NAVAL SHIP RESEARCH AND DEVELOPMENT CENTER
Bethesda, Maryland 20034

PREDICTION OF THREE-DIMENSIONAL PRESSURE DISTRIBUTIONS ON V-SHAPED PRISMATIC WEDGES DURING IMPACT OR PLANING

by

Harry P. Gray, Raymond G. Allen
and
Robert R. Jones

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DEPARTMENT OF STRUCTURAL MECHANICS
RESEARCH AND DEVELOPMENT REPORT

February 1972 Report 3795

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DURING IMPACT OR PLANING

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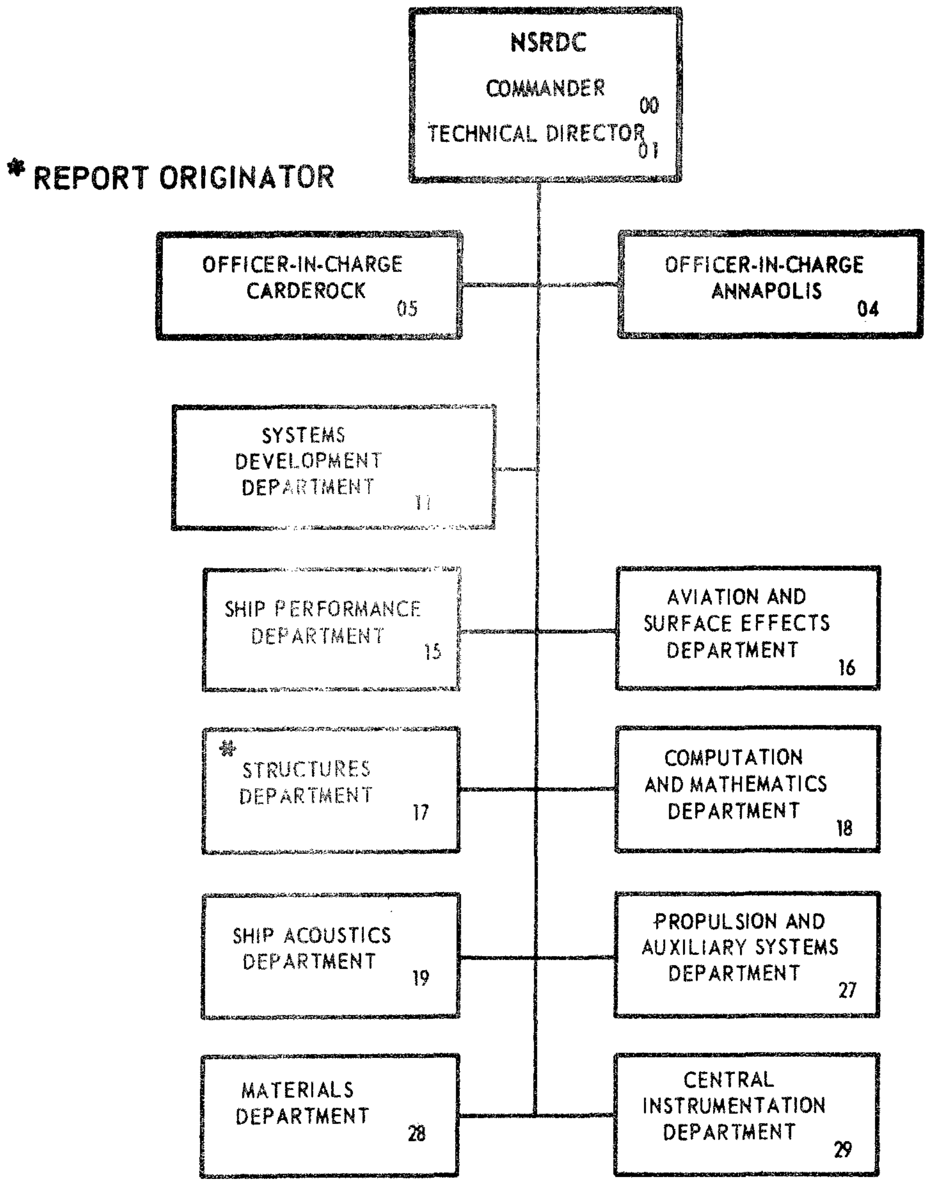

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NOMENCLATURE

C_N	Normal-force coefficient
C_{np}	Normal-load coefficient, $\frac{F_n}{1/2\ \rho\ V^2}$
c	Beam / 2
F_n	Hydrodynamic force normal to keel
$\dot{f}$	Equivalent planing velocity, $\frac{\text{velocity normal to keel}}{\sin \tau}$
h	Theoretical constant defined as $\frac{\pi - 2\beta}{\pi}$
K	Theoretical constant defined by Equation (18)
k	Theoretical constant defined by Equation (17)
L	Lift coefficient as defined by Reference 5
n	Dimensionless exponent of τ
P	Pressure
S	Projection of wetted area normal to the keel
V	Horizontal velocity
W	Wetted semiwidth in the dry-chine region; see Figure 1
X	Distance measured from the trailing edge of the planing or impacting body; see Figure 1
X_m	The X value at which maximum pressure occurs
Y	Distance from the wedge centerline
β	Angle of deadrise in degrees
γ	Planing efficiency factor
δ	Spray thickness at an infinite distance from a planing flat plate
ε	Variable quantity used as a parameter in Equations (16) and (17) having values from 0 to $\pi/2$
η	The ratio between the lift coefficient of a surface and the lift coefficient of a rectangular planform airfoil having the same aspect ratio and angle of attack
θ	Effective deadrise angle in degrees
λ_t	Total wetted length in beams
λ_{wc}	Length of the wet-chine region
ξ	Part of a conformal transformation function known to have the limits $-1 \le \xi \le 1$

ξ_m	The ξ value at which maximum pressure occurs
ρ	Mass density of water
τ	Trim angle in radians
τ_d	Trim angle in degrees

SUBSCRIPTS

c	Centerline
d	Angular degrees
dc	Dry chine
ep	Equivalent plate
iw	Immersing wedge
m	Maximum
wc	Wet chine

ABSTRACT

A computer program has been developed which calculates the water-pressure distribution on V-bottom prismatic wedges during impact or planing. The method of computation is based on previously published semiempirical procedures with several modifications that facilitate programing and result in close correlation to recently published experimental data.

The prismatic wedge may have any positive value of trim, deadrise angle, and wetted length. The pressure distribution for the entire hull or any given section of the hull may be calculated in specified increments by using the appropriate input data. Results obtained from the program are in reasonable agreement with certain published experimental planing data.

ADMINISTRATIVE INFORMATION

The work performed herein was an in-house project funded by the Surface-Effect Ship Project Office (PM-17) through authorization letter F24: MEL:et of 11 August 1971.

INTRODUCTION

Theories developed for V-shaped prismatic wedges are used in many of the existing methods for determining the pressure distributions on realistic hull shapes during impact or planing.[1-3] In some cases, the pressure distribution on a realistic hull may be directly approximated by the pressure distribution on an appropriately chosen wedge shape. Thus a study of the pressure distribution on the bottom of V-shaped prismatic hulls is a logical antecedent to the investigation of pressures on general hull bottoms.

The purpose of the present study was to develop a computer program capable of calculating the pressure distribution on V-shaped prismatic wedges with any positive value of trim angle, deadrise angle, and wetted length. Several methods for performing these calculations were examined, and the methods chosen for application in the computer program were those most adaptable to programing techniques which produced results that could be correlated with available experimental data.

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[1] References are listed on page 29.

THEORETICAL DEVELOPMENT

The normal projection of the wetted hull of a planing wedge is illustrated in Figure 1. As Smiley[1] has suggested, a study of the pressure distribution on the wedge can be made in three phases:

1. The pressure along the centerline of the wedge.
2. The transverse pressure in the wet-chine region.
3. The transverse pressure in the dry-chine region.

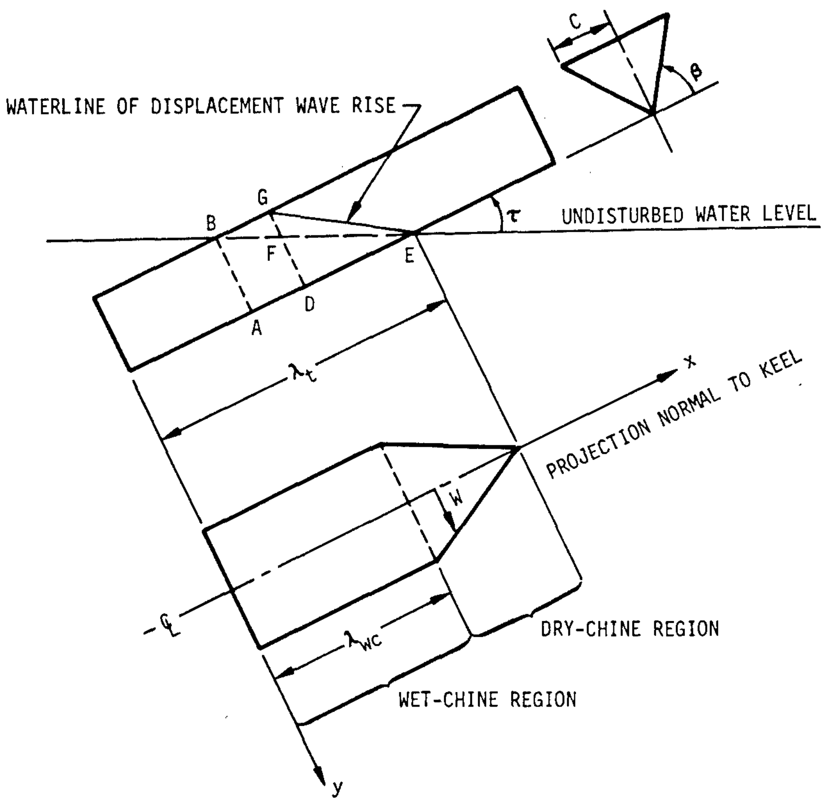


Figure 1 - Planing Wedge

CENTERLINE PRESSURE DISTRIBUTION

A four-step process was employed to determine the centerline pressure distribution on a planing prismatic wedge:

1. The normal-load coefficient C_{np} for the planing prismatic wedge was assumed to be the same as that for a two-dimensional planing flat plate with the same trim and aspect ratio λ_t.

2. An equivalent centerline normal-load coefficient for the prismatic wedge was defined by

$$(C_{np})_c = \frac{C_{np}}{\bar{P}/P_c} \tag{1}$$

where $\bar{P}/P_c$ is the ratio of the average transverse pressure to the centerline pressure in the wet-chine region of the wedge, and C_{np} is that for a two-dimensional flat plate with the characteristics defined in Step 1. The transverse pressure distribution in the wet-chine region was then defined and the ratio $\bar{P}/P_c$ found by integration.

3. This C_{npc} was assumed to be the normal-load coefficient for an infinitely wide planing flat plate with a characteristic longitudinal pressure distribution.

4. Finally the derived pressure distribution on the infinitely wide flat plate was assumed to be the centerline pressure distribution of the prismatic wedge.

The normal-load coefficient is defined by

$$C_{np} = \frac{F_n}{1/2 \; \rho \; V^2 \; S} \tag{2}$$

where F_n is the hydrodynamic force normal to the keel,

ρ is the mass density of water,

V is the horizontal velocity, and

S is the projection of wetted area normal to the keel.

For the semi-infinite flat plate, both C_{np} and the pressure distribution are functions only of the trim angle. From page 6 of Smiley,[1]

$$(C_{np})_c = \frac{2\pi}{\cot \frac{\tau}{2} \cos \tau \; (\tan \frac{\tau}{2}) \; \ell n \; (\frac{2}{1-\cos \tau}) + \pi - \tau - \sin \tau} \tag{3}$$

where τ is the trim angle in radians.

In their description of the longitudinal pressure distribution on the planing semi-infinite flat plate, Pierson and Leshnover[4] used potential flow theory and conformal transformations to develop the following two equations:

$$\frac{P}{1/2\ \rho\ V^2} = 1 - \left(\frac{\xi - \cos\tau}{1 - \xi\cos\tau + \sin\tau\sqrt{1 - \xi^2}} \right)^2 \tag{4}$$

$$\frac{X}{\delta} = \frac{1}{\pi\ (1 - \cos\tau)} \left[(1+\xi)\cos\tau - (1 - \cos\tau)\ \ln\left(\frac{1-\xi}{2}\right) - \sqrt{1 - \xi^2}\ \sin\tau - \sin\tau\ \cos^{-1}\xi + \pi\sin\tau \right] \tag{5}$$

where P is the pressure,

X is the distance measured from the trailing edge of the plate,

V is the horizontal velocity,

δ is the spray thickness at an infinite distance forward of the plate-water interface, and

ξ is a part of the conformal transformation function and is known to have the limits $-1 \leq \xi \leq 1$.

Equations (4) and (5) can be evaluated for a given value of ξ. However, the ratio X/δ is not useful because δ is unknown. Equation (5) may be normalized with respect to the X value at which the maximum pressure occurs X_m by determining the value of ξ that yields maximum pressure ξ_m. Setting

$$\frac{d\left(\frac{P}{1/2\ \rho\ V^2}\right)}{d(\xi)} = 0 \tag{6}$$

in Equation (4) results in

$$\xi_m = \cos\tau \tag{7}$$

Substitution of Equation (7) in Equation (5) produces an expression for X_m/δ:

$$\frac{X_m}{\delta} = \frac{1}{\pi(1-\cos\tau)} \left[(1+\cos\tau)\cos\tau - (1-\cos\tau)\ln\left(\frac{1-\cos\tau}{2}\right) - \sin^2\tau - \tau\sin\tau + \pi\sin\tau\right] \tag{8}$$

Dividing Equation (5) by Equation (8) yields the ratio

$$\frac{X}{X_m} = \frac{(1+\xi)\cos\tau - (1-\cos\tau)\ln\left(\frac{1-\xi}{2}\right) - \sqrt{1-\xi^2}\sin\tau - \sin\tau\cos^{-1}\xi + \pi\sin\tau}{(1+\cos\tau)\cos\tau - (1-\cos\tau)\ln\left(\frac{1-\cos\tau}{2}\right) - \sin^2\tau - \tau\sin\tau + \pi\sin\tau} \tag{9}$$

Equations (4) and (9) may be used to determine the pressure distribution on an infinitely wide planing flat plate having a positive trim angle.

The average normal-load coefficient for a two-dimensional flat plate C_{np}, previously mentioned in Steps 1 and 2, is a function of trim angle and aspect ratio λ_t. Faired curves that depict this functional relationship for aspect ratios of less than 3.5 are presented by Smiley[1] (page 25) and may be approximated by:

$$C_{np} = C_{npo}\, e^{-A\lambda_t^{B}} \tag{10}$$

where C_{npo} equals the value of C_{np} for an aspect ratio of 0 and is defined by Equation (3) and λ_t is the wetted length in beams, as illustrated in Figure 1. The values of A and B were determined empirically and have the following values: $A = 0.51\,(\frac{\pi}{2} - \tau)^2$ and $B = 0.997\sqrt{\tau}$.

The correlation obtained between the values derived by Equation (10) and the Smiley graphical values[1] were sufficient for $\lambda_t < 3.5$.

For $\lambda_t > 3.5$, however, it was necessary to conduct additional studies in order to develop a method for accurately predicting C_{np}. Locke[5] postulated that the lift (or load) coefficient could be approximated closely by the normal-force coefficient. According to Locke, the normal-force coefficient may be defined as:

$$C_N = 2.0\sin^2\tau \tag{11}$$

where τ is the angle of attack for an airfoil of zero aspect ratio. For a planing hull, the aspect ratio λ_t is defined as the reciprocal of the ratio defined for Equation (11), and, therefore, Equation (11) becomes the limit of C_N as λ_t approaches infinity. Locke stated that the sine term of Equation (11) could be approximated by a simple power function. The simple power function for planing surfaces is

$$C_{np} = \eta \gamma L \tau_d^{\,n} \tag{12}$$

where L and n are a function of the length to beam (aspect) ratio,
γ is an "efficiency" term dependent on the deadrise angle, and
τ_d is the angle of attack in degrees.

Since it is a flat plate that is under consideration, the deadrise angle is zero, and $\gamma = 1.0$.

The equation then becomes

$$C_{np} = \eta L \tau_d^{\,n} \tag{13}$$

where $L = 0.667 \ln (1/\lambda_t) - 3.91$,
$n =- 0.156 \ln (1/\lambda_t) + 1.148$, and
λ_t is the wetted length in beams.

The preceding equations for L and n were empirically derived by using the information supplied by Locke.[5] The η of this equation is defined as the ratio between the lift coefficient of a surface and the lift coefficient of a rectangular planform airfoil having the same aspect ratio and angle of attack. Locke suggested that a value of 0.5 was appropriate for n in the case of a flat-bottom planing surface. This results in the following form of Equation (13)

$$C_{np} = 0.5L \tau_d^{\,n} \tag{14}$$

However, for various ranges of aspect ratio and Froude number, η may be greater than the value of 0.5 used by Locke in Figure 6 of Reference 5. In fact, for certain regions, the value of η may be greater than 1.0. Equation (14) may be used to prove this point since C_{np} actually approaches or is less than $\sin^2 \tau$ of λ_t, instead of $2.0 \sin^2 \tau$, the originally stated limiting value. This would seem to indicate that the suggested value of $\eta = 0.5$ should be revised upward.

However, because experimental evidence to support this conjecture was lacking, η was assumed to be equal to 0.5, and the following rationale was employed in order to obtain the most conservative results for C_{np} over the wide variety of λ_t encountered. It was found that Equation (10) gave the most realistic answers for all $\lambda_t < 1.0$, and therefore it was utilized exclusively in this range. For all $\lambda_t > 1.0$, the value of C_{np} was calculated twice, once by using Equation (10) and once by using Equation (14). The higher of the two calculations was selected and compared to $2.0 \sin^2 \tau$, and the greater of the two was selected as the value for C_{np}.

The effect of the deadrise angle of the prismatic wedge on the pressure distribution can be accounted for by using the process suggested by Locke, who incorporated the efficiency term γ in the calculation of C_{np}. However, as stated previously, C_{np} for the wedge was assumed to be the same as that for an equivalent flat plate, in which case γ would always be equal to unity. For this reason, the efficiency term was incorporated in the calculation of the maximum centerline pressure. Locke suggested two different relationships of efficiency versus deadrise angle--one was a curve presented by Bollay and the other was a straight line approximation. Since the cosine of the deadrise angle satisfactorily approximated the behavior of the Bollay curve, the cosine was employed to include the effect of the deadrise angle on the maximum pressure. This procedure was found to give the best correlation between the theoretical and experimental results examined.

Therefore, the maximum pressure was taken to be

$$Pm = 1/2 \rho V^2 \cos \beta$$

rather than

$$P_m = 1/2 \rho V^2$$

Thus, the right side of Equation (4) should be multiplied by cosine β to obtain the centerline pressure distribution which is still normalized to the value of $P_m = 1/2 \rho V^2$, i.e.,

$$\frac{P}{1/2\ \rho\ V^2} = \left(1 - \frac{\xi - \cos\tau}{1 - \xi\cos\tau + \sin\tau\sqrt{1-\xi^2}}\right)^2 \cos\beta \tag{15}$$

In summary, when the trim, deadrise angle, and wetted length of a planing wedge are known, the procedure for finding the centerline pressure distribution is as follows.

1. Calculate C_{np} from either Equation (10) or Equation (14), according to the previously specified conditions, and obtain $\bar{P}/P_c$ by integrating the transverse pressure distribution obtained from Equations (16) and (17) as presented in the section that follows.

2. Calculate $(C_{np})_c$ from Equation (1).

3. Use Equation (3) to find an "equivalent trim angle" for $(C_{np})_c$ calculated from Equation (1). Use iteration to find the inverse function in Equation (3).

4. Substitute the calculated equivalent trim for τ in Equations (15) and (9), and assign to ξ values between +1 and -1 to determine the longitudinal pressure distribution along the centerline.

This distribution is valid only in the wet-chine region. The centerline pressure in the dry-chine region is found by averaging the distribution predicted by Steps 1 to 4 with the centerline distribution predicted by immersing wedge theory. This is explained in the section on transverse pressure distribution in the dry-chine region.

TRANSVERSE PRESSURE DISTRIBUTION IN WET-CHINE REGION

The following equations (taken (pp. 3-15) from a Stevens Institute of Technology report)[7] were used to calculate the transverse pressure distribution in the wet-chine region. The nomenclature is that used by Smiley.[1]

$$\frac{P}{P_c} = 1 - \left(\frac{\cos\varepsilon}{1 + \sin\varepsilon}\right)^{2h} \tag{16}$$

$$\frac{Y}{C} = 4\ k(\cos\beta) \int_{\varepsilon}^{\pi/2} (1 + \sin\varepsilon)^h\ (\cos\varepsilon)^{1-h}\ d\varepsilon \tag{17}$$

where P_c is the pressure at the wedge centerline,

$h = (\pi - 2\beta)/\pi$ (β is the deadrise angle in radians),

y is the distance from the centerline,

c is one-half the beam,

$$k = 1/\left[4 \cos \beta \int_0^{\pi/2} (1 + \sin \varepsilon)^h (\cos \varepsilon)^{1-h} (\sin \varepsilon)\, d\varepsilon\right], \text{ and}$$

ε is a quantity that is known to vary only between 0 and $\pi/2$.

The length of the wetted chine region λ_{wc} will be defined later.

TRANSVERSE PRESSURE DISTRIBUTION IN DRY-CHINE REGION

The following equations were developed[1,7,8] to describe the transverse pressure distribution in the dry-chine region.

$$\frac{P}{1/2\, \rho\, V^2} = \left[\frac{\pi \cot \theta}{\sqrt{1 - (Y/W)^2}} - \frac{1}{(W/Y)^2 - 1}\right] \sin^2 \tau \qquad (18)$$

where $\theta = \tan^{-1}\left(\frac{\pi}{2}\sqrt{\frac{\sin^2 \beta + K^2 \tan^2 \tau}{K^2 - 2 K \sin^2 \beta - K^2 \sin^2 \beta \tan^2 \tau}}\right)$,

$$K \approx \frac{\pi}{2}\left(1 - \frac{3 \tan^2 \beta \cos \beta}{1.7\, \pi^2} - \frac{\tan \beta \sin^2 \beta}{3.3\, \pi}\right), \text{ and}$$

W is the wetted semiwidth; see Figure 1.

For a certain range of combinations of β and τ, the angle θ is undefined, according to Equation (18). For programing purposes, a linear approximation was added to smoothly define the function so that $\theta = 90°$ when $\beta = 90°$. This was required only when θ approached $90°$.

It was desirable to find Y/W in terms of Y/C so that Y/C could be specified, and complete longitudinal pressure lines could be drawn at transverse stations away from the centerline. This was accomplished simply by setting

$$\frac{Y}{W} = \frac{Y}{C}\left(\frac{C}{W}\right)$$

For convenience, W was assumed to range linearly from c at the end of the wetted-chine region to 0 at the end of the wedge. (In reality, this line may be slightly curved.) Thus,

$$W = \left(\frac{\lambda_t - X}{\lambda_t - \lambda_{wc}}\right) C \text{ for } X > \lambda_{wc} \text{ (dry-chine region)}$$

where λ_t is the total wetted length (Figure 1) and

$$\lambda_{wc} = \lambda_t - \frac{\tan \beta}{\pi \tan \tau} \tag{19}$$

as derived in Appendix A.

According to the preceding equations, which were derived by considering the flow around an infinitely long immersing wedge, the centerline pressure was constant throughout the dry-chine region. This would, of course, produce discontinuities at the front edge of the wedge and most probably at the boundary between the dry-chine and wet-chine regions. It would seem that the true pressures lie somewhere between these values and those predicted by Equations (3) and (15) for an equivalent planing flat plate, and this is indicated by available experimental data. Therefore, in the dry-chine region, the numerical average of the two calculated distributions was taken as a first approximation to the centerline pressure distribution. Typical results are shown in Figures 2a and 3a.

A computer program was written to perform the calculations described in the preceding sections; see Appendix B. Figures 2 and 3 compare typical results obtained from the program with experimental data. Although the comparison was generally good, there is still scope for improving the method for calculating the varying wetted width in the dry-chine region. However, the amount of experimental data available for comparison does not seem to justify such a modification at present. A sample of computer input data and printout for Case 3 (Figure 3) is shown in Appendix C.

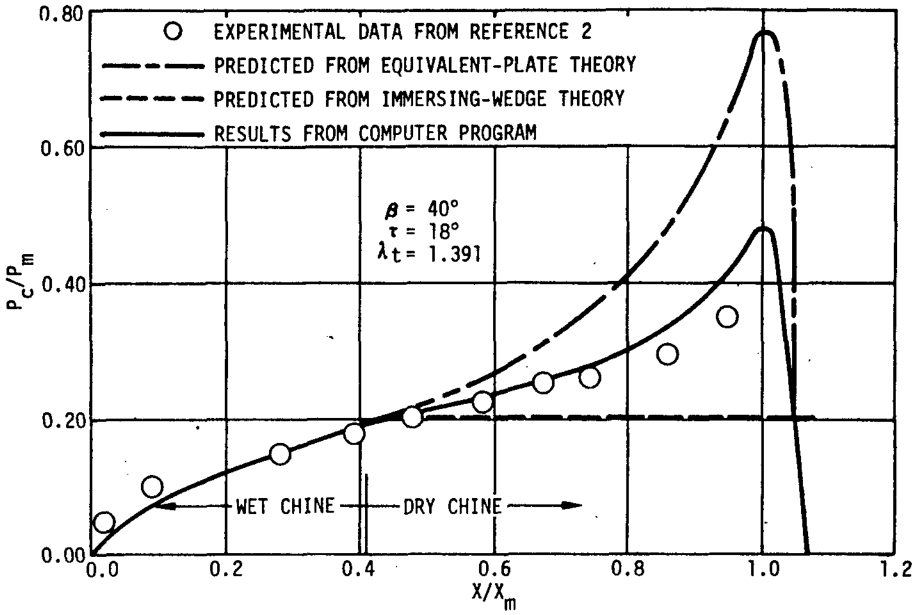


Figure 2a - Centerline

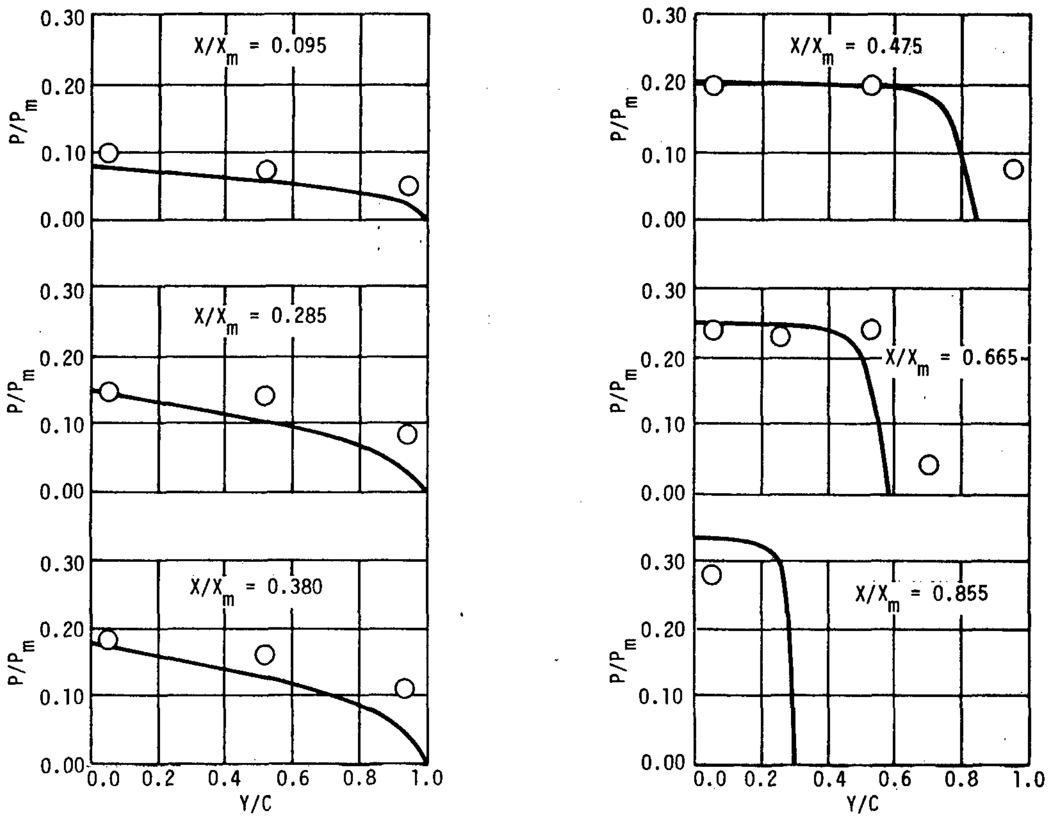


Figure 2b - Transverse

Figure 2 - Pressure Distributions for Case 1

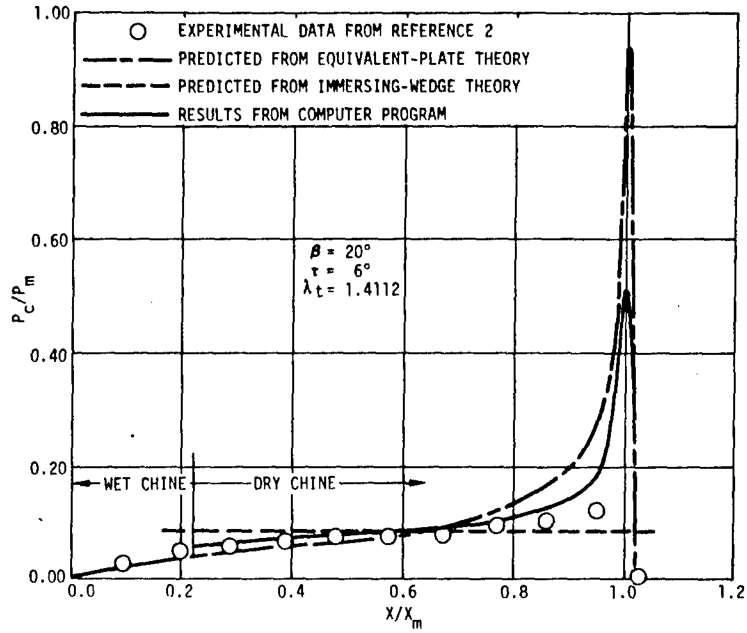


Figure 3a - Centerline

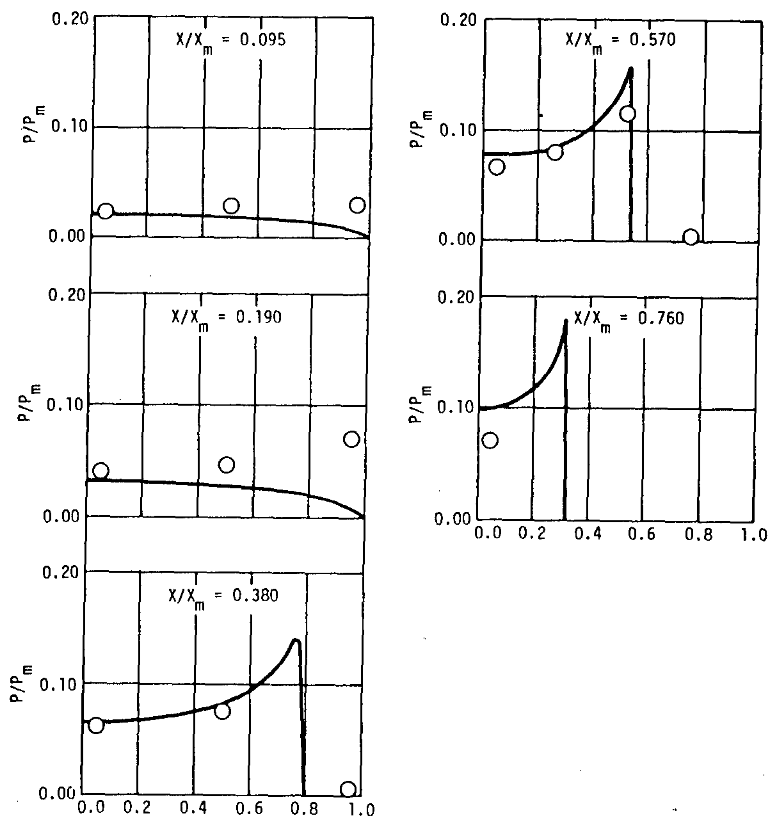


Figure 3b - Transverse

Figure 3 - Pressure Distributions for Case 2

SLAMMING OF PRISMATIC WEDGES

Smiley[1] suggested that with certain exceptions,[1,9,10] the pressure distribution on a wedge impacting with both vertical and horizontal velocity was qualitatively the same as the pressure distribution that occurred during planing. Quantitatively, however, the maximum pressure during this type of slamming is $P_m = 1/2\ \rho\ \dot{f}^2$ rather than $P_m = 1/2\ \rho\ V^2$ as in planing. Here $\dot{f}$ is the "equivalent planing velocity" and is defined by:

$$\dot{f} = V + u \cot \tau = \frac{V_n}{\sin \tau}$$

where u is the vertical velocity, and V_n is the velocity normal to the keel.

Thus the pressure distribution for slamming is found by substituting $\dot{f}$ for V in Equations (15) and (18). This will not change the geometric shape of the distribution.

It would seem that the greatest pressure due to slamming occurs in the dry-chine region. For this case, the pressure distribution would be calculated from Equation (18) written in the form

$$\frac{P}{1/2\ \rho\ \dot{f}^2} = \left[\frac{\pi \cot \theta}{\sqrt{1 - (Y/W)^2}} - \frac{1}{(W/Y)^2 - 1}\right] \sin^2 \tau \qquad (20)$$

Note that for the special case of vertical slamming at a trim angle of 0°, Equation (20) would appear as:

$$\frac{P}{1/2\ \rho\ V_n^2} = \frac{\pi \cot \beta}{\sqrt{1 - (Y/W)^2}} - \frac{1}{(W/Y)^2 - 1} \qquad (21)$$

At present, data are insufficient to prove the validity of Equation (20). It can also be seen that the problem of the pressure ratio approaching infinity as θ approaches zero has not been dealt with. However, this problem has been investigated experimentally by Chuang who has obtained data for the vertical impact of wedges with deadrise angles less than 15°. This work is closely related to the problem under investigation since Equation (20) would appear as Equation (21) for the special case of vertical slamming at a trim angle of 0°. Chuang has demonstrated that classical theories fail at these small angles of deadrise because of the presence of trapped air, and he has presented empirical formulas for determining the maximum pressures. It is planned to utilize these data in the future to allow valued results to be obtained in the low trim, low deadrise angle ranges.

CONCLUDING REMARKS

The computer program developed from the theory presented in this report yields results that are in reasonable agreement with available experimental planing data. Also, there is reason to believe that the Smiley[1] assumption of the qualitative sameness of planing and slamming pressure distributions is valid; even though the evidence available at this time is not truly conclusive.

Most of the experimental data available for comparison are for relatively low aspect ratios of less than 4; however, it is probable that the computer program will provide reasonable results for aspect ratios as high as 10 or more.

The proposed method may yield discontinuities at both ends of the dry-chine region. These discontinuities may not be visible in the theoretical curves presented here because pressures were calculated at finite increments, and the curve was drawn smoothly through the calculated points. In most instances, the discontinuities were slight except at the forward edge of the wedge, where the predicted pressure was a finite value instead of zero.

FUTURE DEVELOPMENTS

Although it appears possible to obtain a reasonable approximation of the centerline pressure in the dry-chine region by taking the numerical average of the pressures predicted for a planing flat plate and for a vertically immersing wedge, it may be desirable to develop a weighted average according to the trim and deadrise angles. Intuitively, it would appear that the dry-chine region of a planing wedge resembles a vertically immersing wedge for cases of high trims and deadrise angles; however, the dry-chine region is more like a planing flat plate for cases of low trims and deadrise angles. In addition, this weighted function could be made to eliminate discontinuities in the pressure distribution at the ends of the dry-chine region.

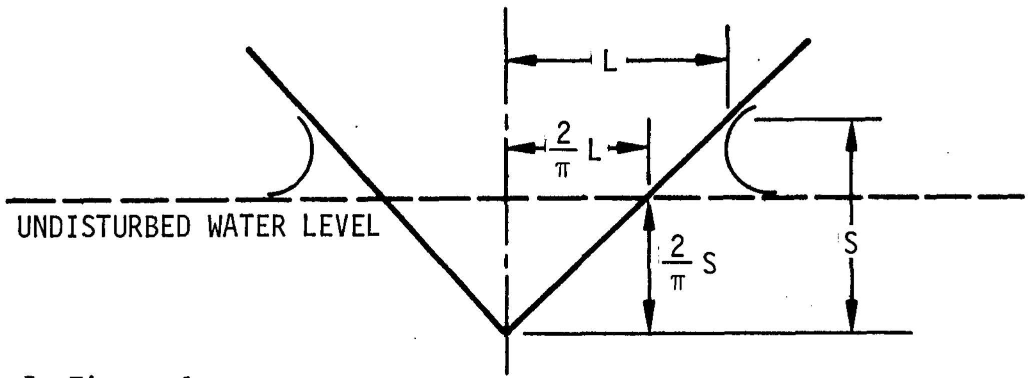
The theories and calculations presented in this report describe the pressure distributions on prismatic V-shaped wedges during impact or planing in calm water. It is believed that a first approximation to the pressure distribution on realistic hulls in various sea states may be obtained by choosing appropriate problem parameters.

A more accurate estimation might be obtained by approximating a realistic hull shape with a series of prismatic V-shaped slices having various deadrise angles and trims. The pressure distribution on each slice could then be calculated as if the whole hull were composed of that particular wedge shape extended to equal the original length of the hull. A procedure similar to that used by Jensen[3] could be employed to determine the dimensions for each wedge increment.

APPENDIX A

DERIVATION OF THE WETTED LENGTH OF THE WET-CHINE REGION λ_{wc}

The wave rise on an immersing wedge is described by the following figure taken from Pierson.[12]



In Figure 1--

$$\overline{AB} = \overline{DG} = \text{height of wedge} = C \tan \beta$$

However, since all lengths may be normalized with respect to the beam and since C = beam/2, the previously described equality may be written as:

$$\overline{AB} = \overline{DG} = (1/2) \tan \beta$$

The length $\overline{AE}$ in Figure 1 may be expressed by

$$\overline{AE} = \frac{\overline{AB}}{\tan \tau} = \frac{\tan \beta}{2 \tan \tau}$$

It can be seen that $\overline{FD}/\overline{AB} = 2/\pi$ because in the figure shown above $\overline{FD}$ corresponds to $2/\pi$ S, and $\overline{AB}$ corresponds to S.

From similar triangles:

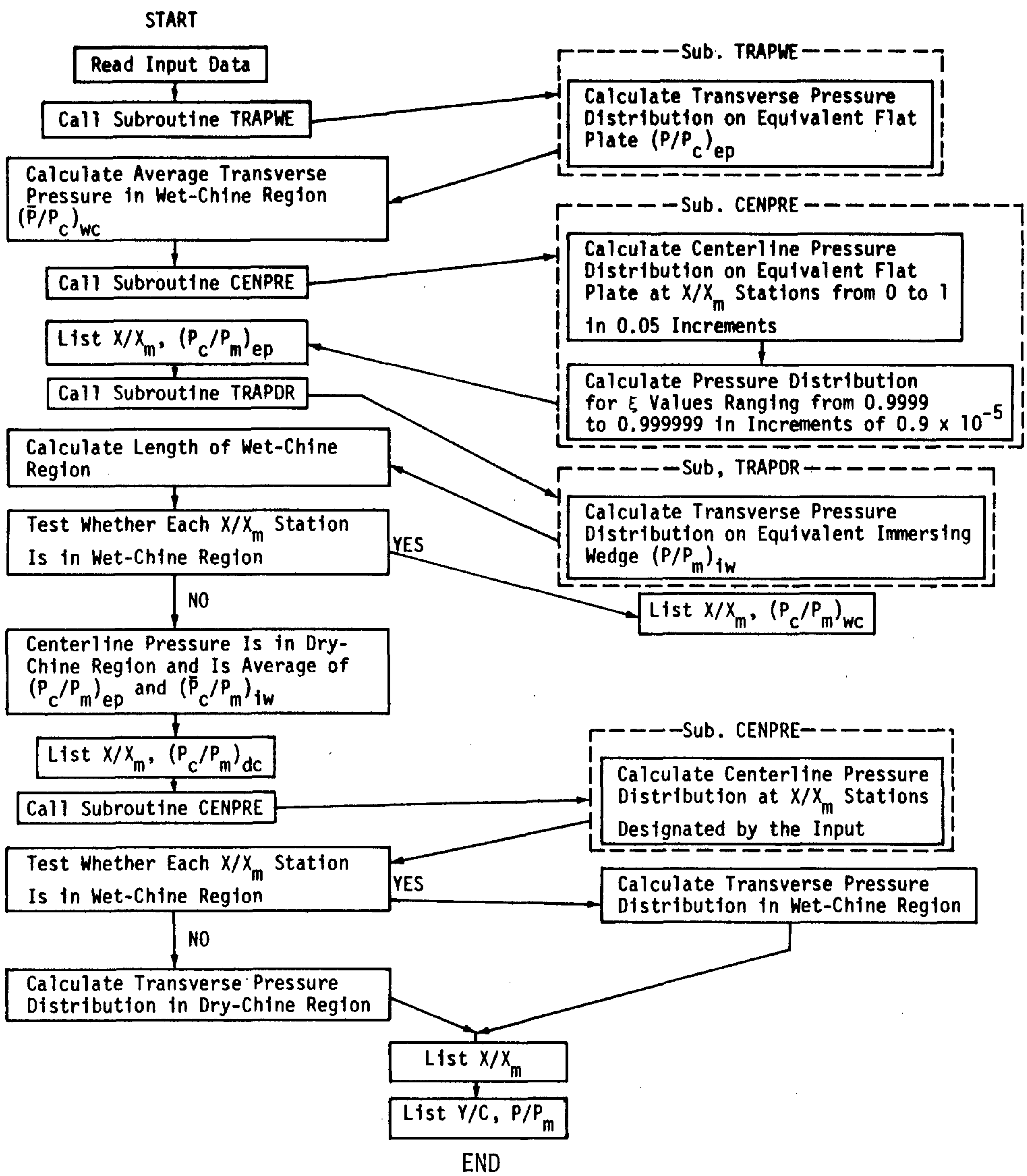
$$\frac{\overline{AB}}{\overline{AE}} = \frac{\overline{FD}}{\overline{DE}} \text{ and } \overline{DE} = \left(\frac{\overline{FD}}{\overline{AB}}\right)\overline{AE} = \frac{2}{\pi}\,\overline{AE} = \frac{1}{\pi}\,\frac{\tan \beta}{\tan \tau}$$

Therefore

$$\lambda_{wc} = \lambda_t - \overline{DE} = \lambda_t - \frac{1}{\pi}\,\frac{\tan \beta}{\tan \tau}$$

APPENDIX B

PROGRAM FLOW DIAGRAM



APPENDIX C

SAMPLE PROBLEM

The sample problem illustrates the program used with the Case 3 data, corresponding to Run 5 of Model 301,[2] namely, $\tau = 6°$, $\beta = 20°$, and $\lambda_t =$ 1.4112 beams. The X/X_m stations were chosen to coincide with the stations at which experimental transverse pressure data were available. They ranged from $X/X_m = 0.095$ to $X/X_m = 0.95$ in increments of 0.095. The Y/C stations ranged from 0 to 1 with increments of 0.05 in the wet-chine region and increments of 0.025 in the dry-chine region. Running time for the problem was 1.32 minutes. Figures 3a and 3b show the results of the sample problem.

THE INPUT DATA ARE--

THE TRIM ANGLE, TAU = 6.000 DEGREES

THE DEAD-RISE ANGLE, BETA = 20.000 DEGREES

THE WETTED LENGTH IN BEAMS (ASPECT RATIO) = 1.4112

X/XMAX VARIES FROM XRO= 0.095 IN INCREMENTS OF XRIN =0.0950
TO XRF = 0.950 OR TO THE END OF THE WEDGE.

Y/BEAM IN WET-CHINE AREA VARIES FROM YRWO = 0. IN INCREMENTS
OF YRWIN =0.0500 TO YRWF = 1.000.
THE NO. OF INCREMENTS FOR TRAPEZOID RULE INTEGRATION, INTRAZ = 100

Y/BEAM IN THE DRY-CHINE AREA VARIES FROM YRDO = 0.
IN INCREMENTS OF YRDIN =0.0250 TO YRDF = 1.000.

PMAX IS (RHO(V)SQUARED)/2

THE CENTERLINE PRESSURE OF AN EQUIVALENT PLANING FLAT PLATE
IS LISTED BELOW.
X/XMAX IS MEASURED FROM THE TRAILING EDGE OF THE PLATE
AND IS TAKEN IN .05 INCREMENTS.

X/XMAX	P/PMAX
0.	0.
0.0500	0.0155
0.1000	0.0224
0.1500	0.0282
C.2000	0.0334
0.2500	0.0385
C.3000	0.0436
0.3500	0.0488
C.4000	0.0542
C.4500	0.0599
0.5000	0.0662
0.5500	0.0730
C.6000	0.0807
C.6500	0.0897
C.7000	0.1003
0.7500	0.1135
0.8000	0.1307
0.8500	0.1549
0.9000	0.1941
C.9500	0.2780
1.0000	0.9397

A CLOSER INSPECTION OF THE PRESSURE DISTRIBUTION AT THE FRONT EDGE OF THE PLATE IS MADE SO THAT THE VALUE OF (WETTED LENGTH)/XMAX MAY BE ESTIMATED.

X/XMAX	P/PMAX
1.0015	0.7680
1.0015	0.7524
1.0016	0.7347
1.0017	0.7146
1.0017	0.6914
1.0018	0.6643
1.0019	0.6321
1.0020	0.5929
1.0021	0.5432
1.0023	0.4767
1.0025	0.3765
1.0033	0.1444

THE LENGTH OF THE WET-CHINE REGION IS 0.3089.
THIS LENGTH DIVIDED BY XMAX IS 0.22

THE CENTERLINE PRESSURE DISTRIBUTION ALONG THE WEDGE IS--

X/XMAX	P/PMAX
C.	0.
0.0500	0.0155
0.1000	0.0224
C.1500	0.0282
C.2000	0.0334
C.2500	0.0599
0.3000	0.0625
0.3500	0.0651
0.4000	0.0678
C.4500	0.0706
0.5000	0.0737
C.5500	0.0772
C.6000	0.0810
0.6500	0.0855
C.7000	0.0908
C.7500	0.0974
0.8000	0.1060
0.8500	0.1181
0.9000	0.1377
0.9500	0.1797
1.0000	0.5105

NOW THE TRANSVERSE PRESSURE DISTRIBUTION AT THE X/XMAX STATIONS DESIGNATED BY THE INPUT ARE LISTED.

X/XMAX = 0.0950 TRANVERSE PRESSURE DISTRIBUTION IS--

Y/C	P/PMAX
0.	0.0218

0.0500	0.0216
0.1000	0.0214
0.1500	0.0211
C.2000	0.0209
0.2500	0.0205
0.3000	0.0202
C.3500	0.0199
0.4000	0.0195
0.4500	0.0190
C.5000	0.0185
C.5500	0.0181
C.6000	0.0174
C.6500	0.0169
C.7000	0.0162
0.7500	0.0151
0.8000	0.0142
0.8500	0.0130
0.9000	0.0114
0.9500	0.0086
1.0000	-0.

X/XMAX = 0.1900 TRANVERSE PRESSURE DISTRIBUTION IS--

Y/C	P/PMAX
0.	0.0324
0.0500	0.0321
C.1000	0.0318
0.1500	0.0314
0.2000	0.0311
0.2500	0.0305
0.3000	0.0301
0.3500	0.0296
0.4000	0.0290
0.4500	0.0282
0.5000	0.0276
0.5500	0.0269
C.6000	0.0259
0.6500	0.0251
0.7000	0.0240
0.7500	0.0225
0.8000	0.0212
0.8500	0.0194
0.9000	0.0170
0.9500	0.0128
1.0000	-0.

THE FOLLOWING X/XMAX STATION IS IN THE DRY-CHINE REGION.

X/XMAX = 0.2850 TRANVERSE PRESSURE DISTRIBUTION IS--

Y/C	P/PMAX
0.	0.0617
0.0250	0.0617
0.0500	0.0618

0.0750	0.0619
C.1000	0.0621
0.1250	0.0623
0.1500	0.0625
C.1750	0.0628
0.2000	0.0632
C.2250	0.0636
0.2500	0.0640
0.2750	0.0646
C.3000	0.0651
C.3250	0.0658
0.3500	0.0665
0.3750	0.0673
0.4000	0.0682
C.4250	0.0692
C.4500	0.0703
0.4750	0.0715
0.5000	0.0728
0.5250	0.0743
0.5500	0.0759
0.5750	0.0778
C.6000	0.0798
C.6250	0.0821
0.6500	0.0847
0.6750	0.0877
C.7000	0.0912
C.7250	0.0952
0.7500	0.0999
0.7750	0.1055
0.8000	0.1123
0.8250	0.1207
C.8500	0.1310
0.8750	0.1415
0.9000	0.1107

THE FOLLOWING X/XMAX STATION IS IN THE DRY-CHINE REGION.

X/XMAX = 0.3800 TRANVERSE PRESSURE DISTRIBUTION IS--

Y/C	P/PMAX
0.	0.0667
0.0250	0.0667
0.0500	0.0668
C.0750	0.0669
0.1000	0.0671
0.1250	0.0674
0.1500	0.0678
0.1750	0.0682
C.2000	0.0686
0.2250	0.0692
0.2500	0.0698
0.2750	0.0705
0.3000	0.0714
C.3250	0.0723
0.3500	0.0733
0.3750	0.0745

0.4000	0.0758
0.4250	0.0772
0.4500	0.0789
0.4750	0.0807
C.5000	0.0828
0.5250	0.0852
0.5500	0.0880
0.5750	0.0912
0.6000	0.0949
0.6250	0.0993
0.6500	0.1047
C.6750	0.1112
0.7000	0.1194
0.7250	0.1298
0.7500	0.1424
0.7750	0.1401

THE FOLLOWING X/XMAX STATION IS IN THE DRY-CHINE REGION.

X/XMAX = 0.4750 TRANVERSE PRESSURE DISTRIBUTION IS--

Y/C	P/PMAX
0.	0.0722
0.0250	0.0722
0.0500	0.0723
0.0750	0.0725
0.1000	0.0728
C.1250	0.0732
C.1500	0.0737
0.1750	0.0743
0.2000	0.0749
C.2250	0.0757
C.2500	0.0767
0.2750	0.0777
C.3000	0.0790
C.3250	0.0804
0.3500	0.0820
0.3750	0.0838
0.4000	0.0860
0.4250	0.0885
0.4500	0.0914
0.4750	0.0948
C.5000	0.0988
0.5250	0.1038
0.5500	0.1099
0.5750	0.1177
0.6000	0.1280
0.6250	0.1415
0.6500	0.1529

THE FOLLOWING X/XMAX STATION IS IN THE DRY-CHINE REGION.

X/XMAX = 0.5700 TRANVERSE PRESSURE DISTRIBUTION IS--

Y/C	P/PMAX
0.	0.0787
0.0250	0.0787
0.0500	0.0789
0.0750	0.0792
0.1000	0.0797
0.1250	0.0802
0.1500	0.0810
0.1750	0.0819
0.2000	0.0829
0.2250	0.0842
0.2500	0.0857
0.2750	0.0875
0.3000	0.0896
0.3250	0.0922
0.3500	0.0952
0.3750	0.0988
0.4000	0.1033
0.4250	0.1089
0.4500	0.1161
0.4750	0.1258
0.5000	0.1394
0.5250	0.1571
0.5500	0.

THE FOLLOWING X/XMAX STATION IS IN THE DRY-CHINE REGION.

X/XMAX = 0.6650 TRANVERSE PRESSURE DISTRIBUTION IS--

Y/C	P/PMAX
0.	0.0870
0.0250	0.0871
0.0500	0.0874
0.0750	0.0879
0.1000	0.0887
0.1250	0.0896
0.1500	0.0909
0.1750	0.0925
0.2000	0.0945
0.2250	0.0969
0.2500	0.1000
0.2750	0.1038
0.3000	0.1087
0.3250	0.1151
0.3500	0.1240
0.3750	0.1368
0.4000	0.1564
0.4250	0.1033

THE FOLLOWING X/XMAX STATION IS IN THE DRY-CHINE REGION.

X/XMAX = 0.7600 TRANVERSE PRESSURE DISTRIBUTION IS--

Y/C	P/PMAX
0.	0.0989
0.0250	0.0991
0.0500	0.0997
0.0750	0.1007
0.1000	0.1023
C.1250	0.1044
0.1500	0.1072
0.1750	0.1111
0.2000	0.1163
0.2250	0.1238
0.2500	0.1350
0.2750	0.1539
0.3000	0.1786

THE FOLLOWING X/XMAX STATION IS IN THE DRY-CHINE REGION.

X/XMAX = 0.8550 TRANVERSE PRESSURE DISTRIBUTION IS--

Y/C	P/PMAX
0.	0.1197
0.0250	0.1202
0.0500	0.1219
0.0750	0.1249
0.1000	0.1300
C.1250	0.1385
0.1500	0.1539
0.1750	0.1895

THE FOLLOWING X/XMAX STATION IS IN THE DRY-CHINE REGION.

X/XMAX = 0.9500 TRANVERSE PRESSURE DISTRIBUTION IS--

Y/C	P/PMAX
0.	0.1797
0.0250	0.1842
0.0500	0.2068

X/XMAX = 1.0025 IS THE FRONT EDGE OF THE WETTED LENGTH (P/PMAX=0.0)

REFERENCES

1. Smiley, R.F., "A Semi-Empirical Procedure for Computing the Water-Pressure Distribution on Flat and V-Bottom Prismatic Surfaces during Impact of Planing," National Advisory Committee for Aeronautics TN 2538 (Dec 1951).

2. Kapryan, W.J. and Boyd, G.M., Jr., "Hydrodynamic Pressure Distributions Obtained during a Planing Investigation of Five Related Prismatic Surfaces," National Advisory Committee for Aeronautics TN 3477 (Sep 1955).

3. Jensen, W.R., "Hydrofoil Boat Hull-Wave Impact Loads," Grumman Aircraft Engineering Corporation Report GE-173 (Aug 1959).

4. Pierson, J.D. and Leshnover, S., "An Analysis of the Fluid Flow in the Spray Root and Wake Regions of Flat Planing Surfaces," Institute of Aeronautical Sciences, Sherman M. Fairchild Fund Paper, Preprint 166 (Oct 1948).

5. Locke, F.W.S., "An Empirical Study of Low Aspect Ratio Lifting Surfaces with Particular Regard to Planing Craft," Journal of the Aeronautical Sciences (Mar 1949).

6. Korvin-Kroukovsky, B.V. and Chabrow, F.R., "The Discontinuous Fluid Flow Past an Immersed Wedge," Stevens Institute of Technology Report 334 (Oct 1948).

7. Pierson, J.D., "On the Pressure Distribution for a Wedge Penetrating a Fluid Surface," Instutute of Aeronautical Sciences, Sherman M. Fairchild Fund Paper FF-2 (May 1950).

9. Smiley, R.F., "An Experimental Study of Water-Pressure Distributions During Landings and Planing of a Heavily Loaded Rectangular Flat-Plate Model," National Advisory Committee for Aeronautics Technical Note 2453 (Sep 1951).

10. Smiley, R.F., "A Study of Water Pressure Distributions During Loadings with Special Reference to a Prismatic Model Having a Heavy Beam Loading and a 30° Angle of Deadrise," National Advisory Committee for Aeronautics TN 2111 (Jul 1950).

11. Chaung, S.L., "Slamming of Rigid Wedge-Shaped Bodies with Various Deadrise Angles," NSRDC Report 2268 (Oct 1966).

12. Pierson, J.D., "The Penetration of a Fluid Surface by a Wedge," Institute of Aeronautical Sciences, Sherman M. Fairchild Final Paper FF-3 (Jul 1950).

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13. ABSTRACT

A computer program has been developed which calculates the water-pressure distribution on V-bottom prismatic wedges during impact or planing. The method of computation is based on previously published semiempirical procedures with several modifications that facilitate programing and result in close correlation to recently published experimental data.

The prismatic wedge may have any positive value of trim, deadrise angle, and wetted length. The pressure distribution for the entire hull or any given section of the hull may be calculated in specified increments by using the appropriate input data. Results obtained from the program are in reasonable agreement with certain published experimental planing data.

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Three-Dimensional Pressure Distributions						
Impact						
Planing						
Prismatic Wedges						