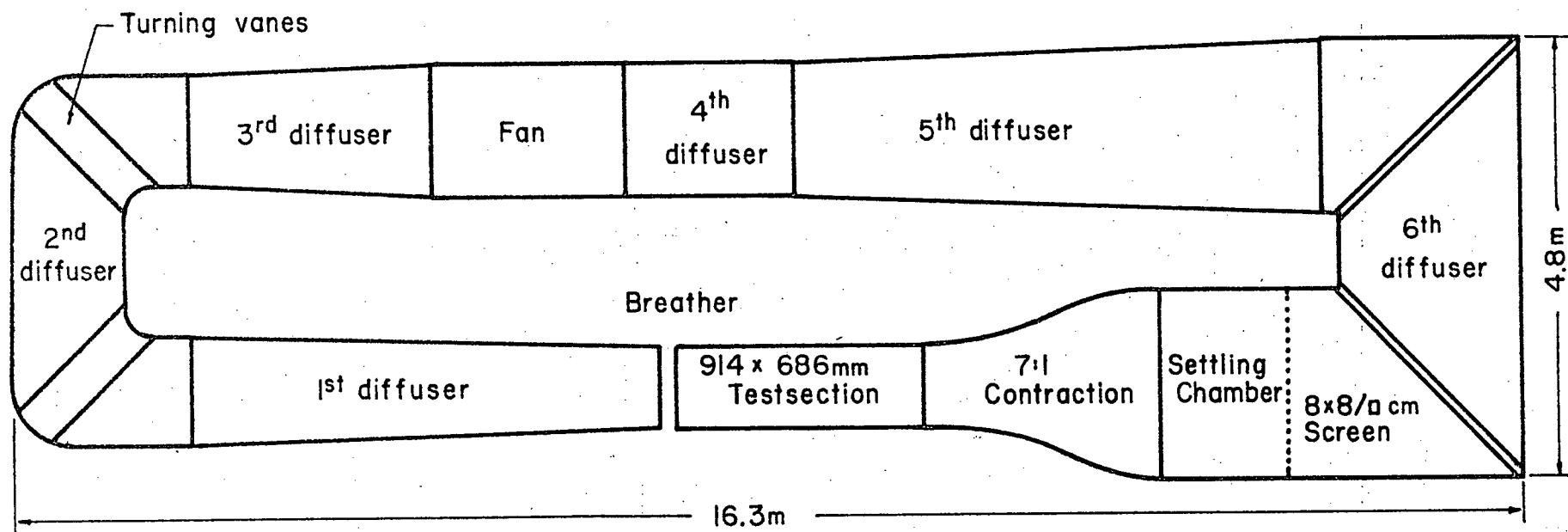


Figure 6.1 U.B.C. Mechanical Engineering low-speed closed-circuit windtunnel

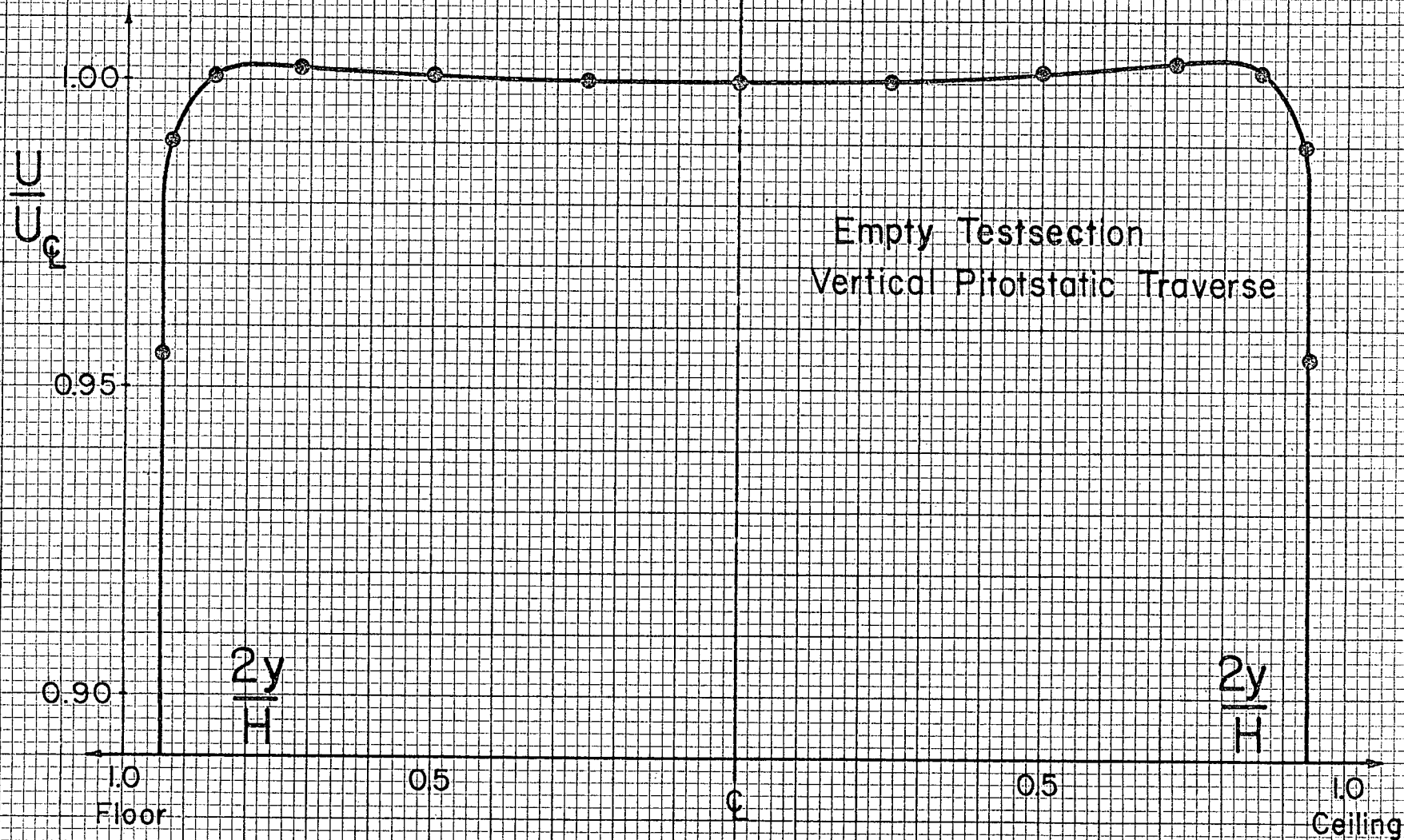


Figure 6.2 Variation of mean windspeed in two-dimensional testsection
insert on vertical pitotstatic traverse

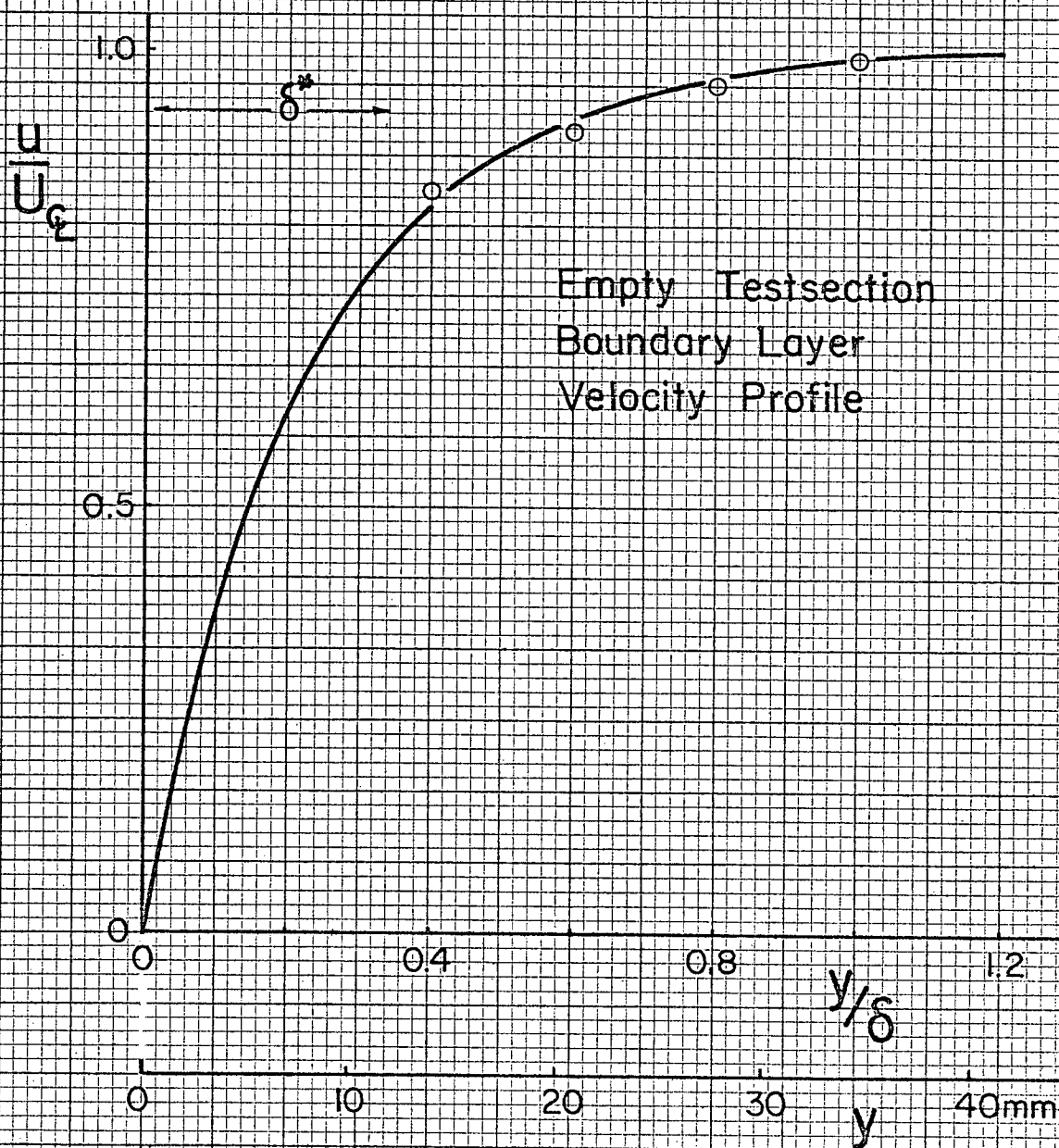


Figure 6.3 Velocity profile in floor boundary layer in two-dimensional testsection insert

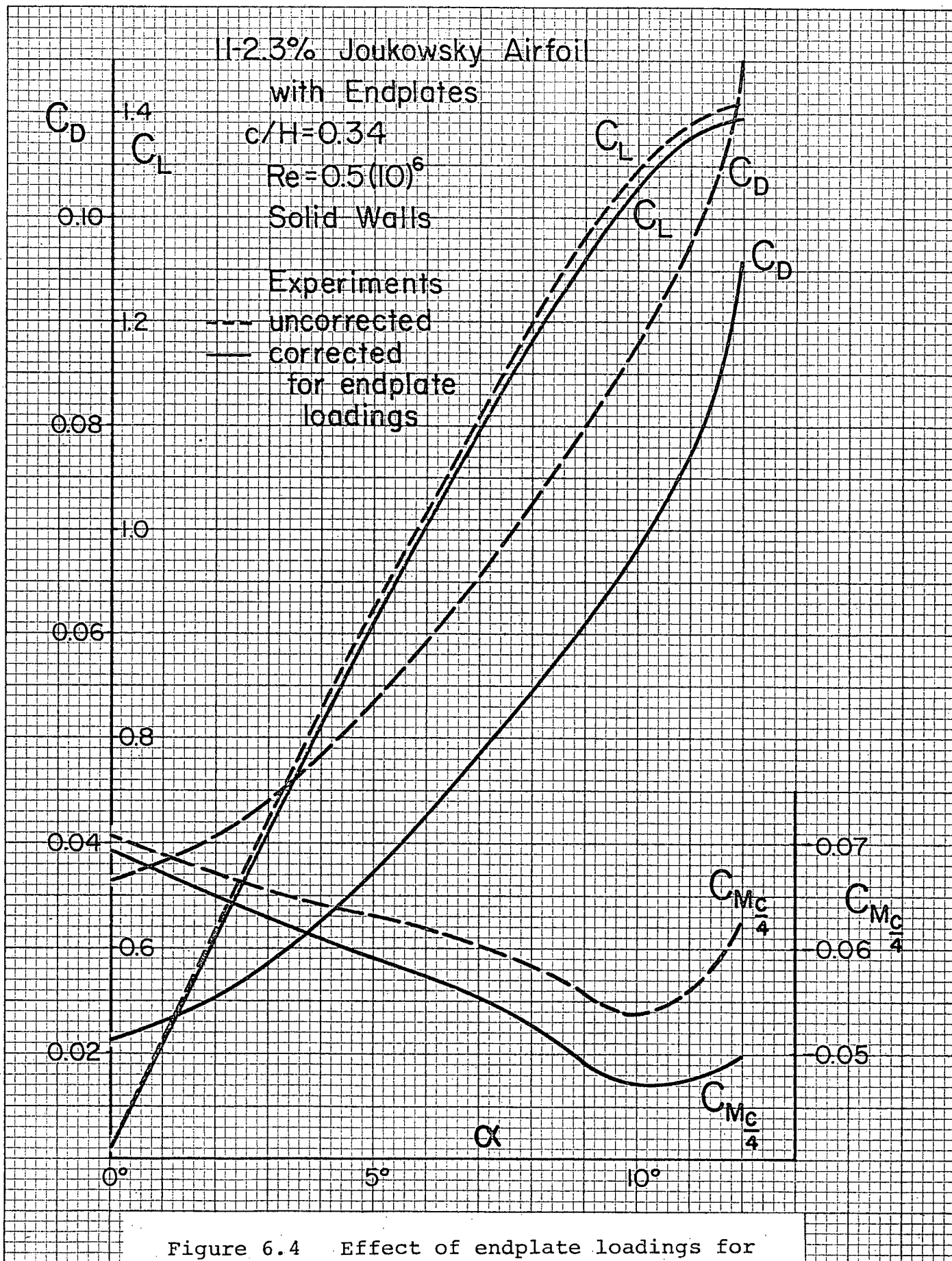


Figure 6.4 Effect of endplate loadings for two-dimensional airfoil tests

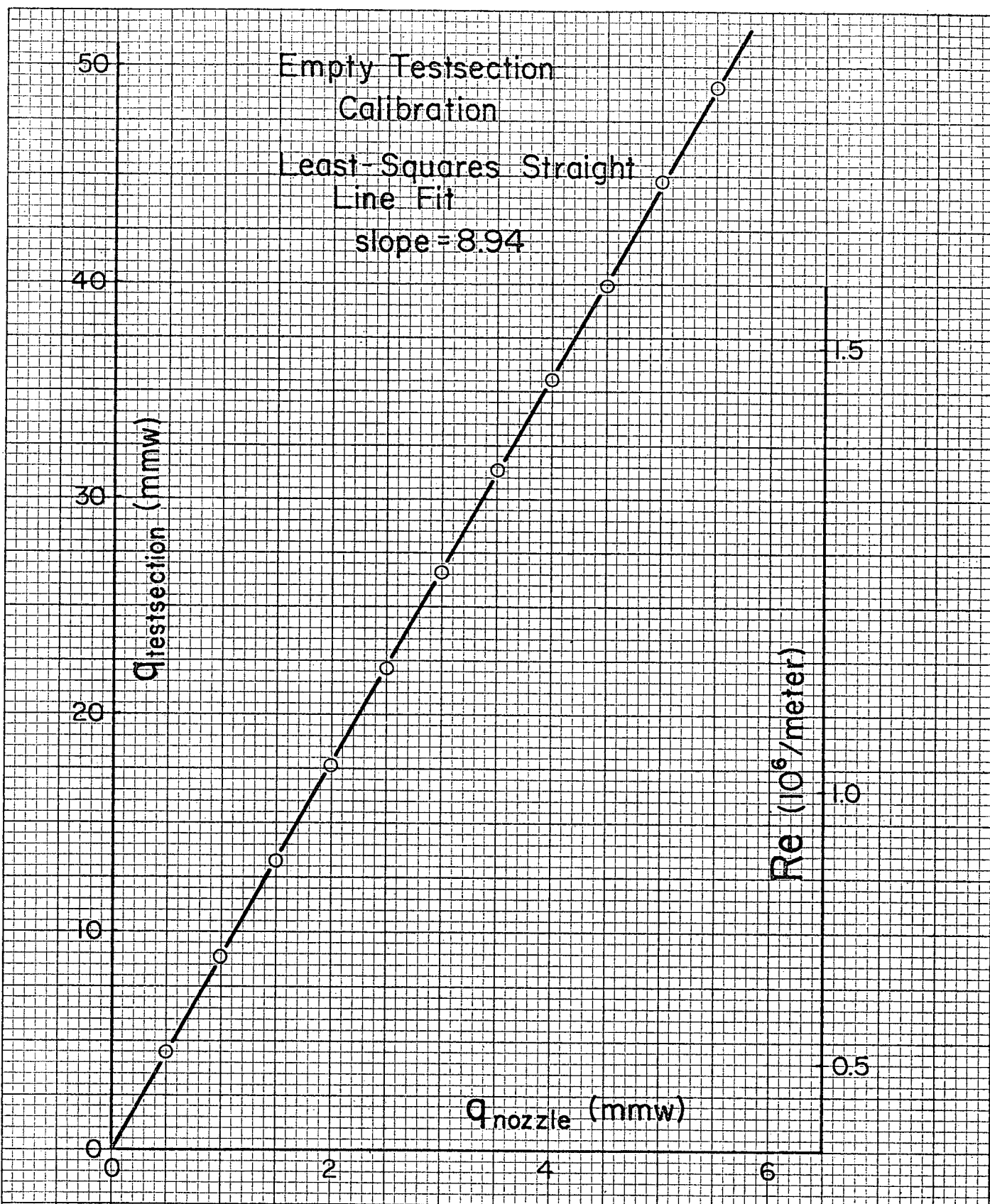


Figure 6.5 Calibration of nozzle and testsection dynamic pressures

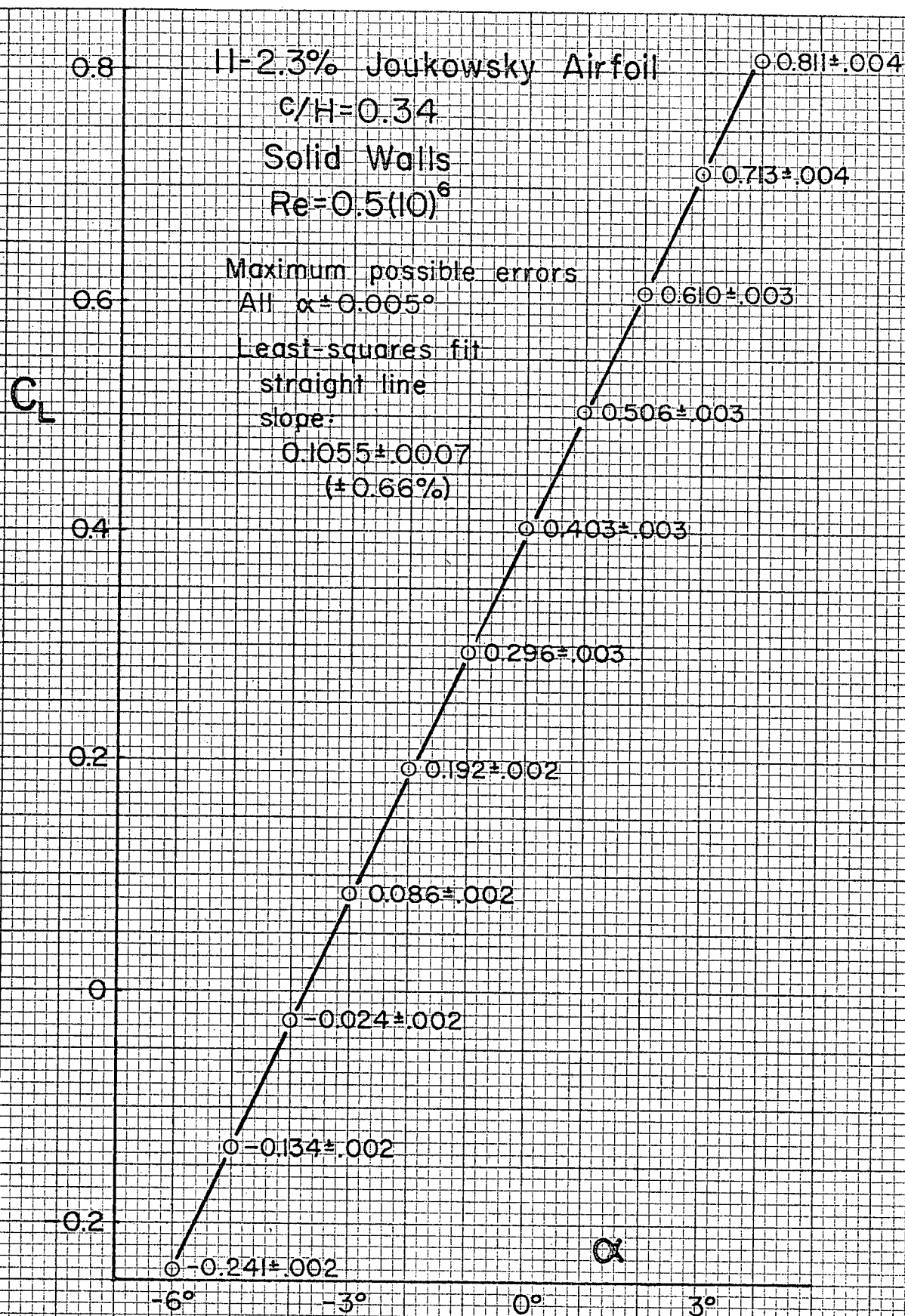


Figure 6.6 Error bars for the measured airfoil lift coefficients

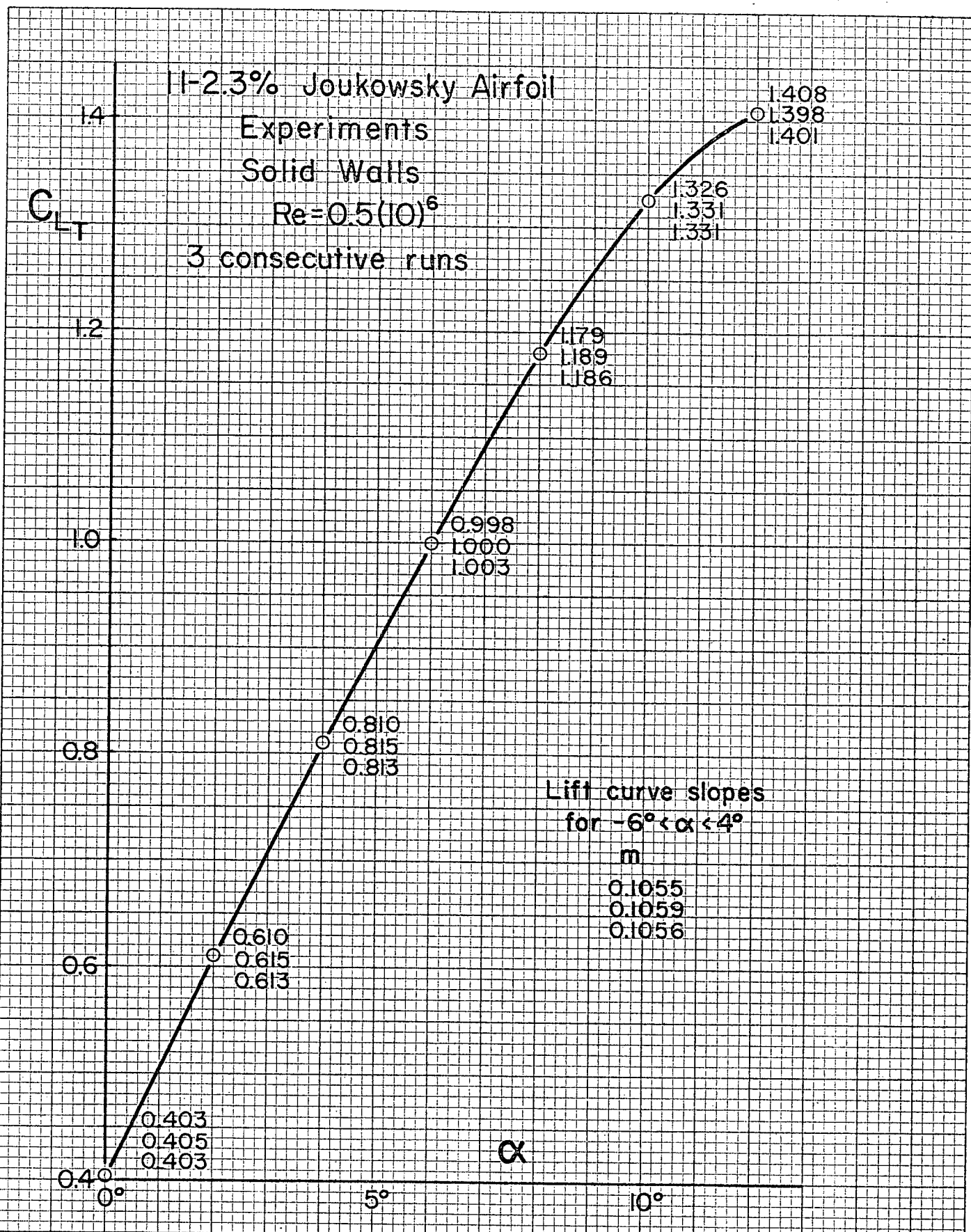


Figure 6.7 Variation of measured airfoil lift coefficients on three consecutive runs

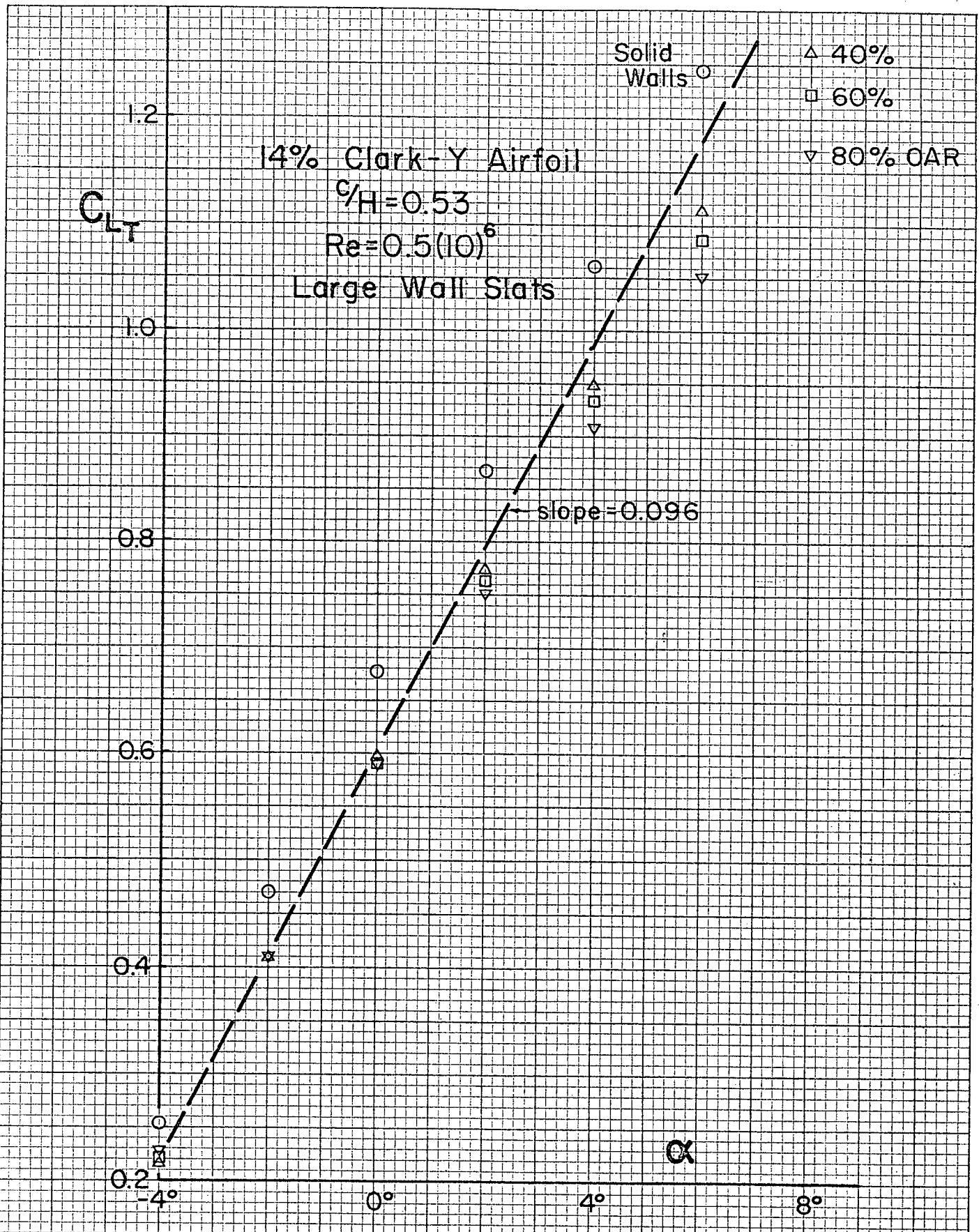


Figure 7.1 Variation of airfoil lift coefficient with slotted-wall open-area ratio: Experiment

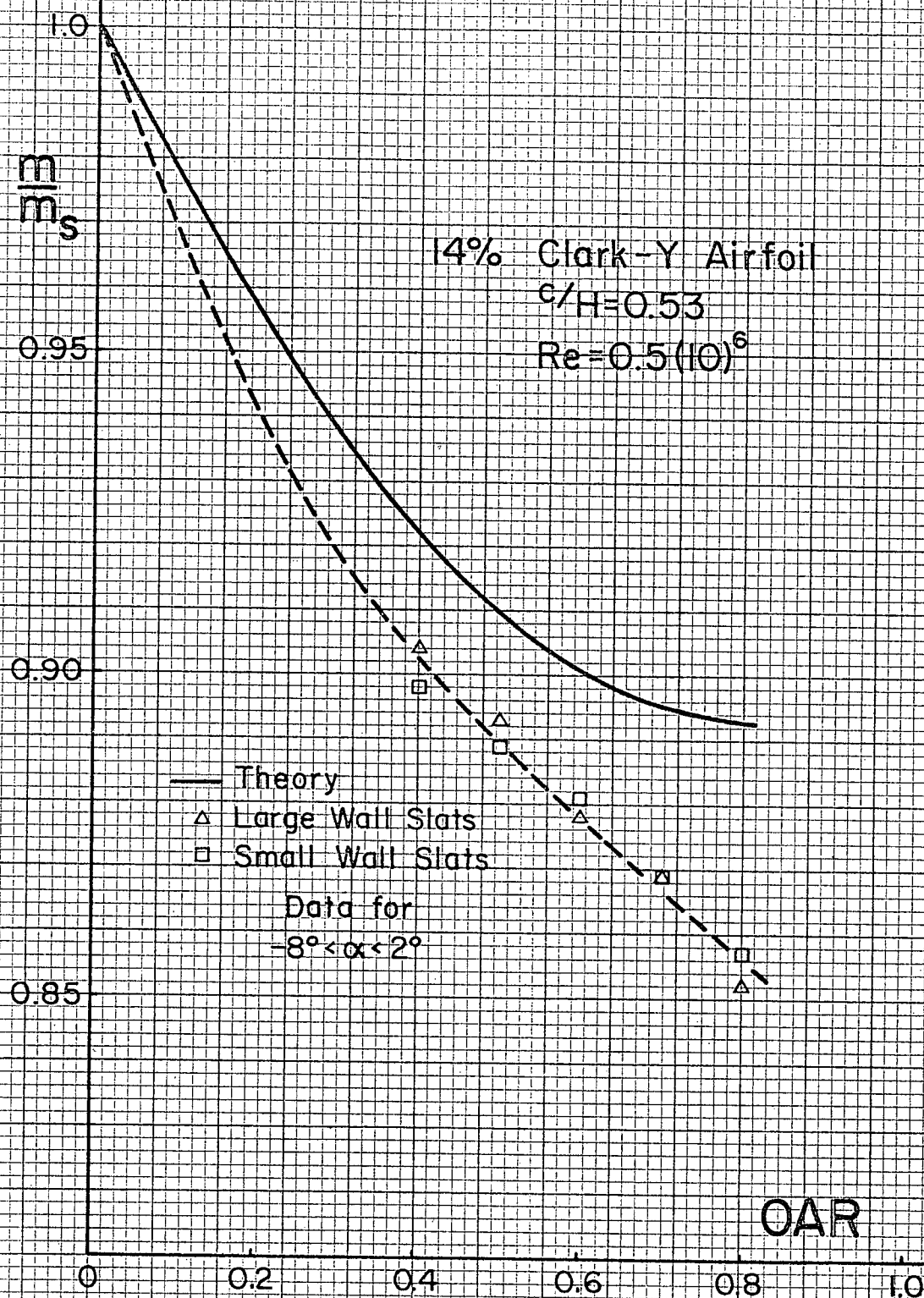


Figure 7.2 Effect of slotted-wall open-area ratio on ratio of lift-curve slopes for Clark-Y airfoil

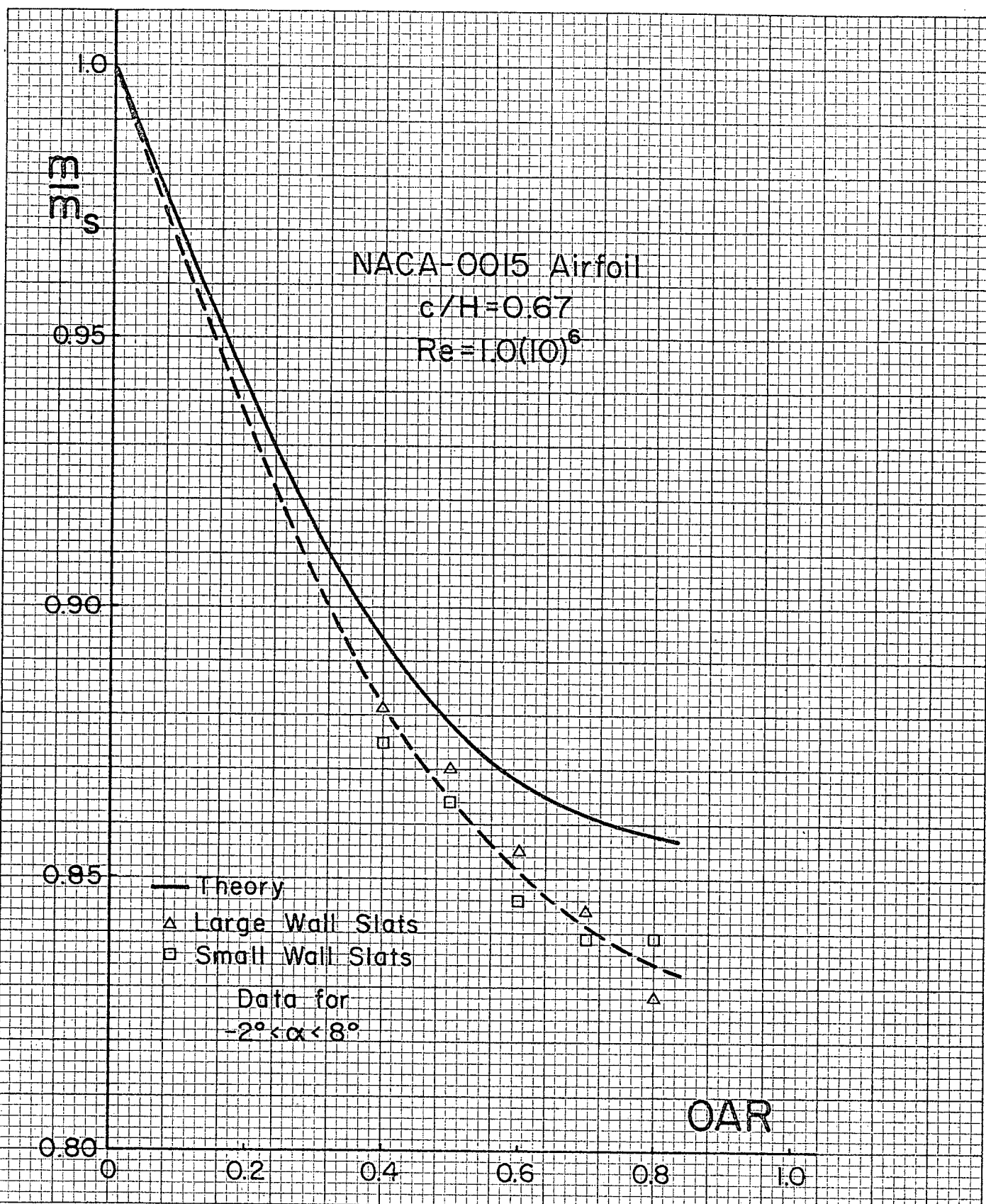


Figure 7.3 Effect of slotted-wall open-area ratio on ratio of lift-curve slopes for NACA-0015 airfoil

NACA-0015 Airfoil

$$Re = 1.0(10)^6$$

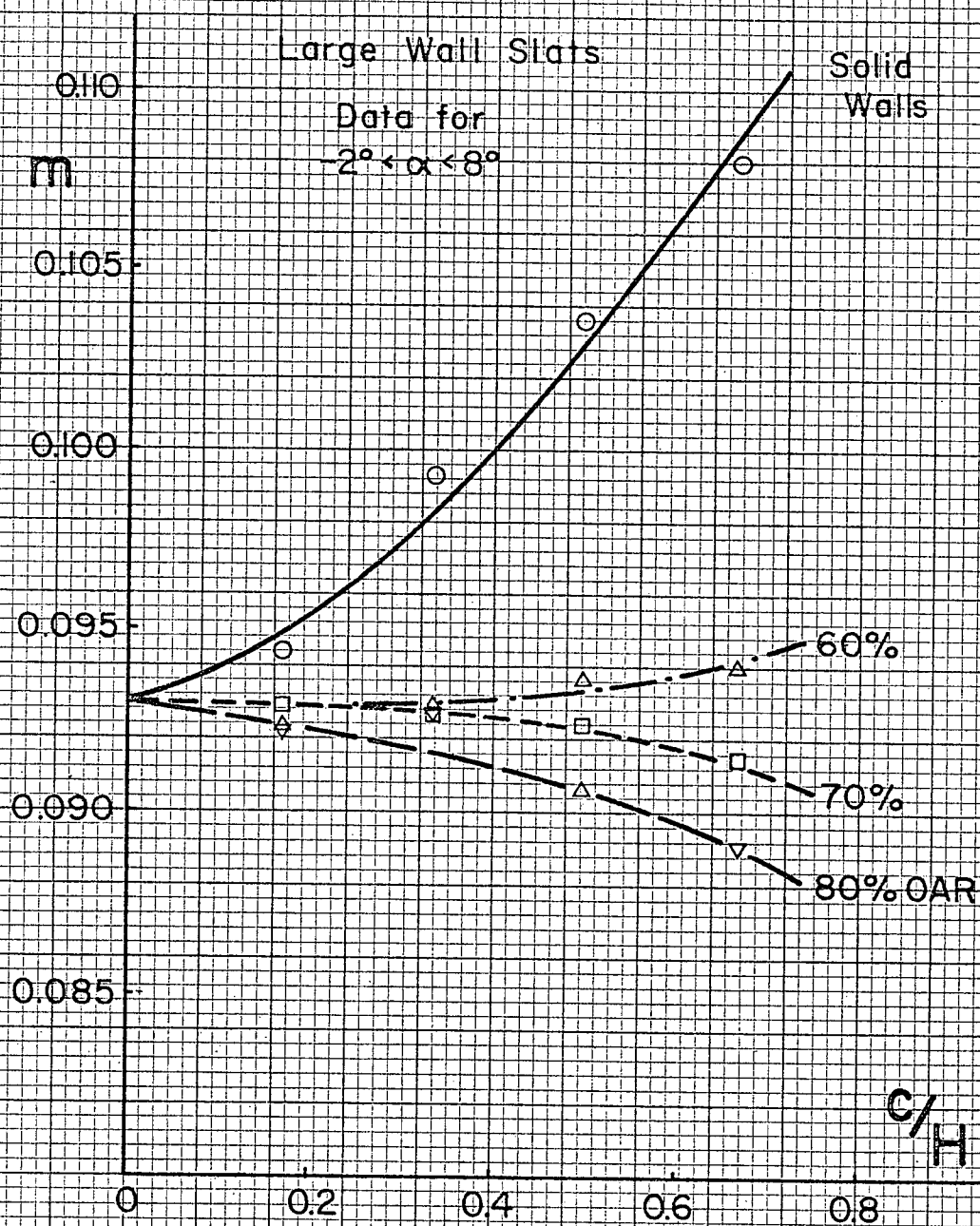


Figure 7.4 Effect of airfoil size on lift-curve slope for NACA-0015 airfoil: Experiment

14% Clark-Y Airfoil
 $Re = 0.5(10)^6$

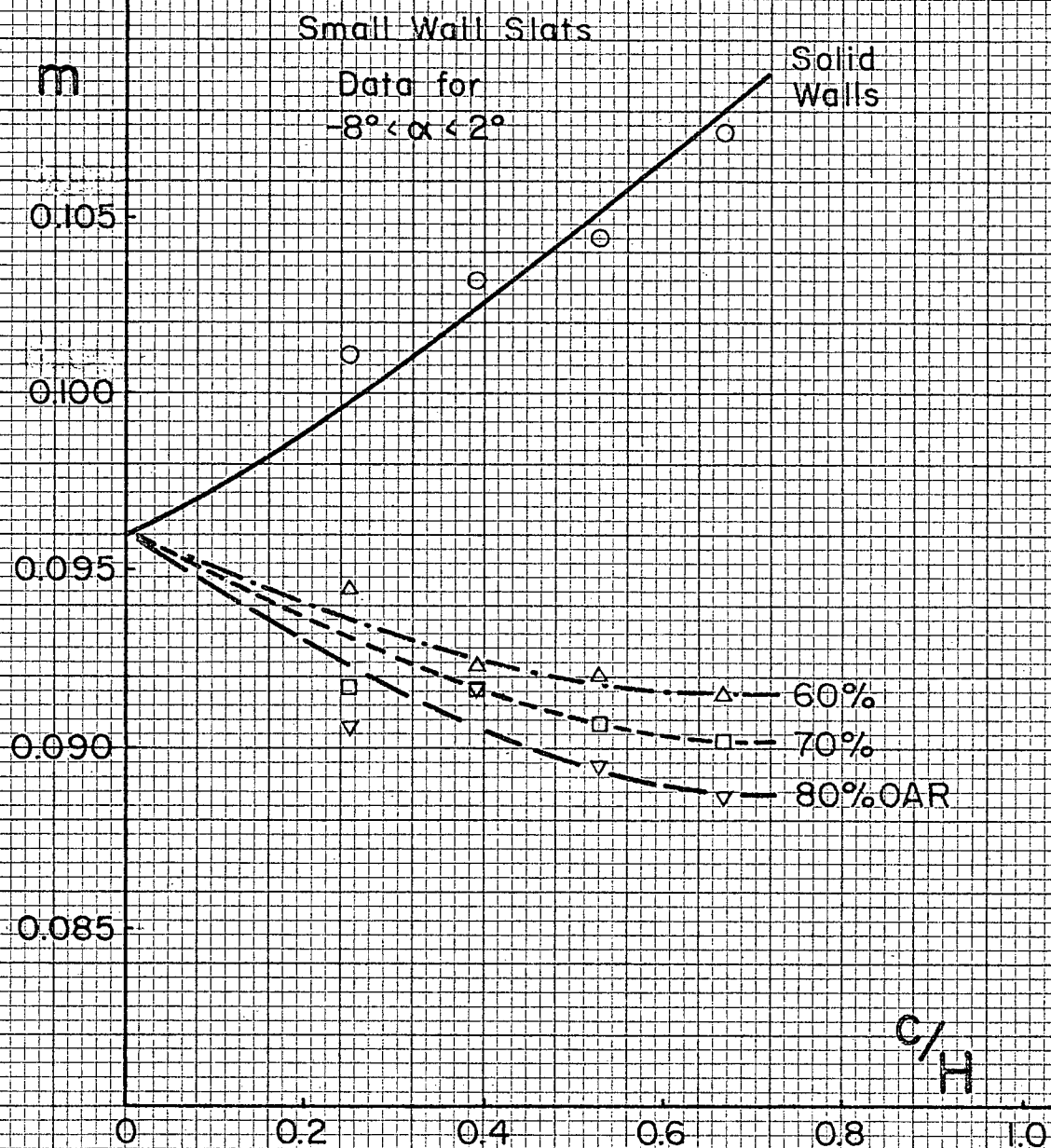


Figure 7.5 Effect of airfoil size on lift-curve slope for Clark-Y airfoil: Experiment

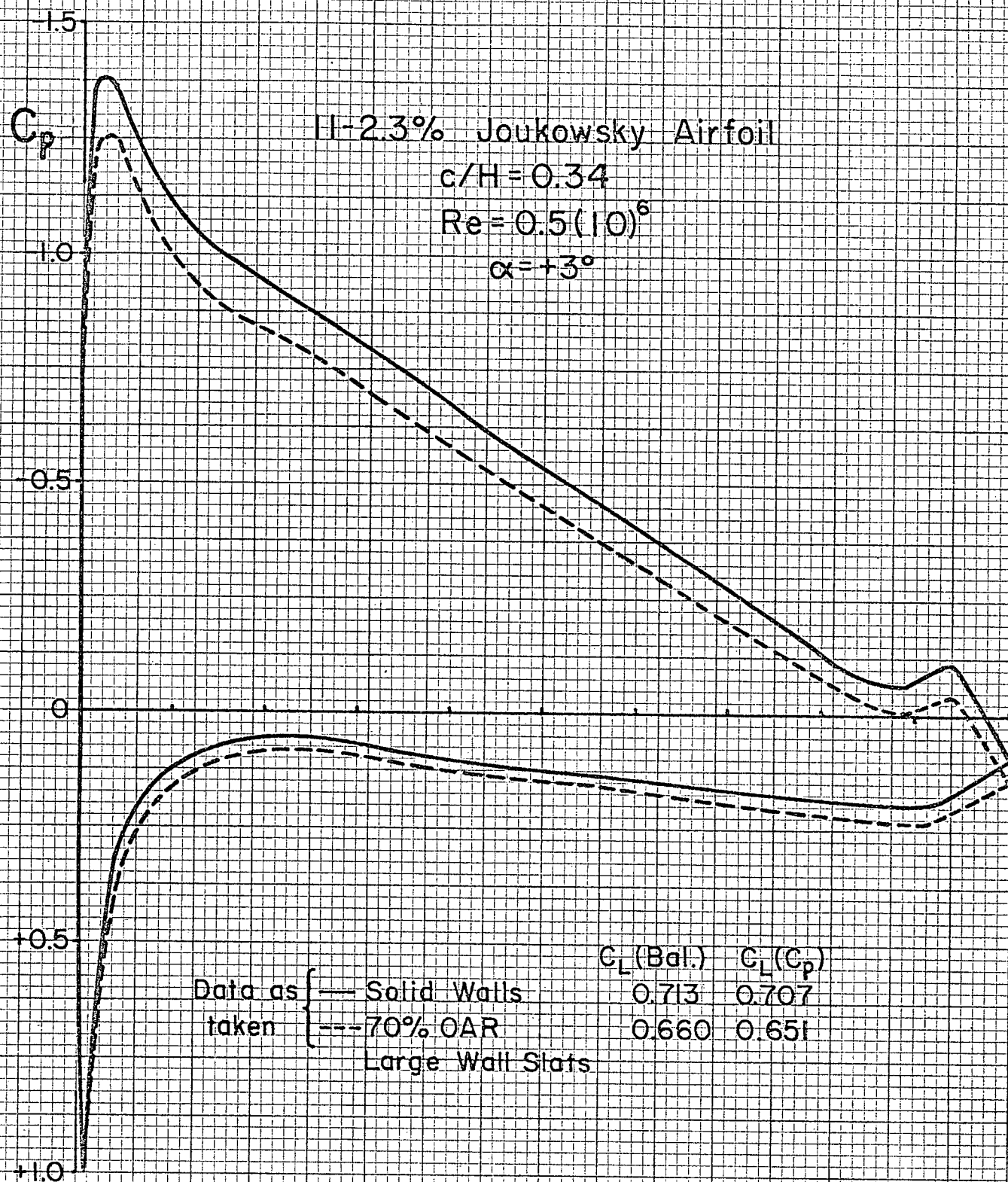
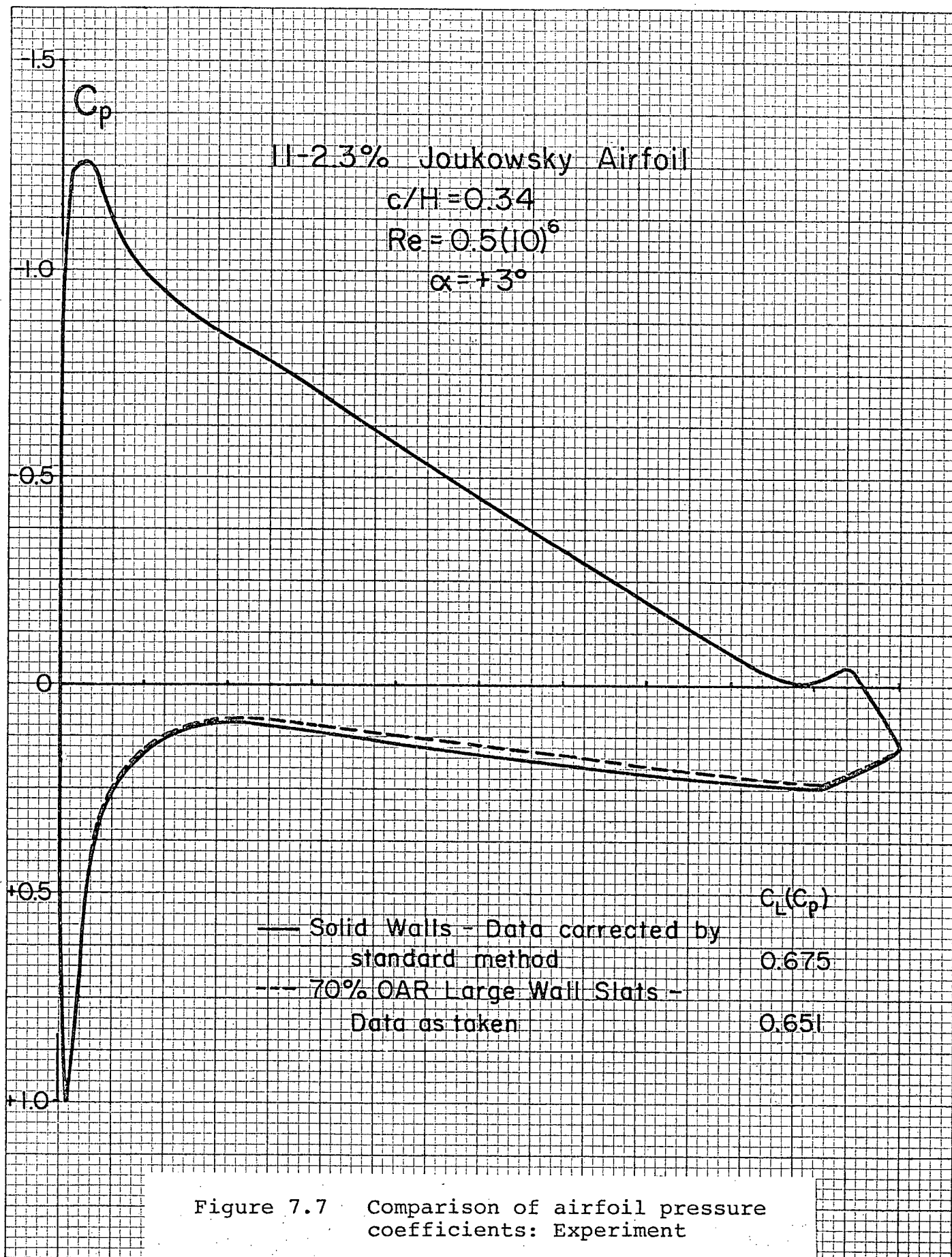


Figure 7.6 Effect of slotted wall on airfoil pressure coefficient: Experiment



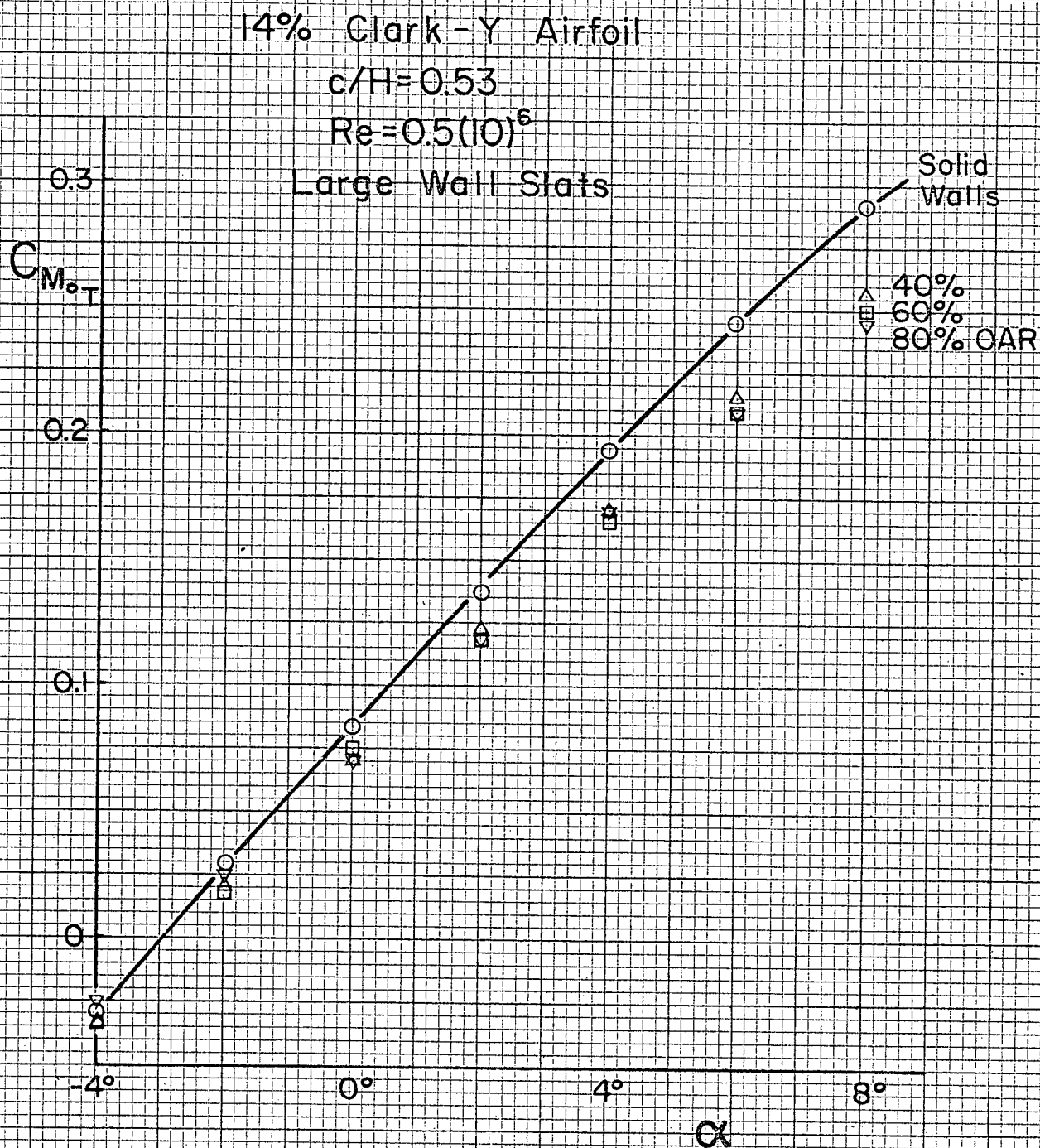


Figure 7.8 Variation of airfoil midchord pitching moment coefficient with slotted-wall open-area ratio: Experiment

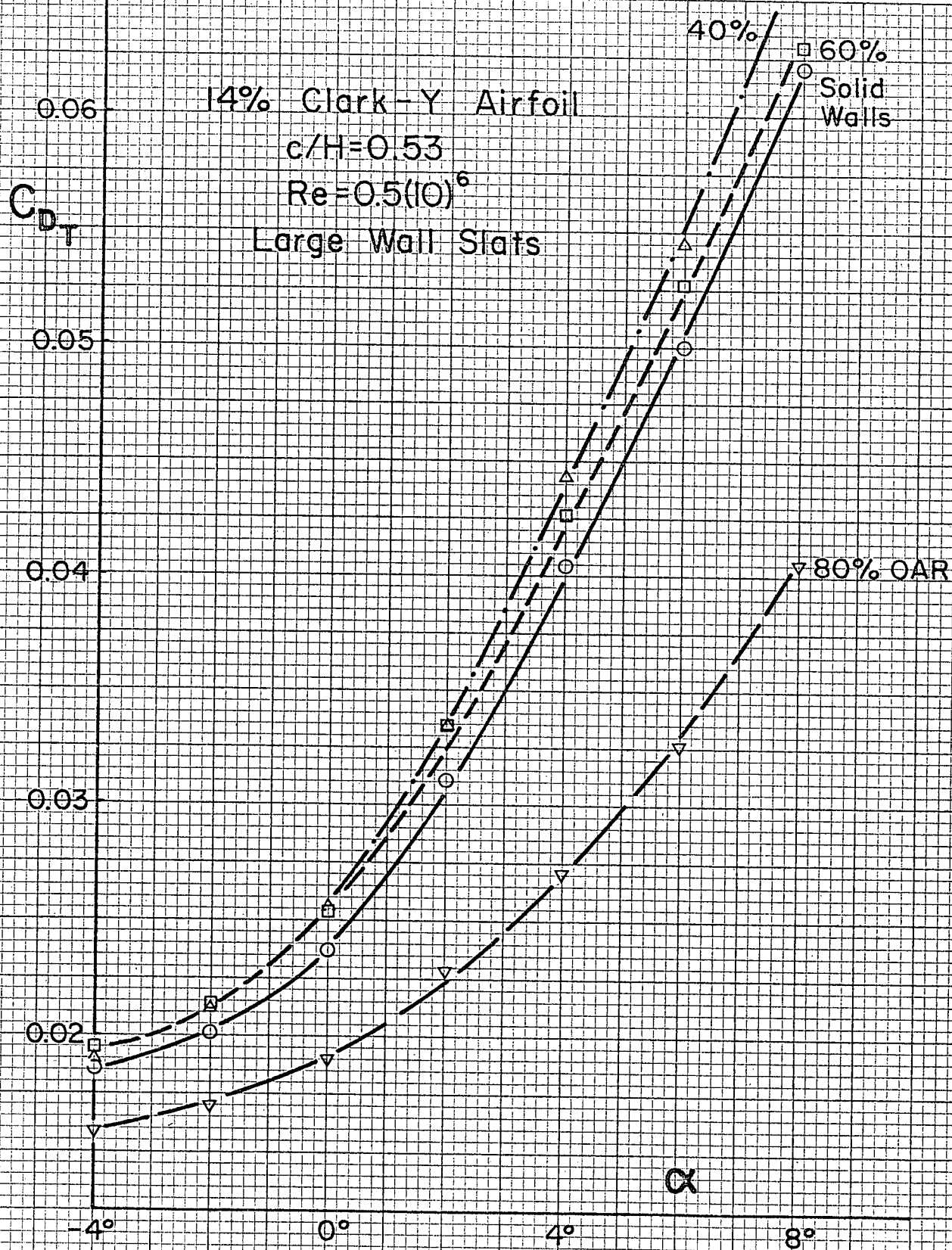
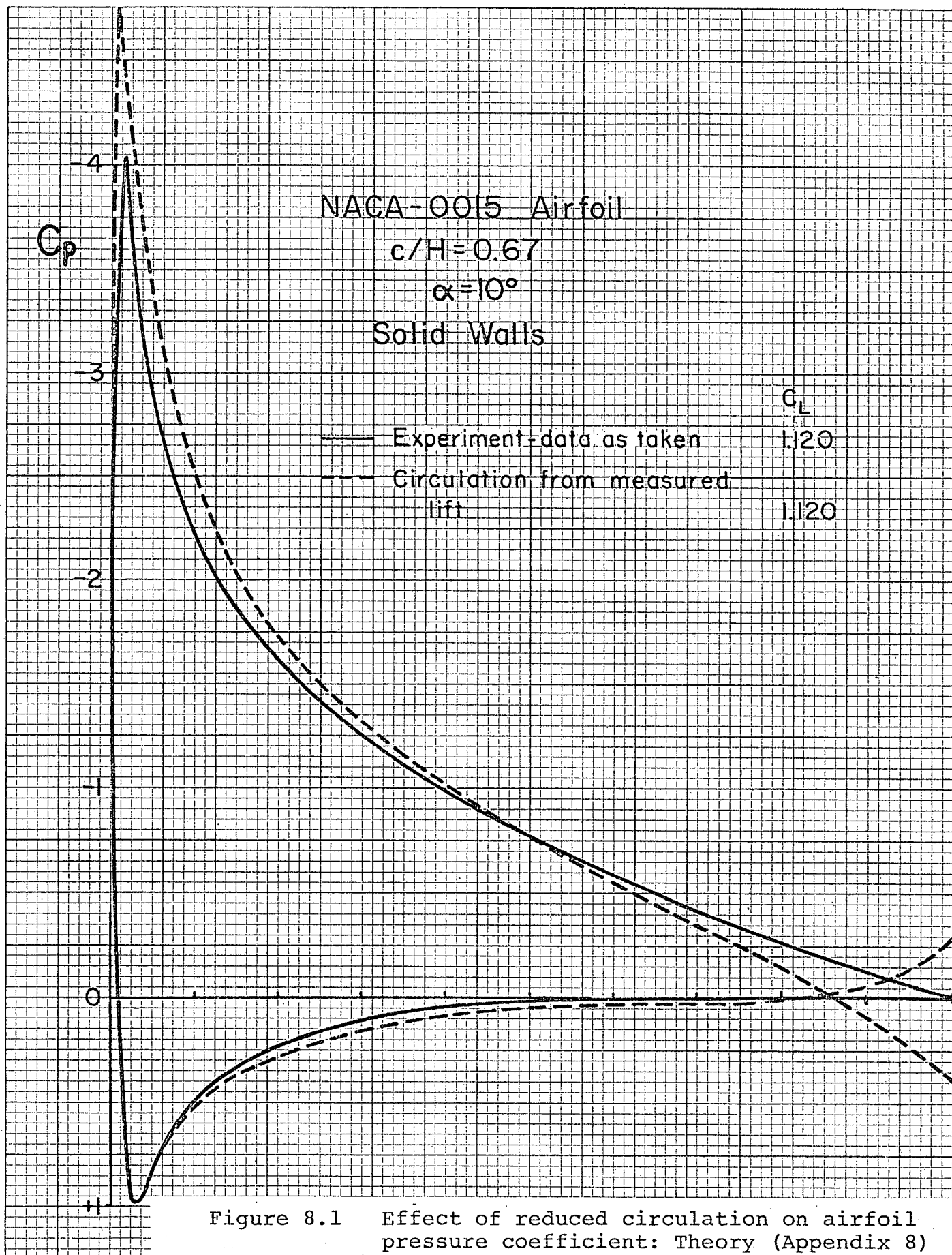


Figure 7.9 Variation of airfoil drag coefficient with slotted-wall open-area ratio: Experiment



NACA-0015 Airfoil

$\alpha = 10^\circ$ $c/H = 0.67$

Solid Walls

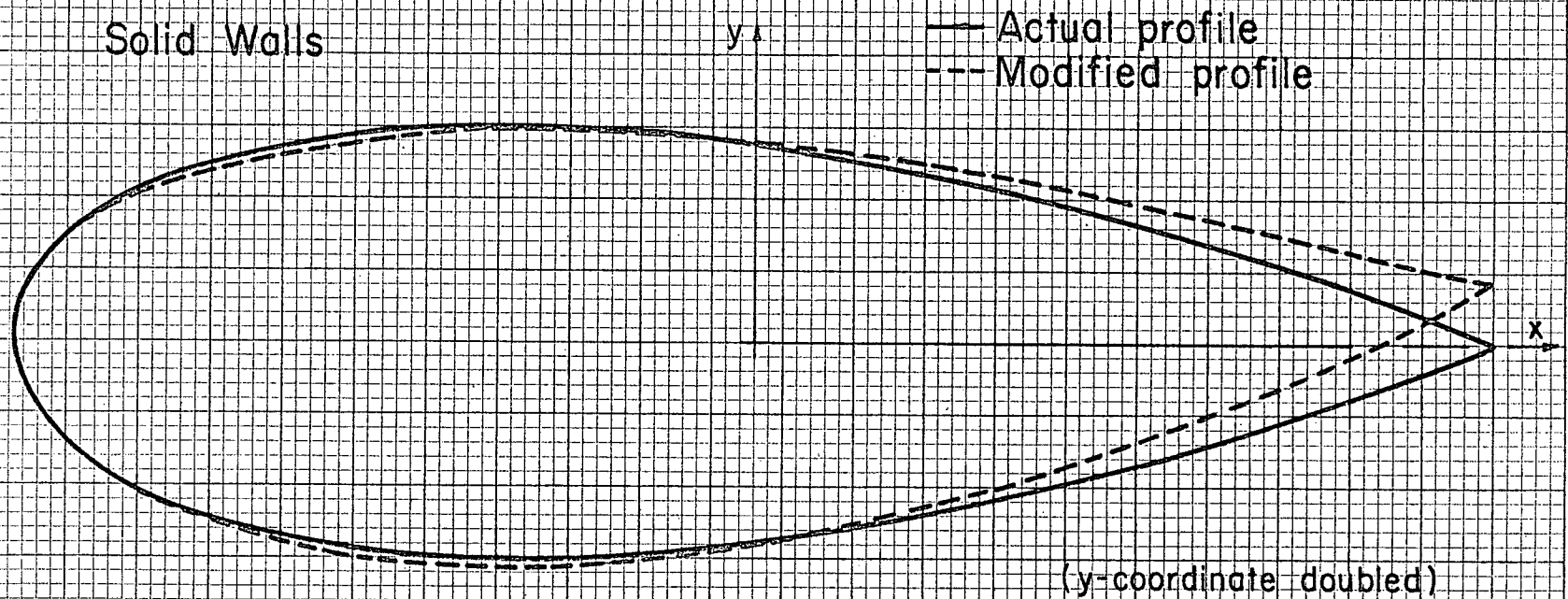
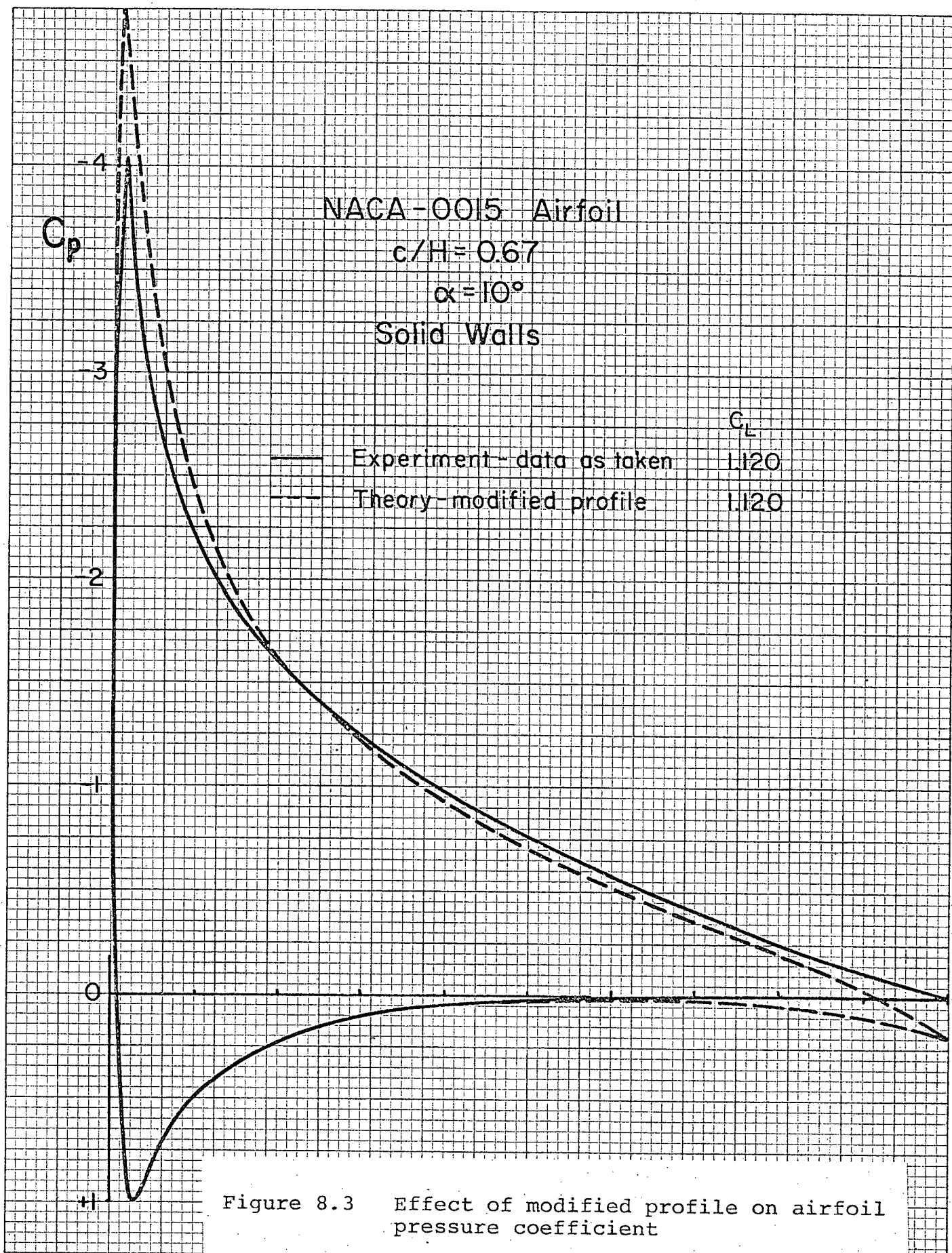
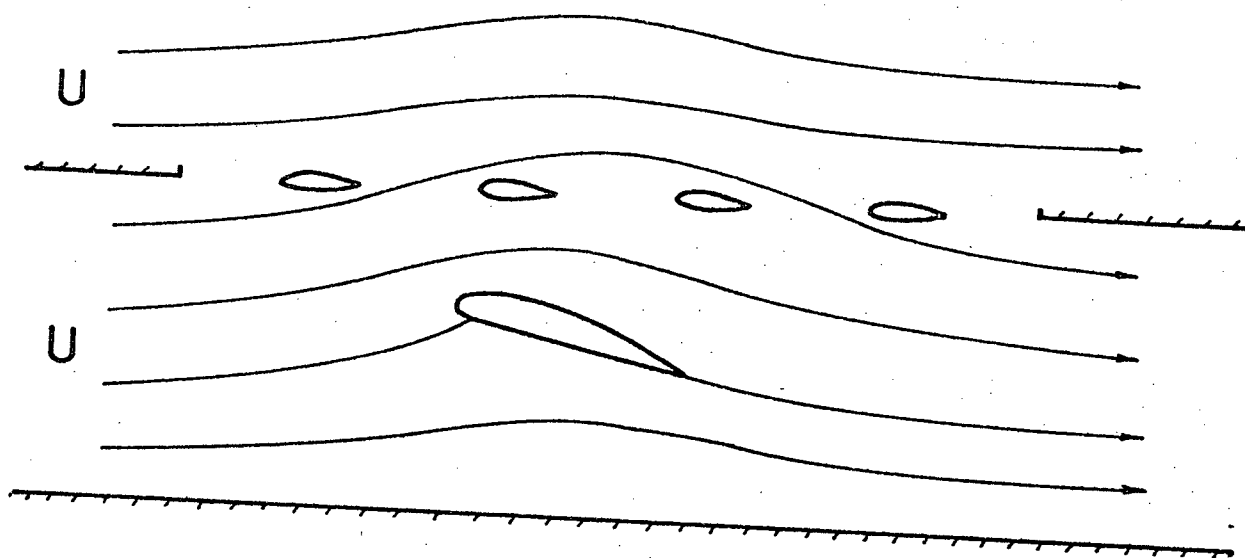
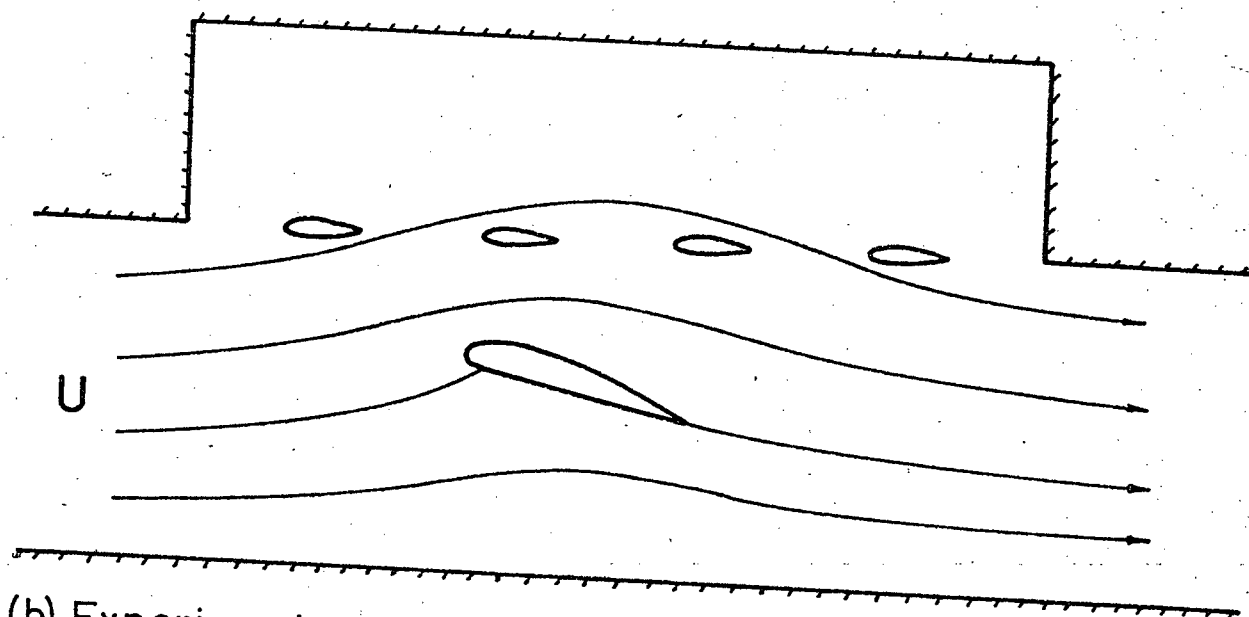


Figure 8.2 Modification of airfoil profile to reduce theoretical circulation to measured value: Theory (Appendix 9)





(a) Theory



(b) Experiment

Figure 8.4 An airfoil between a slotted upper and a solid lower wall with a plenum chamber

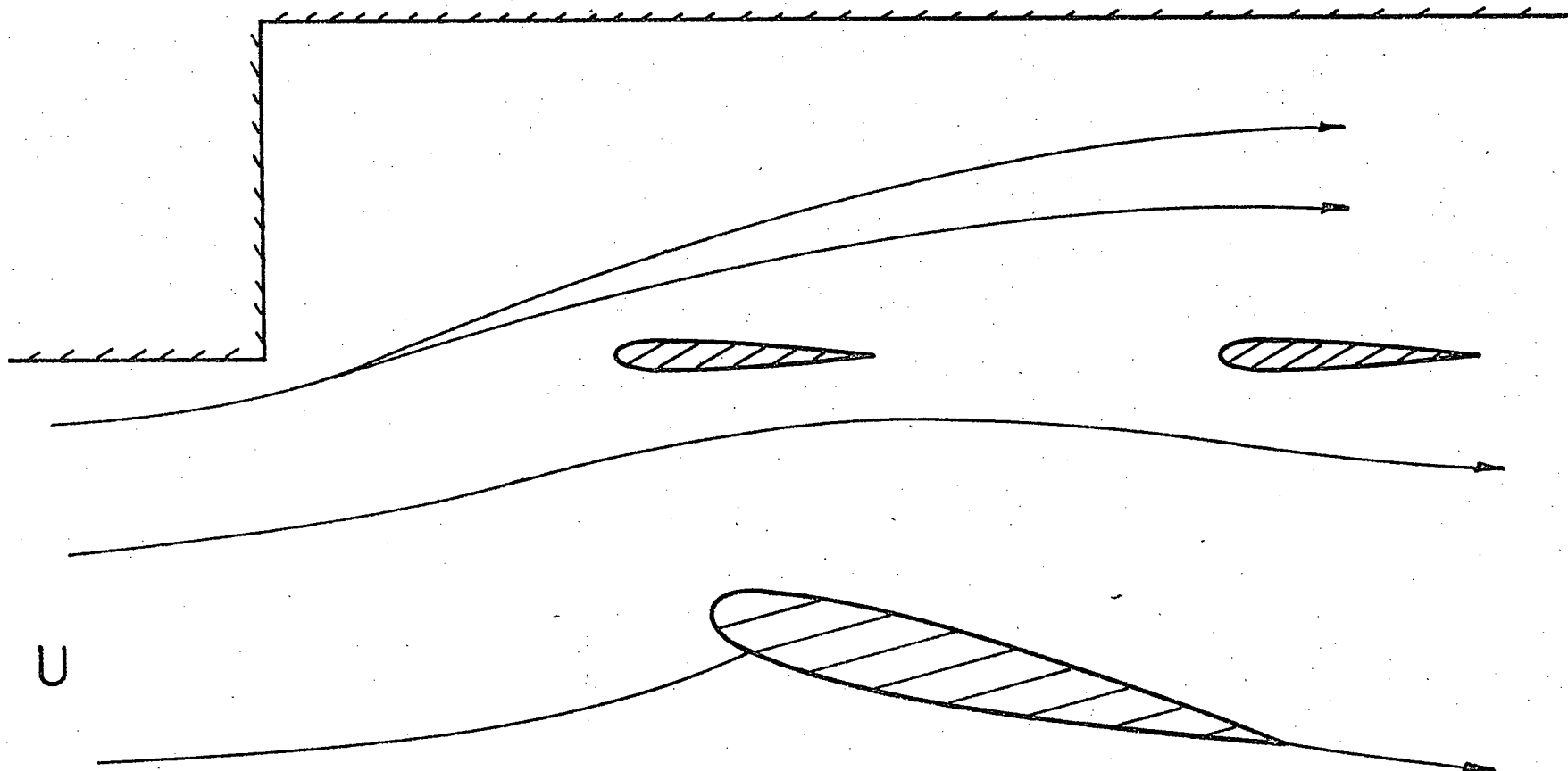


Figure 8.5 The shear layer in the plenum chamber surrounding the slotted wall

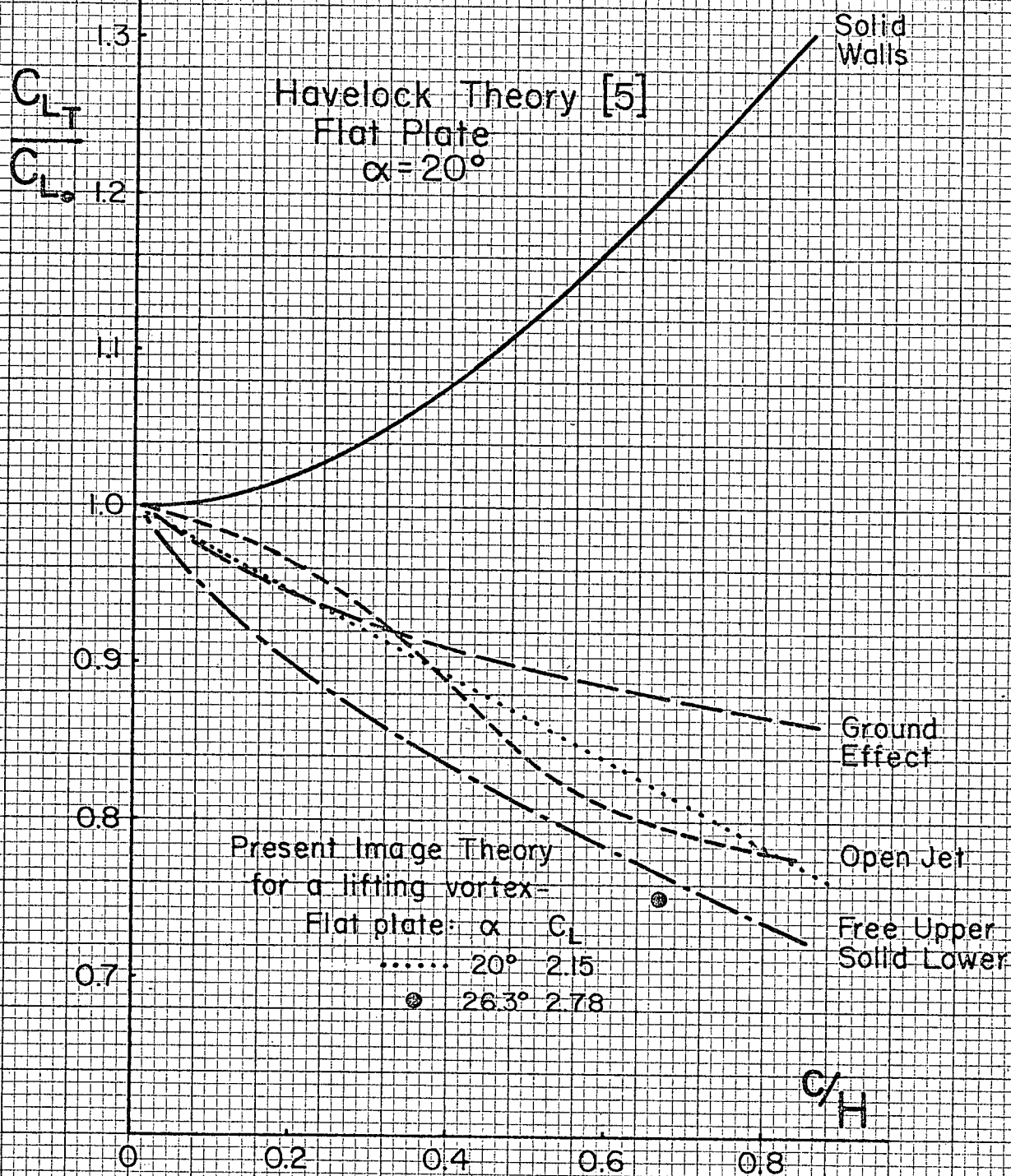


Figure 8.6 Effect of different types of wall boundaries on ratio of lift coefficients: Theory

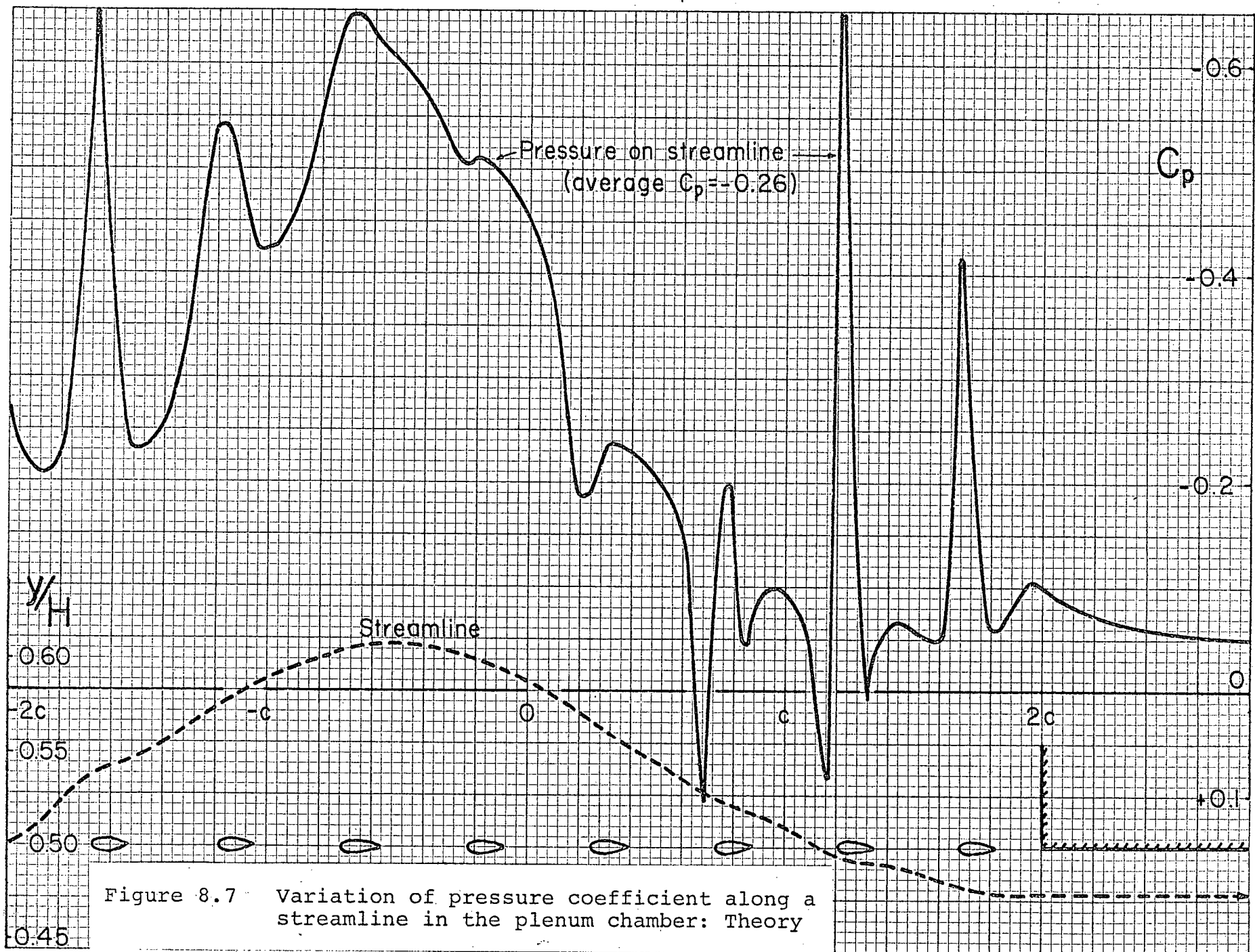


Figure 8.7 Variation of pressure coefficient along a streamline in the plenum chamber: Theory

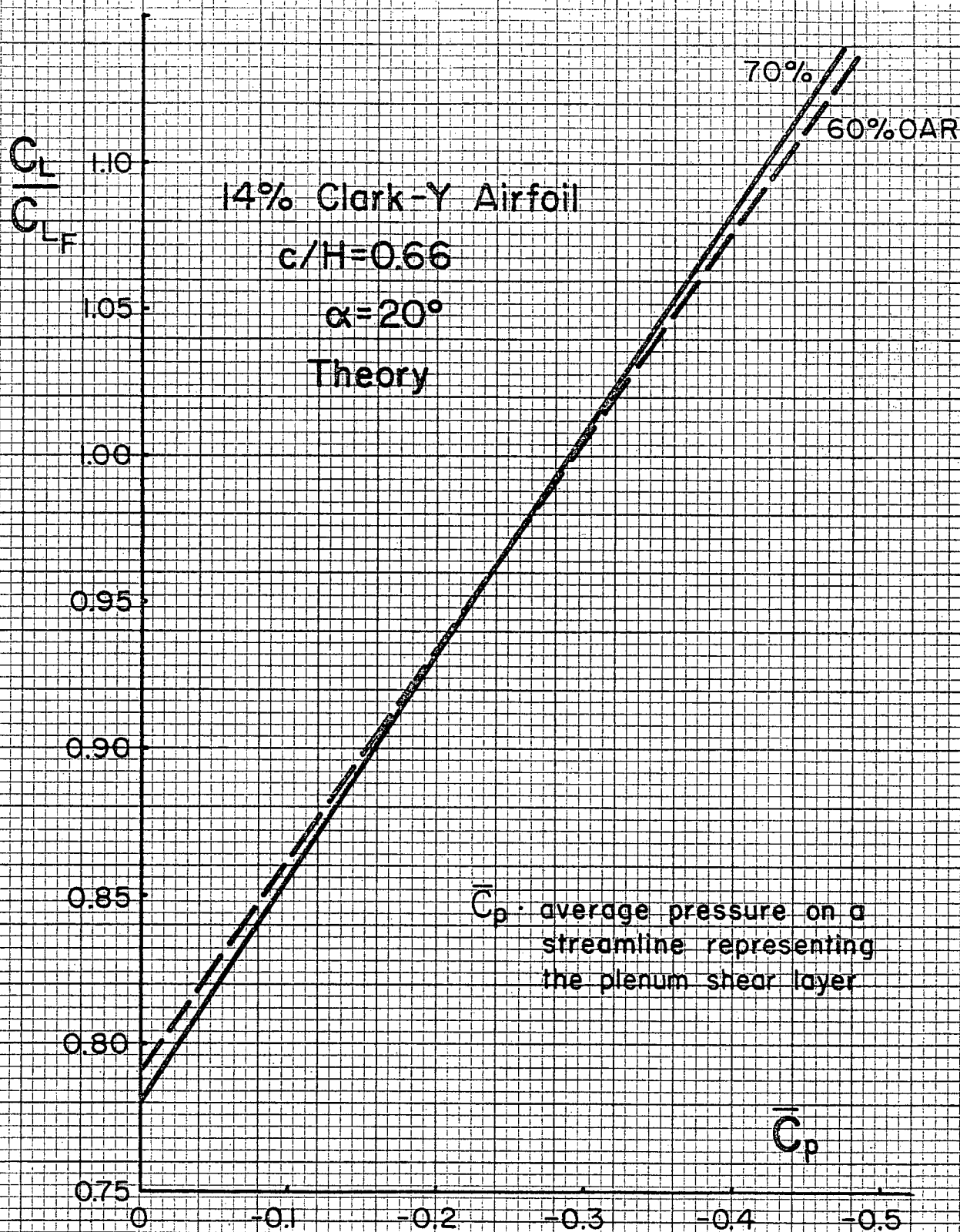


Figure 8.8 Effect on airfoil lift coefficients of assumed pressure coefficients on a streamline representing the plenum shear layer: Theory

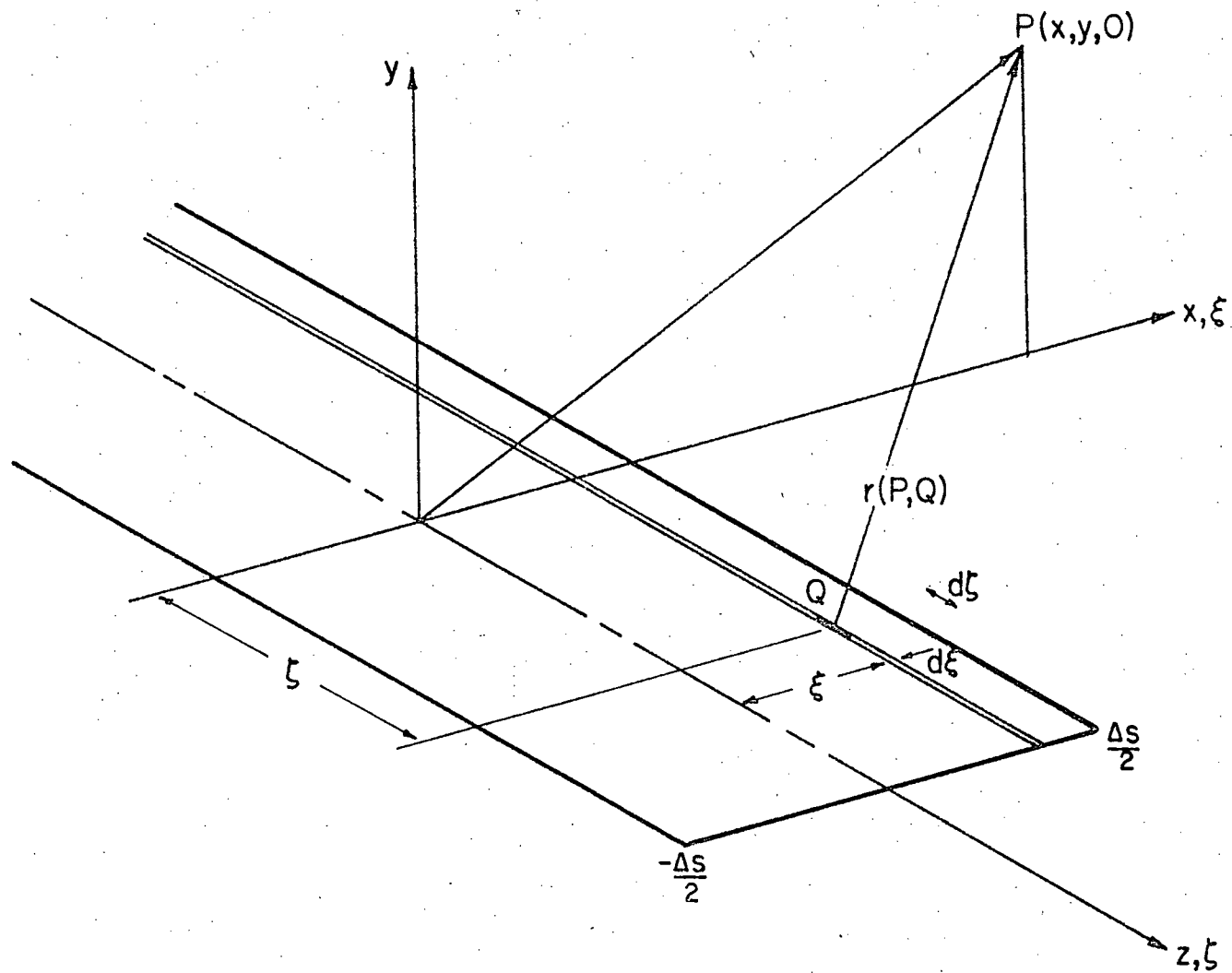
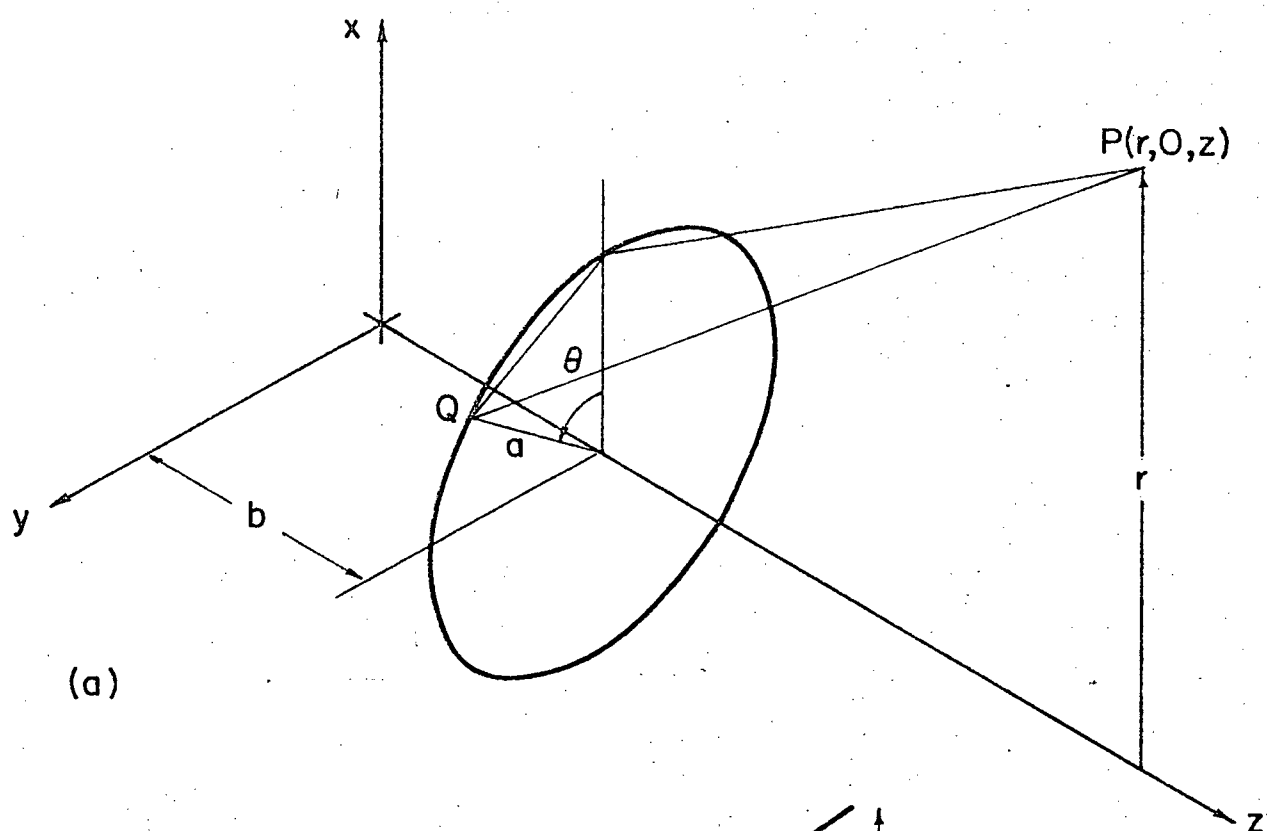
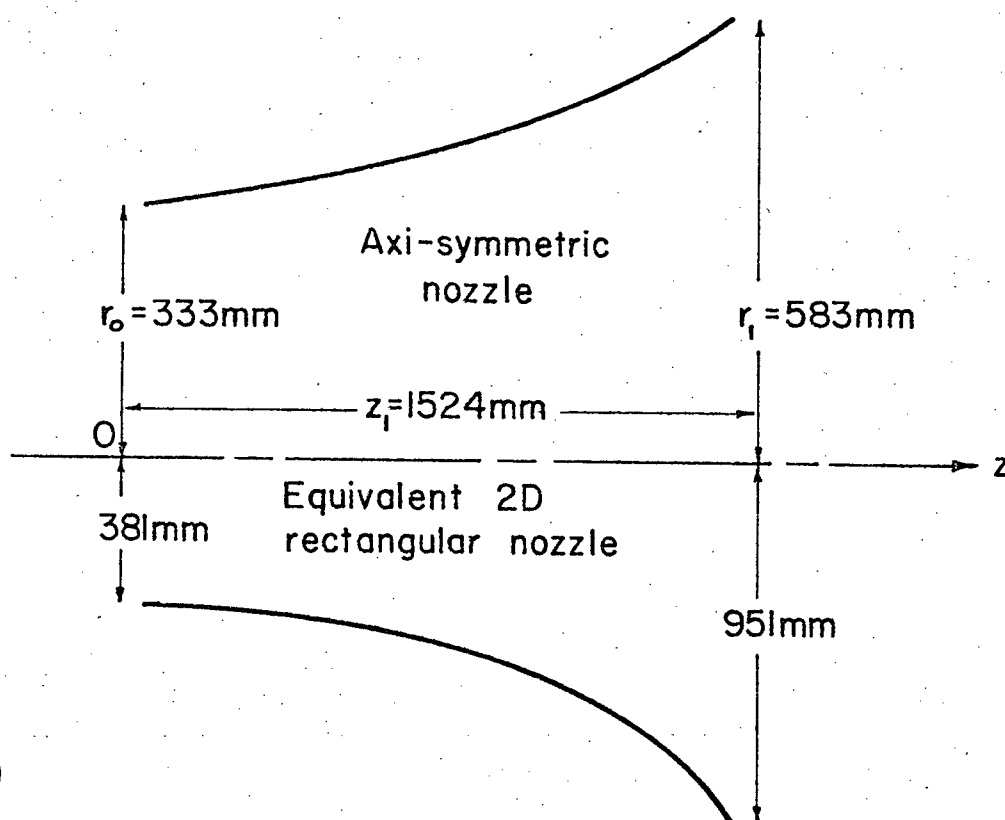


Figure A1.1 Geometry for integration of a point source



(a)



(b)

Figure A5.1 The two-dimensional nozzle insert

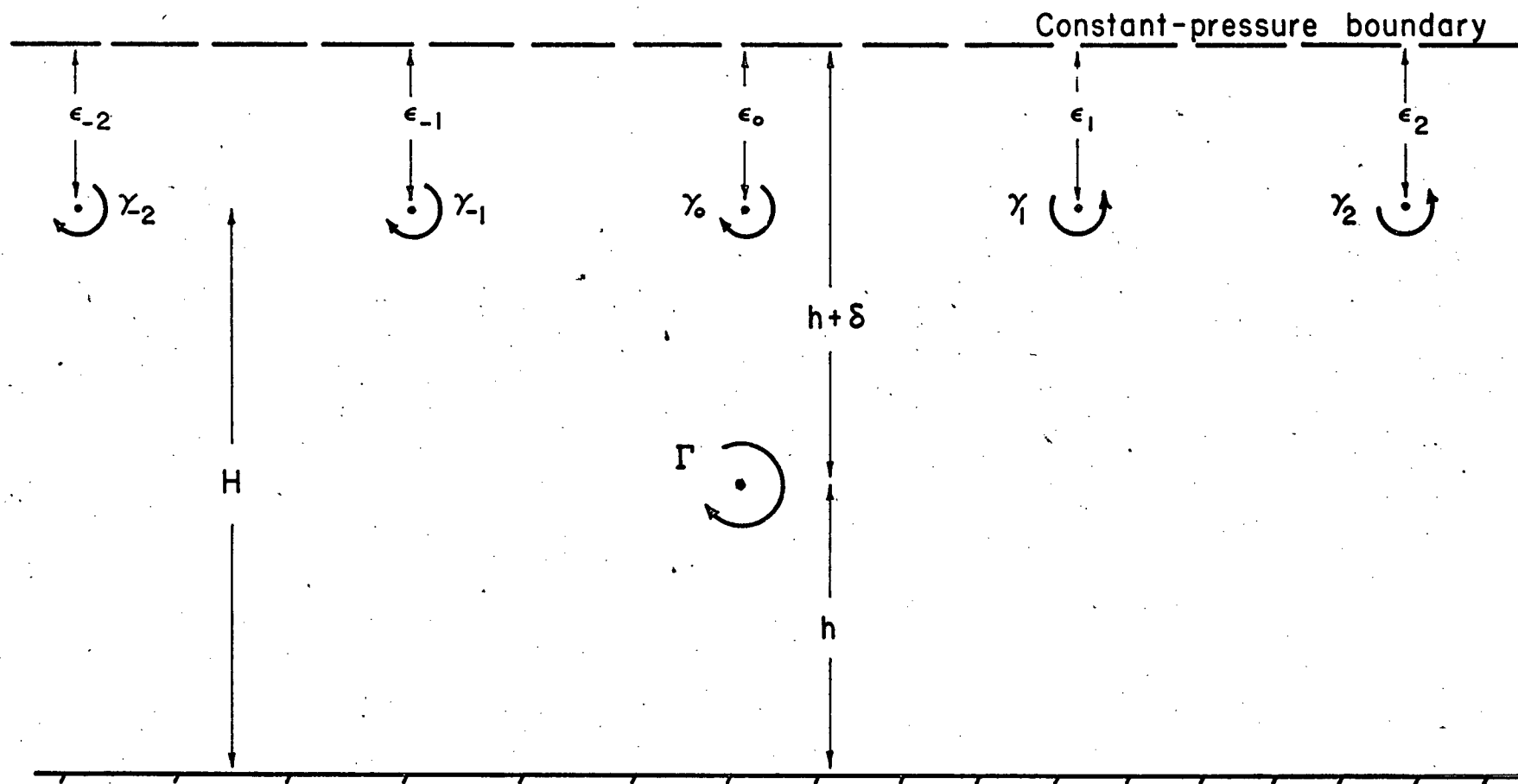


Figure A6.1 A lifting vortex between a solid, a slotted, and a constant pressure boundary: Theory

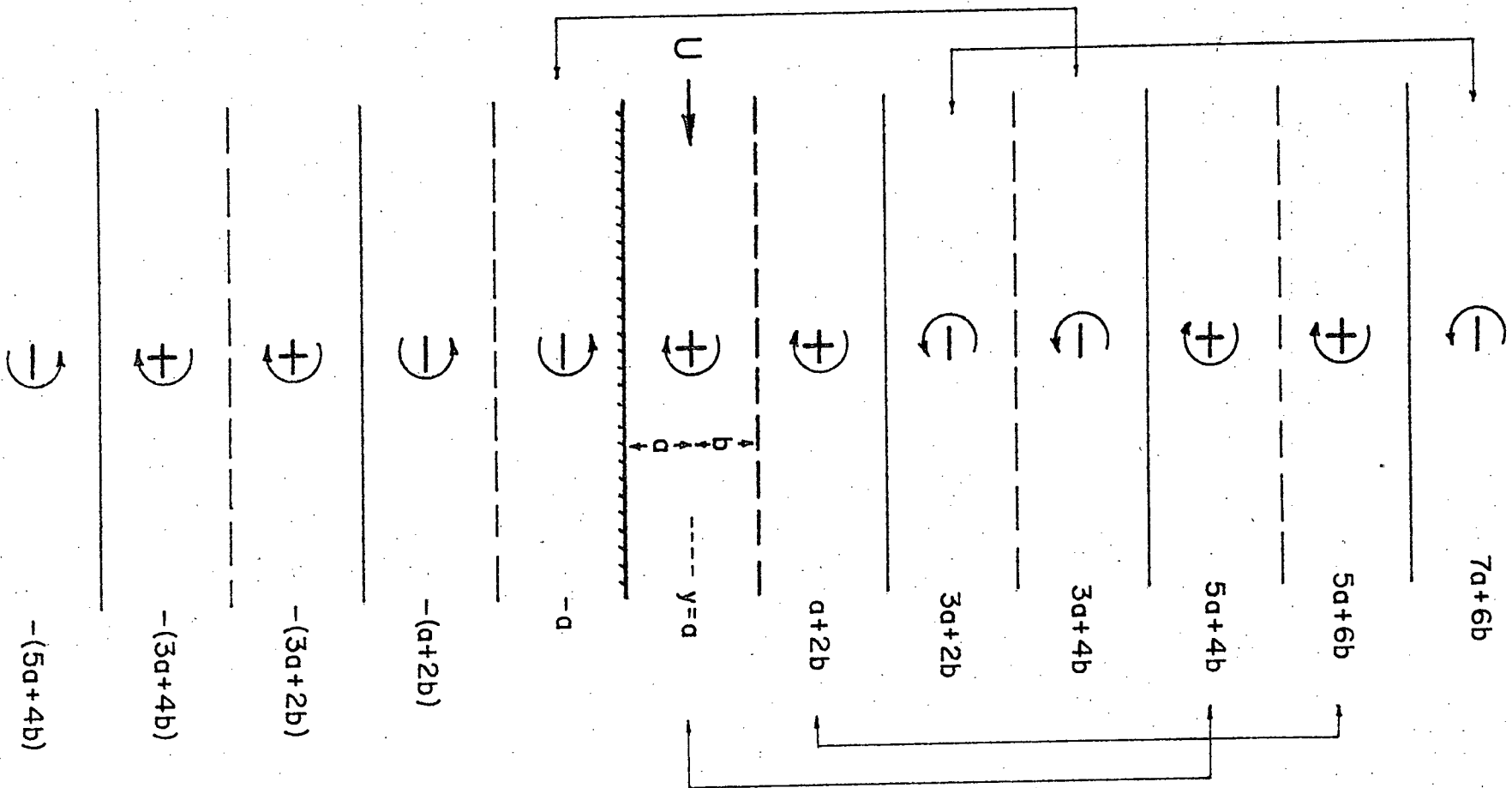


Figure A6.2 The image system for a lifting vortex between a solid and a constant pressure boundary: Theory

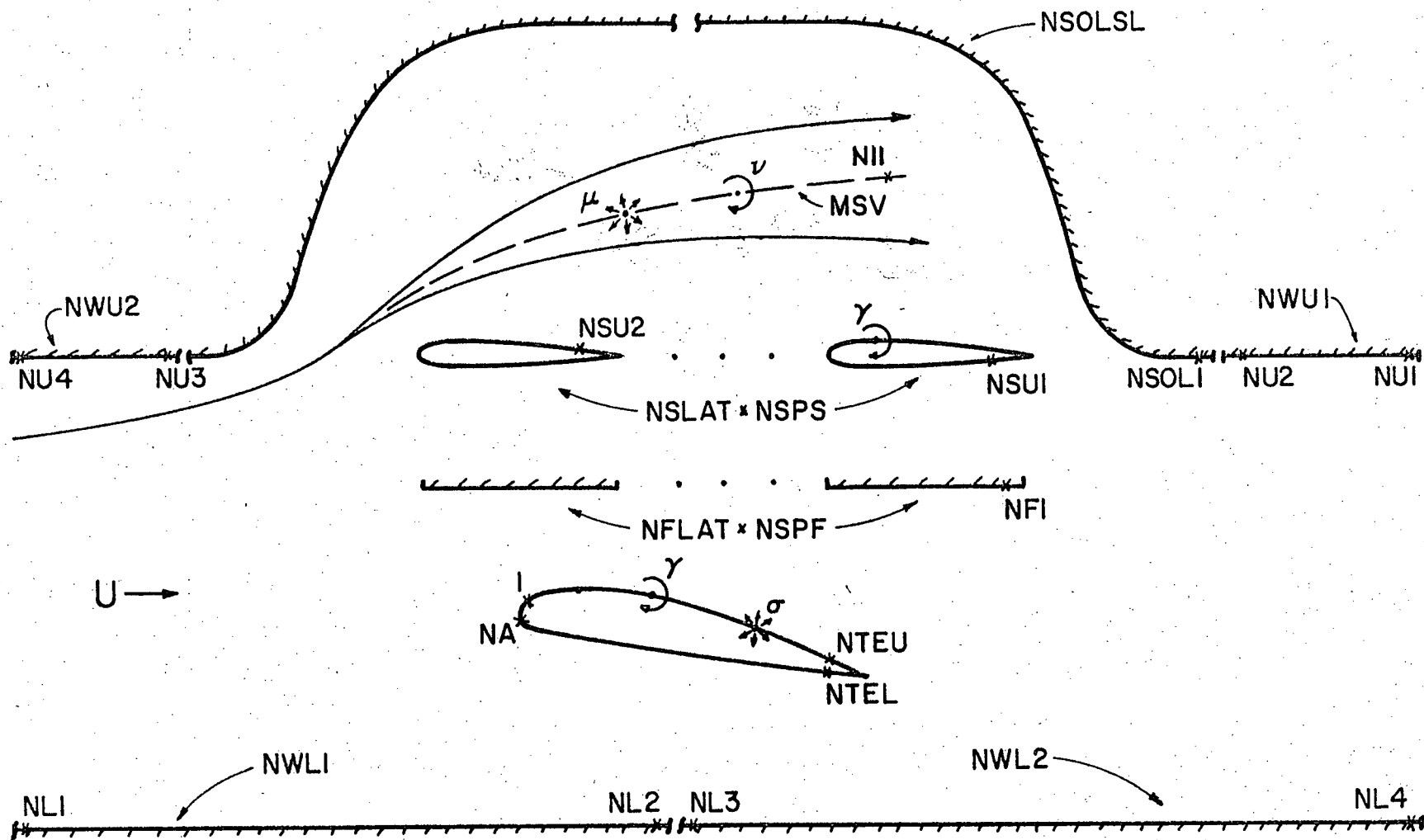


Figure A10.1 Notation for the computer program of Appendix 10

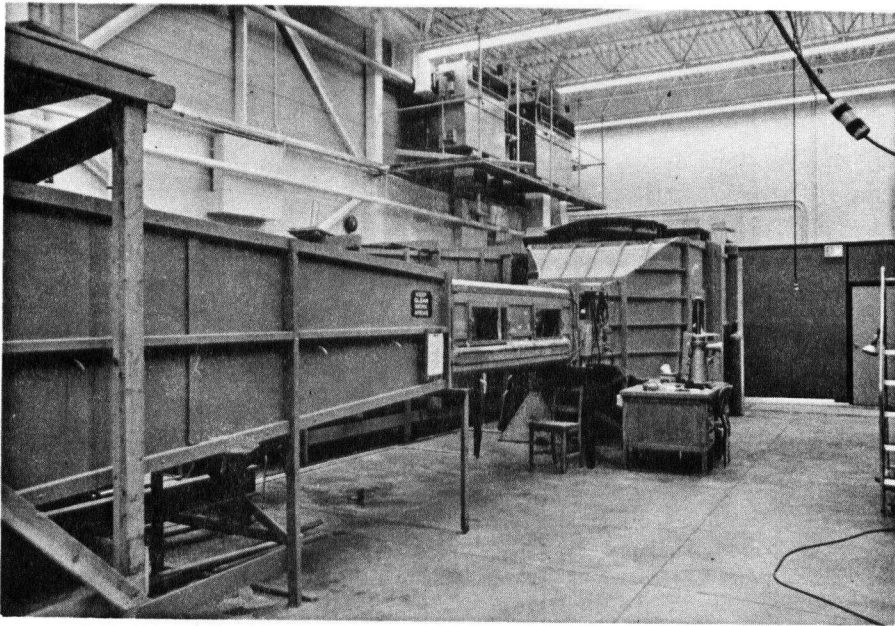


Plate 1a. The U.B.C. Mechanical Engineering low-speed closed-circuit windtunnel

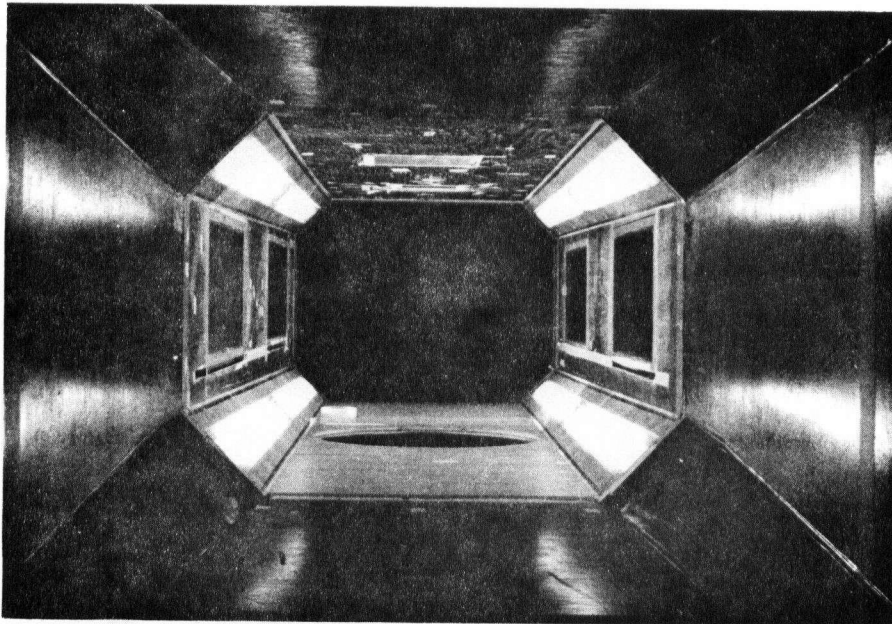


Plate 1b. The octagonal testsection in the windtunnel

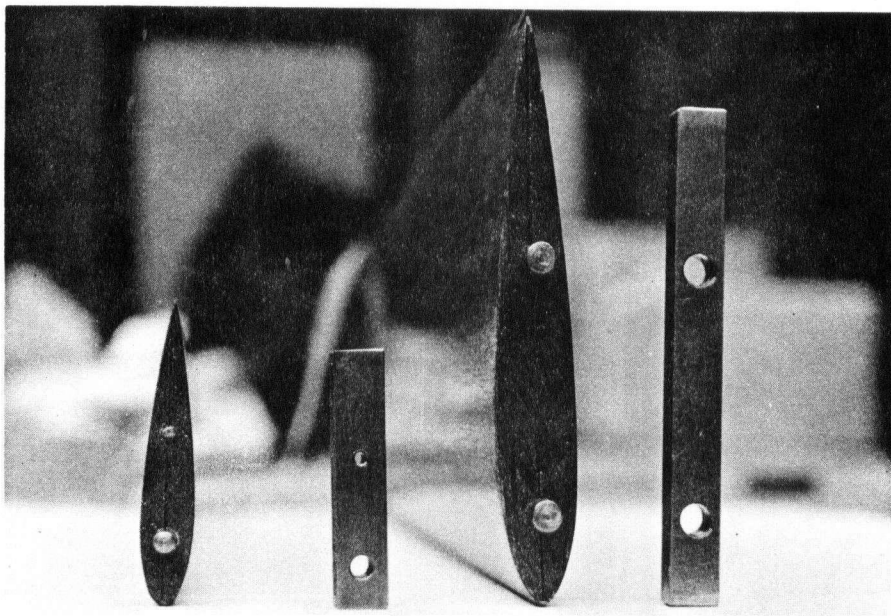


Plate 2. The airfoil-shaped slats

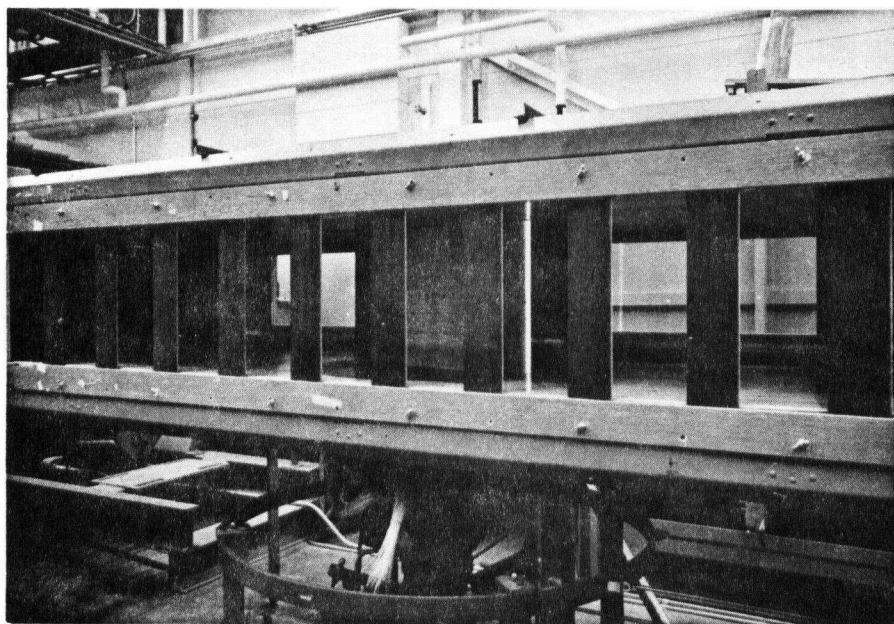


Plate 3. The wall slats in the side wall frame

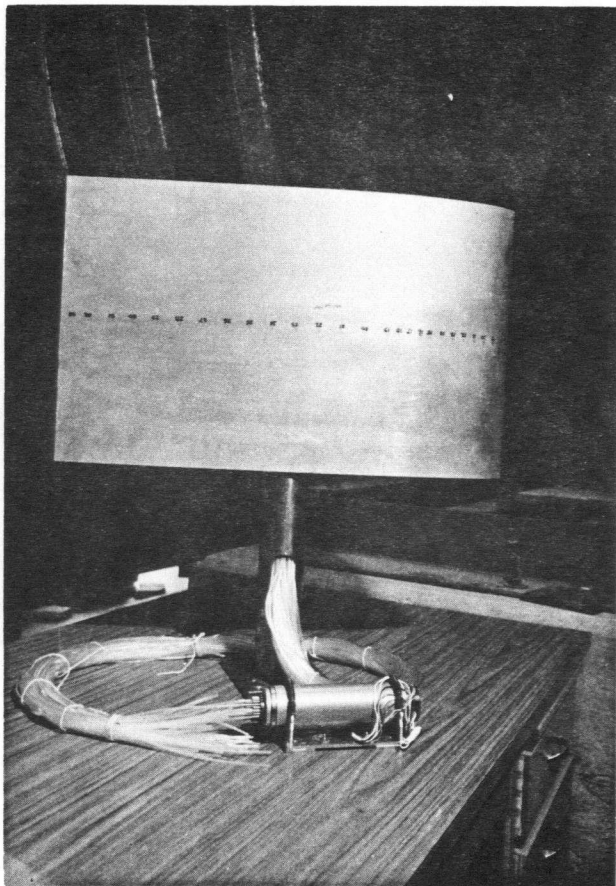


Plate 4. The 616mm NACA-0015 airfoil

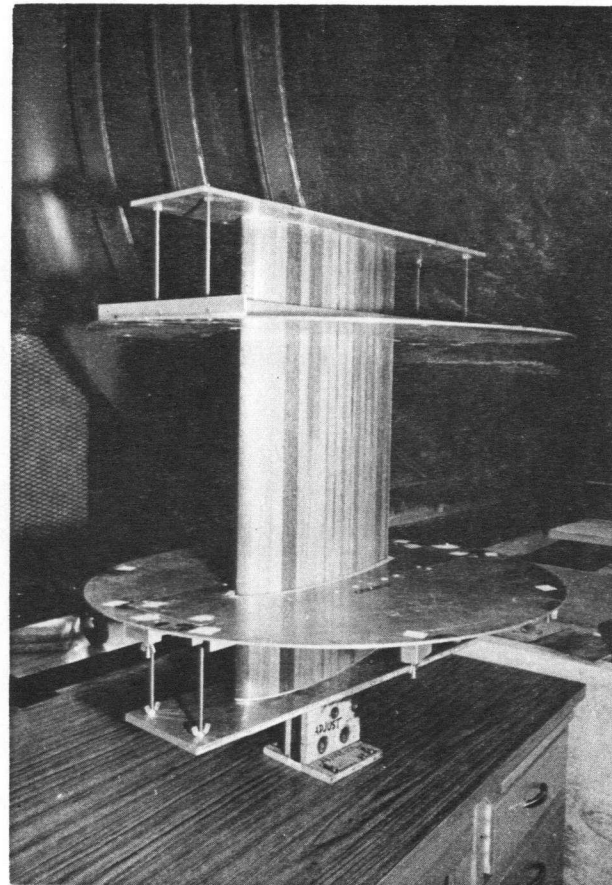


Plate 5. The 354mm Clark-Y airfoil fitted with endplates

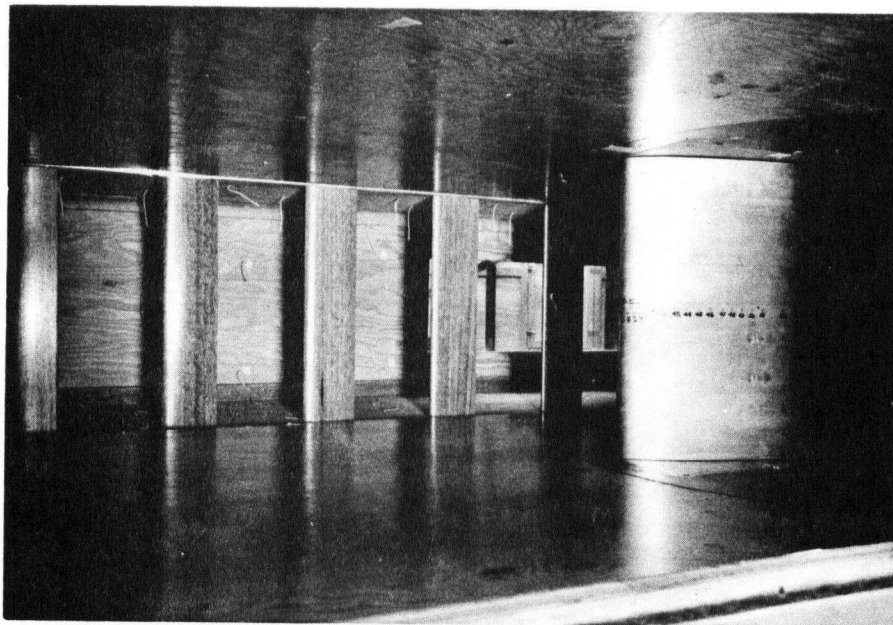


Plate 6. The 616mm NACA-0015 airfoil in the testsection.

Table 1. Airfoil profile coordinates.

14% Clark-Y			NACA-0015		Joukowsky 11%			
x	y _U	y _L	x	y	x	y _U	x	y _L
0.00	4.19	4.19	0.00	0.00	0.00	3.92	0.05	3.53
0.32	5.15	3.15	0.40	1.37	0.02	4.16	0.40	2.90
0.96	6.15	2.49	1.00	2.13	0.35	4.89	1.09	2.31
1.92	7.24	1.98	1.90	2.88	0.97	5.41	2.11	1.77
3.20	8.35	1.54	3.20	3.65	1.91	6.28	3.45	1.29
4.80	9.35	1.15	4.80	4.37	3.15	6.96	5.14	0.88
6.72	10.26	0.84	6.70	5.02	4.74	7.62	7.10	0.55
8.96	11.14	0.60	9.00	5.63	6.63	8.26	9.41	0.29
11.52	11.94	0.38	11.50	6.15	8.77	8.85	11.99	0.12
14.40	12.65	0.21	14.40	6.60	11.17	9.38	14.87	0.02
17.60	13.25	0.09	17.60	6.97	13.86	9.85	18.05	0.00
21.12	13.70	0.02	21.10	7.25	16.76	10.25	21.45	0.07
24.96	13.94	0.00	25.00	7.43	19.89	10.58	25.10	0.20
29.12	14.00	0.00	29.10	7.50	23.24	10.83	28.95	0.40
33.60	13.95	0.00	33.60	7.47	26.74	10.99	33.02	0.65
38.40	13.74	0.00	38.40	7.32	30.44	11.07	37.25	0.96
43.52	13.34	0.00	43.50	7.07	34.27	11.06	41.59	1.29
48.96	12.73	0.00	49.00	6.69	38.22	10.98	46.06	1.66
54.72	11.85	0.00	54.70	6.22	42.26	10.80	50.58	2.04
60.80	10.80	0.00	60.80	5.62	46.39	10.55	55.12	2.41
67.20	9.44	0.00	67.20	4.91	51.15	10.19	59.69	2.77
73.92	7.83	0.00	73.90	4.09	54.75	9.86	64.19	3.10
80.96	5.92	0.00	81.00	3.14	58.93	9.43	68.59	3.40
88.32	3.86	0.00	88.30	2.07	63.05	8.95	72.86	3.66
96.00	1.45	0.00	96.00	0.84	67.12	8.44	76.96	3.86
100.44	0.00	0.00	100.59	0.00	71.09	7.92	80.83	4.01
					74.94	7.38	84.43	4.11
					78.62	6.85	87.73	4.16
					82.12	6.34	90.71	4.17
					85.37	5.85	93.29	4.14
					88.40	5.40	95.50	4.08
					90.71	5.07	97.27	4.01
					93.29	4.70	98.61	3.94
					95.50	4.39	99.50	3.88
					97.27	4.16	100.0	3.84
					98.61	4.00		
					99.50	3.90		
					100.0	3.84		

Table 1 cont'd.

NACA-23012

Main Airfoil			Flap			
x	Y _U	Y _L	x	Y _U	x	Y _L
0.00	1.00	0.00	0.00	0.04	0.00	0.04
1.00	2.40	-1.10	0.45	0.99	0.36	-0.72
2.50	3.61	-1.71	1.08	1.59	0.95	-1.00
4.00	4.45	-2.10	2.11	2.27	1.74	-1.15
7.00	5.65	-2.55	3.65	2.93	2.44	-1.21
10.00	6.43	-2.92	5.17	3.33	3.44	-1.21
15.00	7.19	-3.50	6.68	3.55	4.95	-1.15
20.00	7.50	-3.97	7.69	3.57	6.45	-1.07
25.00	7.60	-4.28	8.69	3.52	7.45	-1.03
30.00	7.55	-4.46	10.18	3.32	8.46	-0.99
35.00	7.43	-4.53	12.66	2.86	9.96	-0.94
40.00	7.14	-4.43	15.13	2.36	12.47	-0.82
45.00	6.80	-4.35	17.61	1.85	14.98	-0.71
50.00	6.41	-4.17	20.09	1.35	17.49	-0.61
55.00	6.00	-3.92	22.07	0.93	20.00	-0.46
60.00	5.47	-3.65	24.05	0.52	22.01	-0.33
65.00	4.95	-3.35	25.54	0.21	24.02	-0.19
67.00	-	-3.18	26.53	0.00	25.52	-0.08
69.00	-	-2.83			26.53	0.00
70.00	4.36	-2.51	Origin of flap coordinates is (78.87,-0.81) for $\delta=20^\circ$.			
71.00	-	-1.98				
72.32	-	-1.02				
74.57	-	+0.67				
75.00	3.78	-				
77.82	-	2.30				
80.00	3.08	2.67				
82.70	2.64	2.64				

Table 2. Free air airfoil coefficients: Theory.

NACA-0015

α°	C_L	C_{M_0}	$C_{\frac{Mc}{4}}$	$\frac{dC_L}{d\alpha}$
0	0.000	0.000	0.0000	0.1193
3	.365	.086	- .0050	.1229
5	.607	.143	- .0086	.1300
10	1.210	.282	- .0204	—

14% Clark-Y

α°	C_L	C_{M_0}	$C_{\frac{Mc}{4}}$	$\frac{dC_L}{d\alpha}$
-6.3	0.000	-0.087	-0.087	0.1206
-3	.401	.012	- .0883	.1208
0	.763	.101	- .0901	.1203
5	1.362	.244	- .0965	—

Table 3. Airfoil and wall configurations examined theoretically.

All solid walls are 4.88m long, with $MWU1 = MWU2 = 20$, and $NWL1 = NWL2 = 40$.

The slotted wall is 2.44m long, composed of large (92mm) NACA-0015 slats with $NSPS = 9$.

Airfoil is in the center of the testsection; $NA = 50$ for Clark-Y and NACA-0015; $NA = 81$ (46 main and 35 flap) for NACA-23012.

Further notes are found at the end of this table.

	α	C_L	C_{M_0}	$C_{M_c \frac{4}{4}}$	c/H
1. Clark-Y airfoil					
a) Free air	-8	-0.203	-0.137	-0.086	
	2	1.003	+ .159	- .092	
	20	3.088	.603	- .169	
b) Solid walls	-8	-0.250	-0.150	-0.087	
$c/H = 0.53$	-3	.444	+ .014	- .097	
	2	1.140	.178	- .108	
	20	3.632	.711	- .197	
c) 40% TSUSL	-8	-0.270	-0.153	-0.086	
$NSLAT = 16$	-3	+ .376	.000	- .094	
$c/H = 0.53$	+2	1.012	.149	- .104	
	20	3.179	.610	- .185	
d) 60% TSUSL	-8	-0.260	-0.151	-0.086	
$NSLAT = 10$	-3	+ .377	+ .003	- .092	
$c/H = 0.53$	+2	.992	.148	- .100	
	20	2.986	.572	- .175	

Table 3 (cont'd).

	α	C_L	C_{M_0}	$C_{\frac{M_c}{4}}$	c/H
1. Clark-Y (cont'd) (60%)	20	3.061	.579	- .186	0.66
e) 70% TSUSL	20	2.929	0.570	-0.162	0.25
NSLAT = 8	20	2.907	.562	- .164	.39
	20	2.923	.560	- .170	.53
	20	2.970	.563	- .180	.66
	20	3.084	.573	- .198	.86
	20	3.200	.587	- .213	1.0
	-8	- .256	- .149	- .085	.53
	-3	+ .381	+ .005	- .091	.53
	+2	.989	.149	- .098	.53
f) 80% TSUSL	-8	-0.250	-0.148	-0.086	0.53
NSLAT = 5	-3	+ .388	+ .007	- .090	.53
	+2	.994	.152	- .097	.53
	20	2.888	.554	- .168	.53
2. NACA-0015 airfoil					
a) Free air	-2	-0.243	-0.058	+0.003	
	+8	+ .970	+ .227	- .015	
	15	1.803	.412	- .038	
	20	2.382	.530	- .065	
b) Solid walls	-2	-0.305	-0.068	+0.008	0.67
	+8	+1.223	+ .272	- .034	.67
	10	1.510	.333	- .045	.67
	20	3.074	.675	- .093	.67
	+3	.371	.087	- .006	.17
	3	.388	.090	- .007	.34

Table 3 (cont'd)

	α	$-C_L$	C_{M_0}	C_{M_c} 4	c/H
2. NACA-0015 (cont'd)					
b) Solid walls (cont'd)	3	.416	.094	-.010	.51
	3	.453	.100	-.013	.67
	3	.546	.116	-.021	1.0
c) 40% TSUSL	-2	-0.327	-0.072	+0.010	0.67
NSLAT = 16	+3	+ .364	+ .081	- .010	.67
	8	1.039	.227	- .033	.67
	20	2.592	.550	- .098	.67
d) 60% TSUSL	-2	-0.320	-0.070	+0.010	0.67
NSLAT = 10	+3	+ .359	+ .081	- .009	.67
	8	1.006	.222	- .230	.67
	20	2.421	.514	- .092	.67
e) 70% TSUSL	+3	0.355	0.084	-0.005	0.17
NSLAT = 8	3	.356	.083	- .006	.34
	3	.358	.083	- .007	.51
	3	.361	.082	- .008	.67
	3	.365	.082	- .009	1.0
f) 80% TSUSL	-2	-0.311	-0.068	+0.010	0.67
NSLAT = 5	+3	+ .367	+ .084	- .007	.67
	8	1.000	.224	- .026	.67
	20	2.335	.500	- .086	.67
3. NACA-23012 airfoil					
a) Free air	+8	2.442	0.320	-0.291	

Table 3 (cont'd).

	α	C_L	C_{M_0}	$C_{\frac{Mc}{4}}$	c/H
3. NACA-23012 (cont'd)					
b) 70% TSUSL	+8	2.415	0.308	-0.295	0.2
NSLAT = 8	8	2.305	.290	- .286	.4
	8	2.318	.283	- .296	.6
	8	2.296	.280	- .312	.8
	8	2.442	.280	- .331	1.0
4. Clark-Y airfoil					
a) Compare $C_L(C_p)$ with $C_L(\Gamma)$, with NA = 110 and $\alpha = 20^\circ$.					
		$C_L(C_p)$	C_{M_0}	$C_{\frac{Mc}{4}}$	$C_L(\Gamma)$
i) Free air		3.117	0.548	-0.231	3.114
ii) Solid walls, $c/H=.66$		4.165	.744	- .298	3.742
b) Circulation on wall slats reduced by modifying slat profiles, NSPS = 15, $\alpha = 20^\circ$, $c/H = 0.66$.					
	k	C_L	C_{M_0}	$C_{\frac{Mc}{4}}$	
70% TSUSL	1.0	3.010	0.569	-0.184	
NSLAT = 8	.8	2.935	.556	- .178	
	.7	2.610	.502	- .150	
c) Shear layer representation. MSV = 20, $\alpha = 20^\circ$, $c/H = 0.66$, $V_t = \sqrt{(1-\bar{C}_p)}$.					
	$\bar{C}_p$	C_L	C_{M_0}	$C_{\frac{Mc}{4}}$	
i) 60% TSUSL	0.0	2.420	0.451	-0.155	
NSLAT = 10	-.12	2.686	.502	- .170	
	-.28	3.305	.572	- .187	

Table 3 (cont'd)

4c) Clark-Y - Shear layer representation (cont'd).

	$\bar{C}_p$	C_L	C_{M_0}	$C_{\frac{M_c}{4}}$
i) 60% TSUSL(cont'd)	-.35	3.188	.600	- .197
NSLAT = 10	-.44	3.390	.640	- .207
ii) 70% TSUSL	0.	2.321	.433	- .147
NSLAT = 8	-.12	2.591	.486	- .162
	-.28	2.951	.558	- .180
	-.35	3.101	.586	- .190
	-.44	3.308	.626	- .200

5. NACA-0015 airfoil with reduced circulation, $\alpha = 10^\circ$,
solid walls; a reduced airfoil circulation determined.

	C_L	C_{M_0}	$C_{\frac{M_c}{4}}$
i) from measured lift			
(k = 0.741)	1.120	.335	+0.0549
ii) by modifying the			
profile (k=0.724)	1.120	.280	- .0003

Notes: The positions of the wall slats correspond exactly to those in the experimental setup. The slats are spaced uniformly, beginning with a slot opening at the upstream end on the sidewall. The number of large slats required for 40, 50, 60, 70 and 80% OAR is 16, 13, 10, 8, and 5 respectively.

The effect of increasing the number of control points on the test airfoil is seen in 1(a) and 4(a)(i); of increasing the number of control points on the wall slats in 1(e) and 4(b) (k=1).

Table 4. Airfoil and endplate loadings.

Joukowsky		Re=.5(10) ⁶		Solid Walls		
α°	C_L^*	C_L	$C_{M_c}^*$ $\frac{4}{4}$	C_{M_c} $\frac{4}{4}$	C_D^*	C_D
-7	-.350	-.345	-.0719	-.0723	.0330	.0194
-6	-.245	-.241	-.0727	-.0728	.0317	.0180
-5	-.137	-.134	-.0728	-.0727	.0309	.0171
-4	-.025	-.024	-.0727	-.0723	.0308	.0168
-3	.086	.086	-.0724	-.0717	.0314	.0172
-2	.194	.192	-.0716	-.0706	.0323	.0179
-1	.299	.296	-.0712	-.0699	.0340	.0193
0	.408	.403	-.0705	-.0689	.0361	.0212
1	.512	.506	-.0693	-.0673	.0384	.0233
2	.617	.610	-.0669	-.0645	.0410	.0259
3	.721	.713	-.0652	-.0625	.0441	.0289
4	.820	.811	-.0639	-.0607	.0482	.0326
5	.917	.907	-.0628	-.0591	.0530	.0370
6	1.009	.998	-.0617	-.0574	.0592	.0425
7	1.103	1.091	-.0600	-.0551	.0652	.0478
8	1.192	1.179	-.0581	-.0524	.0719	.0534
9	1.277	1.265	-.0557	-.0491	.0790	.0594
10	1.340	1.326	-.0536	-.0466	.0869	.0672
11	1.382	1.368	-.0540	-.0465	.0972	.0773
12	1.408	1.394	-.0620	-.0546	.1161	.0959
13	1.199	1.186	-.1611	-.1538	.2551	.2345

$C_L^*, C_{M_c}^*, C_D^*$ loading on airfoil plus two endplates

C_L, C_{M_c}, C_D loading on airfoil only

Table 5. Windtunnel balance results - Clark-Y airfoils

0.25-Clark-Y RE=.45(10)6 SOLID WALLS

CLARK-Y RE=.45(10)6 40%SS+P TSUSL

ALF	CL	CD	CM0	CMC/4
-10.	-0.345	0.0260	-0.186	-0.0916
-9.	-0.251	0.0235	-0.160	-0.0907
-8.	-0.154	0.0221	-0.133	-0.0906
-7.	-0.057	0.0215	-0.107	-0.0910
-6.	0.041	0.0201	-0.080	-0.0908
-5.	0.141	0.0207	-0.053	-0.0911
-4.	0.241	0.0205	-0.026	-0.0908
-3.	0.343	0.0204	0.002	-0.0908
-2.	0.438	0.0221	0.032	-0.0871
-1.	0.553	0.0237	0.060	-0.0905
0.	0.665	0.0256	0.087	-0.0942
1.	0.753	0.0278	0.114	-0.0920
2.	0.845	0.0302	0.140	-0.0905
3.	0.938	0.0330	0.168	-0.0889
4.	1.030	0.0373	0.193	-0.0880
5.	1.108	0.0397	0.218	-0.0845
6.	1.185	0.0438	0.241	-0.0820
7.	1.256	0.0487	0.264	-0.0782
8.	1.321	0.0532	0.286	-0.0736
9.	1.386	0.0588	0.305	-0.0711
10.	1.427	0.0650	0.321	-0.0655
11.	1.435	0.0716	0.331	-0.0572
12.	1.434	0.0798	0.333	-0.0543
13.	1.426	0.1034	0.322	-0.0638
14.	1.388	0.1248	0.308	-0.0682

ALF	CL	CD	CM0	CMC/4
-10.	-0.330	0.0237	-0.187	-0.0963
-9.	-0.237	0.0218	-0.160	-0.0946
-8.	-0.141	0.0195	-0.134	-0.0945
-7.	-0.046	0.0189	-0.107	-0.0938
-6.	0.048	0.0177	-0.082	-0.0942
-5.	0.144	0.0176	-0.055	-0.0941
-4.	0.240	0.0174	-0.027	-0.0924
-3.	0.340	0.0176	0.000	-0.0933
-2.	0.430	0.0185	0.029	-0.0896
-1.	0.533	0.0201	0.055	-0.0916
0.	0.643	0.0231	0.081	-0.0968
1.	0.729	0.0262	0.105	-0.0958
2.	0.815	0.0285	0.130	-0.0945
3.	0.901	0.0315	0.155	-0.0933
4.	0.986	0.0346	0.181	-0.0911
5.	1.062	0.0389	0.204	-0.0885
6.	1.133	0.0426	0.227	-0.0852
7.	1.204	0.0462	0.249	-0.0826
8.	1.268	0.0499	0.269	-0.0795
9.	1.328	0.0550	0.288	-0.0761
10.	1.359	0.0606	0.304	-0.0685
11.	1.377	0.0675	0.316	-0.0609
12.	1.382	0.0765	0.319	-0.0589
13.	1.366	0.0943	0.309	-0.0636
14.	1.333	0.1162	0.294	-0.0704
15.	1.293	0.1378	0.280	-0.0748

CLARK-Y RE=.45(10)6 40%LS+P TSUSL

ALF	CL	CD	CM0	CMC/4
-10.	-0.340	0.0249	-0.185	-0.0928
-9.	-0.245	0.0222	-0.159	-0.0921
-8.	-0.147	0.0200	-0.132	-0.0917
-7.	-0.052	0.0196	-0.107	-0.0924
-6.	0.042	0.0184	-0.081	-0.0921
-5.	0.138	0.0182	-0.055	-0.0919
-4.	0.237	0.0185	-0.028	-0.0923
-3.	0.335	0.0192	-0.000	-0.0909
-2.	0.426	0.0196	0.028	-0.0875
-1.	0.528	0.0213	0.054	-0.0894
0.	0.641	0.0242	0.078	-0.0954
1.	0.725	0.0265	0.103	-0.0937
2.	0.812	0.0291	0.128	-0.0923
3.	0.897	0.0319	0.154	-0.0899
4.	0.984	0.0349	0.178	-0.0888
5.	1.058	0.0395	0.201	-0.0853
6.	1.132	0.0428	0.224	-0.0827
7.	1.203	0.0466	0.246	-0.0796
8.	1.267	0.0502	0.266	-0.0758
9.	1.325	0.0550	0.286	-0.0715
10.	1.361	0.0604	0.302	-0.0648
11.	1.377	0.0666	0.312	-0.0586
12.	1.379	0.0761	0.315	-0.0551
13.	1.365	0.0948	0.307	-0.0594
14.	1.329	0.1165	0.290	-0.0676
15.	1.293	0.1379	0.277	-0.0715

Table 5 - 0.25-Clark-Y

RE=.45(10)6 50%LS+P TSUSL

CLARK-Y RE=.45(10)6 70%LS+P TSUSL

ALF	CL	CD	CMO	CMC/4
-10.	-0.333	0.0239	-0.184	-0.0929
-9.	-0.240	0.0210	-0.158	-0.0915
-8.	-0.143	0.0205	-0.131	-0.0916
-7.	-0.049	0.0184	-0.106	-0.0915
-6.	0.045	0.0185	-0.080	-0.0915
-5.	0.140	0.0173	-0.054	-0.0916
-4.	0.236	0.0175	-0.027	-0.0910
-3.	0.335	0.0181	0.001	-0.0906
-2.	0.422	0.0188	0.029	-0.0870
-1.	0.525	0.0207	0.054	-0.0898
0.	0.634	0.0230	0.080	-0.0942
1.	0.720	0.0251	0.105	-0.0932
2.	0.804	0.0277	0.129	-0.0917
3.	0.894	0.0295	0.155	-0.0903
4.	0.978	0.0320	0.180	-0.0886
5.	1.054	0.0373	0.203	-0.0861
6.	1.127	0.0402	0.226	-0.0835
7.	1.195	0.0437	0.247	-0.0801
8.	1.257	0.0474	0.268	-0.0762
9.	1.314	0.0524	0.286	-0.0724
10.	1.350	0.0577	0.301	-0.0671
11.	1.372	0.0643	0.311	-0.0623
12.	1.370	0.0739	0.315	-0.0575
13.	1.354	0.0925	0.304	-0.0639
14.	1.314	0.1156	0.286	-0.0718
15.	1.282	0.1352	0.275	-0.0749

ALF	CL	CD	CMO	CMC/4
-10.	-0.324	0.0273	-0.183	-0.0925
-9.	-0.228	0.0234	-0.157	-0.0929
-8.	-0.132	0.0222	-0.130	-0.0924
-7.	-0.038	0.0212	-0.103	-0.0922
-6.	0.057	0.0196	-0.077	-0.0920
-5.	0.153	0.0194	-0.051	-0.0926
-4.	0.246	0.0199	-0.024	-0.0919
-3.	0.342	0.0198	0.004	-0.0914
-2.	0.427	0.0202	0.032	-0.0872
-1.	0.533	0.0219	0.058	-0.0910
0.	0.639	0.0239	0.083	-0.0952
1.	0.722	0.0263	0.108	-0.0939
2.	0.807	0.0284	0.133	-0.0926
3.	0.892	0.0293	0.158	-0.0913
4.	0.974	0.0320	0.182	-0.0895
5.	1.050	0.0354	0.205	-0.0877
6.	1.117	0.0379	0.226	-0.0849
7.	1.185	0.0417	0.247	-0.0826
8.	1.243	0.0462	0.268	-0.0778
9.	1.297	0.0510	0.286	-0.0741
10.	1.330	0.0563	0.300	-0.0697
11.	1.339	0.0628	0.309	-0.0613
12.	1.340	0.0732	0.310	-0.0603
13.	1.323	0.0928	0.298	-0.0679
14.	1.285	0.1150	0.283	-0.0734
15.	1.246	0.1337	0.268	-0.0773

CLARK-Y RE=.45(10)6 60%LS+P TSUSL

CLARK-Y RE=.45(10)6 80%LS+P TSUSL

ALF	CL	CD	CMO	CMC/4
-10.	-0.328	0.0236	-0.183	-0.0931
-9.	-0.234	0.0210	-0.158	-0.0933
-8.	-0.137	0.0194	-0.131	-0.0929
-7.	-0.043	0.0175	-0.105	-0.0930
-6.	0.051	0.0161	-0.079	-0.0924
-5.	0.146	0.0154	-0.053	-0.0925
-4.	0.241	0.0158	-0.026	-0.0915
-3.	0.336	0.0161	0.001	-0.0911
-2.	0.425	0.0166	0.029	-0.0878
-1.	0.530	0.0180	0.055	-0.0907
0.	0.637	0.0207	0.080	-0.0955
1.	0.722	0.0229	0.104	-0.0946
2.	0.807	0.0254	0.130	-0.0927
3.	0.893	0.0277	0.155	-0.0909
4.	0.978	0.0302	0.180	-0.0895
5.	1.055	0.0352	0.203	-0.0873
6.	1.127	0.0381	0.226	-0.0840
7.	1.193	0.0416	0.247	-0.0807
8.	1.258	0.0461	0.267	-0.0780
9.	1.310	0.0509	0.286	-0.0727
10.	1.346	0.0562	0.300	-0.0680
11.	1.359	0.0624	0.310	-0.0610
12.	1.359	0.0726	0.314	-0.0568
13.	1.345	0.0914	0.302	-0.0653
14.	1.307	0.1125	0.285	-0.0717
15.	1.270	0.1313	0.274	-0.0739

ALF	CL	CD	CMO	CMC/4
-10.	-0.313	0.0258	-0.174	-0.0881
-9.	-0.214	0.0234	-0.148	-0.0886
-8.	-0.123	0.0226	-0.122	-0.0874
-7.	-0.030	0.0210	-0.095	-0.0863
-6.	0.063	0.0191	-0.073	-0.0900
-5.	0.155	0.0191	-0.048	-0.0896
-4.	0.251	0.0188	-0.021	-0.0893
-3.	0.343	0.0191	0.006	-0.0880
-2.	0.431	0.0190	0.034	-0.0848
-1.	0.538	0.0202	0.060	-0.0880
0.	0.640	0.0219	0.085	-0.0910
1.	0.725	0.0234	0.110	-0.0898
2.	0.806	0.0245	0.135	-0.0873
3.	0.890	0.0270	0.160	-0.0850
4.	0.967	0.0296	0.185	-0.0813
5.	1.042	0.0336	0.206	-0.0800
6.	1.107	0.0366	0.228	-0.0761
7.	1.167	0.0413	0.248	-0.0716
8.	1.230	0.0451	0.268	-0.0692
9.	1.281	0.0500	0.286	-0.0643
10.	1.298	0.0557	0.300	-0.0548
11.	1.315	0.0629	0.308	-0.0508
12.	1.310	0.0743	0.306	-0.0510
13.	1.284	0.0941	0.291	-0.0596
14.	1.246	0.1122	0.275	-0.0650
15.	1.207	0.1278	0.262	-0.0677

Table 5 - 0.25-Clark-Y

RE=.45(I0)6 50XSS+P TSUSL					CLARK-Y RE=.45(I0)6 70XSS+P TSUSL				
ALF	CL	CD	CM0	CMC/4	ALF	CL	CD	CM0	CMC/4
-10.	-0.327	0.0245	-0.181	-0.0912	-10.	-0.338	0.0254	-0.186	-0.0928
-9.	-0.233	0.0230	-0.156	-0.0916	-9.	-0.244	0.0231	-0.161	-0.0930
-8.	-0.138	0.0217	-0.130	-0.0915	-8.	-0.150	0.0212	-0.133	-0.0908
-7.	-0.044	0.0203	-0.104	-0.0909	-7.	-0.056	0.0206	-0.108	-0.0920
-6.	0.048	0.0202	-0.078	-0.0910	-6.	0.033	0.0193	-0.083	-0.0916
-5.	0.144	0.0196	-0.052	-0.0908	-5.	0.124	0.0183	-0.057	-0.0911
-4.	0.239	0.0199	-0.026	-0.0908	-4.	0.215	0.0197	-0.031	-0.0906
-3.	0.334	0.0206	0.001	-0.0901	-3.	0.308	0.0201	-0.005	-0.0899
-2.	0.422	0.0216	0.029	-0.0866	-2.	0.393	0.0212	0.022	-0.0867
-1.	0.526	0.0232	0.055	-0.0894	-1.	0.489	0.0223	0.047	-0.0886
0.	0.633	0.0256	0.080	-0.0938	0.	0.593	0.0252	0.071	-0.0935
1.	0.720	0.0277	0.104	-0.0932	1.	0.679	0.0274	0.095	-0.0935
2.	0.804	0.0303	0.129	-0.0911	2.	0.763	0.0301	0.119	-0.0921
3.	0.889	0.0330	0.155	-0.0891	3.	0.848	0.0323	0.144	-0.0913
4.	0.974	0.0352	0.180	-0.0874	4.	0.932	0.0346	0.168	-0.0900
5.	1.048	0.0390	0.203	-0.0845	5.	1.011	0.0384	0.191	-0.0892
6.	1.120	0.0425	0.224	-0.0824	6.	1.083	0.0408	0.213	-0.0862
7.	1.189	0.0461	0.245	-0.0801	7.	1.154	0.0443	0.235	-0.0837
8.	1.251	0.0505	0.266	-0.0759	8.	1.222	0.0485	0.256	-0.0808
9.	1.307	0.0553	0.284	-0.0730	9.	1.286	0.0527	0.276	-0.0783
10.	1.345	0.0604	0.299	-0.0674	10.	1.327	0.0572	0.292	-0.0747
11.	1.363	0.0669	0.308	-0.0621	11.	1.344	0.0628	0.304	-0.0645
12.	1.363	0.0765	0.312	-0.0579	12.	1.345	0.0709	0.308	-0.0605
13.	1.348	0.0954	0.301	-0.0654	13.	1.332	0.0877	0.299	-0.0658
14.	1.306	0.1171	0.285	-0.0702	14.	1.295	0.1102	0.283	-0.0721
15.	1.269	0.1355	0.272	-0.0740	15.	1.252	0.1300	0.270	-0.0742

CLARK-Y RE=.45(I0)6 60XSS+P TSUSL

CLARK-Y RE=.45(I0)6 80XSS+P TSUSL

ALF	CL	CD	CM0	CMC/4	ALF	CL	CD	CM0	CMC/4
-10.	-0.322	0.0253	-0.178	-0.0902	-10.	-0.325	0.0273	-0.180	-0.0901
-9.	-0.230	0.0234	-0.154	-0.0908	-9.	-0.235	0.0242	-0.154	-0.0884
-8.	-0.133	0.0221	-0.127	-0.0900	-8.	-0.141	0.0224	-0.128	-0.0888
-7.	-0.041	0.0203	-0.100	-0.0885	-7.	-0.047	0.0222	-0.103	-0.0892
-6.	0.052	0.0186	-0.076	-0.0893	-6.	0.043	0.0208	-0.078	-0.0887
-5.	0.149	0.0178	-0.050	-0.0900	-5.	0.132	0.0205	-0.053	-0.0890
-4.	0.244	0.0180	-0.024	-0.0896	-4.	0.223	0.0210	-0.027	-0.0884
-3.	0.338	0.0185	0.003	-0.0891	-3.	0.312	0.0207	-0.002	-0.0878
-2.	0.424	0.0190	0.030	-0.0852	-2.	0.395	0.0208	0.024	-0.0843
-1.	0.527	0.0203	0.055	-0.0884	-1.	0.495	0.0223	0.049	-0.0877
0.	0.634	0.0227	0.080	-0.0928	0.	0.597	0.0246	0.073	-0.0915
1.	0.718	0.0248	0.104	-0.0916	1.	0.678	0.0267	0.097	-0.0906
2.	0.799	0.0273	0.129	-0.0888	2.	0.760	0.0287	0.121	-0.0893
3.	0.887	0.0295	0.154	-0.0879	3.	0.844	0.0311	0.145	-0.0881
4.	0.971	0.0323	0.178	-0.0868	4.	0.925	0.0336	0.168	-0.0870
5.	1.046	0.0369	0.201	-0.0843	5.	0.993	0.0396	0.190	-0.0839
6.	1.117	0.0399	0.222	-0.0819	6.	1.067	0.0423	0.212	-0.0823
7.	1.181	0.0440	0.243	-0.0782	7.	1.129	0.0458	0.233	-0.0811
8.	1.248	0.0485	0.263	-0.0761	8.	1.209	0.0500	0.253	-0.0794
9.	1.301	0.0533	0.282	-0.0707	9.	1.266	0.0547	0.273	-0.0742
10.	1.335	0.0586	0.297	-0.0647	10.	1.305	0.0586	0.289	-0.0689
11.	1.348	0.0649	0.305	-0.0586	11.	1.318	0.0646	0.298	-0.0624
12.	1.348	0.0743	0.308	-0.0554	12.	1.310	0.0739	0.299	-0.0585
13.	1.334	0.0926	0.298	-0.0622	13.	1.292	0.0900	0.289	-0.0643
14.	1.299	0.1133	0.282	-0.0695	14.	1.259	0.1115	0.274	-0.0711
15.	1.262	0.1327	0.268	-0.0737	15.	1.221	0.1292	0.260	-0.0745

Table 5 - 0.39-Clark-Y

CLARK-Y RE=.5(10)6 SOLID WALLS

CLARK-Y RE=.5(10)6 40%SS+P TSUSL

ALF	CL	CD	CMO	CMC/4
-10.	-0.376	0.0243	-0.192	-0.0917
-9.	-0.278	0.0216	-0.166	-0.0923
-8.	-0.176	0.0197	-0.140	-0.0929
-7.	-0.075	0.0183	-0.114	-0.0933
-6.	0.075	0.0176	-0.087	-0.0935
-5.	0.128	0.0179	-0.060	-0.0936
-4.	0.233	0.0186	-0.033	-0.0941
-3.	0.342	0.0196	-0.004	-0.0949
-2.	0.444	0.0206	0.025	-0.0933
-1.	0.546	0.0218	0.052	-0.0936
0.	0.659	0.0240	0.079	-0.0966
1.	0.753	0.0263	0.106	-0.0950
2.	0.841	0.0290	0.133	-0.0912
3.	0.933	0.0327	0.160	-0.0886
4.	1.024	0.0368	0.187	-0.0863
5.	1.107	0.0423	0.212	-0.0829
6.	1.187	0.0470	0.236	-0.0801
7.	1.265	0.0516	0.260	-0.0772
8.	1.341	0.0570	0.283	-0.0735
9.	1.412	0.0635	0.304	-0.0704
10.	1.475	0.0705	0.324	-0.0672
11.	1.522	0.0785	0.339	-0.0635
12.	1.561	0.0887	0.351	-0.0615
13.	1.585	0.1021	0.359	-0.0600
14.	1.598	0.1244	0.354	-0.0675
15.	1.535	0.1952	0.301	-0.1081
16.	1.541	0.2181	0.301	-0.1102

ALF	CL	CD	CMO	CMC/4
-10.	-0.358	0.0239	-0.188	-0.0903
-9.	-0.266	0.0205	-0.163	-0.0902
-8.	-0.170	0.0188	-0.138	-0.0907
-7.	-0.077	0.0178	-0.112	-0.0906
-6.	0.015	0.0175	-0.087	-0.0907
-5.	0.111	0.0175	-0.062	-0.0919
-4.	0.205	0.0183	-0.036	-0.0914
-3.	0.303	0.0192	-0.009	-0.0921
-2.	0.402	0.0202	0.019	-0.0908
-1.	0.488	0.0220	0.045	-0.0889
0.	0.598	0.0247	0.071	-0.0931
1.	0.689	0.0279	0.096	-0.0929
2.	0.771	0.0310	0.122	-0.0901
3.	0.855	0.0345	0.147	-0.0878
4.	0.942	0.0386	0.173	-0.0862
5.	1.015	0.0426	0.195	-0.0838
6.	1.089	0.0469	0.217	-0.0813
7.	1.159	0.0519	0.239	-0.0792
8.	1.226	0.0574	0.260	-0.0759
9.	1.298	0.0634	0.279	-0.0763
10.	1.353	0.0705	0.298	-0.0711
11.	1.398	0.0768	0.312	-0.0685
12.	1.433	0.0859	0.322	-0.0683
13.	1.462	0.0962	0.331	-0.0660
14.	1.480	0.1070	0.336	-0.0657
15.	1.488	0.1332	0.329	-0.0754
16.	1.424	0.1887	0.279	-0.1116

CLARK-Y RE=.5(10)6 40%LS+P TSUSL

ALF	CL	CD	CMO	CMC/4
-10.	-0.360	0.0254	-0.188	-0.0897
-9.	-0.273	0.0221	-0.164	-0.0898
-8.	-0.176	0.0202	-0.139	-0.0903
-7.	-0.081	0.0188	-0.113	-0.0905
-6.	0.014	0.0179	-0.088	-0.0911
-5.	0.110	0.0170	-0.062	-0.0912
-4.	0.206	0.0175	-0.036	-0.0916
-3.	0.305	0.0183	-0.009	-0.0920
-2.	0.401	0.0197	0.019	-0.0903
-1.	0.489	0.0208	0.045	-0.0889
0.	0.597	0.0233	0.070	-0.0928
1.	0.687	0.0261	0.095	-0.0922
2.	0.771	0.0291	0.120	-0.0906
3.	0.852	0.0326	0.145	-0.0876
4.	0.933	0.0366	0.170	-0.0851
5.	1.011	0.0424	0.193	-0.0832
6.	1.079	0.0473	0.214	-0.0800
7.	1.151	0.0526	0.236	-0.0779
8.	1.219	0.0580	0.257	-0.0753
9.	1.288	0.0644	0.276	-0.0742
10.	1.348	0.0708	0.295	-0.0704
11.	1.396	0.0778	0.309	-0.0688
12.	1.431	0.0860	0.323	-0.0642
13.	1.460	0.0947	0.330	-0.0641
14.	1.484	0.1075	0.336	-0.0642
15.	1.485	0.1376	0.330	-0.0711
16.	1.442	0.1932	0.282	-0.1106

Table 5 - 0.39-Clark-Y

CLARK-Y RE=:5(10)6 50%LS+P TSUSL

ALF	CL	CD	CM0	CMC/4
-10.	-0.354	0.0242	-0.184	-0.0882
-9.	-0.263	0.0209	-0.160	-0.0883
-8.	-0.167	0.0187	-0.134	-0.0879
-7.	-0.074	0.0172	-0.108	-0.0879
-6.	0.020	0.0165	-0.084	-0.0887
-5.	0.112	0.0163	-0.058	-0.0883
-4.	0.207	0.0168	-0.033	-0.0888
-3.	0.302	0.0176	-0.007	-0.0892
-2.	0.398	0.0181	0.021	-0.0876
-1.	0.486	0.0193	0.045	-0.0870
0.	0.591	0.0218	0.070	-0.0907
1.	0.680	0.0246	0.095	-0.0904
2.	0.758	0.0274	0.119	-0.0869
3.	0.840	0.0310	0.143	-0.0850
4.	0.919	0.0349	0.167	-0.0823
5.	0.993	0.0410	0.190	-0.0802
6.	1.061	0.0458	0.211	-0.0773
7.	1.132	0.0506	0.232	-0.0754
8.	1.200	0.0555	0.252	-0.0734
9.	1.268	0.0612	0.271	-0.0724
10.	1.326	0.0660	0.289	-0.0690
11.	1.372	0.0744	0.303	-0.0666
12.	1.403	0.0820	0.314	-0.0630
13.	1.433	0.0914	0.322	-0.0636
14.	1.454	0.1039	0.326	-0.0640
15.	1.493	0.1654	0.280	-0.0967
16.	1.576	0.1900	0.266	-0.1077

CLARK-Y RE=:5(10)6 70%LS+P TSUSL

ALF	CL	CD	CM0	CMC/4
-10.	-0.331	0.0259	-0.178	-0.0864
-9.	-0.238	0.0272	-0.154	-0.0873
-8.	-0.147	0.0192	-0.128	-0.0873
-7.	-0.057	0.0171	-0.104	-0.0876
-6.	0.034	0.0158	-0.079	-0.0884
-5.	0.126	0.0151	-0.054	-0.0882
-4.	0.219	0.0150	-0.028	-0.0886
-3.	0.312	0.0154	-0.003	-0.0892
-2.	0.403	0.0161	0.024	-0.0875
-1.	0.489	0.0172	0.048	-0.0875
0.	0.587	0.0194	0.072	-0.0901
1.	0.669	0.0217	0.096	-0.0893
2.	0.745	0.0245	0.120	-0.0868
3.	0.824	0.0273	0.144	-0.0846
4.	0.895	0.0306	0.166	-0.0817
5.	0.962	0.0370	0.187	-0.0797
6.	1.023	0.0415	0.205	-0.0777
7.	1.082	0.0466	0.223	-0.0758
8.	1.145	0.0518	0.241	-0.0753
9.	1.204	0.0575	0.259	-0.0731
10.	1.263	0.0635	0.276	-0.0712
11.	1.307	0.0692	0.285	-0.0671
12.	1.342	0.0763	0.301	-0.0671
13.	1.370	0.0835	0.308	-0.0671
14.	1.391	0.0957	0.312	-0.0681
15.	1.349	0.1416	0.276	-0.0955
16.	1.311	0.1715	0.256	-0.1064

CLARK-Y RE=:5(10)6 60%LS+P TSUSL

ALF	CL	CD	CM0	CMC/4
-10.	-0.335	0.0260	-0.179	-0.0873
-9.	-0.245	0.0225	-0.154	-0.0867
-8.	-0.152	0.0197	-0.130	-0.0882
-7.	-0.060	0.0174	-0.105	-0.0883
-6.	0.030	0.0162	-0.081	-0.0888
-5.	0.122	0.0156	-0.056	-0.0893
-4.	0.215	0.0156	-0.031	-0.0898
-3.	0.309	0.0162	-0.005	-0.0899
-2.	0.403	0.0171	0.022	-0.0887
-1.	0.488	0.0181	0.046	-0.0881
0.	0.590	0.0207	0.071	-0.0913
1.	0.673	0.0231	0.095	-0.0902
2.	0.751	0.0260	0.119	-0.0873
3.	0.831	0.0292	0.143	-0.0851
4.	0.909	0.0329	0.166	-0.0838
5.	0.977	0.0391	0.188	-0.0810
6.	1.038	0.0437	0.207	-0.0782
7.	1.106	0.0487	0.226	-0.0774
8.	1.168	0.0539	0.245	-0.0751
9.	1.237	0.0599	0.264	-0.0745
10.	1.293	0.0657	0.281	-0.0718
11.	1.340	0.0722	0.296	-0.0696
12.	1.376	0.0795	0.307	-0.0674
13.	1.406	0.0883	0.315	-0.0673
14.	1.427	0.1011	0.318	-0.0698
15.	1.415	0.1393	0.293	-0.0930
16.	1.567	0.1786	0.264	-0.1108

CLARK-Y RE=:5(10)6 80%LS+P TSUSL

ALF	CL	CD	CM0	CMC/4
-10.	-0.316	0.0251	-0.171	-0.0828
-9.	-0.225	0.0211	-0.147	-0.0839
-8.	-0.134	0.0182	-0.122	-0.0843
-7.	-0.043	0.0160	-0.098	-0.0857
-6.	0.046	0.0150	-0.074	-0.0864
-5.	0.136	0.0144	-0.050	-0.0873
-4.	0.224	0.0146	-0.025	-0.0874
-3.	0.317	0.0149	0.000	-0.0879
-2.	0.405	0.0158	0.027	-0.0863
-1.	0.492	0.0158	0.051	-0.0863
0.	0.588	0.0173	0.075	-0.0888
1.	0.666	0.0195	0.098	-0.0875
2.	0.735	0.0215	0.122	-0.0834
3.	0.811	0.0240	0.144	-0.0817
4.	0.885	0.0272	0.167	-0.0798
5.	0.945	0.0318	0.185	-0.0777
6.	1.005	0.0358	0.204	-0.0758
7.	1.060	0.0403	0.221	-0.0732
8.	1.112	0.0440	0.239	-0.0699
9.	1.182	0.0484	0.256	-0.0711
10.	1.233	0.0537	0.272	-0.0692
11.	1.281	0.0575	0.286	-0.0677
12.	1.304	0.0643	0.295	-0.0642
13.	1.330	0.0725	0.301	-0.0644
14.	1.328	0.0933	0.289	-0.0768
15.	1.255	0.1414	0.253	-0.0951
16.	1.239	0.1627	0.237	-0.1045

Table 5 - 0.39-Clark-Y
CLARK-Y RE=.5(10) 6 50ZSS+P TSUSL

ALF	CL	CD	CMO	CMC/4
-10.	-0.354	0.0238	-0.184	-0.0882
-9.	-0.261	0.0207	-0.161	-0.0896
-8.	-0.167	0.0192	-0.134	-0.0880
-7.	-0.074	0.0176	-0.109	-0.0886
-6.	0.018	0.0174	-0.085	-0.0890
-5.	0.111	0.0172	-0.060	-0.0893
-4.	0.207	0.0176	-0.034	-0.0901
-3.	0.302	0.0181	-0.008	-0.0899
-2.	0.397	0.0194	0.019	-0.0883
-1.	0.488	0.0208	0.045	-0.0880
0.	0.593	0.0240	0.070	-0.0909
1.	0.683	0.0267	0.095	-0.0906
2.	0.765	0.0295	0.120	-0.0876
3.	0.847	0.0328	0.145	-0.0853
4.	0.927	0.0366	0.170	-0.0823
5.	1.002	0.0418	0.192	-0.0806
6.	1.074	0.0466	0.213	-0.0786
7.	1.136	0.0514	0.234	-0.0747
8.	1.190	0.0569	0.255	-0.0729
9.	1.276	0.0630	0.274	-0.0714
10.	1.332	0.0692	0.292	-0.0679
11.	1.377	0.0764	0.306	-0.0658
12.	1.412	0.0845	0.316	-0.0639
13.	1.435	0.0930	0.324	-0.0619
14.	1.456	0.1047	0.328	-0.0631
15.	1.469	0.1291	0.320	-0.0726
16.	1.378	0.1836	0.275	-0.0988

CLARK-Y RE=.5(10) 6 70ZSS+P TSUSL

ALF	CL	CD	CMO	CMC/4
-10.	-0.330	0.0272	-0.178	-0.0873
-9.	-0.244	0.0231	-0.155	-0.0873
-8.	-0.149	0.0203	-0.129	-0.0879
-7.	-0.060	0.0184	-0.105	-0.0883
-6.	0.031	0.0174	-0.081	-0.0887
-5.	0.122	0.0165	-0.056	-0.0885
-4.	0.215	0.0163	-0.030	-0.0895
-3.	0.311	0.0162	-0.004	-0.0895
-2.	0.403	0.0170	0.023	-0.0880
-1.	0.492	0.0187	0.047	-0.0881
0.	0.593	0.0228	0.072	-0.0911
1.	0.678	0.0248	0.097	-0.0901
2.	0.756	0.0271	0.122	-0.0869
3.	0.838	0.0300	0.145	-0.0855
4.	0.912	0.0328	0.169	-0.0824
5.	0.989	0.0380	0.191	-0.0812
6.	1.055	0.0416	0.211	-0.0787
7.	1.126	0.0460	0.233	-0.0761
8.	1.190	0.0510	0.253	-0.0740
9.	1.250	0.0562	0.272	-0.0707
10.	1.306	0.0627	0.290	-0.0685
11.	1.346	0.0688	0.301	-0.0666
12.	1.369	0.0761	0.310	-0.0631
13.	1.397	0.0847	0.317	-0.0636
14.	1.410	0.0974	0.318	-0.0650
15.	1.368	0.1393	0.284	-0.0902
16.	1.328	0.1678	0.263	-0.1013

CLARK-Y RE=.5(10) 6 60ZSS+P TSUSL

ALF	CL	CD	CMO	CMC/4
-10.	-0.337	0.0252	-0.176	-0.0855
-9.	-0.246	0.0214	-0.153	-0.0869
-8.	-0.155	0.0190	-0.128	-0.0861
-7.	-0.064	0.0177	-0.105	-0.0871
-6.	0.026	0.0167	-0.080	-0.0868
-5.	0.117	0.0165	-0.056	-0.0872
-4.	0.211	0.0167	-0.032	-0.0878
-3.	0.305	0.0172	-0.006	-0.0883
-2.	0.399	0.0184	0.021	-0.0865
-1.	0.485	0.0198	0.045	-0.0853
0.	0.591	0.0227	0.070	-0.0893
1.	0.679	0.0251	0.095	-0.0883
2.	0.757	0.0283	0.118	-0.0859
3.	0.840	0.0317	0.142	-0.0842
4.	0.916	0.0352	0.166	-0.0801
5.	0.990	0.0392	0.188	-0.0789
6.	1.059	0.0431	0.209	-0.0760
7.	1.129	0.0476	0.228	-0.0748
8.	1.195	0.0527	0.249	-0.0715
9.	1.262	0.0583	0.269	-0.0695
10.	1.318	0.0647	0.286	-0.0664
11.	1.360	0.0710	0.300	-0.0633
12.	1.391	0.0788	0.310	-0.0609
13.	1.414	0.0879	0.317	-0.0586
14.	1.436	0.0990	0.320	-0.0615
15.	1.421	0.1348	0.304	-0.0750
16.	1.367	0.1789	0.266	-0.1005

CLARK-Y RE=.5(10) 6 80ZSS+P TSUSL

ALF	CL	CD	CMO	CMC/4
-10.	-0.327	0.0244	-0.180	-0.0887
-9.	-0.235	0.0208	-0.155	-0.0887
-8.	-0.143	0.0187	-0.130	-0.0895
-7.	-0.052	0.0168	-0.103	-0.0883
-6.	0.039	0.0157	-0.079	-0.0897
-5.	0.131	0.0156	-0.054	-0.0905
-4.	0.225	0.0157	-0.028	-0.0907
-3.	0.320	0.0156	-0.003	-0.0917
-2.	0.410	0.0164	0.025	-0.0893
-1.	0.497	0.0173	0.050	-0.0887
0.	0.599	0.0193	0.075	-0.0920
1.	0.680	0.0213	0.100	-0.0906
2.	0.759	0.0238	0.124	-0.0886
3.	0.839	0.0264	0.148	-0.0863
4.	0.913	0.0287	0.171	-0.0838
5.	0.984	0.0330	0.193	-0.0815
6.	1.052	0.0365	0.214	-0.0793
7.	1.118	0.0403	0.234	-0.0778
8.	1.183	0.0443	0.254	-0.0754
9.	1.245	0.0481	0.271	-0.0746
10.	1.287	0.0534	0.286	-0.0709
11.	1.320	0.0592	0.296	-0.0694
12.	1.344	0.0660	0.305	-0.0666
13.	1.362	0.0747	0.309	-0.0660
14.	1.370	0.0904	0.307	-0.0704
15.	1.296	0.1413	0.260	-0.1002
16.	1.281	0.1623	0.247	-0.1097

Table 5 - 0.53-Clark-Y
CLARK-Y RE=.5(10)6 SOLID WALLS

ALF	CL	CD	CNO	CMC/4
-10.	-0.372	0.0262	-0.192	-0.0928
-9.	-0.272	0.0220	-0.166	-0.0932
-8.	-0.166	0.0194	-0.139	-0.0940
-7.	-0.064	0.0178	-0.112	-0.0946
-6.	0.040	0.0165	-0.085	-0.0954
-5.	0.146	0.0158	-0.058	-0.0962
-4.	0.252	0.0160	-0.030	-0.0970
-3.	0.365	0.0165	-0.001	-0.0980
-2.	0.470	0.0176	0.029	-0.0984
-1.	0.569	0.0191	0.056	-0.0956
0.	0.676	0.0214	0.083	-0.0972
1.	0.773	0.0246	0.110	-0.0960
2.	0.866	0.0286	0.137	-0.0936
3.	0.963	0.0333	0.166	-0.0911
4.	1.062	0.0379	0.193	-0.0900
5.	1.154	0.0425	0.219	-0.0882
6.	1.244	0.0473	0.244	-0.0875
7.	1.326	0.0532	0.269	-0.0842
8.	1.403	0.0597	0.292	-0.0809
9.	1.482	0.0689	0.315	-0.0784
10.	1.526	0.0792	0.338	-0.0761
11.	1.568	0.0920	0.358	-0.0768
12.	1.598	0.1067	0.345	-0.0774
13.	1.626	0.1247	0.349	-0.0805
14.	1.639	0.1463	0.345	-0.0867
15.	1.639	0.1702	0.345	-0.0892
16.	1.637	0.1932	0.336	-0.0974
17.	1.640	0.2163	0.335	-0.1000
18.	1.640	0.2403	0.326	-0.1094
19.	1.633	0.2654	0.320	-0.1152
20.	1.618	0.2959	0.309	-0.1233

CLARK-Y RE=.5(10)6 40X35+P TSUCL

ALF	CL	CD	CNO	CMC/4
-10.	-0.351	0.0240	-0.182	-0.0880
-9.	-0.258	0.0199	-0.158	-0.0885
-8.	-0.163	0.0179	-0.132	-0.0884
-7.	-0.068	0.0166	-0.108	-0.0889
-6.	0.025	0.0157	-0.083	-0.0895
-5.	0.120	0.0155	-0.058	-0.0898
-4.	0.215	0.0162	-0.033	-0.0904
-3.	0.312	0.0174	-0.008	-0.0912
-2.	0.409	0.0194	0.020	-0.0901
-1.	0.498	0.0205	0.045	-0.0892
0.	0.594	0.0229	0.069	-0.0904
1.	0.682	0.0265	0.094	-0.0896
2.	0.771	0.0300	0.118	-0.0889
3.	0.857	0.0340	0.143	-0.0873
4.	0.943	0.0389	0.167	-0.0864
5.	1.022	0.0437	0.190	-0.0851
6.	1.102	0.0490	0.212	-0.0842
7.	1.179	0.0545	0.233	-0.0835
8.	1.250	0.0608	0.254	-0.0810
9.	1.317	0.0678	0.275	-0.0780
10.	1.374	0.0778	0.291	-0.0766
11.	1.423	0.0873	0.304	-0.0762
12.	1.462	0.1000	0.314	-0.0762
13.	1.491	0.1124	0.323	-0.0765
14.	1.512	0.1296	0.323	-0.0767
15.	1.519	0.1482	0.320	-0.0848
16.	1.515	0.1694	0.314	-0.0905
17.	1.504	0.1899	0.306	-0.0961
18.	1.495	0.2095	0.293	-0.1064

CLARK-Y RE=.5(10)6 40XLS+P TSUCL

ALF	CL	CD	CNO	CMC/4
-10.	-0.355	0.0228	-0.186	-0.0899
-9.	-0.262	0.0198	-0.161	-0.0898
-8.	-0.166	0.0176	-0.135	-0.0896
-7.	-0.070	0.0162	-0.109	-0.0896
-6.	0.024	0.0160	-0.084	-0.0902
-5.	0.119	0.0162	-0.059	-0.0908
-4.	0.216	0.0164	-0.033	-0.0910
-3.	0.314	0.0175	-0.007	-0.0917
-2.	0.409	0.0186	0.020	-0.0905
-1.	0.497	0.0202	0.045	-0.0892
0.	0.596	0.0232	0.070	-0.0914
1.	0.688	0.0269	0.095	-0.0913
2.	0.773	0.0309	0.120	-0.0895
3.	0.864	0.0363	0.145	-0.0893
4.	0.948	0.0417	0.169	-0.0885
5.	1.031	0.0468	0.192	-0.0878
6.	1.112	0.0520	0.214	-0.0876
7.	1.189	0.0582	0.235	-0.0864
8.	1.262	0.0648	0.257	-0.0843
9.	1.329	0.0716	0.276	-0.0823
10.	1.385	0.0802	0.294	-0.0790
11.	1.430	0.0905	0.307	-0.0780
12.	1.472	0.1020	0.316	-0.0796
13.	1.498	0.1152	0.323	-0.0797
14.	1.517	0.1311	0.326	-0.0815
15.	1.516	0.1424	0.321	-0.0859
16.	1.519	0.1689	0.315	-0.0938
17.	1.516	0.1924	0.308	-0.1000
18.	1.511	0.2155	0.299	-0.1086

Table 5 - 0.53-Clark-Y

CLARK-Y RE=.5(10)6 50ZLS+P TSUSL

ALF	CL	CD	CM0	CMC/4
-10.	-0.344	0.0225	-0.179	-0.0874
-9.	-0.252	0.0190	-0.154	-0.0869
-8.	-0.157	0.0162	-0.129	-0.0872
-7.	-0.063	0.0140	-0.105	-0.0861
-6.	0.030	0.0130	-0.081	-0.0881
-5.	0.124	0.0123	-0.056	-0.0886
-4.	0.221	0.0122	-0.031	-0.0895
-3.	0.319	0.0137	-0.005	-0.0904
-2.	0.409	0.0152	0.021	-0.0881
-1.	0.499	0.0164	0.046	-0.0876
0.	0.595	0.0194	0.070	-0.0891
1.	0.686	0.0230	0.095	-0.0890
2.	0.769	0.0263	0.118	-0.0876
3.	0.855	0.0315	0.143	-0.0861
4.	0.942	0.0375	0.166	-0.0858
5.	1.024	0.0427	0.189	-0.0851
6.	1.101	0.0480	0.211	-0.0835
7.	1.176	0.0541	0.232	-0.0817
8.	1.251	0.0605	0.252	-0.0813
9.	1.319	0.0688	0.272	-0.0791
10.	1.373	0.0763	0.289	-0.0770
11.	1.405	0.0856	0.302	-0.0720
12.	1.442	0.0967	0.310	-0.0729
13.	1.469	0.1101	0.318	-0.0713
14.	1.488	0.1279	0.319	-0.0758
15.	1.490	0.1466	0.313	-0.0824
16.	1.488	0.1684	0.309	-0.0864
17.	1.483	0.1885	0.300	-0.0944
18.	1.463	0.2093	0.292	-0.0976
19.	1.444	0.2283	0.279	-0.1061
20.	1.408	0.2500	0.265	-0.1121

CLARK-Y RE=.5(10)6 60ZLS+P TSUSL

ALF	CL	CD	CM0	CMC/4
-10.	-0.336	0.0246	-0.179	-0.0878
-9.	-0.245	0.0212	-0.155	-0.0883
-8.	-0.151	0.0195	-0.129	-0.0878
-7.	-0.057	0.0177	-0.104	-0.0884
-6.	0.034	0.0171	-0.080	-0.0886
-5.	0.127	0.0168	-0.055	-0.0893
-4.	0.221	0.0169	-0.031	-0.0901
-3.	0.315	0.0175	-0.005	-0.0905
-2.	0.409	0.0188	0.022	-0.0891
-1.	0.493	0.0201	0.046	-0.0875
0.	0.589	0.0228	0.071	-0.0889
1.	0.678	0.0266	0.095	-0.0897
2.	0.762	0.0310	0.118	-0.0890
3.	0.843	0.0352	0.142	-0.0870
4.	0.932	0.0402	0.165	-0.0877
5.	1.005	0.0453	0.188	-0.0851
6.	1.087	0.0503	0.209	-0.0861
7.	1.154	0.0553	0.230	-0.0832
8.	1.223	0.0605	0.250	-0.0813
9.	1.282	0.0677	0.268	-0.0789
10.	1.333	0.0748	0.284	-0.0764
11.	1.379	0.0844	0.296	-0.0756
12.	1.413	0.0960	0.305	-0.0755
13.	1.437	0.1078	0.311	-0.0758
14.	1.451	0.1228	0.312	-0.0783
15.	1.453	0.1400	0.307	-0.0838
16.	1.446	0.1583	0.300	-0.0898
17.	1.434	0.1768	0.289	-0.0975
18.	1.407	0.1949	0.281	-0.0987
19.	1.375	0.2145	0.268	-0.1041

CLARK-Y RE=.5(10)6 70ZLS+P TSUSL

ALF	CL	CD	CM0	CMC/4
-10.	-0.331	0.0237	-0.176	-0.0864
-9.	-0.240	0.0201	-0.151	-0.0860
-8.	-0.148	0.0178	-0.125	-0.0852
-7.	-0.053	0.0161	-0.101	-0.0860
-6.	0.037	0.0140	-0.076	-0.0858
-5.	0.130	0.0128	-0.052	-0.0866
-4.	0.224	0.0129	-0.027	-0.0873
-3.	0.316	0.0132	-0.003	-0.0880
-2.	0.409	0.0136	0.024	-0.0865
-1.	0.494	0.0142	0.048	-0.0853
0.	0.587	0.0164	0.071	-0.0872
1.	0.672	0.0192	0.095	-0.0865
2.	0.756	0.0224	0.118	-0.0858
3.	0.836	0.0262	0.142	-0.0839
4.	0.924	0.0299	0.165	-0.0847
5.	0.992	0.0343	0.186	-0.0819
6.	1.068	0.0392	0.207	-0.0811
7.	1.137	0.0459	0.226	-0.0799
8.	1.198	0.0514	0.245	-0.0772
9.	1.256	0.0571	0.263	-0.0744
10.	1.302	0.0639	0.278	-0.0713
11.	1.342	0.0742	0.289	-0.0708
12.	1.371	0.0841	0.297	-0.0701
13.	1.393	0.0952	0.302	-0.0708
14.	1.401	0.1111	0.298	-0.0761
15.	1.401	0.1260	0.294	-0.0805
16.	1.383	0.1439	0.286	-0.0835
17.	1.361	0.1621	0.274	-0.0900

CLARK-Y RE=.5(10)6 80ZLS+P TSUSL

ALF	CL	CD	CM0	CMC/4
-10.	-0.315	0.0213	-0.171	-0.0840
-9.	-0.224	0.0179	-0.146	-0.0843
-8.	-0.132	0.0157	-0.122	-0.0854
-7.	-0.041	0.0145	-0.097	-0.0854
-6.	0.047	0.0132	-0.073	-0.0855
-5.	0.137	0.0125	-0.050	-0.0870
-4.	0.227	0.0133	-0.025	-0.0875
-3.	0.320	0.0137	0.000	-0.0877
-2.	0.411	0.0144	0.027	-0.0860
-1.	0.493	0.0155	0.051	-0.0850
0.	0.588	0.0165	0.075	-0.0873
1.	0.671	0.0191	0.099	-0.0871
2.	0.751	0.0214	0.122	-0.0853
3.	0.830	0.0224	0.146	-0.0836
4.	0.908	0.0246	0.168	-0.0828
5.	0.982	0.0269	0.189	-0.0821
6.	1.052	0.0302	0.209	-0.0813
7.	1.112	0.0347	0.228	-0.0787
8.	1.168	0.0381	0.245	-0.0762
9.	1.216	0.0424	0.261	-0.0733
10.	1.248	0.0477	0.272	-0.0703
11.	1.282	0.0540	0.280	-0.0711
12.	1.296	0.0623	0.284	-0.0698
13.	1.304	0.0727	0.283	-0.0727
14.	1.290	0.0866	0.277	-0.0751
15.	1.265	0.1010	0.266	-0.0788
16.	1.238	0.1172	0.254	-0.0843

Table 5 0.53-Clark-Y

CLARK-Y RE=.5(10)6 50%SS+P TSUSL

ALF	CL	CD	CM0	CMC/4
-10.	-0.347	0.0234	-0.181	-0.0876
-9.	-0.254	0.0195	-0.157	-0.0882
-8.	-0.159	0.0165	-0.131	-0.0875
-7.	-0.065	0.0151	-0.106	-0.0885
-6.	0.028	0.0143	-0.082	-0.0886
-5.	0.122	0.0140	-0.057	-0.0892
-4.	0.217	0.0145	-0.032	-0.0900
-3.	0.313	0.0159	-0.006	-0.0905
-2.	0.407	0.0177	0.020	-0.0892
-1.	0.494	0.0185	0.045	-0.0881
0.	0.591	0.0205	0.070	-0.0897
1.	0.678	0.0241	0.094	-0.0889
2.	0.763	0.0280	0.117	-0.0883
3.	0.848	0.0322	0.142	-0.0867
4.	0.936	0.0366	0.166	-0.0863
5.	1.012	0.0413	0.188	-0.0846
6.	1.092	0.0463	0.210	-0.0839
7.	1.162	0.0524	0.230	-0.0820
8.	1.235	0.0584	0.252	-0.0800
9.	1.302	0.0668	0.271	-0.0779
10.	1.357	0.0758	0.288	-0.0756
11.	1.401	0.0860	0.300	-0.0744
12.	1.440	0.0972	0.310	-0.0750
13.	1.466	0.1097	0.316	-0.0753
14.	1.481	0.1262	0.318	-0.0770
15.	1.490	0.1454	0.310	-0.0880
16.	1.486	0.1646	0.309	-0.0874
17.	1.476	0.1869	0.299	-0.0961
18.	1.457	0.2042	0.291	-0.0993

CLARK-Y RE=.5(10)6 70%SS+P TSUSL

ALF	CL	CD	CM0	CMC/4
-10.	-0.331	0.0225	-0.177	-0.0874
-9.	-0.242	0.0195	-0.153	-0.0871
-8.	-0.149	0.0173	-0.128	-0.0874
-7.	-0.057	0.0157	-0.102	-0.0864
-6.	0.034	0.0152	-0.078	-0.0867
-5.	0.125	0.0151	-0.054	-0.0877
-4.	0.218	0.0152	-0.029	-0.0881
-3.	0.311	0.0158	-0.005	-0.0889
-2.	0.406	0.0167	0.022	-0.0878
-1.	0.489	0.0179	0.046	-0.0865
0.	0.584	0.0203	0.070	-0.0882
1.	0.669	0.0234	0.093	-0.0882
2.	0.751	0.0270	0.117	-0.0869
3.	0.834	0.0307	0.141	-0.0852
4.	0.916	0.0349	0.164	-0.0843
5.	0.993	0.0386	0.185	-0.0840
6.	1.063	0.0433	0.206	-0.0824
7.	1.130	0.0454	0.225	-0.0803
8.	1.199	0.0514	0.245	-0.0786
9.	1.257	0.0577	0.263	-0.0763
10.	1.304	0.0652	0.277	-0.0743
11.	1.341	0.0738	0.288	-0.0727
12.	1.369	0.0831	0.295	-0.0724
13.	1.387	0.0944	0.301	-0.0709
14.	1.404	0.1096	0.299	-0.0780
15.	1.393	0.1255	0.292	-0.0816
16.	1.380	0.1433	0.284	-0.0867
17.	1.362	0.1693	0.273	-0.0928
18.	1.331	0.1794	0.262	-0.0967

CLARK-Y RE=.5(10)6 60%SS+P TSUSL

ALF	CL	CD	CM0	CMC/4
-10.	-0.342	0.0236	-0.180	-0.0877
-9.	-0.247	0.0205	-0.155	-0.0881
-8.	-0.155	0.0183	-0.130	-0.0882
-7.	-0.061	0.0165	-0.105	-0.0886
-6.	0.030	0.0155	-0.081	-0.0886
-5.	0.124	0.0152	-0.056	-0.0892
-4.	0.218	0.0154	-0.031	-0.0899
-3.	0.315	0.0165	-0.005	-0.0903
-2.	0.406	0.0174	0.021	-0.0888
-1.	0.492	0.0185	0.045	-0.0881
0.	0.587	0.0214	0.069	-0.0896
1.	0.676	0.0241	0.093	-0.0900
2.	0.760	0.0277	0.117	-0.0885
3.	0.842	0.0321	0.141	-0.0863
4.	0.929	0.0362	0.164	-0.0867
5.	1.004	0.0407	0.187	-0.0843
6.	1.085	0.0454	0.209	-0.0839
7.	1.155	0.0508	0.230	-0.0818
8.	1.224	0.0558	0.251	-0.0790
9.	1.286	0.0627	0.270	-0.0759
10.	1.336	0.0708	0.285	-0.0738
11.	1.381	0.0804	0.297	-0.0741
12.	1.416	0.0914	0.305	-0.0743
13.	1.439	0.1019	0.312	-0.0734
14.	1.451	0.1182	0.312	-0.0769
15.	1.453	0.1340	0.309	-0.0805
16.	1.443	0.1533	0.298	-0.0889
17.	1.429	0.1711	0.289	-0.0945
18.	1.413	0.1901	0.280	-0.0996

CLARK-Y RE=.5(10)6 80%SS+P TSUSL

ALF	CL	CD	CM0	CMC/4
-10.	-0.324	0.0222	-0.173	-0.0838
-9.	-0.237	0.0191	-0.149	-0.0832
-8.	-0.141	0.0169	-0.124	-0.0845
-7.	-0.047	0.0157	-0.099	-0.0857
-6.	0.039	0.0143	-0.076	-0.0859
-5.	0.132	0.0135	-0.051	-0.0868
-4.	0.222	0.0139	-0.027	-0.0874
-3.	0.315	0.0142	-0.002	-0.0881
-2.	0.406	0.0151	0.025	-0.0864
-1.	0.493	0.0159	0.050	-0.0857
0.	0.583	0.0173	0.073	-0.0870
1.	0.669	0.0199	0.097	-0.0872
2.	0.749	0.0227	0.121	-0.0845
3.	0.827	0.0259	0.144	-0.0832
4.	0.909	0.0279	0.166	-0.0834
5.	0.978	0.0305	0.188	-0.0805
6.	1.053	0.0331	0.208	-0.0813
7.	1.120	0.0374	0.229	-0.0782
8.	1.182	0.0424	0.246	-0.0778
9.	1.237	0.0478	0.265	-0.0732
10.	1.280	0.0539	0.277	-0.0727
11.	1.310	0.0606	0.287	-0.0699
12.	1.334	0.0693	0.294	-0.0691
13.	1.349	0.0801	0.295	-0.0711
14.	1.353	0.0934	0.290	-0.0769
15.	1.340	0.1095	0.284	-0.0803
16.	1.321	0.1251	0.271	-0.0879
17.	1.279	0.1412	0.260	-0.0880
18.	1.236	0.1557	0.242	-0.0940

Table 5 - 0.66-Clark-Y

CLARK-Y RE=.5(10)6 SOLID WALLS

ALF	CL	CD	CMO	CMC/4
-10.	-0.394	0.0346	-0.203	-0.0988
-9.	-0.290	0.0295	-0.175	-0.0986
-8.	-0.182	0.0258	-0.148	-0.0994
-7.	-0.076	0.0239	-0.121	-0.1003
-6.	0.031	0.0228	-0.093	-0.1004
-5.	0.139	0.0219	-0.065	-0.1012
-4.	0.250	0.0222	-0.037	-0.1020
-3.	0.364	0.0230	-0.007	-0.1030
-2.	0.475	0.0245	0.022	-0.1029
-1.	0.579	0.0246	0.051	-0.1016
0.	0.683	0.0293	0.078	-0.1025
1.	0.785	0.0334	0.105	-0.1018
2.	0.880	0.0380	0.134	-0.0987
3.	0.974	0.0431	0.162	-0.0948
4.	1.070	0.0480	0.190	-0.0930
5.	1.154	0.0536	0.215	-0.0896
6.	1.241	0.0597	0.240	-0.0876
7.	1.328	0.0670	0.264	-0.0859
8.	1.425	0.0747	0.288	-0.0870
9.	1.521	0.0859	0.317	-0.0831
10.	1.593	0.0976	0.334	-0.0844
11.	1.648	0.1122	0.347	-0.0855
12.	1.670	0.1343	0.349	-0.0896
13.	1.686	0.1547	0.351	-0.0912
14.	1.712	0.1735	0.356	-0.0937
15.	1.735	0.1924	0.359	-0.0962

CLARK-Y RE=.5(10)6 40XSS+P TSUSL

ALF	CL	CD	CMO	CMC/4
-10.	-0.363	0.0337	-0.187	-0.0907
-9.	-0.275	0.0265	-0.163	-0.0893
-8.	-0.181	0.0238	-0.138	-0.0891
-7.	-0.089	0.0217	-0.114	-0.0896
-6.	0.003	0.0202	-0.089	-0.0897
-5.	0.095	0.0189	-0.064	-0.0893
-4.	0.192	0.0191	-0.039	-0.0898
-3.	0.288	0.0202	-0.015	-0.0908
-2.	0.383	0.0222	0.010	-0.0911
-1.	0.472	0.0243	0.036	-0.0893
0.	0.562	0.0268	0.060	-0.0894
1.	0.659	0.0307	0.085	-0.0906
2.	0.747	0.0358	0.109	-0.0899
3.	0.832	0.0414	0.133	-0.0880
4.	0.917	0.0480	0.156	-0.0866
5.	1.000	0.0547	0.179	-0.0869
6.	1.068	0.0609	0.199	-0.0849
7.	1.141	0.0682	0.220	-0.0829
8.	1.223	0.0756	0.240	-0.0845
9.	1.296	0.0851	0.260	-0.0838
10.	1.365	0.0955	0.279	-0.0826
11.	1.419	0.1062	0.294	-0.0812
12.	1.463	0.1195	0.305	-0.0820
13.	1.501	0.1335	0.312	-0.0842
14.	1.533	0.1472	0.317	-0.0879
15.	1.567	0.1642	0.325	-0.0889
16.	1.600	0.1854	0.328	-0.0939
17.	1.577	0.2026	0.318	-0.0984
18.	1.568	0.2283	0.306	-0.1089

CLARK-Y RE=.5(10)6 40XLS+P TSUSL

ALF	CL	CD	CMO	CMC/4
-10.	-0.380	0.0317	-0.190	-0.0897
-9.	-0.285	0.0268	-0.165	-0.0895
-8.	-0.189	0.0238	-0.140	-0.0899
-7.	-0.093	0.0218	-0.114	-0.0892
-6.	-0.002	0.0204	-0.090	-0.0889
-5.	0.094	0.0202	-0.065	-0.0894
-4.	0.194	0.0203	-0.040	-0.0902
-3.	0.291	0.0218	-0.014	-0.0903
-2.	0.386	0.0243	0.011	-0.0905
-1.	0.477	0.0270	0.036	-0.0896
0.	0.567	0.0299	0.060	-0.0893
1.	0.663	0.0337	0.085	-0.0906
2.	0.756	0.0385	0.109	-0.0901
3.	0.851	0.0437	0.135	-0.0900
4.	0.940	0.0496	0.159	-0.0892
5.	1.025	0.0554	0.182	-0.0886
6.	1.104	0.0614	0.204	-0.0870
7.	1.187	0.0685	0.227	-0.0859
8.	1.270	0.0768	0.249	-0.0852
9.	1.352	0.0860	0.271	-0.0850
10.	1.421	0.0972	0.289	-0.0841
11.	1.479	0.1077	0.308	-0.0803
12.	1.514	0.1205	0.318	-0.0794
13.	1.545	0.1377	0.323	-0.0823
14.	1.576	0.1561	0.325	-0.0884
15.	1.593	0.1759	0.324	-0.0943
16.	1.601	0.1990	0.318	-0.1029
17.	1.601	0.2236	0.311	-0.1095
18.	1.601	0.2496	0.302	-0.1196

Table 5 - 0.66-Clark-Y
CLARK-Y RE=:5(10)6 50ZLS+P TSUSL

ALF	CL	CD	CM0	CMC/4
-10.	-0.362	0.0324	-0.185	-0.0896
-9.	-0.272	0.0273	-0.160	-0.0882
-8.	-0.174	0.0233	-0.135	-0.0877
-7.	-0.082	0.0205	-0.110	-0.0885
-6.	0.010	0.0187	-0.086	-0.0880
-5.	0.104	0.0181	-0.061	-0.0882
-4.	0.200	0.0192	-0.037	-0.0892
-3.	0.296	0.0205	-0.012	-0.0897
-2.	0.390	0.0225	0.013	-0.0893
-1.	0.478	0.0250	0.037	-0.0883
0.	0.571	0.0268	0.062	-0.0883
1.	0.666	0.0311	0.086	-0.0898
2.	0.754	0.0361	0.109	-0.0891
3.	0.845	0.0416	0.133	-0.0891
4.	0.929	0.0475	0.157	-0.0875
5.	1.009	0.0530	0.179	-0.0862
6.	1.088	0.0592	0.201	-0.0850
7.	1.164	0.0661	0.223	-0.0829
8.	1.246	0.0735	0.244	-0.0832
9.	1.324	0.0823	0.265	-0.0822
10.	1.390	0.0920	0.285	-0.0796
11.	1.438	0.1022	0.299	-0.0769
12.	1.470	0.1155	0.308	-0.0763
13.	1.500	0.1315	0.312	-0.0804
14.	1.520	0.1501	0.314	-0.0837
15.	1.531	0.1694	0.310	-0.0907
16.	1.530	0.1915	0.302	-0.0990
17.	1.515	0.2135	0.295	-0.1019
18.	1.506	0.2356	0.283	-0.1133

CLARK-Y RE=:5(10)6 60ZLS+P TSUSL

ALF	CL	CD	CM0	CMC/4
-10.	-0.354	0.0313	-0.187	-0.0898
-9.	-0.263	0.0268	-0.162	-0.0897
-8.	-0.169	0.0240	-0.137	-0.0903
-7.	-0.075	0.0221	-0.112	-0.0909
-6.	0.013	0.0211	-0.088	-0.0905
-5.	0.108	0.0211	-0.062	-0.0912
-4.	0.200	0.0213	-0.037	-0.0915
-3.	0.297	0.0244	-0.012	-0.0933
-2.	0.389	0.0263	0.014	-0.0924
-1.	0.475	0.0291	0.038	-0.0916
0.	0.561	0.0315	0.063	-0.0906
1.	0.651	0.0357	0.086	-0.0919
2.	0.737	0.0400	0.111	-0.0911
3.	0.823	0.0450	0.135	-0.0911
4.	0.901	0.0504	0.157	-0.0902
5.	0.980	0.0560	0.179	-0.0894
6.	1.055	0.0613	0.199	-0.0897
7.	1.131	0.0677	0.221	-0.0882
8.	1.205	0.0747	0.242	-0.0880
9.	1.268	0.0833	0.262	-0.0846
10.	1.325	0.0918	0.280	-0.0819
11.	1.369	0.1000	0.291	-0.0815
12.	1.398	0.1121	0.297	-0.0836
13.	1.427	0.1253	0.300	-0.0880
14.	1.446	0.1384	0.302	-0.0910
15.	1.447	0.1559	0.297	-0.0961
16.	1.441	0.1755	0.290	-0.1019
17.	1.436	0.1951	0.280	-0.1112
18.	1.400	0.2140	0.265	-0.1173

CLARK-Y RE=:5(10)6 70ZLS+P TSUSL

ALF	CL	CD	CM0	CMC/4
-10.	-0.250	0.0303	-0.182	-0.0864
-9.	-0.260	0.0251	-0.157	-0.0862
-8.	-0.168	0.0217	-0.132	-0.0862
-7.	-0.076	0.0194	-0.109	-0.0877
-6.	0.011	0.0183	-0.084	-0.0867
-5.	0.104	0.0172	-0.060	-0.0880
-4.	0.197	0.0183	-0.035	-0.0880
-3.	0.289	0.0204	-0.011	-0.0887
-2.	0.380	0.0216	0.016	-0.0873
-1.	0.466	0.0232	0.040	-0.0868
0.	0.551	0.0269	0.064	-0.0858
1.	0.644	0.0289	0.086	-0.0888
2.	0.728	0.0321	0.110	-0.0881
3.	0.809	0.0367	0.133	-0.0865
4.	0.889	0.0416	0.155	-0.0861
5.	0.963	0.0458	0.177	-0.0851
6.	1.030	0.0499	0.197	-0.0828
7.	1.106	0.0549	0.216	-0.0834
8.	1.173	0.0606	0.236	-0.0816
9.	1.236	0.0659	0.253	-0.0809
10.	1.286	0.0720	0.270	-0.0770
11.	1.323	0.0805	0.281	-0.0762
12.	1.346	0.0909	0.286	-0.0766
13.	1.365	0.1021	0.288	-0.0794
14.	1.369	0.1167	0.289	-0.0799
15.	1.367	0.1324	0.280	-0.0882
16.	1.341	0.1508	0.267	-0.0941

CLARK-Y RE=:5(10)6 80ZLS+P TSUSL

ALF	CL	CD	CM0	CMC/4
-10.	-0.328	0.0273	-0.177	-0.0854
-9.	-0.243	0.0239	-0.153	-0.0849
-8.	-0.150	0.0209	-0.128	-0.0856
-7.	-0.063	0.0182	-0.103	-0.0848
-6.	0.024	0.0167	-0.079	-0.0855
-5.	0.115	0.0153	-0.054	-0.0861
-4.	0.204	0.0147	-0.031	-0.0872
-3.	0.294	0.0156	-0.005	-0.0863
-2.	0.368	0.0170	0.022	-0.0865
-1.	0.474	0.0185	0.046	-0.0863
0.	0.562	0.0196	0.071	-0.0863
1.	0.645	0.0219	0.094	-0.0864
2.	0.725	0.0246	0.117	-0.0855
3.	0.803	0.0272	0.141	-0.0835
4.	0.879	0.0293	0.163	-0.0826
5.	0.942	0.0319	0.183	-0.0798
6.	1.007	0.0346	0.202	-0.0783
7.	1.064	0.0376	0.221	-0.0753
8.	1.121	0.0418	0.238	-0.0737
9.	1.169	0.0465	0.251	-0.0742
10.	1.200	0.0533	0.261	-0.0715
11.	1.226	0.0615	0.266	-0.0734
12.	1.235	0.0723	0.268	-0.0735
13.	1.237	0.0807	0.265	-0.0763
14.	1.230	0.0912	0.263	-0.0768
15.	1.188	0.1060	0.243	-0.0854
16.	1.075	0.1291	0.210	-0.0883

Table 5 - 0.66-Clark-Y
CLARK-Y RE=:5(10)6 50XSS+P TSUSL

ALF	CL	CD	CM0	CMC/4
-10.	-0.357	0.0325	-0.191	-0.0931
-9.	-0.265	0.0278	-0.166	-0.0934
-8.	-0.170	0.0250	-0.140	-0.0928
-7.	-0.076	0.0220	-0.114	-0.0926
-6.	0.015	0.0203	-0.088	-0.0919
-5.	0.110	0.0193	-0.063	-0.0931
-4.	0.206	0.0198	-0.037	-0.0932
-3.	0.301	0.0210	-0.012	-0.0941
-2.	0.395	0.0222	0.015	-0.0934
-1.	0.485	0.0240	0.040	-0.0927
0.	0.578	0.0262	0.065	-0.0935
1.	0.670	0.0303	0.090	-0.0940
2.	0.753	0.0342	0.114	-0.0926
3.	0.841	0.0394	0.139	-0.0919
4.	0.923	0.0446	0.161	-0.0919
5.	0.999	0.0500	0.183	-0.0908
6.	1.071	0.0559	0.205	-0.0886
7.	1.148	0.0637	0.225	-0.0893
8.	1.220	0.0713	0.244	-0.0891
9.	1.291	0.0797	0.264	-0.0890
10.	1.352	0.0892	0.282	-0.0873
11.	1.399	0.0983	0.297	-0.0843
12.	1.426	0.1085	0.305	-0.0829
13.	1.477	0.1250	0.311	-0.0909
14.	1.495	0.1411	0.316	-0.0908
15.	1.510	0.1594	0.314	-0.0969
16.	1.492	0.1811	0.306	-0.1007
17.	1.456	0.1976	0.283	-0.1149

CLARK-Y RE=:5(10)6 70XSS+P TSUSL

ALF	CL	CD	CM0	CMC/4
-10.	-0.343	0.0310	-0.179	-0.0857
-9.	-0.258	0.0260	-0.156	-0.0863
-8.	-0.165	0.0225	-0.132	-0.0866
-7.	-0.073	0.0199	-0.108	-0.0873
-6.	0.012	0.0183	-0.085	-0.0878
-5.	0.106	0.0168	-0.060	-0.0883
-4.	0.198	0.0170	-0.036	-0.0887
-3.	0.291	0.0179	-0.011	-0.0893
-2.	0.383	0.0186	0.015	-0.0880
-1.	0.470	0.0207	0.040	-0.0873
0.	0.557	0.0224	0.063	-0.0876
1.	0.648	0.0256	0.087	-0.0885
2.	0.732	0.0285	0.110	-0.0880
3.	0.810	0.0328	0.134	-0.0856
4.	0.892	0.0363	0.157	-0.0841
5.	0.959	0.0403	0.177	-0.0819
6.	1.031	0.0452	0.197	-0.0819
7.	1.098	0.0512	0.215	-0.0811
8.	1.164	0.0580	0.235	-0.0791
9.	1.230	0.0650	0.253	-0.0785
10.	1.284	0.0725	0.269	-0.0765
11.	1.323	0.0799	0.281	-0.0741
12.	1.349	0.0908	0.286	-0.0757
13.	1.365	0.1029	0.289	-0.0766
14.	1.374	0.1150	0.298	-0.0801
15.	1.362	0.1322	0.279	-0.0856
16.	1.329	0.1500	0.263	-0.0934

CLARK-Y RE=:5(10)6 60XSS+P TSUSL

ALF	CL	CD	CM0	CMC/4
-10.	-0.356	0.0320	-0.184	-0.0885
-9.	-0.268	0.0273	-0.162	-0.0897
-8.	-0.174	0.0236	-0.136	-0.0882
-7.	-0.082	0.0208	-0.112	-0.0895
-6.	0.007	0.0192	-0.088	-0.0892
-5.	0.100	0.0191	-0.063	-0.0896
-4.	0.193	0.0191	-0.038	-0.0900
-3.	0.288	0.0197	-0.014	-0.0907
-2.	0.383	0.0221	0.012	-0.0907
-1.	0.470	0.0240	0.038	-0.0890
0.	0.558	0.0262	0.061	-0.0888
1.	0.650	0.0297	0.085	-0.0901
2.	0.737	0.0338	0.109	-0.0898
3.	0.821	0.0398	0.133	-0.0886
4.	0.902	0.0448	0.156	-0.0870
5.	0.979	0.0506	0.179	-0.0848
6.	1.051	0.0555	0.199	-0.0839
7.	1.123	0.0613	0.219	-0.0828
8.	1.193	0.0679	0.239	-0.0818
9.	1.260	0.0762	0.257	-0.0808
10.	1.323	0.0843	0.276	-0.0790
11.	1.366	0.0928	0.290	-0.0758
12.	1.394	0.1034	0.298	-0.0749
13.	1.424	0.1160	0.301	-0.0794
14.	1.442	0.1308	0.303	-0.0823
15.	1.449	0.1497	0.299	-0.0886
16.	1.433	0.1686	0.292	-0.0916
17.	1.409	0.1891	0.275	-0.1027

CLARK-Y RE=:5(10)6 80XSS+P TSUSL

ALF	CL	CD	CM0	CMC/4
-10.	-0.346	0.0290	-0.181	-0.0855
-9.	-0.257	0.0256	-0.155	-0.0836
-8.	-0.168	0.0229	-0.130	-0.0830
-7.	-0.072	0.0215	-0.106	-0.0852
-6.	0.012	0.0200	-0.082	-0.0842
-5.	0.105	0.0188	-0.058	-0.0859
-4.	0.192	0.0188	-0.033	-0.0856
-3.	0.286	0.0190	-0.009	-0.0875
-2.	0.378	0.0201	0.018	-0.0845
-1.	0.461	0.0211	0.043	-0.0846
0.	0.549	0.0231	0.067	-0.0857
1.	0.636	0.0261	0.090	-0.0857
2.	0.716	0.0291	0.113	-0.0846
3.	0.796	0.0327	0.136	-0.0838
4.	0.873	0.0361	0.160	-0.0813
5.	0.944	0.0397	0.180	-0.0805
6.	1.014	0.0433	0.201	-0.0786
7.	1.081	0.0478	0.220	-0.0778
8.	1.143	0.0523	0.237	-0.0770
9.	1.205	0.0572	0.255	-0.0761
10.	1.243	0.0619	0.271	-0.0704
11.	1.277	0.0690	0.278	-0.0715
12.	1.286	0.0793	0.280	-0.0712
13.	1.292	0.0892	0.278	-0.0751
14.	1.249	0.1037	0.267	-0.0738
15.	1.194	0.1168	0.242	-0.0843

Table 5 - 0.66-Clark-Y
CLARK-Y RE=(10)6 SOLID WALLS

ALF	CL	CD	CMO	CMC/4
-10.	-0.437	0.0304	-0.196	-0.0843
-9.	-0.319	0.0270	-0.174	-0.0927
-8.	-0.198	0.0244	-0.147	-0.0959
-7.	-0.085	0.0226	-0.120	-0.0977
-6.	0.028	0.0213	-0.092	-0.0986
-5.	0.145	0.0209	-0.063	-0.0999
-4.	0.262	0.0209	-0.035	-0.1011
-3.	0.379	0.0216	-0.005	-0.1016
-2.	0.496	0.0227	0.025	-0.1014
-1.	0.599	0.0245	0.053	-0.0999
0.	0.697	0.0266	0.080	-0.0980
1.	0.807	0.0301	0.108	-0.0983
2.	0.931	0.0354	0.141	-0.0974
3.	1.031	0.0406	0.169	-0.0940
4.	1.134	0.0469	0.196	-0.0932
5.	1.233	0.0534	0.224	-0.0905
6.	1.339	0.0602	0.250	-0.0918
7.	1.426	0.0692	0.276	-0.0879
8.	1.529	0.0791	0.298	-0.0911
9.	1.603	0.0900	0.320	-0.0880
10.	1.657	0.1026	0.335	-0.0864
11.	1.692	0.1201	0.342	-0.0879
12.	1.730	0.1394	0.349	-0.0907
13.	1.770	0.1595	0.352	-0.0974
14.	1.786	0.1806	0.355	-0.0982
15.	1.826	0.2040	0.357	-0.1070
16.	1.837	0.2267	0.359	-0.1084
17.	1.840	0.2554	0.355	-0.1132
18.	1.846	0.2893	0.346	-0.1251
19.	1.837	0.3294	0.335	-0.1361
20.	1.856	0.3729	0.325	-0.1531

CLARK-Y RE=(10)6 40XLS+P TSUSL

ALF	CL	CD	CMO	CMC/4
-10.	-0.417	0.0289	-0.195	-0.0870
-9.	-0.313	0.0252	-0.170	-0.0886
-8.	-0.209	0.0226	-0.144	-0.0889
-7.	-0.107	0.0207	-0.118	-0.0899
-6.	-0.006	0.0196	-0.093	-0.0909
-5.	0.095	0.0199	-0.067	-0.0913
-4.	0.199	0.0208	-0.040	-0.0916
-3.	0.301	0.0218	-0.014	-0.0923
-2.	0.399	0.0234	0.012	-0.0918
-1.	0.491	0.0259	0.036	-0.0912
0.	0.581	0.0289	0.061	-0.0902
1.	0.677	0.0331	0.086	-0.0904
2.	0.789	0.0386	0.115	-0.0904
3.	0.885	0.0450	0.140	-0.0904
4.	0.981	0.0508	0.165	-0.0902
5.	1.075	0.0575	0.190	-0.0901
6.	1.166	0.0643	0.214	-0.0900
7.	1.258	0.0718	0.237	-0.0905
8.	1.346	0.0816	0.259	-0.0909
9.	1.426	0.0912	0.280	-0.0901
10.	1.489	0.1025	0.297	-0.0896
11.	1.537	0.1140	0.312	-0.0866
12.	1.586	0.1269	0.324	-0.0869
13.	1.626	0.1436	0.331	-0.0900
14.	1.663	0.1612	0.336	-0.0945
15.	1.690	0.1788	0.339	-0.0978
16.	1.698	0.1983	0.337	-0.1017
17.	1.693	0.2203	0.332	-0.1063
18.	1.676	0.2471	0.318	-0.1163

CLARK-Y RE=(10)6 40XSS+P TSUSL

ALF	CL	CD	CMO	CMC/4
-10.	-0.411	0.0287	-0.195	-0.0863
-9.	-0.307	0.0252	-0.170	-0.0894
-8.	-0.203	0.0225	-0.144	-0.0901
-7.	-0.101	0.0207	-0.119	-0.0915
-6.	-0.002	0.0198	-0.093	-0.0922
-5.	0.100	0.0199	-0.067	-0.0928
-4.	0.202	0.0207	-0.040	-0.0929
-3.	0.303	0.0219	-0.014	-0.0933
-2.	0.403	0.0230	0.013	-0.0929
-1.	0.493	0.0255	0.037	-0.0926
0.	0.581	0.0285	0.062	-0.0909
1.	0.676	0.0322	0.087	-0.0917
2.	0.788	0.0378	0.115	-0.0923
3.	0.878	0.0431	0.141	-0.0907
4.	0.968	0.0489	0.164	-0.0912
5.	1.059	0.0553	0.188	-0.0909
6.	1.150	0.0624	0.212	-0.0908
7.	1.239	0.0710	0.234	-0.0920
8.	1.324	0.0802	0.256	-0.0919
9.	1.393	0.0902	0.276	-0.0897
10.	1.427	0.0982	0.288	-0.0861
11.	1.483	0.1097	0.302	-0.0865
12.	1.535	0.1237	0.313	-0.0892
13.	1.580	0.1401	0.320	-0.0934
14.	1.620	0.1583	0.325	-0.0988
15.	1.649	0.1779	0.329	-0.1026
16.	1.661	0.1976	0.328	-0.1066
17.	1.665	0.2204	0.322	-0.1139
18.	1.656	0.2489	0.295	-0.1398

Table 5 - 0.66-Clark-Y
CLARK-Y RE=(10)6 50%LS+P TSUSL

ALF	CL	CD	CM0	CYC/4
-10.	-0.407	0.0263	-0.192	-0.0859
-9.	-0.303	0.0245	-0.165	-0.0865
-8.	-0.196	0.0218	-0.140	-0.0884
-7.	-0.098	0.0199	-0.114	-0.0878
-6.	0.002	0.0186	-0.089	-0.0891
-5.	0.102	0.0185	-0.064	-0.0903
-4.	0.203	0.0194	-0.038	-0.0906
-3.	0.303	0.0200	-0.012	-0.0910
-2.	0.400	0.0217	0.014	-0.0901
-1.	0.492	0.0240	0.038	-0.0900
0.	0.581	0.0268	0.062	-0.0888
1.	0.677	0.0309	0.088	-0.0886
2.	0.784	0.0361	0.115	-0.0896
3.	0.877	0.0418	0.140	-0.0890
4.	0.973	0.0475	0.165	-0.0889
5.	1.062	0.0538	0.187	-0.0893
6.	1.155	0.0606	0.211	-0.0898
7.	1.242	0.0686	0.233	-0.0899
8.	1.321	0.0764	0.254	-0.0894
9.	1.390	0.0855	0.275	-0.0863
10.	1.449	0.0959	0.290	-0.0861
11.	1.495	0.1074	0.304	-0.0832
12.	1.529	0.1186	0.314	-0.0845
13.	1.584	0.1346	0.321	-0.0883
14.	1.612	0.1502	0.325	-0.0918
15.	1.632	0.1677	0.326	-0.0958
16.	1.627	0.1869	0.321	-0.0993
17.	1.614	0.2063	0.313	-0.1046
18.	1.584	0.2324	0.300	-0.1104

CLARK-Y RE=(10)6 60%LS+P TSUSL

ALF	CL	CD	CM0	CYC/4
-10.	-0.395	0.0263	-0.189	-0.0860
-9.	-0.291	0.0205	-0.164	-0.0873
-8.	-0.188	0.0216	-0.137	-0.0873
-7.	-0.089	0.0195	-0.112	-0.0882
-6.	0.007	0.0184	-0.087	-0.0887
-5.	0.106	0.0179	-0.062	-0.0899
-4.	0.204	0.0183	-0.037	-0.0902
-3.	0.303	0.0196	-0.012	-0.0908
-2.	0.399	0.0214	0.015	-0.0899
-1.	0.489	0.0237	0.039	-0.0895
0.	0.584	0.0266	0.065	-0.0885
1.	0.673	0.0299	0.088	-0.0892
2.	0.779	0.0351	0.116	-0.0883
3.	0.870	0.0409	0.141	-0.0878
4.	0.963	0.0462	0.164	-0.0889
5.	1.049	0.0524	0.187	-0.0887
6.	1.124	0.0586	0.210	-0.0877
7.	1.218	0.0652	0.232	-0.0876
8.	1.294	0.0731	0.252	-0.0871
9.	1.360	0.0811	0.271	-0.0847
10.	1.412	0.0897	0.286	-0.0836
11.	1.450	0.0988	0.299	-0.0799
12.	1.490	0.1093	0.308	-0.0802
13.	1.518	0.1222	0.314	-0.0818
14.	1.546	0.1371	0.317	-0.0861
15.	1.550	0.1509	0.316	-0.0873
16.	1.536	0.1679	0.311	-0.0894
17.	1.506	0.1886	0.297	-0.0960
18.	1.460	0.2119	0.278	-0.1034

CLARK-Y RE=(10)6 70%LS+P TSUSL

ALF	CL	CD	CM0	CYC/4
-10.	-0.393	0.0281	-0.190	-0.0849
-9.	-0.289	0.0240	-0.165	-0.0873
-8.	-0.188	0.0210	-0.138	-0.0879
-7.	-0.088	0.0189	-0.113	-0.0889
-6.	0.007	0.0177	-0.087	-0.0885
-5.	0.106	0.0177	-0.062	-0.0896
-4.	0.205	0.0182	-0.036	-0.0903
-3.	0.302	0.0192	-0.011	-0.0914
-2.	0.397	0.0207	0.016	-0.0902
-1.	0.489	0.0226	0.040	-0.0903
0.	0.577	0.0248	0.065	-0.0903
1.	0.668	0.0281	0.090	-0.0890
2.	0.774	0.0323	0.119	-0.0885
3.	0.863	0.0369	0.141	-0.0894
4.	0.949	0.0412	0.165	-0.0887
5.	1.035	0.0468	0.188	-0.0892
6.	1.116	0.0522	0.208	-0.0899
7.	1.193	0.0574	0.230	-0.0886
8.	1.261	0.0634	0.250	-0.0860
9.	1.321	0.0704	0.267	-0.0847
10.	1.362	0.0777	0.281	-0.0813
11.	1.400	0.0851	0.292	-0.0797
12.	1.423	0.0933	0.301	-0.0761
13.	1.452	0.1055	0.305	-0.0791
14.	1.471	0.1186	0.305	-0.0838
15.	1.474	0.1334	0.302	-0.0877
16.	1.455	0.1498	0.292	-0.0929
17.	1.404	0.1715	0.274	-0.0989
18.	1.339	0.1964	0.248	-0.1083

CLARK-Y RE=(10)6 80%LS+P TSUSL

ALF	CL	CD	CM0	CYC/4
-10.	-0.366	0.0253	-0.181	-0.0826
-9.	-0.267	0.0217	-0.156	-0.0838
-8.	-0.171	0.0190	-0.130	-0.0835
-7.	-0.072	0.0169	-0.105	-0.0851
-6.	0.017	0.0155	-0.078	-0.0822
-5.	0.114	0.0152	-0.055	-0.0849
-4.	0.206	0.0156	-0.030	-0.0851
-3.	0.303	0.0160	-0.006	-0.0872
-2.	0.397	0.0174	0.021	-0.0857
-1.	0.486	0.0193	0.045	-0.0856
0.	0.571	0.0210	0.070	-0.0843
1.	0.672	0.0241	0.097	-0.0841
2.	0.759	0.0261	0.121	-0.0839
3.	0.843	0.0280	0.144	-0.0830
4.	0.921	0.0297	0.167	-0.0814
5.	0.999	0.0319	0.189	-0.0803
6.	1.068	0.0351	0.209	-0.0789
7.	1.133	0.0371	0.228	-0.0764
8.	1.186	0.0404	0.245	-0.0736
9.	1.219	0.0451	0.256	-0.0711
10.	1.245	0.0513	0.267	-0.0658
11.	1.267	0.0574	0.275	-0.0633
12.	1.289	0.0657	0.278	-0.0654
13.	1.307	0.0761	0.280	-0.0684
14.	1.293	0.0894	0.271	-0.0736
15.	1.261	0.1060	0.257	-0.0785
16.	1.187	0.1258	0.235	-0.0818

Table 5 -- 0.66-Clark-Y
CLARK-Y RE=(10)6 50XSS+P TSUSL

ALF	CL	CD	CM0	CMC/4
-10.	-0.402	0.0285	-0.191	-0.0866
-9.	-0.300	0.0248	-0.166	-0.0875
-8.	-0.199	0.0219	-0.141	-0.0883
-7.	-0.097	0.0197	-0.114	-0.0883
-6.	-0.002	0.0191	-0.090	-0.0885
-5.	0.101	0.0194	-0.065	-0.0906
-4.	0.196	0.0197	-0.038	-0.0884
-3.	0.295	0.0209	-0.013	-0.0890
-2.	0.400	0.0237	0.013	-0.0907
-1.	0.490	0.0260	0.038	-0.0897
0.	0.581	0.0291	0.063	-0.0886
1.	0.674	0.0327	0.087	-0.0888
2.	0.786	0.0380	0.116	-0.0892
3.	0.876	0.0432	0.140	-0.0883
4.	0.966	0.0485	0.164	-0.0882
5.	1.053	0.0550	0.188	-0.0872
6.	1.144	0.0611	0.210	-0.0877
7.	1.229	0.0689	0.233	-0.0868
8.	1.309	0.0758	0.255	-0.0860
9.	1.380	0.0851	0.274	-0.0854
10.	1.433	0.0949	0.289	-0.0835
11.	1.478	0.1038	0.303	-0.0809
12.	1.519	0.1151	0.314	-0.0798
13.	1.564	0.1314	0.321	-0.0837
14.	1.592	0.1466	0.323	-0.0886
15.	1.611	0.1630	0.324	-0.0925
16.	1.615	0.1803	0.320	-0.0981
17.	1.590	0.2006	0.311	-0.1007
18.	1.506	0.2190	0.284	-0.1071

CLARK-Y RE=(10)6 80XSS+P TSUSL

ALF	CL	CD	CM0	CMC/4
-10.	-0.368	0.0249	-0.184	-0.0835
-9.	-0.271	0.0217	-0.158	-0.0842
-8.	-0.174	0.0188	-0.132	-0.0841
-7.	-0.079	0.0168	-0.107	-0.0850
-6.	0.013	0.0155	-0.082	-0.0850
-5.	0.110	0.0148	-0.057	-0.0863
-4.	0.202	0.0151	-0.032	-0.0869
-3.	0.296	0.0162	-0.006	-0.0871
-2.	0.390	0.0179	0.020	-0.0867
-1.	0.478	0.0197	0.044	-0.0863
0.	0.564	0.0213	0.069	-0.0853
1.	0.662	0.0246	0.096	-0.0852
2.	0.750	0.0275	0.120	-0.0850
3.	0.838	0.0308	0.144	-0.0853
4.	0.922	0.0335	0.167	-0.0855
5.	0.996	0.0365	0.189	-0.0832
6.	1.072	0.0399	0.209	-0.0831
7.	1.137	0.0425	0.230	-0.0802
8.	1.190	0.0455	0.246	-0.0780
9.	1.248	0.0579	0.261	-0.0784
10.	1.289	0.0642	0.274	-0.0758
11.	1.302	0.0661	0.281	-0.0718
12.	1.343	0.0794	0.289	-0.0746
13.	1.373	0.0885	0.290	-0.0812
14.	1.367	0.1004	0.286	-0.0832
15.	1.344	0.1128	0.275	-0.0883
16.	1.255	0.1311	0.246	-0.0931

CLARK-Y RE=(10)6 70XSS+P TSUSL

ALF	CL	CD	CM0	CMC/4
-10.	-0.376	0.0266	-0.184	-0.0835
-9.	-0.277	0.0231	-0.160	-0.0853
-8.	-0.178	0.0204	-0.134	-0.0855
-7.	-0.084	0.0190	-0.110	-0.0866
-6.	0.008	0.0175	-0.085	-0.0870
-5.	0.105	0.0177	-0.060	-0.0874
-4.	0.201	0.0179	-0.034	-0.0876
-3.	0.295	0.0193	-0.010	-0.0889
-2.	0.389	0.0211	0.016	-0.0881
-1.	0.478	0.0231	0.041	-0.0872
0.	0.568	0.0252	0.065	-0.0875
1.	0.657	0.0284	0.090	-0.0864
2.	0.762	0.0334	0.117	-0.0869
3.	0.849	0.0373	0.141	-0.0860
4.	0.932	0.0411	0.164	-0.0854
5.	1.014	0.0459	0.187	-0.0850
6.	1.093	0.0506	0.208	-0.0843
7.	1.165	0.0562	0.229	-0.0829
8.	1.236	0.0617	0.247	-0.0830
9.	1.293	0.0712	0.265	-0.0803
10.	1.337	0.0785	0.277	-0.0790
11.	1.365	0.0864	0.289	-0.0748
12.	1.405	0.0948	0.296	-0.0772
13.	1.434	0.1065	0.299	-0.0819
14.	1.443	0.1180	0.298	-0.0851
15.	1.434	0.1311	0.295	-0.0851
16.	1.407	0.1463	0.282	-0.0913

CLARK-Y RE=(10)6 60XSS+P TSUSL

ALF	CL	CD	CM0	CMC/4
-10.	-0.390	0.0272	-0.188	-0.0850
-9.	-0.287	0.0238	-0.162	-0.0863
-8.	-0.184	0.0210	-0.136	-0.0871
-7.	-0.086	0.0194	-0.111	-0.0879
-6.	0.011	0.0183	-0.086	-0.0879
-5.	0.110	0.0183	-0.060	-0.0887
-4.	0.208	0.0186	-0.034	-0.0889
-3.	0.305	0.0197	-0.009	-0.0893
-2.	0.399	0.0224	0.016	-0.0888
-1.	0.486	0.0251	0.040	-0.0882
0.	0.574	0.0282	0.064	-0.0881
1.	0.667	0.0322	0.088	-0.0887
2.	0.770	0.0374	0.116	-0.0881
3.	0.860	0.0422	0.140	-0.0877
4.	0.950	0.0473	0.164	-0.0881
5.	1.047	0.0484	0.189	-0.0921
6.	1.126	0.0543	0.212	-0.0908
7.	1.209	0.0610	0.233	-0.0911
8.	1.281	0.0677	0.253	-0.0900
9.	1.346	0.0789	0.270	-0.0907
10.	1.392	0.0876	0.285	-0.0879
11.	1.435	0.0971	0.298	-0.0859
12.	1.476	0.1079	0.308	-0.0864
13.	1.516	0.1214	0.313	-0.0914
14.	1.532	0.1368	0.317	-0.0917
15.	1.556	0.1515	0.316	-0.0982
16.	1.551	0.1683	0.311	-0.1019
17.	1.496	0.1876	0.297	-0.1024
18.	1.463	0.2089	0.275	-0.1166

Table 6. Windtunnel balance results - NACA-0015 airfoils
 0.17-0015 RE=0.3(10)6 SOLID WALLS 0015 RE=0.3(10)6 40LS+P TSUSL

ALF	CL	CD	CM0	CMC/4
-4.	-0.352	0.0210	-0.100	-0.0142
-3.	-0.252	0.0176	-0.075	-0.0139
-2.	-0.161	0.0154	-0.051	-0.0115
-1.	-0.076	0.0135	-0.026	-0.0073
0.	0.001	0.0126	-0.002	-0.0021
1.	0.077	0.0122	0.022	0.0030
2.	0.161	0.0124	0.046	0.0071
3.	0.253	0.0134	0.071	0.0093
4.	0.352	0.0150	0.098	0.0122
5.	0.470	0.0170	0.125	0.0107
6.	0.598	0.0202	0.151	0.0056
7.	0.729	0.0239	0.175	-0.0013
8.	0.801	0.0265	0.198	0.0042
9.	0.854	0.0297	0.219	0.0126
10.	0.905	0.0336	0.240	0.0218
11.	0.958	0.0385	0.257	0.0271
12.	1.003	0.0441	0.274	0.0338
13.	1.034	0.0511	0.286	0.0388
14.	1.046	0.0613	0.288	0.0378
15.	1.049	0.0767	0.281	0.0304
16.	0.713	0.2246	0.122	-0.0597
17.	0.699	0.2473	0.109	-0.0713
18.	0.605	0.2565	0.099	-0.0600
19.	0.592	0.2692	0.097	-0.0608
20.	0.582	0.2812	0.097	-0.0592

0015 RE=0.3(10)6 40SS+P TSUSL

ALF	CL	CD	CM0	CMC/4
-4.	-0.347	0.0202	-0.099	-0.0146
-3.	-0.250	0.0172	-0.075	-0.0140
-2.	-0.158	0.0150	-0.049	-0.0107
-1.	-0.075	0.0139	-0.024	-0.0058
0.	-0.001	0.0126	-0.001	-0.0006
1.	0.076	0.0123	0.022	0.0035
2.	0.157	0.0127	0.046	0.0077
3.	0.247	0.0134	0.071	0.0105
4.	0.348	0.0150	0.096	0.0120
5.	0.462	0.0173	0.123	0.0108
6.	0.592	0.0209	0.148	0.0043
7.	0.716	0.0248	0.172	-0.0013
8.	0.789	0.0280	0.194	0.0033
9.	0.839	0.0312	0.215	0.0125
10.	0.889	0.0352	0.235	0.0206
11.	0.939	0.0402	0.254	0.0285
12.	0.985	0.0460	0.271	0.0342
13.	1.017	0.0525	0.283	0.0391
14.	1.030	0.0625	0.286	0.0395
15.	1.033	0.0773	0.279	0.0315
16.	0.692	0.2217	0.120	-0.0563
17.	0.638	0.2403	0.105	-0.0604
18.	0.572	0.2473	0.094	-0.0567
19.	0.573	0.2603	0.094	-0.0580
20.	0.573	0.2744	0.096	-0.0576

ALF	CL	CD	CM0	CMC/4
-4.	-0.353	0.0211	-0.100	-0.0137
-3.	-0.251	0.0183	-0.074	-0.0125
-2.	-0.159	0.0160	-0.049	-0.0101
-1.	-0.075	0.0149	-0.025	-0.0063
0.	0.000	0.0135	-0.001	-0.0006
1.	0.075	0.0135	0.022	0.0037
2.	0.157	0.0139	0.046	0.0078
3.	0.246	0.0147	0.071	0.0108
4.	0.343	0.0163	0.096	0.0128
5.	0.454	0.0185	0.123	0.0122
6.	0.580	0.0217	0.147	0.0064
7.	0.709	0.0259	0.172	0.0000
8.	0.785	0.0285	0.194	0.0038
9.	0.838	0.0321	0.215	0.0122
10.	0.886	0.0361	0.234	0.0208
11.	0.937	0.0409	0.253	0.0276
12.	0.981	0.0464	0.269	0.0337
13.	1.013	0.0531	0.281	0.0382
14.	1.025	0.0629	0.284	0.0386
15.	1.029	0.0780	0.277	0.0309
16.	0.633	0.2239	0.106	-0.0568
17.	0.592	0.2373	0.095	-0.0593
18.	0.574	0.2492	0.094	-0.0574
19.	0.568	0.2598	0.094	-0.0567
20.	0.570	0.2731	0.095	-0.0580

Table 6 - 0.17-NACA-0015

0015 RE=0.3(10)6 50LS+P TSUSL

ALF	CL	CD	CM0	CMC/4
-4.	-0.344	0.0195	-0.097	-0.0133
-3.	-0.245	0.0164	-0.073	-0.0135
-2.	-0.154	0.0144	-0.048	-0.0102
-1.	-0.071	0.0129	-0.023	-0.0059
0.	0.005	0.0116	0.000	-0.0010
1.	0.079	0.0112	0.023	0.0039
2.	0.160	0.0115	0.047	0.0078
3.	0.250	0.0125	0.072	0.0109
4.	0.349	0.0138	0.098	0.0131
5.	0.460	0.0165	0.123	0.0116
6.	0.589	0.0197	0.148	0.0050
7.	0.711	0.0234	0.172	-0.0006
8.	0.785	0.0261	0.192	0.0028
9.	0.834	0.0295	0.213	0.0117
10.	0.881	0.0333	0.233	0.0205
11.	0.931	0.0384	0.251	0.0275
12.	0.976	0.0440	0.267	0.0328
13.	1.005	0.0506	0.279	0.0379
14.	1.016	0.0610	0.280	0.0371
15.	1.019	0.0766	0.273	0.0292
16.	0.963	0.2223	0.108	-0.0617
17.	0.589	0.2347	0.094	-0.0597
18.	0.564	0.2452	0.092	-0.0570
19.	0.562	0.2581	0.093	-0.0561
20.	0.561	0.2699	0.095	-0.0561

0015 RE=0.3(10)6 60LS+P TSUSL

ALF	CL	CD	CM0	CMC/4
-4.	-0.343	0.0202	-0.100	-0.0167
-3.	-0.244	0.0174	-0.075	-0.0160
-2.	-0.152	0.0155	-0.049	-0.0125
-1.	-0.067	0.0141	-0.024	-0.0073
0.	0.006	0.0131	0.000	-0.0014
1.	0.083	0.0132	0.024	0.0035
2.	0.166	0.0134	0.048	0.0074
3.	0.256	0.0147	0.074	0.0114
4.	0.355	0.0161	0.100	0.0132
5.	0.466	0.0182	0.125	0.0123
6.	0.592	0.0214	0.151	0.0075
7.	0.718	0.0253	0.175	0.0010
8.	0.793	0.0281	0.198	0.0059
9.	0.839	0.0314	0.218	0.0152
10.	0.889	0.0351	0.238	0.0238
11.	0.939	0.0397	0.257	0.0308
12.	0.981	0.0454	0.273	0.0378
13.	1.012	0.0523	0.284	0.0411
14.	1.022	0.0626	0.285	0.0404
15.	1.024	0.0778	0.277	0.0321
16.	0.703	0.2214	0.109	-0.0699
17.	0.602	0.2362	0.100	-0.0566
18.	0.566	0.2488	0.093	-0.0559
19.	0.563	0.2568	0.094	-0.0558
20.	0.561	0.2705	0.095	-0.0561

0015 RE=0.3(10)6 70LS+P TSUSL

ALF	CL	CD	CM0	CMC/4
-4.	-0.345	0.0195	-0.096	-0.0117
-3.	-0.247	0.0167	-0.072	-0.0113
-2.	-0.155	0.0147	-0.046	-0.0087
-1.	-0.070	0.0132	-0.022	-0.0046
0.	0.001	0.0118	0.002	0.0017
1.	0.081	0.0118	0.025	0.0056
2.	0.163	0.0120	0.049	0.0094
3.	0.254	0.0130	0.074	0.0122
4.	0.356	0.0145	0.100	0.0135
5.	0.474	0.0165	0.126	0.0108
6.	0.603	0.0200	0.151	0.0044
7.	0.722	0.0253	0.175	-0.0001
8.	0.784	0.0260	0.195	0.0053
9.	0.834	0.0290	0.215	0.0138
10.	0.883	0.0331	0.234	0.0211
11.	0.933	0.0376	0.252	0.0281
12.	0.976	0.0431	0.267	0.0331
13.	1.002	0.0498	0.278	0.0382
14.	1.012	0.0604	0.279	0.0372
15.	1.011	0.0758	0.272	0.0298
16.	0.639	0.2220	0.101	-0.0635
17.	0.575	0.2333	0.092	-0.0580
18.	0.563	0.2434	0.092	-0.0565
19.	0.558	0.2559	0.093	-0.0555
20.	0.561	0.2688	0.094	-0.0568

0015 RE=0.3(10)6 80LS+P TSUSL

ALF	CL	CD	CM0	CMC/4
-4.	-0.334	0.0201	-0.095	-0.0132
-3.	-0.234	0.0171	-0.069	-0.0120
-2.	-0.145	0.0148	-0.044	-0.0084
-1.	-0.061	0.0134	-0.020	-0.0047
0.	0.010	0.0127	0.004	0.0014
1.	0.087	0.0125	0.027	0.0057
2.	0.168	0.0127	0.050	0.0093
3.	0.260	0.0136	0.075	0.0119
4.	0.362	0.0147	0.101	0.0127
5.	0.475	0.0174	0.125	0.0100
6.	0.606	0.0203	0.150	0.0033
7.	0.724	0.0233	0.173	-0.0025
8.	0.787	0.0258	0.194	0.0035
9.	0.828	0.0287	0.215	0.0151
10.	0.876	0.0326	0.233	0.0219
11.	0.925	0.0371	0.251	0.0288
12.	0.967	0.0431	0.267	0.0354
13.	0.992	0.0498	0.275	0.0376
14.	1.002	0.0606	0.274	0.0340
15.	0.994	0.0760	0.267	0.0291
16.	0.621	0.2170	0.105	-0.0547
17.	0.555	0.2262	0.089	-0.0555
18.	0.539	0.2375	0.089	-0.0540

Table 6 - 0.17-NACA-0015

0015 RE=0.3(10)6 50SS+P tsuSL						0015 RE=0.3(10)6 70SS+P tsuSL					
ALF	CL	CD	CM0	CMC/4		ALF	CL	CD	CM0	CMC/4	
-4.	-0.344	0.0199	-0.009	-0.0153		-4.	-0.342	0.0197	-0.100	-0.0165	
-3.	-0.249	0.0171	-0.075	-0.0140		-3.	-0.245	0.0169	-0.074	-0.0141	
-2.	-0.159	0.0152	-0.049	-0.0107		-2.	-0.156	0.0149	-0.049	-0.0109	
-1.	-0.074	0.0138	-0.024	-0.0062		-1.	-0.071	0.0138	-0.024	-0.0070	
0.	0.000	0.0128	-0.001	-0.0012		0.	0.002	0.0126	-0.001	-0.0001	
1.	0.074	0.0126	0.023	0.0046		1.	0.078	0.0127	0.023	0.0044	
2.	0.159	0.0129	0.048	0.0090		2.	0.162	0.0127	0.047	0.0080	
3.	0.246	0.0144	0.072	0.0125		3.	0.250	0.0138	0.072	0.0117	
4.	0.348	0.0158	0.098	0.0137		4.	0.350	0.0151	0.098	0.0134	
5.	0.461	0.0184	0.124	0.0118		5.	0.466	0.0174	0.124	0.0113	
6.	0.591	0.0217	0.150	0.0062		6.	0.592	0.0205	0.149	0.0050	
7.	0.712	0.0258	0.173	0.0004		7.	0.712	0.0240	0.172	-0.0006	
8.	0.784	0.0288	0.195	0.0048		8.	0.779	0.0266	0.193	0.0048	
9.	0.833	0.0320	0.215	0.0142		9.	0.830	0.0299	0.214	0.0137	
10.	0.882	0.0362	0.235	0.0227		10.	0.877	0.0337	0.234	0.0223	
11.	0.932	0.0410	0.254	0.0294		11.	0.928	0.0385	0.252	0.0288	
12.	0.977	0.0464	0.270	0.0358		12.	0.971	0.0439	0.268	0.0355	
13.	1.008	0.0532	0.282	0.0400		13.	0.998	0.0505	0.279	0.0396	
14.	1.021	0.0629	0.285	0.0407		14.	1.012	0.0607	0.281	0.0389	
15.	1.024	0.0781	0.277	0.0323		15.	1.011	0.0751	0.273	0.0313	
16.	0.685	0.2210	0.114	-0.0606		16.	0.652	0.2188	0.108	-0.0535	
17.	0.617	0.2378	0.100	-0.0664		17.	0.581	0.2331	0.094	-0.0572	
18.	0.567	0.2449	0.093	-0.0564		18.	0.563	0.2434	0.092	-0.0572	
19.	0.563	0.2520	0.094	-0.0556		19.	0.557	0.2561	0.093	-0.0553	
20.	0.559	0.2718	0.096	-0.0546		20.	0.563	0.2682	0.094	-0.0568	

0015 RE=0.3(10)6 60SS+P tsuSL						0015 RE=0.3(10)6 80SS+P tsuSL					
ALF	CL	CD	CM0	CMC/4		ALF	CL	CD	CM0	CMC/4	
-4.	-0.344	0.0198	-0.098	-0.0145		-4.	-0.345	0.0202	-0.098	-0.0137	
-3.	-0.243	0.0171	-0.073	-0.0136		-3.	-0.243	0.0174	-0.072	-0.0132	
-2.	-0.153	0.0148	-0.047	-0.0101		-2.	-0.152	0.0152	-0.047	-0.0096	
-1.	-0.070	0.0134	-0.023	-0.0055		-1.	-0.068	0.0136	-0.023	-0.0060	
0.	0.002	0.0123	-0.000	-0.0003		0.	0.006	0.0128	-0.001	-0.0005	
1.	0.078	0.0116	0.022	0.0045		1.	0.081	0.0121	0.024	0.0046	
2.	0.159	0.0117	0.047	0.0082		2.	0.164	0.0127	0.049	0.0088	
3.	0.247	0.0131	0.072	0.0115		3.	0.254	0.0158	0.074	0.0122	
4.	0.347	0.0146	0.097	0.0123		4.	0.352	0.0152	0.100	0.0141	
5.	0.459	0.0168	0.122	0.0108		5.	0.468	0.0174	0.126	0.0119	
6.	0.589	0.0204	0.148	0.0048		6.	0.591	0.0209	0.150	0.0069	
7.	0.709	0.0241	0.171	-0.0009		7.	0.714	0.0242	0.174	0.0008	
8.	0.780	0.0267	0.193	0.0048		8.	0.783	0.0266	0.197	0.0071	
9.	0.830	0.0297	0.214	0.0132		9.	0.833	0.0298	0.215	0.0145	
10.	0.878	0.0337	0.234	0.0221		10.	0.882	0.0338	0.236	0.0238	
11.	0.928	0.0384	0.252	0.0288		11.	0.929	0.0383	0.256	0.0320	
12.	0.972	0.0442	0.268	0.0348		12.	0.972	0.0435	0.270	0.0362	
13.	1.002	0.0508	0.280	0.0394		13.	0.999	0.0502	0.280	0.0409	
14.	1.014	0.0611	0.282	0.0392		14.	1.010	0.0605	0.281	0.0309	
15.	1.015	0.0759	0.275	0.0320		15.	1.008	0.0755	0.271	0.0295	
16.	0.678	0.2184	0.111	-0.0623		16.	0.619	0.2297	0.101	-0.0583	
17.	0.581	0.2326	0.094	-0.0580		17.	0.577	0.2311	0.093	-0.0576	
18.	0.567	0.2440	0.093	-0.0564		18.	0.562	0.2435	0.092	-0.0561	
19.	0.558	0.2569	0.093	-0.0554		19.	0.553	0.2551	0.093	-0.0542	
20.	0.564	0.2704	0.095	-0.0566		20.	0.557	0.2674	0.094	-0.0553	

Table 6 0.34-NACA-0015

0015 RE=0.5(10)6 SOLID WALLS							0015 RE=0.5(10)6 40XSPP TSUSL						
ALF	CL	CD	CM0	CMC/4			ALF	CL	CD	CM0	CMC/4		
-4.	-0.358	0.0213	-0.106	-0.0158			-4.	-0.344	0.0293	-0.101	-0.0145		
-3.	-0.263	0.0179	-0.079	-0.0124			-3.	-0.254	0.0174	-0.075	-0.0111		
-2.	-0.169	0.0154	-0.052	-0.0094			-2.	-0.165	0.0150	-0.050	-0.0082		
-1.	-0.077	0.0139	-0.026	-0.0062			-1.	-0.076	0.0135	-0.024	-0.0051		
0.	0.003	0.0131	-0.000	-0.0009			0.	-0.000	0.0129	-0.000	-0.0003		
1.	0.081	0.0126	0.024	0.0034			1.	0.075	0.0127	0.023	0.0042		
2.	0.176	0.0131	0.051	0.0062			2.	0.160	0.0133	0.047	0.0069		
3.	0.268	0.0142	0.077	0.0097			3.	0.246	0.0146	0.072	0.0101		
4.	0.365	0.0159	0.105	0.0127			4.	0.337	0.0164	0.099	0.0136		
5.	0.469	0.0183	0.133	0.0145			5.	0.435	0.0189	0.125	0.0150		
6.	0.591	0.0214	0.161	0.0121			6.	0.545	0.0224	0.150	0.0132		
7.	0.727	0.0258	0.187	0.0046			7.	0.669	0.0270	0.173	0.0050		
8.	0.828	0.0298	0.213	0.0053			8.	0.776	0.0315	0.198	0.0031		
9.	0.889	0.0332	0.236	0.0140			9.	0.836	0.0353	0.219	0.0096		
10.	0.952	0.0376	0.261	0.0229			10.	0.895	0.0398	0.240	0.0161		
11.	1.029	0.0438	0.285	0.0281			11.	0.954	0.0452	0.261	0.0228		
12.	1.096	0.0506	0.306	0.0333			12.	1.017	0.0517	0.279	0.0258		
13.	1.151	0.0578	0.322	0.0357			13.	1.070	0.0588	0.297	0.0306		
14.	1.178	0.0670	0.330	0.0380			14.	1.105	0.0668	0.308	0.0332		
15.	1.167	0.0910	0.308	0.0184			15.	1.113	0.0796	0.305	0.0287		
16.	1.126	0.1292	0.261	-0.0209			16.	1.061	0.0120	0.259	0.0008		
17.	0.867	0.2537	0.145	-0.0824			17.	0.734	0.2337	0.125	-0.0697		

0015 RE=0.5(10)6 40LS+P TSUSL

ALF	CL	CD	CM0	CMC/4		
-4.	-0.357	0.0200	-0.107	-0.0168		
-3.	-0.265	0.0170	-0.080	-0.0131		
-2.	-0.172	0.0149	-0.053	-0.0093		
-1.	-0.083	0.0132	-0.027	-0.0058		
0.	-0.003	0.0125	-0.001	-0.0003		
1.	0.072	0.0122	0.023	0.0043		
2.	0.162	0.0126	0.048	0.0074		
3.	0.249	0.0138	0.074	0.0116		
4.	0.344	0.0157	0.101	0.0148		
5.	0.429	0.0181	0.128	0.0174		
6.	0.550	0.0215	0.155	0.0161		
7.	0.676	0.0261	0.179	0.0096		
8.	0.784	0.0308	0.203	0.0067		
9.	0.848	0.0345	0.225	0.0121		
10.	0.902	0.0387	0.247	0.0218		
11.	0.969	0.0444	0.270	0.0282		
12.	1.038	0.0512	0.291	0.0327		
13.	1.089	0.0584	0.307	0.0364		
14.	1.126	0.0662	0.318	0.0392		
15.	1.133	0.0811	0.311	0.0304		
16.	1.073	0.1207	0.259	-0.0093		
17.	0.725	0.2381	0.130	-0.0619		

Table 6 0.34-MACA-0015

0015 RE=0.5(I0)6 50LS+P TSUSL						0015 RE=0.5(I0)6 70LS+P TSUSL					
ALF	CL	CD	CM0	CMC/4		ALF	CL	CD	CM0	CMC/4	
-4.	-0.351	0.0211	-0.104	-0.0151		-4.	-0.347	0.0208	-0.103	-0.0156	
-3.	-0.260	0.0178	-0.077	-0.0116		-3.	-0.254	0.0178	-0.076	-0.0115	
-2.	-0.169	0.0157	-0.051	-0.0080		-2.	-0.162	0.0157	-0.049	-0.0075	
-1.	-0.081	0.0140	-0.025	-0.0049		-1.	-0.074	0.0140	-0.023	-0.0043	
0.	-0.001	0.0134	-0.000	0.0000		0.	0.002	0.0133	0.002	0.0010	
1.	0.075	0.0130	0.023	0.0043		1.	0.079	0.0126	0.025	0.0047	
2.	0.164	0.0124	0.049	0.0077		2.	0.165	0.0129	0.050	0.0080	
3.	0.249	0.0146	0.075	0.0117		3.	0.251	0.0141	0.075	0.0117	
4.	0.343	0.0161	0.101	0.0150		4.	0.341	0.0157	0.101	0.0149	
5.	0.439	0.0184	0.128	0.0177		5.	0.437	0.0177	0.127	0.0173	
6.	0.552	0.0216	0.155	0.0158		6.	0.548	0.0209	0.154	0.0160	
7.	0.678	0.0263	0.178	0.0078		7.	0.671	0.0247	0.178	0.0090	
8.	0.783	0.0307	0.202	0.0056		8.	0.779	0.0287	0.200	0.0055	
9.	0.842	0.0342	0.223	0.0124		9.	0.831	0.0317	0.222	0.0135	
10.	0.895	0.0386	0.245	0.0270		10.	0.885	0.0359	0.242	0.0210	
11.	0.967	0.0445	0.268	0.0324		11.	0.951	0.0411	0.266	0.0284	
12.	1.026	0.0508	0.289	0.0329		12.	1.012	0.0472	0.284	0.0324	
13.	1.082	0.0579	0.303	0.0343		13.	1.060	0.0533	0.298	0.0346	
14.	1.118	0.0659	0.314	0.0371		14.	1.091	0.0611	0.308	0.0369	
15.	1.118	0.0816	0.305	0.0269		15.	1.086	0.0779	0.295	0.0253	
16.	1.053	0.1208	0.251	-0.0128		16.	1.026	0.1109	0.241	-0.0153	
17.	0.744	0.2356	0.130	-0.0662		17.	0.677	0.2292	0.119	-0.0613	

0015 RE=0.5(I0)6 60LS+P TSUSL

0015 RE=0.5(I0)6 80LS+P TSUSL

ALF	CL	CD	CM0	CMC/4		ALF	CL	CD	CM0	CMC/4	
-4.	-0.345	0.0205	-0.102	-0.0152		-4.	-0.333	0.0200	-0.099	-0.0151	
-3.	-0.255	0.0173	-0.076	-0.0112		-3.	-0.243	0.0171	-0.073	-0.0117	
-2.	-0.164	0.0153	-0.050	-0.0083		-2.	-0.154	0.0148	-0.047	-0.0078	
-1.	-0.075	0.0135	-0.024	-0.0049		-1.	-0.067	0.0132	-0.021	-0.0041	
0.	0.002	0.0129	0.001	0.0003		0.	0.011	0.0121	0.003	0.0005	
1.	0.077	0.0122	0.024	0.0046		1.	0.087	0.0116	0.027	0.0050	
2.	0.162	0.0130	0.049	0.0079		2.	0.175	0.0118	0.052	0.0081	
3.	0.248	0.0145	0.074	0.0117		3.	0.262	0.0126	0.078	0.0120	
4.	0.339	0.0158	0.100	0.0149		4.	0.351	0.0138	0.104	0.0151	
5.	0.436	0.0182	0.126	0.0165		5.	0.446	0.0155	0.130	0.0178	
6.	0.549	0.0216	0.152	0.0142		6.	0.563	0.0185	0.156	0.0144	
7.	0.672	0.0263	0.178	0.0085		7.	0.684	0.0219	0.179	0.0073	
8.	0.776	0.0306	0.200	0.0051		8.	0.774	0.0252	0.201	0.0073	
9.	0.833	0.0341	0.221	0.0121		9.	0.826	0.0279	0.222	0.0155	
10.	0.889	0.0382	0.244	0.0213		10.	0.840	0.0358	0.242	0.0228	
11.	0.948	0.0436	0.263	0.0262		11.	0.930	0.0358	0.262	0.0272	
12.	1.015	0.0504	0.283	0.0297		12.	0.995	0.0412	0.280	0.0321	
13.	1.066	0.0573	0.298	0.0334		13.	1.040	0.0477	0.296	0.0384	
14.	1.101	0.0652	0.309	0.0362		14.	1.056	0.0554	0.298	0.0367	
15.	1.105	0.0802	0.304	0.0295		15.	1.032	0.0797	0.268	0.0120	
16.	1.041	0.1195	0.249	-0.0114		16.	0.607	0.2016	0.108	-0.0528	
17.	0.703	0.2368	0.122	-0.0649							

Table 6 0.34-NACA-0015

0015 RE=0.5(10)6 50XSSP TSUSL

ALF	CL	CD	CM0	CMC/4
-4.	-0.342	0.0199	-0.100	-0.0138
-3.	-0.251	0.0169	-0.074	-0.0107
-2.	-0.162	0.0142	-0.048	-0.0073
-1.	-0.074	0.0132	-0.023	-0.0040
0.	-0.000	0.0124	0.001	0.0008
1.	0.076	0.0120	0.024	0.0051
2.	0.160	0.0124	0.048	0.0078
3.	0.250	0.0138	0.074	0.0109
4.	0.337	0.0153	0.100	0.0144
5.	0.434	0.0177	0.125	0.0159
6.	0.545	0.0213	0.150	0.0123
7.	0.669	0.0257	0.174	0.0061
8.	0.773	0.0301	0.198	0.0045
9.	0.832	0.0337	0.219	0.0105
10.	0.887	0.0379	0.240	0.0186
11.	0.948	0.0432	0.261	0.0245
12.	1.010	0.0498	0.281	0.0297
13.	1.063	0.0568	0.297	0.0329
14.	1.101	0.0648	0.307	0.0340
15.	1.101	0.0700	0.302	0.0287
16.	1.040	0.1187	0.249	-0.0110
17.	0.721	0.2341	0.123	-0.0677

0015 RE=0.5(10)6 70XSSP TSUSL

ALF	CL	CD	CM0	CMC/4
-4.	-0.340	0.0197	-0.101	-0.0154
-3.	-0.253	0.0166	-0.075	-0.0115
-2.	-0.158	0.0144	-0.049	-0.0089
-1.	-0.073	0.0131	-0.024	-0.0052
0.	0.006	0.0125	0.001	-0.0003
1.	0.083	0.0120	0.025	0.0041
2.	0.169	0.0121	0.051	0.0079
3.	0.257	0.0130	0.076	0.0116
4.	0.346	0.0149	0.103	0.0153
5.	0.441	0.0171	0.129	0.0177
6.	0.554	0.0204	0.155	0.0157
7.	0.674	0.0244	0.179	0.0094
8.	0.778	0.0284	0.203	0.0077
9.	0.832	0.0320	0.223	0.0148
10.	0.889	0.0362	0.245	0.0225
11.	0.952	0.0418	0.266	0.0286
12.	1.014	0.0477	0.285	0.0325
13.	1.064	0.0546	0.300	0.0355
14.	1.095	0.0627	0.310	0.0381
15.	1.084	0.0800	0.298	0.0290
16.	1.019	0.1217	0.245	-0.0108
17.	0.698	0.2330	0.124	-0.0617

0015 RE=0.5(10)6 60XSSP TSUSL

ALF	CL	CD	CM0	CMC/4
-4.	-0.341	0.0201	-0.101	-0.0153
-3.	-0.253	0.0168	-0.074	-0.0103
-2.	-0.160	0.0146	-0.049	-0.0084
-1.	-0.072	0.0153	-0.024	-0.0057
0.	0.004	0.0119	0.002	0.0004
1.	0.080	0.0121	0.025	0.0050
2.	0.166	0.0127	0.051	0.0087
3.	0.251	0.0137	0.075	0.0119
4.	0.341	0.0153	0.101	0.0154
5.	0.437	0.0174	0.128	0.0174
6.	0.546	0.0207	0.154	0.0167
7.	0.671	0.0250	0.179	0.0101
8.	0.775	0.0293	0.203	0.0084
9.	0.835	0.0328	0.224	0.0145
10.	0.889	0.0370	0.245	0.0225
11.	0.950	0.0420	0.266	0.0294
12.	1.016	0.0488	0.286	0.0327
13.	1.066	0.0554	0.303	0.0379
14.	1.102	0.0634	0.313	0.0392
15.	1.102	0.0795	0.302	0.0287
16.	1.038	0.1206	0.249	-0.0105
17.	0.702	0.2343	0.124	-0.0623

0015 RE=0.5(10)6 80XSSP TSUSL

ALF	CL	CD	CM0	CMC/4
-4.	-0.337	0.0215	-0.101	-0.0157
-3.	-0.249	0.0181	-0.075	-0.0119
-2.	-0.160	0.0156	-0.048	-0.0078
-1.	-0.069	0.0161	-0.023	-0.0057
0.	0.006	0.0131	0.001	-0.0001
1.	0.079	0.0127	0.025	0.0056
2.	0.166	0.0122	0.050	0.0084
3.	0.254	0.0129	0.075	0.0113
4.	0.344	0.0144	0.101	0.0147
5.	0.439	0.0164	0.128	0.0174
6.	0.553	0.0193	0.153	0.0143
7.	0.672	0.0231	0.178	0.0090
8.	0.774	0.0267	0.201	0.0068
9.	0.831	0.0298	0.223	0.0145
10.	0.883	0.0338	0.243	0.0221
11.	0.943	0.0383	0.263	0.0285
12.	1.008	0.0446	0.284	0.0333
13.	1.054	0.0505	0.297	0.0352
14.	1.078	0.0582	0.304	0.0370
15.	1.060	0.0786	0.282	0.0188
16.	0.717	0.2075	0.113	-0.0753

Table 6 - 0.50-NACA-0015

0015 RE=0.5(10)6 SOLID WALLS

RE=0.5(10)6 40%SS+P TSUSL

ALF	CL	CD	CM0	CMC/4
-4.	-0.367	0.0267	-0.099	-0.0082
-3.	-0.269	0.0229	-0.074	-0.0075
-2.	-0.170	0.0198	-0.049	-0.0066
-1.	-0.077	0.0178	-0.024	-0.0051
0.	-0.000	0.0164	-0.002	-0.0014
1.	0.076	0.0161	0.020	0.0008
2.	0.167	0.0160	0.044	0.0025
3.	0.266	0.0174	0.071	0.0048
4.	0.369	0.0192	0.097	0.0062
5.	0.495	0.0226	0.126	0.0038
6.	0.624	0.0266	0.149	-0.0040
7.	0.767	0.0318	0.174	-0.0144
8.	0.852	0.0362	0.197	-0.0117
9.	0.917	0.0410	0.220	-0.0038
10.	0.993	0.0470	0.243	0.0009
11.	1.073	0.0546	0.267	0.0054
12.	1.148	0.0625	0.288	0.0084
13.	1.217	0.0721	0.306	0.0107
14.	1.266	0.0823	0.320	0.0126
15.	1.288	0.0949	0.325	0.0128
16.	1.281	0.1134	0.304	-0.0069
17.	1.248	0.1479	0.274	-0.0298
18.	1.210	0.1726	0.257	-0.0388
19.	1.165	0.1926	0.243	-0.0429
20.	1.139	0.2178	0.232	-0.0496

0015 RE=0.5(10)6 40%LS+P TSUSL

ALF	CL	CD	CM0	CMC/4
-4.	-0.353	0.0243	-0.094	-0.0073
-3.	-0.262	0.0208	-0.071	-0.0060
-2.	-0.168	0.0174	-0.046	-0.0048
-1.	-0.079	0.0157	-0.023	-0.0035
0.	-0.007	0.0141	-0.002	0.0001
1.	0.066	0.0139	0.020	0.0032
2.	0.146	0.0142	0.042	0.0056
3.	0.235	0.0155	0.065	0.0072
4.	0.327	0.0170	0.090	0.0091
5.	0.427	0.0205	0.114	0.0087
6.	0.550	0.0247	0.137	0.0018
7.	0.684	0.0304	0.159	-0.0087
8.	0.775	0.0357	0.179	-0.0113
9.	0.834	0.0401	0.199	-0.0048
10.	0.897	0.0459	0.220	0.0006
11.	0.971	0.0540	0.242	0.0052
12.	1.037	0.0615	0.259	0.0063
13.	1.097	0.0702	0.276	0.0091
14.	1.156	0.0799	0.290	0.0097
15.	1.197	0.0907	0.302	0.0113
16.	1.214	0.1031	0.304	0.0099
17.	1.203	0.1268	0.280	-0.0119
18.	1.160	0.1571	0.248	-0.0351
19.	1.104	0.1789	0.228	-0.0428
20.	1.064	0.3502	0.146	-0.1292

Table 6 - 0.50-NACA-0015

0015 RE=0.5(10)6 50XL3+P TSUSL

0015 RE=0.5(10)6 70XL3+P TSUSL

ALF	CL	CD	CM0	CMC/4
-4.	-0.355	0.0232	-0.094	-0.0064
-3.	-0.260	0.0200	-0.071	-0.0063
-2.	-0.167	0.0174	-0.046	-0.0046
-1.	-0.078	0.0152	-0.022	-0.0029
0.	-0.004	0.0143	-0.001	0.0004
1.	0.066	0.0137	0.020	0.0034
2.	0.148	0.0142	0.045	0.0062
3.	0.235	0.0151	0.066	0.0083
4.	0.325	0.0172	0.090	0.0099
5.	0.428	0.0204	0.114	0.0090
6.	0.549	0.0246	0.138	0.0026
7.	0.684	0.0303	0.159	-0.0086
8.	0.767	0.0349	0.178	-0.0101
9.	0.827	0.0396	0.198	-0.0048
10.	0.886	0.0450	0.218	0.0018
11.	0.951	0.0519	0.238	0.0055
12.	1.017	0.0595	0.256	0.0084
13.	1.086	0.0690	0.274	0.0096
14.	1.138	0.0781	0.286	0.0103
15.	1.182	0.0885	0.299	0.0127
16.	1.189	0.1009	0.299	0.0115
17.	1.185	0.1251	0.276	-0.0115
18.	1.147	0.1525	0.248	-0.0318
19.	1.085	0.1757	0.224	-0.0426
20.	0.898	0.2305	0.130	-0.1051

ALF	CL	CD	CM0	CMC/4
-4.	-0.351	0.0223	-0.094	-0.0077
-3.	-0.256	0.0190	-0.070	-0.0066
-2.	-0.164	0.0168	-0.046	-0.0050
-1.	-0.077	0.0152	-0.021	-0.0022
0.	0.000	0.0144	0.001	0.0008
1.	0.070	0.0144	0.021	0.0043
2.	0.151	0.0149	0.044	0.0068
3.	0.237	0.0162	0.068	0.0094
4.	0.328	0.0183	0.091	0.0107
5.	0.427	0.0213	0.115	0.0103
6.	0.549	0.0255	0.138	0.0023
7.	0.674	0.0307	0.158	-0.0076
8.	0.759	0.0347	0.179	-0.0072
9.	0.815	0.0391	0.198	-0.0008
10.	0.872	0.0436	0.217	0.0043
11.	0.934	0.0499	0.236	0.0085
12.	0.998	0.0573	0.254	0.0109
13.	1.055	0.0654	0.268	0.0119
14.	1.105	0.0739	0.283	0.0150
15.	1.138	0.0832	0.291	0.0150
16.	1.141	0.0976	0.283	0.0069
17.	1.112	0.1214	0.251	-0.0197
18.	1.052	0.1471	0.222	-0.0354
19.	0.720	0.2779	0.107	-0.0826
20.	0.638	0.2850	0.095	-0.0764

0015 RE=0.5(10)6 60XL3+P TSUSL

0015 RE=0.5(10)6 80XL3+P TSUSL

ALF	CL	CD	CM0	CMC/4
-4.	-0.347	0.0236	-0.094	-0.0084
-3.	-0.258	0.0199	-0.070	-0.0062
-2.	-0.166	0.0171	-0.045	-0.0044
-1.	-0.079	0.0148	-0.022	-0.0030
0.	-0.003	0.0134	-0.000	0.0002
1.	0.067	0.0129	0.020	0.0037
2.	0.147	0.0133	0.043	0.0063
3.	0.238	0.0142	0.067	0.0080
4.	0.328	0.0161	0.091	0.0102
5.	0.429	0.0200	0.115	0.0098
6.	0.552	0.0235	0.138	0.0029
7.	0.684	0.0291	0.160	-0.0081
8.	0.768	0.0336	0.178	-0.0103
9.	0.824	0.0380	0.198	-0.0036
10.	0.882	0.0433	0.219	0.0035
11.	0.944	0.0500	0.237	0.0069
12.	1.007	0.0572	0.254	0.0091
13.	1.072	0.0660	0.271	0.0101
14.	1.124	0.0747	0.285	0.0122
15.	1.158	0.0851	0.294	0.0139
16.	1.171	0.0982	0.292	0.0088
17.	1.137	0.1253	0.263	-0.0156
18.	1.108	0.1471	0.240	-0.0302
19.	1.054	0.1720	0.215	-0.0436
20.	0.743	0.2033	0.103	-0.0947

ALF	CL	CD	CM0	CMC/4
-4.	-0.331	0.0215	-0.089	-0.0069
-3.	-0.241	0.0174	-0.064	-0.0042
-2.	-0.150	0.0147	-0.041	-0.0040
-1.	-0.065	0.0129	-0.018	-0.0021
0.	0.009	0.0121	0.004	0.0017
1.	0.079	0.0119	0.024	0.0047
2.	0.161	0.0132	0.047	0.0074
3.	0.247	0.0128	0.070	0.0092
4.	0.334	0.0142	0.094	0.0113
5.	0.433	0.0166	0.117	0.0104
6.	0.554	0.0196	0.139	0.0023
7.	0.674	0.0256	0.160	-0.0055
8.	0.750	0.0265	0.179	-0.0041
9.	0.800	0.0305	0.198	0.0021
10.	0.854	0.0345	0.215	0.0071
11.	0.913	0.0390	0.234	0.0118
12.	0.961	0.0439	0.249	0.0151
13.	1.012	0.0504	0.263	0.0172
14.	1.049	0.0571	0.271	0.0175
15.	1.052	0.0672	0.271	0.0165
16.	1.016	0.0901	0.239	-0.0073
17.	0.974	0.1979	0.080	-0.1635
18.	0.506	0.2116	0.081	-0.0529
19.	0.560	0.2348	0.084	-0.0652
20.	0.578	0.2581	0.087	-0.0687

Table 6 - 0.50-NACA-0015

0015 RE=0.5(10)6 50%SS+P TSUSL

ALF	CL	CD	CM0	CMC/4
-4.	-0.353	0.0239	-0.093	-0.0063
-3.	-0.261	0.0202	-0.070	-0.0059
-2.	-0.169	0.0173	-0.047	-0.0049
-1.	-0.081	0.0151	-0.023	-0.0034
0.	-0.007	0.0141	-0.001	0.0003
1.	0.066	0.0137	0.019	0.0032
2.	0.146	0.0137	0.042	0.0061
3.	0.238	0.0150	0.066	0.0077
4.	0.324	0.0171	0.090	0.0097
5.	0.426	0.0203	0.113	0.0088
6.	0.547	0.0249	0.136	0.0017
7.	0.674	0.0306	0.157	-0.0089
8.	0.759	0.0355	0.177	-0.0097
9.	0.818	0.0402	0.196	-0.0041
10.	0.877	0.0455	0.216	0.0012
11.	0.943	0.0520	0.236	0.0054
12.	1.015	0.0601	0.256	0.0083
13.	1.075	0.0681	0.271	0.0098
14.	1.131	0.0773	0.285	0.0110
15.	1.173	0.0876	0.296	0.0119
16.	1.187	0.0996	0.297	0.0097
17.	1.172	0.1230	0.274	-0.0107
18.	1.143	0.1510	0.242	-0.0366
19.	1.083	0.0174	0.223	-0.0298
20.	0.870	0.0327	0.142	-0.0614

0015 RE=0.5(10)6 70%SS+P TSUSL

ALF	CL	CD	CM0	CMC/4
-4.	-0.350	0.0238	-0.094	-0.0075
-3.	-0.257	0.0202	-0.070	-0.0065
-2.	-0.167	0.0173	-0.045	-0.0042
-1.	-0.078	0.0153	-0.022	-0.0024
0.	-0.001	0.0138	0.000	0.0006
1.	0.006	0.0134	0.021	0.0193
2.	0.150	0.0137	0.044	0.0066
3.	0.237	0.0148	0.068	0.0092
4.	0.326	0.0164	0.092	0.0116
5.	0.424	0.0194	0.115	0.0112
6.	0.546	0.0238	0.138	0.0043
7.	0.671	0.0290	0.158	-0.0068
8.	0.755	0.0337	0.178	-0.0068
9.	0.812	0.0380	0.199	0.0001
10.	0.868	0.0429	0.217	0.0047
11.	0.930	0.0490	0.236	0.0090
12.	0.997	0.0559	0.254	0.0116
13.	1.052	0.0638	0.270	0.0143
14.	1.103	0.0714	0.283	0.0158
15.	1.133	0.0802	0.292	0.0174
16.	1.138	0.0900	0.285	0.0095
17.	1.111	0.1202	0.253	-0.0166
18.	1.050	0.1445	0.227	-0.0294
19.	0.645	0.2587	0.093	-0.0774
20.	0.620	0.2785	0.094	-0.0733

0015 RE=0.5(10)6 60%SS+P TSUSL

ALF	CL	CD	CM0	CMC/4
-4.	-0.354	0.0238	-0.095	-0.0073
-3.	-0.261	0.0201	-0.071	-0.0069
-2.	-0.169	0.0174	-0.047	-0.0049
-1.	-0.081	0.0153	-0.022	-0.0026
0.	-0.004	0.0141	-0.000	0.0007
1.	0.068	0.0139	0.021	0.0042
2.	0.150	0.0140	0.044	0.0069
3.	0.240	0.0152	0.068	0.0089
4.	0.327	0.0172	0.092	0.0115
5.	0.427	0.0202	0.117	0.0114
6.	0.547	0.0247	0.138	0.0033
7.	0.677	0.0301	0.160	-0.0059
8.	0.761	0.0346	0.180	-0.0062
9.	0.818	0.0391	0.201	0.0005
10.	0.878	0.0446	0.220	0.0060
11.	0.941	0.0508	0.240	0.0101
12.	1.009	0.0583	0.258	0.0126
13.	1.074	0.0668	0.275	0.0143
14.	1.126	0.0757	0.290	0.0164
15.	1.164	0.0860	0.299	0.0165
16.	1.175	0.0985	0.297	0.0122
17.	1.161	0.1249	0.270	-0.0100
18.	1.112	0.1498	0.243	-0.0289
19.	1.062	0.1719	0.219	-0.0418
20.	0.742	0.3052	0.103	-0.0941

0015 RE=0.5(10)6 80%SS+P TSUSL

ALF	CL	CD	CM0	CMC/4
-4.	-0.342	0.0235	-0.092	-0.0074
-3.	-0.252	0.0204	-0.068	-0.0050
-2.	-0.160	0.0175	-0.043	-0.0039
-1.	-0.074	0.0155	-0.021	-0.0023
0.	0.000	0.0141	0.002	0.0017
1.	0.071	0.0135	0.023	0.0052
2.	0.154	0.0136	0.046	0.0075
3.	0.240	0.0144	0.069	0.0100
4.	0.329	0.0160	0.093	0.0118
5.	0.427	0.0186	0.117	0.0115
6.	0.548	0.0222	0.139	0.0043
7.	0.670	0.0265	0.158	-0.0064
8.	0.747	0.0298	0.178	-0.0056
9.	0.799	0.0334	0.197	0.0018
10.	0.854	0.0376	0.216	0.0075
11.	0.913	0.0422	0.233	0.0107
12.	0.974	0.0482	0.251	0.0142
13.	1.028	0.0554	0.265	0.0159
14.	1.071	0.0624	0.276	0.0162
15.	1.094	0.0721	0.282	0.0172
16.	1.084	0.0882	0.264	0.0013
17.	1.042	0.1147	0.231	-0.0224
18.	0.926	0.2212	0.084	-0.0560
19.	0.565	0.2484	0.085	-0.0664
20.	0.593	0.2664	0.088	-0.0710

Table 6 - 0.62-NACA-0015
 RE=0.5(10)6 SOLID WALLS

ALF	CL	CD	CM0	C _M C/4
-4.	-0.377	0.0252	-0.102	-0.0158
-3.	-0.273	0.0215	-0.077	-0.0142
-2.	-0.166	0.0185	-0.050	-0.0116
-1.	-0.071	0.0167	-0.025	-0.0082
0.	0.006	0.0155	-0.000	-0.0017
1.	0.082	0.0161	0.023	0.0042
2.	0.176	0.0174	0.048	0.0079
3.	0.285	0.0195	0.076	0.0104
4.	0.399	0.0225	0.104	0.0121
5.	0.524	0.0264	0.132	0.0120
6.	0.665	0.0318	0.160	0.0077
7.	0.810	0.0380	0.186	0.0011
8.	0.889	0.0428	0.211	0.0077
9.	0.969	0.0488	0.234	0.0136
10.	1.063	0.0558	0.261	0.0187
11.	1.162	0.0647	0.287	0.0234
12.	1.253	0.0744	0.311	0.0271
13.	1.330	0.0845	0.331	0.0303
14.	1.370	0.0949	0.346	0.0322
15.	1.414	0.1109	0.348	0.0289
16.	1.419	0.1395	0.328	0.0068
17.	1.398	0.1740	0.309	-0.0086
18.	1.360	0.2078	0.282	-0.0285
19.	1.363	0.2489	0.271	-0.0425
20.	1.398	0.2929	0.259	-0.0645

0015 RE=0.5(10)6 40XLS+P TSUSL

ALF	CL	CD	CM0	C _M C/4
-4.	-0.377	0.0248	-0.101	-0.0145
-3.	-0.278	0.0213	-0.076	-0.0119
-2.	-0.180	0.0186	-0.050	-0.0088
-1.	-0.085	0.0175	-0.025	-0.0057
0.	-0.014	0.0169	-0.002	0.0014
1.	0.058	0.0173	0.020	0.0068
2.	0.136	0.0190	0.043	0.0120
3.	0.230	0.0217	0.068	0.0147
4.	0.325	0.0251	0.092	0.0171
5.	0.433	0.0296	0.116	0.0168
6.	0.564	0.0358	0.140	0.0110
7.	0.696	0.0430	0.160	0.0009
8.	0.773	0.0486	0.183	0.0061
9.	0.846	0.0543	0.206	0.0126
10.	0.922	0.0604	0.227	0.0167
11.	1.003	0.0681	0.250	0.0217
12.	1.089	0.0781	0.273	0.0256
13.	1.162	0.0869	0.291	0.0269
14.	1.235	0.0971	0.308	0.0286
15.	1.294	0.1082	0.324	0.0309
16.	1.329	0.1224	0.330	0.0274
17.	1.350	0.1433	0.323	0.0183
18.	1.348	0.1714	0.297	-0.0088
19.	1.312	0.2078	0.268	-0.0311
20.	1.258	0.2459	0.240	-0.0501

0015 RE=0.5(10)6 40XLS+P TSUSL

ALF	CL	CD	CM0	C _M C/4
-4.	-0.376	0.0253	-0.099	-0.0123
-3.	-0.276	0.0208	-0.074	-0.0103
-2.	-0.180	0.0181	-0.049	-0.0076
-1.	-0.088	0.0162	-0.025	-0.0046
0.	-0.017	0.0152	-0.002	0.0016
1.	0.057	0.0156	0.020	0.0064
2.	0.134	0.0165	0.042	0.0107
3.	0.223	0.0187	0.065	0.0135
4.	0.318	0.0214	0.088	0.0154
5.	0.425	0.0260	0.112	0.0145
6.	0.560	0.0319	0.135	0.0071
7.	0.687	0.0389	0.157	-0.0005
8.	0.769	0.0445	0.178	0.0027
9.	0.841	0.0503	0.201	0.0087
10.	0.916	0.0573	0.221	0.0127
11.	0.997	0.0655	0.241	0.0142
12.	1.078	0.0753	0.263	0.0183
13.	1.165	0.0861	0.283	0.0186
14.	1.234	0.0975	0.302	0.0218
15.	1.293	0.1099	0.316	0.0233
16.	1.340	0.1259	0.325	0.0227
17.	1.359	0.1436	0.318	0.0112
18.	1.355	0.1731	0.295	-0.0128
19.	1.327	0.2116	0.268	-0.0350
20.	1.277	0.2422	0.241	-0.0531

Table 6 - 0.67-NACA-0015

RE=0.5(10)6 50%LS+P TSUSL

ALF	CL	CD	CM0	CMC/4
-4.	-0.371	0.0253	-0.097	-0.0118
-3.	-0.274	0.0212	-0.072	-0.0093
-2.	-0.177	0.0184	-0.047	-0.0067
-1.	-0.083	0.0164	-0.023	-0.0044
0.	-0.014	0.0152	-0.001	0.0024
1.	0.060	0.0152	0.021	0.0067
2.	0.137	0.0159	0.043	0.0117
3.	0.227	0.0182	0.066	0.0140
4.	0.317	0.0207	0.089	0.0166
5.	0.425	0.0250	0.113	0.0153
6.	0.558	0.0311	0.135	0.0073
7.	0.684	0.0379	0.157	0.0007
8.	0.762	0.0433	0.177	0.0024
9.	0.828	0.0430	0.197	0.0074
10.	0.900	0.0560	0.218	0.0131
11.	0.982	0.0636	0.238	0.0145
12.	1.060	0.0722	0.258	0.0176
13.	1.136	0.0822	0.278	0.0199
14.	1.208	0.0934	0.295	0.0213
15.	1.264	0.1044	0.312	0.0265
16.	1.306	0.1173	0.317	0.0224
17.	1.322	0.1379	0.307	0.0085
18.	1.312	0.1688	0.287	-0.0106
19.	1.283	0.2009	0.249	-0.0436
20.	1.201	0.2350	0.231	-0.0460

0015 RE=0.5(10)6 70%LS+P TSUSL

ALF	CL	CD	CM0	CMC/4
-4.	-0.356	0.0245	-0.094	-0.0121
-3.	-0.262	0.0210	-0.069	-0.0085
-2.	-0.162	0.0174	-0.044	-0.0067
-1.	-0.075	0.0157	-0.020	-0.0032
0.	-0.002	0.0140	0.004	0.0039
1.	0.066	0.0145	0.024	0.0093
2.	0.144	0.0154	0.047	0.0143
3.	0.225	0.0168	0.071	0.0168
4.	0.325	0.0188	0.095	0.0206
5.	0.429	0.0225	0.118	0.0195
6.	0.554	0.0262	0.139	0.0124
7.	0.668	0.0296	0.160	0.0074
8.	0.743	0.0344	0.178	0.0082
9.	0.803	0.0388	0.199	0.0159
10.	0.870	0.0440	0.219	0.0210
11.	0.943	0.0501	0.239	0.0246
12.	1.004	0.0565	0.255	0.0276
13.	1.071	0.0629	0.271	0.0282
14.	1.116	0.0709	0.281	0.0284
15.	1.149	0.0783	0.287	0.0285
16.	1.151	0.0922	0.280	0.0207
17.	1.130	0.1169	0.256	0.0009

0015 RE=0.5(10)6 80%LS+P TSUSL

0015 RE=0.5(10)6 60%LS+P TSUSL

ALF	CL	CD	CM0	CMC/4
-4.	-0.362	0.0243	-0.096	-0.0133
-3.	-0.265	0.0211	-0.072	-0.0107
-2.	-0.169	0.0185	-0.046	-0.0074
-1.	-0.078	0.0170	-0.022	-0.0041
0.	-0.005	0.0166	-0.002	-0.0005
1.	0.066	0.0169	0.023	0.0081
2.	0.144	0.0186	0.046	0.0131
3.	0.234	0.0209	0.070	0.0162
4.	0.328	0.0241	0.095	0.0194
5.	0.436	0.0286	0.118	0.0183
6.	0.562	0.0346	0.141	0.0128
7.	0.683	0.0410	0.163	0.0067
8.	0.765	0.0466	0.183	0.0082
9.	0.832	0.0523	0.204	0.0142
10.	0.895	0.0589	0.227	0.0225
11.	0.972	0.0652	0.245	0.0235
12.	1.042	0.0742	0.264	0.0266
13.	1.123	0.0840	0.284	0.0289
14.	1.179	0.0917	0.298	0.0312
15.	1.230	0.1033	0.310	0.0319
16.	1.261	0.1140	0.314	0.0289
17.	1.253	0.1368	0.295	0.0114
18.	1.225	0.1642	0.267	-0.0116
19.	1.137	0.1923	0.229	-0.0317
20.	0.719	0.3186	0.105	-0.0743

ALF	CL	CD	CM0	CMC/4
-4.	-0.335	0.0223	-0.088	-0.0114
-3.	-0.239	0.0179	-0.064	-0.0087
-2.	-0.148	0.0149	-0.039	-0.0045
-1.	-0.062	0.0123	-0.016	-0.0015
0.	0.009	0.0109	0.008	0.0056
1.	0.076	0.0104	0.028	0.0104
2.	0.154	0.0106	0.050	0.0145
3.	0.242	0.0117	0.073	0.0179
4.	0.330	0.0132	0.096	0.0204
5.	0.424	0.0154	0.120	0.0201
6.	0.557	0.0188	0.141	0.0133
7.	0.660	0.0218	0.162	0.0109
8.	0.728	0.0245	0.180	0.0147
9.	0.776	0.0265	0.196	0.0191
10.	0.835	0.0296	0.215	0.0257
11.	0.895	0.0330	0.231	0.0282
12.	0.944	0.0352	0.246	0.0326
13.	0.983	0.0391	0.253	0.0320
14.	1.013	0.0457	0.260	0.0323
15.	0.517	0.1837	0.078	-0.0472

Table 6 - 0.67-NACA-0015

0015 RE=0.5(10)6 50XS+P TSUSL						0015 RE=0.5(10)6 70XS+P TSUSL					
ALF	CL	CD	CM0	CMC/4		ALF	CL	CD	CM0	CMC/4	
-4.	-0.368	0.0247	-0.098	-0.0133		-4.	-0.366	0.0250	-0.098	-0.0136	
-3.	-0.271	0.0204	-0.073	-0.0105		-3.	-0.268	0.0215	-0.073	-0.0112	
-2.	-0.175	0.0177	-0.048	-0.0077		-2.	-0.172	0.0186	-0.047	-0.0076	
-1.	-0.085	0.0163	-0.024	-0.0047		-1.	-0.079	0.0163	-0.023	-0.0046	
0.	-0.014	0.0147	-0.001	0.0020		0.	-0.006	0.0155	0.001	0.0020	
1.	0.058	0.0149	0.021	0.0071		1.	0.064	0.0159	0.023	0.0078	
2.	0.134	0.0156	0.043	0.0122		2.	0.138	0.0173	0.045	0.0130	
3.	0.222	0.0179	0.066	0.0151		3.	0.228	0.0187	0.068	0.0162	
4.	0.317	0.0210	0.090	0.0170		4.	0.321	0.0212	0.093	0.0191	
5.	0.420	0.0248	0.113	0.0166		5.	0.425	0.0251	0.116	0.0185	
6.	0.548	0.0312	0.136	0.0107		6.	0.548	0.0301	0.138	0.0127	
7.	0.674	0.0378	0.156	0.0014		7.	0.666	0.0338	0.159	0.0064	
8.	0.756	0.0434	0.177	0.0043		8.	0.744	0.0381	0.177	0.0066	
9.	0.825	0.0486	0.199	0.0103		9.	0.804	0.0427	0.198	0.0142	
10.	0.899	0.0554	0.220	0.0146		10.	0.872	0.0485	0.219	0.0203	
11.	0.974	0.0630	0.242	0.0199		11.	0.941	0.0539	0.238	0.0240	
12.	1.054	0.0723	0.262	0.0228		12.	1.014	0.0606	0.257	0.0270	
13.	1.132	0.0723	0.279	0.0226		13.	1.078	0.0678	0.274	0.0300	
14.	1.203	0.0921	0.298	0.0259		14.	1.139	0.0760	0.288	0.0306	
15.	1.260	0.1034	0.312	0.0272		15.	1.186	0.0850	0.300	0.0332	
16.	1.303	0.1170	0.320	0.0259		16.	1.199	0.0991	0.297	0.0263	
17.	1.311	0.1370	0.310	0.0133		17.	1.182	0.1218	0.272	0.0052	
18.	1.200	0.1658	0.284	-0.0111		18.	0.617	0.2532	0.094	-0.0584	
19.	1.252	0.1998	0.255	-0.0308							
20.	1.198	0.2348	0.231	-0.0453							

0015 RE=0.5(10)6 60XS+P TSUSL

0015 RE=0.5(10)6 80XS+P TSUSL

ALF	CL	CD	CM0	CMC/4		ALF	CL	CD	CM0	CMC/4	
-4.	-0.368	0.0248	-0.097	-0.0126		-4.	-0.345	0.0244	-0.090	-0.0105	
-3.	-0.272	0.0205	-0.073	-0.0104		-3.	-0.249	0.0199	-0.061	-0.0094	
-2.	-0.176	0.0172	-0.048	-0.0073		-2.	-0.155	0.0165	-0.041	-0.0057	
-1.	-0.084	0.0153	-0.023	-0.0040		-1.	-0.069	0.0146	-0.019	-0.0028	
0.	-0.015	0.0141	-0.001	0.0023		0.	0.003	0.0128	0.005	0.0040	
1.	0.057	0.0140	0.021	0.0077		1.	0.070	0.0132	0.025	0.0092	
2.	0.133	0.0149	0.043	0.0122		2.	0.145	0.0136	0.048	0.0146	
3.	0.222	0.0168	0.066	0.0152		3.	0.234	0.0146	0.071	0.0175	
4.	0.314	0.0193	0.089	0.0173		4.	0.325	0.0168	0.095	0.0206	
5.	0.419	0.0240	0.113	0.0171		5.	0.428	0.0195	0.117	0.0192	
6.	0.545	0.0294	0.136	0.0107		6.	0.549	0.0238	0.138	0.0130	
7.	0.668	0.0361	0.157	0.0037		7.	0.667	0.0273	0.159	0.0071	
8.	0.747	0.0411	0.177	0.0061		8.	0.734	0.0311	0.179	0.0118	
9.	0.814	0.0460	0.197	0.0114		9.	0.795	0.0338	0.197	0.0165	
10.	0.869	0.0527	0.220	0.0170		10.	0.860	0.0375	0.216	0.0202	
11.	0.961	0.0592	0.237	0.0180		11.	0.925	0.0426	0.236	0.0265	
12.	1.035	0.0678	0.257	0.0217		12.	0.989	0.0473	0.253	0.0295	
13.	1.107	0.0766	0.274	0.0229		13.	1.042	0.0523	0.269	0.0337	
14.	1.172	0.0856	0.291	0.0261		14.	1.084	0.0583	0.279	0.0343	
15.	1.230	0.0964	0.305	0.0278		15.	1.101	0.0679	0.279	0.0317	
16.	1.258	0.1091	0.312	0.0278		16.	1.061	0.0934	0.246	0.0062	
17.	1.250	0.1302	0.294	0.0113		17.	0.567	0.2208	0.086	-0.0532	
18.	1.239	0.1572	0.272	-0.0086							
19.	1.169	0.1891	0.233	-0.0339							
20.	0.723	0.2982	0.104	-0.0748							

Table 6 - 0.67-NACA-0015
0015 RE=1.0(i0)6 SOLID WALLS

ALF	CL	CD	CM0	CMC/4
-4.	-0.394	0.0263	-0.102	-0.0117
-3.	-0.275	0.0227	-0.072	-0.0085
-2.	-0.173	0.0195	-0.047	-0.0073
-1.	-0.080	0.0169	-0.024	-0.0053
0.	0.009	0.0153	0.001	-0.0014
1.	0.094	0.0155	0.024	0.0023
2.	0.202	0.0165	0.050	0.0041
3.	0.320	0.0184	0.079	0.0054
4.	0.434	0.0206	0.108	0.0082
5.	0.553	0.0243	0.136	0.0090
6.	0.674	0.0288	0.164	0.0093
7.	0.811	0.0348	0.190	0.0051
8.	0.936	0.0412	0.197	-0.0162
9.	1.023	0.0468	0.201	-0.0322
10.	1.125	0.0541	0.206	-0.0497
11.	1.222	0.0621	0.214	-0.0635
12.	1.314	0.0683	0.212	-0.0856
13.	1.407	0.0782	0.221	-0.0966
14.	1.479	0.0887	0.225	-0.1083
15.	1.537	0.1034	0.223	-0.1127
16.	1.548	0.1273	0.216	-0.1328
17.	1.528	0.1665	0.220	-0.1255
18.	1.542	0.1966	0.213	-0.1366
19.	1.625	0.2198	0.210	-0.1581

0015 RE=1.0(i0)6 40XSS+P TSUSL

ALF	CL	CD	CM0	CMC/4
-4.	-0.392	0.0249	-0.101	-0.0113
-3.	-0.294	0.0213	-0.077	-0.0091
-2.	-0.197	0.0186	-0.051	-0.0057
-1.	-0.101	0.0166	-0.027	-0.0034
0.	-0.004	0.0157	0.001	0.0020
1.	0.062	0.0159	0.019	0.0052
2.	0.150	0.0168	0.043	0.0086
3.	0.246	0.0188	0.067	0.0105
4.	0.352	0.0218	0.095	0.0138
5.	0.454	0.0260	0.118	0.0145
6.	0.558	0.0309	0.142	0.0144
7.	0.672	0.0377	0.165	0.0114
8.	0.774	0.0449	0.137	0.0053
9.	0.884	0.0523	0.198	-0.0036
10.	0.963	0.0593	0.204	-0.0155
11.	1.051	0.0678	0.209	-0.0303
12.	1.139	0.0766	0.212	-0.0463
13.	1.222	0.0875	0.216	-0.0608
14.	1.304	0.0980	0.219	-0.0760
15.	1.380	0.1106	0.221	-0.0909
16.	1.451	0.1233	0.225	-0.1025
17.	1.514	0.1390	0.225	-0.1155
18.	1.535	0.1605	0.225	-0.1206
19.	1.531	0.1970	0.220	-0.1261
20.	1.569	0.2178	0.219	-0.1355

0015 RE=1.0(i0)6 40XLS+P TSUSL

ALF	CL	CD	CM0	CMC/4
-4.	-0.404	0.0251	-0.104	-0.0108
-3.	-0.302	0.0213	-0.078	-0.0087
-2.	-0.204	0.0191	-0.052	-0.0051
-1.	-0.107	0.0170	-0.027	-0.0025
0.	-0.025	0.0160	-0.004	0.0016
1.	0.060	0.0163	0.020	0.0060
2.	0.145	0.0173	0.043	0.0093
3.	0.250	0.0197	0.069	0.0113
4.	0.348	0.0222	0.094	0.0143
5.	0.450	0.0259	0.118	0.0152
6.	0.553	0.0311	0.142	0.0154
7.	0.668	0.0377	0.165	0.0120
8.	0.791	0.0457	0.186	0.0052
9.	0.886	0.0528	0.198	-0.0041
10.	0.965	0.0602	0.204	-0.0155
11.	1.053	0.0689	0.208	-0.0315
12.	1.141	0.0788	0.211	-0.0484
13.	1.225	0.0890	0.213	-0.0648
14.	1.305	0.1013	0.218	-0.0776
15.	1.383	0.1131	0.220	-0.0921
16.	1.453	0.1269	0.222	-0.1057
17.	1.516	0.1426	0.222	-0.1192
18.	1.548	0.1622	0.223	-0.1257
19.	1.541	0.1929	0.220	-0.1280
20.	1.575	0.2241	0.219	-0.1380

Table 6 - 0.67 - NACA - 0015

RE=1.0(i0)6 50%LS+P TSUSL					
ALF	CL	CD	CM0	CMC/4	
-4.	-0.389	0.0253	-0.099	-0.0096	
-3.	-0.294	0.0220	-0.075	-0.0074	
-2.	-0.199	0.0186	-0.050	-0.0039	
-1.	-0.101	0.0163	-0.026	-0.0027	
0.	-0.021	0.0152	-0.023	-0.0182	
1.	0.060	0.0149	0.020	0.0061	
2.	0.147	0.0157	0.043	0.0089	
3.	0.251	0.0178	0.068	0.0108	
4.	0.347	0.0202	0.093	0.0136	
5.	0.448	0.0241	0.118	0.0150	
6.	0.551	0.0284	0.141	0.0149	
7.	0.664	0.0355	0.163	0.0110	
8.	0.782	0.0420	0.184	0.0054	
9.	0.876	0.0497	0.196	-0.0044	
10.	0.951	0.0569	0.200	-0.0168	
11.	1.038	0.0659	0.204	-0.0319	
12.	1.120	0.0747	0.207	-0.0473	
13.	1.202	0.0846	0.211	-0.0618	
14.	1.278	0.0957	0.213	-0.0758	
15.	1.347	0.1084	0.217	-0.0879	
16.	1.417	0.1201	0.217	-0.1028	
17.	1.466	0.1349	0.221	-0.1094	
18.	1.499	0.1533	0.217	-0.1204	
19.	1.471	0.1848	0.213	-0.1196	

0015 RE=1.0(i0)6 70%LS+P TSUSL					
ALF	CL	CD	CM0	CMC/4	
-4.	-0.376	0.0251	-0.095	-0.0086	
-3.	-0.280	0.0213	-0.071	-0.0064	
-2.	-0.187	0.0181	-0.045	-0.0026	
-1.	-0.093	0.0160	-0.022	-0.0009	
0.	-0.015	0.0142	-0.000	-0.0032	
1.	0.063	0.0138	0.021	0.0069	
2.	0.151	0.0143	0.044	0.0096	
3.	0.244	0.0156	0.067	0.0115	
4.	0.346	0.0176	0.094	0.0145	
5.	0.445	0.0205	0.118	0.0162	
6.	0.541	0.0244	0.140	0.0163	
7.	0.649	0.0294	0.162	0.0136	
8.	0.762	0.0356	0.182	0.0077	
9.	0.842	0.0414	0.194	0.0022	
10.	0.909	0.0474	0.200	-0.0065	
11.	0.980	0.0540	0.202	-0.0210	
12.	1.054	0.0608	0.205	-0.0336	
13.	1.121	0.0685	0.203	-0.0505	
14.	1.183	0.0752	0.209	-0.0680	
15.	1.236	0.0831	0.212	-0.0865	
16.	1.279	0.0911	0.211	-0.0761	
17.	1.316	0.1024	0.211	-0.0845	
18.	1.296	0.1302	0.206	-0.0856	

0015 RE=1.0(i0)6 60%LS+P TSUSL

ALF	CL	CD	CM0	CMC/4	
-4.	-0.382	0.0253	-0.098	-0.0103	
-3.	-0.288	0.0213	-0.074	-0.0077	
-2.	-0.194	0.0186	-0.049	-0.0041	
-1.	-0.099	0.0161	-0.024	-0.0018	
0.	-0.019	0.0151	-0.002	0.0029	
1.	0.062	0.0150	0.021	0.0062	
2.	0.149	0.0158	0.043	0.0090	
3.	0.242	0.0174	0.067	0.0110	
4.	0.346	0.0198	0.093	0.0140	
5.	0.445	0.0236	0.117	0.0155	
6.	0.538	0.0282	0.140	0.0170	
7.	0.655	0.0342	0.161	0.0117	
8.	0.771	0.0413	0.182	0.0057	
9.	0.859	0.0479	0.196	-0.0004	
10.	0.926	0.0548	0.200	-0.0108	
11.	0.998	0.0619	0.205	-0.0224	
12.	1.093	0.0711	0.206	-0.0418	
13.	1.168	0.0797	0.208	-0.0566	
14.	1.238	0.0897	0.211	-0.0691	
15.	1.303	0.0998	0.215	-0.0791	
16.	1.358	0.1083	0.216	-0.0894	
17.	1.403	0.1202	0.216	-0.0989	
18.	1.399	0.1396	0.215	-0.0994	
19.	1.395	0.1700	0.209	-0.1058	

0015 RE=1.0(i0)6 80%LS+P TSUSL

ALF	CL	CD	CM0	CMC/4	
-4.	-0.367	0.0238	-0.095	-0.0103	
-3.	-0.269	0.0188	-0.069	-0.0074	
-2.	-0.177	0.0160	-0.044	-0.0032	
-1.	-0.081	0.0138	-0.018	0.0001	
0.	-0.000	0.0124	0.004	0.0041	
1.	0.076	0.0116	0.027	0.0091	
2.	0.163	0.0123	0.049	0.0114	
3.	0.265	0.0135	0.074	0.0133	
4.	0.355	0.0149	0.098	0.0169	
5.	0.451	0.0174	0.122	0.0190	
6.	0.547	0.0205	0.145	0.0191	
7.	0.649	0.0233	0.165	0.0170	
8.	0.751	0.0268	0.184	0.0127	
9.	0.824	0.0301	0.196	0.0089	
10.	0.882	0.0315	0.200	0.0001	
11.	0.935	0.0341	0.203	-0.0086	
12.	1.002	0.0389	0.204	-0.0221	
13.	1.055	0.0405	0.206	-0.0316	
14.	1.093	0.0451	0.206	-0.0395	
15.	1.123	0.0511	0.207	-0.0445	
16.	1.132	0.0646	0.206	-0.0470	

Table 6. - 0.67 - HACA - 0015

RE=1.0(10)6 50XSS+P TSUSL						0015 RE=1.0(10)6 70XSS+P TSUSL					
ALF	CL	CD	CM0	CMC/4		ALF	CL	CD	CM0	CMC/4	
-4.	-0.395	0.0247	-0.103	-0.0120		-4.	-0.379	0.0241	-0.097	-0.0098	
-3.	-0.296	0.0210	-0.077	-0.0089		-3.	-0.280	0.0200	-0.071	-0.0067	
-2.	-0.201	0.0135	-0.052	-0.0054		-2.	-0.187	0.0174	-0.047	-0.0040	
-1.	-0.103	0.0164	-0.026	-0.0028		-1.	-0.093	0.0153	-0.023	-0.0014	
0.	-0.022	0.0153	-0.004	-0.0015		0.	-0.013	0.0142	-0.000	0.0029	
1.	0.061	0.0156	0.020	0.0060		1.	0.074	0.0140	0.024	0.0069	
2.	0.148	0.0165	0.043	0.0090		2.	0.152	0.0147	0.044	0.0089	
3.	0.242	0.0184	0.067	0.0112		3.	0.246	0.0162	0.067	0.0110	
4.	0.345	0.0211	0.094	0.0144		4.	0.345	0.0183	0.093	0.0141	
5.	0.443	0.0248	0.118	0.0159		5.	0.441	0.0214	0.116	0.0151	
6.	0.546	0.0297	0.140	0.0153		6.	0.541	0.0258	0.139	0.0152	
7.	0.655	0.0360	0.163	0.0129		7.	0.646	0.0312	0.160	0.0121	
8.	0.776	0.0436	0.184	0.0064		8.	0.761	0.0375	0.180	0.0059	
9.	0.871	0.0508	0.197	-0.0014		9.	0.843	0.0431	0.196	0.0038	
10.	0.950	0.0569	0.203	-0.0139		10.	0.914	0.0478	0.201	-0.0075	
11.	1.031	0.0657	0.207	-0.0280		11.	0.988	0.0544	0.205	-0.0192	
12.	1.116	0.0745	0.211	-0.0428		12.	1.062	0.0619	0.206	-0.0347	
13.	1.203	0.0839	0.213	-0.0593		13.	1.132	0.0686	0.209	-0.0470	
14.	1.278	0.0944	0.215	-0.0742		14.	1.195	0.0772	0.209	-0.0604	
15.	1.351	0.1060	0.219	-0.0863		15.	1.258	0.0849	0.212	-0.0708	
16.	1.420	0.1190	0.220	-0.1005		16.	1.304	0.0948	0.212	-0.0812	
17.	1.472	0.1327	0.221	-0.1098		17.	1.324	0.1071	0.216	-0.0834	
18.	1.494	0.1501	0.219	-0.1167		18.	1.301	0.1243	0.208	-0.0839	
19.	1.488	0.1836	0.220	-0.1162							
20.	1.512	0.2093	0.215	-0.1272							

0015 RE=1.0(10)6 60XSS+P TSUSL

0015 RE=1.0(10)6 80XSS+P TSUSL

ALF	CL	CD	CM0	CMC/4		ALF	CL	CD	CM0	CMC/4	
-4.	-0.384	0.0247	-0.099	-0.0109		-4.	-0.375	0.0234	-0.095	-0.0093	
-3.	-0.288	0.0209	-0.074	-0.0080		-3.	-0.280	0.0197	-0.071	-0.0069	
-2.	-0.194	0.0179	-0.049	-0.0044		-2.	-0.188	0.0166	-0.046	-0.0029	
-1.	-0.097	0.0162	-0.024	-0.0021		-1.	-0.093	0.0144	-0.022	-0.0005	
0.	-0.017	0.0153	-0.001	0.0030		0.	-0.013	0.0128	0.001	0.0038	
1.	0.064	0.0152	0.021	0.0060		1.	0.063	0.0123	0.024	0.0080	
2.	0.151	0.0158	0.044	0.0092		2.	0.154	0.0127	0.046	0.0110	
3.	0.245	0.0174	0.068	0.0113		3.	0.254	0.0138	0.072	0.0133	
4.	0.344	0.0195	0.093	0.0145		4.	0.347	0.0151	0.096	0.0163	
5.	0.442	0.0230	0.117	0.0158		5.	0.444	0.0176	0.120	0.0182	
6.	0.540	0.0272	0.139	0.0155		6.	0.541	0.0207	0.142	0.0188	
7.	0.646	0.0330	0.160	0.0127		7.	0.647	0.0244	0.164	0.0158	
8.	0.763	0.0401	0.181	0.0065		8.	0.756	0.0293	0.183	0.0108	
9.	0.855	0.0466	0.197	0.0020		9.	0.837	0.0337	0.196	0.0056	
10.	0.926	0.0529	0.202	-0.0092		10.	0.903	0.0382	0.200	-0.0048	
11.	1.006	0.0607	0.206	-0.0231		11.	0.973	0.0422	0.204	-0.0170	
12.	1.086	0.0683	0.206	-0.0401		12.	1.044	0.0486	0.206	-0.0305	
13.	1.158	0.0774	0.212	-0.0506		13.	1.107	0.0544	0.208	-0.0416	
14.	1.233	0.0870	0.213	-0.0658		14.	1.162	0.0604	0.210	-0.0520	
15.	1.296	0.0968	0.216	-0.0763		15.	1.208	0.0667	0.213	-0.0578	
16.	1.358	0.1075	0.217	-0.0886		16.	1.249	0.0764	0.210	-0.0694	
17.	1.398	0.1196	0.218	-0.0958		17.	1.242	0.1004	0.210	-0.0684	
18.	1.417	0.1386	0.219	-0.0997							
19.	1.391	0.1705	0.214	-0.1002							
20.	1.427	0.1963	0.210	-0.1130							

Table 7. Windtunnel balance results - Joukowski airfoil
 JOUKOWSKY RE=0.5(10)6 SOLID WALLS JOUKOWSKY RE=0.5(10)6 SOLID WALLS

ALF	CL	CD	CM0	CMC/4	ALF	CL	CD	CM0	CMC/4
-7.	-0.346	0.0195	-0.159	-0.0735	-7.	-0.345	0.0194	-0.158	-0.0723
-6.	-0.242	0.0182	-0.133	-0.0732	-6.	-0.241	0.0180	-0.133	-0.0728
-5.	-0.134	0.0174	-0.107	-0.0731	-5.	-0.134	0.0171	-0.106	-0.0727
-4.	-0.023	0.0167	-0.079	-0.0729	-4.	-0.024	0.0168	-0.078	-0.0723
-3.	0.087	0.0168	-0.051	-0.0723	-3.	0.086	0.0172	-0.051	-0.0717
-2.	0.193	0.0174	-0.024	-0.0714	-2.	0.192	0.0179	-0.023	-0.0706
-1.	0.297	0.0188	0.003	-0.0705	-1.	0.296	0.0193	0.003	-0.0699
0.	0.405	0.0206	0.031	-0.0691	0.	0.403	0.0212	0.031	-0.0689
1.	0.511	0.0228	0.059	-0.0675	1.	0.506	0.0233	0.058	-0.0673
2.	0.615	0.0256	0.087	-0.0653	2.	0.610	0.0259	0.087	-0.0645
3.	0.715	0.0290	0.114	-0.0631	3.	0.713	0.0289	0.114	-0.0625
4.	0.815	0.0328	0.141	-0.0615	4.	0.811	0.0326	0.141	-0.0607
5.	0.910	0.0376	0.166	-0.0592	5.	0.907	0.0370	0.166	-0.0591
6.	1.000	0.0403	0.190	-0.0582	6.	0.998	0.0425	0.190	-0.0574
7.	1.096	0.0454	0.215	-0.0559	7.	1.091	0.0478	0.215	-0.0551
8.	1.189	0.0506	0.241	-0.0530	8.	1.179	0.0534	0.239	-0.0524
9.	1.267	0.0567	0.263	-0.0495	9.	1.265	0.0594	0.263	-0.0491
10.	1.331	0.0645	0.281	-0.0471	10.	1.326	0.0672	0.230	-0.0466
11.	1.377	0.0741	0.291	-0.0473	11.	1.368	0.0773	0.290	-0.0465
12.	1.398	0.0921	0.289	-0.0548	12.	1.394	0.0959	0.289	-0.0546
13.	1.176	0.2304	0.142	-0.1547	13.	1.186	0.2345	0.146	-0.1530

JOUKOWSKY RE=0.5(10)6 SOLID WALLS

ALF	CL	CD	CM0	CMC/4
-7.	-0.346	0.0195	-0.159	-0.0733
-6.	-0.241	0.0183	-0.133	-0.0732
-5.	-0.134	0.0174	-0.106	-0.0726
-4.	-0.024	0.0165	-0.078	-0.0723
-3.	0.086	0.0166	-0.051	-0.0718
-2.	0.193	0.0179	-0.023	-0.0709
-1.	0.297	0.0192	0.003	-0.0703
0.	0.403	0.0205	0.031	-0.0689
1.	0.508	0.0223	0.059	-0.0674
2.	0.613	0.0246	0.087	-0.0651
3.	0.713	0.0273	0.114	-0.0628
4.	0.813	0.0307	0.141	-0.0611
5.	0.908	0.0349	0.166	-0.0593
6.	1.003	0.0415	0.191	-0.0579
7.	1.094	0.0469	0.215	-0.0556
8.	1.186	0.0525	0.241	-0.0524
9.	1.266	0.0584	0.263	-0.0495
10.	1.331	0.0660	0.281	-0.0467
11.	1.376	0.0770	0.292	-0.0469
12.	1.401	0.0943	0.291	-0.0540
13.	1.178	0.2357	0.146	-0.1518

Table 7
JOUKOWSKY RE=0.5(10)6 40%SS+P TSUSL

ALF	CL	CD	CM0	CMC/4
-7.	-0.331	0.0189	-0.155	-0.0734
-6.	-0.227	0.0173	-0.129	-0.0722
-5.	-0.125	0.0157	-0.102	-0.0710
-4.	-0.018	0.0152	-0.076	-0.0703
-3.	0.085	0.0157	-0.049	-0.0694
-2.	0.183	0.0161	-0.023	-0.0683
-1.	0.282	0.0169	0.003	-0.0671
0.	0.381	0.0187	0.029	-0.0656
1.	0.477	0.0212	0.054	-0.0641
2.	0.572	0.0238	0.081	-0.0614
3.	0.666	0.0272	0.106	-0.0589
4.	0.755	0.0309	0.130	-0.0575
5.	0.845	0.0347	0.154	-0.0554
6.	0.932	0.0400	0.177	-0.0535
7.	1.014	0.0450	0.200	-0.0515
8.	1.092	0.0507	0.222	-0.0492
9.	1.171	0.0570	0.243	-0.0463
10.	1.239	0.0642	0.262	-0.0438
11.	1.282	0.0727	0.273	-0.0426
12.	1.309	0.0855	0.275	-0.0468
13.	1.078	0.2078	0.134	-0.1380

JOUKOWSKY RE=0.5(10)6 40%LS+P TSUSL

ALF	CL	CD	CM0	CMC/4
-7.	-0.335	0.0195	-0.156	-0.0733
-6.	-0.234	0.0178	-0.130	-0.0723
-5.	-0.131	0.0166	-0.104	-0.0717
-4.	-0.025	0.0162	-0.078	-0.0711
-3.	0.079	0.0158	-0.050	-0.0698
-2.	0.178	0.0165	-0.025	-0.0690
-1.	0.277	0.0178	0.001	-0.0677
0.	0.375	0.0188	0.027	-0.0665
1.	0.472	0.0217	0.052	-0.0650
2.	0.570	0.0244	0.079	-0.0621
3.	0.663	0.0277	0.105	-0.0597
4.	0.751	0.0314	0.128	-0.0580
5.	0.841	0.0358	0.153	-0.0559
6.	0.930	0.0404	0.177	-0.0536
7.	1.017	0.0457	0.200	-0.0516
8.	1.094	0.0520	0.221	-0.0495
9.	1.170	0.0581	0.242	-0.0467
10.	1.237	0.0652	0.261	-0.0438
11.	1.282	0.0738	0.272	-0.0430
12.	1.316	0.0864	0.277	-0.0464
13.	1.101	0.2018	0.138	-0.1393

Table 7

JOUKOWSKY RE=0.5(10)6 50%LS+P TSUSL

ALF	CL	CD	CMO	CMC/4
-7.	-0.327	0.0191	-0.152	-0.0712
-6.	-0.227	0.0174	-0.127	-0.0701
-5.	-0.125	0.0163	-0.101	-0.0700
-4.	-0.022	0.0162	-0.075	-0.0694
-3.	0.081	0.0163	-0.048	-0.0677
-2.	0.178	0.0156	-0.023	-0.0670
-1.	0.274	0.0180	0.002	-0.0660
0.	0.372	0.0195	0.027	-0.0648
1.	0.468	0.0223	0.053	-0.0631
2.	0.564	0.0253	0.079	-0.0612
3.	0.657	0.0282	0.104	-0.0587
4.	0.747	0.0314	0.128	-0.0570
5.	0.832	0.0353	0.151	-0.0551
6.	0.924	0.0384	0.176	-0.0533
7.	1.006	0.0435	0.198	-0.0514
8.	1.084	0.0488	0.219	-0.0487
9.	1.162	0.0556	0.241	-0.0459
10.	1.223	0.0623	0.258	-0.0434
11.	1.268	0.0712	0.270	-0.0424
12.	1.297	0.0838	0.273	-0.0459
13.	1.076	0.1984	0.135	-0.1362

JOUKOWSKY RE=0.5(10)6 70%LS+P TSUSL

ALF	CL	CD	CMO	CMC/4
-7.	-0.314	0.0189	-0.150	-0.0726
-6.	-0.216	0.0172	-0.125	-0.0717
-5.	-0.114	0.0153	-0.099	-0.0707
-4.	-0.009	0.0155	-0.072	-0.0692
-3.	0.091	0.0155	-0.046	-0.0681
-2.	0.188	0.0155	-0.020	-0.0667
-1.	0.283	0.0165	0.005	-0.0652
0.	0.377	0.0179	0.030	-0.0639
1.	0.471	0.0204	0.055	-0.0621
2.	0.564	0.0227	0.080	-0.0598
3.	0.655	0.0256	0.105	-0.0572
4.	0.743	0.0285	0.129	-0.0551
5.	0.835	0.0321	0.154	-0.0533
6.	0.917	0.0370	0.176	-0.0513
7.	0.995	0.0413	0.198	-0.0486
8.	1.070	0.0467	0.218	-0.0460
9.	1.140	0.0524	0.238	-0.0438
10.	1.196	0.0585	0.253	-0.0414
11.	1.239	0.0677	0.264	-0.0412
12.	1.234	0.0787	0.257	-0.0469
13.	0.961	0.1994	0.104	-0.1357

JOUKOWSKY RE=0.5(10)6 60%LS+P TSUSL

ALF	CL	CD	CMO	CMC/4
-7.	-0.323	0.0186	-0.153	-0.0733
-6.	-0.221	0.0170	-0.127	-0.0724
-5.	-0.119	0.0160	-0.101	-0.0716
-4.	-0.016	0.0156	-0.075	-0.0704
-3.	0.088	0.0155	-0.047	-0.0690
-2.	0.186	0.0162	-0.022	-0.0680
-1.	0.279	0.0170	0.002	-0.0667
0.	0.375	0.0188	0.028	-0.0653
1.	0.470	0.0215	0.053	-0.0636
2.	0.564	0.0239	0.079	-0.0614
3.	0.656	0.0266	0.104	-0.0587
4.	0.743	0.0301	0.127	-0.0568
5.	0.829	0.0338	0.150	-0.0551
6.	0.914	0.0395	0.174	-0.0528
7.	0.997	0.0446	0.196	-0.0512
8.	1.078	0.0504	0.218	-0.0484
9.	1.146	0.0562	0.237	-0.0458
10.	1.202	0.0628	0.253	-0.0429
11.	1.268	0.0727	0.269	-0.0429
12.	1.296	0.0835	0.271	-0.0474
13.	1.064	0.2080	0.125	-0.1433

JOUKOWSKY RE=0.5(10)6 80%LS+P TSUSL

ALF	CL	CD	CMO	CMC/4
-7.	-0.304	0.0178	-0.147	-0.0719
-6.	-0.203	0.0153	-0.121	-0.0702
-5.	-0.104	0.0147	-0.095	-0.0694
-4.	-0.000	0.0140	-0.069	-0.0685
-3.	0.101	0.0140	-0.043	-0.0674
-2.	0.197	0.0138	-0.017	-0.0653
-1.	0.288	0.0151	0.007	-0.0644
0.	0.385	0.0159	0.033	-0.0623
1.	0.480	0.0177	0.059	-0.0603
2.	0.572	0.0201	0.084	-0.0580
3.	0.660	0.0227	0.108	-0.0554
4.	0.751	0.0256	0.133	-0.0535
5.	0.837	0.0287	0.156	-0.0511
6.	0.918	0.0319	0.178	-0.0493
7.	0.998	0.0361	0.200	-0.0465
8.	1.071	0.0414	0.220	-0.0444
9.	1.134	0.0470	0.238	-0.0414
10.	1.188	0.0525	0.253	-0.0394
11.	1.224	0.0621	0.261	-0.0399
12.	1.237	0.1263	0.259	-0.0561
13.	0.963	0.1971	0.107	-0.1369

Table 7

JOUKOWSKY RE=0.5(10)6 50%SS+P TSUSL

ALF	CL	CD	CMO	CMC/4
-7.	-0.324	0.0178	-0.151	-0.0712
-6.	-0.225	0.0162	-0.127	-0.0706
-5.	-0.124	0.0152	-0.101	-0.0698
-4.	-0.019	0.0149	-0.074	-0.0689
-3.	0.085	0.0148	-0.047	-0.0682
-2.	0.183	0.0154	-0.021	-0.0666
-1.	0.277	0.0167	0.003	-0.0657
0.	0.375	0.0182	0.029	-0.0641
1.	0.468	0.0206	0.053	-0.0628
2.	0.564	0.0234	0.080	-0.0603
3.	0.653	0.0262	0.104	-0.0579
4.	0.746	0.0296	0.128	-0.0566
5.	0.832	0.0331	0.151	-0.0547
6.	0.921	0.0400	0.176	-0.0526
7.	1.002	0.0455	0.198	-0.0506
8.	1.082	0.0512	0.219	-0.0483
9.	1.156	0.0577	0.240	-0.0454
10.	1.215	0.0648	0.257	-0.0428
11.	1.260	0.0739	0.268	-0.0419
12.	1.288	0.0863	0.271	-0.0459
13.	1.057	0.2078	0.130	-0.1368

JOUKOWSKY RE=0.5(10)6 70%SS+P TSUSL

ALF	CL	CD	CMO	CMC/4
-7.	-0.325	0.0182	-0.156	-0.0751
-6.	-0.221	0.0170	-0.129	-0.0738
-5.	-0.119	0.0158	-0.103	-0.0727
-4.	-0.016	0.0502	-0.076	-0.0715
-3.	0.087	0.0154	-0.049	-0.0699
-2.	0.185	0.0158	-0.023	-0.0690
-1.	0.281	0.0167	0.002	-0.0677
0.	0.374	0.0189	0.026	-0.0664
1.	0.471	0.0215	0.053	-0.0643
2.	0.563	0.0241	0.078	-0.0618
3.	0.660	0.0271	0.104	-0.0594
4.	0.746	0.0300	0.128	-0.0575
5.	0.832	0.0334	0.151	-0.0553
6.	0.916	0.0370	0.174	-0.0530
7.	0.998	0.0424	0.196	-0.0511
8.	1.074	0.0475	0.217	-0.0482
9.	1.148	0.0533	0.238	-0.0452
10.	1.209	0.0603	0.255	-0.0432
11.	1.252	0.0693	0.266	-0.0425
12.	1.252	0.0800	0.260	-0.0475
13.	0.995	0.1925	0.110	-0.1407

JOUKOWSKY RE=0.5(10)6 60%SS+P TSUSL

ALF	CL	CD	CMO	CMC/4
-7.	-0.323	0.0177	-0.152	-0.0720
-6.	-0.222	0.0166	-0.126	-0.0704
-5.	-0.123	0.0160	-0.101	-0.0700
-4.	-0.018	0.0144	-0.073	-0.0687
-3.	0.084	0.0147	-0.047	-0.0678
-2.	0.181	0.0155	-0.022	-0.0668
-1.	0.276	0.0167	0.003	-0.0654
0.	0.371	0.0179	0.028	-0.0639
1.	0.467	0.0203	0.053	-0.0626
2.	0.561	0.0231	0.079	-0.0601
3.	0.653	0.0257	0.104	-0.0576
4.	0.741	0.0284	0.128	-0.0560
5.	0.830	0.0330	0.152	-0.0540
6.	0.914	0.0370	0.174	-0.0522
7.	0.998	0.0427	0.197	-0.0500
8.	1.076	0.0483	0.218	-0.0476
9.	1.148	0.0547	0.239	-0.0442
10.	1.205	0.0620	0.255	-0.0421
11.	1.252	0.0704	0.267	-0.0412
12.	1.277	0.0815	0.268	-0.0460
13.	1.055	0.1950	0.128	-0.1378

JOUKOWSKY RE=0.5(10)6 80%SS+P TSUSL

ALF	CL	CD	CMO	CMC/4
-7.	-0.316	0.0170	-0.152	-0.0734
-6.	-0.218	0.0154	-0.126	-0.0717
-5.	-0.116	0.0143	-0.099	-0.0704
-4.	-0.014	0.0136	-0.073	-0.0695
-3.	0.089	0.0135	-0.046	-0.0682
-2.	0.185	0.0140	-0.022	-0.0673
-1.	0.279	0.0154	0.004	-0.0654
0.	0.374	0.0167	0.029	-0.0633
1.	0.470	0.0180	0.055	-0.0614
2.	0.562	0.0199	0.081	-0.0586
3.	0.655	0.0226	0.106	-0.0567
4.	0.740	0.0257	0.129	-0.0544
5.	0.827	0.0286	0.152	-0.0525
6.	0.909	0.0335	0.175	-0.0505
7.	0.991	0.0374	0.197	-0.0485
8.	1.065	0.0426	0.217	-0.0456
9.	1.137	0.0475	0.238	-0.0427
10.	1.194	0.0549	0.254	-0.0405
11.	1.230	0.0630	0.262	-0.0405
12.	1.246	0.0742	0.259	-0.0470
13.	0.998	0.1872	0.115	-0.1361

Table 8. Quantities derived from balance results.

0.25 Clark-Y $Re = 0.45(10)^6$

Wall	m	α_{10}	x_{ac}	$\frac{dC}{d\alpha} M_0$	α_{m_0}
solid	0.1011	-6.42	0.231	0.0276	-3.12
40%LP	.0970	-6.45	.233	.0263	-2.96
50%LP	.0958	-6.48	.229	.0263	-3.00
60%LP	.0954	-6.54	.228	.0263	-3.02
70%LP	.0947	-6.60	.255	.0265	-3.11
80%LP	.0940	-6.67	.229	.0259	-3.25
40%SP	.0967	-6.51	.228	.0267	-2.99
50%SP	.0952	-6.52	.230	.0261	-3.03
60%SP	.0944	-6.57	.231	.0257	-3.09
70%SP	.0917	-6.36	.277	.0245	-2.77
80%SP	.0906	-6.46	.228	.0250	-2.90

0.39 Clark-Y $Re = 0.5(10)^6$

Wall	m	α_{10}	x_{ac}	$\frac{dC}{d\alpha} M_0$	α_{m_0}
solid	0.1032	-6.28	0.235	0.0275	-2.86
40%LP	.0956	-6.16	.229	.0261	-2.66
50%LP	.0936	-6.22	.230	.0254	-2.73
60%LP	.0914	-6.35	.227	.0251	-2.79
70%LP	.0903	-6.40	.225	.0250	-2.87
80%LP	.0882	-6.54	.223	.0246	-3.01
40%SP	.0952	-6.19	.227	.0261	-2.69
50%SP	.0941	-6.21	.230	.0256	-2.72
60%SP	.0923	-6.30	.233	.0249	-2.78
70%SP	.0917	-6.36	.227	.0253	-2.84
80%SP	.0912	-6.45	.222	.0255	-2.92

0.53 Clark-Y $Re = 0.5(10)^6$

Wall	m	α_{10}	x_{ac}	$\frac{dC}{d\alpha} M_0$	α_{m_0}
solid	0.1044	-6.42	0.235	0.0278	-2.97
40%LP	.0944	-6.27	.231	.0256	-2.73
50%LP	.0932	-6.35	.234	.0250	-2.79
60%LP	.0917	-6.39	.230	.0249	-2.81
70%LP	.0907	-6.43	.232	.0245	-2.90
80%LP	.0889	-6.55	.226	.0246	-3.03
40%SP	.0938	-6.29	.233	.0252	-2.73
50%SP	.0928	-6.32	.233	.0250	-2.75
60%SP	.0920	-6.35	.232	.0249	-2.76
70%SP	.0907	-6.39	.231	.0246	-2.82
80%SP	.0895	-6.47	.227	.0246	-2.96

Table 8 (cont'd).

0.66 Clark-Y $Re = 0.5(10)^6$

Wall	m	α_{10}	x_{ac}	$\frac{dC}{d\alpha} M_0$	α_{m_0}
solid	0.1074	-6.33	0.234	0.0283	-2.74
40%LP	.0947	-6.02	.234	.0250	-2.41
50%LP	.0931	-6.14	.235	.0245	-2.50
60%LP	.0909	-6.19	.224	.0249	-2.50
70%LP	.0899	-6.16	.226	.0244	-2.57
80%LP	.0884	-6.31	.219	.0247	-2.81
40%SP	.0932	-6.05	.232	.0248	-2.41
50%SP	.0930	-6.19	.224	.0255	-2.53
60%SP	.0915	-6.11	.229	.0246	-2.46
70%SP	.0902	-6.18	.228	.0244	-2.57
80%SP	.0887	-6.17	.222	.0245	-2.68

0.66 Clark-Y $Re = 1.0(10)^6$

Wall	m	α_{10}	x_{ac}	$\frac{dC}{d\alpha} M_0$	α_{m_0}
solid	0.1124	-6.28	0.243	0.0287	-2.82
40%LP	.0989	-5.95	.238	.0257	-2.41
50%LP	.0974	-6.03	.238	.0253	-2.49
60%LP	.0962	-6.09	.235	.0253	-2.55
70%LP	.0955	-6.09	.231	.0255	-2.58
80%LP	.0930	-6.21	.228	.0251	-2.82
40%SP	.0982	-6.00	.235	.0259	-2.43
50%SP	.0976	-6.00	.237	.0255	-2.49
60%SP	.0946	-6.13	.233	.0251	-2.60
70%SP	.0934	-6.11	.230	.0250	-2.62
80%SP	.0924	-6.16	.255	.0253	-2.76

Table 8 (cont'd).

0.17 NACA-0015 $Re = 0.3(10)^6$

Wall	m	α_{10}	x_{ac}	$\frac{dC}{d\alpha} M_0$	α_{m_0}
solid	0.0982	0.03	0.230	0.0251	0.08
40%LP	.0958	.04	.231	.0245	.04
50%LP	.0957	-0.01	.232	.0243	- .01
60%LP	.0961	- .04	.227	.0249	.00
70%LP	.0967	- .02	.233	.0244	- .08
80%LP	.0960	- .10	.236	.0240	- .16
40%SP	.0967	.04	.232	.0245	.04
50%SP	.0963	.04	.230	.0247	.03
60%SP	.0954	.00	.232	.0243	- .01
70%SP	.0958	.00	.231	.0245	.00
80%SP	.0956	- .04	.229	.0246	- .05

0.34 NACA-0015 $Re = 0.5(10)^6$

Wall	m	α_{10}	x_{ac}	$\frac{dC}{d\alpha} M_0$	α_{m_0}
solid	0.0993	0.01	0.236	0.0266	0.02
40%LP	.0945	.10	.231	.0258	.07
50%LP	.0941	.07	.233	.0255	.02
60%LP	.0929	.04	.234	.0251	- .01
70%LP	.0927	.03	.233	.0251	- .04
80%LP	.0927	- .07	.234	.0251	- .13
40%SP	.0929	.06	.236	.0249	.03
50%SP	.0925	.04	.237	.0247	- .03
60%SP	.0924	.01	.230	.0253	- .03
70%SP	.0928	.01	.231	.0254	- .04
80%SP	.0925	- .01	.233	.0251	- .05

0.50 NACA-0015 $Re = 0.5(10)^6$

Wall	m	α_{10}	x_{ac}	$\frac{dC}{d\alpha} M_0$	α_{m_0}
solid	0.1036	0.04	0.252	0.0249	0.07
40%LP	.0940	.14	.250	.0228	.07
50%LP	.0935	.13	.249	.0227	.04
60%LP	.0936	.12	.249	.0227	.03
70%LP	.0924	- .01	.247	.0226	- .01
80%LP	.0906	- .04	.246	.0223	- .16
40%SP	.0933	.14	.250	.0226	.07
50%SP	.0929	.14	.249	.0226	.07
60%SP	.0929	.12	.246	.0229	.02
70%SP	.0921	.20	.249	.0226	.00
80%SP	.0913	.06	.247	.0224	- .08

Table 8 (cont'd).

0.67 NACA-0015 $Re = 0.5(10)^6$

Wall	m	α_{10}	x_{ac}	$\frac{dC}{d\alpha} M_0$	α_{m_0}
solid	0.1080	-0.03	0.214	0.0264	0.01
40%LP	.0954	0.25	.219	.0228	.13
50%LP	.0945	.22	.219	.0226	.06
60%LP	.0940	.13	.211	.0232	-.01
70%LP	.0915	.09	.212	.0225	-.12
80%LP	.0891	-.04	.210	.0221	-.31
40%SP	.0960	.22	.214	.0234	.10
50%SP	.0935	.22	.216	.0226	.07
60%SP	.0928	.23	.215	.0226	.07
70%SP	.0921	.16	.212	.0227	.00
80%SP	.0902	.05	.211	.0223	-.18

0.67 NACA-0015 $RE = 1.0(10)^6$

Wall	m	α_{10}	x_{ac}	$\frac{dC}{d\alpha} M_0$	α_{m_0}
solid	0.1114	-0.08	0.226	0.0259	-0.08
40%LP	.0981	.29	.213	.0241	.15
50%LP	.0969	.25	.208	.0242	.25
60%LP	.0952	.23	.213	.0233	.08
70%LP	.0940	.19	.213	.0230	.00
80%LP	.0922	.04	.208	.0230	-.18
40%SP	.0975	.22	.213	.0239	.11
50%SP	.0962	.27	.211	.0237	.14
60%SP	.0943	.22	.212	.0232	.06
70%SP	.0935	.17	.214	.0229	.00
80%SP	.0935	.16	.210	.0232	-.05

Table 8 (cont'd).

Joukowsky $Re = 0.5(10)^6$

Wall . .	m . .	α_{10} . .	x_{ac} . .	$\frac{dC}{d\alpha} M_0$. .	α_{m_0} .
solid#1	0.1059	-3.78	0.236	0.0275	-1.14
solid#2	.1056	-3.78	.236	.0274	-1.14
solid#3	.1055	-3.77	.236	.0274	-1.14
40%LP	.0988	-3.74	.233	.0260	-1.02
50%LP	.0975	-3.77	.234	.0256	-1.07
60%LP	.0965	-3.83	.232	.0255	-1.07
70%LP	.0958	-3.88	.230	.0254	-1.15
80%LP	.0954	-3.98	.230	.0254	-1.29
40%SP	.0984	-3.80	.232	.0259	-1.09
50%SP	.0970	-3.80	.233	.0255	-1.10
60%SP	.0965	-3.80	.232	.0254	-1.10
70%SP	.0968	-3.83	.231	.0257	-1.04
80%SP	.0959	-3.85	.230	.0256	-1.14

Table 9. Pressure coefficients for NACA-0015 airfoil

RE=1.0*(10)6 SOLID WALLS 0.67-NACA-0015

ALPHA X/C	0	2	4	6	8	10	12	14	16
0.0	1.000	0.874	0.527	-0.153	-1.084	-2.101	-3.302	-4.555	-5.567
0.2	0.774	0.777	-0.251	-1.179	-2.396	-3.573	-4.912	-6.330	-7.468
0.4	0.559	0.847	-0.643	-1.694	-2.800	-3.942	-5.301	-6.573	-7.571
1.0	0.151	-0.367	-1.040	-1.943	-3.024	-4.035	-5.112	-6.191	-7.006
1.5	-0.342	-0.845	-1.176	-2.015	-2.948	-3.845	-4.773	-5.776	-6.543
1.9	-0.192	-0.665	-1.275	-2.025	-2.907	-3.701	-4.548	-5.468	-6.286
2.5	-0.268	-0.723	-1.291	-1.994	-2.815	-3.547	-4.368	-5.262	-6.081
2.9	-0.320	-0.765	-1.302	-1.958	-2.718	-3.388	-4.235	-5.159	-5.413
4.9	-0.483	-0.844	-1.275	-1.809	-2.306	-3.024	-3.240	-3.889	-4.246
7.4	-0.656	-0.859	-1.218	-1.645	-2.151	-2.414	-2.902	-3.311	-3.532
9.8	-0.683	-0.844	-1.145	-1.527	-1.855	-2.199	-2.579	-2.898	-3.085
12.4	-0.593	-0.823	-1.098	-1.415	-1.722	-2.030	-2.317	-2.578	-2.715
14.8	-0.588	-0.796	-1.061	-1.312	-1.594	-1.855	-2.117	-2.351	-2.432
17.3	-0.523	-0.765	-1.004	-1.225	-1.487	-1.732	-1.938	-2.135	-2.201
20.2	-0.572	-0.728	-0.941	-1.117	-1.370	-1.589	-1.774	-1.944	-1.970
22.3	-0.556	-0.707	-0.904	-1.086	-1.309	-1.491	-1.671	-1.820	-1.826
24.8	-0.541	-0.681	-0.863	-1.030	-1.242	-1.389	-1.558	-1.675	-1.636
27.2	-0.525	-0.659	-0.816	-0.974	-1.155	-1.317	-1.451	-1.567	-1.497
29.7	-0.509	-0.629	-0.769	-0.932	-1.099	-1.235	-1.363	-1.453	-1.374
32.7	-0.485	-0.571	-0.711	-0.840	-0.977	-1.096	-1.199	-1.273	-1.117
39.6	-0.441	-0.524	-0.643	-0.758	-0.869	-0.978	-1.056	-1.092	-0.896
49.5	-0.357	-0.425	-0.518	-0.594	-0.696	-0.748	-0.810	-0.803	-0.670
59.5	-0.289	-0.341	-0.408	-0.461	-0.537	-0.573	-0.594	-0.555	-0.418
69.3	-0.221	-0.252	-0.303	-0.343	-0.384	-0.409	-0.410	-0.395	-0.343
79.2	-0.143	-0.163	-0.194	-0.215	-0.251	-0.250	-0.251	-0.308	-0.362
89.4	-0.042	-0.047	-0.058	-0.071	-0.093	-0.102	-0.148	-0.256	-0.490
97.0	0.092	0.094	0.088	0.068	0.024	-0.025	-0.102	-0.225	-0.403
0.2	0.769	0.954	0.982	0.765	0.300	-0.281	-1.045	-1.861	-2.576
0.3	0.589	0.859	0.988	0.939	0.668	0.252	-0.297	-0.917	-1.471
1.0	0.172	0.850	0.826	0.991	0.584	0.847	0.616	0.327	0.044
1.5	-0.212	0.777	0.689	0.909	1.005	0.985	0.883	0.709	0.553
2.0	-0.164	0.730	0.564	0.821	0.969	1.001	0.970	0.874	0.774
2.4	-0.274	0.120	0.454	0.734	0.918	0.991	1.000	0.957	0.903
2.9	-0.331	0.042	0.371	0.652	0.867	0.965	1.011	0.998	0.980
4.9	-0.477	-0.152	0.146	0.427	0.668	0.806	0.913	0.972	1.005
7.4	-0.577	-0.130	0.094	0.150	0.361	0.509	0.642	0.735	0.800
9.8	-0.598	-0.388	-0.199	0.011	0.203	0.339	0.462	0.554	0.630
12.4	-0.541	-0.393	-0.251	-0.091	0.060	0.160	0.262	0.343	0.399
14.8	-0.509	-0.383	-0.256	-0.112	0.024	0.114	0.211	0.281	0.322
17.3	-0.557	-0.288	-0.215	-0.117	-0.022	0.032	0.093	0.131	0.152
20.2	-0.516	-0.178	-0.152	-0.086	-0.022	0.001	0.031	0.043	0.024
22.3	-0.413	-0.121	-0.115	-0.086	-0.011	-0.009	0.006	0.002	-0.028
24.8	-0.354	-0.053	-0.037	-0.030	0.014	-0.009	-0.015	-0.050	-0.110
27.2	-0.288	0.073	0.062	0.037	0.050	-0.004	-0.040	-0.117	-0.207
C _L	0.001	0.201	0.427	0.674	0.940	1.120	1.301	1.452	1.541

0015 RE=1.0*(10)6 40%LS DAR UPPER, SOLID LOWER, PLENUM

ALPHA X/C	0	2	4	6	8	10	12	14	16
0.0	1.002	0.914	0.623	0.127	-0.653	-1.541	-2.556	-3.703	-4.931
0.2	0.788	0.467	-0.061	-0.781	-1.778	-2.828	-4.028	-5.313	-6.617
0.4	0.568	0.153	-0.420	-1.169	-2.163	-3.175	-4.294	-5.509	-6.786
1.0	0.206	-0.248	-0.896	-1.514	-2.400	-3.251	-4.228	-5.230	-6.232
1.5	-0.249	-0.417	-0.940	-1.581	-2.379	-3.154	-3.952	-4.849	-5.779
1.9	-0.126	-0.540	-1.042	-1.643	-2.353	-3.042	-3.776	-4.611	-5.502
2.5	-0.203	-0.592	-1.058	-1.612	-2.276	-2.899	-3.623	-4.436	-5.420
2.9	-0.269	-0.643	-1.078	-1.597	-2.189	-2.766	-3.464	-4.343	-4.854
4.9	-0.412	-0.720	-1.073	-1.478	-1.968	-2.429	-2.853	-3.223	-3.755
7.4	-0.479	-0.741	-1.022	-1.349	-1.747	-1.985	-2.402	-2.753	-3.107
9.8	-0.509	-0.725	-0.960	-1.251	-1.557	-1.796	-2.105	-2.408	-2.696
12.4	-0.530	-0.705	-0.919	-1.163	-1.397	-1.633	-1.894	-2.165	-2.403
14.8	-0.514	-0.684	-0.863	-1.065	-1.290	-1.510	-1.735	-1.959	-2.158
17.3	-0.504	-0.659	-0.816	-0.998	-1.197	-1.382	-1.597	-1.783	-1.956
20.2	-0.499	-0.633	-0.770	-0.921	-1.115	-1.275	-1.453	-1.603	-1.761
22.3	-0.484	-0.607	-0.739	-0.880	-1.058	-1.200	-1.366	-1.520	-1.663
24.8	-0.468	-0.576	-0.703	-0.823	-0.997	-1.132	-1.259	-1.412	-1.504
27.2	-0.448	-0.551	-0.662	-0.781	-0.930	-1.050	-1.192	-1.308	-1.411
29.7	-0.438	-0.525	-0.636	-0.751	-0.889	-0.994	-1.120	-1.231	-1.313
32.7	-0.412	-0.479	-0.575	-0.673	-0.796	-0.887	-0.987	-1.076	-1.139
39.6	-0.376	-0.433	-0.523	-0.596	-0.709	-0.775	-0.864	-0.937	-0.979
49.5	-0.305	-0.345	-0.410	-0.467	-0.549	-0.601	-0.659	-0.715	-0.722
59.5	-0.229	-0.273	-0.313	-0.358	-0.426	-0.453	-0.489	-0.529	-0.517
69.3	-0.177	-0.201	-0.225	-0.255	-0.308	-0.330	-0.351	-0.349	-0.342
79.2	-0.111	-0.109	-0.133	-0.152	-0.190	-0.192	-0.202	-0.204	-0.245
89.4	-0.024	-0.011	-0.020	-0.028	-0.056	-0.049	-0.059	-0.106	-0.193
97.0	0.109	0.122	0.119	0.116	0.072	0.058	0.013	-0.054	-0.157
0.2	0.757	0.905	0.998	0.870	0.499	0.007	-0.618	-1.386	-2.213
0.3	0.568	0.863	0.993	0.983	0.782	0.441	-0.012	-0.581	-1.252
1.0	0.165	0.539	0.808	0.963	0.997	0.906	0.731	0.472	0.125
1.5	-0.304	0.364	0.659	0.875	0.992	0.987	0.921	0.792	0.578
2.0	-0.157	0.225	0.535	0.762	0.946	0.992	0.926	0.921	0.776
2.4	-0.268	0.117	0.427	0.689	0.890	0.962	1.003	0.973	0.891
2.9	-0.315	0.040	0.345	0.617	0.828	0.936	0.998	1.004	0.963
4.9	-0.463	-0.145	0.134	0.395	0.633	0.778	0.885	0.967	0.994
7.4	-0.550	-0.314	0.097	0.127	0.345	0.497	0.629	0.740	0.814
9.8	-0.565	-0.376	-0.189	0.008	0.196	0.344	0.465	0.565	0.655
12.4	-0.509	-0.371	-0.241	-0.085	0.072	0.180	0.285	0.379	0.449
14.8	-0.484	-0.355	-0.241	-0.105	0.036	0.140	0.234	0.317	0.388
17.3	-0.336	-0.263	-0.203	-0.100	0.000	0.068	0.126	0.183	0.228
20.2	-0.193	-0.150	-0.138	-0.064	0.006	0.043	0.075	0.106	0.131
22.3	-0.116	-0.093	-0.092	-0.044	0.011	0.037	0.054	0.069	0.079
24.8	-0.034	-0.021	-0.015	-0.013	0.047	0.043	0.044	0.044	0.028
27.2	-0.109	0.107	0.093	0.085	0.078	0.068	0.039	0.008	-0.049
C _L	-0.027	0.148	0.327	0.539	0.785	0.953	1.128	1.295	1.432

Table 9. (cont'd) 0.67-NACA-0015

0015 RE=1.0*(10)6 50%LS OAR UPPER, SOLID LOWER, PLENUM

ALPHA °/C	0	2	4	6	8	10	12	14	16
0.0	1.000	0.917	0.825	0.722	-0.656	-1.510	-2.498	-3.630	-4.763
0.2	0.793	0.854	-0.057	-0.764	-1.768	-2.808	-3.931	-5.180	-6.387
0.4	0.561	-0.107	-0.430	-1.150	-2.142	-3.151	-4.212	-5.392	-6.542
1.0	0.199	-0.244	-0.807	-1.486	-2.375	-3.270	-4.149	-5.107	-6.025
1.5	0.008	-0.016	-0.942	-1.552	-2.355	-3.151	-3.921	-4.718	-5.637
1.9	-0.137	-0.535	-1.030	-1.603	-2.334	-3.021	-3.734	-4.490	-5.409
2.5	-0.209	-0.586	-1.050	-1.573	-2.251	-2.902	-3.547	-4.330	-5.259
2.9	-0.276	-0.633	-1.071	-1.547	-2.173	-2.777	-3.417	-4.210	-4.890
4.9	-0.421	-0.715	-1.071	-1.439	-1.939	-2.450	-2.810	-3.132	-3.641
7.4	-0.483	-0.736	-1.009	-1.325	-1.721	-1.956	-2.316	-2.667	-3.035
9.8	-0.504	-0.715	-0.952	-1.212	-1.513	-1.780	-2.077	-2.350	-2.601
12.4	-0.519	-0.709	-0.900	-1.135	-1.358	-1.629	-1.854	-2.080	-2.270
14.8	-0.514	-0.674	-0.859	-1.047	-1.259	-1.484	-1.693	-1.873	-2.053
17.3	-0.509	-0.608	-0.812	-0.975	-1.176	-1.354	-1.558	-1.702	-1.867
20.2	-0.494	-0.607	-0.750	-0.898	-1.077	-1.260	-1.397	-1.557	-1.670
22.3	-0.483	-0.581	-0.725	-0.846	-1.025	-1.193	-1.314	-1.453	-1.577
24.8	-0.487	-0.555	-0.683	-0.805	-0.968	-1.110	-1.231	-1.349	-1.453
27.2	-0.442	-0.535	-0.647	-0.754	-0.906	-1.037	-1.143	-1.261	-1.344
29.7	-0.426	-0.507	-0.616	-0.723	-0.864	-0.975	-1.080	-1.163	-1.246
34.7	-0.385	-0.463	-0.554	-0.651	-0.766	-0.871	-0.956	-1.038	-1.075
39.6	-0.369	-0.421	-0.497	-0.573	-0.677	-0.762	-0.826	-0.893	-0.936
49.5	-0.302	-0.329	-0.388	-0.455	-0.527	-0.596	-0.639	-0.681	-0.672
59.5	-0.219	-0.253	-0.295	-0.347	-0.407	-0.485	-0.473	-0.494	-0.481
69.3	-0.173	-0.179	-0.213	-0.254	-0.298	-0.315	-0.332	-0.328	-0.320
79.2	-0.101	-0.097	-0.114	-0.146	-0.179	-0.185	-0.187	-0.183	-0.212
88.9	-0.013	-0.034	-0.036	-0.022	-0.044	-0.040	-0.047	-0.060	-0.160
97.0	0.117	0.130	0.134	0.112	0.081	0.064	0.026	-0.028	-0.134
0.2	0.779	0.909	0.992	0.853	0.896	0.012	-0.608	-1.324	-2.141
0.3	0.587	0.861	0.987	0.967	0.782	0.443	-0.305	-0.551	-1.189
1.0	0.189	0.557	0.806	0.956	1.000	0.910	0.737	0.480	0.135
1.5	0.008	0.582	0.661	0.874	0.995	0.999	0.924	0.791	0.574
2.0	-0.127	0.238	0.583	0.771	0.953	0.999	0.997	0.926	0.786
2.4	-0.245	0.130	0.879	0.688	0.891	0.978	1.007	0.988	0.905
2.9	-0.207	0.022	0.356	0.621	0.834	0.932	0.992	1.009	0.962
4.9	-0.452	-0.133	0.144	0.400	0.631	0.791	0.903	0.957	0.998
7.4	-0.545	-0.303	0.083	0.132	0.351	0.505	0.633	0.739	0.823
9.8	-0.556	-0.355	-0.171	0.014	0.206	0.349	0.472	0.579	0.667
14.8	-0.514	-0.360	-0.223	-0.084	0.076	0.188	0.296	0.397	0.488
29.7	-0.473	-0.344	-0.228	-0.100	0.045	0.147	0.244	0.330	0.404
49.5	-0.223	-0.257	-0.187	-0.094	0.003	0.074	0.140	0.205	0.249
69.4	-0.199	-0.138	-0.119	-0.058	0.013	0.048	0.093	0.128	0.150
79.2	-0.116	-0.082	-0.073	-0.033	0.024	0.048	0.073	0.091	0.104
88.5	-0.028	-0.015	0.000	-0.007	0.055	0.053	0.057	0.065	0.052
97.9	0.117	0.109	0.103	0.091	0.081	0.085	0.057	0.024	-0.020
C _L	-0.028	0.146	0.326	0.530	0.770	0.950	1.114	1.266	1.404

0015 RE=1.0*(10)6 60%LS OAR UPPER, SOLID LOWER, PLENUM

ALPHA °/C	0	2	4	6	8	10	12	14	16
0.0	1.000	0.905	0.814	0.098	-0.665	-1.529	-2.507	-3.583	-4.719
0.2	0.793	0.844	-0.079	-0.796	-1.787	-2.765	-3.916	-5.063	-6.324
0.4	0.555	0.129	-0.431	-1.200	-2.150	-3.136	-4.195	-5.300	-6.427
1.0	0.188	-0.259	-0.814	-1.510	-2.374	-3.229	-4.076	-4.997	-5.962
1.5	-0.004	-0.436	-0.943	-1.588	-2.358	-3.079	-3.839	-4.621	-5.549
1.9	-0.143	-0.549	-1.026	-1.624	-2.332	-2.992	-3.653	-4.380	-5.240
2.5	-0.221	-0.606	-1.052	-1.603	-2.244	-2.842	-3.496	-4.241	-5.204
2.9	-0.283	-0.642	-1.067	-1.583	-2.166	-2.729	-3.374	-4.102	-4.450
4.9	-0.428	-0.725	-1.052	-1.469	-1.932	-2.400	-2.863	-3.075	-3.527
7.4	-0.495	-0.735	-1.010	-1.329	-1.724	-1.900	-2.265	-2.602	-2.918
9.8	-0.510	-0.719	-0.953	-1.215	-1.491	-1.740	-2.007	-2.263	-2.505
12.4	-0.526	-0.693	-0.896	-1.133	-1.340	-1.581	-1.816	-2.006	-2.174
14.8	-0.526	-0.673	-0.840	-1.040	-1.252	-1.447	-1.651	-1.826	-1.973
17.3	-0.510	-0.647	-0.798	-0.972	-1.153	-1.339	-1.506	-1.656	-1.782
20.2	-0.495	-0.611	-0.746	-0.890	-1.055	-1.215	-1.372	-1.487	-1.612
22.3	-0.484	-0.590	-0.710	-0.848	-1.013	-1.148	-1.284	-1.389	-1.478
24.8	-0.469	-0.559	-0.669	-0.796	-0.951	-1.071	-1.181	-1.296	-1.364
27.2	-0.448	-0.533	-0.633	-0.750	-0.863	-0.994	-1.104	-1.194	-1.266
29.7	-0.433	-0.507	-0.597	-0.714	-0.834	-0.942	-1.042	-1.122	-1.188
34.7	-0.402	-0.466	-0.545	-0.641	-0.753	-0.839	-0.908	-0.967	-1.039
39.6	-0.366	-0.414	-0.483	-0.564	-0.660	-0.736	-0.794	-0.834	-0.874
49.5	-0.298	-0.326	-0.374	-0.440	-0.504	-0.566	-0.608	-0.649	-0.631
59.5	-0.226	-0.249	-0.281	-0.331	-0.390	-0.422	-0.443	-0.459	-0.415
69.3	-0.169	-0.182	-0.198	-0.233	-0.276	-0.299	-0.309	-0.289	-0.265
79.2	-0.102	-0.104	-0.110	-0.129	-0.161	-0.165	-0.159	-0.145	-0.172
88.9	-0.014	-0.006	-0.003	-0.005	-0.032	-0.026	-0.030	-0.048	-0.131
97.0	0.115	0.139	0.133	0.129	0.086	0.082	0.082	-0.006	-0.090
0.2	0.772	0.967	0.996	0.848	0.493	0.005	-0.619	-1.337	-2.143
0.3	0.586	0.868	0.996	0.972	0.784	0.443	-0.015	-0.556	-1.173
1.0	0.188	0.558	0.815	0.967	0.997	0.906	0.728	0.472	0.143
1.5	0.012	0.367	0.581	0.879	0.997	1.004	0.930	0.785	0.592
2.0	-0.138	0.248	0.552	0.791	0.955	1.004	0.986	0.913	0.783
2.4	-0.241	0.129	0.443	0.703	0.888	0.973	0.997	0.975	0.906
2.9	-0.203	0.056	0.365	0.626	0.831	0.937	0.997	1.001	0.963
4.9	-0.443	-0.130	0.153	0.414	0.649	0.785	0.904	0.960	1.004
7.4	-0.547	-0.300	-0.069	0.150	0.363	0.510	0.646	0.744	-0.998
9.8	-0.562	-0.357	-0.162	0.021	0.218	0.361	0.486	0.585	0.685
14.8	-0.510	-0.363	-0.219	-0.067	0.088	0.201	0.310	0.400	0.488
29.7	-0.474	-0.342	-0.214	-0.088	0.062	0.160	0.253	0.343	0.427
49.5	-0.324	-0.254	-0.167	-0.083	0.020	0.088	0.150	0.215	0.277
69.4	-0.195	-0.140	-0.105	-0.052	0.026	0.067	0.099	0.143	0.164
79.2	-0.117	-0.078	-0.069	-0.031	0.041	0.062	0.083	0.107	0.132
88.5	-0.024	-0.006	0.009	0.005	0.072	0.072	0.068	0.071	0.066
96.9	0.115	0.118	0.107	0.088	0.098	0.093	0.068	0.045	0.019
C _L	-0.026	0.147	0.328	0.529	0.769	0.935	1.088	1.228	1.305

Table 9. (cont'd) O-67-NACA-0015

0015 RE=1.0*(10)6 70%LS OAR UPPER, SOLID LOWER; PLENUM											
ALPHA X/C	0	2	4	6	8	10	12	14	16		
0.0	0.997	0.901	0.574	0.097	-0.654	-1.553	-2.539	-3.568	-4.660		
0.2	0.730	0.449	-0.144	-0.794	-1.753	-2.807	-3.918	-5.024	-6.126		
0.4	0.333	0.149	-0.500	-1.172	-2.111	-3.149	-4.152	-5.206	-6.229		
1.0	0.177	-0.238	-0.822	-1.505	-2.334	-3.196	-4.048	-4.931	-5.784		
1.5	-0.009	-0.421	-0.995	-1.561	-2.287	-3.061	-3.824	-4.516	-5.300		
1.9	-0.149	-0.543	-1.098	-1.618	-2.292	-2.962	-3.606	-4.263	-5.104		
2.5	-0.326	-0.573	-1.114	-1.682	-2.214	-2.822	-3.413	-4.154	-4.939		
2.9	-0.388	-0.624	-1.109	-1.561	-2.105	-2.719	-3.340	-4.014	-4.661		
4.9	-0.427	-0.700	-1.088	-1.423	-1.866	-2.371	-2.560	-3.009	-3.375		
7.4	-0.494	-0.711	-1.037	-1.280	-1.665	-1.900	-2.221	-2.537	-2.699		
9.8	-0.515	-0.705	-0.969	-1.183	-1.458	-1.693	-1.935	-2.153	-2.327		
12.4	-0.520	-0.690	-0.923	-1.090	-1.313	-1.532	-1.727	-1.910	-2.023		
14.8	-0.515	-0.660	-0.871	-1.009	-1.214	-1.387	-1.597	-1.718	-1.801		
17.3	-0.505	-0.610	-0.809	-0.937	-1.121	-1.278	-1.441	-1.552	-1.646		
20.2	-0.494	-0.594	-0.758	-0.860	-1.022	-1.165	-1.300	-1.397	-1.450		
22.3	-0.479	-0.578	-0.717	-0.809	-0.970	-1.102	-1.227	-1.309	-1.337		
23.8	-0.463	-0.553	-0.680	-0.758	-0.898	-1.029	-1.139	-1.190	-1.239		
27.2	-0.443	-0.517	-0.634	-0.717	-0.856	-0.941	-1.035	-1.122	-1.141		
29.7	-0.427	-0.492	-0.598	-0.676	-0.779	-0.894	-0.983	-1.024	-1.032		
32.7	-0.396	-0.451	-0.536	-0.599	-0.711	-0.801	-0.858	-0.879	-0.888		
35.6	-0.360	-0.405	-0.479	-0.533	-0.628	-0.692	-0.738	-0.760	-0.743		
49.5	-0.283	-0.319	-0.366	-0.405	-0.478	-0.511	-0.556	-0.557	-0.501		
59.5	-0.221	-0.234	-0.283	-0.302	-0.359	-0.386	-0.395	-0.392	-0.346		
69.3	-0.159	-0.161	-0.195	-0.205	-0.245	-0.267	-0.265	-0.247	-0.212		
79.2	-0.092	-0.090	-0.097	-0.103	-0.141	-0.148	-0.119	-0.107	-0.129		
88.9	-0.004	0.022	0.011	0.020	-0.017	-0.003	-0.020	-0.024	-0.093		
97.0	0.120	0.144	0.150	0.153	0.108	0.096	0.053	0.018	-0.062		
0.2	0.775	0.468	0.097	0.849	0.491	-0.018	-0.634	-1.273	-2.121		
0.3	0.595	0.866	1.007	0.977	0.771	0.422	-0.041	-0.583	-1.187		
1.0	0.202	0.551	0.852	0.977	0.949	0.894	0.709	0.453	0.108		
1.5	0.022	0.383	0.718	0.890	0.994	0.987	0.901	0.764	0.562		
2.0	-0.123	0.245	0.589	0.808	0.952	1.003	0.974	0.904	0.764		
2.4	-0.226	0.134	0.486	0.721	0.895	0.977	0.995	0.971	0.893		
2.9	-0.292	0.067	0.408	0.644	0.838	0.940	0.995	1.008	0.944		
4.9	-0.417	-0.121	0.202	0.440	0.641	0.795	0.917	0.992	0.991		
9.9	-0.530	-0.278	-0.035	0.169	0.372	0.526	0.677	0.774	0.841		
14.8	-0.551	-0.349	-0.133	0.041	0.232	0.370	0.511	0.624	0.697		
24.8	-0.499	-0.344	-0.195	-0.057	0.102	0.215	0.334	0.427	0.490		
29.7	-0.368	-0.334	-0.195	-0.062	0.071	0.173	0.282	0.375	0.454		
49.5	-0.308	-0.233	-0.154	-0.057	0.035	0.101	0.178	0.251	0.330		
69.4	-0.179	-0.126	-0.092	-0.031	0.035	0.070	0.126	0.168	0.217		
79.2	-0.112	-0.075	-0.056	-0.005	0.045	0.080	0.105	0.142	0.170		
88.5	-0.019	0.035	0.016	0.020	0.087	0.080	0.094	0.116	0.129		
96.9	0.120	0.123	0.119	0.112	0.113	0.111	0.084	0.085	0.067		
C _L	-0.022	0.145	0.348	0.518	0.748	0.911	1.065	1.195	1.284		

0015 RE=1.0*(10)6 80%LS OAR UPPER, SOLID LOWER; PLENUM

ALPHA X/C	0	2	4	6	8	10	12	14		
0.0	0.999	0.885	0.585	0.055	-0.757	-1.659	-2.629	-3.551		
0.2	0.772	0.412	-0.116	-0.855	-1.862	-2.882	-3.953	-4.999		
0.4	0.530	0.104	-0.476	-1.238	-2.228	-3.188	-4.185	-5.082		
1.0	0.170	-0.287	-0.842	-1.528	-2.409	-3.234	-3.968	-4.766		
1.5	-0.026	-0.451	-0.955	-1.605	-2.362	-3.048	-3.747	-4.373		
1.9	-0.160	-0.564	-1.053	-1.621	-2.300	-2.913	-3.525	-4.192		
2.5	-0.332	-0.611	-1.069	-1.621	-2.243	-2.783	-3.340	-4.078		
2.9	-0.299	-0.647	-1.074	-1.574	-2.114	-2.633	-3.314	-3.970		
4.9	-0.427	-0.719	-1.069	-1.474	-1.851	-2.369	-2.387	-2.873		
7.4	-0.494	-0.724	-0.986	-1.305	-1.665	-1.866	-2.119	-2.310		
9.8	-0.510	-0.703	-0.930	-1.181	-1.412	-1.628	-1.815	-1.937		
12.4	-0.525	-0.688	-0.888	-1.068	-1.273	-1.472	-1.594	-1.725		
14.8	-0.510	-0.657	-0.837	-0.995	-1.134	-1.306	-1.419	-1.539		
17.3	-0.505	-0.636	-0.775	-0.923	-1.051	-1.203	-1.290	-1.379		
20.2	-0.489	-0.585	-0.718	-0.855	-0.989	-1.099	-1.125	-1.203		
22.3	-0.469	-0.575	-0.682	-0.814	-0.927	-1.000	-1.058	-1.125		
24.8	-0.443	-0.544	-0.652	-0.752	-0.871	-0.964	-0.950	-0.991		
27.2	-0.433	-0.513	-0.610	-0.711	-0.798	-0.845	-0.904	-0.918		
29.7	-0.422	-0.482	-0.579	-0.664	-0.742	-0.824	-0.806	-0.820		
32.7	-0.386	-0.441	-0.518	-0.571	-0.649	-0.736	-0.713	-0.706		
39.6	-0.340	-0.395	-0.456	-0.514	-0.566	-0.601	-0.574	-0.567		
49.5	-0.273	-0.297	-0.358	-0.385	-0.442	-0.436	-0.449	-0.406		
59.5	-0.211	-0.225	-0.255	-0.276	-0.323	-0.296	-0.260	-0.251		
69.3	-0.139	-0.158	-0.178	-0.193	-0.215	-0.171	-0.142	-0.091		
79.2	-0.082	-0.071	-0.085	-0.085	-0.091	-0.073	-0.018	0.008		
88.9	0.005	0.021	0.028	0.029	0.028	0.002	0.070	0.049		
97.0	0.134	0.150	0.157	0.158	0.131	0.150	0.126	0.080		
0.2	0.793	0.972	0.991	0.830	0.420	-0.093	-0.724	-1.436		
0.3	0.608	0.880	1.002	0.970	0.740	0.368	-0.106	-0.660		
1.0	0.221	0.587	0.837	0.996	0.967	0.876	0.667	0.400		
1.5	0.052	0.417	0.698	0.918	1.003	0.985	0.885	0.726		
2.0	-0.098	0.273	0.585	0.815	0.962	1.005	0.961	0.876		
2.4	-0.191	0.165	0.476	0.748	0.910	1.000	0.997	0.959		
2.9	-0.258	0.093	0.399	0.660	0.869	0.985	1.002	1.000		
4.9	-0.497	-0.087	0.108	0.453	0.688	0.829	0.950	0.990		
9.9	-0.515	-0.266	-0.033	0.184	0.409	0.570	0.703	0.624		
14.8	-0.530	-0.313	-0.131	0.060	0.260	0.414	0.548	0.669		
24.8	-0.479	-0.328	-0.183	-0.033	0.120	0.269	0.384	0.483		
29.7	-0.443	-0.307	-0.188	-0.049	0.100	0.233	0.342	0.431		
49.5	-0.294	-0.230	-0.142	-0.049	0.064	0.155	0.245	0.326		
69.4	-0.155	-0.112	-0.080	-0.012	0.064	0.129	0.183	0.245		
79.2	-0.093	-0.056	-0.049	-0.002	0.095	0.124	0.162	0.204		
88.5	0.000	0.011	0.023	0.034	0.100	0.135	0.152	0.178		
96.9	0.129	0.134	0.126	0.122	0.126	0.160	0.152	0.142		
C _L	-0.012	0.155	0.334	0.523	0.736	0.889	0.994	1.108		

Table 10. Pressure coefficients for Joukowski airfoil.

JOUKOWSKY RE=5(10)6 SOLID WALLS

ALPHA X/C	-7	-5	-3	-1	1	3	5	7	9	11	13
0.0	-0.249	0.530	0.937	1.062	0.757	0.170	-0.724	-1.916	-3.390	-4.791	-1.140
0.4	-0.959	1.000	0.834	0.466	-0.153	-1.001	-2.633	-3.781	-4.830	-5.897	-1.541
1.7	0.876	0.654	0.298	-0.187	-0.737	-1.384	-2.124	-2.927	-3.845	-4.895	-1.179
3.3	0.612	0.354	0.006	-0.266	-0.853	-1.384	-1.934	-2.541	-3.299	-4.062	-1.082
5.0	0.345	0.204	-0.110	-0.451	-0.937	-1.285	-1.728	-2.204	-2.750	-3.391	-1.055
7.1	0.207	0.075	-0.202	-0.494	-0.876	-1.185	-1.558	-1.966	-2.453	-2.978	-1.040
9.9	0.176	0.038	-0.277	-0.529	-0.807	-1.111	-1.467	-1.953	-2.516	-3.191	-1.064
13.5	0.081	-0.105	-0.310	-0.524	-0.765	-1.012	-1.284	-1.656	-2.101	-2.649	-1.089
18.0	-0.022	-0.190	-0.370	-0.557	-0.779	-0.984	-1.105	-1.309	-1.494	-1.626	-1.053
23.5	-0.094	-0.240	-0.398	-0.561	-0.727	-0.887	-1.029	-1.193	-1.343	-1.421	-1.023
29.5	-0.135	-0.259	-0.398	-0.520	-0.676	-0.807	-0.926	-1.051	-1.178	-1.222	-0.985
33.6	-0.164	-0.281	-0.404	-0.524	-0.656	-0.785	-0.895	-1.004	-1.107	-1.182	-0.954
38.5	-0.173	-0.279	-0.394	-0.499	-0.615	-0.702	-0.796	-0.885	-0.958	-1.010	-0.906
43.5	-0.165	-0.263	-0.360	-0.457	-0.568	-0.628	-0.707	-0.779	-0.835	-0.879	-0.894
48.5	-0.148	-0.244	-0.329	-0.417	-0.506	-0.588	-0.631	-0.691	-0.734	-0.769	-0.964
53.5	-0.134	-0.221	-0.301	-0.383	-0.453	-0.539	-0.555	-0.604	-0.637	-0.617	-0.954
58.5	-0.125	-0.191	-0.270	-0.333	-0.367	-0.429	-0.480	-0.516	-0.537	-0.513	-0.939
63.5	-0.102	-0.160	-0.242	-0.265	-0.304	-0.359	-0.395	-0.425	-0.435	-0.427	-0.918
68.5	-0.075	-0.131	-0.185	-0.194	-0.231	-0.281	-0.317	-0.339	-0.353	-0.346	-0.884
73.5	-0.050	-0.112	-0.110	-0.147	-0.180	-0.236	-0.248	-0.269	-0.287	-0.294	-0.844
78.5	-0.031	-0.047	-0.063	-0.097	-0.135	-0.161	-0.181	-0.200	-0.224	-0.264	-0.822
83.5	-0.003	0.033	0.004	-0.030	-0.063	-0.087	-0.109	-0.130	-0.167	-0.230	-0.780
88.5	0.003	0.037	0.002	-0.021	-0.044	-0.063	-0.080	-0.097	-0.126	-0.198	-0.764
93.5	-0.063	-0.043	-0.104	-0.114	-0.120	-0.114	-0.109	-0.103	-0.112	-0.173	-0.695
1.7	-0.341	-0.489	-0.748	-0.142	0.335	0.688	0.900	1.091	0.985	0.900	0.992
4.2	-1.902	-1.323	-0.811	-0.276	0.409	0.302	0.549	0.747	0.866	0.940	0.403
8.3	-1.150	-0.643	-0.596	-0.329	-0.047	0.154	0.346	0.517	0.652	0.701	0.586
12.4	-0.940	-0.696	-0.493	-0.286	-0.047	0.095	0.253	0.399	0.525	0.606	0.474
20.7	-0.670	-0.509	-0.379	-0.223	-0.078	0.054	0.175	0.289	0.388	0.455	0.339
29.0	-0.478	-0.363	-0.206	-0.109	0.040	0.067	0.162	0.253	0.333	0.390	0.274
39.7	-0.298	-0.216	-0.124	-0.073	0.019	0.103	0.170	0.240	0.303	0.347	0.217
50.5	-0.178	-0.117	-0.048	0.015	0.059	0.122	0.181	0.236	0.286	0.317	0.191
61.2	-0.086	-0.033	0.016	0.064	0.091	0.145	0.191	0.236	0.271	0.293	0.162
72.0	0.003	0.041	0.081	0.114	0.144	0.174	0.208	0.244	0.271	0.281	0.140
82.8	0.060	0.087	0.112	0.139	0.171	0.199	0.212	0.238	0.254	0.250	0.083
91.0	0.104	0.115	0.175	0.201	0.208	0.222	0.246	0.250	0.250	0.237	0.043
96.0	0.087	0.097	0.112	0.124	0.142	0.155	0.161	0.168	0.168	0.135	-0.098
C _L	-0.346	-0.134	0.088	0.294	0.504	0.707	0.891	1.068	1.226	1.323	1.116

JOUKOWSKY RE=5(10)6 40%LS OAR UPPER, SOLID LOWER+PLENUM.

ALPHA X/C	-7	-5	-3	-1	1	3	5	7	9	11	13
0.0	-0.201	0.505	0.930	1.002	0.705	0.262	-0.536	-1.614	-2.760	-4.208	-1.001
0.4	-0.967	1.003	0.851	0.494	-0.074	-0.850	-1.790	-2.889	-4.141	-5.298	-1.424
1.7	0.859	0.645	0.305	-0.110	-0.622	-1.247	-1.920	-2.670	-3.354	-4.185	-0.917
3.3	0.586	0.340	0.015	-0.359	-0.771	-1.251	-1.739	-2.283	-2.942	-3.210	-0.917
5.0	0.423	0.186	-0.102	-0.408	-0.765	-1.165	-1.539	-2.045	-2.323	-2.634	-0.917
7.1	0.282	0.066	-0.191	-0.450	-0.758	-1.066	-1.404	-1.739	-2.006	-2.299	-0.938
9.9	0.150	-0.042	-0.271	-0.497	-0.744	-1.011	-1.271	-1.492	-1.755	-1.985	-0.960
13.5	0.053	-0.112	-0.305	-0.501	-0.699	-0.926	-1.105	-1.313	-1.523	-1.679	-0.894
18.0	-0.049	-0.188	-0.364	-0.512	-0.685	-0.853	-0.990	-1.176	-1.333	-1.436	-0.818
23.5	-0.114	-0.247	-0.386	-0.510	-0.651	-0.800	-0.927	-1.072	-1.183	-1.244	-0.884
28.5	-0.154	-0.262	-0.388	-0.493	-0.613	-0.726	-0.820	-0.935	-1.026	-1.076	-0.852
33.6	-0.182	-0.279	-0.356	-0.491	-0.604	-0.682	-0.775	-0.876	-0.950	-0.981	-0.854
38.5	-0.199	-0.275	-0.375	-0.482	-0.558	-0.627	-0.695	-0.787	-0.849	-0.884	-0.854
43.5	-0.186	-0.258	-0.344	-0.449	-0.516	-0.553	-0.624	-0.684	-0.730	-0.750	-0.825
48.5	-0.178	-0.237	-0.312	-0.397	-0.459	-0.488	-0.548	-0.595	-0.629	-0.618	-0.795
53.5	-0.165	-0.214	-0.282	-0.352	-0.395	-0.433	-0.482	-0.522	-0.542	-0.526	-0.770
58.5	-0.144	-0.189	-0.251	-0.308	-0.328	-0.368	-0.407	-0.444	-0.449	-0.433	-0.745
63.5	-0.114	-0.154	-0.221	-0.241	-0.264	-0.304	-0.331	-0.363	-0.371	-0.344	-0.734
68.5	-0.085	-0.129	-0.168	-0.171	-0.201	-0.224	-0.259	-0.269	-0.280	-0.273	-0.684
73.5	-0.061	-0.110	-0.149	-0.119	-0.152	-0.174	-0.192	-0.212	-0.216	-0.237	-0.667
78.5	-0.040	-0.037	-0.043	-0.076	-0.093	-0.115	-0.132	-0.153	-0.155	-0.176	-0.623
83.5	0.017	0.033	0.012	-0.011	-0.030	-0.047	-0.065	-0.085	-0.100	-0.138	-0.581
88.5	0.053	0.037	0.016	-0.003	-0.015	-0.026	-0.034	-0.047	-0.062	-0.109	-0.555
93.5	-0.070	-0.079	-0.088	-0.094	-0.087	-0.077	-0.068	-0.062	-0.058	-0.046	-0.517
1.7	-0.324	-1.454	-0.733	-0.155	0.317	0.673	0.983	0.983	0.992	0.917	0.992
4.2	-1.922	-1.322	-0.801	-0.243	0.014	0.297	0.540	0.727	0.869	0.940	0.834
8.3	-1.153	-0.629	-0.586	-0.320	-0.059	0.184	0.352	0.510	0.651	0.747	0.639
12.4	-0.942	-0.704	-0.493	-0.278	-0.034	0.102	0.272	0.409	0.533	0.621	0.504
20.7	-0.647	-0.508	-0.370	-0.210	-0.069	0.069	0.192	0.299	0.406	0.481	0.386
29.0	-0.472	-0.357	-0.243	-0.141	-0.029	0.081	0.175	0.265	0.350	0.416	0.320
39.7	-0.303	-0.216	-0.127	-0.067	0.028	0.111	0.185	0.256	0.323	0.371	0.295
50.5	-0.182	-0.110	-0.048	0.026	0.070	0.100	0.198	0.244	0.308	0.346	0.259
61.2	-0.085	-0.035	0.021	0.072	0.106	0.161	0.210	0.254	0.297	0.326	0.231
72.0	-0.006	0.038	0.085	0.123	0.163	0.189	0.231	0.265	0.299	0.316	0.208
82.8	0.045	0.094	0.121	0.152	0.149	0.208	0.239	0.265	0.291	0.299	0.186
91.0	0.109	0.130	0.157	0.182	0.216	0.237	0.250	0.267	0.285	0.282	0.011
96.0	0.085	0.101	0.121	0.137	0.157	0.140	0.186	0.197	0.204	0.186	-0.011
C _L	-0.334	-0.134	0.077	0.274	0.457	0.652	0.824	0.990	1.131	1.220	1.020

Table 10. (cont'd)

JOHKOWSKY RE=5(10)6 50XLS OAR UPPER, SOLID LOWER+PLENUM

ALPHA	-7	-5	-3	-1	1	3	5	7	9	11	13
X/C											
0.0	-0.165	0.559	0.942	1.002	0.789	0.251	-0.559	-1.650	-2.943	-4.244	-0.924
0.4	0.969	0.983	0.641	0.489	-0.075	-0.644	-1.771	-2.894	-3.119	-5.352	-1.402
1.7	0.865	0.646	0.501	-0.108	-0.639	-1.251	-1.924	-2.643	-3.452	-4.164	-0.936
3.3	0.587	0.528	0.311	-0.254	-0.765	-1.239	-1.746	-2.283	-2.967	-3.230	-0.915
5.0	0.417	0.179	-0.099	-0.487	-0.759	-1.156	-1.563	-2.051	-2.300	-2.636	-0.873
7.1	0.279	0.056	-0.188	-0.479	-0.740	-1.075	-1.411	-1.729	-2.000	-2.265	-0.851
9.9	0.145	-0.044	-0.253	-0.492	-0.733	-1.008	-1.286	-1.687	-1.759	-1.970	-0.851
13.5	0.052	-0.113	-0.301	-0.497	-0.702	-0.914	-1.107	-1.302	-1.506	-1.666	-0.872
18.6	-0.044	-0.122	-0.350	-0.507	-0.678	-0.855	-0.995	-1.154	-1.307	-1.418	-0.872
23.5	-0.114	-0.239	-0.379	-0.514	-0.647	-0.787	-0.910	-1.052	-1.158	-1.253	-0.851
28.5	-0.148	-0.262	-0.379	-0.484	-0.600	-0.715	-0.817	-0.931	-1.016	-1.059	-0.830
33.6	-0.186	-0.279	-0.384	-0.478	-0.579	-0.681	-0.777	-0.856	-0.930	-0.956	-0.829
38.5	-0.194	-0.277	-0.367	-0.455	-0.559	-0.624	-0.687	-0.776	-0.816	-0.830	-0.829
43.5	-0.188	-0.262	-0.342	-0.415	-0.497	-0.543	-0.611	-0.665	-0.721	-0.714	-0.808
48.5	-0.167	-0.238	-0.302	-0.376	-0.434	-0.477	-0.535	-0.587	-0.619	-0.606	-0.799
53.5	-0.156	-0.209	-0.278	-0.341	-0.372	-0.429	-0.473	-0.504	-0.529	-0.517	-0.776
58.5	-0.157	-0.186	-0.247	-0.285	-0.305	-0.357	-0.401	-0.432	-0.438	-0.419	-0.755
63.5	-0.109	-0.150	-0.215	-0.226	-0.250	-0.295	-0.329	-0.341	-0.347	-0.328	-0.729
68.5	-0.078	-0.129	-0.156	-0.156	-0.189	-0.221	-0.242	-0.269	-0.267	-0.260	-0.710
73.5	-0.059	-0.107	-0.091	-0.110	-0.142	-0.164	-0.187	-0.203	-0.206	-0.211	-0.663
78.5	-0.042	-0.027	-0.038	-0.061	-0.087	-0.104	-0.126	-0.139	-0.140	-0.167	-0.638
83.5	0.020	0.041	0.015	-0.080	-0.022	-0.039	-0.058	-0.076	-0.081	-0.137	-0.617
88.5	0.058	0.041	0.021	0.011	-0.003	-0.013	-0.030	-0.039	-0.049	-0.105	-0.549
93.5	-0.069	-0.076	-0.085	-0.085	-0.079	-0.068	-0.064	-0.052	-0.045	-0.082	-0.515
1.7	-2.283	-1.455	-0.715	-0.124	0.333	0.683	0.125	0.983	0.985	0.915	0.982
4.2	-1.871	-1.281	-0.781	-0.365	-0.001	0.303	0.543	0.741	0.871	0.941	0.831
8.3	-1.134	-0.207	-0.582	-0.301	-0.052	0.169	0.352	0.517	0.658	0.754	0.633
12.4	-0.929	-0.699	-0.481	-0.268	-0.066	0.110	0.265	0.413	0.539	0.629	0.514
20.7	-0.655	-0.498	-0.360	-0.206	-0.056	0.082	0.197	0.309	0.413	0.487	0.394
29.0	-0.477	-0.349	-0.236	-0.128	-0.014	0.090	0.182	0.279	0.362	0.427	0.332
39.7	-0.296	-0.209	-0.115	-0.060	0.043	0.116	0.192	0.268	0.335	0.382	0.299
50.5	-0.182	-0.117	-0.026	0.033	0.084	0.143	0.205	0.264	0.318	0.351	0.254
61.2	-0.082	-0.029	0.024	0.080	0.117	0.167	0.213	0.262	0.307	0.331	0.231
72.0	0.001	0.043	0.086	0.141	0.176	0.198	0.232	0.272	0.309	0.323	0.217
82.8	0.052	0.090	0.123	0.167	0.202	0.215	0.243	0.272	0.299	0.302	0.174
91.0	0.105	0.137	0.168	0.192	0.227	0.234	0.253	0.272	0.288	0.282	0.130
96.0	0.088	0.103	0.126	0.147	0.168	0.183	0.194	0.205	0.217	0.191	-0.010
C _L	-0.327	-0.127	0.081	0.273	0.468	0.652	0.809	0.986	1.125	1.214	1.012

JOHKOWSKY RE=5(10)6 60XLS OAR UPPER, SOLID LOWER+PLENUM

ALPHA	-7	-5	-3	-1	1	3	5	7	9	11	13
X/C											
0.0	-0.114	0.586	0.953	1.000	0.785	0.241	-0.587	-1.673	-3.010	-4.239	-0.870
0.4	0.973	0.996	0.635	0.474	-0.195	-0.871	-1.808	-2.922	-4.157	-5.313	-1.254
1.7	0.854	0.628	0.294	-0.123	-0.637	-1.245	-1.914	-2.679	-3.459	-4.153	-0.921
3.3	0.580	0.320	0.001	-0.353	-0.784	-1.258	-1.745	-2.287	-2.955	-3.184	-0.796
5.0	0.411	0.172	-0.106	-0.415	-0.779	-1.171	-1.559	-2.055	-2.276	-2.610	-0.813
7.1	0.278	0.054	-0.199	-0.461	-0.759	-1.070	-1.385	-1.731	-1.986	-2.266	-0.781
9.9	0.149	-0.052	-0.269	-0.491	-0.736	-0.996	-1.273	-1.479	-1.745	-1.943	-0.791
13.5	0.052	-0.120	-0.305	-0.489	-0.704	-0.911	-1.119	-1.297	-1.506	-1.640	-0.832
18.6	-0.050	-0.200	-0.351	-0.508	-0.670	-0.846	-0.983	-1.155	-1.296	-1.399	-0.796
23.5	-0.117	-0.242	-0.377	-0.511	-0.645	-0.791	-0.905	-1.045	-1.153	-1.214	-0.819
28.5	-0.153	-0.260	-0.373	-0.490	-0.604	-0.706	-0.806	-0.925	-0.996	-1.036	-0.796
33.6	-0.181	-0.274	-0.373	-0.473	-0.583	-0.674	-0.759	-0.853	-0.922	-0.940	-0.804
38.5	-0.192	-0.273	-0.360	-0.443	-0.545	-0.609	-0.691	-0.760	-0.825	-0.817	-0.793
43.5	-0.183	-0.252	-0.331	-0.410	-0.501	-0.537	-0.605	-0.665	-0.704	-0.693	-0.795
48.5	-0.169	-0.233	-0.293	-0.370	-0.427	-0.471	-0.531	-0.584	-0.611	-0.590	-0.780
53.5	-0.158	-0.212	-0.273	-0.334	-0.374	-0.416	-0.461	-0.504	-0.514	-0.499	-0.738
58.5	-0.137	-0.180	-0.237	-0.273	-0.309	-0.351	-0.397	-0.421	-0.430	-0.404	-0.740
63.5	-0.078	-0.151	-0.203	-0.216	-0.247	-0.283	-0.313	-0.335	-0.341	-0.320	-0.727
68.5	-0.078	-0.122	-0.147	-0.151	-0.187	-0.211	-0.237	-0.250	-0.269	-0.251	-0.680
73.5	-0.055	-0.094	-0.084	-0.105	-0.101	-0.161	-0.180	-0.193	-0.199	-0.200	-0.676
78.5	-0.041	-0.016	-0.031	-0.052	-0.084	-0.095	-0.118	-0.123	-0.140	-0.162	-0.642
83.5	0.035	0.045	0.027	0.005	-0.016	-0.034	-0.051	-0.064	-0.083	-0.122	-0.610
88.5	0.065	0.047	0.027	0.017	-0.005	-0.008	-0.021	-0.030	-0.047	-0.095	-0.570
93.5	-0.056	-0.065	-0.068	-0.072	-0.073	-0.068	-0.049	-0.028	-0.039	-0.074	-0.544
1.7	-2.247	-1.406	-0.678	-0.110	0.345	0.694	0.897	0.998	0.987	0.911	0.990
4.2	-1.814	-1.275	-0.746	-0.342	0.016	0.315	0.557	0.742	0.879	0.947	0.829
8.3	-1.116	-0.895	-0.559	-0.281	-0.040	0.180	0.366	0.528	0.661	0.755	0.619
12.4	-0.907	-0.680	-0.464	-0.248	-0.063	0.120	0.275	0.418	0.545	0.634	0.515
20.7	-0.647	-0.486	-0.344	-0.189	-0.051	0.082	0.201	0.316	0.416	0.493	0.396
29.0	-0.459	-0.343	-0.219	-0.119	-0.005	0.093	0.188	0.287	0.363	0.429	0.328
39.7	-0.282	-0.195	-0.100	-0.044	0.043	0.127	0.203	0.272	0.333	0.387	0.288
50.5	-0.160	-0.098	-0.027	0.043	0.085	0.152	0.213	0.270	0.316	0.359	0.245
61.2	-0.074	-0.021	0.040	0.087	0.119	0.175	0.222	0.270	0.309	0.342	0.235
72.0	0.017	0.053	0.095	0.135	0.174	0.205	0.243	0.280	0.307	0.329	0.216
82.8	0.079	0.095	0.131	0.165	0.197	0.222	0.249	0.274	0.294	0.304	0.167
91.0	0.116	0.141	0.172	0.201	0.231	0.239	0.258	0.280	0.294	0.291	0.127
96.0	0.097	0.114	0.130	0.152	0.174	0.194	0.200	0.214	0.216	0.200	-0.017
C _L	-0.314	-0.120	0.087	0.278	0.472	0.653	0.823	0.985	1.119	1.204	0.989

Table 10. (cont'd)
 JOUKOWSKY RE=5(10)6 70XLS DAR UPPER, SOLID LOWER+PLENUM

ALPHA	-7	-5	-3	-1	1	3	5	7	9	11	13
X/C											
0.0	-0.127	0.587	0.953	0.993	0.773	0.240	-0.567	-1.646	-2.985	-4.225	-0.781
0.4	0.970	0.992	0.827	0.475	-0.097	-0.870	-1.793	-2.833	-4.114	-5.235	-1.112
1.7	0.849	0.623	0.286	0.229	-0.675	-1.247	-1.910	-2.645	-3.409	-4.128	-0.774
3.3	0.569	0.324	0.006	-0.355	-0.775	-1.241	-1.739	-2.259	-2.906	-3.185	-0.728
5.0	0.408	0.177	-0.110	-0.410	-0.760	-1.191	-1.532	-2.020	-2.325	-2.566	-0.703
7.1	0.266	0.054	-0.193	-0.457	-0.737	-1.057	-1.380	-1.683	-1.942	-2.216	-0.707
9.9	0.141	-0.052	-0.273	-0.482	-0.735	-0.982	-1.245	-1.450	-1.791	-1.889	-0.717
13.5	0.045	-0.124	-0.337	-0.485	-0.677	-0.898	-1.078	-1.271	-1.454	-1.590	-0.711
18.6	-0.052	-0.196	-0.351	-0.506	-0.661	-0.826	-0.962	-1.119	-1.264	-1.369	-0.732
23.5	-0.129	-0.243	-0.376	-0.504	-0.634	-0.781	-0.886	-1.012	-1.121	-1.180	-0.728
28.5	-0.154	-0.258	-0.379	-0.483	-0.587	-0.698	-0.772	-0.881	-0.962	-1.011	-0.722
33.6	-0.184	-0.281	-0.381	-0.466	-0.568	-0.669	-0.741	-0.817	-0.878	-0.910	-0.732
38.5	-0.190	-0.277	-0.364	-0.440	-0.537	-0.594	-0.661	-0.733	-0.770	-0.776	-0.736
43.5	-0.181	-0.260	-0.332	-0.406	-0.482	-0.522	-0.585	-0.630	-0.677	-0.664	-0.734
48.5	-0.168	-0.237	-0.300	-0.368	-0.419	-0.459	-0.502	-0.550	-0.582	-0.557	-0.717
53.5	-0.155	-0.215	-0.267	-0.326	-0.369	-0.404	-0.439	-0.476	-0.476	-0.471	-0.715
58.5	-0.132	-0.188	-0.241	-0.286	-0.299	-0.340	-0.365	-0.393	-0.401	-0.376	-0.717
63.5	-0.106	-0.158	-0.208	-0.214	-0.237	-0.272	-0.289	-0.315	-0.317	-0.301	-0.705
68.5	-0.079	-0.124	-0.146	-0.148	-0.176	-0.206	-0.222	-0.231	-0.241	-0.231	-0.667
73.5	-0.055	-0.105	-0.077	-0.105	-0.128	-0.149	-0.163	-0.172	-0.173	-0.183	-0.646
78.5	-0.040	-0.029	-0.030	-0.055	-0.075	-0.090	-0.093	-0.107	-0.114	-0.103	-0.627
83.5	0.028	0.046	0.027	0.005	-0.008	-0.026	-0.034	-0.050	-0.059	-0.114	-0.587
88.5	0.060	0.050	0.029	0.022	0.007	0.001	0.000	-0.014	-0.034	-0.086	-0.551
93.5	-0.055	-0.067	-0.075	-0.065	-0.065	-0.050	-0.034	-0.029	-0.017	-0.057	-0.515
1.7	-2.226	-1.412	-0.672	-0.104	0.357	0.693	0.903	0.991	0.979	0.909	0.990
4.2	-1.618	-1.268	-0.748	-0.329	0.022	0.328	0.563	0.748	0.882	0.941	0.823
8.3	-1.126	-0.890	-0.554	-0.232	-0.035	0.181	0.373	0.535	0.669	0.764	0.625
12.4	-0.890	-0.693	-0.455	-0.242	-0.046	0.130	0.288	0.429	0.549	0.646	0.522
20.7	-0.646	-0.487	-0.343	-0.178	-0.042	0.094	0.217	0.326	0.426	0.500	0.401
29.0	-0.464	-0.338	-0.220	-0.119	-0.002	0.101	0.204	0.292	0.374	0.437	0.353
39.7	-0.287	-0.201	-0.102	-0.045	0.051	0.130	0.212	0.281	0.348	0.397	0.306
50.5	-0.169	-0.103	-0.024	0.047	0.091	0.158	0.223	0.277	0.329	-0.277	0.277
61.2	-0.073	-0.022	0.035	0.093	0.125	0.179	0.233	0.281	0.319	0.346	0.247
72.0	0.008	0.048	0.096	0.142	0.178	0.207	0.259	0.287	0.321	0.338	0.239
82.8	0.063	0.072	0.132	0.170	0.203	0.223	0.258	0.281	0.306	0.310	0.178
91.0	0.110	0.139	0.170	0.203	0.232	0.242	0.269	0.287	0.306	0.299	0.104
96.0	0.093	0.109	0.132	0.161	0.171	0.200	0.214	0.224	0.230	0.207	-0.004
C _L	-0.314	-0.119	0.089	0.276	0.467	0.647	0.813	0.968	1.098	1.117	0.952

JOUKOWSKY RE=5(10)6 80XLS DAR UPPER, SOLID LOWER+PLENUM

ALPHA	-7	-5	-3	-1	1	3	5	7	9	11	13
X/C											
0.0	-0.057	0.629	0.960	0.988	0.752	0.175	-0.657	-1.749	-3.074	-4.276	-0.672
0.4	0.979	0.975	0.814	0.445	-0.157	-0.927	-1.885	-2.899	-4.207	-5.270	-0.961
1.7	0.833	0.612	0.280	-0.139	-0.662	-1.266	-1.963	-2.662	-3.402	-4.132	-0.615
3.3	0.565	0.312	-0.015	-0.370	-0.793	-1.277	-1.772	-2.278	-2.985	-3.090	-0.591
5.0	0.405	0.172	-0.112	-0.425	-0.744	-1.160	-1.561	-2.061	-2.217	-2.561	-0.580
7.1	0.265	0.050	-0.199	-0.462	-0.749	-1.063	-1.381	-1.633	-1.987	-2.187	-0.597
9.9	0.147	-0.053	-0.269	-0.491	-0.717	-0.990	-1.258	-1.431	-1.705	-1.884	-0.595
13.5	0.046	-0.119	-0.305	-0.493	-0.675	-0.900	-1.063	-1.240	-1.447	-1.605	-0.606
18.6	-0.052	-0.184	-0.345	-0.500	-0.658	-0.828	-0.934	-1.117	-1.265	-1.317	-0.601
23.5	-0.113	-0.239	-0.370	-0.511	-0.626	-0.760	-0.873	-1.001	-1.104	-1.143	-0.633
28.5	-0.151	-0.250	-0.366	-0.481	-0.584	-0.684	-0.776	-0.882	-0.969	-0.963	-0.633
33.6	-0.178	-0.269	-0.360	-0.466	-0.557	-0.644	-0.727	-0.804	-0.880	-0.851	-0.639
38.5	-0.185	-0.265	-0.347	-0.432	-0.512	-0.587	-0.653	-0.717	-0.772	-0.720	-0.645
43.5	-0.176	-0.250	-0.328	-0.390	-0.466	-0.513	-0.583	-0.628	-0.641	-0.614	-0.654
48.5	-0.166	-0.221	-0.292	-0.362	-0.396	-0.450	-0.492	-0.539	-0.556	-0.504	-0.658
53.5	-0.145	-0.204	-0.261	-0.328	-0.335	-0.378	-0.414	-0.454	-0.461	-0.428	-0.654
58.5	-0.126	-0.170	-0.227	-0.271	-0.282	-0.323	-0.350	-0.380	-0.375	-0.343	-0.649
63.5	-0.101	-0.136	-0.200	-0.203	-0.218	-0.257	-0.278	-0.291	-0.294	-0.274	-0.658
68.5	-0.065	-0.109	-0.124	-0.135	-0.155	-0.192	-0.206	-0.223	-0.207	-0.204	-0.638
73.5	-0.046	-0.084	-0.069	-0.095	-0.106	-0.130	-0.143	-0.164	-0.161	-0.168	-0.642
78.5	-0.029	-0.006	-0.021	-0.046	-0.056	-0.075	-0.088	-0.096	-0.098	-0.142	-0.621
83.5	0.036	0.058	0.039	0.019	0.006	-0.008	-0.018	-0.039	-0.047	-0.115	-0.589
88.5	0.070	0.060	0.043	0.026	0.027	0.015	0.003	0.001	-0.019	-0.085	-0.502
93.5	-0.048	-0.030	-0.054	-0.061	-0.052	-0.029	-0.020	-0.003	-0.017	-0.068	-0.525
1.7	-2.169	-1.346	-0.610	-0.068	0.382	0.714	0.911	0.992	0.967	0.899	0.944
4.2	-1.779	-1.211	-0.715	-0.276	0.052	0.348	0.587	0.763	0.888	0.956	0.812
8.3	-1.093	-0.836	-0.538	-0.259	-0.016	0.208	0.397	0.555	0.681	0.761	0.621
12.4	-0.886	-0.667	-0.433	-0.225	-0.022	0.146	0.314	0.447	0.571	0.645	0.502
20.7	-0.612	-0.463	-0.312	-0.172	-0.070	0.108	0.238	0.340	0.442	0.510	0.388
29.0	-0.447	-0.319	-0.207	-0.098	0.016	0.119	0.215	0.306	0.391	0.440	0.335
39.7	-0.274	-0.182	-0.087	-0.036	0.069	0.146	0.226	0.287	0.363	0.402	0.297
50.5	-0.154	-0.082	-0.011	0.055	0.109	0.174	0.234	0.287	0.346	0.372	0.267
61.2	-0.063	-0.004	0.048	0.101	0.141	0.197	0.245	0.291	0.330	0.351	0.233
72.0	0.017	0.067	0.112	0.150	0.196	0.222	0.264	0.299	0.331	0.342	0.221
82.8	0.076	0.117	0.161	0.190	0.223	0.237	0.268	0.291	0.319	0.317	0.168
91.0	0.118	0.158	0.183	0.212	0.246	0.254	0.283	0.297	0.319	0.306	0.130
96.0	0.099	0.128	0.143	0.169	0.191	0.205	0.221	0.233	0.242	0.207	-0.014
C _L	-0.304	-0.107	0.097	0.289	0.472	0.651	0.816	0.966	1.102	1.164	0.881

$$\sum_j A_{ji} \sigma_j \quad (2) \quad - \sum_k \gamma_k \sum_m B_{mi} \quad (4) \quad - \Gamma \sum_j B_{ji} \quad (6) \quad + \sum_j A_{ji} \mu_p \quad (8) \quad - \sum_j B_{ji} v_p \quad (9) \quad = U \sin \theta_i \quad i=1, NWS \quad (43)$$

$$\sum_j (B_{jU} + B_{jL}) \sigma_j \quad (11) \quad + \sum_k \gamma_k \sum_m (A_{mU} + A_{mL}) \quad (13) \quad + \Gamma \sum_j (A_{jU} + A_{jL}) \quad (15) \quad + \sum_j (B_{jU} + B_{jL}) \mu_p \quad (17) \quad + \sum_j (A_{jU} + A_{jL}) v_p \quad (18) \quad = -U (\cos \theta_U + \cos \theta_L) \quad \begin{matrix} L=NSU1+(k-1)NSPS \\ U=L+NSPS-1 \end{matrix} \quad (45)$$

$$\sum_j (B_{jU} + B_{jL}) \sigma_j \quad (19) \quad + \sum_k \gamma_k \sum_m (A_{mU} + A_{mL}) \quad (21) \quad + \Gamma \sum_j (A_{jU} + A_{jL}) \quad (23) \quad + \sum_j (B_{jU} + B_{jL}) \mu_p \quad (25) \quad + \sum_j (A_{jU} + A_{jL}) v_p \quad (26) \quad = -U (\cos \theta_U + \cos \theta_L) \quad \begin{matrix} U=NTEU \\ L=NTEL \end{matrix} \quad (44)$$

$$\sum_j A_{ji} \sigma_j \quad (28) \quad - \sum_k \gamma_k \sum_m B_{mi} \quad (30) \quad - \Gamma \sum_j B_{ji} \quad (32) \quad + \sum_j A_{ji} \mu_p \quad (33) \quad - \sum_j B_{ji} v_p \quad (34) \quad = U \sin \theta_i \quad \begin{matrix} \ell=1, MSV \\ i=NWS+\ell \end{matrix} \quad (47)$$

$$\sum_j B_{ji} \sigma_j \quad (36) \quad + \sum_k \gamma_k \sum_m A_{mi} \quad (38) \quad + \Gamma \sum_j A_{ji} \quad (40) \quad + \sum_j B_{ji} \mu_p \quad (41) \quad + \sum_j A_{ji} v_p \quad (42) \quad = V_{t\ell} - U \cos \theta_i \quad \begin{matrix} \ell=1, MSV \\ i=NWS+MSV+\ell \end{matrix} \quad (48)$$

j=1, NWS

k=1, NSLAT
r(k) < m < s(k)
r(k) = NSU1 + (k-1) - NPS
s(k) = r(k) + NSPS - 1

j=1, NA

p=1, MSV
j=NKA+p

p=1, MSV
j=NKA+MSV+p

Table A10. Equations for the computer program of Appendix 10

References

- [1] Garner, H.C., Rogers, E.W.E., Acum, W.E.A. and Maskell, E.C.: 'Subsonic Wind Tunnel Wall Corrections', AGARDograph 109, Oct. 1966.
- [2] Allen, H.J. and Vincenti, W.G.: 'Wall Interference in a Two-Dimensional Flow Wind Tunnel, with Consideration of the Effect of Compressibility', NACA TR782, 1944.
- [3] Goldstein, S.: Part I, 'Steady Two-Dimensional Flow Past a Solid Cylinder in a Non-Uniform Stream', Part II, 'Two-Dimensional Wind-Tunnel Interference', R.M. 1902, Oct. 1942.
- [4] Woods, L.C.: 'The Theory of Subsonic Plane Flow', Cambridge, 1961.
- [5] Havelock, T.H.: 'The Lift and Moment on a Flat Plate in a Stream of Finite Width', Proc. Roy. Soc. A, 925, pp178-196, 1938.
- [6] Tomotika, S. et al: Rep. Aero. Res. Inst. Tokyo Imp. Univ. no. 101, 1934.
- [7] deJager, E.M. and van de Vooren, A.I.: 'Tunnel Wall Corrections for a Wing-Flap System Between Two Parallel Walls', NLR-TRW.7, Amsterdam, June 1965.
- [8] de Vries, O. and Schipholt, G.J.L.: 'Two-Dimensional Tunnel Wall Interference for Multi-Element Aerfoils in Incompressible Flow', AGARD Symposium on Wind Tunnel Design and Testing Techniques, Paper No. 20, Oct. 1975.

- [9] Baldwin, B.S., Turner, J.B., Knechtel, E.D.: 'Wall Interference in Wind Tunnels with Slotted and Porous Boundaries at Subsonic Speeds', NACA TN3176, 1954.
- [10] Maeder, P.F. and Wood, A.D.: 'Transonic Wind Tunnel Test Sections', ZAMP, Vol.7, 1956.
- [11] Wood, W.W.: 'Tunnel Interference from Slotted Walls', QJMAM, Vol.17, Pt.2, 1964.
- [12] Parkinson, G.V. and Lim, A.K.: 'On the Use of Slotted Walls in Two-Dimensional Testing of Low-Speed Airfoils', CASI Trans. 4, Sept. 1971.
- [13] Mokry, M.: 'Integral Equation Method for Calculation of Subsonic Flow Past Airfoils in a Ventilated Wind Tunnel; Comparison with NAE High Reynolds Number Measurements', AIAA Paper #74-83, Feb. 1974.
- [14] Parker, A.G.: 'Use of Slotted Walls to Reduce Wind Tunnel Boundary Corrections in Subsonic Flow' AIAA Tech. Notes Vol. 12, No.12, pp1771-1772, Dec. 1974.
- [15] Tsen, L.F.: 'Slotted Wall Interference on Open Cavity Flows in a Free Surface Channel', CANCAM 1975.
- [16] Catherall, D.: 'The Computation of Transonic Flows Past Aerofoils in Solid, Porous or Slotted Windtunnels', AGARD Symposium on Windtunnel Design and Testing Techniques, Paper No. 19, Oct. 1975.
- [17] Sears, W.R.: 'Self Correcting Wind Tunnels', Aero Journal Feb./March 1974, pp80-89.

- [18] Hess, J.L. and Smith, A.M.O.: 'Calculation of Potential Flow about Arbitrary Bodies', Progr. in Aero. Sci., Vol. 8, Pergamon, 1966.
- [19] Craggs, J.W., Mangler, K.W. and Zamir, M.: 'Some Remarks on the Behavior of Surface Source Distributions near the Edge of a Body', Aeronautical Quarterly, pp25-33, Feb. 1973.
- [20] Henshaw, D.H.: 'Two-Dimensional Airfoil Analysis using a Refined Finite Element Technique', NAE Report LTR-LA-124, May 1973.
- [21] Henshaw, D.H.: 'Application of Higher Order Surface Elements to the Solution of the Laplace Equation for the Example of a Conventional Airfoil', NAE Report LTR-LA-127 June 1973.
- [22] Hess, J.L.: 'Higher Order Numerical Solution of the Integral Equation for the Two-Dimensional Neumann Problem', Computer Methods in Applied Mechanics and Engineering, Vol. 2, ppl-15, 1973.
- [23] Jacob, K. and Steinbach, D.: 'A Method for Prediction of Lift for Multi-Element Airfoil systems with Separation', AGARD CPP-143, April 1974.
- [24] Mavriplis, F.: 'Aerodynamic Research of High Lift Systems', CASI Journal, 1971.
- [25] Labrujere, T.E., Schipholt, G.J. and de Vries, O.: 'Potential Flow Calculations to Support Two-Dimensional Wind Tunnel Tests on High Lift Devices', ICAS Paper #72-13.

- [26] Moler, C.B.: 'Matrix Computations with Fortran and Paging', Comm. ACM, Vol. 15, No. 4, April 1972.
- [27] Purcell, E.W.: 'The Vector Method of Solving Simultaneous Linear Equations', Jour. Math. Phys. Vol. 23, p180, 1953.
- [28] Pope, A.: 'On Airfoil Theory and Experiment', J. Aero. Sci. pp407-410, July 1948.
- [29] Smith, R.H. and Wang, C-T.: 'Contracting Cones Giving Uniform Throat Speeds', J. Aero. Sci., pp356-360, Oct. 1944.
- [30] Tani, I.: 'Low Speed Flows Involving Bubble Separations', Progress in Aero. Sci., Vol. 5, 1964.
- [31] Jacobs, E.N. and Sherman, A.: 'Airfoil Section Characteristics as Affected by Variations of the Reynolds Number', NACA TR586, 1937.
- [32] Riegels, F.W.: 'Airfoil Sections', translated by D.G. Randall, London, Butterworths, 1961.
- [33] Silverstein, A.: 'Scale Effect on Clark-Y Airfoil Characteristics from NACA Fullscale Wind-Tunnel Tests', NACA TR502, 1934.
- [34] Pankhurst, R.C. and Holder, D.W.: 'Wind Tunnel Technique', Pitman, 1952.
- [35] Pinkerton, R.M. and Greenberg, H.: 'Aerodynamic Characteristics of a Large Number of Airfoils Tested in the Variable Density Wind Tunnel', NACA TR628, 1938.
- [36] Lim, A.K.: 'Effects of Porous Tunnel Walls on High Lift Airfoil Testing', MASC Thesis, University of British Columbia, 1970.

- [37] Pinkerton, R.M.: 'Calculated and Measured Pressure Distributions over the Midspan Section of the NACA 4412 Airfoil', NACA TR563, 1936.
- [38] Seeböhm, T.: 'Prediction of the Flow Around Airfoils Using Potential Flow and Boundary Layer Theory', Report 68-1, Mech. Eng. Res. Lab. McGill University, May 1968.
- [39] Pope, A. and Harper, J.J.: 'Low-Speed Wind Tunnel Testing', Wiley, 1966.
- [40] Birch, S.F. and Eggers, J.M.: 'A Critical Review of the Experimental Data for Developed Free Turbulent Shear Layers', NASA Conference on Free Turbulent Shear Flows, 1972.
- [41] Milne-Thomson, L.M.: 'Theoretical Hydrodynamics', 5th edition, Macmillan, 1968.