DDS 200-1

1 MARCH 1982

Supersedes Design Data Sheet dated 1 August 1975

CALCULATION OF SURFACE SHIP ENDURANCE FUEL REQUIREMENTS

200-1-a. General

A major consideration in the design of any Naval ship or craft is its ability to meet the endurance requirements established by the Chief of Naval Operations. This Design Data Sheet outlines the procedure followed by NAVSEA to determine the minimum necessary fuel tankage for conventionally powered steam, diesel, or gas turbine propelled ships or craft.

200-1-b. Definitions of major terms

1. Endurance is the theoretical distance which a ship can sail utilizing all of its burnable fuel (excluding cargo), at a specified speed and ambient air and sea water conditions, in deep water, at full load displacement.

2. Design endurance power is the shaft horsepower at the specified endurance speed, as indicated by the latest available speed-power curve applicable to the ship or craft. This curve may be either one prepared in the early design stages and based on predicted performance of the ship or craft, or one based on actual self-propelled model basin test results. It normally includes a correlation allowance (ΔC_f) of 0.0005, which is the equivalent of freshly applied vinyl paint on surface ships. While the 0.0005 value is a reasonable approximation for the majority of endurance calculations, this factor is not a constant, applicable to all designs. Should a different correlation allowance be used, a correction must be applied to allow for the different roughness. Appendix A contains an accepted method for determining this correction.

3. Average endurance power is the design endurance power increased by 10 percent. This increase is an allowance for adverse sea conditions and average bottom fouling over a 2-year period.

4. 24-hour average electric load is the average anticipated electrical load, without growth, over a 24-hour period when operating at the specified endurance speed, ambient air and sea water conditions.

5. Calculated all-purpose fuel rate is the specific fuel rate in lb/SHP/hr based on the total fuel consumption for propulsion machinery, ship service generators, and other services when operating at the specified endurance speed, ambient air and sea water conditions. Unless otherwise specified, PRAIRIE MASKER Systems shall be considered in operation 50 percent of the time for ships so fitted. In the case of steam plants, this is the figure resulting from the heat balance calculations. For a diesel or gas turbine propelled ship or craft, it is necessary to calculate the consumption of each service separately to arrive at the all-purpose fuel rate.

6. Ambient conditions to be utilized in determining the calculated all-purpose fuel rate are 100 degrees F and 40 percent relative humidity air to the fuel consuming services.

7. Specified fuel rate is the calculated all-purpose fuel rate increased by a correction factor to allow a tolerance for instrumentation inaccuracy (torsionmeter and shaft modulus) during ship acceptance trials, and for minor machinery design changes made during the construction period. This factor, used as a multiplier, is 1.04 if the average endurance power is one-third or less of the rated full power of the propulsion plant, 1.03 if between one-third and two-thirds, and 1.02 if between two-thirds and full power.

8. Average endurance fuel rate is the specified rate increased by 5 percent. This is an additional increase which allows for plant deterioration over a 2-year period.

9. Endurance fuel (burnable) is the actual fuel, in tons, required to meet the specified endurance.

10. Tailpipe allowance is a factor applied to the endurance fuel (burnable) to allow for the unavailable fuel remaining in the tank below the tailpipes. If the majority of tanks are broad and shallow, the factor is 0.95; if narrow and deep, it is 0.98.

11. Endurance fuel load is the fuel load in tons obtained by dividing the endurance fuel (burnable) by the tailpipe allowance. It is the full load of ship's fuel for which tankage must be provided to meet its endurance requirement. It does not include an additional 5 percent in equivalent tank volume which must be provided to allow for expansion of fuel. For a compensated system, an allowance of less than 5 percent may be provided, however, this must be determined on a case basis.

200-1-c. Procedure

After calculating the average endurance power and average endurance fuel rate, fuel requirements are determined by the following formulae:
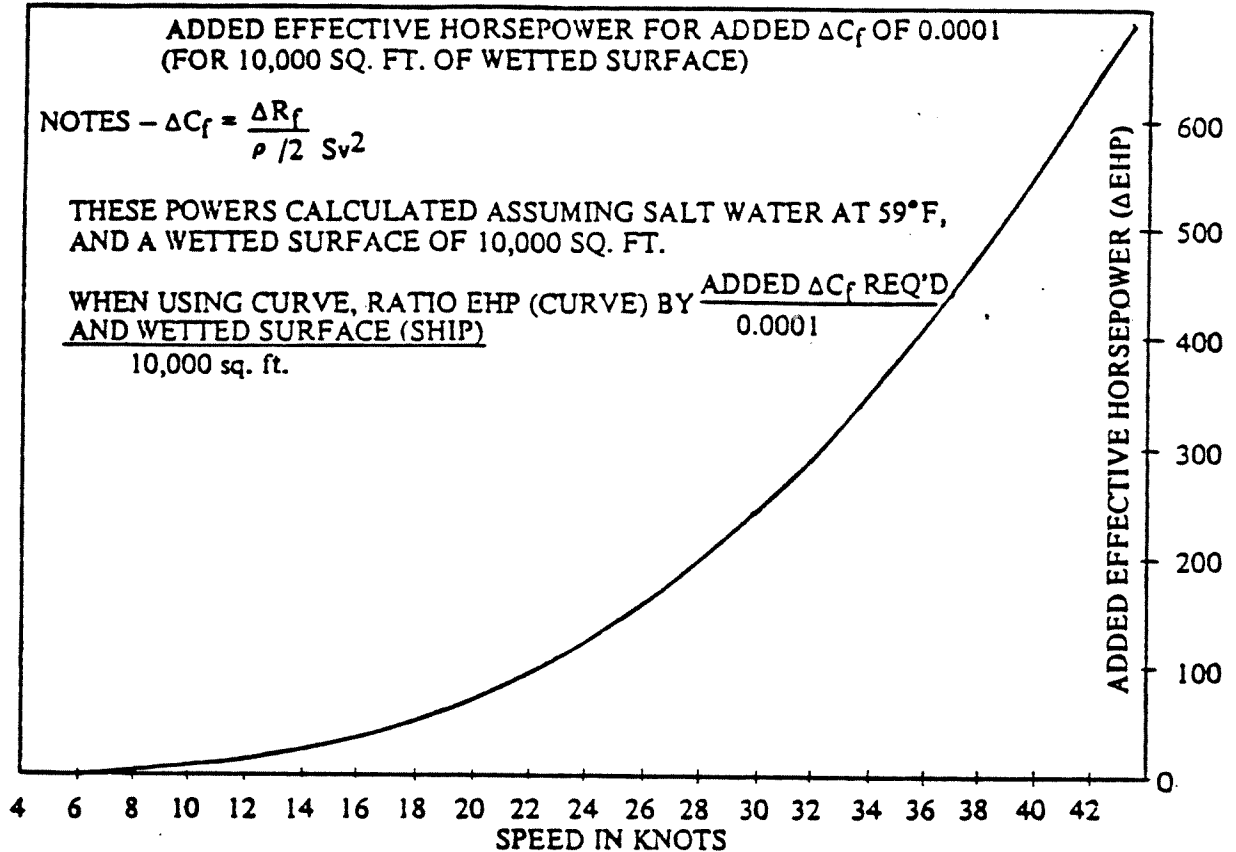
1. Endurance fuel (burnable), tons =

$$\frac{\text{Endurance x Avg. End. Power x Avg. End. Fuel Rate}}{\text{Endurance Speed x 2240}}$$

2. Endurance fuel load, tons =

$$\frac{\text{Endurance Fuel (burnable)}}{\text{Tailpipe Allowance}}$$

Appendix B is a sample calculation form.

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ADDED EFFECTIVE HORSEPOWER FOR ADDED ΔC_f OF 0.0001
(FOR 10,000 SQ. FT. OF WETTED SURFACE)

NOTES — $\Delta C_f = \dfrac{\Delta R_f}{\rho/2\ Sv^2}$

THESE POWERS CALCULATED ASSUMING SALT WATER AT 59°F,
AND A WETTED SURFACE OF 10,000 SQ. FT.

WHEN USING CURVE, RATIO EHP (CURVE) BY $\dfrac{\text{ADDED } \Delta C_f \text{ REQ'D}}{0.0001}$
$\underline{\text{AND WETTED SURFACE (SHIP)}}$
$\quad$ 10,000 sq. ft.

ADDED EFFECTIVE HORSEPOWER (ΔEHP)

SPEED IN KNOTS

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SAMPLE CALCULATION:
  TO FIND THE ADDED EHP FOR A CG AT 30 KTS
  WHEN INCREASING Δ Cf FROM 0.0006 to 0.0008;

  THE WETTED SURFACE OF THE CG IS 32,000 SQ. FT.
  FROM CURVE, Δ EHP = 236 AT 30 KTS.
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$$\text{THEN ADDED EHP} \atop (\text{@ 30 KTS}) = (236) \times \left(\frac{0.0002}{0.0001}\right) \times \left(\frac{32,000}{10,000}\right)$$

$$= (236)(2)(3.2)$$

$$= 1510.4 \quad \underline{\text{ANS.}}$$

CAUTION!

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  NOTE THAT THIS CURVE GIVES ADDED EHP.  FOR ADDED SHP, RESULT MUST
  BE DIVIDED BY P.C. AT SPEED IN QUESTION.
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SYMBOLS USED ABOVE:
ΔC_f = Correlation allowance, treated as an increase in the
$\qquad$ coefficient of frictional drag.
ΔR_f = Increased frictional drag, pounds.
ρ = Density of sea water - pounds x sec 2/ft^4 (= 1.9905 at 59°F).
S = Wetted surface area of ship - ft^2
v = Speed of the ship - ft/sec.

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DESIGN _____
PREPARED BY _____
CHECKED BY _____   EXAMPLES

		STEAM	DIESEL OR GAS TURBINE
(1)	Endurance Required, Nautical Miles	3,000	1,200
(2)	Endurance Speed, Knots	15	6
(3)	Full Load Displacement, tons	3,000	400
(4)	Rated Full Power, SHP	50,000	700
(5)	Design Endurance Power @(2)&(3), SHP	3,000	150
(6)	Average Endurance Power, SHP: (5) x 1.10	3,000 x 1.10 = 3,300	150 x 1.10 = 165
(7)	Ratio, Avg. End SHP/rated F.P. SHP: (6)/(4)	0.066	0.24
(8)	Average Endurance BHP: (6)/Transmission Efficiency	---	165/0.95 = 174
(9)	24-Hour Average Electric Load, kW	500	30
(10)	Calculated Propulsion Fuel Rate @(8), lb/BHP/hr	---	0.479
(11)	Calc. Prop. Fuel Consumption, lb/hr: (10) x (8)	---	0.479 x 174 = 83.4
(12)	Calc. S.S. Gen. Fuel Rate @(9), lb/kW/hr	---	0.690
(13)	Calc. S.S. Gen. Fuel Consumption, lb/hr: (12) x (9)	---	0.690 x 30 = 20.8
(14)	Calc. Fuel Consumption For Other Services, lb/hr	---	15.0(heating)
(15)	Total Calc. All-Purpose Fuel Consumption lb/hr: (11) + (13) + (14)	---	83.4+20.8+15.0 = 119.2
(16)	Calc. All-Purpose Fuel Rate, lb/SHP/hr: (15)/(6) or Heat Balance	1.00	119.2/165 = 0.722
(17)	Fuel Rate Correction Factor Based on (7)	1.04	1.04
(18)	Specified Fuel Rate, lb/SHP/hr: (16) x (17)	1.00 x 1.04 = 1.04	0.722 x 104 = 0.750
(19)	Avg. Endurance Fuel Rate, lb/SHP/hr: (18) x 1.05	1.04 x 1.05 = 1.092	0.750 x 1.05 = 0.787
(20)	Endurance Fuel (burnable), tons: (1) x (6) x (19)/(2) x 2240	$\frac{3,000 \times 3,300 \times 1.092}{15 \times 2240}$ = 322	$\frac{1,200 \times 165 \times 0.787}{6 \times 2240}$ = 11.6
(21)	Tailpipe Allowance Factor	0.98	0.95
(22)	Endurance Fuel Load, tons: (20)/(21)	322/0.98 = 329	11.6/0.95 = 12.2

REFERENCE FOR SOURCE DATA

    Design Endurance Power _____
    Transmission Efficiency _____
    Calc. Prop. Fuel Rate _____
    Calc. S.S. Gen. Fuel Rate _____
    Calc. Fuel Consumption for PRAIRIE MASKER _____
    Calc. Fuel Consumption for Other Services _____
    Heat Balance _____
    Full Load Displacement _____

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