DESIGN IMPLEMENTATION FOR SUPERCAVITATING HYDROFOILS WITH TWO-POINT CAVITY THICKNESS CONTROL

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Technical Memorandum
File No. TM 77-199
16 July 1977
Contract No. N00017-73-C-1418

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NAVY DEPARTMENT
NAVAL SEA SYSTEMS COMMAND
**Design Implementation for Supercavitating Hydrofoils with Two-Point Cavity Thickness Control**

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**Number of Pages:** 70

**Security Class. (of this report):** UNCLASSIFIED

A computer aided inverse design method for supercavitating hydrofoils was given recently by Parkin and Fernandez. This method uses a linearized cavity flow theory to determine the wetted surface shape from a prescribed pressure distribution and to evaluate its overall performance parameters, while controlling the cavity thicknesses at two points along the chord. The numerical analysis for this design method is discussed in this report and the computer program is listed.
Subject: Design Implementation for Supercavitating Hydrofoils with Two-Point Cavity Thickness Control

References: See page 28.

Abstract: A computer aided inverse design method for supercavitating hydrofoils was given recently by Parkin and Fernandez. This method uses a linearized cavity flow theory to determine the wetted surface shape from a prescribed pressure distribution and to evaluate its overall performance parameters, while controlling the cavity thicknesses at two points along the chord. The numerical analysis for this design method is discussed in this report and the computer program is listed.

Acknowledgment: This research was carried out under the Naval Sea Systems Command General Hydromechanics Research Program, Subproject SR 023 01 01, administered by the David W. Taylor Naval Ship Research and Development Center, Contract N00017-73-C-1418.
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INTRODUCTION

This report documents the numerical analysis for the hydrofoil design procedure given recently by Parkin and Fernandez (Ref. 1). It also presents a computer program for the implementation of this design method, along with outputs from sample runs.

The design method given in Ref. (1) uses a linearized cavity flow theory to determine the wetted surface shape from a prescribed pressure distribution and to evaluate its overall performance parameters, while controlling the cavity thicknesses at two points along the chord. These thicknesses are specified at the trailing edge and at an arbitrary point between the leading and the trailing edges. For further details of this design method, the reader should consult Ref. (1).

The computer program is coded in FORTRAN IV and has been implemented to run on IBM system 370/168. The program contains about 1200 statements and consists of a MAIN program and 34 subprograms. The main program reads input data and calls the principal subroutine SECT6, which performs the necessary computations for the design method. The input to the program is described in the comment statements for the MAIN program. The program listing and the sample output are given in the Appendix. The following sections describe the implementation details for the various subprograms. For those subprograms that are included in the program listing, but are not described in this report, the reader is directed to References (2) and (5).

SUBROUTINE SECT6

SECT6 is the major subroutine for the third design method. This subroutine operates in two modes, namely, the estimation mode (NEST=1) and the design mode (NEST=0).
In the estimation mode SECT6 performs the following:

(1) Estimate the value of $C_L$ at which $y_c(1)=0$ for a prescribed $m$. This is the maximum permissible value of $C_L$ for the given $m$.

(2) Estimate the value of $\mu$ for the prescribed $C_L$ and $m$.

For the general case $K \neq 0$, the above estimates are obtained by solving for the cavity length parameter 'a' by using the appropriate equation. These equations are evaluated by FUNCTION FA. For the particular case $K=0$, the above estimates are calculated in SECT6 itself.

In the design mode, SECT6 computes the cavity shape, $y(x)$, camber curve, $\eta(x)$ and the slope of the camber curve, $\eta'(x)$, along with various performance parameters. In this case, the designer prescribes $\mu$ from the range of $\mu$ values obtained in the estimation mode. The following operations are performed by SECT6 in the given order.

Case A. $K \neq 0$

Step 1:

The transcendental equation $f(a)=0$ is solved for $a$ in this step. The expression $f(a)$ is given in the description of FUNCTION FA for various cases that arise in the estimation and design modes. The method for obtaining 'a' consists of two steps. The first step uses a sequential search procedure to obtain $a_L$ and $a_R$ such that

$$0 < a_L < a_R < a_{\text{max}}$$

and

$$f(a_L) f(a_R) < 0$$  \hspace{1cm} (1)
Thus the root of the equation \( f(a) = 0 \) is located within the range \( a_l < a < a_r \). In the second step, the value of 'a' is obtained to within a prescribed tolerance using the method of false positions (Regula Falsi). At this point control is returned to the calling routine if the program were in the estimation mode. Otherwise, SECT6 obtains the following design parameters.

Step 2:

The parameter \( B \) is obtained from the equation

\[
B = \frac{(1-m)c_L}{\pi(1+K)} \frac{(c-x_5)}{a_x(0-ae)} + \frac{m}{4\pi(1+K)a_x} \int_0^{1/2} \frac{(x-2x)P(x)dx}{\sqrt{x}}
\]

(2)

The value of the integral in the above equation is obtained in the subprogram FUNCTION FA and is transmitted through common as \( B_5 \).

The parameters \( \varepsilon \) and \( \delta \) in the above equation* are defined by

\[
\{\delta\} = [\sqrt{1}-1]^{1/2} \pm [\sqrt{1}-1]^{1/2}
\]

(3)

where \( l \), the cavity length is obtained from

The following expansion formulas for \( \varepsilon \) and \( \delta \) are found useful in obtaining various limiting values as \( a \to \infty \) (or, equivalently, as \( K = 0 \))

\[
\delta = \sqrt{a} \{2 + \frac{1}{4a} + O(\frac{1}{a})\}
\]

\[
\varepsilon = \frac{1}{\sqrt{a}} \{1 - \frac{1}{8a} + O(\frac{1}{a})\}
\]

*
Step 3:

The parameter $D$ is obtained from the relation

$$D = \frac{(1-m) C_L \delta}{\pi (1+K)} + \frac{m}{4\pi (1+K)} \int_0^1 \frac{P(x)dx}{x-x} - \frac{B}{2}$$

(4)

The integral in the above equation is obtained in subprogram FUNCTION FA and is transmitted through Common as $B_3$.

Step 4:

Next, the value of the parameter $E$ is obtained from

$$E = \beta - \frac{(1-m) C_L (2a^2 + 3)\epsilon + a\delta}{2\pi (1+K)} \frac{m}{2\pi (1+K)\ell} \int_0^{\sqrt{\ell}} \frac{P(x)dx}{x}$$

(5)

The value of the integral in the above equation is transmitted as $B_2$ from FUNCTION FA.

Step 5:

The parameter $A$ is obtained from the relation

$$A = \frac{-2(1-m) C_L}{\pi (1+K)} \frac{\sqrt{a}}{\delta - a\epsilon}$$

(6)

Step 6:

Next, the value of the drag coefficient, $C_D$, is calculated from

$$C_D = 2\pi (1+K) \ell (aB + \frac{E^2}{2})$$

(7)
Step 7:

The moment coefficient is obtained from the relation

\[
C_M = -(1-m) \frac{CL}{C_L} \left(3\delta - 4ae\right) + \frac{a^2(\delta - 2ac)}{8c\sqrt{a}} - mn \int_0^1 x P(x) \, dx .
\]

(8)

It should be noted that the factor \((3\delta - 4ae)\) in the above formula is of the order \(a^{1/2}\) while the factor \((\delta - 2ac)\) is of the order \((1/a^{3/2})\).

Therefore the later has to be computed in double precision in order to ensure accuracy at large values of \(a\). The integral in the above formula for \(C_M\) is computed by the function subprogram BICM.

Step 8:

Now the contribution from the nose singularity to the cavity thickness at the trailing edge, viz. \(y_c(1)\), is calculated from

\[
y_c(1) = aE .
\]

(9)

Step 9:

The parameter \(\overline{V}_1(0)\) is needed for the off-design calculations. \(\overline{V}_1(x)\) is the well-behaved part of the camber derivative function and is defined as

\[
\overline{V}_1(x) = \eta'(x) + \frac{E_d\sqrt{d}}{2\sqrt{x}} , \quad 0 < x < 2h
\]

(10)

\[
= \eta'(x) , \quad x > 2h
\]

where \(E_d\) and \(d\) are respectively the coefficient of the complementary function and the cavity length at the design conditions. \(\overline{V}_1(0)\) is obtained from
\[
\overline{V}_1(0) = \alpha - \frac{(1-m) C_L}{\pi (1+K)} \frac{\delta}{(\delta-a \varepsilon)} \quad . \tag{11}
\]

**Step 10:**

The cavity function \( y(x) \) is obtained for points along the chord from the relation

\[
y(x) = \alpha x - 2a^2 \varepsilon F_1(x,a) + ab\left[\sqrt{x(\ell-x)} - \ell \tan^{-1} \sqrt{x/(\ell-x)}\right]
\]

\[
-(\frac{B}{2} + D)x + E\sqrt{x(\ell-x)} + \frac{m}{2\pi (1+K)} G(x,a;P) \quad . \tag{12}
\]

The function \( F_1(x,a) \) is described in Ref. 5 and is computed by FUNCTION F1FUNC.

The function \( G(x,a;P) \) is given by

\[
G(x,a;P) = \frac{x}{2} B_3 + \frac{1}{2} \left[\sqrt{x(\ell-x)} + \ell \tan^{-1} \sqrt{x/(\ell-x)}\right] B_1
\]

\[
- \tan^{-1} \sqrt{x/(\ell-x)} B_4 + \frac{C_L}{2} \ln \left(\frac{\ell}{\ell-x}\right) \quad . \tag{13}
\]

\[
- \int_0^1 P(t) \ln \left| \frac{1 + \sqrt{x(\ell-t)}/t(\ell-x)}{2} \right| dt \quad .
\]

The quantities \( B_1, B_3 \) and \( B_4 \) represent integrals involving the function \( P(x) \). These are obtained in FUNCTION FA and are transmitted through COMMON. The integral in the above equation can be rewritten as

\[
\int_0^1 P(t) \ln \left| 1 + \sqrt{x(\ell-t)}/t(\ell-x) \right| dt = \int_0^1 P(t) \ln \left(\sqrt{t(\ell-x)} + \sqrt{x(\ell-t)}\right) dt
\]

\[
- \frac{1}{2} \int_0^1 P(t) \ln t dt - \frac{C_L}{2} \ln(\ell-x) \quad . \tag{14}
\]

\[
\frac{1}{\pi} \int_0^1 P(t) \ln \left| \frac{1 + \sqrt{x(\ell-t)}/t(\ell-x)}{2} \right| dt = \frac{1}{2} \int_0^1 P(t) \ln t dt - \frac{C_L}{2} \ln(\ell-x) \quad . \tag{14}
\]
The first integral on the right-hand side of the above equation is obtained from subprogram FUNCTION BTX7. The second integral is given by BTG5.

Step 11:

The camber function $\eta(x)$ is obtained from the relation

$$
\eta(x) = \alpha x - \frac{B}{2} + D x + aB \left[ \tan^{-1} \frac{\sqrt{x/(\ell-x)}}{\sqrt{x(\ell-x)}} \right] - E \sqrt{x(\ell-x)} 
$$

$$
+ \frac{m}{2\pi(1+k)} \left( \frac{x}{2} B_3 \right) - \frac{1}{2} \left[ \tan^{-1} \frac{\sqrt{x/(\ell-x)}}{\sqrt{x(\ell-x)}} \right] B_1 + \tan^{-1} \frac{\sqrt{x/(\ell-x)}}{B_4} 
$$

$$
+ \frac{2}{e} \ln \left( \frac{\ell}{\ell-x} \right) - \int_{0}^{1} P(t) \ln \left( 1 - \sqrt{x(\ell-t)/t(\ell-x)} \right) dt \right) . \tag{15}
$$

The quantities $B_1$, $B_3$ and $B_4$ are obtained in FUNCTION FA and are transmitted through COMMON. The logarithmic integral can be rewritten as

$$
\int_{0}^{1} P(t) \ln \left( 1 - \sqrt{x(\ell-t)/t(\ell-x)} \right) dt 
$$

$$
= C_L \ln \left( \frac{\ell}{\sqrt{\ell-x}} \right) + \int_{0}^{1} P(t) \ln(t-x) dt - \frac{1}{2} \int_{0}^{1} P(t) \ln t dt 
$$

$$
- \int_{0}^{1} P(t) \ln(\sqrt{t(\ell-x)} + \sqrt{x(\ell-t)}) dt . \tag{16}
$$

The first integral on the right-hand side of the above equation is given by FTJX, the second by BTG5 and the third by BTX7.

Step 12:

The derivative of the camber function, viz. $\eta'(x)$ is calculated in this step. $\eta'(x)$ is given by the relation
\[ \eta'(x) = a - \frac{B}{2} (1 - 2a \sqrt{x/(l-x)}) - D - \frac{E}{2} \frac{x-2x}{x(x-l-x)} \]

\[ + \frac{\pi}{2} \frac{1}{B_3} \frac{B_3}{2} \frac{1}{x(x-l-x)} \]

\[ + \frac{B_1}{2} \frac{x}{x(x-l-x)} + \frac{1}{2} \sqrt{x(x-l-x)} \]

\[ P \left( \frac{t+\sqrt{x(x-l-x)x}}{x-t} \right) \]

\[ \text{P.V.} \int_0^1 P(t)(t+\sqrt{x(x-l-x)x})/x-t \] dt

The quantities \( B_1, B_3 \) and \( B_4 \) are obtained through \text{COMMON} from \text{FUNCTION} \( \text{FA} \).

The Cauchy principal value of the singular integral is obtained from subprogram \text{FUNCTION} \( \text{CPVI} \).

**Step 13:**

The overall design parameters like \( C_m, C_d, y_c(1), A, B, D \) etc. are printed. The cavity shape, camber shape and the camber derivatives are also printed as functions of \( x \).

**Case B: \( K=0 \)**

In the estimation mode, SECT6 performs Steps 14 through 17. In the design mode, Steps 16 and 18 through 27 are performed.

**Step 14:**

In this step, SECT6 computes the maximum value of \( C_L \) for the case \( K=0 \).

This maximum permissible \( C_L \) corresponds to \( y_c(1)=0 \). The \( C_{L_{\text{max}}} \) is given by

\[ C_{L_{\text{max}}} = \frac{\pi T}{(1-m) \{ 3/2 - \ln(1+\sqrt{x}) \} + m \{ \sqrt{x} \} \} \]

\[ = \frac{\pi T}{1} \int_0^1 \frac{q(x)dx}{\sqrt{x}} \frac{1}{2} \int_0^1 q(x) \ln \left( \frac{1+\sqrt{x}}{1-\sqrt{x}} \right) dx \]

where \( q(x) \) is the normalized pressure function and is defined by

\[ q(x) = \frac{P(x)}{\int_0^1 P(x)dx} \]
Thus

\[ \int_0^1 q(x) \, dx = 1. \]

The first integral in Eq. (18) is calculated using BTG9. The second integral can be rewritten as

\[ \int_0^1 q(x) \ln \left( \frac{1 + \sqrt{x}}{1 - \sqrt{x}} \right) \, dx = 2 \int_0^1 q(x) \ln (1 + \sqrt{x}) \, dx - \int_0^1 q(x) \ln (1 - x) \, dx \quad (20) \]

The first integral on the right-hand side of the above equation is evaluated by FUNCTION BTG8 and the second by FUNCTION PTJX.

**Step 15:**

This step computes the value of \( m \) corresponding to \( y_C(1) = 0 \) for a prescribed \( C_L \). This value of \( m \) is given by

\[
m' = \frac{3\sqrt{2} - \ln (1 + \sqrt{2}) - \frac{\pi}{2} C_L}{\frac{1}{2} \int_0^1 q(x) \, dx + \frac{1}{2} \int_0^1 q(x) \ln \left( \frac{1 + \sqrt{x}}{1 - \sqrt{x}} \right) \, dx}
\]

The integrals in the above equation are computed as described in Step 14.

**Step 16:**

This step computes the quantities \( C_1 \) and \( C_2 \). \( C_1 \) and \( C_2 \) are defined as
\[ C_1 = 2C_L \left\{ \left( 3\sqrt{2} - \ln(1+\sqrt{2}) \right) \left( \frac{1}{2} + \frac{1}{2\sqrt{x_0}} \right) \right. \]
\[ - \left. (1+2\sqrt{x_0}) \sqrt{(1+\sqrt{x_0})} x_0^{-3/4} + \frac{1}{x_0} \ln(x_0^{1/4} + \sqrt{1+\sqrt{x_0}}) \right\} \]
\[ C_2 = C_1 + \int_0^1 P(x) \ln(1 + \frac{x}{\sqrt{x}}) \, dx \quad - \frac{1}{x_0} \int_0^1 P(x) \ln(1 + \frac{\sqrt{x}}{x_0}) \, dx \]
\[ - \frac{1}{2} \left( 1 - \frac{1}{x_0} \right) \int_0^1 P(x) \ln 1 \, dx . \quad (22) \]

The quantity \( C_2 \) can be rewritten as
\[ C_2 = \frac{1}{\sqrt{x_0}} \int_0^1 P(x) \ln(1 + \sqrt{x}) \, dx - \frac{1}{x_0} \int_0^1 P(x) \ln(\sqrt{x} + \sqrt{x_0}) \, dx + C_1 \]
\[ - \frac{1}{2} \left( 1 - \frac{1}{x_0} \right) \int_0^1 P(x) \ln 1 \, dx + \left( \frac{1}{2} - \frac{1}{2\sqrt{x_0}} \right) \int_0^1 P(x) \ln(1-x) \, dx . \quad (23) \]

The first and the second integrals in the above equation are computed by SUBROUTINE BTG8, the second by SUBROUTINE BTG5 and the third by SUBROUTINE FTJX.

**Step 17:**

This step computes \( \mu \) for a given \( m \) in the estimation mode. \( \mu \) is given by
\[ \mu = \frac{(m \, C_2 - C_1) \, x_0}{2\pi T} + \frac{x_0 + \sqrt{x_0}}{2} . \quad (24) \]

**Step 18:**

The value of \( m \) is calculated in this step for a given \( \mu \) in the design mode. \( m \) is given by
Step 19:

The value of $y_c(1)$ is computed from the formula

$$y_c(1) = \frac{T}{2} - \frac{(1-m)C_L}{2\pi} \left[ 3\sqrt{2} - \ln(1+\sqrt{2}) \right]$$

$$- \frac{m}{2\pi} \left\{ \int_0^1 \frac{P(x)dx}{\sqrt{x}} - \frac{1}{2} \int_0^1 P(x) \ln(\frac{1+\sqrt{x}}{1-\sqrt{x}}) dx \right\} . \quad (26)$$

The first integral in the above equation is given by BTG9 and the second is computed as described in Step 14.

Step 20:

The value of $\alpha$, the design attack angle, is computed in this step from the relation

$$\alpha = \frac{2(1-m)C_L}{\pi} + y_c(1) + \frac{m}{2\pi} \left\{ \int_0^1 \frac{P(x)dx}{\sqrt{x}} + \int_0^1 P(x) \ln(1 - \frac{1}{\sqrt{x}}) dx \right\} . \quad (27)$$

The first integral in the above equation is given by BTG9. The second can be rewritten as

$$\int_0^1 P(x) \ln(1 - \frac{1}{\sqrt{x}}) dx = \int_0^1 P(x) \ln(1-x) dx - \frac{1}{2} \int_0^1 P(x) \ln x dx$$

$$- \int_0^1 P(x) \ln(1 + \sqrt{x}) dx \quad . \quad (28)$$

The first integral on the right-hand side of the above equation is given by FTJX, the second by BTG5 and the third by BTG8.
Step 21:

The drag coefficient $C_D$ is computed in this step from the relation

$$C_D = \frac{1}{2\pi} \left\{ 2(1-m)C_L + \frac{m}{2} \int_0^1 \frac{P(x)dx}{\sqrt{x}} + \pi y_c(1) \right\}^2. \quad (29)$$

The integral in the above equation is given by BTG9.

Step 22:

The moment coefficient $C_M$ is obtained from

$$C_M = -(1-m) \frac{5}{16} C_L - m \int_0^1 P(x) x \, dx. \quad (30)$$

The integral in the above equation is computed by FUNCTION BICM.

Step 23:

The value of $\bar{V}_1(0)$ needed by the off-design calculations is computed in this step. $\bar{V}_1(0)$ is given by

$$\bar{V}_1(0) = \alpha - 2(1-m) \frac{C_L}{\pi}. \quad (31)$$

Step 24:

This step computes the cavity shape $y(x)$ for points along the chord for the case $K=0$. This is given by

$$y(x) = \alpha x + \frac{(1-m)C_L}{\pi} \left\{ (1+2\sqrt{x}) x^{1/4} \sqrt{1+\sqrt{x}} - 2x - \ln(x^{1/4} + \sqrt{1+x}) \right\}$$

$$+ y_c(1) \frac{1}{\sqrt{x}} \left[ \int_0^1 \frac{P(t)dt}{\sqrt{t}} - \int_0^1 P(t) \ln(1 + \sqrt{x}) \, dt \right]. \quad (32)$$
The first integral is given by BTG9 and the second can be rewritten as

$$\int_0^1 P(t) \ln(1 + \sqrt{\frac{x}{t}}) dt = \int_0^1 P(t) \ln(\sqrt{t} + \sqrt{x}) dt - \frac{1}{2} \int_0^1 P(t) \ln t \, dt \quad (33)$$

The first integral on the right-hand side of the above equation is given by BTG8 and the second by BTG5.

**Step 25:**

In this step, the camber shape of the hydrofoil is obtained from the result

$$\eta(x) = (a - \frac{2(1-m)c_L}{\pi})x - y_c(1) \sqrt{x} - \frac{\sqrt{x}}{2\pi} m \int_0^1 \frac{P(t)dt}{\sqrt{t}}$$

$$- \frac{m}{2\pi} \int_0^1 P(t) \ln \left(1 - \frac{\sqrt{x}}{\sqrt{t}}\right) dt \quad (34)$$

The first integral in the above formula is given by BTG9 and the second can be rewritten as

$$\int_0^1 P(t) \ln \left(1 - \frac{\sqrt{x}}{\sqrt{t}}\right) dt = \int_0^1 P(t) \ln(1-x) dx - \frac{1}{2} \int_0^1 P(t) \ln t \, dt$$

$$- \int_0^1 P(t) \ln (\sqrt{t} + \sqrt{x}) dt \quad (35)$$

The first integral on the right is given by FTJX, the second by BTG5 and the third by BTG8.

**Step 26:**

The slope of the camber function is needed by the off-design calculations and this is given by
\[ \eta'(x) = a - \frac{2(1-m)}{\pi} c_L - \frac{y_C(1)}{2\sqrt{x}} + \frac{m}{4\pi \sqrt{x}} \{ \text{P.V.} \left[ \frac{1}{\sqrt{t-x}} \int_{0}^{1} p(t)dt \right] - \frac{1}{\sqrt{t}} \int_{0}^{1} p(t)dt \} \]  

(36)

The Cauchy Principal value integral in the above equation can be rewritten as

\[ \int_{0}^{1} \frac{p(t)dt}{\sqrt{t-x}} = \int_{0}^{1} \frac{p(t)(\sqrt{t-x})}{t-x} dt \]  

(37)

The integral on the right is evaluated by function CPVI.

**Step 27:**

The overall design parameters like \( K, C_L, T, CM, CD, \) etc. are outputted in this step. The cavity shape, camber shape and the camber slope are also outputted.

**SUBROUTINE EST**

This subroutine computes the limiting values or "estimates" the parameter \( \mu \) for prescribed \( C_L \) and other input variables. These estimates are obtained in two steps.

**Step 1:**

The maximum values of \( C_L \) are obtained at \( m=0 \) and \( m=1 \). These are designated as \( C_{L0} \) and \( C_{L1} \) respectively. The maximum \( C_L \) is obtained by setting \( m \) to the required value. The program switches NEST and NCLM are set to 1 and the subroutine SECT6 is called. The maximum \( C_L \) is obtained through COMMON upon return from SECT6.

**Step 2:**

The limiting value of \( \mu \) is obtained for a specified \( m \) and \( C_L \) in this step. The switch NEST is set to 1 and the switches NEM and NCLM are set
to 0. Various cases arise depending on the value of $C_L$.

**Case a:**

$$C_L \leq \min (C_{L0}, C_{L1})$$

The limiting $\mu$ values are those corresponding to $m=0$ and $m=1$. These are obtained by calling SUBROUTINE SECT6.

**Case b:**

$$C_L < \max (C_{L0}, C_{L1})$$

In this case the diagnostic message "Design $C_L$ is greater than maximum permissible $C_L$" is printed and the control is returned to the calling routine.

**Case c:**

$$C_{L1} \leq C_L \leq C_{L0}$$

In this case the switch NEM is set to 1 and the value of $m'$ in Eq. (39) is obtained from SECT6. The limiting values of $\mu$ correspond to $m=m'$ and $m=0$.

**Case d:**

$$C_{L0} \leq C_L \leq C_{L1}$$

The value of $m'$ is obtained from Eq. (39) by setting NEM=1 and calling SECT6. The limiting values of $\mu$ correspond to $m=m'$ and $m=1$. 
SUBROUTINE FA

This subroutine computes the limiting values of $C_L$ and $\mu$ and also calculates the appropriate functions $f(a)$ for the iterative solution of the equation $f(a)=0$.

Step 1:

The parameters $\varepsilon$ and $\delta$ are computed from

$$\left\{ \begin{array}{c} \delta \\ \varepsilon \end{array} \right\} = \left[ \sqrt{\lambda} + 1 \right]^{1/2} \pm \left[ \sqrt{\lambda} - 1 \right]^{1/2}$$

(3)

where $\lambda = 1 + a^2$.

Step 2:

This step computes the limiting value of $C_L$ for a given $m$. This is given by

$$C_L = \frac{2\pi (1+K) \beta \ell}{(1-m) \left( \frac{2a+3}{\delta - a\varepsilon} + \frac{1}{\delta - a\varepsilon} \right)} + m \int \frac{q(x)}{\sqrt{\lambda - x}} \, dx$$

(38)

where $q(x)$ is the normalized pressure distribution defined by

$$q(x) = \frac{P(x)}{\int_0^1 P(x) \, dx}.$$ 

Step 3:

This step computes the value of $m$ corresponding to $y_c(1)=0$ for a given $C_L$. This is obtained from
\[ m' = \frac{B_2 \pi (1+K) \xi / C_L - T_1}{\int_0^{\sqrt{(\xi-x)/x}} q(x)dx - T_1} \] (39)

where

\[ T_1 = \frac{(2a^2 + 3) \varepsilon + \alpha \delta}{\delta - a \varepsilon} \]

**Step 4:**

The following integrals are evaluated in this step. The values of these integrals are made available to other subprograms through COMMON,

\[ B_1 = \int_0^1 \frac{P(x)dx}{\sqrt{x(\xi-x)}} \] (40)

\( B_1 \) is computed by FUNCTION BINT1.

\[ B_2 = \int_0^1 \frac{P(x) \sqrt{(\xi-x)/x} dx}{x} \] (41)

\( B_2 \) is given by FUNCTION BTG1.

\[ B_3 = \int_0^1 \frac{P(x)dx}{(\xi-x)} \] (42)

\( B_3 \) is obtained from FUNCTION BINT3.

\[ B_4 = \int_0^1 \frac{P(x) \sqrt{x/(\xi-x)} dx}{x} \] (43)

\( B_4 \) is obtained from FUNCTION BINT4.
\[ B_5 = \int_0^1 P(x) \frac{(x-2x)dx}{\sqrt{x(x-x)}} = LB_1 - 2B_4 \]  
\[ (44) \]

\[ B_6 = \int_0^1 P(x)dx = C_L \]  
\[ (45) \]

\[ B_7 = \int_0^1 P(x) \ln \left| \frac{a\sqrt{x} - \sqrt{x-x}}{a\sqrt{x} + \sqrt{x-x}} \right| dx \]  

\[ B_7 \text{ can be rewritten as} \]

\[ B_7 = C_L \ln(x) + \int_0^1 P(x) \ln|a-1|dx \]

\[ - 2 \int_0^1 P(x) \ln(a\sqrt{x} + \sqrt{x-x}) dx \]  
\[ (46) \]

The first integral in the above equation is computed from FUNCTION FTJX, and the second by FUNCTION BTX7.

**Step 5:**

The quantities \( H_\eta \) and \( F_\eta \) are computed in this step. These are given by

\[ H_\eta = \frac{C_L 4a^2}{(\delta - a\varepsilon)} \frac{\sqrt{x-1}}{F_1(1,a) + \{a - \varepsilon \tan^{-1} \left( \frac{1}{a} \right) \} C_L \frac{\varepsilon + a\delta}{2(\delta - a\varepsilon)}} \]

\[ - \frac{a}{L} C_L \frac{(2a^2 + 3)\varepsilon + a\delta}{\delta - a\varepsilon} + \frac{a}{L} B_2 - \frac{1}{2\delta} \{a - \varepsilon \tan^{-1} \left( \frac{1}{a} \right) \} B_5 \]

\[ - \frac{1}{2} \{a + \varepsilon \tan^{-1} \left( \frac{1}{a} \right) \} B_1 + \tan^{-1} \left( \frac{1}{a} \right) B_4 - \frac{B_7}{2} \]  
\[ (47) \]
\[ F_\eta = T - 2a \beta - \frac{C_L}{\pi(1+K)} \frac{4a^2 \sqrt{a}}{(\delta - \alpha \varepsilon)} F_1(1,a) \]

\[ - \frac{C_L}{\pi(1+K)} \left\{ a - \ell \tan^{-1} \left( \frac{1}{a} \right) \right\} \frac{\varepsilon + a \delta}{\ell (\delta - \alpha \varepsilon)} \]

\[ + \frac{C_L}{\pi(1+K)} \frac{a}{\ell} \frac{(2a^2 + 3) \varepsilon + a \delta}{\delta - \alpha \varepsilon} . \] (48)

The function \( F_1(x,a) \) is obtained from F1FUNC.

Step 6:

The quantities \( H_t \) and \( F_t \) are computed from the equations

\[ H_t = C_L \frac{4a^2 \sqrt{a}}{(\delta - \alpha \varepsilon)} \{ F_1(1,a) - \frac{F_1(x_o,a)}{x_o} \} \{ a - \sqrt{\frac{\ell - x_o}{x_o}} - \ell \tan^{-1} \left( \frac{1}{a} \right) \}

\[ + \frac{\ell}{x_o} \tan^{-1} \frac{\sqrt{x_o/(\ell - x_o)}}{2} \frac{C_L}{\ell (\delta - \alpha \varepsilon)} \frac{\varepsilon + a \delta}{2} + \frac{B}{2 \ell} - \frac{C_L}{2} \frac{(2a^2 + 3) \varepsilon + a \delta}{\ell (\delta - \alpha \varepsilon)} \]

\[ \times (a - \sqrt{\frac{\ell - x_o}{x_o}}) + \frac{1}{2} \left\{ G(1,a;P) - \frac{G(x_o,a;P)}{x_o} \right\} . \] (49)

\[ F_t = T - \frac{C_L}{\pi(1+K)} \frac{4a^2 \sqrt{a}}{(\delta - \alpha \varepsilon)} \{ F_1(1,a) - \frac{F_1(x_o,a)}{x_o} \}

\[ - \{ a - \sqrt{\frac{\ell - x_o}{x_o}} - \ell \tan^{-1} \left( \frac{1}{a} \right) + \frac{\ell}{x_o} \tan^{-1} \frac{\sqrt{x_o/(\ell - x_o)}}{2} \frac{C_L}{2\pi(1+K)} \frac{\varepsilon + a \delta}{\ell (\delta - \alpha \varepsilon)} \}

\[ - \{ \beta - \frac{C_L}{2\pi(1+K)} \frac{(2a^2 + 3) \varepsilon + a \delta}{\ell (\delta - \alpha \varepsilon)} \{ a - \sqrt{\frac{\ell - x_o}{x_o}} \} \} . \] (50)

The function \( F_1(x,a) \) is obtained from F1FUNC. The function \( G(x,a;P) \) is given in Eq. (13).
Step 7:

This step is executed if the program is in the estimation mode (NEST=1).

This step computes the appropriate function \( f(a) \) used in the iterative solution for \( a \). \( f(a) \) is given by

\[
f(a) = F_\eta + \frac{m}{\pi(1+K)} H_\eta
\]

The corresponding value of \( \mu \) is obtained from

\[
\mu = \frac{x^o}{t} \{ f_t + \frac{m}{\pi(1+K)} H_t \}
\]

The control returns to the calling routine.

Step 8:

This step is executed if the program is in the design mode (NEST=0).

The function \( f(a) \) is given in this case by

\[
f(a) = F_\eta H_t - (f_t - \frac{u_t}{x^o}) H_\eta
\]

The corresponding value of \( m \) is obtained from

\[
m = - F_\eta \pi(1+K)/H_\eta
\]

The control is now returned to the calling routine.

FUNCTION CPVI

The function subprogram CPVI evaluates the following Cauchy Principal value integral
\[ J = \int_{x_1}^{x_N} \frac{P(t) g(t,x) dt}{t-x} \]  

(55)

where

\[ g(t,x) = (\sqrt{t-x} + \sqrt{x(t-x)}) \sqrt{t-x} \], \( K \neq 0 \)

\[ = (\sqrt{t} + \sqrt{x}) \], \( K = 0 \).

The value of \( x \) and its index \( I \) in an array of \( x \) values are inputted to the subprogram CPVI. Various cases arise depending on the value of \( I \).

**Case A:** \( I = 1 \)

In this case, we write

\[ P(t) g(t,x) = a_1(t-x) + a_2(t,x)^2 \], \( x_1 \leq t \leq x_3 \).

Since

\[ P(x) = 0 \] for \( I = 1 \).  \hspace{1cm} (56)

The values of \( a_1 \) and \( a_2 \) are obtained from DIFF5. The integral \( J \) can be written as

\[ J = \int_{x_1}^{x_1+2h} [a_1 + a_2(t-x_1)] dt + \int_{x_1}^{x_N} \frac{P(t) g(t,x)}{(t-x)} dt. \]  

(57)

The first integral is evaluated as
The second integral is evaluated by subprogram DIFF2.

Case B: \( I = 2 \)

In this case, we write,

\[
P(t) g(t, x) = a_0 + a_1(t-x) + a_2(t-x)^2 , \quad x_1 \leq t \leq x_3
\]

(59)

where the coefficients \( a_0, a_1 \) and \( a_2 \) are obtained from DIFF5. The integral can be written as

\[
J = \int_{x_1}^{x_1+2h} [a_0 + a_1(t-x) + a_2(t-x)^2] \, dt + \int_{x_1}^{x_1+2h} P(t) g(t, x) \, dt
\]

(60)

The value of the first integral is given by function \( F(x_1, x, x_1+2h, a_0, a_1, a_2) \) where \( F \) is defined as

\[
F(x_1, x, x_1, q_0, q_1, q_2) = q_0 \ln \left( \frac{x-u}{x_1-x} \right) + q_1(x_u-x_1)
\]

\[
+ \frac{q_2}{2} \left[ (x-x_1)^2 - (x_u-x)^2 \right]
\]

(61)

The second integral can be evaluated by DIFF2.

Case C:

\[
3 \leq I \leq N-3
\]

In this case, the integral \( J \) is written as
The first and the third integrals in the above equation are evaluated by DIFF2. The second integral is given by 

\[ F(x_{i-1}, x, x_{i+1}, a_0, a_1, a_2) \]

where the constants \( a_0, a_1 \) and \( a_2 \) are defined by the relation

\[ P(t) g(t, x) = a_0 + a_1(t-x) + a_2(t-x)^2 \]

for \( x_{i-1} \leq t \leq x_{i+1} \). \( \quad (63) \)

**Case D:** \( I=N-2 \)

The integral \( J \) is written as

\[ J = \int_{x_1}^{x_{i-1}} \frac{P(t) g(t, x)}{t-x} \, dt + \int_{x_{i+1}}^{x_N} \frac{a_0}{t-x} + a_1 + a_2(t-x) \, dt \]

\[ + \int_{x_{i+1}}^{x_N} P(t) g(t, x) \, dt \]

\[ \quad (62) \]

where \( b_0, b_1, b_2 \) are obtained from the parabolic fit

\[ P(t) g(t, x) = b_0 + b_1(t-x) + b_2(t-x)^2 \]

for

\[ x_{N-3} \leq t \leq x_{N-1} \]

\( \quad (65) \)
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\[ P(t) g(t,x) = c_0 + c_1(t-x) + c_2(t-x)^2 , \quad x_{N-2} \leq t \leq x_N . \]

The first integral in Eq. (64) is evaluated by DIFF2 and the second and the third integrals are given by function F in Eq. (61).

**Case E:** \( I=N-1 \)

In this case the integral \( J \) is given by

\[
J = \int_{x_1}^{x_{N-2}} \frac{P(t) g(t,x) dt}{t-x} + \int_{x_1}^{x_N} \left[ \frac{b_0}{t-x} + b_1 + b_2(t-x) \right] dt \tag{66}
\]

where \((b_0, b_1, b_2)\) are obtained from the approximation

\[ P(t) g(t,x) = b_0 + b_1(t-x) + b_2(t-x)^2 , \quad x_{N-2} \leq t \leq x_N . \tag{67} \]

The first integral in Eq. (66) is given by DIFF2 and the second by function F of Eq. (61).

**Case F:** \( I=N \)

In this case, the integral can be written as

\[
J = \int_{x_1}^{x_{N-2}} \frac{P(t) g(t,x) dt}{t-x} + \int_{x_1}^{x_N} [b_1 + b_2(t-x)] dt \tag{68}
\]

where the constants \( b_1 \) and \( b_2 \) are obtained from the approximation

\[ P(t) g(t,x) = b_1(t-x) + b_2(t-x) , \quad x_{N-2} \leq t \leq x_N \tag{69} \]

which satisfies the condition \( P(x_N) = 0. \)
The first integral in Eq. (68) is given by DIFF2 and the second is given by

\[
\int_{x_{N-2}}^{x_N} [b_1 + b_2(t-x)] dt = 2h(q_1 - q_2 h) \quad .
\]  

(70)
References


COMPUTER PROGRAM FOR THE DESIGN OF
HYDROFOILS WITH TWO POINT CAVITY THICKNESS CONTROL

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MAIN LINE PROGRAM FOR THE THIRD DESIGN PROCEDURE (SECT6)

THIS PROGRAM READS THE INPUT DATA AND CALLS THE PRINCIPAL
ROUTINE SECT6 FOR THE HYDROfoil DESIGN WITH TWO POINT
CAVITY THICKNESS CONTROL.

JUNE 15, 1977

DICTIONARY OF SYMBOLS

A IS THE CAVITY PARAMETER LITTLE A.
ACAP IS THE 'NOSE SINGULARITY' PARAMETER CAPITAL A.
FUNCTIONS F1(NU, A), F2(NU, A), L(NU, A), AND T(NU, A)—SEE SECT5.
ALEFT AND ARITE ARE END-PTS. OF A-INTERVAL FOR REGULUS FALSI ROUT.
ALP IS THE TABLE OF ATTACK ANGLES COMPUTED IN THE OFF-DESIGN CALC.
ALPHA IS THE ATTACK ANGLE (RADIANs)
AMDA IS A UNIVERSAL FUNCTION BOUND USED TO SET SUBINTERVAL LENGTHS
ANU IS THE RATIO OF CAVITY THICKNESSES AT XO AND THE TRAILING EDGE
AONE IS THE FUNCTION A1(A) NEEDED TO COMPUTE SIG1—SECT5.
ASQ IS A**2.
ATJO IS A2(A) REQUIRED BY SIG2.
A1 IS THE CAVITY PARAMETER FOR THE FIRST FOIL (SHOCKLESS ENTRY).
A2 IS THE CAVITY PARAMETER FOR THE SECOND FOIL (NOSE SINGULARITY)
BB IS LITTLE B, THE COEFFICIENT OF THE 'SQUARE ROOT' BEHAVIOR TERM
BET1 AND BET2 ARE FUNCTIONS OF OUGSQ AND A.
BETA AS A VARIABLE IS COMPUTED IN SECT5, = MAX((TAU-SIG2)/SIG1).
BINT IS THE PARAMETER CAPITAL B.
BONE IS B1(A) REQUIRED BY SIG1.
BTJO IS B2(A) REQUIRED FOR SIG2—SECT5.
CAY IS THE CAVITATION NUMBER.
CD IS THE DRAG COEFFICIENT.
CL IS THE LIFT COEFFICIENT.
CM IS THE MOMENT COEFFICIENT.
C0 IS THE FIRST TERM OF FOURIER EXPANSION.
DELTA IS A SPECIAL FUNCTION OF THE CAVITY LENGTH FLL.
DELT1 IS A*BET1/2/OMGSQ.
DELT2 IS A*BET2/2/OMGSQ.
DINT IS THE PARAMETER CAPITAL D.
DLPHA IS THE ATTACK ANGLE IN DEGREES.
DROIT IS THE RIGHT-HAND END-PT. OF SUBINTERVAL COMMUNICATED
TO REGUL THROUGH THE SUBROUTINE LIST.
ECAP IS THE PARAMETER CAPITAL E OF THE ‘SHOCKLESS ENTRY’ CASE.
ELL IS THE CAVITY LENGTH = A**2+1.
EM IS THE PRESSURE FUNCTION MULTIPLIER COMPUTED FOR 2ND. FOIL
EPSILN IS A SPECIAL FUNCTION OF THE CAVITY LENGTH.
ETAL, ETA2, ETA3 ARE FUNCTION VALUES AT XC1, XC2, AND XC3.
ETN1 IS THE CAMBER FUNCTION FOR THE FIRST FOIL.
ETN2 IS THE CAMBER FUNCTION FOR THE SECOND FOIL.
ETP1 IS THE DERIVATIVE OF THE 1ST. CAMBER FUNCTION.
ETP2 IS THE DERIVATIVE OF THE 2ND. CAMBER FUNCTION.
ETPR1 IS THE DERIVATIVE AS COMPUTED BY DIFFER.
FX IS THE TABLE OF ORDINATES NEEDED BY THE INTEGRATION ROUT. NTGR
G IS THE PRESSURE MINUS THE SQ. ROOT TERM - G=P-BB*(1-X)**.5.
GAM1, GAM2 ARE FUNCTIONS OF SMGSQ, A, BET1, BET2.
GAUCHE IS THE LEFT-HAND END PT. OF THE SUBINTERVAL CONTAINING.
ROOT - SUBINTERVAL IS COMMUNICATED TO REGUL.
H IS THE MAPPING OF G UNDER THE MAPPING OF THE Z-PL. TO THE NU-PL.
IFOLS1 IS A FLAG USED IN SECT5 = 1,2 FOR 1ST, 2ND FOILS, RESP.
II IS SUBSCRIPT OF X DURING EVALUATION OF FOIL FUNCTIONS
NA IS THE NUMBER OF LITTLE A VALUES - CAVITY PARAMETER VALUES - INPUT
FOR THE OFF DESIGN CALCULATION.
NM IS THE NO. OF ORDINATES WHICH IS REQUIRED BY NTGRTE.
NN IS THE NUMBER OF MESH POINTS IN INTERVAL (0,1).
NSCH=1 FOR NEXT CASE P=CONST., =2 FOR NEXT CASE NONCONST. P,
=4 FOR NO MORE DATA
OMGSQ IS A*SELL
ONE IS THE INTEGRAL OF G(X) OVER (0,1).
P IS THE INPUT PRESSURE FUNCTION DEFINED OVER (0,1), (Z-PLANE).
PCON IS THE VALUE OF THE INPUT PRESSURE FOR A CONST. P CASE.
Q IS THE TRANSFORMED P UNDER MAPPING FROM Z TO NU PLANES.
SALL IS SQ. ROOT OF A*ELL
SELL IS S) ROOT OF ELL
SIG1 IS THE FUNCTION SIGMA1(X,A)--OFF-DESIGN CALCULATION.
SIG2 IS THE FUNCTION SIGMA2(X,A)--FOR THE OFF-DESIGN CALCULATION.
TAU IS REDUCED CAVITY USED IN OFF-DESIGN CALCULATION.
TEE IS THE STRENGTH PARAMETER APPLIED AT THE TRAILING EDGE.
THETA IS THE CAVITY CONTOUR MULTIPLIER USED IN THE OFF-DESIGN CALC
THR IS THE INTEGRAL OF H(T) OVER (0,1)--IN NU-PLANE.
T11, T12, T13, T14 ARE SPECIAL INTEGRALS COMPUTED BY T11FN, T12FN, T13F
N, T14FN FOR SECT5 FOR THE FINITE CAVITY CASE.
T15, T16 ARE SPECIAL INTEGRALS COMPUTED BY T15FN, T16FN FOR THE
INFINITE CAVITY CASE (CAY=0) OF SECT5.
T2O IS THE INTEGRAL OF X*G(X) OVER (0,1).
WA IS THE FUNCTION W(X) COMPUTED IN SECT5--NEEDED FOR ALPHA.
X IS THE INDEPENDENT VARIABLE. P IS INPUT AS FUNCT. OF X IN (0,1).
XC0, XC1, XC2, XC3 SPECIFY PTS. IN (0,1) FOR QUADRATIC FIT BY PARAB
XH IS THE STEP-SIZE -- XH*(NN-1) = 1.
XKZ IS IMAGE OF X UNDER MAPPING OF Z-PL. TO NU-PL. --
= A*(X/(ELL-X))**.5.
X0 IS THE THICKNESS CONTROL POINT NEAR THE LEADING EDGE
XSQ IS X**2.
HYDROFOIL DESIGN PROGRAM

C YYU1 IS THE CAVITY FUNCTION FOR THE FIRST FOIL.
C YYU2 IS THE CAVITY FUNCTION FOR THE SECOND FOIL.

C INPUT DATA
  FIRST CARD
  NSWCH - SET TO ONE (1) FOR CONSTANT PRESSURE CASE
  - SET TO TWO (2) FOR NORMAL PRESSURE CASE
  IPUNCH - ZERO (0) - NO PUNCH
  - ONE (1) FOR PUNCHED OUTPUT
  KWI T - ZERO (0) - RUN OFF DESIGN CONDITIONS
  - ONE (1) FOR OFF-DESIGN CALCULATIONS
  UPP ER - ONE - UPPER SURFACE CONTOUR IS TO BE CHECKED FOR
    INTERFERENCE WITH CAVITY
  IPRNT - ZERO (0) PRINTS OVERALL DESIGN PARAMETERS ONLY.
  - ONE (1) PRINTS DETAILED RESULTS LIKE CAVITY SHAPE ETC.
  NEST - ONE (1) FOR ESTIMATION MODE
  - ZERO (0) FOR DESIGN MODE.

C SECOND CARD
  NN - NUMBER OF INPUT POINTS ON PRESSURE CURVE

C THIRD CARD
  XH - DELTA X INCREMENTS ALONG THE CHORD LINE
  AMDA - LAMDA FUNCTION USED TO LIMIT INTEGRATION
  BB - COEFFICIENT OF SQUARE ROOT BEHAVIOR
  STEP - STEP SIZE IN THE SEARCH FOR A
  AHX - MAXIMUM VALUE FOR A

C FOURTH CARD
  NA - NUMBER OF OFF-DESIGN CAVITY LENGTH VALUES TO BE COMPUTED

C FIFTH CARD
  AA(I) - ARRAY FOR CAVITY LENGTH VALUES

C SIXTH CARD
  ITHET - NUMBER OF THETA VALUES TO BE COMPUTED

C SEVENTH CARD
  THET(I) - ARRAY FOR THETA VALUES

C NEXT NN/8 CARDS
  SUPPER(I) - ARRAY FOR COORDINATES OF UPPER SURFACE

C NEXT NN CARDS
  X(I) - ARRAY CONTAINING INCREMENTS OF CHORD SPACING
  PP(I) - ARRAY OF PRESSURE DIAGRAM POINTS CORRESPONDING TO EACH X

C NEXT TWO CARDS FOR AS MANY CASES AS ARE TO BE RUN
  KAY - DESIGN CAVITATION NUMBER
  CL - DESIGN LIFT COEFFICIENT
  TEE - MAXIMUM CAVITY THICKNESS AT TRAILING EDGE
  S - PEAK PRESSURE LOCATION

C NEXT CARD
  NHU - NUMBER OF MU VALUES
  AMUV - ARRAY CONTAINING THE MU VALUES

C REAL KAY(50)
REAL LAMDA
DIMENSION AMUV(5)
DIMENSION PP(101)
COMMON P(101), C(101), Q(101), H(101), X(101), XSQ(101), FX(101), ETN1(101)
                        ETN2(101), ETP1(101), ETP2(101), YYU1(101), YYU2(101), TAU(101)
                        ,ALP(2101), DEC(101), AA(50), KAY, CAY, A, A1, A2, ACAP, ALPHA, AMDA, ASQ
          ,RR, BINT, C30, CL, CM, DELTA, DINT, ECAP, ELL, EM, EPSILN, ETA1, ETA2, ETA3, TEE, OKE, T40,
          T4HR, THETA, TSAVE, XG0, XG1, XG2, XG3, XH, XKZ, NM, NN, JL6, JM6, JR6, JL13, JM13,
HYDROFOIL DESIGN PROGRAM

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5JR13, JTT1, JTM1, JTT2, JTM2, JTT3, JTM3, JTT4, JTM4, JTT5, JTM5, JTT7, JTM7, JTT8, JTM8, JTT9, JTM9, JTT10, JTM10, JTT11, JTM11, JTT12, JTM12, JTT21, JTM21
J7, JTT23, JTM23, JTT24, JTM24, JTT25, JTM25
COMMON /BLK1/VIBAR,VIBAR1,ECAP1,YC12
COMMON /BLK2/LAMDA,S,IPUNCH,IERROIPRNT
COMMON /BLK3/SEL1
COMMON /BLK4/NA,ALPA(8),THET(8),IUPPER,SUPPER(101)
COMMON /BLK6/AMU, XO, K,ACL,T,B1,B2,B3,B4,B5,B6,B7,FT,HT,EPSSN,DNM,P
COMMON /BLK7/NS,QA,F11,FIXO,BETA,FE,HETA,NEND,IXO,NCLM,NEST,NEM
COMMON /BLK8/STEP,AMX
C
COMMON /BLK9/AMO,AM1,IMU,EM0,EM1,MSI

C
100 FORMAT (10I2)
110 FORMAT (10I3)
120 FORMAT (5F10.5)
130 FORMAT (2F15.5)
140 FORMAT (36H1)
150 FORMAT (36H1)

LISTING OF INPUT DATA FOLLOWING NO. OF GRID-IPTS. NN=11,17H STEP-SIZE XH=E16.8,24H FUNCTION BOUND AMDA=E1
45X,'S— ' ,F7.3, 'XO= ' ,F7.3)

C
SECTION I. INPUT SECTION
READ (5,100) NSCH,IPUNCH,KJIT,IUPPER,IPRNT,NEST
PI=3.141593
PCON=1.0
IF (NSJCH—3) 170,160,160
160 CALL EXIT
170 READ (5,110) NN,NMU
180 READ (5,120) XH,AMDA,BB,STEP,AMX
190 IF (KJIT) 180,230,180
180 READ (5,210) NA,(AA(I),I=1,NA)
200 DO 190 I=1,8
190 ALPA(I)=FLOAT(I)
210 IF (IUPPER) 220,200,220
200 READ (5,210) ITHET,(ITHET(I),I=1,ITHET)
GO TO 230
210 FORMAT (15,/(8F10.5))
220 READ (5,150) (SUPPER(I),I=1,NN)
230 IF (NSJCH—1) 240,240,260
240 READ (5,120) PCON
X(I)=0.0
250 CONTINUE
P(1)=PCON
P(NN)=PCON
260 CONTINUE
GO TO 270
270 READ (5,130) (X(I),P(I),I=1,NN)
READ (5,120) KAY(1),CL,TEE,S
CAY=KAY(1)
LAMDA=0.05
NNN=NN—1
XO=0.1
HYDROFOIL DESIGN PROGRAM

EPS=1.0E-6
IMU=1
280 FORMAT (I10,7F10.5)
MH=1
IF (NEST.EQ.1) GO TO 300
MU=0
READ 280, NMU, (AMUV(I), I=1,NMU)
290 MU=MU+1
IF (MU.GT.NMU) GO TO 370
IF (MS4.EQ.0) AMU=AMUV(MU)
IF (MS4.EQ.1) EM=AMUV(MU)
300 NEND=NN
IXO=11
C SECTION II. SQUARE ROOT BEHAVIOR.
IF (NS4CH-1) 310,310,330
310 DO 320 I=1,NN
G(I)=P(I)
320 CONTINUE
BB=0.0
GO TO 350
330 DO 340 I=1,NN
H(I)=P(I)/CL
340 G(I)=P(I)-BB*SQRT(1.0-X(I))
350 WRITE (6,140) NN,XH,AMDA,BB,KAY(1),CL,TEE,S,XO
C WRITE (6,150) (I,X(I),P(I),C(I),I=1,NN)
IF (NEST.EQ.1) GO TO 360
NCLM=0
NEM=0
CALL SECT6
GO TO 290
360 CALL EST
370 CONTINUE
GO TO 270
C CALL SECT4 (NS4CH,PCON,KJIT)
IF (KJIT.EQ.0.OR.IERROR.EQ.1) GO TO 270
C CALL SECT5 (NS4CH,PCON)
GO TO 270
END

SUBROUTINE EST
REAL KAY(50),X
COMMON P(101),G(101),Q(101),H(101),X(101),XSQ(101),FX(101),ETN1(10
11),ETN2(101),ETP1(101),ETP2(101),YYU1(101),YYU2(101),TAU(101),ALP(2101),DEE(101),AA(50),KAY,CAY,DUM,A1,A2,ACAP,ALPHA,AMDA,ASQ, BB,BINT
3,CO,CL,CM,DELTA,DINT,ECAP,ELL,EM,EPSLN,ETA1,ETA2,ETA3,TEE,ONE,TIO
4,THR,THETA,TSAVE,XC0,XC1,XC2,XC3,XH,XKZ,NN,NN,JL6,JM6,JR6,JL13,JM1
53,JR13,JTT1,JTM1,JTT2,JTM2,JTT3,JTM3,JTT4,JTM4,JTT5,JTM5,JTT7,JTM7
6,JTT8,JTM8,JTT9,JTM9,JTT10,JTM10,JTT11,JTM11,JTT12,JTM12,JTT21,JTM
721,JTM23,JTM24,JTM25,JTT25,JTM25
COMMON /BLK6/AMU,XO,K,ACL,T,B1,B2,B3,B4,B5,B6,B7,FT,HT,EPSLN,DMIN,P
11,TIASQ,SQA,F11,FIXO,BETA,FE,HETA,NEND,IXO,NCLM,NEST,NEM
COMMON /BLK2/LAMDA,S,IPUNCH,IERROR,IPRT
COMMON /BLK9/AM0,AM1,IMU,EM0,EM1,MS1
IMU=1
IMF=0
NEM=0
NEST=1
NCLM=1
CLD=CL
EM=0
CALL SECT6
CL0=CL
PRINT 170, EM, CL
EM=1
CALL SECT6
CL1=CL
PRINT 170, EM, CL
IF (CL0.LT.CL1) GO TO 100
IMF=1
TEMP=CL0
CL0=CL1
CL1=TEMP
100 IF (CLD.GT.CL1) GO TO 140
CL=CLD
NCLM=0
PRINT 180, CLD
IF (CLD.GT.CL0) GO TO 110
EM=0
CALL SECT6
PRINT 190, EM, AMU
AMO=AMU
EM0=EM
EN=1
CALL SECT6
PRINT 190, EM, AMU
AM1=AMU
EM1=EM
GO TO 150
110 IF (IMF.EQ.1) GO TO 120
EM=1
CALL SECT6
PRINT 190, EM, AMU
AM1=AMU
EM1=EM
GO TO 130
120 EM=0
CALL SECT6
PRINT 190, EM, AMU
AM1=AMU
EM1=EM
130 NEM=1
CALL SECT6
PRINT 190, EM, AMU
AM0=AMU
EM0=EM
GO TO 150
140 PRINT 160
IMU=0
HYDROFOIL DESIGN PROGRAM

-35-  16 June 1977  JF:jep

[Program code follows]

SUBROUTINE SECT6
MAIN PROGRAM FOR THE THIRD DESIGN PROCEDURE

REAL K
EXTERNAL FA
DOUBLE PRECISION DA, DELL, DXO, DQLX, DIFAC, DAMLX, DDDELTA, DEPSLN
DIMENSION XOV(3), IXOV(3), CLV(2), AMUV(3)
REAL KAY(50)
COMMON P(101), C(101), Q(101), H(101), X(101), XSQ(101), FX(101), ETN1(10 11), ETN2(101), ETPL1(101), ETPL2(101), YU1(101), YU2(101), TAU(101), ALP( 2101), DEE(101), AA(50), KAY, CAY, DUN, A1, A2, ACAP, ALPHA, AMDA, ASQ, BB, BINT 3, CO, CL, CM, DELTA, DINT, ECAP, ELL, EM, EPSILN, ETA1, ETA2, ETA3, TEE, ONE, TIO 4, THR, THETA, TSAVE, XC0, XC1, XC2, XC3, XH, XK, NM, NN, JL6, JM6, JR6, JJ13, JM1 53, JR13, JTT1, JTM1, JTT2, JTM2, JTT3, JTM3, JTT4, JTM4, JTT5, JTM5, JTT7, JTM7 6, JTT8, JTM8, JTT9, JTM9, JTT10, JTM10, JTT11, JTM11, JTT12, JTM12, JTT21, JTM 721, JTT23, JTM23, JTT24, JTM24, JTT25, JTM25
COMMON /BLK6/A1U, XO, K, ACL, T, B1, B2, B3, B4, B5, B6, B7, FT, HT, EPSLN, DNM, P II, THASQ, SQA, FI1, FIXO, BETA, FE, HETA, NEND, IXO, NCLM, NEST, NEM
COMMON /BLK7/DDDELTA, DEPSLN
COMMON /BLK8/STEP, AMX
COMMON /BLK2/LANDA, S, IPUNCH, IERROR, IPRNT
COMMON /BLK1/VBAR, VBARI, ECAP1, YC12
COMMON /BLK3/SEL1
COMMON /BLK9/AMO, AM1, IMU, EMO, EM1, MS1
DATA CLV/0.1,2.0/
DATA XOV/0.04,0.1,0.16/
DATA IXOV/0.3,6.9/
G0(XX) = XX*B3/2+(SQRT(XX*(ELL-XX))+ELL*ATAN(SQRT(XX/ELL-XX)))*B1/
12.0-ATAN(SQRT(XX/ELL-XX))*B4+ALOG(ELL)*R6/2.0-(BTX7(XX)-BTG5(1.0 2)/2.0)

SECTION1. INPUT
ACL=CL
T=TEE
PI=3.14159265
K=CAY
IF (K.EQ.0.0) GO TO 280
C 2. ITERATE TO GET THE VALUE OF A
A1=0.1
AL=A1
AR=A1+1.0
SH=STEP
EPS1=0.01
FL=FA(AL,PCON,NS+CH)

100 FR=FA(AR,PCON,NS+CH)
TT=FR*FL
IF (TT.LT.0.0) GO TO 120
AL=AR
FL=FR
AR=AR+SH
IF (AR.LT.AMX) GO TO 100
PRINT 110

110 FORMAT (5X,'NO SOLUTION FOR A IS FOUND IN THE GIVEN RANGE')
RETURN

120 CALL REGUL (FA,0.0,AL,AR,0.00005,A,PCON,NS+CH)
PRINT 130, A

130 FORMAT ('A=',E15.8)

C COMPUTE M, ETC.
ERR1=FA(A,PCON,NS+CH)
PRINT 140, ERR1

140 FORMAT ('ERROR IN FA = ',E15.8)
IF (MSJ.EQ.1) GO TO 150
IF (NEST.EQ.1) RETURN

150 BINT=(1.0-EM)*CL/PI/(1.0+K)/DNM*(EPSLN+A*DELTA)/A/ELL/2.0+EM/A/ELL
     1/4.0/PI/(1.0+K)*B5
     B2PD=(1.0-EM)*CL*DELTA/PI/(1.0+K)/DNM+EM*B3/4.0/PI/(1.0+K)
     DINT=B2PD-BINT/2.0
     ECAP=BE-M-(1.0-EM)*CL*ASQ/2.0/PI/(1.0+K)-EM*B2/2.0/PI/(1.0+K)/EL
     C=1.0/A
     II=NN
     ALPHA=T-(1-EM)*CL*4.0*A**2*ELL*SQA*PI/(1.0+K)/DNM-(A-ELL*ATAN(1.0/A))**2*BFNT+BE-
     AP+1.0-EM)*CL*SQA/PI/(1.0+K)/DNM
     CD=2.0*PI*(1.0+K)*ELL*(A+BINT+ECAP/2.0)**2
     DA=A
     CM=-(1.0-EM)*CL*(((3.0D0+DELTA-4.0D0*EPSLN*DA)+DA**2*(DELT-
     A*DEPSLN))/8.0/DEPSLN/SQRT(ELL)-EM*BICM(A)
     XBAR=CM/CL
     YCl=A*ECAP
     ALOD=CL/C0
     VIBAR=ALPHA-B2PD+EM*B3/4.0/PI/(1.0+K)
     ECAP1=ECAP
     SEL1=SQRT(ELL)
     PRINT 180, K,AMU,XO
     PRINT 190, CL,T,S
     PRINT 200, ALOD,CM,CD,XBAR,ALPHA,YCl,ACAP,EM,BINT,DINT
     PRINT 160, VIBar,ECAP1,SEL1

160 FORMAT ('INPUT FOR OFF-DESIGN CALCULATIONS: ',/,5X,' VIBAR='
     1',E15.7,5X,'ECAP1=',E15.7,5X,'SQRT OF ELL=',E15.7)
IF (IPUNCH.EQ.1) PUNCH 170, K,XO,AMU
IF (IPUNCH.EQ.1) PUNCH 170, CL,T,S,ALOD,CM,CD,XBAR,ALPHA,ELL,YCl,E
     IM,ACAP,BINT,DINT
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170 FORMAT (5E15.7)
180 FORMAT (5X, 'K=', E15.7, 5X, 'AMU=', E15.7, 5X, 'XO=', F7.4)
190 FORMAT (5X, 'CL=', E15.7, 5X, 'T=', F7.4, 5X, 'S=', F7.4)
   CONTINUE
   IF (IPRINT.EQ.0) GO TO 270
   COMPUTE Y, ETA, ETC.
   ETPT(I)=9999.0
   PRINT 210
   DO 260 I=1, NN
      PII=II/FNI
      XX=PII/FNI
      II=(XX-X(I))/XH+1+0.5
      SQXX=SQRT(XX*(ELL-XX))
      C=SQRT(XX/(ELL-XX))
      XNU=A*C
      TH=ARCSIN(1.0-2.0*XNU)
      PI=TH(I)
      IF (I.NE.1.AND.I.NE.NN) GO TO 220
      IF (I.EQ.1) PM1=9998.0
      IF (I.EQ.NN) PM1=0.0
      GO TO 230
220 PM1=1.0/TAN(TH/2.0)
230 PTOT=EM*CL*PI-2.0*ACAP*(1.0+K)*PM1
   YYY(I)=ALPHA*XX-2.0*A**2*ELL*ACAP*F1FUNC(XNU,A)+A*BINT*(SQXX-ELL*1ATAN(C))-B2PD*XX+ECAP*SQXX+EI*GO(XX)/2.0/P1/(1.0+K)
   ETN(I)=ALPHA*XX-B2PD*XX+A*BINT*(ELL*ATAN(C)-SQXX)-ECAP*SQXX+EI2/2.0/P1/(1.0+K)
   10/PI/(1.0+K)*XX*B3/2.0-(SQXX+ELL*ATAN(C))*B1/2.0+ATAN(C)*B4+ALOG(2*ELL/(ELL-XX))*CL/2.0-(ALOG(ELL/SQRT(ELL-XX)))*CL+FTJX(I,XX)-BT5/2.0-BT7(XX)
   IF (XX.EQ.0.0) GO TO 240
   ETPT(I)=ALPHA-BINT*(1.0-2.0*XNU)/2.0-DINT-ECAP*(ELL-2.0*XX)/2.0/SQ
   1XX*XH/2.0/P1/(1.0+K)+B3/2.0-B1/2.0/C+B4/2.0/SQXX+CL*XX/2.0/(ELL-X2X)+CPV(I,XX)/2.0/SQRT(XX)/(ELL-XX))
   240 IF (IPRINT.EQ.1) PRINT 250, II, XX, YYY(I), ETN(I), ETPT(I), PTOT
   IF (IPUNCH,EQ.1) PUNCH 170, XX, YYY(I), ETN(I), ETPT(I), PTOT
250 FORMAT (5X, I3, 5E15.7)
260 CONTINUE
270 CONTINUE
RETURN

C CASE K=0
280 CONTINUE
   DO 290 I=1, NN
      P(I)=H(I)
290 G(I)=P(I)
   STAR=0.66
   BT5=BTC5(1.0)
   BT8=BTC8(1.0)
   BT9=BTC9(1.0)
   FT11=FTJX(NEND,1.0)
   B11=FT11-BT5/2.0-BT8
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B12=2.0*BT8-FT11
SQ2=SQRT(2.0)
IF (NCLM.EQ.0) GO TO 300
CLTM=(1.0-EM)*(3.0*SQ2-ALOG(1.0+SQ2))/PI+EM/2.0/PI*(2.0*BT9-B12)
CLTM=1.0/CLTM
CL=CLTM*T
IF (EM.EQ.1 .AND. S.GT.STAR) CL=99.9
RETURN
300 IF (NEST.EQ.0) GO TO 310
TRSQ=3.0*SQ2-ALOG(1.0+SQ2)
EM=(TRSQ-PI*T/CL)/(TRSQ-BT9+B12/2.0)

310 CL0T=CT/L
SQX0=SQRT(X0)
B1X0=FTJX(IXO,X0)-BT5/2.0-BTG8(SQX0)
C11=2.0*((3.0*SQ2-ALOG(1.0+SQ2))*(0.5+0.5/SQX0)-(1.0+2.0*SQX0)*SQRT(X0+SQX0))/X0
C1=BT8/SQX0-BTG8(SQX0)/X0-(0.5-0.5/X0)*BT5+(0.5-0.5/SQX0)*FT11
CJ=C11+C1
IF (MSJ.EQ.0) GO TO 320
AMU=X0*(EM*CJ-C11)/2.0/PI*CL0T+X0/2.0+SQX0/2.0
GO TO 340
320 IF (NEST.EQ.0) GO TO 330
AMU=X0*(EM*CJ-C11)/2.0/PI*CL0T+X0/2.0+SQX0/2.0
RETURN
330 EM=(C11+T*2.0*PI/CL*(AMU/X0-0.5-0.5/SQX0))/CJ
340 YCIT=1.0-(1.0-EM)*CL0T/PI*(3.0*SQ2-ALOG(1.0+SQ2))-EM*BT9*CL0T/PI+EM*BT9*CL0T/2.0/PI
YC1=YCIT/2.0
YCl=YC1*T
BT5=BT5*CL
BT8=BT8*CL
BT9=BT9*CL
FT11=FT11*CL
B11=B11*CL
B12=B12*CL
DO 350 I=1,NN
P(I)=H(I)*CL
350 G(I)=P(I)
ALPHA=2.0*(1.0-EM)*CL/PI+YC1+EM*BT9/PI/2.0+EM/2.0/PI*(FT11-BT8-BT5
1/2.0)
CD=(2.0*(1.0-EM)*CL+EM*BT9/2.0+PI*YC1)**2/PI/2.0
ACAP=-2.0*(1.0-EM)*CL/PI/(1.0+K)
ALOD=CL/CD
CM=(1.0-EM)*CL*5.0/16.0-EM*BICM(1.0)
XBAR=CM/CL
V1BAR=ALPHA-2.0*(1.0-EM)*CL/PI
ECAP=YC1
SEL1=1.0
PRINT 180, K,AMU,XO
PRINT 190, CL,T,S
PRINT 360, ALOD,CM,CD,XBAR,ALPHA,YC1,ACAP,EM
PRINT 160, V1BAR,ECAP,SEL1
360 FORMAT (5X,'L/D=',E15.7,5X,'CM=',E15.7,5X,'CD=',E15.7,5X,'XBAR=',E15.7,5X,'ALPHA=',E15.7,5X,'ACAP=',E15.7,5X,'EM='
2,E15.7)
IF (IPUNCH.EQ.1) PUNCH 170, K,XO,AMU
IF (IPUNCH.EQ.1) PUNCH 170, CL, T, S, ALOD, CM, CD, XBAR, ALPHA, YC1, EM, AC
1AP
IF (IPRINT.EQ.0) GO TO 410
ETP1(1)=9999.0
PRINT 210
DO 400 I=1,NN
FI1=I-1
FN1=NN-1
XX=FI1/FN1
II=(XX-X(1)) /XH+1+0.5
SQX=SQRT (XX)
BT8X=BTG8(SQX)
XNU=SQX
TH=ARCCOS (1.0-2.0*XNU)
PI=H(I)
IF (I.NE.1.AND.I.NE.NN) GO TO 370
IF (I.EQ.1) PM1=9998.0
IF (I.EQ.NN) PM1=0.0
GO TO 380
370 PM1=1.0/TAN(TH/2.0)
380 PTOT=EM*CL*PI-2.0*ACAP*(1.0+K)*PM1
YYU1(I)=ALPHA*XX*(1.0-EM)*CL/PI*(1.0+2.0*SQX)*XX**0.25*SQRT (1.0+SQX)) +YC1*SQX+EM/2.0/PI*(SQX*BT29+BT5/2.0-BT8X)
ETN1(I)=(ALPHA-2.0*(1.0-EM)*CL/PI)*XX-YC1*SQX-EM*SQX/2.0/PI*BT9-EM
1/2.0/PI*(PTJX(I1,XX)-BT5/2.0-BT8X)
IF (XX.EQ.0.0) GO TO 390
ETP1(I)=ALPHA-2.0*(1.0-EM)*CL/PI-YC1/2.0/SQX+EM/4.0/PI/SQX*(CPVI(I
11,XX)-BT9)
390 IF (IPRINT.EQ.1) PRINT 250, I1, XX, YYU1(I), ETN1(I), ETP1(I), PTOT
IF (IPUNCH.EQ.1) PUNCH 170, XX, YYU1(I), ETN1(I), ETP1(I), PTOT
400 CONTINUE
410 RETURN
END

FUNCTION FA (A, PCON, NSICH)
DOUBLE PRECISION DELL, DTRM1, DTRM2, DDELTA, DEPSLN, DK, DBETA, DA, DX, DQ
1LX, DBFAC, DAHLX
REAL K
REAL KAY(50)
COMMON P(101), G(101), Q(101), H(101), X(101), XSQ(101), FX(101), ETN1(10
11), ETN2(101), ETP1(101), ETP2(101), YYU1(101), YYU2(101), TAU(101), ALP
(2101), DEE(101), AA(50), KAY, CAY, DUM, A1, A2, ACAP, ALPHA, AMDA, ASQ, BB, BINT
3, C0, CL, CM, DELTA, DINT, ECAP, ELL, EM, DEPSLN, ETA1, ETA2, ETA3, TEE, ONE, T40
4, THR, THETA, TSAVE, XCO, XC1, XC2, XC3, XH, XKZ, NH, NN, JL6, JM6, JR6, JL13, JM1
53, JR13, JTT1, JTM1, JTT2, JTM2, JTT3, JTM3, JTT4, JTM4, JTT5, JTM5, JTT7, JTM7
6, JTT8, JTM8, JTT9, JTM9, JTT10, JTM10, JTT11, JTM11, JTT12, JTM12, JTT21, JTM
721, JTT23, JTM23, JTT24, JTM24, JTT25, JTM25
COMMON /BLK6/ ANU, X0, K, ACL, T, B1, B2, B3, B4, B5, B6, B7, FT, HT, DEPSLN, DNM, P
11, TIASQ, SQA, FI1, FIXO, BETAM, FE, HETA, NEND, IXO, NCLM, NEST, NEM
COMMON /BLK7/ DDELTA, DEPSLN
COMMON /BLK9/ AM0, AM1, IMU, EMO, EM1, MS4
GO(XX)=XX*B3/2+(SQRT(XX*(ELL-XX)))+ELL*ATAN(SQRT(XX/(ELL-XX)))*B1/
12.0-ATAN(SQRT(XX/(ELL-XX)))*B4+ALOG(ELL)*B6/2.0-(BTX7(XX)-BTG5(1.0
2))/2.0)
PI=3.14159265
SQA=SQRT(A)
DK=K
DBETA=1.0-1.0/DSQRT(1.0+DK)
BETA=DBETA
ELL= 1.0+A**2
DELL=ELL
DTM1=DSQRT(DSQT(ELL)+1.0)
DTM2=DSQRT(DSQT(ELL)-1.0)
DELTA=DTM1+DTM2
DEPSLN=DEPSLN
DO 100 I=1,NN
P(I)=H(I)
100 C(I)=P(I)
IF (NCLM.EQ.0) GO TO 110
CLDNM=(1.0-EH)*((2.0*A**2+3.0)*EPSLN+A*DELTA)/DNM+EM*BTG1(A)
CL=BETA*2.0*PI*(1.0+K)*ELL/C LDSM
GO TO 120
110 IF (NEM.EQ.0) GO TO 120
TSQ=((2.0*A**2+3)*EPSLN+A*DELTA)/DNM
EM=(BETA*2.0*PI*(1.0+K)*ELL/CL-TSQ)/(BTG1(A)-TSQ)
120 DO 130 I=1,NN
P(I)=H(I)*CL
130 C(I)=P(I)
DUN=A
C COMPUTE THE VARIOUS INTEGRALS
B1=BIJT1(DUN)
B2=BTG1(A)
B3=BIJT3(DUN)
B4=BIJT4(DUN)
B5=ELL*B1-2.0*B4
B6=CL
B7=ALOG(ELL)*B6+FTJX(NEND,1.0)-2.0*BTX7(1.0)
C COMPUTE H(ETA)
F11=F1FNC(1.0,A)
HETA=CL*(4.0*A**2*ELL*SQA*F11/DNM+(A-ELL*ATAN(1.0/A))*EPSLN+A*DEL
1TA)/ELL/DNM-A*((2.0*A**2+3)*EPSLN*A*DELTA)/ELL/DNM-(A-ELL*ATAN(1/
2A))*B5/2.0/ELL+A*B2/ELL-(A+ELL*ATAN(1.0/A))*B1/2.0+ATAN(1.0/A)*B4-
3B7/2.0
FET=T-2.0*A*BETA+CL*(A*((2.0*A**2+3)*EPSLN+A*DELTA)/ELL/DNM-4.0*A**
12*ELL*SQA*F11/DNM-(A-ELL*ATAN(1.0/A))*EPSLN+A*DELTA)/ELL/DNM/P1/
2(1.0+K)
HE1=CL*4.0*A**2*ELL*SQA*F11/DNM
HE2=(A-ELL*ATAN(1.0/A))*CL*(EPSLN+A*DELTA)/ELL/DNM
HE3=(A-ELL*ATAN(1.0/A))*B5/2.0/ELL
HE4=A*CL*(2.0*A**2+3)*EPSLN+A*DELTA)/ELL/DNM
HE5=A*B2/ELL
HE6=(A+ELL*ATAN(1.0/A))*B1/2.0
HE7=ATAN(1.0/A)*34
HE8=-B7/2.0
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H9=FJIX(NEND,1.0)
H10=BTX7(1.0)
C PRINT 100,HE1,HE2,HE3,HE4,HE5,HE6,HE7,HE8,H9,H10
HE=HE1+HE2+HE3+HE4+HE5+HE6+HE7+HE8
IF (NCLM.EQ.0) GO TO 140
FA=FE+EM*HETA/PI/(1+K)
RETURN
C COMPUTE THE FUNCTIONS F1(1,A),F1(X,A)
140 XNU=A*SQR(XO/(ELL-XO))
FIXO=F1FUNC(XNU,A)
II=NN
XX=1.0
GIA=GO(1.0)
II=IXO
XX=XO
GXXA=GO(XO)
SQLX=SQR((ELL-XO)/XO)
TVASQ=((2.0*A**2+3)*EPSLN+A*DELTA)/ELL/DNM
DA=A
DELL=DA**2+1.0
DXO=XO
DQLX=DQR((DELL-DXO)/DXO)
DBFAC=DA-DQLX-DELL*DQAN(1.0/DA)+DELL*DQAN(1.0/DQLX)/DXO
DAHLX=DA-DQLX
FT=T-CL*4.0*A**2*ELL*SQA*(F11-F1XO/XO)/PI/(1.0+K)/DNM-DBFAC*CL*(EP
1SLN+A*DELTA)/2.0/PI/(1.0+K)/ELL/DNM-(BETA-CL*TJ ASQ/2.0/PI/(1.0+K))
2*DAHLX
HT=CL*4.0*A**2*ELL*SQA*(F11-F1XO/XO)/DNM+DBFAC*(CL*(EPSLN+A*DELTA)
1/2.0/DNM/ELL-B5/4.0/ELL)+(-CL*TJ ASQ/2.0+B2/2.0/ELL)*DAHLX-(GIA-GXXO
2A/XO)/2.0
IF (MSJ.EQ.1) GO TO 150
IF (NEST.EQ.0) GO TO 160
150 FA=FE+EM*HETA/PI/(1+K)
AMU=XO*(FT+EM*HT/PI/(1+K))/T
RETURN
160 FT=FT-AMU*T/XO
EM=-FT*PI/(1+K)/HT
FA=FE+EM*HETA/PI/(1+K)
RETURN
END

FUNCTION CPVI (II,XX)

C THE CAUCHY PRINCIPAL VALUE INTEGRAL (NU-PLANE) APPEARING IN THE
C EQUATION FOR THE DERIVATIVE IS TRANSFORMED TO THE SUM OF A WELL-
C BEHAVED INTEGRAL (DIFF1) AND ANOTHER CAUCHY PRINCIPAL VALUE
C INTEGRAL WHEN THE NU-PLANE IS MAPPED INTO THE Z-PLANE. THIS
C ROUTINE EVALUATES THE LATTER INTEGRAL.
NEEDS COMMON.
REAI KAY(50)
COMMON P(101), G(101), Q(101), H(101), X(101), XSQ(101), FX(101), ETN1(101), ETN2(101), ETP1(101), ETP2(101), YTV1(101), YTV2(101), TAU(101), ALP(2101), DEE(101), AA(50), KAY, CAY, A, A1, A2, ACAP, ALPHA, AMDA, ASQ, BB, BINT, C30, CL, CM, DELTA, DINT, EACAP, ELL, EM, EPSILN, ETA1, ETA2, ETA3, TEE, ONE, T00, T4HR, THETA, TSAVE, XCO, XCI, XC2, XH, XKZ, NM, NN, JL6, JM6, JR6, JJ13, JM13, 5JR13, JTT1, JTTM1, JTTN2, JTT3, JTTM3, JTT4, JTTM4, JTT5, JTTM5, JTT7, JTTM7, J6TT8, JTTM8, JTT9, JTTM9, JTT10, JTTM10, JTT11, JTTM11, JTT12, JTTM12, JTT21, JTTM21, JTT23, JTTM23, JTT24, JTTM24, JTT25, JTTM25

FUN(XL, XR, Q0, Q1, Q2)=Q0*CKLOG((XR-X)/XL)+Q1*(XR-X)+Q2*((XR-X)**2)/2.0

NN2—NN—2

IF (II.GT.NN) GO TO 120
IF (II-1) 120, 100, 130

100 CALL DIFF5 (XX, 1, P, CAY, AA0, AA1, AA2)
TD1—DIFF2(XX, 3, NN2, P, CAY)
TD2—DIFF2(XX, NN2, NN, C, CAY)
CALL DIFF8 (XX, CAY, BB0, BB1, BB2)
CPVI—TD1+TD2+AA0*CKLOG((X(1)-XX)/((X(3)-XX)))+AA1*2.0*XH+AA2*((X(3)-X1X)**2—(X(1)-XX)**2)/2.0+BB*DIFF4(X(1), XH, BB0, BB1, BB2)

110 RETURN

120 CPVI=DIFF2(XX, 1, NN, P, CAY)
GO TO 110

130 IF (II-2) 100, 140, 150

140 CALL DIFF5 (XX, 1, P, CAY, AA0, AA1, AA2)
TD1—DIFF2(XX, 3, NN2, P, CAY)
TD2—DIFF2(XX, NN2, NN, C, CAY)
CALL DIFF8 (XX, CAY, BB0, BB1, BB2)
CPVI=TD1+TD2+FUN(X(1), X(3), AA0, AA1, AA2)+BB*DIFF4(X(1), XH, BB0, BB1, BB2)

GO TO 110

150 IF (II-NN+4) 160, 160, 170

160 XCO=XX
IIIM1=II-1
IIIP1=II+1
TD1=DIFF2(XX, 1, IIIM1, P, CAY)
CALL DIFF5 (XX, IIIM1, P, CAY, BB0, BB1, BB2)
TD2=DIFF2(XX, IIIP1, NN2, P, CAY)
TD3=DIFF2(XX, NN2, NN, C, CAY)
CALL DIFF8 (XX, CAY, CCO, CC1, CC2)
CPVI=TD1+TD2+TD3+FUN(X(IIIM1), X(IIIP1), BB0, BB1, BB2)+BB*DIFF4(XCO, XH, 1CC0, CC1, CC2)
GO TO 110

170 IF (II-NN3) 160, 180, 190

180 IIIM1=II-1
IIIP1=II+1
XCO=0.0
TD1=DIFF2(XX, 1, IIIM1, P, CAY)
CALL DIFF5 (XX, IIIM1, P, CAY, BB0, BB1, BB2)
TD2=DIFF2(XX, IIIP1, NN2, NN, C, CAY)
CALL DIFF8 (XX, CAY, CCO, CC1, CC2)
CPVI=TD1+TD2+FUN(X(IIIM1), X(IIIP1), BB0, BB1, BB2)+BB*DIFF4(XCO, XH, CCO, C

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JF:jep
HYDROFOIL DESIGN PROGRAM

1C1,CC2)
GO TO 110
190 IF (II-(NN-2)) 180, 200, 210
200 XC0=0.0
IIM1=II-1
IIP1=II+1
TD1=DIFF2(XX, I, IIM1, P, CAY)
CALL DIFF5 (XX, IIM1, P, CAY, BB0, BB1, BB2)
CALL DIFF5 (XX, NN2, G, CAY, CC0, CC1, CC2)
CALL DIFF8 (XX, CAY, DD0, DD1, DD2)
CPVI=TD1+FUN(X(IIM1)), X(IIP1), BB0, BB1, BB2) +FUN(X(II-1), X(II), CC0, CC1, CC2) +(-DD0*SQRT(2.0*XII)*(ALOG(TEMPI)+1.4142136)+2.0*DD1*XII*XII**0.5/3.0+4.0*DD2*XII**2.5/15.0)*BB
GO TO 110
210 IF (II-(NN-1)) 200, 220, 230
220 XC0=0.0
IIM1=II-1
IIP1=II+1
TD1=DIFF2(XX, 1, IIM1, P, CAY)
CALL DIFF5 (XX, IIM1, G, CAY, BB0, BB1, BB2)
CALL DIFF8 (XX, CAY, CC0, CC1, CC2)
CPVI=TD1+FUN(X(IIM1)), X(IIP1), BB0, BB1, BB2) +BB*DIFF4(XX, XH, CCO, CC1, C1C2)
GO TO 110
230 XC0=0.0
TD1=DIFF2(XX, 1, NN2, P, CAY)
XH=X(II)
XN2=X(II-2)
CALL DIFF5 (XX, NN2, G, CAY, BB0, BB1, BB2)
CALL DIFF8 (XX, CAY, CC0, CC1, CC2)
CPVI=TD1+FUN(XN2, XH, BB0, BB1, BB2) +BB*DIFF4(1.0, XH, CC0, CC1, CC2)
GO TO 110
END

FUNCTION DIFF2 (XX, ILL, IRR, F, CAY)

DIF2

EVALUATE A DEF. INTEGRAL OVER(X(ILL), X(IRR)) WHOSE INTEGRAND IS G(X(II), U)*F(U)/(U-X(II)) WHERE U IS THE DUMMY VARIABLE, F IS P OR G, AND G IS GIVEN BY DIFF7.--NEEDED BY ZZZZ.

NEEDS COMMON
REAL KAY(50)
COMMON P(101), G(101), Q(101), U(101), X(101), XSQ(101), FX(101), ETN1(101), ETH2(101), ETPL(101), ETPL2(101), YU1(101), YU2(101), TAU(101), ALP(2101), DLY(101), AA(50), KAY, B2M, A, A1, A2, ACAP, ALPHA, ANDA, ASQ, BB, BINT, C, CL, CM, DELTA, DINT, ECAP, ILL, EN, EPSIL, ETA1, ETA2, ETA3, TEL, TG1, TG2, TG3, THETA, TSAVE, XC0, XC1, XC2, XC3, XH, XKZ, NH, NN, JL6, JM6, JR6, JL13, JM13,
FUNCTION DIFF4 (XX, XH, BB0, BB1, BB2)  

DIFF4

EVALUATES THE EXPRESSION OBTAINED FOR THE INTEGRAL OVER (1-2H, 1 OF F(XX, U) * SQRT(1-U)/(U-XX)/SQRT(U) WHEN F/SQRT(U) IS REPLACED BY BB0+BB1*(U-XCO)+332*(U-XCO)**2 OBTAINED USING PARAB PREVIOUSLY.  
(F IS GIVEN BY DIFF7).

T1=SQRT(1.0-XX)  
T2=SQRT(2.0*XH)  
DIFF4=BB0*(-T1*CKLOG((T1-T2)/(T1+T2))-2.0*T2)+2.0*BB1*T2*(2.0*XH)/  
13.0+2.0*BB2*((1.0-XX)*T2*(2.0*XH)/3.0-T2*(2.0*XH)**2/5.0)  
RETURN  
END

SUBROUTINE DIFF5 (XX, ILL, F, CAY, AA0, AA1, AA2)  

DIFF5

USES PARAB TO APPROXIMATE Z(XX, U)*F(U)/SQRT(U) BY  
AA0+AA1*(U-XX)+AA2*(U-XX)**2  
ON (U(I), U(I+2)) FOR G, Z(XX, U) IS DIFF7.

NEEDS COMMON
REAL KAY(50)  
COMMON F, G, Q, H, X, XSQ, FX, ETN1, ETN2, ETP1, ETP2, YU1, YU2, TAU, ALP, DEL,  
IAA, KAY, DUN, A, A1, A2, ACAP, ALPHA, ANDA, ASQ, BB, BINT, CO, CL, CM, DELTA, DINT
HYDROFOIL DESIGN PROGRAM

2, ECAP, ELL, EM, EPSILN, ETA1, ETA2, ETA3, TEE, TC1, TC2, TC3, THETA, TSAVE, XCO, 3, XC1, XC2, XC3, XH, XKZ, NM, NN, JL6, JM6, JR6, JL13, JM13, JR13, JTT1, JTM1, JTT2, JTM2, JTT3, JTM3, JTT4, JTM4, JTT5, JTM5, JTT7, JTM7, JTT8, JTM8, JTT9, JTM9, JTT10, JTM10, JTT11, JTM11, JTT12, JTM12, JTT21, JTM21, JTT23, JTM23, JTT24, JTM24, JTT25, JTM25

DIMENSION P(101), G(101), Q(101), H(101), X(101), XSQ(101), FX(101), ETN1(101), ETN2(101), ETP1(101), ETP2(101), YYU1(101), YYU2(101), TAU(101), ALP(101), DEE(101), AA(50)

DIMENSION F(101)

C
XC0=XX
XC1=X(ILL)
XC2=X(ILL+1)
XC3=X(ILL+2)
ETA1=DIFF7(XX, XC1, ELL, CAY)*F(ILL)
ETA2=DIFF7(XX, XC2, ELL, CAY)*F(ILL+1)
ETA3=DIFF7(XX, XC3, ELL, CAY)*F(ILL+2)
CALL PARAB (AA0, AA1, AA2)
RETURN
END

FUNCTION DIFF7 (XX, UU, ELL, CAY)
C
EVAUATES THE FUNCTION z(XX, UU) =
C
SQRT(UU*(ELL-XX))+SQRT(XX*(ELL-UU)), K NONZERO,
C
AND SQRT(UU)+SQRT(XX), K=0.
C
NO COMMON

IF (CAY) 100, 120, 100
100 DIFF7=SQRT(UU*(ELL-XX))+SQRT(XX*(ELL-UU))
DIFF7=DIFF7*SQRT(ELL-UU)
110 RETURN
120 DIFF7=SQRT(UU)+SQRT(XX)
GO TO 110
END

SUBROUTINE DIFF8 (XX, CAY, AA0, AA1, AA2)
DIFS

APPROXIMATES z(XX, U) BY A0+A1(U-XX)+A2(U-XX)**2 OVER
(1-2H, 1)--z(X, U)=DIFF7(X, U, ELL, CAY). USES PARAB.
HYDROFOIL DESIGN PROGRAM

NEEDS COMMON

REAL KAY(50)
COMMON P(101), G(101), Q(101), H(101), X(101), XSQ(101), FX(101), ETN1(101), ETN2(101), ETP1(101), ETP2(101), YYU1(101), YYU2(101), TAU(101), ALP(2101), DEE(101), AA(50), KAY, DUM, A, A1, A2, ACAP, ALPHA, AMDA, ASQ, BB, BINT, C30, CL, CM, DELTA, DINT, ECAP, ELL, EM, EPSILN, ETA1, ETA2, ETA3, TEE, TG1, TG2, T4G3, THETA, TSAVE, XC0, XC1, XC2, XC3, XH, XKZ, NH, NN, JL6, JM6, JR6, JL13, JM13, SJR13, JTT1, JTM1, JTT2, JTM2, JTT3, JTM3, JTT4, JTM4, JTT5, JTM5, JTT7, JTM7, J6T8, JTM8, JTT9, JTM9, JTT10, JTM10, JTT11, JTM11, JTT12, JTM12, JTT21, JTM21, JTT23, JTM23, JTT24, JTM24, JTT25, JTM25

N = NN
XC0 = XX
XC1 = X(N) - 2.0 * XH
XC2 = X(N) - XH
XC3 = X(N)
ETA1 = DIFF7(XC0, XC1, ELL, CAY)
ETA2 = DIFF7(XC0, XC2, ELL, CAY)
ETA3 = DIFF7(XC0, XC3, ELL, CAY)
CALL PARAB (AA0, AA1, AA2)
RETURN

FUNCTION BINT1 (A)

A COMMONLY USED DEFINITE INTEGRAL APPEARING IN SEVERAL EQ'NS. IS EVALUATED BY THIS ROUTINE. THE INTEGRAND TAKES THE FORM --
P(X) * ((ELL - X) / X) **.5. -- SEE WRIT-E-UP.

NEEDS COMMON

REAL KAY(50)
COMMON P(101), G(101), Q(101), H(101), X(101), XSQ(101), FX(101), ETN1(101), ETN2(101), ETP1(101), ETP2(101), YYU1(101), YYU2(101), TAU(101), ALP(2101), DEE(101), AA(50), KAY, CAY, DUM, A1, A2, ACAP, ALPHA, AMDA, ASQ, BB, BINT, C30, CL, CM, DELTA, DINT, ECAP, ELL, EM, EPSILN, ETA1, ETA2, ETA3, TEE, TONE, T1O4, TTHETA, TSAVE, XC0, XC1, XC2, XC3, XH, XKZ, NH, NN, JL6, JM6, JR6, JL13, JM13, SJR13, JTT1, JTM1, JTT2, JTM2, JTT3, JTM3, JTT4, JTM4, JTT5, JTM5, JTT7, JTM7, J6T8, JTM8, JTT9, JTM9, JTT10, JTM10, JTT11, JTM11, JTT12, JTM12, JTT21, JTM21, JTT23, JTM23, JTT24, JTM24, JTT25, JTM25
COMMON /BLKI/VBAR, VBAR1, ECAP1, YC12

ELL = A ** 2 + 1.0
XC0 = 0.0
XC1 = X(1)
HYDROFOIL DESIGN PROGRAM

XC2=X(2)
XC3=X(3)
ETA1=P(1)/SQRT(ELL-XC1)
ETA2=P(2)/SQRT(ELL-XC2)
ETA3=P(3)/SQRT(ELL-XC3)
CALL PARAB (AAO,AA,AA2)
XC1=X(NN-2)
XC2=X(NN-1)
XC3=X(NN)
ETA1=1.0/SQRT((ELL-XC1)*XC1)
ETA2=1.0/SQRT((ELL-XC2)*XC2)
ETA3=1.0/SQRT((ELL-XC3)*XC3)
CALL PARAB (BB0,BB1,BB2)
NM=NN-4
J=3
DO 100 I=1,NM
FX(I)=P(J)/SQRT((ELL-X(J))*X(J))
J=J+1
100 CONTINUE
CALL NTGRTE (TG1)
NM=3
J=NN-2
DO 110 I=1,NM
FX(I)=G(J)/SQRT((ELL-X(J))*X(J))
J=J+1
110 CONTINUE
CALL NTGRTE (TG2)
BINT1=SQ(X(1),X(3),AA0,AA1,AA2)+TG1+TG2+BB*FOUR(XC1,BB0,BB1,BB2)
RETURN
END

FUNCTION BTG8 (DX)
BTG8
THE DEFINITE INTEGRAL OF P(X)*LOG(DX+X**.5), WHICH OCCURS IN
SEVERAL EQUATIONS, IS EVALUATED BY THIS ROUTINE.

NEEDS COMMON
REAL KAY(50)
COMMON P(101),G(101),Q(101),H(101),X(101),XSQ(101),FX(101),ETN1(10
11),ETN2(101),ETP1(101),ETP2(101),YYU1(101),YYU2(101),TAU(101),ALP(
2101),DEE(101),AA(50),KAY,CAY,A,A1,A2,ACAP,ALPHA,ANDA,ASQ,RR,BINT,C
30,CL,CM,DELTA,DINT,ECAP,ELL,EM,EPSI,LN,ETA1,ETA2,ETA3,TEE,ONE,TJ0,T
4UR,THETA,TSAVE,XC0,XC1,XC2,XC3,WH,XKZ,NN,NN,NN,NN,NN,NN,NN,NN,NN,
JL6,JM6,JR6,RL13,JM13,SR13,JMT1,JMT2,JMT3,JMT4,JSMT,JMT5,JMT7,JMT7,
J6TT8,JSMT3,JSMT9,JSMT10,JSMT10,JSMT11,JSMT11,JSMT12,JSMT21,JSMT21

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HYDROFOIL DESIGN PROGRAM

7, JTT23, JTM23, JTT24, JTM24, JTT25, JTM25
COMMON /BLK1/VIBAR, VIBAR1, ECAP1, YC12
C
IF (DX) 100, 100, 110
100 BTG8 = 0.5 * BTG5(DX)
GO TO 140
110 NN = NN - 2
DO 120 I = 1, NN
120 FX(I) = P(I) * CKLOG(DX + X(I) ** 0.5)
CALL NTGRTE (TG1)
J = NN - 2
NN = 3
DO 130 I = 1, NN
130 FX(I) = G(J) * CKLOG(DX + X(J) ** 0.5)
J = J + 1
CONTINUE
CALL NTGRTE (TG2)
XCO = 0.0
XC1 = X(NN - 2)
XC2 = X(NN - 1)
XC3 = X(NN)
ETA1 = CKLOG(DX + XC1 ** 0.5)
ETA2 = CKLOG(DX + XC2 ** 0.5)
ETA3 = CKLOG(DX + XC3 ** 0.5)
CALL PARAM (AA0, AA1, AA2)
BTG8 = TG1 + TG2 + BB * FOUR(X(NN - 2), AA0, AA1, AA2)
140 RETURN
END

FUNCTION BTG9 (A)
BTG9

EVALUATES THE DEFINITE INTEGRAL OF P(X)/X**.5 OVER(0,1).

REAL KAY(50)
COMMON P(101), Q(101), H(101), X(101), XSQ(101), FX(101), ETN1(101),
ETN2(101), ETP1(101), ETP2(101), YU1(101), YU2(101), TAU(101), ALP(2101),
DEL(101), AA(50), KAY, CAY, DUMA, A1, A2, ACAP, ALPHA, AMDA, ASQ, BN, BIN,
3T, CO, CL, CM, DELTA, DINT, ECAP, ELL, EM, EPSLN, ETA1, ETA2, ETA3, TEE, ONE, T1,
40, THR, THETA, TSAVE, XCO, XC1, XC2, XC3, XH, XZ, NM, NN, JL6, JM6, JZ6, JZ13,
JJ513, JR13, JTT1, JTM11, JTT2, JTM12, JTT3, JTM13, JTT4, JTM14, JTT5, JTM15,
JTT7, JTM17, JTT8, JTM18, JTM19, JTT10, JTM10, JTT11, JTM11, JTT12, JTM12,
JTT21, JTM23, JTT24, JTM24, JTT25, JTM25
COMMON /BLK1/VIBAR, VIBAR1, ECAP1, YC12
XCO = 0.0
XC1 = X(1)
XC2 = X(2)
XC3 = X(3)
HYDROFOIL DESIGN PROGRAM

ETA1=P(1)
ETA2=P(2)
ETA3=P(3)
CALL PARAB (AAO,AA1,AA2)
NM=NN-4
J=3
DO 100 I=1,NM
FX(I)=P(J)/SQRT(X(J))
J=J+1
100 CONTINUE
CALL NTGRTE (TG1)
NM=3
J=NN-2
DO 110 I=1,3
FX(I)=G(J)/SQRT(X(J))
J=J+1
110 CONTINUE
CALL NTGRTE (TG2)
BB1=SQRT(X(3))
BB2=SQRT(X(NN-2))
BTG9=SIX(X(1),X(3),AA0,AA1,AA2)+TG1+TG2+BB*(ATAN(BB1/BB2)-BB1*BB2)
RETURN
END

SUBROUTINE NTGRTE (TG)

THIS SPECIAL INTEGRATION ROUTINE IS USED REPEATEDLY BY THE
PROGRAM. HIGH-ORDER NEWTON-COTES FORMULAS ARE USED

REAL KAY(50)
COMMON P(101),Q(101),H(101),X(101),XSQ(101),FX(101),ETN1(101)
,ETN2(101),ETP1(101),ETP2(101),YYU1(101),YYU2(101),TAU(101),ALP(2101)
,DEL(101),AA(50),KAY,CAY,A,A1,A2,ACAP,ALPHA,ANDA,ASQ,BB,BINT,C
30,CL,CM,DELTA,DINT,ECAP,ELL,EM,EPSILN,ETA1,ETA2,ETA3,TEL,TG1,TG2,T
4G3,THE,TS,TSVE,XXC1,XXC2,XXC3,XX,XXZ,NN,NN,NL6,NM6,OX6,OL3,OM6,OS6
,JST1,JST1,JS1,JS2,JS3,JS4,JS5,JS6,JS7,JS8,JS9,JS10,JS11,JS12,JS13,JS14
JS15,JS16,JS17,JS18,JS19,JS20,JS21,JS22,JS23,JS24,JS25,JS26,JS27
DIMENSION YNN(10)

TG=0.0
IF (NM-1) 100,100,120
100 WRITE (6,110)
110 FORMAT (5H0 **ERROR RETURN FROM NTGRTE--NO. OF GRID-PTS. L.T.1)
GO TO 390
120 IF (NM = 8) 140, 130, 140
130 N7 = 1
   LN = 0
   KN = 0
   GO TO 230
140 ND = NM - 1
   N7 = 0
150 IF (ND = 12) 170, 160, 160
160 ND = ND - 7
   N7 = N7 + 1
   GO TO 150
170 IF (ND = 11) 180, 220, 180
180 IF (ND = 7) 190, 200, 210
190 KN = ND
   LN = 0
   GO TO 230
200 N7 = N7 + 1
   KN = 0
   LN = 0
   GO TO 230
210 KN = 4
   LN = ND - KN
   GO TO 230
220 KN = 6
   LN = 5
230 NSTRT = 1
   NN7 = N7
240 IF (NN7) 250, 280, 250
250 IS/I = 7
   J = NSTRT
   DO 260 I = 1, 8
      YNN(I) = FX(J)
      J = J + 1
260 CONTINUE
   ASSIGN 270 TO KLOC
   GO TO 400
270 TG = TG + TGINT
   NSTRT = NSTRT + 7
   NN7 = NN7 - 1
   GO TO 240
280 IF (KN) 290, 320, 290
290 IS/I = KN
   KK = KN + 1
   J = NSTRT
   DO 300 I = 1, KK
      YNN(I) = FX(J)
      J = J + 1
300 CONTINUE
   ASSIGN 310 TO KLOC
   GO TO 400
310 TG = TG + TGINT
320 IF (LN) 330, 360, 330
330 IS/I = LN
   KK = LN + 1
   J = NSTRT
FUNCTION BTG4 (X1, X2, BB0, BB1, BB2)

BTG4

THIS SUBSIDIARY ROUTINE EVALUATES THE DEFINITE INTEGRAL OVER
(0, 2H) WHERE INTEGRAND IS (BB1*X+BB2*X**2)*LOG(X) -- REQUIRED
BY THE ROUTINE BTG5.

NO COMMON.

FLO1 = 0.0
IF (X1. NE. 0.0) FLO1 = BB1*X1**2*(ALOG(X1)-0.5)/2.0 + BB2*X1**3*(ALOG(X1)-1.0)/3.0
BTG4 = BB1*X2**2*(ALOG(X2)-0.5)/2.0 + BB2*X2**3*(ALOG(X2)-1.0)/3.0
1 + BB0*X2*(ALOG(X2)-1.0) - FLO1
RETURN
END

FUNCTION BTG5 (A)

THE DEFINITE INTEGRAL OVER (0,1) WITH INTEGRAND P(X)LOG(X)
IS EVALUATED.

NEEDS COMMON.

REAL KAY(50)
COMMON P(101), Q(101), H(101), X(101), XSQ(101), FX(101), ETN1(101), ETP1(101), ETP2(101), YYU1(101), YYU2(101), TAU(101), ALP(2101), DEX(101), AA(50), KAY, CAY, DUMA, A1, A2, ACAP, ALPHA, AMDA, ASQ, BB, BIN 3T, CO, CL, CM, DELTA, DINT, ECAPI, ELL, EM, EPSILN, ETA1, ETA2, ETA3, TEE, ONE, T1 40, THR, THETA, TSAVE, XC0, XC1, XC2, XC3, XN, XKZ, NM, NN, JL6, JML6, JR6, JL13, JM 513, JR13, JMT1, JMT2, JMT3, JMT4, JMT5, JMT6, JMT7, JMT 67, JMT8, JMT9, JMT10, JMT11, JMT12, JMT13, JMT 7M21, JMT23, JMT24, JMT24, JMT25, JMT25
COMMON /BLK1/VIBAR, VIBAR1, ECAPI, YC12

NM=NN-4
J=3
DO 100 I=1, NM
FX(I) = P(J)*CKLOG(X(J))
J = J + 1
100 CONTINUE
CALL NTGRTE (TG1)
XC0 = 0.0
XC1 = X(1)
XC2 = X(2)
XC3 = X(3)
ETA1 = P(1)
ETA2 = P(2)
ETA3 = P(3)
CALL PARAB (AAO, AA1, AA2)
NH=3
J=NN-2
DO 110 I=1, NM
   FX(I)=G(J)*CKLOG(X(J))
   J=J+1
110 CONTINUE
CALL NTGRTE (TG2)
BTG5=BTG4(X(1), X(3), AAO, AA1, AA2)+TG1+TG2+BB*BTG6(XH)
RETURN
END

FUNCTION BTG6 (XH)

   THE DEFINITE INTEGRAL OVER (1-2H, 1) WITH INTEGRAND
   LOG(X)*(1-X)**.5
   IS EVALUATED. - REQUIRED BY BTG5.

   NO COMMON.
   X1=(2.0*XH)**1.5
   X2=(2.0*XH)**0.5
   X3=(X1-1.0)*CKLOG(X2-1.0)
   X3=X3/(X1-1.0)*CKLOG(X2+1.0)
   X3=X3-2.0*X1/3.0
   X3=X3-2.0*X2
   BTG6=2.0*X3/3.0
RETURN
END

SUBROUTINE PARAB (CON0, CON1, CON2)
PARB

   PUTS A QUADRATIC OF THE FORM
   CON0+CON1*(X-XC0)+CON2*(X-XC0)**2
   THROUGH THE POINTS (XC1, ETA1), (XC2, ETA2), (XC3, ETA3).
HYDROFOIL DESIGN PROGRAM

REAL KAY(50)
COMMON P(101), G(101), Q(101), H(101), X(101), XSQ(101), FX(101), ETN1(10 11), EPN2(101), ETP1(101), ETP2(101), YYU1(101), YYU2(101), TAU(101), ALP( 2101), DEE(101), AA(50), KAY, CAY, A, A1, A2, ACAP, ALPHA, AMDA, ASQ, BR, BINT, C30, CL, CM, DELTA, DINT, ECAP, ELL, EM, EPSILN, ETA1, ETA2, ETA3, TEE, ONE, T10, T14R, THEA, TSAVE, XCO, XC1, XC2, XC3, XM, XKZ, NNN, NN, JL6, JM6, JR6, JL13, JM13, 5JR13, JTT1, JTM1, JTT2, JTM2, JTT3, JTM3, JTT4, JTM4, JTT5, JTM5, JTT7, JTM7, J6TT8, JTM8, JTT9, JTM9, JTT10, JTM10, JTT11, JTM11, JTT12, JTM12, JTT21, JTM21 7, JTT23, JTM23, JTT24, JTM24, JTT25, JTM25

DENM1=(XC2-XC1)*(XC3-XC1)
DENM2=(XC1-XC2)*(XC3-XC2)
DENM3=(XC1-XC3)*(XC2-XC3)
CON0=ETA1*(XC2-XCO)*(XC3-XCO)/DENM1+ETA2*(XC1-XCO)*(XC3-XCO)/DENM2+ ETA3*(XC1-XCO)*(XC2-XCO)/DENM3
CON1=ETA1*(2.0*XCO-XC2-XC3)/DENM1+ETA2*(2.0*XCO-XC1-XC3)/DENM2+ETA 13*(2.0*XCO-XC1-XC2)/DENM3
CON2=ETA1/DENM1+ETA2/DENM2+ETA3/DENM3
RETURN
END

FUNCTION SIX(X1, X2, SF0, SF1, SF2)
EVALUATES THE INTEGRAL FROM 0 TO H OF
SF0+SF1*T+SF2*T**2)/SQR(T).

SIX=0.0666666667*(30.0*SF0+X2*(10.0*SF1+6.0*SF2*X2))*SQR(T)*-0.066 16666667*(30.0*SF0+X1*(10.0*SF1+6.0*SF2*X1))*SQR(T)
RETURN
END

FUNCTION CLOG(GARGLE)
Computes the log of ABSF(GARGLE), returns with zero if GARGLE=0.

IF (GARGLE) 110, 100, 120
100 CLOG=0.0
RETURN
110 CKLOG=ALOG(-CARGLE)
RETURN
120 CKLOG=ALOG(GARGLE)
RETURN
END

FUNCTION FOUR (H,CF0,CF1,CF2)
FOUR
EVALUATES THE EXPRESSION OBTAINED FOR THE INTEGRAL FROM H TO 1 OF
(CF0+CF1*T+CF2*T**2)*SQRT(1-T).
FOUR=0.019047619*(35.0*CF0+7.0*CF1*(3.0*H+2.0)+CF2*(H*(15.0*H+12.0
1)+8.0))*(1.0-H)**1.5
RETURN
END

SUBROUTINE REGUL (FUNNY,HERE,GAUCHE,DROIT,SMALL,ROOT,PCON,NS1CH)
REGU
FINDS THE ROOT OF THE EQUATION --
FUNNY(X,PCON,NS1CH)-HERE=0
BY THE METHOD OF REGULUS FALSI.
FUNNY MUST APPEAR ON AN F-CARD IN THE CALLING ROUTINE
ASSUMES FUNNY (X,PCON,NS1CH)
ICNT=0
VR=FUNNY(DROIT,PCON,NS1CH)
VL=FUNNY(GAUCHE,PCON,NS1CH)
IF ((VL-HERE)*(VR-HERE)) 100, 240, 260
100 EMN=DROIT
110 IF (ICNT=50) 120, 160, 160
120 EM=(DROIT-GAUCHE)*(HERE-VL)/(VR-VL)+GAUCHE
130 IF (ABS(EM-EMN)=SMALL) 140, 170, 170
140 ROOT=EM
150 RETURN
160 EM=0.5*(GAUCHE+DROIT)
   GO TO 130
170 IF (ICNT-100) 180,280,280
180 VM=FUNNY(EM,PCON,NSJCH)
   ICNT=ICNT+1
   IF ((VM-HERE)*(VL-HERE)) 190,220,210
190 DROIT=EM
   VR=VM
200 GAUCHE=EM
   GO TO 110
210 GAUCHE=EM
   VL=VM
   GO TO 200
220 IF (VM-HERE) 230,140,230
230 ROOT=GAUCHE
   GO TO 150
240 IF (VL-HERE) 250,230,250
250 ROOT=DROIT
   GO TO 150
260 WRITE (6,270)
270 FORMAT (6410 ****ERROR EXIT FROM REGUL--END-PTS. INPUT DO NOT BRACKET ROOT)
   GO TO 150
280 WRITE (6,290) GAUCHE,EM,DROIT,VL,VR,HERE
290 FORMAT (3710 ***REGUL ITERATION COUNT PAST 100/6X,14HLEFT-HAND P I T.=E14.6,6X,13ULAST APPROX.=E14.6,6X,6X,13HRT.-HAND PT.=E14.6/6X,1
   25HHFUNCTION AT LEFT=E14.6,6X,14HFUNCT. AT RT.=E14.6,6X,18HINPUT FUNCT 3. VAL.=E14.6)
   STOP
END

FUNCTION BTG1 (A)

A COMMONLY USED DEFINITE INTEGRAL APPEARING IN SEVERAL EQ'NS.
IS EVALUATED BY THIS ROUTINE. THE INTEGRAND TAKES THE FORM --
P(X)*((ELL-X)/X)**.5. -- SEE WRITE-UP.

NEEDS COMMON

REAL KAY(50)
COMMON P(101),G(101),Q(101),H(101),X(101),XSQ(101),FX(101),ETM1(10
11),ETM2(101),ETP1(101),ETP2(101),YYU1(101),YYU2(101),TAU(101),ALP(2101),DEE(101),AA(50),KAY,CAY,DUH,A1,A2,ACAP,ALPHA,A'NDA,ASQ,BB,BINT
3,C0,Cl,CM,DELTA,DINT,ECAP,ELL,EM, EPSILON, ETA1,ETA2,ETA3,TEE,ONE,TWO
4,THET,THETA,TSAVE,XCO,XC1,XC2,XC3,XH,XXZ,NN,JL6,JM6,MR6,MR13,JM1
FUNCTION FTJX (XX)

FTJX

THIS SUBSIDIARY ROUTINE EVALUATES THE DEFINITE INTEGRAL WHOSE INTEGRAND IS P(U)*LOG(U-XX) FOR 0 LT XX LE 1 -- U IS THE DUMMY VARIABLE OF INTEGRATION.
HYDROFOIL DESIGN PROGRAM

C     NEEDS COMMON
REAL KAY(50)
COMMON P(101), Q(101), H(101), X(101), XSQ(101), FX(101), ETN1(101), ETN2(101), ETP1(101), ETP2(101), YUY1(101), YUY2(101), TAU(101), ALP(2101), AAY(50), KAY, CAY, A, A1, A2, ACAP, ALPHA, AMDA, ASQ, BB, BINT, C30, CL, CM, DELTA, DINT, ECAP, ELL, EM, EPSILON, ETA1, ETA2, ETA3, TEE, ONE, T0, T4HR, THETA, TSAVE, XCO, XC1, XC2, XC3, XH, XK2, NM, NN, JL6, JM6, JR6, JL13, JM13, 5JR13, JTT1, JTM1, JTT2, JTM2, JTT3, JTM3, JTT4, JTM4, JTT5, JTM5, JTT7, JTM7, J6TT8, JTM8, JTT9, JTM9, JTT10, JTM10, JTT11, JTM11, JTT12, JTM12, JTT21, JTM21, JTT23, JTM23, JTT24, JTM24, JTT25, JTM25
COMMON /BLK1/VBAR, VBAR1, ECAP1, YC12
IF (II-I) 180, 180, 110
100 IF (II-2) 190, 190, 110
110 IF (II-3) 200, 200, 120
130 IF (II-NN-4) 210, 220, 140
140 IF (II-NN-3) 230, 230, 150
150 IF (II-NN-2) 240, 240, 160
160 IF (II-NN-1) 250, 250, 170
170 WRITE (6, 280)
STOP
180 FTJX=EJ1(1, NN, XX, P)
RETURN
190 XCO=XH+X(1)
   XC1=X(1)
   XC2=X(2)
   XC3=X(3)
   ETA1=P(1)
   ETA2=P(2)
   ETA3=P(3)
   CALL PARAB (AA0, AA1, AA2)
   NN2=NN-2
   FTJX=EJ3(AA0, AA2, XH)+EJ1(3, NN2, XH, P)+EJ1(NN2, NN, XH, G)+BB*EJ4(XH, XH
1)
   GO TO 270
200 XCO=2.0*XH+X(1)
   XC1=X(1)
   XC2=X(2)
   XC3=X(3)
   ETA1=P(1)
   ETA2=P(2)
   ETA3=P(3)
   CALL PARAB (AA0, AA1, AA2)
   XC1=X(3)
   XC2=X(4)
   XC3=X(5)
   ETA1=P(3)
   ETA2=P(4)
   ETA3=P(5)
   CALL PARAB (BB0, BB1, BB2)
   NN2=NN-2
   FTJX=EJ5(AA0, AA1, AA2, BB0, BB1, BB2, XH)+EJ1(5, NN2, XX, P)+EJ1(NN2, NN, XX
1, G)+BB*EJ4(XH, XX)
   GO TO 270
210 II=II-1
   II=II+1
HYDROFOIL DESIGN PROGRAM

XC0=XX
XC1=X(IIL)
XC2=XX
XC3=X(IIR)
ETA1=P(IIL)
ETA2=P(III)
ETA3=P(IIR)
CALL PARAB (AAO,AA1,AA2)
NN2=NN-2
FTJX=EJ1(1,IIL,XX,P)+EJ3(AAO,AA2,XH)+EJ1(IIR,NN2,XX,P)+EJ1(NN2,NN,1XX,G)+BB*EJ4(XH,XX)
GO TO 270

220  NN6=NN-6
      NN2=NN-2
      NN5=NN-5
      NN3=NN-3
      XC0=XX
      XC1=X(NN6)
      XC2=X(NN5)
      XC3=XX
      ETA1=P(NN6)
      ETA2=P(NN5)
      ETA3=P(NN2)
      CALL PARAB (BB0,BB1,BB2)
      FTJX=EJ1(1,NN6,XX,P)+EJ5(AAO,AA1,AA2,BB0,BB1,BB2,XH)+EJ1(NN2,NN,XX1,G)+BB*EJ4(XH,XX)
      GO TO 270

230  XC0=XX
      XC1=X(III-1)
      XC2=XX
      XC3=X(III+1)
      ETA1=P(III-1)
      ETA2=P(III)
      ETA3=P(III+1)
      CALL PARAB (AAO,AA1,AA2)
      IIL=III-1
      IIR=III+1
      FTJX=EJ1(1,IIL,XX,P)+EJ3(AAO,AA2,XH)+EJ1(IIR,NN,XX,G)+BB*EJ4(XH,XX1)
      GO TO 270

240  XC0=XX
      XC1=X(II-2)
      XC2=X(II-1)
      XC3=XX
      ETA1=P(II-2)
      ETA2=P(II-1)
      ETA3=P(II)
      CALL PARAB (AAO,AA1,AA2)
      XC1=XX
HYDROFOIL DESIGN PROGRAM

\[ XC2 = X(II+1) \]
\[ XC3 = X(II+2) \]
\[ ETA1 = G(II) \]
\[ ETA2 = G(II+1) \]
\[ ETA3 = G(II+2) \]
\[ CALL PARAB(BB0, BB1, BB2) \]
\[ IIL = II-2 \]
\[ FTJX = EJ1(1, IIL, XX, P) + EJ5(AA0, AA1, AA2, BB0, BB1, BB2, XH) + BB*EJ4(XH, XX) \]
\[ GO TO 270 \]

250 \[ XC0 = XX \]
\[ XC1 = X(II-1) \]
\[ XC2 = XX \]
\[ XC3 = X(NN) \]
\[ ETA1 = G(NN-2) \]
\[ ETA2 = G(NN-1) \]
\[ ETA3 = G(NN) \]
\[ CALL PARAB(AA0, AA1, AA2) \]
\[ IIL = II-1 \]
\[ FTJX = EJ1(1, IIL, XX, P) + EJ3(AA0, AA2, XH) + BB*EJ4(XH, XX) \]
\[ GO TO 270 \]

260 \[ XC0 = X(NN) \]
\[ XC1 = X(NN-2) \]
\[ XC2 = X(NN-1) \]
\[ XC3 = X(NN) \]
\[ ETA1 = G(NN-2) \]
\[ ETA2 = G(NN-1) \]
\[ ETA3 = G(NN) \]
\[ CALL PARAB(AA0, AA1, AA2) \]
\[ NN2 = NN-2 \]
\[ FTJX = EJ1(1, NN2, XX, P) + EJ5(AA0, AA1, AA2, 0.0, 0.0, 0.0, XH) + BB*EJ4(XH, XX) \]
\[ 270 \ RETURN \]

280 \[ FORMAT(1H0, 10X, 9H**********, 27HERROR IN FORTAB--FTJX ROUT.) \]
END

FUNCTION F1FUNC(XNU, A)

SPECIAL FUNCTION NEEDED FOR THE NOSE SINGULARITY CASE (IN THE
CALCULATION OF THE CAVITY) AND FOR THE OFF-DESIGN CALCULATION.

DOUBLE PRECISION DASQ, DMGSQ, DBET1, DBET2, DCAM1, DGAM2
ASQ = A**2
DASQ = ASQ
DMGSQ = A*DSQRT(DASQ+1.0)
DBET1 = DSQRT((DMGSQ-DASQ)/2.0D0)
DBET2 = DSQRT((DMGSQ+DASQ)/2.0D0)
HYDROFOIL DESIGN PROGRAM

DGAM1 = (A*DBET2+DBET1/2.0)/DMGSQ
DGAM2 = (A*DBET1-DBET2/2.0)/DMGSQ
BET1 = DBET1
BET2 = DBET2
GAM1 = DGAM1
GAM2 = DGAM2
DELT1 = A*DBET2/2.0/DMGSQ
DELT2 = A*DBET1/2.0/DMGSQ
OMGSQ = DMGSQ
F1FUNC = XNU*SQR((XNU*(XNU+1.0))/(XNU**2+ASQ))
F1FUNC = F1FUNC+BET1*ALFUNC(XNU,A,OMGSQ,BET1,BET2,DELT1,DELT2,GAM1,G1AM2)/(4.0*OMGSQ)
F1FUNC = F1FUNC+BET2*TEFUNC(XNU,A,DELT1,DELT2,GAM1,GAM2)/(2.3*OMGSQ)
F1FUNC = 0.5*F1FUNC/ASQ
RETURN
END

FUNCTION EJ1 (IL, IR, XX, F)
NEEDS COMMON -- USES NTGRT
REAL KAY(50)
COMMON P(101), G(101), Q(101), H(101), X(101), XSQ(101), FX(101), ETN1(101), ETN2(101), ETP1(101), ETP2(101), YU1(101), YU2(101), TAU(101), ALP(101), DEE(101), AA(50), KAY, CAY, A, A1, A2, ACAP, ALPHA, AMDA, ASQ, BB, BINT, C30, CL, CM, DELTA, DINT, ECAP, ELL, EM, EPSILON, ETA1, ETA2, ETA3, TEE, ONE, T0, T4HR, THETA, TSAVE, XCO, XCI, XC2, XC3, XH, XZ, NS, NN, J6, J6R, J7, J7M, J7N, J7T, J7TH, J7M1, J7M2, J7M3, J7M4, J7M5, J7M6, J7M7, J7M8, J7M9, J7M10, J7M11, J7M12, J7M13, J7M14, J7M15, J7M16, J7M17, J7M18
COMMON /BLK1/VIBAR, VIBAR1, ECAP1, YC12
DIMENSION F(101)

C
NM = IR-IL+1
J = IL
DO 100 I = 1, NM
FX(I) = F(J)*CKLOG(X(J)-XX)
J = J+1
100 CONTINUE
CALL NTGRT (EJ1)
RETURN
END

FUNCTION EJ3 (AZ, A2, XH)
EVALUATES THE EXPRESSION FOR THE DEFINITE INTEGRAL OF
P(T)*LOG(T-XX) FROM XX-H TO XX+H.
HYDROFOIL DESIGN PROGRAM

C
C (3-PT. INTEGRAL ACROSS LOG. SINGULARITY.)
C
EJ3=2.0*AZ*XH*(CKLOG(XH)-1.0)+0.66666667*A2*XH**3*(CKLOG(XH)-0.333333)
RETURN
END

FUNCTION EJ4 (XH,XX)
EVALUATES THE DEFINITE INTEGRAL OF (1-T)**.5*LOG(T-XX) OVER (1-2H,1) AS OBTAINED IN CLOSED FORM (T THE VARIABLE OF INTEGRATION
INTEGRATE SQ. ROOT TERM FROM 1-2H TO 1.

IF (ABS(XX-(1.0-2.0*XH))-5.0E-07) 120,120,100
100 EJ4=((2.828428*XH**1.5-(1.0-XX)**1.5)*CKLOG(1.414214*SQRT(XH))-SQRT(1.0-XX))+((2.828428*XH**1.5+(1.0-XX)**1.5)*CKLOG(1.414214*SQRT(XH))
2+SQRT(1.0-XX))-1.885619*XH**1.5-2.828428*SQRT(XH)*(1.0-XX))*0.666636667
110 RETURN
120 EJ4=((2.828428*XH**1.5+(1.0-XX)**1.5)*CKLOG(1.414214*SQRT(XH)+SQRT(1.0-XX))-1.8856188*XH**1.5-2.828428*SQRT(XH)*(1.0-XX))*0.66666
GO TO 110
END

FUNCTION EJ5 (BLZ,BL1,BL2,BRZ,BR1,BR2,XH)
EVALUATES THE EXPRESSION FOR THE DEFINITE INTEGRAL OF FTJX OVER THE LIMITS XX-2H TO XX+2H. BLZ,BL1,BL2,BRZ,BR1,BR2 ARE THE COEFFICIENTS OF THE QUADRATIC APPROXIMATIONS TO P(X) OVER (XX-2H,XX) AND (XX,XX+2H), RESPECTIVELY.

(5-PT. INTEGRAL ACROSS LOG. SINGULARITY.)
EJ5=2.0*((BLZ+BRZ)*XH*(CKLOG(2.0*XH)-1.0)+(BR1-BL1)*XH**2*(CKLOG(2.0*XH)-0.5)+4.0*(BR2+BL2)*XH**3*(CKLOG(2.0*XH)-0.33333333)/3.0)
RETURN
END
FUNCTION BINT3 (DUM1)
REAL KAY(50)
COMMON P(101), G(101), Q(101), H(101), X(101), XSQ(101), FX(101), ETN1(10
11), ETN2(101), ETP1(101), ETP2(101), YU1(101), YU2(101), TAU(101), ALP(2101),
DEE(101), AA(50), KAY, CAY, DUM, A1, A2, ACAP, ALPHA, AMDA, ASQ, BB, INT
3, CO, CL, CM, DELTA, DINT, ECAP, ELL, EM, EPSILN, ETA1, ETA2, ETA3, TEE, ONE, T40
4, THR, THETA, TSAVE, XC0, XC1, XC2, XC3, XH, XKZ, NM, NN, JL6, JM6, JR6, JL13, JM1
53, JR13, JTT1, JTM1, JTT2, JTM2, JTT3, JTM3, JTT4, JTM4, JTT5, JTM5, JTT7, JTM7
6, JTT8, JTM8, JTT9, JTM9, JTT10, JTM10, JTT11, JTM11, JTT12, JTM12, JTT21, JTM
721, JTT23, JTM23, JTT24, JTM24, JTT25, JTM25
NM=NN
DO 100 I=1, NM
100 FX(I)=P(I)/SQRT(X(I))- SQRT(ELL-X(I))
CALL NTCRTE (BINT3)
RETURN
END

FUNCTION BINT4 (DUM1)
REAL KAY(50)
COMMON P(101), G(101), Q(101), H(101), X(101), XSQ(101), FX(101), ETN1(10
11), ETN2(101), ETP1(101), ETP2(101), YU1(101), YU2(101), TAU(101), ALP(2101),
DEE(101), AA(50), KAY, CAY, DUM, A1, A2, ACAP, ALPHA, AMDA, ASQ, BB, INT
3, CO, CL, CM, DELTA, DINT, ECAP, ELL, EM, EPSILN, ETA1, ETA2, ETA3, TEE, ONE, T40
4, THR, THETA, TSAVE, XC0, XC1, XC2, XC3, XH, XKZ, NM, NN, JL6, JM6, JR6, JL13, JM1
53, JR13, JTT1, JTM1, JTT2, JTM2, JTT3, JTM3, JTT4, JTM4, JTT5, JTM5, JTT7, JTM7
6, JTT8, JTM8, JTT9, JTM9, JTT10, JTM10, JTT11, JTM11, JTT12, JTM12, JTT21, JTM
721, JTT23, JTM23, JTT24, JTM24, JTT25, JTM25
NM=NN
DO 100 I=1, NM
100 FX(I)=P(I)*SQRT(X(I))/SQRT(ELL-X(I))
CALL NTCRTE (BINT4)
RETURN
END
FUNCTION TEFUNC (XNU, A, DELT1, DELT2, GAM1, GAM2)
TFUN

PLAYS A PART SIMILAR TO THAT OF ALFUNC.

TEFUNC = (GAM2*XNU+DELT2)/(GAM1*XNU+DELT1-SQRT(XNU*(XNU+1.0)))
TEFUNC = ATAN(TEFUNC) - ATAN(DELT2/DELT1) - ATAN(XNU/A)
RETURN
END

FUNCTION ALFUNC (XNU, A, ONGSQ, BET1, BET2, DELT1, DELT2, GAM1, GAM2)

THIS SPECIAL FUNCTION IS PART OF EXPRESSION FOR \(F1(\nu, A)\) -- ALSO
NEEDED BY \(F2(\nu, A)\) IN THE OFF-DESIGN CALCULATION.

ALFUNC = (GAM1*XNU+DELT1-SQRT(XNU*(XNU+1.0)))**2 + (GAM2*XNU+DELT2)**2
ALFUNC = ALFUNC*A**2/(DELT1**2+DELT2**2)/(XNU**2+A**2)
ALFUNC = CKLOG(ALFUNC)
RETURN
END
FUNCTION BICR (A)
REAL KAY(50)
DO 100 I=1,NN
100 FX(I)=P(I)*X(I)
CALL NTRPTE (BICR)
RETURN
END

FUNCTION BTX7 (XX)

THIS SPECIAL ROUTINE EVALUATES A DEFINITE INTEGRAL OVER (0,1)
WHOSE INTEGRAND INVOLVES P(X) AND A LOGARITHMIC FUNCTION OF THE
VARIABLE OF INTEGRATION. THIS INTEGRAL IS NEEDED BY THE ROUTINE HH.

REAL KAY(50)
COMMON /BLK1/V1BAR,V1BAR1,ECAP1,YC12
HYDROFOIL DESIGN PROGRAM

G7(S) = ALOG(SQRT(ELL-XX)*SQRT(S)+SQRT(XX)*SQRT(ELL-S))
XC0=0.0
XC1=X(NN-2)
XC2=X(NN-1)
XC3=X(NN)
ETA1=G7(XC1)
ETA2=G7(XC2)
ETA3=G7(XC3)
CALL PARAB (BBO,BB1,BB2)
NM=NN-2
FX(1)=0.0
DO 100 I=2,NM
100 FX(I)=P(I)*G7(X(I))
CALL NTGRTE (TG1)
NM=3
J=NN-2
DO 110 I=1,NM
FX(I)=G(J)*G7(X(J))
J=J+1
110 CONTINUE
CALL NTGRTE (TG2)
BTX7=TG1+TG2+BB*FOUR(X(NN-2),BBO,BB1,BB2)
RETURN
END
PROGRAM FLOW CHART

START

INPUT
K, CL, T
X0, μ, P(x)

COMPUTE
PERMISSIBLE
RANGE OF μ

IS μ
WITHIN
LIMITS?

NO

PRINT
DIAGNOSTICS

YES

SOLVE FOR a
IN f(a)=0

COMPUTE PERFORMANCE
PARAMETERS CD, CM, X,
α, etc.

COMPUTE CAMBER,
CAVITY SHAPE AND
TOTAL PRESSURE
DISTRIBUTION

PRINT
RESULTS

END
OF
INPUT?

NO

YES

STOP
Sample Calculations for Estimation Mode

**LISTING OF INPUT DATA FOLLOWS**

NO. OF GRID-PTS.   N = 51   STEP-SIZE XR = 0.40000000E-02   FUNCTION BOUND ARDA = 0.50000000E 01
COEF. OF SQ. ROOT COMP. = 0.00000000E 00   CAVITATION NO. K (CAT) = 0.50000000E-01   LIFT COMP. CL = 0.79999998E-01
PARAMETER T (TER) = 0.10000000E 00   S = 0.100   X0 = 0.100
A = 0.24883300E 01
ERROR IN FA = -0.10803343E-06
FOR K = 0.00000000E 00   MAXIMUM VALUE OF CL IS = 0.10855382E 00
A = 0.22659280E 01
ERROR IN FA = -0.29802320E-07
FOR K = 0.10000000E 01   MAXIMUM VALUE OF CL IS = 0.10517292E 00
THE RANGE OF K AND MU FOR DESIGN CL = 0.79999998E-01
A = 0.23781080E 01
ERROR IN FA = -0.74505800E-07
K = 0.00000000E 00   MU = 0.17512462E 00
A = 0.22196870E 01
ERROR IN FA = -0.40978190E-07
K = 0.10000000E 01   MU = 0.15776062E 00
## Sample Calculations for Design Mode

### Listing of Input Data Follows

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<th>NO. OF GRID-PTS.</th>
<th>NH = 51</th>
<th>STEP-SIZE XH = 0.00000010E-02</th>
<th>FUNCTION BOUND AND = 0.50000000E-01</th>
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<td>CD = 0.6182503E-02</td>
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### Sample Calculations for Design Mode (Cont.)

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