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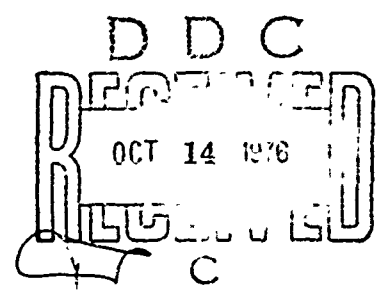
A LIFTING LINE COMPUTER PROGRAM
FOR PRELIMINARY DESIGN OF PROPELLERS

by

E.B. Caster

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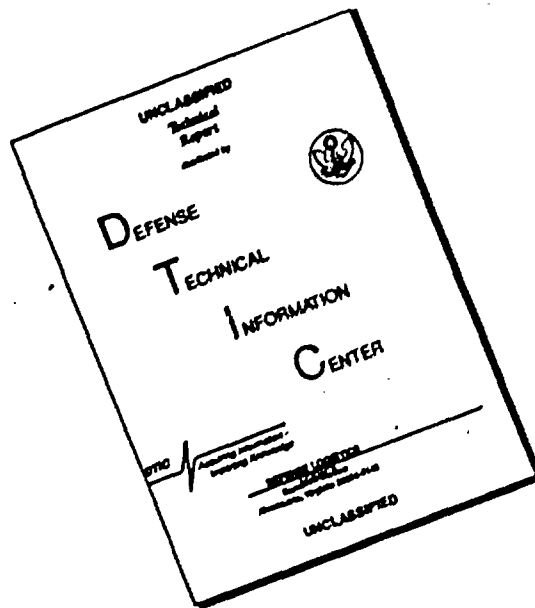
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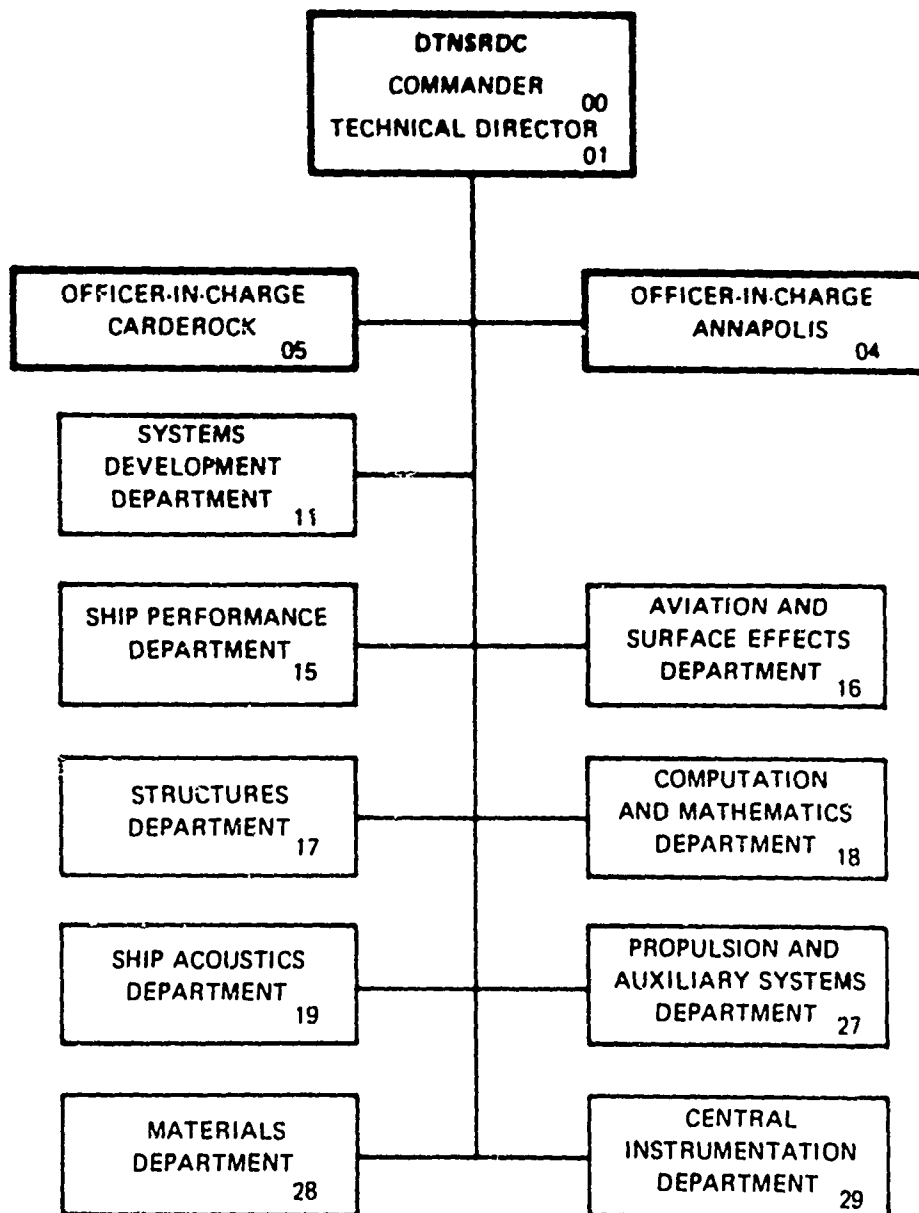
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REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER SPD-595-01	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) A Lifting Line Computer Program for Preliminary Design of Propellers		5. TYPE OF REPORT & PERIOD COVERED Departmental/Final
7. AUTHOR(s) E.B. Caster J.A. Diskin T.A. LaFone		8. PERFORMING ORG. REPORT NUMBER SPD-595-01
9. PERFORMING ORGANIZATION NAME AND ADDRESS David W. Taylor Naval Ship Research and Development Center Bethesda, Maryland 20084		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS Task 15942 Work Unit No. 1524-462 1500-001
11. CONTROLLING OFFICE NAME AND ADDRESS Naval Sea Systems Command (S034) Washington, D.C. 20362		12. REPORT DATE November 1975
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)		13. NUMBER OF PAGES 143
		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE
16. DISTRIBUTION STATEMENT (of this Report) Approved for Public Release; Distribution Unlimited		
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)		
18. SUPPLEMENTARY NOTES		
19. KEY WORDS (Continue on reverse side if necessary and identify by block number) Propeller Lifting Line Stress Design		
20. ABSTRACT (Continue on reverse side if necessary and identify by block number) This report presents a computer program that can be used for the preliminary design and to predict the performance of single screw propellers when designed for a prescribed hydrodynamic pitch distribution. This design program is based on lifting line theory as developed by Lerbs for moderately-loaded finite-bladed propellers. Stress calculations using beam theory are also made for each design, which take into account the effect of blade skew and rake. Design		

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calculations can be made for given design speeds where delivered shaft power is computed (Thrust Option), or for the case when the delivered shaft power is specified and the corresponding speed is computed (Power Option). A FORTRAN listing of the program, developed to run on the computers at the David W. Taylor Naval Ship Research and Development Center (DTNSRDC), is presented as well as input and output obtained for two sample designs, one using the Thrust Option, and the other the Power Option.

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NOTATION

A_E	Expanded blade area, $Z \int_{r_h}^R c \, dr$
A_E/A_0	Propeller expanded area ratio, $(2Z/\pi) \int_{x_h}^1 (c/D) \, dx$
$(A_E/A_0)_k$	Keller's minimum expanded area ratio for eliminating back bubble cavitation, $(2.6+0.6Z)K_T/(\sigma_{0.7}[J^2+(0.7\pi)^2])+K$
A_0	Disc area, $\pi D^2/4$
A_p	Estimated propeller projected area, $[1.067-0.229 (P/D)_i]A_E$
$a(x)$	Area of section, $2c(x)t(x) \int_0^1 t(x, x_\ell) \, dx$
$B(x)$	Distance of CG from hub face, $\bar{y} \cos \phi + \bar{x} \sin(\phi-\theta_S) \times R \tan(\phi-\theta_R) \times D_H/2$
$(c/R)_{LE}, (c/R)_{TE}$	Chord lengths measured from leading edge and trailing edge of blade to propeller reference line
C_D	Section drag coefficient
C_{FO}	Frictional resistance of section
CG	Center of gravity
C_L	Blade section lift coefficient
C_P	Power loading coefficient, $P_D/[(\rho/2)\pi R^2 V_A^3]$
C_{PS}	Power loading coefficient based on ship speed, $P_D/[(\rho/2)\pi R^2 V^3]$; calculated $\int_{x_h}^1 (1 + \epsilon \tan \beta_I) (dC_{PSi}/dx) \, dx$
C_{Th}	Thrust loading coefficient, $T/[(\rho/2)\pi R^2 V_A^2]$
C_{TS}	Thrust loading coefficient based on ship speed, $T/[(\rho/2)\pi R^2 V^2]$; calculated $\int_{x_h}^1 (1 - \epsilon \tan \beta_I) (dC_{TSi}/dx) \, dx$
C_{ThP}	Power loading coefficient, $\int_{x_h}^1 (1 - w_x) (1 - \epsilon \tan \beta_I) (dC_{TSi}/dx) \, dx$
c	Propeller blade chord length, $c(x)$

C_{PSI}	Inviscid power loading coefficient, $(4Z/\lambda_s) \times G[(1-w_x) + U_T/2V]$
C_{TSI}	Inviscid thrust loading coefficient, $4ZG[(x/\lambda_s) - U_A/2V]$
D	Propeller diameter
D_h	Hub diameter
$F(y)$	Parameter for calculating the fluctuating angles of attack, $1/[1+2\pi \tan(\beta_1 - \beta)/C_L]$
f_M	Camber
g	Acceleration due to gravity
$G(r)$	Nondimensional circulation about a blade section $\Gamma/(2\pi RV)$
G_F	Spacing between fillets
G_Z	Spacing between blades at the hub
H	Static head at propeller shaft centerline
I_{x_0}, I_{y_0}	Moment of inertia of blade section about x and y axes
J	Advance coefficient, $V(1-w_T)/(nD) = V_A/(nD)$
J_V	Ship speed advance coefficient, $V/(nD)$
K	Kellers' constant for predicting minimum blade area of propeller (see p. 22)
K_Q	Torque coefficient, $Q/(\rho n^2 D^5)$
K_T	Thrust coefficient, $T/(\rho n^2 D^4)$
L_I	Propeller lift distribution per unit span for finite element stress calculations
M_p	Moment of blades, see page 34

M_{Tb}, M_{Qb}	Moment due to thrust and torque
M_{xo}, M_{yo}	Moment parallel and perpendicular to the nose - tail line
n	Propeller revolution per unit time
$(P/D)_i$	Estimated propeller pitch ratio at 0.7 radius, $0.7\pi \tan \beta_1$ in program
P_D	Delivered power at propeller, $2\pi Qn$
P_E	Effective power
P_S	Shaft power
Q	Propeller torque
R	Propeller tip radius
rpm	Propeller revolutions per minute
r	Propeller local radius
r_h	Propeller hub radius
r_ℓ	Local position along the section chord
T	Propeller thrust
t	Propeller blade maximum thickness $t(x)$, thrust deduction fraction
$t(x, x_\ell)$	Chordwise distribution of section thickness (NACA 66 modified thickness form is used)
$U_A/2V$	Axial induced velocity at lifting line
$U_T/2V$	Tangential induced velocity at lifting line
V	Ship speed
V_A	Speed of advance of the propeller, $V(1-w_T)$

V_x	Local velocity along the x axis at any field point
V_r	Inflow velocity at each propeller section, $V\sqrt{[(1-w_x)+U_A/2V]^2 + [X/\lambda_s - U_T/2V]^2}$
w_a/V	Axial velocity from sources other than the propeller wake $(1-w_x)$
w_B	Weight of blades
w_H	Weight of hub
w_P	Propeller weight
w_c	Circumferential mean wake fraction at each radius calculated from wake survey
w_t/V	Tangential velocity from sources other than the propeller wake $(1-w_x)$
w_T	Propeller effective wake fraction as determined from thrust identity from self propulsion experiment
w_v	Volume mean wake fraction
w_x	Propeller wake fraction, $1-[(1-w_T)/(1-w_v)](1-w_c)$
x	Nondimensional radial distance, r/R
x_h	Nondimensional hub radius, r_h/R
x_ℓ	Nondimensional distance along section chord, r_ℓ/c
Z	Number of blades
Z_R	Propeller rake
Z_T	Total rake, rake plus skew induced rake

α_i	Section ideal angle of attack, $1.54C_L$ for NACA $a=0.8$ meanline in two dimensional flow
α_{max}	Maximum fluctuating angle of attack, $\alpha_i - (-\Delta B)F(x)$
α_{min}	Minimum fluctuating angle of attack, $\alpha_i - (+\Delta B)F(x)$
β	Advance angle of a propeller blade section
β_I	Hydrodynamic flow angle of a propeller blade section
Γ	Circulation about a propeller blade section,
ϵ	Section drag-lift ratio, C_D/C_L
η_D	Propulsive efficiency, $P_E/P_D = (1-t)C_{TS}/C_{PS}$
η_{Pe}	Estimated propeller efficiency, C_{THP}/C_{PS}
θ_R	Blade rake angle in degrees
θ_S	Blade skew angle in degrees
λ_S	Advance ratio of propeller based on ship speed, $V/(\pi nD)$
ρ	Water density
ρ_p	Density of propeller material
ϕ	Pitch angle
σ	Section cavitation number, $2gH/V_r^2$
$\sigma_{0.7}$	Burrill cavitation number, $2gH/[\{V(1-w_{x=0.7})\}^2 + \{0.7\pi nD\}^2]$
τ_C	Burrill thrust loading coefficient, $T/[\{V(1-w_{x=0.7})\}^2 + \{0.7\pi nD\}^2]$

ABSTRACT

This report presents a computer program that can be used for the preliminary design and to predict the performance of single screw propellers when designed for a prescribed hydrodynamic pitch distribution. This design program is based on lifting line theory as developed by Lerbs for moderately-loaded finite-bladed propellers. Stress calculations using beam theory, propeller weight, moments of inertia, and center of gravity for specified hubs are also made for each design, which take into account the effect of blade skew and rake. Design calculations can be made for given design speeds where the corresponding shaft power is computed (thrust option), or for the case when the shaft power is specified and the corresponding speed is computed (power option). A FORTRAN listing of the program, developed to run on the computers at the David W. Taylor Naval Ship Research and Development Center (DTNSRDC) is presented as well as the input and output obtained for two sample designs, one using the thrust option, and the other the power option.

ADMINISTRATIVE INFORMATION

This work was sponsored by the Naval Ship Systems Command, SHIPS 034, and carried out under the David W. Taylor Naval Ship Research and Development Center (DTNSRDC) Work Unit No. 1524-462, Task 15942.

INTRODUCTION

The David W. Taylor Naval Ship Research and Development Center (DTNSRDC), Carderock Laboratory, was requested by the Naval Ship Systems Command (NAVSHIPS) to develop a computer program that can be used as an aid in determining optimum values of propeller design parameters such as diameter, rpm, and blade number for naval vessels. This report has the objective of presenting a computer program that can be easily used for the preliminary design and for prediction of the performance of propellers applicable to specific ships.

The main portion of the computer program makes preliminary propeller design calculations and performance predictions using Lerbs' lifting line moderately-loaded finite-bladed propeller theory of References 1 and 2. Once the lifting

1. Lerbs, H.W., "Moderately Loaded Propellers with a Finite Number of Blades and an Arbitrary Distribution of Circulation," Transactions of the Society of Naval Architects and Marine Engineers, Vol. 60, p 73-117, 1952
2. Morgan, W.B. and Wrench, J.W., Jr., "Some Computational Aspects of Propeller Design," Methods in Computational Physics, Vol. 4, Academic Press Inc., New York, p 301-331, 1965

line calculations for the propeller have been obtained, a computer program based on lifting surface theory must be used to determine the final pitch and camber of the propeller³. Numerous experimental checks⁴ on the design procedure used have verified this procedure.

A computer program for the preliminary design of propellers having a prescribed pitch or circulation distribution was previously published in Reference 5. One of the most important new features of the new computer program is the power option which computes the speed automatically when the design power is specified. Other features included in the present computer program follows:

1. Only one set of basic input data is required for the preliminary design of a series of propellers with rpm, blade number and expanded area ratio varied. Any number of basic sets of data can be specified in the computer program.

-
3. Morgan W.B., Silovic, Vladimir and Denny, Stephen B., "Propeller Lifting-Surface Corrections," Transactions of the Society of Naval Architects and Marine Engineers, Vol. 76, p 309-347, 1968
 4. Boswell, R.J., "Design, Cavitation Performance and Open-Water Performance of a Series of Research Skewed Propellers," Naval Ship Research and Development Center Report 3339, March 1971
 5. Haskins, E.W., "Calculations of Design Data for Moderately Loaded Marine Propellers by Means of Induction Factors," Naval Ship Research and Development Center Report 2380, September 1967

2. The propeller stress, based on beam theory⁶, modified to account for the effect of rake and skew, is computed for each design. An input option is used to make stress calculations for a linear or nonlinear distribution of blade skew.

3. Parameters required to make blade surface cavitation checks using the Burrill cavitation charts of Reference 7 and Brockett's incipient cavitation diagrams of Reference 8 are calculated on the computer. In addition, Keller's method⁹ of predicting the minimum expanded area ratio based on back bubble type cavitation, is calculated. The estimated propeller weight including the hub, and input parameters required for the lifting surface computer program used to calculate the final pitch and camber of propeller designs are some of the other parameters calculated.

-
6. Eckhart, M.K. and Morgan, W.B., "A Propeller Design Method," Transactions of the Society of Naval Architects and Marine Engineers, Vol. 63, p 305-370, 1955
 7. Burrill, L.C. and Emerson, A., "Propeller Cavitation: Further Tests on 16 Inch Propeller Models in the Kings College Cavitation Tunnel," Transactions of the North East Coast Institution of Engineers and Ship Builders, Vol. 78, p 295-320, 1963-64
 8. Brockett, Terry, "Minimum Pressure Envelopes for Modified NACA-66 Sections with NACA a=0.8 Camber and BUSHIPS Type I and Type II, Sections," David Taylor Model Basin Report 1780, 1966
 9. Keller, J. Auf'm, "Enige aspecten bij het ontwerpen van Scheepsschroeven," Schip en Werk, No. 24, p 658-662, 1966

PROPELLER LIFTING LINE THEORY

The availability of high speed digital computers has made it now possible to make use of more adequate mathematical models to represent the hydrodynamic action of marine propellers. The computer has also released the designer from performing laborious computations involved in present design methods.

The lifting line theory used in the computer program presented here is the theory developed by Lerbs (Reference 1) for moderately-loaded finite-bladed propellers. This lifting line design method discussed by Cox and Morgan in Reference 10 also permits the designer to accurately account for propeller parameters such as number of blades, hub size, radial blade-loading, and wake distribution. Since this theory is discussed in detail in References 1 and 2, only some of the assumptions made in developing the theory are mentioned here. The theory developed by Lerbs' considers the influence of the induced velocities on the shape of the helical vortex sheet at the lifting line, but neglects the effect of centrifugal forces and the contraction of the slip-stream. In addition, the change in shape of the vortex lines is neglected in the axial direction, indicating that each vortex line is assumed to be of constant pitch. However, the vortex sheets are not necessarily helical surfaces since the pitch may vary along the radius.

-
10. Cox, G.G. and Morgan, W.B., "The Use of Theory in Propeller Design," Marine Technology, Vol. 9, No. 4, p 419-429, October 1972

The computer program can be used for the preliminary design of a propeller having a prescribed pitch distribution. The viscous effects of the propeller are taken into account by giving as input the blade-section drag coefficient and chord lengths. Blade stresses are computed using simple beam theory by giving as additional input the blade thickness, rake, and skew.

DESCRIPTION OF INPUT DATA

Dimensioned parameters may be input in the appropriate S.I. or English units, as specified by the user illustrated in Table 1. Effective power, shaft power, speed (V), number of blades (Z), diameter (D), rpm, propeller wake ($1-w_x$), and estimate of the hydrodynamic flow angle distribution (β_1) are required input parameters in order to make nonviscous propeller design calculation^{1,2}. The radial distribution of blade chord lengths nondimensionalized on diameter (c/D) and section drag coefficients (C_D) must also be specified as input if design calculations are to account for the propeller viscous effects. Since the computer program presented calculates the propeller principal stresses based on beam theory, the radial distribution of maximum thickness nondimensionalized on chord length (t/c), rake nondimensionalized on diameter (Z_R/D), and skew angle (θ_S) must also be input parameters. The blade section cavitation number (σ) is a required parameter in order to make blade surface cavitation checks using the Burrill cavitation diagrams of Reference 7 and Brockett's incipient cavitation

diagrams of Reference 8. By specifying the static head (H) as input data, the cavitation number (σ) is calculated on the computer. Hub dimensions can be input or assumed to be a circular cylinder of equal length and diameter as described in Appendix A. A brief description of how these input parameters can be determined will be discussed in this section.

Effective Power, Speed, and Shaft Power

Effective power and speed are normally obtained from model self-propulsion experiments. Input effective power (P_E) and shaft power (P_S) are defined as follows:

$$P_E = VT(1-t)$$

$$P_S = 2\pi nQ$$

where n = propeller revolutions

P_S = shaft power,

P_E = effective power,

Q = propeller torque,

T = propeller thrust,

V = ship speed

$(1-t)$ = thrust deduction, which may vary with
diameter and speed.

Nondimensional Radial Distance (X)

This is a reference set of eleven nondimensional radial distances x_i at which all other distributions, either input or calculated by the computer, are defined as existing. In general $x_i = r_i/R$, with the restrictions

$$x_1 = r_h/R$$

$$x_{11} = R/R=1,$$

where r_i = the distance along the propeller reference line from the shaft axis to the i th section,

r_h = propeller hub radius, and

R = propeller tip radius.

Propeller Wake

The radial distribution of the axial wake $(1-w_x)$ which varies with propeller diameter is also required input data. The circumferential mean of the axial velocity distribution $(1-w_c)$ is obtained from a wake survey without the propeller operating. However, the $(1-w_c)$ wake distribution must be corrected for the propeller action. No completely satisfactory method is presently available to obtain this correction, but an approximation of the radial distribution of the wake $(1-w_x)$ with the propeller operating is obtained as follows:

Wake distribution

$$(1-w_x) = [(1-w_T)(1-w_c)]/(1-w_v) \quad [1]$$

where $(1-w_c)$ = radial distribution of the circumferential

mean wake from wake survey data,

$(1-w_T)$ = effective wake from self propulsion data

$(1-w_v)$ = volume mean wake, $[2/(1-x_h^2)] \int_{x_h}^1 (1-w_c) x dx$,

R = propeller radius,

r = propeller local radius

r_h = propeller hub radius,

x = nondimensional radial distance (r/R), and

x_h = nondimensional hub radius (r_h/R).

The propeller wake distribution may also vary with propeller diameter depending on the hull characteristics of the vessel.

Advance Angle Distribution Input Option

The advance angle distribution ($\tan\beta$) is normally calculated from the equation $V(1-w_x)/(\pi n D x)$ using the propeller wake $(1-w_x)$ from Equation [1]. For most single screw propeller designs this approach gives good performance predictions. In a few instances, it may be desired to utilize the computer program presented to design and predict the performance of propellers operating inside a duct or in the vicinity of another propeller as in the case of tandem or contrarotating propellers where the axial (w_a/V) and

tangential (w_t/V) velocities induced by these additional sources near the propeller plane can be predicted. In this case, an option in the computer program allows the input of the estimated $\tan\beta$ distribution which accounts for the axial (w_a/V) and tangential (w_t/V) velocities induced by other sources in the following manner:

Equation for Estimating $\tan\beta$ If Input Option Is Used

$$\tan\beta_{\text{estimated}} = [(1-w_x) + w_a/V] / [(x/\lambda_s) - (w_t/V)] \quad [2]$$

where w_a/V = axial velocity from other sources,

w_t/V = tangential velocity from other sources,

λ_s = advance ratio based on ship speed, $V/(\pi nD)$,

V = ship speed, and

D = propeller diameter.

It can be seen from Equation [2] that for the case where (w_a/V) and (w_t/V) values are specified as zero, the advance angle $\tan\beta$ is calculated in the usual manner when designing single screw propellers. If the $\tan\beta$ input option is used, the $\tan\beta$ values are calculated using Equation [2]. For the normal single screw propeller design case, $\tan\beta$ is calculated on the computer.

Hydrodynamic Flow Angle Distribution

The hydrodynamic flow angle distribution ($\tan\beta_I$) can be specified as input. An option is included so Lerb's optimum

$\tan\beta_I$ distribution⁶ can be calculated by the computer as follows:

$$\tan\beta_I = (\tan\beta/\eta_i)[(1-w_T)/(1-w_X)]^{1/2} \quad [3]$$

where η_i = propeller ideal efficiency

$\eta_i = 0.95$ is used in the program, and

$\tan\beta$ = advance angle distribution

Lerbs' optimum $\tan\beta_I$ distribution usually results in optimum propeller efficiency. If other factors such as cavitation, strength and vibration are considered, the input of an alternate $\tan\beta_I$ distribution may be desired.

Static Head

The static head (H) at the shaft centerline is required input. This parameter (H) is defined as $H_S + H_a - H_v$, where H_S is the shaft submergence, H_a is the atmospheric pressure, and H_v is the vapor pressure of fluid which is normally small compared with H_a and may be neglected. The static head (H) is used to calculate the section cavitation number (σ) in Equation [25] and the Burrill cavitation number $\sigma_{0.7}$ of Equation [30].

Blade Outline and Expanded Area Ratio

The blade outline (c/D) and expanded area ratio (A_E/A_0) must be input for the design. An expanded area ratio (A_E/A_0) is calculated on the computer according to:

$$A_E/A_0 = (2Z/\pi) \int_{x_h}^1 c/D \, dx$$

where c/D = nondimensional chord length, and

Z = number of blades

If the (A_E/A_0) input value differs from the one indicated in equation [4], adjusted (c/D) values used for the design are calculated as follows:

$$(c/D)_{adj} = (c/D)_{input} (A_E/A_0)_{calc} / (A_E/A_0)_{design}$$

The final blade outline and expanded area ratio should be chosen to give satisfactory propeller strength and cavitation characteristics.

Blade Thickness to Chord Ratio

The input of maximum thickness to chord ratio (t/c) values allow an estimate of the propeller principal stresses (see The Propeller Stress Calculations Using Beam Theory section discussed later) based on beam theory⁶ to be calculated during the preliminary design stage of the propellers. From a rough estimate of the blade outline (c/D) for the final design and an estimate of the radial distribution of thickness (t/D) based on fatigue strength⁶, the following equation can be used to obtain initial (t/c) input values:

Blade Thickness Ratio:

$$t/c = (t/D)/(c/D)$$

where t/D = radial distribution of thickness (can be estimated from Reference 6).

Rake and Skew

Nondimensional rake (Z_R/D) and the skew angles (θ_S) for a design are specified to permit adequate predictions of principal propeller stresses using the beam theory method described in Reference 6 and discussed later in the propeller stress section of this report.

The rake (Z_R) is defined consistent with Reference 11 (see Figures 1 through 2d) as the distance from the propeller plane to the generator line in the direction of the shaft axis. Aft displacement is considered positive rake (see Figures 2a).

Since the skew angles (θ_S) significantly affect propeller unsteady forces, a computer program based on the unsteady propeller lifting surface theory of References 12, 13, 14, and 15 can be used to select the skew angles (θ_S) for the propeller design. The input skew angles (θ_S) in degrees are defined as the angular displacement of points on the blade reference line from the propeller reference line in the projected view.

11. Cumming, R.A., Dictionary of Ship Hydrodynamics - Propeller Section, 14th International Towing Tank Conference 1975, Report of Presentation Committee, Appendix VII
12. Tsakonas, S., Breslin, J., and Miller, M., "Correlation and Application of an Unsteady Flow Theory for Propeller Forces," Transactions of the Society of Naval Architects and Marine Engineers, Vol. 75, p 158-193, 1967
13. Breslin, J.P., "Exciting-Force Operators for Ship Propellers," Journal of Hydronautics, Vol. 5, No. 3, p 85-90, July 1971
14. Jacobs, W.K., Mercier, J., and Tsakonas, S., "Theory and Measurements of the Propeller-Induced Vibratory Field," Davidson Laboratory Report SIT-DL-1485, December 1970
15. Tsakonas, S., Jacobs, W.R., and Ali, M.R., "An Exact Linear Lifting Surface Theory for Marine Propeller in a Nonuniform Flow Field," Journal of Ship Research, Vol. 17, No. 4, December 1974

Section Drag Coefficient

In order to account for viscous effects when predicting the performance of a propeller, the section drag coefficient (C_D) must be specified as input. A section drag coefficient (C_D) value of 0.0085 usually gives reasonable estimates of model propeller drag for propeller shapes normally used at DTNSRDC in the past. For propellers having very thick blades, the following equation, available as an input option on the computer, and derived as a function of maximum thickness (t/c) values using experimental data from NACA 66 type sections,^{16,17} will give a better estimate of the section drag coefficient (C_D):

Section Drag Coefficient:

$$C_D = C_{F0} [1 + 1.25(t/c) + 125 (t/c)^4]$$

where C_{F0} is the friction resistance of the section, e.g., $C_{F0} \approx 0.008$ for Reynolds number of approximately 10^6 and $C_{F0} \approx 0.004$ for Reynolds numbers of approximately 10^8 .

Options for using alternate nonlinear C_D distributions, or a constant C_D distributions are also available.

Final Pitch Ratio (P/D) Input Option

The final pitch-diameter ratio (P/D) distribution defined as $\pi \tan \phi$ where ϕ is the pitch angle is normally not known during the preliminary design stage of the propeller. Because of this hydrodynamic flow angle (β_l) from lifting line

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16. Abbot, Ira H. and Von Doenhoff, Albert E., "Theory of Wing Sections Including a Summary of Airfoil Data," Dover Publications Inc., New York, Library of Congress Catalog No. 60-1601, 1949.
 17. Hoerner, S.F., "Fluid-Dynamic Drag," Published by the author, Midland Park, New Jersey, 1965.

calculations is substituted for the pitch angle (ϕ) in the bending moment calculations when making stress calculations using beam theory and when predicting clearance between blades and fillets at the propeller hub. If the final P/D values are known, they can be used.

DESIGN AND PROPULSIVE PERFORMANCE PARAMETERS CALCULATED

In order to simplify propeller design calculation procedures, the design thrust and power of propellers are usually considered in nondimensional form. The nondimensional design thrust loading coefficients (C_{TS} and C_{Th}) and design power loading coefficients (C_{PS} and C_P) are calculated on the computer in the following manner:

Thrust Loading Coefficients:

$$C_{TS} = T/[(\rho/2)\pi R^2 V^2] \text{ or } C_{Th} = T/[(\rho/2)\pi R^2 V_A^2] \quad [7]$$

Power Loading Coefficients:

$$C_{PS} = P_D/[(\rho/2)\pi R^2 V^3] \text{ or } C_P = P_D/[(\rho/2)\pi R^2 V_A^3] \quad [8]$$

where V = ship speed,

V_A = speed of advance of propeller, $V(1-w_T)$, and

ρ = density of fluid

Lerbs lifting line theory is used to determine the propeller lift coefficient (C_L), circulation (G), hydrodynamic flow angle (β_I), axial induced velocity ($U_A/2V$), and

tangential induced velocity ($U_T/2V$). These lifting line calculations take into account propeller viscous effects by specifying as input in the computer program the propeller section nondimensional chord length (c/D) and section drag coefficient (C_D). A method for obtaining values for c/D and C_D is discussed in the Description of Input Data section of the report. Design parameters such as thrust loading coefficient (C_{TS}), thrust power coefficient (C_{ThP}), power loading coefficient (C_{PS}), propeller efficiency (η_p), and propulsive efficiency (η_D) are calculated for each propeller in the following manner:

Thrust Loading Coefficient:

$$C_{TS} = \int_{x_h}^1 (1 - \epsilon \tan \beta_I) (dC_{TSi}/dx) dx = T / [(\rho/2) \pi R^2 V^2] \quad [9]$$

Thrust Power Coefficient:

$$C_{ThP} = \int_{x_h}^1 (1 - w_x) (1 - \epsilon \tan \beta_I) (dC_{TSi}/dx) dx = (1 - w_T) \{ T / [(\rho/2) \pi R^2 V^2] \} \quad [10]$$

Power Loading Coefficient:

$$C_{PSe} = \int_{x_h}^1 (1 + \epsilon / \tan \beta) dC_{PSi}/dx dx = P_S / [(\rho/2) \pi R^2 V^3] \quad [11]$$

Estimated Propeller Efficiency:

$$\eta_{Pe} = C_{ThP} / C_{PS} \approx TV_A / (2\pi Qn) \quad [12]$$

Estimated Propulsive Efficiency:

$$\eta_D = (1 - t) C_{TS} / C_{PS} = P_E / P_D \quad [13]$$

where C_L = section lift coefficient from lifting line theory
 C_{TSi} = nondimensional inviscid local thrust loading coefficient, $4ZG[x/\lambda_S - U_T/2V]$
 C_{PSi} = nondimensional inviscid local power loading coefficient, $(4Z/\lambda_S) \times G[(1-w_x) + U_T/2V]$

G = nondimensional circulation from lifting line theory

$U_A/2V$ = axial induced velocity from lifting line theory

$U_T/2V$ = tangential induced velocity from lifting line theory

The calculated propeller thrust (T) is obtained by substituting the C_{TS} calculated in Equation [9] into Equation [7] and the delivered power P_D is obtained by substituting C_{PS} computed using Equation [11] into Equation [8].

Other parameters useful in designing and evaluating the performance of propellers include the advance coefficient (J), ship speed advance coefficient (J_V), thrust coefficient (K_T), torque coefficient (K_Q), moment due to thrust (M_{Tb}), moment due to torque (M_{Qb}), moment parallel to section nose-tail line (M_{x0}), moment perpendicular to the nose-tail line (M_{y0}) and the blade loading distribution (LJ). These parameters are calculated as follows:

Advance Coefficient:

$$J = V(1-w_T)/(nD) = V_A/(nD) \quad [14]$$

Ship Speed Advance Coefficient:

$$J_V = V/(nD) \quad [15]$$

Thrust Coefficient:

$$K_T = T/(\rho n^2 D^4) = (\pi C_{TS}/8) J_V^2 \quad [16]$$

Torque Coefficient:

$$K_Q = Q/(\rho n^2 D^5) = (C_{PS}/16) J_V^3 \quad [17]$$

Moment Due to Thrust:

$$M_{Tb}(x_o) = [\rho \pi R^3 V^2 / (2Z)] \int_{x_h}^1 (x - x_o) (1 - \epsilon \tan \beta_T) [dC_{TSi}/dx] dx \quad [18]$$

Moment Due to Torque:

$$M_{Qb}(x_o) = [\rho \pi R^3 V^2 / (2Z)] \int_{x_h}^1 (x - x_o) (\tan \beta_T + \epsilon) [dC_{TSi}/dx] dx \quad [19]$$

Moments Parallel to Section Nose-Tail Line:

$$M_{x_o}(x_o) = M_{Tb} \cos \phi + M_{Qb} \sin \phi \quad [20]$$

Moment Perpendicular to Section Nose-Tail Line:

$$M_{y_o}(x_o) = M_{Tb} \sin \phi - M_{Qb} \cos \phi \quad [21]$$

Blade Loading Distribution:

$$L(x) = (1/2) \rho c V_r^2 C_L \quad [22]$$

where x, x_o = propeller nondimensional radial stations,

$$r/R \text{ and } r_o/R$$

$$\phi = \text{propeller pitch angle (input or } \beta_T)$$

$$V_r = \text{section inflow velocity, } V \sqrt{[(1-w_x) + U_A/2V]^2 + [(x/\lambda_s) - U_T/2V]^2}$$

Appendix A presents procedures for calculating propeller weight, center of gravity, mass polar moments of inertia and radius of gyration and Appendix B shows how the American Bureau of Shipping (ABS) coefficients and thickness requirements are calculated. Other

calculations made include stress calculations based on beam theory, parameters for making blade surface cavitation checks, chord lengths for making final pitch and camber calculations, and the prediction of spacing between blades and fillets at the propeller hub.

PROPELLER STRESS CALCULATIONS USING BEAM THEORY

A propeller blade must contain enough material to keep the stresses within a blade below a certain predetermined level. This level depends on the material properties with regard to both steady-state and fatigue strength and to both mean and unsteady blade loading. The material selection controls the allowable stress level and the blade chord, thickness, rake and skew are the main parameters which control the blade stress for a given blade loading. The principal stresses in the propeller blade are computed for each propeller. Both hydrodynamic and centrifugal loadings are considered. In this stress calculation procedure, the propeller blade is represented as a straight cantilever beam of variable cross-section without camber. Experimental results show that the neutral axis of an airfoil section lies approximately along the mean line so camber is not considered in the stress calculations presented. Only the maximum principal stresses calculated at the mid-chord of each section are printed as output in the computer program. Stresses

for the final design should be calculated by finite element techniques if rake and skew for the propeller differ from usual propeller shapes.

PARAMETERS FOR MAKING BLADE SURFACE CAVITATION CHECKS

Brockett's theoretically derived incipient cavitation charts of Reference 8 can be used to predict the blade surface cavitation characteristics of each propeller once the lifting line calculations have been completed. The two-dimensional camber to chord ratio (f_M/c), ideal angle of attack in degrees (α_i), section cavitation number (σ), nondimensionalized with the section inflow velocity (V_r), and the maximum and minimum fluctuating angle of attack (α_{max} , α_{min}) in degrees are parameters that must be determined before Brockett's incipient cavitation charts can be used. These parameters are calculated as follows:

Section Maximum Camber to Chord Ratio for NACA a=0.8 Meanline:

$$f_M/c = 0.0679 C_L \quad [23]$$

Section Ideal Angle of Attack in Degrees for NACA a=0.8 Meanline:

$$\alpha_i = 1.54 C_L \quad [24]$$

Section Cavitation Number:

$$\sigma = 2g(H - xR)/V_r^2 \quad [25]$$

where g = acceleration due to gravity

H = static head at shaft centerline (see section on Static Head).

The maximum and minimum fluctuating angles of attack

$(\alpha_{\max}, \alpha_{\min})$ in degrees are calculated using the method derived by Lerbs and Rader in Reference 18. These calculations can be made using the following equations:

Maximum Fluctuating Angles of Attack:

$$\alpha_{\max} = \alpha_i - (-\Delta\beta)F(x) \quad [26]$$

Minimum Fluctuating Angles of Attack:

$$\alpha_{\min} = \alpha_i - (+\Delta\beta)F(x) \quad [27]$$

where $-\Delta\beta$ = Maximum effective angle of attack in degrees

(from wake survey data), and

$+\Delta\beta$ = Minimum effective angle of attack in degrees

(from wake survey data).

The parameter $F(x)$ in Equations [26] and [27] is dependent on the hydrodynamic flow angle (β_I), the advance angle (β) and the lift coefficient (C_L), and is calculated on the computer using the following equation:

$$F(x) = 1/[1 + 2\pi \tan(\beta_I - \beta)/C_L] \quad [28]$$

The Burrill Cavitation Charts⁷, can also be used to give an approximate check on the cavitation performance of propellers. Burrill's thrust loading coefficient (τ_c) and cavitation number ($\sigma_{0.7}$) at 0.7 radius defined as follows are parameters that must be known to use these cavitation charts.

18. Lerbs, H.W. and Rader, H.P., "Über de Auftriebsgradienten von Profilen im Propeller Verband," Schiffstechnik, Vol. 9, No. 48, p 178-180, 1962

$$\tau_c = T / \{ (\rho / 2) A_p [\{ V(1 - w_{x=0.7}) \}^2 + (0.7\pi n D)^2] \} \quad [29]$$

Burrill Cavitation Number at 0.7 Radius:

$$\sigma_{0.7} = 2gH / [\{ V(1 - w_{x=0.7}) \}^2 + (0.7\pi n D)^2] \quad [30]$$

where A_E = propeller expanded area, $\int_{r_h}^R c \, dr$,

A_0 = propeller disc area, $\pi D^2 / 4$,

A_p = propeller projected area, $[1.067 - 0.229(P/D)_i] A_E$, and

$(P/D)_i$ = propeller pitch ratio at 0.7 radius input or
estimated as $0.7\pi \tan \beta_I$.

Keller's method⁹ of predicting the minimum expanded area ratio of the propeller is also calculated on the computer. The minimum expanded area ratio, based on eliminating back bubble type cavitation, is computed as follows:

$$(A_E/A_0)_K = K_T (2.6 + 0.6Z) K_T / \{ \sigma_{0.7} [J^2 + (0.7\pi)^2] \} \quad [31]$$

The constant $K=0.15$ was used in this program. Many possible alternate values of K may be desired, for example: $K=0.2$ is used for single screw ships with bronze propellers having rake of approximately 10 degrees, $K=0.10$ is used for twin screw ships with copper-aluminum propellers, $K=0.15$ is used for twin screw ships with bronze propellers and for single screw ships with copper-nickel-aluminum propellers, and $K=0$ to 0.05 is used for propellers for fast ships such as destroyers and frigates. If a different value of K is desired, the expanded area ratio calculated in equation [31] should be adjusted to account for changes in the value of K .

CHORD LENGTHS FOR PITCH AND CAMBER CALCULATIONS

The final pitch and camber for each propeller can be calculated using computer programs presented in References 3, 19, 20, 21, 22, and 23. The programs require as input the section chord length, $(c/R)_{LE}$ and $(c/R)_{TE}$ nondimensionalized on propeller radius, in terms of the skew angle (θ_S), hydrodynamic flow angle (β_I) and blade outline (c/D). The parameters $(c/R)_{LE}$ and $(c/R)_{TE}$ measured from the leading edge and trailing edge to its reference line, respectively, are calculated in the following manner on the computer:

-
19. Kerwin, J.E., "The Solution of Propeller Lifting-Surface Problems by Vortex Lattice Methods," Department of the Naval Architecture and Marine Engineering, Massachusetts Institute of Technology, Cambridge, Massachusetts, 1961
 20. Kerwin, J.E., and Leopold, R., "Propeller Incidence Correction Due to Blade Thickness," Journal of Ship Research, Vol.7, No. 2, 1963
 21. Cheng, H.M., "Hydrodynamic Aspects of Propeller Design Based on Lifting-Surface Theory: Part I - Uniform Chordwise Load Distribution," David Taylor Model Basin Report 1802, 1964
 22. Cheng, H.M., "Hydrodynamic Aspects of Propeller Design Based on Lifting Surface Theory: Part II - Arbitrary Chordwise Load Distribution," David Taylor Model Basin Report 1803, 1965
 23. Kerwin, J.E., "Computer Techniques for Propeller Blade Section Design," Transactions of the Second Lips Propeller Symposium, Drunen, Holland, p 1-31, May 1973

Chord Lengths Measured From Blade Leading Edge:

$$(c/R)_{LE} = x_{\theta_S} / (57.296 \cos \phi) - c/D \quad [32]$$

Chord Lengths Measured From Blade Trailing Edge:

$$(c/R)_{TE} = x_{\theta_S} / (57.296 \cos \phi) + c/D \quad [33]$$

($\phi = \beta_I$ is used when pitch is not input)

SPACING BETWEEN BLADES AND FILLETS

Propeller designs should have enough clearance between blades at the hub so fillets are properly applied. Hill, Reference 24, derived the following equation, which is used in the program to estimate spacing between blades at the hub without fillets:

$$G_Z = (2\pi r_h) / Z - (t_h / \sin \phi) \quad [34]$$

where ϕ = input pitch or β_I

Based on a number of full-scale propellers built with standard fillets, Hill's blade clearance equation was modified in the following manner to estimate spacing between fillets at the hub during the preliminary stage of the design:

$$G_F = (2\pi r_h / Z) - (1.9 t_h / \sin \phi) \quad [35]$$

A layout of blade sections is recommended as a final fillet clearance check.

PROPELLER DESIGN THRUST AND POWER OPTIONS

The thrust option can be used to make lifting line calculations for propellers required to produce a given thrust at

24. Hill, J.G., "The Design of Propellers," Transactions of the Society of Naval Architects and Marine Engineers, Vol. 57, p 143-170, 1949.

specified values of speed and rpm (this is accomplished by adjusting the input $\tan \beta_1$ distribution), or the power option can be used if the propeller is required to absorb a specified power at a given rpm (in which case the speed is determined).

From each calculated power, a new value of speed (assumed to vary as the cube root of the ratio of the design and calculated power) is obtained and its corresponding effective power is obtained from the effective power input curve. Design calculations again produce a new calculated power, and the process continues until the closeness criteria of design calculated power is satisfied (two iterations are normally sufficient). Smaller increments of input speeds in general cause faster convergence.

Once the basic shape of the distribution is defined (see the Hydrodynamic Flow Angle Distribution section) the final $\tan \beta_1$ distribution $K_4 \tan \beta_1$ is determined using the thrust or power options, making lifting line calculations of three nondimensional thrust loading coefficients $(C_{Ts})_1$, $(C_{Ts})_2$, and $(C_{Ts})_3$ that correspond to three hydrodynamic pitch distributions, $K_1 \tan \beta_1$, $K_2 \tan \beta_1$, and $K_3 \tan \beta_1$ where $K_1 = 0.975$, $K_2 = 1.0$, and $K_3 = 1.025$. Once these calculations are obtained, the following system of equations are set up:

$$(C_{Ts})_1 = A + BK_1 + CK_1^2$$

$$(C_{Ts})_2 = A + BK_2 + CK_2^2$$

$$(C_{Ts})_3 = A + BK_3 + CK_3^2$$

from which values of A, B, and C are obtained. Then, values of A, B, and C are substituted in the following equation to obtain the value of K_4 .

$$C_{TS} = A + BK_4 + CK_4^2$$

where C_{TS} = design thrust loading coefficient (Equation (7)).

COMPUTER PROGRAM AND SAMPLE DESIGN

CALCULATIONS

Lifting line theory of References 1 and 2 has been used to derive a computer program for the preliminary design of propellers using high speed CDC computers at DTNSRDC. A core size of approximately 60,000 octal is required for the program. The average running time for a design based on thrust is 25 seconds and 100 seconds are required using the power option. As mentioned earlier, Appendix A presents procedures used to calculate propeller weight, center of gravity, mass polar moment of inertia, and radius of gyration. Appendix B shows how the American Bureau of Shipping (ABS) coefficients and thickness requirements are calculated. A detailed description of the input and output formulas for the computer program is present in Appendix C exercising most of the available options. Design calculations are presented in Appendix D for a sample design using the thrust option and results using the power option are shown in Appendix E. A Fortran listing of the computer program is presented in Appendix F.

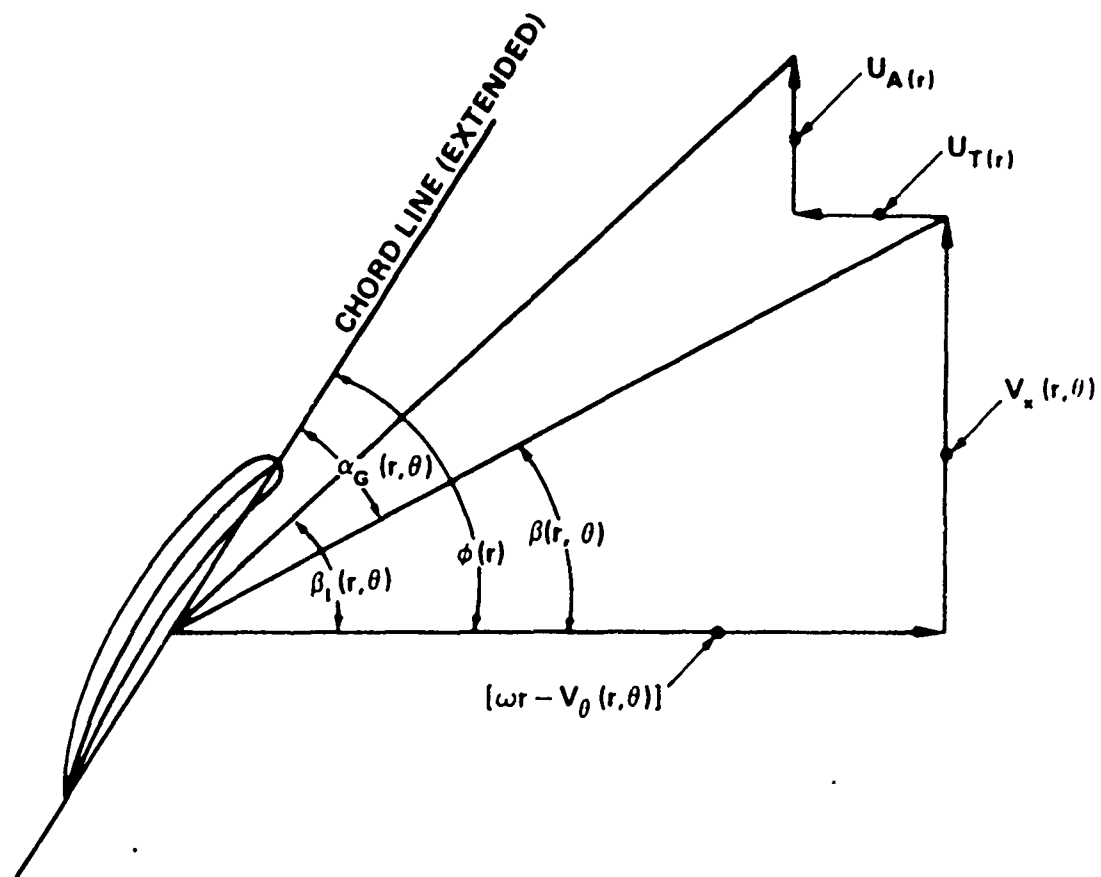


Figure 1 – Typical Velocity Diagram for a Propeller Blade Section at Radius r
 (The diagram is drawn with all quantities positive and the velocity vectors represent the velocity of the propeller blade section relative to the fluid)

Figure 2 — Diagrams Showing Recommended Reference Lines and Terminology

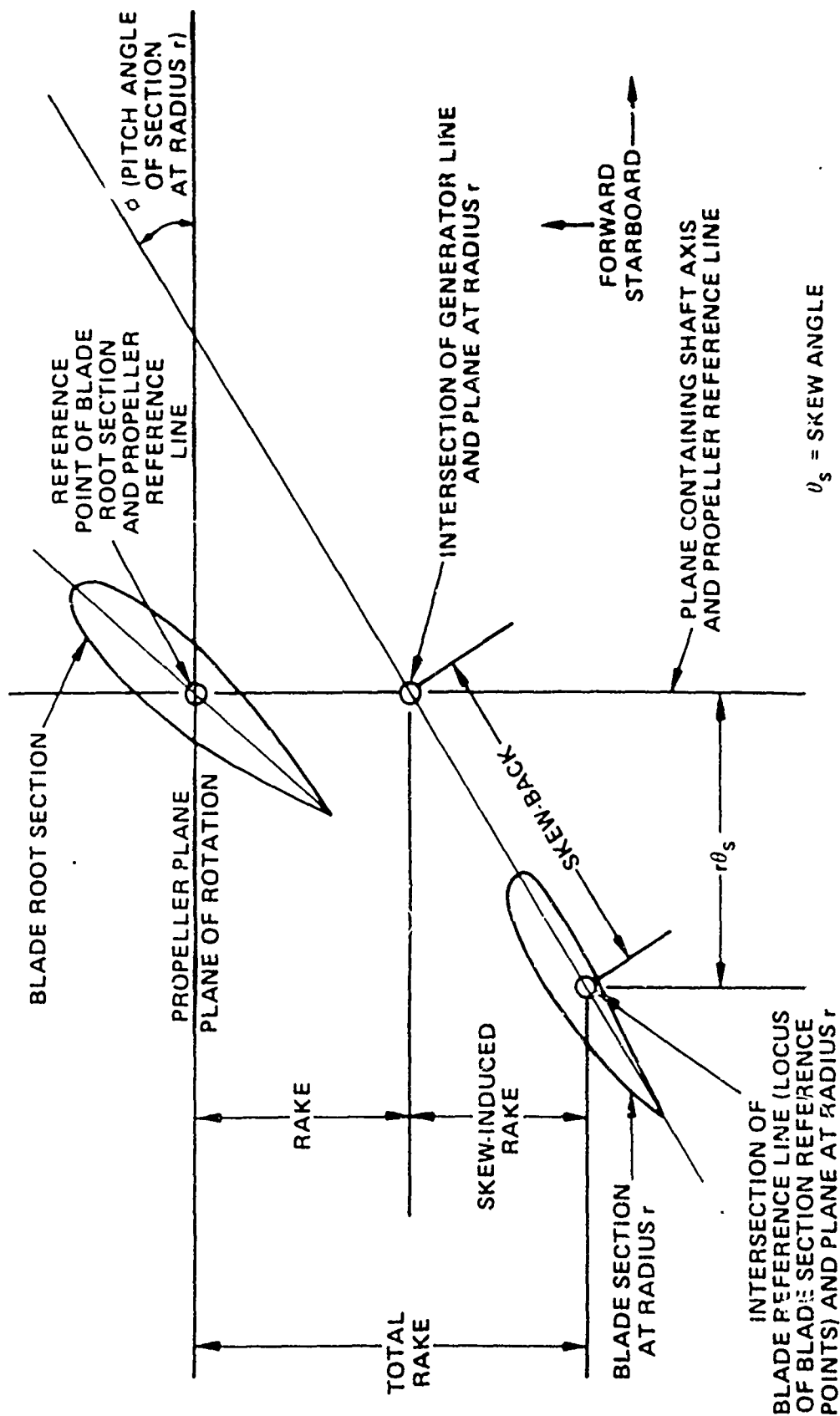


Figure 2a — View of Unrolled Cylindrical Sections at Blade Root and at Any Radius r of a Right-Handed Propeller (Looking Down) Showing Recommended Location of Propeller Plane

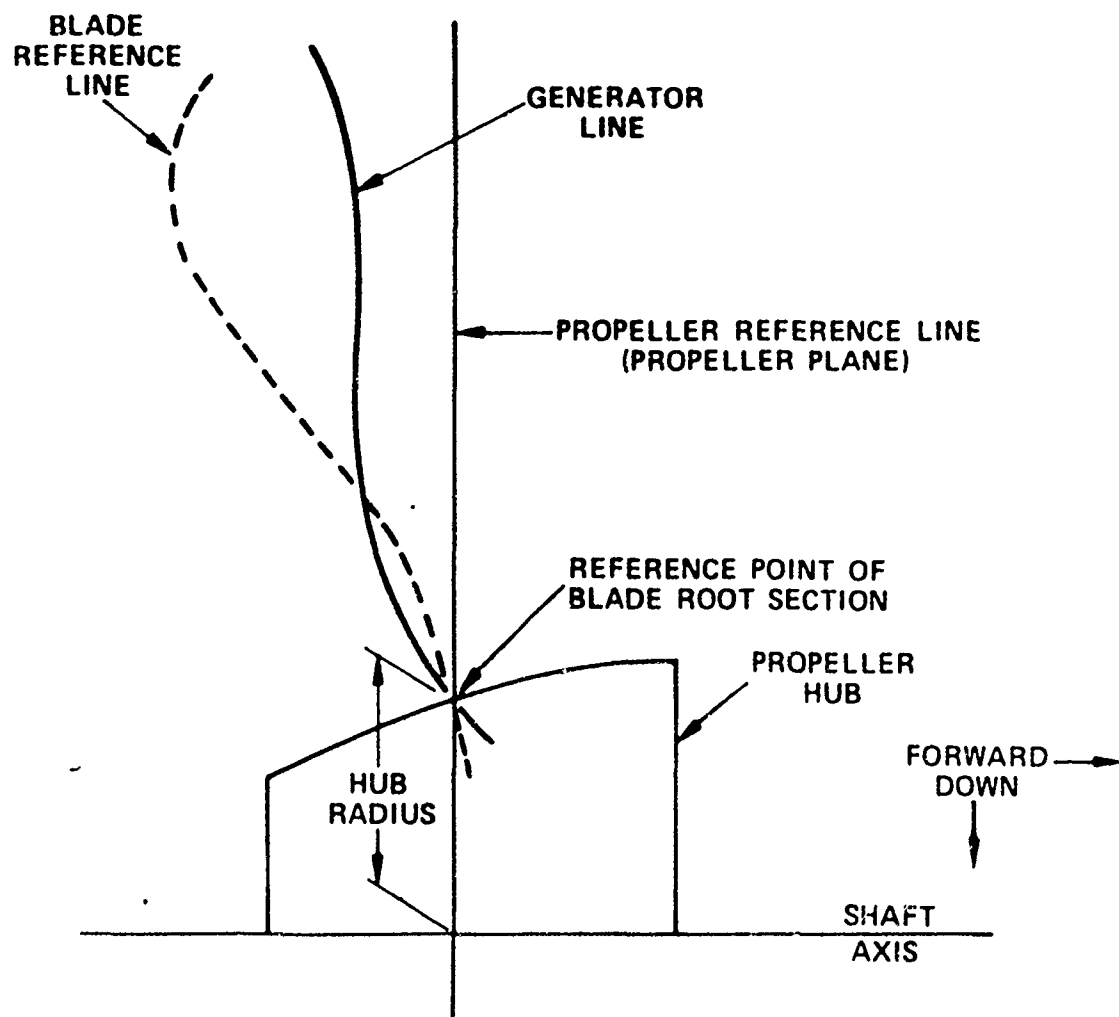
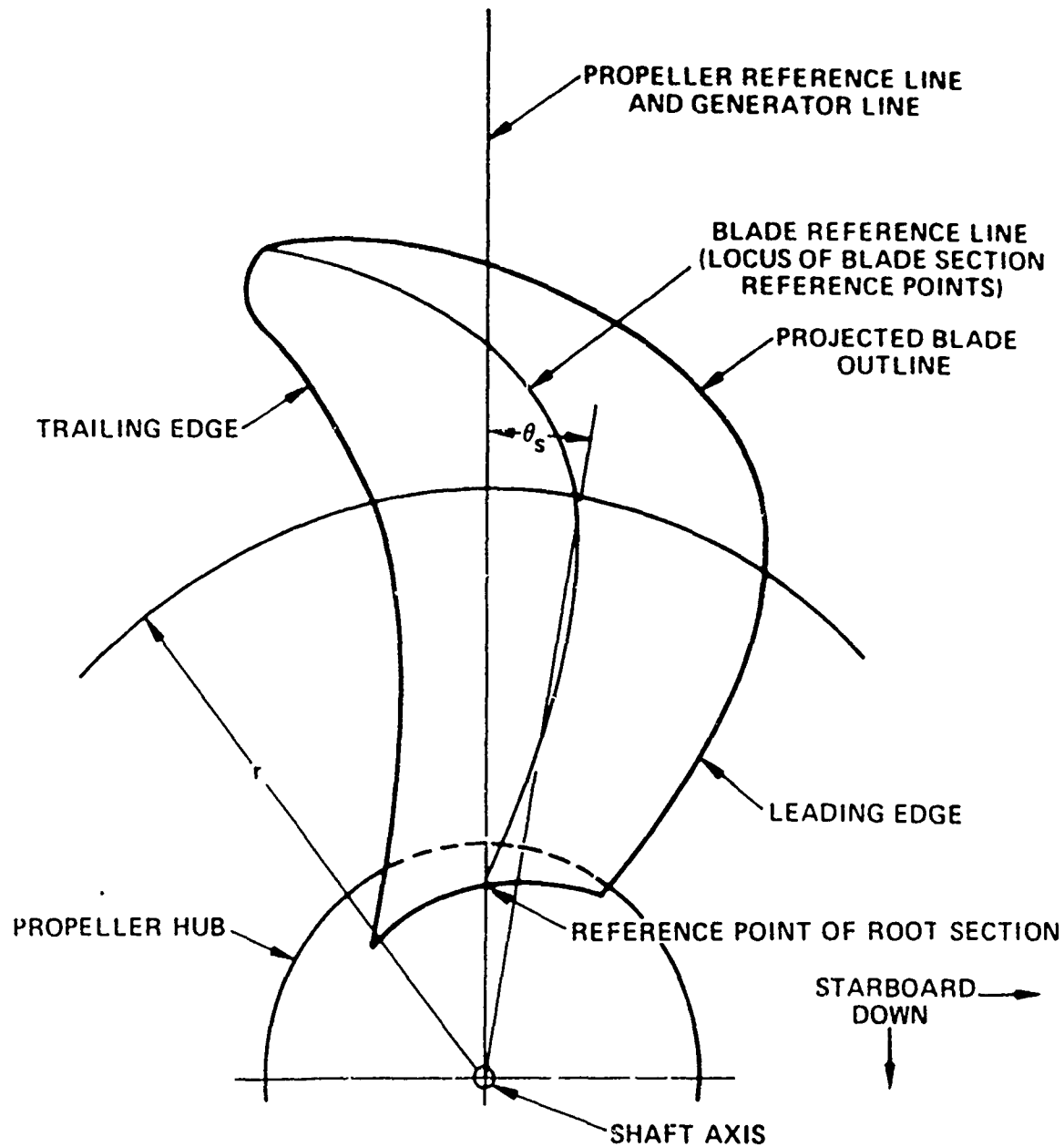


Figure 2b - Diagram Showing Recommended Reference Lines (Looking to Port)



NOTE: THE SKEW ANGLE, θ_s , SHOWN AT RADIUS r IS LESS THAN ZERO.

Figure 2c Diagram Showing Recommended Reference Lines (Looking Forward)

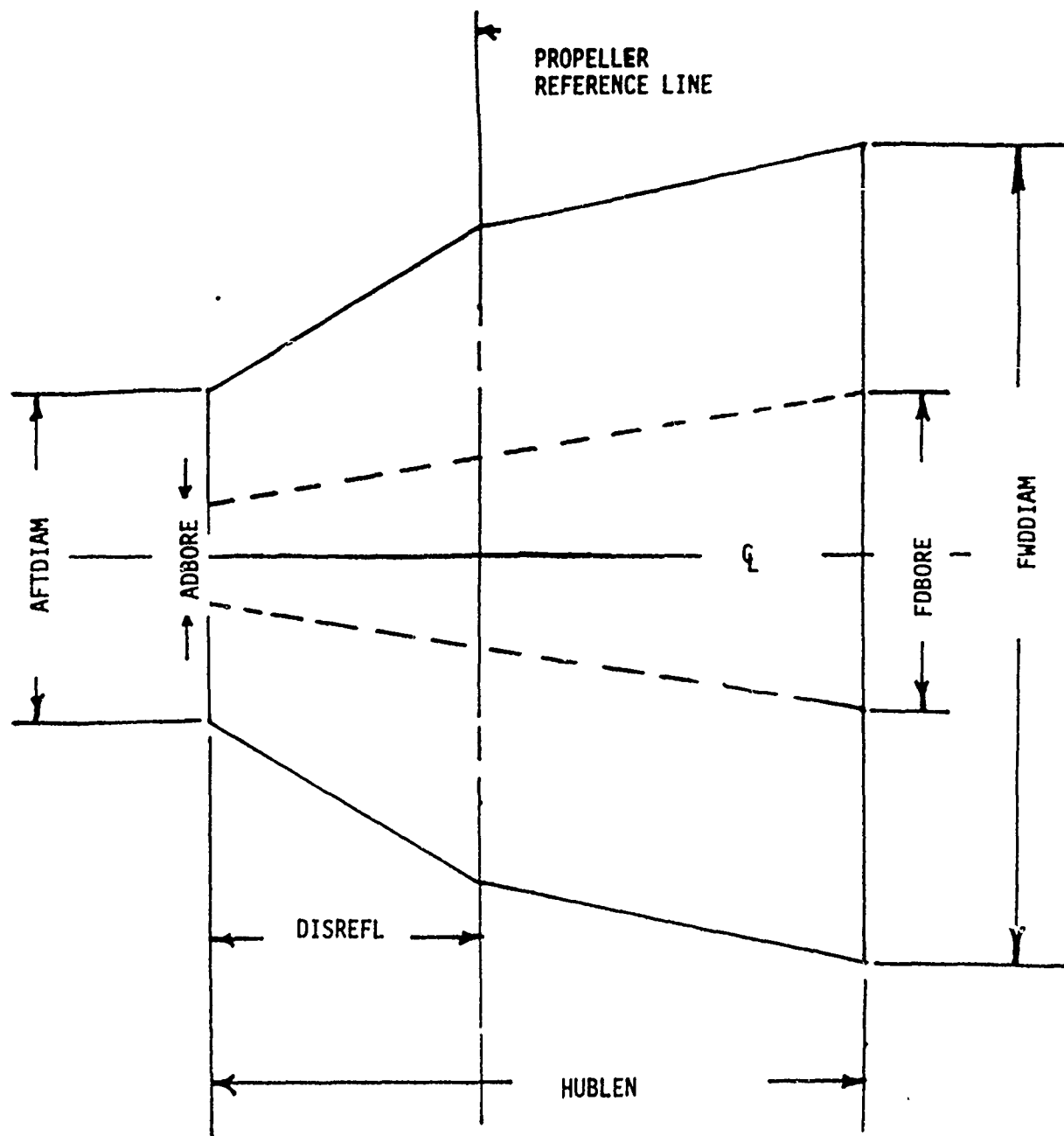


FIGURE 2d - INPUT FOR DETAILED HUB OPTION

TABLE 1

List of dimensioned input and output parameters used by
computer program based on English and SI units

<u>Parameter</u>	<u>English Units</u>	<u>SI Units</u>	<u>KSI⁽¹⁾</u>
Shaft power (P_S)	hp	KW	0.7457
Effective power (P_E)	hp	KW	0.7457
ρ_p	lbm/ft ³	kg/m ³	16.01846
V	knots ⁽²⁾	m/s	0.514444
V	ft/sec	knots ⁽²⁾	0.5924
D	ft	m	0.3048
H	ft	m	0.3048
ρ	lbf sec ² /ft ⁴	kg/m ³	515.3788
n	rev/min	rev/min ⁽³⁾	1.0
T, weight	lbf	N	4.44822
V_r	ft/sec	m/s	0.3048
LI	lbf/ft	N/m	14.5939
M_{Tb}	in lbf	Nn	0.112985
M_{Qb}	in lbf	Nn	0.112985
M_{xo}	in lbf	Nn	0.112985
M_{yo}	in lbf	Nn	0.112985
Max Stress	lbf/in ²	Pa	6894.757
SKEW	deg	deg ⁽³⁾	1.0
RAKE	deg	deg ⁽³⁾	1.0
Mass polar moment of INERTIA	lbm in ²	kgm ²	0.00029264

(1) Multiply English Units by KSI to get SI Units.

(2) Computer program uses knots in both English Units option
and SI Units option.

(3) These are not SI Units but are permitted to be used in the
SI system according to International Standards Organization (ISO)
Standard No. 1000.

APPENDIX A PROPELLER WEIGHT, MASS POLAR MOMENTS OF INERTIA, AND CENTER OF GRAVITY

The approximate propeller weight (W_p) and location of center of gravity (CG) from the propeller center line is also calculated for each design. In order to make these calculations, the density of the material (ρ_p) must be specified as input.

Hub dimensions can be input, or a solid circular cylinder of equal length and diameter, with propeller center line at the mid length of the hub can be assumed. If the cylindrical hub is assumed:

$$W_p = W_B + W_H$$

where W_B = weight of blades, $\rho_p Z \int_{x_h}^1 a(x) dx$

W_H = weight of hub, $(\pi \rho_p D_H^3 / 4)$,

D_H = hub diameter

$a(x)$ = area of section at radius x , $2c(x)t(x) \int_0^1 t(x, x_\ell) dx$,

$c(x)$ = chord length of section at radius x ,

$t(x)$ = maximum thickness of section

$t(x, x_\ell)$ = Chordwise distribution of section thickness (NACA 66 modified thickness form is used in program)

x_ℓ = nondimensional coordinate along the section chord, (r_ℓ / c) ,
and

ρ_p = density of material considered

if calculations are desired for a noncylindrical hub, the following dimensions are input:

D_{FH} = forward hub diameter,

D_A = aft hub diameter,

L_H = length of the hub,

D_{FB} = forward bore diameter,

L_{RL} = distance from aft end of hub to propeller reference line

The hub is then treated as consisting of two frustrums of cones, joined at the propeller reference line. Again

$$W_p = W_B + W_H,$$

but now

$$W_H = W_{AF} + W_{FF} - W_b$$

where W_{AF} = weight of solid aft frustum, $(\pi \rho_p / 3) (D_{AH} D_H + D_H^2) / 4$

W_{FF} = weight of solid forward frustum,

$$(\pi \rho_p / 3) (D_H^2 + D_H D_{FH} + D_{FH}^2) / 4$$

W_b = weight of bore, $(\pi \rho_p / 3) (D_{AB}^2 + D_{AB} D_{FB} + D_{FB}^2) / 4$

The propeller center of gravity (CG) with respect to the blade center line, where plus values represent the distance ahead of the center line and negative values aft of the center line, is calculated in the following manner (see Figures 2b and 2c):

Center of Gravity:

$$CG = M_p / W_p$$

where M_p = moment of the propeller, $\rho_p \int_{x_h}^1 a(x) B(x) dx$

where M_p = moment of the propeller, $\rho_p \int_{x_h}^1 a(x) B(x) dx$

$B(x)$ = distance of center of gravity from propeller reference line, $\bar{x} + \bar{y} + \bar{H}$

x = the distance of the center of gravity of the section along the chord line from the position of maximum thickness,

y = the distance between the center of gravity of the section and the chord line of the section, measured perpendicular to the chord line,

r_i = the radial distance from the shaft axis to the section,

ϵ_R = rake angle in radians of the section,

ϵ_S = skew angle in radians of the section, and

ϕ = pitch angle in radians of the section ($\epsilon = \beta_1$ is used when pitch is not input).

Then $\bar{x}$ = the component of the center of gravity adjusted for pitch, $x \sin \phi + y \cos \phi$;

$\bar{y}$ = the component of the center of gravity adjusted for skew ($= -\epsilon_S r_i \tan \phi$) and rake ($= -\epsilon_R r_i / R$); and

$\bar{H}$ = the component of the center of gravity along the shaft axis of the specified hub, aft of the propeller reference line taken as positive.

If the standard hub is selected,

$$h_{PM} = \text{mass polar moment of hub} = W_H D_H^2 / 8$$

otherwise,

$$H_{PM} = \pi \rho (A_{PM} + F_{PM} - B_{PM}) / 10$$

where A_{PM} = aft mass polar moment =

$$L_{RL} (D_H^4 + D_H^3 D_{AH} + D_H^2 D_{AH}^2 + D_H D_{AH}^3 + D_{AH}^4) / 16$$

F_{PM} = forward mass polar moment =

$$(H_L - L_{RL}) (D_H^4 + D_H^3 D_{FH} + D_H^2 D_{FH}^2 + D_H D_{FH}^3 + D_{FH}^4) / 16$$

B_{PM} = mass polar moment of bore =

$$H_L (D_{AB}^4 + D_{AB}^3 D_{FB} + D_{AB}^2 D_{FB}^2 + D_{AB} D_{FB}^3 + D_{FB}^4) / 16$$

Z_{PM} = mass polar moment of blades =

$$Z \rho R^3 \int_{x_h}^1 x^2 \epsilon_r(x) dx$$

Then P_{PM} = propeller mass polar moment =

$$Z_{PM} + H_{PM}$$

and K_Z = radius of gyration of blades =

$$\sqrt{Z_{PM} / W_B}$$

K_H = Radius of gyration of hub =

$$\sqrt{H_{PM} / W_H}$$

K_P = radius of gyration of propeller =

$$\sqrt{P_{PM} / W_P}$$

APPENDIX B

AMERICAN BUREAU OF SHIPPING (ABS) COEFFICIENT AND THICKNESS REQUIREMENTS

The minimum blade thickness at the one-quarter radius is defined in Reference 25 by:

$$t_1 = K_1 \sqrt{AP_S / (C_N C_Z n)} + C_S B Z_R / (4 C_N C)$$

and

$$t_2 = K_1 \sqrt{AP_S / (C_N C_Z n)} + C_S B Z_T / (4 C_N C)$$

where P_S = shaft power at the maximum continuous rating,

n = propeller revolutions per minute rpm at the maximum continuous rating,

Z = number of blades,

Z_R = rake, positive aft, at the blade tip.

Z_R, Z_T = rake and rake plus skew induced rake, at the blade tip, positive aft taken as positive,

and

$C_S = a_s / (W_s t_{0.25})$ = section area coefficient at the one-quarter radius

$C_N = I_o / (U_r W_s t_{0.25}^2)$ = section modulus coefficient at the one-quarter radius

$$A = 1 + (K_2 / \tan \phi_{0.7}) + K_3 \tan \phi_{0.25}$$

$$B = (K_4 (\Lambda_E / A_0)) / (Z) \quad (n/100)^2 (D/20)^3$$

$$C = (1 + K_5 \tan \phi_{0.25}) W_s f - B$$

where K_1 through K_5 are constants which depend on the system of units employed

25. American Bureau of Shipping, "Rules for Building and Classing Steel Vessels," p 621, 1972.

a_s = area of expanded cylindrical section at $0.25R$ =

$$2c_{0.25}t_{0.25} \int_0^1 t(0.25,x) dx,$$

W_s = expanded width of cylindrical section at the one-quarter radius,

$t_{0.25}$ = maximum thickness at the one-quarter radius,

I_0 = moment of inertia of the expanded cylindrical section at one-quarter radius about a straight line through the center of gravity parallel to the chord line,

U_F = maximum normal distance from the moment of inertia axis to points on the face of the section,

$c_{0.25}$ = section chord length at $0.25R$,

$\phi_{0.25}, \phi_{0.7}$ = the pitch angles at the one-quarter and seven-tenths radius (or β_1 if ϕ not input),

$t(0.25,x)$ = chordwise distribution of section thicknesses at the
0.25 radius

A_E/A_0 = expanded blade area divided by the disc area,

D = propeller diameter,

f = material constants in length/weight as a function of w

w = a nondimensional parameter associated with the material type
as illustrated in the table below.

Type	Materials	Units
		w
2	Manganese bronze	0.30
3	Nickel-manganese bronze	0.29
4	Nickel-aluminum bronze	0.27
5	Mn-Ni-Al bronze	0.27
6	Cast iron	0.26

If $C_N \neq 0.1$, the thicknesses t_1 and t_2 are recomputed with
 $C_N = 0.1$.

APPENDIX C

DESCRIPTION OF INPUT AND OUTPUT

Data are input to the program in unformatted groups. Within each group the data must be in the order specified, and each value must be separated from all others by a blank or comma. Variable names beginning with I,J,K,L,M, or N require an integer input, but other variables which happen to have integer values do not require a decimal point. Zeroes must actually be keypunched. Beyond this there are no restrictions on how many or few data cards are needed for a group, except that each group must start with a new card. The input required is as follows:

Group	Parameters	Description of Input
1	IDD	Number of data sets(each of the groups 2 through end form a data set)
2	UI,UO,Title	Use SI in columns 2,3 to pecify input in SI units. Use SI in columns 4, 5 for output in SI units. The remaining 66 columns are available for identifi- cation of input data.
3	SHP[FL/T]	Design shaft power or 0 if the thrust * option is desired
	TANBI	Use 1 unless use of an exact (not ad- justed by program) $\tan\beta_I$ distribution is required, then use 0 (see hydrodynamic flow angle distribution
	TANB	Use 1 to input $\tan\beta$ distribution, or 0 for machine calculations according to (2)
	XPS	Use -1 to input a skew distribution, or input the skew at the tip for a linear skew distribution (both in degrees)
	RAKE	Use $\text{<RAKE}< 0.01$ to input a rake/D * distribution or input the rake/D at the tip for a linear distribution
	PDO	Use PDO 0 to input a P/D distribution, otherwise $\pi \times \tan\beta_I$ is used as an approxima- tion

* As used within the Fortran Program

Group	Parameter	Description of Input
	CD	Use $CD \geq 10$ to input the radial distribution of drag coefficients (CD); $0 < CD < 10$ to input a constant drag $C_D = CD$ at all radial stations; $CD = 0$ causes the computer program to calculate the radial distribution of drag coefficients using the equation $C_D = 0.008[1 + 1.25(t/c) + 125(t/c)^4]$; $-10 < CD < 0$ causes the computer program to use a constant frictional resistance $C_{F0} = \text{ABS}(C_{F0})$ in Equation 6 $C_D = C_{F0}[1 + 1.25(t/c) + 125(t/c)^4]$; $CD \leq -10$ to input the radial distribution of frictional resistance (CF0) values to be used in Equation 6.
3	TYPE	For ABS minimum blade thickness calculations coefficients use the number corresponding to the material type in the blade thickness section. Use $TYPE = 0$ to suppress these calculations
	HUB	Use $HUB \neq 0$ to input actual dimensions of HUB, or $HUB = 0$ to use solid cylindrical hub in relevant calculations
4	DIAM[L]	Propeller diameter
	EWAKE	Effective wake $(1 - w_T)$
	ETHRUS	Thrust deduction $(1 - t)$

Group	Parameters	Description of Input
5	HEAD[L]	See section on Static Head, at the shaft centerline
	DEN[M/L ³]	Density of propeller materials
	RHO[M/L ³]	Density to be used for water
	IVV	Number of velocities input
	VE1[L/T]	IVV velocities
5	EHP[FL/T]	IVV design effective power values, corresponding to the input velocities
	IZZ	Number of different blade numbers input
	JBL	IZZ values of blade numbers
	IEA	Number of expanded area ratios input
	EXX	IEA values of A_E/A_O . A value of 0 input as the first A_E/A_O will result in calculations being done exactly at the design A_E/A_O . If this default is used, calculations will not be done at other values of A_E/A_O in the list that happen to be within 0.005 of the design A_E/A_O .
	IRPM	Number of different rpms input
	XMM	IRPM values of revolutions per minute

Group	Parameters	Description of Input
-------	------------	----------------------

(The remaining five radial distributions have eleven values each)

	X3	Values of r/R at which other radial distributions are defined
	X4	Propeller wake ($1-w_x$)
	X5	Hydrodynamic flow angles ($\tan \epsilon_f$). If zeroes are input, Lerbs optimum is calculated as a default distribution
	X6	Section chord lengths (c/D)
	AZZ(25)	Thickness to chord ratios

(Groups six through ten which are specified in group three are defined at the eleven radial stations)

6	AZZ(24)	Blade skew angles, degrees (if $XPS < 0$)
7	B(7)	Section drag coefficients (if $CF > 10$) or frictional resistance of section C_{F0} (if $CD \leq 10$)
8	B(8)	Tangents of advance angles (if $TANB > 0$)
9	RAK	Rake/D, aft positive (if $0 < RAKE \leq 0.01$)
10	P	Pitch, P/D (if $PD > 0$)
11	FWDDIAM[L]	Dimensions, as indicated in Figure 2d (if $HUB \neq 0$)
	AFTDIAM[L]	
	HUBLEN[L]	
	FDBORE[L]	
	ADBORE[L]	
	DISREFL[L]	

A Description of the Output Generated by the Program Follows:

Program Output	Description
G	Nondimensional circulation
UT/2V	Tangential velocity induced at lifting line
UA/2V	Axial velocity induced at lifting line
DCTSI	Local nonviscous thrust coefficient (Defined in Equation (9))
DCPSI	Local nonviscous power coefficient (Defined in Equation (11))
VR [L/T]	Section inflow velocity, equation (22)
CAVV	Section cavitation number, Equation (25)
CPTI	Nonviscous thrust power coefficient (Equation (10) when $\epsilon=0$).
CPSI	Nonviscous power coefficient (Equation (11) when $\epsilon=0$)
ETAI	Estimated nonviscous propeller efficiency (Equation (12) when $\epsilon=0$)
CTSI	Nonviscous thrust coefficient (Equation (9) when $\epsilon=0$)
CPT	Thrust power loading coefficient (Equation (10))
CPS	Power loading coefficient (Equation (11)).
TETS	Projected skew angle in degrees
RAKG	Rake/Diameter
PE	Effective power

Program Output	Description
PS	Shaft power
ETA	Estimated propeller efficiency (Equation (12))
CTS	Thrust loading coefficient (Equation (9))
CL	Section lift coefficient
ALI	Section two-dimensional ideal angle of attack in degrees for NACA a=0.8 meanline, Equation (24)
FM/C	Section two-dimensional maximum camber ratio for NACA a=0.8 meanline, Equation (23)
CD/CL	Section drag-lift ratio ($\epsilon = C_D/C_L$)
F(X)	Parameter for calculations section fluctuating angles of attack, Equation (28)
LI[F/L]	Propeller blade loading distribution Equation (22)
(C/R)DLE	Chord lengths for lifting surface pitch and camber calculations, Equation (32)
(C/R)DTE	Chord lengths for lifting surface pitch and camber calculations, Equation (33)
T/RD	Ratio of section thickness to radius
PC	Estimated propulsive efficiency, Equation (13)
PS[FL/T]	Calculated shaft power delivered at the propeller, Equation (13)
DESIGN [F]	Design thrust
CALCULATED [F]	Calculated thrust, Equation (7) and (9)

Program Output	Description
AEPA [L^2]	Area of section
XBAR [L]	Longitudinal position about x axis parallel to nose-tail line from centroid
YBAR [L]	Vertical distance about y axis perpendicular to nose-tail line from centroid
IXO [L^4]	Moment of inertia about y axis perpendicular to nose-tail line
MXO [FL]	Bending moment about the x axis, Equation [20]
MYO [FL]	Bending moment about the y axis, Equation [21]
MTB [FL]	Bending moment due to thrust, Equation [18]
MQB [FL]	Bending moment due to torque, Equation [19]
MAX STRESS (F/L^2)	Maximum stress
WEIGHT OF BLADES [F]	Equation [32], $W_H=0$
WEIGHT OF PROP (BLADES +DESIGNATED HUB) [F]	
(CENTER OF GRAVITY OF PROP/D)	Appendix A
(CENTER OF GRAVITY OF BLADES/D)	Appendix A
KELLERS MINIMUM EAR	Equation [31]
SPEED COEFF(JS)	Equation [15]

Program Output	Description
Advance Coeff (JA)	Equation [14]
THRUST COEFF (KT)	Equation [16]
TORQUE COEFF (KQ)	Equation [17]
PROPULSIVE EFFICIENCY (PC)	Equation [13]
BURRILL THRUST COEFF (TC)	Equation [29]
BURRILL CAVITATION COEFF	Equation [30]
CLEARANCE AT HUB BETWEEN BLADES/D	Equation [34]
CLEARANCE AT HUB BETWEEN FILLETS/D	Equation [35]
MASS POLAR MOMENT OF INERTIA OF BLADES $[FL^2]$	Appendix A
TOTAL MASS POLAR MOMENT OF INERTIA $[FL^2]$	"
RADIUS OF GYRATION OF BLADES/D	"
RADIUS OF GYRATION OF HUB/D	"
TOTAL RADIUS OF GYRATION/D	"
ABS MINIMUM THICKNESS CONVENTIONAL RAKE	Appendix B
CONVENTIONAL + SKEW INDUCED RAKE/D	"
VALUES USED IN DETERMINING THICKNESS	"

Program Output	Description
SECTION AREA COEFFICIENT	Appendix B
SECTION MODULUS COEFFICIENT	"
AREA OF EXPANDED CYLINDRICAL SECTION [L ²]	"

APPENDIX D

SAMPLE DESIGN USING THE THRUST OPTION

OPTIONS EXERCISED IN APPENDIX D

Power or thrust	T
Calculations with input $\tan\beta_I$	N/A
$\tan\beta_I$ (Lerbs or input)	Input
$\tan\beta$ (Calculated from $(1-w_x)$ or input)	Input
C_D (constant, variable, or calculated)	Const
Multiple RPM	No
Multiple Z	No
Multiple AE/AO	No
Check AE/AO of input C/D and modify	No
Skew (Linear/Nonlinear)	L
Rake (Linear/Nonlinear)	L
P/D (input or approximated by $\pi x \tan\beta_I$)	Input
ABS coefficients	No
Hub geometry	Input
Input Units	SI
Output Units	SI

NDW-MSDC-5232.7 (979)

300 000,000

```
ETA0=7.4391E-01      PS(KM) = 1.9376E+04      1-THO=0.3700E-01      1-WTT=7.4510E-01      V(KNOTS) =2.3499E+01      DESIGN TH(M) =1.6245E+06
Z= 6                  N(PEV/MIN)=1.1660E+12      AE/AC=7.6493E-01      V(M/SEC) =1.2049E+01      CALCULATED TH(M) =1.4245E+06
```


MASS POLAR MOMENT OF INERTIA OF BLADES (KG-M2) = .771877E+05
 TOTAL MASS POLAR MOMENT OF INERTIA (KG-M2) = .791262E+05
 RADIUS OF GYPATION OF BLADE/D = .2372
 RADIUS OF GYPATION OF HUB/D = .0699
 TOTAL RADIUS OF GYPATION/D = .2093

AGS COEFFICIENTS (CALCULATED AT THE .25 RADIUS)

ABS MINIMUM THICKNESS IN INCHES (USING P/D INPUT) =
 USING ABS RAKE = CONVENTIONAL RAKE, T/D = .2636E-01
 USING ABS RAKE = CONVENTIONAL + SKEW-INDUCED RAKE, T/D = .3103E-01

VALUES USED IN DETERMINING THICKNESS-
 A = .123053E+02
 B = .752302E+03
 C = .146355E+05

SECTION AREA COEFFICIENT CS = .6942E+00

SECTION MODULUS COEFFICIENT CN = .0550E-01

AREA OF EXPENDED CYLINDRICAL SECTION IN SQ. METERS AS = .2942E+00

FOR CN = .1
 ABS MINIMUM THICKNESS IN INCHES (USING P/D INPUT) =
 USING ABS RAKE = CONVENTIONAL RAKE, T/D = .2490E-01
 USING ABS RAKE = CONVENTIONAL + SKEW-INDUCED RAKE, T/D = .2931E-01

RADIAL PROPELLER DATA FOR INPUT INTO DESIGN PROGRAMS (8 RADIAL STRIPS ASSUMED)

XR	TAN 9ETA I	G	XSL (METERS)	XST (METERS)	I-WX	UA/ZVS	THICKNESS (METERS)
.2750	1.10757	.10235-01	-.62661	.85114	.47103	.1111E+00	.27947
.27930	.64930	.14205-01	-.56011	1.07598	.52733	.1342E+00	.26952
.38200	.76567	.16795-01	-.40629	1.47172	.64531	.1542E+00	.24327
.48500	.64701	.17545-01	-.11612	1.84695	.74391	.1569E+00	.20701
.58800	.55116	.17832-01	.27532	2.29050	.78556	.1697E+00	.16546
.69100	.47559	.17675-01	.78244	2.75878	.81214	.1640E+00	.12335
.79400	.42013	.16575-01	1.44232	3.25147	.83678	.1635E+00	.08609
.89700	.37743	.13455-01	2.31576	3.74934	.86194	.1611E+00	.05632
.94450	.35867	.10302-01	2.86559	3.95717	.87029	.1592E+00	.04688
1.00000			3.81361	3.81461			

SISI CASE B

THRUST OPTION, DENSITY OF PROP(KG/M3) 7750.3717

W(M/SEC) 1.2089E+01 1.2347E+01 1.2604E+01 1.2707E+01 1.2801E+01
 PE(KN) 1.4414E+04 1.5479E+04 1.6589E+04 1.7170E+04 1.8103E+04

D(M) = 7.3104, 1-WT=.7850, 1-TWO=.5370, W(M) = 15.4426, RHO(KG/M3) = 1025.8615

Z 6

AE/AO 7.6483E-01 7.6483E-01
 N(PEV/MIN) 1.5600E+02

X INPUT	1 WX INPUT	C/D INPUT	T/C INPUT	TANBI INPUT	U/2V INPUT	UCTSI	OCPSI	RKGO LINEAR	P/D INPUT	CO INPUT
1.7600E-01	4.3549E-01	1.9100E-01	2.1600E-01	1.3679E+00	8.0222E-01	0.	0.	C.	1.3400E+00	8.3300E-03
2.5000E-01	4.9413E-01	2.1050E-01	1.7340E-01	1.3253E+00	6.4311E-01	5.3843E+03	5.3843E+03	-1.3950E-03	1.3250E+00	8.5000E-03
3.0000E-01	5.5249E-01	2.3790E-01	1.5490E-01	9.0325E-01	5.9566E-01	9.0201E+02	9.0201E+02	-1.4067E-02	1.2743E+00	8.5300E-03
4.0000E-01	6.6423E-01	2.6440E-01	1.2800E-01	7.4299E-01	5.3787E-01	1.6311E+01	1.6311E+01	-2.5412E-02	1.2173E+00	8.5300E-03
5.0000E-01	7.5090E-01	2.9160E-01	1.0190E-01	6.3195E-01	4.8649E-01	2.3592E+01	2.3592E+01	-3.6757E-02	1.2400E+00	8.5300E-03
6.0000E-01	7.9033E-01	2.8760E-01	7.9600E-02	5.4020E-01	4.2657E-01	3.0874E+01	3.0874E+01	-4.8101E-02	1.1760E+00	8.5300E-03
7.0000E-01	8.1420E-01	2.8070E-01	6.0000E-02	4.7037E-01	3.7643E-01	3.6155E+01	3.6155E+01	-5.9446E-02	1.0700E+00	8.5000E-03
8.0000E-01	8.3333E-01	2.5640E-01	4.6400E-02	4.1735E-01	3.1969E-01	4.5437E+01	4.5437E+01	-7.0701E-02	9.6000E+00	8.5000E-03
9.0000E-01	8.5269E-01	2.3200E-01	3.9400E-02	3.1620E-01	3.1043E-01	5.2719E+01	5.2719E+01	-8.2135E-02	9.2000E+00	8.5300E-03
9.5000E-01	8.7383E-01	1.5200E-01	4.3200E-02	3.5911E-01	2.9972E-01	5.6359E+01	5.6359E+01	-9.7808E-02	9.1000E+00	8.5300E-03
1.0000E+02	8.7753E-01	C.	C.	3.4161E-01	2.9432E-01	6.0000E+01	6.0000E+01	-9.3430E-02	9.0100E+00	8.5300E-03

X	TANBI	U/2V	G	U/2V	UCTSI	OCPSI	VR(M/SEC)	CAVV
1.7600E-01	1.3700E+00	8.0222E-01	0.	1.2744E-01	7.1701E-02	0.	7.7590E+00	4.3336E+00
2.5000E-01	1.6269E+00	6.4031E-01	1.2530E-02	1.2744E-01	1.2701E-01	1.4329E-01	1.6635E+01	2.4779E+00
3.0000E-01	1.9493E+00	5.9666E-01	1.4997E-02	1.5990E-01	1.4766E-01	2.7574E-01	1.2757E+01	1.7021E+00
4.0000E-01	2.7445E+00	5.3797E-01	1.7090E-02	1.3222E-01	1.5576E-01	4.5241E-01	1.8967E+01	9.6563E-01
5.0000E-01	4.8204E+00	4.8649E-01	1.7720E-02	1.0717E-01	1.5403E-01	4.1778E-01	2.0942E+01	6.2310E-01
6.0000E-01	5.4135E+00	4.2617E-01	1.7940E-02	9.4360E-02	1.6311E-01	7.5963E-01	2.4703E+01	4.3370E-01
7.0000E-01	6.7200E+00	3.7643E-01	1.7775E-02	9.0213E-02	1.6577E-01	8.9750E-01	2.8392E+01	3.2144E-01
8.0000E-01	7.9033E+00	3.3943E-01	1.6611E-02	7.3367E-02	1.6457E-01	9.5547E-01	3.2107E+01	2.4784E-01
9.0000E-01	8.3768E+00	3.1548E-01	1.3474E-02	6.1267E-02	1.6137E-01	8.7454E-01	3.5846E+01	1.9361E-01
9.5000E-01	8.5470E+00	2.9687E-01	1.0220E-02	5.7852E-02	1.6135E-01	7.0561E-01	3.7700E+01	1.7260E-01
1.0000E+02	8.4215E+00	2.8432E-01	0.	5.4706E-02	1.5075E-01	0.	3.9566E+01	1.5457E-01

CPII=3.9993E-01 CPSI=5.1646E-01 FTAI=7.8773E-01 CTSI=5.0757E-01 CTSI/CPSI=1.0024E+00
 CPII=3.9993E-01 CPSI=5.1646E-01 FTAI=7.8773E-01 CTSI=5.0757E-01 CTSI/CPSI=1.0024E+00

X	CL	ALI(DEC)	FMC	CO/CL	F(X)	LI(N/M)	TETS(DEC)	IC(P/A)LE	IC(AD)TE	T/RO
1.7600E-01	0.	0.	0.	0.	0.	0.	0.	-1.9101E-01	1.9101E-01	9.251E-02
2.5000E-01	4.155E-01	5.444E-01	2.825E-02	2.041E-02	2.213E-01	1.720E+04	5.3843E+00	-1.735E-01	2.657E-01	7.453E-02
3.0000E-01	3.830E-01	5.904E-01	2.503E-02	2.217E-02	2.316E-01	5.317E+04	9.0201E+00	-1.544E-01	3.174E-01	7.560E-02
4.0000E-01	2.953E-01	4.547E-01	2.035E-02	2.879E-02	2.419E-01	1.297E+04	1.6311E+01	-1.037E-01	4.239E-01	5.739E-02
5.0000E-01	2.322E-01	3.546E-01	1.545E-02	3.653E-02	2.445E-01	1.317E+05	2.3592E+01	-1.865E-02	5.445E-01	5.739E-02
6.0000E-01	1.963E-01	3.023E-01	1.332E-02	4.330E-02	2.514E-01	1.219E+05	3.0874E+01	9.347E-02	6.697E-01	4.579E-02
7.0000E-01	1.710E-01	2.665E-01	1.175E-02	4.930E-02	2.565E-01	1.429E+05	3.6155E+01	2.377E-01	7.991E-01	3.419E-02
8.0000E-01	1.565E-01	2.441E-01	1.163E-02	5.430E-02	2.663E-01	1.449E+05	4.5437E+01	4.216E-01	9.362E-01	2.433E-02
9.0000E-01	1.417E-01	2.217E-01	9.753E-03	5.914E-02	2.777E-01	1.347E+05	5.2719E+01	6.644E-01	1.075E+00	1.599E-02
9.5000E-01	1.377E-01	2.121E-01	9.352E-03	6.171E-02	2.817E-01	1.376E+05	5.6359E+01	8.241E-01	1.131E+00	1.320E-02
1.0000E+02	0.	0.	0.	0.	0.	0.	6.0000E+01	1.089E+00	1.033E+00	0.

ETAO=7.4340E-01 P3(KN) = 2.0011E+04 1-TWO=8.1703E-01 1-WT=.7850E-01 V(M/SEC) = 2.4011E+01 DESIGN THIN) = 1.4977E+06
 7 = 6 N(PEV/MIN) = 1.0050E+02 AE/AO = 7.6483E-01 CALCULATED THIN) = 1.4977E+06

X	APC(1M2)	YBAR(M)	IXO(M4)	IYO(M4)	MYO(N-M)	MYO(N-M)	MTB(N-M)	MOB(N-M)	MAXSTRESS(PA)
1.760E-01	2.795E-01	6.335E-01	1.371E-03	2.833E-02	3.128E+05	1.943E+06	4.328E+05	2.292E+05	4.728E+07
2.500E-01	3.187E-01	7.886E-01	1.315E-03	5.016E-02	2.333E+05	1.335E+06	3.258E+05	1.669E+05	3.497E+07
3.000E-01	3.195E-01	8.746E-01	1.315E-03	5.232E-02	1.521E+05	1.043E+06	2.442E+05	1.216E+05	2.927E+07
4.000E-01	2.963E-01	9.337E-01	1.592E-03	6.315E-02	1.705E+05	5.912E+05	1.705E+05	9.235E+04	2.547E+07
5.000E-01	2.333E-01	9.516E-01	6.411E-04	5.367E-02	7.265E+04	4.175E+05	1.076E+05	5.039E+04	2.542E+07
6.000E-01	1.700E-01	9.307E-01	1.435E-04	3.728E-02	2.555E+04	2.500E+05	5.740E+04	2.609E+04	2.596E+07
7.000E-01	1.090E-01	8.501E-01	4.535E-05	1.993E-02	1.352E+04	8.433E+04	2.326E+04	1.024E+04	2.486E+07

X	RAKG/D	PI XTANRI	PI XTANB
1.760E-01	0.	7.575E-01	4.436E-01
2.500E-01	-5.395E-03	9.066E-01	5.329E-01
3.000E-01	-1.437E-02	9.529E-01	5.623E-01
4.000E-01	-2.541E-02	9.351E-01	6.766E-01
5.000E-01	-3.675E-02	9.942E-01	7.642E-01
6.000E-01	-4.810E-02	1.020E+01	8.041E-01
7.000E-01	-5.945E-02	1.035E+01	8.287E-01
8.000E-01	-7.079E-02	1.051E+01	8.532E-01
9.000E-01	-8.214E-02	1.066E+01	8.779E-01
1.000E-01	-9.348E-02	1.071E+01	8.965E-01
1.100E-01	-1.048E-01	1.075E+01	9.132E-01

WEIGHT OF BLADES(N) = 273758.4944

WEIGHT OF PROP (BLADES + DESIGNATED HUB)(N) = 361222.8754

CENTER OF GRAVITY OF PROP REFERENCED FROM MIDCHORD OF ROOT SECTION (- FWD. + AFT)/O = .821123

CENTER OF GRAVITY OF BLADES REFERENCED FROM MIDCHORD OF ROOT SECTION (- FWD. + AFT)/O = .828651

HUB DIMENSIONS/O

LENGTH= .1957

FWD DIAM= .1912

AFT DIAM= .1630

MIDCHORD OF ROOT SECTION TO AFT END OF HUB= .0978

HUB DIAM AT MIDCHORD OF ROOT SECTION= .1760

FWD DIAM OF BORE= .1167

AFT DIAM OF BORE= .0844

KELLEPS MINIMUM EAR= .7470E+00

SPEED COEFF V/(ND) JS= .9969E+00

ADVANCE COEFF V(I-WT)/(ND) JA= .7826E+00

DESIGN THRUST COEFF KT= .1937E+00

TORQUE COEFF KO= .3455E-01

PROPULSIVE EFFICIENCY ETAD= .7435E+00

BURRILL THRUST COEFF TC= .1414E+00

BURRILL CAVITATION COEFF SIGMA(2.7)= .3691E+00

CLEARANCE AT HUB BETWEEN BLADES/O= 4.7523E-02

CLEARANCE AT HUB BETWEEN FILLETS/O= 7.3561E-01

MASS POLAR MOMENT OF INERTIA OF BLADES (KG-M2) = .771877E+05
 TOTAL MASS POLAR MOMENT OF INERTIA (KG-M2) = .793262E+05
 RADIUS OF GYRATION OF BLADE/D = .2372
 RADIUS OF GYRATION OF HUB/D = .6698
 TOTAL RADIUS OF GYRATION/D = .2393

ABS COEFFICIENTS (CALCULATED AT THE .25 RADIUS)

ABS MINIMUM THICKNESS IN INCHES (USING P/D INPUT) -
 USING ABS RATE = CONVENTIONAL RATE, T/D = .2766E-01
 USING ABS RATE = CONVENTIONAL + SKEN-INDUCED RATE, T/D = .3292E-01

VALUES USED IN DETERMINING THICKNESS -
 A = .123553E+02
 B = .252922E+03
 C = .146155E+05

SECTION AREA COEFFICIENT CS = .5942E+00

SECTION MODULUS COEFFICIENT CN = .8558E-01

AREA OF EXPANDED CYLINDRICAL SECTION IN SQ. METERS AS = .2942E+00

FOR CN = 1
 ABS MINIMUM THICKNESS IN INCHES (USING P/D INPUT) -
 USING ABS RATE = CONVENTIONAL RATE, T/D = .2581E-01
 USING ABS RATE = CONVENTIONAL + SKEN-INDUCED RATE, T/D = .3931E-01

RADIAL PROPELLER DATA FOR INPUT INTO DESIGN PROGRAMS (8 RADIAL STRIPS ASSUMED)

YR	TAN BETA I	G	XSL (METERS)	XST (METERS)	1-WX	UA/2VS	THICKNESS (METERS)
.22753	1.10430	.1285E-01	-.62661	.85114	.67133	.1113E+00	.27947
.27900	.94970	.1426E-01	-.58011	1.01598	.52733	.1345E+00	.26952
.39200	.76777	.1685E-01	-.40629	1.42172	.64531	.1549E+00	.24327
.44500	.64902	.1767E-01	-.11610	1.04435	.74091	.1578E+00	.20781
.54030	.55092	.1797E-01	.27532	2.29050	.78656	.1618E+00	.16546
.50120	.47534	.1792E-01	.78244	2.74978	.81214	.1651E+00	.12335
.79430	.42379	.1672E-01	1.44032	3.25197	.83678	.1647E+00	.06609
.89720	.37322	.1357E-01	2.31526	3.74934	.86194	.1614E+00	.05632
.94850	.35923	.1040E-01	2.96450	3.95737	.67029	.1616E+00	.04688
1.00000			3.61951	3.61961			

SISI CASE 8

THRUST OPTION, DENSITY OF PROP(KG/M3)= 7750.3717

V(M/SEC) 1.2347E+01 1.2604E+01 1.2707E+01 1.2961E+01
PE(KM) 1.4414E+04 1.5478E+04 1.6589E+04 1.7193E+04 1.8107E+04

O(M) = 7.0104, 1-WT=7.7450, 1-TMD=0.3370, M(M) = 15.9496, RHO(KG/M3) = 1025.8615

Z
AE/AC 6 7.64A3E-01 7.68C6E-01
N(REV/MIN) 1.86C3E+02

X	INPUT	1-WX	INPUT	C/D	INPUT	T/C	INPUT	TANSI	INPUT	TAMB	INPUT	TETS(DEC)	RAKG/D	P/D	CD
												LINEAR	INPUT		INPUT
1.7500E-01	4.3535E-01	1.9100E-01	2.1600E-01	1.3700E+00	8.0222E-01	0.	5.3935E+00	0.	3.9500E-03	1.3400E+00	0.5000E-03		1.3400E+00		0.5000E-03
2.5000E-01	4.0415E-01	2.1050E-01	1.7500E-01	1.0250E+00	6.4015E-01	5.3935E+00	5.3935E+00	5.3935E+00	1.3250E+00	1.3250E+00	0.5000E-03		1.3250E+00		0.5000E-03
3.0000E-01	5.5200E-01	2.3700E-01	1.5400E-01	9.0400E-01	5.0665E-01	5.0665E-01	5.0665E-01	5.0665E-01	1.2740E+00	1.2740E+00	0.5000E-03		1.2740E+00		0.5000E-03
4.0000E-01	6.6420E-01	2.6400E-01	1.2400E-01	7.4400E-01	4.3787E-01	4.3787E-01	4.3787E-01	4.3787E-01	1.2740E+00	1.2740E+00	0.5000E-03		1.2740E+00		0.5000E-03
5.0000E-01	7.5000E-01	2.9100E-01	1.0100E-01	6.3294E-01	4.2657E-01	4.2657E-01	4.2657E-01	4.2657E-01	1.2740E+00	1.2740E+00	0.5000E-03		1.2740E+00		0.5000E-03
6.0000E-01	7.9000E-01	2.9760E-01	7.9000E-01	5.4100E-01	4.7000E-01	4.7000E-01	4.7000E-01	4.7000E-01	1.2740E+00	1.2740E+00	0.5000E-03		1.2740E+00		0.5000E-03
7.0000E-01	8.1400E-01	2.9700E-01	6.0000E-01	4.7000E-01	3.7600E-01	3.7600E-01	3.7600E-01	3.7600E-01	1.2740E+00	1.2740E+00	0.5000E-03		1.2740E+00		0.5000E-03
8.0000E-01	8.3000E-01	2.9640E-01	4.6000E-01	4.1400E-01	3.3000E-01	3.3000E-01	3.3000E-01	3.3000E-01	1.2740E+00	1.2740E+00	0.5000E-03		1.2740E+00		0.5000E-03
9.0000E-01	8.6200E-01	2.9200E-01	3.5000E-01	3.5000E-01	3.1000E-01	3.1000E-01	3.1000E-01	3.1000E-01	1.2740E+00	1.2740E+00	0.5000E-03		1.2740E+00		0.5000E-03
9.5000E-01	9.7000E-01	1.5200E-01	4.3200E-02	3.1000E-01	2.8000E-01	2.8000E-01	2.8000E-01	2.8000E-01	1.2740E+00	1.2740E+00	0.5000E-03		1.2740E+00		0.5000E-03
1.0000E+00	9.7700E-01	0.	0.	3.1000E-01	2.4000E-01	2.4000E-01	2.4000E-01	2.4000E-01	1.2740E+00	1.2740E+00	0.5000E-03		1.2740E+00		0.5000E-03

X	INPUT	TAMB	INPUT	UAT2V	UAT2V	OCTSI	OCTSI	DCPSI	VPIM/SEC	CAVV
1.7500E-01	1.3200E-01	8.6200E-01	1.7335E-01	7.1730E-02	0.	1.4339E-01	1.4339E-01	1.4339E-01	7.9162E+00	4.1603E+00
2.5000E-01	6.4030E-01	1.0850E+00	1.7140E-01	1.2820E-01	1.8139E-01	1.8139E-01	1.8139E-01	1.8139E-01	1.0852E+01	2.3210E+00
3.0000E-01	5.9682E-01	1.9082E-01	1.6050E-01	1.4410E-01	2.7680E-01	2.7680E-01	2.7680E-01	2.7680E-01	1.3019E+01	1.6338E+00
4.0000E-01	5.3795E-01	1.7070E-02	1.3290E-01	1.5882E-01	4.5479E-01	4.5479E-01	4.5479E-01	4.5479E-01	1.7317E+01	9.2685E-01
5.0000E-01	4.8640E-01	1.7848E-02	1.0881E-01	1.5882E-01	6.1474E-01	6.1474E-01	6.1474E-01	6.1474E-01	2.1417E+01	5.9805E-01
6.0000E-01	4.3760E-01	1.8182E-02	9.2585E-02	1.6195E-01	7.6521E-01	7.6521E-01	7.6521E-01	7.6521E-01	2.5222E+01	4.2237E-01
7.0000E-01	3.7620E-01	1.8022E-02	8.0490E-02	1.6440E-01	8.9654E-01	8.9654E-01	8.9654E-01	8.9654E-01	2.8981E+01	3.1204E-01
8.0000E-01	3.3940E-01	1.6540E-02	7.3700E-02	1.6540E-01	9.6540E-01	9.6540E-01	9.6540E-01	9.6540E-01	3.2774E+01	2.3765E-01
9.0000E-01	3.1440E-01	1.3595E-02	6.1950E-02	1.6349E-01	8.4618E-01	8.4618E-01	8.4618E-01	8.4618E-01	3.6591E+01	1.6585E-01
9.5000E-01	2.9684E-01	1.0370E-02	5.8420E-02	1.6190E-01	7.1181E-01	7.1181E-01	7.1181E-01	7.1181E-01	4.0498E+01	1.6564E-01
1.0000E+00	2.8432E-01	0.	5.5340E-02	1.6112E-01	0.	0.	0.	0.	4.0387E+01	1.4630E-01

CPTI=4.0197E-01 CPSI=5.1102E-01 FTAT=7.8661E-01 CTSI=5.1103E-01 CTSI/CPSI=1.0000E+00
CPT=3.9294E-01 CPS=5.6316E-01 ETA=6.9773E-01 CTS=4.9986E-01 CTS/CPS=0.8776E-01

X	CL	ALI(DEC)	FM/C	CD/CL	FIX	LI(W/M)	TETS(DEC)	IC(R/D)E	IC(R/D)TE	T/RD
1.7600E-01	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
2.5000E-01	4.184E-01	6.444E-01	2.844E-02	2.031E-02	2.215E-01	1.831E+04	5.309E+00	-1.910E-01	1.910E-01	9.251E-02
3.0000E-01	3.453E-01	5.914E-01	2.615E-02	2.006E-02	2.334E-01	5.547E+04	9.029E+00	-1.735E-01	1.735E-01	7.053E-02
4.0000E-01	2.971E-01	4.575E-01	2.017E-02	2.061E-02	2.42E-01	1.432E+04	1.631E+01	-1.585E-01	1.585E-01	7.560E-02
5.0000E-01	2.345E-01	3.609E-01	1.591E-02	3.027E-02	2.497E-01	1.308E+05	2.359E+01	-1.071E-01	1.071E-01	6.779E-02
6.0000E-01	1.978E-01	3.047E-01	1.343E-02	4.096E-02	2.516E-01	1.302E+05	3.007E+01	-1.865E-01	1.865E-01	5.465E-02
7.0000E-01	1.745E-01	2.647E-01	1.185E-02	4.722E-02	2.567E-01	1.479E+05	3.816E+01	-9.347E-02	9.347E-02	4.579E-02
8.0000E-01	1.579E-01	2.432E-01	1.022E-02	5.143E-02	2.661E-01	1.546E+05	4.544E+01	-2.371E-01	2.371E-01	3.419E-02
9.0000E-01	1.453E-01	2.233E-01	9.845E-03	5.862E-02	2.745E-01	1.417E+05	5.272E+01	-4.234E-01	4.234E-01	2.400E-02
9.5000E-01	1.303E-01	2.140E-01	9.434E-03	5.116E-02	2.814E-01	1.131E+05	5.635E+01	-9.241E-01	9.241E-01	1.599E-02
1.0000E+00	0.	0.	0.	0.	0.	0.	6.000E+01	-1.009E-01	1.009E-01	1.320E-02

ETA=7.4366E-01 PS(KM) = 2.2325E+04 1-TMD=0.3700E-01 1-WT=7.7450E-01 V(KNOTS) = 2.4500E+01 DESIGN THIN) = 1.5725E+06
7= 6 N(REV/MIN) = 1.8600E+02 V(M/SEC) = 1.2604E+01 CALCULATED THIN) = 1.5725E+06

X	AREALM2	XBARM	YBARM	IXO(M)	IYO(M)	MXO(M)	MYO(M)	MTB(M)	MOB(M)	MAXSTRESS(PA)
1.760E-01	2.795E-01	6.333E-01	0.000E-01	1.373E-03	2.833E-02	3.313E-05	1.959E-06	4.566E-05	2.408E-05	4.971E+07
3.000E-01	3.187E-01	7.888E-01	3.120E-03	1.315E-03	5.316E-02	2.499E-05	1.343E-06	3.421E+07	1.754E+05	3.694E+07
4.000E-01	3.165E-01	9.780E-01	2.257E-03	1.055E-03	6.202E-02	1.651E-05	1.087E-06	2.566E+05	1.278E+05	3.095E+07
5.000E-01	2.863E-01	9.337E-01	1.606E-03	6.411E-04	6.315E-02	1.303E-05	5.934E-05	1.792E+05	9.655E+04	2.697E+07
6.000E-01	2.332E-01	9.536E-01	8.423E-04	3.532E-04	5.357E-02	7.864E-04	4.182E-05	1.111E+05	3.296E+04	2.681E+07
7.000E-01	1.705E-01	9.337E-01	0.000E-01	1.435E-04	3.726E-02	3.977E-04	2.501E-05	6.034E+04	2.743E+04	2.726E+07
8.000E-01	1.095E-01	0.551E-01	0.000E-01	4.535E-05	1.993E-02	1.642E-04	8.427E-04	2.445E+04	1.077E+04	2.624E+07

X	RAG/D	PI XTANSI	PI XTAND
1.760E-01	0.000E+00	7.596E-01	4.436E-01
2.500E-01	0.395E-03	8.078E-01	5.029E-01
3.000E-01	1.407E-02	8.542E-01	5.623E-01
4.000E-01	2.541E-02	9.355E-01	6.765E-01
5.000E-01	3.675E-02	9.937E-01	7.643E-01
6.000E-01	4.819E-02	1.021E+01	8.041E-01
7.000E-01	5.945E-02	1.037E+01	8.297E-01
8.000E-01	7.079E-02	1.052E+01	8.535E-01
9.000E-01	8.214E-02	1.057E+01	8.775E-01
9.500E-01	8.741E-02	1.072E+01	8.860E-01
1.000E+00	9.345E-02	1.077E+01	8.932E-01

WEIGHT OF BLADES(N) = 273758.4944

WEIGHT OF PROP (BLADES + DESIGNATED HUB)(N) = 351222.8754

CENTER OF GRAVITY OF PROP REFERENCED FROM MIDCHORD OF ROOT SECTION (- FWD, + AFT)/D = .021118

CENTER OF GRAVITY OF BLADES REFERENCED FROM MIDCHORD OF ROOT SECTION (- FWD, + AFT)/D = .028635

HUB DIMENSIONS/D

LENGTH= .1957
 FWD DIAM= .1912
 AFT DIAM= .1938
 MIDCHORD OF ROOT SECTION TO AFT END OF HUB= .0378
 HUB DIAM AT MIDCHORD OF ROOT SECTION= .1768
 FWD DIAM OF BORE= .1187
 AFT DIAM OF BORE= .0844

KELLERS MINIMUM EAP= .7770E+00

SPEED COEFF V/(ND) JS= .101E+01

ADVANCE COEFF V(1-WTT)/(ND) JA= .7999E+00

DESIGN THRUST COEFF KT= .2033E+00

TORQUE COEFF KQ= .3710E-01

PROPULSIVE EFFICIENCY ETAP= .7431E+00

SUPRILL THRUST COEFF TC= .1479E+01

SUPRILL CAVITATION COEFF SIGMA(0.7)= .3673E+00

CLEARANCE AT HUB BETWEEN BLADES/D= 4.7523E-02

CLEARANCE AT HUB BETWEEN FILLETS/D= 7.3561E-03

MASS POLAR MOMENT OF INERTIA OF PLATES (KG-M2) = .771877E+05
 TOTAL MASS POLAR MOMENT OF INERTIA (KG-M2) = .793252E+05
 RADIUS OF GYRATION OF BLADE/D = .2172
 RADIUS OF GYRATION OF HUB/D = .0599
 TOTAL RADIUS OF GYRATION/D = .2393

ABS COEFFICIENTS (CALCULATED AT THE .25 RADIUS)

ABS MINIMUM THICKNESS IN INCHES (USING P/D INPUT) =
 USING ABS RATE = CONVENTIONAL RATE, T/D = .2076E-01
 USING ABS RATE = CONVENTIONAL + SKEM-INDUCED RATE, T/D = .3402E-01

VALUES USED IN DETERMINING THICKNESS-
 A = .123059E+02
 B = .252902E+03
 C = .145355E+05

SECTION AREA COEFFICIENT CS = .6942E+00

SECTION MODULUS COEFFICIENT CM = .8550E-01

AREA OF EXPANDED CYLINDRICAL SECTION IN SQ. METERS AS = .2942E+00

FOR CN=1
 ABS MINIMUM THICKNESS IN INCHES (USING P/D INPUT) =
 USING ABS RATE = CONVENTIONAL RATE, T/D = .2603E-01
 USING ABS RATE = CONVENTIONAL + SKEM-INDUCED RATE, T/D = .3133E-01

RADIAL PROPELLER DATA FOR INPUT INTO DESIGN PROGRAMS (8 RADIAL STRIPS ASSUMED)

XR	TAN BETA I	G	XSL (METERS)	XST (METERS)	1-WX	UA/2VS	THICKNESS (METERS)
.22750	1.10596	.1232E-01	-.62661	.85114	.47103	.1114E+00	.27947
.27900	.95121	.1433E-01	-.58011	1.07518	.52733	.1368E+00	.26952
.31200	.76892	.1698E-01	-.40629	1.47172	.64531	.1555E+00	.24327
.45500	.64599	.1779E-01	-.11610	1.86495	.74391	.1596E+00	.28701
.54800	.55175	.1811E-01	.27502	2.29050	.79556	.1628E+00	.16546
.59130	.47705	.1797E-01	.78244	2.75879	.81214	.1563E+00	.12335
.70400	.42142	.1656E-01	1.44332	3.25197	.83678	.1680E+00	.08659
.83700	.37859	.1369E-01	2.31576	3.74914	.86194	.1628E+00	.05632
.91350	.35977	.1069E-01	2.86553	3.95737	.87129	.1619E+00	.04608
1.00000			3.81951	3.81861			

SISI CASE 8

THRUST OPTION, DENSITY OF PROP(KG/M3)= 7750.3717

V(M/SEC) 1.2347E+01 1.2654E+01 1.2707E+01 1.2961E+01
 PE(KN) 1.4414E+04 1.5478E+04 1.5589E+04 1.7100E+04

D(M) = 7.0104 *1-WTT=7850 *1-THD=9370 *M(M) = 15.8496 *RHO(KG/M3) = 1025.8615

Z 6

AE/A0 7.6403E-01 7.6809E-01
 N(REV/MIN) 1.0600E+02

X	INPUT	1-WX	C/O	TANBI	TANB	TETS(DEC)	RANG/O	P/O	CO
	INPUT	INPUT	INPUT	INPUT	INPUT	LINEAR	LINEAR	INPUT	INPUT
1.7600E-01	4.3500E-01	1.9500E-01	2.1500E-01	1.3721E+00	0.0222E-01	0.	0.	1.3400E+00	0.5000E-03
2.5000E-01	4.9410E-01	2.1960E-01	1.7880E-01	1.0285E+00	6.4311E-01	5.3903E+00	-0.3950E-03	1.3250E+00	0.5000E-03
3.0000E-01	5.5250E-01	2.3790E-01	1.5900E-01	9.0299E-01	5.9666E-01	9.0291E+00	-2.4067E-02	1.2740E+00	0.5000E-03
4.0000E-01	6.5420E-01	2.6490E-01	1.2800E-01	7.4527E-01	5.3797E-01	1.6311E+01	-2.5412E-02	1.2570E+00	0.5000E-03
5.0000E-01	7.5000E-01	2.9160E-01	1.0190E-01	6.3369E-01	4.8549E-01	2.3593E+01	-3.6757E-02	1.2480E+00	0.5000E-03
6.0000E-01	7.9000E-01	2.8760E-01	7.9000E-02	5.4186E-01	4.2857E-01	3.0874E+01	-4.8111E-02	1.1760E+00	0.5000E-03
7.0000E-01	8.1420E-01	2.8720E-01	6.0000E-02	4.7131E-01	3.7643E-01	3.8155E+01	-5.9446E-02	1.0700E+00	0.5000E-03
8.0000E-01	8.3930E-01	2.8640E-01	4.6600E-02	4.1053E-01	3.3949E-01	4.5437E+01	-7.0791E-02	9.6803E-01	0.5000E-03
9.0000E-01	8.6250E-01	2.8290E-01	3.9400E-02	3.7745E-01	3.1046E-01	5.2719E+01	-9.2135E-02	9.2503E-01	0.5000E-03
9.5000E-01	8.7530E-01	1.5290E-01	4.3700E-02	3.5924E-01	2.9617E-01	5.6159E+01	-8.7808E-02	9.1000E-01	0.5000E-03
1.0000E+00	8.7760E-01	0.	0.	3.4266E-01	2.8432E-01	6.0000E+01	-9.3450E-02	9.0100E-01	0.5000E-03

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X	TANBI	TAN 9	UT/2V	UA/2V	DCTSI	DCPSI	VR(M/SEC)	CAV
	INPUT	INPUT	INPUT	INPUT	INPUT	INPUT	INPUT	INPUT
1.7600E-01	1.3751E+00	0.0222E-01	1.7450E-01	7.1751E-02	0.	0.	7.9745E+00	4.0955E+03
2.5000E-01	1.0300E+00	6.4031E-01	1.2672E-02	1.2755E-01	1.0224E-01	1.4496E-01	1.0935E+01	2.2848E+00
3.0000E-01	9.0433E-01	5.9656E-01	1.5179E-02	1.6174E-01	2.7441E-01	2.3617E-01	1.3119E+01	1.6082E+03
4.0000E-01	7.5495E-01	5.3797E-01	1.7354E-02	1.3416E-01	4.5836E-01	4.2270E-01	1.7454E+01	9.1217E-01
5.0000E-01	6.3532E-01	4.8649E-01	1.8035E-02	1.0949E-01	6.2369E-01	5.0858E-01	2.1580E+01	5.8052E-01
6.0000E-01	5.4109E-01	4.2657E-01	1.8332E-02	9.3679E-02	7.7359E-01	7.7256E-01	2.5425E+01	4.1533E-01
7.0000E-01	4.7257E-01	3.7683E-01	1.8142E-02	8.1917E-02	6.0511E-01	9.2417E-01	2.9215E+01	3.0705E-01
8.0000E-01	4.1958E-01	3.3949E-01	1.6970E-02	7.1655E-02	4.0511E-01	1.0117E+00	3.3040E+01	2.3404E-01
9.0000E-01	3.7830E-01	3.1046E-01	1.3775E-02	6.2749E-02	8.9765E-01	9.4334E-01	3.6080E+01	1.8282E-01
9.5000E-01	3.6005E-01	2.9617E-01	1.0458E-02	5.9244E-02	7.2112E-01	7.6133E-01	3.8001E+01	1.6298E-01
1.0000E+00	3.4343E-01	2.8432E-01	0.	5.6100E-02	1.6317E-01	0.	4.0716E+01	1.4595E-01

CPTI=0.0650E-01 CPSI=5.1787E-01 ETAT=7.8493E-01 CTSI=5.1736E-01 CTSI/CPSI=9.9843E-01
 CPT=3.9744E-01 CPSE=5.999E-01 ETAT=6.9729E-01 CTS=5.0557E-01 CTS/CPS=8.6898E-01

X	CL	AL(DEC)	FWC	CD/CL	F(X)	LI(M/N)	TETS(DEC)	(C/ROILE	(C/ROITE	T/RD
	INPUT	INPUT	INPUT	INPUT	INPUT	INPUT	INPUT	INPUT	INPUT	INPUT
1.7600E-01	0.	0.	0.	0.	0.	0.	0.	-1.910E-01	1.911E-01	0.251E-02
2.5000E-01	4.213E-01	5.495E-01	2.861E-02	2.017E-02	2.218E-01	3.975E+04	5.309E+00	-1.735E-01	2.657E-01	7.853E-02
3.0000E-01	3.883E-01	5.940E-01	2.036E-02	2.188E-02	2.341E-01	7.717E+04	9.059E+00	-1.735E-01	3.174E-01	7.560E-02
4.0000E-01	2.998E-01	4.617E-01	2.036E-02	2.835E-02	2.825E-01	0.696E+04	1.631E+01	-1.037E-01	4.229E-01	6.779E-02
5.0000E-01	2.369E-01	3.646E-01	1.509E-02	3.589E-02	2.493E-01	1.114E+05	2.359E+01	-1.865E-02	5.445E-01	5.739E-02
6.0000E-01	2.002E-01	3.042E-01	1.759E-02	4.247E-02	2.519E-01	1.314E+05	3.087E+01	9.347E-02	6.637E-01	4.579E-02
7.0000E-01	1.766E-01	2.726E-01	1.199E-02	4.912E-02	2.570E-01	1.522E+05	3.816E+01	2.377E-01	7.991E-01	3.419E-02
8.0000E-01	1.599E-01	2.463E-01	1.746E-02	5.315E-02	2.644E-01	1.510E+05	4.544E+01	4.234E-01	9.362E-01	2.400E-02
9.0000E-01	1.469E-01	2.263E-01	9.977E-03	5.795E-02	2.732E-01	1.479E+05	5.272E+01	6.644E-01	1.074E+00	1.599E-02
9.5000E-01	1.406E-01	2.169E-01	9.563E-03	6.035E-02	2.822E-01	1.165E+05	5.635E+01	8.241E-01	1.131E+00	1.320E-02
1.0000E+00	0.	0.	0.	0.	0.	0.	6.000E+01	1.009E+00	1.009E+00	0.

ETAD=7.4241E-01 PS(KN) =2.3154E+04 1-THD=6.1700E-01 1-WTT=7.8500E-01 V(KNOTS) =7.4700E+01 DESIGN TH(N) =1.6162E+06
 Z=6 N(REV/MIN)=1.0650E+02 AE/A0=7.6443E-01 V(M/SEC) =1.2747E+01 CALCULATED TH(N) =1.6162E+06

X	AREA(M2)	VBAP(M)	YBAP(M)	YB1R(M)	IXO1(M4)	IYO1(M4)	MYO(N-M)	MTB(N-M)	MOB(N-M)	MAXSTRESS(PA)
1.760E-01	2.732E-01	6.333E-01	0.	1.373E-03	2.033E-02	1.968E-06	4.677E+05	2.478E+05	5.117E+07	
3.003E-01	3.187E-01	7.086E-01	3.144E-03	1.315E-03	5.016E-02	1.343E+06	3.519E+05	1.805E+05	3.812E+07	
4.003E-01	3.190E-01	9.742E-01	2.263E-03	1.055E-03	5.222E-02	1.590E+06	2.642E+05	1.316E+05	3.196E+07	
5.003E-01	2.843E-01	9.337E-01	1.527E-03	6.811E-04	6.335E-02	5.946E+05	1.945E+05	8.911E+04	2.797E+07	
6.003E-01	2.333E-01	9.535E-01	0.	3.532E-04	5.357E-02	4.166E+05	1.164E+05	3.453E+04	2.765E+07	
7.003E-01	1.792E-01	9.377E-01	0.	1.435E-04	3.726E-02	2.501E+05	6.213E+04	2.824E+04	2.804E+07	
8.000E-01	1.092E-01	6.541E-01	0.	4.535E-05	1.993E-02	8.424E+04	2.519E+04	1.109E+04	2.709E+07	

Y	PAK5/D	PI Y1ANG1	PI X1ANG1
1.760E-01	3.	7.603E-01	4.436E-01
2.502E-01	-8.395E-03	9.096E-01	5.029E-01
3.303E-01	-1.497E-02	9.561E-01	5.621E-01
4.003E-01	-2.541E-02	9.396E-01	5.760E-01
5.003E-01	-3.676E-02	9.980E-01	7.542E-01
6.003E-01	-4.810E-02	1.024E+00	8.041E-01
7.003E-01	-5.945E-02	1.039E+00	8.247E-01
8.003E-01	-7.079E-02	1.055E+00	8.532E-01
9.003E-01	-8.214E-02	1.070E+00	8.779E-01
9.503E-01	-9.348E-02	1.079E+00	8.932E-01
1.003E+00	-9.348E-02	1.079E+00	8.932E-01

WEIGHT OF BLADES(M) = 273758.4944

WEIGHT OF PROP (BLADES + DESIGNATED HUB)(M) = 361222.8754

CENTER OF GRAVITY OF PROP REFERENCED FROM MICHORD OF ROOT SECTION (- FWD. + AFT)/O = .821091

CENTER OF GRAVITY OF BLADES REFERENCED FROM MICHORD OF ROOT SECTION (- FWD. + AFT)/O = .828609

HUB DIMENSIONS/D

LENGTH	.1957
FWD DIA	.1812
AFT DIA	.1630
MICHORD OF ROOT SECTION TO AFT END OF HUB	.0978
MICHORD OF ROOT SECTION TO AFT END OF HUB	.1768
MUD DIA AT MICHORD OF ROOT SECTION	.1107
FWD DIA OF PORE	.0944
AFT DIA OF PORE	.0944

KELLERS MINIMUM EAR = .7946E+00

SPEED COEFF V/(ND) JS = .1025E+01

ADVANCE COEFF VII-WTT/(ND) JA = .8054E+00

DESIGN THRUST COEFF KT = .2090E+00

TORQUE COEFF KO = .3847E-01

PROPULSIVE EFFICIENCY ETAD = .7424E+00

BURRILL THRUST COEFF TC = .1517E+00

BURRILL CAVITATION COEFF SIGMA(0.7) = .3665E+00

CLEARANCE AT HUB BETWEEN BLADES/O = 4.7523E-02

CLEARANCE AT HUB BETWEEN FILLETS/O = 7.3561E-03

MASS POLAR MOMENT OF INERTIA OF BLADES (KG-M2)= .771877E+05
 TOTAL MASS POLAR MOMENT OF INERTIA (KG-M2)= .793262E+05
 RADIUS OF GYRATION OF BLADE/D= .2372
 RADIUS OF GYRATION OF HUB/D= .0693
 TOTAL RADIUS OF GYRATION/D= .2093

ABS COEFFICIENTS (CALCULATED AT THE .25 RADIUS)

ABS MINIMUM THICKNESS IN INCHES USING P/D INPUT -
 USING ABS RAKE = CONVENTIONAL RAKE, T/D= .2934E-01
 USING ABS RAKE = CONVENTIONAL + SKEN-INDUCED RAKE, T/D= .3461E-01

VALUES USED IN DETERMINING THICKNESS-
 A= .123050E+02
 B= .252902E+03
 C= .146355E+05

SECTION AREA COEFFICIENT CS= .6942E+00

SECTION MODULUS COEFFICIENT CN= .8556E-01

AREA OF EXPANDED CYLINDRICAL SECTION IN SQ. METERS AS= .2942E+00

FOR CN=.1

ABS MINIMUM THICKNESS IN INCHES USING P/D INPUT -
 USING ABS RAKE = CONVENTIONAL RAKE, T/D= .2737E-01
 USING ABS RAKE = CONVENTIONAL + SKEN-INDUCED RAKE, T/D= .3188E-01

◊ADIAL PROPELLER DATA FOR INPUT INTO DESIGN PROGRAMS(8 RADIAL STRIPS ASSUMED)

XP	TAN BETA I	G	XSL(METERS)	XST(METERS)	I-WX	UA/2VS	THICKNESS(METERS)
.22750	1.13845	.1038E-01	-.62661	.85114	.47103	.1116E+00	.27947
.27900	.95335	.1443E-01	-.58211	1.03598	.52733	.1353E+00	.26952
.34200	.77065	.1713E-01	-.40629	1.42172	.64531	.1564E+00	.24327
.44500	.65045	.1797E-01	-.11010	1.84495	.74091	.1599E+00	.20761
.54800	.55299	.1832E-01	.27502	2.20050	.78656	.1644E+00	.16546
.64100	.47612	.1819E-01	.78244	2.75478	.81214	.1693E+00	.12335
.73400	.42236	.1708E-01	1.44332	3.24107	.83579	.1578E+00	.08609
.82700	.37344	.1387E-01	2.31576	3.74916	.86194	.1647E+00	.05632
.91850	.36658	.1063E-01	2.86350	3.94717	.87029	.1639E+00	.04688
1.00600			3.81861	3.81861			

SISI CASE 8

THRUST OPTION, DENSITY OF PROP(KG/M3)= 7750.3717

V(M/SEC) 1.2309E+01 1.2347E+01 1.2604E+01 1.2707E+01 1.2801E+01
 PE(KN) 1.4414E+04 1.5478E+04 1.6589E+04 1.7193E+04 1.8103E+04

D(M) = 7.01C4 + 1-WTT=7.850 + 1-TWO=.3370 + (M) = 15.8496 + (M0(KG/M3)) = 1025.8615

Z 6

AE/A0 7.6493E-01 7.6800E-01

M(EV/MIN) 1.0600E+02

X	INPUT	1-WY	C/D	T/C	TANBI	TANB	TETS(DEC)	RAKG/D	P/D	CD
	INPUT	INPUT	INPUT	INPUT	INPUT	INPUT	LINEAR	LINEAR	INPUT	INPUT
1.7600E-01	4.3543E-01	1.9100E-01	2.1600E-01	1.3751E+00	8.3222E-01	0.	0.	0.	1.3400E+00	8.5000E-03
2.5000E-01	4.9433E-01	2.1900E-01	1.7800E-01	1.0309E+00	6.4331E-01	5.3803E+00	-0.3950E-03	0.	1.3250E+00	8.5000E-03
3.0000E-01	5.5253E-01	2.3790E-01	1.5890E-01	9.0833E-01	5.0666E-01	9.0201E+00	-1.4067E-02	0.	1.2740E+00	8.5000E-03
4.0000E-01	6.6422E-01	2.6490E-01	1.2800E-01	7.4695E-01	5.3797E-01	1.6311E+01	-2.5412E-02	0.	1.2570E+00	8.5000E-03
5.0000E-01	7.5000E-01	2.8160E-01	1.0190E-01	6.3532E-01	4.4649E-01	2.3592E+01	-3.6757E-02	0.	1.2400E+00	8.5000E-03
6.0000E-01	7.9000E-01	2.9760E-01	7.0900E-02	5.4324E-01	4.2657E-01	3.0874E+01	-4.9141E-02	0.	1.1760E+00	8.5000E-03
7.0000E-01	8.1430E-01	2.9070E-01	6.0900E-02	4.7257E-01	3.7693E-01	3.8155E+01	-5.9446E-02	0.	1.0700E+00	8.5000E-03
8.0000E-01	8.2832E-01	2.5640E-01	4.6820E-02	4.1958E-01	3.3949E-01	4.5437E+01	-7.0791E-02	0.	9.6800E-01	8.5000E-03
9.0000E-01	8.6253E-01	2.0290E-01	3.9400E-02	3.7833E-01	3.1048E-01	5.2714E+01	-8.2135E-02	0.	9.2500E-01	8.5000E-03
9.5000E-01	8.7093E-01	1.5280E-01	4.3200E-02	3.6035E-01	2.9687E-01	5.6359E+01	-8.7800E-02	0.	9.1000E-01	8.5000E-03
1.0000E+00	8.7760E-01	0.	0.	3.4343E-01	2.9312E-01	6.0000E+01	-9.3340E-02	0.	9.0133E-01	8.5000E-03

X	TANBI	TAN B	UT/2V	UA/2V	OCTSI	DCPSI	VR(M/SEC)	CAVV
1.7600E-01	1.3795E+00	8.0222E-01	1.7534E-01	7.1727E-02	0.	0.	8.0610E+00	4.0013E+00
2.5000E-01	1.6344E+00	6.4331E-01	1.7301E-01	1.2402E-01	1.8343E-01	1.463	1.1059E+01	2.2321E+00
3.0000E-01	9.1122E-01	5.9666E-01	1.5335E-02	1.6333E-01	2.8066E-01	2.3682E-01	1.3270E+01	1.5709E+00
4.0000E-01	7.4932E-01	5.3797E-01	1.7572E-02	1.5843E-01	1.5919E-01	4.6340E-01	1.7659E+01	8.9087E-01
5.0000E-01	6.3734E-01	4.8649E-01	1.9300E-02	1.4091E-01	1.6211E-01	6.2910E-01	2.1849E+01	5.7470E-01
6.0000E-01	5.4491E-01	4.2657E-01	1.8620E-02	9.5229E-02	1.6769E-01	7.9259E-01	2.5720E+01	4.0555E-01
7.0000E-01	4.7407E-01	3.7683E-01	1.8455E-02	8.3169E-02	1.7059E-01	9.2308E-01	2.9566E+01	2.9980E-01
8.0000E-01	4.2091E-01	3.3949E-01	1.7278E-02	7.3009E-02	1.7312E-01	9.9355E-01	3.3437E+01	2.2850E-01
9.0000E-01	3.7950E-01	3.1048E-01	1.4031E-02	6.8314E-02	1.6745E-01	9.1390E-01	3.7333E+01	1.7449E-01
9.5000E-01	3.6119E-01	2.9687E-01	1.3654E-02	6.5505E-02	1.6675E-01	7.7773E-01	3.9269E+01	1.5912E-01
1.0000E+00	3.4453E-01	2.8432E-01	5.7362E-02	1.6607E-01	0.	0.	4.1207E+01	1.4249E-01

CPTI=4.1290E-01 CPSI=5.2763E-01 ETAI=7.8255E-01 CTSI=5.2504E-01 CTSI/CPSI=9.9509E-01

CPTI=4.0303E-01 CPSI=5.7970E-01 ETA=6.9662E-01 CTSI=5.1353E-01 CTSI/CPSI=8.8584E-01

X	CL	ALI(DFG)	FMC	CO/CL	FIX	LI(M/H)	TETS(DEC)	(C/RD)ITE	(C/RD)ITE	T/RD
1.7600E-01	0.	0.	0.	0.	0.	0.	0.	1.910E-01	8.251E-02	0.
2.5000E-01	4.255E-01	6.552E-01	2.883E-01	1.998E-02	2.223E-01	4.109E+04	5.380E+00	-1.735E-01	2.657E-01	7.853E-02
3.0000E-01	3.935E-01	6.044E-01	2.665E-02	2.166E-02	2.346E-01	5.912E+04	9.029E+00	-1.584E-01	3.174E-01	7.560E-02
4.0000E-01	3.036E-01	4.676E-01	2.062E-02	2.799E-02	7.429E-01	9.011E+04	1.631E+01	-1.037E-01	4.259E-01	6.779E-02
5.0000E-01	2.434E-01	3.722E-01	1.632E-02	3.536E-02	2.494E-01	1.152E+05	2.359E+01	-1.865E-02	5.445E-01	5.739E-02
6.0000E-01	2.034E-01	3.133E-01	1.381E-02	4.178E-02	2.523E-01	1.191E+05	3.087E+01	9.347E-02	6.687E-01	4.579E-02
7.0000E-01	1.797E-01	2.767E-01	1.225E-02	4.730E-02	2.574E-01	1.595E+05	3.816E+01	2.377E-01	7.991E-01	3.419E-02
8.0000E-01	1.682E-01	2.568E-01	1.106E-02	5.226E-02	2.667E-01	1.573E+05	4.544E+01	4.234E-01	9.362E-01	2.460E-02
9.0000E-01	1.497E-01	2.305E-01	1.016E-02	5.679E-02	2.744E-01	1.593E+05	5.272E+01	6.644E-01	1.074E+00	1.599E-02
9.5000E-01	1.435E-01	2.210E-01	9.743E-03	5.924E-02	2.822E-01	1.216E+05	5.834E+01	8.241E-01	1.130E+00	1.320E-02
1.0000E+00	0.	0.	0.	0.	0.	0.	6.000E+01	1.089E+00	1.089E+00	0.

ETA0=7.415E-01 PS(KN) = 2.4416E+04 1-TWO=8.3700E-01 1-WTT=7.8500E-01 VIKNOTS = 2.500CE+01 DESIGN TH(N) = 1.6817E+06
 Z= 5 H(EV/MIN)=1.1600E+02 VIM/SEC = 1.201E+01 CALCULATED TH(N) = 1.6817E+06

X	AREA(M2)	XBAR(M)	YBAR(M)	IXO(M4)	IYO(M4)	IXO(M-M)	IYO(M-M)	MYO(M-M)	MYO(M-M)	MTB(M-M)	MQB(M-M)	MAXSTRESS(PA)
1.760E-01	2.792E-01	6.333E-01	0.	1.372E-03	2.633E-02	3.633E+05	2.791E+05	1.902E+C6	1.356E+05	4.071E+05	2.581E+05	5.334E+07
3.000E-01	3.187E-01	7.885E-01	3.185E-03	1.315E-03	5.016E-02	2.791E+05	1.356E+05	1.356E+05	1.356E+05	3.667E+05	1.841E+05	3.989E+07
4.000E-01	3.180E-01	8.740E-01	2.321E-03	1.055E-03	6.222E-02	1.451E+05	1.094E+06	1.094E+06	1.094E+06	2.752E+05	1.372E+05	3.340E+07
5.000E-01	2.863E-01	9.377E-01	1.658E-03	6.811E-04	6.215E-02	1.451E+05	5.965E+05	5.965E+05	5.965E+05	1.023E+05	9.291E+04	2.922E+07
6.000E-01	2.333E-01	9.516E-01	8.697E-04	3.532E-04	5.137E-02	8.742E+04	4.193E+05	4.193E+05	4.193E+05	1.214E+05	5.686E+04	2.892E+07
7.000E-01	1.705E-01	9.307E-01	0.	1.435E-04	3.726E-02	4.459E+04	2.502E+05	2.502E+05	2.502E+05	6.481E+04	2.946E+04	2.922E+07
8.000E-01	1.090E-01	8.501E-01	0.	4.535E-05	1.993E-02	1.641E+04	8.418E+C4	8.418E+C4	8.418E+C4	2.627E+04	1.157E+04	2.836E+07

X	RANG/D	PI XTANGI	PI XTANB
1.760E-01	0.395E-03	7.628E-11	4.436E-01
2.500E-01	-1.437E-02	9.599E-11	5.329E-01
3.000E-01	-2.541E-02	9.416E-11	5.623E-01
4.000E-01	-3.476E-02	1.011E-10	6.762E-01
5.000E-01	-4.010E-02	1.027E-10	7.542E-01
6.000E-01	-5.945E-02	1.043E-10	8.041E-01
7.000E-01	-7.579E-02	1.058E-10	8.287E-01
8.000E-01	-8.214E-02	1.073E-10	8.532E-01
9.000E-01	-9.781E-02	1.088E-10	8.779E-01
1.000E-01	-9.348E-02	1.092E-10	8.932E-01

WEIGHT OF BLADES(N) = 273758.4954

WEIGHT OF PROP (BLADES + DESIGNATED HUB)(N) = 361222.8754

CENTER OF GRAVITY OF PROP REFERENCED FROM MIDCHORD OF ROOT SECTION (- FWD, + AFT)/D= .921864

CENTER OF GRAVITY OF BLADES REFERENCED FROM MTCCHRD OF ROOT SECTION (- FWD, + AFT)/D= .828574

HUB DIMENSIONS/O

LENGTH= .1957
 FWD DIAM= .1812
 AFT DIAM= .1538
 MIDCHORD OF ROOT SECTION TO AFT END OF HUB= .8978
 HUB DIAM AT MIDCHORD OF ROOT SECTION= .1760
 FWD DIAM OF BORE= .1287
 AFT DIAM OF BORE= .0844

KELLERS MINIMUM EAR= .8208E+00

SPEED COEFF V/(ND) JS= .1034E+01

ADVANCE COEFF V(1-WTT)/(ND) JA= .0152E+00

DESIGN THRUST COEFF KT= .2175E+00

TOPOUE COEFF KO= .4057E-01

PROPULSIVE EFFICIENCY ETAD= .7415E+00

BURRILL THRUST COEFF TC= .1575E+00

BURRILL CAVITATION COEFF SIGMA(0.7)= .3654E+00

CLEARANCE AT HUB BETWEEN BLADES/D= 4.7523E-02

CLEARANCE AT HUB BETWEEN FILLETS/D= 7.3561E-03

MASS POLAR MOMENT OF INERTIA OF BLADES (KG-M2)= .771877E+05
 TOTAL MASS POLAR MOMENT OF INERTIA (KG-M2)= .793262E+05
 RADIUS OF GYRATION OF BLADE/D= .2372
 RADIUS OF GYRATION OF HUB/D= .0698
 TOTAL RADIUS OF GYRATION/D= .2003

ARS COEFFICIENTS (CALCULATED AT THE .25 RADIUS)

ARS MINIMUM THICKNESS IN INCHES (USING P/D INPUT)-
 USING ABS RAKE = CONVENTIONAL RAKE, T/O= .3022E-01
 USING ABS RAKE = CONVENTIONAL + SKEM-INDUCED RAKE, T/O= .3548E-01

VALUES USED IN DETERMINING THICKNESS-
 A= .123052E+02
 B= .252902E+03
 C= .146355E+05

SECTION AREA COEFFICIENT CS= .6942E+00

SECTION MODULUS COEFFICIENT CM= .8558E-01

AREA OF EXPANDED CYLINDRICAL SECTION IN SQ.METERS AS= .2942E+00

FOR CM=.1

ABS MINIMUM THICKNESS IN INCHES (USING P/D INPUT)-
 USING ABS RAKE = CONVENTIONAL RAKE, T/O= .2818E-01
 USING ABS RAKE = CONVENTIONAL + SKEM-INDUCED RAKE, T/O= .3269E-01

RADIAL PROPELLER DATA FOR INPUT INTO DESIGN PROGRAMS (8 RADIAL STRIPS ASSUMED)

XR	TAN BETA I	G	XSL (METERS)	XST (METERS)	1-MX	UA/2VS	THICKNESS (METERS)
.22750	1.11197	.1047E-01	-.62651	.85114	.47103	.1119E+00	.27947
.27900	.95634	.1457E-01	-.58011	1.01598	.52733	.1359E+00	.26952
.34200	.77310	.1734E-01	-.40629	1.47172	.64531	.1577E+00	.24327
.48530	.45252	.1823E-01	-.11610	1.84435	.74091	.1617E+00	.20701
.58000	.55475	.1861E-01	.27532	2.29050	.78656	.1665E+00	.16546
.63130	.47965	.1855E-01	.74244	2.75470	.81214	.1704E+00	.12335
.72400	.23771	.1735E-01	1.44032	3.25197	.83678	.1704E+00	.08609
.83730	.38265	.1413E-01	2.31576	3.74934	.85194	.1675E+00	.05632
.94850	.36172	.1043E-01	2.86453	3.97717	.87329	.1668E+00	.04688
1.00000			3.81951	3.91451			

APPENDIX E

SAMPLE DESIGN USING POWER OPTION

OPTIONS EXERCISED IN APPENDIX E

Power or thrust	Power
Calculations with input $\tan\beta_I$	N/A
$\tan\beta_I$ (Lerbs or Input)	Lerbs
$\tan\beta$ (calculated from $(1-w_x)$ or input)	Calc
C_D (constant, variable, or calculated)	Calc
Multiple RPM	Yes
Multiple Z	Yes
Multiple AE/AO	Yes
Check AE/AO of input C/D and modify	Yes
SKEW (Linear/nonlinear)	NL
RAKE (Linear/nonlinear)	NL
P/D (input or approximated by $\pi \tan\beta_I$)	Approx Calc
ABS Coefficients	Yes
Hub Geometry	Approx Calc
Input Units	English
Output Units	English

WDW-N5RDC-5230/7 (979)

680 199-921

DOCUMENTATION CASE A

PS(MP)= 3.0000E+04, DENSITY OF PROPL(LBM/FT3)= 483.9400

V(KNOTS) 7.3500E+01 2.4000E+01 2.4500E+01 2.4700E+01 2.5000E+01
 P(HP) 1.9329E+04 2.0756E+04 2.2246E+04 2.3052E+04 2.4277E+04

O(FT)= 23.0000, 1-WTT=.7850, 1-THO=.8370, M(FT)= 52.0000, P(HQ(C/LUG/FT3))= 1.9905

Z 6 5

AE/A0 7.5643E-01 7.6800E-01 9.0000E-01
 N(REV/MIN) 1.0600E+02 1.2000E+02

X	INPUT	1-WX	C/D	T/C	TANPI	TAMB	TETS(DEC)	RAK/D	P/D	CO
		INPUT	INPUT	INPUT	LFPS	CALCULATED	NONLINEAR	NONLINEAR	PIXTANSI	CALCULATED
1.7600E-01	4.3500E-01	1.9100E-01	2.1500E-01	2.1500E-01	1.2655E+00	0.7310E-01	0.	0.	0.	1.2337E-02
2.5000E-01	6.9410E-01	2.1950E-01	1.7800E-01	1.7800E-01	9.9318E-01	6.4022E-01	-3.2000E+00	0.	0.	1.0610E-02
3.0000E-01	5.5250E-01	2.3790E-01	1.5900E-01	1.5900E-01	9.3660E-01	5.9559E-01	-4.0110E+00	0.	0.	1.0227E-02
4.0000E-01	6.6420E-01	2.6440E-01	1.2800E-01	1.2800E-01	6.8796E-01	5.3749E-01	0.	-1.0793E-01	0.	9.5604E-03
5.0000E-01	7.5000E-01	2.8160E-01	1.0100E-01	1.0100E-01	5.8515E-01	4.8642E-01	1.0313E+01	-1.0244E-01	0.	9.1268E-03
6.0000E-01	7.9000E-01	2.9760E-01	7.9600E-02	7.9600E-02	5.0019E-01	4.2591E-01	2.1554E+01	-5.7600E-01	0.	8.6361E-03
7.0000E-01	8.1420E-01	2.8070E-01	6.0000E-02	6.0000E-02	4.3523E-01	3.7674E-01	3.2716E+01	-4.4609E-01	0.	8.4720E-03
8.0000E-01	8.3430E-01	2.5640E-01	4.9800E-02	4.9800E-02	3.8644E-01	3.3944E-01	4.4977E+01	-1.0500E+00	0.	8.3964E-03
9.0000E-01	8.6250E-01	2.3290E-01	3.9400E-02	3.9400E-02	3.1044E-01	2.9444E-01	5.4545E+01	-1.1522E+00	0.	8.4355E-03
1.0000E-01	8.7050E-01	1.5240E-01	4.3200E-02	4.3200E-02	3.3161E-01	2.3642E-01	5.7754E+01	-1.1400E+00	0.	9.0000E-03
1.0000E+00	8.7740E-01	0.	0.	0.	3.1631E-01	2.3424E-01	6.0009E+01	-1.1217E+00	0.	

X	TANRI	TAN 9	UT/2V	U8/2V	OCPSI	VC(FT/SEC)	CAVV
1.7600E-01	1.3720E+00	8.0210E-01	1.2337E-01	7.1741E-02	0.	2.5972E+01	4.1597E+00
2.5000E-01	1.0225E+00	6.4822E-01	1.2597E-02	1.2737E-01	1.3148E-01	3.5607E+01	2.3207E+00
3.0000E-01	9.0631E-01	5.0528E-01	1.5078E-02	1.5078E-01	2.7697E-01	4.2715E+01	1.0336E+00
4.0000E-01	7.4520E-01	5.3769E-01	1.7212E-02	1.7212E-01	2.5512E-01	5.6815E+01	9.2667E-01
5.0000E-01	6.3391E-01	4.8642E-01	1.7815E-02	1.5003E-01	6.1526E-01	7.0272E+01	5.9792E-01
6.0000E-01	5.4147E-01	4.2651E-01	1.8135E-02	1.6747E-01	7.8508E-01	8.2755E+01	4.2199E-01
7.0000E-01	4.7152E-01	3.7674E-01	1.7936E-02	1.6566E-01	8.9536E-01	9.1231E-01	3.1194E-01
8.0000E-01	4.1964E-01	3.3944E-01	1.6769E-02	1.6594E-01	9.6544E-01	9.9817E-01	2.3779E-01
9.0000E-01	3.7746E-01	3.1044E-01	1.3607E-02	1.6244E-01	9.7122E-01	1.2006E+02	1.0576E-01
1.0000E+00	3.5925E-01	2.9642E-01	1.0330E-02	1.6259E-01	7.1259E-01	1.2629E+02	1.0560E-01
1.0000E+00	3.4267E-01	2.8428E-01	5.5404E-02	1.6127E-01	0.	1.3252E+02	1.4830E-01

CPTI=4.0234E-01 CPSI=5.1157E-01 ETAI=7.8649E-01 CTSI=5.1143E-01 CTSI/CPSI=1.2036E+00
 CPTI=3.9301E-01 CPSI=5.6449E-01 ETAI=6.5022E-01 CTSI=6.9905E-01 CTSI/CPSI=8.8569E-01

X	CL	ALI(DEC)	FM/C	CO/CL	FIX)	LI(LBF/FT)	TETS(DEC)	(C/RN)LE	(C/RN)TE	T/RD
1.7600E-01	0.	0.	0.	0.	0.	0.	0.	-1.910E-01	1.910E-01	0.251E-02
2.5000E-01	6.146E-01	6.446E-01	2.842E-02	2.581E-02	2.215E-01	2.565E+03	-3.200E+00	-2.396E-01	1.996E-01	7.853E-02
3.0000E-01	3.855E-01	5.977E-01	2.618E-02	2.631E-02	2.338E-01	3.430E+03	-4.011E+00	-2.662E-01	2.096E-01	7.560E-02
4.0000E-01	2.972E-01	4.577E-01	2.019E-02	3.211E-02	2.422E-01	5.915E+03	0.	-2.648E-01	2.648E-01	6.779E-02
5.0000E-01	2.345E-01	3.611E-01	1.592E-02	3.892E-02	2.447E-01	7.445E+03	0.	-1.719E-01	3.822E-01	5.739E-02
6.0000E-01	1.949E-01	3.049E-01	1.344E-02	4.43E-02	2.516E-01	9.976E+03	2.166E+01	-2.944E-02	5.455E-01	4.579E-02
7.0000E-01	1.744E-01	2.689E-01	1.145E-02	4.939E-02	2.567E-01	1.316E+04	3.272E+01	1.612E-01	7.226E-01	3.419E-02
8.0000E-01	1.540E-01	2.433E-01	1.074E-02	5.362E-02	2.661E-01	1.372E+04	4.498E+01	4.244E-01	9.372E-01	2.400E-02
9.0000E-01	1.451E-01	2.235E-01	9.954E-03	5.766E-02	2.740E-01	9.716E+03	5.455E+01	7.129E-01	1.119E+00	1.599E-02
1.0000E+00	1.371E-01	2.142E-01	9.444E-03	6.065E-02	2.814E-01	7.749E+03	5.775E+01	9.647E-01	1.170E+00	1.320E-02
1.0000E+00	0.	0.	0.	0.	0.	0.	6.000E+01	1.107E+00	1.107E+00	0.

ETA0=7.4133E-01 PS(MP)= 3.0000E+04 1-THO=.8370E-01 1-WTT=.7850E-01 V(KNOTS)= 2.4500E+01 DESIGN TH(LBF)= 3.5350E+05
 Z= 6 N(REV/MIN)= 1.0600E+02 AE/A0= 7.6431E-01 V(FT/SEC)= 4.1351E+01 CALCULATED TH(LBF)= 3.5350E+05

X	AREA (IN ²)	YBAR (IN)	YBAR (IN)	XZO (IN4)	IYO (IN6)	MYO (IN-LRF)	MYO (IN-LRF)	MTB (IN-LRF)	MOB (IN-LRF)	MAXSTRESS (LBF/IN ²)
1.760E-01	4.320E+02	2.493E+01	0.	3.295E+03	6.807E+04	1.245E+05	1.325E+06	4.025E+06	2.135E+06	3.721E+03
3.000E-01	4.910E+02	3.105E+01	0.	3.160E+03	1.205E+05	-6.695E+05	5.195E+06	3.035E+06	1.554E+06	3.423E+03
4.000E-01	4.970E+02	3.457E+01	8.892E-02	2.576E+03	1.600E+05	-1.555E+07	-3.470E+06	2.273E+06	1.132E+06	5.362E+03
5.000E-01	4.433E+02	3.670E+01	6.320E-02	1.638E+03	1.517E+05	-1.145E+07	-2.052E+06	1.635E+06	7.667E+05	2.575E+04
6.000E-01	3.510E+02	3.754E+01	3.319E-02	8.465E+02	1.249E+05	-1.261E+07	-2.594E+06	1.002E+06	4.690E+05	3.093E+04
7.000E-01	2.615E+02	3.664E+01	0.	3.448E+02	8.952E+04	-4.251E+06	5.792E+05	5.347E+05	3.428E+05	5.063E+03
8.000E-01	1.690E+02	3.347E+01	0.	1.049E+02	6.749E+04	-1.146E+06	2.019E+05	2.167E+05	9.524E+04	1.478E+04

X	RAXG/D	PI XTANDI	PI XTAMP
1.760E-01	0.	7.546E-01	4.435E-01
2.500E-01	0.	9.070E-01	5.074E-01
3.000E-01	0.	9.542E-01	5.623E-01
4.000E-01	-1.070E-01	9.366E-01	6.759E-01
5.000E-01	-1.005E-01	9.057E-01	7.641E-01
6.000E-01	-5.761E-01	1.021E+00	8.040E-01
7.000E-01	-0.461E-01	1.037E+00	8.246E-01
8.000E-01	-1.050E+00	1.052E+00	8.531E-01
9.000E-01	-1.152E+00	1.067E+00	8.777E-01
9.500E-01	-1.140E+00	1.072E+00	8.859E-01
1.000E+00	-1.122E+00	1.077E+00	8.931E-01

HEIGHT OF BLADES(LRF)= 61943.3524

HEIGHT OF PROP (BLADES + CYLINDRICAL HUB)(LRF)= 96749.8881

CENTER OF GRAVITY OF PROP REFERENCED FROM MIDCHORD OF ROOT SECTION (- FWD. + AFT)/D= -.207136

CENTER OF GRAVITY OF BLADES REFERENCED FROM MIDCHORD OF ROOT SECTION (- FWD. + AFT)/D= -.291973

HUB DIMENSIONS/D

HUB DIAM = .176"
HUB LENGTH = .176"
MIDCHORD OF ROOT SECTION TO AFT END OF HUB = .0888

KELLERS MINIMUM EAR= .7770E+08

SPEED COEFF V/(ND) JS= .1019E+01

ADVANCE COEFF V(1-WTT)/(ND) JA= .7999E+00

DESIGN THPUST COEFF KT= .2033E+00

TORQUE COEFF KQ= .3718E-01

PROPULSIVE EFFICIENCY ETAP= .7413E+00

PUPILL THPUST COEFF TC= .1479E+00

BUBRILL CAVITATION COEFF SIGMA(0.7)= .3673E+00

CLEARANCE AT HUB BETWEEN BLADES/D= 4.1102E-07

CLEARANCE AT HUB BETWEEN FILLETS/D= -4.9439E-03

MASS POLAR MOMENT OF INERTIA OF BLADES (LRM-IN2) = .263763E+09
 TOTAL MASS POLAR MOMENT OF INERTIA (LRM-IN2) = .261763E+09
 RADIUS OF GYPATION OF BLADE/0 = .2172
 RADIUS OF GYPATION OF HUB/0 = 0.0003
 TOTAL RADIUS OF GYPATION/0 = .1993

ANS COEFFICIENTS (CALCULATED AT THE .25 RADIUS)

ABS MINIMUM THICKNESS IN INCHES (USING $P/D = \text{PI} \times \text{TAN} \theta$) -
 USING ABS RAKE = CONVENTIONAL RAKE, $T/D = -.1986E-01$
 USING ABS RAKE = CONVENTIONAL + SKEW-INDUCED RAKE, $T/D = -.1986E-01$

VALUES USED IN DETERMINING THICKNESS-
 A = .102509E+02
 B = .22922E+01
 C = .109347E+05

SECTION AREA COEFFICIENT CS = .6942E+09

SECTION MODULUS COEFFICIENT CM = .6559E-01

AREA OF EXPANDED CYLINDRICAL SECTION IN SQ. INCHES AS = .4559E+03

FOR CN = .1
 ABS MINIMUM THICKNESS IN INCHES (USING $P/D = \text{PI} \times \text{TAN} \theta$) -
 USING ABS RAKE = CONVENTIONAL RAKE, $T/D = -.1395E-01$
 USING ABS RAKE = CONVENTIONAL + SKEW-INDUCED RAKE, $T/D = -.1395E-01$

RAJAL PROPELLER DATA FOR INPUT INTO DESIGN PROGRAMS (8 RAJAL STOPS ASSUMED)

XR	TAN BETA I	G	XSL (INCHES)	XST (INCHES)	I-MX	UA/2VS	THICKNESS (INCHES)
.22750	1.10595	.1032E-01	-30.99926	27.17974	.47103	.1114E+00	11.00267
.27900	.95122	.1434E-01	-35.41377	28.27714	.52733	.1349E+00	12.01108
.39200	.76694	.1700E-01	-37.43197	34.44412	.64431	.1506E+00	9.57751
.45000	.64921	.1790E-01	-26.57459	50.62463	.74091	.1588E+00	9.15008
.59800	.55176	.1812E-01	-6.30973	72.51954	.74556	.1629E+00	5.51410
.6-100	.47706	.1795E-01	14.65000	97.35846	.81214	.1664E+00	5.85646
.79400	.42142	.1697E-01	56.25706	127.57419	.83478	.1661E+00	3.33921
.99700	.37563	.1371E-01	97.26563	153.74493	.86134	.1629E+00	2.21752
.94850	.35977	.1050E-01	118.58734	161.45577	.87029	.1621E+00	1.84558
1.00000			152.76260	152.76260			

2004 A

X	AREA (IN2)	XRAY (IN)	YRAY (IN)	IXO (IN4)	IYO (IN4)	MYO (IN-LBF)	MTG (IN-LBF)	MOB (IN-LBF)	MAXSTRESS (LBF/IN2)
1.760E-01	4.324E+02	2.403E+01	0.	3.294E+03	6.457E+04	7.139E+05	3.080E+06	1.880E+06	4.792E+03
2.500E-01	4.910E+02	3.105E+01	9.91E-02	3.160E+03	1.255E+05	7.214E+06	2.007E+06	1.364E+06	4.502E+03
3.000E-01	4.920E+02	3.457E+01	6.745E-02	2.536E+03	1.405E+05	-3.559E+06	2.175E+06	9.929E+05	6.707E+03
3.000E-01	4.438E+02	3.676E+01	4.716E-02	1.636E+03	1.517E+05	-1.025E+06	1.514E+06	6.727E+05	3.496E+04
5.000E-01	3.615E+02	3.754E+01	2.505E-02	4.485E+02	1.240E+05	-2.488E+06	9.615E+05	4.124E+05	4.107E+04
7.000E-01	2.635E+02	3.644E+01	0.	3.444E+02	4.087E+04	9.826E+05	5.106E+05	2.144E+05	4.773E+03
8.000E-01	1.690E+02	3.347E+01	0.	1.089E+02	4.749E+04	4.307E+05	2.074E+05	0.464E+04	1.911E+04

X	RAKG/D	PI XTANRI	PI XTANR
1.760E-01	7.	6.531E-01	3.985E-01
2.500E-01	0.	6.956E-01	4.405E-01
3.000E-01	0.	7.356E-01	4.926E-01
4.000E-01	-1.078E-01	8.045E-01	5.922E-01
5.000E-01	-1.004E-01	9.575E-01	6.945E-01
6.000E-01	-5.761E-01	4.705E-01	7.043E-01
7.000E-01	-9.461E-01	4.929E-01	7.250E-01
8.000E-01	-1.052E+00	9.560E-01	7.474E-01
9.000E-01	-1.152E+00	9.190E-01	7.590E-01
9.500E-01	-1.140E+00	9.233E-01	7.761E-01
1.000E+00	-1.122E+00	9.270E-01	7.824E-01

WEIGHT OF BLADES(LBFI)= 61543.3524

WEIGHT OF POOP (BLADES + CYLINDRICAL HUB)(LBFI)= 86749.8881

CENTER OF GRAVITY OF POOP REFERENCED FROM MIDCHORD OF POOP SECTION (- FWD. + AFT)/D= -.289980

CENTER OF GRAVITY OF BLADES REFERENCED FROM MIDCHORD OF ROOT SECTION (- FWD. + AFT)/D= -.295983

HUB DIMENSIONS/D

HUB DIAM = .176"
HUB LENGTH = .176"
MIDCHORD OF ROOT SECTION TO AFT END OF HUB = .0880

WELLS MINIMUM EAP= .7615E+00

SPEED COEFF V/(ND) JS= .8916E+00

ADVANCE COEFF V(1-WT1)/(ND) JA= .6099E+00

DESIGN THRUST COEFF KT= .1550E+00

TORQUE COEFF KQ= .2561E-01

PROPULSIVE EFFICIENCY ETAD= .7149E+00

BURRILL THRUST COEFF TC= .1116E+00

BURRILL CAVITATION COEFF SIGMA(C.7)= .2951E+00

CLEARANCE AT HUB BETWEEN BLADES/D= 3.4104E-02

CLEARANCE AT HUB BETWEEN FILLETS/D= -1.2641E-02

MASS POLAR MOMENT OF INERTIA OF BLADES (LAM-IM2) = .263763E+09
 TOTAL MASS POLAR MOMENT OF INERTIA (LAM-IM2) = .263763E+09
 RADIUS OF GYRATION OF BLADE/D = .2372
 RADIUS OF GYRATION OF HUB/D = 9.0000
 TOTAL RADIUS OF GYRATION/D = .1998

ABS COEFFICIENTS (CALCULATED AT THE .25 RADIUS)

ABS MINIMUM THICKNESS IN INCHES (USING $\phi/D = \text{PI} \tan 91^\circ$) -
 USING ABS RATE = CONVENTIONAL RATE, $T/D = -.4049E-01$
 USING ABS RATE = CONVENTIONAL + SKW-INDUCED RATE, $T/D = -.4049E-01$

VALUES USED IN DETERMINING THICKNESS-
 A = .107106E+02
 B = .124119E+03
 C = .985185E+04

SECTION AREA COEFFICIENT CS = .6942E+00

SECTION MODULUS COEFFICIENT CN = .8558E-01

AREA OF EXPANDED CYLINDRICAL SECTION IN SQ. INCHES AS = .4559E+03

FOR CN=.1
 ABS MINIMUM THICKNESS IN INCHES (USING $\phi/D = \text{PI} \tan 91^\circ$) -
 USING ABS RATE = CONVENTIONAL RATE, $T/D = -.3228E-01$
 USING ABS RATE = CONVENTIONAL + SKW-INDUCED RATE, $T/D = -.3228E-01$

PADIAL PROPELLER DATA FOR INPUT INTO DESIGN PROGRAMS (8 PADIAL STRIPS ASSUMED)

YP	TAN 9FTA I	G	XSL (INCHES)	XST (INCHES)	I-WY	UA/2VS	THICKNESS (INCHES)
.27750	.95236	.10045-01	-30.8569	27.3771	.47103	.12935+00	11.00267
.27000	.81912	.13645-01	-35.1856	29.4796	.52733	.15015+00	10.61108
.34230	.65215	.15415-01	-37.4083	34.5424	.64531	.16375+00	9.57751
.48500	.55887	.15595-01	-27.0417	50.1545	.74091	.16335+00	9.15008
.58000	.47513	.15465-01	-7.9156	71.6115	.78656	.16005+00	5.51410
.50100	.41081	.15165-01	18.0345	95.4475	.91214	.16025+00	4.35646
.79400	.36790	.14195-01	56.4479	125.7403	.83478	.15745+00	3.38921
.89700	.32602	.11615-01	95.2157	151.6449	.86194	.15225+00	2.21752
.94850	.33981	.09615-02	116.4976	159.3463	.87029	.15365+00	1.84558
1.00000			150.6716	150.6716			

MASS POLAR MOMENT OF INERTIA OF PLATES (LRM-IN2) = .365233E+09
 TOTAL MASS POLAR MOMENT OF INERTIA (LRM-IN2) = .355233E+00
 RADIUS OF GYRATION OF PLATE/IN = .2172
 RADIUS OF GYRATION OF HUB/IN = 0.000
 TOTAL RADIUS OF GYRATION/IN = .2086

APS COEFFICIENTS (CALCULATED AT THE .25 RADIUS)

APS MINIMUM THICKNESS IN INCHES (USING P/D=PI/TAN(1)) -
 USING APS RAKE = CONVENTIONAL RAKE, T/D = -.2184E-01
 USING APS RAKE = CONVENTIONAL + SKRM-INDUCED RAKE, T/D = -.2184E-01
 VALUES USED IN DETERMINING THICKNESS -
 A = .12255E+02
 B = .297597E+03
 C = .137129E+05
 SECTION AREA COEFFICIENT CS = .6942E+00
 SECTION MODULUS COEFFICIENT CM = .8548E-01
 AREA OF EXPANDED CYLINDRICAL SECTION IN SQ. INCHES AS = .6313E+03

FOR CM=.1
 APS MINIMUM THICKNESS IN INCHES (USING P/D=PI/TAN(1)) -
 USING APS RAKE = CONVENTIONAL RAKE, T/D = -.1651E-01
 USING APS RAKE = CONVENTIONAL + SKRM-INDUCED RAKE, T/D = -.1651E-01

RADIAL PROPELLER DATA FOR INPUT INTO DESIGN PROGRAMS (A RADIAL STRIPS ASSUMED)

XR	TAN QETA I	G	XSL(INCHES)	XST(INCHES)	1-W	UA/ZVS	THICKNESS(INCHES)
.22750	1.09857	.1031E-01	-36.13113	32.32775	.47103	.1122E+00	12.94715
.27000	.86687	.1413E-01	-41.02021	33.04115	.52733	.1355E+00	12.44636
.31250	.76381	.1692E-01	-43.43671	43.45176	.64531	.1559E+00	11.27012
.36500	.64669	.1769E-01	-33.42456	57.62777	.76001	.1508E+00	9.59043
.41750	.54807	.1799E-01	-13.87241	70.57219	.74656	.1627E+00	7.65533
.47000	.47388	.1784E-01	12.50244	104.24147	.91214	.1550E+00	5.71473
.52250	.41861	.1673E-01	49.86853	133.74814	.81678	.1656E+00	3.98818
.57500	.37607	.1359E-01	92.17350	154.54810	.86104	.1673E+00	2.60942
.62750	.35737	.1042E-01	114.40215	165.11721	.87029	.1516E+00	2.17175
.68000			152.65573	152.65573			

MASS POLAR MOMENT OF INERTIA OF ELAFS (LPM-IN2) = .16521E+09
 TOTAL MASS POLAR MOMENT OF INERTIA (LPM-IN2) = .16523E+09
 RADIUS OF GYRATION OF BLADE/IN = .2172
 RADIUS OF GYRATION OF HUB/IN = 0.0000
 TOTAL RADIUS OF GYRATION/IN = .2384

ARS COEFFICIENTS (CALCULATED AT THE .25 RADIUS)

ARS MINIMUM THICKNESS IN INCHES (USING P/D=PITTING)-
 USING ABS RATE = CONVENTIONAL RATE, T/D = -.6343E-01
 USING ABS RATE = CONVENTIONAL + SKEN-INDUCED RATE, T/D = -.6343E-01

VALUES USED IN DETERMINING THICKNESS-
 A = .127414E+02
 B = .761199E+03
 C = .115467E+05

SECTION AREA COEFFICIENT CS = .4942E+00

SECTION MODULUS COEFFICIENT CM = .0558E-01

AREA OF EXPANDED CYLINDRICAL SECTION IN SQ. INCHES AS = .6313E+03

FOR CM=.1
 ARS MINIMUM THICKNESS IN INCHES (USING P/D=PITTING)-
 USING ABS RATE = CONVENTIONAL RATE, T/D = -.3699E-01
 USING ABS RATE = CONVENTIONAL + SKEN-INDUCED RATE, T/D = -.3699E-01

RADIAL PROPELLER DATA FOR INPUT INTO DESIGN PROGRAMS (8 RADIAL STOPS ASSUMED)

XR	TAN BETA :	G	XSL (INCHES)	XST (INCHES)	I-MX	UA/2VS	THICKNESS (INCHES)
.22750	.94214	.1004E-01	-35.98894	32.47734	.47103	.1358E+00	12.94715
.27900	.81033	.1358E-01	-40.79326	34.67720	.52733	.1514E+00	12.48631
.34200	.65505	.1533E-01	-43.74336	40.92450	.44531	.1646E+00	11.27312
.44500	.55203	.1544E-01	-33.89093	56.05197	.76191	.1609E+00	9.59043
.53810	.47003	.1533E-01	-14.81072	74.47744	.78656	.1633E+00	7.68533
.64100	.40540	.1532E-01	11.07372	102.63016	.81216	.1603E+00	5.71473
.70420	.35900	.1407E-01	48.03371	131.95912	.81678	.1574E+00	3.94818
.89700	.32252	.1152E-01	90.10147	156.51657	.86194	.1521E+00	2.60942
.94450	.20649	.9896E-02	112.58059	161.03445	.87329	.1535E+00	2.11715
1.07000			150.54442	150.54442			

DOCUMENTATION CASE A

PS(MPI)= 3.0000E+04, DENSITY OF PROPILM/FITJ)= 483.4430

V(KNOTS) 2.3500E+01 2.4000E+01 2.4500E+01 2.4700E+01 2.5000E+01

PE(MPI) 1.0379E+04 2.0756E+04 2.2246E+04 2.3052E+04 2.4277E+04

O(FIT)= 23.0733 *1-MFT=-.7650 *1-TMD=-.8370 *MFTJ)= 52.0000 *PHO(SLUG/CM3)= 1.9925

Z 6 5

AE/MO 7.6483E-01 7.6800E-01 9.0000E-01

N(REV/MIN) 1.0600E+02 1.2000E+02

X	INPUT	1-WX	INPUT	C/D	ADJUST	T/C	INPUT	TANB	LCRPS	TANB	CALCULATED	TETSIOEG	MONLINEAR	RAVC/O	P/TAMMI	P/O	CD	CALCULATED
1.7600E-01	4.3590E-01	2.2023E-01	2.1600E-01	1.7480E-01	1.7480E-01	1.7480E-01	1.7480E-01	1.7480E-01	1.7480E-01	1.7480E-01	1.7480E-01	1.7480E-01	1.7480E-01	1.7480E-01	1.7480E-01	1.7480E-01	1.7480E-01	1.7480E-01
2.5000E-01	4.9410E-01	2.6352E-01	1.7480E-01	1.7480E-01	1.7480E-01	1.7480E-01	1.7480E-01	1.7480E-01	1.7480E-01	1.7480E-01	1.7480E-01	1.7480E-01	1.7480E-01	1.7480E-01	1.7480E-01	1.7480E-01	1.7480E-01	1.7480E-01
3.0000E-01	5.5250E-01	2.8544E-01	1.5400E-01	1.5400E-01	1.5400E-01	1.5400E-01	1.5400E-01	1.5400E-01	1.5400E-01	1.5400E-01	1.5400E-01	1.5400E-01	1.5400E-01	1.5400E-01	1.5400E-01	1.5400E-01	1.5400E-01	1.5400E-01
4.0000E-01	6.6420E-01	3.1776E-01	1.2400E-01	1.2400E-01	1.2400E-01	1.2400E-01	1.2400E-01	1.2400E-01	1.2400E-01	1.2400E-01	1.2400E-01	1.2400E-01	1.2400E-01	1.2400E-01	1.2400E-01	1.2400E-01	1.2400E-01	1.2400E-01
5.0000E-01	7.5000E-01	3.3792E-01	1.0190E-01	1.0190E-01	1.0190E-01	1.0190E-01	1.0190E-01	1.0190E-01	1.0190E-01	1.0190E-01	1.0190E-01	1.0190E-01	1.0190E-01	1.0190E-01	1.0190E-01	1.0190E-01	1.0190E-01	1.0190E-01
6.0000E-01	7.9000E-01	3.5120E-01	7.9600E-02	7.9600E-02	7.9600E-02	7.9600E-02	7.9600E-02	7.9600E-02	7.9600E-02	7.9600E-02	7.9600E-02	7.9600E-02	7.9600E-02	7.9600E-02	7.9600E-02	7.9600E-02	7.9600E-02	7.9600E-02
7.0000E-01	8.1200E-01	3.5840E-01	6.0000E-02	6.0000E-02	6.0000E-02	6.0000E-02	6.0000E-02	6.0000E-02	6.0000E-02	6.0000E-02	6.0000E-02	6.0000E-02	6.0000E-02	6.0000E-02	6.0000E-02	6.0000E-02	6.0000E-02	6.0000E-02
8.0000E-01	8.2800E-01	3.6200E-01	4.0000E-02	4.0000E-02	4.0000E-02	4.0000E-02	4.0000E-02	4.0000E-02	4.0000E-02	4.0000E-02	4.0000E-02	4.0000E-02	4.0000E-02	4.0000E-02	4.0000E-02	4.0000E-02	4.0000E-02	4.0000E-02
9.0000E-01	8.3500E-01	3.6400E-01	3.0000E-02	3.0000E-02	3.0000E-02	3.0000E-02	3.0000E-02	3.0000E-02	3.0000E-02	3.0000E-02	3.0000E-02	3.0000E-02	3.0000E-02	3.0000E-02	3.0000E-02	3.0000E-02	3.0000E-02	3.0000E-02
9.5000E-01	8.4000E-01	3.6500E-01	2.0000E-02	2.0000E-02	2.0000E-02	2.0000E-02	2.0000E-02	2.0000E-02	2.0000E-02	2.0000E-02	2.0000E-02	2.0000E-02	2.0000E-02	2.0000E-02	2.0000E-02	2.0000E-02	2.0000E-02	2.0000E-02
1.0000E+00	8.4200E-01	3.6500E-01	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

X	TANB	TANB	UT/2V	UM/2V	NCTST	OCOST	VRIFT/SEC	CAVV
1.7600E-01	1.3790E+00	8.0000E-01	1.7510E-01	1.7510E-01	1.7510E-01	1.7510E-01	1.7510E-01	1.7510E-01
2.5000E-01	1.0340E+00	6.3500E-01	1.7390E-01	1.7390E-01	1.7390E-01	1.7390E-01	1.7390E-01	1.7390E-01
3.0000E-01	9.1170E-01	5.9540E-01	1.7330E-01	1.7330E-01	1.7330E-01	1.7330E-01	1.7330E-01	1.7330E-01
4.0000E-01	7.4950E-01	5.3640E-01	1.7240E-01	1.7240E-01	1.7240E-01	1.7240E-01	1.7240E-01	1.7240E-01
5.0000E-01	6.3750E-01	4.3640E-01	1.7140E-01	1.7140E-01	1.7140E-01	1.7140E-01	1.7140E-01	1.7140E-01
6.0000E-01	5.4420E-01	3.7500E-01	1.7040E-01	1.7040E-01	1.7040E-01	1.7040E-01	1.7040E-01	1.7040E-01
7.0000E-01	4.7200E-01	3.2500E-01	1.6940E-01	1.6940E-01	1.6940E-01	1.6940E-01	1.6940E-01	1.6940E-01
8.0000E-01	4.2100E-01	3.3800E-01	1.6840E-01	1.6840E-01	1.6840E-01	1.6840E-01	1.6840E-01	1.6840E-01
9.0000E-01	3.7960E-01	3.0000E-01	1.6740E-01	1.6740E-01	1.6740E-01	1.6740E-01	1.6740E-01	1.6740E-01
9.5000E-01	3.6120E-01	2.0000E-01	1.6640E-01	1.6640E-01	1.6640E-01	1.6640E-01	1.6640E-01	1.6640E-01
1.0000E+00	3.4400E-01	2.0000E-01	1.6540E-01	1.6540E-01	1.6540E-01	1.6540E-01	1.6540E-01	1.6540E-01

CPTI=4.0141E-01 CPTI=5.1442E-01 FTAI=7.8032E-01 CTSI=5.1078E-01 CTSI/COST=9.9333E-01

CPT=3.9201E-01 CPT=5.6754E-01 ETA=6.9072E-01 CTS=4.4975E-01 CTS/COST=9.7919E-01

X	CL	ALT(DEC)	FWC	CD/CL	FIX	LILOR/FIT	TETSIOEG	IC/MDILE	IC/MDILE	1/80
1.7600E-01	0.	0.	2.7760E-02	2.6440E-02	2.6440E-02	2.6440E-02	2.6440E-02	2.6440E-02	2.6440E-02	1.9310E-02
2.5000E-01	4.0990E-01	5.2070E-01	2.5920E-02	2.6790E-02	2.6790E-02	2.6790E-02	2.6790E-02	2.6790E-02	2.6790E-02	9.6230E-02
3.0000E-01	4.8170E-01	5.8780E-01	2.3360E-02	2.3360E-02	2.3360E-02	2.3360E-02	2.3360E-02	2.3360E-02	2.3360E-02	9.6230E-02
4.0000E-01	2.9950E-01	4.6140E-01	2.0360E-02	2.0360E-02	2.0360E-02	2.0360E-02	2.0360E-02	2.0360E-02	2.0360E-02	9.6230E-02
5.0000E-01	2.3940E-01	3.6720E-01	1.6130E-02	1.6130E-02	1.6130E-02	1.6130E-02	1.6130E-02	1.6130E-02	1.6130E-02	9.6230E-02
6.0000E-01	2.0110E-01	3.3070E-01	1.3650E-02	1.3650E-02	1.3650E-02	1.3650E-02	1.3650E-02	1.3650E-02	1.3650E-02	9.6230E-02
7.0000E-01	1.7500E-01	2.7070E-01	1.1940E-02	1.1940E-02	1.1940E-02	1.1940E-02	1.1940E-02	1.1940E-02	1.1940E-02	9.6230E-02
8.0000E-01	1.5670E-01	2.4130E-01	1.0440E-02	1.0440E-02	1.0440E-02	1.0440E-02	1.0440E-02	1.0440E-02	1.0440E-02	9.6230E-02
9.0000E-01	1.4080E-01	2.1690E-01	9.5420E-03	9.5420E-03	9.5420E-03	9.5420E-03	9.5420E-03	9.5420E-03	9.5420E-03	9.6230E-02
9.5000E-01	1.3130E-01	2.0530E-01	9.3550E-03	9.3550E-03	9.3550E-03	9.3550E-03	9.3550E-03	9.3550E-03	9.3550E-03	9.6230E-02
1.0000E+00	0.	0.	0.	0.	0.	0.	0.	0.	0.	9.6230E-02

ETAD=7.3548E-01 PS(MPI)=2.9999E+04 1-TMD=9.7700E-01 1-UT/2V=9.5700E-01 VIFT/SEC=9.5127E+01 VIFT/SEC=9.5127E+01

7=5 N(REV/MIN)=2.0600E+02

DCSIGN

IML(81)=3.5160E+03

CALCULATED

IML(81)=3.5160E+03

MASS POLAR MOMENT OF INERTIA OF BLADES (LBM-IN2) = .314516E+09
 TOTAL MASS POLAR MOMENT OF INERTIA (LBM-IN2) = .314516E+09
 RADIUS OF GYRATION OF BLADE/D = .2172
 RADIUS OF GYRATION OF HUB/D = 0.0030
 TOTAL RADIUS OF GYRATION/D = .2044

ABS COEFFICIENTS CALCULATED AT THE .75 RADIUS

ABS MINIMUM THICKNESS IN INCHES USING P/D=PIXTANTII-
 USING ABS RAKE = CONVENTIONAL RAKE, T/O = -.1097E-01
 USING ABS RAKE = CONVENTIONAL + SKEM-INDUCED RAKE, T/O = -.1097E-01

VALUES USED IN DETERMINING THICKNESS- A = .102454E+02
 B = .101441E+03
 C = .133422E+05

SECTION AREA COEFFICIENT CS = .6942E+00

SECTION MODULUS COEFFICIENT CN = .8558E-01

AREA OF EXPANDED CYLINDRICAL SECTION IN SQ. INCHES AS = .6565E+03

FOR CN=.1
 ABS MINIMUM THICKNESS IN INCHES USING P/D=PIXTANTII-
 USING ABS RAKE = CONVENTIONAL RAKE, T/O = -.1389E-01
 USING ABS RAKE = CONVENTIONAL + SKEM-INDUCED RAKE, T/O = -.1389E-01

RADIAL PROPELLER DATA FOR INPUT INTO DESIGN PROGRAMS (R ADIAL STRIPS ASSUMED)

XP	TAN BETA I	G	XSL (INCHES)	YST (INCHES)	I-WX	UA/2VS	THICKNESS (INCHES)
.22750	1.11224	.1205E-01	-36.22320	32.90150	.47103	.1137E+00	13.28320
.27920	.75564	.1695E-01	-41.78562	34.84131	.52733	.1376E+00	12.73330
.34230	.77332	.2053E-01	-46.58338	41.60190	.64531	.1593E+00	11.49301
.44500	.65270	.2173E-01	-36.27394	56.35066	.74091	.1534E+00	9.78089
.58830	.55499	.2713E-01	-14.70596	86.51421	.78656	.1643E+00	7.81693
.67132	.47979	.2173E-01	11.73034	105.17117	.81214	.1723E+00	5.32773
.79480	.42382	.2013E-01	49.29001	136.74016	.91478	.1725E+00	6.05786
.89730	.39375	.1613E-01	01.71134	159.41050	.85196	.1696E+00	2.66102
.94450	.36182	.1210E-01	114.39170	165.81618	.87229	.1698E+00	2.21470
1.00000			152.85417	152.85417			

X	AREA (IN ²)	XBAR (IN)	YBAR (IN)	IXO (IN ²)	IYO (IN ²)	MYO (IN-LRF)	MYO (IN-LRF)	MTS (IN-LRF)	MOB (IN-LRF)	MAXSTRESS (LRF/IN ²)
1.760E-01	6.232E+02	2.902E+01	0.	6.839E+03	1.411E+05	-3.713E+06	6.224E+05	4.41E+06	2.25E+06	3.903E+03
3.000E-01	7.113E+02	3.727E+01	1.197E-01	6.553E+03	2.490E+05	-4.211E+06	1.022E+07	3.45E+06	1.535E+06	5.566E+03
4.000E-01	7.109E+02	4.144E+01	4.231E-02	5.258E+03	7.075E+05	-7.024E+07	-5.260E+06	2.70E+06	1.187E+06	5.566E+03
5.000E-01	6.391E+02	4.611E+01	5.677E-02	4.593E+03	3.144E+05	-2.742E+07	-2.837E+06	1.792E+06	3.310E+05	2.909E+04
6.000E-01	5.207E+02	4.503E+01	2.877E-02	1.740E+03	2.674E+05	-2.434E+07	-3.529E+06	1.255E+06	4.99E+05	3.449E+04
7.000E-01	3.795E+02	4.397E+01	0.	7.151E+02	1.254E+05	-4.431E+06	1.425E+06	5.065E+05	2.530E+05	3.320E+03
8.000E-01	2.433E+02	4.015E+01	0.	2.259E+02	0.911E+04	-2.742E+06	6.359E+05	2.411E+05	9.908E+04	1.031E+04

X	RAK/D	PI XTANGI	PI XTANG
1.760E-01	0.	6.560E-01	3.879E-01
2.501E-01	0.	6.085E-01	4.394E-01
3.000E-01	0.	7.347E-01	4.917E-01
4.000E-01	-1.070E-01	9.090E-01	5.912E-01
5.000E-01	-1.004E-01	8.611E-01	6.682E-01
6.000E-01	-5.761E-01	8.835E-01	7.331E-01
7.000E-01	-3.461E-01	8.967E-01	7.247E-01
8.000E-01	-1.050E+00	9.099E-01	7.451E-01
9.000E-01	-1.152E+00	9.229E-01	7.677E-01
9.500E-01	-1.140E+00	9.272E-01	7.749E-01
1.000E+00	-1.122E+00	9.310E-01	7.811E-01

WEIGHT OF BLADES(LRF)= 73852.0224

WEIGHT OF PROP (BLADES + CYLINDRICAL HUB)(LRF)= 99958.5588

CENTER OF GRAVITY OF PROP REFERENCED FROM MIDCHORD OF ROOT SECTION (- FWD. + AFT)/D= -.221399

CENTER OF GRAVITY OF BLADES REFERENCED FROM MIDCHORD OF ROOT SECTION (- FWD. + AFT)/D= -.295965

HUB DIMENSIONS/D

HUB DIA = .1763
HUB LENGTH = .1751
MIDCHORD OF ROOT SECTION TO AFT END OF HUB = .0888

KELLERS MINIMUM ERR= .7050E+03

SPEED COEFF V/(IN) JS= .8990E+00

ADVANCE COEFF V(1-WT)/(IN) JA= .6997E+00

DESIGN THRUST COEFF KT= .1544E+00

TORQUE COEFF KQ= .2561E-01

PROPULSIVE EFFICIENCY ETAQ= .7147E+00

BURRILL THRUST COEFF TC= .1113E+00

BURRILL CAVITATION COEFF SIGMA(0.7)= .2952E+00

CLEARANCE AT HUB BETWEEN BLADES/D= 4.5939E-07

CLEARANCE AT HUB BETWEEN FILLETS/D= -1.2432E-07

MASS POLAR MOMENT OF INERTIA OF BLADES (LPM-IN²) = .314516E+09
 TOTAL MASS POLAR MOMENT OF INERTIA (LPM-IN²) = .316515E+09
 RADIUS OF GYRATION OF BLADE/D = .2772
 RADIUS OF GYRATION OF HUB/D = 0.0000
 TOTAL RADIUS OF GYRATION/D = .2049

ABS COEFFICIENTS (CALCULATED AT THE .29 RADIUS)

ABS MINIMUM THICKNESS, J, IN INCHES (USING P/D=PI/TAN²θ)
 USING ABS RAKE = CONVENTIONAL RAKE, T/D = -.4648E-01
 USING ABS RAKE = CONVENTIONAL + SKREW-INDUCED RAKE, T/D = -.4648E-01

VALUES USED IN DETERMINING THICKNESS -
 A = .105044E+02
 B = .793942E+03
 C = .119639E+05

SECTION AREA COEFFICIENT CS = .6042E+00

SECTION MODULUS COEFFICIENT CM = .8598E-01

AREA OF EXPANDED CYLINDRICAL SECTION IN SQ. INCHES AS = .6565E+03

FOR CM=.1
 ABS MINIMUM THICKNESS IN INCHES (USING P/D=PI/TAN²θ)
 USING ABS RAKE = CONVENTIONAL RAKE, T/D = -.3228E-01
 USING ABS RAKE = CONVENTIONAL + SKREW-INDUCED RAKE, T/D = -.3228E-01

Curve A

RADIAL PROPELLER DATA FOR INPUT INTO DESIGN PROGRAMS (RADIAL STRIPS ASSUMED)

YR	TAN BETA I	G	XSL (INCHES)	XST (INCHES)	I-WY	UA/2VS	THICKNESS (INCHES)
.27750	.95441	.11645-01	-34.47458	32.17470	.47123	.13195+00	13.28328
.27900	.72261	.16535-01	-41.55359	34.70216	.52733	.15275+00	12.73130
.33200	.65497	.18575-01	-44.58714	41.74446	.64531	.16785+00	11.49301
.48500	.56125	.18795-01	-34.75714	57.49124	.74591	.16438+00	9.78009
.58400	.47715	.18905-01	-15.72514	79.49124	.79556	.16455+00	7.31693
.63100	.41256	.18415-01	10.28430	103.65445	.91214	.16517+00	5.82775
.74400	.35844	.16985-01	47.74353	132.94519	.93678	.16265+00	4.06706
.83700	.32741	.13575-01	99.62237	157.34451	.86104	.15775+00	2.66102
.94450	.31113	.10315-01	112.26229	163.79477	.87029	.15621+00	2.21478
1.00000			150.72516	150.72516			

DOCUMENTATION CASE A

PS(MP)= 3.000E+04, DENSITY OF PROP(LBM/FT3)= 483.8400

V(MNOTS) 2.3500E+01 2.4800E+01 2.4700E+01 2.5700E+01

PE(MP) 1.9329E+04 2.2758E+04 2.3059E+04 2.4777E+04

D(FT)= 23.0000 1-WTT=7450 1-TMO=4370 M(T)= 52.0000 PMO(SLUG/FT3)= 1.9905

Z 6 5

AE/AO 7.6483E-01 7.6800E-01 9.0000E-01

M(REV/MIN) 1.0660E+02 1.2000E+02

X	INPUT	1-WY	INPUT	ADJUSTED	C/O	T/C	TANG	LFBS	TANG	CALCULATED	TETS(OG)	NONLINEAR	RARG/D	P/D	CD
1.7600E-01	4.3590E-01	2.6971E-01	2.1400E-01	1.2605E+00	1.2605E+00	4.2710E-01	0.	0.	0.	0.	0.	0.	0.	0.	1.2337E-02
2.5000E-01	4.4410E-01	3.1039E-01	1.7400E-01	1.4939E-01	1.4939E-01	6.4022E-01	-3.2000E+00	0.	0.	0.	0.	0.	0.	0.	1.8010E-02
3.0000E-01	5.5250E-01	3.3591E-01	1.5900E-01	1.3655E-01	1.3655E-01	5.9658E-01	-4.0117E+00	0.	0.	0.	0.	0.	0.	0.	1.5227E-02
4.0000E-01	6.6420E-01	3.7702E-01	1.2000E-01	8.8795E-01	8.8795E-01	4.7749E-01	0.	0.	0.	0.	0.	0.	0.	0.	9.5404E-03
5.0000E-01	7.5080E-01	3.9764E-01	1.0100E-01	3.9764E-01	3.9764E-01	4.4642E-01	1.0313E+01	0.	0.	0.	0.	0.	0.	0.	9.1288E-03
6.0000E-01	7.9090E-01	4.3611E-01	7.9090E-02	5.0100E-01	5.0100E-01	4.2651E-01	2.1854E+01	0.	0.	0.	0.	0.	0.	0.	8.8612E-03
7.0000E-01	8.1420E-01	3.9617E-01	6.9600E-02	4.3525E-01	4.3525E-01	3.7677E-01	3.2116E+01	0.	0.	0.	0.	0.	0.	0.	8.6228E-03
8.0000E-01	8.3430E-01	3.6204E-01	4.6000E-02	3.6204E-01	3.6204E-01	3.1944E-01	1.7944E+01	0.	0.	0.	0.	0.	0.	0.	8.4723E-03
9.0000E-01	8.6250E-01	2.9651E-01	3.9400E-02	1.4242E-01	1.4242E-01	2.9642E-01	5.4544E+01	0.	0.	0.	0.	0.	0.	0.	8.3944E-03
9.5000E-01	9.7050E-01	2.1775E-01	4.3200E-02	3.3161E-01	3.3161E-01	2.9642E-01	5.7754E+01	0.	0.	0.	0.	0.	0.	0.	8.4555E-03
1.0000E+00	9.7750E-01	0.	0.	1.1631E-01	1.1631E-01	2.4749E-01	6.0000E+01	0.	0.	0.	0.	0.	0.	0.	8.0800E-03

X	TANG	TAN R	G	UT/2V	UA/2V	NCST	DCST	VR(FT/SEC)	CAVV
1.7600E-01	1.3704E+00	7.9507E-01	0.	1.7524E-01	7.4454E-02	1.7433E-01	0.	2.5913E+01	4.1325E+00
2.5000E-01	1.2273E+00	5.3524E-01	1.4755E-02	1.7366E-01	1.2652E-01	1.7433E-01	1.4244E-01	3.5533E+01	2.3245E+00
3.0000E-01	9.9524E-01	5.9194E-01	1.7842E-02	1.6300E-01	1.4440E-01	2.7569E-01	2.3277E-01	4.2633E+01	1.6421E+00
4.0000E-01	7.4440E-01	5.3371E-01	2.0742E-02	1.3549E-01	1.6117E-01	4.5992E-01	4.2637E-01	5.6700E+01	9.3005E-01
5.0000E-01	6.3115E-01	4.8264E-01	2.1643E-02	1.1175E-01	1.6164E-01	5.2446E-01	5.1733E-01	7.0152E+01	6.3004E-01
6.0000E-01	5.4123E-01	4.2302E-01	2.1976E-02	9.5107E-02	1.6725E-01	7.7455E-01	7.5555E-01	8.2644E+01	4.2310E-01
7.0000E-01	4.7206E-01	3.7305E-01	2.1937E-02	9.3513E-02	1.7145E-01	9.3714E-01	9.2542E-01	9.4995E+01	3.1269E-01
8.0000E-01	4.2414E-01	3.3640E-01	1.9829E-02	7.3149E-02	1.7145E-01	9.5807E-01	9.7125E-01	1.0744E+02	2.3324E-01
9.0000E-01	3.7015E-01	3.0022E-01	1.5750E-02	6.4202E-02	1.6727E-01	9.6108E-01	9.8827E-01	1.1997E+02	1.8805E-01
1.0000E+00	3.2277E-01	2.8207E-01	0.	5.7537E-02	1.6754E-01	9.8388E-01	7.2530E-01	1.3243E+02	1.6504E-01

CPTI=4.0128E-01 CPSI=5.1340E-01 ETAT=7.8122E-01 CSTICPSI=7.9479E-01
CPT=3.3016E-01 CPS=5.7743E-01 ETAG=6.7560E-01 CSTICPSI=8.6022E-01

X	CL	ALI(ODEG)	FM/C	GO/CL	FIX	LI(LBF/FT)	TETS(ODEG)	IC/PNLE	IC/ROITE	T/RO
1.7600E-01	0.	0.	0.	0.	0.	0.	0.	-2.697E-01	2.697E-01	1.165E-01
2.5000E-01	1.452E-01	5.317E-01	2.344E-02	3.131E-02	1.811E-01	1.7395E+03	-3.200E+00	-3.301E-01	3.301E-01	1.109E-01
3.0000E-01	3.219E-01	4.957E-01	2.114E-02	3.117E-02	2.007E-01	4.4249E+03	-4.811E+00	-3.643E-01	3.643E-01	1.068E-01
4.0000E-01	2.522E-01	3.833E-01	1.712E-02	3.146E-02	2.132E-01	4.741E+03	2.	-3.735E-01	3.735E-01	9.372E-02
5.0000E-01	2.004E-01	3.046E-01	1.316E-02	4.555E-02	2.167E-01	4.976E+03	1.5331E+01	-2.911E-01	2.911E-01	8.104E-02
6.0000E-01	1.648E-01	2.600E-01	1.144E-02	7.244E-02	2.144E-01	1.372E+04	2.166E+01	-1.402E-01	1.402E-01	6.465E-02
7.0000E-01	1.475E-01	2.271E-01	1.001E-02	5.847E-02	2.213E-01	1.277E+04	3.277E+01	4.544E-02	4.544E-02	4.828E-02
8.0000E-01	1.314E-01	2.024E-01	8.923E-03	6.447E-02	2.264E-01	1.175E+04	4.649E+01	3.146E-01	1.043E+00	3.389E-02
9.0000E-01	1.141E-01	1.819E-01	8.021E-03	7.104E-02	2.337E-01	1.115E+04	5.444E+01	6.293E-01	1.207E+00	2.350E-02
1.0000E+00	1.115E-01	1.722E-01	7.503E-03	7.543E-02	2.341E-01	1.076E+03	5.775E+01	9.016E-01	1.231E+00	1.864E-02
	0.	0.	0.	0.	0.	0.	6.000E+01	1.107E+00	1.107E+00	0.

ETAT=7.2071E-01 PSIMP)= 2.9986F+04 1-TMO=4.3700E-01 1-WTT=7.4570E-01 V(MNOTS) =2.4310E+01 DESIGN TH(LBF)=3.4577E+03
Z= 5 M(REV/MIN)=1.6600E+02 CALCULATED TH(LBF)=3.4576E+03

X	AREA (IN2)	YBAR (IN)	ZBAR (IN)	YBAR (IN)	IXO (IN4)	IYO (IN4)	IXO (IN4)	IYO (IN4)	MYO (IN-LRF)	MYO (IN-LRF)	MTR (IN-LRF)	MUB (IN-LRF)	MAXSTRESS (LBF/IN2)
1.750E-01	9.629E+02	3.523E+01	0.	1.311E+04	2.706E+05	-7.293E+05	9.446E+05	1.157E+07	3.533E+06	4.762E+06	2.560E+06	2.249E+03	
3.000E-01	9.849E+02	4.345E+01	0.	1.297E+04	6.792E+05	-4.177E+06	1.157E+07	7.444E+06	1.356E+06	2.560E+06	2.560E+06	2.249E+03	
4.000E-01	9.820E+02	4.841E+01	1.071E-01	1.008E+04	8.925E+05	-3.579E+07	-7.312E+06	1.356E+06	1.356E+06	2.560E+06	2.560E+06	2.249E+03	
5.000E-01	9.849E+02	5.191E+01	7.431E-02	6.505E+03	6.072E+05	-2.375E+07	-4.276E+06	1.356E+06	1.356E+06	2.560E+06	2.560E+06	2.249E+03	
6.000E-01	7.210E+02	5.301E+01	1.744E-02	3.174E+03	5.127E+05	-2.477E+07	-5.231E+06	1.356E+06	1.356E+06	2.560E+06	2.560E+06	2.249E+03	
7.000E-01	5.255E+02	5.174E+01	0.	1.371E+03	3.559E+05	-4.072E+06	1.142E+06	1.142E+06	6.133E+05	2.877E+05	2.877E+05	2.214E+03	
8.000E-01	3.369E+02	4.726E+01	0.	4.311E+02	1.904E+05	-5.437E+05	5.827E+05	5.827E+05	2.464E+05	1.122E+05	1.122E+05	1.087E+04	

X	RAK/O	PI XBAR	PI YBAR	PI ZBAR
1.750E-01	0.	7.577E-01	4.401E-01	0.
3.000E-01	0.	9.069E-01	4.980E-01	0.
4.000E-01	0.	9.512E-01	5.570E-01	0.
5.000E-01	-1.079E-01	9.344E-01	6.707E-01	0.
6.000E-01	-1.094E-01	9.946E-01	7.591E-01	0.
7.000E-01	-5.761E-01	1.020E+00	7.977E-01	0.
8.000E-01	-5.451E-01	1.036E+00	8.221E-01	0.
9.000E-01	-1.059E+00	1.051E+00	9.465E-01	0.
1.000E+00	-1.152E+00	1.066E+00	9.739E-01	0.
1.000E+00	-1.145E+00	1.071E+00	9.792E-01	0.
1.000E+00	-1.122E+00	1.077E+00	9.962E-01	0.

WEIGHT OF BLADES(LBF)= 102262.1554

WEIGHT OF PROP (BLADES + CYLINDRICAL HUB)(LBF)= 127468.6926

CENTER OF GRAVITY OF PROP REFERENCED FROM MIDCHORD OF ROOT SECTION (- FWD, + AFT)/O= -.239036

CENTER OF GRAVITY OF BLADES REFERENCED FROM MIDCHORD OF ROOT SECTION (- FWD, + AFT)/O= -.293967

HUB DIMENSIONS/O

HUB DIAM = .1762
HUB LENGTH = .1740
MIDCHORD OF ROOT SECTION TO AFT END OF HUB = .0840

KELLERS MINIMUM EAR= .7039E+00

SPEED COEFF V/(NO) JS= .1010E+01

ADVANCE COEFF Y(1-MTT)/(NO) JA= .7927E+00

DESIGN THRUST COEFF KT= .1989E+00

TORQUE COEFF KO= .3716E-01

PROPULSIVE EFFICIENCY ETAD= .7200E+00

HUB HILL THRUST COEFF TC= .1233E+00

HUB RILL CAVITATION COEFF SIGMA(0.7)= .3680E+00

CLEARANCE AT HUB BETWEEN BLADES/O= 3.8486E-02

CLEARANCE AT HUB BETWEEN FILLITS/O= -2.6440E-02

MASS POLAR MOMENT OF INERTIA OF BLADES (LPM-IN2) = .439277E+09
 TOTAL MASS POLAR MOMENT OF INERTIA (LPM-IN2) = .439277E+09
 RADIUS OF GYPATION OF PLANE/D = .2172
 RADIUS OF GYPATION OF HUB/D = 0.0000
 TOTAL RADIUS OF GYPATION/D = .2125

ABS COEFFICIENTS (CALCULATED AT THE .75 RADIUS)

ABS MINIMUM THICKNESS IN INCHES (USING $\theta/0.01714171$) -
 USING ABS RATE = CONVENTIONAL RATE, $\gamma/0 = -.2175E-01$
 USING ABS RATE = CONVENTIONAL + SKEW-INDUCED RATE, $\gamma/0 = -.2175E-01$

VALUES USED IN DETERMINING THICKNESS -
 $a = .102425E+02$
 $b = .157117E+03$
 $c = .152495E+05$

SECTION AREA COEFFICIENT $CS = .5942E+00$

SECTION MODULUS COEFFICIENT $CN = .8558E-01$

AREA OF EXPANDED CYLINDRICAL SECTION IN SQ. INCHES $AS = .9291E+03$

FOR $CN=1$
 ABS MINIMUM THICKNESS IN INCHES (USING $\theta/0.01714171$) -
 USING ABS RATE = CONVENTIONAL RATE, $\gamma/0 = -.1646E-01$
 USING ABS RATE = CONVENTIONAL + SKEW-INDUCED RATE, $\gamma/0 = -.1646E-01$

RADIAL PROPELLER DATA FOR INPUT INTO DESIGN PROGRAMS (E MAGNIAL STRIPS ASSUMED)

XR	TAN BETA I	G	YSL(INCHES)	XSL(INCHES)	1-WV	UA/2VS	THICKNESS(INCHES)
.22750	1.10464	.1203E-01	-42.94523	39.44037	.47103	.1145E+00	15.53050
.27423	.95309	.1692E-01	-49.55017	41.31012	.52737	.1183E+00	16.98354
.34223	.76303	.2044E-01	-52.30450	49.31735	.64531	.1546E+00	13.52415
.40580	.64424	.2165E-01	-42.44033	66.51171	.74091	.1615E+00	11.58052
.54450	.55110	.2197E-01	-23.14773	88.87918	.74654	.1692E+00	9.19840
.69123	.47653	.2162E-01	3.40571	113.27233	.91214	.1720E+00	5.85768
.79400	.42032	.1994E-01	41.54890	142.28533	.81479	.1720E+00	4.70502
.89723	.37415	.1544E-01	85.41417	165.71501	.84106	.1690E+00	3.13130
.94450	.35935	.1201E-01	109.73564	170.24027	.47029	.1693E+00	2.60010
1.00000			152.74154	152.74154			

DOCUMENTATION CASE A

PS(MPI)= 3.0000E+04, DENSITY OF PROPL(RM/FI3)= 433.8400

VIMNOTSI 2.3500E+01 2.4000E+01 2.4500E+01 2.4733E+01 2.5000E+01
PE(MPI) 1.9329E+04 2.0756E+04 2.2245E+04 2.3055E+04 2.4277E+04

O(FI3)= 23.0000, 1-WTT=7.950, 1-TMD=.A370, M(FI3)= 52.0000, P(MO(SLU/FI3))= 1.9905

Z 6 5

AE/AD 7.6403E-01 7.6000E-01 9.0000E-01
M(EV/MIN) 1.0600E+02 1.2000E+02

X	INPUT	1-WY	C/D	ADJUSTED	T/C	INPUT	TANRI	LEOPS	CALCULATED	TANQ	YETS(DEC)	MONLINEAR	PARG/O	P/0	PIRMB01	CD	CALCULATED
1.7632E-01	4.3522E-01	2.6071E-01	2.6071E-01	2.6071E-01	2.1600E-01	1.1147E+00	8.3427E-01	8.3427E-01	7.3427E-01	7.3427E-01	0.	0.	0.	0.	0.	0.	1.2337E-02
2.5000E-01	4.9410E-01	3.1000E-01	3.1000E-01	3.1000E-01	1.7400E-01	8.3427E-01	8.3427E-01	8.3427E-01	7.3427E-01	7.3427E-01	0.	0.	0.	0.	0.	0.	1.0010E-02
3.0000E-01	5.5233E-01	3.3500E-01	3.3500E-01	3.3500E-01	1.5400E-01	7.3000E-01	7.3000E-01	7.3000E-01	6.3000E-01	6.3000E-01	0.	0.	0.	0.	0.	0.	1.0222E-02
4.0000E-01	6.6423E-01	3.7300E-01	3.7300E-01	3.7300E-01	1.2400E-01	5.0700E-01	5.0700E-01	5.0700E-01	4.0700E-01	4.0700E-01	0.	0.	0.	0.	0.	0.	9.5084E-03
5.0000E-01	7.5000E-01	3.9700E-01	3.9700E-01	3.9700E-01	1.0100E-01	5.1600E-01	5.1600E-01	5.1600E-01	4.0600E-01	4.0600E-01	0.	0.	0.	0.	0.	0.	9.1260E-03
6.0000E-01	7.0000E-01	4.3611E-01	4.3611E-01	4.3611E-01	7.9600E-02	4.4100E-01	4.4100E-01	4.4100E-01	3.7600E-01	3.7600E-01	0.	0.	0.	0.	0.	0.	8.8361E-03
7.0000E-01	6.1423E-01	3.9617E-01	3.9617E-01	3.9617E-01	6.6000E-02	3.8400E-01	3.8400E-01	3.8400E-01	3.2400E-01	3.2400E-01	0.	0.	0.	0.	0.	0.	8.6220E-03
8.0000E-01	5.3400E-01	3.5700E-01	3.5700E-01	3.5700E-01	5.6000E-02	3.4100E-01	3.4100E-01	3.4100E-01	2.9400E-01	2.9400E-01	0.	0.	0.	0.	0.	0.	8.4720E-03
9.0000E-01	4.5233E-01	2.8551E-01	2.8551E-01	2.8551E-01	3.9400E-02	3.0200E-01	3.0200E-01	3.0200E-01	2.5400E-01	2.5400E-01	0.	0.	0.	0.	0.	0.	8.3964E-03
1.0000E+00	4.7050E-01	2.1176E-01	2.1176E-01	2.1176E-01	2.3700E-02	2.9200E-01	2.9200E-01	2.9200E-01	2.4200E-01	2.4200E-01	0.	0.	0.	0.	0.	0.	8.4355E-03
1.0000E+00	6.7763E-01	0.	0.	0.	0.	2.7041E-01	2.7041E-01	2.7041E-01	2.2112E-01	2.2112E-01	0.	0.	0.	0.	0.	0.	8.8000E-03

CPTI=4.0052E-01 CPS=5.0433E-01 ETAT=7.9369E-01 CTST=5.1222E-01 CTST/CPSI=1.0150E+00
CPI=3.0901E-01 CPS=6.0035E-01 ETAB=6.4611E-01 CTST=6.4611E-01 CTST/CPSI=9.2657E-01

X	CL	ALI(DEC)	FWC	CD/CL	F(X)	U(LI/F/ST)	YETS(DEC)	IC/BC/LE	IC/BC/ITE	Y/BO
1.7600E-01	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
2.5000E-01	2.9670E-01	4.5700E-01	2.0100E-02	3.6430E-02	1.7740E-01	7.2750E-03	-3.2050E+00	-2.0070E-01	2.0970E-01	1.1050E-01
3.0000E-01	2.6940E-01	4.1530E-01	1.9310E-02	3.7030E-02	1.8930E-01	6.5970E-03	-3.2050E+00	-3.2050E-01	2.0970E-01	1.1050E-01
4.0000E-01	2.2220E-01	3.1140E-01	1.7210E-02	4.7220E-02	1.9520E-01	6.1100E-03	-3.2050E+00	-3.2050E-01	2.0970E-01	1.1050E-01
5.0000E-01	1.5520E-01	2.3900E-01	1.0540E-02	5.8810E-02	2.0000E-01	6.5440E-03	1.3310E+01	-2.0970E-01	2.0970E-01	1.1050E-01
6.0000E-01	1.2740E-01	1.9650E-01	8.6660E-03	6.9230E-02	2.0120E-01	1.7340E-03	2.1650E+01	-1.5610E-01	2.0970E-01	1.1050E-01
7.0000E-01	1.1310E-01	1.6960E-01	7.4770E-03	7.9310E-02	2.0420E-01	1.1460E-03	3.2720E+01	3.4520E-02	2.0970E-01	1.1050E-01
8.0000E-01	9.7490E-02	1.5060E-01	6.6420E-03	8.6450E-02	2.1200E-01	1.1250E-03	4.4920E+01	3.0580E-01	2.0970E-01	1.1050E-01
9.0000E-01	8.8150E-02	1.3110E-01	5.7900E-03	9.5700E-02	2.1900E-01	1.1340E-03	5.4520E+01	6.1190E-01	2.0970E-01	1.1050E-01
1.0000E+00	8.4030E-02	1.2640E-01	5.7350E-03	1.0040E-01	2.2240E-01	9.1100E-03	6.5050E+01	1.0910E-01	2.0970E-01	1.1050E-01

ETAD=6.9194E-01 PS(MPI)= 3.0000E+04 1-TMD=8.1730E-01 1-WTT=7.9370E-01 VIMNOTSI= 2.4000E+01 DESIGN TH(LERFI)=3.3673E+05
Z= 5 M(EV/MIN)= 1.2000E+02 INPUT AE/BC=9.7100E-01 VIMNOTSI= 4.3500E+01 CALCULATED TH(LERFI)=3.3673E+05

1000

X	AREA (IN2)	YBAR (IN)	IXO (INL)	IYO (INL)	MYO (IN-LRF)	MVC (IN-LRF)	MTR (IN-LRF)	MGB (IN-LRF)	MAXSTRESS (LBF/IN2)
1.760E-01	8.620E+02	3.521E+01	1.311E+04	2.705E+05	-4.017E+05	-5.170E+04	4.619E+06	2.250E+06	3.002E+03
3.000E-01	9.849E+02	4.385E+01	1.257E+04	4.702E+05	-7.111E+06	1.372E+07	3.791E+06	1.643E+06	3.856E+03
4.250E-01	9.820E+02	4.815E+01	1.079E+04	5.925E+05	-4.145E+07	7.313E+06	2.723E+06	1.191E+06	4.520E+03
5.000E-01	9.849E+02	5.191E+01	6.505E+03	5.072E+05	-3.127E+07	-1.893E+05	1.532E+06	9.072E+05	2.441E+04
6.000E-01	7.210E+02	2.432E-02	3.374E+03	5.127E+05	-3.127E+07	-4.920E+06	1.100E+06	4.937E+05	2.964E+04
7.000E-01	5.255E+02	5.176E+01	1.371E+03	1.555E+05	-1.794E+07	1.775E+04	5.365E+05	2.554E+05	2.100E+03
8.000E-01	3.369E+02	4.726E+01	4.231E+02	1.904E+05	-1.751E+05	4.534E+05	2.350E+05	1.003E+05	1.429E+04

X	RAKG/D	PI XTANNI	PI XTAMP
1.760E-01	0.	6.499E-01	3.439E-01
2.500E-01	0.	6.910E-01	4.351E-01
3.000E-01	0.	7.307E-01	4.864E-01
4.000E-01	-1.078E-01	8.011E-01	5.404E-01
5.000E-01	-1.034E-01	8.518E-01	6.612E-01
6.000E-01	-5.761E-01	8.737E-01	6.347E-01
7.000E-01	-9.441E-01	8.670E-01	7.170E-01
8.000E-01	-1.350E+00	9.000E-01	7.382E-01
9.000E-01	-1.152E+00	9.129E-01	7.565E-01
9.500E-01	-1.140E+00	9.171E-01	7.665E-01
1.000E+00	-1.122E+00	9.209E-01	7.726E-01

WEIGHT OF BLADES (LBF) = 182262.1564

WEIGHT OF PROPS (BLADES + CYLINDRICAL HUB) (LBF) = 127668.6926

CENTER OF GRAVITY OF PROPS REFERENCED FROM MIDDLE OF ROOT SECTION (- FWD. + AFT)/D = -.238975

CENTER OF GRAVITY OF BLADES REFERENCED FROM MIDDLE OF ROOT SECTION (- FWD. + AFT)/D = -.297888

HUB DIMENSIONS/D

HUB DIAM = .1760
HUB LENGTH = .1749
MIDCHORD OF ROOT SECTION TO AFT END OF HUB = .0888

WELLES MINIMUM EAR = .6844E+00

SPEED COEFF V/(ND) JS = .0004E+00

ADVANCE COEFF V(1-MT)/(ND) JA = .6913E+00

DESIGN THRUST COEFF KT = .1511E+00

TORQUE COEFF KQ = .2563E-01

IMPULSIVE EFFICIENCY ETAD = .6918E+00

MURRILL THRUST COEFF TC = .9252E-01

MURRILL CAVITATION COEFF SIGMA(0.7) = .2958E+00

CLEARANCE AT HUB BETWEEN BLADES/D = 3.4348E-02

CLEARANCE AT HUB BETWEEN FILLETS/D = -3.4434E-02

MASS POLAR MOMENT OF INERTIA OF BLADES (LRM-14?) = .438277E+09
 TOTAL MASS POLAR MOMENT OF INERTIA (LRM-IN2) = .438277E+09
 RADIUS OF GYRATION OF BLADE/D = .2172
 RADIUS OF GYRATION OF HUR/D = 0.0000
 TOTAL RADIUS OF GYRATION/D = .2125

ABS COEFFICIENTS (CALCULATED AT THE .25 RADIUS)

ABS MINIMUM THICKNESS IN INCHES (USING P/D=PI/TAN(1/2)) -
 USING ABS RAKE = CONVENTIONAL PAKE, T/D = -.4332E-01
 USING ABS RAKE = CONVENTIONAL + SKREW-INDUCED RAKE, T/D = -.4332E-01

VALUES USED IN DETERMINING THICKNESS- A = .107354E+02
 B = .457679E+03
 C = .139927E+05

SECTION AREA COEFFICIENT CS = .5942E+00

SECTION MODULUS COEFFICIENT CM = .8558E-01

AREA OF EXPANDED CYLINDRICAL SECTION IN SQ. INCHES AS = .9091E+03

FOR CM=.1

ABS MINIMUM THICKNESS IN INCHES (USING P/D=PI/TAN(1/2)) -
 USING ABS RAKE = CONVENTIONAL PAKE, T/D = -.3499E-01
 USING ABS RAKE = CONVENTIONAL + SKREW-INDUCED RAKE, T/D = -.3489E-01

RADIAL PROPELLER DATA FOR INPUT INTO DESIGN PROGRAMS (RADIAL STRIPS ASSUMED)

YP	TAN BETA I	G	XSL (INCHES)	XST (INCHES)	L-WK	UA/2VS	THICKNESS (INCHES)
.22750	.94603	.11645-01	-42.93918	39.31647	.67103	.13311F+00	13.5368R
.27090	.81369	.16305-01	-49.24510	41.55773	.52733	.15411F+00	16.99364
.34220	.65775	.18492-01	-52.23180	49.37164	.66531	.19431F+00	13.52415
.44520	.55515	.18965-01	-42.97190	64.04814	.74091	.16501F+00	11.50952
.54890	.67197	.14775-01	-24.25320	97.44771	.74656	.16501F+00	9.19940
.60100	.63408	.14265-01	1.06413	111.41066	.81214	.16541F+00	6.95768
.70420	.76049	.16455-01	19.64365	140.30414	.81676	.16271F+00	4.70582
.80720	.87395	.13485-01	83.50845	163.27621	.96104	.15771F+00	3.13139
.94450	.30775	.10255-01	107.56505	158.11449	.97729	.15625F+00	2.60610
1.00000			150.59372	150.59372			

APPENDIX F
FORTRAN LISTING OF COMPUTER PROGRAM

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PROGRAM GMAIN(INPUT=256,OUTPUT=512,TAPF5=INPUT,TAPF6=OUTPUT)
DIMENSION CHORD(11),THICKNS(11),CAMBER(11),PITCH(11),SKEWR(11)
1 ,X(11),BT(11)
DIMENSION B(38,38),DENS(6),B2(181),B3(181)
1 ,B11(181),B14(181)
2 ,B15(181),AZ(11,11),BH(11,11),C(12,12),CC(12,12)
DIMENSION X3(11),X4(11),X5(11),X6(11),VFL(9),EHP(9),RLA(9),EXX(9)
DIMENSION AZZ(11,38),ASHP(9),XMM(9),CAV(9),CAE(9),FX(11),BRJ(11)
DIMENSION VEL1(9),EHP1(9),AX(11),RAK(11),PXTBI(11),PXTB(11),SX(7)
DIMENSION VSUBRSQ(11),VSUBP(11)
DIMENSION AREA(7),XBAR(7),YBAR(7),AYEXO(7),AYEYO(7),EMXO(7),EMYO(7)
1 ,FMTB(7),EMOB(7),STRMAX(7)
DIMENSION W(13),FMMX(13),YTX(13),TX(11),CX(11),FMX(11),JBL(11),
1 ARPMI(11),PMOX(11),P(13),S(13),P(13)
DIMENSION TABS(6)
DIMENSION DMV(9),DME(9),DMX(9)
COMMON /UNITS/ SI,UI,UO
COMMON/CWEIGHT/X,CHORD,THICKNS,CAMBER,PITCH,SKEWP,DIAM,ZZ,DEY,PAKE
1,PI,PP7,PP8,PP9,PP11,EWAKE,VS,RPS,SIGMA,FAR,RT,P,P90
2 ,FWOJAM,AFTDIAM,HUBLEN,FDBORE,AOBBORE,OTSRFFL
COMMON B, B2,B3, B11 ,B14,B15,AZ,BH,
1C,CC, ID,JB,JC,JD,JDD,JEE,CL1(11)
COMMON CCONE(11),CCTHO(11),CCTHR(11),CCFOR(11)
COMMON PP1,PP2,PP3,PP4,PP5,PP6,PP10
COMMON SN(73),CO(73)
DIMENSION XR(20),TANBETI(20),G(20),XSL(20),XST(20),WAKE(20)
1,UVFLA(20),THICKP(20)
DIMENSION TLES(10,2)
REAL N,NI,INPUT,LERBS,LINR,NLINR
DATA IAPU,EARF / 8H DESIGN , 8H INPUT /
DATA W /1.,4.,3.,8.,4.,8.,4.,8.,4.,8.,3.,4.,1./
DATA FMMX /0.,.2712,.4482,.5993,.9635,.9515,1.,.9796,.8892,.7027,
1 .3586,.1713,.0/
DATA YTX /0.,.2066,.2907,.4.,.4637,.4952,.4962,.4653,.4035,.311,
2 .1877,.1143,.0333/
DATA DENS / 1.,521.856,1.,493.84,1.,1. /
DATA TABS /1CHABS MINIMU ,10HM THICKNES ,10HS IN INCH ,
2 1CHS (USING P ,10H ,1CH /
DATA TGS,UBS,VBS,XBS / 1CH/D=PIXTANB ,10HT)- ,
2 1CH/D INPUT)- ,10H /
DATA SHPP,SHPT1,SHPT2,DEN1,DEN2,DEN3,ZS,EARS,RPMS,COMMA,ADJJ
1 /5H SHP=,7H THRUST,7H OPTION,10H, DENSITY ,10HOF PROP(LP,
2 8HM/FT3)= ,3H Z=,5H EAR=,5H RPM=,2H, ,10H ADJUSTED /
DATA TLES / 10H X ,10H 1-WX ,10H C/D ,
2 1CH T/C ,10H TANBI ,10H TANR ,
3 10H TETS(DEG) ,10H RAKG/D ,10H P/D ,
4 1CH CO , 10*1H /
DATA INPUT,LERBS,LINR,NLINR,PXTNBI,CONST,CALC /10H INPUT ,
2 1CH LERBS ,10H LINEAR ,10HNONLINEAR ,
3 1CHPIXTANBI ,10HCONSTANT ,10HCALCULATED /
DATA SI /2HSI/
DATA UVE / 7HFT/SEC) /
DATA EXA,URPM / 5HAE/AO ,9H(REV/MIN) /
DATA UEI,UEF,USL /4H(IN) ,4H(FT) , 4H(M) /
DATA VL,PE / 2HV( , 3HPE( /
DATA ULE,ULS / 8H(LBF/FT) , 8H(N/M) /
DATA USV,UEV / 6HM/SEC) ,6H(KNOTS) /

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DATA USP,UEP / 3HKW) , 3HHP) /
DATA UED,USD / 10H(SLUG/FT3) , 10H(KG/M3) /
DATA ULE4,ULS4,ULE2,ULS2,UNM,UIL,UPA,UPIN2 / 5H(IN4),5H(M4) ,
5H(IN2),5H(M2) , 8H(N-M) , 8H(IN-LBF),9H(PA) , 9H(LBF/IN2) /
DATA UFE,UFS / 5H(LBF) , 5H(N) /
DATA U02,U03 / 10HOF PROP(KG,8H/M3)= /
DATA PMI,U07 / 10H(LBM-IN2)= , 10H(KG-M2)= /
DATA GR1,GR2 / 9HRADIUS OF , 9H GYRATION /
DATA EFT,U04 / 4HFT.=, 4HM.= /
DATA EIN,U05 / 5H(INCH), 5HM) /
DATA EINS,U06 / 7H(INCHES)= , 7HMETERS= /
DATA EAV,SIV / 6H RP4= , 6HRA0/S= /
DATA PINS,U08 / 7H(INCHES) , 7HMETERS) /
DATA PINS,U09 / 6H(INCHES) , 6HMETERS /
DATA EFP,U10 / 4HFT)= , 4HM)= /
ELI=1./0.0254
EL2=1./ELI/ELI
F_LF=1./0.3048
DSI=1./16.01846
RHOSI=1./515.3748
VSI=1./0.5144444
PWP=1000./745.6999
SIM=1./0.1129848
UNT=1./4.44822
JC=11
DKTS=1.6978
PI=3.14159265
PI2=2.*PI
DO 31 I=1,73
AC=5.*(I-1)*2.*PI/360.
SY(I)=SIN(AC)
31 C(I)=COS(AC)
READ(5,*) ID0
DO 12.72 NDIA=1,100
SPM=6 ./PI2
READ(5,10008) UI,U0
READ(5,*) SHP,TANBI,TANB,XPS,RAKE,PDO,CD,TYPE,HUB
READ(5,*) DIAM,EWAKE,ETHRUS,HEAD,DEN,RHO
READ(5,*) IVV,(VEL(I),I=1,IVV),(EHP(I),I=1,IVV),IZZ,
1 (JBL(I),I=1,IZZ),IEA, (EXX(I),I=1,IEA),IRPM, (XMM(I),I=1,IRPM)
READ(5,*) (X3(I),I=1,JC),(X4(I),I=1,JC),(X5(I),I=1,JC),(X6(I),
1 I=1,JC),(AZZ(I,25),I=1,JC)
IF(XPS.LT.0.) READ(5,*) (AZZ(I,24),I=1,JC)
IF(ABS(CD).GE.10.) READ(5,*) (B(I,7),I=1,JC)
IF(TANB.GT.0.) READ(5,*) (B(I,8),I=1,JC)
IF(RAKE.GT.0..AND.RAKE.LE..01) READ(5,*) (RAK(I),I=1,JC)
IF(PDU.GT.0.) READ(5,*) (P(I),I=1,JC)
IF(HUB.NE.0.) READ(5,*) FWDIAM,AFTDIAM,HUBLEN,FDBORE,ADB0RE,
1 DISPEFL

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C NO DATA READ ANYWHERE BEYOND THIS STATEMENT

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RF=DIAM
IF(UI.NE.SI) PF=DIAM*12.
IF(RAKE.GT.0..AND.RAKE.LE..01) GO TO 140
RAKE=RAKE*RF
GO TO 142

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140 DO 141 I=1,JC
141 RAK(I)=RAK(I)*RF
142 UDEN=UED
    IDEN=DEN
    IF(IDEN.LT.2) IDEN=4
    IF(IDEN.LT.7) DEN=DENS(IDEN)
    UL=UEF
    VU=UEV
    PU=UEP
    IF(UI.NE.SI) GO TO 2413
    IF(IDEN.LT.7) DEN=DEN/DSI
    UDEN=USD
    UL=USL
    VU=USV
    PU=USP
2413 WRITE(6,11046) IDO
    IF(SHP.EQ.0.) WRITE(6,10020) SHPT1,SHPT2,DEN1,DEN2,DEN3,DEN
    IF(SHP.NE.0.) WRITE(6,10021) PU, SHP,DEN1,DEN2,DEN3,DEN
    WRITE(6,10027) VL,VU,(VEL(I),I=1,IVV)
    WRITE(6,10045) PE,PU,(EHP(I),I=1,IVV)
    WRITE(6,10028) UL,DIAM,EWAKE,FTHRUS,UL,HEAD,UDEN,RHO
    IF(TYPE.LT.2.) TYPE=4
    VU=UEV
    PU=UEP
    UDEN=UED
    UL=UEF
    ESI=EIN
    FSI=EFPP
    ANV=EAV
    SNIP=FINS
    SNIR=FINS
    IF(UO.NE.SI) GO TO 143
    VU=USV
    PU=USP
    UDEN=USD
    UL=JSL
    SNIP=U09
    SNIR=U09
    ANV=SIV
    DEN2=U02
    DEN3=U03
    FSI=U10
    ESI=U05
143 IF(UI.NE.SI) GO TO 149
C  OPTION FOR SYSTEM INTERNATIONAL INPUT UNITS
    SHP=SHP*PWR
    DIAM=DIAM*ELF
    HEAD=HEAD*ELF
    RHO=RHO*RHO SI
    DO 145 I=1,IVV
145  VEL(I)=VEL(I)*VSI
    EHP(I)=EHP(I)*PWR
    IF(HUB.EQ.0.) GO TO 146
    FWD DIAM=FWD DIAM*ELF
    AFT DIAM=AFT DIAM*ELF
    HUB LEN=HUB LEN*ELF
    FDBORE=FDBORE*ELF

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      ADBORE=ADBORE*ELF
      DISPEFL=DISREFL*ELF
146   IF(RAKE.GT.0..AND.RAKE.LE..01) GO TO 147
      RAKE=RAKE*ELI
      GO TO 149
147   DO 148 I=1,JC
148   RAK(I)=RAK(I)*ELI
149   CONTINUE
      IF(XPS.GT.0.) XPS=XPS*JBL(1)/363.
      DIA=DIA
      IV9=IVV
      DO 10150 I=1,10
10150  TLES(I,2)=INPUT
      TLES(7,2)=TLES(8,2)=LINR
      IF(ABS(1).EQ.0.) TLES(5,2)=LEPBC
      IF(TANG.EQ.0.) TLES(6,2)=CALC
      IF(XPS.LT.0.) TLES(7,2)=NLINR
      IF(RAKE.GT.0..AND.RAKE.LE..01) TLES(8,2)=NLINR
      IF(PDO.LE.0.) TLES(9,2)=PXTNRI
      IF(CO.EQ.0.) TLES(10,2)=CALC
      WRITE(6,10046) IDO
10046  FORMAT(1H ,4X,I4,* BASIC DESIGN(S) ASKED FOR* )
      IDEN=DEN
      IF(IDEN.LT.2) IDEN=4
      IF(IDEN.LT.7) DEN=DENS(IDEN)
      IF(IDEN.GE.7.AND.UI.EQ.SI) DEN=DEN*DSI
      IF(RHO.EQ.0.) RHO=1.9905
      IF(RHO.EQ.1.) RHO=1.9384
      PSC=1.44*.3605*DIA*DIA*2
      PTAN= P(1)/(PI*X3(1))
      AID=DIA
      DUN=DFN
      DAEH=HEAD
      OHR=RHO
      IF(UO.NE.SI) GO TO 150
      AID=AID/ELF
      DUN=DUN/DSI
      DAEH=DAEH/ELF
      OHR=OHR/RHOSI
150   CONTINUE
      DO 1 I=1,9
      CAV(I)=VEL(I)
1   CAE(I)=EHP(I)
      IF(SHP) 103,102,103
103   PVEL=VEL(3)
      PEHP=EHP(3)
102   CONTINUE
      R(2,1)=CO
      BLAS=JPL(1)
      IF(XPS.GE.0.) GO TO 7
      DO 26 I=1,JC
26   AZZ(I,38)=AZZ(I,24)
7   EXXS=2.*BLAS /PI*SIMPUN(X3,X6,JC)
10008  FORMAT(2H ,2A2,66H
2   JEA=0
      IF(EXX(1).NE.C.) GO TO 10004

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      EXX(1)=EXXS
      JEA=1
10004 IF(CD.GE.10.) GO TO 90
      TM=B(2,1)
      CFO=.008
      IF(CD.GT.0.) CFO=1.
      IF(CD.GT.-10. .AND.CD.LT.0.) CFO=-CD
      DO 10007 I=1,JC
      IF(CD.LE.0.) TM=1.+1.25*AZZ(I,25)+125.*AZZ(I,25)**4
      IF(CD.LE.-10.) CFP=B(I,7)
10007 B(I,7)=CFO*TM
      9) DO 15 I=1,JC
      15 AZZ(I,23)=X3(I)
         DO 16 I=3,JC
      16 AZZ(I-1,19)=X3(I)
         AZZ(1,19)=X3(1)
         DO 4 I=1,11
            PXTBI(I)=P(I)
            AZZ(I,36)=AZZ(I,25)
4          AZZ(I,37)=AZZ(I,23)
            DO 10071 IE=1,IZZ
            3(9,2)=JBL(IE)
            XSX=XPS*(360.0/B(9,2))
            AS1=XSX/(1.0-X3(1))
            AS2=XSX-AS1
            DO 10073 KE=1,IEA
            TLES(3,2)=TLES(4,2)=INPUT
            EAPU=EARF
            ERA=ABS( EXXS-EXX(KE) )
            IF(ERA.LT..005.AND.KE.GT.1.AND.JEA.EQ.1) GO TO 10070
            IF(ERA.LE..005) EARU=EARD
            DO 10069 IRP=1,IRPM
            KI=0
            RPM=XMM(IRP)
            EAR=EXX(KE)
            DO 100 I=1,JC
            3(I,3)=X3(I)
            3(I,4)=X4(I)
100      B(I,5)=X5(I)
            DO 10051 LE=1,JC
10051 B(LE,6)=(BLAS*EAR*X6(LE))/(B(9,2)*EXXS)
            BDEL=ABS( B(3,6)-X6(3) )
            IF(BDEL.GT..0001) TLES(3,2)=ADDJ
            DO 10052 LE=1,JC
10052 AZZ(LE,25)=AZZ(LE,36)*B(LE,6)
            DO 30 I=1,9
            VEL(I)=CAV(I)
30          EHP(I)=CAE(I)
            3(5,2)=XMM(IRP)/60.0
            IV=1
            IF(SHP.NE. 0.) GO TO 51
            DO 53 IG=1,IVV
            VEL1(IG)=VEL(IG)
53          EHP1(IG)=EHP(IG)
            GO TO 21
51          VEL1(1)=PVEL
            EHP1(1)=PEHP

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21 DO 5 I=1,11
  AZZ(I,24)=AS1*X3(I)+AS2
  SKZ=ABS(AZZ(I,24))
  IF(SKZ.LT..0001) AZZ(I,24)=0.
  IF(XPS.LT. 0.) AZZ(I,24)=AZZ(I,38)
  AZZ(I,38)=AZZ(I,24)
  AZZ(I,25)=AZZ(I,36)
5  AZZ(I,23)=AZZ(I,37)
  IF(SHP.EQ.0..OR.IV.EQ.1) GO TO 19
  DO 114 J=1,IVV
  R11(J)=VEL(J)
114 R3(J)=EHP(J)
  S1=VEL1(IV)
  CALDISCOT(S1,S1,B11,R3,B3,-120,JC,0,S2)
  EHP1(IV)=S2
19 B(6,2)=(325.86*EHP1(IV))/(VEL1(IV)*ETHPUS)
  P(7,2)=1.6878*VEL1(IV)
  NN=0
  RJ=1.0
  JB=BJ
  DDJ=1.0
  JEE=TANBI
  JDD=DDJ
  JD=.666667*F_OAT(JC)
  R(1,1)=3.0
  R(2,1)=CD
  R(3,1)=TANB
  R(4,1)=C.85
  R(6,1)=0.0
  P(7,1)=0.0
  B(8,1)=C.0
  P(9,1)=C.0
  R(1,2)=1.0
  B(2,2)=1.0
  R(8,2)=PHO
  R(5,1)=EWAKE
  R(3,2)=DIA
  R(4,2)=H_OAD
  RSL=B(7,2)/(3.14159265*B(5,2)*R(3,2))
  IF(TANB.GT.0.) GO TO 101
  DO 10035 I=1,JC
10035 R(I,2)=RSL/R(I,3)*R(1,4)
  101 AJJ=1.0
  IF( B(1,5).GT.0.) GO TO 10019
  IF( B(5,1).LE.0.) B(5,1)=B(JJ,4)
  DO 10018 I=1,JC
10018 B(I,5)= RSL*SQRT(B(5,1)*B(I,4))/(B(I,3)*B(4,1))
10019 NN=NN+1
  RAKOP=1
  IF(RAKE.LE..01.AND.RAKE.GT.0.) GO TO 10045
  DO 34 I=1,11
  34 RAK(I)=RAKE*(X3(I)-X3(1))/(X3(11)-X3(1))
10045 VK=B(7,2)/1.6878
  IF(KI.GT.0) GO TO 85
  AJJ=1.0
  WRITE(6,10025)
  PHS=SHP

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DO 152 I=1,IV9
IF(UO.EQ.SI) GO TO 151
DMV(I)=VEL(I)
DME(I)=EHP(I)
GO TO 152
151 DMV(I)=VEL(I)/VSI
DME(I)=EHP(I)/PMR
152 CONTINUE
WRITE(6,10008) UI,UO
IF(SHP.NE.0.) WRITE(6,10021) PU, PHS ,DEN1,DEN2,DEN3,DUN
IF(SHP.EQ.0.) WRITE(6,10020) SHPT1,SHPT2,DEN1,DEN2,DEN3,DUN
WRITE(6,10027) VL,VU,(DMV(I),I=1,IV9)
WRITE(6,10045) PE,PU,(DME(I),I=1,IV9)
WRITE(6,10028) UL, AID,EWAKE,ETHRUS,UL,NAEH,UJFN,OMR
10029 FORMAT(/2X,*D*,A4,*=*,F8.4,* ,1-WTT=*,F5.4,* ,1-THD=*,F5.4,* ,H*,
2 A4,*=*,F8.4,* ,RHO*,A10,*=*,1X,F9.4,/)
WRITE(6,10030) (JBL(I),I=1,I27)
WRITE(6,10031) EXA, (EXX(I),I=1,IEA)
WRITE(6,10032) URPM,(XMM(I),I=1,IRPM)
10025 FORMAT(1H1)
10023 FORMAT(/,2A7,2A10,A8,F10.4,/)
10021 FORMAT(/,* PS(*,A3,,*=*,1PE12.4,2A10,A*,3PF10.4,/)
10033 FORMAT(2X,*Z*,9X,9I3)
10031 FORMAT(2X,A5,5X,1P9E12.4)
10032 FORMAT(2X,*N*,A9,1P9E12.4)
10027 FORMAT(2X,A2,A6,2X,1P9E12.4)
10045 FORMAT(2X,2A3,4X,1P9E12.4)
WRITE(6,10100) (TLES(I,1),I=1,10)
WRITE(6,10101) (TLES(I,2),I=1,10)
10100 FORMAT(/,1X, 10(3X,A10))
10101 FORMAT(1X, 10(3X,A10),/)
DO 10111 I=1,JC
IF(FDO.LE.0.) P(I)=0
SRK=RAK(I)/JIA/12.
10111 WRITE(6,10102) X3(I),X4(I),B(I,6),AZZ(I,25),B(I,5),B(I,8),
2 AZZ(I,24),SRK,P(I),B(I,7)
10102 FORMAT(1P10E13.4)
85 DO 10090 I=1,JC
AZZ(I,25)=AZZ(I,25)*B(I,6)
10090 B(I,30)=B(I,5)*AJJ
IF(JEE.LE.0) GO TO 47
DO 209 IOC=1,3
DO 201 I=1,JC
201 B(I,30)=B(I,30)*AJJ
B14(41)=.975
B14(42)=1.000
B14(43)=1.025
DO 215 IJ=41,43
IJT=IJ+4
IJP=IJ+8
DO 216 I=1,JC
216 B(I,5)=B(I,30)*B14(IJ)
CALL SUB
B14(IJT)=PP7
B14(IJP)=PP8
215 CONTINUE
JK=44

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      TTT=R(6,2)/((B(8,2)*B(3,2)**2*3.1415927*R(7,2)**2)/A.)
      IF( B(1,2).GT.0. ) GO TO 10
      JK=48
      TTT=TTT*550./B(7,2)
10    DO 11 I=1,3
      CC(I,1)=B14(JK+I)
      DO 11 J=1,3
      K=3*(J-1)+I
      B15(40+K)=B14(40+J)**(I-1)
11    C(J,I)=B15(K+40)
      CALL SIMEQ(3,C,CC)
209  AJJ=(-CC(2,1)+SQRT(CC(2,1)**2-4.*CC(3,1)*(CC(1,1)-TTT)))/(2.*CC(3,
      1))
48    DO 49 I=1,JC
49    R(I,5)=B(I,30)*AJJ
47    JEC=0
      CALL SUR
      PP11=B15(181)*ETHRUS
      PP12=EHP1(IV)/PP11
      THP=P(6,2)
      ATHR=3(8,2)/B.C*3.14159*(R(3,2)**2)*(R(7,2)**2)*PP7
      ASHP(IV)=PP12
      IF(SHP) 55,10050,55
55    CONTINUE
      KI=KI+1
      IF(KI.GE.6) GO TO 10050
      IF(ABS((SHP-ASHP(IV))/ASHP(IV))-0.0005) 10050,10050,20
20    NI=.33
      IF(IV.EQ.1) GO TO 820
      NI=ALOG( VEL1(IV-1)/VEL1(IV) )/ALOG( ASHP(IV-1)/ASHP(IV) )
920  VEL1(IV+1)=VEL1(IV)*( (SHP/ASHP(IV))**NI )
      AVL=VEL1(IV+1)
      IF(AVL.GT.CAV(5).OR.AVL.LT.CAV(1)) WRITE(6,922) AVL
922  FORMAT(////13X,*ESTIMATED VELOCITY VALUE IN ITERATION FOR DESIRED
      1SHP IS NOT WITHIN RANGE OF INPUT VELOCITY VALUES...*/15X,*...PROGR
      2AM CANNOT EXTRAPOLATE FOR CORRESPONDING FHP. ESTIMATED VELOCITY
      3VALU: = *1PF10.4)
      IV=IV+1
      GO TO 21
10050 DO 10049 IX=1,IV
      FHP(IX)=EHP1(IX)
10049 VEL(IX)=VEL1(IX)
      DO 40050 I=1,JC
      AZZ(I,26)=B(I,14)
      AZZ(I,27)=B(I,5)
      BI=AZZ(I,27)
      IF(P00.GT.0.) BI= P(I)/PI/X3(I)
      CII=AZZ(I,24) *B(I,3)*SQRT(1.+BI*BI)*PI/190.
      AZZ(I,28)=CII-B(I,6)
      AZZ(I,29)=CII+B(I,6)
      AZZ(I,30)=B(I,6)
      AZZ(I,31)=B(I,4)
      AZZ(I,32)=B(I,12)
      AZZ(I,33)=B(I,13)
      AZZ(I,34)=AZZ(I,25)*2.0
40050 AX(I)=AZZ(I,34)
      IF(AZZ(11,25).NE.0.) GO TO 5555

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SLP=(AZZ(9,34)-AZZ(6,34))/(AZZ(9,23)-AZZ(6,23))
YINT=AZZ(9,34)-(AZZ(9,23)*SLP)
AZZ(10,34)=(SLP*AZZ(10,23))+YINT
AZZ(11,34)=(SLP*AZZ(11,23))+YINT
5555 DO 40052 K=26,34
      DO 40051 J=1,11
        R11(J)=B(J,3)
40051 R3(J)=AZZ(J,K)
      DO 40052 I=1,11
        S1=AZZ(I,23)
        CALL DISCOT(S1,S1,B11,83,93,-120,JC,0,52)
40052 AZZ(I,K)=S2
      DO 5050 I=1,JC
        AZZ(I,2)=B(I,2)
        R(I,20)=B(I,15)
        R(I,21)=B(I,5)
        BI=B(I,21)
        IF(PD0.GT.0.) BI= P(I)/PI/X3(I)
        B(I,22)=B(I,38)
        B(I,23)=B(I,5)
        R(I,24)=AZZ(I,24)
        R(I,25)=AZZ(I,25)
        TX(I)=B(I,25)*DIA*12.0
5050 B(I,24)=B(I,24)*B(I,3)*SQRT(1.+BI*BI)*PI/190.
      RT(11)=B(11,5)
C      OBTAIN DATA AT PROPER RADIAL STATIONS FOR STRESS PROGRAM
      DO 50080 I=1,10
        Q=AZZ(I,19)
        DO 50030 K=20,24
50030 CALL DISCOT(0,0,B(1,3),B(1,K),B(1,K),-120,JC,0,AZZ(I,K))
        CALL DISCOT(0,0,B(1,3),P,P,-120,JC,0,CX(I))
        CALL DISCOT(0,0,B(1,3),B(I,18),B(I,18),-120,JC,0,AZZ(I,18))
50080 CONTINUE
      DO 50090 I=1,10
50090 P(I)=CX(I)

      CALL STRESS(AZZ,AREA,XRAP,YBAR,AYEX0,AYFY0,EMX0,EMYO,EMTR,EMQR,STR
1MAX,RAK,PAKOP)
C      THE FOLLOWING STATEMENTS HAVE BEEN ADDED IN ORDER TO SEND THE R
C      VALUES TO SUBROUTINE WFIGHT. CHORD,THICKNESS, AND CAMBER ARE I
C      PITCH AND SKEWR ARE IN RADIAN.
      VS=VK*1.6878
      DO 999 I=1,JC
        IF(PD0.GT.0.) P(I)=PXTBI(I)
        X(I)=B(I,3)
        IF( X(I).GT. .65 .AND. X(I).LT. .75) SIGMA=B(I,19)
        CHORD(I)=B(I,6)*DIAM
        THICKNS(I)=AZZ(I,34)*DIAM/2.
        PITCH(I)=ATAN(B(I,5))
        BRJ(I)=ATAN(B(I,8))
        FX(I)=0.0
        IF(CL1(I).EQ. 0.) GO TO 29
        FX(I)=1.0/(1.0+(6.2832*TAN(PITCH(I)-BRJ(I))/CL1(I)))
29 CONTINUE
        BI=P(I)/PI/X3(I)
        IF(PD0.GT.0.) PITCH(I)=ATAN(BI)
        SKEWR(I)=AZZ(I,38)/57.2958

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      AZZ(I,34)=AX(I)
      AV  =(9(I,4)+B(I,12))**2
      BV  =(9(I,4)/B(I,8)-B(I,13))**2
      VSUBRSO(I)=VS**2*(AV  +BV  )
      VSUBR(I)=SQRT(VSUBRSO(I))
099  CAMBER(I)=.0679*R(I,18)*DIAM
      RPS=RPM/60.
      DO 996 I=1,J2
      PXTB(I)=PI*B(I,3)*B(I,5)
      PXTB(I)=PI*B(I,3)*B(I,8)
996  CONTINUE
      EA1=(EAR*3.14159*DIAM**2)/4.0
      AL=3.14159*0.7*B(7,5)
      AP=EA1*(1.067-0.229*AL)
      VA=VS*B(7,4)
      VR=SQRT(VA**2+(0.7*3.14159*RPS*DIAM)**2)
      TC=2.0*B(6,2)/(RHO*AP*VR**2)
      SIGMA7=(64.4*HEAD)/VR**2
      WRITE(6,10042)
10042 FORMAT(1H )
      UVP=VU
      IF(UO.NE.SI) UVR=UVE
      WRITE(6,76) UVP
      DO 79 I=1,11
      VPSI=VSUBR(I)
      IF(JO.EQ.SI) VRSI=VRSI*.3048
79  WRITE(6,80)  B(I,3),B(I,5),B(I,8),B(I,14),B(I,17),B(I,12),B(I,13)
1  ,B(I,17),VRSI,B(I,19)
      WRITE(6,10042)
      WRITE(6,77)  PP1,PP3,PP4,PP2,PP5
      WRITE(6,81)  PP6,PP8,PP9,PP7,PP11
      WRITE(6,10042)
      ULO=ULE
      IF(UO.EQ.SI) ULO=ULS
      WRITE(6,76) ULO
      DO 75 I=1,11
      SLI=.5*RHO*VSUBRSO(I)*CL1(I)* B(I,6)*DIAM
      IF(UO.EQ.SI) SLI=SLI*14.5939
75  WRITE(6,20046) B(I,3),CCONE(I),CCTWO(I),CCTHR(I),CCTFO(I),FX(I),
2  SLI,AZZ(I,38),AZZ(I,28),AZZ(I,29),A77(I,34)
      WRITE(6,10042)
      ANV=AV
      P12=PP12
      RTH=THR
      UR=UFI
      UTO=UFE
      RTHF=ATHR
      UST=UPIN2
      VLS=B(7,2)
      V2=UVF
      UO2=ULE2
      UO4=ULE4
      UMO=UIL
      USTR=ULPIN2
      IF(UO.NE.SI) GO TO 100
      UO2=ULS2
      UO4=ULS4

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      UMO=UNH
      USTR=UPA
      UST=UPA
      UB=USL
      UTO=UFS
      V2=USV
      VLS=VLS*.3048
      P12=P12/PHR
      RTH=RTH/UWT
      BTHR=BTHR/UWT
160  WRITE(6,10044) PP11,PU,P12,ETHRUS,EMAKF,VL,UEV,VK,UTO,RTH,J9L(IE)
      2  ,RPM,EARU,EXA,EAR,VL,V2,VLS,UTO,BTHR
      IF(UO.EQ.SI) WRITE(6,10010) UO2,UB,UB,UO4,UO4,UMO,UMO,UMO,UMO,UST
      IF(UO.NE.SI) WRITE(6,20009)
      IF(UO.NE.SI) WRITE(6,20010) UO2,UB,UB,UO4,UO4,UMO,UMO,UMO,UMO,UST
77  FORMAT(4X,*CPTI=*,1PE10.4,4X,*CPSI=*,1PE10.4,4X,*ETAI=*,1PE10.4,
      2  4X,*CTSI=*,1PE10.4,4X,*CTSI/CPSI=*,1PE10.4)
79  FORMAT(6X,* X*,8X,*TANBI*,7X,*TAN B*,9X,*G*,9X,*UT/2V*,7X,
      2  *UA/2V*,7X,*DCTSI*,7X,*DCPSI*,5X,*VR(*,A7,5X,*CAVV*)
80  FORMAT(1P10E12.4)
81  FORMAT(5X,*CPT=*,1PE10.4, 5X,*CPS=*,1PE10.4,5X,*ETA=*,1PE10.4,5X,
      2  *CTS=*,1PE10.4,6X,*CTS/CPS=*,1PE10.4)
75  FORMAT(5X,* X*,8X,*CL*,6X,*ALI(DEG)*5X,*FM/C*,7X,*CD/CL*,7X,
      2  *F(X)*,4X,*LI*,A8,2X,*TETS(DEG)*2X,* (C/PD)LF*,4X,* (C/PD)TE*,6X,
      3  *T/PD* )
20046 FORMAT(1PE10.3,1P10E11.3)
10044 FORMAT(1X,*ETAD=*,1PE10.4,4X,*PS(*,A4,*=*,1PE10.4,3X,*1-THD=*,
      2  ,1PE10.4 ,
      2  3X,*1-WTT=*,1PE10.4,3X,A2,A8,*=*,1PE10.4,7X,*DESIGN TH*,A5,*=*,
      3  1PE10.4,/,4X,*Z=*,I2, 9X,*N(RFV/MIN)=*,1PE10.4,14X,
      4  A8,A5,*=*,1PE10.4,3X,A2,A7, * =* ,1PE10.4,3X,*CALCULATED TH*,
      5  A5,*=*,1PE10.4)
      DO 74 I=1,7
      SX(I)=4ZZ(I,19)
      APR=AREA(I)
      XPP=XBAR(I)
      YPR=YBAR(I)
      XOI=AYEXO(I)
      YOI=AYEYO(I)
      XOM=EMXO(I)
      YOM=EMYO(I)
      TRM=EMTB(I)
      QBM=EMQB(I)
      STRM=STRMAX(I)
      IF(UO.NE.SI) GO TO 74
      APR=APR*EL2
      XPR=XPR/ELI
      YPR=YPR/ELI
      XOI=XOI*EL2*EL2
      YOI=YOI*EL2*EL2
      XOM=XOM/SIM
      YOM=YOM/SIM
      TRM=TRM/SIM
      QBM=QBM/SIM
      STRM=STRM*6894.757
74  WRITE(6,20047) SX(I),APR,XPR,YPR,XOI,YOI,XOM,YOM,TRM,QBM,STRM
20047 FORMAT(1PE10.3,1P5E11.3,1P5E12.3)

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20009 FORMAT(1H1,4X,*X*,9X,*AREA*,7X,*XBAR*,7X,*YBAR*,7X,*IXO*,8X,*IYO*
2 ,9X,*MXO*,9X,*MYO*,9X,*MTR*,9X,*MOB*,6X,*MAXSTRESS* )
20010 FORMAT(15X,A5,6X,A4,7X,A4,6X,A5,6X,A5,6X,A3,4X,A8,4X,A8,4X,A8,3X,
2A9)
10010 FORMAT(1H1,4X,*X*,7X,*AREA*,A5,4X,*XBAR*,A4,2X,*YBAR*,A4,2X,*IXO*
2 ,A5,3X,*IYO*,A5,4X,*MXO*,A8,1X,*MYO*,A8,1X,*MTR*,A8,1X,*MOB*,A8,
3 *MAXSTRESS*,A9)
WRITE(6,10042)
WRITE(6,10042)
WRITE(6,10011)
DO 73 I=1,11
SRK=RAK(I)*DIA/12.
WRITE(6,10012) B(I,3),SRK,PXTBI(I),PXTB(I)
73 IF(PDO.GT.0.) PXTBI(I)=P(I)
10011 FORMAT(5X,*X*,8X,*RAKG/D*,1X,23H PI XTANBI PI XTANB )
10012 FORMAT(1PE10.3,1P3E11.3)
CALL WEIGHT(JC,SIGMA7,HUB,PMHC,WEIGHTB,WEIGHTH,PAK)
SBI=SIN( PITCH(1) )
3214 HUBSPAC=2.0*PI*X(1)*DIA*6.0/R(9,2)
TRI=AX(1)*DIA*6./SBI
BLASPAC=HUBSPAC-TRI
FILSPAC=BLASPAC-.9*TRI
WRITE(6,998) TC,SIGMA7
BLS=BLASPAC/DIA/12.
FILS=FILSPAC/DIA/12.
UF=FT
UMI=PMI
IF(UO.NE.SI) GO TO 158
UF=UOL
UMI=UC7
158 CONTINUE
WRITE(6,994) BLS, FILS
998 FORMAT(/20X,*BURRILL THRUST COEFF TC=*,F10.4//20X,*BURRILL CAVI
1TATION COEFF SIGMA(0.7)=*,E10.4)
994 FORMAT(/20X,*CLEARANCE AT HUB BETWEEN BLADES/G=*,1PE12.4,/,
2 20X,*CLEARANCE AT HUB BETWEEN FILLETS/G=*,1PE12.4)
DO 122 I=1,11
ARPMI(I)=B(I,6)*AZZ(I,25)*PSC
122 PMDX(I)=ARPMI(I)*X(I)**2
PMOFIB=B(9,2)*DEN/1728.*(DIA*6.0)**3*STMPUN(X,PMDX,JC)
TPMIN=PMOFIB+PMHC
RADOGB=SQRT(PMOFIB/WEIGHTB)/12.
RADOGH=SQRT(PMHC/WEIGHTH)/12.
RADOGT=SQRT(TPMIN/(WEIGHTB+WEIGHTH))/12.
PMS=PMOFIB
TPS=TPMIN
GRB=RADOGB/DIA
GPH=RADOGH/DIA
GRT=RADOGT/DIA
IF(UO.NE.SI) GO TO 171
PMS=PMS*.00029264
TPS=TPS*.00029264
171 WRITE(6,995) UMI,PMS,UMI,TPS,GR1,GR2, GP3,GR1,GR2, GRH,
2 GR1,GR2, GRT
995 FORMAT(1H1,19X,*MASS POLAR MOMENT OF INERTIA OF BLADES *,A10,
2 E13.6,/,20X,*TOTAL MASS POLAR MOMENT OF INERTIA *,A10,E13.6,/,
3 20X,2A9,* OF BLADE/D=*,F9.4,/,20X,2A9,* OF HUB/D=*,F9.4,

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      4 //,20X,*TOTAL *,2A9,      */D=*,F9.4)
C   THIS SECTION CALCULATES THE ABS COEFFICIENTS
      IF (TYPE.EQ.0.) GO TO 570
      RAD=C.25
      IF (B(1,3).GE.0.25) RAD=B(1,3)+.05
      IF (B(2,3).EQ.0.25) GO TO 590
      DO 510 J=1,11
      B11(J)=R(J,3)
510  B3(J)=PXTBI(J)
      S1=.25
      IF (B(1,3).GE.0.25) S1=RAD
      CALL DISCOT(S1,S1,B11,B3,B3,-120,JC,0,S2)
      PTWOFIV=S2
      DO 513 J=1,11
      B11(J)=R(J,3)
513  B3(J)=B(J,6)*DIAM*12.0
      S1=.25
      IF (B(1,3).GE.0.25) S1=RAD
      CALL DISCOT(S1,S1,B11,B3,B3,-120,JC,0,S2)
      DURLU=S2
      DO 515 J=1,11
      B11(J)=R(J,3)
515  B3(J)=ARPMI(J)
      S1=.25
      IF (B(1,3).GE.0.25) S1=RAD
      CALL DISCOT(S1,S1,B11,B3,B3,-120,JC,0,S2)
      ATWOFIV=S2
      DO 519 J=1,11
      B11(J)=R(J,3)
519  B3(J)=THICKNS(J)*12.0
      S1=.25
      IF (B(1,3).GE.0.25) S1=RAD
      CALL DISCOT(S1,S1,B11,B3,B3,-120,JC,0,S2)
      TMAX=S2
      UF=0.5*TMAX
      GO TO 592
592  PTWOFIV=PXTBI(2)
      DUBLU=R(2,6)*DIAM*12.0
      ATWOFIV=ARPMI(2)
      TMAX=THICKNS(2)*12.0
      UF=0.5*TMAX
592  CONTINUE
      IF (B(7,3).EQ.0.7) GO TO 596
      DO 595 J=1,11
      B11(J)=R(J,3)
595  B3(J)=PXTBI(J)
      S1=.7
      CALL DISCOT(S1,S1,B11,B3,B3,-120,JC,0,S2)
      PSEVEN=S2
      GO TO 597
596  PSEVEN=PXTBI(7)
597  CONTINUE
      RAKE2=PAK(11)+DIAM*AZZ(11,38)*P(11)/30.
      DO 519 J=1,7
      B11(J)=SX(J)
519  B3(J)=AYEXO(J)
      S1=.25

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IF(SX(1).GE.0.25) S1=SX(1)+0.05
CALL DISCOT(S1,S1,B11,B3,B3,-120,7,0,S2)
AYO=S2
F=INT(TYPE/2)*68.+INT(TYPE/3)*5.-INT(TYPE/4)*56.-INT(TYPE/6)*127.
WL=INT(TYPE/2)*.3-INT(TYPE/3)*.01-INT(TYPE/4)*.32-INT(TYPE/6)*.30
CS=ATWOFIV/(DUBLU*TMAX)
CN=AYO/(UF*JUGLU*TMAX**2)
AA=1.0+6.0/PSEVEN+4.3*PTWOFIV
BA=4300.*WL*EAP /B(9,2)*(RPM/100.)**2*(DIAM/20.)**3
CA=(1.0+1.5*PTWOFIV)*(DUBLU*F-BA)
ANEW=13.*SQRT(AA*PP12/(CA*RPM*R(9,2)))
BNEW=CS*BA/4./CA
BTHICK1= ANEW/SQRT(CN)+BNEW/CN*RAK(11)
BTHICK2=ANEW/SQRT(CN)+BNEW/CN*RAKE2
WRITE(6,530) RAD
530 FORMAT(///29X,*ABS COEFFICIENTS (CALCULATED) AT THE*,F4.2,* RADIUS
1)*)
TABS(5)=TBS
TABS(6)=UBS
IF(PDO.GT.0.) TABS(5)=VBS
IF(PDO.GT.0.) TABS(6)=XBS
BS1=BTHICK1/DIA/12.
BS2=BTHICK2/DIA/12.
ATF=ATWOFIV
IF(UO.NE.SI) GO TO 172
ATF=ATF*.00064516
172 WRITE(6,541) TABS,BS1,BS2,AA,BA,CA,CS,CN,SNIR,ATF
541 FORMAT(//20X,6A10,
2 /40X*USING ABS RAKE = CONVENTIONAL RAKE, T/D= *E10.4/40X*USI
BNG ABS RAKE = CONVENTIONAL + SKEW-INDUCED RAKE, T/D= *E10.4
2 //20X*VALUES USED IN DETERMINING THICKNESS-
3 A= *E12.6/62X*B= *E12.6/62X*C= *E12.6//20X*SECTION AREA COEFF
4 ICIENT CS= *E10.4//20X*SECTION MODULUS COEFFICIENT CN= *E1
50.4//20X*AREA OF EXPANDED CYLINDRICAL SECTION IN SQ.*A6,5X,*AS=*,
6 E10.4)
CN=.1
BTHICK1= ANEW/SQRT(CN)+BNEW/CN*RAK(11)
BTHICK2=ANEW/SQRT(CN)+BNEW/CN*RAKE2
BS2=BTHICK2/DIA/12.
BS1=BTHICK1/DIA/12.
WRITE(6,543) TABS,BS1,BS2
543 FORMAT(////////,20X,*FOR CN=.1*,/,20X,6A10,
2 /40X*USING ABS RAKE = CONVENTIONAL RAKE, T/D= *E10.4/40X*USI
BNG ABS RAKE = CONVENTIONAL + SKEW-INDUCED RAKE, T/D= *E10.4)
570 CONTINUE
BLADEL=B(11,3)-B(1,3)
DELTA=BLADEL/8.
DELTA1=DELTA/2.
DO 132 I=1,11
XR(I)=B(I,3)
TANBETI(I)=B(I,5)
G(I)=B(I,14)
XSL(I)=AZZ(I,29)
XST(I)=AZZ(I,29)
WAKE(I)=B(I,4)
UVELA(I)=B(I,12)
THICKR(I)=AZZ(I,34)

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132 CONTINUE
  XR(12)=XR(1)+DELTA1
  XR(13)=XR(1)+DELTA
  DO 130 I=14,19
    XR(I)=XR(I-1)+DELTA
130 CONTINUE
  XP(20)=XR(19)+DELTA1
  DO 131 I=12,20
    CALL DISCOT(XR(I),XR(I),XR,TANBETI,XR,-044,11,0,TANBETI(I))
    CALL DISCOT(XR(I),XR(I),XR,G,XR,-044,11,0,G(I))
    CALL DISCOT(XR(I),XR(I),XR,XSL,XR,-044,11,0,XSL(I))
    CALL DISCOT(XR(I),XR(I),XR,XST,XP,-044,11,0,XST(I))
    CALL DISCOT(XR(I),XR(I),XR,WAKE,XR,-044,11,0,WAKE(I))
    CALL DISCOT(XR(I),XR(I),XR,UVFLA,XR,-044,11,0,UVFLA(I))
    CALL DISCOT(XR(I),XR(I),XR,THICKR,XR,-044,11,0,THICKR(I))
    XSL(I)=XSL(I)*DIA*6.
    XST(I)=XST(I)*DIA*6.
    THICKR(I)=THICKR(I)*DIA*6.
131 CONTINUE
  WRITE(6,133)
133 FORMAT(1H1,////,10X,*RADIAL PROPELLER DATA FOR INPUT INTO DESIGN P
  1ROGRAMS(A RADIAL STRIPS ASSUMED)*,/)
  WRITE(6,134) SNIP,SNIP,SNIP
134 FORMAT(10X,*XR*,5X,*TAN BETA I*,8X,*G*,7X,*XSL(*,A7,5X,*XST(*,A7,
  2 5X,*1-WX*,8X,*UA/2VS*,5X,*THICKNESS(*,A7,/)
  DO 174 I=12,20
    SSL=XSL(I)
    SST=XST(I)
    STHR=THICKR(I)
    IF(UO.NE.SI) GO TO 174
    SSL=SSL/ELI
    SST=SST/ELI
    STHP=STHR/ELI
174 WRITE(6,135) XR(I),TANBETI(I),G(I),SSL,SST,WAKE(I),UVFLA(I),STHP
135 FORMAT(4X,F10.5,3X,F10.5,3X,E12.4,3X,F10.5,4X,F10.5,1X,F10.5,4X,E1
  12.4,5X,F10.5)
  XSL(11)=XSL(11)*DIA*6.
  XST(11)=XST(11)*DIA*6.
  SSL=XSL(11)
  SST=XST(11)
  IF(UO.NE.SI) GO TO 175
  SSL=SSL/ELI
  SST=SST/ELI
175 WRITE(6,136) XR(11),SSL,SST
136 FORMAT(4X,F10.5,31X,F10.5,4X,F10.5)
  IF(SHP.NE.0.) GO TO 10069
  IV=IV+1
  IF(IV.LE.IVV) GO TO 21
10069 CONTINUE
10070 CONTINUE
10071 CONTINUE
10072 CONTINUE
  STOP
  END

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SUBROUTINE SUB
  DIMENSION CHORD(11),THICKNS(11),CAMBER(11),PITCH(11),SKEWR(11)
1  ,XI(11)
  DIMENSION P(13),BT(11)
  COMMON/CWEIGHT/XI,CHORD,THICKNS,CAMBER,PITCH,SKEWR,DIAM,77,DEN
1 ,PAKE,PI,PP7,PP8,PP9,PP11,EWAKE,VS,RPS,SIGMA,EAP,BT,P,P00
2  ,FWDDIAM,AFTDIAM,HUBLEN,FORORE,A0BORE,DISQFF
  DIMENSION B(38,38),      B2(181),B3(181)
1  ,B11(181),B14(181)
2  ,B15(181),AZ(11,11),BH(11,11),C(12,1),CC(12,12)
  COMMON B,      B2,B3,      R11      ,B14,B15,A7,BH,
1C,CC,      IO,J8,JC,JD,J00,JEE,CL1(11)
  COMMON CCONE(11),CCTWO(11),CCTHP(11),CCFOR(11)
  COMMON PP1,PP2,PP3,PP4,PP5,PP6,PP10
  COMMON SN(73),CS(73)
10252 DO 10025 N=1,JC
      DO 20021 I=1,JC
        AAG=1./9(I,5)
        AAH=B(N,3)/B(I,3)*AAG
        AAO=B(I,5)
        IF(AAH-AAG)10019,10018,10019
10018 B2(I)=1./SQRT(1.+AAQ*AAQ)
        B3(I)=AAQ*B2(I)
        GO TO 20021
10019 S=1.+AAH**2
        T=SQRT(S)
        V=1.+AAG**2
        W=SQRT(V)
        AE=T-W
        U=EXP(AE)
        R=((T-1.)/AAH*(AAG/(W-1.)))*U)**9(9,2)
        JC=1.5
        AD=.25
        X=(1./(2.*8(9,2)*AAG))*((V/S)**AD)
        Y=((9.*AAG**2)+2.)/(V**AC)+((3.*AAH **2-2.)/(S**AC))
        Z=1./(24.*8(9,2))*Y
        IF(AAH-AAG)10021,10021,10021
10020 AF=1.+1./(R-1.)
        AA=X*(1./(R-1.))-Z*ALOG(AF)
        B2(I) =2.*8(9,2)**2*AAG*AAH*(1.-AAG/AAH)*AA
        B3(I) =8(9,2)*(1.-AAG/AAH)*(1.+2.*8(9,2)*AAG*AA)
        GO TO 20021
10021 AG=1.+1./(1./R-1.)
        AB=-X*(1./(1./R-1.))+Z*ALOG(AG)
        B2(I) =8(9,2)*AAG*(1.-AAH/AAG)*(1.-2.*8(9,2)*AAG*AA)
        B3(I) =2.*8(9,2)**2*AAG*(1.-AAG/AAH)*AB
20021 CONTINUE
20024 FORMAT(9F12.4)
      DO 2 I=1,JC
        B11(I)=B(I,3)
        DO 3 I=1,37
          S1 =.5*(1.+8(1,3))-.5*(1.-8(1,3))*CS(I)
          CALL DISCOT(S1,S1,B11,B3 ,B3 , -120,JC,0,S3)
3        B15(I)=S3
          DO 5 I=1,37
            S1 =.5*(1.+8(1,3))-.5*(1.-8(1,3))*CS(I)
            CALL DISCOT(S1,S1,B11,B2 ,B2 , -120,JC,0,S2)

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5      B14(I)=S2
      DO 4 I=1,37
      B2(I)=B14(I)
4      R3(I)=B15(I)
      DO 10022 L=1,35
      N1=37+L
      N2=37-L
      B2(N1)=B2(N2)
10022 B3(N1)=B3(N2)
      C2=2./72.
      NP=72
      NH=36
      XNP=NP
      S=0.0
      SL=0.0
      DO 20 I=1,NP
      S=S+B2(I)
20  SL=SL+B3(I)
      B(1,9)=S/XNP
      R(1,10)=SL/XNP
      DO 40 I=1,NH
      S=0.0
      SL=0.0
      DO 30 J=1,NP
      K=(J-1)*I
      K=MOD(K,72)+1
      S=S+B2(J)*CS(K)
30  SL=SL+B3(J)*CS(K)
      L=I+1
      B(L,9)=S*C2
40  B(L,10)=SL*C2
      CPHI=((1.+B(1,3))-2.*B(N,3))/(1.-B(1,3))
      IF(CPHI.LT.-1.) CPHI=-1.
      IF(CPHI.GT.1.) CPHI=1.
      B(N,11)=ACOS(CPHI)
      R(1,11)=.0
      B(JC,11)=3.1415927
      CON3=3.1415927
      DO 10025 I=1,JC
      SMP=SIN(FLOAT(I)*B(N,11))
      CMP=COS(FLOAT(I)*B(N,11))
      IF(N-1)10027,10026,10027
10027 IF(N-JC)10028,10029,10028
10026 AZN=.0
      RZN=.0
      N2=I+1
      DO 20026 K=1,N2
      IF(K-JC)10070,10070,20026
10070 AZN=AZN+CON3*FLOAT(I)*B(K,9)
      BZN=BZN+CON3*FLOAT(I)*B(K,10)
20026 CONTINUE
      AZL=.0
      RZL=.0
      IF(N2-JC)10060,10030,10030
10060 N1=N2+1
      DO 20036 M=N1,JC
      L=M-1

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      AZL=A7L+FLOAT(L)*B(M,9)*CON3
20036  BZL=BZL+FLOAT(L)*B(M,10)*CON3
      GO TO 10030
10029  AZN=.0
      BZN=.0
      N2=I+1
      DO 20029 K=1,N2
      CKP=COS(FLOAT(K-1)*B(N,11))
      IF(K-JC) 10071,10071,20029
10071  AZN=AZN-CON3*CKP*FLOAT(I)*B(K,9)*CKP
      BZN=BZN-CON3*CKP*FLOAT(I)*B(K,10)*CKP
20029  CONTINUE
      AZL=.0
      BZL=.0
      IF(N2-JC) 10061,10030,10030
10061  N1=N2+1
      DO 20039 M=N1,JC
      L=M-1
      CKP=COS(FLOAT(L)*B(N,11))
      AZL=AZL-CON3*CKP*FLOAT(L)*B(M,9)*CKP
20039  BZL=BZL-CON3*CKP*FLOAT(L)*B(M,10)*CKP
      GO TO 10030
10028  AZN=.0
      BZN=.0
      CON1=3.1415927/SIN(B(N,11))
      N2=I+1
      DO 20028 K=1,N2
      CKP=COS(FLOAT(K-1)*B(N,11))
      IF(K-JC) 10072,10072,20028
10072  AZN=AZN+CON1*CKP*B(K,9)*CKP
      BZN=BZN+CON1*CKP*B(K,10)*CKP
20028  CONTINUE
      AZL=.0
      BZL=.0
      IF(N2-JC) 10062,10030,10030
10062  N1=N2+1
      DO 20038 M=N1,JC
      L=M-1
      SKP=SIN(FLOAT(L)*B(N,11))
      AZL=AZL+CON1*CKP*B(M,9)*SKP
20038  BZL=BZL+CON1*CKP*B(M,10)*SKP
10030  AZ(I,N)=AZN+AZL
      BH(I,N)=BZN+BZL
10025  CONTINUE
      DO 10031 I=1,JC
      DO 10031 J=1,JC
      CC(I,1)=(1.-B(1,3))*(B(I,5)/B(I,8)-1.)*B(I,4)
10031  C(I,J)=FLOAT(J)*(AZ(J,I)+B(I,5)*BH(J,I))
      CALL SIMEQ(JC,C,CC)
      DO 10035 I=1,JC
      B(I,12)=.0
      B(I,13)=.0
      B(I,14)=.0
      DO 10035 J=1,JC
      R(I,12)=B(I,12)+FLOAT(J)*CC(J,1)*AZ(J,I)/B(I,4)*(1./(1.-B(1,3)))
      R(I,13)=B(I,13)+FLOAT(J)*CC(J,1)*BH(J,I)/B(I,4)*(1./(1.-B(1,3)))
10035  B(I,14)=CC(J,1)*SIN(FLOAT(J)*B(I,11))/R(I,4)+B(I,14)

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      B(JC,14)=.0
20001 00 10038 I=1, JC
      B(I,15)=(B(I,14)*B(I,4)*(B(I,4)/B(I,8)-B(I,13)*B(I,4)))**4.*B(9,
12)
      B(I,16)=B(I,15)*B(I,4)
      B(I,17)=(B(I,4)/B(I,8)*B(I,14)*B(I,4)*(B(I,4)+B(I,12)*B(I,4)))**4.
1*B(9,2)
      BTT=ATAN(B(I,8))
      BTI=ATAN(B(I,5))
      P(I,18)=2.*3.1415927*B(I,14)*COS(BTI)/(1./B(I,5)-B(I,13))
      B(I,19)=64.31*(B(4,2)-B(I,3)*B(3,2)/2.)*(SIN(BTT)/(B(I,4)*B(7,2)
1*COS(BTI-BTT)))**2
      IF(I-1)9,9,6
6      IF(I-JC)10,9,9
9      R(I,20)=.0
      R(I,21)=.0
      GO TO 11
10     CONTINUE
      B(I,20)=(1.-B(I,7)*B(I,6)/B(I,18)*B(I,5))*B(I,15)
      R(I,21)=(1.+B(I,7)*B(I,6)/B(I,18)/B(I,5))*B(I,17)
11     CONTINUE
      R(I,22)=B(I,20)*B(I,4)
10038 CONTINUE
      PP1=SIMPUN(B(1,3),B(1,16),JC)
      PP2=SIMPUN(B(1,3),B(1,15),JC)
      PP3=SIMPUN(B(1,3),B(1,17),JC)
      PP4=PP1/PP3
      PP5=PP2/PP3
      PP6=SIMPUN(B(1,3),B(1,22),JC)
      PP7=SIMPUN(B(1,3),B(1,20),JC)
      PP8=SIMPUN(B(1,3),B(1,21),JC)
      PP9=PP6/PP8
      PP10=PP7/PP8
      DO 10039 I=1, JC
      JCI=JC+1-I
      DO 10040 L=1, JC
      XO=B(L,3)-B(I,3)
      IF(XO) 860,850,871
860    XO=C.0
      GO TO 861
871    CONTINUE
      XO=B(L,3)-B(I,3)
861    CONTINUE
      B2(L)=XO*B(L,20)
10040 B3(L)=XO/B(L,3)*B(L,21)
      IF(JCI-2)10041,10041,10059
10041 B(I,25)=.0
      R(I,26)=.0
      B(I,27)=.0
      P(I,28)=.0
      GO TO 10039
10059 B(I,25)=SIMPUN(B(1,3),B(1,15),JC)*B(8,2)*B(3,2)**3*3.1415927*B(7,2)
1)**2/(16.*B(9,2))
      B(I,26)=SIMPUN(B(1,3),B(1,16),JC)*B(8,2)*B(3,2)**2*B(7,2)**3/(16.*
1 B(5,2)*B(9,2))
      BTI=ATAN(B(I,5))
      SBI=SIN(BTI)

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      CBI=COS(8TI)
      B(I,27)=B(I,25)*CBI+B(I,26)*SBI
      B(I,28)=B(I,25)*SBI-B(I,26)*CBI
10039 CONTINUE
      DO 206 I=1,JC
      B(I,12)=B(I,4)*B(I,12)
      B(I,13)=B(I,4)*B(I,13)
206   B(I,14)=B(I,4)*B(I,14)
      IF(JEE.GT.0) GO TO 10081
      H15(181)=PP10
      DO 10049 I=1,JC
      IF(B(I,6)) 702,702,703
702   CC1=C.C
      GO TO 704
703   CC1=B(I,18)/B(I,6)
704   CONTINUE
      CL1(I)=CC1
      CC2=1.54*CC1
      CC3=.0679*CC1
      IF(CC1) 701,700,701
700   CC4=C.C
      H(I,38)=CC4
      GO TO 52
701   CC4=B(I,7)/CC1
      B(I,38)=CC4
52   CCONE(I)=CC1
      CCTWO(I)=CC2
      CCTHR(I)=CC3
10049 CCFOR(I)=CC4
10081 CONTINUE
20041 RETURN
      END

```

SUBROUTINE SIMEQ(JC,C,CC)

C ---- NEW VERSION BY JACK DISKIN -- X71450

```

      DIMENSION BA(12),C(12,12),CC(12,12)
      MPD=JC
      JCI=JC+1
      CC(JCI,1)=0.
      DO 80 I=1,JC
      C(I,JCI)=-CC(I,1)
      DO 78 J=2,JCI
78   CC(I,J)=0.
      CC(I,1)=-C(I,I+1)/C(I,1)
80   CC(I,I+1)=1.
      DO 89 K=2,JC
      DO 86 I=1,MPD
      BA(I)=0.
      DO 86 J=1,JCI
86   BA(I)=BA(I)+C(K,J)*CC(I,J)
      MPD=MPD+1
      DO 89 J=1,JCI
      Z=CC(1,J)/BA(1)
      DO 89 I=1,MPD
89   CC(I,J)=-BA(I+1)*Z+CC(I+1,J)
      DO 99 J=1,JCI
99   CC(J,1)=CC(1,J)
      RETURN
      END

```

```

SUPROUTINE DISCOT (XA,ZA,TABX,TABY,TABZ,NC,NY,NZ,ANS)
DIMENSION TABX(1),TABY(1),TABZ(1),NPX(37),NPY(37),YY(37)

```

C MERGE OF DISCOT,DISSER,AND LAGRAN USING BUILT IN CONSTRAINTS

```

      NL=2
      IF(NC.EQ.-44) NL=3
      ID=2*NL-2
      NUPP=NY-NL
      DO 15 II=NL,NUPP
      NLOC=II
      IF( TABX(II).GE.XA) GO TO 20
15  CONTINUE
      NUPP=NUPP-NL+2
      GO TO 99
20  NUPP=NLOC-NL+1
      NU=NUPP+ID
      DO 25 JJ=NUPP,NU
      NDIS=JJ
      IF( TABX(JJ) .EQ. TABX(JJ+1) ) GO TO 30
25  CONTINUE
      GO TO 99
30  NUPP=NDIS-ID
      IF(TABX(NDIS).LT.XA) NUPP=NDIS+1
99  SUM=C.C
      NN=NUPP
      N=NN+ID
      DO 3 I=NN,N
      PROD=TABY(I)
      DO 2 J=NN,N
      A=TABX(I)-TABX(J)
      IF(A.EQ.0.) GO TO 2
      B=(XA- TABX(J) )/A
      PROD=PROD*B
2  CONTINUE
3  SUM=SUM+PROD
      ANS=SUM
      RETURN
      END

```

```

SUBROUTINE STRESS(AZZ,AREA,XBAR,YBAR,AYEXO,AYEYO,EMXO,EMYO,EMTB,FM
108,STRMAX,RAK,RAKOP)
  DIMENSION CHORD(11),THICKNS(11),CAMBER(11),PITCH(11),SKEWP(11)
  1,XI(11),BT(11)
  COMMON/CWEIGHT/XI,CHORD,THICKNS,CAMBER,PITCH,SKEWP,DIAM,ZZ,DEN
  1,RAKL,PI,PP7,PP8,PP9,PP11,EWAKE,VS,RPS,SIGMA,EAR,RT,P,P00
  2 ,FWODIAM,AFTDIAM,HUBLEN,FDBORE,ADBORE,DISREFL
  COMMON /UNITS/ SI,UI,UO
  DIMENSION RAK(11)
  DIMENSION AZZ(11,38)
  DIMENSION XE(20)
  DIMENSION HA(20),HA1(20),PHI(20),PHI2(20),XU1(20),T1(20),Q1(20),CP
  1HI(20),SPHI(20),X4(20),AE(20),RE(20),PE(20)
  DIMENSION A(13),B(13),C(13),D(13),E(13),F(13),G(13),H(13),O(13),
  XP(13),Q(13),R(13),S(13),T(13),U(13),V(13),W(13),X(13),Y(13),Z(13)
  DIMENSION R1(7,16), S1(7,16)
  DIMENSION CENTST(7), CENT40(7)
  DIMENSION FMX(7),TX(7),FMMX(13),YTX(13),SKEW(13),XU(10)
  DIMENSION VOL(7),CENT4(7),A1(7),A2(7),X2RASP(7),CENTS2(7),R2(13),
  X F5(13),P2(13),O2(13),AA(10),BA(10),CENT42(7),CENTMS(7),
  X TSKEW1(7),TSKEW2(7),ASKEW1(7),ASKEW2(7)
  DIMENSION V2(13),O2(13),F2(13)
  DIMENSION ALPHA(7)
  DIMENSION XMT(10),XL(10),XM(10),XT(10),STM(10),STLT(10)
  DIMENSION AREA(7),XBAR(7),YBAR(7),AYEXO(7),AYEYO(7),FMXO(7),EMYO(7
  1),EMTB(7),EMO9(7),STRMAX(7)
  DATA AF,AT,ATX,ATF,ATFF,AFXX,ATTT,GRAV/1.40795,.72099,.341,.58032
  2 ,.50321,.41733,.12714,32.14 /

```

```

C
C * * * * * SIMPLE BEAM APPROXIMATION INCLUDING
C * * * * * BENDING, CENTRIFUGAL AND TORSIONAL FORCES.

```

```

  PI=3.1415926536
  ATXX=.202084
  NN=1
18 FORMAT(8F9.6)
  ZZ=AZZ(9,2)
  VS=AZZ(7,2)
  DIAM=AZZ(3,2)
  DIA=DIAM
  VEL=60.0*AZZ(5,2)
  ISEC=0
  AZZ(10,20)=0.0
  AZZ(10,21)=BT(11)
  AZZ(10,22)=0.0
  DO 1000 I=1,10
  O(I)=AZZ(I,20)
  T(I)=AZZ(I,21)
  E(I)=AZZ(I,22)
  C(I)=AZZ(I,23)*DIA*12.0
  SKEW(I)=(C(I)/2.0-AZZ(I,24)*DIA*12.0/2.0
1000 XU(I)=AZZ(I,19)
  DO 30 J=2,7
  30 AZZ(J,25)=AZZ(J+1,25)
  DO 1001 I=1,7
  K=14-I
  J=K/13
  U(I)=.1*(I-2)+.05*J*(3-I)

```

```

      U(K)=1-U(I)
      TX(I)=AZZ(I,25)*DIA*12.0
      FMX(I)=.0679*DIA*AZZ(I,18)
      YBAR(I)=.0679*DIA*AZZ(I,18)
      FMX(I)=0.0
      A(I)=C(I)*TX(I)*AT
      X(I)=C(I)*ATX/AT
      Y(I)=FMX(I)*ATF/AT/2.
      G(I)=C(I)*TX(I)*(FMX(I)**2*ATFF+TX(I)**2*ATTT/3.)-A(I)*Y(I)*Y(I)
      H(I)=C(I)**3*TX(I)*ATXX - A(I)*X(I)*X(I)
1001  CONTINUE
C  CALCULATE THE VALUE OF F1 FROM INPUT VALUES.
26  F1=1.9905*(DIAM/2.0)**3*VS**2*PI*6.0/ZZ
      FF1=F1
      IF(PD0.GT.0.) GO TO 52
      DO 215 I=1,10
215  P(I) = T(I)*PI*XU(I)
52  NN=NN+1
C  ===== COMPUTE =====
C  CALCULATIONS FOR CONSTANTS USED IN DETERMINATION OF TOPOUE AND THRUST
C  CALCULATIONS OF BENDING MOMENTS FROM THRUST AND TORQUE.
      DO 360 I5=1,2
      F1=FF1
      RAD1=DIAM*0.5*12.0
      IF(I5-2)55,56,56
55  DO 210 I=1,10
      PE(I)=P(I)
      AE(I)=D(I)*(1-E(I)*T(I))
      B(I)=D(I)*(E(I)+T(I))
      BE(I)=B(I)
      T(I)=P(I)/(PI*XU(I))
      PHI(I)=ATAN(T(I))
      CPHI(I)=COS(PHI(I))
      SPHI(I)=SIN(PHI(I))
      HA(I)=(SKEW(I))*(CPHI(I)/(RAD1*XU(I)))
      YU1(I)=XU(I)*COS(HA(I))
      HA1(I)=C(I)/2.
210  IF(SKEW(I).EQ.HA1(I)) XU1(I)=XU(I)
      GO TO 59
56  DO 57 I=1,10
      P(I)=PE(I)
57  B(I)=BE(I)
58  F1=F1/60.0
      DO 69 I=1,7
      I1=I
      IF(I5-2)62,63,63
62  X0=XU1(I)
      GO TO 64
63  X0=XU(I)
64  I3=0
      DO 68 I2=I1,10
      I3=I3+1
      IF(I5-2)65,66,66
65  X4(I3)=(XU1(I2)-X0)
      XE(I3)=XU(I2)
      GO TO 67
66  X4(I3)=(XU(I2)-X0)

```

```

        XE(I3)=XU(I2)
67  T1(I3)=X4(I3)*AE(I2)
68  Q1(I3)=X4(I3)*B(I2)
        T(I)=SIMPUN(XE,T1,I3)
        Q(I)=SIMPUN(XE,Q1,I3)
        T(I)=T(I)*FF1
69  Q(I)=Q(I)*FF1
C
C  LOOP WHICH APPROXIMATES STRESS DUE TO TORSION RESULTING
C  FROM SKEW
C  XT(I) = LIFT FORCE , XMT(I) = MOMENT DUE TO LIFT.
C
        DO 111 I=1,7
        IF(I5-2) 820,830,830
820  XMT(I)=0.00
        XK=1.9905*(DIAM/2.0)**2.*VS**2.*PI/(2.0**77)
        XA=C(I)/2.0
        XB=TX(I)/2.0
        DO 222 J=I,9
        XL(J)=ABS(SKEW(J)-.45*C(J))
        XL(J)=XL(J)-ABS(SKEW(I)-.5*C(I))
        XT(J)=AE(J)*.1*XK/(COS(PHI(J)+E(J)))
        XM(J)=XT(J)*XL(J)
        XMT(I)=XMT(I)+XM(J)
222  CONTINUE
        STM(I)=XMT(I)*2.0/(PI*XA*XB**2.0)
        STLT(I)=XMT(I)*2.0/(PI*XB*XA**2.0)
        GO TO 840
830  STM(I)=0.00
        STLT(I)=0.00
840  CONTINUE
111  CONTINUE
550  FORMAT(1H0,29X,1HX,10X,4HTAUM,12X,5HTAULF,10Y,7HM SUB T)
500  FORMAT(1H,20X,4F19.6)
600  FORMAT(1H1,50X,32HSHEARING STRESSES DUE TO TORSION)
C
C
C  LOOP WHICH CALCULATES VOL. OF SECTIONS.
        VOLTOT=0.0
        DO 241 I=1,6
        VOL(I)=A(I)*(XU(I+1)-XU(I))*DIAM/288.
241  VOLTOT=VOLTOT+VOL(I)
        VOL(7)=A(7)*(1-XU(7))*DIAM/576.
243  VOLTOT=VOLTOT+VOL(7)
C  LOOP WHICH CALCULATES CENTRIFUGAL FORCE AND STRESS.
        IF(I5-2) 244,246,246
244  DO 245 I=1,6
245  A1(I)=XU1(I)+((XU1(I+1)-XU1(I))/2.0)
        A1(7)=XU1(7)+((XU1(10)-XU1(7))/2.0)
        GO TO 248
246  DO 247 I=1,6
247  A1(I)=XU(I)+((XU(I+1)-XU(I))/2.0)
        A1(7)=XU(7)+((XU(10)-XU(7))/2.0)
C  LOOP TO TRANSFER CONSTANTS FOR DETERMINING X2PAR.
248  DO 236 I=1,7
        X2BAR(I) = 0.0
236  A2(I) = A1(I) * VOL(I)

```

```

C LOOP TO CALCULATE RADIAL CENTROID ( X2BAR ).
DO 251 I=1,7
  X2BAR(I) = ( (A2(1)+A2(2)+A2(3)+A2(4)+A2(5)+A2(6)+A2(7)) / VOLTOT )
  X * (DIAM/2.0)
  A2(I) = 0.0
C UNCORRECTED FORCE AND STRESS FOR OUTPUT OF ANSWERS WITHOUT THE EFFECT
C RAKE AND SKEW TAKEN INTO CONSIDERATION.
264 CENT4(I) = DEN*4.0*PI**2*VEL**2*VOLTOT*X2BAR(I)/(3600.0*GRAV)
  CENTST(I) = CENT4(I) / A(I)
251 VOLTOT = VOLTOT - VOL(I)
C LOOKING AT THE EFFECTS OF RAKE AND SKEW IN THE PROPELLER.
DO 263 I=1,10
  AA(I)=PI*XU(I)
263 BB(I) = SQRT(AA(I)**2+P(I)**2)
DO 267 I=1,7
  TSKEW1(I) = (C(I)/2.0 - SKEW(I)) * AA(I)/BB(I)
  KK = 1
146 IF(X2BAR(I)-XU(KK) *DIAM/2.0) 149,149,151
151 KK= KK+1
  IF(KK-10)146,149,149
149 TSKEW2(I) = (C(KK)/2.0 - SKEW(KK)) * AA(KK)/BB(KK)
  ALPHA(I)=ATAN(TSKEW2(I)/(X2BAR(I) * 12.0) )
  CENT42(I) = CENT4(I)*COS(ALPHA(I))
  CENTMS(I) = CENT42(I)*(TSKEW2(I) - TSKEW1(I))
  CENTS2(I) = CENT42(I) / A(I)
  ASKEW1(I)=(TSKEW1(I)*P(I)/AA(I)) + RAK(I)
  ASKEW2(I)=(TSKEW2(I)*P(I)/AA(I)) + RAK(KK)
77 CONTINUE
267 CENTM0(I) = CENT42(I) * ( ASKEW2(I) - ASKEW1(I) )
DO 281 I=1,7
  Q(I) = ((T(I)+CENTM0(I))*AA(I)+(Q(I)-CENTMS(I))*P(I))/BB(I)
  F(I)=((T(I)+CENTM0(I))*P(I)-(Q(I)-CENTMS(I))*AA(I))/BB(I)
  D2(I)=(T(I)*AA(I)+Q(I)*P(I)) / BB(I)
281 E2(I)=(T(I)*P(I)-Q(I)*AA(I)) / BB(I)
C PROGRAM CONTINUES.
DO 350 I=1,7
  K=1
  S(1)=0
  Z(K)=U(7)
  F2=FMX(I)+.4962*TX(I)-Y(I)
DO 300 L=1,K
  B(L)=((C(I)*Z(L)-X(I))*E(I))/H(I)+F2*D(I)/G(I)+CENTS2(I)
  B2(L)=((C(I)*Z(L)-X(I))*E2(I))/H(I)+F2*D2(I)/G(I)+CENTST(I)
  V2(L) = ABS(B2(L))
300 V(L)=ABS(B(L))
  F3=V(1)
  F4 = V2(1)
  F(I)=B(1)
  F5(I) = B2(1)
DO 320 L=1,K
  F(I)=V(L)
320 F5(I)=V2(L)
  F5(I) = 0.0
340 P(I)=-X(I)*E(I)/H(I)-(C(I)*S(1)-Y(I))*D(I)/G(I)+CENTS2(I)
  P2(I)=-X(I)*E2(I)/H(I)-(C(I)*S(1)-Y(I))*D2(I)/G(I)+CENTST(I)
  O2(I)=(C(I)-X(I))*E2(I)/H(I)-(-Y(I))*D2(I)/G(I)+CENTST(I)
350 O(I)=(C(I)-X(I))*E(I)/H(I)-(-Y(I))*D(I)/G(I)+CENTS2(I)

```

```

DO 100 I=1,7
AREA(I)=A(I)
XBAR(I)=X(I)
AYEXO(I)=G(I)
EMXO(I)=O(I)
AYEYC(I)=H(I)
FMYO(I)=E(I)
STRMAX(I)=AZZ(I,11)
EMTR(I)=T(I)
100 EMQB(I)=Q(I)
IF(I5-2) 351,352,352
351 CONTINUE
CALL PRNSTR (F,P,O,STM,STLT,AZ7)
..... PRINT OUTPUT .....
C
GO TO 360
352 DUMMY=DUMMY
NN = NN+1
360 NN=NN+1
RETURN
END

```

```

SUBROUTINE PRNSTR (XX,YY,ZZ,S1,S2,AZZ)
  DIMENSION AZZ(11,38)
  DIMENSION XX(10),YY(10),ZZ(10),S1(10),S2(10)

C
C
C
C
  CALCULATION OF PRINCIPLE STRESSES
  DUE TO TORSION AND BENDING.

  DIMENSION XI2(10),XI3(10)
  DO 333 K=1,7
    XI2(K)=-S1(K)*S1(K)
    XI3(K)=-S2(K)*S2(K)
333 CONTINUE
    XXX=C.1
    DO 444 L=1,7
      XXX=XXX+0.1
      DO 555 M=1,3
        IF (M-2)/2,22,33
92      XI1=XX(L)
        DD=(ABS(XI1))**.2
        XD=DD-4.*XI2(L)
        CC=(ABS(XD))**.5
        GO TO 44
92      XI1=YY(L)
        GO TO 66
93      XI1=ZZ(L)
66      DD=(ABS(XI1))**.2
        XD=DD-4.*XI3(L)
        CC=(ABS(XD))**.5
44      SIGMA1=(XI1+CC)/2.0
        SIGMA2=(XI1-CC)/2.0
        AZZ(L,M)=XXX
        AZZ(L,M+10)=SIGMA1
555      AZZ(L,M+20)=SIGMA2
444 CONTINUE
70J  FORMAT(1H,20X,F12.2,6X,2E20.6)
95J  FORMAT(1HC,33X,1HX,12X,6HSIGMA1,10X,6HSIGMA2)
960  FORMAT(1H0,2X,99HSTRESSES AT EACH X STATION ARE GIVEN IN THE FOLLO
      XWING ORDER* MIDCHORD, LEADING EDGE, TRAILING EDGE. )
      RETURN
      END

```

```

FUNCTION SIMPUN(X,Y,N)
C  FORTRAN IV FUNCTION FOR SIMPSONS RULE INTEGRATION
C  ARBITRARY NO. AND LENGTH INTERVALS K.HEALS NSRDC CODE 842 10-5-67
  DIMENSION X(2),Y(2)
  IF(N-2) 7, 5,4
5  S=(Y(1)+Y(2))*(X(2)-X(1))/2.
  GO TO 6
  4  M=N-1
  8  IF(M-2) 9,10,11
11  M=M-2
  GO TO 8
  9  S=(X(2)-X(1))/6.*(Y(1)*(3.-(X(2)-X(1))/(X(3)-X(1)))+Y(2)*(3.+(X(2)
  1-X(1))/(X(3)-X(2)))-Y(3)*((X(2)-X(1))*2)/((X(3)-X(1))*(X(3)-X(2)
  2))))
  L=3
  GO TO 12
10  S=0.
  L=2
12  M=N-1
  DO 1 K=L,M,2
  IF(ABS(X(K-1)-X(1)).GE.ABS(X(K)-X(1))) GO TO 3
  IF(ABS(X(K+1)-X(1)).GT.ABS(X(K)-X(1))) GO TO 1
  3  WRITE(6,2) K,X(K-1),Y(K-1),X(K),Y(K),N
  2  FORMAT(* NON MONOTONE X(SIMPUN)*,I4,2X,1P2E12.4,5X,2E12.4,5X,I4)
7  S=0.
  GO TO 6
  1  S=S+(X(K+1)-X(K-1))/6.*(Y(K-1)*(3.-(X(K+1)-X(K-1))/(X(K)-X(K-1)))+
  1(Y(K)*(1.+(X(K+1)-X(K-1))/(X(K)-X(K-1)))+(X(K)-X(K-1))/(X(K+1)-X(K)
  1)))+(Y(K+1)*(2.-(X(K)-X(K-1))/(X(K+1)-X(K))))))
  6  SIMPUN=S
  RETURN
  END

```

SUBROUTINE WEIGHT(JC,SIGMA7,HUB,PMHC,WEIGHT3,WFIGHTH,RAK)

C WEIGHT COMPUTES THE WEIGHT AND CENTER OF GRAVITY. THE VALUES F
C CHORD, THICKNS, CAMBER, PITCH AND SKEW COME FROM GMAIN. DIAM,
C DEN, RAKE AND PI ARE SET IN STRESS. OTHER VALUES ARE COMPUTED
C MAKING CERTAIN ASSUMPTIONS.
C THE ARRAY RAK USED FOR RAKE COME FROM GMAIN

DIMENSION P(13),BT(11),RAK(11)
COMMON /UNITS/ SI,UI,UO
COMMON/CWEIGHT/X,CHORD,THICKNS,CAMBER,PITCH,SKEWP,DIAM,Z7,DEN,PAKE
1,PI,CTS,CPS,EP,PC,WAKE,VS,RPS,SIGMA,EAR ,BT,P,PJO
2 ,FWDIAM,AFTDIAM,HUBLEN,FDBORE,ADBORE,DISREFL
DIMENSION CHORD(11),THICKNS(11),CAMBER(11),PITCH(11),SKEWP(11)
1,X(11)
DIMENSION DISTHF(38),A(38)
DIMENSION R(9),PMT(9)
DATA CNSTNT1,CNSTNT2,CNSTNT3/.3635,.AC71,.C239/
DATA THR1,THR2,THR3,THR4 /6H CYLIN,6HNDICAL,6H DESI,6HGNATED/
DATA UFE,UFS / 5H(LBF) ,5H(N) /
DATA UEI,UEF,USL /4H(IN) ,4H(FT) , 4H(M) /

C *****VALUES COMPUTED AND DATA OUTPUT*****
C THE HUB DIAMETER IS ASSUMED TO BE THE DIAMETER TO THE FIRST RAD
C RATIO TO BE CONSIDERED AND THE HUB ASSUMED TO BE CYLINDRICAL.
C THE HUB LENGTH IS ASSUMED TO EQUAL THE HUB DIAMETER AND THE DIS
C THE REFERENCE LINE FROM THE HUB FACE IS TAKEN AS HALF THE HUB L
C INPUT DATA AND ASSUMED DATA WRITTEN OUT.

CGR(X,Y,H)=H*(X*X+2*X*Y+3*Y*Y)/(X*X+X*Y+Y*Y)/4.
VOL(X,Y,H)=H*(X*X+X*Y+Y*Y)/3.
PMF(X,Y)=X*X*X*X+X*X*X*Y+X*X*Y*Y+X*Y*Y*Y+Y*Y*Y*Y
ATH=THR1
BTH=THR2
IF(HUB.NE.0.) ATH=THR3
IF(HUB.NE.0.) BTH=THR4
HUBDIAM=X(1)*DIAM
IF(HUB.NE.0.) GO TO 50
DISREFL=HUBDIAM/2.
HUBLEN=HUBDIAM
CENGRVH=HUBLEN/2.
GO TO 270
50 FWD RAD=FWDIAM/2.0
AFT RAD=AFTDIAM/2.0
HUB RAD=HUBDIAM/2.0
FRBORE=FDBORE/2.
ARBORE=ADBORE/2.

C *****WEIGHT CALCULATION*****

270 DO 10 I=1,JC
10 A(I)=CHORD(I)*THICKNS(I)
C WEIGHT OF THE BLADES
RSA1=SIMPUN(X,A,JC)
WEIGHTB=CNSTNT1*DIAM*DEN*Z7*RSA1
C WEIGHT OF THE HUB
IF(HUB.EQ.0.) GO TO 200
201 HUBORE=ARBORE+DISREFL*(FRBORE-ARBORE)/HUBLEN

```

WS1=PI*DEN*VOL(AFTRAD,HUBRAD,DISREFL)
WB1=PI*DEN*VOL(ARBORE,HRBORE,DISREFL)
WFR1=WS1-WB1
IF(HRBORE.EQ.ARBORE) HRBORE=ARBORE+.00000001
AFM=WS1*CGR(AFTRAD,HUBRAD,DISREFL)-WB1*CGR(ARBORE,HRBORE,DISREFL)
DS=HUBLEN-DISREFL
WS2=PI*DEN*VOL(HUBRAD,FWD RAD,DS)
WB2=PI*DEN*VOL(HRBORE,FRBORE,DS)
WFR2=WS2-WB2
FWM=DISREFL*WFR2+WS2*CGR(HUBRAD,FWD RAD,DS)
IF(FRBORE.EQ.HRBORE) FRBORE=HRBORE+.00000001
FWM=FWM-WB2*CGR(HRBORE,FRBORE,DS)
WEIGHTH=WFR1+WFR2
CENGRVH=(AFM+FWM)/WEIGHTH
GO TO 202
200 WEIGHTH=PI*HUBDIAM**2*HUBLEN*DEN/4.
202 CONTINUE
C      WEIGHT OF THE PROPELLER
WEIGHTP=WEIGHTB+WEIGHTH

C      ***CENTER OF GRAVITY CALCULATION***
DO 20 I=1,JC
20 DISTHF(I)=CNSTNT2*CAMBER(I)*COS(PITCH(I))+CNSTNT3*CHORD(I)
1*SIN(PITCH(I))+DISREFL

C      THE EFFECT OF RAKE AND SKEW ARE ADDED TO THE DISTANCE OF THE CE
C      GRAVITY FROM THE HUB FACE FOR EACH SECTION.
DO 30 I=1,JC
DISTHF(I)=DISTHF(I)-SKEWR(I)*X(I)/2.*DIAM*TAN(PITCH(I))-PAK(I)/12.
30 A(I)=CHORD(I)*THICKNS(I)*DISTHF(I)
BSA2=SIMPUN(X,A,JC)
CENGRV3=BSA2/BSA1
CENGRVB=DISREFL-CENGRV3
C      CENTER OF GRAVITY CONSIDERING RAKE AND SKEW
CENGRV1=(WEIGHTB*CENGRV3+WEIGHTH*CENGRVH)/WEIGHTP
CENGRVF=DISREFL-CENGRV1

IF(HUB.EQ.0.) GO TO 250
CP=PI*DEN*14.4
PMA=DISREFL*PMFR(HUBRAD,AFTPA)
PMF=DS*PMFR(FWD RAD,HUBRAD)
PMB=HUBLEN*PMFR(FRBORE,ARBORE)
PMHC=CP*(PMA+PMF-PMB)
GO TO 251
250 PMHC=WEIGHTH*HUBRAD**2*72
251 CONTINUE
C      ***RESULTS OUTPUT***
SLF=.3048
UB=WEIGHTB
UP=WEIGHTP
CFL=CENGRVF/DIAM
COL=CENGRVB/DIAM
BA=HUBLEN/DIAM
BB=FWD DIAM/DIAM
BC=AFT DIAM/DIAM
BD=DISREFL/DIAM
BE=HUBDIAM/DIAM

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BF=FORORE/DIAM
BG=ADRORE/DIAM
SW=UFE
IF(UO,NE,SI) GO TO 531
SW=UFS
UP=UB*4.448222
UF=UP*4.448222
531 PRINT 104,SW,UB,ATH,BTH,SW,UP, CFL, CRL
IF(HUP.EQ.0.) GO TO 55
PRINT 106, BA,BB,BC,BD,BE,BF,BG
GO TO 53
55 CONTINUE
PRINT 110, BE,BA,BD
53 CONTINUE

```

C MINIMUM EXPANDED AREA PATIO CALCULATTONS

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AJS=VS/(RPS*DIAM)
AJA=WAKE*AJS
AKT=PI*CTS*AJS**2/8.
AKO=CPS*AJS**3/16.
EARMIN=(2.6+G.6*ZZ)*AKT/(SIGMA7*(AJA**2+(.7*PI)**2))+.15
PRINT 105,EARMIN,AJS,AJA,AKT,AKO, PC

104 FORMAT( //20X,*WEIGHT OF BLADES* ,A5,*=*,F15.4//20X,*WEIGHT OF P
1ROP (BLADES +*2A6,* HUB)* ,A5,*=*,F15.4//20X,*CENTER OF GRA
2VITY OF PROP REFERENCED FROM MIDCHORD OF ROOT SECTION (- FWD, + AF
3T)/D=* ,F9.6//20X,*CENTER OF GRAVITY OF BLADES REFERENCED FROM
4 MIDCHORD OF ROOT SECTION (- FWD, + AFT)/D=* ,F9.6)
105 FORMAT(/20X,*KELLERS MINIMUM EAR=* ,E10.4
1//20X,*SPEED COEFF V/(ND) JS=* ,E10.4//20X,*ADVANCE COEFF V(
21-WT)/(ND) JA=* ,E10.4//20X,*DESIGN THOUST COEFF KT=* ,F
310.4//20X,*TORQUE COEFF KQ=* ,E10.4//
4 20X,*PROPULSIVE EFFICIENCY ETA=* ,E11.4)
110 FORMAT(/20X,*HUB DIMENSIONS/D* ,8X ,* HUB DIAM =*F9.4/47X,*HUB L
1NGTH =* ,F9.4/47X,*MIDCHORD OF ROOT SECTION TO AFT END OF HUB =* ,F
29.4)
100 FORMAT(6F8.4)
107 FORMAT( //20X,*WEIGHT OF BLADES* ,A5,*=*, F15.4//20X,*WEIGHT OF P
1ROP (BLADES + TAPERED HUB)* ,A5,*=*,F15.4 //20X,*CENTER OF GRA
2VITY OF PROP REFERENCED FROM MIDCHORD OF ROOT SECTION (- FWD, + AF
3T)/D=* ,F9.4//20X,*CENTER OF GRAVITY OF BLADES REFERENCED FROM
4 MIDCHORD OF ROOT SECTION (- FWD, + AFT)/D=* ,F9.4)
109 FORMAT(/20X,*HUB DIMENSIONS/D* ,11X,*LENGTH=* ,F9.4/47X,*FWD DIA
1M=* ,F9.4/47X,*AFT DIAM=* ,F9.4/47X,*MIDCHORD OF ROOT SECTION TO AFT
2 END OF HUB=* ,F9.4/47X,*HUB DIAM AT MIDCHORD OF ROOT SECTION=* ,F9.
34/47X,*FWD DIAM OF BORE=* ,F9.4/47X,*AFT DIAM OF BORE=* ,F9.4)
RETURN
END

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