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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:

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

(2) Leading-edge radius:

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

(3) Radius of curvature at maximum thickness:

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

(4) Ordinate at trailing edge:

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

(5) Trailing-edge angle:

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

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.

3-digit.- 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.10H5A-SERIES ) GO TO 110
      PRINT 760
      GO TO 190
```

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 80 TANTHO=2.*CMB/CM
    IF (ABS(CMB).LT.E) TANTHO=E
    YP=10.**10
    YPP=10.**10
    YUP=-1/TANTHO
    YLP=-1/TANTHO
    GO TO 190
 90 TANTHO=CMB*CM**2*(3.0-CM)/6.0
    IF (ABS(CMB).LT.E) TANTHO=E
    YP=10.**10
    YPP=10.**10
    YUP=-1/TANTHO
    YLP=-1/TANTHO
    GO TO 190
100 TANTHO=CMB*(3.*CM**2-K2OK1*(1-CM)**3-CM**3)/6
    IF (ABS(CMB).LT.E) TANTHO=E
    YP=10.**10
    YPP=10.**10
    YUP=-1/TANTHO
    YLP=-1/TANTHO
    GO TO 190
110 L=0
    CLIS=CLI(1)
    AS=A(1)
120 L=L+1
    A(1)=A(L)
    CLI(1)=CLI(L)
    K=2
    U=0.005
    V=-(A-U)/ABS(A-U)
    OMXL=(1.-U)*ALOG(1.-U)
    AMXL=(A-U)*ALOG(ABS(A-U))
    OMXL1=-ALOG(1.-U)-1.
    AMXL1=-ALOG(ABS(A-U))+V
    OMXL2=1./(1.-U)
    AMXL2=-V/ABS(A-U)
    IF (A.LT.E.OR.ABS(1.-A).LT.E) GO TO 130
    G=-(A**2*(.5*ALOG(A)-0.25)+0.25)/(1.-A)
    Q=1.0
    H=(0.5*(1.-A)**2*ALOG(1.-A)-0.25*(1.-A)**2)/(1.-A)+G
    Z=.5*(A-U)*AMXL-.5*(1.-U)*OMXL-.25*(A-U)**2+.25*(1.-U)**2
    Z1=.5*((A-U)*AMXL1-AMXL-(1.-U)*OMXL1+OMXL+(A-U)-(1.-U))
    Z2=.5*(A-U)*AMXL2-AMXL1-.5*(1.-U)*OMXL2+OMXL1
130 CONTINUE
    IF (A.LT.E) GO TO 140
    IF (ABS(A-1.).LT.E) GO TO 150
140 H=-.5
    Q=1.0
    Z1=U*ALOG(U)-.5*U-.5*(1.-U)*OMXL1+.5*OMXL-.5
    GO TO 160
150 H=0.0
    Q=H
    Z1=-OMXL1
    GO TO 160
160 TANTHO(L)=CLI*(Z1/(1.-Q*A)-1.-ALOG(U)-H)/PI/(A+1.)/2.0
    IF (ICKY.GT.1.AND.L.LT.ICKY) GO TO 120
    IF (ICKY.EQ.1) GO TO 180
    DO 170 J=2,ICKY
170 TANTHO(1)=TANTHO(1)+TANTHO(J)
180 CONTINUE
    IF (ABS(CMB).LT.E) TANTHO=E
    YP=10.**10
    YPP=10.**10
    YUP=-1/TANTHO
    YLP=-1/TANTHO
```

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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
```

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```
      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
```

```
360 CONTINUE
    IF (ABS(1.-X).GT.E) GO TO 370
    YCP2(L)=1./E
    GO TO 380
370 PIA=PI*(A+1.)*2.
    YCP2(L)=CLI*(Z2/(1.-Q*A)-1./X)/PIA
380 CONTINUE
C     MODIFIED CAMBERLINE OPTION
    IF (CAMBER.EQ.K6AS) GO TO 390
    GO TO 410
390 YCMB(L)=YCMB(L)*0.97948
    TANTH(L)=TANTH(L)*0.97948
    YCP2(L)=YCP2(L)*0.97948
    IF (ABS(A-.8).LT.E) GO TO 400
    PRINT 780
    READ 600, NPWIPE
    IF (KON.EQ.3) KON=0
    GO TO 20
400 CONTINUE
    IF (TANTH(L).LE.-.24521*CLI) YCMB(L)=0.24521*CLI*(1.-X)
    IF (TANTH(L).LE.-.24521*CLI) YCP2(L)=0.0
    IF (TANTH(L).LE.-.24521*CLI) TANTH(L)=-0.24521*CLI
    IF (TANTH(L).LE.-.24521*CLI) IF6XA(L)=1
410 CONTINUE
    IF (ICKY.GT.1.AND.L.LT.ICKY) GO TO 280
    IF (ICKY.EQ.1) GO TO 430
    DO 420 J=2,ICKY
    YCMB(1)=YCMB(1)+YCMB(J)
    TANTH(1)=TANTH(1)+TANTH(J)
    YCP2(1)=YCP2(1)+YCP2(J)
420 CONTINUE
430 CONTINUE
    F=SQRT(1.+TANTH**2)
    THP=YCP2/F**2
440 CONTINUE
    IF (X.GT.XM) GO TO 550
    IF (ABS(X-XM).LT.E) GO TO 550
    SINTH=TANTH/F
    COSTH=1./F
    I=I+1
    XU(I)=X-Y*SINTH
    YU(I)=YCMB+Y*COSTH
    XL(I)=X+Y*SINTH
    YL(I)=YCMB-Y*COSTH
    IF (ABS(X-XA(K)).GT..1**6) GO TO 450
    XAU(K)=XU(I)
    YAU(K)=YU(I)
    XAL(K)=XL(I)
    YAL(K)=YL(I)
    K=K+1
450 CONTINUE
    XUC=XU(I)*CHD
    YUC=YU(I)*CHD
    XLC=XL(I)*CHD
    YLC=YL(I)*CHD
    IF (ABS(CMB).LE.0.1**6) GO TO 460
    YUP=0.0
    YLP=YUP
    IF (ABS(TANTH).LT.0.1**10) GO TO 460
    YUP=(TANTH*F+YP-TANTH*Y*THP)/(F-YP*TANTH-Y*THP)
    YLP=(TANTH*F-YP+TANTH*Y*THP)/(F+YP*TANTH+Y*THP)
460 CONTINUE
    IF (X.LE.0.0975) FRAC=0.25
    IF (X.LE.0.00225) FRAC=0.025
    IF (ABS(CMB).GT.0.1**6) PRINT 790, X,XU(I),YU(I),XUC,YUC,YUP,XL(I)
```

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```
     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
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      XU(I)=X-Y*SINTH
      YU(I)=YCMB+Y*COSTH
      XL(I)=X+Y*SINTH
      YL(I)=YCMB-Y*COSTH
      IF (ABS(X-XA(K)).GT..1**6) GO TO 570
      XAU(K)=XU(I)
      YAU(K)=YU(I)
      XAL(K)=XL(I)
      YAL(K)=YL(I)
      K=K+1
  570 CONTINUE
      XUC=XU(I)*CHD
      YUC=YU(I)*CHD
      XLC=XL(I)*CHD
      YLC=YL(I)*CHD
      IF (ABS(CMB).LE.0.1**6) GO TO 580
      YUP=0.0
      YLP=YUP
      IF (ABS(TANTH).LT.0.1**10) GO TO 580
      YUP=TANTH*(F+YP/TANTH-Y*THP)/(F-YP*TANTH-Y*THP)
      YLP=TANTH*(F-YP/TANTH+Y*THP)/(F+YP*TANTH+Y*THP)
  580 CONTINUE
      IF (ABS(CMB).GT.0.1**6) PRINT 790, X,YU(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=X+DX
      IF (X.LE.1.0) GO TO 470
      PUNCH 600, (TITLE(I),I=1,8)
      PUNCH 810, (XAU(I),I=1,32)
      PUNCH 810, (YAU(I),I=1,32)
      PUNCH 810, (XAL(I),I=1,32)
      PUNCH 810, (YAL(I),I=1,32)
      CALL PLOT (XU,XL,YU,YL,I)
      GO TO 20
C
  590 FORMAT (I3/(8F10.0))
  600 FORMAT (8A10)
  610 FORMAT (1H ,8A10)
  620 FORMAT (10H1PROFILE  ,A10,10H  CAMBER  ,A10)
  630 FORMAT (7F10.0,A10)
  640 FORMAT (8F10.0)
  650 FORMAT (/10X,A10,10X,A10/)
  660 FORMAT (19H PROFILE PARAMETERS/5H T/C=,F10.5/12H L.E.RADIUS=,F10.5
     1/18H BASIC X INTERVAL=,F10.5/7H CHORD=,F10.5/)
  670 FORMAT (19H PROFILE PARAMETERS/5H T/C=,F10.5/12H L.E.RADIUS=,F10.5
     1/18H BASIC X INTERVAL=,F10.5/7H CHORD=,F10.5/35H POSITION OF MAXIM
     2UM THICKNESS, XM=,F10.5/13H CONSTANT D1=,F10.5/)
  680 FORMAT (23H CAMBER LINE PARAMETERS/16H CAMBER(YCMAX) =,F10.5/28H P
     1OSITION OF MAXIMUM CAMBER=,F10.5/)
  690 FORMAT (23H CAMBER LINE PARAMETERS/21H CAMBER PARAMETER K1=,F10.5/
     140H POSITION OF ZERO CAMBER LINE CURVATURE=,F10.5/)
  700 FORMAT (23H CAMBER LINE PARAMETERS/21H CAMBER PARAMETER K1=,F10.5/
     140H POSITION OF ZERO CAMBER LINE CURVATURE=,F10.5/61H RATIO OF AFT
     2 TO FORWARD CAMBER LINE CURVATURE FACTOR, K2OK1=,F10.5/)
  710 FORMAT (23H CAMBER LINE PARAMETERS/7X,3HCLI,9X,1HA)
  720 FORMAT (2F10.3)
  730 FORMAT (10H A0,1,2,3=,4F13.6/10H D0,1,2,3=,4F13.6/4H RC=,F13.3//)
  740 FORMAT (9X,3HX/C,10X,3HY/C,8X,5HDY/DX,6X,7HD2Y/DX2,22X,1HX,12X,1HY
     1/)
  750 FORMAT (116HOUNCAMBERED                                  UPPER SURFACE VALU
     1ES                                    LOWER SURFACE VALUES /5X,
     23HX/C17X,4HXU/C6X,4HYU/C5X,7H   XU    3X,7H   YU    3X,7HDYU/DXU13X,4H
     3XL/C4X,4HYL/C5X,7H   XL    3X,7H   YL    3X,7HDYL/DXL)
  760 FORMAT (35H BAD HOLLERITH CAMBER SPECIFICATION)
  770 FORMAT (4F13.6,10X,2F13.6)
  780 FORMAT (52H  MODIFIED CAMBER LINE OPTION ONLY ALLOWED IF A=0.8 )
```

ORIGINAL PAGE IS
OF POOR QUALITY

APPENDIX

```
790 FORMAT (F10.5,10X,4F10.5,E11.2,6X,4F10.5,E11.2)
800 FORMAT (36H BAD HOLLERITH PROFILE SPECIFICATION)
810 FORMAT (8F10.5)
    END
    SUBROUTINE PLOT (XU,XL,YU,YL,I)
    COMMON /MAIN/ YSTART(3),CHD,K
    DIMENSION XU(1), XL(1), YU(1), YL(1), X(450), Y(450)
    DIMENSION TITLE1(8), TITLE2(8)
    READ 30, (TITLE1(N),N=1,8)
    IF (MOD(K,3).EQ.1) CALL CALPLT (1.0,0.0,-3)
    HGT=0.14
    L=I
    DO 10 N=1,I
    X(N)=XU(N)
    Y(N)=YU(N)
    X(I+N)=XL(L)
    Y(I+N)=YL(L)
 10 L=L-1
    M=2*I
    XPG=10.0
    XX=XPG/2.0-1.5*(6./7.*HGT)
    XDV=0.0
    XTIC=1.0
    YPG=2.0
    YDV=0.0
    YTIC=1.0
    X(M+1)=0.0
    Y(M+1)=-0.1
    X(M+2)=1.0/XPG
    Y(M+2)=X(M+2)
    CALL AXES (0.,YSTART(K),90.,YPG,Y(M+1),Y(M+2),YTIC,YDV,1H ,HGT,1)
    CALL AXES (0.,YSTART(K),0.,XPG,X(M+1),X(M+2),XTIC,XDV,1H ,HGT,-1)
    YLABEL=YSTART(K)-2.5*HGT
    CALL NOTATE (XX,YLABEL,HGT,3HX/C,0.,3)
    YLABEL=YLABEL-1.5*HGT
    CALL NOTATE (0.0,YLABEL,HGT,TITLE1,.0,80)
    YS=YSTART(K)+1.0
    CALL NOTATE (-.92,YS,HGT,3HZ/C,0.0,3)
    CALL CALPLT (0.0,YSTART(K),-3)
    LAP=0
    CALL LINPLT (X,Y,M,1,LAP,0,1,0)
    CALL CALPLT (0.0,-YSTART(K),-3)
    IF (K.LT.3) GO TO 20
    K=0
    CALL NFRAME
 20 CONTINUE
    RETURN
C
 30 FORMAT (8A10)
    END
```

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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	.045888
.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	.267450
.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

TABLE II.- Continued

X/C	Y/C	DY/DX	D2Y/DX2
.110000	.048432	.152413	-1.538890
.120000	.049892	.137841	-1.380972
.130000	.051193	.124699	-1.251356
.140000	.052380	.112742	-1.143134
.150000	.053452	.101782	-1.051434
.160000	.054418	.091671	-.972731
.170000	.055287	.082293	-.904421
.180000	.056066	.073554	-.844538
.190000	.056760	.065379	-.791579
.200000	.057375	.057703	-.744372
.210000	.057916	.050475	-.701995
.220000	.058386	.043650	-.663711
.230000	.058790	.037189	-.628926
.240000	.059131	.031061	-.597157
.250000	.059412	.025238	-.568005
.260000	.059637	.019694	-.541142
.270000	.059807	.014408	-.516291
.280000	.059926	.009362	-.493223
.290000	.059995	.004538	-.471741
.300000	.060017	-.000078	-.451679
.310000	.059994	-.004500	-.432894
.320000	.059928	-.008740	-.415264
.330000	.059820	-.012808	-.398681
.340000	.059672	-.016716	-.383055
.350000	.059486	-.020472	-.368305
.360000	.059263	-.024085	-.354359
.370000	.059005	-.027562	-.341159
.380000	.058712	-.030911	-.328644
.390000	.058387	-.034137	-.316772
.400000	.058030	-.037248	-.305496
.410000	.057643	-.040249	-.294780
.420000	.057225	-.043145	-.284588
.430000	.056780	-.045942	-.274891
.440000	.056307	-.048645	-.265660
.450000	.055907	-.051257	-.256872
.460000	.055292	-.053784	-.248503
.470000	.054732	-.056228	-.240533
.480000	.054158	-.058595	-.232944
.490000	.053560	-.060898	-.225720
.500000	.052940	-.063111	-.218844
.510000	.052298	-.065266	-.212304
.520000	.051635	-.067358	-.206086
.530000	.050951	-.069389	-.200179
.540000	.050248	-.071363	-.194573
.550000	.049524	-.073282	-.189257
.560000	.048782	-.075149	-.184222
.570000	.048021	-.076967	-.179461
.580000	.047243	-.078739	-.174966
.590000	.046447	-.080467	-.170729
.600000	.045634	-.082154	-.166744
.610000	.044804	-.083803	-.163005
.620000	.043958	-.085415	-.159507
.630000	.043096	-.086994	-.156244
.640000	.042218	-.088541	-.153211
.650000	.041325	-.090059	-.150404
.660000	.040417	-.091550	-.147815
.670000	.039494	-.093016	-.145451
.680000	.038557	-.094459	-.143297
.690000	.037605	-.095882	-.141354
.700000	.036639	-.097287	-.139618
.710000	.035659	-.098676	-.138087
.720000	.034646	-.100050	-.136757
.730000	.033659	-.101411	-.135626
.740000	.032637	-.102763	-.134692
.750000	.031603	-.104106	-.133951
.760000	.030555	-.105442	-.133403
.770000	.029494	-.106775	-.133044
.780000	.028429	-.108104	-.132873

X	Y
.660000	.290591
.720000	.299291
.780000	.307161
.840000	.314278
.900000	.320710
.960000	.326509
1.020000	.331725
1.080000	.336397
1.140000	.340562
1.200000	.344253
1.260000	.347496
1.320000	.350318
1.380000	.352741
1.440000	.354787
1.500000	.356475
1.560000	.357821
1.620000	.358843
1.680000	.359555
1.740000	.359971
1.800000	.360104
1.860000	.359965
1.920000	.359567
1.980000	.358920
2.040000	.358033
2.100000	.356917
2.160000	.355580
2.220000	.354030
2.280000	.352275
2.340000	.350323
2.400000	.348181
2.460000	.345855
2.520000	.343353
2.580000	.340580
2.640000	.337842
2.700000	.334844
2.760000	.331693
2.820000	.328392
2.880000	.324947
2.940000	.321362
3.000000	.317542
3.060000	.313790
3.120000	.309811
3.180000	.305708
3.240000	.301485
3.300000	.297146
3.360000	.292592
3.420000	.288129
3.480000	.283457
3.540000	.278581
3.600000	.273802
3.660000	.268823
3.720000	.263747
3.780000	.258574
3.840000	.253308
3.900000	.247950
3.960000	.242501
4.020000	.236964
4.080000	.231340
4.140000	.225630
4.200000	.219834
4.260000	.213955
4.320000	.207994
4.380000	.201950
4.440000	.195824
4.500000	.189518
4.560000	.183332
4.620000	.176965
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	.116063
.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= .20500

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

A0,1,2,3= .296600 -.244866 .175232 -.266916
B0,1,2,3= .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	[illegible]	.00274	-.00325	.01641	-9.43E+00	.00106	-.00259	.00635	-.01550	-1.91E+00
.00050	-.00044	.00389	-.00361	.02336	-3.87E+01	.00144	-.00359	.00981	-.02153	-1.60E+00
.00075	-.00043	.00474	-.00379	.02475	2.87E+01	.00213	-.00434	.01279	-.02601	-1.42E+00
.00100	-.00053	.00555	-.00751	.03333	1.17E+01	.00259	-.00495	.01551	-.02969	-1.29E+00
.00125	-.00051	.00623	-.00707	.03740	7.72E+00	.00304	-.00547	.01807	-.03285	-1.19E+00
.00150	-.00042	.00585	-.00252	.04110	5.92E+00	.00342	-.00594	.02052	-.03565	-1.10E+00
.00175	-.00021	.00742	-.00188	.04452	4.88E+00	.00381	-.00636	.02289	-.03817	-1.04E+00
.00200	-.00070	.00795	-.00117	.04772	4.19E+00	.00420	-.00675	.02517	-.04048	-9.79E-01
.00225	-.00007	.00444	-.00040	.05075	3.71E+00	.00457	-.00710	.02740	-.04261	-9.29E-01
.00250	.00037	.00937	.00041	.05342	3.35E+00	.00493	-.00743	.02959	-.04459	-8.86E-01
.00500	.00171	.01255	.01024	.07726	1.89E+00	.00829	-.00991	.04976	-.05944	-6.19E-01
.00750	.00342	.01595	.02173	.09591	1.43E+00	.01138	-.01159	.06927	-.06953	-4.83E-01
.01000	.00550	.01866	.03412	.11194	1.13E+00	.01431	-.01287	.09583	-.07723	-3.97E-01
.01250	.00795	.02104	.04712	.12524	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	.02883	.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	.02195	.03216	.13175	.19295	6.34E-01	.03304	-.01771	.19925	-.10627	-1.74E-01
.03000	.02442	.03364	.14653	.20207	6.00E-01	.03558	-.01814	.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	.19154	.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	.24930	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	.26833	.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	.04597	.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	-9.57E-02
.06250	.05776	.04874	.34653	.29243	3.45E-01	.05724	-.02193	.40347	-.13156	-9.84E-02
.06500	.06038	.04963	.36227	.29777	3.33E-01	.06962	-.02215	.41773	-.13295	-9.72E-02

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TABLE III.- Continued

UNCAMBERED X/C	UPPER SURFACE VALUES XU/C	YU/C	XU	YU	DYU/DXU	LOWER SURFACE VALUES XL/C	YL/C	XL	YL	DYL/DXL
.06750	.06301	.05049	.37806	.30293	3.21E-01	.07199	-.02239	.43196	-.13433	-9.64E-02
.07000	.06564	.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	.07091	.05290	.42549	.31738	2.88E-01	.07909	-.02307	.47452	-.13840	-9.50E-02
.07750	.07355	.05365	.44132	.32189	2.79E-01	.08145	-.02329	.48868	-.13974	-9.49E-02
.08000	.07620	.05427	.45719	.32562	2.69E-01	.08380	-.02351	.50281	-.14108	-9.49E-02
.08250	.07884	.05507	.47305	.33042	2.60E-01	.08616	-.02374	.51694	-.14242	-9.50E-02
.08500	.08149	.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	.08679	.05703	.52073	.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	-.02486	.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	.36811	1.77E-01	.11202	-.02625	.67214	-.15751	-1.00E-01
.12000	.11855	.06209	.71127	.37254	1.55E-01	.12145	-.02721	.72873	-.16326	-1.03E-01
.13000	.12908	.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	.17069	.06876	1.02414	.41253	7.37E-02	.16931	-.03228	1.01586	-.19367	-1.06E-01
.18000	.18093	.06946	1.08556	.41677	6.44E-02	.17907	-.03330	1.07444	-.19983	-1.04E-01
.19000	.19109	.07008	1.14653	.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	.21119	.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	3.84E-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	.07266	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	1.62756	.43919	2.30E-02	.26874	-.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	.07358	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	.31129	.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	2.10793	.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	2.40795	.43941	-2.21E-02	.39868	-.04674	2.39205	-.28041	-2.21E-02
.41000	.41132	.07300	2.46795	.43799	-2.56E-02	.40868	-.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	.42868	-.04724	2.57207	-.28344	-1.16E-02
.44000	.44132	.07207	2.64791	.43244	-3.60E-02	.43868	-.04734	2.63209	-.28404	-8.19E-03
.45000	.45132	.07170	2.70789	.43019	-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	.07084	2.82784	.42504	-4.63E-02	.46869	-.04743	2.81216	-.28458	2.12E-03
.48000	.48130	.07036	2.88780	.42216	-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	.50129	.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	.40860	-6.33E-02	.51873	-.04690	3.11238	-.28140	1.90E-02

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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	.06198	3.60704	.37186	-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	-9.96E-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	3.89345	-.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	5.04369	.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	.02088	5.40247	.12531	-1.83E-01	.89959	-.01647	5.39753	-.09881	1.38E-01
.91000	.91038	.01905	5.46225	.11427	-1.86E-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	.01336	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

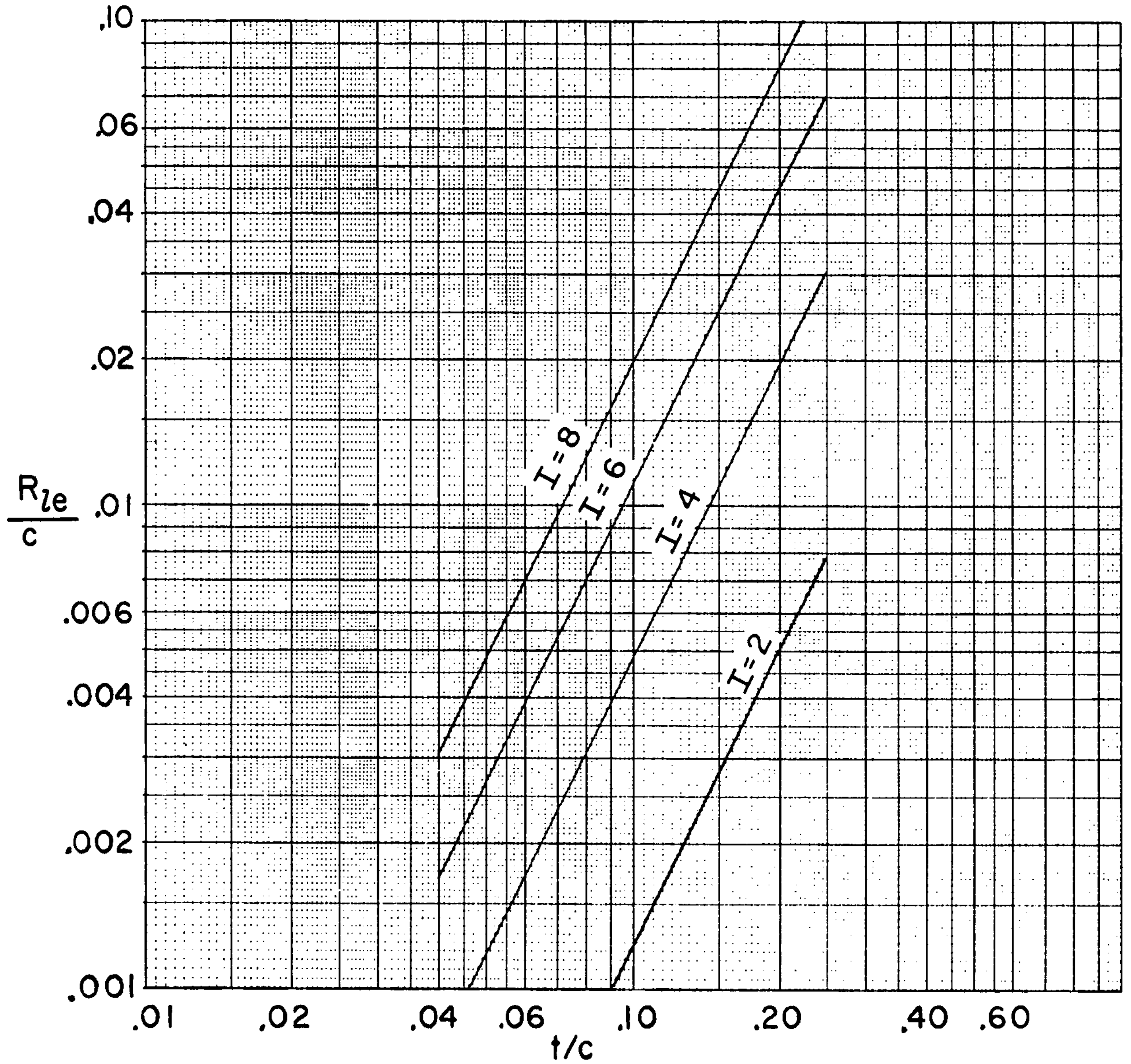

Figure 1.- Ratio of airfoil leading-edge radius to chord as a function of the ratio of thickness to chord and leading-edge index I.

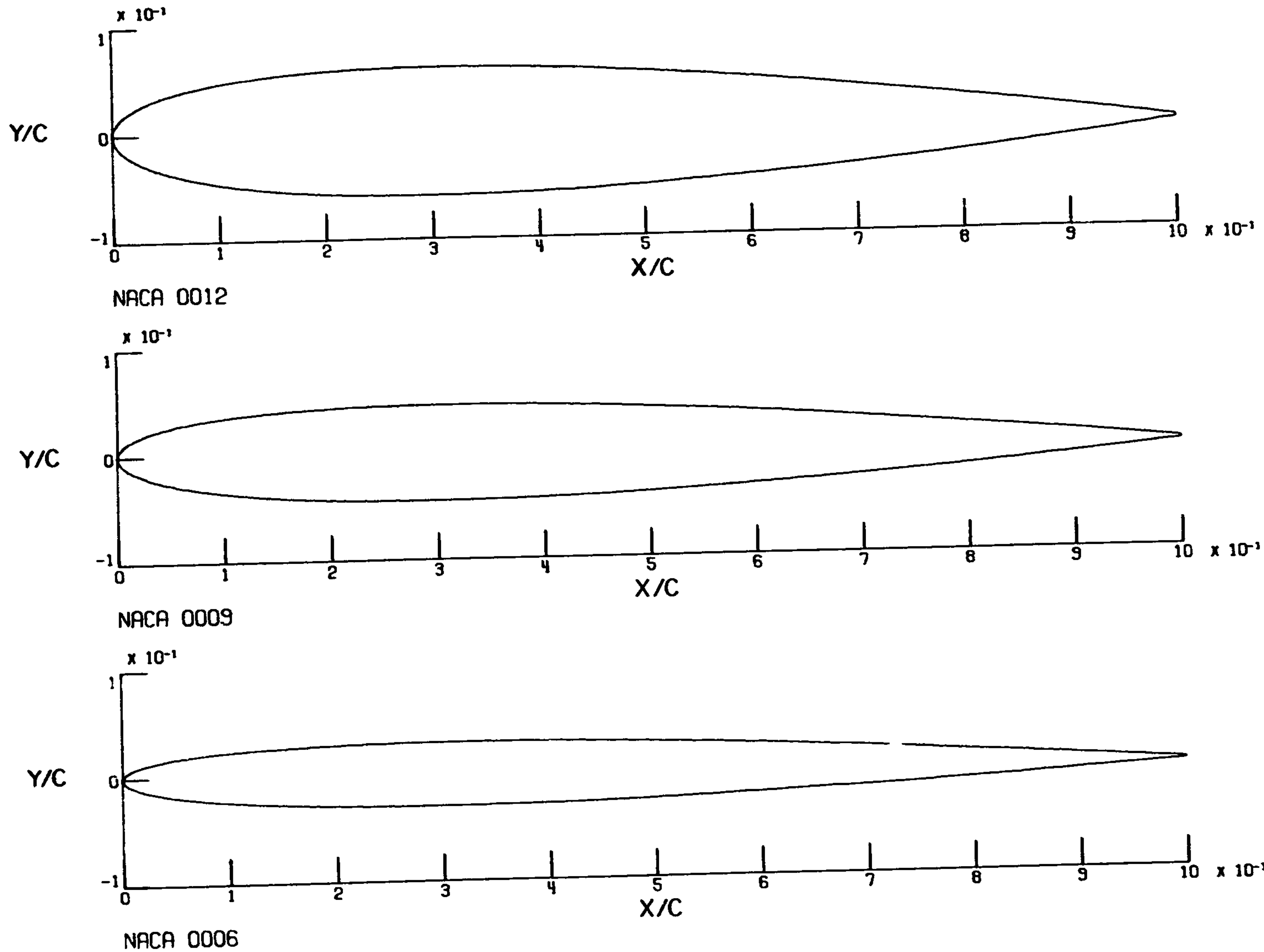

Figure 2.- Variations in thickness-chord ratio for symmetric 4-digit airfoils.

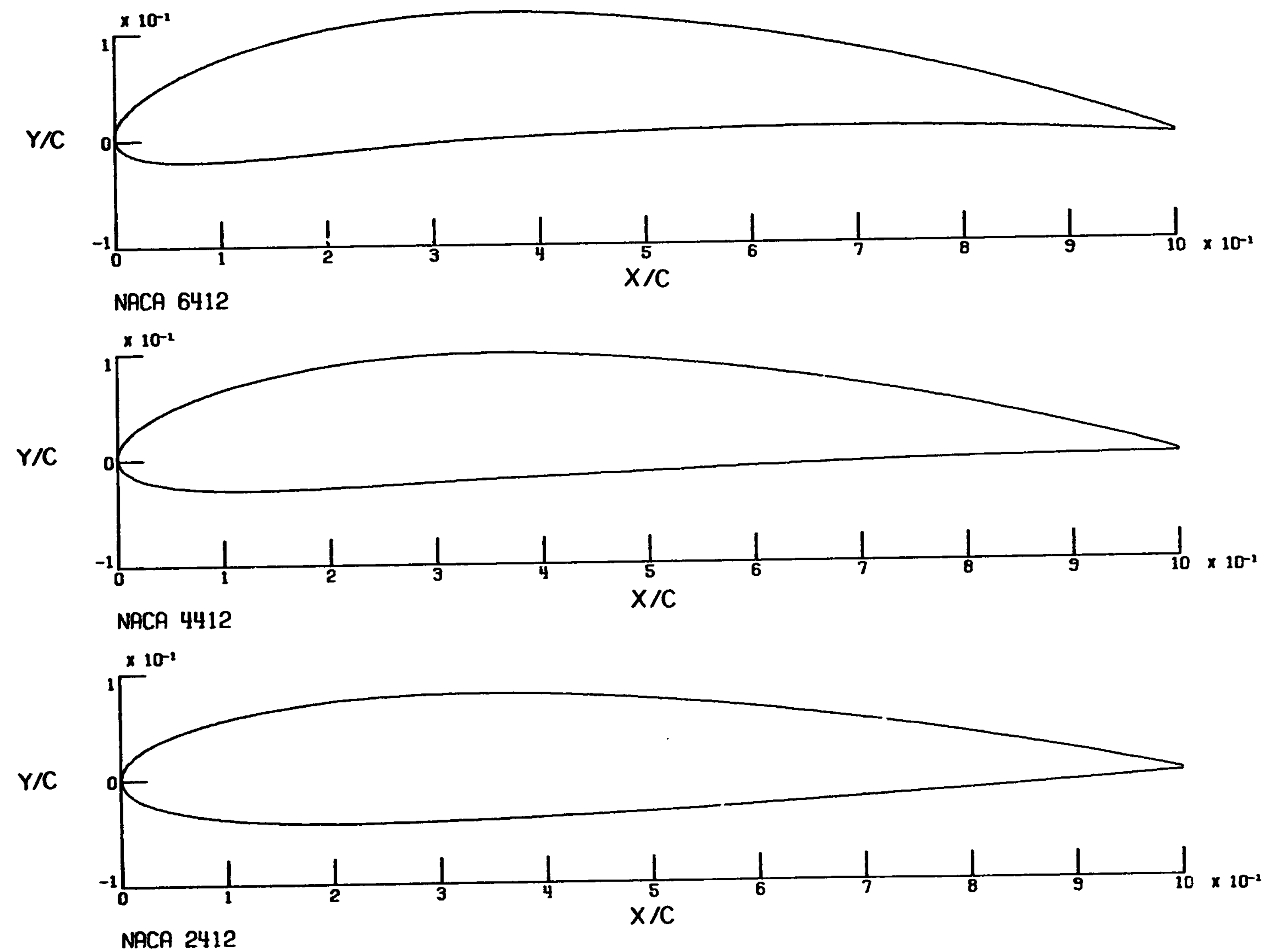

Figure 3.- Variations in amount of camber for 12-percent-thick 4-digit airfoils with 2-digit camber line.

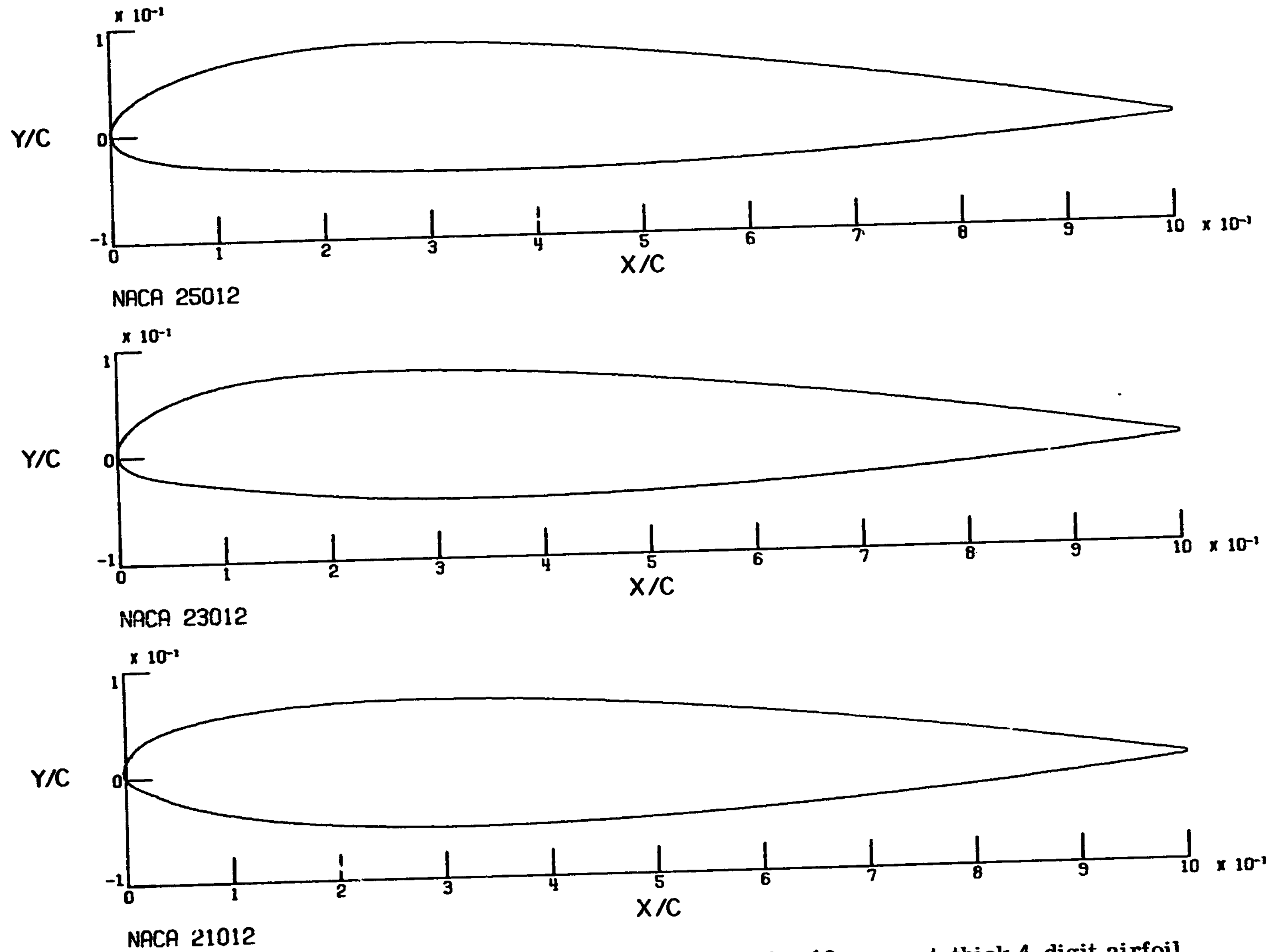

Figure 4.- Variation in location of maximum camber for 12-percent-thick 4-digit airfoil with 3-digit camber line (5-digit airfoil).

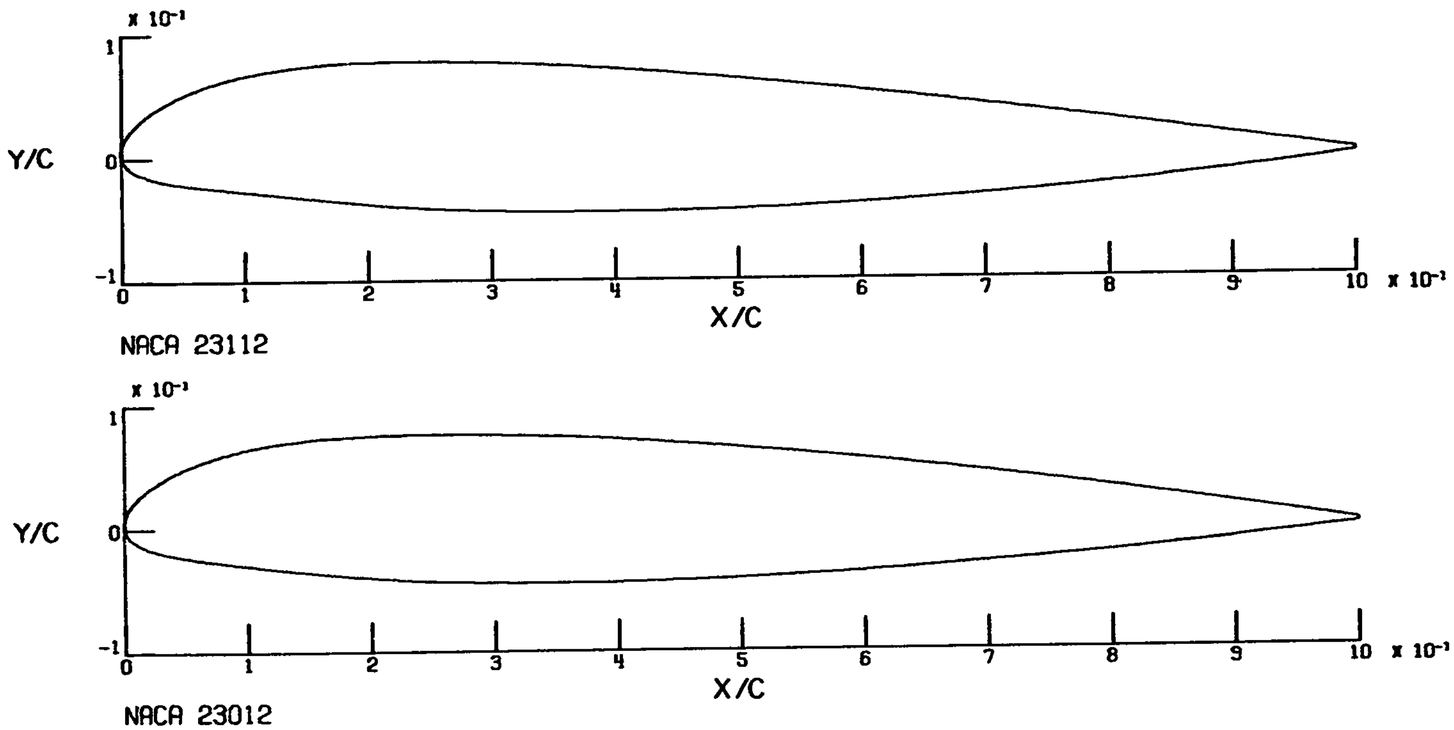

Figure 5.- Comparison of reflexed and nonreflexed 3-digit camber line on 12-percent-thick airfoil.

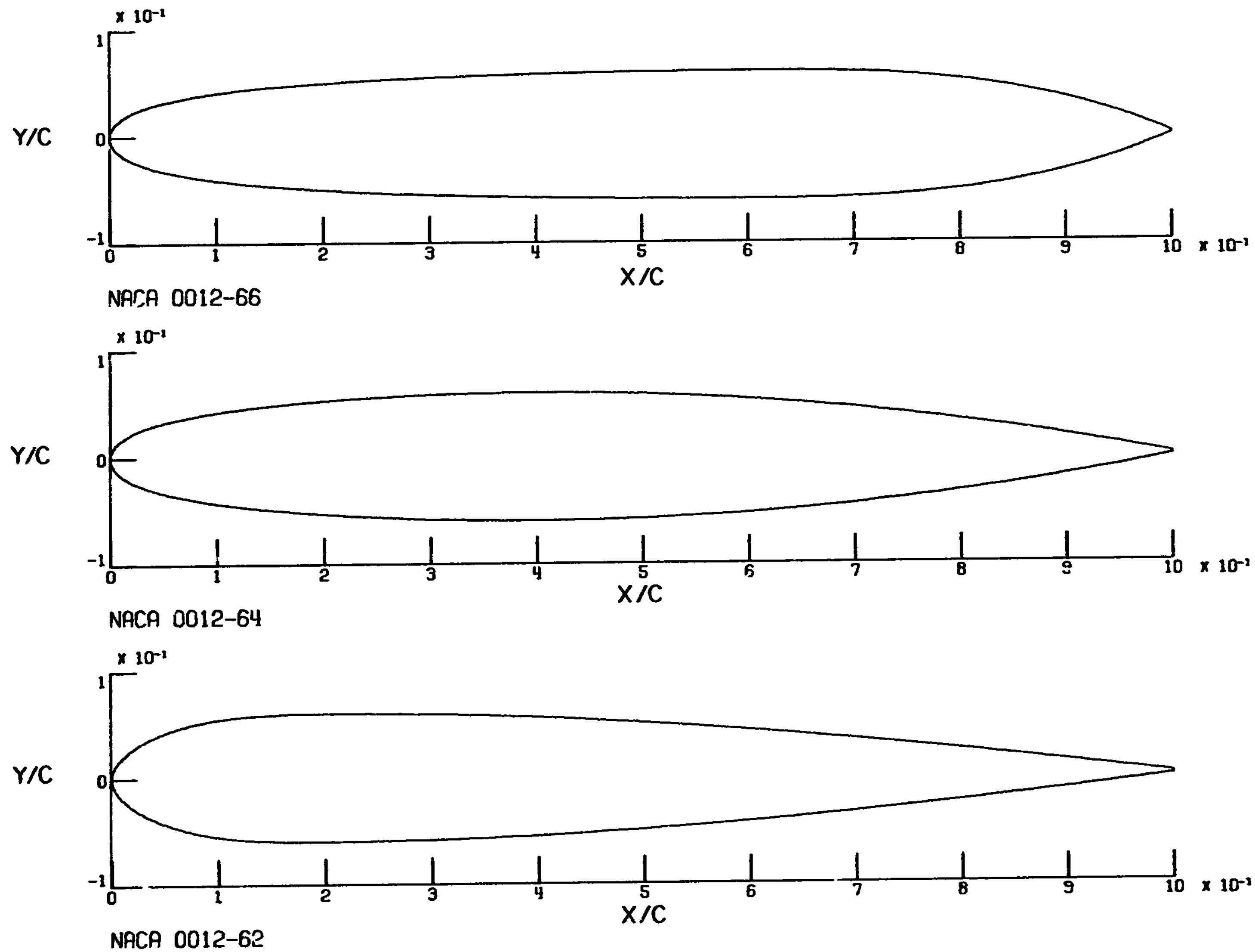

Figure 6.- Variations in location of maximum thickness for 12-percent-thick 4-digit modified airfoils.

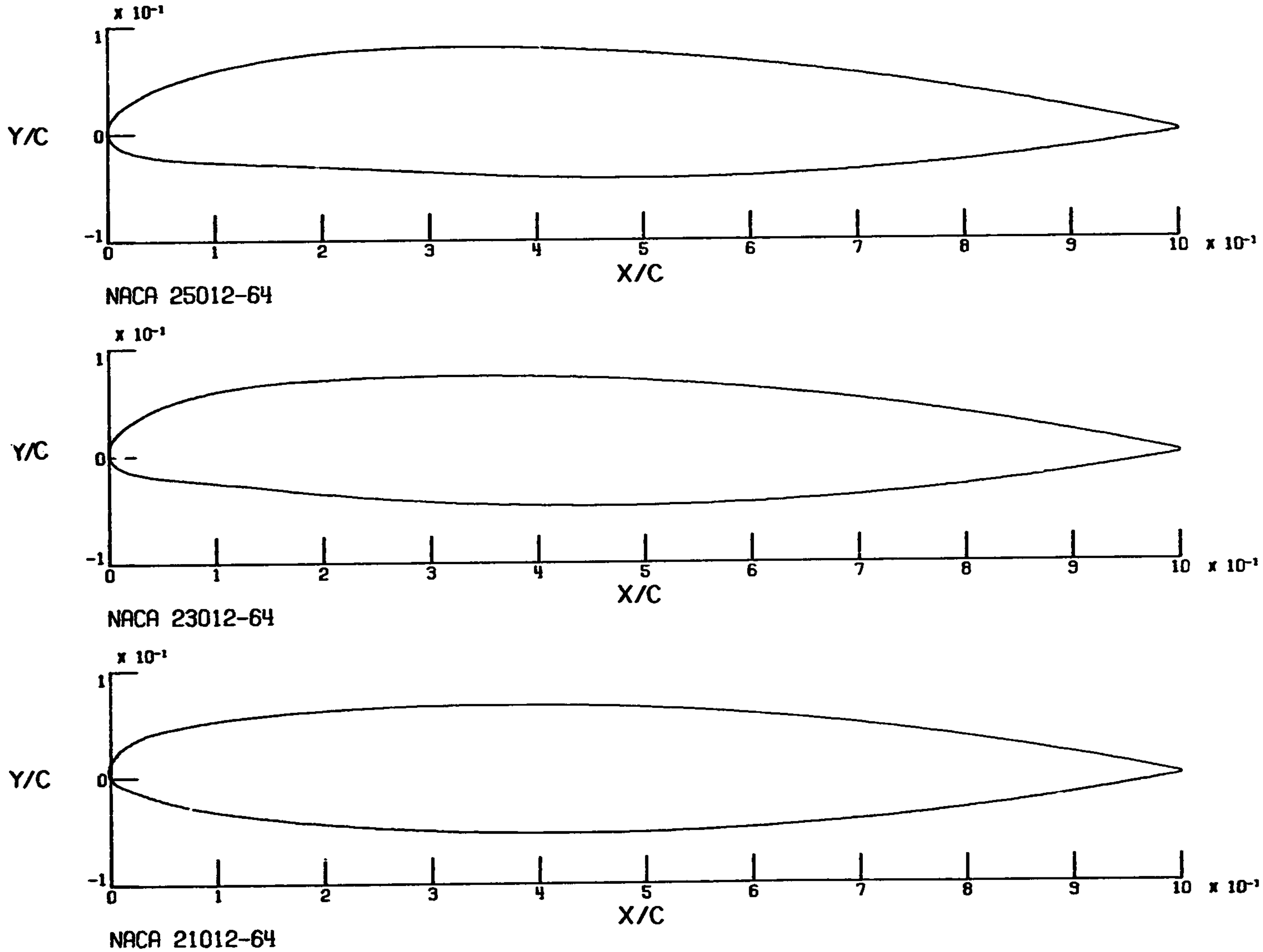

Figure 7.- Variations in location of maximum camber for 12-percent-thick 4-digit modified airfoils with 3-digit camber line.

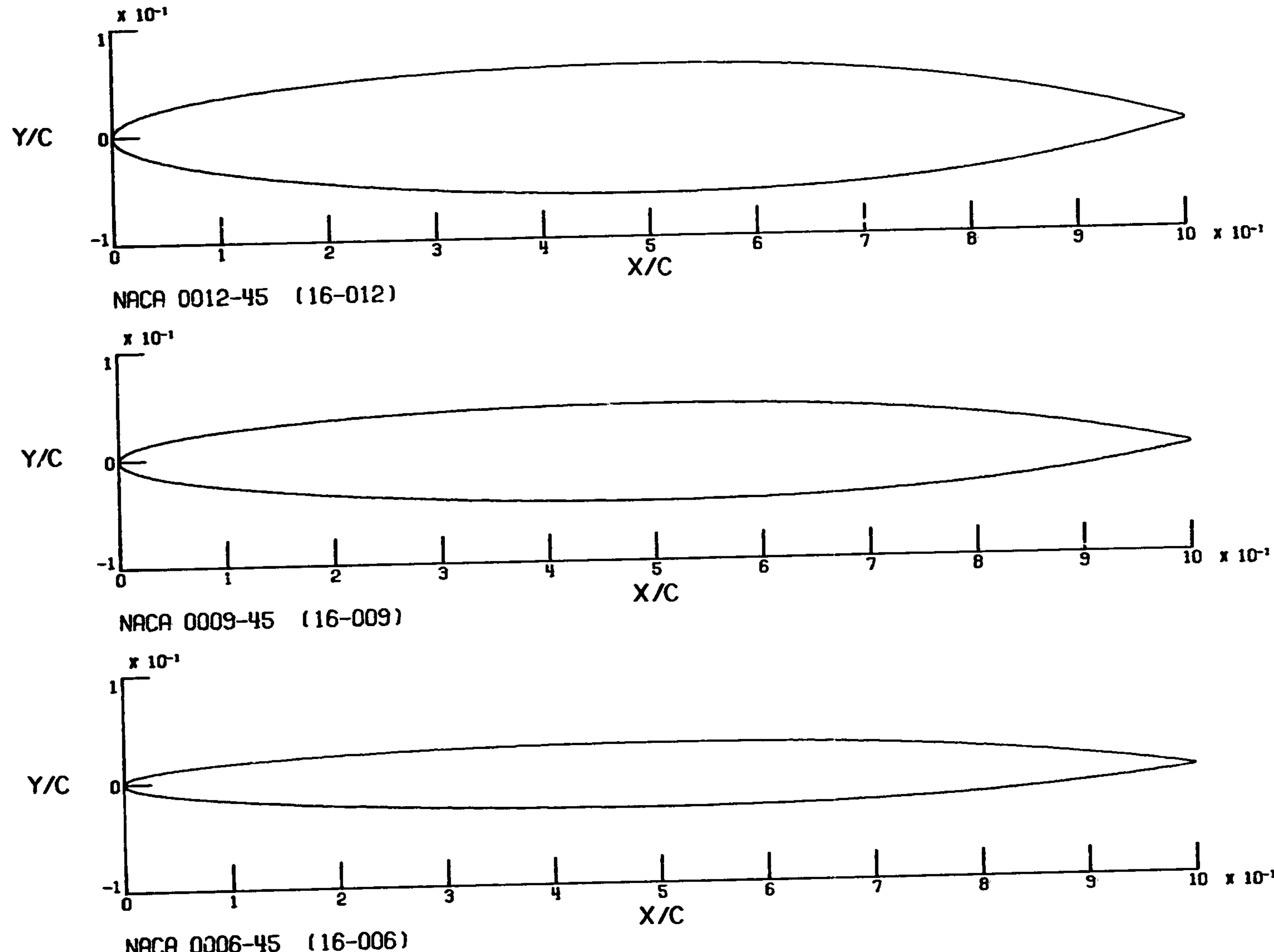

Figure 8.- Variations in thickness-chord ratio for symmetric 16-series airfoils.

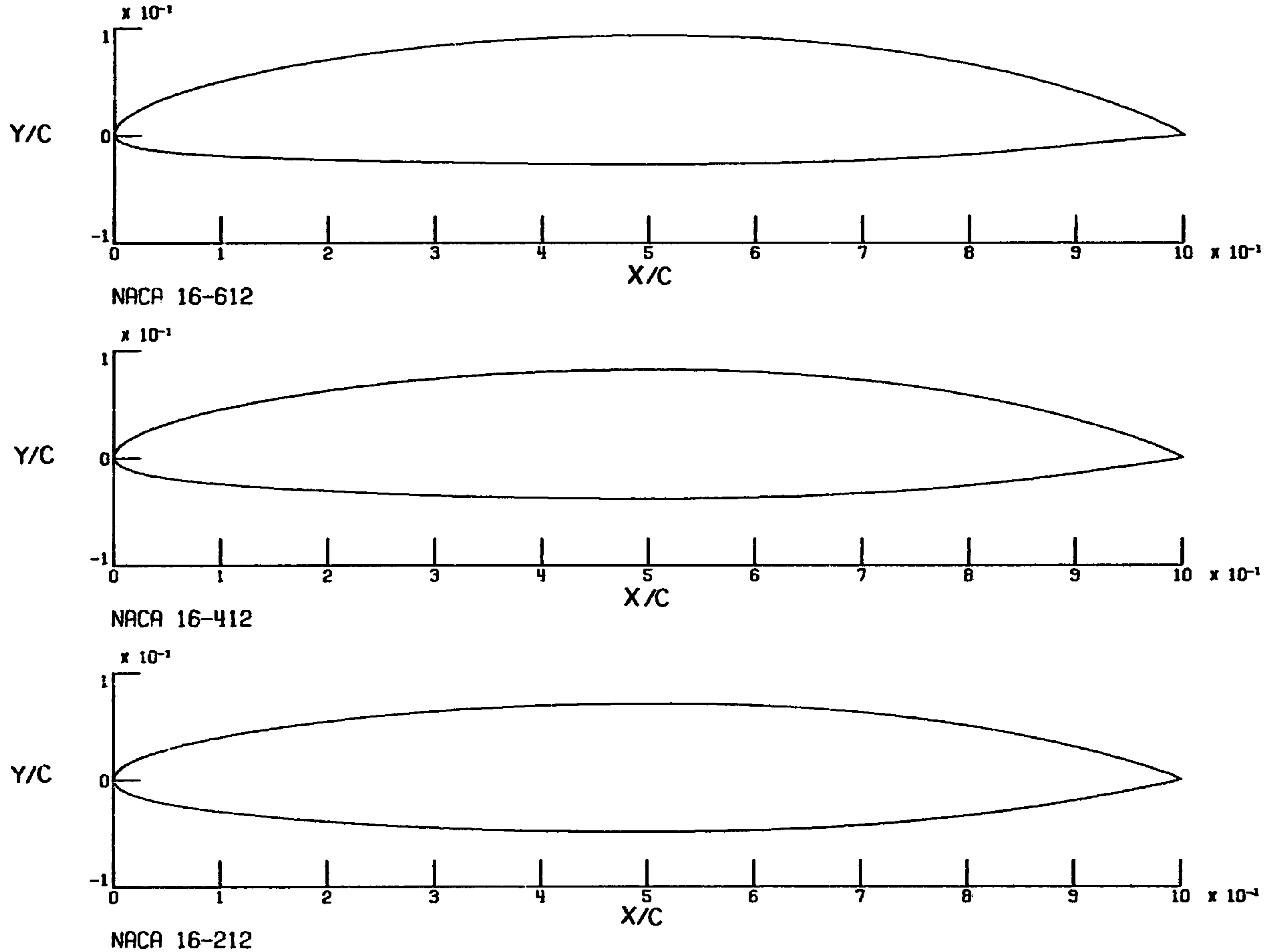

Figure 9.- Variations in amount of camber for 12-percent-thick 16-series airfoils with 6A-series camber line.

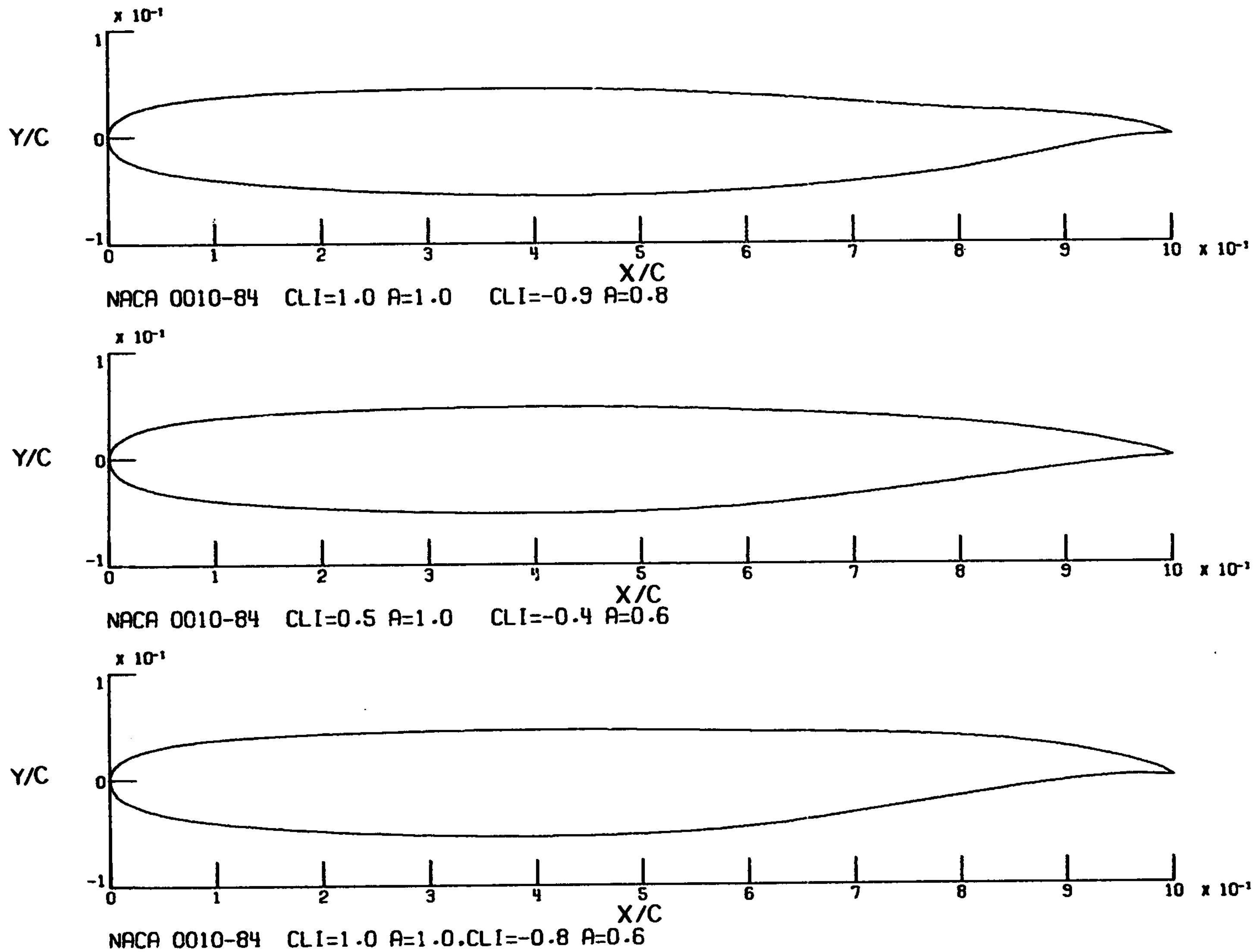

Figure 10.- Combination of two 6-series camber lines with a 10-percent-thick 4-digit modified airfoil.

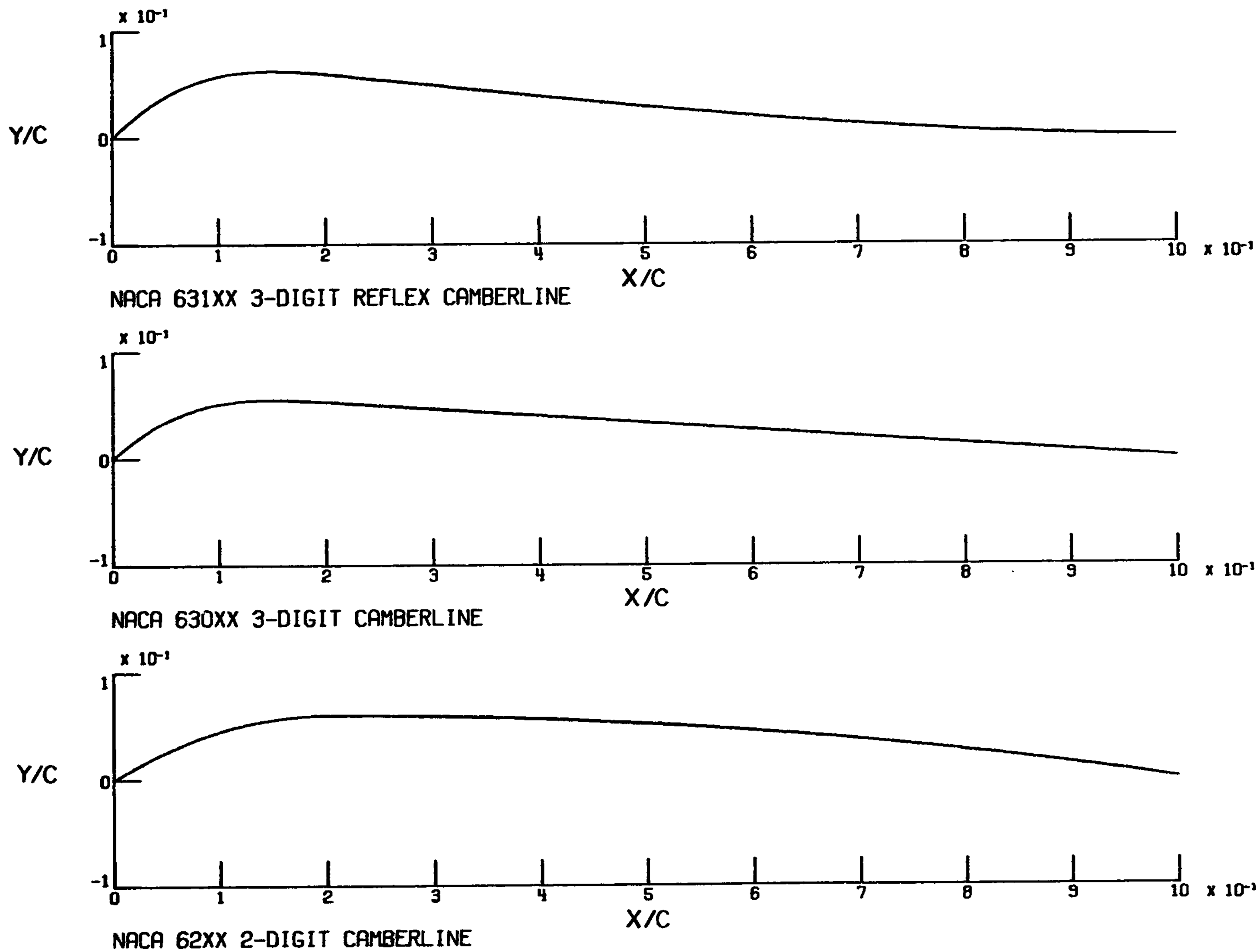

Figure 11.- 2-digit and 3-digit camber lines.

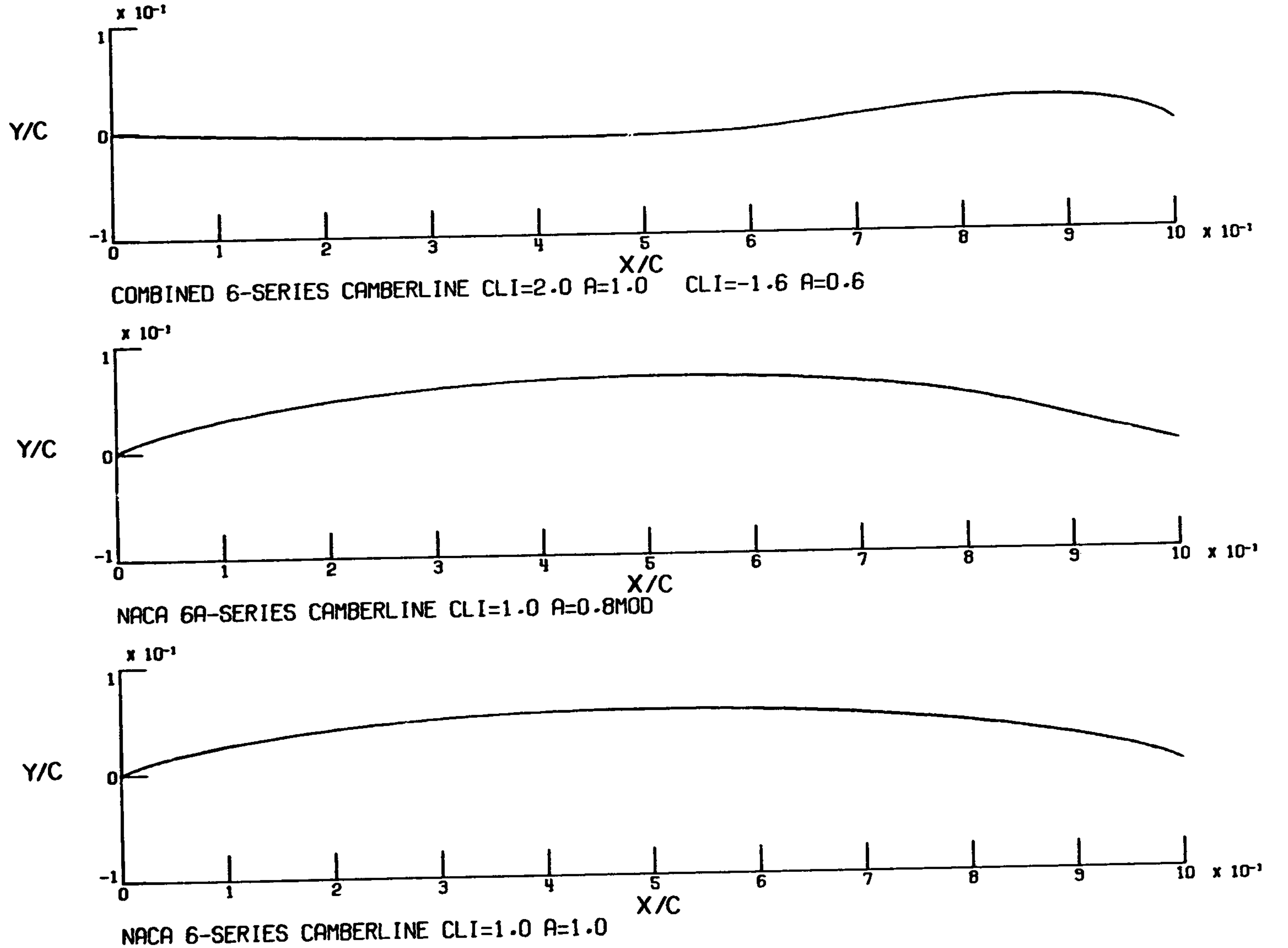

Figure 12.- 6-series single and combined camber lines.

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