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DEVELOPMENT OF A COMPUTER PROGRAM TO OBTAIN ORDINATES FOR NACA 4-DIGIT, 4-DIGIT MODIFIED, 5-DIGIT, AND 16-SERIES AIRFOILS

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16. Abstract

A computer program has been developed to calculate the ordinates and surface slopes of any thickness, symmetrical or cambered NACA airfoil of the 4-digit, 4-digit modified, 5-digit, and 16-series airfoil families. The program is included as an appendix to this report. The program also produces plots of the airfoil nondimensional ordinates and a punch card output of ordinates in the input format of a readily available program for determining the pressure distributions of arbitrary airfoils in subsonic potential viscous flow.

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DEVELOPMENT OF A COMPUTER PROGRAM TO OBTAIN ORDINATES FOR NACA 4-DIGIT, 4-DIGIT MODIFIED, 5-DIGIT, AND 16-SERIES AIRFOILS

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SUMMARY

The analytical design equations for both symmetrical and cambered airfoils in the NACA 4-digit, 4-digit modified, 5-digit, and 16-series airfoil families have been reviewed. A computer program has been developed to calculate rapidly the ordinates and surface slope for these airfoils and the program is included as an appendix to this report. Provisions are made in the program to combine basic airfoil shapes and camber lines from different series so that nonstandard airfoils can also be generated. The program also produces plots of the nondimensional airfoil ordinates and a punch card output of the ordinates in the input format of a readily available program for determining the pressure distributions of arbitrary airfoils in subsonic potential viscous flow.

INTRODUCTION

During the 1930's several families of airfoils and camber lines, all of which have analytic expressions for the ordinates, were developed by the National Advisory Committee for Aeronautics (NACA). These include the NACA 4-digit airfoils (ref. 1), 4-digit modified airfoils (ref. 2), 5-digit airfoils (ref. 3), and 16-series airfoils (refs. 4 and 5). Many of these airfoil shapes have been successfully used over the years as wing and tail sections for general aviation as well as military aircraft. Some have been and are still being used as sections for propellers and helicopter rotors.

Numerous specific airfoils of these series have been computed and ordinates published over the years. However, when performing parametric studies on effects of such variables as thickness, location of maximum thickness, leading-edge radius, amount and location of maximum camber and others, it is not always easy to obtain the ordinates of the desired shapes rapidly. Because these airfoils all have analytic solutions for the ordinates, both with and without camber, a computer program can be written to provide the exact ordinates rapidly and at a low cost. An attempt to do this was made in reference 6, but some limiting assumptions were made so that exact results are not provided for some airfoils.

The purpose of this paper is to review the design parameters for all these airfoils and to describe a computer program which will generate exact ordinates for all airfoils of these series with an acceptable expenditure of computer time. The program will also allow combination of any airfoil and any camber line so that many nonstandard airfoils can be described.

SYMBOLS

When two symbols are given for a concept, the symbol in parenthesis is that used in the computer program and on computer-generated plots.

A	camber line designation, fraction of chord from leading edge over which design load is uniform
a_0,a_1,a_2,a_3,a_4	constants in airfoil equation
b_0,b_1,b_2	constants in camber line equation
c (C)	airfoil chord
$\left(c_L\right)_{design}$ (CLI)	design section lift coefficient
d_0,d_1,d_2,d_3	constants in airfoil equation
I	leading-edge index number
k_1,k_2	constants
m	chordwise location for maximum ordinate of airfoil or camber line
p	maximum ordinate of 2-digit camber line
R	radius of curvature
r	chordwise location for zero value of second derivative of 3-digit camber line equation
t	thickness
x (X)	distance along chord

y (Y)	airfoil ordinate normal to chord, positive above chord
δ	local inclination of camber line

Subscripts:

cam	cambered
l (L)	lower surface
le	leading edge
N	forward portion of camber line
T	aft portion of camber line
t	thickness
u (U)	upper surface

ANALYSIS

The design equations for the analytic NACA airfoils and camber lines have been presented in references 1 to 5. They are repeated herein to provide a better understanding of the computer program and indicate the use of different design variables. A summary of some of the design equations and ordinates for many airfoils from these families is also presented in references 7 to 9.

Thickness Distribution Equations

4-digit.- Ordinates for the NACA 4-digit airfoil family (ref. 1) are described by an equation of the form:

$$\pm\frac{y}{c} = a_0\sqrt{\frac{x}{c}} + a_1\left(\frac{x}{c}\right) + a_2\left(\frac{x}{c}\right)^2 + a_3\left(\frac{x}{c}\right)^3 + a_4\left(\frac{x}{c}\right)^4$$

The constants in the equation were determined from the following constraints:

(1) Maximum ordinate:

$$\frac{x}{c} = 0.30 \qquad \frac{y}{c} = 0.10 \qquad \frac{dy}{dx} = 0$$

(2) Ordinate at trailing edge:

$$\frac{x}{c} = 1.0 \qquad \frac{y}{c} = 0.002$$

(3) Trailing-edge angle:

$$\frac{x}{c} = 1.0 \qquad \frac{dy}{dx} = 0.234$$

(4) Nose shape:

$$\frac{x}{c} = 0.1 \qquad \frac{y}{c} = 0.078$$

The coefficients listed below were determined to meet these constraints very closely:

$a_0 = 0.2969$

$a_1 = -0.1260$

$a_2 = -0.3516$

$a_3 = 0.2843$

$a_4 = -0.1015$

To obtain ordinates for other thickness airfoils in the family, the ordinates for the 0.20-thickness-ratio model are multiplied by the ratio $(t/c)/0.20$. The leading-edge radius of this family is defined as the radius of curvature of the basic equation evaluated at $\frac{x}{c} = 0$. Because of the term $a_0\sqrt{x/c}$ in the equation, the radius of curvature is finite at this point and can be shown to be $a_0^2/2$. Thus, the leading-edge radius varies as the square of the airfoil thickness-chord ratio because the thickness varies linearly with the a constants. To define an airfoil in this family, the only input necessary to the computer program is the desired thickness-chord ratio. Symmetric airfoils in this family are designated by a 4-digit number, that is, NACA 0012. The first two digits indicate a symmetric airfoil and the second two, the thickness-chord ratio.

4-digit modified.- The design equation for the 4-digit airfoil family was modified (ref. 2) so that the same basic shape was retained but variations in leading-edge radius and chordwise location of maximum thickness could be made. Ordinates for these airfoils are determined from the following equations:

From leading edge to maximum thickness,

$$\pm\frac{y}{c} = a_0\sqrt{\frac{x}{c}} + a_1\left(\frac{x}{c}\right) + a_2\left(\frac{x}{c}\right)^2 + a_3\left(\frac{x}{c}\right)^3$$

From maximum thickness to trailing edge,

$$\pm\frac{y}{c} = d_0 + d_1\left(1 - \frac{x}{c}\right) + d_2\left(1 - \frac{x}{c}\right)^2 + d_3\left(1 - \frac{x}{c}\right)^3$$

The constants in these equations can be determined from the following constraints:

(1) Maximum ordinate:

$\frac{x}{c} = m$ $\quad\frac{y}{c} = 0.1$ $\quad\frac{dy}{dx} = 0$

(2) Leading-edge radius:

$\frac{x}{c} = 0$ $\quad R = \frac{{a_0}^2}{2}$

(3) Radius of curvature at maximum thickness:

$\frac{x}{c} = m$ $\quad R = \frac{(1 - m)^2}{2d_1(1 - m) - 0.588}$

(4) Ordinate at trailing edge:

$\frac{x}{c} = 1.0$ $\quad\frac{y}{c} = d_0 = 0.002$

(5) Trailing-edge angle:

$\frac{x}{c} = 1.0$ $\quad\frac{dy}{dx} = d_1 = f(m)$

Thus, the maximum ordinate, slope, and radius of curvature of the two portions of the surface match at $\frac{x}{c} = m$. The values of d_1 were chosen, as stated in reference 2, to avoid reversals of curvature and are given in the following table:

m	d_1
0.2	0.200
.3	.234
.4	.315
.5	.465
.6	.700

By use of these constraints, equations were written for each of the constants (except d_0 and d_1) in the equation for the airfoil family and are included in the computer program. As in the 4-digit airfoil family, ordinates vary linearly with variations in thickness-chord ratio and any desired thickness shape can be obtained by scaling the ordinates by the ratio of the desired thickness ratio to the design thickness ratio.

These airfoils are designated by a 4-digit number followed by a dash and a 2-digit number (that is, NACA 0012-63). The first two digits are zero for a symmetrical airfoil and the second two digits indicate the thickness-chord ratio. The first digit after the dash is a leading-edge radius index number, and the second is the location of maximum thickness in tenths of chord aft of the leading edge. The leading-edge index is an arbitrary number assigned to the leading-edge radius in reference 2 and is proportional to a_0. An index of 0 indicates a sharp leading edge (radius of zero) and an index of 6 corresponds to $a_0 = 0.2969$, the normal design value for the 4-digit airfoil. A value of leading-edge index of 9 for a three times normal leading-edge radius was arbitrarily assigned in reference 2. Values of leading-edge radius for various values of the index number and thickness-chord ratio are listed in table I and plotted in figure 1. The computer program is written so that the desired value of leading-edge radius is the input parameter. The value of a_0 is then computed in the program. The index number is only used in the airfoil designation.

16-series.- The NACA 16-series airfoil family is described in references 4 and 5. Although not directly stated in the references, it will be noted from the equation for the ordinates in reference 5 that this series is a special case of the 4-digit modified family. The 16-series are thus defined as having a leading-edge index of 4 and a location of maximum thickness at 0.50 chord. The designation NACA 16-012 airfoil is equivalent to an NACA 0012-45. The computer program does not have separate inputs for the 16-series so that the 4-digit modified series must be used to obtain ordinates for these airfoils.

Camber-Line Equations

2-digit.- The NACA 2-digit camber line is described in reference 1. This camber line is formed by two parabolic segments which have a general equation of the form $\frac{y}{c} = b_0 + b_1\left(\frac{x}{c}\right) + b_2\left(\frac{x}{c}\right)^2$. The constants for the two equations are determined from the following boundary equations:

(1) Camber-line extremities:

$$\frac{x}{c} = 0 \qquad \frac{y}{c} = 0$$

$$\frac{x}{c} = 1.0 \qquad \frac{y}{c} = 0$$

(2) Maximum ordinate:

$$\frac{x}{c} = m \qquad \frac{y}{c} = p$$

$$\frac{dy}{dx} = 0$$

From these conditions, the camber-line equations then become

$$\frac{y}{c} = \frac{p}{m^2}\left[2m\left(\frac{x}{c}\right) - \left(\frac{x}{c}\right)^2\right]$$

forward of maximum ordinate and

$$\frac{y}{c} = \frac{p}{(1 - m)^2}\left[(1 - 2m) + 2m\left(\frac{x}{c}\right) - \left(\frac{x}{c}\right)^2\right]$$

aft of the maximum ordinate. Both the ordinate and slope of the two parabolic segments match at $\frac{x}{c} = m$. This camber line is designated by a two-digit number and, when used with a 4-digit airfoil, would have the form NACA pmXX where p is the maximum camber in percent chord; m is the chordwise location of maximum camber; and XX is the airfoil thickness in percent chord. Tables of ordinates for some of these camber lines are tabulated in references 8 and 9. The ordinates are linear with amount of camber and these can be scaled up or down as desired.

<u>3-digit</u>.- To provide a camber line with a very far forward location of the maximum camber, the 3-digit camber line was developed and presented in reference 3. This camber line is also made up of two equations so that the second derivative decreases to zero at a point r aft of the maximum ordinate and remains zero from this point to the trailing edge. The equations for these conditions are as follows:

From $\frac{x}{c} = 0$ to $\frac{x}{c} = r$,

$$\frac{d^2y}{dx^2} = k_1\left(\frac{x}{c} - r\right)$$

From $\frac{x}{c} = r$ to $\frac{x}{c} = 1.0$,

$$\frac{d^2y}{dx^2} = 0$$

The design criteria are as follows:

(1) Camber-line extremities:

$$\frac{x}{c} = 0 \qquad \frac{y}{c} = 0$$

$$\frac{x}{c} = 1.0 \qquad \frac{y}{c} = 0$$

(2) At junction point:

$$\frac{x}{c} = r \qquad \left(\frac{y}{c}\right)_N = \left(\frac{y}{c}\right)_T$$

$$\left(\frac{dy}{dx}\right)_N = \left(\frac{dy}{dx}\right)_T$$

The equation for the camber line then becomes

$$\frac{y}{c} = \frac{1}{6} k_1 \left[\left(\frac{x}{c}\right)^3 - 3r\left(\frac{x}{c}\right)^2 + r^2(3 - r)\left(\frac{x}{c}\right)\right]$$

from $\frac{x}{c} = 0$ to $\frac{x}{c} = r$ and

$$\frac{y}{c} = \frac{1}{6} k_1 r^3 \left[1 - \left(\frac{x}{c}\right)\right]$$

from $\frac{x}{c} = r$ to $\frac{x}{c} = 1.0$. These equations were then solved for values of r which would give longitudinal locations of the maximum ordinate of 5, 10, 15, 20, and 25 percent chord. The value of k_1 was adjusted so that a theoretical design lift coefficient of 0.3 was obtained at the ideal angle of attack. The value of k_1 can be linearly scaled to give any desired design lift coefficient. Values of k_1 and r and the camber-line designation were taken from reference 3 and are presented in the following table:

Camber-line designation	x/c for maximum camber, m	r	k_1
210	0.05	0.0580	361.400
220	.10	.1260	51.640
230	.15	.2025	15.957
240	.20	.2900	6.643
250	.25	.3910	3.230

The first digit of the 3-digit camber-line designation is defined as two-thirds of the design lift coefficient, the second digit as twice the longitudinal location of maximum thickness in tenths of chord, and the third digit of zero indicates a nonreflexed trailing edge.

3-digit reflex.- For some applications, for example, rotorcraft main rotors, it may be desirable to produce an airfoil with a quarter-chord pitching-moment coefficient of zero. The three-digit reflexed camber line was thus designed to have a theoretical zero pitching moment as described in reference 3. The forward part of the camber line is identical to the 3-digit camber line but the aft portion was changed from a zero curvature segment to a segment with curvature. The equation for the aft portion of the camber line is expressed by $\frac{d^2y}{dx^2} = k_2\left(\frac{x}{c} - r\right)$. By using the same boundary conditions as were used for the 3-digit camber line, the equations for the ordinates are

$$\frac{y}{c} = \frac{1}{6}k_1\left[\left(\frac{x}{c} - r\right)^3 - \frac{k_2}{k_1}(1 - r)^2\frac{x}{c} - r^3\frac{x}{c} + r^3\right]$$

from $\frac{x}{c} = 0$ to $\frac{x}{c} = r$ and

$$\frac{y}{c} = \frac{1}{6}k_1\left[\frac{k_2}{k_1}\left(\frac{x}{c} - r\right)^3 - \frac{k_2}{k_1}(1 - r)^3\frac{x}{c} - r^3\frac{x}{c} + r^3\right]$$

for $\frac{x}{c} = r$ to $\frac{x}{c} = 1.0$. The ratio k_2/k_1 is expressed as

$$\frac{k_2}{k_1} = \frac{3(r - m)^2 - r^3}{1 - r}$$

Values of k_1, k_2/k_1, and m for several camber-line designations from reference 2 are presented in the following table:

Camber-line designation	x/c for maximum camber, m	r	k_1	k_2/k_1
221	0.10	0.1300	51.99	0.000764
231	.15	.2170	15.793	.00677
241	.20	.3180	6.520	.0303
251	.25	.4410	3.191	.1355

The camber-line designation for this camber line is identical to that for the 3-digit camber line except that the last digit is changed from 0 to 1 to indicate the reflex characteristic.

6- and 6A-series.- The equations for the 6-series camber lines are presented in reference 8. These camber lines are a function of the design lift coefficient $(C_L)_{design}$ and the chordwise extent of uniform loading A. These 16-series cambered airfoils (ref. 4) are derived by using the A = 1.0 camber line of the series. These equations have been programed for use with 6-series airfoils in reference 10 and that part of the program has been incorporated into the present program. As was the case in reference 10, the program is capable of combining up to 10 camber lines of this series to provide many types of loading.

Calculation of Cambered Airfoils

To calculate ordinates for a cambered airfoil, the desired mean line is first computed and then the ordinates of the symmetrical airfoil are measured normal to the mean line at the same chord station. This procedure leads to a set of parametric equations where $(y/c)_t$, $(y/c)_{cam}$, and δ are all functions of the original independent variable x/c. The ordinates on the cambered airfoil $(x/c)_u$ and $(y/c)_u$ are given by

$$\left(\frac{x}{c}\right)_u = \left(\frac{x}{c}\right) - \left(\frac{y}{c}\right)_t \sin\delta$$

$$\left(\frac{y}{c}\right)_u = \left(\frac{y}{c}\right) + \left(\frac{y}{c}\right)_t \cos\delta$$

where δ is the local inclination of the camber line and $(y/c)_t$ is assumed to be negative to obtain the lower surface ordinates $(x/c)_l$ and $(y/c)_l$. This procedure is also described in reference 1. The local slopes of the cambered airfoil can be shown to be

$$\left(\frac{dy}{dx}\right)_u = \frac{\tan\delta\sec\delta + \left(\frac{dy}{dx}\right)_t - \left(\frac{y}{c}\right)_t\left(\frac{d\delta}{dx}\right)\tan\delta}{\sec\delta - \left(\frac{dy}{dx}\right)_t\tan\delta - \left(\frac{y}{c}\right)_t\left(\frac{d\delta}{dx}\right)}$$

and

$$\left(\frac{dy}{dx}\right)_l = \frac{\tan\delta\sec\delta - \left(\frac{dy}{dx}\right)_t + \left(\frac{y}{c}\right)_t\left(\frac{d\delta}{dx}\right)\tan\delta}{\sec\delta + \left(\frac{dy}{dx}\right)_t\tan\delta + \left(\frac{y}{c}\right)_t\left(\frac{d\delta}{dx}\right)}$$

by parametric differentiation of $(x/c)_{u,l}$ and $(y/c)_{u,l}$ with respect to the original x/c and use of the relationship

$$\left(\frac{dy}{dx}\right)_u = \frac{d(y/c)_u/d(x/c)_u}{d(x/c)_u/d(x/c)}$$

Although specific camber lines are generally used with specific thickness distributions, this program has been written in a general format. As a result, any camber line can be used with either type thickness distribution so that any shape desired can be generated.

RESULTS AND DISCUSSION

Program Capabilities

The computer program which was developed to provide the airfoil shapes described by the equations in the analysis section is listed in the appendix. The output of the program consists of tabulated ordinates, computer-generated plots of the nondimensional ordinates, and punched card listings of the ordinates. The punched cards are in the format of the input of the program described in reference 11 so that pressure distributions over the generated shape may be readily obtained. To show graphically the capabilities of the program, sample computer plots of several airfoil shapes are presented in figures 2 to 10.

Figures 2 and 3 illustrate possible variations in the 4-digit airfoil family, figure 2 showing variations in thickness-chord ratio for symmetrical airfoils and figure 3 showing variations in the amount of camber for a fixed thickness-chord ratio and location of maximum camber. Figures 4 and 5 illustrate possible variations in the 5-digit airfoil family. Variations in the longitudinal location of maximum camber are shown in figure 4 and a comparison of the same airfoil with nonreflex and reflex camber lines is shown in figure 5. Examples of the 4-digit modified-series are shown in figure 6 for symmetrical airfoils and in figure 7 for cambered airfoils. The symmetrical airfoils have variations in the longitudinal position of maximum thickness whereas the cambered airfoils show variations in the longitudinal position of maximum camber.

Examples of 16-series airfoils (which, as previously noted, are special cases of 4-digit modified airfoils) are shown for symmetrical and cambered sections in figures 8 and 9, respectively. Figure 10 presents an example of a combination of a 4-digit modified airfoil with a combination of two 6-series camber lines to give an aft-loaded section. This is shown to give an indication of the types of sections which may be generated by combinations of various thickness distributions and types of camber lines. If a thickness-chord ratio of 0.0 is specified in the input to the program, the shape of just the camber line or combination of camber lines is computed. The results of this procedure are shown in figures 11 and 12.

Sample Output Tabulations

Sample computed ordinates for both a symmetric and a cambered airfoil are presented in tables II and III, respectively. Printed at the top of the first page for each table is the airfoil and camber-line family selected, the airfoil designation, and a list of the input parameters for both airfoil shape and camber line. For the 4-digit modified airfoil family, the coefficients of the airfoil equation are also listed for a shape with a thickness-chord ratio of 0.20. Both nondimensional and dimensional ordinates are listed. The dimensional quantities have the same units as the input value of the chord, which is also listed at the top of the page. First and second derivatives of the surface ordinates are also presented for symmetrical airfoils, but only first derivatives are tabulated for the cambered airfoils.

Accuracy of Results

All the airfoils and camber lines generated by this program are defined by closed analytical expressions and no approximations have been made in the program. Thus, all results are exact. Many cases have been run and compared with previously published results to check the procedure and in all cases the comparisons were exact except for occasional differences in the last digit due to rounding differences.

CONCLUDING REMARKS

The analytic design equations for both symmetrical and cambered airfoils in the NACA 4-digit, 4-digit modified, 5-digit, and 16-series airfoil families have been reviewed. A computer program has been developed to calculate rapidly the ordinates and surface slope for these airfoils and the program is included as an appendix to this report. Provisions are made in the program to combine basic airfoil shapes and camber lines from different series so that nonstandard airfoils can also be generated. The program will also produce plots of the nondimensional airfoil ordinates and a punch card output of the ordinates in the input format of a readily available program for determining the pressure distributions of arbitrary airfoils in subsonic potential viscous flow.

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APPENDIX

COMPUTER PROGRAM FOR ORDINATES OF ANALYTICAL NACA AIRFOILS

The program presented herein is written in the Langley Research Center version of FORTRAN IV and has been used on the Control Data series 6000 computer systems. Both the computational program and a plotting program are presented, although the plotting routine is included as a guide for users only. Several unlisted subroutines are used in the plotting program. The computational program requires about 46000_8 storage locations, and requires about 8 seconds to compile and about 1.5 seconds to execute each case on the Control Data 6600 computer system.

Card Input Format

The input to the program is in a card format as follows:

CARD 1 - Number of ordinates to be output on punched cards: (Maximum of 32) (right justified in columns 1 to 3).

CARDS 2, 3, 4, and 5 - Chordwise location of ordinates to be output on punched cards. (Columns 1 to 10, 11 to 20, etc., with decimal point.)

CARD 6 - Tabulated data printout airfoil title card. Any designation may be used in columns 1 to 80.

CARD 7 - Airfoil thickness series and camber-line series designations are as follows:

NACA airfoil family	Card designation*	Columns
4-digit	4-DIGIT	1 to 7
4-digit modified	4-DIGITMOD	1 to 10

Camber line	Card designation*	Columns
NACA 2-digit	2-DIGIT	11 to 17
NACA 3-digit	3-DIGIT	11 to 17
NACA 3-digit reflex	3-DIGITREF	11 to 20
NACA 6-series	6-SERIES	11 to 18
NACA 6A-series	6A-SERIES	11 to 19

*These are hollerith cards; designations must be in exact columns.

APPENDIX

CARD 8 – Airfoil thickness distribution parameter card. (Note that cards 3 to 7 are in floating-point mode. Numbers are entered with a decimal point.)

Description	Variable	Columns
Thickness-chord ratio of airfoil (i.e., 0.120)	TOC	1 to 10
Leading-edge radius to chord ratio. Not used with 4-digit but must be used with 4-digit modified	LER	11 to 20
Basic chordwise increment in x/c for computing ordinates. Usually set to 0.01	DX	21 to 30
Model chord used for listing ordinates in dimensional units	CHD	31 to 40
Nondimensional chordwise location of maximum thickness. Used for 4-digit modified airfoils only	XM	41 to 50
Trailing-edge slope of 4-digit modified airfoils. Take values from text or reference 2 or input 0.0 and approximate value from equation in reference 7 will be used	D1	51 to 60

CARD 9 – Airfoil camber-line parameter card. Set all values equal to 0.0 for a symmetrical airfoil.

Camber line	Description	Variable	Columns
2-digit	Maximum camber ordinate to chord ratio (i.e., 0.04), p	CMB	1 to 10
	Longitudinal location of maximum camber position (i.e., 0.40), m	CM	11 to 20
3-digit	Value of k_1 from text or reference 3 which varies linearly with design lift coefficient	CMB	1 to 10
	Value of r from text or reference 3 which is a function of the longitudinal location of maximum camber	CM	11 to 20

APPENDIX

Camber line	Description	Variable	Columns
3-digit reflex	Value of k_1 from text or reference 3 for reflex airfoils which varies linearly with design lift coefficient	CMB	1 to 10
	Value of r from reference 3 for reflex airfoils which is a function of the longitudinal location of maximum camber	CM	11 to 20
	Value of k_2/k_1 from reference 3 for reflex airfoils which is a function of longitudinal location of maximum camber	K20K1	21 to 30
6 series and 6A-series	Design lift coefficient (i.e., 0.20)	CL1	1 to 10
	Camber line chordwise loading (use 0.80 for 6A-series)	A	11 to 20
	Number of camber line to be summed (if only one, leave blank or insert 1.0)	CMBNMR	21 to 30

CARDS 10, 11, and 12 – Up to nine additional camber lines may be summed on these cards for the 6-series camber line. These cards are not necessary for only one camber line.

Camber line	Description	Variable	Columns
6-series	Design lift for second camber line	CLI	1 to 10
	Loading for second camber line	A	11 to 20
	Design lift for third camber line	CLI	21 to 30
	Loading for third camber line	A	31 to 40
	Design lift for fourth camber line	CLI	41 to 50
	Loading for fourth camber line	A	51 to 60
	Design lift for fifth camber line	CLI	61 to 70
	Loading for fifth camber line	A	71 to 80

CARD 13 – Title card for use in plot of airfoil ordinates. Any designation may be used in columns 1 to 80.

APPENDIX

Program Listing

A program listing follows:

```
      PROGRAM ANALIN(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT,PUNCH)
      DIMENSION XU(200), XL(200), YU(200), YL(200)
      COMMON /MAIN/ YSTART(3),CHD,KON
      DIMENSION COEFFS(4)
      DIMENSION XA(32), XAU(32), YAU(32), XAL(32), YAL(32), NAME(2)
      DIMENSION CLI(10), A(10), TANTHO(10), YCMB(10), TANTH(10), YCP2(10
     1), IF6XA(10)
      INTEGER TITLE(8)
      COMPLEX ROOTS(3),TEMP(8)
      EQUIVALENCE (CLI(1),CMB)
      INTEGER SERIEC
      REAL K2OK1
      INTEGER PROFILE,CAMBER
      YSTART(1)=1.0
      YSTART(2)=4.0
      YSTART(3)=7.0
      K4D=10H4-DIGIT
      K4DMOD=10H4-DIGITMOD
      K2D=10H2-DIGIT
      K3D=10H3-DIGIT
      K3DREF=10H3-DIGITREF
      K6S=10H6-SERIES
      K6AS=10H6A-SERIES
      KON=0
C     INPUT PARAMETERS NORMALIZED BY THE CHORD (CHD)
C     TOC - T/C, THICKNESS, RLE - LEADING EDGE RADIUS, XM - X(YMAX)/CHOR
C     DX - INTERVAL/CHORD, CHD - CHORD IN DESIRED UNITS
C     CMB - CAMBER CONSTANT K1, CM - X(MAX CAMBER)/CHORD
      CALL PSEUDO
      CALL LEROY
      READ (5,590) N,(XA(I),I=1,N)
      D1=0.0
   20 READ (5,600) (TITLE(I),I=1,8)
      IF (ENDFILE 5) 30,40
   30 CALL CALPLT (0,0,999)
      STOP
   40 CONTINUE
      READ (5,600) PROFILE,CAMBER
      KON=KON+1
      ICKY=0.0
      FRAC=1.0
      D1=1.0
      PRINT 620, PROFILE,CAMBER
      PRINT 610, (TITLE(I),I=1,8)
      IF (PROFILE.EQ.10H4-DIGIT   ) READ (5,630) TOC,RLE,DX,CHD,B,B,B,NA
     1ME(1)
      XM=0.5
      IF (PROFILE.EQ.10H4-DIGITMOD) READ (5,630) TOC,RLE,DX,CHD,XM,D1,B,
     1NAME(1)
      IF (CAMBER.EQ.10H2-DIGIT   .OR.CAMBER.EQ.10H3-DIGIT   ) READ (5,63
     10) CMB,CM,BB,BB,BB,BB,BB,NAME(2)
      IF (CAMBER.EQ.10H3-DIGITREF) READ (5,630) CMB,CM,K2OK1,BB,BB,BB,BB
     1,NAME(2)
      IF (CAMBER.EQ.10H6-SERIES   .OR.CAMBER.EQ.10H6A-SERIES ) READ (5,63
     10) CLI(1),A(1),CMBNMR,BB,BB,BB,BB,NAME(2)
      IF (CAMBER.EQ.10H6-SERIES   .OR.CAMBER.EQ.10H6A-SERIES ) ICKY=CMBNM
     1R
      IF (ICKY.GT.1) READ (5,640) (CLI(I),A(I),I=2,ICKY)
      IF (CAMBER.EQ.10H6-SERIES   .OR.CAMBER.EQ.10H6A-SERIES ) CMB=CLI(1)
      PRINT 550, NAME
```

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```
      IF (ICKY.LE.1) ICKY=1
      PI=3.141592654
      E=.1**6
      DO 50 I=1,10
      IF6XA(I)=0
   50 CONTINUE
      IF (PROFILE.EQ.10H4-DIGIT    ) PRINT 660, TOC,RLE,DX,CHD
      IF (PROFILE.EQ.10H4-DIGITMOD) PRINT 670, TOC,RLE,DX,CHD,XM,D1
      IF (CAMBER.EQ.10H2-DIGIT    ) PRINT 680, CMB,CM
      IF (CAMBER.EQ.10H3-DIGIT    ) PRINT 690, CMB,CM
      IF (CAMBER.EQ.10H3-DIGITREF) PRINT 700, CMB,CM,K2OK1
      IF (CAMBER.EQ.10H6-SERIES  .OR.CAMBER.EQ.10H6A-SERIES ) PRINT 710
      IF (CAMBER.EQ.10H6-SERIES  .OR.CAMBER.EQ.10H6A-SERIES ) PRINT 720,
     1 (CLI(I),A(I),I=1,ICKY)
      IF(TOC.LT.E)PROFILE=K4D
      IF (PROFILE.EQ.10H4-DIGIT    ) GO TO 70
C
C     COMPUTED CONSTANTS
C
      A0=SQRT(2.0*RLE)*0.2/TOC
      D0=0.002
      IF (D1.GT.0.0) GO TO 60
      D1=.1*(2.24-5.42*XM+12.3*XM**2)/(1.-0.878*XM)
   60 CONTINUE
      D3=(3.*D1-0.588/(1.-XM))/(3.*(1.-XM)**2)
      D2=-1.5*(1.-XM)*D3-.5*D1/(1.-XM)
      A3=0.1/XM**3+(2.*D1*(1.-XM)-0.588)/(2.*XM*(1.-XM)**2)-3.*A0/(8.*XM
     1**2.5)
      A2=-0.10/XM**2+.5*A0/XM**1.5-2.*XM*A3
      A1=-.5*A0/XM**.5-2.*XM*A2-3.*XM**2*A3
C     RC IS RADIUS OF CURVATURE AT X=XM
      RC=((1.-XM)**2/(2.*D1*(1.-XM)-0.588))*.2/TOC
      PRINT 730, A0,A1,A2,A3,D0,D1,D2,D3,RC
C
C     PROFILE, X LE XM
C
   70 CONTINUE
      IF (ABS(CMB).LE.0.1**6) PRINT 740
      IF (ABS(CMB).GT.0.1**6) PRINT 750
      X=0.0
      Y=0.0
      XC=0.0
      YC=0.0
      XU(1)=0.0
      YU(1)=0.0
      XL(1)=0.0
      YL(1)=0.0
      XUC=0.0
      YUC=0.0
      XLC=0.0
      YLC=0.0
      XAU(1)=0.0
      YAU(1)=0.0
      XAL(1)=0.0
      YAL(1)=0.0
      K=2
      IF (CAMBER.EQ.10H2-DIGIT    ) GO TO 80
      IF (CAMBER.EQ.10H3-DIGIT    ) GO TO 90
      IF (CAMBER.EQ.10H3-DIGITREF) GO TO 100
      IF (CAMBER.EQ.10H6-SERIES   ) GO TO 110
      IF (CAMBER.EQ.10H6A-SERIES  ) GO TO 110
      PRINT 760
      GO TO 190
```

**ORIGINAL PAGE IS
OF POOR QUALITY**

APPENDIX

```
 80 TANTHO=2.*CMB/CM                                                    A1230
    IF (ABS(CMB).LT.E) TANTHO=E                                         A1240
    YP=10.**10                                                          A1250
    YPP=10.**10                                                         A1260
    YUP=-1/TANTHO                                                       A1270
    YLP=-1/TANTHO                                                       A1280
    GO TO 190                                                           A1290
 90 TANTHO=CMB*CM**2*(3.0-CM)/6.0                                       A1300
    IF (ABS(CMB).LT.E) TANTHO=E                                         A1310
    YP=10.**10                                                          A1320
    YPP=10.**10                                                         A1330
    YUP=-1/TANTHO                                                       A1340
    YLP=-1/TANTHO                                                       A1350
    GO TO 190                                                           A1360
100 TANTHO=CMB*(3.*CM**2-K2OK1*(1-CM)**3-CM**3)/6                       A1370
    IF (ABS(CMB).LT.E) TANTHO=E                                         A1380
    YP=10.**10                                                          A1390
    YPP=10.**10                                                         A1400
    YUP=-1/TANTHO                                                       A1410
    YLP=-1/TANTHO                                                       A1420
    GO TO 190                                                           A1430
110 L=0                                                                 A1440
    CLIS=CLI(1)                                                         A1450
    AS=A(1)                                                             A1460
120 L=L+1                                                               A1470
    A(1)=A(L)                                                           A1480
    CLI(1)=CLI(L)                                                       A1490
    K=2                                                                 A1500
    U=0.005                                                             A1510
    V=-(A-U)/ABS(A-U)                                                   A1520
    OMXL=(1.-U)*ALOG(1.-U)                                              A1530
    AMXL=(A-U)*ALOG(ABS(A-U))                                           A1540
    OMXL1=-ALOG(1.-U)-1.                                                A1550
    AMXL1=-ALOG(ABS(A-U))+V                                             A1560
    OMXL2=1./(1.-U)                                                     A1570
    AMXL2=-V/ABS(A-U)                                                   A1580
    IF (A.LT.E.OR.ABS(1.-A).LT.E) GO TO 130                             A1590
    G=-(A**2*(.5*ALOG(A)-0.25)+0.25)/(1.-A)                             A1600
    Q=1.0                                                               A1610
    H=(0.5*(1.-A)**2*ALOG(1.-A)-0.25*(1.-A)**2)/(1.-A)+G                A1620
    Z=.5*(A-U)*AMXL-.5*(1.-U)*OMXL-.25*(A-U)**2+.25*(1.-U)**2           A1630
    Z1=.5*((A-U)*AMXL1-AMXL-(1.-U)*OMXL1+OMXL+(A-U)-(1.-U))             A1640
    Z2=.5*(A-U)*AMXL2-AMXL1-.5*(1.-U)*OMXL2+OMXL1                       A1650
130 CONTINUE                                                            A1660
    IF (A.LT.E) GO TO 140                                               A1670
    IF (ABS(A-1.).LT.E) GO TO 150                                       A1680
140 H=-.5                                                               A1690
    Q=1.0                                                               A1700
    Z1=U*ALOG(U)-.5*U-.5*(1.-U)*OMXL1+.5*OMXL-.5                        A1710
    GO TO 160                                                           A1720
150 H=0.0                                                               A1730
    Q=H                                                                 A1740
    Z1=-OMXL1                                                           A1750
    GO TO 160                                                           A1760
160 TANTHO(L)=CLI*(Z1/(1.-Q*A)-1.-ALOG(U)-H)/PI/(A+1.)/2.0              A1770
    IF (ICKY.GT.1.AND.L.LT.ICKY) GO TO 120                              A1780
    IF (ICKY.EQ.1) GO TO 180                                            A1790
    DO 170 J=2,ICKY                                                     A1800
170 TANTHO(1)=TANTHO(1)+TANTHO(J)                                       A1810
180 CONTINUE                                                            A1820
    IF (ABS(CMB).LT.E) TANTHO=E                                         A1830
    YP=10.**10                                                          A1840
    YPP=10.**10                                                         A1850
    YUP=-1/TANTHO                                                       A1860
    YLP=-1/TANTHO                                                       A1870
```

```
  190 CONTINUE
      I=1
      IF (ABS(CMB).GT.0.1**6) PRINT 790, X,XU(I),YU(I),XUC,YUC,YUP,XL(I)
     1,YL(I),XLC,YLC,YLP
      IF (ABS(CMB).LE.0.1**6) PRINT 770, X,Y,YP,YPP,XC,YC
      X=.00025
  200 CONTINUE
      IF (PROFILE.EQ.10H4-DIGIT   ) GO TO 210
      IF (PROFILE.EQ.10H4-DIGITMOD) GO TO 220
      PRINT 800
      GO TO 230
  210 Y=0.29690*SQRT(X)-0.12600*X-0.35160*X**2+0.28430*X**3-0.1015*X**4
      YP=.5*.2969/SQRT(X)-.126-2.*.3516*X+3.*.2843*X*X-4.*.1015*X**3
      YPP=-.5*.5*.2969/SQRT(X**3)-2.*.3516+2.*3.*.2843*X-3.*4.*.1015*X*X
      GO TO 230
  220 Y=A0*X**.5+A1*X+A2*X**2+A3*X**3
      YP=.5*A0/X**.5+A1+2.*A2*X+3.*A3*X**2
      YPP=-.25*A0/X**1.5+2.*A2+6.*A3*X
  230 CONTINUE
      Y=Y*TOC/.2
      YP=YP*TOC/.2
      YPP=YPP*TOC/.2
      IF (ABS(CMB).LT.E) CM=0.5
      XC=X*CHD
      YC=Y*CHD
      IF (CAMBER.EQ.10H2-DIGIT   ) GO TO 240
      IF (CAMBER.EQ.10H3-DIGIT   ) GO TO 250
      IF (CAMBER.EQ.10H3-DIGITREF) GO TO 260
      IF (CAMBER.EQ.10H6-SERIES  ) GO TO 270
      IF (CAMBER.EQ.10H6A-SERIES ) GO TO 270
      PRINT 760
      GO TO 440
  240 YCMB=CMB*(2.0*CM*X-X*X)/CM**2
      TANTH=2.*CMB*(1.-X/CM)/CM
      IF (X.GT.CM) YCMB=CMB*(1.-2.*CM+2.*CM*X-X*X)/(1.-CM)**2
      IF (X.GT.CM) TANTH=(2.*CM-2.*X)*CMB/(1.-CM)**2
      F=SQRT(1.+TANTH**2)
      THP=-2.*CMB/CM**2/F**2
      IF (X.GT.CM) THP=-2.*CMB/(1.-CM)**2/F**2
      GO TO 440
  250 YCMB=CMB*(X**3-3.*CM*X**2+CM**2*(3.-CM)*X)/6.
      TANTH=CMB*(3.*X**2-6.*CM*X+CM**2*(3.-CM))/6.
      IF (X.GT.CM) YCMB=CMB*CM**3*(1.-X)/6.
      IF (X.GT.CM) TANTH=-CMB*CM**3/6.
      F=SQRT(1.+TANTH**2)
      THP=CMB*(X-CM)/F**2
      IF (X.GT.CM) THP=0.0
      GO TO 440
  260 YCMB=CMB*((X-CM)**3-K20K1*(1-CM)**3*X-CM**3*X+CM**3)/6
      TANTH=CMB*(3.*(X-CM)**2-K20K1*(1-CM)**3-CM**3)/6.
      IF (X.GT.CM) YCMB=CMB*(K20K1*(X-CM)**3-K20K1*(1-CM)**3*X-CM**3*X+C
     1M**3)/6
      IF (X.GT.CM) TANTH=CMB*(3*K20K1*(X-CM)**2-K20K1*(1-CM)**3-CM**3)/6
      F=SQRT(1.+TANTH**2)
      THP=CMB*(X-CM)/F**2
      IF (X.GT.CM) THP=K20K1*CMB*(X-CM)/F**2
      GO TO 440
  270 L=0
      A(1)=AS
      CLI(1)=CLIS
  280 L=L+1
      A(1)=A(L)
      CLI(1)=CLI(L)
      XC=X*CHD
      YC=Y*CHD
```

```
      XLL=X*ALOG(X)
      Q=1.0
      IF (ABS(1.-A).LT.E.AND.ABS(1.-X).LT.E) GO TO 330
      IF (A.LT.E.AND.(1.-X).LT.E) GO TO 340
      IF (ABS(A-X).LT.E) GO TO 290
      IF (ABS(1.-X).LT.E) GO TO 310
      IF (ABS(A-1.).LT.E) GO TO 320
      V=-(A-X)/ABS(A-X)
      OMXL=(1.-X)*ALOG(1.-X)
      AMXL=(A-X)*ALOG(ABS(A-X))
      OMXL1=-ALOG(1.-X)-1.
      AMXL1=-ALOG(ABS(A-X))+V
      OMXL2=1./(1.-X)
      AMXL2=1./(A-X)
      Z=.5*(A-X)*AMXL-.5*(1.-X)*OMXL-.25*(A-X)**2+.25*(1.-X)**2
      Z1=.5*((A-X)*AMXL1-AMXL-(1.-X)*OMXL1+OMXL+(A-X)-(1.-X))
      Z2=.5*(A-X)*AMXL2-AMXL1-.5*(1.-X)*OMXL2+OMXL1
      IF (A.LE.E) GO TO 300
      G=-(A*A*(.5*ALOG(A)-0.25)+0.25)/(1.-A)
      H=(0.5*(1.-A)**2*ALOG(1.-A)-0.25*(1.-A)**2)/(1.-A)+G
      GO TO 350
  290 Z=-.5*(1.-X)**2*ALOG(1.-X)+0.25*(1.-X)**2
      Z1=-.5*(1.-X)*(-ALOG(1.-X)-1.)+.5*(1.-X)*ALOG(1.-X)-.5*(1.-X)
      Z2=-ALOG(1.-X)-0.5
      G=-(A**2*(.5*ALOG(A)-0.25)+0.25)/(1.-A)
      H=(0.5*(1.-A)**2*ALOG(1.-A)-0.25*(1.-A)**2)/(1.-A)+G
      GO TO 350
  300 G=-.25
      H=-.5
      GO TO 350
  310 CONTINUE
      G=-(A**2*(.5*ALOG(A)-0.25)+0.25)/(1.-A)
      H=(0.5*(1.-A)**2*ALOG(1.-A)-0.25*(1.-A)**2)/(1.-A)+G
      Z=.5*(A-1.)**2*ALOG(ABS(A-1.))-0.25*(A-1.)**2
      Z1=-(A-1.)*ALOG(ABS(A-1.))
      Z2=-10.**10
      GO TO 350
  320 G=0.0
      H=G
      Q=G
      Z=-(1.-X)*ALOG(1.-X)
      Z1=ALOG(1.-X)+1.
      Z2=-1./(1.-X)
      GO TO 350
  330 Z=0.0
      G=Z
      H=Z
      Q=Z
      Z1=-10.**10
      Z2=-10.**10
      GO TO 350
  340 G=-.25
      H=-.5
      Q=1.0
      Z=-.25
      Z1=0.0
      Z2=-10.**10
      GO TO 350
  350 YCMB(L)=CLI*(Z/(1.-Q*A)-XLL+G-H*X)/PI/(A+1.)/2.
      XSV=X
      IF (X.LT.0.005) X=0.005
      TANTH(L)=CLI*(Z1/(1.-Q*A)-1.-ALOG(X)-H)/PI/(A+1.)/2.0
      X=XSV
      IF (IF6XA(L).EQ.1) TANTH(L)=-5.
      IF (X.GT.0.005) GO TO 360
      YCP2(L)=0.0
      GO TO 380
```

APPENDIX

```
  360 CONTINUE                                                          A3200
      IF (ABS(1.-X).GT.E) GO TO 370                                     A3210
      YCP2(L)=1./E                                                      A3220
      GO TO 380                                                         A3230
  370 PIA=PI*(A+1.)*2.                                                  A3240
      YCP2(L)=CLI*(Z2/(1.-Q*A)-1./X)/PIA                                A3250
  380 CONTINUE                                                          A3260
C        MODIFIED CAMBERLINE OPTION                                     A3270
      IF (CAMBER.EQ.K6AS) GO TO 390                                     A3280
      GO TO 410                                                         A3290
  390 YCMB(L)=YCMB(L)*0.97948                                           A3300
      TANTH(L)=TANTH(L)*0.97948                                         A3310
      YCP2(L)=YCP2(L)*0.97948                                           A3320
      IF (ABS(A-.8).LT.E) GO TO 400                                     A3330
      PRINT 780                                                         A3340
      READ 600, NPWIPE                                                  A3350
      IF (KON.EQ.3) KON=0                                               A3360
      GO TO 20                                                          A3370
  400 CONTINUE                                                          A3380
      IF (TANTH(L).LE.-.24521*CLI) YCMB(L)=0.24521*CLI*(1.-X)           A3390
      IF (TANTH(L).LE.-.24521*CLI) YCP2(L)=0.0                          A3400
      IF (TANTH(L).LE.-.24521*CLI) TANTH(L)=-0.24521*CLI                A3410
      IF (TANTH(L).LE.-.24521*CLI) IF6XA(L)=1                           A3420
  410 CONTINUE                                                          A3430
      IF (ICKY.GT.1.AND.L.LT.ICKY) GO TO 280                            A3440
      IF (ICKY.EQ.1) GO TO 430                                          A3450
      DO 420 J=2,ICKY                                                   A3460
      YCMB(1)=YCMB(1)+YCMB(J)                                           A3470
      TANTH(1)=TANTH(1)+TANTH(J)                                        A3480
      YCP2(1)=YCP2(1)+YCP2(J)                                           A3490
  420 CONTINUE                                                          A3500
  430 CONTINUE                                                          A3510
      F=SQRT(1.+TANTH**2)                                               A3520
      THP=YCP2/F**2                                                     A3530
  440 CONTINUE                                                          A3540
      IF (X.GT.XM) GO TO 550                                            A3550
      IF (ABS(X-XM).LT.E) GO TO 550                                     A3560
      SINTH=TANTH/F                                                     A3570
      COSTH=1./F                                                        A3580
      I=I+1                                                             A3590
      XU(I)=X-Y*SINTH                                                   A3600
      YU(I)=YCMB+Y*COSTH                                                A3610
      XL(I)=X+Y*SINTH                                                   A3620
      YL(I)=YCMB-Y*COSTH                                                A3630
      IF (ABS(X-XA(K)).GT..1**6) GO TO 450                              A3640
      XAU(K)=XU(I)                                                      A3650
      YAU(K)=YU(I)                                                      A3660
      XAL(K)=XL(I)                                                      A3670
      YAL(K)=YL(I)                                                      A3680
      K=K+1                                                             A3690
  450 CONTINUE                                                          A3700
      XUC=XU(I)*CHD                                                     A3710
      YUC=YU(I)*CHD                                                     A3720
      XLC=XL(I)*CHD                                                     A3730
      YLC=YL(I)*CHD                                                     A3740
      IF (ABS(CMB).LE.0.1**6) GO TO 460                                 A3750
      YUP=0.0                                                           A3760
      YLP=YUP                                                           A3770
      IF (ABS(TANTH).LT.0.1**10) GO TO 460                              A3780
      YUP=(TANTH*F+YP-TANTH*Y*THP)/(F-YP*TANTH-Y*THP)                   A3790
      YLP=(TANTH*F-YP+TANTH*Y*THP)/(F+YP*TANTH+Y*THP)                   A3800
  460 CONTINUE                                                          A3810
      IF (X.LE.0.0975) FRAC=0.25                                        A3820
      IF (X.LE.0.00225) FRAC=0.025                                      A3830
      IF (ABS(CMB).GT.0.1**6) PRINT 790, X,XU(I),YU(I),XUC,YUC,YUP,XL(I) A3840
```

```
     1,YL(I),XLC,YLC,YLP
      IF (ABS(CMB).LE.0.1**6) PRINT 770, X,Y,YP,YPP,XC,YC
      X=X+FRAC*DX
      FRAC=1.0
      IF (ABS(X-XM).LT.E) GO TO 470
      IF (X.LT.XM) GO TO 200
C
C     PROFILE - X GE XM
C
      X=XM
  470 CONTINUE
      IF (PROFILE.EQ.10H4-DIGIT    ) GO TO 480
      IF (PROFILE.EQ.10H4-DIGITMOD) GO TO 490
      PRINT 800
      GO TO 500
  480 Y=0.29690*SQRT(X)-0.12600*X-0.35160*X**2+0.28430*X**3-0.1015*X**4
      YP=.5*.2969/SQRT(X)-.126-2.*.3516*X+3.*.2843*X*X-4.*.1015*X**3
      YPP=-.5*.5*.2969/SQRT(X**3)-2.*.3516+2.*3.*.2843*X-3.*4.*.1015*X*X
      GO TO 500
  490 Y=D0+D1*(1.-X)+D2*(1.-X)**2+D3*(1.-X)**3
      YP=-D1-2.*D2*(1.-X)-3.*D3*(1.-X)**2
      YPP=2.*D2+6.*D3*(1.-X)
  500 CONTINUE
      Y=Y*TOC/.2
      YP=YP*TOC/.2
      YPP=YPP*TOC/.2
      XC=X*CHD
      YC=Y*CHD
      IF (CAMBER.EQ.10H2-DIGIT    ) GO TO 510
      IF (CAMBER.EQ.10H3-DIGIT    ) GO TO 520
      IF (CAMBER.EQ.10H3-DIGITREF) GO TO 530
      IF (CAMBER.EQ.10H6-SERIES   ) GO TO 540
      IF (CAMBER.EQ.10H6A-SERIES  ) GO TO 540
      PRINT 760
      GO TO 560
  510 YCMB=CMB*(2.0*CM*X-X*X)/CM**2
      TANTH=2.*CMB*(1.-X/CM)/CM
      IF (X.GT.CM) YCMB=CMB*(1.-2.*CM+2.*CM*X-X*X)/(1.-CM)**2
      IF (X.GT.CM) TANTH=(2.*CM-2.*X)*CMB/(1.-CM)**2
      F=SQRT(1.+TANTH**2)
      THP=-2.*CMB/CM**2/F**2
      IF (X.GT.CM) THP=-2.*CMB/(1.-CM)**2/F**2
      GO TO 560
  520 YCMB=CMB*(X**3-3.*CM*X**2+CM**2*(3.-CM)*X)/6.
      TANTH=CMB*(3.*X**2-6.*CM*X+CM**2*(3.-CM))/6.
      IF (X.GT.CM) YCMB=CMB*CM**3*(1.-X)/6.
      IF (X.GT.CM) TANTH=-CMB*CM**3/6.
      F=SQRT(1.+TANTH**2)
      THP=CMB*(X-CM)/F**2
      IF (X.GT.CM) THP=0.0
      GO TO 560
  530 YCMB=CMB*((X-CM)**3-K2OK1*(1-CM)**3*X-CM**3*X+CM**3)/6
      TANTH=CMB*(3.*(X-CM)**2-K2OK1*(1-CM)**3-CM**3)/6.
      IF (X.GT.CM) YCMB=CMB*(K2OK1*(X-CM)**3-K2OK1*(1-CM)**3*X-CM**3*X+C
     1M**3)/6
      IF (X.GT.CM) TANTH=CMB*(3*K2OK1*(X-CM)**2-K2OK1*(1-CM)**3-CM**3)/6
      F=SQRT(1.+TANTH**2)
      THP=CMB*(X-CM)/F**2
      IF (X.GT.CM) THP=K2OK1*CMB*(X-CM)/F**2
      GO TO 560
  540 GO TO 270
  550 CONTINUE
  560 CONTINUE
      SINTH=TANTH/F
      COSTH=1./F
      I=I+1
```

```
      XU(I)=X-Y*SINTH                                                   A4510
      YU(I)=YCMB+Y*COSTH                                                A4520
      XL(I)=X+Y*SINTH                                                   A4530
      YL(I)=YCMB-Y*COSTH                                                A4540
      IF (ABS(X-XA(K)).GT..1**6) GO TO 570                              A4550
      XAU(K)=XU(I)                                                      A4560
      YAU(K)=YU(I)                                                      A4570
      XAL(K)=XL(I)                                                      A4580
      YAL(K)=YL(I)                                                      A4590
      K=K+1                                                             A4600
  570 CONTINUE                                                          A4610
      XUC=XU(I)*CHD                                                     A4620
      YUC=YU(I)*CHD                                                     A4630
      XLC=XL(I)*CHD                                                     A4640
      YLC=YL(I)*CHD                                                     A4650
      IF (ABS(CMB).LE.0.1**6) GO TO 580                                 A4660
      YUP=0.0                                                           A4670
      YLP=YUP                                                           A4680
      IF (ABS(TANTH).LT.0.1**10) GO TO 580                              A4690
      YUP=TANTH*(F+YP/TANTH-Y*THP)/(F-YP*TANTH-Y*THP)                   A4700
      YLP=TANTH*(F-YP/TANTH+Y*THP)/(F+YP*TANTH+Y*THP)                   A4710
  580 CONTINUE                                                          A4720
      IF (ABS(CMB).GT.0.1**6) PRINT 790, X,YU(I),YU(I),XUC,YUC,YUP,XL(I)  A4730
     1,YL(I),XLC,YLC,YLP                                                A4740
      IF (ABS(CMB).LE.0.1**6) PRINT 770, X,Y,YP,YPP,XC,YC               A4750
      X=X+DX                                                            A4760
      IF (X.LE.1.0) GO TO 470                                           A4770
      PUNCH 600, (TITLE(I),I=1,8)                                       A4780
      PUNCH 810, (XAU(I),I=1,32)                                        A4790
      PUNCH 810, (YAU(I),I=1,32)                                        A4791
      PUNCH 810, (XAL(I),I=1,32)                                        A4792
      PUNCH 810, (YAL(I),I=1,32)                                        A4793
      CALL PLOT (XU,XL,YU,YL,I)                                         A4800
      GO TO 20                                                          A4810
C                                                                       A4820
  590 FORMAT (I3/(8F10.0))                                              A4830
  600 FORMAT (8A10)                                                     A4840
  610 FORMAT (1H ,8A10)                                                 A4850
  620 FORMAT (10H1PROFILE  ,A10,10H  CAMBER  ,A10)                      A4860
  630 FORMAT (7F10.0,A10)                                               A4870
  640 FORMAT (8F10.0)                                                   A4880
  650 FORMAT (/10X,A10,10X,A10/)                                        A4890
  660 FORMAT (19H PROFILE PARAMETERS/5H T/C=,F10.5/12H L.E.RADIUS=,F10.5  A4900
     1/18H BASIC X INTERVAL=,F10.5/7H CHORD=,F10.5/)                    A4910
  670 FORMAT (19H PROFILE PARAMETERS/5H T/C=,F10.5/12H L.E.RADIUS=,F10.5  A4920
     1/18H BASIC X INTERVAL=,F10.5/7H CHORD=,F10.5/35H POSITION OF MAXIM  A4930
     2UM THICKNESS, XM=,F10.5/13H CONSTANT D1=,F10.5/)                  A4940
  680 FORMAT (23H CAMBER LINE PARAMETERS/16H CAMBER(YCMAX) =,F10.5/28H P  A4950
     1OSITION OF MAXIMUM CAMBER=,F10.5/)                                A4960
  690 FORMAT (23H CAMBER LINE PARAMETERS/21H CAMBER PARAMETER K1=,F10.5/  A4970
     140H POSITION OF ZERO CAMBER LINE CURVATURE=,F10.5/)               A4980
  700 FORMAT (23H CAMBER LINE PARAMETERS/21H CAMBER PARAMETER K1=,F10.5/  A4990
     140H POSITION OF ZERO CAMBER LINE CURVATURE=,F10.5/61H RATIO OF AFT  A5000
     2 TO FORWARD CAMBER LINE CURVATURE FACTOR, K2OK1=,F10.5/)          A5010
  710 FORMAT (23H CAMBER LINE PARAMETERS/7X,3HCLI,9X,1HA)               A5020
  720 FORMAT (2F10.3)                                                   A5030
  730 FORMAT (10H A0,1,2,3=,4F13.6/10H D0,1,2,3=,4F13.6/4H RC=,F13.3//)  A5040
  740 FORMAT (9X,3HX/C,10X,3HY/C,8X,5HDY/DX,6X,7HD2Y/DX2,22X,1HX,12X,1HY  A5050
     1/)                                                                A5060
  750 FORMAT (116H0UNCAMBERED                        UPPER SURFACE VALU  A5070
     1ES                                       LOWER SURFACE VALUES /5X,  A5080
     23HX/C17X,4HXU/C6X,4HYU/C5X,7H   XU   3X,7H   YU   3X,7HDYU/DXU13X,4H  A5090
     3XL/C4X,4HYL/C5X,7H   XL   3X,7H   YL   3X,7HDYL/DXL)              A5100
  760 FORMAT (35H BAD HOLLERITH CAMBER SPECIFICATION)                   A5110
  770 FORMAT (4F13.6,10X,2F13.6)                                        A5120
  780 FORMAT (52H  MODIFIED CAMBER LINE OPTION ONLY ALLOWED IF A=0.8 )  A5130
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APPENDIX

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790 FORMAT (F10.5,10X,4F10.5,E11.2,6X,4F10.5,E11.2)                     A5140
800 FORMAT (36H BAD HOLLERITH PROFILE SPECIFICATION)                    A5150
810 FORMAT (8F10.5)                                                     A5160
    END                                                                 A5170-
    SUBROUTINE PLOT (XU,XL,YU,YL,I)                                     B  10
    COMMON /MAIN/ YSTART(3),CHD,K                                       B  20
    DIMENSION XU(1), XL(1), YU(1), YL(1), X(450), Y(450)                B  30
    DIMENSION TITLE1(8), TITLE2(8)                                      B  40
    READ 30, (TITLE1(N),N=1,8)                                          B  50
    IF (MOD(K,3).EQ.1) CALL CALPLT (1.0,0.0,-3)                         B  60
    HGT=0.14                                                            B  70
    L=I                                                                 B  80
    DO 10 N=1,I                                                         B  90
    X(N)=XU(N)                                                          B 100
    Y(N)=YU(N)                                                          B 110
    X(I+N)=XL(L)                                                        B 120
    Y(I+N)=YL(L)                                                        B 130
 10 L=L-1                                                               B 140
    M=2*I                                                               B 150
    XPG=10.0                                                            B 160
    XX=XPG/2.0-1.5*(6./7.*HGT)                                          B 170
    XDV=0.0                                                             B 180
    XTIC=1.0                                                            B 190
    YPG=2.0                                                             B 200
    YDV=0.0                                                             B 210
    YTIC=1.0                                                            B 220
    X(M+1)=0.0                                                          B 230
    Y(M+1)=-0.1                                                         B 240
    X(M+2)=1.0/XPG                                                      B 250
    Y(M+2)=X(M+2)                                                       B 260
    CALL AXES (0.,YSTART(K),90.,YPG,Y(M+1),Y(M+2),YTIC,YDV,1H ,HGT,1)   B 270
    CALL AXES (0.,YSTART(K),0.,XPG,X(M+1),X(M+2),XTIC,XDV,1H ,HGT,-1)   B 280
    YLABEL=YSTART(K)-2.5*HGT                                            B 290
    CALL NOTATE (XX,YLABEL,HGT,3HX/C,0.,3)                              B 300
    YLABEL=YLABEL-1.5*HGT                                               B 310
    CALL NOTATE (0.0,YLABEL,HGT,TITLE1,.0,80)                           B 320
    YS=YSTART(K)+1.0                                                    B 330
    CALL NOTATE (-.92,YS,HGT,3HZ/C,0.0,3)                               B 340
    CALL CALPLT (0.0,YSTART(K),-3)                                      B 350
    LAP=0                                                               B 360
    CALL LINPLT (X,Y,M,1,LAP,0,1,0)                                     B 370
    CALL CALPLT (0.0,-YSTART(K),-3)                                     B 380
    IF (K.LT.3) GO TO 20                                                B 390
    K=0                                                                 B 400
    CALL NFRAME                                                         B 410
 20 CONTINUE                                                            B 420
    RETURN                                                              B 430
C                                                                       B 440
 30 FORMAT (8A10)                                                       B 450
    END                                                                 B 460-
```

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TABLE I.- VALUES OF RATIO OF LEADING-EDGE RADIUS TO CHORD FOR VARIOUS THICKNESS RATIOS AND LEADING-EDGE INDEX NUMBER

t/c	Leading-edge radius/chord for I of –							
	1	2	3	4	5	6	7	8
0.05	0.000077	0.000306	0.000689	0.001224	0.001913	0.002755	0.003749	0.004897
.06	.000110	.000441	.000992	.001763	.002755	.003967	.005399	.007052
.07	.000150	.000600	.001350	.002400	.003749	.005399	.007349	.009599
.08	.00196	.000784	.001763	.003134	.004897	.007052	.009599	.012537
.09	.000248	.000992	.002231	.003967	.006198	.008925	.012148	.019589
.10	.000306	.001224	.002755	.004897	.007652	.011019	.014998	.019589
.11	.000370	.001481	.003333	.005925	.009259	.013333	.018147	.023703
.12	.000441	.001763	.003967	.007052	.011019	.015867	.021597	.028208
.13	.000517	.002069	.004655	.008276	.012932	.018622	.025346	.033105
.14	.000600	.002400	.005399	.009599	.014998	.021597	.029395	.038394
.15	.000689	.002755	.006198	.011019	.017217	.024792	.033745	.044075
.16	.000784	.003134	.007052	.012537	.019589	.028208	.038394	.050147
.17	.000885	.003438	.007961	.014153	.022114	.031844	.043343	.056612
.18	.000992	.003967	.008925	.015867	.024792	.035701	.048592	.063468
.19	.001105	.004420	.009944	.017679	.027623	.039778	.054142	.070716
.20	.001224	.004897	.011019	.019589	.030608	.044075	.059991	.078355
.21	.001350	.005399	.012148	.021597	.033745	.048592	.066140	.086387

TABLE II.- SAMPLE COMPUTER PRINTOUT OF ORDINATES

FOR SYMMETRIC AIRFOIL

```
PROFILE  4-DIGIT       CAMBER  2-DIGIT
NACA 0012


PROFILE PARAMETERS
T/C=      .12000
L.E.RADIUS=  -0.00000
BASIC X INTERVAL=     .01000
CHORD=    6.00000

CAMBER LINE PARAMETERS
CAMBER(YCMAX) =    0.00000
POSITION OF MAXIMUM CAMBER=    0.00000

      X/C            Y/C          DY/DX       D2Y/DX2                       X            Y

   0.000000     0.000000*00000.000000*00000.000000                   0.000000     0.000000
    .000250      .002798      5.557576-11266.984512                   .001500      .016786
    .000500      .003945      3.907521 -3983.752904                   .003000      .023673
    .000750      .004822      3.176460 -2168.672184                   .004500      .028930
    .001000      .005557      2.740619 -1408.741253                   .006000      .033345
    .001250      .006203      2.443153 -1008.132658                   .007500      .037220
    .001500      .006785      2.223546  -767.012890                   .009000      .040713
    .001750      .007319      2.052843  -608.757344                   .010500      .043915
    .002000      .007815      1.915224  -498.336313                   .012000      .046888
    .002250      .008279      1.801214  -417.699726                   .013500      .049673
    .002500      .008717      1.704748  -356.699366                   .015000      .052300
    .005000      .012213      1.181943  -126.380823                   .030000      .073279
    .007500      .014849       .949756   -68.980403                   .045000      .089091
    .010000      .017037       .810932   -44.946758                   .060000      .102222
    .012500      .018939       .715872   -32.275893                   .075000      .113634
    .015000      .020637       .645439   -24.648516                   .090000      .123820
    .017500      .022179       .590478   -19.641545                   .105000      .133074
    .020000      .023598       .545984   -16.147243                   .120000      .141587
    .022500      .024915       .508963   -13.594817                   .135000      .149491
    .025000      .026147       .477496   -11.663353                   .150000      .156883
    .027500      .027306       .450291   -10.160005                   .165000      .163837
    .030000      .028401       .426442    -8.962638                   .180000      .170409
    .032500      .029441       .405291    -7.990528                   .195000      .176644
    .035000      .030430       .386348    -7.188410                   .210000      .182578
    .037500      .031374       .369240    -6.517307                   .225000      .188243
    .040000      .032277       .353676    -5.949025                   .240000      .193663
    .042500      .033143       .339427    -5.462718                   .255000      .198860
    .045000      .033975       .326308    -5.042677                   .270000      .203852
    .047500      .034776       .314168    -4.676861                   .285000      .208654
    .050000      .035547       .302886    -4.355904                   .300000      .213281
    .052500      .036291       .292358    -4.072424                   .315000      .217745
    .055000      .037009       .282498    -3.820528                   .330000      .222055
    .057500      .037704       .273233    -3.595465                   .345000      .226222
    .060000      .038376       .264501    -3.393365                   .360000      .230255
    .062500      .039027       .256250    -3.211047                   .375000      .234160
    .065000      .039657       .248432    -3.045876                   .390000      .237945
    .067500      .040269       .241008    -2.895651                   .405000      .241615
    .070000      .040863       .233943    -2.758521                   .420000      .245177
    .072500      .041439       .227205    -2.632922                   .435000      .248635
    .075000      .041999       .220769    -2.517521                   .450000      .251994
    .077500      .042543       .214610    -2.411176                   .465000      .255259
    .080000      .043072       .208707    -2.312906                   .480000      .258434
    .082500      .043587       .203040    -2.221863                   .495000      .261522
    .085000      .044088       .197592    -2.137308                   .510000      .264526
    .087500      .044575       .192348    -2.058598                   .525000      .267650
    .090000      .045050       .187295    -1.985171                   .540000      .270297
    .092500      .045512       .182419    -1.916530                   .555000      .273070
    .095000      .045962       .177708    -1.852239                   .570000      .275771
    .097500      .046400       .173154    -1.791910                   .585000      .278402
    .100000      .046828       .168746    -1.735200                   .600000      .280966
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TABLE II.- Continued

X/C	Y/C	DY/DX	D2Y/DX2	X	Y
.110000	.048432	.152413	-1.538890	.660000	.290591
.120000	.049892	.137841	-1.380972	.720000	.299291
.130000	.051193	.124699	-1.251356	.780000	.307161
.140000	.052380	.112742	-1.143134	.840000	.314278
.150000	.053452	.101782	-1.051434	.900000	.320710
.160000	.054418	.091671	-.972731	.960000	.326509
.170000	.055287	.082293	-.904421	1.020000	.331725
.180000	.056066	.073554	-.844538	1.080000	.336397
.190000	.056760	.065379	-.791579	1.140000	.340562
.200000	.057375	.057703	-.744372	1.200000	.344253
.210000	.057916	.050475	-.701995	1.260000	.347496
.220000	.058386	.043650	-.663711	1.320000	.350318
.230000	.058790	.037189	-.628926	1.380000	.352741
.240000	.059131	.031061	-.597157	1.440000	.354787
.250000	.059412	.025238	-.568005	1.500000	.356475
.260000	.059637	.019694	-.541142	1.560000	.357821
.270000	.059807	.014408	-.516291	1.620000	.358843
.280000	.059926	.009362	-.493223	1.680000	.359555
.290000	.059995	.004538	-.471741	1.740000	.359971
.300000	.060017	-.000078	-.451679	1.800000	.360104
.310000	.059994	-.004500	-.432894	1.860000	.359965
.320000	.059928	-.008740	-.415264	1.920000	.359567
.330000	.059820	-.012808	-.398681	1.980000	.358920
.340000	.059672	-.016716	-.383055	2.040000	.358033
.350000	.059486	-.020472	-.368305	2.100000	.356917
.360000	.059263	-.024085	-.354359	2.160000	.355580
.370000	.059005	-.027562	-.341159	2.220000	.354030
.380000	.058712	-.030911	-.328644	2.280000	.352275
.390000	.058387	-.034137	-.316772	2.340000	.350323
.400000	.058030	-.037248	-.305496	2.400000	.348181
.410000	.057643	-.040249	-.294780	2.460000	.345855
.420000	.057225	-.043145	-.284588	2.520000	.343353
.430000	.056780	-.045942	-.274891	2.580000	.340580
.440000	.056307	-.048645	-.265660	2.640000	.337842
.450000	.055807	-.051257	-.256872	2.700000	.334844
.460000	.055282	-.053734	-.248503	2.760000	.331693
.470000	.054732	-.056228	-.240533	2.820000	.328392
.480000	.054158	-.058595	-.232944	2.880000	.324947
.490000	.053560	-.060898	-.225720	2.940000	.321362
.500000	.052940	-.063111	-.218844	3.000000	.317542
.510000	.052298	-.065266	-.212304	3.060000	.313790
.520000	.051635	-.067358	-.206086	3.120000	.309811
.530000	.050951	-.069389	-.200179	3.180000	.305708
.540000	.050248	-.071363	-.194573	3.240000	.301485
.550000	.049524	-.073282	-.189257	3.300000	.297146
.560000	.048782	-.075149	-.184222	3.360000	.292592
.570000	.048021	-.076967	-.179461	3.420000	.288129
.580000	.047243	-.078739	-.174966	3.480000	.283457
.590000	.046447	-.080467	-.170729	3.540000	.278581
.600000	.045634	-.082154	-.166744	3.600000	.273802
.610000	.044804	-.083803	-.163005	3.660000	.268823
.620000	.043958	-.085415	-.159507	3.720000	.263747
.630000	.043096	-.086994	-.156244	3.780000	.258574
.640000	.042218	-.088541	-.153211	3.840000	.253308
.650000	.041325	-.090059	-.150404	3.900000	.247950
.660000	.040417	-.091550	-.147815	3.960000	.242501
.670000	.039494	-.093016	-.145451	4.020000	.236964
.680000	.038557	-.094459	-.143297	4.080000	.231340
.690000	.037605	-.095882	-.141354	4.140000	.225630
.700000	.036639	-.097287	-.139618	4.200000	.219834
.710000	.035659	-.098676	-.138087	4.260000	.213955
.720000	.034666	-.100050	-.136757	4.320000	.207994
.730000	.033658	-.101411	-.135626	4.380000	.201950
.740000	.032637	-.102763	-.134692	4.440000	.195824
.750000	.031603	-.104106	-.133951	4.500000	.189518
.760000	.030555	-.105442	-.133403	4.560000	.183332
.770000	.029494	-.106775	-.133044	4.620000	.176965
.780000	.028420	-.108104	-.132873	4.680000	.170519

TABLE II.- Concluded

X/C	Y/C	DY/DX	D2Y/DX2	X	Y
.790000	.027332	-.109433	-.132888	4.740000	.163993
.800000	.026231	-.110762	-.133088	4.800000	.157387
.810000	.025117	-.112095	-.133470	4.860000	.150701
.820000	.023989	-.113432	-.134033	4.920000	.143936
.830000	.022848	-.114776	-.134776	4.980000	.137089
.840000	.021694	-.116128	-.135697	5.040000	.130162
.850000	.020526	-.117491	-.136794	5.100000	.123154
.860000	.019344	-.118865	-.138068	5.160000	.115063
.870000	.018148	-.120253	-.139516	5.220000	.108890
.880000	.016939	-.121656	-.141137	5.280000	.101633
.890000	.015715	-.123076	-.142931	5.340000	.094291
.900000	.014477	-.124515	-.144896	5.400000	.086863
.910000	.013225	-.125974	-.147031	5.460000	.079348
.920000	.011958	-.127456	-.149336	5.520000	.071746
.930000	.010676	-.128962	-.151809	5.580000	.064053
.940000	.009378	-.130493	-.154450	5.640000	.056270
.950000	.008066	-.132051	-.157258	5.700000	.048394
.960000	.006737	-.133639	-.160232	5.760000	.040423
.970000	.005393	-.135256	-.163371	5.820000	.032356
.980000	.004032	-.136907	-.166675	5.880000	.024192
.990000	.002654	-.138591	-.170143	5.940000	.015927
1.000000	.001260	-.140310	-.173775	6.000000	.007560

TABLE III.- SAMPLE COMPUTER PRINTOUT OF ORDINATES FOR CAMBERED AIRFOILS

```
PROFILE  4-DIGITMOD  CAMBER  3-DIGIT
NACA 23012-64


PROFILE PARAMETERS
T/C=     .12000
L.E.RADIUS=     .01587
BASIC X INTERVAL=     .01000
CHORD=    6.00000
POSITION OF MAXIMUM THICKNESS, XM=     .40000
CONSTANT D1=     .31500

CAMBER LINE PARAMETERS
CAMBER PARAMETER K1=  15.95700
POSITION OF ZERO CAMBER LINE CURVATURE=     .20250

A0,1,2,3=       .296900     -.246856      .175332     -.256916
D0,1,2,3=       .002000      .315000     -.233333     -.032407
RC=       -2.357


UNCAMBERED                        UPPER SURFACE VALUES                                     LOWER SURFACE VALUES
   X/C            XU/C     YU/C      XU        YU       DYU/DXU        XL/C     YL/C      XL        YL       DYL/DXL
 0.00000         0.00000  0.00000  0.00000   0.00000  -3.28E+00      0.00000  0.00000  0.00000   0.00000  -3.28E+00
  .00025         -.00056   .00274  -.00335    .01641  -9.43E+00       .00106  -.00258   .00635   -.01550  -1.91E+00
  .00050         -.00044   .00389  -.00261    .02336  -3.87E+01       .00164  -.00359   .00981   -.02153  -1.60E+00
  .00075         -.00063   .00474  -.00379    .02845   2.87E+01       .00213  -.00434   .01279   -.02601  -1.42E+00
  .00100         -.00059   .00555  -.00351    .03333   1.17E+01       .00259  -.00495   .01551   -.02969  -1.29E+00
  .00125         -.00051   .00623  -.00307    .03740   7.72E+00       .00301  -.00547   .01807   -.03285  -1.19E+00
  .00150         -.00042   .00685  -.00252    .04110   5.92E+00       .00342  -.00594   .02052   -.03565  -1.10E+00
  .00175         -.00031   .00742  -.00184    .04452   4.88E+00       .00381  -.00636   .02289   -.03817  -1.04E+00
  .00200         -.00020   .00795  -.00117    .04772   4.19E+00       .00420  -.00675   .02517   -.04048  -9.79E-01
  .00225         -.00007   .00846  -.00040    .05075   3.71E+00       .00457  -.00710   .02740   -.04261  -9.29E-01
  .00250          .00007   .00894   .00041    .05362   3.35E+00       .00493  -.00743   .02959   -.04459  -8.86E-01
  .00500          .00171   .01288   .01024    .07726   1.99E+00       .00829  -.00991   .04976   -.05944  -6.19E-01
  .00750          .00362   .01599   .02173    .09591   1.43E+00       .01138  -.01159   .06827   -.06953  -4.83E-01
  .01000          .00569   .01866   .03412    .11194   1.19E+00       .01431  -.01287   .08583   -.07723  -3.97E-01
  .01250          .00785   .02104   .04712    .12624   1.03E+00       .01715  -.01391   .10298   -.08345  -3.37E-01
  .01500          .01009   .02322   .06055    .13930   9.21E-01       .01991  -.01477   .11945   -.08864  -2.92E-01
  .01750          .01239   .02523   .07432    .15139   8.38E-01       .02261  -.01551   .13568   -.09309  -2.57E-01
  .02000          .01473   .02711   .08837    .16269   7.73E-01       .02527  -.01616   .15163   -.09697  -2.30E-01
  .02250          .01711   .02889   .10264    .17333   7.19E-01       .02789  -.01673   .16736   -.10040  -2.08E-01
  .02500          .01952   .03057   .11711    .18339   6.73E-01       .03048  -.01725   .18289   -.10348  -1.89E-01
  .02750          .02196   .03216   .13175    .19295   6.34E-01       .03304  -.01771   .19825   -.10627  -1.74E-01
  .03000          .02442   .03368   .14653    .20207   6.00E-01       .03558  -.01914   .21347   -.10882  -1.61E-01
  .03250          .02691   .03513   .16144    .21078   5.69E-01       .03809  -.01853   .22856   -.11118  -1.51E-01
  .03500          .02941   .03652   .17645    .21912   5.42E-01       .04059  -.01889   .24354   -.11336  -1.41E-01
  .03750          .03193   .03785   .19158    .22711   5.17E-01       .04307  -.01923   .25842   -.11541  -1.34E-01
  .04000          .03447   .03913   .20679    .23479   4.94E-01       .04553  -.01956   .27321   -.11733  -1.27E-01
  .04250          .03701   .04036   .22209    .24219   4.73E-01       .04799  -.01986   .28791   -.11916  -1.21E-01
  .04500          .03958   .04155   .23745    .24929   4.53E-01       .05042  -.02015   .30255   -.12090  -1.17E-01
  .04750          .04215   .04269   .25289    .25614   4.35E-01       .05285  -.02043   .31711   -.12256  -1.12E-01
  .05000          .04473   .04379   .26838    .26274   4.18E-01       .05527  -.02069   .33162   -.12417  -1.09E-01
  .05250          .04732   .04485   .28392    .26911   4.02E-01       .05768  -.02095   .34608   -.12572  -1.06E-01
  .05500          .04992   .04587   .29951    .27525   3.86E-01       .06008  -.02120   .36049   -.12723  -1.03E-01
  .05750          .05252   .04686   .31515    .28118   3.72E-01       .06248  -.02145   .37485   -.12870  -1.01E-01
  .06000          .05514   .04782   .33082    .28690   3.58E-01       .06486  -.02169   .38918   -.13014  -9.97E-02
  .06250          .05776   .04874   .34653    .29243   3.45E-01       .06724  -.02193   .40347   -.13156  -9.84E-02
  .06500          .06038   .04963   .36227    .29777   3.33E-01       .06962  -.02216   .41773   -.13295  -9.72E-02
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TABLE III.- Continued

UNCAMBERED	UPPER SURFACE VALUES					LOWER SURFACE VALUES				
X/C	XU/C	YU/C	XU	YU	DYU/DXU	XL/C	YL/C	XL	YL	DYL/DXL
.06750	.06301	.05049	.37804	.30293	3.21E-01	.07199	-.02239	.43196	-.13433	-9.64E-02
.07000	.06544	.05132	.39383	.30791	3.10E-01	.07436	-.02262	.44617	-.13569	-9.58E-02
.07250	.06827	.05212	.40964	.31273	2.99E-01	.07673	-.02284	.46036	-.13705	-9.53E-02
.07500	.07031	.05290	.42549	.31738	2.89E-01	.07909	-.02307	.47452	-.13840	-9.50E-02
.07750	.07255	.05365	.44132	.32189	2.79E-01	.08145	-.02329	.48368	-.13974	-9.49E-02
.08000	.07620	.05437	.45719	.32622	2.69E-01	.08380	-.02351	.50281	-.14108	-9.49E-02
.08250	.07864	.05507	.47305	.33042	2.60E-01	.08616	-.02374	.51694	-.14242	-9.50E-02
.08500	.08143	.05575	.48894	.33449	2.51E-01	.08851	-.02396	.53106	-.14377	-9.52E-02
.08750	.08414	.05640	.50483	.33839	2.42E-01	.09086	-.02419	.54517	-.14511	-9.55E-02
.09000	.08673	.05703	.52072	.34218	2.34E-01	.09321	-.02441	.55928	-.14646	-9.59E-02
.09250	.08944	.05764	.53662	.34583	2.26E-01	.09556	-.02464	.57338	-.14782	-9.63E-02
.09500	.09209	.05823	.55252	.34936	2.19E-01	.09791	-.02485	.58748	-.14918	-9.68E-02
.09750	.09474	.05880	.56842	.35277	2.11E-01	.10026	-.02509	.60158	-.15055	-9.73E-02
.10000	.09739	.05934	.58432	.35606	2.03E-01	.10261	-.02532	.61568	-.15192	-9.79E-02
.11000	.10799	.06135	.64796	.36911	1.77E-01	.11202	-.02625	.67214	-.15751	-1.00E-01
.12000	.11855	.06309	.71127	.37854	1.55E-01	.12145	-.02721	.72873	-.16326	-1.03E-01
.13000	.12903	.06459	.77447	.38754	1.32E-01	.13092	-.02819	.78553	-.16915	-1.05E-01
.14000	.13957	.06588	.83741	.39528	1.14E-01	.14043	-.02919	.84259	-.17517	-1.06E-01
.15000	.15000	.06699	.90003	.40193	9.85E-02	.15000	-.03022	.89997	-.18129	-1.07E-01
.16000	.16038	.06794	.96228	.40763	8.51E-02	.15962	-.03125	.95772	-.18749	-1.07E-01
.17000	.17049	.06876	1.02414	.41253	7.37E-02	.16931	-.03228	1.01586	-.19367	-1.06E-01
.18000	.18033	.06946	1.08556	.41677	6.44E-02	.17907	-.03330	1.07444	-.19983	-1.04E-01
.19000	.19103	.07009	1.14673	.42046	5.71E-02	.18891	-.03431	1.13347	-.20587	-1.01E-01
.20000	.20117	.07062	1.20700	.42374	5.16E-02	.19883	-.03529	1.19300	-.21174	-9.62E-02
.21000	.21113	.07112	1.26711	.42671	4.71E-02	.20881	-.03623	1.25289	-.21735	-9.14E-02
.22000	.22120	.07157	1.32720	.42940	4.27E-02	.21880	-.03712	1.31280	-.22270	-8.70E-02
.23000	.23121	.07197	1.38728	.43184	3.86E-02	.22879	-.03796	1.37272	-.22778	-8.28E-02
.24000	.24123	.07234	1.44736	.43402	3.44E-02	.23877	-.03877	1.43264	-.23262	-7.87E-02
.25000	.25124	.07265	1.50743	.43597	3.05E-02	.24876	-.03954	1.49257	-.23722	-7.47E-02
.26000	.26125	.07295	1.56750	.43769	2.67E-02	.25875	-.04026	1.55250	-.24158	-7.09E-02
.27000	.27126	.07320	1.62755	.43919	2.30E-02	.26974	-.04095	1.61244	-.24572	-6.72E-02
.28000	.28127	.07341	1.68762	.44045	1.93E-02	.27873	-.04161	1.67238	-.24964	-6.36E-02
.29000	.29128	.07359	1.74767	.44150	1.58E-02	.28872	-.04222	1.73233	-.25335	-6.00E-02
.30000	.30129	.07372	1.80772	.44234	1.23E-02	.29871	-.04281	1.79228	-.25684	-5.65E-02
.31000	.31123	.07383	1.86776	.44298	8.81E-03	.30871	-.04335	1.85224	-.26012	-5.30E-02
.32000	.32130	.07390	1.92780	.44340	5.37E-03	.31870	-.04387	1.91220	-.26320	-4.96E-02
.33000	.33131	.07394	1.98784	.44362	1.95E-03	.32869	-.04434	1.97216	-.26607	-4.61E-02
.34000	.34131	.07394	2.04787	.44364	-1.46E-03	.33869	-.04479	2.03213	-.26873	-4.27E-02
.35000	.35132	.07391	2.10789	.44345	-4.87E-03	.34868	-.04520	2.09211	-.27119	-3.93E-02
.36000	.36132	.07384	2.16791	.44305	-8.28E-03	.35868	-.04557	2.15209	-.27345	-3.59E-02
.37000	.37132	.07374	2.22793	.44245	-1.17E-02	.36868	-.04592	2.21207	-.27550	-3.25E-02
.38000	.38132	.07361	2.28794	.44165	-1.51E-02	.37869	-.04622	2.27206	-.27734	-2.90E-02
.39000	.39132	.07344	2.34795	.44063	-1.86E-02	.38868	-.04650	2.33205	-.27898	-2.56E-02
.40000	.40132	.07324	2.40796	.43941	-2.21E-02	.39868	-.04674	2.39205	-.28041	-2.21E-02
.41000	.41132	.07300	2.46795	.43799	-2.56E-02	.40858	-.04694	2.45205	-.28163	-1.86E-02
.42000	.42132	.07272	2.52794	.43635	-2.91E-02	.41868	-.04711	2.51206	-.28264	-1.51E-02
.43000	.43132	.07242	2.58793	.43450	-3.25E-02	.42858	-.04724	2.57207	-.28344	-1.16E-02
.44000	.44132	.07207	2.64791	.43244	-3.60E-02	.43858	-.04734	2.63209	-.28404	-8.19E-03
.45000	.45132	.07170	2.70789	.43018	-3.94E-02	.44868	-.04740	2.69211	-.28443	-4.73E-03
.46000	.46131	.07129	2.76787	.42771	-4.29E-02	.45869	-.04743	2.75213	-.28461	-1.30E-03
.47000	.47131	.07094	2.82784	.42504	-4.63E-02	.46869	-.04743	2.81216	-.28458	2.12E-03
.48000	.48130	.07036	2.88780	.42214	-4.97E-02	.47870	-.04739	2.87220	-.28435	5.53E-03
.49000	.49129	.06985	2.94775	.41907	-5.31E-02	.48871	-.04732	2.93224	-.28392	8.93E-03
.50000	.50123	.06930	3.00772	.41578	-5.65E-02	.49871	-.04721	2.99229	-.28328	1.23E-02
.51000	.51128	.06872	3.06767	.41229	-5.99E-02	.50872	-.04707	3.05233	-.28244	1.57E-02
.52000	.52127	.06810	3.12762	.40880	-6.33E-02	.51873	-.04690	3.11238	-.28140	1.90E-02

ORIGINAL PAGE IS
OF POOR QUALITY

TABLE III.- Concluded

UNCAMBERED	UPPER SURFACE VALUES					LOWER SURFACE VALUES				
X/C	XU/C	YU/C	XU	YU	DYU/DXU	XL/C	YL/C	XL	YL	DYL/DXL
.53000	.53124	.06745	3.18755	.40470	-6.67E-02	.52874	-.04669	3.17244	-.28015	2.24E-02
.54000	.54125	.06677	3.24750	.40061	-7.00E-02	.53875	-.04645	3.23250	-.27871	2.57E-02
.55000	.55124	.06605	3.30744	.39631	-7.33E-02	.54876	-.04618	3.29256	-.27706	2.91E-02
.56000	.56123	.06530	3.36737	.39182	-7.67E-02	.55877	-.04587	3.35263	-.27522	3.24E-02
.57000	.57122	.06452	3.42729	.38712	-8.00E-02	.56878	-.04553	3.41271	-.27317	3.57E-02
.58000	.58120	.06371	3.48721	.38223	-8.33E-02	.57880	-.04515	3.47279	-.27093	3.90E-02
.59000	.59119	.06286	3.54713	.37714	-8.66E-02	.58881	-.04475	3.53287	-.26849	4.22E-02
.60000	.60117	.06199	3.60704	.37196	-8.99E-02	.59883	-.04431	3.59296	-.26585	4.55E-02
.61000	.61116	.06106	3.66695	.36637	-9.31E-02	.60884	-.04384	3.65305	-.26302	4.88E-02
.62000	.62114	.06012	3.72685	.36070	-9.64E-02	.61886	-.04333	3.71315	-.26000	5.20E-02
.63000	.63113	.05914	3.78675	.35483	-9.95E-02	.62887	-.04280	3.77325	-.25677	5.52E-02
.64000	.64111	.05813	3.84665	.34876	-1.03E-01	.63889	-.04223	3.83335	-.25336	5.84E-02
.65000	.65109	.05708	3.90654	.34250	-1.06E-01	.64891	-.04162	3.89346	-.24975	6.16E-02
.66000	.66107	.05601	3.96643	.33605	-1.09E-01	.65893	-.04099	3.95357	-.24595	6.48E-02
.67000	.67105	.05490	4.02631	.32941	-1.13E-01	.66895	-.04033	4.01369	-.24196	6.80E-02
.68000	.68103	.05376	4.08619	.32257	-1.16E-01	.67897	-.03963	4.07381	-.23777	7.12E-02
.69000	.69101	.05259	4.14606	.31555	-1.19E-01	.68899	-.03890	4.13394	-.23340	7.43E-02
.70000	.70099	.05139	4.20593	.30834	-1.22E-01	.69901	-.03814	4.19407	-.22883	7.75E-02
.71000	.71097	.05016	4.26580	.30093	-1.25E-01	.70903	-.03735	4.25420	-.22408	8.06E-02
.72000	.72094	.04889	4.32566	.29334	-1.28E-01	.71906	-.03652	4.31434	-.21914	8.37E-02
.73000	.73092	.04759	4.38552	.28556	-1.32E-01	.72908	-.03567	4.37448	-.21401	8.68E-02
.74000	.74089	.04627	4.44537	.27760	-1.35E-01	.73911	-.03478	4.43463	-.20870	8.99E-02
.75000	.75087	.04491	4.50522	.26945	-1.38E-01	.74913	-.03387	4.49478	-.20319	9.30E-02
.76000	.76084	.04352	4.56506	.26111	-1.41E-01	.75916	-.03292	4.55494	-.19751	9.61E-02
.77000	.77082	.04210	4.62491	.25259	-1.44E-01	.76918	-.03194	4.61509	-.19163	9.91E-02
.78000	.78079	.04065	4.68474	.24388	-1.47E-01	.77921	-.03093	4.67526	-.18558	1.02E-01
.79000	.79076	.03917	4.74458	.23499	-1.50E-01	.78924	-.02989	4.73542	-.17934	1.05E-01
.80000	.80073	.03765	4.80440	.22592	-1.53E-01	.79927	-.02882	4.79560	-.17292	1.08E-01
.81000	.81070	.03611	4.86423	.21666	-1.56E-01	.80930	-.02772	4.85577	-.16631	1.11E-01
.82000	.82067	.03454	4.92405	.20723	-1.59E-01	.81933	-.02659	4.91595	-.15953	1.14E-01
.83000	.83064	.03294	4.98387	.19761	-1.62E-01	.82936	-.02543	4.97613	-.15256	1.17E-01
.84000	.84061	.03130	5.04368	.18782	-1.65E-01	.83939	-.02424	5.03632	-.14542	1.20E-01
.85000	.85058	.02964	5.10349	.17784	-1.68E-01	.84942	-.02302	5.09651	-.13809	1.23E-01
.86000	.86055	.02795	5.16329	.16769	-1.71E-01	.85945	-.02176	5.15671	-.13059	1.26E-01
.87000	.87052	.02623	5.22309	.15736	-1.74E-01	.86948	-.02048	5.21691	-.12291	1.29E-01
.88000	.88048	.02448	5.28289	.14685	-1.77E-01	.87952	-.01918	5.27711	-.11505	1.32E-01
.89000	.89045	.02269	5.34269	.13617	-1.80E-01	.88955	-.01784	5.33731	-.10702	1.35E-01
.90000	.90041	.02089	5.40247	.12531	-1.83E-01	.89959	-.01647	5.39753	-.09881	1.38E-01
.91000	.91038	.01905	5.46225	.11427	-1.85E-01	.90962	-.01507	5.45774	-.09042	1.41E-01
.92000	.92034	.01718	5.52204	.10306	-1.89E-01	.91966	-.01364	5.51796	-.08186	1.44E-01
.93000	.93030	.01528	5.58182	.09169	-1.92E-01	.92970	-.01219	5.57818	-.07313	1.46E-01
.94000	.94027	.01335	5.64159	.08012	-1.95E-01	.93973	-.01070	5.63841	-.06422	1.49E-01
.95000	.95023	.01140	5.70136	.06840	-1.98E-01	.94977	-.00919	5.69864	-.05515	1.52E-01
.96000	.96019	.00942	5.76113	.05650	-2.01E-01	.95981	-.00765	5.75887	-.04590	1.55E-01
.97000	.97015	.00740	5.82089	.04443	-2.03E-01	.96985	-.00608	5.81911	-.03648	1.58E-01
.98000	.98011	.00536	5.88065	.03219	-2.06E-01	.97989	-.00448	5.87935	-.02689	1.61E-01
.99000	.99007	.00330	5.94041	.01978	-2.09E-01	.98993	-.00285	5.93959	-.01713	1.63E-01
1.00000	1.00003	.00120	6.00015	.00720	-2.12E-01	.99997	-.00120	5.99984	-.00720	1.66E-01

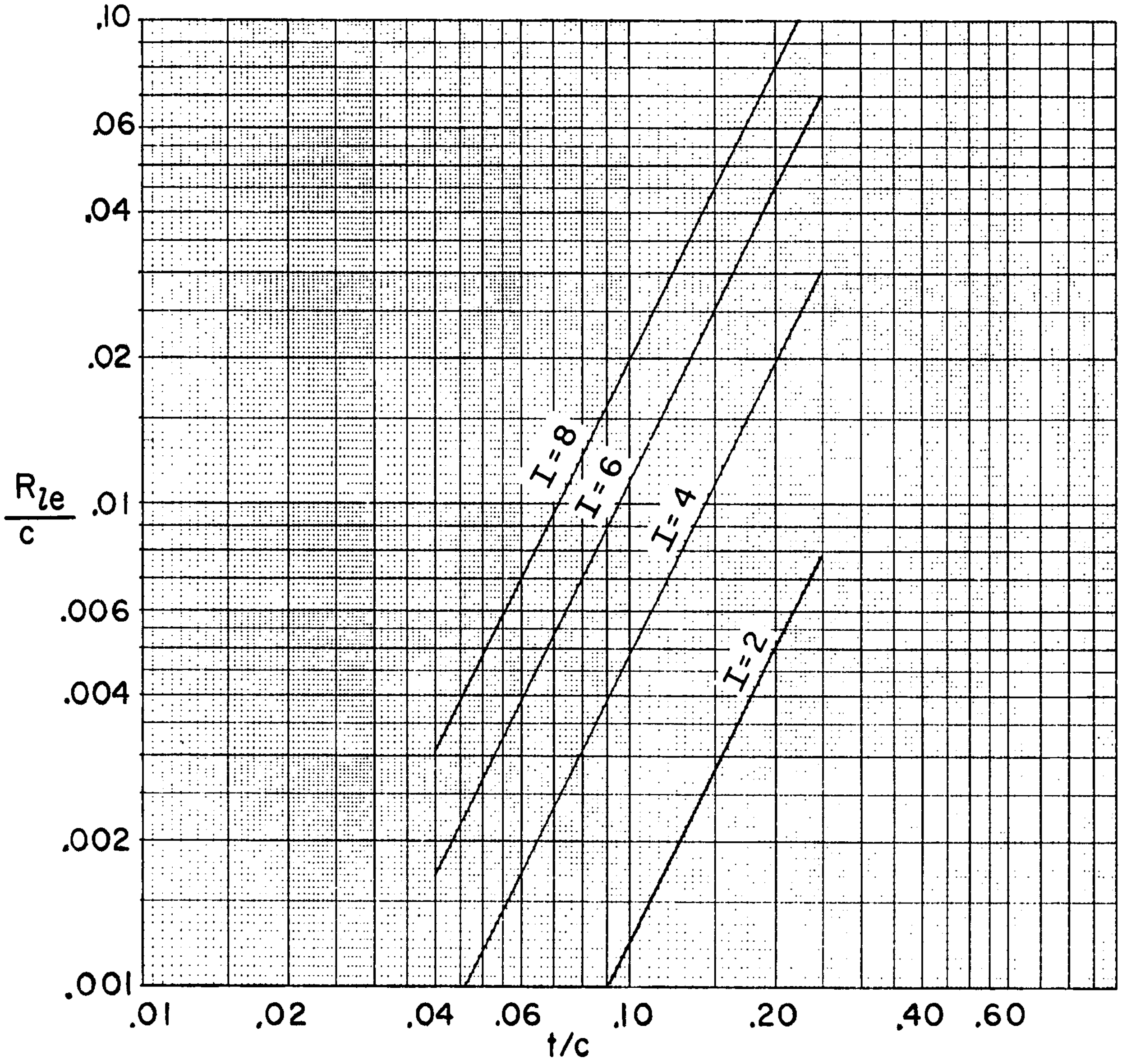


Figure 1.- Ratio of airfoil leading-edge radius to chord as a function of the ratio of thickness to chord and leading-edge index I.

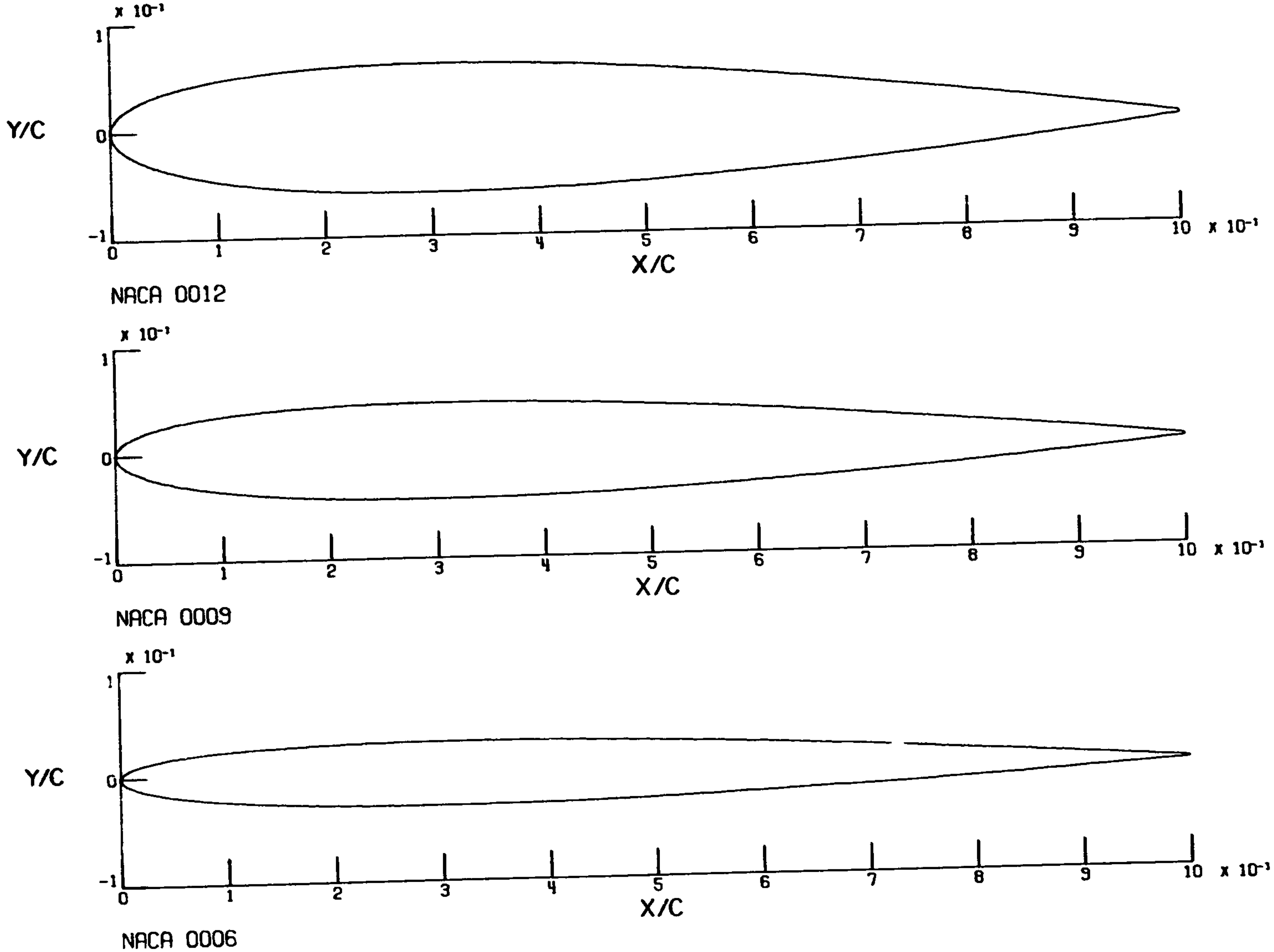
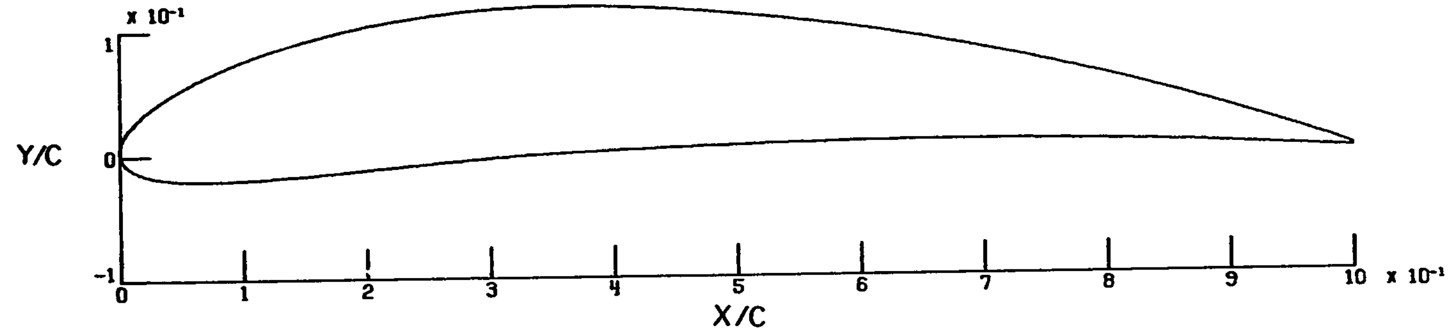
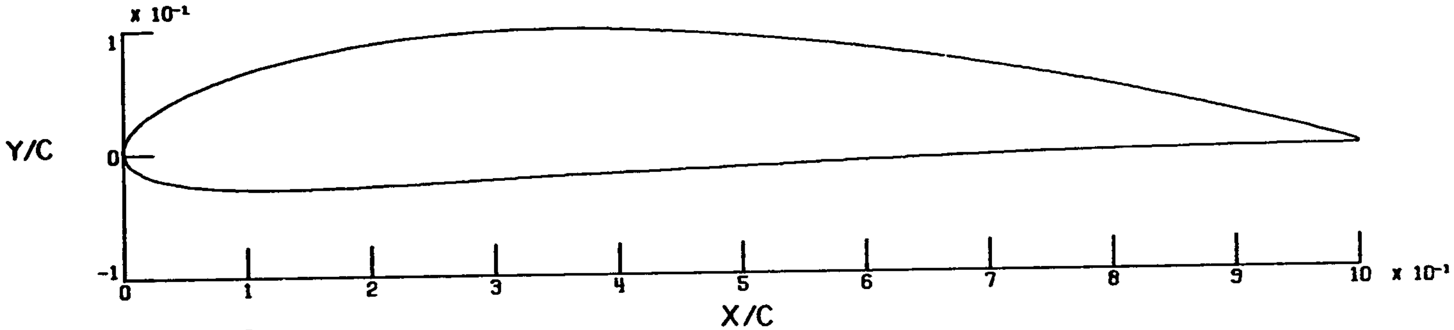


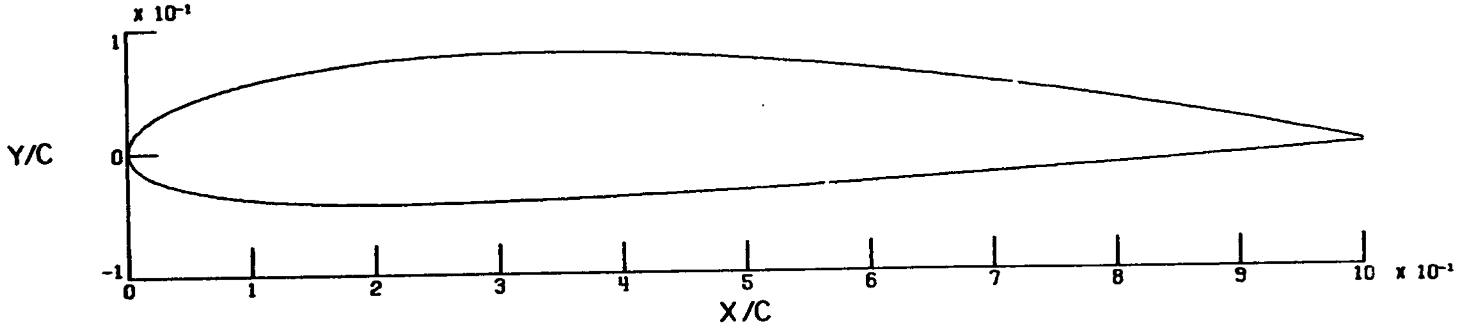
Figure 2.- Variations in thickness-chord ratio for symmetric 4-digit airfoils.



NACA 6412

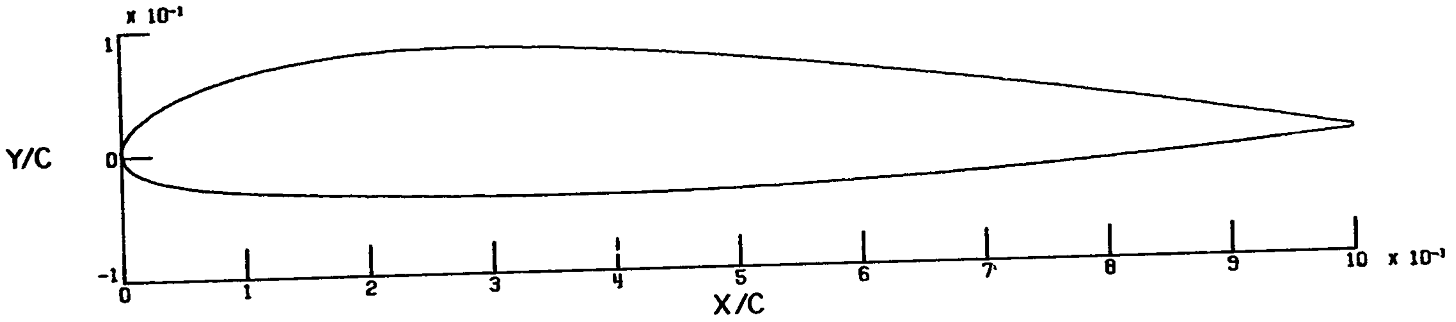


NACA 4412

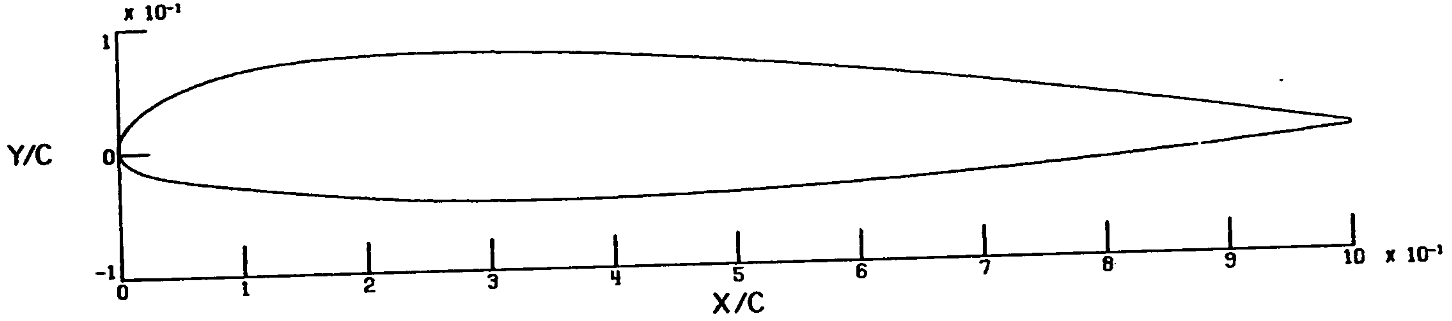


NACA 2412

Figure 3.- Variations in amount of camber for 12-percent-thick 4-digit airfoils with 2-digit camber line.



NACA 25012



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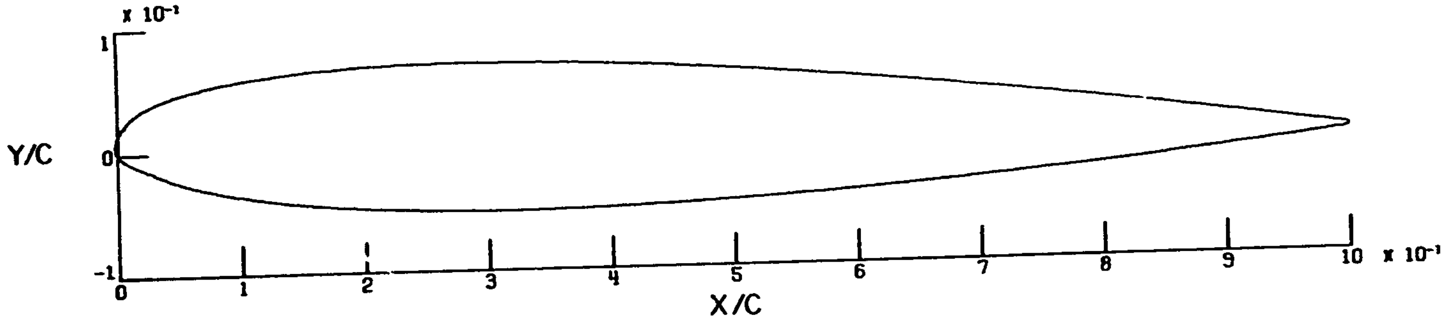
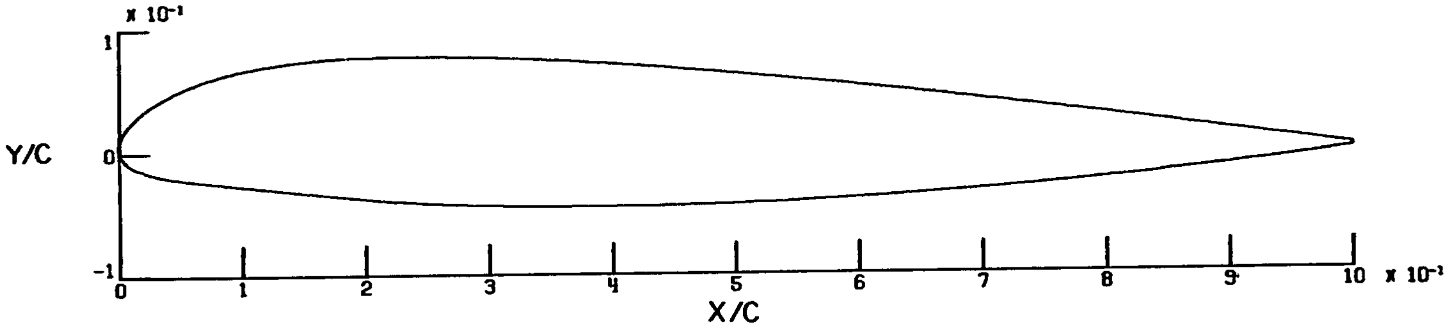
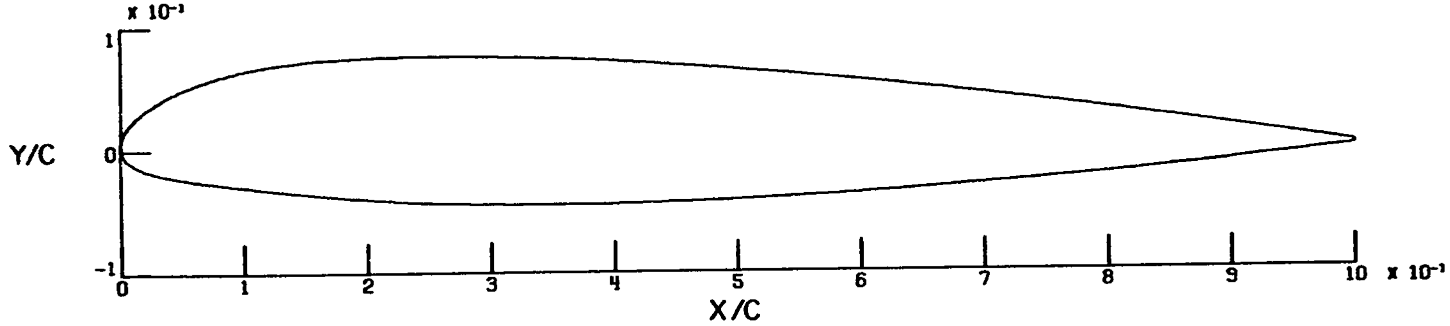


NACA 21012

Figure 4.- Variation in location of maximum camber for 12-percent-thick 4-digit airfoil with 3-digit camber line (5-digit airfoil).



NACA 23112



NACA 23012

Figure 5.- Comparison of reflexed and nonreflexed 3-digit camber line on 12-percent-thick airfoil.

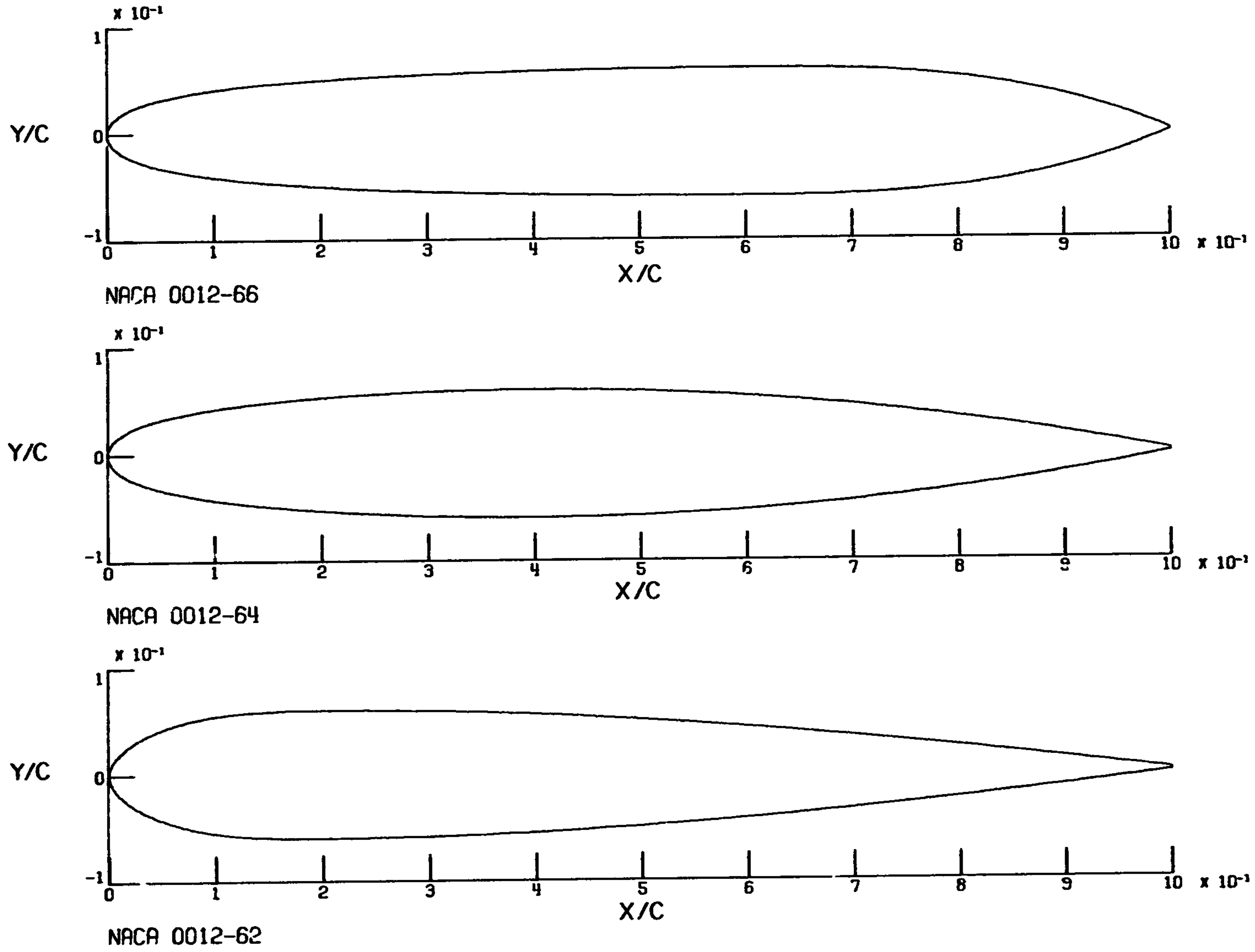


Figure 6.- Variations in location of maximum thickness for 12-percent-thick 4-digit modified airfoils.

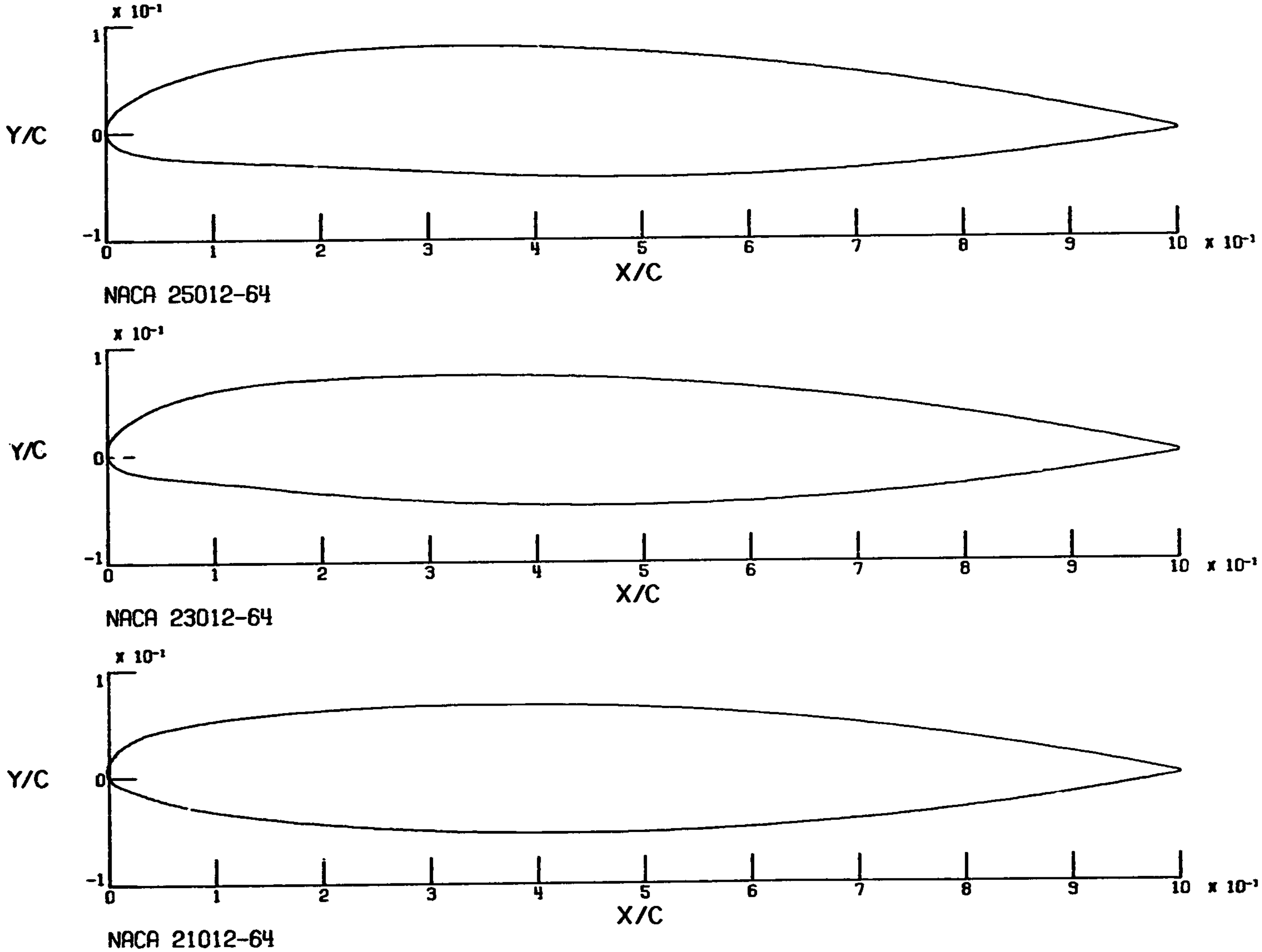
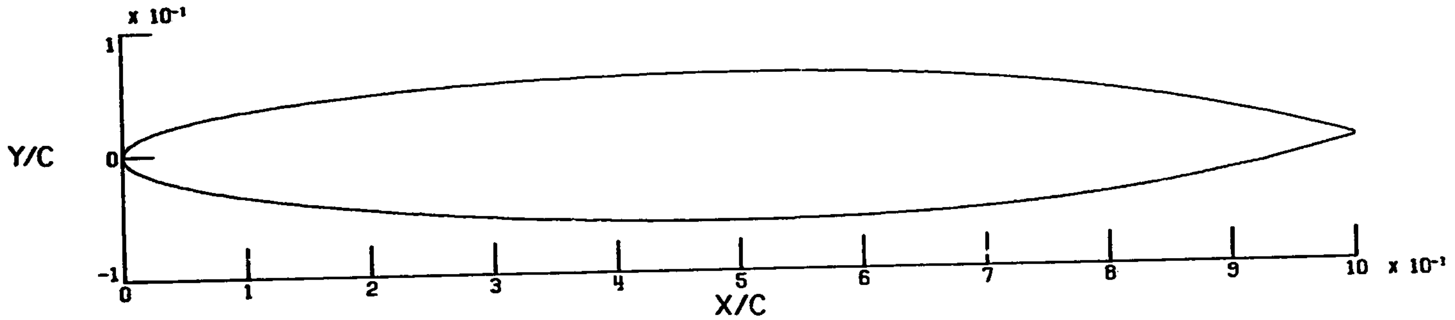
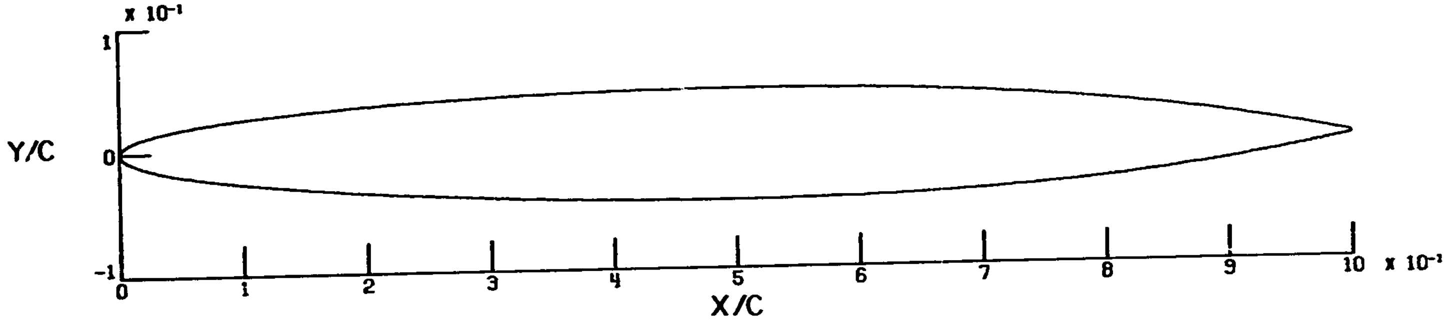


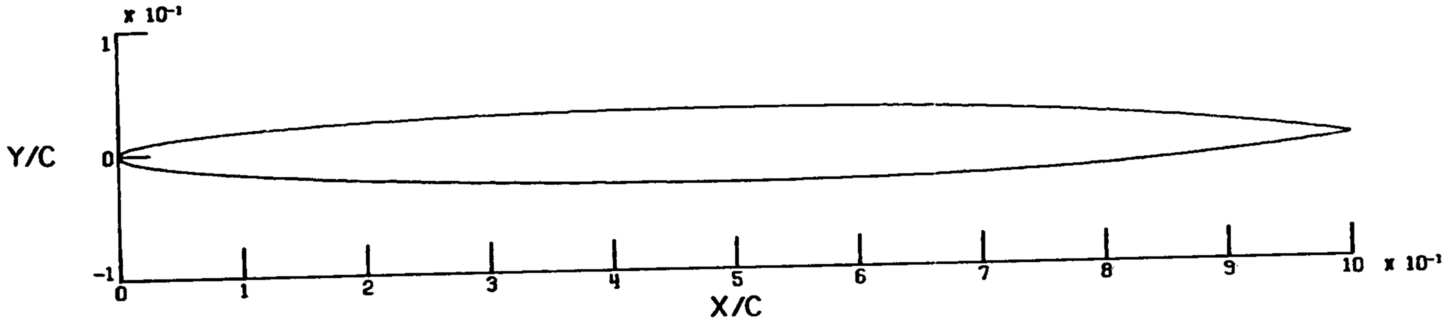
Figure 7.- Variations in location of maximum camber for 12-percent-thick 4-digit modified airfoils with 3-digit camber line.



NACA 0012-45 (16-012)



NACA 0009-45 (16-009)



NACA 0006-45 (16-006)

Figure 8.- Variations in thickness-chord ratio for symmetric 16-series airfoils.

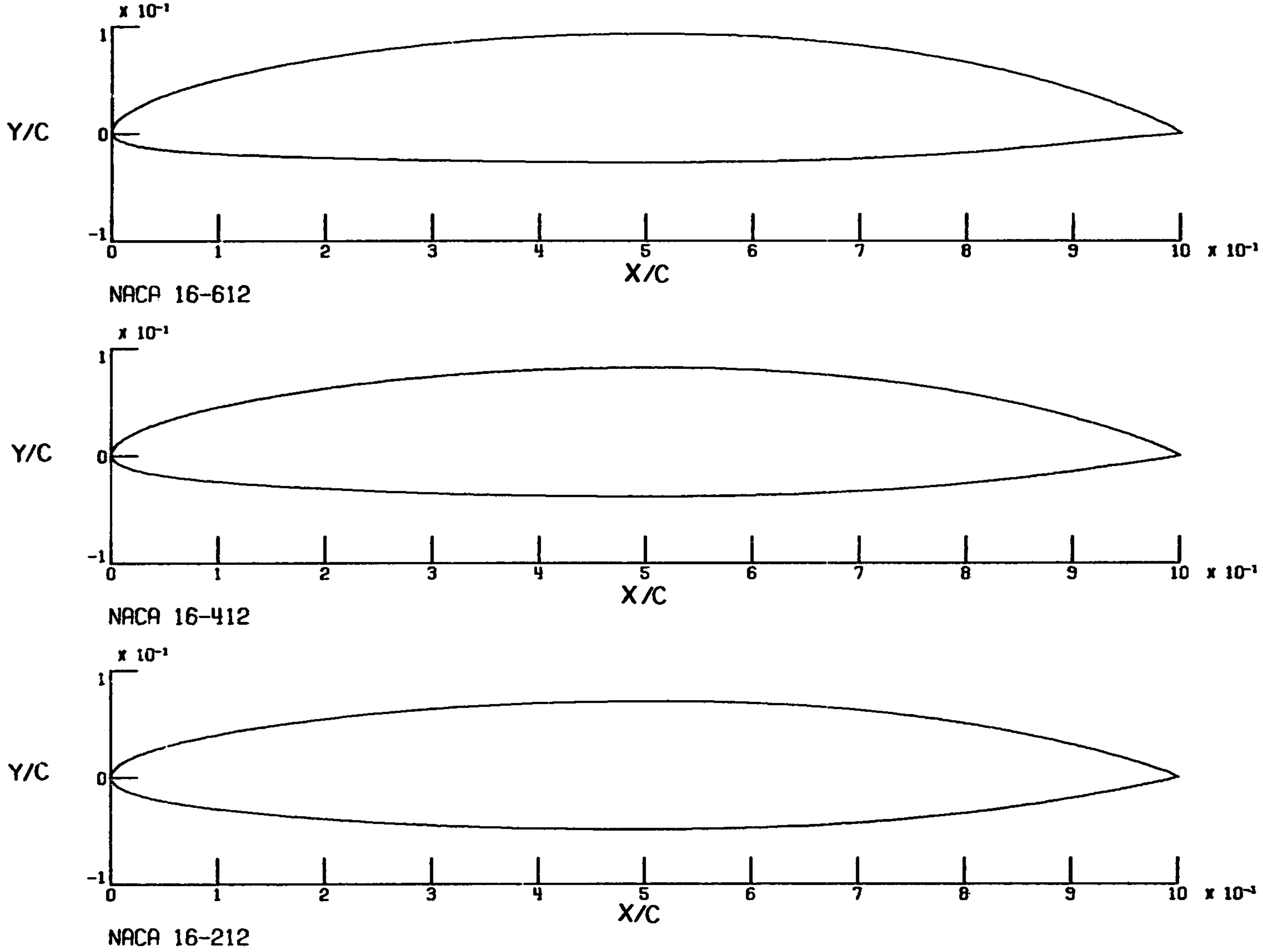
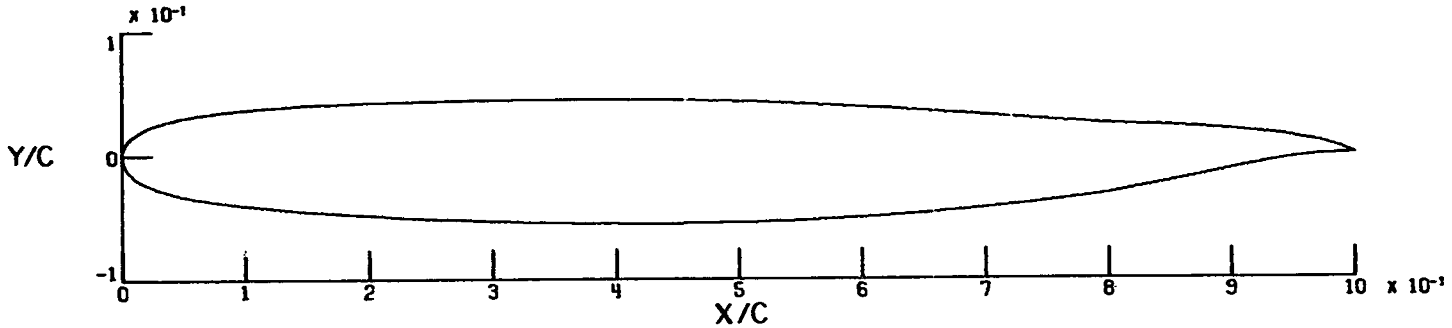
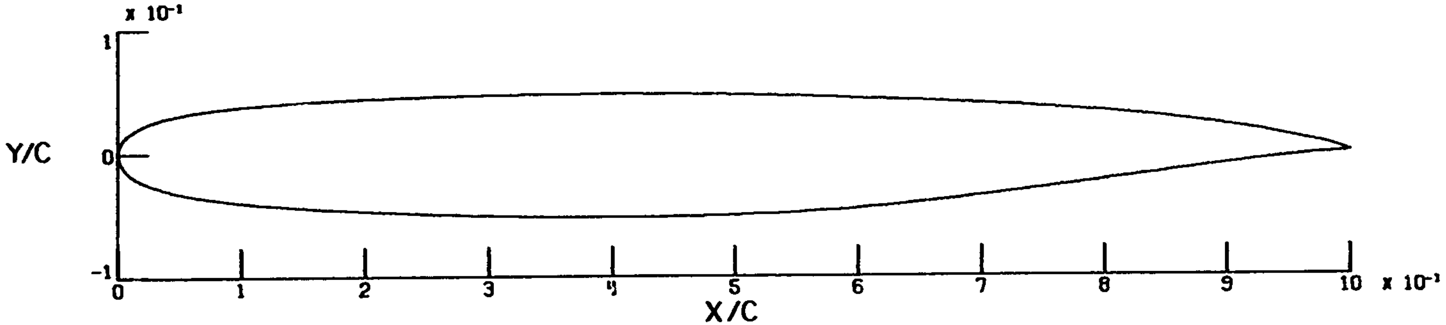


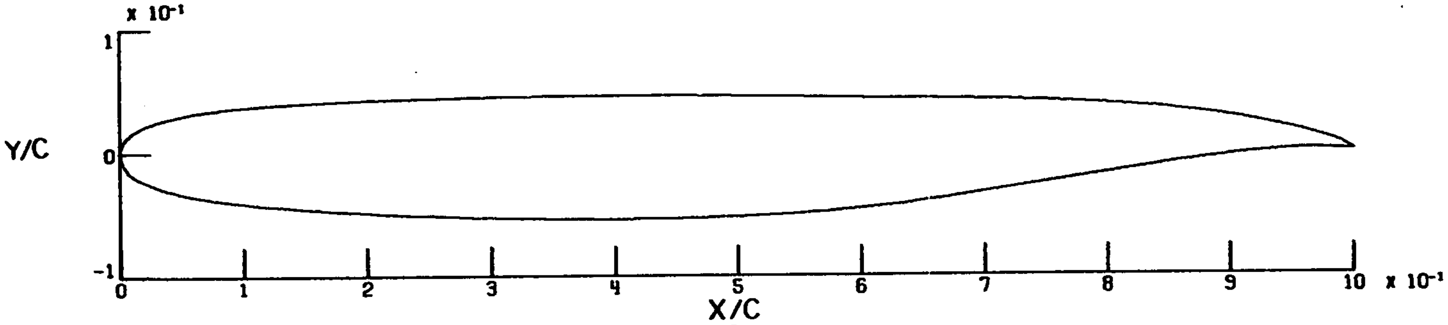
Figure 9.- Variations in amount of camber for 12-percent-thick 16-series airfoils with 6A-series camber line.



NACA 0010-84 CLI=1.0 A=1.0 CLI=-0.9 A=0.8

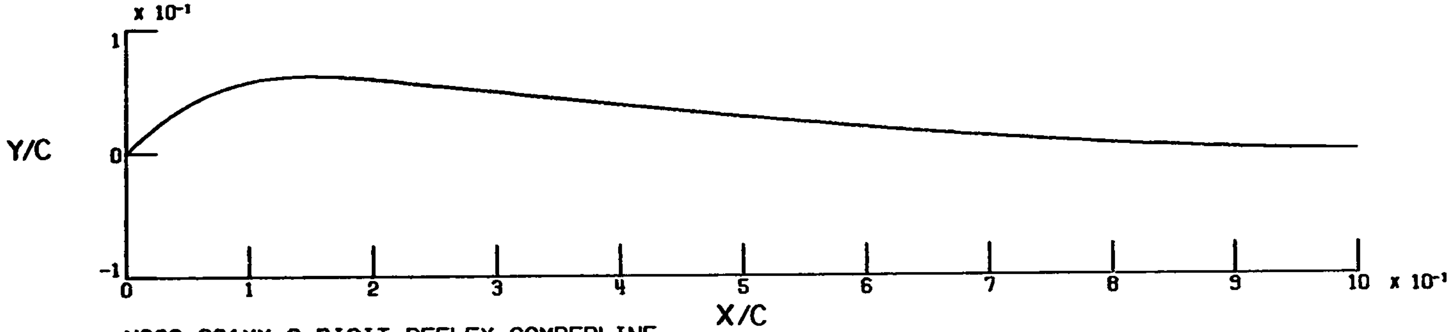


NACA 0010-84 CLI=0.5 A=1.0 CLI=-0.4 A=0.6

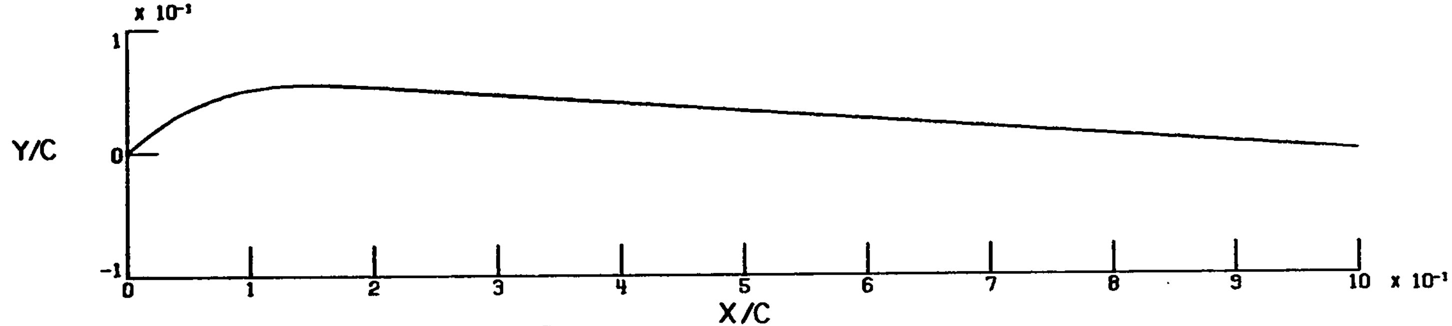


NACA 0010-84 CLI=1.0 A=1.0.CLI=-0.8 A=0.6

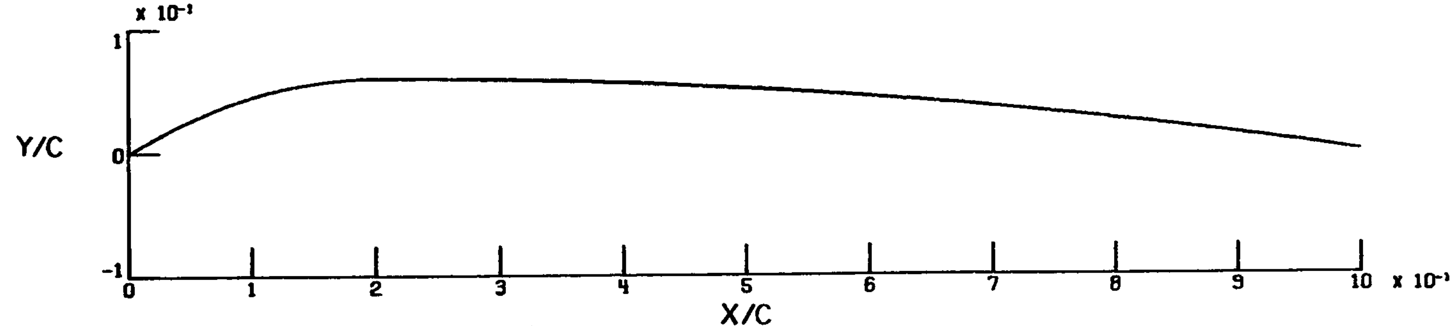
Figure 10.- Combination of two 6-series camber lines with a 10-percent-thick 4-digit modified airfoil.



NACA 631XX 3-DIGIT REFLEX CAMBERLINE

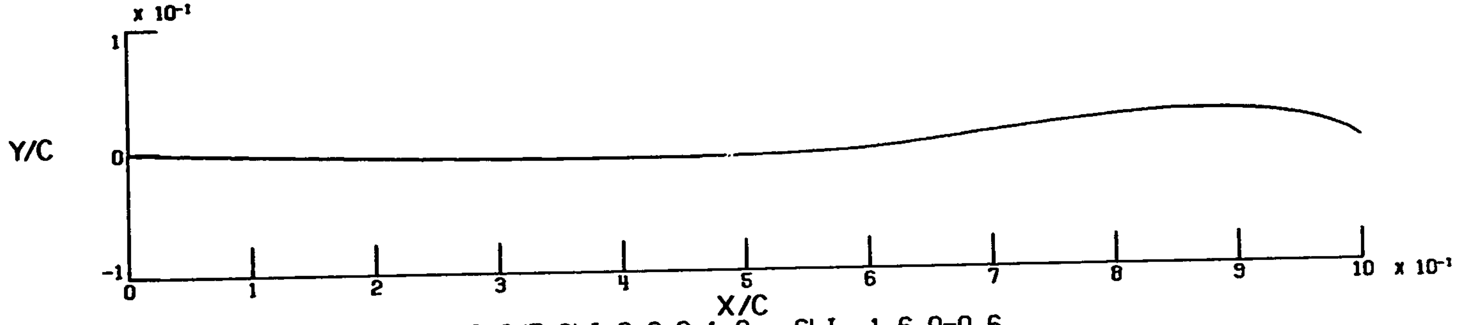


NACA 630XX 3-DIGIT CAMBERLINE

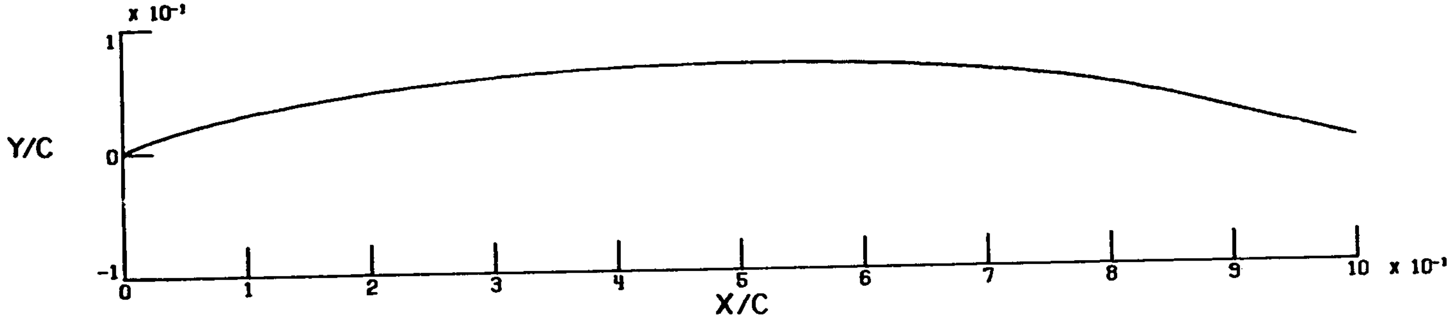


NACA 62XX 2-DIGIT CAMBERLINE

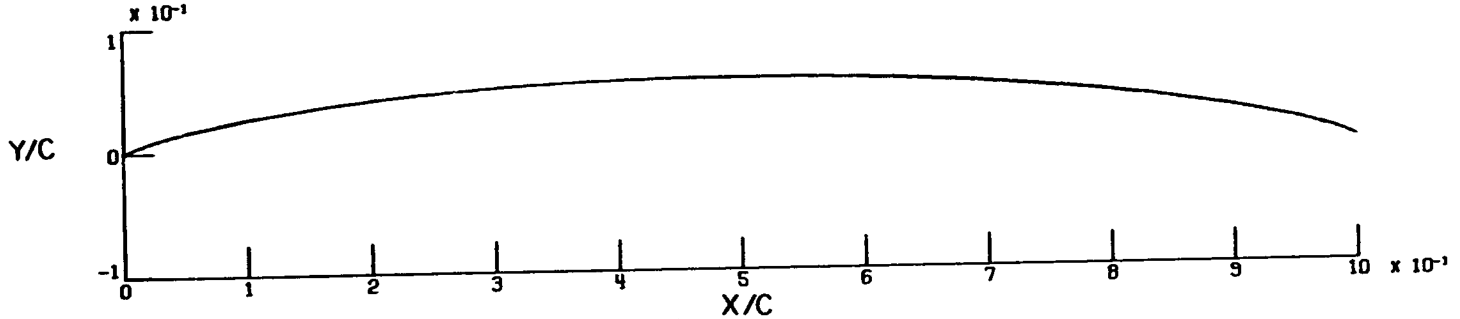
Figure 11.- 2-digit and 3-digit camber lines.



COMBINED 6-SERIES CAMBERLINE CLI=2.0 A=1.0 CLI=-1.6 A=0.6



NACA 6A-SERIES CAMBERLINE CLI=1.0 A=0.8MOD



NACA 6-SERIES CAMBERLINE CLI=1.0 A=1.0

Figure 12.- 6-series single and combined camber lines.

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