PROGRAM PHFMOPT
PLANNING HULL FEASIBILITY MODEL
USER'S MANUAL

by

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Planing Craft, Feasibility Model

Documentation of a computer program for performing design feasibility studies of planing hulls is presented. The mathematical model is oriented to combatant craft but may also be applied to other types of planing ships with full-load displacement up to 1500 tons and speed-displacement coefficient ($F_{MV}$) up to 4. Options are available for structural materials of aluminum or steel or glass reinforced plastic, diesel or gas turbine prime movers with or without auxiliary engines of either type, and propellers on inclined shaft or waterjet pumps. Weight, volume, and vertical center of gravity for the major
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<td>Center of gravity</td>
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<td>CODOG</td>
<td>Combination of diesel or gas turbine propulsion; gas turbine prime movers designed for maximum speed and auxiliary diesels designed for cruise speed</td>
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<td>COGOG</td>
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Lp  Projected chine length

LOA  Overall length of ship

Lp/\(v^{1/3} \)  Slenderness ratio

N  Rotational speed; RPM

NPSH  Net positive suction head of waterjet pump

OPC  Overall performance coefficient = \( P_E/P_D \)

P/D  Propeller pitch ratio

PA  Atmospheric pressure

PC  Total brake power required at cruise speed

Pd  Total brake power required at design speed

PD  Total power delivered at propellers or waterjets

PE  Effective power

PEb  Effective power of bare hull

PH  Static water pressure on rotating axis of propeller or waterjet pump

PV  Vapor pressure

Q  Torque on propeller shaft

Q  Mass flow of waterjet pump = \( A_jV_j = A_1V_1 \)

Qc  Propeller torque load coefficient

R  Resistance

R/W  Resistance/weight ratio

S/\(v^{2/3} \)  Wetted area coefficient

SS  Suction specific speed of waterjet pump

SFC  Specific fuel consumption

T  Thrust

T  Draft at midships; baseline to waterline

Vc  Cruise (range) ship speed

Vd  Design (maximum) ship speed

Vi  Average flow velocity into waterjet pump inlet

VJ  Jet velocity of pump at operating ship speed = \( V_{JB} + \Delta V_J \)
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<td>( W_{CE} )</td>
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<td>( W_F )</td>
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<td>( Y_K )</td>
<td>Half-breadth at keel</td>
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<td>( Y_S )</td>
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<td>( Z_C )</td>
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<td>Height of keel above baseline</td>
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Appendage drag factor

Propulsive coefficient \( = \frac{P_E}{P_D} \)

Propeller efficiency

Viscosity of water

Water density

Propeller cavitation number based on advance velocity

Standard deviation

Stress limit of structural material

Waterjet impeller tip velocity cavitation number

Cavitation number based on resultant water velocity at 0.7 radius of propeller

Thrust load coefficient for propeller or waterjet

Displaced volume

Hull volume up to main deck

Volume of payload inside of hull and superstructure

Volume inside superstructure

Total volume \( = V_h + V_{ss} \)
ABSTRACT

Documentation of a computer program for performing design feasibility studies of planing hulls is presented. The mathematical model is oriented to combatant craft but may also be applied to other types of planing ships with full-load displacement up to 1500 tons and speed-displacement coefficient $F_{n\nu}$ up to 4. Options are available for structural materials of aluminum or steel or glass reinforced plastic, diesel or gas turbine prime movers with or without auxiliary engines of either type, and propellers on inclined shafts or waterjet pumps. Weight, volume, and vertical center of gravity for the major ship components, including loads, are estimated. Hull size may either be fixed or optimized to meet design payload requirements.

ADMINISTRATIVE INFORMATION

Modifications for the current program were authorized and funded by the Naval Sea Systems Command, Detachment Norfolk (NAVSEADET Norfolk) Project Order 00016. The work was performed at the David W. Taylor Naval Ship Research and Development Center (DTNSRDC) under Work Unit 1-1524-718.

INTRODUCTION

A computer program labeled PHFMOPT has been developed at DTNSRDC and utilized in numerous design feasibility studies by NAVSEADET Norfolk for combatant craft projects such as the Special Warfare Craft, Medium SWCM and Landing Craft LCM-9. The computer software has been revised and updated numerous times to keep abreast of the project requirements and state-of-the-art. This report provides a general description of the present mathematical model together with documentation for each module of the computer program in Appendix A. This program is operable on the Control Data Corporation 6000 Computers at DTNSRDC and has also been recently installed on the Digital Equipment Corporation PDP/8 Computer at NAVSEADET Norfolk. Sample input and output are shown in Appendix B.

The planing hull feasibility model PHFMOPT is applicable for a wide range of planing-hull prototypes with slenderness ratio $L_p/V_l^{1/3}$ from 4 to 10, speed-displacement coefficient $F_{n\nu}$ from 0.5 to 4.0, and displacement from 50 to 1500 tons. A comparison of the model with an actual patrol craft and an example of a design study utilizing the model has been presented in Reference 1.

*A complete listing of references is given on page 17.*
GENERAL DESCRIPTION OF MODEL

Computer program PHFMOPT estimates the weight, volume, and vertical center of gravity VCG of major components for the empty ship plus the fuel load, crew, and provisions. Then, either (1) the resultant weight, volume, and VCG of the payload is computed for a hull of fixed size, or (2) the hull depth $H$, maximum chine beam $B_{PX}$, and/or displacement $\Delta_{LT}$ are optimized to meet design payload requirements for a ship of fixed length $L_p$. Computations may be made for several values of $L_p$ to determine the optimum ship length.

Ship components for the U.S. Navy Bureau of Ships Consolidated Index BSCI Groups 1 through 6 are computed at the three-digit level. The data base for the model includes small patrol craft, hydrofoil craft, destroyers DD, and destroyer escorts DE so that planing ships up to 1500 tons can be evaluated. A multiplier (K-factor) is input for each three-digit BSCI group which may be used to modify or eliminate weights and volumes derived from the general equations presented in Appendix A. A K-factor is also applied to the total of each single-digit group, essentially adding a designer's margin.

Input to the program is read by Subroutine READIN and consists of 54 punched data cards which contain offsets for the parent hull form and design constants. Data from the cards are immediately printed for use in checking input errors. In addition, one card for each design condition, containing the length $L_p$ and initial values of $\Delta_{LT}$, $B_{PX}$, and $H$, is read by the executive routine PHFMOPT. A detailed description of the input and the printed output is presented in Appendix A. Output is controlled by Subroutine PRTOUT.

HULL GEOMETRY

The planing hull is represented by a hard-chine model as shown in Figure 1. Offsets input for the parent hull form are nondimensionalized in Subroutine PARENT. Offsets and hydrostatics for each new design condition of $L_p$, $B_{PX}$, and $\Delta_{LT}$ are computed by Subroutine NEWHUL. All parametric variations have the same deadrise as the parent, since the keel and chine offsets are proportioned by the average beam $B_{PA}$ and $B_{PX}/B_{PA}$ is held constant. The hull volume below the main deck $V_h$ and the hull density
$\Delta/V_h$ are computed by Subroutine NEWVOL for each change in $H_h$. Slope of the hull sides is maintained whenever deck height is changed.

The general arrangement of the transverse bulkheads, platforms, and fuel tanks employed by the planing hull model is shown in Figure 2. Nine bulkheads positioned as shown are used for planing hulls over 70 tons and should be sufficient for a two-compartment ship aft and a three-compartment ship forward for most configurations. The number of bulkheads is reduced for smaller craft based on existing designs. The general arrangement used for the landing craft model is shown in Figure 3. For this special case, additional input parameters are required to define the well deck and ramps. A maximum of 15 bulkheads may be input, and a spacing of about 6 ft between bulkheads is used under the well deck.

STRUCTURES

The hull structures (BSCI Group 1) are computed in Subroutine STRUCT. The structural design procedure takes into account sea loads and effects of changes in hull length, beam, and depth. The design methodology is based on References 2, 3, and 4 and explained in detail in Reference 1. Structures of either aluminum, steel, or glass reinforced plastic GRP may be computed. Two interchangeable Subroutines STRUCT are available, one for aluminum or steel hulls, the other for single skin or sandwich plate GRP hulls. Curves of structural weight data used by the math model are shown in Figures 4, 5, 6, 7, and 8.

A third Subroutine STRUCT is available for landing craft of aluminum or steel which accounts for the increased load on the well deck and ramps and changes in the internal arrangement.

RESISTANCE

Bare-hull resistance for the feasibility model is estimated from DTNSRDC Series 62 and 65 hard-chine planing hull data published in Reference 5. Mean values of resistance/weight ratio $R/W$ as a function of $L_p/V^{1/3}$ and $F_{nV}$ were computed from the 21 models of the two series with the longitudinal center of gravity LCG position ranging from $1/3$ to $1/2$ $L_p$ forward of the transom. Mean values of wetted area coefficient $S/V^{2/3}$ were obtained for the same data. Faired curves of the mean $R/W$ for a
100,000-lb planing craft and mean $S/V^{2/3}$ are presented in Figures 9 and 10. Data from the faired curves have been incorporated in Subroutine PHRES (see Tables 1 and 2) so that the mean R/W can be interpolated for $L_p/V^{1/3}$ from 4 to 10 at $F_{nV}$ from 0 to 4 and scaled to the required ship size. Standard deviation $\sigma$ of the base data from the mean values was also computed and faired as a function of $F_{nV}$. A multiplier SDF may be used with $\sigma$ to raise or lower the mean R/W data when attempting to match existing resistance data for a particular hull form.

Predicted R/W = Mean R/W - (SDF x $\sigma$)

Resistance of the appended hull is estimated by applying an appendage drag factor $\eta_a$ to the bare-hull resistance. The factor $\eta_a$ developed by Blount and Fox, Reference 6, is applied only to hulls with propellers on inclined shafts. No increase in resistance is assumed for hulls fitted with waterjets.

Added resistance in rough water $R_{aw}$ is predicted from an empirical equation given in Reference 7 which was developed by a regression of planing hull rough-water experimental data.

$$R_{aw}/\Delta = 1.3 \left(\frac{H_{1/3}}{B_P}\right)^{0.5} F_{nV} (L_p/V^{1/3})^{-2.5}$$

**THRUST**

The feasibility model has the option for either propellers on inclined shafts or waterjet pumps. Thrust deduction $(1-t)$ used for the propellers is 0.92 from Blount and Fox, Reference 6. Thrust deduction assumed for waterjets is 0.95. Total thrust requirement $T = R_t/(1-t)$ where $R_t$ is total resistance.

Subroutine PROPS is utilized to estimate the powering requirements for the ship at design and cruise speed when propellers are employed. If not input, the number of propellers is selected based on maximum power of prime movers available. Subroutine PROPS also determines propeller diameter if not specified, selecting the smallest propeller capable of producing the required thrust at both design and cruise speeds, based on an input constant for $\tau_c/\sigma_{0.7R}$. A value of $\tau_c/\sigma_{0.7R} = 0.6$ corresponds to the 10 percent back cavitatation criteria for Gawn-Burrill type propellers.
Propeller open-water characteristics are derived as a function of pitch ratio \( P/D \), expanded area ratio \( EAR \), and number of blades \( Z \) from polynomials developed from the Wageningen B-Screw Series of airfoil section propellers, Reference 8, or recent modifications of these polynomials for flat face, segmental section propellers such as the Gawn-Burrill Series, Reference 9. Propeller characteristics in the cavitation regime are derived from maximum thrust and torque load coefficient \( \tau_c \) and \( Q_c \) developed as functions of cavitation numbers at the propeller 0.7 radius \( \sigma_{0.7R} \) in Reference 10.

Subroutine WJETS is used to estimate the power requirements with waterjet pumps. Waterjets of fixed size may be input, or the waterjets may be designed within the program using the approach given by Denny in Reference 11. The design pumps are assumed to operate at maximum input power and maximum rpm at the ship's design speed. A ratio of bollard jet velocity \( V_{JB} \) to ship speed \( V_S \) about 2 will result in optimum propulsive efficiency; see Figure 3 of Reference 11. However at low design speeds, e.g., 20 knots, a value of \( V_{JB}/V_S > 2 \) may be required in order to keep the size of the waterjet within reasonable bounds.

PROPULSION

Once the power estimates are made for design and cruise speeds, the propulsion (BSCI Group 2) components are calculated in Subroutine POWER. The following propulsion systems are available in the computer model:

1. diesel prime movers,
2. gas turbine prime movers,
3. CODOG system -- gas turbine prime movers with auxiliary diesels,
4. COGOG system -- gas turbine prime movers with auxiliary gas turbines.

There is always one prime mover for each propeller or waterjet. The prime movers are designed to operate at maximum power at the ship's design speed; the auxiliary engines operate at their maximum power at cruise speed.
General equations for specific weight, rotational speed, and specific fuel consumption SFC have been developed for high speed diesels and second generation gas turbines. Data from the general equations may be modified by input constants to match a particular series of engines, or fixed weights and SFC's may be input to the program. Gear weights may be fixed or derived from a general equation developed by Mandel at Massachusetts Institute of Technology with appropriate constants for either single reduction or planetary gears. Propeller and waterjet weights are primarily a function of their size. Subsidiary propulsion system weights are given as a function of the total power of the prime movers.

Volumes required for the engine room, combustion air supply, and uptakes may be fixed inputs or obtained from the general equations based on existing diesel and gas turbine systems.

OTHER SYSTEMS

The electric plant (BSCI Group 3) components are computed in Subroutine ELECPL. The electric power requirement in kilowatts may be an input or computed as a function of the ship displacement.

The nonelectronic navigation equipment and interior communication system are established in Subroutine COMCON. The remainder of communication and control (BSCI Group 4) is considered part of the payload.

Auxiliary systems (BSCI Group 5) and the outfit and furnishings (BSCI Group 6) are computed in Subroutines AUXIL and OUTFIT. The general equations were primarily derived from DD and DE data. However, changes were made for aluminum components in lieu of steel, using 2/3 the weight of steel where equal stress is required and 1/2 the weight of steel where size is maintained.

LOADS

The fuel requirement is established in Subroutine POWER based on the SFC and range at either cruise speed or design speed, whichever dominates. A five percent margin is added for fuel which cannot be utilized. An additional five percent margin is added to the volume of the fuel tanks.
to allow for expansion. The fuel tanks are generally an integral part of the hull structure, but an option is available for separate fuel tanks when required.

The ship's complement may either be input or calculated in Subroutine CREWSS based on accommodations of numerous small and intermediate-sized warships. The crew concerned with the military payload is included in the total complement and not treated as part of the military payload. Weights and volumes of the crew and their effects based on U.S. Navy standard allowances, as well as personnel stores and potable water for the specified accommodations and days at sea, are computed in Subroutine LOADS.

The components of BSCI Groups 1 through 6 are combined and specified margins added in Subroutine TOTALS to obtain the empty ship weight, volume, and VCG. The difference between the full-load displacement and the empty ship weight is termed the useful load, which includes the fuel, crew and provisions, and the payload. The payload consists of the armament (BSCI Group 7), the military portion of communication and control (Group 4), ammunition, and any special loads required for the ship's mission, such as the tanks carried by a landing craft. The computer model does not separate the various components of the payload.

OPTIMIZATION

Unless the hull size is fixed, the executive routine PHPMOPT iterates until the design payload specifications are met, or until a default condition occurs. The ship displacement is increased or decreased until the resultant payload weight $W_p$ is equal to the input value for design payload. The beam of the hull is varied until the specified VCG of the design payload is obtained, maintaining the input metacentric height $\bar{GM}$. The hull depth is raised or lowered to obtain the design payload volume $V_p$ (payload density $= W_p/V_p$). A flow chart of the optimization process is presented in Appendix A.
Possible default conditions are as follows:

1. $L_p/V^{1/3}$ less than 4 or greater than 10,
2. $F_{nv}$ greater than 4,
3. $\Delta_{LT}$, $B_{px}$, or $H_n$ not converging after 10 iterations for each variable.

A default may occur if the initial values of $\Delta_{LT}$, $B_{px}$, and $H_n$ are not close to the optimums. Therefore, the program user may be wise to begin a new design with several fixed hull sizes to aid in the selection of initial values for the optimization process.

**FINAL HULL**

Weights, VCG's, and volumes for the final (or fixed) hull form are printed from Subroutine PRTOUT at the BSCI 3-digit level. Also output are offsets and hydrostatics for the final hull, speed-power predictions for a range of speeds, and some vertical acceleration predictions in various sea states based on empirical equations in Reference 12. A sample printout is shown in Appendix B.
Figure 1 - Geometry of Computer Model for Planing Hull
Figure 2 - General Arrangement of Typical Planing Hull

Figure 3 - General Arrangement of Typical Landing Craft
Figure 4 - Weight of Stiffened Plating as Function of Design Load
Figure 5 - Weight of Stiffened Plating for Hull Sides

Figure 6 - Hull Framing System Weights
Figure 7 - Propulsion Plant Foundation Weights

Figure 8 - Auxiliary and Other Equipment Foundation Weights
MEAN VALUES OF RESISTANCE-WEIGHT RATIO R/W FROM SERIES 62 AND 65 HARD-CHINE PLANING HULLS
DATA PUBLISHED IN NSRDC REPORT 4307, APR 1974
LCG VARIATION FROM 1/3 TO 1/2 Lp FWD OF TRANSOM

DISPLACEMENT IN SEAWATER AT 59 °F = WEIGHT = 100,000 lb

SPEED-DISPLACEMENT COEFFICIENT CnV

Figure 9 - Mean Values of Resistance/Weight Ratio from Series 62 and 65 Data
MEAN VALUES OF WETTED AREA COEFFICIENT $S/V^{2/3}$
FROM SERIES 62 AND 65 HARD-CHINE PLANING HULLS
DATA PUBLISHED IN NSRDC REPORT 4307, APR 1974
LCG VARIATION FROM 1/3 TO 1/2 $L_p$ FWD OF TRANSOM

Figure 10 – Mean Values of Wetted Area Coefficient
from Series 62 and 65 Data
REFERENCES


APPENDIX A

DOCUMENTATION OF SUBPROGRAMS
FLOW CHART OF EXECUTIVE ROUTINE PHFMOPT

START

CALL READIN

CALL PARENT

READ HULL PARAMETERS

DO 90 KK = 1,10

FINAL DISPL = CURRENT DISPL

IS DISPL FIXED?

NDT = 1

NDT = 3

DO 80 L = 1,NDT

DO 70 JJ = 1,10

FINAL BEAM = CURRENT BEAM

IS BEAM FIXED?

NBX = 1

NBX = 3

DO 60 J = 1, NBX

CALCULATE HULL FORMS WITH 1 OR 3 BEAMS

CALCULATE HULL FORMS AT 1 OR 3 DISPLACEMENTS

BEGIN BEAM OPTIMIZATION 10 ITERATIONS MAXIMUM

BEGIN DISPL OPTIMIZATION

10 ITERATIONS MAXIMUM

FIXED LENGTH; INITIAL VALUES OF DISPLACEMENT, BEAM, AND HULL DEPTH

NONDIMENSIONALIZE PARENT HULL FORM

READ PARENT FORM AND DESIGN CONSTANTS

FIXED LENGTH; INITIAL VALUES OF DISPLACEMENT, BEAM, AND HULL DEPTH

BEGIN DISPL OPTIMIZATION

10 ITERATIONS MAXIMUM

NONDIMENSIONALIZE PARENT HULL FORM

READ PARENT FORM AND DESIGN CONSTANTS

1
LECALCULATE OFFSETS AND HYDROSTATICS FOR CURRENT LENGTH, BEAM, DISPL
CALL CREWSS - DEFINE SHIP'S COMPLEMENT AND SUPERSTRUCTURE SIZE
CALL POWER - ESTIMATE POWER REQUIREMENTS
CALL PROPULSION SYSTEM
BEGIN DEPTH OPTIMIZATION 10 ITERATIONS MAXIMUM

DO 50 II = 1,10

IS HULL DEPTH FIXED?

NVD = 1

NVD = 3

THREE DEPTHS; CURRENT VALUE, ± INCREMENT

CALCULATE HULL FORMS WITH 1 OR 3 DEPTHS
CALL NEWHULL
CALL CREWSS
CALL POWER
DO 40 ! = 1, NVD
CALL NEWVOL
CALL STRUCT
CALL LOADS
CALL ELECPL
CALL COMCON

CALCULATE ENCLOSED VOLUME WITH CURRENT HULL DEPTH
CALL STRUCTURES FOR CURRENT HULL
CALL FUEL LOAD, CREW, AND PROVISIONS
CALL ELECTRIC PLANT COMPONENTS
CALL NONMILITARY COMMUNICATION AND CONTROL

FINAL DEPT = CURRENT DEPTH

21
CALL AUXIL
CALL OUTFIT
CALL TOTALS
END 40 LOOP

YES

IS NVD = 1 ?

CALCULATE NEW HULL DEPTH

NO

IS CHANGE IN DEPTH ≤ 1% ?

END 50 LOOP

END 60 LOOP

YES

IS NBX = 1 ?

CALCULATE NEW BEAM

NO

IS CHANGE IN BEAM ≤ 1% ?

END 70 LOOP

INTERPOLATED AT DESIGN VCC OF PAYLOAD

INTERPOLATED AT DESIGN PAYLOAD DENSITY

CALCULATE AUXILIARY SYSTEMS

CALCULATE OUTFIT AND FURNISHINGS

CALCULATE TOTALS FOR BSCI GROUPS 1 THROUGH 6, USEFUL LOAD, AND PAYLOAD
END 80 LOOP

IS NDT = 1 ?

CALCULATE NEW DISPLACEMENT

INTERPOLATED AT DESIGN PAYLOAD

IS CHANGE IN DISPL < 1% ?

END 90 LOOP

CALL COSTS

CALL PRTOUT

ANY MORE INPUT ?

STOP

ESTIMATE EMPTY SHIP AND LIFE COSTS

PRINT RESULTS FOR FINAL HULL FORM

YES

NO

YES

NO
NAME: PROGRAM PHM OPT

PURPOSE: Executive routine for planing hull feasibility model. If hull size is fixed, estimate weight, volume, and vertical center of gravity VCG of major ship components and determine the resultant payload availability. If hull size is to be optimized, vary hull depth, beam, and/or displacement as specified until the design payload requirements are met.

SUBPROGRAMS CALLED: READIN, PARENT, NEWHUL, CREWSS, POWER, NEWVOL, STRUCT, LOADS, ELECPL, COMCON, AUXIL, OUTFIT, TOTALS, YINTE, COSTS, PRTOUT

INPUT: Via COMMON blocks and Card Set 29
See Subroutine READIN

IOPT Control for optimization of displacement ΔLT, maximum beam B_{PX}, and/or hull depth H_{h}, from Card 6

PL \( L_p \) = projected chine length of ship in ft, from Card 29
DTONS \( \Delta_{LT_o} \) = initial value of displacement in long tons,* from Card 29
BPX \( B_{PX_o} \) = initial value of maximum chine beam in ft, from Card 29
HDM \( H_{h_o} \) = initial value of hull depth at midships in ft, from Card 29
WPDES \( W_p' \) = design payload weight in tons, from input Card 9
VPDES \( V_p' \) = design payload volume in ft\(^3\), from input Card 9
ZPDES \( Z_{p'} \) = VCG of design payload in ft above main deck at midships, from Card 9
DELDT \( d\Delta_{LT} \) = increment of displacement in tons, from Card 28
DELBX \( dB_{PX} \) = increment of \( B_{PX} \) in ft, from Card 28
DELHD \( dH_{h} \) = increment of \( H_{h} \) in ft, from Card 28
BXMIN \( B_{min} \) = minimum value of \( B_{PX} \) in ft, from Card 28
BXMAX \( B_{max} \) = maximum value of \( B_{PX} \) in ft, from Card 28

*Weights in long tons will generally be referred to simply as "tons" in this report. 1 ton = 1 long ton = 2240 lb = 0.9842 metric tons.
PROGRAM PHFMOP

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>HDMIN</td>
<td>minimum value of ( H_h ) in ft, from Card 28</td>
</tr>
<tr>
<td>HDMAX</td>
<td>maximum value of ( H_h ) in ft, from Card 28</td>
</tr>
</tbody>
</table>

**OUTPUT:**

Via COMMON blocks

- **WPLBS**
  
  \[ (W_p)_D \] = design payload weight in lb
  
  \[ 2240 (W_p' \text{ in tons}) \]

- **PLDEN**
  
  \[ (W_p/V_p)_D \] = design payload density in lb/ft
  
  \[ 2240W'/Y' \]

- **ZPDES**
  
  \[ (Z_p)_D \] = design payload VCG in ft above main deck
  
  \[ \text{input } Z'_p \]

**L**  
Index for outer DO LOOP \( L=1, NDT \)

**J**  
Index for middle DO LOOP \( J=1, NBX \)

**I**  
Index for inner DO LOOP \( I=1, NVD \)

**NDT**  
Number of displacements calculated in outer loop

- If \( IOPT < 3 \), then \( NDT = 1 \), and final \( \Delta_{LT} = \Delta_{LT_0} \)
- Otherwise, \( NDT = 3 \), and \( \Delta_{LT} \) is optimized

**NBX**  
Number of beams calculated in middle loop

- If \( IOPT < 2 \), then \( NBX = 1 \), and final \( B_{PX} = B_{PX_0} \)
- If \( B_{PX_0} < B_{min} \), then \( NBX = 1 \), and final \( B_{PX} = B_{min} \)
- If \( B_{PX_0} > B_{max} \), then \( NBX = 1 \), and final \( B_{PX} = B_{max} \)
- Otherwise, \( NBX = 3 \), and \( B_{PX} \) is optimized

**NVD**  
Number of hull depths calculated in inner loop

- If \( IOPT < 1 \), then \( NVD = 1 \), and final \( H_h = H_{h_0} \)
- If \( H_{h_0} < H_{min} \), then \( NVD = 1 \), and final \( H_h = H_{min} \)
- If \( H_{h_0} > H_{max} \), then \( NVD = 1 \), and final \( H_h = H_{max} \)
- Otherwise, \( NVD = 3 \), and \( H_h \) is optimized

**DT(L)**

\[ \Delta_{LT} \] = displacement of current hull

- If \( NDT = 1 \), then \( \Delta_{LT} = \Delta_{LT_0} \)
- If \( NDT = 3 \), then \( \Delta_{LT} = \Delta_{LT_0} - d\Delta_{LT} , \Delta_{LT_0} , \Delta_{LT_0} + d\Delta_{LT} \)

**BX(J)**

\[ B_{PX} \] = maximum chine beam of current hull

- If \( NBX = 1 \), then \( B_{PX} = B_{PX_0} \) or \( B_{min} \) or \( B_{max} \)
- If \( NBX = 3 \), then \( B_{PX} = B_{PX_0} \) or \( B_{min} \) or \( B_{max} \)

\[ B_{PX_0} + dB_{PX} \]
PROGRAM PHFMOPT

HD(I) = hull depth at midships of current hull

If NVD = 1, then \( H_h = H_{ho} \) or \( H_{min} \) or \( H_{max} \)

If NVD = 3, then \( H_h = H_{ho} + dH_h, H_{ho}, H_{ho} - dH_h \)

PDEN(I) = payload density of current hull

ZPL(J) = VCG of payload for current hull

WPD(I) = weight of payload for current hull

HDM = final hull depth in ft

If NVD = 3, interpolate from the array of \( W_p/V_p \) versus \( H_h \) to obtain a new \( H_{ho} \) which approximates the required \( (W_p/V_p)_D \). Iterate until the new \( H_{ho} \) agrees with the old \( H_{ho} \) within one percent.

PDENS = payload density of final hull

BPX = final maximum chine beam in ft

If NBX = 3, interpolate from the array of \( Z_p \) versus \( B_{PX} \) to obtain a new \( B_{PX_o} \) which approximates the required \( (Z_p)_D \). Iterate until the new \( B_{PX_o} \) agrees with the old \( B_{PX_o} \) within one percent.

DTONS = final displacement in tons

If NDT = 3, interpolate from the array of \( W_p \) versus \( \Delta_{LT} \) to obtain a new \( \Delta_{LT_o} \) which approximates the required \( (W_p)_D \). Iterate until the new \( \Delta_{LT_o} \) agrees with the old \( \Delta_{LT_o} \) within one percent.

A maximum of 10 iterations is set on each loop.

If the initial values of \( \Delta_{LT_o}, B_{PX_o}, \) and/or \( H_{ho} \) are too far from the design requirements, convergence may be unattainable with this optimization procedure. Therefore, it is well to run a matrix of fixed hulls (IOPT=0) first to aid in the selection of appropriate initial values.

See Subroutine PRTOUT for complete output from final hull.
NAME: SUBROUTINE READIN

PURPOSE: Read input data from punched cards, and echo the input. Store data in COMMON blocks for use by other routines.

CALLING SEQUENCE: CALL READIN

SUBPROGRAMS CALLED: OWKTQ, CAVKTQ

DATA REQUIRED:

<table>
<thead>
<tr>
<th>Card Columns</th>
<th>Card Columns</th>
<th>Card Columns</th>
</tr>
</thead>
<tbody>
<tr>
<td>Card</td>
<td>Columns</td>
<td>Card</td>
</tr>
<tr>
<td>Via Punched Cards</td>
<td>Card</td>
<td>Columns</td>
</tr>
<tr>
<td>PARENT</td>
<td>Identification for hull design</td>
<td>1</td>
</tr>
<tr>
<td>BPX</td>
<td>Maximum chine beam ( B_{PX} ) of parent form</td>
<td>9-16</td>
</tr>
<tr>
<td>DZS</td>
<td>( \Delta Z_s ) of parent form, see Figure 1</td>
<td>17-24</td>
</tr>
<tr>
<td>NN</td>
<td>Total number of sections input ( \leq 27 )</td>
<td>3</td>
</tr>
<tr>
<td>N</td>
<td>Index of section at ( X/L_p = 1.0 )</td>
<td>7-8</td>
</tr>
<tr>
<td>M</td>
<td>Index of section at ( X/L_p = 0.5 )</td>
<td>11-12</td>
</tr>
<tr>
<td>M40</td>
<td>Index of section at ( X/L_p = 0.6 )</td>
<td>15-16</td>
</tr>
<tr>
<td>M25</td>
<td>Index of section at ( X/L_p = 0.75 )</td>
<td>19-20</td>
</tr>
<tr>
<td>NBA</td>
<td>Number of transverse bulkheads ( \leq 15 )</td>
<td>4</td>
</tr>
<tr>
<td>MTB (1)</td>
<td>Indexes of Sections at which transverse bulkheads are located, from transom to bow. Value of MTB must be 9 and values of MTB must be 1, 4, 6, 9, 12, 15, 18, 21, 26 for conventional planing hulls, but may be varied for landing craft</td>
<td>7-8</td>
</tr>
<tr>
<td>MTB (2)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>XLP (1)</td>
<td>Nondimensional longitudinal location ( X/L_p ) of section</td>
<td>5(I)</td>
</tr>
<tr>
<td>YC (1)</td>
<td>Half-breadth at chine ( Y_{C} )</td>
<td>9-16</td>
</tr>
<tr>
<td>YS (1)</td>
<td>Half-breadth at main deck ( Y_{S} )</td>
<td>17-24</td>
</tr>
<tr>
<td>ZK (1)</td>
<td>Height of keel above baseline ( Z_K )</td>
<td>25-32</td>
</tr>
<tr>
<td>ZC (1)</td>
<td>Height of chine above baseline ( Z_C )</td>
<td>33-40</td>
</tr>
<tr>
<td>ZS (1)</td>
<td>Height of main deck ( Z_{S}' - \Delta Z_s = Z_s )</td>
<td>41-48</td>
</tr>
<tr>
<td>YK (1)</td>
<td>Half-breadth at keel ( Y_K )</td>
<td>49-56</td>
</tr>
</tbody>
</table>

Format for Card 1 is (5 A 10).
Format for Cards 3, 4, and 6 is (20 I 4).
Format for all other cards is (10 F 8.2).
Data read from each card is immediately echoed, i.e., printed on output page, for use in tracing errors.
Card Set 5 contains NN cards, one for each section, in order from transom to bow.

For conventional planing hulls, value of NN must be 27 and sections required are \( \frac{X}{L_p} = 0, 0.025, 0.05, 0.075, 0.1, 0.15, 0.2, 0.25, 0.3, 0.35, 0.4, 0.45, 0.5, 0.55, 0.6, 0.65, 0.7, 0.75, 0.8, 0.85, 0.875, 0.9, 0.925, 0.95, 0.975, 1.0, \) and \( \frac{L_{OA}}{L_p} \).

Values of N, M, M40, M25 are 26, 13, 15, 18. Sections for landing craft are not restricted.

Dimensions of offsets on Card Set 5 must be consistent with values on Card 2. The parent form is nondimensionalized before geometric variations are made.

The planing hull form is approximated by straight line segments as shown in Figure 1. The general arrangements used for conventional planing hulls and landing craft are shown in Figures 2 and 3, respectively.

**IMAT**

Control for hull structural material

- \( IMAT = 1 \) for aluminum hull
- \( IMAT = 2 \) for steel hull
- \( IMAT = 3 \) for GRP single skin hull, with single skin bulkheads*
- \( IMAT = 4 \) for GRP single skin hull, with sandwich plate bulkheads*
- \( IMAT = 5 \) for GRP sandwich plate hull with sandwich plate bulkheads*

* GRP is glass reinforced plastic, i.e., fiberglass.
SUBROUTINE READIN
Card Columns

IOPT  Control for optimization of displacement A, maximum beam B_{px}, and hull depth H_{h}; length L_{p} is fixed in each case.
IOPT = 0 if A, B_{px}, and H_{h} are fixed.
IOPT = 1 if A and B_{px} are fixed but H_{h} is varied to meet required payload density W_{p}/V_{p}.
IOPT = 2 if A is fixed but B_{px} is varied to meet required VCG of payload Z_{p} and H_{h} is varied to meet W_{p}/V_{p}.
IOPT = 3 if A is varied to meet required payload weight W_{p} and B_{px} and H_{h} are varied to meet Z_{p} and W_{p}/V_{p}.
IOPT = 4 if B_{px} and H_{h} are fixed but A is varied to meet W_{p}.
IOPT = 5 if H_{h} is fixed but A is varied to meet W_{p} and B_{px} is varied to meet Z_{p}.

IPRT  Control for printed output
IPRT = 0 for minimum output, major weight groups only, one page for each hull.
IPRT = 1 for complete 4-page output per hull, including BSCI 3-digit level of weight and hull offsets.

IPM  Control for type of engines
IPM = 1 for diesel prime movers
IPM = 2 for gas turbine prime movers
IPM = 3 for CODOG System, gas turbine prime movers with auxiliary diesels
IPM = 4 for COGOG System, gas turbine prime movers with auxiliary gas turbines.
**SUBROUTINE READIN**

<table>
<thead>
<tr>
<th>Card</th>
<th>Columns</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>20</td>
<td>Control for type of thrusters</td>
</tr>
<tr>
<td>6</td>
<td>24</td>
<td>Control for type of vehicle</td>
</tr>
<tr>
<td>6</td>
<td>28</td>
<td>Control for fuel tanks</td>
</tr>
<tr>
<td>6A</td>
<td>1-8</td>
<td>Length of well deck in ft</td>
</tr>
<tr>
<td>6A</td>
<td>9-16</td>
<td>Length of bow ramp in ft</td>
</tr>
<tr>
<td>6A</td>
<td>17-24</td>
<td>Breadth of well deck in ft</td>
</tr>
<tr>
<td>6A</td>
<td>25-32</td>
<td>Breadth of bow ramp in ft</td>
</tr>
<tr>
<td>6A</td>
<td>33-40</td>
<td>Breadth of aft (drive-through) ramp in ft</td>
</tr>
<tr>
<td>6A</td>
<td>41-48</td>
<td>Height of well deck above baseline in ft</td>
</tr>
<tr>
<td>6A</td>
<td>49-56</td>
<td>Height of aft ramp above baseline in ft</td>
</tr>
</tbody>
</table>

**NOTE:**
- Omit Card 6A when ILC = 0
- Not required if cruise range is dominant

### Variables
- **IPROP**: Control for type of thrusters
  - IPROP = 1 for segmental section props (Gawn-Burrill type)
  - IPROP = 2 for Newton-Rader type props (this option not available now)
  - IPROP = 3 for airfoil section propellers (Wageningen B-Screw type)
  - IPROP = 4 for waterjets
- **ILC**: Control for type of vehicle
  - ILC = 0 for conventional planing hull
  - ILC = 1 for landing craft with well
- **IFT**: Control for fuel tanks
  - IFT = 0 if fuel tanks are an integral part of the hull structure
  - IFT = 1 for separate fuel tanks
- **IFRM**: Control for framing of GRP hulls
  - IFRM = 1 for transverse framing
  - IFRM = 2 for longitudinal framing
- **XLWELL**: Length of well deck in ft
- **XLBOWR**: Length of bow ramp in ft
- **BWELL**: Breadth of well deck in ft
- **BBOWR**: Breadth of bow ramp in ft
- **BAFTR**: Breadth of aft (drive-through) ramp in ft
- **ZWELL**: Height of well deck above baseline in ft
- **ZAFTR**: Height of aft ramp above baseline in ft
- **VDES**: Design (maximum) speed \( V_d \) in knots
- **DRANGE**: Range at \( V_d \) in nautical miles
- **HI3D**: Significant wave height at \( V_d \) in ft
- **VCRS**: Cruise speed \( V_c \) in knots < \( V_d \)
- **CRANGE**: Range at \( V_c \) in nautical miles
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
<th>Card</th>
<th>Column</th>
</tr>
</thead>
<tbody>
<tr>
<td>H13C</td>
<td>Significant wave height at ( V_c ) in ft</td>
<td>7</td>
<td>41-48</td>
</tr>
<tr>
<td>SDF</td>
<td>Standard deviation factor for resistance prediction, if R/W not input.</td>
<td></td>
<td>49-56</td>
</tr>
<tr>
<td></td>
<td>Program uses R/W derived from Series 62 and 65. If SDF=0.0, the mean R/W</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>curves are used; if SDF=1.645, the minimum curves are used. SDF can be</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>varied to approximate the bare hull resistance for a particular hull form.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DCF</td>
<td>Correlation allowance ( C_A' ) generally 0.</td>
<td>57</td>
<td>64</td>
</tr>
<tr>
<td>* RWF(1)</td>
<td>Bare hull resistance-weight ratio R/W at design speed</td>
<td>65</td>
<td>72</td>
</tr>
<tr>
<td>* RWF(2)</td>
<td>Bare hull R/W at cruise speed</td>
<td>73</td>
<td>80</td>
</tr>
<tr>
<td>SPEED(1)</td>
<td>Array of 10 speeds, or less, in knots</td>
<td>8</td>
<td>1-8</td>
</tr>
<tr>
<td>SPEED(2)</td>
<td>at which power data and accelerations are to be computed</td>
<td></td>
<td></td>
</tr>
<tr>
<td>WPDES</td>
<td>Design payload weight ( W_p ) in long tons</td>
<td>9</td>
<td>1-8</td>
</tr>
<tr>
<td>VPDES</td>
<td>Design payload volume ( V_p ) in ft(^3)</td>
<td>9</td>
<td>16</td>
</tr>
<tr>
<td>ZPDES</td>
<td>VCG of design payload in ft above main deck at midsips, positive up</td>
<td>17</td>
<td>24</td>
</tr>
<tr>
<td>GM</td>
<td>Required metacentric height ( GM ) in feet</td>
<td>25</td>
<td>32</td>
</tr>
<tr>
<td>CGACC</td>
<td>1/10 highest acceleration criterion at the CG in g’s; generally 1.0 or 1.5</td>
<td>33</td>
<td>40</td>
</tr>
<tr>
<td>* ACC</td>
<td>Total accommodations ( = CREW + CPO + OFF )</td>
<td>10</td>
<td>1-8</td>
</tr>
<tr>
<td>* CREW</td>
<td>Number of enlisted personnel</td>
<td>9</td>
<td>16</td>
</tr>
<tr>
<td>* CPO</td>
<td>Number of CPO’s</td>
<td>17</td>
<td>24</td>
</tr>
<tr>
<td>* OFF</td>
<td>Number of officers</td>
<td>25</td>
<td>32</td>
</tr>
<tr>
<td>DAYS</td>
<td>Number of days for provisions</td>
<td>33</td>
<td>40</td>
</tr>
<tr>
<td>WSPMIN</td>
<td>Minimum unit weight of stiffened plating in lb/ft(^2)</td>
<td>11</td>
<td>1-8</td>
</tr>
<tr>
<td></td>
<td>WSPMIN = 4.0 for medium range aluminum</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>WSPMIN = 7.0 for steel</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>WSPMIN = 3.25 for single skin GRP</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>WSPMIN = 2.5 for sandwich plate GRP</td>
<td></td>
<td></td>
</tr>
<tr>
<td>WSLOPE</td>
<td>Slope of stiffened plating curves as function of load</td>
<td>9</td>
<td>16</td>
</tr>
<tr>
<td></td>
<td>WSLOPE = 0.066667 for aluminum</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>WSLOPE = 0.20 for steel</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>WSLOPE = 0.192 for single skin GRP</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>WSLOPE = 0.140 for sandwich plate GRP</td>
<td></td>
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</tr>
</tbody>
</table>

*Parameters preceded by an asterisk will be calculated by program if blank spaces are left on input card.*
<table>
<thead>
<tr>
<th>Card</th>
<th>Columns</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>DMAT</td>
<td>11 17-34</td>
<td>Density of structural material in ( \text{lb/ft}^3 )</td>
</tr>
<tr>
<td></td>
<td></td>
<td>DMAT = 166 for aluminum</td>
</tr>
<tr>
<td></td>
<td></td>
<td>DMAT = 492 for steel</td>
</tr>
<tr>
<td></td>
<td></td>
<td>DMAT = 103 for GRP</td>
</tr>
<tr>
<td>STRESS</td>
<td>25-32</td>
<td>Stress limit in ( \text{lb/in.}^2 )</td>
</tr>
<tr>
<td></td>
<td></td>
<td>STRESS = 18000 psi for aluminum</td>
</tr>
<tr>
<td></td>
<td></td>
<td>STRESS = 30000 psi for steel</td>
</tr>
<tr>
<td></td>
<td></td>
<td>STRESS = 8000 psi for GRP</td>
</tr>
<tr>
<td>FVOLSS</td>
<td>33-40</td>
<td>Volume of superstructure in ( \text{ft}^3 )</td>
</tr>
<tr>
<td>FKW</td>
<td>41-48</td>
<td>Power of electric plant in KW</td>
</tr>
<tr>
<td>PROPNO</td>
<td>12 1-8</td>
<td>Number of propellers or waterjets</td>
</tr>
<tr>
<td>AUXNO</td>
<td>9-16</td>
<td>Number of auxiliary engines, if any</td>
</tr>
<tr>
<td>PROPDI</td>
<td>17-24</td>
<td>Diameter ( D ) of propeller or waterjet impeller in inches</td>
</tr>
<tr>
<td>PEMAX</td>
<td>25-32</td>
<td>Maximum power of each prime mover ( P_{e,max} )</td>
</tr>
<tr>
<td>REMAX</td>
<td>33-40</td>
<td>Maximum rpm of prime movers ( N_{e,max} )</td>
</tr>
<tr>
<td>PD</td>
<td>41-48</td>
<td>Propeller pitch-diameter ratio ( P/D )</td>
</tr>
<tr>
<td>EAR</td>
<td>49-56</td>
<td>Propeller expanded area ratio ( \text{EAR} )</td>
</tr>
<tr>
<td>Z</td>
<td>57-64</td>
<td>Number of blades per propeller</td>
</tr>
<tr>
<td>TCDES</td>
<td>65-72</td>
<td>Value of ( \tau_c/\sigma_0.7R ) for sizing prop: ( \tau_c/\sigma_0.7R = 0.6 ) corresponds to Gawn-Burrill 10% back cavitation criteria; value not required if ( D ) is input</td>
</tr>
<tr>
<td>AJet</td>
<td>12A 1-8</td>
<td>Area of jet ( (A_j) ) in ( \text{ft}^2 )</td>
</tr>
<tr>
<td>XKI</td>
<td>17-24</td>
<td>Bollard jet velocity/ship speed ( (K_1) ) at the design point; ( K_1 \approx 2.0 ) for peak propulsive efficiency</td>
</tr>
<tr>
<td>XK2</td>
<td>17-24</td>
<td>Constant ( (K_2) ) for inlet head recovery (IHR); ( K_2 = 1.0 ) for maximum IHR; ( K_2 = 0.0 ) for no IHR</td>
</tr>
</tbody>
</table>

*Parameters preceded by an asterisk will be calculated by program if blank spaces are left on input card.*
SUBROUTINE READIN

Card   Columns

XK3  Constant \((K_3)\) for cavitation criteria 12A  25-32

where \(\tau_c \geq \sigma_{\text{TIP}} + 0.14 K_3\)

indicates cavitation; \(K_3 = 0.0\) for
axial flow; \(K_3 = 1.0\) for mixed flow

DHD  Diameter of impeller hub \((D_h)/33-40\)
impeller diameter \((D)\); 33-40

typical value of \(D_h/D = 0.5\)

TLC  Thrust load coefficient \((\tau_c)\) at 41-48
the design point; not used
when \(A_j\) is input

STP  Impeller tip velocity cavitation 49-56
number \((\sigma_{\text{TIP}})\) at design point;

generally \(\sigma_{\text{TIP}} = 0.06\)

Note: If \(\sigma_{\text{TIP}} = 0.06\) and \(K_3 = 1.0\)

then \(\tau_c < \sigma_{\text{TIP}} + 0.14 K_3 = 0.20\)
to avoid cavitation

** ** ** **

Omit Card 12A if \(K \neq 10\)  ** ** ** **

FM1  Multiplier for specific weight of 13  1-8
prime movers

FM2  Multiplier for specific weight of 9-16
auxiliary engines

FM3  Multiplier for specific fuel con-

sumption SFC of prime movers 17-24

FM4  Multiplier for SFC of auxiliary 25-32
engines

FM5  Multiplier for rpm of prime movers 33-40

FM6  Multiplier for rpm of auxiliary 41-48
engines

General equations for engines are
multiplied by above constants. Use
values of 1.0 unless a particular
series of engines are required. The
general equations may be bypassed with
inputs on Card 15.

GEARC  Constant in gear weight equation 14  1-8

GEARC = 16000 for single reduction

gears

GEARC = 9500 for planetary gears

35
**SUBROUTINE READIN**

<table>
<thead>
<tr>
<th>Card</th>
<th>Columns</th>
</tr>
</thead>
<tbody>
<tr>
<td>GEARK</td>
<td>Gear tooth K-factor, generally use 200</td>
</tr>
<tr>
<td>GEARE</td>
<td>Exponent in gear weight equation GEARE = 0.9 for single reduction gears GEARE = 1.0 for planetary gears</td>
</tr>
<tr>
<td>* FWE</td>
<td>Weight in lb for each prime mover</td>
</tr>
<tr>
<td>* FWG</td>
<td>Weight in lb of gears for each prime mover</td>
</tr>
<tr>
<td>* FWEA</td>
<td>Weight in lb of each auxiliary engine</td>
</tr>
<tr>
<td>* FWGA</td>
<td>Weight in lb of gears for each auxiliary engine</td>
</tr>
<tr>
<td>* FVOLE</td>
<td>Volume in ft(^3) of engine room for prime movers</td>
</tr>
<tr>
<td>* FVOLE2</td>
<td>Volume in ft(^3) of inlets and exhausts for prime movers</td>
</tr>
<tr>
<td>* FVOLEA</td>
<td>Volume in ft(^3) of room for auxiliary engines</td>
</tr>
<tr>
<td>* FVOLA2</td>
<td>Volume in ft(^3) of inlets and exhausts for auxiliary engines</td>
</tr>
<tr>
<td>* FSFCD</td>
<td>SFC in lb/hp/hr of each prime mover at its full power</td>
</tr>
<tr>
<td>* FSFCC</td>
<td>SFC in lb/hp/hr of each auxiliary engine at its full power</td>
</tr>
</tbody>
</table>

Weights and volumes for each BSCI 3-digit group and each load derived from the general equations are multiplied by appropriate K constants on Cards 16 through 25. Constants are generally 1.0, except for special cases. For items not to be included, the constant should be set to 0.

A multiplier of 1.15 for the total of a major (single-digit) group indicates a 15 percent margin which is added to the weight only, not to the volume.

*Parameters preceded by an asterisk will be calculated by program if blank spaces are left on input card.*
<table>
<thead>
<tr>
<th>Card</th>
<th>Columns</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>16</td>
<td>1-8</td>
<td>Subroutine READIN</td>
</tr>
</tbody>
</table>

- **K_U**: Multiplier for useful load; $K_U$ must be 1.0
- **K_F**: Multiplier for fuel
- **K_L1**: Multiplier for crew and effects
- **K_L6**: Multiplier for personnel stores
- **K_L12**: Multiplier for potable water
- **K_P**: Multiplier for payload; $K_P$ must be 1.0
- **K_1**: Multiplier for total hull structure
- **K_100A**: Multiplier for hull bottom
- **K_100B**: Multiplier for hull sides
- **K_101**: Multiplier for framing
- **K_103A**: Multiplier for upper platforms
- **K_103B**: Multiplier for lower platforms
- **K_107**: Multiplier for main deck
- **K_114A**: Multiplier for transverse bulkheads
- **K_114B**: Multiplier for longitudinal bulkheads
- **K_111**: Multiplier for superstructure
- **K_112**: Multiplier for propulsion plant foundations
- **K_113**: Multiplier for other foundations
- **K_att**: Multiplier for attachments
- **K_2**: Multiplier for total propulsion
- **K_201**: Multiplier for propulsion units
- **K_203**: Multiplier for shafting, bearings, propellers
- **K_204, 205**: Multiplier for combustion air supply, uptakes
<table>
<thead>
<tr>
<th>Card</th>
<th>Columns</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>X2(5)</td>
<td>K&lt;sub&gt;206&lt;/sub&gt;</td>
<td>Multiplier for propulsion control equipment</td>
</tr>
<tr>
<td>X2(6)</td>
<td>K&lt;sub&gt;208&lt;/sub&gt;</td>
<td>Multiplier for circulating and cooling water system</td>
</tr>
<tr>
<td>X2(7)</td>
<td>K&lt;sub&gt;210&lt;/sub&gt;</td>
<td>Multiplier for fuel oil service system</td>
</tr>
<tr>
<td>X2(8)</td>
<td>K&lt;sub&gt;211&lt;/sub&gt;</td>
<td>Multiplier for lubricating oil system</td>
</tr>
<tr>
<td>X2(9)</td>
<td>K&lt;sub&gt;250&lt;/sub&gt;, K&lt;sub&gt;251&lt;/sub&gt;</td>
<td>Multiplier for repair parts, and operating fluids</td>
</tr>
<tr>
<td>X3(1)</td>
<td>K&lt;sub&gt;3&lt;/sub&gt;</td>
<td>Multiplier for total electric plant</td>
</tr>
<tr>
<td>X3(2)</td>
<td>K&lt;sub&gt;300&lt;/sub&gt;</td>
<td>Multiplier for electric power generation</td>
</tr>
<tr>
<td>X3(3)</td>
<td>K&lt;sub&gt;301&lt;/sub&gt;</td>
<td>Multiplier for power distribution switchboard</td>
</tr>
<tr>
<td>X3(4)</td>
<td>K&lt;sub&gt;302&lt;/sub&gt;</td>
<td>Multiplier for power distribution system cables</td>
</tr>
<tr>
<td>X3(5)</td>
<td>K&lt;sub&gt;303&lt;/sub&gt;</td>
<td>Multiplier for lighting system</td>
</tr>
<tr>
<td>X4(1)</td>
<td>K&lt;sub&gt;4&lt;/sub&gt;</td>
<td>Multiplier for total non-military communication and control</td>
</tr>
<tr>
<td>X4(2)</td>
<td>K&lt;sub&gt;400&lt;/sub&gt;</td>
<td>Multiplier for nonelectronic navigation equipment</td>
</tr>
<tr>
<td>X4(3)</td>
<td>K&lt;sub&gt;401&lt;/sub&gt;</td>
<td>Multiplier for interior communication system</td>
</tr>
<tr>
<td>X5(1)</td>
<td>K&lt;sub&gt;5&lt;/sub&gt;</td>
<td>Multiplier for total auxiliary system</td>
</tr>
<tr>
<td>X5(2)</td>
<td>K&lt;sub&gt;500&lt;/sub&gt;, K&lt;sub&gt;502&lt;/sub&gt;</td>
<td>Multiplier for heating, air conditioning</td>
</tr>
<tr>
<td>X5(3)</td>
<td>K&lt;sub&gt;501&lt;/sub&gt;</td>
<td>Multiplier for ventilation system</td>
</tr>
<tr>
<td>X5(4)</td>
<td>K&lt;sub&gt;503&lt;/sub&gt;</td>
<td>Multiplier for refrigerating spaces</td>
</tr>
<tr>
<td>X5(5)</td>
<td>K&lt;sub&gt;505&lt;/sub&gt;</td>
<td>Multiplier for plumbing installations</td>
</tr>
<tr>
<td>Card</td>
<td>Columns</td>
<td>Description</td>
</tr>
<tr>
<td>------</td>
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<tr>
<td>X5(6)</td>
<td>K506 41-48</td>
<td>Multiplier for firemain, flushing, sprinkling</td>
</tr>
<tr>
<td>X5(7)</td>
<td>K507 49-56</td>
<td>Multiplier for fire extinguishing system</td>
</tr>
<tr>
<td>X5(8)</td>
<td>K508 57-64</td>
<td>Multiplier for drainage and ballast</td>
</tr>
<tr>
<td>X5(9)</td>
<td>K509 65-72</td>
<td>Multiplier for fresh water system</td>
</tr>
<tr>
<td>X5(10)</td>
<td>K510 73-80</td>
<td>Multiplier for scuppers and deck drains</td>
</tr>
<tr>
<td>X5(11)</td>
<td>K511 1-8</td>
<td>Multiplier for fuel and diesel oil filling</td>
</tr>
<tr>
<td>X5(12)</td>
<td>K513 9-16</td>
<td>Multiplier for compressed air system</td>
</tr>
<tr>
<td>X5(13)</td>
<td>K517 17-24</td>
<td>Multiplier for distilling plant</td>
</tr>
<tr>
<td>X5(14)</td>
<td>K518 25-32</td>
<td>Multiplier for steering systems</td>
</tr>
<tr>
<td>X5(15)</td>
<td>K519 33-40</td>
<td>Multiplier for rudders</td>
</tr>
<tr>
<td>X5(16)</td>
<td>K520 41-48</td>
<td>Multiplier for mooring, anchor, deck machinery</td>
</tr>
<tr>
<td>X5(17)</td>
<td>K521 49-56</td>
<td>Multiplier for stores handling</td>
</tr>
<tr>
<td>X5(18)</td>
<td>K528 57-64</td>
<td>Multiplier for replenishment at sea</td>
</tr>
<tr>
<td>X5(19)</td>
<td>K550 65-72</td>
<td>Multiplier for repair parts</td>
</tr>
<tr>
<td>X5(20)</td>
<td>K551 73-80</td>
<td>Multiplier for operating fluids</td>
</tr>
<tr>
<td>X6(1)</td>
<td>K6 1-8</td>
<td>Multiplier for total outfit and furnishing</td>
</tr>
<tr>
<td>X6(2)</td>
<td>K600 9-16</td>
<td>Multiplier for hull fittings</td>
</tr>
<tr>
<td>X6(3)</td>
<td>K601 17-24</td>
<td>Multiplier for boats, stowages, handling</td>
</tr>
<tr>
<td>X6(4)</td>
<td>K602 25-32</td>
<td>Multiplier for rigging and canvas</td>
</tr>
<tr>
<td>X6(5)</td>
<td>K603 33-40</td>
<td>Multiplier for ladders and grating</td>
</tr>
<tr>
<td>Card</td>
<td>Columns</td>
<td>Description</td>
</tr>
<tr>
<td>------</td>
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<td>-------------</td>
</tr>
<tr>
<td>X6(6)</td>
<td>41-48</td>
<td>Multiplier for nonstructural bulkheads</td>
</tr>
<tr>
<td>X6(7)</td>
<td>49-56</td>
<td>Multiplier for painting</td>
</tr>
<tr>
<td>X6(8)</td>
<td>57-64</td>
<td>Multiplier for deck covering</td>
</tr>
<tr>
<td>X6(9)</td>
<td>65-72</td>
<td>Multiplier for hull insulation</td>
</tr>
<tr>
<td>X6(10)</td>
<td>73-80</td>
<td>Multiplier for storerooms, stowage, lockers</td>
</tr>
<tr>
<td>X6(11)</td>
<td>25</td>
<td>Multiplier for equipment for utility spaces</td>
</tr>
<tr>
<td>X6(12)</td>
<td>9-16</td>
<td>Multiplier for workshops</td>
</tr>
<tr>
<td>X6(13)</td>
<td>17-24</td>
<td>Multiplier for galley, pantry, commissary</td>
</tr>
<tr>
<td>X6(14)</td>
<td>25-32</td>
<td>Multiplier for living spaces</td>
</tr>
<tr>
<td>X6(15)</td>
<td>33-40</td>
<td>Multiplier for offices, control center</td>
</tr>
<tr>
<td>X6(16)</td>
<td>41-48</td>
<td>Multiplier for medical-dental spaces</td>
</tr>
<tr>
<td>CKN(1)</td>
<td>26</td>
<td>1-8</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cost factor for hull structures</td>
</tr>
<tr>
<td></td>
<td></td>
<td>CKN(1) = 2.191 for conventional aluminum hull</td>
</tr>
<tr>
<td></td>
<td></td>
<td>CKN(1) = 1.000 for conventional steel hull</td>
</tr>
<tr>
<td>CKN(2)</td>
<td>9-16</td>
<td>Cost factor for propulsion</td>
</tr>
<tr>
<td></td>
<td></td>
<td>CKN(2) = 1.000 for most cases</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Program makes adjustment to general equations in case of diesel prime movers and/or waterjets</td>
</tr>
<tr>
<td>CKN(3)</td>
<td>17-24</td>
<td>Cost factor for electric plant</td>
</tr>
<tr>
<td></td>
<td></td>
<td>CKN(3) = 2.036 for most cases</td>
</tr>
<tr>
<td>CKN(4)</td>
<td>25-32</td>
<td>Cost factor for communication and control</td>
</tr>
<tr>
<td></td>
<td></td>
<td>CKN(4) = 1.000 for most cases</td>
</tr>
<tr>
<td>CKN(5)</td>
<td>33-40</td>
<td>Cost factor for auxiliary systems</td>
</tr>
<tr>
<td></td>
<td></td>
<td>CKN(5) = 1.528 for most cases</td>
</tr>
<tr>
<td>CKN(6)</td>
<td>41-48</td>
<td>Cost factor for outfit and furnishing</td>
</tr>
<tr>
<td></td>
<td></td>
<td>CKN(6) = 1.000 for most cases</td>
</tr>
<tr>
<td>CKN(7)</td>
<td>49-56</td>
<td>Cost factor for payload</td>
</tr>
<tr>
<td></td>
<td></td>
<td>CKN(7) = 1.000 for most cases</td>
</tr>
</tbody>
</table>
**SUBROUTINE READIN**

<table>
<thead>
<tr>
<th>Card</th>
<th>Columns</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>27</td>
<td>1-8</td>
<td>OPHRS: Operating hours per month</td>
</tr>
<tr>
<td>9-16</td>
<td></td>
<td>OPYRS: Total vehicle operating years, @ 15</td>
</tr>
<tr>
<td>17-24</td>
<td></td>
<td>XUNITS: Number of vehicles to be built</td>
</tr>
<tr>
<td>25-32</td>
<td></td>
<td>TIMED: Portion of time operating at maximum speed</td>
</tr>
<tr>
<td>33-40</td>
<td></td>
<td>TIMEC: Portion of time operating at cruise speed</td>
</tr>
<tr>
<td>41-48</td>
<td></td>
<td>FUELR: Cost of fuel per ton in dollars</td>
</tr>
</tbody>
</table>
| 28   | 1-8     | Note: TIMED + TIMEC = 1.0
| 9-16 |         | DELDT: Increment of displacement in tons for optimization routine if IOPT = 3 |
| 33-40|         | DELBX: Increment of max beam B_PX in ft for optimization routine if IOPT > 1 |
| 17-24|         | DELHD: Increment of hull depth H_h in ft for optimization routine if IOPT > 0 |
| 25-32|         | BXMIN: Minimum value of B_PX in ft
|       |         | If not restricted, make BXMIN = 0 |
| 33-40|         | BXMAX: Maximum value of B_PX in ft
|       |         | If not restricted, make BXMAX very large |
| 41-48|         | HDMIN: Minimum value of H_h in ft
|       |         | If not restricted, make HDMIN = 0 |
| 49-56|         | HDMAX: Maximum value of H_h in ft
|       |         | If not restricted, make HDMAX very large |
| 29   | 1-8     | PL: Ship projected chine length L_p in ft |
| 10-16|         | DTONS: Initial value of displacement Δ_LT in long tons |
| 17-24|         | BPX: Initial value of beam B_PX in ft |
| 25-32|         | HDM: Initial value of hull depth H_h in ft |
| 33-40|         | * A1=RWF(1): Bare hull R/W at design speed |
| 41-48|         | * A2=RWF(2): Bare hull R/W at cruise speed |
| 49-56|         | * A3=VOLUMSS: Volume of superstructure in ft³ |

Card Set 29 is actually read by the main routine PHFMOPT, but is included here for convenience. One card is read for each hull variation desired. Blank card is inserted at end to terminate program.

* Optional parameters to supersede corresponding values on Cards 7 and 11.
### CONSTANTS:

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
</tr>
</thead>
</table>
| RHO   | RHO Water density $\rho$ in $\text{lb} \times \text{sec}^2/\text{ft}^4$  
$\rho = 1.9905$ for sea water at 59°F |
| VIS   | Kinematic viscosity of water $\nu$ in $\text{ft}^2/\text{sec}$  
$\nu = 1.2817 \times 10^{-5}$ for sea water at 59°F |
| GA    | Acceleration of gravity $g$ in $\text{ft}/\text{sec}^2$  
$g = 32.174$ at 45° north latitude |
| RHO2  | $\rho/2$ |
| RC    | Density in $\text{lb}/\text{ft}^3 = \rho g$ |
| TON   | Pounds per ton = 2240 |
| DPR   | Multiplier to convert degrees to radians = 57.29578 |
| RPD   | Multiplier to convert radians to degrees = 0.01745329 |
| ZERO  | 0.0 |
| HALF  | 1./2. |
| TWO   | 2.0 |
| FOUR  | 4.0 |
| EIGHT | 8.0 |
| TWELVE| 12.0 |
| THIRD | 1./3. |
| THIRD2| 2./3. |
| NL    | 6 = dimension of arrays for loads |
| N1    | 14 = dimension of arrays for structures, Group 1 |
| N2    | 10 = dimension of arrays for propulsion, Group 2 |
| N3    | 6 = dimension of arrays for electric plant, Group 3 |
| N4    | 4 = dimension of arrays for communication and control, Group 4 |
| N5    | 21 = dimension of arrays for auxiliary systems, Group 5 |
| N6    | 17 = dimension of arrays for outfit and furnishings, Group 6 |

First item in each array is total for the group.  
Last item in each array, except loads, is the margin.  
Intermediate Items are BSCI 3-digit groupings.
SUBROUTINE READIN

L0

Array of numerical identification for loads

L1

L2

L3

Arrays of numerical identification for items in Groups 1, 2, 3, 4, 5, 6 respectively, corresponding to BSCI codes in most cases. The margins are arbitrarily appended with 99.
NAME: SUBROUTINE PRTOUT

PURPOSE: Print out weights, volumes, VCC's and other pertinent data for fixed-size hull (IOPT=0) or optimized hull (IOPT>0)

CALLING SEQUENCE: CALL PRTOUT

SUBPROGRAMS CALLED: PRCOEF, PHRES, SAVIT, PRINTP, SIMPUN, YINTX

INPUT: Via COMMON blocks
Data for ship of length $L_p$ from Program PHFMOPT
If hull depth, beam, and/or displacement has been optimized (IOPT>0), only the results of the final hull is printed.

OUTPUT: Via 132-Column printed pages

PAGE 1 - Minimum Printout

1. $\Delta_{LT}$ = ship displacement in long tons
   PTITLE Identification for propeller series or waterjets
   TPARENT Identification for hull design

2. $L_p/V^{1/3}$ = slenderness ratio
   $L/B$ = length-beam ratio $L_p/B_{PX}$
   $A_p/V^{2/3}$ = loading coefficient
   $L_p$ = ship projected chine length in ft
   $B_{PX}$ = maximum chine beam in ft
   $B_{PA}$ = average chine beam in ft
   $T$ = draft at midships in ft
   $T_t$ = draft at transom in ft
   $L_{sh}$ = shaft length in ft
   $d_0$ = outer diameter of shaft in inches

The following are printed for propellers:
   $P/D$ = propeller pitch ratio
   $EAR$ = expanded area ratio
   $n_{pr}$ = number of propellers
   $\epsilon$ = shaft angle in degrees
   $L_{sh}$ = shaft length in ft
   $d_0$ = outer diameter of shaft in inches

Subroutines where defined

PHFMOPT
READIN
NEWHUL
NEWHUL
NEWHUL
PHFMOPT
PHFMOPT
NEWHUL
NEWHUL
NEWHUL
POWER

Numbers 1., 2., indicate beginning of new line.
SUBROUTINE PRTOUT

The following are printed for waterjets:

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>AJET</td>
<td>$A_J$ = area of jet in ft$^2$</td>
<td>WJETS</td>
</tr>
<tr>
<td>XK1</td>
<td>$K_1$ = bollard jet velocity/ship speed at design point</td>
<td>READIN</td>
</tr>
<tr>
<td>XK2</td>
<td>$K_2$ = constant for inlet head recovery</td>
<td>READIN</td>
</tr>
<tr>
<td>XK3</td>
<td>$K_3$ = constant for $T_v$ vs $\sigma_{TIP}$ cavitation criteria</td>
<td>READIN</td>
</tr>
<tr>
<td>DHD</td>
<td>$D_h/D$ = diameter of impeller hub/diameter of impeller</td>
<td>READIN</td>
</tr>
<tr>
<td>TLC</td>
<td>$T_c$ = thrust load coefficient at design point</td>
<td>READIN</td>
</tr>
<tr>
<td>STIP</td>
<td>$T_{IP_d}$ = impeller tip velocity cavitation number at design point</td>
<td>READIN</td>
</tr>
<tr>
<td>IOPT</td>
<td>Control parameter for optimization</td>
<td>READIN</td>
</tr>
<tr>
<td>DLBS</td>
<td>$\Delta$ = ship displacement in lb</td>
<td>NEWHUL</td>
</tr>
<tr>
<td>DAYS</td>
<td>Days for provisions</td>
<td>READIN</td>
</tr>
<tr>
<td>OFF</td>
<td>Number of officers</td>
<td>READIN or CREWSS</td>
</tr>
<tr>
<td>CPO</td>
<td>Number of CPO's</td>
<td>READIN or CREWSS</td>
</tr>
<tr>
<td>CREW</td>
<td>Number of enlisted men</td>
<td>READIN or CREWSS</td>
</tr>
<tr>
<td>ACC</td>
<td>Total accommodations</td>
<td>READIN or CREWSS</td>
</tr>
<tr>
<td>GM</td>
<td>$\bar{GM}$ = metacentric height in ft</td>
<td>READIN</td>
</tr>
<tr>
<td>KM</td>
<td>$\bar{KM}$ = baseline to metacenter in ft</td>
<td>NEWHUL</td>
</tr>
<tr>
<td>KG</td>
<td>$\bar{KG}$ = net VCG of ship in ft</td>
<td>NEWHUL</td>
</tr>
<tr>
<td>XCG</td>
<td>$L_CG/L_p$ = longitudinal center of gravity forward of transom / ship length</td>
<td>NEWHUL</td>
</tr>
<tr>
<td>VOLH</td>
<td>$V_h$ = hull volume, up to main deck, in ft$^3$</td>
<td>NEWVOL</td>
</tr>
</tbody>
</table>
SUBROUTINE PRTOUT

Subroutines
where defined

VOLSS

V_{ss} = volume enclosed by superstructure in ft$^3$

CREWSS

NTB

n_{tb} = number of transverse bulkheads

STRUCT

IFRM

IFRM = 1 or 2 for transversely or longitudinally framed GRP hull

READIN

4. MAT

Structural material:

Aluminum IMAT = 1

Steel IMAT = 2

GRP(A-A) IMAT = 3

GRP(A-B) IMAT = 4

GRP(B-B) IMAT = 5

A indicates single skin GRP
B indicates sandwich plate GRP
1st letter refers to the hull
2nd letter refers to the bulkheads

READIN

WSFMIN

S_{min} = minimum unit weight of plating in lb/ft$^2$

READIN

WSLOPE

S_p = slope of unit weight curve, Figure 4

READIN

DMAT

\gamma_{mat} = density of structural material in lb/ft$^3$

READIN

STRESS

\sigma_{limit} = stress limit of material in lb/in.$^2$

READIN

TAU(1) TAU(2)

\tau = trim angles at design speed and cruise speed in degrees

SAVIT

RWS(1) RWS(2)

(R/W)_s = resistance-weight ratios at design speed and cruise speed from Savitsky equations

SAVIT

CLOAD

C_{\Delta} = beam loading coefficient

PRTOUT

= \Delta/\rho \ g \ B_{Px}^3 = \nabla/\nabla_{B_{Px}}^3
**SUBROUTINE PRTOUT**

**Subroutines**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>H13X</td>
<td>Variable not used in current program</td>
</tr>
<tr>
<td>RANCED</td>
<td>Range at design speed in nautical miles</td>
</tr>
<tr>
<td>RANCED</td>
<td>Range at cruise speed in nautical miles</td>
</tr>
<tr>
<td>VKT(1)</td>
<td>$V_d$ = design (max) speed in knots</td>
</tr>
<tr>
<td>FNV(1)</td>
<td>$P_nV$ = speed-displacement coefficient</td>
</tr>
<tr>
<td>SIG(1)</td>
<td>$\sigma$ = propeller cavitation number or waterjet cavitation no. based on inlet velocity</td>
</tr>
<tr>
<td>H13(1)</td>
<td>$H_{1/3}$ = significant wave height in ft specified for design speed</td>
</tr>
<tr>
<td>RWB(1)</td>
<td>$(R/W)_b$ = resistance-weight ratio of bare hull</td>
</tr>
<tr>
<td>RWA(1)</td>
<td>$(R/W)_a$ = resistance-weight ratio of appendaged hull</td>
</tr>
<tr>
<td>RWW(1)</td>
<td>$(R/W)<em>w$ = resistance-weight ratio of appendaged hull in seaway at wave height $H</em>{1/3}$</td>
</tr>
</tbody>
</table>

The following are printed for propellers:

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>TWF(1)</td>
<td>$1-w$ = thrust wake factor</td>
</tr>
<tr>
<td>TDF(1)</td>
<td>$1-t$ = thrust deduction factor</td>
</tr>
<tr>
<td>THLD(1)</td>
<td>$K_t/J^2$ = thrust loading coefficient</td>
</tr>
<tr>
<td>TJ(1)</td>
<td>$J$ = propeller advance coefficient</td>
</tr>
<tr>
<td>EP(1)</td>
<td>$\eta_0$ = propeller efficiency</td>
</tr>
<tr>
<td>PC(1)</td>
<td>$\eta_D$ = propulsive coefficient</td>
</tr>
</tbody>
</table>

The following are printed for waterjets:

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>TWF(1)</td>
<td>$1-w$ = wake factor = 1.0</td>
</tr>
<tr>
<td>TDF(1)</td>
<td>$1-t$ = thrust deduction factor</td>
</tr>
<tr>
<td>XJ(1)</td>
<td>$J'$ = effective advance coefficient</td>
</tr>
</tbody>
</table>

**Notes:** The letter C printed to the right of $K_t/J^2$ indicates that the Gawn-Burrill 10% back cavitation criteria is exceeded. A star * printed to the right of $K_t/J^2$ indicates thrust limit due to cavitation. A star * printed to the right of $\eta_0$ indicates that the propeller is operating at a $J$ greater than maximum efficiency.
SUBROUTINE PRTOUT

Subroutines where defined

QC(1) Q' = mass flow in gal/min x 10^-3 \( WJETS \)

SS(1) \( S_s \) = suction specific speed x 10^-3 \( WJETS \)

TCD \( T_{\text{max}} - T_c \) = (maximum thrust load coefficient at cavitation point) - (actual thrust load coefficient); negative value indicates cavitation

The following are printed for either propellers or waterjets:

PCO(1) OPC = overall performance coefficient \( POWER \)

THRUST(1) \( T \) = total thrust requirement in lb \( POWER \)

TORQUE(1) \( Q \) = total torque in shafts ft-lb \( POWER \)

RPM(1) \( N \) = speed of propellers or waterjets in rpm \( PROPS \) or \( WJETS \)

EHP(1) \( P_E \) = total effective power \( POWER \)

DHP(1) \( P_D \) = total power delivered at propellers or waterjets \( PROPS \) or \( WJETS \)

BHP(1) \( P_B \) = total brake power \( POWER \)

5b. VKT(2) \( V_c \) = cruise speed in knots \( POWER \)

Line 5b contains parameters for cruise speed in same order as line 5a for design speed.
Line 5b not printed if cruise speed same as design.

6a. SPEED(I) \( V_K \) = speed in knots \( READIN \)

6b. Lines 6a, 6b, etc., contain same parameters as lines 5 for array of speeds input on Card 8.

7. VMAX \( V_{\text{max}} \) = maximum speed in knots \( PRTOUT \)

Line 7 contains same parameters as lines 5 & 6 for speed attainable at maximum power.
SUBROUTINE PRTOUT
Subroutines where defined

8a. PMTIT Type of prime movers
VDES \( V_d \) = design (maximum) speed in knots
PRN \( n_{pr} \) = number of prime movers
PE \( P_e \) = maximum horsepower of each prime mover
RE \( N_e \) = speed of prime movers in rpm
SFCD \( SFC_d \) = specific fuel consumption of prime movers at design speed in lb/hp/hr
RANGED Range in nautical miles at design speed on prime movers with full fuel load
SWE \( S_{we} \) = specific weight of prime movers in lb/hp
WE \( W_e \) = weight of each prime mover in lb
GR \( m_g \) = gear ratio for prime mover
WG \( W_g \) = weight of gears for each prime mover in lb
WPR \( W_{pr} \) = weight of each propeller or waterjet in lb
WSH \( W_{sh} \) = weight of each propeller shaft in lb
WB \( W_b \) = weight of couplings, bearings, etc. for each shaft in lb

GEARC READIN
GEARK READIN
GEARE READIN

8b. VCRS \( V_c \) = cruise speed in knots
AUXNO \( n_{aux} \) = number of auxiliary engines, if any

POWER
READIN
<table>
<thead>
<tr>
<th>SUBROUTINE PRTOUT Subroutines where defined</th>
</tr>
</thead>
<tbody>
<tr>
<td>PEA</td>
</tr>
<tr>
<td>REA</td>
</tr>
<tr>
<td>SFCC</td>
</tr>
<tr>
<td>RANGEC</td>
</tr>
<tr>
<td>SWA</td>
</tr>
<tr>
<td>WEA</td>
</tr>
<tr>
<td>GRA</td>
</tr>
<tr>
<td>WGA</td>
</tr>
</tbody>
</table>

If there are no auxiliary engines, only $V_c$, $SFC_c$, and $Range_c$ are printed on line 8b and $SFC_c$ and $Range_c$ apply to the prime movers operating at cruise speed.

| WPLBS | $(W_p)^D$ = design payload weight in lb |
| VPDES | $(V_p)^D$ = design payload volume in ft$^3$ |
| ZPDES | $(Z_p)^D$ = design payload VCG |
| PLDEN | $(W_p/V_p)^D$ = design payload density in lb/ft$^3$ |
| VDENS | $\Delta/V_h$ = vehicle density in lb/ft$^3$ |
11. PDENS

payload density in lb/ft³; PHFMOPT

12. DLBS

Δ = displacement (total weight) in lb

R(1) \( W_1/W_T \) = Group 1 weight fraction
R(2) \( W_2/W_T \) = Group 2 weight fraction
R(3) \( W_3/W_T \) = Group 3 weight fraction
R(4) \( W_4/W_T \) = Group 4 weight fraction
R(5) \( W_5/W_T \) = Group 5 weight fraction
R(6) \( W_6/W_T \) = Group 6 weight fraction
R(7) \( W_E/W_T \) = Empty ship weight fraction
R(8) \( W_U/W_T \) = Useful load weight fraction
R(9) \( W_C/W_T \) = Crew and provisions weight fraction
R(10) \( W_F/W_T \) = Fuel weight fraction
R(11) \( W_P/W_T \) = Payload weight fraction

13. HDM

\( H_h \) = hull depth at midships in ft

G(1) \( Z_1 \) = Group 1 VCG / hull depth
G(2) \( Z_2 \) = Group 2 VCG / hull depth
G(3) \( Z_3 \) = Group 3 VCG / hull depth
G(4) \( Z_4 \) = Group 4 VCG / hull depth
G(5) \( Z_5 \) = Group 5 VCG / hull depth
G(6) \( Z_6 \) = Group 6 VCG / hull depth
G(7) \( Z_E \) = Empty ship VCG / hull depth
G(8) \( Z_U \) = Useful load VCG / hull depth

SUBROUTINE PRTOUT

Subroutines where defined
SUBROUTINE PRTOUT
Subroutines where defined

G(9) \[ Z_{CE} = \text{Crew and provisions VCG / hull depth} \]
G(10) \[ Z_F = \text{Fuel VCG / hull depth} \]
G(11) \[ Z_P = \text{Payload VCG / hull depth} \]

14. VOLT

\[ V_T = \text{total volume, including superstructure, in ft}^3 \]
\[ S(1) \quad V_1/V_T = \text{Group 1 volume fraction} \]
\[ S(2) \quad V_2/V_T = \text{Group 2 volume fraction} \]
\[ S(3) \quad V_3/V_T = \text{Group 3 volume fraction} \]
\[ S(4) \quad V_4/V_T = \text{Group 4 volume fraction} \]
\[ S(5) \quad V_5/V_T = \text{Group 5 volume fraction} \]
\[ S(6) \quad V_6/V_T = \text{Group 6 volume fraction} \]
\[ S(7) \quad V_E/V_T = \text{Empty ship volume fraction} \]
\[ S(8) \quad V_U/V_T = \text{Useful load volume fraction} \]
\[ S(9) \quad V_{CE}/V_T = \text{Crew and provisions volume fraction} \]
\[ S(10) \quad V_F/V_T = \text{Fuel volume fraction} \]
\[ S(11) \quad V_P/V_T = \text{Payload volume fraction} \]

15. C(1) \[ C_1 = \text{cost of Group 1} \]
C(2) \[ C_2 = \text{cost of Group 2} \]
C(3) \[ C_3 = \text{cost of Group 3} \]
C(4) \[ C_4 = \text{cost of Group 4} \]
C(5) \[ C_5 = \text{cost of Group 5} \]
C(6) \[ C_6 = \text{cost of Group 6} \]
C(7) \[ C_7 = \text{cost of empty ship} \]
C(8) \[ C_8 = \text{cost of payload} \]

16. C(9) \[ C_9 = \text{base cost of first ship} \]
C(10) \[ C_{10} = \text{average cost per ship} \]
C(11) \[ C_{11} = \text{life cost of personnel pay and allowances} \]
### SUBROUTINE PRTOUT

Subroutine where defined

<table>
<thead>
<tr>
<th>Column</th>
<th>Description</th>
<th>Formula</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>C(12)</td>
<td>Life cost of maintenance</td>
<td>( C_{12} )</td>
<td>COSTS</td>
</tr>
<tr>
<td>C(13)</td>
<td>Life cost of operations, except energy</td>
<td>( C_{13} )</td>
<td>COSTS</td>
</tr>
<tr>
<td>C(14)</td>
<td>Life cost of major support</td>
<td>( C_{14} )</td>
<td>COSTS</td>
</tr>
<tr>
<td>C(15)</td>
<td>Life cost of fuel</td>
<td>( C_{15} )</td>
<td>COSTS</td>
</tr>
<tr>
<td>C(16)</td>
<td>Total life cost</td>
<td>( C_{16} )</td>
<td>COSTS</td>
</tr>
</tbody>
</table>

**PAGES 2 and 3 - BSCI 3-digit Breakdown**

<table>
<thead>
<tr>
<th>Column</th>
<th>Description</th>
<th>Formula</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Identification</td>
<td></td>
<td>PRTOUT</td>
</tr>
<tr>
<td>2</td>
<td>BSCI number</td>
<td></td>
<td>READIN</td>
</tr>
<tr>
<td>3</td>
<td>Weight fractions = weight / ( W_T )</td>
<td></td>
<td>PRTOUT</td>
</tr>
<tr>
<td>4</td>
<td>Volume fractions = volume / ( V_T )</td>
<td></td>
<td>PRTOUT</td>
</tr>
<tr>
<td>5</td>
<td>VCG / hull depth</td>
<td></td>
<td>TOTALS</td>
</tr>
<tr>
<td>6</td>
<td>Weight in lb</td>
<td>2240</td>
<td>PRTOUT</td>
</tr>
<tr>
<td>7</td>
<td>Weight in long tons</td>
<td></td>
<td>TOTALS</td>
</tr>
<tr>
<td>8</td>
<td>Weight in metric tons</td>
<td>1.016047</td>
<td>PRTOUT</td>
</tr>
<tr>
<td>9</td>
<td>Volume in ( ft^3 )</td>
<td></td>
<td>TOTALS</td>
</tr>
<tr>
<td>10</td>
<td>Volume in ( M^3 )</td>
<td></td>
<td>PRTOUT</td>
</tr>
<tr>
<td>11</td>
<td>K-factor from input Cards 16-25</td>
<td></td>
<td>READIN</td>
</tr>
</tbody>
</table>

\( W_T \) and \( V_T \) are in long tons and \( M^3 \) respectively.
### SUBROUTINE PRTOUT

Subroutines where defined

#### PAGE 4 - Hull Geometry

<table>
<thead>
<tr>
<th>1. TPARENT</th>
<th>Identification for hull design</th>
<th>READIN</th>
</tr>
</thead>
<tbody>
<tr>
<td>DLBS</td>
<td>$\Delta$</td>
<td>displacement in lb</td>
</tr>
<tr>
<td>DTONS</td>
<td>$\Delta_{LT}$</td>
<td>displacement in tons</td>
</tr>
<tr>
<td>PL</td>
<td>$L_P$</td>
<td>projected chine length in ft</td>
</tr>
<tr>
<td>BPX</td>
<td>$B_{PX}$</td>
<td>maximum chine beam in ft</td>
</tr>
<tr>
<td>HM</td>
<td>$T$</td>
<td>draft at midships in ft</td>
</tr>
<tr>
<td>HDM</td>
<td>$H_{h}$</td>
<td>hull depth at midships in ft</td>
</tr>
<tr>
<td>DZS</td>
<td>$\Delta Z_S$</td>
<td>in ft (see Figure 1)</td>
</tr>
<tr>
<td>KB</td>
<td>$K_B$</td>
<td>vertical center of buoyancy above baseline in ft</td>
</tr>
<tr>
<td>BM</td>
<td>$B_M$</td>
<td>transverse metacenter above center of buoyancy in ft</td>
</tr>
<tr>
<td>KM</td>
<td>$K_M$</td>
<td>transverse metacenter above baseline in ft</td>
</tr>
<tr>
<td>CM</td>
<td>$C_M$</td>
<td>transverse metacentric height in ft</td>
</tr>
<tr>
<td>KG</td>
<td>$K_G$</td>
<td>vertical center of gravity above baseline in ft</td>
</tr>
<tr>
<td>XLCG</td>
<td>$A_G$</td>
<td>longitudinal center of gravity forward of transom in ft</td>
</tr>
</tbody>
</table>

| 3a. XLP(1) | $X/L_P$ | longitudinal location of section, nondimensionalized | READIN |
| XFT | $X$ | distance of section forward of transom in ft | PRTOUT |
| ZS(1) | $Z_S$ | deck height in ft | NEWVOL |
| ZC(1) | $Z_C$ | chine height in ft | NEWHUL |
| ZK(1) | $Z_K$ | keel height in ft | NEWHUL |
| YS(1) | $Y_S$ | half-breadth at deck in ft | NEWVOL |
| YC(1) | $Y_C$ | half-breadth at chine in ft | NEWHUL |
| YK(1) | $Y_K$ | half-breadth at keel in ft | NEWHUL |
SUBROUTINE PRTOUT

Subroutines
where defined

BETA(1) \( \beta \) = deadrise angle in degrees

AS(1) \( A_S \) = sectional area below
         deck in ft\(^2\)

VOLX \( V_S \) = volume from current
         section to transom in ft\(^3\)

\[ V_S = \int_0^X A_S \, dX \]

3b. XLP(2) etc. One line printed for each of NN
    sections in same order as line 3

PAGE 4 - Additional Printout for Landing Craft Only

4a. XLBOWR \( L_{bow} \) = length of bow ramp in ft
    BBOWR \( B_{bow} \) = breadth of bow ramp in ft

4b. XLWELL \( L_{well} \) = length of well deck
    in ft
    BWELL \( B_{well} \) = breadth of well deck in ft

4c. XLAFT \( L_{aft} \) = length of aft (drive-through) ramp in ft
    BAFTR \( B_{aft} \) = breadth of aft ramp in ft

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SUBROUTINE PRTOUT

Subroutines where defined

5. SEA STATE

6. H1/3-FT

7a. SPEED(1)

7b. SPEED(2)

7c. One line printed for each input speed

Notes:

\[ a_{CG} = 7.0 \left( \frac{H_{1/3}}{B_{PX}} \right) \left( 1 + \frac{\tau}{2} \right)^{0.25} \left( \frac{L_p}{B_{PX}} \right)^{-1.25} \left( \frac{\nu}{\nu_s} \right) \]

\[ a_{BOW} = 10.5 \left( \frac{H_{1/3}}{B_{PX}} \right) \left( 1 + \frac{\tau}{2} \right)^{0.5} \left( \frac{L_p}{B_{PX}} \right)^{-0.75} \left( \frac{\nu}{\nu_s} \right)^{0.75} \]
NAME: SUBROUTINE PARENT
PURPOSE: Nondimensionalize offsets of parent hull form
CALLING SEQUENCE: CALL PARENT
SUBPROGRAM CALLED: SIMPUN
INPUT: Via COMMON blocks
PL \( L_p \) = projected chine length of parent form, from input Card 2
BPX \( B_{PX} \) = maximum chine beam of parent form, from input Card 2
NN n = total number of sections, from input Card 3
M m = index of section at midships, from input Card 3
OFFSETS \( Y_K', Z_K', Y_C', Z_C', Y_S', Z_S \) at each section \( X/L_p \), from Card Set 5
DZS \( \Delta Z_S \) of parent, constant at all sections, from input Card 2
ZS(M) \( Z_{S_m} \) = (hull depth - \( \Delta Z_S \)) of parent at midships
OUTPUT: Via COMMON blocks
AAP \( A_p \) = projected planing bottom area of parent
\[ = \int Y_C \, dX \]
bPA \( B_{PA} \) = mean beam over chine of parent \( = A_p/L_p \)
BPXBPA \( (B_{PX}/B_{PA}) \)
DZSZSM \( (\Delta Z_S/Z_{S_m}) \)
I Index for DO LOOP \( I = 1, NN \)
YCBPA(I) \( (Y_C/B_{PA}) \) = nondimensional half-breadth at chine
YKBPA(I) \( (Y_K/B_{PA}) \) = nondimensional half-breadth at keel
ZCBPA(I) \( (Z_C/B_{PA}) \) = nondimensional height of chine from baseline
ZKBPA(I) \( (Z_K/B_{PA}) \) = nondimensional height of keel from baseline
ZSZSM(I) \( (Z_S/Z_{S_m}) \) = nondimensional deck height
GAMA(I) \( \gamma \) = angle of hull sides from vertical in deg
SUBROUTINE PARENT

TANG(I) \[ \tan \gamma = \frac{(Y_S - Y_C)}{(Z_S - Z_C)} \]
COSC(I) \[ \cos \gamma \]
BETA(I) \[ \beta = \text{deadrise angle in deg} \]
TANB(I) \[ \tan \beta = \frac{(Z_C - Z_K)}{(Y_C - Y_K)} \]
COSB(I) \[ \cos \beta \]
NAME: SUBROUTINE NEWHUL

PURPOSE: Calculate offsets and hydrostatics for hull with new length, beam, and displacement from nondimensionalized parent form

CALLING SEQUENCE: CALL NEWHUL

SUBPROGRAM CALLED: SIMPUN, YINTX

INPUT: Via COMMON blocks

- PL = \( \text{L}_p \) = projected chine length of new hull in ft, from input Card 29
- BPX = \( \text{B}_{PX} \) = maximum chine beam of new hull in ft, from PHFMOPT
- DTONS = \( \text{A}_{LT} \) = displacement of new hull in long tons, from PHFMOPT
- GM = \( \text{GM} \) = required metacentric height in ft, from Card 9
- NN = \( n \) = total number of sections, from Card 3

Other Nondimensional data from Subroutine PARENT

OUTPUT: Via COMMON blocks

- DLBS = \( \Delta \) = displacement in lb = \( \text{A}_{LT} \times 2240 \)
- VOL = \( \text{V} \) = displaced volume in ft\(^3\) = \( \Delta/\rho \)
- RLB = \( \text{L}/B \) = length-beam ratio = \( \text{L}_p/\text{B}_{PX} \)
- SLR = \( \text{L}_p/V^{1/3} \) = slenderness ratio
- BPA = \( \text{B}_{PA} \) = average chine beam of new hull in ft = \( \text{B}_{PX}/(\text{B}_{PX}/\text{B}_{PA}) \)
- AAP = \( \text{A}_p \) = projected planing bottom area of new hull in ft = \( \text{B}_{PA} \times \text{L}_p \)
- APV = \( \text{A}_p/V^{2/3} \) = loading coefficient of new hull
- I = Index for DO LOOP I = 1, NN
- YC(I) = \( \text{Y}_C \) = new half-breadth at chine in ft = \( (\text{Y}_C/\text{B}_{PA}) \times \text{B}_{PA} \)
- YK(I) = \( \text{Y}_K \) = new half-breadth at keel in ft = \( (\text{Y}_K/\text{B}_{PA}) \times \text{B}_{PA} \)
- ZC(I) = \( \text{Z}_C \) = new height at chine in ft = \( (\text{Z}_C/\text{B}_{PA}) \times \text{B}_{PA} \)
- ZK(I) = \( \text{Z}_K \) = new height at keel in ft = \( (\text{Z}_K/\text{B}_{PA}) \times \text{B}_{PA} \)

All hulls have same deadrise angles \( \beta \) as parent

- GKCI = \( \text{G}_{KC} \) = half-girth of hull bottom in ft, keel centerline to chine = \( \text{Y}_K + (\text{Y}_C - \text{Y}_K)/\cos \beta \)
SUBROUTINE NEHWUL

ZF, ZW, ZH, ZHT = height of still waterline above baseline in ft

Program calculates displacements at six arbitrary waterlines, and interpolates to obtain the waterline for the required displaced volume V. Only waterlines parallel to the baseline are considered.

AW(I) = total sectional area below waterline in ft

AWZ(I) = moment of AW about the baseline

Each section is divided into triangles and rectangles below the waterline to calculate AW and MZ.

AWX(I) = moment of AW about the transom

YW3(I) = half-breadth at waterline, cubed

VOLW = check of displaced volume in ft^3 = \int A_W dX

XCG = distance of center of gravity forward of transom in ft

KB = vertical center of buoyancy VCB above baseline in ft

BM = vertical distance from VCB to metacenter in ft

KM = height of metacenter above baseline in ft

KG = vertical center of gravity VCG above baseline in ft

HM = draft at midships in ft = ZW

HT = draft at transom in ft = ZW - ZK

HTM = T / T

CB = block coefficient = V/(LP BPX T)

VOLSM(K), ZSMZWL(K), (K=1,6) Array of hull volumes calculated at six arbitrary deck heights

Not used in current program, see Subroutine NEWVOL

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NAME: SUBROUTINE NEWVOL

PURPOSE: Calculate enclosed volume and hull density for new hull depth

CALLING SEQUENCE: CALL NEWVOL

INPUT: Via COMMON blocks
- \( H_m \) = new hull depth, keel to main deck at midships, in ft from PHFMOPT
- Other Keel and chine offsets for new hull from Subroutine NEWHUL
- Other Nondimensional deck offsets from Subroutine PARENT
- Other Superstructure dimensions from Subroutine CREWSS

OUTPUT: Via COMMON blocks
- \( ZS(M) \) = hull depth at midships - \( \Delta Z \) in ft
  \( m \) = \( H_m / [1 + (\Delta Z_m/Z_m)] \)
- \( DZS \) = \( \Delta Z \) of new hull in ft = \( ZS_m \times (\Delta Z_m/Z_m) \)
- \( I \) = Index of DO LOOP I = 1, NN
- \( ZS(I) \) = deck height - \( \Delta Z \) in ft = \( (ZS_m/Z_m) \times Z_m \)
- \( ZS(I) \) = new deck height in ft - \( Z_s + \Delta Z \)
- \( YS(I) \) = new half-breadth at deck in ft
  = \( Y_C + (Z_S - Z_C) \tan \gamma \)
- \( GCS(I) \) = girth of one side, chine to deck, in ft
  = \( \Delta Z_S + (Z_S - Z_C) / \cos \gamma \)

Sides maintain same slope \( \gamma \) as parent form.

- \( AS(I) \) = total sectional area, keel to deck, in ft^2
- \( ZM(I) \) = height of centroid of \( A_s \) above baseline in ft

Each section is divided into triangles and rectangles to calculate \( A_s \) and \( C_s \).

- \( VOLH \) = hull volume, up to main deck, in ft^3
  = \( \int A_s \, dX \)
- \( VOLSS \) = volume enclosed by superstructure in ft^3
- \( VOLT \) = total volume in ft^3 = \( V_H + V_{ss} \)
- \( VDENS \) = vehicle density in lb/ft^3

\[ \Delta V_H / V_H = \text{vehicle density in lb/ft}^3 \]
SUBROUTINE NEWVOL

ZSSFT

\[ Z_{ss}' = \text{height of centroid of superstructure above deck in ft} \]

\[ Z_{ss}' = 6.0 \text{ if } H_{ss} = 8.0; \quad Z_{ss}' = 9.0 \text{ if } H_{ss} = 16.0 \]

ZSS

\[ Z_{ss} = \frac{\text{superstructure centroid above baseline}}{\text{hull depth}} \]

\[ Z_{ss} = \frac{(H_{h} + Z_{ss}')}{H_{h}} \]

ARH

\[ A_{h} = \text{area of profile up to main deck in ft} \]

ARSS

\[ A_{ss} = \text{area of profile of superstructure in ft} \]

\[ A_{ss} = L_{ss} \times H_{ss} \]

ZPC

\[ Z_{pc} = \frac{\text{height of profile centroid above baseline}}{\text{hull depth}} \]

\[ Z_{pc} = \frac{(0.5 A_{h} + Z_{ss} A_{ss})}{(A_{h} + A_{ss})} \]

HMB

\[ H_{mb} = \text{height of machinery box, main engine room, in ft} \]

\[ H_{mb} = H_{h} \]

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NAME: SUBROUTINE CREWSS

PURPOSE: Define ship's complement if not specified on input cards
Define superstructure dimensions

CALLING SEQUENCE: CALL CREWSS

INPUT: Via COMMON blocks

DTONS Δ_LT = ship displacement in long tons, from PHFMOPT
PL L_p = ship length in ft, from input Card 29
ACC Total accommodations--optional input on Card 10
CREW Number of enlisted men--optional input on Card 10
CPO Number of CPO's--optional input on Card 10
OFF Number of officers--optional input on Card 10
FVOLSS Volume of superstructure in ft^3--optional input on Card 11

OUTPUT: Via COMMON blocks

W W = total ship weight in long tons = Δ_LT
DMULT M_Δ = multiplier for items which vary with ship size
= [ln (W+90)-2.55]/4.92 for W < 2000
= 1.0 for W ≥ 2000
NACCM Number of personnel concerned with military payload
NACCM = 0.052 W if W ≤ 100
NACCM = 0.012 W + 4 if W > 100
NACCS Number of personnel for operation of ship = 0.035W + 4
ACC Total accommodations = NACCM + NACCS, rounded up
unless ACC has been specified on Card 10
CREW Number of enlisted men = 5/7 × ACC unless CREW has
been specified on Card 10
CPO Number of CPO's = 1/7 × ACC unless CREW has been
specified on Card 10
OFF Number of officers = 1/7 × ACC unless CREW has been
specified on Card 10

Note: CPO and/or OFF can be set to 0 by input card
if CREW is specified greater than 0. However, if
CREW is set to 0 or blank space left on input card,
then CREW, CPO, and OFF are calculated from above
equations.
SUBROUTINE CREWSS

VOLSS = volume enclosed by superstructure in ft\(^3\)

If input value of FVOLSS > 0, then \( V_{ss} = FVOLSS \)
Otherwise, \( V_{ss} = 70 \times W \times M_{ss} \)

HSS = height of superstructure in ft = 8.0 initially

BSS = breadth of superstructure in ft = B_{PA}

XLSS = length of superstructure in ft = \( \frac{V_{ss}}{H_{ss} \times B_{ss}} \)

If \( L_{ss} \) calculated is greater than 0.7 \( L_p \), increase \( H_{ss} \) by increment of 8 ft, and recalculate \( B_{ss} \) and \( L_{ss} \).

ARSS = profile area of superstructure in ft\(^2\)

\[ A_{ss} = L_{ss} \times H_{ss} \]

VSSW = \( \frac{V_{ss}}{W} \)
NAME: SUBROUTINE STRUCT (to be used when ILC=0 and IMAT<3)
PURPOSE: Calculate weights, volumes, and VCC's of major structures, Group 1, for conventional planing hull of aluminum or steel
CALLING SEQUENCE: CALL STRUCT
INPUT:
  IMAT Control for type of structural material, from input Card 6
  IMAT = 1 for aluminum
  IMAT = 2 for steel
  WSFMIN $S_{\text{min}}$ = minimum unit weight of plating in lb/ft$^2$, from Card 11
  WSLOPE $S_p$ = Slope of unit weight curves for stiffened plating as function of design load, from Card 11
  STRESS $\sigma_{\text{limit}}$ = Stress limit of material in lb/in.$^2$, from Card 11
  DMAT $\gamma_{\text{mat}}$ = density of structural material in lb/ft$^3$, from Card 11
  Other Hull geometry from Subroutines NEWHUL, NEWVOL, etc.
OUTPUT:
  Via COMMON blocks
A. GENERAL EQUATIONS
  PRES $P$ = design pressure on plating in lb/in.$^2$
  $S$ = unit weight of stiffened plating in lb/ft$^2$
  * UNITWT $S = S_{\text{min}} + (P \times S_p)$ for hull bottom, decks, and bulkheads
    Curves shown in Figure 4 for different materials
  $S = f(L_p)$ for hull sides
    Curves shown in Figure 5 for different materials
  * THICKN $t$ = thickness of plating in inches = 12 $S/\gamma_{\text{mat}}$
  D = depth of plating web in ft
  * DEPTH A $D = (S-1.45)/12$ for aluminum
  * DEPTHS $D = (3.0+0.1P)/12$ for steel
  DMIN $D_{\text{min}}$ = minimum depth of plating web = 0.25 ft

*UNITWT, THICKN, DEPTH A and DEPTHS are Statement Functions defined at beginning of Subroutine STRUCT.
SUBROUTINE STRUCT

B. PLATFORM DECKS

NPL

- number of platform decks, excluding main deck

npl

- 0 if Hh is 10 ft or less

npl

- 1 if Hh is between 10 and 20 ft

npl

- 2 if Hh is 20 ft or greater

Hpl

- distance from lower, upper platforms to main deck

ZSP1

- 8 or 16 ft – see location of platforms in Figure 2

ZSP2

PRES

- design pressure on platform in lb/in. 2

pl

= 64 (Hpl*4)/144

WSF

- unit weight of platform in lb/ft

pl

= 8 or 16 ft

AFL1

- area of platform in ft

pl

= Platforms extend length of hull, except engine room

AFL2

DPL1

- depth of platform web in ft

Dpl

use general equations for aluminum or steel

DPL2

WPL1

- weight of platform in lb

Wpl

= Apl * S pl

WPL2

VPL1

- volume of platform in ft

Vpl

= Apl * Dpl

VPL2

ZPL1

- VCG of platform in ft

Zpl

= (ZS at X/LF=0.75) - Hpl

ZPL2

C. TRANSVERSE BULKHEADS

NTB

- number of transverse bulkheads input = 9

ntb

see location of transverse bulkheads in Figure 2

number will be reduced later if displacement is less than 70 tons

J

Index for DO LOOP J = 1, NTB

ZKS

- height of transverse bulkhead in ft

Htb

= (ZS-ZK) at location of bulkhead

ZF

- height of fuel tank coincident with bulkhead

Hft

see location of fuel tanks in Figure 2

N

design acceleration in g's at bulkhead

= 2.0, 4.0, 5.5 g's for aft, mid, forward fuel tanks

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SUBROUTINE STRUCT

PRES

\( \text{P}_{tb} \) = design pressure on bulkhead in lb/in.²
= \( 64 \left( \frac{H_{tb}}{144} + \frac{4}{144} \right) \) or
= \( 52 \left( \frac{H_{ft}}{144} \right) \) whichever is greater

WSF

\( \text{S}_{tb} \) = unit weight of transverse bulkhead, Figure 4

AS

\( \text{A}_{tb} \) = area of transverse bulkhead in ft² = \( A_S \)
= total sectional area from Subroutine NEWVOL

DTB

\( \text{D}_{tb} \) = depth of bulkhead web in ft

WTB(J)

\( \text{W}_{tb} \) = weight of transverse bulkhead in lb
= \( \text{A}_{tb} \times \text{S}_{tb} \)

VTB

\( \text{V}_{tb} \) = volume of transverse bulkhead in ft³
= \( \text{A}_{tb} \times \text{D}_{tb} \)

ZTB(J)

\( \text{Z}_{tb} \) = VCG of transverse bulkhead in ft = \( C_S \)
= centroid of section from Subroutine NEWVOL

WTBJ

\( \Sigma \text{W}_{tb} \) = total weight of all transverse bulkheads in lb

VTBT

\( \Sigma \text{V}_{tb} \) = total volume of transverse bulkheads in ft³

ZTB

\( \bar{Z}_{tb} \) = net VCG of all transverse bulkheads in ft
= \( \frac{\Sigma (\text{Z}_{tb} \times \text{W}_{tb})}{\Sigma \text{W}_{tb}} \)

D. LONGITUDINAL BULKHEADS

NLB

\( n_{lb} \) = number of longitudinal bulkheads
\( n_{lb} = 0 \) if hull depth is 10 ft or less
\( n_{lb} = 1 \) if midship chine beam is 20 ft or less
\( n_{lb} = 2 \) if midship chine beam is between 20 and 30 ft
\( n_{lb} = 3 \) if midship chine beam is greater than 30 ft

Longitudinal bulkheads are equally spaced across breadth of hull; a single bulkhead is on centerline. Longitudinal bulkheads extend full length of hull below the lower platform deck. Bulkheads not on centerline are watertight; centerline bulkhead is not watertight.

WSF

\( S_{lb} \) = unit weight of non-centerline bulkheads in lb/ft²
= unit weight of lower platform deck (same design pressure)
SUBROUTINE STRUCT

WSFMIN

\( S_{lb} \) = unit weight of centerline bulkhead in \( \text{lb/ft}^2 \)
\( S_{\text{min}} \) (design pressure = 0, since not watertight)

J

Index for DO LOOP J = 1, NLB

AREAP

\( A_{lb} \) = area of longitudinal bulkhead in \( \text{ft}^2 \)

WLB(J)

\( W_{lb} \) = weight of longitudinal bulkhead in lb

\( A_{lb} \times S_{lb} \)

DLB

\( D_{lb} \) = depth of longitudinal bulkhead web in ft

\( V_{lb} \) = volume of longitudinal bulkhead in \( \text{ft}^3 \)

\( A_{lb} \times D_{lb} \)

ZLB(J)

\( Z_{lb} \) = VCG of longitudinal bulkhead in ft

WLBT

\( E_{lb} \) = total weight of all longitudinal bulkheads in lb

VLBT

\( E_{lb} \) = total volume of all longitudinal bulkheads in \( \text{ft}^3 \)

ZLBT

\( E_{lb} \) = net VCG of all longitudinal bulkheads in \( \text{ft}^3 \)

\( \Sigma(W_{lb} \times Z_{lb})/ZW_{lb} \)

E. HULL BOTTOM - KEEL TO CHINE

PRESHH

\( P_{hh} \) = pressure due to hydrostatic head in \( \text{lb/in.}^2 \)

\( = 64 (S_{S_m} + 4)/144 \)

GKC(M40)

\( G_b \) = half-girth from keel to chine in ft at \( X/L_p = 0.6 \)

\( N_{CG} \) = design acceleration at CG in g's = 3.0

PRESF

\( P_{bf} \) = design pressure on forward 40 percent of bottom in \( \text{lb/in.}^2 \)

\( = 9 \Delta (1 + N_{CG})/(2G_b L_p)/144 \) or \( P_{hh} \) if greater

PRESA

\( P_{ba} \) = design pressure on aft 60 percent of bottom in \( \text{lb/in.}^2 \)

\( = 1/2 P_{bf} \) or \( P_{hh} \) whichever is greater

WSFIF

\( S_{bf} \) = unit weight of forward bottom plating in \( \text{lb/ft}^2 \), Figure 4

WSFIA

\( S_{ba} \) = unit weight of aft bottom plating in \( \text{lb/ft}^2 \), Figure 4

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SUBROUTINE STRUCT

\( A_{bf} \) = area of forward 40 percent of bottom in \( \text{ft}^2 \)
\[
= 2 \int_{0.6 L_p}^{L_p} G_{KC} \, dX
\]

\( A_{ba} \) = area of aft 60 percent of bottom in \( \text{ft}^2 \)
\[
= 2 \int_{0}^{0.6 L_p} G_{KC} \, dX
\]

\( W_b \) = weight of bottom plating in lb
\[
= (A_{bf} \times S_{bf}) + (A_{ba} \times S_{ba})
\]

\( V_b \) = volume of bottom plating in \( \text{ft}^3 \) = \( W_b / \gamma_{\text{mat}} \)

\( Z_b \) = VCG of bottom plating in ft

F. HULL SIDES - CHINE TO MAIN DECK

\( S_s \) = unit weight of side plating in \( \text{lb/ft}^2 \), Figure 5

Aluminum hull: \( S_s = 2.4 + 0.022 L_p \), if \( L_p \leq 150 \text{ ft} \)
\( S_s = 1.2 + 0.030 L_p \), if \( L_p > 150 \text{ ft} \)

Steel hull: \( S_s = 5.5 + 0.0188 L_p \), for all \( L_p \)
minimum value of \( S_s \) is \( S_{\text{min}} \)

\( A_s \) = area of both sides in \( \text{ft}^2 \)
\[
= 2 \int_{0}^{L_p} G_{CS} \, dX
\]

\( W_s \) = weight of side plating in lb = \( A_s \times S_s \)

\( D_s \) = depth of side plating web in ft

\( V_s \) = volume of side plating in \( \text{ft}^3 \) = \( A_s \times D_s \)

\( Z_s \) = VCG of side plating in ft

G. MAIN DECK

\( P_d \) = design pressure on main deck in \( \text{lb/in.}^2 \)
\[
= 64 \times 4/144
\]

\( S_d \) = unit weight of main deck in \( \text{lb/ft}^2 \), Figure 4

\( A_d \) = area of main deck in \( \text{ft}^2 \)
\[
= 2 \int_{Y_S}^V \, dX
\]

\( D_d \) = depth of main deck web in ft

\( W_d \) = weight of main deck in lb = \( A_d \times S_d \)
SUBROUTINE STRUCT

VDECK

\( V_d \) = volume of main deck in ft\(^2\) = \( A_d \times D_d \)

ZDECK

\( Z_d \) = VCG of main deck in ft

H. STRESS CALCULATION AT MIDSHIPS

T1

\( t_1 \) = thickness of bottom plating in inches
\[ = 12 \frac{S_{ba}}{\gamma_{mat}} \]

T2

\( t_2 \) = thickness of side plating in inches
\[ = 12 \frac{S_b}{\gamma_{mat}} \]

T3

\( t_3 \) = thickness of main deck in inches
\[ = 12 \frac{S_d}{\gamma_{mat}} \]

Y1

\( \ell_1 \) = half length of bottom at midships in inches
\[ = 12 \frac{G_{K_m}}{s} \]

Y2

\( \ell_2 \) = half length of sides at midships in inches
\[ = 12 \frac{G_{S_m}}{s} \]

Y3

\( \ell_3 \) = effective half length of deck at midships in inches
\[ = \frac{2}{3} (12 \frac{Y_s}{s}) \]

A1

\( A_1 \) = half area of bottom plating at midships in in.\(^2\)
\[ = t_1 \ell_1 \]

A2

\( A_2 \) = half area of side plating at midships in in.\(^2\)
\[ = t_2 \ell_2 \]

A3

\( A_3 \) = half area of main deck at midships in in.\(^2\)
\[ = t_3 \ell_3 \]

Z1

\( Z_1 \) = VCG of \( A_1 \) in inches
\[ = 12 \left[ \frac{Z_{K_m}}{s} + \frac{1}{2} \left( \frac{Z_{C_m}}{s} - Z_{K_m} \right) \right] \]

Z2

\( Z_2 \) = VCG of \( A_2 \) in inches
\[ = 12 \left[ \frac{Z_{C_m}}{s} + \frac{1}{2} \left( \frac{Z_{S_m}}{s} - Z_{C_m} \right) \right] \]

Z3

\( Z_3 \) = VCG of \( A_3 \) in inches
\[ = 12 \times \frac{Z_{S_m}}{s} \]

Z22

\( Z_{22} \) = vertical height of sides in inches
\[ = 12 \left( \frac{Z_{S_m}}{s} - Z_{C_m} \right) \]

ZNA

\( Z_{NA} \) = height of neutral axis at midships above keel in inches
\[ = \frac{A_1 Z_1 + A_2 Z_2 + A_3 Z_3}{(A_1 + A_2 + A_3)} \]

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SUBROUTINE STRUCT

$SI = \text{sectional inertia in } \text{in.}^4$

$$SI = \left[ 2 \left( A_1 Z_1^2 + A_2 Z_2^2 + A_3 Z_3^2 + \frac{A_2 Z_{22}^2}{12} \right) - \left( A_1 + A_2 + A_3 \right) Z_{NA}^2 \right]$$

$SM = \text{least section modulus in } \text{in.}^3$

$$SM = \frac{1}{Z_{NA}} \text{ or } \frac{1}{(H_h - Z_{NA})} \text{ whichever is smaller}$$

$N_B = \text{design bow acceleration in g's } = 7.55$

$N_{CG} = \text{design CG acceleration in g's } = 3.0$

$TM = \text{bending moment at midships in in.-lb}$

$$TM = \frac{12 L_p \Delta (128 N_B - 178 N_{CG} - 50)}{1920}$$

$PSI = \text{maximum stress in lb/in.}^2 = \frac{M_b}{S_m}$

If $\sigma_{max} < \sigma_{limit}$, original plating thicknesses are OK

If $\sigma_{max} > \sigma_{limit}$ and $Z_{NA} < 0.5 H_h$, increase $t_3$ by 0.02 in. and recalculate $\sigma_{max}$

If $\sigma_{max} > \sigma_{limit}$ and $Z_{NA} > 0.5 H_h$, increase $t_3$ and $t_1$ by 0.02 in. and recalculate $\sigma_{max}$

$WSF1A = \text{unit weight of aft bottom plating in lb/ft}^2$

$$WSF1A = t_1 \frac{Y_{mat}}{12} \text{ recalculated if } t_1 \text{ is increased}$$

$WSF3 = \text{unit weight of deck in lb/ft}^2$

$$WSF3 = t_3 \frac{Y_{mat}}{12} \text{ recalculated if } t_3 \text{ is increased}$$

I. FRAMING - LONGITUDINAL AND TRANSVERSE

$W_{fr} = \text{total weight of framing in lb, Figure 6}$

Aluminum hull: $W_{fr} = 0.70 \overline{V}_h$

Steel hull: $W_{fr} = 2.1 \overline{V}_h$; if $\overline{V}_h < 3 \times 10^4$

$$W_{fr} = 1.1 \overline{V}_h + 3 \times 10^4; \quad \text{if } 3 \times 10^4 < \overline{V}_h < 1 \times 10^5$$

$$W_{fr} = 0.93 \overline{V}_h + 4.7 \times 10^4; \quad \text{if } \overline{V}_h > 1 \times 10^5$$

$V_{fr} = \text{volume of framing in ft}^3$

Aluminum hull: $V_{fr} = 0.06 \overline{V}_h$

Steel hull: $V_{fr} = 0.03 \overline{V}_h$

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### J. SUMMARY OF STRUCTURES--Group 1

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>( W_{100A} )</td>
<td>weight of plating for hull bottom in tons; ( W_b / 2240 )</td>
</tr>
<tr>
<td>( Z_{100A} )</td>
<td>VCG of bottom plating / hull depth = ( Z_b / H_h )</td>
</tr>
<tr>
<td>( V_{100A} )</td>
<td>volume of bottom plating in ( \text{ft}^3 ) = ( V_b )</td>
</tr>
<tr>
<td>( W_{100B} )</td>
<td>weight of plating for hull sides in tons; ( W_s / 2240 )</td>
</tr>
<tr>
<td>( Z_{100B} )</td>
<td>VCG of side plating / hull depth = ( Z_s / H_h )</td>
</tr>
<tr>
<td>( V_{100B} )</td>
<td>volume of side plating in ( \text{ft}^3 ) = ( V_s )</td>
</tr>
<tr>
<td>( W_{101} )</td>
<td>weight of framing in tons; ( W_{fr} / 2240 )</td>
</tr>
<tr>
<td>( Z_{101} )</td>
<td>VCG of framing / hull depth = ( Z_{fr} / H_h )</td>
</tr>
<tr>
<td>( V_{101} )</td>
<td>volume of framing in ( \text{ft}^3 ) = ( V_{fr} )</td>
</tr>
<tr>
<td>( W_{103A} )</td>
<td>weight of upper platform in tons; ( W_{pl_2} / 2240 )</td>
</tr>
<tr>
<td>( Z_{103A} )</td>
<td>VCG of upper platform / hull depth = ( Z_{pl_2} / H_h )</td>
</tr>
<tr>
<td>( V_{103A} )</td>
<td>volume of upper platform in ( \text{ft}^3 ) = ( V_{pl_2} )</td>
</tr>
<tr>
<td>( W_{103B} )</td>
<td>weight of lower platform in tons; ( W_{pl_1} / 2240 )</td>
</tr>
<tr>
<td>( Z_{103B} )</td>
<td>VCG of lower platform / hull depth = ( Z_{pl_1} / H_h )</td>
</tr>
<tr>
<td>( V_{103B} )</td>
<td>volume of lower platform in ( \text{ft}^3 ) = ( V_{pl_1} )</td>
</tr>
<tr>
<td>( W_{107} )</td>
<td>weight of main deck in tons; ( W_d / 2240 )</td>
</tr>
<tr>
<td>( Z_{107} )</td>
<td>VCG of main deck / hull depth = ( Z_d / H_h )</td>
</tr>
<tr>
<td>( V_{107} )</td>
<td>volume of main deck in ( \text{ft}^3 ) = ( V_d )</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>( n_{tb} )</td>
<td>revised number of transverse bulkheads</td>
</tr>
<tr>
<td>( n_{tb}' )</td>
<td>1, if ( \Delta_L &lt; 10 )</td>
</tr>
<tr>
<td>( n_{tb}' )</td>
<td>( 3.663 \ln (\Delta_L/8.1) ), if ( 10 &lt; \Delta_L &lt; 70 )</td>
</tr>
<tr>
<td>( n_{tb}'' )</td>
<td>9, if ( \Delta_L \geq 70 )</td>
</tr>
</tbody>
</table>
SUBROUTINE STRUCT

\[ W_{14A} = \text{weight of transverse bulkheads in tons} \]
\[ = \sum_{n} w_{tb} (n_{tb} / 9) / 2240 \]

\[ Z_{14A} = \text{VCG of transverse bulkheads / hull depth} \]
\[ = \bar{Z}_{tb} / H_h \]

\[ V_{14A} = \text{volume of transverse bulkheads in ft}^3 \]
\[ = \sum_{n} v_{tb} (n_{tb} / 9) \]

\[ W_{14B} = \text{weight of longitudinal bulkheads in tons} \]
\[ = \sum w_{lb} / 2240 \]

\[ Z_{14B} = \text{VCG of longitudinal bulkheads / hull depth} \]
\[ = \bar{Z}_{lb} / H_h \]

\[ V_{14B} = \text{volume of longitudinal bulkheads in ft}^3 \]
\[ = \sum v_{lb} \]

Subscripts are BSCI 3-digit code

The superstructure, foundations for propulsion and other equipment, and attachment are calculated in Subroutine TOTALS.
NAME: SUBROUTINE STHUCT (to be used when ILC=0 and IMAT>2)

PURPOSE: Calculate weights, volumes, and VCG's of major structures, Group 1, for planing hulls of glass reinforced plastic (GRP)

CALLING SEQUENCE: CALL STRUCT

INPUT:

IMAT

Control for type of construction, from input Card 6
IMAT = 3 for GRP single skin, with single skin bulkheads
IMAT = 4 for GRP single skin, with sandwich plate bulkheads
IMAT = 5 for GRP sandwich plate, with sandwich plate bulkheads

IFRM

Control type of framing
IFRM = 1 for transverse framing
IFRM = 2 for longitudinal framing

WSFMIN

Smin = minimum unit weight of plating in lb/ft, from Card 11; 2.5 lb/ft$^2$ for sandwich plate; 3.25 lb/ft$^2$ for single skin

WSLOPE

St = slope of unit weight curves for bottom plating as function of design load, from Card 11

STRESS

$\sigma_{\text{limit}}$ = stress limit in lb/in$^2$, from Card 11

DMAT

$\gamma_{\text{mat}}$ = density of material in lb/ft$^3$, from Card 11

Other

Hull geometry for subroutines NEWHULL, NEWVOL, etc.

OUTPUT:

A. GENERAL

PRES

p = design pressure on plating in lb/in$^2$

UNITWT

S = unit weight of plating in lb/ft$^2$

Curves of unit weight for GRP single skin and sandwich plate are shown in Figures 4 and 5.

B. PLATFORM DECKS

NPL

$n_{pl}$ = number of platform decks, excluding main deck

$n_{pl}$ = 0 if $H_h$ is 10 ft or less
$n_{pl}$ = 1 if $H_h$ is between 10 and 20 ft
$n_{pl}$ = 2 if $H_h$ is 20 ft or greater
SUBROUTINE STRUCT for GRP

ZSP1  

\[ \text{Hp}_1 = \text{distance from lower, upper platforms to main deck} \]
\[ \text{ZSP2 } = 8 \text{ or } 16 \text{ ft - see location of platforms in Figure 2} \]

PRES  

\[ \text{P}_1 = \text{design pressure on platform in lb/in.}^2 \]
\[ \text{P}_1 = 64 \left( \frac{\text{Hp}_1 + 4}{144} \right) \]

WSF  

\[ \text{S}_1 = \text{unit weight of platform in lb/ft}^2, \text{Figure 4} \]
\[ \text{S}_1 = 2.50 + 0.140 \text{P}_1 \text{ for sandwich plate (IMAT=5)} \]
\[ \text{S}_1 = 3.25 + 0.192 \text{P}_1 \text{ for single skin (IMAT=3 or 4)} \]

APL1  

\[ A_p = \text{area of platform in ft}^2; \text{platforms extend length of hull, except engine room} \]

WPL1  

\[ W_1 = \text{weight of platform in lb} \]
\[ W_1 = A_p \times S_p \]

ZPL1  

\[ Z_p = \text{VCG of platform in ft} \]
\[ Z_p = (Z_s \text{ at } X/L_p=0.75) - H_p \]

C. TRANSVERSE BULKHEADS

NTB  

\[ n_{tb} = \text{number of transverse bulkheads input} = 9 \]
\[ \text{see location of transverse bulkheads in Figure 2} \]
\[ \text{number will be reduced later if displacement is less than 70 tons} \]

J  

\[ I = 1, \text{NTB} \]

ZKS  

\[ H_{tb} = \text{height of transverse bulkhead in ft} \]
\[ H_{tb} = (Z_s - Z_k) \text{ at location of bulkhead} \]

ZF  

\[ H_{ft} = \text{height of fuel tank coincident with bulkhead} \]
\[ \text{see location of fuel tanks in Figure 2} \]

N  

\[ N = \text{design acceleration in g's at bulkhead} \]
\[ N = 2.0, 4.0, 5.5 \text{ g's for aft, mid, forward fuel tanks} \]

PRES  

\[ P_{tb} = \text{design pressure on bulkhead in lb/in.}^2 \]
\[ P_{tb} = 64 \left( \frac{H_{tb} + 4}{144} \right) \text{ or } 52 \left( \frac{H_{ft} + N}{144} \right) \text{ whichever is greater} \]

WSF  

\[ S_{tb} = \text{unit weight of transverse bulkhead, Figure 4} \]
\[ S_{tb} = 2.50 + 0.221 \text{P}_1 \text{ for sandwich plate (IMAT=4 or 5)} \]
\[ S_{tb} = 3.25 + 0.280 \text{P}_1 \text{ for single skin (IMAT=3)} \]

AS  

\[ A_{tb} = \text{area of transverse bulkhead in ft}^2 = A_s \]
\[ = \text{total sectional area from Subroutine NEWVOL} \]

WTB(J)  

\[ W_{tb} = \text{weight of transverse bulkhead in lb} \]
\[ W_{tb} = A_{tb} \times S_{tb} \]

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SUBROUTINE STRUCT for GRP

ZTB(J)  \( Z_{tb} \)  = VCG of transverse bulkhead in ft = \( C_S \)
               = centroid of section from Subroutine NEWVOL

WTBJ  \( \Sigma W_{tb} \)  = total weight of all transverse bulkheads in lb

ZTBT  \( \overline{Z}_{tb} \)  = net VCG of all transverse bulkheads in ft
               = \( \Sigma (Z_{tb}X_{tb})/\Sigma W_{tb} \)

D. LONGITUDINAL BULKHEADS

NLB

\( n_{\ell b} \)  = number of longitudinal bulkheads
\( n_{\ell b} = 0 \) if hull depth is 10 ft or less
\( n_{\ell b} = 1 \) if midship chine beam is 20 ft or less
\( n_{\ell b} = 2 \) if midship chine beam is between 20 and 30 ft
\( n_{\ell b} = 3 \) if midship chine beam is greater than 30 ft

Longitudinal bulkheads are equally spaced across breadth of hull; a single bulkhead is on centerline. Longitudinal bulkheads extend full length of hull below the lower platform deck. Bulkheads not on centerline are watertight; centerline bulkhead is not watertight.

WSF

\( S_{\ell b} \)  = unit weight of noncenterline bulkheads
\( S_{\ell b} = 2.50 + 0.221 P_{\ell b} \) for sandwich plate (IMAT = 4 or 5)
\( S_{\ell b} = 3.25 + 0.280 P_{\ell b} \) for single skin (IMAT = 3)
where \( P_{\ell b} \) = design pressure on bulkhead
               = pressure on lower platform deck

WSMIN

\( S_{\ell b} \)  = unit weight of centerline bulkhead in lb/ft\(^2\)
\( S_{\ell b} = S_{min} \) (design pressure = 0, since not watertight)

J  Index for DO LOOP J = 1, NLB

AREAP  \( A_{\ell b} \)  = area of longitudinal bulkhead in ft\(^2\)

WLBJ  \( W_{\ell b} \)  = weight of longitudinal bulkhead in lb
\( W_{\ell b} = A_{\ell b} \times S_{\ell b} \)

ZLB(J)  \( Z_{\ell b} \)  = VCG of longitudinal bulkhead in ft

WLB  \( \Sigma W_{\ell b} \)  = total weight of all longitudinal bulkheads in lb

ZLB  \( \overline{Z}_{\ell b} \)  = net VCG of all longitudinal bulkheads in ft\(^3\)
\( \overline{Z}_{\ell b} = \Sigma (W_{\ell b} \times Z_{\ell b})/\Sigma W_{\ell b} \)
SUBROUTINE STRUCT for GRP

E. HULL BOTTOM - KEEL TO CHINE

**PRESHH**
- \( P_{hh} \) = pressure due to hydrostatic head in \( \text{lb/in.}^2 \)
  - \( = 64 \left( \frac{Z_{sm}}{2} + 4 \right) / 144 \)

**GKC(M40)**
- \( C_b \) = half-girth from keel to chine in ft at \( X/L_p = 0.6 \)

**PRESF**
- \( P_{bf} \) = design pressure on forward 40 percent of bottom in \( \text{lb/in.}^2 \)
  - \( = 9 \Delta (1 + N_{CG}) / (2G_b L_p) / 144 \) or \( P_{hh} \) if greater

**PRESA**
- \( P_{ba} \) = design pressure on aft 60 percent of bottom in \( \text{lb/in.}^2 \)
  - \( = 1/2 P_{bf} \) or \( P_{hh} \), whichever is greater

**WSF1F**
- \( S_{bf} \) = unit weight of forward bottom plating
  - \( = 2.50 + 0.140 P_{bf} \) for sandwich plate (IMAT=5)
  - \( = 3.25 + 0.192 P_{bf} \) for single skin (IMAT=3 or 4)

**WSF1A**
- \( S_{ba} \) = unit weight of aft bottom plating
  - \( = 2.50 + 0.140 P_{ba} \) for sandwich plate
  - \( = 3.25 + 0.192 P_{ba} \) for single skin

**ABOTTF**
- \( A_{bf} \) = area of forward 40 percent of bottom in \( \text{ft}^2 \)
  - \( = \int_{0}^{L_p} 2 \left( G_{KC} dX \right) / 0.6 L_p \)

**ABOTTA**
- \( A_{ba} \) = area of aft 60 percent of bottom in \( \text{ft}^2 \)
  - \( = \int_{0}^{L_p} 0.6 L_p G_{KC} dX \)

**WBOTT**
- \( W_b \) = weight of bottom plating in lb
  - \( = (A_{bf} S_{bf}) + (A_{ba} S_{ba}) \)

**ZBOTT**
- \( Z_b \) = VCG of bottom plating in ft

F. HULL SIDES - CHINE TO MAIN DECK

**WSF2**
- \( S_s \) = unit weight of side plating in \( \text{lb/ft}^2 \), Figure 5
  - \( = 1.4 + 0.0350 L_p \) for sandwich plate (IMAT=5)
  - \( = 2.3 + 0.0395 L_p \) for single skin (IMAT=3 or 4)
  (minimum value of \( S_s \) is \( S_{min} \))
SUBROUTINE STRUCT for GRP

ASIDE

\( A_s = \text{area of both sides in } \text{ft}^2 = 2 \int_0^L p G \, dx \)

WSIDE

\( W_s = \text{weight of side plating in lb} = A_s \times S_s \)

ZSIDE

\( Z_s = \text{VCG of side plating in ft} \)

G. MAIN DECK

WSP3

\( S_d = \text{unit weight of main deck in lb/ft}^2, \text{Figure 5} \)

\( A_d = \text{area of main deck in ft}^2 = 2 \int Y_s \, dx \)

ADECK

\( W_d = \text{weight of main deck in lb} = A_d \times S_d \)

ZDECK

\( Z_d = \text{VCG of main deck in ft} \)

H. FRAMING - TRANSVERSE OR LONGITUDINAL

WFRAM

\( W_{fr} = \text{weight of framing in lb, Figure 6} \)

\( = 0.75 V_h \text{ for transverse framing (IFRM=1)} \)

\( = 1.20 V_h \text{ for longitudinal framing (IFRM=2)} \)

ZFRAM

\( Z_{fr} = \text{VCG of framing in ft = centroid of } V_h \)

I. STRESS CALCULATION AT MIDSHEIPS

WFLE

\( W_{fle} = \text{longitudinally effective framing weight in lb} \)

\( = 0.36 W_{fr} \text{ for transverse framing} \)

\( = 0.48 W_{fr} \text{ for longitudinal framing} \)

AFLE

\( A_{fle} = \text{longitudinally effective framing half-area in ft}^2 \)

\( = W_{fle} / 1.40 / 2 \)

A1P

\( A_1' = \text{effective half-area added to bottom at midship} \)

\( = 0.80 A_{fle} \text{ for transverse framing} \)

\( = 0.90 A_{fle} \text{ for longitudinal framing} \)

A3P

\( A_3' = \text{effective half-area added to deck at midship} \)

\( = 0.20 A_{fle} \text{ for transverse framing} \)

\( = 0.10 A_{fle} \text{ for longitudinal framing} \)

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SUBROUTINE STRUCT for GRP

\[ K_f = \text{constant to take care of weight in core of stiffeners which are not effective in strength} \]

\[ = 0.94 \quad \text{for single skin, longitudinally framed} \]

\[ = 0.94 \times 0.90 \quad \text{for sandwich plate, longitudinally framed} \]

\[ = 0.60 \quad \text{for single skin, transversely framed} \]

\[ = 0.60 \times 0.70 \quad \text{for sandwich plate, transversely framed} \]

\[ t_1 = \text{thickness of bottom plating in inches} \]

\[ = (12 \frac{S_{ba}}{\gamma_{mat}}) \times K_f \]

\[ t_2 = \text{thickness of side plating in inches} \]

\[ = (12 \frac{S_s}{\gamma_{mat}}) \times K_f \]

\[ t_3 = \text{thickness of main deck in inches} \]

\[ = (12 \frac{S_d}{\gamma_{mat}}) \times K_f \]

\[ \ell_1 = \text{half length of bottom at midships in inches} \]

\[ = 12 C_{KC_m} \]

\[ \ell_2 = \text{half length of sides at midships in inches} \]

\[ = 12 C_{CS_m} \]

\[ \ell_3 = \text{effective half length of deck at midships in inches} \]

\[ = (2/3) (12 Y_s) \]

\[ A_1 = \text{half area of bottom plating at midships in in.}^2 \]

\[ = t_1 \ell_1 + A_1' \]

\[ A_2 = \text{half area of side plating at midships in in.}^2 \]

\[ = t_2 \ell_2 \]

\[ A_3 = \text{half area of main deck at midships in in.}^2 \]

\[ = t_3 \ell_3 + A_3' \]

\[ Z_1 = \text{VCG of } A_1 \text{ in inches} = 12[Z_{ km} + 1/2 (Z_{ C_m} - Z_{ K_m})] \]

\[ Z_2 = \text{VCG of } A_2 \text{ in inches} = 12[Z_{ C_m} + 1/2 (Z_{ S_m} - Z_{ C_m})] \]
SUBROUTINE STRUCT for CRP

Z3

\[ Z_3 = \text{VCG of } A_3 \text{ in inches in } 12 \times Z_{S_m} \]

Z22

\[ Z_{22} = \text{vertical height of sides in inches} \]

\[ = 12 \left( Z_{S_m} - Z_{C_m} \right) \]

ZNA

\[ Z_{NA} = \text{height of neutral axis at midships above keel in inches} \]

\[ = \left( A_1 Z_1 + A_2 Z_2 + A_3 Z_3 \right) / \left( A_1 + A_2 + A_3 \right) \]

SI

\[ I_m = \text{sectional inertia in in.}^4 \]

\[ = 2 \left( A_1 Z_1^2 + A_2 Z_2^2 + A_3 Z_3^2 + A_2 Z_{22}^2 / 12 \right) \]

\[ - \left( A_1 + A_2 + A_3 \right) Z_{NA}^2 \]

SM

\[ S_m = \text{least section modulus in in.}^3 \]

\[ = 1/Z_{NA} \text{ or } 1/(H_{h} - Z_{NA}) \text{ whichever is smaller} \]

NB

\[ = \text{design bow acceleration in g's} = 7.55 \]

NGG

\[ = \text{design CG acceleration in g's} = 3.0 \]

TM

\[ M_b = \text{bending moment at midships in in.-lb} \]

\[ = 12 L_p \Delta \left( 128 N_B - 178 N_{CG} - 50 \right) / 1920 \]

PSI

\[ \sigma_{max} = \text{maximum stress in lb/in.}^2 = M_b / S_m \]

If \( \sigma_{max} \leq \sigma_{limit} \), original plating thicknesses are OK

If \( \sigma_{max} > \sigma_{limit} \),

\[ Z_{NA} < 0.5 H_{h}, \text{ increase } t_3 \text{ by 0.02 in. and recalculate } \sigma_{max} \]

If \( \sigma_{max} > \sigma_{limit} \) and \( Z_{NA} > 0.5 H_{h} \),

\[ \text{increase } t_3 \text{ and } t_1 \text{ by 0.02 in. and recalculate } \sigma_{max} \]

WSFA

\[ S_{ba} = \text{unit weight of aft bottom plating in lb/ft}^2 \]

\[ = t_1 \sigma_{mat} / 12 / K_f \]

recalculate if \( t_1 \) is increased

WSF3

\[ S_{d} = \text{unit weight of deck in lb/ft}^2 \]

\[ = t_3 \sigma_{mat} / 12 / K_f \]

recalculate if \( t_3 \) is increased

J. VOLUME LOST

VI(1)

\[ V_1 = \text{total volume of structure in ft}^3 \]

\[ = 0.11 V_h + (W_{fr} / 43) \]

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SUBROUTINE STRUCT for GRP

ATOT = total area of hull side, bottom, main deck, platforms, and bulkheads
   = \( A_s + A_{bf} + A_{ba} + A_d + A_{p1} + A_{p2} \)
   + \( \Sigma A_{tb} + \Sigma A_{kb} \)

VSIDE = volume of sides = \( V_1 \frac{A_s}{A_{tot}} \)

VBOTT = volume of bottom = \( V_1 \frac{(A_{bf} + A_{ba})}{A_{tot}} \)

VDECK = volume of main deck = \( V_1 \frac{A_d}{A_{tot}} \)

VPL1 = volume of lower platform = \( V_1 \frac{A_{p1}}{A_{tot}} \)

VPL2 = volume of upper platform = \( V_1 \frac{A_{p2}}{A_{tot}} \)

VTBT = volume of transverse bulkheads = \( V_1 \frac{(\Sigma A_{tb})}{A_{tot}} \)

VLBT = volume of longitudinal bulkheads = \( V_1 \frac{(\Sigma A_{kb})}{A_{tot}} \)

VFRAM = volume of framing = \( W_{fr}/43 = 0.02326 W_{fr} \)

K. SUMMARY OF STRUCTURES--Group 1

W1(2) = weight of plating for hull bottom in tons
   = \( W_b/2240 \)

Z1(2) = VCG of bottom plating / hull depth = \( Z_b/H_h \)

V1(2) = volume of bottom plating in \( ft^3 \) = \( V_b \)

W1(3) = weight of plating for hull sides in tons
   = \( W_s/2240 \)

Z1(3) = VCG of side plating / hull depth = \( Z_s/H_h \)

V1(3) = volume of side plating in \( ft^3 \) = \( V_s \)

W1(4) = weight of framing in tons = \( W_{fr}/2240 \)

Z1(4) = VCG of framing / hull depth = \( Z_{fr}/H_h \)

V1(4) = volume of framing in \( ft^3 \) = \( V_{fr} \)

W1(5) = weight of upper platform in tons
   = \( W_{p12}/2240 \)

Z1(5) = VCG of upper platform / hull depth
   = \( Z_{p12}/H_h \)

V1(5) = volume of upper platform in \( ft^3 \) = \( V_{p12} \)

W1(6) = weight of lower platform in tons
   = \( W_{p11}/2240 \)

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SUBROUTINE STRUCT for GRP

\[
Z_{103B} = \text{VCG of lower platform / hull depth} = \frac{Z_{p1}}{H_h}
\]

\[
V_{103B} = \text{volume of lower platform in ft}^3 = V_{p1}
\]

\[
W_{107} = \text{weight of main deck in tons} = \frac{W_d}{2240}
\]

\[
Z_{107} = \text{VCG of main deck / hull depth} = \frac{Z_d}{H_h}
\]

\[
V_{107} = \text{volume of main deck in ft}^3 = V_d
\]

\[
\text{NTB}
\]

\[
t_{tb}' = \text{revised number of transverse bulkheads}
\]

\[
t_{tb} = 1, \text{ if } A_{LT} \leq 10
\]

\[
t_{tb} = 3.663 \times (A_{LT}/8.1), \text{ if } 10 < A_{LT} < 70
\]

\[
t_{tb} = 9, \text{ if } A_{LT} \geq 70
\]

\[
W_{114A} = \text{weight of transverse bulkheads in tons}
\]

\[
= \sum W_{tb} \left(\frac{n_{tb}'}{9}\right)/2240
\]

\[
Z_{114A} = \text{VCG of transverse bulkheads / hull depth}
\]

\[
= \frac{Z_{tb}}{H_h}
\]

\[
V_{114A} = \text{volume of transverse bulkheads in ft}^3
\]

\[
= \sum V_{tb} \left(\frac{n_{tb}}{9}\right)
\]

\[
W_{114B} = \text{weight of longitudinal bulkheads in tons}
\]

\[
= \sum W_{zb}/2240
\]

\[
Z_{114B} = \text{VCG of longitudinal bulkheads / hull depth}
\]

\[
= \frac{Z_{zb}}{H_h}
\]

\[
V_{114B} = \text{volume of longitudinal bulkheads in ft}^3
\]

\[
= \sum V_{zb}
\]

Subscripts are BSCI 3-digit code

The superstructure, foundations for propulsion and other equipment, and attachment are calculated in Subroutine TOTALS.
NAME: SUBROUTINE STRUCT (to be used when ILC=1 and IMAT<3)

PURPOSE: Calculate weight, volumes, and VCG's of major structures, Group 1, for landing craft with well

CALLING SEQUENCE: CALL STRUCT

INPUT: Via COMMON blocks

<table>
<thead>
<tr>
<th>NAME</th>
<th>DESCRIPTIVE</th>
<th>VALUE</th>
</tr>
</thead>
<tbody>
<tr>
<td>IMAT</td>
<td>IMAT = 1,2 for structures of aluminum or steel, from Card 11</td>
<td></td>
</tr>
<tr>
<td>WSFMIN</td>
<td>S_min = minimum unit weight of plating in lb/ft², from Card 11</td>
<td></td>
</tr>
<tr>
<td>WSLOPE</td>
<td>S_p = slope of unit weight curves, from Card 11</td>
<td></td>
</tr>
<tr>
<td>DMAT</td>
<td>Y_mat = density of structural material in lb/ft³, from Card 11</td>
<td></td>
</tr>
<tr>
<td>XLWELL</td>
<td>L_well = length of well deck in ft, excluding aft ramp, from Card 6A</td>
<td></td>
</tr>
<tr>
<td>XLBOWR</td>
<td>L_bow = length of bow ramp in ft, from Card 6A</td>
<td></td>
</tr>
<tr>
<td>BWELL</td>
<td>B_well = breadth of well deck in ft, from Card 6A</td>
<td></td>
</tr>
<tr>
<td>BBOWR</td>
<td>B_bow = breadth of bow ramp in ft, from Card 6A</td>
<td></td>
</tr>
<tr>
<td>BAFTR</td>
<td>B_aft = breadth of aft (drive through) ramp in ft, from Card 6A</td>
<td></td>
</tr>
<tr>
<td>ZWELL</td>
<td>Z_well = height of well deck above baseline in ft, from Card 6A</td>
<td></td>
</tr>
<tr>
<td>ZAFTR</td>
<td>Z_aft = height of aft ramp above baseline in ft, from Card 6A</td>
<td></td>
</tr>
</tbody>
</table>

Other Hull geometry from Subroutines NEWHUL, NEWVOL, etc.

OUTPUT: Via COMMON blocks

A. GENERAL EQUATIONS

Same as Subroutine STRUCT for conventional planing hulls.

B. GEOMETRY OF WELL AND RAMPS

<table>
<thead>
<tr>
<th>NAME</th>
<th>DESCRIPTIVE</th>
<th>VALUE</th>
</tr>
</thead>
<tbody>
<tr>
<td>XLAFTR</td>
<td>L_aft = length of aft ramp in ft = L_p - L_well</td>
<td></td>
</tr>
<tr>
<td>I</td>
<td>Index for DO LOOP I = 1, NN</td>
<td></td>
</tr>
<tr>
<td>HWELL(I)</td>
<td>H_well = depth from main deck to well deck or aft ramp in ft</td>
<td></td>
</tr>
</tbody>
</table>

= Z_s - Z_well if X > L_aft
= Z_s - Z_aft if X ≤ L_aft
SUBROUTINE STRUCT for Landing Craft

\[ A_{\text{well}} = \text{sectional area below main deck, not enclosed, in ft} \]

\[ = B_{\text{well}} \times H_{\text{well}} \text{ if } X > L_{\text{aft}} \]
\[ = B_{\text{aft}} \times H_{\text{well}} \text{ if } X \leq L_{\text{aft}} \]

\[ \text{V}_{\text{well}} = \text{volume below main deck, not enclosed, in ft}^3 \]
\[ = \int A_{\text{well}} \, dx \]

C. PLATFORM DECKS

none

D. TRANSVERSE BULKHEADS

\[ n_{tb} = \text{number of transverse bulkheads input \( \leq 15 \) may be adjusted later so that bulkheads are spaced about 6 ft apart under well deck} \]
\[ J = \text{Index for DO LOOP } J = 1, NTB \]
\[ H_{tb} = \text{height of bulkhead in ft} = Z_S - Z_K \]
\[ P_{tb} = \text{design pressure on bulkhead in lb/in.}^2 = 64 (H_{tb} + 4)/144 \]
\[ \text{no addition required for fuel tanks} \]
\[ S_{tb} = \text{unit weight of transverse bulkhead, Figure 4} \]
\[ A_{tb} = \text{area of transverse bulkhead in ft}^2 = A_S - A_{\text{well}} \]
\[ D_{tb} = \text{depth of bulkhead web in ft--from general equation} \]
\[ W_{tb} = \text{weight of transverse bulkhead in lb} = A_{tb} \times S_{tb} \]
\[ \text{V}_{tb} = \text{volume of transverse bulkhead in ft}^3 = A_{tb} \times D_{tb} \]
\[ Z_{tb} = \text{VCG of transverse bulkhead in ft} = [(A_S \times C_S) - A_{\text{well}} (Z_{\text{well}} + 1/2 H_{\text{well}})] / (A_S - A_{\text{well}}) \]
\[ \text{WTB} J = \text{total weight of all transverse bulkheads in lb} \]
\[ \text{VTB} J = \text{total volume of all transverse bulkheads in ft}^3 \]
\[ Z_{tb} = \text{net VCG of all transverse bulkheads in ft} = \Sigma (W_{tb} \times Z_{tb}) / \Sigma W_{tb} \]
E. LONGITUDINAL BULKHEADS

\[ n_{Lb} = \text{number of longitudinal bulkheads} \]
\[ n_{pr} = \text{number of propulsion units } n_{pr} - 1 \]

Longitudinal bulkheads extend from transom to aft end of well deck and from bottom of hull up to bottom of aft ramp.

\[ Z_{Kb} \]
\[ H_{Lb} = \text{mean height of longitudinal bulkheads in ft} \]
\[ P_{Lb} = \text{design pressure in lb/in.}^2 = \frac{64(H_{Lb} + 4)}{144} \]
\[ S_{Lb} = \text{unit weight in lb/ft}^2, \text{Figure 4} \]
\[ A_{Lb} = \text{total area of longitudinal bulkheads in ft}^2 \]
\[ D_{Lb} = \text{depth of longitudinal bulkhead web in ft} \]
\[ W_{Lb} = \text{total weight of longitudinal bulkheads in lb} \]
\[ V_{Lb} = \text{total volume of longitudinal bulkheads in ft}^3 \]
\[ Z_{Lb} = \text{net VCG of longitudinal bulkheads in ft} \]

F. HULL BOTTOM – KEEL TO CHINE

Same as Subroutine STRUCT for regular planing hull

\[ W_b = \text{weight of bottom plating in lb} \]
\[ V_b = \text{volume of bottom plating in ft}^3 \]
\[ Z_b = \text{VCG of bottom plating in ft} \]

G. HULL SIDES – CHINE TO MAIN DECK + WALLS OF THE WELL

\[ S_{so} = \text{unit weight of outer side plating, Figure 5} \]
\[ S_{sw} = \text{unit weight of plating for well walls} = S_{\text{min}} \]
\[ A_{so} = \text{area of both outer sides in ft}^2 \]

\[ = 2 \int_0^{L_p} G_{CS} \, dX \]
SUBROUTINE STRUCT
for Landing Craft

ASWELL

\[ A_{sw} = \text{area of both sides of well in ft}^2 \]

\[ = 2 \int_{0}^{L_p} H_{\text{well}} \, dX \]

DSIDE

\[ D_{so} = \text{depth of side plating web in ft} \]

WSIDE

\[ W_s = \text{weight of side plating, including well walls, in lb} \]

\[ = (A_{so} \times S_{so}) + (A_{sw} \times S_{sw}) \]

VSIDE

\[ V_s = \text{volume of side plating, including well walls, in ft}^3 \]

\[ = (A_{so} \times D_{so}) + (A_{sw} \times D_{sw}) \]

ZSIDE

\[ Z_s = \text{VCG of side plating in ft, assumed same as well wall} \]

H. MAIN DECK

PRES

\[ P_d = \text{design pressure on main deck in lb/in.}^2 \]

\[ = 64 \times \frac{4}{144} \]

WSF3

\[ S_d = \text{unit weight of main deck, Figure 4} \]

ABWELL

\[ A_{bw} = \text{area of bottom of well in ft}^2 = L_{\text{well}} \times B_{\text{well}} \]

AAFTR

\[ A_{ba} = \text{area of bottom of aft ramp in ft} = L_{\text{aft}} \times B_{\text{aft}} \]

ADECK

\[ A_d = \text{area of main deck in ft}^2 \]

\[ = 2 \int_{0}^{L_p} Y_s \, dX - (A_{bw} + A_{ba}) \]

DDECK

\[ D_d = \text{depth of main deck web in ft} \]

WDECK

\[ W_d = \text{weight of main deck in lb} = A_d \times S_d \]

VDECK

\[ V_d = \text{volume of main deck in ft}^3 = A_d \times D_d \]

ZDECK

\[ Z_d = \text{VCG of main deck in ft} \]

I. STRESS CALCULATION AT MIDSHIPS

Not required for landing craft

J. WELL DECK, INCLUDING AFT DRIVE-THROUGH RAMP

PRES

\[ P_{wd} = \text{design pressures on well deck in lb/in.}^2 \]

\[ = 70.0 \]

WSF4

\[ S_{wd} = \text{unit weight of well deck, Figure 4} \]
SUBROUTINE STRUCT
for Landing Craft

ADECLKW

\[ A_{wd} = \text{area of well deck, including aft ramp, in ft}^2 \]
\[ = A_{bw} + A_{ba} \]

DDECLKW

\[ D_{wd} = \text{depth of well deck web in ft} \]

WDECLKW

\[ W_{wd} = \text{weight of well deck in lb} = A_{wd} \times S_{wd} \]

VDECLKW

\[ V_{wd} = \text{volume of well deck in ft}^3 = A_{wd} \times D_{wd} \]

ZDECLKW

\[ Z_{wd} = \text{VCG of well deck in ft} \]
\[ = [(A_{bw} \times Z_{well}) + (A_{ba} \times Z_{aft})] / (A_{bw} + A_{ba}) \]

K. BOW RAMP

WSF

\[ S_{br} = \text{unit weight of bow ramp in lb/ft}^2 \]

Aluminum hull: \( S_{br} = 25.0 \)

Steel hull: \( S_{br} = 41.3 \)

ABOWR

\[ A_{br} = \text{area of bow ramp in ft}^2 = L_{bow} \times B_{bow} \]

DBOWR

\[ D_{br} = \text{depth of bow ramp in ft} \]

WBOWR

\[ W_{br} = \text{weight of bow ramp in lb} = A_{br} \times S_{br} \]

VBOWR

\[ V_{br} = \text{volume of bow ramp in ft}^3 = A_{br} \times D_{br} \]

ZBOWR

\[ Z_{br} = \text{VCG of bow ramp in ft} = 1.4 \times Z_{well} \]

L. FRAMING - LONGITUDINAL AND TRANSVERSE

Same as regular planing hull, except that volume of well \( V_{well} \) is subtracted from hull volume \( V_{h} \)

WFRAM

\[ W_{fr} = \text{total weight of framing in lb} = f(V_{h}) \]
\[ = f(V_{h}') \text{ where } V_{h}' = V_{h} - V_{well} \]

VFRAM

\[ V_{fr} = \text{volume of framing in ft}^3 \]
\[ = 0.06 W_{fr} \text{ or } 0.03 W_{fr} \text{ for aluminum or steel} \]

ZFRAM

\[ Z_{fr} = \text{VCG of framing in ft} \]

M. SUMMARY OF STRUCTURES--Group 1

WL(2)

\[ W_{100A} = \text{weight of bottom plating in tons} = W_b / 2240 \]

WL(3)

\[ W_{100B} = \text{weight of side plating, including walls of well, in tons} = W_s / 2240 \]

WL(4)

\[ W_{101} = \text{weight of framing in tons} = W_{fr} / 2240 \]

WL(5)

\[ W_{107A} = \text{weight of bow ramp in tons} = W_{br} / 2240 \]

WL(6)

\[ W_{107B} = \text{weight of well deck, including drive-through ramp, in tons} = W_{wd} / 2240 \]
SUBROUTINE STRUCT
for Landing Craft

W1(7) \( W_{107C} = \) weight of main deck in tons = \( W_d/2240 \)

NTB \( n_{tb} = \) reversed number of transverse bulkheads
        = \( \frac{L_{well}}{6.0} + 2 \)

W1(8) \( W_{114A} = \) weight of transverse bulkheads in tons
        = \( \Sigma W_{tb} \left( \frac{n_{tb}}{n_{tb}} \right) / 2240 \)

W1(9) \( W_{114B} = \) weight of longitudinal bulkheads in tons
        = \( \Sigma W_{lb} / 2240 \)

Z1 array \( VCG/H_h \) of structural components in same order as W1 array

V1 array Volume in ft\(^3\) of structural components in same order as W1 and Z1 arrays

The superstructure, foundations, and attachments are calculated in Subroutine TOTALS.

Subscripts are BSCI 3-digit code
NAME: SUBROUTINE POWER

PURPOSE: Estimate power requirements at design and cruise speeds. Calculate weights, volumes, and VCG's of major components of propulsion system, Group 2. Calculate fuel required for range specifications.

CALLING SEQUENCE: CALL POWER

SUBROUTINES CALLED: PHRES, PRCOEF, SAVIT, PROPS, WJETS

INPUT: Via COMMON blocks

VDES \( V_d \) = design (maximum) speed in knots, from input Card 7

VCRS \( V_c \) = cruise speed in knots \( < V_d \), from Card 7

RANGED \( \text{Range}_d \) = range requirement at design speed in nautical miles, from Card 7

May be 0 if cruise range dominates

RANGEC \( \text{Range}_c \) = range requirement at cruise speed in nautical miles, from Card 7

H13D \( H_{1/3}^d \) = maximum significant wave height in ft specified for operation of ship at \( V_d \), from Card 7

H13C \( H_{1/3}^c \) = maximum significant wave height in ft specified for operation of ship at \( V_c \), from Card 7

IPROP = Control for type of thrusters, from Card 6
IPROP = 1 for Gawm-Burrill type propellers
IPROP = 2 for Newton-Rader type propellers
IPROP = 3 for Wageningen B-screw type propellers
IPROP = 4 for waterjet pumps

IPM = Control for type of engines, from Card 6
IPM = 1 for diesel prime movers
IPM = 2 for gas turbine prime movers
IPM = 3 for CODOG system
IPM = 4 for COGOG system

DLBS \( \Delta \) = ship displacement in lb, from Subroutine NEWHUL

PRN \( n_{\text{pr}} \) = number of prime movers = number of thrusters, from input Card 12 or Subroutine PROPS

AUXNO \( n_{\text{aux}} \) = number of auxiliary engines, from Card 12

Other Various constants relating to engines and gears from input Cards 13, 14, and 15
SUBROUTINE POWER

OUTPUT: Via COMMON blocks

A. POWER REQUIREMENTS AT DESIGN AND CRUISE SPEEDS

NV Number of speeds = 2 (if \( V_c < V_d \)); 1 (if \( V_c = V_d \))
I Index for DO LOOP \( I = 1, NV \)
VKT(I) \( V_K \) = ship speed in knots = \( V_d \), \( V_c \) when \( I = 1,2 \)
VFPS \( V \) = ship speed in ft/sec = 1.6878 \( V_K \)
FNV(I) \( F_{nV} \) = speed-displacement coefficient
\( = \frac{V}{(gV^{1/3})^{1/2}} \)
H13(I) \( H_{1/3} \) = significant wave height in ft
ADF(I) \( \eta_a \) = appendage drag factor
TDF(I) 1-t = thrust deduction factor
TWF(I) 1-w = thrust wake factor = torque wake factor

Propellers: \( \eta_a = 1.0; 1-t = 0.95; 1-w = 1.0 \)
Waterjets: \( \eta_a = 1.0; 1-t = 0.95; 1-w = 1.0 \)

TAU(I) \( \tau \) = trim angle in degrees from Subroutine SAVIT
RWS(I) \( (R/W)_a \) = resistance-weight ratio from Subroutine SAVIT, not used for the power predictions
RWB(I) \( (R/W)_b \) = resistance-weight ratio of bare hull
\( = \frac{R_b}{\Delta} \)
RWA(I) \( (R/W)_a \) = resistance-weight ratio of appended hull
\( = \frac{R_a}{\Delta} \)
RWW(I) \( (R/W)_w \) = resistance-weight ratio in seaway
\( = \frac{R_T}{\Delta} \)

RBH \( R_b \) = bare hull resistance from Subroutine PHRES
or input from Card 7 or Card 29
R_a = appended hull resistance = \( \frac{R_b}{\eta_a} \)

RT \( R_T \) = total resistance at \( H_{1/3} = \frac{R_a + R_{aw}}{\eta_a} \)
R_{aw} = added resistance in waves

EHPBH \( P_{F_b} \) = bare hull effective power = \( R_b \frac{V}{550} \)

EHP(I) \( P_F \) = total effective power = \( R_T \frac{V}{550} \)
THRUST(I) \( T \) = total thrust in lb = \( \frac{R_T}{(1-t)} \)
DHP(I) \( P_D \) = total power delivered at thrusters

Note: \( \frac{R_{aw}}{\Delta} = 1.3 (H_{1/3}/L_P)^0.5 (L_P/V^{1/3})^{-2.5} F_{nV} \)
**SUBROUTINE POWER**

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SHP(I)</td>
<td>$P_S$ = total shaft power</td>
</tr>
<tr>
<td>RPM(I)</td>
<td>$N$ = speed of thrusters in revolutions per minute</td>
</tr>
<tr>
<td>PC(I)</td>
<td>$\eta_D$ = propulsive coefficient $= \frac{P_E}{P_D}$</td>
</tr>
<tr>
<td></td>
<td>For propellers: $P_d, P_S, N, \eta_D$ from Subroutine PROPS</td>
</tr>
<tr>
<td></td>
<td>For waterjets: $P_d, P_S, N, \eta_D$ from Subroutine WJETS</td>
</tr>
<tr>
<td>BHP(I)</td>
<td>$P_B$ = total brake power</td>
</tr>
<tr>
<td>PCO(I)</td>
<td>$OPC$ = overall performance coefficient $= \frac{P_E}{P_D}$</td>
</tr>
<tr>
<td>TORQUE(I)</td>
<td>$Q$ = total torque in ft-lb $= \frac{33000 P_B}{(2\pi \eta_D)}$</td>
</tr>
<tr>
<td>BHP (1)</td>
<td>$P_{d_1}$ = total brakepower at $V_d$</td>
</tr>
<tr>
<td>BHP (2)</td>
<td>$P_{c_2}$ = total brakepower at $V_c$</td>
</tr>
</tbody>
</table>

**B. PRIME MOVERS AND GEARS**

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>PE</td>
<td>$P_e$ = maximum brake power of each prime mover $= \frac{P_d}{n_{pr}}$ or $P_e^\text{max}$ from input Card 12, whichever is smaller</td>
</tr>
<tr>
<td>THP</td>
<td>$P_d$ = total brake power of prime movers $= P_e \times n_{pr}$</td>
</tr>
<tr>
<td>SWE</td>
<td>$SW_e$ = specific weight of engines in lb/hp</td>
</tr>
<tr>
<td></td>
<td>Diesels: $SW_e = FMI (25.1/P_e^{0.207})$</td>
</tr>
<tr>
<td></td>
<td>Gas Turbines: $SW_e = FMI (0.42+2.88\times10^6/P_e^{2.67})$</td>
</tr>
<tr>
<td>WE</td>
<td>$W_e$ = weight of each prime mover in lb $= SW_e \times P_e$</td>
</tr>
<tr>
<td></td>
<td>$W_e$ from general equations may be superseded by value of FWE on Card 15</td>
</tr>
<tr>
<td>RE</td>
<td>$N_e$ = speed of prime movers in rpm</td>
</tr>
<tr>
<td></td>
<td>Diesels: $N_e = FM5 (2.09\times10^4 P_e^{0.884}/W_e)$</td>
</tr>
<tr>
<td></td>
<td>Gas Turbines: $N_e = FM5 (5.4\times10^5/P_e^{0.49})$</td>
</tr>
<tr>
<td>RD</td>
<td>$N_d$ = speed of thrusters at $V_d$ in rpm</td>
</tr>
<tr>
<td>GR</td>
<td>$m_g$ = gear ratio $= N_e/N_d$</td>
</tr>
<tr>
<td>QE</td>
<td>$Q_e$ = gear weight factor $= \frac{(P_e/N_e)(m+1)^3}{m_g}$</td>
</tr>
</tbody>
</table>

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SUBROUTINE POWER

\[ W_g = \text{weight of gears for each prime mover in lb} \]
\[ = 16000 \left( \frac{Q_e}{K} \right)^{0.9} \text{ for single reduction gears} \]
\[ = 9500 \left( \frac{Q_e}{K} \right) \text{ for planetary gears} \]
\[ K = \text{gear tooth factor input on Card 14} \]
\[ W \text{ from general equations may be superseded by value of FWG input on Card 15} \]

C. AUXILIARY ENGINES AND GEARS (By-pass if IPM < 3)

AHP
\[ P_c = \text{total horsepower of auxiliary engines} \]
\[ = P_B \text{ at } V_c \]

PEA
\[ P_a = \text{horsepower of each auxiliary engine} \]
\[ = \frac{P_c}{n_{aux}} \]

SWA
\[ SW_a = \text{Specific weight of auxiliary engines in lb/hp} \]
\[ \text{Diesels: } SW_a = FM2 \left( \frac{25.1}{P_a} \right)^{0.207} \]
\[ \text{Gas Turbines: } SW_a = FM2 \left( 0.42 + 2.88 \times 10^6 / P_a \right) \]

WEA
\[ W_a = \text{weight of each auxiliary engine in lb} \]
\[ = SW_a \times P_a \]
\[ W \text{ from general equations may be superseded by value of FWEA input on Card 15} \]

REA
\[ N_a = \text{speed of auxiliary engines in rpm} \]
\[ \text{Diesels: } N_a = FM6 \left( 2.09 \times 10^4 / P_a \right)^{0.884 / W_a} \]
\[ \text{Gas Turbines: } N_a = FM6 \left( 5.4 \times 10^5 / P_a \right)^{0.49} \]

RC
\[ N_c = \text{speed of thrusters at } V_c \text{ in rpm} \]

GRA
\[ m_{g_a} = \text{gear ratio} = \frac{N_a}{N_c} \]

QE
\[ Q_a = \text{gear weight factor} = \left( \frac{P_a}{N_a} \right) \left( m_{g_a} + 1 \right)^3 / m_{g_a} \]

WGA
\[ W_{g_a} = \text{weight of gears for each auxiliary engine in lb} \]
\[ = 16000 \left( \frac{Q_a}{K} \right)^{0.9} \text{ for single reduction gears} \]
\[ = 9500 \left( \frac{Q_a}{K} \right) \text{ for planetary gears} \]
\[ K = \text{gear tooth factor input on Card 14} \]
\[ W \text{ from general equations may be superseded by value of FWGA input on Card 15} \]
SUBROUTINE POWER

D. PROPELLERS, SHAFTING, BEARINGS, ETC. (By-pass if IPROP = 4)

DFT  \( D \) = diameter of propeller in ft from Subroutine PROPS

EAR \( EAR \) = propeller expanded area ratio

input on Card 12

WPR \( W_{pr} \) = weight of each propeller in lb

\( = D^3 \times (5.05 \times EAR + 3.3) \)

SHL \( L_{sh} \) = shaft length in ft from Subroutine PROPS

QD \( Q_{sh} \) = torque per shaft in ft-lb = \( Q_{ud} / n_{pr} \)

\( S_s \) = shear stress due to torsion in lb/in\(^2\)

\( = 14000 \)

\( \zeta \) = shaft inner diameter/outer diameter

initial value of 0.67 used for hollow shaft

SHDO \( d_o \) = outer shaft diameter in inches

\( = \left( \frac{192 \times Q_{sh} \times (\pi S_s)}{(1-\zeta^4)} \right)^{1/3} \)

If \( d_o < 6 \) inches, set \( \zeta = 0 \) for solid shaft, and recalculate \( d_o \)

SHDI \( d_i \) = inner shaft diameter in inches = \( \zeta \times d_o \)

WSH \( W_{sh} \) = weight of each shaft in lb

\( = 3.396 \times L_{sh} \times (d_o^2-d_i^2) \pi / 4 \)

\( L_{max} \) = maximum length of unsupported shafting

in ft

\( = 178.5 \times (d_o / N_d)^{1/2} \)

NSEG \( n_{seg} \) = number of shaft segments = \( L_{sh} / L_{max} \)

rounded up

SEGL \( L_{seg} \) = length of each segment in ft = \( L_{sh} / n_{seg} \)

WB \( W_b \) = weight of coupling, bearings, etc. for each shaft in lb

\( = n_{seg} \times (0.00792 \times Q_{ud} + 5.0 \times d_o \times L_{seg}) \)

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E. WATERJET PUMPS (By-pass if IPROP < 4)

SUBROUTINE POWER

DFT

\[ D = \text{diameter of waterjet impeller in ft} \]

from Subroutine WJETS

AJ

\[ A_j = \text{area of jet in ft}^2 \]

from Subroutine WJETS

WJW

\[ B_{wj} = \text{breadth of each waterjet unit in ft} \]

\[ B_{wj} = 1.10 \times D \]

WJL

\[ L_{wj} = \text{length of waterjet unit inside of hull, in ft} \]

\[ L_{wj} = 4.8 \times D \]

WJH

\[ H_{wj} = \text{height of waterjet unit in ft} \]

\[ H_{wj} = 1.8 \times D \]

V2(3)

\[ V_{wj} = \text{internal volume required for waterjets in ft}^3 \]

\[ V_{wj} = [n_{pr} B_{wj} + c(1 + n_{pr})][H_{wj} + c][L_{wj}] \]

where \( c \) is clearance of 1.5 ft around units

Z2(3)

\[ ZCG_{wj} = \text{VCG of waterjets above baseline in ft} \]

\[ ZCG_{wj} = Z_{K_1} + 0.5 (Z_{C_1} - Z_{K_1}) + 1.15 \times D \]

HPD

\[ P_{d} = \frac{\text{maximum input horsepower per unit}}{n_{pr}} \]

\[ P_{d} = \frac{(\text{DHP at } V_d)}{n_{pr}} \]

WPR

\[ W_{wj} = \text{weight of each complete waterjet unit in lb*} \]

\[ W_{wj} = 1.4 \times A_j (b_0 P_d e_0 + b_1 P_d e_1 + b_2 P_d e_2 + b_3 P_d e_3) \]

where \( b_0 = -695241 \)

\[ e_0 = -1.0556 \]

\[ b_1 = 4321.3 \]

\[ e_1 = -0.0556 \]

\[ b_2 = 1.2156 \]

\[ e_2 = 0.9444 \]

\[ b_3 = -0.0000395 \]

\[ e_3 = 1.9444 \]

WSH

\[ W_{sh} = 0 \]

Weight of shaftings, bearings, etc. included in \( W_{wj} \)

WB

\[ W_{b} = 0 \]

Factor of 1.4 in equation for waterjet weight takes care of steering-reversing gear.
F. VOLUME REQUIRED FOR PROPULSION SYSTEM

VOLE

- \( V_e \) = volume of main engine room for prime movers in \( \text{ft}^3 \)
  - Diesels: \( V_e = 31.95 P_d \Delta L / V_d \)
  - Gas Turbines: \( V_e = 0.274 P_d \)

VOLEA

- \( V_a \) = volume of space for auxiliary engines in \( \text{ft}^3 \)
  - Diesels: \( V_a = 31.95 P_c \Delta L / V_c \)
  - Gas Turbines: \( V_a = 0.137 P_c \)

VOLE2

- \( V_{e2} \) = volume of inlets and exhausts for prime movers in \( \text{ft}^3 \)
  - Diesels: \( V_{e2} = 0.0357 P_d \)
  - Gas Turbines: \( V_{e2} = 0.06135 P_d \)

VOLEA2

- \( V_{a2} \) = volume of inlets and exhausts for auxiliary engines in \( \text{ft}^3 \)
  - Diesels: \( V_{a2} = 0.0357 P_c \)
  - Gas Turbines: \( V_{a2} = 0.06135 P_c \)

\( V_e, V_a, V_{e2}, V_{a2} \) from general equations above may be superseded by values of FVOLE, FVOLEA, FVOLE2, FVOLA2, respectively, input on Card 15.

Space for all other components of propulsion system assumed to be included in main engine room \( V_e \), except for waterjets. See Section D for additional volume required for waterjets.
G. SUMMARY OF PROPULSION—Group 2

$W_{201}$ = weight of propulsion units, engines and gears in tons

$W_{203}$ = weight of shafting, bearings, and propellers (or waterjets) in tons

$W_{204,205}$ = weight of combustion air supply and uptakes in tons = $0.0002 P_d$

$W_{206}$ = weight of propulsion control equipment in tons = $0.00005 P_d$

$W_{209}$ = weight of circulating and cooling water system in tons = $0.000036 P_d$

$W_{210}$ = weight of fuel oil service system in tons = $0.000076 P_d + W_{ft}$

$W_{211}$ = weight of lubricating oil system in tons = $0.000036 P_d$

$W_{250,251}$ = weight of repair parts and operating fluids in tons = $0.00018 P_d$

$V_{201}$ = volume of propulsion units in ft$^3$

$V_{203}$ = 0.0 except when waterjets are used; see section on waterjets

$V_{204,205}$ = volume of air supply and uptakes in ft$^3$

$V_{pr}$ = total volume of propulsion system in ft$^3$

$Z_{204,205}$ = VCG of air supply and uptakes / hull depth = 1.13

H. FUEL REQUIREMENT

$SFC_{d}$ = specific fuel consumption of prime movers at design speed in lb/hp/hr

Diesels: $SFC_{d} = FM3 [0.859 - 0.247 \log P_e + 0.0309 (\log P_e)^2]$

Gas Turbines: $SFC_{d} = FM3 [1.565 - 0.488 \log P_e + 0.0501 (\log P_e)^2]$
SUBROUTINE POWER

\( SFC_d \) from general equations may be superseded by
value of FSFCD input on Card 15.

\[ SFC_C = \text{specific fuel consumption of prime movers} \]
\[ \text{at cruise speed in lb/hp/hr (by-pass if} \]
\[ \text{auxiliary engines are used)} \]

Diesels: \[ SFC_C = SFC_d \left[ \frac{0.853}{P_C/P_d} \right]^{0.214} + 0.147 \left( \frac{P_C}{P_d} \right)^3 \]

Gas Turbines: \[ SFC_C = SFC_d \left[ \frac{(-0.181 P_e^{0.11} + 0.762)}{/(P_c/P_d)^{0.825} + 0.377 P_e^{0.0734}} \right] \]

\( SFC_C \) from general equations may be superseded by
value of FSFCC input on Card 15.

\[ FRD = \text{total fuel rate in lb/hr at design speed} \]
\[ = SFC_d \times P_d \]

\[ FRC = \text{total fuel rate at cruise speed in lb/hr} \]
\[ = SFC_c \times P_c \]

\[ H_C = \text{operating time for cruise speed range in} \]
\[ \text{hours} \]
\[ = \text{Range}_c / V_c \]

\[ H_{RD} = \text{operating time for design speed range in} \]
\[ \text{hours} \]
\[ = \text{Range}_d / V_d \]

\[ WF = \text{fuel required for cruise speed range in} \]
\[ \text{tons} \]
\[ = H_c \times FRC / 0.95 / 2240 \]

\[ WFDES = \text{fuel required for design speed range in} \]
\[ \text{tons} \]
\[ = H_d \times FRD / 0.95 / 2240 \]
SUBROUTINE POWER

WF

\[ W_f = \text{weight of fuel in tons} \]

\[ = W_f \text{ or } W_f^c, \text{ whichever is greater} \]

Range\textsubscript{c} or Range\textsubscript{d} is recalculated based on the dominating fuel weight \( W_f \).

WFT

\( W_{ft} = \text{weight of fuel tanks in tons} \)

If IFT = 0, then \( W_{ft} = 0 \), since fuel tanks, are included with the hull structures.

If IFT = 1, then \( W_{ft} = 0.15 W_f \), for separate fuel tanks (1.0 lb / gallon of fuel)
NAME: SUBROUTINE ELECPL

PURPOSE: Calculate weights, volumes, and VCG's of the major components of the electric plant, Group 3

CALLING SEQUENCE: CALL ELECPL

INPUT: Via COMMON blocks
FKW KW = electric power in kilowatts, optional input on Card 11
W W = total ship weight in tons = $\Delta_L/T$, from PHFMOPT
HMB $H_{mb}$ = height of machinery box in ft, from Subroutine NEWVOL
HDM $H_h$ = hull depth at midships in ft, from PHFMOPT
PL $L_p$ = ship projected chine length in ft, from input Card 29
BPA $B_{PA}$ = average chine beam in ft, from Subroutine NEWHUL
VOLT $V_T$ = total enclosed volume, including superstructure, in $ft^3$, from Subroutine NEWVOL.

OUTPUT: Via COMMON blocks
PKW KW = electric power in kilowatts = $4.29 \times W^{0.79}$ or value of FKW input on Card 11
W3(2) $W_{300}$ = weight of electric power generation in tons
$= 0.352 + 0.0408 \times KW$ if $KW \leq 40$
$= 1.8 + 0.0046 \times KW$ if $KW > 40$
Z3(2) $Z_{300}$ = VCG of electric power generation / hull depth
$= \frac{(2.0 + 0.63 \times H_{mb})}{H_h}$
W3(3) $W_{301}$ = weight of power distribution switchboard in tons
$= 0.0033 \times KW$
Z3(3) $Z_{301}$ = VCG of power distribution switchboard / hull depth
$= 0.786 \times H_{mb}/H_h$
W3(4) $W_{302}$ = weight of power distribution system cables
$= 0.000085 \times V_T$
Z3(4) $Z_{302}$ = VCG of power cables / hull depth $= 0.699$
W3(5) $W_{303}$ = weight of lighting system in tons
$= 0.0000265 \times L_p \times B_{PA} \times H_h$
Z3(5) $Z_{303}$ = VCG of lighting system / hull depth $= 1.383$

No volume is added for electric plant assumed to be included in volume of main engine room.

Subscripts are BSCI 3-digit code
NAME: SUBROUTINE COMCON

PURPOSE: Calculate weights, volumes, and VCG's of the non-military components of communication and control, Group 4

CALLING SEQUENCE: CALL COMCON

INPUT: Via COMMON blocks

- **VOLT** \( V_T \): total enclosed volume, including superstructure, in \( ft^3 \), from Subroutine NEWBOL
- **PL** \( L_P \): ship projected chine length in ft, from input Card 29
- **BPA** \( B_{PA} \): average chine beam in ft, from Subroutine NEWHUL
- **HDM** \( H_h \): hull depth at midships in ft, from PHFMOPT
- **ZPC** \( Z_{PC} \): centroid of profile above baseline / hull depth, from Subroutine NEWVOL

OUTPUT: Via COMMON blocks

- **W4(2)** \( W_{400} \): weight of non-electronic navigation equipment in tons
  \( = 0.0000035 V_T \)
- **Z4(2)** \( Z_{400} \): VCG of navigation equipment / hull depth
  \( = 2.18 Z_{PC} \)
- **V4(2)** \( V_{400} \): volume of navigation equipment in \( ft^3 \)
  \( = 0.10 V_T \)
- **W4(3)** \( W_{401} \): weight of interior communication system in tons
  \( = 0.0000465 L_P B_{PA} H_h \)
- **Z4(3)** \( Z_{401} \): VCG of communication system / hull depth
  \( = 0.786 \)
- **V4(3)** \( V_{401} \): volume of communication system in \( ft^3 \)
  \( = 0.0036 V_T \)

Remainder of communication and control is considered part of the payload.
NAME: SUBROUTINE AUXIL

PURPOSE: Calculate weights, volumes, and VCG's of major components of auxiliary systems, Group 5

CALLING SEQUENCE: CALL AUXIL

INPUT: Via COMMON blocks

VOLT $V_T$ = total enclosed volume in ft$^3$, from Subroutine NEWHUL

PL $L_P$ = ship length in ft, from input Card 29

BPA $B_{PA}$ = average chine beam in ft, from Subroutine NEWHUL

HMB $H_{mb}$ = height of machinery box in ft, from Subroutine NEWVOL

HM $H$ = draft at midships in ft, from Subroutine NEWHUL

DMULT $M_{\Delta}$ = multiplier for ship size, from Subroutine CREWSS

ZPC $Z_{PC}$ = centroid of hull profile above baseline / $H_h$, from Subroutine NEWVOL

ACC $acc$ = total accommodations, from input Card 10 or Subroutine CREWSS

DAYS $days$ = number of days for provisions, from Card 10

WF $W_F$ = weight of fuel in tons, from Subroutine POWER

W $W$ = total ship weight in tons = $\Delta_{LT}$ from PHFMOPT

OUTPUT: Via COMMON blocks

A. GENERAL NOTATION

W denotes weight in long tons
Z denotes VCG / hull depth
$\nabla$ denotes volume in ft$^3$

Subscript is BSCI 3-digit code

B. HEATING AND AIR-CONDITIONING SYSTEMS

$W_5(2)$ $W_{500,502} = 0.000036 \ nabla_T$

$Z_5(2)$ $Z_{500,502} = 1.271 \ Z_{PC}$

C. VENTILATION SYSTEM

$W_5(3)$ $W_{501} = 0.000025 \ nabla_T$

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SUBROUTINE AUXIL

\[ Z5(3) \quad Z5_{01} = 1.528 \, Z_{PC} \]
\[ V5(3) \quad V5_{01} = 0.03 \, V_T \]

D. REFRIGERATING SPACES

\[ W5(4) \quad W5_{03} = N_\lambda (0.26 + 0.0113 \, \text{acc}) \]
\[ Z5(4) \quad Z5_{03} = 0.465 \]
\[ V5(4) \quad V5_{03} = 0.69 \, \text{acc} \times \text{days} \]

E. PLUMBING INSTALLATIONS

\[ W5(5) \quad W5_{05} = 0.0267 \, \text{acc} \]
\[ Z5(5) \quad Z5_{05} = 1.29 \, Z_{PC} \]
\[ V5(5) \quad V5_{05} = 26.4 \, \text{acc} + 100.0 \]

F. FIREFMAIN, FLUSHING, SPRINKLING

\[ W5(6) \quad W5_{06} = 0.00004 \, V_T \]
\[ Z5(6) \quad Z5_{06} = 0.6689 \]

G. FIRE EXTINGUISHING SYSTEM

\[ W5(7) \quad W5_{07} = 0.0000131 \, V_T \]
\[ Z5(7) \quad Z5_{07} = 0.750 \]

H. DRAINAGE AND BALLAST

\[ W5(8) \quad W5_{08} = 0.0000194 \, V_T \]
\[ Z5(8) \quad Z5_{08} = 0.292 \]
\[ V5(8) \quad V5_{08} = 0.00438 \, V_T \]

I. FRESH WATER SYSTEM

\[ W5(9) \quad W5_{09} = 0.023 \, \text{acc} \]
\[ Z5(9) \quad Z5_{09} = 1.005 \, Z_{PC} \]

J. SCUPPERS AND DECK DRAINS

\[ W5(10) \quad W5_{10} = 0.00000333 \, V_T \]
\[ Z5(10) \quad Z5_{10} = 0.9806 \]

K. FUEL AND DIESEL OIL FILLING

\[ W5(11) \quad W5_{11} = 0.0003 \, W_F \]
\[ Z5(11) \quad Z5_{11} = 0.418 \]
<table>
<thead>
<tr>
<th>L. COMPRESSED AIR SYSTEM</th>
</tr>
</thead>
<tbody>
<tr>
<td>W5(12) ( W_{513} ) = 0.0</td>
</tr>
<tr>
<td>Z5(12) ( Z_{513} ) = 0.0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>M. DISTILLING PLANT</th>
</tr>
</thead>
<tbody>
<tr>
<td>W5(13) ( W_{517} ) = 0.000848 ((15 \text{ acc})^{1.021})</td>
</tr>
<tr>
<td>Z5(13) ( Z_{517} ) = 0.540</td>
</tr>
<tr>
<td>V5(13) ( V_{517} ) = ( H_{mb} [160.0 + 0.0031 (15 \text{ acc})] )</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>N. STEERING SYSTEMS</th>
</tr>
</thead>
<tbody>
<tr>
<td>W5(14) ( W_{518} ) = 0.001205 ( H_{Lp} )</td>
</tr>
<tr>
<td>Z5(14) ( Z_{518} ) = 0.656</td>
</tr>
<tr>
<td>V5(14) ( V_{518} ) = 0.2176 ( B_{PA} H_{Lp} )</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>O. RUDDERS</th>
</tr>
</thead>
<tbody>
<tr>
<td>W5(15) ( W_{519} ) = 0.00313 ( H_{Lp} )</td>
</tr>
<tr>
<td>Z5(15) ( Z_{519} ) = 0.382</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>P. MOORING, TOWING, ANCHOR, DECK MACHINERY</th>
</tr>
</thead>
<tbody>
<tr>
<td>W5(16) ( W_{520} ) = 0.000002 ( V_T )</td>
</tr>
<tr>
<td>Z5(16) ( Z_{520} ) = 0.702</td>
</tr>
<tr>
<td>V5(16) ( V_{520} ) = 0.5 ( W )</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Q. STORES HANDLING</th>
</tr>
</thead>
<tbody>
<tr>
<td>W5(17) ( W_{521} ) = 0.00000865 ( V_T )</td>
</tr>
<tr>
<td>Z5(17) ( Z_{521} ) = 1.0</td>
</tr>
<tr>
<td>V5(17) ( V_{521} ) = 0.00088 ( V_T )</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>R. REPLENISHMENT AT SEA</th>
</tr>
</thead>
<tbody>
<tr>
<td>W5(18) ( W_{528} ) = 0.0000025 ( V_T )</td>
</tr>
<tr>
<td>Z5(18) ( Z_{528} ) = 0.807</td>
</tr>
<tr>
<td>V5(18) ( V_{528} ) = 0.00168 ( V_T )</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>S. REPAIR PARTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>W5(19) ( W_{550} ) = 0.0053 ((W_{500,502}+W_{501}+W_{503}+W_{505}+W_{506}+W_{507}+W_{509}+W_{513}+W_{517}+W_{518}+W_{520}))</td>
</tr>
</tbody>
</table>

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SUBROUTINE AUXIL

\[ Z_{550} = 0.5335 \]

\[ V_{550} = 0.004 \, V_T \]

T. OPERATING FLUIDS

\[ W_{551} = 0.04 \text{ (Sum of all preceding Group 5 weights)} \]

\[ Z_{551} = 0.9039 \]

Volumes of items not specified are assumed to either be negligible or included in the machinery box.

Weights and volumes from these general equations for the auxiliary systems may be changed or eliminated by appropriate multipliers (K-factors) input on Cards 22 and 23. The multiplications are performed in Subroutine TOTALS together with the summation of all Group 5 weights.
NAME: SUBROUTINE OUTFIT

PURPOSE: Calculate weights, volumes, and VCC's of major components of outfit and furnishings, Group 6

CALLING SEQUENCE: CALL OUTFIT

INPUT: Via COMMON blocks

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>VOLT</td>
<td>$V_T$ = total enclosed volume in ft$^3$, from Subroutine NEWVOL</td>
</tr>
<tr>
<td>VPR</td>
<td>$V_{pr}$ = total volume of propulsion system in ft$^3$, from Subroutine POWER</td>
</tr>
<tr>
<td>VF</td>
<td>$V_F$ = volume of fuel tanks in ft$^3$, from Subroutine LOADS</td>
</tr>
<tr>
<td>PL</td>
<td>$L_P$ = ship length in ft, from input Card 29</td>
</tr>
<tr>
<td>BPA</td>
<td>$B_{PA}$ = average chine beam in ft, from Subroutine NEWVOL</td>
</tr>
<tr>
<td>DMULT</td>
<td>$M_\Delta$ = multiplier for ship size, from Subroutine CREWSS</td>
</tr>
<tr>
<td>ZPC</td>
<td>$Z_{PC}$ = centroid of hull profile above baseline / hull depth, from Subroutine NEWHUL</td>
</tr>
<tr>
<td>ACC</td>
<td>acc = total accommodations, from Card 10 or CREWSS</td>
</tr>
<tr>
<td>CREW</td>
<td>crew = number of enlisted men, from Card 10 or CREWSS</td>
</tr>
<tr>
<td>CPO</td>
<td>CPO's = number of CPO's, from Card 10 or CREWSS</td>
</tr>
<tr>
<td>OFF</td>
<td>officers = number of officers, from Card 10 or CREWSS</td>
</tr>
</tbody>
</table>

OUTPUT: Via COMMON blocks

A. GENERAL NOTATION

- $W$ denotes weight in long tons
- $Z$ denotes VCG / hull depth
- $V$ denotes volume in ft$^3$

B. HULL FITTINGS

<table>
<thead>
<tr>
<th>Subscript</th>
<th>Formula</th>
</tr>
</thead>
<tbody>
<tr>
<td>W6(2)</td>
<td>$W_{600} = 0.00034 L_P B_{PA}$</td>
</tr>
<tr>
<td>Z6(2)</td>
<td>$Z_{600} = 1.064$</td>
</tr>
</tbody>
</table>

C. BOATS, STOWAGES, AND HANDLING

<table>
<thead>
<tr>
<th>Subscript</th>
<th>Formula</th>
</tr>
</thead>
<tbody>
<tr>
<td>W6(3)</td>
<td>$W_{601} = 0.02232$ acc</td>
</tr>
<tr>
<td>Z6(3)</td>
<td>$Z_{601} = 1.248$</td>
</tr>
</tbody>
</table>
### Subroutine Outfit

#### D. Rigging and Canvas
\[
W_6(4) \quad W_602 = 0.005 \text{ (sum of all Group 6 weights)} \\
Z_6(4) \quad Z_602 = 2.15 Z_{PC}
\]

#### E. Ladders and Grating
\[
W_6(5) \quad W_603 = 0.000032 M_\Delta (3 V_{pr} + V_T) \\
Z_6(5) \quad Z_603 = 0.469 \\
V_6(5) \quad V_603 = 0.10 M_\Delta (V_T - V_{pr} - V_F)
\]

#### F. Nonstructural Bulkheads and Doors
\[
W_6(6) \quad W_604 = 0.0000209 M_\Delta V_T \\
Z_6(6) \quad Z_604 = 1.438 Z_{PC}
\]

#### G. Painting
\[
W_6(7) \quad W_605 = 0.00003348 \quad V_T \\
Z_6(7) \quad Z_605 = 0.958 Z_{PC}
\]

#### H. Deck Covering
\[
W_6(8) \quad W_606 = 0.0000368 \quad V_T \\
Z_6(8) \quad Z_606 = 1.331 Z_{PC}
\]

#### I. Hull Insulation
\[
W_6(9) \quad W_607 = 0.00022 \quad V_T \\
Z_6(9) \quad Z_607 = 1.271 Z_{PC}
\]

#### J. Storerooms, Stowage, and Lockers
\[
W_6(10) \quad W_608 = 0.0688 \text{ acc} \\
Z_6(10) \quad Z_608 = 0.633 \\
V_6(10) \quad V_608 = 1.125 \text{ acc}
\]

#### K. Equipment for Utility Spaces
\[
W_6(11) \quad W_609 = 0.01 \text{ acc} \\
Z_6(11) \quad Z_609 = 0.728 \\
V_6(11) \quad V_609 = 0.552 \text{ acc}
\]

#### L. Equipment for Workshops
\[
W_6(12) \quad W_610 = 2.0 + 0.000005 \quad V_T, \text{ if } V_T \geq 300,000 \\
= 0.00001165 \quad V_T, \text{ if } V_T < 300,000
\]
SUBROUTINE OUTFIT

\[
\begin{align*}
Z_6(12) &= 1.207 Z_{PC} \\
V_6(12) &= 8.0 \left(100.0 + 0.00025 V_T\right), \text{ if } V_T \geq 300,000 \\
&= 8.0 \left(0.000585 V_T\right), \text{ if } V_T < 300,000
\end{align*}
\]

M. GALLEY, PANTRY, SCULLERY, COMMISSARY

\[
\begin{align*}
W_6(13) &= 0.01833 \text{ acc} \\
Z_6(13) &= 1.45 Z_{PC} \\
V_6(13) &= 29.6 \text{ acc}
\end{align*}
\]

N. LIVING SPACES

\[
\begin{align*}
W_6(14) &= 0.03693 \left(\text{Crew} + 1.55 \text{ CPO's} + 4.35 \text{ officers}\right) \\
&\quad + 0.00529 \left(\text{Crew} + 4.17 \text{ CPO's} + 6.36 \text{ officers}\right) \\
Z_6(14) &= 1.32 Z_{PC} \\
V_6(14) &= 8.0 \left[19.8 \left(\text{Crew} + 1.55 \text{ CPO's} + 2.75 \text{ officers}\right) + 140.0 + 4.46 \left(\text{Crew} + 3.36 \text{ CPO's} + 4.68 \text{ officers}\right)\right]
\end{align*}
\]

O. OFFICERS, CONTROL CENTER

\[
\begin{align*}
W_6(15) &= 0.02 \text{ acc} \\
Z_6(15) &= 1.538 Z_{PC} \\
V_6(15) &= 149.3 W_6(15)
\end{align*}
\]

P. MEDICAL - DENTAL SPACES

\[
\begin{align*}
W_6(16) &= 0.0035 \text{ acc} \\
Z_6(16) &= 1.38 Z_{PC} \\
V_6(16) &= 149.3 W_6(16)
\end{align*}
\]

Volumes of items not specified are assumed to be negligible.

Weights and volumes from these general equations for the outfit and furnishings will be multiplied by appropriate K-factors input on Cards 24 and 25. These multiplications and summations of all Group 6 weights are performed in Subroutine TOTALS.
NAME: SUBROUTINE LOADS

PURPOSE: Calculate weights, volumes, and VCG's of the fuel load, crew and effects, personnel stores, and potable water

CALLING SEQUENCE: CALL LOADS

INPUT: Via COMMON blocks
- WF = weight of fuel in tons to meet range requirement(s), from Subroutine POWER
- HDM = hull depth at midships in ft, from PHFMOPT
- ACC = total accommodations, from Card 10 or Subroutine CREWSS
- DAYS = number of days for provisions, from Card 10
- XL array = K-factors for the loads, from card 16

OUTPUT: Via COMMON blocks
- WL(2) = weight of fuel in tons
- ZL(2) = VCG of fuel / hull depth, see Figure 2
- VL(2) = volume of fuel in ft³ = 42.96 x WF x 1.05
- WL(3) = weight of crew and personnel effects in tons = 0.120 x ACC
- ZL(3) = VCG of crew and effects / hull depth = 0.732
- VL(3) = volume of crew and effects in ft³ = 0.344 x ACC
- WL(4) = weight of personnel stores in tons = 0.00284 x ACC x DAYS
- ZL(4) = VCG of personnel stores / hull depth = 0.536
- VL(4) = volume of personnel stores in ft³ = (1.05 x ACC x DAYS) + (0.265 x ACC x DAYS) + (4.38 x ACC x DAYS) + (0.4 x DAYS) + 8.0
- WL(5) = weight of potable water in tons = 0.1485 x ACC (40 gal per man)
- ZL(5) = VCG of potable water / hull depth = 0.138
SUBROUTINE LOADS

\[ V_{L12} = \text{volume of potable water in ft}^3 = 5.35 \times \text{acc} \]

Weights and volumes of loads from the preceding general equations are multiplied by appropriate K-factors input on Card 16. Normally the K values are 1.0. VCG's are not affected by the multipliers.

\[ W_{CE} = \text{total weight of crew and provisions in tons} = W_{L1} + W_{L6} + W_{L12} \]

\[ Z_{CE} = \text{net VCG of crew and provisions / hull depth} = \frac{(W_{L1}Z_{L1} + W_{L6}Z_{L6} + W_{L12}Z_{L12})}{(W_{L1} + W_{L6} + W_{L12})} \]

\[ V_{CE} = \text{volume of crew and provisions in ft}^3 = V_{L1} + V_{L6} + V_{L12} \]
NAME: SUBROUTINE TOTALS

PURPOSE: Calculate remaining weights for Groups 1 through 6 and apply multipliers from input Cards 17 through 25. Calculate margins and totals for each weight group. Calculate weight, volume, and VCG of the resultant useful load and the payload.

CALLING SEQUENCE: CALL TOTALS

INPUT: Via COMMON blocks

W = total ship weight, full load, in tons = \Delta_{LT} from PHFMOPT
VOLT = total volume of ship, including superstructure, in ft\(^3\), from Subroutine NEWVOL
KG = net VCG of ship in ft, from Subroutine NEWHUL
HDM = hull depth at midships in ft, from PHFMOPT
HMB = height of machinery box in ft, from Subroutine NEWVOL
ZPC = centroid of hull profile above baseline / \(H_h\), from Subroutine NEWVOL
ZSS = VCG of superstructure / \(H_h\), from Subroutine NEWVOL
VOLSS = volume enclosed by superstructure in ft\(^3\), from input Card 10 or Subroutine CREWSS

W1 array = Weight in tons
Z1 array = VCC's / hull depth Structural components, Group 1, from Subroutine STRUCT
V1 array = Volumes in ft\(^3\)
W2 array = Weight in tons
Z2 array = VCC's / hull depth Propulsion components, Group 2, from Subroutine POWER
V2 array = Volumes in ft\(^3\)
W3 array = Weight in tons
Z3 array = VCC's / hull depth Electric plant components, Group 3, from Subroutine ELECPL
V3 array = Volumes in ft\(^3\)
W4 array = Weight in tons
Z4 array = VCC's / hull depth Non-military communication and control components, Group 4 from Subroutine COMCON
V4 array = Volumes in ft\(^3\)
W5 array = Weight in tons
Z5 array = VCC's / hull depth Auxiliary systems, Group 5, from Subroutine AUXIL
V5 array = Volumes in ft\(^3\)
SUBROUTINE TOTALS

W6 array  Weight in tons
Z6 array  VCG's / hull depth  Outfit and furnishings, Group 6,
V6 array  Volumes in ft^3  from Subroutine OUTFIT
X1 array  Group 1  K-factors for each BSCI 3-digit group
X2 array  Group 2  from input Cards 17 through 25. Weights
X3 array  Group 3  and volumes from the general equations
X4 array  Group 4  will be multiplied by the corresponding
X5 array  Group 5  K-factor
X6 array  Group 6
WF  Weight in tons
ZF  VCG's / hull depth  fuel load, from Subroutine LOADS
VF  Volume in ft^3
WCE  Weight in tons  total of crew and effects,
ZCE  VCG's / hull depth  personnel stores, and potable
VCE  Volume in ft^3  water from Subroutine LOADS

OUTPUT:  Via COMMON blocks

A. PROPULSION--Group 2

\[ Z_{201} = Z_{206} = Z_{209} = Z_{210} = Z_{211} = Z_{250,251} \]
\[ = \text{VCG of machinery box / hull depth} = 0.615 H_{mb} \]
\[ Z_{203} = \text{VCG of shafting, bearings, and propellers / hull depth} \]
\[ = 0.0, \text{propellers assumed at baseline, if} \]
\[ \text{IPROP} < 3 \]
\[ = \text{VCG of waterjets / } H_h, \text{if IPROP} = 3 \]

L
Index for DO LOOP L = 2, 9

W2(L)  Weights in tons of propulsion components from
       general equations in Subroutine POWER multiplied
       by corresponding K-factors from input Card 19
Z2(L)  VCG's / hull depth of propulsion components from
       general equations. Not affected by K-factors
V2(L)  Volumes in ft^3 of propulsion components from general
       equations multiplied by corresponding K-factors
W2(10)  W_{zm} = \text{weight margin for propulsion in tons} \]
       = (K_2 - 1.0) (\text{sum of weights of propulsion}
       components)
Z2(10)  Z_{zm} = \text{VCG of margin / hull depth} \]
       = \text{net VCG ratio of all propulsion components}
V2(10)  V_{zm} = \text{volume margin for propulsion} = 0.0

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SUBROUTINE TOTALS

\[ W_2(l) \quad W_2 = \text{total weight of propulsion, including margin, in tons} \]
\[ Z_2(1) \quad Z_2 = \text{net VCG of propulsion / hull depth} \]
\[ V_2(l) \quad V_2 = \text{total volume of propulsion in ft}^3 \]

B. ELECTRIC PLANT--Group 3

L \quad \text{Index for DO LOOP } L = 2,5
\[ W_3(L) \quad W_3 = \text{Weight in tons, VCG's / hull depth, volumes in ft}^3 \]
\[ Z_3(L) \quad Z_3 = \text{VCG of electric plant components. Weights and volumes from general equations multiplied by K-factors from Card 20} \]
\[ V_3(L) \quad V_3 = \text{total volume of electric plant in ft}^3 \]
\[ W_3(6) \quad W_{3m} = \text{weight margin for electric plant in tons} \]
\[ = (K_3 - 1.0) \times \text{Sum of weights of electric plant components} \]
\[ Z_3(6) \quad Z_{3m} = Z_{3m} = \text{VCG of margin / hull depth = net of all components} \]
\[ V_3(6) \quad V_{3m} = \text{volume margin for electric plant in ft}^3 = 0.0 \]
\[ W_3(1) \quad W_3 = \text{total weight of electric plant, including margin in tons} \]
\[ Z_3(1) \quad Z_3 = \text{net VCG of electric plant / hull depth} \]
\[ V_3(1) \quad V_3 = \text{total volume of electric plant in ft}^3 \]

C. COMMUNICATION AND CONTROL--Group 4 (Non-military)

L \quad \text{Index for DO LOOP } L = 2,3
\[ W_4(L) \quad W_4 = \text{Weight in tons, VCG's / hull depth, volumes in ft}^3 \]
\[ Z_4(L) \quad Z_4 = \text{Weights and volumes multiplied by K-factors from Card 21} \]
\[ V_4(L) \quad V_4 = \text{total volume in ft}^3 \]
\[ W_4(4) \quad W_{4m} = \text{weight margin in tons} \]
\[ = (K_4 - 1.0) \times \text{Sum of non-military weight components} \]
\[ Z_4(4) \quad Z_{4m} = Z_{4m} = \text{VCG of margin / hull depth = net of components} \]
\[ V_4(4) \quad V_{4m} = \text{volume margin = 0.0} \]
\[ W_4(1) \quad W_4 = \text{total weight of non-military communication and control, including margin in tons} \]
\[ Z_4(1) \quad Z_4 = \text{net VCG / hull depth} \]
\[ V_4(1) \quad V_4 = \text{total volume in ft}^3 \]
D. AUXILIARY SYSTEMS—Group 5

Index for DO LOOP L = 2, 20

Weight in tons, VCG's / hull depth, volumes in ft$^3$

of auxiliary systems. Weights and volumes from
general equations multiplied by K-factors from
Cards 22 and 23

W5(L)  = weight margin in tons
Z5(L)  = VCG of margin / hull depth = net of components
V5(L)  = volume margin in ft$^3$

W5(21)  = weight margin in tons
Z5(21)  = VCG of margin / hull depth = net of components
V5(21)  = volume margin in ft$^3$

W5(1)  = total weight of auxiliary systems, including
margin, in tons
Z5(1)  = net VCG of auxiliary systems / hull depth
V5(1)  = total volume of auxiliary system, including
margin, in ft$^3$

E. OUTFIT AND FURNISHINGS—Group 6

Index for DO LOOP L = 2, 16

Weight in tons, VCG's / hull depth, volumes in ft$^3$

of outfit and furnishings. Weight and volumes
multiplied by K-factors from Cards 24 and 25

W6(L)  = weight margin in tons
Z6(L)  = VCG of margin / hull depth = net of components
V6(L)  = volume margin in ft$^3$

W6(17)  = weight margin in tons
Z6(17)  = VCG of margin / hull depth = net of components
V6(17)  = volume margin in ft$^3$

W6(1)  = total weight of outfit and furnishings, including
margin, in tons
Z6(1)  = net VCG of outfit and furnishings / hull depth
V6(1)  = total volume of outfit and furnishings, including
margin, in ft$^3$
F. STRUCTURES--Group 1

\[ W_{11} \] = Weight of superstructure in tons = \( \frac{V_{SS}}{2240} \)

\[ Z_{11} \] = VCG of superstructure / hull depth = \( Z_{SS} \)

\[ V_{11} \] = volume of structural materials for superstructure, assumed negligible

\[ W_{112} \] = weight of foundations for propulsion plant in tons, Figure 7

\[
\begin{align*}
W_{112} &= 0.04911 W_2, \quad \text{if } W_2 < 10.0 \\
W_{112} &= 0.1785 + 0.03125 W_2, \quad \text{if } W_2 \geq 10.0
\end{align*}
\]

\[ Z_{112} \] = VCG of propulsion plant foundation / hull depth = 0.15

\[ V_{112} \] = volume of propulsion foundations, assumed negligible

\[ W_{113} \] = weight of foundations for auxiliary and other equipment in tons, Figure 8

\[
\begin{align*}
W_{113} &= 0.03884 W_A, \quad \text{if } W_A < 10.0 \\
W_{113} &= 0.1295 + 0.03884 W_A, \quad \text{if } W_A \geq 10.0
\end{align*}
\]

\[ Z_{113} \] = VCG of other foundations / hull depth = 0.78

\[ V_{113} \] = volume of other foundations, assumed negligible

\[ W_{att} \] = weight of attachments in tons

Aluminum or Steel: \( W_{att} = 0.05 \times \text{total structures} \)

GRP hulls: \( W_{att} = 0.02 \times \text{total structures} \)

\[ Z_{att} \] = VCG of attachment / hull depth

\[ V_{att} \] = volume of attachments, assumed negligible

The attachments, which encompass several BSCI codes, are arbitrarily designated 198 in this program.
SUBROUTINE TOTALS

L

Index for DO LOOP L = 2,13

W1(L)
Z1(L)
V1(L)

Weight in tons, VCG's / hull depth, volumes in ft³ of structural components. Weights and volumes from general equations multiplied by K-factors from Cards 17 and 18

W1(14)
Z1(14)
V1(14)

W₁₄ = weight margin for structures in tons
Z₁₄ = VCG of margin / hull depth = net of components
V₁₄ = volume margin for structures = 0.0

W₁ = total weight of structures, including margin, in tons
Z₁ = net VCG of structures / hull depth
V₁ = total volume of structures in ft³

G. EMPTY SHIP

WE₁
ZE₁
VE₁

Wₑ = weight of empty ship, less fixed payload items, in tons
Zₑ = VCG of empty ship / hull depth
Vₑ = volume of empty ship in ft³

= W₁ + W₂ + W₃ + W₄ + W₅ + W₆
= (W₁Z₁ + W₂Z₂ + W₃Z₃ + W₄Z₄ + W₅Z₅ + W₆Z₆)/Wₑ

H. MOMENTS

ZKG
WZKG
WZE₁

Zₚ = VCG of total ship weight / hull depth
WₜZₚ = total weight moment
WₑZₑ = empty ship weight moment

= KG / Hₙ

I. USEFUL LOADS

WU = Wₑ = useful load in tons = Wₜ - Wₑ

WL(1) = total of fuel, crew and effects, personnel store, potable water, and payload
SUBROUTINE TOTALS

\[ Z_U = \frac{VCG \text{ of useful load}}{\text{hull depth}} \]

\[ ZL(1) = \frac{(W_T Z_T - W_E Z_E)}{(W_T - W_E)} \]

\[ V_U = \frac{V}{T} \]

\[ V_{U} = \text{volume of useful load in ft}^3 \]

\[ V_L(l) = V_T - V_E \]

\[ V_P = \frac{V}{U} \]

\[ V_{P} = \text{volume of payload in ft}^3 \]

J. PAYLOAD

\[ WP = \text{weight of payload in tons} \]

\[ W_L(6) = W_U - W_F - W_C \]

\[ ZP = \frac{VCG \text{ of payload}}{\text{hull depth}} \]

\[ ZL(6) = \frac{(W_T Z_T - W_E Z_E - W_F Z_F - W_C Z_C)}{W_P} \]

Payload includes the armament, Group 7, the military portion of communication and control, Group 4, and ammunition loads in addition to any special loads required for the ship's mission, such as the tanks carried by a landing craft.

This program does not break down the payload into its various components.

K. WEIGHT FRACTIONS

\[ R(1) = \frac{W_1}{W_T} \]

\[ R(2) = \frac{W_2}{W_T} \]

\[ R(3) = \frac{W_3}{W_T} \]

\[ R(4) = \frac{W_4}{W_T} \]

\[ R(5) = \frac{W_5}{W_T} \]

\[ R(6) = \frac{W_6}{W_T} \]

\[ R(7) = \frac{W_E}{W_T} \]

\[ R(8) = \frac{W_U}{W_T} \]

\[ R(9) = \frac{W_C}{W_T} \]

\[ R(10) = \frac{W_F}{W_T} \]

\[ R(11) = \frac{W_P}{W_T} \]
L. VCG / HULL DEPTH RATIOS

G(1) \( z_1 \)
G(2) \( z_2 \)
G(3) \( z_3 \)
G(4) \( z_4 \)
G(5) \( z_5 \)
G(6) \( z_6 \)
G(7) \( z_E \)
G(8) \( z_U \)
G(9) \( z_{CE} \)
G(10) \( z_F \)
G(11) \( z_P \)

M. VOLUME FRACTIONS

S(1) \( \frac{v_1}{v_T} \)
S(2) \( \frac{v_2}{v_T} \)
S(3) \( \frac{v_3}{v_T} \)
S(4) \( \frac{v_4}{v_T} \)
S(5) \( \frac{v_5}{v_T} \)
S(6) \( \frac{v_6}{v_T} \)
S(7) \( \frac{v_E}{v_T} \)
S(8) \( \frac{v_U}{v_T} \)
S(9) \( \frac{v_{CE}}{v_T} \)
S(10) \( \frac{v_F}{v_T} \)
S(11) \( \frac{v_P}{v_T} \)
NAME: SUBROUTINE COSTS

PURPOSE: Estimate base cost of ship by major weight groups. Also estimate life costs of ship.

CALLING SEQUENCE: CALL COSTS

INPUT: Via COMMON blocks
- CKN array: Cost factors for weight Groups 1 through 6 and payload input on Card 26
- OPHRS: Operating hours per month, from input Card 27
- OPHYRS: Total vehicle operating years, from Card 27
- XUNITS: Number of vehicles to be built, from Card 27
- TIMED: Portion of time operating at maximum speed, from Card 27
- TIMEC: Portion of time operating at cruise speed, from Card 27
- FUELR: Cost of fuel in dollars per ton, from Card 27

OUTPUT: Via COMMON blocks
- \( C(1) \): Cost of structures
- \( C(2) \): Cost of propulsion
- \( C(3) \): Cost of electric plant
- \( C(4) \): Cost of non-military communication and control
- \( C(5) \): Cost of auxiliary systems
- \( C(6) \): Cost of outfit and furnishings
- \( C(7) \): Cost of empty ship = \( C_1 + C_2 + C_3 + C_4 + C_5 + C_6 \)
- \( C(8) \): Cost of payload
- \( C(9) \): Base cost of first unit = \( C_7 + C_8 \)
- \( C(10) \): Average cost of \( XUNITS \)
- \( C(11) \): Life cost of personnel pay and allowances
- \( C(12) \): Life cost of maintenance
- \( C(13) \): Life cost of operations, except energy
- \( C(14) \): Life cost of major support
- \( C(15) \): Life cost of fuel
- \( C(16) \): Total life cost = \( C_{10} + C_{11} + C_{12} + C_{13} + C_{14} + C_{15} \)

Cost estimates are in millions of FY 77 dollars.
SUBROUTINE COSTS

The cost equations used are based on statistics developed under the ANCVE project and are not for public release.

Cost data from this program should be used only for comparative purposes, i.e., percentage change from some parent configuration, and not as absolute cost figures.
NAME: SUBROUTINE PHRES

PURPOSE: Estimate the bare-hull, smooth-water resistance of a hard-chine planing hull from synthesis of Series 62 and 65 experimental data.

CALLING SEQUENCE: CALL PHRES (DLBS, FNV, SLR, DCF, SDF, RLBS)

SUBPROGRAMS CALLED: DISCOT, YINTX, CIDSF

INPUT:
- DLBS = ship displacement in lb
- FNV = speed-displacement coefficient \( V/(gV^{1/3})^{1/2} \)
- SLR = slenderness ratio \( L_p/V^{1/3} \)
- DCF = correlation allowance; may be 0
- SDF = Standard deviation factor
  - SDF = 0.0 corresponds to mean resistance-weight R/W curves derived from Series 62 and 65 data
  - SDF = 1.645 corresponds to minimum R/W curves
  - SDF can be used to approximate the resistance curves for a particular hull form

OUTPUT:
- RLBS = bare-hull, smooth-water resistance in lb
  \( R_b = \Delta (\text{mean } R/W - \text{SDF} \times \sigma) \)
- \( \sigma \) = standard deviation of Series 62-65 data from mean R/W

PROCEDURE:
- XFNV array = Tabulated values of \( F_{nV} \) from 0.0 to 4.0
- ZSLR array = Tabulated values of \( L_p/V^{1/3} \) from 4.0 to 10.0
- YRWM matrix = Tabulated values of mean R/W as \( f(F_{nV}, L_p/V^{1/3}) \) for 100,000-lb planing craft derived from Series 62 and 65 experimental data. See Table 1 and Figure 9
- YWSR matrix = Tabulated values of mean wetted area coefficients \( S/r^{2/3} \) from Series 62 and 65 hulls. See Table 2 and Figure 10
- SD array = Tabulated values of standard deviation \( \sigma \) as \( f(F_{nV}) \) See Table 1 and Figure 9
- RWm = R/W for 100,000-lb planing craft interpolated from YRWM matrix of mean R/W values at input \( F_{nV} \) and \( L_p/V^{1/3} \)
SUBROUTINE PHRES

WSR  \( S/V^{2/3} \) interpolated from WSR matrix at input \( F_{nV} \) and \( L_p/V^{1/3} \)

Subroutine DISCOT used for the double interpolation

SDM  \( \sigma \) interpolated from SD array at input \( F_{nV} \)
Function YINTX used for single interpolation

RWM  \( (R/W)_m = \text{corrected} \ R/W \ \text{for} \ 100,000-\text{lb planing craft} = (\text{mean} \ R/W \ \text{interpolated}) - (\text{SDF} \times \sigma \ \text{interpolated}) \)

DLBM  \( \Delta_m = \text{displacement of} \ 100,000-\text{lb planing craft} \)

XL  \( \lambda = \text{linear ratio of actual ship to} \ 100,000-\text{lb craft} = (\Delta/\Delta_m)^{1/3} \)

VFPSM  \( V_m = \text{speed of} \ 100,000-\text{lb craft in ft/sec} = 19.32 \ (\text{input} \ F_{nV}) \)

VFSSS  \( V_s = \text{speed of actual ship in ft/sec} = V_m^{1/2} \)

PLM  \( L_m = \text{length of} \ 100,000-\text{lb craft in ft} = 11.6014 \ (\text{input} \ L_p/V^{1/3}) \)

PLS  \( L_s = \text{length of actual ship in ft} = L_m \lambda \)

REM  \( R_{nm} = \text{Reynolds number of} \ 100,000-\text{lb craft} = V_m L_m/\nu_m \)

RES  \( R_{ns} = \text{Reynolds number of actual ship} = V_s L_s/\nu_s \)

CFM  \( C_{Fm} = \text{Schoenherr frictional resistance coefficient for} \ 100,000-\text{lb craft} \)

CFS  \( C_{Fs} = \text{Schoenherr frictional resistance coefficient for actual ship} \)
Function CIDSF used to obtain Schoenherr frictional resistance coefficients

SM  \( S_m = \text{wetted area of} \ 100,000-\text{lb craft in ft}^2 = 134.5925 \ S/V^{2/3} \)

SS  \( S_s = \text{wetted area of actual ship in ft}^2 = S_m \lambda^2 \)

RM  \( R_m = \text{resistance of} \ 100,000-\text{lb craft in lb} = (R/W)_m \Delta_m \)
SUBROUTINE PHRES

CTM $C_T^m =$ total resistance coefficient of 100,000-lb craft
$= R_m/(V_m^2 S_m \rho_m/2)$

CR $C_R^m =$ residual resistance coefficient $= C_T^m - C_F^m$

CTS $C_T^s =$ total resistance coefficient of actual ship
$= C_F^s + C_R + C_A^s$

RLBS $R_b^s =$ resistance of actual ship in lb
$= C_T^s V_s^2 S_s \rho_s/2$

VIS $V_s =$ kinematic viscosity for actual ship, input via COMMON

VISM $V_m =$ kinematic viscosity for tabulated data $= 1.2817 \times 10^{-5}$

RHO2 $\rho_s/2 =$ 1/2 water density for actual ship, input via COMMON

RHO2M $\rho_m/2 =$ 1/2 water density for tabulated data $= 1.9905/2$
**TABLE 1 - MEAN VALUES OF RESISTANCE/WEIGHT RATIOS FOR 100,000-POUNDS PLANING CRAFT**

From Series 62 and 65 Experimental Data Published in NSRDC Report 4307
with LCG Ranging from 1/3 to 1/2 \(L_p\) Forward of Transom

<table>
<thead>
<tr>
<th>SPEED (KNOTS)</th>
<th>(f_n)</th>
<th>(L_p) (FT) (46.4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.00</td>
<td>0.00</td>
<td>0.0000</td>
</tr>
<tr>
<td>5.72</td>
<td>0.50</td>
<td>0.0120</td>
</tr>
<tr>
<td>8.59</td>
<td>0.75</td>
<td>0.0420</td>
</tr>
<tr>
<td>11.45</td>
<td>1.00</td>
<td>0.1050</td>
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<tr>
<td>14.31</td>
<td>1.25</td>
<td>0.1800</td>
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<tr>
<td>17.17</td>
<td>1.50</td>
<td>0.1980</td>
</tr>
<tr>
<td>20.03</td>
<td>1.75</td>
<td>0.1995</td>
</tr>
<tr>
<td>22.89</td>
<td>2.00</td>
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<td>25.76</td>
<td>2.25</td>
<td>0.1775</td>
</tr>
<tr>
<td>28.62</td>
<td>2.50</td>
<td>0.1690</td>
</tr>
<tr>
<td>31.48</td>
<td>2.75</td>
<td>0.1645</td>
</tr>
<tr>
<td>34.34</td>
<td>3.00</td>
<td>0.1610</td>
</tr>
<tr>
<td>37.20</td>
<td>3.25</td>
<td>0.1590</td>
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<td>40.06</td>
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<td>0.1595</td>
</tr>
<tr>
<td>42.93</td>
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<td>0.1735</td>
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<tr>
<td>45.79</td>
<td>4.00</td>
<td>0.1890</td>
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</table>

<table>
<thead>
<tr>
<th>(L_p/) (FT) (1/3)</th>
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<tbody>
<tr>
<td>(46.4)</td>
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<tr>
<td>(6.0)</td>
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<td>(104.4)</td>
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<td>(63.8)</td>
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<th>Standard Deviation</th>
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<td>(0.000)</td>
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<tr>
<td>(0.000)</td>
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<tr>
<td>(0.000)</td>
</tr>
</tbody>
</table>

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### Table 2 - Mean Values of Wettability Coefficient $S^2/2/3$ for Planning Hulls With 1/2 L_p Forward of Transom

<table>
<thead>
<tr>
<th>$L_p/1/3$</th>
<th>$F_n$</th>
<th>0.00</th>
<th>0.50</th>
<th>1.00</th>
<th>1.50</th>
<th>2.00</th>
<th>2.50</th>
<th>3.00</th>
<th>3.50</th>
<th>4.00</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.0</td>
<td>6.45</td>
<td>7.20</td>
<td>7.07</td>
<td>7.15</td>
<td>7.20</td>
<td>7.22</td>
<td>7.21</td>
<td>7.21</td>
<td>7.21</td>
<td>7.21</td>
</tr>
<tr>
<td>5.0</td>
<td>6.33</td>
<td>7.07</td>
<td>7.15</td>
<td>7.20</td>
<td>7.22</td>
<td>7.21</td>
<td>7.21</td>
<td>7.21</td>
<td>7.21</td>
<td>7.21</td>
</tr>
<tr>
<td>6.0</td>
<td>6.22</td>
<td>7.07</td>
<td>7.15</td>
<td>7.20</td>
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<td>7.21</td>
<td>7.21</td>
<td>7.21</td>
<td>7.21</td>
<td>7.21</td>
</tr>
<tr>
<td>7.0</td>
<td>6.16</td>
<td>7.07</td>
<td>7.15</td>
<td>7.20</td>
<td>7.22</td>
<td>7.21</td>
<td>7.21</td>
<td>7.21</td>
<td>7.21</td>
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<td>8.0</td>
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<td>9.0</td>
<td>6.08</td>
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<td>7.15</td>
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<td>7.21</td>
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<td>7.21</td>
<td>7.21</td>
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<td>10.0</td>
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<td>7.20</td>
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<td>7.21</td>
<td>7.21</td>
<td>7.21</td>
<td>7.21</td>
<td>7.21</td>
</tr>
</tbody>
</table>

From Series 62 and 65 Experimental Data Published in SSRDC Report 4307
NAME: SUBROUTINE SAVIT

PURPOSE: Estimate the bare-hull, smooth-water resistance and trim for a hard-chine planing hull using Savitsky's equations for prismatic planing surfaces

CALLING SEQUENCE: CALL SAVIT (DISPL, LCG, VCG, VFPS, BEAM, BETA, TANB, COSB, SINB, HW, WDCST, RHO, VIS, AG, DELCF, R, TD, NT, CLM, GDB)

SUBPROGRAM CALLED: C1DSF

INPUT:

<table>
<thead>
<tr>
<th>DISPL</th>
<th>A</th>
<th>ship displacement in lb</th>
</tr>
</thead>
<tbody>
<tr>
<td>LCG</td>
<td>AG</td>
<td>distance of center of gravity transom in ft</td>
</tr>
<tr>
<td>VCG</td>
<td>KG</td>
<td>distance of</td>
</tr>
<tr>
<td>VFPS</td>
<td>V</td>
<td>speed in ft/sec</td>
</tr>
<tr>
<td>BEAM</td>
<td>b</td>
<td>beam in ft</td>
</tr>
<tr>
<td>BETA</td>
<td>B</td>
<td>deadrise angle in degrees</td>
</tr>
<tr>
<td>TANB</td>
<td>tan β</td>
<td></td>
</tr>
<tr>
<td>COSB</td>
<td>cos β</td>
<td></td>
</tr>
<tr>
<td>SINB</td>
<td>sin β</td>
<td></td>
</tr>
<tr>
<td>HW</td>
<td>H_W</td>
<td>height of center of wind drag above baseline in ft</td>
</tr>
<tr>
<td>WDCST</td>
<td>C_D_W</td>
<td>horizontal wind force in lb / V^2</td>
</tr>
<tr>
<td>RHO</td>
<td>ρ</td>
<td>water density in lb x sec^2/ft^4</td>
</tr>
<tr>
<td>VIS</td>
<td>ν</td>
<td>kinematic viscosity of water in ft^2/sec</td>
</tr>
<tr>
<td>AG</td>
<td>g</td>
<td>acceleration of gravity in ft/sec^2</td>
</tr>
<tr>
<td>DELCF</td>
<td>C_A</td>
<td>correlation allowance; may be 0</td>
</tr>
</tbody>
</table>

OUTPUT:

| R | R_b | bare hull, smooth-water resistance in lb |
| TD | T | trim angle in degrees |
| NT | NT | Number of iterations to obtain trim angle |
| CLM | λ | mean wetted length-beam ratio L_m/b not used by Program PHFMOPT |
SUBROUTINE SAVIT

GDB $\bar{AP} = \text{longitudinal center of pressure, distance forward of transom, in ft}$
not used by Program PHMOP

PROCEDURE:

TD $\tau = \text{trim angle of planing surface from horizontal in deg}$
first approximation of $\tau = 4 \text{ deg}$

CV $C_V = \text{speed coefficient} = V/(gb)^{1/2}$

CLM $\lambda = \text{mean wetted length-beam ratio} = L_m/b = (L_K + L_C)/2b$

CLO $C_{L_o} = \text{lift coefficient for flat surface}$

$C_{L_o} = (0.012 \lambda^{1/2} + 0.0055 \lambda^{5/2}/C_V^2)$

CLB $C_{L_B} = \text{lift coefficient for deadrise surface}$

$C_{L_B} = \Delta/[V^2 b^2 \rho/2] = C_{L_o} - 0.0065 C_{L_o}^{0.6}$

$C_{L_o}$ and $\lambda$ obtained by Newton-Raphson iteration
first approximations: $C_{L_o} = 0.085; \lambda = 1.5$

XK $L_K = \text{wetted keel length in ft}$

$b[\lambda + \tan \beta/(2\pi \tan \tau)]$

XC $L_C = \text{wetted chine length in ft} = 2 b \lambda - L_K$

GDB $\bar{AP} = \text{longitudinal center of pressure forward of transom in ft}$

$b[0.75 - 1/(5.21 C_V^2/\lambda^2 + 2.39)]$

CLD $C_{L_d} = \text{dynamic component of lift coefficient}$

$C_{L_d} = 0.012 \lambda^{1/2} 1.1$

VM $V_m = \text{mean velocity over planing surface in ft/sec}$

$V \left[1 - \left(C_{L_d} - 0.0065 \beta C_{L_d}^{0.6}\right)/\left(\lambda \cos \tau\right)\right]^{1/2}$

RE $R_n = \text{Reynolds number for planing surface}$

$V_m b \lambda/v$

CF $C_F + C_A = \text{Schoenherr frictional resistance coefficient as } f(R_n) \text{ plus correction allowance}$

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SUBROUTINE SAVIT

DFX \[ D_F = \text{viscous force due to wetted surface, parallel to the planing surface, in lb} \]
\[ = (C_F + C_A) \left( \rho / 2 \right) \left( V_m^2 \right) \left( b^2 \lambda / \cos \beta \right) \]

CK \[ C_K = 1.5708 \left( 1 - 0.1788 \tan \beta \cos \beta - 0.09646 \tan \beta \sin^2 \beta \right) \]

CKI \[ C_{K_1} = C_K \tan \tau / \sin \beta \]

Al \[ a_1 = \frac{\left[ \sin^2 \tau (1 - 2C_K) + C_{K_1} \tan^2 \tau \left( 1 / \sin^2 \beta - \sin^2 \tau \right) \right]^{1/2}}{\cos \tau + C_K \tan \tau \sin \tau} \]

TANO \[ \tan \phi = \frac{a_1 + C_{K_1}}{1 - a_1 - C_{K_1}} \]

THETA \[ \theta = \text{angle between outer spray edge and keel in radians} \]
\[ = \arctan(\tan \phi \cos \beta) \]

DLM \[ \Delta \lambda = \text{effective increase in length-beam ratio due to spray} \]
\[ = \left[ \tan \beta / (\pi \tan \tau) - 1 / (2 \tan \theta) \right] / (2 \cos \theta) \]

RE \[ R_{n_s} = \text{Reynolds number for spray} \]
\[ = V b / (3 \cos \beta \sin \theta) \]

CF \[ C_{FS} = \text{Schoenherr frictional resistance coefficient for spray drag} \]

DSX \[ D_S = \text{viscous force due to spray drag, parallel to the planing surface, in lb} \]
\[ = C_{FS} \left( \rho / 2 \right) \left( V^2 \right) \left( b^2 \Delta \lambda / \cos \beta \right) \]

DWX \[ D_W = \text{component of wind drag parallel to planing surface in lb} \]
\[ = C_{P_W} \left( \rho / 2 \right) \left( V^2 \right) \cos \tau \]

DTX \[ D_T = \text{total drag force parallel to planing surface in lb} \]
\[ = D_F + D_S + D_W \]

PDBX \[ P_T = \text{total pressure force perpendicular to surface in lb} \]
\[ = \Delta / \cos \tau + D_T \tan \tau \]
SUBROUTINE SAVIT

EDB  $e_p = \text{moment arm from center of pressure to center of gravity in ft}$
      $= AG - AP$

FF   $f_f = \text{moment arm from center of viscous force to center of gravity in ft}$
      $= KG - \left(b \tan \beta / 4\right)$

FW   $f_w = \text{moment arm from center of wind drag to center of gravity in ft}$
      $= KG - H_w$

RMT  $\Sigma M = \text{sum of moments about CG in ft-lb}$
      $= P_T e_p + (D + D_s) f_f + D_w f_w$

Iterate with small changes in $\tau$ until $\Sigma M < 0.001 \Delta$

NT   $\text{Number of iterations required to obtain equilibrium trim; maximum of 15 iterations}$

R    $R_h = \text{total horizontal resistance force in lb}$
      $= D_T \cos \tau + P_T \sin \tau$
NAME: SUBROUTINE PRCOEF

PURPOSE: Estimate propulsion coefficients for planing hull with propellers on inclined shafts

CALLING SEQUENCE: CALL PRCOEF (FNV, TDF, ADF, TWF)

SUBPROGRAMS CALLED: MINP, YINTE

INPUT:

FNV = speed-displacement coefficient = V/(gV1/3)^1/2

OUTPUT:

TDF = thrust deduction factor

= total horizontal resistance of appended hull / total shaft-line thrust

ADF = appendage drag factor

= resistance of bare hull / resistance of appended hull

TWF = thrust wake factor = torque wake factor

REFERENCE: Blount, D.L. and D.L. Fox, "Small Craft Power Predictions," Western Gulf Section of the Society of Naval Architects and Marine Engineers (Feb 1975)

PROCEDURE: l-t, l-w, and ηa interpolated from following table of values at input value of FNV. The tabulated data represent mean values from a bandwidth of data collected for numerous twin-screw planing craft and reported in the above reference.

FV array

TDF

TW array

AD array

<table>
<thead>
<tr>
<th>FNV</th>
<th>0.5</th>
<th>1.0</th>
<th>1.5</th>
<th>2.0</th>
<th>2.5</th>
<th>3.0</th>
<th>3.5</th>
<th>4.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>TDF</td>
<td>0.92</td>
<td>0.92</td>
<td>0.92</td>
<td>0.92</td>
<td>0.92</td>
<td>0.92</td>
<td>0.92</td>
<td>0.92</td>
</tr>
<tr>
<td>TW</td>
<td>1.05</td>
<td>1.06</td>
<td>1.04</td>
<td>0.99</td>
<td>0.97</td>
<td>0.975</td>
<td>0.98</td>
<td>0.975</td>
</tr>
<tr>
<td>AD</td>
<td>0.951</td>
<td>0.948</td>
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<td>0.934</td>
<td>0.925</td>
<td>0.913</td>
<td>0.900</td>
<td>0.885</td>
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NAME: SUBROUTINE OWKTQ

PURPOSE: Calculate propeller open-water characteristics as a function of pitch ratio, expanded area ratio, and number of blades from coefficients derived from Wageningen B-Screw Series for airfoil section propellers or modified coefficients for flat face, segmental section propellers.


CALLING SEQUENCE: CALL OWKTQ

INPUT:

IPROP Control for type of propellers
   = 1 for Gawn-Burrill type (flat face, segmental sections)
   = 3 for Wageningen B-Screw type (airfoil sections)

PD P/D = propeller pitch/diameter ratio (0.6 to 1.6)

EAR EAR = propeller expanded area ratio (0.5 to 1.1)

Z Z = number of propeller blades (3 to 7)

OUTPUT:

N n_j = number of J values generated -- max of 60

JT J = array of propeller advance coefficients in ascending order from (J=0) to (J at K_T=0) in increments of 0.025 if P/D<1.2 in increments of 0.050 if P/D>1.2

KT K_T = array of open-water thrust coefficients = f (P/D, EAR, Z, J )

KQ K_Q = array of open-water torque coefficients = f (P/D, EAR, Z, J )

K_T and K_Q developed from equation in above references for airfoil section propellers. For Gawn-Burrill type propellers (IPROP=1) the equations are modified to produce slightly higher K_T and K_Q than B-Screw Series.
NAME: SUBROUTINE CAVKTQ

PURPOSE: Calculate propeller characteristics in cavitation regime as function of pitch ratio, expanded area ratio and cavitation number.


CALLING SEQUENCE: CALL CAVKTQ

SUBPROGRAMS CALLED: TQMAX

INPUT:

IPROP Control for type of propellers
   = 1 for Gawn-Burrill type
      (flat face, segmental sections)
   = 2 for Newton-Rader types
   = 3 for Wageningen B-Screw (airfoil sections)

PD P/D = propeller pitch/diameter ratio

EAR EAR = propeller expanded area ratio

NJ nJ = number of J values input from open-water curves -- max. of 60

JT J = array of propeller advance coefficients

KTO KTo = corresponding array of propeller open-water thrust coefficients

KQO KQo = corresponding array of propeller open-water torque coefficients

NS nS = number of cavitation numbers -- max. of 8
   -- at which propeller characteristics are to be computed and printed from this routine (if nS = 0 only the constants are computed)

SIGMA σ = array of cavitation numbers
GENERAL NOTATION FOR PROPELLERS:

\[ V_A = \text{propeller speed of advance} \]
\[ n = \text{rate of revolution} \]
\[ D = \text{propeller diameter} \]
\[ T = \text{thrust} \]
\[ Q = \text{torque} \]
\[ \rho = \text{water density} \]
\[ P_o = \text{pressure at center of propeller} = \rho A^+ p_h - p_v \]
\[ J = \text{advance coefficient} = \frac{V_A}{nD} \]
\[ K_T = \text{thrust coefficient} = \frac{T}{\rho n^2 D^4} \]
\[ K_Q = \text{torque coefficient} = \frac{Q}{\rho n^2 D^5} \]
\[ K_T/J^2 = \text{thrust loading} = \frac{T}{\rho D^2 V_A^2} \]
\[ K_Q/J^2 = \text{torque loading} = \frac{Q}{\rho D^2 V_A^2} \]
\[ K_Q/J^3 = \text{power loading} = \frac{Q/\rho D^3}{V_A^3} \]
\[ \sigma = \text{cavitation number based on advance velocity} \]
\[ = \frac{P_o}{(1/2 \rho V_A^2)} \]
\[ V_{0.7R^2} = \text{velocity} \text{ at 0.7 radius of propeller} \]
\[ = \frac{V_A^2 + (0.7 \pi n D)^2}{V_A^2 J^2 + 4.84} \]
\[ \sigma_{0.7R} = \text{cavitation number based on } V_{0.7R} \]
\[ = \frac{P_o/(1/2 \rho V_{0.7R}^2)}{\sigma J^2 (J^2 + 4.84)} \]
\[ A_p = \text{projected area of propeller} \]
\[ = (\pi D^2/4) \text{ EAR (1.067-0.229 P/D)} \]
\[ \tau_c = \text{thrust load coefficient} \]
\[ = \frac{T}{(1/2 \rho A_p V_{0.7R}^2)} \]
\[ = K_T \left[ \frac{1/2 (A_p/D^2)}{(J^2 + 4.84)} \right] \]
\[ Q_c = \text{torque load coefficient} \]
\[ = \frac{Q}{(1/2 \rho D A_p V_{0.7R}^2)} \]
\[ = K_Q \left[ \frac{1/2 (A_p/D^2)}{(J^2 + 4.84)} \right] \]
MAXIMUM THRUST AND TORQUE LOADS:

Blount and Fox (see reference) give equations for maximum thrust and torque load coefficients in a cavitating environment based on regression of experimental data for the three propeller series used herein.

\[
\begin{align*}
\tau_{cm} &= \text{maximum thrust load coefficient} \\
&= \alpha_0.7R^b \text{ (transition region)} \\
&= \tau_{cx} \text{ (fully cavitating region)} \\
Q_{cm} &= \text{maximum torque load coefficient} \\
&= \beta_0.7R^d \text{ (transition region)} \\
&= Q_{cx} \text{ (fully cavitating region)}
\end{align*}
\]

OUTPUT:

<table>
<thead>
<tr>
<th>T1</th>
<th>a</th>
<th>= 1.2</th>
<th>1</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>a</td>
<td>= 0.703 + 0.25 P/D</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>a</td>
<td>= 1.27</td>
<td>3</td>
</tr>
<tr>
<td>T2</td>
<td>b</td>
<td>= 1.0</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>b</td>
<td>= 0.65 + 0.1 P/D</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>b</td>
<td>= 1.0</td>
<td>3</td>
</tr>
<tr>
<td>Q1</td>
<td>c</td>
<td>= 0.200 P/D</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>c</td>
<td>= 0.240 P/D - 0.12</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>c</td>
<td>= 0.247 P/D - 0.0167</td>
<td>3</td>
</tr>
<tr>
<td>Q2</td>
<td>d</td>
<td>= 0.70 + 0.31 EAR^0.9</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>d</td>
<td>= 0.50 + 0.165 P/D</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>d</td>
<td>= 1.04</td>
<td>3</td>
</tr>
<tr>
<td>TCX</td>
<td>\tau_{cx}</td>
<td>= 0.0725 P/D - 0.0340 EAR</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>\tau_{cx}</td>
<td>= 0.0833 P/D - 0.0142 EAR</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>\tau_{cx}</td>
<td>= 0.0</td>
<td>3</td>
</tr>
<tr>
<td>QCX</td>
<td>Q_{cx}</td>
<td>= \left[0.0185 (P/D)^2 - 0.0166 P/D + 0.00594\right] /\text{EAR}^{1/3}</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Q_{cx}</td>
<td>= 0.0335 P/D - 0.024 EAR^{1/2}</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Q_{cx}</td>
<td>= 0.0</td>
<td>3</td>
</tr>
</tbody>
</table>

RMAX

k = 0.8

Since full-scale trial data (see Figures 5 and 6 of reference) indicates actual thrust and torque in the transition region less than the maximums derived from the propeller series data, the factor k is applied to \( \tau_{cm} \) and \( Q_{cm} \) in the transition region. The factor k is not applied to \( \tau_{cx} \) and \( Q_{cx} \).
SUBROUTINE CAVKTQ

APD2 \( \frac{A_p}{D^2/2} \) = Constant for calculation of \( \tau_c \) and \( Q_c \)

J = advance coefficient from input array

OPEN WATER \( \{ K_T, K_Q \} \) = input values of open-water thrust and torque coefficients

SIGMA \( \sigma \) = cavitation number from input array

KT = thrust coefficient as \( f(J, \sigma) \) = \( K_{To} \) or \( K_{Tm} \), whichever is smaller

\( K_{Tm} = \tau_{cm} \left( \frac{1}{2} \frac{A_p}{D^2} \right) (J^2 + 4.84) \)

\( \tau_{cm} = (k \sigma 0.7 R^b) \) or \( (\tau_{cx}) \), whichever is greater

LC = 1 character identifier for propeller cavitation

C indicates more than 10% back cavitation for Gawn props: \( \tau_c > 0.494 \sigma 0.7 R^{0.88} \)

* indicates thrust limit due to cavitation \( K_T = K_{Tm} \)

KQ = torque coefficient as \( f(J, \sigma) \) = \( K_{Qo} \) or \( K_{Qm} \), whichever is smaller

\( K_{Qm} = Q_{cm} \left( \frac{1}{2} \frac{A_p}{D^2} \right) (J^2 + 4.84) \)

\( Q_{cm} = (k \sigma 0.7 R^d) \) or \( (Q_{cx}) \), whichever is greater

\( K_{Tm} \) and \( K_{Qm} \) generated by Function TQMAX
NAME: FUNCTION TQMAX

PURPOSE: Calculate maximum thrust or torque coefficient in a cavitating environment as function of cavitation number and advance coefficient

CALLING SEQUENCE: \( X = \text{TQMAX} (\sigma, J, T) \)

INPUT:

\( \sigma \) = cavitation number
\( J \) = advance coefficient
\( T \) = 1 if maximum thrust coefficient required
\( T \) = 2 if maximum torque coefficient required

Variables: \( a, b, c, d, \tau_{c_X}, Q_{c_X}, k, \frac{1}{2} \frac{A_p}{D^2} \)
generated by Subroutine CAVKTQ

OUTPUT:

\( T \) = maximum thrust load coefficient
\( K_{T_m} = \tau_{c_m} \left( \frac{1}{2} \frac{A_p}{D^2} \right) (J^2 + 4.84) \)

\( Q \) = maximum torque load coefficient
\( K_{Q_m} = Q_{c_m} \left( \frac{1}{2} \frac{A_p}{D^2} \right) (J^2 + 4.84) \)
NAME: SUBROUTINE PRINTP

PURPOSE: Interpolate for propeller performance at specified value of (1) advance coefficient $J$, (2) thrust loading $K_T/J^2$, (3) torque loading, $K_Q/J^2$, or (4) power loading $K_Q/J^3$.

CALLING SEQUENCE: CALL PRINTP (IP, PCOEF, SIGMA)

SUBPROGRAMS: TQMAX, YINTE

INPUT:
- **IP** = Option = 1, 2, 3, or 4
- **PCOEF**: input propeller coefficient, dependent on value of IP
  - $J_T$ = advance coefficient, input if IP=1
  - $K_T/J^2$ = thrust loading, input if IP=2
  - $K_Q/J^2$ = torque loading, input if IP=3
  - $K_Q/J^3$ = power loading, input if IP=4
- **SIGMA** $\sigma$ = cavitation number
- **NJ** $n_J$ = number of $J$ values defining propeller characteristics
- **JT** $J$ = array of advance coefficient, in ascending order
- **KT** $K_{To}$ = array of open-water thrust coefficients
- **KQ** $K_{Qo}$ = array of open-water torque coefficients

PERFORMANCE AT SPECIFIC $J$:
- **JTP** $J_T$ = input advance coefficient
- **KTP** $K_T$ = thrust coefficient at $J_T$
- **KQP** $K_Q$ = torque coefficient at $J_T$

The thrust coefficient $K_T$ is open-water thrust coefficient interpolated from input array of $K_{To}$ versus $J$, or maximum thrust coefficient in cavitating regime $K_T$ calculated by Function TQMAX, whichever is smaller.

The torque coefficient $K_Q$ is open-water value interpolated from $K_{Qo}$ vs $J$, or maximum cavitation value $K_{Qo}$ calculated from TQMAX, whichever is smaller.
SUBROUTINE PRINTP

PERFORMANCE AT SPECIFIC LOADING:

PLOG
  ln(KT/J^2) if IP=2 | natural log of
  ln(KQ/J^2) if IP=3 | input loading
  ln(KQ/J^3) if IP=4 | coefficient

XLOG
  ln(K'r/J'_2) if IP=2 | array of natural logs
  ln(KQ'o/J'_3) if IP=3 | of open-water loading
  ln(KQ'o/J'_3) if IP=4 | coefficient at J value
  from input array

JTP
  JTO = open-water advance coefficient interpolated
  from array of open-water loading
  coefficients versus J at the specific
  loading required (logs are used because of
  the rapid change of loading coefficient at
  low J's)

If JTO is in non-cavitating region (KT'O < KT'M)

KTP
  KT | thrust and torque coefficients at JTO

KQP
  KQ | interpolated from arrays of KT'O and KQ'O vs J

If JTO is in cavitating region (KT'O > KT'M)

XLOG
  ln(KT'm/J'^2) if IP=2 | array of natural logs
  ln(KQ'm/J'^2) if IP=3 | of loading coefficients
  ln(KQ'm/J'^3) if IP=4 | based on KT' or
  KQ'm as function J

JTP
  JTM = advance coefficient interpolated from array
  of cavitation loading coefficients vs J at
  the specific loading required

KTP
  KT | maximum cavitation thrust and torque

KQP
  KQ | coefficients at JTM calculated from TQMAX

OUTPUT:

JTP
  JT = final advance coefficient

KTP
  KT = final thrust coefficient

KQP
  KQ = final torque coefficient

EP
  nO = propeller efficiency
    = JT KT/(2 π KQ)

PCOEF and SIGMA
SUBROUTINE PRINTP

\[ \tau_c = \text{thrust load coefficient} \]
\[ = \frac{K_T}{\left[ \frac{1}{2} \left( \frac{A_p}{D^2} \right) (J^2 + 4.84) \right]} \]

\[ \sigma_{0.7R} = \text{cavitation number based on velocity at 0.7 radius of propeller} \]
\[ = \sigma \frac{J^2}{(J^2 + 4.84)} \quad 4.84 = (0.7\pi)^2 \]

\[ X_{SIG7} 4.94 \sigma_{0.7R} = \text{term representing 10% back cavitation line for Gawn-Burrill propeller series} \]

\[ L_T \] = 1 character identifier for propeller cavitation

* indicates thrust limit due to cavitation:
\[ K_T = \frac{K_T}{m} \]

C indicates more than 10% back cavitation for Gawn-Burrill propellers, but less than thrust limit cavitation
\[ \tau_c > 0.494 \sigma_{0.7R} \]

NAME SUBROUTINE PROPS

PURPOSE: Estimate powering requirements for ship at design
and cruise speeds with propellers on inclined
shafts. Select appropriate number of propellers
and/or propeller diameter, if not already specified

CALLING SEQUENCE: CALL PROPS

SUBPROGRAMS CALLED: YINTX, PRINTP

INPUT: Via COMMON blocks

PROPNO $n_{pr}$ = number of propellers--optional input on
Card 12

PROPD1 $D_{in}$ = propeller diameter in inches--optional input
on Card 12

AUXNO $n_{aux}$ = number of auxiliary propulsion units for
auxiliary speed operation, from input Card 12

PEMAX $P_{e_{max}}$ = maximum horsepower of each prime mover,
from input Card 12

PL $L_{p}$ = ship length in ft, from input Card 29

HT $H_{t}$ = draft at transom in ft, from Subroutine
NEWHUL

NV Number of speeds, from Subroutine POWER

VKT(I) $V_{K}$ = ship speed in knots, from Subroutine POWER
= design speed $V_{d}$, cruise speed $V_{c}$ when $I = 1, 2$

TWF(I) $1-w$ = thrust wake factor, from Subroutine PROCOEF

THRUST(I) $T$ = total shaft-line thrust in lb, from
Subroutine POWER

EHP(I) $P_{e_{r}}$ = total effective power, from Subroutine POWER

APD2 $\frac{1}{4} A_{p}/D^{2}$ = propeller constant, from Subroutine CAVYTQ

TCDES $(\tau_{c}/0.7R)^{*}$ = constant for sizing propeller, from Card 12
= 0.6 for Cawn-Burrill 10% back cavitation
criteria

CONSTANTS:

PRA $P_{A}$ = atmospheric pressure in lb/ft$^{2}$ = 2116

PRV $P_{V}$ = vapor pressure in lb/ft$^{2}$ = 36
SUBROUTINE PROPS

\( P_H \) = static water pressure at propeller center in \( \text{lb/ft}^2 \)
\( = \rho g h_{pr} \)

\( h_{pr} \) = depth of propeller center below waterline in ft
\( = H_t + 0.75 D \approx 1.5 H_t \), if \( D \) not defined

\( \epsilon_{\text{max}} \) = maximum shaft angle in degrees = 15

OPC Preliminary estimate of \( \eta_o = 0.55 \)

OUTPUT:

\( P_{\text{RSHP}} \) = preliminary estimate of total brake horsepower
\( = 0.55 P_E \) at design speed

\( n_{pr} \) = number of prime movers = number of propellers
\( = \frac{P_{\text{BO}}}{P_E \epsilon_{\text{max}}} \) (rounded up)
or value specified on input Card 12

Limits: \( 4 \leq n_{pr} \leq 2 \)

I Index for DO LOOP I=1, NV

\( V_A \) = speed of advance of propeller in ft/sec
\( = 1.6878 V_K (1-w) \)

\( \sigma \) = cavitation number \( = \frac{(p_A + p_H - p_w)}{0.5 \rho V_A^2} \)

\( T_{\text{MAX}} \) = upper limit on thrust loading
\( = \frac{1}{4} (A_p / D^2) \sigma (\tau_c / \sigma_{0.7R})^* \)

\( D_{\text{MIN}} \) = diameter in inches of smallest propeller capable of producing required thrust at current speed
\( = 12 \left[ \frac{T}{\rho V_A^2 n_{po} (K_T/J^2)^*} \right]^{1/2} \)
SUBROUTINE PROPS

\[ \text{n}_p = \text{number of propellers in operation} \]
\[ \text{n}_p = \text{n}_p \text{ at design speed} \]
\[ \text{n}_p = \text{n}_p \text{ at cruise speed, if no auxiliary engine} \]
\[ \text{n}_p = \text{n}_p \text{ at cruise speed, if n} \text{aux} > 0 \]

DIN
\[ \text{D}_{in} = \text{final propeller diameter in inches} \]
\[ = 1.05 \text{D}_{min} \text{ at design speed} \]
\[ \text{or } 1.05 \text{D}_{min} \text{ at cruise speed, whichever if larger} \]
\[ \text{or value specified on input Card 12} \]

XSH
\[ \text{X}_{sh} = \text{longitudinal distance from transom to point where shafting enters hull in ft} \]
\[ = 0.2 \text{L}_p \]

XSF
\[ \text{X}_{sf} = \text{longitudinal distance from transom to forward end of shafting in ft} \]
\[ = 0.3 \text{L}_p \]

CRUD
\[ \text{C}_r = \text{chord length of rudder in ft} \]
\[ = 0.03464 \frac{\text{L}_p}{\text{n}_p^{1/2}} \]

Trailing edge of rudder assumed flush with transom
Projected area of each rudder = \[ 0.0016 \frac{\text{L}_p^2}{\text{n}_p^{1/2}} \]
\[ = 4/3 \text{C}_r^2 \]

DMAX
\[ \text{D}_{max} = \text{maximum propeller diameter in inches, limited by } \epsilon_{max} \text{ and 0.25 D} \text{ tip clearance} \]
\[ = 12 \left( \text{X}_{sh} - \text{C}_r \right) \tan \epsilon_{max} / 0.75 \left( 1 + \tan \epsilon_{max} \right) \]
If \[ \text{D}_{in} > \text{D}_{max}' \text{ in } \text{n}_p \text{ is increased and } \text{D}_{max}' \text{ is recalc-} \]
ulated, unless \[ \text{n}_p \text{ is a fixed input value or up to the limit of 4} \text{ } \text{pr} \]

PRN
\[ \text{n}_{pr} = \text{final number of propellers, prime movers} \]

DINMAX
\[ \text{D}_{max} = \text{maximum propeller diameter in inches, limited by hull breadth over chines at transom} \]
\[ = 12 \left( 2 \text{Y}_{Cl} / [\text{n}_{pr} + 0.25 \left( \text{n}_{pr} - 1 \right)] \right) \]
If \[ \text{D}_{in} > \text{D}_{max}' \text{, set final } \text{D}_{in} = \text{D}_{max}' \]

DFT
\[ \text{D} = \text{final propeller diameter in ft} = \text{D}_{in} / 12 \]

XSA
\[ \text{X}_{sa} = \text{longitudinal distance from transom to aft end of shafting at propeller centerline} \]
\[ = 0.75 \text{D} + \text{C}_r, \text{ assuming 0.25 D} \text{ from rudder to propeller} \]

D75
\[ \text{H}_{sa} = \text{height from aft end of shafting to hull in ft} \]
\[ = 0.75 \text{D}, \text{ assuming 0.25 D} \text{ propeller tip clearance} \]
SUBROUTINE PROPS

EE  = shaft angle in degrees
     = arctan[Hsa/(Xsf-Xsa)]

SHL  = shaft length in ft = (Xsf-Xsa)/cos \( \varepsilon \)

THLD(I)  = thrust loading of final propellers

TJ  = advance coefficient, from Subroutine PRCHAR

EP(I)  = propeller efficiency, from Subroutine PRCHAR

RCF  = rpm correction factor, from Subroutine PRCHAR

RPM(I)  = propeller rpm = 60 V (l-w) N \(_{corr}\)/(J D)

PC(I)  = propulsive coefficient = \( \eta_0 \eta_H \eta_R \)

\( \eta_H \)  = hull efficiency = (1-t)/(1-w)

\( \eta_R \)  = relative rotative efficiency = 1.0 since
thrust wake and torque wake are assumed equal

DHP(I)  = total horsepower developed at propellers
     = \( P_E / \eta_D \)

SHP(I)  = total shaft horsepower = 1.02 \( P_D \) assuming
2 percent shaft transmission losses
NAME: SUBROUTINE WJETS

PURPOSE: Design waterjet pumps capable of producing required thrust at design and cruise speeds and estimated powering requirements. Select appropriate number of waterjets if not already specified.


CALLING SEQUENCE: CALL WJETS

SUBPROGRAMS CALLED: YINTE

INPUT: Via COMMON blocks

PROPNO

\[
n_{\text{pr}} = \text{number of prime movers} = \text{number of waterjet pumps} \quad (\text{optional input on Card 12})
\]

AUXNO

\[
n_{\text{aux}} = \text{number of auxiliary propulsion units for cruise speed operation, from input Card 12}
\]

PEMAX

\[
P_{\text{max}} = \text{maximum horsepower of each prime mover, from Card 12; required if } n_{\text{pr}} \text{ not specified}
\]

PROPDI

\[
D_{\text{in}} = \text{impeller diameter in inches} \quad (\text{optional input on Card 12})
\]

AJET

\[
A_{j} = \text{area of jet in ft}^{2} \quad (\text{optional input on Card 12A})
\]

XK1

\[
K_{1} = \text{bollard jet velocity/ship speed at design point, input from Card 12A}
\]

XK2

\[
K_{2} = \text{constant for inlet head recovery IHR, from Card 12A}
\]

XK3

\[
K_{3} = \text{constant for } \tau_{c} \text{ vs. } \sigma_{\text{TIP}} \text{ cavitation criterion, from Card 12A}
\]

DHD

\[
D_{h}/D = \text{diameter of impeller hub/diameter of impeller, input from Card 12A}
\]

TLC

\[
\tau_{\text{cd}} = \text{thrust load coefficient at design point, from Card 12A; not used if } A_{j} \text{ is input}
\]

STP

\[
\sigma_{\text{TIP,d}} = \text{impeller tip velocity cavitation number at design point, from Card 12A}
\]

HT

\[
H_{t} = \text{draft at transom in ft, from Subroutine NEWHUL}
\]

NV

Number of speeds, from Subroutine POWER

VKI(I)

\[
V_{K} = \text{ship speed in knots, from Subroutine POWER}
\]

\[
V_{d}, \text{ cruise speed } V_{c}, \text{ when } I=1,2
\]
SUBROUTINE WJETS

THRTUS(1) = total thrust required in lb, from Subroutine POWER

CONSTANTS:
- PRA \( p_A \): atmospheric pressure in lb/ft\(^2\) = 2116
- PRV \( p_v \): vapor pressure in lb/ft\(^2\) = 36
- PRH \( p_h \): static water pressure on rotating axis in lb/ft\(^2\) = \( p_g h_{ra} \)
- h_{ra}: depth of rotating axis below waterline in ft \( \geq 0 \)
- OPC: Preliminary estimate of \( n_D = 0.4 \)
- RHO \( \rho \): water density in lbs x sec\(^2\)/ft\(^4\) = 1.9905
- GA \( g \): acceleration of gravity in ft/sec\(^2\) = 32.174

OUTPUT:
- PRSHP \( P_{Bo} \): preliminary estimate of total brake power = 0.4 \( P_E \) at design speed
- NPR \( n_{pr} \): number of prime movers = number of waterjets
  \[ n_{pr} = \frac{P_{Bo}}{P_E} \quad \text{or value specified on Card 12} \]
  \[ \text{Limits: } 4 \leq n_{pr} \leq 2 \]
- VFPS(1) \( V_{Sd} \): design ship speed in ft/sec = 1.6878 \( V_{K_1} \)
- VFPS(2) \( V_{Sc} \): cruise ship speed in ft/sec = 1.6878 \( V_{K_2} \)
- THI(1) \( T_{d} \): thrust requirement in lb for each waterjet at design speed = \( T_1/n_{pr} \)
- THI(2) \( T_{c} \): thrust in lb for each waterjet at cruise speed = \( T_2/n_{aux} \) or \( T_2/n_{pr} \) when \( n_{aux} = 0 \)
- VJB \( V_{JBd} \): bollard jet velocity in ft/sec at full power
  \[ V_{JBd} = K_1 V_{Sd} \]
- DVJ \( \Delta V_{Jd} \): increase in jet velocity due to THR at \( V_{Sd} \)
  \[ \Delta V_{Jd} = K_2 V_{Sd} \left[ (V_{JBd}/V_{Sd})^2 + 1 \right] - 1.737 \]
- VJ \( V_{Jd} \): jet velocity in ft/sec at \( V_{Sd} \)
  \[ V_{Jd} = V_{JBd} + \Delta V_{Jd} \]
- Q \( Q_d \): mass flow in ft\(^3\)/sec at \( V_{Sd} \)
  \[ Q_d = A J V_{Jd} \quad \text{if } A J \text{ is input} \]
  \[ = T_d/\left[ \rho \left( V_J - V_S \right) \right] \quad \text{if } A J \text{ is not specified} \]
SUBROUTINE WJETS

AJ  $A_J = \text{area of jet in ft} = \frac{Q_d}{V_J}$, or value from Card 12A

AI  $A_I = \text{open area of pump inlet in ft}^2$

$= \left(\pi D^2/4\right)\left(1 - \frac{D_h^2}{D^2}\right)$, if $D$ is input

$= \frac{T_d \sigma_{\text{tip}}}{\tau_c \sigma_d} \left(\frac{P_H^d - P_V^d}{P_A^d + P_H^d - P_V^d}\right)$, if $D$ not specified

VLD  $V_l = \text{average flow velocity into pump inlet at design point in ft/sec} = \frac{Q_d}{A_l}$

DMAX  $D_{\text{max}} = \text{maximum impeller diameter in ft, so that the center of rotating axis will not be above the still waterline}$

$= H'/1.25$, where $H'$ is draft at 1/4 buttock at transom

DFT  $D = \text{diameter of pump impeller in ft}$

$= \frac{D_{\text{in}}}{12}$, if $D_{\text{in}}$ is input

$= \left[\frac{4A_I}{\pi \left(1 - \frac{D_h^2}{D^2}\right)}\right]^{1/2}$, if $D_{\text{in}}$ not specified

If $D$ calculated $> D_{\text{max}}$, set $D = D_{\text{max}}$

DIN  $D_{\text{in}} = \text{diameter of pump impeller in inches}$

$= 12 \, D$, or value input on Card 12

DHPMAX  $P_{\text{max}} = \text{maximum input horsepower}$

$= (\phi A_J V_{J_B}^d)^{3/620.517} 0.94733$

RPNMAX  $N_{\text{max}} = \text{pump speed in rpm at full power}$

$= 60 \left[\frac{P_{A^d} + P_H^d - P_V^d}{(1/2 \sigma_{\text{tip}})} - V_l^2\right]^{1/2} / (\pi D)$

I  $\text{Index for DO LOOP } I = 1, NV \ (NV = \text{number of speeds} = 2)$

VS  $V_S = \text{ship speed in ft/sec (design speed, cruise speed, } i = 1, 2)$

J  $\text{Index for DO LOOP } J = 1, NHP \ (NHP = 4)$

Calculate thrust at 4 selected values of horsepower

Interpolate to obtain horsepower required at specified speed

HP(J)  $P_j = \text{selected horsepower} = (J/4) P_d$

VJB  $V_{JB} = \text{bullard jet velocity in ft/sec at } P_j$

$= \left[620.517 P_j^1 1.0556 / (\phi A_J)\right]^{1/3}$
SUBROUTINE WJETS

\[ \Delta V_j = \text{increase in jet velocity at } P_j \text{ and } V_{S_1} \]
\[ = K_2 V_{S_1} [(V_{JB}/V_{S_1}) + 1]^{-1.737} \]

\[ V_j = \text{jet velocity at } P_j \text{ and } V_{S_1} = V_{JB} + \Delta V_j \]

\[ Q_j = \text{mass flow at } P_j \text{ and } V_{S_1} = A_j V_j \]

\[ T_j = \text{thrust in lb at } P_j \text{ and } V_{S_1} = \rho Q_j (V_j - V_{S_1}) \]

\[ P_i = \text{input horsepower for required thrust at } \text{specified ship speed. interpolated from array of } P_j \text{ vs } T_j \text{ at input value of } T_i \]

\[ N_i = \text{pump speed in rpm} = N_{max} \left( \frac{P_i}{P_{max}} \right)^{1/3} \]

\[ V_{JB} = \text{bollard jet velocity at required input horsepower in ft/sec} = [620.517 P_i^{1.0556}/(\rho A_j)]^{1/3} \]

\[ \Delta V_{J_i} = \text{increase in jet velocity due to IHR} = K_2 V_{S_1} [(V_{JB}/V_{S_1}) + 1]^{-1.737} \]

\[ V_{J_i} = \text{jet velocity in ft/sec} = V_{JB} + \Delta V_{J_i} \]

\[ Q_i = \text{mass flow in ft}^3/\text{sec} = A_j V_{J_i} \]

\[ V_{I_i} = \text{average flow velocity into pump inlet in ft/sec} = Q_i/A_i \]

\[ \sigma_i = \text{cavitation number} = (P_A + P_H - P_V)/(1/2 \rho V_{I_i}^2) \]

\[ n_i = \text{pump speed in rps} = N_i/60 \]

\[ \sigma_{TIP_i} = \text{impeller tip velocity cavitation number} = (P_A + P_H - P_V)/(1/2 \rho (V_{I_i}^2 + \pi^2 n_i^2 D^2)) \]

\[ \tau_{c_i} = \text{thrust load coefficient} = T_i/[1/2 \rho A_i (V_{I_i}^2 + \pi^2 n_i^2 D^2)] \]

\[ \tau_{max_i} = \text{cavitation limit on thrust load coefficient} = \sigma_{TIP_i} + 0.14 K_3 \]

\[ \tau_{c_i} - \tau_{max_i} \text{ negative value indicates cavitation} \]

\[ Q_i' = \text{mass flow in gal/min} = 448.828 Q_i \]
SUBROUTINE WJETS

XNPSH(I)  NPSH = net positive suction head
       = \((V_{1}^{2}/2g)(1 + a)\)

SS(I)    SS = suction specific speed
       = \(N_{1}(Q_{1}^{1/2} / (NPSH)^{3/4}\)

XJ(I)    J' = effective advance coefficient = \(V_{1} / n_{1}D\)

PRNN     npoi = number of pumps in operation
       = np if \(n_{aux} > 0\) (i=2)
       = np at design speed \((i = 1)\)
       = np at cruise speed if \(n_{aux} = 0\) (i=2)

DHP(I)   PD = total horsepower developed at pumps
       = \(P_{i} n_{poi}\)

SHP(I)   PS = total shaft horsepower = \(P_{D}\)
NAME: SUBROUTINE DISCOT

PURPOSE: Single or double interpolation for continuous or discontinuous function using Lagrange's formula

CALLING SEQUENCE: CALL DISCOT (XA, ZA, TABX, TABY, TABZ, NC, NY, NZ, ANS)

SUBPROGRAMS CALLED: UNS, DISSER, LAGRAN

These subroutines are concerned with the interpolation, and are not documented separately

INPUT:
XA x value (first independent variable) for interpolated point
ZA z value (second independent variable) for interpolated point
Same as x value for single-line function interpolation
TABX array Table of x values--first independent variable
TABY array Table of y values--dependent variable
TABZ array Table of z values--second independent variable
NC Three digit control integer with + sign
Use + sign if NX = NY/NZ = points in X array
Use - sign if NX = NY
Use 1 in hundreds position for no extrapolation above maximum Z
Use 0 in hundreds position for extrapolation above maximum Z
Use 1-7 in tens position for degree of interpolation desired in X direction
Use 1-7 in units position for degree of interpolation desired in Z direction
NY Number of points in y array
NZ Number of points in z array

OUTPUT:
ANS y value (dependent variable) interpolated at x, z

DISCOT is a "standard" routine used at DTNSRDC. Consult User Services Branch of the Computation, Mathematics and Logistics Department for additional information.
NAME: FUNCTION MINP

PURPOSE: Select index of minimum x value to be used for
Lagrange interpolation, from an array of x values
greater than required.

CALLING SEQUENCE: I = MINP (M, N, XA, X)

INPUT:
M
m = number of points required for interpolation of
degree m-1

N
n = total number of points in x array ≥ m

XA
x value to be used for interpolation

X array
Table of x values, must be in ascending order, but
need not be equally spaced.

OUTPUT:
MINP
Index of minimum x value from the array to be used by
FUNCTION YINTE for Lagrange interpolation of
degree m-1.

SAMPLE PROGRAM USING FUNCTIONS MINP AND YINTE:
DIMENSION X(10), Y(10)
N = 10
M = 4
READ (5, 10) (X(J), J=1, N), (Y(J), J=1, N), XA
I = MINP (M, N, XA, X)
YA = YINTE (XA, X(I), Y(I), M)

ALTERNATE PROGRAM USING FUNCTION YINTX:
DIMENSION X(10), Y(10)
N = 10
M = 4
READ (5, 10) (X(J), J=1, N), (Y(J), J=1, N), XA
YA = YINTX (XA, X, Y, M, N)

The result from either program is the same. In either case, only the
M points closest to XA are considered in the interpolation formula. The
first combination should be used whenever several dependent variables are
to be interpolated at some value of the independent variable, since MINP
need only be called once. FUNCTION YINTE may be used alone whenever
N = M.
NAME: FUNCTION YINTE

PURPOSE: Single interpolation of degree n-1 for function represented by n (x,y) points using Lagrange's formula

CALLING SEQUENCE: YA = YINTE (XA, X, Y, N)

INPUT:
- XA x value (independent variable) for interpolated point
- X array Table of x values—inddependent variable
  x values can be in either ascending or descending order and do not need to be equally spaced
- Y array Table of y values—dependent variable
- N n = number of (x,y) values defining the function

OUTPUT:
- YINTE Interpolated y value (dependent variable) derived from Lagrange formula of degree n-1
  For example, when n = 4, cubic interpolation is performed

Lagrange's Interpolation Formula

\[
y = \frac{(x-x_1)(x-x_2) \ldots (x-x_n)}{(x_0-x_1)(x_0-x_2) \ldots (x_0-x_n)} y_0 + \frac{(x-x_0)(x-x_2) \ldots (x-x_n)}{(x_1-x_0)(x_1-x_2) \ldots (x_1-x_n)} y_1 + \frac{(x-x_0)(x-x_1)(x-x_3) \ldots (x-x_n)}{(x_2-x_0)(x_2-x_1)(x_2-x_3) \ldots (x_2-x_n)} y_2 + \ldots + \frac{(x-x_0)(x-x_1)(x-x_2) \ldots (x-x_{n-1})}{(x_{n-0})(x_{n-1})(x_{n-2}) \ldots (x_{n-n-1})} y_n
\]
NAME: FUNCTION YINTX

PURPOSE:
Single interpolation of degree m-1 for function represented by n (x,y) points using Lagrange's formula. If n > m, only the m closest points are considered in the interpolation formula.

CALLING SEQUENCE:
YA = YINTX (XA, X, Y, M, N)

INPUT:
XA
x value (independent variable) for interpolated point
X array
Table of x values—independent variable x values must be in ascending order, but need not be equally spaced
Y array
Table of y values—dependent variable
M
m = number of (x,y) values considered for the interpolation process of degree m-1
N
n = total number of (x,y) values ≥ m

OUTPUT:
YINTX
Interpolated y value (dependent variable) derived from Lagrange formula of degree m-1

FUNCTION YINTX may be used instead of FUNCTION MINP and FUNCTION YINTE together

See Sample Programs using these three functions
NAME: FUNCTION SIMPUN

PURPOSE: Numerical integration of area under curve defined by set of (x,y) points at either equal or unequal intervals

CALLING SEQUENCE: AREA = SIMPUN (X, Y, N)

INPUT:
X array Table of x values—indepenent variable
x values must be in ascending order
Y array Table of y values—dependent variable
N Number of (x,y) values

OUTPUT:
SIMPUN Area under curve ≈ ∫ y dx

NAME: FUNCTION C1DSF

PURPOSE: Calculate Schoenherr frictional resistance coefficient

CALLING SEQUENCE: CF = C1DSF (XN1RE)

INPUT:
XN1RE Rn = Reynolds number = V L / ν

OUTPUT:
C1DSF Cp = Schoenherr frictional resistance coefficient

PROCEDURE: Iteration with Newton-Raphson method
Schoenherr formula: 0.242 / √Cp = log10 Rn Cp
LIBRARY SUBPROGRAMS:

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Note: Angle A must be in radians for trigonometric functions SIN, COS, TAN
APPENDIX B

SAMPLE INPUT AND OUTPUT
**SAMPLE INPUT FOR PROGRAM PHMOPT**

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171
### Hull Structures (Alum.)

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#### Lower Platform Deck

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#### Hull Bottom (Below Chine)

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*Structural data from subroutine struct (printed only if Iopt = 0)
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### PROPELLER OPEN-WATER AND CAVITATION CHARACTERISTICS FROM SUBROUTINE CAVKTO
### 177.36-Ton Planing Hull Feasibility Model: Gawn-Burrill "RPS"

**Sample (Dec 80)**

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| CRUISE | 2.80 | 1.06  | 7.36  | 0.1157| 0.1240| 0.1465| 0.985 | 0.920     | 0.170 | 1.0830 | 663.80 | 625.475| 7733.9 | 11118.1| 743.0 | 9826.0 | 15720.6 | 16355.0 |

| 10.0 | 0.49 | 0.28  | 5.66  | 0.0103| 0.0198| 0.0174| 1.057 | 0.920     | 0.158 | 1.1000 | 663.80 | 625.475| 7733.9 | 11118.1| 743.0 | 9826.0 | 15720.6 | 16355.0 |

| 0.04 | 0.28 | 5.66  | 0.0103| 0.0198| 0.0174| 1.057 | 0.920     | 0.158 | 1.1000 | 663.80 | 625.475| 7733.9 | 11118.1| 743.0 | 9826.0 | 15720.6 | 16355.0 |

| 15.0 | 1.04 | 3.67  | 5.66  | 0.0537| 0.0566| 0.0665| 1.059 | 0.920     | 0.267 | 0.9840 | 635.25 | 556.475| 7733.9 | 11118.1| 743.0 | 9826.0 | 15720.6 | 16355.0 |

| 20.0 | 1.37 | 1.01  | 5.66  | 0.0921| 0.0955| 0.1068| 1.047 | 0.920     | 0.251 | 0.9980 | 640.56 | 566.475| 7733.9 | 11118.1| 743.0 | 9826.0 | 15720.6 | 16355.0 |

### PAYLOAD REQUIREMENTS

**WT**: 34720.0 LBS  **VOL**: 250.0 FT3  **VCG**: 4.00 FT + HULL DEPTH  **PAYLOAD DENSITY**: 138.88 LBS/FT3

| VEHICLE DENSITY = 17.01 LBS/FT3 | GROUP 1 | GROUP 2 | GROUP 3 | GROUP 4 | GROUP 5 | GROUP 6 | EMPTY | USEFUL | CREW | FUEL | PAY- |
| VEHICLE DENSITY = 17.01 LBS/FT3 | STRUCT. | PROL. | COMM. | AUX. | OUTFIT | SHIP | LOAD | PROVI. | LOAD | LOAD |
| Weigh/Total WT. (39728.0 LBS) | 0.2226 | 0.2270 | 0.0373 | 0.0073 | 0.0506 | 0.0526 | 0.6004 | 0.3996 | 0.0273 | 0.2849 | 0.0874 |
| VCG/Hull Depth (14.00 FT) | 0.6093 | 0.5517 | 0.8068 | 0.8410 | 0.8615 | 0.7588 | 0.6209 | 0.6159 | 0.4184 | 0.4286 | 1.2884 |
| Volume/Total Vol. (28361.0 FT3) | 0.1169 | 0.2799 | 0.0000 | 0.1036 | 0.0788 | 0.2174 | 0.7966 | 0.2034 | 0.0134 | 0.0804 | 0.1097 |
| Cost - Millions of FY77 Dollars | 0.8540 | 2.0950 | 0.5730 | 0.0860 | 0.5420 | 0.3980 | 4.5480 | 0.0840 |

| PAYLOAD DENSITY = 11.16 LBS/FT3 | STRUCT. | PROL. | COMM. | AUX. | OUTFIT | SHIP | LOAD | PROVI. | LOAD | LOAD |
| VOLUME/Total Vol. (28361.0 FT3) | 0.1169 | 0.2799 | 0.0000 | 0.1036 | 0.0788 | 0.2174 | 0.7966 | 0.2034 | 0.0134 | 0.0804 | 0.1097 |
| Cost - Millions of FY77 Dollars | 0.8540 | 2.0950 | 0.5730 | 0.0860 | 0.5420 | 0.3980 | 4.5480 | 0.0840 |

| PAYLOAD DENSITY = 11.16 LBS/FT3 | STRUCT. | PROL. | COMM. | AUX. | OUTFIT | SHIP | LOAD | PROVI. | LOAD | LOAD |
| VOLUME/Total Vol. (28361.0 FT3) | 0.1169 | 0.2799 | 0.0000 | 0.1036 | 0.0788 | 0.2174 | 0.7966 | 0.2034 | 0.0134 | 0.0804 | 0.1097 |
| Cost - Millions of FY77 Dollars | 0.8540 | 2.0950 | 0.5730 | 0.0860 | 0.5420 | 0.3980 | 4.5480 | 0.0840 |

| PAYLOAD DENSITY = 11.16 LBS/FT3 | STRUCT. | PROL. | COMM. | AUX. | OUTFIT | SHIP | LOAD | PROVI. | LOAD | LOAD |
| VOLUME/Total Vol. (28361.0 FT3) | 0.1169 | 0.2799 | 0.0000 | 0.1036 | 0.0788 | 0.2174 | 0.7966 | 0.2034 | 0.0134 | 0.0804 | 0.1097 |
| Cost - Millions of FY77 Dollars | 0.8540 | 2.0950 | 0.5730 | 0.0860 | 0.5420 | 0.3980 | 4.5480 | 0.0840 |
### 177.3t-Ton Flaming Hull Feasibility Model Sample (Dec 80)

#### Loads

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<th>WEIGHT (M.TONS)</th>
<th>VOLUME (Ft#3)</th>
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**PAGE 3 FROM SUBROUTINE PRTOUT**
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SUN FM

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*READIN, OMKTQ2, CAVKT2
*PARENT, NEWHUL, CREWSS, POWER, PROPS, WJETS
*NEWVOL, STPHA, LOADS, ELECPL, COMCON, AUXIL, OUTFIT
*TOTALS, COSTS
*PROU1, PROU2/O
*TOMAX, PINT2, SIMPUN
*PROF, PROEF, SAVIT, TIME, DISCOT, DISPER, LAGRA, UNS/0
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LOAD MAP FOR DEC PDP/8 COMPUTER

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PLANING HULL FEASIBILITY MODEL

READIN COMPLETED
PARENT COMPLETED
NEWHUL COMPLETED
CREWSS COMPLETED
POWER COMPLETED
NEWVOL COMPLETED
STRUCT COMPLETED
LOADS COMPLETED
ELE:PL COMPLETED
COMCON COMPLETED
AUXIL COMPLETED
OUTFIT COMPLETED
TOTALS COMPLETED
COSTS COMPLETED
PRTOUT COMPLETED
END OF PROGRAM

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SAMPLE RUN ON DEC PDP/8 COMPUTER AT NAVSEADET NORFOLK
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