AD-A150 941 DEVELOPMENT OF A CALCULATION PROCEDURE FOR THE DETERMINATION OF TOW RESISTANCE (UNABRIDGED REPORT)(U) ROSENBLATT (M) AND SON INC NEW YORK APR 76 1/6

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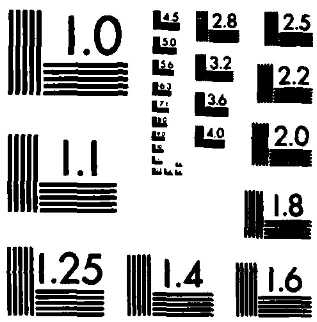

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DEVELOPMENT OF A CALCULATION PROCEDURE FOR THE DETERMINATION OF TOW RESISTANCE

(UNABRIDGED REPORT)

April, 1976

Prepared for

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By

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New York, New York

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Abstract

A method of calculating the resistance of a ship being towed is necessary in order to calculate the maximum allowable towing speed for a given tow and towline and the loads for the sizing of the towing gear. To develop such a method, available methods of calculating hull, locked propeller and wind resistance and added resistance in waves of a tow were investigated. With results of the investigation of these four resistance components, a new step by step calculation procedure for determining tow resistance was developed. A correlation study was conducted to compare the results obtained using the new procedure with the method currently used by the U.S. Navy and with data obtained from full scale tests. General conclusions are reached as to the accuracy and applicability of the new method for determining tow resistance developed in this report. Recommendations are made for future research and development.

CONTENTS

APPENDICES

1. INTRODUCTION

This is the final report on the subject of the development of a calculation procedure for the determination of tow resistance, NAVSEC contract number N00024-75-C-5508, task number 6140-808.

This task originated from the need for a better method of calculating the resistance of a ship or barge under tow. The calculation procedure must be simple enough for a sh.p operator to quickly calculate the tow resistance while towing yet be sufficiently accurate for sizing towing gear and for determination of the maximum tow speed. The method currently employed by the U.S. Navy to calculate tow resistance may be found in the U.S. Navy Towing Manual, NAVSHIPS report number 0925-000-1000 which was published in 1971. The basic approach was to calculate hull resistance for a wide range of naval ship classes and to re-examine and if possible verify the calculation of propeller, wind and sea state resistance. Sufficient documentation was presented so the proposed procedure for calculating tow resistance would be amendable for future development.

The specific task requirements were as follows:

1) Calculate hull resistance for tow speeds from 0-12 knots for a wide range of naval ship classes.
2) Investigate the available calculation methods for determining locked propeller resistance.
3) Develop a method for determining the added resistance due to waves for the range of Beaufort numbers from zero to seven.
4) Investigate the available procedures for calculating wind resistance and improve the present procedure if possible.
5) Prepare a format for the presentation of the data and the calculation procedure developed by MR&S in this study.

6) Perform a correlation study to compare results obtained from full scale towing tests at sea with the results obtained from the U.S. Navy towing manual and the MR&S proposed method.

Section 2 presents considerations in the determination of tow resistance to provide an overall view of the towing problem, describe the basic assumptions made in the formulation of a calculation procedure, and state the limitations involved in the use of the calculation procedure. The importance of problems related to towing not considered in the development of a calculation procedure for tow resistance is discussed.

Sections 3, 4, 5 and 6 treat the rationale for the development of the major tow resistance components, hull, propeller sea state and wind resistance respectively. Each section discusses the problems of determination, methods of determination, presentation of results and accuracy of results.

Section 7 combines the material of the previous sections into a step by step calculation procedure for determining tow resistance. It also includes the data necessary for performing resistance calculations for the complete range of naval ship classes.

Section 8 presents a correlation study which compares results from the calculation procedure of the U.S. Navy Towing Manual with results from the MR&S procedure (Section 7) with respect to to the four major resistance components. Results of full scale towing tests of the LST 1179 class were also compared with the two methods of calculation above.

Sections 8 and 9 contain conclusions and recommendations for future research and development.

2. THEORY OF TOWING

The determination of tow resistance is really a three-dimensional problem since the tow, towing ship and towline are not usually in the same plane. However, this study restricts itself to a two-dimensional problem by assuming that the tow follows directly behind the towing ship with zero yaw and only the resistance of the towed ship at that end of the towline is considered. Towline drag is not treated in this report.

Four basic components of tow resistance are considered in this report:

(1) Hull resistance which is composed of frictional and residuary resistance with an allowance for hull roughness.

(2) Locked propeller resistance which for certain ship types may be three times greater than the hull resistance.

(3) Added resistance due to waves which can become a significant component when towing is conducted in higher sea states.

(4) Wind resistance, which is always present due to the velocity of the tow, may be a significant component at high wind speeds.

These four tow resistance components are further discussed in the following sections and Section 7 combines these components in a calculation procedure to determine the tow resistance.

In conducting a rigorous analysis of the towing system other factors in addition to the four components above should be considered. As mentioned before the towline hydrodynamic drag must be considered in the calculation of the towline loading.

The tow resistance itself will be larger if all six degrees of motion are considered. The sea state resistance as developed, consideres the added

R_α = resistance at same heading angle lb.

α = heading angle in degrees

Average values for C_W for various naval ship types are for carriers 0.45 (CV 9 and CVE 55), for combatant types 0.70 (CA 139, CL 145, DD 445, DD 692, LST 1156), for cargo ships 0.75 in design condition, and 0.90 for the light condition (Ref. 13, 14).

Curves for average values of K for tankers, cargo ships and combatant types have been constructed (see figures 5-1 to 5-3). To allow some margin of resistance for drift multiply K by 1.5.

Combining the conversion constant for tow speed, $\rho/2$ and the factor of 1.5 yields the equation for wind resistance.

$$R_W = 0.00506\ C_W\ A_T\ K\ V_R^{\ 2}$$

where V_R is tow speed in knots.

The advantages of this method over the other methods aside from simplicity is the use of drag coefficients developed specifically for naval ships, a method for accounting for heading angle and use of data which is available for most all U.S. naval ship classes. Uniform gradient is implicitly assumed which adds a progressively larger factor to safety as wind speed increases.

5.3 Accuracy of Results

It is expected that the above method will generally yield conservative results. The greatest error will probably result from the inaccuracy of the assumption for drift and the determination of wind velocity at sea. The wind resistance will generally be less than 12% of the tow resistance so extreme accuracy is not required when compared with the other resistance components.

6. Sea State Resistance

6.1 Problem of Determination

The determination of a "simple" method of calculation to apply to all naval ship classes in all sea conditions is the most difficult problem of this study. Unfortunately sea state can be a significant factor for the tow resistance calculation at higher wind speeds as indicated in Table 6-1 (Ref. 20). The percentages in the table will be greater

Table 6-1. Percentages of Total Ship Resistance With Weather Head On (From Ref. 20)

Wind speed, knots	30	40	50	60	70
Hull resistance in smooth water	56	46	36	28	21
Extra hull resistance in rough water	33	36	37	36	31
Wind resistance	10	16	24	32	39
Rudder resistance	1	2	3	4	6

than those for a towed ship due to the addition of locked propeller resistance. At the present time, a sea state factor, K_1 is used in the U.S. Navy Towing Manual (Ref.8). This K_1 factor is multiplied by the calm water resistance of the hull and locked propeller to yield the tow resistance in a sea state (without wind). No documentation of the development of this K_1 factor was available, so it is not known why the propeller resistance should be involved in a correction for sea state. The K_1 factor is presented in Table 6-2.

The MR&S study separates the hull and propeller resistance and corrects only the hull resistance for sea state. In this method, the added resistance in waves is added to the calm water hull resistance instead of using it as a percentage factor since the added resistance in waves is independent of the calm water resistance (Ref. 27).

WIND FORCE (BEAUFORT SCALE)	WIND VELOCITY (KNOTS)	AVERAGE WAVE LENGTH DUE TO WIND (FEET)[1]	PROBABLE MAXIMUM WAVE HEIGHT (FEET)[2]	TOWING FACTOR K_1
0	0 - 1	--	--	1.0
1	1 - 3	25	--	1.1
2	4 - 6	52	1.7	1.2
3	7 - 10	84	3.4	1.3
4	11 - 16	124	7.9	1.4
5	17 - 21	179	13.2	1.5
6	22 - 27	243	19.7	1.6
7	28 - 33	317	27.1	1.7
8	34 - 40	421	36.5	1.8
9	41 - 47	572	(2)	2.0
10	48 - 55	827	(2)	2.2
11	56 - 63	--	(2)	2.5
12 - 17	64 - 118	--	(2)	2.8

Table 6-2. Towing Factor K_1 from U.S.N. Towing Manual (Ref.8)

Three basic approaches are used here in the development of a correction for sea state: 1) use of full scale data taken at sea, 2) use of approximate methods for calculating added resistance for a stationary ship, and 3) use of an analytical method which uses the principal characteristics of Series 60 hulls and the Pierson Moskowitz sea spectrum. It was beyond the scope of this task to perform an exhaustive literature survey for these approaches, but a few sources were examined to obtain up to date methods of predicting added resistance in waves.

Very few full scale tests for added resistance in waves have been conducted and the data collected is generally for small low powered ships.

Bonebakker collected powering data for hundreds of observations of a low powered motor tanker over a range of weather conditions. Figure 6-1 shows a plot of percentage increase in power in waves versus Beaufort number and Table 6-3 gives the ship particulars for the motor tanker (Ref. 20).

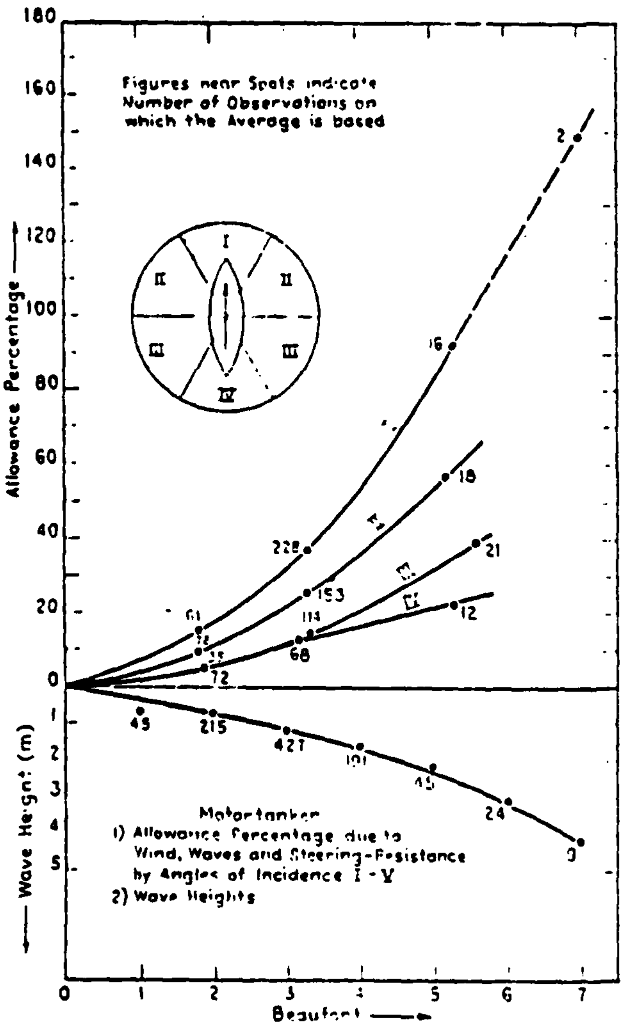


Fig. 6-1. Increase of shaft horsepower in rough weather (from Bonebakker, 1954)

Table 6-3. Particulars of the Ship Investigated by Bonebakker (1954)

	Motor tanker
Hull	
L (b pp)	148 74 m = 487' 8"
L (on lwl)	152 31
B	22 25
Draught	8 57
Displacement	21,111 m³
Block coefficient	0 744
Propeller	
D (diameter)	5·75 m
P (pitch)	4 68
P (0·7 R)	4 415
P (hub)	3 25
P (virtual)	4 80
Number of blades	4
F_a/F	0 40
Speed, designed	12·5 knots
$V/\sqrt{L ft}$	0 565
1. Model regression equation	[illegible] 4·30
2. Ship trial regression equation	[illegible] 0 0562 [illegible] 3 88
3. Mean service regression equation	[illegible] 4 31

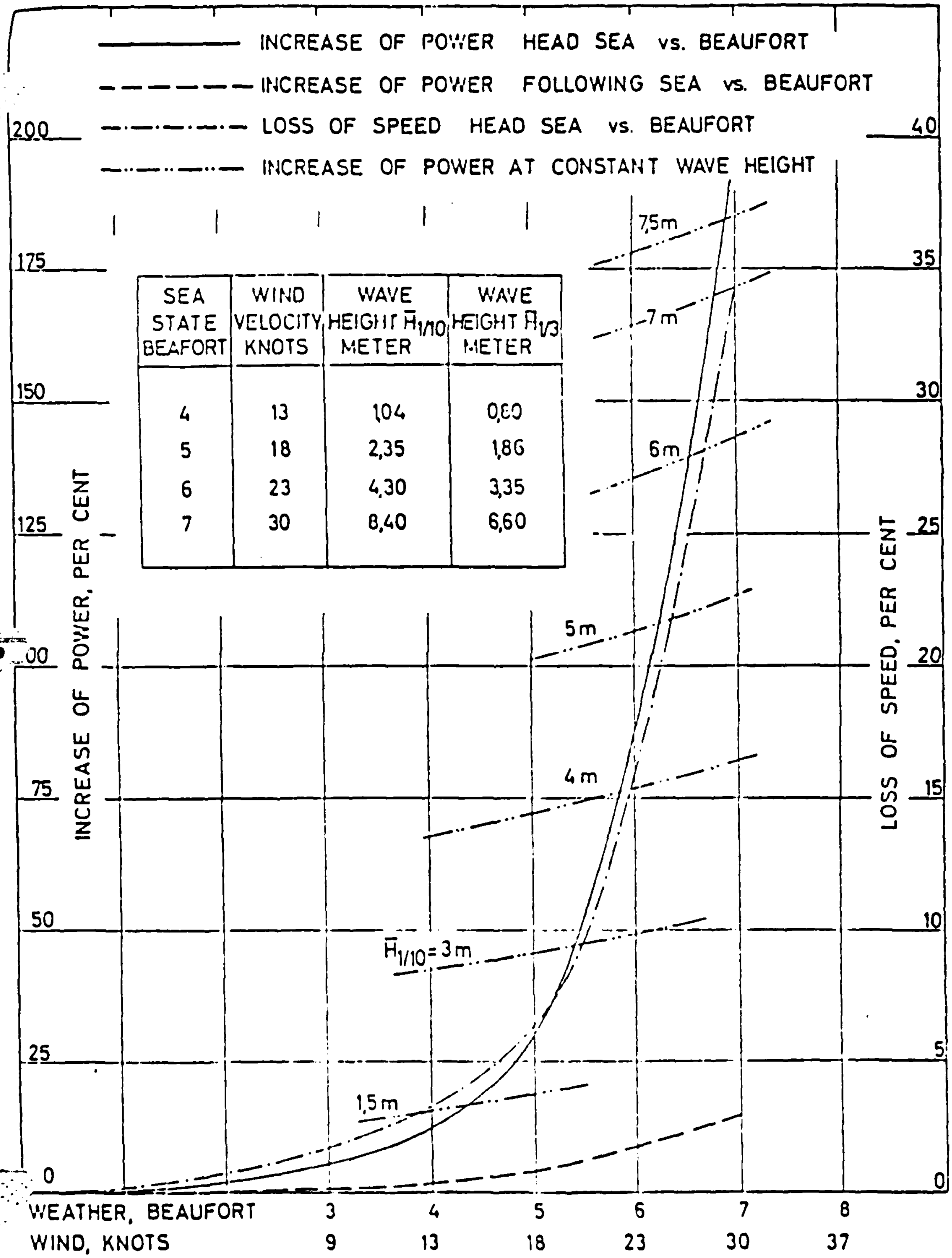
Note that the allowance percentage of Figure 6-1 includes wind and steering resistance along with the resistance due to waves. No direct comparison be made with Table 6-2 since the K_1 values of Table 6-2 are multiplied by the sum of the hull and locked propeller resistance.

Figure 6-2 provides a curve showing the percent increase of power for the ship Lukuga again considering both wind and waves combined for head seas versus the Beaufort scale (Ref. 16).

Table 6-4 gives the ship particulars of the Lukuga and Figure 6-3 shows the contribution of wind and waves to the total increase of resistance in adverse weather.

Ship's name	m.v. Lukuga
Shipowners	Compagnie Maritime Belge
Shipbuilders	Cockerill-Ougrée
Hull condition	Shell welded, frames riveted
Length between perpendiculars Lpp, meter	136,000
Breadth moulded Bm, meter	18,700
Depth to upperdeck (deck C) C, meter	12,000
Draught heavy-loaded condition, meter	Fore 8,630 Aft 8,945
Draught light-loaded condition, meter	Fore 4,935 Aft 6,555
Deadweight, tons	11.000
Service speed, knots	16

Table 6-4



SEA STATE BEAFORT	WIND VELOCITY KNOTS	WAVE HEIGHT $\bar{H}_{1/10}$ METER	WAVE HEIGHT $\bar{H}_{1/3}$ METER
4	13	1,04	0,80
5	18	2,35	1,86
6	23	4,30	3,35
7	30	8,40	6,60

Figure 6-2 (Ref. 16)

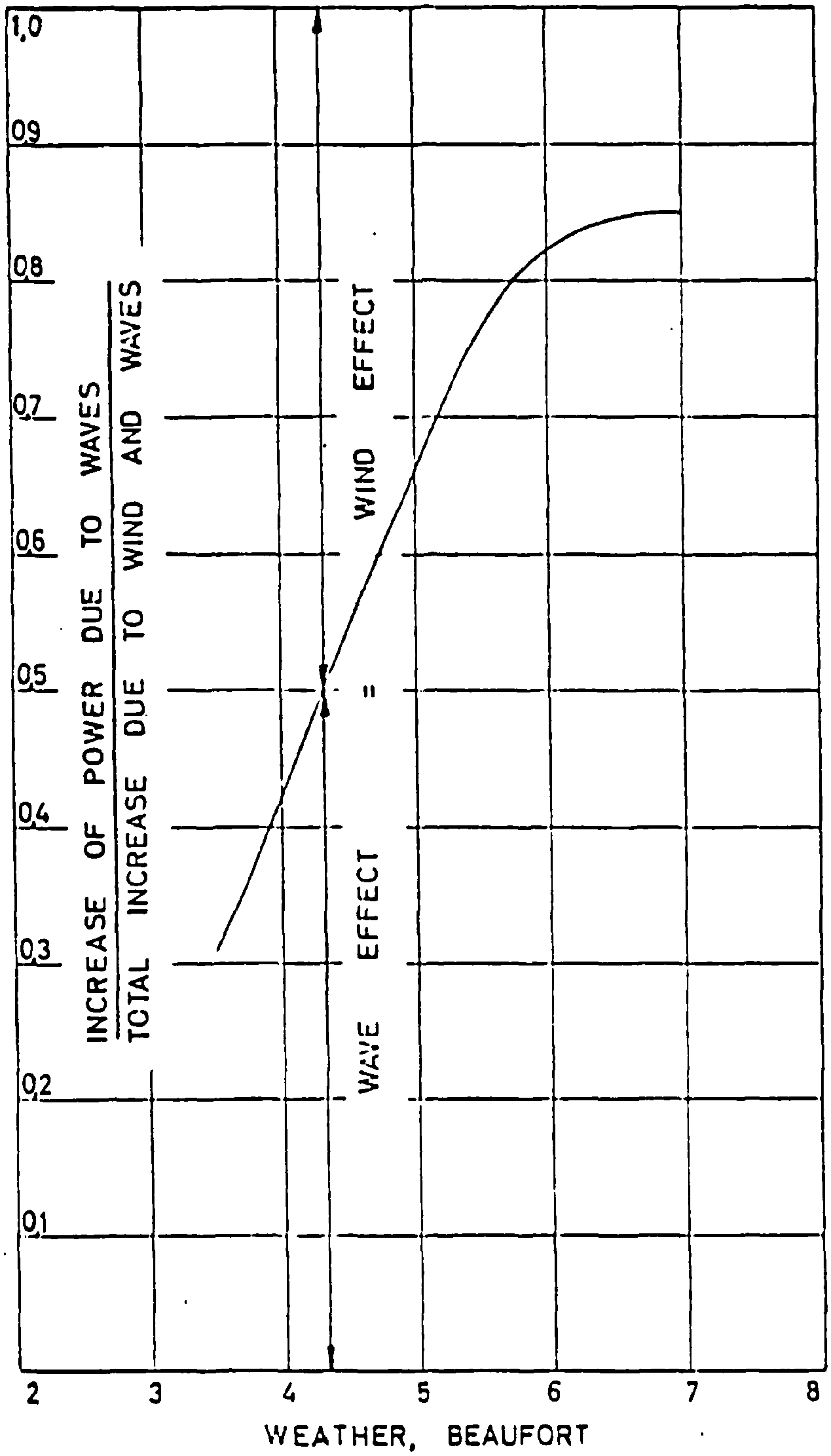


Figure 6-3 (Ref. 16)

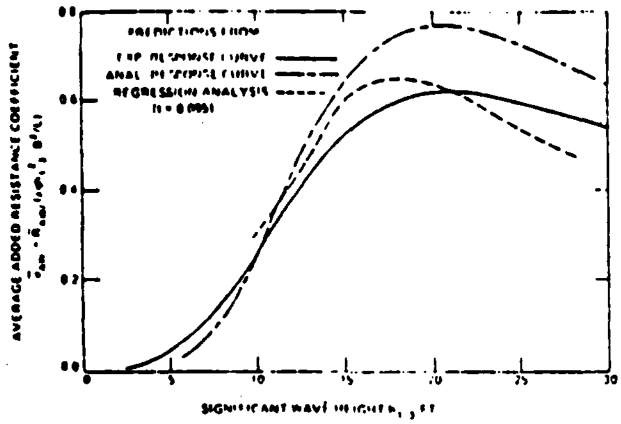
The problem with the full scale experiments discussed is that they apply only to two ships for very limited sea spectra. It is known that the added resistance in waves is dependent on the ship characteristics and the particular environment or sea conditions the ship is operating in. Thus the above methods alone are inadequate for establishing a single criteria for correcting the hull resistance for waves.

Another problem is that the delivered horsepower is a function of the quasi-propulsive coefficient and ship speed in addition to ship resistance. The delivered horsepower invariably increases faster than resistance if ship speed is maintained constant as the ship encounters waves. This results from the increased propeller thrust which leads to an increase of the propeller thrust loading coefficient and a decrease of propeller efficiency. Thus the quasi-propulsive coefficient decreases and the delivered horsepower increases. It is generally assumed that the thrust deduction and wake fraction are not greatly effected by waves (Ref. 20). In the tests shown in figures 6-1 and 6-2 the speed was reduced somewhat as the ship encountered higher Beaufort numbers to avoid damage from slamming. Because of these problems the plots of percent increase of power versus Beaufort number do not directly indicate the percent increase of resistance.

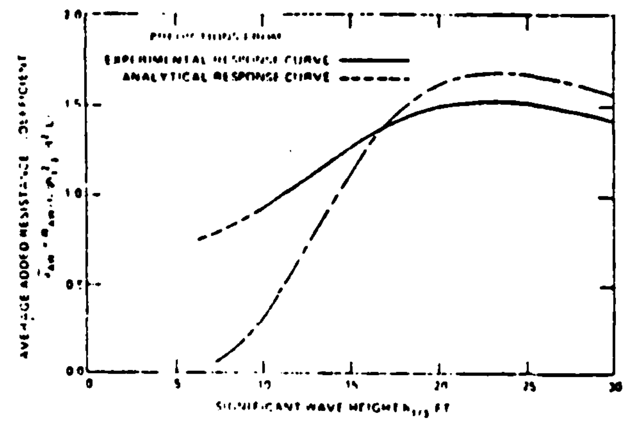
Analytical methods of calculating the added resistance of a ship in waves have shown reasonably good correlation with model tests. This study deals strictly with a ship encountering head seas since the calculation for added resistance in other seas becomes very complicated with the consideration of roll, yaw and sway motion. Only heave and pitch motions are considered. Fortunately added resistance is greatest for most ships in head seas (Ref. 21). The effect of the towline on added resistance is not considered.

A comparison of results of experimental and analytical predictions of added resistance can be seen in Figure 6-4. The spread of these curves is an indication of the degree of accuracy possible in calculating added resistance. This correspondence is partly dependent on the choice of the sea spectrum. The sea spectrum used in the development of these curves is the one parameter Pierson-Moskowitz. The curve for the regression analysis is derived from a sea spectrum recommended by the British Towing Tank Panel (BTTP) and is not of particular use in this study, since its use is restricted to ship forms which fall within the data base of the regression analysis.

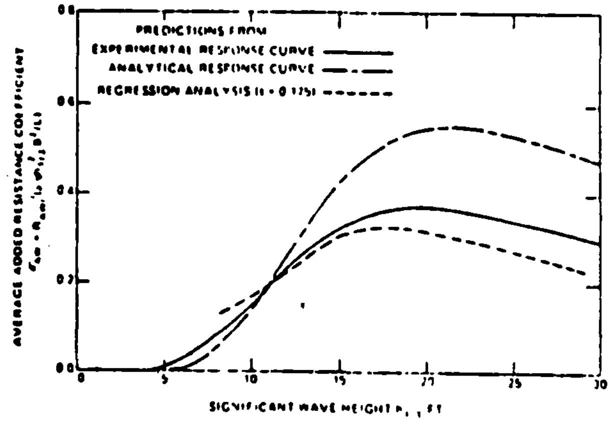
Reference 22 presents a tabular method for computing the added resistance of cruiser stern Series 60 ships. The method utilizes the Pierson-Moskowitz sea spectrum. It is possible using this method to obtain curves of added resistance for a particular cruiser stern ship as a function of ship speed and significant wave height. According to the authors, the added resistance calculated is generally low for short waves and high for long waves and for low speeds. The method is most accurate for Froude number ranging between 0.15 and 0.30 and for non-dimensional sea state of 0.02 and 0.04. The non-dimensional sea state is defined as significant wave height $H_{\frac{1}{3}}$ divided by ship length L. Figure 6-5 indicates that the results of the seakeeping tables for a Series 60 hull are close to those given by the analytical method. NSRDC has recently developed a method of computation for transom stern ships which was unavailable for this study.



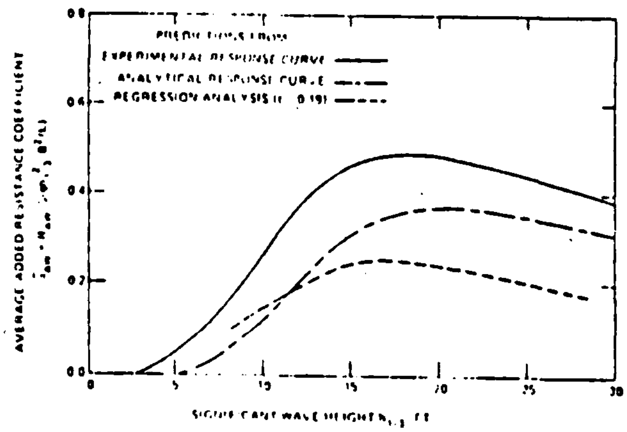
Destroyer hull form: $F_n = 0.35$



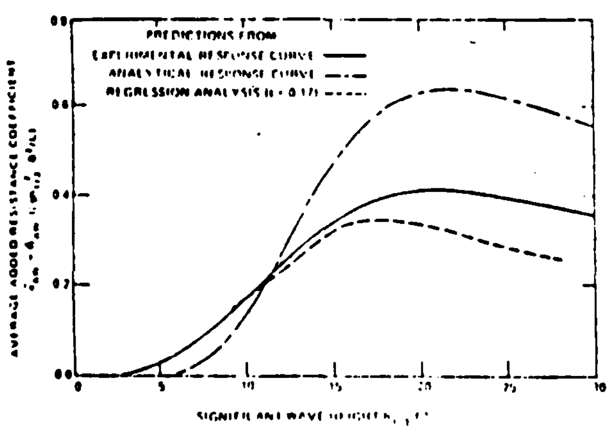
High-speed hull form: $F_n = 0.50$



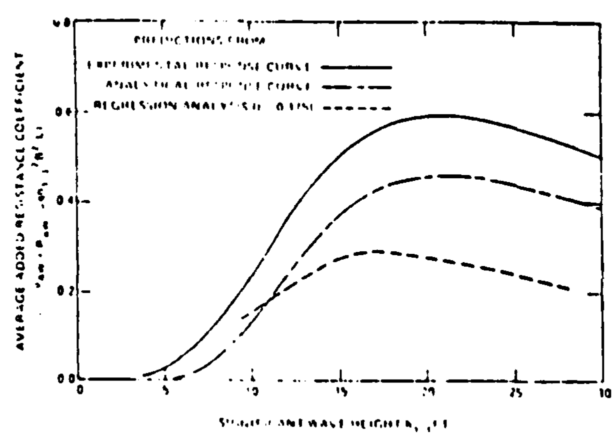
Series 60; $C_B = 0.70$, $F_n = 0.207$



Series 60; $C_B = 0.80$, $F_n = 0.147$



Series 60; $C_B = 0.65$, $F_n = 0.237$



Series 60; $C_B = 0.75$, $F_n = 0.177$

Figure 6-4

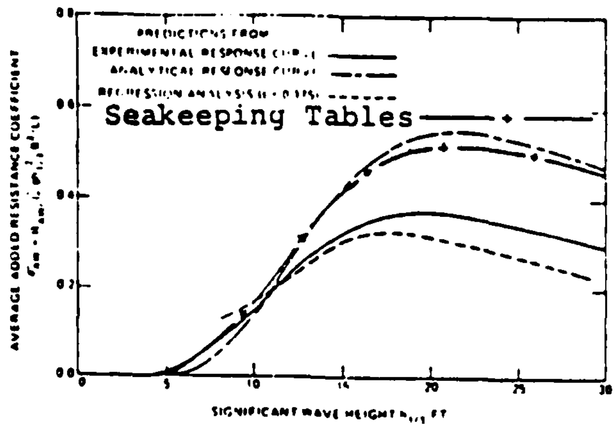


Fig6-5 Series 60, C_B = 0.70, F_n = 0.207 [Figure 20(c) of paper with discusser's seakeeping table predictions superimposed.]

Another difficult task in the analysis of added resistance is the selection of the proper sea spectrum to represent a seaway. The Pierson-Moskowitz spectrum is for fully developed seas but as indicated in Figure 6-6, a developing or decaying sea may have its spectral peak at a different frequency even at the same significant wave height.

As shown in Table 6-5 the average added resistance can change by as much as a factor of three with these changes in spectrum shape. Many investigators now feel a two parameter wave spectrum is necessary to describe a seaway and even this analysis may not properly account for short crested seas.

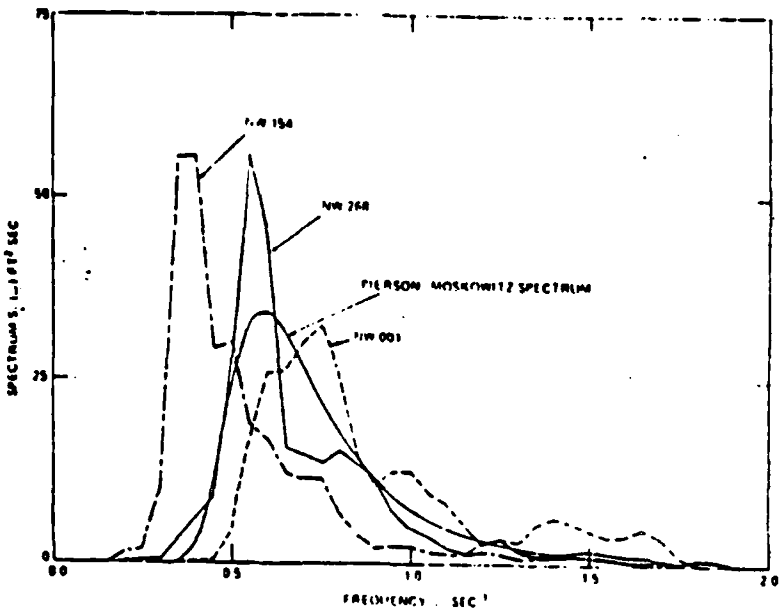
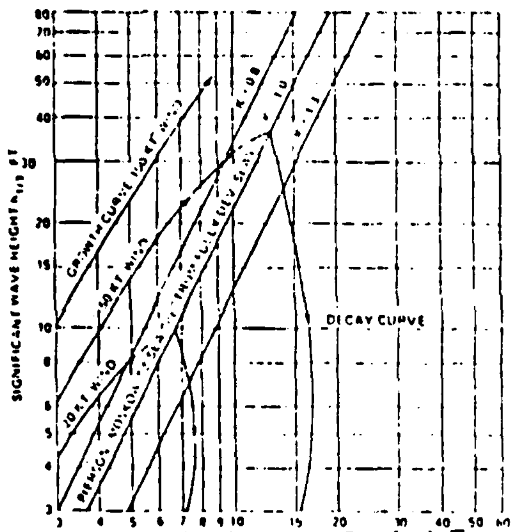


Fig. 6-6 Three typical North Atlantic sea spectra compared with Pierson-Moskowitz spectrum for same significant wave height (Ref. 21)

Ship Type	Ship Speed V, Knots	Froude No. F_n	Added Resistance, R_{AW}, lb, for Various Sea Spectra*			
			NW 001	NW 154	NW 268	Pierson-Moskowitz
Destroyer	14.8	0.20	[illegible]	31,800	[illegible]	56,500
	21.0	[illegible]	[illegible]	[illegible]	[illegible]	65,000
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
High Speed Hull Form	16.8	0.23	[illegible]	[illegible]	[illegible]	67,400
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	85,400
	33.6	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	42.0	0.50	[illegible]	[illegible]	[illegible]	[illegible]
Series 60 C_B = 0.60	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Series 60 C_B = 0.65	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	80,100
Series 60 C_B = 0.70	17.4	0.207	[illegible]	[illegible]	[illegible]	77,100
	18.7	[illegible]	[illegible]	[illegible]	[illegible]	76,900
Series 60 C_B = 0.75	14.9	0.177	[illegible]	[illegible]	[illegible]	77,100
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	72,700
Series 60 C_B = 0.80	[illegible]	0.147	[illegible]	[illegible]	[illegible]	66,500
	11.9	[illegible]	[illegible]	[illegible]	[illegible]	67,300

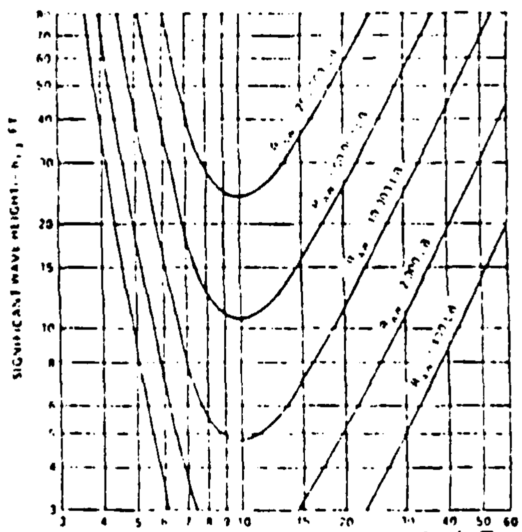
Table 6-5. Added resistance for various 625-ft ship forms in Pierson-Moskowitz and three North Atlantic sea spectra (all at approximately the same significant wave height h 1/3 = 15 ft) (Ref. 21)

A two parameter spectrum of the Bretschneider form which was recommended by the 12th ITTC (Rome 1969) is shown in Figure 6-7. This spectra has the parameters of significant wave height and wave period. Partially developed seas lie to the left of the Pierson-Moskowitz curve (K=1) for fully developed seas and dying seas and swell lie to the right of this line. Figure 6-8 shows the added resistance for one series 60 hull with the two parameters of significant wave height and wave period.



Characteristic Wave Period T_1, sec

Fig.6-7. Characteristic Seas in the $T_1 - h\,1/3$ Plane (Ref. 21)



Characteristic Wave Period T_1, sec

Fig.6-8. Typical Added Resistance Response Contours in the $T_1 - h\,1/3$ Plane for 625-ft Ship (Series 60, $C_B = 0.70$) at 17.4 knots (Ref. 21)

By using Figures 6-7 and 6-8 together, it can be seen that for a 20 knot wind the characteristic wave period may vary from 5 to 7 seconds for a significant wave height of 8 feet. This results in an added resistance range of 400 to 10,000 pounds. (Ref.21).

Miles provides data for 323 wave spectra measured in the North Atlantic Ocean (Ref. 23). This data was used to calculate the added resistance for the one parameter, significant wave height, and is shown in Figure 6-9 (Ref. 21). The curve for the Pierson-Moskowitz spectra has been included. This demonstrates the error possible with the use of only one parameter and one spectrum.

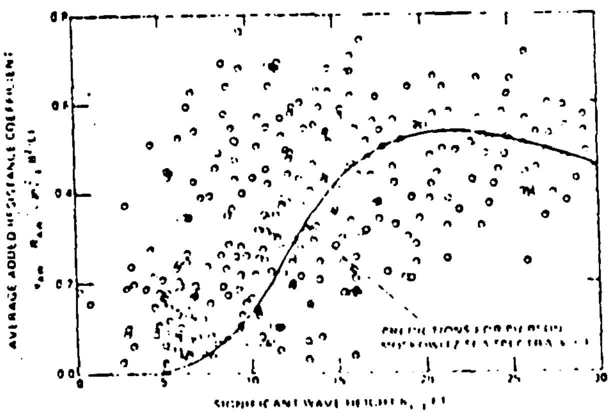


Fig. 6-9 Nondimensional added resistance versus significant wave height for 625-ft ship in 307 sample North Atlantic sea spectra (predictions from analytical response curve, Series 60, $C_B = 0.70$, $F_n = 0.207$) (Ref.21)

This study demonstrates that selection of the appropriate sea state may be equally important as the method of calculating the added resistance in obtaining accurate results.

6.2 Method of Calculation

To develop a simple method for determining the added resistance in waves, calculations were performed using the seakeeping tables for a Series 60 cruiser stern hull for nine ship classes. These classes were selected to provide a wide range of ship lengths. Low Froude numbers of 0.1 to 0.15 were selected to provide a reasonable speed that could be employed while towing in a sea state. The added resistance in pounds (R_s) was plotted versus significant wave height and its corresponding wind force (Beaufort). The resulting curves for R_s are shown in figures 6-10 and 6-11. A curve from these two figures is assigned to each of the naval ship classes chiefly on the basis of ship length and to a lesser extent on the basis of block coefficient and length-beam ratio.

Since the lowest non-dimensional sea state used in the tables is 0.015 it was not possible to obtain added resistance data for Beaufort numbers below 5 for ships greater than 450 feet in length. Figure 6-11 shows that for the larger ships the added resistance converge together as they approach zero so one extrapolation line was used below a significant wave height of seven feet. In an effort to verify the accuracy of the extrapolated portion of figure 6-11 and the calculated points for low significant wave heights of figure 6-10 an empirical formula was used. As discussed in reference 27, several formulas exist for calculating added resistance for stationary or for moving ships but they give radically different results and do not account for all aspects of the added resistance problem. However, to compare with the results obtained by extrapolating the data from the seakeeping tables, the formula developed by Jacobs and Lewis was used to calculate added resistance for a significant wave height of 5 feet for the nine ships studied. Their equation is expressed:

$$R_s = 0.174\ g\rho\ (h/2)^{1.67}\ (\sin\alpha)^{0.33}\ B^{1.33}$$

where R_s = added resistance (lb.)

h = wave height (ft.)

α = mean waterline entrance slope (deg.)

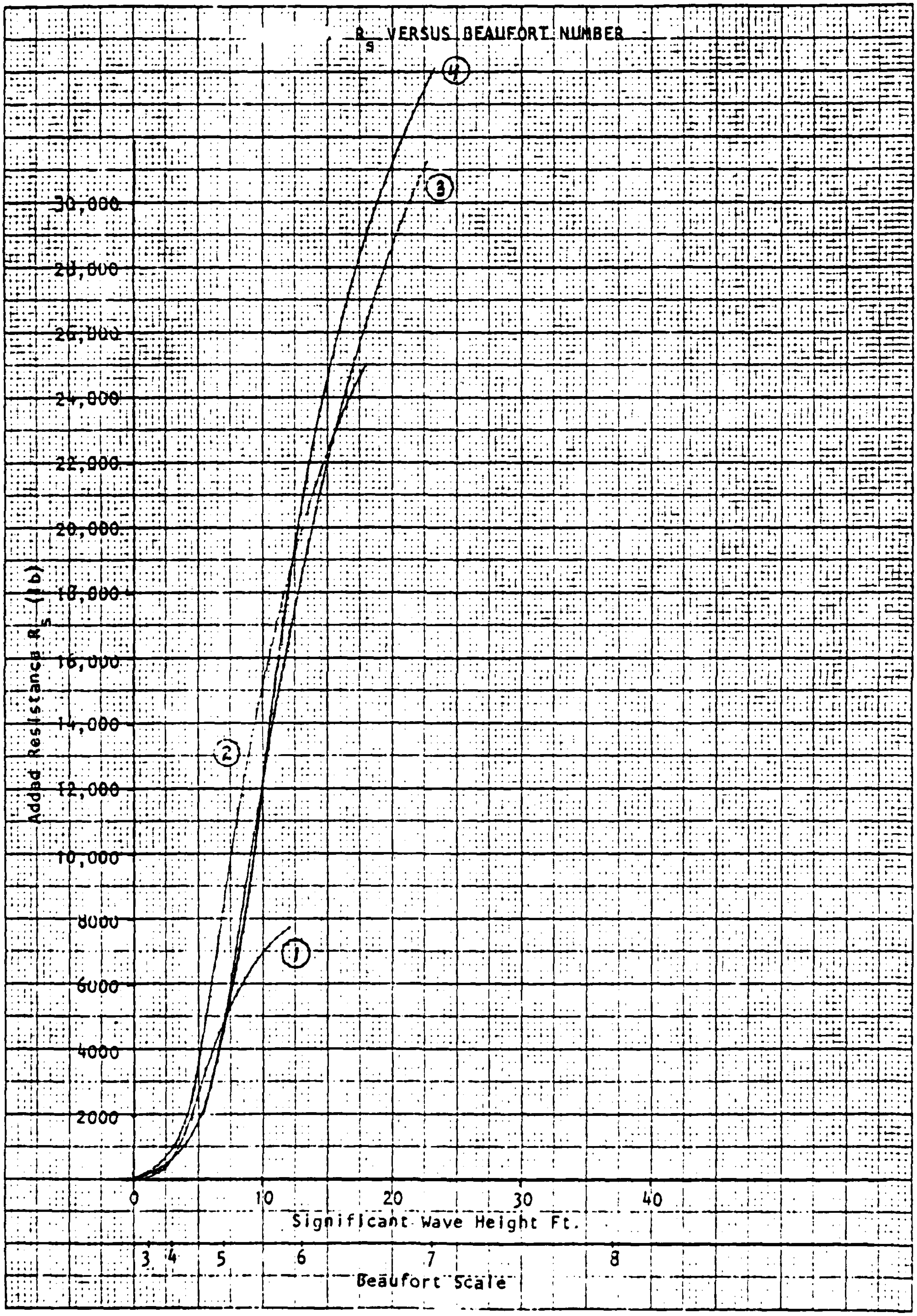
B = ship beam (feet)

This equation was developed for a stationary ship in short waves with the assumption that added resistance is due mainly to wave reflection and that added resistance due to pitching and heaving is negligible. This particular formulation was selected among others principally because Jacobs and Lewis obtained excellent agreement when they compared it with the results of model tests (Ref. 20).

The results of the calculations using the formulation above are presented in Appendix C. The mean waterline entrance slope was not known but was approximated on the basis of the ship characteristics. The results show close correlation with the seakeeping tables for the two smallest ships but differ by as much as a factor of 3 for larger ships. It is expected that the results of the seakeeping tables would be lower than that indicated by the Jacobs and Lewis formulation since these calculations were performed for tow speeds from six to nine knots. For low sea states, added resistance decreases as ship speed increases. Even if it is assumed that the formulation of Jacobs and Lewis is correct, the resulting error of 8000 pounds of added resistance amounts to less than 10 per cent of the tow resistance for the larger ships. On this basis the extrapolation for the lower significant wave heights is considered acceptable.

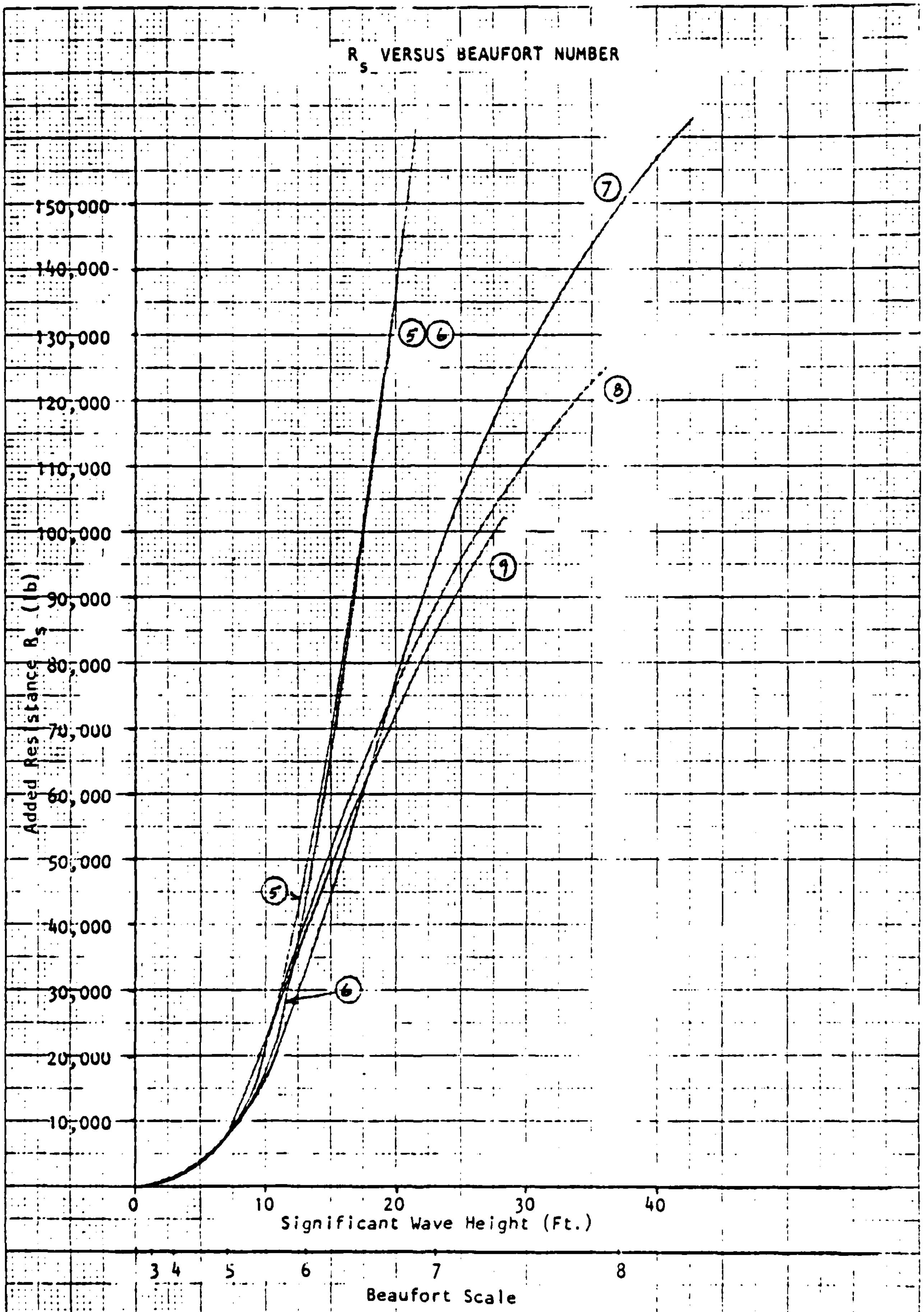
6.3 Accuracy of Results

The calculation of added resistance in wave is the least accurate of the four resistance components. The method of calculating added resistance in this study applies only to cruiser stern ships in head seas with a Pierson-Moskowitz sea spectrum. Only a one parameter wave spectrum was considered and it has been shown that small differences in wave period can produce substantial differences in added resistance due to waves. Until full scale testing in a sea state can be performed to verify the data presented by figures 6-10 and 6-11 especially for low sea states, this data should be used with caution. If for no other reason than added resistance in wave is now independent of calm water hull and propeller resistance, this approach can be considered an advance over the previous method as indicated by table 6-2.



R_s VERSUS BEAUFORT NUMBER
Added Resistance R_s (lb)
30,000
28,000
26,000
24,000
22,000
20,000
18,000
16,000
14,000
12,000
10,000
8000
6000
4000
2000
0
10
20
30
40
Significant Wave Height Ft.
3
4
5
6
7
8
Beaufort Scale
1
2
3
4

FIGURE 6-10



R_s VERSUS BEAUFORT NUMBER
Added Resistance R_s (lb)
150,000
140,000
130,000
120,000
110,000
100,000
90,000
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
10
20
30
40
Significant Wave Height (Ft.)
3 4 5 6 7 8
Beaufort Scale
5
6
7
8
9

FIGURE 6-11

7. Calculation Procedure for the Determination of Tow Resistance

The previous sections have described the method of calculation for various components of the resistance: hull, propeller, wind and sea state. This section combines all of these components into one calculation for the determination of tow resistance. Resistance of the towline is not considered. The calculation of tow resistance is presented as a step by step procedure below. The items are summarized in tabular form in Table 1.

Item

1. Ship class

2-8 Data for given ship class taken from Table 2

2. Displacement Δ in long tons

3. Frontal windage area A_T in Feet^2

4. Wind drag coefficient C_w

5. Projected area of all propellers A_p in Feet^2

6. Curve number for hull resistance

7. Curve number for K factor

8. Curve number for sea state resistance R_s

9. Determine wind Beaufort number based on measurement of wind velocity and observation of the sea state with the aid of Table 3. The estimate should be conservative and should account for anticipated changes of weather.

10. Relative wind speed V_R in knots

11. Relative wind direction α measured in degrees measured from the bow

12. Using the appropriate curve from item 7 find the heading coefficient K for the heading angle α from item 11. See Figures 1-3.

Item

13. Using the appropriate curve from item 8 determine the sea state resistance R_s for the appropriate Beaufort number from item 9. See Figures 4 and 5.

14. Select tow speed V_{TOW} in knots

15. Using curve number from item 6 and Figures (6) through (13), find the value for R_H/Δ for the tow speed selected, item 14.

16. Calculate the hull resistance R_H.

$$R_H = R_H/\Delta \times \Delta \times 1.25$$

17. Calculate the propeller resistance R_p.

$$R_p = 3.737\, A_p V_{tow}^2$$

18. Calculate the wind resistance R_w

$$R_w = 0.00506\, C_w A_t K V_R^2$$

19. Calculate the total resistance R_T.

$$R_T = R_s + R_H + R_p + R_w$$

Special Note: If the tow does not track directly behind the towing vessel or if it is towing at an angle of yaw then the ship speed should be reduced below the maximum speed permitted by the above calculation. Speed should always be reduced below this maximum value while turning.

TABLE - 1

CALCULATION OF TOWING RESISTANCE

SHIP: ______________________ DATE: ______________

BY: ______________

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		
2	TOW DISPLACEMENT, Δ (SEE TABLE-2)	LONG TONS	
3	FRONTAL WINDAGE AREA, A_T, (SEE TABLE 2)	SQ. FEET	
4	WIND DRAG COEFFICIENT, C_w, (SEE TABLE 2)	—	
5	TOTAL PROJECTED AREA OF PROPELLERS, A_p, (SEE TABLE 2)	SQ. FEET	
6	CURVE NUMBER FOR HULL RESISTANCE, $R_{H/\Delta}$, (SEE TABLE 2)	—	
7	CURVE NUMBER FOR WIND FACTOR, K, (SEE TABLE 2)	—	
8	CURVE NUMBER FOR SEA STATE RESISTANCE, R_s, (SEE TABLE 2)	—	
9	BEAUFORT NUMBER (WIND) - (SEE TABLE-3)	—	
10	RELATIVE WIND SPEED, V_R	KNOTS	
11	RELATIVE WIND DIRECTION, α	DEGREES	
12	HEADING COEFFICIENT K, (SEE FIG. 1-3)	—	
13	SEA STATE RESISTANCE R_s, (SEE FIG. 4-5)	POUNDS	
14	SELECT A TOW SPEED, V_{TOW}	KNOTS	
15	$R_{H/\Delta}$ (SEE FIG. 6-13)	—	
16	HULL RESISTANCE = R_H = (15) × (2) × 1.25	POUNDS	
17	PROPELLER RESISTANCE = R_p = 3.737 × (5) × (14) × (14)	POUNDS	
18	WIND RESISTANCE = R_w = 0.00506 × (4) × (3) × (12) × (10) × (10)	POUNDS	
19	TOTAL TOW RESISTANCE = R_T = (13) + (16) + (17) + (18)	POUNDS	

TABLE 2 - CHARACTERISTICS OF NAVAL VESSELS

CLASS	DESCRIPTION	DISPLACEMENT Δ (L. TONS)	LIGHT SHIP FRONTAL WINDAGE AREA (SQ. FT.)	WIND COEFF. C_w	TOTAL PROJECTED AREA OF ALL PROPELLERS A_p (FEET)^2	CURVE FOR HULL RESISTANCE See Fig.(6-12)	CURVE FOR K FACTOR See Fig. (1 - 3)	CURVE FOR SEA STATE R_s See Fig.(4-5)
AD 14-19	Destroyer Tender	17176	6200	0.75	136	14	1	9
AD 16	"	16600	4130	0.75	142	26	1	8
AD 23-36	"	16900	4200	0.75	142	26	1	8
AD 37-38	"	21000	5600	0.75	136	21	1	5
ADG 8-10	Degaussing Ship	900	1100	0.75	24	13	1	1
ADG 383	"	1235	--	0.75	--	30	1	2
AE 4-9	Ammunition Ship	14225	4600	0.75	103	26	1	8
AE 12-19	"	15295	4500	0.75	103	26	1	8
AE 21-25	"	17500	6490	0.75	187	13	1	8
AE 26-35	"	20500	--	0.75	--	15	1	9
AE 30-31	"	14000	4375	0.75	106	26	1	8
AF 28-29	Stores Ship	15300	4460	0.75	106	26	1	2
AF 42-44	"	7435	2600	0.75	38	26	1	8
AF 48-61	"	15500	4405	0.75	106	26	1	8
T-AF 50-51	"	12800	4375	0.75	106	26	1	8
AF 56-57	"	12130	4100	0.75	119	26	1	8
AF 58-59	"	15540	5400	0.75	198	12	1	8
T-AF 63-64	"	12130	4100	0.75	119	26	1	8
AFS 1-7	Combat Stores Ship	16500	6350	0.70	216	17	3	3
AG 153-154	Exper. Navigation Ship	17600	5550	0.75	--	17	1	8
T-AG 162	Exper. Sound Testing	17000	--	0.75	--	--	1	--
T-AG 164	Hydrographic Research	12450	4340	0.75	119	13	1	8
T-AG 169-171	Special Mission	7460	2600	0.75	38	26	1	4

TABLE 2 - CHARACTERISTICS OF NAVAL VESSELS

CLASS	DESCRIPTION	DISPLACEMENT Δ (L. TONS)	LIGHT SHIP FRONTAL WINDAGE AREA (SQ. FT.)	WIND COEFF. C_w	TOTAL PROJECTED AREA OF ALL PROPELLERS A_p (FEET)^2	CURVE FOR HULL RESISTANCE See Fig.(6-12)	CURVE FOR K FACTOR See Fig. (1 - 3)	CURVE FOR SEA STATE R_s See Fig.(4-5)
AD 14-19	Destroyer Tender	17176	6200	0.75	136	14	1	9
AD 16	"	16600	4130	0.75	142	26	1	8
AD 23-36	"	16900	4200	0.75	142	26	1	8
AD 37-38	"	21000	5600	0.75	136	21	1	5
ADG 8-10	Degaussing Ship	900	1100	0.75	24	13	1	1
ADG 383	"	1235	--	0.75	--	30	1	2
AE 4-9	Ammunition Ship	14225	4600	0.75	103	26	1	8
AE 12-19	"	15295	4500	0.75	103	26	1	8
AE 21-25	"	17500	6490	0.75	187	13	1	8
AE 26-35	"	20500	--	0.75	--	15	1	9
AE 30-31	"	14000	4375	0.75	106	26	1	8
AF 28-29	Stores Ship	15300	4460	0.75	106	26	1	2
AF 42-44	"	7435	2600	0.75	38	26	1	8
AF 48-61	"	15500	4405	0.75	106	26	1	8
T-AF 50-51	"	12800	4375	0.75	106	26	1	8
AF 56-57	"	12130	4100	0.75	119	26	1	8
AF 58-59	"	15540	5400	0.75	198	12	1	8
T-AF 63-64	"	12130	4100	0.75	119	26	1	8
AFS 1-7	Combat Stores Ship	16500	6350	0.70	216	17	3	3
AG 153-154	Exper. Navigation Ship	17600	5550	0.75	--	17	1	8
T-AG 162	Exper. Sound Testing	17000	--	0.75	--	--	1	--
T-AG 164	Hydrographic Research	12450	4340	0.75	119	13	1	8
T-AG 169-171	Special Mission	7460	2600	0.75	38	26	1	4

TABLE 2 - CHARACTERISTICS OF NAVAL VESSELS

CLASS	DESCRIPTION	DISPLACEMENT Δ (L. TONS)	LIGHT SHIP FRONTAL WINDAGE AREA (SQ. FT.)	WIND COEFF. C_w	TOTAL PROJECTED AREA OF ALL PROPELLERS A_p $(FEET)^2$	CURVE FOR HULL RESISTANCE See Fig.(6-12)	CURVE FOR K FACTOR See Fig. (1 - 3)	CURVE FOR SEA STATE R_s See Fig.(4-5)
T-AG 172-174	Cargo	12400	4100	0.75	119	13	1	8
T-AG 175	Surveying Ship	7400	2600	0.75	38	26	1	4
AG 176	Miscellaneous	--	--	0.75	--	--	1	2
T-AG 178	Hydrographic Research	11000	4375	0.75	106	37	1	8
AG 191	Sonar Test Ship	8200	2600	0.75	--	2	1	3
AG 335	Cargo	1095	990	0.75	22	29	1	1
AGDE 1	Escort Research	3426	1715	0.75	131	10	1	4
AGF 1	Misc. Command Ship	2800	1600	0.75	47	16	1	2
T-AGM 1-11	Missile Range Inst. Ship	11100	4100	0.70	119	20	3	8
T-AGM 2	"	550	--	0.70	--	--	--	--
T-AGM 9-10	"	16600	4900	0.70	--	17	3	5
T-AGM 13-16	"	7460	2600	0.70	38	26	3	4
T-AGM 19-21	"	21626	5020	0.70	--	37	3	9
AGMR 1	Communications Relay	22500	--	0.75	--	15	1	9
AGMR 2	"	19600	6000	0.75	300	3	1	7
T-AGS 29-32	Surveying Ship	4200	--	0.75	--	11	1	4
AGTR 1-3	Technical Research	11365	3250	0.75	94	26	1	8
AGTR 4-5	"	10680	4100	0.75	119	13	1	8
AH 16-17	Hospital Ship	15900	4900	0.75	115	17	1	8
T-AK 180-250	Cargo Ship	7450	3100	0.75	38	26	1	4
T-AK 237-276	"	12450	4100	0.75	119	13	1	8
T-AK 241-254	"	12400	4100	0.75	119	13	1	8
T-AK 255-267	"	--	4900	0.75	--	17	1	5

TABLE 2 - CHARACTERISTICS OF NAVAL VESSELS

CLASS	DESCRIPTION	DISPLACEMENT Δ (L. TONS)	LIGHT SHIP FRONTAL WINDAGE AREA (SQ. FT.)	WIND COEFF. C_w	TOTAL PROJECTED AREA OF ALL PROPELLERS A_p (FEET)^2	CURVE FOR HULL RESISTANCE See Fig.(6-12)	CURVE FOR K FACTOR See Fig. (1 - 3)	CURVE FOR SEA STATE R_s See Fig.(4-5)
AK 260	CARGO SHIP	12420	4100	0.75	119	13	1	8
T-AK 271	"	4942	--	0.75	--	26	1	2
T-AK 277	"	15800	5400	0.75	142	13	1	8
T-AK 279-281	"	11150	4100	0.75	119	20	1	8
T-AK 283	"	14000	4375	0.75	106	26	1	8
T-AKD 1	Dock Cargo Ship	14094	6856	0.75	--	26	1	8
T-AKR 7	Vehicle Cargo Ship	18150	--	0.75	--	13	1	8
T-AKR 9	"	21700	--	0.75	--	20	1	9
T-AKV 8-37	Cargo/Aircraft Ferry	24560	5400	0.75	158	20	1	9
T-AKV 40-43	"	15700	5340	0.75	--	13	1	8
AO 24-53	Oiler	25400-34700	5540	1.00	174	20	2	5
AO 36-47	"	21850	4290	1.00	108	26	2	9
T-AO 49-142	"	22380	4610	1.00	108	26	2	9
AO 105-109	"	34750	5480	1.00	346	26	2	5
AO 143-148	"	38000	6300	1.00	198	26	2	5
T-AO 149-152	"	--	--	1.00	--	--	2	--
T-AO 165	"	--	--	1.00	--	--	2	--
AOE 1-5	Fast Combat Support	53600	9750	0.75	456	22	1	6
AOG 1-56	Gasoline Tanker	4570	2200	1.00	54	26	2	2
T-AOG 77-80	"	6000	--	1.00	--	26	2	4
T-AOG 81-82	"	5720	--	1.00	--	--	2	--
AOR 1-6	Replenishment Oiler	38100	7590	1.00	274	20	2	5
T-AP 110-119	Transport	20175	6800	0.75	200	23	1	9

TABLE 2 - CHARACTERISTICS OF NAVAL VE

CLASS	DESCRIPTION	DISPLACEMENT Δ (L. TONS)	LIGHT SHIP FRONTAL WINDAGE AREA (SQ. FT.)	WIND COEFF. C_w	TOTAL PROJECTED AREA OF ALL PROPELLERS A_p $(FEET)^2$	R[illegible] See [illegible]	
T-AP 122-127	Transport	20620	--	0.75	--	--	
T-AP 196-198	"	19600	--	0.75	--	13	
APB 35-48	Self Propelled Barracks	4080	1910	0.75	30	26	
APC 116	Coastal Transport	7460	2600	0.75	38	26	
APL 2-58	Barracks Barges	2660	--	0.75	--	--	
AR 5-8	Repair Ship	16130	5460	0.75	136	14	1
AR 9-12	"	14500	4100	0.75	142	20	1
AR 13-14	"	14490	4200	0.75	142	15	1
AR 22-23	"	16900	4180	0.75	142	26	1
ARB 4-8	Battle Damage Repair	4080	2320	0.75	30	37	1
ARC 2-6	Cable Repair Ship	7380	--	0.75	--	26	
ARC 3-4	"	7080	--	0.75	62	19	
ARG-4	Engine Repair Ship	14350	3250	0.75	94	[illegible]	
ARL 1-38	Landing Craft Repair	3830	2320	0.75	30		
ARS 6-43	Salvage Ship	1900	1500	0.75	56		
ARSD 1-2	Salvage Lift Ship	1095	990	0.75	[illegible]		
ARST 1-2	Salvage Craft Tender	4080	2320	0.75			
ARVA 5-6	Aircraft Airframe Rpr.	4080	2320	[illegible]			
ARVE 4	Aircraft Engine Rpr.	4080	2320				
T-ARV H1	Helicopter Repair Ship	13475	[illegible]				
AS 13-14	Submarine Tender	14500					
AS 11-18	"	18000					
AS 19	"	[illegible]					

TABLE 2 - CHARACTERISTICS OF NAVAL VESSELS

CLASS	DESCRIPTION	DISPLACEMENT Δ (L. TONS)	LIGHT SHIP FRONTAL WINDAGE AREA (SQ. FT.)	WIND COEFF. C_w	TOTAL PROJECTED AREA OF ALL PROPELLERS A_p $(FEET)^2$	CURVE FOR HULL RESISTANCE See Fig.(6-12)	CURVE FOR K FACTOR See Fig. (1 - 3)	CURVE FOR SEA STATE R_s See Fig.(4-5)
AS 22	Submarine Tender	15400	4300	0.75	142	26	1	8
AS 23	"	16100	4300	0.75	142	26	1	8
AS 31-32	"	18300	6440	0.75	140	12	1	8
AS 33-34	"	22250	7550	0.75	136	23	1	5
AS 36-37	"	22640	7550	0.75	136	23	1	5
ASR 7-16	"	2290	1200	0.75	50	21	1	2
ASR 12-20	"	1760	1170	0.75	50	8	1	1
ASR 21-22	"	3411	--	0.75	--	--	1	--
ATF 67-162	Fleet Ocean Tug	1675	1200	0.75	43	9	1	2
AV 7-13	Sea Plane Tender	15090	5100	0.75	136	17	1	9
AV 10	"	14200	4500	0.75	142	20	1	8
AVB 2	Advanced Aviation Base	6000	3940	0.75	54	37	1	4
AVM 1	Guided Missile Ship	15170	5300	0.75	136	37	1	3
AVT 9	Electronics Test Ship	38500	8300	0.75	--	10	1	6
AW 4	Distilling Ship	22380	4600	0.75	108	26	1	9
BB 61-64	Battleship	59000	8500	0.70	664	14	3	6
CA 68-130	Heavy Cruiser	17500	5300	0.70	308	7	3	7
CA 122-124	Heavy Cruiser	17500	5300	0.70	308	7	3	7
CA 134-148	"	21470	4500	0.70	324	7	3	7
CC 1	Command Ship	17200	5300	0.70	308	7	3	7
CC 2	"	19600	6000	0.70	300	10	3	7
CG 10-12	Guided Missile Cruiser	17700	6300	0.70	308	6	3	7
CGN 9	"	17350	7900	0.70	312	6	3	7

TABLE 2 - CHARACTERISTICS OF NAVAL VESSELS

CLASS	DESCRIPTION	DISPLACEMENT Δ (L. TONS)	LIGHT SHIP FRONTAL WINDAGE AREA (SQ. FT.)	WIND COEFF. C_w	TOTAL PROJECTED AREA OF ALL PROPELLERS A_p $(FEET)^2$	CURVE FOR HULL RESISTANCE See Fig.(6-12)	CURVE FOR K FACTOR See Fig. (1 - 3)	CURVE FOR SEA STATE R_s See Fig.(4-5)
CL 65-103	Light Cruiser	13755	4300	0.70	256	4	3	5
CL 106	"	14055	4300	0.70	256	4	3	5
CL 144-145	"	18700	5000	0.70	324	7	3	7
CLG 3-8	Guided Missile Lt. Cruiser	14600	4000	0.70	256	7	3	5
CVA 14-34	Attack Aircraft Carrier	42600	8300	0.45	300	27	3	6
CVA 41-43	"	62000	--	0.45	--	27	3	6
CVA 59-62	"	78040	13100	0.45	1028	28	3	6
CVA 63	"	75200	13100	0.45	1028	28	3	6
CVA 64	"	75200	13100	0.45	1028	28	3	6
CVA 66	"	78250	13100	0.45	1028	28	3	6
CVA 67	"	83000	13100	0.45	1028	28	3	6
CVAN	"	85350	16600	0.45	--	27	3	6
CVAN 68-70	"	95100	--	0.45	--	27	3	6
CVS 9-39	ASW Aircraft Carrier	41000	8300	0.45	300	27	3	6
CVT 16	Training Carrier	41000	8300	0.45	300	27	3	6
DD 422-617	Destroyer	2575	1400	0.70	74	3	3	2
DD 423-647	"	2590	1400	0.70	74	3	3	2
DD 445-795	"	3040	1400	0.70	134	35	3	4
DD 692-857	"	3400	1400	0.70	158	35	3	4
DD 710-890	"	3540	1450	0.70	158	35	3	4
DD 712	"	3480	1450	0.70	158	35	3	4
DD 719-824	"	3500	1450	0.70	158	35	3	4

TABLE 2 - CHARACTERISTICS OF NAVAL VESSELS

CLASS	DESCRIPTION	DISPLACEMENT Δ (L. TONS)	LIGHT SHIP FRONTAL WINDAGE AREA (SQ. FT.)	WIND COEFF. C_w	TOTAL PROJECTED AREA OF ALL PROPELLERS A_p $(FEET)^2$	CURVE FOR HULL RESISTANCE See Fig.(6-13)	CURVE FOR K FACTOR See Fig. (1 - 3)	CURVE FOR SEA STATE R_s See Fig.(4-5)
DD 825-827	Destroyer	3410	1450	0.70	158	35	3	4
DD 931-951	"	4200	2100	0.70	194	3	3	4
DD 963-967	"	7000	--	0.70	254	32	3	4
DDG 2-24	Guided Missile Destroyer	4500	2256	0.70	176	31	3	8
DDG 31-34	"	4200	2100	0.70	194	35	3	4
DDG 35-36	"	4730	2800	0.70	222	30	3	8
DE 129-399	Escort Ship	1990	1400	0.70	52	35	3	4
DE 162-767	"	2230	1200	0.70	52	35	3	4
DE 202-800	"	2230	1200	0.70	52	35	3	4
DE 224-708	"	2230	1200	0.70	52	35	3	4
DE 339-538	"	2100	1200	0.70	52	1	3	4
DE 1006-1037	"	1914	1342	0.70	79	1	3	4
DE 1033-1036	"	1750	1340	0.70	--	1	3	4
DE 1037-1038	"	2650	--	0.70	--	1	3	4
DE 1040-1051	"	3400	1715	0.70	131	2	3	4
DE 1052-1097	"	4100	2020	0.70	131	30	3	4
DEG 1-6	Guided Missile Escorts	3600	1715	0.70	131	2	3	4
DER 147-400	Radar Picket Escorts	1850	1400	0.70	52	1	3	2
DER 539-540	"	2100	1400	0.70	52	1	3	2
DL1	Frigate	7300	2600	0.70	--	36	3	3
DL 4-5	"	4730	2800	0.70	222	30	3	3
DLG 6-15	Guided Missile Frigate	5800	--	0.70	--	32	3	3
DLG 16-24	"	7800	--	0.70	--	4	3	3

TABLE 2 - CHARACTERISTICS OF NAVAL VESSELS

CLASS	DESCRIPTION	DISPLACEMENT Δ (L. TONS)	LIGHT SHIP FRONTAL WINDAGE AREA (SQ. FT.)	WIND COEFF. C_w	TOTAL PROJECTED AREA OF ALL PROPELLERS A_p $(FEET)^2$	CURVE FOR HULL RESISTANCE See Fig.(6-13)	CURVE FOR K FACTOR See Fig. (1 - 3)	CURVE FOR SEA STATE R_s See Fig.(4-5)
DLG 26-34	Guided Missile Frigate	7930	3675	0.70	296	34	3	3
DLGN 25	"	8580	3040	0.70	--	5	3	3
DLGN 35	"	9200	2960	0.70	--	5	3	3
DLGN 36-37	"	10150	--	--	--	--	--	--
DLGN 38-41	"	10000	--	--	--	--	--	--
IX 21	Sail Frigate	2200	--	--	--	--	--	--
IX 304	Experimental Target	13755	4300	0.70	--	7	3	5
LCC 7-17	Amphibious Command	12560	4300	0.70	97	26	3	8
LCC 19-20	"	17100	--	0.70	--	38	3	3
LHA 1-3	Amphibious Assault Ship	40000	8800	0.70	262	25	3	6
LKA 19-97	Amphibious Cargo Ship	14000	4300	0.75	113	26	1	8
LKA 103-108	"	14160	4300	0.75	113	26	1	8
LKA 112	"	15970	4900	0.75	--	12	1	9
LKA 113	"	20700	--	0.75	--	--	--	--
LPA 33-44	Amphibious Transport	15200	5400	0.75	143	13	1	8
LPA 194-237	"	10470	4100	0.75	119	13	1	8
LPA 248-249	"	16840	4900	0.75	--	14	1	9
LPD 1-3	Amphibious Dock	13500	6050	0.75	--	12	1	9
LPD 4-15	"	16900	6050	0.75	--	16	1	9
LPH 2-12	Amphibious Assault Ship	18300	--	0.75	--	39	1	9
LPH 4-8	"	40600	8300	0.75	300	28	1	6
LPR 55-135	Amphibious Trans. Small	2130	1400	0.75	52	1	1	2
LPSS 315	Amphibious Trans. Sub.	2045	450	0.75	--	30	1	2

TABLE 2 - CHARACTERISTICS OF NAVAL VESSELS

CLASS	DESCRIPTION	DISPLACEMENT Δ (L. TONS)	LIGHT SHIP FRONTAL WINDAGE AREA (SQ. FT.)	WIND COEFF. C_w	TOTAL PROJECTED AREA OF ALL PROPELLERS A_p (FEET)^2	CURVE FOR HULL RESISTANCE See Fig.(6-13)	CURVE FOR K FACTOR See Fig. (1 - 3)	CURVE FOR SEA STATE R_s See Fig.(4-5)
LPSS 574	Amphibious Trans. Sub.	2670	--	0.75	--	--	1	--
LSD 1-7	Dock Landing Ship	8700	4100	0.75	64	19	1	8
LSD 13-27	"	9375	--	0.75	64	19	1	8
LSD 28-35	"	11270	5695	0.75	174	19	1	9
LSD 36-40	"	13650	5700	0.75	--	19	1	6
T-LST 47-1088	Tank Landing Ship	4080	2000	0.75	30	37	1	2
LST 334-509	"	4080	2000	0.75	30	37	1	2
LST 515-1150	"	4080	2000	0.75	30	37	1	2
LST 1153	"	6000	3940	0.75	54	37	1	4
LST 1156-1170	"	5800	3940	0.75	54	37	1	4
LST 1171-1178	"	8000	3400	0.75	82	37	1	8
LST 1179-1198	"	8342	--	0.75	108.14	18	1	9
MCS 1-2	Mine Counter Measures	9040	4230	0.75	76	16	1	8
MHC 43	Coastal Mine Hunter	--	--	0.75	--	--	1	1
MMD 23-33	Fast Minelayers	3320	1400	0.75	158	35	1	4
MMF 5	Fleet Minelayer	8680	--	0.75	76	11	1	8
MSO 421-496	Ocean Minesweeper	750	--	0.75	40.28	8	1	1

TABLE 3 - BEAUFORT SCALE

SEA STATE	SEA DESCRIPTION	WIND: WIND FORCE (BEAUFORT)	WIND: DESCRIPTION	WIND: RANGE (KNOTS)	WIND: WIND VELOCITY (KNOTS)	WAVE HEIGHT (FEET): AVERAGE	WAVE HEIGHT (FEET): SIGNIFICANT	WAVE HEIGHT (FEET): AVERAGE 1/10 HIGHEST
	SEA LIKE A MIRROR	0	CALM	<1	**0****	0	0	0
0	RIPPLES WITH THE APPEARANCE OF SCALES ARE FORMED, BUT WITHOUT FOAM CRESTS	1	LIGHT AIRS	1-3	**2**	0.05	0.08	0.10
1	SMALL WAVELETS, STILL SHORT BUT MORE PRONOUNCED. CRESTS HAVE A GLASSY APPEARANCE BUT DO NOT BREAK	2	LIGHT BREEZE	4-6	**5**	0.18	0.29	0.37
	LARGE WAVELETS. CRESTS BEGIN TO BREAK. FOAM OF GLASSY APPEARANCE. PERHAPS SCATTERED WHITE HORSES	3	GENTLE BREEZE	7-10	**8.5**	0.6	1.0	1.2
					10	0.88	1.4	1.8
2	SMALL WAVES, BECOMING LARGER, FAIRLY FREQUENT WHITE HORSES	4	MODERATE BREEZE	11-16	12	1.4	2.2	2.8
					13.5	1.8	2.9	3.7
3					14	2.0	3.3	4.2
					16	2.9	4.6	5.8
4	MODERATE WAVES, TAKING A MORE PRONOUNCED LONG FORM. MANY WHITE HORSES ARE FORMED. (CHANCE OF SOME SPRAY)	5	FRESH BREEZE	17-21	18	3.8	6.1	7.8
					19	4.3	6.9	8.7
					20	5.0	8.0	10
5	LARGE WAVES BEGIN TO FORM. THE WHITE FOAM CRESTS ARE MORE EXTENSIVE EVERYWHERE. (PROBABLY SOME SPRAY)	6	STRONG BREEZE	22-27	22	6.4	10	13
					24	7.9	12	16
					24.5	8.2	13	17
6					26	9.6	15	20
	SEA HEAPS UP AND WHITE FOAM FROM BREAKING WAVES BEGINS TO BE BLOWN IN STREAKS ALONG THE DIRECTION OF THE WIND. (SPINDRIFT BEGINS TO BE SEEN)	7	MODERATE GALE	28-33	28	11	18	23
					30	14	22	28
					30.5	14	23	29
					32	16	26	33
7	MODERATELY HIGH WAVES OF GREATER LENGTH. EDGES OF CRESTS BREAK INTO SPINDRIFT. THE FOAM IS BLOWN IN WELL MARKED STREAKS ALONG THE DIRECTION OF THE WIND. SPRAY AFFECTS VISIBILITY	8	FRESH GALE	34-40	34	19	30	38
					36	21	35	44
					37	23	37	46.7
					38	25	40	50
					40	28	45	58
8	HIGH WAVES. DENSE STREAKS OF FOAM ALONG THE DIRECTION OF THE WIND. SEA BEGINS TO ROLL. VISIBILITY AFFECTED	9	STRONG GALE	41-47	42	31	50	64
					44	36	58	73
					46	40	64	81
	VERY HIGH WAVES WITH LONG OVERHANGING CRESTS. THE RESULTING FOAM IS IN GREAT PATCHES AND IS BLOWN IN DENSE WHITE STREAKS ALONG THE DIRECTION OF THE WIND. ON THE WHOLE THE SURFACE OF THE SEA TAKES A WHITE APPEARANCE. THE ROLLING OF THE SEA BECOMES HEAVY AND SHOCKLIKE. VISIBILITY IS AFFECTED	10	WHOLE GALE *	48-55	48	44	71	90
					50	49	78	99
					51.5	52	83	106
					52	54	87	110
					54	59	95	121
9	EXCEPTIONALLY HIGH WAVES (SMALL AND MEDIUM-SIZED SHIPS MIGHT FOR A LONG TIME BE LOST TO VIEW BEHIND THE WAVES.) THE SEA IS COMPLETELY COVERED WITH LONG WHITE PATCHES OF FOAM LYING ALONG THE DIRECTION OF THE WIND. EVERYWHERE THE EDGES OF THE WAVE CRESTS ARE BLOWN INTO FROTH. VISIBILITY AFFECTED	11	STORM *	56-63	56	64	103	130
					59.5	73	116	148
	AIR FILLED WITH FOAM AND SPRAY. SEA COMPLETELY WHITE WITH DRIVING SPRAY. VISIBILITY VERY SERIOUSLY AFFECTED	12	HURRICANE *	64-71	>64	>80**	>128**	>164**

* FOR HURRICANE WINDS (AND OFTEN WHOLE GALE AND STORM WINDS) REQUIRED DURATIONS AND FETCHES ARE RARELY ATTAINED. SEAS ARE THEREFORE NOT FULLY ARISEN.

** A HEAVY BOX AROUND THIS VALUE MEANS THAT THE VALUES TABULATED ARE AT THE CENTER OF THE BEAUFORT RANGE.

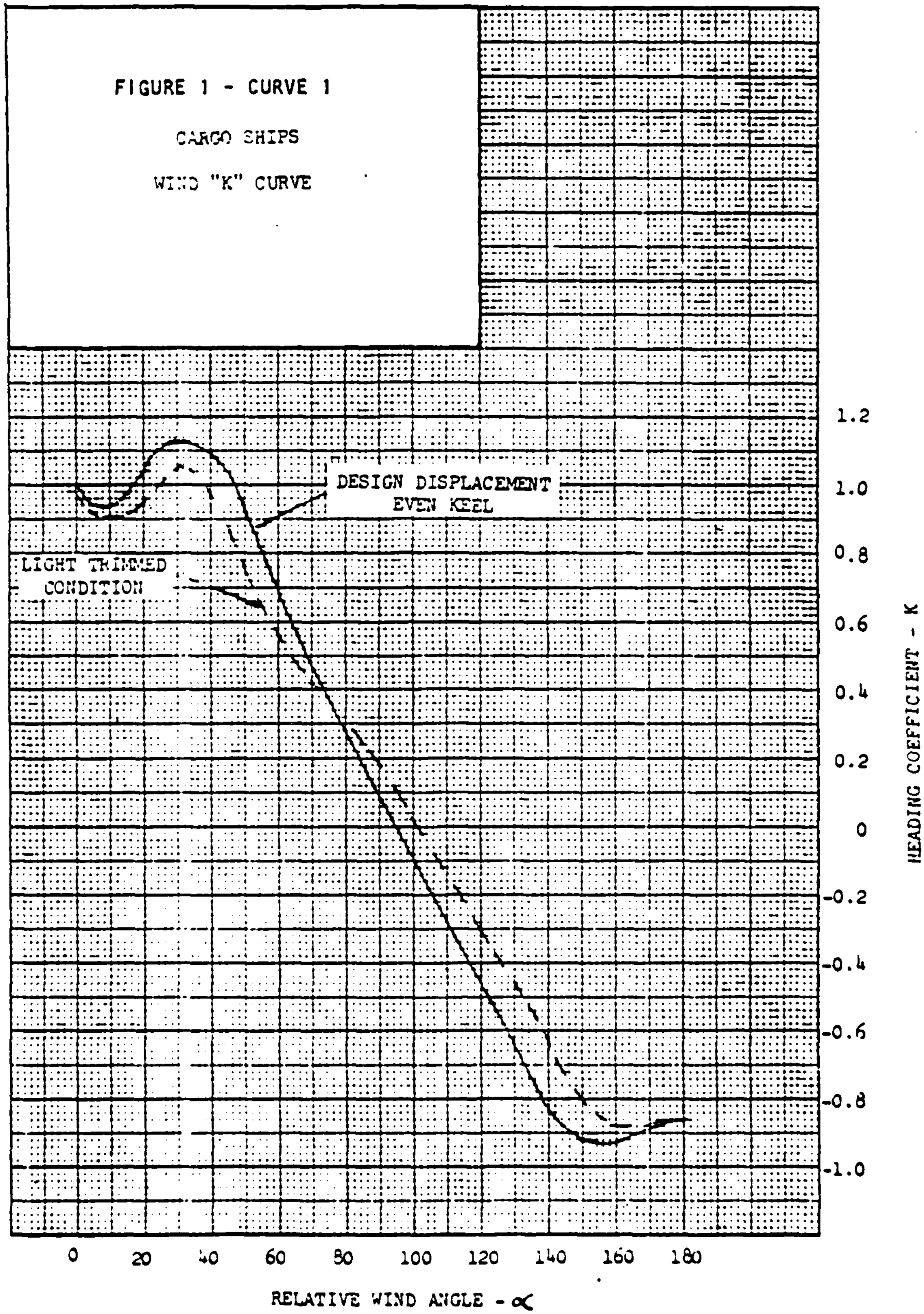
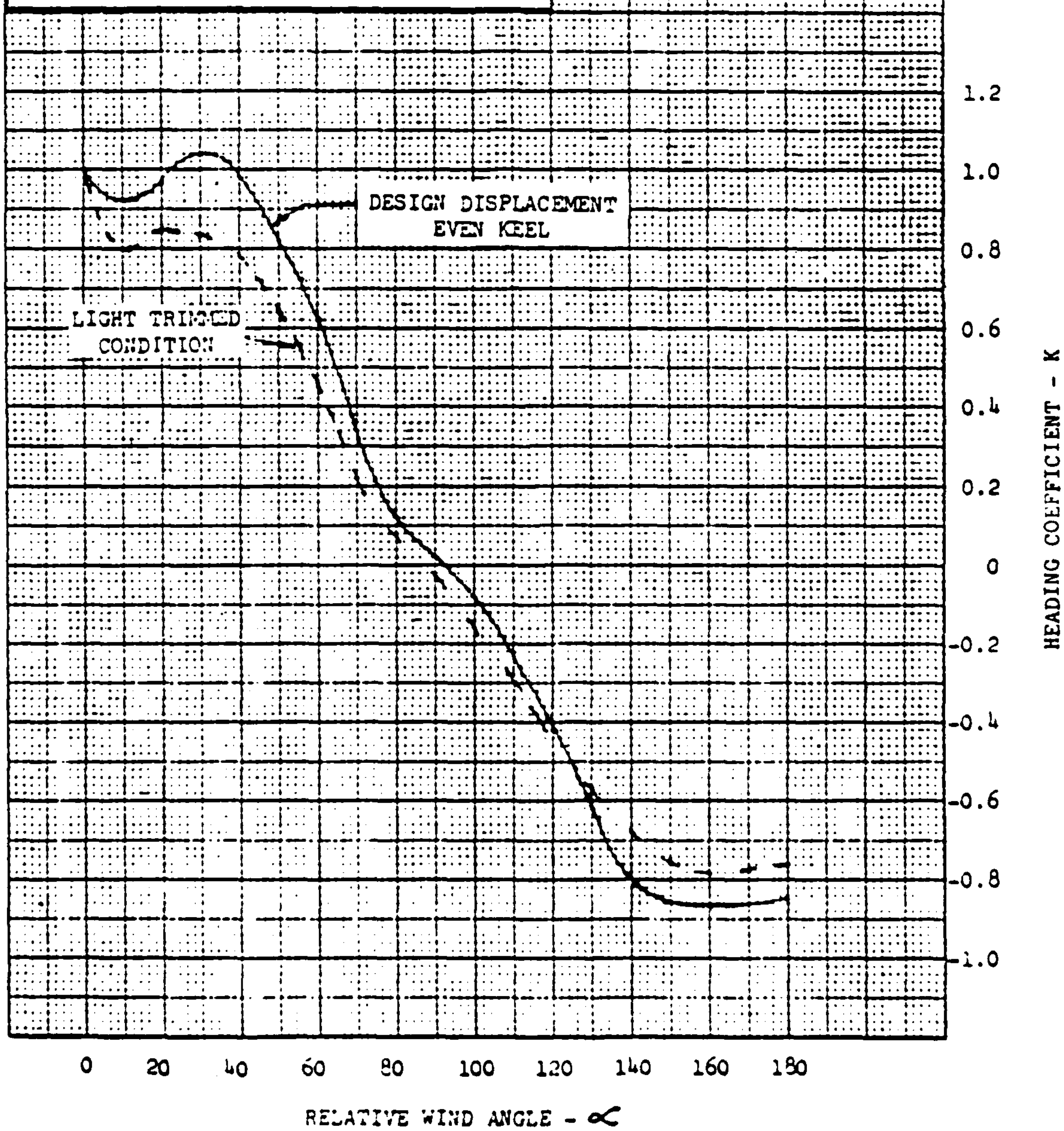


FIGURE 1 - CURVE 1
CARGO SHIPS
WIND "K" CURVE
DESIGN DISPLACEMENT
EVEN KEEL
LIGHT TRIMMED
CONDITION
1.2
1.0
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1.0
HEADING COEFFICIENT - K
0
20
40
60
80
100
120
140
160
180
RELATIVE WIND ANGLE - α

FIGURE 2 - CURVE 2

TANKERS

WIND "K" CURVES



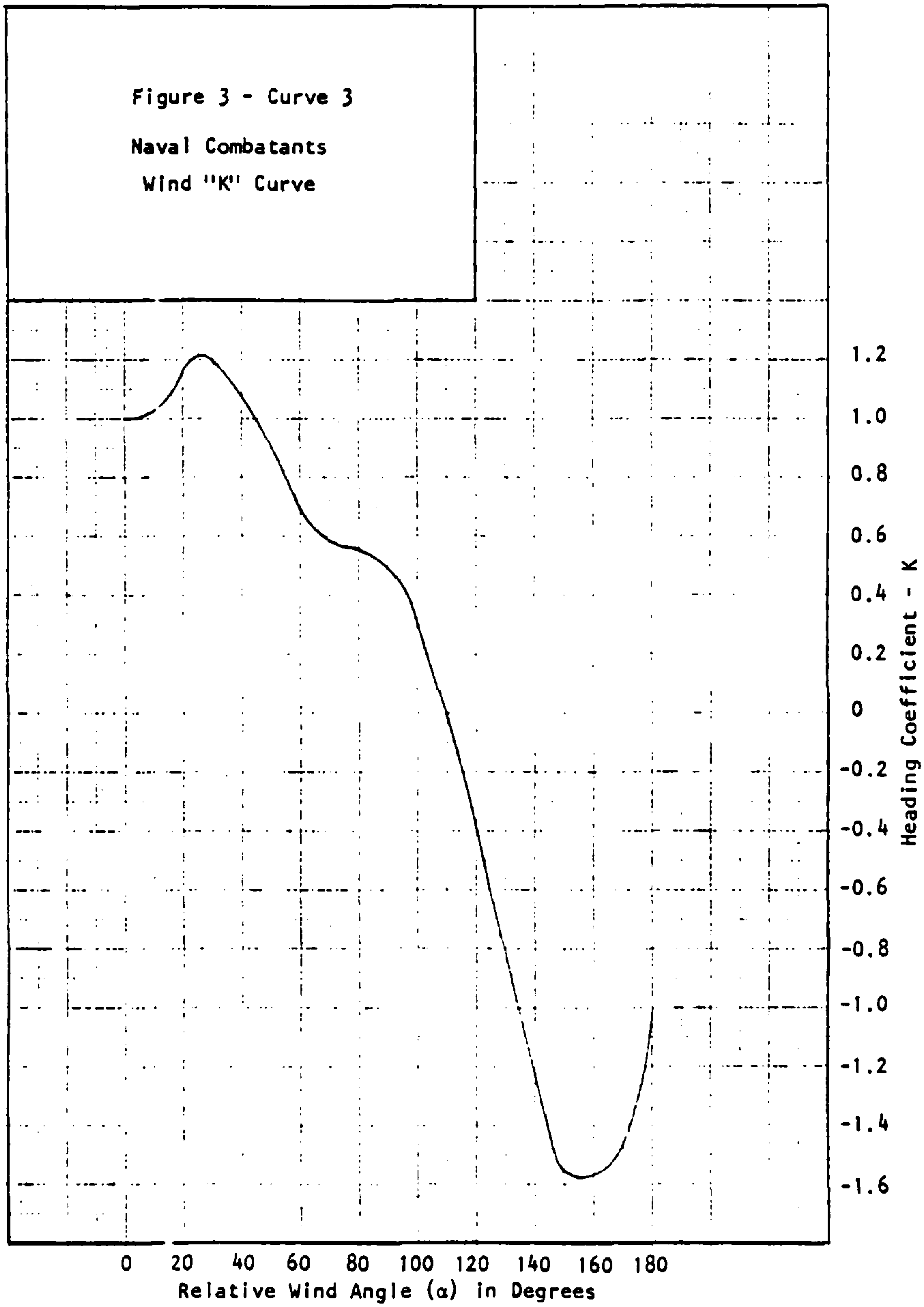


Figure 3 - Curve 3
Naval Combatants
Wind "K" Curve
1.2
1.0
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1.0
-1.2
-1.4
-1.6
Heading Coefficient - K
0
20
40
60
80
100
120
140
160
180
Relative Wind Angle (α) in Degrees

FIGURE 4. R_s VERSUS BEAUFORT NUMBER

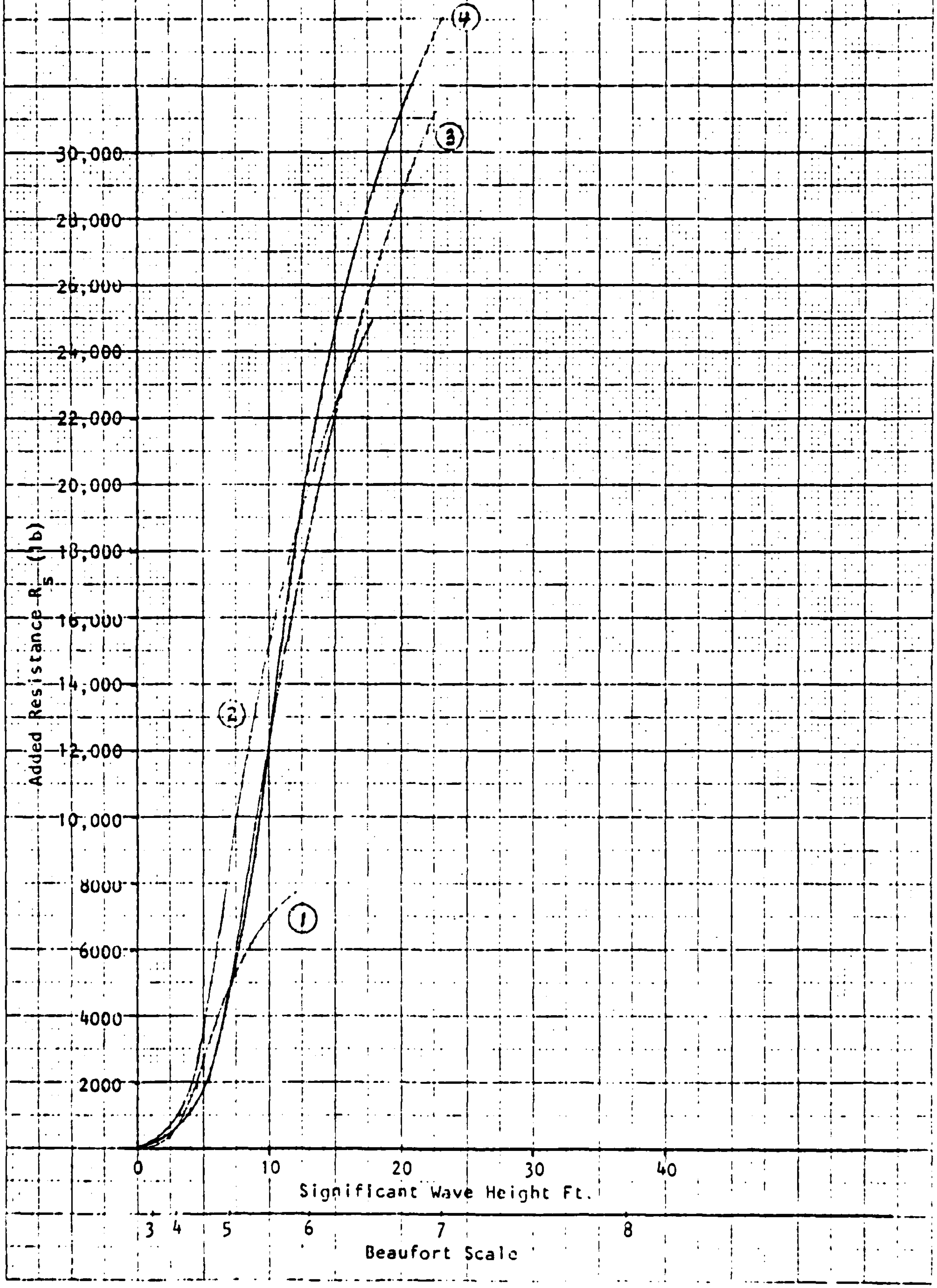


FIGURE 5. R_s VERSUS BEAUFORT NUMBER

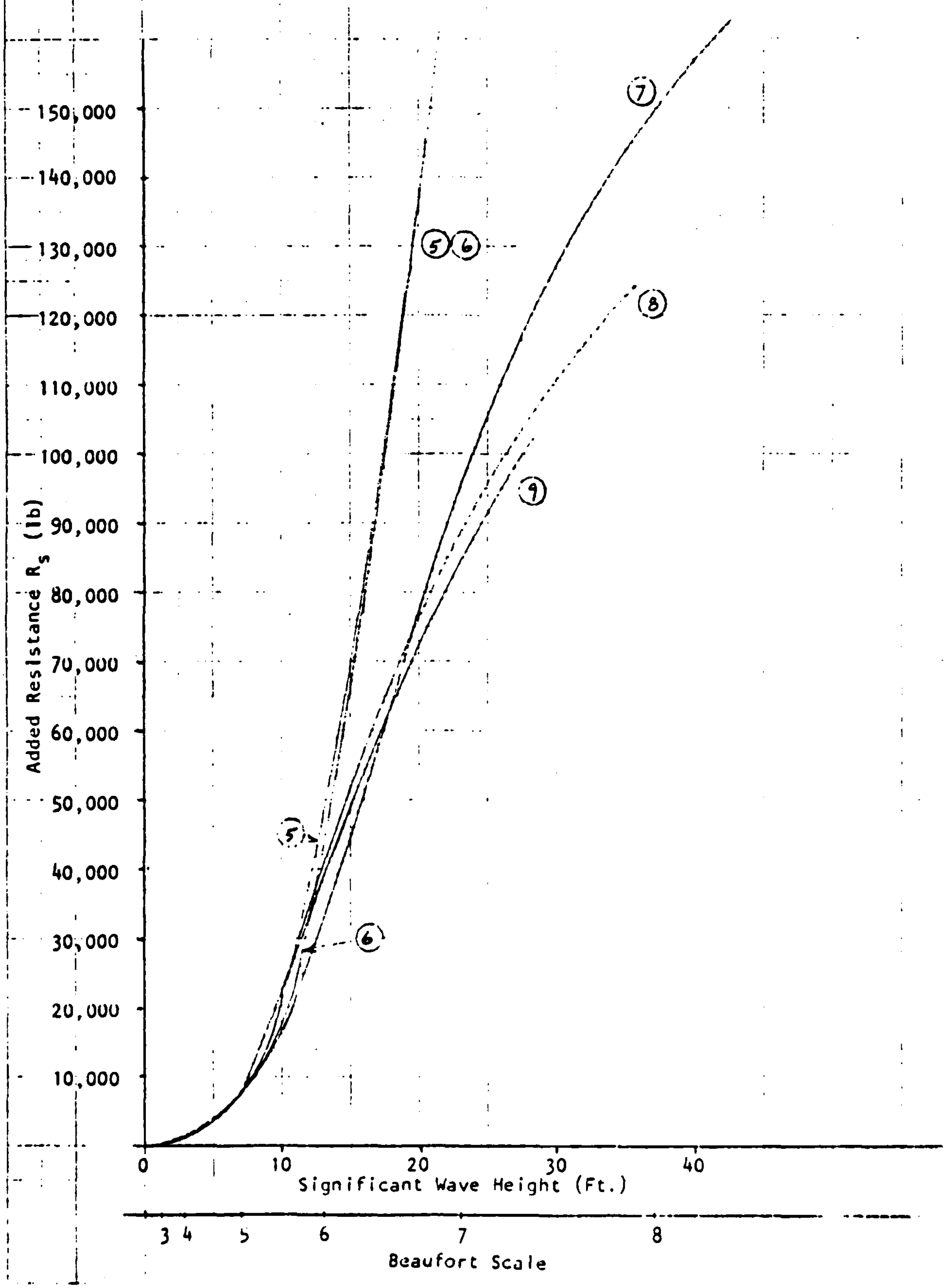


FIGURE 6

$R_{H/\Delta}$ VERSUS TOW SPEED

(Curves 1 through 3)

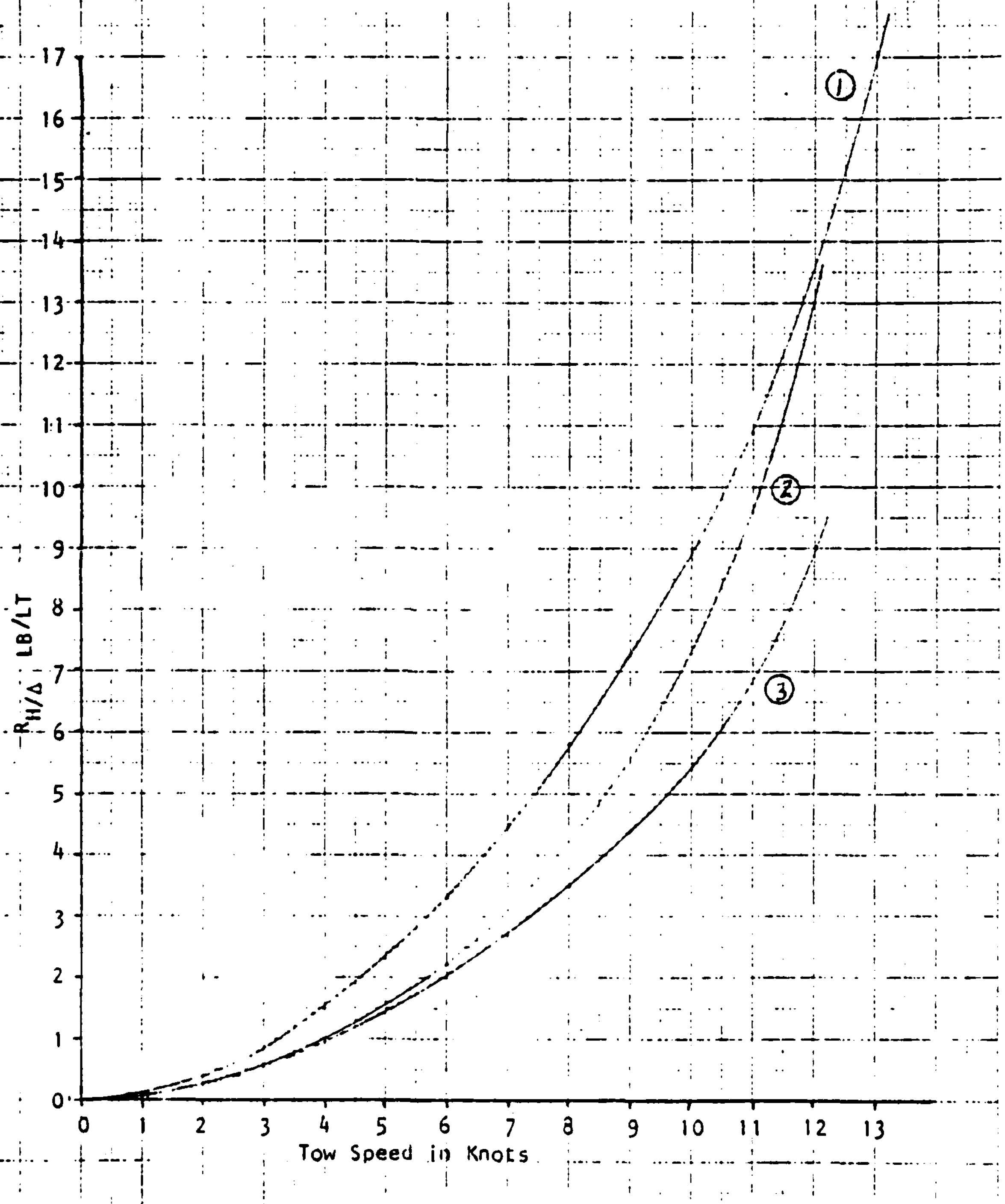


FIGURE 7.

$R_{H/\Delta}$ VERSUS TOW SPEED

(Curves 4 through 7)

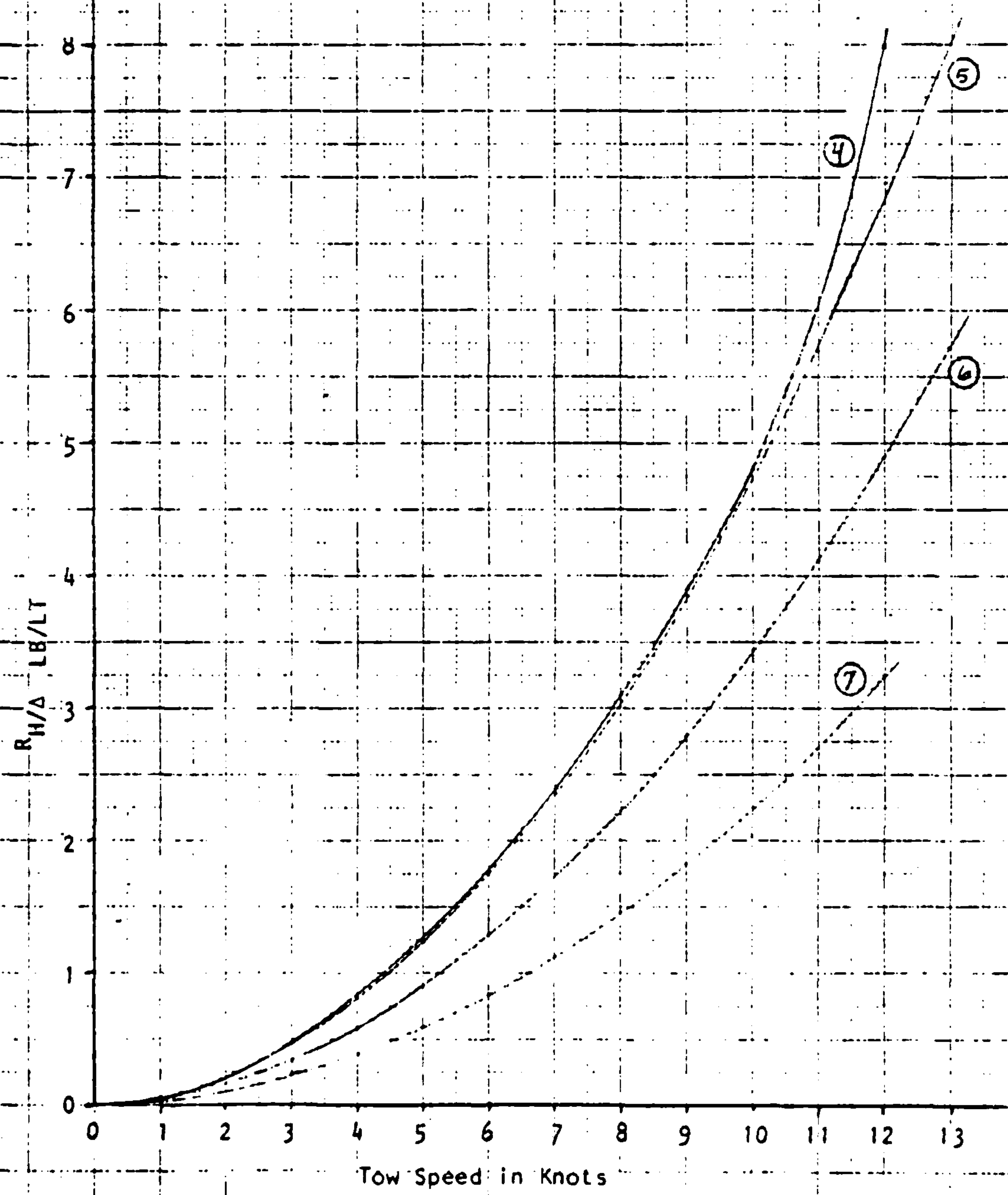


FIGURE 8.

$R_{H/\Delta}$ VERSUS TOW SPEED

(Curves 8 through 13)

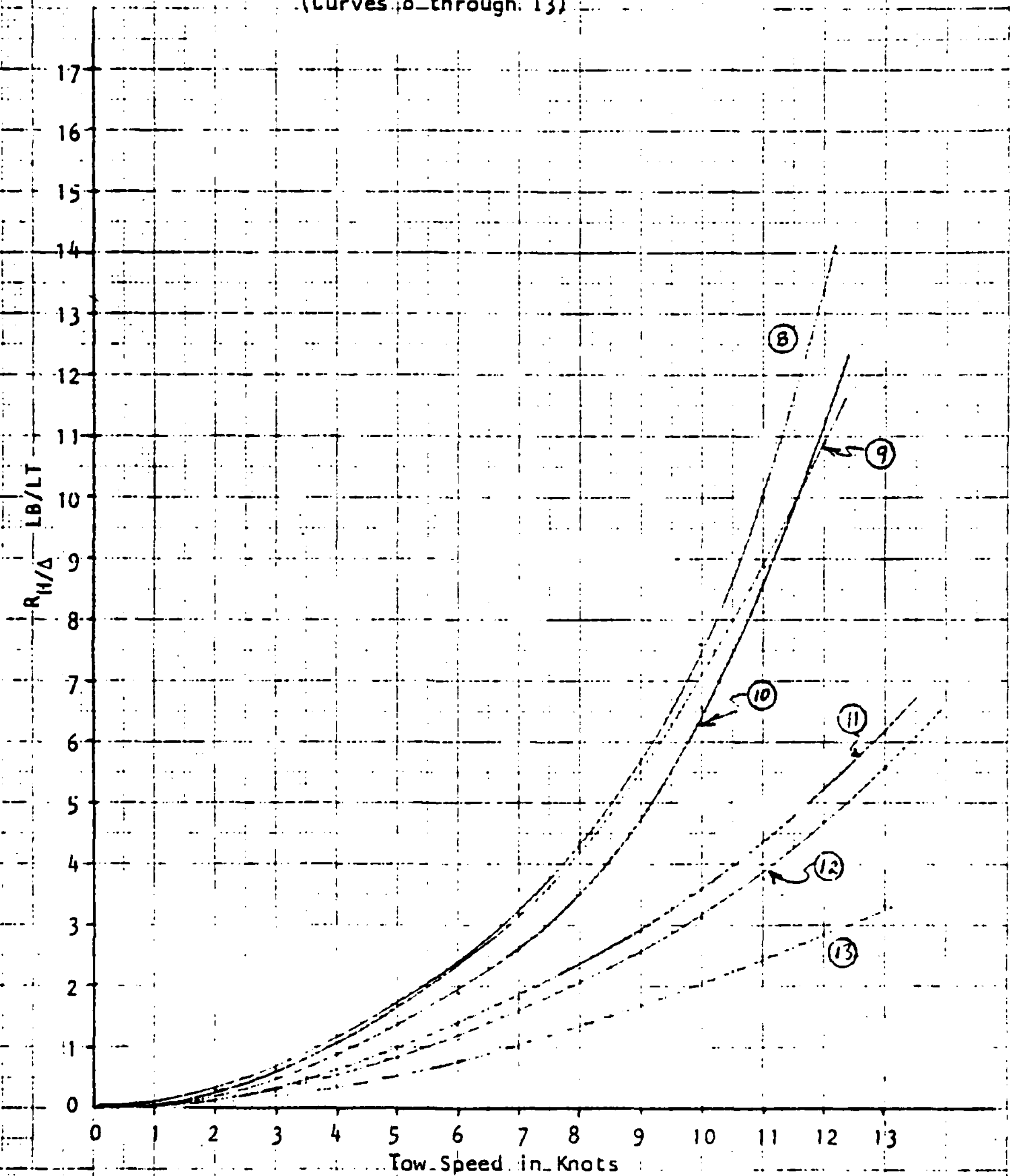


FIGURE 9.

$R_{H/\Delta}$ VERSUS TOW SPEED

(Curves 14 through 19)

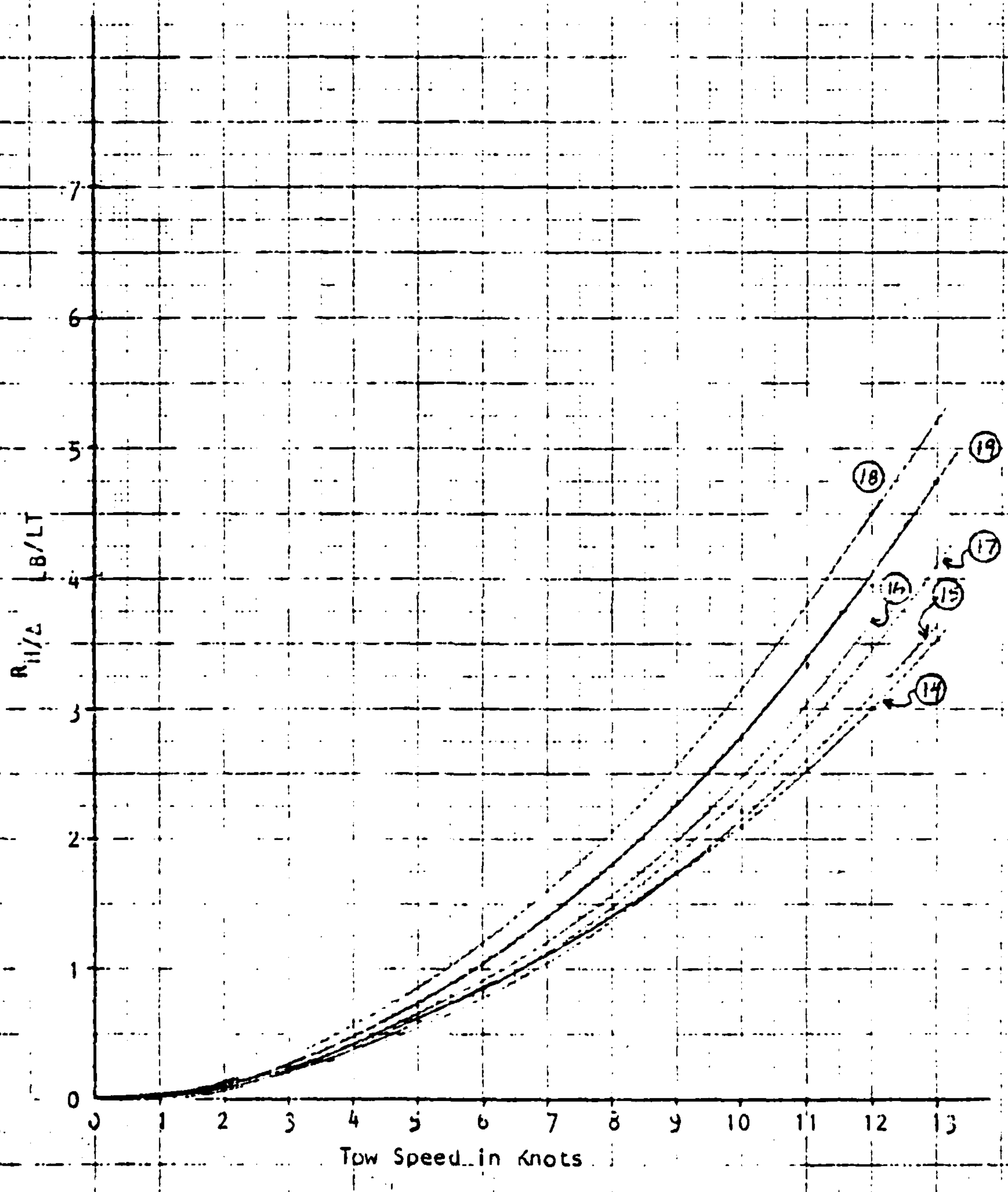


FIGURE 10.

$R_{H/\Delta}$ VERSUS TOW SPEED

(Curves 20 through 23)

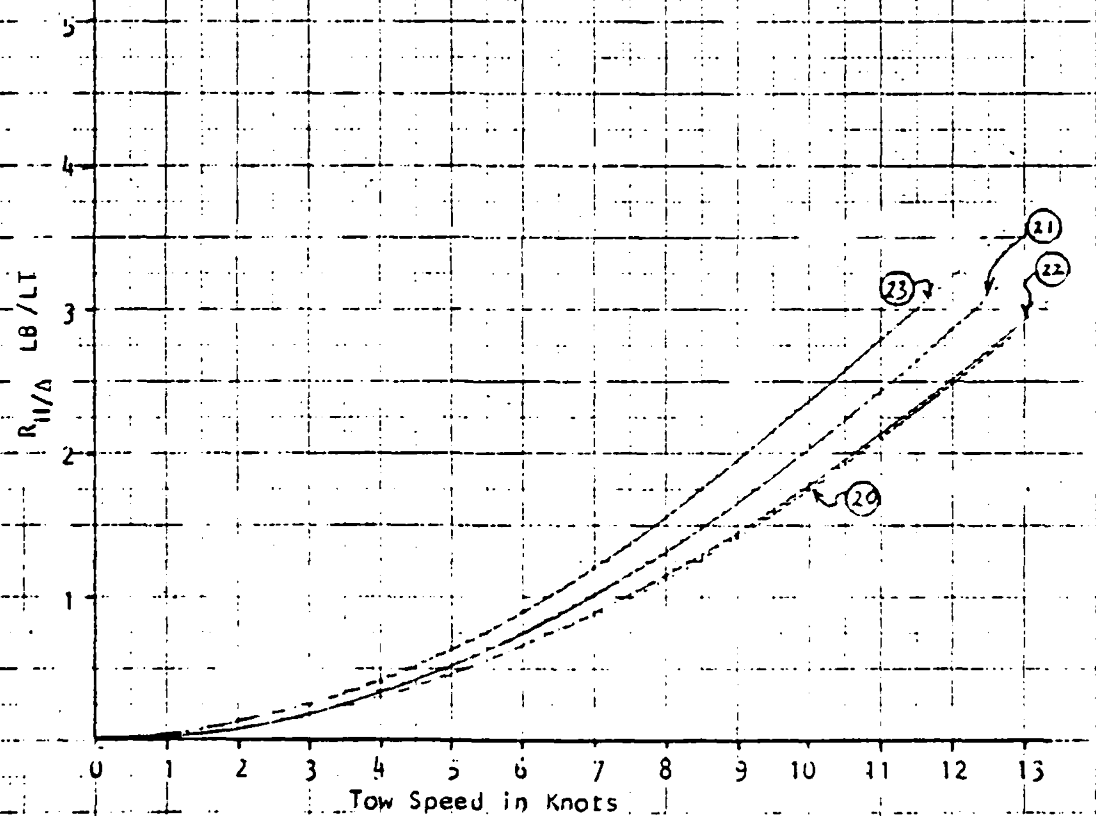
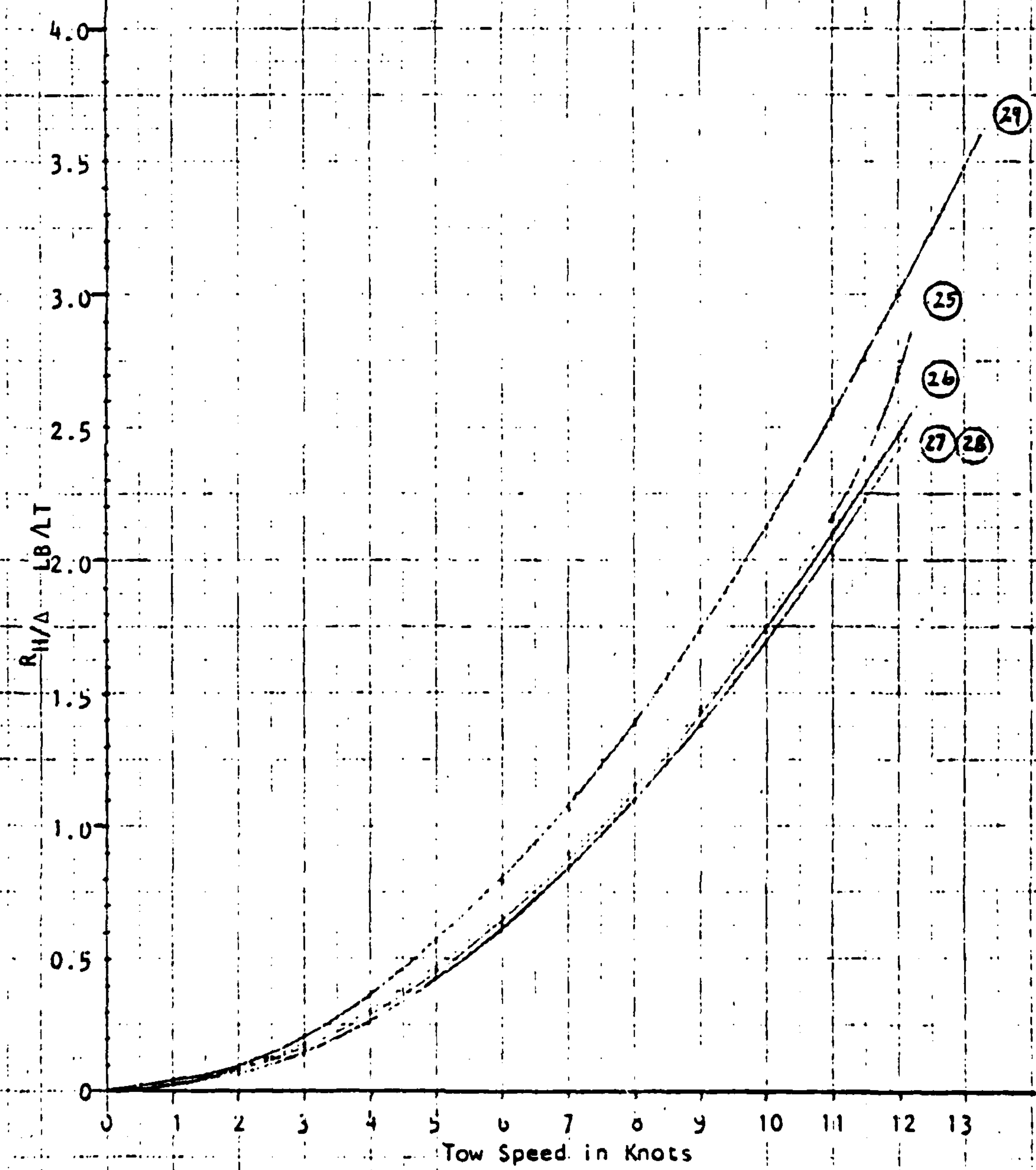


FIGURE 11

$R_{H/\Delta}$ VERSUS TOW SPEED

(Curves 24 through 28)



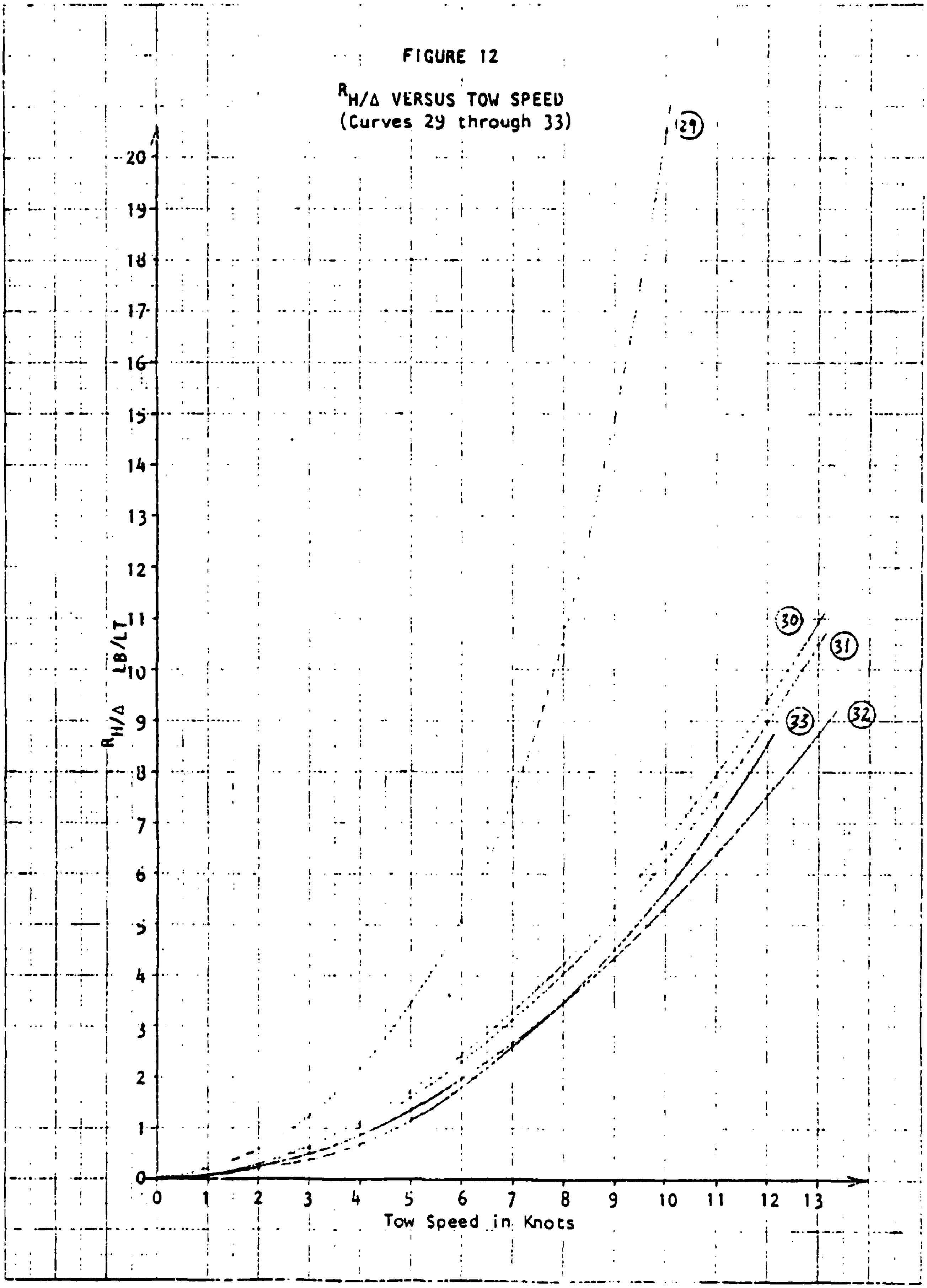


FIGURE 12
$R_{H/\Delta}$ VERSUS TOW SPEED
(Curves 29 through 33)
$R_{H/\Delta}$ LB/LT
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
Tow Speed in Knots
29
30
31
32
33
K&E 10 X 10 TO THE CENTIMETER 46 1512
KEUFFEL & ESSER CO

FIGURE 12

$R_{H/\Delta}$ VERSUS TOW SPEED
(Curves 29 through 33)

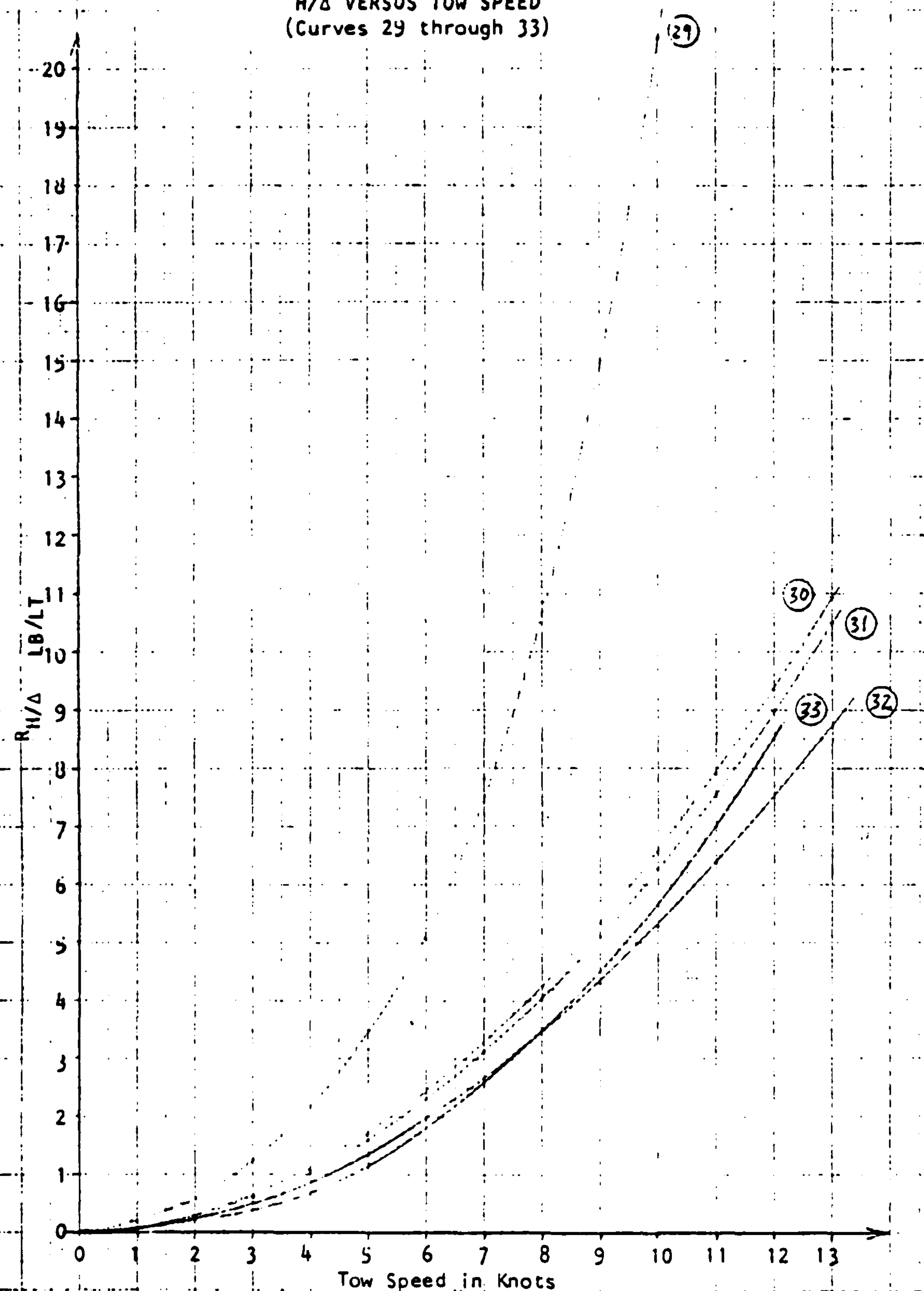
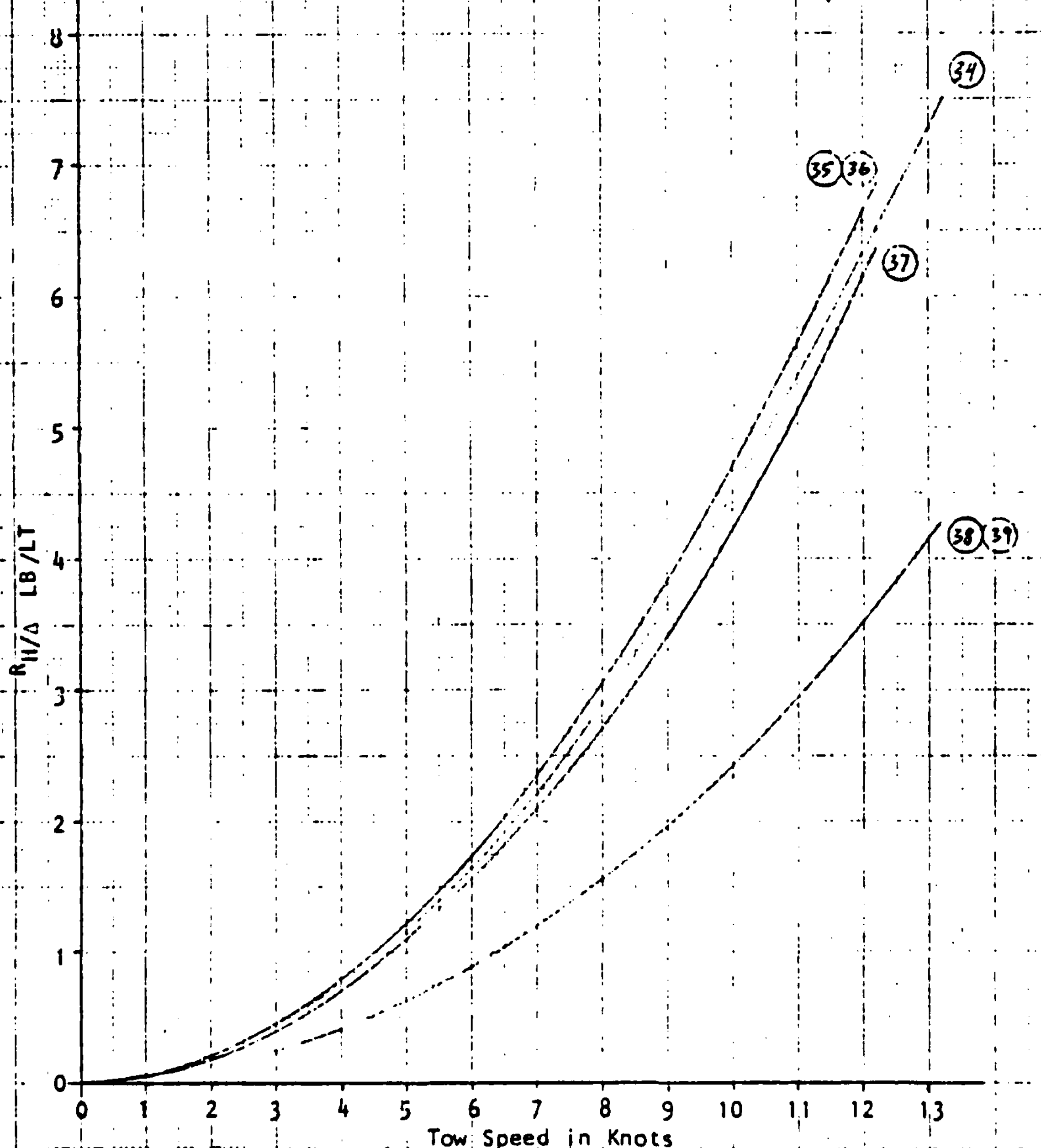


FIGURE 13

$R_{H/\Delta}$ VERSUS TOW SPEED

(Curves 34 through 39)



... conducted in ...cedure for tow resista... ...t to the U.S. Navy calculation... The study is conducted in two steps. In ...e performed using both the U.S. Navy method and t... MR&S for eight ships for which complete data exists. ... each method is separated into the four resistance compon... sea state and wind resistance. Three Beaufort numbers and ... were examined for each of three tow speeds. The resulting da... in Table 8-1.

The second part of the study compares the actual towline tens... measured in full scale tests with the resistance obtained for the U.S... and MR&S calculation procedures. Several towing tests have been conduc... but documentation of these tests is sufficient to permit correlation for ... only the LST 1179 class. As more data becomes available, it would be beneficial to extend this part of the correlation study.

8.2 Results of Correlation Study

8.2.1 Part I Comparison of MR&S and U.S. Navy Methods of Calculation

A comparison of the MR&S and U.S. Navy calculations is done for each component of resistance as shown in Table 8-1.

The differences in hull resistance are quite large, sometimes varying by a factor of three. The effect of this difference on the total tow resistance can be seen by comparing the total resistance

Table 8-1 CORRELATION STUDY COMPARING THE RESULTS FROM MR&S METHOD WITH THE CURRENT U.S. NAVY TOWING MANUAL

SHIP CLASS	TOW SPEED KT.	REL. WIND SPEED KT.	REL. WIND DIRECT & DEG.	BEAU-FORT NO.	HULL RESISTANCE LB.		PROPELLER RESISTANCE LB.		SEA STATE RESISTANCE LB.		WIND RESISTANCE LB.		TOTAL RESISTANCE LB.		% DIFF. TOT. RESIS LB.
					USN	MR&S	USN	MR&S	USN	MR&S	USN	MR&S	USN	MR&S	
AFT-148 OCEAN TUG	10	10.0	0	0	1821	14866	14594	16069	0	0	360	455	16775	31390	47%
	8	21.5	0	4	1213	7035	9340	10284	4221	900	1080	2105	15854	20324	22
	8	19.82	30	4	"	"	"	"	"	"	840	2022	15614	20241	23
	8	10.87	90	4	"	"	"	"	"	"	0	54	14774	18273	20
	5	29.5	0	6	-2309	3664	3649	4017	-	23500	2848	3963	-	35144	-
	5	28.7	30	6	-	"	-	"	-	"	-	4239	-	35419	-
	5	23.98	90	6	-	"	-	"	-	"	-	262	-	31443	-
AOR-1 OILER	10	10.0	0	0	40354	66675	92996	102394	0	0	2277	3841	135627	172910	22
	8	21.5	0	4	24303	53340	59517	65532	33528	1300	6831	17753	124179	136625	9
	8	19.82	30	4	"	"	"	"	"	"	3795	15690	12143	135862	9
	8	10.87	90	4	"	"	"	"	"	"	0	4538	117348	124710	6
	5	29.5	0	6	3421	21908	23249	25598	16002	47500	12903	33422	55572	128428	57
	5	28.7	30	6	"	"	"	"	"	"	8349	32900	51021	127906	60
	5	73.98	90	6	"	"	"	"	"	"	0	442	42672	95447	55
AOE-1 FAST COMBAT SUPPORT	10	10.0	0	0	32834	118590	154766	170407	0	0	2925	3700	190525	292697	35
	8	21.5	0	4	18870	77050	99050	109061	47168	1300	7800	17103	172888	204514	15
	8	19.82	30	4	"	"	"	"	"	"	4875	16425	169963	203836	17
	8	10.87	90	4	"	"	"	"	"	"	0	393	165088	187804	12
	5	29.5	0	6	4188	77050	38692	42602	25728	44000	16575	32200	85183	195852	56
	5	28.7	30	6	"	"	"	"	"	"	9750	34440	78358	198092	60
	5	23.98	90	6	"	"	"	"	"	"	0	1915	68608	165567	58

Table 8-1 (Cont'd) CORRELATION STUDY COMPARING THE RESULTS FROM MR&S METHOD WITH THE CURRENT U.S. NAVY TOWING MANUAL

SHIP CLASS	TOW SPEED KT.	REL. WIND SPEED KT.	REL. WIND DIRECT & DEG.	BEAUFORT NO.	HULL RESISTANCE LB.		PROPELLER RESISTANCE LB.		SEA STATE RESISTANCE LB.		WIND RESISTANCE LB.		TOTAL RESISTANCE LB.		% DIFF. TOT. RESIS LB.
					USN	MR&S	USN	MR&S	USN	MR&S	USN	MR&S	USN	MR&S	
	10	10.0	0	0	25817	31237	44461	48955	0	0	1715	607	71993	80799	11%
	8	21.5	0	4	14045	17850	28455	31331	17000	600	2573	2808	62073	52589	-18
FF 140	8	19.82	30	4	"	"	"	"	"	"	2058	2863	61558	52644	-17
ESCORT	8	10.87	90	4	"	"	"	"	"	"	0	3445	59500	50126	-19
	5	29.5	0	6	5205	6630	11115	12238	9792	20800	4116	5286	30228	44954	33
	5	28.7	30	6	"	"	"	"	"	"	3430	6004	29542	45672	35
	5	23.98	90	6	"	"	"	"	"	"	0	1677	26112	41344	37
	10	10.0	0	0	19824	61031	35976	39612	0	0	1322	1672	57122	102315	44
	8	21.5	0	4	12625	39719	23025	25352	14260	1500	3965	7727	53875	74298	27
AF 58	8	19.82	30	4	"	"	"	"	"	"	2203	7421	52113	73992	30
STORES	8	10.87	90	4	"	"	"	"	"	"	0	1580	49910	68151	27
SHIP	5	29.5	0	6	1856	16081	8994	9903	6510	41000	7489	14548	24849	81532	70
	5	28.7	30	6	"	"	"	"	"	"	4846	15560	22206	82544	73
	5	23.98	90	6	"	"	"	"	"	"	0	7690	17360	74674	77
	10	10.0	0	0	72529	59848	109966	121079	0	0	4500	1594	186995	182521	- 2
	8	21.5	0	4	47708	30058	70377	77490	47234	1300	6750	7368	172069	116216	-48
CA 139	8	19.82	30	4	"	"	"	"	"	"	5400	7514	170719	116362	-47
HEAVY	8	10.87	90	4	"	"	"	"	"	"	0	904	165319	109752	-50
CRUISER	5	29.5	0	6	17596	15566	27491	30270	27052	32500	10800	13871	82939	92207	10
	5	28.7	30	6	"	"	"	"	"	"	9000	15755	81139	94091	14
	5	23.98	90	6	"	"	"	"	"	"	0	4399	72139	82735	13

Table 8-1 (Cont'd) CORRELATION STUDY COMPARING THE RESULTS FROM MR&S METHOD WITH THE CURRENT U.S. NAVY TOWING MANUAL

SHIP CLASS	TOW SPEED KT.	REL. WIND SPEED KT.	REL. WIND DIRECT & DEG.	BEAU-FORT NO.	HULL RESISTANCE LB.		PROPELLER RESISTANCE LB.		SEA STATE RESISTANCE LB.		WIND RESISTANCE LB.		TOTAL RESISTANCE LB.		% DIFF. TOT. RESIS LB.
					USN	MR&S	USN	MR&S	USN	MR&S	USN	MR&S	USN	MR&S	
	10	10.0	0	0	45883	32951	36703	40412	0	0	1970	1396	84556	74759	-13%
	8	21.5	0	4	29065	22002	23490	25864	21021	1300	5122	6451	78698	55617	-41
LST-1179	8	19.82	30	4	"	"	"	"	"	"	3940	6579	81918	55745	-47
TANK	8	10.87	90	4	"	"	"	"	"	"	0	791	73576	49957	-47
LANDING	5	29.5	0	6	11679	9064	9176	10103	12513	38500	9850	12145	43218	69812	38
SHIP	5	28.7	30	6	"	"	"	"	"	"	7880	13794	41248	71461	42
	5	23.98	90	6	"	"	"	"	"	"	0	3852	33368	61519	45
	10	10.0	0	0	96368	50944	80981	89165	0	0	1520	1077	178869	141186	-27
	8	21.5	0	4	55422	32497	51828	57065	42900	500	3648	4977	153798	95039	-62
CGN-25	8	19.82	30	4	"	"	"	"	"	"	3040	5076	153190	95138	-61
GUIDED	8	10.87	90	4	"	"	"	"	"	"	0	611	150150	90673	-66
MISSILE	5	29.5	0	6	20939	13299	20245	22291	24711	18650	7904	9371	73799	63611	-16
FRIGATE	5	28.7	30	6	"	"	"	"	"	"	6080	10643	71975	64883	-11
	5	23.98	90	6	"	"	"	"	"	"	0	2972	65895	57212	-15

values for a zero Beaufort number since the values for propeller resistance are within eleven per cent of each other. The differences in hull resistance result from a small data base used in the U.S. Navy towing manual. Only five resistance curves exist to apply to all ship classes whereas the MR&S method has 39 resistance curves. The biggest differences occur with ships like the ATF-148 or the AOE-1 which do not seem to fit any of the five ship classifications used in the towing manual.

The MR&S calculation for propeller resistance always yields value eleven per cent higher than the method from the towing manual since the equation for propeller resistance is the same but the MR&S coefficient is eleven per cent greater than that from the towing manual. One difference between the two methods which is not evident in the correlation study is that in the MR&S method, propeller resistance is separate from hull resistance so it is not a function of ship displacement. Thus the total propeller projected area, which can vary greatly even among similar ships, is accurately accounted for.

There is very poor correlation between the two methods of calculation for sea state resistance. The reason for the discrepancy is that in the Navy method the sea state factor K_1 is a percentage of the calm water resistance which is not correct as demonstrated by Marou's work (Ref.27). The K_1 factor is also multiplied by the propeller resistance which should not be involved in the correction for sea state. The MR&S method presents nine curves for the added resistance in waves which is added to the calm water resistance. Only one ship speed was used for each curve but this is considered a reasonable simplification since added resistance in waves does not vary greatly over the speed range considered. Note that the added resistance in waves decreased greatly as the Beaufort number increased from 4 to 6 in the Navy calculation. This is a result of the reduction in speed which causes a significant change in calm water resistance. If the Beaufort remained the same, as ship speed decreased the actual added resistance would probably increase for low significant wave heights but the method in the towing manual would indicate a substantial decrease in added resistance. The MR&S calculation for added resistance in waves appears to yield more consistent results.

The results of the MR&S calculation for wind resistance are always greater than those of the towing manual, in some cases by a factor of three. Since documentation for the development of the calculation procedure in the towing manual was not available, it is not possible to fully explain this discrepancy. Use of the K factor in the MR&S method produces a longitudinal force with a beam wind while the method in the towing manual always produces a force of zero for a beam wind. The difference in wind resistance generally amounts to less than eight per cent of the total resistance. When more wind tunnel data becomes available it may be possible to reduce the factors of safety used in the present calculation.

All of the differences of the individual resistance components above combine together to produce the differences in total tow resistance. The per cent difference ranges from 2% to 77%.

8.2.2 Part II-Comparison of Calculation Procedures with Full Scale Tests

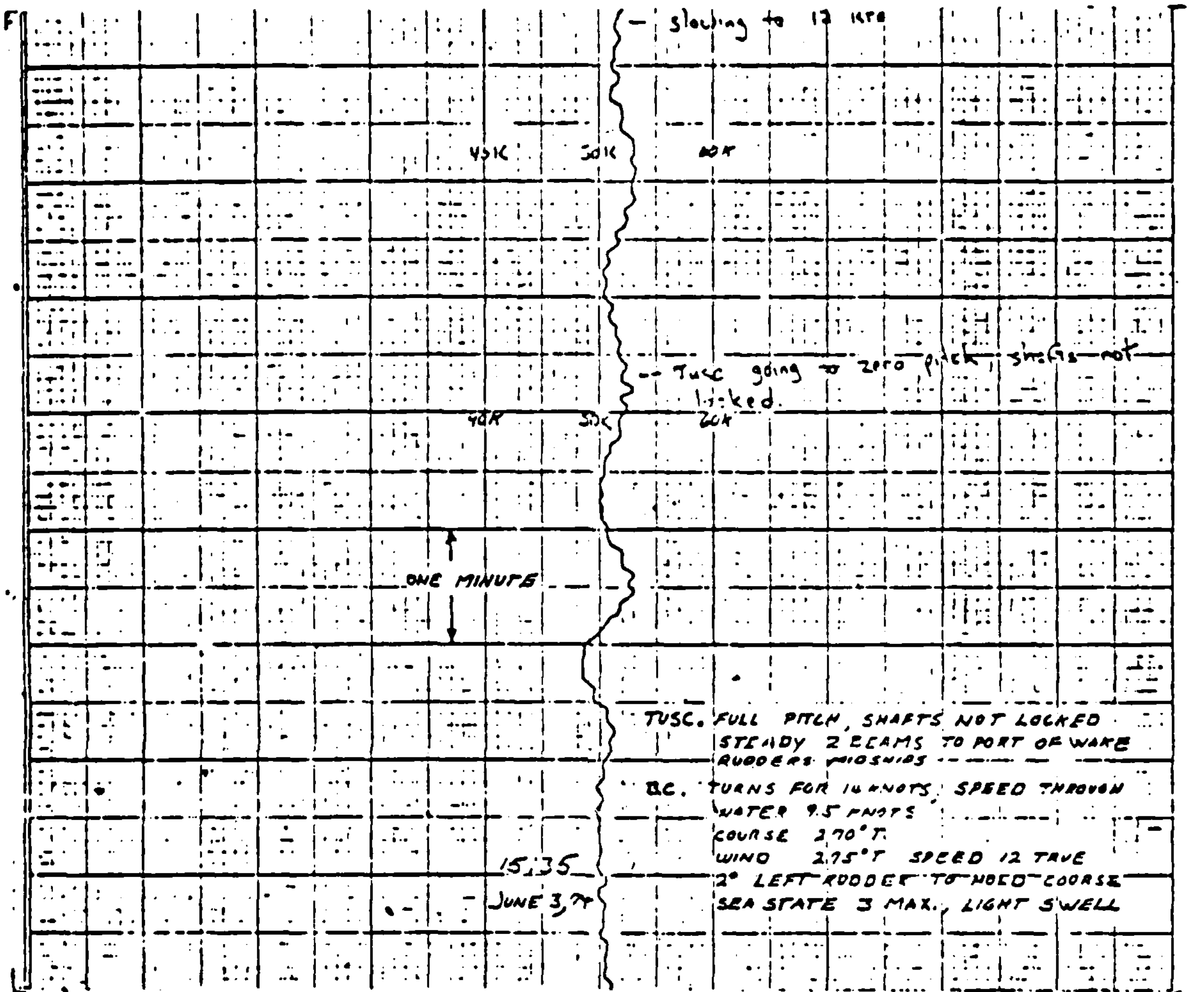
Results were obtained from full scale towing tests of the LST 1179 class for several tow conditions (Ref. 28). Two straight line towing tests were used since direct correlation could be made between these tests and the results of the calculation procedures. The shaft was not locked during the test runs but observers on board the tow noted the shafts never rotated due to the friction of the shafting and gears. Thus the calculations for locked propeller drag are valid. Figures 8-1 and 8-2 provide the data obtained during tests number 1 and 2 respectively. Table 8-2 summarizes the results.

Table 8-2. Summary of Results for Tests #1 & #2 of LST 1179 Class

Test No.	Tow Speed KT.	Rel. Wind Speed KT.	Rel. Wind Dir. Deg.	Measured Tow Resis. Lb. LST 1187 Test (Average)	MR&S Calc. Tow Resis.		U.S.N. Calc. Tow Resis.	
					LB.	% Diff.	LB.	% Dif
1	9.5	21.48	3	51,000	74234	45	108946	114
2	9	1.44	175	48,000	60990	27	92263	92.2

TEST #1

TOWING AT HIGH SPEED, STRAIGHT COURSE



B.C. TURNS FOR 14 KNOTS
PIT LOG - 9.5 KNOTS
6-ENGINES
COURSE 270° T
WIND 275° T SPEED 12 KNOTS TRUE
2° LEFT RUDDER TO HOLD COURSE
SEA STATE 3 MAX, LIGHT SWELL

TUSC. FULL PITCH, SHAFTS NOT LOCKED
STEADY 2 BEAMS TO PORT OF WAKE
RUDDERS ϕ DEGREES

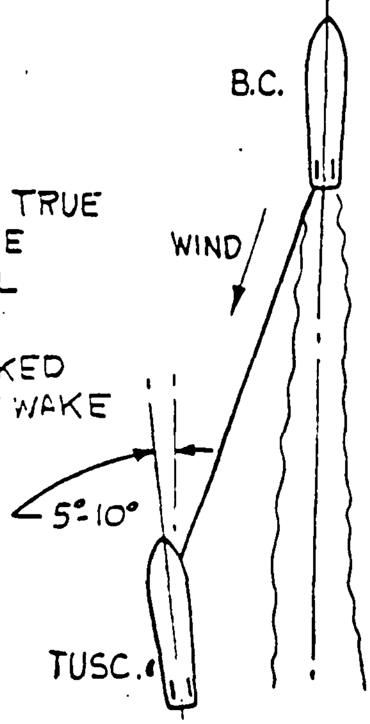
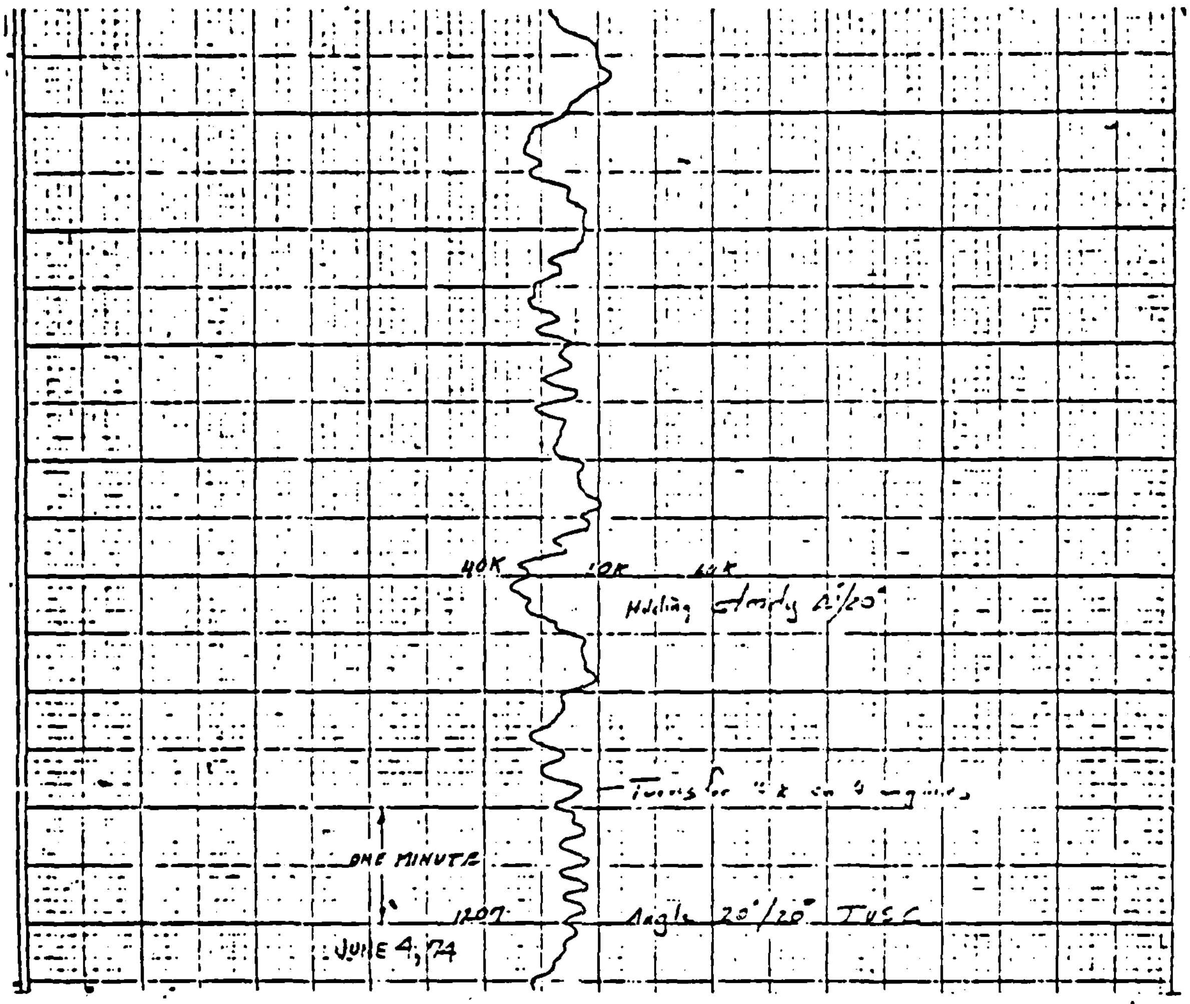


FIGURE 8-1 (Ref. 28)

Test #2

TURNS FOR 14 KNOTS DOWN WIND



B.C. TURNS FOR 14 KNOTS
PIT LOG 9 KNOTS
4 ENGINES
COURSE 070°T
WIND 254°T SPEED 10 KNOTS TRUE
SEA STATE 3 MAX LIGHT SWELL
RUDDER 4° LEFT TO HOLD COURSE

TUSC FULL PITCH, SHAFTS NOT LOCKED
RUDDERS Φ DEGREES

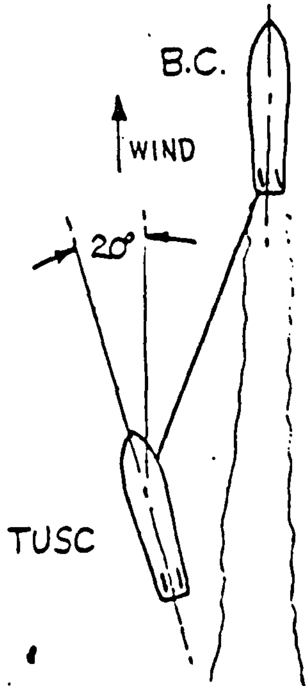


FIGURE 8-2 (Ref. 28)

9. Conclusions

This study has examined the four basic components of tow resistance, hull, propeller, wind and sea state and has combined these components into a calculation procedure for tow resistance. As described in section 2, other factors such as yaw and surge may exist which are not considered in the proposed calculation procedure. These additional factors could significantly increase the tow resistance and should be considered in future studies. No factor of safety has been applied to the final tow resistance since the individual resistance components all have a conservative margin built into them.

The calculation procedure for tow resistance developed in this study is somewhat more complex than the procedure in the present towing manual (Ref. 8) but has the advantages of being more rigorous and fully documented. The biggest difference between the two methods is that calm water hull resistance is considered separately from the propeller resistance unlike the present towing manual which presents the two resistance components together as one curve. The disadvantage of combining hull and propeller resistance on one plot of resistance divided by ship displacement versus speed is that propeller resistance appears to vary with displacement which is not true. With the components combined, it is not possible to disregard the propeller resistance if a ship is towed without propellers. The calculation for propeller resistance derived in this study is quite similar to that used in the Navy towing manual except that the propeller coefficient was increased slightly on the basis of available model tests. The calculation for wind resistance developed in this study is based on the procedure used in powering prediction of U.S. Naval ships (Reference 14) with a few modifications. The advantage of this method over that used in the current towing manual is that it more rigorously accounts for the effect of heading angle relative to the wind. The sea state factor K_1 as used in the towing manual was eliminated and was replaced by a set of curves of added resistance in waves versus Beaufort number and significant wave height. These curves of added resistance are independent of the propeller resistance and of the calm water resistance. This change should result in more realistic results than were obtained from the calculation procedure currently in use.

The correlation study indicates that significant differences exist between the results obtained from the calculation procedure developed in this report and the U.S. Navy Towing Manual currently in use. The available full scale tow resistance data is too limited to draw final conclusions, but the data obtained thus far indicates that the MR&S calculation procedure yields conservative but more accurate results than the method used in the current U.S. Navy Towing Manual. As additional full scale results become available, it should be possible to make the present calculation procedure less conservative.

10. Recommendations

The calculation procedure for the determination of tow resistance shown in section 7 was developed within the limited scope of the subject task. Further research and development can be undertaken to improve the accuracy of this calculation and extend its applicability. The following recommendations will vary in feasibility and cost.

10.1 Full Scale Tow Resistance Tests

Full scale tow resistance tests are the most effective means of checking the accuracy of the proposed calculation procedure. Full scale tests in calm water would yield valuable information on the magnitude of locked propeller drag since small scale tank tests lose some accuracy due to scaling effects. Tests should be conducted in a range of weather conditions and relative wind headings to determine the accuracy of assumptions made in the calculations for wind resistance and added resistance in waves.

10.2 Inclusion of Additional Parameters

Additional parameters as discussed in section 2 could be included in an extended study. The problem of calculating tow resistance should be considered as a three dimensional rather than two dimensional problem so all six degrees of motion are considered. The increase of resistance while turning is another significant parameter to consider.

10.3 Work on Existing Parameters

Additional research could be conducted on the parameters examined in this study. More hull resistance curves could be added to more accurately define the hull resistance of the naval fleet. In particular, curves for barges and submarines could be included. The problem of submarine resistance is particularly difficult since submarines are directionally unstable and show a great tendency to yaw while being towed.

The method for determining added resistance in waves used in this study is approximate and can be improved by calculating curves for more ship classes for a range of tow speeds. Instead of assuming a series 60 hull form, computer programs can be used to calculate added resistance for the specific hull shapes considered and in particular would consider transome stern ships. More accurate results would be possible if a two parameter study including wave period as well as significant wave height were used.

The wind resistance is a small component of the total resistance, generally less than 12 percent. However, additional work could be performed to increase the accuracy of this calculation. The most important improvement would be to calculate for a number of ships the additional drag due to yaw which is a function of the relative wind wind angle and immersed lateral area. Presently this additional drag is assumed to be fifty percent of the wind resistance for all relative wind angles and is based on very limited data.

10.4 Digital Simulations

The most elegant solution to the tow resistance problem would utilize simulation studies based on data from captive model tests. Work has already been done in this area as described in reference 29 where a Continuous System Modeling Program (CSMP) was used to study a tow trajectory versus time.

Using this approach towline forces could be determined for the actual motion of the tow (including yaw and sway motions) which is not considered in the simplified model used in this study. To be effective this would have to be performed for a large number of ships in varying sea conditions which would be quite costly.

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FIGURE 10.

$R_{H/\Delta}$ VERSUS TOW SPEED

(Curves 20 through 23)

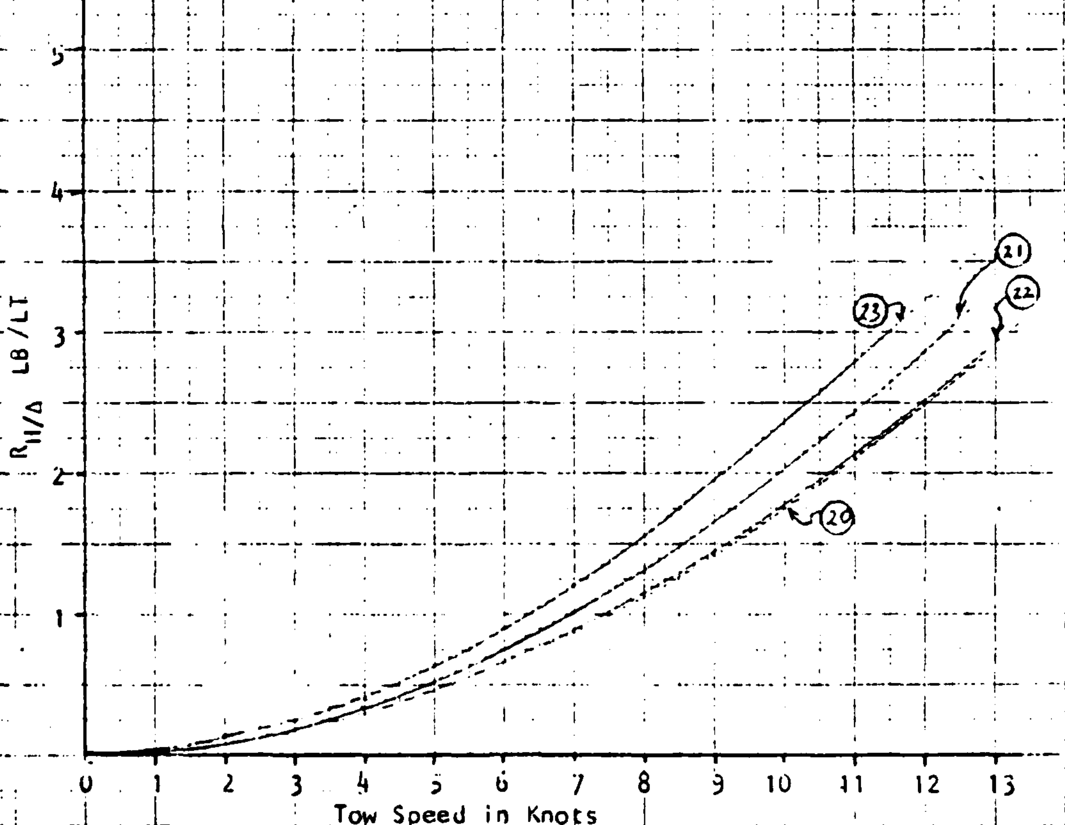


FIGURE 11

$R_{H/\Delta}$ VERSUS TOW SPEED

(Curves 24 through 28)

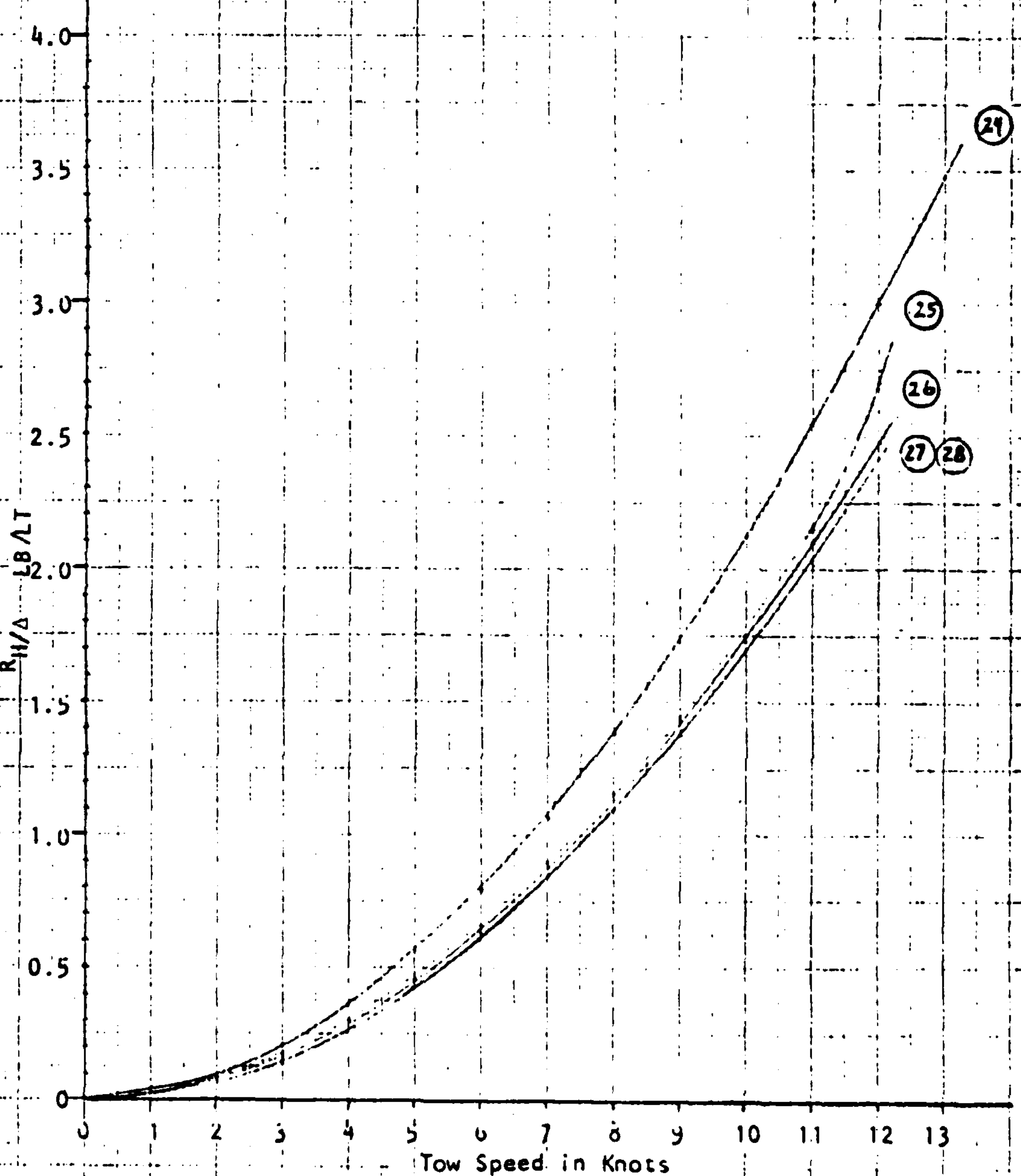


FIGURE 12

$R_{H/\Delta}$ VERSUS TOW SPEED
(Curves 29 through 33)

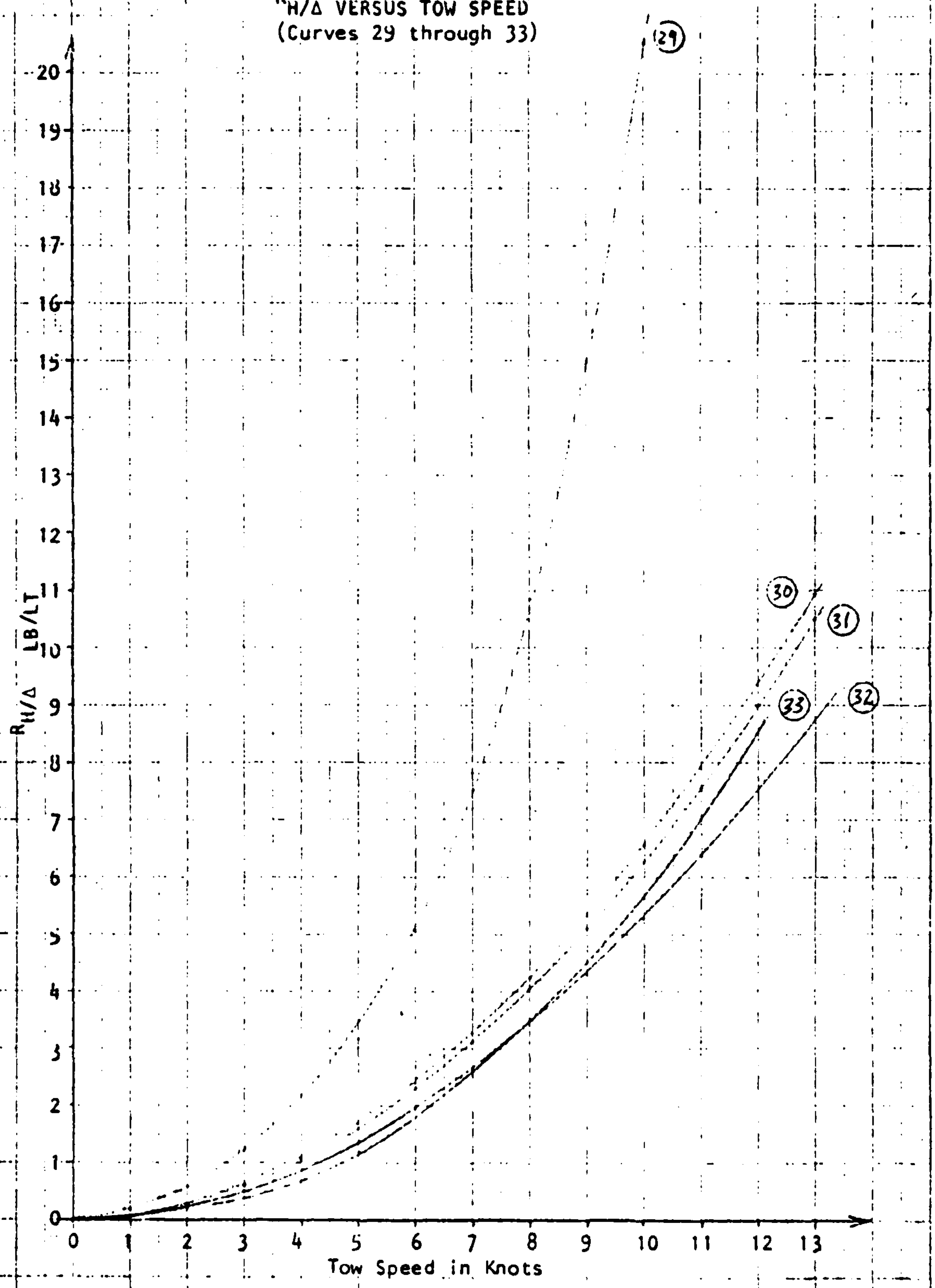


FIGURE 12

$R_{H/\Delta}$ VERSUS TOW SPEED
(Curves 29 through 33)

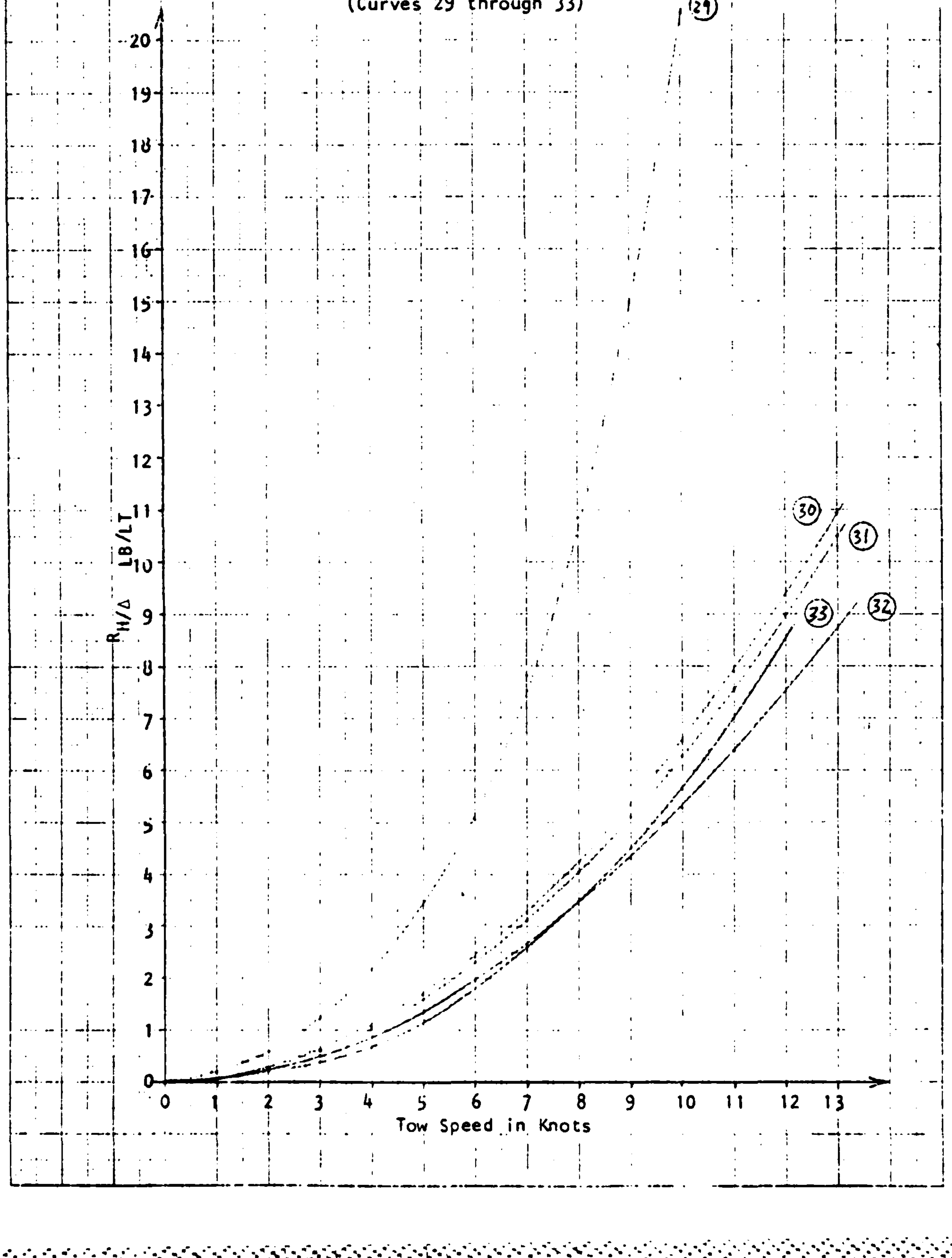
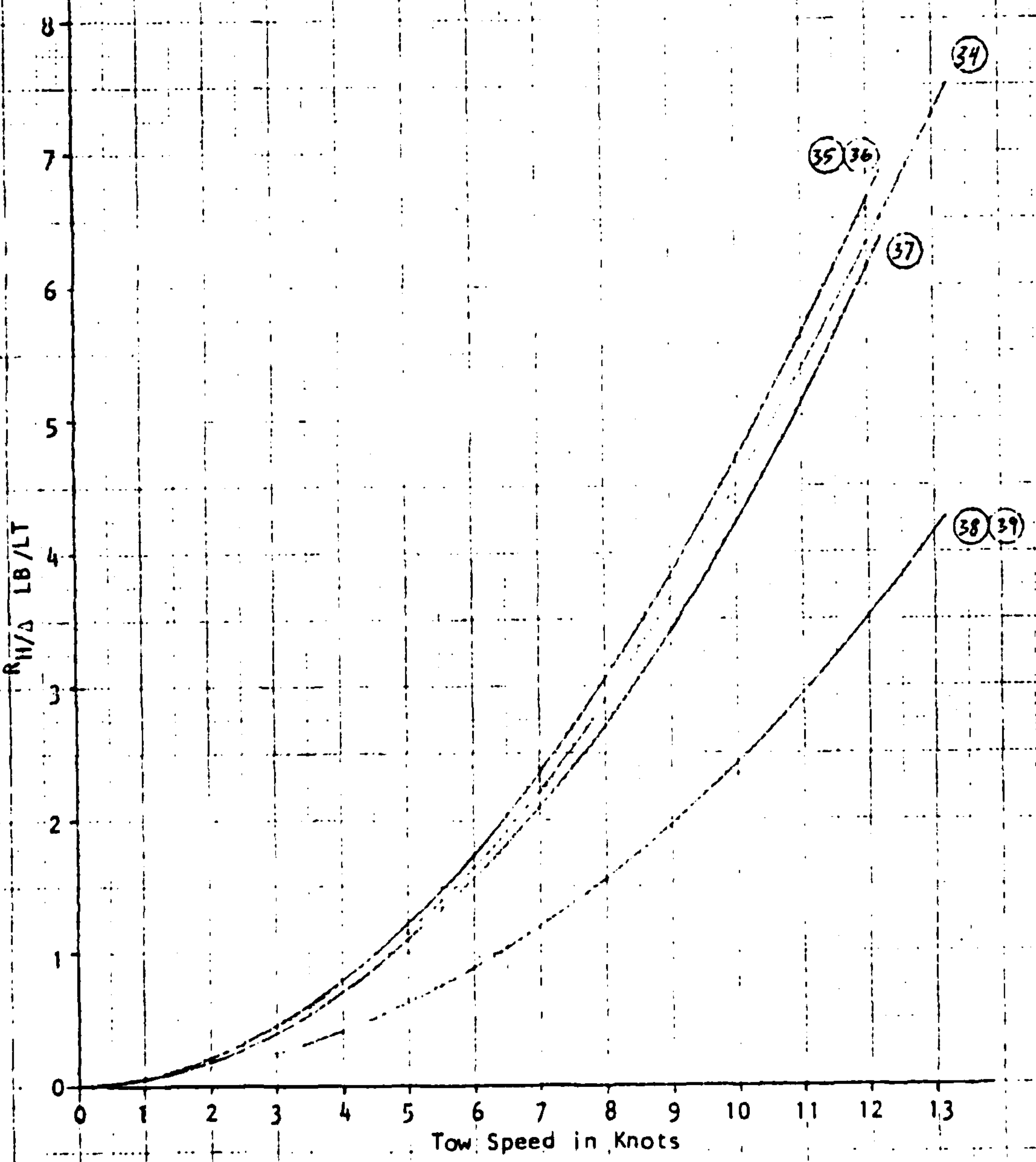


FIGURE 13

$R_{H/\Delta}$ VERSUS TOW SPEED

(Curves 34 through 39)



8. Correlation Study

8.1 Description of Study

A correlation study was conducted in an effort to verify the accuracy of the calculation procedure for tow resistance developed in this report and to compare it to the U.S. Navy calculation procedure which is currently in use. The study is conducted in two steps. In the first step calculations are performed using both the U.S. Navy method and the method developed by MR&S for eight ships for which complete data exists. The tow resistance for each method is separated into the four resistance components, hull, propeller, sea state and wind resistance. Three Beaufort numbers and three wind directions were examined for each of three tow speeds. The resulting data is presented in Table 8-1.

The second part of the study compares the actual towline tension measured in full scale tests with the resistance obtained for the U.S. Navy and MR&S calculation procedures. Several towing tests have been conducted but documentation of these tests is sufficient to permit correlation for only the LST 1179 class. As more data becomes available, it would be beneficial to extend this part of the correlation study.

8.2 Results of Correlation Study

8.2.1 Part I Comparison of MR&S and U.S. Navy Methods of Calculation

A comparison of the MR&S and U.S. Navy calculations is done for each component of resistance as shown in Table 8-1.

The differences in hull resistance are quite large, sometimes varying by a factor of three. The effect of this difference on the total tow resistance can be seen by comparing the total resistance

Table 8-1 CORRELATION STUDY COMPARING THE RESULTS FROM MR&S METHOD WITH THE CURRENT U.S. NAVY TOWING MANUAL

SHIP CLASS	TOW SPEED KT.	REL. WIND SPEED KT.	REL. WIND DIRECT & DEG.	BEAU-FORT NO.	HULL RESISTANCE LB.		PROPELLER RESISTANCE LB.		SEA STATE RESISTANCE LB.		WIND RESISTANCE LB.		TOTAL RESISTANCE LB.		% DIFF. TOT. RESIS LB.
					USN	MR&S	USN	MR&S	USN	MR&S	USN	MR&S	USN	MR&S	
	10	10.0	0	0	1821	14866	14594	16069	0	0	360	455	16775	31390	47%
	8	21.5	0	4	1213	7035	9340	10284	4221	900	1080	2105	15854	20324	22
AFT-148	8	19.82	30	4	"	"	"	"	"	"	840	2022	15614	20241	23
OCEAN	8	10.87	90	4	"	"	"	"	"	"	0	54	14774	18273	20
TUG	5	29.5	0	6	-2309	3664	3649	4017	-	23500	2848	3963	-	35144	-
	5	28.7	30	6	-	"	-	"	-	"	-	4239	-	35419	-
	5	23.98	90	6	-	"	-	"	-	"	-	262	-	31443	-
	10	10.0	0	0	40354	66675	92996	102394	0	0	2277	3841	135627	172910	22
	8	21.5	0	4	24303	53340	59517	65532	33528	1300	6831	17753	124179	136625	9
AOR-1	8	19.82	30	4	"	"	"	"	"	"	3795	15690	12143	135862	9
OILER	8	10.87	90	4	"	"	"	"	"	"	0	4538	117348	124710	6
	5	29.5	0	6	3421	21908	23249	25598	16002	47500	12903	33422	55572	128428	57
	5	28.7	30	6	"	"	"	"	"	"	8349	32900	51021	127906	60
	5	73.98	90	6	"	"	"	"	"	"	0	442	42672	95447	55
	10	10.0	0	0	32834	118590	154766	170407	0	0	2925	3700	190525	292697	35
	8	21.5	0	4	18870	77050	99050	109061	47168	1300	7800	17103	172888	204514	15
AOE-1	8	19.82	30	4	"	"	"	"	"	"	4875	16425	169963	203836	17
FAST	8	10.87	90	4	"	"	"	"	"	"	0	393	165088	187804	12
COMBAT	5	29.5	0	6	4188	77050	38692	42602	25728	44000	16575	32200	85183	195852	56
SUPPORT	5	28.7	30	6	"	"	"	"	"	"	9750	34440	78358	198092	60
	5	23.98	90	6	"	"	"	"	"	"	0	1915	68608	165567	58

Table 8-1 (Cont'd) CORRELATION STUDY COMPARING THE RESULTS FROM MR&S METHOD WITH THE CURRENT U.S. NAVY TOWING MANUAL

SHIP CLASS	TOW SPEED KT.	REL. WIND SPEED KT.	REL. WIND DIRECT & DEG.	BEAU-FORT NO.	HULL RESISTANCE LB.		PROPELLER RESISTANCE LB.		SEA STATE RESISTANCE LB.		WIND RESISTANCE LB.		TOTAL RESISTANCE LB.		% DIFF. TOT. RESIS LB.
					USN	MR&S	USN	MR&S	USN	MR&S	USN	MR&S	USN	MR&S	
FF 140 ESCORT	10	10.0	0	0	25817	31237	44461	48955	0	0	1715	607	71993	80799	11%
	8	21.5	0	4	14045	17850	28455	31331	17000	600	2573	2808	62073	52589	-18
	8	19.82	30	4	"	"	"	"	"	"	2058	2863	61558	52644	-17
	8	10.87	90	4	"	"	"	"	"	"	0	3445	59500	50126	-19
	5	29.5	0	6	5205	6630	11115	12238	9792	20800	4116	5286	30228	44954	33
	5	28.7	30	6	"	"	"	"	"	"	3430	6004	29542	45672	35
	5	23.98	90	6	"	"	"	"	"	"	0	1677	26112	41344	37
AF 58 STORES SHIP	10	10.0	0	0	19824	61031	35976	39612	0	0	1322	1672	57122	102315	44
	8	21.5	0	4	12625	39719	23025	25352	14260	1500	3965	7727	53875	74298	27
	8	19.82	30	4	"	"	"	"	"	"	2203	7421	52113	73992	30
	8	10.87	90	4	"	"	"	"	"	"	0	1580	49910	68151	27
	5	29.5	0	6	1856	16081	8994	9903	6510	41000	7489	14548	24849	81532	70
	5	28.7	30	6	"	"	"	"	"	"	4846	15560	22206	82544	73
	5	23.98	90	6	"	"	"	"	"	"	0	7690	17360	74674	77
CA 139 HEAVY CRUISER	10	10.0	0	0	72529	59848	109966	121079	0	0	4500	1594	186995	182521	- 2
	8	21.5	0	4	47708	30058	70377	77490	47234	1300	6750	7368	172069	116216	-48
	8	19.82	30	4	"	"	"	"	"	"	5400	7514	170719	116362	-47
	8	10.87	90	4	"	"	"	"	"	"	0	904	165319	109752	-50
	5	29.5	0	6	17596	15566	27491	30270	27052	32500	10800	13871	82939	92207	10
	5	28.7	30	6	"	"	"	"	"	"	9000	15755	81139	94091	14
	5	23.98	90	6	"	"	"	"	"	"	0	4399	72139	82735	13

Table 8-1 (Cont'd) CORRELATION STUDY COMPARING THE RESULTS FROM MR&S METHOD WITH THE CURRENT U.S. NAVY TOWING MANUAL

SHIP CLASS	TOW SPEED KT.	REL. WIND SPEED KT.	REL. WIND DIRECT & DEG.	BEAU-FORT NO.	HULL RESISTANCE LB.		PROPELLER RESISTANCE LB.		SEA STATE RESISTANCE LB.		WIND RESISTANCE LB.		TOTAL RESISTANCE LB.		% DIFF. TOT. RESIS LB.
					USN	MR&S	USN	MR&S	USN	MR&S	USN	MR&S	USN	MR&S	
	10	10.0	0	0	45883	32951	36703	40412	0	0	1970	1396	84556	74759	-13%
	8	21.5	0	4	29065	22002	23490	25864	21021	1300	5122	6451	78698	55617	-41
LST-1179	8	19.82	30	4	"	"	"	"	"	"	3940	6579	81918	55745	-47
TANK	8	10.87	90	4	"	"	"	"	"	"	0	791	73576	49957	-47
LANDING	5	29.5	0	6	11679	9064	9176	10103	12513	38500	9850	12145	43218	69812	38
SHIP	5	28.7	30	6	"	"	"	"	"	"	7880	13794	41248	71461	42
	5	23.98	90	6	"	"	"	"	"	"	0	3852	33368	61519	45
	10	10.0	0	0	96368	50944	80981	89165	0	0	1520	1077	178869	141186	-27
	8	21.5	0	4	55422	32497	51828	57065	42900	500	3648	4977	153798	95039	-62
CGN-25	8	19.82	30	4	"	"	"	"	"	"	3040	5076	153190	95138	-61
GUIDED	8	10.87	90	4	"	"	"	"	"	"	0	611	150150	90673	-66
MISSILE	5	29.5	0	6	20939	13299	20245	22291	24711	18650	7904	9371	73799	63611	-16
FRIGATE	5	28.7	30	6	"	"	"	"	"	"	6080	10643	71975	64883	-11
	5	23.98	90	6	"	"	"	"	"	"	0	2972	65895	57212	-15

values for a zero Beaufort number since the values for propeller resistance are within eleven per cent of each other. The differences in hull resistance result from a small data base used in the U.S. Navy towing manual. Only five resistance curves exist to apply to all ship classes whereas the MR&S method has 39 resistance curves. The biggest differences occur with ships like the ATF-148 or the AOE-1 which do not seem to fit any of the five ship classifications used in the towing manual.

The MR&S calculation for propeller resistance always yields value eleven per cent higher than the method from the towing manual since the equation for propeller resistance is the same but the MR&S coefficient is eleven per cent greater than that from the towing manual. One difference between the two methods which is not evident in the correlation study is that in the MR&S method, propeller resistance is separate from hull resistance so it is not a function of ship displacement. Thus the total propeller projected area, which can vary greatly even among similar ships, is accurately accounted for.

There is very poor correlation between the two methods of calculation for sea state resistance. The reason for the discrepancy is that in the Navy method the sea state factor K_1 is a percentage of the calm water resistance which is not correct as demonstrated by Marou's work (Ref.27). The K_1 factor is also multiplied by the propeller resistance which should not be involved in the correction for sea state. The MR&S method presents nine curves for the added resistance in waves which is added to the calm water resistance. Only one ship speed was used for each curve but this is considered a reasonable simplification since added resistance in waves does not vary greatly over the speed range considered. Note that the added resistance in waves decreased greatly as the Beaufort number increased from 4 to 6 in the Navy calculation. This is a result of the reduction in speed which causes a significant change in calm water resistance. If the Beaufort remained the same, as ship speed decreased the actual added resistance would probably increase for low significant wave heights but the method in the towing manual would indicate a substantial decrease in added resistance. The MR&S calculation for added resistance in waves appears to yield more consistent results.

The results of the MR&S calculation for wind resistance are always greater than those of the towing manual, in some cases by a factor of three. Since documentation for the development of the calculation procedure in the towing manual was not available, it is not possible to fully explain this discrepancy. Use of the K factor in the MR&S method produces a longitudinal force with a beam wind while the method in the towing manual always produces a force of zero for a beam wind. The difference in wind resistance generally amounts to less than eight per cent of the total resistance. When more wind tunnel data becomes available it may be possible to reduce the factors of safety used in the present calculation.

All of the differences of the individual resistance components above combine together to produce the differences in total tow resistance. The per cent difference ranges from 2% to 77%.

8.2.2 Part 11 - Comparison of Calculation Procedures with Full Scale Tests

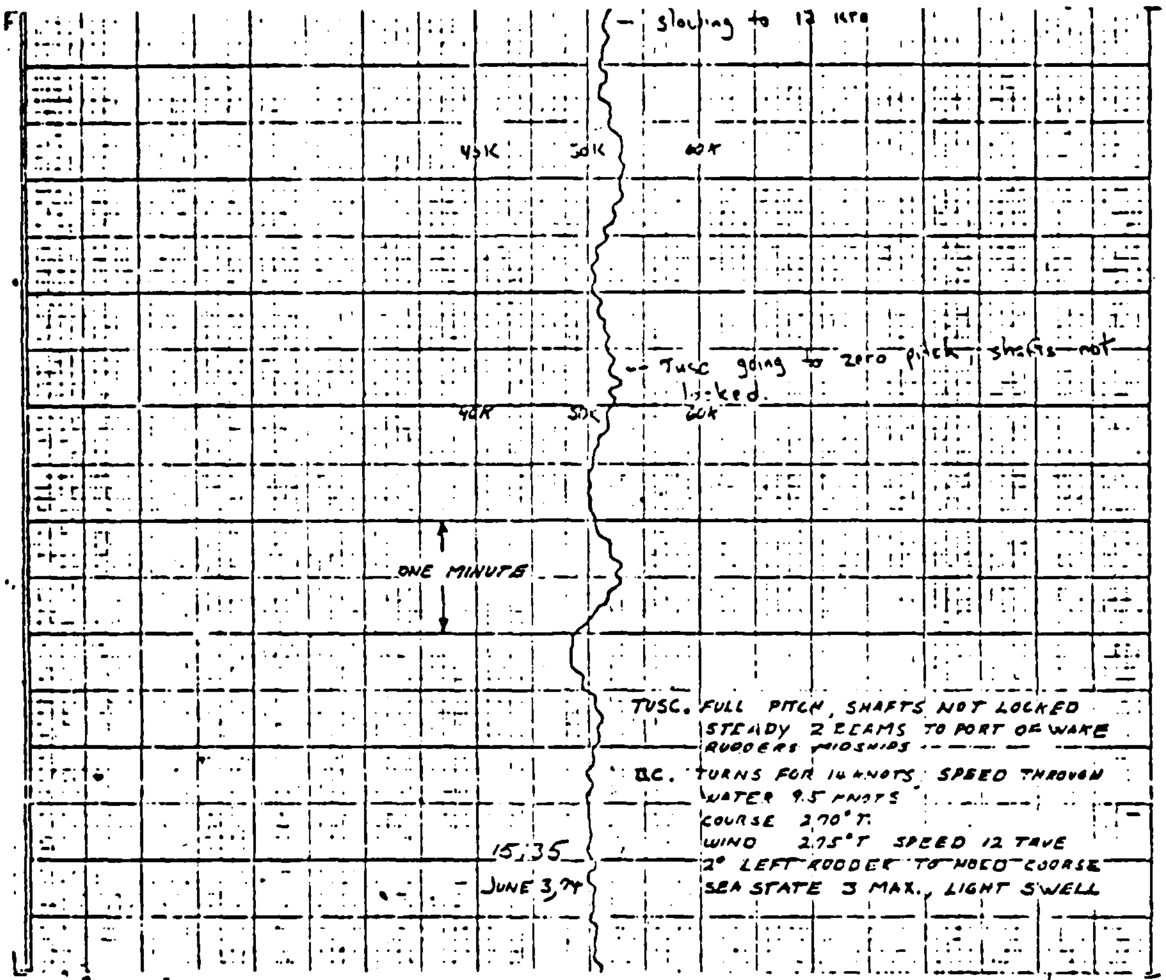
Results were obtained from full scale towing tests of the LST 1179 class for several tow conditions (Ref. 28). Two straight line towing tests were used since direct correlation could be made between these tests and the results of the calculation procedures. The shaft was not locked during the test runs but observers on board the tow noted the shafts never rotated due to the friction of the shafting and gears. Thus the calculations for locked propeller drag are valid. Figures 8-1 and 8-2 provide the data obtained during tests number 1 and 2 respectively. Table 8-2 summarizes the results.

Table 8-2. Summary of Results for Tests #1 & #2 of LST 1179 Class

Test No.	Tow Speed KT.	Rel. Wind Speed KT.	Rel. Wind Dir. Deg.	Measured Tow Resis. Lb. LST 1187 Test (Average)	MR&S Calc. Tow Resis.		U.S.N. Calc. Tow Resis.	
					LB.	% Diff.	LB.	% Diff
1	9.5	21.48	3	51,000	74234	45	108946	114
2	9	1.44	175	48,000	60990	27	92263	92.2

Test #1

TOWING AT HIGH SPEED, STRAIGHT COURSE



B.C. TURNS FOR 14 KNOTS
PIT LOG - 9.5 KNOTS
6-ENGINES
COURSE 270° T
WIND 275° T SPEED 12 KNOTS TRUE
2° LEFT RUDDER TO HOLD COURSE
SEA STATE 3 MAX, LIGHT SWELL

TUSC. FULL PITCH, SHAFTS NOT LOCKED
STEADY 2 BEAMS TO PORT OF WAKE
RUDDERS Ø DEGREES

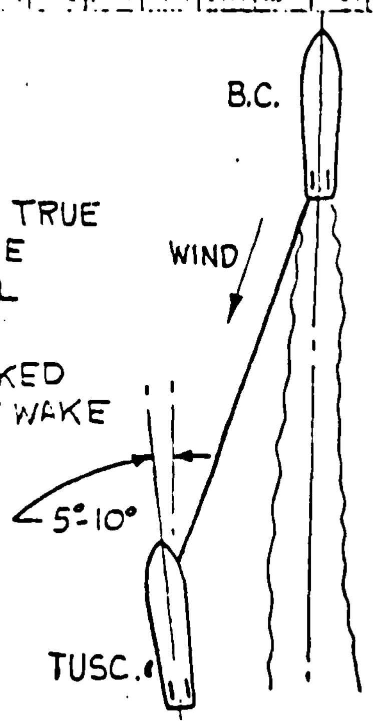
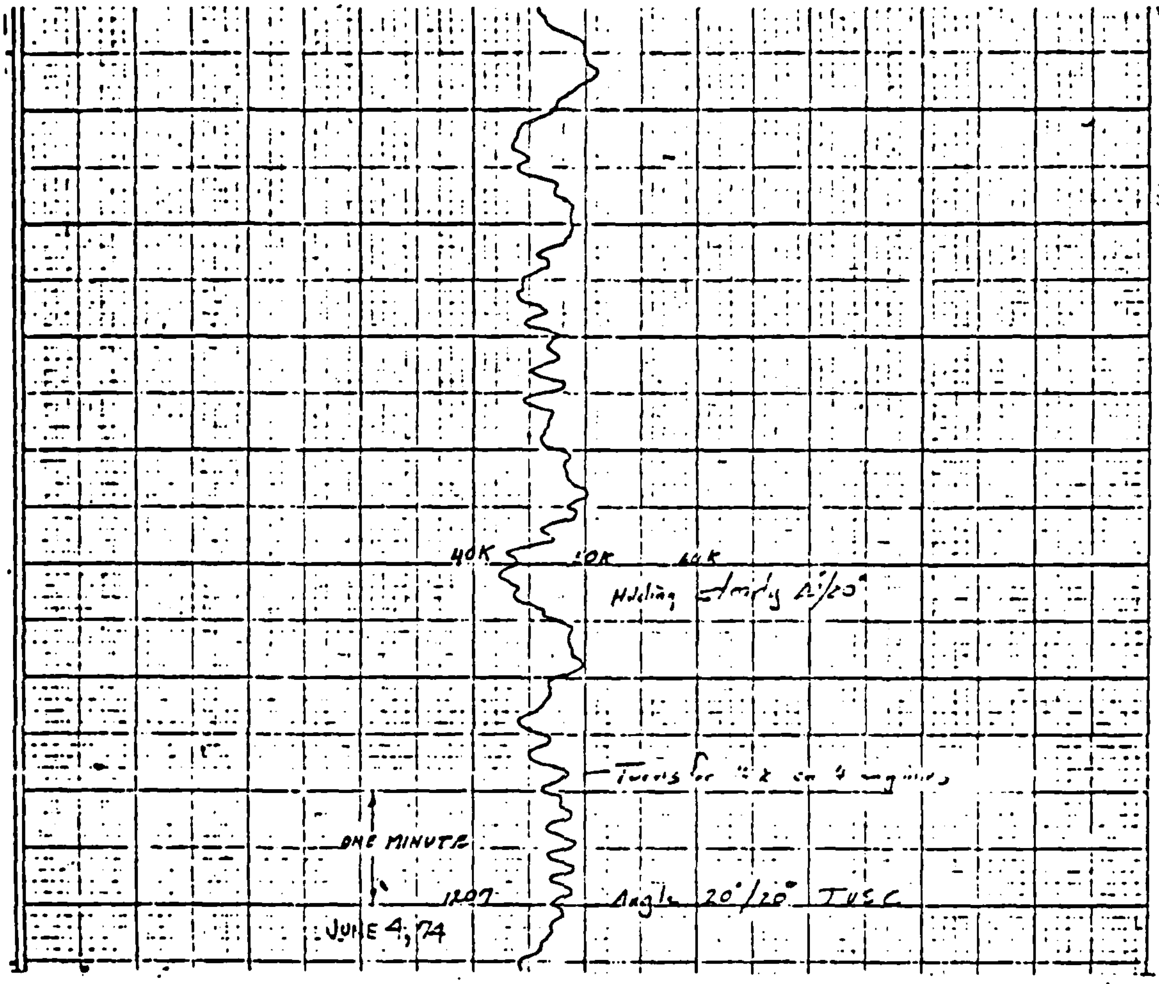


FIGURE 8-1 (Ref. 28)

TEST #2

TURNS FOR 14 KNOTS DOWN WIND



B.C. TURNS FOR 14 KNOTS
PIT LOG 9 KNOTS
4 ENGINES
COURSE 070°T
WIND 254°T SPEED 10 KNOTS TRUE
SEA STATE 3 MAX LIGHT SWELL
RUDDER 4° LEFT TO HOLD COURSE

TUSC FULL PITCH, SHAFTS NOT LOCKED
RUDDERS ϕ DEGREES

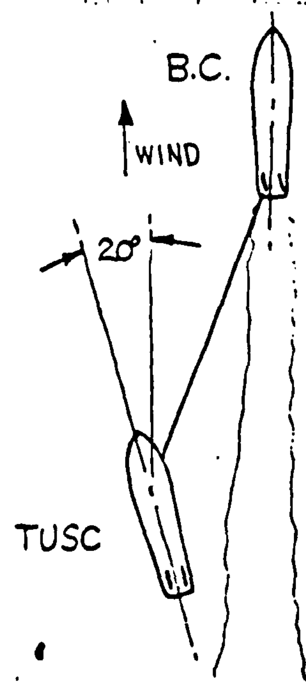


FIGURE 8-2 (Ref. 28)

9. Conclusions

This study has examined the four basic components of tow resistance, hull, propeller, wind and sea state and has combined these components into a calculation procedure for tow resistance. As described in section 2, other factors such as yaw and surge may exist which are not considered in the proposed calculation procedure. These additional factors could significantly increase the tow resistance and should be considered in future studies. No factor of safety has been applied to the final tow resistance since the individual resistance components all have a conservative margin built into them.

The calculation procedure for tow resistance developed in this study is somewhat more complex than the procedure in the present towing manual (Ref. 8) but has the advantages of being more rigorous and fully documented. The biggest difference between the two methods is that calm water hull resistance is considered separately from the propeller resistance unlike the present towing manual which presents the two resistance components together as one curve. The disadvantage of combining hull and propeller resistance on one plot of resistance divided by ship displacement versus speed is that propeller resistance appears to vary with displacement which is not true. With the components combined, it is not possible to disregard the propeller resistance if a ship is towed without propellers. The calculation for propeller resistance derived in this study is quite similar to that used in the Navy towing manual except that the propeller coefficient was increased slightly on the basis of available model tests. The calculation for wind resistance developed in this study is based on the procedure used in powering prediction of U.S. Naval ships (Reference 14) with a few modifications. The advantage of this method over that used in the current towing manual is that it more rigorously accounts for the effect of heading angle relative to the wind. The sea state factor K_1 as used in the towing manual was eliminated and was replaced by a set of curves of added resistance in waves versus Beaufort number and significant wave height. These curves of added resistance are independent of the propeller resistance and of the calm water resistance. This change should result in more realistic results than were obtained from the calculation procedure currently in use.

The correlation study indicates that significant differences exist between the results obtained from the calculation procedure developed in this report and the U.S. Navy Towing Manual currently in use. The available full scale tow resistance data is too limited to draw final conclusions, but the data obtained thus far indicates that the MR&S calculation procedure yields conservative but more accurate results than the method used in the current U.S. Navy Towing Manual. As additional full scale results become available, it should be possible to make the present calculation procedure less conservative.

10. Recommendations

The calculation procedure for the determination of tow resistance shown in section 7 was developed within the limited scope of the subject task. Further research and development can be undertaken to improve the accuracy of this calculation and extend its applicability. The following recommendations will vary in feasibility and cost.

10.1 Full Scale Tow Resistance Tests

Full scale tow resistance tests are the most effective means of checking the accuracy of the proposed calculation procedure. Full scale tests in calm water would yield valuable information on the magnitude of locked propeller drag since small scale tank tests lose some accuracy due to scaling effects. Tests should be conducted in a range of weather conditions and relative wind headings to determine the accuracy of assumptions made in the calculations for wind resistance and added resistance in waves.

10.2 Inclusion of Additional Parameters

Additional parameters as discussed in section 2 could be included in an extended study. The problem of calculating tow resistance should be considered as a three dimensional rather than two dimensional problem so all six degrees of motion are considered. The increase of resistance while turning is another significant parameter to consider.

10.3 Work on Existing Parameters

Additional research could be conducted on the parameters examined in this study. More hull resistance curves could be added to more accurately define the hull resistance of the naval fleet. In particular, curves for barges and submarines could be included. The problem of submarine resistance is particularly difficult since submarines are directionally unstable and show a great tendency to yaw while being towed.

The method for determining added resistance in waves used in this study is approximate and can be improved by calculating curves for more ship classes for a range of tow speeds. Instead of assuming a series 60 hull form, computer programs can be used to calculate added resistance for the specific hull shapes considered and in particular would consider transome stern ships. More accurate results would be possible if a two parameter study including wave period as well as significant wave height were used.

The wind resistance is a small component of the total resistance, generally less than 12 percent. However, additional work could be performed to increase the accuracy of this calculation. The most important improvement would be to calculate for a number of ships the additional drag due to yaw which is a function of the relative wind wind angle and immersed lateral area. Presently this additional drag is assumed to be fifty percent of the wind resistance for all relative wind angles and is based on very limited data.

10.4 Digital Simulations

The most elegant solution to the tow resistance problem would utilize simulation studies based on data from captive model tests. Work has already been done in this area as described in reference 29 where a Continuous System Modeling Program (CSMP) was used to study a tow trajectory versus time.

Using this approach towline forces could be determined for the actual motion of the tow (including yaw and sway motions) which is not considered in the simplified model used in this study. To be effective this would have to be performed for a large number of ships in varying sea conditions which would be quite costly.

11. References

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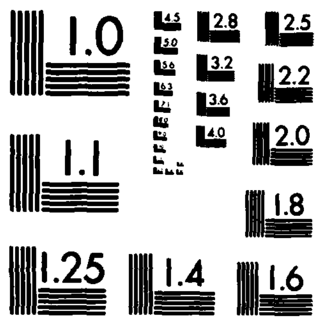
APPENDIX A

HULL RESISTANCE CALCULATIONS

AD-A150 941 DEVELOPMENT OF A CALCULATION PROCEDURE FOR THE DETERMINATION OF TOW RESISTANCE (UNABRIDGED REPORT)(U) ROSENBLATT (M) AND SON INC NEW YORK APR 76 2/6

UNCLASSIFIED N00024-74-C-5508 F/G 13/10 NL



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

Appendix A

A.1 Introduction

Appendix A contains the calculations performed for the calm water hull resistance of 39 Naval ship classes. Figures 6-13 show the results of these calculations as they appear in section 7. The list of ship classes below relates the ship classes to the hull resistance curve numbers and gives the sheet number on which the detailed calculations are given in the unabridged report. The unabridged report also provides resistance data for barges. The abridged report presents only a sample calculation for one ship.

A description of the calculation procedure along with a list of symbols used is presented below. Note the change in nomenclature from that used in section 7.

A.2 List of Ships Corresponding to the Hull Resistance Curves

Hull Resistance Curve Numbers (See Fig. 6-13)	Naval Ship Class	Sheet number for Detailed Calculations in Unabridged Report
1	FF-1037	1
2	FF-1040	4
3	DD-931	7
4	CG-16	11
5	CGN-25	14
6	CGN-9	17
7	CA-139	20
8	MSO-422	23
9	ATF-148	26
10	AGFF-1	29
11	T-AGS-29	32
12	AF-58	35
13	AE21 & 23	38
14	AD-14	41

A.2 List of Ships Corresponding to the Hull Resistance Curves (Continued)

Hull Resistance Curve Numbers (See Fig. 6-13)	Naval Ship Class	Sheet number for Detailed Calculations in Unabridged Report
15	AE-26	44
16	LPD-4	47
17	AFS-1	50
18	LST-1179	53
19	LSD-36	56
20	AOR-1	59
21	AD-37	62
22	AOE-1	65
23	AS-34	68
24	AKA-113	71
25	LHA	74
26	AO-93	77
27	CVA(N)-65	80
28	CVA-59	83
29	LCU-FY	86
30	FF-1052	89
31	DDG-2	93
32	DD-963	96
33	T-AGOR	99
34	CG-26	102
35	DD-710	106
36	D2-1	110
37	LST-1171	113
38	LCC-19	116
39	LPH-3	118-A

A.3 Description of Steps in Calculation of Hull Resistance

Symbols Used			Units
LWL	=	load waterline length	Ft.
B	=	beam	Ft.
T	=	draft	Ft.
Δ	=	displacement	Long Tons
WS	=	wetted surface	$Ft.^2$
C_p	=	prismatic coefficient	--
ΔC_F	=	ship-model correlation allowance	--
R_T	=	calm water hull resistance	LB.

Note: R_T is equivalent to R_H in section 7.

V_K	=	ship speed	knots
V_s	=	ship speed	Ft./sec.
R_n	=	Reynolds number	--
C_f	=	frictional resistance coefficient	--
C_R	=	residuary resistance	--
C_{TS}	=	total coefficient resistance coefficient	--
R_F	=	frictional resistance	LB.
R_R	=	Residuary resistance	LB.

Steps in Calculation Procedure

1. Record data for EHP.
2. Calculate speed from $V_K = 0.55\sqrt{LWL}$ and check to see that data exists for this speed or lower. If not then use reference 2 to be sure that C_R is constant at the speed for the lowest EHP available.
3. Calculate the total resistance for the lowest EHP available.
4. Calculate R_n for speed corresponding to this lowest EHP.
5. If the wetted surface is not provided then it may be approximated with the equation

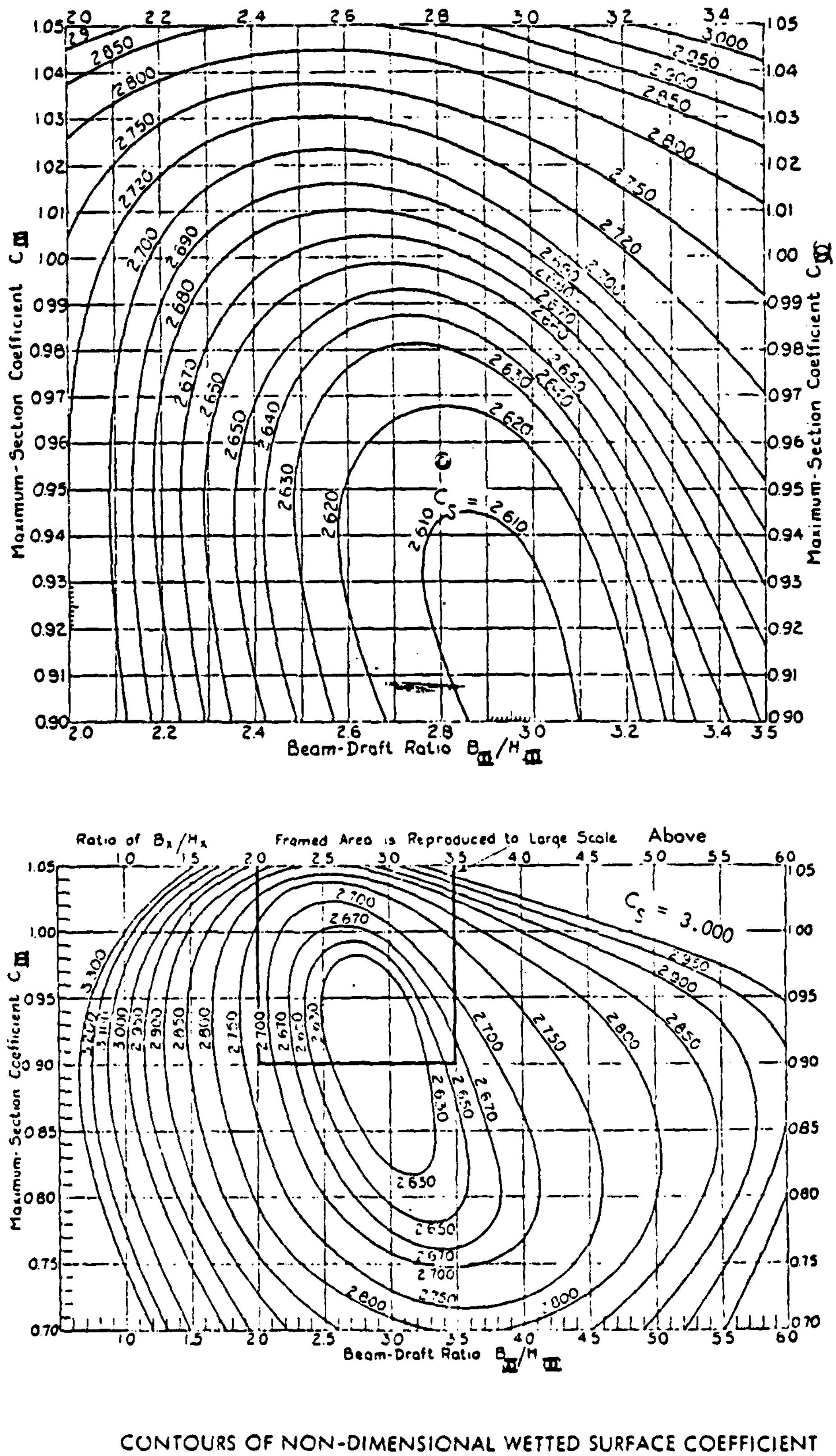
$$S = C_s\sqrt{\nabla \cdot LWL}$$

where C_s is obtained from the contours of the non-dimensional wetted surface coefficient (see p. A-6)

∇ = volumetric displacement in cubic feet.

6. Calculate the frictional coefficient using Schoenherr coefficients
7. Calculate frictional resistance.
8. Subtract frictional resistance from total resistance to obtain residuary resistance.
9. Calculate the residuary coefficient which is assumed constant for lower speeds.
10. Calculate Reynold's numbers for speeds from 0-12 knots or from 0 - speed corresponding to lowest EHP.
11. For Reynold's numbers in 9 find C_F using Schoenherr data.
12. Add ΔC_F and C_R to C_F to obtain C_{TS}.
13. Calculate total hull resistance R_H for all towing speeds.
14. Divide R_H by Δ and plot on curves of R_H/Δ versus ship speed V_K.

For more information regarding the above calculation or for the use of the barge resistance data, consult reference 6 or any standard text on naval architecture.



CONTOURS OF NON-DIMENSIONAL WETTED SURFACE COEFFICIENT
(REFERENCE: SAUNDERS, 1957)

... Rosenblatt & Son, Inc.

No. 5414

DESIGN CALCULATION SHEET

Subject: HULL RESISTANCE & PROPELLER DATA SHEET

Ship or Project: EMERGENCY TOWING GEAR CRITERIA

Section: B?DD Prepared by Date Checked Reviewed

SHIP CLASS: FF 1037 OR DE 1037

DATA SOURCE:

SHIP CHARACTERISTICS

LWL = 350

B = 40.5

T = 13.5

Δ = 2725

WS = 17,440

C_p =

EHP/SHP =

ΔC_F = 0.0007

PROPELLER CHARACTERISTICS

DIA. = 12.75

PITCH = 12.64

BLADES = 5

EXP. A./D.A. = 0.??

EXPANDED AREA = 78.31

DEVELOPED AREA =

PROJ AREA/D.A. =

PROJECTED AREA =

PROPELLERS = 1

V KNOTS	SHP	EHP/SHP	EHP	R_T POUNDS	$EHP_{FRIC.}$
10			750		
11			1000		
12			1450		
13			1850		
14			2300		
15			2750		

DESIGN CALCULATION SHEET

Subject: HULL RESISTANCE CALCULATION - SCB-199 (FF1037)

Ship or Project: EMERGENCY TOWING GEAR CRITERIA

Section: BSDD Prepared by: RCS Date: 10/29/75 Checked: Reviewed:

SHIP - SCB-199 OR FF1037

CALCULATION FOR MAX. SPEED WHERE C_R IS CONSTANT

$$V_K = 0.55\sqrt{LWL} = 10.29 \quad \underline{\text{USE 10 KT.}}$$

$$R_T = \frac{EHP \times 326}{V_K} = 24450$$

$$V_s = 1.687\ V_K = 16.89$$

$$R_n = \frac{V_s L}{\nu} = \frac{(16.89)(350)}{1.2791 \times 10^{-5}} = 4.622 \times 10^{8}$$

$$C_f = 1.687 \times 10^{-3} \quad \text{(SCHOENHERR COEFF.)}$$

$$\Delta C_f = 0.90 \times 10^{-3}$$

$$C_{f_T} = 2.587 \times 10^{-3}$$

$$R_F = \tfrac{1}{2}\rho S V_s^2 C_{f_T}$$
$$= \tfrac{1}{2}(1.9905)(17{,}440)(16.89)^2(2.587 \times 10^{-3})$$
$$= 12{,}810$$

$$R_R = R_T - R_F = 11640$$

$$C_R = \frac{(11640)}{\tfrac{1}{2}\rho(17{,}440)(16.89)^2}$$

$C_R = 2.351 \times 10^{-3}$ CONSTANT C_R FOR SHIP SPEEDS LESS THAN 10 KT.

DESIGN CALCULATION SHEET

Subject HULL RESISTANCE CALCULATION - SCB-199 (FF 1037)

Ship or Project EMERGENCY TOWING GEAR CRITERIA

Section BSDD Prepared by RCS Date 10/29/75 Checked Reviewed

SHIP -

$$R_{ns} = \frac{V_s L}{\nu} = \frac{V_s (350)}{1.2791 \times 10^{-5}}$$

$$R_T = \tfrac{1}{2} \rho S V_K^2 C_{TS} (1.689)^2$$

$$R_T = \tfrac{1}{2} (1.9905) S V_K^2 C_{TS} (1.689)^2$$

TABLE FOR CALCULATION OF R_T

V_K KT.	V_S FT./SEC.	R_{ns} $\times 10^8$	C_F $\times 10^{-3}$	ΔC_F $\times 10^{-3}$	C_R $\times 10^{-3}$	C_{TS} $\times 10^{-3}$	R_T LB.	R_T/Δ LB./LT.
0	0	—	—	—	—	—	0	0
1	1.689	0.4622	2.135	0.9	2.351	5.386	267	0.097
2	3.378	0.9244	2.095	"	"	5.346	1059	0.389
3	5.067	1.387	1.980	"	"	5.231	2331	0.855
4	6.756	1.848	1.904	"	"	5.155	4084	1.499
5	8.445	2.311	1.847	"	"	5.098	6311	2.316
6	10.134	2.773	1.803	"	"	5.054	9009	3.306
7	11.823	3.235	1.766	"	"	5.017	12172	4.467
8	13.512	3.698	1.736	"	"	4.987	15804	5.80
9	15.201	4.160	1.710	"	"	4.961	19897	7.302
10	16.89	—	—	—	—	—	24450	8.972
11	18.579	—	—	—	—	—	29636	10.876
12	20.268	—	—	—	—	—	~~65558~~	BAD DATA
13	21.957	—	—	—	—	—	46392	17.02

DESIGN CALCULATION SHEET

Subject: HULL RESISTANCE & PROPELLER DATA SHEET

Ship or Project: EMERGENCY TOWING GEAR CRITERIA

Section: BSDD Prepared by: Date: Checked: Reviewed:

SHIP CLASS: FF 1040 OR DE 1040

DATA SOURCE:

SHIP CHARACTERISTICS

LWL = 39[illegible]'
B = 44.2'
T = 14.0'
Δ = 3131
WS =
C_P =
EHP/SHP =
ΔC_F = 0.0006

PROPELLER CHARACTERISTICS

DIA. = 15.0
PITCH = 15.12
# BLADES = 5
EXP. A./D.A. =
EXPANDED AREA =
DEVELOPED AREA = 153.1
~~PROJ. AREA~~ / D.A. =
PROJECTED AREA = 131.3
PROPELLERS = 1

V KNOTS	SHP	EHP/SHP	EHP	R_T POUNDS	$EHP_{FRIC.}$
7			200		
8			250		
9			400		
10			700		
12			1500		
14			2200		

DESIGN CALCULATION SHEET

Subject: HULL RESISTANCE CALCULATION - DE 1040 (FF 1040)

Project: EMERGENCY TOWING GEAR CRITERIA

Section: BSDD Prepared by: RCS Date: 10/29/75 Checked: Reviewed:

SHIP -

CALCULATION FOR MAX. SPEED WHERE C_R IS CONSTANT

$$V_K = 0.55\sqrt{LWL} = 10.86 \quad \underline{\text{USE } 7 \text{ KT.}}$$

$$R_T = \frac{EHP \times 326}{V_K} = 9314$$

$$V_s = 1.687\ V_K = 11.823$$

$$R_n = \frac{V_s L}{\nu} = \frac{(11.823)(390)}{1.2791 \times 10^{-5}} = 3.604 \times 10^{8}$$

$$C_f = 1.742 \times 10^{-3} \quad \text{(SCHOENHERR COEFF.)}$$

Assume C_x = 0.97

$$\Delta C_f = 0.6 \times 10^{-3}$$

B_x/H_x = 3.157 $\quad C_s = 2.66$

$$C_{f_T} = 2.342 \times 10^{-3}$$

$$S = C_s\sqrt{\nabla \cdot LWL} = 2.66\sqrt{109585 \cdot 390} = 17{,}390$$

$$R_F = \tfrac{1}{2}\rho\, S\, V_s^2\, C_{f_T}$$
$$= \tfrac{1}{2}(1.9905)(17{,}390)(11.823)^2(2.342 \times 10^{-3})$$
$$5666$$

$$R_R = R_T - R_F = 3648$$

$$C_R = \frac{(3648)}{\tfrac{1}{2}\rho(17{,}390)(11.823)^2}$$

$$C_R = 1.508$$

CONSTANT C_R FOR SHIP SPEEDS LESS THAN <u>7 KT.</u>

Subject HULL RESISTANCE CALCULATION - DE 1040 (FF 1040)

Ship or Project EMERGENCY TOWING GEAR CRITERIA

Section BSDD Prepared by Date Checked Reviewed

SHIP - DE 1040 (FF 1040)

$$R_{ns} = \frac{V_s L}{\nu} = \frac{V_s (390)}{1.2791 \times 10^{-5}}$$

$$R_T = \tfrac{1}{2} \rho S V_K^2 C_{TS} (1.687)^2$$

$$R_T = \tfrac{1}{2} (1.9905) S V_K^2 C_{TS} (1.689)^2$$

TABLE FOR CALCULATION OF R_T

V_K KT.	V_S FT./SEC.	R_{ns} $\times 10^8$	C_F $\times 10^{-3}$	ΔC_F $\times 10^{-3}$	C_R $\times 10^{-3}$	C_{TS} $\times 10^{-3}$	R_T LB.	R_T/Δ LB./LT.
0	0	—	—	—	—	—	0	0
1	1.689	.515	2.279	0.6	1.508	4.387	217	0.069
2	3.378	1.030	2.063	"	"	4.171	824	0.263
3	5.067	1.545	1.951	"	"	4.059	1804	0.576
4	6.756	2.060	1.871	"	"	3.979	3143	1.004
5	8.445	2.575	1.821	"	"	3.929	4850	1.549
6	10.134	3.09	1.778	"	"	3.886	6907	2.206
7	11.823	—	—	—	—	—	9314	2.975
8	13.512	—	—	—	—	—	10188	3.254
9	15.201	—	—	—	—	—	14489	4.627
10	16.89	—	—	—	—	—	22820	7.288
11	18.579	—	—	—	—	—	—	
12	20.268	—	—	—	—	—	40750	13.015
13	21.957	—	—	—	—	—	—	

DESIGN CALCULATION SHEET

Subject: HULL RESISTANCE & PROPELLER DATA SHEET

Ship or Project: EMERGENCY TOWING GEAR CRITERIA

Section: BSDD Prepared by Date Checked Reviewed

SHIP CLASS: DD 931

DATA SOURCE: Ref. 1

SHIP CHARACTERISTICS

LWL = 407

B = 44.4

T = 14.52

Δ = 3890

WS = 20,600

C_P =

EHP/SHP =

ΔC_F = 0.001141

9.445

PROPELLER CHARACTERISTICS

DIA. = 13.25'

PITCH = 13.84

BLADES = 4

EXP. A./D.A. =

EXPANDED AREA =

DEVELOPED AREA =

PROJ. ~~AREA~~/D.A. = 0.706

PROJECTED AREA = 97.37

PROPELLERS = 2

V KNOTS	SHP	EHP/SHP	EHP	R_T POUNDS	$EHP_{FRIC.}$
11			850		
12			1300		
14			2300		
16			3300		
18			4600		

Subject: HULL RESISTANCE CALCULATION - DD 931

Ship or Project: EMERGENCY TOWING GEAR CRITERIA

Section: BSDD Prepared by: RCS Date: 10/28/75 Checked Reviewed

SHIP -

CALCULATION FOR MAX. SPEED WHERE C_R IS CONSTANT

$$V_K = 0.55\sqrt{LWL} = 11.09\ KT.$$ USE EXTRAPOLATED EHP DATA FOR 11 KT.

$$R_T = \frac{EHP \times 326}{V_K} = 25{,}191$$

$$V_S = 1.687\ V_K = 18.579$$

$$R_n = \frac{V_S L}{\nu} = \frac{(18.579)(407)}{1.2791 \times 10^{-5}} = 5.912 \times 10^{8}$$

$$C_f = 1.635 \times 10^{-3}$$ (SCHOENHERR COEFF.)

$$\Delta C_f = 1.141 \times 10^{-3}$$

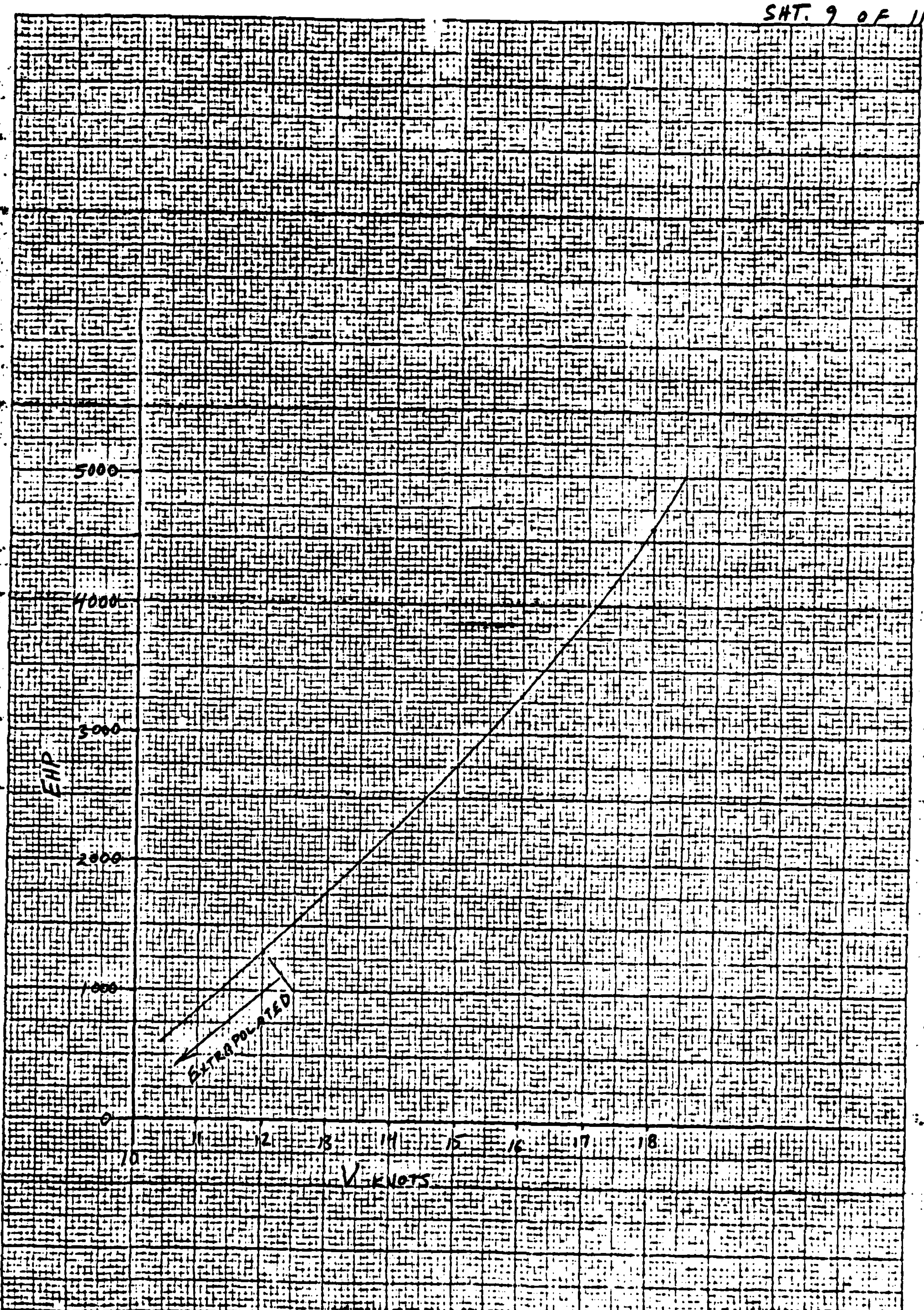
$$C_{f_T} = 2.776 \times 10^{-3}$$

$$R_F = \tfrac{1}{2}\rho\, S\, V_s^2\, C_{f_T}$$
$$= \tfrac{1}{2}(1.9905)(20{,}600)(18.579)^2(2.776 \times 10^{-3})$$
$$= 19{,}646$$

$$R_R = R_T - R_F = 5545$$

$$C_R = \frac{(5545)}{\tfrac{1}{2}\rho(20600)(18.579)^2}$$

$$C_R = 0.784 \times 10^{-3}$$ CONSTANT C_R FOR SHIP SPEEDS LESS THAN 11 KT.


5000
4000
3000
2000
1000
0
EHP
EXTRAPOLATED
10
11
12
13
14
15
16
17
18
V-KNOTS

DESIGN CALCULATION SHEET

Subject: HULL RESISTANCE CALCULATION - DD 931

Ship or Project: EMERGENCY TOWING GEAR CRITERIA

Section: BSDD Prepared by: RCS Date: 10/28/75 Checked: Reviewed:

SHIP -

$$R_{ns} = \frac{V_s L}{\nu} = \frac{V_s (407)}{1.2791 \times 10^{-5}}$$

$$R_T = \tfrac{1}{2} \rho S V_K^2 C_{TS} (1.689)^2$$

$$R_T = \tfrac{1}{2} (1.9905) S V_K^2 C_{TS} (1.689)^2$$

TABLE FOR CALCULATION OF R_T

V_K KT.	V_S FT./SEC.	R_{ns} $\times 10^8$	C_F $\times 10^{-3}$	ΔC_F $\times 10^{-3}$	C_R $\times 10^{-3}$	C_{TS} $\times 10^{-3}$	R_T LB.	R_T/Δ LB./LT.
0	0	—	—	—	—	—	0	0
1	1.689	0.5374	2.265	1.141	0.784	4.190	245	0.063
2	3.378	1.075	2.051	"	"	3.976	930	0.239
3	5.067	1.612	1.940	"	"	3.865	2034	0.523
4	6.756	2.150	1.865	"	"	3.790	3547	0.919
5	8.445	2.687	1.810	"	"	3.735	5461	1.404
6	10.134	3.224	1.768	"	"	3.693	7776	1.999
7	11.823	3.762	1.734	"	"	3.659	10486	2.696
8	13.512	4.299	1.703	"	"	3.628	13581	3.491
9	15.201	4.837	1.677	"	"	3.602	17064	4.387
10	16.89	5.374	1.655	"	"	3.580	20938	5.383
11	18.579	5.911	1.635	"	"	3.560	25191	6.476
12	20.268	—	—	—	—	—	35317	9.079
13	21.957	—						

M. Rosenblatt & Son, Inc.
DESIGN CALCULATION SHEET

No. 3419
Sheet 11 of 118

Subject: HULL RESISTANCE & PROPELLER DATA SHEET
Ship or Project: EMERGENCY TOWING GEAR CRITERIA
Section: BSDD Prepared by: RCS Date: 12/2/75 Checked: Reviewed:

SHIP CLASS: DLG 16

DATA SOURCE: Ref. 1

SHIP CHARACTERISTICS

LWL = 510
B = 51
T = 18
Δ = 6800
WS = 30980
C_p =
EHP/SHP =
ΔC_F = 0.000955

PROPELLER CHARACTERISTICS

DIA. = 14.0
PITCH = 13.95
# BLADES = 5
EXP. A./D.A. = 0.995
EXPANDED AREA =
DEVELOPED AREA =
PROJ. AREA/D.A. =
PROJECTED AREA =
PROPELLERS = 2

V KNOTS	SHP	EHP/SHP	EHP	R_T POUNDS	$EHP_{FRIC.}$
10			1000		
11			1100		
12			2000		
13			2100		
14			3000		
15			3500		

DESIGN CALCULATION SHEET

Subject HULL RESISTANCE CALCULATION - DLG 16

Ship or Project EMERGENCY TOWING GEAR CRITERIA

Section BSDD **Prepared by** RCS **Date** **Checked** **Reviewed**

SHIP - DLG 16

CALCULATION FOR MAX. SPEED WHERE C_R IS CONSTANT

$$V_K = 0.55\sqrt{LWL} = 12.42 \quad \underline{\text{USE 10 KT.}}$$

$$R_T = \frac{EHP \times 326}{V_K} = 32600$$

$$V_S = 1.687\ V_K = 16.89$$

$$R_n = \frac{V_S L}{\nu} = \frac{(16.89)(510)}{1.2791 \times 10^{-5}} = 6.734 \times 10^{8}$$

$$C_f = 1.608 \times 10^{-3} \quad \text{(SCHOENHERR COEFF.)}$$

$$\Delta C_f = 0.955 \times 10^{-3}$$

$$C_{f_T} = 2.563 \times 10^{-3}$$

$$R_F = \tfrac{1}{2}\rho\, S\, V_S^2\, C_{F_T}$$
$$= \tfrac{1}{2}(1.9905)(30980)(16.89)^2(2.563 \times 10^{-3})$$
$$= 22543$$

$$R_R = R_T - R_F = 10057$$

$$C_R = \frac{(10057)}{\tfrac{1}{2}\rho(30980)(16.89)^2}$$

$$C_R = 1.143$$

CONSTANT C_R FOR SHIP SPEEDS LESS THAN <u>10 KT.</u>

No. 3419

DESIGN CALCULATION SHEET

Sheet 13 of 113

Subject HULL RESISTANCE CALCULATION - DLG 24 (DLG 16)

Ship or Project EMERGENCY TOWING GEAR CRITERIA

Section BSDD Prepared by RCS Date 10/29/75 Checked Reviewed

SHIP -

$$R_{ns} = \frac{V_s L}{\nu} = \frac{V_s (510)}{1.2791 \times 10^{-5}}$$

$$R_T = \tfrac{1}{2} \rho S V_K^2 C_{TS} (1.689)^2$$

$$R_T = \tfrac{1}{2} (1.9905) S V_K^2 C_{TS} (1.689)^2$$

TABLE FOR CALCULATION OF R_T

V_K KT.	V_S FT./SEC.	R_{ns} $\times 10^8$	C_F $\times 10^{-3}$	ΔC_F $\times 10^{-3}$	C_R $\times 10^{-3}$	C_{TS} $\times 10^{-3}$	R_T LB.	R_T/Δ LB./LT.
0	0	—	—	—	—	—	0	0
1	1.689	0.6734	2.192	0.955	1.143	4.290	377	0.055
2	3.378	1.347	1.987	"	"	4.085	1437	0.211
3	5.067	2.020	1.881	"	"	3.979	3150	0.463
4	6.756	2.694	1.810	"	"	3.908	5500	0.809
5	8.445	3.367	1.757	"	"	3.855	8477	1.247
6	10.134	4.041	1.716	"	"	3.814	12077	1.776
7	11.823	4.714	1.683	"	"	3.781	16296	2.396
8	13.512	5.387	1.654	"	"	3.752	21121	3.106
9	15.201	6.061	1.630	"	"	3.728	26560	3.906
10	16.89	—	—	—	—	—	32600	4.794
11	18.579	—	—	—	—	—	—	—
12	20.268	—	—	—	—	—	54333	7.99
13	21.957	—	—	—	—	—	—	—

M. Rosenblatt & Son, Inc.

DESIGN CALCULATION SHEET

No. 3419

Sheet 14 of 118

Subject: HULL RESISTANCE & PROPELLER DATA SHEET

Ship or Project: EMERGENCY TOWING GENR CRITERIA

Section: B3DD Prepared by Date Checked Reviewed

SHIP CLASS: DLGN-25 (CGN-25)

DATA SOURCE:

SHIP CHARACTERISTICS

LWL = 540.0

B = 56.66

T = 18.89

Δ = 7,800

WS = ?

C_P =

EHP/SHP =

ΔC_F = 0.000872

PROPELLER CHARACTERISTICS

DIA. = 15.0 FT.

PITCH = 15.71 FT.

BLADES = 5

EXP. A./D.A. =

EXPANDED AREA =

DEVELOPED AREA = 141.6

PROJ. AREA/D.A. = 119.3

PROJECTED AREA =

PROPELLERS = 2

V KNOTS	SHP	EHP/SHP	EHP	R_T POUNDS	$EHP_{FRIC.}$
11			1,500		
12			2000		
13			2500		
14			3000		
15			3700		

DESIGN CALCULATION SHEET

Subject: HULL RESISTANCE CALCULATION - DLGN-25 (CGN-25)

Ship or Project: EMERGENCY TOWING GEAR CRITERIA

Section: BSDD   Prepared by: RCS   Date: 10/30/75   Checked   Reviewed

SHIP - DLGN-25 (CGN-25)

CALCULATION FOR MAX. SPEED WHERE C_R IS CONSTANT

$$V_K = 0.55\sqrt{LWL} = 12.78$$ USE 11 KT.

$$R_T = \frac{EHP \times 326}{V_K} = 44{,}455$$

$$V_S = 1.687\ V_K = 18.579$$

$$R_n = \frac{V_s L}{\nu} = \frac{(18.579)(540)}{1.2791 \times 10^{-5}} = 7.844 \times 10^{8}$$

$C_f = 1.578 \times 10^{-3}$ (SCHOENHERR COEFF.)

$\Delta C_f = 0.872 \times 10^{-3}$ $C_x = 0.97$ ASSUMED

$C_{f_T} = 2.450 \times 10^{-3}$ $B/H = 2.999$ $C_s = 2.632$

$$S = C\sqrt{\nabla \cdot LWL} = 2.632\sqrt{7800(35)(540)} = 31{,}957$$

$$R_F = \tfrac{1}{2}\rho\, S\, V_s^2\, C_{f_T}$$
$$= \tfrac{1}{2}(1.9905)(31{,}957)(18.579)^2(2.45 \times 10^{-3})$$
$$= 26897$$

$$R_R = R_T - R_F = 17558$$

$$C_R = \frac{(17558)}{\tfrac{1}{2}\rho(31957)(18.579)^2}$$

$C_R = 1.599 \times 10^{-3}$ CONSTANT C_R FOR SHIP SPEEDS LESS THAN 11 KT.

Subject: HULL RESISTANCE CALCULATION – DLGN-25 (CGN-25)

Ship or Project: EMERGENCY TOWING GEAR CRITERIA

Section: BSDD   Prepared by: RCS   Date: 10/30/75   Checked: Reviewed:

SHIP – DLGN-25 (CGN-25)

$$R_{ns} = \frac{V_s L}{\nu} = \frac{V_s (540)}{1.2791 \times 10^{-5}}$$

$$R_T = \tfrac{1}{2} \rho S V_k^2 C_{TS} (1.689)^2$$

$$R_T = \tfrac{1}{2} (1.9905) S V_k^2 C_{TS} (1.689)^2$$

TABLE FOR CALCULATION OF R_T

V_K KT.	V_S FT./SEC.	R_{ns} $\times 10^8$	C_F $\times 10^{-3}$	ΔC_F $\times 10^{-3}$	C_R $\times 10^{-3}$	C_{TS} $\times 10^{-3}$	R_T LB.	R_T/Δ LB./LT.
0	0	—	—	—	—	—	0	0
1	1.689	0.7130	2.174	0.872	1.599	4.645	421	0.054
2	3.378	1.426	1.972	"	"	4.443	1612	0.207
3	5.067	2.139	1.866	"	"	4.337	3542	0.454
4	6.756	2.852	1.797	"	"	4.268	6196	0.794
5	8.445	3.565	1.744	"	"	4.215	9561	1.226
6	10.134	4.278	1.704	"	"	4.175	13637	1.748
7	11.823	4.991	1.670	"	"	4.141	18410	2.360
8	13.512	5.704	1.642	"	"	4.113	23,883	3.062
9	15.201	6.417	1.618	"	"	4.089	30051	3.853
10	16.89	7.130	1.597	"	"	4.068	36910	4.732
11	18.579	—	—	—	—	—	44455	5.699
12	20.268	—	—	—	—	—	54333	6.966
13	21.957	—	—	—	—	—	62692	8.037

M. Rosenblatt & Son, Inc. No. 3419
DESIGN CALCULATION SHEET Sheet 17 of 118

Subject: HULL RESISTANCE & PROPELLER DATA SHEET
Ship or Project: EMERGENCY TOWING GEAR CRITERIA
Section: BSDD Prepared by: RCS Date: 12/5/75 Checked: Reviewed:

SHIP CLASS: CG(N) 9

DATA SOURCE: Ref. 1

SHIP CHARACTERISTICS

LWL = 691.8
B = 71.0
T = 21.5
Δ = 14,080
WS = 52,600
C_p =
EHP/SHP =
ΔC_F = 0.00078

PROPELLER CHARACTERISTICS

DIA. = 17.0
PITCH = 19.35
# BLADES = 4
EXP. A./D.A. = 0.834
EXPANDED AREA = 189.3
DEVELOPED AREA =
PROJ. AREA/D.A. =
PROJECTED AREA =
PROPELLERS = 2

V KNOTS	SHP	EHP/SHP	EHP	R_T POUNDS	EHP FRIC.
14			4000		
15			5000		
16			6500		

Subject HULL RESISTANCE CALCULATION - CG(N) 9

Ship or Project EMERGENCY TOWING GEAR CRITERIA

Section BSDD Prepared by RCS Date 10/28/75 Checked Reviewed

SHIP -

CALCULATION FOR MAX. SPEED WHERE C_R IS CONSTANT

$$V_K = 0.55 \sqrt{LWL} = 14.47 \text{ KT.} \quad \underline{\text{USE 14 KT.}}$$

$$R_T = \frac{EHP \times 326}{V_K} = 93143$$

$$V_S = 1.687 \; V_K = 23.646$$

$$R_n = \frac{V_S L}{\nu} = \frac{(23.646)(691.8)}{1.2791 \times 10^{-5}} = 1.2789 \times 10^9$$

$$C_f = 1.486 \times 10^{-3} \quad \text{(SCHOENHERR COEFF.)}$$

$$\Delta C_f = 0.78 \times 10^{-3}$$

$$C_{fT} = 2.266 \times 10^{-3}$$

$$R_F = \tfrac{1}{2} \rho \, S \, V_S^2 \, C_{fT}$$

$$= \tfrac{1}{2} (1.9905)(52{,}600)(23.464)^2 (2.266 \times 10^{-3})$$

$$= 66552$$

$$R_R = R_T - R_F = 26591$$

$$C_R = \frac{(26591)}{\tfrac{1}{2}\rho (52{,}600)(23.646)^2}$$

$C_R = 0.908 \times 10^{-3}$ CONSTANT C_R FOR SHIP SPEEDS LESS THAN 14 KT.

DESIGN CALCULATION SHEET

Subject HULL RESISTANCE CALCULATION - CG(N) 9

Ship or Project EMERGENCY TOWING GEAR CRITERIA

Section BSDD **Prepared by** RCS **Date** 10/28/75 **Checked** **Reviewed**

SHIP -

$$R_{ns} = \frac{V_s L}{\nu} = \frac{V_s (691.8)}{1.2791 \times 10^{-5}}$$

$$R_T = \tfrac{1}{2} \rho S V_K^2 C_{TS} (1.689)^2$$

$$R_T = \tfrac{1}{2} (1.9905) S V_K^2 C_{TS} (1.689)^2$$

TABLE FOR CALCULATION OF R_T

V_K KT.	V_S FT./SEC.	R_{ns} $\times 10^8$	C_F $\times 10^{-3}$	ΔC_F $\times 10^{-3}$	C_R $\times 10^{-3}$	C_{TS} $\times 10^{-3}$	R_T LB.	R_T/Δ LB./LT.
0	0	—	—	—	—	—	0	0
1	1.689	0.9135	2.098	0.78	0.908	3.786	565	0.040
2	3.378	1.827	1.906	"	"	3.594	2147	0.152
3	5.067	2.741	1.806	"	"	3.494	4696	0.334
4	6.756	3.654	1.739	"	"	3.427	8189	0.582
5	8.445	4.568	1.689	"	"	3.377	12608	0.895
6	10.134	5.481	1.651	"	"	3.339	17951	1.275
7	11.823	6.395	1.618	"	"	3.306	24192	1.718
8	13.512	7.309	1.592	"	"	3.280	31,350	2.227
9	15.201	8.222	1.568	"	"	3.256	39,386	2.797
10	16.89	9.135	1.548	"	"	3.236	48327	3.432
11	18.579	10.049	1.530	"	"	3.218	58150	4.130
12	20.268	10.962	1.514	"	"	3.202	68859	4.891
13	21.957	11.876	1.499	"	"	3.187	80435	5.713

DESIGN CALCULATION SHEET

Subject: HULL RESISTANCE & PROPELLER DATA SHEET

Ship or Project: EMERGENCY TOWING GEAR CRITERIA

Section: BSDD Prepared by: RCS Date: 12/5/75 Checked: Reviewed:

SHIP CLASS: CA 139

DATA SOURCE: USED TEST 5

SHIP CHARACTERISTICS

LWL = 700
B = 75.4
T = 25.6
Δ = 20,950
WS = 61,884
C_p =
EHP/SHP =
ΔC_F = ———

PROPELLER CHARACTERISTICS

DIA. = 12.66
PITCH = 13.16
# BLADES = 4
EXP. A./D.A. =
EXPANDED AREA =
DEVELOPED AREA =
PROJ. AREA/D.A. = 0.65
PROJECTED AREA = 81.82
PROPELLERS = 4

V KNOTS	SHP	EHP/SHP	EHP	R_T POUNDS	EHP FRIC. GEBER'S FORM
10			1300		900
12			2500		1600
14			4100		2600

Subject: HULL RESISTANCE CALCULATION - CA-139
Ship or Project: EMERGENCY TOWING GEAR CRITERIA
Section: BSDD Prepared by: RCS Date: 10/24/75 Checked: Reviewed:

SHIP - CA-139

CALCULATION FOR MAX. SPEED WHERE C_R IS CONSTANT

$$V_K = 0.55\sqrt{LWL} = 14.55 \quad \text{USE 10 KT.}$$

$$R_T = \frac{EHP \times 326}{V_K} = \frac{1300 \times 326}{10} = 42380$$

$$V_s = 1.687\ V_K = 16.89$$

$$R_n = \frac{V_s L}{\nu} = \frac{(16.89)(700)}{1.2791 \times 10^{-5}} = 9.243 \times 10^8$$

C_f = ____ (SCHOENHERR COEFF.)

ΔC_f = ?____

C_{fT} = ____

$$R_F = \tfrac{1}{2}\rho\, S\, V_s^2\, C_{FT}$$
$$= \tfrac{1}{2}(1.9905)(\quad)(\quad)^2(\quad)$$
$$= \_\_\_\_$$

$$R_F = \frac{EHP \times 326}{10} = \frac{900 \times 326}{10} = 29,340$$

$$R_R = R_T - R_F = 13,040$$

$$C_R = \frac{(13,040)}{\tfrac{1}{2}\rho(61884)(16.89)^2}$$

$C_R = 0.742 \times 10^{-3}$ CONSTANT C_R FOR SHIP SPEEDS LESS THAN 10 KT.

Subject: HULL RESISTANCE CALCULATION – CA-139

Ship or Project: EMERGENCY TOWING GEAR CRITERIA

Section: BSDD Prepared by: RCS Date: 10/24/75 Checked: Reviewed:

SHIP – CA-139

$$R_{ns} = \frac{V_s L}{\nu} = \frac{V_s (700)}{1.2791 \times 10^{-5}}$$

$$R_T = \tfrac{1}{2} \rho S V_K^2 C_{TS} (1.689)^2$$

$$R_T = \tfrac{1}{2} (1.9905) S V_K^2 C_{TS} (1.689)^2$$

TABLE FOR CALCULATION OF R_T

V_K KT.	V_S FT./SEC.	R_{ns} $\times 10^8$	C_F $\times 10^{-3}$	ΔC_F $\times 10^{-3}$	C_R $\times 10^{-3}$	C_{TS} $\times 10^{-3}$	R_T LB.	R_T/Δ LB./LT.
				ASSUMED				
0	0	—	—	—	—	—	0	0
1	1.689	0.9243	2.095	0.40	0.742	3.237	568	0.027
2	3.378	1.849	1.905	"	"	3.047	2140	0.102
3	5.067	2.773	1.803	"	"	2.945	4654	0.222
4	6.756	3.697	1.736	"	"	2.878	8085	0.386
5	8.445	4.622	1.687	"	"	2.829	12418	0.593
6	10.134	5.546	1.648	"	"	2.79	17636	0.842
7	11.823	6.470	1.616	"	"	2.758	23729	1.133
8	13.512	7.395	1.589	"	"	2.731	30690	1.465
9	15.201	8.319	1.566	"	"	2.708	38514	1.838
10	16.89	—	—	—	—	—	42380	2.023
11	18.579	—	—	—	—	—	—	—
12	20.268	—	—	—	—	—	67917	3.242
13	21.957	—	—	—	—	—	—	

Subject: HULL RESISTANCE & PROPELLER DATA SHEET
Ship or Project: EMERGENCY TOWING GEAR CRITERIA
Section: BSDD Prepared by Date Checked Reviewed

SHIP CLASS: MSO 422

DATA SOURCE: AM 421 FILE JULY 28, 1950 TEST

SHIP CHARACTERISTICS

LWL = 165.2
B = 34.6
T = 10.5
Δ = 880
WS = 6230
C_p =
EHP/SHP =
ΔC_F = 0.0004

PROPELLER CHARACTERISTICS

DIA. = 6.50'
PITCH = 6.0'
# BLADES = 4
EXP. A./D.A. =
EXPANDED AREA =
DEVELOPED AREA =
PROJ. AREA/D.A. = 0.607
PROJECTED AREA =
PROPELLERS = 2

V KNOTS	SHP	EHP/SHP	EHP	R_T POUNDS	EHP FRIC. SCHOENHERR FORMULA
5			22		15
6			38		26
7			60		42
8			92		62
9			138		91
10			205(?)		120 ?
11			297		162
12			433		208
13			620		262

SHIP - MSO 422

CALCULATION FOR MAX. SPEED WHERE C_R IS CONSTANT

$$V_K = 0.55\sqrt{LWL} = 12.85 \quad \text{USE } 5\text{ KT.}$$

$$R_T = \frac{EHP \times 326}{V_K} = 1434.4$$

$$V_S = 1.687\, V_K = 8.445$$

$$R_n = \frac{V_S L}{\nu} = \frac{(8.445)(165.2)}{1.2791 \times 10^{-5}} = 1.091 \times 10^{8}$$

$$C_f = 2.047 \times 10^{-3} \quad \text{(SCHOENHERR COEFF.)}$$

$$\Delta C_f = 0.4 \times 10^{-3}$$

$$C_{fT} = 2.447 \times 10^{-3}$$

USE THIS → $C_{fT} = 2.212 \times 10^{-3}$ (CALCULATED FROM EHP FRIC. RESISTANCE)

$$R_F = \tfrac{1}{2}\rho\, S\, V_S^2\, C_{fT}$$
$$= \tfrac{1}{2}(1.9905)(6230)(8.445)^2(2.212 \times 10^{-3})$$
$$= 978.15$$

$$R_R = R_T - R_F = 456.3$$

$$C_R = \frac{(456.3)}{\tfrac{1}{2}\rho(6230)(8.445)^2}$$

$C_R = 1.032 \times 10^{-3}$ CONSTANT C_R FOR SHIP SPEEDS LESS THAN 5 KT.

M. Rosenblatt & Son, Inc.

DESIGN CALCULATION SHEET

No. 3414

Sheet 25 of 118

Subject: HULL RESISTANCE CALCULATION - MSO 422

Ship or Project: EMERGENCY TOWING GEAR CRITERIA

Section: BSDD Prepared by: RCS Date: 10/24/75 Checked: Reviewed:

SHIP - MSO 422

$$R_{ns} = \frac{V_s L}{\nu} = \frac{V_s (165.2)}{1.2791 \times 10^{-5}}$$

$$R_T = \tfrac{1}{2} \rho S V_K^2 C_{TS} (1.689)^2$$

$$R_T = \tfrac{1}{2} (1.9905) S V_K^2 C_{TS} (1.689)^2$$

TABLE FOR CALCULATION OF R_T

V_K KT.	V_S FT./SEC.	R_{ns} $\times 10^8$	C_F $\times 10^{-3}$	ΔC_F $\times 10^{-3}$	C_R $\times 10^{-3}$	C_{TS} $\times 10^{-3}$	R_T LB.	R_T/Δ LB/LT.
0	0	—	—	—	—	—	0	0
1	1.689	0.2181	2.595	0.40	1.032	4.027	71.23	0.081
2	3.378	0.4363	2.335	"	"	3.767	266.5	0.303
3	5.067	0.6544	2.201	"	"	3.633	578.3	0.657
4	6.756	0.8726	2.191	"	"	3.623	1025.3	1.165
5	8.445	1.091	—	—	—	—	1434.4	1.63
6	10.134	1.309	—	—	—	—	2065	2.347
7	11.823	1.527	—	—	—	—	2794	3.175
8	13.512	1.745	—	—	—	—	3749	4.260
9	15.201	1.963	—	—	—	—	4999	5.681
10	16.89	2.181	—	—	—	—	6683	7.594
11	18.579	2.400	—	—	—	—	8802	10.002
12	20.268	2.618	—	—	—	—	11763	13.367
13	21.957	2.836	—	—	—	—	15548	17.668

M. Rosenblatt & Son, Inc.
DESIGN CALCULATION SHEET

No. 3419

Subject HULL RESISTANCE & PROPELLER DATA SHEET
Ship or Project EMERGENCY TOWING GEAR CRITERIA
Section B3DD Prepared by RCS Date 12/5/75 Checked Reviewed

SHIP CLASS: ATF-148

DATA SOURCE:

SHIP CHARACTERISTICS

LWL = 224
B = 44.9
T = 15.75
Δ = 2080
WS = 10,654
C_P = 0.566
EHP/SHP =
ΔC_F = 0.0006

PROPELLER CHARACTERISTICS

DIA. = 13.0'
PITCH = 13.0'
# BLADES = 4
EXP. A./D.A. = 0.541
EXPANDED AREA =
DEVELOPED AREA =
PROJ. AREA/D.A. =
PROJECTED AREA =
PROPELLERS = 1

V KNOTS	SHP	EHP/SHP	EHP	R_T POUNDS	$EHP_{FRIC.}$
6			90		
7			160		
8			220		
9			310		
10			420		
11			570		
12			750		
13			980		

Subject: HULL RESISTANCE CALCULATION - ATF 148

Ship or Project: EMERGENCY TOWING GEAR CRITERIA

Section: BSDD Prepared by: RCS Date: 10/24/75 Checked: Reviewed:

SHIP - AFT - 148

CALCULATION FOR MAX. SPEED WHERE C_R IS CONSTANT

$$V_K = 0.55\sqrt{LWL} = 8.23 \quad \text{USE } \underline{6 \text{ KT.}}$$

$$R_T = \frac{EHP \times 326}{V_K} = \frac{90 \times 326}{6} = 4890$$

$$V_s = 1.687\ V_K = 10.134$$

$$R_n = \frac{V_s L}{\nu} = \frac{(10.134)(224)}{1.2791 \times 10^{-5}} = 1.775 \times 10^{8}$$

$$C_f = 1.914 \times 10^{-3} \quad \text{(SCHOENHERR COEFF.)}$$

$$\Delta C_f = 0.60 \times 10^{-3}$$

$$C_{f_T} = 2.514 \times 10^{-3}$$

$$R_F = \tfrac{1}{2}\rho\, S\, V_s^2\, C_{f_T}$$
$$= \tfrac{1}{2}(1.9905)(10{,}654)(10.134)^2(2.514 \times 10^{-3})$$
$$= 27381$$

$$R_R = R_T - R_F = 2152$$

$$C_R = \frac{(2152)}{\tfrac{1}{2}\rho(10{,}654)(10.134)^2}$$

$$C_R = 1.986 \times 10^{-3}$$ CONSTANT C_R FOR SHIP SPEEDS LESS THAN 6 KT.

Subject: HULL RESISTANCE CALCULATION - ATF - 148

Ship or Project: EMERGENCY TOWING GEAR CRITERIA

Section: BSDD Prepared by: RCS Date: 10/24/75 Checked: Reviewed:

SHIP - ATF - 148

$$R_{ns} = \frac{V_s L}{\nu} = \frac{V_s (224)}{1.2791 \times 10^{-5}}$$

$$R_T = \tfrac{1}{2} \rho\, S\, V_K^2\, C_{TS}\, (1.689)^2$$

$$R_T = \tfrac{1}{2} (1.9905)\, S\, V_K^2\, C_{TS}\, (1.689)^2$$

TABLE FOR CALCULATION OF R_T

V_K KT.	V_S FT./SEC.	R_{ns} $\times 10^8$	C_F $\times 10^{-3}$	ΔC_F $\times 10^{-3}$	C_R $\times 10^{-3}$	C_{TS} $\times 10^{-3}$	R_T LB.	R_T/Δ LB./LT.
0	0	—	—	—	—	—	0	0
1	1.689	0.2958	2.475	0.60	1.986	5.061	153	0.074
2	3.378	0.5916	2.233	"	"	4.819	583	0.280
3	5.067	0.8873	2.107	"	"	4.693	1278	0.614
4	6.756	1.183	2.025	"	"	4.611	2232	1.073
5	8.445	1.479	1.962	"	"	4.548	3439	1.653
6	10.134	—	—	—	—	—	4890	2.351
7	11.823	—	—	—	—	—	7451	3.582
8	13.512	—	—	—	—	—	8965	4.310
9	15.201	—	—	—	—	—	11229	5.399
10	16.89	—	—	—	—	—	13692	6.583
11	18.579	—	—	—	—	—	16893	8.122
12	20.268	—	—	—	—	—	20375	9.796
13	21.957	—	—	—	—	—	24575	11.815

No. 3419
Sheet 29 of 11

DESIGN CALCULATION SHEET

Subject: HULL RESISTANCE & PROPELLER DATA SHEET
Ship or Project: EMERGENCY TOWING GENR CRITERIA
Section: BSDD Prepared by Date Checked Reviewed

SHIP CLASS: AGFF-1 OR AGDE-1

DATA SOURCE: TEST 14 MODEL 4881-1

SHIP CHARACTERISTICS

LWL = 390'
B = 43.7'
T = 14.7'
Δ = 3500 LT.
WS = 20,220 FT.²
C_P =
EHP/SHP =
ΔC_F = 0.0006

PROPELLER CHARACTERISTICS

DIA. = 15.0
PITCH = 15.71
\# BLADES = 5
EXP. A./D.A. =
EXPANDED AREA =
~~DEVELOPED~~ AREA =
PROJ. AREA/D.A. =
PROJECTED AREA = 262
\# PROPELLERS = 2

V KNOTS	SHP	EHP/SHP	EHP	R_T POUNDS	$EHP_{FRIC.}$
9			400		
10			700		
11			1050		
12			1400		
13			1800		
14			2250		
15			2700		

Subject: HULL RESISTANCE CALCULATION - AGDE-1 OR AGFF-1
Ship or Project: EMERGENCY TOWING GEAR CRITERIA
Section: BSDD Prepared by: RCS Date: 10/27/75 Checked: Reviewed:

SHIP - AGDE-1 (AGFF-1)

CALCULATION FOR MAX. SPEED WHERE C_R IS CONSTANT

$$V_K = 0.55\sqrt{LWL} = 10.86 \quad \underline{\text{USE } 9\text{ KT.}}$$

$$R_T = \frac{EHP \times 326}{V_K} = 14489$$

$$V_S = 1.689\ V_K = 15.201$$

$$R_n = \frac{V_S L}{\nu} = \frac{(15.201)(390)}{1.2791 \times 10^{-5}} = 4.635 \times 10^{8}$$

$$C_f = 1.687 \times 10^{-3} \quad \text{(SCHOENHERR COEFF.)}$$

$$\Delta C_f = 0.6 \times 10^{-3}$$

$$C_{f_T} = 2.287 \times 10^{-3}$$

$$R_F = \tfrac{1}{2}\rho\, S\, V_s^2\, C_{f_T}$$
$$= \tfrac{1}{2}(1.9905)(20{,}220)(15.201)^2(2.287 \times 10^{-3})$$
$$= 10635$$

$$R_R = R_T - R_F = 3854$$

$$C_R = \frac{(3854)}{\tfrac{1}{2}\rho(20{,}220)(15.201)^2}$$

$C_R = 0.828 \times 10^{-3}$ CONSTANT C_R FOR SHIP SPEEDS LESS THAN 9 KT.

Subject: HULL RESISTANCE CALCULATION – AGDE-1 (AGFF-1)

Ship or Project: EMERGENCY TOWING GEAR CRITERIA

Section: BSDD Prepared by: RCS Date: 10/27/75 Checked: Reviewed:

SHIP – AGDE-1 (AGFF-1)

$$R_{ns} = \frac{V_s L}{\nu} = \frac{V_s (390)}{1.2791 \times 10^{-5}}$$

$$R_T = \tfrac{1}{2} \rho S V_K^2 C_{TS} (1.689)^2$$

$$R_T = \tfrac{1}{2} (1.9905) S V_K^2 C_{TS} (1.689)^2$$

TABLE FOR CALCULATION OF R_T

V_K KT.	V_S FT./SEC.	R_{ns} $\times 10^8$	C_F $\times 10^{-3}$	ΔC_F $\times 10^{-3}$	C_R $\times 10^{-3}$	C_{TS} $\times 10^{-3}$	R_T LB.	R_T/Δ LB./LT.
	0	—	—	—	—	—	0	0
1	1.689	0.5150	2.279	0.6	0.828	3.707	213	0.061
2	3.378	1.030	2.063	"	"	3.491	802	0.229
3	5.067	1.545	1.951	"	"	3.379	1746	0.499
4	6.756	2.060	1.876	"	"	3.304	3035	0.867
5	8.445	2.575	1.820	"	"	3.248	4662	1.332
6	10.134	3.09	1.778	"	"	3.206	6626	1.893
7	11.823	3.605	1.742	"	"	3.170	8917	2.548
8	13.512	4.120	1.712	"	"	3.14	11537	3.296
9	15.201	—	—	—	—	—	14489	4.140
10	16.89	—	—	—	—	—	22820	6.52
11	18.579	—	—	—	—	—	31118	8.891
12	20.268	—	—	—	—	—	38033	10.867
13	21.957	—	—	—	—	—	45138	12.897

DESIGN CALCULATION SHEET

No. 3419
Sheet 32 of 118

Subject: HULL RESISTANCE & PROPELLER DATA SHEET

Ship or Project: EMERGENCY TOWING GEAR CRITERIA

Section: BSDD Prepared by Date Checked Reviewed

SHIP CLASS: T-AGS-29

DATA SOURCE:

SHIP CHARACTERISTICS

LPP (~~LWL~~) = 357
B = 54
T = 16
Δ = 4325
WS = 19470
C_p =
EHP/SHP =
ΔC_F = 0.0004

PROPELLER CHARACTERISTICS

DIA. = 10.98'
PITCH = 12.59'
# BLADES = 4
EXP. A./D.A. = 0.550
EXPANDED AREA = 68.47
DEVELOPED AREA =
PROJ. AREA/D.A. =
PROJECTED AREA =
PROPELLERS =

V KNOTS	SHP	EHP/SHP	EHP	R_T POUNDS	$EHP_{FRIC.}$
7			167		
8			244		
9			346		
10			475		
11			635		
12			827		
13			1061		

Subject HULL RESISTANCE CALCULATION - T-AGS-29
Ship or Project EMERGENCY TOWING GEAR CRITERIA
Section BSDD Prepared by RCS Date 10/29/75 Checked Reviewed

SHIP - T-AGS-29

CALCULATION FOR MAX. SPEED WHERE C_R IS CONSTANT

$$V_K = 0.55\sqrt{LWL} = 10.39 \quad \underline{\text{USE 7 KT.}}$$

$$R_T = \frac{EHP \times 326}{V_K} = 7777$$

$$V_s = 1.687\ V_K = 11.823$$

$$R_n = \frac{V_s L}{\nu} = \frac{(11.823)(357)}{1.2791 \times 10^{-5}} = 3.30 \times 10^8$$

$$C_f = 1.762 \times 10^{-3} \quad \text{(SCHOENHERR COEFF.)}$$

$$\Delta C_f = 0.4 \times 10^{-3}$$

$$C_{fT} = 2.162 \times 10^{-3}$$

$$R_F = \tfrac{1}{2}\rho\ S\ V_s^2\ C_{fT}$$

$$= \tfrac{1}{2}(1.9905)(19470)(11.823)^2(2.162 \times 10^{-3})$$

$$= 5856$$

$$R_R = R_T - R_F = 1921$$

$$C_R = \frac{(1921)}{\tfrac{1}{2}\rho(19470)(11.823)^2}$$

$$C_R = 0.709 \times 10^{-3}$$ CONSTANT C_R FOR SHIP SPEEDS LESS THAN 7 KT.

DESIGN CALCULATION SHEET

Subject: HULL RESISTANCE CALCULATION - T-AGS-29

Ship or Project: EMERGENCY TOWING GEAR CRITERIA

Section: BSDD Prepared by: RCS Date: 10/29/75 Checked: Reviewed:

SHIP -

$$R_{NS} = \frac{V_S L}{\nu} = \frac{V_S (357)}{1.2791 \times 10^{-5}}$$

$$R_T = \tfrac{1}{2} \rho \, S \, V_K^2 \, C_{TS} \, (1.687)^2$$

$$R_T = \tfrac{1}{2} (1.9905) \, S \, V_K^2 \, C_{TS} \, (1.689)^2$$

TABLE FOR CALCULATION OF R_T

V_K KT.	V_S FT./SEC.	R_{NS} $\times 10^8$	C_F $\times 10^{-3}$	ΔC_F $\times 10^{-3}$	C_R $\times 10^{-3}$	C_{TS} $\times 10^{-3}$	R_T LB.	R_T/Δ LB./LT.
0	0	—	—	—	—	—	0	0
1	1.689	0.4714	2.309	0.4	0.709	3.418	189	0.044
2	3.378	0.9428	2.089	"	"	2.317	512	0.118
3	5.067	1.414	1.974	"	"	2.189	1089	0.252
4	6.756	1.886	1.898	"	"	3.007	2660	0.615
5	8.445	2.357	1.842	"	"	2.951	4078	0.943
6	10.134	2.828	1.798	"	"	2.907	5785	1.338
7	11.823	—	—	—	—	—	7777	1.798
8	13.512	—	—	—	—	—	9943	2.299
9	15.201	—	—	—	—	—	12533	2.898
10	16.89	—	—	—	—	—	15485	3.580
11	18.579	—	—	—	—	—	18819	4.351
12	20.268	—	—	—	—	—	22467	5.195
13	21.957	—	—	—	—	—	26607	6.152

No. 3419
Sheet 35 of 118

...CULATION SHEET

Subject HULL RESISTANCE & PROPELLER DATA SHEET
Ship or Project EMERGENCY TOWING GEAR CRITERIA
Section BSDD Prepared by RCS Date Checked Reviewed

SHIP CLASS: AF 58

DATA SOURCE: TEST 18

SHIP CHARACTERISTICS

LWL = 483.5
B = 72
T = 19.72
Δ = 16,000
WS = 35,913
C_P =
EHP/SHP =
C_F = 0.00077

PROPELLER CHARACTERISTICS

DIA. = 22
PITCH = 21.69
# BLADES = 4
EXP. A./D.A. =
EXPANDED AREA =
DEVELOPED AREA =
PROJ. AREA/D.A. = 0.509
PROJECTED AREA = 193.49
PROPELLERS = 1

V KNOTS	SHP	EHP/SHP	EHP	R_T POUNDS	$EHP_{FRIC.}$
11			1400		
12			1900		
13			2450		
14			3050		
15			3850		

M. Rosenblatt & Son, Inc.
DESIGN CALCULATION SHEET

No. 3419
Sheet 36 of 113

Subject: HULL RESISTANCE CALCULATION - AF 58
Ship or Project: EMERGENCY TOWING GEAR CRITERIA
Section: BSDD | Prepared by: RCS | Date: 10/27/75 | Checked | Reviewed

SHIP - AF 58
CALCULATION FOR MAX. SPEED WHERE C_R IS CONSTANT

$$V_K = 0.55\sqrt{LWL} = 12.094 \quad \underline{\text{USE } 11 \text{ KT.}}$$

$$R_T = \frac{EHP \times 326}{V_K} = 41491$$

$$V_S = 1.687\ V_K = 18.579$$

$$R_n = \frac{V_S L}{\nu} = \frac{(18.579)(483.5)}{1.2791 \times 10^{-5}} = 7.023 \times 10^8$$

$$C_f = 1.600 \times 10^{-3} \quad \text{(SCHOENHERR COEFF.)}$$

$$\Delta C_f = 0.77 \times 10^{-3}$$

$$C_{fT} = 2.37 \times 10^{-3}$$

$$R_F = \tfrac{1}{2}\rho\, S\, V_s^2\, C_{fT}$$
$$= \tfrac{1}{2}(1.9905)(35913)(18.579)^2(2.37 \times 10^{-3})$$
$$= 29240$$

$$R_R = R_T - R_F = 12251$$

$$C_R = \frac{(12251)}{\tfrac{1}{2}\rho(35913)(18.579)^2}$$

$C_R = 0.993 \times 10^{-3}$ CONSTANT C_R FOR SHIP SPEEDS LESS THAN 11 KT.

M. Rosenblatt & Son, Inc.

DESIGN CALCULATION SHEET

No. 5417

Sheet 37 of 118

Subject: HULL RESISTANCE CALCULATION – AF 58

Ship or Project: EMERGENCY TOWING GEAR CRITERIA

Section: BSDD Prepared by: RCS Date: 10/27/75 Checked: Reviewed:

SHIP – AF 58

$$R_{ns} = \frac{V_s L}{\nu} = \frac{V_s (483.5)}{1.2791 \times 10^{-5}}$$

$$R_T = \tfrac{1}{2} \rho S V_K^2 C_{TS} (1.689)^2$$

$$R_T = \tfrac{1}{2} (1.9905) S V_K^2 C_{TS} (1.689)^2$$

TABLE FOR CALCULATION OF R_T

V_K KT.	V_S FT./SEC.	R_{ns} $\times 10^8$	C_F $\times 10^{-3}$	ΔC_F $\times 10^{-3}$	C_R $\times 10^{-3}$	C_{TS} $\times 10^{-3}$	R_T LB.	R_T/Δ LB./LT.
0	0	—	—	—	—	—	0	0
1	1.689	0.6384	2.209	0.77	0.993	3.972	405	0.037
2	3.378	1.277	2.003	"	"	3.766	1536	0.139
3	5.067	1.915	1.894	"	"	3.657	3356	0.305
4	6.756	2.554	1.823	"	"	3.586	5850	0.532
5	8.445	3.192	1.770	"	"	3.533	9006	0.819
6	10.134	3.831	1.728	"	"	3.491	12814	1.165
7	11.823	4.469	1.694	"	"	3.457	17272	1.570
8	13.512	5.108	1.665	"	"	3.428	22370	2.034
9	15.201	5.746	1.641	"	"	3.404	28114	2.556
10	16.89	6.384	1.619	"	"	3.382	34484	3.135
11	18.579	—	—	—	—	—	41491	3.772
12	20.268	—	—	—	—	—	51617	4.692
13	21.957	—	—	—	—	—	61438	5.585

Subject: HULL RESISTANCE & PROPELLER DATA SHEET

Ship or Project: EMERGENCY TOWING GEAR CRITERIA

Section: BSDD   Prepared by: RCS   Date: 12/5/75   Checked: Reviewed:

SHIP CLASS: AE 21 & 23

DATA SOURCE: DTMB report No. 923 - TEST 3

SHIP CHARACTERISTICS

LWL = 482'
B = 72'
T = 29'
Δ = 17303
WS = 44606
C_p =
EHP/SHP =
ΔC_F = 0.00077

PROPELLER CHARACTERISTICS

DIA. = 22.0
PITCH = 21.7
# BLADES = 4
EXP. A./D.A. =
EXPANDED AREA =
DEVELOPED AREA =
PROJ. AREA/D.A. = 0.431
PROJECTED AREA =
PROPELLERS = 1

V KNOTS	SHP	EHP/SHP	EHP	R_T POUNDS	EHP FRIC. @ ΔC_F = 0.0004
9			790		610
10			1020		790
11			1380		1040
12			1810		1310
13			2280		1680
14			2870		1620 ?
15			3630		2550

Subject: HULL RESISTANCE CALCULATION - AE 21 & AE 23
Project: EMERGENCY TOWING GEAR CRITERIA
Division: BSDD Prepared by RCS Date 10/23/75 Checked Reviewed

SHIP - AE 21 & AE 23

CALCULATION FOR MAX. SPEED WHERE C_R IS CONSTANT

$$V_K = 0.55\sqrt{LWL} = 12.07 \text{ KT.}$$ USE 9 KT.

$$R_T = \frac{EHP \times 326}{V_K} = 28616$$

$$V_S = 1.689\ V_K = 15.201$$

$$R_n = \frac{V_s L}{\nu} = \frac{(\quad)(\quad)}{1.2791 \times 10^{-5}} = \_\_\_$$

C_f = ___ (SCHOENHERR COEFF.)

ΔC_f = ___

C_{fT} = ___

$$R_F = \tfrac{1}{2}\rho\, S\, V_s^2\, C_{fT}$$
$$= \tfrac{1}{2}(1.9905)\cdot(\quad)(\quad)^2(\quad)$$

$$R_F = \frac{EHP \times 326}{9} = 22096$$

$$R_R = R_T - R_F = 6520$$

$$C_R = \frac{(6520)}{\tfrac{1}{2}\rho(44606)(15.201)^2}$$

$$C_R = 0.636 \times 10^{-3}$$ CONSTANT C_R FOR SHIP SPEEDS LESS THAN 9 KT.

DESIGN CALCULATION SHEET

Subject: HULL RESISTANCE CALCULATION - AE 21 & AE 23

Ship or Project: EMERGENCY TOWING GEAR CRITERIA

Section: BSDD Prepared by: RCS Date: 10/23/75 Checked: Reviewed:

SHIP - AE 21 & AE 23

$$R_{ns} = \frac{V_s L}{\nu} = \frac{V_s (482)}{1.2791 \times 10^{-5}}$$

$$R_T = \tfrac{1}{2} \rho S V_K^2 C_{TS} (1.689)^2$$

$$R_T = \tfrac{1}{2} (1.9905) S V_K^2 C_{TS} (1.689)^2$$

TABLE FOR CALCULATION OF R_T

V_K KT.	V_S FT./SEC.	R_{ns} $\times 10^8$	C_F $\times 10^{-3}$	ΔC_F $\times 10^{-3}$	C_R $\times 10^{-3}$	C_{TS} $\times 10^{-3}$	R_T LB.	R_T/Δ LB./LT.
0	0	—	—	—	—	—	0	0
1	1.689	0.6365	2.209	0.4	0.636	3.245	126	0.0073
2	3.378	1.273	2.004	"	"	3.04	1540	0.089
3	5.067	1.909	1.895	"	"	2.931	3341	0.193
4	6.756	2.546	1.822	"	"	2.858	5791	0.335
5	8.445	3.182	1.771	"	"	2.807	8887	0.514
6	10.134	3.819	1.729	"	"	2.765	12606	0.729
7	11.823	4.455	1.695	"	"	2.731	16947	0.979
8	13.512	5.092	1.670	"	"	2.706	21933	1.268
9	15.201	—	—	—	—	—	28616	1.654
10	16.89	—	—	—	—	—	33252	1.922
11	18.579	—	—	—	—	—	40898	2.364
12	20.268	—	—	—	—	—	49172	2.842
13	21.957	—	—	—	—	—	57175	3.304

DESIGN CALCULATION SHEET

Subject: HULL RESISTANCE & PROPELLER DATA SHEET
Ship or Project: EMERGENCY TOWING GEAR CRITERIA
Section: BSDD | Prepared by | Date | Checked | Reviewed

SHIP CLASS: AD-14

DATA SOURCE: AD-19 DATA EXP. #8

SHIP CHARACTERISTICS

LWL = 531
B = 73
T = 26
Δ_{TESTED} = 17,000
WS = 48,934
C_P =
EHP/SHP =
ΔC_F = —

PROPELLER CHARACTERISTICS

DIA. = 15.4
PITCH = 15.4
# BLADES = 3
EXP. A./D.A. =
EXPANDED AREA =
DEVELOPED AREA =
PROJ. AREA/D.A. = 0.335
PROJECTED AREA = 62.4
PROPELLERS = 2

V KNOTS	SHP	EHP/SHP	EHP	R_T POUNDS	$EHP_{FRIC.}$
8			650		420
9			850		600
10			1150		830
11			1530		1080
12			2000		1390
13			2560		1750
14			3260		2150

DESIGN CALCULATION SHEET

Subject: HULL RESISTANCE CALCULATION - AD-14
Ship or Project: EMERGENCY TOWING GEAR CRITERIA
Section: BSDD Prepared by: RCS Date: 10/24/75 Checked: Reviewed:

SHIP - AD-14

CALCULATION FOR MAX. SPEED WHERE C_R IS CONSTANT

$$V_K = 0.55\sqrt{LWL} = 12.7 \cdot \text{ USE } \underline{8 \text{ KT.}}$$

$$R_T = \frac{EHP \times 326}{V_K} = \frac{650 \times 326}{8} = 26488$$

$$V_S = 1.687\ V_K = 13.512$$

$$R_n = \frac{V_s L}{\nu} = \frac{(13.512)(531)}{1.2791 \times 10^{-5}} = 5.609 \times 10^8$$

$$C_f = 1.646 \times 10^{-3} \quad \text{(SCHOENHERR COEFF.)}$$

$$\Delta C_f = 0.40 \times 10^{-3}$$

$$C_{fT} = 2.046 \times 10^{-3}$$

USE THIS → $C_{fT} = \dfrac{420 \times 326}{8\ (1/2)\ \rho\ (47934)\ (13.512)^2} = 1.925 \times 10^{-3}$ (FROM EHP_f

$$R_F = 1/2\ \rho\ S\ V_s^2\ C_{fT}$$
$$= 1/2\ (1.9905)\ (48,934)\ (13.512)^2\ (1.925 \times 10^{-3})$$
$$= 17,115$$

$$R_R = R_T - R_F = 9373$$

$$C_R = \frac{(9373)}{1/2\ \rho\ (48,934)\ (13.512)^2}$$

$C_R = 1.054 \times 10^{-3}$ CONSTANT C_R FOR SHIP SPEEDS LESS THAN 8KT.

Subject HULL RESISTANCE CALCULATION - AD-14

Ship or Project EMERGENCY TOWING GEAR CRITERIA

Section BSDD Prepared by RCS Date 10/24/75 Checked Reviewed

SHIP - AD-14

$$R_{ns} = \frac{V_s L}{\nu} = \frac{V_s (531)}{1.2791 \times 10^{-5}}$$

$$R_T = \tfrac{1}{2} \rho S V_K^2 C_{TS} (1.689)^2$$

$$R_T = \tfrac{1}{2} (1.9905) S V_K^2 C_{TS} (1.689)^2$$

TABLE FOR CALCULATION OF R_T

V_K KT.	V_S FT./SEC.	R_{ns} $\times 10^8$	C_F $\times 10^{-3}$	ΔC_F $\times 10^{-3}$	C_R $\times 10^{-3}$	C_{TS} $\times 10^{-3}$	R_T LB.	R_T/Δ LB./LT.
0	0	—	—	—	—	—	0	0
1	1.689	0.7012	2.179	0.400	1.054	3.633	505	0.028
2	3.378	1.402	1.977	"	"	3.431	1907	0.106
3	5.067	2.103	1.871	"	"	3.325	4158	0.231
4	6.756	2.805	1.801	"	"	3.255	7236	0.402
5	8.445	3.506	1.748	"	"	3.202	11,122	0.618
6	10.134	4.207	1.707	"	"	3.161	15,810	0.878
7	11.823	4.908	1.674	"	"	3.128	21,294	1.183
8	13.512	—	—	—	—	—	26,486	1.471
9	15.201	—	—	—	—	—	30,789	1.711
10	16.89	—	—	—	—	—	37,490	2.083
11	18.579	—	—	—	—	—	45,344	2.519
12	20.268	—	—	—	—	—	54,333	3.019
13	21.957	—	—	—	—	—	64,197	3.567

M. Rosenblatt & Son, Inc. No. 3419

DESIGN CALCULATION SHEET Sheet 44 of 118

Subject: HULL RESISTANCE & PROPELLER DATA SHEET

Ship or Project: EMERGENCY TOWING GEAR CRITERIA

Section: BSDD Prepared by: RCS Date: 12/5/75 Checked: Reviewed:

SHIP CLASS: AE-26

DATA SOURCE: TEST 4

SHIP CHARACTERISTICS

- LWL = 540.0
- B = 81.0
- T = 28.4
- Δ = 20,600
- WS = 54,240
- C_p =
- EHP/SHP =
- ΔC_F = 0.0005

PROPELLER CHARACTERISTICS

- DIA. = 20.0
- PITCH = 23.84
- # BLADES = 4
- EXP. A./D.A. = 0.62
- EXPANDED AREA =
- DEVELOPED AREA =
- PROJ. AREA/D.A. =
- PROJECTED AREA =
- # PROPELLERS = 1

V KNOTS	SHP	EHP/SHP	EHP	R_T POUNDS	$EHP_{FRIC.}$
9			1,000		
10			1,390		
11			1,800		
12			2,350		
13			3,000		
14			3,750		
15			4,650		

Sub: HULL RESISTANCE CALCULATION - AE-26

Ship Project: EMERGENCY TOWING GEAR CRITERIA

Section: BSDD Prepared by: RCS Date: 10/23/75 Checked Reviewed

SHIP - AE-26

CALCULATION FOR MAX. SPEED WHERE C_R IS CONSTANT

$$V_K = 0.55\sqrt{LWL} = 12.781 \quad \underline{\text{USE } 9 \text{ KT.}}$$

$$R_T = \frac{EHP \times 326}{V_K} = 36222$$

$$V_S = 1.689\ V_K = 15.201$$

$$R_n = \frac{V_S L}{\nu} = \frac{(15.201)(540)}{1.2791 \times 10^{-5}} = 3.126 \times 10^{8}$$

$$C_f = 1.774 \times 10^{-3} \quad \text{(SCHOENHERR COEFF.)}$$

$$\Delta C_f = 0.50 \times 10^{-3}$$

$$C_{fT} = 2.274 \times 10^{-3}$$

$$R_F = \tfrac{1}{2}\rho\, S\, V_S^2\, C_{fT}$$
$$= \tfrac{1}{2}(1.9905)(54{,}240)(15.201)^2(2.274 \times 10^{-3})$$
$$= 28{,}365$$

$$R_R = R_T - R_F = 7857$$

$$C_R = \frac{(7857)}{\tfrac{1}{2}\rho(54{,}240)(15.201)^2}$$

$C_R = 0.630 \times 10^{-3}$ CONSTANT C_R FOR SHIP SPEEDS LESS THAN <u>9 KT.</u>

DESIGN CALCULATION SHEET

Subject: HULL RESISTANCE CALCULATION - AE-26

Ship or Project: EMERGENCY TOWING GEAR CRITERIA

Section: BSDD Prepared by: RCS Date: 10/23/75 Checked Reviewed

SHIP -

$$R_{ns} = \frac{V_s L}{\nu} = \frac{V_s (540)}{1.2791 \times 10^{-5}}$$

$$R_T = \tfrac{1}{2} \rho S V_K^2 C_{TS} (1.689)^2$$

$$R_T = \tfrac{1}{2} (1.9905) S V_K^2 C_{TS} (1.689)^2$$

TABLE FOR CALCULATION OF R_T

V_K KT.	V_S FT./SEC.	R_{ns} $\times 10^8$	C_F $\times 10^{-3}$	ΔC_F $\times 10^{-3}$	C_R $\times 10^{-3}$	C_{TS} $\times 10^{-3}$	R_T LB.	R_T/Δ LB./LT.
0	0	—	—	—	—	—	0	0
1	1.689	0.7130	2.174	0.5	0.63	3.304	509	0.025
2	3.378	1.426	1.972	"	"	3.102	1911	0.093
3	5.067	2.139	1.866	"	"	2.996	4152	0.202
4	6.756	2.852	1.797	"	"	2.927	7212	0.350
5	8.445	3.565	1.745	"	"	2.875	11067	0.537
6	10.134	4.278	1.704	"	"	2.834	15711	0.763
7	11.823	4.991	1.670	"	"	2.80	21128	1.026
8	13.512	5.704	1.642	"	"	2.772	27320	1.326
9	15.201	—	—	—	—	—	36222	1.758
10	16.89	—	—	—	—	—	45314	2.20
11	18.579	—	—	—	—	—	53345	2.590
12	20.268	—	—	—	—	—	63842	3.10
13	21.957	—	—	—	—	—	75231	3.652

HULL RESISTANCE & PROPELLER DATA SHEET

Ship or Project: EMERGENCY TOWING GENR CRITERIA

Section BSDD | Prepared by | Date | Checked | Reviewed

SHIP CLASS: LPD 4

DATA SOURCE: REF. 1

SHIP CHARACTERISTICS

LWL = 548.2
B = 82.1
T = 22.0
Δ = 17,000
WS = 51,720
C_P =
EHP/SHP =
ΔC_F = 0.0005

PROPELLER CHARACTERISTICS

DIA. = 12.5
PITCH = 11.83
# BLADES = 5
EXP. A./D.A. = 0.852
EXPANDED AREA =
DEVELOPED AREA = 102
PROJ. AREA/D.A. =
PROJECTED AREA = 87.7
PROPELLERS = 2

V KNOTS	SHP	EHP/SHP	EHP	R_T POUNDS	$EHP_{FRIC.}$
8			650		
9			900		
10			1300		
11			1800		
12			2300		
13			2750		
14			3750		

Subject: HULL RESISTANCE CALCULATION - LPD 4
Ship or Project: EMERGENCY TOWING GEAR CRITERIA
Section: BSDD Prepared by: RCS Date: 10/29/75 Checked: Reviewed:

SHIP - LPD 4

CALCULATION FOR MAX. SPEED WHERE C_R IS CONSTANT

$$V_K = 0.55 \sqrt{LWL} = 12.88 \quad \underline{\text{USE } 8 \text{ KT.}}$$

$$R_T = \frac{EHP \times 326}{V_K} = 26488$$

$$V_S = 1.687 \; V_K = 13.512$$

$$R_n = \frac{V_S L}{\nu} = \frac{(13.52)(548.2)}{1.2791 \times 10^{-5}} = 5.791 \times 10^{8}$$

$$C_f = 1.639 \times 10^{-3} \quad \text{(SCHOENHERR COEFF.)}$$

$$\Delta C_f = 0.5 \times 10^{-3}$$

$$C_{fT} = 2.139 \times 10^{-3}$$

$$R_F = \tfrac{1}{2} \rho \, S \, V_S^2 \, C_{fT}$$
$$= \tfrac{1}{2} (1.9905)(51{,}720)(13.512)^2 (2.139 \times 10^{-3})$$
$$= 20{,}102$$

$$R_R = R_T - R_F = 6386$$

$$C_R = \frac{(6386)}{\tfrac{1}{2} \rho (51{,}720)(13.512)^2}$$

$C_R = 0.680 \times 10^{-3}$ CONSTANT C_R FOR SHIP SPEEDS LESS THAN <u>8 KT.</u>

HULL RESISTANCE CALCULATION - LPD 4

Ship or Project EMERGENCY TOWING GEAR CRITERIA

Section BSDD Prepared by RCS Date 10/29/75 Checked Reviewed

SHIP -

$$R_{ns} = \frac{V_s L}{\nu} = \frac{V_s (548.2)}{1.2791 \times 10^{-5}}$$

$$R_T = \tfrac{1}{2} \rho S V_K^2 C_{TS} (1.689)^2$$

$$R_T = \tfrac{1}{2} (1.9905) S V_K^2 C_{TS} (1.689)^2$$

TABLE FOR CALCULATION OF R_T

V_K KT.	V_S FT./SEC.	R_{ns} $\times 10^8$	C_F $\times 10^{-3}$	ΔC_F $\times 10^{-3}$	C_R $\times 10^{-3}$	C_{TS} $\times 10^{-3}$	R_T LB.	R_T/Δ LB./Δ
0	0	—	—	—	—	—	0	0
1	1.689	0.7239	2.170	0.5	0.68	3.35	492	0.029
2	3.378	1.448	1.968	"	"	3.148	1849	0.109
3	[illegible]067	2.172	1.863	"	"	3.043	4022	0.237
[illegible]	[illegible].756	2.896	1.792	"	"	2.972	6983	0.411
	8.445	2.619	1.741	"	"	2.921	10723	0.631
	10.134	4.343	1.701	"	"	2.881	15230	0.896
	11.823	5.067	1.667	"	"	2.847	20485	1.205
	13.512	—	—	—	—	—	26488	1.558
	15.201	—	—	—	—	—	32600	1.918
	16.89	—	—	—	—	—	42380	2.493
	18.579	—	—	—	—	—	53345	3.138
	20.268	—	—	—	—	—	62483	3.675
	21.957	—	—	—	—	—	68962	4.056

Subject: HULL RESISTANCE & PROPELLER DATA SHEET

Ship or Project: EMERGENCY TOWING GENR CRITERIA

Section: BSDD Prepared by Date Checked Reviewed

SHIP CLASS: AFS-1

DATA SOURCE: REF. 1

SHIP CHARACTERISTICS

LWL = 530'
B = 75.0'
T = 25.75'
Δ = 17,500
WS = 48,800
C_p = 0.61
EHP/SHP =
ΔC_F = 0.0008

PROPELLER CHARACTERISTICS

DIA. = 20.0
PITCH = 21.384
# BLADES = 6
EXP. A./D.A. =
EXPANDED AREA =
DEVELOPED AREA = 256.32
PROJ. AREA/D.A. =
PROJECTED AREA = 216.5
PROPELLERS = 1

V KNOTS	SHP	EHP/SHP	EHP	R_T POUNDS	EHP FRIC.
10			1200		
11			1700		
12			2250		
13			2850		
14			3300		
15			50500		

Subject: HULL RESISTANCE CALCULATION - AFS-1

Ship or Project: EMERGENCY TOWING GEAR CRITERIA

Section: BSDD Prepared by: RCS Date: 10/27/75 Checked Reviewed

SHIP -

CALCULATION FOR MAX. SPEED WHERE C_R IS CONSTANT

$$V_K = 0.55\sqrt{LWL} = 12.66 \quad \underline{\text{USE } 10 \text{ KT.}}$$

$$R_T = \frac{EHP \times 326}{V_K} = 39120$$

$$V_s = 1.689 \; V_K = 16.89$$

$$R_n = \frac{V_s L}{\nu} = \frac{(16.89)(530)}{1.2791 \times 10^{-5}} = 6.998 \times 10^8$$

$$C_f = 1.600 \times 10^{-3} \quad \text{(SCHOENHERR COEFF.)}$$

$$\Delta C_f = 0.8 \times 10^{-3}$$

$$C_{f_T} = 2.4 \times 10^{-3}$$

$$R_F = \tfrac{1}{2}\rho \, S \, V_s^2 \, C_{f_T}$$
$$= \tfrac{1}{2}(1.9905)(48{,}800)(16.89)^2(2.4 \times 10^{-3})$$
$$= 33252$$

$$R_R = R_T - R_F = 5868$$

$$C_R = \frac{(5868)}{\tfrac{1}{2}\rho(48{,}800)(16.89)^2}$$

$$C_R = 0.423 \times 10^{-3}$$ CONSTANT C_R FOR SHIP SPEEDS LESS THAN 10 KT.

Subject: HULL RESISTANCE CALCULATION - AFS-1

Ship or Project: EMERGENCY TOWING GEAR CRITERIA

Section: BSDD Prepared by: RCS Date: 10/27/75 Checked Reviewed

SHIP -

$$R_{ns} = \frac{V_s L}{\nu} = \frac{V_s (530')}{1.2791 \times 10^{-5}}$$

$$R_T = \tfrac{1}{2} \rho S V_K^2 C_{TS} (1.689)^2$$

$$R_T = \tfrac{1}{2} (1.9905) S V_K^2 C_{TS} (1.689)^2$$

TABLE FOR CALCULATION OF R_T

V_K KT.	V_S FT./SEC.	R_{ns} $\times 10^8$	C_F $\times 10^{-3}$	ΔC_F $\times 10^{-3}$	C_R $\times 10^{-3}$	C_{TS} $\times 10^{-3}$	R_T LB.	R_T/Δ LB./LT.
0	0	—	—	—	—	—	0	0
1	1.689	0.6998	2.180	0.8	0.423	3.403	472	0.027
2	3.378	1.400	1.977	"	"	3.20	1773	0.101
3	5.067	2.100	1.871	"	"	3.094	3858	0.220
4	6.756	2.799	1.801	"	"	3.024	6704	0.383
5	8.445	3.499	1.749	"	"	2.972	10294	0.588
6	10.134	4.199	1.708	"	"	2.931	14619	0.835
7	11.823	4.899	1.674	"	"	2.897	19668	1.124
8	13.512	5.599	1.646	"	"	2.869	25440	1.454
9	15.201	6.299	1.622	"	"	2.845	31929	1.825
10	16.89	—	—	—	—	—	39120	2.235
11	18.579	—	—	—	—	—	50382	2.879
12	20.268	—	—	—	—	—	61125	3.493
13	21.957	—	—	—	—	—	71469	4.084

Subject: HULL RESISTANCE & PROPELLER DATA SHEET
Ship or Project: EMERGENCY TOWING GEAR CRITERIA
Section: BSDD Prepared by: RCS Date: 12/2/75 Checked: Reviewed:

SHIP CLASS: LST-1179

DATA SOURCE: Ref. 1

SHIP CHARACTERISTICS

~~LWL~~ LBP = 500'
B = 68'
T = 15.75'
Δ = 8500
WS = 34360
C_p = 0.56
EHP/SHP = 0.64
ΔC_F = 0.0005

PROPELLER CHARACTERISTICS

DIA. = 11.5'
PITCH = 12.33'
# BLADES = 4
EXP. A./D.A. =
EXPANDED AREA =
DEVELOPED AREA = 61.488
PROJ. AREA/D.A. =
PROJECTED AREA = 54.072
PROPELLERS = 2

V KNOTS	SHP	EHP/SHP	EHP	R_T POUNDS	$EHP_{FRIC.}$
12	2200	0.64	1408		
13	2750	"	1760		
14	3500	"	2240		
15	4350	"	2780		

Subject: HULL RESISTANCE CALCULATION – LST 1179

Ship or Project: EMERGENCY TOWING GEAR CRITERIA

Section: BSDD Prepared by Date Checked Reviewed

SHIP - LST 1179

CALCULATION FOR MAX. SPEED WHERE C_R IS CONSTANT

$$V_K = 0.55\sqrt{LWL} = 12.29 \quad (\text{USE } 12.0 \text{ KT.})$$

$$R_T = \frac{EHP \times 326}{V_K} = \frac{1408 \times 326}{12} = 38251$$

$$V_S = 1.689\ V_K = 20.268$$

$$R_n = \frac{V_S L}{\nu} = \frac{(20.268)(500)}{1.2791 \times 10^{-5}} = 7.922 \times 10^{8}$$

$$C_f = 1.576 \times 10^{-3} \quad (\text{SCHOENHERR COEFF.})$$

$$\Delta C_f = 0.5 \times 10^{-3}$$

$$C_{fT} = 2.076 \times 10^{-3}$$

$$R_F = \tfrac{1}{2}\rho\, S\, V_S^2\, C_{fT}$$
$$= \tfrac{1}{2}(1.9905)(34360)(20.268^2)(2.076) \times 10^{-3}$$
$$= 29,163$$

$$R_R = R_T - R_F = 38251 - 29,163 = 9088$$

$$C_R = \frac{R_R}{\tfrac{1}{2}\rho(34360)(20.268)^2}$$

$C_R = 0.647 \times 10^{-3}$ CONSTANT C_R FOR SHIP SPEEDS LESS THAN 12 KT.

... Rosenblatt & Son, Inc.

DESIGN CALCULATION SHEET

No. 5417

Sheet 55 of 118

Subject HULL RESISTANCE CALCULATION – LST 1179

Ship or Project EMERGENCY TOWING GEAR CRITERIA

Section BSDD Prepared by Date Checked Reviewed

SHIP - LST 1179

$$R_{ns} = \frac{V_s L}{\nu} = \frac{V_s (500)}{1.2791 \times 10^{-5}}$$

$$R_T = \tfrac{1}{2} \rho S V_K^2 C_{TS} (1.689)^2$$

$$R_T = \tfrac{1}{2} (1.9905) S V_K^2 C_{TS} (1.689)^2$$

TABLE FOR CALCULATION OF R_T

V_K KT.	V_S FT./SEC	R_{ns} $\times 10^8$	C_F $\times 10^{-3}$	ΔC_F $\times 10^{-3}$	C_R $\times 10^{-3}$	C_{TS} $\times 10^{-3}$	R_T LB.	R_T/Δ LB./LT.
0	0	—	—	—	—	—	0	0
1	1.689	0.660	2.198	0.5	0.647	3.345	326	0.038
2	3.378	1.320	1.993	"	"	3.14	1225	0.144
3	5.067	1.981	1.886	"	"	3.033	2663	0.313
4	6.756	2.641	1.814	"	"	2.961	4622	0.544
5	8.445	3.301	1.762	"	"	2.909	7095	0.835
6	10.134	3.961	1.721	"	"	2.868	10072	1.185
7	11.823	4.622	1.687	"	"	2.834	13547	1.594
8	13.512	5.282	1.658	"	"	2.805	17513	2.060
9	15.201	5.942	1.634	"	"	2.781	21975	2.585
10	16.89	6.602	1.612	"	"	2.759	26915	3.166
11	18.579	7.263	1.593	"	"	2.74	32343	3.805
12	20.268	7.923	1.576	"	"	2.723	38251	4.500
13	21.957	8.583	—	"	—	—	44135	5.192

Subject HULL RESISTANCE & PROPELLER DATA SHEET

Ship or Project EMERGENCY TOWING GENR CRITERIA

Section BSDD Prepared by Date Checked Reviewed

SHIP CLASS: LSD 36

DATA SOURCE: REF. 1

SHIP CHARACTERISTICS

- LWL = 540.0
- B = 32.0
- T = 19.11
- Δ = 14,010
- WS = 45,190
- C_p =
- EHP/SHP = 0.68
- ΔC_F = 0.0006

PROPELLER CHARACTERISTICS

- DIA. = 12.50
- PITCH = 11.89
- # BLADES = 5
- EXP. A./D.A. =
- EXPANDED AREA =
- DEVELOPED AREA = 102
- PROJ. AREA/D.A. = 0.713
- PROJECTED AREA = 87.7
- # PROPELLERS = 2

V KNOTS	SHP	EHP/SHP	EHP	R_T POUNDS	$EHP_{FRIC.}$
12	3000	0.68	2040	55420	
13	3900	"	2652	66504	
14	4500	"	3060	71254	
15	6300	"	4284	93106	

DESIGN CALCULATION SHEET

Subject HULL RESISTANCE CALCULATION - LSD 36

Ship or Project EMERGENCY TOWING GEAR CRITERIA

Section BSDD Prepared by RCS Date 10/29/75 Checked Reviewed

SHIP - LSD 36

CALCULATION FOR MAX. SPEED WHERE C_R IS CONSTANT

$$V_K = 0.55 \sqrt{LWL} = 12.78 \quad \underline{\text{USE } 12 \text{ KT.}}$$

$$R_T = \frac{EHP \times 326}{V_K} = 55420$$

$$V_s = 1.689 \; V_K = 20.268$$

$$R_n = \frac{V_s L}{\nu} = \frac{(20.268)(540)}{1.2791 \times 10^{-5}} = 8.557 \times 10^{8}$$

$$C_f = 1.561 \times 10^{-3} \quad \text{(SCHOENHERR COEFF.)}$$

$$\Delta C_f = 0.6 \times 10^{-3}$$

$$C_{fT} = 2.161 \times 10^{-3}$$

$$R_F = \tfrac{1}{2} \rho \, S \, V_s^2 \, C_{fT}$$
$$= \tfrac{1}{2}(1.9905)(45190)(20.268)^2(2.161 \times 10^{-3})$$
$$= 39{,}926$$

$$R_R = R_T - R_F = 15{,}494$$

$$C_R = \frac{(15494)}{\tfrac{1}{2}\rho(45190)(20.268)^2}$$

$C_R = 0.839 \times 10^{-3}$ CONSTANT C_R FOR SHIP SPEEDS LESS THAN 12 KT.

Subject: HULL RESISTANCE CALCULATION – LSD 36

Ship or Project: EMERGENCY TOWING GEAR CRITERIA

Section: BSDD Prepared by: RCS Date: 10/29/75 Checked Reviewed

SHIP –

$$R_{ns} = \frac{V_s L}{\nu} = \frac{V_s (540)}{1.2791 \times 10^{-5}}$$

$$R_T = \tfrac{1}{2} \rho S V_K^2 C_{TS} (1.689)^2$$

$$R_T = \tfrac{1}{2} (1.9905) S V_K^2 C_{TS} (1.689)^2$$

TABLE FOR CALCULATION OF R_T

V_K KT.	V_S FT./SEC.	R_{ns} $\times 10^8$	C_F $\times 10^{-3}$	ΔC_F $\times 10^{-3}$	C_R $\times 10^{-3}$	C_{TS} $\times 10^{-3}$	R_T LB.	R_T/Δ LB./LT.
0	0	—	—	—	—	—	0	0
1	1.689	0.713	2.174	0.6	0.839	3.613	464	0.033
2	3.378	1.426	1.972	"	"	3.411	1751	0.125
3	5.067	2.139	1.866	"	"	3.305	3816	0.272
4	6.756	2.852	1.797	"	"	3.236	6643	0.474
5	8.445	3.565	1.744	"	"	3.183	10210	0.729
6	10.134	4.278	1.704	"	"	3.143	14517	1.04
7	11.823	4.991	1.670	"	"	3.109	19546	1.40
8	13.512	5.704	1.642	"	"	3.081	25299	1.81
9	15.201	6.417	1.618	"	"	3.057	31770	2.27
10	16.89	7.130	1.597	"	"	3.036	38953	2.78
11	18.579	7.844	1.578	"	"	3.017	46838	3.34
12	20.268	—	—	—	—	—	55420	3.96
13	21.957	—	—	—	—	—	66504	4.75

M. Rosenblatt & Son, Inc.
DESIGN CALCULATION SHEET

No. 3419
Sheet 59 of 118

Subject: HULL RESISTANCE & PROPELLER DATA SHEET
Ship or Project: EMERGENCY TOWING GEAR CRITERIA
Section: BSDD Prepared by Date Checked Reviewed

SHIP CLASS: AOR-1

DATA SOURCE: REF. 1

SHIP CHARACTERISTICS

LWL = 640.0'
B = 96'
T = 32.5'
Δ = 36,700
WS = 76,690
C_P =
EHP/SHP =
ΔC_F = 0.0004

PROPELLER CHARACTERISTICS

DIA. = 20.5'
PITCH = 23.78
# BLADES = 4
EXP. A./D.A. = 0.486
EXPANDED AREA =
DEVELOPED AREA =
PROJ. AREA/D.A. =
PROJECTED AREA =
PROPELLERS = 2

V KNOTS	SHP	EHP/SHP	EHP	R_T POUNDS	$EHP_{FRIC.}$
12	4900	0.69	3381		
13	6,000	0.692	4152		
14	7500	0.695	5213		
15	9250	0.699	6466		

Subject: HULL RESISTANCE CALCULATION - AOR-1

Ship or Project: EMERGENCY TOWING GEAR CRITERIA

Section: BSDD Prepared by: RCS Date: 10/28/75 Checked Reviewed

SHIP - AOR-1

CALCULATION FOR MAX. SPEED WHERE C_R IS CONSTANT

$$V_K = 0.55\sqrt{LWL} = 13.91 \quad \underline{\text{USE } 12 \text{ KT.}}$$

$$R_T = \frac{EHP \times 326}{V_K} = 91851$$

$$V_S = 1.687 \; V_K = 20.268$$

$$R_n = \frac{V_S L}{\nu} = \frac{(20.268)(640.0)}{1.2791 \times 10^{-5}} = 1.01141 \times 10^{9}$$

$$C_f = 1.528 \times 10^{-3} \quad (\text{SCHOENHERR COEFF.})$$

$$\Delta C_f = 0.4 \times 10^{-3}$$

$$C_{f_T} = 1.928 \times 10^{-3}$$

$$R_F = \tfrac{1}{2}\rho \, S \, V_S^2 \, C_{f_T}$$

$$= \tfrac{1}{2}(1.9905)(76{,}690)(20.268)^2(1.928 \times 10^{-3})$$

$$= 60450.$$

$$R_R = R_T - R_F = 31400$$

$$C_R = \frac{(31400)}{\tfrac{1}{2}\rho(76{,}690)(20.268)^2}$$

$$C_R = 1.001 \times 10^{-3}$$ CONSTANT C_R FOR SHIP SPEEDS LESS THAN 12 KT.

Subject HULL RESISTANCE CALCULATION – AOR-1

Ship or Project EMERGENCY TOWING GEAR CRITERIA

Section BSDD **Prepared by** RCS **Date** 10/28/75 **Checked** **Reviewed**

SHIP – AOR-1

$$R_{ns} = \frac{V_s L}{\nu} = \frac{V_s (610.)}{1.2791 \times 10^{-5}}$$

$$R_T = \tfrac{1}{2} \rho S V_K^2 C_{TS} (1.689)^2$$

$$R_T = \tfrac{1}{2} (1.9905) S V_K^2 C_{TS} (1.689)^2$$

TABLE FOR CALCULATION OF R_T

V_K KT.	V_S FT./SEC.	R_{ns} $\times 10^8$	C_F $\times 10^{-3}$	ΔC_F $\times 10^{-3}$	C_R $\times 10^{-3}$	C_{TS} $\times 10^{-3}$	R_T LB.	R_T/Δ LB./LT.
0	0	—	—	—	—	—	0	0
1	1.689	0.8334	2.126	0.4	1.001	3.527	768	0.021
2	3.378	1.667	1.931	"	"	3.332	2902	0.079
3	5.067	2.500	1.828	"	"	3.229	6328	0.172
4	6.756	3.333	1.760	"	"	3.161	11012	0.300
5	8.445	4.167	1.709	"	"	3.110	16929	0.461
6	10.134	5.000	1.670	"	"	3.071	24072	0.656
7	11.823	5.834	1.638	"	"	3.039	32423	0.883
8	13.512	6.667	1.610	"	"	3.011	41959	1.143
9	15.201	7.500	1.586	"	"	2.987	52681	1.435
10	16.89	8.334	1.566	"	"	2.967	64602	1.760
11	18.579	9.167	1.547	"	"	2.948	77668	2.116
12	20.268	—	—	—	—	—	91851	2.503
13	21.957	—	—	—	—	—		

M. Rosenblatt & Son, Inc. No. 3419
DESIGN CALCULATION SHEET Sheet 62 of 118

Subject HULL RESISTANCE & PROPELLER DATA SHEET
Ship or Project EMERGENCY TOWING GEAR CRITERIA
Section BSDD Prepared by Date Checked Reviewed

SHIP CLASS: AD 37

DATA SOURCE: SHEET FOR TAYLOR STD SERIES FROM FILE

SHIP CHARACTERISTICS

LWL = 660.0
B = 85.0
T = 24.0
Δ = 24235
WS =
C_p = 0.654
EHP/SHP =
ΔC_F = 0.0004

PROPELLER CHARACTERISTICS

DIA. = 18.00
PITCH = 16.848
# BLADES =
EXP. A./D.A. =
EXPANDED AREA =
DEVELOPED AREA =
PROJ. AREA/D.A. = 0.534
PROJECTED AREA = 136
PROPELLERS = 1

V KNOTS	SHP	EHP/SHP	EHP	R_T POUNDS	$EHP_{FRIC.}$
12			2552		
13			3292		
14			4152		
15			5145		
16			6259		

Subject: HULL RESISTANCE CALCULATION - AD-37

Ship or Project: EMERGENCY TOWING GEAR CRITERIA

Section: BSDD Prepared by: RCS Date: 10/24/75 Checked Reviewed

SHIP - AD-37

CALCULATION FOR MAX. SPEED WHERE C_R IS CONSTANT

$$V_K = 0.55\sqrt{LWL} = 14.13 \quad \text{USE 12 KT.}$$

$$R_T = \frac{EHP \times 326}{V_K} = 69329$$

$$V_S = 1.689\ V_K = 20.268$$

$$R_n = \frac{V_S L}{\nu} = \frac{(20.268)(660.0)}{1.2791 \times 10^{-5}} = 10.458 \times 10^8$$

$$C_f = 1.523 \times 10^{-3} \quad \text{(SCHOENHERR COEFF.)}$$

$$\Delta C_f = 0.4 \times 10^{-3}$$

$$C_{fT} = 1.923 \times 10^{-3}$$

$$\frac{B}{T} = 3.54 \qquad C_S = 2.71$$

$$C_X = \frac{V}{LBT\,C_P} = 0.963$$

$$S = 2.71\sqrt{848225 \cdot 660} = 64{,}120 \text{ FT.}^2$$

$$R_F = \tfrac{1}{2}\rho\, S\, V_S^2\, C_{fT}$$
$$= \tfrac{1}{2}(1.9905)(64{,}120)(20.268)^2(1.923 \times 10^{-3})$$
$$= 50419 \ \#$$

$$R_R = R_T - R_F = 18910.$$

$$C_R = \frac{(18910)}{\tfrac{1}{2}\rho(64{,}120)(20.268)^2}$$

$$C_R = 0.721 \times 10^{-3}$$ CONSTANT C_R FOR SHIP SPEEDS LESS THAN 12 KT.

M. Rosenblatt & Son, Inc.

DESIGN CALCULATION SHEET

No. 5417

Sheet 64 of 118

Subject: HULL RESISTANCE CALCULATION - AD-37

Ship or Project: EMERGENCY TOWING GEAR CRITERIA

Section: BSDD Prepared by: RCS Date: 10/27/75 Checked: Reviewed:

SHIP -

$$R_{ns} = \frac{V_s L}{\nu} = \frac{V_s (660)}{1.2791 \times 10^{-5}}$$

$$R_T = \tfrac{1}{2} \rho S V_K^2 C_{TS} (1.689)^2$$

$$R_T = \tfrac{1}{2} (1.9905) S V_K^2 C_{TS} (1.689)^2$$

TABLE FOR CALCULATION OF R_T

V_K KT.	V_s FT./SEC.	R_{ns} $\times 10^8$	C_F $\times 10^{-3}$	ΔC_F $\times 10^{-3}$	C_R $\times 10^{-3}$	C_{TS} $\times 10^{-3}$	R_T LB.	R_T/Δ LB./LT.
0	0	—	—	—	—	—	0	0
1	1.689	0.8715	2.112	0.4	0.721	3.233	589	0.024
2	3.378	1.743	1.919	"	"	3.040	2214	0.091
3	5.067	2.615	1.818	"	"	2.939	4815	0.197
4	6.756	3.486	1.751	"	"	2.872	8365	0.345
5	8.445	4.358	1.700	"	"	2.821	12,839	0.530
6	10.134	5.229	1.660	"	"	2.781	18226	0.752
7	11.823	6.105	1.628	"	"	2.749	24522	1.012
8	13.512	6.972	1.601	"	"	2.722	31714	1.309
9	15.201	7.844	1.578	"	"	2.699	39799	1.642
10	16.89	8.715	1.557	"	"	2.678	48752	2.012
11	18.579	9.587	1.539	"	"	2.660	58594	2.418
12	20.268	—	—	—	—	—	69329	2.861
13	21.957	—	—	—	—	—	~~89433~~	~~3.69~~ BAD DATA

M. Rosenblatt & Son, Inc.
DESIGN CALCULATION SHEET

No. 3419

Subject: HULL RESISTANCE & PROPELLER DATA SHEET
Ship or Project: EMERGENCY TOWING GEAR CRITERIA
Section: BSDD Prepared by: RCS Date: 12/8/75 Checked: Reviewed:

SHIP CLASS: AOE-1

DATA SOURCE: REPORT C-1189-3, MODEL 4834 PROPELLERS 3924 & 3925

SHIP CHARACTERISTICS

LWL = 720
B = 107
T = 39.5
Δ = 53,600
WS = 103,520
C_P =
EHP/SHP =
ΔC_F = 0.000725

PROPELLER CHARACTERISTICS

DIA. = 23.0
PITCH = 23.33
# BLADES = 6
EXP. A./D.A. = 0.661
EXPANDED AREA =
DEVELOPED AREA =
PROJ. AREA/D.A. = 0.548
PROJECTED AREA = 228
PROPELLERS = 2

V KNOTS	SHP	EHP/SHP	EHP	R_T POUNDS	$EHP_{FRIC.}$
14			7800		
15			9400		
16			11,300		
17			13,800		
18			16,400		
19			19,400		
20			23,100		

M. Rosenblatt & Son, Inc.
DESIGN CALCULATION SHEET

No. 5717
Sheet 66 of 118

Subject: HULL RESISTANCE CALCULATION - AOE-1
Ship or Project: EMERGENCY TOWING GEAR CRITERIA
Section: BSDD Prepared by: RCS Date: 10/27/75 Checked: Reviewed:

SHIP -
CALCULATION FOR MAX. SPEED WHERE C_R IS CONSTANT

$$V_K = 0.55\sqrt{LWL} = 15.26 \quad \underline{\text{USE 14 KT.}}$$

$$R_T = \frac{EHP \times 326}{V_K} = 181629$$

$$V_s = 1.689\ V_K = 23.65$$

$$R_n = \frac{V_s L}{\nu} = \frac{(23.65)(770)}{1.2791 \times 10^{-5}} = 1.4237 \times 10^9$$

$$C_f = 1.467 \times 10^{-3} \quad \text{(SCHOENHERR COEFF.)}$$

$$\Delta C_f = 0.725 \times 10^{-3}$$

$$C_{f_T} = 2.192 \times 10^{-3}$$

$$R_F = \tfrac{1}{2}\rho\, S\, V_s^2\, C_{f_T}$$
$$= \tfrac{1}{2}(1.9905)(103{,}520)(23.65)^2(2.192 \times 10^{-3})$$
$$= 126{,}316$$

$$R_R = R_T - R_F = 55312$$

$$C_R = \frac{(55312)}{\tfrac{1}{2}\rho(103{,}520)(23.65)^2}$$

$$C_R = 0.955 \times 10^{-3}$$ CONSTANT C_R FOR SHIP SPEEDS LESS THAN 14 KT.

DESIGN CALCULATION SHEET

Subject HULL RESISTANCE CALCULATION - AOE-1

Ship or Project EMERGENCY TOWING GEAR CRITERIA

Section BSDD **Prepared by** RCS **Date** 10/27/75 **Checked** **Reviewed**

SHIP - AOE-1

$$R_{ns} = \frac{V_s L}{\nu} = \frac{V_s (770)}{1.2791 \times 10^{-5}}$$

$$R_T = \tfrac{1}{2} \rho S V_K^2 C_{TS} (1.689)^2$$

$$R_T = \tfrac{1}{2} (1.9905) S V_K^2 C_{TS} (1.689)^2$$

TABLE FOR CALCULATION OF R_T

V_K KT.	V_S FT./SEC.	R_{ns} $\times 10^8$	C_F $\times 10^{-3}$	ΔC_F $\times 10^{-3}$	C_R $\times 10^{-3}$	C_{TS} $\times 10^{-3}$	R_T LB.	R_T/Δ LB./LT.
0	0						0	0
1	1.689	1.017	2.067	0.725	0.955	3.747	1101	0.021
2	3.378	2.034	1.879	"	"	3.561	4186	0.078
3	5.067	3.050	1.781	"	"	3.463	9160	0.171
4	6.756	4.067	1.715	"	"	3.397	15975	0.298
5	8.445	5.083	1.667	"	"	3.349	24608	0.459
6	10.134	6.100	1.628	"	"	3.310	35022	0.653
7	11.823	7.117	1.597	"	"	3.279	47223	0.881
8	13.512	8.134	1.571	"	"	3.253	61190	1.142
9	15.201	9.151	1.548	"	"	3.230	76876	1.435
10	16.89	10.168	1.528	"	"	3.210	94345	1.760
11	18.579	11.184	1.510	"	"	3.192	113518	2.118
12	20.268	12.201	1.494	"	"	3.176	134418	2.508
13	21.957	13.218	1.480	"	"	3.162	157,060	2.93

Subject HULL RESISTANCE & PROPELLER DATA SHEET

Ship or Project EMERGENCY TOWING GEAR CRITERIA

Section BSDD Prepared by Date Checked Reviewed

SHIP CLASS: AS-34

DATA SOURCE: REF. 3

SHIP CHARACTERISTICS

LWL = 620'
B = 85.0'
T = 24.4'
Δ = 22,250
WS = 59,630
C_P =
EHP/SHP =
ΔC_F = 0.0005

PROPELLER CHARACTERISTICS

DIA. = 33.0
PITCH = 16.85
# BLADES = 6
EXP. A./D.A. = 0.626
EXPANDED AREA =
DEVELOPED AREA =
PROJ. AREA/D.A. =
PROJECTED AREA =
PROPELLERS =

V KNOTS	SHP	EHP/SHP	EHP	R_T POUNDS	$EHP_{FRIC.}$
9			1200		
10			1400		
11			1900		
12			2400		
13			3175		
14			3900		

Subject HULL RESISTANCE CALCULATION - AS 33

Ship or Project EMERGENCY TOWING GEAR CRITERIA

Section BSDD Prepared by RCS Date 10/29/75 Checked Reviewed

SHIP - AS 33

CALCULATION FOR MAX. SPEED WHERE C_R IS CONSTANT

$$V_K = 0.55\sqrt{LWL} = 13.69 \quad \underline{\text{USE } 9 \text{ KT.}}$$

$$R_T = \frac{EHP \times 326}{V_K} = 43467$$

$$V_s = 1.687\ V_K = 15.201$$

$$R_n = \frac{V_s L}{\nu} = \frac{(15.201)(620)}{1.2791 \times 10^{-5}} = 7.368 \times 10^8$$

$$C_f = 1.590 \times 10^{-3} \quad \text{(SCHOENHERR COEFF.)}$$

$$\Delta C_f = 0.5 \times 10^{-3}$$

$$C_{fT} = 2.09 \times 10^{-3}$$

$$R_F = \tfrac{1}{2}\rho S V_s^2 C_{fT}$$
$$= \tfrac{1}{2}(1.9905)(59,630)(15.201)^2(2.09 \times 10^{-3})$$
$$= 28661$$

$$R_R = R_T - R_F = 14806$$

$$C_R = \frac{(14806)}{\tfrac{1}{2}\rho(59,630)(15.201)^2}$$

$C_R = 1.08$ CONSTANT C_R FOR SHIP SPEEDS LESS THAN 9 KT.

DESIGN CALCULATION SHEET Sheet 70 of 118

Subject: HULL RESISTANCE CALCULATION - AS-33

Ship or Project: EMERGENCY TOWING GEAR CRITERIA

Section: BSDD Prepared by: RCS Date: 10/28/75 Checked: Reviewed:

SHIP - AS-33

$$R_{ns} = \frac{V_s L}{\nu} = \frac{V_s (620)}{1.2791 \times 10^{-5}}$$

$$R_T = \tfrac{1}{2} \rho S V_K^2 C_{TS} (1.689)^2$$

$$R_T = \tfrac{1}{2} (1.9905) S V_K^2 C_{TS} (1.689)^2$$

TABLE FOR CALCULATION OF R_T

V_K KT.	V_S FT./SEC.	R_{ns} $\times 10^8$	C_F $\times 10^{-3}$	ΔC_F $\times 10^{-3}$	C_R $\times 10^{-3}$	C_{TS} $\times 10^{-3}$	R_T LB.	R_T/Δ LB./LT.
0	0	—	—	—	—	—	0	0
1	1.689	0.3187	2.131	0.5	1.08	3.711	628	0.028
2	3.378	1.637	1.935	"	"	3.515	2380	0.107
3	5.067	2.456	1.832	"	"	3.412	5199	0.234
4	6.756	3.275	1.764	"	"	3.344	9058	0.407
5	8.445	4.093	1.714	"	"	3.294	13942	0.637
6	10.134	4.912	1.674	"	"	3.254	19832	0.891
7	11.823	5.731	1.641	"	"	3.221	26720	1.201
8	13.512	6.549	1.614	"	"	3.194	34608	1.555
9	15.201	—	—	—	—	—	43467	1.954
10	16.89	—	—	—	—	—	45640	2.051
11	18.579	—	—	—	—	—	56309	2.531
12	20.268	—	—	—	—	—	65200	2.930
13	21.957	—	—	—	—	—	~~97800~~	~~4.396~~ BAD DATA

M. Rosenblatt & Son, Inc.
DESIGN CALCULATION SHEET

No. 3419
Sheet 71 of 118

Subject: HULL RESISTANCE & PROPELLER DATA SHEET
Ship or Project: EMERGENCY TOWING GENR CRITERIA
Section: BSDD Prepared by: RCS Date: 3/2/76 Checked: Reviewed:

SHIP CLASS: AKA 113

DATA SOURCE: MARCH 1965 O.M. REPORT (FINAL)

SHIP CHARACTERISTICS

LPP / DWL = 550.0
B = 82
T = 26.05
Δ = 19230
WS = 50,447
C_P =
EHP/SHP =
ΔC_F = 0.0005

C_B = 0.57

PROPELLER CHARACTERISTICS

DIA. = 20.04
PITCH = 19.08
# BLADES = 5
EXP. A./D.A. = 0.708
EXPANDED AREA =
DEVELOPED AREA =
PROJ. AREA/D.A. =
PROJECTED AREA =
PROPELLERS =

V KNOTS	SHP	EHP/SHP	EHP $\times 10^{-3}$	R_T POUNDS	$EHP_{FRIC.}$
11			1.65		
12			2.12		
13			2.67		

Subject HULL RESISTANCE CALCULATION - AKA-113

Ship or Project EMERGENCY TOWING GEAR CRITERIA

Section BSDD Prepared by RCS Date 3/4/76 Checked Reviewed

SHIP -

CALCULATION FOR MAX. SPEED WHERE C_R IS CONSTANT

$$V_K = 0.55\sqrt{LWL} = 12.90 \quad \text{USE 11 KT.}$$

$$R_T \underset{\text{AT 11 KT.}}{=} \frac{EHP \times 326}{V_K} = 48900$$

$$V_S = 1.687\ V_K = 18.579$$

$$R_n = \frac{V_S L}{\nu} = \frac{(18.579)(550)}{1.2791 \times 10^{-5}} = 7.989 \times 10^{8}$$

$$C_f = 1.574 \times 10^{-3} \quad \text{(SCHOENHERR COEFF.)}$$

$$\Delta C_f = 0.5 \times 10^{-3}$$

$$C_{fT} = 2.074 \times 10^{-3}$$

$$R_F = \tfrac{1}{2}\rho\, S\, V_S^{2}\, C_{fT}$$
$$= \tfrac{1}{2}(1.9905)(50{,}447)(18.579)^2(2.074 \times 10^{-3})$$
$$= 35944$$

$$R_R = R_T - R_F = 12956$$

$$C_R = \frac{(12956)}{\tfrac{1}{2}\rho(50447)(18.579)^2}$$

$$C_R = 0.748 \times 10^{-3}$$ CONSTANT C_R FOR SHIP SPEEDS LESS THAN 11 KT.

Subject HULL RESISTANCE CALCULATION - AKA 113

Ship or Project EMERGENCY TOWING GEAR CRITERIA

Section BSDD Prepared by RCS Date 3/4/76 Checked Reviewed

SHIP -

$$R_{ns} = \frac{V_s L}{\nu} = \frac{V_s (550)}{1.2791 \times 10^{-5}}$$

$$R_T = \tfrac{1}{2} \rho S V_K^2 C_{TS} (1.689)^2$$

$$R_T = \tfrac{1}{2} (1.9905) S V_K^2 C_{TS} (1.689)^2$$

TABLE FOR CALCULATION OF R_T

V_K KT.	V_S FT./SEC.	R_{ns} $\times 10^8$	C_F $\times 10^{-3}$	ΔC_F $\times 10^{-3}$	C_R $\times 10^{-3}$	C_{TS} $\times 10^{-3}$	R_T LB.	R_T/Δ LB./LT.
0	0	—	—	—	—	—	0	
1	1.689	0.7262	2.168	0.5	0.748	3.416	489	0.03
2	3.378	1.453	1.967	"	"	3.215	1842	0.096
3	5.067	2.179	1.862	"	"	3.110	4009	0.21
4	6.756	2.905	1.792	"	"	3.040	6967	0.36
5	8.445	3.631	1.740	"	"	2.988	10699	0.56
6	10.134	4.358	1.700	"	"	2.948	15200	0.79
7	11.823	5.084	1.667	"	"	2.915	20458	1.06
8	13.512	5.81	1.638	"	"	2.886	26455	1.38
9	15.201	6.537	1.614	"	"	2.862	33203	1.73
10	16.89	7.263	1.593	"	"	2.841	40691	2.12
11	18.579	7.989	1.574	"	"	—	48900	2.54
12	20.268	8.715	1.557	"	"	—	57593	2.99
13	21.957	9.441	1.542	"	"	—	66955	3.48

M. Rosenblatt & Son, Inc.
DESIGN CALCULATION SHEET

No. 3419
Sheet 74 of 118

Subject HULL RESISTANCE & PROPELLER DATA SHEET
Ship or Project EMERGENCY TOWING GEAR CRITERIA
Section BSDD Prepared by RCS Date 3/4/76 Checked Reviewed

SHIP CLASS: LHA

DATA SOURCE: MODEL 5072

SHIP CHARACTERISTICS

LWL = 700
B = 88
T = 27
Δ = 22020
WS = 64,790
C_P = 0.563
EHP/SHP =
ΔC_F = 0.0002
C_B = 0.463

PROPELLER CHARACTERISTICS

DIA. = 19.5
PITCH = 28.42
# BLADES = 5
EXP. A./D.A. = 0.514
EXPANDED AREA =
DEVELOPED AREA =
PROJ. AREA/D.A. =
PROJECTED AREA =
PROPELLERS = 1

V KNOTS	SHP	EHP/SHP	EHP	R_T POUNDS	EHP FRIC.
10			1200		1000
11			1600		1300
12			2200		1600

Subject HULL RESISTANCE CALCULATION - LHA

Ship or Project EMERGENCY TOWING GEAR CRITERIA

Section BSDD Prepared by RCS Date 3/4/76 Checked Reviewed

SHIP -

CALCULATION FOR MAX. SPEED WHERE C_R IS CONSTANT

$$V_K = 0.55 \sqrt{LWL} = 14.55 \quad \underline{\text{USE 10 KT.}}$$

$$R_T \text{ (AT 10 KT.)} = \frac{EHP \times 326}{V_K} = 39120$$

$$V_S = 1.687 \ V_K = 16.89$$

$$R_n = \frac{V_S L}{\nu} = \frac{(16.89)(700)}{1.2791 \times 10^{-5}} = 9.243 \times 10^{8}$$

$$C_f = 1.546 \times 10^{-3} \quad \text{(SCHOENHERR COEFF.)}$$

$$\Delta C_f = 0.2 \times 10^{-3}$$

$$C_{f_T} = 1.746 \times 10^{-3}$$

$$R_F = 1/2 \rho \ S \ V_s^2 \ C_{F_T}$$
$$= 1/2 (1.9905)(64,790)(16.89)^2 (1.746 \times 10^{-3})$$
$$= 32118$$

$$R_R = R_T - R_F = 7002$$

$$C_R = \frac{(7002)}{1/2 \rho (64,790)(16.89)^2}$$

$C_R = 0.3?? \times 10^{-3}$ CONSTANT C_R FOR SHIP SPEEDS LESS THAN <u>10 KT.</u>

DESIGN CALCULATION SHEET

Subject HULL RESISTANCE CALCULATION – LHA

Ship or Project EMERGENCY TOWING GEAR CRITERIA

Section BSDD Prepared by RCS Date 3/4/76 Checked Reviewed

SHIP –

$$R_{ns} = \frac{V_s L}{\nu} = \frac{V_s (700)}{1.2791 \times 10^{-5}}$$

$$R_T = \tfrac{1}{2} \rho S V_K^2 C_{TS} (1.689)^2$$

$$R_T = \tfrac{1}{2} (1.9905) S V_K^2 C_{TS} (1.689)^2$$

TABLE FOR CALCULATION OF R_T

V_K KT.	V_S FT./SEC.	R_{ns} $\times 10^8$	C_F $\times 10^{-3}$	ΔC_F $\times 10^{-3}$	C_R $\times 10^{-3}$	C_{TS} $\times 10^{-3}$	R_T LB.	R_T/Δ LB./LT.
0	0	—	—	—	—	—	0	
1	1.689	0.9243	2.095	0.2	0.381	2.676	492	0.02
2	3.378	1.849	1.904	"	"	2.485	1828	0.08
3	5.067	2.773	1.803	"	"	2.384	3947	0.18
4	6.756	3.697	1.736	"	"	2.317	6819	0.31
5	8.445	4.622	1.687	"	"	2.268	10430	0.47
6	10.134	5.546	1.648	"	"	2.229	14761	0.67
7	11.823	6.470	1.616	"	"	2.197	19803	0.90
8	13.512	7.395	1.589	"	"	2.170	25547	1.16
9	15.201	8.319	1.566	"	"	2.147	31990	1.45
10	16.89	9.243	1.546	"	"	—	39120	1.77
11	18.579	10.167	1.527	"	"	—	47418	2.15
12	20.268	11.091	1.512	"	"	—	59767	2.71
13	21.957	12.016	1.497	"	"	—		

M. Rosenblatt & Son, Inc.
DESIGN CALCULATION SHEET

No. 3419
Sheet 77 of 118

Subject: HULL RESISTANCE & PROPELLER DATA SHEET
Ship or Project: EMERGENCY TOWING GEAR CRITERIA
Section: BSDD | Prepared by | Date | Checked | Reviewed

SHIP CLASS: AO-93

DATA SOURCE: RESISTANCE DATA NOT AVAILABLE

SHIP CHARACTERISTICS

LWL = 502
B = 68
T = 30.17'
Δ = 21 880
WS = ?
C_P = 0.752
EHP/SHP =
ΔC_F = 0.0004
C_X = 0.9882
C_B = 0.74

PROPELLER CHARACTERISTICS

DIA. =
PITCH =
BLADES =
EXP. A./D.A. =
EXPANDED AREA =
DEVELOPED AREA =
PROJ. AREA/D.A. =
PROJECTED AREA =
PROPELLERS =

V KNOTS	SHP	EHP/SHP	EHP	R_T POUNDS	$EHP_{FRIC.}$

Subject: TAYLOR STANDARD SERIES - RESISTANCE CALCULATION

Ship or Project: TOWING RESISTANCE CRITERIA

Section: Prepared by: RCS Date: 3/5/76 Checked: Reviewed:

CALCULATION OF BARE HULL RESISTANCE USING THE TAYLOR STANDARD SERIES

SHIP CLASS AO-93

WATERLINE LENGTH L = 502

BEAM B = 68

DRAFT H = 30.17

DISPLACEMENT Δ = 21880

IMMERSED VOLUME $\forall$ = 765800

WETTED SURFACE S = 52,449

IF S IS NOT GIVEN THEN CALCULATE BY EQUATION

$$S = C_s \sqrt{\nabla \cdot LWL}$$

(FOR C_s COEFFICIENTS SEE REF. 4)

BEAM - DRAFT RATIO B/H = 2.25

LONG'L PRISMATIC C_p = 0.752

VOLUMETRIC COEFFICIENT $C_\forall = \forall / L^3$ = 6.05×10^{-3}

WETTED SURFACE COEFFICIENT $C_s = S/\sqrt{\forall L}$ = 2.675

ΔC_f = 0.0004

$$K = \frac{3.00 - B/H}{0.75} = 1.00$$

NOTE: SCHOENHERR'S FRICTIONAL FORMULATIONS ARE USED TO OBTAIN C_f

$$R_e = \frac{1.687\ V_K\ (L)}{\nu}$$

$C_R = 0.56 \times 10^{-3}$ from TAYLOR'S SERIES

WHERE $\nu = 1.2791 \times 10^{-5}$

$$R_T = \tfrac{1}{2} \rho\ S\ V_K^2\ (1.687)^2\ C_t$$

WHERE $\rho = 1.9905$

Subject: HULL RESISTANCE CALCULATION - AO 93

Ship or Project: EMERGENCY TOWING GEAR CRITERIA

Section: BSDD Prepared by: RCS Date: 3/5/76 Checked: Reviewed:

SHIP -

$$R_{ns} = \frac{V_s L}{\nu} = \frac{V_s (502)}{1.2791 \times 10^{-5}}$$

$$R_T = \tfrac{1}{2} \rho S V_K^2 C_{TS} (1.689)^2$$

$$R_T = \tfrac{1}{2} (1.9905) S V_K^2 C_{TS} (1.689)^2$$

TABLE FOR CALCULATION OF R_T

V_K KT.	V_S FT./SEC.	R_{ns} $\times 10^8$	C_F $\times 10^{-3}$	ΔC_F $\times 10^{-3}$	C_R $\times 10^{-3}$	C_{TS} $\times 10^{-3}$	R_T LB.	R_T/Δ LB./LT.
					USING TAYLORS SERIES			
0	0	—				—	0	0
1	1.689	0.6629	2.197	0.4	0.56	3.157	470	0.02
2	3.378	1.326	1.992	"	"	2.952	1758	0.08
3	5.067	1.989	1.885	"	"	2.845	3813	0.17
4	6.756	2.651	1.814	"	"	2.774	6609	0.30
5	8.445	3.314	1.762	"	"	2.722	10133	0.46
6	10.134	3.977	1.720	"	"	2.68	14367	0.66
7	11.823	4.64	1.686	"	"	2.646	19307	0.88
8	13.512	5.303	1.656	"	"	2.616	24931	1.14
9	15.201	5.966	1.633	"	"	2.593	31276	1.43
10	16.89	6.629	1.611	"	"	2.571	38285	1.75
11	18.579	7.292	1.592	"	"	2.552	45983	2.10
12	20.268	7.954	1.575	"	"	2.535	54359	2.48
13	21.957	8.617	1.559	"	"	2.519	63393	2.90

Subject: HULL RESISTANCE & PROPELLER DATA SHEET

Ship or Project: EMERGENCY TOWING GEAR CRITERIA

Section: BSDD Prepared by: RCS Date: 3/2/76 Checked Reviewed

SHIP CLASS: CVA(N) 65

DATA SOURCE: REF. 1

SHIP CHARACTERISTICS

LWL = 1040
B = 133
T = 35.89
Δ = 85500
WS = 156,990
C_p =
EHP/SHP = 0.68
ΔC_F = 0.00076

C_B = 0.60

PROPELLER CHARACTERISTICS

DIA. = 21
PITCH = 24.12
# BLADES = 5
EXP. A./D.A. =
EXPANDED AREA =
DEVELOPED AREA = 275.43
PROJ. AREA/D.A. =
PROJECTED AREA = 223.33
PROPELLERS = 4

V KNOTS	SHP	EHP/SHP	EHP	R_T POUNDS	EHP FRIC.
14			12,000		
16			17,500		
18			25,000		

Subject HULL RESISTANCE CALCULATION - CVA(N) -65

Ship or Project EMERGENCY TOWING GEAR CRITERIA

Section BSDD Prepared by RCS Date 3/4/76 Checked Reviewed

SHIP-

CALCULATION FOR MAX. SPEED WHERE C_R IS CONSTANT

$$V_K = 0.55 \sqrt{LWL} = 17.73 \text{ KT.} \quad \underline{\text{USE } 14 \text{ KT.}}$$

$$R_T = \frac{EHP \times 326}{V_K} = 279429 \quad (\text{AT } 14 \text{ KT.})$$

$$V_S = 1.687 \; V_K = 23.646$$

$$R_n = \frac{V_S L}{\nu} = \frac{(23.65)(1040)}{1.2791 \times 10^{-5}} = 1.923 \times 10^{9}$$

$$C_f = 1.415 \times 10^{-3} \quad (\text{SCHOENHERR COEFF.})$$

$$\Delta C_f = 0.76 \times 10^{-3}$$

$$C_{fT} = 2.175 \times 10^{-3}$$

$$R_F = \tfrac{1}{2} \rho \, S \, V_S^2 \, C_{FT}$$
$$= \tfrac{1}{2}(1.9905)(156{,}990)(23.65)^2(2.175 \times 10^{-3})$$
$$= 190075$$

$$R_R = R_T - R_F = 89354$$

$$C_R = \frac{(89354)}{\tfrac{1}{2}\rho(156{,}990)(23.65)^2}$$

$$C_R = 1.022$$

CONSTANT C_R FOR SHIP SPEEDS LESS THAN 14 KT.

DESIGN CALCULATION SHEET

Subject: HULL RESISTANCE CALCULATION – CVA(N)-65

Ship or Project: EMERGENCY TOWING GEAR CRITERIA

Section: BSDD Prepared by: RCS Date: 3/4/76 Checked: Reviewed:

SHIP –

$$R_{ns} = \frac{V_s L}{\nu} = \frac{V_s (1040)}{1.2791 \times 10^{-5}}$$

$$R_T = \tfrac{1}{2} \rho S V_K^2 C_{TS} (1.689)^2$$

$$R_T = \tfrac{1}{2} (1.9905) S V_K^2 C_{TS} (1.689)^2$$

TABLE FOR CALCULATION OF R_T

V_K KT.	V_S FT./SEC.	R_{ns} $\times 10^8$	C_F $\times 10^{-3}$	ΔC_F $\times 10^{-3}$	C_R $\times 10^{-3}$	C_{TS} $\times 10^{-3}$	R_T LB.	R_T/Δ LB./LT.
0	0	—	—	—	—	—	0	
1	1.689	1.373	1.982	0.76	1.022	3.764	1678	0.02
2	3.378	2.747	1.805	"	"	3.587	6395	0.07
3	5.067	4.120	1.712	"	"	3.494	14016	0.16
4	6.756	5.493	1.65	"	"	3.432	24475	0.29
5	8.445	6.866	1.604	"	"	3.386	37730	0.44
6	10.134	8.240	1.568	"	"	3.350	53754	0.63
7	11.823	9.613	1.538	"	"	3.320	72510	0.85
8	13.512	10.99	1.513	"	"	3.295	93994	1.10
9	15.201	12.36	1.492	"	"	3.274	118203	1.38
10	16.89	13.73	1.473	"	"	3.255	145082	1.70
11	18.579	15.11	1.456	"	"	3.238	174632	2.04
12	20.268	16.48	1.441	"	"	3.223	206865	2.42
13	21.957	17.85	1.427	"	"	3.209	241724	2.83

Subject: HULL RESISTANCE & PROPELLER DATA SHEET
Ship or Project: EMERGENCY TOWING GEAR CRITERIA
Section: BSDD Prepared by: RCS Date: 3/2/76 Checked: Reviewed:

SHIP CLASS: CVA 59

DATA SOURCE: REF. 1

SHIP CHARACTERISTICS

LWL = 990
B = 129.33'
T = 32.65
Δ = 72,000
WS = 147,700
C_p =
EHP/SHP =
ΔC_F = 0.000778
$C_B = 0.60$

PROPELLER CHARACTERISTICS

DIA. = 21.0
PITCH = 24.87
# BLADES = 5
EXP. A./D.A. = 0.791
EXPANDED AREA =
DEVELOPED AREA =
PROJ. AREA/D.A. =
PROJECTED AREA =
PROPELLERS = 4

V KNOTS	SHP	EHP/SHP	EHP	R_T POUNDS	EHP FRIC.
14			10,000		
16			15,000		
18			23000		

Subject HULL RESISTANCE CALCULATION - CVA 59

Ship or Project EMERGENCY TOWING GEAR CRITERIA

Section BSDD Prepared by RCS Date 3/4/76 Checked Reviewed

SHIP -

CALCULATION FOR MAX. SPEED WHERE C_R IS CONSTANT

$$V_K = 0.55\sqrt{LWL} = 17.31 \quad \underline{\text{USE } 14 \text{ KT.}}$$

$$R_T = \frac{EHP \times 326}{V_K} = 232857$$

$$V_s = 1.687 \; V_K = 23.65$$

$$R_n = \frac{V_s L}{\nu} = \frac{(23.65)(990)}{1.2791 \times 10^{-5}} = 1.8302 \times 10^{9}$$

$$C_f = 1.423 \times 10^{-3} \quad \text{(SCHOENHERR COEFF.)}$$

$$\Delta C_f = 0.778 \times 10^{-3}$$

$$C_{f_T} = 2.201 \times 10^{-3}$$

$$R_F = \tfrac{1}{2}\rho \, S \, V_s^2 \, C_{f_T}$$
$$= \tfrac{1}{2}(1.9905)(147{,}700)(23.65)^2(2.201 \times 10^{-3})$$
$$= 180965$$

$$R_R = R_T - R_F = 51891$$

$$C_R = \frac{(51891)}{\tfrac{1}{2}\rho(147{,}700)(23.65)^2}$$

$$C_R = 0.631 \times 10^{-3}$$

CONSTANT C_R FOR SHIP SPEEDS LESS THAN 14 KT.

Subject: HULL RESISTANCE CALCULATION - CVA 59

Ship or Project: EMERGENCY TOWING GEAR CRITERIA

Section: BSDD Prepared by: RCS Date: 3/4/76 Checked: Reviewed:

SHIP - CVA 59

$$R_{ns} = \frac{V_s L}{\nu} = \frac{V_s (990)}{1.2791 \times 10^{-5}}$$

$$R_T = \tfrac{1}{2} \rho S V_K^2 C_{TS} (1.689)^2$$

$$R_T = \tfrac{1}{2} (1.9905) S V_K^2 C_{TS} (1.689)^2$$

TABLE FOR CALCULATION OF R_T

V_K KT.	V_S FT./SEC.	R_{ns} $\times 10^8$	C_F $\times 10^{-3}$	ΔC_F $\times 10^{-3}$	C_R $\times 10^{-3}$	C_{TS} $\times 10^{-3}$	R_T LB.	R_T/Δ LB./LT.
0	0	—	—	—	—	—	0	0
1	1.689	1.307	1.996	0.778	0.631	3.405	419	0.006
2	3.378	2.615	1.817	"	"	3.226	5411	0.075
3	5.067	3.922	1.723	"	"	3.132	11820	0.16
4	6.756	5.229	1.660	"	"	3.069	20592	0.29
5	8.445	6.536	1.614	"	"	3.023	31692	0.44
6	10.134	7.843	1.578	"	"	2.987	45093	0.63
7	11.823	9.151	1.548	"	"	2.957	60760	0.84
8	13.512	10.46	1.523	"	"	2.932	78689	1.09
9	15.201	11.77	1.501	"	"	2.910	98944	1.37
10	16.89	13.07	1.481	"	"	2.89	121191	1.68
11	18.579	14.38	1.464	"	"	2.873	145778	2.02
12	20.268	15.69	1.449	"	"	2.858	172582	2.40
13	21.957			"	"			

Subject: HULL RESISTANCE & PROPELLER DATA SHEET

Ship or Project: EMERGENCY TOWING GENR CRITERIA

Section: BSDD Prepared by: RCS Date: 3/2/76 Checked: Reviewed:

SHIP CLASS: LCU FY

DATA SOURCE: REPORT 178-H-02, MODEL 5090, FEB. 1967 (SHIP HAS NOZZLES FITTED)

SHIP CHARACTERISTICS

LWL = 120.7

B = 29

T = 5.12

Δ = 375

WS = 3941

C_P = 0.729

EHP/SHP =

ΔC_F = 0.00145

C_B = 0.709

PROPELLER CHARACTERISTICS

DIA. = 4.0

PITCH =

BLADES = 4

EXP. A./D.A. =

EXPANDED AREA =

DEVELOPED AREA =

PROJ. AREA/D.A. =

PROJECTED AREA =

PROPELLERS = 2

V KNOTS	SHP	EHP/SHP	EHP	$R_T = \frac{326(EHP)}{V_K}$ POUNDS	$EHP_{FRIC.}$
4			10	815	
5			18	1174	
6			35	1902	
7			63	2934	
8			100	4075	
9			155	5614	
10			236	7694	
11			345	10225	
12			510	13855	
13			725	18181	

Subject: HULL RESISTANCE CALCULATION - LCU F4
Ship or Project: EMERGENCY TOWING GEAR CRITERIA
Section: BSDD   Prepared by: RCS   Date: 3/4/76   Checked   Reviewed

SHIP - LCU F4

CALCULATION FOR MAX. SPEED WHERE C_R IS CONSTANT

$$V_K = 0.55\sqrt{LWL} = 6.04 \quad \text{USE } 4\text{KT.}$$

$$R_T = \frac{EHP \times 326}{V_K} = 815 \quad (\text{AT } 4 \text{ KT.})$$

$$V_s = 1.687\ V_K = 6.756$$

$$R_n = \frac{V_s L}{\nu} = \frac{(6.756)(120.7)}{1.2791 \times 10^{-5}} = 6.375 \times 10^7$$

$$C_f = 2.209 \times 10^{-3} \quad (\text{SCHOENHERR COEFF.})$$

$$\Delta C_f = 1.45 \times 10^{-3}$$

$$C_{f_T} = 3.659 \times 10^{-3}$$

$$R_F = \tfrac{1}{2}\rho\, S\, V_s^2\, C_{f_T}$$
$$= \tfrac{1}{2}(1.9905)(3941)(6.756)^2(3.659 \times 10^{-3})$$
$$= 655$$

$$R_R = R_T - R_F = 160$$

$$C_R = \frac{(160)}{\tfrac{1}{2}\rho(3941)(6.756)^2}$$

$$C_R = 0.893$$

CONSTANT C_R FOR SHIP SPEEDS LESS THAN 4 KT.

Subject: HULL RESISTANCE CALCULATION – LCU FY

Ship or Project: EMERGENCY TOWING GEAR CRITERIA

Section: BSDD Prepared by: RCS Date: 3/6/76 Checked Reviewed

SHIP –

$$R_{ns} = \frac{V_s L}{\nu} = \frac{V_s (120.7)}{1.2791 \times 10^{-5}}$$

$$R_T = \tfrac{1}{2} \rho S V_K^2 C_{TS} (1.689)^2$$

$$R_T = \tfrac{1}{2} (1.9905) S V_K^2 C_{TS} (1.689)^2$$

TABLE FOR CALCULATION OF R_T

V_K KT.	V_S FT./SEC.	R_{ns} $\times 10^8$	C_F $\times 10^{-3}$	ΔC_F $\times 10^{-3}$	C_R $\times 10^{-3}$	C_{TS} $\times 10^{-3}$	R_T LB.	R_T/Δ LB./LT.
0	0	—	—	—	—	—	0	
1	1.689	0.1594	2.723	1.45	0.893	5.066	56.7	0.15
2	3.378	0.3188	2.447	"	"	4.790	214	0.57
3	5.067	0.4781	2.304	"	"	4.647	468	1.25
4	6.756	—	—	—	—	—	815	2.17
5	8.445	—	—	—	—	—	1174	3.13
6	10.134	—	—	—	—	—	1902	5.07
7	11.823	—	—	—	—	—	2934	7.82
8	13.512	—	—	—	—	—	4075	10.87
9	15.201	—	—	—	—	—	5614	14.97
10	16.89	—	—	—	—	—	7694	20.52
11	18.579	—	—	—	—	—	10225	27.27
12	20.268	—	—	—	—	—	13855	36.95
13	21.957	—	—	—	—	—	18181	48.48

M. Rosenblatt & Son, Inc.
DESIGN CALCULATION SHEET

No. 3419
Sheet 89 of 118

Subject HULL RESISTANCE & PROPELLER DATA SHEET
Ship or Project EMERGENCY TOWING GENR CRITERIA
Section BSDD Prepared by RCS Date 2/13/76 Checked Reviewed

SHIP CLASS: FF 1052 (DE 1052)

DATA SOURCE:

SHIP CHARACTERISTICS

LWL = 419
B = 46.6
T = 25
Δ = 4200
WS = 21818 (CALCULATED)
C_p = 0.577
EHP/SHP =
ΔC_F = 0.0006 (ASSUMED)

PROPELLER CHARACTERISTICS

DIA. = 15.00
PITCH = 15.12
# BLADES = 5
EXP. A./D.A. =
EXPANDED AREA =
DEVELOPED AREA = 153.1
PROJ. AREA/D.A. =
PROJECTED AREA = 131.3
PROPELLERS = 1

V KNOTS	SHP	EHP/SHP	EHP	R_T POUNDS	$EHP_{FRIC.}$
15			2800		
16			3350		
17			3900		
18			4500		

Subject: TAYLOR STANDARD SERIES - RESISTANCE CALCULATION

Ship or Project: TOWING RESISTANCE CRITERIA

Section: Prepared by: RCS Date: 12/10/75 Checked: Reviewed:

CALCULATION OF BARE HULL RESISTANCE USING THE TAYLOR STANDARD SERIES

SHIP CLASS FF 1052 OR DE 1052

WATERLINE LENGTH L = 419

BEAM B = 46.6

DRAFT H = 25

DISPLACEMENT Δ = 4200

IMMERSED VOLUME $\forall$ = 147000

WETTED SURFACE S = 21818

IF S IS NOT GIVEN THEN CALCULATE BY EQUATION

$$S = C_s \sqrt{\nabla \cdot L_{W/L}}$$

(FOR C_s COEFFICIENTS SEE REF. 4)

BEAM - DRAFT RATIO B/H = 1.86

LONG'L PRISMATIC C_p = 0.577

VOLUMETRIC COEFFICIENT $C_\forall = \forall / L^3 = 1.998 \times 10^{-3}$

WETTED SURFACE COEFFICIENT $C_s = S/\sqrt{\forall L} = 2.78$

ΔC_f = ______

$$K = \frac{3.00 - B/H}{0.75} = \_\_\_\_\_\_$$

NOTE: SCHOENHERR'S FRICTIONAL FORMULATIONS ARE USED TO OBTAIN C_f

$$R_e = \frac{1.687\, V_K (L)}{\nu}$$

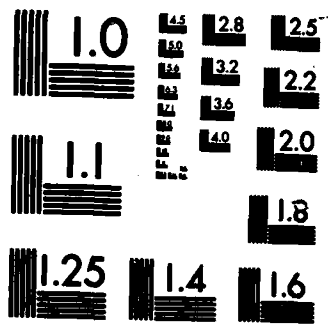
WHERE $\nu = 1.2791 \times 10^{-5}$

$$R_T = \tfrac{1}{2} \rho\, S\, V_K^2 (1.689)^2 C_t$$

WHERE $\rho = 1.9905$

AD-A150 941 DEVELOPMENT OF A CALCULATION PROCEDURE FOR THE DETERMINATION OF TOW RESISTANCE (UNABRIDGED REPORT)(U) ROSENBLATT (M) AND SON INC NEW YORK APR 76 3/6

UNCLASSIFIED N00024-74-C-5508 F/G 13/10 NL



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

Subject: HULL RESISTANCE CALCULATION - FF 1052

Ship or Project: EMERGENCY TOWING GEAR CRITERIA

Section: BSDD Prepared by: RCS Date: 2/13/76 Checked Reviewed

SHIP -

CALCULATION FOR MAX. SPEED WHERE C_R IS CONSTANT

$$V_K = 0.55\sqrt{LWL} = 11.25$$

TAYLOR'S SERIES INDICATES THAT C_R IS CONSTANT BELOW $V/\sqrt{L} = 0.7$[illegible] $\cong$ 15 k[illegible]

$$R_T = \frac{EHP \times 326}{V_K} = 60853$$

AT 15 KT.

$$V_S = 1.687\ V_K = 25.335$$

$$R_n = \frac{V_S L}{\nu} = \frac{(25.335)(419)}{1.2791 \times 10^{-5}} = 8.299 \times 10^{8}$$

$C_f = 1.567 \times 10^{-3}$ (SCHOENHERR COEFF.)

$\Delta C_f = 0.6 \times 10^{-3}$

$C_{fT} = 2.167 \times 10^{-3}$

$$R_F = \tfrac{1}{2}\rho\, S\, V_s^{2}\, C_{fT}$$
$$= \tfrac{1}{2}(1.9905)(21818)(25.335)^2(2.167 \times 10^{-3})$$
$$= 30203$$

$$R_R = R_T - R_F = 30650.$$

$$C_R = \frac{(30650)}{\tfrac{1}{2}\rho(21818)(25.335)^2}$$

$C_R = 2.20 \times 10^{-3}$ CONSTANT C_R FOR SHIP SPEEDS LESS THAN 15 KT.

DESIGN CALCULATION SHEET

Subject: HULL RESISTANCE CALCULATION – FF 1052

Ship or Project: EMERGENCY TOWING GEAR CRITERIA

Section: BSDD Prepared by: RCS Date: 2/13/76 Checked Reviewed

SHIP –

$$R_{ns} = \frac{V_s L}{\nu} = \frac{V_s (419)}{1.2791 \times 10^{-5}}$$

$$R_T = \tfrac{1}{2} \rho S V_k^2 C_{TS} (1.689)^2$$

$$R_T = \tfrac{1}{2}(1.9905) S V_k^2 C_{TS} (1.689)^2$$

TABLE FOR CALCULATION OF R_T

V_K KT.	V_S FT./SEC.	R_{ns} $\times 10^8$	C_F $\times 10^{-3}$	ΔC_F $\times 10^{-3}$	C_R $\times 10^{-3}$	C_{TS} $\times 10^{-3}$	R_T LB.	R_T/Δ LB./LT.
0	0	—	—	—	—	—	0	0
1	1.689	0.553	2.255	0.6	2.20	5.055	313	0.08
2	3.378	1.107	2.043	"	"	4.843	1200	0.29
3	5.067	1.660	1.932	"	"	4.732	2638	0.63
4	6.756	2.213	1.858	"	"	4.658	4617	1.10
5	8.445	2.766	1.803	"	"	4.603	7128	1.70
6	10.134	3.320	1.761	"	"	4.561	10171	2.42
7	11.823	3.873	1.726	"	"	4.526	13738	3.27
8	13.512	4.426	1.696	"	"	4.496	17824	4.24
9	15.201	4.979	1.671	"	"	4.471	22433	5.34
10	16.89	5.533	1.649	"	"	4.449	27559	6.56
11	18.579	6.086	1.629	"	"	4.429	33197	7.90
12	20.268	6.639	1.611	"	"	4.411	39346	9.37
13	21.957	7.192	1.595	"	"	4.395	46010	10.95

M. Rosenblatt & Son, Inc.
DESIGN CALCULATION SHEET

No. 3419
Sheet 93 of 118

Subject HULL RESISTANCE & PROPELLER DATA SHEET
Ship or Project EMERGENCY TOWING GEAR CRITERIA
Section BSDD Prepared by RCS Date 2/13/76 Checked Reviewed

SHIP CLASS: DDG 2

DATA SOURCE: REF. 3

SHIP CHARACTERISTICS

LWL = 431
B = 47.03
T = 15.0
Δ = 4544
WS = 22470
C_p = 0.643
EHP/SHP =
ΔC_F = 0.0011

PROPELLER CHARACTERISTICS

DIA. = 13.5'
PITCH = 14.85
# BLADES = 4
EXP. A./D.A. = 0.835
EXPANDED AREA =
DEVELOPED AREA =
PROJ. AREA/D.A. =
PROJECTED AREA = 176
PROPELLERS = 2

V KNOTS	SHP	EHP/SHP	EHP	R_T POUNDS	$EHP_{FRIC.}$
12			1,500		
13			1700		
14			2300		
15			2800		
16			3,500		

Subject HULL RESISTANCE CALCULATION - DDG-2

Ship or Project EMERGENCY TOWING GEAR CRITERIA

Section BSDD Prepared by RCS Date 2/13/76 Checked Reviewed

SHIP -

CALCULATION FOR MAX. SPEED WHERE C_R IS CONSTANT

$$V_K = 0.55\sqrt{LWL} = 11.42$$

$$R_T = \frac{EHP \times 326}{V_K} = 40{,}750$$

TAYLOR'S SERIES INDICATES C_R IS CONSTANT AT $V/\sqrt{L} = 0.58 \equiv 12$ K

$$V_s = 1.687\ V_K = 20.268$$

$$R_n = \frac{V_s L}{\nu} = \frac{(20.268)(431)}{1.2791 \times 10^{-5}} = 6.829 \times 10^{8}$$

$$C_f = 1.605 \times 10^{-3} \quad \text{(SCHOENHERR COEFF.)}$$

$$\Delta C_f = 1.10 \times 10^{-3}$$

$$C_{f_T} = 2.705 \times 10^{-3}$$

$$R_F = \tfrac{1}{2}\rho\, S\, V_s^2\, C_{f_T}$$

$$= \tfrac{1}{2}(1.9905)(22470)(20.268)^2(2.705 \times 10^{-3})$$

$$= 24850$$

$$R_R = R_T - R_F = 15900$$

$$C_R = \frac{(15900)}{\tfrac{1}{2}\rho(22470)(20.268)^2}$$

$$C_R = 1.73 \times 10^{-3}$$

CONSTANT C_R FOR SHIP SPEEDS LESS THAN 12 KT.

Subject: HULL RESISTANCE CALCULATION - DDG-2

Ship or Project: EMERGENCY TOWING GEAR CRITERIA

Section: BSDD Prepared by: RCS Date: 2/13/76 Checked Reviewed

SHIP -

$$R_{ns} = \frac{V_s L}{\nu} = \frac{V_s (431)}{1.2791 \times 10^{-5}}$$

$$R_T = \tfrac{1}{2} \rho S V_K^2 C_{TS} (1.689)^2$$

$$R_T = \tfrac{1}{2} (1.9905) S V_K^2 C_{TS} (1.689)^2$$

TABLE FOR CALCULATION OF R_T

V_K KT.	V_S FT./SEC.	R_{ns} $\times 10^8$	C_F $\times 10^{-3}$	ΔC_F $\times 10^{-3}$	C_R $\times 10^{-3}$	C_{TS} $\times 10^{-3}$	R_T LB.	R_T/Δ LB./LT.
0	0	—	—	—	—	—	0	0
1	1.689	0.569	2.246	1.10	1.73	5.076	324	0.071
2	3.378	1.138	2.035	"	"	4.865	1241	0.27
3	5.067	1.707	1.929	"	"	4.759	2730	0.60
4	6.756	2.276	1.851	"	"	4.681	4778	1.05
5	8.445	2.846	1.797	"	"	4.627	7380	1.62
6	10.134	3.415	1.754	"	"	4.584	10528	2.32
7	11.823	3.984	1.720	"	"	4.55	14223	3.13
8	13.512	4.553	1.690	"	"	4.52	18455	4.06
9	15.201	5.122	1.665	"	"	4.495	23228	5.11
10	16.89	5.691	1.643	"	"	4.473	28536	6.28
11	18.579	6.260	1.623	"	"	4.453	34374	7.56
12	20.268	6.829	1.605	"	"	4.435	40742	8.97
13	21.957	7.399	1.589	"	"	4.419	47643	10.48

DESIGN CALCULATION SHEET

Subject: HULL RESISTANCE & PROPELLER DATA SHEET

Ship or Project: EMERGENCY TOWING GEAR CRITERIA

Section: BSDD Prepared by: Date: Checked: Reviewed:

SHIP CLASS: DD 963

DATA SOURCE: DON CALLUM - TRIAL CONDITION & MODEL 5265-1 BY LIN AND MURRAY JAN. 1975.

SHIP CHARACTERISTICS

LWL = 530.2

B = 55.0

T = 19.74

Δ = 8000

WS = 35410

C_P = 0.5804

EHP/SHP =

ΔC_F = 0.0005

C_B = 0.49

PROPELLER CHARACTERISTICS

DIA. = 17.00

PITCH = 26.18

BLADES = 5

EXP. A./D.A. = 0.730

EXPANDED AREA =

DEVELOPED AREA =

PROJ. AREA/D.A. =

PROJECTED AREA =

PROPELLERS = 2

V KNOTS	SHP	EHP/SHP	EHP $\times 10^{-3}$	R_T POUNDS	$EHP_{FRIC.}$
16			5.2		
17			6.3		
18			7.5		

Subject HULL RESISTANCE CALCULATION - DD 963

Ship or Project EMERGENCY TOWING GEAR CRITERIA

Section BSDD Prepared by RCS Date 3/3/76 Checked Reviewed

SHIP -

CALCULATION FOR MAX. SPEED WHERE C_R IS CONSTANT

$$V_K = 0.55\sqrt{LWL} = 12.66 \text{ KT.}$$

AT $V/\sqrt{L} = 0.69$ C_R IS STILL CONSTANT

$$R_T = \frac{EHP \times 326}{V_K} = 105950$$

$$V_s = 1.687\ V_K = 27.024$$

$$R_n = \frac{V_s L}{\nu} = \frac{(27.024)(530.2)}{1.2791 \times 10^{-5}} = 1.1202 \times 10^9$$

$$C_f = 1.51 \times 10^{-3} \quad \text{(SCHOENHERR COEFF.)}$$

$$\Delta C_f = 0.5 \times 10^{-3}$$

$$C_{fT} = 2.01 \times 10^{-3}$$

$$R_F = \tfrac{1}{2}\rho\, S\, V_s^2\, C_{fT}$$
$$= \tfrac{1}{2}(1.9905)(35410)(27.024)^2(2.01 \times 10^{-3})$$
$$= 51731$$

$$R_R = R_T - R_F = 54219$$

$$C_R = \frac{(54219)}{\tfrac{1}{2}\rho(35410)(27.024)^2}$$

$$C_R = 2.107 \times 10^{-3}$$

CONSTANT C_R FOR SHIP SPEEDS LESS THAN 16 KT.

Subject HULL RESISTANCE CALCULATION – DD 963
Ship or Project EMERGENCY TOWING GEAR CRITERIA
Section BSDD Prepared by RCS Date 3/3/76 Checked Reviewed

SHIP –

$$R_{ns} = \frac{V_s L}{\nu} = \frac{V_s (530.2)}{1.2791 \times 10^{-5}}$$

$$R_T = \tfrac{1}{2} \rho S V_K^2 C_{TS} (1.689)^2$$

$$R_T = \tfrac{1}{2} (1.9905) S V_K^2 C_{TS} (1.689)^2$$

TABLE FOR CALCULATION OF R_T

V_K KT.	V_S FT./SEC.	R_{ns} $\times 10^8$	C_F $\times 10^{-3}$	ΔC_F $\times 10^{-3}$	C_R $\times 10^{-3}$	C_{TS} $\times 10^{-3}$	R_T LB.	R_T/Δ
0	0	—	—	—	—	—	0	0
1	1.689	0.700	2.180	0.5	2.107	4.787	481	0.06
2	3.378	1.400	1.977	"	"	4.584	1843	0.23
3	5.067	2.100	1.871	"	"	4.478	4052	0.51
4	6.756	2.800	1.801	"	"	4.408	7091	0.88
5	8.445	3.500	1.749	"	"	4.356	10948	1.37
6	10.134	4.201	1.708	"	"	4.315	15617	1.95
7	11.823	4.900	1.674	"	"	4.281	21089	2.64
8	13.512	5.601	1.646	"	"	4.253	27365	3.42
9	15.201	6.301	1.622	"	"	4.229	34438	4.30
10	16.89	7.001	1.600	"	"	4.207	42295	5.29
11	18.579	7.701	1.581	"	"	4.188	50946	6.37
12	20.268	8.401	1.564	"	"	4.171	60384	7.55
13	21.957	9.101	1.549	"	"	4.156	70612	8.83

DESIGN CALCULATION SHEET

Subject: HULL RESISTANCE & PROPELLER DATA SHEET

Ship or Project: EMERGENCY TOWING GEAR CRITERIA

Section: BSDD Prepared by: RCS Date: 3/2/76 Checked: Reviewed:

SHIP CLASS: T-AGOR

DATA SOURCE: MODEL 5042 REPORT 072-H-08 NOV. 1966

SHIP CHARACTERISTICS

LWL = 220
B = 46
T = 15
Δ = 1922
WS = 11107 (BARE HULL)
C_P =
EHP/SHP =
ΔC_F = 0.0005

C_B = 0.44

PROPELLER CHARACTERISTICS

CYCLOIDAL PROPELLERS

DIA. =
PITCH =
BLADES =
EXP. A./D.A. =
EXPANDED AREA =
DEVELOPED AREA =
PROJ. AREA/D.A. =
PROJECTED AREA =
PROPELLERS =

V KNOTS	SHP	EHP/SHP	EHP $\times 10^{-2}$ (?)	R_T POUNDS	EHP FRIC.
7			1.05		
8			1.67		
9			2.43		
10			3.33		
11			4.5		
12			6.05		

DESIGN CALCULATION SHEET

Subject: HULL RESISTANCE CALCULATION - T-AGOR

Ship or Project: EMERGENCY TOWING GEAR CRITERIA

Section: BSDD   Prepared by: RCS   Date: 3/4/76   Checked: Reviewed:

SHIP -

CALCULATION FOR MAX. SPEED WHERE C_R IS CONSTANT

$$V_K = 0.55\sqrt{LWL} = 8.16 \quad \text{USE 7 KT.}$$

$$R_T = \frac{EHP \times 326}{V_K} = 4890 \quad (\text{AT 7 KT.})$$

$$V_s = 1.687\ V_K = 11.823$$

$$R_n = \frac{V_s L}{\nu} = \frac{(11.823)(220)}{1.2791 \times 10^{-5}} = 2034 \times 10^{8}$$

$$C_f = 2.621 \times 10^{-3} \quad (\text{SCHOENHERR COEFF.})$$

$$\Delta C_f = 0.5 \times 10^{-3}$$

$$C_{f_T} = 3.121 \times 10^{-3}$$

$$R_F = \tfrac{1}{2}\rho\, S\, V_s^2\, C_{f_T}$$
$$= \tfrac{1}{2}(1.9905)(11107)(11.823)^2(3.121 \times 10^{-3})$$
$$= 4823$$

$$R_R = R_T - R_F = 67$$

$$C_R = \frac{(67)}{\tfrac{1}{2}\rho(11107)(11.823)^2}$$

$$C_R = 0.043$$

CONSTANT C_R FOR SHIP SPEEDS LESS THAN 7 KT.

Subject: HULL RESISTANCE CALCULATION - T-AGOR

Ship or Project: EMERGENCY TOWING GEAR CRITERIA

Section: BSDD Prepared by: RCS Date: 3/4/76 Checked: Reviewed:

SHIP -

$$R_{ns} = \frac{V_s L}{\nu} = \frac{V_s (220)}{1.2791 \times 10^{-5}}$$

$$R_T = \tfrac{1}{2} \rho S V_K^2 C_{TS} (1.689)^2$$

$$R_T = \tfrac{1}{2} (1.9905) S V_K^2 C_{TS} (1.689)^2$$

TABLE FOR CALCULATION OF R_T

V_K KT.	V_S FT./SEC.	R_{ns} $\times 10^8$	C_F $\times 10^{-3}$	ΔC_F $\times 10^{-3}$	C_R $\times 10^{-3}$	C_{TS} $\times 10^{-3}$	R_T LB.	R_T/Δ LB./LT.
0	0	—	—	—	—	—	0	
1	1.689	0.2905	2.482	0.5	0.043	3.025	95.39	0.05
2	3.378	0.5810	2.239	"	"	2.782	351	0.18
3	5.067	0.8715	2.112	"	"	2.655	754	0.39
4	6.756	1.162	2.029	"	"	2.572	1298	0.68
5	8.445	1.453	1.967	"	"	2.510	1979	1.03
6	10.134	1.743	1.919	"	"	2.462	2795	1.45
7	11.823	—	—	—	—	—	4890	2.54
8	13.512	—	—	—	—	—	6805	3.54
9	15.201	—	—	—	—	—	8802	4.58
10	16.89	—	—	—	—	—	10,856	5.65
11	18.579	—	—	—	—	—	13336	6.94
12	20.268	—	—	—	—	—	16436	8.55
13	21.957	—						

Subject HULL RESISTANCE & PROPELLER DATA SHEET
Ship or Project EMERGENCY TOWING GEAR CRITERIA
Section BSDD Prepared by Date 2/12/76 Checked Reviewed

SHIP CLASS: DLG-26 (CG-26)

DATA SOURCE: .

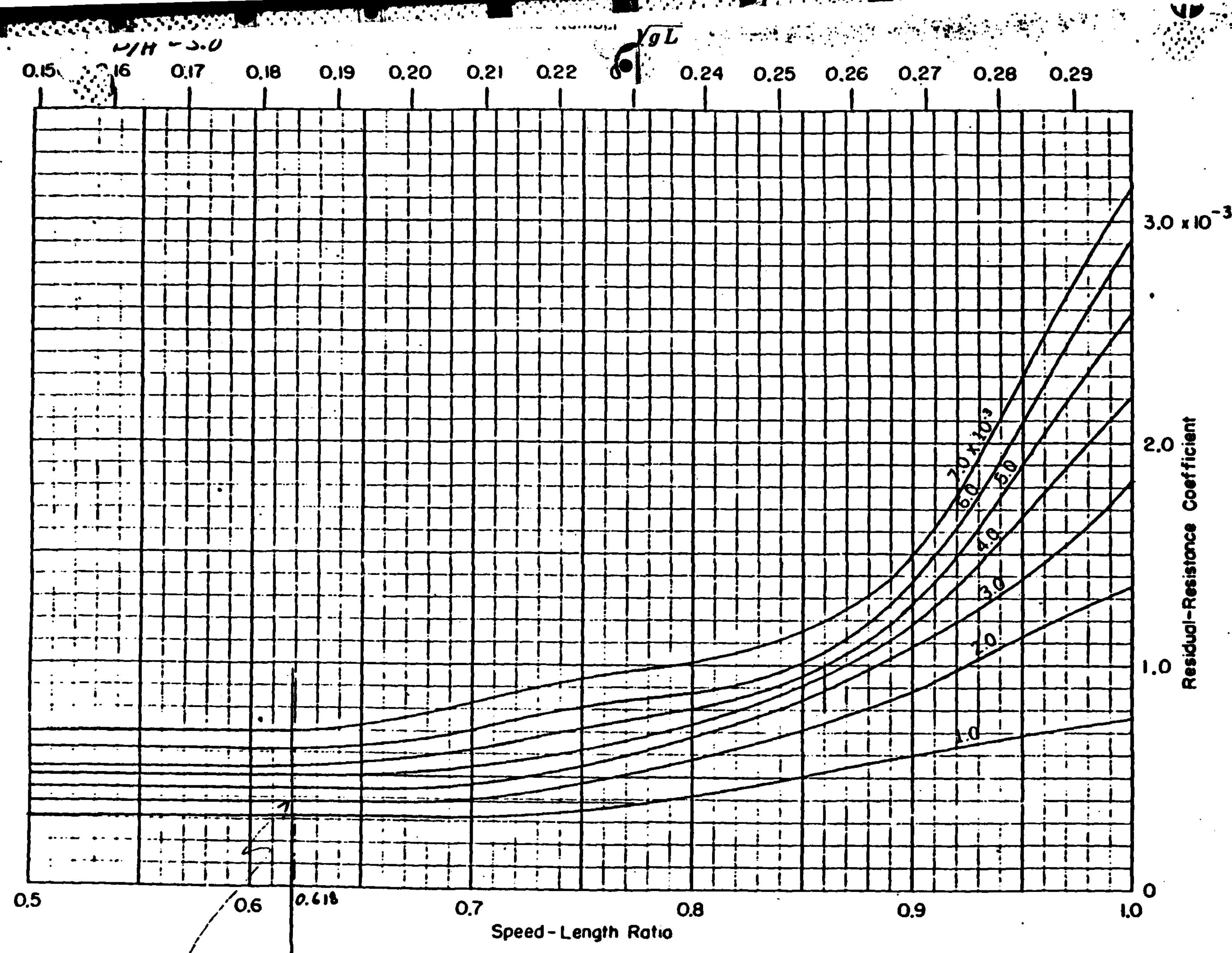
SHIP CHARACTERISTICS

LWL = 524.6
B = 54.4
T = 19.1
Δ = 7,928
WS = 34,620
C_P = 0.618
EHP/SHP =
ΔC_F = 0.0006

PROPELLER CHARACTERISTICS

DIA. = 14.75
PITCH = 16.58
# BLADES = 6
EXP. A./D.A. = 1.035
EXPANDED AREA =
DEVELOPED AREA =
PROJ. AREA/D.A. =
PROJECTED AREA = 296
PROPELLERS = 2

V KNOTS	SHP	EHP/SHP	EHP	R_T POUNDS	$EHP_{FRIC.}$
14			2900		
15			3800		
16			4100		
17			5000		



C_r IS STILL CONSTANT AT $V/\sqrt{L} = 0.61 \equiv 14$ KT.

DESIGN CALCULATION SHEET

Subject HULL RESISTANCE CALCULATION - DLG-26 (CG-26)

Ship or Project EMERGENCY TOWING GEAR CRITERIA

Section BSDD Prepared by RCS Date 2/12/76 Checked Reviewed

SHIP- DLG -26

CALCULATION FOR MAX. SPEED WHERE C_R IS CONSTANT

$$V_K = 0.55 \sqrt{LWL} = 12.59$$

HOWEVER TAYLOR'S SERIES C_R IS CONSTANT BELOW

$$R_T = \frac{EHP \times 326}{V_K} = 67529 \quad V/\sqrt{L} = 0.61 \equiv 14 \text{ KT.}$$

AT 14 KT.

$$V_S = 1.687 \; V_K = 23.646$$

$$R_n = \frac{V_S L}{\nu} = \frac{(23.646)(524.6)}{1.2791 \times 10^{-5}} = 9.698 \times 10^{8}$$

$$C_f = 1.537 \times 10^{-3} \quad \text{(SCHOENHERR COEFF.)}$$

$$\Delta C_f = 0.6 \times 10^{-3}$$

$$C_{fT} = 2.137 \times 10^{-3}$$

$$R_F = \tfrac{1}{2} \rho \, S \, V_s^2 \, C_{fT}$$

$$= \tfrac{1}{2}(1.9905)(34{,}620)(23.646)^2(2.137 \times 10^{-3})$$

$$= 41170$$

$$R_R = R_T - R_F = 26359$$

$$C_R = \frac{(26359)}{\tfrac{1}{2} \rho (34{,}620)(23.646)^2}$$

$C_R = 1.368 \times 10^{-3}$ CONSTANT C_R FOR SHIP SPEEDS LESS THAN 14 KT.

DESIGN CALCULATION SHEET

Sheet 105 of 118

Subject: HULL RESISTANCE CALCULATION – DLG-26 (CG-26)

Ship or Project: EMERGENCY TOWING GEAR CRITERIA

Section: BSDD Prepared by: RCS Date: 2/12/76 Checked: Reviewed:

SHIP – DLG-26

$$R_{ns} = \frac{V_s L}{\nu} = \frac{V_s (524.6)}{1.2791 \times 10^{-5}}$$

$$R_T = \tfrac{1}{2} \rho S V_K^2 C_{TS} (1.687)^2$$

$$R_T = \tfrac{1}{2} (1.9905) S V_K^2 C_{TS} (1.689)^2$$

TABLE FOR CALCULATION OF R_T

V_K KT.	V_S FT./SEC.	R_{ns} $\times 10^8$	C_F $\times 10^{-3}$	ΔC_F $\times 10^{-3}$	C_R $\times 10^{-3}$	C_{TS} $\times 10^{-3}$	R_T LB.	R_T/Δ LB./LT.
0	0	—	—	—	—	—	0	0
1	1.687	0.693	2.183	0.60	1.368	4.151	215	0.027
2	3.378	1.385	1.980	"	"	3.948	1552	0.196
3	5.067	2.078	1.874	"	"	3.842	3399	0.429
4	6.756	2.771	1.803	"	"	3.771	5931	0.748
5	8.445	3.463	1.751	"	"	3.719	9139	1.15
6	10.134	4.156	1.709	"	"	3.677	13011	1.64
7	11.823	4.849	1.677	"	"	3.645	17555	2.21
8	13.512	5.541	1.648	"	"	3.616	22,747	2.87
9	15.201	6.234	1.624	"	"	3.592	28,598	3.61
10	16.89	6.927	1.602	"	"	3.570	35,096	4.43
11	18.579	7.620	1.583	"	"	3.551	42,233	5.33
12	20.268	8.313	1.566	"	"	3.534	50020	6.31
13	21.757	9.005	1.551	"	"	3.519	58455	7.37

DESIGN CALCULATION SHEET

Subject: HULL RESISTANCE & PROPELLER DATA SHEET
Ship or Project: EMERGENCY TOWING GEAR CRITERIA
Section: BSDD Prepared by: Date: 2/12/76 Checked: Reviewed:

SHIP CLASS: DD 710 & 825

DATA SOURCE: REPORT: DD 692 CLASS LENGTHENED 14'
MODEL NUMBER 3869-2

SHIP CHARACTERISTICS

LWL = 383'
B = 40.89'
T = 14.04'
Δ = 3400 LT
WS = 18673 FT.²
C_p = 0.638
EHP/SHP =
ΔC_F = 0.001141 (ASSUMED = DD931)

PROPELLER CHARACTERISTICS

DIA. = 12.25
PITCH = 12.58
# BLADES = 3
EXP. A./D.A. =
EXPANDED AREA =
DEVELOPED AREA =
PROJ. AREA/D.A. = 0.589
PROJECTED AREA = 158
PROPELLERS = 2

V KNOTS	SHP	EHP/SHP	EHP	R_T POUNDS	EHP FRIC. GEBER'S
12			830		500
14			1430		800
16			2220		980
18			3280		1620

Subject: HULL RESISTANCE CALCULATION - DD 710 & 825

Ship or Project: EMERGENCY TOWING GEAR CRITERIA

Section: BSDD Prepared by Date 2/12/76 Checked Reviewed

SHIP -

CALCULATION FOR MAX. SPEED WHERE C_R IS CONSTANT

$$V_K = 0.55\sqrt{LWL} = 10.76$$

HOWEVER TAYLOR'S SERIES C_R IS CONSTANT BELOW $V/\sqrt{L} = 0.64 \equiv 12$ KT.

$$R_T = \frac{EHP \times 326}{V_K} = 22548 \quad (V_K = 12 \text{ KT.})$$

$$V_s = 1.687\, V_K = 20.27$$

$$R_n = \frac{V_s L}{\nu} = \frac{(20.27)(383)}{1.2791 \times 10^{-5}} = 6.069 \times 10^8$$

$$C_f = 1.629 \times 10^{-3} \quad \text{(SCHOENHERR COEFF.)}$$

$$\Delta C_f = 1.141 \times 10^{-3}$$

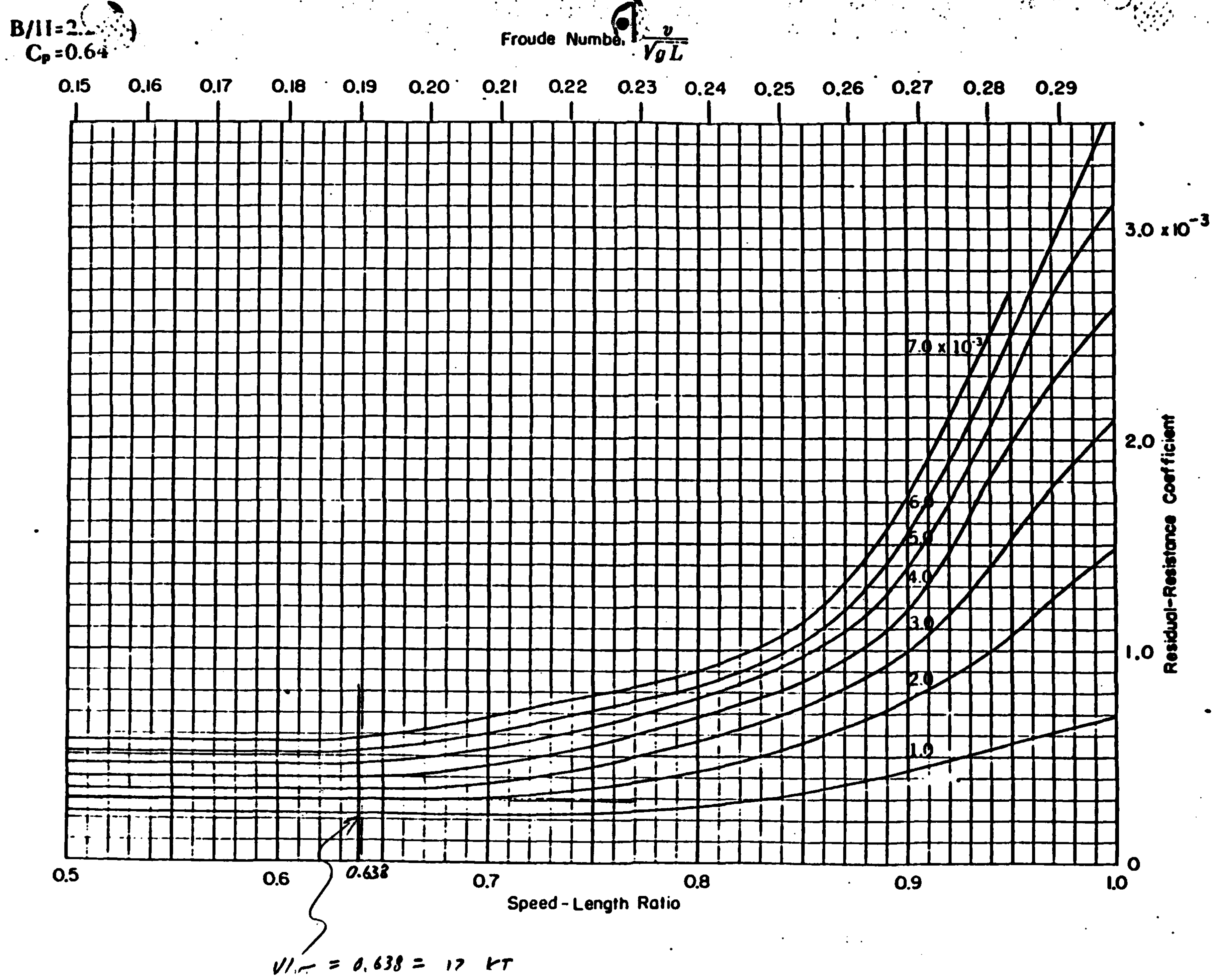
$$C_{fT} = 2.77 \times 10^{-3}$$

$$R_F = \tfrac{1}{2}\rho S V_s^2 C_{fT}$$
$$= \tfrac{1}{2}(1.9905)(18673)(20.27)^2(2.77 \times 10^{-3})$$
$$= 21151$$

$$R_R = R_T - R_F = 22548 - 21151 = 1396.8$$

$$C_R = \frac{(1396.8)}{\tfrac{1}{2}\rho(18673)(20.27)^2}$$

$C_R = 0.183 \times 10^{-3}$ CONSTANT C_R FOR SHIP SPEEDS LESS THAN 12 KT.



B/H=2.
C_p=0.64
Froude Number, $\frac{v}{\sqrt{gL}}$
0.15
0.16
0.17
0.18
0.19
0.20
0.21
0.22
0.23
0.24
0.25
0.26
0.27
0.28
0.29
3.0 x 10^{-3}
2.0
1.0
0
Residual-Resistance Coefficient
7.0 x 10^{-3}
6.0
5.0
4.0
3.0
2.0
1.0
0.5
0.6
0.638
0.7
0.8
0.9
1.0
Speed - Length Ratio
V/√ = 0.638 = 17 KT

Subject: HULL RESISTANCE CALCULATION - DD 710 & 825
Ship or Project: EMERGENCY TOWING GEAR CRITERIA
Section: BSDD Prepared by: RCS Date: 2/12/76 Checked Reviewed

SHIP -

$$R_{ns} = \frac{V_s L}{\nu} = \frac{V_s (383)}{1.2791 \times 10^{-5}}$$

$$R_T = \tfrac{1}{2} \rho S V_K^2 C_{TS} (1.687)^2$$

$$R_T = \tfrac{1}{2} (1.9905) S V_K^2 C_{TS} (1.689)^2$$

TABLE FOR CALCULATION OF R_T

V_K KT.	V_S FT./SEC.	R_{ns} $\times 10^8$	C_F $\times 10^{-3}$	ΔC_F $\times 10^{-3}$	C_R $\times 10^{-3}$	C_{TS} $\times 10^{-3}$	R_T LB.	R_T/Δ LB./LT.
0	0	—	—	—	—	—	0	0
1	1.687	0.506	2.285	1.141	0.183	3.609	191	0.001
2	3.378	1.011	2.069	"	"	3.393	719	0.211
3	5.067	1.517	1.956	"	"	3.280	1565	0.46
4	6.756	2.023	1.881	"	"	3.205	2719	0.80
5	8.445	2.529	1.825	"	"	3.149	4174	1.23
6	10.134	3.034	1.782	"	"	3.106	5928	1.74
7	11.823	3.540	1.746	"	"	3.070	7975	2.35
8	13.512	4.046	1.716	"	"	3.040	10315	3.03
9	15.201	4.552	1.690	"	"	3.014	12943	3.81
10	16.89	5.057	1.668	"	"	2.992	15862	4.67
11	18.579	5.563	1.648	"	"	2.972	19065	5.61
12	20.268	—	—	—	—	—	22548	6.63
13	21.957	—	—	—	—	—		

Subject HULL RESISTANCE & PROPELLER DATA SHEET

Ship or Project EMERGENCY TOWING GEAR CRITERIA

Section BSDD Prepared by Date Checked Reviewed

SHIP CLASS: DL-1 (ex. CLK 1)

DATA SOURCE: REF. 1

SHIP CHARACTERISTICS

LWL = 520
B = 54
T = 18.00
Δ = 6625
WS = 31685
C_p =
EHP/SHP =
ΔC_F = 0.000923
C_B = 0.46

PROPELLER CHARACTERISTICS

DIA. = 18'-4"
PITCH = 22.5
# BLADES = 6
EXP. A./D.A. =
EXPANDED AREA =
DEVELOPED AREA =
PROJ. AREA/D.A. = 0.706
PROJECTED AREA = 186.37
PROPELLERS = 2

V KNOTS	SHP	EHP/SHP	EHP	R_T POUNDS	EHP FRIC.
10			1000		
12			1600		

Subject HULL RESISTANCE CALCULATION - DL-1

Ship or Project EMERGENCY TOWING GEAR CRITERIA

Section BSDD Prepared by RCS Date 3/4/76 Checked Reviewed

SHIP -

CALCULATION FOR MAX. SPEED WHERE C_R IS CONSTANT

$$V_K = 0.55 \sqrt{LWL} = 12.54 \quad \underline{\text{USE } 10 \text{ KT.}}$$

$$R_T = \frac{EHP \times 326}{V_K} = 32600$$

$$V_S = 1.689 \, V_K = 16.89$$

$$R_n = \frac{V_s L}{\nu} = \frac{(16.89)(520)}{1.2791 \times 10^{-5}} = 6.866 \times 10^{-3}$$

$$C_f = 1.604 \times 10^{-3} \quad \text{(SCHOENHERR COEFF.)}$$

$$\Delta C_f = 0.923 \times 10^{-3}$$

$$C_{fT} = 2.527 \times 10^{-3}$$

$$R_F = \tfrac{1}{2} \rho \, S \, V_s^2 \, C_{fT}$$
$$= \tfrac{1}{2}(1.9905)(32600)(16.89)^2(2.527 \times 10^{-3})$$
$$= 23389$$

$$R_R = R_T - R_F = 9211$$

$$C_R = \frac{(9211)}{\tfrac{1}{2}\rho(32600)(16.89)^2}$$

$C_R = 0.995 \times 10^{-3}$ CONSTANT C_R FOR SHIP SPEEDS LESS THAN 10 KT.

Subject HULL RESISTANCE CALCULATION – DL-1

Ship or Project EMERGENCY TOWING GEAR CRITERIA

Section BSDD **Prepared by** RCS **Date** 3/4/76 **Checked** **Reviewed**

SHIP –

$$R_{ns} = \frac{V_s L}{\nu} = \frac{V_s (520)}{1.2791 \times 10^{-5}}$$

$$R_T = \tfrac{1}{2} \rho S V_K^2 C_{TS} (1.687)^2$$

$$R_T = \tfrac{1}{2} (1.9905) S V_K^2 C_{TS} (1.689)^2$$

TABLE FOR CALCULATION OF R_T

V_K KT.	V_S FT./SEC.	R_{ns} $\times 10^8$	C_F $\times 10^{-3}$	ΔC_F $\times 10^{-3}$	C_R $\times 10^{-3}$	C_{TS} $\times 10^{-3}$	R_T LB.	R_T/Δ LB./LT.
0	0	—	—	—	—	—	0	0
1	1.687	0.6866	2.185	0.923	0.995	4.103	369	0.06
2	3.378	1.373	1.982	"	"	3.900	1403	0.21
3	5.067	2.060	1.876	"	"	3.794	3072	0.46
4	6.756	2.747	1.805	"	"	3.723	5359	0.81
5	8.445	3.433	1.753	"	"	3.671	8256	1.25
6	10.134	4.120	1.712	"	"	3.63	11756	1.77
7	11.823	4.806	1.678	"	"	3.596	15851	2.39
8	13.512	5.493	1.650	"	"	3.568	20542	3.10
9	15.201	6.180	1.626	"	"	3.544	25824	3.89
10	16.89	—	—	—	—	—	32600	4.92
11	18.579	—	—	—	—	—		
12	20.268	—	—	—	—	—	43467	6.56
13	21.957	—	—	—	—	—		

Subject HULL RESISTANCE & PROPELLER DATA SHEET

Ship or Project EMERGENCY TOWING GEAR CRITERIA

Section BSDD Prepared by RCS Date 3/4/76 Checked Reviewed

SHIP CLASS: LST 1171

DATA SOURCE: REF. 1

SHIP CHARACTERISTICS

LWL = 426
B = 62
T = 12.29
Δ = 7084
WS = 30384
C_p =
EHP/SHP =
ΔC_F = 0.00086

C_B = 0.76

PROPELLER CHARACTERISTICS

DIA. = 9.25
PITCH = 8.35
# BLADES = 5
EXP. A./D.A. =
EXPANDED AREA =
DEVELOPED AREA = 49.0
PROJ. AREA/D.A. =
PROJECTED AREA = 42.8
PROPELLERS = 2

V KNOTS	SHP	EHP/SHP	EHP	R_T POUNDS	EHP FRIC.
6			200		
7			350		
8			500		
9			650		
10			950		
11			1200		
12			1600		
13			2250		

Subject HULL RESISTANCE CALCULATION - LST-1171

Ship or Project EMERGENCY TOWING GEAR CRITERIA

Section BSDD Prepared by RCS Date 3/4/76 Checked Reviewed

SHIP-

CALCULATION FOR MAX. SPEED WHERE C_R IS CONSTANT

$$V_K = 0.55\sqrt{LWL} = 11.35 \quad \underline{\text{USE 6 KT.}}$$

$$R_T = \frac{EHP \times 326}{V_K} = 10867$$

$$V_s = 1.687\ V_K = 10.134$$

$$R_n = \frac{V_s L}{\nu} = \frac{(10.134)(426)}{1.2771 \times 10^{-5}} = 3.375 \times 10^{8}$$

$$C_f = 1.733 \times 10^{-3} \quad \text{(SCHOENHERR COEFF.)}$$

$$\Delta C_f = 0.86 \times 10^{-3}$$

$$C_{fT} = 2.593 \times 10^{-3}$$

$$R_F = \tfrac{1}{2}\rho S V_s^2 C_{fT}$$
$$= \tfrac{1}{2}(1.9905)(30384)(10.134)^2(2.593 \times 10^{-3})$$
$$= 8053$$

$$R_R = R_T - R_F = 2814$$

$$C_R = \frac{(2814)}{\tfrac{1}{2}\rho(30384)(10.134)^2}$$

$$C_R = 0.906$$

CONSTANT C_R FOR SHIP SPEEDS LESS THAN 6 KT.

Subject: HULL RESISTANCE CALCULATION – LST-1171

Ship or Project: EMERGENCY TOWING GEAR CRITERIA

Section: BSDD Prepared by: RCS Date: 3/4/76 Checked Reviewed

SHIP –

$$R_{ns} = \frac{V_s L}{\nu} = \frac{V_s (426)}{1.2791 \times 10^{-5}}$$

$$R_T = \tfrac{1}{2} \rho \, S \, V_K^2 \, C_{TS} \, (1.689)^2$$

$$R_T = \tfrac{1}{2} (1.9905) \, S \, V_K^2 \, C_{TS} \, (1.689)^2$$

TABLE FOR CALCULATION OF R_T

V_K KT.	V_S FT./SEC.	R_{ns} $\times 10^8$	C_F $\times 10^{-3}$	ΔC_F $\times 10^{-3}$	C_R $\times 10^{-3}$	C_{TS} $\times 10^{-3}$	R_T LB.	R_T/Δ LB./LT.
0	0	—	—	—	—	—	0	
1	1.689	0.5625	2.249	0.86	0.906	4.015	346	0.05
2	3.378	1.125	2.038	"	"	3.804	1313	0.19
3	5.067	1.688	1.927	"	"	3.693	2867	0.40
4	6.756	2.250	1.854	"	"	3.620	4996	0.71
5	8.445	2.813	1.800	"	"	3.566	7691	1.09
6	10.134	—	—	—	—	—	10867	1.53
7	11.823	—	—	—	—	—	16300	2.30
8	13.512	—	—	—	—	—	20375	2.88
9	15.201	—	—	—	—	—	23544	3.32
10	16.89	—	—	—	—	—	30970	4.37
11	18.579	—	—	—	—	—	35564	5.02
12	20.268	—	—	—	—	—	43467	6.14
13	21.957	—	—	—	—	—	56423	7.96

M. Rosenblatt & Son, Inc.

DESIGN CALCULATION SHEET

No. 3419

Sheet 116 of 118

Subject: HULL RESISTANCE & PROPELLER DATA SHEET

Ship or Project: EMERGENCY TOWING GEAR CRITERIA

Section: BSDD | Prepared by | Date | Checked | Reviewed

SHIP CLASS: LCC-19

DATA SOURCE: REF. 1

SHIP CHARACTERISTICS

LWL = 556

B = 82.0

T = 26

Δ = 18,500

WS = 49,540

C_P = 0.5479

EHP/SHP =

ΔC_F = 0.0005

C_B = 0.51

PROPELLER CHARACTERISTICS

DIA. = 20.0

PITCH = 24.82

BLADES = 4

EXP. A./D.A. =

EXPANDED AREA = 234.54

DEVELOPED AREA =

PROJ. AREA/D.A. =

PROJECTED AREA = 185.48

PROPELLERS = 1

V KNOTS	SHP	EHP/SHP	EHP	R_T POUNDS	EHP FRIC.
10			1350		
11			1800		
12			2400		
13			3000		
14			3750		
15			4600		

Subject HULL RESISTANCE CALCULATION - LCC-19
Ship or Project EMERGENCY TOWING GEAR CRITERIA
Section BSDD Prepared by RCS Date 3/4/76 Checked Reviewed

SHIP -
CALCULATION FOR MAX. SPEED WHERE C_R IS CONSTANT

$$V_K = 0.55\sqrt{LWL} = 12.96 \quad \underline{\text{USE } 10 \text{ KT.}}$$

$$R_T = \frac{EHP \times 326}{V_K} = 44010$$

$$V_S = 1.687\ V_K = 16.89$$

$$R_n = \frac{V_S L}{\nu} = \frac{(16.89)(556)}{1.2791 \times 10^{-5}} = 7.342 \times 10^{8}$$

$$C_f = 1.591 \times 10^{-3} \quad \text{(SCHOENHERR COEFF.)}$$

$$\Delta C_f = 0.5 \times 10^{-3}$$

$$C_{fT} = 2.091 \times 10^{-3}$$

$$R_F = \tfrac{1}{2}\rho\ S\ V_s^2\ C_{FT}$$
$$= \tfrac{1}{2}(1.9905)(49{,}540)(16.89)^2(2.091 \times 10^{-3})$$
$$= 29410$$

$$R_R = R_T - R_F = 14600$$

$$C_R = \frac{(14600)}{\tfrac{1}{2}\rho(49540)(16.89)^2}$$

$C_R = 1.038 \times 10^{-3}$ CONSTANT C_R FOR SHIP SPEEDS LESS THAN 10 KT.

Subject: HULL RESISTANCE CALCULATION - LCC-19

Ship or Project: EMERGENCY TOWING GEAR CRITERIA

Section: BSDD Prepared by: RCS Date: 3/4/76 Checked Reviewed

SHIP -

$$R_{ns} = \frac{V_s L}{\nu} = \frac{V_s (556)}{1.2791 \times 10^{-5}}$$

$$R_T = \tfrac{1}{2} \rho S V_K^2 C_{TS} (1.689)^2$$

$$R_T = \tfrac{1}{2} (1.9905) S V_K^2 C_{TS} (1.689)^2$$

TABLE FOR CALCULATION OF R_T

V_K KT.	V_S FT./SEC.	R_{ns} $\times 10^8$	C_F $\times 10^{-3}$	ΔC_F $\times 10^{-3}$	C_R $\times 10^{-3}$	C_{TS} $\times 10^{-3}$	R_T LB.	R_T/Δ LB./LT.
0	0	—	—	—	—	—	0	
1	1.689	0.7342	2.165	0.5	1.038	3.703	521	0.03
2	3.378	1.468	1.964	"	"	3.502	1970	0.11
3	5.067	2.203	1.859	"	"	3.397	4300	0.23
4	6.756	2.937	1.789	"	"	3.327	7487	0.40
5	8.445	3.671	1.738	"	"	3.276	11519	0.62
6	10.134	4.405	1.697	"	"	3.235	16380	0.88
7	11.823	5.139	1.664	"	"	3.202	22068	1.19
8	13.512	5.873	1.636	"	"	3.174	28572	1.54
9	15.201	6.608	1.612	"	"	3.150	35887	1.94
10	16.89	—	—	—	—	—	44010	2.38
11	18.579	—	—	—	—	—	53345	2.88
12	20.268	—	—	—	—	—	65200	3.52
13	21.957	—	—	—	—	—	75231	4.07

DESIGN CALCULATION SHEET Sheet 116A of 118

Subject: HULL RESISTANCE & PROPELLER DATA SHEET

Ship or Project: EMERGENCY TOWING GEAR CRITERIA

Section: B3DD Prepared by: RCS Date: 3/2/76 Checked: Reviewed:

SHIP CLASS: LPH-3

DATA SOURCE: REF. 1

SHIP CHARACTERISTICS		PROPELLER CHARACTERISTICS	
LWL =	543.02	DIA. =	21.0
B =	84.17	PITCH =	22.5
T =	26.5	# BLADES =	4
Δ =	18080	EXP. A./D.A. =	
WS =	49045	EXPANDED AREA =	
C_p =		DEVELOPED AREA =	
EHP/SHP =		PROJ. AREA/D.A. =	
ΔC_F =	0.00071	PROJECTED AREA =	155.3
C_B =	0.52	# PROPELLERS =	

V KNOTS	SHP	EHP/SHP	EHP	R_T POUNDS	EHP FRIC.
8			700		
9			1000		
10			1300		
11			1800		
12			2300		
13			2900		

Subject HULL RESISTANCE CALCULATION - LPH-3

Ship or Project EMERGENCY TOWING GEAR CRITERIA

Section BSDD Prepared by RCS Date 3/4/76 Checked Reviewed

SHIP -

CALCULATION FOR MAX. SPEED WHERE C_R IS CONSTANT

$$V_K = 0.55 \sqrt{LWL} = 12.81 \quad \underline{\text{USE } 8 \text{ KT.}}$$

$$R_T = \frac{EHP \times 326}{V_K} = 28525 \quad (\text{AT } 8 \text{ KT.})$$

$$V_s = 1.689 \; V_K = 13.512$$

$$R_n = \frac{V_s L}{\nu} = \frac{(13.512)(543.02)}{1.2791 \times 10^{-5}} = 5.736 \times 10^{8}$$

$$C_f = 1.641 \times 10^{-3} \quad (\text{SCHOENHERR COEFF.})$$

$$\Delta C_f = 0.71 \times 10^{-3}$$

$$C_{f_T} = 2.351 \times 10^{-3}$$

$$R_F = \tfrac{1}{2} \rho \, S \, V_s^2 \, C_{f_T}$$
$$= \tfrac{1}{2}(1.9905)(49045)(13.512)^2(2.351 \times 10^{-3})$$
$$= 20952$$

$$R_R = R_T - R_F = 7573$$

$$C_R = \frac{(7573)}{\tfrac{1}{2}\rho(49045)(13.512)^2}$$

$C_R = 0.850$ CONSTANT C_R FOR SHIP SPEEDS LESS THAN 8 KT.

Subject: HULL RESISTANCE CALCULATION – LPH-3

Ship or Project: EMERGENCY TOWING GEAR CRITERIA

Section: BSDD Prepared by: RCS Date: 3/4/76 Checked Reviewed

SHIP –

$$R_{ns} = \frac{V_s L}{\nu} = \frac{V_s (543.02)}{1.2791 \times 10^{-5}}$$

$$R_T = \tfrac{1}{2} \rho S V_K^2 C_{TS} (1.689)^2$$

$$R_T = \tfrac{1}{2} (1.9905) S V_K^2 C_{TS} (1.689)^2$$

TABLE FOR CALCULATION OF R_T

V_K KT.	V_S FT./SEC.	R_{ns} $\times 10^8$	C_F $\times 10^{-3}$	ΔC_F $\times 10^{-3}$	C_R $\times 10^{-3}$	C_{TS} $\times 10^{-3}$	R_T LB.	R_T/Δ LB./LT.
0	0	—	—	—	—	—	0	0
1	1.689	0.7170	2.172	0.71	0.85	3.732	520	0.03
2	3.378	1.434	1.971	"	"	3.531	1967	0.11
3	5.067	2.151	1.865	"	"	3.425	4292	0.24
4	6.756	2.868	1.795	"	"	3.355	7475	0.41
5	8.445	3.585	1.743	"	"	3.303	11498	0.64
6	10.134	4.302	1.703	"	"	3.263	16357	0.90
7	11.823	5.019	1.669	"	"	3.229	22032	1.22
8	13.512	—	—	—	—	—	28525	1.58
9	15.201	—	—	—	—	—	36222	2.00
10	16.89	—	—	—	—	—	42380	2.34
11	18.579	—	—	—	—	—	53345	2.95
12	20.268	—	—	—	—	—	62493	3.46
13	21.957	—	—	—	—	—	72723	4.02

BARGE RESISTANCE DATA

Special Note: The following pages are stamped restricted but this classification was canceled by authorization of the Ad Hoc Committee Action November 27, 1953 and signed by B.C. Taylor, security officer.

CALCULATION OF TOW RESISTANCE BY METHOD USED IN U.S. NAVY TOWING MANUAL

SHIP: CA 139 HEAVY CRUISER

DATE: 2/25/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		CA 139
2	TOW DISPLACEMENT, Δ (SEE TABLE 7)	LONG TONS	21470
3	FRONTAL WINDAGE AREA, A_T	SQ. FT.	4500
4	TOW SPEED, V_{TOW}	KNOTS	10
5	DIRECTION OF TRUE WIND FROM BOW, θ	DEGREES	0
6	TRUE WIND VELOCITY, V_{WIND}	KNOTS	0
7	WIND VELOCITY COMPONENT V_T = (4) + [(6) x COS (5)]	KNOTS	10
8	WIND PRESSURE P, (SEE GRAPH 1)	LBS/SQ.FT.	1
9	WIND RESISTANCE, R_W = (3) x (8)	POUNDS	4500
10	HYDRODYNAMIC UNIT RESISTANCE r_H, (SEE GRAPH 2)	--	8.5
11	SEA STATE CORRECTION FACTOR K_1 (SEE TABLE 8)	--	1.0
12	HYDRODYNAMIC RESISTANCE R_H = (2) x (10) x (11)	POUNDS	182495
13	TOTAL PROJECTED AREA OF PROPELLERS, A_p	SQ. FT.	324
14	PROPELLER RESISTANCE = R_p = 3.394 x (13) x (4) x (4)	POUNDS	109966
15	HULL RESISTANCE = (10) x (2) - (14)	POUNDS	72529
16	SEA STATE RESISTANCE = R_s = (12) - (15) - (14)	POUNDS	0
17	TOTAL TOW RESISTANCE = R_T = (9) + (12)	POUNDS	186995

CALCULATION OF TOW RESISTANCE BY METHOD USED IN U.S. NAVY TOWING MANUAL

SHIP: CA 139 HEAVY CRUISER

DATE: 2/24/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		CA 139
2	TOW DISPLACEMENT, Δ (SEE TABLE 7)	LONG TONS	21470
3	FRONTAL WINDAGE AREA, A_T	SQ. FT.	4500
4	TOW SPEED, V_{TOW}	KNOTS	8
5	DIRECTION OF TRUE WIND FROM BOW, θ	DEGREES	0
6	TRUE WIND VELOCITY, V_{WIND}	KNOTS	13.5
7	WIND VELOCITY COMPONENT V_T = (4) + [(6) x COS (5)]	KNOTS	21.5
8	WIND PRESSURE P, (SEE GRAPH 1)	LBS/SQ.FT.	1.5
9	WIND RESISTANCE, R_W = (3) x (8)	POUNDS	6750
10	HYDRODYNAMIC UNIT RESISTANCE r_H, (SEE GRAPH 2)	--	5.5
11	SEA STATE CORRECTION FACTOR K_1 (SEE TABLE 8)	--	1.4
12	HYDRODYNAMIC RESISTANCE R_H = (2) x (10) x (11)	POUNDS	165319
13	TOTAL PROJECTED AREA OF PROPELLERS, A_P	SQ. FT.	324
14	PROPELLER RESISTANCE = R_P = 3.394 x (13) x (4) x (4)	POUNDS	70377
15	HULL RESISTANCE = (10) x (2) - (14)	POUNDS	47708
16	SEA STATE RESISTANCE = R_S = (12) - (15) - (14)	POUNDS	47234
17	TOTAL TOW RESISTANCE = R_T = (9) + (12)	POUNDS	172069

CALCULATION OF TOW RESISTANCE BY METHOD USED IN U.S. NAVY TOWING MANUAL

SHIP: CA 139 HEAVY CRUSER

DATE: 2/24/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		CA 139
2	TOW DISPLACEMENT, Δ (SEE TABLE 7)	LONG TONS	21470
3	FRONTAL WINDAGE AREA, A_T	SQ. FT.	4500
4	TOW SPEED, V_{TOW}	KNOTS	8
5	DIRECTION OF TRUE WIND FROM BOW, θ	DEGREES	47.23
6	TRUE WIND VELOCITY, V_{WIND}	KNOTS	13.5
7	WIND VELOCITY COMPONENT V_T = (4) + [(6) x COS (5)]	KNOTS	17.17
8	WIND PRESSURE P, (SEE GRAPH 1)	LBS/SQ.FT	1.2
9	WIND RESISTANCE, R_W = (3) x (8)	POUNDS	5400
10	HYDRODYNAMIC UNIT RESISTANCE r_H, (SEE GRAPH 2)	--	5.5
11	SEA STATE CORRECTION FACTOR K_1 (SEE TABLE 8)	--	1.4
12	HYDRODYNAMIC RESISTANCE R_H = (2) x (10) x (11)	POUNDS	165319
13	TOTAL PROJECTED AREA OF PROPELLERS, A_p	SQ. FT.	324
14	PROPELLER RESISTANCE = R_p = 3.394 x (13) x (4) x (4)	POUNDS	70377
15	HULL RESISTANCE = (10) x (2) - (14)	POUNDS	47708
16	SEA STATE RESISTANCE = R_s = (12) - (15) - (14)	POUNDS	47234
17	TOTAL TOW RESISTANCE = R_T = (9) + (12)	POUNDS	170719

CALCULATION OF TOW RESISTANCE BY METHOD USED IN U.S. NAVY TOWING MANUAL

SHIP: CA 139

DATE: 2/24/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		CA 139
2	TOW DISPLACEMENT, Δ (SEE TABLE 7)	LONG TONS	21470
3	FRONTAL WINDAGE AREA, A_T	SQ. FT.	4500
4	TOW SPEED, V_{TOW}	KNOTS	8
5	DIRECTION OF TRUE WIND FROM BOW, θ	DEGREES	126.34
6	TRUE WIND VELOCITY, V_{WIND}	KNOTS	13.5
7	WIND VELOCITY COMPONENT V_T = (4) + [(6) x COS (5)]	KNOTS	0
8	WIND PRESSURE P, (SEE GRAPH 1)	LBS/SQ.FT	0
9	WIND RESISTANCE, R_W = (3) x (8)	POUNDS	0
10	HYDRODYNAMIC UNIT RESISTANCE r_H, (SEE GRAPH 2)	--	5.5
11	SEA STATE CORRECTION FACTOR K_1 (SEE TABLE 8)	--	1.4
12	HYDRODYNAMIC RESISTANCE R_H = (2) x (10) x (11)	POUNDS	165319
13	TOTAL PROJECTED AREA OF PROPELLERS, A_P	SQ. FT.	324
14	PROPELLER RESISTANCE = R_P = 3.394 x (13) x (4) x (4)	POUNDS	70377
15	HULL RESISTANCE = (10) x (2) - (14)	POUNDS	47708
16	SEA STATE RESISTANCE = R_S = (12) - (15) - (14)	POUNDS	47234
17	TOTAL TOW RESISTANCE = R_T = (9) + (12)	POUNDS	165319

CALCULATION OF TOW RESISTANCE BY METHOD USED IN U.S. NAVY TOWING MANUAL

SHIP: CA 139

DATE: 2/24/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		CA 139
2	TOW DISPLACEMENT, Δ (SEE TABLE 7)	LONG TONS	21470
3	FRONTAL WINDAGE AREA, A_T	SQ. FT.	4500
4	TOW SPEED, V_{TOW}	KNOTS	5
5	DIRECTION OF TRUE WIND FROM BOW, θ	DEGREES	0
6	TRUE WIND VELOCITY, V_{WIND}	KNOTS	24.5
7	WIND VELOCITY COMPONENT V_T = (4) + [(6) x COS (5)]	KNOTS	29.5
8	WIND PRESSURE P, (SEE GRAPH 1)	LBS/SQ.FT.	2.4
9	WIND RESISTANCE, R_W = (3) x (8)	POUNDS	10800
10	HYDRODYNAMIC UNIT RESISTANCE r_H, (SEE GRAPH 2)	--	2.1
11	SEA STATE CORRECTION FACTOR K_1 (SEE TABLE 8)	--	1.6
12	HYDRODYNAMIC RESISTANCE R_H = (2) x (10) x (11)	POUNDS	72139
13	TOTAL PROJECTED AREA OF PROPELLERS, A_p	SQ. FT.	324
14	PROPELLER RESISTANCE = R_p = 3.394 x (13) x (4) x (4)	POUNDS	27491
15	HULL RESISTANCE = (10) x (2) - (14)	POUNDS	17596
16	SEA STATE RESISTANCE = R_s = (12) - (15) - (14)	POUNDS	27052
17	TOTAL TOW RESISTANCE = R_T = (9) + (12)	POUNDS	82939

CALCULATION OF TOW RESISTANCE BY METHOD USED IN U.S. NAVY TOWING MANUAL

SHIP: CA 139

DATE: 2/24/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		CA 139
2	TOW DISPLACEMENT, Δ (SEE TABLE 7)	LONG TONS	21470
3	FRONTAL WINDAGE AREA, A_T	SQ. FT.	4500
4	TOW SPEED, V_{TOW}	KNOTS	5
5	DIRECTION OF TRUE WIND FROM BOW, θ	DEGREES	35.86
6	TRUE WIND VELOCITY, V_{WIND}	KNOTS	24.5
7	WIND VELOCITY COMPONENT V_T = (4) + [(6) x COS (5)]	KNOTS	24.86
8	WIND PRESSURE P, (SEE GRAPH 1)	LBS/SQ.FT.	2.0
9	WIND RESISTANCE, R_W = (3) x (8)	POUNDS	9000
10	HYDRODYNAMIC UNIT RESISTANCE r_H, (SEE GRAPH 2)	--	2.1
11	SEA STATE CORRECTION FACTOR K_1 (SEE TABLE 8)	--	1.6
12	HYDRODYNAMIC RESISTANCE R_H = (2) x (10) x (11)	POUNDS	72139
13	TOTAL PROJECTED AREA OF PROPELLERS, A_P	SQ. FT.	324
14	PROPELLER RESISTANCE = R_p = 3.394 x (13) x (4) x (4)	POUNDS	27491
15	HULL RESISTANCE = (10) x (2) - (14)	POUNDS	17596
16	SEA STATE RESISTANCE = R_s = (12) - (15) - (14)	POUNDS	27052
17	TOTAL TOW RESISTANCE = R_T = (9) + (12)	POUNDS	81139

CALCULATION OF TOW RESISTANCE BY METHOD USED IN U.S. NAVY TOWING MANUAL

SHIP: CA 139

DATE: 2/24/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		CA 139
2	TOW DISPLACEMENT, Δ (SEE TABLE 7)	LONG TONS	21470
3	FRONTAL WINDAGE AREA, A_T	SQ. FT.	4500
4	TOW SPEED, V_{TOW}	KNOTS	5
5	DIRECTION OF TRUE WIND FROM BOW, θ	DEGREES	101.8
6	TRUE WIND VELOCITY, V_{WIND}	KNOTS	24.5
7	WIND VELOCITY COMPONENT V_T = (4) + [(6) x COS (5)]	KNOTS	-0.01
8	WIND PRESSURE P, (SEE GRAPH 1)	LBS/SQ.FT.	0
9	WIND RESISTANCE, R_W = (3) x (8)	POUNDS	0
10	HYDRODYNAMIC UNIT RESISTANCE r_H, (SEE GRAPH 2)	--	2.1
11	SEA STATE CORRECTION FACTOR K_1 (SEE TABLE 8)	--	1.6
12	HYDRODYNAMIC RESISTANCE R_H = (2) x (10) x (11)	POUNDS	72139
13	TOTAL PROJECTED AREA OF PROPELLERS, A_P	SQ. FT.	324
14	PROPELLER RESISTANCE = R_p = 3.394 x (13) x (4) x (4)	POUNDS	27491
15	HULL RESISTANCE = (10) x (2) - (14)	POUNDS	17596
16	SEA STATE RESISTANCE = R_s = (12) - (15) - (14)	POUNDS	27052
17	TOTAL TOW RESISTANCE = R_T = (9) + (12)	POUNDS	72139

CALCULATION OF TOWING RESISTANCE

SHIP: CA 139 DATE: 2/24/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		CA 139
2	TOW DISPLACEMENT, Δ (SEE TABLE-7)	LONG TONS	21478
3	FRONTAL WINDAGE AREA, A_T, (SEE TABLE 7)	SQ. FEET	4500
4	WIND DRAG COEFFICIENT, C_w, (SEE TABLE 7)	—	0.70
5	TOTAL PROJECTED AREA OF PROPELLERS, A_p, (SEE TABLE 7)	SQ. FEET	324
6	CURVE NUMBER FOR HULL RESISTANCE, R_H/Δ, (SEE TABLE 7)	—	7
7	CURVE NUMBER FOR WIND FACTOR, K, (SEE TABLE 7)	—	3
8	CURVE NUMBER FOR SEA STATE RESISTANCE, R_s, (SEE TABLE 7)	—	7
9	BEAUFORT NUMBER (WIND) - (SEE TABLE-8)	—	0
10	RELATIVE WIND SPEED, V_R	KNOTS	10
11	RELATIVE WIND DIRECTION, α	DEGREES	0
12	HEADING COEFFICIENT K, (SEE FIG. 13-15)	—	1.0
13	SEA STATE RESISTANCE R_s, (SEE FIG. 16)	—	0
14	SELECT A TOW SPEED, V_{TOW}	KNOTS	10
15	$R_{H/\Delta}$ (SEE FIG. 17)	—	2.23
16	HULL RESISTANCE = R_H = (15) × (2) × 1.25	POUNDS	59848
17	PROPELLER RESISTANCE = R_p = 3.737 × (5) × (14) × (14)	POUNDS	121079
18	WIND RESISTANCE = R_w = 0.00506 × (4) × (3) × (12) × (10) × (10)	POUNDS	1594
19	TOTAL TOW RESISTANCE = R_T = (13) + (16) + (17) + (18)	POUNDS	182521

TABLE - 6

CALCULATION OF TOWING RESISTANCE

SHIP: CA 139 DATE: 2/24/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		CA 139
2	TOW DISPLACEMENT, Δ (SEE TABLE-7)	LONG TONS	21470
3	FRONTAL WINDAGE AREA, A_T, (SEE TABLE 7)	SQ. FEET	4500
4	WIND DRAG COEFFICIENT, C_w, (SEE TABLE 7)	—	0.70
5	TOTAL PROJECTED AREA OF PROPELLERS, A_p, (SEE TABLE 7)	SQ. FEET	324
6	CURVE NUMBER FOR HULL RESISTANCE, $R_{H/\Delta}$, (SEE TABLE 7)	—	7
7	CURVE NUMBER FOR WIND FACTOR, K, (SEE TABLE 7)	—	3
8	CURVE NUMBER FOR SEA STATE RESISTANCE, R_s, (SEE TABLE 7)	—	7
9	BEAUFORT NUMBER (WIND) - (SEE TABLE-8)	—	4
10	RELATIVE WIND SPEED, V_R	KNOTS	21.5
11	RELATIVE WIND DIRECTION, α	DEGREES	0
12	HEADING COEFFICIENT K, (SEE FIG. 13-15)	—	1.0
13	SEA STATE RESISTANCE R_s, (SEE FIG. 16)	—	1,300
14	SELECT A TOW SPEED, V_{TOW}	KNOTS	8
15	$R_{H/\Delta}$ (SEE FIG. 17)	—	1.4
16	HULL RESISTANCE = R_H = (15) × (2) × 1.25	POUNDS	30058
17	PROPELLER RESISTANCE = R_p = 3.737 × (5) × (14) × (14)	POUNDS	77490
18	WIND RESISTANCE = R_w = 0.00506 × (4) × (3) × (12) × (10) × (10)	POUNDS	7368
19	TOTAL TOW RESISTANCE = R_T = (13) + (16) + (17) + (18)	POUNDS	116216

TABLE - 6

CALCULATION OF TOWING RESISTANCE

SHIP: *CA 139* DATE: *2/24/76*

BY: *RCS*

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		CA 139
2	TOW DISPLACEMENT, Δ (SEE TABLE-7)	LONG TONS	21470
3	FRONTAL WINDAGE AREA, A_T, (SEE TABLE 7)	SQ. FEET	4500
4	WIND DRAG COEFFICIENT, C_w, (SEE TABLE 7)	—	0.70
5	TOTAL PROJECTED AREA OF PROPELLERS, A_p, (SEE TABLE 7)	SQ. FEET	324
6	CURVE NUMBER FOR HULL RESISTANCE, $R_{H/\Delta}$, (SEE TABLE 7)	—	7
7	CURVE NUMBER FOR WIND FACTOR, K, (SEE TABLE 7)	—	3
8	CURVE NUMBER FOR SEA STATE RESISTANCE, R_s, (SEE TABLE 7)	—	7
9	BEAUFORT NUMBER (WIND) - (SEE TABLE-8)	—	4
10	RELATIVE WIND SPEED, V_R	KNOTS	19.82
11	RELATIVE WIND DIRECTION, α	DEGREES	30
12	HEADING COEFFICIENT K, (SEE FIG. 13-15)	—	1.2
13	SEA STATE RESISTANCE R_s, (SEE FIG. 16)	—	1300
14	SELECT A TOW SPEED, V_{TOW}	KNOTS	8
15	$R_{H/\Delta}$ (SEE FIG. 17)	—	1.4
16	HULL RESISTANCE = R_H = (15) x (2) x 1.25	POUNDS	30058
17	PROPELLER RESISTANCE = R_p = 3.737 x (5) x (14) x (14)	POUNDS	77490
18	WIND RESISTANCE = R_w = 0.00506 x (4) x (3) x (12) x (10) x (10)	POUNDS	7514
19	TOTAL TOW RESISTANCE = R_T = (13) + (16) + (17) + (18)	POUNDS	116362

CALCULATION OF TOWING RESISTANCE

SHIP: CA 139

DATE: 2/24/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		CA 139
2	TOW DISPLACEMENT, Δ (SEE TABLE-7)	LONG TONS	21470
3	FRONTAL WINDAGE AREA, A_T, (SEE TABLE 7)	SQ. FEET	4500
4	WIND DRAG COEFFICIENT, C_w, (SEE TABLE 7)	—	0.70
5	TOTAL PROJECTED AREA OF PROPELLERS, A_p, (SEE TABLE 7)	SQ. FEET	324
6	CURVE NUMBER FOR HULL RESISTANCE, R_H/Δ, (SEE TABLE 7)	—	7
7	CURVE NUMBER FOR WIND FACTOR, K, (SEE TABLE 7)	—	3
8	CURVE NUMBER FOR SEA STATE RESISTANCE, R_s, (SEE TABLE 7)	—	7
9	BEAUFORT NUMBER (WIND) - (SEE TABLE-8)	—	4
10	RELATIVE WIND SPEED, V_R	KNOTS	10.87
11	RELATIVE WIND DIRECTION, α	DEGREES	90
12	HEADING COEFFICIENT K, (SEE FIG. 13-15)	—	0.48
13	SEA STATE RESISTANCE R_s, (SEE FIG. 16)	—	1300
14	SELECT A TOW SPEED, V_{TOW}	KNOTS	8
15	$R_{H/\Delta}$ (SEE FIG. 17)	—	1.4
16	HULL RESISTANCE = R_H = (15) x (2) x 1.25	POUNDS	30058
17	PROPELLER RESISTANCE = R_P = 3.737 x (5) x (14) x (14)	POUNDS	77490
18	WIND RESISTANCE = R_W = 0.00506 x (4) x (3) x (12) x (10) x (10)	POUNDS	904
19	TOTAL TOW RESISTANCE = R_T = (13) + (16) + (17) + (18)	POUNDS	109752

CALCULATION OF TOWING RESISTANCE

SHIP: CA 139

DATE: 2/25/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		CA 139
2	TOW DISPLACEMENT, Δ (SEE TABLE-7)	LONG. TONS	21470
3	FRONTAL WINDAGE AREA, A_T, (SEE TABLE 7)	SQ. FEET	4500
4	WIND DRAG COEFFICIENT, C_w, (SEE TABLE 7)	—	0.70
5	TOTAL PROJECTED AREA OF PROPELLERS, A_p, (SEE TABLE 7)	SQ. FEET	324
6	CURVE NUMBER FOR HULL RESISTANCE, $R_{H/\Delta}$, (SEE TABLE 7)	—	7
7	CURVE NUMBER FOR WIND FACTOR, K, (SEE TABLE 7)	—	3
8	CURVE NUMBER FOR SEA STATE RESISTANCE, R_s, (SEE TABLE 7)	—	7
9	BEAUFORT NUMBER (WIND) - (SEE TABLE-8)	—	6
10	RELATIVE WIND SPEED, V_R	KNOTS	29.5
11	RELATIVE WIND DIRECTION, α	DEGREES	0
12	HEADING COEFFICIENT K, (SEE FIG. 13-15)	—	1.0
13	SEA STATE RESISTANCE R_s, (SEE FIG. 16)	—	32,500
14	SELECT A TOW SPEED, V_{TOW}	KNOTS	5
15	$R_{H/\Delta}$ (SEE FIG. 17)	—	0.58
16	HULL RESISTANCE = R_H = (15) × (2) × 1.25	POUNDS	15566
17	PROPELLER RESISTANCE = R_P = 3.737 × (5) × (14) × (14)	POUNDS	30270
18	WIND RESISTANCE = R_W = 0.00506 × (4) × (3) × (12) × (10) × (10)	POUNDS	13871
19	TOTAL TOW RESISTANCE = R_T = (13) + (16) + (17) + (18)	POUNDS	92207

CALCULATION OF TOWING RESISTANCE

SHIP: CA 139	DATE: 2/25/76
	BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		CA 139
2	TOW DISPLACEMENT, Δ (SEE TABLE-7)	LONG TONS	21470
3	FRONTAL WINDAGE AREA, A_T, (SEE TABLE 7)	SQ. FEET	4500
4	WIND DRAG COEFFICIENT, C_w, (SEE TABLE 7)	—	0.70
5	TOTAL PROJECTED AREA OF PROPELLERS, A_p, (SEE TABLE 7)	SQ. FEET	324
6	CURVE NUMBER FOR HULL RESISTANCE, R_H/Δ, (SEE TABLE 7)	—	7
7	CURVE NUMBER FOR WIND FACTOR, K, (SEE TABLE 7)	—	3
8	CURVE NUMBER FOR SEA STATE RESISTANCE, R_s, (SEE TABLE 7)	—	7
9	BEAUFORT NUMBER (WIND) - (SEE TABLE-8)	—	6
10	RELATIVE WIND SPEED, V_R	KNOTS	28.7
11	RELATIVE WIND DIRECTION, α	DEGREES	30
12	HEADING COEFFICIENT K, (SEE FIG. 13-15)	—	1.2
13	SEA STATE RESISTANCE R_s, (SEE FIG. 16)	—	32,500
14	SELECT A TOW SPEED, V_{TOW}	KNOTS	5
15	$R_{H/\Delta}$ (SEE FIG. 17)	—	0.58
16	HULL RESISTANCE = R_H = (15) x (2) x 1.25	POUNDS	15566
17	PROPELLER RESISTANCE = R_P = 3.737 x (5) x (14) x (14)	POUNDS	30270
18	WIND RESISTANCE = R_W = 0.00506 x (4) x (3) x (12) x (10) x (10)	POUNDS	15755
19	TOTAL TOW RESISTANCE = R_T = (13) + (16) + (17) + (18)	POUNDS	94091

CALCULATION OF TOWING RESISTANCE

SHIP: CA 139

DATE: 2/25/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		CA 139
2	TOW DISPLACEMENT, Δ (SEE TABLE-7)	LONG TONS	21470
3	FRONTAL WINDAGE AREA, A_T, (SEE TABLE 7)	SQ. FEET	4500
4	WIND DRAG COEFFICIENT, C_w, (SEE TABLE 7)	—	0.70
5	TOTAL PROJECTED AREA OF PROPELLERS, A_p, (SEE TABLE 7)	SQ. FEET	324
6	CURVE NUMBER FOR HULL RESISTANCE, R_H/Δ, (SEE TABLE 7)	—	7
7	CURVE NUMBER FOR WIND FACTOR, K, (SEE TABLE 7)	—	3
8	CURVE NUMBER FOR SEA STATE RESISTANCE, R_s, (SEE TABLE 7)	—	7
9	BEAUFORT NUMBER (WIND) - (SEE TABLE-8)	—	6
10	RELATIVE WIND SPEED, V_R	KNOTS	23.98
11	RELATIVE WIND DIRECTION, α	DEGREES	30
12	HEADING COEFFICIENT K, (SEE FIG. 13-15)	—	0.45
13	SEA STATE RESISTANCE R_s, (SEE FIG. 16)	—	32,500
14	SELECT A TOW SPEED, V_{TOW}	KNOTS	5
15	$R_{H/\Delta}$ (SEE FIG. 17)	—	0.58
16	HULL RESISTANCE = R_H = (15) x (2) x 1.25	POUNDS	15566
17	PROPELLER RESISTANCE = R_p = 3.737 x (5) x (14) x (14)	POUNDS	30270
18	WIND RESISTANCE = R_w = 0.00506 x (4) x (3) x (12) x (10) x (10)	POUNDS	4399
19	TOTAL TOW RESISTANCE = R_T = (13) + (16) + (17) + (18)	POUNDS	82735

CALCULATION OF TOW RESISTANCE BY METHOD USED IN U.S. NAVY TOWING MANUAL

SHIP: LST - 1179 TANK LANDING SHIP

DATE: 2/27/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		LST-1179
2	TOW DISPLACEMENT, Δ (SEE TABLE 7)	LONG TONS	3342
3	FRONTAL WINDAGE AREA, A_T	SQ. FT.	3940 #
4	TOW SPEED, V_{TOW}	KNOTS	10
5	DIRECTION OF TRUE WIND FROM BOW, θ	DEGREES	0
6	TRUE WIND VELOCITY, V_{WIND}	KNOTS	0
7	WIND VELOCITY COMPONENT V_T = (4) + [(6) x COS (5)]	KNOTS	10
8	WIND PRESSURE P, (SEE GRAPH 1)	LBS/SQ.FT	0.5
9	WIND RESISTANCE, R_W = (3) x (8)	POUNDS	1970
10	HYDRODYNAMIC UNIT RESISTANCE r_{H} (SEE GRAPH 2)	--	9.9
11	SEA STATE CORRECTION FACTOR K_1 (SEE TABLE 8)	--	1.0
12	HYDRODYNAMIC RESISTANCE R_H = (2) x (10) x (11)	POUNDS	82586
13	TOTAL PROJECTED AREA OF PROPELLERS, A_p	SQ. FT.	108.14
14	PROPELLER RESISTANCE = R_p = 3.394 x (13) x (4) x (4)	POUNDS	36703
15	HULL RESISTANCE = (10) x (2) - (14)	POUNDS	45883
16	SEA STATE RESISTANCE = R_s = (12) - (15) - (14)	POUNDS	0
17	TOTAL TOW RESISTANCE = R_T = (9) + (12)	POUNDS	84556

FRONTAL AREA NOT AVAILABLE SO ASSUMED TO BE SAME AS LST 1156

CALCULATION OF TOW RESISTANCE BY METHOD USED IN U.S. NAVY TOWING MANUAL

SHIP: LST 1179 - TANK LANDING SHIP

DATE: 2/27/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		LST-1179
2	TOW DISPLACEMENT, Δ (SEE TABLE 7)	LONG TONS	8342
3	FRONTAL WINDAGE AREA, A_T	SQ. FT.	3940
4	TOW SPEED, V_{TOW}	KNOTS	8
5	DIRECTION OF TRUE WIND FROM BOW, θ	DEGREES	0
6	TRUE WIND VELOCITY, V_{WIND}	KNOTS	13.5
7	WIND VELOCITY COMPONENT V_T = (4) + [(6) x COS (5)]	KNOTS	21.5
8	WIND PRESSURE P, (SEE GRAPH 1)	LBS/SQ.FT	1.3
9	WIND RESISTANCE, R_W = (3) x (8)	POUNDS	5122
10	HYDRODYNAMIC UNIT RESISTANCE r_H, (SEE GRAPH 2)	--	6.3
11	SEA STATE CORRECTION FACTOR K_1 (SEE TABLE 8)	--	1.4
12	HYDRODYNAMIC RESISTANCE R_H = (2) x (10) x (11)	POUNDS	73576
13	TOTAL PROJECTED AREA OF PROPELLERS, A_p	SQ. FT.	108.14
14	PROPELLER RESISTANCE = R_p = 3.394 x (13) x (4) x (4)	POUNDS	23490
15	HULL RESISTANCE = (10) x (2) - (14)	POUNDS	29065
16	SEA STATE RESISTANCE = R_s = (12) - (15) - (14)	POUNDS	21021
17	TOTAL TOW RESISTANCE = R_T = (9) + (12)	POUNDS	78698

CALCULATION OF TOW RESISTANCE BY METHOD USED IN U.S. NAVY TOWING MANUAL

SHIP: LST 1179

DATE: 2/27/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		LST-1179
2	TOW DISPLACEMENT, Δ (SEE TABLE 7)	LONG TONS	8342
3	FRONTAL WINDAGE AREA, A_T	SQ. FT.	3940
4	TOW SPEED, V_{TOW}	KNOTS	8
5	DIRECTION OF TRUE WIND FROM BOW, θ	DEGREES	47.23
6	TRUE WIND VELOCITY, V_{WIND}	KNOTS	13.5
7	WIND VELOCITY COMPONENT V_T = (4) + [(6) x COS (5)]	KNOTS	17.17
8	WIND PRESSURE P, (SEE GRAPH 1)	LBS/SQ.FT.	1.0
9	WIND RESISTANCE, R_W = (3) x (8)	POUNDS	3940
10	HYDRODYNAMIC UNIT RESISTANCE r_H, (SEE GRAPH 2)	--	6.3
11	SEA STATE CORRECTION FACTOR K_1 (SEE TABLE 8)	--	1.4
12	HYDRODYNAMIC RESISTANCE R_H = (2) x (10) x (11)	POUNDS	73576
13	TOTAL PROJECTED AREA OF PROPELLERS, A_P	SQ. FT.	108.14
14	PROPELLER RESISTANCE = R_P = 3.394 x (13) x (4) x (4)	POUNDS	23490
15	HULL RESISTANCE = (10) x (2) - (14)	POUNDS	29065
16	SEA STATE RESISTANCE = R_S = (12) - (15) - (14)	POUNDS	21021
17	TOTAL TOW RESISTANCE = R_T = (9) + (12)	POUNDS	81918

...ON OF TOW RESISTANCE BY METHOD USED IN U.S. NAVY TOWING MANUAL

SHIP: LST 1179

DATE: 2/27/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		LST-1179
2	TOW DISPLACEMENT, Δ (SEE TABLE 7)	LONG TONS	8342
3	FRONTAL WINDAGE AREA, A_T	SQ. FT.	3940
4	TOW SPEED, V_{TOW}	KNOTS	8
5	DIRECTION OF TRUE WIND FROM BOW, θ	DEGREES	126.34
6	TRUE WIND VELOCITY, V_{WIND}	KNOTS	13.5
7	WIND VELOCITY COMPONENT V_T = (4) + [(6) x COS (5)]	KNOTS	0
8	WIND PRESSURE P, (SEE GRAPH 1)	LBS/SQ.FT.	0
9	WIND RESISTANCE, R_W = (3) x (8)	POUNDS	0
10	HYDRODYNAMIC UNIT RESISTANCE r_H, (SEE GRAPH 2)	--	6.3
11	SEA STATE CORRECTION FACTOR K_1 (SEE TABLE 8)	--	1.4
12	HYDRODYNAMIC RESISTANCE R_H = (2) x (10) x (11)	POUNDS	73576
13	TOTAL PROJECTED AREA OF PROPELLERS, A_P	SQ. FT.	103.14
14	PROPELLER RESISTANCE = R_P = 3.394 x (13) x (4) x (4)	POUNDS	23490
15	HULL RESISTANCE = (10) x (2) - (14)	POUNDS	29065
16	SEA STATE RESISTANCE = R_S = (12) - (15) - (14)	POUNDS	21021
17	TOTAL TOW RESISTANCE = R_T = (9) + (12)	POUNDS	73576

CALCULATION OF TOW RESISTANCE BY METHOD USED IN U.S. NAVY TOWING MANUAL

SHIP: LST 1179

DATE: 2/27/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		LST-1179
2	TOW DISPLACEMENT, Δ (SEE TABLE 7)	LONG TONS	8342
3	FRONTAL WINDAGE AREA, A_T	SQ. FT.	3940
4	TOW SPEED, V_{TOW}	KNOTS	5
5	DIRECTION OF TRUE WIND FROM BOW, θ	DEGREES	0
6	TRUE WIND VELOCITY, V_{WIND}	KNOTS	24.5
7	WIND VELOCITY COMPONENT V_T = (4) + [(6) x COS (5)]	KNOTS	29.5
8	WIND PRESSURE P, (SEE GRAPH 1)	LBS/SQ.FT	2.5
9	WIND RESISTANCE, R_W = (3) x (8)	POUNDS	9850
10	HYDRODYNAMIC UNIT RESISTANCE r_H, (SEE GRAPH 2)	--	2.5
11	SEA STATE CORRECTION FACTOR K_1 (SEE TABLE 8)	--	1.6
12	HYDRODYNAMIC RESISTANCE R_H = (2) x (10) x (11)	POUNDS	33368
13	TOTAL PROJECTED AREA OF PROPELLERS, A_P	SQ. FT.	108.14
14	PROPELLER RESISTANCE = R_P = 3.394 x (13) x (4) x (4)	POUNDS	9176
15	HULL RESISTANCE = (10) x (2) - (14)	POUNDS	11679
16	SEA STATE RESISTANCE = R_s = (12) - (15) - (14)	POUNDS	12513
17	TOTAL TOW RESISTANCE = R_T = (9) + (12)	POUNDS	43218

CALCULATION OF TOW RESISTANCE BY METHOD USED IN U.S. NAVY TOWING MANUAL

SHIP: LST 1179

DATE: 2/27/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		LST-1179
2	TOW DISPLACEMENT, Δ (SEE TABLE 7)	LONG TONS	3342
3	FRONTAL WINDAGE AREA, A_T	SQ. FT.	3940
4	TOW SPEED, V_{TOW}	KNOTS	5
5	DIRECTION OF TRUE WIND FROM BOW, θ	DEGREES	35.86
6	TRUE WIND VELOCITY, V_{WIND}	KNOTS	24.5
7	WIND VELOCITY COMPONENT V_T = (4) + [(6) x COS (5)]	KNOTS	24.86
8	WIND PRESSURE P, (SEE GRAPH 1)	LBS/SQ.FT	2.0
9	WIND RESISTANCE, R_W = (3) x (8)	POUNDS	7880
10	HYDRODYNAMIC UNIT RESISTANCE r_H, (SEE GRAPH 2)	--	2.5
11	SEA STATE CORRECTION FACTOR K_1 (SEE TABLE 8)	--	1.6
12	HYDRODYNAMIC RESISTANCE R_H = (2) x (10) x (11)	POUNDS	33368
13	TOTAL PROJECTED AREA OF PROPELLERS, A_P	SQ. FT.	108.14
14	PROPELLER RESISTANCE = R_p = 3.394 x (13) x (4) x (4)	POUNDS	9176
15	HULL RESISTANCE = (10) x (2) - (14)	POUNDS	11679
16	SEA STATE RESISTANCE = R_s = (12) - (15) - (14)	POUNDS	12513
17	TOTAL TOW RESISTANCE = R_T = (9) + (12)	POUNDS	41248

CALCULATION OF TOW RESISTANCE BY METHOD USED IN U.S. NAVY TOWING MANUAL

SHIP: LST 1179

DATE: 2/27/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		LST-1179
2	TOW DISPLACEMENT, Δ (SEE TABLE 7)	LONG TONS	8342
3	FRONTAL WINDAGE AREA, A_T	SQ. FT.	3940
4	TOW SPEED, V_{TOW}	KNOTS	5
5	DIRECTION OF TRUE WIND FROM BOW, θ	DEGREES	101.8
6	TRUE WIND VELOCITY, V_{WIND}	KNOTS	24.5
7	WIND VELOCITY COMPONENT V_T = (4) + [(6) x COS (5)]	KNOTS	-0.01
8	WIND PRESSURE P, (SEE GRAPH 1)	LBS/SQ.FT	0
9	WIND RESISTANCE, R_W = (3) x (8)	POUNDS	0
10	HYDRODYNAMIC UNIT RESISTANCE r_H, (SEE GRAPH 2)	--	2.5
11	SEA STATE CORRECTION FACTOR K_1 (SEE TABLE 8)	--	1.6
12	HYDRODYNAMIC RESISTANCE R_H = (2) x (10) x (11)	POUNDS	33368
13	TOTAL PROJECTED AREA OF PROPELLERS, A_p	SQ. FT.	108.14
14	PROPELLER RESISTANCE = R_p = 3.394 x (13) x (4) x (4)	POUNDS	9176
15	HULL RESISTANCE = (10) x (2) - (14)	POUNDS	11679
16	SEA STATE RESISTANCE = R_s = (12) - (15) - (14)	POUNDS	12513
17	TOTAL TOW RESISTANCE = R_T = (9) + (12)	POUNDS	33368

CALCULATION OF TOWING RESISTANCE

SHIP: LST-1179 TANK LANDING SHIP   DATE: 2/27/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		LST-1179
2	TOW DISPLACEMENT, Δ (SEE TABLE-7)	LONG TONS	8342
3	FRONTAL WINDAGE AREA, A_T, (SEE TABLE 7)	SQ. FEET	3940
4	WIND DRAG COEFFICIENT, C_w, (SEE TABLE 7)	—	0.70
5	TOTAL PROJECTED AREA OF PROPELLERS, A_p, (SEE TABLE 7)	SQ. FEET	108.14
6	CURVE NUMBER FOR HULL RESISTANCE, R_H/Δ, (SEE TABLE 7)	—	18
7	CURVE NUMBER FOR WIND FACTOR, K, (SEE TABLE 7)	—	3
8	CURVE NUMBER FOR SEA STATE RESISTANCE, R_s, (SEE TABLE 7)	—	9
9	BEAUFORT NUMBER (WIND) - (SEE TABLE-8)	—	0
10	RELATIVE WIND SPEED, V_R	KNOTS	10
11	RELATIVE WIND DIRECTION, α	DEGREES	0
12	HEADING COEFFICIENT K, (SEE FIG. 13-15)	—	1.0
13	SEA STATE RESISTANCE R_s, (SEE FIG. 16)	—	0
14	SELECT A TOW SPEED, V_{TOW}	KNOTS	10
15	$R_{H/\Delta}$ (SEE FIG. 17)	—	3.16
16	HULL RESISTANCE = R_H = (15) x (2) x 1.25	POUNDS	32951
17	PROPELLER RESISTANCE = R_p = 3.737 x (5) x (14) x (14)	POUNDS	40412
18	WIND RESISTANCE = R_w = 0.00506 x (4) x (3) x (12) x (10) x (10)	POUNDS	1396
19	TOTAL TOW RESISTANCE = R_T = (13) + (16) + (17) + (18)	POUNDS	74759

CALCULATION OF TOWING RESISTANCE

SHIP: LST-1179

DATE: 2/27/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		LST-1179
2	TOW DISPLACEMENT, Δ (SEE TABLE-7)	LONG. TONS	8342
3	FRONTAL WINDAGE AREA, A_T, (SEE TABLE 7)	SQ. FEET	3940
4	WIND DRAG COEFFICIENT, C_w, (SEE TABLE 7)	—	0.70
5	TOTAL PROJECTED AREA OF PROPELLERS, A_p, (SEE TABLE 7)	SQ. FEET	103.14
6	CURVE NUMBER FOR HULL RESISTANCE, R_H/Δ, (SEE TABLE 7)	—	18
7	CURVE NUMBER FOR WIND FACTOR, K, (SEE TABLE 7)	—	3
8	CURVE NUMBER FOR SEA STATE RESISTANCE, R_s, (SEE TABLE 7)	—	9
9	BEAUFORT NUMBER (WIND) - (SEE TABLE-8)	—	4
10	RELATIVE WIND SPEED, V_R	KNOTS	21.5
11	RELATIVE WIND DIRECTION, α	DEGREES	0
12	HEADING COEFFICIENT K, (SEE FIG. 13-15)	—	1.0
13	SEA STATE RESISTANCE R_s, (SEE FIG. 16)	—	1300
14	SELECT A TOW SPEED, V_{TOW}	KNOTS	8
15	$R_{H/\Delta}$ (SEE FIG. 17)	—	2.11
16	HULL RESISTANCE = R_H = (15) x (2) x 1.25	POUNDS	22002
17	PROPELLER RESISTANCE = R_p = 3.737 x (5) x (14) x (14)	POUNDS	25864
18	WIND RESISTANCE = R_w = 0.00506 x (4) x (3) x (12) x (10) x (10)	POUNDS	6451
19	TOTAL TOW RESISTANCE = R_T = (13) + (16) + (17) + (18)	POUNDS	55617

TABLE - [illegible]

CALCULATION OF TOWING RESISTANCE

SHIP: *LST-1179* DATE: *2/27/76*

BY: *RCS*

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		*LST-1179*
2	TOW DISPLACEMENT, Δ (SEE TABLE-7)	LONG TONS	*8342*
3	FRONTAL WINDAGE AREA, A_T, (SEE TABLE 7)	SQ. FEET	*3940*
4	WIND DRAG COEFFICIENT, C_w, (SEE TABLE 7)	—	*0.70*
5	TOTAL PROJECTED AREA OF PROPELLERS, A_p, (SEE TABLE 7)	SQ. FEET	*108.14*
6	CURVE NUMBER FOR HULL RESISTANCE, $R_{H/\Delta}$, (SEE TABLE 7)	—	*18*
7	CURVE NUMBER FOR WIND FACTOR, K, (SEE TABLE 7)	—	*3*
8	CURVE NUMBER FOR SEA STATE RESISTANCE, R_s, (SEE TABLE 7)	—	*9*
9	BEAUFORT NUMBER (WIND) - (SEE TABLE-8)	—	*4*
10	RELATIVE WIND SPEED, V_R	KNOTS	*19.82*
11	RELATIVE WIND DIRECTION, α	DEGREES	*30*
12	HEADING COEFFICIENT K, (SEE FIG. 13-15)	—	*1.20*
13	SEA STATE RESISTANCE R_s, (SEE FIG. 16)	—	*1300*
14	SELECT A TOW SPEED, V_{TOW}	KNOTS	*8*
15	$R_{H/\Delta}$ (SEE FIG. 17)	—	*2.11*
16	HULL RESISTANCE = R_H = ⑮ × ② × 1.25	POUNDS	*27002*
17	PROPELLER RESISTANCE = R_p = 3.737 × ⑤ × ⑭ × ⑭	POUNDS	*25864*
18	WIND RESISTANCE = R_w = 0.00506 × ④ × ③ × ⑫ × ⑩ × ⑩	POUNDS	*6579*
19	TOTAL TOW RESISTANCE = R_T = ⑬ + ⑯ + ⑰ + ⑱	POUNDS	*55745*

TABLE [illegible]

CALCULATION OF TOWING RESISTANCE

SHIP: LST 1179 DATE: 2/27/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		LST-1179
2	TOW DISPLACEMENT, Δ (SEE TABLE-7)	LONG TONS	8342
3	FRONTAL WINDAGE AREA, A_T, (SEE TABLE 7)	SQ. FEET	3940
4	WIND DRAG COEFFICIENT, C_w, (SEE TABLE 7)	—	0.70
5	TOTAL PROJECTED AREA OF PROPELLERS, A_p, (SEE TABLE 7)	SQ. FEET	108.14
6	CURVE NUMBER FOR HULL RESISTANCE, R_H/Δ, (SEE TABLE 7)	—	18
7	CURVE NUMBER FOR WIND FACTOR, K, (SEE TABLE 7)	—	3
8	CURVE NUMBER FOR SEA STATE RESISTANCE, R_s, (SEE TABLE 7)	—	9
9	BEAUFORT NUMBER (WIND) - (SEE TABLE-8)	—	4
10	RELATIVE WIND SPEED, V_R	KNOTS	10.87
11	RELATIVE WIND DIRECTION, α	DEGREES	90
12	HEADING COEFFICIENT K, (SEE FIG. 13-15)	—	0.98
13	SEA STATE RESISTANCE R_s, (SEE FIG. 16)	—	1300
14	SELECT A TOW SPEED, V_{TOW}	KNOTS	8
15	$R_{H/\Delta}$ (SEE FIG. 17)	—	2.11
16	HULL RESISTANCE = R_H = (15) x (2) x 1.25	POUNDS	22002
17	PROPELLER RESISTANCE = R_P = 3.737 x (5) x (14) x (14)	POUNDS	25864
18	WIND RESISTANCE = R_W = 0.00506 x (4) x (3) x (12) x (10) x (10)	POUNDS	791
19	TOTAL TOW RESISTANCE = R_T = (13) + (16) + (17) + (18)	POUNDS	49957

TABLE - 6

CALCULATION OF TOWING RESISTANCE

SHIP: LST 1179 DATE: 2/27/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		LST-1179
2	TOW DISPLACEMENT, Δ (SEE TABLE-7)	LONG TONS	8432
3	FRONTAL WINDAGE AREA, A_T, (SEE TABLE 7)	SQ. FEET	3940
4	WIND DRAG COEFFICIENT, C_w, (SEE TABLE 7)	—	0.70
5	TOTAL PROJECTED AREA OF PROPELLERS, A_p, (SEE TABLE 7)	SQ. FEET	108.14
6	CURVE NUMBER FOR HULL RESISTANCE, R_H/Δ, (SEE TABLE 7)	—	18
7	CURVE NUMBER FOR WIND FACTOR, K, (SEE TABLE 7)	—	3
8	CURVE NUMBER FOR SEA STATE RESISTANCE, R_s, (SEE TABLE 7)	—	9
9	BEAUFORT NUMBER (WIND) - (SEE TABLE-8)	—	6
10	RELATIVE WIND SPEED, V_R	KNOTS	29.5
11	RELATIVE WIND DIRECTION, α	DEGREES	0
12	HEADING COEFFICIENT K, (SEE FIG. 13-15)	—	1.0
13	SEA STATE RESISTANCE R_s, (SEE FIG. 16)	—	38,500
14	SELECT A TOW SPEED, V_{TOW}	KNOTS	5
15	$R_{H/\Delta}$ (SEE FIG. 17)	—	0.86
16	HULL RESISTANCE = R_H = (15) × (2) × 1.25	POUNDS	9064
17	PROPELLER RESISTANCE = R_p = 3.737 × (5) × (14) × (14)	POUNDS	10103
18	WIND RESISTANCE = R_w = 0.00506 × (4) × (3) × (12) × (10) × (10)	POUNDS	12145
19	TOTAL TOW RESISTANCE = R_T = (13) + (16) + (17) + (18)	POUNDS	69812

CALCULATION OF TOWING RESISTANCE

SHIP: LST 1179 DATE: 2/27/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		LST-1179
2	TOW DISPLACEMENT, Δ (SEE TABLE-7)	LONG TONS	8432
3	FRONTAL WINDAGE AREA, A_T, (SEE TABLE 7)	SQ. FEET	3940
4	WIND DRAG COEFFICIENT, C_w, (SEE TABLE 7)	—	0.70
5	TOTAL PROJECTED AREA OF PROPELLERS, A_p, (SEE TABLE 7)	SQ. FEET	108.14
6	CURVE NUMBER FOR HULL RESISTANCE, $R_{H/\Delta}$, (SEE TABLE 7)	—	18
7	CURVE NUMBER FOR WIND FACTOR, K, (SEE TABLE 7)	—	3
8	CURVE NUMBER FOR SEA STATE RESISTANCE, R_s, (SEE TABLE 7)	—	9
9	BEAUFORT NUMBER (WIND) - (SEE TABLE-8)	—	6
10	RELATIVE WIND SPEED, V_R	KNOTS	28.7
11	RELATIVE WIND DIRECTION, α	DEGREES	30
12	HEADING COEFFICIENT K, (SEE FIG. 13-15)	—	1.2
13	SEA STATE RESISTANCE R_s, (SEE FIG. 16)	—	38500
14	SELECT A TOW SPEED, V_{TOW}	KNOTS	5
15	$R_{H/\Delta}$ (SEE FIG. 17)	—	0.86
16	HULL RESISTANCE = R_H = (15) × (2) × 1.25	POUNDS	9064
17	PROPELLER RESISTANCE = R_p = 3.737 × (5) × (14) × (14)	POUNDS	10103
18	WIND RESISTANCE = R_w = 0.00506 × (4) × (3) × (12) × (10) × (10)	POUNDS	13794
19	TOTAL TOW RESISTANCE = R_T = (13) + (16) + (17) + (18)	POUNDS	71461

CALCULATION OF TOWING RESISTANCE

SHIP: LST 1179 DATE: 2/27/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		LST-1179
2	TOW DISPLACEMENT, Δ (SEE TABLE-7)	LONG TONS	8432
3	FRONTAL WINDAGE AREA, A_T, (SEE TABLE 7)	SQ. FEET	3940
4	WIND DRAG COEFFICIENT, C_w, (SEE TABLE 7)	—	0.70
5	TOTAL PROJECTED AREA OF PROPELLERS, A_p, (SEE TABLE 7)	SQ. FEET	108.14
6	CURVE NUMBER FOR HULL RESISTANCE, R_H/Δ, (SEE TABLE 7)	—	18
7	CURVE NUMBER FOR WIND FACTOR, K, (SEE TABLE 7)	—	3
8	CURVE NUMBER FOR SEA STATE RESISTANCE, R_s, (SEE TABLE 7)	—	9
9	BEAUFORT NUMBER (WIND) - (SEE TABLE-8)	—	6
10	RELATIVE WIND SPEED, V_R	KNOTS	23.98
11	RELATIVE WIND DIRECTION, α	DEGREES	90
12	HEADING COEFFICIENT K, (SEE FIG. 13-15)	—	0.48
13	SEA STATE RESISTANCE R_s, (SEE FIG. 16)	—	38500
14	SELECT A TOW SPEED, V_{TOW}	KNOTS	5
15	$R_{H/\Delta}$ (SEE FIG. 17)	—	0.86
16	HULL RESISTANCE = R_H = (15) x (2) x 1.25	POUNDS	9064
17	PROPELLER RESISTANCE = R_p = 3.737 x (5) x (14) x (14)	POUNDS	10103
18	WIND RESISTANCE = R_w = 0.00506 x (4) x (3) x (12) x (10) x (10)	POUNDS	3352
19	TOTAL TOW RESISTANCE = R_T = (13) + (16) + (17) + (18)	POUNDS	61519

CALCULATION OF TOW RESISTANCE BY METHOD USED IN U.S. NAVY TOWING MANUAL

SHIP: CGN-25 GUIDED MISSILE FRIGATE

DATE: 2/27/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		CGN-25
2	TOW DISPLACEMENT, Δ (SEE TABLE 7)	LONG TONS	8580
3	FRONTAL WINDAGE AREA, A_T	SQ. FT.	3040
4	TOW SPEED, V_{TOW}	KNOTS	10
5	DIRECTION OF TRUE WIND FROM BOW, θ	DEGREES	0
6	TRUE WIND VELOCITY, V_{WIND}	KNOTS	0
7	WIND VELOCITY COMPONENT V_T = (4) + [(6) x COS (5)]	KNOTS	10
8	WIND PRESSURE P, (SEE GRAPH 1)	LBS/SQ.FT.	0.5
9	WIND RESISTANCE, R_W = (3) x (8)	POUNDS	1520
10	HYDRODYNAMIC UNIT RESISTANCE r_H, (SEE GRAPH 2)	--	20.67*
11	SEA STATE CORRECTION FACTOR K_1 (SEE TABLE 8)	--	1.0
12	HYDRODYNAMIC RESISTANCE R_H = (2) x (10) x (11)	POUNDS	177349
13	TOTAL PROJECTED AREA OF PROPELLERS, A_P	SQ. FT.	238.6
14	PROPELLER RESISTANCE = R_P = 3.394 x (13) x (4) x (4)	POUNDS	80981
15	HULL RESISTANCE = (10) x (2) - (14)	POUNDS	96368
16	SEA STATE RESISTANCE = R_s = (12) - (15) - (14)	POUNDS	0
17	TOTAL TOW RESISTANCE = R_T = (9) + (12)	POUNDS	178869

* USED DESTROYER CURVE

[illegible] RESISTANCE BY METHOD USED IN U.S. NAVY TOWING MANUAL

SHIP: CGN-25

DATE: 2/27/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		CGN-25
2	TOW DISPLACEMENT, Δ (SEE TABLE 7)	LONG TONS	8580
3	FRONTAL WINDAGE AREA, A_T	SQ. FT.	3040
4	TOW SPEED, V_{TOW}	KNOTS	8
5	DIRECTION OF TRUE WIND FROM BOW, θ	DEGREES	0
6	TRUE WIND VELOCITY, V_{WIND}	KNOTS	13.5
7	WIND VELOCITY COMPONENT V_T = (4) + [(6) x cos (5)]	KNOTS	21.5
8	WIND PRESSURE P, (SEE GRAPH 1)	LBS/SQ.FT	1.2
9	WIND RESISTANCE, R_W = (3) x (8)	POUNDS	3648
10	HYDRODYNAMIC UNIT RESISTANCE r_H, (SEE GRAPH 2)	--	12.5
11	SEA STATE CORRECTION FACTOR K_1 (SEE TABLE 8)	--	1.4
12	HYDRODYNAMIC RESISTANCE R_H = (2) x (10) x (11)	POUNDS	150150
13	TOTAL PROJECTED AREA OF PROPELLERS, A_P	SQ. FT.	233.6
14	PROPELLER RESISTANCE = R_P = 3.394 x (13) x (4) x (4)	POUNDS	51828
15	HULL RESISTANCE = (10) x (2) - (14)	POUNDS	55422
16	SEA STATE RESISTANCE = R_S = (12) - (15) - (14)	POUNDS	42900
17	TOTAL TOW RESISTANCE = R_T = (9) + (12)	POUNDS	153798

CALCULATION OF TOW RESISTANCE BY METHOD USED IN U.S. NAVY TOWING MANUAL

SHIP: CGN-25

DATE: 2/27/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		CGN-25
2	TOW DISPLACEMENT, Δ (SEE TABLE 7)	LONG TONS	8580
3	FRONTAL WINDAGE AREA, A_T	SQ. FT.	3040
4	TOW SPEED, V_{TOW}	KNOTS	8
5	DIRECTION OF TRUE WIND FROM BOW, θ	DEGREES	47.23
6	TRUE WIND VELOCITY, V_{WIND}	KNOTS	13.5
7	WIND VELOCITY COMPONENT V_T = (4) + [(6) x COS (5)]	KNOTS	17.17
8	WIND PRESSURE P, (SEE GRAPH 1)	LBS/SQ.FT	1.0
9	WIND RESISTANCE, R_W = (3) x (8)	POUNDS	3040
10	HYDRODYNAMIC UNIT RESISTANCE r_H, (SEE GRAPH 2)	--	12.5
11	SEA STATE CORRECTION FACTOR K_1 (SEE TABLE 8)	--	1.4
12	HYDRODYNAMIC RESISTANCE R_H = (2) x (10) x (11)	POUNDS	150150
13	TOTAL PROJECTED AREA OF PROPELLERS, A_P	SQ. FT.	239.6
14	PROPELLER RESISTANCE = R_p = 3.394 x (13) x (4) x (4)	POUNDS	51828
15	HULL RESISTANCE = (10) x (2) - (14)	POUNDS	55422
16	SEA STATE RESISTANCE = R_s = (12) - (15) - (14)	POUNDS	42900
17	TOTAL TOW RESISTANCE = R_T = (9) + (12)	POUNDS	

CALCULATION OF TOW RESISTANCE BY METHOD USED IN U.S. NAVY TOWING MANUAL

SHIP: CGN-25

DATE: 2/27/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		CGN-25
2	TOW DISPLACEMENT, Δ (SEE TABLE 7)	LONG TONS	8580
3	FRONTAL WINDAGE AREA, A_T	SQ. FT.	3040
4	TOW SPEED, V_{TOW}	KNOTS	8
5	DIRECTION OF TRUE WIND FROM BOW, θ	DEGREES	126.34
6	TRUE WIND VELOCITY, V_{WIND}	KNOTS	13.5
7	WIND VELOCITY COMPONENT V_T = (4) + [(6) x COS (5)]	KNOTS	0
8	WIND PRESSURE P, (SEE GRAPH 1)	LBS/SQ.FT.	0
9	WIND RESISTANCE, R_W = (3) x (8)	POUNDS	0
10	HYDRODYNAMIC UNIT RESISTANCE r_H, (SEE GRAPH 2)	--	12.5
11	SEA STATE CORRECTION FACTOR K_1 (SEE TABLE 8)	--	1.4
12	HYDRODYNAMIC RESISTANCE R_H = (2) x (10) x (11)	POUNDS	150150
13	TOTAL PROJECTED AREA OF PROPELLERS, A_P	SQ. FT.	238.6
14	PROPELLER RESISTANCE = R_P = 3.394 x (13) x (4) x (4)	POUNDS	51828
15	HULL RESISTANCE = (10) x (2) - (14)	POUNDS	55422
16	SEA STATE RESISTANCE = R_S = (12) - (15) - (14)	POUNDS	42900
17	TOTAL TOW RESISTANCE = R_T = (9) + (12)	POUNDS	150150

CALCULATION OF TOW RESISTANCE BY METHOD USED IN U.S. NAVY TOWING MANUAL

SHIP: CGN-25

DATE: 3/1/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		CGN-25
2	TOW DISPLACEMENT, Δ (SEE TABLE 7)	LONG TONS	8580
3	FRONTAL WINDAGE AREA, A_T	SQ. FT.	3040
4	TOW SPEED, V_{TOW}	KNOTS	5
5	DIRECTION OF TRUE WIND FROM BOW, θ	DEGREES	0
6	TRUE WIND VELOCITY, V_{WIND}	KNOTS	24.5
7	WIND VELOCITY COMPONENT V_T = (4) + [(6) x COS (5)]	KNOTS	29.5
8	WIND PRESSURE P, (SEE GRAPH 1)	LBS/SQ.FT.	2.6
9	WIND RESISTANCE, R_W = (3) x (8)	POUNDS	7904
10	HYDRODYNAMIC UNIT RESISTANCE r_H, (SEE GRAPH 2)	--	4.8
11	SEA STATE CORRECTION FACTOR K_1 (SEE TABLE 8)	--	1.6
12	HYDRODYNAMIC RESISTANCE R_H = (2) x (10) x (11)	POUNDS	65895
13	TOTAL PROJECTED AREA OF PROPELLERS, A_P	SQ. FT.	238.6
14	PROPELLER RESISTANCE = R_P = 3.394 x (13) x (4) x (4)	POUNDS	20245
15	HULL RESISTANCE = (10) x (2) - (14)	POUNDS	20939
16	SEA STATE RESISTANCE = R_s = (12) - (15) - (14)	POUNDS	24711
17	TOTAL TOW RESISTANCE = R_T = (9) + (12)	POUNDS	73799

CALCULATION OF TOW RESISTANCE BY METHOD USED IN U.S. NAVY TOWING MANUAL

SHIP: CGN-25

DATE: 3/1/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		CGN-25
2	TOW DISPLACEMENT, Δ (SEE TABLE 7)	LONG TONS	8580
3	FRONTAL WINDAGE AREA, A_T	SQ. FT.	3040
4	TOW SPEED, V_{TOW}	KNOTS	5
5	DIRECTION OF TRUE WIND FROM BOW, θ	DEGREES	35.86
6	TRUE WIND VELOCITY, V_{WIND}	KNOTS	24.5
7	WIND VELOCITY COMPONENT V_T = (4) + [(6) x COS (5)]	KNOTS	24.86
8	WIND PRESSURE P, (SEE GRAPH 1)	LBS/SQ.FT	2.0
9	WIND RESISTANCE, R_W = (3) x (8)	POUNDS	6080
10	HYDRODYNAMIC UNIT RESISTANCE r_H, (SEE GRAPH 2)	--	4.8
11	SEA STATE CORRECTION FACTOR K_1 (SEE TABLE 8)	--	1.6
12	HYDRODYNAMIC RESISTANCE R_H = (2) x (10) x (11)	POUNDS	65895
13	TOTAL PROJECTED AREA OF PROPELLERS, A_P	SQ. FT.	238.6
14	PROPELLER RESISTANCE = R_P = 3.394 x (13) x (4) x (4)	POUNDS	20245
15	HULL RESISTANCE = (10) x (2) - (14)	POUNDS	20939
16	SEA STATE RESISTANCE = R_S = (12) - (15) - (14)	POUNDS	24711
17	TOTAL TOW RESISTANCE = R_T = (9) + (12)	POUNDS	71975

CALCULATION OF TOW RESISTANCE BY METHOD USED IN U.S. NAVY TOWING MANUAL

SHIP: CGN-25

DATE: 3/1/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		CGN-25
2	TOW DISPLACEMENT, Δ (SEE TABLE 7)	LONG TONS	8580
3	FRONTAL WINDAGE AREA, A_T	SQ. FT.	3040
4	TOW SPEED, V_{TOW}	KNOTS	5
5	DIRECTION OF TRUE WIND FROM BOW, θ	DEGREES	101.8
6	TRUE WIND VELOCITY, V_{WIND}	KNOTS	24.5
7	WIND VELOCITY COMPONENT V_T = (4) + [(6) x COS (5)]	KNOTS	-0.01
8	WIND PRESSURE P, (SEE GRAPH 1)	LBS/SQ.FT.	0
9	WIND RESISTANCE, R_W = (3) x (8)	POUNDS	0
10	HYDRODYNAMIC UNIT RESISTANCE r_H, (SEE GRAPH 2)	--	4.8
11	SEA STATE CORRECTION FACTOR K_1 (SEE TABLE 8)	--	1.6
12	HYDRODYNAMIC RESISTANCE R_H = (2) x (10) x (11)	POUNDS	65895
13	TOTAL PROJECTED AREA OF PROPELLERS, A_p	SQ. FT.	238.6
14	PROPELLER RESISTANCE = R_p = 3.394 x (13) x (4) x (4)	POUNDS	20245
15	HULL RESISTANCE = (10) x (2) - (14)	POUNDS	20939
16	SEA STATE RESISTANCE = R_s = (12) - (15) - (14)	POUNDS	24711
17	TOTAL TOW RESISTANCE = R_T = (9) + (12)	POUNDS	65895

TABLE - 8

CALCULATION OF TOWING RESISTANCE

SHIP: CGN-25

DATE: 3/1/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		CGN-25
2	TOW DISPLACEMENT, Δ (SEE TABLE-7)	LONG TONS	8530
3	FRONTAL WINDAGE AREA, A_T, (SEE TABLE 7)	SQ. FEET	3040
4	WIND DRAG COEFFICIENT, C_w, (SEE TABLE 7)	—	0.70
5	TOTAL PROJECTED AREA OF PROPELLERS, A_p, (SEE TABLE 7)	SQ. FEET	238.6
6	CURVE NUMBER FOR HULL RESISTANCE, $R_{H/\Delta}$, (SEE TABLE 7)	—	5
7	CURVE NUMBER FOR WIND FACTOR, K, (SEE TABLE 7)	—	3
8	CURVE NUMBER FOR SEA STATE RESISTANCE, R_s, (SEE TABLE 7)	—	3
9	BEAUFORT NUMBER (WIND) - (SEE TABLE-8)	—	0
10	RELATIVE WIND SPEED, V_R	KNOTS	10
11	RELATIVE WIND DIRECTION, α	DEGREES	0
12	HEADING COEFFICIENT K, (SEE FIG. 13-15)	—	1.0
13	SEA STATE RESISTANCE R_s, (SEE FIG. 16)	—	0
14	SELECT A TOW SPEED, V_{TOW}	KNOTS	10
15	$R_{H/\Delta}$ (SEE FIG. 17)	—	4.75
16	HULL RESISTANCE = R_H = (15) × (2) × 1.25	POUNDS	50944
17	PROPELLER RESISTANCE = R_P = 3.737 × (5) × (14) × (14)	POUNDS	89165
18	WIND RESISTANCE = R_W = 0.00506 × (4) × (3) × (12) × (10) × (10)	POUNDS	1077
19	TOTAL TOW RESISTANCE = R_T = (13) + (16) + (17) + (18)	POUNDS	141186

TABLE - 6

CALCULATION OF TOWING RESISTANCE

SHIP: CGN-25 DATE: 3/1/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		CGN-25
2	TOW DISPLACEMENT, Δ (SEE TABLE-7)	LONG TONS	8580
3	FRONTAL WINDAGE AREA, A_T, (SEE TABLE 7)	SQ. FEET	3040
4	WIND DRAG COEFFICIENT, C_w, (SEE TABLE 7)	—	0.70
5	TOTAL PROJECTED AREA OF PROPELLERS, A_p, (SEE TABLE 7)	SQ. FEET	238.6
6	CURVE NUMBER FOR HULL RESISTANCE, R_H/Δ, (SEE TABLE 7)	—	5
7	CURVE NUMBER FOR WIND FACTOR, K, (SEE TABLE 7)	—	3
8	CURVE NUMBER FOR SEA STATE RESISTANCE, R_s, (SEE TABLE 7)	—	3
9	BEAUFORT NUMBER (WIND) - (SEE TABLE-8)	—	4
10	RELATIVE WIND SPEED, V_R	KNOTS	21.5
11	RELATIVE WIND DIRECTION, α	DEGREES	0
12	HEADING COEFFICIENT K, (SEE FIG. 13-15)	—	1.0
13	SEA STATE RESISTANCE R_s, (SEE FIG. 16)	—	500
14	SELECT A TOW SPEED, V_{TOW}	KNOTS	8
15	$R_{H/\Delta}$ (SEE FIG. 17)	—	3.03
16	HULL RESISTANCE = R_H = (15) x (2) x 1.25	POUNDS	32497
17	PROPELLER RESISTANCE = R_P = 3.737 x (5) x (14) x (14)	POUNDS	57065
18	WIND RESISTANCE = R_W = 0.00506 x (4) x (3) x (12) x (10) x (10)	POUNDS	4977
19	TOTAL TOW RESISTANCE = R_T = (13) + (16) + (17) + (18)	POUNDS	95039

TABLE - [illegible]

CALCULATION OF TOWING RESISTANCE

SHIP: CGN-25　　　　DATE: 3/1/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		CGN-25
2	TOW DISPLACEMENT, Δ (SEE TABLE-7)	LONG TONS	8580
3	FRONTAL WINDAGE AREA, A_T, (SEE TABLE 7)	SQ. FEET	3040
4	WIND DRAG COEFFICIENT, C_w, (SEE TABLE 7)	—	0.70
5	TOTAL PROJECTED AREA OF PROPELLERS, A_p, (SEE TABLE 7)	SQ. FEET	238.6
6	CURVE NUMBER FOR HULL RESISTANCE, R_H/Δ, (SEE TABLE 7)	—	5
7	CURVE NUMBER FOR WIND FACTOR, K, (SEE TABLE 7)	—	3
8	CURVE NUMBER FOR SEA STATE RESISTANCE, R_s, (SEE TABLE 7)	—	3
9	BEAUFORT NUMBER (WIND) - (SEE TABLE-8)	—	4
10	RELATIVE WIND SPEED, V_R	KNOTS	19.82
11	RELATIVE WIND DIRECTION, α	DEGREES	30
12	HEADING COEFFICIENT K, (SEE FIG. 13-15)	—	1.2
13	SEA STATE RESISTANCE R_s, (SEE FIG. 16)	—	500
14	SELECT A TOW SPEED, V_{TOW}	KNOTS	8
15	$R_{H/\Delta}$ (SEE FIG. 17)	—	3.03
16	HULL RESISTANCE = R_H = (15) x (2) x 1.25	POUNDS	32497
17	PROPELLER RESISTANCE = R_p = 3.737 x (5) x (14) x (14)	POUNDS	57065
18	WIND RESISTANCE = R_w = 0.00506 x (4) x (3) x (12) x (10) x (10)	POUNDS	5076
19	TOTAL TOW RESISTANCE = R_T = (13) + (16) + (17) + (18)	POUNDS	95133

CALCULATION OF TOWING RESISTANCE

SHIP: CGN-25 DATE: 3/1/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		CGN-25
2	TOW DISPLACEMENT, Δ (SEE TABLE-7)	LONG. TONS	8580
3	FRONTAL WINDAGE AREA, A_T, (SEE TABLE 7)	SQ. FEET	3040
4	WIND DRAG COEFFICIENT, C_w, (SEE TABLE 7)	—	0.70
5	TOTAL PROJECTED AREA OF PROPELLERS, A_p, (SEE TABLE 7)	SQ. FEET	238.6
6	CURVE NUMBER FOR HULL RESISTANCE, R_H/Δ, (SEE TABLE 7)	—	5
7	CURVE NUMBER FOR WIND FACTOR, K, (SEE TABLE 7)	—	3
8	CURVE NUMBER FOR SEA STATE RESISTANCE, R_s, (SEE TABLE 7)	—	3
9	BEAUFORT NUMBER (WIND) - (SEE TABLE-8)	—	4
10	RELATIVE WIND SPEED, V_R	KNOTS	10.87
11	RELATIVE WIND DIRECTION, α	DEGREES	90
12	HEADING COEFFICIENT K, (SEE FIG. 13-15)	—	0.48
13	SEA STATE RESISTANCE R_s, (SEE FIG. 16)	—	500
14	SELECT A TOW SPEED, V_{TOW}	KNOTS	8
15	$R_{H/\Delta}$ (SEE FIG. 17)	—	3.03
16	HULL RESISTANCE = R_H = (15) × (2) × 1.25	POUNDS	32497
17	PROPELLER RESISTANCE = R_p = 3.737 × (5) × (14) × (14)	POUNDS	57065
18	WIND RESISTANCE = R_w = 0.00506 × (4) × (3) × (12) × (10) × (10)	POUNDS	611
19	TOTAL TOW RESISTANCE = R_T = (13) + (16) + (17) + (18)	POUNDS	90673

TABLE - 8

CALCULATION OF TOWING RESISTANCE

SHIP: CGN-25 DATE: 3/1/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		CGN-25
2	TOW DISPLACEMENT, Δ (SEE TABLE-7)	LONG TONS	8580
3	FRONTAL WINDAGE AREA, A_T, (SEE TABLE 7)	SQ. FEET	3040
4	WIND DRAG COEFFICIENT, C_w, (SEE TABLE 7)	—	0.70
5	TOTAL PROJECTED AREA OF PROPELLERS, A_p, (SEE TABLE 7)	SQ. FEET	238.6
6	CURVE NUMBER FOR HULL RESISTANCE, R_H/Δ, (SEE TABLE 7)	—	5
7	CURVE NUMBER FOR WIND FACTOR, K, (SEE TABLE 7)	—	3
8	CURVE NUMBER FOR SEA STATE RESISTANCE, R_s, (SEE TABLE 7)	—	3
9	BEAUFORT NUMBER (WIND) - (SEE TABLE-8)	—	6
10	RELATIVE WIND SPEED, V_R	KNOTS	29.5
11	RELATIVE WIND DIRECTION, α	DEGREES	0
12	HEADING COEFFICIENT K, (SEE FIG. 13-15)	—	1.0
13	SEA STATE RESISTANCE R_s, (SEE FIG. 16)	—	18650
14	SELECT A TOW SPEED, V_{TOW}	KNOTS	5
15	$R_{H/\Delta}$ (SEE FIG. 17)	—	1.24
16	HULL RESISTANCE = R_H = (15) x (2) x 1.25	POUNDS	13299
17	PROPELLER RESISTANCE = R_p = 3.737 x (5) x (14) x (14)	POUNDS	22291
18	WIND RESISTANCE = R_w = 0.00506 x (4) x (3) x (12) x (10) x (10)	POUNDS	9371
19	TOTAL TOW RESISTANCE = R_T = (13) + (16) + (17) + (18)	POUNDS	63611

CALCULATION OF TOWING RESISTANCE

SHIP: CGN-25

DATE: 3/1/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		CGN-25
2	TOW DISPLACEMENT, Δ (SEE TABLE-7)	LONG TONS	8580
3	FRONTAL WINDAGE AREA, A_T, (SEE TABLE 7)	SQ. FEET	3040
4	WIND DRAG COEFFICIENT, C_w, (SEE TABLE 7)	—	0.70
5	TOTAL PROJECTED AREA OF PROPELLERS, A_p, (SEE TABLE 7)	SQ. FEET	238.6
6	CURVE NUMBER FOR HULL RESISTANCE, R_H/Δ, (SEE TABLE 7)	—	5
7	CURVE NUMBER FOR WIND FACTOR, K, (SEE TABLE 7)	—	3
8	CURVE NUMBER FOR SEA STATE RESISTANCE, R_s, (SEE TABLE 7)	—	3
9	BEAUFORT NUMBER (WIND) - (SEE TABLE-8)	—	6
10	RELATIVE WIND SPEED, V_R	KNOTS	28.7
11	RELATIVE WIND DIRECTION, α	DEGREES	30
12	HEADING COEFFICIENT K, (SEE FIG. 13-15)	—	1.2
13	SEA STATE RESISTANCE R_s, (SEE FIG. 16)	—	18650
14	SELECT A TOW SPEED, V_{TOW}	KNOTS	5
15	R_H/Δ (SEE FIG. 17)	—	1.24
16	HULL RESISTANCE = R_H = (15) × (2) × 1.25	POUNDS	13299
17	PROPELLER RESISTANCE = R_p = 3.737 × (5) × (14) × (14)	POUNDS	22291
18	WIND RESISTANCE = R_w = 0.00506 × (4) × (3) × (12) × (10) × (10)	POUNDS	10643
19	TOTAL TOW RESISTANCE = R_T = (13) + (16) + (17) + (18)	POUNDS	64883

CALCULATION OF TOWING RESISTANCE

SHIP: CGN-25 DATE: 3/1/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		CGN-25
2	TOW DISPLACEMENT, Δ (SEE TABLE-7)	LONG TONS	8580
3	FRONTAL WINDAGE AREA, A_T, (SEE TABLE 7)	SQ. FEET	3040
4	WIND DRAG COEFFICIENT, C_w, (SEE TABLE 7)	—	0.70
5	TOTAL PROJECTED AREA OF PROPELLERS, A_p, (SEE TABLE 7)	SQ. FEET	238.6
6	CURVE NUMBER FOR HULL RESISTANCE, $R_{H/\Delta}$, (SEE TABLE 7)	—	5
7	CURVE NUMBER FOR WIND FACTOR, K, (SEE TABLE 7)	—	3
8	CURVE NUMBER FOR SEA STATE RESISTANCE, R_s, (SEE TABLE 7)	—	3
9	BEAUFORT NUMBER (WIND) - (SEE TABLE-8)	—	6
10	RELATIVE WIND SPEED, V_R	KNOTS	23.98
11	RELATIVE WIND DIRECTION, α	DEGREES	90
12	HEADING COEFFICIENT K, (SEE FIG. 13-15)	—	0.48
13	SEA STATE RESISTANCE R_s, (SEE FIG. 16)	—	18650
14	SELECT A TOW SPEED, V_{TOW}	KNOTS	5
15	$R_{H/\Delta}$ (SEE FIG. 17)	—	1.24
16	HULL RESISTANCE = R_H = (15) x (2) x 1.25	POUNDS	13299
17	PROPELLER RESISTANCE = R_p = 3.737 x (5) x (14) x (14)	POUNDS	22291
18	WIND RESISTANCE = R_w = 0.00506 x (4) x (3) x (12) x (10) x (10)	POUNDS	2972
19	TOTAL TOW RESISTANCE = R_T = (13) + (16) + (17) + (18)	POUNDS	57212

FINAL REPORT
1 JUNE 1950

PROJECT 9-57-01-04

HULL FORMS

VOL. 1
BARGE HULL FORM STUDIES

TRANSPORTATION BOARD
NEW YORK PORT OF EMBARKATION, BROOKLYN, NEW YORK

RESTRICTED

UNCLASSIFIED

TRANSPORTATION BOARD
NEW YORK PORT OF EMBARKATION

1 June 1950

This report covers the activities of the Transportation Board in accordance with Army Regulations No. 15-30, dated 1 August 1949.

FOR THE PRESIDENT OF THE BOARD:

ROBERT C. HANES
Lt Colonel Inf
Secretary

UNCLASSIFIED

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CONTENTS

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SCOPE

To examine hull forms of Transportation Corps equipment with a view toward improvement; to evaluate hull forms, by model tests and operating experience, for operating conditions of existing standard TC floating equipment, and of items selected for future use; to explore simplified hull forms in order to combine good performance with ease of production.

DISCUSSION

The development of barge hull forms to their present stage runs parallel with the development of marine operations. The Transportation Corps procured a large number of tugs, barges, and supply vessels during World War II. Many of these hulls, produced under the stress of wartime conditions, lacked the benefit of model testing and refinement of hull design. The hull-forms project was initiated to determine which of these forms were satisfactory as designed, and what improvements could be made to the poorer forms to meet operating requirements annex I.-A.

Eight existing TC barge forms were selected for model tests to determine their resistance and yaw characteristics. Two new forms designated BX 10 and BX 11 were designed and tested to replace forms of the original designs which were unsatisfactory. Additional data for comparative purposes were obtained from existing TC Board designs 7002 and 7003 (annex I.-B).

The 12 model tests covered by this report were conducted in two model-testing basins, one located at University of Michigan and the other at the Stevens Institute of Technology (annex I.-C).

Model testing and expansion of model results in this report are in conformance with the approved standards set forth by the Society of Naval Architects and Marine Engineers Hydromechanics Subcommittee (annexes I.-D and I.-E).

A comparative analysis indicates that TC barge designs range from the best to the poorest encountered in commercial practice. Generally, those barges which had long rakes flowing smoothly into the parallel middle body had the lowest relative resistance ratios. (annex I.-F).

CONCLUSIONS

It is concluded that:

Of the barge models tested, from a towing-resistance standpoint, the following designs are unsatisfactory: 267, 336 B, 417 S, 430, and 380. The following designs are considered satisfactory: 230, 231 A, 7001, 7002, 7003, BX 10, and BX 11.

RECOMMENDATIONS

It is recommended that:

1. Results contained in this study be adopted as a guide for the development of barges for the standard TC fleet.

2. Barge designs 267, 336 B, 417 S, and 430 be declared obsolete.

3. Barge design 380 be retained in its present classification of limited standard until present stocks are exhausted.

Designs of military barges are usually restricted to some extent, owing to stipulated dimensions of length, beam, and draft, therefore, attempts to lower resistance must be confined to proportioning and shaping the rake ends (annex I.-G).

Comparison of performance of barges with and without skegs indicates that barges equipped with properly designed skegs eliminated yaw and increased directional stability on the majority of models tested (annexes I.-H and I.-I).

ANNEX I

DETAILED DISCUSSION AND FINDINGS

ANNEX I.-A

Background

The development of barge hull forms to their present stage of design runs parallel with the commercial development of the inland waterways of the United States.

The first rafts of logs poled down the Mississippi gave way to wooden barges lashed to steamboats as early as 1832 (4)*, and by the late seventies, fleets of barges were in general use. With the development of the iron and steel industries the movement of coal increased in importance, and flatboats, which had been too cheap to warrant return upstream, gave way to more permanent types of barges. In the period between 1910 and 1920, steel was introduced as a hull material, but the construction methods employed produced barges which could carry only a limited cargo, owing to an excess of internal structure (6).

In the Rivers and Harbors Act of 1910, Congress authorized the Secretary of War to design and construct two experimental towboats, with a suitable complement of barges, for towing and delivering supplies along the Mississippi River and its tributaries. A board appointed by the Chief of Engineers made a thorough study of all available design and operating information, and conducted a series of model and full-scale trials of towboats and barges. The resulting published data (3) (9) constituted the first step in the improvement of barge hull forms for river transportation.

River traffic decreased sharply in 1914 and 1915. In 1918, a large portion of the river tonnage was destroyed or carried away by ice floes which filled the rivers. But in the early twenties, the Government sponsored programs for the canalization of the Ohio River, and established the Federal Barge Line. These advances were followed by projects for the improvement of the Upper Mississippi, the Missouri, the Tennessee, and the Illinois Rivers. Forerunners of the modern common-carrier barge line appeared, and the improvements discovered in the studies of 1910 to 1915 were put to use. The Corps of Engineers Towboat Board was reorganized in 1928, and a complete analysis was made of the latest practice in water transportation on the Mississippi and its tributaries (2).

*Note: Numbers in parentheses refer to technical references listed in appendix V.

During the period between 1930 and World War II, barge operators and builders began to utilize model-testing basins for the improvement of individual barges and flotillas. With the increase in industrial activities in the Gulf states, the movement up river of large cargoes steadily increased, and reductions in barge resistance became increasingly important.

Developments on the inland waterways have improved not only the performance of river barges, but canal, harbor, and seagoing barges have also shown the effects of these design changes. Barges now in existence have been especially designed for movement of a large variety of cargoes. Weatherproof covered barges, tank barges, merchandise carriers, automobile carriers, and many other types are operating commercially. The entire inland and intracoastal waterway system, with dependable river stages and efficient towboats and barges, is now an extremely important factor in the nation's transportation system. A survey of the barge forms designed, built, and operated by the Transportation Corps during World War II disclosed the fact that the design of military craft of this type lagged considerably behind the development of similar commercial equipment. Some of the existing TC barges contained construction features which are entirely outdated, and forms which have been commercially obsolete for a decade.

ANNEX I.-B

Selection of barge hulls for testing

At the time the Transportation Corps Board barge-testing program was initiated, the selection of hull forms proved rather difficult. No standard TC fleet had been defined, and the choice of hulls which would eventually be used for this fleet could not be definitely predicted. Of the wide range of types of barges available, the Barge, Dry Cargo, Non-Propelled, Steel, 1700-Ton, 210-Foot, Design 230, and Barge, Deck Cargo, Non-Propelled, Steel, 585-Ton, 120-Foot, Design 231 A, appeared similar to representative types of successful commercial barges, and the most likely to be included in a standard TC fleet. Aside from these two designs, there seemed to be no outstandingly good hulls with the possible exception of Barge, Dry Cargo, Steel, 130-Foot, Design 267. This 130-foot cargo barge had been designed with rather complicated forward rake-end sections which, if justified by markedly lower resistance characteristics, might be considered as a future standard design.

During World War II, there was an urgent need for small harbor barges which could be shipped overseas in a compact form. Barge, Dry Cargo, Non-Propelled, Steel, 375-Ton, 112-Foot, Design 430, Knock-Down is representative of the solution evolved at that time. Although barges of this type were not entirely successful, owing to assembly difficulties, it was desired to compare the hull forms of this design and the more recent development along these lines such as Barge, Deck Cargo, Non-Propelled, Steel, Sectionalized, Nesting, 81-Foot, Design 7001.

In order to round out this series for comparative purposes, three other barges were selected: Barge, Pier, Non-Propelled, Steel, 150-Foot, Knock-Down, Design 380, a pier barge with an extremely large beam-to-length ratio; Barge, Deck Cargo, Non-Propelled, Wood, 700-Ton, 130-Foot, Design 336 B; Barge, Cargo, Steel, 112-Foot, Design 417 S, a fine-ended barge representing the so-called "simplified form."

In addition to the above hulls, contracts were issued for the design of Barge, Liquid Cargo, Non-Propelled, Steel, 9000 Bbl., 195-Foot, Design 7002, and Barge, Dry or Liquid Cargo, Non-Propelled, Steel, 500-Ton, 130-Foot, Design 7003, which both called for model tests.

Test results for designs 7002 and 7003 have been included in the analysis. Further developments to be described later indicated the need for replacement hull forms for a 112-foot and a 130-foot barge, which are included as BX 10 and BX 11.

ANNEX I.-B (contd)

The above designs were selected for model testing in order to determine which hulls were satisfactory for further use by the Transportation Corps, and to secure basic design information which would prevent repetition of the mistakes made in barge procurement in World War II.

ANNEX I.-C

Model-testing tanks

The twelve model tests covered by this report were carried out in two model-testing basins. Designs 267, 430, 336 B, 417, BX 10, and BX 11 were tested in the Naval Tank at the University of Michigan. Designs 7001, 7002, 7003, 230, 231 A, and 380 were tested in Tank No. 1, Experimental Towing Tank, Stevens Institute of Technology.

In the 22-by 300-foot Naval Tank, Models are towed under a carriage running the length of the basin on rails fitted along each side. A motor, which is mounted on the carriage, propels it at constant speed.

The Stevens tank No. 1 is 9 feet by 100 feet. Models are towed by a dynamometer riding on an overhead central rail. The dynamometer is propelled by means of a continuous wire running along the rail and around a motor-driven pulley. A dc motor is used to bring the model up to constant speed, and an ac synchronous motor mounted on the same shaft is cut in to tow the model at constant speed down the tank.

In the prediction of full-scale resistance values, the model results of both tanks are equally reliable. In the prediction of full-scale yaw characteristics, however, the larger size and type of carriage propulsion of the Naval Tank permits, to some extent, the quantitative evaluation of yaw, whereas the yaw results of the Stevens Tank are qualitative only. In the Naval Tank, the model can swing freely through its full amplitude of yaw throughout several cycles. The smaller dimensions of the Stevens tank No. 1 do not permit full swing of a badly yawing barge, and it is seldom that a model can complete more than 1½ cycles. In addition, the cutting in of the synchronous motor often accelerates the model abruptly. If the model is not heading straight down the tank at this instant, the first swing is overemphasized. Thus the correction of yaw in this tank can be considered satisfactory for full-scale predictions, but uncorrected yaw cannot be measured with accuracy.

ANNEX I.-D

Expansion of model results

The expansion of all model results covered by this report has been in conformance with the latest standards set forth by the Society of Naval Architects and Marine Engineers Hydromechanics Subcommittee, Bulletin 1-2. The Schoenherr friction formulation was used for both model and full scale. A constant addition of 0.0004 was made to the frictional-resistance coefficient for roughness. All full-scale predictions are based on immersion in salt water at 15°C (59°F).

It has been the practice at the Naval Tank, in the expansion of results of models with major appendages such as barge skegs, to add to the bare-hull results only 50 percent of the additional resistance incurred by the use of skegs. This apparant departure from Froude's law of comparison may have some merit owing to the fact that velocity past the skegs differs from barge velocity. However, no reliable full-scale barge tests have been made to justify the use of a definite percentage of the skeg resistance. Tests on Thames barges reported by Baker (5) showed close correlation between model and full-scale tests with no scale correction. All expansions covered by this report have included the full resistance of the model skeg.

ANNEX I.-E

Model tests

Contracts placed with the Naval Tank and with the Experimental Towing Tank for the eight barges originally selected (designs 7001, 231 A, 230, 380, 267, 430, 417 S, and 336 B) called for resistance tests and yaw tests at three displacements for each barge. Alterations were to be made to each hull to lower resistance and reduce yaw, and the altered models were to be similarly tested. The basic resistance and yaw tests were completed in accordance with these requirements, and the plotted results, together with the rake profile and body plans of these vessels are shown in figures 1A through 8C inclusive of appendix III. A description of the alterations made and discussion of the performance of each form follow:

Design 7001 (fig 1A, app III.)*

This 81-foot barge was designed specifically for sectionalization and nesting of the individual sections. The hull form has necessarily been designed to meet these requirements. However, in spite of the restrictions to shaping of the hull, the resistance of this barge is quite satisfactory (fig 1B). When towed behind a single line, a distinct tendency to yaw was demonstrated. This was overcome to some extent by towing with a bridle. Because of the design restrictions, no alterations were attempted to improve resistance or yaw characteristics.

Design 231 A (fig 2A)

For a simply shaped, symmetrically ended hull form, this 120-foot barge showed exceptionally low resistance characteristics (fig 2B). Three alternate bow-and-stern combinations with considerably more shape than the original rake ends failed to reduce the resistance. Rounding off of the bilges to a 12-inch radius showed no improvement over the original 1-inch radius. The single centerline skeg, however, proved to be entirely ineffective in preventing yaw, which was uncontrollable in the model basin. The substitution of two outboard plate skegs with prisms at the after ends (fig 2C) was required to insure directional stability. The total resistance was thus considerably increased (fig 2D).

Design 230 (fig 3A)

This 210-foot cargo barge had the lowest resistance characteristics of all barges tested (fig 3B) owing to the ship-form bow. The yaw was satisfactorily corrected by the Ingalls, a pyramid-type skeg, but with a prohibitive increase in resistance. By the substitution of plate skegs with prisms (fig 3C) the yaw was corrected with a definitely lower resistance penalty (fig 3D).

*Note: All figures (except figure 1) referred to in this report are shown in appendix III.

ANNEX I.-B (contd)

Design 380 (fig 4A)

This 150-foot pier barge has a fairly high resistance (fig 4B), which could be reduced 15 to 25 percent by shaping of the forward rake-end bilges. However, as this barge would seldom be used for actual towing, the reduction in resistance would not justify the added construction cost. In the even-keel condition, this barge had an uncontrollable yaw which could not be reduced, even with the addition of three plate skegs with prisms. Additional tests proved that directional stability could be restored by operating with a bridle, and with approximately 1 foot of trim. Little increase in resistance was indicated when operating under these conditions.

Design 267 (fig 5A)

This 130-foot steel barge has favorable resistance characteristics which have been obtained by a complicated bow design. From a resistance standpoint the vessel is satisfactory, but the additional cost of construction required appears unwarranted. The curves of total resistance are given in figure 5B, and curves of yaw amplitude in figure 5C. The barge as designed is directionally unstable.

Design 430 (fig 6A)

The knock-down principle employed in the construction of this 112-foot steel barge necessitated to some extent the abrupt form contours. The resistance penalty of this barge (fig 6B) was tremendous, its resistance being the highest of all barges tested. The directional stability without the use of skegs was exceptional (fig 6C).

Design 417 S (fig 7A)

This 112-foot steel barge of the "straight-element" form also showed a high resistance for the amount of cargo carried (fig 7B). The vessel was directionally unstable (fig 7C); hand-operated rudders of the type used on this barge are entirely ineffective in overcoming yaw.

Design 336 B (fig 8A)

This 130-foot wooden lighter barge had a very high resistance (fig 8B), owing chiefly to the paneled construction used on the sides. The vessel could not be considered directionally stable, but the yaw amplitude was not too great (fig 8C).

Design BX 10 (fig 11A)

Because of the unsatisfactory performance of designs 430 and 417 S, it was felt that there would be no advantage in altering these hulls. Professor L. A. Baier of the University of Michigan agreed to submit a new "straight-element form" design, embodying in general the over-all dimensions and tonnages of these two barges. This form, designated BX 10, was tested with and without skegs (figs 11B, 11C), and showed exceptionally good performance. Although the skegs increased the resistance considerable, yaw was completely eliminated.

Design BX 11 (fig 12A)

Owing to the high construction cost expected for design 267 and the high resistance of design 336 B, a "straight-element form" replacement was designed by Professor Baier. This barge also had a low resistance, and complete directional stability was attained (figs 12B, 12C).

Design 7002 (fig 9A)

This 196-foot steel barge was recently designed by the TC Board as a liquid carrier. The easy forward rake and the forming of the deck line forward and aft give exceptionally low resistance. The model testing of this barge was accomplished under its design contract, and the data obtained cover only one deep-water test which can be compared with other barge tests (fig 9B). The barge was directionally unstable when tested with designed skegs, and the substitution of the skeg shown in figure 9C is recommended. The additional resistance incurred by this skeg would probably lie somewhere between the values for designs 230 and 231 A (fig 19).

Design 7003 (fig 10A)

This 130-foot oil barge was also designed recently by the TC Board. The only deep-water test which can be compared with the other barges (fig 10B) was conducted with yaw corrected by the skegs shown in figure 10C, which are recommended as replacements for the skegs originally designed. The test indicated that this form was one of the best of the group.

ANNEX I.-F

Comparison of resistance results

Comparative results of the model tests are shown in the graph on the next page. Design 7001 was left unchanged. On design 380 the yaw was corrected by trimming by the stern, and without use of skegs. No attempt was made to correct design 7002 because the yaw was small, and experience had proved that when yaws are of very small amplitude in tank tests they are not apparent in the full-size vessel. Design 7003 was towed with skegs only, and no base hull data are available. Skegs of designs 231 A and 230 were altered to reduce yawing with a minimum increase in resistance. Design 267 has good resistance characteristics, but lacks directional stability. Designs 417 S, 430, and 336 B are considered entirely unsatisfactory, and should serve as an example of types to be avoided in the future. Designs BX 10 and BX 11 offer low resistance together with low initial construction costs, owing to simplification of form.

It is recommended that the conclusions of this report be adopted as guides for the design and procurement of future barges for Transportation Corps use.

Resistance results for all barges at load displacement in deep water are compared in figures 13, 14, 15, and 16. The values have been reduced to a comparative basis by plotting against the Froude number. This has been used in preference to the normally accepted speed-length ratio because of the confusion often occurring in rating barges in knots or in statute miles per hour. In figures 13 and 14 the total resistance has been expressed in pounds per pound displacement rather than pounds per ton, to permit use with either long or short displacement tons. Use has been made (figs 15, 16) of the "volumetric" residual resistance coefficient to permit dimensionless comparison of residual resistance on a basis which indicates the carrying capacity of the barge.

A comparison of the curves of figure 13 with model-test results for 14 barges given by Baier (1) shows that design 230 has a lower resistance than any of them. Designs BX 10 and 7002 are on a par with the best of the barges shown. Designs BX 11, 231 A, 267, and 7002 are better than average, and designs 380, 7001, 336 B, and 417 S graduate throughout the range. Design 430 is quite similar to the poorest of the 14 barges tested. This indicates, therefore, that TC barge designs range from the best to the worst encountered in commercial practice.

Basic barge performance can best be analyzed by reference to the curves of figure 15. Here the comparative bare-hull form resistances are clearly shown. The averages of these values between Froude numbers of 0.10 and 0.20 are shown in the graph (fig 1) which serves as a rating index for this group of barges.

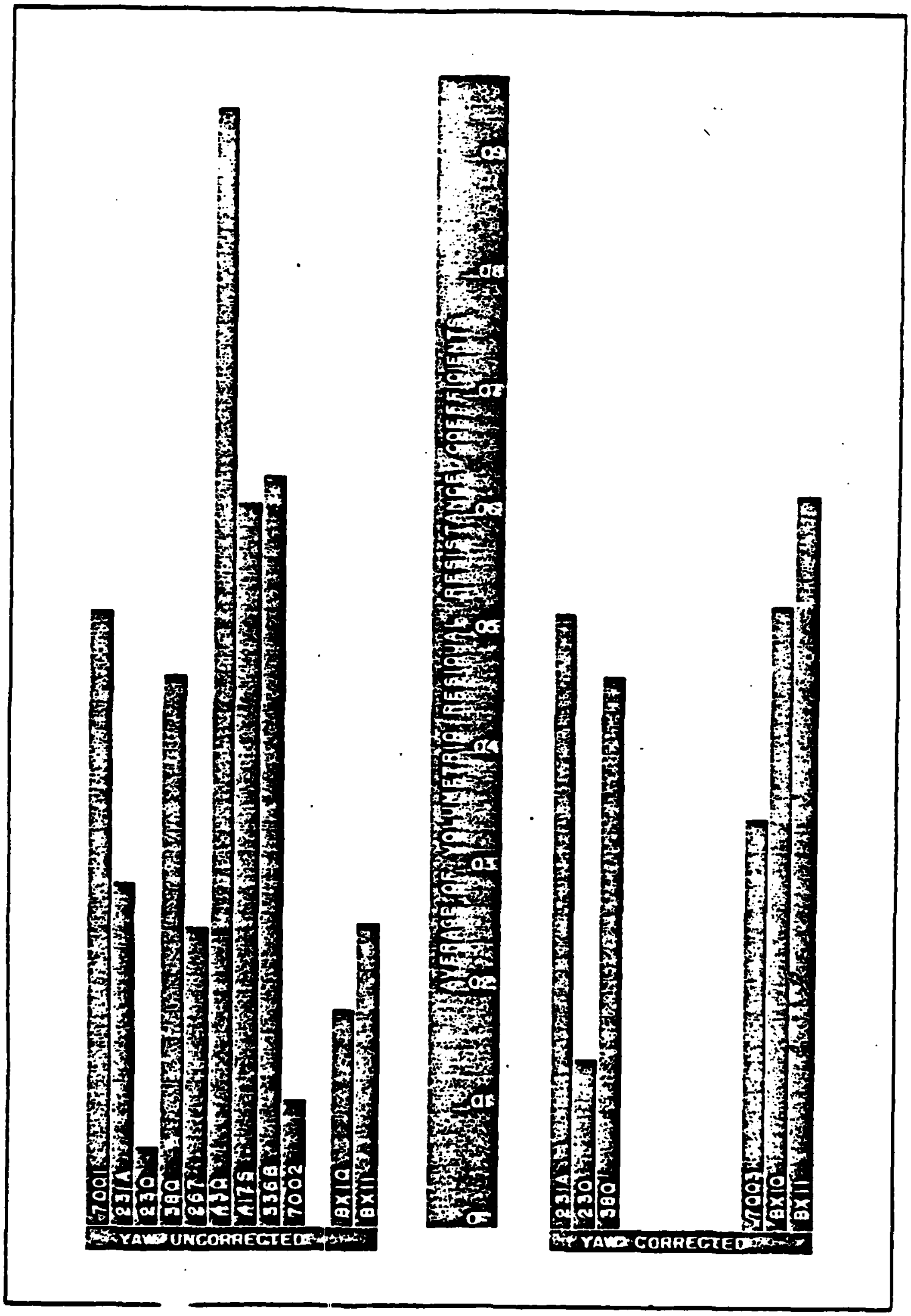

Figure 1. Comparison of specific volumetric residual resistances of barges tested.

Reference to the proportional sectional-area curves (fig 17) gives a visual description of the basic cause of the high resistance of some of these barges. These curves have been staggered for clarity. The ordinates represent the ratio of section area to midship section area for each barge. The abscissas represent the ratio of rake-end length (on waterline) of each barge to the maximum rake-end length of the barges tested (design 230 forebody; design BX 11 afterbody).

The high resistances of designs 430 and 417 S can be attributed directly to the sharp break in the sectional-area curve where the rake-end meets the middlebody. The resistance of design 430 is greater, owing to the shorter rake length.

The short rake lengths of designs 380, 7001, and 336 B raise the resistances, but the fair curvature of the sectional-area curves gives an indication of good form. Design 336 B has a higher resistance, as the paneling of the parallel sides causes severe eddying. The easy sweep of the sectional-area curves of designs 231 A and 267 combined with fairly long rake ends give good forms with reasonably low resistance. From the appearance of the relative resistances, the change in curvature of the sectional-area curve at the bow, giving a smaller entrance angle combined with greater rake length, is conducive to very low resistance values as exemplified by designs 230, 7002, 7003, BX 10, and BX 11. The differences in average specific resistance of these designs can be caused by waterline shape, length-to-beam ratio, and beam-to-draft ratio as listed in table II. For the four bare-hull tests available, the specific resistances vary almost linearly with the length-to-draft ratio, but there have not been sufficient tests to accept this as a general statement.

ANNEX I.-G

Discussion of barge-form design

Certain design considerations are apparent from the comparison of the barge-model tests completed under this project. These may be listed as follows:

a. The shape of the sectional-area curve is a definite factor in determining barge resistance. In general a small slope of the curve at entrance combined with a low prismatic coefficient and fair curvature throughout tend to lower resistance.

b. The length of the rake ends is a controlling factor. Normally, the longer the rake end, the lower the resistance. However, where resistance is compared with displacement tonnage, a certain optimum length is indicated. A series of tests at the University of Michigan established the optimum length of the forward rake end as 25 percent of the length over-all. It was also found that the after rake end could be of the same form as the forward rake, but with the after end cut off to reduce the after rake length to 80 percent of the forward rake length. This gave the lowest values of resistance per ton of displacement.

c. The slope and shape of the forward rake-end keel line have often been considered quite critical. Tests by Sadler (3), Baier (1), and Hay (7) (8) demonstrated wide variations in resistances with various slopes and shapes. However, the tests conducted on modifications of design 231 A, and the low resistances of designs 267 and 230 indicate that these variations were due more to changes in the sectional-area curve than to changes in the rake profile. Three sets of bow-and-stern rake ends were constructed for design 231 A. These ends had lateral-area coefficients of 0.67, 0.75, and 0.83, respectively, with a parabolic profile. The sectional-area curve (and therefore entrance and run prismatic coefficients) were identical for all three sets. The resistance results obtained by any combination of these forms was identical. It is therefore believed that the shape and slope of the rake profile are important for resistance only insofar as they affect the sectional-area curve. For a fairly full formed rake end, a rake angle of 30 degrees seems to give the most satisfactory sectional-area curve.

d. The ratios of length-to-beam and beam-to-draft have a decided effect on resistance. Designs BX 10 and BX 11, which have otherwise nearly identical coefficients, show a 30 percent difference in residual resistance. In general, the resistance decreases with increasing values of these ratios.

e. Any unnecessary eddy-making appendages such as the paneling on design 336 B are to be avoided.

f. Good barge forms can be obtained without complicated construction features.

ANNEX I.-G (contd)

g. Deadrise and a large bilge radius are important factors in shallow-water operation (1), but may be less significant for deep-water operation.

The dimensions of length, beam, and draft are usually stipulated in the design of military barges, which restricts the designer to some extent. In these cases, attempts to lower resistance must be confined to the proportioning and shaping of rake-ends. He is also restricted to shapes which lend themselves to simple and inexpensive construction. In dealing with a rounded bilge form, the use of a constant radius simplifies fitting by reducing the rolling or furnacing operation to a single pair of strakes. Figure 18A shows two types of barges which employ this principle. The rake end profiles are identical, but in one barge a good sectional-area curve has been obtained by tapering in the sides to the headlog. Where a large deck area is required, the sectional-area curve can be retained by varying the deadrise as shown in the second body plan. The fore and after rakes are symmetrical, with 15 percent cut from the rake aft. This feature has the added advantage that if flotilla operation is desired, the barges may be secured stern to stern.

As a third alternative type, the "straight element" form for barge rake ends is employed in figure 18B. Considerable experimentation was done along these lines at the University of Michigan for the Ingalls Corporation, and the proportions shown represent the optimum values found. This form is adaptable to the use of developed plates between the upper and lower chine. The Ingalls "Patented Bow" uses the developed surface of a cone with the apex at point A to form this plate. A cylindrical development is also possible, or straight sections may be used as shown.

By reference to the three suggested standards and principles set forth above, it should be possible for a designer with relatively little barge experience to design a good hull form, easily constructed, and with low-resistance characteristics.

ANNEX I.-H

Comparison of skeg performance

Of the 12 barges tested, 8 were originally fitted with some type of device expected to insure directional stability. Design 231 A had a single, straight-sided centerline skeg. Design 230 had two Ingalls patented pyramid-type skegs. Designs 267, 7002, and 7003 had pairs of straight-sided skegs. Design 417 S had a centerline rudder, and designs BK 10 and BK 11 had pairs of offset Dravo-type skegs. Of the eight tested, only those on designs 230, BK 10, and BK 11 actually eliminated yaw.

Types of skegs recommended by the Experimental Towing Tank were fitted to designs 231 A, 230 380, and 7003. The yaw was eliminated on all but design 380, which required the combination of trim and a bridle to attain stability. The relative resistances of the skegs which actually corrected yaw are shown in figure 19.

From these curves it appears that the yaw-correcting skegs of lowest resistance are of the Experimental Towing Tank type, consisting of plate skegs with vertical, triangular prisms fitted to the after ends.

ANNEX I.-I

Discussion of directional stability

Directional stability, or the ability of a barge to follow a straight course behind a towing vessel, is an extremely important factor in the operations of tugs and barges. A yawing barge is a danger to navigation and to the towing vessel. The sheering of a barge in a turn has been known to capsize the towing vessel. It also greatly reduces the efficiency of towing operation.

When an external force such as a wave throws a barge off course, a new transverse resistance force is added. If the moment of this force about the center of gravity opposes and exceeds the restoring moment of the force exerted by the towline, the barge will be directionally unstable. The stability may be restored by several methods:

> The use of a towing bridle increases the moment arm of the restoring force.
>
> The use of skegs or a rudder decreases the moment arm of the transverse resistance by moving aft the center of lateral resistance. (Rudders have been unsuccessful, as they do not exert a great enough force unless the yaw is anticipated by the helmsman).
>
> The trimming of the barge moves the center of lateral resistance aft, and by relocation of the center of gravity, increases the moment arm of the restoring force.
>
> Fining the forward lines to reduce transverse resistance, or filling out the after lines, tends to move the center of lateral resistance aft.

Studies at the University of Michigan (10) showed that a bridle length of 1-1/2 barge beams was the most effective in overcoming yaw. A series of tests on skegs carried out at the University of Michigan in 1938 for the Dravo Corporation (1) resulted in the design of a very efficient skeg; this type was used on designs BX 10 and BX 11. However, barge tests of project 9-57-01-04 indicate that a skeg of the type developed by the Stevens Experimental Towing Tank corrects yaw with less resistance penalty than the Dravo or the Ingalls skegs. This type of skeg (fig 20) is recommended as a standard for future TC designs until further studies can be made. Consideration should also be given to retractable skegs for TC barges operating in both rivers and harbors.

Investigations of the relationship between directional stability and form design have been limited mainly to ship-form vessels propelled and controlled from the stern. The same techniques could be applied to barge-hull forms to give very worthwhile information on this subject. The great

AD-A150 941 DEVELOPMENT OF A CALCULATION PROCEDURE FOR THE DETERMINATION OF TOW RESISTANCE (UNABRIDGED REPORT)(U) ROSENBLATT (M) AND SON INC NEW YORK APR 76

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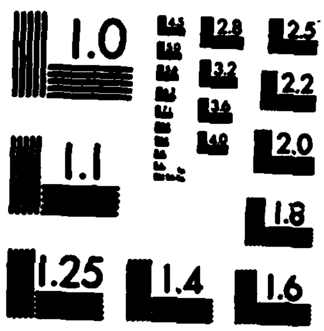

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

improvements in barge resistance effected in the last 10 years have been nullified to a large extent by the necessity of adding high-resistance skegs. This phase of the barge-design problem has been sadly neglected, and further studies by the Transportation Board along these lines are strongly advocated.

CONCLUSIONS

It is concluded that:

1. Barge designs 417 S, 430, and 336 B are entirely unsatisfactory.

2. Design 380 has satisfactory resistance characteristics for a special-purpose barge. Yaw can be controlled by the use of trim and bridle.

3. Design 7001 is a distinct improvement over design 430, and fulfills satisfactorily the requirement for a sectionalized barge.

4. Design 231 A can be improved for shallow-water operation by increase of the bilge radius to 12 inches. Yaw can be eliminated by substitution of the revised skegs shown in figure 30.

5. Design 230 has extremely low resistance which can be further reduced by substitution of the skegs shown in figure 30.

6. Design 267 has reasonably low resistance, but the complicated bow formation indicates high construction cost. Yaw of barge as now designed is excessive.

7. Designs 7002 and 7003 have excellent resistance characteristics. Directional stability can be increased by substitution of the skegs shown in figures 30 and 100.

8. Designs BK 10 and BK 11 are satisfactory replacements for designs 417 S, 430, 336 B, and 267.

9. Recent TC Board barge designs compare favorably with the most recent commercial designs of the same type barges.

10. Retractable skegs are practicable for TC barges operating both in rivers and harbors.

11. A great deal of study is required to determine and correct the directional instability of barges.

RECOMMENDATIONS

It is recommended that:

1. Designs 417 S, 336 B, 430, and 267 be classified obsolete.

2. Skeg revisions of the type shown be incorporated on designs 231 A,

230, 700S, and 700S.

3. The bilge radius on design 231 A be increased to 12 inches.

4. The full-scale resistance data on all operating barges covered by this report be published for the use of the operating services.

5. The lines drawings of designs BK 10 and BK 11 be retained, to fulfill future requirements for a 112-foot or a 120-foot barge.

6. Consideration be given to retractable skegs for use on barges operating both in rivers and harbors.

7. The types of forms shown in figures 18A and 18B and the skeg shown in figure 20 be used as guides in future barge designs.

APPENDICES

APPENDIX I

ARMY SERVICE FORCES
Office of the Chief of Transportation
Washington 25, D. C.

SPTDR-6 2 May 1946

MEMORANDUM FOR THE COMMANDING GENERAL, ARMY SERVICE FORCES
Attention: Chief, Research and Development Branch

SUBJECT: Research and Development Project 57 M-38, Hull Forms; approval requested.

1. The Transportation Corps Technical Committee recommends that Research and Development Project 57 M-38, Hull Forms, be approved.

2. The recommendations contained in the inclosed subcommittee report were approved at Transportation Corps Technical Committee meeting held 1 May 1946. This paper is forwarded for formal approval.

FOR THE CHIEF OF TRANSPORTATION:

(signed)
CARL R. GRAY
Colonel, TC
Chief, Research & Development Branch

2 Incl.
1. Report 4/22/46 (quad)
2. Concurrence sheet

SUBJECT: Research and Development Project 57 M-38, Hull Forms, approval requested.

SPRCG (2 May 1946) 1st Indorsement

Headquarters, Army Service Forces, Washington, D. C., 15 May 1946.

To: Chief of Transportation
Attention: Research and Development Division

1. Project 57 M-38, Hull Forms, is approved.

2. The recommendations contained in Paragraphs 3b. and 3c., attached subcommittee report, are approved.

3. The expenditure of funds in the amount of $50,000, from funds available to the Chief of Transportation, is authorized.

4. Priority Classification 3-A is assigned to this project.

FOR THE COMMANDING GENERAL:

(signed)

2 Incls:
1 - quad & trip w/d
2 - n/c

M. M. IRVINE
Colonel, General Staff Corps
Acting Chief, Research & Development Branch

Coefficients

L_R/L	Ratio, length of run/length
B_X/H	Ratio, beam/draft
$S/\nabla^{2/3}$	Ratio, wetted area/(volume of displacement) $^{2/3}$
S/L^2	Ratio, wetted area/length ^{2}
C_B	Coefficient, block. The volume of the underwater body of the vessel divided by the volume of a rectangular solid having the same dimensions, L, B_X, H, as the vessel.
C_P	Coefficient, prismatic or longitudinal. The volume of the underwater body of the vessel divided by the volume of a prism having the length L and the cross-section of area A_X.
C_X	Coefficient, maximum section. The area A_X of the maximum vertical transverse section of the underwater body of the vessel divided by the area of a rectangle having the dimensions B_X and H.
C_W	Coefficient, waterplane. The area A_W, of the waterline plane, WL divided by the area of a rectangle having the dimensions L and B_X.
C_{PV}	Coefficient, prismatic, vertical. The volume of the underwater body of the vessel divided by the volume of a vertical prism having a horizontal section equal to the waterplane area A_W, and a height equal to the draft H; in terms of the other coefficients:

$$C_{PV} = \frac{(C_P)\,(C_X)}{C_W}$$

C_{PE}	Coefficient, prismatic, entrance. The volume of the entrance of the vessel divided by the volume of a prism having the length of the entrance and the same cross-section area A_X as that of the maximum section of the vessel.

APPENDIX II (contd)

Coefficients

C_{pR} Coefficient, prismatic, run. The volume of the run of the vessel divided by the volume of a prism having the length of the run and the same cross-section area A_X as that of the maximum section of the vessel.

C_{pvE} Coefficient, prismatic, vertical, entrance. The volume of the entrance of the vessel divided by the volume of a vertical prism having a horizontal section equal to the waterplane area of the entrance and a height equal to the draft at midlength of the vessel.

C_{pvR} Coefficient, prismatic, vertical, run. The volume of the run of the vessel divided by the volume of a vertical prism having a horizontal section equal to waterplane area of the run and a height equal to the draft at midlength of the vessel.

C_{pTE} Coefficient, prismatic, transverse, entrance. The volume of the entrance of the vessel divided by the volume of a transverse prism having a vertical section equal to the lateral area of the entrance and a transverse dimension equal to the beam of the vessel.

C_{pTR} Coefficient, prismatic, transverse, run. The volume of the run of the vessel, divided by the volume of a transverse prism having a vertical section equal to the lateral area of the run and a transverse dimension equal to the beam of the vessel.

v Speed of vessel in feet per second

V_K Speed of vessel in knots

g Acceleration of gravity in feet per second ^{2}

Mass density in pounds seconds ^{2} per feet ^{4}

R Resistance in pounds

R_r Residual resistance in pounds

TABLE I.

Tabulation of Total Resistances of Barges
- as designed - Deep Water

Design	[illegible]			[illegible]			[illegible]			[illegible]		
Δ tons H feet	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
V_k	Total resistance in pounds											
4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
6	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
7	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
8	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
9	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
10	[illegible]			[illegible]	[illegible]		[illegible]	[illegible]		[illegible]		

Design	[illegible]			[illegible]			[illegible]			[illegible]		
Δ tons H feet	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
V_k	Total resistance in pounds											
4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
6	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
7	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
8	[illegible]	[illegible]		[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
9	[illegible]			[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]		
10	[illegible]			[illegible]			[illegible]	[illegible]		[illegible]		

Design	[illegible]			[illegible]			[illegible]			[illegible]		
Δ tons H feet		[illegible]			[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
V_k	Total resistance in pounds											
4					[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
5		[illegible]			[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
6		[illegible]			[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
7		[illegible]			[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
8		[illegible]					[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
9		[illegible]					[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
10							[illegible]			[illegible]		

TABLE 13. Hull-Form Data and Coefficients

Design	[illegible]	331 A	[illegible]	[illegible]	[illegible]	[illegible]	417 A	[illegible]	[illegible]	[illegible]	XX 10	XX 11
[illegible]	[illegible]	116.2	[illegible]	[illegible]	[illegible]	112.7	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	7.0	[illegible]	7.0	[illegible]	[illegible]	[illegible]	[illegible]	7.0	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

TABLE III. Sectional-Area Curves

Design Station	7001	231 A	230	300	307	430	417 S	336 B	7002	7003	SK 10	SK 11
0	0	0	0	0.200	0	0.087	0	0	0	0	0	0
1	0.142	0.230	0.077	0.443	0.276	0.151	0.047	0.257	0.106	0.137	0.100	0.105
2	0.270	0.452	0.314	0.578	[illegible]	0.246	0.105	0.448	0.226	0.272	[illegible]	0.257
3	0.402	0.613	[illegible]	[illegible]	[illegible]	0.340	0.173	[illegible]	[illegible]	0.410	[illegible]	0.437
4	0.530	0.753	[illegible]	0.771	[illegible]	0.434	[illegible]	0.713	[illegible]	0.544	[illegible]	0.610
5	0.671	[illegible]	[illegible]	[illegible]	0.944	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.910	0.770
6	0.775	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.743	0.775	[illegible]	[illegible]
7	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.717	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
8	[illegible]	[illegible]	[illegible]	0.974	[illegible]	0.811	0.704	0.971	[illegible]	[illegible]	0.977	[illegible]
9	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.975	[illegible]	[illegible]
10	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
11	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
12	[illegible]	[illegible]	[illegible]	0.974	[illegible]	0.811	0.704	0.971	[illegible]	[illegible]	[illegible]	[illegible]
13	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.717	[illegible]	[illegible]	[illegible]	0.964	[illegible]	[illegible]
14	0.775	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.775	[illegible]	[illegible]
15	0.671	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.903
16	0.530	[illegible]	[illegible]	0.771	[illegible]	0.434	[illegible]	0.713	[illegible]	-0.544	0.704	[illegible]
17	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.173	[illegible]	[illegible]	0.410	[illegible]	[illegible]
18	0.270	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.272	[illegible]	[illegible]
19	0.142	[illegible]	[illegible]	0.443	[illegible]	0.151	0.047	0.257	[illegible]	0.137	[illegible]	[illegible]
20	0	0	0	[illegible]	0	0.087	0	0	0	0	[illegible]	[illegible]

TABLE IV.

Resistance of Barges in Pounds per Pound Displacement
Yaw Uncorrected

$V/\sqrt{gL}$	Values of R/D X 10^3										
	7002	231 A	230	380	267	417 S	430	336 B	7032	BX 10	BX 11
0.08		0.534	0.345	0.940						0.440	0.479
0.10	1.575	0.810	0.535	1.315	0.907	1.720	2.208	1.543	0.615	0.678	0.740
0.12	2.235	1.150	0.785	1.715	1.132	2.482	3.172	2.155	0.910	0.967	1.060
0.14	2.870	1.575	1.085	2.365	1.516	3.417	4.364	2.861	1.265	1.307	1.449
0.16	3.445	2.045	1.465	3.243	1.986	4.618	5.796	3.495	1.690	1.727	1.941
0.18	4.960	2.640	1.880	4.440	2.722	6.044	7.500	5.016	2.310	2.264	2.559
0.20	6.240	3.470	2.715	6.000	4.150	7.715		6.325	3.390	3.008	3.333
0.22	7.760	4.580	3.770			9.590				4.082	4.345
0.24	9.400	6.010				12.082				5.444	
0.26	12.635	7.975				15.000					
0.28	16.443										
0.30	20.270										

TABLE V.

Resistance of Barges in Pounds per Pound Displacement
Yaw Corrected

$V/\sqrt{gL}$	Values of R/D X 10^3					
	231 A	230	380	7003	BX 10	BX 11
0.08	0.868	0.505	0.940	0.70[illegible]	0.923	0.976
0.10	1.210	0.[illegible]	1.27[illegible]	1.325	1.440	1.515
0.12	1.[illegible]	1.145	1.725	1.42[illegible]	2.082	2.172
0.14	2.[illegible]	1.[illegible]	2.180	1.925	2.796	2.946
0.16	3.[illegible]	2.[illegible]	3.290	2.[illegible]	3.635	3.945
0.18	4.1[illegible]	2.735	4.425	3.[illegible]	4.694	4.986
0.20	[illegible]	[illegible]	5.860	4.130	5.793	6.[illegible]
0.22	6.7[illegible]	5.786			7.106	7.421
0.24					9.657	

TABLE VI.

Volumetric Residual Resistance Coefficients
Tow Uncorrected

$V/\sqrt{L}$	Values of $R_r/\frac{1}{2}\rho\nabla^{2/3}v^2 \times 10^3$										
	7001	231 A	230	380	267	480	417 S	326 S	7002	SK 10	SK 11
0.08		29.36	4.00	46.38						17.18	23.66
0.10	52.66	29.23	3.83	42.78	23.42	90.31	86.94	62.00	7.31	17.15	23.62
0.12	51.75	27.87	4.60	40.87	22.76	90.30	86.61	61.77	8.33	17.18	23.76
0.14	51.42	27.91	5.70	41.90	22.42	91.73	88.67	61.83	9.18	17.23	24.10
0.16	51.30	29.16	6.00	46.90	22.88	98.62	61.33	62.67	8.00	17.37	25.43
0.18	51.75	29.50	6.20	50.78	26.14	96.90	64.70	64.34	12.27	19.28	27.32
0.20	52.50	32.12	11.73	57.30	3[illegible].90	100.26	67.31	66.40	17.79	22.08	30.72
0.22	55.30	36.39	18.20				70.62			26.67	33.38
0.24	60.30	42.00					76.72			31.90	38.01
0.26	60.34	48.82									
0.28	70.30										
0.30	86.00										
Av. 0.10 to 0.20	51.89	29.88	6.75	46.84	23.21	93.84	60.81	63.36	10.76	18.48	25.67

TABLE VII.

Volumetric Residual Resistance Coefficients
Tow Corrected

$V/\sqrt{L}$	Values of $R_r/\frac{1}{2}\rho\nabla^{2/3}v^2 \times 10^3$					
	231 A	230	380	7002	SK 10	SK 11
0.08	51.89	10.08	46.40	37.43	51.89	61.33
0.10	51.30	11.66	42.78	34.63	51.70	61.33
0.12	50.95	12.61	40.87	33.61	51.90	61.36
0.14	50.93	13.71	41.90	32.40	51.79	61.34
0.16	51.42	14.60	46.90	34.79	51.61	61.32
0.18	52.35	15.64	50.78	35.41	52.32	62.20
0.20	53.71	17.40	57.30	37.40	53.57	62.33
0.22	56.32	20.19			54.60	62.66
0.24					56.48	
Av. 0.10 to 0.20	51.40	14.29	46.84	34.72	52.35	61.74

APPENDIX III

Hull Forms, Skegs, and Resistance Curves

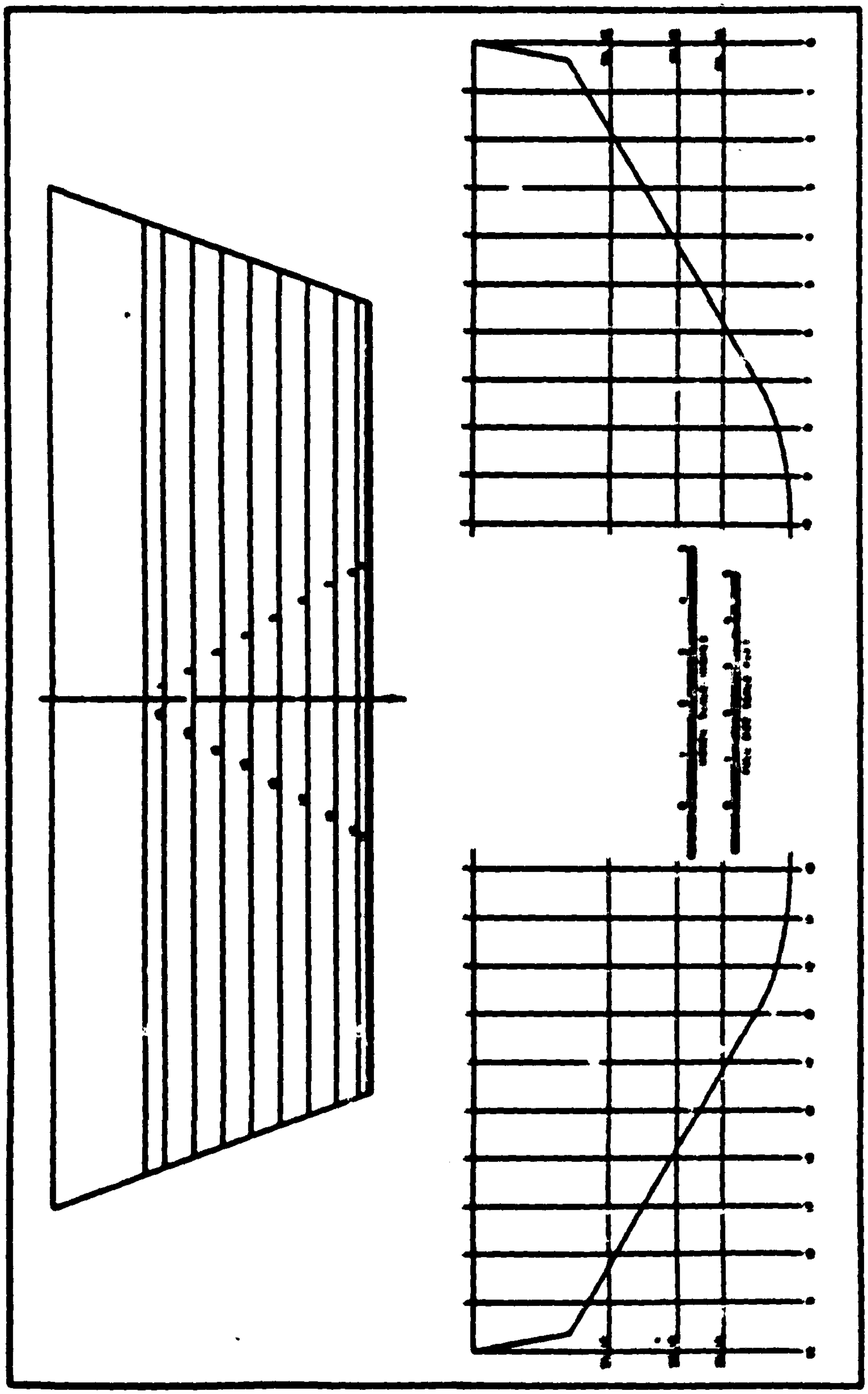

Figure 1A. Design 7001. 81-foot nesting barge. Model lines drawing.

APPENDIX III (contd)

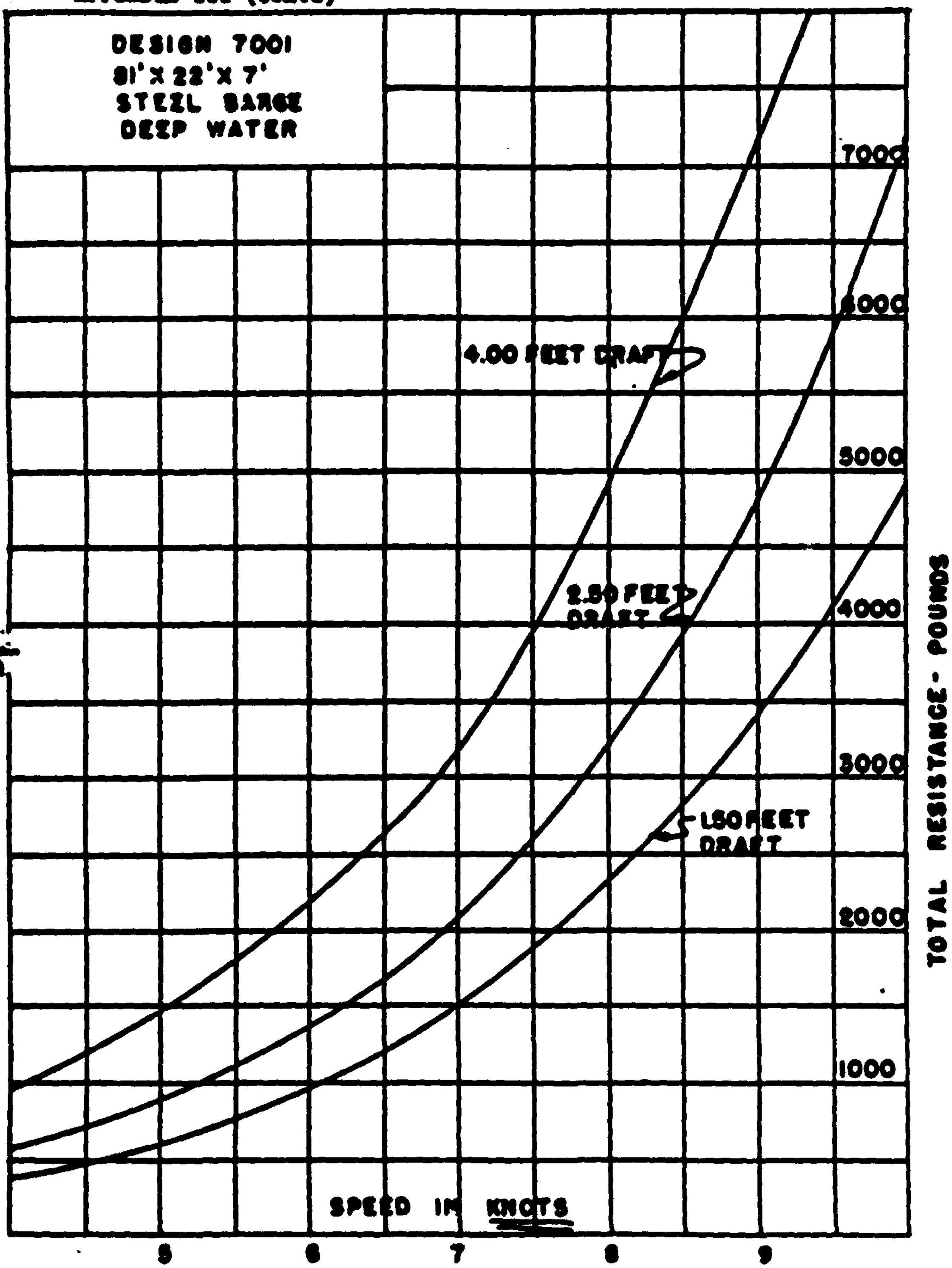

Figure 1B. Design 7001. Curves of total resistance.

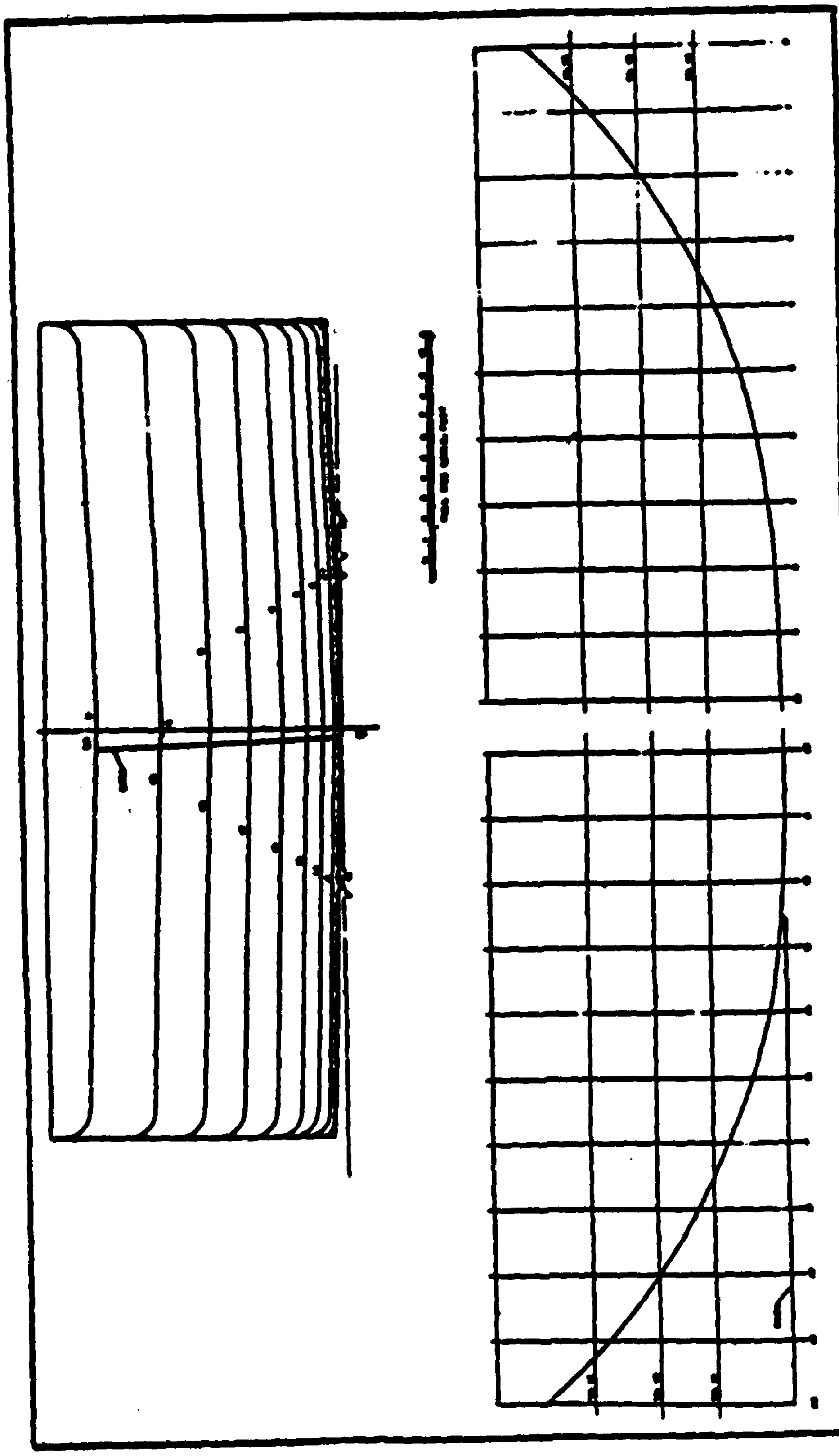

Figure 2A. Design 231 A, 120-foot cargo barge. Model lines drawing.

APPENDIX III (contd)

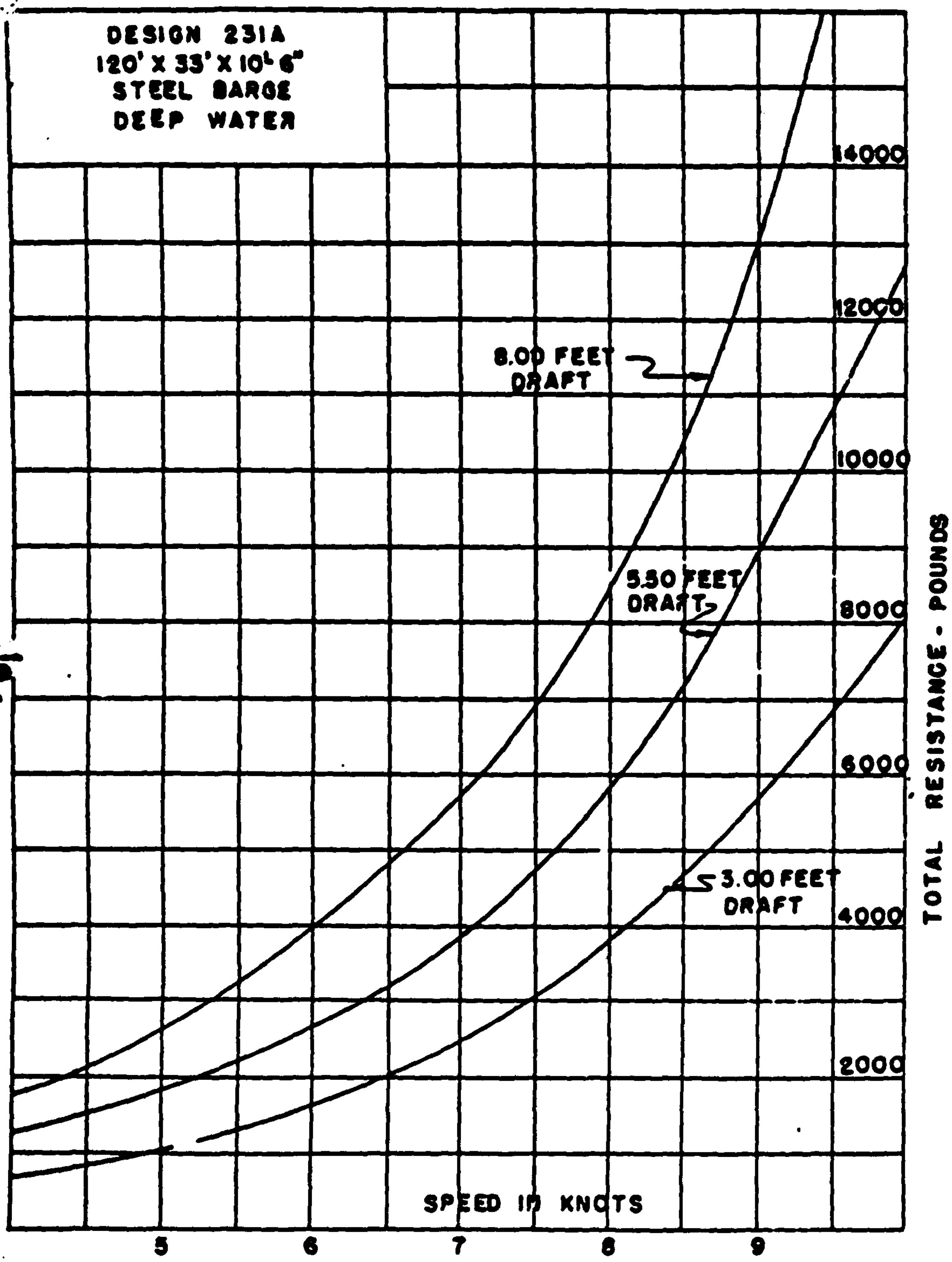

Figure 23. Design 231 A. Curves of total resistance.

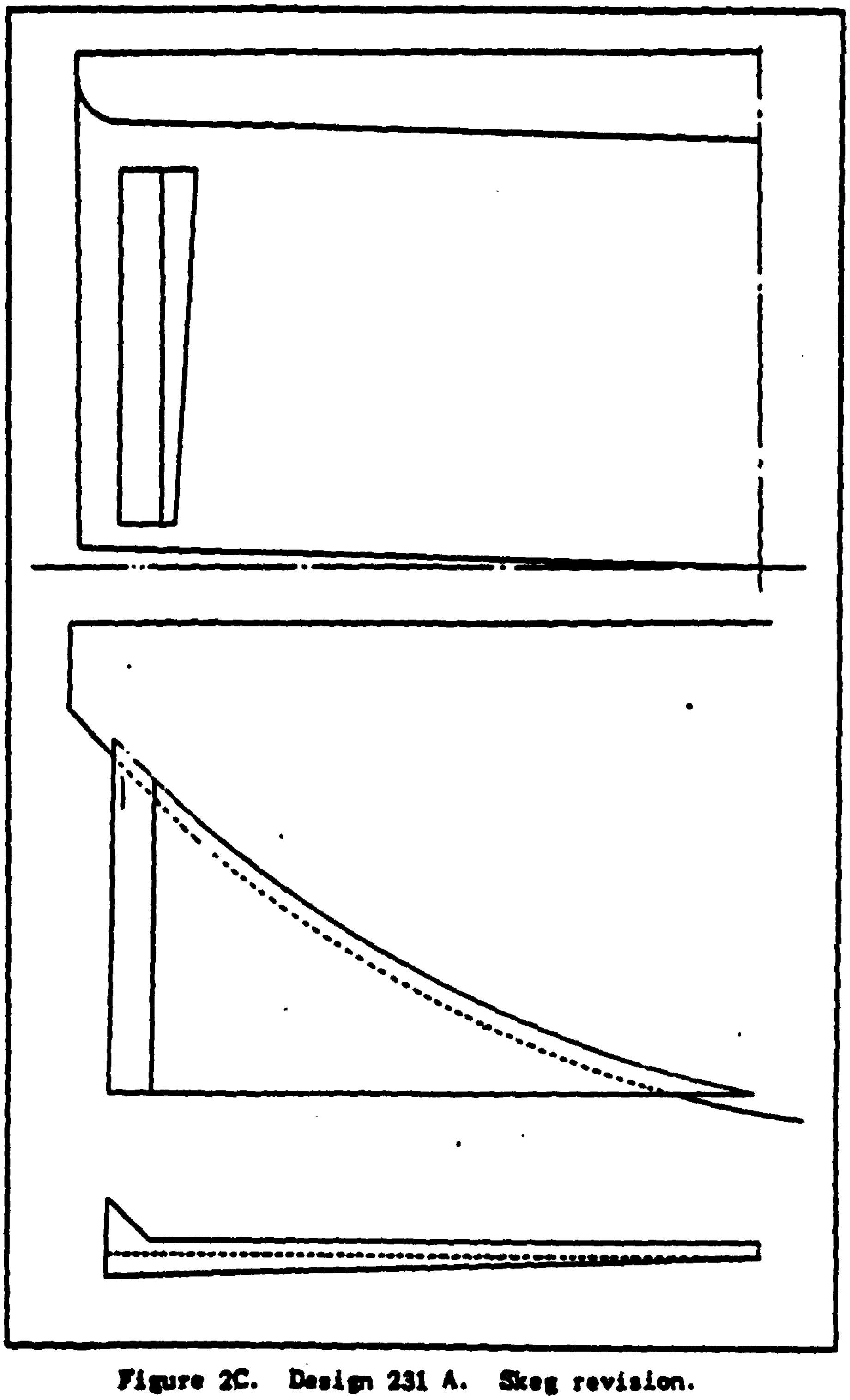

Figure 2C. Design 231 A. Skeg revision.

APPENDIX III (contd)

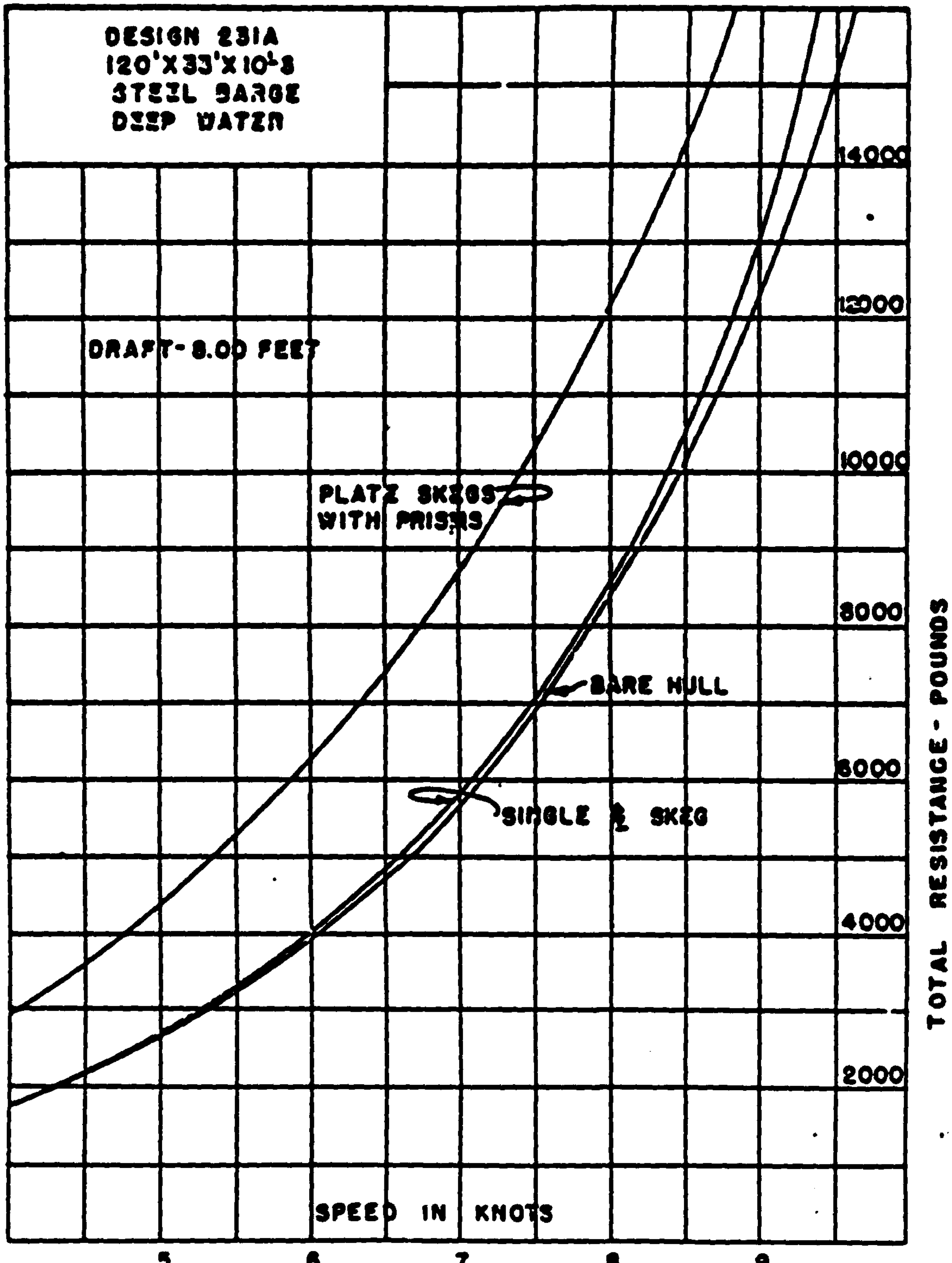

Figure 2D. Design 231 A. Curves of total resistance, showing increased resistance resulting from revised skeg design.

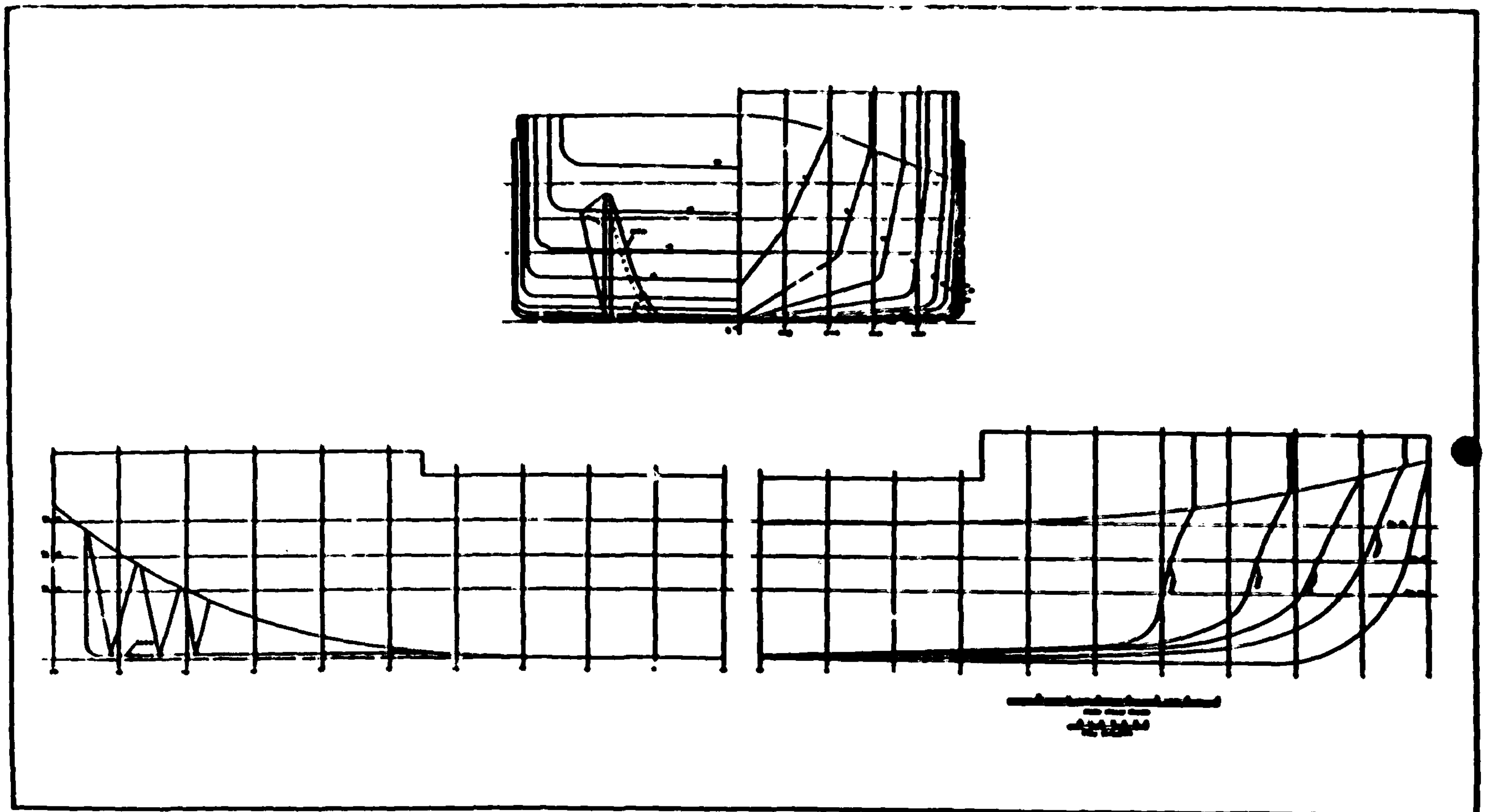

Figure 34. Design 230, 210-foot dry-cargo barge. Model lines drawing.

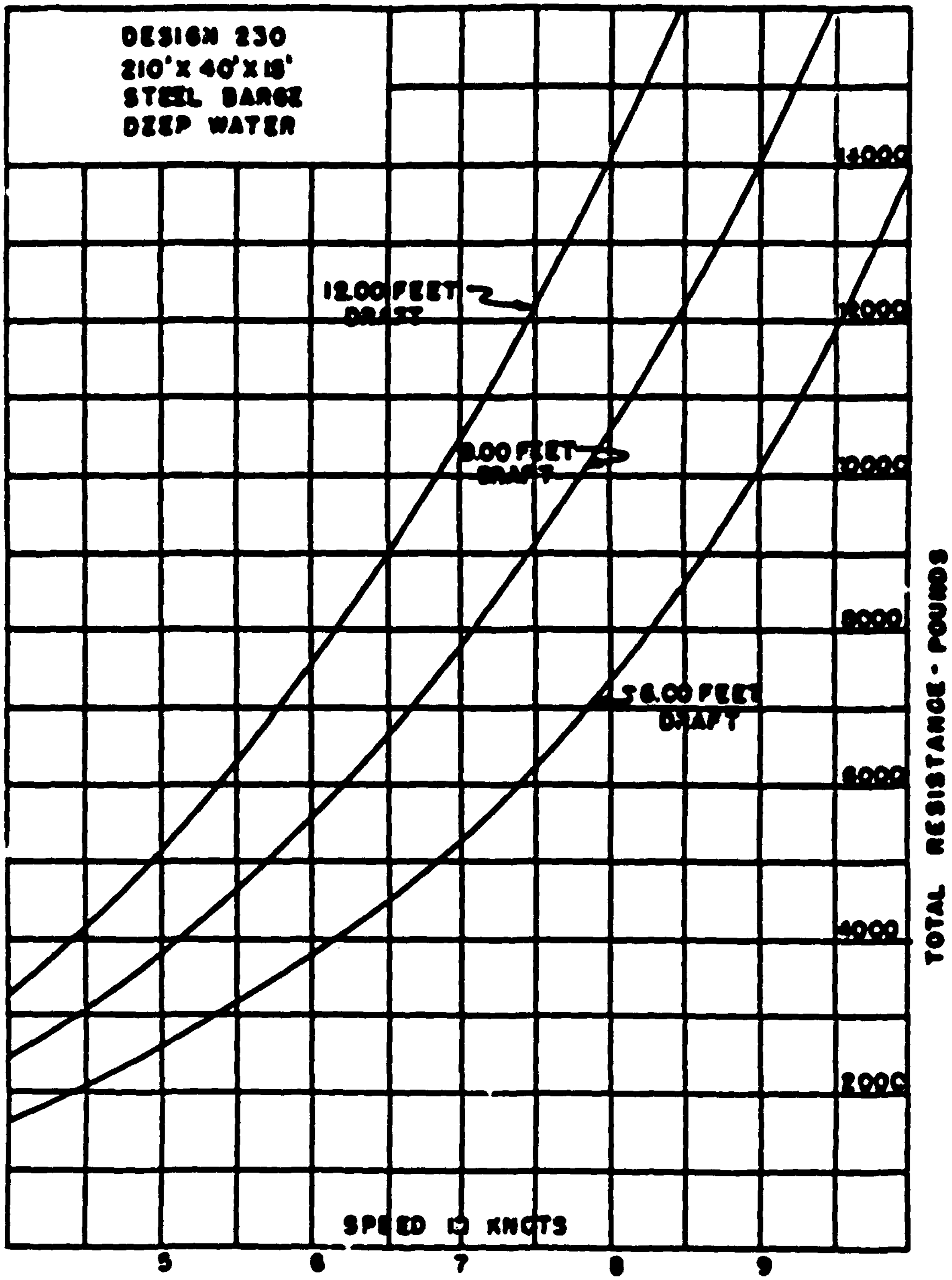

Figure 38. Design 230. Curves of total resistance.

APPENDIX III (contd)

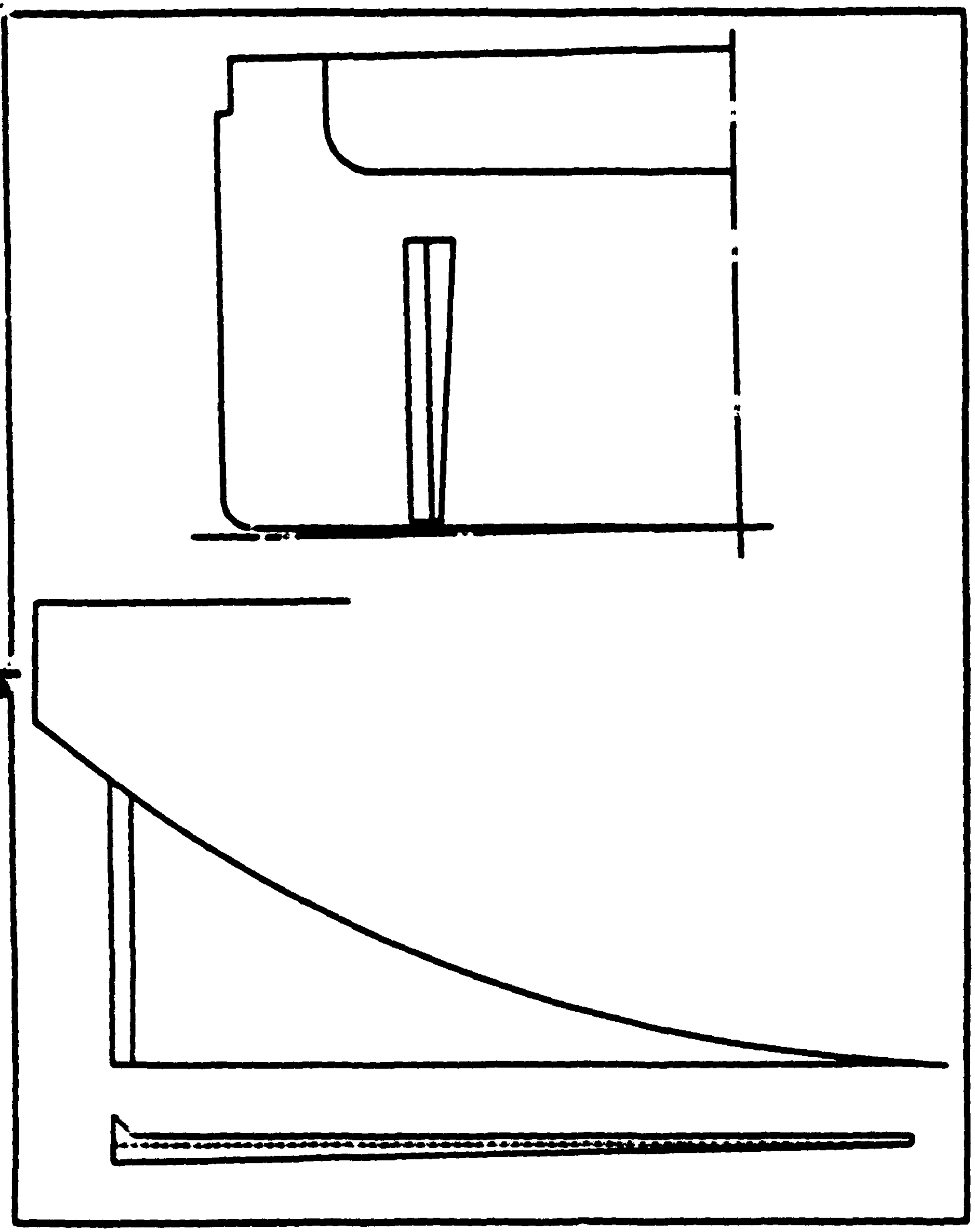

Figure 3C. Design 230. Skeg revision.

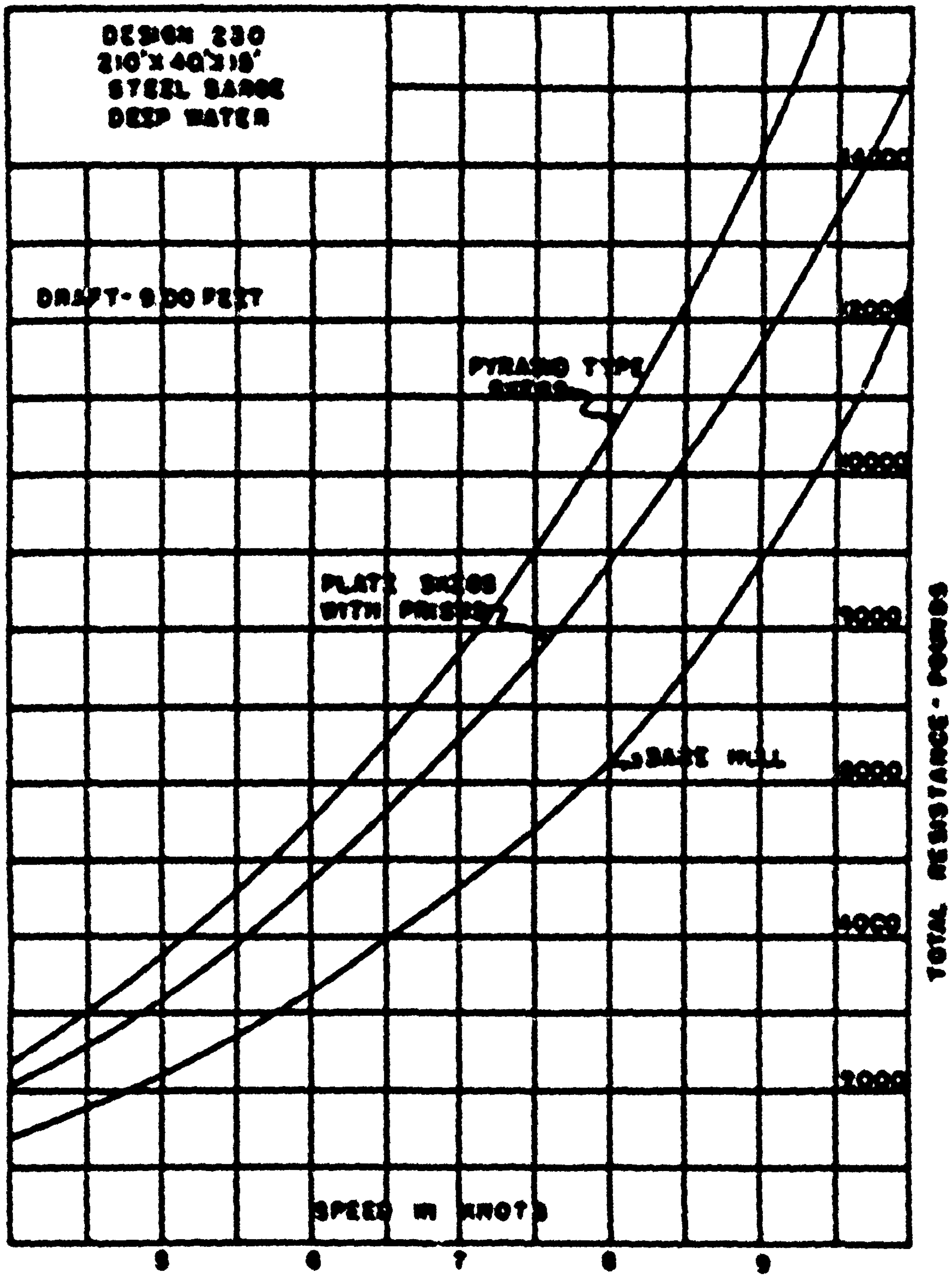

Figure 28. Design 230. Curves of total resistance, showing change in resistance resulting from revised skeg design.

APPENDIX III (contd)

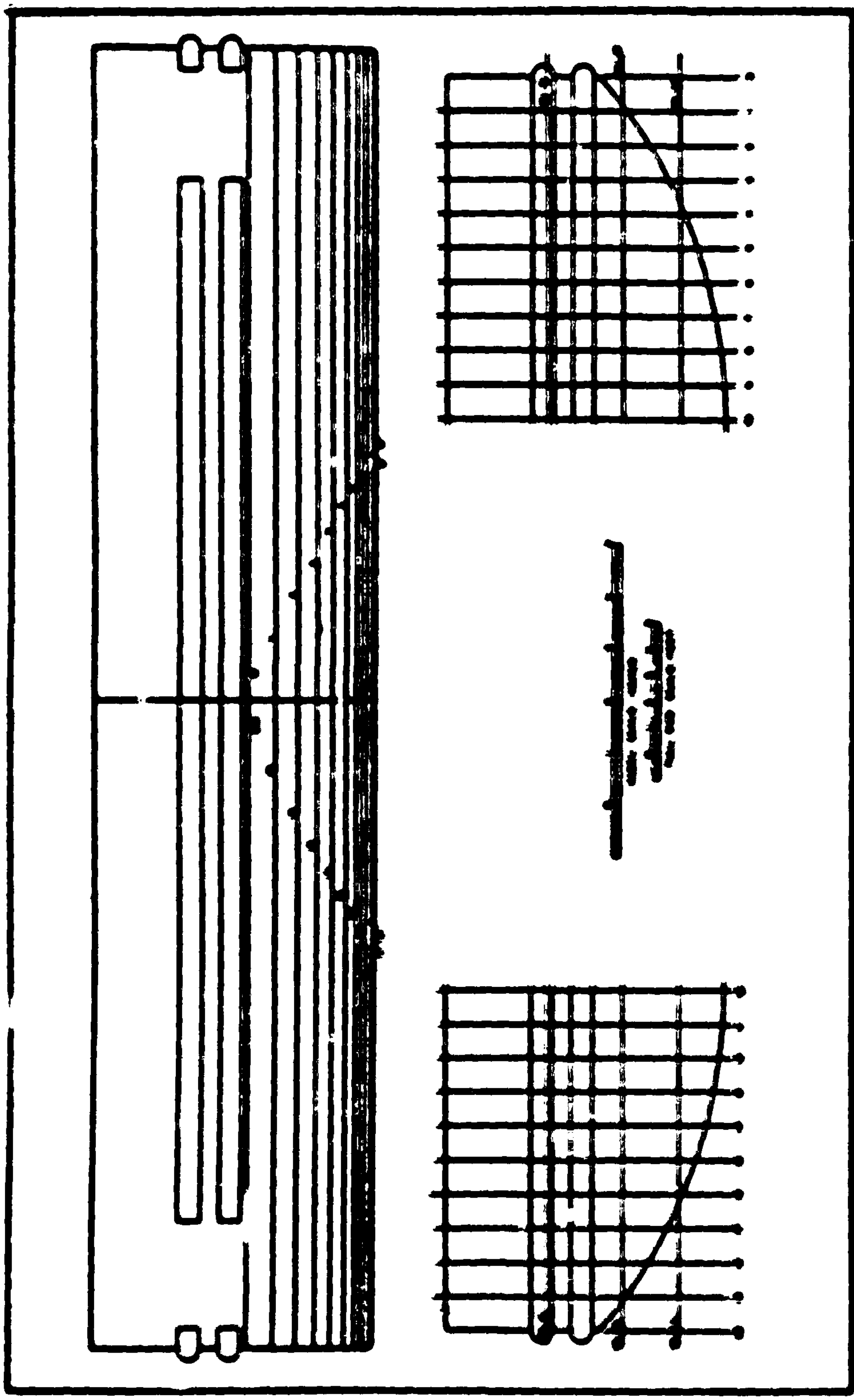

Figure 4A. Design 388. 150-foot pier barge. Model lines drawing.

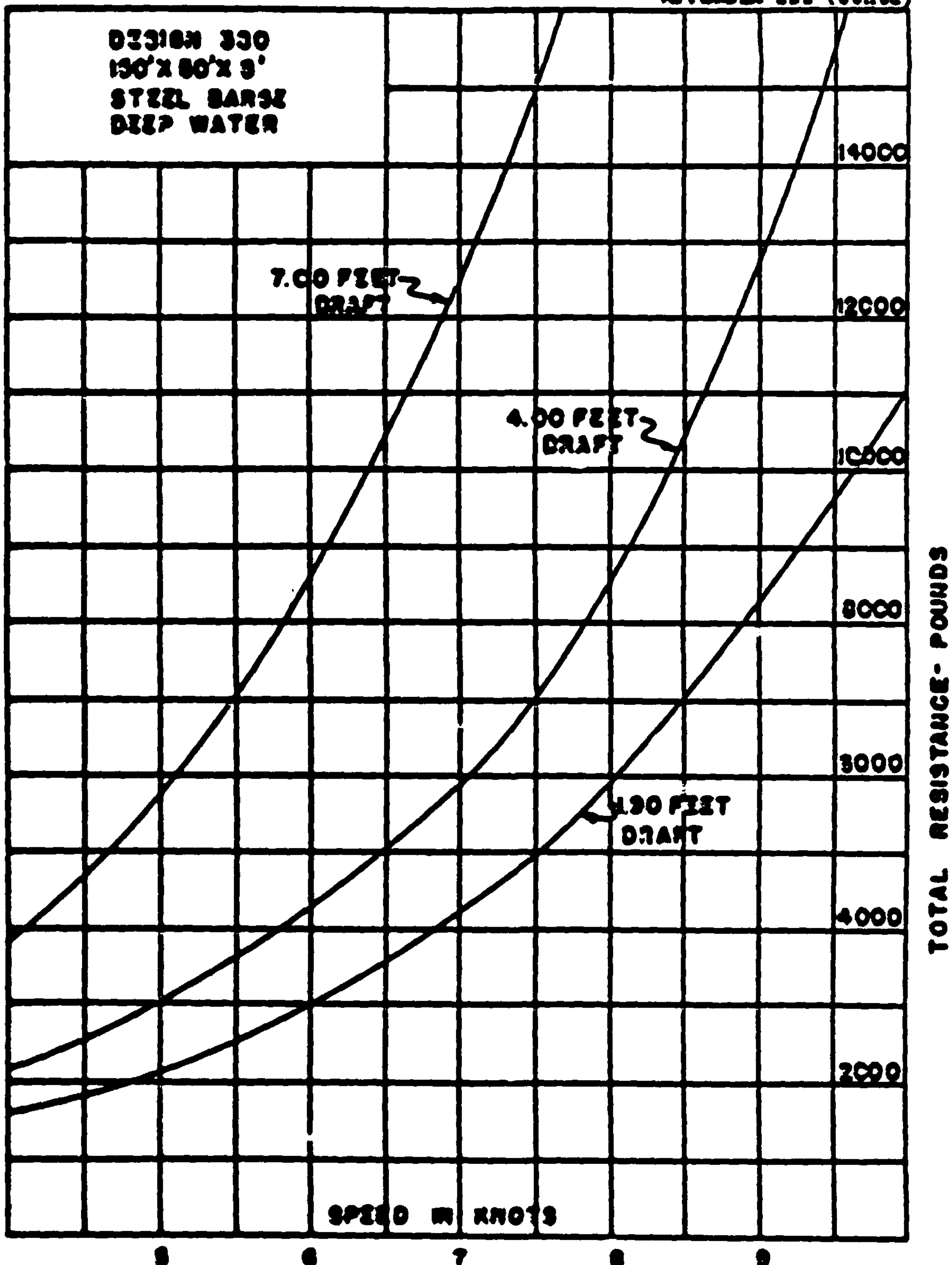

Figure 4B. Design 330. Curves of total resistance.

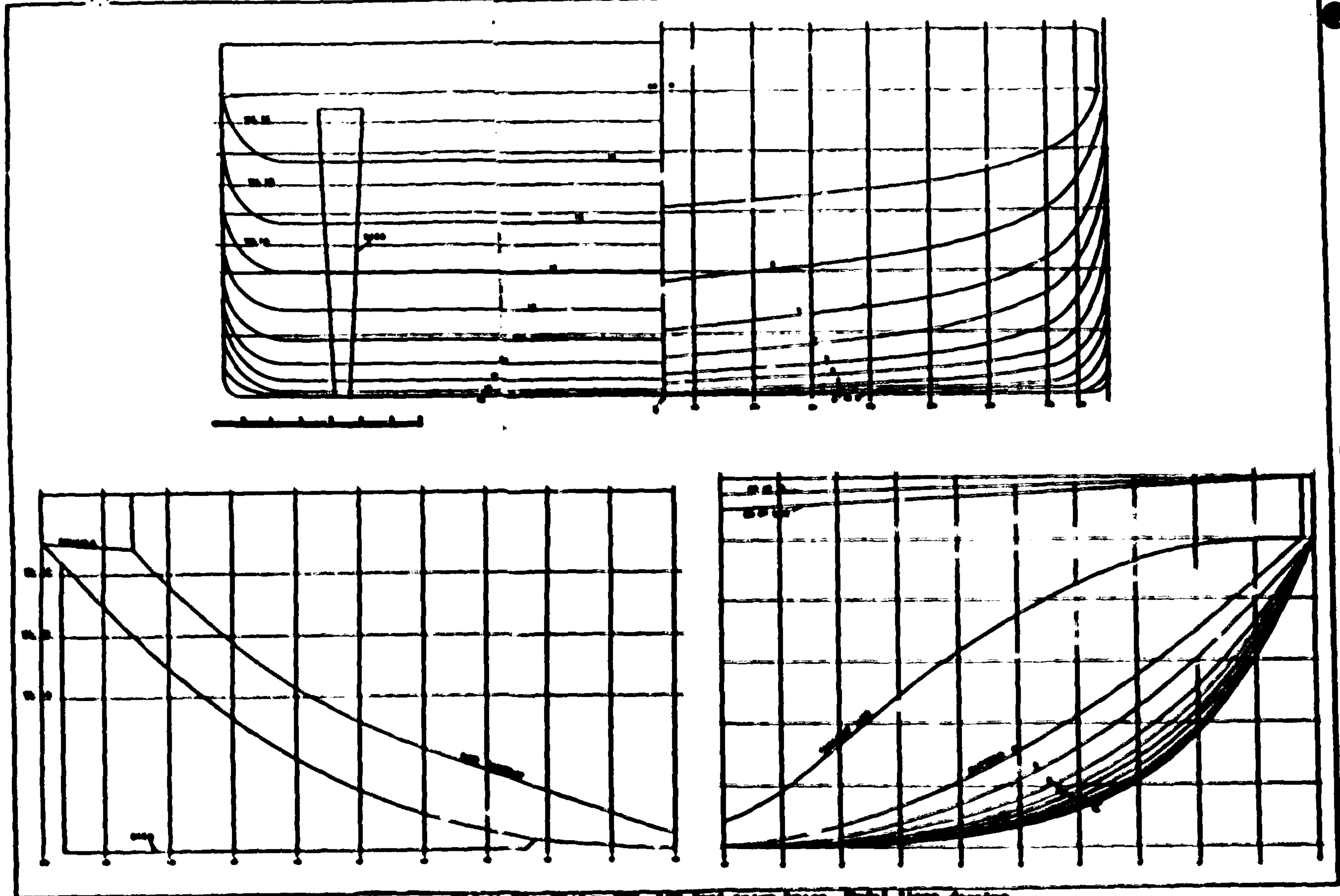

Figure [illegible]. Design [illegible], [illegible]-foot cargo barge. Model lines drawing.

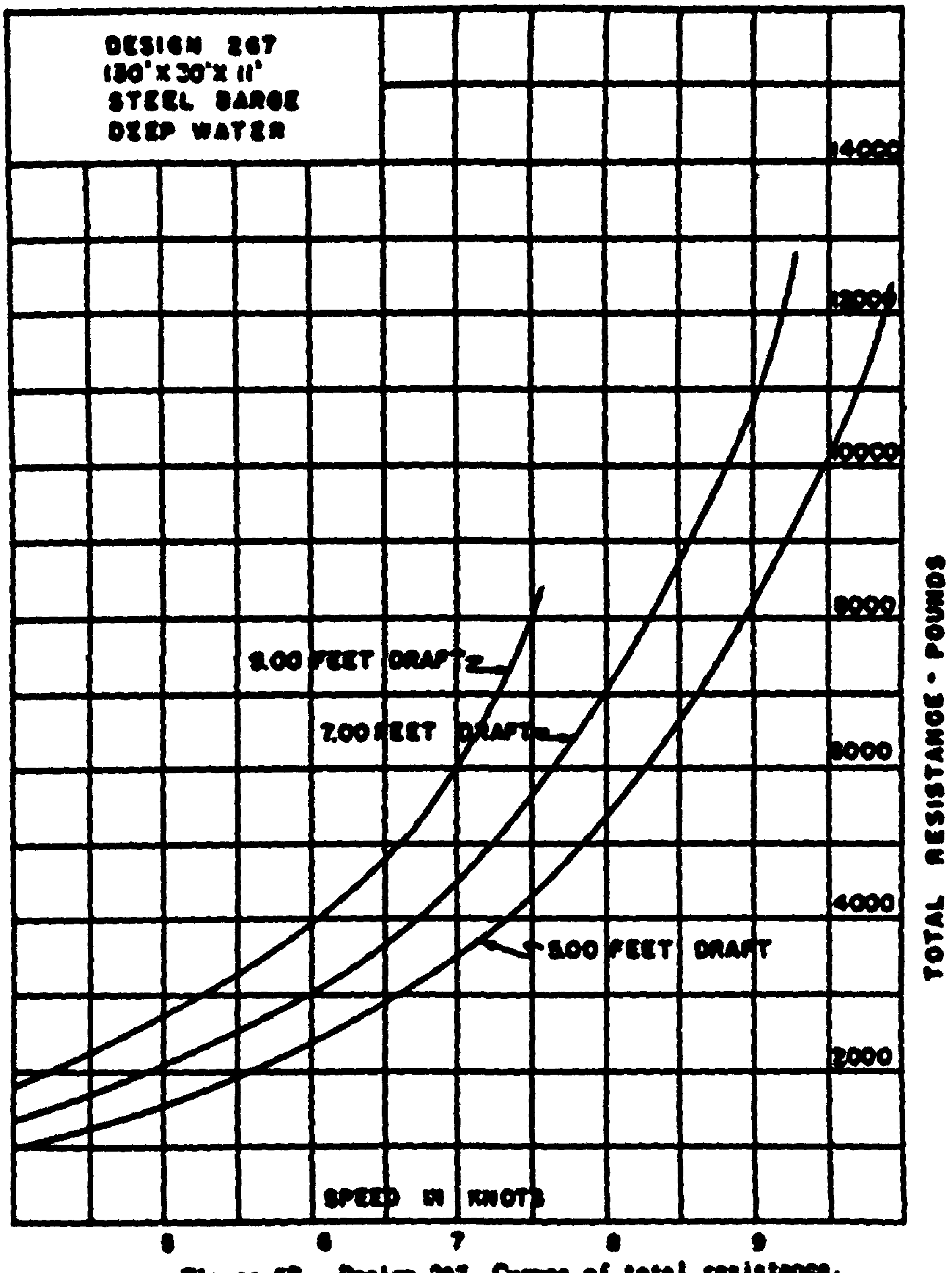

Figure 58. Design 267. Curves of total resistance.

APPENDIX III (contd)

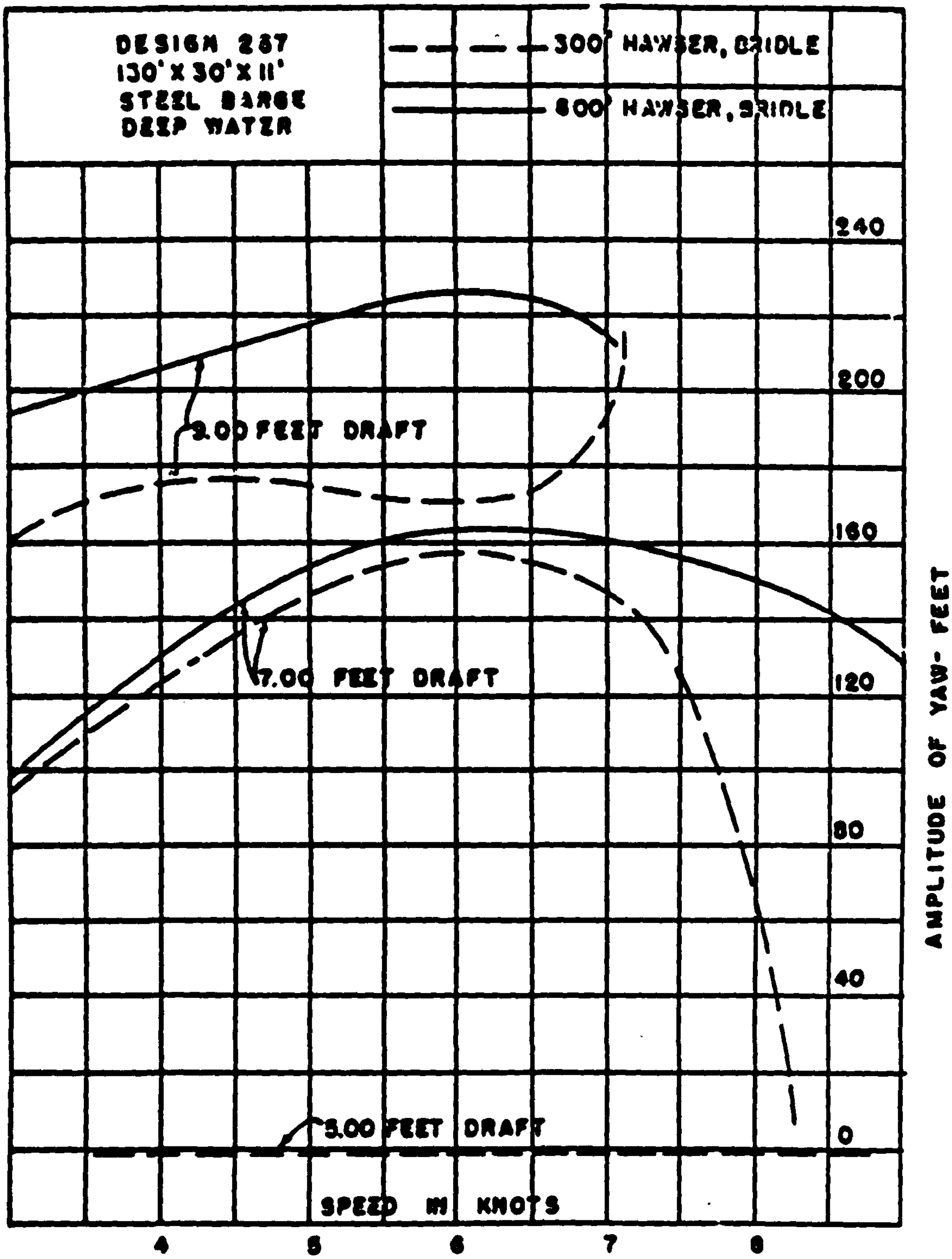

Figure 5C. Design 267. Curves of yaw amplitude.

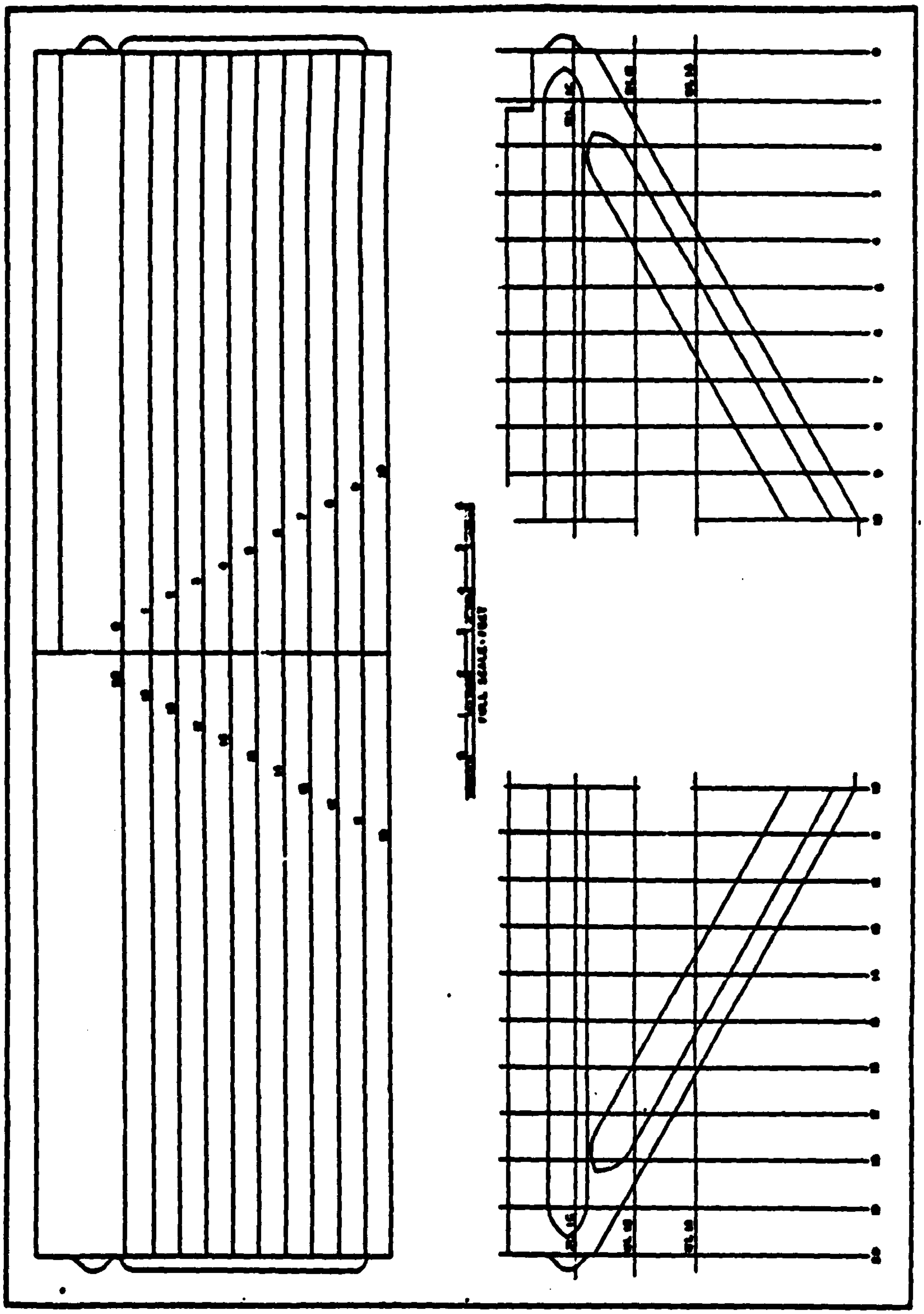

Figure 6A. Design 430, 112-foot knock-down fuel-oil cargo barge. Model lines drawings.

APPENDIX III (contd)

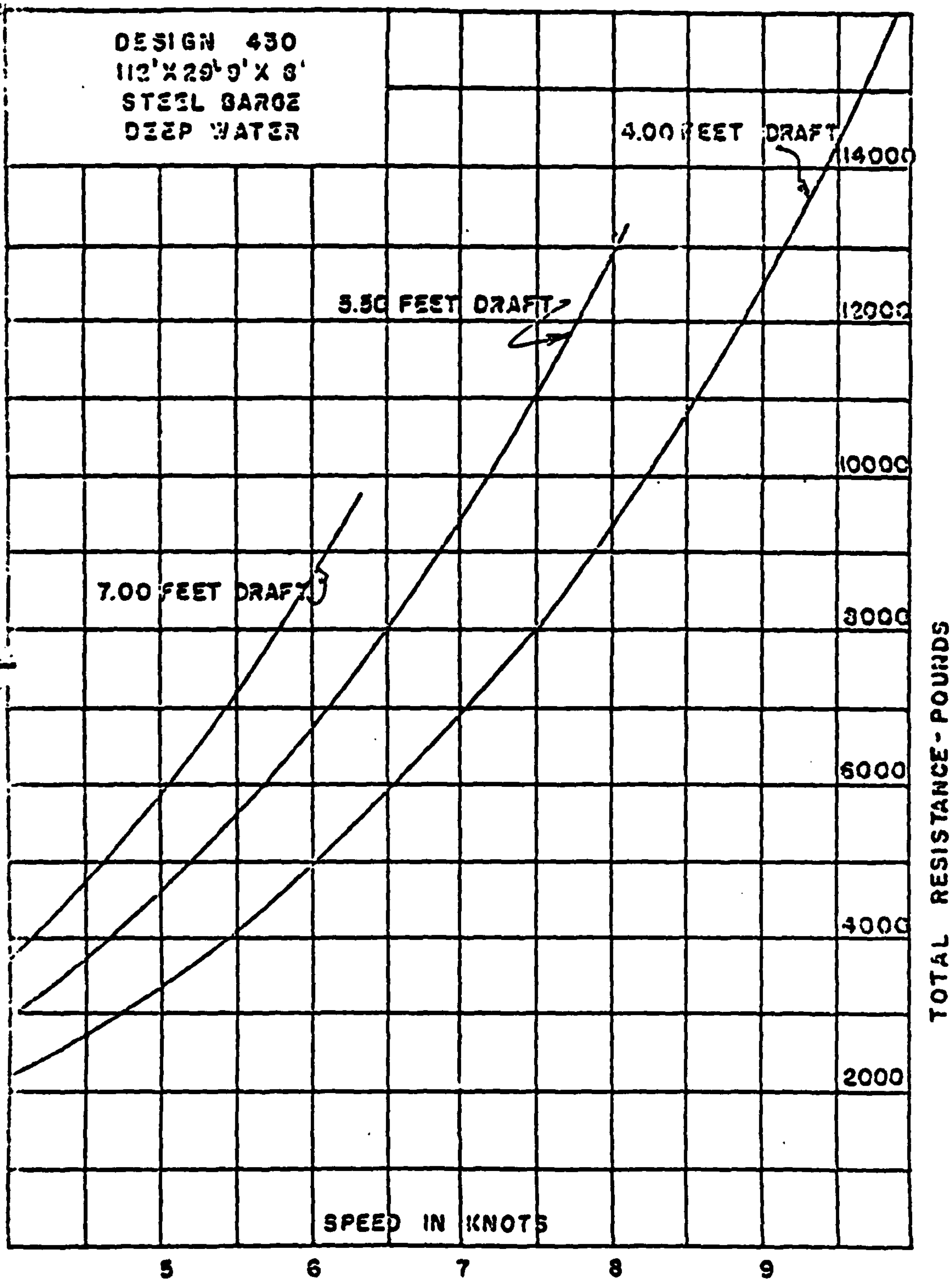

Figure 6B. Design 430. Curves of total resistance.

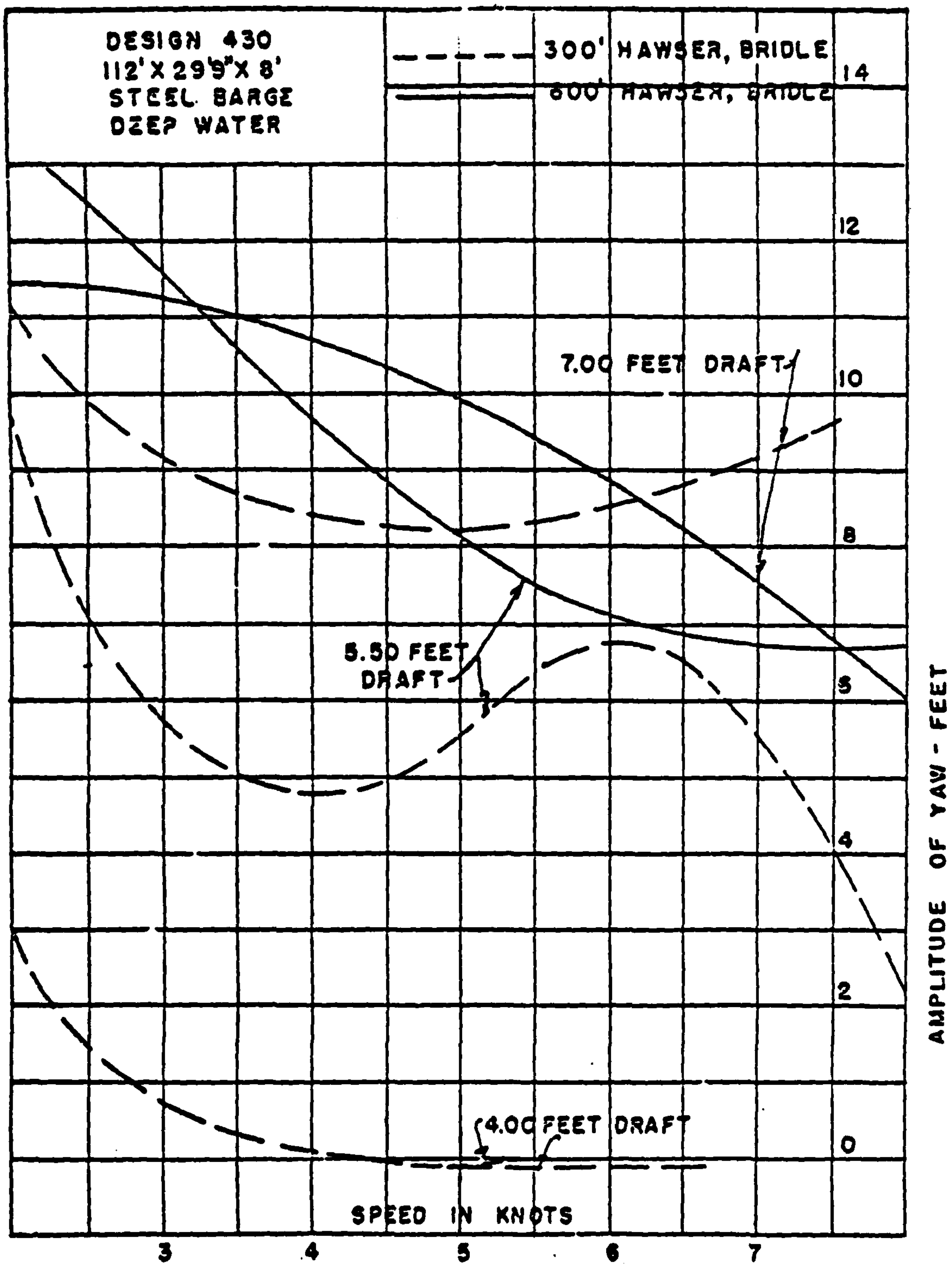

Figure 6C. Design 430. Curves of yaw amplitude.

APPENDIX III (contd)

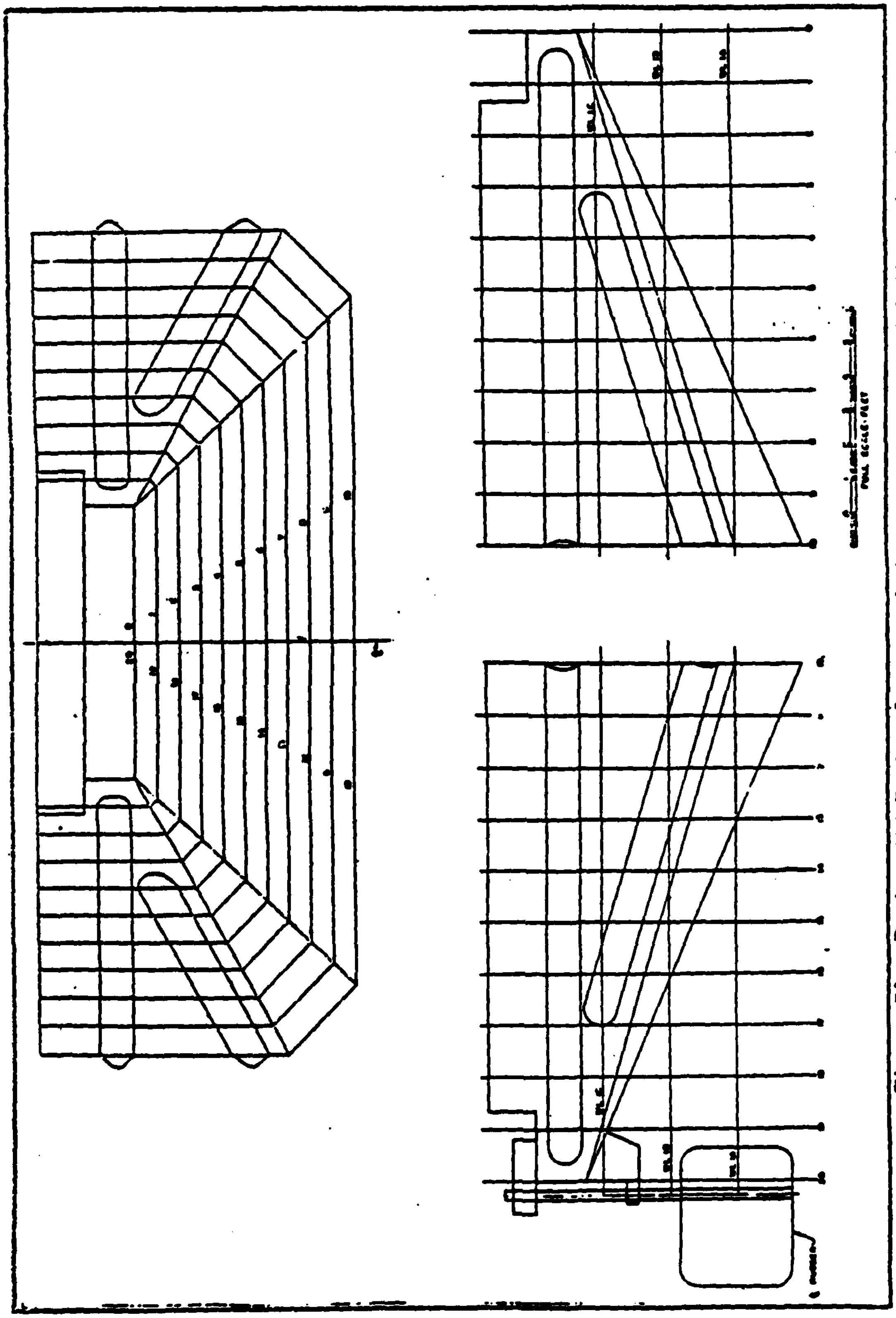

Figure 7A. Design 417 S, 112-foot steel dry-cargo barge. Model lines drawing.

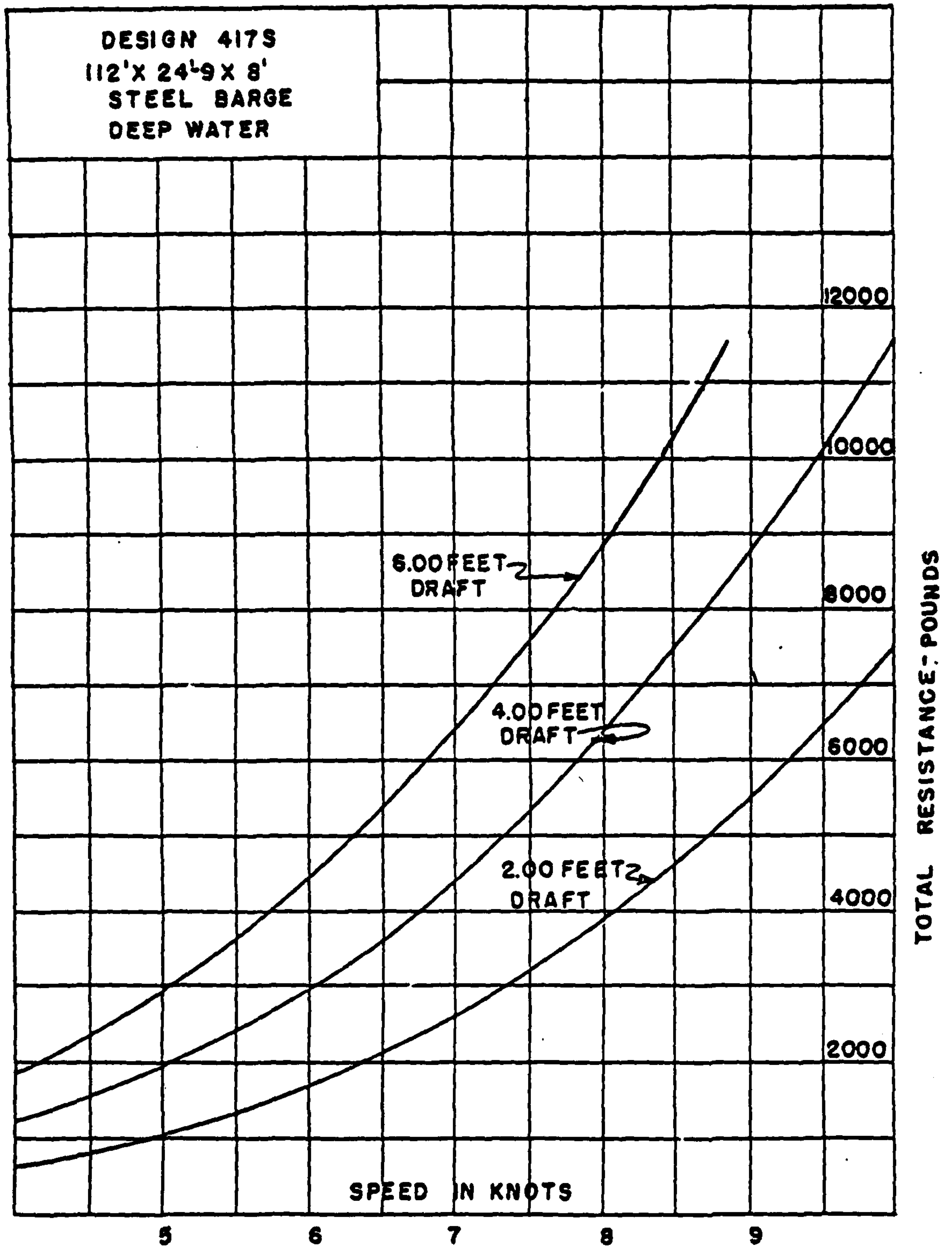

Figure 7B. Design 417 S. Curves of total resistance.

APPENDIX III (contd)

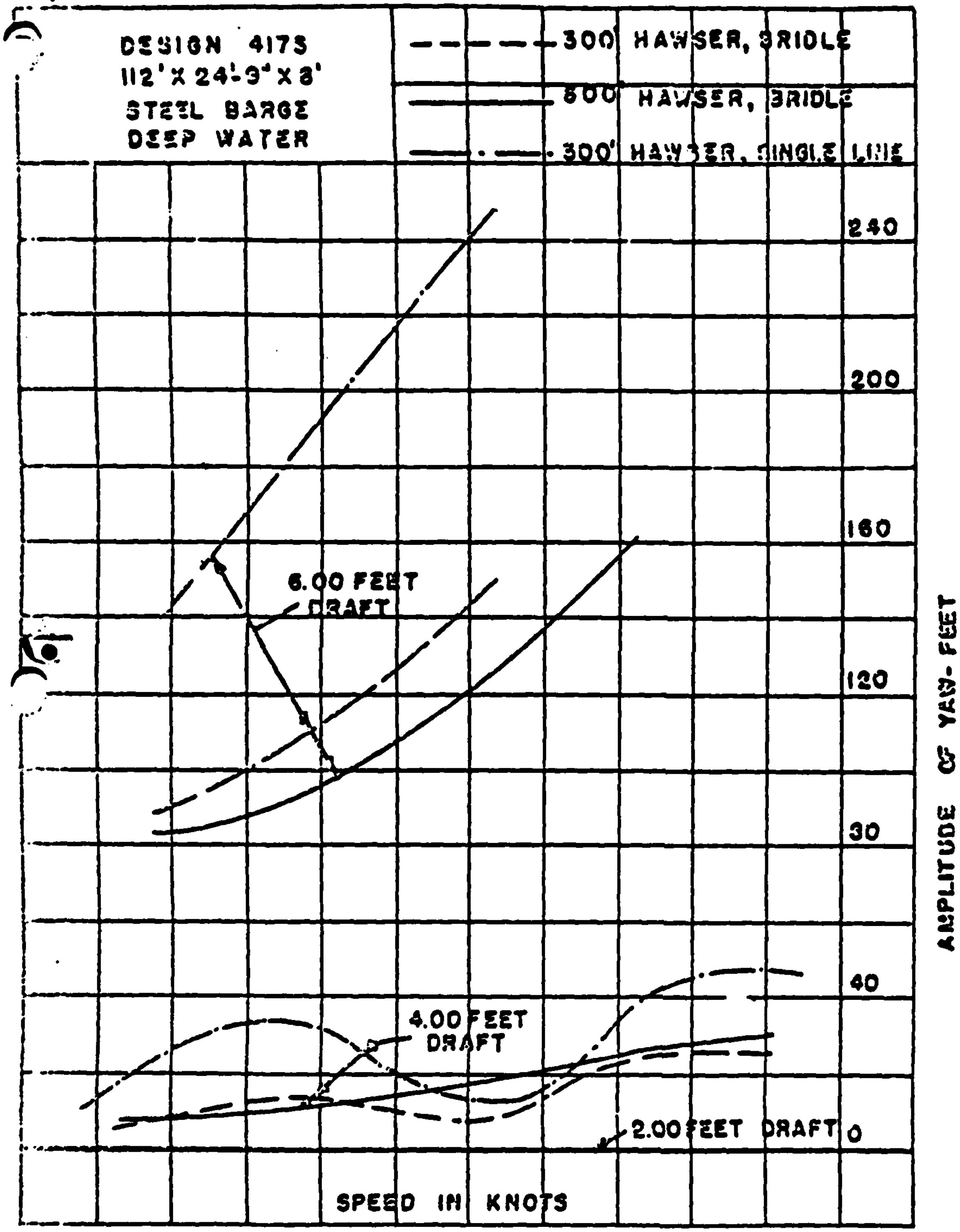

Figure 7C. Design 417 S. Curves of yaw amplitude.

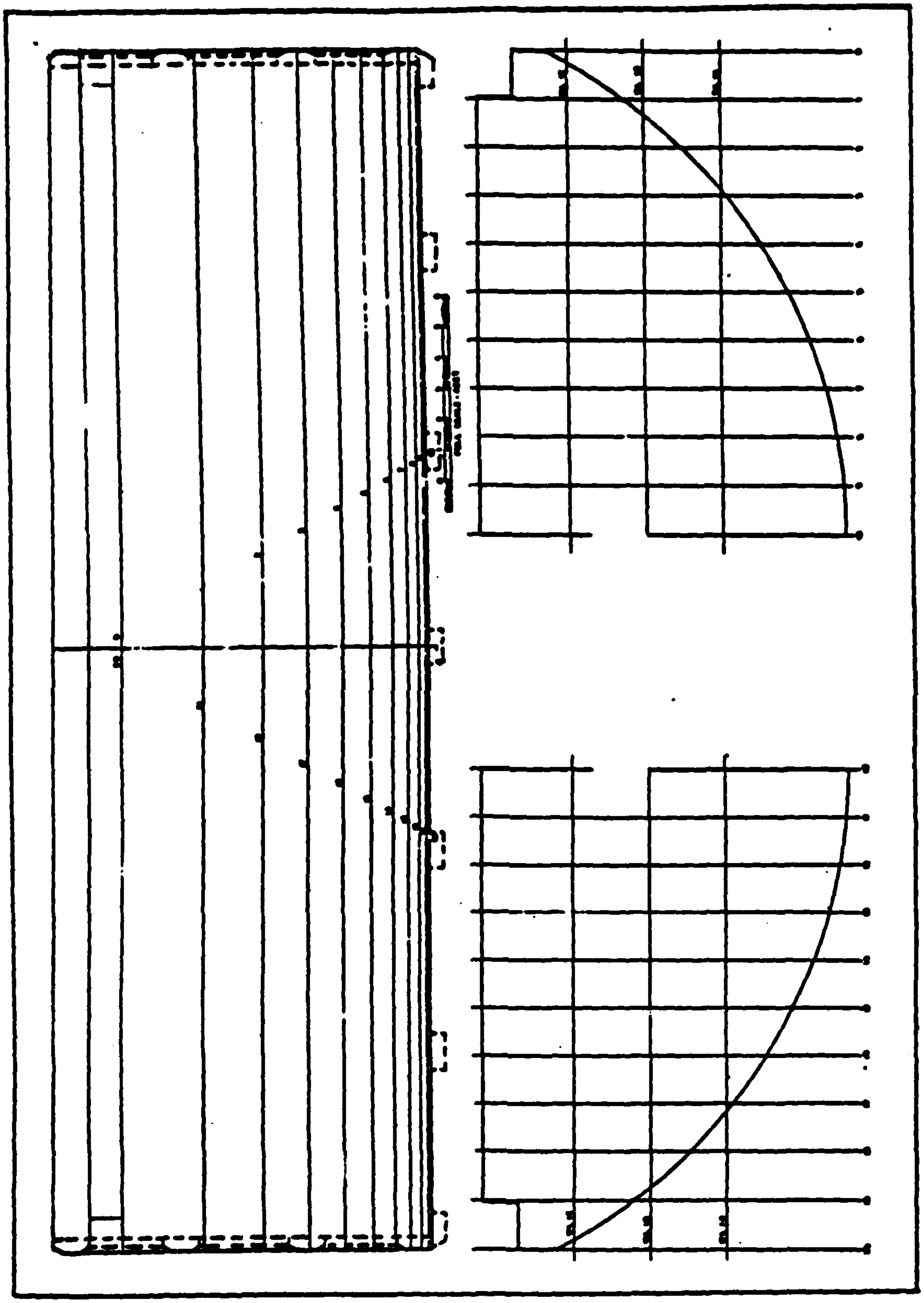

Figure 8A. Design 336 B, 130-foot wooden lighter barge. Model lines drawing.

APPENDIX III (contd)

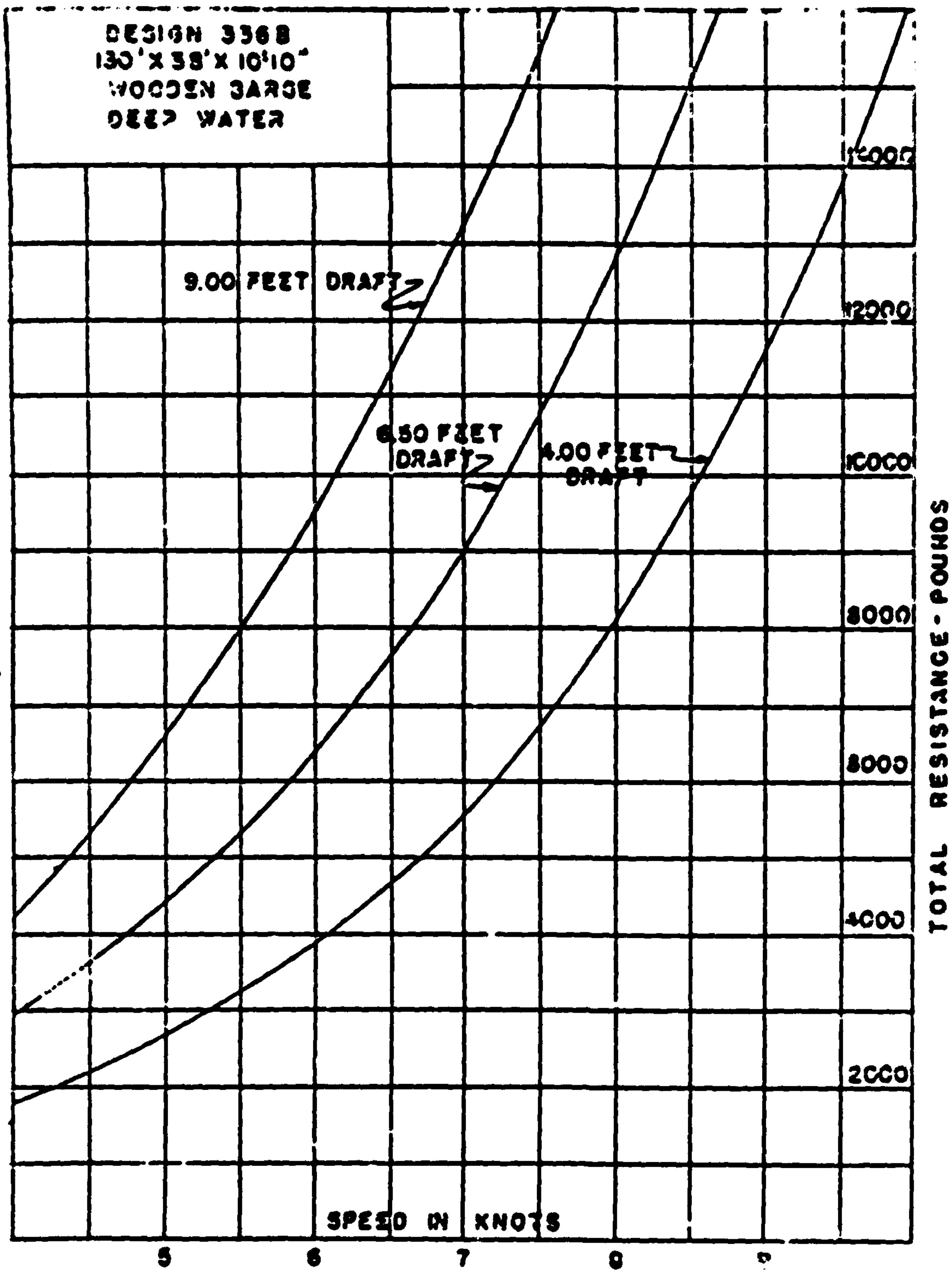

Figure 83. Design 336 B. Curves of total resistance.

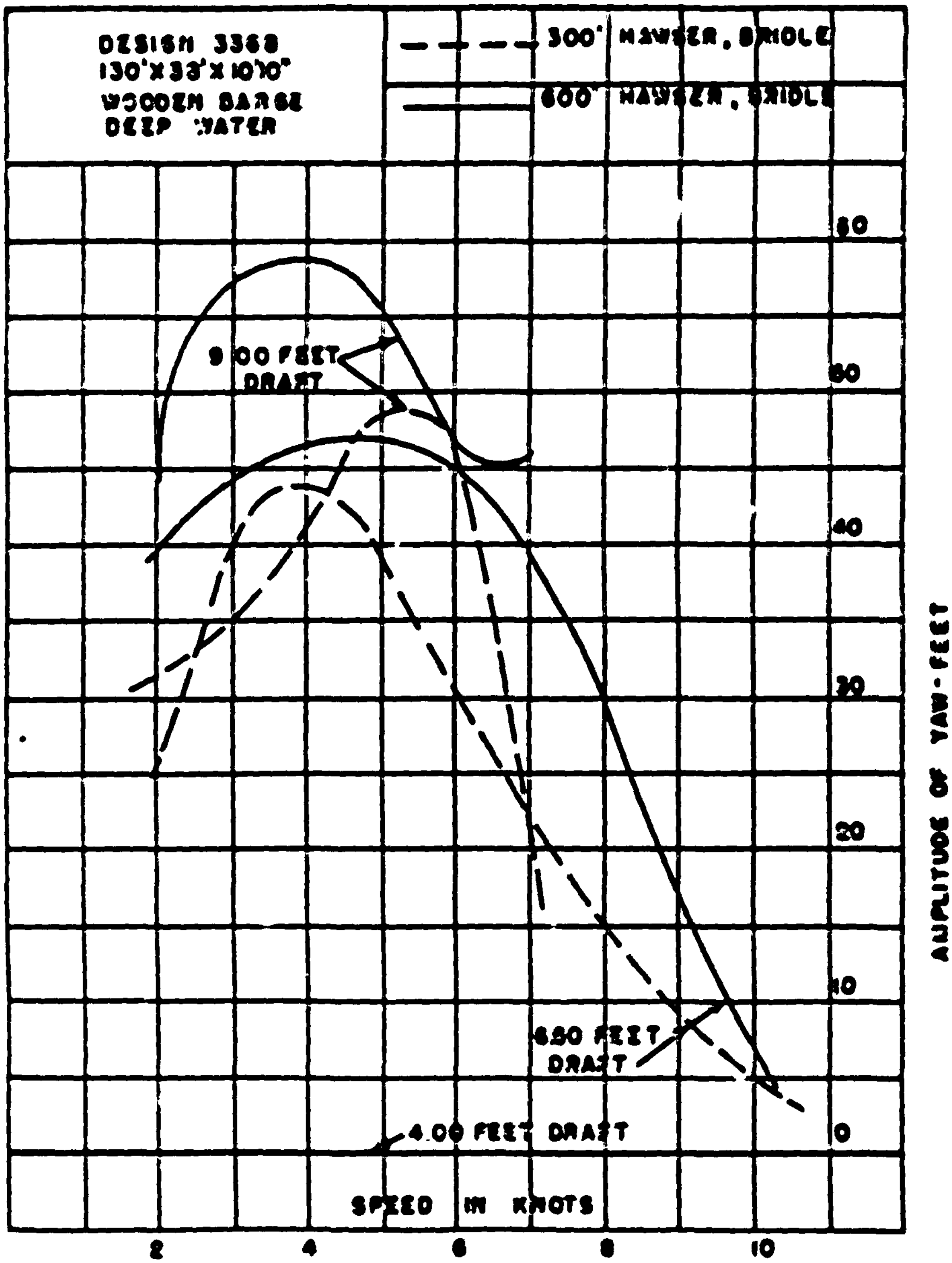

Figure 8C. Design 336 B. Curves of yaw amplitude.

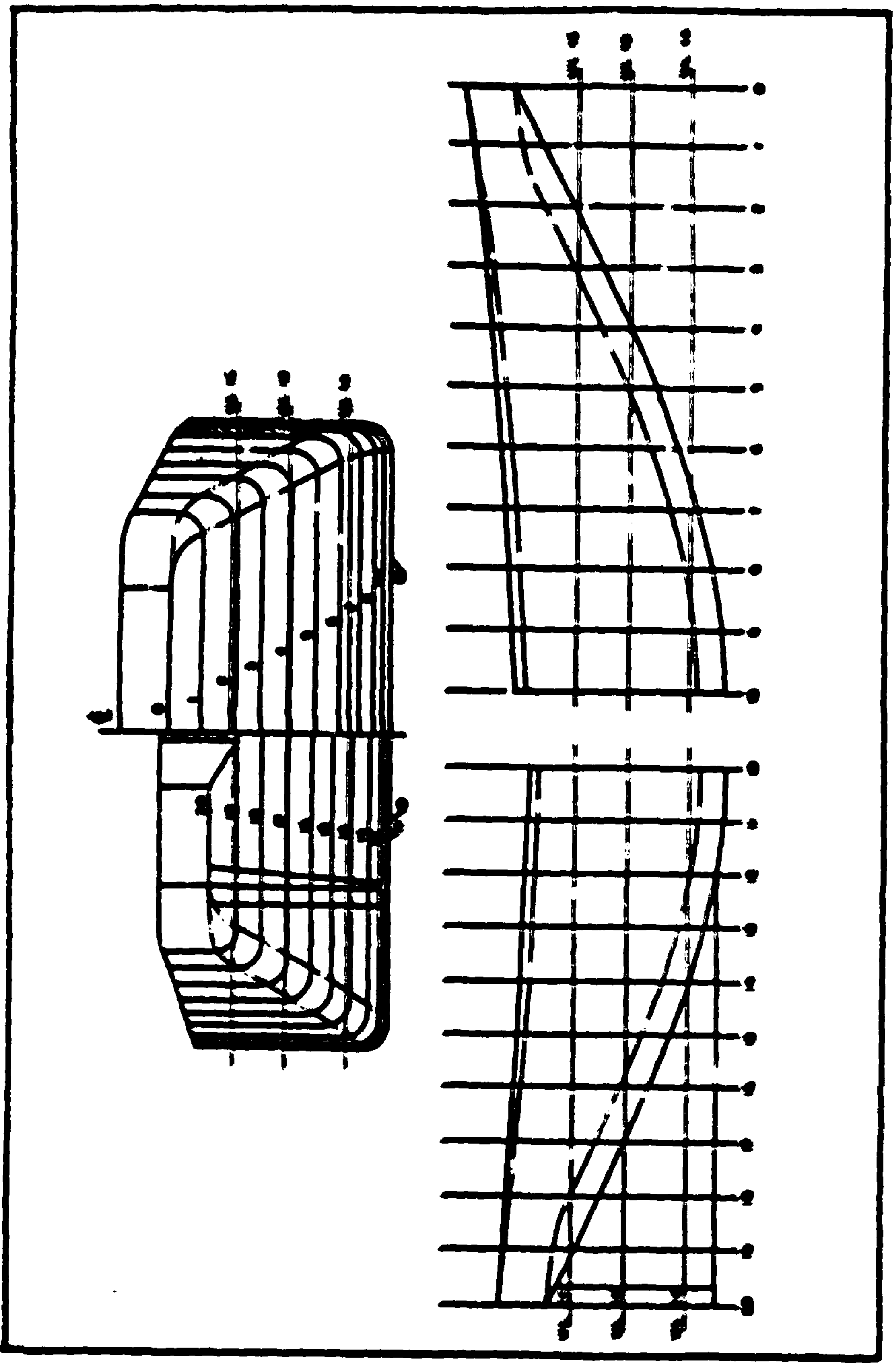

Figure 96. Design 7002. 105-foot steel barge. Model lines drawing.

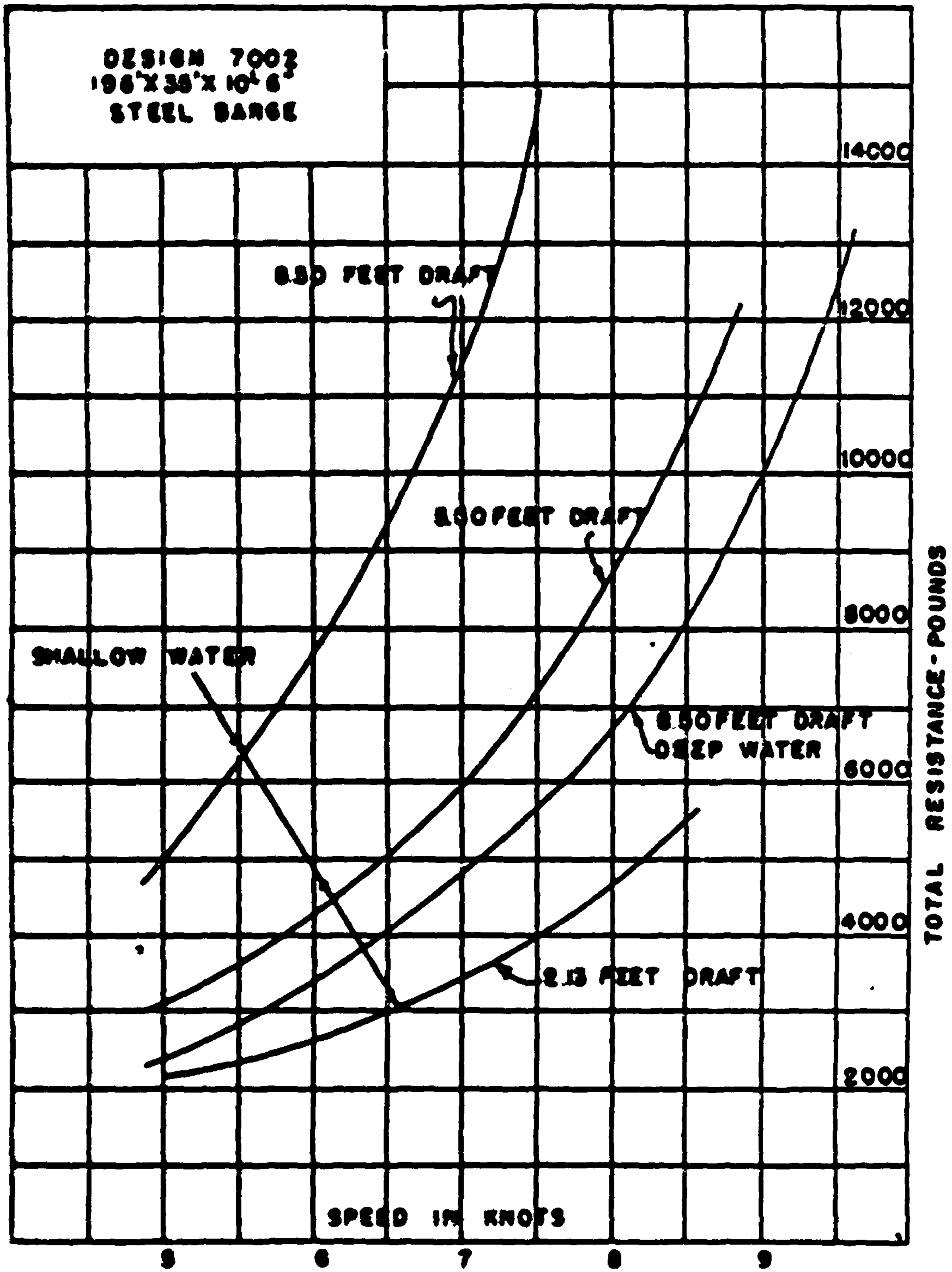

Figure 9B. Design 7002. Curves of total resistance.

APPENDIX III (contd)

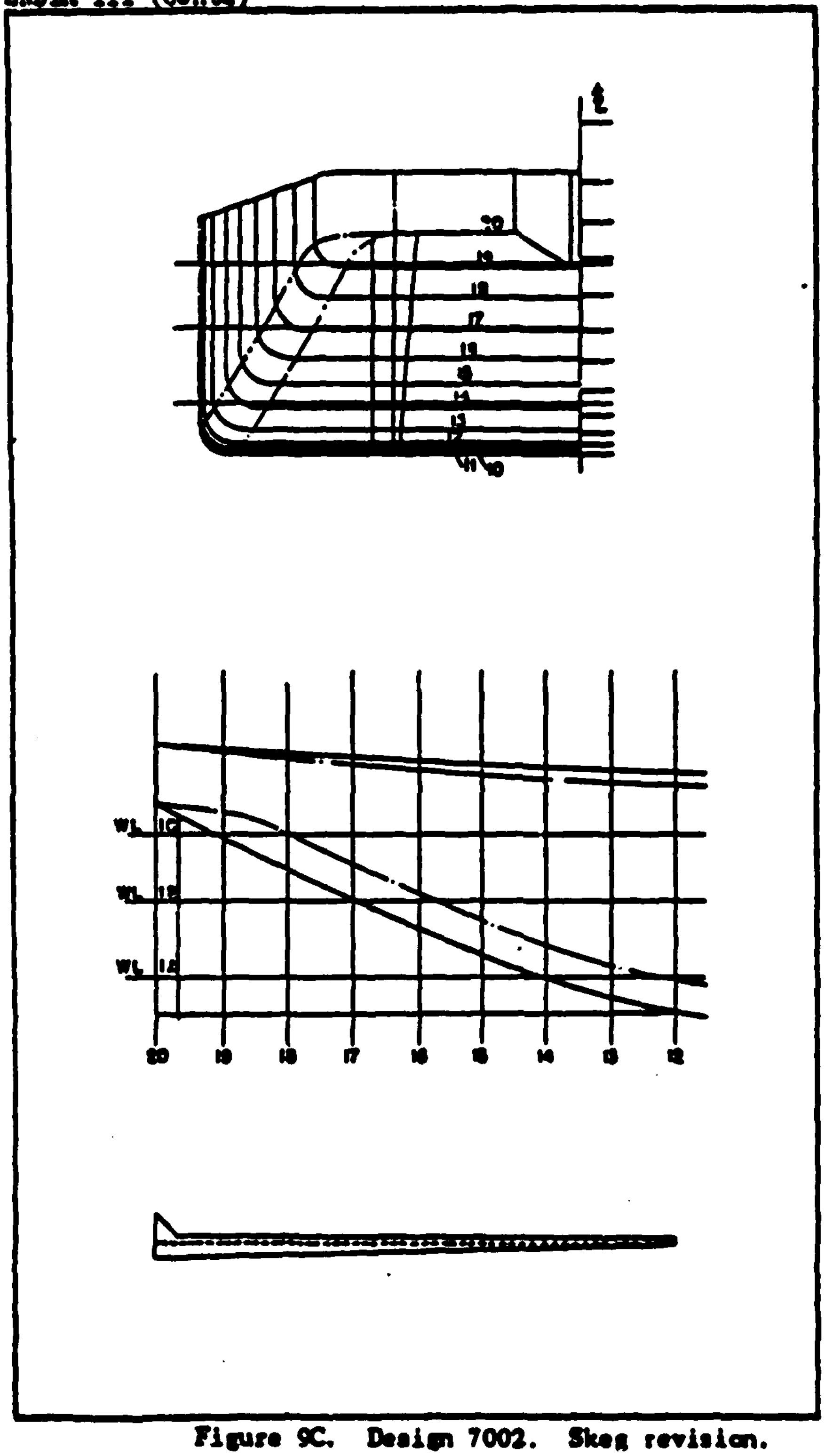

Figure 9C. Design 7002. Skeg revision.

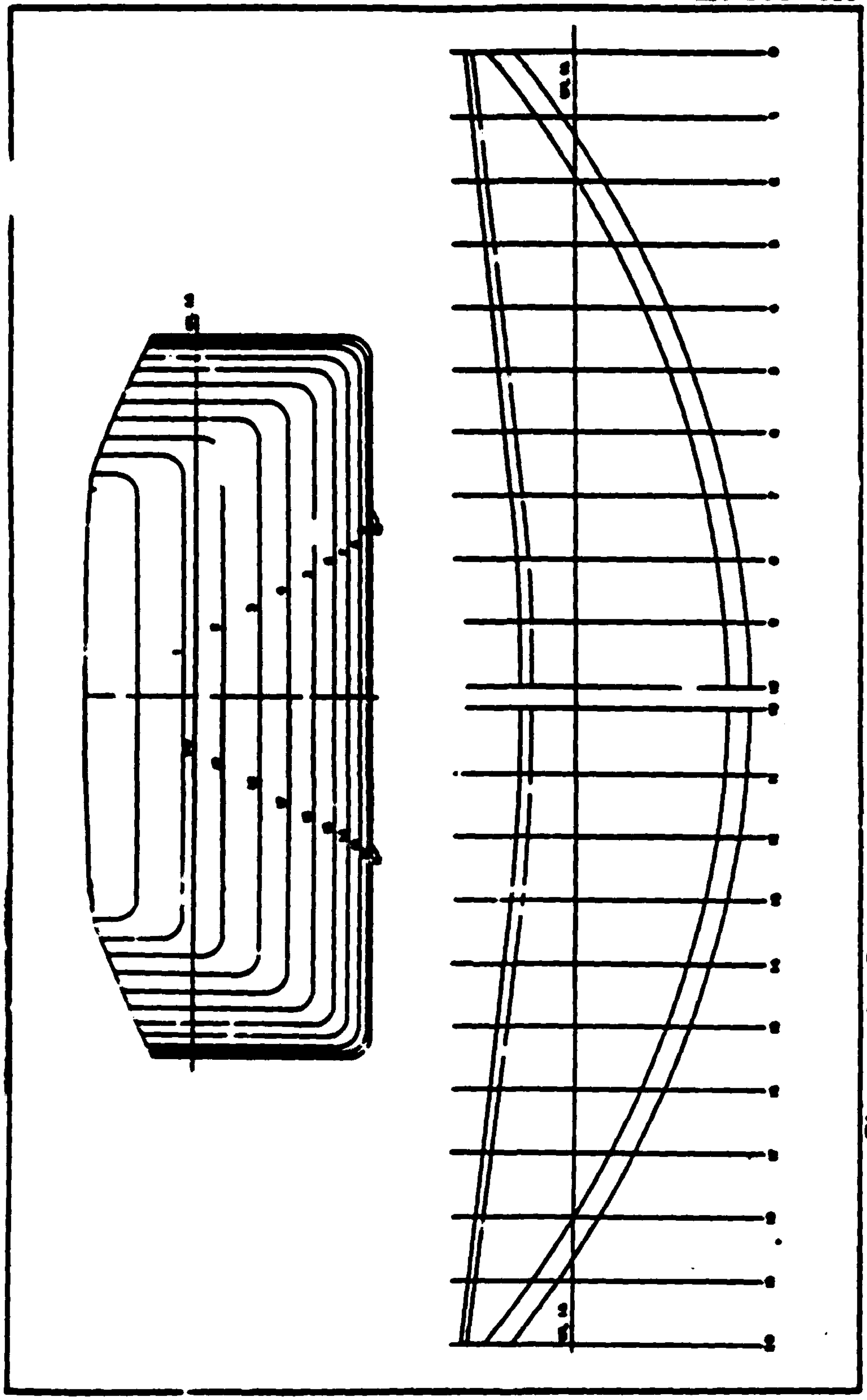

Figure 104. Design 7003, 130-foot steel barge. Model lines drawing.

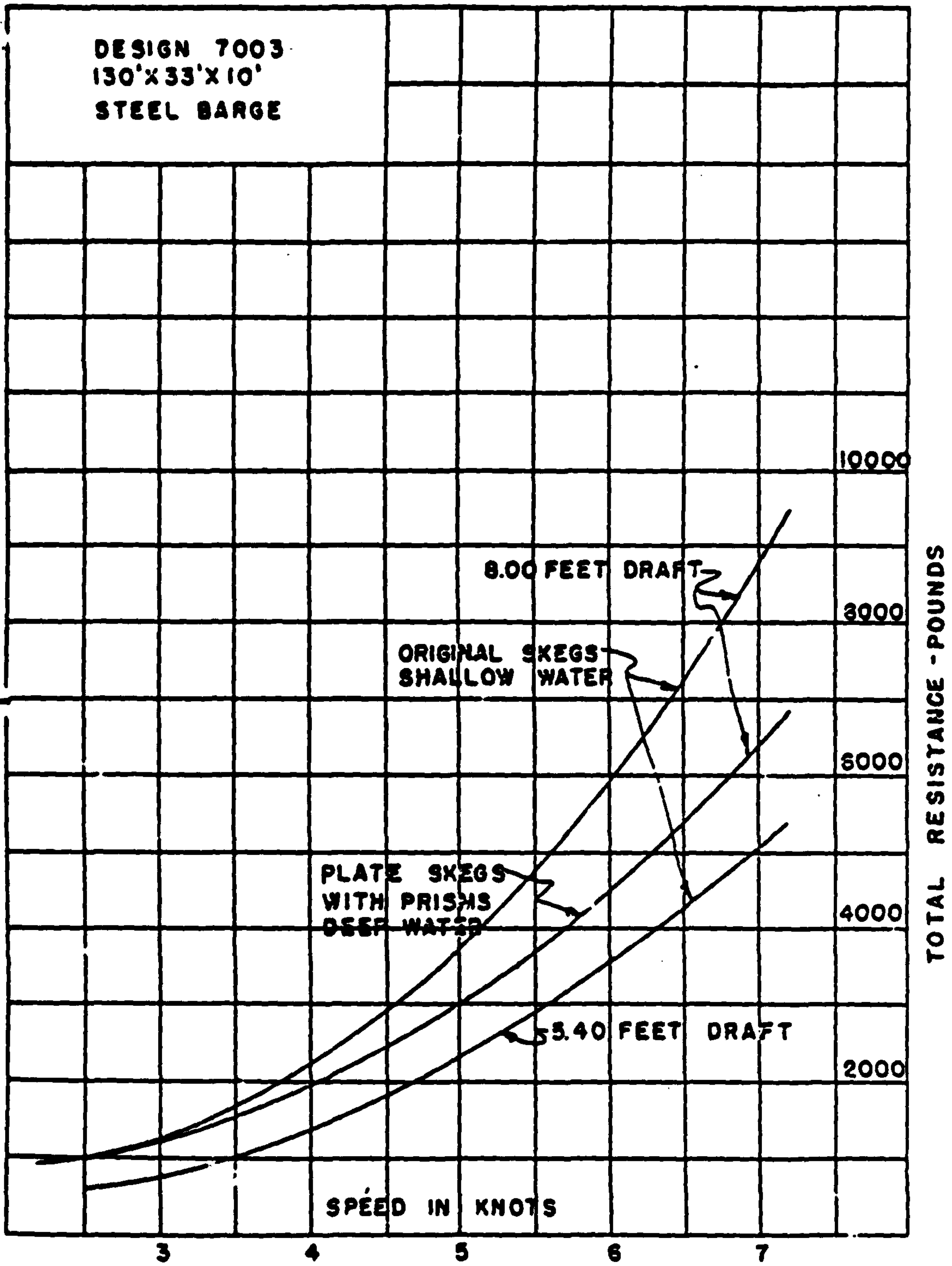

Figure 10B. Design 7003. Curves of total resistance.

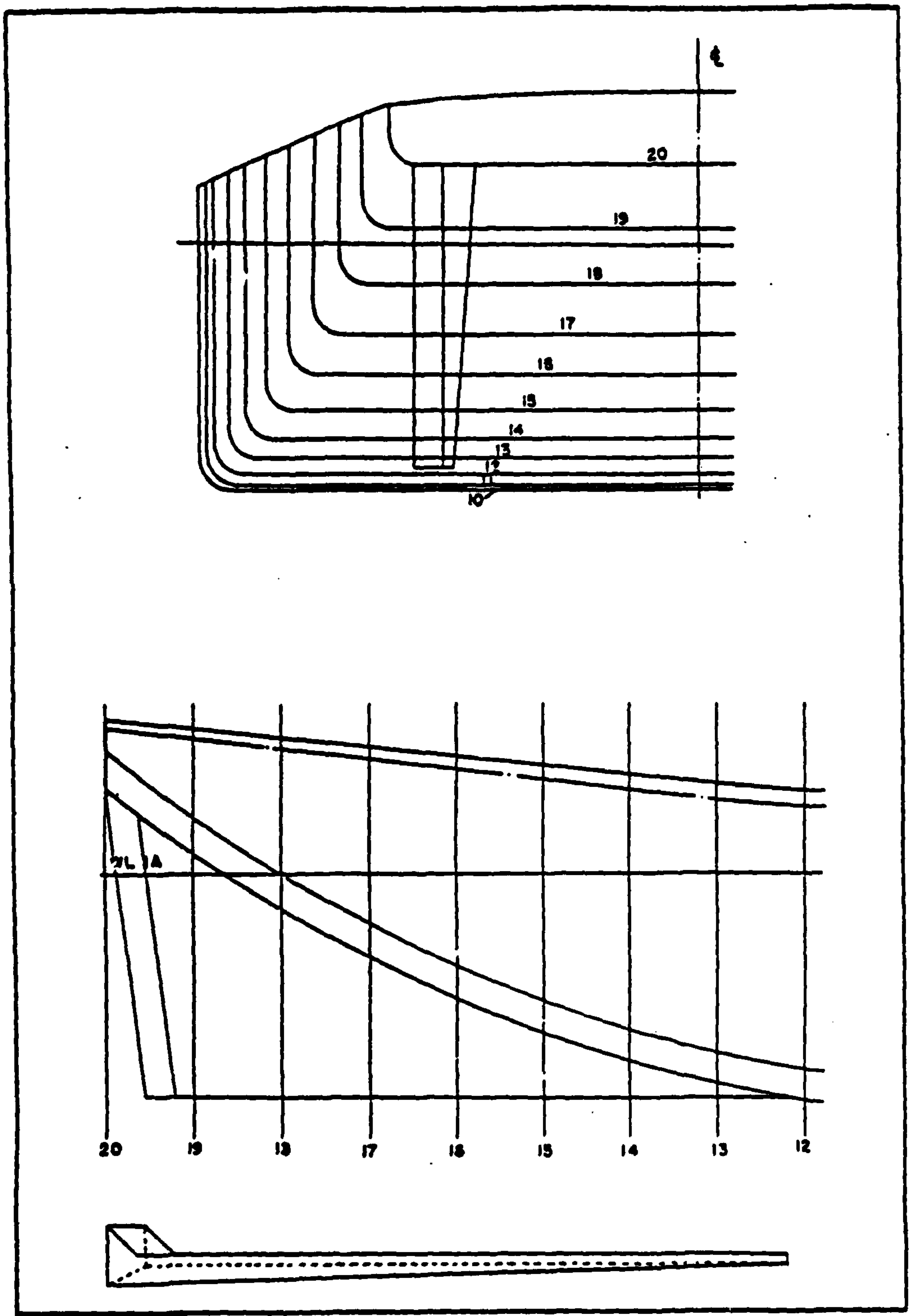

Figure 10C. Design 7003. Skeg revision.

APPENDIX III (contd)

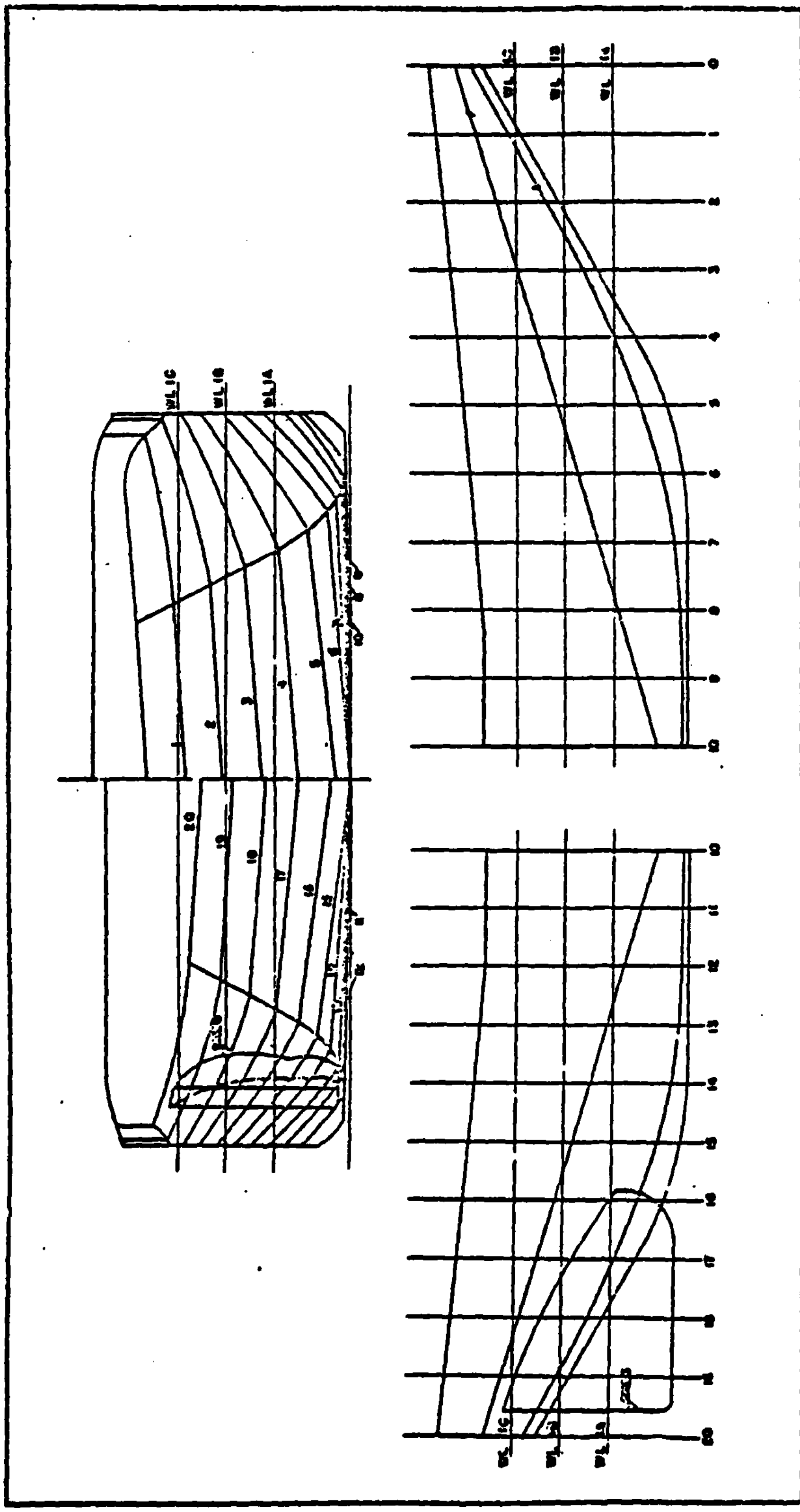

Figure 11A. Design BK 10, 112-foot steel barge. Model lines drawing.

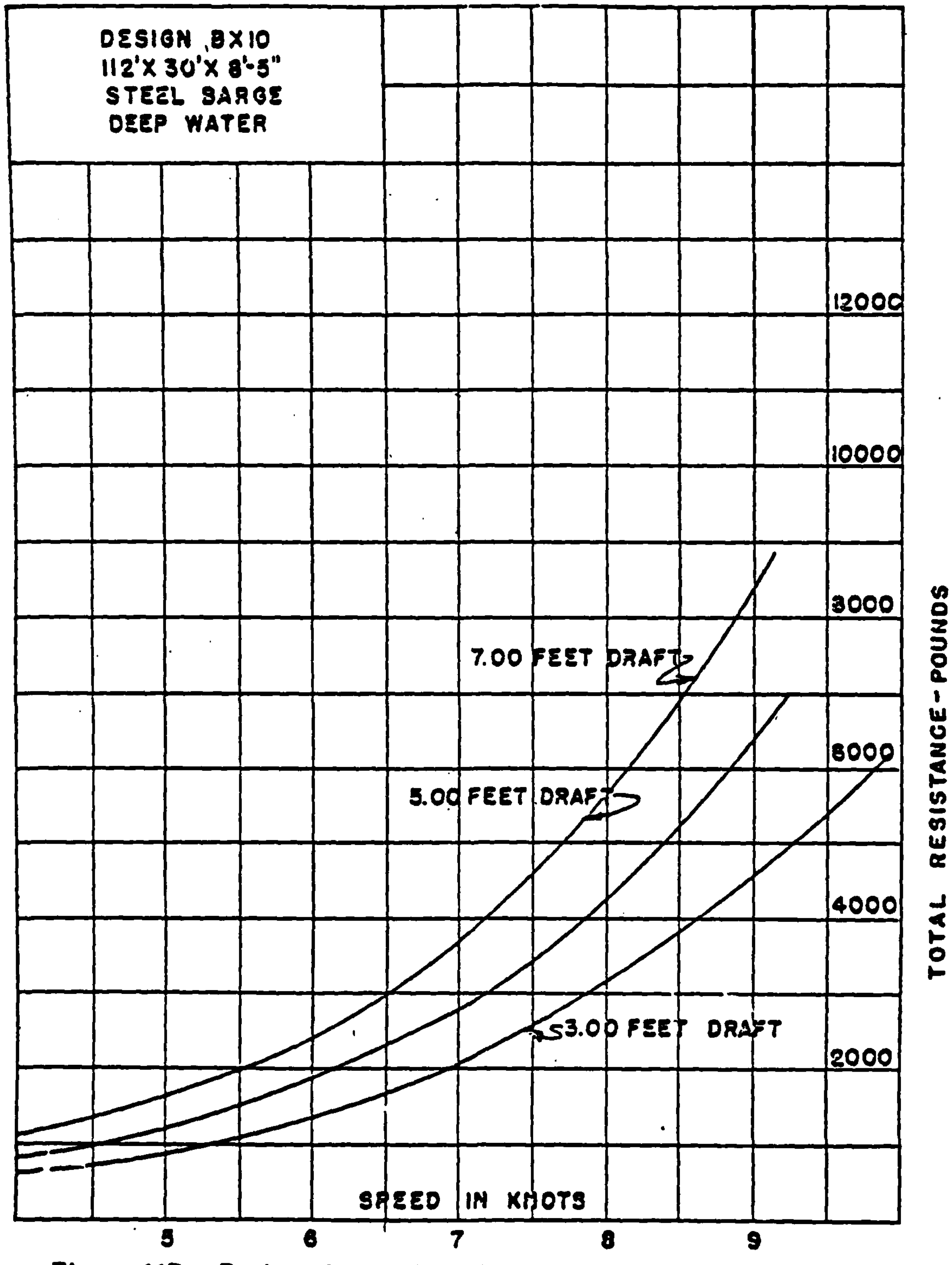

Figure.11B. Design BX 10.- Bare-hull curves of total resistance.

APPENDIX III (contd)

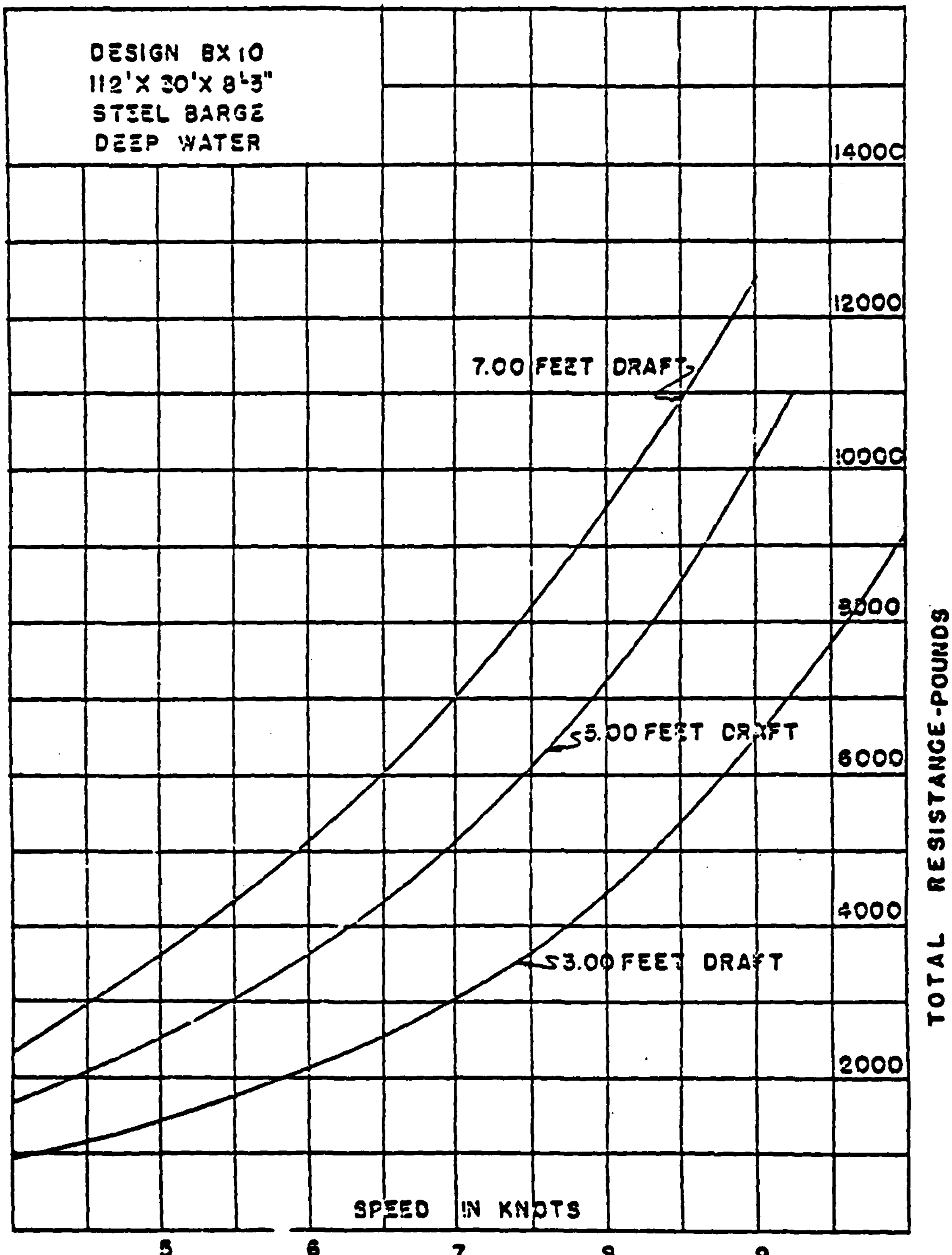

Figure 11C. Design BX10, with skegs. Curves of total resistance.

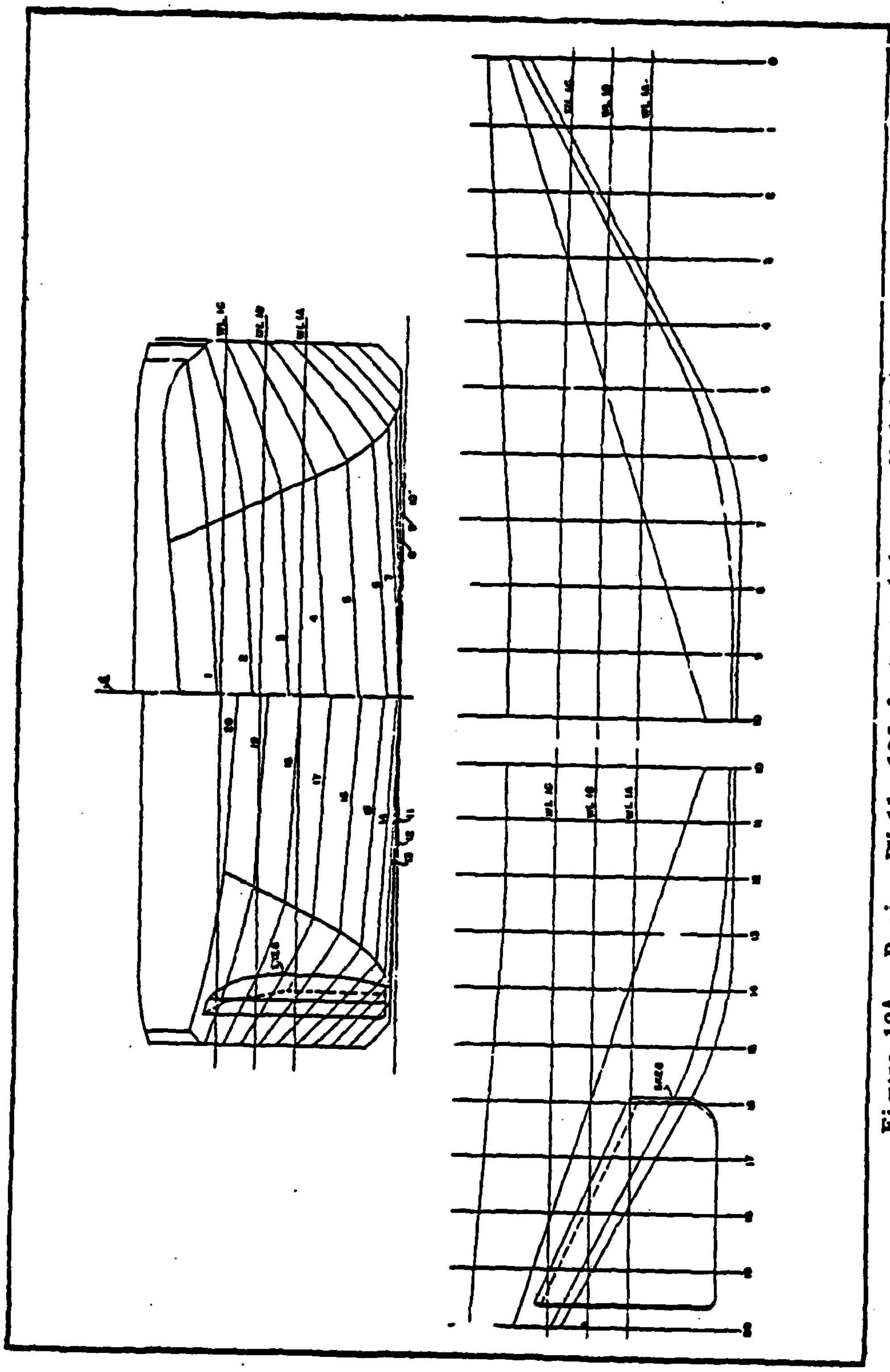

Figure 12A. Design BX 11, 130-foot steel barge. Model lines drawing.

APPENDIX III (contd)

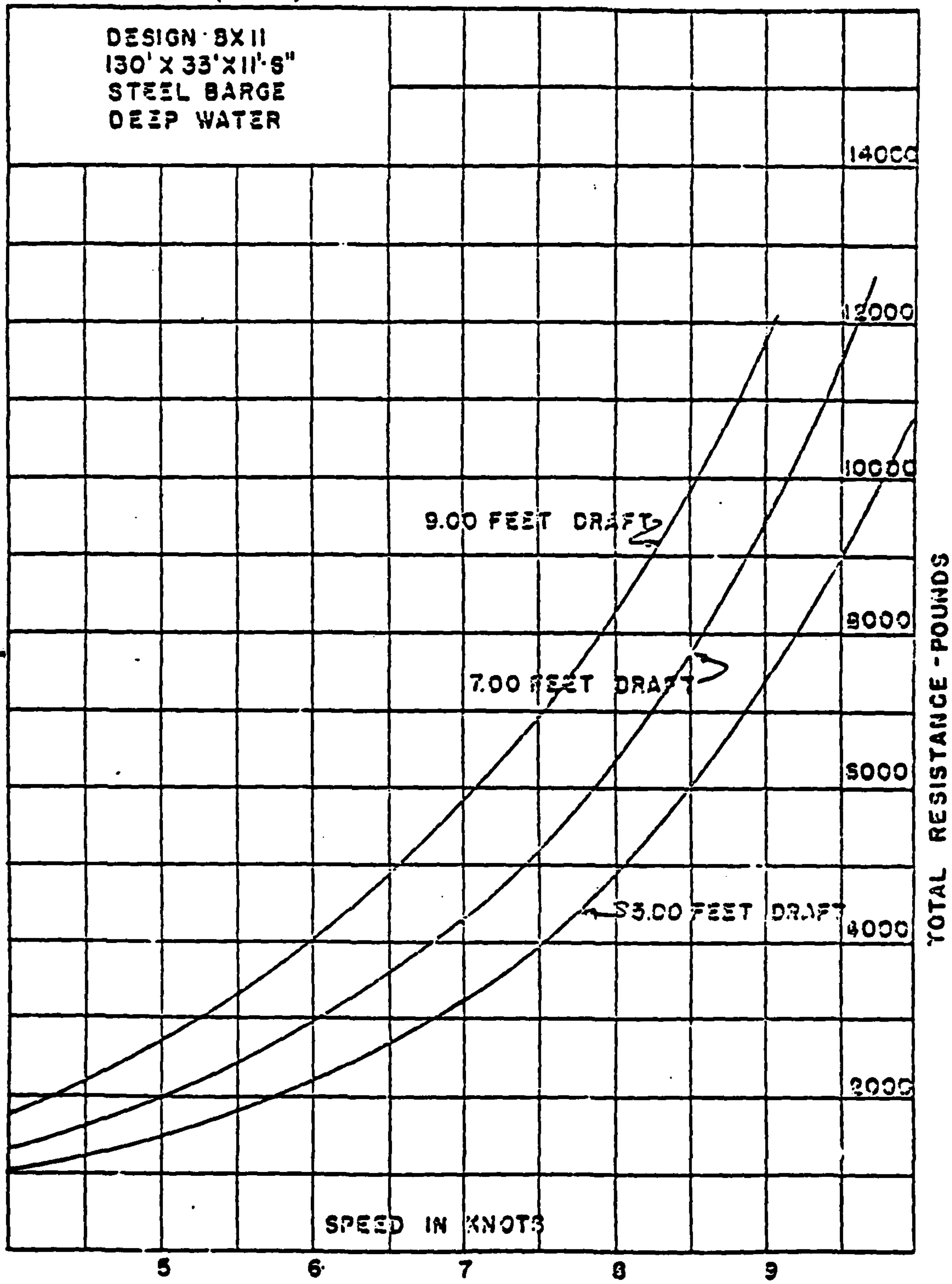

Figure 12B. Design BX 11. Bare-hull curves of total resistance.

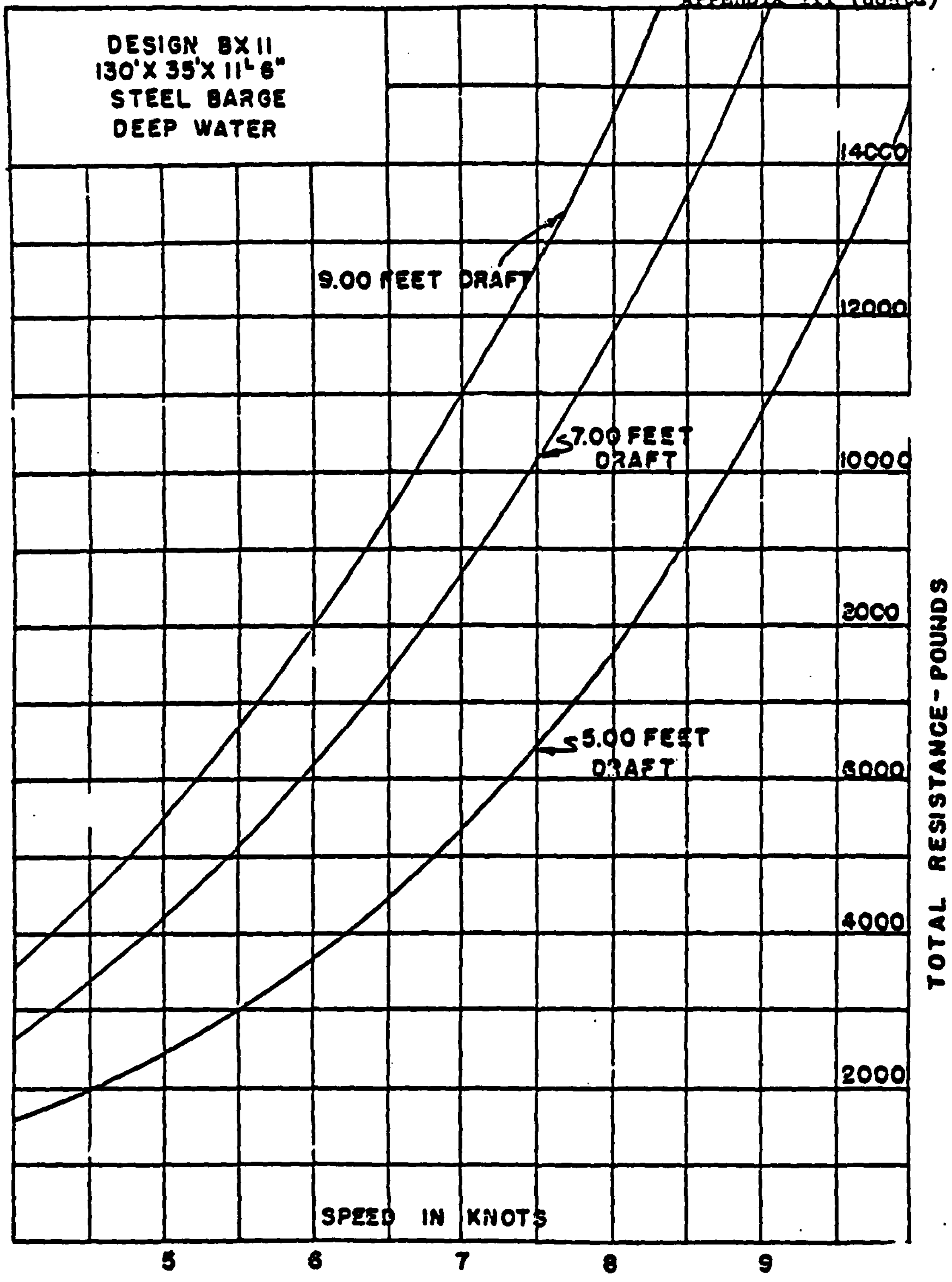

Figure 12C. Design BX 11, with skegs. Curves of total resistance.

APPENDIX III (contd)

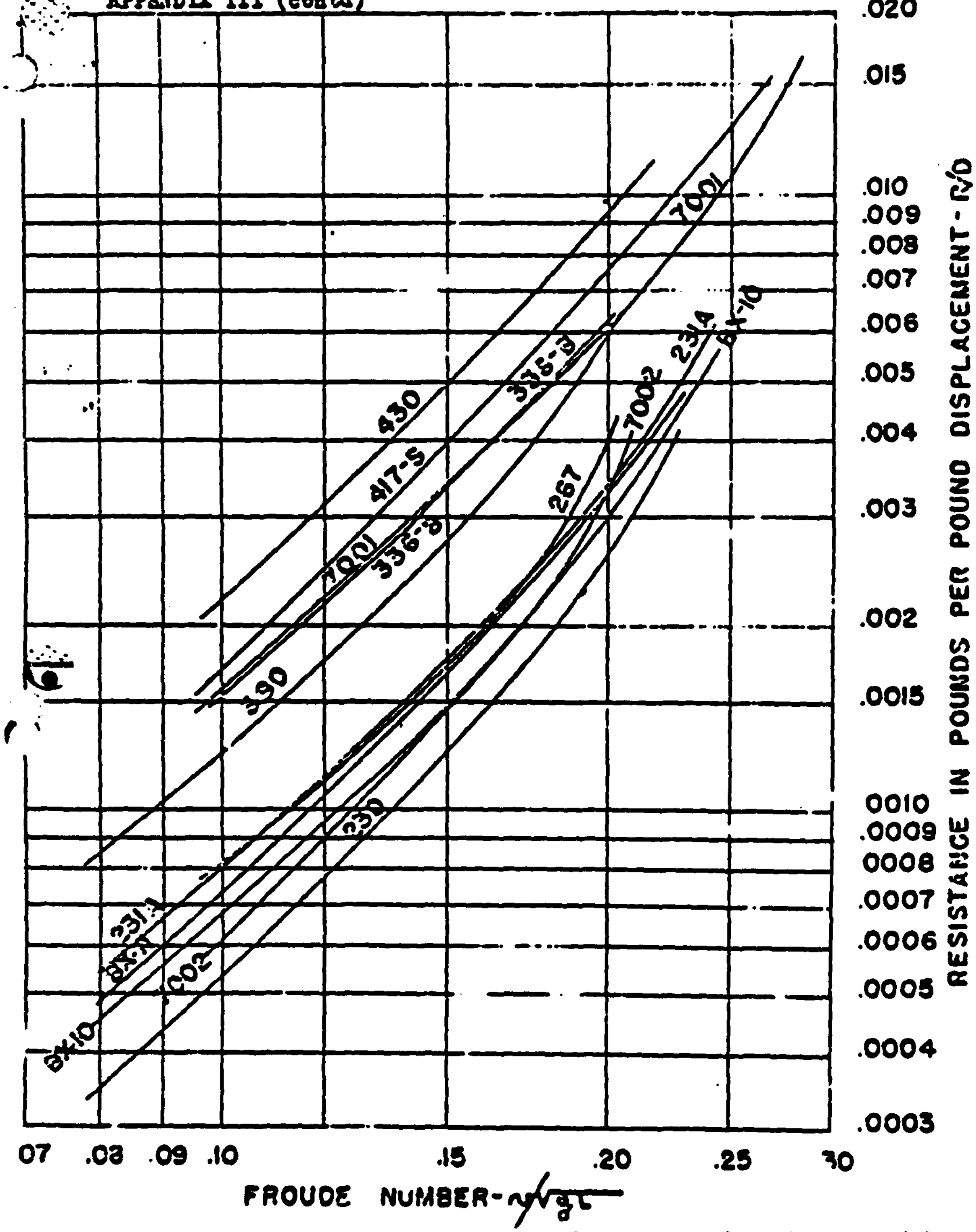

Figure 13. Comparative curves of barge total resistance with yaw uncorrected.

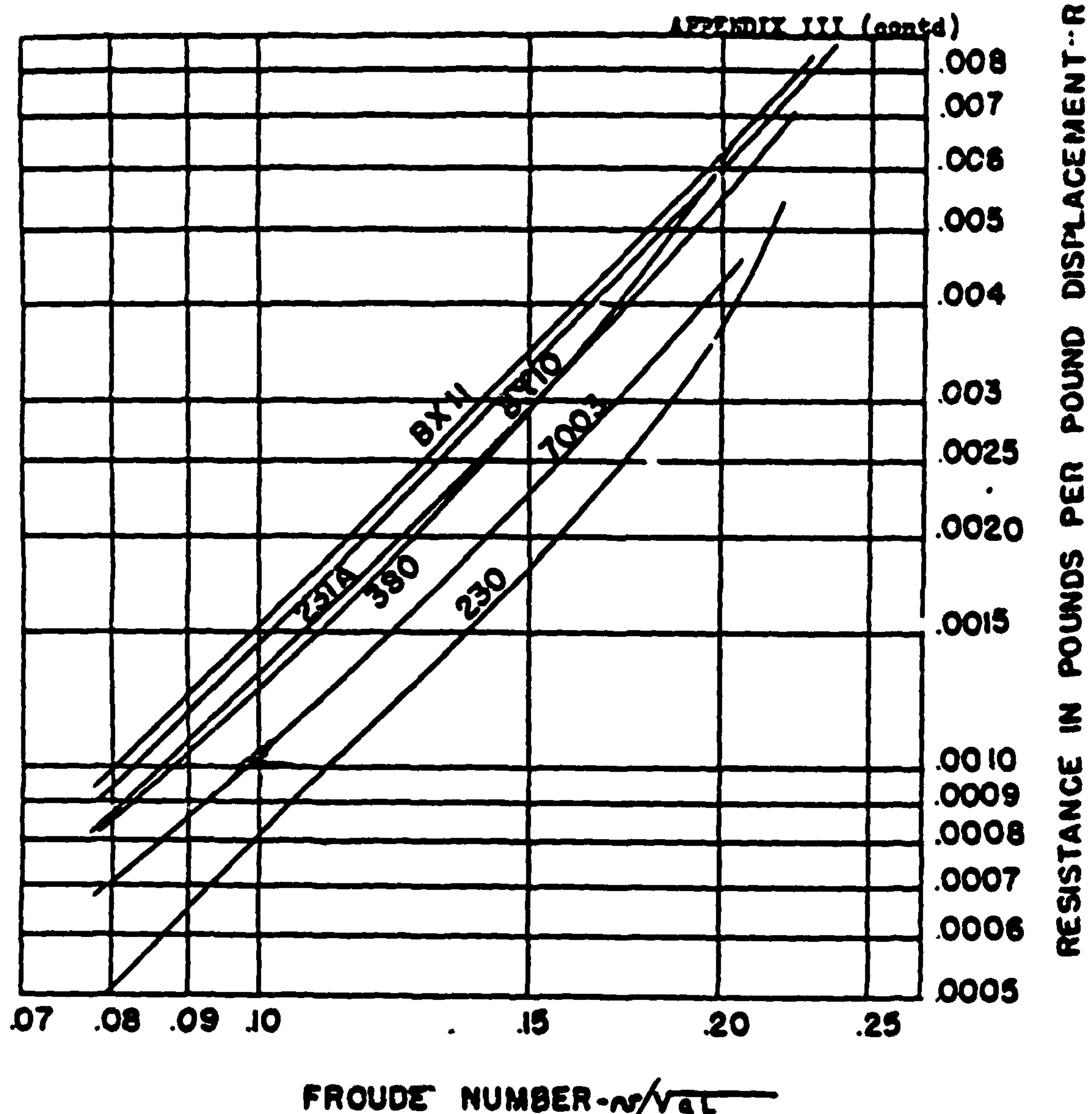

Figure 14. Comparative curves of barge total resistance with yaw corrected.

APPENDIX III (contd)

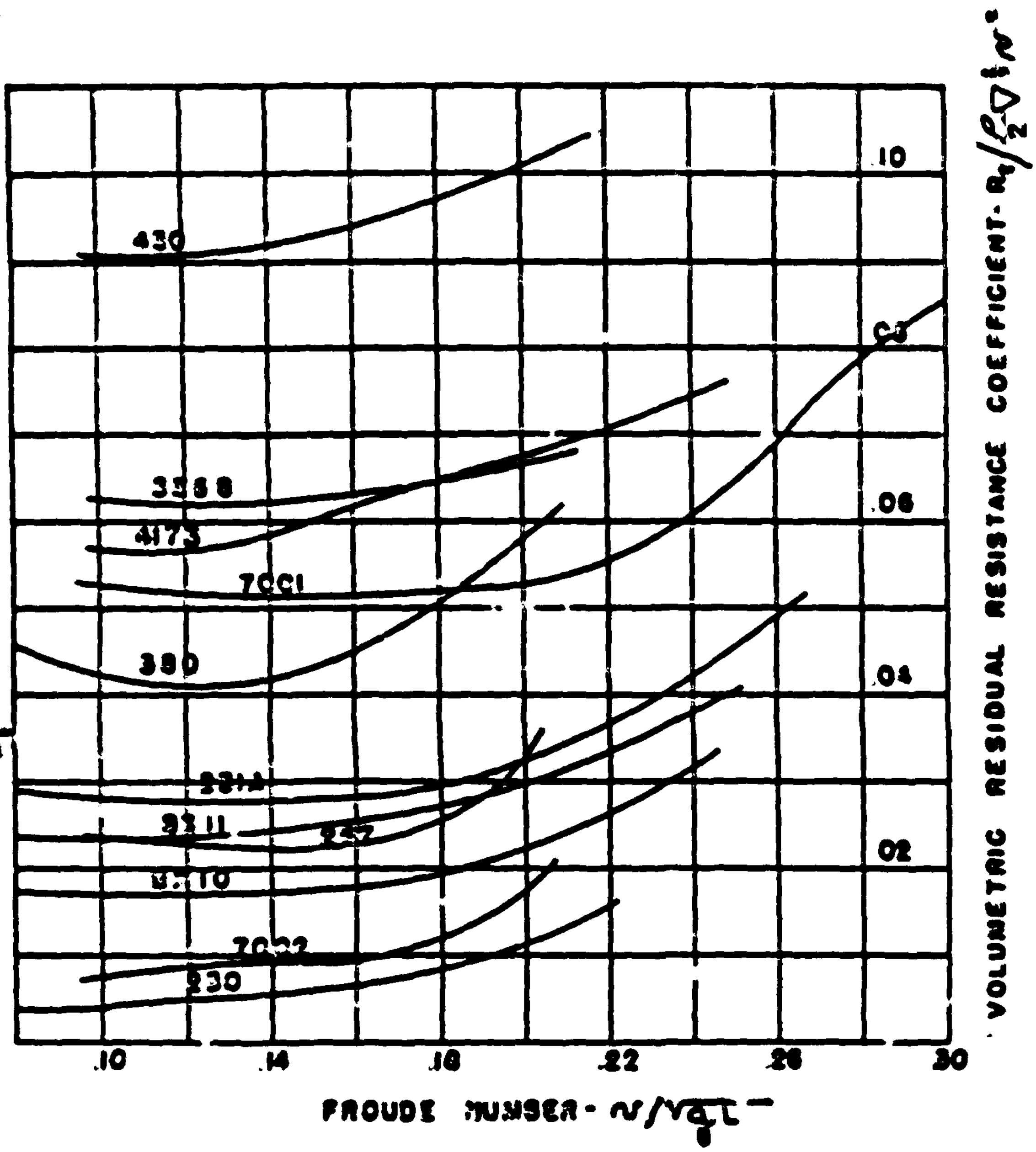

Figure 15. Comparative curves of barge residual resistance with yaw uncorrected.

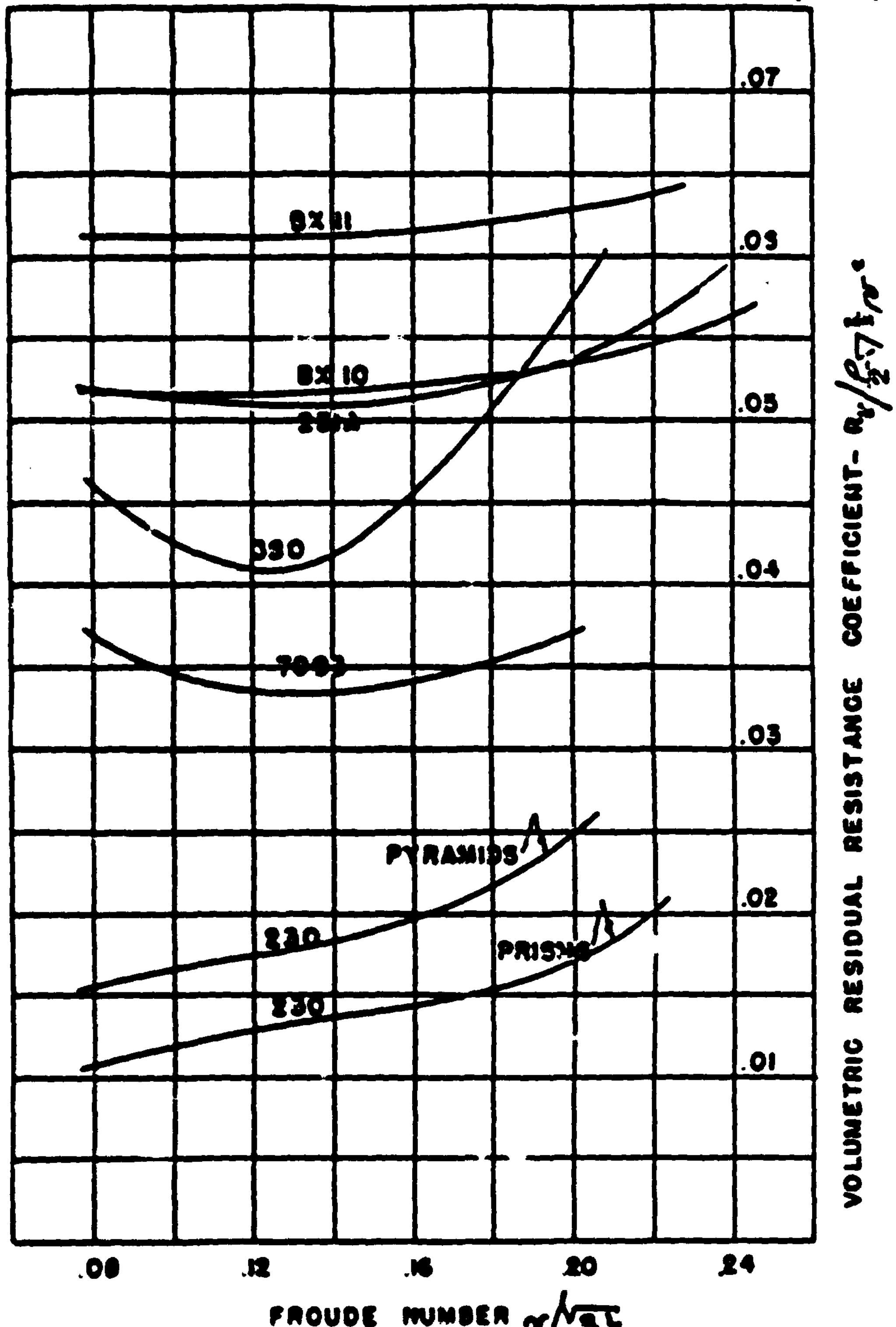

Figure 16. Comparative curves of barge residual resistance with yaw corrected.

APPENDIX III (contd)

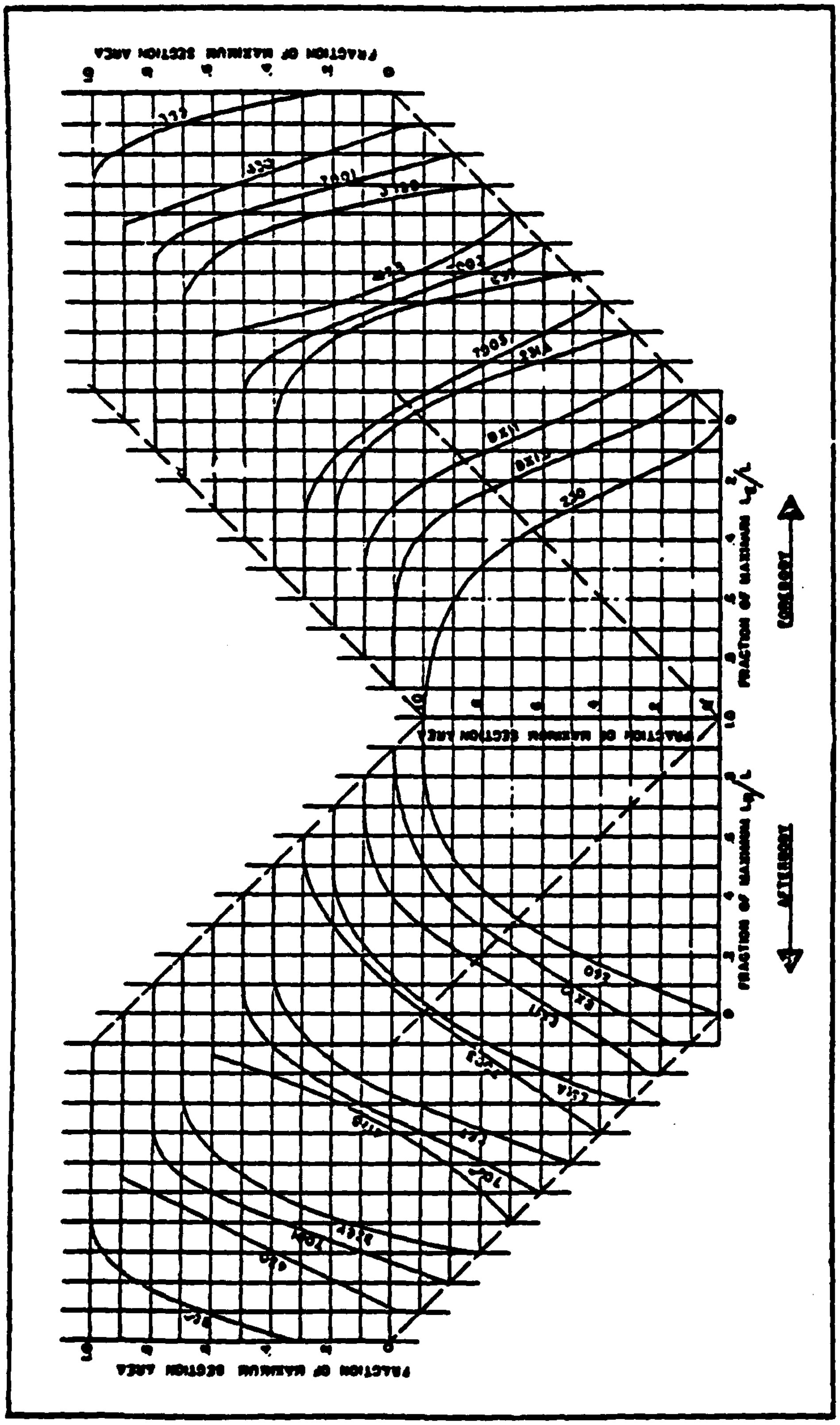

Figure 17. Comparison of sectional-area curves.

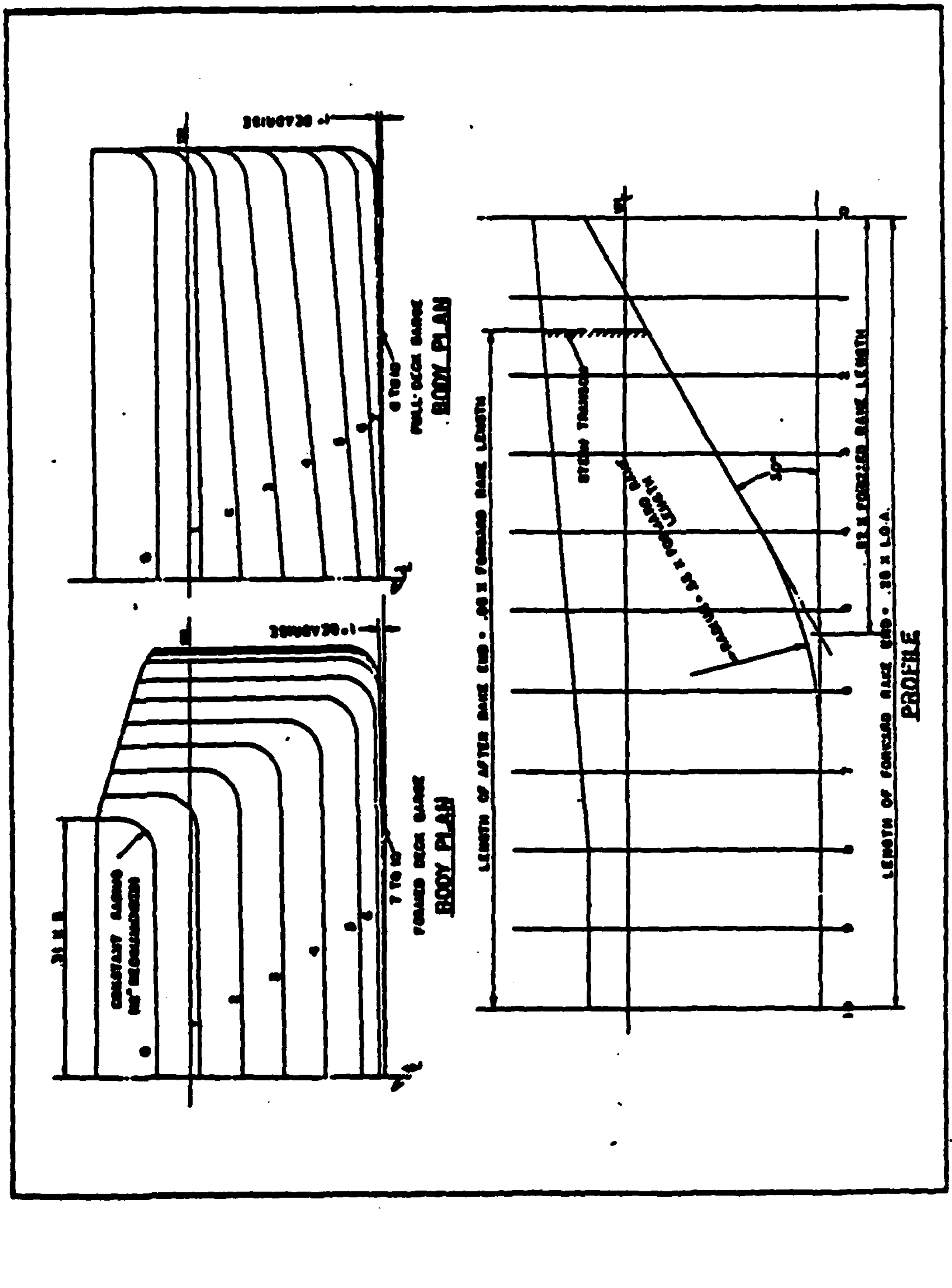

Figure 18A. Recommended standards for formed rake ends. Lines development.

APPENDIX III (contd)

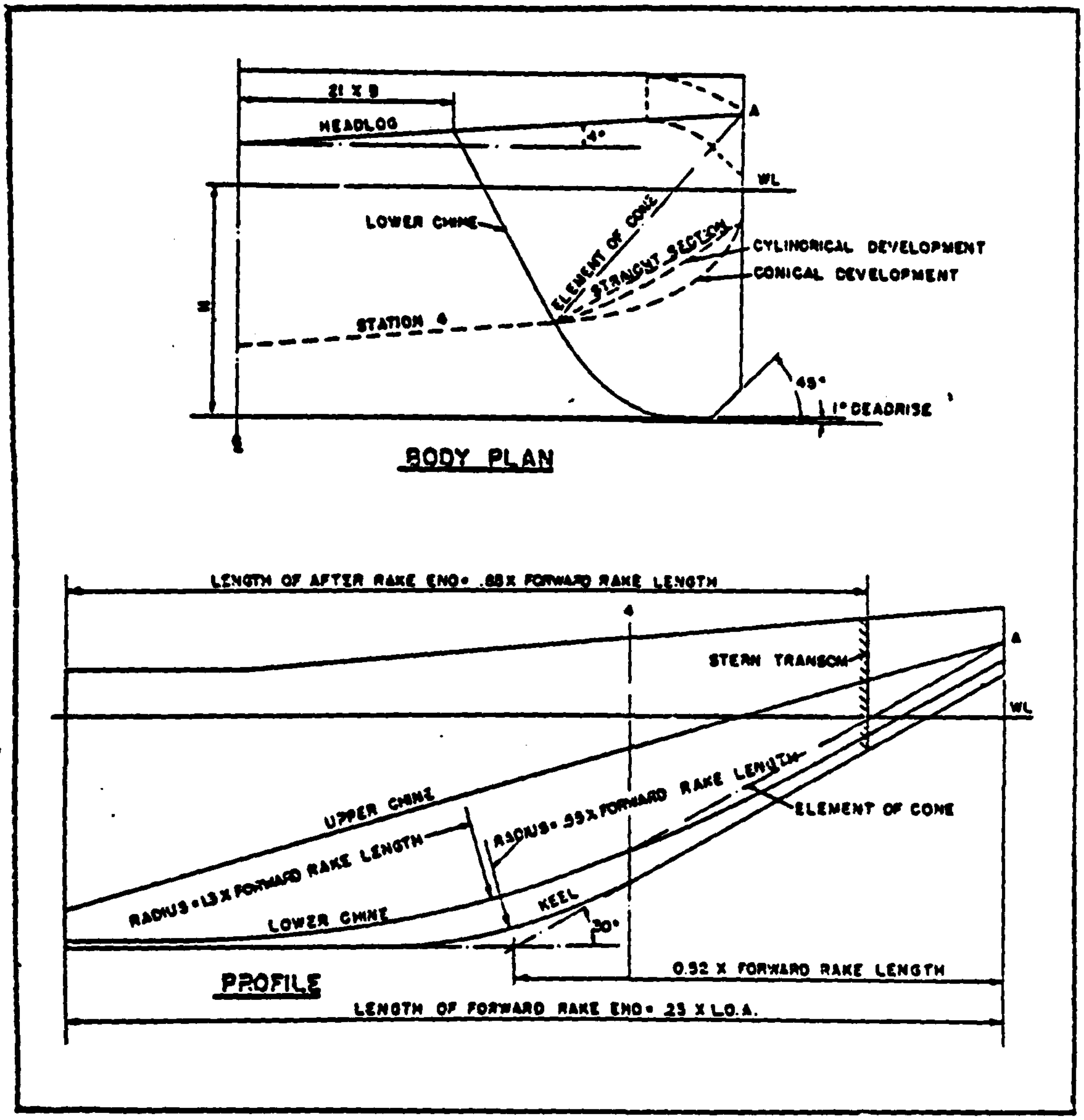

Figure 18B. Recommended standard "straight element form." Lines development.

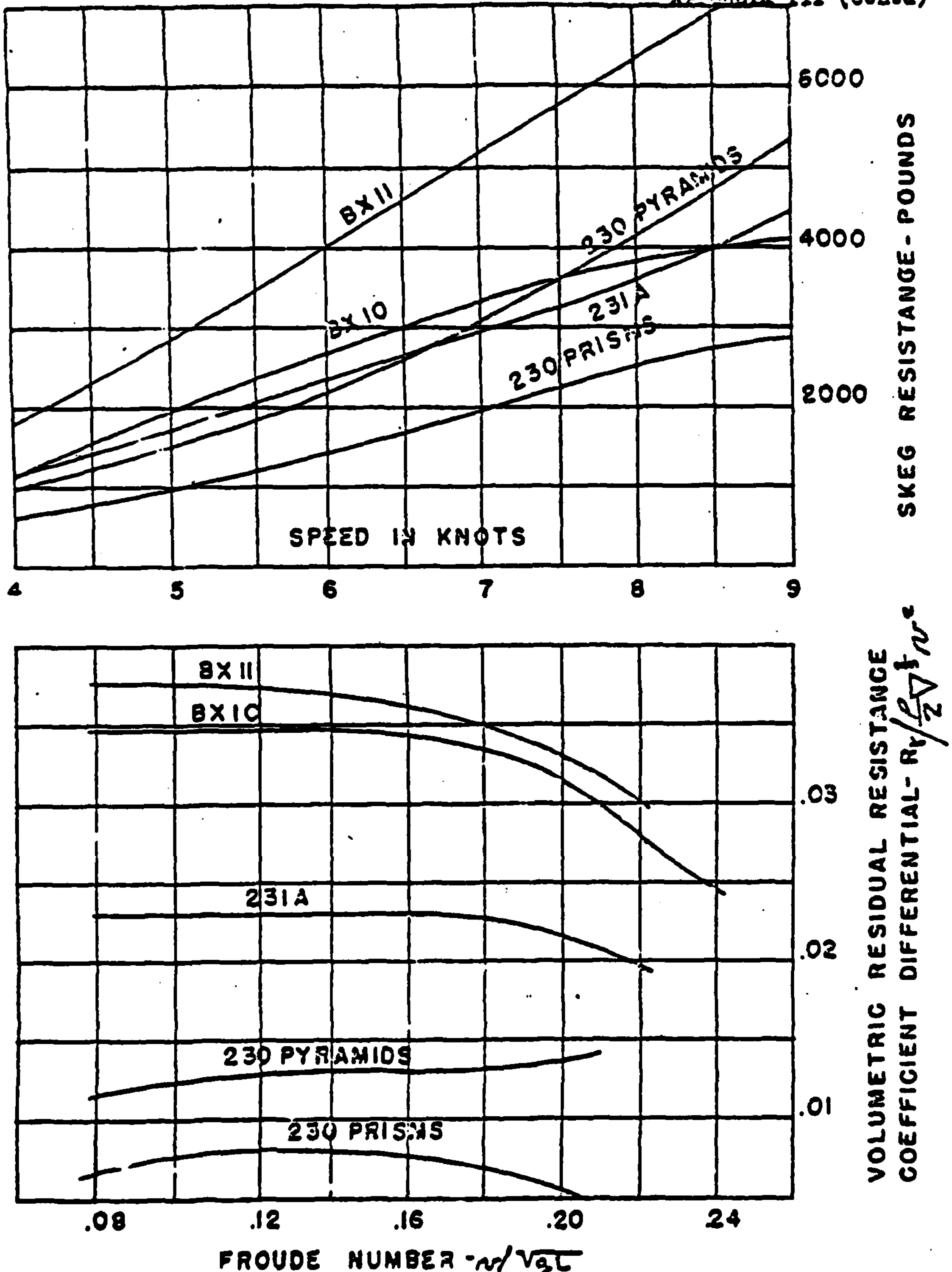

Figure 19. Increase in resistance resulting from yaw-correcting skegs.

APPENDIX III (contd)

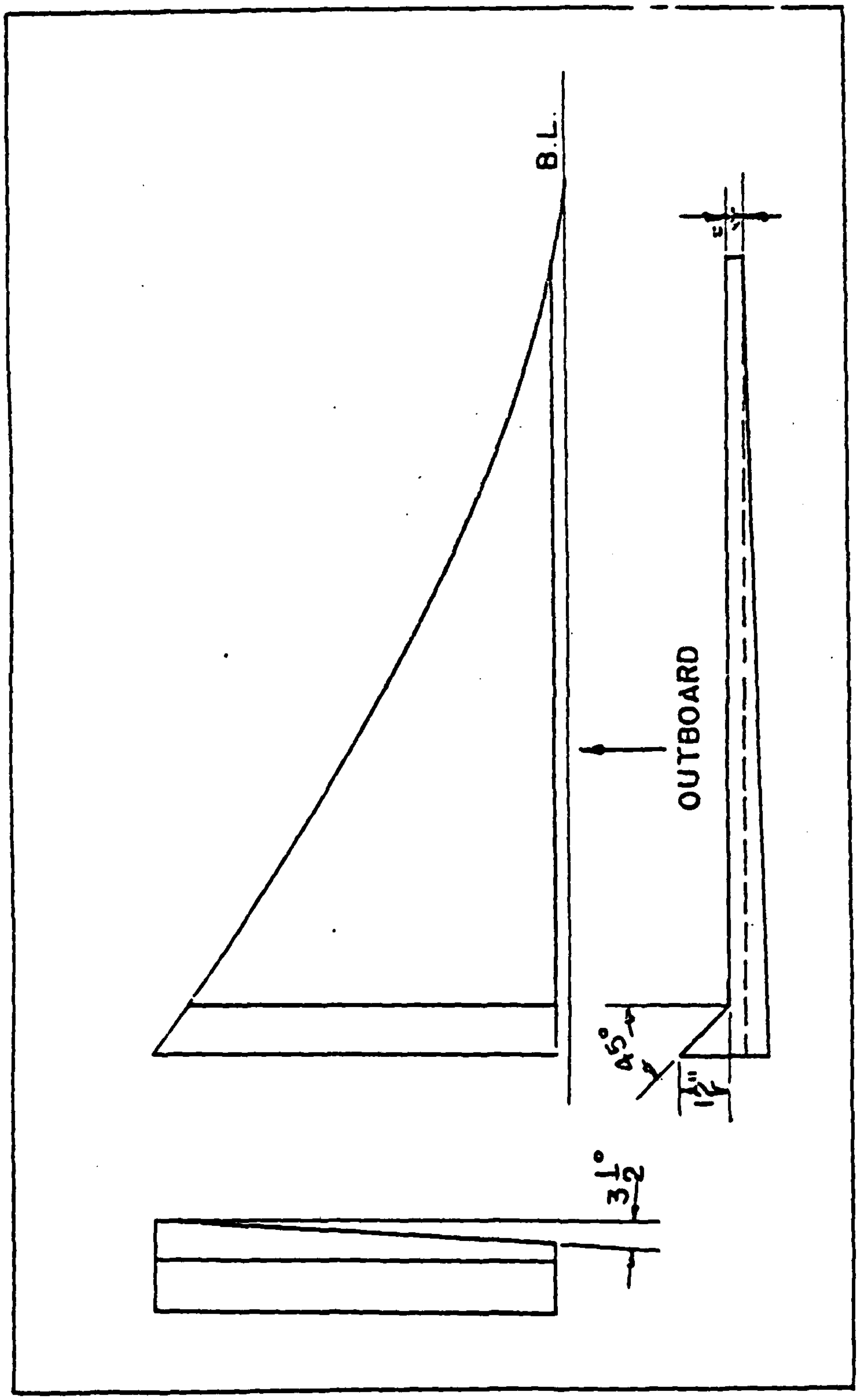

Figure 20. Standard skeg development.

APPENDIX IV

Hull-form data and resistance tables

APPENDIX V

TECHNICAL REFERENCES

(1) BAIER, L.A., 1947, SOC. NAVAL ARCHITECTS AND MARINE ENGRS.
The Resistance of Barges and Flotillas.

(2) CORPS OF ENGINEERS, US ARMY, 17 JUNE 1929.
Investigations of the Board on Experimental Towboats for Mississippi Rivers and Tributaries.

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The Resistance of Various Types of Barges in Shallow and Deep Water

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Water Transportation on Inland Rivers.

(5) BAKER, G.S., 1930, INST. NAVAL ARCHITECTS.
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(7) HAY, A.D., 1 NOV. 1946, PRINCETON UNIVERSITY.
Effects of Varying One End of Barge Forms with Simple Geometrically Shaped Ends.

(8) HAY, A.D., AUG. 1948, MARINE ENG. AND SHIPPING REVIEW.
Resistance of Barge Forms With Simple Geometrically Shaped Ends.

(9) 63D CONGRESS, 2D SESSION, *House Document No. 857.*
67TH CONGRESS, 1ST SESSION, *House Document No. 108.*

(10) GERMAN, J.G., AND MC PHERSON, R.P., 1947, UNIVERSITY OF MICHIGAN
Bridle Effect on the Yaw of Towed Barges.

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Army-Ft Eustis, Va. 1954-M-1635

M. ROSENBLATT & SON
NAVAL ARCHITECTS · MARINE ENGINEERS
111 BROADWAY
NEW YORK, 6, NEW YORK

FINAL REPORT

1 June 1950

PROJECT 9-57-01-04

HULL FORMS

VOLUME I

BARGE HULL FORM STUDIES

ARMY, NEW YORK PORT OF EMBARKATION, BROOKLYN, NEW YORK

RESTRICTED

APPENDIX B

LOCKED PROPELLER DRAG STUDY

Appendix B

The problem of propeller drag was approached by comparing the various available methods of computing locked propeller drag with each other for 2 ships. When possible the rationale was studied for each method in an effort to develop a method which is "simple" and suitable for all naval ship classes.

Symbols

R_p = Resistance of 1 propeller (LB.)

R_{TP} = Total propeller resistance (LB.)

R_H = Hull resistance (in calm water w/o propellers) (LB.)

A_p = Projected area (FT.^{2})

A_D = Developed Area (FT.^{2})

A_E = Expanded area (FT.^{2})

BAR = Blade area ratio

V = Ship speed Ft./sec.

V_K = Ship speed KT.

V_A = Speed of advance

C_p = Propeller drag coefficient

All of the methods of computing locked propeller drag follow the form $R_p = C_p\ \rho/2\ AV^2$ where A & V may vary depending on the area considered or the units for speed used. To compare various methods of calculation it is useful to reduce the equation above to the form $R_p = K V_K^2$ where K combines C_p, $\rho/2$ (if used), and the appropriate area for each method. The K values are compared by dividing by K for method which corresponds to the equation from Ref. 5. In addition R_{TP} is calculated for each method and is compared with the calm water hull resistance with the ratio R_{TP}/R_H.

THE PROBLEM OF PROPELLER DRAG WAS APPROACHED BY COMPARING THE VARIOUS AVAILABLE METHODS OF COMPUTING LOCKED PROPELLER DRAG WITH EACH OTHER FOR 2 SHIPS. WHEN POSSIBLE THE RATIONALE WAS STUDIED FOR EACH METHOD IN AN EFFORT TO DEVELOP A METHOD WHICH IS "SIMPLE" AND SUITABLE FOR ALL NAVAL SHIP CLASSES.

SYMBOLS

R_P = RESISTANCE OF 1 PROPELLER (LB.)
R_{TP} = TOTAL PROPELLER RESISTANCE (LB)
R_H = HULL RESISTANCE (IN CALM WATER W/O PROPELLERS) (LB)
A_P = PROJECTED AREA ($FT.^2$)
A_D = DEVELOPED AREA (")
A_E = EXPANDED AREA (")
BAR = BLADE AREA RATIO
V = SHIP SPEED FT./SEC.
V_K = SHIP SPEED KT.
V_A = SPEED OF ADVANCE
C_P = PROPELLER DRAG COEFFICIENT

ALL OF THE METHODS OF COMPUTING LOCKED PROPELLER DRAG FOLLOW THE FORM $R_P = C_P \, \rho/2 \, A V^2$ WHERE A & V MAY VARY DEPENDING ON THE AREA CONSIDERED OR THE UNITS FOR SPEED USED. TO COMPARE VARIOUS METHODS OF CALCULATION IT IS USEFUL TO REDUCE THE EQUATION ABOVE TO THE FORM $R_P = K V_K^2$ WHERE K COMBINES C_P, $\rho/2$ (IF USED), AND THE APPROPRIATE AREA FOR EACH METHOD. THE K VALUES ARE COMPARED BY DIVIDING BY K FOR METHOD WHICH CORRESPONDS TO THE EQUATION FROM REF. 5. IN ADDITION R_{TP} IS CALCULATED FOR EACH METHOD AND IS COMPARED WITH THE CALM WATER HULL RESISTANCE WITH THE RATIO R_P/ [illegible]

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DESIGN CALCULATION SHEET Sheet B-2 of

Subject PROPELLER DRAG STUDY

Ship or Project TOWING RESISTANCE CRITERIA

Section Prepared by RCS Date 10/23/75 Checked Reviewed

THE CALM WATER HULL RESISTANCE WITH THE RATIO R_{TP}/R_H.

METHODS OF COMPUTING LOCKED PROPELLER DRAG — EQUATIONS & REFERCES

METHOD	EQUATION	REFERENCES
(1)	$R_p = 3.17\ A_p V_k^2$	5
(2)	$R_p = 1.0\ \rho/2\ A_D V_A^2$ OR $R_p = 1.67\ \rho/2\ A_D V_A^2$	6, 7
(3)	$R_p = 1.19\ A_p V^2$	8, 9
(4)	$R_p = 1/2\ \rho\ V^2 A_E C_p$ WHERE C_p IS FROM FIG. B1	4

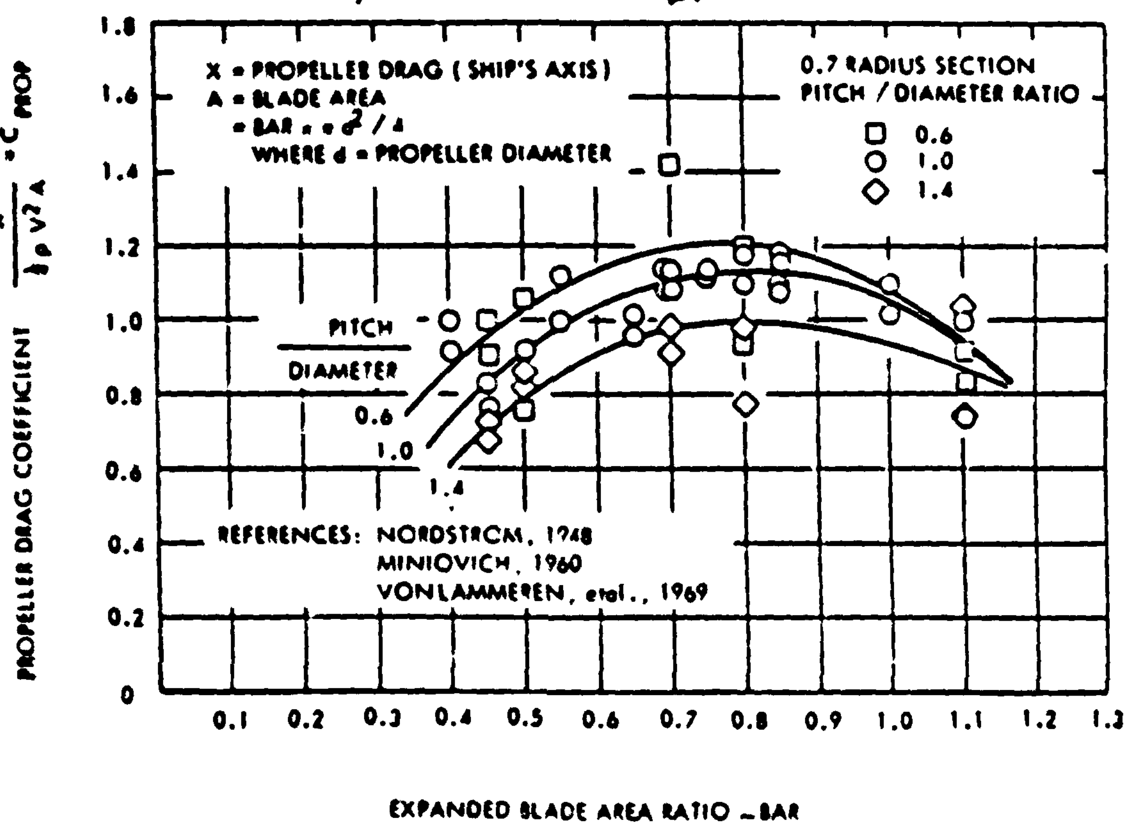

FIG. B-1

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Sheet B-3 of

Subject: PROPELLER DRAG STUDY
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Section: Prepared by: RCS Date: 10/23/75 Checked: Reviewed:

METHOD	EQUATION	REFERENCE
(5)	$R_P = 1.14\,A_D\,(\tfrac{1}{2}\rho)V^2$	11

COMPARISON OF METHODS FOR 2 SHIPS: LST-1179 & CA 139

SHIP LST-1179 – (SEE SHT. B-4)

METHOD		K	$K/K_{①}$	R_{TP}/R_H $V_K = 1$ KT.	R_{TP}/R_H $V_K = 12$ KT.
①		343	1.0	1.05	1.29
②	$C_P = 1.0$	364	1.06	1.12	1.37
	$C_P = 1.67$	607	1.77	1.86	2.29
③		367.1	1.07	1.13	1.38
④		403.7	1.18	1.25	1.52
⑤		400.	1.17	1.22	1.51

SHIP CA-139 – (SEE SHT. B-6)

METHOD		K	$K/K_{①}$	R_{TP}/R_H $V_K = 1$ KT.	R_{TP}/R_H $V_K = 12$ KT.
①		1037	1.0	1.82	2.19
②	$C_P = 1.0$	1173	1.13	2.06	2.48
	$C_P = 1.67$	1959	1.89	3.44	4.15
③		1111	1.07	1.96	2.36
④		1255	1.21	2.21	2.66
⑤		1278	1.23	2.27	2.73

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Sheet B-4 of

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Ship or Project: TOWING RESISTANCE CRITERIA
Section — Prepared by: RCS — Date: 10/23/75 — Checked — Reviewed

CALCULATIONS FOR LST-1179

PROPELLER CHARACTERISTICS

DIA. = 11.5
PITCH = 12.33'
DEVELOPED AREA = 61.488
PROJECTED AREA = 54.072
PROPELLERS = 2

$$BAR = \frac{\text{PROJ. AREA} / \text{D.A.}}{1.067 - 0.229\left(\frac{12.33}{11.5}\right)} = 0.633$$ (EQ. FROM REF. 4)

$A_E = BAR(103.1) = 65.82$

$V_A = (1-w)V$ — $C_B = 0.55$, $w = -0.021$ TAYLORS FROM REF. 6
$= 1.021\,V$

$V_A^2 = (1.021)^2 (1.689)^2 V_K^2$ — $R_{H\ 1KT.} = 326$
$= 2.973\ V_K^2$

$V^2 = (1.689)^2\ V_K^2 = 2.853\ V_K^2$ — $R_{H\ 12KT.} = 38251$

METHOD 1

$K = 3.17(54.072)(2) = 343$
$R_{TP} = 343$ 1 KT.
$= 49392$ 12 KT.

METHOD 2

$K = 1.0\left(\frac{1.9905}{2}\right)(61.488)(2)(2.973) = 364$
OR
$K = 1.67\left(\quad " \quad \right) = 607$

$R_{TP} = 364$ (1 KT.) OR 607 — ($C_p = 1.0$ / $C_p = 1.67$)
$R_{TP} = 52416$ OR 87408 AT 12 KT.

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DESIGN CALCULATION SHEET

No. 3419

Sheet B-5 of

Subject PROPELLER DRAG STUDY

Ship or Project TOWING RESISTANCE CRITERIA

Section

Prepared by RCS

Date 11/6/75

Checked

Reviewed

METHOD 3

$$K = 1.19\,(54.072)(2)(1.689)^2 = 367.1$$

$R_{TP} = 367.1$ 1 KT.

$= 52865$ 12 KT.

METHOD 4

$$K = 1/2\,(1.9905)(1.08)(65.82)(2)(1.689)^2 = 403.6$$

$C_p = 1.08$

$R_{TP} = 404$ 1 KT.

$= 58125$ 12 KT.

METHOD 5

$$K = 1.14\,(A_D)(2)(2.853) = 399.96$$

$R_{TP} = 400$ (1 KT.)

$R_{TP} = 57600$ (12 KT.)

M. Rosenblatt & Son, Inc. No. 3419
DESIGN CALCULATION SHEET Sheet B-6 of

Subject: PROPELLER DRAG STUDY
Ship or Project: TOWING RESISTANCE CRITERIA
Section — Prepared by RCS — Date 11/6/75 — Checked — Reviewed

CALCULATIONS FOR CA - 139

PROPELLER CHARACTERISTICS

DIA. = 12.66 $\qquad$ R_H = 568 lb. 1 KT.

PITCH = 13.16 $\qquad$ R_H = 67917 lb. 12 KT.

A_D = —

A_P = 81.82

\# PROP. = 4

$$BAR = \frac{A_P/D.A.}{1.067 - 0.229\left(\frac{13.16}{12.66}\right)} = 0.784$$

A_E = BAR (125.9) = 98.69

C_B = 0.543 $\quad$ w = −0.023 (TAYLORS REF. 6)

$V_A = (1-w)V = 1.023\,V$

$V_A^2 = (1.023)^2(1.689)^2 V_K^2 = 2.985\,V_K^2$

$V^2 = 2.853\,V_K^2$

METHOD 1

$K = 3.17\,(81.82)(4) = 1037$

R_{TP} = 1037 $\quad$ 1 KT.

= 149 396 $\quad$ 12 KT.

METHOD 2

$C_D = 1.0$ $\quad$ $K = 1.0\left(\frac{1.9905}{2}\right)(98.69)(2.985)(4) = 1173$

$C_D = 1.67$ $\quad$ $K = 1959$

	$C_D = 1.0$		$C_D = 1.67$
R_{TP} =	1173 (1 KT.)	OR	1959 (1 KT.)
=	168912 (12 KT.)	OR	282096 (12 KT.)

M. Rosenblatt & Son, Inc. No. 3419

DESIGN CALCULATION SHEET Sheet B-7 of

Subject PROPELLER DRAG STUDY

Ship or Project TOWING RESISTANCE CRITERIA

Section Prepared by RCS Date 11/6/75 Checked Reviewed

METHOD 3

$$K = 1.19\, A_P (4)(2.853) = 1111$$

$R_{TP} = 1111$ 1 KT.
$= 160003$ 12 KT.

METHOD 4

$$K = \tfrac{1}{2}(1.9905)(2.853)(1.12)(4)(98.7)$$
$= 1255$ $C_p = 1.12$ FROM FIG. B-1

$R_{TP} = 1255$ 1 KT.
$= 18080$ 12 KT.

METHOD 5

$$K = 1.14(98.7)(\tfrac{1}{2})(1.9905)(4)(2.853)$$
$= 1278$

$R_{TP} = 1278$ (1 KT.)
$= 184032$ (12 KT.)

CONCLUSIONS

IF THE COEFFICIENT OF 1.19 IN METHOD 3 IS INCREASED BY 10% TO GIVE $C_p = 1.31$ THEN METHODS 3, 4 & 5 WILL GIVE CLOSE AGREEMENT. AS SEEN IN FIGURE B-2 THIS PRODUCES A SMALL CHANGE OF SLOPE FOR THE LINE WHICH GIVES A COEFFICIENT OF 1.19. BECAUSE THE DATA DOES SHOW SCATTER IN THE AREA OF INTEREST, SOME CONSERVATISM IS CALLED FOR.

FINAL EQUATION FOR PROPELLER DRAG

$$R_P = 1.31\, A_P V^2 \quad \text{OR} \quad R_P = 1.31(2.853)\, A_P V_K^2$$

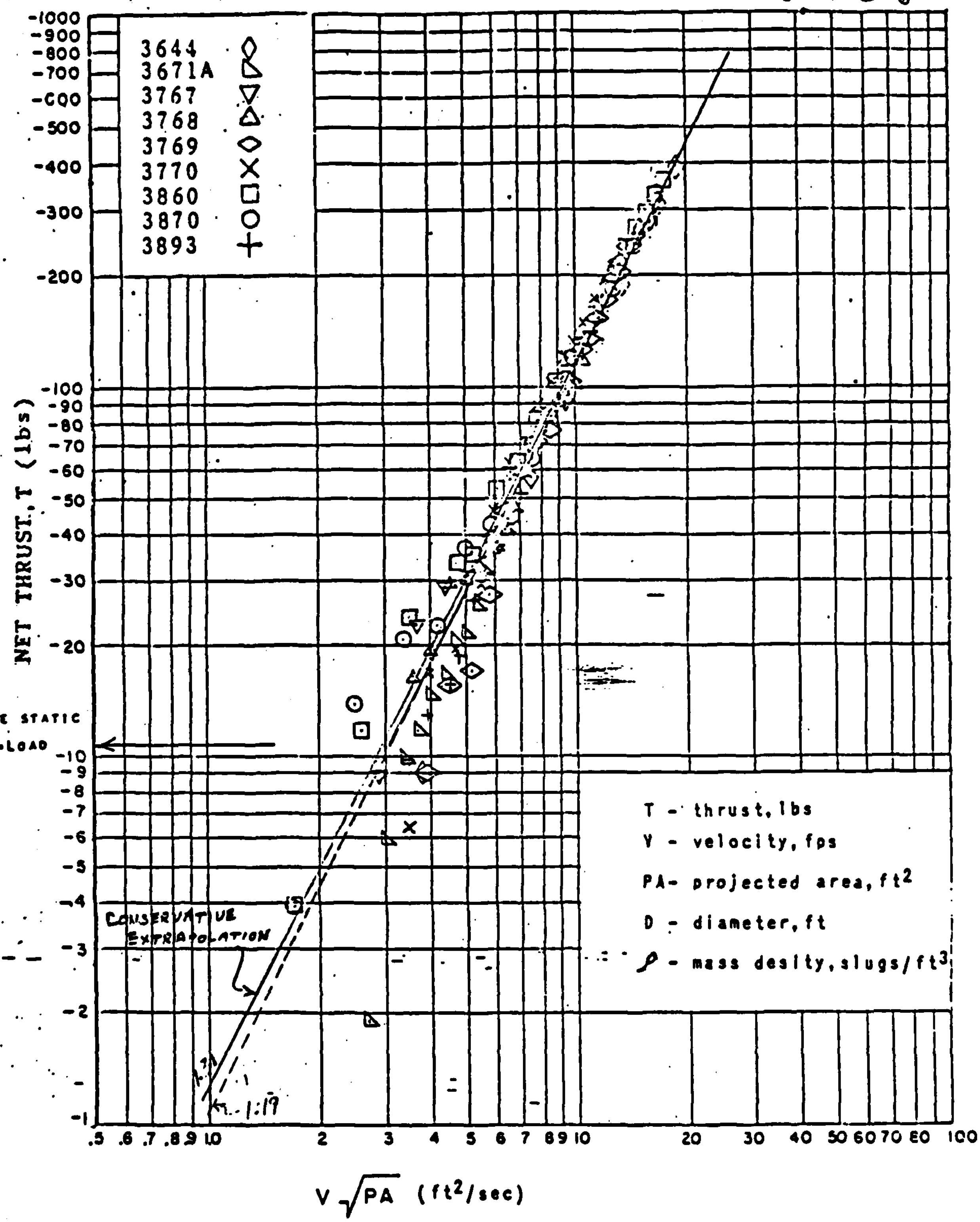

Figure B-2 - Thrust Developed by Nonrotating Propellers

APPENDIX C

CALCULATIONS FOR ADDED RESISTANCE IN WAVES

Appendix C

As with Appendix A the unabridged report contains all of the detailed calculations (sheets 1-57) while the abridged report contains only sample calculations. The added resistance in waves is calculated by two methods. The first is very approximate and utilizes a formula derived by Jacobs and Lewis for a stationary ship in waves. This serves as a rough check for the second method which utilizes the seakeeping tables of reference 22.

List of Ships and in Study

Number of Added Resistance Curve (See Fig.4&5)	Ship Class	Sheet number for Detailed Calculations
1	MSO-422	2
2	ATF-148	9
3	CGN-25	16
4	FF-1040	22
5	AOR-1	28
6	AOE-1	34
7	CA-139	40
8	AF-58	46
9	LST-1179	51

M. Rosenblatt & Son, Inc.
DESIGN CALCULATION SHEET

No. 3419
Sheet 1 of 57

Subject: ADDED RESISTANCE FOR SEA STATE
Ship or Project: TOWING RESISTANCE
Section: Prepared by: RCS Date: 2/20/76 Checked: Reviewed:

The calculation below compares the added resistance in waves obtained from the formula of Jacobs and Lewis with the seakeeping standard series. The formula of Jacobs and Lewis is applicable for stationary ships in short waves where resistance due to pitching and heaving is assumed negligible. The authors of the seakeeping standard series have stated the added resistance calculated will generally be high for low FROUDE numbers and for long waves. Because the lowest non-dimensional seastate ratio is 0.015, the larger ships have no added resistance values calculated for Beafort numbers below 5 so correlation is conducted for a significant wave height of 5.0 FT. TO CHECK the extrapolation of the data.

FORMULA DERIVED BY JACOBS & LEWIS:

$$R = 0.174\, g \rho \left(h/2\right)^{1.67} \left(\sin \alpha\right)^{0.33} B^{1.33}$$

α = 1/2 ANGLE OF MEAN WATERLINE, h = WAVE HEIGHT

SHIP No.	SHIP	SIG. WAVE HEIGHT FT. (h)	BEAM (B) FT.	α (ASSUMED) DEG.	RESIS. R lb.	STD. SERIES RESIS. lb.
1	MSO 422	5.0	34.6	7°	2843	2700
2	ATF 148	"	44.9	9°	4421	3650
3	CGN 25	"	56.66	10°	6166	1800
4	FF 1040	"	44.2	8°	4166	1800
5	AOR-1	"	96.0	10°	12604	4000
6	AOE-1	"	107	6°	12300	4000
7	CA 139	"	75.4	9°	8822	4000
8	AF 58	"	72.0	10°	8590	4000
9	LST 1179	"	68.0	10°	7960	4000

M. Rosenblatt & Son, Inc.
DESIGN CALCULATION SHEET

No. 3419
Sheet 2 of 57

Subject: ADDED RESISTANCE FOR SEA STATE - MSO 422
Ship or Project: TOWING RESISTANCE
Section: Prepared by: RCS   Date: 11/11/75   Checked: Reviewed:

CALCULATIONS FOR SHIP MSO-422

FOR ALL CALCULATIONS THE FOLLOWING RELATIONSHIPS APPLY:

$LBP/LWL = 0.983$ (ASSUMED)

$L = LBP = 0.983(165.2) = 162.39$

FROUDE No. OF 0.10 = 4.32 KT.

$B/T = 3.295$, $L/B = 4.693$ $CB = 0.522$

$B/T^{+} = 4.0$ $B/T^{-} = 3.0$

$L/B^{+} = 7.0$ $L/B^{-} = 5.5$

$CB^{+} = 0.60$ $CB^{-} = 0.55$

CALM WATER RESISTANCE AT 4.32 KT. = 1162 LB.

$$\text{MULTIPLIER} = \frac{.99(LBP)^3}{10^7} = 27.425$$

CALC. No.	FR. No.	SIGNIFICANT WAVE HGT. FT.	COEFF.	COEFF. MULT.	ADDED RESIS. LB.	CALM WATER RESIS. LB.	S_1
1	0.10	2.44	11.96	27.425	328	1162	1.28
2	0.10	4.06	68.93	"	1890	"	2.63
3	0.10	3.24	36.50	"	1001	"	1.86
4	0.10	12.18	279.5	"	7665	"	7.60
5	0.10	6.5	166.2	"	4558	"	4.92

M. Rosenblatt & Son, Inc.
DESIGN CALCULATION SHEET

No. 3419
Sheet 3 of 57

Subject: ADDED RESISTANCE FOR SEA STATE - MSO422
Ship or Project: TOWING RESISTANCE
Section:
Prepared by: RCS
Date: 11/23/75
Checked:
Reviewed:

CALCULATION #1 FROUDE # = 0.10 (4.32 KT.)
SEA STATE = 0.015 $H^{1/3}$ = 2.44 FT.

$F^+ = 0.15$ $F^- = 0.10$
$S^+ = 0.020$ $S^- = 0.015$

CALCULATION #2 FROUDE # = 0.10
SEA STATE = 0.025 $H^{1/3}$ = 4.06 FT.
$F^+ = 0.15$ $F^- = 0.10$
$S^+ = 0.030$ $S^- = 0.025$

CALCULATION #3 FROUDE # = 0.10
SEA STATE = 0.02 $H^{1/3}$ = 3.24'
$F^+ = 0.15$ $F^- = 0.10$
$S^+ = 0.025$ $S^- = 0.02$

CALCULATION #4 FROUDE # = 0.10
SEA STATE S = 0.075 $H^{1/3}$ = 12.18 FT.
$F^+ = 0.15$ $F^- = 0.10$
$S^+ = 0.10$ $S^- = 0.075$

CALCULATION #5 FROUDE # = 0.10
SEA STATE = 0.04 $H^{1/3}$ = 6.50
$F^+ = 0.15$ $F^- = 0.10$
$S^+ = 0.050$ $S^- = 0.040$

M. Rosenblatt & Son, Inc.

DESIGN CALCULATION SHEET CALCULATION #1

No. 3419

Sheet 4 of 57

Subject: ADDED RESISTANCE FOR SEA STATE - MASO 422

Ship or Project: EMER. TOWING GEAR

Section: Prepared by: RCS Date: 11/12/75 Checked: Reviewed:

#1		$\frac{F-F^-}{F^+-F^-} = 0$	$\frac{S-S^-}{S^+-S^-} = 0$	$\frac{(B/T)-(B/T)^-}{B/T^+-B/T^-} = 0.295$	$\frac{L/B-L/B^-}{L/B^+-L/B^-} = -0.553$	$\frac{CB-CB^-}{CB^+-CB^-} = -0.56$
COLUMN	1	2	3	4	5	6
LINE		FOR DESIRED FROUDE No.	FOR DESIRED SEA STATE	FOR DESIRED B/T	FOR DESIRED L/B	FOR DESIRED CB
1	11	11				
2	9		11			
3	32	32				
4	32			11.59		
5	13	13				
6	12		13			
7	34	34				
8	34				12.13	
9	10	10				
10	9		10			
11	25	25				
12	27			10.59		
13	12	12				
14	11		12			
15	27	27				11.96
16	28					
17	11	11				
18	9		11			
19	32	32				
20	32			11.89		
21	14	14				
22	12		14			
23	35	35				
24	35				12.43	
25	10	10				
26	9		10			
27	26	26				
28	27			10.89		
29	13	13				
30	12		13			
31	29	29				
32	9					

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DESIGN CALCULATION SHEET — CALCULATION #2

No. 3419

Sheet 5 of 57

Subject: ADDED RESISTANCE FOR SEA STATE - MSO 422

Ship or Project: EMER. TOWING GEAR

Section: | Prepared by: RCS | Date: 11/13/75 | Checked: | Reviewed:

#2		$\frac{F-F^{\circ}}{F^{+}-F^{\circ}}=0$	$\frac{S-S^{\circ}}{S^{+}-S^{\circ}}=0$	$\frac{(B/T)-(B/T)^{\circ}}{B/T^{+}-B/T^{\circ}}=0.295$	$\frac{L/B-L/B^{\circ}}{L/B^{+}-L/B^{\circ}}=0.53$	$\frac{CB-CB^{\circ}}{CB^{+}-CB^{\circ}}=0.56$
COLUMN	1	2	3	4	5	6
LINE		FOR DESIRED FROUDE No.	FOR DESIRED SEA STATE	FOR DESIRED B/T	FOR DESIRED L/B	FOR DESIRED CB
1	61	61				
2	65		61			
3	91	91				
4	103			60.705		
5	60	60				
6	65		60			
7	89	88				
8	99				69.69	
9	44	44				
10	51		44			
11	63	63				
12	76			44		
13	44	44				
14	49		44			
15	63	63				
16	71					68.93
17	62	62				
18	66		62			
19	95	95				
20	106			62.59		
21	64	64				
22	67		64			
23	94	99				
24	102				71.04	
25	46	46				
26	52		46			
27	67	67				
28	78			46.88		
29	49	49				
30	52		49			
31	67	69				
32	76					

M. Rosenblatt & Son, Inc. No. 3419

DESIGN CALCULATION SHEET CALCULATION #3 Sheet 6 of 57

Subject: ADDED RESISTANCE FOR SEA STATE – MSO 422

Ship or Project: EMER. TOWING GEAR

Section: Prepared by: RCS Date: 11/ Checked: Reviewed:

#3		$\frac{F-F^{\circ}}{F^{+}-F^{\circ}}=0$	$\frac{S-S^{\circ}}{S^{+}-S^{\circ}}=0$	$\frac{(B/T)-(B/T)^{\circ}}{(B/T)^{+}-(B/T)^{\circ}}=0.295$	$\frac{L/B-L/B^{\circ}}{L/B^{+}-L/B^{\circ}}=0.55?$	$\frac{CB-CB^{\circ}}{CB^{+}-CB^{\circ}}=-0.56$
COLUMN	1	2	3	4	5	6
LINE		FOR DESIRED FROUDE No.	FOR DESIRED SEA STATE	FOR DESIRED B/T	FOR DESIRED L/B	FOR DESIRED CB
1	32	32				
2	32		32			
3	61	61				
4	65			32.59		
5	34	34				
6	34		34			
7	60	60				
8	65				36.36	
9	25	25				
10	27		25			
11	44	44				
12	51			25.59		
13	27	27				
14	28		27			
15	44	44				36.50
16	49					
17	32	32				
18	32		32			
19	62	62				
20	66			32.885		
21	35	35				
22	35		35			
23	64	64				
24	67				36.11	
25	26	26				
26	27		26			
27	46	46				
28	52			26.885		
29	29	29				
30	29		29			
31	49	49				
32	57?					

M. Rosenblatt & Son, Inc. No. 3419

DESIGN CALCULATION SHEET CALCULATION #4 Sheet 7 of 57

Subject: ADDED RESISTANCE FOR SEA STATE – MSO 422

Ship or Project: EMER. TOWING GEAR

Section: Prepared by: RCS Date: 12/10/75 Checked: Reviewed:

		$\frac{F-F^-}{F^+-F^-} = 0$	$\frac{S-S^-}{S^+-S^-} = 0$	$\frac{(B/T)-(B/T)^-}{B/T^+-B/T^-} = 0.295$	$\frac{L/B-L/B^-}{L/B^+-L/B^-} = -0.538$	$\frac{CB-CB^-}{CB^+-CB^-} = -0.56$
COLUMN	1	2	3	4	5	6
LINE		FOR DESIRED FROUDE No.	FOR DESIRED SEA STATE	FOR DESIRED B/T	FOR DESIRED L/B	FOR DESIRED CB
1	248	248				
2	332		248			
3	282	282				
4	405			243		
5	231	231				
6	305		231			
7	262	262				
8	377				289.5	
9	158	158				
10	217		158			
11	178	178				
12	262			156.53		
13	153	153				
14	203		153			
15	172	172				
16	250					279.48
17	263	263				
18	352		263			
19	300	300				
20	434			260.1		
21	253	253				
22	331		253			
23	289	289				
24	418				307.4	
25	172	172				
26	233		172			
27	194	194				
28	285			172.3		
29	173	173				
30	[illegible]		173			
31	195	195				

M. Rosenblatt & Son, Inc.

DESIGN CALCULATION SHEET CALCULATION #5

No. 3417

Sheet 8 of 57

Subject ADDED RESISTANCE FOR SEA STATE – MSO 422

Ship or Project TOWING RESISTANCE

Section **Prepared by** RCS **Date** 2/2/75 **Checked** **Reviewed**

		$\frac{F-F^-}{F^+-F^-}=0$	$\frac{S-S^-}{S^+-S^-}=0$	$\frac{(B/T)-(B/T)^-}{B/T^+-B/T^-}=0.295$	$\frac{L/B-L/B^-}{L/B^+-L/B^-}=-0.538$	$\frac{CB-CB^-}{CB^+-CB^-}=-0.56$
COLUMN	1	2	3	4	5	6
LINE		FOR DESIRED FROUDE No.	FOR DESIRED SEA STATE	FOR DESIRED B/T	FOR DESIRED L/B	FOR DESIRED CB
1	148	148				
2	175		148			
3	191	191				
4	234			145.6		
5	140	140				
6	161		140			
7	179	179				
8	214				171.1	
9	99	99				
10	120		99			
11	124	124				
12	157			98.11		
13	96	96				
14	112		96			
15	120	120				
16	146					166.2
17	155	155				
18	181		155			
19	201	201				
20	244			154.11		
21	152	152				
22	172		152			
23	194	194				
24	230				179.8	
25	106	106				
26	128		106			
27	134	134				
28	166			106.30		
29	107	107				
30	122		107			
31	135	135				
32	160					

Subject: ADDED RESISTANCE FOR SEA STATE - ATF 148
Ship or Project: TOWING RESISTANCE
Section | Prepared by: RCS | Date: 2/3/76 | Checked | Reviewed

CALCULATIONS FOR ATF 148

$LBP/LWL = 0.983$ (ASSUMED)

$L = LBP = 0.983(224) = 220.19$

FROUDE No. FOR 12 KT. $= \frac{12. \times 1.689}{\sqrt{32.174 \times 224}} = 0.238$

USE FR. NO. = 0.15 ≡ 7.54 KT.

$B/T = 2.85$, $L/B = 4.99$, $CB = 0.459$

$B/T^{+} = 3.0$ $\quad B/T^{-} = 2.0$

$L/B^{+} = 7.0$ $\quad L/B^{-} = 5.5$

$CB^{+} = 0.60$ $\quad CB^{-} = 0.55$

STILL WATER RESISTANCE AT 7.54 KT. = 7654 LB.

MULTIPLIER $= \frac{\rho g (LBP^3)}{10^7} = 68.37$

CALC. No.	FR. No.	SIGNIFICANT WAVE HGT. FT.	COEFF.	COEFF. MULT.	ADDED RESIS. LB.	CALM WATER RESIS. LB.	S_1
1	0.15	3.3	8.35	68.37	570.8	7654	1.07
2	0.15	4.3	31.99	"	2187	"	1.29
3	0.15	6.61	106.1	"	7252	"	1.94
4	0.15	16.51	346.5	"	23690	"	4.10
5	0.15	11.0	248.12	"	16964	"	3.22

M. Rosenblatt & Son, Inc.
DESIGN CALCULATION SHEET

No. 3419
Sheet 10 of 57

Subject: ADDED RESISTANCE FOR SEA STATE - ATF 148
Ship or Project: TOWING RESISTANCE
Section: | Prepared by: RCS | Date: 2/3/76 | Checked: | Reviewed:

CALCULATION #1 FROUDE No. = 0.15 (7.54 KT.)
SEA STATE = 0.015 $H_{1/3}$ = 3.30 FT.

F^+ = 0.20 F^- = 0.15
S^+ = 0.020 S^- = 0.015

CALCULATION #2 FROUDE No. = 0.15
SEA STATE = 0.020 $H_{1/3}$ = 4.40 FT.

F^+ = 0.20 F^- = 0.15
S^+ = 0.030 S^- = 0.020

CALCULATION #3 FROUDE No. = 0.15
SEA STATE = 0.03 $H_{1/3}$ = 6.61 FT.

F^+ = 0.20 F^- = 0.15
S^+ = 0.04 S^- = 0.03

CALCULATION #4 FROUDE No. = 0.15
SEA STATE = 0.075 $H_{1/3}$ = 16.51 FT.

F^+ = 0.20 F^- = 0.15
S^+ = 0.10 S^- = 0.075

CALCULATION #5 FROUDE No. = 0.15
SEA STATE = 0.05 $H_{1/3}$ = 11.0 FT.

F^+ = 0.20 F^- = 0.15
S^+ = 0.075 S^- = 0.050

DESIGN CALCULATION SHEET CALCULATION #1 Sheet 11 of [illegible]

Subject: ADDED RESISTANCE FOR SEA STATE – ATF 148

Ship or Project: TOWING RESISTANCE

Section: Prepared by: RCS Date: 2/3/76 Checked: Reviewed:

		$\frac{F-F^-}{F^+-F^-}=0$	$\frac{S-S^-}{S^+-S^-}=0$	$\frac{(B/T)-(B/T)^-}{(B/T)^+-(B/T)^-}=0.85$	$\frac{L/B-L/B^-}{L/B^+-L/B^-}=-0.5$[illegible]	$\frac{C_B-C_B^-}{C_B^+-C_B^-}=-1.82$
COLUMN	1	2	3	4	5	6
LINE		FOR DESIRED FROUDE No.	FOR DESIRED SEA STATE	FOR DESIRED B/T	FOR DESIRED L/B	FOR DESIRED CB
1	5	5				
2	3		5			
3	23	23				
4	17			8.4		
5	9	9				
6	7		9			
7	32	32				
8	31				8.35	
9	6	6				
10	5		6			
11	25	25				
12	25			8.55		
13	9	9				
14	8		9			
15	27	27				8.35
16	29					
17	5	5				
18	3		5			
19	23	23				
20	16			8.4		
21	9	9				
22	7		9			
23	32	32				
24	31					
25	6	6			8.35	
26	4		6			
27	25	25				
28	24					
29	9	9		8.55		
30	8		9			
31	27	27				
32	29					

DESIGN CALCULATION SHEET — CALCULATION #2

Subject: ADDED RESISTANCE FOR SEA STATE - ATF 148

Ship or Project: TOWING RESISTANCE

Section: | Prepared by: RCS | Date: 2/3/76 | Checked: | Reviewed:

		$\frac{F-F^-}{F^+-F^-}=0$	$\frac{S-S^-}{S^+-S^-}=0$	$\frac{(B/T)-(B/T)^-}{B/T^+-B/T^-}=0.85$	$\frac{L/B-L/B^-}{L/B^+-L/B^-}=-.34$	$\frac{CB-CB^-}{CB^+-CB^-}=-1.82$
COLUMN	1	2	3	4	5	6
LINE		FOR DESIRED FROUDE No.	FOR DESIRED SEA STATE	FOR DESIRED B/T	FOR DESIRED L/B	FOR DESIRED CB
1	23	23				
2	17		23			
3	59	59				
4	56			30.65		
5	32	32				
6	31		32			
7	65	65				
8	70				31.99	
9	25	25				
10	25		25			
11	54	54				
12	58			26.7		
13	27	27				
14	29		27			
15	51	51				
16	57					31.99
17	23	23				
18	16		23			
19	60	60				
20	56			30.65		
21	32	32				
22	31		32			
23	66	66				
24	70				31.99	
25	25	25				
26	24		25			
27	54	54				
28	58					
29	27	27		26.7		
30	29					
31	52	52	27			
32	57					

DESIGN CALCULATION SHEET CALCULATION #3

Subject: ADDED RESISTANCE FOR SEA STATE – ATF 148

Ship or Project: TOWING RESISTANCE

Section: | Prepared by: RCS | Date: 2/3/76 | Checked: | Reviewed:

		$\frac{F-F^-}{F^+-F^-}=0$	$\frac{S-S^-}{S^+-S^-}=0$	$\frac{(B/T)-(B/T)^-}{B/T^+-B/T^-}=0.85$	$\frac{L/B-L/B^-}{L/B^+-L/B^-}=-.034$	$\frac{CB-CB^-}{CB^+-CB^-}=-1.82$
COLUMN	1	2	3	4	5	6
LINE		FOR DESIRED FROUDE No.	FOR DESIRED SEA STATE	FOR DESIRED B/T	FOR DESIRED L/B	FOR DESIRED CB
1	105	105				
2	107		105			
3	203	203				
4	229			103.3		
5	103	103				
6	116		103			
7	175	175				
8	202				111.97	
9	88	88				
10	99		88			
11	147	147				
12	174			77.8		
13	76	76				
14	88		76			
15	120	120				
16	141					106.1
17	107	107				
18	108		107			
19	208	208				
20	234			106.15		
21	106	106				
22	117		106			
23	181	181				
24	208				115.21	
25	88	88				
26	99		88			
27	149	149				
28	176			79.5		
29	78	78				
30	89		78			
31	126	126				
32	146					

DESIGN CALCULATION SHEET CALCULATION #4 Sheet 14 of 5

Subject ADDED RESISTANCE FOR SEA STATE — ATF 148

Ship or Project TOWING RESISTANCE

Section Prepared by RCS Date 2/3/76 Checked Reviewed

		$\frac{F-F^-}{F^+-F^-}=0$	$\frac{S-S^-}{S^+-S^-}=0$	$\frac{(B/T)-(B/T)^-}{B/T^+-B/T^-}=0.85$	$\frac{L/B-L/B^-}{L/B^+-L/B^-}=-0.34$	$\frac{CB-CB^-}{CB^+-CB^-}=-1.82$
COLUMN	1	2	3	4	5	6
LINE		FOR DESIRED FROUDE No.	FOR DESIRED SEA STATE	FOR DESIRED B/T	FOR DESIRED L/B	FOR DESIRED CB
1	412	412				
2	509		412			
3	496	496				
4	632			344		
5	332	332				
6	416		332			
7	405	405				
8	528				384.38	
9	272	272				
10	344		272			
11	322	322				
12	421			225.25		
13	217	217				
14	275		217			
15	262	262				
16	346					341.5
17	427	427				
18	528		427			
19	516	516				
20	660			363.25		
21	352	352				
22	441		352			
23	434	434				
24	568				405.19	
25	279	279				
26	355		279			
27	334	334				
28	439			239.9		
29	233	233				
30	294		233			
31	285	285				
32	372					

No. 3711

DESIGN CALCULATION SHEET — CALCULATION #5 — Sheet 15 of 5

Subject: ADDED RESISTANCE FOR SEA STATE - ATF 148

Ship or Project: TOWING RESISTANCE

Section: — Prepared by: RCS — Date: 2/4/76 — Checked: — Reviewed:

		$\frac{F-F^-}{F^+-F^-}=0$	$\frac{S-S^-}{S^+-S^-}=0$	$\frac{(B/T)-(B/T)^-}{B/T^+-B/T^-}=0.85$	$\frac{L/B-L/B^-}{L/B^+-L/B^-}=-0.34$	$\frac{CB-CB^-}{CB^+-CB^-}=-1.82$
COLUMN	1	2	3	4	5	6
LINE		FOR DESIRED FROUDE No.	FOR DESIRED SEA STATE	FOR DESIRED B/T	FOR DESIRED L/B	FOR DESIRED CB
1	278	278				
2	321		278			
3	412	412				
4	509			240.6		
5	234	234				
6	277		234			
7	332	332			267.04	
8	416					
9	196	196				
10	237		196			
11	272	272				
12	344			162.85		
13	157	157				
14	190		157			
15	217	217				
16	275					248.12
17	287	287				
18	331		287			
19	427	427				
20	528			250.45		
21	244	244				
22	288		244			
23	352	352				
24	441					
25	200	200			277.43	
26	242		200			
27	279	279				
28	355					
29	166	166		171.1		
30	198		166			
31	233	233				
32	294					

Subject: ADDED RESISTANCE FOR SEA STATE – CGN-25
Ship or Project: TOWING RESISTANCE
Section: Prepared by: RCS Date: 2/4/76 Checked: Reviewed:

CALCULATIONS FOR SHIP – CGN-25

$LBP/LWL = 0.983$ (ASSUMED)
$L = LBP = 0.983\ (540) = 530.82$

FROUDE No. FOR 12 KT. $= \dfrac{12.0 \times 1.6889}{\sqrt{32.174 \times (540)}} = 0.153$

USE FROUDE No. $= 0.10 \equiv 7.8$ KT.

$B/T = 3.0$, $L/B = 9.53$, $CB = 0.472$

$B/T^{+} = 4.0$ $B/T^{-} = 3.0$
$L/B^{+} = 8.5$ $L/B^{-} = 7.0$
$CB^{+} = 0.60$ $CB^{-} = 0.55$

CALM WATER RESISTANCE AT 7.8 KT. = 22386

MULTIPLIER $= \dfrac{\rho g\,(LBP)^3}{10^7} = 957.87$

CALC. No.	FR. No.	SIGNIFICANT WAVE HGT. FT.	COEFF.	COEFF. MULT.	ADDED RESIS. LB.	CALM WATER RESIS. LB.	S_1
1	0.10	7.96	7.31	957.87	7002	22386	1.31
2	0.10	10.62	14.99	"	14358	"	1.64
3	0.10	15.92	28.03	"	26849	"	2.20
4	0.10	39.81	62.88	"	60231	"	3.69

M. Rosenblatt & Son, Inc. — DESIGN CALCULATION SHEET

No. 3419
Sheet 17 of 57

Subject: ADDED RESISTANCE FOR SEA STATE CGN-25
Ship or Project: TOWING RESISTANCE
Section: | Prepared by: RCS | Date: | Checked: | Reviewed:

CALCULATION #1 — FROUDE No. = 0.10 (7.8 KT.)
SEA STATE = 0.015 — $H\,1/3 = 7.96$ FT.

$F^+ = 0.15$ — $F^- = 0.10$
$S^+ = 0.020$ — $S^- = 0.015$

CALCULATION #2 — FROUDE No. = 0.10 (7.8 KT.)
SEA STATE = 0.020 — $H\,1/3 = 10.62$ FT.

$F^+ = 0.15$ — $F^- = 0.10$
$S^+ = 0.025$ — $S^- = 0.020$

CALCULATION #3 — FROUDE No. = 0.10 (7.8 KT.)
SEA STATE = 0.030 — $H\,1/3 = 15.92$ FT.

$F^+ = 0.15$ — $F^- = 0.10$
$S^+ = 0.040$ — $S^- = 0.030$

CALCULATION #4 — FROUDE No. = 0.10 (7.8 KT.)
SEA STATE = 0.075 — $H\,1/3 = 39.81$ FT.

$F^+ = 0.15$ — $F^- = 0.10$
$S^+ = 0.100$ — $S^- = 0.075$

CALCULATION #5 — FROUDE No. = (KT.)
SEA STATE = — $H\,1/3 =$ FT.

$F^+ =$ — $F^- =$
$S^+ =$ — $S^- =$

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DESIGN CALCULATION SHEET CALCULATION #1 No. 5717 Sheet 18 of 5

Subject: ADDED RESISTANCE FOR SEA STATE – CGN-25

Ship or Project: TOWING RESISTANCE

Section: Prepared by: RCS Date: 2/4/76 Checked: Reviewed:

		$\frac{F - F^-}{F^+ - F^-} = 0$	$\frac{S - S^-}{S^+ - S^-} = 0$	$\frac{(B/T) - (B/T)^-}{B/T^+ - B/T^-} = 1$	$\frac{L/B - L/B^-}{L/B^+ - L/B^-} = 1.69$	$\frac{CB - CB^-}{CB^+ - CB^-} = -1.56$
COLUMN	1	2	3	4	5	6
LINE		FOR DESIRED FROUDE No.	FOR DESIRED SEA STATE	FOR DESIRED B/T	FOR DESIRED L/B	FOR DESIRED CB
1	8	8				
2	6		8			
3	26	26				
4	25			10		
5	10	10				
6	9		10			
7	25	25			7.31	
8	27					
9	7	7				
10	7		7			
11	21	21				
12	23			9		
13	9	9				
14	8		9			
15	20	20				7.31
16	22					
17	8	8				
18	6		8			
19	26	26				
20	25			10		
21	10	10				
22	9		10			
23	26	26				
24	27					
25	7	7			7.31	
26	6		7			
27	21	21				
28	22			9		
29	9	9				
30	9		9			
31	21	21				
[illegible]	[illegible]					

M. Rosenblatt & Son, Inc. — No. 5711

DESIGN CALCULATION SHEET — CALCULATION #2 — Sheet 17 of 57

Subject: ADDED RESISTANCE FOR SEA STATE — CGN-25

Ship or Project: TOWING RESISTANCE

Section: — Prepared by: RCS — Date: 2/4/76 — Checked: — Reviewed:

		$\frac{F^{\cdot} - F^{-}}{F^{+} - F^{-}} = 0$	$\frac{S - S^{-}}{S^{+} - S^{-}} = 0$	$\frac{(B/T) - (B/T)^{-}}{B/T^{+} - B/T^{-}} = 0$	$\frac{L/B - L/B^{-}}{L/B^{+} - L/B^{-}} = 1.69$	$\frac{CB - CB^{-}}{CB^{+} - CB^{-}} = -1.56$
COLUMN	1	2	3	4	5	6
LINE		FOR DESIRED FROUDE No.	FOR DESIRED SEA STATE	FOR DESIRED B/T	FOR DESIRED L/B	FOR DESIRED CB
1	25	25				
2	27		25			
3	44	44				
4	51			25		
5	27	27				
6	28		27			
7	44	44				
8	49				16.55	
9	20	20				
10	22		20			
11	33	33				
12	38			20		
13	21	21				
14	23		21			
15	34	34				
16	38					14.99
17	26	26				
18	27		26			
19	46	46				
20	52			26		
21	29	29				
22	29		29			
23	49	49				
24	52				17.55	
25	21	21				
26	23		21			
27	36	36				
28	40			21		
29	24	24				
30	24		24			
31	38	38				
32	41					

M. Rosenblatt & Son, Inc.

DESIGN CALCULATION SHEET CALCULATION #[illegible]

No. 3419

Sheet [illegible] of [illegible]

Subject: ADDED RESISTANCE FOR SEA STATE - [illegible]

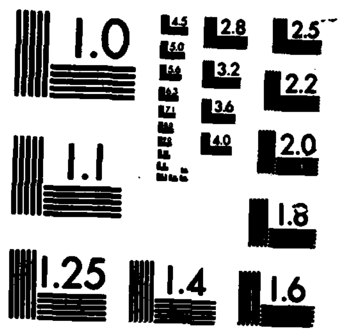
Ship or Project: TOWING RESISTANCE

Section: Prepared by RCS Date 2/4/76 Checked Reviewed

		$\frac{F-F^-}{F^+-F^-}=0$	$\frac{S-S^-}{S^+-S^-}=0$	$\frac{(B/T)-(B/T)^-}{B/T^+-B/T^-}=0$	$\frac{L/B-L/B^-}{L/B^+-L/B^-}=1.69$	$\frac{CB-CB^-}{CB^+-CB^-}=-1.56$
COLUMN	1	2	3	4	5	6
LINE		FOR DESIRED FROUDE No.	FOR DESIRED SEA STATE	FOR DESIRED B/T	FOR DESIRED L/B	FOR DESIRED CB
1	63	63				
2	76		63			
3	99	99				
4	120			63		
5	63	63				
6	71		63			
7	96	96				
8	112				34.27	
9	46	46				
10	55		46			
11	69	69				
12	86			46		
13	47	47				
14	53		47			
15	70	70				
16	82					28.03
17	67	67				
18	78		67			
19	106	106				
20	126			67		
21	69	69				
22	76		69			
23	107	107				
24	122				38.27	
25	50	50				
26	58		50			
27	77	77				
28	92			50		
29	53	53				
30	58		53			
31	80	80				
32	97					

AD-A150 941 DEVELOPMENT OF A CALCULATION PROCEDURE FOR THE DETERMINATION OF TOW RESISTANCE (UNABRIDGED REPORT)(U) ROSENBLATT (M) AND SON INC NEW YORK APR 76 5/6

UNCLASSIFIED N00024-74-C-5508 F/G 13/10 NL



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

M. Rosenblatt & Son, Inc. No. 3417

DESIGN CALCULATION SHEET — CALCULATION #4 — Sheet 21 of 57

Subject: ADDED RESISTANCE FOR SEA STATE - CGN-25

Ship or Project: TOWING RESISTANCE

Section: Prepared by: RCS Date: 2/4/76 Checked: Reviewed:

		$\frac{F-F^-}{F^+-F^-}=0$	$\frac{S-S^-}{S^+-S^-}=0$	$\frac{(B/T)-(B/T)^-}{B/T^+-B/T^-}=0$	$\frac{L/B-L/B^-}{L/B^+-L/B^-}=1.69$	$\frac{CB-CB^-}{CB^+-CB^-}=-1.56$
COLUMN	1	2	3	4	5	6
LINE		FOR DESIRED FROUDE No.	FOR DESIRED SEA STATE	FOR DESIRED B/T	FOR DESIRED L/B	FOR DESIRED CB
1	158	158				
2	217		158			
3	178	178				
4	262			158		
5	153	153				
6	203		153			
7	172	172				
8	250				75.19	
9	109	109				
10	150		109			
11	122	122				
12	182			109		
13	145	145				
14	183		145			
15	178	178				
16	236					62.88
17	172	172				
18	233		172			
19	194	194				
20	285			172		
21	173	173				
22	228		173			
23	195	195				
24	283				87.5	
25	122	122				
26	165		122			
27	137	137				
28	203			122		
29	125	125				
30	167		125			
31	139	139				
32	206					

M. Rosenblatt & Son, Inc.
DESIGN CALCULATION SHEET

No. 3419
Sheet 22 of 57

Subject: ADDED RESISTANCE FOR SEA STATE - FF 1040

Ship or Project: TOWING RESISTANCE

Section | Prepared by RCS | Date 11/23/75 | Checked | Reviewed

CALCULATIONS FOR SHIP FF 1040

$LBP/LWL = 0.983$ (ASSUMED)

$L = LBP = 0.983\,(390) = 383.37$

FROUDE No. FOR 12 KT. $= \dfrac{12.0 \times 1.6889}{\sqrt{32.174 \times 390}} = 0.18$ USE FROUDE NO. = 0.15

$B/T = 3.157$, $L/B = 8.67$, $CB = 0.454$

$B/T^{+} = 4.0$ $\quad B/T^{-} = 3.0$

$L/B^{+} = 8.5$ $\quad L/B^{-} = 7.0$

$CB^{+} = 0.60$ $\quad CB^{-} = 0.55$

FROUDE No. = 0.15 SPEED = 9.94 KT.

CALM WATER RESISTANCE AT 10 KT. = 22820

MULTIPLIER $= \dfrac{\rho g\,(LBP)^3}{10^7} = 360.8$

CALC. No.	FR. No.	SIGNIFICANT WAVE HGT. FT.	COEFF.	COEFF. MULT.	ADDED RESIS. LB.	CALM WATER RESIS. LB.	S_1
1	0.15	5.75	7.0	360.8	2526	22820	1.11
2	0.15	11.5	47.11	"	16997	"	1.74
3	0.15	28.75	104.8	"	37801	"	2.66
4	0.15	9.58	31.8	"	11427	"	1.5

M. Rosenblatt & Son, Inc.
DESIGN CALCULATION SHEET

No. 3419
Sheet 23 of 57

Subject: ADDED RESISTANCE - SEA STATE - FF1040
Ship or Project: TOWING RESISTANCE
Section: Prepared by: RCS Date: 12/10/75 Checked: Reviewed:

CALCULATION #1 FROUDE # = 0.15 (9.94 KT.)
SEA STATE = 0.015 $H^{1/3}$ = 5.75

F^+ = 0.20 F^- = 0.15
S^+ = 0.020 S^- = 0.015

CALCULATION #2 FROUDE # = 0.15
SEA STATE = 0.30 (11.5 FT.)

F^+ = 0.20 F^- = 0.15
S^+ = 0.040 S^- = 0.030

CALCULATION #3 FROUDE # = 0.15
SEA STATE = 0.075 (28.75 FT.)

F^+ = 0.20 F^- = 0.15
S^+ = 0.100 S^- = 0.075

CALCULATION #4 FROUDE # = 0.15
SEA STATE = 0.025 (9.58 FT.)

F^+ = 0.20 F^- = 0.15
S^+ = 0.030 S^- = 0.025

M. Rosenblatt & Son, Inc. No. 3419

DESIGN CALCULATION SHEET CALCULATION #1 Sheet 24 of 57

Subject: ADDED RESISTANCE FOR SEA STATE – FF 1040

Ship or Project: TOWING RESISTANCE

Section: Prepared by: RCS Date: 12/10/75 Checked: Reviewed:

		$\frac{F-F^-}{F^+-F^-} = 0$	$\frac{S-S^-}{S^+-S^-} = 0$	$\frac{(B/T)-(B/T)^-}{B/T^+ - B/T^-} = 0.157$	$\frac{L/B - L/B^-}{L/B^+ - L/B^-} = 1.213$	$\frac{CB - CB^-}{CB^+ - CB^-} = -1.92$
COLUMN	1	2	3	4	5	6
LINE		FOR DESIRED FROUDE No.	FOR DESIRED SEA STATE	FOR DESIRED B/T	FOR DESIRED L/B	FOR DESIRED CB
1	9	9				
2	8		9			
3	27	27				
4	29			9.3		
5	11	11				
6	10		11			
7	28	28				
8	29				8.1	
9	8	8				
10	8		8			
11	22	22				
12	24			8.3		
13	10	10				
14	9		10			
15	23	23				
16	24					7.0
17	9	9				
18	8		9			
19	27	27				
20	29			9.5		
21	12	12				
22	10		12			
23	29	29				
24	30				9.3	
25	9	9				
26	8		9			
27	23	23				
28	24			9.3		
29	11	11				
30	10		11			
31	24	24				
32	25					

M. Rosenblatt & Son, Inc.

No. 3419

DESIGN CALCULATION SHEET — CALCULATION #2 — Sheet 25 of 57

Subject: ADDED RESISTANCE - SEA STATE - FF 1040

Ship or Project: TOWING RESISTANCE

Section — Prepared by: RCS — Date: 2/2/76 — Checked — Reviewed

		$\frac{F-F^-}{F^+-F^-}=0$	$\frac{S-S^-}{S^+-S^-}=0$	$\frac{(B/T)-(B/T)^-}{B/T^+-B/T^-}=0.157$	$\frac{L/B-L/B^-}{L/B^+-L/B^-}=1.213$	$\frac{CB-CB^-}{CB^+-CB^-}=-1.92$
COLUMN	1	2	3	4	5	6
LINE		FOR DESIRED FROUDE No.	FOR DESIRED SEA STATE	FOR DESIRED B/T	FOR DESIRED L/B	FOR DESIRED CB
1	76	76				
2	88		76			
3	120	120				
4	141			75.22		
5	71	71				
6	79		71			
7	112	112				
8	128				50.32	
9	55	55				
10	64		55			
11	86	86				
12	102			54.69		
13	53	53				
14	60		53			
15	82	82				
16	94					47.11
17	78	78				
18	89		78			
19	126	126				
20	146			77.69		
21	76	76				
22	83		76			
23	122	122				
24	137				53.81	
25	58	58				
26	66		58			
27	92	92				
28	107			58		
29	58	58				
30	64					
31	92		58			

M. Rosenblatt & Son, Inc.

DESIGN CALCULATION SHEET — CALCULATION #3

No. 3419

Sheet 26 of 57

Subject: ADDED RESISTANCE - SEA STATE - FF 1040

Ship or Project: TOWING RESISTANCE

Section: — Prepared by: RCS — Date: 2/2/76 — Checked: — Reviewed:

		$\frac{F-F^-}{F^+-F^-}=0$	$\frac{S-S^-}{S^+-S^-}=0$	$\frac{(B/T)-(B/T)^-}{B/T^+-B/T^-}=0.157$	$\frac{L/B-L/B^-}{L/B^+-L/B^-}=1.213$	$\frac{CB-CB^-}{CB^+-CB^-}=-1.92$
COLUMN	1	2	3	4	5	6
LINE		FOR DESIRED FROUDE No.	FOR DESIRED SEA STATE	FOR DESIRED B/T	FOR DESIRED L/B	FOR DESIRED CB
1	253	253				
2	275		253			
3	269	269				
4	294			253.79		
5	258	258				
6	281		258			
7	275	275				
8	299				126.95	
9	150	150				
10	192		150			
11	182	182				
12	242			149.22		
13	145	145				
14	183		145			
15	178	178				
16	236					104.8
17	233	233				
18	294		233			
19	285	285				
20	377			232.22		
21	228	228				
22	283		228			
23	283	283				
24	372				151.06	
25	165	165				
26	208		165			
27	203	203				
28	268			165.31		
29	167	167				
30	208		167			
31	206	206				
32	172					

M. Rosenblatt & Son, Inc.

DESIGN CALCULATION SHEET — CALCULATION #4

No. 3419

Sheet 27 of 57

Subject: ADDED RESISTANCE - SEA STATE - FF 1040

Ship or Project: TOWING RESISTANCE

Section: | Prepared by: RCS | Date: 2/2/76 | Checked: | Reviewed:

		$\frac{F-F^-}{F^+-F^-}=0$	$\frac{S-S^-}{S^+-S^-}=0$	$\frac{(B/T)-(B/T)^-}{B/T^+-B/T^-}=0.157$	$\frac{L/B-L/B^-}{L/B^+-L/B^-}=1.213$	$\frac{C_B-C_B^-}{C_B^+-C_B^-}=-1.92$
COLUMN	1	2	3	4	5	6
LINE		FOR DESIRED FROUDE No.	FOR DESIRED SEA STATE	FOR DESIRED B/T	FOR DESIRED L/B	FOR DESIRED CB
1	51	51				
2	57		51			
3	76	76				
4	88			50.69		
5	49	49				
6	53		49			
7	71	71				
8	79				34.53	
9	38	38				
10	44		38			
11	55	55				
12	64			37.37		
13	34	34				
14	38		34			
15	47	47				
16	53					31.67
17	52	52				
18	57		52			
19	78	78				
20	89			52		
21	52	52				
22	55		52			
23	76	76				
24	83				37.64	
25	40	40				
26	45		40			
27	58	58				
28	66			40.16		
29	41	41				
30	44		41			
31	58	58				
32	[illegible]					

M. Rosenblatt & Son, Inc.
DESIGN CALCULATION SHEET

No. 3419
Sheet 23 of 57

Subject: ADDED RESISTANCE FOR SEA STATE - AOR-1
Ship or Project: TOWING RESISTANCE
Section | Prepared by: RCS | Date 2/4/76 | Checked | Reviewed

CALCULATIONS FOR SHIP - AOR-1

$LBP/LWL = 0.983$ (ASSUMED)

$L = LBP = 0.983\ (640\ ) = 629.12$

FROUDE No. FOR 12 KT. $= \dfrac{12.0 \times 1.6889}{\sqrt{32.174 \times (640\ )}} = 0.14$

USE FROUDE No. $= 0.10 \equiv 8.5$ KT.

$B/T = 2.95$, $L/B = 6.67$, $CB = 0.64$

$B/T^{+} = 3.0$ $\quad B/T^{-} = 2.0$

$L/B^{+} = 7.0$ $\quad L/B^{-} = 5.5$

$CB^{+} = 0.65$ $\quad CB^{-} = 0.60$

CALM WATER RESISTANCE AT 8.5 KT. = 48077

MULTIPLIER $= \dfrac{\rho g\ (LBP)^3}{10^7} = 1594.7$

CALC. No.	FR. No.	SIGNIFICANT WAVE HGT. FT.	COEFF.	COEFF. MULT.	ADDED RESIS. LB.	CALM WATER RESIS. LB.	S_1
1	0.10	9.44	10.06	1594.7	16043	48077	1.33
2	0.10	12.58	27.26	"	43472	"	1.90
3	0.10	18.87	74.39	"	118633	"	3.47
4	0.10	31.46	154.16	"	245833	"	6.11
						"	

M. Rosenblatt & Son, Inc.
DESIGN CALCULATION SHEET

No. 3419
Sheet 29 of 57

Subject: ADDED RESISTANCE FOR SEA STATE - AOR-1
Ship or Project: TOWING RESISTANCE
Section: Prepared by: RCS Date: 2/4/76 Checked: Reviewed:

CALCULATION #1 FROUDE No. = 0.10 (8.5 KT.)
SEA STATE = 0.015 H 1/3 = 9.44 FT.

$F^+ = 0.15$ $F^- = 0.10$
$S^+ = 0.020$ $S^- = 0.015$

CALCULATION #2 FROUDE No. = 0.10 (8.5 KT.)
SEA STATE = 0.020 H 1/3 = 12.58 FT.

$F^+ = 0.20$ $F^- = 0.10$
$S^+ = 0.025$ $S^- = 0.02$

CALCULATION #3 FROUDE No. = 0.10 (8.5 KT.)
SEA STATE = 0.030 H 1/3 = 18.87 FT.

$F^+ = 0.20$ $F^- = 0.10$
$S^+ = 0.040$ $S^- = 0.03$

CALCULATION #4 FROUDE No. = 0.10 (8.5 KT.)
SEA STATE = 0.05 H 1/3 = 31.46 FT.

$F^+ = 0.20$ $F^- = 0.10$
$S^+ = 0.075$ $S^- = 0.05$

CALCULATION #5 FROUDE No. = (KT.)
SEA STATE = H 1/3 = FT.

$F^+ =$ $F^- =$
$S^+ =$ $S^- =$

DESIGN CALCULATION SHEET CALCULATION #1

No. 5711

Sheet 30 of 5

Subject ADDED RESISTANCE FOR SEA STATE – AOR-1

Ship or Project TOWING RESISTANCE

Section **Prepared by** RCS **Date** 2/4/76 **Checked** **Reviewed**

		$\frac{F-F^-}{F^+-F^-}=0$	$\frac{S-S^-}{S^+-S^-}=0$	$\frac{(B/T)-(B/T)^-}{(B/T)^+-(B/T)^-}=0.95$	$\frac{L/B-L/B^-}{L/B^+-L/B^-}=0.78$	$\frac{CB-CB^-}{CB^+-CB^-}=0.8$
COLUMN	1	2	3	4	5	6
LINE		FOR DESIRED FROUDE No.	FOR DESIRED SEA STATE	FOR DESIRED B/T	FOR DESIRED L/B	FOR DESIRED CB
1	6	6				
2	5		6			
3	29	29				
4	23			10.75		
5	11	11				
6	9		11			
7	32	32			10.09	
8	32					
9	8	8				
10	6		8			
11	26	26				
12	25			9.9		
13	10	10				
14	9		10			
15	26	26				10.06
16	27					
17	6	6				
18	4		6			
19	29	29				
20	22			10.75		
21	11	11				
22	9		11			
23	32	32				
24	31					
25	7	7			10.05	
26	6		7			
27	25	25				
28	25					
29	10	10		9.85		
30	9		10			
31	26	26				
32	27					

No. 5711

DESIGN CALCULATION SHEET — CALCULATION #2 — Sheet 31 of 5

Subject: ADDED RESISTANCE FOR SEA STATE - AOR-1

Ship or Project: TOWING RESISTANCE

Section: — Prepared by: RCS — Date: 2/4/76 — Checked: — Reviewed:

		$\frac{F-F^-}{F^+-F^-}=0$	$\frac{S-S^-}{S^+-S^-}=0$	$\frac{(B/T)-(B/T)^-}{B/T^+-B/T^-}=0.95$	$\frac{L/B-L/B^-}{L/B^+-L/B^-}=0.78$	$\frac{CB-CB^-}{CB^+-CB^-}=0.8$
COLUMN	1	2	3	4	5	6
LINE		FOR DESIRED FROUDE No.	FOR DESIRED SEA STATE	FOR DESIRED B/T	FOR DESIRED L/B	FOR DESIRED CB
1	29	29				
2	23		29			
3	64	64				
4	60			31.85		
5	32	32				
6	32		32			
7	62	62				
8	66				27.29	
9	26	26				
10	25		26			
11	51	51				
12	54			26		
13	26	26				
14	27		26			
15	46	46				
16	52					27.26
17	29	29				
18	22		29			
19	65	65				
20	61			31.85		
21	32	32				
22	31		32			
23	63	63				
24	66				27.25	
25	25	25				
26	25		25			
27	50	50				
28	54			25.95		
29	26	26				
30	27		26			
31	47	47				
32	52					

DESIGN CALCULATION SHEET — CALCULATION #3 — Sheet 32 of 5

Subject: ADDED RESISTANCE FOR SEA STATE - AOR-1

Ship or Project: TOWING RESISTANCE

Section: — Prepared by: RCS — Date: 2/4/76 — Checked: — Reviewed:

		$\frac{F-F^-}{F^+-F^-}=0$	$\frac{S-S^-}{S^+-S^-}=0$	$\frac{(B/T)-(B/T)^-}{B/T^+-B/T^-}=0.95$	$\frac{L/B-L/B^-}{L/B^+-L/B^-}=0.78$	$\frac{CB-CB^-}{CB^+-CB^-}=0.8$
COLUMN	1	2	3	4	5	6
LINE		FOR DESIRED FROUDE No.	FOR DESIRED SEA STATE	FOR DESIRED B/T	FOR DESIRED L/B	FOR DESIRED CB
1	107	107				
2	107		107			
3	182	182				
4	208			95.6		
5	95	95				
6	106		95			
7	155	155				
8	181				73.68	
9	77	77				
10	88		77			
11	122	122				
12	149			67.5		
13	67	67				
14	78		67			
15	106	106				
16	126					74.39
17	109	109				
18	109		109			
19	187	187				
20	214			96.65		
21	96	96				
22	107		96			
23	159	159				
24	186				74.62	
25	76	76				
26	38		76			
27	123	123				
28	151			68.4		
29	68	68				
30	79		68			
31	110	110				
32	129					

DESIGN CALCULATION SHEET — CALCULATION #4

No. 5717 Sheet 33 of 5

Subject: ADDED RESISTANCE FOR SEA STATE – AOR-1

Ship or Project: TOWING RESISTANCE

Section: Prepared by: RCS Date: 2/4/76 Checked: Reviewed:

		$\frac{F-F^-}{F^+-F^-}=0$	$\frac{S-S^-}{S^+-S^-}=0$	$\frac{(B/T)-(B/T)^-}{B/T^+-B/T^-}=0.95$	$\frac{L/B-L/B^-}{L/B^+-L/B^-}=0.78$	$\frac{CB-CB^-}{CB^+-CB^-}=0.80$
COLUMN	1	2	3	4	5	6
LINE		FOR DESIRED FROUDE No.	FOR DESIRED SEA STATE	FOR DESIRED B/T	FOR DESIRED L/B	FOR DESIRED CB
1	242	242				
2	287		242			
3	325	325				
4	427			203.05		
5	201	201				
6	244		201			
7	263	263			150.13	
8	352					
9	158	158				
10	200		158			
11	203	203				
12	279			135.2		
13	134	134				
14	166		134			
15	172	172				
16	233					154.16
17	249	249				
18	297		249			
19	336	336				
20	446			209.1		
21	207	207				
22	252		207			
23	271	271				
24	366				155.16	
25	158	158				
26	203		158			
27	205	205				
28	286			139.95		
29	139	139				
30	171		139			
31	179	179				
32	243					

Subject: ADDED RESISTANCE FOR SEA STATE – AOE-1

Ship or Project: TOWING RESISTANCE

Section — Prepared by RCS — Date 2/5/76 — Checked — Reviewed

CALCULATIONS FOR SHIP – AOE-1

$LBP/LWL = 0.983$ (ASSUMED)

$L = LBP = 0.983\,(770) = 756.91$

FROUDE No. FOR 12 KT. $= \dfrac{12.0 \times 1.6889}{\sqrt{32.174 \times (770)}} = 0.128$

USE FROUDE No. $= 0.10 \cong 9.32$

$B/T = 2.71$, $L/B = 7.07$, $CB = 0.58$

$B/T^{+} = 3.0$ $B/T^{-} = 2.0$

$L/B^{+} = 8.5$ $L/B^{-} = 7.0$

$CB^{+} = 0.60$ $CB^{-} = 0.55$

CALM WATER RESISTANCE AT 9.32 KT. = 86296

MULTIPLIER $= \dfrac{\rho g\,(LBP)^3}{10^7} = 2777.1$

CALC. No.	FR. No.	SIGNIFICANT WAVE HGT. FT.	COEFF.	COEFF. MULT.	ADDED RESIS. LB.	CALM WATER RESIS. LB.	S_1
1	0.10	11.35	9.37	2777.1	26021	86296	1.30
2	0.10	15.13	25.47	"	70722	"	1.82
3	0.10	22.7	67.82	"	188348	"	3.18
4	0.10	37.85	135.67	"	376780	"	5.37

M. Rosenblatt & Son, Inc.
DESIGN CALCULATION SHEET

No. 3419
Sheet 35 of 57

Subject: ADDED RESISTANCE FOR SEA STATE - AOE-1
Ship or Project: TOWING RESISTANCE
Section | Prepared by: RCS | Date: 2/5/76 | Checked | Reviewed

CALCULATION #1 — FROUDE No. = 0.10 (9.32 KT.)
SEA STATE = 0.015 — $H^{1/3}$ = 11.35 FT.

$F^+ = 0.15$ $F^- = 0.10$
$S^+ = 0.020$ $S^- = 0.015$

CALCULATION #2 — FROUDE No. = 0.10 (9.32 KT.)
SEA STATE = 0.020 — $H^{1/3}$ = 15.13 FT.

$F^+ = 0.15$ $F^- = 0.10$
$S^+ =$ $S^- =$

CALCULATION #3 — FROUDE No. = 0.10 (9.32 KT.)
SEA STATE = 0.03 — $H^{1/3}$ = 22.7 FT.

$F^+ = 0.15$ $F^- = 0.10$
$S^+ = 0.040$ $S^- = 0.030$

CALCULATION #4 — FROUDE No. = 0.10 (9.32 KT.)
SEA STATE = 0.05 — $H^{1/3}$ = 37.85 FT.

$F^+ = 0.15$ $F^- = 0.10$
$S^+ = 0.075$ $S^- = 0.05$

CALCULATION #5 — FROUDE No. = (KT.)
SEA STATE = — $H^{1/3}$ = FT.

$F^+ =$ $F^- =$
$S^+ =$ $S^- =$

M. Rosenblatt & Son, Inc.

DESIGN CALCULATION SHEET — CALCULATION #1

No. 3419 — Sheet 36 of 57

Subject: ADDED RESISTANCE FOR SEA STATE – AOE-1

Ship or Project: TOWING RESISTANCE

Section: — Prepared by: RCS — Date: 2/5/76 — Checked: — Reviewed:

		$\frac{F-F^-}{F^+-F^-}=0$	$\frac{S-S^-}{S^+-S^-}=0$	$\frac{(B/T)-(B/T)^-}{B/T^+-B/T^-}=0.71$	$\frac{L/B-L/B^-}{L/B^+-L/B^-}=0.05$	$\frac{CB-CB^-}{CB^+-CB^-}=0.60$
COLUMN	1	2	3	4	5	6
LINE		FOR DESIRED FROUDE No.	FOR DESIRED SEA STATE	FOR DESIRED B/T	FOR DESIRED L/B	FOR DESIRED CB
1	8	8				
2	6		8			
3	26	26				
4	25			9.42		
5	10	10				
6	9		10			
7	25	25				
8	27				9.37	
9	7	7				
10	7		7			
11	21	21				
12	23			8.42		
13	9	9				
14	8		9			9.37
15	20	20				
16	22					
17	8	8				
18	6		8			
19	26	26				
20	25			9.42		
21	10	10				
22	9		10			
23	26	26				
24	27				9.37	
25	7	7				
26	6		7			
27	21	21				
28	22			8.42		
29	9	9				
30	9		9			
31	21	21				
32	23					

M. Rosenblatt & Son, Inc.

DESIGN CALCULATION SHEET CALCULATION #2

No. 3417

Sheet 37 of 57

Subject: ADDED RESISTANCE FOR SEA STATE – AOE-1

Ship or Project: TOWING RESISTANCE

Section: Prepared by: RCS Date: 2/5/76 Checked: Reviewed:

		$\frac{F-F^-}{F^+-F^-}=0$	$\frac{S-S^-}{S^+-S^-}=0$	$\frac{(B/T)-(B/T)^-}{B/T^+-B/T^-}=0.71$	$\frac{L/B-L/B^-}{L/B^+-L/B^-}=0.05$	$\frac{CB-CB^-}{CB^+-CB^-}=0.60$
COLUMN	1	2	3	4	5	6
LINE		FOR DESIRED FROUDE No.	FOR DESIRED SEA STATE	FOR DESIRED B/T	FOR DESIRED L/B	FOR DESIRED CB
1	26	26				
2	25		26			
3	51	51				
4	54			25.29		
5	25	25				
6	27		25			
7	44	44			25.04	
8	51					
9	21	21				
10	23		21			
11	37	37		20.29		
12	45					
13	20	20				
14	22		20			25.47
15	33	33				
16	39					
17	26	26				
18	25		26			
19	51	51				
20	54			26		
21	26	26				
22	27		26			
23	46	46				
24	52				25.75	
25	21	21				
26	22		21			
27	38	38				
28	44			21		
29	21	21				
30	23		21			
31	36	36				
32	40					

M. Rosenblatt & Son, Inc. — No. 3419

DESIGN CALCULATION SHEET — CALCULATION #3 — Sheet 38 of 57

Subject: ADDED RESISTANCE FOR SEA STATE - AOE-1

Ship or Project: TOWING RESISTANCE

Section: — Prepared by: RCS — Date: 2/5/76 — Checked: — Reviewed:

		$\frac{F-F^-}{F^+-F^-}=0$	$\frac{S-S^-}{S^+-S^-}=0$	$\frac{(B/T)-(B/T)^-}{B/T^+-B/T^-}=0.71$	$\frac{L/B-L/B^-}{L/B^+-L/B^-}=0.05$	$\frac{CB-CB^-}{CB^+-CB^-}=0.60$
COLUMN	1	2	3	4	5	6
LINE		FOR DESIRED FROUDE No.	FOR DESIRED SEA STATE	FOR DESIRED B/T	FOR DESIRED L/B	FOR DESIRED CB
1	77	77				
2	88		77			
3	120	120				
4	147			67.06		
5	63	63				
6	76		63			
7	99	99			66.11	
8	120					
9	53	53				
10	67		53			
11	83	83				
12	107			48.03		
13	46	46				
14	55		46			67.82
15	69	69				
16	86					
17	77	77				
18	88		77			
19	122	122				
20	149			69.9		
21	67	67				
22	78		67			
23	106	106				
24	126				68.96	
25	54	54				
26	68		54			
27	85	85				
28	108			51.16		
29	50	50				
30	58		50			
31	77	77				
[illegible]	[illegible]					

M. Rosenblatt & Son, Inc.
DESIGN CALCULATION SHEET — CALCULATION #3

No. 3419
Sheet 3B of 57

Subject: ADDED RESISTANCE FOR SEA STATE - AOE-1
Ship or Project: TOWING RESISTANCE
Section: — Prepared by: RCS — Date: 2/5/76 — Checked: — Reviewed:

		$\frac{F-F^-}{F^+-F^-}=0$	$\frac{S-S^-}{S^+-S^-}=0$	$\frac{(B/T)-(B/T)^-}{B/T^+-B/T^-}=0.71$	$\frac{L/B-L/B^-}{L/B^+-L/B^-}=0.05$	$\frac{CB-CB^-}{CB^+-CB^-}=0.60$
COLUMN	1	2	3	4	5	6
LINE		FOR DESIRED FROUDE No.	FOR DESIRED SEA STATE	FOR DESIRED B/T	FOR DESIRED L/B	FOR DESIRED CB
1	77	77				
2	88		77			
3	120	120				
4	147			67.06		
5	63	63				
6	76		63			
7	99	99			66.11	
8	120					
9	53	53				
10	67		53			
11	83	83				
12	107			48.03		
13	46	46				
14	55		46			67.82
15	69	69				
16	86					
17	77	77				
18	88		77			
19	122	122				
20	149			69.9		
21	67	67				
22	78		67			
23	106	106				
24	126				68.96	
25	54	54				
26	68		54			
27	85	85				
28	108			51.16		
29	50	50				
30	58		50			
31	77	77				
32	97					

M. Rosenblatt & Son, Inc.
DESIGN CALCULATION SHEET

No. 3417
Sheet 39 of 57

CALCULATION #4

Subject: ADDED RESISTANCE FOR SEA STATE — AOE-1

Ship or Project: TOWING RESISTANCE

Section: Prepared by: RCS Date: 2/5/76 Checked: Reviewed:

		$\frac{F-F^-}{F^+-F^-}=0$	$\frac{S-S^-}{S^+-S^-}=0$	$\frac{(B/T)-(B/T)^-}{B/T^+-B/T^-}=0.71$	$\frac{L/B-L/B^-}{L/B^+-L/B^-}=0.05$	$\frac{CB-CB^-}{CB^+-CB^-}=0.60$
COLUMN	1	2	3	4	5	6
LINE		FOR DESIRED FROUDE No.	FOR DESIRED SEA STATE	FOR DESIRED B/T	FOR DESIRED L/B	FOR DESIRED CB
1	155	155				
2	196		155			
3	199	199				
4	272			132.99		
5	124	124				
6	157		124			
7	158	158				
8	217				130.89	
9	103	103				
10	138		103			
11	129	129				
12	186			90.93		
13	86	86				
14	110		86			
15	109	109				135.67
16	150					
17	158	158				
18	200		158			
19	203	203				
20	279			140.96		
21	134	134				
22	166		134			
23	172	172				
24	233				138.86	
25	106	106				
26	141		106			
27	135	135				
28	193			98.9		
29	96	96				
30	119		96			
31	122	122				
32	165					

Subject ADDED RESISTANCE FOR SEA STATE – CA 139

Ship or Project TOWING RESISTANCE

Section Prepared by RCS Date 11/7/75 Checked Reviewed

CALCULATIONS FOR SHIP CA 139

FOR ALL CALCULATIONS THE FOLLOWING RELATIONSHIPS APPLY:

$LBP/LWL = 0.983$ (ASSUMED)

$L = LBP = 0.983(700) = 688.1$

FROUDE No. FOR 12 KT. $= \frac{12.0 \times 1.689}{\sqrt{32.174 \times 700}} = 0.135$ USE FR. No. = 0.1

$B/T = 2.945$, $L/B = 9.126$, $CB = 0.593$

$B/T^{+} = 3.0$ $B/T^{-} = 2.0$

$L/B^{+} = 8.5$ $L/B^{-} = 7.0$

$CB^{+} = 0.60$ $CB^{-} = 0.55$

STILL WATER RESISTANCE AT 8.89 KT. = 37082 LB.

MULTIPLIER $= \frac{\rho g (LBP)^3}{10^7} = 2087$

CALC. No.	FR. No.	SIGNIFICANT WAVE HGT. FT.	COEFF.	COEFF. MULT.	ADDED RESIS. LB.	CALM WATER RESIS. LB.	S_1
1	0.10	10.32	8.473	2087	17683	37082	1.48
2	0.10	20.64	38.6	"	80558	"	3.17
3	0.10	40.	75.18	"	156909	"	5.23
4	0.10	27.52	55.97	"	116812	"	4.15

DESIGN CALCULATION SHEET

Subject: ADDED RESISTANCE FOR SEA STATE - CA 139

Ship or Project: TOWING RESISTANCE

Section: Prepared by: RCS Date: 11/7/75 Checked: Reviewed:

CALCULATION #1 FROUDE # = 0.1 (8.89 KT.)
SEA STATE S = 0.015 $H^{1/3}$ = 10.32

$F^+ = 0.15$ $F^- = 0.1$
$S^+ = 0.020$ $S^- = 0.015$

CALCULATION #2 FROUDE # = 0.10
SEA STATE = 0.030 $H^{1/3}$ = 20.64

$F^+ = 0.15$ $F^- = 0.10$
$S^+ = 0.030$ $S^- = 0.025$

CALCULATION #3 FROUDE # = 0.10
SEA STATE = 0.058 $H^{1/3}$ = 40'

$F^+ = 0.15$ $F^- = 0.1$
$S^+ = 0.075$ $S^- = 0.050$

CALCULATE #4 FROUDE # = 0.10
SEA STATE = 0.04 $H^{1/3}$ = 27.52

$F^+ = 0.15$ $F^- = 0.1$
$S^+ = 0.05$ $S^- = 0.04$

M. Rosenblatt & Son, Inc.

DESIGN CALCULATION SHEET CALCULATION #1

No. 3419

Sheet 42 of 57

Subject ADDED RESISTANCE FOR SEA STATE - CA 139

Ship or Project EMER. TOWING GEAR

Section Prepared by RCS Date 11/7/75 Checked Reviewed

#1		$\frac{F-F^-}{F^+-F^-} = 0$	$\frac{S-S^-}{S^+-S^-} = 0$	$\frac{(B/T)-(B/T)^-}{B/T^+ - B/T^-} = 0.945$	$\frac{L/B - L/B^-}{L/B^+ - L/B^-} = 1.417$	$\frac{CB - CB^-}{CB^+ - CB^-} = -0.14$
COLUMN	1	2	3	4	5	6
LINE		FOR DESIRED FROUDE No.	FOR DESIRED SEA STATE	FOR DESIRED B/T	FOR DESIRED L/B	FOR DESIRED CB
1	8	8				
2	6		8			
3	26	26				
4	25					
5	10	10		9.89		
6	9		10			
7	25	25				
8	27					
9	7	7			8.473	
10	7		7			
11	21	21				
12	23					
13	9	9		8.89		
14	8		9			8.473
15	20	20				
16	22					
17	8	8				
18	6		8			
19	26	26				
20	25			9.89		
21	10	10				
22	9		10			
23	26	26				
24	27				8.473	
25	7	7				
26	6		7			
27	21	21				
28	22			8.89		
29	9	9				
30	9		9			
31	21	21				
32	22					

M. Rosenblatt & Son, Inc.

DESIGN CALCULATION SHEET CALCULATION #2

No. 3419

Sheet 43 of 57

Subject: ADDED RESISTANCE FOR SEA STATE - CM 137

Ship or Project: EMER. TOWING GEAR

Section: Prepared by: RCS Date: 11/7/75 Checked: Reviewed:

#2		$\frac{F-F^-}{F^+-F^-}=0$	$\frac{S-S^-}{S^+-S^-}=1$	$\frac{(B/T)-(B/T)^-}{B/T^+-B/T^-}=0.745$	$\frac{L/B-L/B^-}{L/B^+-L/B^-}=1.417$	$\frac{CB-CB^-}{CB^+-CB^-}=-0.14$
COLUMN	1	2	3	4	5	6
LINE		FOR DESIRED FROUDE No.	FOR DESIRED SEA STATE	FOR DESIRED B/T	FOR DESIRED L/B	FOR DESIRED CB
1	51	51				
2	54		77			
3	77	77				
4	88			63.77		
5	44	44				
6	51		63			
7	63	63				
8	76				39.14	
9	37	37				
10	45		53			
11	53	53				
12	67			46.39		
13	33	33				
14	38		46			38.6
15	46	46				
16	55					
17	51	51				
18	54		77			
19	77	77				
20	88			67.55		
21	46	46				
22	52		67			
23	67	67				
24	78				42.99	
25	38	38				
26	44		54			
27	54	54				
28	68			50.22		
29	36	36				
30	40		50			
31	50	50				
32	[illegible]					

M. Rosenblatt & Son, Inc.

DESIGN CALCULATION SHEET CALCULATION #2

No. 3419

Sheet 44 of 57

Subject: ADDED RESISTANCE FOR SEA STATE - CA 139

Ship or Project: EMERG. TOWING GEAR

Section: Prepared by: RCS Date: 11/7/75 Checked: Reviewed:

#3		$\frac{F-F^-}{F^+-F^-}=0$	$\frac{S-S^-}{S^+-S^-}=0.32$	$\frac{(B/T)-(B/T)^-}{B/T^+-B/T^-}=0.945$	$\frac{L/B-L/B^-}{L/B^+-L/B^-}=1.417$	$\frac{CB-CB^-}{CB^+-CB^-}=-0.14$
COLUMN	1	2	3	4	5	6
LINE		FOR DESIRED FROUDE No.	FOR DESIRED SEA STATE	FOR DESIRED B/T	FOR DESIRED L/B	FOR DESIRED CB
1	155	155				
2	196		169.1			
3	199	199				
4	272			136.76		
5	124	124.				
6	157		134.88			
7	158	158				
8	217				76.65	
9	103	103				
10	138		111.3			
11	129	129				
12	126			94.34		
13	86	86				
14	110		93.36			
15	109	109				75.18
16	150					
17	158	158				
18	200		172.4			
19	203	203				
20	279			147.6		
21	134	134				
22	166		146.16			
23	172	172				
24	233				87.12	
25	106	106				
26	141		115.28			
27	135	135				
28	193			104.92		
29	96	96				
30	119		104.32			
31	122	122				
32	[illegible]					

M. Rosenblatt & Son, Inc.
DESIGN CALCULATION SHEET — CALCULATION #4

No. 3419
Sheet 45 of 57

Subject: ADDED RESISTANCE FOR SEA STATE – CA 139
Ship or Project: TOWING RESISTANCE
Section: Prepared by: RCS Date: 2/3/76 Checked: Reviewed:

#4		$\frac{F-F^-}{F^+-F^-}=0$	$\frac{S-S^-}{S^+-S^-}=0$	$\frac{(B/T)-(B/T)^-}{B/T^+-B/T^-}=0.945$	$\frac{L/B-L/B^-}{L/B^+-L/B^-}=1.417$	$\frac{CB-CB^-}{CB^+-CB^-}=-0.14$
COLUMN	1	2	3	4	5	6
LINE		FOR DESIRED FROUDE No.	FOR DESIRED SEA STATE	FOR DESIRED B/T	FOR DESIRED L/B	FOR DESIRED CB
1	120	120				
2	147		120			
3	155	155				
4	196			100.16		
5	99	99				
6	120		99			
7	124	124				
8	157				57.1	
9	83	83				
10	107		83			
11	103	103				
12	138			69.77		
13	69	69				
14	86		69			
15	86	86				
16	110					55.97
17	122	122				
18	149		122			
19	158	158				
20	200			106.88		
21	106	106				
22	126		106			
23	134	134				
24	166				65.2	
25	85	85				
26	108		85			
27	106	106				
28	141			77.44		
29	77	77				
30	92		77			
31	96	96				
32	119					

CALCULATIONS FOR SHIP - AF 58

$LBP/LWL = 0.983$ (ASSUMED)

$L = LBP = 0.983\,(483.5) = 475.28$

FROUDE No. FOR 12 KT. $= \dfrac{12.0 \times 1.6889}{\sqrt{32.174 \times (483.5)}} = 0.16$

USE FROUDE No. $= 0.10 \equiv 7.38$ KT.

$B/T = 3.65$, $L/B = 6.60$, $CB = 0.56$

$B/T^{+} = 4.0$ $\quad B/T^{-} = 3.0$

$L/B^{+} = 7.0$ $\quad L/B^{-} = 5.5$

$CB^{+} = 0.60$ $\quad CB^{-} = 0.55$

CALM WATER RESISTANCE AT 7.38 KT. = 19,470

MULTIPLIER $= \dfrac{\rho g\,(LBP)^3}{10^7} = 687.6$

CALC. No.	FR. No.	SIGNIFICANT WAVE HGT. FT.	COEFF.	COEFF. MULT.	ADDED RESIS. LB.	CALM WATER RESIS. LB.	S_1
1	0.10	7.13	11.7	687.6	8045	19470	1.41
2	0.10	9.51	28.84	"	19832	"	2.02
3	0.10	14.26	71.06	"	48861	"	3.51
4	0.10	35.65	180.61	"	124187	"	7.38

M. Rosenblatt & Son, Inc.
DESIGN CALCULATION SHEET CALCULATION #1

No. 3417
Sheet 47 of 57

Subject: ADDED RESISTANCE FOR SEA STATE – AF 58

Ship or Project: TOWING RESISTANCE

Section: Prepared by: RCS Date: 2/4/76 Checked: Reviewed:

		$\frac{F-F^-}{F^+-F^-} = 0$	$\frac{S-S^-}{S^+-S^-} = 0$	$\frac{(B/T)-(B/T)^-}{B/T^+ - B/T^-} = 0.65$	$\frac{L/B - L/B^-}{L/B^+ - L/B^-} = 1.73$	$\frac{CB - CB^-}{CB^+ - CB^-} = 0.20$
COLUMN	1	2	3	4	5	6
LINE		FOR DESIRED FROUDE No.	FOR DESIRED SEA STATE	FOR DESIRED B/T	FOR DESIRED L/B	FOR DESIRED CB
1	11	11				
2	9		11			
3	32	32				
4	32			12.3		
5	13	13				
6	12		13			
7	34	34				
8	34				11.57	
9	10	10				
10	9		10			
11	25	25				
12	27			11.3		
13	12	12				
14	11		12			
15	27	27				
16	28					11.7
17	11	11				
18	9		11			
19	32	32				
20	32			12.95		
21	14	14				
22	12		14			
23	35	35				
24	35				12.22	
25	10	10				
26	9		10			
27	26	26				
28	27			11.95		
29	13	13				
30	12		13			
31	29	29				
32	29					

M. Rosenblatt & Son, Inc.

DESIGN CALCULATION SHEET — CALCULATION # 2

No. 3417 — Sheet 48 of 57

Subject: ADDED RESISTANCE FOR SEA STATE – AF 58

Ship or Project: TOWING RESISTANCE

Section: — Prepared by: RCS — Date: 2/4/76 — Checked: — Reviewed:

		$\frac{F-F^-}{F^+-F^-}=0$	$\frac{S-S^-}{S^+-S^-}=0$	$\frac{(B/T)-(B/T)^-}{B/T^+-B/T^-}=0.65$	$\frac{L/B-L/B^-}{L/B^+-L/B^-}=0.73$	$\frac{CB-CB^-}{CB^+-CB^-}=0.20$
COLUMN	1	2	3	4	5	6
LINE		FOR DESIRED FROUDE No.	FOR DESIRED SEA STATE	FOR DESIRED B/T	FOR DESIRED L/B	FOR DESIRED CB
1	32	32				
2	32		32			
3	61	61				
4	65			33.3		
5	34	34				
6	34		34			
7	60	60				
8	65				28.66	
9	25	25				
10	27		25			
11	44	44				
12	51			26.95		
13	27	27				
14	28		27			
15	44	44				28.84
16	49					
17	32	32				
18	32		32			
19	62	62				
20	66			33.95		
21	35	35				
22	35		35			
23	64	64				
24	67				29.57	
25	26	26				
26	27		26			
27	46	46				
28	52			27.95		
29	29	29				
30	29		29			
31	49	49				
32	52					

M. Rosenblatt & Son, Inc.

DESIGN CALCULATION SHEET CALCULATION #3

No. 5717

Sheet 49 of 57

Subject: ADDED RESISTANCE FOR SEA STATE - AF 58

Ship or Project: TOWING RESISTANCE

Section: Prepared by: RCS Date: 2/4/76 Checked: Reviewed:

		$\frac{F-F^-}{F^+-F^-}=0$	$\frac{S-S^-}{S^+-S^-}=0$	$\frac{(B/T)-(B/T)^-}{B/T^+-B/T^-}=0.65$	$\frac{L/B-L/B^-}{L/B^+-L/B^-}=0.73$	$\frac{CB-CB^-}{CB^+-CB^-}=0.20$
COLUMN	1	2	3	4	5	6
LINE		FOR DESIRED FROUDE No.	FOR DESIRED SEA STATE	FOR DESIRED B/T	FOR DESIRED L/B	FOR DESIRED CB
1	91	91				
2	103		91			
3	148	148				
4	175			89.05		
5	88	88				
6	99		88			
7	140	140			70.03	
8	161					
9	63	63				
10	76		63			
11	99	99				
12	120			63		
13	63	63				
14	71		63			
15	96	96				71.06
16	112					
17	95	95				
18	106		95			
19	155	155				
20	181			94.35		
21	94	94				
22	103		94			
23	152	152				
24	172				75.33	
25	67	67				
26	78		67			
27	106	106				
28	126			68.3		
29	69	69				
30	76		69			
31	107	107				
32	122					

M. Rosenblatt & Son, Inc.

DESIGN CALCULATION SHEET — CALCULATION #4

No. 3417

Sheet 50 of 57

Subject: ADDED RESISTANCE FOR SEA STATE - AF 5B

Ship or Project: TOWING RESISTANCE

Section: | Prepared by: RCS | Date: 2/4/76 | Checked: | Reviewed:

		$\frac{F-F^-}{F^+-F^-}=0$	$\frac{S-S^-}{S^+-S^-}=0$	$\frac{(B/T)-(B/T)^-}{B/T^+-B/T^-}=0.65$	$\frac{L/B-L/B^-}{L/B^+-L/B^-}=0.73$	$\frac{CB-CB^-}{CB^+-CB^-}=0.20$
COLUMN	1	2	3	4	5	6
LINE		FOR DESIRED FROUDE No.	FOR DESIRED SEA STATE	FOR DESIRED B/T	FOR DESIRED L/B	FOR DESIRED CB
1	248	248				
2	332		248			
3	282	282				
4	405			236.95		
5	231	231				
6	305		231			
7	262	262				
8	377				176.94	
9	158	158				
10	217		158			
11	178	178				
12	262			154.75		
13	153	153				
14	203		153			
15	172	172				
16	250					180.61
17	263	263				
18	352		263			
19	300	300				
20	434			256.5		
21	253	253				
22	334		253			
23	289	289				
24	418				195.29	
25	172	172				
26	233		172			
27	194	194				
28	285			172.65		
29	173	173				
30	228		173			
31	195	195				
32	283					

M. Rosenblatt & Son, Inc.
DESIGN CALCULATION SHEET

No. 3419
Sheet 51 of 5

Subject ADDED RESISTANCE FOR SEA STATE – LST 1179
Ship or Project TOWING RESISTANCE
Section Prepared by RCS Date 2/5/76 Checked Reviewed

CALCULATIONS FOR SHIP – LST 1179

$LBP/LWL = 0.983$ (ASSUMED)

$L = LBP = 0.983\,(508.7) = 500$ (APPROX.)

$$\text{FROUDE No. FOR 12 KT.} = \frac{12.0 \times 1.6889}{\sqrt{32.174 \times (508.7)}} = 0.16$$

USE FROUDE No. = 0.10 ≡ 7.57 KT.

$B/T = 4.32$, $L/B = 7.35$, $CB = 0.56$

$B/T^{+} = 4.0$ $\quad B/T^{-} = 3.0$
$L/B^{+} = 8.5$ $\quad L/B^{-} = 7.0$
$CB^{+} = 0.60$ $\quad CB^{-} = 0.55$

CALM WATER RESISTANCE AT 7.57 KT. = 15470

$$\text{MULTIPLIER} = \frac{\rho g\,(LBP)^3}{10^7} = 800.5$$

CALC. No.	FR. No.	SIGNIFICANT WAVE HGT. FT.	COEFF.	COEFF. MULT.	ADDED RESIS. LB.	CALM WATER RESIS. LB.	S_1
1	0.10	7.5	12.37	800.5	9906	15470	1.64
2	0.10	10	26.71	"	21385	"	2.38
3	0.10	15	60.72	"	48605	"	4.14
4	0.10	25	114.39	"	91568	"	6.92

Subject: ADDED RESISTANCE FOR SEA STATE - LST 1179

Ship or Project: TOWING RESISTANCE

Section: Prepared by: RCS Date: 2/5/76 Checked: Reviewed:

CALCULATION #1 FROUDE No. = 0.10 (7.57 KT.)
SEA STATE = 0.015 $H\,1/3$ = 7.5 FT.

$F^+ = 0.15$ $F^- = 0.10$
$S^+ = 0.020$ $S^- = 0.015$

CALCULATION #2 FROUDE No. = 0.10 (7.57 KT.)
SEA STATE = 0.020 $H\,1/3$ = 10 FT.

$F^+ = 0.15$ $F^- = 0.10$
$S^+ = 0.025$ $S^- = 0.020$

CALCULATION #3 FROUDE No. = 0.10 (7.57 KT.)
SEA STATE = 0.030 $H\,1/3$ = 15 FT.

$F^+ = 0.15$ $F^- = 0.10$
$S^+ = 0.04$ $S^- = 0.03$

CALCULATION #4 FROUDE No. = 0.10 (7.57 KT.)
SEA STATE = 0.05 $H\,1/3$ = 25.0 FT.

$F^+ = 0.15$ $F^- = 0.10$
$S^+ = 0.075$ $S^- = 0.05$

CALCULATION #5 FROUDE No. = (KT.)
SEA STATE = $H\,1/3$ = FT.

$F^+ =$ $F^- =$
$S^+ =$ $S^- =$

M. Rosenblatt & Son, Inc.

DESIGN CALCULATION SHEET — CALCULATION #1

No. 5717

Sheet 53 of 57

Subject: ADDED RESISTANCE FOR SEA STATE – LST 1179

Ship or Project: TOWING RESISTANCE

Section: | Prepared by: RCS | Date: 2/4/76 | Checked: | Reviewed:

		$\frac{F-F^-}{F^+-F^-}=0$	$\frac{S-S^-}{S^+-S^-}=0$	$\frac{(B/T)-(B/T)^-}{B/T^+-B/T^-}=1.32$	$\frac{L/B-L/B^-}{L/B^+-L/B^-}=0.23$	$\frac{CB-CB^-}{CB^+-CB^-}=0.20$
COLUMN	1	2	3	4	5	6
LINE		FOR DESIRED FROUDE No.	FOR DESIRED SEA STATE	FOR DESIRED B/T	FOR DESIRED L/B	FOR DESIRED CB
1	10	10				
2	9		10			
3	25	25				
4	27			12.64		
5	12	12				
6	11		12			
7	27	27				
8	28				12.11	
9	9	9				
10	8		9			
11	20	20				
12	22			10.32		
13	10	10				
14	10		10			
15	21	21				12.37
16	23					
17	10	10				
18	9		10			
19	26	26				
20	27			13.96		
21	13	13				
22	12		13			
23	29	29				
24	29				13.43	
25	9	1				
26	9		9			
27	21	21				
28	23			11.64		
29	11	11				
30	11		11			
31	24	24				
32	24					

M. Rosenblatt & Son, Inc.

DESIGN CALCULATION SHEET — CALCULATION #2

No. 3417

Sheet 54 of 5

Subject: ADDED RESISTANCE FOR SEA STATE - LST 1179

Ship or Project: TOWING RESISTANCE

Section: Prepared by: RCS Date: 2/4/76 Checked: Reviewed:

		$\frac{F-F^-}{F^+-F^-}=0$	$\frac{S-S^-}{S^+-S^-}=0$	$\frac{(B/T)-(B/T)^-}{B/T^+-B/T^-}=.32$	$\frac{L/B-L/B^-}{L/B^+-L/B^-}=0.23$	$\frac{CB-CB^-}{CB^+-CB^-}=0.20$
COLUMN	1	2	3	4	5	6
LINE		FOR DESIRED FROUDE No.	FOR DESIRED SEA STATE	FOR DESIRED B/T	FOR DESIRED L/B	FOR DESIRED CB
1	25	25				
2	27		25			
3	44	44				
4	51			27.64		
5	27	27				
6	28		27			
7	44	44			26.19	
8	49					
9	20	20				
10	22		20			
11	33	33				
12	38			21.32		
13	21	21				
14	23		21			
15	34	34				
16	38					
17	26	26				26.71
18	27		26			
19	46	46				
20	52			29.96		
21	29	29				
22	29		29			
23	49	49				
24	52				28.81	
25	21	21				
26	23		21			
27	36	36				
28	40			24.96		
29	24	24				
30	24		24			
31	38	38				
32	41					

M. Rosenblatt & Son, Inc.

DESIGN CALCULATION SHEET CALCULATION #3

No. 3419

Sheet 55 of 57

Subject: ADDED RESISTANCE FOR SEA STATE – LST 1179

Ship or Project: TOWING RESISTANCE

Section: Prepared by RCS Date 2/5/76 Checked Reviewed

		$\frac{F-F^-}{F^+-F^-}=0$	$\frac{S-S^-}{S^+-S^-}=0$	$\frac{(B/T)-(B/T)^-}{B/T^+-B/T^-}=1.32$	$\frac{L/B-L/B^-}{L/B^+-L/B^-}=0.23$	$\frac{CB-CB^-}{CB^+-CB^-}=0.20$
COLUMN	1	2	3	4	5	6
LINE		FOR DESIRED FROUDE No.	FOR DESIRED SEA STATE	FOR DESIRED B/T	FOR DESIRED L/B	FOR DESIRED CB
1	63	63				
2	76		63			
3	99	99				
4	120			63		
5	63	63				
6	71		63			
7	96	96				
8	112				59.39	
9	46	46				
10	55		46			
11	69	69				
12	86			47.32		
13	47	47				
14	53		47			
15	70	70				60.72
16	82					
17	67	67				
18	78		67			
19	106	106				
20	126			69.64		
21	69	69				
22	76		69			
23	107	107				
24	122				66.03	
25	50	50				
26	58		50			
27	77	77				
28	92			53.96		
29	53	53				
30	58		53			
31	80	80				
32	97					

M. Rosenblatt & Son, Inc.

DESIGN CALCULATION SHEET CALCULATION #4 No. 3419

Sheet 56 of 57

Subject: ADDED RESISTANCE FOR SEA STATE - LST 1179

Ship or Project: TOWING RESISTANCE

Section: Prepared by: RCS Date: 2/5/76 Checked: Reviewed:

		$\frac{F-F^-}{F^+-F^-}=0$	$\frac{S-S^-}{S^+-S^-}=0$	$\frac{(B/T)-(B/T)^-}{B/T^+-B/T^-}=1.32$	$\frac{L/B-L/B^-}{L/B^+-L/B^-}=0.23$	$\frac{CB-CB^-}{CB^+-CB^-}=0.20$
COLUMN	1	2	3	4	5	6
LINE		FOR DESIRED FROUDE No.	FOR DESIRED SEA STATE	FOR DESIRED B/T	FOR DESIRED L/B	FOR DESIRED CB
1	124	124				
2	157		124			
3	158	158				
4	217			118.72		
5	120	120				
6	146		120			
7	153	153				
8	203				111.19	
9	86	86				
10	110		86			
11	109	109				
12	150			86		
13	86	86				
14	165		86			
15	108	108				
16	145					114.39
17	134	134				
18	166		134			
19	172	172				
20	233			135.32		
21	135	135				
22	160		135			
23	173	173				
24	228				127.19	
25	96	96				
26	119		96			
27	122	122				
28	165			99.96		
29	99	99				
30	118		99			
31	125	125				
32	127					

Subject ADDED RESISTANCE FOR SEA STATE - AF SB

Ship or Project TOWING RESISTANCE

Section | Prepared by RCS | Date 2/4/76 | Checked | Reviewed

CALCULATION #1 FROUDE No. = 0.10 (7.38 KT.)
SEA STATE = 0.015 H 1/3 = 7.13 FT.

$F^+ = 0.15$ $F^- = 0.10$
$S^+ = 0.020$ $S^- = 0.015$

CALCULATION #2 FROUDE No. = 0.10 (7.38 KT.)
SEA STATE = 0.020 H 1/3 = 9.51 FT.

$F^+ = 0.15$ $F^- = 0.10$
$S^+ = 0.025$ $S^- = 0.02$

CALCULATION #3 FROUDE No. = 0.10 (7.38 KT.)
SEA STATE = 0.03 H 1/3 = 14.26 FT.

$F^+ = 0.15$ $F^- = 0.10$
$S^+ = 0.04$ $S^- = 0.03$

CALCULATION #4 FROUDE No. = 0.10 (7.38 KT.)
SEA STATE = 0.075 H 1/3 = 35.65 FT.

$F^+ = 0.15$ $F^- = 0.10$
$S^+ = 0.100$ $S^- = 0.075$

CALCULATION #5 FROUDE No. = (KT.)
SEA STATE = H 1/3 = FT.

$F^+ =$ $F^- =$
$S^+ =$ $S^- =$

APPENDIX D

DEVELOPMENT OF DATA TABLE FOR CHARACTERISTICS

OF NAVAL VESSELS

Appendix D

Two data tables of naval ship characteristics were developed in order to assign calm water hull resistance curves and curves for added resistance in waves to those ship classes for which calculations were not performed.

The first two sheets 1 & 2 give the curve numbers for those ships for which calculations were performed. Calculations for hull resistance were performed for 39 ships and calculations for added resistance in waves for 9 ships.

Sheets 3 through 7 give the hull form characteristics for all the naval ship classes although blanks in the table appear when data was not readily available in the literature.

Hull resistance curves were assigned principally on the basis of block coefficient, prismatic coefficient, volumetric coefficient, L/B, and ship description. Curves for added resistance in waves were assigned principally on the basis of ship length and to a lesser extent on block coefficient.

M. Rosenblatt & Son, Inc.
DESIGN CALCULATION SHEET

No. 7419 Sheet 1 of 7

Subject:

Ship or Project: Towing Resistance

Section: Prepared by: RCS Date: 2/9/76 Checked: Reviewed:

CALCULATIONS FOR SHIPS USED IN THIS STUDY

SHIP CLASS	DESCRIPTION	DISPL. Δ LT.	LWL L	BEAM B	DRAFT T	B/T	L/B	C_B	C_P*	C_T $\times 10^{-3}$	CURVE FOR HULL RESISTANCE	CURVE FOR R_S
FF 1037	ESCORT SHIP	2725	350	40.5	13.5	3	8.64	0.51	0.51	2.22	1	
FF 1040	"	3131	390 (T)	44.2	14.0	3.16	8.82	0.45	0.47	1.84	2	4†
DD 931	DESTROYER	3890	407	44.4	14.52	3.06	9.17	0.52	0.65	2.01	3	
DLG 16	GUIDED MISSILE FRIGATE	6800	510	51	18	2.83	10	0.51	0.64	1.79	4	
CGN-25	"	7,300	540 (T)	56.66	13.89	3.0	9.53	0.47	0.59	1.70	5	3†
CG(N)-9	GUIDED MISSILE CRUISER	14,090	691.3	71.0	21.5	3.30	9.74	0.47	0.58	1.49	6	
CA 139	HEAVY CRUISER	20,950	700 (T)	75.4	25.6	2.95	9.29	0.54	0.60	2.13	7	7†
MSO 422	MINESWEEPER	380	165 (T)	34.6	10.5	3.30	4.77	0.51	0.52	6.83	8	1†
ATF 148	FLEET OCEAN TUG	2080	224 (T)	44.9	15.75	2.85	4.99	0.46	0.50	6.47	9	2†
AGFF-1	ESCORT RESEARCH	3500	390	43.7	14.7	2.97	8.92	0.49	0.50	2.07	10	
TAGS-29	SURVEYING SHIP	4325	357	54	16	3.38	6.11	0.49	0.50	3.32	11	
AF 58	STORES SHIP	11,000	483.5 (T)	72	19.72	3.65	6.72	0.56	0.57	3.41	12	8†
AE 21	AMMUNITION SHIP	17,303	482	72	29	2.48	6.69	0.60	0.61	5.41	13	
AD-14	DESTROYER TENDER	17,000	531	73	26	2.81	7.27	0.59	0.61	3.97	14	
AE 26	AMMUNITION SHIP	20,500	540	81	28.4	2.85	6.67	0.58	0.59	4.58	15	
LPD 4	AMPHIBIOUS DOCK	17,000	548.2	82.1	22.0	3.73	6.68	0.60	0.61	3.61	16	
AFS 1	COMBAT STORES SHIP	17,500	530	75	25.75	2.91	7.07	0.60	0.61	4.11	17	
LST 1179	TANK LANDING SHIP	3500	500 (T)	68	15.75	4.32	7.35	0.56	0.57	2.38	18	9†
LSD 36	DOCK LANDING SHIP	14,010	540	84	19.11	4.40	6.42	0.57	0.58	3.11	19	
AOR 1	REPLENISHMENT OILER	36,700	640 (T)	96	32.5	2.95	6.67	0.64	0.65	4.50	20	5†
AD 37	DESTROYER TENDER	24,235	660	85	24	3.54	7.76	0.63	0.64	2.95	21	
AOE-1	FAST COMBAT SUPP.	53,600	770 (T)	107	39.5	2.70	7.20	0.58	0.62	4.11	22	6†
AS-34	SUBMARINE TENDER	22,250	620	85	24.4	3.48	7.29	0.61	0.62	3.27	23	
AKA-113		19230	LPP 550	82	26.05	3.15	6.71	0.57	0.59	4.64	24	
LHA	AMPHIBIOUS ASSAULT	22,020	700	38	27	3.26	7.95	0.76	0.48	2.25	25	
AO-93	OILER	21,880	502	68	30.17	2.25	7.33	0.74	0.76	6.05	26	

* C_P IS ESTIMATED

M. Rosenblatt & Son, Inc.
DESIGN CALCULATION SHEET

No. 5417 Sheet 2 of 7

Subject

Ship or Project: Towing Resistance

Section | Prepared by: RCS | Date: 5/13/76 | Checked | Reviewed

CALCULATIONS FOR SHIPS USED IN THIS STUDY

SHIP CLASS	DESCRIPTION	DISPL. Δ LT.	LWL L	BEAM B	DRAFT T	B/T	L/B	C_B	C_P^*	$C_\nabla \times 10^{-3}$	CURVE FOR HULL RESISTANCE	CURVE FOR R_S
CVA(N)65	AIRCRAFT CARRIER	85500	1040	133	35.89	3.71	7.82	0.60	0.62	2.66	27	
CVA 59	" "	72,000	990	129.33	32.65	3.96	7.65	0.60	0.62	2.59	28	
LCU F1	LANDING CRAFT U.	375	120.7	29	5.12	5.60	4.16	0.73	0.75	2.46	29	
FF 1052	ESCORT	4200	419	46.6	25	1.86	8.99	0.501	0.52	2.00	30	
DDG 2	GUIDED MISSILE DESTROYER	4544	431	47.03	15.0	3.14	9.16	0.52	0.56	1.99	31	
DD963	DESTROYER	3000	530.2	55	19.74	2.79	9.64	0.49	0.61	1.88	32	
T-AGOS		1922	220	46	15	3.07	4.78	0.44	0.45	6.31	33	
DLG-26	GUIDED MISSILE FRIGATE	7300	524.6	54.4	18.9	2.85	9.64	0.51	0.55	1.92	34	
DD710	DESTROYER	3400	383	40.89	14.04	2.91	9.37	0.54	0.67	2.12	35	
DL-1	FRIGATE	6625	520	54	18.00	3.0	9.63	0.46	0.57	1.65	36	
LST-1171	TANK LANDING SHIP	7034	426	62	12.29	5.04	6.87	0.76	0.78	3.21	37	
LCC-119	AMPHIBIOUS COMMAND	18,500	556	82	26	3.15	6.78	0.55	0.59	3.77	38	
LPH-3	LPH-3	18000	543.02	84.17	26.5	3.18	6.45	0.52	0.57	3.95	39	

* C_P IS ESTIMATED

TABLE - 5
CHARACTERISTICS OF NAVAL VESSELS

CLASS	DESCRIPTION	DISPLACEMENT (L. TONS)	LIGHT SHIP FRONTAL WINDAGE AREA (SQ. FT.)	LENGTH LWL L	BEAM B	DRAFT T	B/T	L/B	C_B	$C_P^{\#}$	C_V $\times 10^{-5}$	CURVE FOR HULL RESIS.	CURVE FOR ADDED RESISTANCE
AD-14-19	Destroyer Tender	17176	6200	520	73	25.5	2.86	7.12	0.62	0.65	4.28	14+	9
AD 16	"	16600	4130	465	70	24.0	2.92	6.64	0.74	0.75	5.78	26	8
AD 23-36	"	16900	4200	465	70	23.5	2.97	6.64	0.77	0.79	5.88	26	8
AD 37-38	"	21000	5600	613	85	26.0	3.27	7.21	0.54	0.55	3.12	21+	5
ADG 8-10	Degaussing Ship	900	1100	180	33	9	3.67	5.45	0.57	0.50	5.4	13	1
ADG 383	"	1235		215	52	11.0	4.72	4.13	0.35	0.36	4.34	30	2
AE 4-9	Ammunition Ship	14225	4600	435	63	26.5	2.38	6.9	0.69	0.70	6.04	26	8
AE 12-19	"	15295	4500	435	63	26.7	3.12	2.36	0.73	0.74	6.50	26	8
AE 21-25	"	17500	6490	482	72	29.0	2.48	6.69	0.61	0.62	5.47	13+	8
AE 26-35	"	20500		540	81	26.0	3.14	6.67	0.63	0.64	4.56	15+	9
AE 30-31	"	14000	4375	434	63	24.0	2.62	6.89	0.73	0.75	6.0	26	8
AF 28-29	Stores Ship	15300	4460	445	63	24.5	2.57	7.06	0.78	0.80	6.1	26	2
AF 42-44	"	7435	2600	320	50	19.0	2.63	6.4	0.55	0.86	7.95	26	8
AF 48-61	"	15500	4405	445	63	24.5	2.57	2.66	0.79	0.80	6.16	26	8
T-AF 50-51	"	12800	4375	445	63	22.0						26	8
AF 56-57	"	12130	4100	440	62	22.0	2.67	6.98	0.68	0.69	4.98	26	8
AF 58-59	"	15540	5400	475	72	28.0	2.57	6.60	0.67	0.68	5.01	12+	8+
T-AF 63-64	"	12130	4100	440	62	23.0						26	8
AFS 1-7	Combat Stores Ship	16500	6350	530	79	24						17+	3
AG 127	Miscellaneous	2804	1600	323	37	13.7	2.7	13.1	0.52	0.53	1.91	10	8
AG 153-154	Exper. Navigation Ship	17600	5550	529	76	29.0	2.62	6.96	0.53	0.54	4.16	17	8
T-AG 162	Exper. Sound Testing	17000			68	31.0						?	?
T-AG 164	Hydrographic Research	12450	4340	437	62	24.0	2.58	7.05	0.67	0.69	5.22	13	8
T-AG 169-171	Special Mission	7460	2600	320	50	19.0	2.63	6.40	0.26	0.33	7.97	26	4
T-AG 172-174	Cargo	12400	4100	440	62	24.0	2.58	7.10	0.66	0.67	5.1	13	8
T-AG 175	Surveying Ship	7400	2600	320	50	21.0	3.11	6.4	0.77	0.79	7.9	26	4
AG 176	Miscellaneous			215	32	10.3	3.11	6.72				?	2
T-AG 178	Hydrographic Research	11000	4375	440	63	19.5	3.63	6.98	0.71	0.73	4.51	37	8
AG 191	Sonar Test Ship	8200	2600	530	53	25.0	2.12	10.0	0.41	0.42	1.92	2	3
AG 335	Cargo	1095	990	197	35	7.5	4.67	5.63	0.74	0.76	5.0	29	1
AGDE 1	Escort Research	3426	1715	371	44	24.0	1.83	8.43	0.71	-		10+	4
AGF 1	Misc. Command Ship	2800	1600	300	41	13.0	3.15	7.32	0.61	0.62	3.63	16	2
T-AGM 1-11	Missile Range Inst. Ship	11100	4100	444	62	22.0	2.82	7.16	0.64	0.65	4.93	20	8
T-AGM 2	"	550			32	11.5						?	?
T-AGM 9-10	"	16600	4900	528	72	26.0						17	5
T-AGM 13-16	"	7460	2600	320	50	19.0						26	4
T-AGM 19-21	"	21626	5020	577	75	25.0	3.0	7.69	0.70	0.71	3.94	37	9
AGMR 1	Communications Relay	22500		525	75							15	9
AGMR 2	"	19600	6000	664	78	25.3	3.08	8.51	0.52	0.53	2.34	3	7
AGTR 1-3	Technical Research	11365	3250	416	57	22.0	2.59	7.30	0.76	0.78	5.52	26	8
AGTR 4-5	"	10680	4100	440	62	24						13	8
AH 16-17	Hospital Ship	15900	4900	496	72	23.4	3.08	6.81	0.66	0.68	4.56	17	8
T-AK 180-250	Cargo Ship	7450	3100	320	50	19.4						26	4
T-AK 237-276	"	12450	4100	437	62	24						13	8
T-AK 241-254	"	12400	4100	437	62	24						13	8
T-AK 255-267	"		4900	528	72	33	2.18	7.33				17	5
AK 260	"	12420	4100	437	62	24						13	8

$C_B = 0.982$ → (AD 23-36)

$C_P = 0.624$ → (AF 48-61)

C_P IS ESTIMATED

+ ACTUAL CALCULATION PERFORMED

TABLE 5 (CONT'D)
CHARACTERISTICS OF NAVAL VESSELS

CLASS	DESCRIPTION	DISPLACEMENT (L. TONS)	LIGHT SHIP FRONTAL WINDAGE AREA (SQ. FT.)	LENGTH LWL L	BEAM B	DRAFT T	B/T	L/B	C_B	C_p*	C_V	CURVE FOR HULL RESIS.	CURVE ADDED RESIS.
T-AK 271	Cargo Ship	4942		257	52	18.7	2.78	4.94	0.69	0.71	10.18	26	2
T-AK 277	"	15800	5400	465	66	29.0	2.27	7.04	0.62	0.63	5.5	13	8
T-AK 279-281	"	11150	4100	435	62	22.0	2.82	7.02	0.66	0.67	4.79	20	8
T-AK 283	"	14000	4375	445	63	24	2.63	7.06	0.73	0.74	5.56	16	8
T-AKD 1	Dock Cargo Ship	14094	6856	475	78	22	3.55	6.09	0.73	0.75	4.60	26	8
T-AKR 7	Vehicle Cargo Ship	18150		465	78	29.0	2.69	5.96	0.60	0.62	6.32	13	8
T-AKR 9	"	21700		500	83	23.0	2.46	6.02	0.63	0.64	6.08	20	9
T-AKV 8-37	Cargo/Aircraft Ferry	24560	5400	525	75	32.0	2.34	7.0	0.68	0.70	5.94	20	9
T-AKV 40-43	"	15700	5340	465	70	26	2.69	6.64	0.65	0.66	5.47	13	8
AO 24-53	Oiler	25400-34700	5540	525/620	75	31.5/35.5	–	–	–	–	–	20	5
AO 36-47	"	21850	4290	488	68	29.9	2.2	7.18	0.74	0.75	6.58	26	9
T-AO 49-142	"	22380	4610	503	68	30.8	2.21	7.40	0.74	0.75	6.15	26*	9
AO 105-109	"	34750	5480	620	75	35.5	2.11	7.21	0.74	0.75	5.10	26	5
AO 143-148	"	38000	6300	610	86	35.1	2.45	7.09	0.69	0.70	5.07	26	5
T-AO 149-152	"			591	83	?						—	—
T-AO 165	"			591	80	?						—	—
AOE 1-5	Fast Combat Support	53600	9750	770	107	39						22*	6*
AOG 1-56	Gasoline Tanker	4570	2200	292	49	16.1	3.04	5.96	0.69	0.67	6.42	26	2
T-AOG 77-80	"	6000		325	48	19.0	2.52	6.77	0.71	0.72	6.12	26	4
T-AOG 81-82	"	5720		?	46	19.0						—	—
AOR 1-6	Replenishment Oiler	38100	7590	659	96	35	2.74	6.86	0.60	0.61	4.66	20*	5*
T-AP 110-119	Transport	20175	6800	573	76	25.5	2.98	7.54	0.64	0.65	5.75	23	9
T-AP 122-127	"	20620		?	76	26.5						—	—
T-AP 196-198	"	19600		500	73	29.6	2.47	6.85	0.63	0.65	5.49	13	9
APB 35-48	Self-Propelled Barracks	4080	1910	316	50	10.2	4.90	6.32	0.89	0.90	4.52	26	4
APC 116	Coastal Transport	7460	2600	320	50	13.0	3.78	6.4	0.91	0.93	7.97	26	4
APL 2-58	Barracks Barges	2660		?	49	3.5						—	—
AR 5-8	Repair Ship	16130	5460	520	73	23.2	3.15	7.12	0.64	0.65	4.02	14	9
AR 9-12	"	14500	4100	465	70	24.0	2.92	6.64	0.65	0.66	5.05	20	9
AR 13-14	"	14490	4200	465	70	28.0	2.50	6.64	0.56	0.57	5.01	15	9
AR 22-23		16900	4180	465	70	23.8	2.94	6.64	0.76	0.78	5.88	26	8
ARB 4-8	Battle Damage Repair	4080	2320	316	50	11.0	4.55	6.32	0.93	0.64	4.52	37	4
ARC 2-6	Cable Repair Ship	7380		322	47	19	2.61	6.85	0.95	0.96	7.74	26	4
ARC 3-4	"	7080		400	64	16.0	4.0	6.25	0.60	0.62	3.97	19	8
ARG 4	Engine Repair Ship	14350	3250	416	57	23.0	2.48	7.30	0.72	0.74	6.98	26	8
ARL 1-38	Landing Craft Repair	3830	2320	316	50	10.6	4.72	6.32	0.80	0.82	4.29	37	2
ARS 6-43	Salvage Ship	1900	1500	207	39	13.0	3.0	5.31	0.62	0.65	2.49	26	1
ARSD 1-2	Salvage Lift Ship	1095	990	197	34	7.0	4.86	5.79	0.82	0.84	5.01	26	1
ARST 1-2	Salvage Craft Tender	4080	2320	316	50	11.0	4.55	6.32	0.82	0.84	4.53	26	4
ARVA 5-6	Aircraft Airframe Rpr.	4080	2320	316	50	11.0	"	"	"	"	"	26	4
ARVE 4	Aircraft Engine Repair	4080	2320	316	50	11.0	"	"	"	"	"	26	4
T-ARVH 1	Helicopter Repair Ship	13475	5100	503	69	21	3.29	7.36	0.64	0.65	3.60	21	9
AS 13-14	Submarine Tender	14500	4130	465	70	24	2.92	6.64	0.65	0.66	5.05	20	8
AS 11-18	"	18000	6200	520	73	24.5	2.98	7.12	0.68	0.69	4.48	37	9
AS 19	"	18500	6200	564	73	24.5	2.98	7.73	0.64	0.66	3.61	21	5
AS 22	"	15400	4300	465	70	25.0	2.8	6.64	0.66	0.68	5.36	26	8
AS 23	"	16100	4300	465	70	22.7	3.08	6.64	0.76	0.78	5.60	26	8

C_R = 0.97? → (margin note at T-AO 49-142)

C_p = 0.67 (margin note at AOG 1-56)

* C_p is ESTIMATED

TABLE - 5 (CONT'D)
CHARACTERISTICS OF NAVAL VESSELS

CLASS	DESCRIPTION	DISPLACEMENT (L. TONS)	LIGHT SHIP FRONTAL WINDAGE AREA (SQ. FT.)	LENGTH LWL L	BEAM B	DRAFT T	B/T	L/B	C_B	C_P*	C_W	CURVE FOR HULL RESIS.	CURVE FOR ADDED RESISTANCE
AS 31-32	Submarine Tender	18300	6440	520	83	29	2.96	6.57	0.55	0.57	3.46	12	8
AS 33-34	"	22250	7550	626	85	26						23*	5
AS 36-37	"	22640	7550	626	85	26.1						23	5
ASR 7-16	Submarine Rescue	2290	1200	240	42	14.14	4.41	5.71	0.56	0.57	5.8	21	2
ASR 12-20	"	1760	1170	195	39	15.3	2.55	5.0	0.53	0.54	8.31	8	1
ASR 21-22	"	3411			86							—	—
AV 7-13	Seaplane Tender	15090	5100	520	69	22.2	3.11	7.54	2.55	2.53	3.26	17	9
AV 10	"	14200	4500	465	70	24.0	2.92	6.64	0.64	0.65	4.94	20	8
AVB 2	Advanced Aviation Base	6000	3940	368	54	12.9	4.19	6.81	0.82	0.84	4.21	37	4
AVM 1	Guided Missile Ship	15170	5300	520	72	20.3	3.55	7.22	0.70	0.71	3.78	37	3
AVT 2-5	Aircraft Transport	15800	6000	600	72	26.0	2.77	8.33	0.49	0.50	2.56	1	5
AVT 9	Electronics Test Ship	38500	8300	820	102	31.0	3.29	8.04	0.52	0.53	2.44	10	6
AW 4	Distilling Ship	22380	4600	503	68	30.8	2.21	7.40	0.74	0.76	6.15	26	9
BB 61-64	Battleship	59000	8500	860	108	36.2	3.18	7.96	0.51	0.66	3.24	14	6
CA 68-130	Heavy Cruiser	17500	5300	664	71	24.0	2.96	9.35	0.57	0.58	2.09	7	7
CA 122-124	"	17500	5300	654	71	24.5						7	7
CA 134-148	"	21470	4500	700	76	26.0						7*	7*
CC 1	Command Ship	17200	5300	664	71	29.0						7	7
CC 2	"	19600	6000	664	78	28.0	2.78	8.51	0.47	0.51	2.34	10	7
CG 10-12	Guided Missile Cruiser	17700	6300	664	71	26.0	2.73	9.35	0.51	0.55	2.12	6	7
CGN 9	"	17350	7900	699	74	27.0						6*	7
CL 65-103	Light Cruiser	13755	4300	600	66	25.0	2.64	9.09	0.49	0.52	2.22	4	5
CL 106	"	14055	4300	600	66	25.1						4	5
CL 144-145	"	18700	5000	664	71	25.0	2.84	9.35	0.56	0.60	2.24	7	7
CLG 3-8	Guided Missile LtCruiser	14600	4000	600	66	25.0	2.64	9.09	0.53	0.56	2.37	7	5
CVA 14-34	Attack Aircraft Carrier	42600	8300	820	103	31.0	3.32	7.96	0.57	0.61	2.70	27	6
CVA 41-43	"	62000		900	121	36.0	3.36	7.44	0.55	0.61	2.98	27	6
CVA 59-62	"	78040	13100	990	130	35.8	3.63	7.62	0.59	0.64	2.32	28*	6
CVA 63	"	75200	13100	990	130	37.0	3.51	7.62	0.55	0.59	2.71	28	6
CVA 64	"	75200	13100	990	130	37.0	"	"	"	"	"	28	6
CVA 66	"	78250	13100	990	130	37.0	"	"	0.58	0.59	2.82	25	6
CVA 67	"	83000	13100	990	130	37.0	"	"	0.61	0.68	3.00	28	6
CVAN 65	"	85350	16600	1040	133	37.0	3.59	7.82	0.58	0.63	2.66	27*	6
CVAN 68-70	"	95100		1040	134	—						27	6
CVS 9-39	ASW Aircraft Carrier	41000	8300	820	102	30.3						27	6
CVT 16	Training Carrier	41000	8300	820	102	30.3						27	6
DD 422-617	Destroyer	2575	1400	341	36	14.0	2.57	9.47	0.52	0.66	2.27	3	2
DD 423-647	"	2590	1400	341	36	13.8						3	2
DD 445-795	"	3040	1400	369	40	14.1	2.84	9.23	0.51	0.69	2.12	35	4
DD 692-857	"	3400	1400	369	41	14.5						35	4
DD 710-890	"	3540	1450	383	41	14.5						35*	4
DD 712	"	3480	1450	383	41	14.5						35	4
DD 719-824	"	3500	1450	383	41	14.5						35	4
DD 825-827	"	3410	1450	383	41	14.5						35*	4
DD 931-951	"	4200	2100	407	44	15.0						3*	4
DD 963-967	"	7000										32*	4

* C_P IS ESTIMATED

TABLE - 5 (CONT'D)
CHARACTERISTICS OF NAVAL VESSELS

CLASS	DESCRIPTION	DISPLACEMENT (L. TONS)	LIGHT SHIP FRONTAL WINDAGE AREA (SQ. FT.)	LENGTH LWL L	BEAM B	DRAFT T	B/T	L/B	C_B	C_P^*	C_∇	CURVE FOR HULL RESIS.	CURVE FOR ADDED RESISTANCE
DDG 2-24	Guided Missile Destroyer	4500	2256	431	47	20.0	2.35	9.17	0.39	0.42	1.97	31*	8
DDG 31-34	"	4200	2100	407	44	15.0	2.93	9.25	0.55	0.61	2.18	35	4
DDG 35-36	"	4730	2800	476	50	26.0	1.92	9.52	0.27	0.33	1.53	30	8
DE 129-399	Escort Ship	1990	1400	300	37	12.0	2.64	8.11	0.52	0.65	2.58	35	4
DE 162-767	"	2230	1200	300	37	14.0	2.64	8.11	[illegible]	[illegible]	2.89	35	4
DE 202-800	"	2230	1200	300	37	14.0	"	"	"	"	"	35	4
DE 224-708	"	2230	1200	300	37	14.0	"	"	"	"	"	35	4
DE 339-538	"	2100	1200	300	37	11.0	3.36	8.11	0.31	0.37	1.56	1	4
DE 1006-1037	"	1914	1342	308	37	12.0	3.05	8.32	0.47	0.61	2.29	1	4
DE 1033-1036	"	1750	1340	303	37	18.0	2.06	8.11	0.30	0.34	2.20	1	4
DE 1037-1038	"	2650		350	41	23.0						1*	4
DE 1040-1051	"	3400	1715	391	44	24.0	1.83	8.89	0.29	0.32	1.99	2*	4*
DE 1052-1097	"	4100	2020	419	47	25.0	1.88	8.91	[illegible]	[illegible]	1.95	30*	4
DEG 1-6	Guided Missile Escorts	3600	1715	391	44	24.0	1.83	8.89	[illegible]	0.31	1.99	2	4
DER 147-400	Radar Picket Escorts	1850	1400	300	37	11.0	3.36	8.11	0.53	0.54	2.40	1	2
DER 539-540	"	2100	1400	300	37	11.0	"	"	0.60	0.61	2.72	1	2
DL 1	Frigate	7300	2600	520	54	19.0	2.84	9.63	0.48	0.49	1.82	36*	3
DL 4-5	"	4730	2800	476	50	26.0	1.92	9.52	0.27	0.28	1.53	30	3
DLG 6-15	Guided Missile Frigate	5800		513	52	20	2.6	9.86	0.38	0.41	1.50	32	5
DLG 16-24	"	7800			54	19						4*	3
DLG 26-34	"	7930	3675	525	55	20.0	2.75	9.55	0.42	0.52	1.92	34*	3
DLGN 25	"	8580	3040	550	58	25.0	2.32	9.48	0.38	0.40	1.80	5*	3*
DLGN 35	"	9200	2960	550	58	26.0	"	"				5	3
DLGN 36-37	"	10150			61								
DLGN 38-41	"	10000											
IX 21	Sail Frigate	2200											
IX 304	Experimental Target	13755	4300	600	66	25.0	2.64	9.09	0.49	0.50	2.32	7	5
LCC 7-17	Amphibious Command	12560	4300	435	63	22.0	2.86	6.90	0.73	0.74	5.34	26	8
LCC 19-20	"	17100		580	82	27.0	3.04	7.07	0.47	0.48	3.07	30*	3
LHA 1-3	Amphibious Assault Ship	40000	8800	755	106							25*	6
LKA 19-97	Amphibious Cargo Ship	14000	4300	435	63	24.0	2.63	6.90	0.79	0.76	5.95	26	8
LKA 103-108	"	14160	4300	435	63	22.4	2.81	6.90	0.81	0.81	6.02	26	8
LKA 112	"	15970	4900	528	76	26.0	2.92	6.95	0.54	0.55	3.80	12	9
LKA 113-117	"	20700		?	82	25.5						—	—
LPA 33-44	Amphibious Transport	15200	5400	465	70	27.0	2.59	6.64	0.61	0.62	5.29	13	8
LPA 194-237	"	10470	4100	437	62	24.0	2.58	7.05	0.56	0.58	4.39	13	8
LPA 248-249	"	16840	4900	528	76	25.0	3.04	6.95	0.59	0.60	4.00	14	9
LPD 1-3	" Dock	13500	6050	500	84	21.0	4.0	5.95	0.54	0.55	3.78	12	9
LPD 4-15	" Dock	16900	6050	548	84	23.0	3.65	6.52	0.56	0.57	3.59	16*	9
LPH 2-12	Amphibious Assault Ship	18300		556	84	26.0	3.23	6.62	0.53	0.54	3.73	39*	9
LPH 4-3	"	40600	8300	820	93	31.0	3.0	8.82	0.60	0.61	2.58	28	6
LPR 55-135	Amphibious Trans., Small	2130	1400	300	37	13.0	2.85	8.11	0.52	0.53	2.76	1	2
LPSS 315	Amphibious Trans., Sub.	2045	450	307	27	17.0	1.59	11.37	0.51	0.54	2.47	30	2
LPSS 574	"	2670			30	17.3						—	—
LSD 1-7	Dock Landing Ship	8700	4100	454	72.0	17.0	4.29	6.31	0.55	0.56	3.25	19	8
LSD 13-27	"	9375		472	76.0	18.0	4.32	6.21	0.51	0.53	3.12	19	8
LSD 28-35	"	11270	5695	500	84	18.0	4.67	5.95	0.52	0.53	3.16	19	9
LSD 36-40	"	13650	5700	544	84							19*	6

* C_P IS ESTIMATED

TABLE - 5 (CONT'D)
CHARACTERISTICS OF NAVAL VESSELS

CLASS	DESCRIPTION	DISPLACEMENT (L. TONS)	LIGHT SHIP FRONTAL WINDAGE AREA (SQ. FT.)	LENGTH LWL L	BEAM B	DRAFT T	B/T	L/B	C_B	C_P *	C_V	CURVE FOR HULL RESIS.	CURVE FOR ADDED RESIS.
T-LST47-1088	Tank Landing Ship	4080	2000	316	50	11.0	4.55	6.32	0.82	0.83	4.53	37	2
LST 334-509	"	4080	2000	316	50	11.0	"	"	"	"	"	37	2
LST 515-1150	"	4080	2000	316	50	11.0	"	"	"	"	"	37	2
LST 1153	"	6000	3940	368	54	12.9	4.19	6.81	0.82	0.83	4.21	37	4
LST1156-1170	"	5800	3940	368	55	12.9						37	4
LST1171-1178	"	8000	3400	426	62	13.3	4.66	6.87	0.80	0.81	3.62	37†	8
LST1179-1198	"	8342		500	70	15.0						18†	9*
MCS 1-2	Mine Counter Measures	9040	4230	440	60	20	3.0	7.33	0.60	0.61	3.71	16	8
MHC 43	Coastal Mine Hunter			130	25	8.3	3.01	5.2				—	1
MMD 23-33	Fast Minelayers	3320	1400	369	41	14.4	2.85	9.0	0.53	0.54	2.31	35	4
MMF 5	Fleet Minelayer	8680		440	60	19.4	3.09	7.33	0.59	0.61	3.57	11	8

* C_P IS ESTIMATED

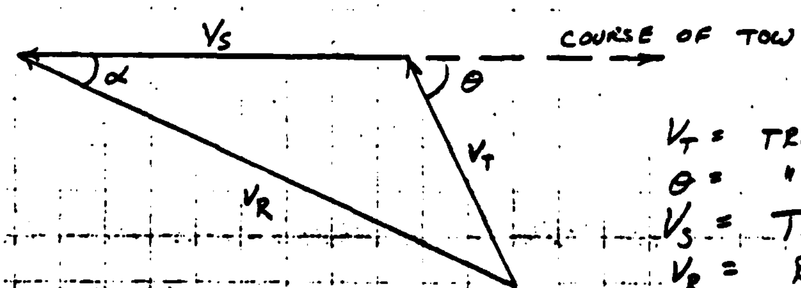
APPENDIX E

CORRELATION STUDY

DATA FROM THE TOWING TEST REPORT OF THE LST 1179 CLASS (REF. 28) WAS EXAMINED IN ORDER TO CORRELATE FULL SCALE TEST RESULTS WITH THE RESULTS OBTAINED FROM THE CALCULATION PROCEDURE DEVELOPED IN THIS STUDY AND WITH THE CALCULATION PROCEDURE OF THE U.S. NAVY TOWING MANUAL.

ALTHOUGH SEVERAL FULL SCALE TESTS WERE CONDUCTED, ONLY 2 TESTS WERE SELECTED FOR STUDY SINCE THE OTHERS WERE CONDUCTED IN CONDITIONS WHICH COULD NOT BE DIRECTLY CORRELATED WITH THE TWO EMPIRICAL METHODS OF CALCULATION, SINCE THE TOW WAS UNDERGOING A TURN OR RUDDERS OF THE TOW WERE SPLAYED. ALTHOUGH THE SHAFTS WERE NOT LOCKED, THE FRICTION OF THE SHAFT BEARINGS WAS SUFFICIENT TO PREVENT ROTATION, SO FOR PRACTICAL PURPOSES THE SHAFTS CAN BE CONSIDERED LOCKED.

IN ORDER TO COMPARE THE TEST RESULTS WITH THE MR&S CALCULATION PROCEDURE, TRUE WIND VELOCITY AND DIRECTION WERE CONVERTED TO RELATIVE WIND VELOCITY AND DIRECTION BY THE FOLLOWING CALCULATIONS:



V_T = TRUE WIND SPEED
θ = " " DIRECTION
V_S = TOW SPEED
V_R = RELATIVE WIND SPEED
α = " " DIRECTION

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DESIGN CALCULATION SHEET Sheet of

Subject: Use of Full Scale Towing Tests for Correlation

Ship or Project: Tow Resistance

Section Prepared by RCS Date 3/15/76 Checked Reviewed

$$V_R = \sqrt{V_S^2 + V_T^2 - 2(V_S)(V_T)\cos(180-\theta)}$$

$$\sin\alpha = \frac{V_T \sin(180-\theta)}{V_R}$$

$$\alpha = \sin^{-1}\left(\frac{V_T \sin(180-\theta)}{V_R}\right) \quad (\text{IF } \theta < 90^\circ)$$

$$\alpha = 180 - \left[\sin^{-1}\left(\frac{V_S \sin(180-\theta)}{V_R}\right) + (180-\theta)\right] \quad (\text{IF } \theta > 90$$

Calculations for Test #1

$$V_R = \left(9.5^2 + 12^2 - 2(9.5)(12)\cos(180-5)\right)^{1/2}$$

$$V_R = 21.48 \text{ KT}$$

$$\alpha = \sin^{-1}\frac{12 \sin(180-5)}{21.48}$$

$$\alpha \cong 3^\circ$$

Calculations for Test #2

$$V_R = \left[9^2 + 10^2 - 2(9)(10)\cos(180-176)\right]^{1/2}$$
$$= 1.44 \text{ KT.}$$

$$\alpha = 180 - \left[\sin^{-1}\left(\frac{1.44 \sin(180-176)}{9}\right) + 4\right]$$

$$= 175.36^\circ$$

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DESIGN CALCULATION SHEET

No. 5717

Sheet of

Subject: USE OF FULL SCALE TOWING TESTS FOR CORRELATION

Ship or Project: TOW RESISTANCE

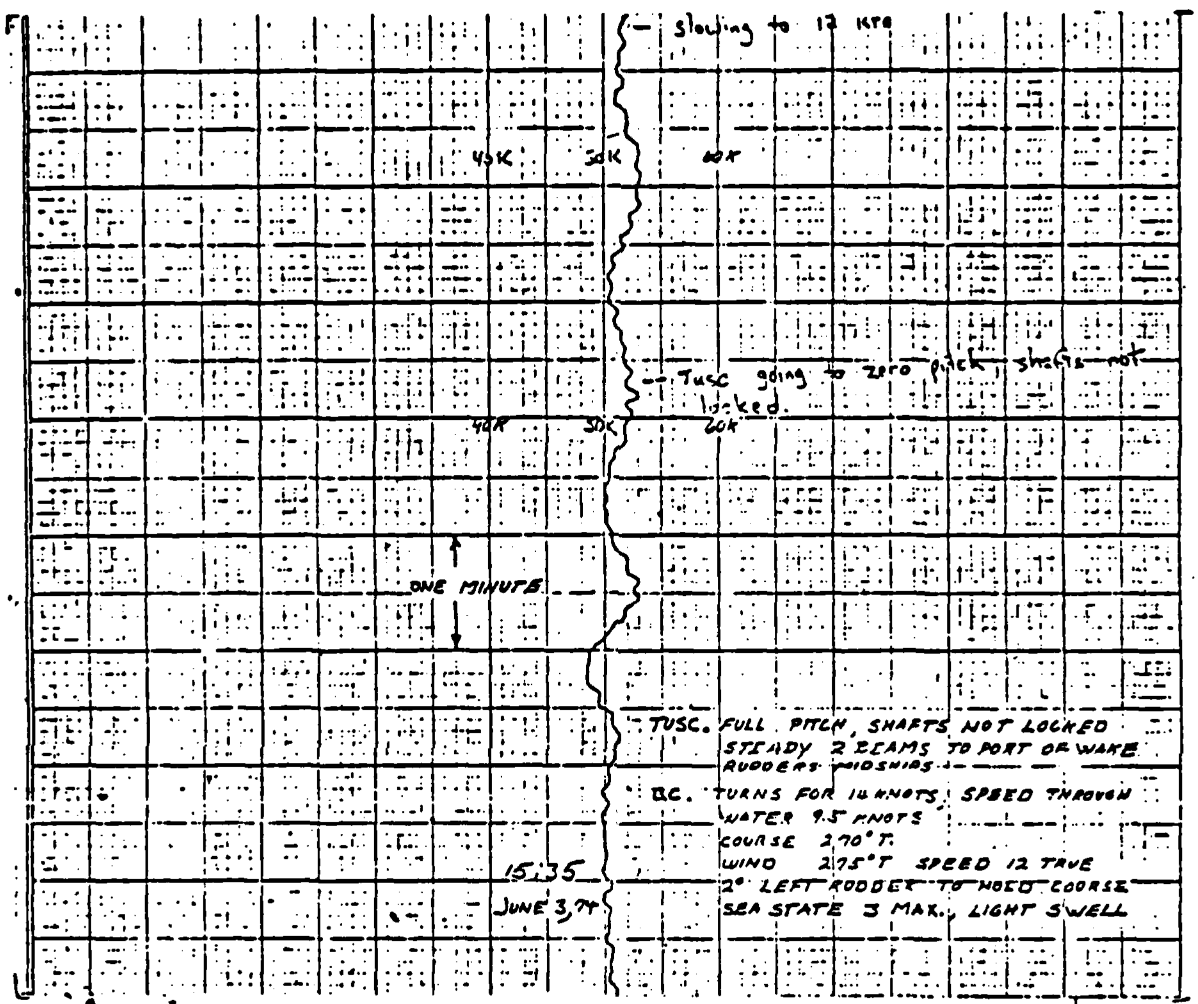
Section | Prepared by: RCS | Date: 3/15/76 | Checked | Reviewed

SUMMARY OF RESULTS FOR TESTS #1 & #2 OF LST 1179 CLASS

TEST No.	TOW SPEED KT.	REL WIND SPEED KT.	REL WIND DIR DEG.	MEASURED TOW RESIS. LST 1187 TEST (AVERAGE)	MR&S CALC. TOW RESIS. LB.	MR&S CALC. TOW RESIS. % DIFF	U.S.N CALC. TOW RESIS. LB.	U.S.N CALC. TOW RESIS. % DIFF
#1	9.5	21.48	3°	51,000	74234	45%	108946	114%
#2	9	1.44	175	48,000	60990	27%	92,263	92.2%

TEST #1

TOWING AT HIGH SPEED, STRAIGHT COURSE



B.C. TURNS FOR 14 KNOTS
PIT LOG - 9.5 KNOTS
6-ENGINES
COURSE 270° T
WIND 275° T SPEED 12 KNOTS TRUE
2° LEFT RUDDER TO HOLD COURSE
SEA STATE 3 MAX, LIGHT SWELL

TUSC. FULL PITCH, SHAFTS NOT LOCKED
STEADY 2 BEAMS TO PORT OF WAKE
RUDDERS ϕ DEGREES

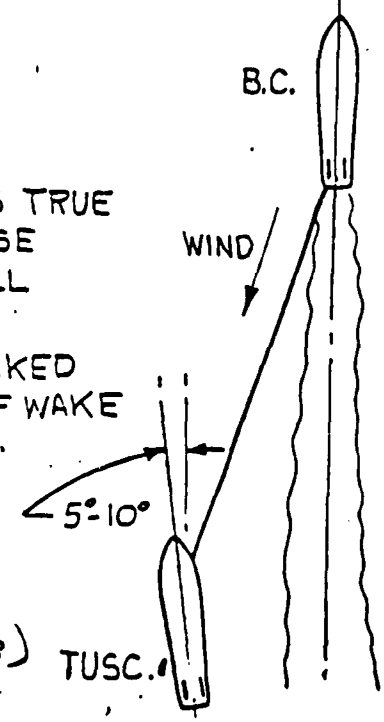


FIGURE (REF. 28)

CALCULATION OF TOWING RESISTANCE

SHIP: LST 1179 - TEST* 1 DATE: 3/12/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		LST 1179
2	TOW DISPLACEMENT, Δ (SEE TABLE-7)	LONG TONS	8342
3	FRONTAL WINDAGE AREA, A_T, (SEE TABLE 7)	SQ. FEET	3940 *
4	WIND DRAG COEFFICIENT, C_w, (SEE TABLE 7)	—	0.70
5	TOTAL PROJECTED AREA OF PROPELLERS, A_p, (SEE TABLE 7)	SQ. FEET	108.14
6	CURVE NUMBER FOR HULL RESISTANCE, R_H/Δ, (SEE TABLE 7)	—	18
7	CURVE NUMBER FOR WIND FACTOR, K, (SEE TABLE 7)	—	3
8	CURVE NUMBER FOR SEA STATE RESISTANCE, R_s, (SEE TABLE 7)	—	9
9	BEAUFORT NUMBER (WIND) - (SEE TABLE-8)	—	4
10	RELATIVE WIND SPEED, V_R	KNOTS	21.48
11	RELATIVE WIND DIRECTION, α	DEGREES	3°
12	HEADING COEFFICIENT K, (SEE FIG. 13-15)	—	1.0
13	SEA STATE RESISTANCE R_s, (SEE FIG. 16)	—	1500
14	SELECT A TOW SPEED, V_{TOW}	KNOTS	9.5
15	$R_{H/\Delta}$ (SEE FIG. 17)	—	2.86
16	HULL RESISTANCE = R_H = (15) x (2) x 1.25	POUNDS	29823
17	PROPELLER RESISTANCE = R_p = 3.737 x (5) x (14) x (14)	POUNDS	36472
18	WIND RESISTANCE = R_w = 0.00506 x (4) x (3) x (12) x (10) x (10)	POUNDS	6439
19	TOTAL TOW RESISTANCE = R_T = (13) + (16) + (17) + (18)	POUNDS	74234

NOTES: 1) ASSUME A_T IS SAME AS LST 1156.
2) TRUE WIND SPEED = 12 KT.
3) TRUE WIND DIRECTION = 275°, COURSE = 270° T
4) SHAFTS NOT LOCKED

CALCULATION OF TOW RESISTANCE BY METHOD USED IN U.S. NAVY TOWING MANUAL

SHIP: LST 1179 - TEST #1

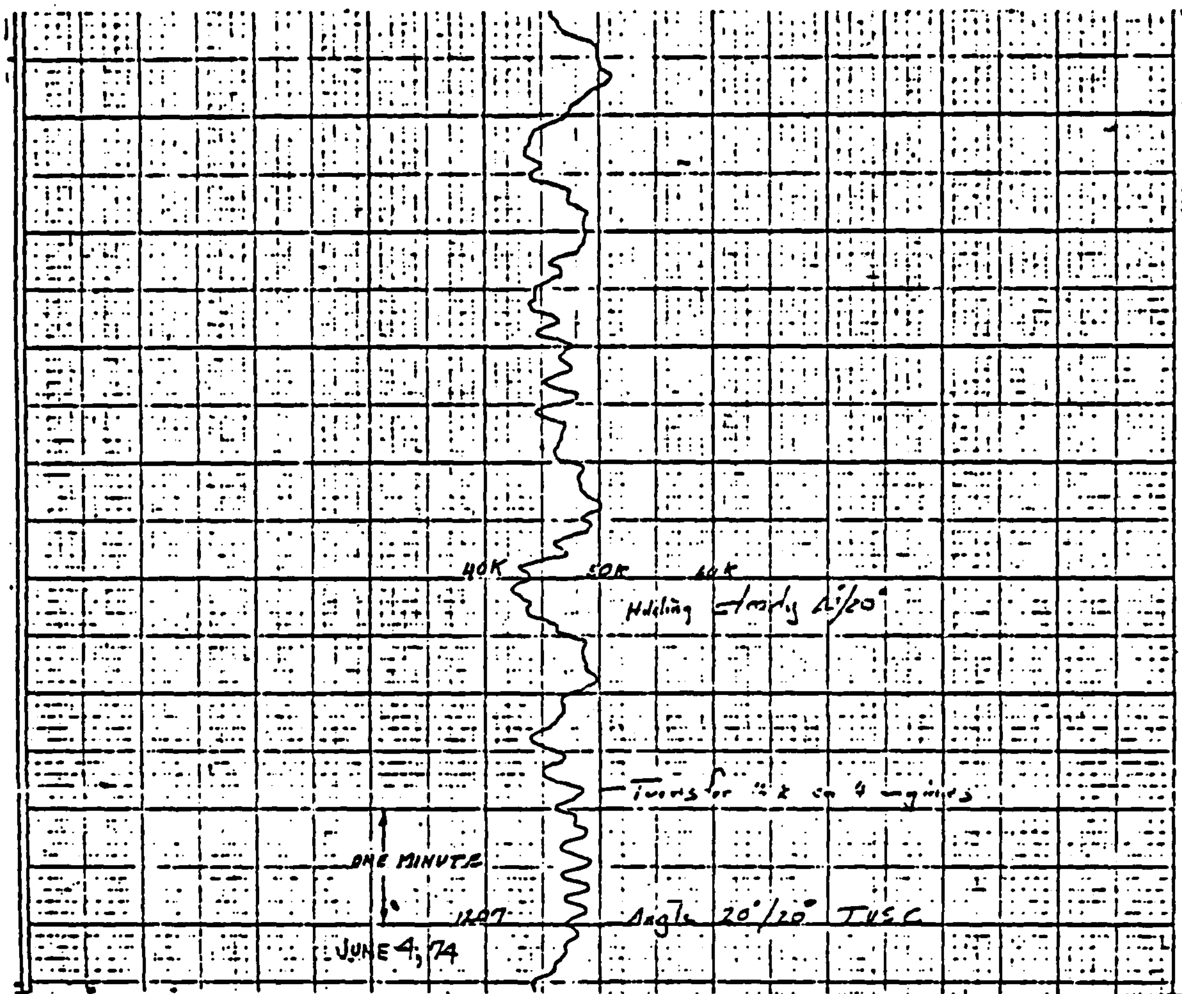
DATE: 3/12/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		LST-1179
2	TOW DISPLACEMENT, Δ (SEE TABLE 7)	LONG TONS	8342
3	FRONTAL WINDAGE AREA, A_T	SQ. FT.	3940
4	TOW SPEED, V_{TOW}	KNOTS	9.5
5	DIRECTION OF TRUE WIND FROM BOW, θ	DEGREES	5°
6	TRUE WIND VELOCITY, V_{WIND}	KNOTS	12
7	WIND VELOCITY COMPONENT V_T = (4) + [(6) x COS (5)]	KNOTS	21.45
8	WIND PRESSURE P, (SEE GRAPH 1)	LBS/SQ.FT.	0.6
9	WIND RESISTANCE, R_W = (3) x (8)	POUNDS	5005
10	HYDRODYNAMIC UNIT RESISTANCE r_H, (SEE GRAPH 2)	--	8.9
11	SEA STATE CORRECTION FACTOR K_1 (SEE TABLE 8)	--	1.4
12	HYDRODYNAMIC RESISTANCE R_H = (2) x (10) x (11)	POUNDS	103941
13	TOTAL PROJECTED AREA OF PROPELLERS, A_P	SQ. FT.	108.14
14	PROPELLER RESISTANCE = R_P = 3.394 x (13) x (4) x (4)	POUNDS	33124
15	HULL RESISTANCE = (10) x (2) - (14)	POUNDS	41120
16	SEA STATE RESISTANCE = R_S = (12) - (15) - (14)	POUNDS	29697
17	TOTAL TOW RESISTANCE = R_T = (9) + (12)	POUNDS	108946

TEST #2

TURNS FOR 14 KNOTS DOWN WIND



B.C. TURNS FOR 14 KNOTS
PIT LOG 9 KNOTS
4 ENGINES
COURSE 070°T
WIND 254°T SPEED 10 KNOTS TRUE
SEA STATE 3 MAX LIGHT SWELL
RUDDER 4° LEFT TO HOLD COURSE

TUSC FULL PITCH, SHAFTS NOT LOCKED
RUDDERS φ DEGREES

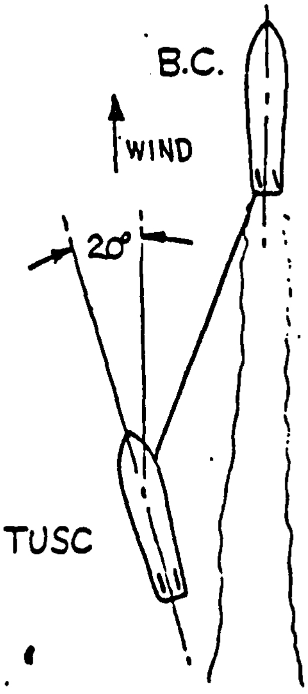


FIGURE (REF. 28)

CALCULATION OF TOWING RESISTANCE

SHIP: LST 1179 TEST #2

DATE: 3/12/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		LST 1179
2	TOW DISPLACEMENT, Δ (SEE TABLE-7)	LONG TONS	8342
3	FRONTAL WINDAGE AREA, A_T, (SEE TABLE 7)	SQ. FEET	3940
4	WIND DRAG COEFFICIENT, C_w, (SEE TABLE 7)	—	0.70
5	TOTAL PROJECTED AREA OF PROPELLERS, A_p, (SEE TABLE 7)	SQ. FEET	108.14
6	CURVE NUMBER FOR HULL RESISTANCE, $R_{H/\Delta}$, (SEE TABLE 7)	—	18
7	CURVE NUMBER FOR WIND FACTOR, K, (SEE TABLE 7)	—	3
8	CURVE NUMBER FOR SEA STATE RESISTANCE, R_s, (SEE TABLE 7)	—	9
9	BEAUFORT NUMBER (WIND) - (SEE TABLE-8)	—	4
10	RELATIVE WIND SPEED, V_R	KNOTS	1.44 KT.
11	RELATIVE WIND DIRECTION, α	DEGREES	175
12	HEADING COEFFICIENT K, (SEE FIG. 13-15)	—	-1.47
13	SEA STATE RESISTANCE R_s, (SEE FIG. 16)	—	1500
14	SELECT A TOW SPEED, V_{TOW}	KNOTS	9
15	$R_{H/\Delta}$ (SEE FIG. 17)	—	2.57
16	HULL RESISTANCE = R_H = (15) x (2) x 1.25	POUNDS	26799
17	PROPELLER RESISTANCE = R_p = 3.737 x (5) x (14) x (14)	POUNDS	32734
18	WIND RESISTANCE = R_w = 0.00506 x (4) x (3) x (12) x (10) x (10)	POUNDS	-42.5
19	TOTAL TOW RESISTANCE = R_T = (13) + (16) + (17) + (18)	POUNDS	60990

NOTES: 1) ASSUME A_T IS SAME AS LST 1156
2) TRUE WIND SPEED = 10 KT.
3) TRUE WIND DIRECTION = 254°, COURSE = 070° T θ = 18
4) SHAFTS NOT LOCKED

CALCULATION OF TOW RESISTANCE BY METHOD USED IN U.S. NAVY TOWING MANUAL

SHIP: LST 1179 - TEST #2

DATE: 3/15/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		LST 1179
2	TOW DISPLACEMENT, Δ (SEE TABLE 7)	LONG TONS	8342
3	FRONTAL WINDAGE AREA, A_T	SQ. FT.	3940
4	TOW SPEED, V_{TOW}	KNOTS	9
5	DIRECTION OF TRUE WIND FROM BOW, θ	DEGREES	176
6	TRUE WIND VELOCITY, V_{WIND}	KNOTS	10
7	WIND VELOCITY COMPONENT V_T = (4) + [(6) x COS (5)]	KNOTS	-1.0
8	WIND PRESSURE P, (SEE GRAPH 1)	LBS/SQ.FT	≈ 0
9	WIND RESISTANCE, R_W = (3) x (8)	POUNDS	≈ 0
10	HYDRODYNAMIC UNIT RESISTANCE r_H, (SEE GRAPH 2)	--	7.9
11	SEA STATE CORRECTION FACTOR K_1 (SEE TABLE 8)	--	1.4
12	HYDRODYNAMIC RESISTANCE R_H = (2) x (10) x (11)	POUNDS	92263
13	TOTAL PROJECTED AREA OF PROPELLERS, A_P	SQ. FT.	108.14
14	PROPELLER RESISTANCE = R_P = 3.394 x (13) x (4) x (4)	POUNDS	29729
15	HULL RESISTANCE = (10) x (2) - (14)	POUNDS	36173
16	SEA STATE RESISTANCE = R_S = (12) - (15) - (14)	POUNDS	26361
17	TOTAL TOW RESISTANCE = R_T = (9) + (12)	POUNDS	92263

Subject: CORRELATION STUDY COMPARING U.S.N. TOWING MANUAL WITH MR&S METHOD

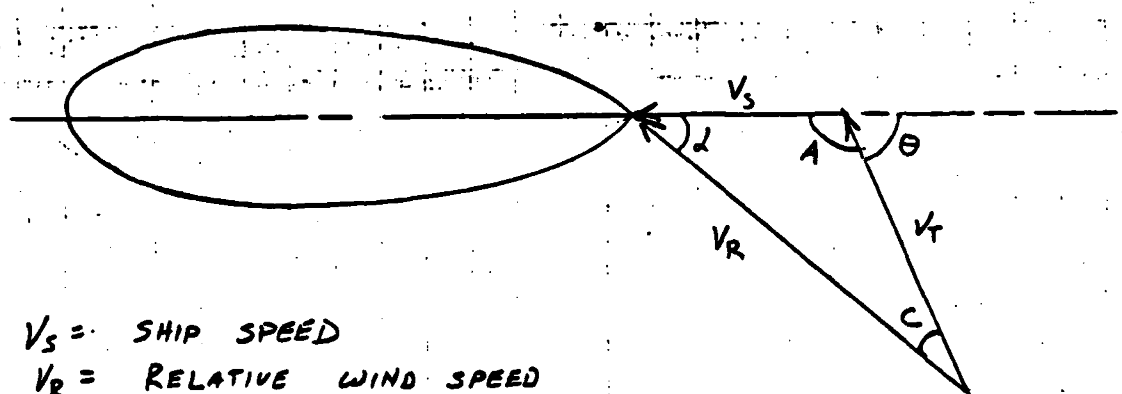
Ship or Project: TOWING RESISTANCE CRITERIA

Section: BSDD Prepared by: RCS Date: 3/1/76 Checked Reviewed

THE FOLLOWING STUDY COMPARES THE RESULTS OF A SERIES OF TOW RESISTANCE CALCULATIONS USING THE U.S. NAVY TOWING MANUAL (DATE 1971) AND THE MR&S METHOD DEVELOPED IN THIS REPORT.

THE U.S. NAVY CALCULATION PROCEDURE USES THE TRUE WIND VELOCITY AND DIRECTION RELATIVE TO THE SHIP COURSE WHILE THE MR&S METHOD USES A RELATIVE WIND VELOCITY AND RELATIVE (OR APPARENT) WIND DIRECTION. TO INSURE THAT EQUIVALENT WEATHER CONDITIONS WERE USED FOR THE TWO METHODS, A TRUE WIND STRENGTH AND RELATIVE WIND DIRECTION WERE SELECTED AND A TRUE WIND DIRECTION AND RELATIVE WIND VELOCITY WERE CALCULATED.

VECTOR DIAGRAM



V_S = SHIP SPEED
V_R = RELATIVE WIND SPEED
V_T = TRUE WIND SPEED

$$\sin(C) = \frac{V_S \sin\alpha}{V_T}$$

$$A = 180° - C - \alpha$$

$$V_R = \frac{V_T \sin A}{\sin\alpha} \qquad \theta = \alpha + C$$

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No. 3419
Sheet of

Subject CORRELATION STUDY COMPARING U.S.N. TOWING MANUAL WITH MR&S METHOD
Ship or Project TOWING RESISTANCE CRITERIA
Section Prepared by RCS Date 3/1/76 Checked Reviewed

CONDITIONS CHOSEN FOR CORRELATION STUDY

BEAUFORT No.	SHIP SPEED KT.	RELATIVE WIND α (DEG.)	RELATIVE WIND V_R (KT.)	TRUE WIND θ (DEG.)	TRUE WIND V_T (KT.)
0	10	0	10	0	0
4	8	0	21.5	0	13.5
	8	30	19.82	47.23	13.5
	8	90	10.87	126.34	13.5
6	5	0	29.5	0	24.5
	5	30	28.7	35.86	24.5
	5	90	23.98	101.8	24.5

CALCULATION OF TOW RESISTANCE BY METHOD USED IN U.S. NAVY TOWING MANUAL

SHIP: ATF-148 OCEAN TUG

DATE: 2/25/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		ATF 148
2	TOW DISPLACEMENT, Δ (SEE TABLE 7)	LONG TONS	1675
3	FRONTAL WINDAGE AREA, A_T	SQ. FT.	1200
4	TOW SPEED, V_{TOW}	KNOTS	10
5	DIRECTION OF TRUE WIND FROM BOW, θ	DEGREES	0
6	TRUE WIND VELOCITY, V_{WIND}	KNOTS	0
7	WIND VELOCITY COMPONENT V_T = (4) + [(6) x COS (5)]	KNOTS	10
8	WIND PRESSURE P, (SEE GRAPH 1)	LBS/SQ.FT	0.3
9	WIND RESISTANCE, R_W = (3) x (8)	POUNDS	360
10	HYDRODYNAMIC UNIT RESISTANCE r_H, (SEE GRAPH 2)	--	9.8*
11	SEA STATE CORRECTION FACTOR K_1 (SEE TABLE 8)	--	1.0
12	HYDRODYNAMIC RESISTANCE R_H = (2) x (10) x (11)	POUNDS	16,415
13	TOTAL PROJECTED AREA OF PROPELLERS, A_P	SQ. FT.	43
14	PROPELLER RESISTANCE = R_P = 3.394 x (13) x (4) x (4)	POUNDS	14594
15	HULL RESISTANCE = (10) x (2) - (14)	POUNDS	1821
16	SEA STATE RESISTANCE = R_s = (12) - (15) - (14)	POUNDS	0
17	TOTAL TOW RESISTANCE = R_T = (9) + (12)	POUNDS	16775

* NOTE: USED LST CURVE TO OBTAIN r_H SO A POSITIVE HULL RESISTANCE COULD BE ATTAINED.

CALCULATION OF TOW RESISTANCE BY METHOD USED IN U.S. NAVY TOWING MANUAL

SHIP: ATF-148 OCEAN TUG

DATE: 2/25/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		ATF 148
2	TOW DISPLACEMENT, Δ (SEE TABLE 7)	LONG TONS	1675
3	FRONTAL WINDAGE AREA, A_T	SQ. FT.	1200
4	TOW SPEED, V_{TOW}	KNOTS	8
5	DIRECTION OF TRUE WIND FROM BOW, θ	DEGREES	0
6	TRUE WIND VELOCITY, V_{WIND}	KNOTS	13.5
7	WIND VELOCITY COMPONENT V_T = (4) + [(6) x cos (5)]	KNOTS	21.5
8	WIND PRESSURE P, (SEE GRAPH 1)	LBS/SQ.FT.	0.9
9	WIND RESISTANCE, R_W = (3) x (8)	POUNDS	1080
10	HYDRODYNAMIC UNIT RESISTANCE r_H, (SEE GRAPH 2)	--	6.3
11	SEA STATE CORRECTION FACTOR K_1 (SEE TABLE 8)	--	1.4
12	HYDRODYNAMIC RESISTANCE R_H = (2) x (10) x (11)	POUNDS	14774
13	TOTAL PROJECTED AREA OF PROPELLERS, A_P	SQ. FT.	43
14	PROPELLER RESISTANCE = R_P = 3.394 x (13) x (4) x (4)	POUNDS	9340
15	HULL RESISTANCE = (10) x (2) - (14)	POUNDS	1213
16	SEA STATE RESISTANCE = R_s = (12) - (15) - (14)	POUNDS	4221
17	TOTAL TOW RESISTANCE = R_T = (9) + (12)	POUNDS	15854

CALCULATION OF TOW RESISTANCE BY METHOD USED IN U.S. NAVY TOWING MANUAL

SHIP: ATF-148

DATE: 2/25/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		ATF-148
2	TOW DISPLACEMENT, Δ (SEE TABLE 7)	LONG TONS	1675
3	FRONTAL WINDAGE AREA, A_T	SQ. FT.	1200
4	TOW SPEED, V_{TOW}	KNOTS	8
5	DIRECTION OF TRUE WIND FROM BOW, θ	DEGREES	47.23
6	TRUE WIND VELOCITY, V_{WIND}	KNOTS	13.5
7	WIND VELOCITY COMPONENT V_T = (4) + [(6) x COS (5)]	KNOTS	17.17
8	WIND PRESSURE P, (SEE GRAPH 1)	LBS/SQ.FT.	0.7
9	WIND RESISTANCE, R_W = (3) x (8)	POUNDS	840
10	HYDRODYNAMIC UNIT RESISTANCE r_H, (SEE GRAPH 2)	--	6.3
11	SEA STATE CORRECTION FACTOR K_1 (SEE TABLE 8)	--	1.4
12	HYDRODYNAMIC RESISTANCE R_H = (2) x (10) x (11)	POUNDS	14774
13	TOTAL PROJECTED AREA OF PROPELLERS, A_P	SQ. FT.	43
14	PROPELLER RESISTANCE = R_P = 3.394 x (13) x (4) x (4)	POUNDS	9340
15	HULL RESISTANCE = (10) x (2) - (14)	POUNDS	1213
16	SEA STATE RESISTANCE = R_s = (12) - (15) - (14)	POUNDS	4221
17	TOTAL TOW RESISTANCE = R_T = (9) + (12)	POUNDS	15614

CALCULATION OF TOW RESISTANCE BY METHOD USED IN U.S. NAVY TOWING MANUAL

SHIP: ATF- 148

DATE: 2/25/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		ATF-148
2	TOW DISPLACEMENT, Δ (SEE TABLE 7)	LONG TONS	1675
3	FRONTAL WINDAGE AREA, A_T	SQ. FT.	1200
4	TOW SPEED, V_{TOW}	KNOTS	8
5	DIRECTION OF TRUE WIND FROM BOW, θ	DEGREES	126.34
6	TRUE WIND VELOCITY, V_{WIND}	KNOTS	13.5
7	WIND VELOCITY COMPONENT V_T = (4) + [(6) x COS (5)]	KNOTS	0
8	WIND PRESSURE P, (SEE GRAPH 1)	LBS/SQ.FT.	0
9	WIND RESISTANCE, R_W = (3) x (8)	POUNDS	0
10	HYDRODYNAMIC UNIT RESISTANCE r_H, (SEE GRAPH 2)	--	6.3
11	SEA STATE CORRECTION FACTOR K_1 (SEE TABLE 8)	--	1.4
12	HYDRODYNAMIC RESISTANCE R_H = (2) x (10) x (11)	POUNDS	14774
13	TOTAL PROJECTED AREA OF PROPELLERS, A_P	SQ. FT.	43
14	PROPELLER RESISTANCE = R_P = 3.394 x (13) x (4) x (4)	POUNDS	9340
15	HULL RESISTANCE = (10) x (2) - (14)	POUNDS	1213
16	SEA STATE RESISTANCE = R_S = (12) - (15) - (14)	POUNDS	4221
17	TOTAL TOW RESISTANCE = R_T = (9) + (12)	POUNDS	14774

CALCULATION OF TOW RESISTANCE BY METHOD USED IN U.S. NAVY TOWING MANUAL

SHIP: ATF -148

DATE: 2/25/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		ATF-148
2	TOW DISPLACEMENT, Δ (SEE TABLE 7)	LONG TONS	1675
3	FRONTAL WINDAGE AREA, A_T	SQ. FT.	1200
4	TOW SPEED, V_{TOW}	KNOTS	5
5	DIRECTION OF TRUE WIND FROM BOW, θ	DEGREES	0
6	TRUE WIND VELOCITY, V_{WIND}	KNOTS	24.5
7	WIND VELOCITY COMPONENT V_T = (4) + [(6) x COS (5)]	KNOTS	29.5
8	WIND PRESSURE P, (SEE GRAPH 1)	LBS/SQ.FT.	1.7
9	WIND RESISTANCE, R_W = (3) x (8)	POUNDS	2848
10	HYDRODYNAMIC UNIT RESISTANCE r_H, (SEE GRAPH 2)	--	0.8
11	SEA STATE CORRECTION FACTOR K_1 (SEE TABLE 8)	--	1.6
12	HYDRODYNAMIC RESISTANCE R_H = (2) x (10) x (11)	POUNDS	2144
13	TOTAL PROJECTED AREA OF PROPELLERS, A_P	SQ. FT.	43
14	PROPELLER RESISTANCE = R_P = 3.394 x (13) x (4) x (4)	POUNDS	3649
15	HULL RESISTANCE = (10) x (2) - (14)	POUNDS	-2309* ← ?
16	SEA STATE RESISTANCE = R_s = (12) - (15) - (14)	POUNDS	—
17	TOTAL TOW RESISTANCE = R_T = (9) + (12)	POUNDS	—

NOTE: EVEN USING LST CURVE PRODUCES A NEGATIVE HULL RESISTANCE.

CALCULATION OF TOWING RESISTANCE

SHIP: ATF - 148 DATE: 2/25/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		ATF-148
2	TOW DISPLACEMENT, Δ (SEE TABLE-7)	LONG TONS	1675
3	FRONTAL WINDAGE AREA, A_T, (SEE TABLE 7)	SQ. FEET	1200
4	WIND DRAG COEFFICIENT, C_w, (SEE TABLE 7)	—	0.75
5	TOTAL PROJECTED AREA OF PROPELLERS, A_p, (SEE TABLE 7)	SQ. FEET	43
6	CURVE NUMBER FOR HULL RESISTANCE, R_H/Δ, (SEE TABLE 7)	—	9
7	CURVE NUMBER FOR WIND FACTOR, K, (SEE TABLE 7)	—	1
8	CURVE NUMBER FOR SEA STATE RESISTANCE, R_s, (SEE TABLE 7)	—	2
9	BEAUFORT NUMBER (WIND) - (SEE TABLE-8)	—	0
10	RELATIVE WIND SPEED, V_R	KNOTS	10
11	RELATIVE WIND DIRECTION, α	DEGREES	0
12	HEADING COEFFICIENT K, (SEE FIG. 13-15)	—	1.0
13	SEA STATE RESISTANCE R_s, (SEE FIG. 16)	—	0
14	SELECT A TOW SPEED, V_{TOW}	KNOTS	10
15	$R_{H/\Delta}$ (SEE FIG. 17)	—	7.1
16	HULL RESISTANCE = R_H = (15) × (2) × 1.25	POUNDS	14866
17	PROPELLER RESISTANCE = R_p = 3.737 × (5) × (14) × (14)	POUNDS	1605[illegible]
18	WIND RESISTANCE = R_w = 0.00506 × (4) × (3) × (12) × (10) × (10)	POUNDS	455
19	TOTAL TOW RESISTANCE = R_T = (13) + (16) + (17) + (18)	POUNDS	313[illegible]

CALCULATION OF TOWING RESISTANCE

SHIP: *ATF-148* DATE: *2/25/76*

BY: *RCS*

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		ATF-148
2	TOW DISPLACEMENT, Δ (SEE TABLE-7)	LONG TONS	1675
3	FRONTAL WINDAGE AREA, A_T, (SEE TABLE 7)	SQ. FEET	1200
4	WIND DRAG COEFFICIENT, C_w, (SEE TABLE 7)	—	0.75
5	TOTAL PROJECTED AREA OF PROPELLERS, A_p, (SEE TABLE 7)	SQ. FEET	43
6	CURVE NUMBER FOR HULL RESISTANCE, R_H/Δ, (SEE TABLE 7)	—	9
7	CURVE NUMBER FOR WIND FACTOR, K, (SEE TABLE 7)	—	1
8	CURVE NUMBER FOR SEA STATE RESISTANCE, R_s, (SEE TABLE 7)	—	2
9	BEAUFORT NUMBER (WIND) - (SEE TABLE-8)	—	4
10	RELATIVE WIND SPEED, V_R	KNOTS	21.5
11	RELATIVE WIND DIRECTION, α	DEGREES	0
12	HEADING COEFFICIENT K, (SEE FIG. 13-15)	—	1.0
13	SEA STATE RESISTANCE R_s, (SEE FIG. 16)	—	900
14	SELECT A TOW SPEED, V_{TOW}	KNOTS	8
15	$R_{H/\Delta}$ (SEE FIG. 17)	—	4.2
16	HULL RESISTANCE = R_H = (15) x (2) x 1.25	POUNDS	7035
17	PROPELLER RESISTANCE = R_p = 3.737 x (5) x (14) x (14)	POUNDS	10284
18	WIND RESISTANCE = R_w = 0.00506 x (4) x (3) x (12) x (10) x (10)	POUNDS	2105
19	TOTAL TOW RESISTANCE = R_T = (13) + (16) + (17) + (18)	POUNDS	20324

CALCULATION OF TOWING RESISTANCE

SHIP: ATF-148 DATE: 2/25/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		ATF-148
2	TOW DISPLACEMENT, Δ (SEE TABLE-7)	LONG TONS	1675
3	FRONTAL WINDAGE AREA, A_T, (SEE TABLE 7)	SQ. FEET	1200
4	WIND DRAG COEFFICIENT, C_w, (SEE TABLE 7)	—	0.75
5	TOTAL PROJECTED AREA OF PROPELLERS, A_p, (SEE TABLE 7)	SQ. FEET	43
6	CURVE NUMBER FOR HULL RESISTANCE, R_H/Δ, (SEE TABLE 7)	—	9
7	CURVE NUMBER FOR WIND FACTOR, K, (SEE TABLE 7)	—	1
8	CURVE NUMBER FOR SEA STATE RESISTANCE, R_s, (SEE TABLE 7)	—	2
9	BEAUFORT NUMBER (WIND) - (SEE TABLE-8)	—	4
10	RELATIVE WIND SPEED, V_R	KNOTS	21.5
11	RELATIVE WIND DIRECTION, α	DEGREES	0
12	HEADING COEFFICIENT K, (SEE FIG. 13-15)	—	1.0
13	SEA STATE RESISTANCE R_s, (SEE FIG. 16)	—	900
14	SELECT A TOW SPEED, V_{TOW}	KNOTS	8
15	$R_{H/\Delta}$ (SEE FIG. 17)	—	4.2
16	HULL RESISTANCE = R_H = (15) x (2) x 1.25	POUNDS	7035
17	PROPELLER RESISTANCE = R_p = 3.737 x (5) x (14) x (14)	POUNDS	10284
18	WIND RESISTANCE = R_w = 0.00506 x (4) x (3) x (12) x (10) x (10)	POUNDS	2105
19	TOTAL TOW RESISTANCE = R_T = (13) + (16) + (17) + (18)	POUNDS	20324

CALCULATION OF TOWING RESISTANCE

SHIP: *ATF-148* DATE: *2/25/76*

BY: *RCS*

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		*ATF-148*
2	TOW DISPLACEMENT, Δ (SEE TABLE-7)	LONG TONS	*1675*
3	FRONTAL WINDAGE AREA, A_T, (SEE TABLE 7)	SQ. FEET	*1200*
4	WIND DRAG COEFFICIENT, C_w, (SEE TABLE 7)	—	*0.75*
5	TOTAL PROJECTED AREA OF PROPELLERS, A_p, (SEE TABLE 7)	SQ. FEET	*43*
6	CURVE NUMBER FOR HULL RESISTANCE, $R_{H/\Delta}$, (SEE TABLE 7)	—	*9*
7	CURVE NUMBER FOR WIND FACTOR, K, (SEE TABLE 7)	—	*1*
8	CURVE NUMBER FOR SEA STATE RESISTANCE, R_s, (SEE TABLE 7)	—	*2*
9	BEAUFORT NUMBER (WIND) - (SEE TABLE-8)	—	*4*
10	RELATIVE WIND SPEED, V_R	KNOTS	*10.87*
11	RELATIVE WIND DIRECTION, α	DEGREES	*90*
12	HEADING COEFFICIENT K, (SEE FIG. 13-15)	—	*0.1*
13	SEA STATE RESISTANCE R_s, (SEE FIG. 16)	—	*900*
14	SELECT A TOW SPEED, V_{TOW}	KNOTS	*8*
15	$R_{H/\Delta}$ (SEE FIG. 17)	—	*4.2*
16	HULL RESISTANCE = R_H = (15) × (2) × 1.25	POUNDS	*7035*
17	PROPELLER RESISTANCE = R_p = 3.737 × (5) × (14) × (14)	POUNDS	*10284*
18	WIND RESISTANCE = R_w = 0.00506 × (4) × (3) × (12) × (10) × (10)	POUNDS	*53.81*
19	TOTAL TOW RESISTANCE = R_T = (13) + (16) + (17) + (18)	POUNDS	*18273*

CALCULATION OF TOWING RESISTANCE

SHIP: ATF-148

DATE: 2/25/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		ATF-148
2	TOW DISPLACEMENT, Δ (SEE TABLE-7)	LONG TONS	1675
3	FRONTAL WINDAGE AREA, A_T, (SEE TABLE 7)	SQ. FEET	1200
4	WIND DRAG COEFFICIENT, C_w, (SEE TABLE 7)	—	0.75
5	TOTAL PROJECTED AREA OF PROPELLERS, A_p, (SEE TABLE 7)	SQ. FEET	43
6	CURVE NUMBER FOR HULL RESISTANCE, $R_{H/\Delta}$, (SEE TABLE 7)	—	9
7	CURVE NUMBER FOR WIND FACTOR, K, (SEE TABLE 7)	—	1
8	CURVE NUMBER FOR SEA STATE RESISTANCE, R_s, (SEE TABLE 7)	—	2
9	BEAUFORT NUMBER (WIND) - (SEE TABLE-8)	—	4
10	RELATIVE WIND SPEED, V_R	KNOTS	10.87
11	RELATIVE WIND DIRECTION, α	DEGREES	90
12	HEADING COEFFICIENT K, (SEE FIG. 13-15)	—	0.1
13	SEA STATE RESISTANCE R_s, (SEE FIG. 16)	—	900
14	SELECT A TOW SPEED, V_{TOW}	KNOTS	8
15	$R_{H/\Delta}$ (SEE FIG. 17)	—	4.2
16	HULL RESISTANCE = R_H = (15) × (2) × 1.25	POUNDS	7035
17	PROPELLER RESISTANCE = R_p = 3.737 × (5) × (14) × (14)	POUNDS	10284
18	WIND RESISTANCE = R_w = 0.00506 × (4) × (3) × (12) × (10) × (10)	POUNDS	53.81
19	TOTAL TOW RESISTANCE = R_T = (13) + (16) + (17) + (18)	POUNDS	18273

CALCULATION OF TOWING RESISTANCE

SHIP: ATF-148

DATE: 2/25/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		ATF-148
2	TOW DISPLACEMENT, Δ (SEE TABLE-7)	LONG TONS	1675
3	FRONTAL WINDAGE AREA, A_T, (SEE TABLE 7)	SQ. FEET	1200
4	WIND DRAG COEFFICIENT, C_w, (SEE TABLE 7)	—	0.75
5	TOTAL PROJECTED AREA OF PROPELLERS, A_p, (SEE TABLE 7)	SQ. FEET	43
6	CURVE NUMBER FOR HULL RESISTANCE, $R_{H/\Delta}$, (SEE TABLE 7)	—	9
7	CURVE NUMBER FOR WIND FACTOR, K, (SEE TABLE 7)	—	1
8	CURVE NUMBER FOR SEA STATE RESISTANCE, R_s, (SEE TABLE 7)	—	2
9	BEAUFORT NUMBER (WIND) - (SEE TABLE-8)	—	4
10	RELATIVE WIND SPEED, V_R	KNOTS	10.87
11	RELATIVE WIND DIRECTION, α	DEGREES	90
12	HEADING COEFFICIENT K, (SEE FIG. 13-15)	—	0.1
13	SEA STATE RESISTANCE R_s, (SEE FIG. 16)	—	900
14	SELECT A TOW SPEED, V_{TOW}	KNOTS	8
15	$R_{H/\Delta}$ (SEE FIG. 17)	—	4.2
16	HULL RESISTANCE = R_H = (15) x (2) x 1.25	POUNDS	7035
17	PROPELLER RESISTANCE = R_p = 3.737 x (5) x (14) x (14)	POUNDS	10284
18	WIND RESISTANCE = R_w = 0.00506 x (4) x (3) x (12) x (10) x (10)	POUNDS	53.81
19	TOTAL TOW RESISTANCE = R_T = (13) + (16) + (17) + (18)	POUNDS	18273

CALCULATION OF TOWING RESISTANCE

SHIP: *ATF-148*

DATE: *2/25/76*

BY: *RCS*

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		*ATF-148*
2	TOW DISPLACEMENT, Δ (SEE TABLE-7)	LONG TONS	*1675*
3	FRONTAL WINDAGE AREA, A_T, (SEE TABLE 7)	SQ. FEET	*1200*
4	WIND DRAG COEFFICIENT, C_w, (SEE TABLE 7)	—	*0.75*
5	TOTAL PROJECTED AREA OF PROPELLERS, A_p, (SEE TABLE 7)	SQ. FEET	*43*
6	CURVE NUMBER FOR HULL RESISTANCE, R_H/Δ, (SEE TABLE 7)	—	*9*
7	CURVE NUMBER FOR WIND FACTOR, K, (SEE TABLE 7)	—	*1*
8	CURVE NUMBER FOR SEA STATE RESISTANCE, R_s, (SEE TABLE 7)	—	*2*
9	BEAUFORT NUMBER (WIND) - (SEE TABLE-8)	—	*6*
10	RELATIVE WIND SPEED, V_R	KNOTS	*28.7*
11	RELATIVE WIND DIRECTION, α	DEGREES	*30*
12	HEADING COEFFICIENT K, (SEE FIG. 13-15)	—	*1.13*
13	SEA STATE RESISTANCE R_s, (SEE FIG. 16)	—	*23,500*
14	SELECT A TOW SPEED, V_{TOW}	KNOTS	*5*
15	$R_{H/\Delta}$ (SEE FIG. 17)	—	*1.75*
16	HULL RESISTANCE = R_H = (15) x (2) x 1.25	POUNDS	*3664*
17	PROPELLER RESISTANCE = R_p = 3.737 x (5) x (14) x (14)	POUNDS	*4017*
18	WIND RESISTANCE = R_W = 0.00506 x (4) x (3) x (12) x (10) x (10)	POUNDS	*4239*
19	TOTAL TOW RESISTANCE = R_T = (13) + (16) + (17) + (18)	POUNDS	*35,419*

CALCULATION OF TOWING RESISTANCE

SHIP: *ATF-148*   DATE: *2/25/76*

BY: *RCS*

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		*ATF-148*
2	TOW DISPLACEMENT, Δ (SEE TABLE-7)	LONG TONS	*1675*
3	FRONTAL WINDAGE AREA, A_T, (SEE TABLE 7)	SQ. FEET	*1200*
4	WIND DRAG COEFFICIENT, C_w, (SEE TABLE 7)	—	*0.75*
5	TOTAL PROJECTED AREA OF PROPELLERS, A_p, (SEE TABLE 7)	SQ. FEET	*43*
6	CURVE NUMBER FOR HULL RESISTANCE, R_H/Δ, (SEE TABLE 7)	—	*9*
7	CURVE NUMBER FOR WIND FACTOR, K, (SEE TABLE 7)	—	*1*
8	CURVE NUMBER FOR SEA STATE RESISTANCE, R_s, (SEE TABLE 7)	—	*2*
9	BEAUFORT NUMBER (WIND) - (SEE TABLE-8)	—	*6*
10	RELATIVE WIND SPEED, V_R	KNOTS	*28.7*
11	RELATIVE WIND DIRECTION, α	DEGREES	*30*
12	HEADING COEFFICIENT K, (SEE FIG. 13-15)	—	*1.13*
13	SEA STATE RESISTANCE R_s, (SEE FIG. 16)	—	*23,500*
14	SELECT A TOW SPEED, V_{TOW}	KNOTS	*5*
15	$R_{H/\Delta}$ (SEE FIG. 17)	—	*1.75*
16	HULL RESISTANCE = R_H = (15) x (2) x 1.25	POUNDS	*3664*
17	PROPELLER RESISTANCE = R_p = 3.737 x (5) x (14) x (14)	POUNDS	*4017*
18	WIND RESISTANCE = R_w = 0.00506 x (4) x (3) x (12) x (10) x (10)	POUNDS	*4239*
19	TOTAL TOW RESISTANCE = R_T = (13) + (16) + (17) + (18)	POUNDS	*35,419*

CALCULATION OF TOW RESISTANCE BY METHOD USED IN U.S. NAVY TOWING MANUAL

SHIP: AOE-1 FAST COMBAT SUPPORT

DATE: 2/26/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		AOE-1
2	TOW DISPLACEMENT, Δ (SEE TABLE 7)	LONG TONS	53,600
3	FRONTAL WINDAGE AREA, A_T	SQ. FT.	9750
4	TOW SPEED, V_{TOW}	KNOTS	10
5	DIRECTION OF TRUE WIND FROM BOW, θ	DEGREES	0
6	TRUE WIND VELOCITY, V_{WIND}	KNOTS	0
7	WIND VELOCITY COMPONENT V_T = (4) + [(6) x COS (5)]	KNOTS	10
8	WIND PRESSURE P, (SEE GRAPH 1)	LBS/SQ.FT	0.3
9	WIND RESISTANCE, R_W = (3) x (8)	POUNDS	2925
10	HYDRODYNAMIC UNIT RESISTANCE r_H, (SEE GRAPH 2)	--	3.5
11	SEA STATE CORRECTION FACTOR K_1 (SEE TABLE 8)	--	1.0
12	HYDRODYNAMIC RESISTANCE R_H = (2) x (10) x (11)	POUNDS	187600
13	TOTAL PROJECTED AREA OF PROPELLERS, A_P	SQ. FT.	456
14	PROPELLER RESISTANCE = R_P = 3.394 x (13) x (4) x (4)	POUNDS	154766
15	HULL RESISTANCE = (10) x (2) - (14)	POUNDS	32834
16	SEA STATE RESISTANCE = R_S = (12) - (15) - (14)	POUNDS	0
17	TOTAL TOW RESISTANCE = R_T = (9) + (12)	POUNDS	190525

CALCULATION OF TOW RESISTANCE BY METHOD USED IN U.S. NAVY TOWING MANUAL

SHIP: AOE-1 FAST COMBAT SUPPORT

DATE: 2/26/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		AOE-1
2	TOW DISPLACEMENT, Δ (SEE TABLE 7)	LONG TONS	53,600
3	FRONTAL WINDAGE AREA, A_T	SQ. FT.	9750
4	TOW SPEED, V_{TOW}	KNOTS	10
5	DIRECTION OF TRUE WIND FROM BOW, θ	DEGREES	0
6	TRUE WIND VELOCITY, V_{WIND}	KNOTS	0
7	WIND VELOCITY COMPONENT V_T = (4) + [(6) x COS (5)]	KNOTS	10
8	WIND PRESSURE P, (SEE GRAPH 1)	LBS/SQ.FT.	0.3
9	WIND RESISTANCE, R_W = (3) x (8)	POUNDS	2925
10	HYDRODYNAMIC UNIT RESISTANCE r_H, (SEE GRAPH 2)	--	3.5
11	SEA STATE CORRECTION FACTOR K_1 (SEE TABLE 8)	--	1.0
12	HYDRODYNAMIC RESISTANCE R_H = (2) x (10) x (11)	POUNDS	187600
13	TOTAL PROJECTED AREA OF PROPELLERS, A_P	SQ. FT.	456
14	PROPELLER RESISTANCE = R_P = 3.394 x (13) x (4) x (4)	POUNDS	154766
15	HULL RESISTANCE = (10) x (2) - (14)	POUNDS	32834
16	SEA STATE RESISTANCE = R_S = (12) - (15) - (14)	POUNDS	0
17	TOTAL TOW RESISTANCE = R_T = (9) + (12)	POUNDS	190525

CALCULATION OF TOW RESISTANCE BY METHOD USED IN U.S. NAVY TOWING MANUAL

SHIP: AOE-1

DATE: 2/26/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		AOE-1
2	TOW DISPLACEMENT, Δ (SEE TABLE 7)	LONG TONS	53,600
3	FRONTAL WINDAGE AREA, A_T	SQ. FT.	9750
4	TOW SPEED, V_{TOW}	KNOTS	8
5	DIRECTION OF TRUE WIND FROM BOW, θ	DEGREES	47.23
6	TRUE WIND VELOCITY, V_{WIND}	KNOTS	13.5
7	WIND VELOCITY COMPONENT V_T = (4) + [(6) x COS (5)]	KNOTS	17.17
8	WIND PRESSURE P, (SEE GRAPH 1)	LBS/SQ.FT.	0.5
9	WIND RESISTANCE, R_W = (3) x (8)	POUNDS	4875
10	HYDRODYNAMIC UNIT RESISTANCE r_H, (SEE GRAPH 2)	--	2.2
11	SEA STATE CORRECTION FACTOR K_1 (SEE TABLE 8)	--	1.4
12	HYDRODYNAMIC RESISTANCE R_H = (2) x (10) x (11)	POUNDS	165088
13	TOTAL PROJECTED AREA OF PROPELLERS, A_P	SQ. FT.	456
14	PROPELLER RESISTANCE = R_P = 3.394 x (13) x (4) x (4)	POUNDS	99050
15	HULL RESISTANCE = (10) x (2) - (14)	POUNDS	18870
16	SEA STATE RESISTANCE = R_S = (12) - (15) - (14)	POUNDS	47168
17	TOTAL TOW RESISTANCE = R_T = (9) + (12)	POUNDS	169963

CALCULATION OF TOW RESISTANCE BY METHOD USED IN U.S. NAVY TOWING MANUAL

SHIP: AOE-1

DATE: 2/26/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		AOE-1
2	TOW DISPLACEMENT, Δ (SEE TABLE 7)	LONG TONS	53,600
3	FRONTAL WINDAGE AREA, A_T	SQ. FT.	9750
4	TOW SPEED, V_{TOW}	KNOTS	8
5	DIRECTION OF TRUE WIND FROM BOW, θ	DEGREES	47.23
6	TRUE WIND VELOCITY, V_{WIND}	KNOTS	13.5
7	WIND VELOCITY COMPONENT V_T = (4) + [(6) x COS (5)]	KNOTS	17.17
8	WIND PRESSURE P, (SEE GRAPH 1)	LBS/SQ.FT.	0.5
9	WIND RESISTANCE, R_W = (3) x (8)	POUNDS	4875
10	HYDRODYNAMIC UNIT RESISTANCE r_H, (SEE GRAPH 2)	--	2.2
11	SEA STATE CORRECTION FACTOR K_1 (SEE TABLE 8)	--	1.4
12	HYDRODYNAMIC RESISTANCE R_H = (2) x (10) x (11)	POUNDS	165088
13	TOTAL PROJECTED AREA OF PROPELLERS, A_p	SQ. FT.	456
14	PROPELLER RESISTANCE = R_p = 3.394 x (13) x (4) x (4)	POUNDS	99050
15	HULL RESISTANCE = (10) x (2) - (14)	POUNDS	18870
16	SEA STATE RESISTANCE = R_s = (12) - (15) - (14)	POUNDS	47168
17	TOTAL TOW RESISTANCE = R_T = (9) + (12)	POUNDS	169963

CALCULATION OF TOW RESISTANCE BY METHOD USED IN U.S. NAVY TOWING MANUAL

SHIP: AOE-1

DATE: 2/26/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		AOE-1
2	TOW DISPLACEMENT, Δ (SEE TABLE 7)	LONG TONS	53,600
3	FRONTAL WINDAGE AREA, A_T	SQ. FT.	9750
4	TOW SPEED, V_{TOW}	KNOTS	5
5	DIRECTION OF TRUE WIND FROM BOW, θ	DEGREES	0
6	TRUE WIND VELOCITY, V_{WIND}	KNOTS	24.5
7	WIND VELOCITY COMPONENT V_T = (4) + [(6) x COS (5)]	KNOTS	29.5
8	WIND PRESSURE P, (SEE GRAPH 1)	LBS/SQ.FT	1.7
9	WIND RESISTANCE, R_W = (3) x (8)	POUNDS	16575
10	HYDRODYNAMIC UNIT RESISTANCE r_H, (SEE GRAPH 2)	--	0.8
11	SEA STATE CORRECTION FACTOR K_1 (SEE TABLE 8)	--	1.6
12	HYDRODYNAMIC RESISTANCE R_H = (2) x (10) x (11)	POUNDS	68608
13	TOTAL PROJECTED AREA OF PROPELLERS, A_P	SQ. FT.	456
14	PROPELLER RESISTANCE = R_p = 3.394 x (13) x (4) x (4)	POUNDS	38692
15	HULL RESISTANCE = (10) x (2) - (14)	POUNDS	4188
16	SEA STATE RESISTANCE = R_s = (12) - (15) - (14)	POUNDS	25728
17	TOTAL TOW RESISTANCE = R_T = (9) + (12)	POUNDS	85183

CALCULATION OF TOW RESISTANCE BY METHOD USED IN U.S. NAVY TOWING MANUAL

SHIP: AOE-1

DATE: 2/26/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		AOE-1
2	TOW DISPLACEMENT, Δ (SEE TABLE 7)	LONG TONS	53,600
3	FRONTAL WINDAGE AREA, A_T	SQ. FT.	9750
4	TOW SPEED, V_{TOW}	KNOTS	5
5	DIRECTION OF TRUE WIND FROM BOW, θ	DEGREES	0
6	TRUE WIND VELOCITY, V_{WIND}	KNOTS	24.5
7	WIND VELOCITY COMPONENT V_T = (4) + [(6) x COS (5)]	KNOTS	29.5
8	WIND PRESSURE P, (SEE GRAPH 1)	LBS/SQ.FT	1.7
9	WIND RESISTANCE, R_W = (3) x (8)	POUNDS	16575
10	HYDRODYNAMIC UNIT RESISTANCE r_H, (SEE GRAPH 2)	--	0.8
11	SEA STATE CORRECTION FACTOR K_1 (SEE TABLE 8)	--	1.6
12	HYDRODYNAMIC RESISTANCE R_H = (2) x (10) x (11)	POUNDS	68608
13	TOTAL PROJECTED AREA OF PROPELLERS, A_P	SQ. FT.	456
14	PROPELLER RESISTANCE = R_P = 3.394 x (13) x (4) x (4)	POUNDS	38692
15	HULL RESISTANCE = (10) x (2) - (14)	POUNDS	4188
16	SEA STATE RESISTANCE = R_S = (12) - (15) - (14)	POUNDS	25728
17	TOTAL TOW RESISTANCE = R_T = (9) + (12)	POUNDS	85183

CALCULATION OF TOW RESISTANCE BY METHOD USED IN U.S. NAVY TOWING MANUAL

SHIP: AOE-1 DATE: 2/26/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		AOE-1
2	TOW DISPLACEMENT, Δ (SEE TABLE 7)	LONG TONS	53,600
3	FRONTAL WINDAGE AREA, A_T	SQ. FT.	9750
4	TOW SPEED, V_{TOW}	KNOTS	5
5	DIRECTION OF TRUE WIND FROM BOW, θ	DEGREES	101.8
6	TRUE WIND VELOCITY, V_{WIND}	KNOTS	24.5
7	WIND VELOCITY COMPONENT V_T = (4) + [(6) x COS (5)]	KNOTS	-0.21
8	WIND PRESSURE P, (SEE GRAPH 1)	LBS/SQ.FT	0
9	WIND RESISTANCE, R_W = (3) x (8)	POUNDS	0
10	HYDRODYNAMIC UNIT RESISTANCE r_H, (SEE GRAPH 2)	--	0.8
11	SEA STATE CORRECTION FACTOR K_1 (SEE TABLE 8)	--	1.6
12	HYDRODYNAMIC RESISTANCE R_H = (2) x (10) x (11)	POUNDS	68608
13	TOTAL PROJECTED AREA OF PROPELLERS, A_P	SQ. FT.	456
14	PROPELLER RESISTANCE = R_P = 3.394 x (13) x (4) x (4)	POUNDS	38692
15	HULL RESISTANCE = (10) x (2) - (14)	POUNDS	4188
16	SEA STATE RESISTANCE = R_S = (12) - (15) - (14)	POUNDS	25728
17	TOTAL TOW RESISTANCE = R_T = (9) + (12)	POUNDS	68608

CALCULATION OF TOW RESISTANCE BY METHOD USED IN U.S. NAVY TOWING MANUAL

SHIP: AOE-1

DATE: 2/26/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		AOE-1
2	TOW DISPLACEMENT, Δ (SEE TABLE 7)	LONG TONS	53,600
3	FRONTAL WINDAGE AREA, A_T	SQ. FT.	9750
4	TOW SPEED, V_{TOW}	KNOTS	5
5	DIRECTION OF TRUE WIND FROM BOW, θ	DEGREES	101.8
6	TRUE WIND VELOCITY, V_{WIND}	KNOTS	24.5
7	WIND VELOCITY COMPONENT V_T = (4) + [(6) x COS (5)]	KNOTS	-0.21
8	WIND PRESSURE P, (SEE GRAPH 1)	LBS/SQ.FT.	0
9	WIND RESISTANCE, R_W = (3) x (8)	POUNDS	0
10	HYDRODYNAMIC UNIT RESISTANCE r_H, (SEE GRAPH 2)	--	0.8
11	SEA STATE CORRECTION FACTOR K_1 (SEE TABLE 8)	--	1.6
12	HYDRODYNAMIC RESISTANCE R_H = (2) x (10) x (11)	POUNDS	68608
13	TOTAL PROJECTED AREA OF PROPELLERS, A_P	SQ. FT.	456
14	PROPELLER RESISTANCE = R_P = 3.394 x (13) x (4) x (4)	POUNDS	38692
15	HULL RESISTANCE = (10) x (2) - (14)	POUNDS	4188
16	SEA STATE RESISTANCE = R_s = (12) - (15) - (14)	POUNDS	25728
17	TOTAL TOW RESISTANCE = R_T = (9) + (12)	POUNDS	68608

CALCULATION OF TOWING RESISTANCE

SHIP: AOE-1 DATE: 2/26/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		AOE-1
2	TOW DISPLACEMENT, Δ (SEE TABLE-7)	LONG. TONS	53,600
3	FRONTAL WINDAGE AREA, A_T, (SEE TABLE 7)	SQ. FEET	9750
4	WIND DRAG COEFFICIENT, C_w, (SEE TABLE 7)	—	0.75
5	TOTAL PROJECTED AREA OF PROPELLERS, A_p, (SEE TABLE 7)	SQ. FEET	456
6	CURVE NUMBER FOR HULL RESISTANCE, R_H/Δ, (SEE TABLE 7)	—	22
7	CURVE NUMBER FOR WIND FACTOR, K, (SEE TABLE 7)	—	1
8	CURVE NUMBER FOR SEA STATE RESISTANCE, R_s, (SEE TABLE 7)	—	6
9	BEAUFORT NUMBER (WIND) - (SEE TABLE-8)	—	4
10	RELATIVE WIND SPEED, V_R	KNOTS	21.5
11	RELATIVE WIND DIRECTION, α	DEGREES	0
12	HEADING COEFFICIENT K, (SEE FIG. 13-15)	—	1.0
13	SEA STATE RESISTANCE R_s, (SEE FIG. 16)	—	1300
14	SELECT A TOW SPEED, V_{TOW}	KNOTS	8
15	$R_{H/\Delta}$ (SEE FIG. 17)	—	1.15
16	HULL RESISTANCE = R_H = (15) × (2) × 1.25	POUNDS	77050
17	PROPELLER RESISTANCE = R_p = 3.737 × (5) × (14) × (14)	POUNDS	109061
18	WIND RESISTANCE = R_w = 0.00506 × (4) × (3) × (12) × (10) × (10)	POUNDS	17103
19	TOTAL TOW RESISTANCE = R_T = (13) + (16) + (17) + (18)	POUNDS	

TABLE - 8

CALCULATION OF TOWING RESISTANCE

SHIP: AOE-1 DATE: 2/26/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		AOE-1
2	TOW DISPLACEMENT, Δ (SEE TABLE-7)	LONG. TONS	53,600
3	FRONTAL WINDAGE AREA, A_T, (SEE TABLE 7)	SQ. FEET	9750
4	WIND DRAG COEFFICIENT, C_w, (SEE TABLE 7)	—	0.75
5	TOTAL PROJECTED AREA OF PROPELLERS, A_p, (SEE TABLE 7)	SQ. FEET	456
6	CURVE NUMBER FOR HULL RESISTANCE, R_H/Δ, (SEE TABLE 7)	—	22
7	CURVE NUMBER FOR WIND FACTOR, K, (SEE TABLE 7)	—	1
8	CURVE NUMBER FOR SEA STATE RESISTANCE, R_s, (SEE TABLE 7)	—	6
9	BEAUFORT NUMBER (WIND) - (SEE TABLE-8)	—	4
10	RELATIVE WIND SPEED, V_R	KNOTS	21.5
11	RELATIVE WIND DIRECTION, α	DEGREES	0
12	HEADING COEFFICIENT K, (SEE FIG. 13-15)	—	1.0
13	SEA STATE RESISTANCE R_s, (SEE FIG. 16)	—	1300
14	SELECT A TOW SPEED, V_{TOW}	KNOTS	8
15	$R_{H/\Delta}$ (SEE FIG. 17)	—	1.15
16	HULL RESISTANCE = R_H = (15) x (2) x 1.25	POUNDS	77050
17	PROPELLER RESISTANCE = R_p = 3.737 x (5) x (14) x (14)	POUNDS	109061
18	WIND RESISTANCE = R_w = 0.00506 x (4) x (3) x (12) x (10) x (10)	POUNDS	17103
19	TOTAL TOW RESISTANCE = R_T = (13) + (16) + (17) + (18)	POUNDS	

CALCULATION OF TOWING RESISTANCE

SHIP: AOE-1 DATE: 2/26/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		AOE-1
2	TOW DISPLACEMENT, Δ (SEE TABLE-7)	LONG TONS	53,600
3	FRONTAL WINDAGE AREA, A_T, (SEE TABLE 7)	SQ. FEET	9750
4	WIND DRAG COEFFICIENT, C_w, (SEE TABLE 7)	—	0.75
5	TOTAL PROJECTED AREA OF PROPELLERS, A_p, (SEE TABLE 7)	SQ. FEET	456
6	CURVE NUMBER FOR HULL RESISTANCE, $R_{H/\Delta}$, (SEE TABLE 7)	—	22
7	CURVE NUMBER FOR WIND FACTOR, K, (SEE TABLE 7)	—	1
8	CURVE NUMBER FOR SEA STATE RESISTANCE, R_s, (SEE TABLE 7)	—	6
9	BEAUFORT NUMBER (WIND) - (SEE TABLE-8)	—	4
10	RELATIVE WIND SPEED, V_R	KNOTS	10.87
11	RELATIVE WIND DIRECTION, α	DEGREES	90
12	HEADING COEFFICIENT K, (SEE FIG. 13-15)	—	0.09
13	SEA STATE RESISTANCE R_s, (SEE FIG. 16)	—	1300
14	SELECT A TOW SPEED, V_{TOW}	KNOTS	8
15	$R_{H/\Delta}$ (SEE FIG. 17)	—	1.15
16	HULL RESISTANCE = R_H = (15) x (2) x 1.25	POUNDS	77050
17	PROPELLER RESISTANCE = R_p = 3.737 x (5) x (14) x (14)	POUNDS	109061
18	WIND RESISTANCE = R_w = 0.00506 x (4) x (3) x (12) x (10) x (10)	POUNDS	373
19	TOTAL TOW RESISTANCE = R_T = (13) + (16) + (17) + (18)	POUNDS	187804

CALCULATION OF TOWING RESISTANCE

SHIP: AOE-1

DATE: 2/26/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		AOE-1
2	TOW DISPLACEMENT, Δ (SEE TABLE-7)	LONG TONS	53,600
3	FRONTAL WINDAGE AREA, A_T, (SEE TABLE 7)	SQ. FEET	9750
4	WIND DRAG COEFFICIENT, C_w, (SEE TABLE 7)	—	0.75
5	TOTAL PROJECTED AREA OF PROPELLERS, A_p, (SEE TABLE 7)	SQ. FEET	456
6	CURVE NUMBER FOR HULL RESISTANCE, R_H/Δ, (SEE TABLE 7)	—	22
7	CURVE NUMBER FOR WIND FACTOR, K, (SEE TABLE 7)	—	1
8	CURVE NUMBER FOR SEA STATE RESISTANCE, R_s, (SEE TABLE 7)	—	6
9	BEAUFORT NUMBER (WIND) - (SEE TABLE-8)	—	4
10	RELATIVE WIND SPEED, V_R	KNOTS	10.87
11	RELATIVE WIND DIRECTION, α	DEGREES	90
12	HEADING COEFFICIENT K, (SEE FIG. 13-15)	—	0.09
13	SEA STATE RESISTANCE R_s, (SEE FIG. 16)	—	1300
14	SELECT A TOW SPEED, V_{TOW}	KNOTS	8
15	$R_{H/\Delta}$ (SEE FIG. 17)	—	1.15
16	HULL RESISTANCE = R_H = (15) x (2) x 1.25	POUNDS	77050
17	PROPELLER RESISTANCE = R_p = 3.737 x (5) x (14) x (14)	POUNDS	109061
18	WIND RESISTANCE = R_w = 0.00506 x (4) x (3) x (12) x (10) x (10)	POUNDS	393
19	TOTAL TOW RESISTANCE = R_T = (13) + (16) + (17) + (18)	POUNDS	187804

CALCULATION OF TOWING RESISTANCE

SHIP: AOE-1 DATE: 2/26/75

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		AOE-1
2	TOW DISPLACEMENT, Δ (SEE TABLE-7)	LONG TONS	53,600
3	FRONTAL WINDAGE AREA, A_T, (SEE TABLE 7)	SQ. FEET	9750
4	WIND DRAG COEFFICIENT, C_w, (SEE TABLE 7)	—	0.75
5	TOTAL PROJECTED AREA OF PROPELLERS, A_p, (SEE TABLE 7)	SQ. FEET	456
6	CURVE NUMBER FOR HULL RESISTANCE, R_H/Δ, (SEE TABLE 7)	—	22
7	CURVE NUMBER FOR WIND FACTOR, K, (SEE TABLE 7)	—	1
8	CURVE NUMBER FOR SEA STATE RESISTANCE, R_s, (SEE TABLE 7)	—	6
9	BEAUFORT NUMBER (WIND) - (SEE TABLE-8)	—	6
10	RELATIVE WIND SPEED, V_R	KNOTS	23.98
11	RELATIVE WIND DIRECTION, α	DEGREES	90
12	HEADING COEFFICIENT K, (SEE FIG. 13-15)	—	0.09
13	SEA STATE RESISTANCE R_s, (SEE FIG. 16)	—	44,000
14	SELECT A TOW SPEED, V_{TOW}	KNOTS	5
15	$R_{H/\Delta}$ (SEE FIG. 17)	—	0.52
16	HULL RESISTANCE = R_H = (15) x (2) x 1.25	POUNDS	77050
17	PROPELLER RESISTANCE = R_p = 3.737 x (5) x (14) x (14)	POUNDS	42602
18	WIND RESISTANCE = R_w = 0.00506 x (4) x (3) x (12) x (10) x (10)	POUNDS	1915
19	TOTAL TOW RESISTANCE = R_T = (13) + (16) + (17) + (18)	POUNDS	165567

CALCULATION OF TOWING RESISTANCE

SHIP: AOE-1

DATE: 2/26/75

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		AOE-1
2	TOW DISPLACEMENT, Δ (SEE TABLE-7)	LONG TONS	53,600
3	FRONTAL WINDAGE AREA, A_T, (SEE TABLE 7)	SQ. FEET	9750
4	WIND DRAG COEFFICIENT, C_w, (SEE TABLE 7)	—	0.75
5	TOTAL PROJECTED AREA OF PROPELLERS, A_p, (SEE TABLE 7)	SQ. FEET	456
6	CURVE NUMBER FOR HULL RESISTANCE, R_H/Δ, (SEE TABLE 7)	—	22
7	CURVE NUMBER FOR WIND FACTOR, K, (SEE TABLE 7)	—	1
8	CURVE NUMBER FOR SEA STATE RESISTANCE, R_s, (SEE TABLE 7)	—	6
9	BEAUFORT NUMBER (WIND) - (SEE TABLE-8)	—	6
10	RELATIVE WIND SPEED, V_R	KNOTS	23.98
11	RELATIVE WIND DIRECTION, α	DEGREES	90
12	HEADING COEFFICIENT K, (SEE FIG. 13-15)	—	0.09
13	SEA STATE RESISTANCE R_s, (SEE FIG. 16)	—	44,000
14	SELECT A TOW SPEED, V_{TOW}	KNOTS	5
15	R_H/Δ (SEE FIG. 17)	—	0.52
16	HULL RESISTANCE = R_H = (15) × (2) × 1.25	POUNDS	77050
17	PROPELLER RESISTANCE = R_p = 3.737 × (5) × (14) × (14)	POUNDS	42602
18	WIND RESISTANCE = R_w = 0.00506 × (4) × (3) × (12) × (10) × (10)	POUNDS	1915
19	TOTAL TOW RESISTANCE = R_T = (13) + (16) + (17) + (18)	POUNDS	165567

CALCULATION OF TOW RESISTANCE BY METHOD USED IN U.S. NAVY TOWING MANUAL

SHIP: AOR-1

DATE: 2/26/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		AOR-1
2	TOW DISPLACEMENT, Δ (SEE TABLE 7)	LONG TONS	38100
3	FRONTAL WINDAGE AREA, A_T	SQ. FT.	7590
4	TOW SPEED, V_{TOW}	KNOTS	10
5	DIRECTION OF TRUE WIND FROM BOW, θ	DEGREES	0
6	TRUE WIND VELOCITY, V_{WIND}	KNOTS	0
7	WIND VELOCITY COMPONENT V_T = (4) + [(6) x COS (5)]	KNOTS	10
8	WIND PRESSURE P, (SEE GRAPH 1)	LBS/SQ.FT.	0.3
9	WIND RESISTANCE, R_W = (3) x (8)	POUNDS	2277
10	HYDRODYNAMIC UNIT RESISTANCE r_H, (SEE GRAPH 2)	--	3.5
11	SEA STATE CORRECTION FACTOR K_1 (SEE TABLE 8)	--	1.0
12	HYDRODYNAMIC RESISTANCE R_H = (2) x (10) x (11)	POUNDS	133350
13	TOTAL PROJECTED AREA OF PROPELLERS, A_P	SQ. FT.	274
14	PROPELLER RESISTANCE = R_P = 3.394 x (13) x (4) x (4)	POUNDS	92996
15	HULL RESISTANCE = (10) x (2) - (14)	POUNDS	40354
16	SEA STATE RESISTANCE = R_s = (12) - (15) - (14)	POUNDS	0
17	TOTAL TOW RESISTANCE = R_T = (9) + (12)	POUNDS	135627

CALCULATION OF TOW RESISTANCE BY METHOD USED IN U.S. NAVY TOWING MANUAL

SHIP: [illegible]

DATE: 2/2[illegible]/76

BY: [illegible]

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		[illegible]
2	TOW DISPLACEMENT, Δ (SEE TABLE 7)	LONG TONS	[illegible]
3	FRONTAL WINDAGE AREA, A_T	SQ. FT.	[illegible]
4	TOW SPEED, V_{TOW}	KNOTS	8
5	DIRECTION OF TRUE WIND FROM BOW, θ	DEGREES	17.23
6	TRUE WIND VELOCITY, V_{WIND}	KNOTS	13.5
7	WIND VELOCITY COMPONENT V_T = (4) + [(6) x COS (5)]	KNOTS	17.17
8	WIND PRESSURE P, (SEE GRAPH 1)	LBS/SQ.FT	[illegible]
9	WIND RESISTANCE, R_W = (3) x (8)	POUNDS	3795
10	HYDRODYNAMIC UNIT RESISTANCE r_H, (SEE GRAPH 2)	--	[illegible]
11	SEA STATE CORRECTION FACTOR K_1 (SEE TABLE 8)	--	1.4
12	HYDRODYNAMIC RESISTANCE R_H = (2) x (10) x (11)	POUNDS	117348
13	TOTAL PROJECTED AREA OF PROPELLERS, A_P	SQ. FT.	[illegible]
14	PROPELLER RESISTANCE = R_P = 3.394 x (13) x (4) x (4)	POUNDS	[illegible]
15	HULL RESISTANCE = (10) x (2) - (14)	POUNDS	21303
16	SEA STATE RESISTANCE = R_S = (12) - (15) - (14)	POUNDS	[illegible]
17	TOTAL TOW RESISTANCE = R_T = (9) + (12)	POUNDS	121143

CALCULATION OF TOW RESISTANCE BY METHOD USED IN U.S. NAVY TOWING MANUAL

SHIP: AOR-1

DATE: 2/26/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		AOR-1
2	TOW DISPLACEMENT, Δ (SEE TABLE 7)	LONG TONS	38100
3	FRONTAL WINDAGE AREA, A_T	SQ. FT.	7590
4	TOW SPEED, V_{TOW}	KNOTS	5
5	DIRECTION OF TRUE WIND FROM BOW, θ	DEGREES	0
6	TRUE WIND VELOCITY, V_{WIND}	KNOTS	24.5
7	WIND VELOCITY COMPONENT V_T = (4) + [(6) x COS (5)]	KNOTS	29.5
8	WIND PRESSURE P, (SEE GRAPH 1)	LBS/SQ.FT.	1.7
9	WIND RESISTANCE, R_W = (3) x (8)	POUNDS	12903
10	HYDRODYNAMIC UNIT RESISTANCE r_H, (SEE GRAPH 2)	--	0.7
11	SEA STATE CORRECTION FACTOR K_1 (SEE TABLE 8)	--	1.6
12	HYDRODYNAMIC RESISTANCE R_H = (2) x (10) x (11)	POUNDS	42672
13	TOTAL PROJECTED AREA OF PROPELLERS, A_P	SQ. FT.	274
14	PROPELLER RESISTANCE = R_p = 3.394 x (13) x (4) x (4)	POUNDS	23249
15	HULL RESISTANCE = (10) x (2) - (14)	POUNDS	3421
16	SEA STATE RESISTANCE = R_s = (12) - (15) - (14)	POUNDS	16002
17	TOTAL TOW RESISTANCE = R_T = (9) + (12)	POUNDS	55575

CALCULATION OF TOW RESISTANCE BY METHOD USED IN U.S. NAVY TOWING MANUAL

SHIP: AOE-1

DATE: 2/26/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		AOE-1
2	TOW DISPLACEMENT, Δ (SEE TABLE 7)	LONG TONS	38100
3	FRONTAL WINDAGE AREA, A_T	SQ. FT.	7590
4	TOW SPEED, V_{TOW}	KNOTS	5
5	DIRECTION OF TRUE WIND FROM BOW, θ	DEGREES	0
6	TRUE WIND VELOCITY, V_{WIND}	KNOTS	24.5
7	WIND VELOCITY COMPONENT V_T = (4) + [(6) x COS (5)]	KNOTS	29.5
8	WIND PRESSURE P, (SEE GRAPH 1)	LBS/SQ.FT.	1.7
9	WIND RESISTANCE, R_W = (3) x (8)	POUNDS	12900
10	HYDRODYNAMIC UNIT RESISTANCE r_H, (SEE GRAPH 2)	--	0.7
11	SEA STATE CORRECTION FACTOR K_1 (SEE TABLE 8)	--	1.6
12	HYDRODYNAMIC RESISTANCE R_H = (2) x (10) x (11)	POUNDS	42672
13	TOTAL PROJECTED AREA OF PROPELLERS, A_p	SQ. FT.	274
14	PROPELLER RESISTANCE = R_p = 3.394 x (13) x (4) x (4)	POUNDS	23249
15	HULL RESISTANCE = (10) x (2) - (14)	POUNDS	3421
16	SEA STATE RESISTANCE = R_s = (12) - (15) - (14)	POUNDS	16002
17	TOTAL TOW RESISTANCE = R_T = (9) + (12)	POUNDS	55572

CALCULATION OF TOW RESISTANCE BY METHOD USED IN U.S. NAVY TOWING MANUAL

SHIP: AOE-1

DATE: 2/26/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		AOE-1
2	TOW DISPLACEMENT, Δ (SEE TABLE 7)	LONG TONS	38100
3	FRONTAL WINDAGE AREA, A_T	SQ. FT.	7590
4	TOW SPEED, V_{TOW}	KNOTS	5
5	DIRECTION OF TRUE WIND FROM BOW, θ	DEGREES	101.3
6	TRUE WIND VELOCITY, V_{WIND}	KNOTS	24.5
7	WIND VELOCITY COMPONENT V_T = (4) + [(6) x COS (5)]	KNOTS	-0.01
8	WIND PRESSURE P, (SEE GRAPH 1)	LBS/SQ.FT.	0
9	WIND RESISTANCE, R_W = (3) x (8)	POUNDS	0
10	HYDRODYNAMIC UNIT RESISTANCE r_H, (SEE GRAPH 2)	--	0.7
11	SEA STATE CORRECTION FACTOR K_1 (SEE TABLE 8)	--	1.6
12	HYDRODYNAMIC RESISTANCE R_H = (2) x (10) x (11)	POUNDS	42672
13	TOTAL PROJECTED AREA OF PROPELLERS, A_P	SQ. FT.	[illegible]74
14	PROPELLER RESISTANCE = R_P = 3.394 x (13) x (4) x (4)	POUNDS	23249
15	HULL RESISTANCE = (10) x (2) - (14)	POUNDS	3421
16	SEA STATE RESISTANCE = R_S = (12) - (15) - (14)	POUNDS	16002
17	TOTAL TOW RESISTANCE = R_T = (9) + (12)	POUNDS	42672

CALCULATION OF TOW RESISTANCE BY METHOD USED IN U.S. NAVY TOWING MANUAL

SHIP: AOE-1

DATE: 2/26/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		AOE-1
2	TOW DISPLACEMENT, Δ (SEE TABLE 7)	LONG TONS	38100
3	FRONTAL WINDAGE AREA, A_T	SQ. FT.	7590
4	TOW SPEED, V_{TOW}	KNOTS	5
5	DIRECTION OF TRUE WIND FROM BOW, θ	DEGREES	101.3
6	TRUE WIND VELOCITY, V_{WIND}	KNOTS	24.5
7	WIND VELOCITY COMPONENT V_T = (4) + [(6) x COS (5)]	KNOTS	-0.01
8	WIND PRESSURE P, (SEE GRAPH 1)	LBS/SQ.FT.	0
9	WIND RESISTANCE, R_W = (3) x (8)	POUNDS	0
10	HYDRODYNAMIC UNIT RESISTANCE r_H, (SEE GRAPH 2)	--	0.7
11	SEA STATE CORRECTION FACTOR K_1 (SEE TABLE 8)	--	1.6
12	HYDRODYNAMIC RESISTANCE R_H = (2) x (10) x (11)	POUNDS	42672
13	TOTAL PROJECTED AREA OF PROPELLERS, A_P	SQ. FT.	274
14	PROPELLER RESISTANCE = R_P = 3.394 x (13) x (4) x (4)	POUNDS	23249
15	HULL RESISTANCE = (10) x (2) - (14)	POUNDS	3421
16	SEA STATE RESISTANCE = R_S = (12) - (15) - (14)	POUNDS	16002
17	TOTAL TOW RESISTANCE = R_T = (9) + (12)	POUNDS	42672

CALCULATION OF TOWING RESISTANCE

SHIP: AOR-1

DATE: 2/26/76

BY: [illegible]

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		AOR-1
2	TOW DISPLACEMENT, Δ (SEE TABLE-7)	LONG TONS	28100
3	FRONTAL WINDAGE AREA, A_T, (SEE TABLE 7)	SQ. FEET	7590
4	WIND DRAG COEFFICIENT, C_w, (SEE TABLE 7)	—	1.00
5	TOTAL PROJECTED AREA OF PROPELLERS, A_p, (SEE TABLE 7)	SQ. FEET	274
6	CURVE NUMBER FOR HULL RESISTANCE, $R_{H/\Delta}$, (SEE TABLE 7)	—	20
7	CURVE NUMBER FOR WIND FACTOR, K, (SEE TABLE 7)	—	2
8	CURVE NUMBER FOR SEA STATE RESISTANCE, R_s, (SEE TABLE 7)	—	5
9	BEAUFORT NUMBER (WIND) - (SEE TABLE-8)	—	4
10	RELATIVE WIND SPEED, V_R	KNOTS	21.5
11	RELATIVE WIND DIRECTION, α	DEGREES	0
12	HEADING COEFFICIENT K, (SEE FIG. 13-15)	—	1.0
13	SEA STATE RESISTANCE R_s, (SEE FIG. 16)	—	1300
14	SELECT A TOW SPEED, V_{TOW}	KNOTS	8
15	$R_{H/\Delta}$ (SEE FIG. 17)	—	1.12
16	HULL RESISTANCE = R_H = (15) x (2) x 1.25	POUNDS	[illegible]
17	PROPELLER RESISTANCE = R_p = 3.737 x (5) x (14) x (14)	POUNDS	[illegible]
18	WIND RESISTANCE = R_w = 0.00506 x (4) x (3) x (12) x (10) x (10)	POUNDS	17753
19	TOTAL TOW RESISTANCE = R_T = (13) + (16) + (17) + (18)	POUNDS	[illegible]625

TABLE - [illegible]

CALCULATION OF TOWING RESISTANCE

SHIP: AOR-1 DATE: 2/26/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		AOR-1
2	TOW DISPLACEMENT, Δ (SEE TABLE-7)	LONG TONS	38100
3	FRONTAL WINDAGE AREA, A_T, (SEE TABLE 7)	SQ. FEET	7590
4	WIND DRAG COEFFICIENT, C_w, (SEE TABLE 7)	—	1.00
5	TOTAL PROJECTED AREA OF PROPELLERS, A_p, (SEE TABLE 7)	SQ. FEET	274
6	CURVE NUMBER FOR HULL RESISTANCE, R_H/Δ, (SEE TABLE 7)	—	20
7	CURVE NUMBER FOR WIND FACTOR, K, (SEE TABLE 7)	—	2
8	CURVE NUMBER FOR SEA STATE RESISTANCE, R_s, (SEE TABLE 7)	—	5
9	BEAUFORT NUMBER (WIND) - (SEE TABLE-8)	—	4
10	RELATIVE WIND SPEED, V_R	KNOTS	21.5
11	RELATIVE WIND DIRECTION, α	DEGREES	0
12	HEADING COEFFICIENT K, (SEE FIG. 13-15)	—	1.0
13	SEA STATE RESISTANCE R_s, (SEE FIG. 16)	—	1300
14	SELECT A TOW SPEED, V_{TOW}	KNOTS	8
15	$R_{H/\Delta}$ (SEE FIG. 17)	—	1.12
16	HULL RESISTANCE = R_H = (15) × (2) × 1.25	POUNDS	53340
17	PROPELLER RESISTANCE = R_p = 3.737 × (5) × (14) × (14)	POUNDS	[illegible]
18	WIND RESISTANCE = R_w = 0.00506 × (4) × (3) × (12) × (10) × (10)	POUNDS	17753
19	TOTAL TOW RESISTANCE = R_T = (13) + (16) + (17) + (18)	POUNDS	[illegible]

CALCULATION OF TOWING RESISTANCE

SHIP: [illegible]   DATE: [illegible]

BY: [illegible]

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		AOE-1
2	TOW DISPLACEMENT, Δ (SEE TABLE-7)	LONG TONS	[illegible]
3	FRONTAL WINDAGE AREA, A_T, (SEE TABLE 7)	SQ. FEET	7590
4	WIND DRAG COEFFICIENT, C_w, (SEE TABLE 7)	—	1.00
5	TOTAL PROJECTED AREA OF PROPELLERS, A_p, (SEE TABLE 7)	SQ. FEET	774
6	CURVE NUMBER FOR HULL RESISTANCE, $R_{H/\Delta}$, (SEE TABLE 7)	—	[illegible]
7	CURVE NUMBER FOR WIND FACTOR, K, (SEE TABLE 7)	—	[illegible]
8	CURVE NUMBER FOR SEA STATE RESISTANCE, R_s, (SEE TABLE 7)	—	[illegible]
9	BEAUFORT NUMBER (WIND) - (SEE TABLE-8)	—	4
10	RELATIVE WIND SPEED, V_R	KNOTS	[illegible]
11	RELATIVE WIND DIRECTION, α	DEGREES	30
12	HEADING COEFFICIENT K, (SEE FIG. 13-15)	—	1.04
13	SEA STATE RESISTANCE R_s, (SEE FIG. 16)	—	1300
14	SELECT A TOW SPEED, V_{TOW}	KNOTS	8
15	$R_{H/\Delta}$ (SEE FIG. 17)	—	1.12
16	HULL RESISTANCE = R_H = (15) x (2) x 1.25	POUNDS	[illegible]
17	PROPELLER RESISTANCE = R_p = 3.737 x (5) x (14) x (14)	POUNDS	[illegible]
18	WIND RESISTANCE = R_w = 0.00506 x (4) x (3) x (12) x (10) x (10)	POUNDS	[illegible]
19	TOTAL TOW RESISTANCE = R_T = (13) + (16) + (17) + (18)	POUNDS	[illegible]

CALCULATION OF TOWING RESISTANCE

SHIP: [illegible]

DATE: [illegible]

BY: [illegible]

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		[illegible]
2	TOW DISPLACEMENT, Δ (SEE TABLE-7)	LONG TONS	[illegible]
3	FRONTAL WINDAGE AREA, A_T, (SEE TABLE 7)	SQ. FEET	7570
4	WIND DRAG COEFFICIENT, C_w, (SEE TABLE 7)	—	1.00
5	TOTAL PROJECTED AREA OF PROPELLERS, A_p, (SEE TABLE 7)	SQ. FEET	[illegible]
6	CURVE NUMBER FOR HULL RESISTANCE, R_H/Δ, (SEE TABLE 7)	—	20
7	CURVE NUMBER FOR WIND FACTOR, K, (SEE TABLE 7)	—	2
8	CURVE NUMBER FOR SEA STATE RESISTANCE, R_s, (SEE TABLE 7)	—	5
9	BEAUFORT NUMBER (WIND) - (SEE TABLE-8)	—	6
10	RELATIVE WIND SPEED, V_R	KNOTS	[illegible]
11	RELATIVE WIND DIRECTION, α	DEGREES	0
12	HEADING COEFFICIENT K, (SEE FIG. 13-15)	—	[illegible]
13	SEA STATE RESISTANCE R_s, (SEE FIG. 16)	—	[illegible]
14	SELECT A TOW SPEED, V_{TOW}	KNOTS	5
15	$R_{H/\Delta}$ (SEE FIG. 17)	—	[illegible]
16	HULL RESISTANCE = R_H = (15) x (2) x 1.25	POUNDS	[illegible]
17	PROPELLER RESISTANCE = R_p = 3.737 x (5) x (14) x (14)	POUNDS	[illegible]
18	WIND RESISTANCE = R_w = 0.00506 x (4) x (3) x (12) x (10) x (10)	POUNDS	[illegible]
19	TOTAL TOW RESISTANCE = R_T = (13) + (16) + (17) + (18)	POUNDS	[illegible]

AD-A150 941 DEVELOPMENT OF A CALCULATION PROCEDURE FOR THE DETERMINATION OF TOW RESISTANCE (UNABRIDGED REPORT)(U) ROSENBLATT (M) AND SON INC NEW YORK APR 76 6/6

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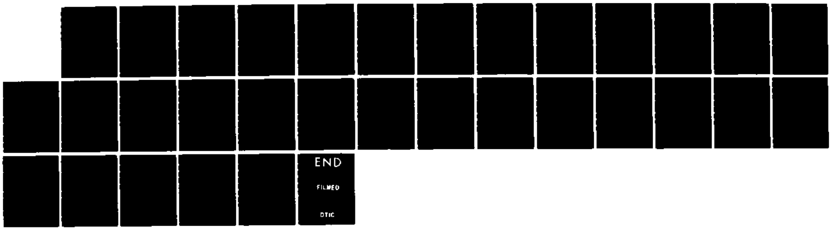

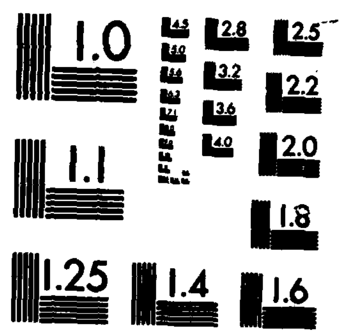

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

CALCULATION OF TOWING RESISTANCE

SHIP: [illegible]   DATE: [illegible]

BY: [illegible]

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		[illegible]
2	TOW DISPLACEMENT, Δ (SEE TABLE-7)	LONG TONS	[illegible]
3	FRONTAL WINDAGE AREA, A_T, (SEE TABLE 7)	SQ. FEET	7570
4	WIND DRAG COEFFICIENT, C_w, (SEE TABLE 7)	—	1.00
5	TOTAL PROJECTED AREA OF PROPELLERS, A_p, (SEE TABLE 7)	SQ. FEET	[illegible]
6	CURVE NUMBER FOR HULL RESISTANCE, $R_{H/\Delta}$, (SEE TABLE 7)	—	[illegible]
7	CURVE NUMBER FOR WIND FACTOR, K, (SEE TABLE 7)	—	[illegible]
8	CURVE NUMBER FOR SEA STATE RESISTANCE, R_s, (SEE TABLE 7)	—	5
9	BEAUFORT NUMBER (WIND) - (SEE TABLE-8)	—	6
10	RELATIVE WIND SPEED, V_R	KNOTS	[illegible]
11	RELATIVE WIND DIRECTION, α	DEGREES	[illegible]
12	HEADING COEFFICIENT K, (SEE FIG. 13-15)	—	[illegible]
13	SEA STATE RESISTANCE R_s, (SEE FIG. 16)	—	[illegible]
14	SELECT A TOW SPEED, V_{TOW}	KNOTS	5
15	$R_{H/\Delta}$ (SEE FIG. 17)	—	[illegible]
16	HULL RESISTANCE = R_H = (15) × (2) × 1.25	POUNDS	[illegible]
17	PROPELLER RESISTANCE = R_P = 3.737 × (5) × (14) × (14)	POUNDS	[illegible]
18	WIND RESISTANCE = R_W = 0.00506 × (4) × (3) × (12) × (10) × (10)	POUNDS	[illegible]
19	TOTAL TOW RESISTANCE = R_T = (13) + (16) + (17) + (18)	POUNDS	[illegible]

CALCULATION OF TOWING RESISTANCE

SHIP: AOE-1 DATE: [illegible]/24/75

BY: [illegible]

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		AOE-1
2	TOW DISPLACEMENT, Δ (SEE TABLE-7)	LONG TONS	[illegible]
3	FRONTAL WINDAGE AREA, A_T, (SEE TABLE 7)	SQ. FEET	[illegible]
4	WIND DRAG COEFFICIENT, C_w, (SEE TABLE 7)	—	1.00
5	TOTAL PROJECTED AREA OF PROPELLERS, A_p, (SEE TABLE 7)	SQ. FEET	[illegible]
6	CURVE NUMBER FOR HULL RESISTANCE, $R_{H/\Delta}$, (SEE TABLE 7)	—	70
7	CURVE NUMBER FOR WIND FACTOR, K, (SEE TABLE 7)	—	2
8	CURVE NUMBER FOR SEA STATE RESISTANCE, R_s, (SEE TABLE 7)	—	5
9	BEAUFORT NUMBER (WIND) - (SEE TABLE-8)	—	6
10	RELATIVE WIND SPEED, V_R	KNOTS	[illegible]
11	RELATIVE WIND DIRECTION, α	DEGREES	90
12	HEADING COEFFICIENT K, (SEE FIG. 13-15)	—	[illegible]
13	SEA STATE RESISTANCE R_s, (SEE FIG. 16)	—	[illegible]
14	SELECT A TOW SPEED, V_{TOW}	KNOTS	[illegible]
15	$R_{H/\Delta}$ (SEE FIG. 17)	—	[illegible]
16	HULL RESISTANCE = R_H = (15) × (2) × 1.25	POUNDS	[illegible]
17	PROPELLER RESISTANCE = R_P = 3.737 × (5) × (14) × (14)	POUNDS	[illegible]
18	WIND RESISTANCE = R_W = 0.00506 × (4) × (3) × (12) × (10) × (10)	POUNDS	[illegible]
19	TOTAL TOW RESISTANCE = R_T = (13) + (16) + (17) + (18)	POUNDS	[illegible]

CALCULATION OF TOWING RESISTANCE

SHIP: [illegible]

DATE: [illegible]

BY: [illegible]

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		[illegible]
2	TOW DISPLACEMENT, Δ (SEE TABLE-7)	LONG TONS	[illegible]
3	FRONTAL WINDAGE AREA, A_T, (SEE TABLE 7)	SQ. FEET	[illegible]
4	WIND DRAG COEFFICIENT, C_w, (SEE TABLE 7)	—	1.00
5	TOTAL PROJECTED AREA OF PROPELLERS, A_p, (SEE TABLE 7)	SQ. FEET	[illegible]
6	CURVE NUMBER FOR HULL RESISTANCE, R_H/Δ, (SEE TABLE 7)	—	[illegible]
7	CURVE NUMBER FOR WIND FACTOR, K, (SEE TABLE 7)	—	[illegible]
8	CURVE NUMBER FOR SEA STATE RESISTANCE, R_s, (SEE TABLE 7)	—	[illegible]
9	BEAUFORT NUMBER (WIND) - (SEE TABLE-8)	—	[illegible]
10	RELATIVE WIND SPEED, V_R	KNOTS	[illegible]
11	RELATIVE WIND DIRECTION, α	DEGREES	90
12	HEADING COEFFICIENT K, (SEE FIG. 13-15)	—	[illegible]
13	SEA STATE RESISTANCE R_s, (SEE FIG. 16)	—	[illegible]
14	SELECT A TOW SPEED, V_{TOW}	KNOTS	[illegible]
15	$R_{H/\Delta}$ (SEE FIG. 17)	—	[illegible]
16	HULL RESISTANCE = R_H = (15) × (2) × 1.25	POUNDS	[illegible]
17	PROPELLER RESISTANCE = R_p = 3.737 × (5) × (14) × (14)	POUNDS	[illegible]
18	WIND RESISTANCE = R_w = 0.00506 × (4) × (3) × (12) × (10) × (10)	POUNDS	[illegible]
19	TOTAL TOW RESISTANCE = R_T = (13) + (16) + (17) + (18)	POUNDS	[illegible]

CALCULATION OF TOW RESISTANCE BY METHOD USED IN U.S. NAVY TOWING MANUAL

SHIP: FF 1040 ESCORT

DATE: 2/24/75

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		FF 1040
2	TOW DISPLACEMENT, Δ (SEE TABLE 7)	LONG TONS	3400
3	FRONTAL WINDAGE AREA, A_T	SQ. FT.	1715
4	TOW SPEED, V_{TOW}	KNOTS	8
5	DIRECTION OF TRUE WIND FROM BOW, θ	DEGREES	0
6	TRUE WIND VELOCITY, V_{WIND}	KNOTS	13.5
7	WIND VELOCITY COMPONENT V_T = (4) + [(6) x COS (5)]	KNOTS	21.5
8	WIND PRESSURE P, (SEE GRAPH 1)	LBS/SQ.FT.	1.5
9	WIND RESISTANCE, R_W = (3) x (8)	POUNDS	2573
10	HYDRODYNAMIC UNIT RESISTANCE r_H, (SEE GRAPH 2)	--	12.5
11	SEA STATE CORRECTION FACTOR K_1 (SEE TABLE 8)	--	1.4
12	HYDRODYNAMIC RESISTANCE R_H = (2) x (10) x (11)	POUNDS	59500
13	TOTAL PROJECTED AREA OF PROPELLERS, A_P	SQ. FT.	131
14	PROPELLER RESISTANCE = R_P = 3.394 x (13) x (4) x (4)	POUNDS	28455
15	HULL RESISTANCE = (10) x (2) - (14)	POUNDS	14045
16	SEA STATE RESISTANCE = R_S = (12) - (15) - (14)	POUNDS	17000
17	TOTAL TOW RESISTANCE = R_T = (9) + (12)	POUNDS	62073

CALCULATION OF TOW RESISTANCE BY METHOD USED IN U.S. NAVY TOWING MANUAL

SHIP: FF 1040 ESCORT

DATE: 2/24/75

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		FF 1040
2	TOW DISPLACEMENT, Δ (SEE TABLE 7)	LONG TONS	3400
3	FRONTAL WINDAGE AREA, A_T	SQ. FT.	1715
4	TOW SPEED, V_{TOW}	KNOTS	8
5	DIRECTION OF TRUE WIND FROM BOW, θ	DEGREES	0
6	TRUE WIND VELOCITY, V_{WIND}	KNOTS	13.5
7	WIND VELOCITY COMPONENT V_T = (4) + [(6) x COS (5)]	KNOTS	21.5
8	WIND PRESSURE P, (SEE GRAPH 1)	LBS/SQ.FT.	1.5
9	WIND RESISTANCE, R_W = (3) x (8)	POUNDS	2573
10	HYDRODYNAMIC UNIT RESISTANCE r_H, (SEE GRAPH 2)	--	12.5
11	SEA STATE CORRECTION FACTOR K_1 (SEE TABLE 8)	--	1.4
12	HYDRODYNAMIC RESISTANCE R_H = (2) x (10) x (11)	POUNDS	59500
13	TOTAL PROJECTED AREA OF PROPELLERS, A_P	SQ. FT.	131
14	PROPELLER RESISTANCE = R_P = 3.394 x (13) x (4) x (4)	POUNDS	28455
15	HULL RESISTANCE = (10) x (2) - (14)	POUNDS	14045
16	SEA STATE RESISTANCE = R_S = (12) - (15) - (14)	POUNDS	17000
17	TOTAL TOW RESISTANCE = R_T = (9) + (12)	POUNDS	62073

CALCULATION OF TOW RESISTANCE BY METHOD USED IN U.S. NAVY TOWING MANUAL

SHIP: FF 1040

DATE: 2/24/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		FF 1040
2	TOW DISPLACEMENT, Δ (SEE TABLE 7)	LONG TONS	3400
3	FRONTAL WINDAGE AREA, A_T	SQ. FT.	1715
4	TOW SPEED, V_{TOW}	KNOTS	8
5	DIRECTION OF TRUE WIND FROM BOW, θ	DEGREES	126.34
6	TRUE WIND VELOCITY, V_{WIND}	KNOTS	13.5
7	WIND VELOCITY COMPONENT V_T = (4) + [(6) x COS (5)]	KNOTS	0
8	WIND PRESSURE P, (SEE GRAPH 1)	LBS/SQ.FT	0
9	WIND RESISTANCE, R_W = (3) x (8)	POUNDS	0
10	HYDRODYNAMIC UNIT RESISTANCE r_H, (SEE GRAPH 2)	--	13.5
11	SEA STATE CORRECTION FACTOR K_1 (SEE TABLE 8)	--	1.4
12	HYDRODYNAMIC RESISTANCE R_H = (2) x (10) x (11)	POUNDS	59500
13	TOTAL PROJECTED AREA OF PROPELLERS, A_P	SQ. FT.	131
14	PROPELLER RESISTANCE = R_P = 3.394 x (13) x (4) x (4)	POUNDS	28455
15	HULL RESISTANCE = (10) x (2) - (14)	POUNDS	17445
16	SEA STATE RESISTANCE = R_s = (12) - (15) - (14)	POUNDS	13600
17	TOTAL TOW RESISTANCE = R_T = (9) + (12)	POUNDS	59500

CALCULATION OF TOW RESISTANCE BY METHOD USED IN U.S. NAVY TOWING MANUAL

SHIP: *FF 1040*

DATE: *2/24/76*

BY: *RCS*

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		*FF 1040*
2	TOW DISPLACEMENT, Δ (SEE TABLE 7)	LONG TONS	*3400*
3	FRONTAL WINDAGE AREA, A_T	SQ. FT.	*1715*
4	TOW SPEED, V_{TOW}	KNOTS	*8*
5	DIRECTION OF TRUE WIND FROM BOW, θ	DEGREES	*126.34*
6	TRUE WIND VELOCITY, V_{WIND}	KNOTS	*13.5*
7	WIND VELOCITY COMPONENT V_T = (4) + [(6) x COS (5)]	KNOTS	*0*
8	WIND PRESSURE P, (SEE GRAPH 1)	LBS/SQ.FT.	*0*
9	WIND RESISTANCE, R_W = (3) x (8)	POUNDS	[illegible]
10	HYDRODYNAMIC UNIT RESISTANCE r_H, (SEE GRAPH 2)	--	*12.5*
11	SEA STATE CORRECTION FACTOR K_1 (SEE TABLE 8)	--	*1.4*
12	HYDRODYNAMIC RESISTANCE R_H = (2) x (10) x (11)	POUNDS	*59500*
13	TOTAL PROJECTED AREA OF PROPELLERS, A_P	SQ. FT.	*131*
14	PROPELLER RESISTANCE = R_P = 3.394 x (13) x (4) x (4)	POUNDS	[illegible]
15	HULL RESISTANCE = (10) x (2) - (14)	POUNDS	[illegible]
16	SEA STATE RESISTANCE = R_S = (12) - (15) - (14)	POUNDS	[illegible]
17	TOTAL TOW RESISTANCE = R_T = (9) + (12)	POUNDS	[illegible]

CALCULATION OF TOW RESISTANCE BY METHOD USED IN U.S. NAVY TOWING MANUAL

SHIP: FF 1040 ESCORT

DATE: 7/24/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		FF 1040
2	TOW DISPLACEMENT, Δ (SEE TABLE 7)	LONG TONS	3400
3	FRONTAL WINDAGE AREA, A_T	SQ. FT.	1715
4	TOW SPEED, V_{TOW}	KNOTS	5
5	DIRECTION OF TRUE WIND FROM BOW, θ	DEGREES	35.86
6	TRUE WIND VELOCITY, V_{WIND}	KNOTS	24.5
7	WIND VELOCITY COMPONENT V_T = (4) + [(6) x COS (5)]	KNOTS	24.86
8	WIND PRESSURE P, (SEE GRAPH 1)	LBS/SQ.FT.	2
9	WIND RESISTANCE, R_W = (3) x (8)	POUNDS	3430
10	HYDRODYNAMIC UNIT RESISTANCE r_H, (SEE GRAPH 2)	--	4.8
11	SEA STATE CORRECTION FACTOR K_1 (SEE TABLE 8)	--	1.6
12	HYDRODYNAMIC RESISTANCE R_H = (2) x (10) x (11)	POUNDS	26,112
13	TOTAL PROJECTED AREA OF PROPELLERS, A_P	SQ. FT.	131
14	PROPELLER RESISTANCE = R_P = 3.394 x (13) x (4) x (4)	POUNDS	11,115
15	HULL RESISTANCE = (10) x (2) - (14)	POUNDS	5205
16	SEA STATE RESISTANCE = R_S = (12) - (15) - (14)	POUNDS	9792
17	TOTAL TOW RESISTANCE = R_T = (9) + (12)	POUNDS	[illegible]

CALCULATION OF TOW RESISTANCE BY METHOD USED IN U.S. NAVY TOWING MANUAL

SHIP: FF 1040 ESCORT

DATE: 2/24/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		FF 1040
2	TOW DISPLACEMENT, Δ (SEE TABLE 7)	LONG TONS	3400
3	FRONTAL WINDAGE AREA, A_T	SQ. FT.	1715
4	TOW SPEED, V_{TOW}	KNOTS	5
5	DIRECTION OF TRUE WIND FROM BOW, θ	DEGREES	35.86
6	TRUE WIND VELOCITY, V_{WIND}	KNOTS	24.5
7	WIND VELOCITY COMPONENT V_T = (4) + [(6) x COS (5)]	KNOTS	24.86
8	WIND PRESSURE P, (SEE GRAPH 1)	LBS/SQ.FT.	2
9	WIND RESISTANCE, R_W = (3) x (8)	POUNDS	3430
10	HYDRODYNAMIC UNIT RESISTANCE r_H, (SEE GRAPH 2)	--	4.8
11	SEA STATE CORRECTION FACTOR K_1 (SEE TABLE 8)	--	1.6
12	HYDRODYNAMIC RESISTANCE R_H = (2) x (10) x (11)	POUNDS	26,112
13	TOTAL PROJECTED AREA OF PROPELLERS, A_P	SQ. FT.	131
14	PROPELLER RESISTANCE = R_P = 3.394 x (13) x (4) x (4)	POUNDS	11,115
15	HULL RESISTANCE = (10) x (2) - (14)	POUNDS	5205
16	SEA STATE RESISTANCE = R_S = (12) - (15) - (14)	POUNDS	9792
17	TOTAL TOW RESISTANCE = R_T = (9) + (12)	POUNDS	29542

TABLE - 6

CALCULATION OF TOWING RESISTANCE

SHIP: EF 1040 ESCORT DATE: 7/24/76

BY: ECS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		FF 1040
2	TOW DISPLACEMENT, Δ (SEE TABLE-7)	LONG TONS	3400
3	FRONTAL WINDAGE AREA, A_T, (SEE TABLE 7)	SQ. FEET	1715
4	WIND DRAG COEFFICIENT, C_w, (SEE TABLE 7)	—	0.70
5	TOTAL PROJECTED AREA OF PROPELLERS, A_p, (SEE TABLE 7)	SQ. FEET	131
6	CURVE NUMBER FOR HULL RESISTANCE, R_H/Δ, (SEE TABLE 7)	—	2
7	CURVE NUMBER FOR WIND FACTOR, K, (SEE TABLE 7)	—	3
8	CURVE NUMBER FOR SEA STATE RESISTANCE, R_s, (SEE TABLE 7)	—	4
9	BEAUFORT NUMBER (WIND) - (SEE TABLE-8)	—	0
10	RELATIVE WIND SPEED, V_R	KNOTS	10
11	RELATIVE WIND DIRECTION, α	DEGREES	0
12	HEADING COEFFICIENT K, (SEE FIG. 13-15)	—	1.0
13	SEA STATE RESISTANCE R_s, (SEE FIG. 16)	—	0
14	SELECT A TOW SPEED, V_{TOW}	KNOTS	10
15	$R_{H/\Delta}$ (SEE FIG. 17)	—	7.35
16	HULL RESISTANCE = R_H = (15) × (2) × 1.25	POUNDS	31237
17	PROPELLER RESISTANCE = R_p = 3.737 × (5) × (14) × (14)	POUNDS	48955
18	WIND RESISTANCE = R_w = 0.00506 × (4) × (3) × (12) × (10) × (10)	POUNDS	607
19	TOTAL TOW RESISTANCE = R_T = (13) + (16) + (17) + (18)	POUNDS	80799

TABLE - 6

CALCULATION OF TOWING RESISTANCE

SHIP: FF 1040 ESCORT DATE: 7/24/76

BY: ECS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		FF 1040
2	TOW DISPLACEMENT, Δ (SEE TABLE-7)	LONG TONS	3400
3	FRONTAL WINDAGE AREA, A_T, (SEE TABLE 7)	SQ. FEET	1715
4	WIND DRAG COEFFICIENT, C_w, (SEE TABLE 7)	—	0.70
5	TOTAL PROJECTED AREA OF PROPELLERS, A_p, (SEE TABLE 7)	SQ. FEET	131
6	CURVE NUMBER FOR HULL RESISTANCE, R_H/Δ, (SEE TABLE 7)	—	2
7	CURVE NUMBER FOR WIND FACTOR, K, (SEE TABLE 7)	—	3
8	CURVE NUMBER FOR SEA STATE RESISTANCE, R_s, (SEE TABLE 7)	—	4
9	BEAUFORT NUMBER (WIND) - (SEE TABLE-8)	—	0
10	RELATIVE WIND SPEED, V_R	KNOTS	10
11	RELATIVE WIND DIRECTION, α	DEGREES	0
12	HEADING COEFFICIENT K, (SEE FIG. 13-15)	—	1.0
13	SEA STATE RESISTANCE R_s, (SEE FIG. 16)	—	0
14	SELECT A TOW SPEED, V_{TOW}	KNOTS	10
15	$R_{H/\Delta}$ (SEE FIG. 17)	—	7.35
16	HULL RESISTANCE = R_H = (15) x (2) x 1.25	POUNDS	31237
17	PROPELLER RESISTANCE = R_P = 3.737 x (5) x (14) x (14)	POUNDS	48955
18	WIND RESISTANCE = R_W = 0.00506 x (4) x (3) x (12) x (10) x (10)	POUNDS	607
19	TOTAL TOW RESISTANCE = R_T = (13) + (16) + (17) + (18)	POUNDS	80799

TABLE - [illegible]

CALCULATION OF TOWING RESISTANCE

SHIP: FF 1040 Escort

DATE: 7/24/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		FF 1040
2	TOW DISPLACEMENT, Δ (SEE TABLE-7)	LONG TONS	[illegible]
3	FRONTAL WINDAGE AREA, A_T, (SEE TABLE 7)	SQ. FEET	1715
4	WIND DRAG COEFFICIENT, C_w, (SEE TABLE 7)	—	0.70
5	TOTAL PROJECTED AREA OF PROPELLERS, A_p, (SEE TABLE 7)	SQ. FEET	131
6	CURVE NUMBER FOR HULL RESISTANCE, R_H/Δ, (SEE TABLE 7)	—	2
7	CURVE NUMBER FOR WIND FACTOR, K, (SEE TABLE 7)	—	3
8	CURVE NUMBER FOR SEA STATE RESISTANCE, R_s, (SEE TABLE 7)	—	4
9	BEAUFORT NUMBER (WIND) - (SEE TABLE-8)	—	4
10	RELATIVE WIND SPEED, V_R	KNOTS	19.82
11	RELATIVE WIND DIRECTION, α	DEGREES	30
12	HEADING COEFFICIENT K, (SEE FIG. 13-15)	—	1.20
13	SEA STATE RESISTANCE R_s, (SEE FIG. 16)	—	600
14	SELECT A TOW SPEED, V_{TOW}	KNOTS	8
15	$R_{H/\Delta}$ (SEE FIG. 17)	—	4.2
16	HULL RESISTANCE = R_H = (15) × (2) × 1.25	POUNDS	179[illegible]
17	PROPELLER RESISTANCE = R_p = 3.737 × (5) × (14) × (14)	POUNDS	31[illegible]31
18	WIND RESISTANCE = R_w = 0.00506 × (4) × (3) × (12) × (10) × (10)	POUNDS	[illegible]363
19	TOTAL TOW RESISTANCE = R_T = (13) + (16) + (17) + (18)	POUNDS	52644

TABLE - 6

CALCULATION OF TOWING RESISTANCE

SHIP: FF 1040 Escort DATE: 7/24/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		FF 1040
2	TOW DISPLACEMENT, Δ (SEE TABLE-7)	LONG TONS	[illegible]
3	FRONTAL WINDAGE AREA, A_T, (SEE TABLE 7)	SQ. FEET	1715
4	WIND DRAG COEFFICIENT, C_w, (SEE TABLE 7)	—	0.70
5	TOTAL PROJECTED AREA OF PROPELLERS, A_p, (SEE TABLE 7)	SQ. FEET	131
6	CURVE NUMBER FOR HULL RESISTANCE, R_H/Δ, (SEE TABLE 7)	—	2
7	CURVE NUMBER FOR WIND FACTOR, K, (SEE TABLE 7)	—	3
8	CURVE NUMBER FOR SEA STATE RESISTANCE, R_s, (SEE TABLE 7)	—	4
9	BEAUFORT NUMBER (WIND) - (SEE TABLE-8)	—	4
10	RELATIVE WIND SPEED, V_R	KNOTS	19.8[illegible]
11	RELATIVE WIND DIRECTION, α	DEGREES	30
12	HEADING COEFFICIENT K, (SEE FIG. 13-15)	—	1.20
13	SEA STATE RESISTANCE R_s, (SEE FIG. 16)	—	600
14	SELECT A TOW SPEED, V_{TOW}	KNOTS	8
15	$R_{H/\Delta}$ (SEE FIG. 17)	—	[illegible]
16	HULL RESISTANCE = R_H = (15) x (2) x 1.25	POUNDS	[illegible]
17	PROPELLER RESISTANCE = R_P = 3.737 x (5) x (14) x (14)	POUNDS	[illegible]
18	WIND RESISTANCE = R_W = 0.00506 x (4) x (3) x (12) x (10) x (10)	POUNDS	[illegible]
19	TOTAL TOW RESISTANCE = R_T = (13) + (16) + (17) + (18)	POUNDS	52644

CALCULATION OF TOWING RESISTANCE

SHIP: FF 1040 Escort

DATE: 2/24/76

BY: ECS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		FF 1040
2	TOW DISPLACEMENT, Δ (SEE TABLE-7)	LONG TONS	3400
3	FRONTAL WINDAGE AREA, A_T, (SEE TABLE 7)	SQ. FEET	1715
4	WIND DRAG COEFFICIENT, C_w, (SEE TABLE 7)	—	0.70
5	TOTAL PROJECTED AREA OF PROPELLERS, A_p, (SEE TABLE 7)	SQ. FEET	131
6	CURVE NUMBER FOR HULL RESISTANCE, R_H/Δ, (SEE TABLE 7)	—	2
7	CURVE NUMBER FOR WIND FACTOR, K, (SEE TABLE 7)	—	3
8	CURVE NUMBER FOR SEA STATE RESISTANCE, R_s, (SEE TABLE 7)	—	4
9	BEAUFORT NUMBER (WIND) - (SEE TABLE-8)	—	6
10	RELATIVE WIND SPEED, V_R	KNOTS	29.5
11	RELATIVE WIND DIRECTION, α	DEGREES	0
12	HEADING COEFFICIENT K, (SEE FIG. 13-15)	—	1.0
13	SEA STATE RESISTANCE R_s, (SEE FIG. 16)	—	[illegible]
14	SELECT A TOW SPEED, V_{TOW}	KNOTS	5
15	$R_{H/\Delta}$ (SEE FIG. 17)	—	1.56
16	HULL RESISTANCE = R_H = (15) x (2) x 1.25	POUNDS	[illegible]
17	PROPELLER RESISTANCE = R_p = 3.737 x (5) x (14) x (14)	POUNDS	[illegible]
18	WIND RESISTANCE = R_w = 0.00506 x (4) x (3) x (12) x (10) x (10)	POUNDS	[illegible]
19	TOTAL TOW RESISTANCE = R_T = (13) + (16) + (17) + (18)	POUNDS	44754

CALCULATION OF TOWING RESISTANCE

SHIP: FF 1040 Escort DATE: 2/24/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		FF 1040
2	TOW DISPLACEMENT, Δ (SEE TABLE-7)	LONG TONS	[illegible]
3	FRONTAL WINDAGE AREA, A_T, (SEE TABLE 7)	SQ. FEET	1715
4	WIND DRAG COEFFICIENT, C_w, (SEE TABLE 7)	—	0.70
5	TOTAL PROJECTED AREA OF PROPELLERS, A_p, (SEE TABLE 7)	SQ. FEET	121
6	CURVE NUMBER FOR HULL RESISTANCE, R_H/Δ, (SEE TABLE 7)	—	2
7	CURVE NUMBER FOR WIND FACTOR, K, (SEE TABLE 7)	—	3
8	CURVE NUMBER FOR SEA STATE RESISTANCE, R_s, (SEE TABLE 7)	—	4
9	BEAUFORT NUMBER (WIND) - (SEE TABLE-8)	—	6
10	RELATIVE WIND SPEED, V_R	KNOTS	29.5
11	RELATIVE WIND DIRECTION, α	DEGREES	0
12	HEADING COEFFICIENT K, (SEE FIG. 13-15)	—	1.0
13	SEA STATE RESISTANCE R_s, (SEE FIG. 16)	—	[illegible]
14	SELECT A TOW SPEED, V_{TOW}	KNOTS	5
15	$R_{H/\Delta}$ (SEE FIG. 17)	—	1.56
16	HULL RESISTANCE = R_H = (15) × (2) × 1.25	POUNDS	[illegible]
17	PROPELLER RESISTANCE = R_p = 3.737 × (5) × (14) × (14)	POUNDS	12230
18	WIND RESISTANCE = R_w = 0.00506 × (4) × (3) × (12) × (10) × (10)	POUNDS	[illegible]
19	TOTAL TOW RESISTANCE = R_T = (13) + (16) + (17) + (18)	POUNDS	44354

TABLE - 8

CALCULATION OF TOWING RESISTANCE

SHIP: FF [illegible]   DATE: 7/24/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		FF [illegible]
2	TOW DISPLACEMENT, Δ (SEE TABLE-7)	LONG TONS	3400
3	FRONTAL WINDAGE AREA, A_T, (SEE TABLE 7)	SQ. FEET	1715
4	WIND DRAG COEFFICIENT, C_w, (SEE TABLE 7)	—	0.70
5	TOTAL PROJECTED AREA OF PROPELLERS, A_p, (SEE TABLE 7)	SQ. FEET	131
6	CURVE NUMBER FOR HULL RESISTANCE, $R_{H/\Delta}$, (SEE TABLE 7)	—	7
7	CURVE NUMBER FOR WIND FACTOR, K, (SEE TABLE 7)	—	3
8	CURVE NUMBER FOR SEA STATE RESISTANCE, R_s, (SEE TABLE 7)	—	4
9	BEAUFORT NUMBER (WIND) - (SEE TABLE-8)	—	6
10	RELATIVE WIND SPEED, V_R	KNOTS	23.98
11	RELATIVE WIND DIRECTION, α	DEGREES	90
12	HEADING COEFFICIENT K, (SEE FIG. 13-15)	—	0.48
13	SEA STATE RESISTANCE R_s, (SEE FIG. 16)	—	20,000
14	SELECT A TOW SPEED, V_{TOW}	KNOTS	5
15	$R_{H/\Delta}$ (SEE FIG. 17)	—	1.56
16	HULL RESISTANCE = R_H = (15) x (2) x 1.25	POUNDS	6630
17	PROPELLER RESISTANCE = R_p = 3.737 x (5) x (14) x (14)	POUNDS	1[illegible]
18	WIND RESISTANCE = R_w = 0.00506 x (4) x (3) x (12) x (10) x (10)	POUNDS	1677
19	TOTAL TOW RESISTANCE = R_T = (13) + (16) + (17) + (18)	POUNDS	41344

TABLE - [illegible]

CALCULATION OF TOWING RESISTANCE

SHIP: FF [illegible]

DATE: 7/2[illegible]/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		FF [illegible]
2	TOW DISPLACEMENT, Δ (SEE TABLE-7)	LONG TONS	3400
3	FRONTAL WINDAGE AREA, A_T, (SEE TABLE 7)	SQ. FEET	1715
4	WIND DRAG COEFFICIENT, C_w, (SEE TABLE 7)	—	0.70
5	TOTAL PROJECTED AREA OF PROPELLERS, A_p, (SEE TABLE 7)	SQ. FEET	131
6	CURVE NUMBER FOR HULL RESISTANCE, R_H/Δ, (SEE TABLE 7)	—	2
7	CURVE NUMBER FOR WIND FACTOR, K, (SEE TABLE 7)	—	2
8	CURVE NUMBER FOR SEA STATE RESISTANCE, R_s, (SEE TABLE 7)	—	4
9	BEAUFORT NUMBER (WIND) - (SEE TABLE-8)	—	6
10	RELATIVE WIND SPEED, V_R	KNOTS	22.98
11	RELATIVE WIND DIRECTION, α	DEGREES	90
12	HEADING COEFFICIENT K, (SEE FIG. 13-15)	—	0.43
13	SEA STATE RESISTANCE R_s, (SEE FIG. 16)	—	20,000
14	SELECT A TOW SPEED, V_{TOW}	KNOTS	5
15	$R_{H/\Delta}$ (SEE FIG. 17)	—	1.56
16	HULL RESISTANCE = R_H = (15) x (2) x 1.25	POUNDS	6630
17	PROPELLER RESISTANCE = R_p = 3.737 x (5) x (14) x (14)	POUNDS	12[illegible]
18	WIND RESISTANCE = R_w = 0.00506 x (4) x (3) x (12) x (10) x (10)	POUNDS	1677
19	TOTAL TOW RESISTANCE = R_T = (13) + (16) + (17) + (18)	POUNDS	41344

CALCULATION OF TOW RESISTANCE BY METHOD USED IN U.S. NAVY TOWING MANUAL

SHIP: AF 58 STORES SHIP

DATE: 3/24/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		AF 58
2	TOW DISPLACEMENT, Δ (SEE TABLE 7)	LONG TONS	15500
3	FRONTAL WINDAGE AREA, A_T	SQ. FT.	4105
4	TOW SPEED, V_{TOW}	KNOTS	8
5	DIRECTION OF TRUE WIND FROM BOW, θ	DEGREES	0
6	TRUE WIND VELOCITY, V_{WIND}	KNOTS	13.5
7	WIND VELOCITY COMPONENT V_T = (4) + [(6) x COS (5)]	KNOTS	21.5
8	WIND PRESSURE P, (SEE GRAPH 1)	LBS/SQ.FT.	0.9
9	WIND RESISTANCE, R_W = (3) x (8)	POUNDS	[illegible]
10	HYDRODYNAMIC UNIT RESISTANCE r_H, (SEE GRAPH 2)	--	2.3
11	SEA STATE CORRECTION FACTOR K_1 (SEE TABLE 8)	--	1.4
12	HYDRODYNAMIC RESISTANCE R_H = (2) x (10) x (11)	POUNDS	49910
13	TOTAL PROJECTED AREA OF PROPELLERS, A_P	SQ. FT.	106
14	PROPELLER RESISTANCE = R_P = 3.394 x (13) x (4) x (4)	POUNDS	[illegible]
15	HULL RESISTANCE = (10) x (2) - (14)	POUNDS	126[illegible]
16	SEA STATE RESISTANCE = R_s = (12) - (15) - (14)	POUNDS	14260
17	TOTAL TOW RESISTANCE = R_T = (9) + (12)	POUNDS	53875

CALCULATION OF TOW RESISTANCE BY METHOD USED IN U.S. NAVY TOWING MANUAL

SHIP: AF 53 STORES SHIP

DATE: 3/24/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		AF 53
2	TOW DISPLACEMENT, Δ (SEE TABLE 7)	LONG TONS	[illegible]
3	FRONTAL WINDAGE AREA, A_T	SQ. FT.	4405
4	TOW SPEED, V_{TOW}	KNOTS	8
5	DIRECTION OF TRUE WIND FROM BOW, θ	DEGREES	0
6	TRUE WIND VELOCITY, V_{WIND}	KNOTS	13.5
7	WIND VELOCITY COMPONENT V_T = (4) + [(6) x COS (5)]	KNOTS	21.5
8	WIND PRESSURE P, (SEE GRAPH 1)	LBS/SQ.FT.	[illegible]
9	WIND RESISTANCE, R_W = (3) x (8)	POUNDS	[illegible]
10	HYDRODYNAMIC UNIT RESISTANCE r_H, (SEE GRAPH 2)	--	2.3
11	SEA STATE CORRECTION FACTOR K_1 (SEE TABLE 8)	--	1.4
12	HYDRODYNAMIC RESISTANCE R_H = (2) x (10) x (11)	POUNDS	49910
13	TOTAL PROJECTED AREA OF PROPELLERS, A_P	SQ. FT.	106
14	PROPELLER RESISTANCE = R_P = 3.394 x (13) x (4) x (4)	POUNDS	[illegible]
15	HULL RESISTANCE = (10) x (2) - (14)	POUNDS	12675
16	SEA STATE RESISTANCE = R_S = (12) - (15) - (14)	POUNDS	14260
17	TOTAL TOW RESISTANCE = R_T = (9) + (12)	POUNDS	[illegible]

CALCULATION OF TOW RESISTANCE BY METHOD USED IN U.S. NAVY TOWING MANUAL

SHIP: AF 58 STORES SHIP

DATE: 2/24/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		AF 58
2	TOW DISPLACEMENT, Δ (SEE TABLE 7)	LONG TONS	15500
3	FRONTAL WINDAGE AREA, A_T	SQ. FT.	4405
4	TOW SPEED, V_{TOW}	KNOTS	8
5	DIRECTION OF TRUE WIND FROM BOW, θ	DEGREES	126.34
6	TRUE WIND VELOCITY, V_{WIND}	KNOTS	13.5
7	WIND VELOCITY COMPONENT V_T = (4) + [(6) x COS (5)]	KNOTS	0
8	WIND PRESSURE P, (SEE GRAPH 1)	LBS/SQ.FT.	0
9	WIND RESISTANCE, R_W = (3) x (8)	POUNDS	0
10	HYDRODYNAMIC UNIT RESISTANCE r_H, (SEE GRAPH 2)	--	2.3
11	SEA STATE CORRECTION FACTOR K_1 (SEE TABLE 8)	--	1.4
12	HYDRODYNAMIC RESISTANCE R_H = (2) x (10) x (11)	POUNDS	49910
13	TOTAL PROJECTED AREA OF PROPELLERS, A_P	SQ. FT.	106
14	PROPELLER RESISTANCE = R_P = 3.394 x (13) x (4) x (4)	POUNDS	23025
15	HULL RESISTANCE = (10) x (2) - (14)	POUNDS	12625
16	SEA STATE RESISTANCE = R_s = (12) - (15) - (14)	POUNDS	14260
17	TOTAL TOW RESISTANCE = R_T = (9) + (12)	POUNDS	49910

CALCULATION OF TOW RESISTANCE BY METHOD USED IN U.S. NAVY TOWING MANUAL

SHIP: AF 58 STORES SHIP

DATE: 2/24/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		AF 58
2	TOW DISPLACEMENT, Δ (SEE TABLE 7)	LONG TONS	15500
3	FRONTAL WINDAGE AREA, A_T	SQ. FT.	4405
4	TOW SPEED, V_{TOW}	KNOTS	8
5	DIRECTION OF TRUE WIND FROM BOW, θ	DEGREES	126.34
6	TRUE WIND VELOCITY, V_{WIND}	KNOTS	13.5
7	WIND VELOCITY COMPONENT V_T = (4) + [(6) x COS (5)]	KNOTS	0
8	WIND PRESSURE P, (SEE GRAPH 1)	LBS/SQ.FT.	0
9	WIND RESISTANCE, R_W = (3) x (8)	POUNDS	0
10	HYDRODYNAMIC UNIT RESISTANCE r_H, (SEE GRAPH 2)	--	2.3
11	SEA STATE CORRECTION FACTOR K_1 (SEE TABLE 8)	--	1.4
12	HYDRODYNAMIC RESISTANCE R_H = (2) x (10) x (11)	POUNDS	49910
13	TOTAL PROJECTED AREA OF PROPELLERS, A_P	SQ. FT.	106
14	PROPELLER RESISTANCE = R_P = 3.394 x (13) x (4) x (4)	POUNDS	23025
15	HULL RESISTANCE = (10) x (2) - (14)	POUNDS	12625
16	SEA STATE RESISTANCE = R_S = (12) - (15) - (14)	POUNDS	14260
17	TOTAL TOW RESISTANCE = R_T = (9) + (12)	POUNDS	49910

CALCULATION OF TOW RESISTANCE BY METHOD USED IN U.S. NAVY TOWING MANUAL

SHIP: AF 58 STORES SHIP

DATE: 2/24/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		AF 58
2	TOW DISPLACEMENT, Δ (SEE TABLE 7)	LONG TONS	15500
3	FRONTAL WINDAGE AREA, A_T	SQ. FT.	4405
4	TOW SPEED, V_{TOW}	KNOTS	5
5	DIRECTION OF TRUE WIND FROM BOW, θ	DEGREES	0
6	TRUE WIND VELOCITY, V_{WIND}	KNOTS	24.5
7	WIND VELOCITY COMPONENT V_T = (4) + [(6) x COS (5)]	KNOTS	29.5
8	WIND PRESSURE P, (SEE GRAPH 1)	LBS/SQ.FT.	1.7
9	WIND RESISTANCE, R_W = (3) x (8)	POUNDS	7489
10	HYDRODYNAMIC UNIT RESISTANCE r_H, (SEE GRAPH 2)	--	0.7
11	SEA STATE CORRECTION FACTOR K_1 (SEE TABLE 8)	--	1.6
12	HYDRODYNAMIC RESISTANCE R_H = (2) x (10) x (11)	POUNDS	17360
13	TOTAL PROJECTED AREA OF PROPELLERS, A_P	SQ. FT.	106
14	PROPELLER RESISTANCE = R_P = 3.394 x (13) x (4) x (4)	POUNDS	8994
15	HULL RESISTANCE = (10) x (2) - (14)	POUNDS	1856
16	SEA STATE RESISTANCE = R_s = (12) - (15) - (14)	POUNDS	6510
17	TOTAL TOW RESISTANCE = R_T = (9) + (12)	POUNDS	24849

CALCULATION OF TOW RESISTANCE BY METHOD USED IN U.S. NAVY TOWING MANUAL

SHIP: AF 58 STORES SHIP

DATE: 2/24/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		AF 58
2	TOW DISPLACEMENT, Δ (SEE TABLE 7)	LONG TONS	15500
3	FRONTAL WINDAGE AREA, A_T	SQ. FT.	4405
4	TOW SPEED, V_{TOW}	KNOTS	5
5	DIRECTION OF TRUE WIND FROM BOW, θ	DEGREES	35.86
6	TRUE WIND VELOCITY, V_{WIND}	KNOTS	24.5
7	WIND VELOCITY COMPONENT V_T = (4) + [(6) x COS (5)]	KNOTS	24.86
8	WIND PRESSURE P, (SEE GRAPH 1)	LBS/SQ.FT.	1.1
9	WIND RESISTANCE, R_W = (3) x (8)	POUNDS	4846
10	HYDRODYNAMIC UNIT RESISTANCE r_H, (SEE GRAPH 2)	--	0.7
11	SEA STATE CORRECTION FACTOR K_1 (SEE TABLE 8)	--	1.6
12	HYDRODYNAMIC RESISTANCE R_H = (2) x (10) x (11)	POUNDS	17360
13	TOTAL PROJECTED AREA OF PROPELLERS, A_P	SQ. FT.	106
14	PROPELLER RESISTANCE = R_P = 3.394 x (13) x (4) x (4)	POUNDS	8994
15	HULL RESISTANCE = (10) x (2) - (14)	POUNDS	1856
16	SEA STATE RESISTANCE = R_S = (12) - (15) - (14)	POUNDS	6510
17	TOTAL TOW RESISTANCE = R_T = (9) + (12)	POUNDS	22206

CALCULATION OF TOW RESISTANCE BY METHOD USED IN U.S. NAVY TOWING MANUAL

SHIP: AE 58 STORES SHIP

DATE: 2/24/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		AE 58
2	TOW DISPLACEMENT, Δ (SEE TABLE 7)	LONG TONS	15500
3	FRONTAL WINDAGE AREA, A_T	SQ. FT.	4405
4	TOW SPEED, V_{TOW}	KNOTS	5
5	DIRECTION OF TRUE WIND FROM BOW, θ	DEGREES	101.8
6	TRUE WIND VELOCITY, V_{WIND}	KNOTS	24.5
7	WIND VELOCITY COMPONENT V_T = (4) + [(6) x COS (5)]	KNOTS	-0.01
8	WIND PRESSURE P, (SEE GRAPH 1)	LBS/SQ.FT.	0
9	WIND RESISTANCE, R_W = (3) x (8)	POUNDS	0
10	HYDRODYNAMIC UNIT RESISTANCE r_H, (SEE GRAPH 2)	--	0.7
11	SEA STATE CORRECTION FACTOR K_1 (SEE TABLE 8)	--	1.6
12	HYDRODYNAMIC RESISTANCE R_H = (2) x (10) x (11)	POUNDS	17360
13	TOTAL PROJECTED AREA OF PROPELLERS, A_p	SQ. FT.	106
14	PROPELLER RESISTANCE = R_p = 3.394 x (13) x (4) x (4)	POUNDS	8994
15	HULL RESISTANCE = (10) x (2) - (14)	POUNDS	1856
16	SEA STATE RESISTANCE = R_s = (12) - (15) - (14)	POUNDS	6510
17	TOTAL TOW RESISTANCE = R_T = (9) + (12)	POUNDS	17360

CALCULATION OF TOWING RESISTANCE

SHIP: AF 58 STORES SHIP

DATE: 2/24/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		AF 58
2	TOW DISPLACEMENT, Δ (SEE TABLE-7)	LONG TONS	15500
3	FRONTAL WINDAGE AREA, A_T, (SEE TABLE 7)	SQ. FEET	4405
4	WIND DRAG COEFFICIENT, C_w, (SEE TABLE 7)	—	0.75
5	TOTAL PROJECTED AREA OF PROPELLERS, A_p, (SEE TABLE 7)	SQ. FEET	106
6	CURVE NUMBER FOR HULL RESISTANCE, $R_{H/\Delta}$, (SEE TABLE 7)	—	12
7	CURVE NUMBER FOR WIND FACTOR, K, (SEE TABLE 7)	—	1
8	CURVE NUMBER FOR SEA STATE RESISTANCE, R_s, (SEE TABLE 7)	—	8
9	BEAUFORT NUMBER (WIND) - (SEE TABLE-8)	—	0
10	RELATIVE WIND SPEED, V_R	KNOTS	10
11	RELATIVE WIND DIRECTION, α	DEGREES	0
12	HEADING COEFFICIENT K, (SEE FIG. 13-15)	—	1.0
13	SEA STATE RESISTANCE R_s, (SEE FIG. 16)	—	0
14	SELECT A TOW SPEED, V_{TOW}	KNOTS	10
15	$R_{H/\Delta}$ (SEE FIG. 17)	—	3.15
16	HULL RESISTANCE = R_H = (15) x (2) x 1.25	POUNDS	61031
17	PROPELLER RESISTANCE = R_P = 3.737 x (5) x (14) x (14)	POUNDS	39612
18	WIND RESISTANCE = R_W = 0.00506 x (4) x (3) x (12) x (10) x (10)	POUNDS	1672
19	TOTAL TOW RESISTANCE = R_T = (13) + (16) + (17) + (18)	POUNDS	102315

CALCULATION OF TOWING RESISTANCE

SHIP: AF 58 STORES SHIP

DATE: 2/24/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		AF 58
2	TOW DISPLACEMENT, Δ (SEE TABLE-7)	LONG TONS	15500
3	FRONTAL WINDAGE AREA, A_T, (SEE TABLE 7)	SQ. FEET	4405
4	WIND DRAG COEFFICIENT, C_w, (SEE TABLE 7)	—	0.75
5	TOTAL PROJECTED AREA OF PROPELLERS, A_p, (SEE TABLE 7)	SQ. FEET	106
6	CURVE NUMBER FOR HULL RESISTANCE, R_H/Δ, (SEE TABLE 7)	—	12
7	CURVE NUMBER FOR WIND FACTOR, K, (SEE TABLE 7)	—	1
8	CURVE NUMBER FOR SEA STATE RESISTANCE, R_s, (SEE TABLE 7)	—	8
9	BEAUFORT NUMBER (WIND) - (SEE TABLE-8)	—	4
10	RELATIVE WIND SPEED, V_R	KNOTS	21.5
11	RELATIVE WIND DIRECTION, α	DEGREES	0
12	HEADING COEFFICIENT K, (SEE FIG. 13-15)	—	1.0
13	SEA STATE RESISTANCE R_s, (SEE FIG. 16)	—	1500
14	SELECT A TOW SPEED, V_{TOW}	KNOTS	8
15	$R_{H/\Delta}$ (SEE FIG. 17)	—	2.05
16	HULL RESISTANCE = R_H = (15) × (2) × 1.25	POUNDS	39719
17	PROPELLER RESISTANCE = R_p = 3.737 × (5) × (14) × (14)	POUNDS	25352
18	WIND RESISTANCE = R_W = 0.00506 × (4) × (3) × (12) × (10) × (10)	POUNDS	7727
19	TOTAL TOW RESISTANCE = R_T = (13) + (16) + (17) + (18)	POUNDS	74298

CALCULATION OF TOWING RESISTANCE

SHIP: *AF 58 STORES SHIP*

DATE: *2/24/76*

BY: *RCS*

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		AF 58
2	TOW DISPLACEMENT, Δ (SEE TABLE-7)	LONG TONS	15500
3	FRONTAL WINDAGE AREA, A_T, (SEE TABLE 7)	SQ. FEET	4405
4	WIND DRAG COEFFICIENT, C_w, (SEE TABLE 7)	—	0.75
5	TOTAL PROJECTED AREA OF PROPELLERS, A_p, (SEE TABLE 7)	SQ. FEET	106
6	CURVE NUMBER FOR HULL RESISTANCE, R_H/Δ, (SEE TABLE 7)	—	12
7	CURVE NUMBER FOR WIND FACTOR, K, (SEE TABLE 7)	—	1
8	CURVE NUMBER FOR SEA STATE RESISTANCE, R_s, (SEE TABLE 7)	—	8
9	BEAUFORT NUMBER (WIND) - (SEE TABLE-8)	—	4
10	RELATIVE WIND SPEED, V_R	KNOTS	19.82
11	RELATIVE WIND DIRECTION, α	DEGREES	30
12	HEADING COEFFICIENT K, (SEE FIG. 13-15)	—	1.13
13	SEA STATE RESISTANCE R_s, (SEE FIG. 16)	—	1500
14	SELECT A TOW SPEED, V_{TOW}	KNOTS	8
15	$R_{H/\Delta}$ (SEE FIG. 17)	—	2.05
16	HULL RESISTANCE = R_H = (15) × (2) × 1.25	POUNDS	39719
17	PROPELLER RESISTANCE = R_P = 3.737 × (5) × (14) × (14)	POUNDS	25352
18	WIND RESISTANCE = R_W = 0.00506 × (4) × (3) × (12) × (10) × (10)	POUNDS	7421
19	TOTAL TOW RESISTANCE = R_T = (13) + (16) + (17) + (18)	POUNDS	73992

CALCULATION OF TOWING RESISTANCE

SHIP: AF 58 STORES SHIP

DATE: 2/24/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		AF 58
2	TOW DISPLACEMENT, Δ (SEE TABLE-7)	LONG TONS	15500
3	FRONTAL WINDAGE AREA, A_T, (SEE TABLE 7)	SQ. FEET	4405
4	WIND DRAG COEFFICIENT, C_w, (SEE TABLE 7)	—	0.75
5	TOTAL PROJECTED AREA OF PROPELLERS, A_p, (SEE TABLE 7)	SQ. FEET	106
6	CURVE NUMBER FOR HULL RESISTANCE, R_H/Δ, (SEE TABLE 7)	—	12
7	CURVE NUMBER FOR WIND FACTOR, K, (SEE TABLE 7)	—	1
8	CURVE NUMBER FOR SEA STATE RESISTANCE, R_s, (SEE TABLE 7)	—	8
9	BEAUFORT NUMBER (WIND) - (SEE TABLE-8)	—	4
10	RELATIVE WIND SPEED, V_R	KNOTS	10.87
11	RELATIVE WIND DIRECTION, α	DEGREES	90
12	HEADING COEFFICIENT K, (SEE FIG. 13-15)	—	0.8
13	SEA STATE RESISTANCE R_s, (SEE FIG. 16)	—	1500
14	SELECT A TOW SPEED, V_{TOW}	KNOTS	8
15	$R_{H/\Delta}$ (SEE FIG. 17)	—	2.05
16	HULL RESISTANCE = R_H = (15) x (2) x 1.25	POUNDS	39719
17	PROPELLER RESISTANCE = R_p = 3.737 x (5) x (14) x (14)	POUNDS	25352
18	WIND RESISTANCE = R_w = 0.00506 x (4) x (3) x (12) x (10) x (10)	POUNDS	1580
19	TOTAL TOW RESISTANCE = R_T = (13) + (16) + (17) + (18)	POUNDS	68151

CALCULATION OF TOWING RESISTANCE

SHIP: AF 58 STORES SHIP

DATE: 2/24/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		AF 58
2	TOW DISPLACEMENT, Δ (SEE TABLE-7)	LONG TONS	15500
3	FRONTAL WINDAGE AREA, A_T, (SEE TABLE 7)	SQ. FEET	4405
4	WIND DRAG COEFFICIENT, C_w, (SEE TABLE 7)	—	0.75
5	TOTAL PROJECTED AREA OF PROPELLERS, A_p, (SEE TABLE 7)	SQ. FEET	106
6	CURVE NUMBER FOR HULL RESISTANCE, R_H/Δ, (SEE TABLE 7)	—	12
7	CURVE NUMBER FOR WIND FACTOR, K, (SEE TABLE 7)	—	1
8	CURVE NUMBER FOR SEA STATE RESISTANCE, R_s, (SEE TABLE 7)	—	8
9	BEAUFORT NUMBER (WIND) - (SEE TABLE-8)	—	6
10	RELATIVE WIND SPEED, V_R	KNOTS	29.5
11	RELATIVE WIND DIRECTION, α	DEGREES	0
12	HEADING COEFFICIENT K, (SEE FIG. 13-15)	—	1.0
13	SEA STATE RESISTANCE R_s, (SEE FIG. 16)	—	41,000
14	SELECT A TOW SPEED, V_{TOW}	KNOTS	5
15	$R_{H/\Delta}$ (SEE FIG. 17)	—	0.83
16	HULL RESISTANCE = R_H = (15) x (2) x 1.25	POUNDS	16081
17	PROPELLER RESISTANCE = R_p = 3.737 x (5) x (14) x (14)	POUNDS	9903
18	WIND RESISTANCE = R_w = 0.00506 x (4) x (3) x (12) x (10) x (10)	POUNDS	14548
19	TOTAL TOW RESISTANCE = R_T = (13) + (16) + (17) + (18)	POUNDS	81532

CALCULATION OF TOWING RESISTANCE

SHIP: AF 58 STORES SHIP

DATE: 2/24/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		AF 58
2	TOW DISPLACEMENT, Δ (SEE TABLE-7)	LONG. TONS	15500
3	FRONTAL WINDAGE AREA, A_T, (SEE TABLE 7)	SQ. FEET	4405
4	WIND DRAG COEFFICIENT, C_w, (SEE TABLE 7)	—	0.75
5	TOTAL PROJECTED AREA OF PROPELLERS, A_p, (SEE TABLE 7)	SQ. FEET	106
6	CURVE NUMBER FOR HULL RESISTANCE, $R_{H/\Delta}$, (SEE TABLE 7)	—	12
7	CURVE NUMBER FOR WIND FACTOR, K, (SEE TABLE 7)	—	1
8	CURVE NUMBER FOR SEA STATE RESISTANCE, R_s, (SEE TABLE 7)	—	8
9	BEAUFORT NUMBER (WIND) - (SEE TABLE-8)	—	6
10	RELATIVE WIND SPEED, V_R	KNOTS	28.7
11	RELATIVE WIND DIRECTION, α	DEGREES	30
12	HEADING COEFFICIENT K, (SEE FIG. 13-15)	—	1.13
13	SEA STATE RESISTANCE R_s, (SEE FIG. 16)	—	41,000
14	SELECT A TOW SPEED, V_{TOW}	KNOTS	5
15	$R_{H/\Delta}$ (SEE FIG. 17)	—	0.83
16	HULL RESISTANCE = R_H = (15) × (2) × 1.25	POUNDS	16081
17	PROPELLER RESISTANCE = R_P = 3.737 × (5) × (14) × (14)	POUNDS	9903
18	WIND RESISTANCE = R_W = 0.00506 × (4) × (3) × (12) × (10) × (10)	POUNDS	15560
19	TOTAL TOW RESISTANCE = R_T = (13) + (16) + (17) + (18)	POUNDS	82544

CALCULATION OF TOWING RESISTANCE

SHIP: *AF 58 STORES SHIP*

DATE: *2/24/76*

BY: *RCS*

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		*AF 58*
2	TOW DISPLACEMENT, Δ (SEE TABLE-7)	LONG. TONS	*15500*
3	FRONTAL WINDAGE AREA, A_T, (SEE TABLE 7)	SQ. FEET	*4405*
4	WIND DRAG COEFFICIENT, C_w, (SEE TABLE 7)	—	*0.75*
5	TOTAL PROJECTED AREA OF PROPELLERS, A_p, (SEE TABLE 7)	SQ. FEET	*106*
6	CURVE NUMBER FOR HULL RESISTANCE, R_H/Δ, (SEE TABLE 7)	—	*12*
7	CURVE NUMBER FOR WIND FACTOR, K, (SEE TABLE 7)	—	*1*
8	CURVE NUMBER FOR SEA STATE RESISTANCE, R_s, (SEE TABLE 7)	—	*8*
9	BEAUFORT NUMBER (WIND) - (SEE TABLE-8)	—	*6*
10	RELATIVE WIND SPEED, V_R	KNOTS	*23.98*
11	RELATIVE WIND DIRECTION, α	DEGREES	*90*
12	HEADING COEFFICIENT K, (SEE FIG. 13-15)	—	*0.8*
13	SEA STATE RESISTANCE R_s, (SEE FIG. 16)	—	*41,000*
14	SELECT A TOW SPEED, V_{TOW}	KNOTS	*5*
15	R_H/Δ (SEE FIG. 17)	—	*0.83*
16	HULL RESISTANCE = R_H = (15) × (2) × 1.25	POUNDS	*16081*
17	PROPELLER RESISTANCE = R_p = 3.737 × (5) × (14) × (14)	POUNDS	*9903*
18	WIND RESISTANCE = R_w = 0.00506 × (4) × (3) × (12) × (10) × (10)	POUNDS	*7690*
19	TOTAL TOW RESISTANCE = R_T = (13) + (16) + (17) + (18)	POUNDS	*74674*

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