NASA CONTRACTOR REPORT

NASA CR-1674

AN EXPLORATORY AERODYNAMIC AND STRUCTURAL INVESTIGATION OF ALL-FLEXIBLE PARAWINGS

by J. N. Nielsen, S. B. Spangler, S. S. Stahara, and A. L. Lee

Prepared by
NIELSEN ENGINEERING & RESEARCH, INC.
Mountain View, Calif. 94022
for

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION • WASHINGTON, D. C. • DECEMBER 1970

1. Report No.
NASA CR-1674

2. Government Accession No.

3. Recipient's Catalog No.

4. Title and Subtitle
AN EXPLORATORY AERODYNAMIC AND STRUCTURAL INVESTIGATION OF ALL-FLEXIBLE PARAWINGS

5. Report Date
December 1970

6. Performing Organization Code

7. Author(s)
J. N. Nielsen, S. B. Spangler, S. S. Stahara, and A. L. Lee

8. Performing Organization Report No.
NEAR TR 20

9. Performing Organization Name and Address
Nielsen Engineering & Research, Inc.
Mountain View, California.

10. Work Unit No.
124-07-19-04

11. Contract or Grant No.
NAS 1-8477

12. Sponsoring Agency Name and Address
National Aeronautics and Space Administration
Washington, D.C. 20546

13. Type of Report and Period Covered
Contractor Report

14. Sponsoring Agency Code

15. Supplementary Notes

16. Abstract

A theoretical investigation was made of the aerodynamic and structural aspects of all-flexible parawings. These wings are characterized by large amounts of spanwise camber. Consequently, planar lifting surface theory is inadequate for predicting the aerodynamic load distribution on the canopy. An aerodynamic method was developed through the use of slender-body theory to account for the principal nonplanar effects. The method considers sections in the plane normal to the root chord to be circular arcs which may translate and dilate with distance along the root chord. The method yields spanwise and chordwise distributions of loading, the distribution of suction along the leading edge and the induced drag. Various static equilibrium models were examined for the purpose of determining the canopy tension distribution and rigging line loads. The methods were applied to a single- and a twin-keel parawing for which data on inflated shape, overall aerodynamic loads, and line loads were obtained by the Langley Research Center, NASA. Comparisons with these load data were made using the measured canopy shapes.

17. Key Words (Suggested by Author(s))
~~All-flexible parawing~~
Slender-body theory to account for nonplanar effects

18. Distribution Statement
Unclassified - Unlimited

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price*
Unclassified	Unclassified	158	$3.00

*For sale by the National Technical Information Service, Springfield, Virginia 22151

TABLE OF CONTENTS

AN EXPLORATORY AERODYNAMIC AND STRUCTURAL

INVESTIGATION OF ALL-FLEXIBLE PARAWINGS

By J. N. Nielsen, S. B. Spangler,
S. S. Stahara, and A. L. Lee
Nielsen Engineering & Research, Inc.

SUMMARY

A theoretical investigation was made of the aerodynamic and structural aspects of all-flexible parawings. These wings are characterized by large amounts of spanwise camber. Consequently, planar lifting surface theory is inadequate for predicting the aerodynamic load distribution on the canopy. An aerodynamic method was developed through the use of slender-body theory to account for the principal nonplanar effects. The method considers sections in the plane normal to the root chord to be circular arcs which may translate and dilate with distance along the root chord. The method yields spanwise and chordwise distributions of loading, the distribution of suction along the leading edge and the induced drag. Various static equilibrium models were examined for the purpose of determining the canopy tension distribution and rigging line loads. The methods were applied to a single- and a twin-keel parawing for which data on inflated shape, overall aerodynamic loads, and line loads were obtained by the Langley Research Center, NASA. Comparisons with these load data were made using the measured canopy shapes.

Systematic calculations on conical parawings indicate that spanwise camber increases the lift-curve slope considerably and has a favorable effect on the ratio of normal force to induced drag. These calculations indicate that if a parawing could be rigged closer to a conical shape so that the entire leading edge could be operated close to luffing, a significant increase in lift-drag ratio could be achieved. Comparisons with lift and drag data for single- and twin-keel parawings indicate reasonably good agreement and show that the induced drag constitutes most of the total drag. Line load comparisons illustrate the proper behavior for the analytical structural models, but indicate that the models are not sufficiently detailed to be predictive in nature.

INTRODUCTION

Because the all-flexible parawing is completely stowable, it has received much attention for applications such as aerial delivery schemes, parachute jumping, and space capsule recovery where this property is of prime importance (refs. 1-3). In contrast to the rigid boom parawing, however, its stowability feature has made it more difficult to specify the aerodynamic shape of the inflated parawing and to develop rational aerodynamic and structural theories of the device. Accordingly, almost all progress to date in developing all-flexible parawings has been through experimental means. It is the purpose of this report to present some exploratory work aimed at obtaining insight into the aerodynamic and structural problems of all-flexible parawings.

It was recognized before the present investigation started that no substantial theoretical progress could be made unless good measurements of all-flexible parawing shapes were made to guide the analysis. Accordingly, measurements were made at Langley Research Center in the 7- by 10-Foot Wind Tunnel using stereoscopic photography to determine the inflated shapes of a single-keel and a twin-keel all-flexible parawing. These measured shapes have been utilized together with a specially developed nonplanar slender-wing lifting-surface theory to obtain approximate aerodynamic loadings on the parawings. In this manner the necessary aerodynamic loadings for a preliminary structural analysis have been obtained.

In the present report, the aerodynamic theory developed for all-flexible parawings is presented first. Next, the theory is utilized to describe the aerodynamic characteristics of idealized all-flexible parawings and to assess the importance of various factors in their aerodynamic efficiency. The measured shapes are presented, and are then used together with the theory to estimate the lift and drag characteristics of the single-keel and twin-keel parawings. Finally, results on predicted and measured line loads are presented.

LIST OF SYMBOLS

a	radius of circle in ζ_3 or ζ_4 plane
a_n	complex coefficients in Laurent series for $W_2(\zeta_4)$
AR	aspect ratio
A_n	real part of C_n
B_n	imaginary part of C_n
c_r	root chord of inflated parawing
C_D	drag coefficient, D/qS_R
C_{D_i}	induced-drag coefficient, D_i/qS_R
C_{D_o}	friction drag coefficient, nondimensionalized by qS_R
C_L	lift coefficient, L/qS_R
C_s	suction-force coefficient, S/qS_R
C_{T_k}	keel-line tension coefficient, T_k/qS_R
C_{T_ℓ}	leading-edge line tension coefficient, T_ℓ/qS_R
C_X	chord-force coefficient, X/qS_R
C_Y	lateral-force coefficient on half of the canopy, Y/qS_R
C_Z	normal-force coefficient, Z/qS_R
C_X',C_Y',C_Z'	components of C_X, C_Y, and C_Z due to differential pressure loading on canopy

$(\Delta C_X)_s$, $(\Delta C_Y)_s$, $(\Delta C_Z)_s$, $(\Delta C_{D_i})_s$	components of C_X, C_Y, C_Z, and C_{D_i}, respectively, due to leading-edge suction
$(\Delta C_X)_v$, $(\Delta C_Z)_v$, $(\Delta C_{D_i})_v$	components of C_X, C_Z, and C_{D_i}, respectively, associated with vortex lift
c_{11}	coefficient of ζ^{-1} term in Laurent series for $W_1(\zeta)$
c_{12}	coefficient of ζ^{-1} term in Laurent series for $W_2(\zeta)$
$d\ell$	element of length lying in canopy surface cut out by plane parallel to x-axis, fig. 2(a)
$D_o, C_o, C_1, \ldots$	complex coefficients in Laurent series for $W(\zeta)$, eq. (72)
D	total drag
D_i	induced drag of canopy
e	distance between top of canopy and x_1-axis, measured parallel to z-axis, positive downward
e'	distance between top of canopy and x-axis, measured parallel to z-axis, positive downward
$\vec{e}_x$	unit vector along x-axis
e_1, e_2	values of e associated with contours C_1 and C_2, respectively, fig. 2(b)
e_1', e_2'	values of e' associated with contours C_1 and C_2, respectively, fig. 2(b)
f	circular arc camber in crossflow plane, defined in fig. 1
h	rigging line length, figs. 14 and 17
h_k	keel length of theoretical wing canopy flat pattern, measured from theoretical apex to trailing edge of the plane of symmetry

I_1, I_2, I_3, I_4	definite integrals given by eq. (93)
$J(k)$	definite integral given by eq. (99)
k	$\sqrt{f/2r}$
K	ratio of lift-curve slope of segment of circular cone to that of the uncambered wing corresponding to its chord plane, eq. (139) or eq. (140)
ℓ	$s/2$
L	lift of canopy
M_y	moment of canopy about y-axis
M_z	moment of canopy about z-axis
n	summation index
$\vec{n}$	unit vector normal to canopy
$\vec{n}_1$	unit upward vector perpendicular to canopy at right-hand leading edge
$\vec{n}_2$	unit normal tangent to canopy and normal to right-hand leading edge, directed away from canopy
p	local static pressure
p_∞	free-stream static pressure
Δp	pressure difference across the canopy
P	pressure coefficient, $(p - p_\infty)/q$
ΔP	$P_\ell - P_u$, wing loading
P_ℓ	pressure coefficient for lower wing surface
P_n, Q_n	coefficients in a Laurent series, eq. (50)
P_u	pressure coefficient for upper wing surface
q	free-stream dynamic pressure
$\vec{q}$	vector flow velocity
r	radius of curvature of circular arc in ζ_1 and ζ_2 planes

r_1, r_2	values of r associated with contours C_1 and C_2, respectively, fig. 2(b)
s	parawing local semispan
s_m	maximum semispan of conical parawing formed from surface of circular cone
S	leading-edge suction force associated with both leading edges
S_R	reference area, taken as flat canopy area unless otherwise indicated
T_k	keel rigging line tension
T_ℓ	leading-edge rigging line tension
u,v,w	perturbation velocities along x, y, and z axes, respectively
u_ℓ, w_ℓ	values of u and w on lower surface, respectively
u_u, w_u	values of u and w on upper surface, respectively
$(u_u)_{odd}$	$(u_u - u_\ell)/2$
v_r, v_ϕ	radial and tangential perturbation velocity components in yz plane
v_{r_1}, v_{ϕ_1}	radial and tangential perturbation velocity components on circular arc in ζ_1 plane associated with ϕ_1
v_{r_2}, v_{ϕ_2}	radial and tangential perturbation velocity components on circular arc in ζ_2 plane associated with ϕ_2
V_∞	free-stream velocity
$(w_u)_{odd}$	$(w_u - w_\ell)/2$
w_1	velocity component along z-axis associated with ϕ_1
w_2	velocity component along z-axis associated with ϕ_2
$W(\zeta)$	complex potential for total flow
$W_1(\zeta_1)$	complex potential for circular arc translating upward at unit velocity with fluid stationary at infinity

$W_1'(\zeta_4)$ — complex potential for flow about a fixed circle with center at the origin with unit free-stream directed along the negative z-axis

$W_2(\zeta_4)$ — complex potential in ζ_4 plane for flow which in the ζ_1 plane yields a circular arc dilating at unit velocity with the flow velocity zero at infinity

x,y,z — axis system with origin at leading edge of parawing with positive x rearward along the root chord, positive y laterally to the right facing forward, and positive z vertically up

x',y',z' — axis system used in canopy shape measurement tests, with origin at the rigging line confluence point. x' is parallel to the keel chord, positive aft; z' is positive up; and y' is positive to right facing forward in tunnel

x_1,y_1,z_1 — axis system with origin at leading edge of parawing with positive x_1 rearward in streamwise direction, positive y_1 laterally to right facing forward, and positive z_1 vertical upward

X — chordwise force directed along x-axis

Y — lateral force on half of the canopy, directed along y-axis

Z — normal force on canopy in direction of z-axis

α — angle between free-stream velocity and root chord direction

α_{ideal} — angle of attack for conical parawing at which the leading-edge suction is zero

$\alpha_k,\beta_k,\gamma_k$ — direction cosines of vectors representing the keel line tension, positive downward

$\alpha_\ell,\beta_\ell,\gamma_\ell$ — direction cosines of vectors representing the leading-edge line tension, positive downward

α_o — angle of zero lift of segment of a circular cone

α_7 — "angle of attack" for a single-keel parawing, defined as the angle between the number 7 keel line and the vertical direction

α_8 — "angle of attack" for twin-keel parawing, defined as the angle between the projection of number 8 keel line onto vertical plane of symmetry and the vertical direction

β — polar angle in ζ_3 plane, fig. 4

ζ	complex variable, $y + iz$
ζ_1	$y_1 + iz_1$
ζ_2	$\zeta_1 + i(e + f)$
ζ_3	$\frac{\zeta_2}{2} + \frac{1}{2}\left(\zeta_2^2 - 4\ell^2\right)^{1/2}$
ζ_4	$\zeta_3 - \frac{if}{2}$
η	fraction of semispan
θ	polar angle in ζ_4 plane, fig. 4
λ_1	$-\left(\frac{dr}{dx} + \frac{de}{dx}\right)$
λ_2	$+\frac{dr}{dx}$
λ_3	$xV_\infty \cos \alpha + zV_\infty \sin \alpha$
ν	coordinate in $\vec{\nu}$ direction
$\vec{\nu}$	unit vector normal to canopy contour lying in crossflow plane
$\sigma_x, \sigma_y, \sigma_z$	components in the x, y, and z directions, respectively, of canopy tension per unit width
$\vec{\tau}$	unit vector tangent to canopy contour lying in crossflow plane
ϕ	polar angle of points on canopy surface in yz plane, fig. 2(b)
ϕ_o	$\Phi/V_\infty \cos \alpha$
ϕ_1	velocity potential for circular arc translating upward at unit velocity
$(\phi_1)_{odd}$	$\left(\phi_{1_u} - \phi_{1_\ell}\right)/2$
ϕ_2	velocity potential for expanding circular arc with unit radial velocity
$(\phi_2)_{odd}$	$\left(\phi_{2_u} - \phi_{2_\ell}\right)/2$
Φ	velocity potential for complete flow past parawing

Subscripts

ee	associated with	$(de/dx)^2$
ef	associated with	$\frac{de}{dx}\ \frac{df}{dx}$
er	associated with	$\frac{de}{dx}\ \frac{dr}{dx}$
2e	associated with	d^2e/dx^2
rf	associated with	$\frac{dr}{dx}\ \frac{df}{dx}$
rr	associated with	$(dr/dx)^2$
2r	associated with	d^2r/dx^2

AERODYNAMIC THEORY

Preliminary Considerations

As part of a general investigation of the structural and aerodynamic characteristics of all-flexible parawings, it is desired to develop an aerodynamic theory that will predict the detailed load distribution on such wings. None of the existing planar lifting-surface theories is applicable to all-flexible parawings because the canopies of such wings are not even approximately planar. Since the rigging lines from the wing tips slant inward toward the vertical plane of symmetry, the canopy must be nearly vertical near the tips. Accordingly, the rigging method of all-flexible parawings effectively provides the wing with end plates which preclude the use of planar lifting-surface theory if accurate predictions are desired.

No nonplanar lifting-surface theory exists which is applicable to all-flexible parawings with the accuracy of linearized wing theory. However, it appears possible to develop a slender-wing nonplanar lifting-surface theory that will account for the principal nonplanar effects of canopy shape. The principal assumption used in the analysis is that the shape of the canopy in any crossflow plane can be approximated in the mean by a circular arc. The circular arcs will vary chordwise in span, camber ratio, and vertical location of the center of curvature. The variation of these quantities with chordwise distance in the cases considered in this report is obtained from measurement, but in other cases may have to be obtained by other means. The aerodynamic theory will be complete in that loading distributions as well as gross forces and moments will be obtained.

A line joining the wing leading edge and trailing edge in the vertical plane of symmetry is defined as the root chord of the parawing (fig. 1). The apex of the wing is taken as the origin of the wing axis system with x taken positive rearward, along the root chord, and y and z as shown in the figure. The free-stream velocity V_∞ is in the vertical plane of symmetry for the present analysis, and the x-axis is inclined at the angle α to V_∞. For the purposes of the analysis, crossflow planes are considered perpendicular to the x-axis. In these crossflow planes, the canopy shape is assumed to be representable by a circular arc. The circular arc is described by three quantities which vary with x. Besides the camber, f, and the local semispan, s, there is the distance e between the top of the canopy and the x_1-axis, measured in the z direction.

The crossflow planes have been set up normal to the root chord rather than normal to the free-stream direction so that the canopy shape for a rigid canopy will not change with angle of attack. Also, the local crossflow section of maximum span will be farther aft than if the crossflow planes are taken normal to the free-stream direction. Since slender-body theory usually predicts negative lift on sections of decreasing span in the downstream direction, the present choice of crossflow planes will tend to reduce the extent of regions of negative lift on the rear of the parawing.

Boundary Conditions

Consider the two contours C_1 and C_2 lying in the canopy in crossflow planes dx apart as shown in figure 2(a). Let $\vec{\tau}$ and $\vec{\nu}$ be unit vectors tangent to and perpendicular to the contour C_1, respectively at some point. Consider a plane parallel to the x-axis and containing $\vec{\nu}$. This plane intersects the body surface between C_1 and C_2 along an element $d\ell$. Let $\vec{n}$ be normal to $\vec{\tau}$ and $d\ell$ so that it is the unit normal to the surface. If Φ is the entire velocity potential and if the unit vector along the x-axis is $\vec{e}_x$, then the velocity vector $\vec{q}$ is

$$\vec{q} = \frac{\partial \Phi}{\partial x} \vec{e}_x + \frac{\partial \Phi}{\partial \nu} \vec{\nu} + \frac{\partial \Phi}{\partial \tau} \vec{\tau} \tag{1}$$

The tangency condition is

$$\vec{q} \cdot \vec{n} = 0 \tag{2}$$

or

$$\frac{\partial \Phi}{\partial x} \cos\ (\vec{e}_x, \vec{n}) + \frac{\partial \Phi}{\partial \nu} \cos\ (\vec{\nu}, \vec{n}) = 0 \tag{3}$$

It is noted that $\vec{\nu}$, $d\ell$, and dx are coplanar by construction, lying in a plane normal to $\vec{\tau}$. Since $\vec{n}$ also lies in this plane, $\vec{n}$, $\vec{\nu}$, $d\ell$, and dx are coplanar, with $\vec{n}$ and $\vec{\nu}$ perpendicular to $d\ell$ and dx, respectively. If we make the small angle assumption for $d\nu/dx$, we have

$$\left.\begin{aligned} \cos\ (\vec{e}_x, \vec{n}) &= -\frac{d\nu}{dx} \\ \cos\ (\vec{\nu}, \vec{n}) &= 1 \end{aligned}\right\} \tag{4}$$

Thus the boundary condition becomes

$$\frac{\partial \Phi/d\nu}{\partial \Phi/dx} = \frac{d\nu}{dx} \tag{5}$$

We can write on the basis of small perturbation velocities

$$\frac{\partial \Phi}{\partial \nu} = (V_\infty \cos\ \alpha) \frac{d\nu}{dx} \tag{6}$$

It is desirable to relate the tangency condition to the geometric parameters of the canopy shape. For this purpose consider a fixed crossflow plane through which the wing is passing. Let the contours C_1 and C_2 as seen in the fixed crossflow plane be circular arcs as shown in figure 2(b) where the traces of the x- and x_1-axes are shown. Then

$$-\Delta\nu = OA + AB \tag{7}$$

$$\left.\begin{aligned} OA &= r_1 - r_2 \\ AB &= \left[(r_2 + e_2') - (r_1 + e_1')\right] \sin \phi \end{aligned}\right\} \qquad (8)$$

$$-\Delta\nu = +(r_2 - r_1)(-1 + \sin \phi) + (e_2' - e_1') \sin \phi$$

or with $dr = r_2 - r_1$ and $de' = e_2 - e_1$, we obtain

$$\frac{d\nu}{dx} = + \frac{dr}{dx} - \sin \phi \left(\frac{dr}{dx} + \frac{de'}{dx}\right) = \frac{dr}{dx} - \sin \phi \left(\frac{dr}{dx} + \frac{de}{dx} - \tan \alpha\right) \qquad (9)$$

The change from e' to e is desirable for computational purposes because of the way the canopy shape is measured in the wind tunnel.

This boundary condition suggests two potential problems that must be solved. The first term dr/dx is the boundary condition for an expanding circular arc. For a translating arc the velocity normal to the arc varies as $\sin \phi$ so that the second term of equation (9) describes the boundary condition of a translating arc. Let ϕ_1 be the potential function for a translating arc with the normal velocity equal to $\sin \phi$ and no velocity at infinity. Let ϕ_2 be the crossflow potential function for an expanding arc with unit normal velocity and no velocity at infinity. Thus, the boundary conditions are, from figure 3,

$$\left.\begin{aligned} &\frac{\partial \phi_1}{\partial \nu} = \sin \phi \quad \text{on the arc} \\ &\frac{\partial \phi_1}{\partial y}, \frac{\partial \phi_1}{\partial z} \rightarrow 0 \quad \text{as} \quad y,z \rightarrow \infty \end{aligned}\right\} \qquad (10)$$

$$\left.\begin{aligned} &\frac{\partial \phi_2}{\partial \nu} = 1 \quad \text{on the arc} \\ &\frac{\partial \phi_2}{\partial y}, \frac{\partial \phi_2}{\partial z} \rightarrow 0 \quad \text{as} \quad y,z \rightarrow \infty \end{aligned}\right\} \qquad (11)$$

We can construct the total potential function as follows.

$$\Phi = xV_\infty \cos \alpha + zV_\infty \sin \alpha - \left(\frac{dr}{dx} + \frac{de}{dx}\right) V_\infty \cos \alpha \, \phi_1 + V_\infty \cos \alpha \, \frac{dr}{dx} \, \phi_2 \tag{12}$$

To verify the boundary condition on the body, differentiate equation (12) with respect to ν.

$$\frac{\partial \Phi}{\partial \nu} = \frac{\partial z}{\partial \nu} V_\infty \sin \alpha - V_\infty \cos \alpha \left(\frac{dr}{dx} + \frac{de}{dx}\right) \sin \phi + V_\infty \cos \alpha \, \frac{dr}{dx} \tag{13}$$

On the body $\partial z/\partial \nu$ is $\sin \phi$ so that

$$\frac{\partial \Phi}{\partial \nu} = V_\infty \cos \alpha \left[\frac{dr}{dx} - \left(\frac{dr}{dx} + \frac{de}{dx} - \tan \alpha\right) \sin \phi\right] \tag{14}$$

Using equation (9), we obtain

$$\frac{\partial \Phi}{\partial \nu} = V_\infty \cos \alpha \, \frac{d\nu}{dx} \tag{15}$$

a result fulfilling the boundary condition, equation (6). The only other condition that the potential must fulfill is that it must give the parallel flow at infinity. Since ϕ_1 and ϕ_2 yield no velocities at infinity, it can be seen from equation (12) that $\partial\Phi/\partial x$ and $\partial\Phi/\partial z$ have the proper behavior at infinity.

Pressure Coefficient

Let u, v, and w be the perturbation velocities along the x, y, and z axes, respectively, such that

$$\left.\begin{aligned} \frac{\partial \Phi}{\partial x} &= V_\infty \cos \alpha + u \\ \frac{\partial \Phi}{\partial y} &= v \\ \frac{\partial \Phi}{\partial z} &= V_\infty \sin \alpha + w \end{aligned}\right\} \tag{16}$$

Then from reference 4, p. 48, the pressure coefficient for zero yaw angle is given by

$$P = \frac{-2(u + \alpha w)}{V_\infty} - \frac{(v^2 + w^2)}{V_\infty{}^2} \tag{17}$$

With regard to the square terms, it is easier to evaluate the sum by means of the following equality

$$(v^2 + w^2) = (v_r^2 + v_\phi^2) \tag{18}$$

where

$$\left.\begin{aligned} v_r &= \frac{\partial}{\partial r}\,(\Phi - xV_\infty\cos\alpha - zV_\infty\sin\alpha) \\ v_\phi &= \frac{1}{r}\frac{\partial}{\partial \phi}\,(\Phi - xV_\infty\cos\alpha - zV_\infty\sin\alpha) \end{aligned}\right\} \tag{19}$$

Carrying out the operation to obtain the velocity components, we find that

$$\frac{u}{V_\infty\cos\alpha} = -\phi_1\frac{d}{dx}\left(\frac{dr}{dx} + \frac{de}{dx}\right) - \left(\frac{dr}{dx} + \frac{de}{dx}\right)\frac{\partial\phi_1}{\partial x} + \phi_2\frac{d^2r}{dx^2} + \frac{dr}{dx}\frac{\partial\phi_2}{\partial x} \tag{20}$$

$$\frac{w}{V_\infty\cos\alpha} = -\left(\frac{dr}{dx} + \frac{de}{dx}\right)\frac{\partial\phi_1}{\partial z} + \frac{dr}{dx}\frac{\partial\phi_2}{\partial z} \tag{21}$$

and on the canopy

$$\frac{v_r}{V_\infty\cos\alpha} = -\left(\frac{dr}{dx} + \frac{de}{dx}\right)\sin\phi + \frac{dr}{dx} \tag{22}$$

$$\frac{v_\phi}{V_\infty\cos\alpha} = -\frac{1}{r}\left(\frac{dr}{dx} + \frac{de}{dx}\right)\frac{\partial\phi_1}{\partial\phi} + \frac{1}{r}\frac{dr}{dx}\frac{\partial\phi_2}{\partial\phi} \tag{23}$$

It is noted that the pressure coefficient depends not only on dr/dx and de/dx, but also on $d^2(r + e)/dx^2$.

Solution for Translating Circular Arc

Complex potential.- It is desired to obtain the potential for a translating arc with unit upward velocity with the flow stationary at infinity. The arc is shown in figure 1(a), together with its dimensions and its position with respect to the x, y, z coordinate system. The potential is obtained in several steps, as illustrated in figure 4. We start with the known potential for a circle with its center at the origin with downward flow parallel to the z-axis at unit speed in the far field (fig. 4(d)).

$$W_1'(\zeta_4) = i\left(\zeta_4 - \frac{a^2}{\zeta_4}\right) \tag{24}$$

This potential can be transformed through the planes $\zeta_4 \rightarrow \zeta_3 \rightarrow \zeta_2 \rightarrow \zeta_1$ to obtain a flow past the translating arc in the ζ_1 plane with the velocity at infinity unchanging. The first transformation simply shifts the origin of the circle up onto the imaginary axis.

$$\zeta_3 = \zeta_4 + \frac{if}{2} \tag{25}$$

The second transformation is the Joukowski transformation which carries a circle with the center offset on the imaginary axis into a circular arc.

$$\zeta_2 = \zeta_3 + \frac{\ell^2}{\zeta_3} \tag{26}$$

or

$$\zeta_3 = \frac{\zeta_2}{2} + \frac{1}{2}\sqrt{\zeta_2^2 - 4\ell^2} \tag{27}$$

where we have used the positive sign on the square root. The last transformation merely changes the vertical position of the circular arc.

$$\zeta_1 = \zeta_2 - i(e + f) \tag{28}$$

By simply making the appropriate transformations in the complex potential, we obtain the flows in the several planes since the contours are streamlines and the flow velocity at infinity is unaltered. Accordingly,

$$W_1'(\zeta_3) = i\left[\zeta_3 - \frac{if}{2} - \frac{a^2}{\zeta_3 - \frac{if}{2}}\right] \tag{29}$$

$$W_1'(\zeta_2) = i\left[\frac{\zeta_2}{2} - \frac{if}{2} + \frac{1}{2}\sqrt{\zeta_2^2 - 4\ell^2} - \frac{a^2}{\frac{\zeta_2}{2} - \frac{if}{2} + \frac{1}{2}\sqrt{\zeta_2^2 - 4\ell^2}}\right] \tag{30}$$

$$\begin{aligned} W_1'(\zeta_1) = i\Bigg[&\frac{\zeta_1}{2} + \frac{ie}{2} + \frac{1}{2}\sqrt{\left[\zeta_1 + i(e + f)\right]^2 - 4\ell^2} \\ &- \frac{a^2}{\frac{\zeta_1}{2} + \frac{ie}{2} + \frac{1}{2}\sqrt{\left[\zeta_1 + i(e + f)\right]^2 - 4\ell^2}}\Bigg] \end{aligned} \tag{31}$$

The complex potential for the upward moving arc is now obtained by imposing a flow given by $-i\zeta_1$ which makes the velocity at infinity zero and imparts a uniform upward velocity to the circular arc. The final complex potential in the ζ_1 plane is thus

$$W_1(\zeta_1) = W_1'(\zeta_1) - i\zeta_1 \tag{32}$$

This complex function $W_1(\zeta_1)$ is now transformed back to the ζ_4 plane, resulting in the following simple form, correct except for a constant.

$$W_1(\zeta_4) = -i\left[\frac{a^2}{\zeta_4} + \frac{\ell^2}{\zeta_4 + \frac{if}{2}}\right] \tag{33}$$

<u>Velocity components</u>.- With the complex potential for the terms known, it is possible to obtain the velocity components. The following scheme is used.

$$\left(v_{r_1} - iv_{\phi_1}\right)e^{-i\phi} = \frac{dW_1}{d\zeta_1} = \frac{dW_1}{d\zeta_4}\,\frac{d\zeta_4}{d\zeta_3}\,\frac{d\zeta_3}{d\zeta_2}\,\frac{d\zeta_2}{d\zeta_1} \tag{34}$$

Carrying out the operations yields the following results on the contour

$$\left.\begin{aligned}
\frac{dW_1}{d\zeta_4} &= i\left[e^{-2i\theta} + \frac{(1 - k^2)}{(e^{i\theta} + ik)^2}\right]; \quad k^2 = \frac{f}{2r} \\
\frac{d\zeta_4}{d\zeta_3} &= 1 \\
\frac{d\zeta_3}{d\zeta_2} &= \frac{(e^{i\theta} + ik)^2}{2ie^{i\theta}(\sin\theta + k)} \\
\frac{d\zeta_2}{d\zeta_1} &= 1
\end{aligned}\right\} \tag{35}$$

where θ is the polar angle in the ζ_3 plane (fig. 4). In order to separate the velocity components into components which are symmetric and antisymmetric with respect to the top and bottom surfaces of the wing, we must express the results in terms of some angle other than θ. An appropriate angle is β, the polar angle in the ζ_3 plane (fig. 4). Use of equation (25) yields the following relationships

$$\left.\begin{aligned}
\sin\theta &= -k\cos^2\beta + \sin\beta\sqrt{1 - k^2\cos^2\beta} \\
\cos\theta &= \cos\beta\left[k\sin\beta + \sqrt{1 - k^2\cos^2\beta}\right]
\end{aligned}\right\} \tag{36}$$

between θ and β. The equation of the circular arc in the ζ_2 plane in terms of β is

$$\zeta_2 = 2a\cos\beta\sqrt{1 - k^2\cos^2\beta} + 2aik\sin^2\beta \tag{37}$$

Accordingly, β and $-\beta$ yield corresponding points on the top and bottom of the circular arc.

With the use of equations (34), (35), and the following relationship

$$e^{i\phi} = \frac{ke^{2i\theta} + ie^{i\theta}}{e^{i\theta} + ik} \tag{38}$$

it can be shown that in terms of θ and ϕ

$$\left.\begin{aligned} v_{r_1} &= \sin\phi \\ v_{\phi_1} &= \frac{-\cos\theta}{\sin\theta + k}\,(1 + k^2 + 2k\sin\theta) + \cos\phi \end{aligned}\right\} \tag{39}$$

It is seen that v_{r_1} satisfies the boundary condition for the arc translating upward at unit velocity.

In order to bring out the symmetry properties of the velocity components, both velocities are given in terms of β with the help of equation (36) as follows:

$$\left.\begin{aligned} v_{r_1} &= 1 - 2k^2\cos^2\beta \\ v_{\phi_1} &= -\frac{\cos\beta}{\sin\beta}\left[1 + k^2(\sin^2\beta - \cos^2\beta)\right] \end{aligned}\right\} \tag{40}$$

It is seen that v_{r_1} is an even function of β and v_{ϕ_1} is an odd function of β.

The vertical velocity w_1 is also used in the loading equation

$$w_1 = v_{r_1}\sin\phi + v_{\phi_1}\cos\phi \tag{41}$$

Equation (41) can be expressed entirely in terms of β by use of equation (40) and the relationships

$$\left.\begin{aligned} \sin\phi &= 1 - 2k^2\cos^2\beta \\ \cos\phi &= 2k\cos\beta\sqrt{1 - k^2\cos^2\beta} \end{aligned}\right\} \tag{42}$$

with the result that

$$w_1 = 1 - \frac{2k\cos^2\beta}{\sin\beta}\left(k\sin\beta + \sqrt{1 - k^2\cos^2\beta}\right)^2 \tag{43}$$

Solution for Dilating Circular Arc

Complex potential.- The complex potential and velocities for a dilating arc can be obtained in a manner similar to that for a translating arc. The boundary conditions in the ζ_1 plane, figure 5(a), are that $\partial\phi/\partial\nu$ be unity on the arc and the velocity at infinity be zero. The flow external to a circular arc with an as yet undetermined normal velocity distribution in the ζ_4 plane can be transformed as before to a circular arc with a uniform normal velocity distribution. The specification of the normal velocity distribution in the ζ_4 plane is determined by the boundary conditions in the ζ_1 plane.

The flow due to any distribution of normal velocity on the circle in the ζ_4 plane can be represented by a Laurent series

$$W_2(\zeta_4) = \sum_{n=1}^{\infty} \frac{a_n}{\zeta_4^n} \tag{44}$$

The problem is to determine the coefficients a_n which will satisfy the normal boundary condition in the ζ_1 plane; that is, unit normal velocity on the circular arc. We satisfy the boundary condition in the following way

$$\begin{aligned}\left(v_{r_2} - iv_{\phi_2}\right) e^{-i\phi} &= \frac{dW_2}{d\zeta_1} = \frac{dW_2}{d\zeta_4}\,\frac{d\zeta_4}{d\zeta_3}\,\frac{d\zeta_3}{d\zeta_2}\,\frac{d\zeta_2}{d\zeta_1} \\ &= \frac{-1}{1 - \frac{\ell^2}{\zeta_3^2}} \sum_{n=1}^{\infty} \frac{na_n}{\zeta_4^{n+1}}\end{aligned} \tag{45}$$

Equation (45) is a Laurent series in ζ_4 valid over the complete interval $0 \leq \theta \leq 2\pi$. On the circle, we find that

$$\frac{e^{i\phi}\zeta_3^2}{\zeta_3^2 - \ell^2} = \frac{(ke^{i\theta} + i)(e^{i\theta} + ik)}{2i(\sin\theta + k)} \tag{46}$$

so that equation (45) becomes

$$\left(v_{r_2} - iv_{\phi_2}\right)_{\zeta_1 \text{arc}} = - \sum_{n=1}^{\infty} \frac{na_n}{a^{n+1}} e^{-i(n+1)\theta} \frac{(ke^{i\theta} + i)(e^{i\theta} + ik)}{2i(\sin\theta + k)} \tag{47}$$

or

$$\left(v_{r_2} - iv_{\phi_2}\right)_{\zeta_1 \text{arc}} (\sin\theta + k) = - \frac{1}{2} \sum_{n=1}^{\infty} \frac{na_n}{a^{n+1}} e^{-in\theta} (1 + 2k\sin\theta + k^2) \tag{48}$$

Defining

$$\frac{na_n}{a^{n+1}} = P_n + iQ_n \tag{49}$$

we get

$$\left(v_{r_2} - iv_{\phi_2}\right)_{\zeta_1 \text{arc}} (\sin\theta + k) = - \frac{1}{2} \sum_{n=1}^{\infty} (P_n + iQ_n) e^{-in\theta} (1 + 2k\sin\theta + k^2) \tag{50}$$

Since v_{r_2} is unity on the arc in the ζ_1 plane, we obtain for the real part of equation (50) after some manipulation

$$\frac{\sin\theta + k}{1 + 2k\sin\theta + k^2} = - \frac{1}{2} \sum_{n=1}^{\infty} (P_n \cos n\theta + Q_n \sin n\theta) \tag{51}$$

We have the known Fourier series

$$\frac{\sin\theta + k}{1 + 2k\sin\theta + k^2} = - \sum_{n=1}^{\infty} (-1)^n k^{2n-2} \left[k\cos 2n\theta + \sin(2n-1)\theta\right]$$

$$0 \leq \theta \leq \pi;\ k < 1 \tag{52}$$

from which

$$\left.\begin{aligned} P_{2n} &= (2)(-1)^n k^{2n-1} \\ P_{2n-1} &= 0 \end{aligned}\right\} \quad n = 1,2,3,\ldots \tag{53}$$

$$\left.\begin{aligned} Q_{2n-1} &= (2)(-1)^n k^{2n-2} \\ Q_{2n} &= 0 \end{aligned}\right\} \tag{54}$$

Accordingly, the complex potential is

$$W_2(\zeta_4) = 2\sum_{n=1}^{\infty} \frac{(-1)^n k^{2n-1} a^{2n+1}}{2n\zeta_4^{2n}} + 2i\sum_{n=1}^{\infty} \frac{(-1)^n k^{2n-1} a^{2n}}{(2n - 1)\zeta_4^{2n-1}} \tag{55}$$

The series can be rewritten as follows

$$W_2(\zeta_4) = -\frac{a}{k}\sum_{n=1}^{\infty} \frac{(-1)^{n+1}}{n}\left(\frac{k^2a^2}{\zeta_4^2}\right)^n - 2i\,\frac{a}{k}\sum_{n=0}^{\infty} \frac{(-1)^n}{(2n + 1)}\left(\frac{ka}{\zeta_4}\right)^{2n+1} \tag{56}$$

From the known expansions for $\ln(1 + x)$ and $\tan^{-1} x$, we can sum the series

$$W_2(\zeta_4) = -\frac{2a}{k}\left\{\frac{1}{2}\ln\left(1 + \frac{k^2a^2}{\zeta_4^2}\right) + i\tan^{-1}\left(\frac{ka}{\zeta_4}\right)\right\} \tag{57}$$

The expression for W_2 can be further simplified to

$$W_2(\zeta_4) = -\frac{2a}{k}\ln\left(1 + \frac{ika}{\zeta_4}\right) \tag{58}$$

Velocity components.- The velocity components have been evaluated in the same manner as for the previous case. The results for the radial and tangential velocities on the arc are

$$\left.\begin{aligned} v_{r_2} &= \frac{\partial\phi_2}{\partial r} = 1 \\ v_{\phi_2} &= \frac{1}{r}\frac{\partial\phi_2}{\partial\phi} = -\frac{\cos\beta}{\sin\beta} \end{aligned}\right\} \tag{59}$$

It is noted that v_{r_2} is an even function of β while v_{ϕ_2} is an odd function analogous to the v_{r_1} and v_{ϕ_1} velocity components. We are also interested in w_2 for determining the wing loading

$$\begin{aligned} w_2 &= v_{r_2}\sin\phi + v_{\phi_2}\cos\phi \\ &= \sin\phi - \frac{\cos\beta}{\sin\beta}\cos\phi \end{aligned} \tag{60}$$

With the help of equation (42) the result for w_2 becomes

$$w_2 = 1 - \frac{2k^2\cos^2\beta}{\sin\beta}\left(k\sin\beta + \sqrt{1 - k^2\cos^2\beta}\right) \tag{61}$$

Wing Loading

The wing loading equations will now be determined with the help of equation (17). The loading is considerably simpler to obtain than the pressure distribution because the even terms in β do not contribute to the loading. Consider, for instance, the squares term, $v^2 + w^2$, in equation (17), or its equal, $v_r^2 + v_\phi^2$. From equations (40) and (59), it is clear that v_{r_1} and v_{r_2} are even in β. The quantities v_{ϕ_1} and v_{ϕ_2} are both odd in β by the same equations. Accordingly, the square term contributes nothing to the loading.

The loading is given with the help of equation (17) as

$$\Delta P = P_\ell - P_u = \frac{2(u_u - u_\ell)}{V_\infty} + \frac{2\alpha(w_u - w_\ell)}{V_\infty} \tag{62}$$

where the subscripts u and ℓ refer to corresponding points on the upper and lower surfaces respectively. Considering now only the parts of u and w odd in β, we have

$$\Delta P = 4\left(\frac{u_u}{V_\infty} + \frac{\alpha w_u}{V_\infty}\right)_{odd} \tag{63}$$

where the subscript odd applies to quantities of the upper surface. From equations (20) and (21) taking $\cos\alpha$ equal to unity

$$\frac{(u_u)_{odd}}{V_\infty} = -\frac{d^2}{dx^2}(e + r)(\phi_1)_{odd} - \frac{d}{dx}(e + r)\left.\frac{\partial\phi_1}{\partial x}\right|_{odd} + \frac{d^2r}{dx^2}\left.\phi_2\right|_{odd} + \frac{dr}{dx}\left.\frac{\partial\phi_2}{\partial x}\right|_{odd} \tag{64}$$

$$\frac{(w_u)_{odd}}{V_\infty} = -\frac{d}{dx}(e + r)\left.\frac{\partial\phi_1}{\partial z}\right|_{odd} + \frac{dr}{dx}\left.\frac{\partial\phi_2}{\partial z}\right|_{odd} \tag{65}$$

At the wing surface, we find the following results from equations (33) and (58) for the velocity potentials, from which the odd and even parts can readily be separated.

$$\phi_1 = rk\left[k - 2\sin\beta\sqrt{1 - k^2\cos^2\beta}\right] \tag{66}$$

$$\begin{aligned}\phi_2 &= -r\ln\left(\sqrt{1 - k^2\cos^2\beta} + k\sin\beta\right)\\ &= -2r\tanh^{-1}\left(\frac{k\sin\beta}{\sqrt{1 - k^2\cos^2\beta}}\right) - r\ln(1 - k^2)\end{aligned} \tag{67}$$

The odd parts of the derivatives are found first by taking the derivatives of $W_1(\zeta)$ and $W_2(\zeta)$ with respect to x, determining the value of the resulting complex expressions at the canopy surface, and then extracting the real parts. These processes, which are quite lengthy, yield the following results.

$$\left.\frac{\partial\phi_1}{\partial x}\right|_{odd} = -\frac{k\sqrt{1 - k^2\cos^2\beta}}{\sin\beta}\left[2\cos^2\beta\,(1 + k^2 - 2k^2\cos^2\beta)\left(\frac{de'}{dx}\right) + (1 + 2k^2\cos^2\beta - 4k^4\cos^4\beta)\left(\frac{dr}{dx}\right) + \frac{1}{2k^2}\left(\frac{df}{dx}\right)\right] \tag{68}$$

$$\left.\frac{\partial \phi_2}{\partial x}\right|_{odd} = \frac{k\sqrt{1 - k^2\cos^2\beta}}{2\sin\beta}\left[-4\cos^2\beta\left(\frac{de'}{dx}\right) + \frac{2}{1 - k^2}\left(1 - 2\cos^2\beta\right.\right.$$

$$\left.\left. + 2k^2\cos^2\beta\right)\left(\frac{dr}{dx}\right) - \frac{1}{k^2(1 - k^2)}\left(\frac{df}{dx}\right)\right] \tag{69}$$

It is noted that the three independent parameters specifying the shape have been taken to be r, e, and f together with their x derivatives. The total loading can then be written

$$\begin{aligned}
\Delta P = &+ 8r\,\frac{d^2e}{dx^2}\,k\sin\beta\sqrt{1 - k^2\cos^2\beta} \\
&+ 4r\,\frac{d^2r}{dx^2}\left[2k\sin\beta\sqrt{1 - k^2\cos^2\beta} - \ln\left(\frac{\sqrt{1 - k^2\cos^2\beta} + k\sin\beta}{\sqrt{1 - k^2\cos^2\beta} - k\sin\beta}\right)\right] \\
&+ 8\left(\frac{de}{dx}\right)^2\frac{k\cos^2\beta}{\sin\beta}\sqrt{1 - k^2\cos^2\beta}\,\left(1 + k^2 - 2k^2\cos^2\beta\right) \\
&+ 4\left(\frac{dr}{dx}\right)^2\frac{k\sqrt{1 - k^2\cos^2\beta}}{\sin\beta}\left[1 + \frac{1}{1 - k^2} - 2(1 - k^2)\cos^2\beta - 4k^2\cos^4\beta\right. \\
&\qquad\left. - \frac{\sin\beta}{k\sqrt{1 - k^2\cos^2\beta}}\ln\left(\frac{\sqrt{1 - k^2\cos^2\beta} + k\sin\beta}{\sqrt{1 - k^2\cos^2\beta} - k\sin\beta}\right)\right] \\
&+ 2\left(\frac{de}{dx}\right)\left(\frac{df}{dx}\right)\frac{\sqrt{1 - k^2\cos^2\beta}}{k\sin\beta} \\
&- 2\left(\frac{dr}{dx}\right)\left(\frac{df}{dx}\right)\frac{k}{(1 - k^2)}\,\frac{\sqrt{1 - k^2\cos^2\beta}}{\sin\beta} \\
&+ 4\left(\frac{dr}{dx}\right)\left(\frac{de}{dx}\right)\frac{k\sqrt{1 - k^2\cos^2\beta}}{\sin\beta}\left(1 + 4k^2\cos^2\beta - 8k^2\cos^4\beta\right);
\end{aligned}$$

$$0 \leq \beta \leq \pi \tag{70}$$

It is noted that the loading depends on the shape parameters dr/dx, de/dx, and df/dx as well as d^2r/dx^2, d^2e/dx^2, and α. There are a number of distinct types of loading associated with the seven characteristic terms in the foregoing result. All but those associated with d^2e/dx^2 and d^2r/dx^2 exhibit the usual square-root singularity at the edges of the wing. Integration of these pressure distributions spanwise across the canopy will yield the chordwise load distribution without any effects of leading-edge suction.

Normal Force and Moment Distributions

Quite simple results can be obtained for the chordwise normal-force and pitching-moment distributions despite the complicated wing loading equations. The complex potential for the total flow can be found by combining perturbation complex potentials with the free-stream complex potential. Thus

$$W(\zeta) = xV_\infty \cos\alpha - i\zeta \sin\alpha - V_\infty \cos\alpha \left(\frac{dr}{dx} + \frac{de}{dx}\right) W_1(\zeta)$$

$$+ V_\infty \cos\alpha \left(\frac{dr}{dx}\right) W_2(\zeta) \tag{71}$$

The quantity $W(\zeta)$ can be expanded in a Laurent series

$$W(\zeta) = V_\infty \cos\alpha \left[D_o \ln\zeta + C_o + \sum_{n=1}^{\infty} \frac{C_n}{\zeta_n}\right] \tag{72}$$

Herein ζ is the complex variable in the y,z coordinate system.

$$\zeta = y + iz = \zeta_1 - ix \tan\alpha \tag{73}$$

The coefficients D_o and C_n are generally complex, and D_o is zero for the present case wherein the wing has no volume. If we express C_n as follows

$$C_n = A_n + iB_n \tag{74}$$

then from equations (3-64) and (3-66), reference 4, we have for the normal force (Z) and the pitching-moment coefficient M_y

$$\frac{Z}{q} = 4\pi B_1(x) \tag{75}$$

$$M_y + iM_z = 4\pi i x C_1(x) - 4\pi i \int_o^x C_1 \, dx \tag{76}$$

where the values of Z and M_y are those for the wing canopy from its leading edge up to some chordwise distance x. A result of this nature yields the chordwise load distribution by differentiation. The chordwise loading includes the effects of leading-edge suction.

The coefficient C_1 for $W(\zeta)$ can be written from equation (71) as

$$C_1 = -V_\infty \cos\alpha \left(\frac{dr}{dx} + \frac{de}{dx}\right) C_{11} + V_\infty \cos\alpha \left(\frac{dr}{dx}\right) C_{12}$$

where C_{11} and C_{12} are the coefficients of ζ^{-1} in the Laurent expansions for $W_1(\zeta)$ and $W_2(\zeta)$, respectively. Since the series of transformations $\zeta_4 \to \zeta_3 \to \zeta_2 \to \zeta_1 \to \zeta$ are the identity transformations at infinity, the coefficients C_{11} and C_{12} are the same in all planes. Collecting together previous results from equations (33) and (58)

$$W_1(\zeta_4) = -i\left(\frac{a^2}{\zeta_4} + \frac{\ell^2}{\zeta_4 + \frac{if}{2}}\right) \tag{77}$$

$$W_2(\zeta_4) = -\frac{2a}{k} \ln\left(1 + \frac{ika}{\zeta_4}\right) \tag{78}$$

we can see by inspection that

$$C_{11} = -i(a^2 + \ell^2) \tag{79}$$

and

$$C_{12} = -2ia^2 \tag{80}$$

The assumption is now made that $\cos\alpha$ does not differ significantly from unity. These results lead directly to the equation for the normal force

$$\frac{Z}{q} = 4\pi\left[(a^2 + \ell^2)\left(\frac{dr}{dx} + \frac{de}{dx}\right) - 2a^2\left(\frac{dr}{dx}\right)\right] \tag{81}$$

or

$$\frac{Z}{q} = \pi s^2\left(1 + \frac{1}{1 - k^2}\right)\left(\frac{dr}{dx} + \frac{de}{dx}\right) - \frac{2\pi s^2}{1 - k^2}\left(\frac{dr}{dx}\right) \tag{82}$$

and for the pitching moment about the apex

$$\frac{M_y}{q} = 4\pi x\left[(a^2 + \ell^2)\left(\frac{dr}{dx} + \frac{de}{dx}\right) - 2a^2\left(\frac{dr}{dx}\right)\right]$$

$$- 4\pi\int_0^x \left[(a^2 + \ell^2)\left(\frac{dr}{dx} + \frac{de}{dx}\right) - 2a^2\left(\frac{dr}{dx}\right)\right] dx \tag{83}$$

or

$$\frac{M_y}{q} = \pi s^2 x\left(1 + \frac{1}{1 - k^2}\right)\left(\frac{dr}{dx} + \frac{de}{dx}\right) - \frac{2\pi s^2 x}{1 - k^2}\left(\frac{dr}{dx}\right)$$

$$- \pi\int_0^x \left[s^2\left(1 + \frac{1}{1 - k^2}\right)\left(\frac{dr}{dx} + \frac{de}{dx}\right) - \frac{2s^2}{1 - k^2}\left(\frac{dr}{dx}\right)\right] dx \tag{84}$$

Induced Drag

For the present lifting surface which has no volume, the induced drag is given by equation (3-74) of reference 4, as

$$\frac{D_i}{q} = -\oint_C \Phi_o \frac{\partial \Phi_o}{\partial \nu}\, d\tau \tag{85}$$

where C is a contour enclosing the base of the lifting surface in the rearmost crossflow plane, $\vec{\nu}$ is the outward normal in the crossflow plane, and $\vec{\tau}$ is the tangent. Now repeating equation (12)

$$\Phi = -V_\infty \cos\alpha\left(\frac{dr}{dx} + \frac{de}{dx}\right)\phi_1 + V_\infty \cos\alpha\,\frac{dr}{dx}\,\phi_2$$

$$+ xV_\infty \cos\alpha + zV_\infty \sin\alpha \tag{86}$$

and making the assumption that $\cos\alpha$ is unity, we define the following quantities

$$\phi_o \equiv \frac{\Phi}{V_\infty \cos\alpha} \equiv \lambda_1\phi_1 + \lambda_2\phi_2 + \lambda_3 \tag{87}$$

wherein

$$\lambda_1 \equiv -\left(\frac{dr}{dx} + \frac{de}{dx}\right)$$

$$\lambda_2 \equiv \frac{dr}{dx}$$

$$\lambda_3 \equiv x + z \tan \alpha$$

The values of ϕ_1 and ϕ_2 on the surface have odd and even parts, and since $\partial\phi/\partial\nu$ is an odd function of β, only the odd parts of ϕ_1 and ϕ_2 at the surface contribute to the induced drag. From equations (66) and (67), we find

$$(\phi_1)_{odd} = -2a \sin \beta\sqrt{1 - k^2\cos^2 \beta} \tag{88}$$

$$(\phi_2)_{odd} = -\frac{a}{k} \ln\left(\frac{k \sin \beta + \sqrt{1 - k^2\cos^2 \beta}}{-k \sin \beta + \sqrt{1 - k^2\cos^2 \beta}}\right) \tag{89}$$

or

$$= -\frac{2a}{k} \tanh^{-1}\left(\frac{k \sin \beta}{\sqrt{1 - k^2\cos^2 \beta}}\right)$$

On the wing surface

$$\frac{\partial\phi_1}{\partial r} = \sin \phi \tag{90}$$

$$\frac{\partial\phi_2}{\partial r} = 1 \tag{91}$$

Equation (85) for the drag can be written

$$\frac{D_i}{q} = \lambda_1^2 I_1 + \lambda_1\lambda_2(I_2 + I_3) + \lambda_2^2 I_4 \tag{92}$$

where

$$
\left.
\begin{aligned}
I_1 &= -\oint_C \phi_1 \frac{\partial \phi_1}{\partial \nu}\, d\tau \\
I_2 &= -\oint \phi_1 \frac{\partial \phi_2}{\partial \nu}\, d\tau \\
I_3 = I_2 &= -\oint \phi_2 \frac{\partial \phi_1}{\partial \nu}\, d\tau \\
I_4 &= -\oint \phi_2 \frac{\partial \phi_2}{\partial \nu}\, d\tau
\end{aligned}
\right\} \qquad (93)
$$

$$
\left.
\begin{aligned}
\sin \phi &= 1 - 2k^2\cos^2 \beta \\
\cos \phi &= 2k \cos \beta \sqrt{1 - k^2\cos^2 \beta} \\
d\tau = r\, d\phi &= \frac{4rk^2\cos \beta \sin \beta\, d\beta}{\cos \phi} = \frac{2rk \sin \beta\, d\beta}{\sqrt{1 - k^2\cos^2 \beta}}
\end{aligned}
\right\} \qquad (94)
$$

The integrals can be evaluated as follows.

$$
I_1 = -2 \int_0^{\pi} (-2a \sin \beta \sqrt{1 - k^2\cos^2 \beta}) \sin \phi \; \frac{(2rk \sin \beta)\, d\beta}{\sqrt{1 - k^2\cos^2 \beta}}
$$

$$
= + 8ark \int_0^{\pi} \sin^2 \beta\, (1 - 2k^2\cos^2 \beta)\, d\beta
$$

Now

$$
\int_0^{\pi} \sin^2 \beta\, d\beta = \frac{\pi}{2}
$$

and

$$\int_0^\pi \sin^2\beta\cos^2\beta = \int_0^\pi \sin^2\beta\, d\beta - \int_0^\pi \sin^4\beta\, d\beta = \frac{\pi}{2} - \frac{3\pi}{8} = \frac{\pi}{8}$$

Therefore,

$$I_1 = +8ark\left(\frac{\pi}{2} - k^2\frac{\pi}{4}\right) = +2\pi ark\left(2 - k^2\right) \tag{95}$$

Also,

$$I_2 = -2\int_0^\pi \left(-2a\sin\beta\sqrt{1 - k^2\cos^2\beta}\right)\frac{(2rk\sin\beta)\,d\beta}{\sqrt{1 - k^2\cos^2\beta}}$$

$$= 8ark\int_0^\pi \sin^2\beta\, d\beta$$

$$= 4\pi ark \tag{96}$$

Also

$$I_3 = -2\int_0^\pi \left[-\frac{2a}{k}\tanh^{-1}\left(\frac{k\sin\beta}{\sqrt{1 - k^2\cos^2\beta}}\right)\right](1 - 2k^2\cos^2\beta)\frac{2rk\sin\beta\, d\beta}{\sqrt{1 - k^2\cos^2\beta}}$$

$$= +8ar\int_0^\pi \tanh^{-1}\left(\frac{k\sin\beta}{\sqrt{1 - k^2\cos^2\beta}}\right)\frac{(1 - 2k^2\cos^2\beta)\sin\beta\, d\beta}{\sqrt{1 - k^2\cos^2\beta}}$$

$$= 4\pi ark \tag{97}$$

Finally,

$$I_4 = -2\int_0^\pi \left[-\frac{2a}{k}\tanh^{-1}\left(\frac{k\sin\beta}{\sqrt{1 - k^2\cos^2\beta}}\right)\right]\frac{2rk\sin\beta\, d\beta}{\sqrt{1 - k^2\cos^2\beta}}$$

$$= +\frac{8ar}{k}\int_0^\pi \tanh^{-1}\left(\frac{k\sin\beta}{\sqrt{1 - k^2\cos^2\beta}}\right)\frac{k\sin\beta}{\sqrt{1 - k^2\cos^2\beta}}\, d\beta \tag{98}$$

The value of this integral is worked out in appendix A. With the notation

$$J(k) = \frac{1}{k^2}\int_0^{\pi} \tanh^{-1}\left(\frac{k \sin \beta}{\sqrt{1 - k^2\cos^2 \beta}}\right) \frac{k \sin \beta}{\sqrt{1 - k^2\cos^2 \beta}}\, d\beta$$

$$= \frac{-\pi}{2k^2} \ln (1 - k^2) \tag{99}$$

we have

$$I_4 = 8arkJ(k) \tag{100}$$

From equation (92) the induced drag is found to be

$$\frac{D_i}{q} = 2\pi ark \left[\left(\frac{dr}{dx} + \frac{de}{dx}\right)^2 (2 - k^2) - 4 \frac{dr}{dx}\left(\frac{dr}{dx} + \frac{de}{dx}\right) + \frac{4J}{\pi}\left(\frac{dr}{dx}\right)^2\right] \tag{101}$$

This result can be applied to the trailing edge of the nonplanar lifting surface to determine the induced drag. Such induced drag includes components associated with lift and with zero lift. For a cylindrical parawing dr/dx is zero, and if it is further at zero angle of attack, then de/dx is also zero. Accordingly, the induced drag given by equation (101) is zero, as it should be.

It is of interest to consider the ratio of normal force to induced drag as given by equations (82) and (101). From these results it is readily shown that

$$\frac{Z}{D_i} = \frac{2\left[\left(\frac{dr}{dx} + \frac{de}{dx}\right)(2 - k^2) - 2\frac{dr}{dx}\right]}{\left(\frac{dr}{dx} + \frac{de}{dx}\right)^2 (2 - k^2) - 4\frac{dr}{dx}\left(\frac{dr}{dx} + \frac{de}{dx}\right) + \frac{4J}{\pi}\left(\frac{dr}{dx}\right)^2} \tag{102}$$

For a flat plate at angle of attack α, it can be shown from equation (102) that

$$\frac{Z}{D_i} = \frac{2}{\alpha} \tag{103}$$

This is the well-known result of slender-body theory that the induced drag due to lift corresponds to a rearward inclination of the resultant force vector due to lift of $\alpha/2$.

Leading-Edge Suction and Vortex Lift

In the present case of a nonplanar lifting surface, the leading-edge suction forces can change the magnitude of the lift and drag as well as the side force of either panel. It is of interest to know how important the effect of leading-edge suction is on these aerodynamic quantities for nonplanar lifting-surface shapes typical of all-flexible parawings.

Leading-edge suction.- Usually an evaluation of the leading-edge suction is made by the method of Jones and Cohen, reference 5, which utilizes complex integration around a contour partially surrounding the edge. In the present case, a different method is utilized. The normal force as obtained from equation (82) includes the leading-edge suction force. We may determine the normal force without leading-edge suction by integrating the pressure distributions given by equation (70) over the lifting surface exclusive of contours around the leading edges. The difference in normal force for the two calculations is the component of leading-edge suction force in the normal-force direction. The leading-edge suction force is normal to the leading edge in a plane tangent to the lifting surface. Knowing the direction and the one component of the leading-edge suction, we can therefore determine its other components.

The integration of equation (70) to obtain the normal-force chordwise distribution without suction has been carried out for all seven terms of that equation. Introducing the following subscript notation

$$\left.\begin{array}{l} \dfrac{d^2e}{dx^2} \sim 2e \qquad \dfrac{d^2r}{dx^2} \sim 2r \qquad \left(\dfrac{de}{dx}\right)^2 \sim ee \qquad \left(\dfrac{dr}{dx}\right)^2 \sim rr \\ \qquad \dfrac{de}{dx}\dfrac{df}{dx} \sim ef \qquad \dfrac{dr}{dx}\dfrac{df}{dx} \sim rf \qquad \dfrac{de}{dx}\dfrac{dr}{dx} \sim er \end{array}\right\} \qquad (104)$$

we find the following result for the first component

$$\frac{dC_{Z_{2e}}}{dx} = \frac{1}{S_R}\int_{\phi_\ell}^{\phi_r} \Delta P_{2e} \sin\phi \; r \; d\phi$$

$$= \frac{16\,k^2 r^2}{S_R} \;\frac{d^2 e}{dx^2}\int_0^{\pi} \sin^2\beta\,(1 - 2k^2\cos^2\beta)\,d\beta$$

$$= \frac{4\pi r^2}{S_R}\;\frac{d^2 e}{dx^2}\,k^2(2 - k^2) \tag{105}$$

The results for all seven components of the loading <u>without suction</u> are:

$$\frac{dC_{Z_{2e}}}{dx} = \frac{4\pi r^2}{S_R}\;\frac{d^2 e}{dx^2}\,k^2(2 - k^2) \tag{106}$$

$$\frac{dC_{Z_{2r}}}{dx} = -\frac{4\pi r^2}{S_R}\;\frac{d^2 r}{dx^2}\,k^4 \tag{107}$$

$$\frac{dC_{Z_{ee}}}{dx} = \frac{8\pi r}{S_R}\left(\frac{de}{dx}\right)^2 k^2(1 - k^2)^2 \tag{108}$$

$$\frac{dC_{Z_{rr}}}{dx} = \frac{8\pi r}{S_R}\left(\frac{dr}{dx}\right)^2 k^6 \tag{109}$$

$$\frac{dC_{Z_{ef}}}{dx} = \frac{4\pi r}{S_R}\left(\frac{de}{dx}\right)\left(\frac{df}{dx}\right)(1 - k^2) \tag{110}$$

$$\frac{dC_{Z_{rf}}}{dx} = -\frac{4\pi r}{S_R}\left(\frac{dr}{dx}\right)\left(\frac{df}{dx}\right)k^2 \tag{111}$$

$$\frac{dC_{Z_{re}}}{dx} = \frac{8\pi r}{S_R}\left(\frac{dr}{dx}\right)\left(\frac{de}{dx}\right)k^2(1 - 2k^2 + 2k^4) \tag{112}$$

where the induced drag associated with vortex lift $(\Delta C_{D_i})_v$ by analogy with equation (126) is

$$\begin{aligned}(\Delta C_{D_i})_v &= (\Delta C_Z)_v \sin\alpha + (\Delta C_X)_v \cos\alpha \\ &= C_s \left[\alpha \cos(n_1,z) + \cos(n_1,x)\right] \\ &= \frac{(\Delta C_Z)_s}{\cos(n_2,z)} \left[\alpha \cos(n_1,z) + \cos(n_1,x)\right]\end{aligned} \tag{132}$$

Theory for Conical Parawings

While an all-flexible parawing is not conical, the qualitative effects of spanwise camber for a conical parawing are of interest to the extent they lead to an understanding of all-flexible parawings with large spanwise camber. Therefore, the foregoing theoretical results will be applied to a conical parawing to obtain closed algebraic results for the effects of spanwise camber.

The configuration type is illustrated in figure 6 with the straight leading edges lying in the x-y plane and all sections of the canopy in planes parallel to the y-z plane being circular arcs of uniform k. The canopy is thus part of a circular cone. For a canopy which is half of a right circular cone in particular, the cross sections are semi-circular and $k = 0.707$.

For a conical canopy, the angle of attack of the chord plane is

$$\alpha = \frac{de}{dx} + \frac{df}{dx} \tag{133}$$

so that

$$\frac{dr}{dx} + \frac{de}{dx} = \alpha + \frac{(1 - 2k^2)}{2k\sqrt{1 - k^2}} \frac{ds}{dx} \tag{134}$$

where s is the local semispan.

Also,

$$\frac{dr}{dx} = \frac{1}{2k\sqrt{1 - k^2}} \frac{ds}{dx} \tag{135}$$

Writing equation (82) in the following form

$$\frac{Z}{q} = \pi s^2 \left(1 + \frac{1}{1 - k^2}\right) \alpha + \pi s^2 \left(1 + \frac{1}{1 - k^2}\right)\left(\frac{dr}{dx} - \frac{df}{dx}\right) - \frac{2\pi s^2}{1 - k^2} \frac{dr}{dx} \tag{136}$$

and utilizing equations (133) to (135), we obtain the normal-force coefficient

$$C_Z = \frac{\pi s^2}{S_R} \left\{\frac{2 - k^2}{1 - k^2}\left[\alpha + \frac{1 - 2k^2}{2k\sqrt{1 - k^2}} \frac{ds}{dx}\right] - \frac{1}{k(1 - k^2)^{3/2}} \frac{ds}{dx}\right\} \tag{137}$$

Alternately, it is convenient to form a normal-force parameter

$$\frac{S_R}{s_m^2} \frac{C_Z}{\alpha} = \left(\frac{4}{A\!\!\!R} \frac{C_Z}{\alpha}\right) = \frac{\pi(2 - k^2)}{(1 - k^2)} \left[1 - \frac{k(5 - 2k^2)}{2(2 - k^2)\sqrt{1 - k^2}} \left(\frac{ds/dx}{\alpha}\right)\right] \tag{138}$$

which depends only on k and $\alpha/(ds/dx)$. From equation (137), the term proportional to α is associated with the slope of the normal-force curve. For fixed values of ds/dx and α, the ratio of normal force due to α with and without spanwise camber is given by

$$K \equiv \frac{(Z)_{k \neq o}}{(Z)_{k=o}} = \frac{(2 - k^2)}{2(1 - k^2)} \; ; \qquad \beta \leq 90^\circ \tag{139}$$

The quantity K can be thought of as an apparent mass ratio which indicates the extent to which spanwise camber increases the lift-curve slope. If $\beta > 90^\circ$, we can form a similar ratio. The ratio chosen is that of the normal force due to α for the cambered surface to that of the flat surface having the same maximum span, which is now the cone diameter. In this case, we have

$$K \equiv \frac{(Z)_{k \neq o}}{(Z)_{k=o}} = \frac{4\left(\frac{f}{s}\right)^2 \left(1 + \frac{1}{2}\frac{f^2}{s^2}\right)}{\left(1 + \frac{f^2}{s^2}\right)^2} = 2k^2(2 - k^2) \; ; \qquad 90^\circ \leq \beta \leq 180^\circ \tag{140}$$

With regard to the angle of zero normal force, the analysis yields

$$\frac{\alpha_o}{df/dx} = \frac{1}{2} \frac{5 - 2k^2}{2 - k^2} = \frac{5 + 3\frac{f^2}{s^2}}{2\left(2 + \frac{f^2}{s^2}\right)} ; \qquad 0 \leq \beta < 180^o \tag{141}$$

or in terms of the parameter ds/dx

$$\frac{\alpha_o}{(ds/dx)} = \frac{k(5 - 2k^2)}{2(2 - k^2)\sqrt{1 - k^2}} \tag{142}$$

Results similar to those for normal force can also be obtained for induced drag. From equation (101) and equations (133) and (134) we find

$$\frac{4}{A\!\!\!R} \frac{C_{D_i}}{\alpha^2} = \frac{\pi}{2}\left(\frac{2 - k^2}{1 - k^2}\right)\left\{1 - \frac{k(5 - k^2)}{\sqrt{1 - k^2}\,(2 - k^2)}\left(\frac{ds/dx}{\alpha}\right) + \frac{\left[4J/\pi - (1 - 2k^2)(2 + 5k^2 - 2k^4)\right]}{4k^2(1 - k^2)(2 - k^2)}\left(\frac{ds/dx}{\alpha}\right)^2\right\} \tag{143}$$

To obtain the part of the normal force due to leading-edge suction, we write equation (123) as

$$\frac{d(\Delta C_Z)_s}{dx} = -\frac{8\pi k^2 r}{S_R}\left\{(1 - k^2)\left[\alpha + \frac{1 - 2k^2}{2k\sqrt{1 - k^2}}\frac{ds}{dx}\right] - \frac{1}{2k\sqrt{1 - k^2}}\frac{ds}{dx}\right\}^2 \tag{144}$$

Integration of the foregoing equation over the root chord yields the normal-force coefficient

$$(\Delta C_Z)_s = -\frac{8\pi k^2}{S_R}\left\{(1 - k^2)\left[\alpha + \frac{1 - 2k^2}{2k\sqrt{1 - k^2}}\frac{ds}{dx}\right] - \frac{1}{2k\sqrt{1 - k^2}}\frac{ds}{dx}\right\}^2 \int_0^{c_r} r\,dx \tag{145}$$

Since

$$\frac{ds}{dx} = \frac{s}{c_r} \; ; \qquad \frac{r}{s} = \frac{1}{2k\sqrt{1 - k^2}} \tag{146}$$

it can easily be shown that

$$\frac{4}{A\!R} \; \frac{(\Delta C_Z)_s}{\alpha} = -2\pi k(1 - k^2)^{3/2} \left(\frac{\alpha}{dx/dx}\right) \left[1 - \frac{k(3 - 2k^2)}{2(1 - k^2)^{3/2}} \; \frac{ds/dx}{\alpha}\right]^2 \tag{147}$$

It is seen that the fractional part of the total normal force due to leading-edge suction thus depends only on the parameters k and $\alpha/(ds/dx)$. If k is zero as for a flat plate, no normal force is associated with leading-edge suction. However, if k is greater than zero, a negative normal force is associated with such suction, and loss of suction results in an increase in normal force.

The induced drag associated with leading-edge suction can be readily obtained from $(\Delta C_Z)_s$ with the help of equation (127). Using the direction cosines derived in Appendix B, we find

$$\frac{4}{A\!R} \; \frac{(\Delta C_{D_i})_s}{\alpha^2} = \frac{4}{A\!R} \; \frac{(\Delta C_Z)_s}{\alpha} \left[1 + \frac{(1 - 2k^2)(ds/dx)/\alpha}{2k\sqrt{1 - k^2}\left(1 + \frac{A\!R^2}{16}\right)}\right] \tag{148}$$

From equations (143) and (148), the induced drag with and without leading-edge suction can be readily calculated.

An additional item is of interest. It is noted in equation (147) that the leading-edge suction is zero at a certain angle of attack. By analogy with airfoil practice, we term this angle of attack the ideal angle of attack, α_{ideal}. From equation (147), this angle is given by

$$\frac{\alpha_{ideal}}{(ds/dx)} = \frac{k(3 - 2k^2)}{2(1 - k^2)^{3/2}} \tag{149}$$

Using the direction cosines we find

$$(\Delta C_{D_i})_s = (\Delta C_Z)_s \left[\alpha + \frac{\cos(n_2,x)}{\cos(n_2,z)} \right] \tag{127}$$

Vortex lift.- It is of interest to determine the probable importance of the vortex-lift concept of Polhamus, reference 6, for all-flexible parawing applications. In this concept, the force of leading-edge suction is no longer assumed to act normal to the leading edge in a plane tangent to the canopy. It is assumed that a separation bubble occurs on the upper surface of the wing extending from the leading edge inward and that the suction force is changed only in direction but not in magnitude. For the present purpose, it is assumed that this bubble is of such a small extent that the force is rotated 90° on the average to a direction along $\vec{n}_1$ normal to the canopy and the leading edge.

To obtain the vortex normal force, $(\Delta C_Z)_v$, we have

$$(\Delta C_Z)_v = C_s \cos(n_1,z) \tag{128}$$

and from equation (125)

$$(\Delta C_Z)_v = (\Delta C_Z)_s \frac{\cos(n_1,z)}{\cos(n_2,z)} \tag{129}$$

The total normal force with vortex lift is then

$$(C_Z)_v = (C_Z) - (\Delta C_Z)_s + (\Delta C_Z)_v \tag{130}$$

In order to obtain the total induced drag with vortex lift, $(C_{D_i})_v$, we have

$$(C_{D_i})_v = (C_{D_i}) - (\Delta C_{D_i})_s + (\Delta C_{D_i})_v \tag{131}$$

Let us turn now to evaluating the increments in normal force and drag associated with vortex lift. From the direction cosines given in Appendix B, we find using equation (129) that

$$\frac{4}{AR}\frac{(\Delta C_Z)_v}{\alpha} = -\frac{4}{AR}\frac{(\Delta C_Z)_s}{\alpha}\frac{(1-2k^2)}{2k\sqrt{1-k^2}\sqrt{1+\left(\frac{AR}{4}\right)^2}} \tag{150}$$

The induced drag associated with vortex lift becomes, using equation (132),

$$(\Delta C_{D_i})_v = -\frac{\alpha(\Delta C_Z)_s(1-2k^2)}{2k\sqrt{1-k^2}\sqrt{1+\left(\frac{AR}{4}\right)^2}}\left[1-\frac{2k\sqrt{1-k^2}}{1-2k^2}\left(\frac{ds/dx}{\alpha}\right)\right] \tag{151}$$

For purposes of later comparison, it is desired to obtain specific results for $k = 0$. In this case, the results of equations (138) and (143) yield the following nondimensional results for lift, induced drag, and drag-rise factor with full suction

$$\left.\begin{aligned}\left(\frac{4}{AR}\right)^2 C_Z &= 2\pi\left(\frac{\alpha}{ds/dx}\right)\\ \left(\frac{4}{AR}\right)^3 C_{D_i} &= \pi\left(\frac{\alpha}{ds/dx}\right)^2\\ \frac{C_{D_i}}{C_Z^2} &= \frac{1}{\pi AR}\end{aligned}\right\} \tag{152}$$

With no leading-edge suction, we find the same result for C_Z, but for the other quantities we have

$$\left.\begin{aligned}\left(\frac{4}{AR}\right)^3 C_{D_i} &= 2\pi\left(\frac{\alpha}{ds/dx}\right)^2\\ \frac{C_{D_i}}{C_Z^2} &= \frac{2}{\pi AR}\end{aligned}\right\} \tag{153}$$

With vortex lift the corresponding results are

$$\left.\begin{aligned} \left(\frac{4}{A\!R}\right)^2 C_Z &= 2\pi\left(\frac{\alpha}{ds/dx}\right) + \pi\left(\frac{\alpha}{ds/dx}\right)^2 \\ \left(\frac{4}{A\!R}\right)^3 C_{D_i} &= 2\pi\left(\frac{\alpha}{ds/dx}\right)^2 + \pi\left(\frac{\alpha}{ds/dx}\right)^3 \end{aligned}\right\} \tag{154}$$

$$\frac{C_{D_i}}{C_Z^{\,2}} = \frac{2}{\pi A\!R}\left[\frac{1}{1 + \frac{1}{2}\left(\frac{\alpha}{ds/dx}\right)}\right] \tag{155}$$

RESULTS AND DISCUSSION

Theoretical Results for Conical Canopies

The nonplanar slender-body theory described in the preceding section of the report has been used to make a systematic set of calculations for conical canopies formed by segments of circular cones. These calculations illustrate a number of significant qualitative effects which have bearing on the aerodynamics of real parawings. Let us then consider the results for conical parawings and their implications for all-flexible parawings.

It is of interest to have a knowledge of the shape parameters of an all-flexible parawing in order to assess the probable applicability of the theoretical results for conical parawings to those of the all-flexible type. The variation of s and k with chordwise distance are shown in figure 7 as obtained from shape measurements on a twin-keel all-flexible parawing. Examination of the variation of s with x near the trailing edge of the root chord shows that it is not possible to characterize the parawing by a single value of ds/dx as for a conical one. However, figure 7(b) shows that a value of $k = 0.5$ is a good average value for the parawing.

Considering first normal-force results, the apparent mass factor K given by equations (139) and (140) is shown as a function of the spanwise camber parameter k in figure 8(a). It is noted that a surface of semicircular cross section has a normal-force curve slope 50 percent greater than that for a triangular flat wing of the same span. For the limiting case of $k = 1$, the slope is doubled. The limiting configuration for $k = 1$ is not a solid circle because there is still a slit in the bottom meridian, and pressures exist on both sides of the wing surface. Corresponding results for the angle of zero normal force are shown in figure 8(b). The angle is greater than df/dx because the wing has geometric washout.

There exists an ideal angle of attack, calculable from equation (149), for which the leading-edge suction becomes zero at all points along the leading edges. The ratio of ideal angle of attack to ds/dx is shown as a function of k in figure 9 together with corresponding results for α_o. The ideal angle of attack varies from $1.2\ \alpha_o$ at $k = 0$ to $1.5\ \alpha_o$ at $k = 0.707$. For a wing of aspect ratio 2, $ds/dx = 0.5$. For $k = 0.5$, this wing would have an ideal angle of attack close to 0.5 radian. If the wing were operated at an angle less than the ideal angle of attack, the stagnation point would move to the upper canopy surface, and luffing would occur.

It is of interest to examine the effects of leading-edge suction and vortex lift on normal-force and drag characteristics of conical canopies. The effects are functions of the amount of spanwise camber. As a basis of comparison for the effect of spanwise camber, let us examine the effects of leading-edge suction and vortex lift first for $k = 0$. Figure 10 has been prepared for this purpose, based on the simple results given by equations (152) to (155) in a form independent of aspect ratio. Figure 10(a) shows no effect of leading-edge suction on normal force, but a large effect of vortex lift is exhibited at the larger values of $\alpha/(ds/dx)$ attainable with low-aspect-ratio wings. The drag curves in a non-dimensional form are shown in figure 10(b). At small normal-force coefficients the induced drag associated with vortex lift can exceed that with no suction, but at high normal-force coefficients the induced drag with vortex lift approaches that with full suction. The ratio Z/D_i is plotted in figure 10(c) to show the approximate magnitude of the ratio of normal force to induced drag. It is clear the vortex-lift effects on this ratio are important only for smaller values of the ratio. At large values of C_Z, the ratio Z/D_i with vortex lift can be greater than that for full suction.

For comparison with the foregoing results in figure 10 for $k = 0$, a corresponding set is shown in figure 11 for $k = 0.5$. This value of k was chosen because it is the average value measured for a twin-keel all-flexible parawing. In figure 11(a), it is noted that the loss of leading-edge suction now causes an increase in normal force where none was manifest previously. The difference in normal force between the full-suction and no-suction cases is almost as great as that between the vortex-lift and full-suction cases. One important effect of spanwise camber is thus that leading-edge suction can have significant effects on normal force where none occurred for $k = 0$.

For $k = 0.5$, the strength of the leading-edge suction is zero along the entire lengths of the leading edges at a value of $\alpha/(ds/dx)$ equal to 0.96 regardless of aspect ratio. Hence, all three normal-force curves for all three cases have the samé normal force at the ideal angle of attack. At the ideal angle of attack, the leading-edge streamline is tangent to the camberline, and small changes in the angle of attack can put a stagnation point on either the lower surface or upper surface of the canopy.

In figure 11(b), the low ranges of the drag curves are presented for the cases of full suction, no suction, and vortex lift. At the normal-force coefficient corresponding to the ideal angle of attack, all drag curves are tangent. The point of maximum Z/D_i for any drag curve corresponds to the point of tangency to the curve of a straight line from the origin. It can thus be seen that the points of maximum Z/D_i ratio occur for values of normal force less than that corresponding to the ideal angle of attack. However, a conical parawing must operate above the ideal angle of attack so that it cannot attain the maximum value of Z/D_i. In figure 11(c), the ratio of Z/D_i is shown versus the C_Z parameter for the three cases. The results of this figure for $k = 0.5$ are qualitatively the same as those in figure 10(c) for $k = 0$.

Direct comparisons of Z/D_i ratios for two values of k are given in figure 12 for the full-suction case and the vortex-lift cases. In this figure it is seen that spanwise camber has a favorable effect on the Z/D_i ratio for both cases.

It appears that appreciable gains in the ratio of lift to induced drag could be realized if an all-flexible parawing could be rigged into a conical shape. For example, the twin-keel all-flexible parawing on which the shape data were taken has a Z/D_i ratio of 2.90 and an L/D_i ratio of 2.76 based on the present theory using measured geometric quantities. Assume that the all-flexible parawing could be rigged into a conical shape with $k = 0.5$. At the point of maximum Z/D_i corresponding to the luffing boundary, figure 11(b) gives the following values

$$\left(\frac{4}{A\!\!R}\right)^2 \frac{C_Z}{\pi} = 0.5 \qquad \left(\frac{4}{A\!\!R}\right)^3 \frac{C_{D_i}}{\pi} = 0.065$$

The ratio Z/D_i is thus

$$\frac{Z}{D_i} = \frac{0.5}{0.065}\left(\frac{4}{A\!\!R}\right) \approx \frac{30}{A\!\!R}$$

It thus appears that for any small or moderate aspect ratio all-flexible parawing, substantial gains would result if the parawing could be rigged closer to the conical shape. The gain would result principally from operating closer to the luffing condition which corresponds to the highest useful Z/D_i ratio. This point cannot be attained with present all-flexible parawings because of nose collapse. As long as the ideal angle of attack cannot be attained, vortex lift will be a factor in improved performance.

Measured Shapes and Aerodynamic Coefficients

During the course of this investigation, the Langley Research Center conducted a wind-tunnel program to obtain data on the inflated shapes of both a single-keel and a twin-keel all-flexible parawing. Prior attempts to find the inflated shapes had involved measuring, photographing, or rigidizing the models. These methods were not generally satisfactory, and the method finally adopted by Langley was the use of stereo photography. The experimental arrangement is shown in figure 13. The wing is marked with 1-inch squares. From the stereo pair of photographs, data are obtained on the line intersection points on the wing and read directly into punch cards for use in a computer program which calculates the coordinates of the points in a tunnel axis system. The crosses on the tunnel ceiling are used as control points in setting up the stereo model. In addition to obtaining the stereo photographs, aerodynamic performance was measured.

The measurements described above were made on a single-keel and a twin-keel all-flexible parawing, for both of which considerable prior aerodynamic data had been obtained at the Langley Research Center. The major part of the analysis and data comparisons of the present investigation was conducted using these two configurations. In the following sections of this report, the single-keel and twin-keel parawings referred to are those described below.

Single-keel parawing.- The single-keel parawing configuration used during this investigation is the basic wing configuration of reference 7. The flat canopy arrangement, line attachment locations, and line lengths are shown in figure 14. The inflated configuration is shown mounted in the tunnel in figure 13.

This configuration was tested in the wind tunnel over a range of angles of attack, α_7, from 26° to 35°. The angle at which the highest L/D ratio occurred is 27°, which is the angle at which the inflated shape data were obtained. At this angle the following aerodynamic data were obtained:

$$C_L = 0.95$$

$$C_D = 0.39$$

$$L/D = 2.43$$

The canopy coordinates of the inflated shape, as obtained from the stereo photography, are listed in Appendix C. In order to use these data, it is necessary to know something of the coordinate system set up in the stereo model and the order in which the points were read. This information is contained on the first page of Appendix C.

For purposes of applying aerodynamic theories to the known canopy shape, the data of Appendix C were used to construct chordwise sections at various spanwise stations. These sections are shown in figure 15. The sections were obtained for a given spanwise station by locating those points in the tabular data having y' values within ± 0.10 inch of the nominal y' value of the desired semispan station and plotting the points on an x'-z' graph. This procedure gives acceptable results over most of the canopy. Near the maximum span and near the line attachment points along the leading edge, however, the canopy surface is nearly vertical, and small differences in y' give large differences in the z' coordinate. This difficulty can be most easily visualized by examining figures 16(a) and 16(b), which are photographs showing the side and rear views of a single-keel parawing having the same configuration and rigging characteristics as that used in the shape determination tests. Consequently, it is difficult to obtain an accurate section near the tip, as indicated by the sections having η values near 1 in figure 15(b). The most forward points for a given span station are close to, but do not necessarily indicate, the section leading edges, because the high curvature at the leading edge sometimes prevented the first one or two points from being seen properly in the photographs.

<u>Twin-keel parawing</u>.- The twin-keel parawing configuration used in the present investigation is that described in reference 8. The canopy shape data, however, were obtained on a wing having an h_k of 75 inches rather than the 15-foot size used in the investigation reported in reference 8. The flat canopy arrangement, line attachment locations, and line lengths are shown in figure 17.

The configuration described in figure 17 was tested in the wind tunnel over a range of angles of attack, α_s, from 24.2° to 31.8°. The shape data were obtained at an angle of 24.8° which is near the maximum L/D ratio condition. At this angle, the following aerodynamic data were obtained:

$$C_L = 0.840$$

$$C_D = 0.329$$

$$L/D = 2.56$$

The canopy coordinates of the inflated configuration, as obtained from the stereo photography, are listed in Appendix D. As for the single-keel data of Appendix C, an explanation of the data is included in the appendix.

Chordwise sections of the canopy were plotted for purposes of predicting the aerodynamic performance of the parawing. The sections are shown in figure 18. The comments given in the preceding section concerning the methods of obtaining these sections and the accuracy of the section shapes apply equally to the twin-keel data. Generally, however, the twin-keel parawing tends to have a more regular and smoother shape than the single-keel parawing because of the absence of leading-edge lines in the center lobe and the fact that the inflation of the forward portion of the outer lobes is assisted by the presence of the center lobe. These characteristics can be seen by comparing figures 19(a) and 19(b) with figures 16(a) and 16(b).

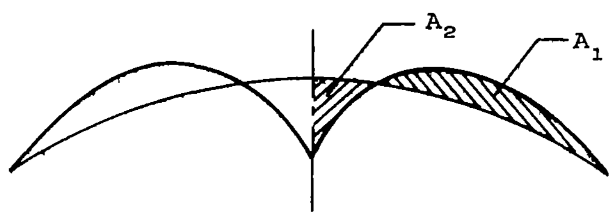
Aerodynamic Performance Comparisons

The slender-wing analysis was applied to the two parawings just described in order to evaluate the method. To apply the method, it is necessary to obtain spanwise canopy sections in planes normal to the root chord and fit circular arcs to these sections. Using the chordwise variation of the circular-arc section properties, the detailed aerodynamic load distribution on the parawing can be computed, from which the gross aerodynamic performance and the rigging line load distributions can be obtained and compared with measured results. A computer program was written to perform the calculations. The canopy fitting procedure and the aerodynamic load calculations are described below. The aerodynamic calculations and comparisons with data were made assuming full leading-edge suction.

As an additional standard of comparison, a planar lifting-surface method was also applied to the two parawing configurations. The method used is that of Multhopp, as modified and programmed by Lamar (ref. 9). An arrangement of 21 spanwise and 10 chordwise control points was used. The predicted angles of attack at which the measured lift coefficients are obtained were compared with measured angles. The predicted angles were low by 10 and 27 percent for the single- and twin-keel parawings, respectively. The differences are due both to an overprediction of the effect of chordwise camber and the inability of the method to account for spanwise camber. The slender-wing results, which follow, illustrate better agreement, which is felt to be the result of accounting for the large amount of spanwise camber.

Single-keel parawing.- The first task in applying the theory to the known parawing shape is to determine spanwise sections in planes normal to the root chord. The procedure adopted was to use the chordwise shape data of figure 15 to obtain a y-z crossplot at regular intervals of x. Some typical y-z plots are shown in figure 20 for several stations along the chord.

It is evident from figure 20 that these spanwise sections do not resemble circular arcs, and fitting circular arcs to the shapes is a somewhat arbitrary process. In order to fit the arcs in a consistent manner, the following approach was used. The circular arc was first made to pass through and terminate at the tip of the section. Then, an attempt was made to adjust the circular arc radius and the center of curvature so that the area (A_1 in the sketch below) between the circular arc and canopy sections outboard of the point where these two lines cross is equal to the area (A_2) between the arc and canopy inboard of the point.



Circular-arc sections were fitted in this manner at 2-inch intervals (intervals in x/c_r of 0.051 where c_r = 38.9 inches) along the root chord, and the quantities r, f, and e were measured. These quantities were then plotted versus x and the resulting curves smoothed. Finally, the semispan values, s, were computed using equation (114) and compared with the planform deduced directly from the photogrammetric data. Any sizable discrepancies in span were eliminated by modifying the values of r and f, and the r and f curves were again smoothed. The resulting circular-arc fits to several spanwise sections are shown in figure 20. The planform fit that was obtained using this procedure is compared with the actual planform obtained from the photogrammetric data (as viewed normal to the root chord) in figure 21. The two planforms are in reasonable agreement, considering the complexity of the leading-edge shape. A table of the circular-arc properties used in the single-keel parawing calculations is given in table I. Since only three quantities may be independently specified, the s values in table I are calculated from the e, f, and r values.

After a satisfactory planform fit was obtained, the slopes of the curves of r, e, and f versus x were obtained graphically to determine dr/dx, de/dx, and df/dx. These values were then plotted versus x to obtain the second derivatives d^2r/dx^2 and d^2e/dx^2. The resulting values were then used as tabular input to the computer program to compute the loading distribution. The pressure distribution was computed using equation (70). From a knowledge of the circular-arc canopy shape, the direction cosines of the local normal to the canopy were obtained and used with the pressure distribution to obtain force distributions in the normal, axial, and side directions. The normal force per unit chordwise length was checked with the analytically integrated values for no suction represented by equations (106)-(112). Finally, the chordwise integrated loadings using 19 stations along the root chord were checked with the analytically integrated normal-force coefficient with and without leading-edge suction using equations (113) and (123). The differences between the numerically and analytically integrated values were generally less than 2 percent.

The normal-force results for the single-keel parawing are shown in figure 22. The ordinate represents the total normal force with leading-edge suction up to the chord station of interest, as predicted from equation (113). The irregular shape of the curve near the nose is caused by the difficulty in fitting circular arcs to the actual canopy spanwise sections. The canopy span begins to decrease rapidly near the 87-percent chord station, which causes the loading to become negative in the slender-wing analysis. Consequently, the total wing normal force is taken as the maximum value, which occurs at $x/c_r = 0.85$.

For purposes of applying the theory as a predictive method, the normal force and induced drag coefficients predicted by the theory should be modified according to the following comments. In the development of the expressions for normal force (eq. (81)) and induced drag (eq. (101)), the factor $\cos\alpha$ was assumed nearly unity and dropped from the force expressions. The angle α is in fact not small, and the $\cos\alpha$ factor should probably be retained. Accordingly, the normal-force coefficient presented in figure 22 should be interpreted as $C_Z/\cos\alpha$ and the values indicated should be multiplied by $\cos\alpha$ to obtain C_Z. For induced drag, equations (87) and (85) indicate that a correction of $\cos^2\alpha$ is applicable to the induced-drag coefficient. Consequently, the induced-drag coefficient computed from equation (101) should be interpreted as $C_{D_i}/\cos^2\alpha$. Secondly, it is well known that slender-wing theory tends to overpredict aerodynamic force coefficients, with the difference increasing with increasing aspect ratio. Thus, a slenderness correction should be applied to the predicted force coefficients. Finally, since normal and drag forces represent a mixed set, the lift force should be determined according to the following equations.

$$C_L = C_Z\cos\alpha - C_X\sin\alpha$$

$$C_{D_i} = C_Z\sin\alpha + C_X\cos\alpha$$

Therefore,

$$C_L = \frac{1}{\cos\alpha}\left[C_Z - C_{D_i}\sin\alpha\right] \tag{156}$$

With the above noted corrections, the predicted results can be compared with the measured results given in the previous section. The predicted normal-force coefficient from figure 22 is 1.53 and the induced-drag coefficient is 0.727. The photogrammetric data (fig. 15) indicate that the root chord makes an angle with the wind vector of 41°. Thus, the normal-force and induced-drag coefficients corrected for the $\cos\alpha$ effect are 1.154 and 0.413, respectively. Using equation (156), the predicted lift coefficient is 1.17. The slenderness correction is based on the aspect ratio of the planform shown in figure 21, which is 1.56. Figure 6-10 of reference 10 illustrates some results for lift-curve slope for triangular wings having aspect ratios up to 4 and indicates for an aspect ratio of 1.56 that slender-wing theory overpredicts measured values by about 32 percent. This correction was applied to the lift and induced-drag coefficients noted above in order to obtain the final predicted values.

The measured drag includes the effect of frictional effects as well as induced drag. In order to make a comparison with measured drag, rough estimates of the canopy skin friction and line drag were made using a flat plate, turbulent-boundary-layer skin-friction coefficient, and a two-dimensional drag coefficient for a cylinder. This calculation indicates a frictional drag coefficient C_{D_o} of 0.06 based on flat canopy area.

The predicted results are compared with the measured values in the following table.

	Predicted	Measured
C_L	0.89	0.95
C_{D_i}	.31	----
C_D	.37	.39
L/D_i	2.83	----
L/D	2.40	2.43

The predicted lift coefficient is somewhat lower than the measured value. This quantity is dependent only on the cross section properties at the last station developing positive lift, according to equation (113). In order to determine the sensitivity of the predicted lift to the circular-arc fits to the sections near the trailing edge, the actual sections at four chordwise stations were refit, keeping the same semispan but varying the radius and spanwise camber of the circular arc. These changes cause a change in C_Z principally through dr/dx. It was found that the predicted C_Z could be increased about 20 percent through changes in r, e, and f that did not appear unreasonably large. Thus, for the single-keel parawing, additional work is required to develop a rational approach for obtaining a unique circular-arc fit to a given spanwise section.

The measured and predicted drag coefficients agree reasonably well. From the relative sizes of the induced drag and estimated frictional drag, it is apparent that the induced drag is a major part of the total drag of a single-keel parawing. The lift-drag ratios agree very well as a result of the underprediction of both lift and drag coefficients.

Twin-keel parawing.- The approach to calculating the aerodynamic performance of the twin-keel parawing is similar to that described above for the single-keel parawing. The first step is to obtain spanwise sections by crossplotting the chordwise section data of figure 18. The results for several chordwise stations are shown in figure 23. The fitting of circular arcs to these sections can be made on a more rational basis than was the case with the single-keel parawing. The procedure followed is to pass the circular arc through the actual canopy points at the vertical plane of symmetry and at the maximum span station (the leading edge). Towards the center, chordwise, of the parawing, the tips of the canopy are reentrant, as shown in figure 23. In this case, the maximum span station does not correspond to the leading edge, and the maximum span station is used. The circular-arc fits are also shown in figure 23. The tabulation of the circular-arc parameters is shown in table II. The nondimensional chordwise values are based on a root chord length c_r of 51.4 inches. The resulting fit of the circular-arc planform to the actual planform obtained from the photogrammetric data is shown in figure 24.

The normal force results obtained using the circular-arc fit properties described above are shown in figure 25. The local span begins to decrease rapidly beyond $x/c_r = 0.86$ and a negative normal force is predicted aft of this point. Thus the total normal force is taken as that at $x/c_r = 0.86$. The dip in the curve at $x/c_r = 0.6$ occurs in the region where the canopy tip is reentrant (see fig. 23), and could possibly be smoothed by a somewhat different approach to the circular-arc fit for this type of spanwise section.

For purposes of comparing predicted and measured performance of the twin-keel parawing, the same corrections were made to the theoretical results as were discussed in the previous section. The predicted normal-force (from fig. 25) and induced-drag coefficients are 1.385 and 0.551, respectively. When these values are corrected for the $\cos \alpha$ and slender-wing effects and the wing lift coefficient is computed, the following results are obtained.

	Predicted	Measured
C_L	0.86	0.84
C_{D_i}	.31	----
C_D	.36	.33
L/D_i	2.76	----
L/D	2.38	2.55

In these calculations, the aspect ratio is that of the planform illustrated in figure 24, which is 1.76. The slenderness correction is then 0.745, based on the values shown in reference 10. The total frictional drag coefficient is estimated to be 0.05, based on the same approach as noted for the single-keel parawing. The predicted total drag coefficient is somewhat larger than the measured value, which gives a lower lift-drag ratio than is measured.

Structural Characteristics

One of the principal advantages of a capability for predicting the detailed load distribution on the canopy is the potential for determining line loads. Using the slender-wing theory, an investigation was made for both the single- and twin-keel parawings to attempt to obtain an understanding of the manner in which the distributed loading on the canopy is led into the discrete support loads represented by the rigging line tensions. In order to make a detailed stress analysis of this problem, it would be necessary to know the shape of the "scalloped" leading edge and the resulting canopy aerodynamic load distribution near the leading edge. It would then be possible to predict the canopy stresses and to solve the static force equilibrium problem at the line attachment points. Since the canopy shape along the leading edge is imperfectly known, and the theory does not model the "scalloped" shape, a simplified approach was taken.

Methods of approach.- It was assumed first that the canopy was made up of circular-arc sections of chordwise width dx, on each of which the spanwise load distribution was known. Further, it was assumed that each section was supported at the leading edge by a "distributed" line tension dT_ℓ/dx and at the keel(s) by a line tension dT_k/dx. The static equilibrium equations were then solved for the distributed line tensions on each section to obtain the chordwise variation of the distributed line tensions. These tension distributions were then apportioned to the discrete lines by assigning a chordwise length of influence to each line and integrating the distributed tension to obtain the line load. In this process, a single confluence point for all lines was assumed known. Thus, in the static equilibrium equations where the distributed line tension is used, direction cosines were assigned to the line tension force as if a discrete line existed between the leading edge (or keel) at that chordwise station and the confluence point.

Four approaches to the static equilibrium equations were examined. These are described briefly below (as applied to the twin-keel parawing) together with comments on the difficulties with the approach.

Method (a): The x and z equilibrium equations on a section were considered, as indicated below.

$$\frac{d(\Delta C_X)_s}{dx} + \frac{dC_X'}{dx} + 2\frac{dC_{T_\ell}}{dx}\cos\alpha_\ell + 2\frac{dC_{T_k}}{dx}\cos\alpha_k = 0$$

$$\frac{d(\Delta C_Z)_s}{dx} - \frac{dC_Z'}{dx} + 2\frac{dC_{T_\ell}}{dx}\cos\gamma_\ell + 2\frac{dC_{T_k}}{dx}\cos\gamma_k \doteq 0$$

where the leading-edge suction coefficient is taken as positive down and C_X' and C_Z' are the aerodynamic force coefficients due to the pressure difference loading. The assumption is made in these equations that there is no chordwise variation in the canopy stress. However, near the nose and trailing edge of the parawing, the canopy loads are taken only by the keel lines. At these sections, a differential chordwise canopy tension force $d\sigma_X/dx$ (assumed uniform over the section span) was used in the x equation, with the value thus computed being high at the leading and trailing edges and dropping to zero (uniform chordwise canopy tension) over the central (chordwise) portion of the canopy where the leading-edge lines exist. A major problem with this approach is that the axial canopy tension force is not constant over most of the chord but varies considerably. As a result, the C_X' and $(\Delta C_X)_s$ forces, which are weakly coupled into the line tension because $\cos\alpha_\ell$ and

$\cos \alpha_k$ are small, tend to cause unreasonably large variations in line tension to create equilibrium in the x direction.

Method (b): The y and z equilibrium equations were applied to a strip of width dx extending over only the semispan, using the fact that on the vertical plane of symmetry, a knowledge of the principal radii of curvature of the canopy and the Δp value will yield the canopy stress components. Thus, in the plane of symmetry

$$\frac{\sigma_x}{r_x} + \frac{\sigma_y}{r} = \Delta p$$

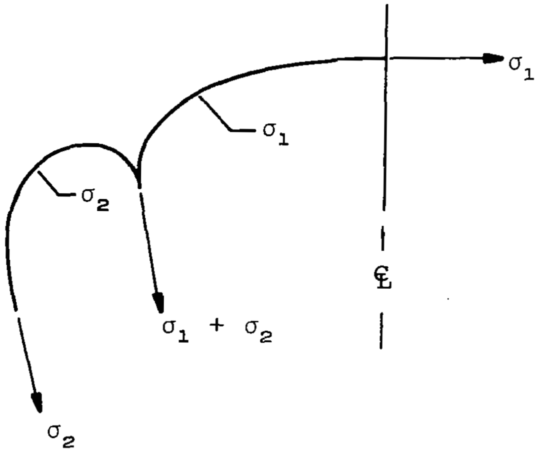
where r_x is the radius of curvature of the canopy in the $y = 0$ plane, and r is the radius of curvature in a constant x plane. The shape data indicate that r_x is generally larger than r, and the assumption was made that σ_x/r_x could be ignored over the entire canopy. The resulting force equilibrium equations neglecting higher-order terms are then

$$\frac{dC'_Y}{dx} + \frac{d(\Delta C_Y)_s}{dx} + \frac{dC_{T_\ell}}{dx} \cos \beta_\ell + \frac{dC_{T_k}}{dx} \cos \beta_k + \frac{\sigma_Y}{qS_R} = 0$$

$$-\frac{dC'_Z}{dx} + \frac{d(\Delta C_{T_Z})_s}{dx} + 2\frac{dC_{T_\ell}}{dx} \cos \gamma_\ell + 2\frac{dC_{T_k}}{dx} \cos \gamma_k = 0$$

Because of the weak coupling of the line tension into the y force balance equation (small $\cos \beta$), this set of equations is not well conditioned. Consequently, one difficulty with this approach is that if the assumption of $r_x \gg r$ is not sufficiently good over the chord, the computed values of line tension tend to vary widely along the chord.

Method (c): It is evident from considerations of two-dimensional static equilibrium that the canopy tension (say, σ_1) in a y-z plane must be constant from the plane of symmetry out to the keel line attachment point and must also be constant over the outer lobe (say, at σ_2), as shown below.



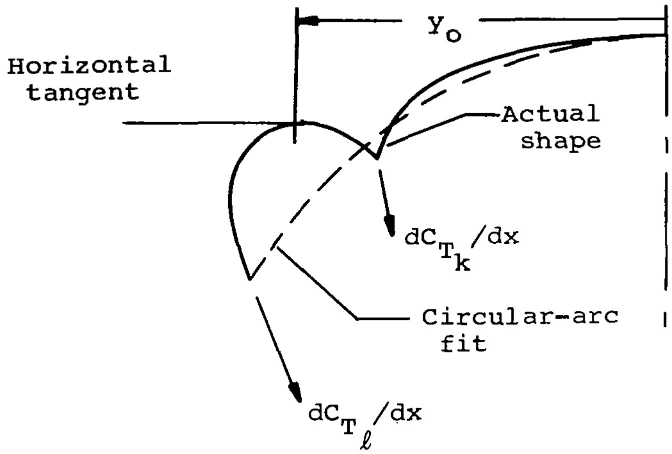
The line tensions must then be $\sigma_1 + \sigma_2$ and σ_2 for the keel and leading-edge lines, respectively, from considerations of force equilibrium at the line attachment points, assuming the cusp angle at the keel line is zero. Thus, y and z equilibrium equations can be written as follows.

$$\frac{dC'_Y}{dx} + \frac{d(\Delta C_Y)_s}{dx} + \frac{\sigma_2}{qS_R} \cos \beta_\ell + \frac{(\sigma_1 + \sigma_2)}{qS_R} \cos \beta_k + \frac{\sigma_1}{qS_R} = 0$$

$$-\frac{dC'_Z}{dx} + \frac{d(\Delta C_Z)_s}{dx} + \frac{\sigma_2}{qS_R} \cos \gamma_\ell + \frac{(\sigma_1 + \sigma_2)}{qS_R} \cos \gamma_k = 0$$

This set of equations tends to have the poor conditioning of those of the previous two approaches, but the assumptions used in the derivation are not so restrictive.

Method (d): The chordwise section of width dx was divided spanwise into portions, as shown in the following sketch.



The inner portion is that part between the span stations (noted y_o) on the actual canopy section where the tangent to the canopy shape in a y-z plane is horizontal. The two outer portions are those parts outboard of $\pm y_o$. For each portion of the canopy, the lateral component (σ_y) of the canopy stress at $\pm y_o$ is horizontal and does not enter into a z equilibrium equation. Thus, the following two equations can be written for the inner and outer portions of the canopy, respectively, assuming that the chordwise canopy stress σ_x is uniform over the section ($d\sigma_x/dx = 0$).

$$-\left.\frac{dC_Z'}{dx}\right|_i + 2\,\frac{dC_{T_k}}{dx}\cos\gamma_k = 0$$

$$-\left.\frac{dC_Z'}{dx}\right|_o + \frac{d(\Delta C_Z)_s}{dx} + 2\,\frac{dC_{T_\ell}}{dx}\cos\gamma_\ell = 0$$

The division of normal force between the inner and outer portions of the canopy section can be approximated by integrating the loading equations from 0 to y_o and from y_o to s, respectively. The assumption is made in so doing that the load out to the span station y_o on the circular-arc section is the same as that on the actual section. This approach has the advantage over the other three of employing only the z

direction equations, into which the line tension forces are strongly coupled.

Theoretical results.- A preliminary investigation of the first two methods described above indicated that unreasonable results would be obtained, in accordance with the comments already noted. Consequently, calculations were made only for the latter two methods. The methods were applied first to the twin-keel parawing, since there is less uncertainty in the circular-arc fits for the twin-keel parawing than for the single-keel parawing.

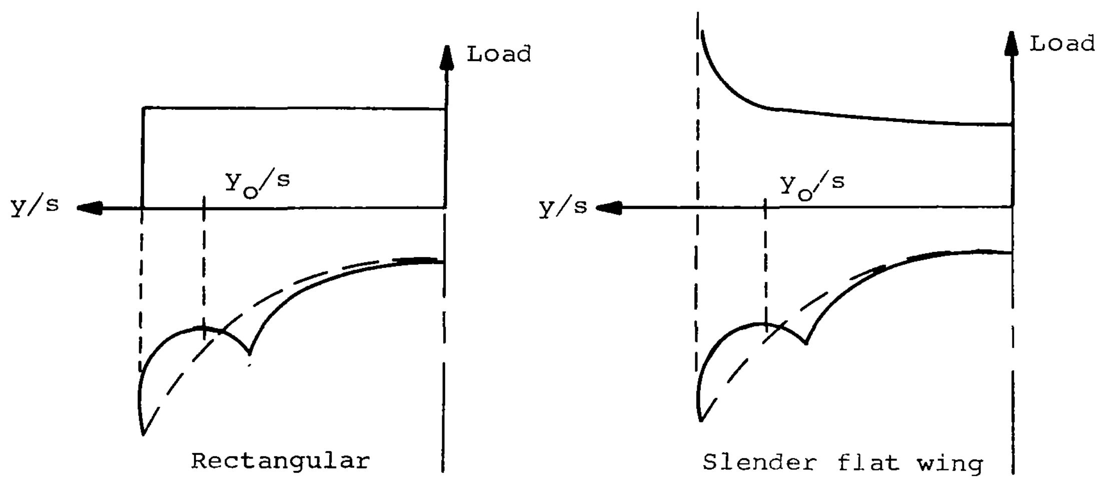
The distributed line tension results for the canopy tension approach (method (c)) are shown in figure 26. The chordwise variation for both the keel and leading edge is large. Near the 65-percent chord station, the loadings for both the keel and leading edge become negative, as a result of the properties of the circular-arc fits in this region. (This result is also illustrated in figure 25.)

Similar results for the z equilibrium approach (method (d)) are shown in figure 27. Again, the chordwise variation is large, and a region of very small loading is indicated near the 0.60 chord station.

These two sets of results were used to construct discrete line load predictions in the following way. The line attachment points for the twin-keel parawing are shown in figure 24. The x/c_r value of the midpoint of the line joining two adjacent line attachment points was located for all points along the keel and leading edge. Each line was then considered to take the distributed load over an x/c_r range from the midpoint forward of the line attachment point to the midpoint aft of the point. The appropriate distributed loads from figures 26 and 27 were integrated for each line and are shown in figure 28. The large chordwise variation in distributed loading from figures 25 and 26 is carried over into the discrete line loads and is particularly evident near $x/c_r = 0.6$ for both the keel and leading-edge lines. The measured values obtained from unpublished Langley Research Center data are shown in figure 28 to indicate that there is not the degree of chordwise variation in the actual case that is indicated by the predicted values, particularly for the keel lines.

It is possible that some refitting of the circular arc sections would provide a more even chordwise variation of the predicted line loads, particularly since the detailed load distribution is affected by the second derivatives of r and e as well as the first derivatives. A more detailed examination of the structural aspects of all-flexible parawings should include such a study. However, an alternate approach was examined, based on attempting to derive a simple engineering method for estimating line loads.

It was noted previously that the predicted total forces on the parawing are determined by the circular-arc section properties near the maximum span station toward the trailing edge. First, it is assumed that the total normal force is distributed uniformly chordwise over the planform, so that dC_Z/dx is constant. This assumption appears reasonable based on the results of figures 22 and 25. Method (d) was then adopted for computing the distributed line loads. The further assumption is made that the division of load spanwise between the inner and outer portions of any section is determined in part by the y_o/s value at the maximum span station. A further assumption must now be made as to the form of the span load distribution curve. The two alternatives examined were a rectangular span load distribution and a distribution given by the slender-body solution for a flat wing $(1/\sqrt{1 - (y^2/s^2)})$, both illustrated in the sketch below.



The goal with this approach is to derive a method based on knowledge only of the parawing section properties at the chord station near the trailing edge where the loading just goes negative according to the slender-wing method. This approach was applied to both the single- and twin-keel parawings, and the predictions were compared with measured values. The results are described in the following sections.

<u>Single-keel parawing results</u>.- The approach described above was applied to the single-keel parawing defined in configuration by figures 14 and 21 and table I. The discrete line loads were predicted using the aerodynamic loads predicted by the slender-wing theory, as corrected for the $\cos \alpha$ and slender-wing factors discussed previously.

The measured line loads were obtained from reference 7. The values for $q = 2$ psf were used. An initial check was made on the force balance on the parawing by comparing the measured normal force obtained from the lift and drag with the sum of the z components of the line tensions obtained from the measured line tensions and the direction cosines of the lines. The C_Z value obtained from the measured C_L and C_D is 0.973, and the sum of the line tension components in the normal-force direction is 1.1, which is 13 percent greater. Although the line tension and aerodynamic data were obtained in different tests, the only known difference between the tests is the q value, which should not account for the 13-percent difference.

The comparison of discrete line loads is shown in figure 29. For the keel lines (fig. 29(a)), the predicted values generally tend to follow the chordwise variations shown by the data. The two predicted curves bracket the data, with the rectangular span load results being higher, as would be expected. For the leading-edge lines (fig. 29(b)), both predicted curves are generally lower than the measured values, with the slender-wing solution giving the higher values.

It is apparent from these results first that both span load distributions place relatively too much lift on the inner part of the canopy and too little on the outer part. One possible reason is an overestimation of leading-edge suction. All of the line load calculations were carried out assuming full suction. Since suction acts in the same general direction as the line tension, loss of suction would require additional line loading to balance the lift due to pressure difference.

Secondly, the sum of the keel and leading-edge line tensions appears low compared to the measured values. The reasons for this are first that the total predicted lift is lower than the measured value by about 7 percent and secondly that the measured line loads exceed the measured lift by 13 percent, as indicated above.

Twin-keel parawing.- The twin-keel parawing to which the line load method was applied is defined by figures 17 and 24 and table II. As in the single-keel parawing case, the aerodynamic loading was corrected for the $\cos \alpha$ and slender-wing factors discussed previously.

The measured line loads were obtained from unpublished NASA data obtained at the Langley Research Center. The data were obtained at $q = 2$ psf. The force balance check between the line loads and the canopy aerodynamic loads indicate that the sum of the z components of the line tension is 14 percent greater than the normal force obtained from the measured lift and drag coefficients.

The comparison of discrete line loads is shown in figure 30. For the keel lines (fig. 30(a)), the predicted values generally tend to follow the chordwise variation indicated by the data, except at the leading and trailing edges. At these two stations (keel lines 1 and 12), the keel lines were considered to carry the entire span load rather than having the load divided between the keel and leading-edge lines; this assumption then accounts for the high predicted loads. The rectangular span load curve tends to agree well with the data, whereas the slender-wing span load results are generally low. For the leading-edge lines (fig. 30(b)), the chordwise variation of the predicted line loads follows the variation shown by the data. The slender-wing span load results tend to agree well with the data, whereas the rectangular span load results are generally low.

These results indicate first that the sum of the keel and leading-edge loads is somewhat lower than that indicated by the data. The comparison on overall aerodynamic loads indicates that the theory predicts reasonably well the measured lift and drag on this parawing. However, the measured line loads exceed the measured normal force, which would tend to account for the line load data being generally higher than predicted loads. Secondly, the actual division of load between the keel and leading-edge lines seems to fall about halfway between the rectangular and slender-wing span load results.

CONCLUDING REMARKS

All-flexible parawings are characterized by large amounts of spanwise camber. Consequently, planar lifting-surface theory is inadequate for predicting the canopy aerodynamic load distribution and a new aerodynamic theory was developed specifically adapted to the all-flexible parawing. The method is based on the use of slender-body theory and considers spanwise sections in the crossflow plane to consist of circular arcs which, from section to adjacent section, may translate and dilate. The theory yields the spanwise and chordwise distribution of loading, the distribution of suction along the leading edge, and the induced drag.

Since the circular-arc fits to all-flexible parawings tend to yield nearly conical wings, systematic calculations were made for conical parawings to assess the importance of spanwise camber. The lift-curve slope increases with increasing camber, such that a parawing having a semicircular cross section has a 50-percent higher slope than a flat wing of the same aspect ratio. Spanwise camber also affects the role that leading-edge suction plays in the overall forces, in that loss of suction causes an increase in normal force with camber but no change in normal force without camber. In addition, spanwise camber has a favorable effect on the ratio of normal force to induced drag for both the full-suction and the vortex-lift cases.

The slender-wing, circular-arc method was applied to two specific parawings for which both aerodynamic, line tension, and shape data exist. For both the single- and twin-keel parawings, the measured shape data were used to obtain spanwise sections normal to the root chord, which were then fit with circular arcs. Application of the aerodynamic theory to the two circular-arc parawing models resulted in predicted lift coefficients that are within 3 and 6 percent of the measured values. In making the comparisons, a correction was made to account for the tendency of slender-wing theory to overpredict lift at moderate aspect ratios. The predicted induced drag was within 20 percent of the measured total drag, which tends to indicate that most of the drag for a parawing is induced drag. With the addition of rough estimates of the line and canopy frictional drag, the predicted total drag coefficients were within 6 and 9 percent of the measured values. It is felt on the basis of these comparisons that the slender-wing, circular-arc method does account properly for the chordwise and spanwise camber present in all-flexible parawings.

The manner in which the predicted canopy aerodynamic loading is transmitted by stresses in the canopy to the rigging lines was investigated. An approach was evolved in which "distributed" line tensions were computed using section span-load distributions, and discrete line loads were then calculated by allotting portions of the continuous line loads to each line. Use of the predicted chord load distributions for both the single- and twin-keel parawings resulted in considerably greater variations chordwise between the line loads than are indicated by the measured values. The probable cause is the circular-arc fits, since there is no way of assessing how accurately the distribution of loading over the canopy is predicted. An engineering method was evolved in which the total normal force was distributed uniformly over the chord, and the division of load spanwise between the keel and leading-edge lines was governed by either a rectangular or a slender flat-wing span-load distribution. This approach was found to give reasonable agreement with measured line loads, with the comparisons indicating that for the twin-keel parawing the actual span load distribution is probably between the rectangular and slender-wing loadings on the average. It is felt that this approach would be useful in assessing the general distribution of aerodynamic loads between lines, but a much more complex canopy stress analysis considering the local canopy shape in the line attachment regions would be necessary to obtain accurate predictions of each line load. Such an investigation should probably await the verification of the capability of the slender-wing method to predict accurately the detailed aerodynamic load distribution on the canopy.

Finally, several comments are in order with regard to basic limitations and growth potential of the slender-body method developed. One basic deficiency of slender-body theory is that the Kutta condition is not imposed at the trailing edge. In the present application, this limitation does not permit calculation of canopy loads aft of approximately the maximum span station, which occurs near the 85-percent chord point. Thus, the tension distribution in the canopy cannot be completely determined, and the line tensions for the most rearward lines cannot be predicted. Secondly, a shape determination method starting with the flat canopy and rigging line characteristics has not been developed. Such a method is necessary to provide a complete capability for predicting aerodynamic load distributions and canopy and line structural loadings. It is felt that some additional work should be done to verify, and perhaps improve, the methods described herein before a shape determination method is evolved.

With regard to growth potential, one important feature of the slender-body method is its potential for handling both deliberate canopy shape changes and bumps. The sorts of deliberate canopy shape changes that might be considered are aspect ratio changes, changes in the size and shape of the center panel of a twin-keel parawing, or changes due to shortening lines for control purposes. The present method could be employed to predict the relative changes in the aerodynamic performance due to these types of shape changes. For bumps, it is felt that the present method could be extended to consider deviations of the canopy spanwise sections from circular arcs by including higher harmonics in the spanwise shape specification. Such an extension would provide a capability, in particular, for examining the aerodynamic and tension loadings due to the local bumps near line attachment points. However, it is probable that many Fourier harmonics would be required, and the calculations would be lengthy.

Nielsen Engineering & Research, Inc.
Mountain View, California
February 27, 1970

APPENDIX A

EVALUATION OF AN INTEGRAL OCCURRING IN THE INDUCED-DRAG CALCULATION

It is required in the derivation of the expression for induced drag that the following integral be evaluated.

$$J(k) = \frac{1}{k^2}\int_0^{\pi} \tanh^{-1}\left(\frac{k \sin\beta}{\sqrt{1 - k^2\cos^2\beta}}\right) \frac{k \sin\beta}{\sqrt{1 - k^2\cos^2\beta}}\, d\beta$$

$$= \frac{1}{2k^2}\int_0^{\pi} \ln\left[\frac{k \sin\beta + \sqrt{1 - k^2\cos^2\beta}}{-k \sin\beta + \sqrt{1 - k^2\cos^2\beta}}\right] \frac{k \sin\beta}{\sqrt{1 - k^2\cos^2\beta}}\, d\beta$$

$$= \frac{1}{k^2}\int_0^{\pi/2} \ln\left[\frac{k \sin\beta + \sqrt{1 - k^2\cos^2\beta}}{-k \sin\beta + \sqrt{1 - k^2\cos^2\beta}}\right] \frac{k \sin\beta}{\sqrt{1 - k^2\cos^2\beta}}\, d\beta \tag{A-1}$$

If

$$I(k) = \int_0^{\pi} \ln\left[k \sin\beta + \sqrt{1 - k^2\cos^2\beta}\right] \frac{k \sin\beta}{\sqrt{1 - k^2\cos^2\beta}}\, d\beta \tag{A-2}$$

then

$$J(k) = \frac{1}{k^2}\left[I(k) + I(-k)\right] \tag{A-3}$$

Integration by parts yields

$$I(k) = -\ln\left[k \sin\beta + \sqrt{1 - k^2\cos^2\beta}\right] \sin^{-1}(k \cos\beta)\Big|_0^{\pi/2}$$

$$+ \int_0^{\pi/2} \frac{\sin^{-1}(k \cos\beta)}{\sqrt{1 - k^2\cos^2\beta}}\, k \cos\beta\, d\beta \tag{A-4}$$

$$= \sin^{-1} k \ln\sqrt{1 - k^2} + \int_0^1 \frac{kx \sin^{-1}(kx)\, dx}{\sqrt{(1 - x^2)(1 - k^2x^2)}} \tag{A-5}$$

The integral is to be found in reference 11, p. 607.

$$I(k) = \sin^{-1}(k) \ln\sqrt{1 - k^2} - \frac{\pi}{2}\sqrt{1 - k^2} \tag{A-6}$$

The final result is from equation (A-3)

$$J(k) = - \frac{\pi}{2k^2} \ln (1 - k^2) \tag{A-7}$$

APPENDIX B

DETERMINATION OF CERTAIN DIRECTION COSINES

In determining the effect of leading-edge suction and vortex lift on normal force and induced drag, it is necessary to know the direction cosines of certain directions associated with the lifting surface. For surfaces formed from the segments of circular cones, such as that shown in figure 6, the cross sections parallel to the y-z plane are all circular arcs, and the x-y plane is the chord plane. Plane OAC is tangent to the lifting surface at its left edge. The unit vector $\vec{n}_2$ is in the plane OAC and lies normal to the leading edge. It is the direction in which the leading-edge suction is usually directed. Under the assumption used herein to evaluate vortex-lift effects, it is assumed that the leading-edge suction force is rotated 90° from $\vec{n}_2$ to $\vec{n}_1$, where it is perpendicular to the leading edge and the lifting surface.

Let us first determine the direction cosines of $\vec{n}_1$. If the plane OAC has the equation

$$Ax + By + Cz = 0 \tag{B-1}$$

then

$$\left.\begin{aligned}
\cos(n_1,x) &= \frac{A}{\sqrt{A^2 + B^2 + C^2}} \\
\cos(n_1,y) &= \frac{B}{\sqrt{A^2 + B^2 + C^2}} \\
\cos(n_1,z) &= \frac{C}{\sqrt{A^2 + B^2 + C^2}}
\end{aligned}\right\} \tag{B-2}$$

From the equation of OA

$$sx + c_r y = 0 \tag{B-3}$$

and that for OC

$$\frac{s_m}{c_r} x - z \tan \phi = 0 \tag{B-4}$$

we can write the equation of plane OAC as

$$\frac{s_m}{c_r} x + y - z \tan \phi = 0 \tag{B-5}$$

With the definitions

$$k = \frac{f}{\sqrt{f^2 + s^2}} \tag{B-6}$$

$$\tan \phi = \frac{1 - 2k^2}{2k\sqrt{1 - k^2}} \tag{B-7}$$

the direction cosines for $\vec{n}_1$ are

$$\left.\begin{aligned}
\cos(n_1,x) &= \frac{-2k\sqrt{1 - k^2}\,\left(s_m/c_r\right)}{R} \\
\cos(n_1,y) &= \frac{-2k\sqrt{1 - k^2}}{R} \\
\cos(n_1,z) &= \frac{(1 - 2k^2)}{R} \\
R^2 &= 1 + 4k^2(1 - k^2)\,\frac{s_m^{\,2}}{c_r^{\,2}}
\end{aligned}\right\} \tag{B-8}$$

The direction cosines of $\vec{n}_2$ are obtainable from the coordinates of the line CD lying in the plane OAC and normal to OA. The coordinates of C are

$$C \sim (c_r,\ 0,\ s_m/\tan \phi) \tag{B-9}$$

and the coordinates of D are

$$D \sim \left(\frac{c_r}{1 + \frac{s_m^2}{c_r^2}} , \frac{-s}{1 + \frac{s_m^2}{c_r^2}} , 0 \right) \tag{B-10}$$

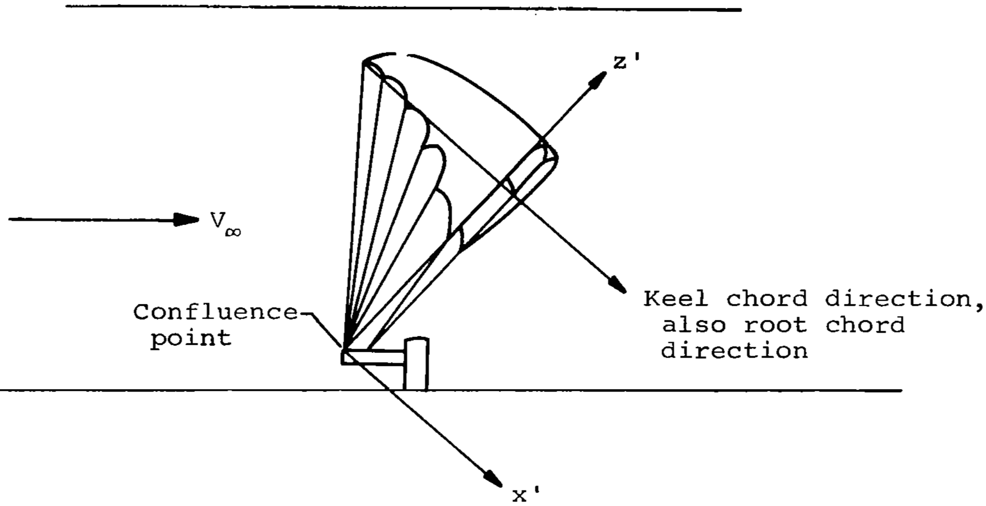
From the coordinates of these points, the direction cosines of $\vec{n}_2$ are found to be

$$\left.\begin{aligned}
\cos(n_2,x) &= \frac{-(1 - 2k^2)(s_m/c_r)}{\sqrt{1 + \frac{s_m^2}{c_r^2}}\ R} \\
\cos(n_2,y) &= \frac{-(1 - 2k^2)}{\sqrt{1 + \frac{s_m^2}{c_r^2}}\ R} \\
\cos(n_2,z) &= \frac{-2k\sqrt{1 - k^2}\sqrt{1 + \frac{s_m^2}{c_r^2}}}{R}
\end{aligned}\right\} \tag{B-11}$$

APPENDIX C

TABULATION OF CANOPY COORDINATES
FOR SINGLE-KEEL PARAWING

The following pages are a reproduction of the printed computer output for the canopy coordinates obtained photogrammetrically at the Langley Research Center from the stereo photographs of the single-keel parawing in the wind tunnel. The coordinate system used in the data presentation is illustrated in the sketch below.



The origin of the axis system is on the sting at the confluence point of all the rigging lines except the two tip lines and the last keel line. The x'-axis is parallel to the keel chord, positive downstream. The positive z' direction is upwards towards the canopy, and the positive y' direction is in accordance with a right-hand system.

The data consist of a point identification number, followed by the x', y', and z' coordinates of the point, nondimensionalized by the characteristic length h_k. For the parawing tested, h_k = 60 inches. Points 1-11 are the canopy line attachment point coordinates for the keel lines 1-11, respectively. Points 12-17 are the canopy line attachment point coordinates of the leading-edge lines 1-6, respectively. For the remainder of the coordinates, generally a single streamwise set of points having about the same y' coordinate was read starting at the leading edge and working aft. The sets start at the keel and move out towards the tip.

Point No.	x'/h_k	y'/h_k	z'/h_k	
1	-.70271	.00000	1.12923	K1
2	-.67370	.00901	1.16419	K2
3	-.60197	.00603	1.17326	K3
4	-.54556	.00280	1.18731	K4
5	-.48164	.00670	1.20354	K5
6	-.40816	.00220	1.20334	K6
7	-.32587	.00946	1.22515	K7
8	-.23689	.01045	1.21868	K8
9	-.16808	.00401	1.20567	K9
10	-.10847	.00775	1.17831	K10
11	-.05536	.00000	1.12923	K11
12	-.68955	.09288	1.14844	LE1
13	-.60195	.16424	1.11181	LE2
14	-.52192	.22916	1.11602	LE3
15	-.40689	.31746	1.07370	LE4
16	-.28448	.36787	1.02747	LE5
17	-.17171	.38207	.96742	LE6
18	-.71220	.02126	1.15514	
19	-.67408	.01873	1.17712	
20	-.66029	.00662	1.18125	
21	-.64875	.01174	1.19542	
22	-.62977	.00211	1.19047	
23	-.59538	.00576	1.19733	
24	-.59403	.00384	1.22543	
25	-.57215	.00901	1.21395	
26	-.54445	.01183	1.21886	
27	-.53027	.00916	1.22680	
28	-.51403	.00783	1.22549	
29	-.49935	.00754	1.22061	
30	-.47032	.00746	1.22048	
31	-.45765	.00326	1.22953	
32	-.44271	.00480	1.22696	
33	-.42794	.00553	1.22353	
34	-.40104	.00035	1.22787	
35	-.38851	.00937	1.23600	
36	-.38905	.00630	1.24192	
37	-.37351	.00730	1.24646	
38	-.37217	.01165	1.23782	
39	-.35601	.00596	1.23261	
40	-.34019	.00271	1.22567	
41	-.31591	.00019	1.23744	
42	-.30486	.01781	1.25132	
43	-.28716	.00974	1.23620	
44	-.27495	.01537	1.24022	
45	-.25763	.01459	1.23861	
46	-.23932	.01064	1.23499	
47	-.21896	.02062	1.23163	
48	-.20258	.01787	1.22740	
49	-.18376	.01316	1.22446	
50	-.16707	.02735	1.23372	

Suspension line attachment points

Point No.	x'/h_k	y'/h_k	z'/h_k
51	-.71767	.00388	1.14019
52	-.71481	.00456	1.14723
53	-.71514	.00127	1.16528
54	-.69457	.00155	1.17567
55	-.68571	.00464	1.17270
56	-.68115	.00120	1.17640
57	-.67815	.00345	1.18254
58	-.67061	.00337	1.18569
59	-.66707	.00934	1.19345
60	-.65845	.00714	1.19560
61	-.62511	.00378	1.20756
62	-.61820	.00322	1.21054
63	-.60865	.00335	1.20851
64	-.60224	.00375	1.21117
65	-.55339	.00376	1.21870
66	-.54513	.00173	1.22006
67	-.53701	.00198	1.22253
68	-.52936	.00106	1.22429
69	-.51503	.00164	1.22847
70	-.50759	.00280	1.22957
71	-.49445	.00393	1.22779
72	-.48716	.00042	1.22484
73	-.48082	.00277	1.22851
74	-.47439	.00370	1.23200
75	-.46657	.00381	1.23452
76	-.45860	.00090	1.23543
77	-.45241	.00428	1.23828
78	-.44432	.00293	1.23637
79	-.43577	.00169	1.23449
80	-.42771	.00064	1.23372
81	-.41551	.00081	1.23305
82	-.41141	.00293	1.23697
83	-.40487	.00178	1.24064
84	-.39694	.00168	1.24293
85	-.39036	.00374	1.24841
86	-.38329	.00797	1.25436
87	-.37586	.00652	1.25534
88	-.36790	.00739	1.25700
89	-.35969	.00582	1.25487
90	-.35106	.00365	1.25182
91	-.33738	.00169	1.24294
92	-.32927	.00370	1.23958
93	-.32498	.00306	1.24709
94	-.31467	.00272	1.24959
95	-.31067	.00170	1.24974
96	-.30339	.00314	1.25432
97	-.29714	.00601	1.25918
98	-.28933	.00231	1.25776
99	-.28215	.00403	1.25861
100	-.27428	.00299	1.25496

101	-.25770	.00317	1.25320
102	-.26040	.00567	1.25264
103	-.25151	.00069	1.24362
104	-.24584	.00084	1.24371
105	-.23918	.00254	1.24390
106	-.23325	.00282	1.24370
107	-.22607	.00454	1.24402
108	-.21895	.00527	1.24561
109	-.21170	.01225	1.25135
110	-.20327	.00846	1.24617
111	-.19524	.00807	1.24325
112	-.18753	.00530	1.23852
113	-.18066	.00368	1.23458
114	-.17380	.00060	1.22869
115	-.16778	.00234	1.22861
116	-.16153	.00785	1.23233
117	-.15433	.01160	1.23438
118	-.14650	.00623	1.23024
119	-.12602	.00702	1.21757
120	-.11978	.00556	1.21248
121	-.11092	.00195	1.20147
122	-.10296	.00530	1.20013
123	-.09596	.00657	1.19691
124	-.08833	.00809	1.19323
125	-.08138	.01131	1.19168
126	-.07549	.00438	1.18092
127	-.05613	.00362	1.15582
128	-.72100	.00005	1.17402
129	-.69184	.00607	1.18107
130	-.68153	.00122	1.18799
131	-.66747	.00133	1.19291
132	-.65451	.00438	1.20565
133	-.63993	.00303	1.21227
134	-.62750	.00012	1.21487
135	-.60538	.00885	1.21677
136	-.59448	.00925	1.22959
137	-.57881	.00201	1.23117
138	-.54734	.00325	1.22578
139	-.53293	.00083	1.23454
140	-.51658	.00326	1.23435
141	-.50208	.00484	1.23046
142	-.48854	.00548	1.22956
143	-.47458	.00554	1.23439
144	-.45966	.00284	1.24103
145	-.44431	.00362	1.24091
146	-.42867	.00557	1.23848
147	-.41530	.00985	1.23304
148	-.40587	.00433	1.24471
149	-.39091	.00394	1.25127
150	-.37569	.00058	1.25813
151	-.35046	.00432	1.25523
152	-.33062	.00867	1.24608
153	-.32108	.00194	1.25930
154	-.30594	.00017	1.26120
155	-.28953	.00160	1.26101
156	-.27372	.00497	1.25717
157	-.25848	.00348	1.25398
158	-.24661	.00410	1.24942
159	-.23166	.00516	1.24641
160	-.21752	.00248	1.24844
161	-.20132	.01128	1.24931
162	-.18684	.00010	1.24350
163	-.17491	.00139	1.24126
164	-.16030	.00052	1.23611
165	-.14442	.00518	1.23586
166	-.13024	.00308	1.22681
167	-.10855	.00351	1.21247
168	-.09283	.00312	1.20354
169	-.07969	.00929	1.20051
170	-.72478	.02014	1.14208
171	-.72422	.01690	1.15175
172	-.72211	.01597	1.15830
173	-.72058	.01107	1.17292
174	-.71489	.00952	1.17878
175	-.70366	.00714	1.18533
176	-.70039	.01058	1.18499
177	-.69553	.01034	1.18641
178	-.69078	.00716	1.19102
179	-.68247	.00947	1.19078
180	-.68045	.00057	1.20238
181	-.67376	.00029	1.20500
182	-.66633	.00129	1.20981
183	-.65924	.00265	1.21454
184	-.65114	.00047	1.21508
185	-.64262	.00205	1.21792
186	-.63593	.00238	1.22024
187	-.62870	.00773	1.21867
188	-.62112	.01067	1.21941
189	-.60957	.01109	1.22535
190	-.60327	.00318	1.23032
191	-.59545	.00436	1.23320
192	-.58834	.00789	1.23506
193	-.58037	.00843	1.23543
194	-.57233	.01001	1.23275
195	-.55931	.00994	1.22536
196	-.54950	.00768	1.23281
197	-.54111	.00718	1.23501
198	-.53510	.00422	1.24082
199	-.52411	.00335	1.24365
200	-.51910	.00475	1.24302
201	-.51036	.00948	1.23807
202	-.50359	.01076	1.23661
203	-.49063	.01057	1.23692
204	-.48556	.00436	1.24569
205	-.47712	.00931	1.24290
206	-.46388	.00854	1.24476
207	-.46121	.00826	1.24703
208	-.45404	.00759	1.24865
209	-.44504	.00743	1.24618
210	-.43700	.01151	1.24474
211	-.42973	.01246	1.24262
212	-.41917	.01254	1.24200
213	-.41335	.01293	1.24446
214	-.40687	.01144	1.24961
215	-.39943	.01195	1.25278
216	-.39214	.00922	1.25766
217	-.38369	.01080	1.25862
218	-.37648	.00834	1.26197
219	-.36850	.00967	1.26101
220	-.36014	.01317	1.25760
221	-.34580	.01155	1.25571
222	-.33226	.01236	1.25423
223	-.32597	.01216	1.25611
224	-.31977	.01236	1.25847
225	-.31261	.00970	1.26241
226	-.30537	.00816	1.26593
227	-.29756	.00708	1.26725
228	-.28859	.00915	1.26519
229	-.28228	.00631	1.26770
230	-.27312	.00680	1.26514
231	-.25842	.00955	1.25991
232	-.24529	.01210	1.25394
233	-.23843	.01071	1.25456
234	-.23134	.00896	1.25481
235	-.22490	.00812	1.25602
236	-.21745	.00792	1.25555
237	-.20947	.00456	1.25793
238	-.20125	.00215	1.25781
239	-.19386	.00287	1.25607
240	-.18531	.00738	1.24918
241	-.17215	.00871	1.24325
242	-.16582	.00664	1.24290
243	-.15792	.00425	1.24267
244	-.14969	.00189	1.24263
245	-.14230	.00022	1.24262
246	-.13467	.00138	1.23706
247	-.12813	.00285	1.23293
248	-.12129	.00499	1.22695
249	-.10375	.00799	1.21191
250	-.09600	.00446	1.21027

251	-.08941	.00174	1.20921	301	-.06769	.01248	1.19136	351	-.37741	.02506	1.26793
252	-.08288	.00134	1.20519	302	-.73319	.03387	1.14924	352	-.37009	.02392	1.26904
253	-.06482	.01191	1.17740	303	-.73012	.03313	1.15600	353	-.36259	.02565	1.26656
254	-.05927	.01027	1.17295	304	-.72879	.03140	1.16387	354	-.35433	.02658	1.26579
255	-.05475	.01707	1.16137	305	-.72802	.02741	1.17370	355	-.34633	.02736	1.26379
256	-.72767	.02015	1.16361	306	-.72285	.02904	1.17743	356	-.33401	.02755	1.26303
257	-.72317	.01703	1.17726	307	-.71694	.02376	1.18196	357	-.32759	.02501	1.26776
258	-.71082	.01438	1.18897	308	-.71123	.02537	1.18941	358	-.31989	.02504	1.26853
259	-.69732	.01980	1.18822	309	-.70485	.02809	1.18910	359	-.31272	.02489	1.27078
260	-.68679	.01130	1.19934	310	-.69859	.02829	1.19105	360	-.30489	.02285	1.27330
261	-.67676	.00409	1.21127	311	-.69487	.02029	1.20061	361	-.29797	.02044	1.27706
262	-.66272	.00107	1.22079	312	-.68885	.01740	1.20598	362	-.28992	.01931	1.27794
263	-.64559	.00711	1.22303	313	-.68290	.01439	1.21123	363	-.28197	.01777	1.27925
264	-.63159	.01316	1.22475	314	[illegible]	.01472	1.21382	364	-.27453	.01620	1.27942
265	-.61056	.01396	1.22810	315	-.67242	.00491	1.22249	365	-.26602	.02197	1.27280
266	-.59638	.01504	1.23698	316	-.66543	.00733	1.22650	366	-.25850	.02303	1.26965
267	-.58111	.01733	1.23709	317	-.65644	.01366	1.22473	367	-.25194	.02511	1.26534
268	-.54983	.01690	1.23509	318	-.64884	.01430	1.22809	368	-.24551	.02468	1.26582
269	-.53626	.01167	1.24455	319	-.64002	.02013	1.22584	369	-.23705	.02284	1.26646
270	-.51913	.01545	1.24379	320	-.63364	.02075	1.22876	370	-.22976	.02318	1.26518
271	-.50407	.01385	[illegible]	321	-.62512	.02490	1.22885	371	-.22385	.02034	1.26745
272	-.49146	.01984	[illegible]	322	-.61196	.02751	1.23259	372	-.21584	.01902	1.26859
273	-.47702	.01843	1.24529	323	-.60494	.02475	1.23798	373	-.20791	.01678	1.26857
274	-.46202	.01519	1.25125	324	-.59788	.02246	1.24201	374	-.19921	.01780	1.26675
275	-.44565	.01793	1.24904	325	-.59132	.02232	1.24404	375	-.19143	.01979	1.26256
276	-.43072	.01811	1.24812	326	-.58190	.02685	1.24003	376	-.18471	.01785	1.26250
277	-.42034	.02022	1.24563	327	-.56466	.02558	1.23346	377	-.17796	.01924	1.25912
278	-.40741	.01964	1.25216	328	-.55782	.02646	1.23614	378	-.17000	.01690	1.25899
279	-.39353	.01581	1.26183	329	-.55136	.02307	1.24096	379	-.16249	.01725	1.25598
280	-.37750	.01491	1.26620	330	-.54433	.02095	1.24666	380	-.15408	.01478	1.25578
281	-.36148	.01743	1.26316	331	-.53676	.02025	1.24840	381	-.14597	.01513	1.25354
282	-.34636	.01308	1.26060	332	-.52827	.02279	1.24756	382	-.13927	.01249	1.25260
283	-.33298	.02017	1.25773	333	-.52061	.02193	1.24314	383	-.13133	.01213	1.24937
284	-.31952	.01968	1.26173	334	-.51209	.02496	1.24651	384	-.12542	.01055	1.24763
285	-.30501	.01531	1.26945	335	-.50515	.02501	1.24604	385	-.11396	.00836	1.24164
286	-.28941	.01320	1.27219	336	-.49325	.02615	1.24520	386	-.10573	.01410	1.23208
287	-.27439	.01040	1.27393	337	-.48484	.02585	1.24771	387	-.09981	.01374	1.22859
288	-.25777	.01839	1.26191	338	-.47845	.02391	1.25136	388	-.09145	.01417	1.22405
289	-.24511	.01731	1.25930	339	-.47011	.02335	1.25353	389	-.08578	.01200	1.22248
290	-.23025	.01623	1.25934	340	-.46296	.02273	1.25521	390	-.07035	.01965	1.20040
291	-.21733	.01010	1.26476	341	-.45419	.02465	1.25280	391	-.06461	.02199	1.19267
292	-.19957	.01194	1.25903	342	-.44609	.02588	1.25227	392	-.05716	.02450	1.18201
293	-.17247	.00925	1.25296	343	-.43858	.02597	1.25121	393	-.05402	.02252	1.18055
294	-.15646	.00738	1.25061	344	-.43091	.02753	1.25087	394	-.73079	.03597	1.16823
295	-.14989	.01437	1.24862	345	-.42178	.02792	1.24967	395	-.72338	.03529	1.18044
296	-.12591	.01264	1.24394	346	-.41565	.02429	1.25220	396	-.71280	.03363	1.19163
297	-.11564	.00981	1.22992	347	-.40782	.02384	1.25553	397	-.70018	.03315	1.19536
298	-.10124	[illegible]	1.22046	348	-.40164	.02517	1.26175	398	-.68839	.02650	1.20683
299	-.08404	.00559	1.21404	349	-.39435	.02271	1.26648	399	-.67696	.02023	1.21731
300	-.07518	.00814	1.20420	350	-.38578	.02447	1.26674	400	-.66339	.01986	1.23261

401	-.65122	.02029	1.23103	451	-.65446	.02584	1.23492	501	-.22033	.03427	1.27640
402	-.63602	.02576	1.23300	452	-.63904	.03513	1.23438	502	-.22237	.03218	1.27808
403	-.61575	.02792	1.24254	453	-.63258	.03268	1.24106	503	-.21444	.03051	1.27875
404	-.59805	.03159	1.24721	454	-.62572	.03546	1.23968	504	-.20605	.02967	1.27828
405	-.58294	.03279	1.24295	455	-.61547	.03821	1.24333	505	-.19714	.03024	1.27553
406	-.55153	.03147	1.24336	456	-.60765	.03783	1.24553	506	-.18970	.02921	1.27451
407	-.53326	.02569	1.25349	457	-.60625	.02597	1.25825	507	-.18284	.03066	1.27077
408	-.52234	.02547	1.25450	458	-.57202	.03816	1.24707	508	-.17552	.02923	1.26969
409	-.49444	.03248	1.24457	459	-.58455	.03907	1.24708	509	-.16757	.02716	1.26989
410	-.47972	.03151	1.25423	460	-.55114	.03620	1.24725	510	-.16023	.02540	1.26934
411	-.46344	.03041	1.25310	461	-.55338	.03595	1.24957	511	-.15163	.02950	1.26309
412	-.44629	.03452	1.25404	462	-.54541	.03300	1.25564	512	-.14348	.02722	1.26312
413	-.43152	.03459	1.25398	463	-.53904	.03261	1.25767	513	-.13646	.02448	1.26263
414	-.42214	.03559	1.25219	464	-.53057	.03441	1.25691	514	-.12967	.02442	1.25884
415	-.40965	.03377	1.26088	465	-.52229	.03542	1.25540	515	-.12351	.02812	1.25199
416	-.39412	.03254	1.26751	466	-.51437	.03765	1.25428	516	-.11516	.02518	1.24990
417	-.37903	.03126	1.27145	467	-.50225	.04030	1.25060	517	-.10403	.02583	1.24548
418	-.36362	.02907	1.27366	468	-.49487	.04107	1.25213	518	-.10148	.02309	1.24439
419	-.34610	.03634	1.26479	469	-.48748	.03799	1.25664	519	-.09449	.02684	1.23651
420	-.33383	.03441	1.26564	470	-.47984	.03782	1.25902	520	-.08761	.02748	1.23174
421	-.31985	.03353	1.27033	471	-.47230	.03735	1.26103	521	-.08266	.02813	1.22717
422	-.30451	.03233	1.27413	472	-.46392	.03799	1.26083	522	-.07686	.03086	1.21931
423	-.28999	.02420	1.28393	473	-.45613	.03855	1.26082	523	-.07089	.03277	1.21230
424	-.27404	.02423	1.28174	474	-.44987	.03770	1.26227	524	-.06598	.03094	1.20955
425	-.25753	.03212	1.27120	475	-.43016	.04259	1.25725	525	-.06122	.03343	1.20253
426	-.24419	.03081	1.25994	476	-.43119	.04355	1.25589	526	-.05738	.03546	1.19644
427	-.22952	.02772	1.27120	477	-.42348	.04300	1.25645	527	-.05405	.03838	1.19089
428	-.21497	.02747	1.25981	478	-.41869	.04046	1.26207	528	-.70201	.04571	1.20555
429	-.19795	.02330	1.27053	479	-.41150	.03860	1.26749	529	-.69089	.03661	1.21865
430	-.18371	.02549	1.25516	480	-.40367	.03917	1.26990	530	-.67854	.03494	1.22573
431	-.16899	.02337	1.26255	481	-.39573	.03889	1.27275	531	-.65829	.03172	1.23948
432	-.15364	.01930	1.26190	482	-.38674	.03918	1.27331	532	-.64201	.03992	1.23978
433	-.13752	.01919	1.25586	483	-.37914	.03864	1.27523	533	-.62833	.04493	1.24125
434	-.11036	.01663	1.24385	484	-.37179	.03791	1.27685	534	-.61832	.04177	1.25005
435	-.09691	.02070	1.23237	485	[illegible]	.03884	1.27464	535	-.60377	.04547	1.24933
436	-.07312	.02523	1.20392	486	-.35459	.03985	1.27308	536	-.58468	.04814	1.24831
437	-.06275	.02624	1.19984	487	-.34105	.04319	1.26782	537	-.56609	.04696	1.24456
438	-.73446	.04865	1.15250	488	-.33556	.03968	1.27337	538	-.55360	.04395	1.25285
439	-.73151	.04714	1.15917	489	-.32880	.03934	1.27527	539	-.53923	.04150	1.25962
440	-.72377	.04522	1.16748	490	-.32024	.03984	1.27543	540	-.52440	.04215	1.25969
441	-.72589	.04365	1.17546	491	-.31316	.03924	1.27814	541	-.49704	.04446	1.25927
442	-.72373	.04238	1.18312	492	-.30513	.03861	1.28011	542	-.48117	.04367	1.26373
443	-.72157	.03804	1.19204	493	-.29788	.03424	1.28432	543	-.46395	.04722	1.26242
444	-.71573	.03991	1.19524	494	-.28084	.03336	1.28599	544	-.44943	.04516	1.26481
445	-.70158	.03847	1.20175	495	-.28165	.03531	1.28362	545	-.42466	.05012	1.26040
446	-.69676	.03360	1.20916	496	-.26550	.03632	1.28005	546	-.41122	.04817	1.26826
447	-.69125	.02880	1.21596	497	-.25831	.03753	1.27745	547	-.39558	.04708	1.27416
448	-.68363	.02358	1.21329	498	-.25188	.03536	1.27748	548	-.37967	.04466	1.27945
449	-.67741	.02748	1.22153	499	-.24426	.03547	1.27595	549	-.36307	.04961	1.27461
450	-.66054	.02356	1.22857	500	-.23656	.03389	1.27756	550	-.33657	.04675	1.27784

551	-.32113	.04567	1.28181	601	-.41295	.05473	1.27420	651	-.07693	.05123	1.23477
552	-.30596	.04251	1.28689	602	-.40559	.05353	1.27855	652	-.08871	.05268	1.24255
553	-.28881	.04477	1.28513	603	-.39633	.05533	1.27725	653	-.10241	.04719	1.25587
554	-.25840	.04514	1.28009	604	-.38785	.05414	1.28058	654	-.11597	.04926	1.26174
555	-.24457	.03997	1.28411	605	-.38043	.05352	1.28235	655	-.13067	.04914	1.27004
556	-.22930	.03816	1.28388	606	-.37201	.05534	1.28085	656	-.14689	.04958	1.27496
557	-.21341	.03952	1.28076	607	-.36397	.05685	1.27979	657	-.16248	.04842	1.28135
558	-.19608	.03552	1.28181	608	-.35556	.05519	1.28064	658	-.17821	.04892	1.28619
559	-.18133	.03826	1.27455	609	-.34169	.06033	1.27339	659	-.19355	.05314	1.28608
560	-.16567	.03625	1.27238	610	-.33567	.05680	1.27951	660	-.21149	.05142	1.29071
561	-.15041	.03291	1.27033	611	-.32893	.05321	1.28541	661	-.22668	.05319	1.29086
562	-.13434	.03283	1.26528	612	-.32151	.05243	1.28703	662	-.24254	.05523	1.29121
563	-.12059	.03066	1.26055	613	-.31343	.05191	1.28901	663	-.25703	.06173	1.28591
564	-.10584	.03332	1.24949	614	-.30569	.05093	1.29059	664	-.28872	.05671	1.29449
565	-.09214	.03417	1.24093	615	-.29734	.04954	1.29173	665	-.30512	.05933	1.29208
566	-.08000	.03799	1.22725	616	-.28935	.04859	1.29329	666	-.32109	.06081	1.28842
567	-.06876	.04037	1.21615	617	-.28190	.04765	1.29377	667	-.33579	.06274	1.28388
568	-.05952	.04333	1.20352	618	-.26470	.05204	1.28721	668	-.34993	.06346	1.27994
569	-.70876	.05188	1.20636	619	-.25805	.05247	1.28586	669	-.36433	.06293	1.28281
570	-.70083	.05290	1.20836	620	-.25092	.04841	1.28843	670	-.38015	.06183	1.28307
571	-.69677	.04706	1.21763	621	-.24285	.05132	1.28549	671	-.39703	.06110	1.28117
572	-.68903	.04729	1.22055	622	-.23510	.04983	1.28633	672	-.41299	.06153	1.27626
573	-.68505	.04123	1.22914	623	-.22782	.04819	1.28680	673	-.42704	.06438	1.26838
574	-.64429	.04997	1.23894	624	-.22043	.04648	1.28724	674	-.44815	.06713	1.26452
575	-.63084	.05492	1.24275	625	-.21249	.04455	1.28802	675	-.46477	.06423	1.26662
576	-.62643	.05168	1.24951	626	-.20454	.04276	1.28813	676	-.48263	.05909	1.26993
577	-.61992	.05024	1.25292	627	-.19485	.04455	1.28534	677	-.49895	.05843	1.26788
578	-.60953	.05442	1.24939	628	-.18791	.04252	1.28524	678	-.51255	.06343	1.25885
579	-.60206	.05406	1.25147	629	-.18017	.04237	1.28306	679	-.52558	.06028	1.26196
580	-.59402	.05534	1.25095	630	-.17271	.04025	1.28306	680	-.54078	.06016	1.26000
581	-.58651	.05563	1.25194	631	-.16431	.04174	1.27952	681	-.55424	.05957	1.25999
582	-.56847	.05212	1.25096	632	-.15725	.03952	1.27922	682	-.56808	.06127	1.25210
583	-.56042	.05417	1.25137	633	-.14932	.04027	1.27600	683	-.57634	.06014	1.24792
584	-.55524	.04974	1.25928	634	-.14054	.04039	1.27233	684	-.58499	.05822	1.24933
585	-.54724	.04926	1.26094	635	-.13270	.04034	1.26949	685	-.59358	.05692	1.25012
586	-.54051	.04885	1.26275	636	-.12547	.03735	1.26833	686	-.60282	.06137	1.25282
587	-.53414	.04815	1.26407	637	-.11869	.03950	1.26244	687	-.61815	.06228	1.24827
588	-.52509	.05209	1.26088	638	-.11151	.04105	1.25691	688	-.63465	.05879	1.24759
589	-.51779	.05112	1.26220	639	-.10414	.03971	1.25421	689	-.64607	.05855	1.23910
590	-.50611	.05231	1.26188	640	-.09739	.04065	1.24967	690	-.68650	.05493	1.22097
591	-.49668	.05540	1.26023	641	-.09079	.04075	1.24542	691	-.69983	.05968	1.21117
592	-.48992	.05141	1.26676	642	-.08429	.04391	1.23693	692	-.70439	.06720	1.20822
593	-.48116	.05293	1.26634	643	-.07905	.04282	1.23389	693	-.69763	.06710	1.21182
594	-.47309	.05446	1.26571	644	-.07336	.04389	1.22840	694	-.69252	.06255	1.21953
595	-.46535	.05373	1.26747	645	-.06763	.04346	1.22374	695	-.68574	.06009	1.22364
596	-.45829	.05291	1.26888	646	-.06256	.04853	1.21522	696	-.67732	.05888	1.22358
597	-.44865	.05772	1.26430	647	-.05796	.04842	1.20980	697	-.64953	.06231	1.24196
598	-.44058	.05670	1.26582	648	-.05366	.05287	1.20174	698	-.64157	.06634	1.24374
599	-.42551	.05996	1.26314	649	-.05575	.05903	1.20851	699	-.63514	.06724	1.24702
600	-.42085	.05425	1.27093	650	-.06500	.05735	1.21997	700	-.63024	.06399	1.25389

701	-.62065	.05830	1.25134	751	-.15409	.05506	1.28496	801	-.63771	.07208	1.24864
702	-.61275	.05301	1.25364	752	-.14549	.05541	1.28169	802	-.64869	.07408	1.23594
703	-.60315	.07128	1.25177	753	-.13766	.05586	1.27852	803	-.68204	.06733	1.22170
704	-.59590	.06873	1.25555	754	-.13011	.05594	1.27431	804	-.69551	.07325	1.21193
705	-.58740	.07392	1.25221	755	-.12282	.05559	1.27157	805	-.70533	.08037	1.19928
706	-.56587	.07275	1.25258	756	-.11544	.05523	1.26739	806	-.73128	.07775	1.15196
707	-.56067	.07017	1.25775	757	-.10850	.05357	1.26598	807	-.72841	.07460	1.15669
708	-.54345	.06644	1.26289	758	-.10136	.05471	1.26092	808	-.72518	.07108	1.16202
709	-.53612	.06652	1.26549	759	-.09439	.05607	1.25524	809	-.72543	.07574	1.17531
710	-.52872	.05602	1.26741	760	-.08876	.05478	1.25252	810	-.72185	.07257	1.18034
711	-.51524	.06785	1.26659	761	-.08162	.05991	1.24329	811	-.71917	.07371	1.18919
712	-.50822	.06801	1.26870	762	-.07560	.05907	1.23910	812	-.71501	.07449	1.19799
713	-.49915	.06885	1.26903	763	-.06983	.05716	1.23699	813	-.70903	.07260	1.20230
714	-.49159	.06620	1.27360	764	-.06385	.06260	1.22633	814	-.70361	.07229	1.20869
715	-.48250	.06950	1.27072	765	-.05890	.06346	1.22093	815	-.68929	.06784	1.21631
716	-.47478	.06383	1.27253	766	-.05439	.06527	1.21535	816	-.69064	.08084	1.22223
717	-.46653	.06998	1.27200	767	-.06226	.06888	1.22935	817	-.68687	.08564	1.21884
718	-.45787	.07276	1.26987	768	-.07423	.06505	1.24297	818	-.69402	.08775	1.21387
719	-.45054	.07094	1.27204	769	-.08581	.06783	1.24841	819	-.69906	.08712	1.20712
720	-.42468	.07155	1.27367	770	-.09974	.06195	1.26279	820	-.70596	.08493	1.20259
721	-.42247	.07035	1.27758	771	-.11402	.06225	1.26974	821	-.71118	.09200	1.19690
722	-.41359	.07174	1.27906	772	-.12910	.06302	1.27665	822	-.71475	.08849	1.18807
723	-.40537	.07154	1.28159	773	-.14471	.06247	1.28407	823	-.71916	.09047	1.18194
724	-.39710	.07103	1.28378	774	-.16061	.06178	1.29003	824	-.71721	.08653	1.16471
725	-.38896	.07030	1.28567	775	-.17542	.06630	1.29047	825	-.71887	.08892	1.15817
726	-.38094	.06970	1.28767	776	-.19212	.06713	1.29440	826	-.71948	.08900	1.15067
727	-.37298	.06970	1.28803	777	-.20949	.06708	1.29755	827	-.70393	.09531	1.14839
728	-.36487	.07069	1.28685	778	-.22542	.06749	1.29995	828	-.70655	.09816	1.16154
729	-.35054	.07052	1.28502	779	-.24170	.07065	1.29824	829	-.70720	.09896	1.16809
730	-.34397	.07169	1.28543	780	-.25605	.07367	1.29699	830	-.70775	.10153	1.17630
731	-.33676	.06836	1.29081	781	-.30514	.07223	1.30072	831	-.70841	.10419	1.18492
732	-.32957	.06787	1.29267	782	-.32115	.07556	1.29558	832	-.70597	.10622	1.19495
733	-.32165	.06708	1.29442	783	-.33621	.07694	1.29209	833	-.69926	.10230	1.19772
734	-.31358	.06618	1.29606	784	-.35092	.07987	1.28606	834	-.69328	.10210	1.20427
735	-.30554	.06516	1.29757	785	-.36450	.07964	1.28762	835	-.68697	.10015	1.20876
736	-.29767	.06203	1.30203	786	-.38149	.07607	1.29003	836	-.67948	.09878	1.21296
737	-.26491	.06456	1.29627	787	-.39918	.07369	1.29001	837	-.67266	.09767	1.21663
738	-.25737	.06775	1.29288	788	-.41359	.07827	1.28087	838	-.66650	.09682	1.21974
739	-.24976	.06512	1.29476	789	-.42922	.07851	1.27584	839	-.64966	.10044	1.22964
740	-.24232	.06352	1.29535	790	-.45032	.08080	1.27143	840	-.64157	.10098	1.23070
741	-.23472	.06178	1.29583	791	-.46687	.07559	1.27378	841	-.63464	.10044	1.23374
742	-.22585	.06323	1.29373	792	-.48284	.07650	1.27200	842	-.62700	.10057	1.23616
743	-.21835	.05172	1.29445	793	-.49964	.07473	1.27216	843	-.62025	.10322	1.24166
744	-.21064	.06012	1.29512	794	-.51691	.07377	1.27034	844	-.61340	.10505	1.24607
745	-.20239	.05798	1.29534	795	-.52904	.07772	1.26344	845	-.59479	.11076	1.25626
746	-.19345	.05748	1.29457	796	-.54406	.07415	1.26296	846	-.57692	.10763	1.25753
747	-.18582	.05572	1.29503	797	-.56806	.07637	1.25749	847	-.56845	.10634	1.25819
748	-.17767	.05636	1.29130	798	-.58793	.08251	1.25163	848	-.56188	.10959	1.26297
749	-.16994	.05649	1.28910	799	-.60322	.07888	1.25092	849	-.55341	.10799	1.26403
750	-.16114	.05863	1.28375	800	-.62294	.07214	1.25374	850	-.54532	.10974	1.26702

851	-.53953	.11284	1.27151
852	-.51611	.11240	1.27305
853	-.50672	.11047	1.27161
854	-.49905	.11231	1.27469
855	-.49065	.11135	1.27391
856	-.48216	.11286	1.27499
857	-.47383	.11273	1.27477
858	-.46582	.11384	1.27617
859	-.45845	.11741	1.27864
860	-.42714	.11504	1.27886
861	-.42009	.11494	1.28137
862	-.41178	.11500	1.28414
863	-.40329	.11558	1.28634
864	-.39600	.11580	1.28856
865	-.38865	.11636	1.29041
866	-.37948	.11521	1.29014
867	-.37192	.11419	1.29025
868	-.36330	.11504	1.29217
869	-.33551	.11389	1.29511
870	-.32009	.11406	1.30018
871	-.30399	.11124	1.30072
872	-.29537	.11203	1.30264
873	-.28663	.10886	1.30006
874	-.25542	.08263	1.29890
875	-.24880	.07819	1.30305
876	-.24199	.07690	1.30383
877	-.23297	.07923	1.30061
878	-.22437	.07758	1.30157
879	-.21683	.07548	1.30158
880	-.20874	.07618	1.29968
881	-.20069	.07257	1.30213
882	-.19102	.07525	1.29783
883	-.18363	.07212	1.29925
884	-.17503	.07318	1.29533
885	-.16734	.07083	1.29507
886	-.15939	.07373	1.28962
887	-.15241	.07128	1.28903
888	-.14413	.07121	1.28590
889	-.13620	.06835	1.28603
890	-.12854	.06840	1.28244
891	-.12137	.06747	1.28023
892	-.11382	.06789	1.27533
893	-.10666	.06916	1.27048
894	-.09902	.07066	1.26524
895	-.09209	.07204	1.25961
896	-.08565	.07305	1.25481
897	-.07954	.06987	1.25303
898	-.07339	.07000	1.24878
899	-.06737	.07140	1.24219
900	-.06136	.07381	1.23608
901	-.05470	.07674	1.22662
902	-.05852	.08378	1.23723
903	-.07066	.08515	1.24536
904	-.08406	.08169	1.25678
905	-.09726	.07912	1.26736
906	-.11213	.07915	1.27589
907	-.12659	.08378	1.27789
908	-.14288	.08094	1.28795
909	-.15864	.08221	1.29167
910	-.17350	.08545	1.29367
911	-.19000	.08499	1.29871
912	-.22334	.08428	1.30453
913	-.24003	.08718	1.30554
914	-.25567	.08999	1.30368
915	-.24814	.09364	1.31019
916	-.23953	.09577	1.30754
917	-.23197	.09363	1.30753
918	-.19905	.09044	1.30536
919	-.19007	.09059	1.30369
920	-.18248	.08828	1.30347
921	-.17354	.08875	1.30034
922	-.16613	.08661	1.30026
923	-.15755	.09053	1.29367
924	-.15029	.08838	1.29353
925	-.14236	.08810	1.29059
926	-.13405	.08907	1.28621
927	-.12621	.08826	1.28439
928	-.11865	.08643	1.28203
929	-.11177	.08416	1.28165
930	-.10385	.08620	1.27542
931	-.09689	.08482	1.27355
932	-.08983	.08761	1.26634
933	-.08309	.08768	1.26265
934	-.07628	.08634	1.25900
935	-.06969	.08929	1.25201
936	-.06410	.08867	1.24847
937	-.05639	.08990	1.24158
938	-.06773	.09618	1.25464
939	-.08172	.09198	1.26834
940	-.09520	.09415	1.27372
941	-.10911	.09952	1.27551
942	-.12503	.09600	1.28630
943	-.14193	.09369	1.29439
944	-.15647	.09811	1.29481
945	-.17318	.09446	1.30333
946	-.18904	.09865	1.30392
947	-.18793	.10582	1.30584
948	-.18094	.10253	1.30782
949	-.17220	.10610	1.30183
950	-.16455	.10399	1.30187
951	-.15621	.10460	1.29842
952	-.14858	.10298	1.29724
953	-.14084	.10387	1.29482
954	-.13239	.10185	1.29304
955	-.12464	.10043	1.29131
956	-.11747	.09786	1.29063
957	-.10969	.10126	1.28391
958	-.10167	.10414	1.27766
959	-.09459	.10140	1.27674
960	-.08688	.10253	1.27124
961	-.08020	.10502	1.26454
962	-.07341	.10232	1.26358
963	-.06661	.10517	1.25664
964	-.06054	.10649	1.25107
965	-.05593	.10844	1.24707
966	-.06546	.11193	1.26020
967	-.07896	.11157	1.26781
968	-.09324	.10996	1.27810
969	-.10780	.10957	1.28556
970	-.12314	.11107	1.29038
971	-.13942	.11262	1.29497
972	-.15497	.11235	1.30034
973	-.17156	.11107	1.30542
974	-.18736	.11548	1.30539
975	-.18631	.12254	1.30724
976	-.17927	.12072	1.30787
977	-.17044	.12366	1.30309
978	-.16293	.11767	1.30667
979	-.15445	.11949	1.30259
980	-.14723	.11748	1.30261
981	-.13923	.11835	1.29986
982	-.13109	.11522	1.30012
983	-.13109	.11522	1.30012
984	-.12287	.11868	1.29366
985	-.11503	.11578	1.29281
986	-.10713	.11795	1.28778
987	-.09963	.11885	1.28373
988	-.09238	.11511	1.28421
989	-.08504	.11517	1.27995
990	-.07805	.11682	1.27500
991	-.07097	.11362	1.27352
992	-.06369	.11952	1.26371
993	-.05903	.11975	1.26097
994	-.06276	.12662	1.26805
995	-.07636	.12322	1.27908
996	-.09143	.12174	1.28789
997	-.10601	.12674	1.28902
998	-.12121	.12874	1.29312
999	-.13808	.12724	1.30063
1000	-.15391	.12567	1.30676

1001	-.17002	.12864	1.30793	1051	-.18362	.16363	1.31087	1101	-.62280	.12180	1.24055
1002	-.18667	.12877	1.31120	1052	-.18330	.17012	1.31337	1102	-.61668	.12381	1.24510
1003	-.18549	.13827	1.31005	1053	-.17506	.16994	1.31171	1103	-.60929	.12155	1.24547
1004	-.17798	.13834	1.30838	1054	-.16699	.17019	1.31051	1104	-.60119	.12218	1.24749
1005	-.16867	.14014	1.30506	1055	-.15887	.16846	1.31116	1105	-.59328	.12248	1.24982
1006	-.16143	.13594	1.30758	1056	-.15086	.16767	1.31038	1106	-.58630	.12452	1.25462
1007	-.15346	.13370	1.30756	1057	-.14232	.16872	1.30735	1107	-.57812	.12464	1.25724
1008	-.14608	.13319	1.30598	1058	-.13474	.16758	1.30726	1108	-.56938	.12134	1.25656
1009	-.13788	.13505	1.30244	1059	-.12595	.16657	1.30651	1109	-.56274	.12455	1.26255
1010	-.12947	.13266	1.30196	1060	-.11788	.16747	1.30279	1110	-.55545	.12565	1.26589
1011	-.12142	.13409	1.29826	1061	-.10997	.16582	1.30222	1111	-.54648	.12387	1.26621
1012	-.11374	.13150	1.29772	1062	-.10221	.16549	1.30073	1112	-.54013	.12700	1.27057
1013	-.10548	.13241	1.29394	1063	-.09354	.16626	1.29664	1113	-.53248	.12943	1.27353
1014	-.09731	.13494	1.28745	1064	-.08571	.16852	1.29169	1114	-.51631	.12947	1.27518
1015	-.09000	.13261	1.28713	1065	-.07816	.16500	1.29164	1115	-.50757	.12663	1.27339
1016	-.08260	.13306	1.28302	1066	-.07070	.16501	1.29093	1116	-.50017	.13044	1.27732
1017	-.07500	.13416	1.27767	1067	-.06905	.16454	1.29092	1117	-.49179	.12928	1.27617
1018	-.06840	.13155	1.27674	1068	-.08434	.17380	1.29523	1118	-.48291	.12744	1.27440
1019	-.06166	.13612	1.26960	1069	-.10098	.17451	1.30044	1119	-.47443	.12825	1.27632
1020	-.07382	.14080	1.28114	1070	-.11710	.17427	1.30506	1120	-.46630	.12944	1.27767
1021	-.08865	.14134	1.28766	1071	-.13452	.17437	1.30973	1121	-.42881	.13534	1.28656
1022	-.10433	.13964	1.29588	1072	-.14942	.17778	1.30882	1122	-.42083	.13330	1.28800
1023	-.11979	.14287	1.29837	1073	-.16608	.18062	1.30831	1123	-.41260	.13399	1.28998
1024	-.13638	.14341	1.30236	1074	-.18173	.18371	1.30760	1124	-.40446	.13421	1.29249
1025	-.15178	.14755	1.30215	1075	-.17426	.18584	1.31274	1125	-.39637	.13537	1.29386
1026	-.16836	.14487	1.30913	1076	-.16603	.18379	1.31303	1126	-.38022	.13265	1.29513
1027	-.18497	.14536	1.31188	1077	-.15797	.18230	1.31394	1127	-.36474	.13381	1.29902
1028	-.18467	.15367	1.31263	1078	-.14952	.18442	1.31061	1128	-.35049	.12434	1.29343
1029	-.17635	.15351	1.31089	1079	-.14170	.18329	1.30978	1129	-.33384	.12974	1.29879
1030	-.16832	.15201	1.31182	1080	-.13347	.18441	1.30728	1130	-.32720	.13326	1.30488
1031	-.16023	.15157	1.30975	1081	-.12493	.18198	1.30806	1131	-.31907	.13220	1.30467
1032	-.15195	.15166	1.30840	1082	-.11709	.18383	1.30425	1132	-.31057	.13085	1.30598
1033	-.14430	.14940	1.30823	1083	-.10877	.18288	1.30387	1133	-.30265	.12987	1.30562
1034	-.13583	.15232	1.30358	1084	-.10036	.18237	1.30194	1134	-.29432	.13022	1.30806
1035	-.12704	.14992	1.30365	1085	-.09250	.18035	1.30218	1135	-.28617	.12564	1.30525
1036	-.11987	.14798	1.30372	1086	-.08403	.18020	1.29949	1136	-.27063	.12727	1.30860
1037	-.11188	.14935	1.29923	1087	-.07623	.17783	1.29883	1137	-.23958	.12850	1.31138
1038	-.10382	.15026	1.29589	1088	-.07271	.17680	1.29875	1138	-.70237	.12616	1.17395
1039	-.09564	.14966	1.29243	1089	-.69714	.10795	1.15326	1139	-.69569	.12664	1.18786
1040	-.08817	.14758	1.29245	1090	-.70442	.11912	1.17577	1140	-.68331	.12555	1.19759
1041	-.08035	.15036	1.28638	1091	-.69946	.11933	1.18998	1141	-.66948	.12012	1.20351
1042	-.07313	.14905	1.28432	1092	-.69267	.11790	1.19402	1142	-.64687	.11867	1.21511
1043	-.06499	.15019	1.27853	1093	-.68616	.11608	1.19842	1143	-.63468	.12485	1.22579
1044	-.07155	.15527	1.28824	1094	-.67914	.11472	1.20245	1144	-.62117	.12657	1.23534
1045	-.08672	.15512	1.29542	1095	-.67254	.11310	1.20664	1145	-.60758	.12616	1.24048
1046	-.10214	.15880	1.29716	1096	-.66644	.11204	1.20946	1146	-.59160	.12674	1.24523
1047	-.11803	.15984	1.30101	1097	-.64894	.11501	1.22147	1147	-.57608	.12801	1.25222
1048	-.13579	.15731	1.30880	1098	-.64234	.11672	1.22650	1148	-.56286	.13230	1.26186
1049	-.15093	.16087	1.30798	1099	-.63333	.11423	1.22668	1149	-.54699	.13279	1.26670
1050	-.16629	.16433	1.30697	1100	-.62811	.11701	1.23317	1150	-.53183	.13401	1.27041

1151	-.51671	.13943	1.27662	1201	-.68786	.14116	1.18330	1251	-.29127	.15916	1.30928
1152	-.69670	.12633	1.15920	1202	-.67433	.13631	1.18831	1252	-.26814	.16000	1.31396
1153	-.69922	.13333	1.17063	1203	-.64435	.13471	1.20743	1253	-.26085	.16062	1.31571
1154	-.69598	.13275	1.17722	1204	-.63335	.13900	1.21898	1254	-.25141	.15589	1.31166
1155	-.69064	.13347	1.18404	1205	-.61957	.14171	1.22802	1255	-.23499	.15370	1.31027
1156	-.68534	.13269	1.18947	1206	-.60781	.14624	1.23805	1256	-.21913	.15961	1.31555
1157	-.67845	.12995	1.19244	1207	-.59249	.14581	1.24380	1257	-.20314	.15369	1.30999
1158	-.67047	.12507	1.19302	1208	-.57607	.14525	1.25007	1258	-.18543	.15275	1.30700
1159	-.66320	.12171	1.19420	1209	-.56272	.14825	1.25812	1259	-.16909	.15119	1.30391
1160	-.64508	.12578	1.21040	1210	-.54694	.14795	1.26387	1260	-.15295	.14878	1.29916
1161	-.64094	.13039	1.21863	1211	-.50001	.15261	1.27432	1261	-.66698	.14797	1.18008
1162	-.63430	.13153	1.22279	1212	-.48411	.15482	1.27708	1262	-.64016	.14762	1.19877
1163	-.62671	.13140	1.22554	1213	-.69516	.16004	1.18247	1263	-.63043	.15324	1.21159
1164	-.62070	.13387	1.23164	1214	-.68450	.14906	1.17976	1264	-.61757	.15522	1.22015
1165	-.61698	.14071	1.24103	1215	-.67762	.14659	1.18237	1265	-.60583	.16012	1.23088
1166	-.60796	.13730	1.24002	1216	-.67041	.14281	1.18401	1266	-.59268	.16510	1.24206
1167	-.60082	.13744	1.24228	1217	-.66302	.13781	1.18450	1267	-.57671	.16443	1.24832
1168	-.59256	.13717	1.24543	1218	-.64118	.13848	1.20079	1268	-.56282	.16583	1.25579
1169	-.58273	.15203	1.26418	1219	-.63870	.14682	1.21159	1269	-.50138	.17178	1.27463
1170	-.57016	.14240	1.25817	1220	-.63164	.14628	1.21465	1270	-.48522	.17350	1.27808
1171	-.56335	.14198	1.26099	1221	-.62585	.14758	1.21997	1271	-.46951	.17182	1.27712
1172	-.55572	.14310	1.26443	1222	-.61977	.15037	1.22579	1272	-.44332	.17306	1.28792
1173	-.54780	.14304	1.26721	1223	-.61473	.15515	1.23327	1273	-.41187	.17567	1.29547
1174	-.53167	.14144	1.26919	1224	-.60753	.15476	1.23620	1274	-.39596	.17487	1.29855
1175	-.51567	.14312	1.27264	1225	-.59998	.15499	1.23843	1275	-.37943	.17254	1.29981
1176	-.50888	.14591	1.27489	1226	-.59196	.15468	1.24155	1276	-.66626	.15262	1.16994
1177	-.50031	.14689	1.27664	1227	-.58566	.15825	1.24878	1277	-.66165	.15153	1.17279
1178	-.48472	.14898	1.27945	1228	-.57705	.15677	1.25020	1278	-.65537	.14825	1.17405
1179	-.46826	.14960	1.28212	1229	-.56942	.15655	1.25304	1279	-.63731	.15341	1.19339
1180	-.45450	.15089	1.28421	1230	-.56357	.15859	1.25865	1280	-.63390	.15829	1.20114
1181	-.42860	.14984	1.28828	1231	-.54873	.16080	1.26604	1281	-.63074	.16619	1.21126
1182	-.41143	.14677	1.28968	1232	-.53298	.16244	1.26945	1282	-.62288	.16311	1.21272
1183	-.39581	.14772	1.29388	1233	-.51758	.16372	1.27319	1283	-.61674	.16536	1.21812
1184	-.38762	.14832	1.29590	1234	-.50079	.15184	1.27393	1284	-.61068	.16740	1.22323
1185	-.38039	.14883	1.29775	1235	-.48469	.16384	1.27705	1285	-.60479	.16875	1.22805
1186	-.37231	.14901	1.30030	1236	-.46940	.16568	1.28009	1286	-.59796	.17002	1.23216
1187	-.36385	.14802	1.30003	1237	-.44236	.15201	1.28378	1287	-.59053	.17057	1.23623
1188	-.35062	.14293	1.30041	1238	-.42718	.16357	1.28708	1288	-.58413	.17352	1.24264
1189	-.31775	.14519	1.30616	1239	-.41212	.16688	1.29486	1289	-.57574	.17136	1.24480
1190	-.30144	.14470	1.30803	1240	-.40337	.16548	1.29343	1290	-.56883	.17257	1.24902
1191	-.28559	.14522	1.31122	1241	-.39583	.16521	1.29635	1291	-.56210	.17371	1.25327
1192	-.26921	.14131	1.31026	1242	-.38724	.16046	1.29404	1292	-.55572	.17674	1.25961
1193	-.25310	.14162	1.31325	1243	-.37924	.16378	1.29825	1293	-.54848	.17585	1.26149
1194	-.23704	.13946	1.31070	1244	-.37171	.16407	1.30047	1294	-.53316	.17765	1.26508
1195	-.22788	.13909	1.31000	1245	-.36276	.16177	1.29912	1295	-.51804	.17905	1.27023
1196	-.21913	.13788	1.30805	1246	-.33279	.16483	1.30786	1296	-.51013	.18004	1.27175
1197	-.20472	.13635	1.30745	1247	-.32463	.16528	1.30956	1297	-.50068	.17714	1.27119
1198	-.18787	.14009	1.30869	1248	-.31713	.16611	1.31112	1298	-.49258	.17796	1.27298
1199	-.17081	.13466	1.30172	1249	-.30847	.16271	1.30998	1299	-.48547	.18217	1.27763
1200	-.15501	.13628	1.29939	1250	-.30046	.16196	1.31039	1300	-.47052	.18095	1.27698

1301	-.45735	.18127	1.28327	1351	-.61205	.17556	1.20693	1401	-.13369	.18357	1.30355
1302	-.44381	.18487	1.29084	1352	-.61767	.17281	1.20119	1402	-.11768	.17597	1.29590
1303	-.42762	.18275	1.29165	1353	-.62451	.17375	1.19773	1403	-.10205	.18082	1.29541
1304	-.41962	.18151	1.29139	1354	-.62942	.17062	1.19221	1404	-.63886	.15471	1.15389
1305	-.41119	.18265	1.29459	1355	-.63319	.16785	1.18664	1405	-.60980	.18223	1.20192
1306	-.39562	.18229	1.29757	1356	-.60712	.18022	1.21460	1406	-.62192	.17931	1.19255
1307	-.38739	.18277	1.29980	1357	-.60035	.17951	1.21776	1407	-.59825	.18749	1.21336
1308	-.37853	.17819	1.29722	1358	-.58736	.18388	1.22858	1408	-.58591	.19232	1.22458
1309	-.36407	.18265	1.30513	1359	-.57192	.18307	1.23403	1409	-.55400	.19493	1.24157
1310	-.34861	.18299	1.30830	1360	-.56677	.18903	1.24336	1410	-.54789	.20108	1.25167
1311	-.33204	.18003	1.30810	1361	-.56174	.19323	1.25011	1411	-.53245	.19924	1.25463
1312	-.31606	.18069	1.31167	1362	-.54749	.19004	1.25318	1412	-.51943	.20606	1.26421
1313	-.29995	.18114	1.31388	1363	-.54114	.19171	1.25673	1413	-.50022	.19994	1.26310
1314	-.28345	.17959	1.31476	1364	-.53347	.19362	1.26042	1414	-.47104	.20270	1.27200
1315	-.26718	.17690	1.31476	1365	-.52528	.19267	1.26155	1415	-.45817	.20575	1.28119
1316	-.25048	.17576	1.31528	1366	-.51705	.19314	1.26376	1416	-.44320	.20940	1.28763
1317	-.23365	.17439	1.31448	1367	-.50957	.19362	1.26574	1417	-.42756	.20799	1.29173
1318	-.21644	.17091	1.31206	1368	-.50146	.19409	1.26800	1418	-.41029	.20653	1.29154
1319	-.20124	.17271	1.31293	1369	-.49489	.19944	1.27449	1419	-.39411	.20753	1.29587
1320	-.18372	.16980	1.30891	1370	-.48575	.19684	1.27283	1420	-.37820	.20816	1.29940
1321	-.16706	.16726	1.30594	1371	-.47804	.19863	1.27332	1421	-.36304	.20890	1.30428
1322	-.15108	.16663	1.30312	1372	-.47115	.19657	1.27479	1422	-.34632	.20638	1.30511
1323	-.13542	.16644	1.30076	1373	-.46527	.19749	1.27962	1423	-.33015	.20667	1.30804
1324	-.11964	.16450	1.29530	1374	-.45969	.19998	1.28590	1424	-.31355	.20396	1.30859
1325	-.10372	.16282	1.28971	1375	-.44414	.20206	1.29099	1425	-.29695	.20193	1.30883
1326	-.08921	.15211	1.28412	1376	-.43054	.20327	1.29214	1426	-.28067	.20200	1.31038
1327	-.65828	.15757	1.16832	1377	-.42742	.20080	1.29257	1427	-.26497	.20152	1.31245
1328	-.61408	.17039	1.21244	1378	-.41187	.20199	1.29646	1428	-.24852	.20189	1.31427
1329	-.62646	.15767	1.20273	1379	-.39426	.19735	1.29562	1429	-.23196	.19865	1.31277
1330	-.63651	.16393	1.19238	1380	-.37819	.19528	1.29803	1430	-.21455	.19880	1.31413
1331	-.60217	.17373	1.22127	1381	-.36246	.19532	1.30109	1431	-.19870	.19565	1.31121
1332	-.58854	.17534	1.23121	1382	-.34703	.19596	1.30559	1432	-.18153	.19339	1.30944
1333	-.57385	.17630	1.23951	1383	-.33077	.19752	1.30926	1433	-.16471	.19127	1.30693
1334	-.56156	.18204	1.25072	1384	-.32243	.19547	1.30842	1434	-.63168	.15689	1.14901
1335	-.54785	.18155	1.25599	1385	-.31385	.19354	1.30752	1435	-.61993	.18703	1.18840
1336	-.53223	.18087	1.25821	1386	-.30551	.19435	1.30937	1436	-.61344	.19627	1.19152
1337	-.51800	.18748	1.26802	1387	-.29740	.19153	1.30891	1437	-.60930	.19254	1.20083
1338	-.50212	.18865	1.27207	1388	-.28957	.19472	1.31278	1438	-.60616	.20088	1.21076
1339	-.48478	.18698	1.27266	1389	-.28088	.19086	1.30981	1439	-.59455	.19064	1.20531
1340	-.47172	.19135	1.27749	1390	-.26561	.19226	1.31338	1440	-.58223	.19595	1.21860
1341	-.45874	.18963	1.28398	1391	-.25776	.19286	1.31478	1441	-.56724	.19558	1.22480
1342	-.44327	.19043	1.28831	1392	-.24914	.19193	1.31499	1442	-.55578	.20106	1.23665
1343	-.42771	.19148	1.29238	1393	-.24052	.19161	1.31440	1443	-.54426	.19951	1.23963
1344	-.41168	.19213	1.29598	1394	-.23209	.18875	1.31249	1444	-.53180	.20655	1.25124
1345	-.39576	.19146	1.29827	1395	-.22319	.19006	1.31393	1445	-.51713	.21090	1.25891
1346	-.37898	.18919	1.29942	1396	-.21474	.18916	1.31355	1446	-.50921	.20642	1.25715
1347	-.31473	.18577	1.30822	1397	-.19937	.18673	1.31190	1447	-.50098	.21117	1.26293
1348	-.29814	.18478	1.30955	1398	-.18197	.18580	1.30971	1448	-.49228	.20807	1.26229
1349	-.64713	.15388	1.15950	1399	-.16557	.18297	1.30799	1449	-.48530	.21218	1.26708
1350	-.64297	.15275	1.16227	1400	-.14986	.18418	1.30699	1450	-.47193	.21261	1.27232

1451	-.45710	.21224	1.27780	1501	-.31199	.21956	1.30503	1551	-.31091	.22604	1.30216
1452	-.44276	.21794	1.28723	1502	-.29575	.21835	1.30637	1552	-.29523	.22719	1.30613
1453	-.42600	.21514	1.28720	1503	-.27943	.21888	1.30904	1553	-.28641	.22557	1.30544
1454	-.41089	.22039	1.29518	1504	-.26326	.21606	1.30899	1554	-.27863	.22702	1.30803
1455	-.39419	.21803	1.29630	1505	-.24672	.21541	1.31095	1555	-.26219	.22263	1.30711
1456	-.37802	.21431	1.29782	1506	-.23044	.21507	1.31249	1556	-.25376	.22074	1.30607
1457	-.37104	.21802	1.30197	1507	-.21277	.21253	1.31101	1557	-.24620	.22330	1.31006
1458	-.36198	.21538	1.30140	1508	-.19761	.21249	1.31182	1558	-.23775	.22465	1.31135
1459	-.35426	.21589	1.30343	1509	-.17971	.20875	1.30916	1559	-.22903	.22013	1.30855
1460	-.34447	.20867	1.29907	1510	-.14637	.20466	1.30466	1560	-.22092	.22015	1.30964
1461	-.32862	.21008	1.30279	1511	-.13137	.20659	1.30528	1561	-.21227	.22142	1.31107
1462	-.32055	.21238	1.30616	1512	-.11490	.20555	1.30297	1562	-.19640	.21899	1.30996
1463	-.31246	.20982	1.30528	1513	-.09866	.20403	1.29901	1563	-.18854	.22104	1.31183
1464	-.30422	.21119	1.30696	1514	-.61170	.14517	1.12398	1564	-.17936	.21746	1.30987
1465	-.29621	.20890	1.30632	1515	-.61520	.20047	1.18048	1565	-.16980	.21253	1.30527
1466	-.28772	.20967	1.30828	1516	-.60908	.19964	1.18358	1566	-.15474	.21657	1.30880
1467	-.28026	.21027	1.31013	1517	-.60354	.20297	1.18974	1567	-.14595	.21389	1.30630
1468	-.27190	.21106	1.31148	1518	-.59574	.20266	1.19277	1568	-.13035	.21184	1.30427
1469	-.26370	.20906	1.31050	1519	-.58459	.20940	1.20569	1569	-.12181	.21407	1.30445
1470	-.25628	.20966	1.31232	1520	-.57661	.20643	1.20641	1570	-.11377	.21392	1.30413
1471	-.24673	.20482	1.30918	1521	-.56911	.20674	1.21139	1571	-.09751	.21071	1.29943
1472	-.23071	.20466	1.31100	1522	-.56140	.20666	1.21467	1572	-.08193	.20823	1.29433
1473	-.22150	.20626	1.31218	1523	-.54325	.21638	1.23328	1573	-.07024	.21204	1.29430
1474	-.21341	.20444	1.31161	1524	-.53690	.21867	1.23776	1574	-.08073	.21783	1.29667
1475	-.19795	.20270	1.31017	1525	-.52903	.21905	1.24056	1575	-.09602	.21844	1.29930
1476	-.18033	.19962	1.30839	1526	-.52315	.22403	1.24796	1576	-.12965	.22131	1.30514
1477	-.16372	.20003	1.30871	1527	-.50800	.22452	1.25256	1577	-.14501	.22487	1.30826
1478	-.14745	.19965	1.30648	1528	-.49947	.22502	1.25484	1578	-.16077	.22254	1.30737
1479	-.13187	.19663	1.30356	1529	-.49303	.22698	1.25987	1579	-.17810	.22778	1.31007
1480	-.11610	.19824	1.30273	1530	-.48540	.22725	1.26214	1580	-.19557	.22870	1.31026
1481	-.10012	.19735	1.29853	1531	-.47743	.22513	1.26109	1581	-.21098	.22998	1.31017
1482	-.06909	.19604	1.28836	1532	-.47150	.22870	1.26853	1582	-.22815	.22972	1.30855
1483	-.61677	.19123	1.18276	1533	-.46448	.22884	1.27076	1583	-.24499	.23034	1.30713
1484	-.60617	.19728	1.19453	1534	-.45630	.22897	1.27342	1584	-.26219	.23749	1.31014
1485	-.57978	.20120	1.21270	1535	-.44830	.22898	1.27614	1585	-.27777	.23517	1.30592
1486	-.56637	.20575	1.22352	1536	-.44083	.22924	1.27840	1586	-.29383	.23478	1.30316
1487	-.54540	.21080	1.23920	1537	-.43353	.23197	1.28278	1587	-.30954	.23349	1.29934
1488	-.51657	.21834	1.25471	1538	-.42419	.22855	1.28148	1588	-.32605	.23377	1.29679
1489	-.50073	.21869	1.25973	1539	-.41674	.22980	1.28420	1589	-.34310	.23677	1.29648
1490	-.48594	.22120	1.26632	1540	-.40789	.22798	1.28483	1590	-.35959	.23826	1.29479
1491	-.47180	.22136	1.27096	1541	-.39257	.23177	1.27128	1591	-.37536	.23827	1.29167
1492	-.45689	.22114	1.27632	1542	-.38517	.23202	1.29350	1592	-.39177	.23920	1.28837
1493	-.44107	.22150	1.28128	1543	-.37663	.23252	1.29583	1593	-.40779	.23803	1.28434
1494	-.42506	.22284	1.28515	1544	-.36743	.22732	1.29260	1594	-.42375	.23744	1.27957
1495	-.40965	.22332	1.28983	1545	-.36070	.23117	1.29773	1595	-.43943	.23695	1.27479
1496	-.39360	.22461	1.29380	1546	-.35205	.22819	1.29687	1596	-.45502	.23669	1.26974
1497	-.37765	.22509	1.29864	1547	-.34424	.22897	1.29916	1597	-.47013	.23663	1.26466
1498	-.36181	.22486	1.30151	1548	-.33652	.23023	1.30201	1598	-.48472	.23385	1.25729
1499	-.34498	.22235	1.30229	1549	-.32700	.22670	1.29983	1599	-.49923	.23410	1.25205
1500	-.32866	.22230	1.30508	1550	-.31962	.23075	1.30543	1600	-.52806	.22605	1.23595

1601	-.54052	.22002	1.22591
1602	-.55705	.20826	1.20584
1603	-.57286	.21125	1.20019
1604	-.58580	.20767	1.19071
1605	-.58684	.21000	1.19252
1606	-.60123	.21100	1.18642
1607	-.61076	.20283	1.17258
1608	-.60815	.17799	1.12814
1609	-.61200	.19811	1.15326
1610	-.61108	.20590	1.16109
1611	-.60617	.20754	1.16573
1612	-.60084	.20923	1.17045
1613	-.59687	.21580	1.17993
1614	-.59009	.21460	1.18258
1615	-.58301	.21414	1.18554
1616	-.57638	.21561	1.19048
1617	-.56854	.21399	1.19289
1618	-.55532	.21827	1.20393
1619	-.53918	.22757	1.22185
1620	-.53215	.22752	1.22433
1621	-.52605	.23217	1.23047
1622	-.51995	.23643	1.23650
1623	-.49879	.23952	1.24691
1624	-.49118	.23975	1.24923
1625	-.48528	.24487	1.25599
1626	-.47017	.24476	1.26188
1627	-.45471	.24507	1.26676
1628	-.44678	.24517	1.26934
1629	-.43999	.24788	1.27419
1630	-.43169	.24631	1.27546
1631	-.42313	.24560	1.27692
1632	-.41575	.24532	1.27924
1633	-.40702	.24607	1.28189
1634	-.39108	.24696	1.28625
1635	-.38333	.24769	1.28799
1636	-.37510	.24686	1.28950
1637	-.35850	.24441	1.29065
1638	-.35070	.24514	1.29244
1639	-.34762	.24556	1.29470
1640	-.33445	.24651	1.29634
1641	-.32527	.24218	1.29494
1642	-.31700	.24304	1.29675
1643	-.30874	.24023	1.29552
1644	-.30020	.24085	1.29714
1645	-.29299	.24330	1.30059
1646	-.28474	.24079	1.30023
1647	-.27612	.23820	1.29888
1648	-.26843	.24149	1.30383
1649	-.26048	.24041	1.30388
1650	-.25266	.24239	1.30699
1651	-.24381	.23706	1.30397
1652	-.23570	.23790	1.30573
1653	-.22780	.23859	1.30763
1654	-.21933	.23946	1.30947
1655	-.21040	.23672	1.30790
1656	-.20338	.23715	1.30922
1657	-.19507	.23585	1.30856
1658	-.18686	.23666	1.31043
1659	-.17751	.23369	1.30824
1660	-.16885	.23223	1.30739
1661	-.15313	.23303	1.30844
1662	-.14455	.23429	1.30987
1663	-.12911	.23246	1.30792
1664	-.12034	.23013	1.30544
1665	-.11233	.22957	1.30499
1666	-.09636	.23096	1.30441
1667	-.08006	.23029	1.30145
1668	-.07527	.22769	1.29861
1669	-.09466	.23314	1.30011
1670	-.11141	.23816	1.30545
1671	-.12801	.23974	1.30732
1672	-.14337	.23756	1.30523
1673	-.15988	.24150	1.30825
1674	-.17666	.24352	1.30902
1675	-.19427	.24467	1.30840
1676	-.20975	.24562	1.30762
1677	-.22716	.24896	1.30783
1678	-.24439	.24985	1.30662
1679	-.25979	.24894	1.30238
1680	-.27539	.24778	1.29842
1681	-.29285	.25122	1.29862
1682	-.30881	.24926	1.29443
1683	-.32473	.25151	1.29370
1684	-.34090	.25055	1.28929
1685	-.35788	.25264	1.28848
1686	-.37367	.25363	1.28533
1687	-.38963	.25283	1.28141
1688	-.40694	.25595	1.28046
1689	-.42271	.25544	1.27569
1690	-.43877	.25523	1.27042
1691	-.45477	.25484	1.26543
1692	-.46924	.25318	1.25845
1693	-.48491	.25296	1.25279
1694	-.49960	.25333	1.24733
1695	-.52427	.23791	1.22528
1696	-.53516	.22862	1.21292
1697	-.55153	.22014	1.19683
1698	-.56700	.22127	1.19023
1699	-.57972	.21815	1.17961
1700	-.59256	.21708	1.17325
1701	-.60395	.21463	1.16235
1702	-.61025	.20572	1.14960
1703	-.60637	.19272	1.12410
1704	-.60704	.21030	1.14361
1705	-.60434	.21500	1.14974
1706	-.59991	.21894	1.15637
1707	-.59447	.22160	1.16219
1708	-.58753	.22138	1.16647
1709	-.57583	.22245	1.17414
1710	-.56882	.22185	1.17671
1711	-.56237	.22354	1.18187
1712	-.54745	.22256	1.18979
1713	-.53308	.23574	1.20906
1714	-.52105	.24032	1.21670
1715	-.50408	.25233	1.23433
1716	-.49578	.25017	1.23520
1717	-.48802	.25069	1.23778
1718	-.48184	.25442	1.24402
1719	-.46733	.25732	1.25244
1720	-.46016	.25788	1.25479
1721	-.45215	.25778	1.25765
1722	-.44457	.25857	1.26100
1723	-.43721	.26023	1.26499
1724	-.42998	.26342	1.27001
1725	-.42213	.26303	1.27201
1726	-.41441	.26168	1.27340
1727	-.40569	.26223	1.27569
1728	-.39770	.26473	1.28005
1729	-.38916	.26060	1.27866
1730	-.38104	.26154	1.28029
1731	-.37356	.26300	1.28400
1732	-.36591	.26362	1.28587
1733	-.35670	.25960	1.28400
1734	-.34918	.26062	1.28651
1735	-.34078	.26141	1.28841
1736	-.33225	.25916	1.28828
1737	-.32445	.25976	1.29023
1738	-.31566	.26047	1.29238
1739	-.30750	.25737	1.29144
1740	-.29955	.26122	1.29641
1741	-.29167	.25903	1.29601
1742	-.27614	.26100	1.30185
1743	-.26005	.25808	1.30226
1744	-.25223	.25993	1.30497
1745	-.24324	.25442	1.30154
1746	-.23410	.25245	1.30073
1747	-.22645	.25458	1.30421
1748	-.21708	.25293	1.30369
1749	-.20927	.25320	1.30548
1750	-.20169	.25278	1.30632

1751	-.19330	.24931	1.30488	1801	-.60423	.21594	1.13786	1851	-.21543	.26893	1.29935
1752	-.18497	.25054	1.30625	1802	-.60470	.22151	1.12825	1852	-.20741	.27166	1.30336
1753	-.17594	.24754	1.30451	1803	-.60050	.22042	1.13098	1853	-.20008	.26929	1.30303
1754	-.16762	.24880	1.30580	1804	-.59734	.22633	1.13911	1854	-.19235	.26834	1.30341
1755	-.15976	.24944	1.30716	1805	-.59201	.22831	1.14460	1855	-.18386	.26702	1.30333
1756	-.15204	.25034	1.30873	1806	-.58430	.22744	1.14827	1856	-.17492	.26586	1.30324
1757	-.14314	.24754	1.30615	1807	-.57836	.22846	1.15346	1857	-.16618	.26684	1.30502
1758	-.13622	.24905	1.30838	1808	-.56084	.22972	1.16397	1858	-.15891	.26958	1.30820
1759	-.12831	.24856	1.30837	1809	-.55306	.22605	1.16498	1859	-.15097	.26810	1.30754
1760	-.11964	.25018	1.30935	1810	-.54714	.22974	1.17194	1860	-.14248	.26634	1.30749
1761	-.11093	.24486	1.30482	1811	-.53857	.22565	1.17315	1861	-.13487	.26456	1.30601
1762	-.10284	.24630	1.30581	1812	-.53591	.23683	1.18503	1862	-.12666	.26230	1.30476
1763	-.09479	.24710	1.30595	1813	-.53170	.24140	1.19104	1863	-.11743	.26084	1.30404
1764	-.08707	.24468	1.30320	1814	-.52578	.24173	1.19265	1864	-.10973	.26204	1.30523
1765	-.08102	.24412	1.30212	1815	-.52282	.25063	1.20155	1865	-.10173	.26325	1.30651
1766	-.09409	.25502	1.30612	1816	-.51712	.25422	1.20712	1866	-.09343	.26503	1.30721
1767	-.11055	.25522	1.30696	1817	-.51265	.26068	1.21459	1867	-.08596	.26211	1.30432
1768	-.12697	.25533	1.30625	1818	-.49869	.26057	1.21950	1868	-.09267	.26898	1.30446
1769	-.14259	.25501	1.30579	1819	-.49083	.26055	1.22222	1869	-.10925	.27374	1.30770
1770	-.15880	.25592	1.30536	1820	-.48442	.26490	1.22832	1870	-.12607	.27340	1.30688
1771	-.17529	.25760	1.30504	1821	-.47833	.26858	1.23408	1871	-.14078	.27429	1.30587
1772	-.19273	.25918	1.30454	1822	-.47153	.27067	1.23911	1872	-.15758	.27472	1.30477
1773	-.19273	.25918	1.30454	1823	-.46410	.27091	1.24193	1873	-.17403	.27537	1.30293
1774	-.20779	.26014	1.30277	1824	-.44932	.27200	1.24800	1874	-.19099	.27648	1.30152
1775	-.22519	.26069	1.30016	1825	-.44141	.27189	1.25082	1875	-.20629	.27601	1.29856
1776	-.24255	.26395	1.30062	1826	-.43477	.27557	1.25679	1876	-.22445	.28021	1.29883
1777	-.25829	.26444	1.29809	1827	-.42672	.27363	1.25779	1877	-.24046	.28078	1.29500
1778	-.27428	.26794	1.29701	1828	-.42045	.27934	1.26536	1878	-.25673	.27931	1.29175
1779	-.29063	.26523	1.29176	1829	-.41199	.27682	1.26543	1879	-.27322	.28140	1.29059
1780	-.30618	.26275	1.28717	1830	-.40288	.27365	1.26535	1880	-.28903	.28053	1.28618
1781	-.32405	.26889	1.28866	1831	-.39556	.27631	1.27050	1881	-.30548	.28334	1.28410
1782	-.33970	.26786	1.28455	1832	-.38759	.27770	1.27272	1882	-.32188	.28329	1.28151
1783	-.35668	.26840	1.28280	1833	-.37966	.27642	1.27347	1883	-.33792	.28239	1.27712
1784	-.37293	.27083	1.28128	1834	-.37167	.27620	1.27532	1884	-.35386	.28190	1.27283
1785	-.38886	.27097	1.27800	1835	-.35581	.27712	1.27962	1885	-.36928	.28073	1.26893
1786	-.40482	.26924	1.27226	1836	-.34767	.27813	1.28119	1886	-.38597	.28320	1.26728
1787	-.42075	.26877	1.26738	1837	-.33889	.27567	1.28133	1887	-.40226	.28324	1.26342
1788	-.43645	.26891	1.26185	1838	-.33092	.27646	1.28308	1888	-.44743	.27649	1.2415[illegible]
1789	-.45113	.26630	1.25417	1839	-.32304	.27668	1.28554	1889	-.48997	.27054	1.21973
1790	-.46591	.26621	1.24923	1840	-.31418	.27560	1.28639	1890	-.51275	.25663	1.19836
1791	-.48106	.26391	1.24162	1841	-.31418	.27560	1.28639	1891	-.52225	.24449	1.18494
1792	-.49568	.26458	1.23582	1842	-.30750	.27723	1.28903	1892	-.53200	.23948	1.17760
1793	-.50941	.25936	1.22702	1843	-.29780	.27544	1.28985	1893	-.53615	.23242	1.16971
1794	-.52011	.24905	1.21399	1844	-.29053	.27425	1.29030	1894	-.55060	.23371	1.16267
1795	-.52923	.23842	1.19988	1845	-.27403	.27467	1.29430	1895	-.57172	.22799	1.14422
1796	-.54249	.22319	1.18133	1846	-.26559	.27323	1.29425	1896	-.58547	.23036	1.13668
1797	-.55877	.22783	1.17632	1847	-.25807	.27358	1.29644	1897	-.58730	.23561	1.12762
1798	-.57257	.22740	1.16881	1848	-.23301	.27253	1.29933	1898	-.58384	.23882	1.13479
1799	-.58233	.22429	1.15927	1849	-.24177	.27385	1.29940	1899	-.57710	.23936	1.13974
1800	-.59575	.22293	1.14977	1850	-.22459	.27147	1.30002	1900	-.57014	.23808	1.14364

1901	-.55688	.23147	1.14733	1951	-.10858	.28099	1.30664	2001	-.43505	.30078	1.21273
1902	-.54505	.23244	1.15349	1952	-.09978	.27788	1.30427	2002	-.42874	.30485	1.21871
1903	-.53715	.23091	1.15584	1953	-.09197	.27755	1.30401	2003	-.42149	.30501	1.22100
1904	-.52986	.24483	1.17253	1954	-.09099	.28001	1.30593	2004	-.41441	.30625	1.22484
1905	-.51993	.25076	1.18106	1955	-.10737	.28925	1.30569	2005	-.40783	.31028	1.23098
1906	-.51475	.25306	1.18455	1956	-.12407	.28682	1.30233	2006	-.39756	.32050	1.24350
1907	-.51147	.26247	1.19410	1957	-.13972	.29250	1.30442	2007	-.38826	.31821	1.24290
1908	-.50020	.26996	1.20432	1958	-.15571	.29097	1.30081	2008	-.38061	.31858	1.24503
1909	-.49421	.27133	1.20815	1959	-.17223	.29053	1.29799	2009	-.37216	.31541	1.24465
1910	-.48720	.27377	1.21279	1960	-.18928	.29307	1.29602	2010	-.36459	.31806	1.24879
1911	-.48058	.27663	1.21796	1961	-.20547	.29510	1.29617	2011	-.35697	.31864	1.25129
1912	-.47307	.27666	1.22049	1962	-.22248	.29384	1.29189	2012	-.34941	.32022	1.25494
1913	-.45929	.27815	1.22803	1963	-.23874	.29619	1.28983	2013	-.34039	.31747	1.25424
1914	-.44566	.28208	1.23666	1964	-.25561	.29760	1.28824	2014	-.33264	.31763	1.25672
1915	-.43162	.28603	1.24545	1965	-.27185	.29813	1.28498	2015	-.32504	.31792	1.25899
1916	-.40943	.28874	1.25558	1966	-.28755	.29637	1.27999	2016	-.31665	.31871	1.26091
1917	-.40304	.29584	1.26333	1967	-.30380	.29676	1.27629	2017	-.30794	.31792	1.26244
1918	-.39269	.28938	1.26052	1968	-.31929	.29577	1.27217	2018	-.30053	.31922	1.26578
1919	-.38602	.29294	1.26560	1969	-.33617	.29834	1.27031	2019	-.29268	.32157	1.26918
1920	-.37831	.29328	1.26782	1970	-.35293	.30024	1.26814	2020	-.28476	.31797	1.26859
1921	-.37036	.29352	1.26966	1971	-.36848	.29958	1.26360	2021	-.26861	.32069	1.27495
1922	-.36183	.29476	1.27163	1972	-.38406	.29831	1.25923	2022	-.25955	.31834	1.27377
1923	-.35373	.29155	1.27123	1973	-.38406	.29831	1.25923	2023	-.25318	.32040	1.27822
1924	-.34641	.29482	1.27629	1974	-.40128	.30121	1.25693	2024	-.24429	.31671	1.27689
1925	-.33867	.29522	1.27847	1975	-.45830	.29123	1.22714	2025	-.23637	.31670	1.27903
1926	-.32978	.29275	1.27742	1976	-.47144	.28461	1.21671	2026	-.22745	.31362	1.27817
1927	-.32093	.28942	1.27686	1977	-.48496	.28022	1.20758	2027	-.21958	.31536	1.28167
1928	-.31237	.28982	1.27932	1978	-.49834	.27784	1.20013	2028	-.20291	.31551	1.28545
1929	-.30592	.29513	1.28506	1979	-.50833	.26693	1.18700	2029	-.19539	.31606	1.28737
1930	-.29681	.29415	1.28585	1980	-.51940	.26231	1.17974	2030	-.18732	.31639	1.28974
1931	-.28901	.29138	1.28544	1981	-.52700	.25077	1.16748	2031	-.17854	.31401	1.28920
1932	-.27177	.28715	1.28591	1982	-.54018	.23413	1.14603	2032	-.17004	.31419	1.29189
1933	-.26357	.29015	1.28973	1983	-.55148	.23419	1.14210	2033	-.16180	.31392	1.29271
1934	-.25678	.28931	1.29078	1984	-.56520	.23375	1.13583	2034	-.15372	.31433	1.29498
1935	-.24888	.28977	1.29294	1985	-.54222	.23889	1.11575	2035	-.14650	.31519	1.29642
1936	-.24017	.28300	1.29283	1986	-.53782	.24080	1.12199	2036	-.13745	.31253	1.29630
1937	-.23157	.28866	1.29498	1987	-.53146	.23995	1.12517	2037	-.13072	.31282	1.29768
1938	-.22332	.28628	1.29545	1988	-.51649	.25427	1.15158	2038	-.12225	.31409	1.29963
1939	-.21465	.28752	1.29807	1989	-.50813	.26867	1.15697	2039	-.11379	.31489	1.30156
1940	-.20642	.28463	1.29745	1990	-.50468	.27418	1.16273	2040	-.10500	.31099	1.29943
1941	-.19836	.28539	1.29930	1991	-.49923	.27726	1.16709	2041	-.10080	.31156	1.30018
1942	-.19055	.28573	1.30035	1992	-.49404	.28257	1.17320	2042	-.10408	.31508	1.29486
1943	-.18200	.28338	1.29977	1993	-.48946	.28825	1.18049	2043	-.12114	.31752	1.29415
1944	-.17360	.28526	1.30270	1994	-.48228	.28844	1.18267	2044	-.13643	.31864	1.29223
1945	-.16464	.28327	1.30242	1995	-.47630	.29216	1.18826	2045	-.15215	.32082	1.29001
1946	-.15656	.28170	1.30189	1996	-.46944	.29403	1.19296	2046	-.16927	.32488	1.29039
1947	-.14029	.28014	1.30307	1997	-.46175	.29401	1.19562	2047	-.18631	.32386	1.28577
1948	-.13361	.28303	1.30644	1998	-.45483	.29553	1.19959	2048	-.20195	.32365	1.28247
1949	-.12528	.28077	1.30515	1999	-.44850	.29873	1.20542	2049	-.21857	.32283	1.27777
1950	-.11599	.28001	1.30528	2000	-.44148	.29844	1.20816	2050	-.23488	.32194	1.27325

2051	-.25147	.32493	1.27221	2101	-.22555	.32950	1.27157	2151	-.49127	.28955	1.13606
2052	-.26705	.32416	1.26780	2102	-.21712	.32747	1.27160	2152	-.48559	.29261	1.14105
2053	-.28322	.32353	1.26302	2103	-.20890	.33173	1.27745	2153	-.47412	.30039	1.15137
2054	-.29881	.32291	1.25843	2104	-.20119	.33273	1.27948	2154	-.46845	.30367	1.15672
2055	-.31492	.32208	1.25393	2105	-.19333	.33293	1.28194	2155	-.46115	.30556	1.16149
2056	-.33043	.32216	1.24970	2106	-.18541	.33189	1.28238	2156	-.45405	.30547	1.16401
2057	-.34773	.32440	1.24758	2107	-.17654	.32875	1.28217	2157	-.44697	.30582	1.16771
2058	-.36265	.32381	1.24321	2108	-.16836	.33029	1.28546	2158	-.43977	.30561	1.17043
2059	-.37898	.32384	1.23933	2109	-.15967	.33085	1.28777	2159	-.43290	.30708	1.17499
2060	-.39452	.32109	1.23257	2110	-.15222	.33111	1.28998	2160	-.42026	.31148	1.18373
2061	-.41866	.31056	1.21589	2111	-.14456	.33184	1.29173	2161	-.41344	.31342	1.18774
2062	-.43238	.30751	1.20790	2112	-.13614	.32883	1.29121	2162	-.40761	.31960	1.19617
2063	-.44571	.30422	1.19979	2113	-.12917	.33217	1.29481	2163	-.39955	.32422	1.20151
2064	-.45908	.29919	1.18978	2114	-.12130	.33089	1.29614	2164	-.38758	.33178	1.21054
2065	-.47249	.29530	1.18124	2115	-.11122	.32986	1.29610	2165	-.37973	.33291	1.21305
2066	-.49628	.28291	1.16187	2116	-.10676	.33226	1.29886	2166	-.37427	.34081	1.22069
2067	-.51781	.23908	1.10823	2117	-.11944	.33608	1.28996	2167	-.35898	.34382	1.22704
2068	-.51286	.25607	1.12519	2118	-.13423	.33485	1.28639	2168	-.35215	.34716	1.23127
2069	-.50765	.26503	1.13322	2119	-.15054	.33795	1.28526	2169	-.34298	.34174	1.22906
2070	-.50171	.27821	1.14546	2120	-.16751	.34100	1.28404	2170	-.33497	.34151	1.23212
2071	-.49243	.28599	1.15445	2121	-.18396	.33839	1.27804	2171	-.32697	.34214	1.23469
2072	-.48094	.29245	1.16359	2122	-.19974	.33762	1.27356	2172	-.31909	.34284	1.23656
2073	-.47552	.29664	1.16948	2123	-.21620	.33711	1.26855	2173	-.31114	.34302	1.23906
2074	-.46790	.29643	1.17233	2124	-.23251	.33691	1.26497	2174	-.29529	.34393	1.24339
2075	-.46145	.29908	1.17707	2125	-.24894	.33794	1.26167	2175	-.28678	.34380	1.24524
2076	-.45514	.30211	1.18245	2126	-.26384	.33755	1.25698	2176	-.27882	.34123	1.24577
2077	-.44860	.30575	1.18836	2127	-.28063	.33723	1.25342	2177	-.27064	.34169	1.24803
2078	-.44211	.30731	1.19273	2128	-.29668	.33754	1.24936	2178	-.26320	.34506	1.25238
2079	-.43417	.30571	1.19446	2129	-.31260	.33660	1.24507	2179	-.25496	.34492	1.25537
2080	-.42819	.30857	1.19884	2130	-.32870	.33858	1.24247	2180	-.24804	.34542	1.25715
2081	-.42136	.31009	1.20283	2131	-.34432	.33560	1.23540	2181	-.23969	.34569	1.25968
2082	-.41407	.31133	1.20673	2132	-.35993	.33470	1.23115	2182	-.23179	.34616	1.26182
2083	-.40763	.31434	1.21285	2133	-.39104	.33366	1.22171	2183	-.22362	.34632	1.26443
2084	-.39046	.31859	1.22060	2134	-.40224	.32053	1.20846	2184	-.21550	.34363	1.26457
2085	-.37759	.32960	1.23292	2135	-.41113	.31646	1.20215	2185	-.20669	.34409	1.26704
2086	-.36205	.33024	1.23748	2136	-.42508	.31361	1.19388	2186	-.19882	.34451	1.26922
2087	-.35434	.33059	1.23969	2137	-.43750	.30771	1.18403	2187	-.19081	.34303	1.26963
2088	-.34643	.33082	1.24215	2138	-.45083	.30184	1.17396	2188	-.18295	.34350	1.27174
2089	-.33788	.32915	1.24293	2139	-.46408	.30004	1.16589	2189	-.17495	.34638	1.27627
2090	-.32986	.33008	1.24637	2140	-.47667	.29442	1.15532	2190	-.16592	.34371	1.27667
2091	-.32251	.33165	1.24936	2141	-.48830	.28627	1.14609	2191	-.15760	.34620	1.28005
2092	-.31426	.33238	1.25131	2142	-.49832	.28012	1.13770	2192	-.14969	.34062	1.27772
2093	-.29802	.32936	1.25338	2143	-.50636	.27309	1.12952	2193	-.14202	.34090	1.28002
2094	-.29014	.33243	1.25829	2144	-.51141	.26151	1.12031	2194	-.13412	.34125	1.28234
2095	-.28271	.33289	1.26029	2145	-.51141	.26436	1.11038	2195	-.12680	.34329	1.28469
2096	-.26618	.33368	1.26501	2146	-.50891	.26603	1.11304	2196	-.11924	.34339	1.28717
2097	-.25730	.33193	1.26477	2147	-.50585	.26901	1.11597	2197	-.11212	.34465	1.28869
2098	-.25040	.33398	1.26880	2148	-.50374	.27668	1.12285	2198	-.11771	.34956	1.28208
2099	-.24252	.33103	1.26797	2149	-.49966	.28006	1.12627	2199	-.13242	.34866	1.27870
2100	-.23368	.32843	1.26832	2150	-.49605	.28546	1.13172	2200	-.14847	.34766	1.27385

2201	-.16485	.35154	1.27299	2251	-.33100	.34877	1.21660	2301	-.47751	.30355	1.10896
2202	-.18196	.35303	1.26948	2252	-.32349	.35319	1.22209	2302	-.46526	.31174	1.12113
2203	-.19729	.35136	1.26450	2253	-.31617	.35436	1.22556	2303	-.45750	.31066	1.12398
2204	-.21404	.35074	1.25951	2254	-.30784	.35256	1.22585	2304	-.45175	.31300	1.12872
2205	-.23006	.34924	1.25407	2255	-.29219	.35310	1.23056	2305	-.44384	.31233	1.13223
2206	-.24559	.34640	1.24803	2256	-.28307	.35310	1.23309	2306	-.43033	.31250	1.13940
2207	-.26169	.35093	1.24766	2257	-.27621	.35579	1.23692	2307	-.41834	.31866	1.15024
2208	-.27750	.34836	1.24121	2258	-.26050	.35629	1.24174	2308	-.41079	.31733	1.15216
2209	-.29416	.35012	1.23873	2259	-.25086	.35200	1.24012	2309	-.40371	.31689	1.15511
2210	-.30979	.34963	1.23397	2260	-.24446	.35517	1.24437	2310	-.39844	.32991	1.16574
2211	-.32557	.34866	1.22980	2261	-.23591	.35295	1.24469	2311	-.38898	.34048	1.17529
2212	-.34089	.34842	1.22476	2262	-.22901	.35680	1.25009	2312	-.38342	.34186	1.17729
2213	-.35724	.34800	1.21966	2263	-.21913	.34829	1.24544	2313	-.37862	.34953	1.18427
2214	-.37225	.34446	1.21349	2264	-.21213	.35476	1.25239	2314	-.36645	.35818	1.19327
2215	-.38648	.34132	1.20769	2265	-.20361	.35663	1.25662	2315	-.35846	.35641	1.19463
2216	-.39742	.33017	1.19625	2266	-.19590	.35722	1.25856	2316	-.35072	.35698	1.19659
2217	-.41764	.31807	1.18017	2267	-.18033	.35802	1.26285	2317	-.34298	.35736	1.19879
2218	-.42972	.31238	1.16968	2268	-.17174	.35555	1.26347	2318	-.33598	.36100	1.20386
2219	-.44397	.31068	1.16289	2269	-.16384	.35748	1.26742	2319	-.32796	.36148	1.20661
2220	-.45711	.30742	1.15439	2270	-.15539	.35622	1.26890	2320	-.32001	.36352	1.20983
2221	-.47089	.30594	1.14638	2271	-.14775	.35670	1.27094	2321	-.31210	.36377	1.21224
2222	-.48174	.29572	1.13356	2272	-.14010	.35695	1.27326	2322	-.30424	.36441	1.21474
2223	-.49279	.28895	1.12455	2273	-.13155	.35748	1.27555	2323	-.29748	.37034	1.22113
2224	-.50224	.28383	1.11808	2274	-.12510	.36080	1.27966	2324	-.29034	.37053	1.22341
2225	-.50933	.27555	1.11078	2275	-.11659	.36105	1.28168	2325	-.28148	.37081	1.22614
2226	-.50290	.28507	1.10757	2276	-.14600	.36035	1.26365	2326	-.27356	.36882	1.22646
2227	-.49907	.28544	1.10953	2277	-.16205	.36253	1.26142	2327	-.26454	.36636	1.22657
2228	-.49435	.28910	1.11336	2278	-.21113	.36196	1.24827	2328	-.25734	.36641	1.22900
2229	-.48943	.29173	1.11685	2279	-.22737	.36238	1.24399	2329	-.24866	.36683	1.23147
2230	-.48439	.29633	1.12302	2280	-.24310	.36182	1.23929	2330	-.24189	.37055	1.23580
2231	-.47840	.29981	1.12816	2281	-.25866	.36137	1.23509	2331	-.23380	.37086	1.23820
2232	-.47194	.30102	1.13169	2282	-.27485	.36067	1.23038	2332	-.22620	.36896	1.23894
2233	-.46508	.30204	1.13506	2283	-.29084	.36063	1.22615	2333	-.21783	.36770	1.24037
2234	-.45933	.30419	1.13948	2284	-.30706	.36340	1.22437	2334	-.20999	.37141	1.24511
2235	-.45221	.30660	1.14577	2285	-.32228	.35935	1.21696	2335	-.20156	.37097	1.24794
2236	-.44692	.31054	1.15134	2286	-.33805	.35655	1.21080	2336	-.19327	.37033	1.24917
2237	-.43926	.31013	1.15445	2287	-.35330	.35615	1.20606	2337	-.18530	.36825	1.24907
2238	-.43225	.30980	1.15723	2288	-.36751	.35174	1.19880	2338	-.17803	.37284	1.25431
2239	-.42482	.30966	1.15992	2289	-.38069	.34369	1.18877	2339	-.16997	.37301	1.25680
2240	-.41900	.31384	1.16596	2290	-.39172	.33651	1.18139	2340	-.16034	.36898	1.25670
2241	-.41238	.31531	1.16987	2291	-.40141	.32673	1.17194	2341	-.14522	.37375	1.26382
2242	-.40630	.31823	1.17531	2292	-.40776	.31548	1.16097	2342	-.13756	.37164	1.26422
2243	-.39825	.32209	1.18033	2293	-.42198	.31555	1.15609	2343	-.12927	.37285	1.26739
2244	-.39347	.32947	1.18634	2294	-.43476	.31260	1.14738	2344	-.12314	.37287	1.26948
2245	-.38287	.33884	1.19611	2295	-.44902	.31353	1.14139	2345	-.12030	.37402	1.26967
2246	-.37531	.33910	1.19838	2296	-.46180	.30908	1.13112	2346	-.12770	.37498	1.25833
2247	-.37013	.34879	1.20729	2297	-.48763	.30146	1.11410	2347	-.15850	.37432	1.24975
2248	-.35518	.35152	1.21326	2298	-.49809	.29052	1.10488	2348	-.17565	.37573	1.24632
2249	-.34732	.35147	1.21544	2299	-.48857	.30757	1.10650	2349	-.19091	.37536	1.24151
2250	-.34003	.35173	1.21765	2300	-.48315	.30006	1.10292	2350	-.20764	.37482	1.23643

2351	-.22370	.37441	1.23143	2401	-.19733	.37970	1.23360	2451	-.32838	.37950	1.17793
2352	-.23929	.37097	1.22607	2402	-.18972	.38195	1.23765	2452	-.32046	.38037	1.17956
2353	-.25511	.37062	1.22119	2403	-.18254	.38228	1.23973	2453	-.31215	.38035	1.18240
2354	-.27155	.37170	1.21778	2404	-.17479	.38205	1.24145	2454	-.30457	.38081	1.18444
2355	-.28815	.37405	1.21581	2405	-.16617	.37934	1.24171	2455	-.29733	.38301	1.18842
2356	-.30362	.37186	1.21019	2406	-.15734	.38012	1.24439	2456	-.28994	.38705	1.19379
2357	-.31894	.37052	1.20540	2407	-.14240	.38579	1.25339	2457	-.28226	.38502	1.19415
2358	-.33538	.36980	1.20064	2408	-.13457	.38193	1.25180	2458	-.27331	.38667	1.19759
2359	-.35013	.36613	1.19289	2409	-.12675	.38531	1.25697	2459	-.26598	.38693	1.19976
2360	-.36341	.35852	1.18397	2410	-.12323	.38292	1.25504	2460	-.25762	.38742	1.20260
2361	-.37615	.35237	1.17649	2411	-.14052	.38726	1.24399	2461	-.25032	.38785	1.20461
2362	-.38604	.34347	1.16811	2412	-.15618	.38912	1.24115	2462	-.24198	.38752	1.20667
2363	-.39539	.33240	1.15810	2413	-.17324	.38626	1.23461	2463	-.23448	.38736	1.20882
2364	-.41382	.31904	1.14225	2414	-.18762	.38319	1.22805	2464	-.22685	.38765	1.21109
2365	-.42759	.31810	1.13538	2415	-.20468	.38482	1.22497	2465	-.21874	.38662	1.21213
2366	-.43955	.31335	1.12524.	2416	-.22038	.38161	1.21814	2466	-.21063	.38687	1.21461
2367	-.45272	.30969	1.11456	2417	-.23589	.37901	1.21177	2467	-.20296	.38681	1.21672
2368	-.46726	.31248	1.10951	2418	-.25211	.38172	1.21009	2468	-.19403	.38704	1.21952
2369	-.47084	.32214	1.10402	2419	-.26818	.38154	1.20605	2469	-.18638	.39073	1.22420
2370	-.45869	.32028	1.11040	2420	-.28359	.37963	1.20008	2470	-.17853	.38730	1.22393
2371	-.44937	.31538	1.11106	2421	-.29947	.38024	1.19630	2471	-.17113	.39022	1.22765
2372	-.44329	.31637	1.11528	2422	-.31503	.37925	1.19156	2472	-.16250	.38960	1.22953
2373	-.43488	.31563	1.11903	2423	-.33078	.37772	1.18564	2473	-.15411	.39015	1.23237
2374	-.42205	.31735	1.12694	2424	-.34639	.37737	1.18191	2474	-.14593	.39005	1.23471
2375	-.41597	.31698	1.12946	2425	-.35991	.37033	1.17278	2475	-.13833	.39239	1.23867
2376	-.40894	.31785	1.13415	2426	-.37238	.36195	1.16339	2476	-.13134	.39209	1.24022
2377	-.39177	.33436	1.15072	2427	-.38143	.35028	1.15345	2477	-.12677	.39226	1.24158
2378	-.38886	.34494	1.15963	2428	-.38925	.34039	1.14551	2478	-.13603	.39286	1.22887
2379	-.38298	.34443	1.16001	2429	-.39848	.33208	1.13754	2479	-.15172	.39512	1.22602
2380	-.37342	.35367	1.16834	2430	-.40473	.31792	1.12659	2480	-.16929	.39487	1.22213
2381	-.36961	.36667	1.17854	2431	-.41809	.31921	1.12050	2481	-.18460	.39445	1.21741
2382	-.36192	.36646	1.17965	2432	-.43034	.31521	1.11114	2482	-.20135	.39320	1.21145
2383	-.34824	.37366	1.18923	2433	-.44236	.31984	1.09537	2483	-.21653	.38975	1.20447
2384	-.34012	.37166	1.18972	2434	-.44012	.31929	1.09788	2484	-.23235	.38864	1.19977
2385	-.33251	.37202	1.19187	2435	-.43281	.31496	1.09842	2485	-.24776	.38895	1.19588
2386	-.32413	.37003	1.19242	2436	-.42584	.31677	1.10414	2486	-.26468	.39188	1.19429
2387	-.31621	.37127	1.19601	2437	-.41392	.32105	1.11414	2487	-.28043	.39188	1.18949
2388	-.30872	.37159	1.19817	2438	-.40216	.32352	1.12248	2488	-.29482	.38376	1.17958
2389	-.30125	.37563	1.20293	2439	-.39855	.32776	1.12532	2489	-.31040	.38458	1.17621
2390	-.29448	.38107	1.20942	2440	-.39447	.33259	1.12989	2490	-.32629	.38405	1.17142
2391	-.28628	.37856	1.20930	2441	-.39049	.33861	1.13533	2491	-.34233	.38659	1.16997
2392	-.27749	.37872	1.21212	2442	-.38409	.35026	1.14467	2492	-.35577	.37899	1.15979
2393	-.27014	.37923	1.21399	2443	-.37888	.35201	1.14607	2493	-.36816	.36993	1.15069
2394	-.26165	.37983	1.21618	2444	-.37354	.35347	1.14786	2494	-.37510	.35392	1.13814
2395	-.25363	.37661	1.21628	2445	-.36952	.36282	1.15527	2495	-.39129	.33475	1.12219
2396	-.24558	.37966	1.22069	2446	-.36379	.36854	1.16024	2496	-.39918	.32502	1.11382
2397	-.23872	.37992	1.22273	2447	-.35712	.37179	1.16383	2497	-.40874	.32053	1.10651
2398	-.23064	.38029	1.22506	2448	-.35058	.37512	1.16852	2498	-.42270	.32159	1.10053
2399	-.22278	.38076	1.22716	2449	-.34242	.37591	1.17034	2499	-.42300	.32116	1.08942
2400	-.20657	.37932	1.23089	2450	-.33583	.37920	1.17512	2500	-.41656	.31676	1.09030

2501	-.41039	.31977	1.09592	2551	-.33642	.38805	1.15033	2601	-.28674	.40259	1.15346
2502	-.40401	.31908	1.09892	2552	-.35058	.38376	1.14360	2602	-.30088	.39724	1.14685
2503	-.39865	.32051	1.10234	2553	-.37207	.36473	1.12678	2603	-.31539	.39149	1.13833
2504	-.39482	.32607	1.10692	2554	-.38473	.33716	1.10705	2604	-.33078	.39249	1.13535
2505	-.39153	.33153	1.11147	2555	-.40273	.32929	1.08824	2605	-.34607	.39109	1.13010
2506	-.38790	.33684	1.11528	2556	-.38899	.33068	1.09345	2606	-.36906	.37282	1.11306
2507	-.37440	.35953	1.13340	2557	-.38330	.34140	1.10078	2607	-.38282	.34595	1.09386
2508	-.37080	.36868	1.14029	2558	-.38119	.35027	1.10706	2608	-.38637	.33221	1.08368
2509	-.36616	.37425	1.14509	2559	-.37364	.35901	1.11386	2609	-.39093	.33492	1.07498
2510	-.35936	.37529	1.14613	2560	-.36931	.36348	1.11677	2610	-.38649	.33535	1.07655
2511	-.35270	.37762	1.14970	2561	-.36511	.37020	1.12151	2611	-.38396	.34603	1.08392
2512	-.34547	.37844	1.15175	2562	-.35542	.38697	1.13585	2612	-.38124	.35055	1.08723
2513	-.33857	.38308	1.15728	2563	-.34861	.38756	1.13747	2613	-.37922	.35905	1.09332
2514	-.33076	.38384	1.15962	2564	-.34090	.38808	1.13950	2614	-.37508	.36328	1.09582
2515	-.32375	.38537	1.16252	2565	-.33357	.38829	1.14177	2615	-.37117	.37032	1.10113
2516	-.31662	.38969	1.16738	2566	-.32574	.38863	1.14405	2616	-.36705	.37691	1.10599
2517	-.30837	.39009	1.16973	2567	-.31957	.39495	1.15020	2617	-.36072	.37557	1.10636
2518	-.30097	.39014	1.17218	2568	-.31177	.39525	1.15248	2618	-.34289	.39261	1.12181
2519	-.29300	.39058	1.17439	2569	-.30419	.39536	1.15499	2619	-.33545	.39356	1.12436
2520	-.28500	.39087	1.17678	2570	-.29656	.39591	1.15691	2620	-.32776	.39337	1.12726
2521	-.27774	.39233	1.17930	2571	-.28885	.39883	1.16071	2621	-.32043	.39457	1.13008
2522	-.26202	.39270	1.18424	2572	-.28044	.39737	1.16183	2622	-.31310	.39486	1.13225
2523	-.25369	.39536	1.18861	2573	-.27443	.40463	1.16929	2623	-.30679	.40168	1.13957
2524	-.24574	.39190	1.18780	2574	-.26510	.40204	1.16911	2624	-.29748	.39626	1.13705
2525	-.23738	.39203	1.19050	2575	-.25804	.40183	1.17119	2625	-.28493	.40655	1.14700
2526	-.22961	.39309	1.19242	2576	-.24932	.40062	1.17209	2626	-.27637	.40547	1.14774
2527	-.22305	.39686	1.19782	2577	-.24175	.40066	1.17463	2627	-.26891	.40560	1.15013
2528	-.21499	.39619	1.19961	2578	-.23369	.40120	1.17731	2628	-.25314	.40637	1.15460
2529	-.19921	.39753	1.20522	2579	-.22577	.39696	1.17635	2629	-.24465	.40696	1.15737
2530	-.19050	.39787	1.20780	2580	-.21867	.40262	1.18247	2630	-.23659	.40718	1.15986
2531	-.18266	.39752	1.20972	2581	-.21034	.40312	1.18473	2631	-.22916	.40979	1.16391
2532	-.17437	.39496	1.20974	2582	-.20253	.40304	1.18749	2632	-.22250	.41284	1.16779
2533	-.16681	.39541	1.21175	2583	-.19520	.40552	1.19115	2633	-.21403	.40978	1.16791
2534	-.15894	.39911	1.21769	2584	-.18597	.40296	1.19150	2634	-.20634	.41068	1.17122
2535	-.15011	.39916	1.21946	2585	-.17760	.39916	1.19132	2635	-.19866	.41107	1.17339
2536	-.14230	.39455	1.21825	2586	-.17038	.40101	1.19451	2636	-.19046	.41097	1.17632
2537	-.13404	.39479	1.22076	2587	-.16270	.40117	1.19694	2637	-.18164	.40663	1.17523
2538	-.12923	.39454	1.22096	2588	-.15411	.40233	1.20023	2638	-.17351	.40817	1.17849
2539	-.14765	.39987	1.20945	2589	-.14612	.40550	1.20445	2639	-.16652	.40829	1.18075
2540	-.16459	.39996	1.20533	2590	-.13760	.40462	1.20604	2640	-.15847	.40837	1.18340
2541	-.17999	.40019	1.20154	2591	-.13156	.40963	1.21151	2641	-.14144	.40748	1.18797
2542	-.19629	.40022	1.19651	2592	-.14389	.40853	1.19750	2642	-.13401	.40558	1.18696
2543	-.21251	.39707	1.19004	2593	-.16050	.40579	1.19042	2643	-.13908	.40973	1.18086
2544	-.22817	.39862	1.18633	2594	-.17573	.40524	1.18585	2644	-.15552	.40502	1.17215
2545	-.24383	.39994	1.18354	2595	-.19193	.40486	1.18077	2645	-.17090	.40842	1.17036
2546	-.25966	.39672	1.17671	2596	-.20837	.40644	1.17795	2646	-.18792	.40858	1.16610
2547	-.27536	.39612	1.17204	2597	-.22391	.40628	1.17283	2647	-.20394	.41027	1.16268
2548	-.29110	.39534	1.16760	2598	-.23919	.40341	1.16637	2648	-.21970	.41029	1.15778
2549	-.30585	.39187	1.16142	2599	-.25546	.40537	1.16312	2649	-.23486	.41110	1.15402
2550	-.32219	.39257	1.15798	2600	-.27134	.40361	1.15806	2650	-.25125	.41016	1.14836

2651	-.26670	.40946	1.14391
2652	-.28243	.40810	1.13899
2653	-.29640	.40101	1.13291
2654	-.30966	.39277	1.12262
2655	-.32574	.39806	1.12235
2656	-.34009	.39384	1.11500
2657	-.36506	.37778	1.09770
2658	-.37432	.36763	1.08976
2659	-.38089	.35660	1.08230
2660	-.38463	.35500	1.06964
2661	-.38149	.36226	1.07531
2662	-.37765	.36770	1.07959
2663	-.37293	.37145	1.08229
2664	-.36925	.38092	1.08909
2665	-.36298	.38158	1.09048
2666	-.35757	.38693	1.09560
2667	-.34226	.38899	1.10002
2668	-.33726	.39751	1.10868
2669	-.32253	.39845	1.11376
2670	-.31484	.39891	1.11584
2671	-.30749	.39897	1.11829
2672	-.29942	.39916	1.12077
2673	-.29399	.40348	1.12497
2674	-.28679	.40666	1.12705
2675	-.27914	.40733	1.12887
2676	-.27116	.40778	1.13106
2677	-.26351	.40931	1.13358
2678	-.25549	.40959	1.13598
2679	-.24826	.41243	1.14026
2680	-.23998	.41273	1.14273
2681	-.23251	.41309	1.14486
2682	-.22405	.41334	1.14802
2683	-.21696	.41375	1.14995
2684	-.20955	.41349	1.15222
2685	-.20147	.41213	1.15374
2686	-.18542	.41219	1.15917
2687	-.17722	.41262	1.16146
2688	-.16949	.41277	1.16392
2689	-.16186	.41048	1.16464
2690	-.15399	.41069	1.16707
2691	-.14552	.41082	1.16980
2692	-.13537	.41404	1.17524
2693	-.15154	.41022	1.15808
2694	-.16645	.41039	1.15280
2695	-.18282	.41188	1.14885
2696	-.19886	.41214	1.14423
2697	-.21451	.41325	1.14043
2698	-.22991	.41302	1.13542
2699	-.24572	.41273	1.13035
2700	-.26177	.41246	1.12581
2701	-.27590	.40542	1.11787
2702	-.29055	.40384	1.11474
2703	-.30492	.40235	1.11164
2704	-.31964	.40247	1.10648
2705	-.33263	.39424	1.09646
2706	-.34708	.39194	1.08973
2707	-.36079	.38648	1.08314
2708	-.37064	.37481	1.07289
2709	-.37511	.38183	1.06805
2710	-.36941	.38039	1.06838
2711	-.36365	.38043	1.06918
2712	-.35876	.39008	1.07726
2713	-.35189	.39254	1.08062
2714	-.34440	.39296	1.08268
2715	-.33631	.39291	1.08551
2716	-.32917	.39340	1.08903
2717	-.32232	.39315	1.09166
2718	-.31488	.39418	1.09351
2719	-.30124	.39593	1.10006
2720	-.29398	.40005	1.10443
2721	-.28842	.40677	1.10854
2722	-.28164	.40755	1.10993
2723	-.27444	.41070	1.11321
2724	-.26698	.41532	1.11771
2725	-.25978	.41607	1.11988
2726	-.25086	.41701	1.12293
2727	-.24360	.41503	1.12317
2728	-.23561	.41742	1.12765
2729	-.22791	.41505	1.12853
2730	-.21946	.41486	1.13049
2731	-.21212	.41511	1.13269
2732	-.20494	.41480	1.13551
2733	-.19707	.41752	1.13954
2734	-.18928	.41509	1.14050
2735	-.18085	.41316	1.14169
2736	-.17272	.41488	1.14587
2737	-.16441	.41140	1.14599
2738	-.15733	.41175	1.14856
2739	-.15003	.41127	1.15166
2740	-.14141	.41230	1.15448
2741	-.13916	.41273	1.15474
2742	-.14752	.41261	1.14343
2743	-.16245	.41272	1.13819
2744	-.17821	.41587	1.13477
2745	-.19465	.41859	1.13106
2746	-.20979	.41878	1.12565
2747	-.22505	.41848	1.12078
2748	-.24123	.41835	1.11542
2749	-.25695	.41787	1.11063
2750	-.27184	.41378	1.10530
2751	-.28563	.40893	1.10063
2752	-.29827	.39889	1.09300
2753	-.31160	.39701	1.08616
2754	-.32573	.39687	1.08208
2755	-.34022	.39601	1.07478
2756	-.35551	.39541	1.07026
2757	-.35682	.39509	1.05900
2758	-.35227	.39530	1.06198
2759	-.34545	.39776	1.06529
2760	-.33701	.39536	1.06655
2761	-.33084	.40428	1.07601
2762	-.32363	.40168	1.07762
2763	-.31718	.40093	1.08072
2764	-.30941	.39882	1.08079
2765	-.30237	.39914	1.08339
2766	-.29402	.39564	1.08305
2767	-.28943	.40446	1.08929
2768	-.28297	.40867	1.09219
2769	-.27626	.41172	1.09419
2770	-.26856	.41115	1.09530
2771	-.26188	.41805	1.10072
2772	-.25441	.42052	1.10431
2773	-.24625	.42112	1.10695
2774	-.23892	.42154	1.10895
2775	-.23061	.42172	1.11157
2776	-.22311	.42171	1.11416
2777	-.21413	.41410	1.11147
2778	-.20736	.41823	1.11682
2779	-.20091	.42009	1.12139
2780	-.19267	.41777	1.12241
2781	-.18502	.41765	1.12517
2782	-.17662	.41799	1.12765
2783	-.16772	.41491	1.12865
2784	-.16089	.41408	1.13202
2785	-.15351	.41250	1.13299
2786	-.14530	.41246	1.13469
2787	-.14024	.41092	1.13487
2788	-.15878	.41256	1.12310
2789	-.17449	.42008	1.12130
2790	-.18927	.41162	1.10933
2791	-.20539	.42049	1.11021
2792	-.22141	.42503	1.10793
2793	-.23682	.42284	1.10126
2794	-.25245	.42221	1.09668
2795	-.26663	.41709	1.08992
2796	-.28046	.40998	1.08467
2797	-.29207	.40027	1.07821
2798	-.30567	.40012	1.07371
2799	-.31934	.40130	1.06935
2800	-.33487	.40253	1.06261

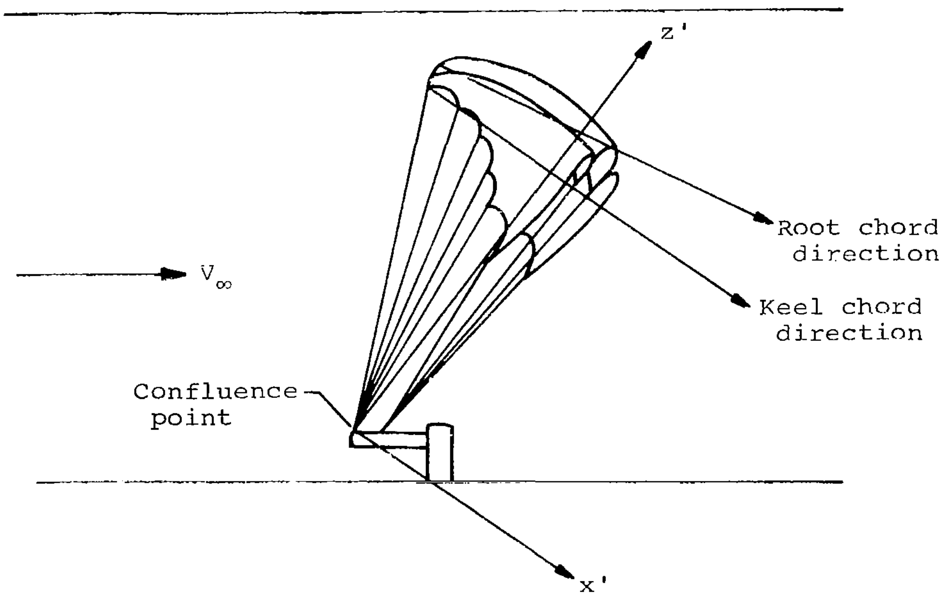
2801	-.33751	.40712	1.05569
2802	-.33154	.40149	1.05492
2803	-.31620	.40009	1.06124
2804	-.30853	.39399	1.06109
2805	-.30229	.39551	1.06476
2806	-.29502	.39589	1.06679
2807	-.28938	.39744	1.06966
2808	-.28489	.40721	1.07522
2809	-.27786	.40847	1.07611
2810	-.27198	.41754	1.08135
2811	-.26514	.41909	1.08356
2812	-.25837	.42792	1.09010
2813	-.24984	.42275	1.08896
2814	-.24138	.42350	1.09152
2815	-.23458	.42619	1.09513
2816	-.22618	.42586	1.09786
2817	-.21825	.42268	1.09754
2818	-.21065	.42239	1.10048
2819	-.20339	.42229	1.10308
2820	-.19586	.41823	1.10371
2821	-.18786	.41706	1.10501
2822	-.18061	.41890	1.10917
2823	-.17154	.41327	1.10883
2824	-.16375	.41257	1.11234
2825	-.15668	.41233	1.11505
2826	-.14948	.41276	1.11700
2827	-.14326	.41293	1.11836
2828	-.15457	.41082	1.10575
2829	-.16984	.41597	1.10283
2830	-.18488	.41626	1.09621
2831	-.20026	.41852	1.09161
2832	-.21560	.42186	1.08858
2833	-.23174	.42457	1.08498
2834	-.24735	.42651	1.08189
2835	-.26300	.42490	1.07849
2836	-.27541	.41398	1.07034
2837	-.29920	.39841	1.05957
2838	-.31203	.39741	1.05194
2839	-.31562	.41074	1.04984
2840	-.30911	.39898	1.04605
2841	-.30176	.39454	1.04613
2842	-.29545	.39564	1.05027
2843	-.29042	.39956	1.05452
2844	-.28489	.40398	1.05668
2845	-.27923	.40833	1.05897
2846	-.27242	.41161	1.06127
2847	-.26639	.41844	1.06523
2848	-.26005	.42122	1.06804
2849	-.25240	.42806	1.07263
2850	-.24509	.42848	1.07463
2851	-.23676	.42840	1.07757
2852	-.22922	.42555	1.07790
2853	-.22112	.42606	1.08062
2854	-.21406	.42543	1.08319
2855	-.20598	.42547	1.08591
2856	-.19846	.42090	1.08548
2857	-.18360	.42071	1.09075
2858	-.17658	.41982	1.09424
2859	-.16742	.41339	1.09325
2860	-.15973	.41246	1.09701
2861	-.15973	.41246	1.09701
2862	-.15234	.40845	1.09651
2863	-.14547	.40861	1.09866
2864	-.15085	.41269	1.09198
2865	-.16577	.41333	1.08609
2866	-.18126	.41766	1.08177
2867	-.19600	.42127	1.07742
2868	-.21114	.42339	1.07305
2869	-.22731	.42867	1.07196
2870	-.24195	.42547	1.06461
2871	-.25701	.42394	1.06013
2872	-.26984	.41614	1.05506
2873	-.28167	.40621	1.04949
2874	-.29290	.39682	1.04480
2875	-.29236	.39062	1.03103
2876	-.28290	.39895	1.03957
2877	-.27880	.40728	1.04370
2878	-.27322	.41197	1.04439
2879	-.26662	.41307	1.04531
2880	-.26088	.42000	1.04952
2881	-.25452	.42439	1.05263
2882	-.23952	.42739	1.05755
2883	-.23084	.42774	1.06007
2884	-.22422	.42312	1.06060
2885	-.21541	.42136	1.06068
2886	-.20899	.42195	1.06439
2887	-.20121	.42328	1.06765
2888	-.19391	.42287	1.07064
2889	-.18655	.41730	1.07092
2890	-.17851	.41735	1.07359
2891	-.17181	.41701	1.07741
2892	-.16400	.41277	1.07849
2893	-.15599	.41245	1.08162
2894	-.14912	.41174	1.08262
2895	-.16189	.41203	1.07122
2896	-.17676	.41705	1.06626
2897	-.19138	.41841	1.05957
2898	-.20741	.42610	1.05940
2899	-.22211	.42612	1.05436
2900	-.23661	.42675	1.04865
2901	-.25171	.42572	1.04473
2902	-.26454	.41491	1.03776
2903	-.28056	.41650	1.03094
2904	-.27447	.40598	1.02415
2905	-.26907	.41354	1.02906
2906	-.26329	.42090	1.03268
2907	-.25611	.42223	1.03353
2908	-.24847	.42339	1.03475
2909	-.24060	.42528	1.03683
2910	-.23337	.42672	1.04036
2911	-.22530	.42771	1.04414
2912	-.21863	.42455	1.04518
2913	-.21141	.42465	1.04697
2914	-.20438	.42433	1.04976
2915	-.19684	.42419	1.05306
2916	-.19004	.42419	1.05537
2917	-.18278	.41824	1.05556
2918	-.17486	.41514	1.05758
2919	-.16833	.41465	1.06039
2920	-.15988	.40660	1.05920
2921	-.15111	.40681	1.06246
2922	-.14909	.40965	1.06467
2923	-.15957	.41806	1.05980
2924	-.17304	.41439	1.04976
2925	-.18716	.41559	1.04294
2926	-.20180	.42223	1.04153
2927	-.21588	.42278	1.03605
2928	-.24590	.42274	1.02585
2929	-.26078	.42027	1.02373
2930	-.26538	.42499	1.01709
2931	-.25810	.41832	1.01444
2932	-.25154	.42332	1.01778
2933	-.24401	.42413	1.01938
2934	-.23624	.42793	1.02351
2935	-.22000	.42416	1.02642
2936	-.21299	.42396	1.02904
2937	-.20048	.42302	1.03444
2938	-.19352	.42234	1.03763
2939	-.17833	.41589	1.04013
2940	-.17089	.41521	1.04345
2941	-.16462	.41153	1.04512
2942	-.15618	.41123	1.04833
2943	-.15216	.41104	1.04994
2944	-.16990	.41377	1.03459
2945	-.19771	.41898	1.02435
2946	-.21032	.42556	1.02254
2947	-.22380	.42015	1.01236
2948	-.24042	.42212	1.00929
2949	-.24264	.42224	.99968
2950	-.23871	.42666	1.00504

2951	-.23032	.42721	1.00725
2952	-.22329	.42940	1.01083
2953	-.21528	.42800	1.01360
2954	-.20831	.42403	1.01471
2955	-.19557	.41837	1.01709
2956	-.18846	.41759	1.02045
2957	-.17548	.41704	1.02554
2958	-.16751	.41061	1.02564
2959	-.16046	.40970	1.02913
2960	-.15487	.40758	1.02872
2961	-.16517	.40709	1.01723
2962	-.19375	.41580	1.00887
2963	-.20572	.42299	1.00700
2964	-.21971	.42397	.99998
2965	-.22141	.42518	.99098
2966	-.21771	.42962	.99610
2967	-.21000	.42540	.99615
2968	-.20289	.42150	.99841
2969	-.19116	.41399	1.00010
2970	-.18401	.41566	1.00483
2971	-.17769	.41531	1.00741
2972	-.16370	.40965	1.01195
2973	-.15715	.40813	1.01341
2974	-.16094	.40365	1.00040
2975	-.20025	.42187	.99132
2976	-.21582	.42784	.98963
2977	-.20114	.42261	.98056
2978	-.19735	.42185	.98262
2979	-.18593	.41332	.98613
2980	-.17351	.40800	.98988
2981	-.16677	.40372	.99043
2982	-.15819	.40001	.99148
2983	-.16268	.40388	.97897
2984	-.17007	.40460	.97559
2985	-.18044	.40674	.96952
2986	-.18514	.42096	.97347
2987	-.17983	.41531	.96839
2988	-.16583	.40209	.95869

APPENDIX D

TABULATION OF CANOPY COORDINATES FOR TWIN-KEEL PARAWING

The following pages are a reproduction of the printed computer output for the canopy coordinates obtained photogrammetrically at the Langley Research Center from the stereo photographs of the twin-keel parawing in the wind tunnel. The coordinate system used in the data presentation is illustrated in the sketch below.



The origin of the axis system is on the sting at the confluence point of all the rigging lines except those on the trailing edge. The positive x' direction is parallel to the keel chord direction, which differs slightly from the root chord direction, with positive x' downstream. The positive z' direction is upward towards the canopy, and the positive y' direction is consistent with a right-hand system.

The data consist of a point identification number, followed by the x', y', and z' coordinates of the point, nondimensionalized by the characteristic length h_k, which is 75 inches for the parawing tested. Points 1-12 are the canopy line attachment points for keel lines 1-12, respectively. The six leading-edge line attachment points are listed as points 13-18. For the remainder of the coordinates, generally, a single streamwise set of points having about the same y' coordinate was read, with the sets starting near the vertical plane of symmetry and moving out toward the tip.

Point No.	x'/h_k	y'/h_k	z'/h_k	
1	-.41920	.10703	.86478	K1
2	-.38668	.13789	.88237	K2
3	-.33674	.14857	.89325	K3
4	-.27954	.16197	.90401	K4
5	-.22207	.17916	.93441	K5
6	-.16443	.17318	.93674	K6
7	-.11003	.16909	.94245	K7
8	-.04790	.17185	.94557	K8
9	.00896	.16517	.93223	K9
10	.06727	.15954	.92205	K10
11	.11607	.15628	.89836	K11
12	.15994	.15061	.86478	K12
13	-.38303	.17650	.82932	LE1
14	-.30536	.26011	.81751	LE2
15	-.23315	.34008	.78933	LE3
16	-.14934	.40491	.72147	LE4
17	-.06162	.42228	.65039	LE5
18	.02084	.36495	.57049	LE6
[illegible]	-.48273	.01552	.94830	
[illegible]	-.48610	.00622	.94999	
[illegible]	-.48780	.01687	.96861	
[illegible]	-.48478	.02689	.96133	
23	-.48155	.03106	.94659	
24	-.47942	.04186	.93856	
25	-.47577	.05374	.93150	
26	-.47534	.06436	.92592	
27	-.47477	.07617	.92056	
28	-.47222	.08537	.91757	
29	-.47014	.09019	.90510	
30	-.46633	.09701	.89360	
31	-.46470	.10282	.87967	
32	-.45754	.10845	.87026	
33	-.44772	.11461	.86722	
34	-.43404	.11591	.85867	
35	-.49393	.01736	.94905	
36	-.50335	.02229	.94390	
37	-.47140	.00116	.98910	
38	-.45855	.00000	.99241	
39	-.44503	.00050	.99417	
40	-.43236	.00187	.99482	
41	-.41910	.00211	.99619	
42	-.40589	.00102	.99912	
43	-.39253	.00228	.99897	
44	-.37979	.00417	.99737	
45	-.36690	.00381	.99918	
46	-.35326	.00237	1.00206	
47	-.34029	.00241	1.00205	
48	-.32659	.00147	1.00348	
49	-.31418	.00310	1.00200	
50	-.30098	.00485	1.00127	

Suspension line attachment points

Point No.	x'/h_k	y'/h_k	z'/h_k
51	-.28740	.00437	1.00346
52	-.27411	.00299	1.00242
53	-.25087	.00136	1.00887
54	-.23919	.00293	1.00656
55	-.22581	.00244	1.00863
56	-.21177	.00110	1.01179
57	-.19864	.00031	1.01490
58	-.18583	.00225	1.01271
59	-.17361	.00460	1.01164
60	-.16136	.00512	1.01643
61	-.14768	.00319	1.01989
62	-.13398	.00240	1.02091
63	-.12140	.00425	1.01930
64	-.10768	.00199	1.02255
65	-.09430	.00199	1.02322
66	-.08042	.00072	1.02562
67	-.06704	.00001	1.02658
68	-.05550	.00395	1.02203
69	-.04057	.00040	1.02698
70	-.02732	.00113	1.02598
71	-.01524	.00274	1.02308
72	-.00063	.00007	1.02568
73	.01087	.00377	1.02023
74	.02540	.00113	1.02320
75	.03814	.00232	1.02095
76	.05237	.00065	1.02125
77	.06560	.00081	1.01918
78	.07885	.00001	1.01744
79	.09098	.00001	1.01429
80	.10396	.00093	1.00930
81	.11815	.00136	1.00878
82	.12988	.00021	1.00315
83	.14116	.00227	.99656
84	.15412	.00087	.99407
85	.16727	.00049	.99093
86	.18203	.00232	.98978
87	.19267	.00000	.98237
88	.20505	.00102	.97733
89	.21737	.00027	.97407
90	-.49483	.00333	.95219
91	-.50400	.00697	.94845
92	-.48346	.01185	.98245
93	-.47150	.01277	.98814
94	-.45852	.01186	.98962
95	-.44519	.01156	.99211
96	-.43229	.01212	.99479
97	-.41878	.01125	.99589
98	-.40579	.01167	.99762
99	-.39265	.01281	.99981
100	-.37938	.01291	1.00127

101	-.36634	.00978	.99848	151	-.49506	.00749	.95082	201	.16906	.02831	.99133
102	-.35237	.01279	1.00329	152	-.48262	.02267	.97847	202	.17996	.02570	.98336
103	-.33968	.01116	1.00146	153	-.47057	.02407	.98349	203	.19260	.02619	.97932
104	-.32675	.00932	.99976	154	-.45779	.02550	.98784	204	.20397	.02440	.97240
105	-.31352	.01124	1.00303	155	-.44466	.02489	.98989	205	.21528	.02415	.96723
106	-.29992	.01155	1.00486	156	-.43132	.02756	.99557	206	-.49383	.02047	.94927
107	-.28705	.01033	1.00544	157	-.41839	.02294	.99196	207	-.49370	.01849	.94713
108	-.27341	.01271	1.00490	158	-.40504	.02419	.99538	208	-.49370	.01849	.94713
109	-.26405	.01267	.99518	159	-.39186	.02460	.99658	209	-.49370	.01849	.94713
110	-.25100	.01324	1.00747	160	-.37884	.02424	.99744	210	-.46967	.03638	.97962
111	-.25082	.01374	1.00783	161	-.36571	.02437	.99923	211	-.45763	.03520	.98028
112	-.23904	.01052	1.00708	162	-.35174	.02513	1.00082	212	-.44381	.03710	.9851[illegible]
113	-.22507	.01189	1.01057	163	-.33930	.02419	.99986	213	-.43096	.03492	.9848[illegible]
114	-.21141	.01219	1.01226	164	-.32616	.02224	.99820	214	-.41769	.03697	.98977
115	-.19903	.01024	1.01078	165	-.31340	.02266	.99931	215	-.40473	.03497	.98905
116	-.18576	.01076	1.01298	166	-.29948	.02348	1.00121	216	-.39128	.03717	.99278
117	-.17282	.01043	1.01430	167	-.28689	.02309	1.00256	217	-.37823	.03519	.99172
118	-.16081	.01052	1.01901	168	-.27407	.02403	1.00127	218	-.36522	.03634	.99462
119	-.14719	.01088	1.02106	169	-.25129	.02384	1.00299	219	-.35130	.03590	.99479
120	-.13396	.01080	1.02124	170	-.23803	.02546	1.00850	220	-.33875	.03564	.99517
121	-.12108	.00908	1.01943	171	-.22471	.02502	1.00893	221	-.32539	.03578	.99584
122	-.10747	.01075	1.02183	172	-.21126	.02501	1.01070	222	-.31281	.03615	.99652
123	-.09408	.01104	1.02288	173	-.19809	.02461	1.01115	223	-.29909	.03562	.99715
124	-.08216	.00814	1.01999	174	-.18600	.02164	1.00891	224	-.28752	.03465	.99817
125	-.06842	.00947	1.02213	175	-.17268	.02266	1.01247	225	-.27475	.03587	.9966[illegible]
126	-.05485	.01053	1.02368	176	-.16025	.02290	1.01611	226	-.26504	.03775	.99246
127	-.04063	.01190	1.02541	177	-.14763	.02213	1.01738	227	-.25134	.03334	.99686
128	-.02825	.01035	1.02327	178	-.13429	.02287	1.01862	228	-.25134	.03334	.99686
129	-.01471	.01084	1.02327	179	-.12055	.02357	1.01981	229	-.23844	.03560	1.00220
130	-.00132	.01134	1.02331	180	-.10734	.02400	1.02080	230	-.22543	.03491	1.00323
131	.01208	.01203	1.02349	181	-.09436	.02285	1.02027	231	-.21153	.03627	1.00572
132	.02585	.01250	1.02317	182	-.08050	.02504	1.02379	232	-.19839	.03714	1.0083[illegible]
133	.03864	.01235	1.02245	183	-.06782	.02313	1.02127	233	-.18523	.03643	1.0087[illegible]
134	.05208	.01161	1.01992	184	-.05533	.02267	1.02088	234	-.17237	.03624	1.0097[illegible]
135	.06523	.01247	1.01850	185	-.04099	.02395	1.02271	235	-.16073	.03285	1.00827
136	.07810	.01215	1.01544	186	-.02762	.02405	1.02281	236	-.14801	.03459	1.01353
137	.09230	.01416	1.01521	187	-.01497	.02312	1.02127	237	-.13487	.03464	1.01427
138	.10545	.01414	1.01180	188	-.00155	.02421	1.02142	238	-.12087	.03612	1.01654
139	.11671	.01168	1.00520	189	.01228	.02499	1.02176	239	-.10838	.03552	1.01655
140	.13022	.01202	1.00167	190	.02640	.02614	1.02263	240	-.09607	.03350	1.01515
141	.14228	.01229	.99800	191	.03974	.02644	1.02263	241	-.08123	.03672	1.01966
142	.15554	.01367	.99578	192	.05169	.02391	1.01710	242	-.06867	.03551	1.01778
143	.16642	.01126	.98834	193	.06463	.02380	1.01507	243	-.05571	.03504	1.01758
144	.18064	.01297	.98619	194	.07832	.02492	1.01393	244	-.04301	.03324	1.01588
145	.19302	.01283	.98155	195	.09128	.02481	1.01065	245	-.02919	.03527	1.01815
146	.20535	.01254	.97708	196	.10463	.02545	1.00784	246	-.01619	.03393	1.0159[illegible]
147	.21575	.01077	.96983	197	.11747	.02555	1.00441	247	-.00322	.03453	1.01544
148	-.49506	.00749	.95082	198	.13028	.02583	1.00083	248	.00940	.03222	1.01267
149	-.49506	.00749	.95082	199	.14350	.02727	.99860	249	.02523	.03698	1.01732
150	-.49506	.00749	.95082	200	.15391	.02442	.99127	250	.03647	.03373	1.01294

251	.05103	.03633	1.01399	301	-.06820	.05031	1.01861	351	-.18354	.06237	1.00374
252	.06458	.03772	1.01359	302	-.05658	.04659	1.01428	352	-.17051	.06251	1.00504
253	.07864	.03942	1.01344	303	-.04178	.04937	1.01690	353	-.15991	.06063	1.00518
254	.09069	.03772	1.00805	304	-.02969	.04791	1.01537	354	-.14727	.06084	1.00805
255	.10422	.03830	1.00526	305	-.01524	.04983	1.01674	355	-.13385	.06214	1.01041
256	.11683	.03836	1.00192	306	-.00159	.05030	1.01650	356	-.12094	.06153	1.01096
257	.12979	.03887	.99840	307	.00959	.04630	1.01092	357	-.10833	.06121	1.01133
258	.14233	.03925	.99448	308	.02373	.04784	1.01210	358	-.09498	.06214	1.01350
259	.15402	.03866	.98884	309	.03733	.04831	1.01189	359	-.08195	.06133	1.01299
260	.16617	.03791	.98353	310	.05136	.04951	1.01157	360	-.06868	.06122	1.01304
261	.17900	.03815	.97904	311	.06440	.05006	1.01051	361	-.05544	.06181	1.01342
262	.19166	.03872	.97399	312	.07837	.05177	1.01008	362	-.04224	.06142	1.01313
263	.20291	.03720	.96683	313	.09027	.05043	1.00501	363	-.02932	.06119	1.01248
264	.21372	.03679	.96191	314	.10278	.04932	1.00022	364	-.01568	.06200	1.01289
265	-.49188	.03048	.94221	315	.11588	.04981	.99668	365	-.00350	.06084	1.01075
266	-.49188	.03048	.94221	316	.12866	.05006	.99312	366	.01155	.06302	1.01210
267	-.49188	.03048	.94221	317	.14095	.05006	.98867	367	.02292	.05916	1.00693
268	-.48184	.05719	.98230	318	.15299	.05082	.98486	368	.03722	.06186	1.00929
269	-.46873	.04646	.97208	319	.16608	.05053	.97982	369	.05015	.06082	1.00653
270	-.45567	.04759	.97584	320	.17692	.04946	.97294	370	.06512	.06451	1.00918
271	-.44336	.04590	.97719	321	.18827	.04819	.96581	371	.07786	.06407	1.00623
272	-.42997	.04928	.98367	322	.20058	.04853	.96075	372	.08913	.06146	.99991
273	-.41688	.04679	.98306	323	.21110	.04851	.95588	373	.10242	.06214	.99711
274	-.40342	.04945	.98779	324	-.49011	.03970	.93437	374	.11523	.06197	.99297
275	-.39087	.04811	.98799	325	-.49011	.03970	.93437	375	.12787	.06260	.98911
276	-.37731	.04840	.98956	326	-.49011	.03970	.93437	376	.13994	.06268	.98431
277	-.36411	.04868	.99069	327	-.46699	.05886	.96687	377	.15205	.06281	.97977
278	-.35081	.04751	.99028	328	-.47931	.06333	.96881	378	.16360	.06112	.97291
279	-.33811	.04861	.99227	329	-.45444	.06049	.97121	379	.17559	.06161	.96809
280	-.32434	.04664	.99046	330	-.44146	.06061	.97380	380	.18589	.05924	.95940
281	-.31223	.04618	.98973	331	-.42898	.06051	.97676	381	.19771	.05918	.95358
282	-.29819	.04723	.99260	332	-.41550	.06154	.98129	382	.20789	.05929	.94865
283	-.28728	.04546	.99136	333	-.40263	.06062	.98159	383	-.48839	.05333	.93066
284	-.27495	.04984	.99521	334	-.38969	.05975	.98183	384	-.48839	.05333	.93066
285	-.26251	.05113	.99724	335	-.37648	.06262	.98689	385	-.48839	.05333	.93066
286	-.26251	.05113	.99724	336	-.36377	.05945	.98472	386	-.46484	.07136	.96205
287	-.24964	.05107	1.00039	337	-.34969	.06292	.98939	387	-.45284	.07061	.96318
288	-.23735	.04839	.99958	338	-.33703	.06023	.98679	388	-.43982	.07008	.96553
289	-.22397	.04883	1.00218	339	-.32343	.06086	.98816	389	-.42676	.07221	.97109
290	-.21056	.05053	1.00545	340	-.31088	.05919	.99611	390	-.41396	.07262	.97441
291	-.19810	.04866	1.00449	341	-.29730	.06006	.98787	391	-.40105	.07364	.97749
292	-.18392	.05114	1.00872	342	-.28635	.05702	.98429	392	-.38871	.07157	.97642
293	-.17192	.04790	1.00610	343	-.27675	.06153	.98993	393	-.37531	.07199	.97826
294	-.16012	.04687	1.00754	344	-.26194	.06278	.99316	394	-.36201	.07336	.98158
295	-.14854	.04541	1.00885	345	-.24883	.06370	.99717	395	-.34830	.07273	.98174
296	-.13409	.04871	1.01331	346	-.26175	.06308	.99283	396	-.33534	.07507	.98493
297	-.12137	.04813	1.01354	347	-.23734	.05953	.99437	397	-.32222	.07333	.98310
298	-.10882	.04737	1.01309	348	-.22308	.06279	1.00047	398	-.30977	.07150	.98150
299	-.09633	.04526	1.01173	349	-.21023	.06181	1.00069	399	-.29615	.07272	.98355
300	-.08212	.04821	1.01547	350	-.19713	.06268	1.00279	400	-.27809	.07360	.98537

401	-.27809	.07360	.98537
402	-.26372	.07432	.98845
403	-.26077	.07432	.98845
404	-.24774	.07625	.99311
405	-.23574	.07572	.99494
406	-.22225	.07508	.99678
407	-.20952	.07410	.99735
408	-.19716	.07197	.99603
409	-.18347	.07167	.99635
410	-.17005	.07371	.99949
411	-.15832	.07186	.99961
412	-.14754	.07269	1.00244
413	-.13352	.07517	1.00792
414	-.12098	.07452	1.00801
415	-.10790	.07503	1.00971
416	-.09512	.07363	1.00949
417	-.08203	.07454	1.01150
418	-.06799	.07535	1.01243
419	-.05482	.07554	1.01228
420	-.04210	.07434	1.01004
421	-.02908	.07518	1.01062
422	-.01637	.07312	1.00818
423	-.00355	.07324	1.00695
424	.00956	.07214	1.00482
425	.02404	.07462	1.00707
426	.03645	.07319	1.00446
427	.05094	.07613	1.00635
428	.06441	.07629	1.00492
429	.07833	.07835	1.00491
430	.09002	.07571	.99908
431	.10260	.07507	.99412
432	.11569	.07634	.99150
433	.12783	.07578	.98628
434	.13953	.07536	.98073
435	.15162	.07565	.97605
436	.16295	.07378	.96842
437	.17540	.07426	.96381
438	.18440	.07105	.95489
439	.19499	.06961	.94686
440	.20379	.06762	.93983
441	.19996	.07740	.93212
442	.19071	.07842	.93796
443	.18033	.08019	.94563
444	.17113	.08244	.95417
445	.16084	.09425	.96123
446	.14802	.08332	.96539
447	.13774	.08640	.97423
448	.12874	.09064	.98401
449	.11388	.08625	.98442
450	.10309	.08949	.99239
451	.08907	.08735	.99376
452	.07594	.08781	.99678
453	.06297	.08689	.99907
454	.04920	.08522	.99805
455	.03568	.08548	.99944
456	.02363	.08658	1.00161
457	.00949	.08442	1.00023
458	-.00408	.08459	1.00171
459	-.01655	.08583	1.00386
460	-.02988	.08659	1.00476
461	-.04271	.08409	1.00277
462	-.05571	.08567	1.00475
463	-.06858	.08692	1.00699
464	-.08203	.08597	1.00601
465	-.09501	.08589	1.00539
466	-.10868	.08480	1.00245
467	-.12113	.08631	1.00373
468	-.13356	.08613	1.00156
469	-.14645	.08615	.99996
470	-.14645	.08615	.99996
471	-.16967	.08313	.99162
472	-.18184	.08608	.99427
473	-.19590	.08616	.99392
474	-.20871	.08495	.99138
475	-.22206	.08394	.98825
476	-.23442	.08688	.98884
477	-.24662	.08674	.98736
478	-.25953	.08731	.98605
479	-.25953	.08731	.98605
480	-.27949	.08172	.97591
481	-.27949	.08172	.97591
482	-.29534	.08163	.97455
483	-.30797	.08551	.97873
484	-.32097	.08435	.97760
485	-.33483	.08449	.97760
486	-.34720	.08499	.97689
487	-.36066	.08284	.97366
488	-.37379	.08443	.97392
489	-.38719	.08386	.97135
490	-.39995	.08513	.97182
491	-.41229	.08392	.96873
492	-.42507	.08288	.96454
493	-.43752	.08233	.96043
494	-.45075	.08024	.95465
495	-.46204	.07715	.94800
496	-.46204	.07715	.94800
497	-.48697	.06384	.92359
498	-.48697	.06384	.92359
499	-.48938	.08620	.91467
500	-.46464	.07952	.92399
501	-.46464	.07952	.92399
502	-.45906	.08380	.93700
503	-.44776	.08827	.94429
504	-.43561	.09225	.95141
505	-.42321	.09299	.95508
506	-.40992	.09413	.95934
507	-.39818	.09692	.96514
508	-.38533	.09802	.96799
509	-.37223	.09678	.96742
510	-.35969	.09550	.96790
511	-.34667	.09429	.96763
512	-.33396	.09599	.97063
513	-.32042	.09637	.97143
514	-.30763	.09600	.97137
515	-.29480	.09416	.96938
516	-.28338	.09031	.96463
517	-.28367	.09026	.96474
518	-.25842	.09861	.97926
519	-.24555	.09756	.98044
520	-.23322	.09772	.98248
521	-.22091	.09742	.98436
522	-.20783	.09857	.98779
523	-.19486	.09843	.98879
524	-.18117	.09806	.98860
525	-.16833	.09693	.98841
526	-.16829	.09695	.98838
527	-.14664	.09743	.99336
528	-.13436	.09696	.99491
529	-.12193	.09598	.99532
530	-.10810	.09952	1.00041
531	-.09413	.10100	1.00331
532	-.08178	.09882	1.00171
533	-.06874	.09837	1.00124
534	-.05536	.09965	1.00167
535	-.04291	.09737	.99792
536	-.03128	.09673	.99736
537	-.01724	.09832	.99927
538	-.00373	.10028	1.00103
539	.00883	.09704	.99584
540	.02353	.10037	.99799
541	.03554	.09807	.99467
542	.04867	.09941	.99550
543	.06119	.09862	.99293
544	.07407	.09807	.99005
545	.08710	.09858	.98749
546	.10003	.09854	.98383
547	.11475	.10117	.98247
548	.12514	.09882	.97476
549	.13577	.09715	.96739
550	.14661	.09593	.96055

551	.15988	.09631	.95575	601	-.35760	.10696	.96034	651	.00816	.12296	.98606
552	.16976	.09420	.94877	602	-.37067	.10741	.95900	652	.01921	.11802	.97827
553	.17750	.09136	.93985	603	-.38445	.10588	.95649	653	.03315	.12123	.98172
554	.18590	.08714	.92930	604	-.39630	.10841	.95730	654	.04632	.12439	.98549
555	.19520	.08635	.92355	605	-.40858	.10303	.94969	655	.05839	.12355	.98309
556	.19130	.09638	.91562	606	-.42072	.10274	.94605	656	.07153	.12324	.97992
557	.18121	.09676	.92100	607	-.43341	.10014	.94051	657	.08366	.12240	.97588
558	.17244	.10033	.93162	608	-.44527	.09718	.93492	658	.09777	.12434	.97437
559	.16492	.10258	.93816	609	-.45463	.08963	.92420	659	.11065	.12422	.96981
560	.15525	.10552	.94658	610	-.45463	.08963	.92420	660	.12149	.12303	.96414
561	.14489	.10830	.95572	611	-.46690	.09267	.91237	661	.13111	.12077	.95623
562	.13371	.10899	.96121	612	-.46012	.10297	.90683	662	.14152	.11934	.94868
563	.12406	.11237	.97038	613	-.44178	.10075	.92049	663	.15281	.11707	.94042
564	.11091	.11007	.97297	614	-.44178	.10075	.92049	664	.16162	.11351	.93149
565	.09931	.11200	.97977	615	-.43099	.10492	.92683	665	.16976	.11007	.92396
566	.08624	.11202	.98316	616	-.41909	.10626	.93112	666	.17676	.10698	.91462
567	.07407	.11348	.98861	617	-.40627	.10815	.93614	667	.18390	.10201	.90333
568	.05848	.10825	.98473	618	-.39442	.11293	.94372	668	.18027	.11364	.89821
569	.04622	.10921	.98708	619	-.38245	.11651	.94853	669	.17165	.11560	.90641
570	.03485	.10979	.98824	620	-.36975	.11418	.94731	670	.16518	.11814	.91266
571	.02192	.11020	.98933	621	-.35668	.11565	.95065	671	.15731	.12172	.92153
572	.00710	.10742	.98800	622	-.34467	.11360	.94937	672	.14961	.12741	.93268
573	-.00542	.11039	.99245	623	-.33306	.11422	.95072	673	.13893	.13059	.94190
574	-.01966	.10728	.98970	624	-.31955	.11648	.95391	674	.12720	.13003	.94642
575	-.03255	.10738	.98979	625	-.30634	.11878	.95691	675	.11904	.13274	.95482
576	-.04353	.10899	.99121	626	-.29387	.11556	.95304	676	.10804	.13506	.96246
577	-.05598	.11091	.99466	627	-.28197	.11196	.94790	677	.09471	.13273	.96314
578	-.06899	.11038	.99566	628	-.26864	.12258	.96476	678	.08229	.13343	.96771
579	-.08279	.10963	.99518	629	-.26962	.12259	.96475	679	.06932	.13361	.97126
580	-.09609	.10957	.99398	630	-.25584	.12482	.97055	680	.05602	.13305	.97361
581	-.10804	.11221	.99569	631	-.24396	.11999	.96636	681	.04470	.13537	.97743
582	-.12188	.10900	.99119	632	-.23085	.12025	.96784	682	.03030	.13054	.97256
583	-.13528	.10728	.98750	633	-.21986	.11906	.96966	683	.01922	.13199	.97416
584	-.14696	.10871	.98649	634	-.20679	.12212	.97569	684	.00645	.13302	.97656
585	-.16775	.10842	.98108	635	-.19418	.12140	.97549	685	-.00676	.13439	.98042
586	-.16775	.10842	.98108	636	-.18050	.12113	.97523	686	-.01876	.13558	.98216
587	-.18100	.10865	.98097	637	-.16733	.11917	.97355	687	-.03206	.13357	.97971
588	-.19399	.11068	.98254	638	-.16731	.11919	.97354	688	-.04403	.13234	.97722
589	-.20609	.11275	.98352	639	-.14733	.11988	.98005	689	-.05609	.13431	.98115
590	-.21926	.11177	.98113	640	-.13523	.12038	.98328	690	-.06918	.13509	.98387
591	-.23085	.11293	.97977	641	-.12205	.12153	.98570	691	-.08284	.13399	.98332
592	-.24481	.10800	.97216	642	-.10884	.12257	.98729	692	-.09499	.13523	.98315
593	-.25726	.11042	.97323	643	-.09506	.12434	.99097	693	-.10739	.13604	.98314
594	-.26980	.11290	.97427	644	-.08197	.12507	.99295	694	-.12021	.13663	.98310
595	-.28224	.10435	.96029	645	-.06845	.12421	.99146	695	-.13347	.13482	.97934
596	-.29456	.10412	.96018	646	-.05552	.12390	.98965	696	-.14683	.13184	.97361
597	-.30674	.10591	.96173	647	-.04504	.11771	.98163	697	-.14683	.13184	.97361
598	-.31974	.10734	.96383	648	-.03345	.11936	.98380	698	-.16691	.12966	.96471
599	-.33309	.10858	.96472	649	-.01898	.12263	.98733	699	-.18056	.13012	.96510
600	-.34539	.10531	.95922	650	-.00684	.12110	.98552	700	-.19243	.13618	.97170

701	-.20513	.13356	.96750
702	-.21835	.12945	.96362
703	-.22958	.12854	.95692
704	-.24223	.13042	.95814
705	-.25516	.13283	.95934
706	-.26692	.13437	.95832
707	-.27826	.13041	.95049
708	-.27826	.13041	.95049
709	-.28262	.12325	.94125
710	-.29393	.12750	.94631
711	-.30615	.12628	.94465
712	-.31825	.13025	.94951
713	-.33166	.12650	.94437
714	-.34273	.12345	.94041
715	-.35491	.12247	.93783
716	-.36847	.12264	.93749
717	-.38112	.12266	.93562
718	-.39183	.12172	.93327
719	-.40303	.11616	.92679
720	-.41542	.11719	.92324
721	-.42752	.11508	.91912
722	-.43749	.11032	.91307
723	-.46679	.09699	.91706
724	-.45179	.10773	.89566
725	-.43241	.11186	.89771
726	-.43241	.11186	.89771
727	-.42430	.11837	.90498
728	-.41219	.12057	.91031
729	-.39902	.12031	.91403
730	-.38978	.12506	.91911
731	-.37883	.13100	.92591
732	-.36613	.13380	.92952
733	-.35306	.13107	.92936
734	-.34138	.12846	.92759
735	-.33097	.13296	.93206
736	-.31834	.13512	.93529
737	-.30485	.13719	.93761
738	-.29299	.13561	.93587
739	-.28204	.13237	.93193
740	-.28204	.13237	.93193
741	-.27740	.13626	.93900
742	-.26640	.13996	.94546
743	-.25377	.14296	.95117
744	-.23771	.14420	.95395
745	-.22788	.14049	.95116
746	-.21749	.14180	.95516
747	-.20484	.14337	.95930
748	-.19257	.14289	.96085
749	-.17840	.14432	.96267
750	-.16705	.13920	.95658
751	-.15730	.14028	.95969
752	-.14648	.14151	.96553
753	-.13238	.14933	.97654
754	-.12106	.14408	.97289
755	-.10908	.14223	.97080
756	-.09497	.14547	.97561
757	-.08248	.14578	.97718
758	-.06960	.14414	.97528
759	-.05733	.14272	.97207
760	-.04422	.14353	.97079
761	-.03397	.14305	.97108
762	-.01942	.14714	.97623
763	-.00733	.14492	.97376
764	.00616	.14424	.97085
765	.01849	.14235	.96705
766	.02974	.14356	.96820
767	.04293	.14467	.96927
768	.05635	.14692	.96995
769	.06804	.14404	.96490
770	.07919	.14067	.95785
771	.09336	.14403	.95798
772	.10541	.14271	.95210
773	.11571	.14055	.94583
774	.12404	.13899	.93958
775	.13334	.13601	.93054
776	.14610	.13731	.92604
777	.15673	.13578	.91925
778	.16349	.12943	.90709
779	.16715	.12420	.89930
780	.17419	.12069	.88892
781	.17013	.13044	.88098
782	.16216	.13204	.88839
783	.15843	.13888	.89907
784	.15027	.14117	.90604
785	.14073	.14447	.91441
786	.13056	.14717	.92355
787	.11789	.14415	.92700
788	.11157	.14813	.93404
789	.10253	.15244	.94288
790	.09035	.15341	.94877
791	.07653	.14976	.94786
792	.06581	.15276	.95446
793	.05338	.15462	.95931
794	.04210	.15702	.96337
795	.02766	.15235	.95865
796	.01529	.14680	.95173
797	.00542	.15375	.96062
798	-.00811	.15438	.96359
799	-.02078	.15500	.96505
800	-.03442	.15419	.96316
801	-.04623	.15057	.95899
802	-.05711	.15505	.96550
803	-.06988	.15503	.96725
804	-.08284	.15551	.96861
805	-.09463	.15614	.96925
806	-.10625	.15720	.96715
807	-.11978	.15553	.96488
808	-.13266	.15644	.96490
809	-.14576	.15370	.95946
810	-.15728	.15218	.95418
811	-.16535	.15167	.94994
812	-.17730	.15551	.95488
813	-.19211	.15179	.95066
814	-.20414	.15384	.95227
815	-.21603	.15286	.94859
816	-.22604	.15119	.94388
817	-.23891	.15074	.94098
818	-.25133	.15282	.94297
819	-.26341	.15277	.94014
820	-.27495	.14990	.93438
821	-.27493	.14991	.93437
822	-.28099	.14651	.92835
823	-.29264	.14381	.92499
824	-.30424	.14824	.93048
825	-.31683	.14691	.92907
826	-.32906	.14225	.92420
827	-.33919	.13899	.92053
828	-.35124	.13941	.91870
829	-.36477	.13978	.91732
830	-.37681	.13743	.91460
831	-.38655	.13239	.90981
832	-.39522	.12406	.90146
833	-.40724	.12682	.89963
834	-.42043	.12466	.89405
835	-.42044	.12468	.89404
836	-.43605	.11129	.89406
837	-.44472	.11440	.88740
838	-.45222	.11185	.87998
839	-.46038	.10843	.88825
840	-.40356	.12725	.88445
841	-.40356	.12725	.88445
842	-.40356	.12725	.88445
843	-.39211	.12794	.88985
844	-.38422	.13362	.89482
845	-.37546	.14194	.90239
846	-.36301	.14595	.90656
847	-.34991	.14603	.90850
848	-.33777	.14372	.90771
849	-.32906	.14593	.90921
850	-.31651	.15314	.91706

851	-.30346	.15561	.91963
852	-.29207	.15446	.91771
853	-.28100	.15320	.91597
854	-.28100	.15320	.91597
855	-.27335	.15515	.92074
856	-.26231	.15940	.92800
857	-.25009	.16059	.93213
858	-.23734	.16055	.93487
859	-.22479	.16061	.93579
860	-.21625	.16011	.93704
861	-.20212	.16638	.94580
862	-.18980	.16657	.94766
863	-.17752	.16207	.94292
864	-.16559	.16045	.94034
865	-.15629	.16156	.94557
866	-.14538	.16463	.95246
867	-.13304	.16480	.95474
868	-.11902	.16753	.95812
869	-.10715	.16465	.95569
870	-.09504	.16644	.96015
871	-.08365	.16469	.95873
872	-.06982	.16601	.96001
873	-.05565	.16882	.96152
874	-.04562	.16444	.95446
875	-.03465	.16644	.95719
876	-.02133	.16783	.95958
877	-.00956	.16402	.95472
878	.00358	.16318	.95174
879	.01468	.16188	.94806
880	.02800	.16587	.95330
881	.03934	.16559	.95287
882	.04994	.16120	.94687
883	.06287	.16084	.94381
884	.07453	.16063	.94063
885	.08758	.16390	.94045
886	.10253	.16852	.94156
887	.11172	.16319	.93185
888	.11725	.15547	.91962
889	.12410	.15313	.91229
890	.13540	.15280	.90552
891	.14693	.15336	.90171
892	.15622	.15120	.89461
893	.16065	.14268	.88022
894	.16461	.13973	.87202
895	.16069	.14989	.86400
896	.15266	.14765	.86808
897	.14492	.14687	.87355
898	.13976	.15383	.88657
899	.12876	.15540	.89335
900	.11759	.15730	.89988
901	.10815	.15692	.90363
902	.10061	.16007	.91097
903	.09184	.16551	.92053
904	.08183	.16633	.92754
905	.07153	.16614	.93038
906	.05955	.16541	.93416
907	.04942	.16896	.94205
908	.03928	.17177	.94667
909	.02609	.17135	.94405
910	.01276	.17066	.94040
911	.00323	.17297	.94437
912	-.00876	.17626	.94941
913	-.02070	.17757	.95136
914	-.03356	.17815	.95259
915	-.04540	.17666	.95089
916	-.05756	.17306	.94893
917	-.06945	.17544	.95311
918	-.08298	.17418	.95137
919	-.09399	.17712	.95354
920	-.10537	.17747	.95205
921	-.11758	.17680	.95042
922	-.13053	.17676	.95130
923	-.14223	.17618	.94698
924	-.15497	.17106	.93800
925	-.16428	.17119	.93506
926	-.17873	.16779	.93172
927	-.19123	.16763	.93053
928	-.20197	.17216	.93295
929	-.21403	.16798	.92613
930	-.22392	.16953	.92611
931	-.23511	.17077	.92610
932	-.24776	.16750	.92179
933	-.25863	.16953	.92101
934	-.26993	.17148	.91924
935	-.27838	.16634	.91210
936	-.29051	.16681	.91276
937	-.30228	.16349	.91203
938	-.31487	.16156	.90974
939	-.32681	.15532	.90225
940	-.33643	.14898	.89505
941	-.34820	.15020	.89447
942	-.36085	.15096	.89481
943	-.37253	.15194	.89668
944	-.38143	.14708	.89294
945	-.38757	.13701	.88390
946	-.39985	.12610	.87323
947	-.41155	.12726	.87467
948	-.41155	.12726	.87467
949	-.42967	.12662	.86739
950	-.43573	.09888	.84281
951	-.39583	.15152	.83060
952	-.40646	.14422	.84426
953	-.42153	.13079	.85505
954	-.42153	.13079	.85505
955	-.42153	.13079	.85505
956	-.40744	.13832	.83979
957	-.40744	.13832	.83979
958	-.39613	.15150	.83044
959	-.39613	.15150	.83044
960	-.38987	.16506	.89061
961	-.38987	.16506	.89061
962	-.38987	.16506	.89061
963	-.36264	.15606	.89666
964	-.34922	.16112	.89861
965	-.34923	.16120	.89855
966	-.34923	.16120	.89855
967	-.29173	.17284	.91213
968	-.29173	.17284	.91213
969	-.29173	.17284	.91213
970	-.26215	.17046	.91694
971	-.24924	.17685	.92527
972	-.23795	.17342	.91997
973	-.22444	.18170	.92725
974	-.21432	.18411	.93289
975	-.20256	.18391	.93772
976	-.19065	.18209	.93625
977	-.17725	.18407	.93626
978	-.16415	.18500	.93576
979	-.15570	.18424	.93955
980	-.14411	.18558	.94636
981	-.13181	.18425	.94720
982	-.11713	.18879	.95270
983	-.10595	.18665	.94977
984	-.09527	.18430	.95067
985	-.08226	.18752	.95665
986	-.06873	.18840	.95525
987	-.05636	.18746	.95123
988	-.04512	.18524	.94736
989	-.03421	.18441	.94912
990	-.02151	.18482	.95065
991	-.00810	.18378	.94808
992	.00332	.18216	.94198
993	.01366	.17830	.93722
994	.02721	.18286	.94784
995	.04018	.18502	.95305
996	.05206	.18031	.94557
997	.06285	.17872	.93795
998	.07870	.18855	.94441
999	.16534	.17778	.88891
1000	.16411	.17869	.87626

1001	.15794	.16659	.87515	1051	-.27373	.19098	.92148	1101	.06633	.20455	.94307
1002	.15191	.17440	.88011	1052	-.29420	.18350	.91098	1102	.08133	.20600	.94622
1003	.15191	.17440	.88011	1053	-.30782	.17827	.91000	1103	.09414	.20529	.94349
1004	.14979	.17912	.89646	1054	-.32002	.17857	.91143	1104	.11352	.20278	.92461
1005	.14240	.18204	.90706	1055	-.33121	.17925	.90990	1105	.11352	.20278	.92461
1006	.13012	.18062	.91153	1056	-.34201	.17193	.90003	1106	.12176	.19248	.91648
1007	.11676	.18165	.91152	1057	-.35277	.17002	.89247	1107	.13694	.19863	.91887
1008	.15112	.16882	.88226	1058	-.36621	.16571	.89239	1108	.14676	.19630	.91047
1009	.14439	.16873	.89300	1059	-.37841	.16613	.89404	1109	.15184	.19308	.89766
1010	.13259	.17238	.89875	1060	-.38952	.16350	.89023	1110	.15939	.19203	.88693
1011	.12346	.17330	.90720	1061	-.39991	.15545	.87895	1111	.16393	.19106	.87956
1012	.10941	.17964	.90724	1062	-.39993	.15547	.87894	1112	.16546	.20571	.88609
1013	.10433	.18352	.91486	1063	-.39224	.17266	.88279	1113	.16211	.20295	.88586
1014	.09654	.18181	.92864	1064	-.38018	.18001	.89068	1114	.15509	.20512	.89780
1015	.08645	.18208	.93561	1065	-.36846	.18285	.89515	1115	.14813	.20786	.90838
1016	.07166	.18595	.93501	1066	-.34593	.18393	.90022	1116	.13862	.20817	.91656
1017	.06285	.18655	.93778	1067	-.34593	.18393	.90022	1117	.12835	.20917	.92167
1018	.11168	.18884	.92368	1068	-.33567	.18660	.90542	1118	.11390	.20699	.92275
1019	.09963	.18783	.93069	1069	-.32302	.18918	.90956	1119	.10489	.21445	.93149
1020	.08996	.19075	.93952	1070	-.30989	.19307	.91189	1120	.10489	.21445	.93149
1021	.07675	.19038	.94034	1071	-.29745	.19454	.91124	1121	.08214	.21430	.94129
1022	.06417	.19161	.93824	1072	-.28558	.19838	.91134	1122	.06722	.21397	.94246
1023	.05078	.18823	.94213	1073	-.27660	.19874	.91773	1123	.05499	.21537	.94440
1024	.03997	.19320	.94844	1074	-.26527	.20011	.92270	1124	.04367	.21937	.94987
1025	.02802	.19441	.94882	1075	-.25324	.20156	.92472	1125	.03237	.22475	.95415
1026	.01623	.19375	.94097	1076	-.23999	.20485	.92790	1126	.02009	.22323	.94756
1027	.00370	.19340	.94064	1077	-.22742	.20549	.92932	1127	.00800	.22575	.95050
1028	-.00714	.19778	.94941	1078	-.21671	.20787	.93472	1128	-.00545	.22404	.94949
1029	-.02127	.19606	.95037	1079	-.20437	.20731	.93641	1129	-.01897	.22368	.95034
1030	-.03349	.19746	.95067	1080	-.19194	.20624	.93413	1130	-.03154	.22379	.95085
1031	-.04506	.19813	.94787	1081	-.17923	.20682	.93281	1131	-.04363	.22362	.94950
1032	-.05960	.19372	.94229	1082	-.16568	.21141	.93756	1132	-.05705	.22314	.94680
1033	-.06985	.19936	.95293	1083	-.15697	.21088	.94215	1133	-.06730	.22744	.94996
1034	-.08243	.19900	.95524	1084	-.14594	.20962	.94457	1134	-.07926	.22976	.95503
1035	-.09350	.20131	.95607	1085	-.13188	.21164	.94942	1135	-.09293	.22823	.95531
1036	-.10573	.19916	.95143	1086	-.11930	.21041	.94723	1136	-.10648	.22416	.94925
1037	-.11891	.19729	.94657	1087	-.10634	.21326	.95270	1137	-.11834	.22696	.9501[illegible]
1038	-.13229	.19671	.94801	1088	-.09452	.21317	.95527	1138	-.13163	.22590	.94837
1039	-.14399	.19887	.94722	1089	-.08106	.21450	.95649	1139	-.14528	.22422	.94463
1040	-.15527	.19829	.94303	1090	-.06887	.21163	.95091	1140	-.15639	.22583	.94318
1041	-.16401	.19735	.93570	1091	-.05650	.21468	.95089	1141	-.16477	.22945	.94149
1042	-.17770	.19479	.93307	1092	-.04540	.21115	.94916	1142	-.17827	.22465	.93736
1043	-.19084	.19489	.93641	1093	-.03196	.21508	.95473	1143	-.19149	.22119	.93429
1044	-.20380	.19342	.93548	1094	-.01935	.21250	.95373	1144	-.20484	.21932	.93310
1045	-.21442	.19628	.93601	1095	-.00748	.20865	.94707	1145	-.21557	.22458	.93820
1046	-.22440	.19758	.93341	1096	.00518	.20777	.94454	1146	-.22841	.22095	.93210
1047	-.23754	.19170	.92696	1097	.01698	.20624	.94150	1147	-.24075	.21908	.92975
1048	-.25107	.19042	.92702	1098	.02919	.20794	.95043	1148	-.25324	.21715	.92691
1049	-.26346	.18725	.92212	1099	.04212	.20767	.95230	1149	-.26602	.21636	.92536
1050	-.27373	.19098	.92148	1100	.05380	.20419	.94633	1150	-.27789	.21319	.92016

1151	-.28750	.20790	.91030
1152	-.29978	.20856	.91321
1153	-.31147	.20470	.91003
1154	-.32380	.20497	.91057
1155	-.33669	.20253	.90715
1156	-.34791	.20026	.90261
1157	-.35948	.19462	.89364
1158	-.37045	.19637	.89318
1159	-.38187	.19241	.88726
1160	-.38187	.19241	.88726
1161	-.38187	.19241	.88726
1162	-.40786	.15052	.83431
1163	-.40786	.15052	.83431
1164	-.38118	.20549	.88206
1165	-.38118	.20549	.88206
1166	-.38118	.20549	.88206
1167	-.37206	.20703	.88674
1168	-.36146	.20799	.89072
1169	-.34952	.21070	.89699
1170	-.33858	.21305	.90216
1171	-.32625	.21524	.90599
1172	-.31281	.22083	.91234
1173	-.30124	.22125	.91262
1174	-.28995	.22323	.91406
1175	-.27968	.22577	.91836
1176	-.26744	.22702	.92121
1177	-.25516	.22794	.92374
1178	-.24187	.23254	.92940
1179	-.22968	.23484	.93211
1180	-.21754	.23244	.93140
1181	-.20419	.23487	.93438
1182	-.19084	.23805	.93675
1183	-.17989	.23675	.93570
1184	-.16732	.23588	.93546
1185	-.15636	.23991	.94367
1186	-.14494	.23707	.94321
1187	-.13133	.24037	.94856
1188	-.11808	.24113	.95073
1189	-.10457	.24305	.95449
1190	-.09151	.24357	.95531
1191	-.07865	.24233	.95304
1192	-.06540	.24410	.95068
1193	-.05611	.23765	.94726
1194	-.04303	.23836	.94992
1195	-.03219	.23492	.94714
1196	-.01793	.23723	.94977
1197	-.00385	.23945	.95086
1198	.00725	.23496	.94721
1199	.02089	.23698	.94931
1200	.03300	.23330	.94941
1201	.04620	.23477	.95181
1202	.05940	.23408	.95136
1203	.07136	.23037	.94639
1204	.08438	.22880	.94303
1205	.09556	.22568	.93607
1206	.09556	.22568	.93607
1207	.12078	.22577	.93038
1208	.13089	.22179	.92283
1209	.14186	.22102	.91626
1210	.15101	.22049	.90831
1211	.15948	.22066	.89960
1212	.16692	.22030	.89236
1213	.16546	.23081	.89532
1214	.16274	.23392	.90063
1215	.15122	.22955	.90396
1216	.14484	.23462	.91618
1217	.13533	.23719	.92489
1218	.12093	.23322	.92540
1219	.10958	.23800	.93299
1220	.09560	.23666	.93306
1221	.08672	.24306	.94165
1222	.07510	.24727	.94856
1223	.05979	.24534	.94775
1224	.04850	.24895	.95095
1225	.03500	.24754	.94884
1226	.02166	.24855	.94904
1227	.00808	.24730	.94550
1228	-.00286	.25126	.94826
1229	-.01615	.25137	.94892
1230	-.02897	.25206	.94961
1231	-.04165	.25124	.94822
1232	-.05501	.25121	.94702
1233	-.06732	.25096	.94271
1234	-.07843	.25502	.94976
1235	-.09127	.25706	.95233
1236	-.10412	.25515	.95031
1237	-.11740	.25522	.94867
1238	-.13034	.25502	.94722
1239	-.14311	.25437	.94480
1240	-.15596	.25307	.94137
1241	-.16717	.25354	.93894
1242	-.17915	.25153	.93599
1243	-.19147	.24929	.93338
1244	-.20389	.24859	.93206
1245	-.21718	.24937	.93258
1246	-.22952	.24901	.93193
1247	-.24237	.24562	.92741
1248	-.25410	.24516	.92579
1249	-.26683	.24329	.92223
1250	-.28011	.23912	.91747
1251	-.29135	.23951	.91631
1252	-.30274	.23693	.91351
1253	-.31449	.23265	.90837
1254	-.32672	.23084	.90492
1255	-.33800	.22808	.89971
1256	-.34816	.22680	.89509
1257	-.35942	.22136	.88593
1258	-.36988	.22030	.88078
1259	-.37932	.21747	.87499
1260	-.37932	.21747	.87499
1261	-.38142	.18369	.82301
1262	-.36688	.22751	.87039
1263	-.36688	.22751	.87039
1264	-.36688	.22751	.87039
1265	-.35670	.22941	.87601
1266	-.34620	.23207	.88274
1267	-.33657	.23502	.88837
1268	-.32653	.24181	.89754
1269	-.31552	.24325	.90166
1270	-.30366	.24821	.90803
1271	-.29227	.25101	.91224
1272	-.28101	.24917	.91094
1273	-.26827	.25314	.91604
1274	-.25549	.25719	.92148
1275	-.24343	.25491	.92037
1276	-.23051	.26002	.92625
1277	-.21758	.26082	.92865
1278	-.20386	.26295	.93097
1279	-.19134	.26389	.93144
1280	-.18035	.26185	.93038
1281	-.16811	.26578	.93554
1282	-.15574	.26606	.93869
1283	-.14317	.26626	.94056
1284	-.12921	.26840	.94472
1285	-.11741	.26564	.94342
1286	-.10338	.26725	.94573
1287	-.09113	.26745	.94574
1288	-.07832	.26497	.94356
1289	-.06746	.26402	.94157
1290	-.05332	.26723	.94761
1291	-.03968	.26866	.94997
1292	-.02873	.26404	.94640
1293	-.01584	.26272	.94419
1294	-.00219	.26422	.94511
1295	.01049	.26386	.94763
1296	.02360	.26316	.94862
1297	.03722	.26396	.95093
1298	.04924	.26183	.94968
1299	.06363	.26269	.95002
1300	.07442	.25629	.94383

1301	.08767	.25708	.94242
1302	.09970	.25394	.93753
1303	.11101	.24933	.93005
1304	.12541	.25051	.92867
1305	.13592	.24707	.92140
1306	.14671	.24751	.91577
1307	.15655	.24696	.90889
1308	.16525	.24329	.89970
1309	.16276	.25175	.89855
1310	.15889	.25566	.90633
1311	.14930	.26036	.91567
1312	.13953	.26158	.92164
1313	.12620	.26098	.92569
1314	.11268	.26165	.92862
1315	.10000	.26254	.93151
1316	.08850	.26670	.93710
1317	.07627	.26924	.94084
1318	.06396	.27289	.94434
1319	.05103	.27437	.94641
1320	.03751	.27385	.94518
1321	.02486	.27605	.94654
1322	.01028	.27441	.94277
1323	-.00285	.27276	.93869
1324	-.01434	.27737	.94313
1325	-.02591	.28111	.94700
1326	-.03924	.27913	.94430
1327	-.05279	.27934	.94353
1328	-.06634	.27884	.94100
1329	-.07900	.27740	.93981
1330	-.09060	.27964	.94118
1331	-.10216	.28252	.94404
1332	-.11528	.28395	.94382
1333	-.12908	.27825	.93759
1334	-.14194	.28075	.93805
1335	-.15549	.27817	.93383
1336	-.16819	.27757	.93168
1337	-.17894	.27982	.93249
1338	-.19079	.27786	.92903
1339	-.20403	.27556	.92633
1340	-.21663	.27654	.92645
1341	-.23023	.27530	.92489
1342	-.24252	.27514	.92369
1343	-.25487	.27111	.91821
1344	-.26755	.26836	.91372
1345	-.28047	.26682	.91148
1346	-.29211	.26530	.90794
1347	-.30365	.26277	.90410
1348	-.31415	.25760	.89683
1349	-.32338	.25407	.89130
1350	-.33292	.24631	.88127
1351	-.34015	.24383	.87697
1352	-.35079	.24142	.87028
1353	-.36090	.23869	.86416
1354	-.36994	.23252	.85427
1355	-.37838	.19989	.82110
1356	-.37709	.21912	.82095
1357	-.37292	.23361	.83637
1358	-.36454	.23949	.84496
1359	-.35539	.23998	.85082
1360	-.34646	.24339	.85654
1361	-.33531	.24594	.86345
1362	-.32861	.24961	.86854
1363	-.32061	.25920	.87932
1364	-.31209	.26797	.88891
1365	-.30238	.27362	.89598
1366	-.29135	.27818	.90260
1367	-.27955	.27904	.90543
1368	-.26677	.28204	.91029
1369	-.25554	.28222	.91204
1370	-.24313	.28282	.91376
1371	-.23068	.28258	.91494
1372	-.21598	.28948	.92297
1373	-.20413	.28727	.92185
1374	-.19126	.28939	.92453
1375	-.17937	.29216	.92861
1376	-.16654	.29287	.93100
1377	-.15387	.29256	.93200
1378	-.14139	.29272	.93399
1379	-.12786	.29348	.93520
1380	-.11464	.29404	.93738
1381	-.10199	.29278	.93724
1382	-.08898	.29398	.93893
1383	-.07563	.29548	.94030
1384	-.06473	.29289	.93976
1385	-.05112	.29425	.94155
1386	-.03753	.29461	.94359
1387	-.02549	.29254	.94227
1388	-.01267	.29033	.94086
1389	.00019	.29155	.94235
1390	.01227	.28900	.94144
1391	.02577	.28952	.94376
1392	.03996	.28944	.94504
1393	.05117	.28540	.94146
1394	.06613	.28709	.94344
1395	.07878	.28462	.94125
1396	.09212	.28305	.93913
1397	.10421	.28002	.93441
1398	.11711	.27886	.93169
1399	.12951	.27412	.92562
1400	.14075	.27182	.91948
1401	.15085	.26915	.91296
1402	.16170	.26909	.90600
1403	.16075	.28043	.90760
1404	.15594	.28616	.91638
1405	.14417	.28637	.92104
1406	.13271	.29949	.92730
1407	.11827	.28970	.92843
1408	.10663	.29319	.93229
1409	.09325	.29453	.93462
1410	.08095	.29864	.93918
1411	.06896	.30290	.94284
1412	.05364	.30089	.94045
1413	.04095	.30140	.93941
1414	.02796	.30320	.94088
1415	.01429	.30312	.93958
1416	.00133	.30395	.93871
1417	-.01054	.30629	.93975
1418	-.02459	.30451	.93730
1419	-.03646	.30659	.93822
1420	-.05036	.30521	.93540
1421	-.06352	.30542	.93484
1422	-.07572	.30808	.93603
1423	-.08806	.30598	.93350
1424	-.10065	.30599	.93231
1425	-.11376	.30679	.93194
1426	-.12698	.30574	.92983
1427	-.14082	.30310	.92593
1428	-.15356	.30339	.92495
1429	-.16517	.30655	.92654
1430	-.17849	.30688	.92569
1431	-.19059	.30399	.92168
1432	-.20329	.30079	.91718
1433	-.21663	.29894	.91404
1434	-.22942	.29878	.91292
1435	-.24191	.29683	.90974
1436	-.25537	.29199	.90328
1437	-.26638	.29369	.90336
1438	-.27815	.29451	.90216
1439	-.28967	.28861	.89445
1440	-.30024	.28412	.88764
1441	-.30841	.27630	.87931
1442	-.31530	.26872	.87099
1443	-.32134	.26093	.86316
1444	-.32936	.25353	.85515
1445	-.33981	.25077	.84796
1446	-.34855	.24581	.84069
1447	-.35792	.24621	.83555
1448	-.36768	.24283	.82738
1449	-.37359	.24154	.82355
1450	-.36268	.25063	.81860

1451	−.35264	.25036	.92537
1452	−.34273	.25322	.93271
1453	−.34172	.25325	.93265
1454	−.32370	.25676	.94434
1455	−.31763	.26527	.95268
1456	−.31014	.27342	.96000
1457	−.30459	.28158	.96977
1458	−.29740	.29159	.97310
1459	−.28720	.29519	.98398
1460	−.27705	.30022	.99041
1461	−.26538	.30344	.99525
1462	−.25367	.30665	.99932
1463	−.24124	.30837	.90320
1464	−.22976	.30958	.90616
1465	−.21559	.31083	.90949
1466	−.20259	.31436	.91283
1467	−.19034	.31520	.91497
1468	−.17347	.31609	.91679
1469	−.15441	.31774	.91975
1470	−.15174	.31863	.92246
1471	−.13926	.31842	.92312
1472	−.12598	.31840	.92445
1473	−.11398	.31579	.92363
1474	−.10027	.31741	.92617
1475	−.09763	.31796	.92755
1476	−.07464	.31783	.92842
1477	−.06154	.31915	.93046
1478	−.04878	.31905	.93016
1479	−.03652	.31507	.92392
1480	−.02193	.32026	.93452
1481	−.01074	.31573	.93208
1482	.00284	.31659	.93411
1483	.01570	.31573	.93470
1484	.02918	.31531	.93590
1485	.04301	.31547	.93666
1486	.05510	.31326	.93581
1487	.06841	.31154	.93455
1488	.08173	.30934	.93319
1489	.09530	.30852	.93230
1490	.10824	.30692	.93032
1491	.12124	.30512	.92850
1492	.13478	.30337	.92613
1493	.14810	.30270	.92324
1494	.15367	.30087	.91929
1495	.16251	.29853	.91639
1496	.15772	.31047	.91536
1497	.14707	.31019	.91716
1498	.13656	.31585	.92351
1499	.12251	.31640	.92456
1500	.10939	.31906	.92637
1501	.09654	.32113	.92796
1502	.08339	.32557	.93163
1503	.06952	.32342	.92903
1504	.05776	.32920	.93271
1505	.04391	.32595	.93017
1506	.02976	.32502	.92840
1507	.01626	.32710	.92848
1508	.00378	.32656	.92638
1509	−.00191	.32307	.92784
1510	−.02220	.32914	.92537
1511	−.03421	.31063	.92597
1512	−.04744	.31975	.92428
1513	−.06145	.32753	.92034
1514	−.07335	.32992	.92176
1515	−.08682	.32404	.91355
1516	−.09894	.31925	.91941
1517	−.11271	.32732	.91645
1518	−.12459	.32023	.91744
1519	−.13838	.32005	.91322
1520	−.15042	.32918	.91439
1521	−.16371	.32711	.91053
1522	−.17717	.32797	.91024
1523	−.18385	.32349	.90510
1524	−.20164	.32662	.90573
1525	−.21443	.32350	.90251
1526	−.22792	.32265	.89994
1527	−.23881	.31157	.89513
1528	−.25240	[illegible]	.88385
1529	−.26391	[illegible]	.88573
1530	−.27594	.30912	.88000
1531	−.28435	.30561	.87455
1532	−.29392	.30283	.87031
1533	−.29975	.29189	.86040
1534	−.30595	.28325	.85351
1535	−.31671	.26426	.83645
1536	−.31671	.26426	.83645
1537	−.32442	.25731	.82886
1538	−.32442	.25731	.82886
1539	−.33387	.25605	.82175
1540	−.34473	.25681	.81560
1541	−.34561	.25764	.81507
1542	−.32738	.26592	.81430
1543	−.31782	.25643	.81325
1544	−.31782	.25643	.81325
1545	−.31782	.25643	.81325
1546	−.29222	.30187	.85399
1547	−.29222	.30187	.85399
1548	−.28232	.31017	.86198
1549	−.27215	.31823	.87081
1550	−.26221	.31798	.87260
1551	−.25087	.32534	.88015
1552	−.23952	.32674	.88409
1553	−.22707	.33222	.89041
1554	−.21439	.33362	.89315
1555	−.20357	.33649	.89639
1556	−.18915	.33504	.89775
1557	−.17634	.34001	.90193
1558	−.16251	.33933	.90375
1559	−.14922	.34032	.90599
1560	−.13712	.33983	.90723
1561	−.12328	.34109	.90937
1562	−.11384	.34205	.91110
1563	−.09833	.33755	.91005
1564	−.08542	.33437	.91122
1565	−.07218	.34175	.91445
1566	−.05952	.34150	.91512
1567	−.04723	.33992	.91419
1568	−.03375	.34047	.91675
1569	−.02151	.34191	.91943
1570	−.00711	.34284	.92185
1571	.00327	.33561	.91595
1572	.01712	.33830	.91986
1573	.03168	.33673	.91980
1574	.04162	.33592	.92075
1575	.05752	.33717	.92316
1576	.07205	.33996	.92432
1577	.08220	.33239	.92000
1578	.09577	.33024	.91853
1579	.11185	.33390	.92260
1580	.12464	.33143	.92138
1581	.13838	.33115	.92097
1582	.15073	.32791	.91732
1583	.15632	.32731	.91603
1584	.15469	.34096	.91520
1585	.13962	.34297	.91628
1586	.12493	.34110	.91379
1587	.11217	.34309	.91504
1588	.10189	.34883	.91872
1589	.08523	.34545	.91495
1590	.07256	.34722	.91600
1591	.05882	.34763	.91499
1592	.04682	.34937	.91607
1593	.03249	.34725	.91211
1594	.01927	.34978	.91333
1595	.00726	.35241	.91416
1596	−.00610	.35130	.91187
1597	−.01991	.34917	.90952
1598	−.03789	.35360	.91101
1599	−.04425	.35289	.90914
1600	−.05980	.35055	.90553

1601	-.07199	.34846	.90317
1602	-.08314	.35319	.90572
1603	-.09581	.35313	.90457
1604	-.11000	.34975	.90090
1605	-.12320	.34897	.89852
1606	-.13505	.35149	.89937
1607	-.14777	.35225	.89928
1608	-.16087	.35042	.89614
1609	-.17460	.35069	.89473
1610	-.18696	.34754	.89061
1611	-.20062	.34313	.88538
1612	-.21339	.34286	.88331
1613	-.22530	.34178	.88076
1614	-.23752	.33718	.87556
1615	-.24732	.33793	.87418
1616	-.25721	.33118	.86723
1617	-.26830	.32498	.85997
1618	-.27830	.31961	.85378
1619	-.28738	.31497	.84840
1620	-.29423	.30406	.83833
1621	-.29406	.30414	.83821
1622	-.30424	.27945	.81646
1623	-.30355	.27819	.80083
1624	-.29019	.31138	.82865
1625	-.29019	.31138	.82865
1626	-.28353	.31747	.83466
1627	-.27440	.32152	.83951
1628	-.26389	.32952	.84814
1629	-.25295	.33445	.85423
1630	-.24470	.33977	.85953
1631	-.23478	.34733	.86678
1632	-.22351	.35254	.87235
1633	-.21190	.35421	.87578
1634	-.19846	.35829	.88033
1635	-.18522	.36164	.88502
1636	-.17345	.35941	.88426
1637	-.16102	.35674	.88407
1638	-.14758	.35950	.88762
1639	-.13445	.36049	.89015
1640	-.12003	.36393	.89469
1641	-.10899	.35939	.89134
1642	-.09574	.36028	.89365
1643	-.08242	.36310	.89738
1644	-.06918	.36283	.89800
1645	-.05745	.36014	.89732
1646	-.04390	.36103	.89859
1647	-.03143	.35992	.89912
1648	-.01785	.36215	.90207
1649	-.00483	.36095	.90291
1650	.00884	.36226	.90529

1651	.02136	.36161	.90580
1652	.03442	.36039	.90633
1653	.04832	.36088	.90800
1654	.06082	.35890	.90756
1655	.07332	.35719	.90723
1656	.08564	.35498	.90596
1657	.10088	.35786	.90992
1658	.11392	.35520	.90888
1659	.12758	.35744	.91131
1660	.14123	.35619	.91138
1661	.14910	.35526	.91013
1662	.14396	.36170	.89948
1663	.13953	.36044	.89812
1664	.12836	.36598	.90199
1665	.11475	.36537	.90027
1666	.10276	.36696	.90055
1667	.09333	.36728	.89933
1668	.07513	.36666	.89796
1669	.06226	.36807	.89790
1670	.05015	.36992	.89835
1671	.03679	.37103	.89799
1672	.02172	.36767	.89383
1673	.01018	.37205	.89655
1674	-.00395	.36920	.89281
1675	-.01556	.37206	.89331
1676	-.02940	.36976	.89049
1677	-.04273	.37010	.88912
1678	-.05453	.37559	.89263
1679	-.06883	.36810	.88480
1680	-.08022	.37390	.88923
1681	-.09366	.37252	.88601
1682	-.10735	.37070	.88359
1683	-.11968	.36946	.88137
1684	-.13384	.36807	.87842
1685	-.14643	.36906	.87811
1686	-.15916	.37049	.87786
1687	-.17141	.36863	.87517
1688	-.18448	.36679	.87178
1689	-.19705	.36544	.86923
1690	-.21003	.36394	.86629
1691	-.22198	.36011	.86124
1692	-.23111	.35615	.85763
1693	-.24050	.34809	.85038
1694	-.24729	.34002	.84364
1695	-.25775	.33298	.83589
1696	-.26823	.32813	.83046
1697	-.27793	.32712	.82677
1698	-.28590	.32172	.82046
1699	-.29147	.31413	.81411
1700	-.29813	.30236	.80423

1701	-.29099	.31741	.79880
1702	-.28161	.32416	.80533
1703	-.27282	.32998	.81276
1704	-.26162	.33399	.82012
1705	-.25231	.33651	.82570
1706	-.25231	.33651	.82570
1707	-.23576	.35265	.83928
1708	-.22793	.36231	.84673
1709	-.22001	.36607	.84982
1710	-.20861	.37095	.85435
1711	-.19621	.37355	.85843
1712	-.18432	.37312	.85972
1713	-.17121	.37548	.86359
1714	-.15794	.37677	.86573
1715	-.14375	.38175	.87086
1716	-.13111	.38000	.87092
1717	-.11827	.38037	.87229
1718	-.10488	.38180	.87440
1719	-.09237	.37944	.87356
1720	-.08017	.37693	.87261
1721	-.06732	.37899	.87539
1722	-.05426	.38052	.87827
1723	-.04039	.38129	.88026
1724	-.02764	.38116	.88197
1725	-.01551	.38014	.88181
1726	-.00169	.37932	.88281
1727	.01126	.38036	.88525
1728	.02454	.38071	.88718
1729	.03775	.38065	.88843
1730	.05072	.37814	.88724
1731	.06513	.38203	.89260
1732	.07766	.37955	.89155
1733	.08978	.37814	.89108
1734	.10266	.37549	.89013
1735	.11674	.37764	.89317
1736	.13058	.37785	.89446
1737	.14121	.37554	.89371
1738	.13766	.38789	.88582
1739	.13122	.38532	.88320
1740	.11865	.38585	.88238
1741	.10552	.38778	.88230
1742	.09215	.38779	.88181
1743	.07967	.38931	.88230
1744	.06713	.38991	.88143
1745	.05284	.38745	.87835
1746	.03835	.38526	.87515
1747	.02614	.38854	.87652
1748	.01310	.38784	.87521
1749	-.00058	.38776	.87320
1750	-.01359	.38681	.87110

1751	-.02492	.39062	.87209	1801	.06710	.39550	.86918	1851	-.09841	.41018	.82981
1752	-.03958	.38887	.86951	1802	.08029	.39550	.86970	1852	-.08687	.40748	.82920
1753	-.05171	.38960	.86951	1803	.09307	.39411	.86974	1853	-.07305	.40877	.83161
1754	-.06530	.38762	.86645	1804	.10634	.39375	.87055	1854	-.05989	.40997	.83362
1755	-.07909	.38703	.86403	1805	.12011	.39510	.87336	1855	-.04706	.40980	.83525
1756	-.09070	.38772	.86401	1806	.13201	.39247	.87257	1856	-.03358	.40867	.83653
1757	-.10347	.39017	.86414	1807	.12933	.40259	.86410	1857	-.02175	.40796	.83753
1758	-.11638	.38884	.86216	1808	.12242	.40149	.86229	1858	-.00874	.40670	.83803
1759	-.12356	.38859	.86103	1809	.10918	.40141	.86077	1859	.00412	.40624	.83888
1760	-.14277	.38628	.85758	1810	.09616	.40279	.86006	1860	.01681	.40632	.84003
1761	-.15504	.38877	.85933	1811	.08230	.40160	.85793	1861	.03106	.40839	.84298
1762	-.16876	.38609	.85450	1812	.06934	.40120	.85703	1862	.04354	.40578	.84193
1763	-.18123	.38509	.85225	1813	.05595	.39983	.85501	1863	.05709	.40584	.84362
1764	-.19397	.38132	.84791	1814	.04261	.40135	.85465	1864	.06922	.40332	.84267
1765	-.20646	.38018	.84556	1815	.02920	.40133	.85323	1865	.08290	.40367	.84371
1766	-.21726	.37545	.84140	1816	.01548	.40000	.85095	1866	.09656	.40588	.84673
1767	-.21713	.37535	.84146	1817	.00224	.39962	.84914	1867	.11019	.40515	.84776
1768	-.24646	.33711	.81310	1818	-.01026	.40063	.84937	1868	.12241	.40225	.84712
1769	-.24646	.33711	.81310	1819	-.02262	.40223	.84912	1869	.12039	.40748	.83590
1770	-.25577	.33667	.80951	1820	-.03611	.40099	.84614	1870	.11091	.40658	.83378
1771	-.26616	.33351	.80209	1821	-.04930	.40397	.84671	1871	.09952	.40887	.83426
1772	-.27601	.33012	.79527	1822	-.06144	.40360	.84491	1872	.08438	.40795	.83170
1773	-.26039	.33908	.79351	1823	-.07327	.40555	.84558	1873	.07035	.40532	.82991
1774	-.24990	.33858	.79737	1824	-.08656	.40502	.84402	1874	.05967	.41111	.83184
1775	-.24890	.33859	.79797	1825	-.09944	.40662	.84355	1875	.04632	.41052	.82989
1776	-.21505	.37850	.82829	1826	-.11283	.40288	.83978	1876	.03341	.41338	.83074
1777	-.25372	.34259	.79626	1827	-.12525	.40540	.84079	1877	.01885	.41044	.82704
1778	-.21505	.37850	.82829	1828	-.13841	.40199	.83639	1878	.00533	.40908	.82454
1779	-.21505	.37850	.82829	1829	-.15126	.40068	.83452	1879	-.00690	.41183	.82529
1780	-.20374	.38452	.83238	1830	-.16440	.39874	.83230	1880	-.02051	.41096	.82308
1781	-.19102	.38915	.83816	1831	-.17534	.39927	.83202	1881	-.03200	.41361	.82373
1782	-.17919	.39045	.84056	1832	-.18837	.39342	.82538	1882	-.04511	.41462	.82283
1783	-.16642	.39259	.84336	1833	-.20080	.39118	.82174	1883	-.05799	.41561	.82223
1784	-.15364	.39408	.84576	1834	-.21266	.38340	.81616	1884	-.07105	.41477	.82024
1785	-.14099	.39363	.84691	1835	-.22072	.37147	.80773	1885	-.08383	.41534	.81899
1786	-.12864	.39477	.84877	1836	-.22072	.37147	.80773	1886	-.09669	.41629	.81880
1787	-.11473	.39558	.85021	1837	-.22072	.37147	.80773	1887	-.10924	.41603	.81723
1788	-.10239	.39620	.85191	1838	-.24110	.33808	.78576	1888	-.12351	.41263	.81355
1789	-.08347	.39511	.85225	1839	-.23150	.35544	.78364	1889	-.13534	.41152	.81329
1790	-.07595	.39702	.85529	1840	-.21865	.37900	.79701	1890	-.14701	.40883	.81174
1791	-.06269	.39863	.85902	1841	-.21865	.37900	.79701	1891	-.15919	.40411	.80754
1792	-.05094	.39620	.85711	1842	-.20909	.38749	.80255	1892	-.16916	.40131	.80575
1793	-.03767	.39426	.85674	1843	-.19912	.39089	.80659	1893	-.18148	.40182	.80328
1794	-.02515	.39459	.85873	1844	-.18624	.39484	.81108	1894	-.19472	.39863	.79790
1795	-.01219	.39463	.86021	1845	-.17283	.39680	.81632	1895	-.20703	.39241	.79189
1796	.00065	.39344	.86071	1846	-.16182	.40144	.81955	1896	-.21646	.38685	.78755
1797	.01333	.39285	.86144	1847	-.14997	.40206	.82055	1897	-.22404	.37631	.78071
1798	.02470	.39357	.86295	1848	-.13926	.40438	.82276	1898	-.22903	.37053	.77785
1799	.03997	.39380	.86495	1849	-.12534	.40749	.82536	1899	-.22443	.38683	.77177
1800	.05391	.39318	.86541	1850	-.11141	.40861	.82749	1900	-.21558	.38929	.77298

1901	-.20356	.39779	.77982	1951	-.17400	.39803	.77289	2001	-.13737	.41348	.75683
1902	-.19143	.39936	.78257	1952	-.18812	.39814	.76789	2002	-.15600	.39660	.75021
1903	-.17879	.39933	.78602	1953	-.20046	.39708	.76481	2003	-.16644	.40280	.75212
1904	-.16636	.40140	.79158	1954	-.21146	.40029	.76482	2004	-.18251	.39771	.74126
1905	-.15597	.40608	.79412	1955	-.19919	.40249	.75380	2005	-.16710	.39948	.73599
1906	-.14497	.40895	.79589	1956	-.18559	.39775	.75474	2006	-.16411	.39801	.73652
1907	-.13293	.41617	.80051	1957	-.17102	.40077	.76077	2007	-.15339	.39406	.73725
1908	-.12203	.41751	.80079	1958	-.16074	.39919	.76426	2008	-.15339	.39406	.73725
1909	-.10758	.42174	.80393	1959	-.14056	.40504	.76722	2009	-.13685	.41089	.74446
1910	-.09463	.42205	.80566	1960	-.14105	.40705	.76609	2010	-.12551	.42083	.74560
1911	-.08147	.42231	.80705	1961	-.12872	.42160	.77446	2011	-.11468	.42990	.74976
1912	-.06918	.41954	.80630	1962	-.11931	.42604	.77565	2012	-.10085	.43517	.75312
1913	-.05572	.42140	.80961	1963	-.10441	.43031	.77915	2013	-.08791	.43711	.75519
1914	-.04276	.42106	.81097	1964	-.09111	.43203	.78169	2014	-.07535	.43464	.75476
1915	-.02984	.42038	.81230	1965	-.07761	.43355	.78420	2015	-.06221	.43526	.75768
1916	-.01792	.41780	.81147	1966	-.06593	.42901	.78252	2016	-.04830	.43533	.75993
1917	-.00552	.41475	.81093	1967	-.05305	.42608	.78174	2017	-.03575	.43222	.75975
1918	.00818	.41661	.81395	1968	-.03952	.42793	.78529	2018	-.02334	.42869	.75964
1919	.02040	.41602	.81507	1969	-.02704	.42386	.78429	2019	-.01115	.42697	.76031
1920	.03463	.41705	.81733	1970	-.01632	.41894	.78251	2020	-.00009	.42371	.75931
1921	.04848	.41717	.81917	1971	-.00306	.41886	.78391	2021	.01332	.42399	.76086
1922	.06145	.41592	.82039	1972	.01047	.42120	.78696	2022	.02503	.42032	.76106
1923	.07393	.41354	.81922	1973	.02238	.42035	.78842	2023	.03840	.41915	.76262
1924	.08685	.41336	.82091	1974	.03764	.42108	.79085	2024	.05191	.41681	.76353
1925	.10040	.41319	.82245	1975	.05110	.42013	.79184	2025	.06423	.41314	.76352
1926	.11126	.40679	.81964	1976	.06457	.42066	.79443	2026	.07622	.41052	.76435
1927	.11483	.40653	.82001	1977	.07619	.41463	.79228	2027	.08936	.40540	.76385
1928	.11124	.40607	.80699	1978	.08924	.41407	.79417	2028	.09557	.40403	.76410
1929	.10076	.41015	.80609	1979	.09915	.40521	.79020	2029	-.13737	.41241	.73217
1930	.08925	.41499	.80758	1980	.10352	.40437	.79007	2030	-.12342	.42205	.73256
1931	.07529	.41391	.80490	1981	.09739	.39720	.77325	2031	-.12342	.42205	.73256
1932	.06288	.41584	.80471	1982	.08752	.40603	.77483	2032	-.11273	.43045	.73592
1933	.04992	.41920	.80546	1983	.07640	.41126	.77645	2033	-.09953	.43445	.73788
1934	.03656	.41892	.80403	1984	.06423	.41480	.77640	2034	-.08639	.43875	.74225
1935	.02412	.42188	.80470	1985	.05093	.41816	.77702	2035	-.07381	.43678	.74207
1936	.01049	.42173	.80230	1986	.03999	.42160	.77708	2036	-.05937	.43879	.74547
1937	-.00274	.41969	.79963	1987	.02421	.42045	.77489	2037	-.04579	.43775	.74638
1938	-.01692	.41789	.79643	1988	.01106	.41942	.77155	2038	-.03409	.43303	.74573
1939	-.02735	.42403	.79914	1989	-.00112	.42231	.77217	2039	-.02186	.42831	.74511
1940	-.04055	.42596	.79917	1990	-.01330	.42538	.77262	2040	-.01043	.42636	.74549
1941	-.05411	.42516	.79699	1991	-.02576	.42472	.77046	2041	.00029	.42170	.74422
1942	-.06696	.42495	.79514	1992	-.03693	.43182	.77374	2042	.01217	.41915	.74359
1943	-.08059	.42381	.79267	1993	-.04931	.43330	.77222	2043	.02635	.42120	.74867
1944	-.09232	.42900	.79540	1994	-.06324	.43351	.77044	2044	.03925	.41783	.74930
1945	-.10516	.42789	.79312	1995	-.07621	.43556	.77035	2045	.05131	.41292	.74739
1946	-.11989	.42155	.78797	1996	-.08794	.43927	.77175	2046	.06350	.40672	.74591
1947	-.12961	.42246	.78971	1997	-.10161	.43621	.76880	2047	.07353	.40002	.74404
1948	-.14152	.41261	.78452	1998	-.11587	.42965	.76393	2048	.08627	.39606	.74423
1949	-.15346	.40513	.78035	1999	-.12690	.42124	.75905	2049	.09752	.39576	.74418
1950	-.16264	.40370	.77919	2000	-.13737	.41348	.75683	2050	.08368	.39551	.73146

2051	.07220	.39228	.72707
2052	.06294	.40294	.73155
2053	.05071	.40832	.73224
2054	.03870	.41266	.73150
2055	.02635	.41655	.73190
2056	.01319	.41856	.73065
2057	.00168	.42147	.73106
2058	-.00734	.42796	.73314
2059	-.01994	.42999	.73268
2060	-.03162	.43619	.73443
2061	-.04558	.43584	.73158
2062	-.05818	.43809	.73029
2063	-.07202	.43684	.72760
2064	-.08342	.44241	.72948
2065	-.09685	.43985	.72693
2066	-.11034	.43438	.72417
2067	-.12194	.42722	.72065
2068	-.13237	.41643	.71679
2069	-.13930	.40593	.71166
2070	-.13517	.41494	.70075
2071	-.12206	.42841	.70685
2072	-.10945	.43765	.71188
2073	-.09641	.43919	.71247
2074	-.08251	.44207	.71514
2075	-.06890	.44240	.71735
2076	-.05664	.43930	.71691
2077	-.04405	.43522	.71695
2078	-.03044	.43551	.72019
2079	-.01944	.43062	.71949
2080	-.00511	.43092	.72281
2081	.00608	.42643	.72322
2082	.01489	.41852	.71834
2083	.02576	.41084	.71566
2084	.03658	.40564	.71429
2085	.05010	.40385	.71649
2086	.06023	.39319	.71355
2087	.07111	.38643	.71135
2088	.07544	.38517	.71135
2089	.06750	.37617	.69354
2090	.06014	.38894	.69922
2091	.04915	.39694	.70117
2092	.03749	.40225	.70135
2093	.02635	.40776	.70121
2094	.01691	.41719	.70564
2095	.00502	.41915	.70700
2096	-.00389	.42707	.70766
2097	-.01618	.43100	.70738
2098	-.02822	.43640	.70825
2099	-.04158	.43722	.70593
2100	-.05611	.43646	.70250
2101	-.06872	.43862	.70260
2102	-.08167	.43757	.70033
2103	-.09374	.44058	.70047
2104	-.10832	.43550	.69634
2105	-.12003	.43543	.69760
2106	-.10684	.43532	.69197
2107	-.09156	.44224	.68815
2108	-.07960	.43826	.68765
2109	-.06833	.43484	.68715
2110	-.05528	.43445	.68844
2111	-.04221	.43226	.68916
2112	-.02865	.43164	.69211
2113	-.01520	.42994	.69544
2114	-.00168	.43005	.69811
2115	.00730	.42054	.69637
2116	.01670	.41449	.69305
2117	.02576	.40333	.68761
2118	.03716	.39709	.68713
2119	.04863	.39150	.68666
2120	.05954	.38272	.68461
2121	.06803	.38838	.69055
2122	.06274	.38435	.67594
2123	.04919	.38949	.67551
2124	.03786	.39505	.67593
2125	.02760	.40253	.67618
2126	.01681	.40925	.67759
2127	.01010	.42210	.68518
2128	-.00229	.42446	.68259
2129	-.01635	.42361	.67867
2130	-.02899	.42616	.67662
2131	-.04058	.43093	.67630
2132	-.05262	.43595	.67897
2133	-.06700	.43177	.67601
2134	-.07794	.43691	.67610
2135	-.08981	.43889	.67466
2136	-.07535	.43470	.66428
2137	-.06461	.43130	.66483
2138	-.05206	.42845	.66350
2139	-.03982	.42713	.66150
2140	-.02824	.42298	.66218
2141	-.01397	.42336	.66633
2142	-.00243	.42039	.66872
2143	.01075	.41906	.67137
2144	.01842	.40886	.66683
2145	.02622	.39569	.66088
2146	.03802	.39078	.66219
2147	.04906	.38424	.66157
2148	.05494	.37534	.65947
2149	.05271	.37551	.64771
2150	.04892	.37922	.64891
2151	.03628	.38323	.64803
2152	.02773	.39541	.65120
2153	.01926	.40548	.65486
2154	.01115	.41415	.65738
2155	-.00184	.41560	.65586
2156	-.01425	.41673	.65178
2157	-.02653	.42143	.65079
2158	-.02749	.41936	.64961
2159	-.05099	.42578	.65055
2160	-.05598	.42728	.65114
2161	-.04759	.42182	.63663
2162	-.03562	.42213	.64093
2163	-.03562	.42213	.64093
2164	-.01383	.41297	.63898
2165	-.00237	.40828	.64017
2166	.00931	.40666	.64213
2167	.02041	.40172	.64364
2168	.02852	.39263	.64020
2169	.03883	.38385	.63921
2170	.04708	.37336	.63509
2171	.04393	.37576	.62487
2172	.03901	.37969	.62609
2173	.02708	.38358	.62543
2174	.02012	.39525	.63041
2175	.01109	.40491	.63175
2176	-.00133	.40445	.62693
2177	-.01291	.40908	.62580
2178	-.01291	.40908	.62580
2179	-.02403	.41108	.62661
2180	-.03058	.41535	.62599
2181	-.01391	.42010	.62271
2182	-.00034	.40254	.61768
2183	-.00034	.40254	.61768
2184	.00981	.39751	.61779
2185	.01933	.39009	.61792
2186	.02797	.38010	.61402
2187	.04036	.37643	.61410
2188	.03699	.37418	.60316
2189	.02768	.37365	.60075
2190	.01900	.38291	.60313
2191	.00748	.38516	.60047
2192	-.00104	.39410	.60342
2193	-.00740	.40118	.60217
2194	.00547	.39931	.59770
2195	.00908	.38669	.59369
2196	.01866	.37842	.59189
2197	.02954	.37467	.59241
2198	.03206	.37420	.59218
2199	.02906	.37629	.58393
2200	.02064	.37865	.58291
2201	.02071	.37880	.58302

REFERENCES

1. Rogallo, F. M.: Flexible Wings. Astronautics and Aeronautics, vol. 16, no. 8, Aug. 1968, pp. 50-54.

2. Sleeman, W. C., Jr. and Gainer, T. G.: Status of Research on Parawing Lifting Decelerators. AIAA Paper No. 68-967, presented at AIAA 2nd Aerodynamic Decelerator Systems Conference, El Centro, Calif., Sept. 22-25, 1968.

3. Naeseth, R. L.: Recent Flexible-Wing Research, NASA Langley Research Center. Presented at the course on Aerodynamic Deceleration at the Center for Continuation Study, University of Minnesota, Minneapolis, Minnesota, July 17, 1969.

4. Nielsen, J. N.: Missile Aerodynamics. McGraw-Hill Book Co., New York, N. Y., 1960.

5. Jones, R. T. and Cohen, D.: High Speed Wing Theory. Princeton University Press, 1960.

6. Polhamus, E. D.: A Concept of the Vortex Lift of Sharp-Edge Delta Wings Based on a Leading-Edge-Suction Analogy. NASA TN D-3767, Dec. 1966.

7. Naeseth, R. L. and Fournier, P. G.: Low-Speed Wind Tunnel Investigation of Tension Structure Parawings. NASA TN D-3940, June 1967.

8. Ware, G. M.: Wind-Tunnel Investigation of the Aerodynamic Characteristics of a Twin-Keel Parawing. NASA TN D-5199, May 1969.

9. Lamar, J. E.: A Modified Multhopp Approach for Predicting Lifting Pressures and Camber Shape for Composite Planforms in Subsonic Flow. NASA TN D-4427, July 1968.

10. Ashley, H. and Landahl, M.: Aerodynamics of Wings and Bodies. Addison-Wesley, Reading, Mass., 1965.

11. Gradshteyn, I. S. and Ryzhik, I. M.: Table of Integrals, Series, and Products. Fourth Edition, Academic Press, New York and London, 1965.

TABLE I

PROPERTIES OF THE CIRCULAR-ARC FITS
TO THE SINGLE-KEEL PARAWING

x (in.)	x/c_r	e (in.)	f (in.)	r (in.)	s (in.)
2	0.052	0.60	5.40	8.60	7.98
4	.103	.50	6.50	9.50	9.01
6	.154	1.65	7.60	13.30	12.02
8	.206	3.05	8.60	15.50	13.88
10	.256	4.50	9.50	16.50	14.94
12	.308	5.95	10.30	17.80	16.14
14	.360	7.40	11.00	19.10	17.30
16	.411	8.80	11.60	20.60	18.53
18	.462	10.30	12.10	22.40	19.89
20	.514	11.85	12.50	24.20	21.18
22	.575	13.45	12.85	25.60	22.20
24	.616	15.15	13.15	26.00	22.60
26	.668	16.90	13.40	26.00	22.74
28	.720	18.70	13.50	26.20	22.92
30	.771	20.50	13.50	27.00	23.38
32	.822	22.00	13.50	27.00	23.38
34	.874	23.75	13.50	27.00	23.38
36	.925	25.00	10.00	18.00	16.12
38	.977	27.00	6.00	17.00	12.96

TABLE II

PROPERTIES OF THE CIRCULAR-ARC FITS
TO THE TWIN-KEEL PARAWING

x (in.)	x/c_r	e (in.)	f (in.)	r (in.)	s (in.)
2	0.039	-0.9	4.0	11.4	8.67
4	.078	.1	9.6	13.6	13.00
6	.117	1.1	10.5	18.0	16.36
8	.156	2.1	11.2	23.7	20.14
10	.194	3.2	11.9	25.5	21.57
12	.234	4.2	12.5	28.5	23.58
14	.272	5.2	13.1	31.2	25.41
16	.312	6.2	13.8	33.4	27.04
18	.350	7.3	14.5	34.3	28.01
20	.389	8.3	15.4	35.5	29.26
22	.429	9.3	16.5	35.9	30.21
24	.466	10.3	18.4	36.0	31.40
26	.505	11.3	21.4	36.0	32.91
28	.545	12.3	24.0	36.0	33.94
30	.585	13.4	25.4	36.1	34.48
32	.622	14.6	25.6	36.3	34.69
34	.662	15.8	23.7	36.9	34.46
36	.700	17.1	20.4	37.7	33.50
38	.740	18.4	18.5	38.8	33.07
40	.780	19.9	17.0	40.0	32.73
42	.818	21.4	16.1	41.4	32.77
44	.856	23.2	15.4	43.0	32.97
46	.895	24.9	10.0	24.5	19.75
48	.934	26.7	5.8	12.0	10.27
50	.973	28.5	2.2	4.5	3.87

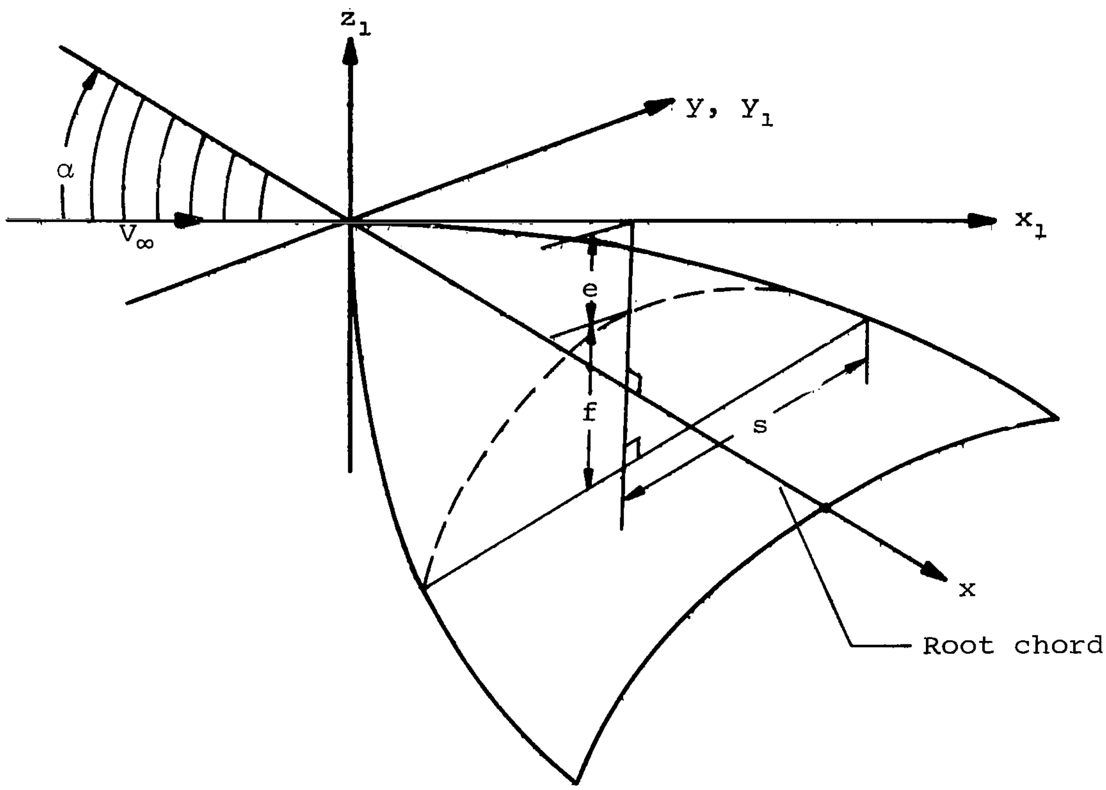
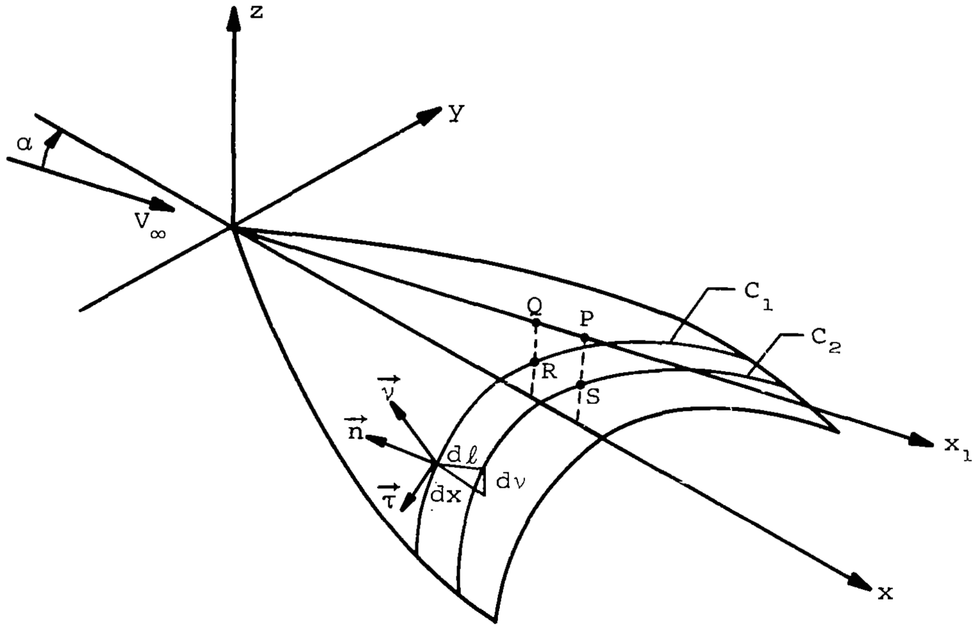
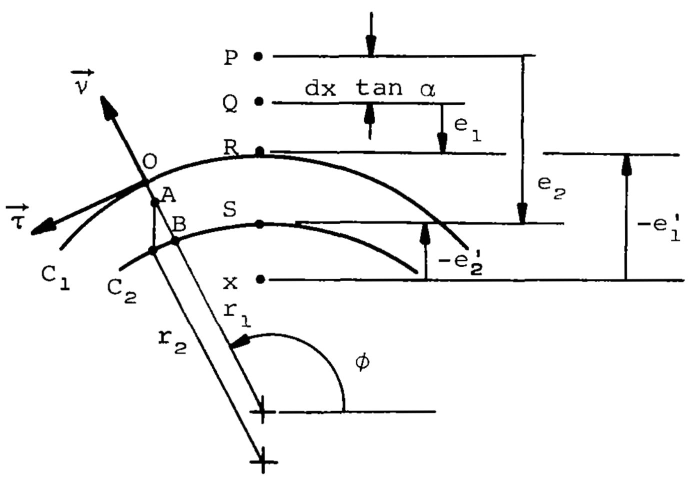


Figure 1.- Axes and crossflow plane used in theory.

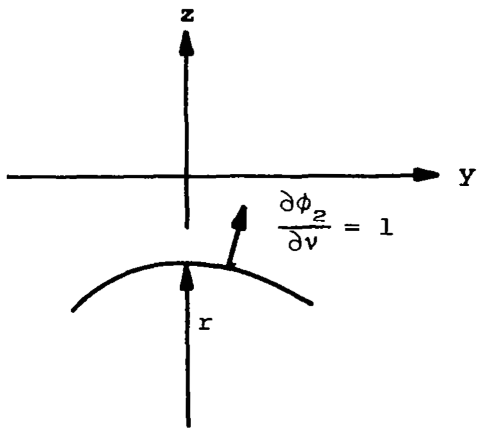


(a) Boundary condition for stationary parawing.

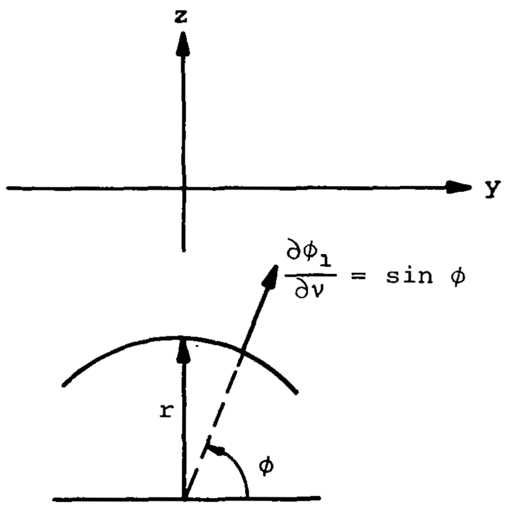


(b) Boundary condition in fixed crossflow plane through which parawing is moving.

Figure 2.- Boundary conditions for all-flexible slender parawing.

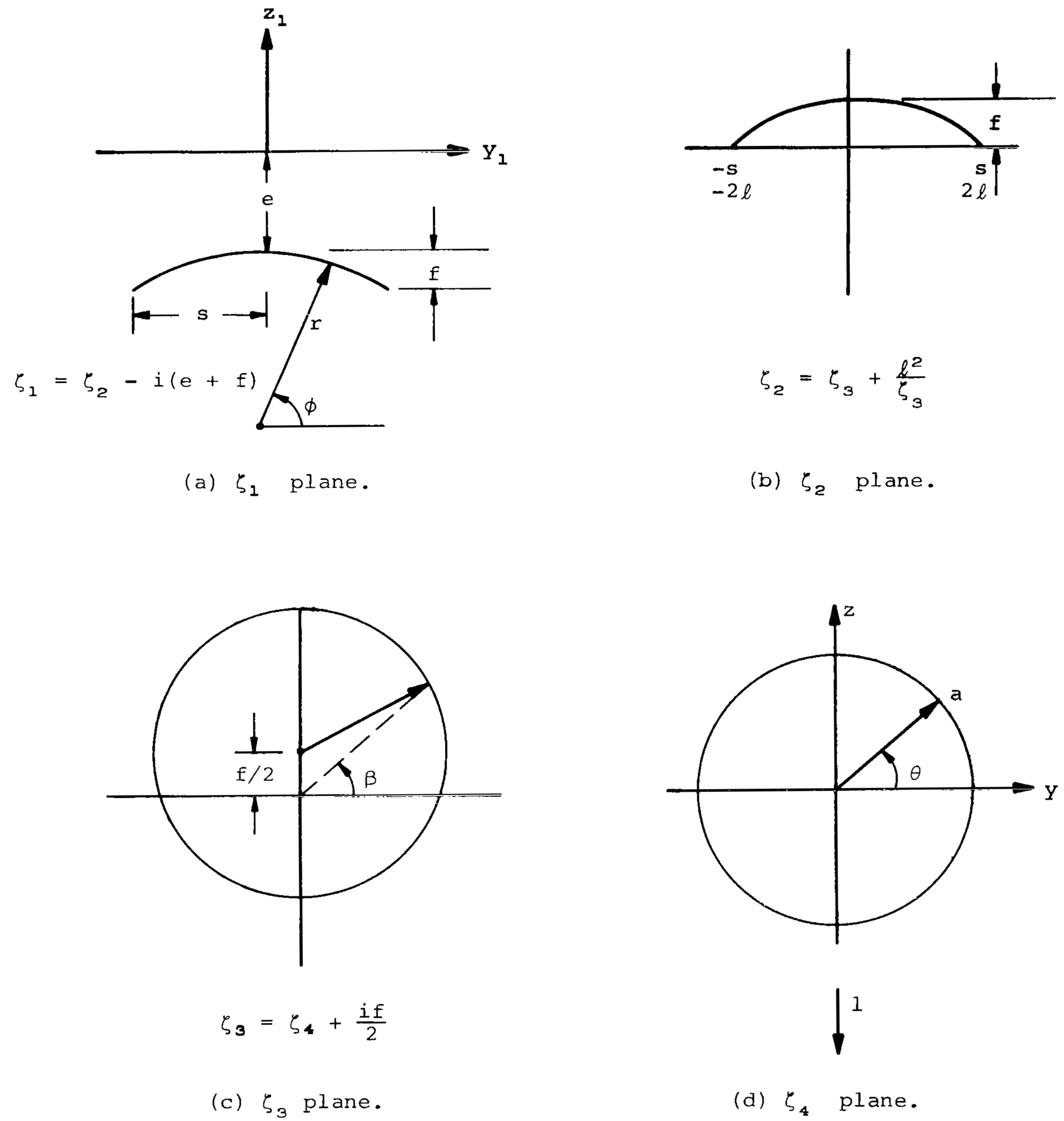


(a) ϕ_2 boundary condition for an expanding circular arc.



(b) ϕ_1 boundary condition for a translating circular arc.

Figure 3.- Unit potential solutions arising in all-flexible slender parawing theory.



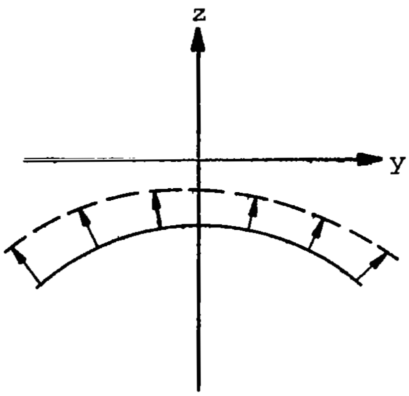
(a) ζ_1 plane.

(b) ζ_2 plane.

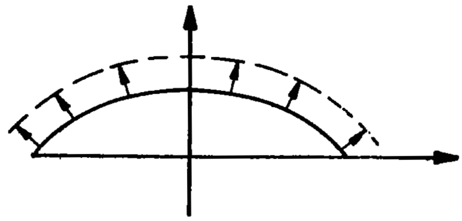
(c) ζ_3 plane.

(d) ζ_4 plane.

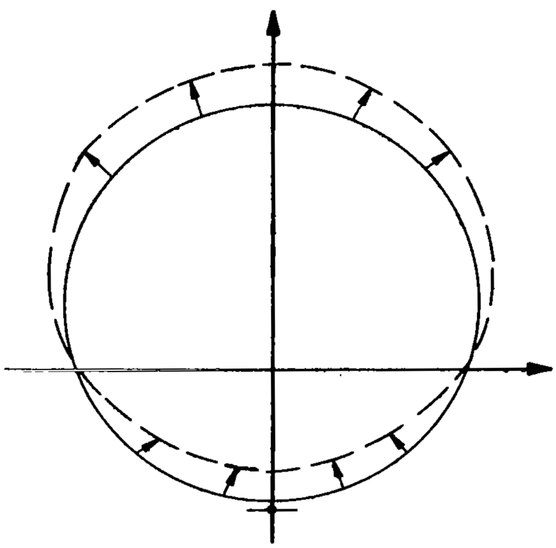
Figure 4.- Transformations used in obtaining complex potential for translating arc.



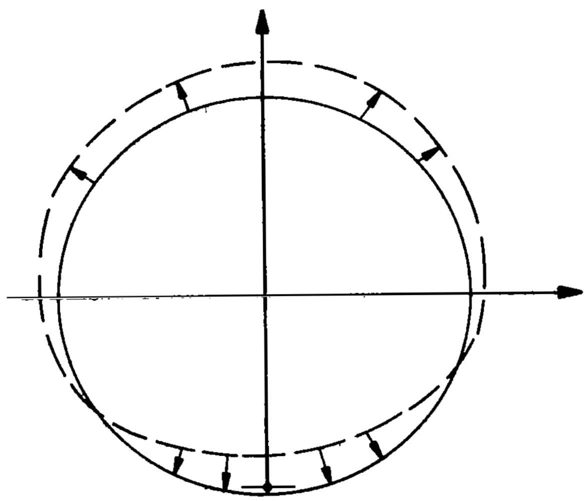
(a) ζ_1 plane.



(b) ζ_2 plane.



(c) ζ_3 plane.



(d) ζ_4 plane.

Figure 5.- Transformations and flows used in obtaining complex potential for dilating arc.

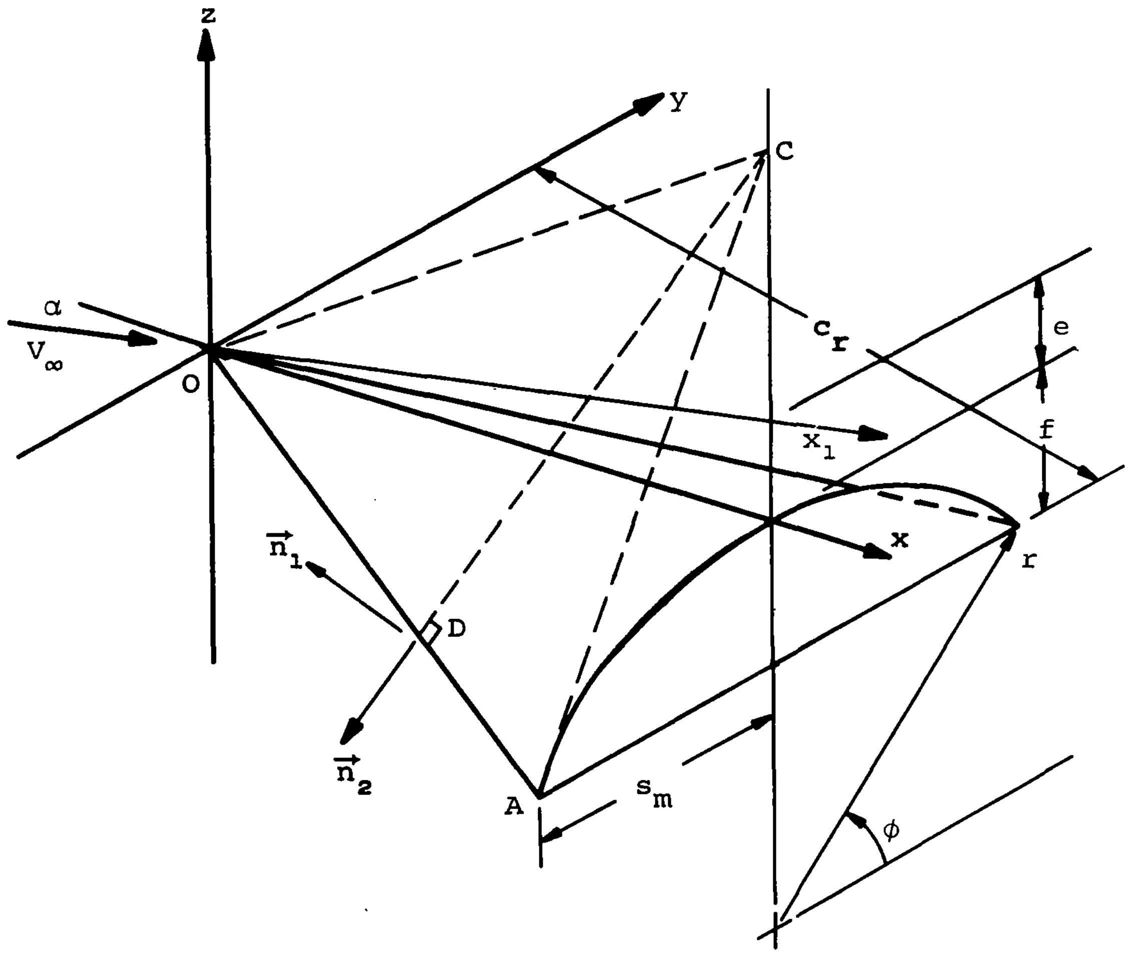
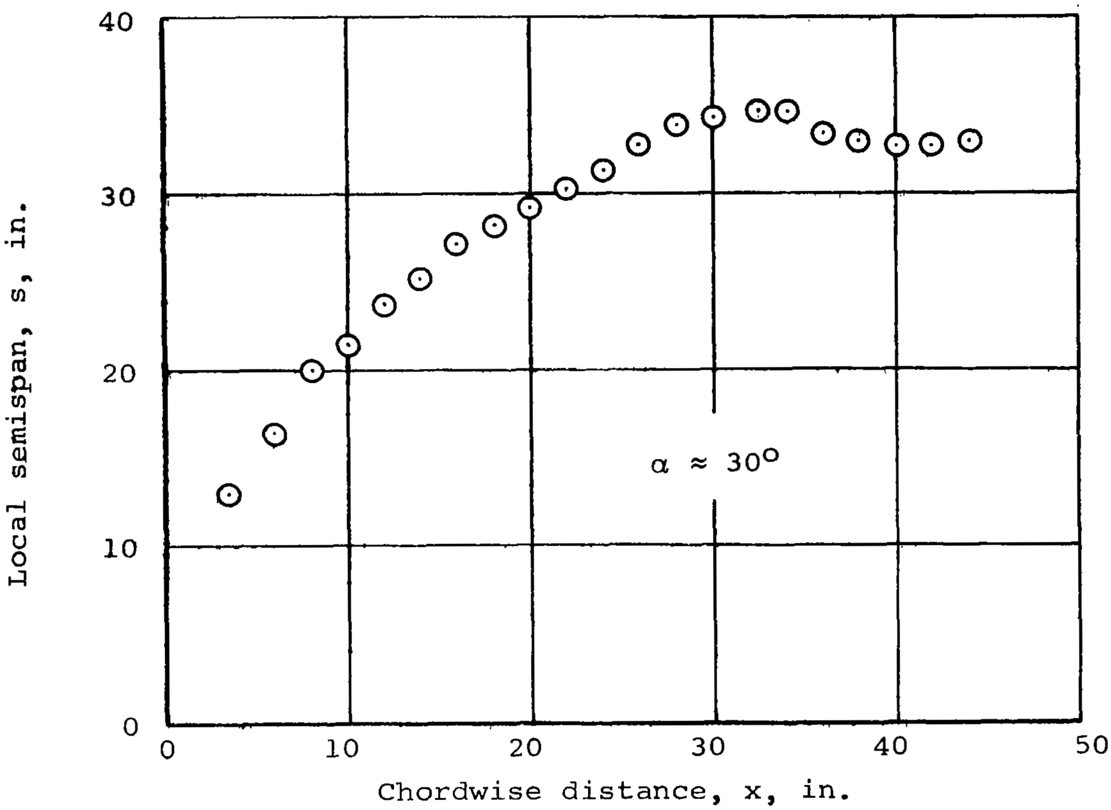
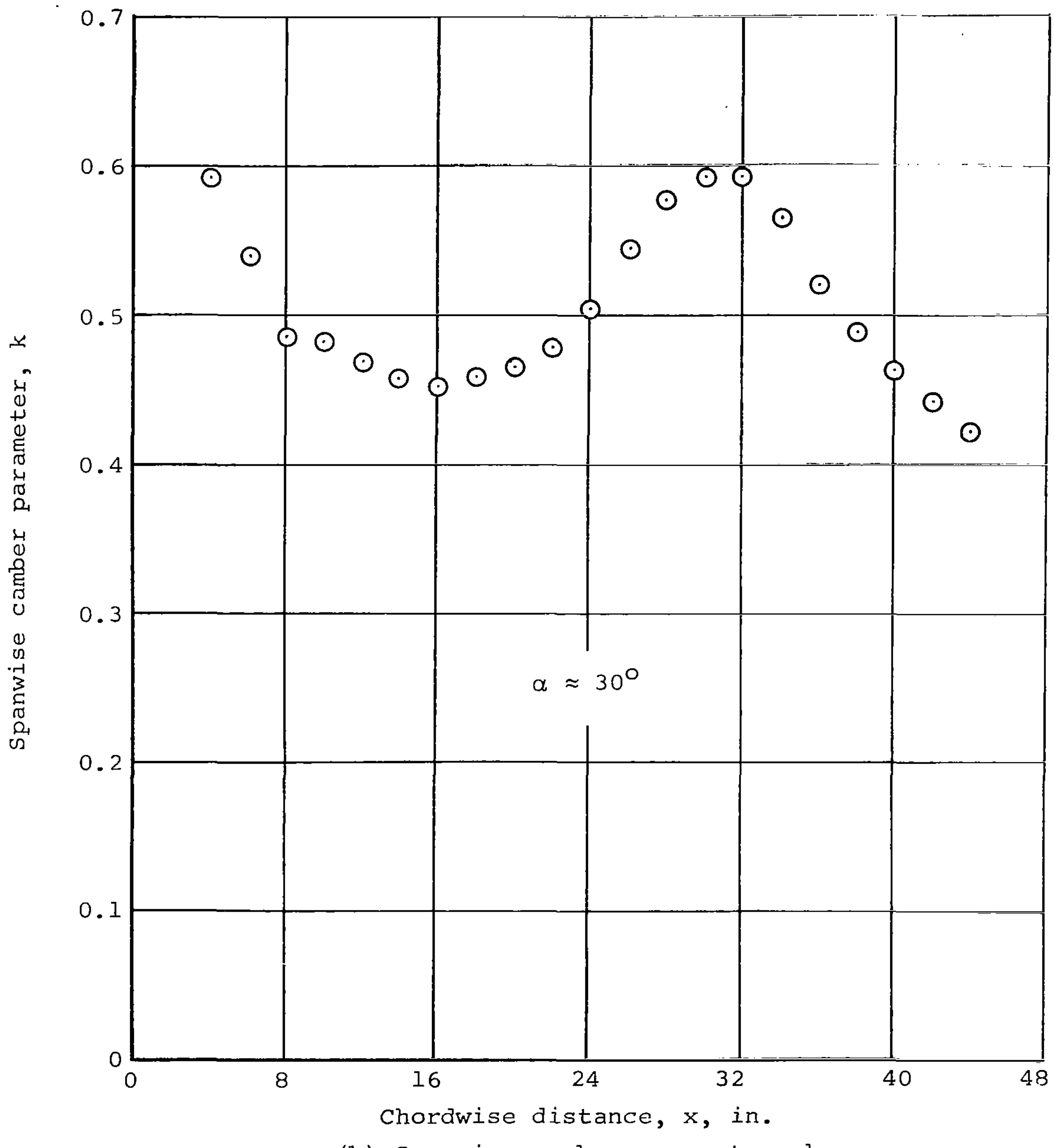


Figure 6.- Normal directions associated with surface formed from segment of a circular cone.



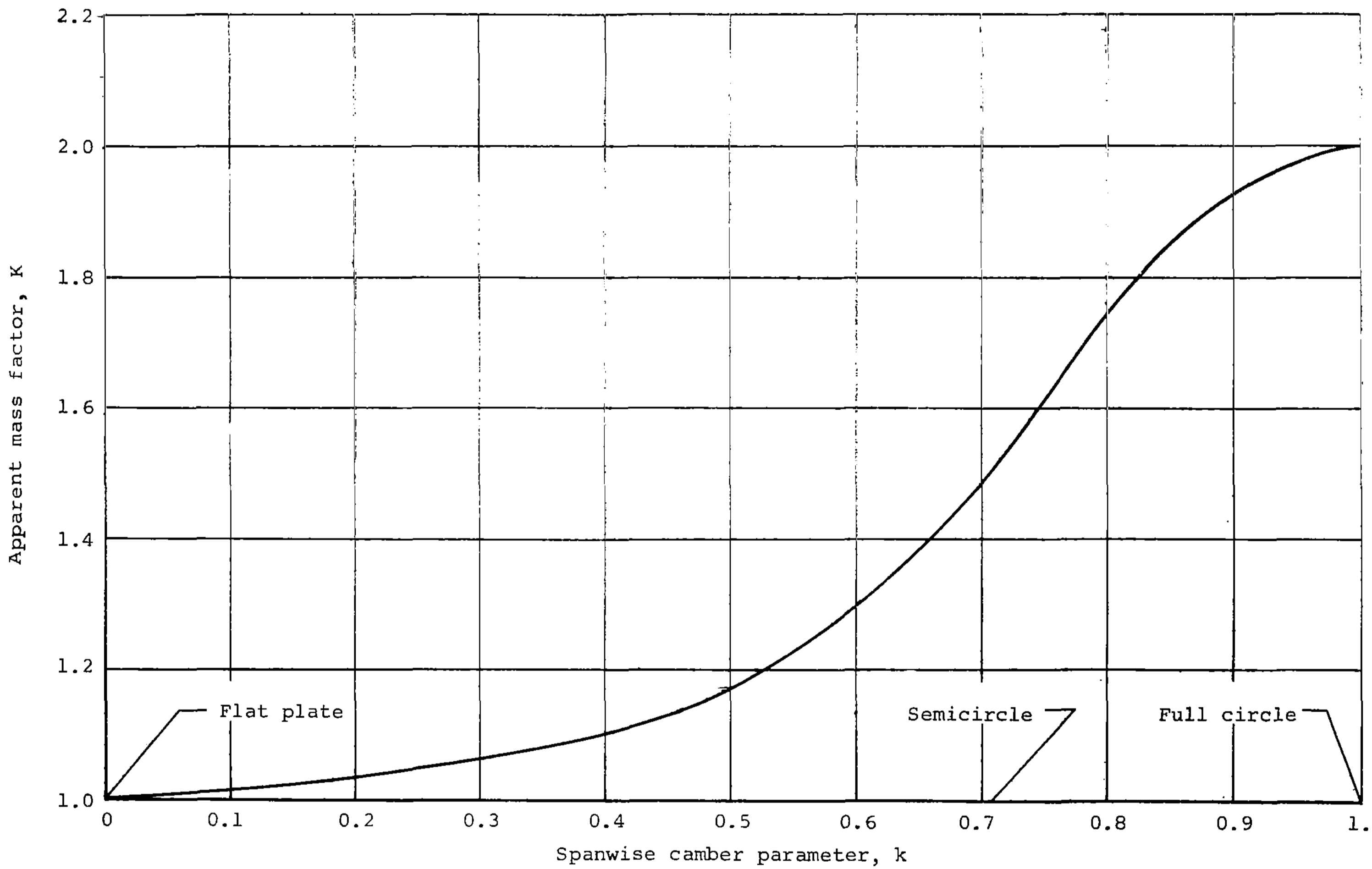
(a) Local semispan.

Figure 7.- Geometric characteristics of twin-keel, all-flexible parawing based on wing tunnel shape measurements.



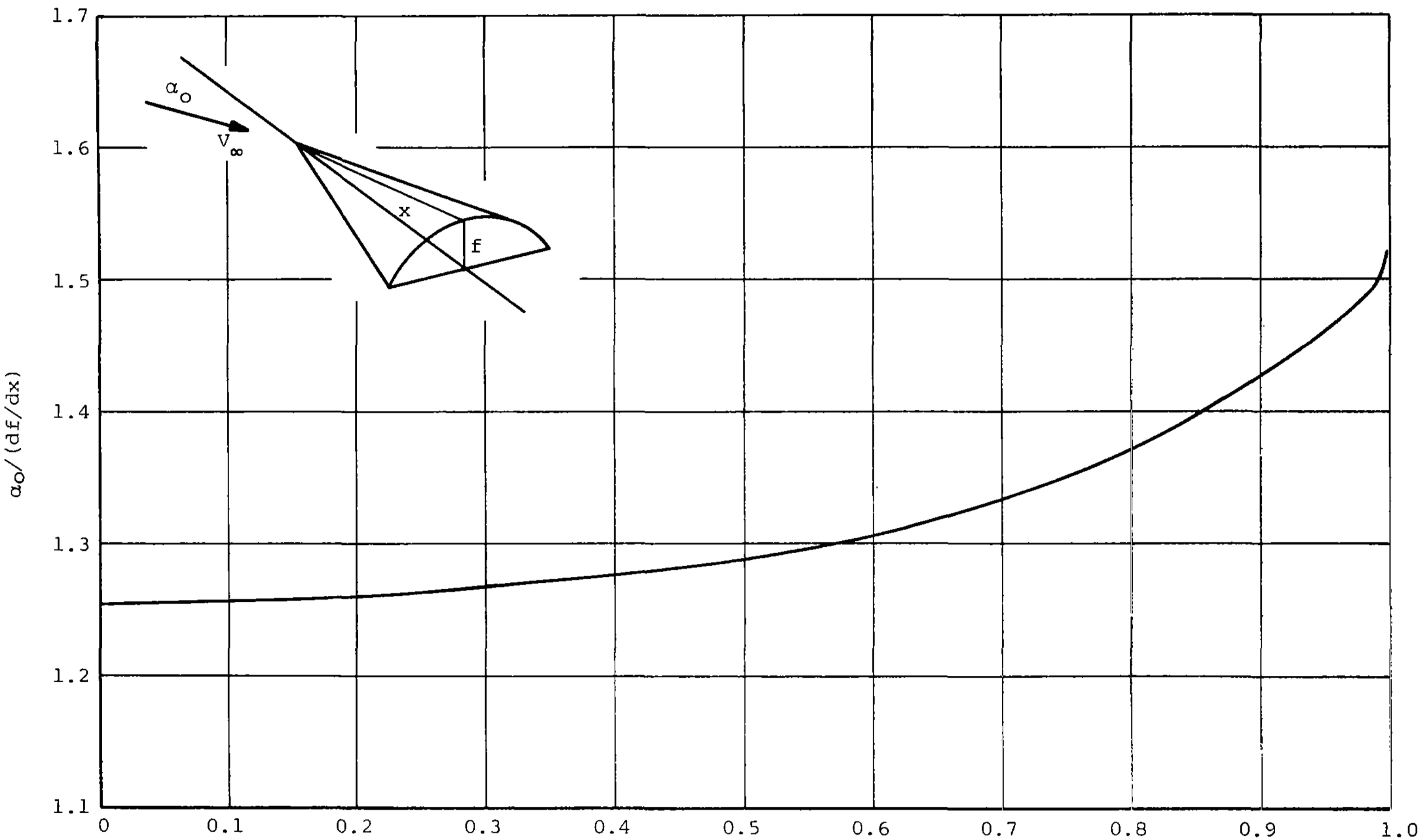
(b) Spanwise camber parameter, k.

Figure 7.- Concluded.



(a) Apparent mass factor.

Figure 8.- Effect of spanwise camber on normal-force curve slope and angle of zero normal force for conical parawing.



Spanwise camber parameter, k

(b) Angle of zero normal force.

Figure 8.- Concluded.

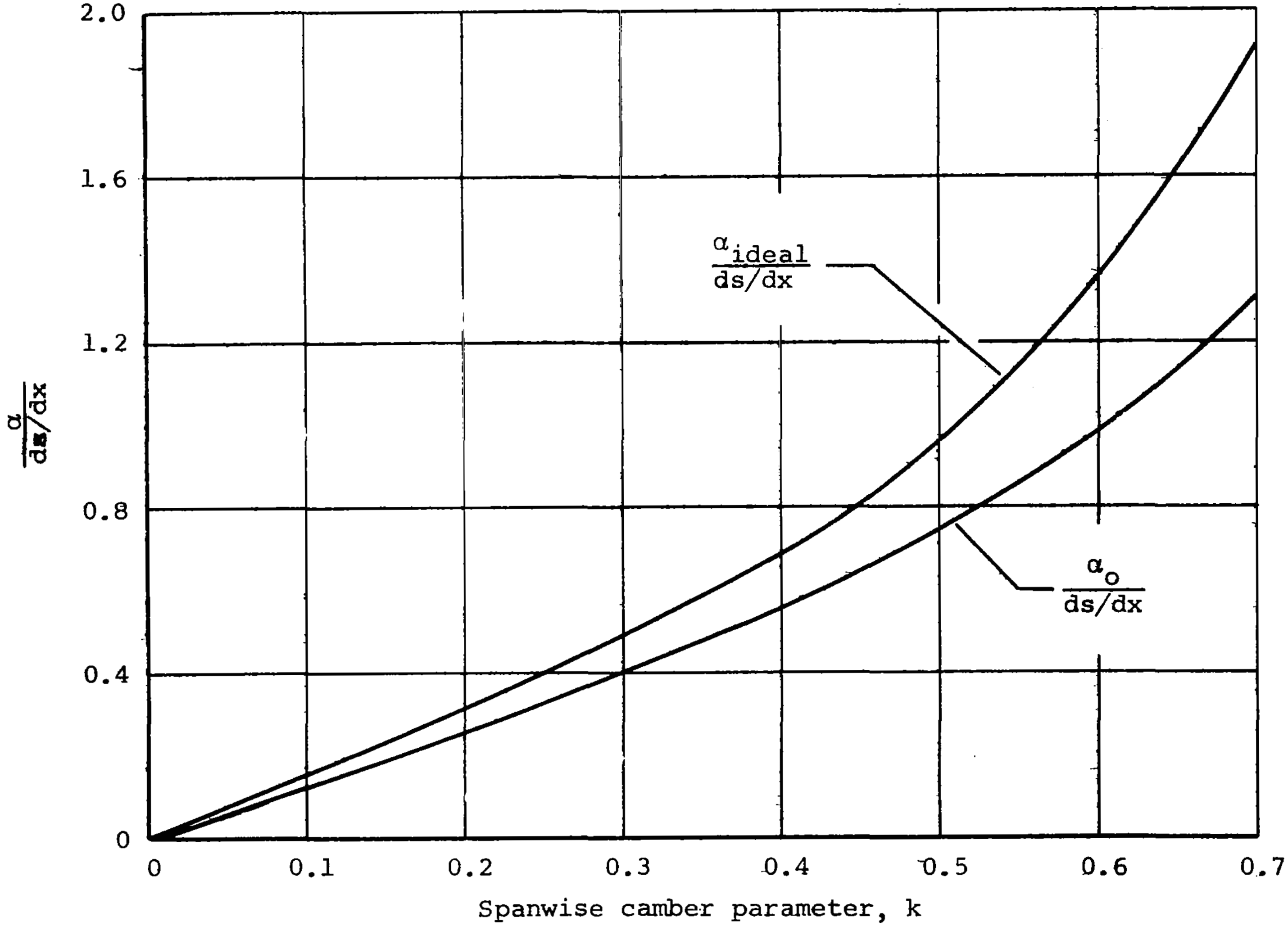
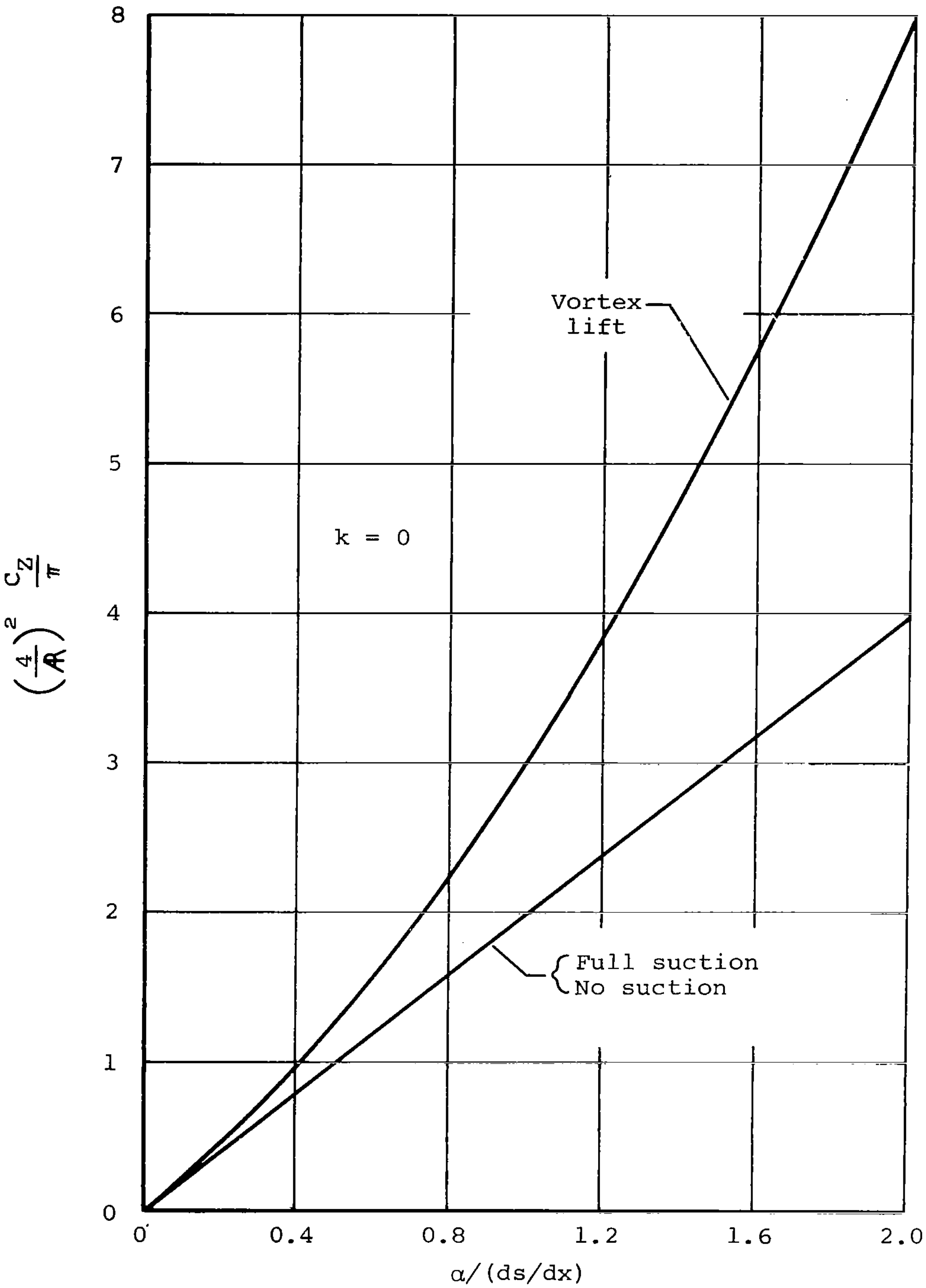
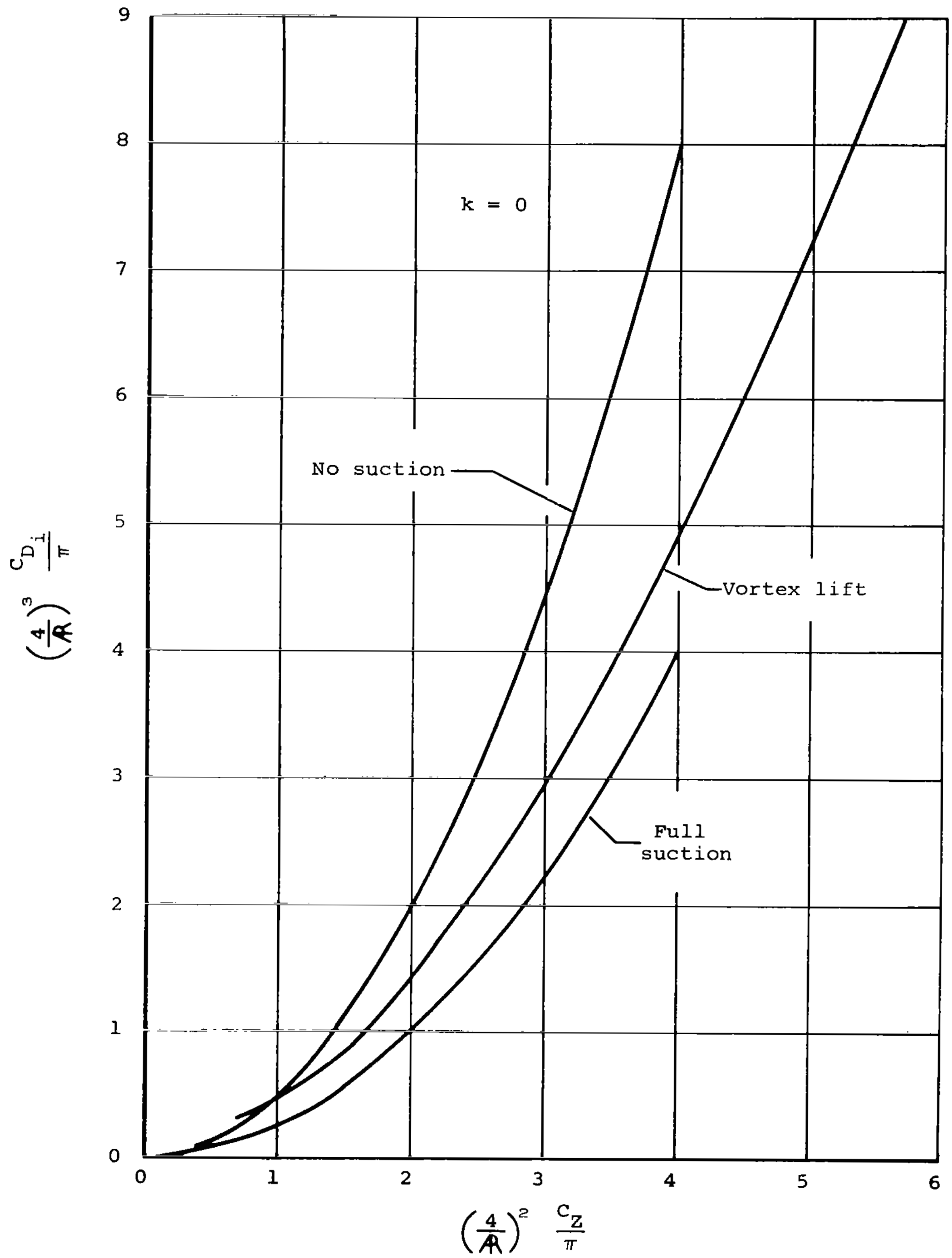


Figure 9.- Effect of spanwise camber on angle of zero normal force and ideal angle of attack.



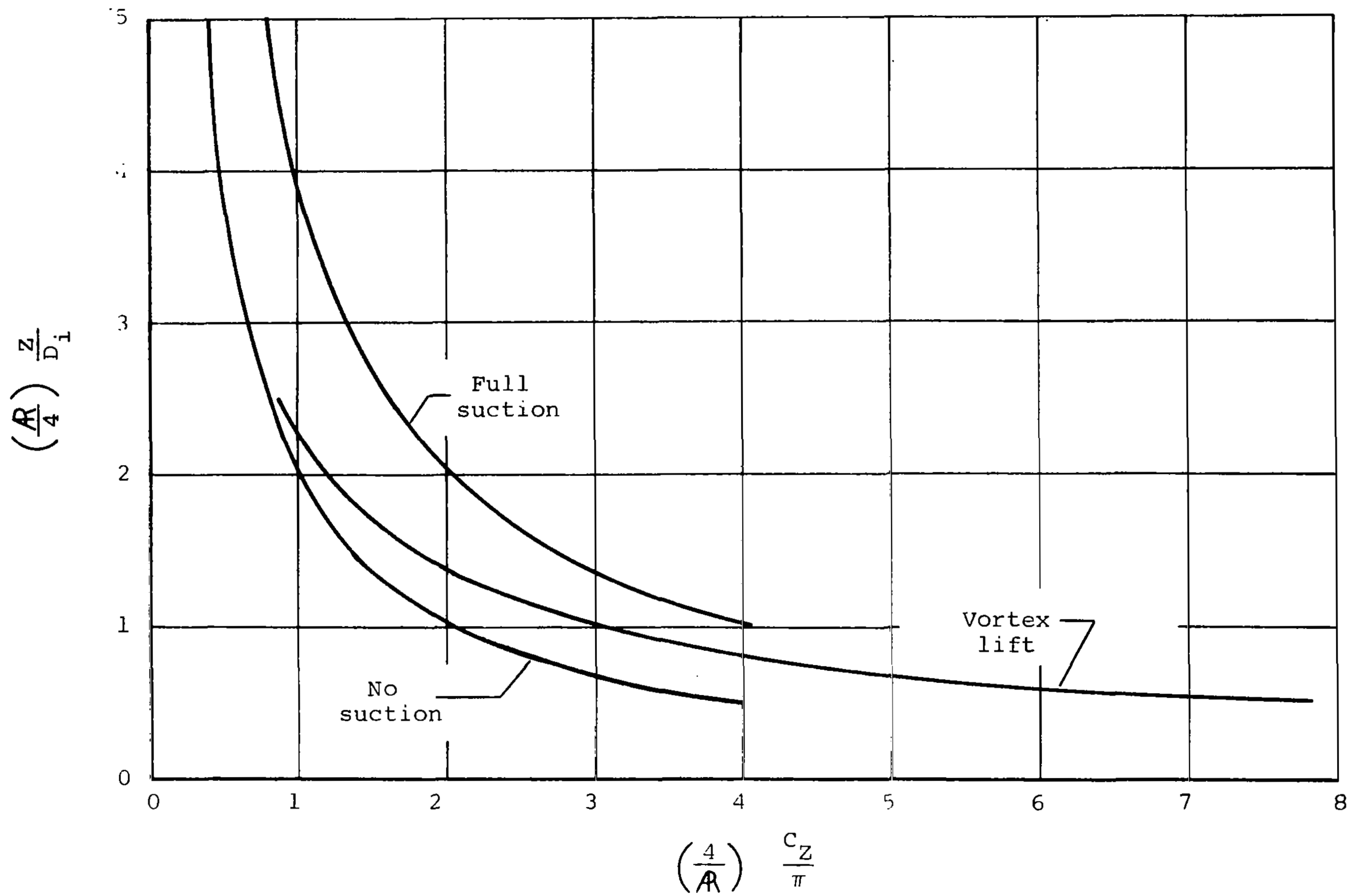
(a) Normal-force curves.

Figure 10.- Effect of leading-edge suction and vortex lift on aerodynamic characteristics of flat delta wings of low aspect ratio.



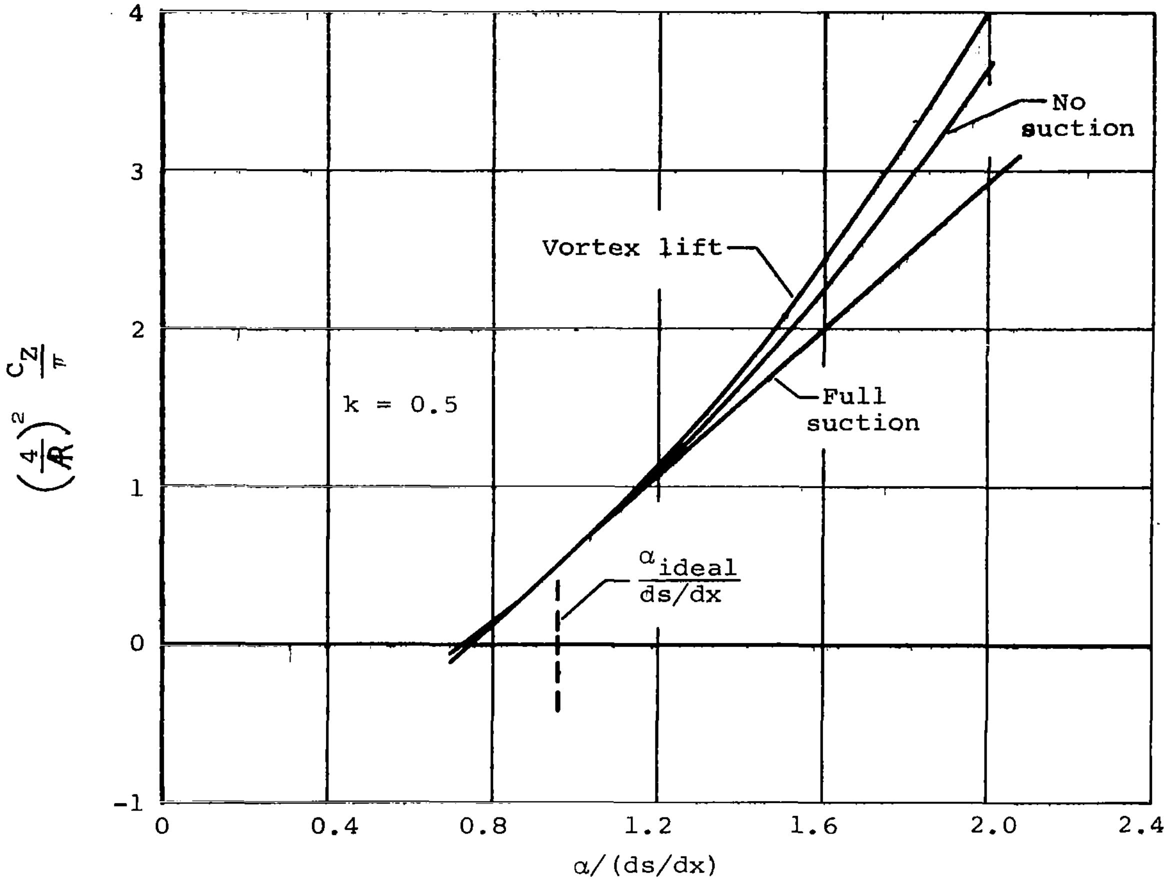
(b) Drag curves.

Figure 10.- Continued.



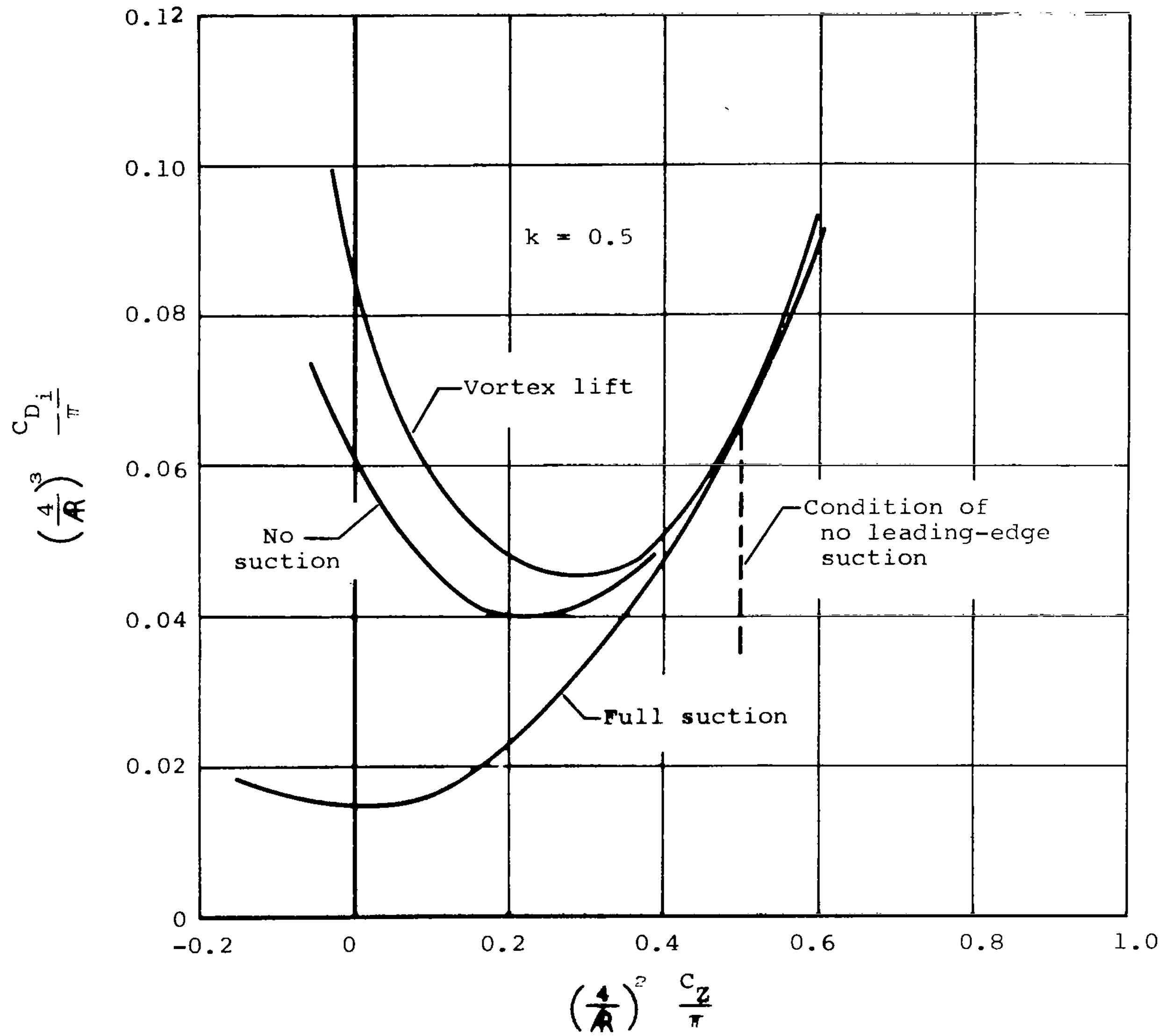
(c) Z/C_{D_i} ratio.

Figure 10.- Concluded.



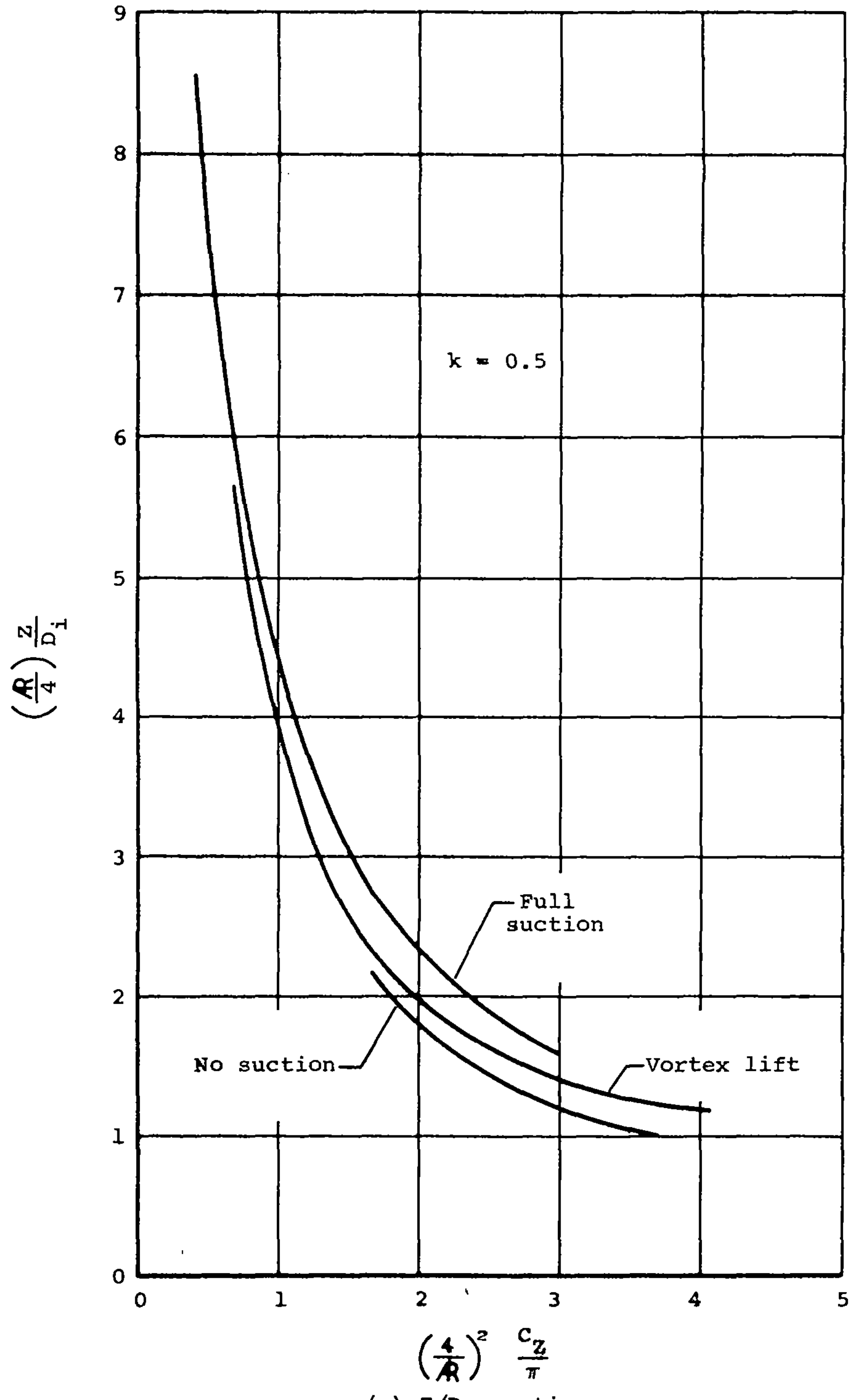
(a) Normal-force curves.

Figure 11.- Effect of leading-edge suction and vortex lift on aerodynamic characteristics of parawing formed by segments of circular cones.



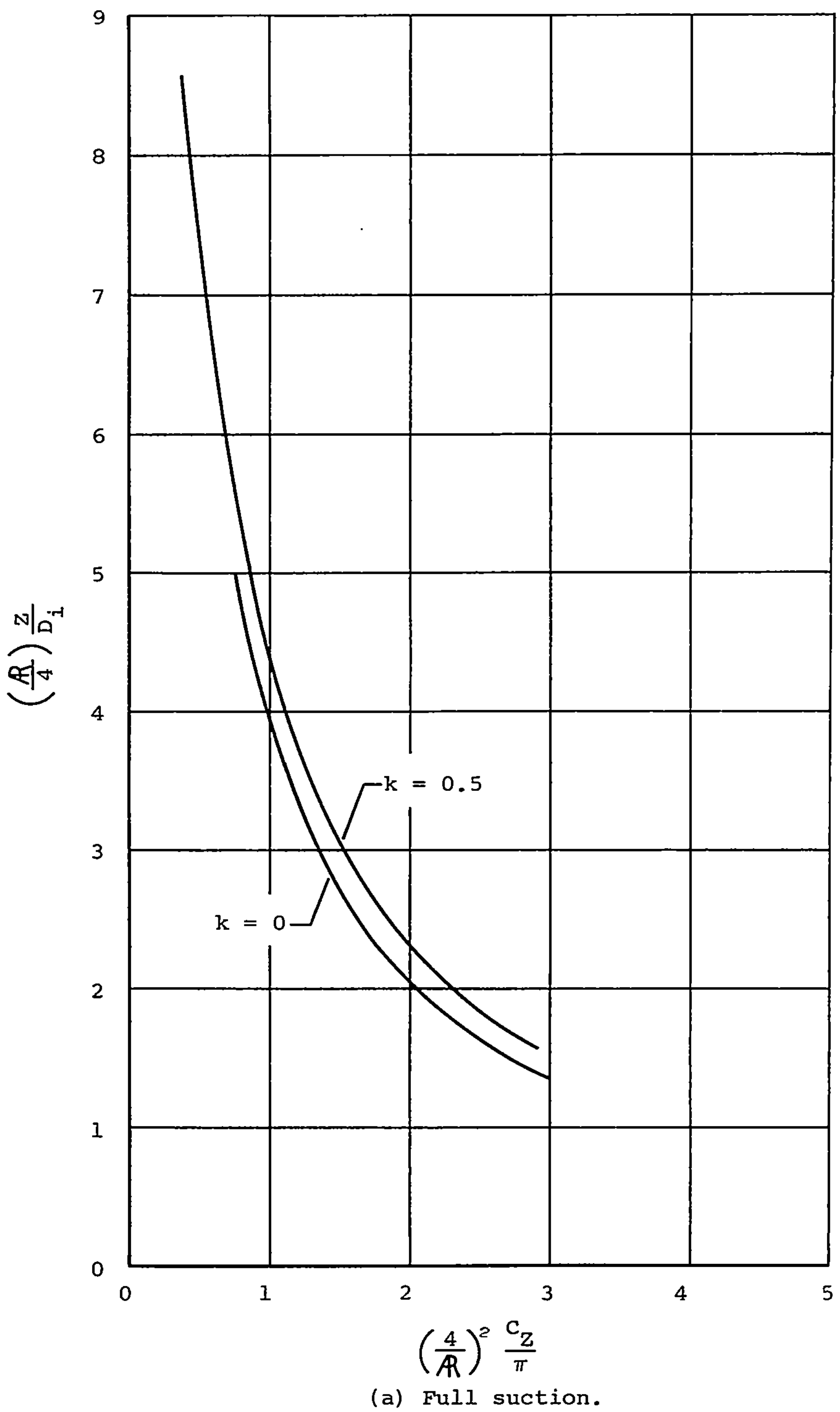
(b) Drag curves.

Figure 11.- Continued.



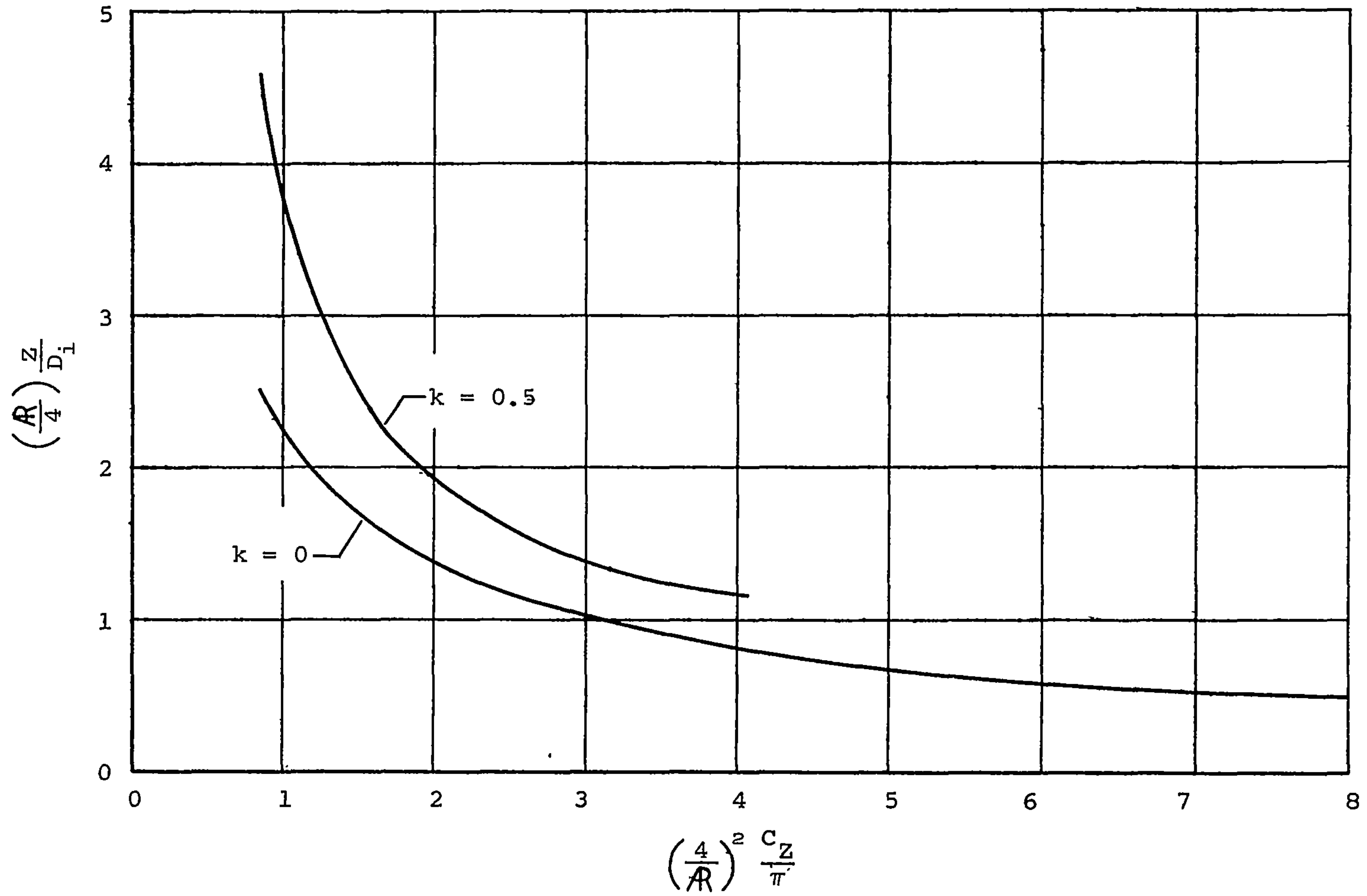
(c) Z/D_i ratio.

Figure 11.- Concluded.



(a) Full suction.

Figure 12.- Effect of k on ratio of normal force to induced drag for conical lifting surfaces.



(b) Vortex lift.

Figure 12.- Concluded.

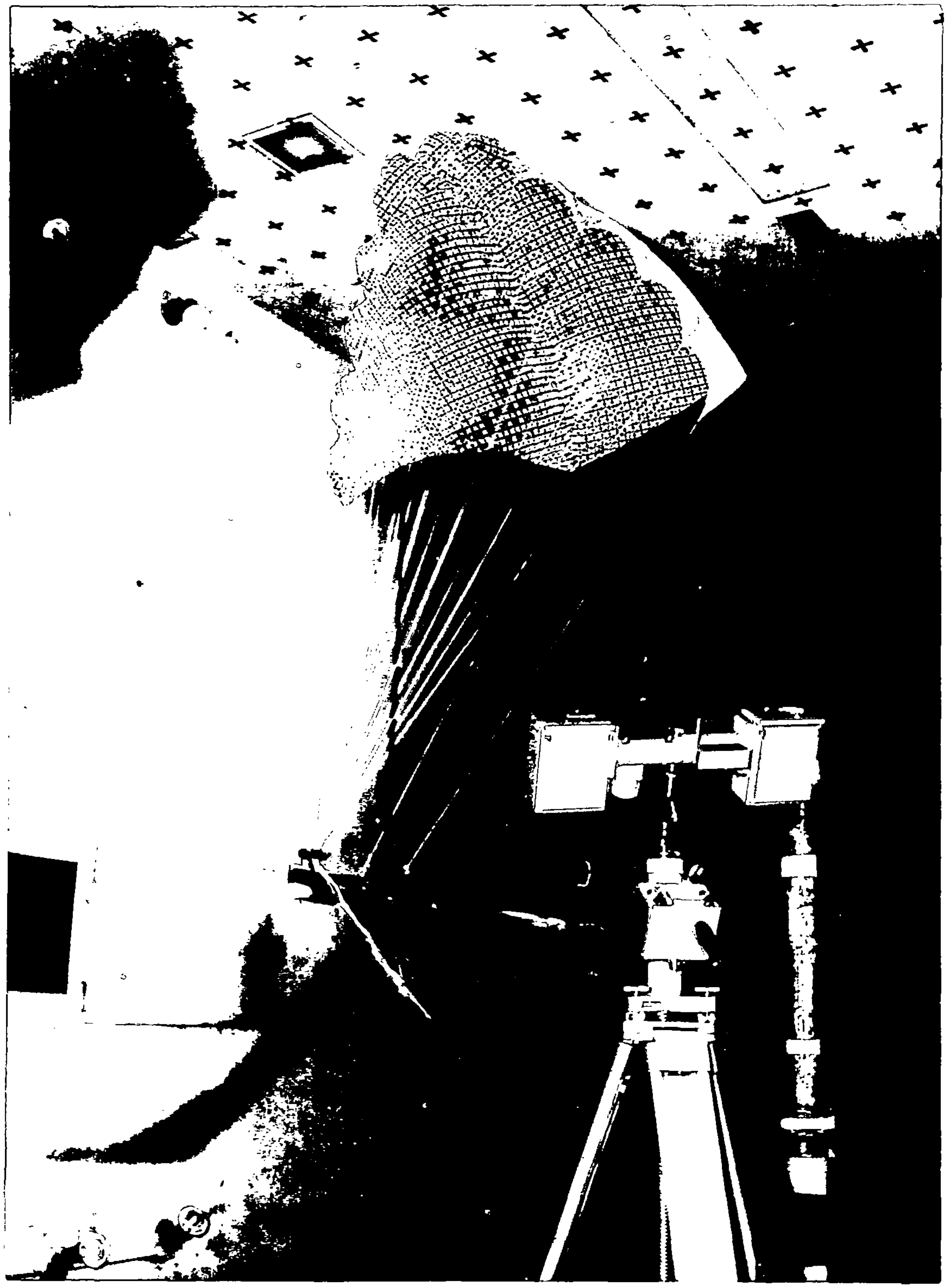
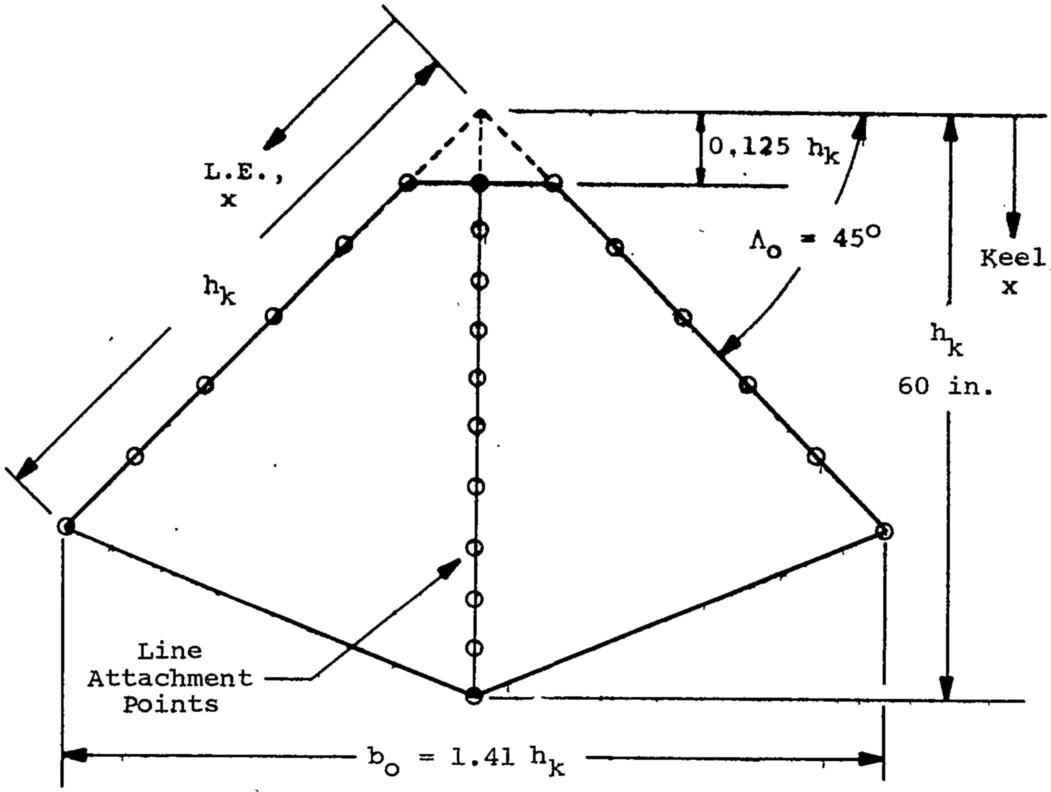
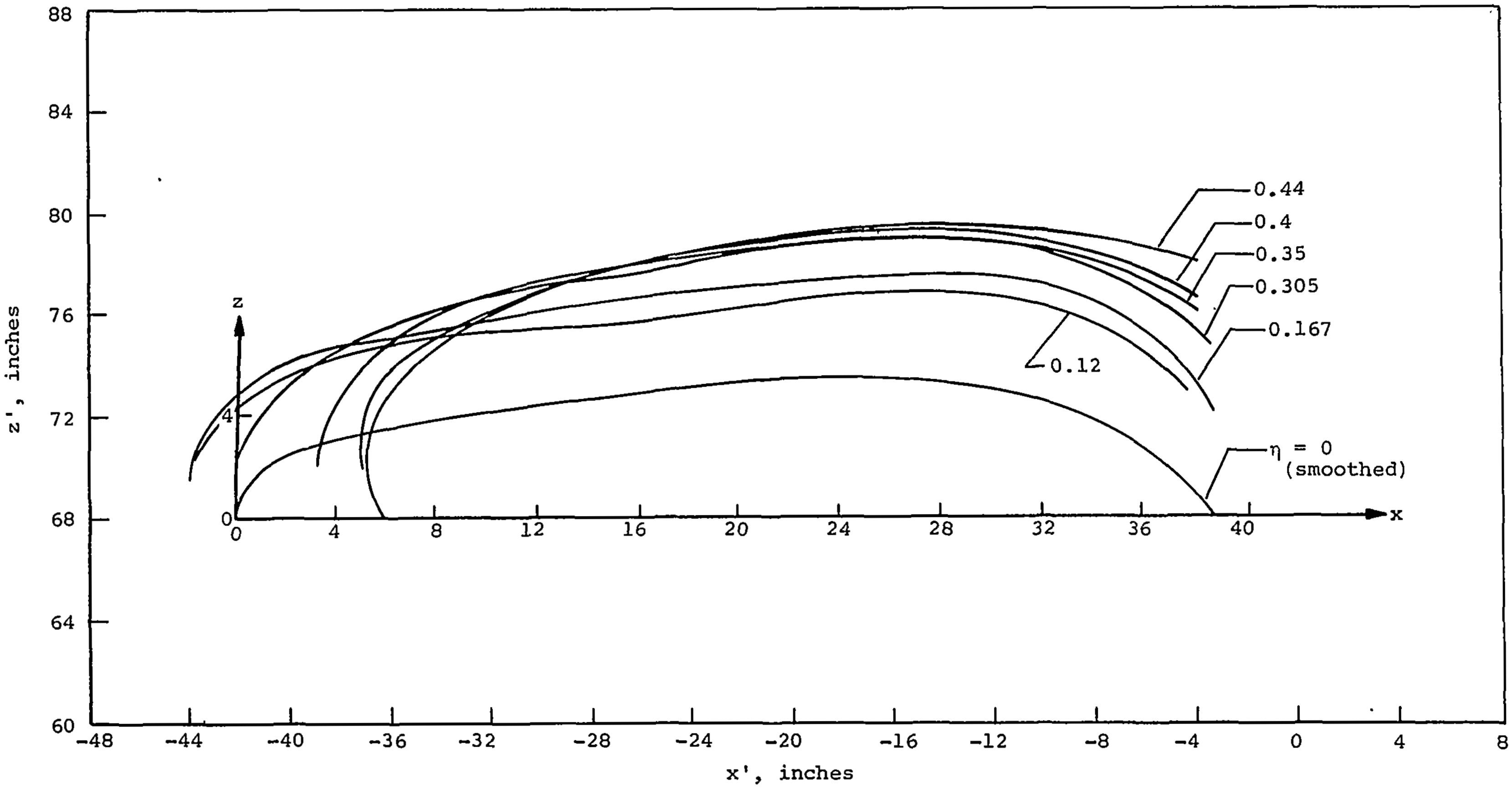


Figure 13.- Equipment setup for photogrammetric test.



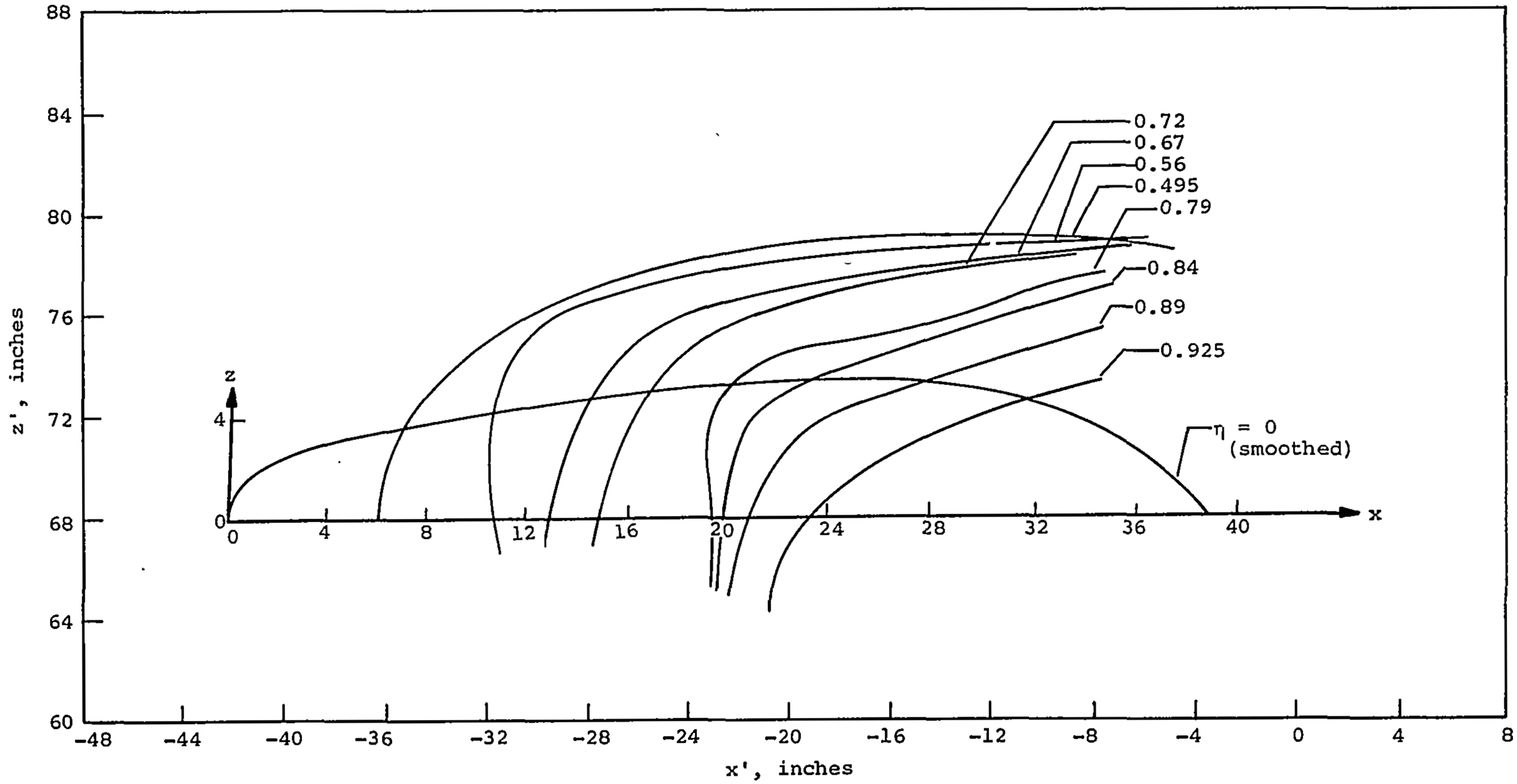
h/h_k			x/h_k	
Keel	Leading Edge Right	Leading Edge Left	Keel	Leading Edge
1.35	1.368	1.365	0.125	0.177
1.36	1.304	1.317	.208	.333
1.352	1.309	1.26	.292	.500
1.34	1.202	1.216	.375	.667
1.322	1.168	1.162	.459	.833
1.308	.994	.985	.542	1.000
1.292			.645	
1.270			.750	
1.242			.833	
1.205			.917	
1.092			1.000	
Line Lengths			Line Attachment Location	

Figure 14.- Single-keel parawing configuration.



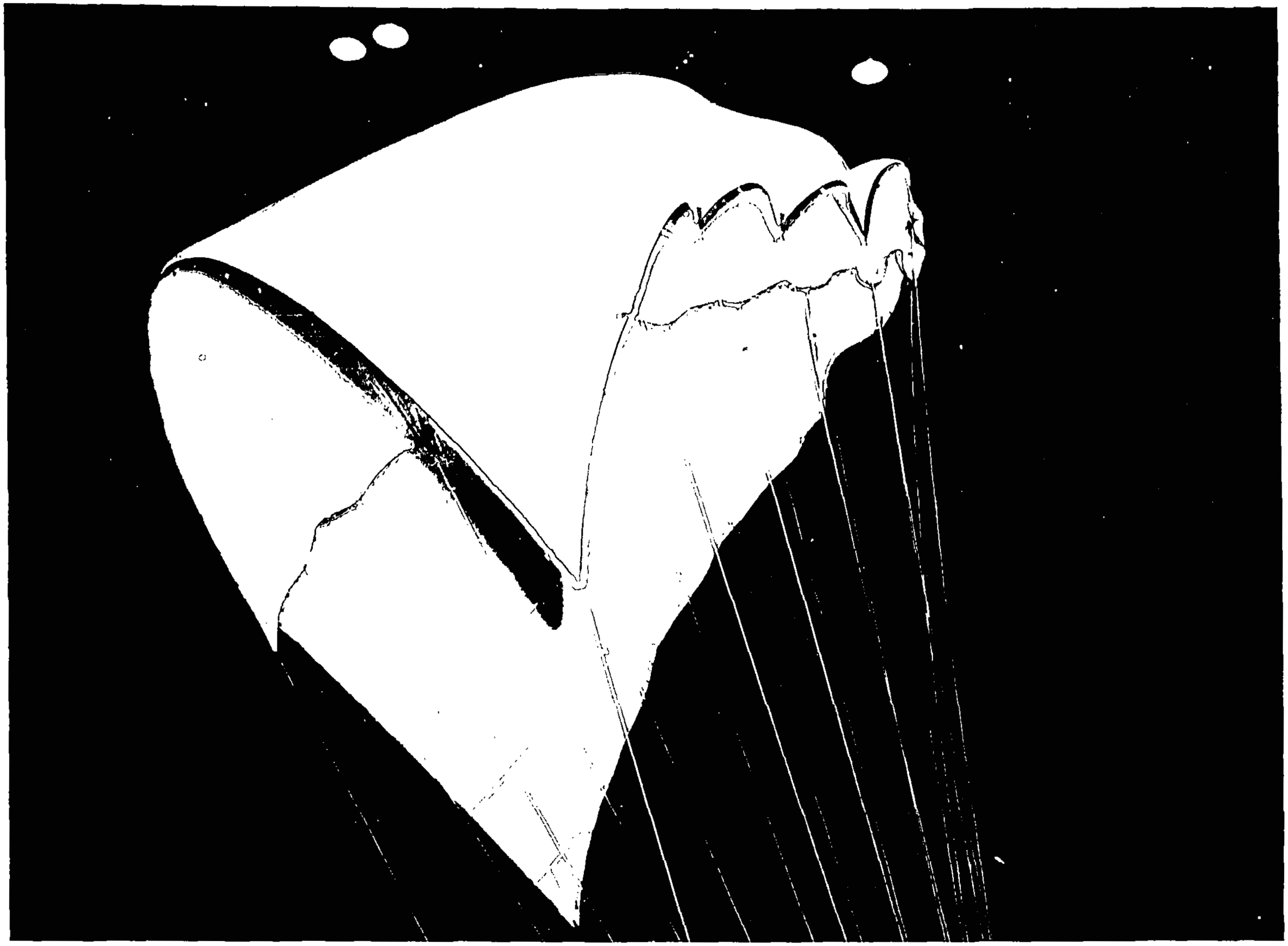
(a) Sections for $0 < \eta < 0.44$.

Figure 15.- Chordwise sections of single-keel parawing obtained from measured canopy shape data.



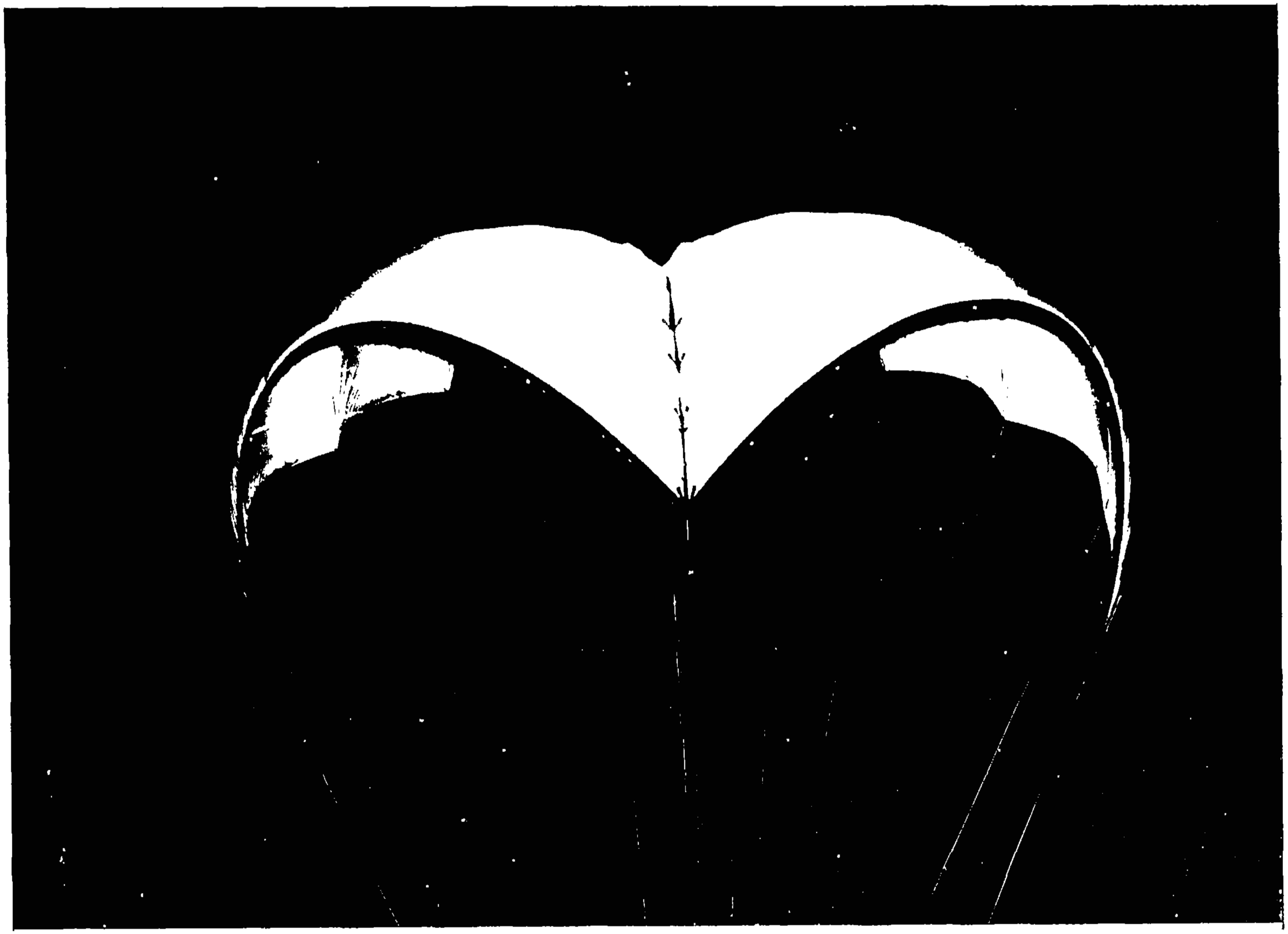
(b) Sections for $0.56 < \eta < 0.925$.

Figure 15.- Concluded.



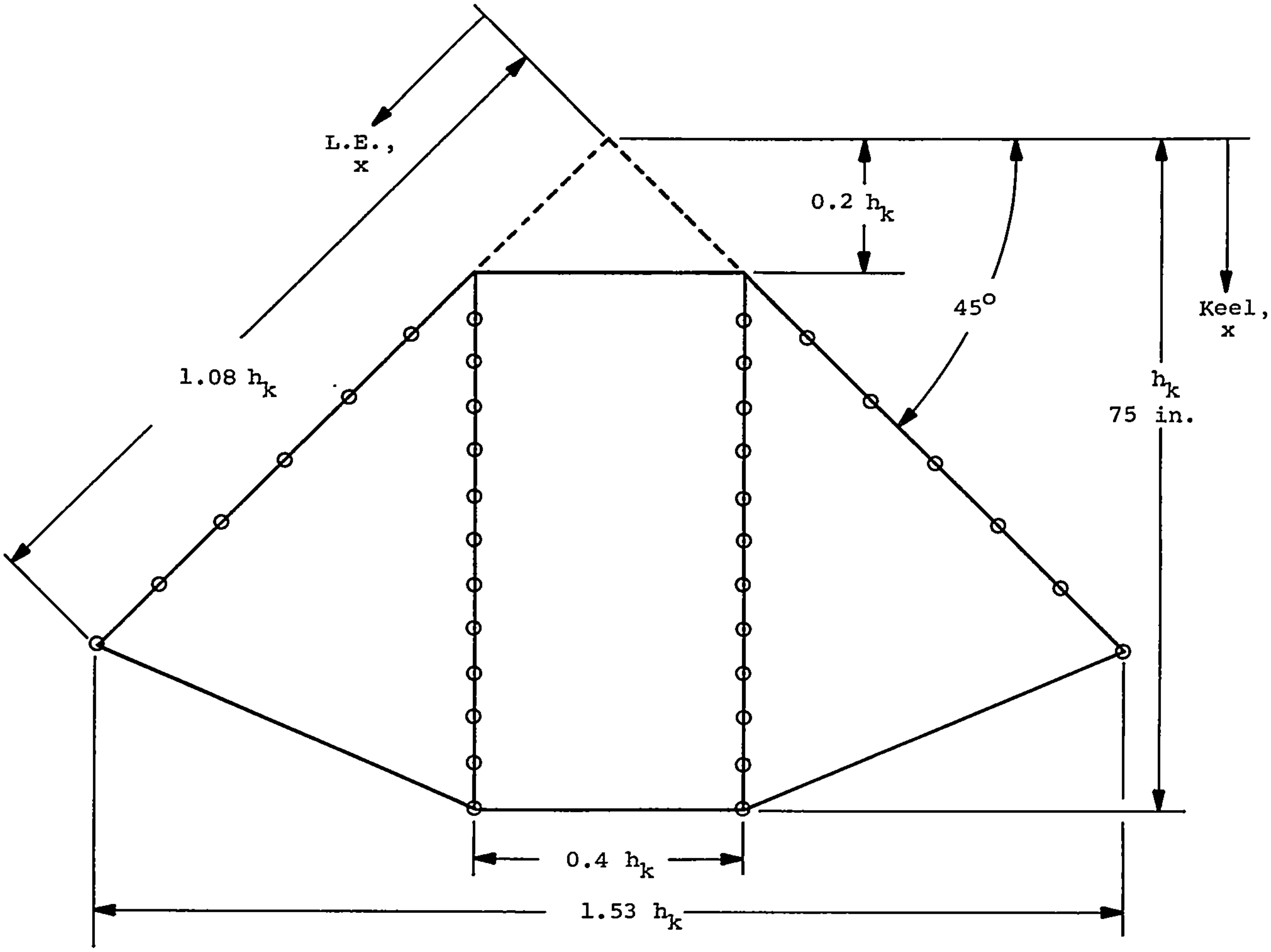
(a) Side view.

Figure 16.- Photographs of single-keel parawing in Langley Research Center wind tunnel.



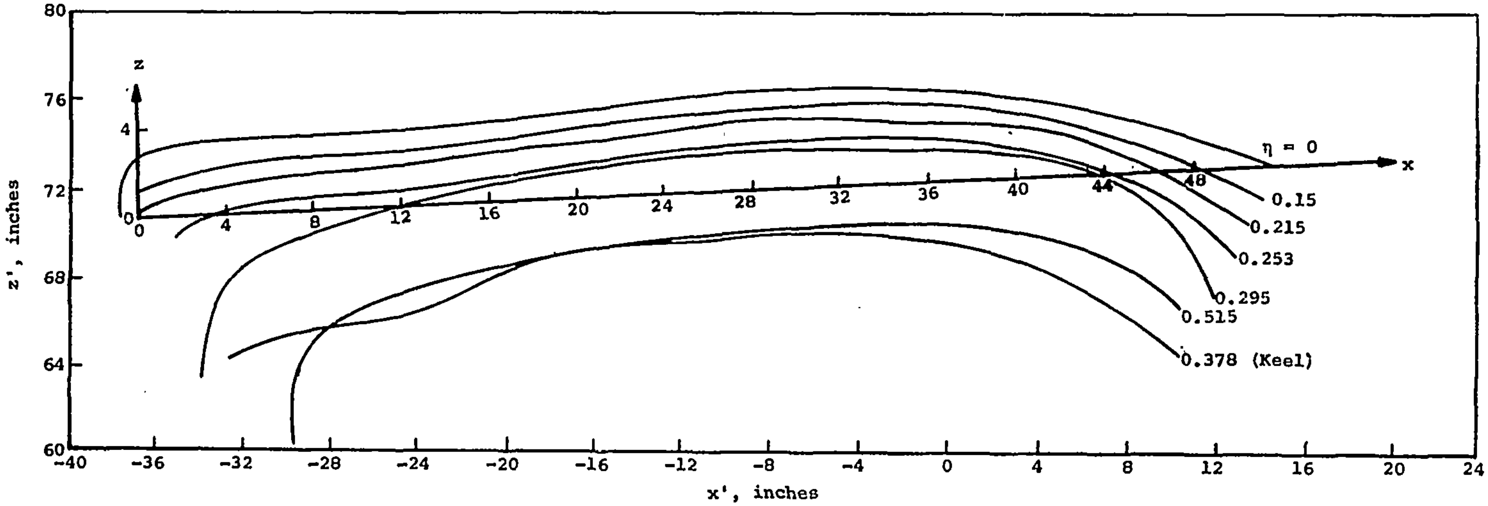
(b) Rear view.

Figure 16.- Concluded.



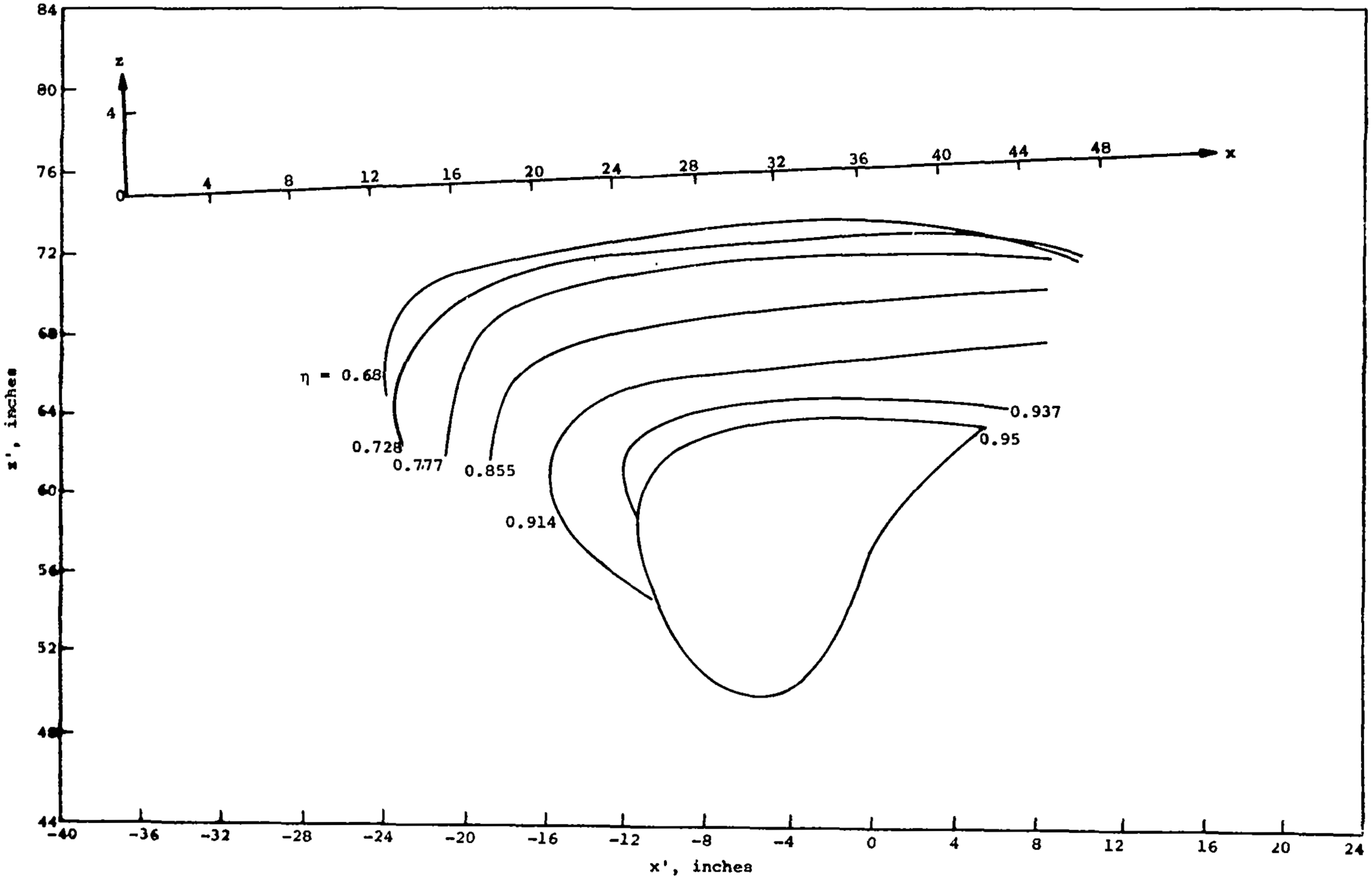
h/h_k				x/h_k	
Keel		Leading Edge		Keel	Leading Edge
Left	Right	Left	Right		
0.975	0.973	0.935	0.935	0.267	0.416
.988	.985	.911	.911	.333	.549
.982	.982	.895	.885	.400	.684
.975	.973	.848	.846	.466	.816
.981	.978	.785	.787	.533	.950
.980	.977	.622	.62	.600	1.083
.988	.982			.667	
.981	.977			.733	
.970	.969			.800	
.964	.963			.867	
.938	.938			.933	
.856	.856			1.000	
Line Lengths				Line Attachment Location	

Figure 17.- Twin-keel parawing configuration.



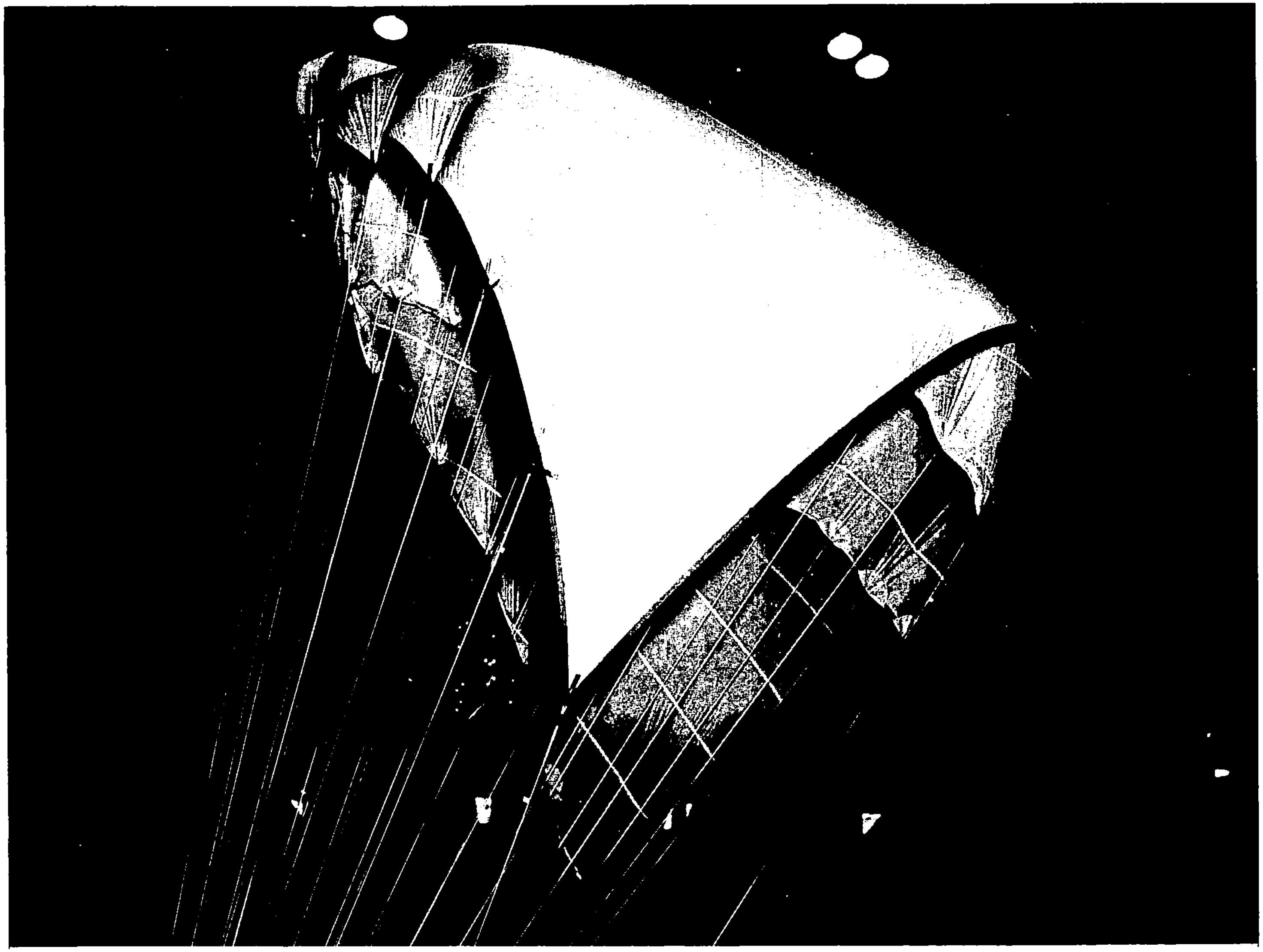
(a) Sections for $0 < \eta < 0.515$.

Figure 18.- Chordwise sections of twin-keel parawing obtained from measured canopy shape data.



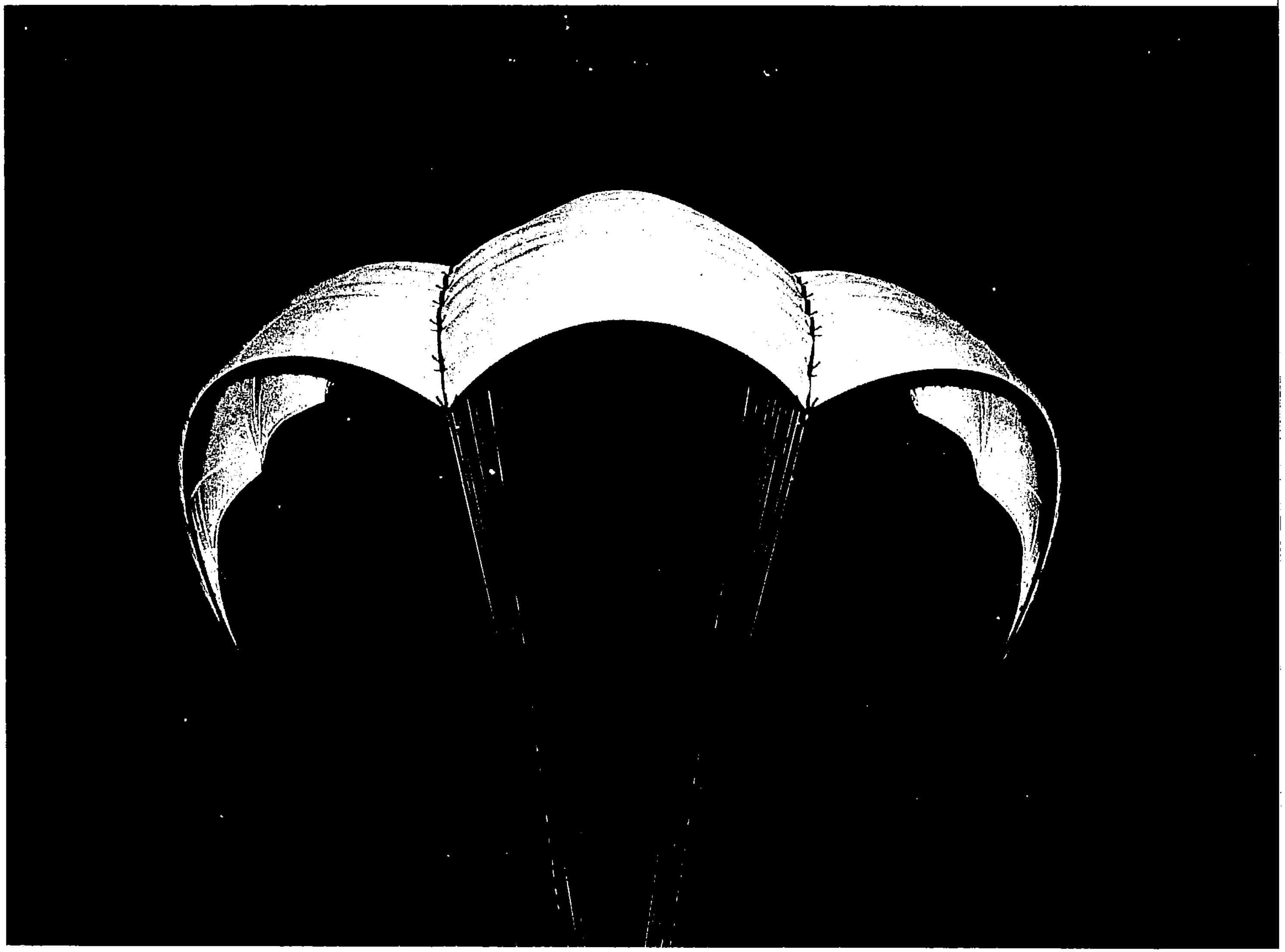
(b) Sections for $0.68 < \eta < 0.95$.

Figure 18.- Concluded.



(a) Side view.

Figure 19.- Photographs of twin-keel parawing in Langley Research Center tunnel.



(b) Rear view.

Figure 19.- Concluded.

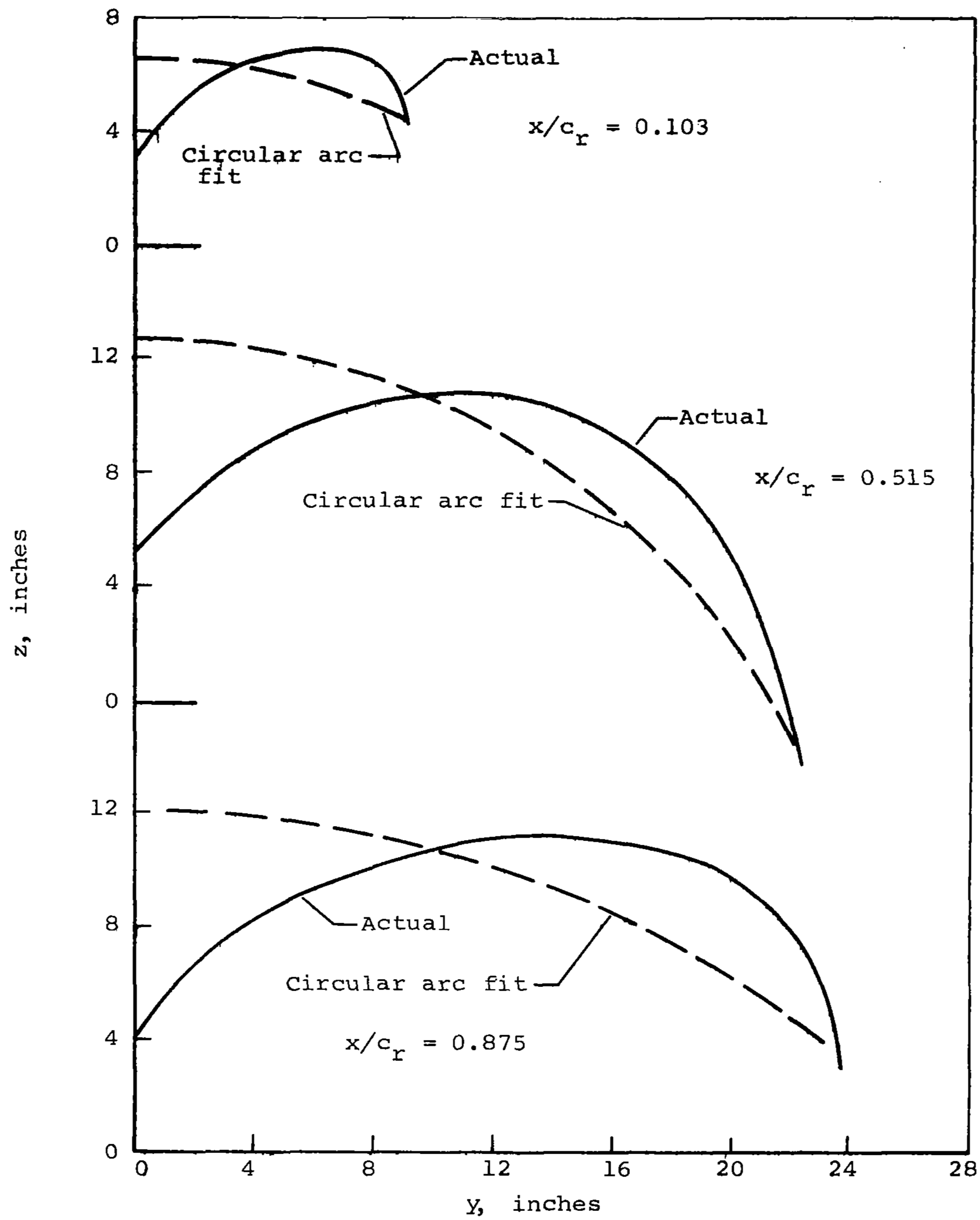


Figure 20.- Spanwise sections for single-keel parawing.

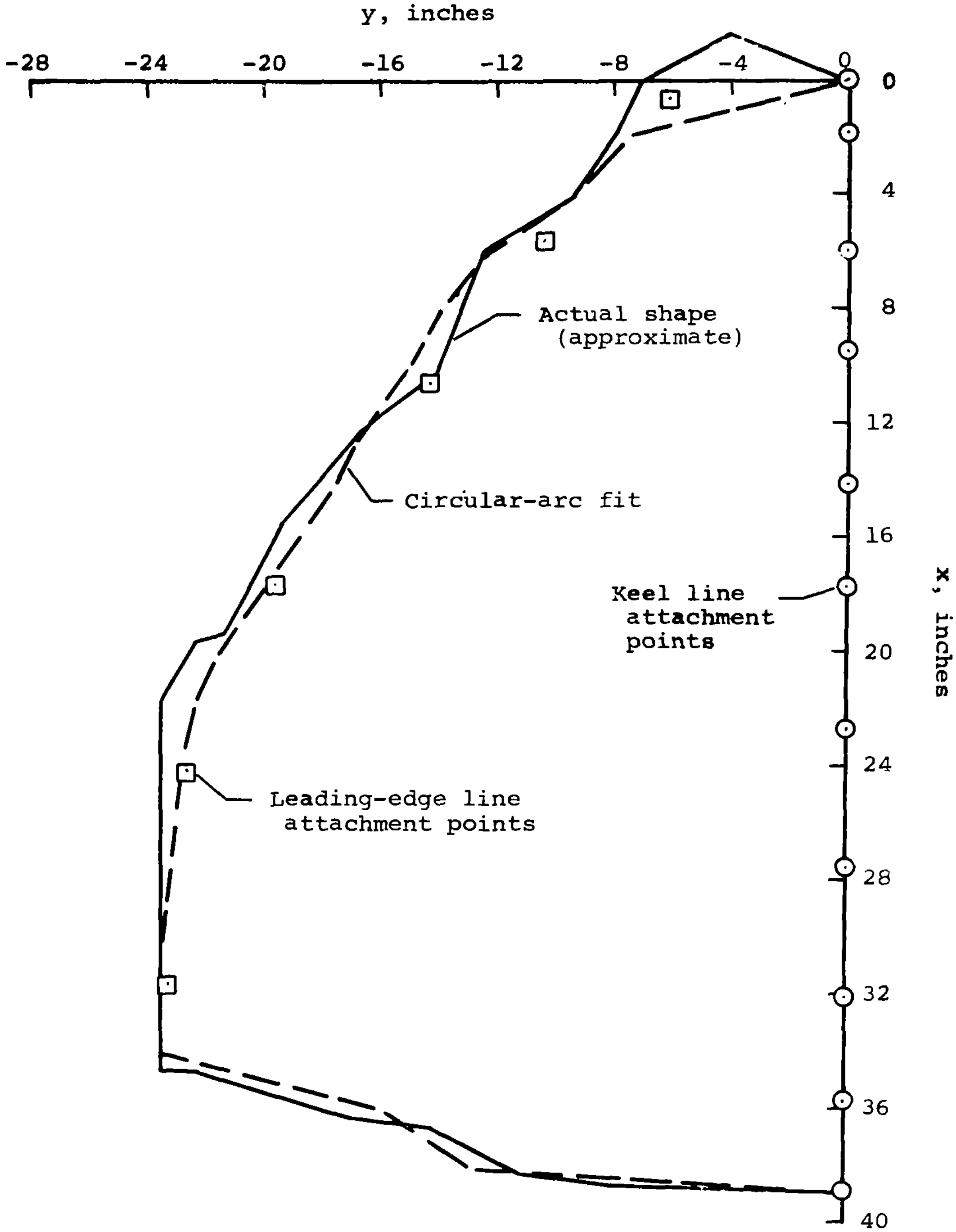


Figure 21.- Comparison of actual planform with circular-arc planform for single-keel parawing.

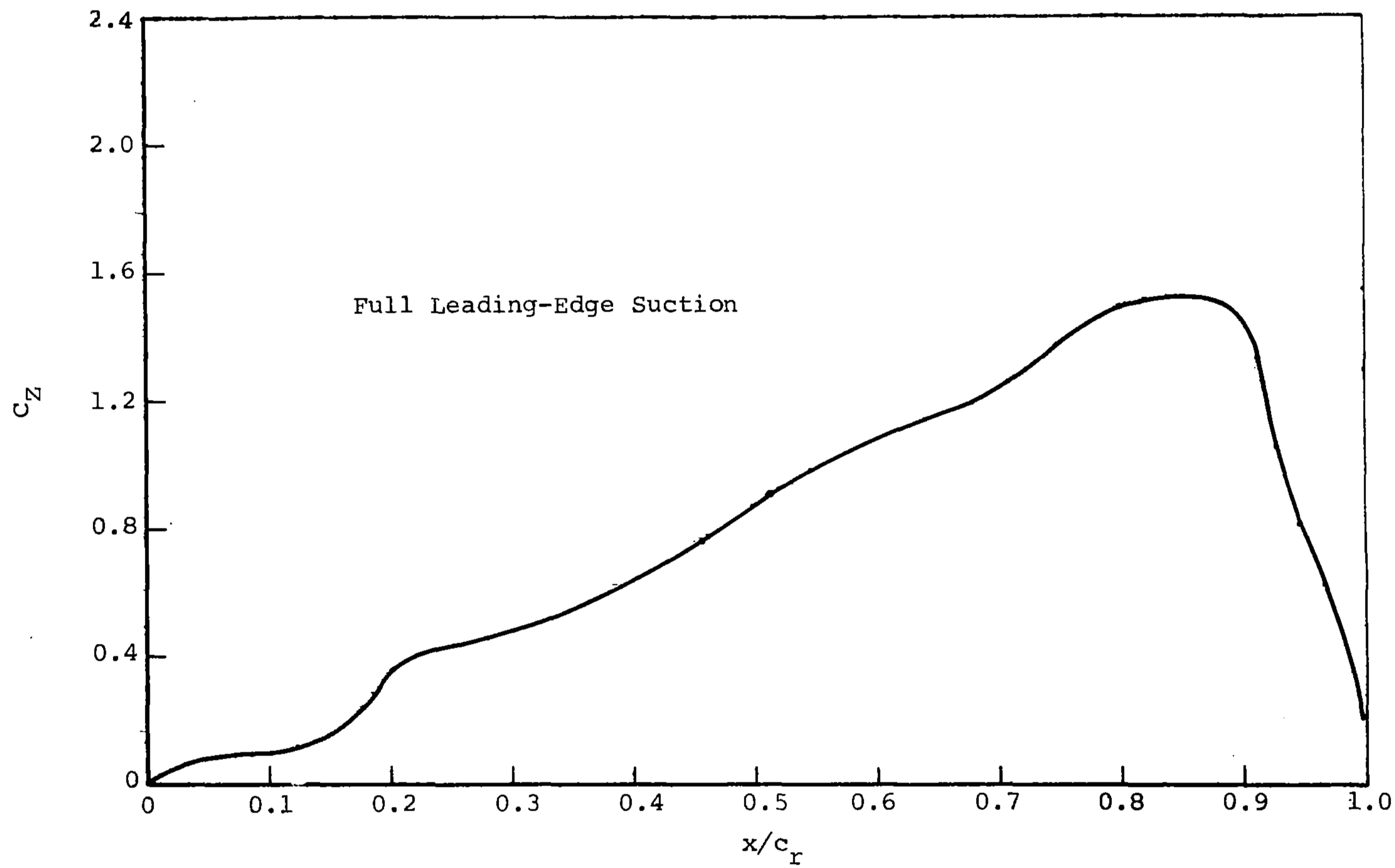


Figure 22.- Predicted chordwise buildup of normal force on single-keel parawing.

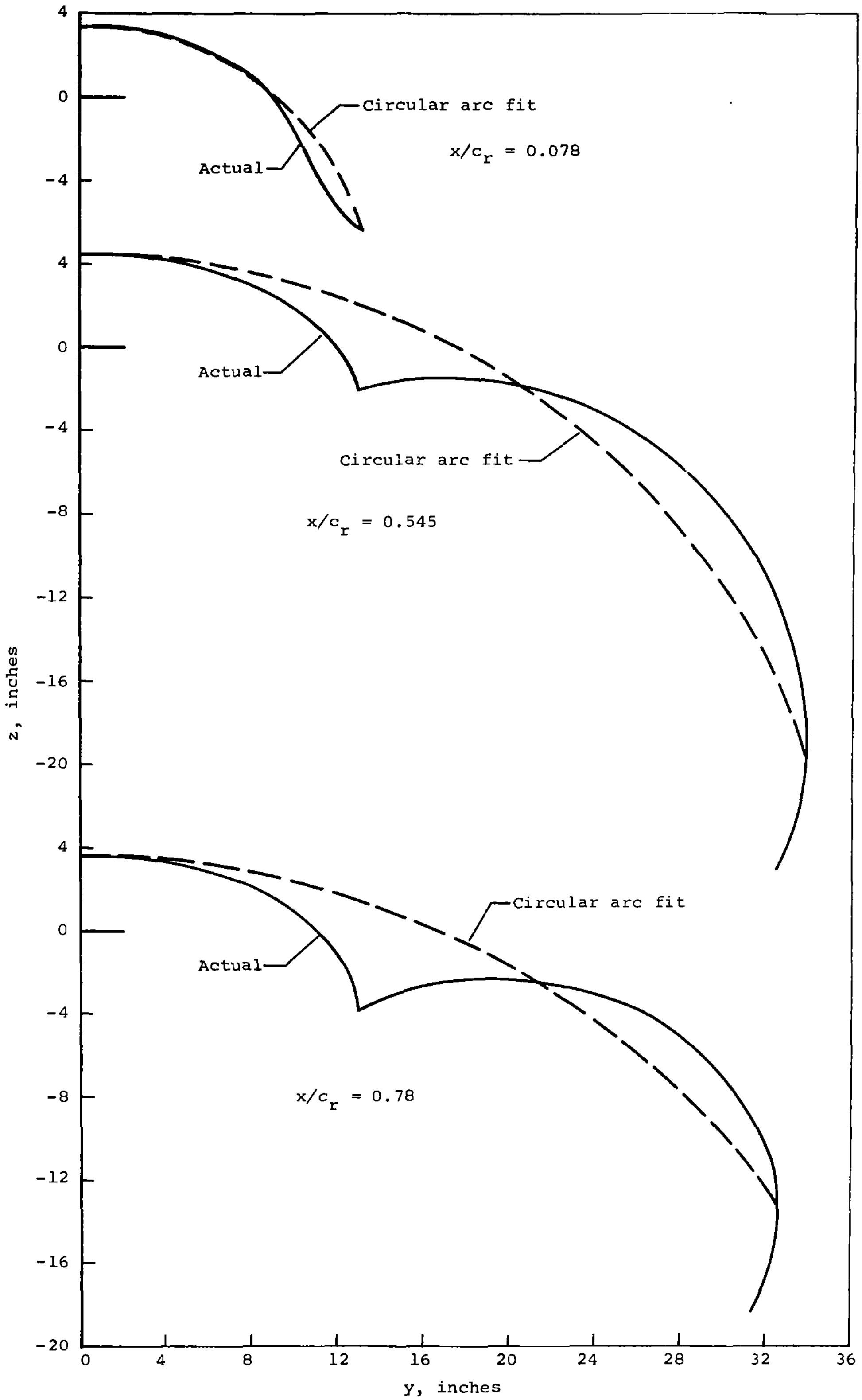


Figure 23.- Spanwise sections for twin-keel parawing.

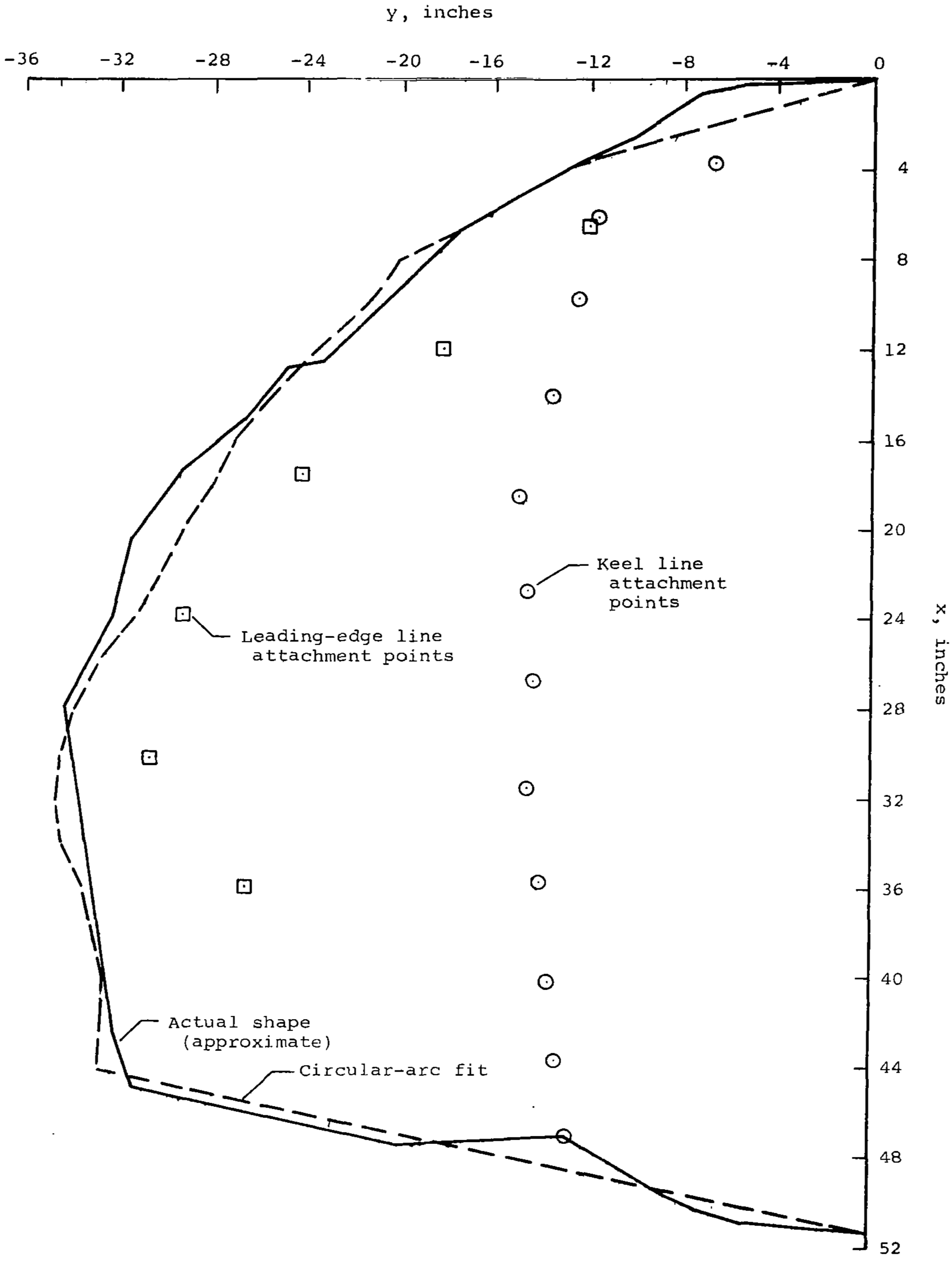


Figure 24.- Comparison of actual planform with circular-arc fit planform for twin-keel parawing.

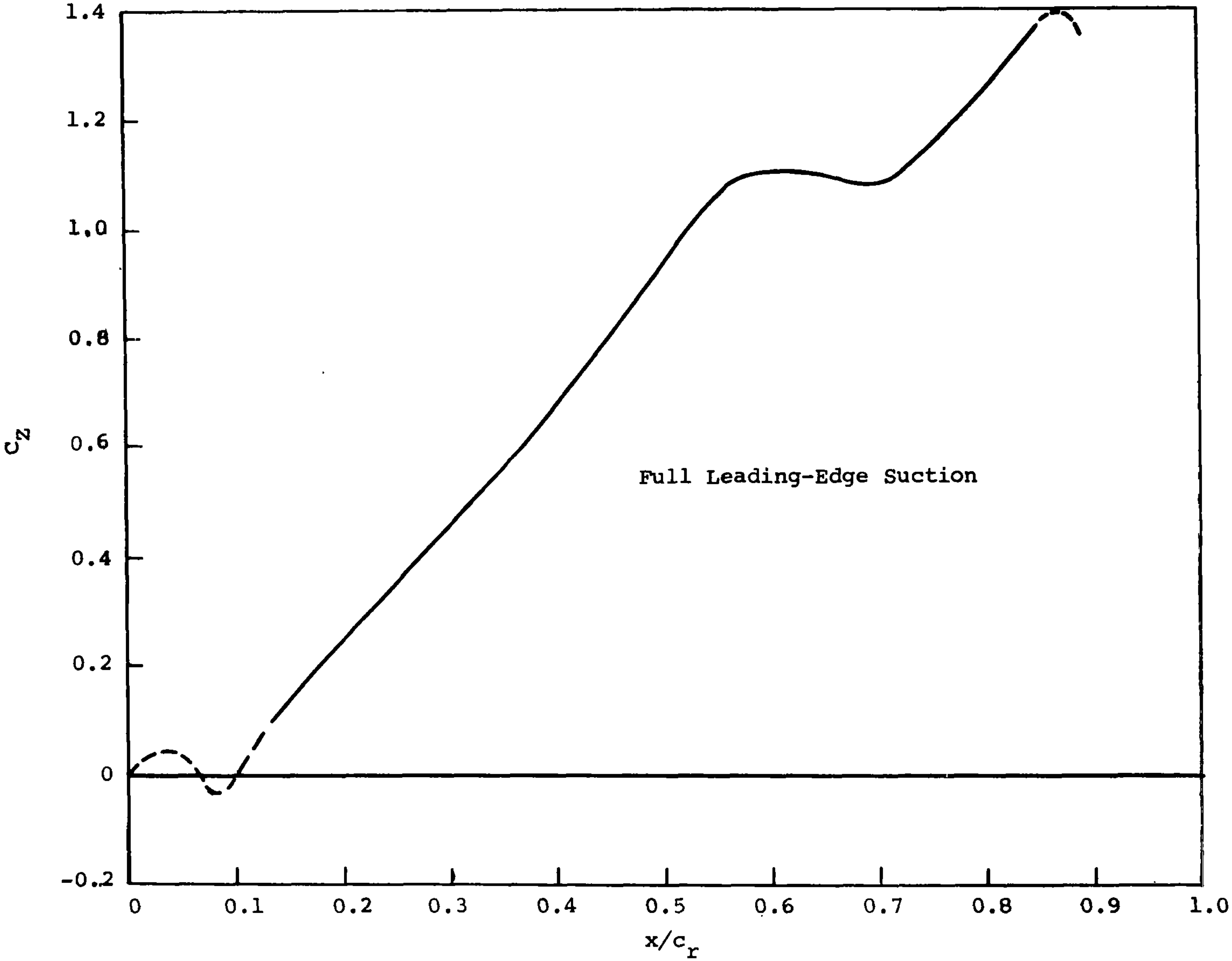


Figure 25.- Predicted chordwise buildup of normal force on twin-keel parawing.

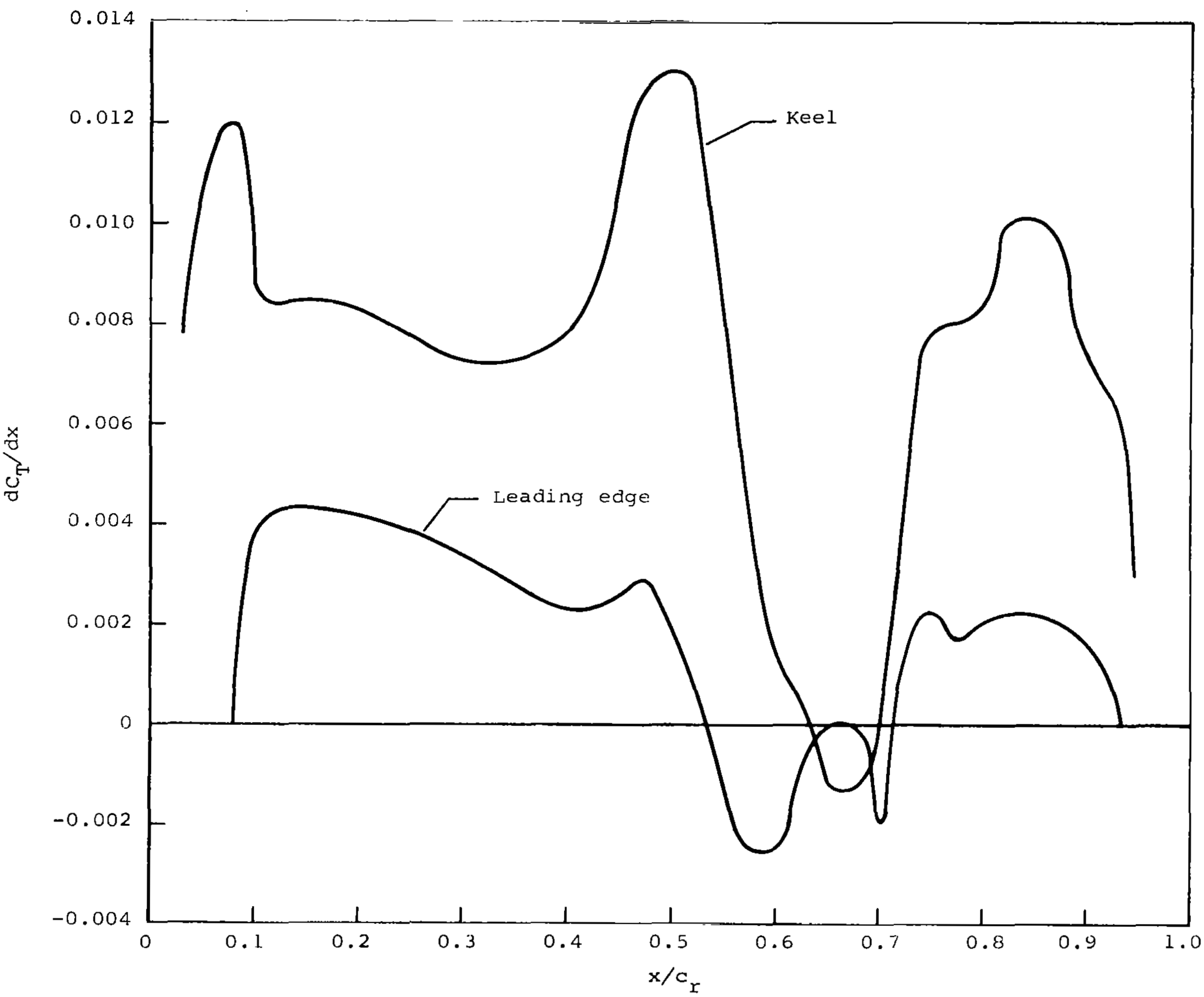


Figure 26.- Predicted distributed line tension load on twin-keel parawing obtained from Canopy Tension Approach (method c).

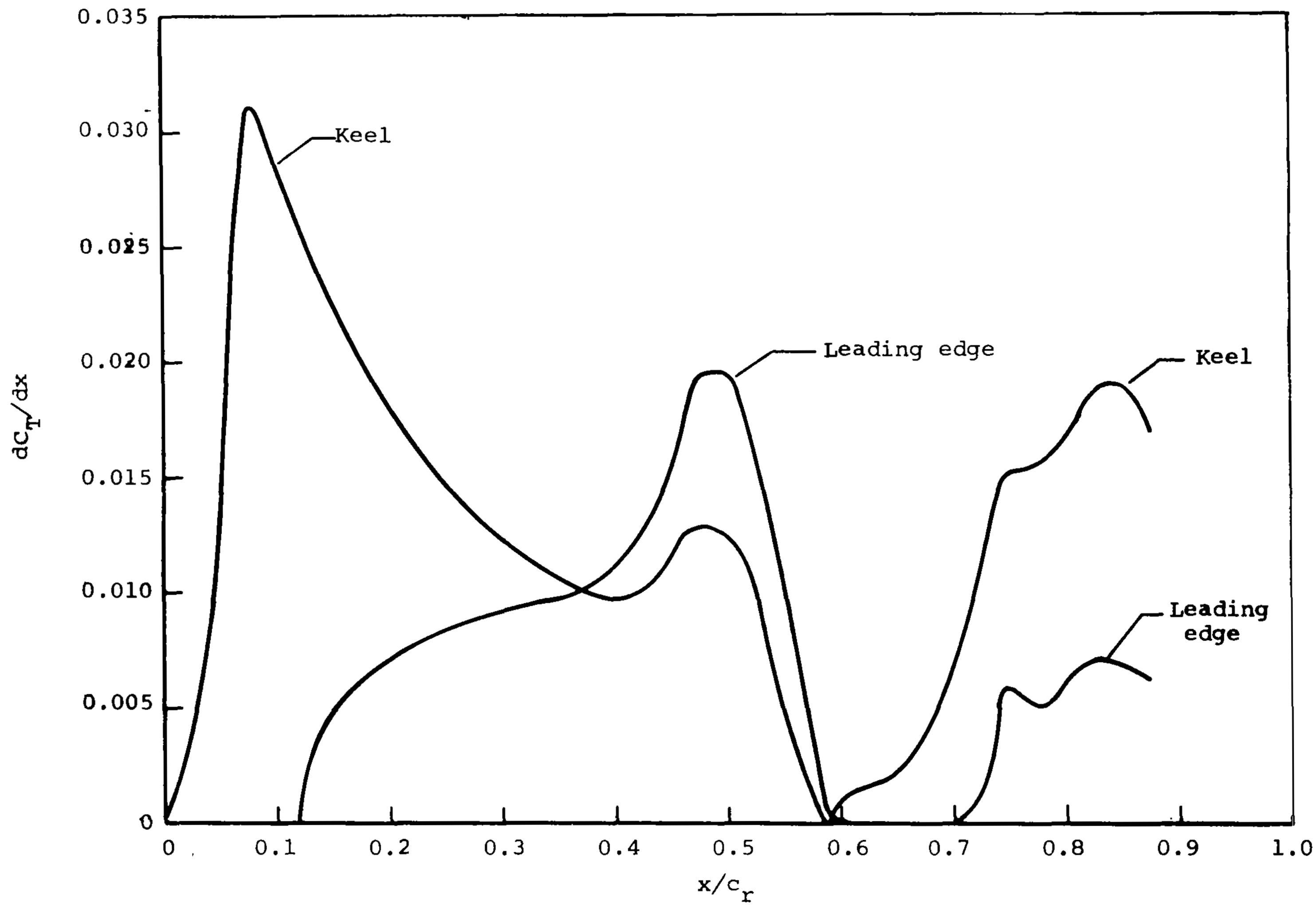
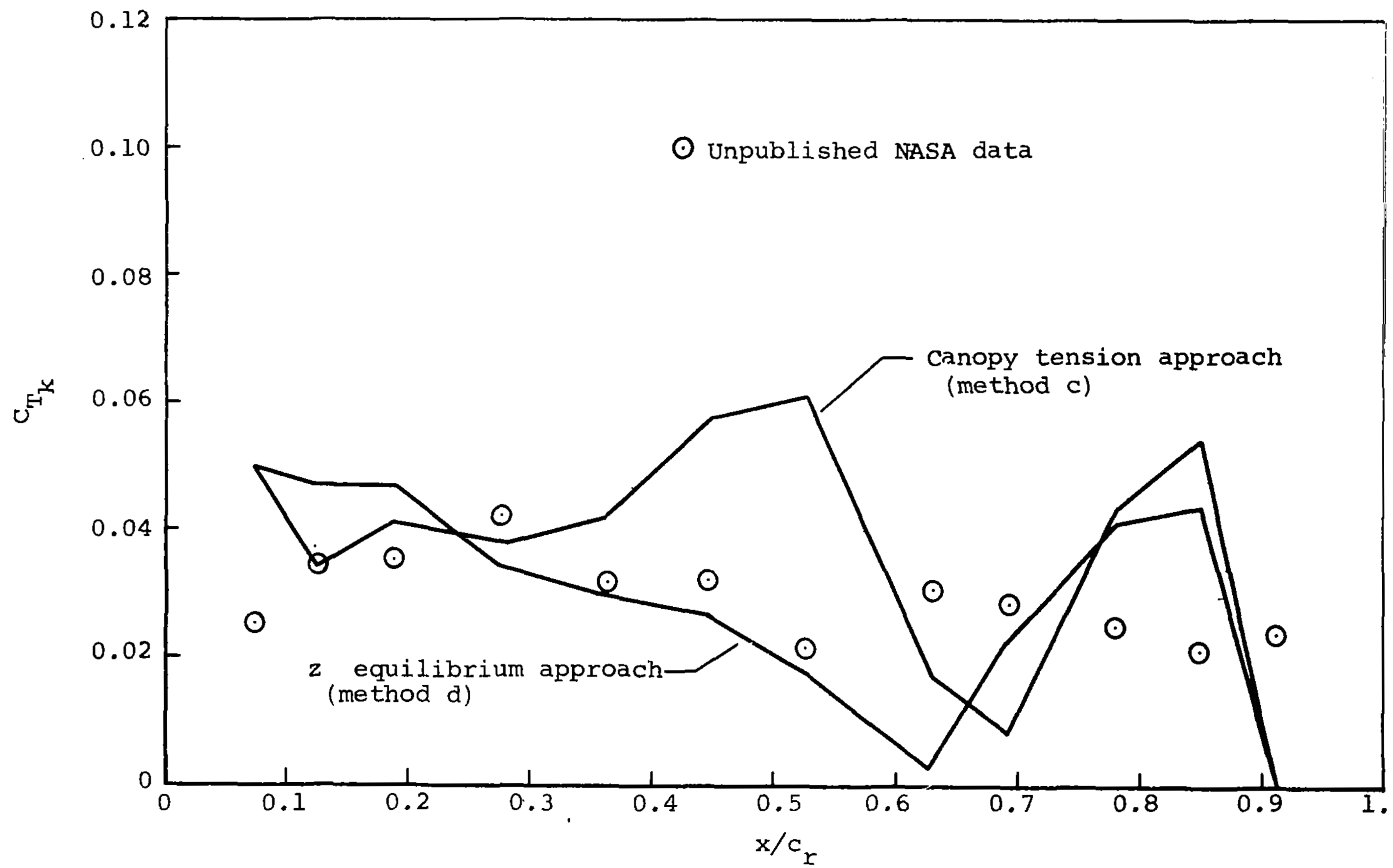
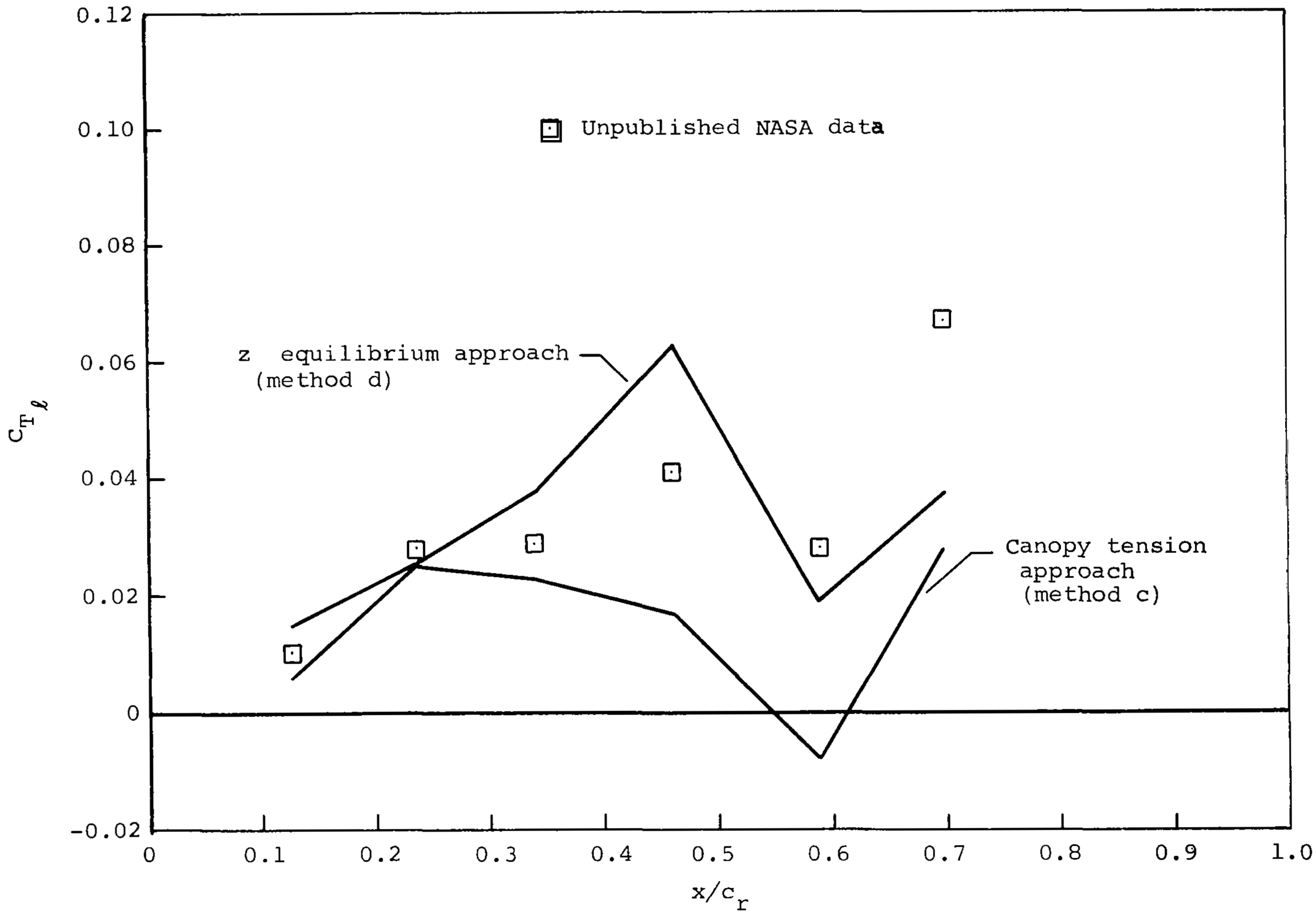


Figure 27.- Predicted distributed line tension load on twin-keel parawing obtained from z Equilibrium Approach (method d).



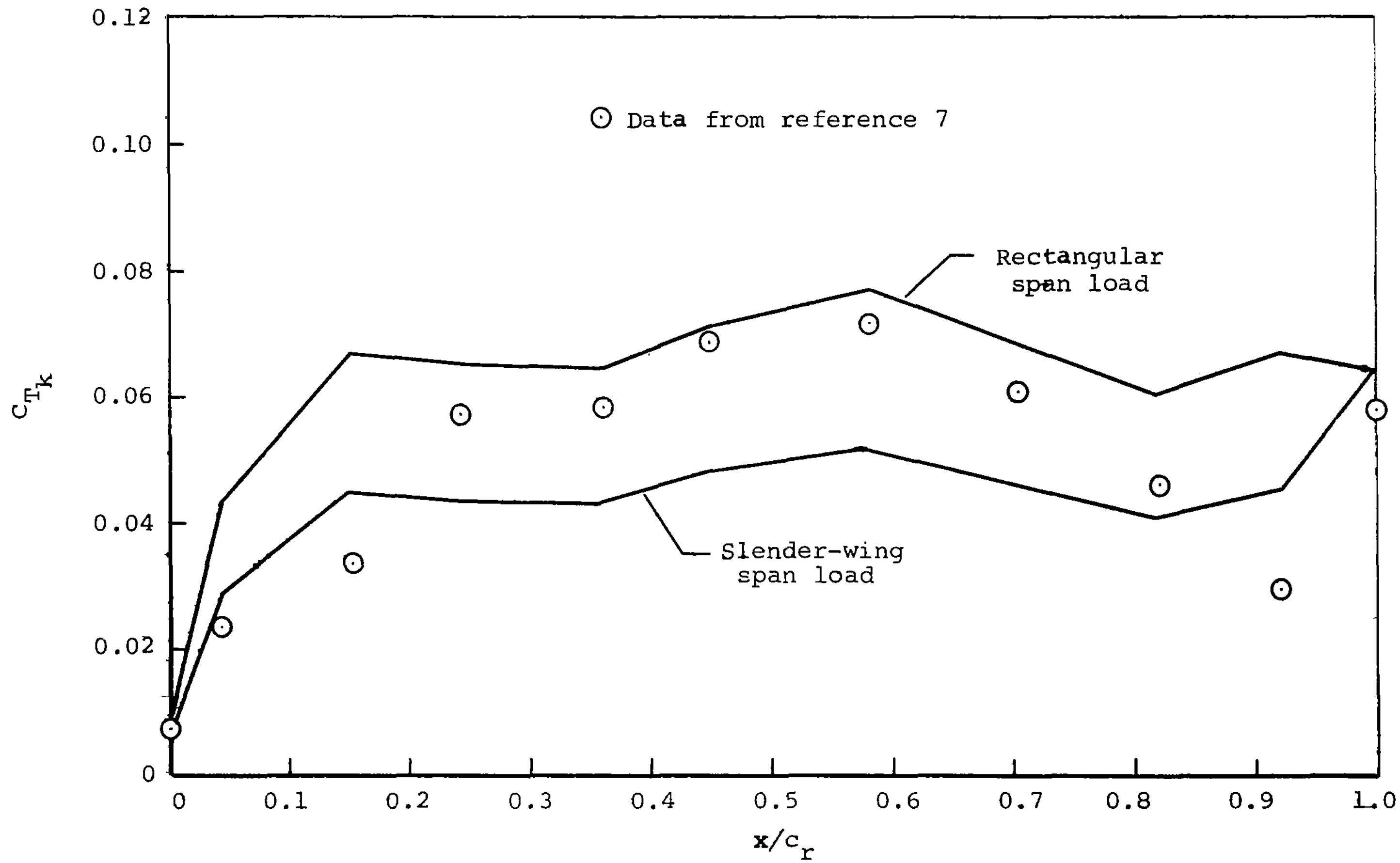
(a) Keel line loads.

Figure 28.- Comparison of line loads for two theoretical load distribution models for twin-keel parawing.



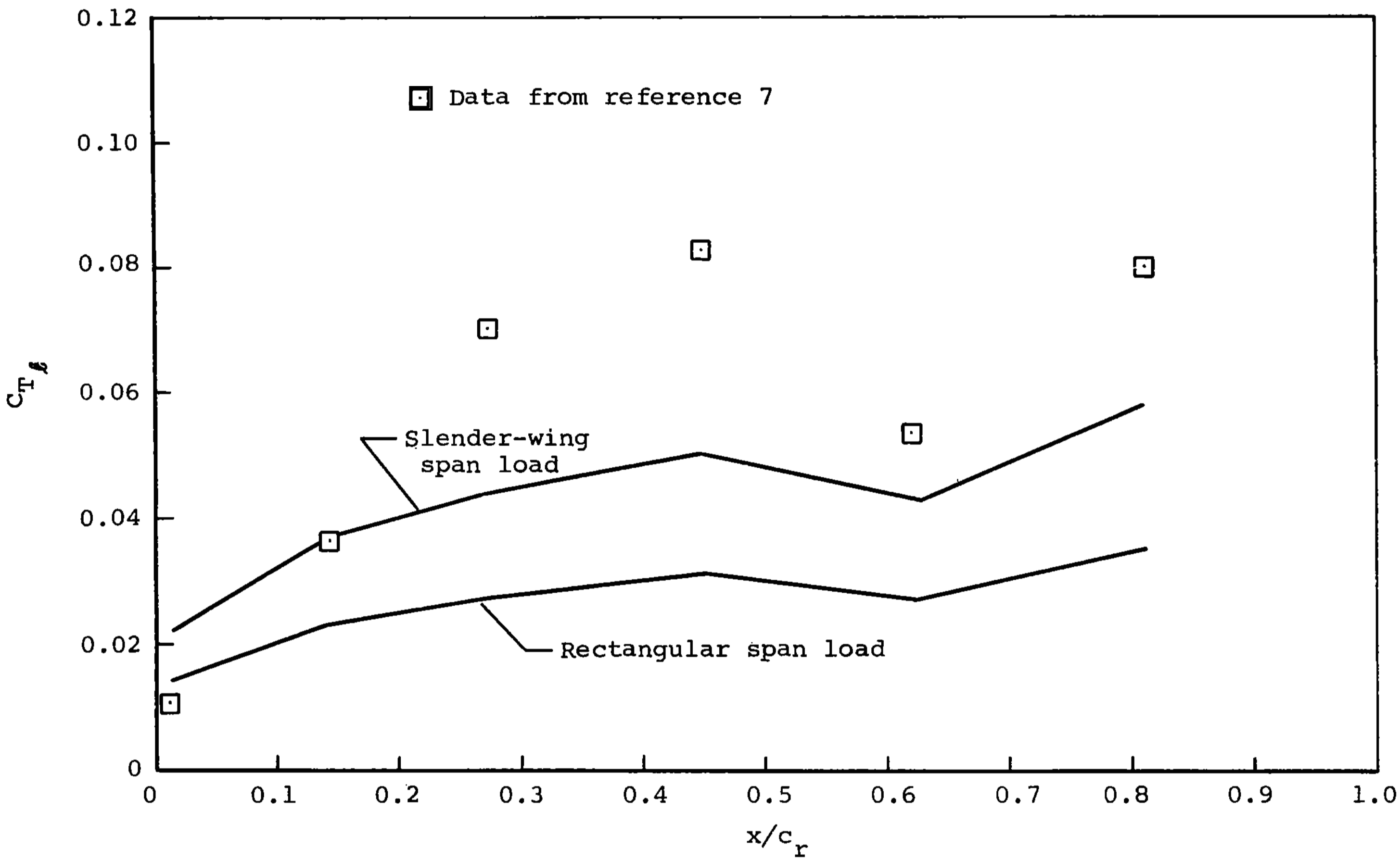
(b) Leading-edge line loads.

Figure 28.- Concluded.



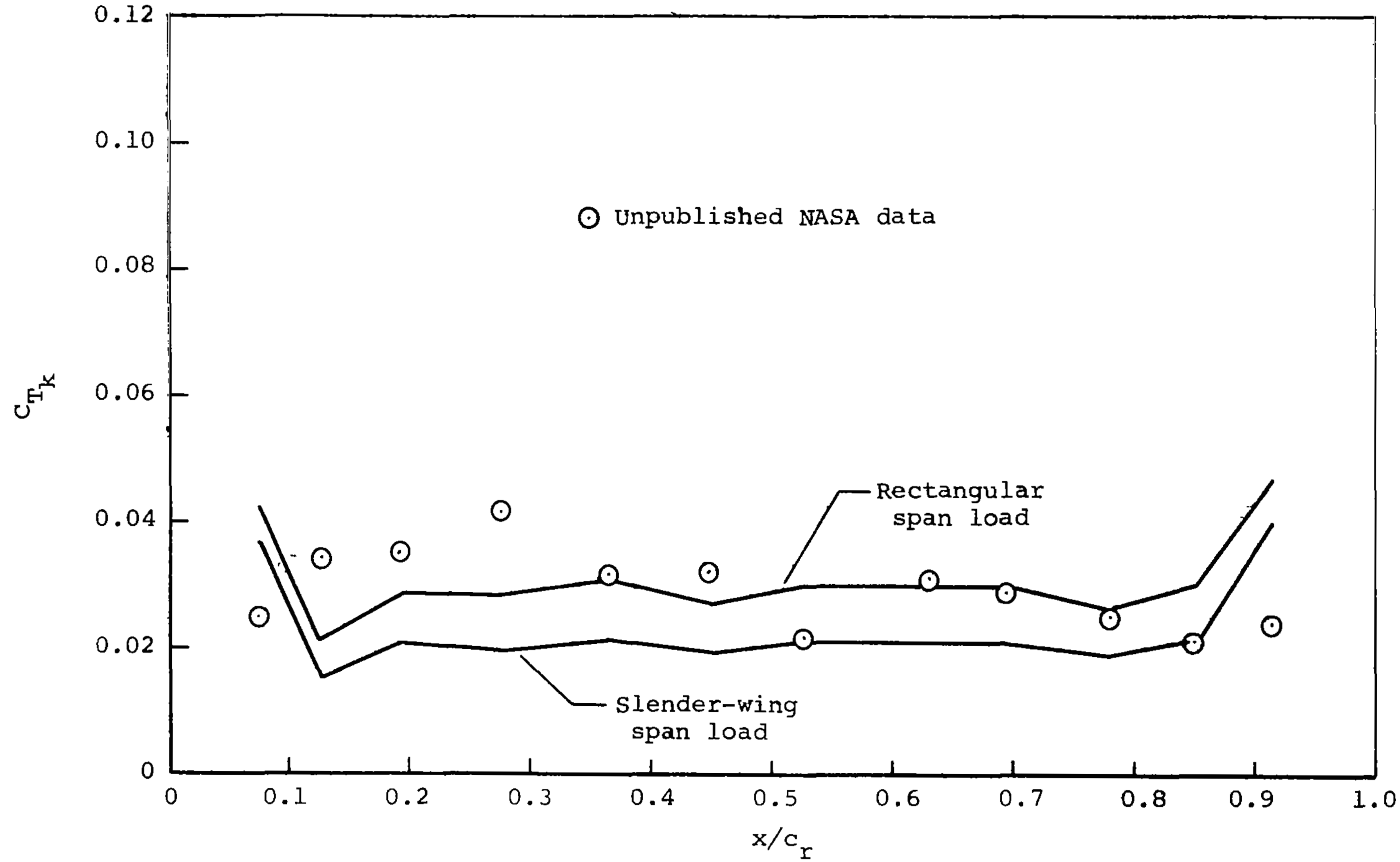
(a) Keel line loads.

Figure 29.- Comparison of predicted and measured line loads for the single-keel parawing.



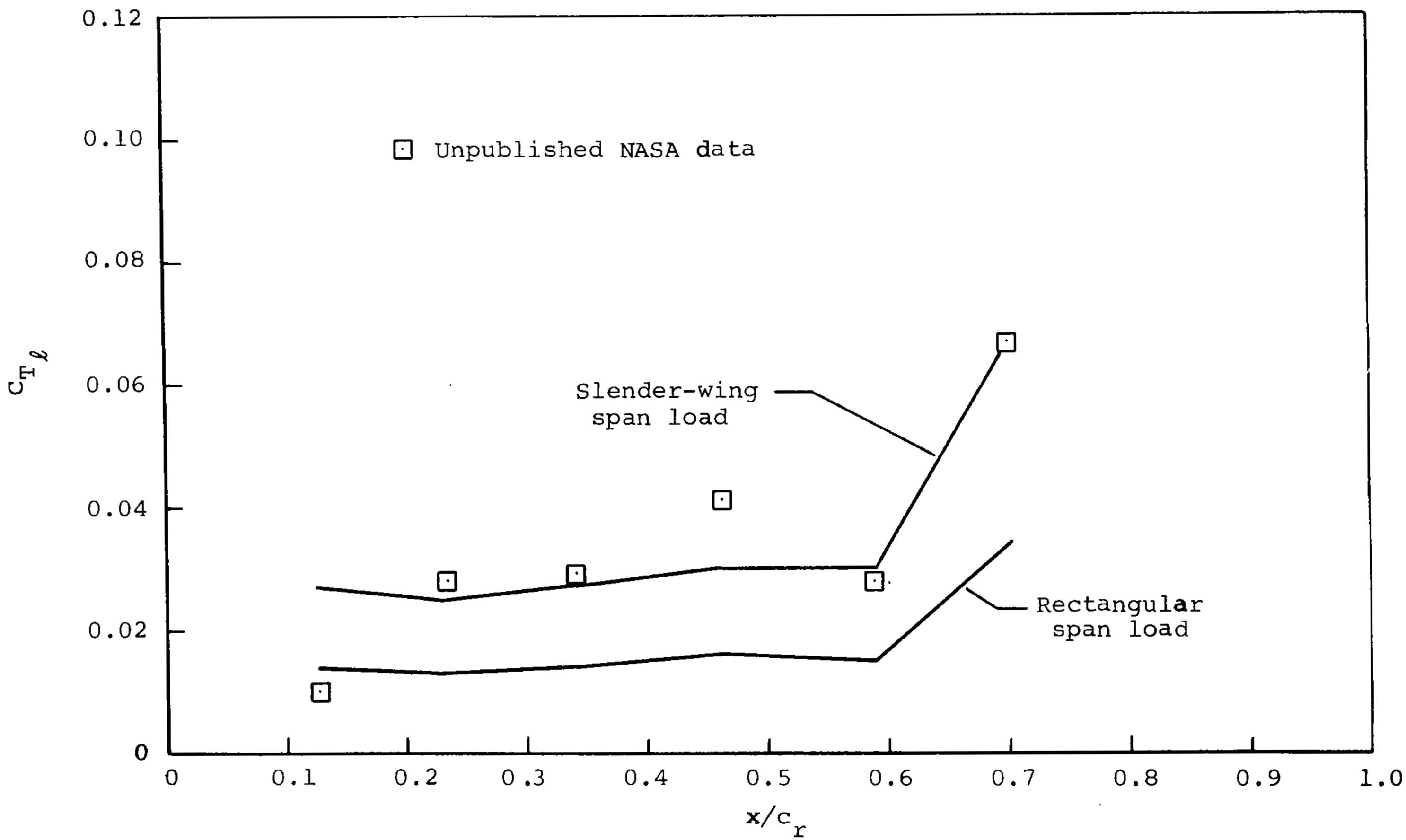
(b) Leading-edge line loads.

Figure 29.- Concluded.



(a) Keel line loads.

Figure 30.- Comparison of predicted and measured line loads for the twin-keel parawing.



(b) Leading-edge line loads.

Figure 30.- Concluded.

NASA-Langley, 1970 — 1 CR-1674