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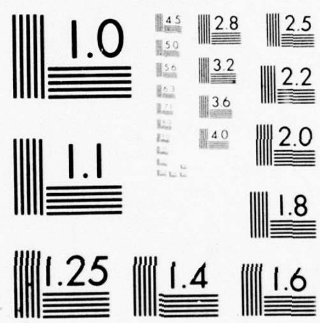

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DESIGN IMPLEMENTATION FOR SUPERCAVITATING HYDROFOILS WITH TWO-POINT CAVITY THICKNESS CONTROL.

(10) J. Fernandez

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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.

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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.

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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 μ 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 esimates 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 μ from the range of μ 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

$$0 < a_\ell < a_r < a_{max}$$

and (1)

$$f(a_\ell)\, f(a_r) < 0 \quad .$$

Thus the root of the equation f(a)=0 is located within the range $a_\ell < a < a_r$. 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

$$B = \frac{(1-m)C_L}{\pi(1+K)} \frac{(\varepsilon+a\delta)}{a\ell(\delta-a\varepsilon)} + \frac{m}{4\pi(1+K)a\ell} \int_0^1 \frac{(\ell-2x)P(x)dx}{\sqrt{x(\ell-x)}} \quad . \tag{2}$$

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 ε and δ in the above equation* are defined by

$$\left\{ {\delta \atop \varepsilon} \right\} = [\sqrt{\ell}+1]^{1/2} \pm [\sqrt{\ell}-1]^{1/2} \tag{3}$$

where ℓ, the cavity length is obtained from

*The following expansion formulas for ε and δ are found useful in obtaining various limiting values as $a \to \infty$ (or, equivalently, as $K \to 0$)

$$\delta \simeq \sqrt{a}\, \{2 + \frac{1}{4a^2} + 0(\frac{1}{a^4})\}$$

$$\varepsilon \simeq \frac{1}{\sqrt{a}}\, \{1 - \frac{1}{8a^2} + 0(\frac{1}{a^4})\}$$

$$\ell = 1 + a^2 \quad .$$

Step 3:

The parameter D is obtained from the relation

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

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

$$E = \beta - \frac{(1-m)\ C_L}{2\pi(1+K)} \frac{(2a^2+3)\varepsilon + a\delta}{\ell(\delta - a\varepsilon)} - \frac{m}{2\pi(1+K)\ell} \int_0^1 \sqrt{(\ell - x)/x}\ P(x)\ dx \quad . \tag{5}$$

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

$$A = \frac{-2(1-m)\ C_L}{\pi(1+K)} \frac{\sqrt{a}}{(\delta - a\varepsilon)} \quad . \tag{6}$$

Step 6:

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

$$C_D = 2\pi(1+K)\ \ell(aB + \frac{E}{2})^2 \quad . \tag{7}$$

Step 7:

The moment coefficient is obtained from the relation

$$C_M = -(1-m)\, C_L \frac{(3\delta-4a\varepsilon) + a^2(\delta-2a\varepsilon)}{8\varepsilon\sqrt{\ell}} - m\int_0^1 x\, P(x)\, dx \quad . \tag{8}$$

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

$$y_c(1) = aE \quad . \tag{9}$$

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

$$\begin{aligned} \overline{V}_1(x) &= \eta'(x) + \frac{E_d\sqrt{\ell_d}}{2\sqrt{x}} \quad , \quad 0<x<2h \\ &= \eta'(x) \quad , \quad x>2h \end{aligned} \tag{10}$$

where E_d and ℓ_d are respectively the coefficient of the complementary function and the cavity length at the design conditions. $\overline{V}_1(0)$ is obtained from

$$\bar{V}_1(0) = \alpha - \frac{(1-m)\ C_L}{\pi(1+K)} \frac{\delta}{(\delta - a\varepsilon)} \quad . \tag{11}$$

Step 10:

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

$$y(x) = \alpha x - 2a^2\ell\ AF_1(x,a) + aB[\sqrt{x(\ell-x)} - \ell\ \tan^{-1}\sqrt{x/(\ell-x)}]$$

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

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

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

$$- \tan^{-1}\sqrt{x/(\ell-x)}\ B_4 + \frac{C_L}{2}\ \ell n\ (\frac{\ell}{\ell-x}) \tag{13}$$

$$- \int_0^1 P(t)\ \ell n \left| 1 + \sqrt{x(\ell-t)/t(\ell-x)} \right| dt \quad .$$

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

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

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

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

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

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

$$+ \frac{C_L}{2} \ell n \left(\frac{\ell}{\ell-x}\right) - \int_0^1 P(t)\, \ell n \left|1 - \sqrt{x(\ell-t)/t(\ell-x)}\right| dt\} \quad . \qquad (15)$$

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

$$\int_0^1 P(t)\, \ell n \left|1 - \sqrt{x(\ell-t)/t(\ell-x)}\right| dt$$

$$= C_L\, \ell n\, (\ell/\sqrt{\ell-x}) + \int_0^1 P(t)\, \ell n(t-x)dt - \frac{1}{2}\int_0^1 P(t)\, \ell n\, t\, dt$$

$$- \int_0^1 P(t)\, \ell n(\sqrt{t(\ell-x)} + \sqrt{x(\ell-t)})dt \quad . \qquad (16)$$

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

$$\eta'(x) = \alpha - \frac{B}{2}(1 - 2a\sqrt{x/(\ell-x)}) - D - \frac{E}{2}\frac{\ell-2x}{\sqrt{x(\ell-x)}}$$

$$+ \frac{m}{2\pi(1+K)}\{\frac{1}{2}B_3 - \frac{1}{2}\sqrt{(\ell-x)/x}\,B_1 + \frac{B_4}{2\sqrt{x(\ell-x)}} \tag{17}$$

$$+ \frac{C_L}{2}\frac{x}{(\ell-x)} + \frac{1}{2\sqrt{x}(\ell-x)}\,\text{P.V.}\int_0^1 \frac{P(t)(\sqrt{t(\ell-x)} + \sqrt{x(\ell-t)})\sqrt{\ell-t}}{t-x}\,dt\} \quad .$$

The quantities B_1, B_3 and B_4 are obtained through COMMON from FUNCTION FA. The Cauchy principal value of the singular integral is obtained from subprogram FUNCTION 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 $C_{L_{max}}$ is given by

$$C_{L_{max}} = \frac{\pi T}{(1-m)\{3\sqrt{2} - \ell n(1+\sqrt{2})\} + m\{\int_0^1 \frac{q(x)dx}{\sqrt{x}} - \frac{1}{2}\int_0^1 q(x)\ell n\,(\frac{1+\sqrt{x}}{1-\sqrt{x}})\,dx\}} \tag{18}$$

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

$$q(x) = \frac{P(x)}{\int_0^1 P(x)dx} \quad . \tag{19}$$

Thus

$$\int_0^1 q(x)dx = 1 \quad .$$

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

$$\int_0^1 q(x)\ln\left(\frac{1+\sqrt{x}}{1-\sqrt{x}}\right)dx = 2\int_0^1 q(x)\ln(1+\sqrt{x})dx - \int_0^1 q(x)\ln(1-x)dx \quad . \tag{20}$$

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

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

$$m' = \frac{3\sqrt{2} - \ln(1+\sqrt{2}) - \pi T/C_L}{3\sqrt{2} - \ln(1+\sqrt{2}) - \int_0^1 \frac{q(x)dx}{\sqrt{x}} + \frac{1}{2}\int_0^1 q(x)\ \ln\left(\frac{1+\sqrt{x}}{1-\sqrt{x}}\right)\ dx} \quad . \tag{21}$$

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

$$C_1 = 2C_L[\{3\sqrt{2} - \ln(1+\sqrt{2})\} (\frac{1}{2} + \frac{1}{2\sqrt{x_o}})$$

$$- (1+2\sqrt{x_o}) \sqrt{(1+\sqrt{x_o})}\, x_o^{-3/4} + \frac{1}{x_o} \ln(x_o^{1/4} + \sqrt{1+\sqrt{x_o}})]$$

$$C_2 = C_1 + \int_0^1 P(x) \ln(1 + \frac{1}{\sqrt{x}})\, dx - \frac{1}{x_o} \int_0^1 P(x) \ln (1 + \frac{\sqrt{x_o}}{\sqrt{x}})\, dx$$

$$- (\frac{1}{2} - \frac{1}{2\sqrt{x_o}}) \int_0^1 P(x) \ln (\frac{1+\sqrt{x}}{1-\sqrt{x}})\, dx \quad . \tag{22}$$

The quantity C_2 can be rewritten as

$$C_2 = \frac{1}{\sqrt{x_o}} \int_0^1 P(x) \ln(1 + \sqrt{x})dx - \frac{1}{x_o} \int_0^1 P(x) \ln(\sqrt{x} + \sqrt{x_o})\, dx + C_1$$

$$- \frac{1}{2} (1 - \frac{1}{x_o}) \int_0^1 P(x) \ln x\, dx + (\frac{1}{2} - \frac{1}{2\sqrt{x_o}}) \int_0^1 P(x) \ln(1-x)dx \quad . \tag{23}$$

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 μ for a given m in the estimation mode. μ is given by

$$\mu = \frac{(m\, C_2 - C_1)\, x_o}{2\pi T} + \frac{x_o + \sqrt{x_o}}{2} \quad . \tag{24}$$

Step 18:

The value of m is calculated in this step for a given μ in the design mode. m is given by

$$m = \frac{C_1 + 2\pi T(\frac{\mu}{x_o} - \frac{1}{2} - \frac{1}{2\sqrt{x_o}})}{C_2} \quad . \tag{25}$$

Step 19:

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

$$y_c(1) = \frac{T}{2} - \frac{(1-m)C_L}{2\pi}\{3\sqrt{2} - \ell n(1 + \sqrt{2})\}$$
$$- \frac{m}{2\pi}\{\int_0^1 \frac{P(x)dx}{\sqrt{x}} - \frac{1}{2}\int_0^1 P(x)\ \ell n(\frac{1+\sqrt{x}}{1-\sqrt{x}})\ dx\} \quad . \tag{26}$$

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 α, the design attack angle is computed in this step from the relation

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

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

$$\int_0^1 P(x)\ \ell n(1 - \frac{1}{\sqrt{x}})\ dx = \int_0^1 P(x)\ \ell n(1-x)dx - \frac{1}{2}\int_0^1 P(x)\ \ell n\ x\ dx$$
$$- \int_0^1 P(x)\ \ell n(1 + \sqrt{x})dx \quad . \tag{28}$$

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

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

The integral in the above equation is given by BTG9.

Step 22:

The moment coefficient C_M is obtained from

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

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

Step 23:

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

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

Step 24:

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

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

$$+ y_c(1) \sqrt{x} + \frac{m}{2\pi} \{\sqrt{x} \int_0^1 \frac{P(t)dt}{\sqrt{t}} - \int_0^1 P(t) \ln(1 + \frac{\sqrt{x}}{\sqrt{t}})\ dt\} \quad . \tag{32}$$

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

$$\int_0^1 P(t)\ \ell n(1 + \frac{\sqrt{x}}{\sqrt{t}})dt = \int_0^1 P(t)\ \ell n\ (\sqrt{t} + \sqrt{x})dt - \frac{1}{2}\int_0^1 P(t)\ell n\ t\ dt \quad . \tag{33}$$

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

$$\eta(x) = (\alpha - \frac{2(1-m)C_L}{\pi})x - y_c(1)\ \sqrt{x} - \frac{\sqrt{x}}{2\pi}\ m \int_0^1 \frac{P(t)dt}{\sqrt{t}}$$
$$- \frac{m}{2\pi}\int_0^1 P(t)\ell n\ (\left|1 - \frac{\sqrt{x}}{\sqrt{t}}\right|)dt \quad . \tag{34}$$

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

$$\int_0^1 P(t)\ell n\ (\left|1 - \frac{\sqrt{x}}{\sqrt{t}}\right|)dt = \int_0^1 P(t)\ell n(|t-x|)dx - \frac{1}{2}\int_0^1 P(t)\ell n\ t\ dt$$
$$- \int_0^1 P(t)\ell n\ (\sqrt{t} + \sqrt{x})dt \quad . \tag{35}$$

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

$$\eta'(x) = \alpha - \frac{2(1-m)}{\pi} C_L - \frac{y_c(1)}{2\sqrt{x}}$$

$$+ \frac{m}{4\pi\sqrt{x}} \{P.V. \int_0^1 \frac{P(t)dt}{\sqrt{t}-\sqrt{x}} - \int_0^1 \frac{P(t)dt}{\sqrt{t}}\} \quad . \qquad (36)$$

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

$$\int_0^1 \frac{P(t)dt}{\sqrt{t}-\sqrt{x}} = \int_0^1 \frac{P(t)(\sqrt{t}+\sqrt{x})}{t-x} dt \quad . \qquad (37)$$

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 μ 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 μ 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:

$$C_L \leq \min (C_{L_0} , C_{L_1}) \quad .$$

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

Case b:

$$C_L < \max (C_{L_0} , C_{L_1}) \quad .$$

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:

$$C_{L_1} \leq C_L \leq C_{L_0} \quad .$$

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 μ correspond to m=m' and m=0.

Case d:

$$C_{L_0} \leq C_L \leq C_{L_1} \quad .$$

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

SUBROUTINE FA

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

Step 1:

The parameters ε and δ are computed from

$$\left\{{\delta \atop \varepsilon}\right\} = [\sqrt{\ell}+1]^{1/2} \pm [\sqrt{\ell}-1]^{1/2} \tag{3}$$

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

Step 2:

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

$$C_L = \frac{2\pi(1+K)\beta\ell}{(1-m)\,\dfrac{(2a^2+3)\varepsilon + a\delta}{\delta-a\varepsilon} + m\displaystyle\int_0^1 \sqrt{(\ell-x)/x}\; q(x)\, dx} \tag{38}$$

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

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

Step 3:

This step computes the value of m corresponding to $y_c(1)=0$ for a given C_L. This is obtained from

$$m' = \frac{\beta 2\pi(1+K)\ell/C_L - T_1}{\int_0^1 \sqrt{(\ell-x)/x}\; q(x)dx - T_1} \tag{39}$$

where

$$T_1 = \frac{(2a^2+3)\varepsilon + a\delta}{\delta - a\varepsilon} \quad .$$

Step 4:

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

$$B_1 = \int_0^1 \frac{P(x)dx}{\sqrt{x(\ell-x)}} \quad . \tag{40}$$

B_1 is computed by FUNCTION BINT1.

$$B_2 = \int_0^1 P(x)\ \sqrt{(\ell-x)/x}\ dx \quad . \tag{41}$$

B_2 is given by FUNCTION BTG1.

$$B_3 = \int_0^1 \frac{P(x)dx}{(\ell-x)} \quad . \tag{42}$$

B_3 is obtained from FUNCTION BINT3.

$$B_4 = \int_0^1 P(x)\ \sqrt{x/(\ell-x)}\ dx \quad . \tag{43}$$

B_4 is obtained from FUNCTION BINT4.

$$B_5 = \int_0^1 P(x) \frac{(\ell-2x)dx}{\sqrt{x(\ell-x)}} = \ell B_1 - 2B_4 \quad . \tag{44}$$

$$B_6 = \int_0^1 P(x)dx = C_L \tag{45}$$

$$B_7 = \int_0^1 P(x) \ \ell n \left| \frac{a\sqrt{x} - \sqrt{\ell-x}}{a\sqrt{x} + \sqrt{\ell-x}} \right| dx \quad .$$

B_7 can be rewritten as

$$B_7 = C_L \ \ell n(\ell) + \int_0^1 P(x)\ell n|x-1|dx$$

$$- 2 \int_0^1 P(x) \ \ell n(a\sqrt{x} + \sqrt{\ell-x}) \ dx \quad . \tag{46}$$

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

Step 5:

The quantities H_η and F_η are computed in this step. These are given by

$$H_\eta = \frac{C_L \ 4a^2 \ \ell\sqrt{a}}{(\delta-a\varepsilon)} F_1(1,a) + \{a - \ell \tan^{-1} (\frac{1}{a})\} C_L \frac{\varepsilon+a\delta}{\ell(\delta-a\varepsilon)}$$

$$- \frac{a}{\ell} C_L \frac{(2a^2+3)\varepsilon + a\delta}{\delta-a\varepsilon} + \frac{a}{\ell} B_2 - \frac{1}{2\ell} \{a - \ell \tan^{-1} (\frac{1}{a})\} B_5$$

$$- \frac{1}{2} \{a + \ell \tan^{-1} (\frac{1}{a})\} B_1 + \tan^{-1}(\frac{1}{a}) B_4 - \frac{B_7}{2} \quad . \tag{47}$$

$$F_\eta = T - 2a\beta - \frac{C_L}{\pi(1+K)} \frac{4a^2\ell\sqrt{a}}{(\delta-a\varepsilon)} F_1\,(1,a)$$

$$- \frac{C_L}{\pi(1+K)} \{a - \ell \tan^{-1} (\frac{1}{a})\} \frac{\varepsilon+a\delta}{\ell(\delta-a\varepsilon)}$$

$$+ \frac{C_L}{\pi(1+K)} \frac{a}{\ell} \frac{(2a^2+3)\varepsilon + a\delta}{\delta-a\varepsilon} \quad . \tag{48}$$

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

Step 6:

The quantities H_t and F_t are computed from the equations

$$H_t = C_L \frac{4a^2\ell\sqrt{a}}{(\delta-a\varepsilon)} \{F_1(1,a) - \frac{F_1(x_o,\ a)}{x_o}\}\{a - \sqrt{(\ell-x_o)/x_o} - \ell \tan^{-1} (\frac{1}{a})$$

$$+ \frac{\ell}{x_o} \tan^{-1} \sqrt{x_o/(\ell-x_o)}\}\{\frac{C_L}{2} \frac{\varepsilon+a\delta}{\ell(\delta-a\varepsilon)} - \frac{B_5}{4\ell}\} + \{\frac{B_2}{2\ell} - \frac{C_L}{2} \frac{(2a^2+3)\varepsilon + a\delta}{\ell(\delta-a\varepsilon)}\}$$

$$\times (a - \sqrt{(\ell- x_o)/x_o}) + \frac{1}{2} \{G(1,a;P) - \frac{G(x_o;a;P)}{x_o}\} \quad . \tag{49}$$

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

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

$$- \{\beta - \frac{C_L}{2\pi(1+K)} \frac{(2a^2+3)\varepsilon + a\delta}{\ell(\delta-a\varepsilon)}\}\{a - \sqrt{\ell-x_o/x_o}\} \quad . \tag{50}$$

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

$$f(a) = F_\eta + \frac{m}{\pi(1+K)} H_\eta \quad . \tag{51}$$

The corresponding value of μ is obtained from

$$\mu = \frac{x_o}{T} \{f_t + \frac{m}{\pi(1+K)} H_t\} \quad . \tag{52}$$

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

$$f(a) = F_\eta H_t - (f_t - \frac{\mu T}{x_o}) H_\eta \quad . \tag{53}$$

The corresponding value of m is obtained from

$$m = - F_\eta \, \pi(1+K)/H_\eta \quad . \tag{54}$$

The control is now returned to the calling routine.

FUNCTION CPVI

The function subprogram CPVI evaluates the following Cauchy Principal value integral

$$J = \int_{x_1}^{x_N} \frac{P(t)\ g(t,x)dt}{t-x} \tag{55}$$

where

$$g(t,x) = (\sqrt{t(\ell-x)} + \sqrt{x(\ell-t)})\ \sqrt{\ell-t} \quad , \quad K\neq 0$$

$$= (\sqrt{t} + \sqrt{x}) \quad , \quad K=0 \quad .$$

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

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

Since

$$P(x) = 0 \quad \text{for} \quad I=1 \quad . \tag{56}$$

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

$$J = \int_{x_1}^{x_1+2h} [a_1 + a_2(t - x_1)]dt + \int_{x_1+2h}^{x_N} \frac{P(t)\ g(t,x)}{(t-x)}\ dt \quad . \tag{57}$$

The first integral is evaluated as

$$\int_{x_1}^{x_1+2h} [a_1 + a_2(t-x_1)]dt = 2h(a_1 + a_2 h) \quad . \tag{58}$$

The second integral is evaluated by subprogram DIFF2.

Case B: I=2

In this case, we write,

$$P(t)\ g(t,x) = a_0 + a_1(t-x) + a_2(t-x)^2 \quad , \quad x_1 \le t \le x_3 \tag{59}$$

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

$$J = \int_{x_1}^{x_1+2h} [\frac{a_0}{t-x} + a_1 + a_2(t-x)]dt + \int_{x_1+2h}^{x_N} \frac{P(t)\ g(t,x)dt}{(t-x)} \quad . \tag{60}$$

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

$$F(x_\ell, x, x_u, q_0, q_1, q_2) = q_0 \ \ell n \ (\frac{x_u-x}{x_\ell-x}) + q_1(x_u-x_\ell) + \frac{q_2}{2}[(x_u-x)^2 - (x_\ell-x)^2)] \quad . \tag{61}$$

The second integral can be evaluated by DIFF2.

Case C:

$$3 \le I \le N-3 \quad .$$

In this case, the integral J is written as

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

$$+ \int_{x_{i+1}}^{x_N} \frac{P(t)\ g(t,x)}{t-x}\, dt \quad . \tag{62}$$

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

$$P(t)\ g(t,x) = a_0 + a_1(t-x) + a_2(t-x)^2 \quad , \quad x_{i-1} \le t \le x_{i+1} \quad . \tag{63}$$

Case D: I=N-2

The integral J is written as

$$J = \int_{x_1}^{x_{N-3}} \frac{P(t)\ g(t,x)dt}{t-x} + \int_{x_{N-3}}^{x_{N-1}} \left[\frac{b_0}{t-x} + b_1 + b_2(t-x)\right] dt$$

$$+ \int_{x_{N-1}}^{x_N} \left[\frac{c_0}{t-x} + c_1 + c_2(t-x)\right] dt \tag{64}$$

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

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

for

$$x_{N-3} \le t \le x_{N-1} \tag{65}$$

and (c_0, c_1, c_2) are obtained from the approximation

$$P(t)\ g(t,x) = c_0 + c_1(t-x) + c_2(t-x)^2 \quad , \quad x_{N-2} \le t \le x_N \quad .$$

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

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

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

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

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

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

where the constants b_1 and b_2 are obtained from the approximation

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

which satisfies the condition $P(x_N)=0$.

The first integral in Eq. (68) is given by DIFF2 and the second is given by

$$\int_{x_{N-2}}^{x_N} [b_1 + b_2(t-x)]dt = 2h(q_1-q_2h) \quad . \tag{70}$$

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

by

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C       MAIN LINE PROGRAM FOR THE THIRD DESIGN PROCEDURE (SECT6)
C         THIS PROGRAM READS THE INPUT DATA AND CALLS THE PRICIPAL
C       ROUTINE SECT6 FOR THE HYDROFOIL DESIGN WITH TWO POINT
C       CAVITY THICKNESS CONTROL.
C
C       JUNE 15, 1977
C
C
C                            DICTIONARY OF SYMBOLS
C       A IS THE CAVITY PARAMETER LITTLE A.
C       ACAP IS THE 'NOSE SINGULARITY' PARAMETER CAPITAL A.
C       AJ1,AJ2,AJ3,AJ4 ARE THE EXPRESSIONS J1,J2,J3,J4 WHICH INVOLVE THE
C       FUNCTIONS F1(NU,A),F2(NU,A),L(NU,A),AND T(NU,A)--SEE SECT5.
C       ALEFT AND ARITE ARE END-PTS. OF A-INTERVAL FOR REGULUS FALSI ROUT.
C       ALP IS THE TABLE OF ATTACK ANGLES COMPUTED IN THE OFF-DESIGN CALC.
C       ALPHA IS THE ATTACK ANGLE (RADIANS)
C       AMDA IS A UNIVERSAL FUNCTION BOUND USED TO SET SUBINTERVAL LENGTHS
C       AMU IS THE RATIO OF CAVITY THICKNESSES AT XO AND THE TRAILING EDGE
C       AONE IS THE FUNCT. A1(A) NEEDED TO COMPUTE SIG1--SECT5.
C       ASQ IS A**2.
C       ATWO IS A2(A) REQUIRED BY SIG2.
C       A1 IS THE CAVITY PARAMETER FOR THE FIRST FOIL (SHOCKLESS ENTRY).
C       A2  IS THE CAVITY PARAMETER FOR THE SECOND FOIL (NOSE SINGULARITY)
C       BB IS LITTLE B, THE COEFFICIENT OF THE 'SQUARE ROOT' BEHAVIOR TERM
C       BET1 AND BET2 ARE FUNCTIONS OF OMGSQ AND A.
C       BETA AS A VARIABLE IS COMPUTED IN SECT5,=MAX((TAU-SIG2)/SIG1).
C       BINT IS THE PARAMETER CAPITAL B.
C       BONE IS B1(A) REQUIRED BY SIG1.
C       BTWO IS B2(A) NEEDED FOR SIG2--SECT5.
C       CAY IS THE CAVITATION NUMBER.
C       CD IS THE DRAG COEFFICIENT.
C       CL IS THE LIFT COEFFICIENT.
C       CM IS THE MOMENT COEFFICIENT.
C       CO IS THE FIRST TERM OF FOURIER EXPANSION.
C       DELTA IS A SPECIAL FUNCTION OF THE CAVITY LENGTH ELL.
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```
C       DELT1 IS A*BET1/2/OMGSQ.
C       DELT2 IS A*BET2/2/OMGSQ.
C       DINT IS THE PARAMETER CAPITAL D.
C       DLPHA IS THE ATTACK ANGLE IN DEGREES.
C       DROIT IS THE RIGHT-HAND END-PT. OF SUBINTERVAL COMMUNICATED
C       TO REGUL THROUGH THE SUBROUTINE LIST.
C       ECAP IS THE PARAMETER CAPITAL E OF THE 'SHOCKLESS ENTRY' CASE.
C       ELL IS THE CAVITY LENGTH = A**2+1.
C       EM IS THE PRESSURE FUNCTION MULTIPLIER COMPUTED FOR 2ND. FOIL
C       EPSILN IS A SPECIAL FUNCTION OF THE CAVITY LENGTH.
C       ETA1, ETA2, ETA3 ARE FUNCTION VALUES AT XC1, XC2, AND XC3.
C       ETN1 IS THE CAMBER FUNCTION FOR THE FIRST FOIL.
C       ETN2 IS THE CAMBER FUNCTION FOR THE SECOND FOIL.
C       ETP1 IS THE DERIVATIVE OF THE 1ST. CAMBER FUNCTION.
C       ETP2 IS THE DERIVATIVE OF THE 2ND. CAMBER FUNCTION.
C       ETPRM IS THE DERIVATIVE AS COMPUTED BY DIFFER.
C       FX IS THE TABLE OF ORDINATES NEEDED BY THE INTEGRATION ROUT. NTGRT
C       G IS THE PRESSURE MINUS THE SQ. ROOT TERM - G=P-BB*(1-X)**.5.
C       GAM1, GAM2 ARE FUNCTIONS OF SMGSQ, A, BET1, BET2.
C       GAUCHE IS THE LEFT-HAND END PT. OF THE SUBINTERVAL CONTAINING.
C       ROOT - SUBINTERVAL IS COMMUNICATED TO REGUL.
C       H IS THE MAPPING OF G UNDER THE MAPPING OF THE Z-PL. TO THE NU-PL.
C       IFOLSW IS A FLAG USED IN SECT5 - =1,2 FOR 1ST, 2ND FOILS, RESP.
C       II IS SUBSCRIPT OF X DURING EVALUATION OF FOIL FUNCTIONS
C       NA IS THE NUMBER OF LITTLE A VALUES-CAVITY PARAMETER VALUES-INPUT
C         FOR THE OFF DESIGN CALCULATION.
C       NM IS THE NO. OF ORDINATES WHICH IS REQUIRED BY NTGRTE.
C       NN IS THE NUMBER OF MESH POINTS IN INTERVAL (0,1).
C       NSWCH=1 FOR NEXT CASE P=CONST., =2 FOR NEXT CASE NONCONST. P,
C          =4 FOR NO MORE DATA
C       OMGSQ IS A*SELL
C       ONE IS THE INTEGRAL OF G(X) OVER (0,1).
C       P IS THE INPUT PRESSURE FUNCTION DEFINED OVER (0,1), (Z-PLANE).
C       PCON IS THE VALUE OF THE INPUT PRESSURE FOR A CONST. P CASE.
C       Q IS THE TRANSFORMED P UNDER MAPPING FROM Z TO NU PLANES.
C       SALL IS SQ. ROOT OF A*ELL
C       SELL IS S} ROOT OF ELL
C       SIG1 IS THE FUNCTION SIGMA1(X,A)--OFF-DESIGN CALCULATION.
C       SIG2 IS THE FUNCTION SIGMA2(X,A)--FOR THE OFF-DESIGN CALCULATION.
C       TAU IS REDUCED CAVITY USED IN OFF-DESIGN CALCULATION.
C       TEE IS THE STRENGTH PARAMETER APPLIED AT THE TRAILING EDGE.
C       THETA IS THE CAVITY CONTOUR MULTIPLIER USED IN THE OFF-DESIGN CALC
C       THR IS THE INTEGRAL OF H(T) OVER(0,1)--IN NU-PLANE.
C       TI1,TI2,TI3,TI4 ARE SPECIAL INTEGRALS COMPUTED BY TI1FN,TI2FN,TI3F
C       N , TI4FN FOR SECT5 FOR THE FINITE CAVITY CASE.
C       TI5,TI6 ARE SPECIAL INTEGRALS COMPUTED BY TI5FN,TI6FN FOR THE
C       INFINITE CAVITY CASE (CAY=0) OF SECT5.
C       TWO IS THE INTEGRAL OF X*G(X) OVER (0,1).
C       WA IS THE FUNCT. W(A) COMPUTED IN SECT5--NEEDED FOR ALPHA.
C       X IS THE INDEPENDENT VARIABLE. P IS INPUT AS FUNCT. OF X IN (0,1).
C       XC0,XC1,XC2,XC3 SPECIFY PTS. IN (0,1) FOR QUADRATIC FIT BY PARAB
C       XH IS THE STEP-SIZE -- XH*(NN-1) = 1.
C       XKZ IS IMAGE OF X UNDER MAPPING OF Z-PL. TO NU-PL. --
C         = A*(X/(ELL-X))**.5.
C       XO IS THE THICKNESS CONTOL POINT NEAR THE LEADING EDGE
C       XSQ IS X**2.
```

```
C      YYU1 IS THE CAVITY FUNCTION FOR THE FIRST FOIL.
C      YYU2 IS THE CAVITY FUNCTION FOR THE SECOND FOIL.
C
C      INPUT DATA
C        FIRST CARD -
C          NSWCH - SET TO ONE (1) FOR CONSTANT PRESSURE CASE
C                - SET TO TWO (2) FOR NORMAL PRESSURE CASE
C          IPUNCH - ZERO (0) - NO PUNCH
C                 - ONE (1) FOR PUNCHED OUTPUT
C          KWIT - ZERO (0) - RUN OFF DESIGN CONDITIONS
C               - ONE (1) NO OFF-DESIGN CALCULATIONS
C          IUPPER - ONE - UPPER SURFACE CONTOUR IS TO BE CHECKED FOR
C                         INTERFERENCE WITH CAVITY
C          IPRNT -  ZERO (0)  PRINTS OVERALL DESIGN PARAMETERS ONLY.
C                -  ONE (1) PRINTS DETAILED RESULTS LIKE CAVITY SHAPE ETC.
C          NEST - ONE (1) FOR ESTIMATION MODE
C               - ZERO (0) FOR DESIGN MODE.
C      SECOND CARD
C          NN - NUMBER OF INPUT POINTS ON PRESSURE CURVE
C      THIRD CARD
C          XH - DELTA X INCREMENTS ALONG THE CHORD LINE
C          AMDA - LAMDA FUNCTION USED TO LIMIT INTEGRATION
C          BB - COEFFICIENT OF SQUARE ROOT BEHAVIOR
C          STEP - STEP SIZE IN THE SEARCH FOR A
C          AMX - MAXIMUM VALUE FOR A
C      FOURTH CARD
C          NA - NUMBER OF OFF-DESIGN CAVITY LENGTH VALUES TO BE COMPUTED
C      FIFTH CARD
C          AA(I) - ARRAY FOR CAVITY LENGTH VALUES
C      SIXTH CARD
C          ITHET - NUMBER OF THETA VALUES TO BE COMPUTED
C      SEVENTH CARD
C          THET(I) - ARRAY FOR THETA VALUES
C      NEXT NN/8 CARDS
C          SUPPER(I) - ARRAY FOR COORDINATES OF UPPER SURFACE
C      NEXT NN CARDS
C          X(I) - ARRAY CONTAINING INCREMENTS OF CHORD SPACING
C          PP(I) - ARRAY OF PRESSURE DIAGRAM POINTS COORSPONDING TO EACH X
C      NEXT TWO  CARDS   FOR AS MANY CASES AS ARE TO BE RUN
C          KAY - DESIGN CAVITATION NUMBER
C          CL - DESIGN LIFT COEFFICIENT
C          TEE - MAXIMUN CAVITY THICKNESS AT TRAILING EDGE
           S - PEAK PRESSURE LOCATION
C      NEXT CARD
C          NMU - NUMBER OF MU VALUES
C          AMUV - ARRAY CONTAINING THE MU VALUES
C
       REAL KAY(50)
       REAL LAMDA
       DIMENSION AMUV(5)
       DIMENSION PP(101)
       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,AMDA,ASQ,BB,BINT,C
     30,CL,CM,DELTA,DINT,ECAP,ELL,EM,EPSILN,ETA1,ETA2,ETA3,TEE,ONE,TWO,T
     4HR,THETA,TSAVE,XC0,XC1,XC2,XC3,XH,XKZ,NM,NN,JL6,JM6,JR6,JL13,JM13,
```

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     5JR13,JTT1,JTM1,JTT2,JTM2,JTT3,JTM3,JTT4,JTM4,JTT5,JTM5,JTT7,JTM7,J
     6TT8,JTM8,JTT9,JTM9,JTT10,JTM10,JTT11,JTM11,JTT12,JTM12,JTT21,JTM21
     7,JTT23,JTM23,JTT24,JTM24,JTT25,JTM25
      COMMON /BLK1/V1BAR,V1BAR1,ECAP1,YC12
      COMMON /BLK2/LAMDA,S,IPUNCH,IERROR,IPRNT
      COMMON /BLK3/SEL1
      COMMON /BLK4/NA,ALPA(8),THET(8),ITHET,IUPPER,SUPPER(101)
      COMMON /BLK6/AMU,XO,K,ACL,T,B1,B2,B3,B4,B5,B6,B7,FT,HT,EPSLN,DNM,P
     1I,TWASQ,SQA,F11,F1XO,BETA,FE,HETA,NEND,IXO,NCLM,NEST,NEM
      COMMON /BLK8/STEP,AMX
      COMMON /BLK9/AMO,AM1,IMU,EMO,EM1,MSW
C
  100 FORMAT (10I2)
  110 FORMAT (10I3)
  120 FORMAT (5F10.5)
  130 FORMAT (2F15.5)
  140 FORMAT (36H1       LISTING OF INPUT DATA FOLLOWS/23H0  NO. OF GRID-
     1PTS. NN=I3,17H    STEP-SIZE XH=E16.8,24H    FUNCTION BOUND AMDA=E1
     26.8/28H    COEF. OF SQ. ROOT COMP.=E16.8,27H    CAVITATION NO. K (
     3CAY)=E16.8,16H  LIFT COEF. CL=E16.8/21H   PARAMETER T (TEE)=E16.8,
     45X,'S=',F7.3,5X,'XO=',F7.3)
  150 FORMAT (8F10.5)
C     SECTION I.  INPUT SECTION
      READ (5,100) NSWCH,IPUNCH,KWIT,IUPPER,IPRNT,NEST
      PI=3.141593
      PCON=1.0
      IF (NSWCH-3) 170,160,160
  160 CALL EXIT
  170 READ (5,110) NN,NMU
      READ (5,120) XH,AMDA,BB,STEP,AMX
      IF (KWIT) 180,230,180
  180 READ (5,210) NA,(AA(I),I=1,NA)
      DO 190  I=1,8
  190 ALPA(I)=FLOAT(I)
      IF (IUPPER) 220,200,220
  200 READ (5,210) ITHET,(THET(I),I=1,ITHET)
      GO TO 230
  210 FORMAT (I5,/(8F10.5))
  220 READ (5,150) (SUPPER(I),I=1,NN)
  230 IF (NSWCH-1) 240,240,260
  240 READ (5,120) PCON
      X(1)=0.0
      NNN=NN-1
      DO 250  I=1,NNN
      X(I+1)=X(I)+XH
      P(I)=PCON
  250 CONTINUE
      P(NN)=PCON
      GO TO 270
  260 CONTINUE
  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
```

```
      EPS=1.0E-6
      IMU=1
  280 FORMAT (I10,7F10.5)
      MSW =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 (MSW.EQ.0) AMU=AMUV(MU)
      IF (MSW.EQ.1) EM=AMUV(MU)
  300 NEND=NN
      IXO=11
C     SECTION II.  SQUARE ROOT BEHAVIOR.
      IF (NSWCH-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),G(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 (NSWCH,PCON,KWIT)
      IF (KWIT.EQ.0.OR.IERROR.EQ.1) GO TO 270
C     CALL SECT5 (NSWCH,PCON)
      GO TO 270
      END




      SUBROUTINE EST
      REAL KAY(50),K
      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,EPSILN,ETA1,ETA2,ETA3,TEE,ONE,TWO
     4,THR,THETA,TSAVE,XCO,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
      COMMON /BLK6/AMU,XO,K,ACL,T,B1,B2,B3,B4,B5,B6,B7,FT,HT,EPSLN,DNM,P
     11,TWASQ,SQA,F11,F1XO,BETA,FE,HETA,NEND,IXO,NCLM,NEST,NEM
      COMMON /BLK2/LAMDA,S,IPUNCH,IERROR,IPRNT
```

```
      COMMON /BLK9/AMO,AM1,IMU,EMO,EM1,MSW
      IMU=1
      IMF=0
      NEM=0
      NEST=1
      NCLM=1
      CLD=CL
      EM=0
      CALL SECT6
      CLO=CL
      PRINT 170, EM,CL
      EM=1
      CALL SECT6
      CL1=CL
      PRINT 170, EM,CL
      IF (CLO.LT.CL1) GO TO 100
      IMF=1
      TEMP=CLO
      CLO=CL1
      CL1=TEMP
  100 IF (CLD.GT.CL1) GO TO 140
      CL=CLD
      NCLM=0
      PRINT 180, CLD
      IF (CLD.GT.CLO) GO TO 110
      EM=0
      CALL SECT6
      PRINT 190, EM,AMU
      AMO=AMU
      EMO=EM
      EM=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
      AMO=AMU
      EMO=EM
      GO TO 150
  140 PRINT 160
      IMU=0
```

```
      CL=CLD
      EM0=0.0
      EM1=0.0
      AM0=0.0
      AM1=0.0
  150 CONTINUE
C     IF(IPUNCH.EQ.1) PUNCH 150,K,CL,T,S,AM0,AM1
      RETURN
  160 FORMAT (5X,' DESIGN CL IS GREATER THAN MAXIMIUM PERMISSIBLE CL')
  170 FORMAT (5X,' FOR M=',E15.7,'  MAXIMUM VALUE OF CL IS=',E15.7)
  180 FORMAT (5X,' THE RANGE OF M AND MU FOR DESIGN CL=',E15.7)
  190 FORMAT (5X,'M=',E15.7,5X,'MU=',E15.7)
      END



      SUBROUTINE SECT6
C     MAIN PROGRAM FOR THE THIRD DESIGN PROCEDURE
C
C
      REAL K
      EXTERNAL FA
      DOUBLE PRECISION DA,DELL,DXO,DQLX,DBFAC,DAMLX,DDELTA,DEPSLN
      DIMENSION XOV(3),IXOV(3),CLV(2),AMUV(3)
      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,CO,CL,CM,DELTA,DINT,ECAP,ELL,EM,EPSILN,ETA1,ETA2,ETA3,TEE,ONE,TWO
     4,THR,THETA,TSAVE,XCO,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
      COMMON /BLK6/AMU,XO,K,ACL,T,B1,B2,B3,B4,B5,B6,B7,FT,HT,EPSLN,DNM,P
     1I,TWASQ,SQA,FII,FIXO,BETA,FE,HETA,NEND,IXO,NCLM,NEST,NEM
      COMMON /BLK7/DDELTA,DEPSLN
      COMMON /BLK8/STEP,AMX
      COMMON /BLK2/LAMDA,S,IPUNCH,IERROR,IPRNT
      COMMON /BLK1/V1BAR,V1BAR1,ECAP1,YC12
      COMMON /BLK3/SEL1
      COMMON /BLK9/AM0,AM1,IMU,EM0,EM1,MSW
      DATA CLV/0.1,2.0/
      DATA XOV/0.04,0.1,0.16/
      DATA IXOV/3,6,9/
      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)
C     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,NSWCH)
  100   FR=FA(AR,PCON,NSWCH)
        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,NSWCH)
        PRINT 130, A
  130   FORMAT ('  A=',E15.8)
C       COMPUTE M,ETC.
        ERR1=FA(A,PCON,NSWCH)
        PRINT 140, ERR1
  140   FORMAT (' ERROR IN FA = ',E15.8)
        IF (MSW.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=BETA-(1.0-EM)*CL*TWASQ/2.0/PI/(1.0+K)-EM*B2/2.0/PI/(1.0+K)/EL
       1L
        C=1.0/A
        II=NN
        ALPHA=T-(1-EM)*CL*4.0*A**2*ELL*SQA*F11/PI/(1.0+K)/DNM-(A-ELL*ATAN(
       11.0/A))*A*BINT+B2PD-ECAP*A-EM*G0(1.0)/2.0/PI/(1.0+K)
        ACAP=-2.0*(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*DDELTA-4.0D0*DEPSLN*DA)+DA**2*(DDELTA-2.0D
       10*DA*DEPSLN))/8.0/DEPSLN/SQRT(ELL)-EM*BICM(A)
        XBAR=-CM/CL
        YC1=A*ECAP
        ALOD=CL/CD
        V1BAR=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,YC1,ACAP,EM,BINT,DINT
        PRINT 160, V1BAR,ECAP1,SEL1
  160   FORMAT ('         INPUT FOR OFF-DESIGN CALCULATIONS:',/,5X,'    V1BAR=
       1',E15.7,5X,'ECAP1=',E15.7,5X,'SQRT OF ELL1=',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,YC1,E
       1M,ACAP,BINT,DINT
```

```
  170 FORMAT (5E15.7)
  180 FORMAT (5X,'K=',F7.4,5X,'AMU=',E15.7,5X,'XO=',F7.4)
  190 FORMAT (5X,'CL=',E15.7,5X,'T=',F7.4,5X,'S=',F7.4)
  200 FORMAT (5X,'L/D=',E15.7,5X,'CM=',E15.7,5X,'CD=',E15.7,5X,'XBAR=',E
     115.7,5X,'ALPHA=',E15.7,/,5X,'YC1=',E15.7,5X,'ACAP=',E15.7,5X,'EM='
     2,E15.7,5X,'B=',E15.7,5X,'D=',E15.7)
      CONTINUE
      IF (IPRNT.EQ.0) GO TO 270
C     COMPUTE Y, ETA, ETC.
      BT5=BTG5(1.0)
      ETP1(1)=9999.0
  210 FORMAT (14X,'X',14X,'Y',13X,'ETA',12X,'ETP',12X,'PTOT')
      PRINT 210
      DO 260  I=1,NN
      FI1=I-1
      FN1=NN-1
      XX=FI1/FN1
      II=(XX-X(1))/XH+1+0.5
      SQXX=SQRT(XX*(ELL-XX))
      C=SQRT(XX/(ELL-XX))
      XNU=A*C
      TH=ARCOS(1.0-2.0*XNU)
      P1=H(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*P1-2.0*ACAP*(1.0+K)*PM1
      YYU1(I)=ALPHA*XX-2.0*A**2*ELL*ACAP*F1FUNC(XNU,A)+A*BINT*(SQXX-ELL*
     1ATAN(C))-B2PD*XX+ECAP*SQXX+EM*G0(XX)/2.0/PI/(1.0+K)
      ETN1(I)=ALPHA*XX-B2PD*XX+A*BINT*(ELL*ATAN(C)-SQXX)-ECAP*SQXX+EM/2.
     10/PI/(1.0+K)*(XX*B3/2.0-(SQXX+ELL*ATAN(C))*B1/2.0+ATAN(C)*B4+ALOG(
     2ELL/(ELL-XX))*CL/2.0-(ALOG(ELL/SQRT(ELL-XX))*CL+FTJX(II,XX)-BT5/2.
     30-BTX7(XX)))
      IF (XX.EQ.0.0) GO TO 240
      ETP1(I)=ALPHA-BINT*(1.0-2.0*XNU)/2.0-DINT-ECAP*(ELL-2.0*XX)/2.0/SQ
     1XX+EM/2.0/PI/(1.0+K)*(B3/2.0-B1/2.0/C+B4/2.0/SQXX+CL*XX/2.0/(ELL-X
     2X)+CPVI(II,XX)/2.0/SQRT(XX)/(ELL-XX))
  240 IF (IPRNT.EQ.1) PRINT 250, II,XX,YYU1(I),ETN1(I),ETP1(I),PTOT
      IF (IPUNCH.EQ.1) PUNCH 170, XX,YYU1(I),ETN1(I),ETP1(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 C(I)=P(I)
      STAR=0.66
      BT5=BTG5(1.0)
      BT8=BTG8(1.0)
      BT9=BTG9(1.0)
      FT11=FTJX(NEND,1.0)
      B11=FT11-BT5/2.0-BT8
```

```
      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 (NEM.EQ.0) GO TO 310
      TRSQ=3.0*SQ2-ALOG(1.0+SQ2)
      EM=(TRSQ-PI*T/CL)/(TRSQ-BT9+B12/2.0)
  310 CLOT=CL/T
      SQXO=SQRT(XO)
      B1XO=FTJX(IXO,XO)-BT5/2.0-BTG8(SQXO)
      C11=2.0*((3.0*SQ2-ALOG(1.0+SQ2))*(0.5+0.5/SQXO)-(1.0+2.0*SQXO)*SQR
     1T(1.0+SQXO)/XO**0.75+ALOG(XO**0.25+SQRT(1.0+SQXO))/XO)
      CI=BT8/SQXO-BTG8(SQXO)/XO-(0.5-0.5/XO)*BT5+(0.5-0.5/SQXO)*FT11
      CJ=C11+CI
      IF (MSJ.EQ.0) GO TO 320
      AMU=XO*(EM*CJ-C11)/2.0/PI*CLOT+XO/2.0+SQXO/2.0
      GO TO 340
  320 IF (NEST.EQ.0) GO TO 330
      AMU=XO*(EM*CJ-C11)/2.0/PI*CLOT+XO/2.0+SQXO/2.0
      RETURN
  330 EM=(C11+T*2.0*PI/CL*(AMU/XO-0.5-0.5/SQXO))/CJ
  340 YC1T=1.0-(1.0-EM)*CLOT/PI*(3.0*SQ2-ALOG(1.0+SQ2))-EM*BT9*CLOT/PI+E
     1M*B12*CLOT/2.0/PI
      YC1T=YC1T/2.0
      YC1=YC1T*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
      ECAP1=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,ECAP1,SEL1
  360 FORMAT (5X,'L/D=',E15.7,5X,'CM=',E15.7,5X,'CD=',E15.7,5X,'XBAR=',E
     115.7,5X,'ALPHA=',E15.7,/,5X,'YC1=',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 (IPRNT.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=ARCOS(1.0-2.0*XNU)
      P1=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*P1-2.0*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+S
     1QX)-2.0*XX-ALOG(XX**0.25+SQRT(1.0+SQX)))+YC1*SQX+EM/2.0/PI*(SQX*BT
     29+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*(FTJX(II,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
     1I,XX)-BT9)
  390 IF (IPRNT.EQ.1) PRINT 250, II,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,NSWCH)
      DOUBLE PRECISION DELL,DTRM1,DTRM2,DDELTA,DEPSLN,DK,DBETA,DA,DXO,DQ
     1LX,DBFAC,DAMLX
      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,CO,CL,CM,DELTA,DINT,ECAP,ELL,EM,EPSILN,ETA1,ETA2,ETA3,TEE,ONE,TWO
     4,THR,THETA,TSAVE,XCO,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
      COMMON /BLK6/AMU,XO,K,ACL,T,B1,B2,B3,B4,B5,B6,B7,FT,HT,EPSLN,DNM,P
     1I,TWASQ,SQA,FI1,FIXO,BETA,FE,HETA,NEND,IXO,NCLM,NEST,NEM
      COMMON /BLK7/DDELTA,DEPSLN
      COMMON /BLK9/AMO,AM1,IMU,EMO,EM1,MSW
```

```
      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
      DTRM1=DSQRT(DSQRT(DELL)+1.0)
      DTRM2=DSQRT(DSQRT(DELL)-1.0)
      DDELTA=DTRM1+DTRM2
      DEPSLN=DTRM1-DTRM2
      DNM=DDELTA-A*DEPSLN
      DELTA=DDELTA
      EPSLN=DEPSLN
      DO 100  I=1,NN
      P(I)=H(I)
  100 G(I)=P(I)
      IF (NCLM.EQ.0) GO TO 110
      CLDNM=(1.0-EM)*((2.0*A**2+3.0)*EPSLN+A*DELTA)/DNM+EM*BTG1(A)
      CL=BETA*2.0*PI*(1.0+K)*ELL/CLDNM
      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 G(I)=P(I)
      DUM=A
C     COMPUTE THE VARIOUS INTEGRALS
      B1=BINT1(DUM)
      B2=BTG1(A)
      B3=BINT3(DUM)
      B4=BINT4(DUM)
      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=F1FUNC(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
      FE=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)/PI/
     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)*B4
      HE8=-B7/2.0
```

```
      H9=FTJX(NEND,1.0)
      H10=BTX7(1.0)
C     PRINT 100,HE1,HE2,HE3,HE4,HE5,HE6,HE7,HE8,H9,H10
      HETA=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*SQRT(XO/(ELL-XO))
      F1XO=F1FUNC(XNU,A)
      II=NN
      XX=1.0
      G1A=G0(1.0)
      II=IXO
      XX=XO
      GXOA=G0(XO)
      SQLX=SQRT((ELL-XO)/XO)
      TWASQ=((2.0*A**2+3)*EPSLN+A*DELTA)/ELL/DNM
      DA=A
      DELL=DA**2+1.0
      DXO=XO
      DQLX=DSQRT((DELL-DXO)/DXO)
      DBFAC=DA-DQLX-DELL*DATAN(1.0/DA)+DELL*DATAN(1.0/DQLX)/DXO
      DAMLX=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*TWASQ/2.0/PI/(1.0+K))
     2*DAMLX
      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*TWASQ/2.0+B2/2.0/ELL)*DAMLX-(G1A-GXO
     2A/XO)/2.0
      IF (MSW.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
C
C
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.
```

```
C
C     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,AMDA,ASQ,BB,BINT,C
     30,CL,CM,DELTA,DINT,ECAP,ELL,EM,EPSILN,ETA1,ETA2,ETA3,TEE,ONE,TWO,T
     4HR,THETA,TSAVE,XC0,XC1,XC2,XC3,XH,XKZ,NM,NN,JL6,JM6,JR6,JL13,JM13,
     5JR13,JTT1,JTM1,JTT2,JTM2,JTT3,JTM3,JTT4,JTM4,JTT5,JTM5,JTT7,JTM7,J
     6TT8,JTM8,JTT9,JTM9,JTT10,JTM10,JTT11,JTM11,JTT12,JTM12,JTT21,JTM21
     7,JTT23,JTM23,JTT24,JTM24,JTT25,JTM25
C
      FUN(XL,XR,Q0,Q1,Q2)=Q0*CKLOG((XR-XX)/(XL-XX))+Q1*(XR-XL)+Q2*((XR-X
     1X)**2-(XL-XX)**2)/2.0
      NN2=NN-2
      TEMP1=0.4142136/2.4142136
      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,G,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)-
     1XX)**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,G,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,B
     1B2)
      GO TO 110
  150 IF (II-NN+4) 160,160,170
  160 XC0=XX
      IIM1=II-1
      IIP1=II+1
      TD1=DIFF2(XX,1,IIM1,P,CAY)
      CALL DIFF5 (XX,IIM1,P,CAY,BB0,BB1,BB2)
      TD2=DIFF2(XX,IIP1,NN2,P,CAY)
      TD3=DIFF2(XX,NN2,NN,G,CAY)
      CALL DIFF8 (XX,CAY,CC0,CC1,CC2)
      CPVI=TD1+TD2+TD3+FUN(X(IIM1),X(IIP1),BB0,BB1,BB2)+BB*DIFF4(XC0,XH,
     1CC0,CC1,CC2)
      GO TO 110
  170 IF (II-(NN-3)) 160,180,190
  180 IIM1=II-1
      IIP1=II+1
      XC0=0.0
      TD1=DIFF2(XX,1,IIM1,P,CAY)
      CALL DIFF5 (XX,IIM1,P,CAY,BB0,BB1,BB2)
      TD2=DIFF2(XX,NN2,NN,G,CAY)
      CALL DIFF8 (XX,CAY,CC0,CC1,CC2)
      CPVI=TD1+TD2+FUN(X(IIM1),X(IIP1),BB0,BB1,BB2)+BB*DIFF4(XX,XH,CC0,C
```

```
    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,1,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(NN-1),X(NN),CC0,CC
    11,CC2)+(-DD0*SQRT(2.0*XH)*(ALOG(TEMP1)+1.4142136)+2.0*DD1*XH*XH**0
    2.5/3.0+14.0*DD2*XH**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,CC0,CC1,C
    1C2)
     GO TO 110
 230 XC0=0.0
     TD1=DIFF2(XX,1,NN2,P,CAY)
     XN=X(NN)
     XN2=X(NN-2)
     CALL DIFF5 (XX,NN2,G,CAY,BB0,BB1,BB2)
     CALL DIFF8 (XX,CAY,CC0,CC1,CC2)
     CPVI=TD1+FUN(XN2,XN,BB0,BB1,BB2)+BB*DIFF4(1.0,XH,CC0,CC1,CC2)
     GO TO 110
     END


     FUNCTION DIFF2 (XX,ILL,IRR,F,CAY)
C    DIF2
C
C
C
C       EVALUATE A DEF. INTEGRAL OVER(X(ILL),X(IRR) WHOSE INTEGRAND
C    IS G(X(II),U)*F(U)/(U-X(II))          WHERE U IS THE DUMMY
C    VARIABLE, F IS P OR G, AND G IS GIVEN BY DIFF7.--NEEDED BY ZZZZ.
C
C
C
C    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,DUM,A,A1,A2,ACAP,ALPHA,AMDA,ASQ,BB,BINT,C
    30,CL,CM,DELTA,DINT,ECAP,ELL,EM,EPSILN,ETA1,ETA2,ETA3,TEE,TG1,TG2,T
    4G3,THETA,TSAVE,XC0,XC1,XC2,XC3,XH,XKZ,NM,NN,JL6,JM6,JR6,JL13,JM13,
```

```
     5JR13,JTT1,JTM1,JTT2,JTM2,JTT3,JTM3,JTT4,JTM4,JTT5,JTM5,JTT7,JTM7,J
     6TT8,JTM8,JTT9,JTM9,JTT10,JTM10,JTT11,JTM11,JTT12,JTM12,JTT21,JTM21
     7,JTT23,JTM23,JTT24,JTM24,JTT25,JTM25
      DIMENSION F(101)
C
      NM=IRR-ILL+1
      J=ILL
      DO 100  I=1,NM
      FX(I)=DIFF7(XX,X(J),ELL,CAY)*F(J)/(X(J)-XX)
      J=J+1
  100 CONTINUE
      CALL NTGRTE (DIFF2)
      RETURN
      END




      FUNCTION DIFF4 (XX,XH,BB0,BB1,BB2)
C     DIF4
C
C
C
C        EVALUATES THE EXPRESSION OBTAINED FOR THE INTEGRAL OVER (1-2H,1
C     OF F(XX,U)*SQRT(1-U)/(U-XX)/SQRT(U) WHEN F/SQRT(U) IS REPLACED BY
C     BB0+BB1*(U-XC0)+BB2*(U-XC0)**2 OBTAINED USING PARAB PREVIOUSLY.
C     (F IS GIVEN BY DIFF7).
C
C
C
C
      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)
C     DIF5
C
C     USES PARAB TO APPROXIMATE Z(XX,U)*F(U)/SQRT(U) BY
C          A0+A1*(U-XX)+A2*(U-XX)**2
C     ON (U(ILL),U(ILL+2))--F=P OR G, Z(XX,U) IS DIFF7.
C
C
C
C     NEEDS COMMON
      REAL KAY(50)
      COMMON P,G,Q,H,X,XSQ,FX,ETN1,ETN2,ETP1,ETP2,YYU1,YYU2,TAU,ALP,DEE,
     1AA,KAY,DUM,A,A1,A2,ACAP,ALPHA,AMDA,ASQ,BB,BINT,CO,CL,CM,DELTA,DINT
```

```
     2,ECAP,ELL,EM,EPSILN,ETA1,ETA2,ETA3,TEE,TG1,TG2,TG3,THETA,TSAVE,XC0
     3,XC1,XC2,XC3,XH,XKZ,NM,NN,JL6,JM6,JR6,JL13,JM13,JR13,JTT1,JTM1,JTT
     42,JTM2,JTT3,JTM3,JTT4,JTM4,JTT5,JTM5,JTT7,JTM7,JTT8,JTM8,JTT9,JTM9
     5,JTT10,JTM10,JTT11,JTM11,JTT12,JTM12,JTT21,JTM21,JTT23,JTM23,JTT24
     6,JTM24,JTT25,JTM25
      DIMENSION P(101),G(101),Q(101),H(101),X(101),XSQ(101),FX(101),ETN1
     1(101),ETN2(101),ETP1(101),ETP2(101),YYU1(101),YYU2(101),TAU(101),A
     2LP(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
C
C     NO COMMON
C
      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)
C     DIF8
C
C
C
C        APPROXIMATES Z(XX,U)         BY A0+A1(U-XX)+A2(U-XX)**2 OVER
C     (1-2H,1)--Z(X,U)=DIFF7(X,U,ELL,CAY).  USES PARAB.
C
```

```
C     NEEDS COMMON
C
      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,DUM,A,A1,A2,ACAP,ALPHA,AMDA,ASQ,BB,BINT,C
     30,CL,CM,DELTA,DINT,ECAP,ELL,EM,EPSILN,ETA1,ETA2,ETA3,TEE,TG1,TG2,T
     4G3,THETA,TSAVE,XC0,XC1,XC2,XC3,XH,XKZ,NM,NN,JL6,JM6,JR6,JL13,JM13,
     5JR13,JTT1,JTM1,JTT2,JTM2,JTT3,JTM3,JTT4,JTM4,JTT5,JTM5,JTT7,JTM7,J
     6TT8,JTM8,JTT9,JTM9,JTT10,JTM10,JTT11,JTM11,JTT12,JTM12,JTT21,JTM21
     7,JTT23,JTM23,JTT24,JTM24,JTT25,JTM25
C
      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
      END




      FUNCTION BINT1 (A)
C
C
C
C          A COMMONLY USED DEFINITE INTEGRAL APPEARING IN SEVERAL EQ'NS.
C     IS EVALUATED BY THIS ROUTINE.  THE INTEGRAND TAKES THE FORM --
C               P(X)*((ELL-X)/X)**.5.   -- SEE WRITE-UP.
C
C
C
C
C     NEEDS COMMON
C
      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,EPSILN,ETA1,ETA2,ETA3,TEE,ONE,TWO
     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
      COMMON /BLK1/V1BAR,V1BAR1,ECAP1,YC12
C
C
      ELL=A**2+1.0
      XC0=0.0
      XC1=X(1)
```

```
      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 (AA0,AA1,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=SIX(X(1),X(3),AA0,AA1,AA2)+TG1+TG2+BB*FOUR(XC1,BB0,BB1,BB2)
      RETURN
      END




      FUNCTION BTG8 (DX)
C     BTG8
C
C
C
C          THE DEFINITE INTEGRAL OF P(X)*LOG(DX+X**.5), WHICH OCCURS IN
C     SEVERAL EQUATIONS, IS EVALUATED BY THIS ROUTINE.
C
C
C
C
C     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,AMDA,ASQ,BB,BINT,C
     30,CL,CM,DELTA,DINT,ECAP,ELL,EM,EPSILN,ETA1,ETA2,ETA3,TEE,ONE,TWO,T
     4HR,THETA,TSAVE,XC0,XC1,XC2,XC3,XH,XKZ,NM,NN,JL6,JM6,JR6,JL13,JM13,
     5JR13,JTT1,JTM1,JTT2,JTM2,JTT3,JTM3,JTT4,JTM4,JTT5,JTM5,JTT7,JTM7,J
     6TT8,JTM8,JTT9,JTM9,JTT10,JTM10,JTT11,JTM11,JTT12,JTM12,JTT21,JTM21
```

```
     7,JTT23,JTM23,JTT24,JTM24,JTT25,JTM25
      COMMON /BLK1/V1BAR,V1BAR1,ECAP1,YC12
C
      IF (DX) 100,100,110
  100 BTG8=0.5*BTG5(DX)
      GO TO 140
  110 NM=NN-2
      DO 120  I=1,NM
  120 FX(I)=P(I)*CKLOG(DX+X(I)**0.5)
      CALL NTGRTE (TG1)
      J=NN-2
      NM=3
      DO 130  I=1,NM
      FX(I)=G(J)*CKLOG(DX+X(J)**0.5)
      J=J+1
  130 CONTINUE
      CALL NTGRTE (TG2)
      XC0=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 PARAB (AA0,AA1,AA2)
      BTG8=TG1+TG2+BB*FOUR(X(NN-2),AA0,AA1,AA2)
  140 RETURN
      END




      FUNCTION BTG9 (A)
C     BTG9
C
C
C
C     EVALUATES THE DEFINITE INTEGRAL OF P(X)/X**.5 OVER(0,1).
C
C
      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,DUMA,A1,A2,ACAP,ALPHA,AMDA,ASQ,BB,BIN
     3T,C0,CL,CM,DELTA,DINT,ECAP,ELL,EM,EPSILN,ETA1,ETA2,ETA3,TEE,ONE,TW
     40,THR,THETA,TSAVE,XC0,XC1,XC2,XC3,XH,XKZ,NM,NN,JL6,JM6,JR6,JL13,JM
     513,JR13,JTT1,JTM1,JTT2,JTM2,JTT3,JTM3,JTT4,JTM4,JTT5,JTM5,JTT7,JTM
     67,JTT8,JTM8,JTT9,JTM9,JTT10,JTM10,JTT11,JTM11,JTT12,JTM12,JTT21,JT
     7M21,JTT23,JTM23,JTT24,JTM24,JTT25,JTM25
      COMMON /BLK1/V1BAR,V1BAR1,ECAP1,YC12
      XC0=0.0
      XC1=X(1)
      XC2=X(2)
      XC3=X(3)
```

```
      ETA1=P(1)
      ETA2=P(2)
      ETA3=P(3)
      CALL PARAB (AA0,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)
C     NTGR
C
C
C
C          THIS SPECIAL INTEGRATION ROUTINE IS USED REPEATEDLY BY THE
C     PROGRAM.  HIGH-ORDER NEWTON-COTES FORMULAS ARE USED
C
C
C
C
      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,AMDA,ASQ,BB,BINT,C
     30,CL,CM,DELTA,DINT,ECAP,ELL,EM,EPSILN,ETA1,ETA2,ETA3,TEE,TG1,TG2,T
     4G3,THETA,TSAVE,XC0,XC1,XC2,XC3,XH,XKZ,NM,NN,JL6,JM6,JR6,JL13,JM13,
     5JR13,JTT1,JTM1,JTT2,JTM2,JTT3,JTM3,JTT4,JTM4,JTT5,JTM5,JTT7,JTM7,J
     6TT8,JTM8,JTT9,JTM9,JTT10,JTM10,JTT11,JTM11,JTT12,JTM12,JTT21,JTM21
     7,JTT23,JTM23,JTT24,JTM24,JTT25,JTM25
      DIMENSION YNN(10)
C
      TG=0.0
      IF (NM-1) 100,100,120
  100 WRITE (6,110)
  110 FORMAT (54H0  ***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 ISWI=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 ISWI=KN
    KK=KN+1
    J=NSTRT
    DO 300  I=1,KK
    YNN(I)=FX(J)
    J=J+1
300 CONTINUE
    NSTRT=NSTRT+KN
    ASSIGN 310 TO KLOC
    GO TO 400
310 TG=TG+TGINT
320 IF (LN) 330,360,330
330 ISWI=LN
    KK=LN+1
    J=NSTRT
```

```
      DO 340  I=1,KK
      YNN(I)=FX(J)
      J=J+1
  340 CONTINUE
      NSTRT=NSTRT+LN
      ASSIGN 350 TO KLOC
      GO TO 400
  350 TC=TC+TGINT
  360 IF (NM-NSTRT) 370,390,370
  370 WRITE (6,380)
  380 FORMAT (67H0   ****ERROR IN FINAL VALUE OF STEP COUNTER (NSTRT)--NT
     1GRTE ROUTINE)
      GO TO 390
  390 RETURN
  400 IF (ISWI) 410,410,430
  410 WRITE (6,420)
  420 FORMAT (47H0   *****ERROR IN ISWI SETTING IN NTGRTE ROUTINE)
      GO TO 390
  430 IF (ISWI-2) 470,480,440
  440 IF (ISWI-4) 490,500,450
  450 IF (ISWI-6) 510,520,460
  460 IF (ISWI-7) 370,530,370
  470 TGINT=(YNN(1)+YNN(2))*XH/2.0
      GO TO 540
  480 TGINT=(YNN(1)+4.0*YNN(2)+YNN(3))*XH/3.0
      GO TO 540
  490 TGINT=(YNN(1)+3.0*YNN(2)+3.0*YNN(3)+YNN(4))*3.0*XH/8.0
      GO TO 540
  500 TGINT=(7.0*YNN(1)+32.0*YNN(2)+12.0*YNN(3)+32.0*YNN(4)+7.0*YNN(5))*
     14.0*XH/90.0
      GO TO 540
  510 TGINT=(19.0*YNN(1)+75.0*YNN(2)+50.0*YNN(3)+50.0*YNN(4)+75.0*YNN(5)
     1+19.0*YNN(6))*5.0*XH/288.0
      GO TO 540
  520 TGINT=(41.0*YNN(1)+216.0*YNN(2)+27.0*YNN(3)+272.0*YNN(4)+27.0*YNN(
     15)+216.0*YNN(6)+41.0*YNN(7))*6.0*XH/840.0
      GO TO 540
  530 TGINT=(751.0*YNN(1)+3577.0*YNN(2)+1323.0*YNN(3)+2989.0*YNN(4)+2989
     1.0*YNN(5)+1323.0*YNN(6)+3577.0*YNN(7)+751.0*YNN(8))*7.0*XH/17280.0
  540 CONTINUE
      GO TO KLOC, (270,310,350)
      END


      FUNCTION BTG4 (X1,X2,BB0,BB1,BB2)
C     BTG4
C
C
C
C
C          THIS SUBSIDIARY ROUTINE EVALUATES THE DEFINITE INTEGRAL OVER
C     (0,2H) WHOSE INTEGRAND IS (BB1*X+BB2*X**2)*LOG(X) -- REQUIRED
```

```
C      BY THE ROUTINE BTG5.
C
C
C
C      NO COMMON.
C
       FLOW=0.0
       IF (X1.NE.0.0) FLOW=BB1*X1**2*(ALOG(X1)-0.5)/2.0+BB2*X1**3*(ALOG(X
      11)-1.0/3.0)/3.0+BB0*X1*(ALOG(X1)-1.0)
       BTG4=BB1*X2**2*(ALOG(X2)-0.5)/2.0+BB2*X2**3*(ALOG(X2)-1.0/3.0)/3.0
      1+BB0*X2*(ALOG(X2)-1.0)-FLOW
       RETURN
       END




       FUNCTION BTG5 (A)
C
C
C
C           THE DEFINITE INTEGRAL OVER (0,1) WITH INTEGRAND P(X)LOG(X)
C      IS EVALUATED.
C
C
C
C
C      NEEDS COMMON.
C
       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,DUMA,A1,A2,ACAP,ALPHA,AMDA,ASQ,BB,BIN
      3T,CO,CL,CM,DELTA,DINT,ECAP,ELL,EM,EPSILN,ETA1,ETA2,ETA3,TEE,ONE,TW
      40,THR,THETA,TSAVE,XC0,XC1,XC2,XC3,XH,XKZ,NM,NN,JL6,JM6,JR6,JL13,JM
      513,JR13,JTT1,JTM1,JTT2,JTM2,JTT3,JTM3,JTT4,JTM4,JTT5,JTM5,JTT7,JTM
      67,JTT8,JTM8,JTT9,JTM9,JTT10,JTM10,JTT11,JTM11,JTT12,JTM12,JTT21,JT
      7M21,JTT23,JTM23,JTT24,JTM24,JTT25,JTM25
       COMMON /BLK1/V1BAR,V1BAR1,ECAP1,YC12
C
       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 (AA0,AA1,AA2)
      NM=3
      J=NN-2
      DO 110  I=1,NM
      FX(I)=G(J)*CKLOG(X(J))
      J=J+1
  110 CONTINUE
      CALL NTCRTE (TG2)
      BTG5=BTG4(X(1),X(3),AA0,AA1,AA2)+TG1+TG2+BB*BTG6(XH)
      RETURN
      END
```

```
      FUNCTION BTG6 (XH)
C
C
C
C
C        THE DEFINITE INTEGRAL OVER (1-2H,1) WITH INTEGRAND
C                 LOG(X)*(1-X)**.5
C     IS EVALUATED. - REQUIRED BY BTG5.
C
C
C
C
C
C     NO COMMON.
C
      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)
C     PARB
C
C
C
C           PUTS A QUADRATIC OF THE FORM
C                 CON0+CON1*(X-XC0)+CON2*(X-XC0)**2
C     THROUGH THE POINTS (XC1,ETA1),(XC2,ETA2),(XC3,ETA3).
C
```

```
C
C
      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,AMDA,ASQ,BB,BINT,C
     30,CL,CM,DELTA,DINT,ECAP,ELL,EM,EPSILN,ETA1,ETA2,ETA3,TEE,ONE,TWO,T
     4HR,THETA,TSAVE,XC0,XC1,XC2,XC3,XH,XKZ,NM,NN,JL6,JM6,JR6,JL13,JM13,
     5JR13,JTT1,JTM1,JTT2,JTM2,JTT3,JTM3,JTT4,JTM4,JTT5,JTM5,JTT7,JTM7,J
     6TT8,JTM8,JTT9,JTM9,JTT10,JTM10,JTT11,JTM11,JTT12,JTM12,JTT21,JTM21
     7,JTT23,JTM23,JTT24,JTM24,JTT25,JTM25
C
      DENM1=(XC2-XC1)*(XC3-XC1)
      DENM2=(XC1-XC2)*(XC3-XC2)
      DENM3=(XC1-XC3)*(XC2-XC3)
      CON0=ETA1*(XC2-XC0)*(XC3-XC0)/DENM1+ETA2*(XC1-XC0)*(XC3-XC0)/DENM2
     1+ETA3*(XC1-XC0)*(XC2-XC0)/DENM3
      CON1=ETA1*(2.0*XC0-XC2-XC3)/DENM1+ETA2*(2.0*XC0-XC1-XC3)/DENM2+ETA
     13*(2.0*XC0-XC1-XC2)/DENM3
      CON2=ETA1/DENM1+ETA2/DENM2+ETA3/DENM3
      RETURN
      END


      FUNCTION SIX (X1,X2,SF0,SF1,SF2)
C     EVALUATES THE INTEGRAL FROM 0 TO H OF
C           SF0+SF1*T+SF2*T**2)/SQRT(T).
C
C
C
C
      SIX=0.066666667*(30.0*SF0+X2*(10.0*SF1+6.0*SF2*X2))*SQRT(X2)-0.066
     1666667*(30.0*SF0+X1*(10.0*SF1+6.0*SF2*X1))*SQRT(X1)
      RETURN
      END


      FUNCTION CKLOG (GARGLE)
C     CKLG
C
C
C     COMPUTES THE LOG OF ABSF(GARGLE),RETURNS WITH ZERO IF GARGLE=0.
C
C
C
C
      IF (GARGLE) 110,100,120
  100 CKLOG=0.0
```

```
      RETURN
  110 CKLOG=ALOG(-GARGLE)
      RETURN
  120 CKLOG=ALOG(GARGLE)
      RETURN
      END



      FUNCTION FOUR (H,CF0,CF1,CF2)
C     FOUR
C
C     EVALUATES THE EXPRESSION OBTAINED FOR THE INTEGRAL FROM H TO 1 OF
C          (CF0+CF1*T+CF2*T**2)*SQRT(1-T).
C
C
C
C
C
      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,NSWCH)
C     REGU
C
C
C
C
C     FINDS THE ROOT OF THE EQUATION --
C               FUNNY(X,PCON,NSWCH)-HERE=0
C     BY THE METHOD OF REGULUS FALSI.
C
C
C
C
C     FUNNY MUST APPEAR ON AN F-CARD IN THE CALLING ROUTINE
C     ASSUMES FUNNY (X,PCON,NSWCH)
      ICNT=0
      VR=FUNNY(DROIT,PCON,NSWCH)
      VL=FUNNY(GAUCHE,PCON,NSWCH)
      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,NSWCH)
    ICNT=ICNT+1
    IF ((VM-HERE)*(VL-HERE)) 190,220,210
190 DROIT=EM
    VR=VM
200 EMN=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 (64H0 *****ERROR EXIT FROM REGUL--END-PTS. INPUT DO NOT BRA
   1CKET ROOT)
    GO TO 150
280 WRITE (6,290) GAUCHE,EM,DROIT,VL,VR,HERE
290 FORMAT (37H0 **** REGUL ITERATION COUNT PAST 100/6X,14HLEFT-HAND P
   1T.=E14.6,6X,13HLAST APPROX.=E14.6,6X,6X,13HRT.-HAND PT.=E14.6/6X,1
   25HFUNCT.-AT LEFT=E14.6,6X,14HFUNCT. AT RT.=E14.6,6X,18HINPUT FUNCT
   3. VAL.=E14.6)
    STOP
    END



    FUNCTION BTG1 (A)
C
C
C
C        A COMMONLY USED DEFINITE INTEGRAL APPEARING IN SEVERAL EQ'NS.
C     IS EVALUATED BY THIS ROUTINE.  THE INTEGRAND TAKES THE FORM --
C             P(X)*((ELL-X)/X)**.5.   -- SEE WRITE-UP.
C
C
C
C
C     NEEDS COMMON
C
      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,CO,CL,CM,DELTA,DINT,ECAP,ELL,EM,EPSILN,ETA1,ETA2,ETA3,TEE,ONE,TWO
     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
      COMMON /BLK1/V1BAR,V1BAR1,ECAP1,YC12
C
C
      ELL=A**2+1.0
      XC0=0.0
      XC1=X(1)
      XC2=X(2)
      XC3=X(3)
      ETA1=P(1)*SQRT(ELL-XC1)
      ETA2=P(2)*SQRT(ELL-XC2)
      ETA3=P(3)*SQRT(ELL-X(3))
      CALL PARAB (AA0,AA1,AA2)
      XC1=X(NN-2)
      XC2=X(NN-1)
      XC3=X(NN)
      ETA1=SQRT((ELL-XC1)/XC1)
      ETA2=SQRT((ELL-XC2)/XC2)
      ETA3=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)=C(J)*SQRT((ELL-X(J))/X(J))
      J=J+1
  110 CONTINUE
      CALL NTGRTE (TG2)
      BTG1=SIX(X(1),X(3),AA0,AA1,AA2)+TG1+TG2+BB*FOUR(XC1,BB0,BB1,BB2)
      RETURN
      END




      FUNCTION FTJX (II,XX)
C     FTJX
C
C
C
C         THIS SUBSIDIARY ROUTINE EVALUATES THE DEFINITE INTEGRAL WHOSE
C     INTEGRAND IS P(U)*LOG(U-XX) FOR 0 LT XX LE 1 -- U IS THE DUMMY
C     VARIABLE OF INTEGRATION.
```

```
C     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,AMDA,ASQ,BB,BINT,C
     30,CL,CM,DELTA,DINT,ECAP,ELL,EM,EPSILN,ETA1,ETA2,ETA3,TEE,ONE,TWO,T
     4HR,THETA,TSAVE,XC0,XC1,XC2,XC3,XH,XKZ,NM,NN,JL6,JM6,JR6,JL13,JM13,
     5JR13,JTT1,JTM1,JTT2,JTM2,JTT3,JTM3,JTT4,JTM4,JTT5,JTM5,JTT7,JTM7,J
     6TT8,JTM8,JTT9,JTM9,JTT10,JTM10,JTT11,JTM11,JTT12,JTM12,JTT21,JTM21
     7,JTT23,JTM23,JTT24,JTM24,JTT25,JTM25
      COMMON /BLK1/V1BAR,V1BAR1,ECAP1,YC12
      IF (II-1) 180,180,100
  100 IF (II-2) 190,190,110
  110 IF (II-3) 200,200,120
  120 IF (II-NN) 130,260,180
  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 XC0=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 XC0=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 IIL=II-1
      IIR=II+1
```

```
      XC0=XX
      XC1=X(IIL)
      XC2=XX
      XC3=X(IIR)
      ETA1=P(IIL)
      ETA2=P(II)
      ETA3=P(IIR)
      CALL PARAB (AA0,AA1,AA2)
      NN2=NN-2
      FTJX=EJ1(1,IIL,XX,P)+EJ3(AA0,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(II)
      CALL PARAB (AA0,AA1,AA2)
      XC1=XX
      XC2=X(NN3)
      XC3=X(NN2)
      ETA1=P(II)
      ETA2=P(NN3)
      ETA3=P(NN2)
      CALL PARAB (BB0,BB1,BB2)
      FTJX=EJ1(1,NN6,XX,P)+EJ5(AA0,AA1,AA2,BB0,BB1,BB2,XH)+EJ1(NN2,NN,XX
     1,G)+BB*EJ4(XH,XX)
      GO TO 270
  230 XC0=XX
      XC1=X(II-1)
      XC2=XX
      XC3=X(II+1)
      ETA1=P(II-1)
      ETA2=P(II)
      ETA3=P(II+1)
      CALL PARAB (AA0,AA1,AA2)
      IIL=II-1
      IIR=II+1
      FTJX=EJ1(1,IIL,XX,P)+EJ3(AA0,AA2,XH)+EJ1(IIR,NN,XX,G)+BB*EJ4(XH,XX
     1)
      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 (AA0,AA1,AA2)
      XC1=XX
```

```
      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)
C     F1FN
C
C
C
C        SPECIAL FUNCTION NEEDED FOR THE NOSE SINGULARITY CASE (IN THE
C     CALCULATION OF THE CAVITY) AND FOR THE OFF-DESIGN CALCULATION.
C
C
C
C
      DOUBLE PRECISION DASQ,DMGSQ,DBET1,DBET2,DGAM1,DGAM2
      ASQ=A**2
      DASQ=ASQ
      DMGSQ=A*DSQRT(DASQ+1.0)
      DBET1=-DSQRT((DMGSQ-DASQ)/2.0D0)
      DBET2=-DSQRT((DMGSQ+DASQ)/2.0D0)
```

```
      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*SQRT(XNU*(XNU+1.0))/(XNU**2+ASQ)
      F1FUNC=F1FUNC+BET1*ALFUNC(XNU,A,OMGSQ,BET1,BET2,DELT1,DELT2,GAM1,G
     1AM2)/(4.0*OMGSQ)
      F1FUNC=F1FUNC+BET2*TEFUNC(XNU,A,DELT1,DELT2,GAM1,GAM2)/(2.0*OMGSQ)
      F1FUNC=0.5*F1FUNC/ASQ
      RETURN
      END



      FUNCTION EJ1 (IL,IR,XX,F)
C     NEEDS COMMON -- USES NTGRTE
      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,AMDA,ASQ,BB,BINT,C
     30,CL,CM,DELTA,DINT,ECAP,ELL,EM,EPSILN,ETA1,ETA2,ETA3,TEE,ONE,TWO,T
     4HR,THETA,TSAVE,XC0,XC1,XC2,XC3,XH,XKZ,NM,NN,JL6,JM6,JR6,JL13,JM13,
     5JR13,JTT1,JTM1,JTT2,JTM2,JTT3,JTM3,JTT4,JTM4,JTT5,JTM5,JTT7,JTM7,J
     6TT8,JTM8,JTT9,JTM9,JTT10,JTM10,JTT11,JTM11,JTT12,JTM12,JTT21,JTM21
     7,JTT23,JTM23,JTT24,JTM24,JTT25,JTM25
      COMMON /BLK1/V1BAR,V1BAR1,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 NTGRTE (EJ1)
      RETURN
      END



      FUNCTION EJ3 (AZ,A2,XH)
C
C     EVALUATES THE EXPRESSION FOR THE DEFINITE INTEGRAL OF
C     P(T)*LOG(T-XX) FROM XX-H TO XX+H.
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)-0.333
     133333)
      RETURN
      END




      FUNCTION EJ4 (XH,XX)
C
C        EVALUATES THE DEFINITE INTEGRAL OF (1-T)**.5*LOG(T-XX) OVER
C     (1-2H,1) AS OBTAINED IN CLOSED FORM (T THE VARIABLE OF INTEGRATION
C
C
C
C     INTEGRATE SQ. ROOT TERM FROM 1-2H TO 1.
C
      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(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))*0.6666
     36667
  110 RETURN
  120 EJ4=((2.828428*XH**1.5+(1.0-XX)**1.5)*CKLOG(1.414214*SQRT(XH)+SQRT
     1(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)
C
C
C
C        EVALUATES THE EXPRESSION FOR THE DEFINITE INTEGRAL OF FTJX OVER
C  TH E LIMITS XX-2H TO XX+2H. BLZ,BL1,BL2,BRZ,BR1,BR2 ARE THE COEF-
C  FI CIENTS OF THE QUADRATIC APPROXIMATIONS TO P(X) OVER(XX-2H,XX) AND
C  (X X,XX+2H), RESPECTIVELY.
C
C
C
C     (5-PT. INTEGRAL ACROSS LOG. SINGULARITY.)
C
      EJ5=2.0*((BLZ+BRZ)*XH*(CKLOG(2.0*XH)-1.0)+(BR1-BL1)*XH**2*(CKLOG(2
     1.0*XH)-0.5)+4.0*(BR2+BL2)*XH**3*(CKLOG(2.0*XH)-0.33333333)/3.0)
      RETURN
      END
```

HYDROFOIL DESIGN PROGRAM

```
      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),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,EPSILN,ETA1,ETA2,ETA3,TEE,ONE,TWO
     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)/(ELL-X(I))
      CALL NTGRTE (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),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,EPSILN,ETA1,ETA2,ETA3,TEE,ONE,TWO
     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 NTGRTE (BINT4)
      RETURN
      END
```

```
      FUNCTION TEFUNC (XNU,A,DELT1,DELT2,GAM1,GAM2)
C     TFUN
C
C
C
C     PLAYS A PART SIMILAR TO THAT OF ALFUNC.
C
C
C
      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,OMGSQ,BET1,BET2,DELT1,DELT2,GAM1,GAM2)
C     ALFN
C
C
C
C        THIS SPECIAL FUNCTION IS PART OF EXPRESSION FOR F1(NU,A)--ALSO
C     NEEDED BY F2(NU,A) IN THE OFF-DESIGN CALCULATION.
C
C
C
C
      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
```

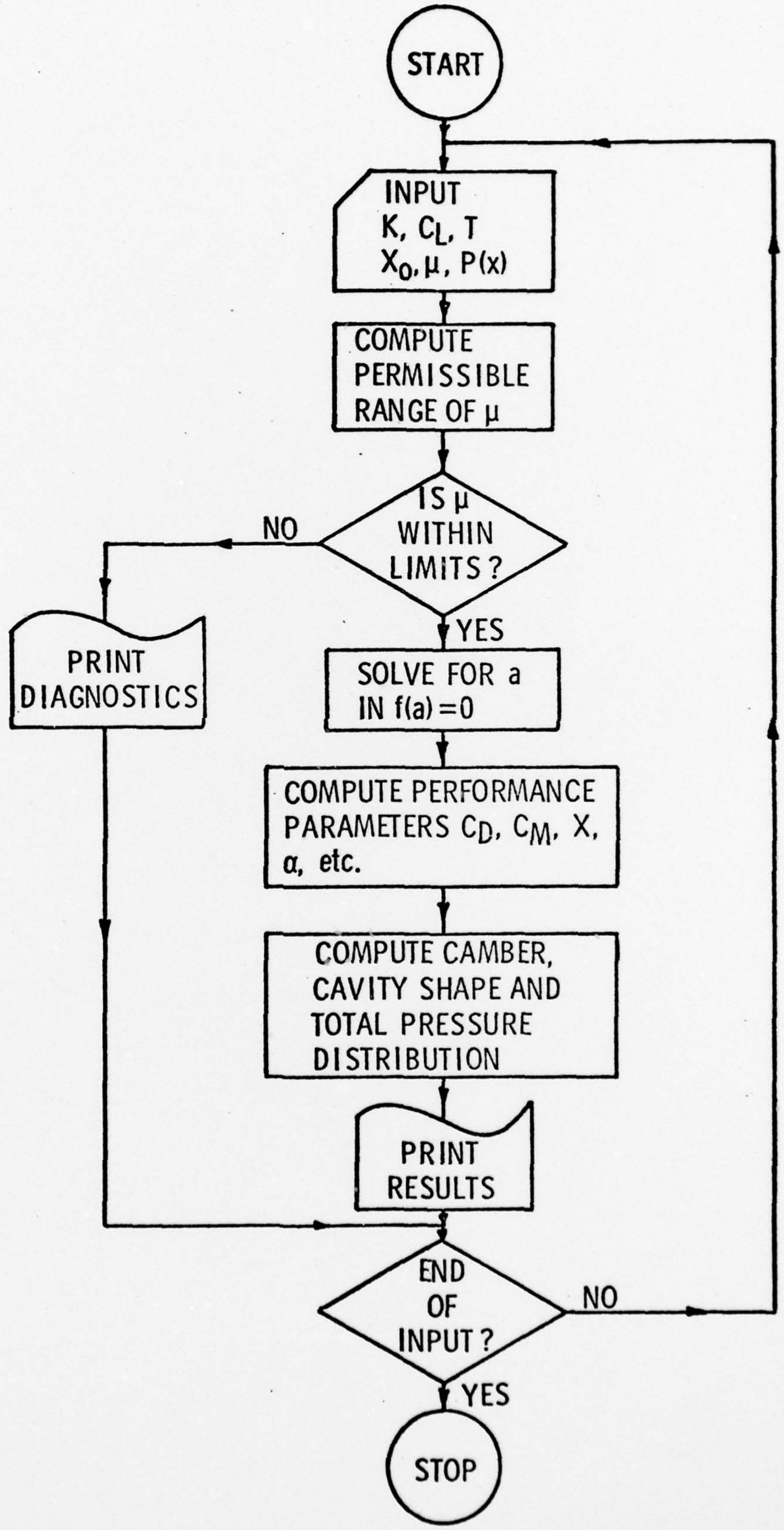
```
      FUNCTION BICM (A)
      REAL KAY(50)
      COMMON P(101),G(101),Q(101),H(101),X(101),XSQ(101),FX(101),ETN1(10
     11),ETN2(101),ETP1(101),ETP2(101),YYU1(101),YYU2(101),TAU(101),ALP(
     2101),DEE(101),AA(50),KAY,CAY,DUM,A1,A2,ACAP,ALPHA,AMDA,ASQ,BB,BINT
     3,CO,CL,CM,DELTA,DINT,ECAP,ELL,EM,EPSILN,ETA1,ETA2,ETA3,TEE,ONE,TWO
     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)*X(I)
      CALL NTGRTE (BICM)
      RETURN
      END




      FUNCTION BTX7 (XX)
C     BTX7
C
C
C
C          THIS SPECIAL ROUTINE EVALUATES A DEFINITE INTEGRAL OVER (0,1)
C     WHOSE INTEGRAND INVOLVES P(X) AND A LOGARITHMIC FUNCTION OF THE
C     VARIABLE OF INTEGRATION.  THIS INTEGRAL IS NEEDED BY THE ROUTINE
C     HH.
C
C
C
C
      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,DUMA,A1,A2,ACAP,ALPHA,AMDA,ASQ,BB,BIN
     3T,CO,CL,CM,DELTA,DINT,ECAP,ELL,EM,EPSILN,ETA1,ETA2,ETA3,TEE,ONE,TW
     4O,THR,THETA,TSAVE,XC0,XC1,XC2,XC3,XH,XKZ,NM,NN,JL6,JM6,JR6,JL13,JM
     513,JR13,JTT1,JTM1,JTT2,JTM2,JTT3,JTM3,JTT4,JTM4,JTT5,JTM5,JTT7,JTM
     67,JTT8,JTM8,JTT9,JTM9,JTT10,JTM10,JTT11,JTM11,JTT12,JTM12,JTT21,JT
     7M21,JTT23,JTM23,JTT24,JTM24,JTT25,JTM25
      COMMON /BLK1/V1BAR,V1BAR1,ECAP1,YC12
C
```

```
      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 (BB0,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),BB0,BB1,BB2)
      RETURN
      END
```

PROGRAM FLOW CHART



Sample Calculations for Estimation Mode

```
    LISTING OF INPUT DATA FOLLOWS

 NO. OF GRID-PTS. NN= 51    STEP-SIZE XH=  0.40000000E-02    FUNCTION BOUND AMDA=  0.50000000E 01
  COEF. OF SQ. ROOT COMP.=  0.00000000E 00    CAVITATION NO. K (CAY)=  0.50000000E-01  LIFT COEF. CL=  0.79999980E-01
 PARAMETER T (TEE)=  0.10000000E 00     S=  0.100     XO=  0.100
 A= 0.24883300E 01
ERROR IN FA = -0.10803340E-06
    FOR M=  0.0000000E 00  MAXIMUM VALUE OF CL IS=  0.1085538E 00
 A= 0.22659280E 01
ERROR IN FA =  0.29802320E-07
    FOR M=  0.1000000E 01  MAXIMUM VALUE OF CL IS=  0.1051729E 00
    THE RANGE OF M AND MU FOR DESIGN CL=  0.7999998E-01
 A= 0.23781080E 01
ERROR IN FA = -0.74505800E-07
   M=  0.0000000E 00     MU=  0.1781246E 00
 A= 0.22196870E 01
ERROR IN FA = -0.40978190E-07
   M=  0.1000000E 01     MU=  0.1577606E 00
```

Sample Calculations for Design Mode

```
 LISTING OF INPUT DATA FOLLOWS

NO. OF GRID-PTS. NN= 51    STEP-SIZE XH=  0.40000000E-02    FUNCTION BOUND AMDA=  0.50000000E 01
 COEF. OF SQ. ROOT COMP.=  0.00000000E 00    CAVITATION NO. K (CAY)=  0.50000000E-01  LIFT COEF. CL=  0.79999980E-01
 PARAMETER T (TEE)=  0.10000000E 00      S=  0.100      XO=  0.100
A= 0.23780990E 01
ERROR IN FA =  0.14822970E-06
   K= 0.0500       AMU=  0.1781236E 00       XO= 0.1000
   CL=  0.7999998E-01       T= 0.1000       S= 0.1000
   L/D=  0.1293974E 02     CM= -0.2520269E-01      CD=  0.6182503E-02      XBAR=  0.3150337E 00      ALPHA=  0.5763370E-01
   YC1=  0.1347394E-01     ACAP= -0.4564844E-01      EM=  0.4098873E-04      B=  0.3798536E-02      D=  0.4470709E-01
   INPUT FOR OFF-DESIGN CALCULATIONS:
     V1BAR=  0.1102738E-01      ECAP1=  0.5665846E-02      SQRT OF ELL1=  0.2579798E 01
```

	X	Y	ETA	ETP	PTOT
1	0.0000000E 00	0.2658527E-08	-0.4633380E-09	0.9999000E 04	0.9584243E 03
6	0.2000000E-01	0.5777325E-02	-0.1836732E-02	-0.3991598E-01	0.2473887E 00
11	0.4000000E-01	0.9307619E-02	-0.2454532E-02	-0.2447797E-01	0.2012747E 00
16	0.6000000E-01	0.1237114E-01	-0.2867865E-02	-0.1754027E-01	0.1770059E 00
21	0.7999998E-01	0.1517754E-01	-0.3173814E-02	-0.1334678E-01	0.1607790E 00
26	0.9999996E-01	0.1781237E-01	-0.3410187E-02	-0.1044551E-01	0.1486718E 00
31	0.1199999E 00	0.2032108E-01	-0.3596448E-02	-0.8274652E-02	0.1390440E 00
36	0.1400000E 00	0.2273152E-01	-0.3744221E-02	-0.6564576E-02	0.1310599E 00
41	0.1600000E 00	0.2506221E-01	-0.3861094E-02	-0.5167630E-02	0.1242394E 00
46	0.1799999E 00	0.2732625E-01	-0.3952395E-02	-0.3995027E-02	0.1182811E 00
51	0.2000000E 00	0.2953348E-01	-0.4022010E-02	-0.2989095E-02	0.1129783E 00
56	0.2200000E 00	0.3169125E-01	-0.4072763E-02	-0.2107042E-02	0.1082126E 00
61	0.2399999E 00	0.3380549E-01	-0.4106976E-02	-0.1329616E-02	0.1038707E 00
66	0.2600000E 00	0.3588096E-01	-0.4126504E-02	-0.6348840E-03	0.9987688E-01
71	0.2800000E 00	0.3792150E-01	-0.4132826E-02	-0.7899973E-05	0.9617352E-01
76	0.3000000E 00	0.3993035E-01	-0.4127190E-02	0.5626744E-03	0.9271568E-01
81	0.3200000E 00	0.4191030E-01	-0.4110627E-02	0.1085649E-02	0.8946675E-01
86	0.3400000E 00	0.4386362E-01	-0.4084043E-02	0.1568000E-02	0.8639783E-01
91	0.3600000E 00	0.4579238E-01	-0.4048146E-02	0.2015322E-02	0.8348483E-01
96	0.3800000E 00	0.4769829E-01	-0.4003625E-02	0.2432194E-02	0.8070761E-01
101	0.4000000E 00	0.4958290E-01	-0.3951039E-02	0.2822383E-02	0.7804930E-01
106	0.4200000E 00	0.5144754E-01	-0.3890887E-02	0.3189025E-02	0.7549542E-01
111	0.4400000E 00	0.5329345E-01	-0.3823613E-02	0.3534760E-02	0.7303351E-01
116	0.4600000E 00	0.5512170E-01	-0.3749617E-02	0.3861834E-02	0.7065260E-01
121	0.4800000E 00	0.5693323E-01	-0.3669248E-02	0.4172154E-02	0.6834310E-01
126	0.5000000E 00	0.5872911E-01	-0.3582839E-02	0.4467376E-02	0.6609637E-01
131	0.5200000E 00	0.6050985E-01	-0.3490655E-02	0.4748914E-02	0.6390482E-01
136	0.5400000E 00	0.6227623E-01	-0.3392962E-02	0.5018026E-02	0.6176134E-01
141	0.5599999E 00	0.6402892E-01	-0.3290008E-02	0.5275793E-02	0.5965938E-01
146	0.5800000E 00	0.6576878E-01	-0.3182002E-02	0.5523171E-02	0.5759292E-01

Sample Calculations for Design Mode (Cont.)

151	0.6000000E 00	0.6749600E-01	-0.3069144E-02	0.5761016E-02	0.5555611E-01
156	0.6199999E 00	0.6921130E-01	-0.2951602E-02	0.5990077E-02	0.5354336E-01
161	0.6400000E 00	0.7091504E-01	-0.2829593E-02	0.6211031E-02	0.5154945E-01
166	0.6600000E 00	0.7260782E-01	-0.2703209E-02	0.6424468E-02	0.4956857E-01
171	0.6799999E 00	0.7428986E-01	-0.2572659E-02	0.6630950E-02	0.4759562E-01
176	0.7000000E 00	0.7596159E-01	-0.2438019E-02	0.6830946E-02	0.4562463E-01
181	0.7200000E 00	0.7762343E-01	-0.2299451E-02	0.7024899E-02	0.4364960E-01
186	0.7399999E 00	0.7927567E-01	-0.2157075E-02	0.7213220E-02	0.4166392E-01
191	0.7600000E 00	0.8091861E-01	-0.2010958E-02	0.7396266E-02	0.3966012E-01
196	0.7800000E 00	0.8255243E-01	-0.1861234E-02	0.7574368E-02	0.3762997E-01
201	0.8000000E 00	0.8417779E-01	-0.1708012E-02	0.7747829E-02	0.3556352E-01
206	0.8200000E 00	0.8579457E-01	-0.1551366E-02	0.7916935E-02	0.3344911E-01
211	0.8400000E 00	0.8740300E-01	-0.1391374E-02	0.8081935E-02	0.3127163E-01
216	0.8600000E 00	0.8900350E-01	-0.1228106E-02	0.8243062E-02	0.2901205E-01
221	0.8800000E 00	0.9059626E-01	-0.1061672E-02	0.8400541E-02	0.2664448E-01
226	0.9000000E 00	0.9218138E-01	-0.8921081E-03	0.8554563E-02	0.2413192E-01
231	0.9200000E 00	0.9375918E-01	-0.7195075E-03	0.8705322E-02	0.2141834E-01
236	0.9400000E 00	0.9532970E-01	-0.5439224E-03	0.8852988E-02	0.1840906E-01
241	0.9600000E 00	0.9689325E-01	-0.3654088E-03	0.8997720E-02	0.1491999E-01
246	0.9800000E 00	0.9844989E-01	-0.1840340E-03	0.9139664E-02	0.1047370E-01
251	0.1000000E 01	0.9999979E-01	0.1613780E-06	0.9278968E-02	0.0000000E 00

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