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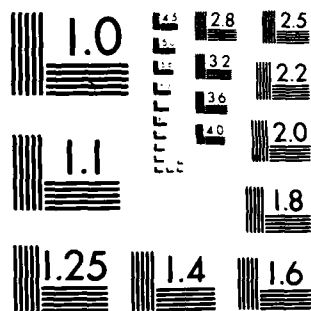
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HYDROMECHANICS, INC.

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by

Paul Kaplan, James Bentson and Moshe Benatar

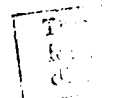
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face which represents the boundary for the lower half-plane. The integral equation for solution of this problem to determine the pressure is established and solved analytically, with evaluation carried out by means of digital computation in terms of the various physical parameters and those obtained from the mapping procedure.

The solution provides the pressure distribution at different sections on the hull, from which the total forces are then determined via integration with this strip theory approach. In addition the effects of different mode shapes of hull vibration are incorporated in order to obtain generalized forces for determining hull vibration responses. Illustrations of results are given for a representative naval auxiliary vessel.

The effect of different section shapes and dimensions in establishing body solid boundary factors (relative to the free space pressure) is also demonstrated. An extension of the basic analysis is applied to the problem of a ship section with adjacent rigid boundaries on the free surface similar to the case of particular cavitation tunnel test facilities, thereby providing a method of evaluating boundary effects of laboratory test facilities relative to full scale flow conditions.



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ANALYTICAL PREDICTION OF PRESSURES
AND FORCES ON A SHIP HULL DUE TO
CAVITATING PROPELLERS

ABSTRACT

An existing technique for determining free space pressures generated by a cavitating propeller operating in a ship wake is used as the basic input for determining the pressure distribution on various ship sections. The procedure involves establishing a boundary value problem on the ship section and the free surface, with appropriate conformal mapping operations that allow conversion of the problem to a more simplified boundary, viz. a flat plate and its adjacent free surface which represents the boundary for the lower half-plane. The integral equation for solution of this problem to determine the pressure is established and solved analytically, with evaluation carried out by means of digital computation in terms of the various physical parameters and those obtained from the mapping procedure.

The solution provides the pressure distribution at different sections on the hull, from which the total forces are then determined via integration with this strip theory approach. In addition the effects of different mode shapes of hull vibration are incorporated in order to obtain generalized forces for determining hull vibration responses. Illustrations of results are given for a representative naval auxiliary vessel.

The effect of different section shapes and dimensions in establishing body solid boundary factors (relative to the free space pressure) is also demonstrated. An extension of the basic analysis is applied to the problem of a ship section with adjacent rigid boundaries on the free surface similar to the case of particular cavitation tunnel test facilities, thereby providing a method of evaluating boundary effects of laboratory test facilities relative to full scale flow conditions.

INTRODUCTION

During the past 25 years extensive studies have been carried out, both theoretically and experimentally, relating to the bearing forces acting on a propeller in a ship wake as well as determining the free space hydrodynamic pressure generated by such a propeller in that operating mode. While most of these studies were initially concerned with propellers for which cavitation was not present, the occurrence of cavitation on the propeller has led to free space pressures that are an order of magnitude larger than those associated with the noncavitating propeller. The occurrence of cavitation is usually present in a limited angular region about the upright (i.e. 12 o'clock) position of the propeller blade as it encounters a wake field that varies significantly in that region. This large pressure due to cavitation results from the rapid growth and collapse of the cavity volume which begins in the region of the blade tips.

In view of the importance of this effect of cavitation which leads to these high pressures, and the interest by designers in various propeller modifications that could result in reduced tip clearance and changes in the local hull shape in proximity to the propeller, it is important to have a method that could predict the magnitude of the pressures as well as the forces acting on the ship hull due to the effects of the cavitation that may occur on the propellers under those conditions. Some work has been previously published (Kaplan et al, 1979) that allows determination of the vibratory hydrodynamic pressures arising from propeller cavitation, and that work has demonstrated a fair degree of success in prediction and correlation with a number of experimental measurements (both model and full scale). This particular tool can be used as a basic element to determine the extent of possible vibratory problems associated with design variations of propeller-hull form

configurations for different applications.

The method of (Kaplan et al, 1979) is primarily concerned with determining the basic free space pressures associated with the occurrence of cavitation. What is important for further practical utility would be a method that allowed accurate determination of the pressure distribution on various sections of a ship hull due to these cavitating propellers. The usual procedure has been to multiply the free space pressure by a factor of 2, reflecting the influence of a large flat boundary. Since all ship sections do not necessarily have such a characteristic, an appropriate analysis should be made to determine the proper pressure distribution on a ship section.

In addition to the determination of pressure per se, it is recognized that any vibration analysis would require determining the total forces acting on the ship hull due to the propeller-induced pressures. There are a number of different ways in which this can be done at present, either by solution of a diffraction problem as in the work of (Breslin and Eng, 1965) or by use of the reciprocity relations derived by (Vorus, 1974). Another possibility would be to integrate the pressure distribution along each section, if that information is available. Regardless of which way is considered for determining the force by any of the methods discussed above, an extensive degree of analysis and/or computation is necessary in order to determine the total forces with the present state-of-the-art.

The present report describes a technique for determining the pressure distribution at various ship sections as a function of the ship section geometry, using information on the free space pressure field due to a cavitating propeller in a wake. Another element of this work is a simple determination of the total force on different ship sections, from which the entire vibratory force can be evaluated. A description of the procedures that are used to obtain all of these results is given in the following sections of this report.

FREE SPACE PRESSURES, INCLUDING CAVITATION EFFECTS

Since the present work applies and extends the procedures developed by (Kaplan et al, 1979), some of the basic concepts used in that particular study are described here. The procedure in (Kaplan et al, 1979) initially makes use of an existing computer program and analysis (Tsakonas et al, 1976, 1977) developed at Davidson Laboratory to predict the blade forces acting on a non-cavitating propeller operating in a ship wake. The information on the radial distribution of blade forces from (Tsakonas et al, 1976) is used to establish values of local camber and angle of attack distributions along the propeller span. These quantities, which establish local propeller blade section inflow velocity, cavitation index, etc., are used to evaluate the cavitation quantities appropriate to a particular propeller and wake at each propeller section of interest by use of a two-dimensional quasi-steady model of cavity flow (Geurst and Verbrugh, 1959). The cavitation quantities of interest in this case are the section force coefficients (C_L , C_m , etc.) and the local cavity area for each section, which are found for conditions appropriate to partial cavitating flow ($\ell/c < 1$, where ℓ = cavity length and c = chord length), supercavitating flow ($\ell/c > 1$), and the important "transition" range between these two cavitation regions.

With the basic cavitation properties described above, the analysis of (Kaplan et al, 1979) establishes a general representation of the velocity potential and hydrodynamic pressure field associated with a time-varying cavity on a propeller blade. The expressions contain terms associated with the effect of changing thickness and loading of the propeller, as well as the important source-like contribution associated with the changing volume of the cavity on the propeller (obtained in terms of the distribution of cavity sectional area along the span of each propeller blade). The total free space pressure at any point is then found by

the sum of the terms corresponding to the cavitation effect (cavity source effect and loading) as well as the effects of the non-cavitating propeller found from (Tsakonas et al, 1977). In most practical cases the non-cavitating propeller contribution is essentially negligible in comparison with the contributions arising from cavitation.

The expression for the field pressure due to the cavity effect on the propeller is given in terms of variables related to the coordinate system shown in Figure 1, and is given by

$$p_c = \frac{\rho_f \Omega}{4\pi} \int_{r_c(\theta)}^{r_o} \left\{ \frac{1}{R^3} \frac{\partial A_c}{\partial \theta} \left[\bar{U}x - \Omega r \left(1 + \frac{1}{2r} \frac{\partial l}{\partial \theta} \right) \cdot \sin \left[\theta + \sigma_s - \phi - \frac{(c-l)}{2r} \right] \right] \right. \\ \left. + \frac{\Omega}{R} \frac{\partial^2 A_c}{\partial \theta^2} \right\} dr \quad (1)$$

In this expression R is the distance from any blade element to the field point; $\bar{U}$ is the mean axial velocity averaged over the propeller disc; r is the radial coordinate along the propeller blade; A_c is the cavity area; Ω is the propeller angular velocity; σ_s is the skew angle of the blade. The radiated field pressure due to the cavity can be seen to contain sources with strength proportional to $\partial^2 A_c / \partial t^2$ and dipoles (axial and transverse) with strength proportional to $\partial A_c / \partial t$, together with a dependence on the cavity length and its variation with time.

The field pressure due to the change in loading arising from cavitation is expressed by

$$p_l = - \frac{1}{4\pi} \int_{r_c}^{r_o} \frac{\partial}{\partial n} \left(\frac{1}{R} \right) \Delta L_{cav}(r,t) dr \quad (2)$$

where the integration is carried out over the cavitated region on the blade. The quantity ΔL_{cav} is the change in lift of each radial section of the propeller blade due to cavitation, and the operation $\partial / \partial n$ represents the normal derivative relative to the helicoidal surface. The various operations to obtain the lift due to cavitation, the angle of attack, force coefficients, cavity characteristics, etc. used in

the evaluation of Eqns. (1) and (2) are described by (Kaplan et al, 1979).

The values of pressure due to cavity geometry variations (from Eqn. (1)) and pressure due to load changes due to cavitation (from Eqn. (2)) are added together to produce the total pressure due to cavitation for a single blade. This is evaluated as a function of time (or blade angle) during a single propeller rotation, and the resulting time history is then Fourier analyzed in terms of the shaft rate and higher harmonics. With proper allowance for relative blade phasing the total effect for the entire propeller is obtained by summing all the harmonic components, which results in final output pressure at the propeller blade rate and its harmonics.

The results obtained by this method (Kaplan et al, 1979) showed good agreement for measured point pressures on a ship hull, for both model and full scale conditions. The model test results were obtained in European research establishment water tunnels using simulated wakes and dummy stern regions, while full scale data was obtained from direct measurements at sea. In view of the good agreement with measurements exhibited by (Kaplan et al, 1979), which includes the important higher harmonics of blade rate, the basic theory used there appears to be a valid representation of the important effects occurring due to propeller blade cavitation.

METHOD OF ANALYSIS - PRESSURE DISTRIBUTION ON SHIP SECTIONS

With knowledge of the free space pressure due to the propeller it is necessary to determine the effect of different ship sections on the actual pressures experienced on the ship hull boundary, i.e. the effect of the ship hull in changing the magnitude of the incident free space pressure. The basic method of analysis used here assumes that a strip theory method is applicable, with the effect of the ship hull section determined by means of a two-dimensional analysis. This procedure is considered to be applicable to the present case since the rate of spatial decay of the pressure field is primarily due to the changing volume of the cavity, which acts as a source whose rate of spatial variation is much smaller than that due to loading variations that has been the primary influence for non-cavitating propellers.

The effect of the ship hull section is evaluated by assuming that the sections can be represented in terms of a multi-parameter conformal mapping that generalizes the Lewis form method (Lewis, 1929) for ship sections. In the present case the incident flow field is that due to the free space pressure field of the propeller, which is evaluated in the plane of the ship section of interest. The method of formulating the boundary value problem appropriate to this type of approach is given below.

Boundary Value Problem

The boundary value problem is established in terms of the pressure as the dependent variable, with the pressure determined by a linear operation on the velocity potential, i.e.

$$p = - \rho_f \left(\frac{\partial}{\partial t} + \bar{U} \frac{\partial}{\partial x} \right) \phi \quad (3)$$

where ϕ = the velocity potential and the pressure is expressed with respect to atmospheric pressure as a reference. On that basis the boundary value problem for any ship section

is expressed as shown in Figure 2, where the pressure is assumed to be zero on the free surface due to the high frequencies associated with propeller vibratory effects. The requirement that the normal derivative of the pressure is zero on the section boundary follows from the requirement that $\partial\phi/\partial n = 0$ on that boundary; since pressure is defined in terms of linear differentiation operations on the potential, this boundary relationship then follows.

The problem can be simplified further by decomposing the pressure field into a sum of contributions due to the incident flow field p_p due to the propeller free space pressure, p_i due to the image with respect to the free surface, and the additional pressure p' representing the effects of the ship section

$$p = p_p + p_i + p' \quad (4)$$

The image pressure is selected so that $p_p + p_i = 0$ on the free surface. This is easily accomplished using the representation in Eqns. (1) and (2) (Kaplan et al, 1979) with a simple change in the definition of the distance R for the image terms. The resulting boundary value problem on the free surface and on the ship section boundary is given in Figure 2 in terms of values of the pressure p' , i.e.

$$p' = 0 \quad , \quad \text{on free surface} \quad (5)$$

and

$$\frac{\partial p'}{\partial n} = -\left(\frac{\partial p_p}{\partial n} + \frac{\partial p_i}{\partial n}\right), \quad \text{on the section boundary} \quad (6)$$

The normal derivative of the propeller free space pressure and its image are known functions determined from the properties of the pressure field due to the cavitating propeller, which can be determined from the work of (Kaplan et al, 1979).

This boundary value problem can be put into a simpler form by means of conformal transformations from a ship section

to a unit radius semicircle and from there to a flat plate. In this manner the various boundary values of the pressure and its derivatives are also transformed in such a way that the problem complexity is reduced and the boundary is simplified.

Introducing the complex potential W , whose real part is taken as the pressure, the complex derivative of W in the physical body plane defined by $Z = y + iz$ is given by

$$\frac{dW}{dZ} = \frac{\partial p}{\partial y} - i \frac{\partial p}{\partial z} \quad (7)$$

The flow in the body plane is then transformed to the circle plane (ζ -plane) by means of a conformal mapping defined by

$$Z = a_1 \left[\zeta + \sum_{n=1}^{\infty} a_{n+1} \zeta^{(-2n+1)} \right] \quad (8)$$

The mapping function from the body plane to the circle plane defined by Eqn. (8) requires a_{n+1} to be found in order to relate the coordinates in the body plane to points along the semicircle. The coefficient a_1 is selected as a normalizing factor so that the transformation goes from the body to a semicircle of unit radius.

The complex pressure gradient determined from the complex potential W is then transformed into the circle plane by means of the operation

$$\frac{dW}{d\zeta} = \frac{dW}{dZ} \frac{dZ}{d\zeta} \quad (9)$$

With $\zeta = \xi + i\eta = e^{-i\phi}$ on the unit circle, Eqn. (9) then becomes

$$\frac{dW}{d\zeta} = \frac{\partial p}{\partial \xi} - i \frac{\partial p}{\partial \eta} = a_1 \left(\frac{\partial p}{\partial y} - i \frac{\partial p}{\partial z} \right) \left[1 - \sum_{n=1}^{\infty} (2n-1) a_{n+1} e^{i2n\phi} \right] \quad (10)$$

which leads to

$$\frac{\partial p}{\partial \xi} = a_1 \frac{\partial p}{\partial y} \left[1 - \sum_{n=1}^{\infty} (2n-1) a_{n+1} \cos 2n\phi \right] - a_1 \frac{\partial p}{\partial z} \sum_{n=1}^{\infty} (2n-1) a_{n+1} \sin 2n\phi \quad (11)$$

and

$$\frac{\partial p}{\partial \eta} = a_1 \frac{\partial p}{\partial z} \left[1 - \sum_{n=1}^{\infty} (2n-1) a_{n+1} \cos 2n \eta \right] + a_1 \frac{\partial p}{\partial y} \sum_{n=1}^{\infty} (2n-1) a_{n+1} \sin 2n \eta \quad (12)$$

As shown in Figure 3, the mapping then proceeds from the unit semicircle to a flat plate (w -plane) by means of the transformation

$$w = \frac{1}{2} \left(\zeta + \frac{1}{\zeta} \right) \quad (13)$$

where $w = x + i\beta$. The pressure gradient relations are then

$$\frac{dW}{dw} = \frac{\partial p}{\partial \alpha} - i \frac{\partial p}{\partial \beta} = \frac{dW}{d\zeta} \frac{d\zeta}{dw} \quad (14)$$

where

$$\frac{d\zeta}{dw} = 1 \pm \frac{w}{\sqrt{w^2 - 1}} \quad (15)$$

Since in conformal mapping procedures the normal to the surface is preserved, the pressure gradient $\partial p / \partial \beta$ normal to the flat plate corresponds to the transformed value of the normal derivative of the pressure on the original body section. For the lower surface of the flat plate, which corresponds to the body section boundary, this leads to

$$\frac{\partial p}{\partial \beta} = \frac{\partial p}{\partial \eta} - \frac{\partial p}{\partial \xi} \frac{\alpha}{\sqrt{1-\alpha^2}} \quad (16)$$

The boundary value problem is then shown in Figure 3 as a mixed boundary value problem for the pressure p' along the entire real axis of the w -plane. All that is needed for establishing the values of the normal derivative along the plate boundary are the values of the a_n quantities in the transformation to the circle plane give by Eqn. (8). Those values are found by a method based upon a least squares-sequential iterative procedure (von Kerczek and Tuck, 1969) for which a computer program was established. The program considered 7 values of the a_{n+1} coefficients (plus the value of a_1) for proper representation of ship sections of practical interest.

INTEGRAL EQUATION - FORMULATION AND SOLUTION

The boundary value problem on the flat plate plane (w -plane) can be solved by establishing an integral equation by the use of Green's theorem. The Green's function is selected as

$$G(u, v; \alpha, \beta) = \ln \sqrt{(u-\alpha)^2 + (v-\beta)^2} - \ln \sqrt{(u-\alpha)^2 + (v+\beta)^2} \quad (17)$$

for which

$$G(u, 0; \alpha, \beta) = 0 \quad (18)$$

$$G_v(u, 0; \alpha, \beta) = \frac{-2\beta}{(u-\alpha)^2 + \beta^2} \quad (19)$$

Applying Green's theorem to a contour along the real axis with a large circular arc in the lower half-plane and small arcs about the points ± 1 , and on the limit as to the small arcs $\rightarrow 0$ and the radius of the large circle $\rightarrow \infty$, this leads to

$$\begin{aligned} p'(\alpha, \beta) &= \frac{1}{2\pi} \int_{\text{real axis}} (G p'_v - p' G_v) du \\ &= \frac{1}{2\pi} \int_{-1}^1 p'(u, 0) \frac{\partial}{\partial \beta} \ln \left[(u-\alpha)^2 + \beta^2 \right] du \end{aligned} \quad (20)$$

which is the Poisson formula for the half plane.

Since p'_β is known on the plate, differentiate with respect to β leading to

$$\begin{aligned} p'_\beta(\alpha, \beta) &= \frac{1}{2\pi} \int_{-1}^1 p'(u, 0) \frac{\partial^2}{\partial \beta^2} \ln \left[(u-\alpha)^2 + \beta^2 \right] du \\ &= -\frac{1}{2\pi} \frac{\partial^2}{\partial \alpha^2} \int_{-1}^1 p'(u) \ln \left[(u-\alpha)^2 + \beta^2 \right] du \end{aligned} \quad (21)$$

by means of the Laplace equation. Integrating both sides with respect to α (from -1 up to α), and letting $\beta \rightarrow 0$ while taking ap-

appropriate limits and values, leads to

$$c + \int_{-1}^{\alpha} f(s) ds = \frac{1}{\pi} \int_{-1}^1 \frac{p'(u)}{u-\alpha} du \quad (22)$$

where $f(x)$ is the known value of p'_g along the flat plate. As discussed previously that value is found at any ship section from knowledge of the propeller and free surface image pressure gradients and the mapping coefficients (multiparameter transformation from Z to ζ -planes), with the basic expressions shown in Eqns. (11), (12) and (16).

The singular integral equation in Eqn. (22) is essentially the same as that in (Kaplan and Sargent, 1972) and the solution is also similar. With the requirement of the solution being bounded at both ends (± 1), it is given by

$$p'(\alpha) = -\frac{1}{\pi} \sqrt{1-\alpha^2} \int_{-1}^1 \frac{\int_{-1}^u f(s) ds du}{\sqrt{1-u^2} (u-\alpha)} \quad (23)$$

as indicated by the methods in (Muskhelishvili, 1963).

The solution in Eqn. (23) is evaluated by defining new variables, i.e. $u = \cos \theta$, $\alpha = \cos \theta_0$ and it is assumed that the integral $\int_{-1}^u f(s) ds$ can be expanded into a Fourier series form in terms of cosines, viz.

$$\int_{-1}^u f(s) ds = \sum_{n=1}^{\infty} A_n \cos n\theta \quad (24)$$

Substituting the new variables and the Fourier expression of Eqn. (24) leads to

$$p'(\alpha) = -\sum_{n=1}^{\infty} A_n \sin n\theta_0 \quad (25)$$

where $\theta_0 = \cos^{-1} \alpha$, by use of the Glauert integrals of airfoil theory (Glauert, 1937).

The pressure distribution along the ship section boundary of interest is found by adding the contribution from Eqn. (25)

together with the free space pressure of the cavitating propeller as well as its free surface image. The computational procedure considers the separate sine and cosine harmonic terms at blade rate and higher harmonics from each constituent term, adding all contributions to each oscillatory function and then determining the resulting amplitude and phase of the final total pressure signal on the boundary.

The pressure distribution is determined at points along the section boundary that correspond to points that are equally spaced in the unit circle in the ξ -plane, i.e. equally spaced angles. This procedure assists in the determination of the Fourier cosine coefficients in the expansion of Eqn. (24). The location of the points on the section in the Z-plane is readily determined by use of Eqn. (8), which establishes the locations at which the pressures and pressure gradients from the cavitating propeller and its free surface image are to be calculated.

The total lateral and vertical force on each section are determined by integrating the pressure along the boundary, with appropriate account of directions, separate sine and cosine components for each harmonic of blade rate, etc. With knowledge of the sectional forces obtained in this manner the total forces are obtained by integrating the section forces along the length of the hull, which is the conventional procedure employed in strip theory analyses. Devoting the local sectional forces as $F'_z(x)$ and $F'_y(x)$ for the vertical and lateral forces, the total vertical and lateral forces on the ship due to the pressures arising from a cavitating propeller are represented by

$$F_z = \int F'_z(x) dx, \quad F_y = \int F'_y(x) dx \quad (26)$$

The integrations in Eqn. (26) extend over a length region for which appreciable pressures and forces exist on the ship, which is determined either computationally, or by establishing a cut-off level, or arbitrarily to some location such as up

to midships at which the pressures and forces will generally be negligible. When considering the force information to determine forced vibratory response of a ship, by use of a modal method of analysis as an example (McGoldrick, 1960), the total force integral is weighted by a modal weighting function, viz. the normal mode shape $X_i(x)$ for the i^{th} normal mode. The generalized modal force is then represented by

$$F_{z_i} = \int F'_z(x) X_i(x) dx \quad (27)$$

as a typical example, with appropriate consideration of the particular blade rate harmonic force values being used in such expressions. The use of a strip theory approach, with modal weighting from response analysis, has been used in various ship dynamic problems such as slamming response analysis (Kaplan and Sargent, 1972) and has proven to be a useful method for response predictions.

A listing of the computer program that solves the integral equation in the manner described above for use in determining the pressure distribution along the ship section is given in the Appendix. This computer program includes within its various procedures the calculation of the free space pressure due to a cavitating propeller; the pressure contribution due to the image; the determination of the various required pressure gradients; the conformal mapping and other coordinate transformations; etc. The procedures for determining the total forces acting on the ship, as well as the generalized modal forces, are also included in this program.

APPLICATION AND DISCUSSION OF RESULTS

In order to illustrate the nature of the results obtained from the preceding analysis, some representative calculations are carried out. The basic computational procedures that are necessary for the case of a cavitating propeller for a particular ship are described in block diagram form in Figs. 4 and 5. The procedure in Fig. 4 represents the various steps associated with the calculation of the pressure field arising from a particular propeller in a specified wake field, as described by (Kaplan et al, 1979). The diagram in Fig. 5 essentially describes the procedures developed in the present report.

The particular case illustrated here considers the auxiliary naval vessel designated as AO-177, which is a single screw tanker vessel. The propeller has 7 blades, with 45 deg. skew angle, with a 21 ft. diameter. This ship has been studied in a number of special investigations, with consideration of the occurrence of cavitation on the propeller blades due to the particular ship wake, e.g. (Bentson and Kaplan, 1981a, 1981b). Model tests have been carried out by David Taylor Naval Ship Research and Development Center for the basic ship to measure its wake field, as well as for the case where special flow-modifying fins were installed on the ship, with that data provided as input information that is used for the present calculations.

For the present purpose the particular wake, propeller design, etc. of the AO-177 is used only as a means of illustrating the nature of results for representative ship sections when using the present analysis. The various representative ship sections used for illustrating the present results are not necessarily those of the AO-177, although the flow field from which the propeller cavitation disturbing flows arise does correspond to that particular ship. The first case illustrated is that of a flat plate with a width of 60 ft. which is located in the free surface, where that section is assumed to be located at a distance of

5 ft. aft of the propeller plane (i.e. $x=5$ ft.). The wake field is that corresponding to the AO-177 fitted with the fins.

Calculations were made to determine the free space pressure along this flat plate section, as well as using the methods of the present analysis to determine the actual pressure inclusive of all other flows that would satisfy the boundary conditions of the present problem. An important feature of the results is not necessarily the pressures per se, but the ratio of the pressure along the plate to that of the free space pressure at each point along the plate. The results of this computation are shown in Fig. 6 illustrating the ratio of the pressure on the plate to the local free space pressure. Two curves are shown here in order to illustrate the accuracy of the results as a function of the number of points along the plate that are taken as input information for the integral equations. The differences due to the different number of points are more predominant in the region of the larger pressures, although the extent of such differences is not very significant. It can be seen by examination of Fig. 6 that the pressure on the plate increases to a value of the order of 2.6 times the local free space pressure, with the values of the pressure falling off to zero at the ends of the plate as expected. The average pressure for this distribution was found by means of integration, and was found to be 1.94 as is also illustrated in Fig. 6, with that value being close to the usual assumed value of the factor of 2 that is applied to free space pressures when determining pressure effects along a boundary.

While the results in Fig. 6 are informative, that only illustrates information appropriate to a particular special case. Other results are described below which have different numerical values and provide a different interpretation for the effect of the interaction of a representative ship section and the incident flow from a cavitating propeller.

Another case considers a flat plate section of 21.6 ft. width which is located in the free surface at the same position (i.e. $x=5$ ft.) in the wake due to the AO-177 with fins. The ratio of the pressure to the local free space pressure due to the propeller along this plate is shown in Fig. 7. It can be seen that this ratio has a maximum value of just under 1.4, with that maximum occurring near the plate center but slightly to port. This result illustrates the nature of the influence of the size of the plate relative to the disturbing flow field and/or the propeller.

Another application of the analysis considers an actual ship section taken from the AO-177, with that section being the profile corresponding to Station 19.5 on that vessel as illustrated in Figure 8. This section is essentially a shallow V-wedge shape, with the total lateral extent equal to 21.6. Assuming that this particular section is located at the position corresponding to $x=5$ ft. relative to the propeller, and with the wake the same as that of the AO-177 fitted with fins (the same case as for Figs. 6 and 7), the ratio of the pressure to the free space pressure along this section is shown in Fig. 9. In that situation the ratio reaches a maximum value of 2.0, with that maximum occurring somewhat to the starboard of the middle of the section. This result, when contrasted with that in Fig. 7, illustrates the effects of the actual section shape as well as the influence of the proximity of the center of the wedge region relative to the propeller tip.

Another illustration considers the same section corresponding to Station 19.5 of the AO-177, with the propeller operating in the basic wake of that ship without any flow-modifying fins. The section is assumed to be located 6 ft. forward of the propeller plane ($x=-6$ ft.) and the results for the ratio of the pressure along the plate to that of the local free space pressure due to the propeller are shown in Fig. 10. In that case the maximum value of this particular pressure ratio is 1.4, occurring somewhat to port

of the center of the section.

All of the above results illustrate the effect of the size of the section as well as its shape in regard to determining the magnitude of the pressures along different ship sections. The so-called boundary factor that accounts for the influence of the body section results in an increase in the value of the free space pressure to some factor that ranges both above and below the number 2, with the particular maximum value dependent upon the nature of the lateral size extent of the section, the shape of the section, the nature of the distribution of the free space pressure, etc. In addition the requirement that the pressure goes to zero at the ends of the section at the free surface is also a significant aspect of the present analysis that will affect the magnitude of the pressure distribution acting on various ship sections. All of these features influence the resulting pressure distribution values, indicating the basic complexity of determining the pressures on different ship sections and reducing the significance of the use of simplified factors for prediction of propeller-induced pressures and forces.

EFFECT OF RIGID FREE SURFACE CONDITIONS

In the preceding analysis the mathematical problem was formulated with the boundary condition corresponding to $p=0$ on the free surface. This particular boundary condition applies to the physical conditions corresponding to high frequencies, which is generally appropriate for the case of propeller-induced unsteady flows. There has been some previous analysis which considered the effects of different boundary conditions on the free surface (Vorus, 1976), where that analysis was applied to noncavitated propellers and was concerned with the total force as well as the local force on a strip section of a semi-infinite flat plate.

Aside from the basic interest in the influence of the free surface boundary condition, the consideration of a rigid wall free surface condition is important because it is representative of the flow conditions associated with model test procedures for ships in specialized water tunnel facilities that simulate full scale operation. In that case the free surface region is covered by rigid plates whose extent laterally can generally be represented by employing the boundary conditions of a rigid wall out to $\pm \infty$. On that basis the boundary condition for the pressure would correspond to $\partial p / \partial n = 0$ for the free surface as well as on the ship section boundary.

This problem can be analyzed by methods similar to that used for the case with a free surface boundary condition corresponding to $p=0$ by introducing a special image flow that results in satisfying the condition $\partial p / \partial z = 0$ on the free surface. This particular image is essentially the negative of the previous free surface image used for the earlier boundary condition, so that the total pressure can be represented by the expression

$$p = p_p + p_r + p' \quad (28)$$

where p_r = the pressure induced by the rigid wall image ($p_r = -p_i$, as defined previously). The resulting boundary

value problem on the ship section and the free surface is given by

$$\frac{\partial p'}{\partial n} = 0, \text{ on the free surface} \quad (29)$$

$$\frac{\partial p'}{\partial n} = - \left(\frac{\partial p_p}{\partial n} + \frac{\partial p_r}{\partial n} \right), \text{ on the section boundary} \quad (30)$$

where the required normal derivatives can be found from the cavitating propeller and the appropriate image.

By carrying out the same mapping procedures to the ζ and w -planes, the resulting boundary value problem in the w -plane is shown in Fig. 11. This boundary value problem can be solved by the use of Green's theorem, with the Green's function selected as

$$G(u, v; \alpha, \beta) = \ln \sqrt{(u-\alpha)^2 + (v-\beta)^2} + \ln \sqrt{(u-\alpha)^2 + (v+\beta)^2} \quad (31)$$

for which

$$G(u, 0; \alpha, \beta) = 2 \ln \sqrt{(u-\alpha)^2 + \beta^2} \quad (32)$$

$$G_v(u, 0; \alpha, \beta) = 0 \quad (33)$$

By applying Green's theorem to the same type contour as was done previously, the basic solution for the pressure is given in terms of the values of the derivative p'_β on the plate, which is represented by the function $g(\alpha)$, in the form

$$p'(\alpha) = \frac{1}{\pi} \int_{-1}^1 g(u) \ln |u-\alpha| du \quad (34)$$

The value of $g(\alpha)$ is determined from the same basic relations as in Eqn. (16) applied to the combined pressure values found from the propeller and the rigid wall image. With the expression for the value of p' on the flat plate given above by Eqn. (34), this value is then transformed back to the appropriate points along the actual ship section boundary in the body plane. To this value is added the pressure values arising from the propeller and the rigid wall image,

resulting in the total pressure distribution as defined by Eqn. (28).

The above procedure describes the method for determining the pressure distribution on the ship section when considering a rigid wall free surface boundary condition rather than the conditions that are appropriate to the real physical case in full scale. Numerical evaluation for particular cases (which is not done here) will provide information on the pressure distribution appropriate to both sets of boundary conditions on the free surface, so that comparisons can then be made between the different results that arise from each set of conditions. In that way it is possible to evaluate the influence of the boundary effects applied in laboratory test facilities that do not employ an actual free surface, so that the influence of these boundary effects can be determined relative to what would be present for full scale flow conditions.

CONCLUSION

The method of analysis described herein provides a technique for determining the pressure distribution along different ship sections due to a cavitating propeller, with appropriate account of the effects of the free surface boundary condition and the influence of the body shape. The major results are presented for the case wherein the free surface boundary condition corresponding to zero pressure is imposed, with the resulting pressure distribution illustrating the manner in which the pressure reduces toward zero at the intersection of the section with the free surface. The figures illustrating the results demonstrate the difference between a more precise method of solution and the simplified methods that are usually applied in engineering practice.

As a result of the analysis presented here, a straightforward procedure is then available for determining pressure distributions, local forces at various sections of a ship, and also the total force due to the disturbing flows arising from a cavitating propeller, including a procedure for modal weighting for use in vibratory analysis. The analytical tool described here is recommended for further practical applications to various problems of interest involving propeller-excited vibrations.

The analysis in the case of a rigid wall free surface boundary condition provides an entirely different type of solution that describes the pressure distribution under such a boundary condition. Since that type of boundary condition corresponds to the physical characteristics associated with particular types of model test facilities used for determining propeller vibratory pressures on ship hull sections, the analysis shown herein provides a means of representing the effects due to an imposed propeller pressure field. Comparisons can be made between the results predicted with the rigid wall boundary condition vis-a-vis

those from the zero pressure free surface condition as a means of illustrating the effects of model test facility boundary influence on measured pressures on ship hulls obtained from tests in such facilities.

It is recommended that extended calculations be carried out by these different approaches in order to provide guidance that will assist in interpreting the relation of model test values to the actual full scale pressures on ships with cavitating propellers. In view of the present use of such test facilities for predicting propeller-induced vibratory pressures and their associated effects, as well as possible new facilities built with the same basic testing concept, such an investigation has practical importance.

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APPENDIX

COMPUTER PROGRAM LISTING

PROGRAM CAV

LINE	CODE	TEXT	LINE	CODE	TEXT
1	C	PROGRAM CAVINPUT,OUTPUT,TAPE5=INPUT,TAPE8=OUTPUT	2	CAV	
2	C	PROGRAM CAV	3	CAV	
3	C		4	CAV	
4	C	PROGRAM CAV CALCULATES RADIATED PRESSURE AND CHARGES IN STEADY	5	CAV	
5	C	AND UNSTEADY FORCE AND MOMENT COEFFICIENTS DUE TO PROPELLER	6	CAV	
6	C	CAVITATION - METHOD IS BASED ON CUASI-STEADY APPLICATION OF THE	7	CAV	
7	C	CAVITATION SOLUTIONS OF GEORST FOR AN EQUIVALENT PARABOLIC ARC	8	CAV	
8	C	FOLI WITH THE SAME SECTIONAL (SPANWISE) LOADING	9	CAV	
9	C		10	CAV	
10	C	PROGRAM WRITTEN BY HYDROMECHANICS INC.	11	FINAL4	
11	C		12	CAV	
12	C		13	CAV	
13	C	COMMON/CONST,PI,RHOF,U,OMEGA,DEPTH,PV,G,RAD	14	CAV	
14	C	COMMON/EXEC/TOL, NPTS,DTHETA,ISOL,INITMAX ,RNMXX	15	CAV	
15	C	CUMPN/FCRCS/XLO,XLREAL(22),XLIPAG(22)	16	CAV	
16	C	CUMPN/GEGR/ NRAD,ROARINO,OMNO,PSKEM(8),PCHGRD(8)	17	CAV	
17	C	CUMPN/PLCITS/NPLCC,XPT(100),RHP(1100),PHIPT(100)	18	NEWFIX	
18	C	CUMPN/ZERU/ YIUT(6),ZTUT(6)	19	FINAL1	
19	C	CUMPN/SOLUT/DLIFT(8,181),VEL(8)	20	ADUGRAD	
20	C	CUMPN/UKITS/NIN,NDUT ,DATE(TITLE(15))	21	CAV	
21	C	CUMPN/GRADS/DXLDTP(8,181),USDTH(8,181),DZSDTH(8,181),NREG(8),	22	ADUGRAD	
22	C	IP(181),DPOY(181),DPOZ(181),NX(18,30),NXZ(8,30),XL(8,181)	23	ADUGRAD	
23	C	DIMENSION CCEFM(181),AREAL(181),	24	ADUGRAD	
24	C	ALPHA(181),SIGMAP(181),XLSVNM(181)	25	CAV	
25	C	DIMENSION DUMPT(181)	26	CAV	
26	C	DIMENSION DUMMY(1)	27	CAV	
27	C	DIMENSION IREGN(30)	28	CAV	
28	C	DIMENSION WORK(181),WORK2(181),WORK3(181)	29	CAV	
29	C	DIMENSION NIT(30),A2(30),XL(181)	30	CAV	
30	C	DIMENSION TYPES(9)	31	CAV	
31	C	DATA TYPES/4HPART,4HICAL ,4H ,4HIRON,4HSITI,4HONAL,4HFULL,	32	CAV	
32	C		33	CAV	
33	C	ZERO SOLUTION ARRAYS	34	CAV	
34	C		35	CAV	
35	C	DO 85 J=1,NPTS	36	CAV	
36	C	DO 89 K=1,8	37	CAV	
37	C	DLJFK(J)=0.0	38	CAV	
38	C	CENTRALE	39	CAV	
39	C		40	CAV	
40	C	START LUGR OVER RADIAL STRIPS	41	CAV	
41	C		42	CAV	
42	C	DL 1000 K=1,NRAD	43	CAV	
43	C	DL 587 J=1,30	44	CAV	
44	C	N1(J)=C.C	45	CAV	
45	C	N2(J)=0.0	46	ADUGRAD	
46	C	CENTRALE	47	ADUGRAD	
47	C		48	CAV	
48	C		49	CAV	
49	C	GET GEOMETRIC PROPERTIES FOR GIVEN RADIAL STRIP	50	CAV	
50	C		51	CAV	
51	C	RNC=RING*(K-1)+CRNC	52	CAV	
52	C	R=RNLRAD	53	CAV	
53	C	CHLRD=PLCGRD(IK)	54	CAV	
54	C		55	CAV	

82/08/10. 14.39.12

FTN 4.6+4330

76/74 OPT=0 TRACE

PROGRAM CAV

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89 ADDGRAD
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113 CAV

SKEN=PSREN(K)
VSCU=0.0+R *OMEGA1**2
V=SQRT(VSCU)
VEL(K)=V
FACLT1=.5*RNUP*CHORD*VSQD
DENOM=FACLT1*INCPI
FACRAS=FACLT1*OMEGA*CHORD/V

65 C GET NON-CAVITATING LOADING FOR GIVEN RADIAL STRIP
C CALL INLESI NOMAX)
C
70 C CALCULATE EFFECTIVE CAMBER FROM THE STEADY LIFT
C CAMBER=-XLO/DENOM
C
75 C SUPPARIZE INPUT FOR CURRENT RADIAL STRIP
C CALL HEADIN
WRITE(NDUT,200)NDU,V,CAMBER
WRITE(NDUT,2000)
J=0
80 WRITE(NDUT,201)J,XLO
DO 4455 J=1,NOMAX
WRITE(NDUT,201)J,XCREACT(J),XLINAG(J)
4455 CONTINUE
ITGLD=0
NRENS=0
85 C START LOOP OVER ANGULAR POSITIONS
C
90 DO 3 I=1,NPTS
DXLDT(K,I)=0.0
USDT(K,I)=0.0
USDT(K,I)=0.0
UCPUT(I)=0.0
95 C CALCULATE EFFECTIVE (QUASI-STEADY) ANGLE OF ATTACK FROM UNSTEADY
C LIFT
C
100 ALPHA=0.0
THETA=(1-I)*THETA
XLIFT=-XLO
DO 2 J=1,NCPAX
G=J
CUSOTH=CUS(C*THE(A)
SINUTH=SIN(C*THETA)
ARG=(C*G*FECA*CHORD)/(1+.9V)
DALPHA=-(COSGTH*(XLREAL(J)+ARCSXLIPAG(J))+SINGTH*(XLINAG(J)
1 -ARG*XLREAL(J))/(1+.9ARG*ARG*DENOM)
XLIFT=XLIFT-(CUSOTH*XLREAL(J)+SINGTH*XLINAG(J))
ALPHA=ALPHA+DALPHA
CONTINUE
XLSTN(I)=XLIFT
110 C
C
C CALCULATE NON-CAVITATING LIFT AND MOMENT COEFFICIENTS

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LINE	CODE	TEXT	LINE	CODE	TEXT
111	C	CLNOCV=TSOPI*ALPHA*(CAMBER)	111	C	
112	C	CMNOCV=-.5*PI*ALPHA	112	C	
113	C	IF(ALPHA.LE. 0.0) GO TO 78	113	C	
114	C	PA=2*PI*.RHO*F*G*(DEPTH-R *COS(THETA+SKEW))	114	C	
115	C	SIGMA=2.*(PA-PV)/(RHO*F*VSQD)	115	C	
116	C		116	C	
117	C		117	C	
118	C		118	C	
119	C		119	C	
120	C	FIND APPROPRIATE CAVITATION SOLUTION (PARTIAL, TRANSITIONAL)	120	C	
121	C	FULL)	121	C	
122	C		122	C	
123	C		123	C	
124	C	ALPHA=.255*SIGMA-.JG9013*CAMBER	124	C	
125	C	ALMIN=.085786 *SIGMA-.20711 *CAMBER	125	C	
126	C	IF(ALPHA.LT. ALMIN) GO TO 5	126	C	
127	C	IF(ALPHA.GT. ALPHA) GO TO 6	127	C	
128	C	TRANSITIONAL CAVITY SOLUTION	128	C	
129	C		129	C	
130	C	CALL TRANS(ALPHA,SIGMA,CAMBER,CAVLEN,CL,CMASS,S,ALPHA,ALMAX)	130	C	
131	C	ITYPE=2	131	C	
132	C	GO TO 7	132	C	
133	C	CONTINUE	133	C	
134	C	PARTIAL CAVITY SOLUTION	134	C	
135	C		135	C	
136	C		136	C	
137	C	CALL PARCAV(ALPHA,SIGMA,CAMBER,CAVLEN,CL,CMASS,S,0)	137	C	
138	C	ITYPE=1	138	C	
139	C	IF(CAVLEN.EQ. 0.0) GO TO 78	139	C	
140	C		140	C	
141	C	GET CAVITY AREA FROM CUBIC CURVE FIT (TRANSITIONAL OR	141	C	
142	C	PARTIAL SOLUTIONS ONLY)	142	C	
143	C		143	C	
144	C	CALL CUBICCTALPHA,SIGMA,CAMBER,ALMAX,S)	144	C	
145	C	GO TO 77	145	C	
146	C	CONTINUE	146	C	
147	C		147	C	
148	C	FULL CAVITY SOLUTION	148	C	
149	C		149	C	
150	C	CALL FULCAVIALPHA,SIGMA,CAMBER,CAVLEN,CL,CMASS,S,0)	150	C	
151	C	ITYPE=3	151	C	
152	C	GO TO 77	152	C	
153	C		153	C	
154	C	NG CAVITATION	154	C	
155	C		155	C	
156	C	CAVLEN=0.0	156	C	
157	C	CL=CLNOCV	157	C	
158	C	CMASS=CMACCV	158	C	
159	C	S=C.C	159	C	
160	C	ITYPE=0	160	C	
161	C	CONTINUE	161	C	
162	C		162	C	
163	C	COMPUTE AND STORE DIMENSIONAL CAVITY SOLUTION	163	C	
164	C		164	C	
165	C	ALPHA(1)=ALPHA*RAD	165	C	
166	C	SIGMAP(1)=SIGMA	166	C	
167	C	XLIN(1)=CAVLEN*CHORD	167	C	
168	C		168	C	
169	C	DIFFERENCE BETWEEN CAVITATING AND ACA-CAVITATING LIFT IS USED	169	C	
170	C		170	C	

Line	Code	Statement	Address
230	C	RELOAD DERIVATIVES INTO TWO DIMENSIONAL ARRAYS	ADDRAD
231	C		ADDRAD
232	C		ADDRAD
233	C		ADDRAD
234	C		ADDRAD
235	C		ADDRAD
236	C		ADDRAD
237	C		ADDRAD
238	C		ADDRAD
239	C		ADDRAD
240	C		ADDRAD
241	C		ADDRAD
242	C		ADDRAD
243	C		ADDRAD
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245	C		ADDRAD
246	C		ADDRAD
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248	C		ADDRAD
249	C		ADDRAD
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251	C		ADDRAD
252	C		ADDRAD
253	C		ADDRAD
254	C		ADDRAD
255	C		ADDRAD
256	C		ADDRAD
257	C		ADDRAD
258	C		ADDRAD
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300	C		ADDRAD

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290      CALL PRESS
          CONTINUE
          CALL TRANSF
          GO TO 53
333      FORMAT(43X,6H(ONE))
200      FORMAT(10X,23H(RADIAL LOCATION IN 700X 1F5.315X12ZHINFLON VELO CAV
          ICITY (FPS)= 1F8.2,5X,23HEFFECTIVE BLADE CAMBER, 1F7.4,1)
100      FORMAT(138X,18H(CAVITATION SUMMARY /37X120(1H6)1)1)
295      1 19X,55H(ITAL BLADE POSITION FINAL BLADE POSITION TYPE /
          2 19X,55H (DEG) /) CAV
150      FORMAT(1F31.0,F23.0,16X,34X)
400      FORMAT(72X,105H(BLADE POSITION ANGLE OF ATTACK CAVITATION NUMBER CAV
          1 CAVITY LENGTH/CHORD CAVITY AREA CL/CL(NO CAVITY) /
          2 7X,5H(DEG),11X,5H(DEG),49X,7H(F102) /) CAV
300      403  FORMAT(1F12.0,F16.3,F18.4,F19.4,F18.4,F16.4)
          2000 FORMAT(23X,47HHARMONIC DISTRIBUTION OF INPUT SPANNISE LOAD CAV
          KING /22X,49(1H6) CAV
305      1 772E11HARMONIC REAL PART 1HARMONIC PART /)
          2 /22X,41H (LBS/F1) (LBS/F1) /) CAV
          201  FORMAT(12X,12,F10.2,F16.2) CAV
          404  FORMAT(7) CAV
          END CAV
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FTM 4.6+4330

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SUBROUTINE CUBIC

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1 SUBROUTINE CUBIC(ALPHA,SIGMA,CAMBER,CL,CPASS,SI,SI)
2 CUBIC
3 C
4 C SUBROUTINE CUBIC CALCULATES THE CAVITY AREA (NON-DIM) IN THE
5 C TRANSITION AND PARTIAL CAVITATION REGION BY A CUBIC CURVE FIT
6 C WHICH MATCHES THE VALUE AND DERIVATIVE WITH RESPECT TO ALPHA
7 C AT THE END POINTS WITH THE FULL AND NON-CAVITATING SOLUTIONS
8 C
9 C DATA DRATIO/.01/
10 C
11 C CALCULATE INDEPENDENT VARIABLE
12 C
13 C RATIO=ALPHA/ALMAX
14 C
15 C GET VALUE OF AREA AT FULL CAVITY END POINT
16 C
17 C CALL FULCAV(ALMAX,SIGMA,CAMBER,XL,CL,CPASS,SI,SI)
18 C
19 C VALUE= SI
20 C
21 C INCREMENT ALPHA AT END POINT TO GET SLOPE
22 C
23 C ANG=(1.+DRATIO)*ALMAX
24 C CALL FULCAV(ANG,SIGMA,CAMBER,XL,CL,CPASS,SI,SI)
25 C SLOPE=( SI2- SI)/DRATIO
26 C
27 C CALCULATE CUBIC COEFFICIENTS AND CAVITY AREA
28 C
29 C C1=SLOPE-2.*VALUE
30 C C2=VALUE-C1
31 C S=-(C1+RATIO*(C2)*RATIO)*RATIO
32 C RETURN
33 C
34 C END

```

82/08/10. 14.39.12

FTN 4.6+433D

SUBROUTINE DERIV 76/74 OPT=0 TRACE

```
1 SUBROUTINE DERIV(NFIRST,NLAST,DX,YYOYX1,DZYOX2,IEND)
2 DIMENSION Y(1),DYDX(1),DZYOX2(1)
3 N1=NFIRST+1
4 N2=NLAST-1
5 DO C=J,N1,N2
6   IF(IIFIRST.NE.O) GO TO 1
7   DYDX(J)=5*(Y(J)-Y(J-1))/DX
8   IF(IISCND.NE.O) GO TO 2
9   DZYOX2(J)=(Y(J)-2.*Y(J+1))/(DX+DX1)
10  CONTINUE
11  IF(IENDC.NE.O) RETURN
12  IF(IIFIRST.NE.O) GO TO 3
13  DYDX(NLAST)=5*(Y(NLAST)-Y(NLAST-1))/DX
14  CYDX(NLAST)=5*(Y(NLAST)-Y(NLAST-1))/DX
15  IF(IISCND.NE.O) RETURN
16  DZYOX2(NLAST)=DZYOX2(NLAST-1)
17  RETURN
18  END
```

```
1 SUBROUTINE ERRORTIER)
C
C SUBROUTINE ERROR IS USED TO PRINT ERROR MESSAGES AND STOP JOB
C
5 COMMON/UNITS/NIN,ALUT ,DATE(5),TITLE(15)
C
CALL FEACIN
WRITE(INOUT,100)IER
100 FORMAT(//21X,34ERROR ENCOUNTERED -- ERROR NUMBER=,13,15H -- JOB
      LABOURIED )
      STOP
      END
```

```
2 ERROR
3 ERROR
4 ERROR
5 ERROR
6 ERROR
7 ERROR
8 ERROR
9 ERROR
10 ERROR
11 ERROR
12 ERROR
13 ERROR
```

82/CB/IC. 14.39.12

FTN 4.6.4330

76/74 OPT=0 TRACE

SUBROUTINE EQPTS

SUBROUTINE EQPTS

```

1      C
2      C
3      C
4      C
5      C
6      C
7      C
8      C
9      C
10     C
11     C
12     C
13     C
14     C
15     C
16     C
17     C
18     C
19     C
20     C
21     C
22     C
23     C
24     C
25     C
26     C
27     C
28     C
29     C
30     C
31     C
32     C
33     C
34     C
35     C
36     C
37     C
38     C
39     C
40     C
41     C
42     C

```

SUBROUTINE EQPTS USES THE MAPPING COEFFICIENTS AND THE NUMBER OF
 POINTS (NPLOC) FOR INTEGRATION TO FIND THE POINTS ON THE BODY
 CORRESPONDING TO POINT WITH EQUAL ANGLE INTERVALS IN THE
 UNIT CIRCLE.

COMMON/SGOUT/NCDEF,PHI(100),A(100),ARX,TCORV,NCOUNT
 COMMON/CGORD/YLOC(100),ZLOC(100)
 COMMON/UNITS/NIN,NOUT,DATE(5),TITLE(15)
 COMMON/PGINTS/NPLCC,XPT(100),RHOPT(100),PHIPT(100)
 PI=4.*ATAN(1.0)
 DPHI=PI/(NPLOC-1)
 DO 10 I=1,NPLOC
 YY=0.0
 ZZ=0.0
 DO 15 J=1,NCDEF
 ARG=13-24J*(1-1)*DPHI
 YY=YY+(J)*COS(ARG)
 ZZ=ZZ+(J)*SIN(ARG)
 15 CONTINUE
 YLOC(I)=YY
 ZLOC(I)=ZZ
 10 CONTINUE
 RETURN
 END

SUBROUTINE FOURAN

LINE	STATEMENT	FINAL
1	SUBROUTINE FOURTAN(KAT,MWORD1,MORD2,IPRINT)	FINAL
2	C	FOURAN
3	C	FOURAN
4	C	FOURAN
5	C	FOURAN
6	C	FOURAN
7	C	FOURAN
8	C	FOURAN
9	C	FOURAN
10	C	FOURAN
11	C	FOURAN
12	C	FOURAN
13	C	FOURAN
14	C	FOURAN
15	C	FOURAN
16	C	FOURAN
17	C	FOURAN
18	C	FOURAN
19	C	FOURAN
20	C	FOURAN
21	C	FOURAN
22	C	FOURAN
23	C	FOURAN
24	C	FOURAN
25	C	FOURAN
26	C	FOURAN
27	C	FOURAN
28	C	FOURAN
29	C	FOURAN
30	C	FOURAN
31	C	FOURAN
32	C	FOURAN
33	C	FOURAN
34	C	FOURAN
35	C	FOURAN
36	C	FOURAN
37	C	FOURAN
38	C	FOURAN
39	C	FOURAN
40	C	FOURAN
41	C	FOURAN
42	C	FOURAN
43	C	FOURAN
44	C	FOURAN
45	C	FOURAN
46	C	FOURAN
47	C	FOURAN
48	C	FOURAN
49	C	FOURAN
50	C	FOURAN
51	C	FOURAN
52	C	FOURAN
53	C	FOURAN
54	C	FOURAN
55	C	FOURAN
56	C	FOURAN
57	C	FOURAN
58	C	FOURAN
59	C	FOURAN
60	C	FOURAN
61	C	FOURAN
62	C	FOURAN
63	C	FOURAN
64	C	FOURAN
65	C	FOURAN
66	C	FOURAN
67	C	FOURAN
68	C	FOURAN
69	C	FOURAN
70	C	FOURAN
71	C	FOURAN
72	C	FOURAN
73	C	FOURAN
74	C	FOURAN
75	C	FOURAN
76	C	FOURAN
77	C	FOURAN
78	C	FOURAN
79	C	FOURAN
80	C	FOURAN
81	C	FOURAN
82	C	FOURAN
83	C	FOURAN
84	C	FOURAN
85	C	FOURAN
86	C	FOURAN
87	C	FOURAN
88	C	FOURAN
89	C	FOURAN
90	C	FOURAN
91	C	FOURAN
92	C	FOURAN
93	C	FOURAN
94	C	FOURAN
95	C	FOURAN
96	C	FOURAN
97	C	FOURAN
98	C	FOURAN
99	C	FOURAN
100	C	FOURAN

```
1 SUBROUTINE FULCAV(PI, K, HUF, U, OMEGA, DEPTH, PV, G, RAD)
2 FULCAV
3 C
4 SUBROUTINE FULCAV CALCULATES THE SOLUTION FOR A SUPERCAVITATING
5 PARABOLIC ARC FOIL BASED ON THE SOLUTION OF GEURST
6 FULCAV
7 C
8 COMMON/CONST/PI, K, HUF, U, OMEGA, DEPTH, PV, G, RAD
9 COMPONZ/REZ/TOC, NPTS, IOT, THETA, ISOL, INTR, INTRMAX
10 FULCAV
11 C
12 INITIALIZE VARIABLES FOR FIRST PASS
13 FULCAV
14 NITER=0
15 XL=1.25
16 DXL=40.0
17 IFIRST=0
18 GO TO 7
19 FULCAV
20 C
21 START SECOND PASS
22 FULCAV
23 ERR=ERR2
24 PONI=SIGN(1.,ERR1)
25 XL=41.25
26 CONTINUE
27 NITER=NITER+1
28 FULCAV
29 C
30 END JOB IF NUMBER OF ITERATIONS EXCEED MAXIMUM
31 IF (NITER.GT.NITMAX) CALL ERROR(20)
32 CONTINUE
33 FULCAV
34 C
35 SET UP REQUIRED PARAMETERS FOR SOLUTION
36 B=1./5*CRIT(XL-1.)
37 GAMMA=2.*ATAN(1./B)
38 BETA=(PI-GAMMA)/4.
39 SINDEL=SIN(GAMMA/2.)
40 SINB=SIN(BETA)
41 SIN3B=SIN(3.*BETA)
42 SIN5B=SIN(5.*BETA)
43 SIN7B=SIN(7.*BETA)
44 COSDEL=COS(GAMMA/2.)
45 COSB=COS(BETA)
46 COS3B=COS(3.*BETA)
47 COS5B=COS(5.*BETA)
48 COS7B=COS(7.*BETA)
49 F110=-CAPHER*(2.+(1.-XL)*COSB+XL*SINDEL*(2.*COS3B+B*SIN3B))
50 F120=.5*CAPHER*(XL-2.)*COSB+SINDEL*(2.*XL-1.)*COS5B
51 F130=.5*CAPHER*(XL-2.)*SIN3B+SINDEL*(.75*(B*B-4.)*COS5B
52 F140=.5*CAPHER*(XL-2.)*SIN5B
53 F150=.5*CAPHER*(XL-2.)*SIN7B
54 F160=.5*CAPHER*(XL-2.)*SIN9B
55 F170=.5*CAPHER*(XL-2.)*SIN11B
56 F180=.5*CAPHER*(XL-2.)*SIN13B
57 F190=.5*CAPHER*(XL-2.)*SIN15B
58 F200=.5*CAPHER*(XL-2.)*SIN17B
59 F210=.5*CAPHER*(XL-2.)*SIN19B
60 F220=.5*CAPHER*(XL-2.)*SIN21B
61 F230=.5*CAPHER*(XL-2.)*SIN23B
62 F240=.5*CAPHER*(XL-2.)*SIN25B
63 F250=.5*CAPHER*(XL-2.)*SIN27B
64 F260=.5*CAPHER*(XL-2.)*SIN29B
65 F270=.5*CAPHER*(XL-2.)*SIN31B
66 F280=.5*CAPHER*(XL-2.)*SIN33B
67 F290=.5*CAPHER*(XL-2.)*SIN35B
68 F300=.5*CAPHER*(XL-2.)*SIN37B
69 F310=.5*CAPHER*(XL-2.)*SIN39B
70 F320=.5*CAPHER*(XL-2.)*SIN41B
71 F330=.5*CAPHER*(XL-2.)*SIN43B
72 F340=.5*CAPHER*(XL-2.)*SIN45B
73 F350=.5*CAPHER*(XL-2.)*SIN47B
74 F360=.5*CAPHER*(XL-2.)*SIN49B
75 F370=.5*CAPHER*(XL-2.)*SIN51B
76 F380=.5*CAPHER*(XL-2.)*SIN53B
77 F390=.5*CAPHER*(XL-2.)*SIN55B
78 F400=.5*CAPHER*(XL-2.)*SIN57B
79 F410=.5*CAPHER*(XL-2.)*SIN59B
80 F420=.5*CAPHER*(XL-2.)*SIN61B
81 F430=.5*CAPHER*(XL-2.)*SIN63B
82 F440=.5*CAPHER*(XL-2.)*SIN65B
83 F450=.5*CAPHER*(XL-2.)*SIN67B
84 F460=.5*CAPHER*(XL-2.)*SIN69B
85 F470=.5*CAPHER*(XL-2.)*SIN71B
86 F480=.5*CAPHER*(XL-2.)*SIN73B
87 F490=.5*CAPHER*(XL-2.)*SIN75B
88 F500=.5*CAPHER*(XL-2.)*SIN77B
89 F510=.5*CAPHER*(XL-2.)*SIN79B
90 F520=.5*CAPHER*(XL-2.)*SIN81B
91 F530=.5*CAPHER*(XL-2.)*SIN83B
92 F540=.5*CAPHER*(XL-2.)*SIN85B
93 F550=.5*CAPHER*(XL-2.)*SIN87B
94 F560=.5*CAPHER*(XL-2.)*SIN89B
95 F570=.5*CAPHER*(XL-2.)*SIN91B
96 F580=.5*CAPHER*(XL-2.)*SIN93B
97 F590=.5*CAPHER*(XL-2.)*SIN95B
98 F600=.5*CAPHER*(XL-2.)*SIN97B
99 F610=.5*CAPHER*(XL-2.)*SIN99B
100 F620=.5*CAPHER*(XL-2.)*SIN101B
101 F630=.5*CAPHER*(XL-2.)*SIN103B
102 F640=.5*CAPHER*(XL-2.)*SIN105B
103 F650=.5*CAPHER*(XL-2.)*SIN107B
104 F660=.5*CAPHER*(XL-2.)*SIN109B
105 F670=.5*CAPHER*(XL-2.)*SIN111B
106 F680=.5*CAPHER*(XL-2.)*SIN113B
107 F690=.5*CAPHER*(XL-2.)*SIN115B
108 F700=.5*CAPHER*(XL-2.)*SIN117B
109 F710=.5*CAPHER*(XL-2.)*SIN119B
110 F720=.5*CAPHER*(XL-2.)*SIN121B
111 F730=.5*CAPHER*(XL-2.)*SIN123B
112 F740=.5*CAPHER*(XL-2.)*SIN125B
113 F750=.5*CAPHER*(XL-2.)*SIN127B
114 F760=.5*CAPHER*(XL-2.)*SIN129B
115 F770=.5*CAPHER*(XL-2.)*SIN131B
116 F780=.5*CAPHER*(XL-2.)*SIN133B
117 F790=.5*CAPHER*(XL-2.)*SIN135B
118 F800=.5*CAPHER*(XL-2.)*SIN137B
119 F810=.5*CAPHER*(XL-2.)*SIN139B
120 F820=.5*CAPHER*(XL-2.)*SIN141B
121 F830=.5*CAPHER*(XL-2.)*SIN143B
122 F840=.5*CAPHER*(XL-2.)*SIN145B
123 F850=.5*CAPHER*(XL-2.)*SIN147B
124 F860=.5*CAPHER*(XL-2.)*SIN149B
125 F870=.5*CAPHER*(XL-2.)*SIN151B
126 F880=.5*CAPHER*(XL-2.)*SIN153B
127 F890=.5*CAPHER*(XL-2.)*SIN155B
128 F900=.5*CAPHER*(XL-2.)*SIN157B
129 F910=.5*CAPHER*(XL-2.)*SIN159B
130 F920=.5*CAPHER*(XL-2.)*SIN161B
131 F930=.5*CAPHER*(XL-2.)*SIN163B
132 F940=.5*CAPHER*(XL-2.)*SIN165B
133 F950=.5*CAPHER*(XL-2.)*SIN167B
134 F960=.5*CAPHER*(XL-2.)*SIN169B
135 F970=.5*CAPHER*(XL-2.)*SIN171B
136 F980=.5*CAPHER*(XL-2.)*SIN173B
137 F990=.5*CAPHER*(XL-2.)*SIN175B
140 F1000=.5*CAPHER*(XL-2.)*SIN177B
141 F1010=.5*CAPHER*(XL-2.)*SIN179B
142 F1020=.5*CAPHER*(XL-2.)*SIN181B
143 F1030=.5*CAPHER*(XL-2.)*SIN183B
144 F1040=.5*CAPHER*(XL-2.)*SIN185B
145 F1050=.5*CAPHER*(XL-2.)*SIN187B
146 F1060=.5*CAPHER*(XL-2.)*SIN189B
147 F1070=.5*CAPHER*(XL-2.)*SIN191B
148 F1080=.5*CAPHER*(XL-2.)*SIN193B
149 F1090=.5*CAPHER*(XL-2.)*SIN195B
150 F1100=.5*CAPHER*(XL-2.)*SIN197B
151 F1110=.5*CAPHER*(XL-2.)*SIN199B
152 F1120=.5*CAPHER*(XL-2.)*SIN201B
153 F1130=.5*CAPHER*(XL-2.)*SIN203B
154 F1140=.5*CAPHER*(XL-2.)*SIN205B
155 F1150=.5*CAPHER*(XL-2.)*SIN207B
156 F1160=.5*CAPHER*(XL-2.)*SIN209B
157 F1170=.5*CAPHER*(XL-2.)*SIN211B
158 F1180=.5*CAPHER*(XL-2.)*SIN213B
159 F1190=.5*CAPHER*(XL-2.)*SIN215B
160 F1200=.5*CAPHER*(XL-2.)*SIN217B
161 F1210=.5*CAPHER*(XL-2.)*SIN219B
162 F1220=.5*CAPHER*(XL-2.)*SIN221B
163 F1230=.5*CAPHER*(XL-2.)*SIN223B
164 F1240=.5*CAPHER*(XL-2.)*SIN225B
165 F1250=.5*CAPHER*(XL-2.)*SIN227B
166 F1260=.5*CAPHER*(XL-2.)*SIN229B
167 F1270=.5*CAPHER*(XL-2.)*SIN231B
168 F1280=.5*CAPHER*(XL-2.)*SIN233B
169 F1290=.5*CAPHER*(XL-2.)*SIN235B
170 F1300=.5*CAPHER*(XL-2.)*SIN237B
171 F1310=.5*CAPHER*(XL-2.)*SIN239B
172 F1320=.5*CAPHER*(XL-2.)*SIN241B
173 F1330=.5*CAPHER*(XL-2.)*SIN243B
174 F1340=.5*CAPHER*(XL-2.)*SIN245B
175 F1350=.5*CAPHER*(XL-2.)*SIN247B
176 F1360=.5*CAPHER*(XL-2.)*SIN249B
177 F1370=.5*CAPHER*(XL-2.)*SIN251B
178 F1380=.5*CAPHER*(XL-2.)*SIN253B
179 F1390=.5*CAPHER*(XL-2.)*SIN255B
180 F1400=.5*CAPHER*(XL-2.)*SIN257B
181 F1410=.5*CAPHER*(XL-2.)*SIN259B
182 F1420=.5*CAPHER*(XL-2.)*SIN261B
183 F1430=.5*CAPHER*(XL-2.)*SIN263B
184 F1440=.5*CAPHER*(XL-2.)*SIN265B
185 F1450=.5*CAPHER*(XL-2.)*SIN267B
186 F1460=.5*CAPHER*(XL-2.)*SIN269B
187 F1470=.5*CAPHER*(XL-2.)*SIN271B
188 F1480=.5*CAPHER*(XL-2.)*SIN273B
189 F1490=.5*CAPHER*(XL-2.)*SIN275B
190 F1500=.5*CAPHER*(XL-2.)*SIN277B
191 F1510=.5*CAPHER*(XL-2.)*SIN279B
192 F1520=.5*CAPHER*(XL-2.)*SIN281B
193 F1530=.5*CAPHER*(XL-2.)*SIN283B
194 F1540=.5*CAPHER*(XL-2.)*SIN285B
195 F1550=.5*CAPHER*(XL-2.)*SIN287B
196 F1560=.5*CAPHER*(XL-2.)*SIN289B
197 F1570=.5*CAPHER*(XL-2.)*SIN291B
198 F1580=.5*CAPHER*(XL-2.)*SIN293B
199 F1590=.5*CAPHER*(XL-2.)*SIN295B
200 F1600=.5*CAPHER*(XL-2.)*SIN297B
201 F1610=.5*CAPHER*(XL-2.)*SIN299B
202 F1620=.5*CAPHER*(XL-2.)*SIN301B
203 F1630=.5*CAPHER*(XL-2.)*SIN303B
204 F1640=.5*CAPHER*(XL-2.)*SIN305B
205 F1650=.5*CAPHER*(XL-2.)*SIN307B
206 F1660=.5*CAPHER*(XL-2.)*SIN309B
207 F1670=.5*CAPHER*(XL-2.)*SIN311B
208 F1680=.5*CAPHER*(XL-2.)*SIN313B
209 F1690=.5*CAPHER*(XL-2.)*SIN315B
210 F1700=.5*CAPHER*(XL-2.)*SIN317B
211 F1710=.5*CAPHER*(XL-2.)*SIN319B
212 F1720=.5*CAPHER*(XL-2.)*SIN321B
213 F1730=.5*CAPHER*(XL-2.)*SIN323B
214 F1740=.5*CAPHER*(XL-2.)*SIN325B
215 F1750=.5*CAPHER*(XL-2.)*SIN327B
216 F1760=.5*CAPHER*(XL-2.)*SIN329B
217 F1770=.5*CAPHER*(XL-2.)*SIN331B
218 F1780=.5*CAPHER*(XL-2.)*SIN333B
219 F1790=.5*CAPHER*(XL-2.)*SIN335B
220 F1800=.5*CAPHER*(XL-2.)*SIN337B
221 F1810=.5*CAPHER*(XL-2.)*SIN339B
222 F1820=.5*CAPHER*(XL-2.)*SIN341B
223 F1830=.5*CAPHER*(XL-2.)*SIN343B
224 F1840=.5*CAPHER*(XL-2.)*SIN345B
225 F1850=.5*CAPHER*(XL-2.)*SIN347B
226 F1860=.5*CAPHER*(XL-2.)*SIN349B
227 F1870=.5*CAPHER*(XL-2.)*SIN351B
228 F1880=.5*CAPHER*(XL-2.)*SIN353B
229 F1890=.5*CAPHER*(XL-2.)*SIN355B
230 F1900=.5*CAPHER*(XL-2.)*SIN357B
231 F1910=.5*CAPHER*(XL-2.)*SIN359B
232 F1920=.5*CAPHER*(XL-2.)*SIN361B
233 F1930=.5*CAPHER*(XL-2.)*SIN363B
234 F1940=.5*CAPHER*(XL-2.)*SIN365B
235 F1950=.5*CAPHER*(XL-2.)*SIN367B
236 F1960=.5*CAPHER*(XL-2.)*SIN369B
237 F1970=.5*CAPHER*(XL-2.)*SIN371B
238 F1980=.5*CAPHER*(XL-2.)*SIN373B
239 F1990=.5*CAPHER*(XL-2.)*SIN375B
240 F2000=.5*CAPHER*(XL-2.)*SIN377B
241 F2010=.5*CAPHER*(XL-2.)*SIN379B
242 F2020=.5*CAPHER*(XL-2.)*SIN381B
243 F2030=.5*CAPHER*(XL-2.)*SIN383B
244 F2040=.5*CAPHER*(XL-2.)*SIN385B
245 F2050=.5*CAPHER*(XL-2.)*SIN387B
246 F2060=.5*CAPHER*(XL-2.)*SIN389B
247 F2070=.5*CAPHER*(XL-2.)*SIN391B
248 F2080=.5*CAPHER*(XL-2.)*SIN393B
249 F2090=.5*CAPHER*(XL-2.)*SIN395B
250 F2100=.5*CAPHER*(XL-2.)*SIN397B
251 F2110=.5*CAPHER*(XL-2.)*SIN399B
252 F2120=.5*CAPHER*(XL-2.)*SIN401B
253 F2130=.5*CAPHER*(XL-2.)*SIN403B
254 F2140=.5*CAPHER*(XL-2.)*SIN405B
255 F2150=.5*CAPHER*(XL-2.)*SIN407B
256 F2160=.5*CAPHER*(XL-2.)*SIN409B
257 F2170=.5*CAPHER*(XL-2.)*SIN411B
258 F2180=.5*CAPHER*(XL-2.)*SIN413B
259 F2190=.5*CAPHER*(XL-2.)*SIN415B
260 F2200=.5*CAPHER*(XL-2.)*SIN417B
261 F2210=.5*CAPHER*(XL-2.)*SIN419B
262 F2220=.5*CAPHER*(XL-2.)*SIN421B
263 F2230=.5*CAPHER*(XL-2.)*SIN423B
264 F2240=.5*CAPHER*(XL-2.)*SIN425B
265 F2250=.5*CAPHER*(XL-2.)*SIN427B
266 F2260=.5*CAPHER*(XL-2.)*SIN429B
267 F2270=.5*CAPHER*(XL-2.)*SIN431B
268 F2280=.5*CAPHER*(XL-2.)*SIN433B
269 F2290=.5*CAPHER*(XL-2.)*SIN435B
270 F2300=.5*CAPHER*(XL-2.)*SIN437B
271 F2310=.5*CAPHER*(XL-2.)*SIN439B
272 F2320=.5*CAPHER*(XL-2.)*SIN441B
273 F2330=.5*CAPHER*(XL-2.)*SIN443B
274 F2340=.5*CAPHER*(XL-2.)*SIN445B
275 F2350=.5*CAPHER*(XL-2.)*SIN447B
276 F2360=.5*CAPHER*(XL-2.)*SIN449B
277 F2370=.5*CAPHER*(XL-2.)*SIN451B
278 F2380=.5*CAPHER*(XL-2.)*SIN453B
279 F2390=.5*CAPHER*(XL-2.)*SIN455B
280 F2400=.5*CAPHER*(XL-2.)*SIN457B
281 F2410=.5*CAPHER*(XL-2.)*SIN459B
282 F2420=.5*CAPHER*(XL-2.)*SIN461B
283 F2430=.5*CAPHER*(XL-2.)*SIN463B
284 F2440=.5*CAPHER*(XL-2.)*SIN465B
285 F2450=.5*CAPHER*(XL-2.)*SIN467B
286 F2460=.5*CAPHER*(XL-2.)*SIN469B
287 F2470=.5*CAPHER*(XL-2.)*SIN471B
288 F2480=.5*CAPHER*(XL-2.)*SIN473B
289 F2490=.5*CAPHER*(XL-2.)*SIN475B
290 F2500=.5*CAPHER*(XL-2.)*SIN477B
291 F2510=.5*CAPHER*(XL-2.)*SIN479B
292 F2520=.5*CAPHER*(XL-2.)*SIN481B
293 F2530=.5*CAPHER*(XL-2.)*SIN483B
294 F2540=.5*CAPHER*(XL-2.)*SIN485B
295 F2550=.5*CAPHER*(XL-2.)*SIN487B
296 F2560=.5*CAPHER*(XL-2.)*SIN489B
297 F2570=.5*CAPHER*(XL-2.)*SIN491B
298 F2580=.5*CAPHER*(XL-2.)*SIN493B
299 F2590=.5*CAPHER*(XL-2.)*SIN495B
300 F2600=.5*CAPHER*(XL-2.)*SIN497B
301 F2610=.5*CAPHER*(XL-2.)*SIN499B
302 F2620=.5*CAPHER*(XL-2.)*SIN501B
303 F2630=.5*CAPHER*(XL-2.)*SIN503B
304 F2640=.5*CAPHER*(XL-2.)*SIN505B
305 F2650=.5*CAPHER*(XL-2.)*SIN507B
306 F2660=.5*CAPHER*(XL-2.)*SIN509B
307 F2670=.5*CAPHER*(XL-2.)*SIN511B
308 F2680=.5*CAPHER*(XL-2.)*SIN513B
309 F2690=.5*CAPHER*(XL-2.)*SIN515B
310 F2700=.5*CAPHER*(XL-2.)*SIN517B
311 F2710=.5*CAPHER*(XL-2.)*SIN519B
312 F2720=.5*CAPHER*(XL-2.)*SIN521B
313 F2730=.5*CAPHER*(XL-2.)*SIN523B
314 F2740=.5*CAPHER*(XL-2.)*SIN525B
315 F2750=.5*CAPHER*(XL-2.)*SIN527B
316 F2760=.5*CAPHER*(XL-2.)*SIN529B
317 F2770=.5*CAPHER*(XL-2.)*SIN531B
318 F2780=.5*CAPHER*(XL-2.)*SIN533B
319 F2790=.5*CAPHER*(XL-2.)*SIN535B
320 F2800=.5*CAPHER*(XL-2.)*SIN537B
321 F2810=.5*CAPHER*(XL-2.)*SIN539B
322 F2820=.5*CAPHER*(XL-2.)*SIN541B
323 F2830=.5*CAPHER*(XL-2.)*SIN543B
324 F2840=.5*CAPHER*(XL-2.)*SIN545B
325 F2850=.5*CAPHER*(XL-2.)*SIN547B
326 F2860=.5*CAPHER*(XL-2.)*SIN549B
327 F2870=.5*CAPHER*(XL-2.)*SIN551B
328 F2880=.5*CAPHER*(XL-2.)*SIN553B
329 F2890=.5*CAPHER*(XL-2.)*SIN555B
330 F2900=.5*CAPHER*(XL-2.)*SIN557B
331 F2910=.5*CAPHER*(XL-2.)*SIN559B
332 F2920=.5*CAPHER*(XL-2.)*SIN561B
333 F2930=.5*CAPHER*(XL-2.)*SIN563B
334 F2940=.5*CAPHER*(XL-2.)*SIN565B
335 F2950=.5*CAPHER*(XL-2.)*SIN567B
336 F2960=.5*CAPHER*(XL-2.)*SIN569B
337 F2970=.5*CAPHER*(XL-2.)*SIN571B
338 F2980=.5*CAPHER*(XL-2.)*SIN573B
339 F2990=.5*CAPHER*(XL-2.)*SIN575B
340 F3000=.5*CAPHER*(XL-2.)*SIN577B
341 F3010=.5*CAPHER*(XL-2.)*SIN579B
342 F3020=.5*CAPHER*(XL-2.)*SIN581B
343 F3030=.5*CAPHER*(XL-2.)*SIN583B
344 F3040=.5*CAPHER*(XL-2.)*SIN585B
345 F3050=.5*CAPHER*(XL-2.)*SIN587B
346 F3060=.5*CAPHER*(XL-2.)*SIN589B
347 F3070=.5*CAPHER*(XL-2.)*SIN591B
348 F3080=.5*CAPHER*(XL-2.)*SIN593B
349 F3090=.5*CAPHER*(XL-2.)*SIN595B
350 F3100=.5*CAPHER*(XL-2.)*SIN597B
351 F3110=.5*CAPHER*(XL-2.)*SIN599B
352 F3120=.5*CAPHER*(XL-2.)*SIN601B
353 F3130=.5*CAPHER*(XL-2.)*SIN603B
354 F3140=.5*CAPHER*(XL-2.)*SIN605B
355 F3150=.5*CAPHER*(XL-2.)*SIN607B
356 F3160=.5*CAPHER*(XL-2.)*SIN609B
357 F3170=.5*CAPHER*(XL-2.)*SIN611B
358 F3180=.5*CAPHER*(XL-2.)*SIN613B
359 F3190=.5*CAPHER*(XL-2.)*SIN615B
360 F3200=.5*CAPHER*(XL-2.)*SIN617B
361 F3210=.5*CAPHER*(XL-2.)*SIN619B
362 F3220=.5*CAPHER*(XL-2.)*SIN621B
363 F3230=.5*CAPHER*(XL-2.)*SIN623B
364 F3240=.5*CAPHER*(XL-2.)*SIN625B
365 F3250=.5*CAPHER*(XL-2.)*SIN627B
366 F3260=.5*CAPHER*(XL-2.)*SIN629B
367 F3270=.5*CAPHER*(XL-2.)*SIN631B
368 F3280=.5*CAPHER*(XL-2.)*SIN633B
369 F3290=.5*CAPHER*(XL-2.)*SIN635B
370 F3300=.5*CAPHER*(XL-2.)*SIN637B
371 F3310=.5*CAPHER*(XL-2.)*SIN639B
372 F3320=.5*CAPHER*(XL-2.)*SIN641B
373 F3330=.5*CAPHER*(XL-2.)*SIN643B
374 F3340=.5*CAPHER*(XL-2.)*SIN645B
375 F3350=.5*CAPHER*(XL-2.)*SIN647B
376 F3360=.5*CAPHER*(XL-2.)*SIN649B
377 F3370=.5*CAPHER*(XL-2.)*SIN651B
378 F3380=.5*CAPHER*(XL-2.)*SIN653B
379 F3390=.5*CAPHER*(XL-2.)*SIN655B
380 F3400=.5*CAPHER*(XL-2.)*SIN657B
381 F3410=.5*CAPHER*(XL-2.)*SIN659B
382 F3420=.5*CAPHER*(XL-2.)*SIN661B
383 F3430=.5*CAPHER*(XL-2.)*SIN663B
384 F3440=.5*CAPHER*(XL-2.)*SIN665B
385 F3450=.5*CAPHER*(XL-2.)*SIN667B
386 F3460=.5*CAPHER*(XL-2.)*SIN669B
387 F3470=.5*CAPHER*(XL-2.)*SIN671B
388 F3480=.5*CAPHER*(XL-2.)*SIN673B
389 F3490=.5*CAPHER*(XL-2.)*SIN675B
390 F3500=.5*CAPHER*(XL-2.)*SIN677B
391 F3510=.5*CAPHER*(XL-2.)*SIN679B
392 F3520=.5*CAPHER*(XL-2.)*SIN681B
393 F3530=.5*CAPHER*(XL-2.)*SIN683B
394 F3540=.5*CAPHER*(XL-2.)*SIN685B
395 F3550=.5*CAPHER*(XL-2.)*SIN687B
396 F3560=.5*CAPHER*(XL-2.)*SIN689B
397 F3570=.5*CAPHER*(XL-2.)*SIN691B
398 F3580=.5*CAPHER*(XL-2.)*SIN693B
399 F3590=.5*CAPHER*(XL-2.)*SIN695B
400 F3600=.5*CAPHER*(XL-2.)*SIN697B
401 F3610=.5*CAPHER*(XL-2.)*SIN699B
402 F3620=.5*CAPHER*(XL-2.)*SIN701B
403 F3630=.5*CAPHER*(XL-2.)*SIN703B
404 F3640=.5*CAPHER*(XL-2.)*SIN705B
405 F3650=.5*CAPHER*(XL-2.)*SIN707B
406 F3660=.5*CAPHER*(XL-2.)*SIN709B
407 F3670=.5*CAPHER*(XL-2.)*SIN711B
408 F3680=.5*CAPHER*(XL-2.)*SIN713B
409 F3690=.5*CAPHER*(XL-2.)*SIN715B
410 F3700=.5*CAPHER*(XL-2.)*SIN717B
411 F3710=.5*CAPHER*(XL-2.)*SIN719B
412 F3720=.5*CAPHER*(XL-2.)*SIN721B
413 F3730=.5*CAPHER*(XL-2.)*SIN723B
414 F3740=.5*CAPHER*(XL-2.)*SIN725B
415 F3750=.5*CAPHER*(XL-2.)*SIN727B
416 F3760=.5*CAPHER*(XL-2.)*SIN729B
417 F3770=.5*CAPHER*(XL-2.)*SIN731B
418 F3780=.5*CAPHER*(XL-2.)*SIN733B
419 F3790=.5*CAPHER*(XL-2.)*SIN735B
420 F3800=.5*CAPHER*(XL-2.)*SIN737B
421 F3810=.5*CAPHER*(XL-2.)*SIN739B
422 F3820=.5*CAPHER*(XL-2.)*SIN741B
423 F3830=.5*CAPHER*(XL-2.)*SIN743B
424 F3840=.5*CAPHER*(XL-2.)*SIN745B
425 F3850=.5*CAPHER*(XL-2.)*SIN747B
426 F3860=.5*CAPHER*(XL-2.)*SIN749B
427 F3870=.5*CAPHER*(XL-2.)*SIN751B
428 F3880=.5*CAPHER*(XL-2.)*SIN753B
429 F3890=.5*CAPHER*(XL-2.)*SIN755B
430 F3900=.5*CAPHER*(XL-2.)*SIN757B
431 F3910=.5*CAPHER*(XL-2.)*SIN759B
432 F3920=.5*CAPHER*(XL-2.)*SIN761B
433 F3930=.5*CAPHER*(XL-2.)*SIN763B
434 F3940=.5*CAPHER*(XL-2.)*SIN765B
435 F3950=.5*CAPHER*(XL-2.)*SIN767B
436 F3960=.5*CAPHER*(XL-2.)*SIN769B
437 F3970=.5*CAPHER*(XL-2.)*SIN771B
438 F3980=.5*CAPHER*(XL-2.)*SIN773B
439 F3990=.5*CAPHER*(XL-2.)*SIN775B
440 F4000=.5*CAPHER*(XL-2.)*SIN777B
441 F4010=.5*CAPHER*(XL-2.)*SIN779B
442 F4020=.5*CAPHER*(XL-2.)*SIN781B
443 F4030=.5*CAPHER*(XL-2.)*SIN783B
444 F4040=.5*CAPHER*(XL-2.)*SIN785B
445 F4050=.5*CAPHER*(XL-2.)*SIN787B
446 F4060=.5*CAPHER*(XL-2.)*SIN789B
447 F4070=.5*CAPHER*(XL-2.)*SIN791B
448 F4080=.5*CAPHER*(XL-2.)*SIN793B
449 F4090=.5*CAPHER*(XL-2.)*SIN795B
450 F4100=.5*CAPHER*(XL-2.)*SIN797B
451 F4110=.5*CAPHER*(XL-2.)*SIN799B
452 F4120=.5*CAPHER*(XL-2.)*SIN801B
453 F4130=.5*CAPHER*(XL-2.)*SIN803B
454 F4140=.5*CAPHER*(XL-2.)*SIN805B
455 F4150=.5*CAPHER*(XL-2.)*SIN807B
456 F4160=.5*CAPHER*(XL-2.)*SIN809B
457 F4170=.5*CAPHER*(XL-2.)*SIN811B
458 F4180=.5*CAPHER*(XL-2.)*SIN813B
459 F4190=.5*CAPHER*(XL-2.)*SIN815B
460 F4200=.5*CAPHER*(XL-2.)*SIN817B
461 F4210=.5*CAPHER*(XL-2.)*SIN819B
462 F4220=.5*CAPHER*(XL-2.)*SIN821B
463 F4230=.5*CAPHER*(XL-2.)*SIN823B
464 F4240=.5*CAPHER*(XL-2.)*SIN825B
465 F4250=.5*CAPHER*(XL-2.)*SIN827B
466 F4260=.5*CAPHER*(XL-2.)*SIN829B
467 F4270=.5*CAPHER*(XL-2.)*SIN831B
468 F4280=.5*CAPHER*(XL-2.)*SIN833B
469 F4290=.5*CAPHER*(XL-2.)*SIN835B
470 F4300=.5*CAPHER*(XL-2.)*SIN837B
471 F4310=.5*CAPHER*(XL-2.)*SIN839B
472 F4320=.5*CAPHER*(XL-2.)*SIN841B
473 F4330=.5*CAPHER*(XL-2.)*SIN843B
474 F4340=.5*CAPHER*(XL-2.)*SIN845B
475 F4350=.5*CAPHER*(XL-2.)*SIN847B
476 F4360=.5*CAPHER*(XL-2.)*SIN849B
477 F4370=.5*CAPHER*(XL-2.)*SIN851B
478 F4380=.5*CAPHER*(XL-2.)*SIN853B
479 F4390=.5*CAPHER*(XL-2.)*SIN855B
480 F4400=.5*CAPHER*(XL-2.)*SIN857B
481 F4410=.5*CAPHER*(XL-2.)*SIN859B
482 F4420=.5*CAPHER*(XL-2.)*SIN861B
483 F4430=.5*CAPHER*(XL-2.)*SIN863B
484 F4440=.5*CAPHER*(XL-2.)*SIN865B
485 F4450=.5*CAPHER*(XL-2.)*SIN867B
486 F4460=.5*CAPHER*(XL-2.)*SIN869B
487 F4470=.5*CAPHER*(XL-2.)*SIN871B
488 F4480=.5*CAPHER*(XL-2.)*SIN873B
489 F4490=.5*CAPHER*(XL-2.)*SIN875B
490 F4500=.5*CAPHER*(XL-2.)*SIN877B
491 F4510=.5*CAPHER*(XL-2.)*SIN879B
492 F4520=.5*CAPHER*(XL-2.)*SIN881B
493 F4530=.5*CAPHER*(XL-2.)*SIN883B
494 F4540=.5*CAPHER*(XL-2.)*SIN885B
495 F4550=.5*CAPHER*(XL-2.)*SIN887B
496 F4560=.5*CAPHER*(XL-2.)*SIN889B
497 F4570=.5*CAPHER*(XL-2.)*SIN891B
498 F4580=.5*CAPHER*(XL-2.)*SIN893B
499 F4590=.5*CAPHER*(XL-2.)*SIN895B
500 F4600=.5*CAPHER*(XL-2.)*SIN897B
501 F4610=.5*CAPHER*(XL-2.)*SIN899B
502 F4620=.5*CAPHER*(XL-2.)*SIN901B
503 F4630=.5*CAPHER*(XL-2.)*SIN903B
504 F4640=.5*CAPHER*(XL-2.)*SIN905B
505 F4650=.5*CAP
```

82/08/1C. 14.39.12

FTN 4.64330

OPT=C TRACE

76/74

SUBROUTINE FULCAV

```

C      IF CALLED FROM TRANSITIONAL SUBPROGRAM DO NOT ITERATE
C      IF (TRANS.NE.0) GO TO 5
C      CALCULATE ERROR
C      ERR2=SINB*(F110-F120)-COSB*F121-.25*(COSDEL*F11+SINDEL)*ALPHA
C      1 -.125*(SINDEL*(1.+SINDEL))+SIGNA
C      IF FIRST PASS - START SECOND PASS
C      IF (FIRST.EQ.0 .AND. XL.EQ.1.25) GO TO 8
C      TEST IF SOLUTION HAS CONVERGED
C      DIFF=DXL/XL
C      IF (ABS(DIFF).LT. TOL) GO TO 5
C      PUM2=SIGN(1.,ERR2)
C      IF (FIRSTSTREQ.1) GO TO 1
C      IF FIRST=1
C      CONTINUE
C      IF (POM1.NE.POM2) GO TO 3
C      NO CHANGE IN SIGN OF ERROR - CONTINUE IN SAME DIRECTION
C      XL=XL+DXL
C      POM1=POM2
C      GO TO 4
C      3 CONTINUE
C      SIGN OF ERROR HAS CHANGED - GO BACK 1/2 STEP
C      DXL=-DXL*.5
C      XL=XL+DXL
C      POM1=POM2
C      GO TO 4
C      5 CONTINUE
C      CALCULATE SOLUTION USING CONVERGED CAVITY LENGTH
C      CL=PI*(4.+*(COSB*(F110-F120)+SINB*F121)/(COSDEL+COSDEL)
C      1 +(ALPHA*(SINDEL+.5*(SIGMA*(COSDEL)/(1.+SINDEL)))
C      CM=PI*(13.+SINDEL)*(COSB*F110-17.+SINDEL)*(COSB*F120
C      1 +15.-SINDEL)*(SINB*F121+4.*COSB*F130-4.*SINB*F131)/(COSDEL**4
C      2 +125*PI*(1.-1.44.*SINDEL+2.*SINDEL*(SINDEL)*ALPHA
C      3 *(COSDEL+12.+SINDEL)*(SIGMA)/(1.+SINDEL)+42
C      CMAS=CM-.5*CL
C      5 -.5*PI*(11-3.*SINDEL)*(SINB*F110+17.-SINDEL)*(SINB*F120+15.*SINDEL
C      1 *(COSB*F121-4.*SINB*F130-4.*COSB*F131)/(COSDEL**4+PI*12.*COSDEL
C      2 *(1-2.*SINDEL)*ALPHA+.5*(11+4.*SINDEL-2.*SINDEL*(SINDEL)*(SIGMA)/
C      3 *(14*(1.-SINDEL)+42
C      RETURN
C      END

```

59 FULCAV
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67 FULCAV
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69 FULCAV
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74 FULCAV
75 FULCAV
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111 FULCAV


```

1  SUBROUTINE GETPHI
   COMMON/REPRES/NPTS1,X(100),Y(100),BEAM,DRAFT,AREA,DX(66),GCT(60)
   COMMON/SCOUT/NCDEF,PHI(100),A(10),ANAL,ICONT,NCOUNT
   PHI(1)=0.0
   PHINPTS1=-1.570796
   NPTS1=NPTS1-1
   DO I=1,NPTS1
     XX=X(I)
     YY=Y(I)
     OPHI1=-0.0174532
     IF(1-GT.2) OPHI1=(PHI(1)-PHI(1-2))/10.
     PHIN=PHI(1-1)
     CALL INTERP(XX,YY,OPHI1,PHIN)
     PHIN=PHIN-2.*OPHI1
     OPHI2=OPHI1/10.
     CALL INTERP(XX,YY,OPHI2,PHIN)
     PHIN=PHIN-2.*OPHI2
     OPHI3=OPHI2/10.
     CALL INTERP(XX,YY,OPHI3,PHIN)
     PHI(1)=PHIN-OPHI3
     CONTINUE
     RETURN
   END
20  1
21  1
22  1

```

GETPHI 2
 NEWFTX 12
 GETPHI 4
 GETPHI 5
 FINAL1 11
 FINAL1 12
 FINAL1 13
 GETPHI 7
 GETPHI 8
 GETPHI 9
 GETPHI 10
 GETPHI 11
 GETPHI 12
 GETPHI 13
 GETPHI 14
 GETPHI 15
 GETPHI 16
 GETPHI 17
 GETPHI 18
 GETPHI 19
 GETPHI 20
 GETPHI 21
 GETPHI 22


```
1 SUBROUTINE INLOS( KMAX) INLOS 2
C SUBROUTINE INLOS IS USED TO READ THE MODAL LOADING SOLUTION FOR INLOS 3
C THE NON-CAVITATING PROPELLER AND TO CALCULATE THE SPANWISE INLOS 4
5 LOADING FOR EACH HARMONIC INLOS 5
C INLOS 6
C INLOS 7
C COMMON/FORCES/XLR,XLREAL(22),XLIMAG(22) INLOS 8
C COMPCN/UNITS/MIN,NGUT ,DATE(15),TITLE(15) INLOS 9
10 READ TOTAL STEADY LOADING INLOS 10
C INLOS 11
C READIN(100)XLO INLOS 12
C INLOS 13
C LOOP OVER UNSTEADY HARMONICS INLOS 14
15 DO 1 J=1,KMAX INLOS 15
C READ(NIN,100) XLR1,XLIMG1,XLR2,XLIMG2 INLOS 16
C XLREAL(1J)=XLR1+.5*XLR2 INLOS 17
C XLIMAG(1J)=XLIMG1+.5*XLIMG2 INLOS 18
20 CONTINUE INLOS 19
100 FORMAT(10F10.0) INLOS 20
RETURN INLOS 21
END INLOS 22
INLOS 23
INLOS 24
```

```
1 SUBROUTINE INTERP(X,Y,DPHI,PHI)
  COMMON/SOLUT/NGDEF,PHI(100),A(10),ARAX,ICOMV,NCOUNT
  COMMON/UNITS/NIN,NOUT,DATE(5),TITLE(15)
  5 K=-1
  EGO=0.0
  ISLOPE=1
  PHII=PHI
  1 CONTINUE
  PHII=PHII+K*DPHI
  10 SUP1=0.0
  SUP2=0.0
  DO 2 L=1,ACDEF
    ARG=T3-24L*PHII
    SUP1=SUM1+A(L)*COS(ARG)
    SUP2=SUM2+A(L)*SIN(ARG)
    2 CONTINUE
    ENR=(XX-SUM1)**2+(YY-SUM2)**2
    IF(OLD.GT.ENR) ISLOPE=-1
    IF(ISLOPE.GT.0) GO TO 3
    IF(OLD.LE.ENR) RETURN
    3 CONTINUE
    K=K+1
    IF(K.GT.100) WRITE(NOUT,100)
    IF(K.GT.100) STOP 10
    25 EOLT=ENR
    GO TO 1
  100 FORMAT(//,5X,64HTHE TRANSFORMATION COEFFICIENTS FOR THIS SECTION D
    10 NOT CONVERGE,7,5X,64H)
  END
```

```

1      SUBROUTINE INPUT
2      SUBROUTINE INPUT READS INPUT AND INITIALIZES VARIOUS CONSTANTS
3      INPUT
4      INPUT
5      INPUT
6      INPUT
7      INPUT
8      INPUT
9      INPUT
10     INPUT
11     INPUT
12     INPUT
13     INPUT
14     INPUT
15     INPUT
16     INPUT
17     INPUT
18     INPUT
19     INPUT
20     INPUT
21     INPUT
22     INPUT
23     INPUT
24     INPUT
25     INPUT
26     INPUT
27     INPUT
28     INPUT
29     INPUT
30     INPUT
31     INPUT
32     INPUT
33     INPUT
34     INPUT
35     INPUT
36     INPUT
37     INPUT
38     INPUT
39     INPUT
40     INPUT
41     INPUT
42     INPUT
43     INPUT
44     INPUT
45     INPUT
46     INPUT
47     INPUT
48     INPUT
49     INPUT
50     INPUT
51     INPUT
52     INPUT
53     INPUT
54     INPUT
55     INPUT
56     INPUT
57     INPUT
58     INPUT
59     INPUT

```

```

60      C      PRINT PROPELLER SPANWISE INPUT      INPUT
        C      WRITE(ROUT,2051)                    INPUT
        C      DU 1 J=1,NRAD                        INPUT
        C      RND=KIND(J-1)*DRND                    INPUT
        C      WRITE(ROUT,209)RND,PCRGROU(J),PSKENT(J) INPUT
        C      CONTINUE                              INPUT
        C      RETURN                                INPUT
        C      FORMAT(54,15A4)                        INPUT
        C      FORMAT(1615)                            INPUT
        C      FORMAT(8F10.0)                          INPUT
        C      201  FORMAT( 5X,17HPROP RADIUS (FT)=,F6.2,3X,17HNUMBER OF RADIAL STRIPS INPUT
        C      1=,12,3X,30HNON-DIM RADIUS OF FIRST STRIP=,F5.3,3X,27HNON-DIP INCRE INPUT
        C      2MENT IN RADII=,F5.3/ )                INPUT
        C      202  FORMAT( 5X,9HPROP APH=,F7.2,3X,17HSHIP SPEED (FPS)=,F6.2, INPUT
        C      1 3X,26HPRINT OPTION FOR SOLUTION=,A4/ ) INPUT
        C      75  FORMAT( 5X,13HNG OF BLADES=,13,3X,51HNO OF HARMONICS USED IN UNSTE INPUT
        C      1ADY LIFT CALCULATIONS=,13)             INPUT
        C      204  FORMAT( 5X,                        INPUT
        C      1 3CHDEPTH TO PROP CENTERLINE (FT)=,F6.2,3X,18HVAPOR PRESS (PSF)=, INPUT
        C      3 F6.2,3X,28HWATER DENSITY (SLUGS/FT**3)=,F5.2/ ) INPUT
        C      80  FORMAT(//29X,24HPROPELLER SPANWISE INPUT /20X,26(1H*) INPUT
        C      1 //30X,23HR/RD CHORD SKEN            INPUT
        C      1/ 30X, 23H (FT)                        INPUT
        C      209  FORMAT(25X,F9.3,F10.3,F9.3)        INPUT
        C      END                                      INPUT
    
```

```

1      SUBROUTINE INPUT2
2      C
3      C
4      C THIS ROUTINE READS THE INPUT FOR EVERY SECTION GEOMETRY
5      C
6      C
7      C
8      C
9      C
10     C
11     C
12     C
13     C
14     C
15     C
16     C
17     C
18     C
19     C
20     C
21     C
22     C
23     C
24     C
25     C
26     C
27     C
28     C
29     C
30     C
31     C
32     C
33     C
34     C
35     C
36     C
37     C
38     C
39     C
40     C
41     C
42     C
43     C
44     C
45     C
46     C
47     C
48     C
49     C
50     C
51     C
52     C
53     C
54     C
55     C
56     C
57     C
58     C
59     C
60     C
61     C

```

READ THE NUMBER OF POINTS DESCRIBING HALF THE SECTION AND THE
 NUMBER OF LOCATIONS DESIRED FOR PRESSURE CALCULATIONS.

READ(NIN,100) NPST,NPLUC

IF(NPST.LT.0) STOP
 IF(NPLUC.LE.0) CALL ERROR(7)
 IF(NPLUC.GT.99) CALL ERROR(4)
 NX=(NPLUC-1)/2
 NPLUX=(2*NX)+1
 IF(NPLUX.NE.NPLUC) GO TO 40

12 CONTINUE

READ(NIN,110) SEC,BEAM,DRAFT,AREA,DXSEC,XDIST,SECTION
 WRITE(OUT,200)
 XSEC=ABS(SEC)
 WRITE(OUT,210) XSEC,XDIST
 WRITE(OUT,180) NPST
 WRITE(OUT,170) BEAM,DRAFT,AREA
 WRITE(OUT,175) DXSEC,SECTION
 WRITE(OUT,160)
 BEAM=BEAM/2.0

35

READ THE COORDINATES OF THE POINTS DESCRIBING THE HALF SECTION

READ(NIN,110) (X(I),I=1,NPST)
 READ(NIN,110) (Y(I),I=1,NPST)

40

EVALUATE THE TRANSFORMATION COEFFICIENTS

CALL MAPS

CALCULATE RHOP(I),PHIP(I)

DO 15 I=1,NPLUC
 ZBAR=2*LOC(I)*DEPTH
 RHOP(I)=SQRT(YLOC(I)*YLOC(I)+ZBAR*ZBAR)/RO
 15 PHIP(I)=ATAN2(-YLOC(I),ZBAR)*RAD

DO 2 J=1,NPLUC
 XPT(J)=XGIST
 2 CONTINUE
 RETURN

```

60      40 WRITE(NDUT,998)
        WRITE(NDUT,999) NPLOC,NPLOC
        NPLOC=NPLOC
        GO TO 12

        100 FORMAT(5I10)
        110 FORMAT(8F10.4)
        160 FORMAT(7,5X,80H)THE FOLLOWING IS A TABLE OF THE COORDINATES INPUT
        170 FORMAT(5X,29H)THE BEAM FOR THIS SECTION IS ,F10.4,17HFT, THE DRAFT
        115 ,F10.4,20H FT AND THE AREA IS ,F10.4,12H FT SQUARED )
        175 FORMAT(7,5X, 42H AT THIS STATION THE SECTION THICKNESS IS ,F10.3,
        143HFT , THE MODAL WEIGHTING FUNCTION VALUE IS ,F10.3)
        180 FORMAT(7,5X,108H)THE ARE ,F12.37H POINTS TO DESCRIBE THIS HALF SECT
        110N )
        200 FORMAT(11,1H )
        210 FORMAT(11F,7,75X,42H)THE FOLLOWING ARE THE RESULTS FOR SECTION ,
        1F5.2,5H LOCATED ,F10.3,28H FT FORWARD OF THE PROPELLER/3X,95(1H*))
        998 FORMAT(11H,1,25(1,1),20(1H*),9H WARNING ,20(1H*))
        999 FORMAT(7,50H YOU HAVE INPUT AN EVEN NUMBER FOR NPLOC EQUAL TO ,F12,
        140H THE NUMBER TO BE USED AS NPLOC WILL BE ,F12)
        END

```

INPUT2 65
 INPUT2 66
 INPUT2 67
 INPUT2 68
 INPUT2 69
 INPUT2 70
 FINAL1 23
 FINAL1 24
 FINAL4 9
 FINAL4 10
 FINAL1 25
 FINAL1 26
 FINAL1 27
 FINAL1 28
 INPUT2 79
 FINAL4 11
 FINAL4 12
 FINAL4 13
 FINAL4 14
 FINAL4 15
 INPUT2 91

```

1      SUBROUTINE MAPS
COMMON/SOLUT/NCDEF,PHI(100),ALIC(1),AMAX,ICONV,NCOUNT
COMMON/REPRES/NTSI,X(100),Y(100),BEAM,DRAFT,AREA,DXSEC,GCTION
COMMON/UNIT/NTIN,NCOUT,DATETS(5),TITLE(15)
5      PI=4.*ATAN(1.)
C      LEWIS FORM AS FIRST GUESS
A(2)=0.59*(BEAM-DRAFT)
A(3)=0.25*(-(BEAM+DRAFT)+SQRT((BEAM+DRAFT)**2+8.*(BEAM-DRAFT-2.*AR
LEA/PI)))
10     DO 1 J=4,10
A(J)=0.5*(BEAM+DRAFT)-A(3)
DO 1 J=4,10
A(J)=0.0
CONTINUE
15     NMAX=8
WRITE(NCOUT,120)
DO 4 K=-4,NMAX
NCDEF=N
NCOUNT=0
20     CONTINUE
NCOUNT=NCOUNT+1
AMAX=0.0
DO 15 J=1,NCDEF
AMAX=AMAX+AMAX*A(J)
15     CONTINUE
CALL GETPT
CALL GETA
DO 3 J=1,NPISI
XX=0.0
YY=6.0
O C 2 1=1,NCDEF
ARG=73-2*PI*PHI(J)
XX=XX+A(1)*COS(ARG)
YY=YY+A(1)*SIN(ARG)
2     CONTINUE
IF(NGDEF.LT. 8) GO TO 3
IF(NCLLNT.EQ. 2) GO TO 5
IF(NCOUNT.EQ. 10) GO TO 5
GO TO 3
5     WRITE(NCOUT,110) J,PHI(J),X(J),XX,Y(J),YY
CONTINUE
3     IFIN=EQ,NMAX) CALL EQPTS
IF(NCLLNT.EQ.10) GO TO 4
IF(NCOUNT.EQ.11) GO TO 12
IF(ICONV.LT. 0) GO TO 12
CONTINUE
4     RETURN
110    FORMAT(1X,12,1X,F10.6,5X,F10.6,11X,F10.6,12X,F10.6,10.6)
120    FORMAT(7,5X,13HPUNIT NUMBER ,5X,1CHANGLE PHI ,5X,5H INPUT Y ,10X,
113PCALCULATED Y ,10X,9H INPUT Z ,1CX,13H CALCULATED Z,77)
50     END

```

MAPS 2
 MAPS 3
 NEWFIX 16
 MAPS 5
 MAPS 7
 MAPS 9
 MAPS 10
 MAPS 11
 MAPS 12
 MAPS 13
 MAPS 14
 MAPS 15
 MAPS 16
 MAPS 17
 MAPS 18
 MAPS 19
 MAPS 20
 MAPS 21
 MAPS 22
 MAPS 23
 MAPS 24
 MAPS 25
 MAPS 26
 MAPS 27
 MAPS 28
 MAPS 29
 MAPS 30
 MAPS 31
 MAPS 32
 MAPS 33
 MAPS 34
 MAPS 35
 MAPS 36
 MAPS 37
 MAPS 38
 MAPS 39
 MAPS 40
 MAPS 41
 MAPS 42
 MAPS 43
 MAPS 44
 MAPS 45
 MAPS 46
 MAPS 47
 MAPS 48
 FINAL 31
 MAPS 49
 MAPS 16
 FINAL 4
 MAPS 17
 FINAL 4
 MAPS 53

Line	Code	Statement	Label
1	C	SUBROUTINE PARCAVALPHASIGMA,CAMBERX1,CUTCURSSYS,ITRANSJ	PARCAV
3	C		PARCAV
4	C	SUBROUTINE PARCAV CALCULATES THE SOLUTION FOR A PARTIALLY	PARCAV
5	C	CAVITATING PARABOLIC FOIL BASED ON THE SOLUTION OF GEURST	PARCAV
6	C		PARCAV
7	C	COMMON/CONST/PI,RHO,V,OMEGA,DEPTH,PV,G,RAD	PARCAV
8	C	COPRON/EXEC/TOL, NPTS,OTHEIATA,ISOL,INITMAX, ITRMAX	PARCAV
9	C		PARCAV
10	C	INITIALIZE VARIABLES FOR FIRST PASS	PARCAV
11	C		PARCAV
12	C	NITER=0	PARCAV
13	C	XL=.5	PARCAV
14	C	DXL=-.225	PARCAV
15	C	IFIRST=0	PARCAV
16	C	GO TO 7	PARCAV
17	C		PARCAV
18	C	START SECOND PASS	PARCAV
19	C		PARCAV
20	C	ERR1=ERR2	PARCAV
21	C	POM1=SIGN(1.,ERR1)	PARCAV
22	C	XL=.05	PARCAV
23	C	CONTINUE	PARCAV
24	C	NITER=NITER+1	PARCAV
25	C		PARCAV
26	C	END JOB IF NUMBER OF ITERATIONS EXCEED MAXIMUM	PARCAV
27	C		PARCAV
28	C	IF(NITER.GT.NITMAX) CALL ERROR(10)	PARCAV
29	C	CONTINUE	PARCAV
30	C		PARCAV
31	C	SET UP REQUIRED PARAMETERS FOR SOLUTION	PARCAV
32	C		PARCAV
33	C	SINVAL=SQRT(XL)	PARCAV
34	C	COSVAL=SQRT(1-XL)	PARCAV
35	C		PARCAV
36	C	IF CALLED FROM TRANSITIONAL SUBPROGRAM DO NOT ITERATE	PARCAV
37	C		PARCAV
38	C	IF(ITRANS.NE.0) GO TO 5	PARCAV
39	C		PARCAV
40	C	CALCULATE ERROR	PARCAV
41	C		PARCAV
42	C	ERR2=ALPHA*(1.+COSVAL)*SINVAL-.5*SIGMA*(1.-COSVAL)*COSVAL+	PARCAV
43	C	1/CAMBER*(COSVAL*SINVAL**3	PARCAV
44	C		PARCAV
45	C	IF FIRST PASS - START SECOND PASS	PARCAV
46	C		PARCAV
47	C	IF(IFIRST.EQ.0.AND.XL.EQ.0.50) GO TO 8	PARCAV
48	C		PARCAV
49	C	TEST IF SOLUTION HAS CONVERGED	PARCAV
50	C		PARCAV
51	C	DIFF=DXL/XL	PARCAV
52	C	IF(ABS(DIFF).LT.TOL) GO TO 5	PARCAV
53	C	POM2=SIGN(1.,ERR2)	PARCAV
54	C	IF(IFIRST.EQ.1) GO TO 1	PARCAV
55	C	IFIRST=1	PARCAV
56	C	IF(POM1.EQ.POM2) GO TO 2	PARCAV
57	C	GO TO 3	PARCAV
58	C	CONTINUE	PARCAV

82/08/10. 14.39.12

FTN 4.6+433D

SUBROUTINE PARCAV 76/74 OPT=0 TRACE

```

60      C      IF(POM1.NE.POM2) GO TO 3
        C      NO CHANGE IN SIGN OF ERROR - CONTINUE IN SAME DIRECTION
        C
        XL=XL+DXL
        POM1=POM2
        GO TO 4
65      3      CONTINUE
        C
        C      SIGN OF ERROR HAS CHANGED - GO BACK 1/2 STEP
        C
        DXL=-DXL*.5
        XL=XL+DXL
        POM1=POM2
        GO TO 4
70      2      IF(ABS(ERR1).LT. ABSTERR2) GO TO 2C
        C
        C      SOLUTION LIES BETWEEN 0.0 AND .05 REPLACE BY 0.0
        C
        XL=0.0
        CL=0.0
        CHASS=0.0
        S=0.0
        RETURN
80      5      XL=.50
        C      CONTINUE
        C
85      C      CALCULATE SOLUTION USING CONVERGED CAVITY LENGTH
        C
        COSVAL=SCRT(1-XL)
        SINVAL=SQRT(XL)
        COSPLS=1.+COSVAL
        COSMNS=1.-COSVAL
        CL=PI*ALPHA*(COSPLS+COSVAL+.5*(SICHA+COSPN5)*SINVAL+.5*CHAMBER
        1 *COSPLS+(COSPLS+.2.*COSVAL+COSMAS))
        CH=-.125*PI*ALPHA*(COSPLS+COSPLS*(1-1.8.*COSVAL+.6.*COSVAL+COSVAL)
        1 -SIGPA*(COSMNS*SINVAL+COSPLS*(1-2.73*(COSVAL+.72*CHAMBER+COSPLS
        2*(1.+COSVAL+.2.*COSVAL*(1.+COSVAL*(1-3.*COSVAL*(1-4.4.*COSVAL))))))
        CHASS=CH-.59CL
        S=0.0
        RETURN
        END
90
95
100
```



```
60 DRDRHO=TRHO-R*COSARG/DIST
   DRCPHI=-RHO+R*SINARG/DIST
   DPCORH=PFACR+TERM1+DRDRHO+TERM2+(-SINARG)
   DPCPHI=PFACR+TERP1+DRCPHI+TERM2+RHO+COSARG
   DPLOY=-(SINPHI+DPCORH+COSPHI+DPCPHI/RHO)
   DPLOY=-(COSPHI+DPCORH-SINPHI+DPCPHI/RHO)

65 C MIRROR IMAGE PRESSURE AND GRADIENTS EVALUATION
   C
   DIST2=SQRT(DIST**2+4*DEPTH-R*COSBET)**2+RHO*COSPHI**2
   PFAC1=PCONST/DIST2**2
   ARG2=ARG1-2*PI*REGA/DEPTH-RHO*CLSPHI*(R*5*DXLOTH(K,1))**SINBET
   P2=-(ARG2*DSOETH(K,1)/DIST2**3+REGA*DSOETH(K,1)/DIST2**3+PCONST
   DR2RHO=IDIST+DRDRHC-2*COSPHI*(DEPTH-R*COSBET)/DIST2
   DR2PHI=IDIST+DRCPHI+2*RHO*SINPHI*(DEPTH-R*COSBET)/DIST2
   TERP3=-(13./DIST2**3)*DSOETH(K,1)*ARG2*REGA*DSOETH(K,1)
   TERM4=TERM2*DIST/DIST2
   DP2RHC=-PFAC1*(TERM3+DR2RHO+TERM4+(-SINARG+2*COSPHI*SINBET))
   DP2PHI=-PFAC1*(TERM3+DR2PHI+TERM4+RHO*COSARG+2*SINPHI*SINBET)
   DP2DY=-1SINPHI+DP2RHO+COSPHI*DP2PHI/RHO
   DP2DZ=ICOSPFI+DP2RHO-SINPHI*DP2PHI/RHO
   PFREE11=PFREE11*PI
   P(1)=P(1)+P1+P2

80 DPOY(1)=DPOY(1)+DPOY+DP2DY
   DPOZ(1)=DPOZ(1)+DPOZ+DP2DZ
   70 CONTINUE
   80 CONTINUE
   A=REGA/ZU
   DR=DRNG+RU
   PCONST=OR/(4*PI)

90 C CALCULATE PRESSURE INCREMENT DUE TO LIFT CHANGES DUE TO CAVITY
   C
   DO 16 K=1,NRAD
   R=(RIND*(K-1)+DRND)*RO
   FACTOR=R/SORT(1+A*AR*R)
   SKEW=PSKEW(K)
   DO 16 I=1,NPTS
   THETA=(I-1)*OTHETA
   IF(LIFT(K,1).EQ. C.O) GO TO 16
   DIST=SCRTX(X*AR+RHO+RHO-2*AR*RU+COS(THETA+SKEW-PHI))
   ORMION=FACTOR*(A*(RHO/R)+SIN(THETA+SKEW-PHI)/DIST**3
   P1=-CLFT(K,1)+GRPION*PCONST
   SINARG=SIN(THETA+SKEW-PHI)
   COSARG=COS(THETA+SKEW-PHI)
   DRCHG=(RHO-R*COSARG)/DIST
   DRCPHI=-RHO+R*SINARG/DIST
   TERP1=(1./R)*SINARG/DIST**3-((A*(RHO/R)+SINARG)*3*GRKFI/(DI
   IST**4))
   TERP2=(-1./DIST**3)*(RPG/R)*COSARG*(1+A*(RHO/R)+SINARG)*3*GRPI
   11/DIST)
   DPLRHC=-PCONST*FACTOR*DLIFT(K,1)+TERP1
   DPLPHI=-PCONST*FACTOR*DLIFT(K,1)+TERP2
   DPLICY=-(1SINPHI+DPLRHO+COSPHI+DPLPHI/RHO)
   DPLIDZ=-(COSPHI+DPLRHO-SINPHI+DPLPHI/RHO)

100 C EVALUATE THE LOADING FROM THE IMAGE SOURCE
   C
```


80 CONTINUE

RETURN

220 FORMAT(//,1H)

207

FORMAT(// 24X,36HCOORDINATES FOR PRESSURE CALCULATION 72X,30H(1H)

1 //

24X,36H GAUGE X RHO/R0 PHI /

2

24X,36H (FT) (DEG) /)

206

FORMAT(// 24X,36HCOORDINATES FOR PRESSURE CALCULATION 72X,30H(1H)

200

FORMAT(// 5X,37H TOTAL PRESSURE EXCLUDING HULL EFFECTS)

300

FORMAT(// 16X,62H (ALL VALUES ARE (PSF) AS MEASURED AT THE GIVEN GAUG

1E LOCATION)

END

ADDGRAD	178
ADDGRAD	179
NEWFIX	29
PRESS	88
PRESS	89
PRESS	90
PRESS	91
FINAL2	2
PRESS	96
PRESS	97
PRESS	98

60 CONTINUE

RETURN

220 FORMAT(//,1H,)

207 FORPAT 24X,36HCOORDINATES FOR PRESSURE CALCULATION 723X,3811H)

1 //

24X,36H GAUGE

24X,36H (FT)

24X,36H X

24X,36H RHO/RD

24X,36H PHI

24X,36H (DEG) /)

24X,36H /)

24X,36H /)

24X,36H /)

24X,36H /)

24X,36H /)

24X,36H /)

24X,36H /)

24X,36H /)

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24X,36H /)

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24X,36H /)

24X,36H /)

24X,36H /)

24X,36H /)

24X,36H /)

24X,36H /)

ADDRESS 178
ADDRESS 179
NEWFIX 29
PRESS 88
PRESS 89
PRESS 90
PRESS 91
FINAL2 2
PRESS 96
PRESS 97
PRESS 98

SUBROUTINE SINC(A,B,N,KSI)

C THE SERVICE ROUTINE PERFORMS MATRIX INVERSION

C DIMENSION A(1),B(1)

C FORWARD SOLUTION

TOL=0.0

KS=0

JJ=-N

DO 65 J=1,N

JV=J+1

JJ=JJ+N+1

BIGA=0.4

II=JJ-J

DO 30 I=J,N

C SEARCH FOR MAXIMUM COEFFICIENT IN COLUMN

IJ=II+1

IF(ABS(BIGA)-ABS(A(IJ)))20,30,30

20 BIGA=A(IJ)

IMAX=I

30 CONTINUE

C TEST FOR PIVOT LESS THAN TOLERANCE (SINGULAR MATRIX)

IF(ABS(BIGA)-TOL)35,35,40

35 KS=1

RETURN

C INTERCHANGE ROWS IF NECESSARY

40 II=J+N*(J-2)

II=IMAX-J

DO 50 K=J,N

11=II+N

12=II+1

SAVE=A(11)

A(11)=A(12)

A(12)=SAVE

C DIVIDE EQUATION BY LEADING COEFFICIENT

50 A(11)=A(11)/BIGA

SAVE=B(IMAX)

B(IMAX)=B(IJ)

B(IJ)=SAVE/BIGA

C ELIMINATE NEXT VARIABLE

IF(J=N) 55,70,55

55 IC=N*(J-1)

DO 65 IX=JY,N

IXJ=IC+IX

II=J-1X

2 SINC
3 SINC
4 SINC
5 SINC
6 SINC
7 SINC
8 SINC
9 SINC
10 SINC
11 SINC
12 SINC
13 SINC
14 SINC
15 SINC
16 SINC
17 SINC
18 SINC
19 SINC
20 SINC
21 SINC
22 SINC
23 SINC
24 SINC
25 SINC
26 SINC
27 SINC
28 SINC
29 SINC
30 SINC
31 SINC
32 SINC
33 SINC
34 SINC
35 SINC
36 SINC
37 SINC
38 SINC
39 SINC
40 SINC
41 SINC
42 SINC
43 SINC
44 SINC
45 SINC
46 SINC
47 SINC
48 SINC
49 SINC
50 SINC
51 SINC
52 SINC
53 SINC
54 SINC
55 SINC
56 SINC
57 SINC
58 SINC

```
60      DO 80 JX=JYIN  
          IXJX=N*(JX-1)+IX  
          JX=IXJX+17  
          60 A(IIXJX)=A(IIXJX)-(A(IIXJX)+A(IIXJX))  
          65 B(IIX)=B(IIX)-(B(IIX)+A(IIXJX))  
          C  
          C  
          C      BACK SOLUTION  
          65      C  
          70 NY=N-1  
          71      II=NY  
          80 J=1,NY  
          72      IA=II-J  
          73      IB=R-J  
          74      IC=N  
          75      DO 80 K=1,J  
              76      B(II)=B(II)+A(II)+B(II)  
              77      IA=IA-N  
              78      IC=IC-1  
          79      RETURN  
          80      END
```

```

SUBROUTINE TRANSALPHA(STGNACAMBER,CAYLEN,CCLF,CMASSF,ALPHAX) TRANS
C
C SUBROUTINE TRANS CALCULATES SOLUTION IN TRANSITION REGION BY
C LINEAR INTERPOLATION VS ALPHA
C
C      RATIO=(ALPHA-ALMIN)/(ALMAX-ALMIN)
C      CALL PRCALPHALMIN,STGNACAMBER,CAYLEN,CCLF,CMASSF,SP11
C      CALL FULCAYALMAX,STGNACAMBER,CAYLEN,CCLF,CMASSF,SP11
C      CAYLEN=CAYLEN*(CAYLEN-CAYLNP)*RATIO
C      CCLF=CCLF*(CCLF-CCLFP)*RATIO
C      CMASS=CMASS*(CMASSF-CMASSP)*RATIO
C      S=0.0
C      RETURN
C      END
    
```

2
3
4
5
6
7
8
9
10
11
12
13
14
15


```
115 VFORCE(J)=VFORCE(J)+YTOT(J)*DXSEC*GCTION
HFORCE(J)=HFORCE(J)+ZTOT(J)*DXSEC*GCTION
30 CONTINUE
PAPPL(I)=0.0
PPHASE(L)=0.0
PAPPL(NPLOC)=0.0
PPHASE(L,NPLOC)=0.0
DO 31 M=2,NPLOC
PAPPL(M)=SORT(PTOT(INFIRST,M)+PTOT(INLAST,M)+PTOT
11(INLAST,M))
125 PPHASE(L,M)=ATAN2(PTOT(INLAST,M),PTOT(INFIRST,M))*RAD
31 CONTINUE
AMPYL(I)=SORT(YTOT(INFIRST)+YTOT(INLAST)+YTOT(INLAST))
IF(YTOT(INLAST).EQ.0.0 .AND. YTOT(INFIRST).EQ.0.0) GO TO 62
PPHASE(L)=ATAN2(YTOT(INLAST),YTOT(INFIRST))*RAD
GO TO 32
130 62 PPHASE(L)=0.0
32 AMPZ(L)=SORT(ZTOT(INFIRST)+ZTOT(INLAST)+ZTOT(INLAST))
IF(ZTOT(INLAST).EQ.0.0 .AND. ZTOT(INFIRST).EQ.0.0) GO TO 63
PPHASE(L)=ATAN2(ZTOT(INLAST),ZTOT(INFIRST))*RAD
GO TO 33
135 63 PPHASE(L)=0.0
33 IF(SEC .GE. 0.0) GO TO 39
VAMP(L)=SORT(VFORCE(INFIRST)+VFORCE(INLAST)+
140 VFORCE(INLAST))
IF(VFORCE(INLAST).EQ.0.0 .AND. VFORCE(INFIRST).EQ.0.0) GO TO 64
VPHASE(L)=ATAN2(VFORCE(INLAST),VFORCE(INFIRST))*RAD
GO TO 34
145 64 VPHASE(L)=0.0
34 HAMP(L)=SORT(HFORCE(INFIRST)+HFORCE(INLAST)+
150 HFORCE(INLAST))
IF(HFORCE(INLAST).EQ.0.0 .AND. HFORCE(INFIRST).EQ.0.0) GO TO 65
HPHASE(L)=ATAN2(HFORCE(INLAST),HFORCE(INFIRST))*RAD
GO TO 35
155 65 HPHASE(L)=0.0
35 I=1+2
111=ANBLADE
112=111+111
113=112+111
XSEC=ABS(SEC)
WRITE(NUOT,130) XSEC,XD1ST
WRITE(NUOT,140) 111,112,113
WRITE(NUOT,150)
WRITE(NUOT,160)
DO 41 J=1,NPLOC
WRITE(NUOT,170) 1,XPT(1),YLOC(1),ZLOC(1),(PAPPL(I),PPHASE(L,I),
160 IL=1,J)
41 CONTINUE
WRITE(NUOT,180) XSEC,XD1ST
WRITE(NUOT,190)
WRITE(NUOT,200)
J=1
DO 50 L=1,J
LL=ANBLADE
WRITE(NUOT,210) LL,YTOT(J),YTOT(J+1),APPY(L),PPHASE(L),ZTOT(J),
170 ZTOT(J+1),AMPZ(L),PPHASEZ(L)
```

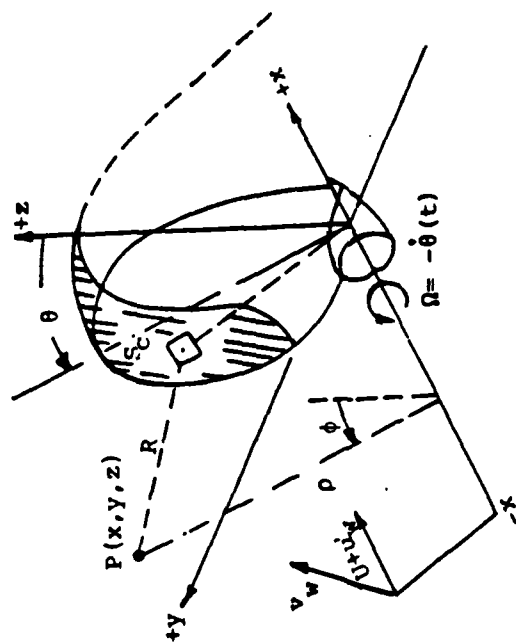



Figure 1 Coordinate definition

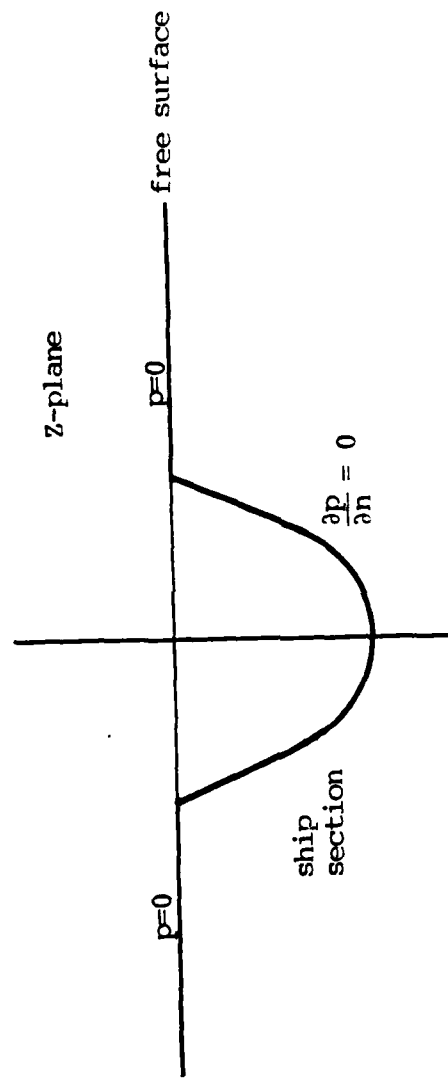


Figure 2 Boundary value problem in physical plane

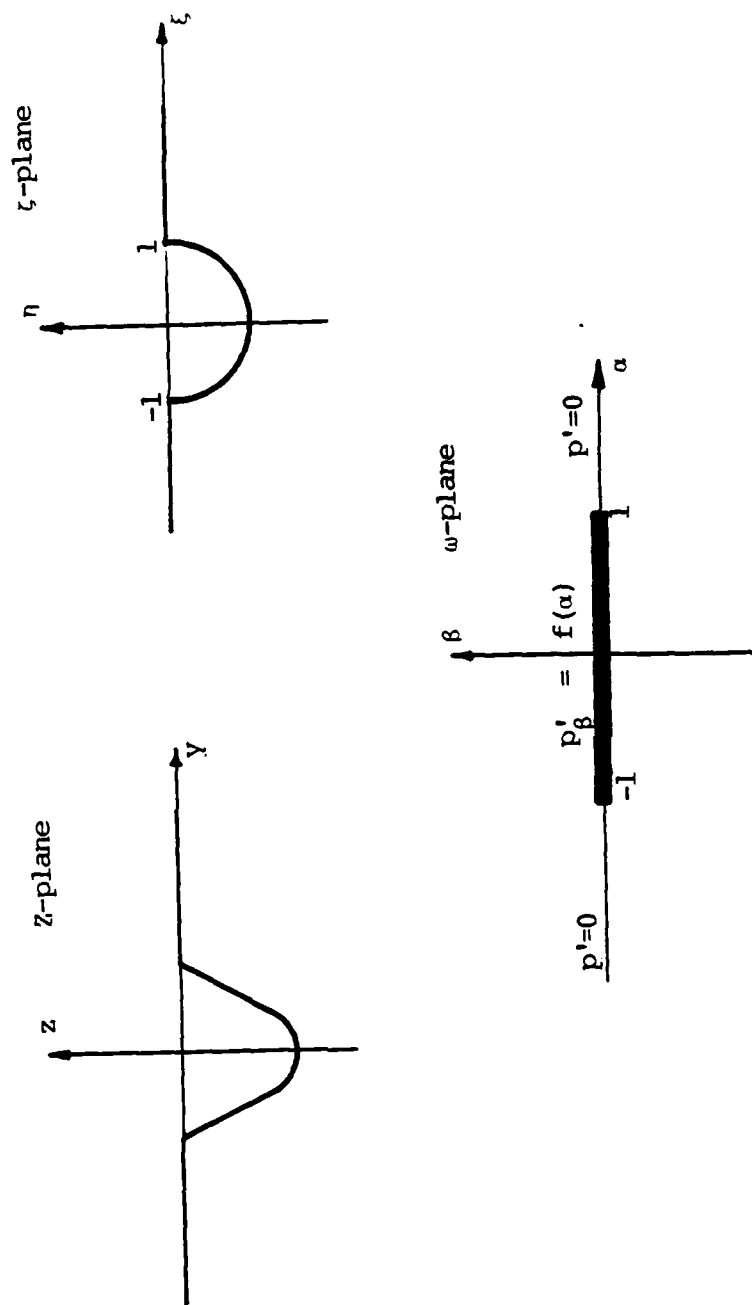


Figure 3 Conformal mappings and mixed boundary value problem

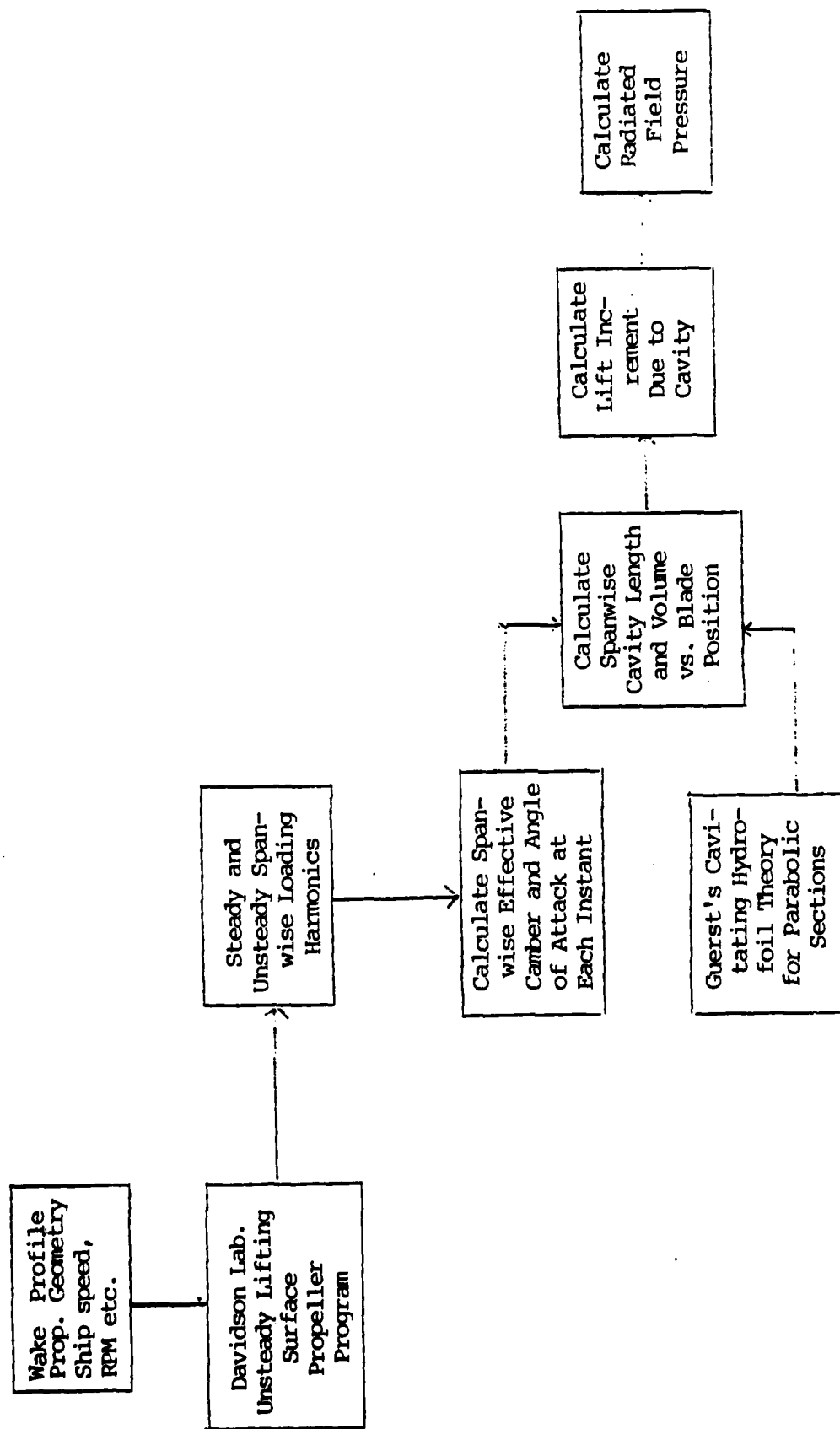


Figure 4 Computational procedure for cavitation program

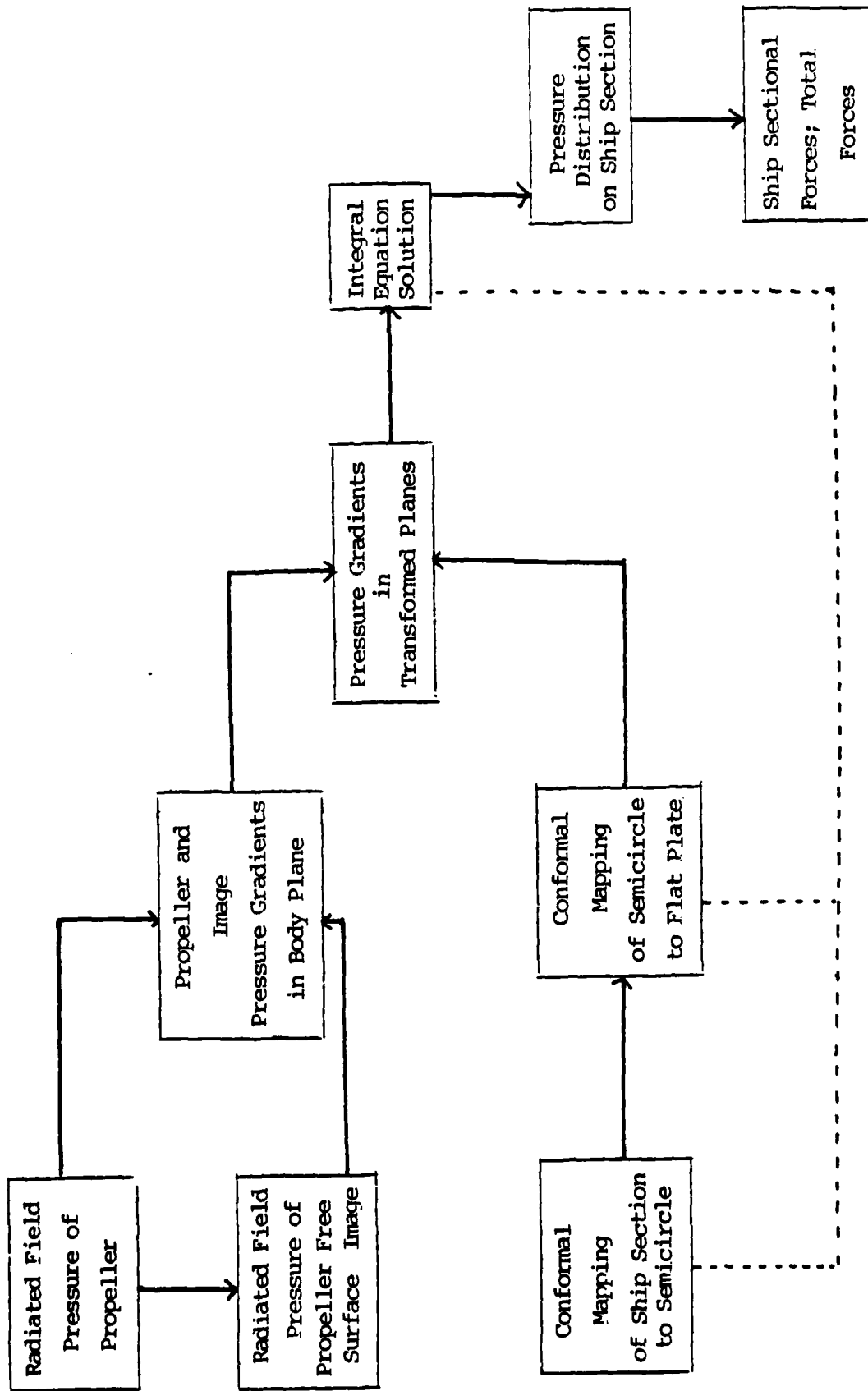


Figure 5 Computational procedure for determining pressure distribution and forces

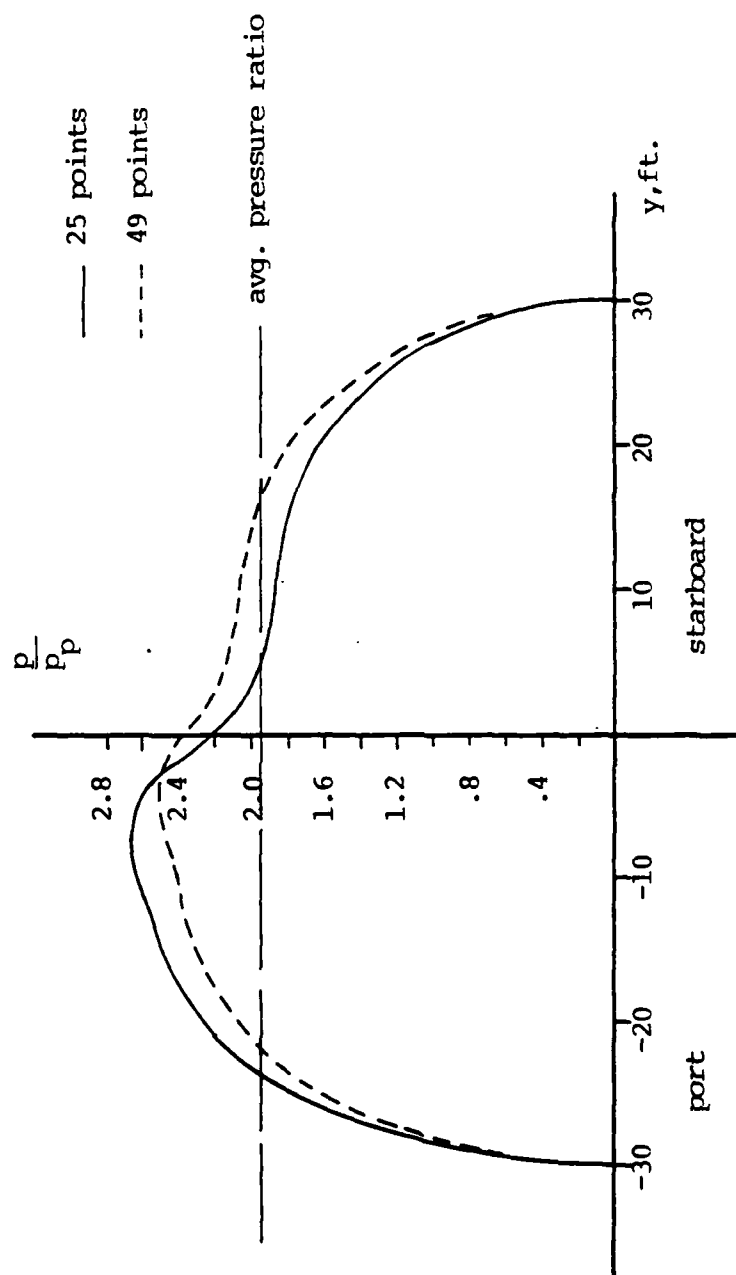


Figure 6 Variation of pressure relative to local propeller free space pressure on 60 ft. width flat plate, flow field due to AO-177 propeller in wake with fins, $x=5$ ft. location

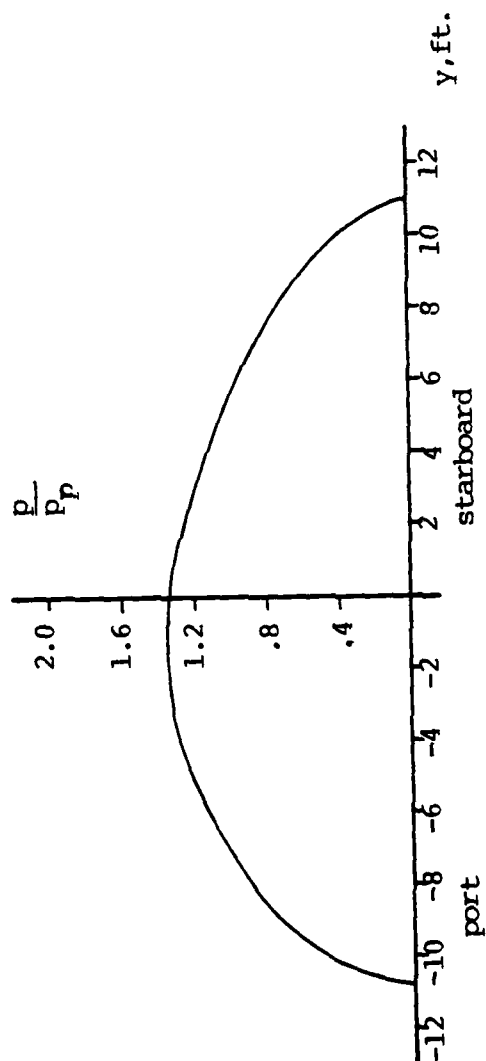


Figure 7 Variation of pressure relative to local propeller free space pressure on 21.6 ft. width plate plate, flow field due to AO-177 propeller in wake with fins, $x=5$ ft. location

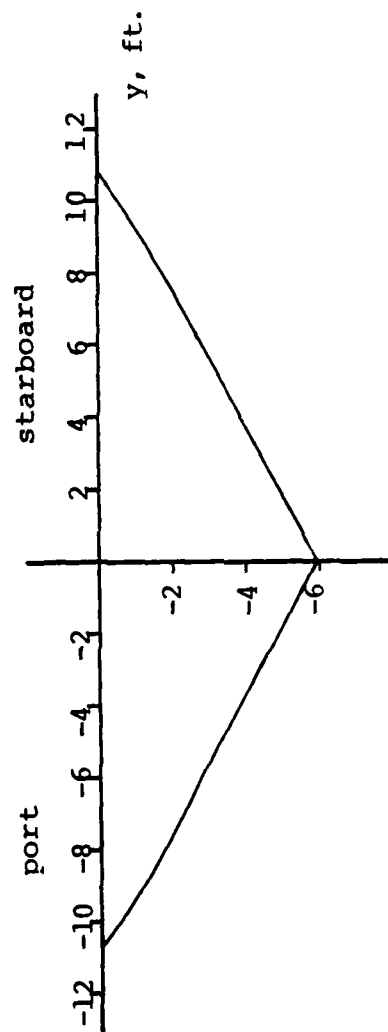


Figure 8 Section shape of AO-177 at Station 19.5

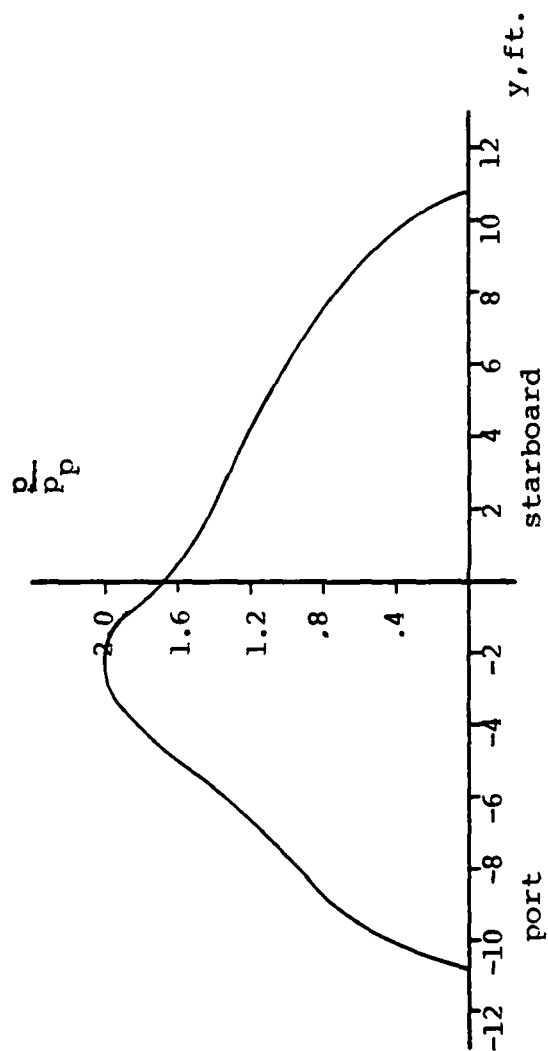


Figure 9 Variation of pressure relative to local propeller free space pressure along ship section corresponding to AO-177 Station 19.5, flow field due to AO-177 propeller in wake with fins, $x=5$ ft. location

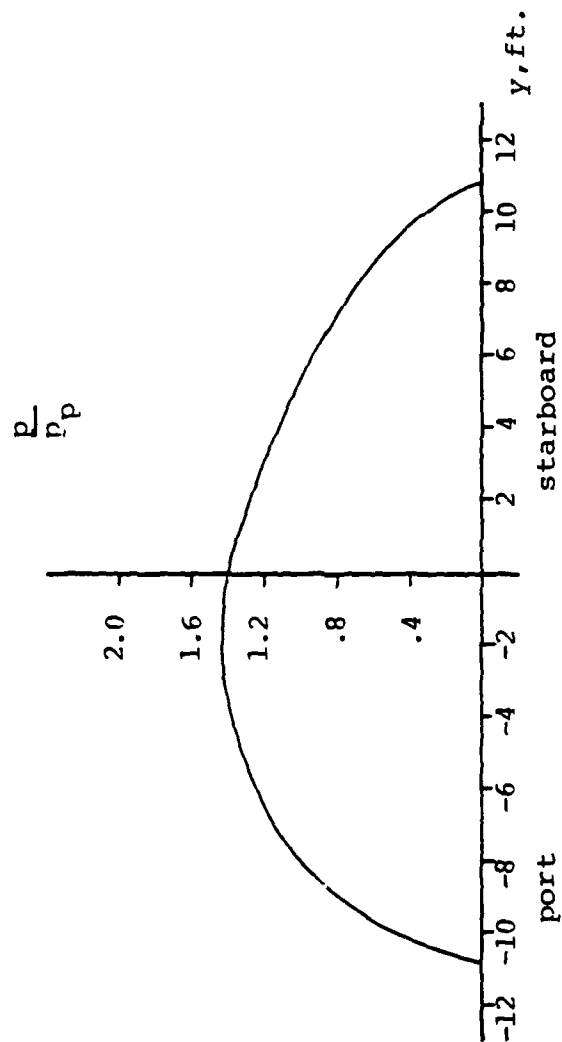


Figure 10 Variation of pressure relative to local propeller free space pressure along ship section corresponding to AO-177 Station 19.5, flow field due to AO-177 propeller in ship wake, $x=-6$ ft. location

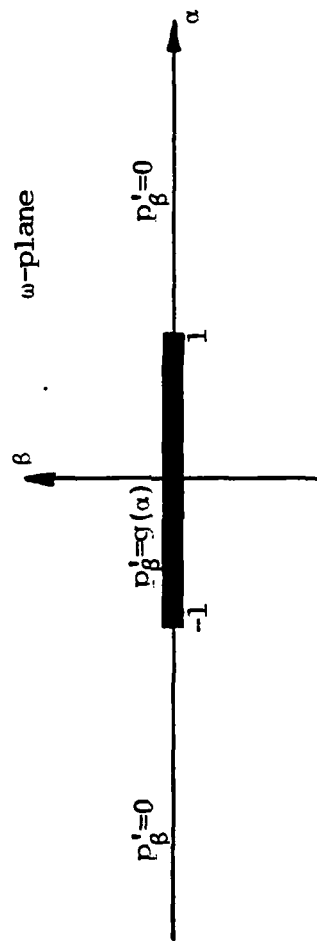


Figure 11 Boundary value problem in transformed w -plane for free surface rigid wall condition

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