DESIGN DATA SHEET
DEPARTMENT OF THE NAVY
NAVAL SEA SYSTEMS COMMAND

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DDS 051-1

PREDICTION OF SMOOTH-WATER POWERING PERFORMANCE FOR SURFACE-DISPLACEMENT SHIPS

CONTENTS

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051-1-b. Nomenclature

Symbol	Definition
A	Section Area
A_{FINS}	(Area of fin centerplane) x (number of fins)
ATTC	American Towing Tank Conference
A_V	Ship above-water transverse area
A_X	Section area at Station of Maximum Area
A_0	Section area at Station 0
A_{20}	Section area at Station 20
B_{WL}	Maximum beam of waterline, at a particular draft
B_X	Beam, at DWL, at Station of Maximum Area
B_{20}	Beam, at DWL, at Station 20
B/T, B_X/T_X	Beam-to-draft ratio
C_A	Correlation-allowance cofficient
C_{AA}	Air drag coefficient, based on ship frontal area
C_D	Drag coefficient
$C_{D(AP)}$	Appendage drag coefficient Note: The formula given herein for $P_{E(AP)}$ is not non-dimensional; the values of $C_{D(AP)}$ given herein and used to compute $P_{E(AP)}$ are applicable for English-unit computations, only.
$C_{D(BTD)}$	Drag coefficient for bow thruster duct openings
$C_{D(FIN)}$	Drag coefficient for stabilizer fins
C_F	Frictional resistance coefficient
C_P	Longitudinal prismatic coefficient
C_R	Residuary resistance coefficient
CRPP	Controllable-reversible-pitch propeller
$C_{R(TSS)}$	Residuary resistance coefficient for TSS hull forms
C_S	Wetted surface coefficient [$= S/(\nabla \times L_{WL})^{0.5}$]

051-1-b. Nomenclature

Symbol	Definition
$C_{S(TSS)}$	Wetted surface coefficient for TSS hull forms
C_{WP}	Waterplane area coefficient, at DWL
C_X	Section coefficient at Station of Maximum Area
C_{∇}	Volumetric coefficient
D_{BTD}	Diameter of bow thruster duct openings
D_P	Propeller diameter
DWL	Design waterline
EAR	Propeller expanded-area-ratio
FPP	Fixed-pitch propeller
ITTC	International Towing Tank Conference
i_E	DWL entrance half-angle, in degrees
J	Propeller advance coefficient
K_T	Propeller thrust coefficient
K_1	Constant required to convert to standard units of power
L	Ship length
L_{PP}	Length between perpendiculars
L_{WL}	Length on waterline, at DWL
L/B, L_{WL}/B_X	Length-to-beam ratio
P/D	Propeller pitch-to-diameter ratio
P_E	Effective power
$P_{E(AA)}$	Effective power due to still-air drag
$P_{E(AP)}$	Effective power due to appendages Note: The formula given herein for $P_{E(AP)}$ is not non-dimensional; the values of $C_{D(AP)}$ given herein and used to compute $P_{E(AP)}$ are applicable for English-unit computations, only.

051-1-b. Nomenclature

Symbol	Definition
$P_{E(BH)}$	Bare hull effective power
$P_{E(BTD)}$	Effective power due to bow thruster duct openings
$P_{E(FIN)}$	Effective power due to stabilizer fins
$P_{E(MISC)}$	Effective power due to miscellaneous appendage items, hull openings, etc.
$P_{E(TOT)}$	Ship total effective power, inclusive of effective power added by still-air drag and by power margin
PMF	Power margin factor
P_S	Shaft power
R_{AA}	Resistance due to still air
R_{AP}	Resistance of appendages
R_{BH}	Bare hull resistance
R_F	Frictional resistance
R_n	Reynolds Number
R_R	Residuary resistance
Ship R_R	Residuary resistance for a specific hull form
TSS R_R	Residuary resistance of equivalent TSS hull form
R_R/Δ	Residuary resistance per ton of displacement
R_T	Total resistance (= $R_{BH} + R_{AP} + R_{AA}$)
rps	Revolutions per second
S	Wetted surface
S_{SHIP}	Wetted surface of a specific ship
S_{TSS}	Wetted surface of equivalent TSS hull form
$S/(\Delta \times L)^{0.5}$	Wetted surface factor (S in ft^2, Δ in long tons, L in feet)
t	Thrust-deduction fraction [= (Thrust − R_T)/Thrust]
T_{mean}	Ship mean draft

051-1-b. Nomenclature

Symbol	Definition
TSS	Taylor Standard Series
T_X	Ship draft at Station of Maximum Area, to DWL
T_{WL}	Ship draft to a particular waterline
V_A	Propeller speed of advance
V_S	Ship speed
$V/(L)^{0.5}$	Speed-length ratio (speed in knots, length in feet)
WCF	Worm curve factor
w	Taylor wake fraction $[= (V_S - V_A)/V_S]$
Δ	Ship displacement
Δ_{AP}	Displacement of appendages
Δ_{BH}	Bare hull displacement, to DWL
Δ_T	Displacement of fully-appended hull, to DWL
$\Delta/(L/100)^3$	Displacement-length ratio (Δ in long tons, L in feet)
∇_{BH}	Bare hull volume, to DWL
η_D	Propulsive coefficient
η_O	Propeller open-water efficiency
η_R	Propeller relative-rotative efficiency
λ	Ship model linear scale ratio
ν	Kinematic viscosity of water
ρ	Mass density of water
ρ_A	Mass density of air

Note: The above symbols which are applicable to dimensional quantities are equally appropriate for English and metric units of measurement, unless noted above. As noted in Section 051-1-c, the use of English units in the powering performance calculations (described herein) has been assumed in this design data sheet.

051-1-c. Introduction.

The purpose of DDS 051-1 is to establish a design practice for development of smooth-water powering performance predictions for surface-displacement ships. The design practice established herein is applicable to the development of powering performance predictions prior to the availability of full-scale trials results. When full-scale trials results are available for the ship or class in question, a different approach is used for development of powering performance predictions.

The basic methodology for preliminary prediction of the smooth water powering performance of new naval surface-displacement ships is depicted in Figure 1. The practices described in Reference (1) are generally applicable. The manner in which these predictions are carried out, and the data on which they are based, normally varies at successive stages of design, as is explained below.

The nature of the supporting data base currently used for powering performance calculations is such that it is convenient to carry out these calculations using English units; hence, the use of these units is assumed herein.

Sample smooth water powering performance estimates are presented in Section 051-1-h. The first sample estimate utilizes a table, a blank copy of which is included herein as Table 1, which has been prepared to facilitate "longhand" preparation of speed-power estimates; note that, for the reason stated above, Table 1 is applicable only to powering calculations in English units. The second sample estimate utilizes a computer program, called TSS 84, for the development of the data. This program is evolutionary and is updated on a continuing basis. The documentation of the current version of the program (TSS 84) is presented in Reference (2).

051-1-d. Methodology for Predictions Made Prior to Availability of Model Test Results

During the early stages of design, powering performance predictions must normally be made before any model test results, for the ship design in question, are available. The inputs required for such predictions are as follows.

- L_{WL}, B_X, T_X, C_X, and C_P values, and estimated S and A_V values
- Selected value of C_A
- Worm curve factors for the speed range of interest
- Selected appendage-drag coefficients
- Drag coefficients for miscellaneous items (e.g., bow thruster openings)
- Selected value of still-air drag coefficient
- Selected value of power margin factor
- Estimated value(s) of η_D

The prediction methodology illustrated in Figure 1 is followed. Table 1 may be used or the current version of the powering prediction program may be executed. Explanations of selected elements of the prediction methodology are given below.

Estimate Ship Wetted Surface. If no body plan exists, an appropriate ship wetted surface factor (i.e., S_{SHIP}/S_{TSS}) is selected from a compilation of such data, taking into account such factors as general ship type, bow bulb or dome, transom size and skeg size. The normal practice is to include the bow dome and skeg wetted surface in the estimated ship wetted surface. S_{TSS} is determined from Figure 2 (which has been reproduced from Reference (3)). An alternate method is to select a wetted surface factor (e.g., $S/(\Delta \times L)^{0.5}$ from a compilation of such data, taking into account C_P, C_X, $\Delta/(L/100)^3$, B/T, general ship type, bow bulb, transom size, etc. To assess the effects of C_X and B/T variations on wetted surface coefficient, the plot given in Figure 3 (reproduced from Reference (4)) may be used. After a body plan has been developed, the wetted surface can be measured; however, if this body plan does not include the bow bulb or dome and skeg(s) which may eventually be incorporated, then an estimate must be made of the wetted surface added by these items. Estimates of the wetted surface added by a skeg, bow bulb, or bow dome can be made using data from similar hull form designs.

Determine Frictional Resistance Coefficient. Unless otherwise specified, the 1957 ITTC friction formulation should be used to determine the value of the Frictional Resistance Coefficient (C_F) at each speed; this formulation is as follows:

$$C_F = 0.075/(\text{Log}_{10} R_n - 2)^2$$

where $R_n = V_S \times L_{WL}/\nu$

The values of the kinematic viscosity (ν) of water to be used in computing R_n are given in Table 2. For preliminary speed-power estimates, the normal practice is to use the value of ν for sea water at 59 degrees. Tabulated values of C_F (ITTC) versus R_n (e.g., Reference (5)) may be used for convenience.

Determine Correlation Allowance Coefficient (C_A) Value. The required C_A value is dependent upon the type of bottom paint and the condition of the bottom (e.g., the bottom roughness and fouling). C_A values which are appropriate for new U.S. Navy ships having the Navy vinyl paint system applied over sandblasted bottom plating, and having been out of drydock for only a short time, are determined from the C_A formulation included in Table 3. For estimating the resistance of such ships two years after the initial drydocking, the value of C_A determined from the formula should be increased by 0.0007. (This increment is based on previous practice, which was to use a C_A of 0.0005 for new, vinyl-painted ships just after initial drydocking and a C_A of 0.0012 for such ships two years out of drydock.)

Calculate Ship Frictional Resistance. Ship frictional resistance (R_F) is calculated, at each speed, as follows:

$$R_F = (\rho/2) \times S \times V_S^2 \times (C_F + C_A)$$

For preliminary estimates, the normal practice is to use the value of ρ for sea water at 59 degrees F; values of ρ for the practical range of water temperatures are given in Table 4.

Calculate TSS R_R/Δ. The first step is to obtain C_R values for a TSS hull form with the same B/T, Cp and $\Delta/(L/100)^3$ values as the ship in question, using Reference (6) or Reference (7), or both. Reference (6) provides C_R values for TSS hull forms with B/T values of 2.25, 3.00, and 3.75, and Reference (7) provides C_R values for TSS hull forms with a B/T values of 4.50. A parabolic interpolation method is included in Table 1, such that $C_{R(TSS)}$ values at the desired B/T value can be obtained if $2.25 \leq B/T \leq 3.75$. $C_{R(TSS)}$ data, and appropriate interpolation subroutines, (for $2.25 \leq B/T \leq 3.75$) have been incorporated into Program TSS 84. For $3.75 \leq B/T \leq 4.50$, determination of C_R values by linear interpolation between the values from Reference (6), for B/T = 3.75, and from Reference (7), for B/T = 4.50, is also incorporated into TSS 84. The $C_{R(TSS)}$ values are converted into TSS R_R/Δ values, using appropriate TSS wetted surface (S_{TSS}) and ship displacement values, as follows:

$$\text{TSS } R_R/\Delta = \rho \times S_{TSS} \times V_S^2 \times C_{R(TSS)}/(2 \times \Delta)$$

S_{TSS} values can be estimated using Figure 2. The normal practice is to include the bow dome and skeg volume in the Δ_{BH} and C_P values used for determination of TSS R_R/Δ.

Estimate Worm Curve Factors. Worm curve factors (WCFs) are the values of $(\text{Ship}R_R/\Delta)/(\text{TSS } R_R/\Delta)$ at specific values of $V/(L)^{0.5}$. The TSS R_R/Δ values are those applicable to the equivalent TSS hull form (i.e., TSS hull form with same B/T, C_P and $\Delta/(L/100)^3$ values as the new ship design). The WCF values selected for use must be synthesized from those determined from model tests of hull forms similar to the new hull form (for which the powering estimate is being made). Similarities and differences in secondary characteristics (e.g., bow bulb or dome type and size, B_{20}/B_X, A_{20}/A_X, and skeg configuration) must be considered when selecting WCF values. Tabulations and plots of WCF values for selected destroyer-type hull forms are presented in Reference (8); WCF data for additional hull forms is included in Reference (7).

Calculate Ship Residuary Resistance. Ship residuary resistance (R_R) is calculated, at each speed, as follows:

$$R_R = (\text{TSS } R_R/\Delta) \times \text{WCF} \times \Delta_{BH}$$

Calculate Bare Hull Effective Power. Ship bare hull effective power $[P_{E(BH)}]$ is calculated, at each speed, as follows:

$$P_{E(BH)} = (R_F + R_R) \times V_S/K_1$$

Estimate Ship Appendage Effective Power. Ship appendage effective power $[P_{E(AP)}]$ can be calculated by several related methods. The general form of a frequently used appendage drag equation is as follows:

$$P_{E(AP)} = L \times D_p \times V_S^3 \times C_{D(AP)}/K_1$$

$C_{D(AP)}$ data for single and twin-screw, destroyer-type hull form/appendage configurations are presented in Reference (9). Recommended average values of $C_{D(AP)}$, for twin and single-screw, destroyer-type ships are indicated in Figures 4 and 5 respectively. The data presented in Reference (9) is considered to be more up-to-date than the similar data (for a different drag coefficient formulation) presented in Reference (10); however, the appendage drag data applicable to quadruple-screw ships, which is presented in Reference (10), may provide guidance for the early-stage predictions to which it is applicable. (Note that these $C_{D(AP)}$ values are not nondimensional and apply to total effective horsepower added by appendages.) For non-destroyer hull form/appendage configurations, $P_{E(AP)}$ can be proportioned from the results of model tests of generally similar ships.

It should be noted that the effective power added by sea chest openings and other small hull openings is normally considered to be included in the appendage effective power as determined by the method noted above [e.g., use of $C_{D(AP)}$ values from Reference (9)]. When hull openings become significant, such as is the case for large wells and for tunnel-type bow thrusters (without covers), then the drag of these items should be accounted for separately. The general form of an equation for estimating the effective power increment due to a bow thruster duct, with openings port and starboard, is as follows:

$$P_{E(BTD)} = (\rho/2) \times (V_S^3/K_1) \times (\pi D_{BTD}^2/4) \times C_{D(BTD)}$$

A $C_{D(BTD)}$ value of 0.08 has been used within NAVSEA for development of preliminary estimates of $P_{E(BTD)}$.

It should also be noted that the $C_{D(AP)}$ values in Figures 4 and 5 are considered to apply only to appendage sets which do not include roll stabilizer fins. A limited amount of experimental data on the drag of stabilizer fins is available. In Reference (9), for instance, $P_{E(FIN)} = 0.025\ P_{E(BH)}$ was found to approximate the effective power added by actual fins on certain destroyer-type ships, based on limited data. The general formula for estimating the effective power increment due to stabilizer fins is as follows:

$$P_{E(FIN)} = (\rho/2) \times (V_S^3/K_1) \times A_{FINS} \times C_{D(FINS)}$$

Estimate Effective Power Due to Still-Air Drag. The following general form of an equation for calculating effective power due still-air drag [$P_{E(AA)}$] is:

$$P_{E(AA)} = (\rho_A/2) \times A_V \times V_S^3 \times C_{AA}/K_1$$

where C_{AA} = 0.45 for aircraft carriers

= 0.70 for destroyer-type ships

= 0.75 for naval auxiliaries

The still-air drag prediction method given in Reference (11) may also be used.

Select Power Margin Factor. Unless specified otherwise, select Power Margin Factor (PMF) in accordance with the NAVSEA speed-power margin policy. The policy is given in Table 3.

Calculate Ship Total Effective Power. Ship total effective horsepower is calculated as follows:

$$P_{E(TOT)} = PMF \times [P_{E(BH)} + P_{E(AP)} + P_{E(AA)}]$$

Estimate Propulsive Coefficient. Ship propulsive coefficient (η_D) is defined as follows:

$$\eta_D = [(1 - t)/(1 - w)] \times \eta_R \times \eta_O$$

During the early stages of design, η_D values derived, at least in part, from model tests of similar hull/appendage/propulsor configurations should be used. The effects of anticipated differences in hull and propeller characteristics (e.g., differences in D_P/T values between the new design and the data base ships) on η_D should be estimated. As soon as the hull form dimensions, C_P, C_X, and are defined, the η_D, at one or more speeds, can be estimated by estimating values for $1 - t$, $1 - w$, η_R, and η_O. It is sometimes possible to estimate $1 - t$, $1 - w$, and η_R values using results of model tests of similar hull form/appendage/propulsor configurations. The general formulae for estimating $1 - t$ and $1 - w$ which are given in Reference (11) may be of use in certain cases; other general information which can be used for predictions of these values is given in References (1) and (12). Hull-propeller interaction coefficients derived from model tests have been analyzed statistically. Typical results, applicable primarily to commercial ships, are presented in References (13), (14), (15), (16), and (17). Statistically-derived relationships have also been developed for predictions of $1 - t$ and $1 - w$ for twin-screw naval ships; these relationships, based primarily on results of model tests of U.S. Navy ships, are presented in Reference (18). It must be noted, however, that statistically-derived relationships for hull/propeller interaction coefficients may not be completely appropriate for use with the relatively larger, slower-turning propellers being considered for some naval ship designs; hence, these statistically-derived relationships or data should be used only for basic estimates which can then be corrected to reflect deviations caused by differences in propeller characteristics. Using estimated values of total P_E (including effects of still-air drag and power margin), $1 - t$, $1 - w$, and η_R, an estimate of η_O values can be made from propeller series data [such as Reference (19)], lifting line calculations, or open water test data for a propeller which has approximately correct physical characteristics.

If series data or open-water data of an existing propeller is used, a useful method of finding the rps and η_O at which such a propeller would operate is to compute K_T/J^2 for the ship, using estimated values of $1 - t$ and $1 - w$, for a specific speed; note that:

$$K_T/J^2 = (\text{Thrust per propeller})/(\rho \times D_P{}^2 \times V_A{}^2)$$

$$= R_T/[\rho \times D_P{}^2 \times V_S{}^2 \times (1 - t) \times (1 - w)^2 \times (\text{no of propellers})]$$

K_T and J values which give the K_T/J^2 value computed for the ship, when plotted (K_T versus J), represent the trace of conditions at which a propeller must operate for the ship in question. The intersection of this "ship K_T versus J" trace and an actual propeller K_T versus J plot (determined from open-water tests) represents the K_T, J point at which such a propeller would operate and yields the associated rps and η_0 values. To minimize the possibility of incompatibility between the initial estimate and the final-design estimate of propeller characteristics and performance, the lifting-line method of predicting propeller characteristics and performance should be utilized as early as possible in the design process; further, propeller characteristics must be matched to machinery characteristics, as early as possible, for the same reason. Finally, it should be noted that propeller noise and cavitation requirements must be taken into consideration when selecting propeller characteristics for a new design.

Calculate Shaft Power. For selected speeds, over the speed range of interest, shaft horsepower is calculated as follows:

$$P_S = P_{E(TOT)}/\eta_D$$

Prepare Speed-Power Plot. Prepare a speed power plot, similar to the sample depicted in Figure 6. The plot may consist solely of a shaft power versus speed curve or may include curves of ship total effective power versus speed, and of propulsive coefficient versus speed. In all cases, it is advisable to include the ship characteristics and data source information, either on the plot page or attached as a supplementary information page, such that the plot is self-explanatory; to this end, the use of the standard form, attached hereto as Figure 7, is recommended.

Predict Achievable Speeds. Using the curve of shaft power versus speed, the achievable speed at 100 percent installed shaft power is the predicted Trial Speed. Similarly, the current practice is that the achievable speed at 80 percent installed shaft power is considered to be the Sustained Speed. These speed capabilities are normally determined for the ship in the clean-bottom, full load displacement condition.

051-1-e. Methodology for Prediction Made After Availability of Bare Hull Effective Horsepower Model Tests

After bare hull effective power model test data for the new ship design is available, and assuming that the test data was extrapolated to full-scale values using ITTC frictional resistance coefficients and the specified C_A value, for the correct values of ship displacement, the powering performance predictions should be carried out as follows:

Calculate Ship Bare Hull Effective Power. Full scale $P_{E(BH)}$ values should be used. If model resistance values were not extrapolated to full-scale using ITTC frictional resistance coefficients, or if a powering performance prediction based on a C_A value other than that used for extrapolation of the model data is desired, then corrections must be made. Corrections to the full scale $P_{E(BH)}$ values, <u>for each 0.0001 change</u> in the C_A value, can be made at each speed as follows:

$$P_{E(BH)} \text{ increment} = (\rho/2) \times S \times V_S^3 \times 0.0001/K_1$$

Corrections to the extrapolated model test $P_{E(BH)}$ values occasioned by the use of different frictional resistance coefficients (e.g., the Schoenerr coefficients) must be made to the actual model test data and then this corrected data must be extrapolated to full scale. If $P_{E(BH)}$ values are required for a ship displacement which is different from that represented in the existing model tests results, then the data must be corrected. In general, the use of the methodology presented in Section 051-1-d is appropriate; however, it should be possible to use the model $S/(\Delta \times L)^{0.5}$ value for reestimating wetted surface and R_F, and the worm curve factors derived from the tests for reestimating R_R.

<u>Estimate Ship Appendage Effective Power</u>. Use methodology in Section 051-1-d.

<u>Estimate Effective Power Due to Still-Air Drag</u>. Use methodology in Section 051-1-d; update A_V value, if possible.

<u>Select Power Margin Factor</u>. Unless otherwise specified, select the power margin factor in accordance with the NAVSEA policy. The policy is given in Table 4.

<u>Calculate Ship Total Effective Power</u>. Use methodology in Section 051-1-d.

<u>Estimate Propulsive Coefficient</u>. Use methodology in Section 051-1-d.

<u>Calculate Shaft Power</u>. Use methodology in Section 051-1-d.

<u>Prepare Speed-Power Plot</u>. Use methodology in Section 051-1-d.

<u>Predict Achievable Speeds</u>. Use methodology in Section 051-1-d.

051-1-f. <u>Methodology for Predictions Made After Availability of Self-Propulsion Model Tests, Using Stock Propeller(s) or Initial-Design Propellers</u>

After the data from self-propulsion model tests, in which the stock (or initial-design) propeller was used, are available, and assuming that the effective power tests were extrapolated using ITTC frictional resistance coefficients and the desired C_A value, that the self propulsion tests were carried out accordingly, and that the displacement(s) represented by the tests was (were) equal to the displacement(s) for which predictions are to be made, the powering performance predictions should be carried out as follows:

<u>Calculate Fully-Appended Ship Effective Power</u>. Extrapolated model test values of fully-appended ship effective power should be used. Corrections for the use of a different C_A than that used for extrapolation of the model tests can be made as noted in Section 051-1-e.

(Corrections for the use of different frictional resistance coefficients or a different displacement than represented by the test data can be made in a manner similar to that noted in Section 051-1-e; however, in the case of appended ship effective power, the residuary resistance can be considered to include the non-frictional portion of the appendage resistance, and the faired model test data extrapolated accordingly.)

Estimate Effective Power Due to Still-Air Drag. Use methodology in Section 051-1-d; update A_V value if possible.

Select Power Margin Factor. Unless otherwise specified, select the power margin factor in accordance with the NAVSEA policy. The policy is given in Table 4.

Calculate Ship Total Effective Power. Use methodology in Section 051-1-d.

Estimate Propulsive Coefficient. The 1 - t, 1 - w and η_R values determined from the self-propelled model tests with stock propellers can be used. Normally, the stock (or initial-design) propeller η_O values should not be used. Instead, η_O values anticipated to be achievable with the final design propeller should be used. In addition to the 1 - t, 1 - w and η_R values determined from the model tests, the ship total effective power values, including effects of power margin, still-air resistance, and all corrections should be included in the propeller loading used for determining the achievable η_O values and the η_D values. Normally, the anticipated performance of the final propeller is predicted using a lifting-line program; the ship design requirements with respect to propeller noise and cavitation must also be considered at this time. Even if the final propeller design cannot be completely defined before a new powering estimate is required, it is usually possible to estimate the achievable η_O values using the above means. It should also be noted that powering tests with the final design model propellers sometimes result in different measurements of 1 - t, 1 - w and η_R than do tests with stock propellers; in particular, this has been noticed when a highly-skewed final propeller design is used. If such differences are anticipated, an attempt must be made to estimate the effects these differences will have on the final propeller design and on the η_D estimate. Finally, it can be noted that, when a new ship design is very similar to a previous design, it is likely that the design propeller of the previous ship would be used as the stock propeller for the model tests of the new ship; in this case, it will be possible to use the open-water data of the final propeller of the previous ship design for making any η_O adjustments at this stage of design. (See note under "Estimate Propulsive Coefficient", Section 051-1-d, regarding the use of ship K_T/J^2 data.)

Calculate Shaft Power. Use methodology in Section 051-1-d.

Prepare Speed-Power Plot. Use methodology in Section 051-1-d.

Predict Achievable Speeds. Use methodology in Section 051-1-d.

051-1-g. Methodology for Predictions Made After Availability of Self-Propulsion Model Tests, Using Final Design Propeller(s)

After the data from self-propulsion model tests, in which the final-design propeller was used, are available, and assuming that the effective power tests were extrapolated using ITTC frictional resistance coefficients and the desired C_A value that the self-propulsion tests were carried out accordingly, and that the displacement(s) represented by the tests was (were) equal to the displacement(s) for which predictions are to be made, the powering performance predictions should be carried out as follows:

Calculate Fully-Appended-Ship Effective Power. Use methodology in Section 051-1-f.

Estimate Effective Power Due to Still-Air Drag. Use methodology in Section 051-1-d; update A_V value.

Select Power Margin Policy. Unless otherwise specified, select the power margin factor in accordance with the NAVSEA policy. The policy is given in Table 4. At this stage of design, when using the smallest PMF values from the NAVSEA policy, it must be clear that the performance of the final-design propeller has been demonstrated to be acceptable, based on analyses of the propeller open-water, the propeller cavitation, and the final self-propulsion model tests.

Calculate Ship Total Effective Power. Use methodology in Section 051-1-d.

Estimate Propulsive Coefficient. Using values of ship total effective power (with effects of still-air drag and power margin included) at successive speed values, plots of ship K_T versus J (using K_T/J^2 values determined from the model tests results) are overlaid on the open-water K_T versus J plot of the final propeller design at each speed. (See note under "Estimate Propulsive Coefficient", Section 051-1-d, regarding the use of K_T/J^2 data.) These η_O values, together with the $1 - t$, $1 - w$ and η_R values, at each speed which were determined from the model tests with the final propeller, are used to develop the ship propulsive coefficient estimates.

Calculate Shaft Power. Use methodology in Section 051-1-d.

Prepare Speed-Power Plot. Use methodology in Section 051-1-d.

Predict Achievable Speeds. Use methodology in Section 051-1-d.

051-1-h. Sample Smooth-Water Powering Performance Estimates for a Surface-Displacement Ship

Sample Estimate, Using Table 1. A sample smooth-water powering performance estimate for a twin-screw, naval surface-displacement ship, using the format presented in Table 1, is presented in Table 5. The P_S versus V_S and η_D versus V_S data presented in Table 5 is depicted in plot form in Figure 6.

Sample Estimate, Using Program TSS 84. A sample smooth-water powering performance estimate for a twin-screw, naval surface-displacement ship, which was carried out using Program TSS 84, is presented in Table 6. The input used for the estimate presented in Table 6 is the same as the input for the estimate presented in Table 5; the plots depicted in Figure 6 are also applicable to the estimate presented in Table 6.

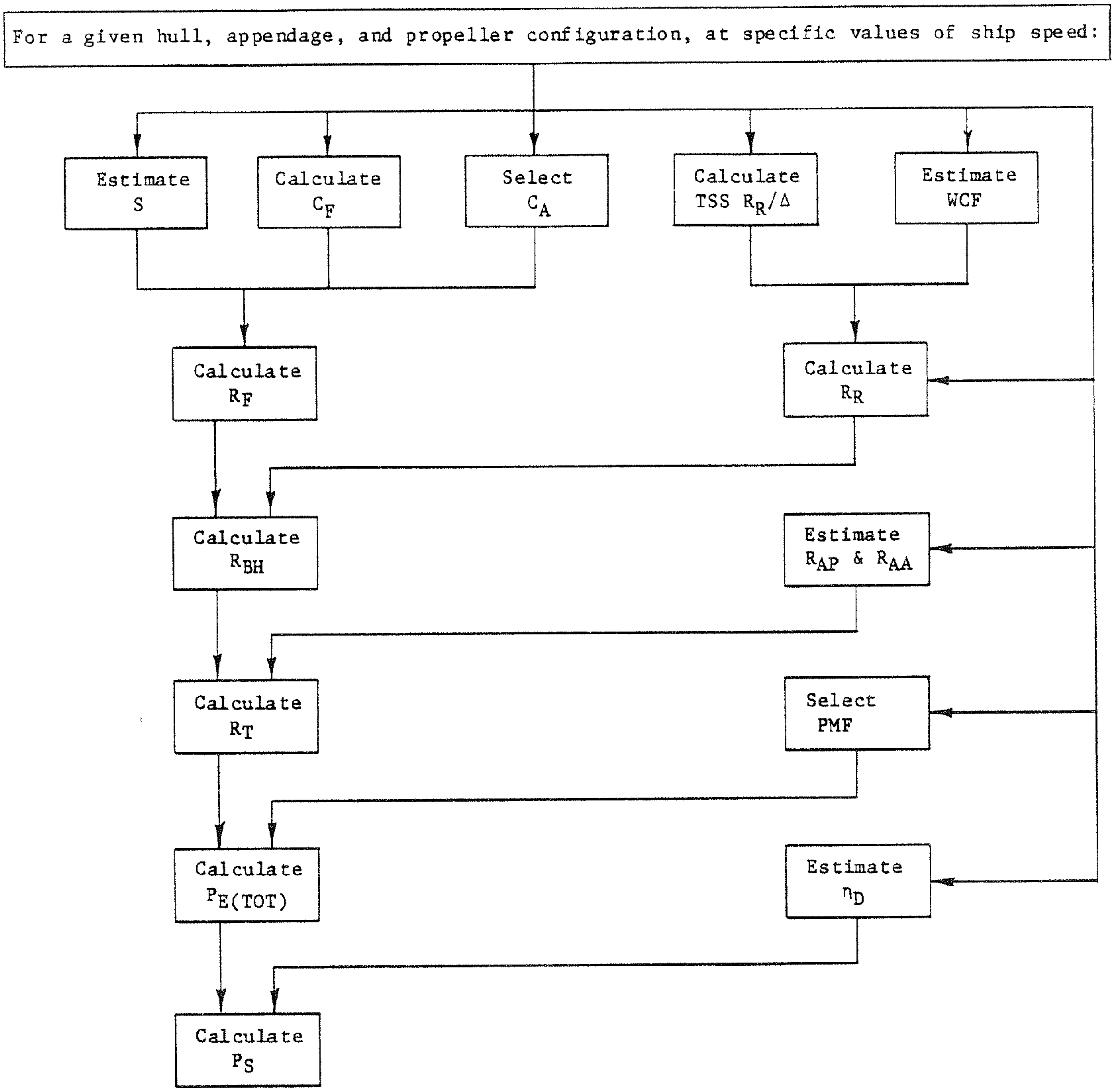


FIGURE 1. Methodology for Prediction of Smooth-Water Powering Performance for Surface-Displacement Ships

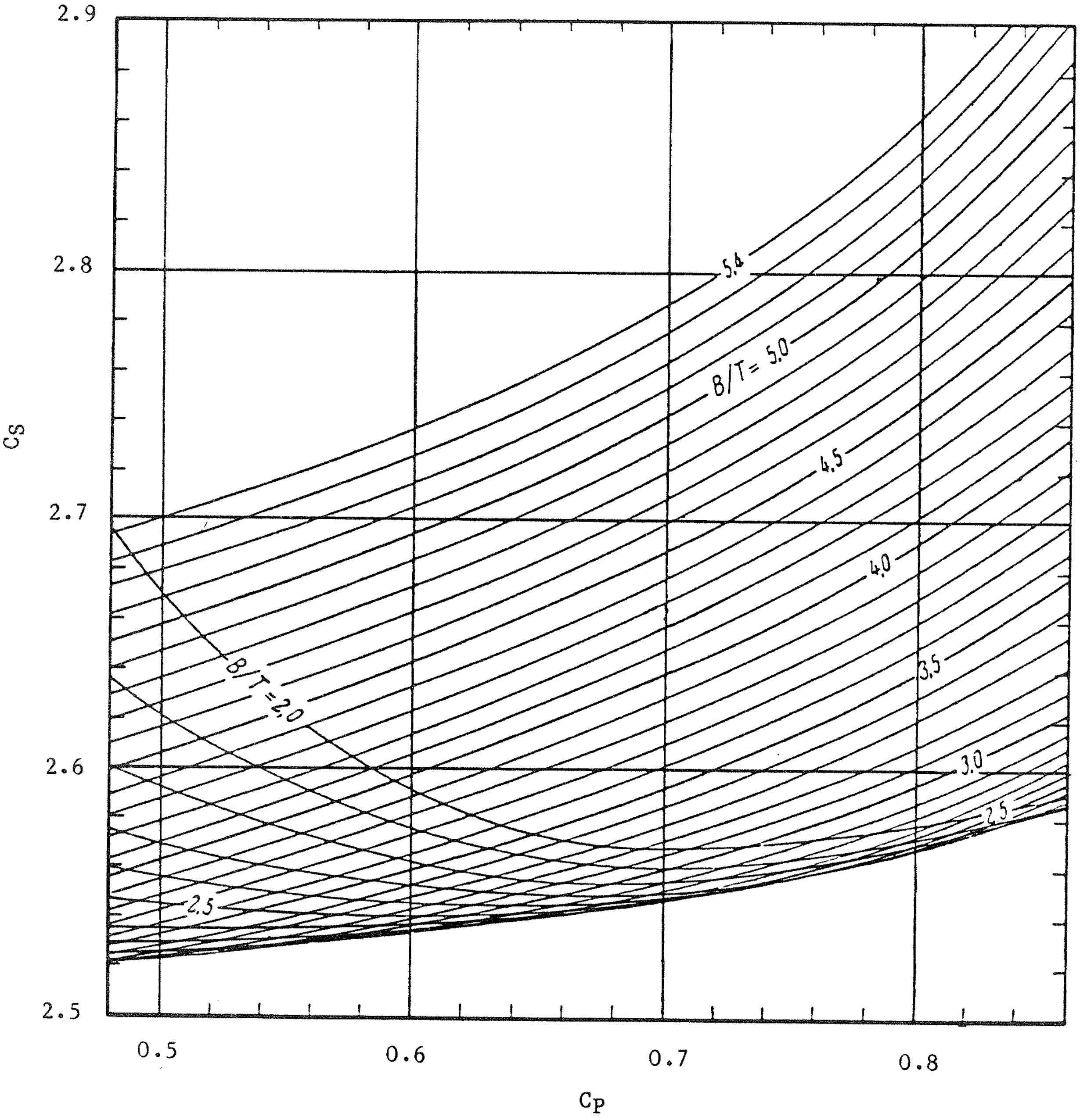


FIGURE 2. Surface Coefficients $C_S = S/(Vol \times L_{WL})^{0.5}$ for the Taylor Standard Series

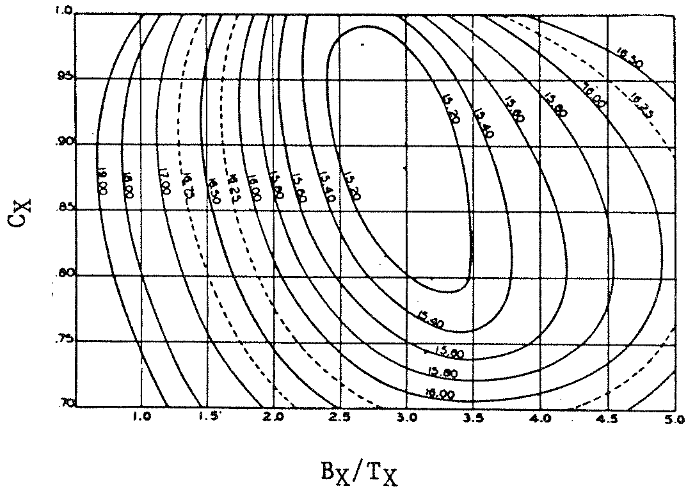


FIGURE 3. Contours of Wetted Surface Factor

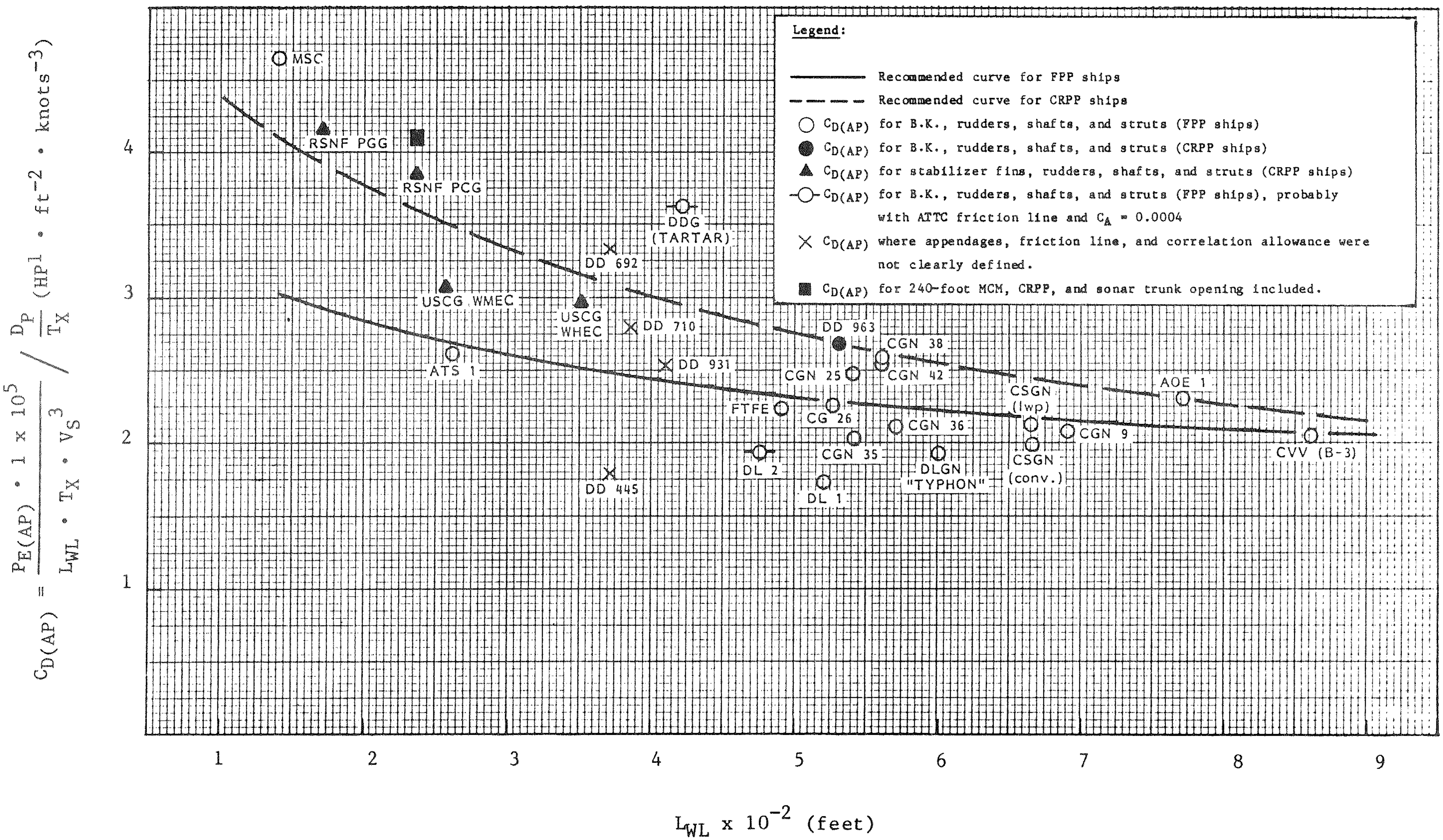


FIGURE 4. Appendage Drag Coefficients for Twin-Screw Naval Ships With Strut-Supported Shafts
Sheet 1: Plot

Notes:

1. $C_{D(AP)}$ values based on PE data calculated with ITTC friction line and $C_A = 0.0005$, except as noted.
2. When selecting the recommended curves for FPP ships, the "X" points were ignored.
3. When selecting the recommended curve for CRPP ships, the $C_{D(AP)}$ values for PCG and PGG were given more "weight" than $C_{D(AP)}$ values for WHEC and WMEC.
4. The two CSGN points represent model test data for two difference hull forms.
5. Compared to the typical D_P/T_X value of ships represented on this plot, the D_P/T_X value of the AOE 1 is small.

FIGURE 4. Sheet 2: Notes

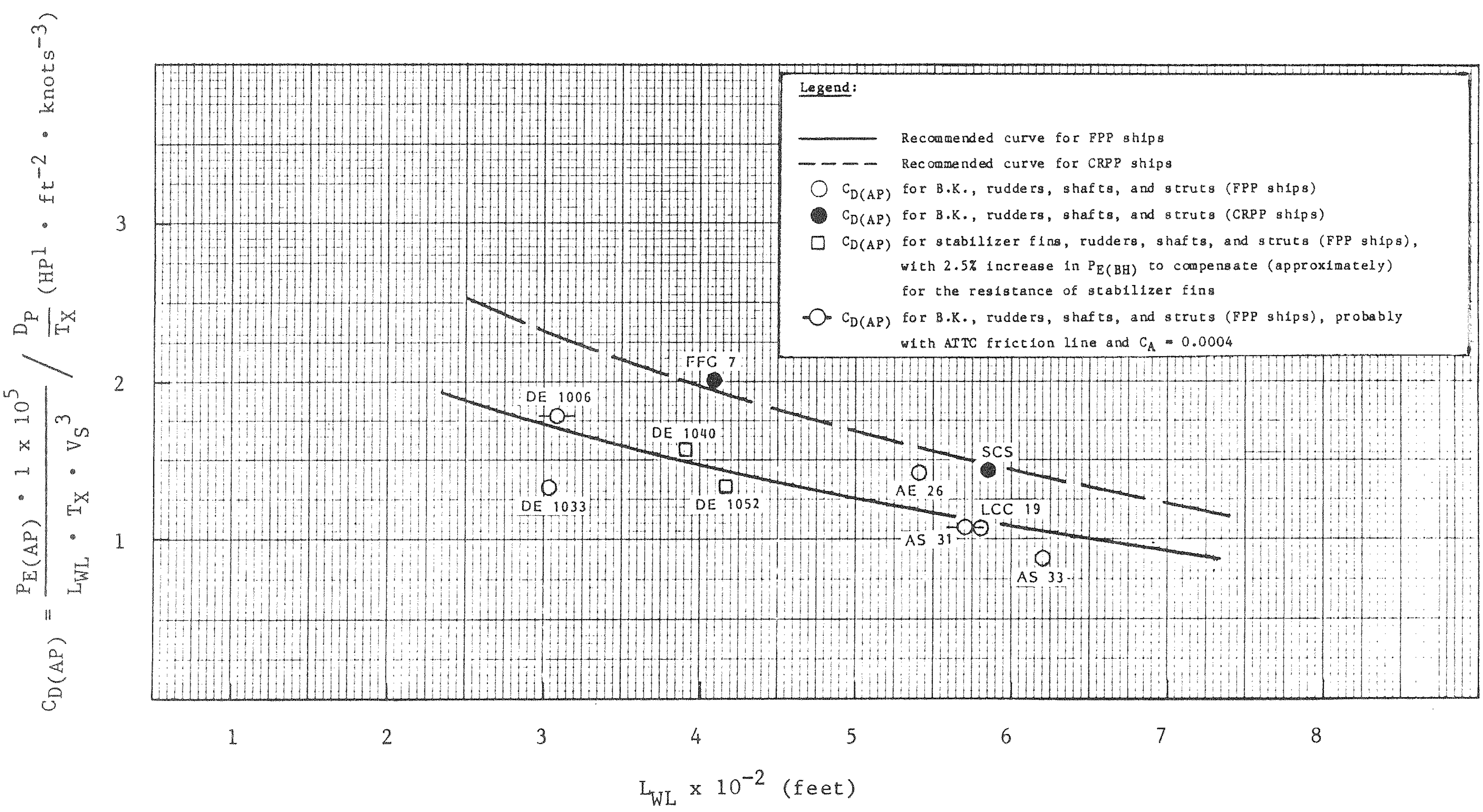


FIGURE 5. Appendage Drag Coefficients for Single-Screw
Naval Ships With Strut-Supported Shafts
Sheet 1: Plot

Notes:

1. $C_{D(AP)}$ values based on P_E data calculated with ITTC friction line and $C_A = 0.0005$, except as noted.
2. $C_{D(AP)}$ value for the SCS is based on only three $P_{E(AP)}$ values at closely spaced speeds.
3. $C_{D(AP)}$ value for the DE 1006 may include the effect on appendage resistance of two small sound domes.
4. $C_{D(AP)}$ value for the FFG 7 includes the effect on appendage resistance of a skeg and a small, keel-mounted sound dome.
5. Compared to the typical D_P/T_X value of ships represented on this plot, the D_P/T_X value of the AE 26 is small.

FIGURE 5. Sheet 2: Notes

Ship Condition

Δ_{FL} (l.t.) 8500*

T (ft.) 20.01

Trim ( ) (by bow/stern) ______

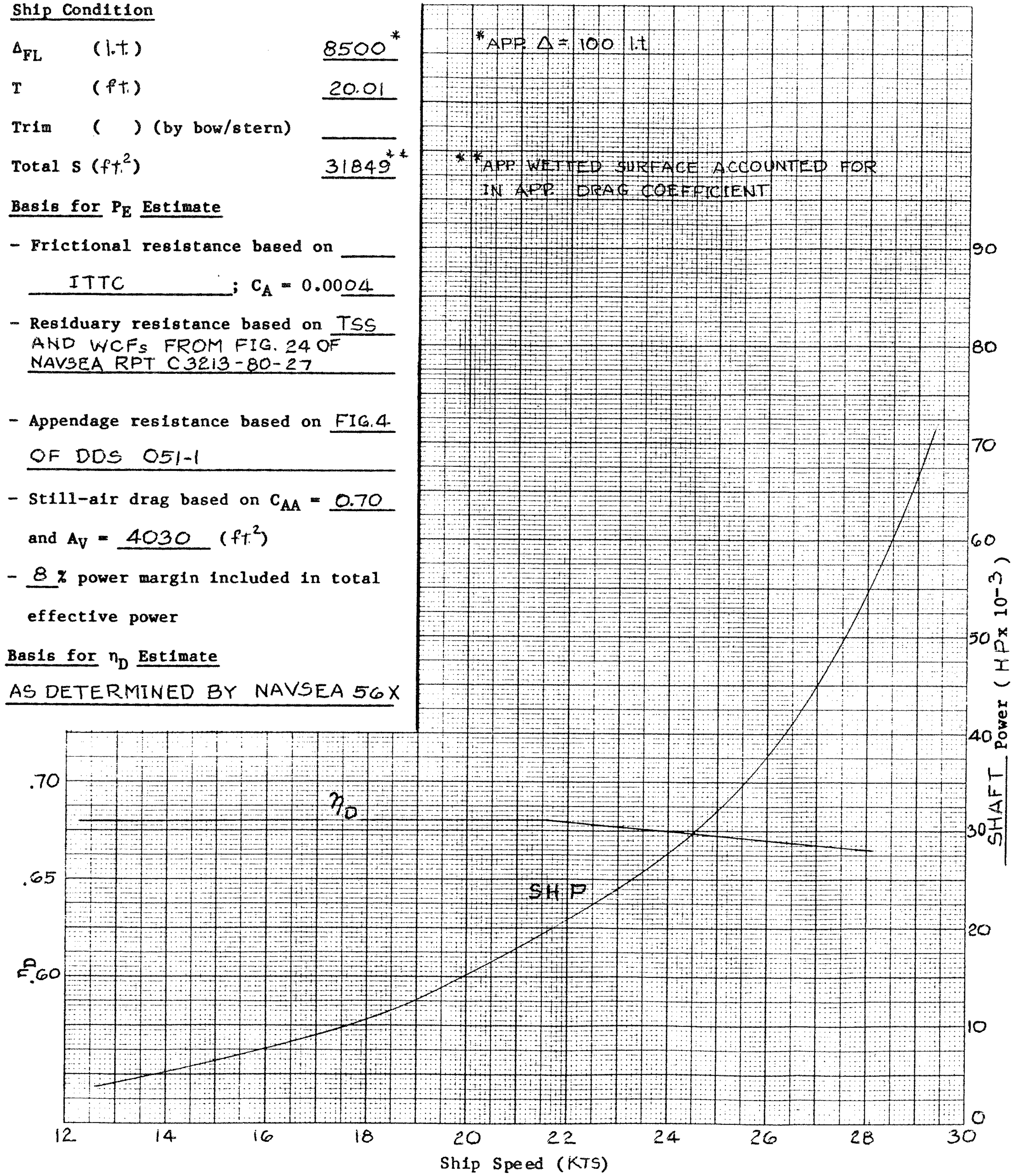
Total S (ft.^{2}) 31849**

Basis for P_E Estimate

- Frictional resistance based on ______ ITTC ; C_A = 0.0004
- Residuary resistance based on TSS AND WCFs FROM FIG. 24 OF NAVSEA RPT C3213-80-27
- Appendage resistance based on FIG. 4 OF DDS 051-1
- Still-air drag based on C_{AA} = 0.70 and A_V = 4030 (ft.^{2})
- 8 % power margin included in total effective power

Basis for η_D Estimate

AS DETERMINED BY NAVSEA 56X



*APP Δ = 100 l.t

**APP WETTED SURFACE ACCOUNTED FOR IN APP. DRAG COEFFICIENT

FIGURE . PRELIMINARY Speed-Power Curve(s) for
(Design Stage)
EXAMPLE SHIP ; FULL LOAD
(Ship, or Ship Design) (Ship Condition)

PERTINENT HULL FORM, APPENDAGE, AND PROPELLER DATA

Bare Hull Characteristics, to DWL:

L_{WL} (ft.)	465.88
B_X (ft.)	62.00
T_X (ft.)	20.01
C_X	0.825
C_P	0.610
Δ_{BH} (l.t.)	8400
S (ft.^{2})	31849
A_0/A_X	0
A_{20}/A_X	0.040
i_E ( )	
B_{20}/B_X	0.540
C_{WP}	0.780
$\overline{FB}/L_{PP}$	
L_{PP}/B_X	7.51
B_X/T_X	3.098
$\Delta/(0.01L_{PP})^3$	84.54
C_S	2.71

Bow Bulb or Bow-Mounted Sonar Dome Description:

SQS 53 SONAR DOME

Skeg:

Included in bare hull Δ and Cp?
Yes (✓) No ( )

Fore and Aft Extent: Sta. ___ to Sta. ___

Type: Appended ( ) Integral (✓)

Hull Model Description:

Model No. ______
λ ______

Lines and/or Body Plan Drawing No.:

______

Prepared by: ______

Date: ______

Appendage Description:

Rudders
Number 2
Wetted Area (each) ( ) ______

Bilge Keels:
Depth (Maximum) (ft.) 4.00
Extent Sta. ___ to Sta. ___

Stabilizer Fins:
Number NONE
Wetted Area (each) ( ) ______

Main Shaft Strut Arms:
Type RADIAL, VEE
Section ______
Chord ( ) ______
Thickness ( ) ______
Length ( ) ______

Intermediate Shaft Strut Arms:
Type NONE
Section ______
Chord ( ) ______
Thickness ( ) ______
Length ( ) ______

Keel-Mounted Dome:
Type NONE
Location Sta. ______

Description of Estimated Final Propeller(s):

Number of Propellers 2
Diameter (ft.) 17.00
Type: FP ( ) CRP (✓)
Nominal Ahead P/D ______
E.A.R. ______
Direction of Ahead Rotation:
Outboard (✓) Inboard ( )

Miscellaneous Data:

Propeller tip-to-hull clearance (ft.) 5.413

Other:

______

______

FIGURE 6. Sample Speed-Power Curve

Ship Condition

Δ_{FL} ( ) ______

T ( ) ______

Trim ( ) (by bow/stern) ______

Total S ( ) ______

Basis for P_E Estimate

- Frictional resistance based on ______

______; C_A = 0.00____

- Residuary resistance based on ______

______

- Appendage resistance based on ______

______

- Still-air drag based on C_{AA} = ______

and A_V = ______ ( )

- ___% power margin included in total effective power

Basis for η_D Estimate

______

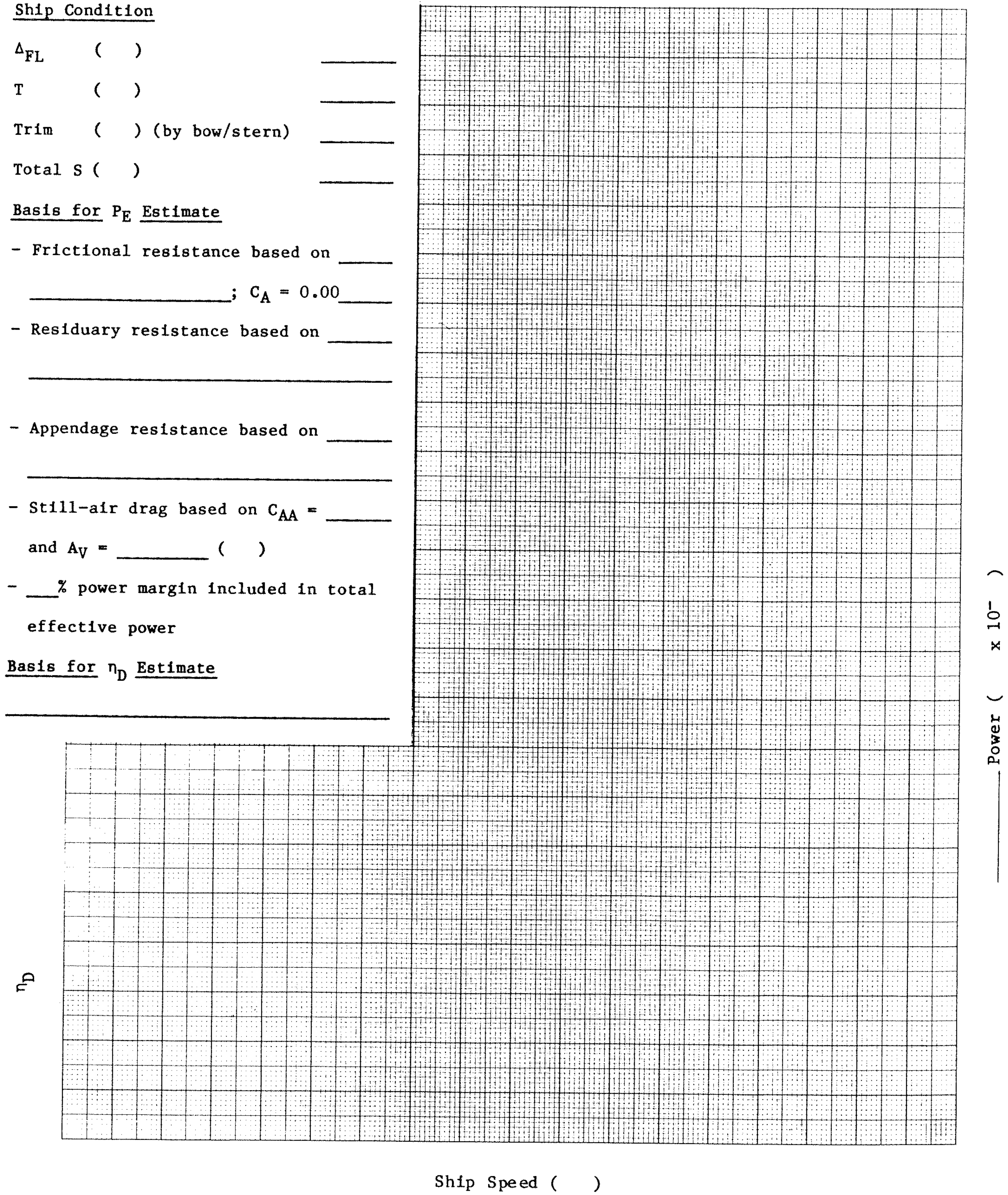


FIGURE ______ Speed-Power Curve(s) for
(Design Stage)

______; ______
(Ship, or Ship Design) (Ship Condition)

PERTINENT HULL FORM, APPENDAGE, AND PROPELLER DATA

Bare Hull Characteristics, to DWL:

L_{WL} ( ) ______
B_X ( ) ______
T_X ( ) ______
C_X ______
C_P ______
Δ_{BH} ( ) ______
S ( ) ______
A_0/A_X ______
A_{20}/A_X ______
i_E ( ) ______
B_{20}/B_X ______
C_{WP} ______
$\overline{FB}/L_{PP}$ ______
L_{PP}/B_X ______
B_X/T_X ______
$\Delta/(0.01L_{PP})^3$ ______
C_S ______

Bow Bulb or Bow-Mounted Sonar Dome Description:

______

______

______

______

Skeg:

Included in bare hull Δ and C_P?
Yes ( ) No ( )

Fore and Aft Extent: Sta. ___ to Sta. ___

Type: Appended ( ) Integral ( )

Hull Model Description:

Model No. ______
λ ______

Lines and/or Body Plan Drawing No.:

______

Prepared by: ______

Date: ______

Appendage Description:

Rudders
Number ______
Wetted Area (each) ( ) ______

Bilge Keels:
Depth (Maximum) ( ) ______
Extent Sta. ___ to Sta. ___

Stabilizer Fins:
Number ______
Wetted Area (each) ( ) ______

Main Shaft Strut Arms:
Type ______
Section ______
Chord ( ) ______
Thickness ( ) ______
Length ( ) ______

Intermediate Shaft Strut Arms:
Type ______
Section ______
Chord ( ) ______
Thickness ( ) ______
Length ( ) ______

Keel-Mounted Dome:
Type ______
Location Sta. ______

Description of Estimated Final Propeller(s):

Number of Propellers ______
Diameter ( ) ______
Type: FP ( ) CRP ( )
Nominal Ahead P/D ______
E.A.R. ______
Direction of Ahead Rotation:
Outboard ( ) Inboard ( )

Miscellaneous Data:

Propeller tip-to-hull clearance ( ) ______

Other:

______

______

FIGURE 7. NAVSEA Design Data Sheet 051-1 Standard Form for Speed Power Curves

TABLE 1

NAVSEA FORM FOR SMOOTH-WATER SPEED-POWER ESTIMATES FOR SURFACE DISPLACEMENT SHIPS

Ship ______________. Lines or Body Plan Drawing No. ________________. Estimate Date __/__/__. Estimator ____________.

SHIP CHARACTERISTICS

① L_{WL} (ft) = ________
② B_X (ft) = ________
③ T_X (ft) = ________
④ Δ_T (l. tons) = ________
⑤ Δ_{APP} (l. tons) = ________
⑥ Δ_{BH} (l. tons) = ________
⑦ C_X = ________
⑧ C_P = ________
⑨ B_X/T_X = ________
⑩ ∇_{BH} (ft^3) = ________
⑪ $C_{\nabla(BH)}$ = ________
⑫ D_P (ft) = ________
⑬ No./Type of Props. = ___/___
⑭ A_V (ft^2) = ________

CONSTRAINTS, RATIOS, AND FACTORS

⑮ **Seawater Temperature (°F)** = ________
⑯ **ρ (lb · sec^2 · ft^4)** = ________
(per Table 3, DDS 051-1)
⑰ **ν (ft^2 · sec^{-1})** = ________
(per Table 2, DDS 051-1)
⑱ **C_A** = ________
⑲ **$[\frac{C_{S(SHIP)}}{C_{S(TSS)}}]$** = ________
(*)
⑳ **$C_{S(TSS)}$** = ________
(per Fig. 2, DDS 051-1)
㉑ **$[\frac{S}{(\Delta \times L_{WL})^{0.5}}]$ (ft$^{1.5}$ · tons$^{-0.5}$)** = ________
(*)
㉒ **$C_{D(AP)}$ (HP · ft^{-2} · knots^{-3}** = ________
(per Fig. 4 or 5, DDS 051-1, or
source: ____________________) = ________
㉓ **C_{AA}** = ________
(source: ____________________)
㉔ **PMF** = ________
(per Table 4, DDS 051-1)

*** Determine from data for similar hull forms; data in Ref. (7), DDS 051-1 can be used.**

COMPUTATIONS

㉕ $S_{(TSS)}$ (ft^2) = [⑳ x (⑩ x ①)$^{0.5}$] = ____________
㉖ $S_{(Ship)}$ (ft^2) = (㉕ x ⑲) = ____________
or
[㉑ x (⑥ x ①)$^{0.5}$] = ____________
㉗ R_n = (1.689 x ① x ⓐ/⑰)
㉘ C_F = [0.075 / (Log$_{10}$ ㉗ − 2)^2]
㉙ R_F (lb) = [1.4264 x ⑯ x ㉖ x ⓐ^{2} x (⑱ + ㉘)]
= [____________ ⓐ^{2} x (0.______ + ㉘)]
㉚ $C_{R(TSS)}$
(per Reference (6), DDS 051-1)

㉛ 4/3[⑨ − (3.00)] = ________
㉜ $R_{R(TSS)}$ (lb) = (1.4264 x ⑯ x ㉕ x ⓐ^{2} x ⓜ)
= ____________ x ⓐ^{2} x ⓜ)
㉝ $P_{E(AP)}$ (HP) = (① x ⑫ x ⓐ^{3} x ㉒) = ________ x ⓐ^{3}
or
Explain derivation of $P_{E(AP)}$ values (note if keel domes included):
____
____
㉞ $P_{E(AA)}$ (HP) = (⑭ x ㉓ x ⓐ^{3} / 96,500) = ________ x ⓐ^{3}
㉟ $P_{E(MISC)}$ (HP) = ________
Explain derivation of $P_{E(MISC)}$ values or formulae:
____
____
㊱ η_D
Explain derivation of η_D values ______________________
____
____

ⓐ	ⓑ	ⓒ	ⓓ	ⓔ	ⓕ	ⓖ	ⓗ	ⓘ	ⓙ	ⓚ	ⓛ	ⓜ	ⓝ	ⓞ	ⓟ	ⓠ	ⓡ	ⓢ	ⓣ	ⓤ	ⓥ	ⓦ	ⓧ	ⓨ
V_S (knots)	$V/(L)^{0.5}$	R_n	C_F	R_F	B/T = 2.25	B/T = 3.00	B/T = 3.75	(ⓗ−ⓕ)/2	(ⓕ+ⓗ)/2 −ⓖ	㉛ x ⓘ	㉛^2 x ⓙ	$C_{R(TSS)}$	$R_{R(TSS)}$	WCF	$R_{R(Ship)}$	R_T	$P_{E(BH)}$	$P_{E(AP)}$	$P_{E(AA)}$	$P_{E(MISC)}$	ΣP_E	$P_{E(TOT)}$	η_D	P_S
	ⓐ/①$^{0.5}$	㉗	㉘	㉙	㉚	㉚	㉚					ⓖ+ⓚ+ⓛ	㉜		ⓝxⓞ	ⓔ+ⓟ	ⓐxⓠ / 325.6	㉝	㉞	㉟	ⓡ+ⓢ+ ⓣ+ⓤ	ⓥx ㉔	㊱	ⓦ/ⓧ
		x10 (**)	x10^{-3}		x 10^{-3}	x 10^{-3}	x 10^{-3}	x 10^{-3}	x 10^{-3}	x 10^{-3}	x 10^{-3}	x 10^{-3}												
		"	"		"	"	"	"	"	"	"	"												
		"	"		"	"	"	"	"	"	"	"												
		"	"		"	"	"	"	"	"	"	"												
		"	"		"	"	"	"	"	"	"	"												
		"	"		"	"	"	"	"	"	"	"												
		"	"		"	"	"	"	"	"	"	"												
		"	"		"	"	"	"	"	"	"	"												
		"	"		"	"	"	"	"	"	"	"												
		"	"		"	"	"	"	"	"	"	"												
		"	"		"	"	"	"	"	"	"	"												
		"	"		"	"	"	"	"	"	"	"												
		"	"		"	"	"	"	"	"	"	"												
		"	"		"	"	"	"	"	"	"	"												
		"	"		"	"	"	"	"	"	"	"												

** Indicate Appropriate Power of 10, e.g. 10^8

TABLE 1. NAVSEA Form for Smooth-Water Speed-Power Estimates for Surface Displacement Ships

TABLE 2. Kinematic Viscosity of Water

(Values Adopted by ATTC in 1942)

Kinematic Viscosity of Fresh Water $\nu \times 10^5$ (ft^2/sec)	Temperature (degree F)	Kinematic Viscosity of Sea Water $\nu \times 10^5$ (ft^2/sec)
1.9291	32	
1.9822	33	
1.8565	34	
1.8219	35	
1.7883	36	
1.7558	37	
1.7242	38	
1.6935	39	
1.6638	40	
1.6349	41	1.6846
1.6068	42	1.6568
1.5795	43	1.6298
1.5530	44	1.6035
1.5272	45	1.5780
1.5021	46	1.5531
1.4776	47	1.5289
1.4538	48	1.5053
1.4306	49	1.4823
1.4080	50	1.4599
1.3860	51	1.4381
1.3646	52	1.4168
1.3437	53	1.3961
1.3233	54	1.3758
1.3034	55	1.3561
1.2840	56	1.3368
1.2651	57	1.3180
1.2466	58	1.2996
1.2285	59	1.2817
1.2109	60	1.2641
1.1937	61	1.2470
1.1769	62	1.2303
1.1605	63	1.2139
1.1444	64	1.1979
1.1287	65	1.1822
1.1133	66	1.1669
1.0983	67	1.1519
1.0836	68	1.1372
1.0692	69	1.1229
1.0552	70	1.1088
1.0414	71	1.0951
1.0279	72	1.0816
1.0147	73	1.0684
1.0018	74	1.0554
0.98918	75	1.0427
0.97680	76	1.0303
0.96466	77	1.0181
0.95276	78	1.0062
0.94111	79	0.99447
0.92969	80	0.98299
0.91850	81	0.97172
0.90752	82	0.96067
0.89676	83	0.94982
0.88621	84	0.93917
0.87586	85	0.92873
0.86570	86	0.91847

TABLE 3. Speed-Power Margin Policy for Surface Ship Design

The NAVSEA speed-power margin policy for surface ship design is as follows:

- The power margin applicable during each stage of the design shall be applied to effective power(1), over the entire speed range.
- The effects of still-air drag shall be included in the estimates of effective power.
- The following margins(2) shall be applied to effective power(3):

  10% - During Feasibility and Preliminary Design, prior to development of a preliminary body plan, appendage configuration, etc.

  8% - During Preliminary and Contract Design, prior to conduct of self-propelled model tests.

  6% - During Preliminary and Contract Design, after self-propelled model tests with the stock propeller have been conducted. This margin is to be used with model test data which has been corrected for the difference between the anticipated performance of the final design propeller and the measured performance of the stock propeller.

  4% - During the final stages of Contract Design, after self-propelled model tests with the design propeller have been conducted.

---

(1) Although the power margins are applied to effective power estimates, they are intended to cover all the uncertainties in the resistance, hull-propeller interaction, and propeller efficiency estimates.

(2) The margins are given as percentages; however, they are frequently applied by means of a Power Margin Factor (PMF). Note that PMF = [1 + (margin, in percent)/100)]

(3) The estimates of effective power to which this policy applies are those which are appropriate for the condition of clean hull and propeller(s) and which are based on use of C_A values derived from the following formula for ship lengths between 190 feet and 960 feet:

$$C_A = [0.008289/L^{1/3}] - 0.00064$$

where L is ship length in feet. For ship lengths less than 190 feet, C_A has the value 0.0008; and for ship lengths greater than 960 feet, C_A has the value 0.0002.

TABLE 4. Density of Water

(Values Adopted by ATTC in 1942)

Density of Fresh Water ρ (lb x sec^2/ft^4)	Temperature (degree F)	Density of Sea Water ρ (lb x sec^2/ft^4)
1.9399	32	1.9947
1.9399	33	1.9946
1.9400	34	1.9946
1.9400	35	1.9945
1.9401	36	1.9944
1.9401	37	1.9943
1.9401	38	1.9942
1.9401	39	1.9941
1.9401	40	1.9940
1.9401	41	1.9939
1.9401	42	1.9937
1.9401	43	1.9936
1.9400	44	1.9934
1.9400	45	1.9933
1.9399	46	1.9931
1.9398	47	1.9930
1.9398	48	1.9928
1.9397	49	1.9926
1.9396	50	1.9924
1.9395	51	1.9923
1.9394	52	1.9921
1.9393	53	1.9919
1.9392	54	1.9917
1.9390	55	1.9914
1.9389	56	1.9912
1.9387	57	1.9910
1.9386	58	1.9908
1.9384	59	1.9905
1.9383	60	1.9903
1.9381	61	1.9901
1.9379	62	1.9898
1.9377	63	1.9895
1.9375	64	1.9893
1.9373	65	1.9890
1.9371	66	1.9888
1.9369	67	1.9885
1.9367	68	1.9882
1.9365	69	1.9879
1.9362	70	1.9876
1.9360	71	1.9873
1.9358	72	1.9870
1.9355	73	1.9867
1.9352	74	1.9864
1.9350	75	1.9861
1.9347	76	1.9858
1.9344	77	1.9854
1.9342	78	1.9851
1.9339	79	1.9848
1.9336	80	1.9844
1.9333	81	1.9841
1.9330	82	1.9837
1.9327	83	1.9834
1.9324	84	1.9830
1.9321	85	1.9827
1.9317	86	1.9823

NAVSEA FORM FOR SMOOTH-WATER SPEED-POWER ESTIMATES FOR SURFACE DISPLACEMENT SHIPS

Ship *Example*. Lines or Body Plan Drawing No. ______. Estimate Date *11/18/83* Estimator ______.

SHIP CHARACTERISTICS

① L_{WL} (ft) = *465.88*
② B_X (ft) = *62.00*
③ T_X (ft) = *20.00*
④ Δ_T (l. tons) = *8500.*
⑤ Δ_{APP} (l. tons) = *100.*
⑥ Δ_{BH} (l. tons) = *8400.*
⑦ C_X = *.825*
⑧ C_P = *.610*
⑨ B_X/T_X = *3.098*
⑩ ∇_{BH} (ft³) = *294000*
⑪ $C_{\nabla(BH)}$ = *2.908×10^{-3}*
⑫ D_P (ft) = *17.00*
⑬ No./Type of Props. = *2/CRP*
⑭ A_V (ft²) = *4030*

CONSTRAINTS, RATIOS, AND FACTORS

⑮ Seawater Temperature (°F) = *59.0*
⑯ ρ (lb · sec² · ft⁴) (per Table 3, DDS 051-1) = *1.9905*
⑰ ν (ft² · sec⁻¹) (per Table 2, DDS 051-1) = *1.2817×10^{-5}*
⑱ C_A = *.0004*
⑲ $\left[\frac{C_{S(SHIP)}}{C_{S(TSS)}}\right]$ (*) = *1.07*
⑳ $C_{S(TSS)}$ (per Fig. 2, DDS 051-1) = *2.540*
㉑ $\left[\frac{S}{(\Delta \times L_{WL})^{0.5}}\right]$ (ft$^{1.5}$ · tons$^{-0.5}$) (*) = *16.10*
㉒ $C_{D(AP)}$ (HP · ft^{-2} · knots^{-3} (per Fig. 4 or 5, DDS 051-1, or source: ______) = *2.80×10^{-5}* = ______
㉓ C_{AA} (source: ______) = *0.70*
㉔ PMF (per Table 4, DDS 051-1) = *1.08*

* Determine from data for similar hull forms; data in Ref. (7), DDS 051-1 can be used.

COMPUTATIONS

㉕ $S_{(TSS)}$ (ft²) = [⑳ x (⑩ x ①)$^{0.5}$] = *29726*
㉖ $S_{(Ship)}$ (ft²) = (㉕ x ⑲) = ______
or
[㉑ x (⑥ x ①)$^{0.5}$] = *31849*
㉗ R_n = (1.689 x ① x ⓐ/ ⑰)
㉘ C_F = [0.075 / (Log$_{10}$ ㉗ - 2)²]
㉙ R_F (lb) = [1.4264 x ⑯ x ㉖ x ⓐ² x (⑱ + ㉘)]
= [*90427.3* ⓐ² x (0.*0004* + ㉘)]
㉚ $C_{R(TSS)}$ (per Reference (6), DDS 051-1)

㉛ 4/3[⑨ - (3.00)] = *0.1307*
㉜ $R_{R(TSS)}$ (lb) = (1.4264 x ⑯ x ㉕ x ⓐ² x ⓜ)
= *84399.5* x ⓐ² x ⓜ)
㉝ $P_{E(AP)}$ (HP) = (① x ⑫ x ⓐ³ x ㉒) = *.2218* x ⓐ³
or
Explain derivation of $P_{E(AP)}$ values (note if keel domes included): ______
㉞ $P_{E(AA)}$ (HP) = (⑭ x ㉓ x ⓐ³ / 96,500) = *.0292* x ⓐ³
㉟ $P_{E(MISC)}$ (HP) = ______
Explain derivation of $P_{E(MISC)}$ values or formulae: ______
㊱ η_D
Explain derivation of η_D values *no value determined by NAVSEA 56X*

ⓐ	ⓑ	ⓒ	ⓓ	ⓔ	ⓕ	ⓖ	ⓗ	ⓘ	ⓙ	ⓚ	ⓛ	ⓜ	ⓝ	ⓞ	ⓟ	ⓠ	ⓡ	ⓢ	ⓣ	ⓤ	ⓥ	ⓦ	ⓧ	ⓨ
V_S (knots)	$V/(L)^{0.5}$	R_n	C_F	R_F	B/T = 2.25	B/T = 3.00	B/T = 3.75	(ⓗ-ⓕ)/2	(ⓕ+ⓗ)/2 - ⓖ	㉛ x ⓘ	㉛² x ⓙ	$C_{R(TSS)}$	$R_{R(TSS)}$	WCF	$R_{R(Ship)}$	R_T	$P_{E(BH)}$	$P_{E(AP)}$	$P_{E(AA)}$	$P_{E(MISC)}$	ΣP_E	$P_{E(TOT)}$	η_D	P_S
	ⓐ/①$^{0.5}$	㉗	㉘	㉙	㉚	㉚	㉚					ⓖ+ⓚ+ⓛ	㉜		ⓝ x ⓞ	ⓔ+ⓟ	ⓐ x ⓠ / 325.6	㉝	㉞	㉟	ⓡ+ⓢ+ⓣ+ⓤ	ⓥ x ㉔	㊱	ⓦ/ⓧ
12.95	0.60	7.950 x 10^{8}	1.575x 10^{-3}	29951	.345x 10^{-3}	.427x 10^{-3}	.540x 10^{-3}	.098x 10^{-3}	.016 x 10^{-3}	.013x 10^{-3}	0 x 10^{-3}	.440x 10^{-3}	6228	3.45	21486	51437	2046	482	63	-	2591	2798	.680	4115
15.11	0.70	9.276 "	1.532 "	39887	.355 "	.455 "	.555 "	.100 "	0 "	.013 "	0 "	.468 "	9018	3.22	29037	68924	3198	765	101	-	4064	4389	.680	6455
17.27	0.80	10.602 "	1.519 "	51756	.475 "	.655 "	.660 "	.093 "	-.088 "	.012 "	-.0015"	.666 "	16764	2.20	36883	88639	4701	1142	151	-	5994	6474	.680	9520
19.43	0.90	11.929 "	1.497 "	64761	.825 "	1.015 "	1.01 "	.093 "	-.098 "	.012 "	-.0017"	1.025 "	32659	1.54	50295	115057	6866	1627	214	-	8707	9404	.680	13829
21.58	1.00	13.248 "	1.478 "	79086	1.575 "	1.635 "	1.60 "	.013 "	-.048 "	.0017 "	-.0008"	1.636 "	64302	1.09	70089	149175	9887	2229	294	-	12410	13403	.680	19710
23.74	1.10	14.574 "	1.461 "	94843	1.620 "	1.940 "	2.03 "	.205 "	-.115 "	.0268"	-.0020"	1.965 "	93468	0.92	85990	180833	13184	2968	391	-	16543	17866	.675	26469
25.90	1.20	15.901 "	1.466 "	111977	2.110 "	2.520 "	2.680"	.285 "	-.125 "	.0372"	-.0021"	2.555 "	144654	0.83	120063	232040	18458	3854	508	-	22820	24646	.670	36784
28.06	1.30	17.227 "	1.432 "	130437	3.570 "	3.710 "	4.000"	.215 "	.075 "	.0281 "	.0013 "	3.737 "	248321	0.80	198657	329094	28361	4900	646	-	33407	36620	.665	55067
		"	"		"	"	"	"	"	"	"	"												
		"	"		"	"	"	"	"	"	"	"												
		"	"		"	"	"	"	"	"	"	"												
		"	"		"	"	"	"	"	"	"	"												
		"	"		"	"	"	"	"	"	"	"												
		"	"		"	"	"	"	"	"	"	"												
		"	"		"	"	"	"	"	"	"	"												

TABLE 5. Sample Speed-Power Estimate

TABLE 6. Example of Speed-Power Estimate Using Program TSS 84
Sheet 1

Length, W.L. (ft) = 465.88
Beam at Sta. X (ft) = 62.00
Draft at Sta. X (ft) = 20.01
Displacement, B.H. (l.t.) = 8,400
Wetted Surface (ft^2) = 31,849

C_B = 0.5087
C_P = 0.6100
C_X = 0.8250
C_V = 2.908
B/T = 3.098

Density (lb • sec^2/ft^4) = 1.9905
Viscosity (ft^2/sec) x 10^5 = 1.2791*
Correlation Allowance = 0.0004**
Taylor Wetted Surface (ft^2) = 29,719

Ship Speed (knots)	Speed/ Length Ratio	TSS R_R/ Displ (lb/ton)	Worm Curve Factor	Residuary Resistance (lb)	C_F (ITTC) x 1000	Frictional Resistance (lb)	Total Resistance (lb)	Bare Hull EHP
12.95	0.60	0.74	3.45	21,468	1.575	29,944	51,412	2,045
15.11	0.70	1.07	3.22	28,960	1.545	40,136	69,096	3,206
17.27	0.80	2.00	2.20	36,913	1.519	51,738	88,651	4,701
19.43	0.90	3.88	1.54	50,216	1.497	64,734	114,950	6,857
21.58	1.00	7.66	1.09	70,157	1.478	79,111	149,268	9,893
23.74	1.10	11.15	0.92	86,129	1.461	94,856	180,985	13,195
25.90	1.20	17.25	0.83	120,298	1.446	111,959	232,257	18,472
28.06	1.30	29.60	0.80	198,914	1.432	130,410	329,324	28,375
30.22	1.40	49.54	0.80	332,882	1.419	150,200	483,082	44,825

* TSS 84 default value for kinematic viscosity.

** For this example, C_A value was rounded off from 0.00043 to 0.0004; the recommended practice is to use C_A values rounded to two significant figures.

TABLE 6. Sheet 2

Length, W.L. (ft) = 465.88 C_B = 0.5087
Beam at Sta. X (ft) = 62.00 C_P = 0.6100
Draft at Sta. X (ft) = 20.01 C_X = 0.8250
Displacement, B.H. = 8,400 C_V = 2.908
Wetted Surface (ft^2) = 31,849 B/T = 3.098

Power Margin (percent) = 8.0
Still-Air Drag Coefficient = 0.700
Frontal Area (ft^2) = 4,030
Appendage Drag Coefficient = 2.800
Propeller Diameter (ft) = 17.00

Ship Speed (knots)	Speed/ Length Ratio	Bare Hull EHP	Still-Air EHP	Appendage EHP	Total EHP (no margin)	Total EHP (w/margin)	P.C.	SHP
12.95	0.60	2,045	63	482	2,590	2,797	0.680	4,113
15.11	0.70	3,206	101	765	4,071	4,397	0.680	6,466
17.27	0.80	4,701	151	1,142	5,993	6,472	0.680	9,518
19.43	0.90	6,857	214	1,626	8,697	9,393	0.680	13,815
21.58	1.00	9,893	294	2,230	12,417	13,411	0.680	19,721
23.74	1.10	13,195	391	2,968	16,554	17,879	0.675	26,487
25.90	1.20	18,472	508	3,853	22,834	24,660	0.670	36,807
28.06	1.30	28,375	646	4,899	33,920	36,634	0.665	55,089
30.22	1.40	44,825	807	6,119	51,751	55,891	0.665	84,047