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DAVID W. TAYLOR NAVAL SHIP RESEARCH AND DEVELOPMENT CENTER

Bethesda, Maryland 20084

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EFFECTS OF PROPULSION POD LONGITUDINAL LOCATION ON THE RESISTANCE CHARACTERISTICS OF A SHIP

by

Steven C. Fisher

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SHIP PERFORMANCE DEPARTMENT
DEPARTMENTAL REPORT

SEPTEMBER 1981

DTNSRDC/SPD-1011-01

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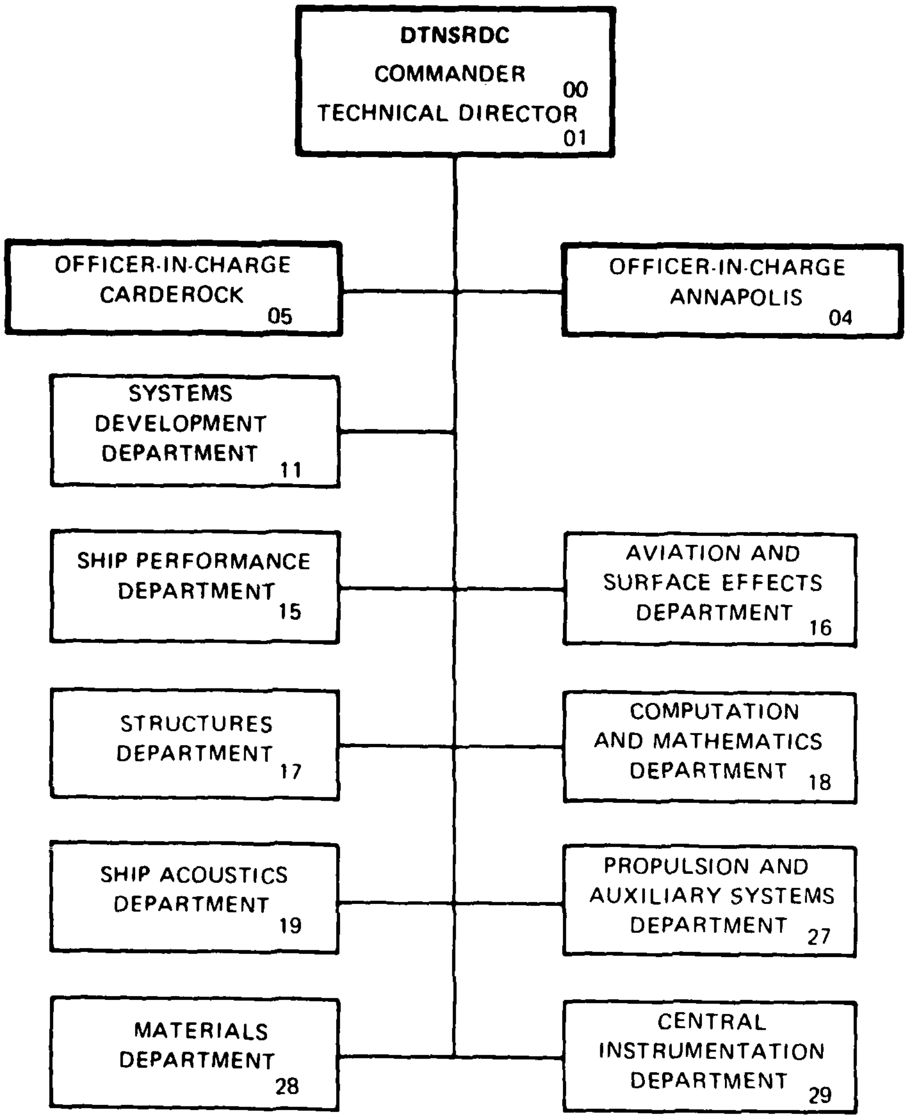

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REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER DTNSRDC/SPD-1011-01	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) EFFECTS OF PROPULSION POD LONGITUDINAL LOCATION ON THE RESISTANCE CHARACTERISTICS OF A SHIP.		5. TYPE OF REPORT & PERIOD COVERED Final rept.,
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Steven C. Fisher		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Commanding Officer David W. Taylor Naval Ship R&D Center Bethesda, Md. 20084		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS PE 62543N Work Unit No. 1507-101-22
11. CONTROLLING OFFICE NAME AND ADDRESS		12. REPORT DATE September 1981
		13. NUMBER OF PAGES 27
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)		15. SECURITY CLASS. (of this report) UNCLASSIFIED
		15a. DECLASSIFICATION DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

APPROVED FOR PUBLIC RELEASE: DISTRIBUTION UNLIMITED

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Propulsion Pods
Wavemaking Resistance
Sharmas' method

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A series of resistance and longitudinal wavecut experiments were performed with Model 5359-5B, representing a DD963 hull at the David Taylor Naval Ship R&D Center (DTNSRDC) to investigate the change in resistance caused by varying the longitudinal position of a single propulsion pod. Sharma's[1] method of bulb optimization was used in an attempt to find the otpimum longitudinal pod position. The experimental results indicate that the pod could be located between 80 to 90 percent of the ship length with virtually no change in total resistance. It was found that Sharmas method could not be

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered) used to determine the optimum pod location.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

NOMENCLATURE

C_R	Residuary Resistance Coefficient
C_W	Wavemaking Resistance Coefficient
F_N	Froude Number
L	Ship length
P_E	Effective Power
x	Distance from forward perpendicular to the center of volume for the Pod and strut
η	Pod influence factor (C_W (with a pod)/C_W (without a pod))

ENGLISH/SI EQUIVALENTS

1 degree (angle)	= 0.01745 rad (radians)
1 foot	= 0.3048 m (meters)
1 foot per second	= 0.3048 m/sec (meters per second)
1 inch	= 25.40 mm (millimeters)
1 knot	= 0.5144 m/s (meters per second)
1 lb (force)	= 4.448 N (Newtons)
1 lb (force) - inch	= 0.1130 N·m (Newton-meter)
1 long ton (2240)	= 1.016 metric tons, or 1016 kilograms
1 horsepower	= 0.746 kW (kilowatts)

ABSTRACT

A series of resistance and longitudinal wavecut experiments were performed with Model 5359-5B, representing a DD963 hull at the David Taylor Naval Ship R&D Center (DTNSRDC) to investigate the change in resistance caused by varying the longitudinal position of a single propulsion pod. Sharma's[1] method of bulb optimization was used in an attempt to find the optimum longitudinal pod position. The experimental results indicate that the pod could be located between 80 to 90 percent of the ship length with virtually no change in total resistance. It was found that Sharmas method could not be used to determine the optimum pod location.

ADMINISTRATIVE INFORMATION

This project was authorized and funded by the Naval Material Command (NAVMAT) Ship Performance and Hydromechanics Program under Program Element 62543N, Subproject Number 421-100-200, Work Unit Number 1507-101-22.

INTRODUCTION

There is considerable interest in using propulsion pods external to the hull to power surface ships instead of the conventional system of using propeller shafts and struts with the propulsion machinery internal to the hull. The propulsion pods contain the electric motors to drive the propellers. Since the ship engines are not mechanically connected to the propellers (except through electric power lines), the engine rooms may be placed anywhere in the ship, similarly the location of the propulsion pods on the hull is flexible.

Due to its large size, it is expected that the pod has a considerable effect on the resistance of the hull. Therefore, the purpose of this project is to investigate the effects on resistance due to changing the longitudinal position of a single propulsion pod on a typical surface ship hull, and to determine the optimum pod location.

Because the pod is similar in size and shape to a bow bulb, the pod may have a noticable effect on the wavemaking resistance of the hull. If the wavemaking resistance of the pod is significant, and if the trends of the wavemaking resistance versus pod position agree with the trends of the residuary resistance, it may be possible to determine the optimum pod location by minimizing the wavemaking resistance.

We have a number of design tools that can optimize a hull by minimizing its wavemaking resistance. One method, developed by Sharma,[1] can optimize the

[1] References are listed on page 6.

longitudinal position of a bulbous bow. This method can also be applied to a propulsion pod. Sharma's method has a higher probability of success than the other optimization methods because it makes only one assumption - that the wave spectra of the hull and pod are linearly superimposed. Therefore, Sharmas method is used to determine the optimum longitudinal pod location.

The experimental program consists of a series of resistance and longitudinal wavecut experiments performed on a model representing a DD963 class hull form fitted with a single centerline mounted propulsion pod. The pod is positioned in four different longitudinal locations between 80 and 95 percent (X/L = 0.80 and X/L = 0.95) of the ship length aft of the forward perpendicular.

The results of the resistance and wavecut experiments are presented in this report. The results from using Sharma's method to optimize the longitudinal pod position are also included.

EXPERIMENTS

MODELS

Model 5359-5B represented a DD 963 class variant built to a scale ratio of 24.824. Table 1 shows the principal dimensions of the ship and model, Figure 1 shows the stern lines, and Figures 2 and 3 show photographs of the model with the pod in the four longitudinal positions and without the pod. The hull of Model 5359-5B was raised slightly along the centerline, compared to the DD 963 hull form, to give more clearance for centerline mounted propellers. The displacement of the model without the propulsion pod corresponded to a full scale displacement of 7892 t (7768 tons) and a even keel draft of 5.93 m (19.44 ft). The displacement of the model with the propulsion pod corresponded to a full scale displacement of 7971 t (7845 tons), and an even keel draft of 5.93 m (19.44 ft). The only appendages on the model were the sonar dome and the propulsion pod.

A single centerline mounted propulsion pod model was used in the experiments. Drawings of the propulsion pod are shown in Figure 3. The pod shape was a Series 58 body of revolution. The pod size was determined from data that was supplied by the DTNSRDC Energy Office for a contrarotating propulsion pod containing technologically advanced machinery, with a delivered power of 60 mW (80,000 hp) at 140 rpm. The strut length was sized so that if the pod propellers were at the same longitudinal position as the propellers in a conventional (shafts and struts) arrangement, the propeller centerlines would be at the same depth.

TEST MATRIX

The propulsion pod was placed in four different longitudinal positions. The pod positions were given as ratios of the distance from the forward perpendicular to the center of volume of the pod and strut, to the model length (x/L). The pod positions were x/L = 0.95, 0.90, 0.85, and 0.80. The pod position x/L = 0.90 is referred to as the standard pod position because the pod propeller would have been in the same longitudinal position as a propeller driven through a conventional shafting arrangement.

The resistance and the longitudinal wavecut experiments were performed on the model with the pod in each of the four different longitudinal positions and with the pod removed over a speed range of 5.2 m/s (10 knots) to 17 m/s (33 knots). The longitudinal wavecuts were taken both during and after the resistance experiments.

EXPERIMENTAL PROCEDURE

The resistance values were measured using a block gauge. The resistance values were extrapolated to the ship scale using the ITTC correlation line with a correlation allowance of 0.0005. It should be noted that the wetted surface for the model with the pod includes the wetted surface of the pod and strut. The draft of the model was held constant for both the model with and without the pod. Therefore, the model without a pod has a lower displacement than the model with a pod.

The longitudinal wavecut data measurements were taken with a wire waveprobe. The wavemaking resistance was calculated from the wave spectra which was derived from the wavecut data using the Newman-Sharma method. Since it is impossible to take an infinitely long longitudinal wavecut record in a model basin without getting interference from the waves reflected by the basin sides, the wavecut data records were truncated in length, and a truncation correction applied to compensate for the non-infinite record length. A more detailed description of this procedure is given in Reed[2].

DISCUSSION OF RESULTS

RESISTANCE EXPERIMENTS

The effective power (P_E) values associated with the various model and pod configurations are shown in Figure 4 and Tables 2 to 6. The pod configurations include x/L = 0.95, 0.90, 0.85, and 0.80; and the model without a pod. Figure 5 shows the curves of the P_E values for the ship with the various pod positions divided by the P_E values for the ship with pod at the standard pod position of x/L = 0.90. The standard pod position was chosen to normalize the P_E values since the pod propellers would be in the same longitudinal position as the propellers in a conventional propeller shafts and struts configuration arrangement. There is virtually no difference between the P_E values for the three forward pod positions (x/L = 0.90, 0.85, and 0.80). The P_E values for the aftmost pod configuration (x/L = 0.95) are slightly higher than the P_E values for the other pod positions. The differences between the P_E values for the ship with the three most forward pod positions are within 1½ percent of each other. It should be noted that, for resistance experiments, the experimental accuracy is considered to be $\pm 1\frac{1}{2}$ percent. Therefore, the P_E values for the ship with the three most forward pod positions are considered to have nominally the same values.

The P_E values for the ship with the aftmost pod position are as much as 2.7 percent higher than the P_E values for the ship with the pod at the standard position. It should be noted that, when the pod is in the aftmost position, part of the pod extends aft of the transom. The pod may be effecting the flow off the transom; this could explain its higher P_E values compared to the P_E values for the ship with the other pod positions.

Figure 6 shows the curves of the residuary resistance values, C_R, associated with the various pod positions. The C_R curves of the model with the pod in various positions have shapes similar to that of the C_R curve of the model without the pod. Figure 7 shows the curves of the C_R values of the model with a pod normalized by the C_R values of the model with the pod at the standard position (x/L = 0.90). Since the wetted surface is constant regardless of the pod position, the trends of these curves are similar to the trends of the P_E (with pod)/P_E (standard pod position) curves shown in Figure 5.

WAVEMAKING RESISTANCE COMPUTATIONS

The curves of the wavemaking resistance coefficient values, C_W, associated with the various ship and pod configurations are shown in Figure 8. The C_W values are calculated[2] from the wave spectra which are derived from the longitudinal wave-cut data. Figure 9 shows the curves of the C_W values for the ship with a pod normalized by the C_W values for the ship with the pod at the standard position.

A comparison of the curves of the C_R and the C_W values shows that there is no correlation between the minimum wavemaking resistance and the minimum residuary resistance. For example, above $F_N = 0.32$, the model with the pod in the aftmost position has the lowest C_W values of all of the model and pod combinations; however, above $F_N = 0.22$, it has the highest C_R values of all of the model and pod combinations. Between $F_N = 0.24$ and $F_N = 0.32$, the model with the pod in the standard position has the highest C_W values; yet over the same speed range it has either the lowest or next to the lowest C_R values of the four pod positions. These examples indicate that the values of the components of the residuary resistance other than the wavemaking resistance, such as the form drag and local wave drag, show large enough changes to offset the trends in the wavemaking resistance values. This implies that if the pod location is optimized by minimizing the wavemaking resistance, the total resistance for the ship with the pod in the optimized position may be higher than the total resistance for the ship with the pod in the original position. Therefore, an attempt to optimize the pod location by minimizing the wavemaking resistance will be unsuccessful.

The above indicates that an optimization technique based on minimizing the wavemaking resistance, such as Sharmas method, would not be successful in minimizing the total resistance. However, the results of the analysis using Sharmas method are presented below to help show the effects of pod position on the wavemaking resistance of the ship.

Since Sharmas' method requires only one wavecut of the model with the pod to find the optimum pod location for a given speed, the results of Sharmas method using a wavecut of the model with the pod in one position can be compared to the results of Sharmas' method using a wavecut of the model with the pod in a different position. Figure 10 shows the curves of the pod influence factor versus the pod longitudinal location for three different speeds: 10.3 m/s (20 knots), 13.4 m/s (26 knots), and 16.5 m/s (32 knots). These three speeds correspond to Froude numbers of 0.26, 0.34, and 0.41. The pod influence factor, η, is the ratio of the predicted wavemaking resistance of the model with the pod in a given position to the wavemaking resistance of the model without a pod.

Ideally, the results of Sharma's method should be the same whether the original pod location is at $x/L = 0.95$ or at $x/L = 0.80$. A comparison of the η curves shown in Figure 10 indicates that the results of the Sharma method of analysis are highly dependent upon the original pod position. For example, at $F_n = 0.26$, the results of the analysis using the wavecut data with the pod in the aftmost position show that the optimum pod location is at x/L = 0.92; however, the results of the analysis using the wavecut data with the pod in the standard position indicate that x/L = 0.92 is one of the worst locations for the pod. This indicates that Sharma's method of bulb optimization cannot determine the optimum longitudinal pod position, for the configuration explored here. One possible explanation for the lack of success of Sharma's method is that the linear superposition assumption may not hold here. This may be a result of the stern shielding the pod from the free surface.

CONCLUSIONS

1. There is virtually no difference between the P_E values for the ship with the propulsion pod in the three forward most positions (x/L=0.90, 0.85, and 0.80). The P_E values for the ship with the propulsion pod in the aftmost position were higher than the P_E values for the ship with the other pod positions above 8.2 m/s (16 knots):
2. Above 12.3 m/s (24 knots), the ship and pod configuration with the lowest wavemaking resistance had the highest total resistance indicating that the pod longitudinal position cannot be optimized by minimizing the wavemaking resistance alone.
3. Sharmas' method of bulb optimization does not predict correctly the optimum pod longitudinal position for minimizing the wavemaking resistance.

REFERENCES

1. Sharma, S.D., "An Attempted Application of Wave Analysis Technique to Achieve Bow-Wave Reduction", Sixth ONR Symposium on Naval Hydrodynamics. pp. 731-733 (1966).
2. Reed, A.M., "Documentation for a Series of Computer Programs for Analyzing Longitudinal Wave Cuts and Designing Bow Bulbs", DTNSRDC/SPD-0820-01, June 1979.

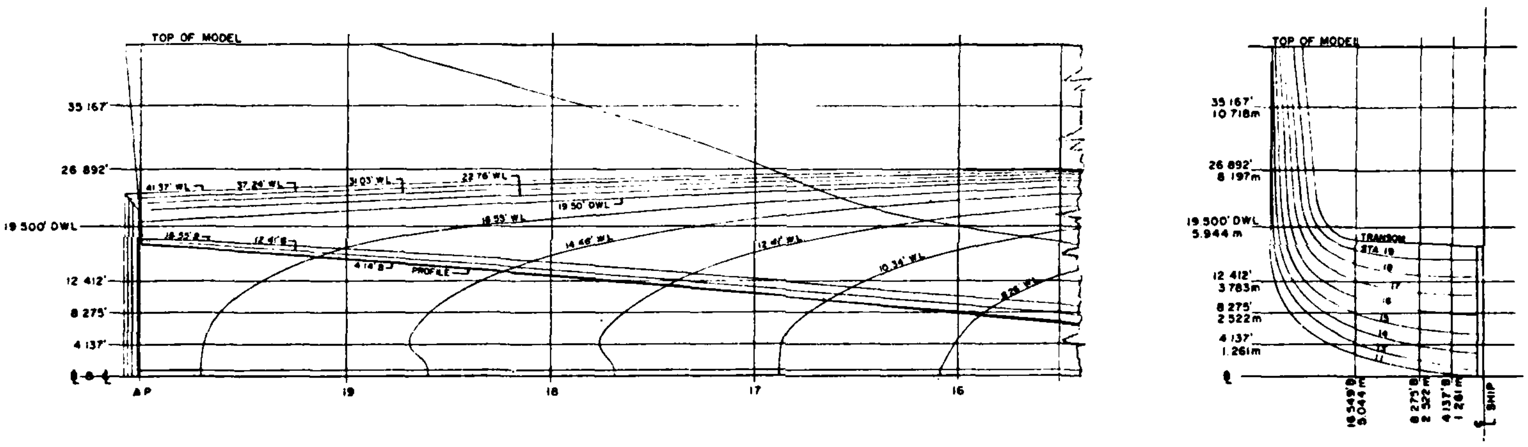
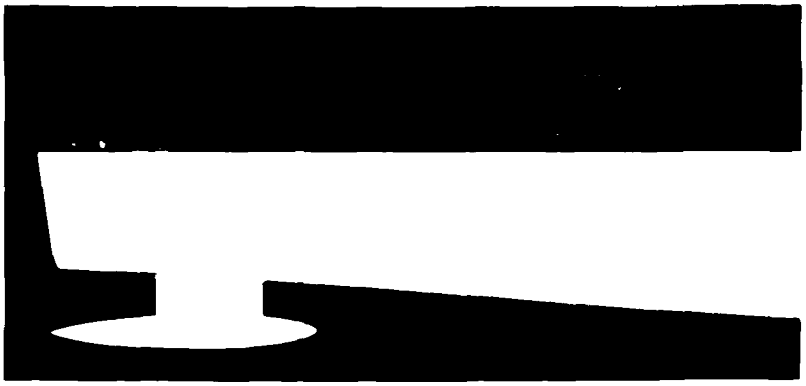
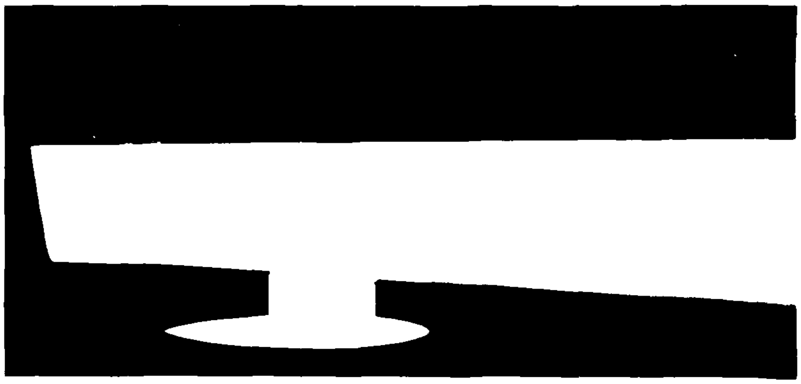


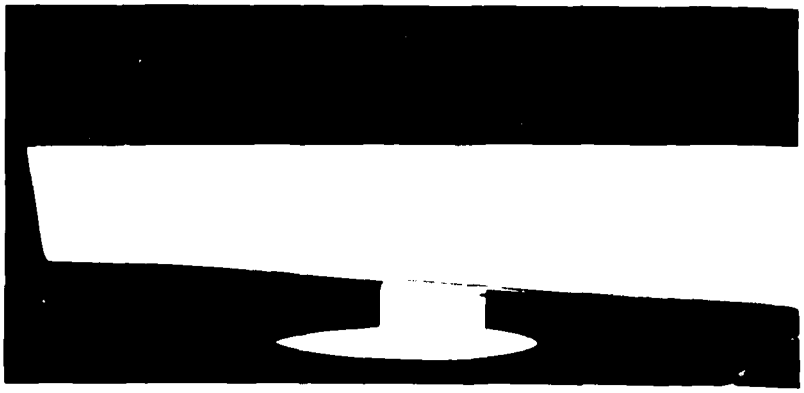
Figure 1 - Stern Lines of Model 5359-5B



x/L = 0.95

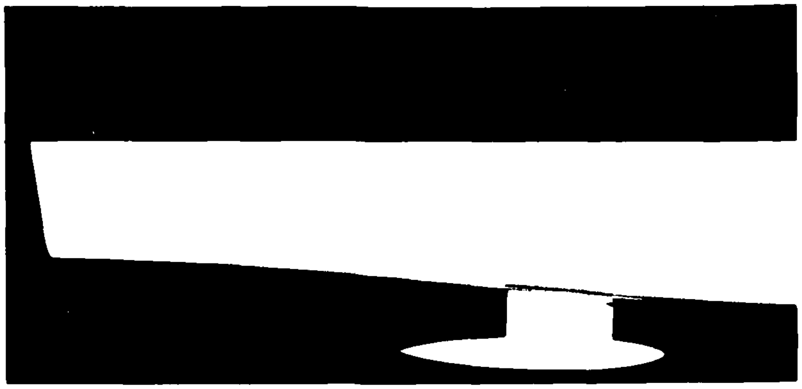


x/L = 0.90 (Standard Position)

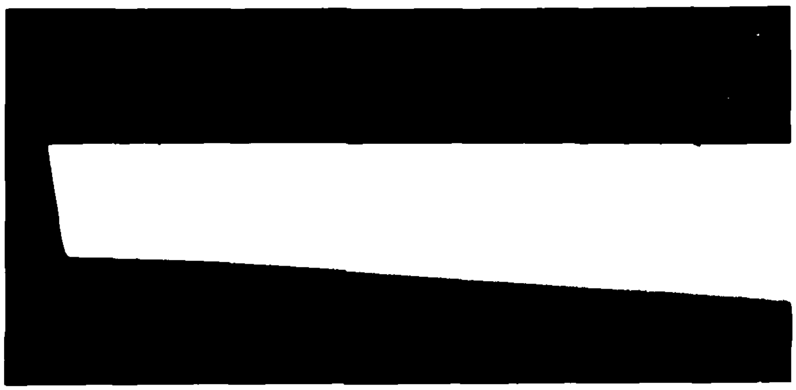


x/L = 0.85

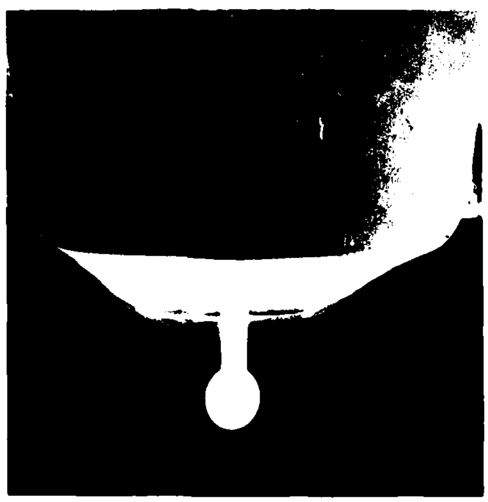
Figure 2 — Photographs of Model 5359-5B With the Various Propulsion Pod Configurations



x/L = 0.80

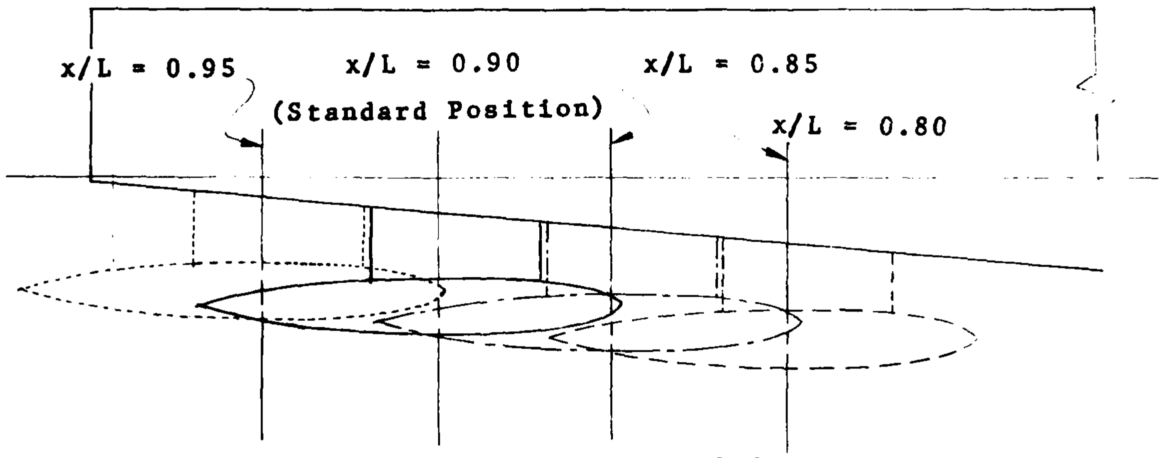


No Pod

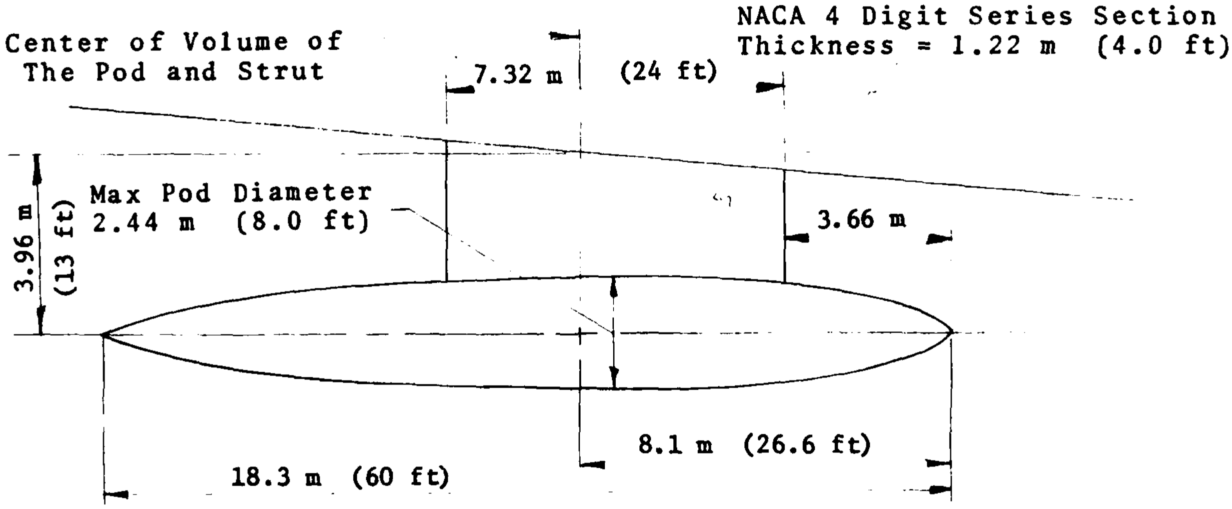


Stern View With x/L = 0.90

Figure 2 — Photographs of Model 5359-5B With the Various Propulsion Pod Configurations (continued)



POD LONGITUDINAL LOCATIONS



DIMENSIONS OF THE POD AND STRUT

ALL DIMENSIONS ARE AT THE SHIP SCALE

Figure 3 - Pod and Strut Locations and Dimensions

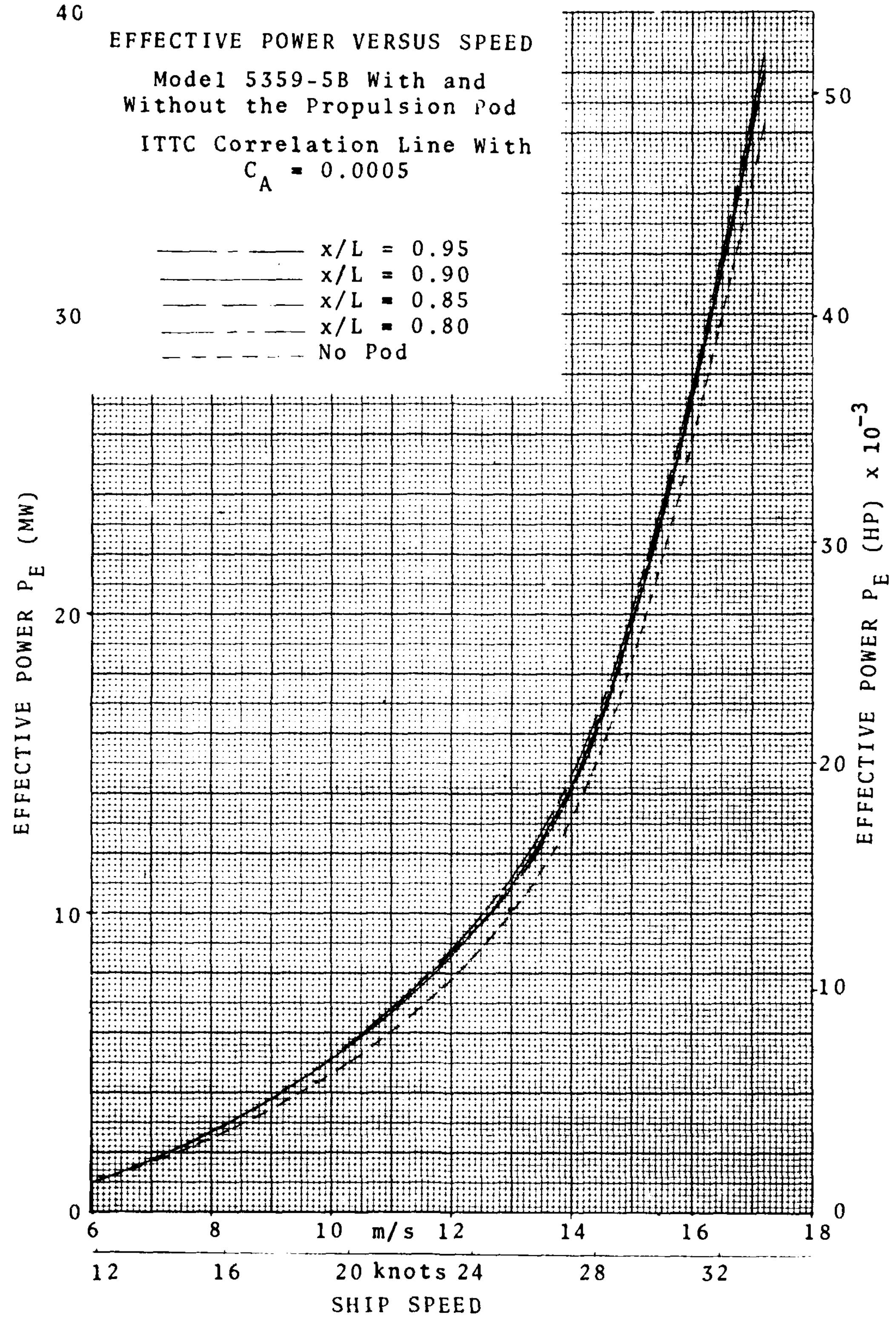


Figure 4 - Effective Power Curves for Model 5359-5B With and Without the Propulsion Pod

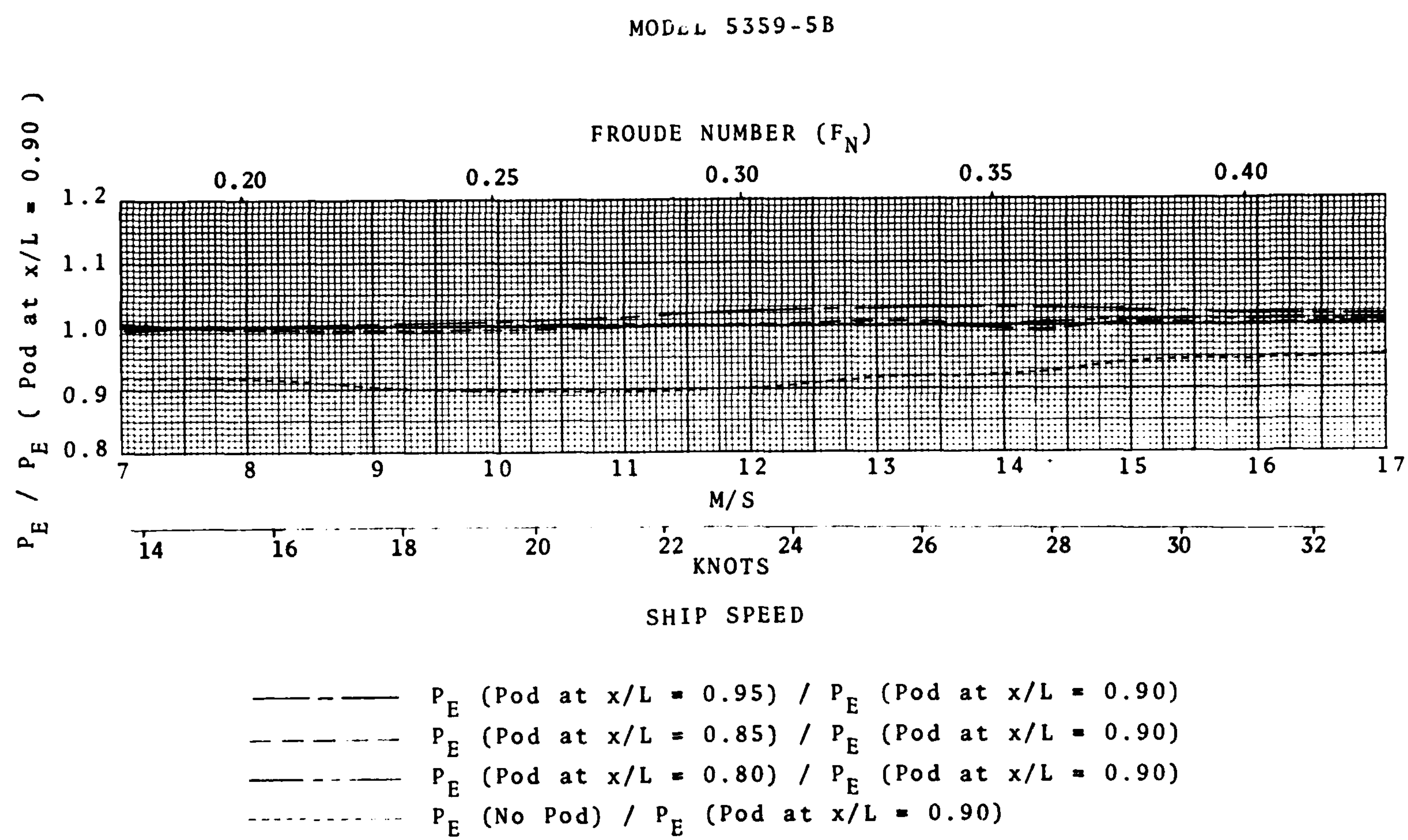


Figure 5 - Curves of Effective Power With a Pod Normalized by the Effective Power With the Pod at the Standard Position (x/L = 0.90) for Model 5359-5B

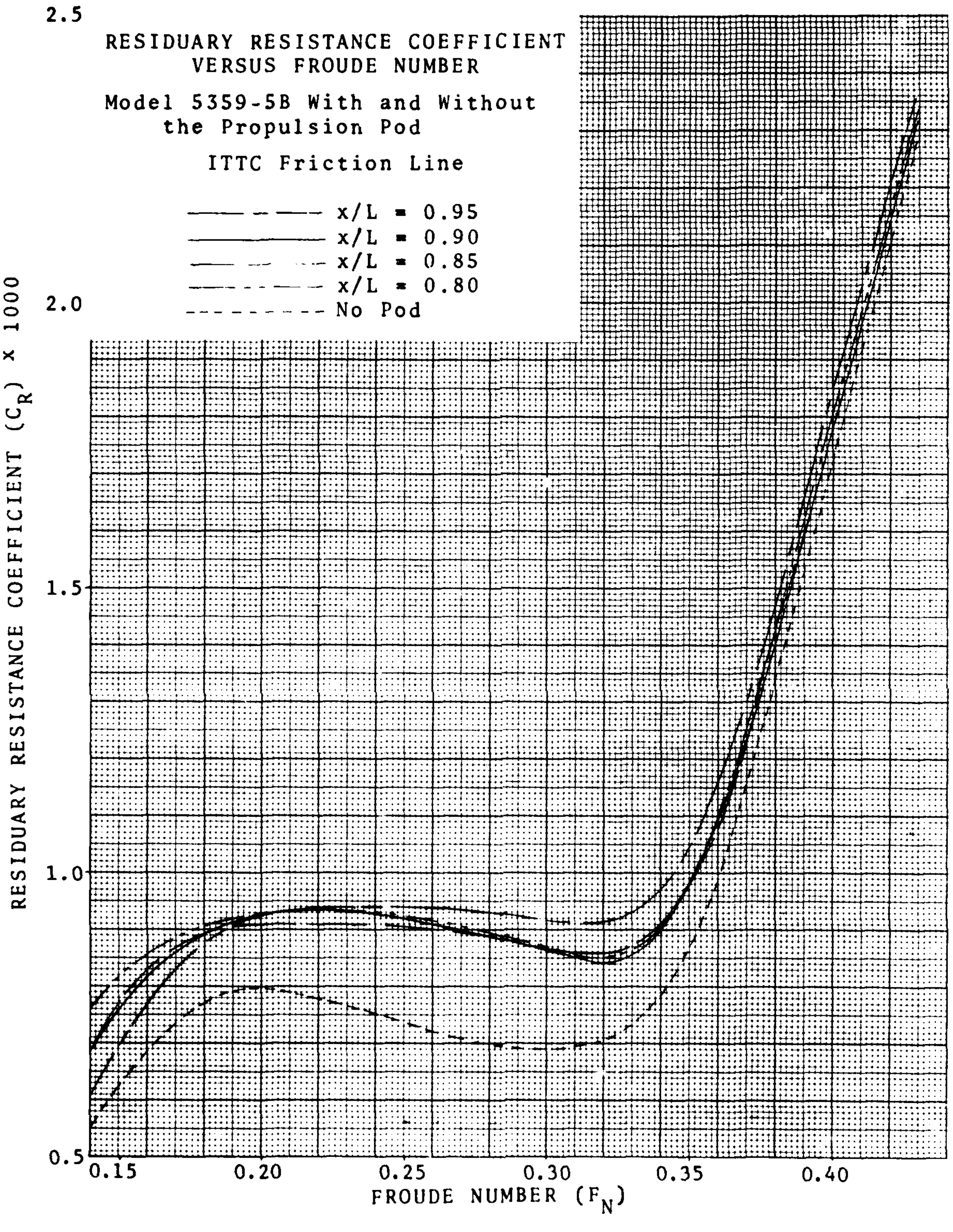


Figure 6 - Residuary Resistance Coefficient Curves for Model 5359-5B With and Without the Propulsion Pod

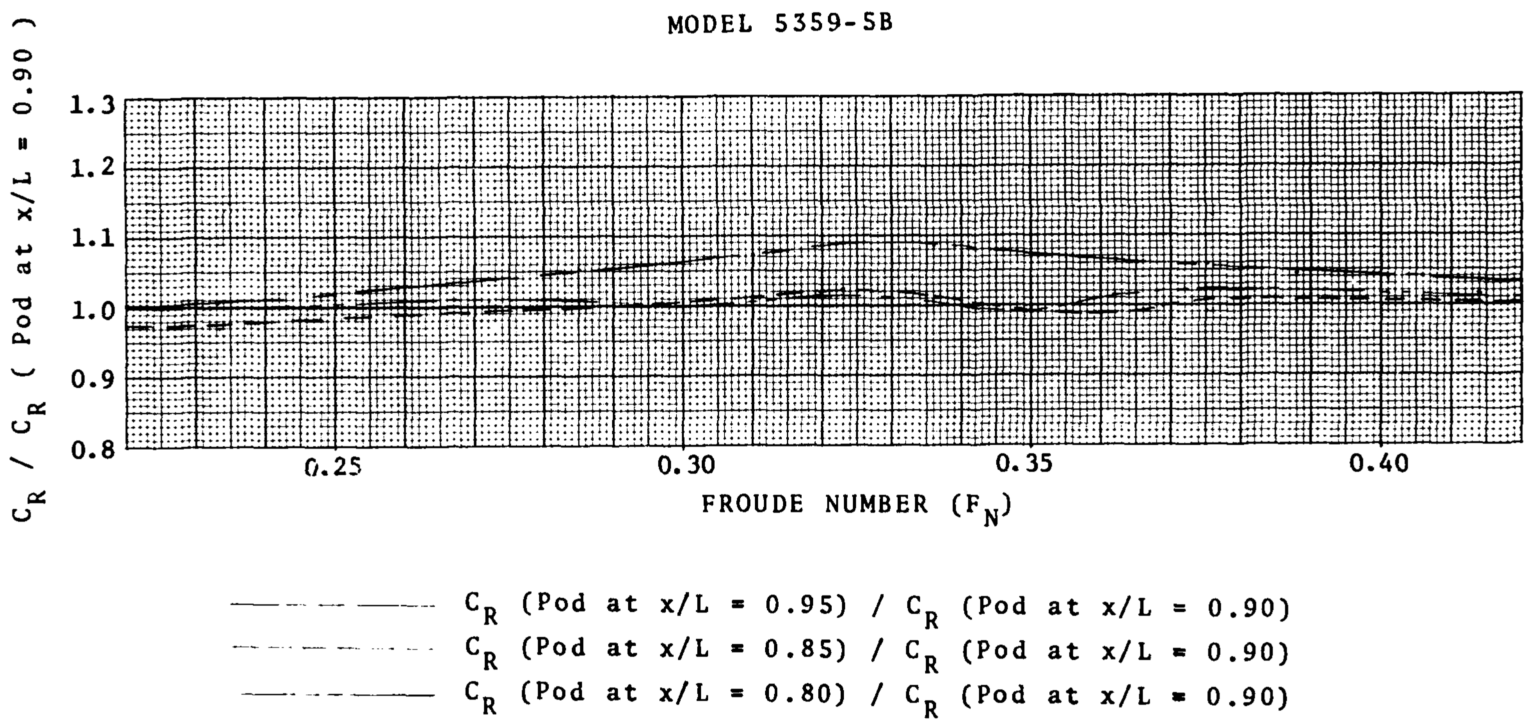


Figure 7 - Curves of Residuary Resistance With a Pod Normalized by the Residuary Resistance With the Pod at the Standard Position (x/L = 0.90) for Model 5359-5B

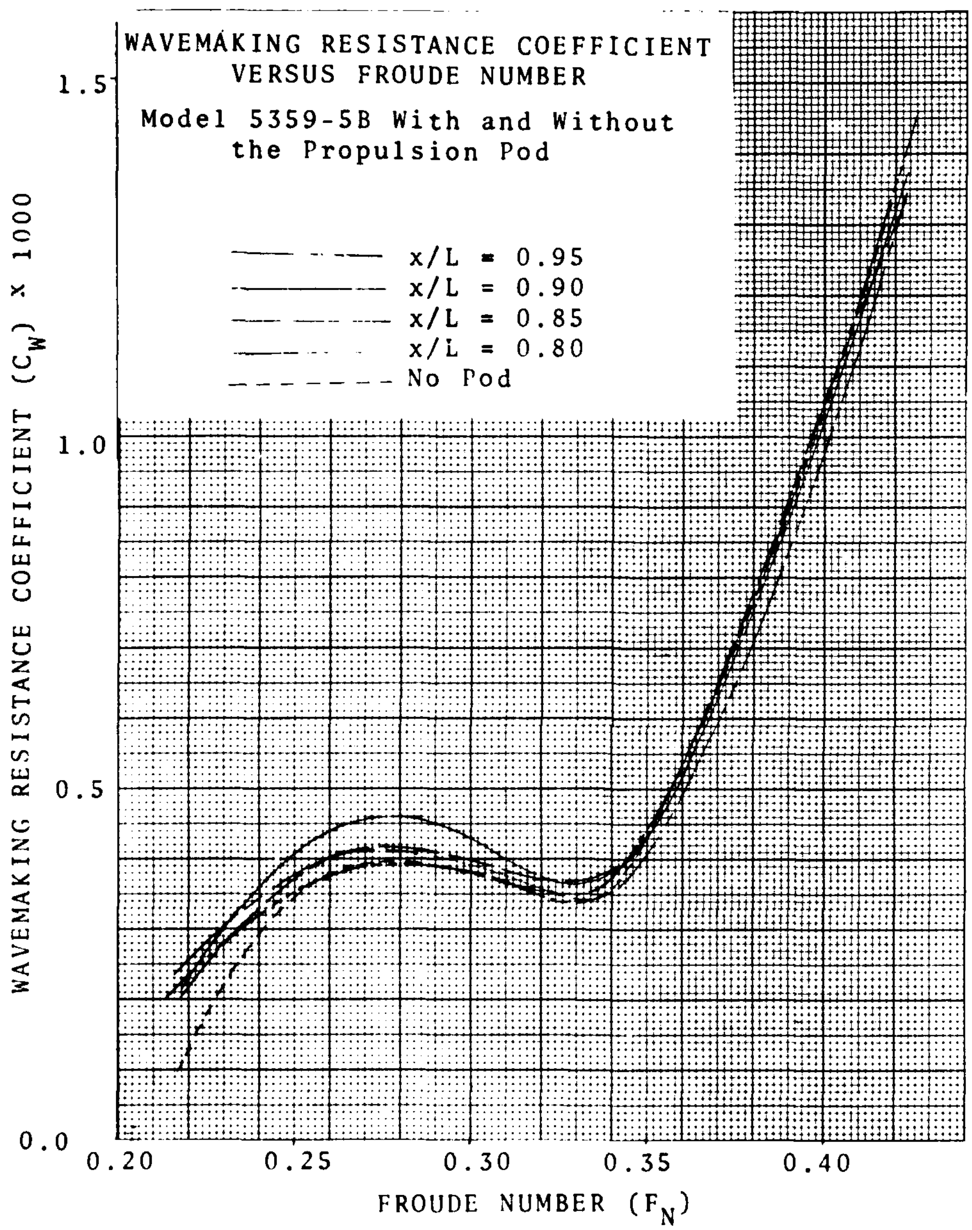


Figure 8 - Wavemaking Resistance Coefficient Curves for Model 5359-5B
With and Without the Propulsion Pod

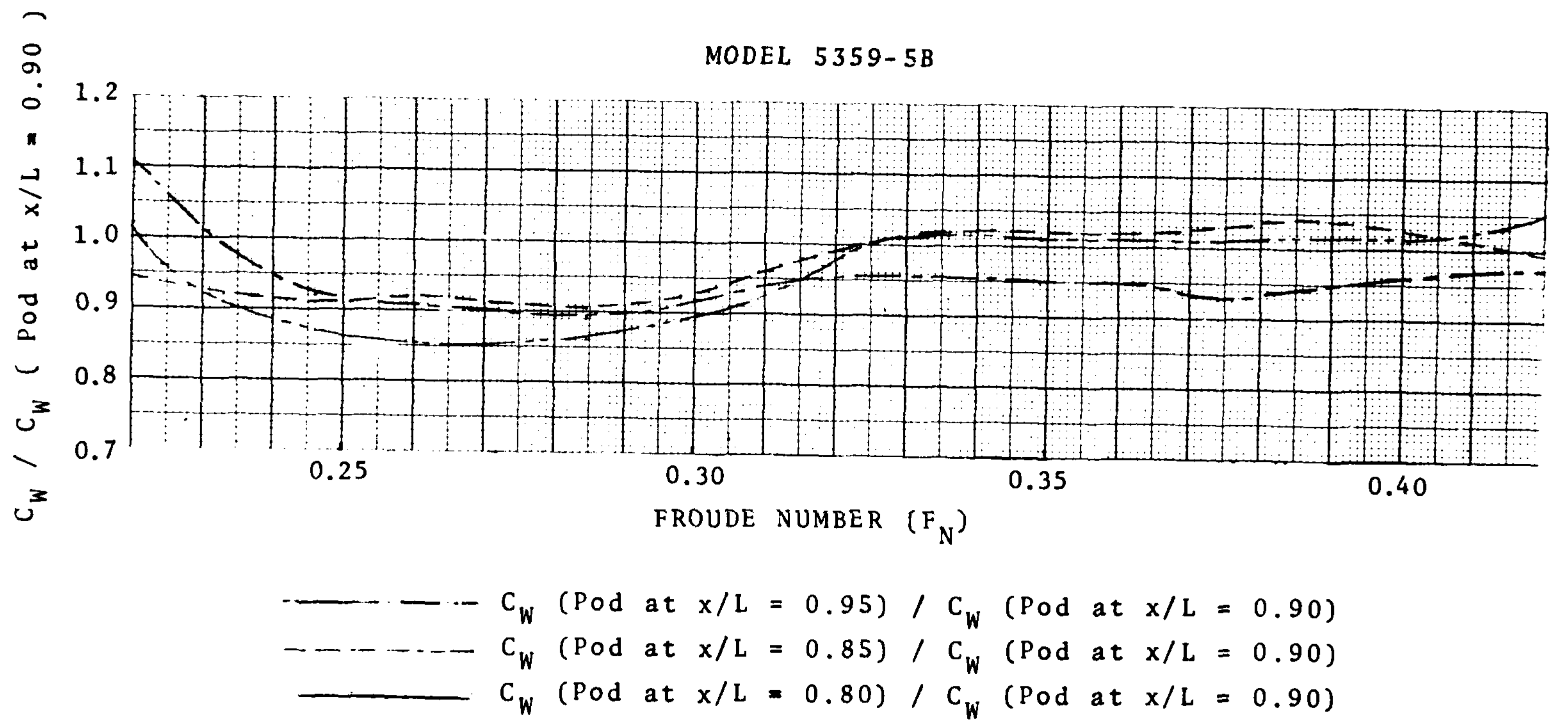
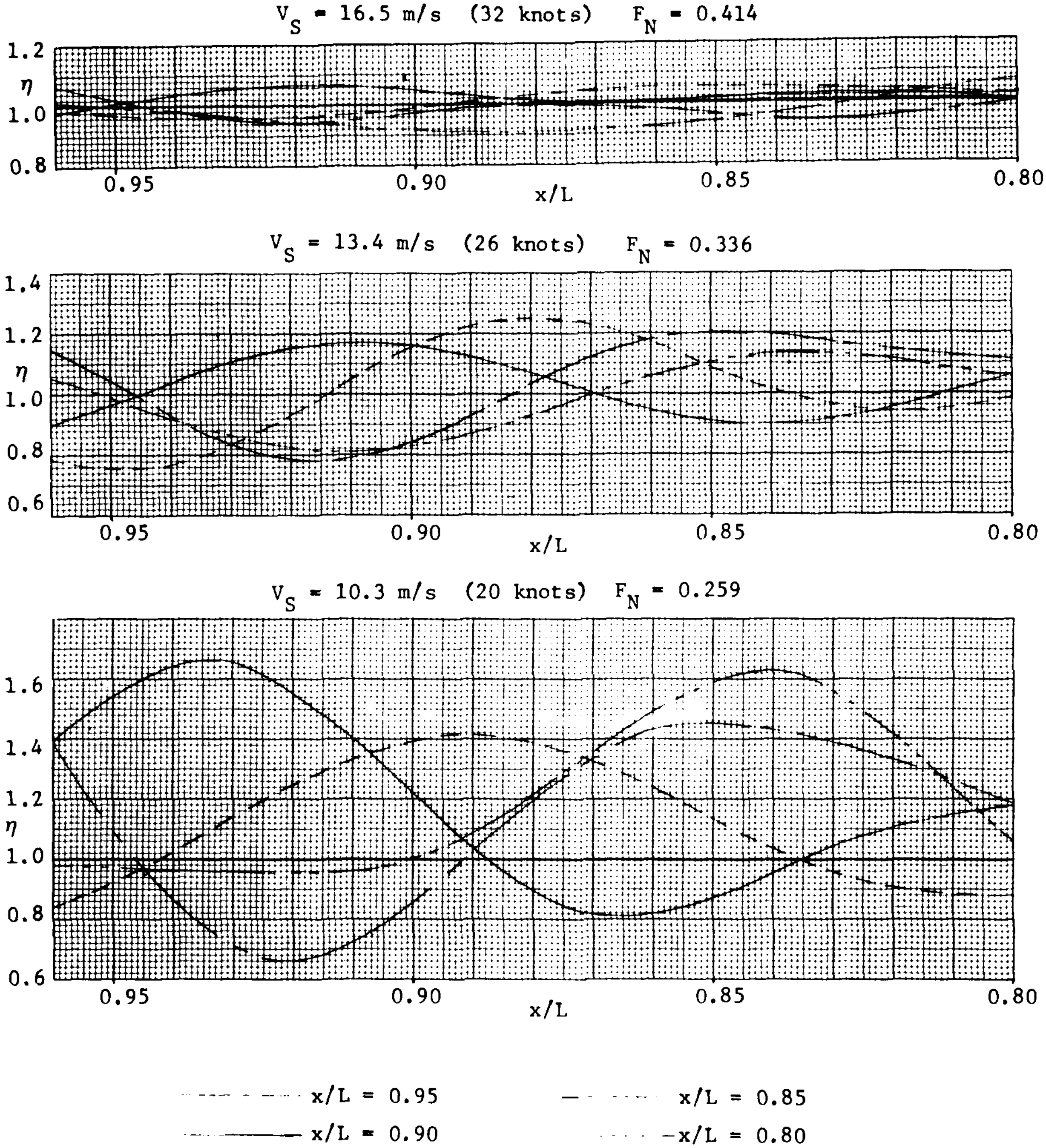


Figure 9 - Curves of Wavemaking Resistance With a Pod Normalized by the Wavemaking Resistance With the Pod at the Standard Position (x/L = 0.90) for Model 5359-5B



η = Predicted C_W With a Pod / C_W Without a Pod

Figure 10 - Pod Influence Factor Versus Pod Longitudinal Location

TABLE 1

Principal Dimensions of Ship and Model

	SHIP		MODEL	
Length	161.1 m	530 ft	6.510 m	21.36 ft
Draft	5.925 m	19.44 ft	0.239 m	0.783 ft
Displacement (no pod)	7892 t	7768 tons	502 kg	1107 lbs
Displacement (with pod)	7971 t	7845 tons	505 kg	1113 lbs
Wetted Surface (no pod)	3340 m^2	35951 ft^2	5.42 m^2	58.34 ft^2
Wetted Surface (with pod)	3480 m^2	37461 ft^2	5.65 m^2	60.79 ft^2

Scale ratio = 24.824

TABLE 2

EFFECTIVE POWER VALUES FOR MODEL 5359-5B WITH THE PROPULSION

POD AT x/L = 0.95

	SHIP	MODEL
LENGTH	530.19 FT (161.6 M)	21.36 FT (6.510 M)
WETTED SURFACE	37461.SQ FT (3480. SQ M)	60.79 SQ FT (5.65 SQ M)
DISPLACEMENT	7845.TONS (7971. T)	.50 TONS (.51 T)

LINEAR RATIO	24.824
ITTC FRICTION LINE	
CORRELATION ALLOWANCE (CA)	.00050

VS		PE		FRICTIONAL POWER		FN	V-L	1000CR
KNOTS	M/S	HP	KW	HP	KW			
10.00	5.14	847.5	631.9	684.8	510.7	.129	.434	.499
11.00	5.66	1175.2	876.3	903.2	673.5	.142	.478	.627
12.00	6.17	1576.8	1175.8	1162.9	867.1	.155	.521	.735
13.00	6.69	2053.7	1531.5	1467.3	1094.2	.168	.565	.819
14.00	7.20	2607.8	1944.6	1819.9	1357.1	.181	.608	.881
15.00	7.72	3232.7	2410.6	2224.0	1658.4	.194	.651	.917
16.00	8.23	3925.8	2927.5	2683.0	2000.7	.207	.695	.931
17.00	8.75	4698.9	3504.0	3200.2	2386.4	.220	.738	.936
18.00	9.26	5561.8	4147.5	3778.9	2817.9	.233	.782	.938
19.00	9.77	6523.8	4864.8	4422.5	3297.8	.246	.825	.940
20.00	10.29	7577.2	5650.3	5134.2	3828.5	.258	.869	.937
21.00	10.80	8733.3	6512.5	5917.3	4412.5	.271	.912	.933
22.00	11.32	9992.0	7451.1	6775.0	5052.1	.284	.955	.927
23.00	11.83	11347.0	8461.5	7710.7	5749.9	.297	.999	.917
24.00	12.35	12836.5	9572.2	8727.5	6508.1	.310	1.042	.912
25.00	12.86	14498.6	10811.6	9828.8	7329.3	.323	1.086	.917
26.00	13.38	16476.7	12286.7	11017.6	8215.8	.336	1.129	.953
27.00	13.89	18917.6	14106.9	12297.3	9170.1	.349	1.173	1.032
28.00	14.40	22163.5	16527.3	13671.1	10194.5	.362	1.216	1.187
29.00	14.92	26198.8	19536.4	15142.0	11291.4	.375	1.259	1.391
30.00	15.43	31021.8	23133.0	16713.4	12463.2	.388	1.303	1.626
31.00	15.95	36506.1	27222.6	18388.4	13712.2	.401	1.346	1.866
32.00	16.46	42565.3	31741.0	20170.1	15040.8	.414	1.390	2.097
33.00	16.98	49211.3	36696.9	22061.7	16451.4	.426	1.433	2.318

TABLE 3

EFFECTIVE POWER VALUES FOR MODEL 5359-5B WITH THE PROPULSION

POD AT x/L = 0.90

	SHIP	MODEL
LENGTH	530.19 FT (161.6 M)	21.36 FT (6.510 M)
WETTED SURFACE	37461.SQ FT (3480. SQ M)	60.79 SQ FT (5.65 SQ M)
DISPLACEMENT	7845.TONS (7971. T)	.50 TONS (.51 T)

LINEAR RATIO	24.824
ITTC FRICTION LINE	
CORRELATION ALLOWANCE (CA)	.00050

VS		PE		FRICTIONAL POWER		FN	V-L	1000CR
KNOTS	M/S	HP	KW	HP	KW			
10.00	5.14	873.8	651.6	684.8	510.7	.129	.434	.580
11.00	5.66	1206.8	899.9	903.2	673.5	.142	.478	.700
12.00	6.17	1606.6	1198.1	1162.9	867.1	.155	.521	.788
13.00	6.69	2077.4	1549.1	1467.3	1094.2	.168	.565	.852
14.00	7.20	2619.4	1953.3	1819.9	1357.1	.181	.608	.894
15.00	7.72	3233.8	2411.4	2224.0	1658.4	.194	.651	.918
16.00	8.23	3925.8	2927.5	2683.0	2000.7	.207	.695	.931
17.00	8.75	4694.1	3500.4	3200.2	2386.4	.220	.738	.933
18.00	9.26	5548.5	4137.5	3778.9	2817.9	.233	.782	.931
19.00	9.77	6485.8	4836.5	4422.5	3297.8	246	.825	.923
20.00	10.29	7512.1	5601.7	5134.2	3828.5	.258	.869	.912
21.00	10.80	8624.7	6431.4	5917.3	4412.5	.271	.912	.897
22.00	11.32	9835.9	7334.6	6775.0	5052.1	.284	.955	.882
23.00	11.83	11144.8	8310.6	7710.7	5749.9	.297	.999	.866
24.00	12.35	12561.7	9367.3	8727.5	6508.1	.310	1.042	.851
25.00	12.86	14116.6	10526.8	9828.8	7329.3	.323	1.086	.842
26.00	13.38	16047.1	11966.3	11017.6	8215.8	.336	1.129	.878
27.00	13.89	18558.4	13839.0	12297.3	9170.1	.349	1.173	.976
28.00	14.40	21669.8	16159.2	13671.1	10194.5	.362	1.216	1.118
29.00	14.92	25586.7	19080.0	15142.0	11291.4	.375	1.259	1.314
30.00	15.43	30388.2	22660.5	16713.4	12463.2	.388	1.303	1.554
31.00	15.95	35826.5	26715.8	18388.4	13712.2	.401	1.346	1.796
32.00	16.46	41817.8	31183.5	20170.1	15040.8	.414	1.390	2.027
33.00	16.98	48450.0	36129.2	22061.7	16451.4	.426	1.433	2.253

TABLE 4

EFFECTIVE POWER VALUES FOR MODEL 5359-5B WITH THE PROPULSION POD AT x/L = 0.85

	SHIP	MODEL
LENGTH	530.19 FT (161.6 M)	21.36 FT (6.510 M)
WETTED SURFACE	37461.SQ FT (3480. SQ M)	60.79 SQ FT (5.65 SQ M)
DISPLACEMENT	7845.TONS (7971. T)	.50 TONS (.51 T)

LINEAR RATIO	24.824
ITTC FRICTION LINE	
CORRELATION ALLOWANCE (CA)	.00050

VS		PE		FRICTIONAL POWER		FN	V-L	1000CR
KNOTS	M/S	HP	KW	HP	KW			
10.00	5.14	871.2	649.7	684.8	510.7	.129	.434	.572
11.00	5.66	1207.7	900.6	903.2	673.5	.142	.478	.702
12.00	6.17	1611.7	1201.9	1162.9	867.1	.155	.521	.797
13.00	6.69	2084.5	1554.4	1467.3	1094.2	.168	.565	.862
14.00	7.20	2621.2	1954.6	1819.9	1357.1	.181	.608	.896
15.00	7.72	3223.9	2404.0	2224.0	1658.4	.194	.651	.909
16.00	8.23	3899.1	2907.6	2683.0	2000.7	.207	.695	.911
17.00	8.75	4657.3	3473.0	3200.2	2386.4	.220	.738	.910
18.00	9.26	5504.8	4104.9	3778.9	2817.9	.233	.782	.908
19.00	9.77	6447.8	4808.1	4422.5	3297.8	.246	.825	.906
20.00	10.29	7483.4	5580.4	5134.2	3828.5	.258	.869	.901
21.00	10.80	8609.6	6420.2	5917.3	4412.5	.271	.912	.892
22.00	11.32	9835.9	7334.6	6775.0	5052.1	.284	.955	.882
23.00	11.83	11156.7	8319.5	7710.7	5749.9	.297	.999	.869
24.00	12.35	12602.3	9397.5	8727.5	6508.1	.310	1.042	.860
25.00	12.86	14213.4	10598.9	9828.8	7329.3	.323	1.086	.861
26.00	13.38	16121.6	12021.9	11017.6	8215.8	.336	1.129	.891
27.00	13.89	18507.1	13800.7	12297.3	9170.1	.349	1.173	.968
28.00	14.40	21584.0	16095.2	13671.1	10194.5	.362	1.216	1.106
29.00	14.92	25674.2	19145.2	15142.0	11291.4	.375	1.259	1.325
30.00	15.43	30476.2	22726.1	16713.4	12463.2	.388	1.303	1.564
31.00	15.95	35913.8	26780.9	18388.4	13712.2	.401	1.346	1.805
32.00	16.46	41892.5	31239.3	20170.1	15040.8	.414	1.390	2.034
33.00	16.98	48485.1	36155.4	22061.7	16451.4	.426	1.433	2.256

TABLE 5

EFFECTIVE POWER VALUES FOR MODEL 5359-5B WITH THE PROPULSION POD AT x/L = 0.80

	SHIP	MODEL
LENGTH	530.19 FT (161.6 M)	21.36 FT (6.510 M)
WETTED SURFACE	37461.SQ FT (3480. SQ M)	60.79 SQ FT (5.65 SQ M)
DISPLACEMENT	7845.TONS (7971. T)	.50 TONS (.51 T)

LINEAR RATIO	24.824
ITTC FRICTION LINE	
CORRELATION ALLOWANCE (CA)	.00050

VS		PE		FRICTIONAL POWER		FN	V-L	1000CR
KNOTS	M/S	HP	KW	HP	KW			
10.00	5.14	898.3	669.9	684.8	510.7	.129	.434	.655
11.00	5.66	1237.6	922.9	903.2	673.5	.142	.478	.771
12.00	6.17	1635.9	1219.9	1162.9	867.1	.155	.521	.840
13.00	6.69	2097.4	1564.0	1467.3	1094.2	.168	.565	.880
14.00	7.20	2629.3	1960.6	1819.9	1357.1	.181	.608	.905
15.00	7.72	3236.0	2413.1	2224.0	1658.4	.194	.651	.920
16.00	8.23	3921.8	2924.5	2683.0	2000.7	.207	.695	.928
17.00	8.75	4692.5	3499.2	3200.2	2386.4	.220	.738	.932
18.00	9.26	5548.5	4137.5	3778.9	2817.9	.233	.782	.931
19.00	9.77	6488.1	4838.1	4422.5	3297.8	.246	.825	.924
20.00	10.29	7527.7	5613.4	5134.2	3828.5	.258	.869	.918
21.00	10.80	8645.8	6447.2	5917.3	4412.5	.271	.912	.904
22.00	11.32	9856.7	7350.1	6775.0	5052.1	.284	.955	.888
23.00	11.83	11152.7	8316.6	7710.7	5749.9	.297	.999	.868
24.00	12.35	12575.2	9377.3	8727.5	6508.1	.310	1.042	.854
25.00	12.86	14182.8	10576.1	9828.8	7329.3	.323	1.086	.855
26.00	13.38	16075.7	11987.7	11017.6	8215.8	.336	1.129	.883
27.00	13.89	18507.1	13800.7	12297.3	9170.1	.349	1.173	.968
28.00	14.40	21777.2	16239.2	13671.1	10194.5	.362	1.216	1.133
29.00	14.92	25825.2	19257.9	15142.0	11291.4	.375	1.259	1.344
30.00	15.43	30661.0	22863.9	16713.4	12463.2	.388	1.303	1.585
31.00	15.95	36088.6	26911.3	18388.4	13712.2	.401	1.346	1.823
32.00	16.46	42116.8	31406.5	20170.1	15040.8	.414	1.390	2.055
33.00	16.98	48672.5	36295.1	22061.7	16451.4	.426	1.433	2.272

TABLE 6

EFFECTIVE POWER VALUES FOR MODEL 5359-5B WITHOUT A PROPULSION POD

	SHIP	MODEL
LENGTH	530.19 FT (161.6 M)	21.36 FT (6.510 M)
WETTED SURFACE	35951.SQ FT (3340. SQ M)	58.34 SQ FT (5.42 SQ M)
DISPLACEMENT	7768.TONS (7892. T)	.49 TONS (.50 T)

LINEAR RATIO	24.824
ITTC FRICTION LINE	
CORRELATION ALLOWANCE (CA)	.00050

VS		PE		FRICTIONAL POWER		FN	V-L	1000CR
KNOTS	M/S	HP	KW	HP	KW			
10.00	5.14	801.1	597.4	657.2	490.1	.129	.434	.460
11.00	5.66	1103.2	822.7	866.8	646.3	.142	.478	.568
12.00	6.17	1471.1	1097.0	1116.0	832.2	.155	.521	.65[illegible]
13.00	6.69	1906.4	1421.6	1408.2	1050.1	.168	.565	.72[illegible]
14.00	7.20	2409.1	1796.5	1746.5	1302.4	.181	.608	.772
15.00	7.72	2973.6	2217.4	2134.4	1591.6	.194	.651	.7[illegible]5
16.00	8.23	3589.5	2676.7	2574.9	1920.1	.207	.695	.792
17.00	8.75	4266.8	3181.7	3071.2	2290.2	.220	.738	.778
18.00	9.26	5013.0	3738.2	3626.6	2704.4	.233	.782	.760
19.00	9.77	5834.0	4350.4	4244.2	3164.9	.246	.825	.741
20.00	10.29	6736.4	5023.3	4927.2	3674.2	.258	.869	.723
21.00	10.80	7729.6	5764.0	5678.8	4234.7	.271	.912	.708
22.00	11.32	8823.3	6579.5	6502.0	4848.5	.284	.955	.697
23.00	11.83	10025.8	7476.2	7399.9	5518.1	.297	.993	.690
24.00	12.35	11376.6	8483.5	8375.8	6245.8	.310	1.042	.694
25.00	12.86	12917.2	9632.4	9432.6	7033.9	.323	1.086	.713
26.00	13.38	14757.2	11004.4	10573.6	7884.7	.336	1.129	.761
27.00	13.89	17084.0	12739.5	11801.7	8800.5	.349	1.173	.858
28.00	14.40	20116.7	15001.0	13120.1	9783.6	.362	1.216	1.019
29.00	14.92	24052.0	17935.6	14531.7	10836.3	.375	1.259	1.248
30.00	15.43	28690.6	21394.6	16039.8	11960.9	.388	1.303	1.498
31.00	15.95	33907.3	25284.7	17647.3	13159.6	.401	1.346	1.745
32.00	16.46	39681.4	29590.4	19357.2	14434.6	.414	1.390	1.983
33.00	16.98	46126.4	34396.5	21172.6	15788.4	.426	1.433	2.220

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