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Propeller Performance and Weight Predictions Appended to the Navy/NASA Engine Program

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PROPELLER PERFORMANCE AND WEIGHT PREDICTIONS

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SUMMARY

The Navy/NASA Engine Program (NNEP) is a general purpose computer program currently employed by government, industry and university personnel to simulate the thermodynamic cycles of turbine engines. NNEP is a modular program which has the ability to evaluate the performance of an arbitrary engine configuration defined by the user.

In 1979, a program to calculate engine weight (WATE-2) was developed by Boeing's Military Division under NASA contract. This program uses a preliminary design approach to determine engine weights and dimensions. Because the thermodynamic and configuration information required by the weight code was available in NNEP, the weight code was appended to NNEP.

Due to increased emphasis on fuel economy, a renewed interest has developed in propellers. This report describes the modifications developed by NASA to both NNEP and WATE-2 to determine the performance, weight and dimensions of propellers and the corresponding gearbox. The propeller performance model has three options, two of which are based on propeller map interpolation. Propeller and gearbox weights are obtained from empirical equations which may easily be modified by the user.

INTRODUCTION

Due to the tremendous cost of turbine engine hardware, the ability to analytically study the feasibility of advanced engine concepts is essential. One tool used to model the thermodynamic cycles of turbine engines is the Navy/NASA Engine Program (NNEP). NNEP has the ability to model arbitrary turbine cycles defined by the user. For design point calculations, the user inputs the engine configuration, component performance and optimization information. For off-design calculations, component performance is determined using component maps. User-defined free variables are iterated to match component gas flows, rotational speeds, and power. For a further discussion of NNEP the user is referred to reference 1.

In 1979, under NASA sponsorship, Boeing developed a computer program called WATE-2 that predicts weights of turbine engines (ref. 2). This program uses a preliminary design approach in which components are sized using geometric and physical constraints along with thermodynamic cycle data. A logical source of this thermodynamic information is NNEP. Therefore, WATE-2 was written to be an integral part of NNEP but can be adapted to any thermodynamic cycle code.

Renewed interest in propellers has grown rapidly due to high fuel prices. While NNEP is a very versatile program, its ability to model propellers is quite limited. The purpose of this paper is to describe modifications made to both NNEP and WATE-2 to determine propeller performance and weight. Three options of modeling propeller performance with varying degrees of sophistication are available. The first option is simply a constant efficiency input. The second option interpolates from a generalized propeller map which is scaled for various integrated design lift coefficients, number of blades, activity factors and power coefficients. The third option interpolates from a user-supplied propeller performance map.

Propeller weight and gearbox weight and dimensions are obtained from empirical relationships. These relationships are defaulted into WATE-2. The user may input his own empirical relations. The method is described later in the section on weight and dimension analysis. In the following discussions it is assumed that the reader has a basic understanding of NNEP and WATE-2.

SYMBOLS

AF	Blade activity factor	ORIGINAL PAGE IS OF POOR QUALITY
B	Number of blades	
Cp	Power coefficient = $\frac{550 \text{ SHP}}{\rho n^3 D^5}$	
Ct	Thrust coefficient = $\frac{T}{\rho n^2 D^4}$	
Cw	Weight of propeller counterweights, lb	
D	Propeller diameter, ft	
GR	Gear ratio = propeller speed/engine speed	
J	Propeller advance ratio = V/nD	
M	Airplane Mach number	
N	Propeller speed, rpm	
n	Propeller speed, rps	
PL	Power loading, SHP/D^2	
SHP	Shaft horsepower	
T	Propeller thrust, lb	
TS	Propeller tip speed, ft/sec	
V	Flight velocity - true airspeed, ft/sec	
Wt	Component weight, lb	
η	Propeller efficiency, $J(Ct/Cp)$	
ρ	Mass density of air, slug/ft ³	

PROPELLER PERFORMANCE

The first option of propeller performance modeling uses a fixed propeller efficiency. The efficiency may be input as a different value from case to case but it is not dependent on propeller operating conditions. Propeller thrust is then simply calculated from

$$T = 550 \times \text{SHP} \times \eta / V$$

where η is the input propeller efficiency and V is the forward velocity in ft/sec.

For the static case this equation is indeterminate. Therefore, the thrust is calculated from the input static thrust-to-horsepower ratio.

$$T = (\text{thrust/SHP})_{\text{static}} \times \text{SHP}$$

Thus, only the shaft power, the efficiency, and static thrust-to-horsepower ratio are required for this option. However, if the component weight is desired the propeller tip speed, power loading, number of blades, and activity factor are also required.

The second option utilizes a generalized propeller map. This procedure was developed by Hamilton Standard under NASA contract (ref. 3). The advance ratio J and power coefficient C_p are first determined from the following equations:

$$J = \frac{\pi V}{TS}$$

$$C_p = \frac{550 \text{ SHP}}{\rho n^3 D^5}$$

where

$$D = \sqrt{\text{SHP/DL}}$$

$$n = \frac{TS}{\pi D}$$

These values of C_p and J are used in a generalized map defined for the specified number of blades to obtain a thrust coefficient C_t . The generalized maps have a base activity factor of 150 and a base integrated design lift coefficient of 0.5. Thus, the value of C_t is then modified through the use of adjustment factors to account for the effects of integrated design lift coefficient and activity factor. Finally, the propeller efficiency and thrust are determined by

$$\eta = J \left(\frac{C_t}{C_p} \right)$$

$$T = C_t \rho n^2 D^4$$

For this option it is necessary for the user to know shaft horsepower, propeller power loading, number of blades, integrated design lift coefficient, blade activity factor, and design tip speed.

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The generalized maps were developed to be capable of predicting performance for propellers with 2 to 8 blades, 80 to 200 blade activity factors, and 0.3 to 0.8 integrated design lift coefficients. It should be noted that the original study only covered general aviation powerplants in the size range of 100 to 1500 shaft horsepower. The validity of performance predictions of propellers used for powerplants outside this size range is unknown.

The third option allows the user to input his own propeller map. Propeller maps are input with C_t as a function of C_p and J . The format of the map and a typical map are listed in appendix A. The format is the standard format required for all NNEP maps. The method of analysis is essentially the same for option 3 as it was for option 2. Advance ratio and power coefficient are first determined. These values are then used to obtain C_t from the input map. However, the value of C_t is not corrected for activity factor, number of blades, and integrated lift coefficient since these values are assumed implicitly fixed for a given map. Therefore, inputting these values has no effect on the performance calculated using option 3. The propeller efficiency and thrust are then obtained the same as in option 2.

In both option 2 and option 3 the user has two inputs available which allow the results predicted by the maps to be scaled. One input allows the user to apply a constant scale factor to all thrusts and efficiencies predicted by the maps. The other input allows the user to input a desired design point propeller efficiency. The program then sets up a scale factor which is the ratio of the desired design point efficiency to the map calculated efficiency. This scale factor is then applied to the map predicted performance in subsequent off-design cases. If both of these inputs are specified the constant scale factor overrides the desired design point efficiency.

A list of the user-required inputs for each of the three options is given in table I. A more complete description of all the inputs is given in the User Manual (appendix B).

While using any of the above options the user may desire a specified thrust from the engine. This may be obtained by the use of NNEP controls. To obtain the desired thrust for the design case the user may vary the inlet airflow or the design turbine inlet temperature. For the off-design case the user may vary the turbine inlet temperature to obtain the desired thrust.

PERFORMANCE PROGRAM STRUCTURE

Propeller performance calculations are controlled by a subroutine called NNPROP. NNPROP is called from subroutine FLOCAL after the engine matching is complete. A copy of subroutine NNPROP is given in appendix C.

When a constant efficiency is input (option 1) all propeller performance calculations are performed within NNPROP. Note that for this option NNPROP uses the same three inputs that were originally required by NNEP to run a propeller. Therefore, any data sets which were previously used on NNEP should run with this new version without change.

When the generalized maps are used (option 2) NNPROP makes a call to subroutine PERFM. This subroutine contains the generalized maps and the correction for integrated lift coefficient, number of blades, and activity factor.

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The interpolation of the maps is done by two utility subroutines, BIQUAD and UNINT. A copy and a detailed description of these three subroutines are given in reference 4.

For user-supplied maps (option 3), NNPROP calls the NNEP subroutine TLOOK to do the map interpolations.

WEIGHT AND DIMENSION ANALYSIS

WATE-2 was originally constructed to give weights and dimensions of components based on a preliminary design analysis. The routine to determine propeller and gearbox weight and dimensions, however, is based entirely on empirical data.

Generalized propeller weight equations were obtained from Hamilton Standard, reference 5. One equation defines the weight of double-acting propellers as follows:

$$Wt_{PROP} = K_w \left[\left(\frac{D}{10} \right)^2 \left(\frac{B}{4} \right)^{0.7} \left(\frac{AF}{100} \right)^{0.75} \left(\frac{ND}{20\ 000} \right)^{0.5} (M+1)^{0.5} \left(\frac{SHP}{10\ D^2} \right)^{0.12} \right], \text{ lb}$$

where $K_w = 355$.

A second set of equations predicts the weight for single acting propellers with counterweights:

$$Wt_{PROP} = K_w \left[\left(\frac{D}{10} \right)^2 \left(\frac{B}{4} \right)^{0.7} \left(\frac{AF}{100} \right)^{0.7} \left(\frac{ND}{20\ 000} \right)^{0.4} (M+1)^{0.5} \left(\frac{SHP}{10\ D^2} \right)^{0.12} \right] + C_w, \text{ lb}$$

where $K_w = 220$ and

$$C_w = 5 \left[\left(\frac{D}{10} \right)^2 B \left(\frac{AF}{100} \right)^2 \left(\frac{20\ 000}{ND} \right)^{0.3} \right]$$

To provide full flexibility, the propeller weight equation may be defaulted at the above values or the constant K_w and the parameter exponents may be input by the user. However, if the user desires to change any part of the equation, the constant and all the exponents must be input. It is also possible to input a constant value for the counterweights C_w , if desired.

The value of K_w is defaulted at 355 for double-acting propellers and at 220 for single-acting counterweighted propellers. These values imply current technology propellers using solid aluminum blades. The value of 355 represents a higher speed application normally associated with double-acting propellers, than the 220 value. Values of K_w ranging between 160 to 180 may be assumed for advanced technology fiberglass or composite propellers. Other parameters required for the propeller weight equation, such as shaft horsepower, propeller rpm, etc., are obtained from maximum power conditions encountered in NNEP.

There is also a provision for calculating gearbox weight. Figure 1 represents a defaulted curve used to estimate the gearbox weight as a function of output torque for a gear ratio of 0.118. For other gear ratios

$$Wt_{GB} = (Wt_{GB})_{unscaled} \left(\frac{.118}{GR} \right)^{0.5}$$

The user may specify a different equation for weight as a function of torque by inputting the slope and y intercept. This curve must be input at a gear ratio of 0.118.

Dimensions of the gearbox can also be calculated if desired. Defaulted values of these equations are

$$\text{Length} = 0.125 (\text{SHP})^{0.5} (1/GR)^{0.33}, \text{ in.}$$

$$\text{Diameter} = 0.230 (\text{SHP})^{0.5} (1/GR)^{0.33}, \text{ in.}$$

These equations are based on empirical data for in-line gearboxes in the 1000 to 2500 horsepower range. All of the above equations may be modified by the user (see appendix B, User Manual). No provision is currently available for offset gearbox dimensions.

WEIGHT PROGRAM STRUCTURE

The control routine for WATE-2 is called WTEST. WTEST calls a subroutine (PROPWT) which performs the weight and dimension calculations. Copies of both routines are given in appendix C. Changes to the original WTEST are denoted by comment cards.

CONCLUSION

As interest increases in propeller research, analytical tools which accurately model both engine and propeller performance will be required. The modifications described herein to NNEP and WATE-2 provide such models. The program has been kept general enough to permit the user to update models as more detailed information becomes available. The weight and dimension calculations, however, should be used with the understanding that the results are only rough estimates. It is suggested that the user examine these equations and make changes as required.

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APPENDIX A

PROPELLER MAP INPUTS

Each propeller map has the following input data card setup.

- Card 1 Table reference number (Integer, col 2-5) Table identification label, Col 6-75
- Card 2 Z-Identifier (4 Character Symbol, col 1-4). Enter any dummy symbol because Z values are not used.
NZ-Number of Z values (Integer, col 6 & 7). Must enter a value of 1.
Z-Variable values, 7F10., Beginning in Column 11. Must enter a value of 0.
- Card 3 Advance ratio identifier (4 Character Symbol, col. 1-4)
NJ-Number of advance ratio values (Integer, col 6 & 7)
XJ-Advance ratio values, 7F10., Beginning in Column 11. If needed, extra cards follow 10X,7F10. Format.
Advance ratio values MUST be in ascending order.
- Card 4 Power coefficient identifier (4 Character Symbol, col 1-4)
NCP-Number of Cp values (Integer, col 6 & 7)
Cp values, 7F10., Beginning in Column 11. If needed, extra cards follow 10X,7F10. Format.
Cp values MUST be in ascending order.
- Card 5 Thrust coefficient identifier (4 Character Symbol, col 1-4)
NCP-Number of Cp values (Integer, col 6 & 7)
Ct values, 7F10., Beginning in Column 11. If needed, extra cards follow 10X,7F10. Format. These Values correspond to the values on the Cp Identifier Card.

Last Card 3 Character Symbol EOT in col 1-3

The propeller maps must be in the same dataset containing the other maps to be used by NNEP (i.e. turbine maps, compressor maps, etc.)

SAMPLE PROPELLER MAP

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4100	H.S. ADV	PROP	4 BLADE	100 AF	.55 CLI		
Z 1	0.0						
J 16	0.0	0.2	0.4	0.6	0.8	1.0	1.2
	1.4	1.6	1.8	2.0	2.2	2.4	2.6
	2.8	3.0					
CP 10	0.0568	0.0737	0.0926	0.1170	0.1484	0.1866	0.2287
	0.2747	0.3192	0.3558				
CT 10	0.1456	0.1732	0.1965	0.2179	0.2327	0.2456	0.2531
	0.2559	0.2565	0.2541				
CP 10	0.0499	0.0655	0.0841	0.1058	0.1299	0.1614	0.1999
	0.2406	0.2818	0.3200				
CT 10	0.1084	0.1354	0.1626	0.2890	0.2083	0.2300	0.2480
	0.2580	0.2605	0.2600				
CP 11	0.0406	0.0564	0.0769	0.1001	0.1253	0.1547	0.1885
	0.2234	0.2673	0.3840	0.3200			
CT 11	0.0622	0.0931	0.1237	0.1532	0.1812	0.2075	0.2290
	0.2371	0.2470	0.2620	0.2640			
CP 10	0.0369	0.0564	0.0819	0.1110	0.1421	0.1758	0.2133
	0.2561	0.3007	0.3200				
CT 10	0.0362	0.0712	0.1051	0.1376	0.1685	0.1972	0.2229
	0.2439	0.2551	0.2600				
CP 9	0.0482	0.0797	0.1156	0.1541	0.1940	0.2378	0.2850
	0.3347	0.3857					
CT 9	0.0447	0.0828	0.1186	0.1525	0.1844	0.2136	0.2389
	0.2572	0.2649					
CP 10	0.0323	0.0697	0.1141	0.1607	0.2093	0.2597	0.3149
	0.3722	0.4264	0.4821				
CT 10	0.0158	0.0585	0.0985	0.1355	0.1706	0.2025	0.2321
	0.2561	0.2694	0.2696				
CP 8	0.0536	0.1070	0.1639	0.2222	0.2821	0.4117	0.4777
	0.5345						
CT 8	0.0341	0.0785	0.1194	0.1527	0.1930	0.2533	0.2740
	0.2782						
CP 9	0.0337	0.0965	0.1654	0.2346	0.3055	0.3768	0.4542
	0.5307	0.5997					
CT 9	0.0108	0.0600	0.1052	0.1462	0.1850	0.2188	0.2505
	0.2754	0.2893					
CP 9	0.0695	0.1337	0.2011	0.2657	0.3323	0.4006	0.4667
	0.5395	0.6084					
CT 9	0.0339	0.0744	0.1121	0.1466	0.1796	0.2105	0.2364
	0.2624	0.2823					
CP 8	0.0407	0.1134	0.1913	0.2692	0.3464	0.4246	0.5015
	0.5815						
CT 8	0.0094	0.0543	0.0957	0.1338	0.1691	0.2026	0.2318
	0.2588						
CP 6	0.0937	0.1836	0.2749	0.3643	0.4542	0.5855	
CT 6	0.0368	0.0821	0.1238	0.1617	0.1976	0.2308	
CP 6	0.0773	0.1797	0.2853	0.3891	0.4916	0.5951	

CT	6	0.0227	0.0720	0.1170	0.1578	0.1958	0.2312	
CP	7	0.0675	0.1531	0.2433	0.3341	0.4231	0.5103	0.5980
CT	7	0.0130	0.0532	0.0905	0.1254	0.1576	0.1878	0.2167
CP	7	0.0968	0.1794	0.2649	0.3510	0.4361	0.5188	0.6010
CT	7	0.0223	0.0576	0.0904	0.1213	0.1503	0.1773	0.2031
CP	8	0.0759	0.1473	0.2230	0.3005	0.3784	0.4556	0.5312
		0.6046						
CT	8	0.0080	0.0387	0.0674	0.0947	0.1209	0.1457	0.1689
		0.1909						
CP	7	0.0996	0.1810	0.2666	0.3537	0.4410	0.5272	0.6112
CT	7	0.0132	0.0451	0.0754	0.1039	0.1309	0.1565	0.1804
EOT								

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APPENDIX B

USER MANUAL

The first part of this manual describes the inputs required to run propeller performance calculations, while the later part presents the weight code inputs. It is assumed that the user is familiar with NNEP and its method of input. For instructions the reader is directed to "KONFIG/REKONFIG" (ref. 6) which is an interactive input preprocessing program. A sample input data set is given at the end of this Appendix.

The NNEP input string used to read in propeller performance data is the KONFIG statment. All propellers will be read in the following form:

`KONFIG(1,N)='LOAD',SPEC(1,N)= (1),(2),....(10)`

where N is the component number.

INPUT PROPELLER ARRAY

- Spec(1,N) = Shaft horsepower (negative) delivered to the propeller
- Spec(2,N) = One of three options:
- 1) constant efficiency - if a constant efficiency is specified, the value must be $0 < \eta < 1$
 - 2) negative value - any input, negative in sign, will initiate the generalized propeller table interpolation (PERFM).
Example: -.1, -100, etc. Input magnitude has no significance.
 - 3) Table number - table number of user input propeller performance table. This value must be < 1 .
- Note: loads other than propellers may be connected to shafts in NNEP engine configurations; for such loads SPEC(2) must be set to 0.0.
- Spec(3,N) = Propeller thrust divided by shaft horsepower (T/SHP) for static thrust calculations.^a
- Spec(4,N) = Design point power loading, $PL = SHP/D^2$.^b
- Spec(5,N) = Number of blades of the propeller.^c
- Spec(6,N) = Integrated design lift coefficient.^d
- Spec(7,N) = Blade activity factor.^c
- Spec(8,N) = A constant scaling factor which is multiplied by the results taken from the propeller map. This input scales the efficiency, thrust, and coefficient of thrust when using option (2) or option (3) of Spec(2,N). Spec(8,N) will override Spec(9,N) if both are input non-zero.
- Spec(9,N) = Desired propeller design point efficiency. This input also determines a scale factor which will be applied to all subsequent off-design cases.
Spec(8,N) will override Spec(9,N) if both are input non-zero.
- Spec(10,N) = Design tip speed of propeller (ft/sec).^d

^aThis input is only used for option(1) of Spec(2,N)

^bThis input used to get prop diameter and rpm which are required for options (2) and (3) of Spec(2,N) and for propeller weight calculations.

^cThis input only used for option (2) of spec(2,N) and for propeller weight calculations.

^dThis input only used for option (2) of spec(2,N).

OUTPUT PROPELLER ARRAY

Datout(1,N) = Shaft horsepower delivered to the propeller.

Datout(2,N) = Propeller rotational speed (rpm).

Datout(3,N) = Propeller thrust, (lbf).

Datout(4,N) = Advance ratio, J.

Datout(5,N) = Coefficient of power, Cp.

Datout(6,N) = Coefficient of thrust, Ct.

Datout(7,N) = Propeller tip speed, (ft/sec).

Datout(8,N) = Unadjusted propeller efficiency.

Datout(9,N) = Adjusted propeller efficiency,
(using SPEC(8,N) or SPEC(9,N)).

MECHANICAL DESIGN INDICATORS

The mechanical design indicators (IWMEC) are required to determine whether the propeller and gearbox are to be weighed. IWMEC is a two dimensional integer array, and is of the form IWMEC(M,N) where N is the component number of the prop as used in NNEP, and M is the variable identifier as defined below. For a propeller:

IWMEC ARRAY
LOCATION M

DESCRIPTION

- | | |
|---|---|
| 1 | Type of component being weighted.
'PROP' -- indicates propeller. |
| 2 | Indicates whether propeller weight is to be calculated.
0 -- Do not calculate propeller weight.
1 -- Calculate propeller weight. |
| 3 | Indicates presence of counterweights on propeller.
0 -- No counterweights (double acting prop).
1 -- Prop contains counterweights. |
| 4 | Indicates whether gearbox weight is to be calculated.
0 -- Do not calculate gearbox weight.
1 -- Calculate gearbox weight. |
| 5 | Indicates whether gearbox dimensions are to be calculated.
0 -- Do not calculate gearbox dimensions.
1 -- Calculate gearbox dimensions. |
| 6 | Blank |
| 7 | Blank |

Notes on IWMEC Inputs

If IWMEC(2,N) is input as 0, a message is printed informing the user that propeller weight will not be calculated. If input is 1, the exponents of the propeller weight equation are alterable. See DESVAL array discussion.

If IWMEC(4,N) is input as 0, a message is printed informing the user that gearbox weight will not be calculated.

If IWMEC(5,N) is input as 0, a message is printed informing the user that gearbox dimensions will not be calculated. It is assumed that the propeller adds no length to the engine beyond that of the gearbox.

ILENG Array

The ILENG array indicates which components will be included in the length summation. The propeller component number should be included to add the length of the gearbox to the engine.

DESIGN VALUES

This section describes mechanical and aerodynamic design data necessary to determine the weight and dimensions of the propeller. The data required is in the floating-point two-dimensional array DESVAL(M,N), where M is the variable array location identifier. N is the component number of the prop as used in NNEP.

The following equations are used to calculate propeller weight and gearbox weight, length, and diameter:

$$Wt_{PROP} = DESVAL(2) \left[\left(\frac{D}{10} \right)^{DESVAL(10)} \left(\frac{B}{4} \right)^{DESVAL(11)} \left(\frac{AF}{100} \right)^{DESVAL(12)} \left(\frac{ND}{20000} \right)^{DESVAL(13)} (DESVAL(1)+1)^{DESVAL(14)} \left(\frac{SHP}{100^2} \right)^{DESVAL(15)} \right] + Cw \quad (1B)$$

$$Cw = 5 \left[\left(\frac{D}{10} \right)^2 B \left(\frac{AF}{100} \right)^2 \left(\frac{20000}{ND} \right)^{0.3} \right] \quad (2B)$$

or if DESVAL(7) > 0.0

$$Cw = DESVAL(7)$$

$$Wt_{GB} = DESVAL(4) * \left[DESVAL(5) * TORQUE + DESVAL(6) \right] \left(\frac{0.118}{GR} \right)^{DESVAL(17)} \quad (3B)$$

$$LENGTH_{GB} = DESVAL(8) (SHP)^{0.5} (1/GR)^{0.33} \quad (4B)$$

$$DIAMETER_{GB} = DESVAL(9) (SHP)^{0.5} (1/GR)^{0.33} \quad (5B)$$

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The DESVAL variables used in the above equations are described as follows:

DESVAL ARRAY
LOCATION

DESCRIPTION

- (1) Design Mach number of aircraft (see equation 1B). Default input of zero yeilds zero Mach number input.
- (2) Kw - Coefficient of propeller weight equation (see equation (1B)). A multiplier representing the level of propeller technology, described in the body of this report. If Kw is input as non-zero, the exponents of the weight equation (DESVAL(10,N)-(15,N)) must be input. If Kw is defaulted (zero), default values are used.
- (3) Gear ratio (prop rpm/shaft rpm); see equations 3B,4B, and 5B. OR Shaft RPM. The user can choose whether to specify a gear ratio (usually < 1) or an RPM of the shaft delivering power to the prop. This RPM is independent of the RPM calculated by NNEP. If DESVAL(3,N) > 200. The input is assumed to be RPM and the corresponding gear ratio is calculated and stored in DESVAL(3,N). If DESVAL(3,N) < 200. The input is assumed to be the gear ratio.
- (4) Coefficient of gearbox weight equation (see equation 3B). No scaling will occur if 0.0 or 1.0 is input.
- (5-6) Slope and Y-Intercept, respectively, of optional user input gearbox weight curve (see equation 3B). If slope is input a Y-Intercept must also be input. Any input curve must be scaled at 0.118 gear ratio. To use default curve described in the body of the report input 0.0 for both values.
- (7) Input value of counterweight weight (see equation 2B). The default calculation value may be used by inputting DESVAL(7,N)=0.0.
- (8) Scale factor for gearbox length (see equation 4B). No scaling will occur if 0.0 or 1.0 is input.
- (9) Scale factor for gearbox diameter (see equation 5B). No scaling will occur if 0.0 or 1.0 is input.
- (10-15) Exponents of propeller weight equation (see equation 1B). The default values are used if DESVAL(2,N) = 0.0. If DESVAL(2,N) = 0, all of the exponent values must be input.
- (16) Not used.
- (17) Exponent on gear ratio term of gearbox weight equation (see equation 3B).

DESVAL DEFAULT VALUES

DESVAL DEFAULT ARRAY LOCATION	VALUE	ABBREVIATED DESCRIPTION
1	0.0	Design Mach number
2	355.0 (220.0) ^a	Kw--prop weight scalar
3	1.0	Gear ratio
4	1.0	Gearbox weight scalar
5	0.0174	Gearbox weight curve slope
6	45.0	Gearbox weight curve Y-Intercept
7	0.0 (equ. 2B) ^a	Weight of counterweights
8	1.0	Gearbox length scalar
9	1.0	Gearbox diameter scalar
10	2.0	Prop weight equation exponents
11	0.7	
12	0.75 (0.70) ^a	
13	0.5 (0.4) ^a	
14	0.5	
15	0.12	
16	---	Not used
17	0.5	Exponent on gear ratio term in equation 3B.

^aDefaults for propellers with counterweights.

SAMPLE INPUT CASE

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THIS IS A TITLE CARD
&D CALBLD=T,AMAC=F &END
&D MODE=1,IWT=1
KONFIG(1,1)=4HINLT,1,0,2,0,SPEC(1,1)=14.3,0,0,0,.23,0,0,0,5000,
KONFIG(1,2)=4HCOMP,2,0,3,0,SPEC(1,2)=1.278,0,1,3707,1,3708,.982,3709,1,0,0,.87,
5.896,.919,
KONFIG(1,3)=4HCOMP,3,0,4,20,SPEC(1,3)=1.803,.05,1,3404,1,3405,.78,3406,1,0,0,
.864,3.887,0.988,
KONFIG(1,4)=4HDUCT,4,0,5,0,SPEC(1,4)=.05,0,0,2710,.985,18300,
KONFIG(1,5)=4HTURB,5,20,6,0,SPEC(1,5)=3.5,.95,1,3801,1,3802,.8881,1,.85,1,.91,
5665,1,08,1,
KONFIG(1,6)=4HTURB,6,20,7,0,SPEC(1,6)=2.49,.05,1,3803,1,3804,.9154,1,1,1,.9156,
5124,1,000000,3,
KONFIG(1,7)=4HNOZZ,7,0,8,0,SPEC(1,7)=30,1,0,0,.95,3*0,1,
KONFIG(1,8)=4HLOAD,SPEC(1,8)=-2686,.985,3.5,9.6,4,.5,180,1.0115,0.00,900.,
KONFIG(1,9)=4HSHFT,2,3,5,0,SPEC(1,9)=38834,4*1,2*1,.99,
KONFIG(1,10)=4HSHFT,8,11,6,0,SPEC(1,10)=18000,.0611,1,1,1,.97,1,1
KONFIG(1,15)=4HCNTL,SPCNTL(1,15)=1,1,4HSTAP,8,2,0
KONFIG(1,11)=4HLOAD,SPEC(1,11)=-68,
KONFIG(1,16)=4HCNTL,SPCNTL(1,16)=1,2,4HSTAP,8,3,0
KONFIG(1,17)=4HCNTL,SPCNTL(1,17)=1,3,4HSTAP,8,5,0
KONFIG(1,18)=4HCNTL,SPCNTL(1,18)=1,5,4HSTAP,8,6,0
KONFIG(1,19)=4HCNTL,SPCNTL(1,19)=1,6,4HSTAP,8,7,0
KONFIG(1,20)=4HCNTL,SPCNTL(1,20)=1,9,4HDOUT,8,9,0
KONFIG(1,21)=4HCNTL,SPCNTL(1,21)=1,8,4HDOUT,8,10,0
KONFIG(1,22)=4HCNTL,SPCNTL(1,22)=2,3,4HPERF,15,0,0,1
KONFIG(1,23)=4HCNTL,SPCNTL(1,23)=10,2,4HDOUT,5,2,15,0,-5,10,
&END
&D CALBLD=F,SPEC(9,22)=0,SPEC(9,15)=1,SPEC(9,16)=1,SPEC(9,17)=1,SPEC(9,18)=1,
IWT=1,SPEC(5,1)=0,SPEC(9,1)=0,SPEC(4,4)=2760,SPEC(9,19)=1,SPEC(9,20)=1,
SPEC(9,21)=1, &END
&D SPEC(5,1)=0.0,IWT=1, &END
&D SPEC(5,1)=.1,IWT=2, &END
&W ISII=F,ISIO=F,IOUTCD=2,DISKWI=1
ILENG=8,2,3,4,5,6,7,
IWMEC(1,2)='LPC',1,1,0,0,0,3
IWMEC(1,3)='HPC',2,0,1,0,0,1
IWMEC(1,4)='PBUR',1
IWMEC(1,5)='HPT',1,2,0,1,0
IWMEC(1,6)='LPT',1,2,0,3,0
IWMEC(1,7)='NOZZ',1,0,0
IWMEC(1,8)='PROP',1,0,1,1
IWMEC(1,9)='SHFT',2,5,0,0,2
IWMEC(1,10)='SHFT',1,6,0,0,8
DESVAL(1,2)=.55,1.9,0.5,1.5,4.0,3.0,0.45,0.0,0.0,1.0,0.0,1.0,1.0,4*0.0,
DESVAL(1,3)=0.4,1.4,0.7,1.5,3.0,1.5,0.3,0.0,0.0,1.0,0.0,1.0,1.0,4*0.0,
DESVAL(1,4)=150.,0.015,13*0.0

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DESVAL(1,5)=0.3,0.28,1.5,1.5,1.5,0.45,125000.,3.0,1.0,6*0.0
DESVAL(1,6)=0.45,0.28,1.5,2.0,4.0,0.55,125000.,3.0,1.0,6*0.0
DESVAL(1,7)=1.3,14*0.0
DESVAL(1,8)=.23,150.,.1,4*0.0,1.0,1.0,2.0,0.7,0.75,0.5,0.5,0.12,0.,0.
DESVAL(1,9)=50000.,0.286,0.85,2,3,5,11*0.0
DESVAL(1,10)=50000.,0.286,0.85,8,6,12*0.0
&END

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APPENDIX C
PROGRAM LISTING

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C*****
C*****
C
C  SUBROUTINE NNPROP
C  -----
C  PURPOSE:          THIS ROUTINE CALCULATES PROPELLER PERFORMANCE
C                   USING ONE OF THREE OPTIONS
C
C  DATE OPERATIONAL: 08/13/82
C
C  AUTHOR:           R. M. PLENCNER
C
C  DESCRIPTION:      SUBPROGRAM CALCUALTES PROPELLER THRUST FROM
C                   ONE OF THREE OPTIONS:
C                   1) INPUT CONSTANT EFFICIENCY
C                   2) GENERALIZED HAMILTON STANDARD PROPELLER MAP
C                   3) USER SUPPLIED PROPELLER MAP
C*****
C*****
C  SUBROUTINE NNPROP (VKTS,ALT)
C  IMPLICIT REAL*8 (A-H,O-Z)
C  DIMENSION ZMS(2)
C  COMMON /DBL/ DATINP(15,60),DATOUT(9,60),WTF(40),TOPRES(40),TOTEMP(-
C 140),FAR(40),CORFLO(40),VMACH(40),STATP(40),ERROR(40),TOL,TOLT,TOLT-
C 2T,DEPV(20),DTOL(20),PERPF(20),RCH,STOC,TFUEL
C  COMMON /SGL/ JM1,JM2,JP1,JP2,JCX,LOCTBL(9,60),JCOMP(70),IWAY,NIT,-
C 1ITAB(70),JCONF(60,4),JTYPE(60),JFLOW(70),IDEDAP(15),KKINDS(14,25),-
C 2NCOMP,NOSTAT,NITER,NFINIS,NPASS,JCC,NTBL,NCTS,JCIND(20),JCDEP(20),-
C 3JCVIND(20),JCVDEP(20),KDTYP(20),IDONE(60)
C  N11=KKINDS(11,1)
C  DO 2 IK=1,N11
C  JXSHFT=KKINDS(11,IK+1)
C  DO 2 IISHFT=1,4
C  IF(JCX.EQ.JCONF(JXSHFT,IISHFT))GO TO 5

```

2 CONTINUE
5 DATINP(15,JCX) = JXSHFT
PTRPM=DATOUT(2,JXSHFT)
SHP = -DATOUT(1,JCX)
PL = DATINP(4,JCX)
BLADT = DATINP(5,JCX)
CLI = DATINP(6,JCX)
ATF = DATINP(7,JCX)
XFT = DATINP(8,JCX)
ETADES = DATINP(9,JCX)
TSDES = DATINP(10,JCX)
LTAB=0

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C --- THIS IS TO IMPLEMENT THE PERFM SUBROUTINE W/ GENERAL MAPS---
IF(DATINP(2,JCX).LT.0.0)LTAB=-777777.
C --- IF TABLE NO. IS SPECIFIED,SKIP NEXT 4 LINES---
IF(DATINP(2,JCX).LE.0.0.OR.DATINP(2,JCX).GT.1.0)GO TO 633
ETA1=DATINP(2,JCX)
IF(VKTS.EQ.0.0)ETA1=0.0
C --- SET ETA1 EQUAL TO SPECIFIED ETA,CALCULATE THR FOR STATIC CASE ---
IF(VKTS.EQ.0.0)THR=DATINP(3,JCX)*SHP
633 IF(LOCTBL(2,JCX).GT.0) LTAB=LOCTBL(2,JCX)
C --- GO TO 10 TO IMPLEMENT SUB. PERFM ---
IF(LTAB.NE.0.0)GO TO 10
C --- IF DATINP(9) DOES NOT AGREE W/ ETA1,WRITE AN ERROR MESSAGE ---
IF(NIT.LE.1.AND.ETADES.GT.0.0.AND.ETA1.NE.ETADES)WRITE(10,300)JCX
C --- CALCULATE THRUST FOR NON-STATIC CASE ---
IF(VKTS.GT.0.0) THR=550*SHP*ETA1/(VKTS*1.6878)
THR1=THR
IF(VKTS.GT.0.0)ETA=ETA1
IF(PL.EQ.0.0.OR.TSDES.EQ.0.0)GO TO 101
C --- CLACULATIONS BELOW WILL NOT BE REQUIRED FOR SPECIFIED
C ETA OR TABLE LOOK-UP CASES ----
10 CALL ICAO (ALT,TP,PRESS,SSFPS,DNSTY)
DRAT = .002377/DNSTY
IF (IWAY.EQ.1) DIA = DSQRT(SHP/PL)
IF (IWAY.EQ.1) TS=TSDES
IF (IWAY.EQ.1) DESRPM=60.0*TS/(3.14159*DIA)
IF (IWAY.EQ.1) RPMRAT=DESRPM/PTRPM
RPM=RPMRAT*PTRPM
TS = 3.14159*RPM*DIA/60.
IW = 1
CP = SHP*10.E10 * DRAT/(2. * TS**3 * DIA**2 * 6959.26)
ZJI = 101.27 * VKTS/(RPM * DIA)
ZMS(1) = VKTS* 1.6878/SSFPS
20 ZMS(2) = TS/SSFPS
ZZ=0.0
IF(LTAB.LT.0.0) CALL PERFM (IW,CP,ZJI,AFT,BLADT,CLI,CT1,ZMS,LIMIT)
IF(LTAB.GT.0.0) CALL TLOOK (LTAB,CP,ZJI,ZZ,CT1)
IF(LTAB.NE.0.0)THR1 = CT1* TS**2 * DIA**2 * 2.4084E-4/DRAT
IF(LTAB.NE.0.0)ETA1 = ZJI*CT1/CP
IF(NIT.LE.1.AND.ETADES.NE.0.0.AND.ETA1.EQ.0.0) WRITE(10,100)JCX
IF(NIT.LE.1.AND.ETADES.NE.0.0.AND.XFT.NE.0.0.AND.XFT.NE.1.0)-
1WRITE(10,200)JCX
IF(IWAY.NE.1)GO TO 40

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ETAFIX=ETADES
IF(ETADES.EQ.0.0)ETAFIX=ETA1
ETARAT=1.0
IF(ETA1.NE.0.0)ETARAT=ETAFIX/ETA1
IF(XFT.NE.1.0.AND.XFT.NE.0.0)ETARAT=XFT
40 ETA=ETARAT*ETA1
THR = THR1*ETARAT
CT = THR*DRAT/(TS**2 * DIA**2 * 2.4084E-4)
101 DATINP(IISHFT+1,JXSHFT)=RPM/DATOUT(2,JXSHFT)
DATOUT(IISHFT+2,JXSHFT)=RPM
DATINP(3,JCX) = THR/SHF
DATOUT(2,JCX) = RPM
DATOUT(3,JCX) = THR
DATOUT(4,JCX) = ZJI
DATOUT(5,JCX) = CP
DATOUT(6,JCX) = CT
DATOUT(7,JCX) = TS
DATOUT(8,JCX) = ETA1
DATOUT(9,JCX) = ETA
100 FORMAT(' ','*** WARNING *** FOR LOAD#',I2,' DATINP(9) IGNORED-
1 BECAUSE VELOCITY=0 FOR DESIGN CASE')
200 FORMAT(' ','10X','*** WARNING ***'/' BOTH DATINP(8) AND (9) HAVE-
1 BEEN SPECIFIED FOR LOAD #',I2,/' DATINP(8) WILL OVERRIDE DATINP(9)')
300 FORMAT(' ','*** WARNING *** FOR LOAD#',I2,-
1' DATINP(9) NOT = DATINP(2) --| DATINP(2) OVERRIDES ')
RETURN
END
```

C

C*****

C

C SUBROUTINE PROPWT

C -----

C PURPOSE: THIS ROUTINE CALCULATES THE WEIGHT OF A PROPELLER
C AS WELL AS WEIGHT OF AN APPROPRIATE GEARBOX.

C DATE OPERATIONAL: 08/13/82

C AUTHOR: PETER SENTY,NASA SUMMER EMPLOYEE 1982

C DESCRIPTION: SUBPROGRAM UTILIZES GEOMETRICAL DATA FROM
C BOEING "WATE-2" PROGRAM ASWELL AS THERMODYNAMIC
C DATA FROM THE NAVY/NASA ENGINE PROGRAM TO PREDICT
C THE WEIGHT OF A PROPELLER,WEIGHT OF A COMPATIBLE
C GEARBOX AND THE DIMENSIONS OF THAT GEARBOX.

C

C*****

C*****

SUBROUTINE PROPWT(NC)

REAL*8 DATINP,DATOUT,WTF,TOPRES,TOTEMP,FAR,CORFLO,VMACH,STATP,ERRO-

1R,TOL,TOLT,TOLTT,DEPV,DTOL,PERPF,RPMNT,TMTEMP,TMPRES,DATOUN,DATMAC-
 2,DATALT,DESLIM,TNPRES,TNTEMP,CNRFLO,CORFLM,WNTF,DATOUN,FARN,DANINP-
 3,DEBUG,DEPQ,SELAST,DD,TOLOPT

* COMMON BLOCKS *

COMMON /DBL/ DATINP(15,60),DATOUT(9,60),WTF(40),TOPRES(40),TCTEMP(-
 140),FAR(40),CORFLO(40),VMACH(40),STATF(40),ERROR(40),TOL,TOLT,TOLT-
 2T,DEPV(20),DTOL(20),PERPF(20)

COMMON /SNGL/ JM1,JM2,JP1,JP2,JCX,LOCTBL(9,60),JCOMP(70),IWAY,NIT,-
 1ITAB(70),JCONF(60,4),JTYPE(60),JFLOW(70),IDEDAP(15),KKINDS(14,25),-
 2NCOMP,NOSTAT,NITER,NFINIS,NPASS,JCC,NTBL,NCTS,JCIND(20),JCDEP(20),-
 3JCVIND(20),JCVDEP(20),KDTYP(20),IDONE(60)

COMMON /DEFAULT/ DEFAULT(15,20),ISCALE(3),SCALE(6)

COMMON /WMECH/ IWMEC(7,60),WATE(60),ALENG(60),TLENG(40),RI(2,40),R-
 10(2,40),DESVAL(17,60),DSHAF(5),RPMT(60),IWT,IPLT,IERR,ISII,ISIO,IO-
 2UTCD,NSTAG(60)

COMMON /CONVER/ CONVER(15)

COMMON /NEOPT/ DEBUG,DEPQ,SELAST,DD,TOLOPT,NDSET,NPARTS,IOPTP,NPA-

ISSO,NVOPT,NJOPT,NOPT

COMMON /TERMON/ TNPRES(40),TNTEMP(40),CNRFLO(40),WNTF(40),RPMNT(40-
 1),DATOUN(9,60),FARN(40),DANINP(15,60),TMTEMP(40),TMPRES(40),CORFLM-
 2(40),DATOUN(9,60),DATMAC(4,60),DATALT(4,60),DESLIM(15)

COMMON /CENTER/ CGARM(60)

COMMON /ARM/ ACCARM

COMMON /DISKK/ DISKWI,ENGINE

COMMON /SKIP/ SKIPIT

* DATA STORAGE DEFINITION *

LOGICAL PINP,IPLT,ISIO,ISII,PLOT,SKIPIT

INTEGER IDID(60),ILENG(40)

DIMENSION NUMNUM(17),IRNAME(17),CORFLC(40)

NAMelist / W/IWMEC,DESVAL,ACCS,IWT,IPLT,ISII,ISIO,IOUTCD,ILENG,DES-

1LIM,ISCALE,SCALE,ACCARM,DISKWI,ENGINE,PLOT

DIMENSION X(17),DEFAULT(17)

* DATA STATEMENTS *

DATA IDUC,LSHAF,ENGU,SIU,IVALV/4HDUCT,4HSHAF,4HENGL,4HSIU,4HVALV/

DATA ILPC,IHPC,IFAN,IFO,IFI,IHPT,ILPT/3HLPC,3HHPC,3HFAN,2HFO,2HFI,-
 13HHPT,3HLPT/

DATA IPROP/4HPROP/,DEFAULT/0.0,355.,1.0,1.0,0.0174,45.0,0.0,1.0,-
 11.0,2.0,0.7,0.75,0.5,0.5,0.12,220.,0.5/

C ---- TEST CALL TO PROPT --

IF(IWMEC(1,NC).NE.IPROP) RETURN

C --- INITIALIZE "X" ARRAY---

DO 5 I=1,17

X(I)=0.0

5 CONTINUE

C--- FILL X ARRAY WITH INPUTS OR DEFAULT VALS.---

DO 10 I=2,4

IF(DESVAL(I,NC).NE.0.0) X(I)=DESVAL(I,NC)

IF(DESVAL(I,NC).EQ.0.0) X(I)=DEFAULT(I)

10 CONTINUE

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C
C ***** BEGIN CALC. OF GEAR BOX WT. & DIMENSIONS *****
C --- ATTAIN MAX. VALUE PARAMETERS ---
    SHP=DATOUM(1,NC)
    RPMAX=DATOUM(2,NC)
C --- LOCATE SHAFT ---
    JSHP=DATINP(15,NC)+.01
C --- CHECK FOR GEAR RATIO OR RPM INPUT ---
    IF(DESVAL(3,NC).NE.0.0.AND.DESVAL(3,NC).LT.200.) SGR=DESVAL(3,NC)
    IF(DESVAL(3,NC).NE.0.0.AND.DESVAL(3,NC).GT.200.)-
1    SGR=RPMAX/DESVAL(3,NC)
    IF(DESVAL(3,NC).NE.0.0)GO TO 35
    RSMAX=RPMAX/SGR
    DO 500 IX=1,4
    IF(NC.EQ.JCONF(JSHP,IX))SGR=DATOUT(2,JSHP)
    WRITE(10,110)SGR,RPMAX,SHP
500  CONTINUE
35  CONTINUE
C --- SEND RPM BACK TO SUB."TURBINE" FOR USE IN DIMENSION CALCS ---
    JSHP=DATOUT(15,NC)
    RPMT(NC)=RSMAX
C--- CALCULATE TORQUE ---
    TORK=SHP*5252./RPMAX
C --- CHECK OPTION TO WEIGH G.B. ---
    IF(IWMEC(4,NC).EQ.0) WRITE(10,210)
    IF(IWMEC(4,NC).EQ.0) GO TO 100
C --- INITIALIZE VALUES TO BE PRINTED OUT ---
    GBWT=0.0
    GBKW=DEFAULT(4)
    IF(DESVAL(4,NC).NE.0.0) GBKW=DESVAL(4,NC)
C
C --- CHECK OPTION FOR G.B. WT.CURVE ---
    X(5)=DESVAL(5,NC)
    X(6)=DESVAL(6,NC)
    IF(DESVAL(5,NC).EQ.0.0.AND.DESVAL(6,NC).EQ.0.0) X(5)=DEFAULT(5)
    IF(DESVAL(5,NC).EQ.0.0.AND.DESVAL(6,NC).EQ.0.0) X(6)=DEFAULT(6)
    GBM=X(5)
    GBB=X(6)
C --- CHECK FOR INPUT GEAR RATIO SCALAR EXPONENT ---
    IF(DESVAL(17,NC).NE.0.0) X(17)=DESVAL(17,NC)
    IF(DESVAL(17,NC).EQ.0.0) X(17)=DEFAULT(17)
C--- INTERPOLATE CURVE FOR GEARBOX WEIGHT ---
    GBWT=GBKW*(GBM*TORK+C3B)*((1./SGR)/8.5)**X(17)
100  CONTINUE
C --- CHECK FOR INPUT SCALE FACTORS FOR G.B. DIMENSIONS ---
    GBLN=0.0
    GBDI=0.0
    IF(IWMEC(5,NC).EQ.0) WRITE(10,220)
    IF(IWMEC(5,NC).EQ.0) GO TO 101
    X(8)=DEFAULT(8)
    X(9)=DEFAULT(9)
    IF(IWMEC(5,NC).NE.0) X(8)=DESVAL(8,NC)
    IF(IWMEC(5,NC).NE.0) X(9)=DESVAL(9,NC)
    GBKL=X(8)
    GBKD=X(9)

```



```

C ---CALCULATE G.B. DIMENSIONS ---
  GBLN=0.005*46.*(SHP**.5)*((1/SGR)**.33)*GBKL
  GBDI=0.005*25.*(SHP**.5)*((1/SGR)**.33)*GBKD
  ILENG(NC)=GBLN
C -- ABOVE CALCS. BASED ON 1980 DDA "STAT" REPORT BASELINE ENG ---
101  CONTINUE
    WRITE(10,120)TORK,GBWT,GBLN,GBDI
C
C
C --- TEST FOR CHOICE TO WEIGH PROP ---
    IF(IWMEC(2,NC).EQ.0) WRITE(10,230)
    IF(IWMEC(2,NC).EQ.0) GO TO 300
C
C ***** BEGIN CALCS OF PROP WT. *****
C --- CHECK FOR INPUT VALUES OF PROP WT. EQ. EXPONENTS---
    DO 20 I=10,15
      X(I)=DEFAULT(I)
      IF(IWMEC(2,NC).NE.0.AND.DESVAL(2,NC).NE.0.0) X(I)=DESVAL(I,NC)
20  CONTINUE
C --- DEFINE COEFFICIENTS OF PROP WT EQ ---
    D=SQRT(DATOUM(1,NC)/DATOUM(3,NC))
    B=DATINP(5,NC)
    AF=DATINP(7,NC)
    PN=DATOUM(2,NC)
    SHP=DATOUM(1,NC)
    PM=DESVAL(1,NC)
    WRITE(10,130)D,B,AF,PN
    IF(DESVAL(2,NC).EQ.0.0) PKW=DEFAULT(2)
    IF(DESVAL(2,NC).NE.0.0) PKW=DESVAL(2,NC)
C --- CHECK FOR COUNTERWEIGHTS ---
    IF(IWMEC(3,NC).NE.0) GO TO 200
C
C
C *** BEGIN CALC OF PROP WT. (NO COUNTERWEIGHTS) *****
C
C---- NOTE:PROP WT.EQ. IS BROKEN INTO THREE PARTS FOR CLARITY ----
    PART1=(D/10.)*X(10)*(B/4.0)*X(11)*(AF/100.)*X(12)
    PART2=((PN*D)/20000.)*X(13)*(PM+1.0)*X(14)
    PART3=(SHP/(10.*D**2))*X(15)
    PRPWT=PKW*(PART1*PART2*PART3)
C --- COMBINE PROP WT. W/ G.B. WT. ---
    WATE(NC)=PRPWT+GBWT
    WRITE(10,140)PRPWT,WATE(NC)
C--- SKIP OVER NEXT PROP WT. CALC ---
    GO TO 300
200  CONTINUE
C
C ***** BEGIN PROP WT. CALC FOR SINGLE ACTING PROP (W/COUNTERWEIGHTS)
C
    CW=0.0
C --- SET EXPONENT VALUES FOR COUNTERWEIGHT WT. EQ. ---
    X(12)=0.7
    X(13)=0.4

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C --- CHECK FOR INPUT WT. EQ. SCALAR("KW" VALUE) ---
C---- NOTE:PROP WT.EQ. IS BROKEN INTO THREE PARTS FOR CLARITY ----
      PART1=(D/10.)*X(10)*(B/4.0)*X(11)*(AF/100.)*X(12)
      PART2=((PN*D)/20000.)*X(13)*(PM+1.0)*X(14)
      PART3=(SHP/(10.*D**2))*X(15)
      PRPWT=PKW*(PART1*PART2*PART3)
C --- CHECK FOR INPUT OF CON'T. VALUE CW WT. ---
      IF(DESV(7,NC).NE.0.0) X(7)=DESV(7,NC)
      IF(DESV(7,NC).EQ.0.0) -
      I X(7)=5*((D/10.)*X(10)**2*(AF/100.)*X(12)**2*(20000./(PN*D))**3)
      CWT=X(7)
C --- SUM PROP + CW WTS. ---
      PRPWT=PRPWT+CWT
      WATE(NC)=PRPWT+GBWT
      WRITE(10,150)PRPWT,CWT,WATE(NC)
C
300  CONTINUE
C
C
110  FORMAT('0',2X,'SHAFT-PROP GEAR RATIO=',F10.5,5X,-
111  'MAX RPM=',F15.4,5X,'SHAFT H.P.',F15.4)
120  FORMAT('0',2X,'TORQUE=',F15.4,11X,'GEAR BOX WT.',F15.4/2X,
121  'GEAR BOX LENGTH=',F15.4,5X,'GEAR BOX DIA.',F15.4)
130  FORMAT('0',2X,'PROP DIA.',F15.4,9X,'NUMBER BLADES=',-
131  'F15.4/'ACTIVITY FACTOR=',F15.4,6X,'PROP RPM=',F15.4)
140  FORMAT('0',2X,'PROP WT.',F15.4,9X,'PROP + GB WT.',F15.4)
150  FORMAT('0',2X,'PROP WT.',F15.4,5X,'COUNTERWEIGHT WT.',-
151  'F15.4,2X,'PROP + CW WT.',F15.4)
210  FORMAT(3X,'*** GEARBOX WEIGHT WILL NOT BE CALCULATED ***')
220  FORMAT(3X,'*** GEARBOX DIMENSIONS WILL NOT BE CALCULATED ***')
230  FORMAT(3X,'*** PROPELLER WEIGHT WILL NOT BE CALCULATED ***')
C
      IDID(NC)=1.0
C
      RETURN
      END

C  SUBROUTINE WTEST
C  -----
C
C  PURPOSE
C  -----
C  TO CONTROL THE CALLING OF SUBROUTINES WHICH WILL ESTIMATE THE
C  WEIGHT AND LENGTH OF INDIVIDUAL COMPONENTS
C
C  DESCRIPTION
C  -----
C  THE OVERALL LENGTH OF THE ENGINE IS CALCULATED BY PROCESSING THE
C  ILENG ARRAY.ALL COMPONENTS EXCEPT DUCTS AND SHAFTS, THEN DUCTS.
C  THE REMAINING COMPONENTS EXCEPT DUCTS AND SHAFTS ARE PROCESSED.
C  THE DUCTS ARE PROCESSED AND FINIALLY THE SHAFTS.
C  A BUILT-IN ASSUMPTION IN THE DUCT ROUTINE IS THAT NO DUCT IS

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C CONNECTED TO ANOTHER DUCT I.E. THE DUCT SIZE IS DETERMINED BY THE
 C ADJOINING COMPONENTS.
 C THEN THE MAXIMUM RADIUS IS FOUND. THEN DEPENDING ON THE PRINT
 C FLAG -IOJTC- THE REQUIRED PRINTING IS DONE
 C IF THE PLOT CODE FLAG -IPLT- IS TRUE ROUTINE EPLT IS CALLED
 C USAGE
 C -----
 C CALL WTEST
 C
 C CALLING ROUTINES
 C -----
 C FLOCAL-
 C ZTOPZ -
 C
 C REQUIRED SUBROUTINES
 C -----
 C COMP -COMPRESSOR WEIGHT/LENGTH
 C TURB -TURBINE
 C SHAFT -SHAFT
 C DUCTW -DUCT
 C COMBWT -PRIMARY BURNER WEIGHT/LENGTH
 C WTN0Z -NOZZLE WEIGHT/LENGTH
 C WMIXR -MIXER
 C WSPLT -SPLITTER
 C EPLT -PRINTER/PLOTTER
 C
 C MODIFICATION HISTORY
 C -----

DATE	ID	ANALYST	DESCRIPTION
MO/DA/YR	IDENT	NAME	DESCRIPTION OF CHANGES
9/21/81		ROBERT CORBAN	INCORPORATE INTERACTIVE MODE AND GR
HICS OPTION			
8/21/82		PETE SENTRY	INCORPORATE PROPELLER WEIGHT MODEL

 C AUTHOR/LANGUAGE/DATE
 C -----
 C NORMAN PREWITT-BOEING COMPUTER SERV. /FORTRAN IV / OCT 10,1976
 C
 C GLOSSARY
 C -----

NAME	ORIGIN	USAGE	DESCRIPTION
IWMEC	/WMECH/	I	CONTROL INFORMATION
WATE	/WMECH/	O	WEIGHT OF EACH COMPONENT
ALENG	/WMECH/	O	ACTUAL LENGTH OF EACH COMPONENT
TLENG	/WMECH/	O	ACCUMULATED LENGTH TO END OF COMPONENT
RI	/WMECH/	O	RADIUS INNER INLET,OUTLET EACH STATION
RO	/WMECH/	O	RADIUS OUTER INLET,OUTLET EACH STATION
DESVAL	/WMECH/	I	MECHANICAL DESIGN DATA OVERRIDES DEFAULT
DSHAF	/WMECH/	O	SHAFT DIAMETER INNER TO OUTER
RPMT	/WMECH/	I	ACTUAL COMPONENT RPM
IWT	/WMECH/	I	WEIGHT ESTIMATION FLAG TRUE= DO IT

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C      IPLT      /WMECH/ I      PLOTTER FLAG TRUE= DO IT
C      PLOT              L      GRAPHICS PLOTTING FLAG TRUE= DO IT
C      IERR      /WMECH/ 0      ERROR FLAG
C      ISIO      /WMECH/ 1      OUTPUT UNITS 0=ENGLISH, 0 SI
C      ISII      /WMECH/ 1      INPUT UNITS 0=ENGLISH, 0 SI
C      IOUTCD    /WMECH/ 1      PRINT FLAG 0=SUMMARY, 1=GENERAL, 2=DIAGNOSTIC
C      ILENG     /WMECH/ 1      COMPONENTS CONTRIBUTING TO OVERALL LENGTH
C      IDID      0              FLAG = 0 COMPONENT NOT YET WEIGHED =1 YES
C      SKIPIT    L              BACKGROUND FLAG YES=SKIP PROMPTS

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SUBROUTINE WTEST

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REAL*8 DATINP,DATOUT,WTF,TOPRES,TOTEMP,FAR,CORFLO,VMACH,STATP,ERRO-
IR,TOL,TOLT,TOLTT,DEPV,DTOL,PERPF,RPMNT,TMTEMP,TMPRES,DATCUM,DATMAC-
2,DATALT,DESLIM,TNPRES,TNTEMP,CNRFLO,CORFLM,WNTF,DATOUN,FARN,DANINP-
3,DEBUG,DEPQ,SELAST,DD,TOLOPT,RCH,STOC,TFUEL

```

* COMMON BLOCKS *

```

COMMON /DBL/ DATINP(15,60),DATOUT(9,60),WTF(40),TOPRES(40),TOTEMP(-
140),FAR(40),CORFLO(40),VMACH(40),STATP(40),ERROR(40),TOL,TOLT,TOLT-
2T,DEPV(20),DTOL(20),PERPF(20),RCH,STOC,TFUEL

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COMMON /SNG/ JMI,JM2,JP1,JP2,JCX,LOCTBL(9,60),JCOMP(70),IWAY,NIT,-
1ITAB(70),JCONF(60,4),JTYPE(60),JFLOW(70),IDEDAP(15),KKINDS(14,25),-
2NCGMP,NUSTAT,NITER,NFINIS,NPASS,JCC,NFBL,NCTS,JCIND(20),JCDEP(20),-
3JCVIND(20),JCVDEP(20),KDTYP(20),IDONE(60)

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COMMON /DEFAUL/ DEFAUL(15,20),ISCALE(3),SCALE(6)

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```

COMMON /WMECH/ IWMEC(7,60),WATE(60),ALENG(60),TLENG(40),RI(2,40),R-
10(2,40),DESVAL(17,60),DSHAF(5),RPMNT(60),IWT,IPLT,IERR,ISII,ISIO,I0-
2UTCD,NSTAG(60)

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```

COMMON /CONVER/ CONVER(15)

```

```

COMMON /NEOPT/ DEBUG,DEPQ,SELAST,DD,TOLOPT,NDSET,NPARTS,IOPTP,NPA-
1SSO,NVOPT,NJOPT,NOPT

```

```

COMMON /TERMON/ TNPRES(40),TNTEMP(40),CNRFLO(40),WNTF(40),RPMNT(40-
1),DATOUN(9,60),FARN(40),DANINP(15,60),TMTEMP(40),TMPRES(40),CORFLM-
2(40),DATCUM(9,60),DATMAC(4,60),DATALT(4,60),DESLIM(15)

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COMMON /CENTER/ CGARM(60)

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COMMON /ARM/ ACCARM

```

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COMMON /DISK/ DISKWI,ENGINE

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COMMON /SKIP/ SKIPIT

```

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COMMON /WTLDAT/ WATENG,WATACC

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* DATA STORAGE DEFINITION *

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LOGICAL PINP,IPLT,ISIO,ISII,PLOT,SKIPIT

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INTEGER IDID(60),ILENG(40)

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DIMENSION NUMNUM(17), IRNAME(17), CORFLC(40)

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NAMELIST /W/ IWMEC,DESVAL,ACCS,IWT,IPLT,ISII,ISIO,IOUTCD,ILENG,DES-
1LIM,ISCALE,SCALE,ACCARM,DISKWI,ENGINE,PLOT,IDID

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* DATA STATEMENTS *

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IF (TOPRES(1).GT.TMPRES(1)) DATMAC(1,1)=DATINP(5,11)
IF (TOPRES(1).GT.TMPRES(1)) DATA1(1,1)=DATINP(9,11)
IF (TOTEMP(1).GT.TMTEMP(1)) DATMAC(2,1)=DATINP(5,11)
IF (TOTEMP(1).GT.TMTEMP(1)) DATA1(2,1)=DATINP(9,11)
IF (DATOUT(2,1).GT.DATOUN(2,1)) DATMAC(3,1)=DATINP(5,11)
IF (DATOUT(2,1).GT.DATOUN(2,1)) DATA1(3,1)=DATINP(9,11)
IF (CORFLC(1).GT.CORFLM(1)) DATMAC(4,1)=DATINP(5,11)
IF (CORFLC(1).GT.CORFLM(1)) DATA1(4,1)=DATINP(9,11)
IF (TOPRES(1).GT.TMPRES(1)) TMPRES(1)=TOPRES(1)
IF (TOTEMP(1).GT.TMTEMP(1)) TMTEMP(1)=TOTEMP(1)
IF (CORFLC(1).GT.CORFLM(1)) CORFLM(1)=CORFLC(1)
IF (DATOUT(2,1).GT.DATOUN(2,1)) DATOUN(2,1)=DATOUT(2,1)
K=1+20
IF (1.LE.20) GO TO 70
IF (DATOUT(2,K).GT.DATOUN(2,K)) DATOUN(2,K)=DATOUT(2,K)
70 IF (JTYPE(1).NE.5) GO TO 80
DATTRQ=DATOUT(1,1)/DATOUT(2,1)
IF (DATTRQ.GT.DATOUN(1,1)) DATOUN(3,1)=DATOUT(2,1)
IF (DATTRQ.GT.DATOUN(1,1)) DATOUN(1,1)=DATTRQ
IF (1.LE.20.OR.JTYPE(K).NE.5) GO TO 80
DATTRQ=DATOUT(1,K)/DATOUT(2,K)
IF (DATTRQ.GT.DATOUN(1,K)) DATOUN(3,K)=DATOUT(2,K)
IF (DATTRQ.GT.DATOUN(1,K)) DATOUN(1,K)=DATTRQ
C THE FOLLOWING MAY BE USEFUL FOR DEBUGGING AND HAS BEEN LEFT IN
C WRITE(10,992)JTYPE(1)
C 992 FORMAT(//' COMP TYPE'13)
C WRITE(10,997)
C 997 FORMAT(' DES TOTPRES N D TOTEMP')
C WRITE(10,999)TOPRES(1),TMPRES(1),TOTEMP(1),TMTEMP(1)
C WRITE(10,996)
C 996 FORMAT(' DES CORFLO N D M WTF')
C WRITE(10,999)CORFLO(1),CNRFLO(1),CORFLM(1),WNTF(1)
C WRITE(10,993)
C 993 FORMAT(' DES EFF N D PR')
C WRITE(10,999)DATOUT(8,1),DATOUN(8,1),DATOUT(9,1),DATOUN(9,1)
C WRITE(10,995)
C 995 FORMAT(' MAX TOTPRES N M TOTEMP')
C WRITE(10,999)TOPRES(1),TMPRES(1),TOTEMP(1),TMTEMP(1)
C WRITE(10,994)
C 994 FORMAT(' MAX RPM N M D')
C WRITE(10,999)DATOUT(2,1),DATOUN(2,1),DATOUN(2,1)
C WRITE(10,991)
C 991 FORMAT(' MTRQ N M TRPM MIRPM ')
C WRITE(10,999)DATTRQ,DATOUN(1,1),DATOUT(2,1),DATOUN(3,1)
C 999 FORMAT(4F12.3)
C WRITE(10,999)DATMAC(1,1),DATMAC(2,1),DATMAC(3,1)
C WRITE(10,999)DATA1(1,1),DATA1(2,1),DATA1(3,1)
80 CONTINUE
IF (1WT.GE.2) GO TO 90
C ---- ZERO OUT OUTPUT ARRAYS
GO TO 620
90 JSCALE=0
ISAVE=1W1
IF (1WT.NE.4) GO TO 130

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100 JSCALE=JSCALE+1
    IF (JSCALE.GT.ISCALE(2)) GO TO 620
    IF (JSCALE.GT.1.AND.ISCALE(1).EQ.2) IOUTCD=1
    SCALEF=SCALE(JSCALE)
    IF (JSCALE.GT.1) SCALEF=SCALE(JSCALE)/SCALE(JSCALE-1)
110 IF (REVISE.EQ.YES) SCALEF=1.0
    DO 120 I=1,40
        WNTF(I)=WNTF(I)*SCALEF
        CNRFLO(I)=CNRFLO(I)*SCALEF
        CORFLM(I)=CORFLM(I)*SCALEF
        IDID(I)=0
        DATOUN(1,I)=DATOUN(1,I)*SCALEF
120 CONTINUE
    IF (JSCALE.GT.1.AND.IWT.EQ.4) GO TO 190
    IF (REVISE.EQ.YES) GO TO 180
130 DO 140 I=1,5
140 DSHAF(I)=0.
    DO 150 I=1,60
        WATE(I)=0
        NSTAG(I)=0
        IDID(I)=0
        RPMT(I)=0.
150 ALENG(I)=0
    DO 160 I=1,40
        TLENG(I)=0
        RI(1,I)=0
        ILENG(I)=0
        RI(2,I)=0
        RO(1,I)=0
160 RO(2,I)=0

C
C   ---- NAMELIST READ OF WTEST DATA
C
    CALL NAMEPR (9,10,8,PINP)
    READ (8,W)
    DO 170 I=1,60
    DO 170 K=1,17
        IF (IWMEC(1,I).EQ.NUMNUM(K)) IWMEC(1,I)=IRNAME(K)
170 CONTINUE
    GO TO 190
180 WRITE (20,760)
    CALL NAMEPR (20,10,8,PINP)
    READ (8,W)

C
C   ---- PROCESS LENGTH CONTRIBUTING VECTOR EXCEPT DUCTS AND SHAFTS
C
190 DO 310 I=1,40
    NC=ILENG(I)
C   WRITE(10,777)NC,ILENG(I),JTYPE(NC)
    IF (NC.EQ.0) GO TO 320
    JT=JTYPE(NC)
    GO TO (310,230,270,200,210,280,260,220,250,295,310,310,310,310), J-
    IT
C   ---- COMPRESSOR

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200 CALL COMP (NC)
   GO TO 300
C   ---- TURBINE
210 CALL TURB (NC)
   GO TO 300
C   ---- MIXER
220 CALL WMIXR (NC)
   GO TO 300
C   ---- PRIMARY BURNER
230 IF (IWMEC(1,NC).EQ.IDUC) GO TO 240
   IF (IWMEC(1,NC).EQ.IVALV) GO TO 290
   CALL COMBWT (NC)
   GO TO 300
C   --- DUCTS
240 CALL DUCTW (NC)
   GO TO 300
C   ---- NOZZLES
250 CALL WTNOZ (NC)
   GO TO 300
C   ---- SPLITTER
260 CALL WSPLT (NC)
   GO TO 300
C   TRANSFER DIMENSIONS FOR WATER INJECTION
270 CALL DUMMY (NC)
   GO TO 300
C   HEAT EXCHANGER WEIGHT
280 CALL HMEC (NC)
   GO TO 300
C   VALVES
290 CALL VALVWT (NC)
C   ***** 07/15/82 *****
   GO TO 300
295 IF (DATINP(2,NC).EQ.0.0) GO TO 310
   CALL PROPWT (NC)
   IUP=JCONF(1,1)
   IDN=JCONF(1,3)
   GO TO 305
C   ***** 07/15/82 *****
C   ---- ACCUME LENGTH
300 IUP=JCONF(NC,1)
   IDN=JCONF(NC,3)
305 TLENG(IDN)=TLENG(IUP)+ALENG(NC)
   IF (JT.EQ.6) TLENG(IDN)=TLENG(IUP)
   ID2=JCONF(NC,4)
   IF (ID2.GT.0) TLENG(ID2)=TLENG(IUP)+ALENG(NC)
   IF (JT.EQ.6) TLENG(ID2)=TLENG(IUP)
   IU2=JCONF(NC,2)
   IF (IU2.GT.0) TLENG(IU2)=TLENG(IUP)
   IDID(NC)=1
310 CONTINUE
C   ---- LAST COMPONENT WAS A NOZZLE SET ENGINE MAXIMUM LENGTH
320 ENGLN=TLENG(IDN)
C

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C      PROCESS REMAINING COMPONENTS
C
C      DO 410 I=1,60
C      WRITE(10,7777)NC,I,IDID(I)
C      IF (IDID(I).EQ.1) GO TO 410
C
C      -- PROCESS COMPRESSORS,TURBINES,MIXERS,BURNERS,SPLITTERS
C      NC=JTYPE(I)
C      IF (NC.LE.0) GO TO 410
C      GO TO (410,360,400,330,340,390,380,350,410,410,410,410,410), N-
C      IC
C      -- COMPRESSOR
C      330 CALL COMP (I)
C      GO TO 410
C      -- TURBINES
C      340 CALL TURB (I)
C      GO TO 410
C      -- MIXER
C      350 CALL WMIXR (I)
C      GO TO 410
C      -- BURNERS
C      360 IF (IWMEC(1,I).EQ.IDUC) GO TO 410
C      IF (IWMEC(1,I).EQ.1VALV) GO TO 370
C      CALL COMBWT (I)
C      GO TO 410
C      VALVES
C      370 CALL VALVWT (I)
C      GO TO 410
C      --- SPLITTER
C      380 CALL WSPLT (I)
C      GO TO 410
C      HEAT EXCHANGERS
C      390 CALL HMEC (I)
C      GO TO 410
C      TRANSFER DIMENSIONS FOR WATER INJECTION
C      400 CALL DUMMY (I)
C      410 CONTINUE
C      WRITE(10,7771)JTYPE
C
C      ---- PROCESS DUCTS
C      DO 420 I=1,60
C      IF (IDID(I).EQ.1) GO TO 420
C      NC=JTYPE(I)
C      IF (NC.NE.2) GO TO 420
C      IF (IWMEC(1,I).NE.IDUC) GO TO 420
C      CALL DUCTW (I)
C      420 CONTINUE
C      WRITE(10,7771)JTYPE
C      ---- PROCESS NOZZLES
C      DO 430 I=1,60
C      IF (IDID(I).EQ.1) GO TO 430
C      NC=JTYPE(I)
C      IF (NC.NE.9) GO TO 430
C      CALL WTNOZ (I)
C      430 CONTINUE

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C      WRITE(10,7771)JTYPE
C      ---- ACCUME LENGTH
      DO 450 I=1,40
C      WRITE(10,7777)NC,I,IDID(I)
      IF (JTYPE(I).LE.0) GO TO 440
      IF (IDID(I).EQ.1) GO TO 450
      NC=JTYPE(I)
      GO TO (450,440,440,440,440,440,440,440,440,450,450,450,450,450), N-
1C
440  IUP=JCONF(1,1)
      IU2=JCONF(1,2)
      IDN=JCONF(1,3)
      ID2=JCONF(1,4)
      TLENG(IDN)=TLENG(IUP)+ALENG(1)
      IF (NC.EQ.6) TLENG(IDN)=TLENG(IUP)
      IF (IU2.GT.0) TLENG(IU2)=TLENG(IUP)
      IF (ID2.GT.0) TLENG(ID2)=TLENG(IDN)
      IDID(I)=1
450  CONTINUE
C      ---- PROCESS SHAFTS
      DO 470 J=1,5
      DO 460 I=1,25
      NC=KKINDS(11,I)
      IF (NC.LE.0) GO TO 470
      IF (IWMEC(1,NC).NE.LSHAF) GO TO 460
      IF (IWMEC(2,NC).EQ.J) CALL SHAFT (NC)
460  CONTINUE
470  CONTINUE
C
C      ---- FIND ENGINE MAXIMUM RADIUS
      XR=0
      DO 490 I=1,NOSTAT
      IF (XR.GE.RO(1,1)) GO TO 480
      XR=RO(1,1)
480  IF (XR.GE.RO(2,1)) GO TO 490
      XR=RO(2,1)
490  CONTINUE
C
C      ---- GET ENGINE TOTAL WEIGHT AND ALENG CONVERSION
      WATENG=0
      IF (ACCS.EQ.0) ACCS=.1
      WAT=0.
      DO 500 I=1,60
      IF (JTYPE(I).EQ.9) GO TO 500
      WAT=WATE(I)+WAT
500  CONTINUE
      WATACC=ACCS*WAT
      IF (IOUTCD.GT.1) WRITE (10,660) IOUTCD
      IF (ISIO) WATACC=WATACC*CONVER(3)
      IF (IOUTCD.GT.1) WRITE (10,690) WATACC
      DO 510 I=1,60
      WFACTR=1.
      IF (DESVAL(15,I).NE.0.) WFACTR=DESVAL(15,I)
      WATE(I)=WATE(I)*WFACTR

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      IF ((JTYPE(I).EQ.4.OR.JTYPE(I).EQ.5).AND.WATE(I).EQ.0.) WATE(I)=+1-
1.E6
      IF (.NOT.ISIO) GO TO 510
      WATE(I)=WATE(I)*CONVER(3)
      ALENG(I)=ALENG(I)*CONVER(1)
510 WATENG=WATENG+WATE(I)
C
C      ---- CONVERT RADIAL DIMENSIONS AND TLENG
      IF (.NOT.ISIO) GO TO 530
      DO 520 I=1,NOSTAT
      RI(1,I)=RI(1,I)*CONVER(1)
      RI(2,I)=RI(2,I)*CONVER(1)
      RO(1,I)=RO(1,I)*CONVER(1)
      RO(2,I)=RO(2,I)*CONVER(1)
      TLENG(I)=TLENG(I)*CONVER(1)
520 CONTINUE
C
C      ---- WRITE COMPONENT WEIGHT INFO
530 UNITSI=ENGU
      IF (ISII) UNITSI=SIU
      UNITSO=ENGU
      IF (ISIO) UNITSO=SIU
      WRITE (10,670) UNITSI,UNITSO
      IF (IWT.EQ.4) WRITE (10,630)
      IF (IWT.EQ.4) WRITE (10,640)
      IF (IWT.EQ.4) WRITE (10,650) SCALE(JSCALE)
      IF (IWT.EQ.4) WRITE (10,640)
      IF (IOUTCD.LT.1) GO TO 580
      WRITE (10,680)
      HLENG=0.
      CGLENG=0.
      CGWATE=0.
      CGTOTM=0.
      CGCOMP=0.
      DO 570 I=1,60
      NC=JTYPE(I)
      IF (NC.LE.0) GO TO 570
C      WRITE(10,7777)JT
      GO TO (540,540,540,540,540,540,540,540,570,540,570,570,570), N-
1C
C      ***** 07/15/82 *****
540 IF (NC.EQ.10.AND.DATINP(2,I).EQ.0.0) GO TO 570
      IUP1=JCONF(I,1)
      IUP2=JCONF(I,2)
      IDN1=JCONF(I,3)
      IDN2=JCONF(I,4)
      IF (NC.EQ.10) IUP1=JCONF(I,1)
      IF (NC.EQ.10) IUP2=JCONF(I,2)
      IF (NC.EQ.10) IDN1=JCONF(I,3)
      IF (NC.EQ.10) IDN2=JCONF(I,4)
C      ***** 07/15/82 *****
      WRITE (10,700) I,WATE(I),ALENG(I),TLENG(IDN1),RI(1,IUP1),RO(1,IUP1-
1),RI(1,IUP2),RO(1,IUP2),RI(2,IDN1),RO(2,IDN1),RI(2,IDN2),RO(2,IDN2-
2),NSTAG(I)

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IF (ALENG(I).EQ.0.) GO TO 550
HLENG=ALENG(I)/2.
IF (IWMEC(1,I).EQ.ILPC.OR.IWMEC(1,I).EQ.IHPC) CGX=ALENG(I)-CGARM(I-
1)
IF (IWMEC(1,I).EQ.IFAN.OR.IWMEC(1,I).EQ.IFO) CGX=ALENG(I)-CGARM(I)
IF (IWMEC(1,I).EQ.IFI.OR.IWMEC(1,I).EQ.IHPT) CGX=ALENG(I)-CGARM(I)
IF (IWMEC(1,I).EQ.ILPT) CGX=ALENG(I)-CGARM(I)
IF (IWMEC(1,I).EQ.ILPC.OR.IWMEC(1,I).EQ.IHPC) HLENG=CGX
IF (IWMEC(1,I).EQ.IFAN.OR.IWMEC(1,I).EQ.IFO) HLENG=CGX
IF (IWMEC(1,I).EQ.IFI.OR.IWMEC(1,I).EQ.IHPT) HLENG=CGX
IF (IWMEC(1,I).EQ.ILPT) HLENG=CGX
CGLENG=TLENG(IDN1)-HLENG
GO TO 560
550 IF (IWMEC(1,I).EQ.ISHAF) CGLENG=CGARM(I)
IF (IWMEC(1,I).NE.ISHAF) GO TO 570
560 CGWATE=WATE(I)
CGCOMP=CGWATE*CGLENG
CGTOTM=CGTOTM+CGCOMP
570 CONTINUE
CENGR=(CGTOTM+(WATACC*ACCARM))/WATENG
C
C ---- MAKE SUMMARY PRINT
580 IF (.NOT.ISIO) GO TO 590
XR=XR*CONVER(1)
ENGLN=ENGLN*CONVER(1)
CENGR=CENGR*CONVER(1)
590 WRITE (10,710) WATENG,WATACC,ENGLN,XR
IF (SCALE(JSCALE).EQ.1.) SEXPO1=WATENG
SEXPO2=1.
IF (SCALE(JSCALE).NE.1..AND.IWT.EQ.4) SEXPOE=ALOG(WATENG/SEXPO1)/A-
1LOG(SCALE(JSCALE)/SEXPO2)
IF (SCALE(JSCALE).EQ.1.) SEXPOE=1.
WRITE (10,720) CENGR
IF (IWT.EQ.4) WRITE (10,730) SEXPOE
IF (JSCALE.GT.1.AND.ISCALE(1).EQ.2) GO TO 610
IF (ENGINE.EQ.2.) GO TO 610
IF (IPLT) CALL ENGLPT (ENGLN,XR)
IF (PLOT) GO TO 600
GO TO 610
600 IF (SKIPIT) CALL EGLOT (ENGLN,WATENG)
IF (SKIPIT) GO TO 610
WRITE (20,740)
READ (20,770) ANSWER
IF (ANSWER.NE.YES) GO TO 610
CALL EGLOT (ENGLN,WATENG)
WRITE (20,750)
READ (20,770) REVISE
IF (REVISE.EQ.YES) IWT=2
610 ENGINE=1.
IF (REVISE.EQ.YES) GO TO 110
IWT=ISAVE
IF (IWT.EQ.4) GO TO 100
620 IWT=0
IOUTCD=2
RETURN

```

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630 FORMAT (1H /24H ENGINE SCALING DATA      )
640 FORMAT (20H *****)
650 FORMAT (14H SCALE FACTOR ,F5.2)
660 FORMAT (1H /14H *****/14H *                */14H * ACCS WT *-
1/14H *                */13H *****,11)
670 FORMAT (1H1,26H      WEIGHT INPUT DATA IN ,A4,6H UNITS/27H      WEIG-
1HT OUTPUT DATA IN ,A4,6H UNITS//)
680 FORMAT (69H      COMP  WT  COMP  ACCU  UPSTREAM RADIUS  DOWNS-
1TREAM RADIUS /77H      NO  EST  LEN  LEN  RI  RO  RI  RO -
2 RI  RO  RI  RO  NSTAGE//)
690 FORMAT (/11H      ACCS WT=,F8.3)
700 FORMAT (17,F6.0,F7.0,F6.0,4F5.0,F6.0,3F5.0,I8)
710 FORMAT (/27H      TOTAL BARE ENGINE WEIGHT=,F6.0,2X,12HACCESSORIES=,F-
17.2,2X,23HESTIMATED TOTAL LENGTH=,F6.0,2X,25HESTIMATED MAXIMUM RAD-
2IUS=,F5.0)
720 FORMAT (30H      ESTIMATED CENTER OF GRAVITY=,F6.0)
730 FORMAT (39H      ESTIMATED AIRFLOW SCALING EXPONENT IS,F6.3)
740 FORMAT (46H      DO YOU WISH A GRAPHICS PICTURE? YES=Y ; NO=N)
750 FORMAT (54H      DO YOU WISH TO MAKE CHANGES TO THE INPUT? YES=Y;NO=N)
760 FORMAT (42H      ENTER DESIRED CHANGES FROM TERMINAL,I.E./39H      &W DE-
1SVAL(1,6)=****(DATA)**** &END)
770 FORMAT (A4)
END
```

C*****

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TABLE I. - USER INPUT FOR PROPELLER PERFORMANCE

SPEC	Option 1, fixed efficiency	Option 2, generalized map	Option 3, user-input map
1	(-) Shaft horsepower	(-) Shaft horsepower	(-) Shaft horsepower
2	Efficiency	Any negative number	Map number
3	Static T/SHP	---	---
4	Power loading ^a	Power loading	Power loading
5	Number of blades ^a	Number of blades	Number of blades ^a
6	---	Lift coefficient	---
7	Activity factor ^a	Activity factor	Activity factor ^a
8	---	Optional scaling factor	Optional scaling factor
9	---	Optional desired design efficiency	Optional desired design efficiency
10	Tip speed ^a	Tip speed	Tip speed

^aRequired only for weight calculation, not for performance.

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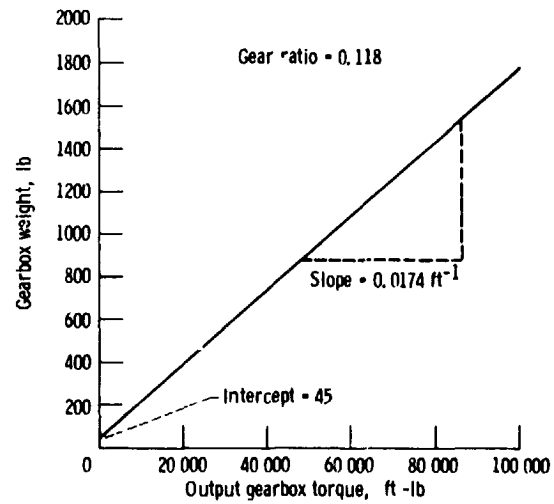


Figure 1. - Baseline gearbox weight as a function of torque for gear ratio = 0.118.