

DESIGN DATA SHEET  
DEPARTMENT OF THE NAVY, BUREAU OF SHIPS

DDS9400-1

## CALCULATION OF SURFACE SHIP ENDURANCE FUEL REQUIREMENTS

1 November 1963

9400-1-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 the Bureau of Ships to determine the necessary fuel tankage for conventionally powered steam, diesel, or gas turbine propelled ships or craft.

9400-1-b. Definitions of major terms

1. Endurance is the theoretical distance which a ship can run utilizing all of its available fuel (excluding cargo), at a specified speed, in deep water, commencing 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 ( $\Delta C_f$ ) 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 bottom paint such as hot plastic ( $\Delta C_f = 0.0009$ ) be used, a correction must be applied to allow for the increased 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 two-year period.
4. Cruising electric load is the average of the anticipated electric load over a 24-hour period when operating at the specified endurance speed.
5. Calculated all-purpose fuel rate is the specific fuel rate in lbs/SHP-hr. based on the total fuel consumption for propulsion machinery, auxiliary generators, and other services when operating at the specified endurance speed. 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. Specified fuel rate is the calculated all-purpose fuel rate increased by an arbitrary correction factor to allow for torsionmeter inaccuracy during ship acceptance trials, and for minor 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.
7. Average endurance fuel rate is the specified fuel rate increased by five percent. This is an arbitrary additional increase which allows for plant deterioration over a two-year period.
8. Endurance fuel (burnable) is the actual fuel, in tons, required to meet the specified endurance.
9. 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.
10. 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. It is the amount of fuel carried in the weight summary "Full Load Condition." It does not include an additional five percent in equivalent tank volume which must be provided to allow for expansion of oil. For a compensated system an allowance of less than five percent may be provided; however, this must be determined on a case basis.

9400-1-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 =

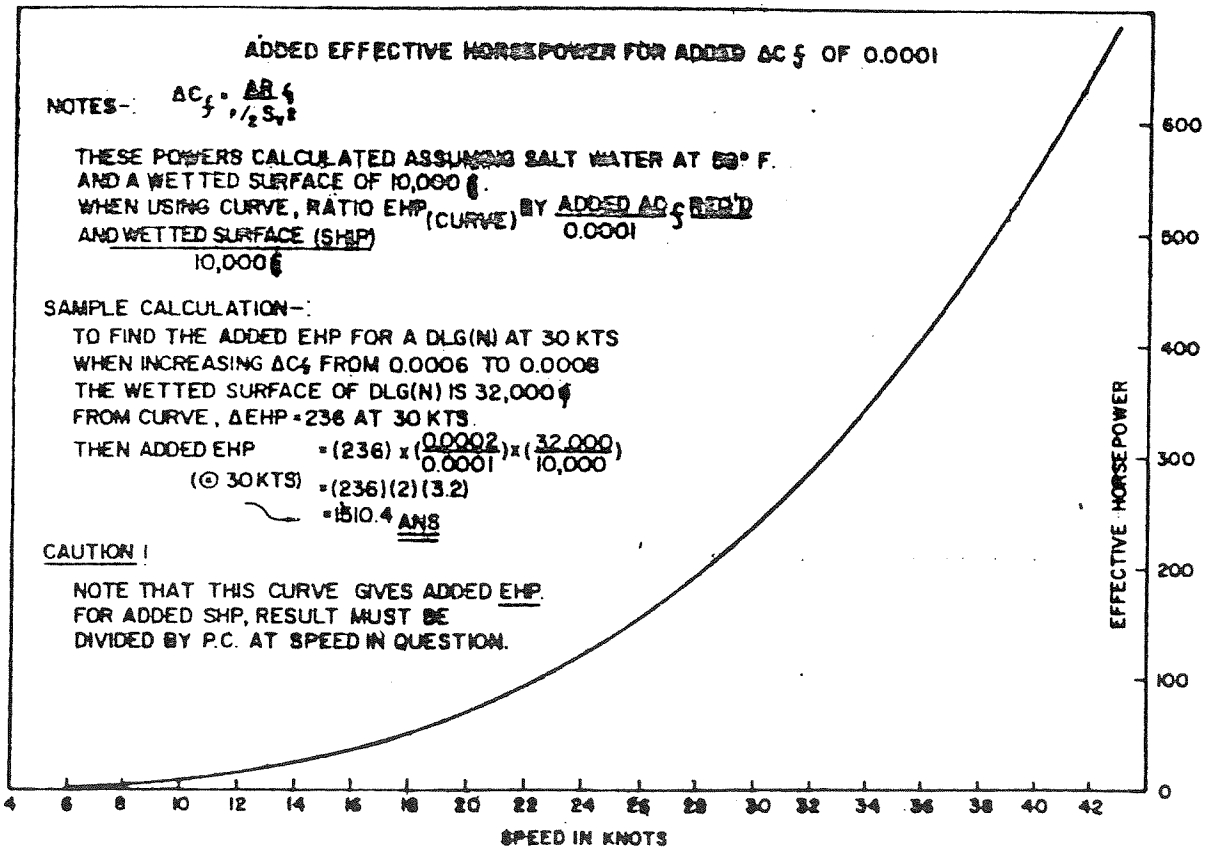
$$\frac{\text{Endurance} \times \text{Avg. End. Power} \times \text{Avg. End. Fuel Rate}}{\text{Endurance Speed} \times 2240}$$

2. Endurance fuel load, tons =

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

Appendix B is a sample calculation form.

Appendix A



APPENDIX B  
 SURFACE SHIP ENDURANCE CALCULATION FORM

DESIGN \_\_\_\_\_  
 PREPARED BY \_\_\_\_\_  
 CHECKED BY \_\_\_\_\_

EXAMPLES

	Steam	Diesel or Gas Turbine
(1) Endurance Required, 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) × 1.10	3,000 × 1.10 = 3,300	150 × 1.10 = 165
(7) Ratio, Avge. End. SHP/rated F.P. SHP: (6)/(4)	.066	0.24
(8) Cruising Electric Load, KW	500	30
(9) Calculated Propulsion Fuel Rate @ (6), lbs/SHP-hr.	---	0.505
(10) Calc. Prop. Fuel Consumption, lbs/hr: (9) × (6)	---	0.505 × 165 = 83.4
(11) Calc. Aux. Gen. Fuel Rate @ (8), lbs/KW-hr.	---	0.690
(12) Calc. Aux. Gen. Fuel Consumption, lbs/hr: (11) × (8)	---	0.690 × 30 = 20.8
(13) Calc. Fuel Consumption For Other Services, lbs/hr.	---	15.0 (heating)
(14) Total Calc. all-purpose Fuel Consump- tion, lbs/hr: (10) + (12) + (13)	---	83.4 × 20.8 + 15.0 = 119.2
(15) Calc. All-purpose Fuel Rate, lbs/SHP-hr: (14)/(6) or Heat Balance	1.00	119.2/165 = 0.722
(16) Fuel Rate Correction Factor Based on (7)	1.04	1.04
(17) Specified Fuel Rate, lbs/SHP-hr: (15) × (16)	1.00 × 1.04 = 1.04	0.722 × 1.04 = 0.750
(18) Avge. Endurance Fuel Rate, lbs/SHP-hr: (17) × 1.05	1.04 × 1.05 = 1.092	0.750 × 1.05 = 0.787
(19) Endurance Fuel (Burnable), Tons: (1) × (6) × (18)/(2) × 2240	$\frac{3000 \times 3300 \times 1.092}{15 \times 2240} = 322$	$\frac{1200 \times 165 \times 0.787}{6 \times 2240} = 11.6$
(20) Tailpipe Allowance Factor	0.98	0.95
(21) Endurance Fuel Load, tons: (19)/(20)	322/0.98 = 329	11.6/0.95 = 12.2

REFERENCES FOR SOURCE OF DATA

Design Endurance Power \_\_\_\_\_  
 All-Purpose Fuel Rate \_\_\_\_\_  
 Installed Fuel Load \_\_\_\_\_

525  
 526/Jan