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Report C-1652

DEPARTMENT OF THE NAVY

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HYDROMECHANICS

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ACOUSTICS AND VIBRATION

POWERING CHARACTERISTICS FOR A 154-FOOT HIGH SPEED PGM FROM TESTS OF MODELS 4932, 4942, AND 4950 (U)

by

David R. Hoekzema

HYDROMECHANICS LABORATORY

RESEARCH AND DEVELOPMENT REPORT

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22

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ABSTRACT

Three models representing two Bureau of Ships designs and a David Taylor Model Basin design for a proposed 154-ft PGM were tested for resistance and propulsion characteristics. One of the BuShips designs was canceled from the test program after initial bare hull effective horsepower tests. Of the remaining two, the TMB design proved the better in both still water and waves. Significant improvements were made in the performance of the TMB design by the addition of transom wedges. Also of considerable value was the installation of TMB-designed appendages incorporating a single contraflow strut behind the propeller supporting both the propeller shaft and the rudder.

INTRODUCTION

The Bureau of Ships requested that the David Taylor Model Basin conduct model tests of three new designs, A, B, and C, of a high speed PGM.[1] Hull forms A and B (Models 4932 and 4942, respectively) were built in accordance with BuShips plans.[2,3] Hull form C was proposed by the TMB staff as an alternate design. The underwater form of this model was derived from TMB Series 64, and the above-water form was developed by using the sheer line and the feature of a forebody intermediate knuckle of hull form B.[4]

The test program consisted of resistance in still water and propulsion in still water and waves. Motion in a seaway, directional stability, and turning characteristics studies were also included.[5,6] After initial bare hull resistance tests, hull form B was canceled from the test program.

The propellers used in the propulsion testing were purchased from the Michigan Wheel Company and were their style MP. The full-scale diameter was 5.5 ft with a P/D of 1.375 and a blade area ratio of about 0.50. The hubs were built up to represent a controllable pitch propeller in accordance with Bureau of Ships specifications.

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[1]References are listed on page 49

[redacted]

Additional propulsion tests were conducted on hull form C with a series of TMB-designed transom wedges and a TMB-designed appendage arrangement incorporating rudders of increased area and using the rudder horn for shafting support instead of V-struts.

All still water data calculations were performed in accordance with standard TMB practice and are for the ship operating in smooth, deep, salt water having a temperature of 59 F.[7]

This report presents the results of the resistance and propulsion tests.

RESISTANCE AND PROPULSION IN STILL WATER

Models 4932, 4942, and 4950 were tested for resistance in the bare hull condition with a centerline docking skeg. Model 4942 was also tested after the addition of spray rails. Wave profile photographs were taken of each model at ship speeds of 0, 16, and 40 knots, 16 and 40 knots being the cruising and top speeds.

Based upon the results of these tests, Model 4942 was canceled from the test program. Shafts, struts, and rudders were installed on Models 4932 and 4950, and the two models were tested for resistance and propulsion characteristics.[8,9]

As a result of weights and centers calculations carried out at the Bureau of Ships, it was found that hull form A only would have to be operated with an 18-in. trim by the stern. Model 4932 was tested for resistance in this trimmed condition.

In an effort to reduce the resistance of hull form C, Model 4950 was tested for resistance and trim at speeds corresponding to 16 and 40 knots with a series of TMB-designed wedges under the transom. The maximum depth of wedge tested was determined experimentally as that which gave the maximum drag reduction. This depth was found to be about 5 in., ship scale. The length of wedge was always about 2 ft, ship scale. The selection of an optimum wedge depth was a compromise between resistance reduction and running trim for the ship. The 3-in. wedge reduced resistance about 6 percent and retained a running trim of about 2 ft at a speed of 40 knots; a larger wedge would have a greater effect upon trim

[redacted]

than upon resistance and, therefore, could not be justified. As a result a 3-in. wedge was selected and used for complete resistance and propulsion tests.

It was felt that further improvements in propulsion, as well as turning characteristics, could be achieved by a redesign of the appendages fitted to hull form C. The large V-struts were replaced by a TMB-designed single strut-rudder horn combination behind the propeller.[10] The strut and rudder leading edges were designed with contraflow sections. The rudder area was increased 50 percent and the docking skeg was reduced in size to improve turning characteristics. The shaft line was relocated at the request of the Bureau of Ships. These modifications provided further improvements (at 40 knots) of about 4 percent in resistance and 13 percent in shaft horsepower. It must be borne in mind, however, that although some improvement over V-struts should be expected with such appendages, these large figures are due, in part, to the fact that the original V-struts were not optimum.

PROPULSION TESTS IN REGULAR WAVES

Both models were given propulsion tests in regular waves without wedges and with the original appendages, thrust torque, and revolutions per minute being measured. Pitch, heave, surge, and bow acceleration were also measured.[5] Each hull form was tested to 32 knots in head seas and at 40 knots in following seas. The seas consisted of regular waves of wave length to ship length (λ/L) of 0.50, 0.75, and 1.00 at a wave height to wave length (r/λ) of 1/40 and of λ/L equal to 1.50, 2.00 and 2.50 at an r/λ of 1/50.

Propulsion data in waves were calculated in dimensionless form by the method set forth by Gerritsma.[11] By using these dimensionless transfer functions and an appropriate wave spectrum, it is possible to calculate the thrust, torque, revolutions per minute, or power increase due to a complex sea.[11] This was done for power increase with the Neumann spectrum for a fully developed sea at a wind speed of 22 knots (a State 5 sea).

[redacted]

CONCLUSIONS

Of the three hull forms tested, form C (Model 4950) demonstrated the most desirable propulsion characteristics in still water and waves. Transom wedges or flaps improved the propulsive characteristics as did the use of the single strut-rudder horn combination behind the propellers.

RECOMMENDATIONS

It is recommended that hull form C be used with adjustable flaps behind the transom. Adjustable flaps would allow the optimum flap angle to be selected for each speed and sea condition. In some circumstances, for example, overtaking a heavy following sea, a fixed wedge, with its tendency to drive the bow down, could be a real disadvantage. It is similarly recommended that testing be done to determine the effect of wedges upon the handling and seakeeping characteristics of these ships.

[redacted]

TABLE 1

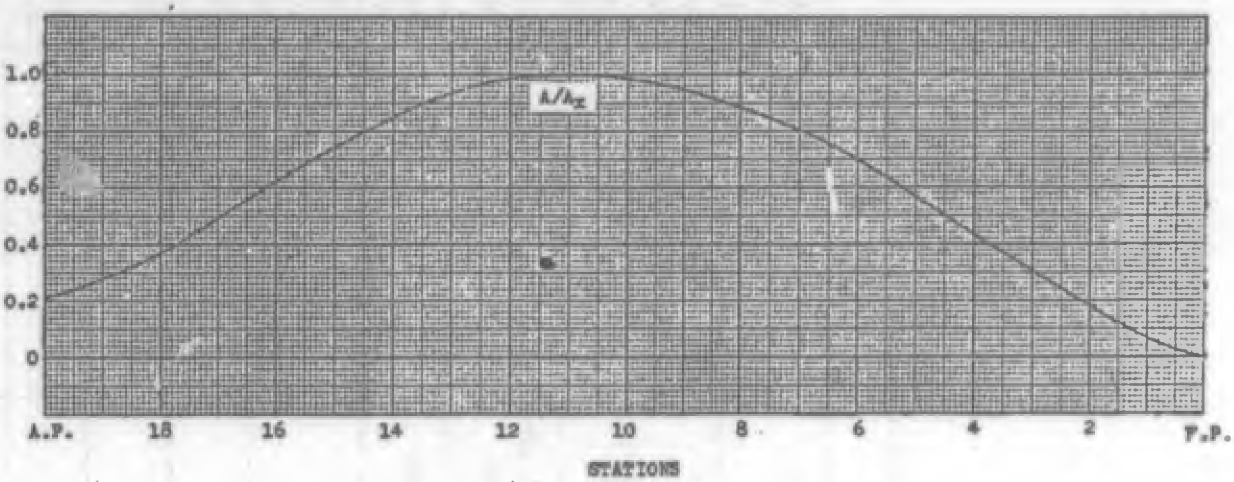
The Test Program

Test	Model 4932	Model 4942	Model 4950
1	EHP, bare hull with docking skeg	EHP, bare hull with docking skeg	EHP, bare hull without docking skeg
2	EHP, fully appended	EHP, bare hull with skeg and spray rail	EHP, bare hull with docking skeg
3	SHP, fully appended		EHP, fully appended with V-struts
4	EHP, fully appended and trimmed 18 in. by the stern		SHP, fully appended with V-struts
5	SHP, in regular waves		SHP, in regular waves with V-struts
6			EHP, at 16 and 40 Knots with V-struts and various wedges
7			EHP, complete with V-struts and 3 in. wedges
8			SHP, with V-struts and 3 in. wedges
9			EHP, with TMB appendages and 3 in. wedges
10			SHP, with TMB appendages and 3 in. wedges

[redacted]

[redacted]

SHIP AND MODEL DATA FOR PGM A MODEL 4932				
APPENDAGES: SHAFTS & STRUTS AND RUDDERS				
DIMENSIONS WITH SKEG			COEFFICIENTS WITHOUT SKEG	
	SHIP	MODEL	C_B .465	C_{WP} .59
LENGTH (LWL)	154 FT.	19.25 FT.	C_P .61	C_{WA} .93
LENGTH (LBP)	154 FT.	19.25 FT.	C_X .761	L_E/L .55
BEAM (MAX.)	21.91 FT.	2.74 FT.	C_W .76	L_X/L .55
DRAFT (H)	4.77 FT.	.60 FT.	C_{PF} .55	L_R/L .45
DISPL. IN TONS	213.5	0.412	C_{PA} .70	L/B_X 7.03
	SW TONS	FW TONS	C_{PE} .52	B_X/H_X 4.60
WETTED SURF. SQ. FT.	3307	51.67	C_{PR} .72	$\Delta/(.01L)^3$ 55.49
DESIGN V IN KTS.	16 & 40	5.7 & 14.1	C_{PV} .61	$S/\sqrt{\Delta L}$ 17.35
LCB_{LWL} = 81.9 FT. AFT OF F.P.			C_{PVA} .53	f 0
LCB_{LBP} = AFT OF F.P.			C_{PVF} .66	t .48
W.L. ENTRANCE HALF ANGLE = 11.75°				
λ = 8.0	$V/\sqrt{L_{LWL}}$ = 1.29, 3.22			
Ⓚ = 2.54, 6.35	Ⓟ = .87, 1.37			
LINES & APPENDAGES: BUSHIPS DRAWING PD 5022, GIBBS & COX DRAWING OF PROPOSED SINGLE STRUTS, AND BUSHIPS HULL GUIDANCE PLAN				



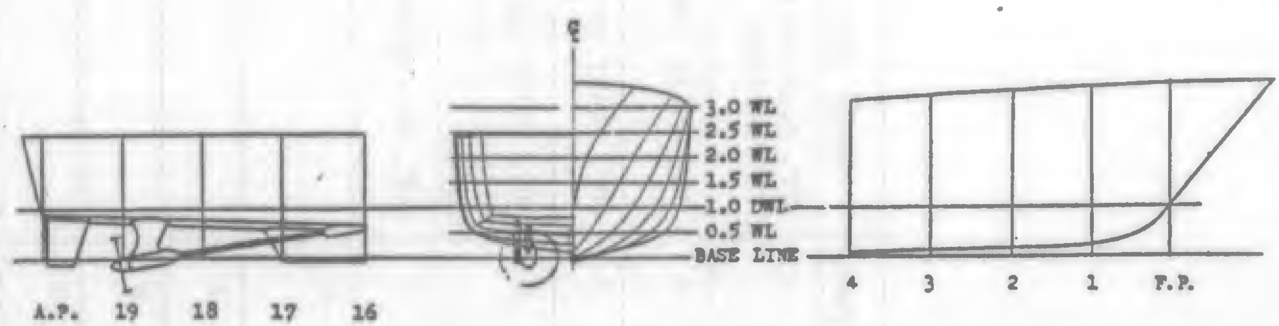


Figure 1

[redacted]

[redacted]

SHIP AND MODEL DATA FOR PGM B MODEL 4942				
APPENDAGES: SHAFTS & STRUTS AND RUDDERS				
DIMENSIONS WITH SKEG			COEFFICIENTS WITHOUT SKEG	
	SHIP	MODEL	C_B .473	C_{WF} .59
LENGTH (LWL)	154 FT.	18.67 FT.	C_P .61	C_{WA} .93
LENGTH (LBP)	154 FT.	18.67 FT.	C_X .783	L_E/L .55
BEAM (MAX.)	21.95 FT.	2.66 FT.	C_W .76	L_X/L .55
DRAFT (H)	4.63 FT.	.56 FT	C_{PF} .54	L_R/L .45
DISPL. IN TONS	213.5 SW TONS	0.380 FW TONS	C_{PA} .67	L/B_X 7.02
			C_{PE} .64	B_X/H_X 4.73
WETTED SURF. SQ. FT.	3229	47.44	C_{PR} .57	$\Delta/(.01L)^3$ 59.7
DESIGN V IN KTS.	16 & 40	5.6 & 13.9	C_{PV} .62	$S/\sqrt{\Delta L}$ 17.2
LCB_{LWL} = 82.2 FT. AFT OF F.P.			C_{PVA} .57	f 0
LCB_{LBP} = AFT OF F.P.			C_{PVF} .71	f .47
W.L. ENTRANCE HALF ANGLE = 10.13°				
λ = 8.25	$V/\sqrt{L_{LWL}}$ = 1.29, 3.22			
ⓚ = 2.54, 6.35	ⓟ = .86, 1.37			
LINES: BUSHIPS DRAWING 802-1895769				

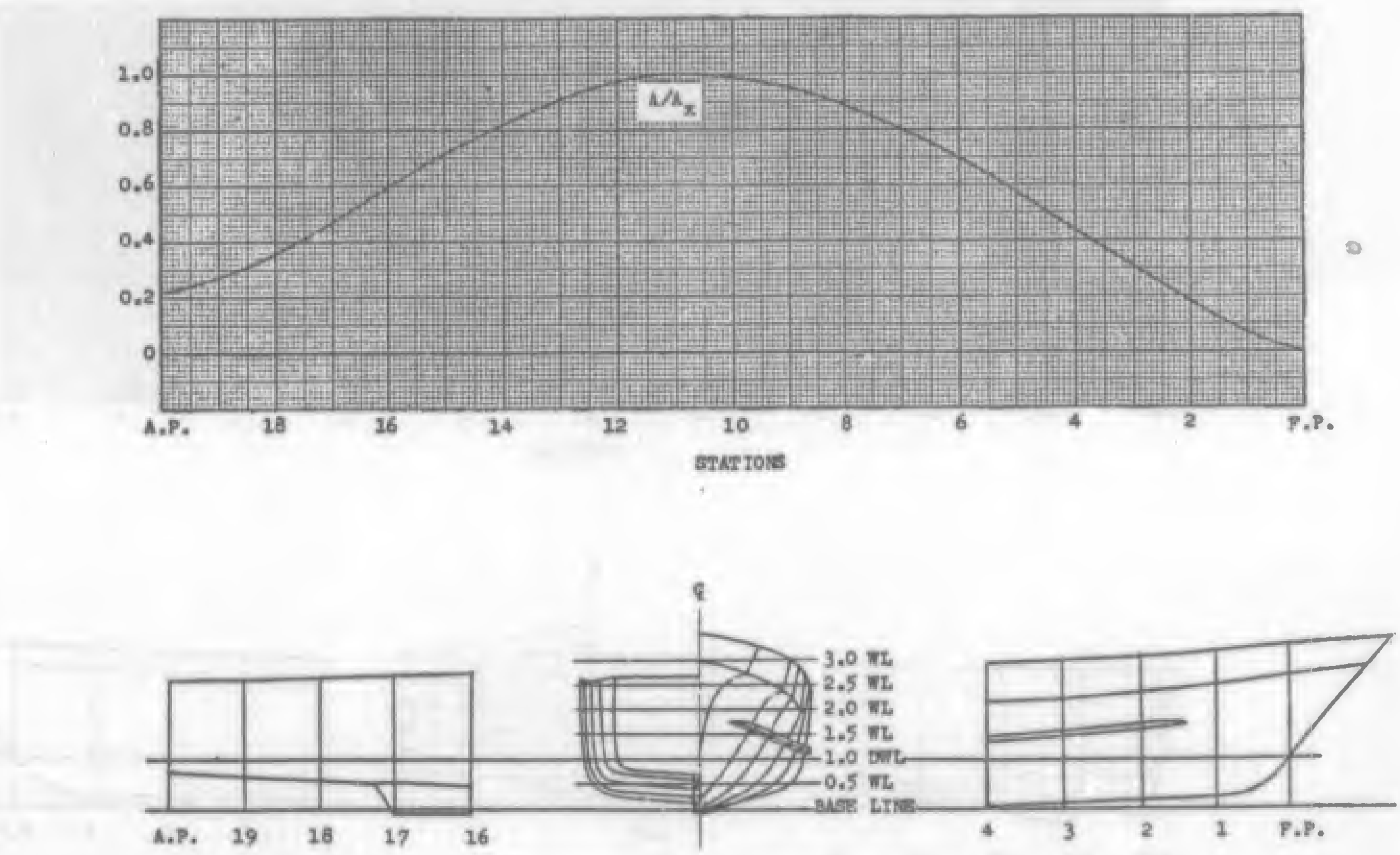


Figure 2

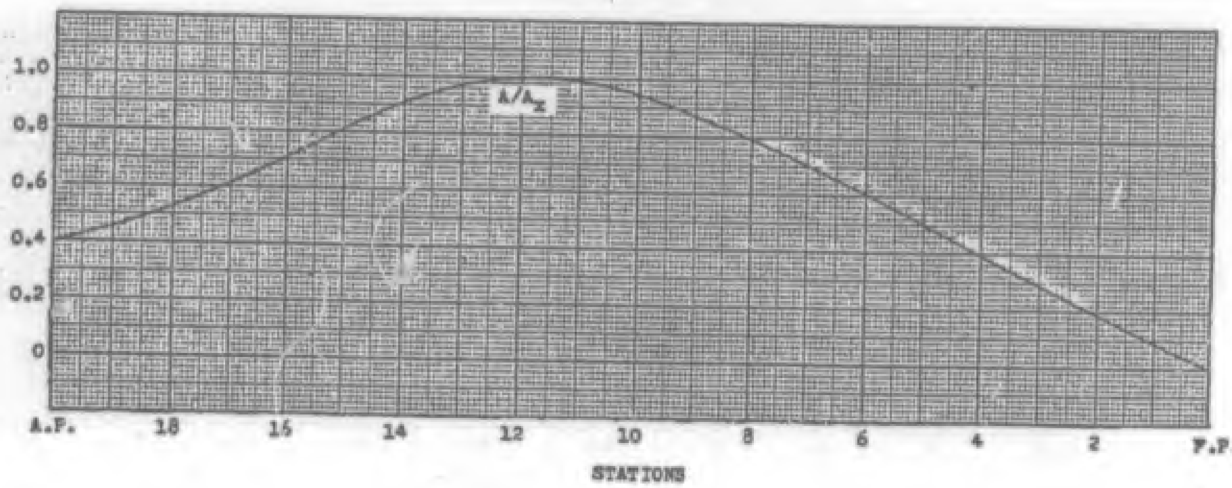
[redacted]

[redacted]

SHIP AND MODEL DATA
FOR
PGM C
MODEL 4950

APPENDAGES: SHAFTS & STRUTS AND RUDDERS

DIMENSIONS WITH SKEG			COEFFICIENTS WITHOUT SKEG	
	SHIP	MODEL	C_B .436	C_{WF} .57
LENGTH (LWL)	154 FT.	18.67FT.	C_P .63	C_{WA} 1.04
LENGTH (LBP)	154 FT.	18.67FT.	C_X .697	L_E/L .60
BEAM (MAX.)	21.9FT.	2.66FT.	C_W .76	L_X/L .60
DRAFT (H)	5.0FT.	0.61FT.	C_{PF} .52	L_R/L .40
DISPL. IN TONS	213.5 SW TONS	0.380 FW TONS	C_{PA} .81	L/B_X 7.03
			C_{PE} .57	B_X/H_X 4.38
WETTED SURF. SQ. FT.	3205	47.09	C_{PR} .69	$\Delta/(.01L)^3$ 58.5
DESIGN V IN KTS.	16 & 40	5.6 & 13.9	C_{PV} .59	$S/\sqrt{\Delta L}$ 17.06
LCB_{LWL} = 87.0 FT. AFT OF F.P.			C_{PVR} .54	f 0
LCB_{LBP} = AFT OF F.P.			C_{PVF} .64	t .90
W.L. ENTRANCE HALF ANGLE = 8.33°				
λ = 8.25	$V/\sqrt{L_{WL}}$ = 1.29, 3.22			
Ⓚ = 2.54, 6.35	Ⓒ = .87, 1.38			
LINES & APPENDAGES: DTMB DRAWINGS 522-4950-01, 522-4950-02, 522-4950-03 AND GIBBS & COX DRAWING OF 11/29/62				



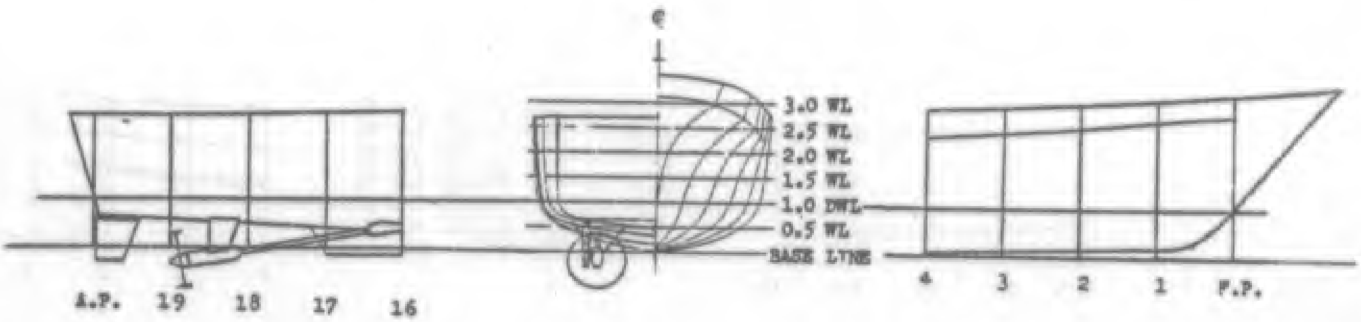


Figure 3

[redacted]

[redacted]

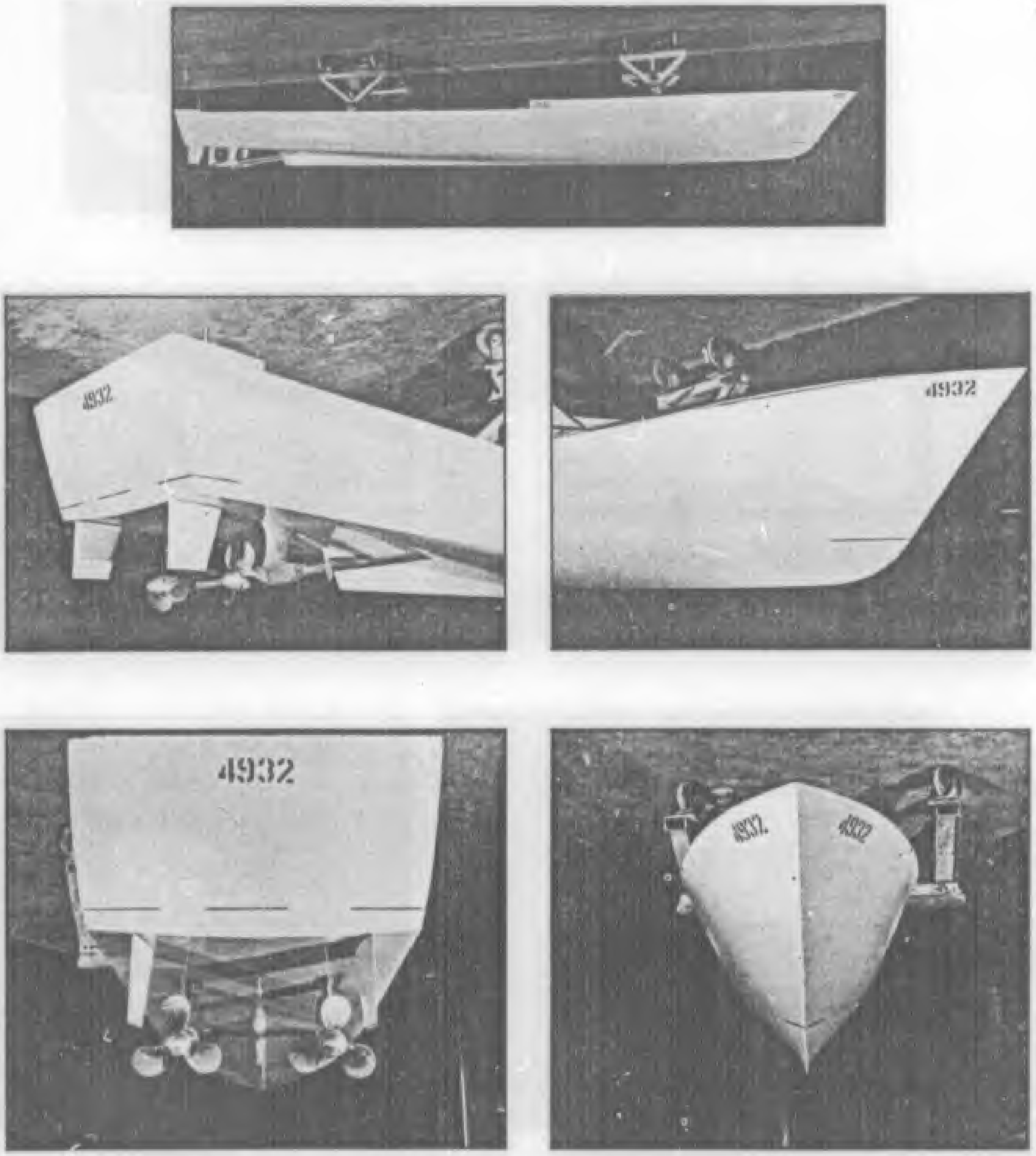


Figure 4 - Model 4932, Representing Hull Form A

[redacted]

[redacted]

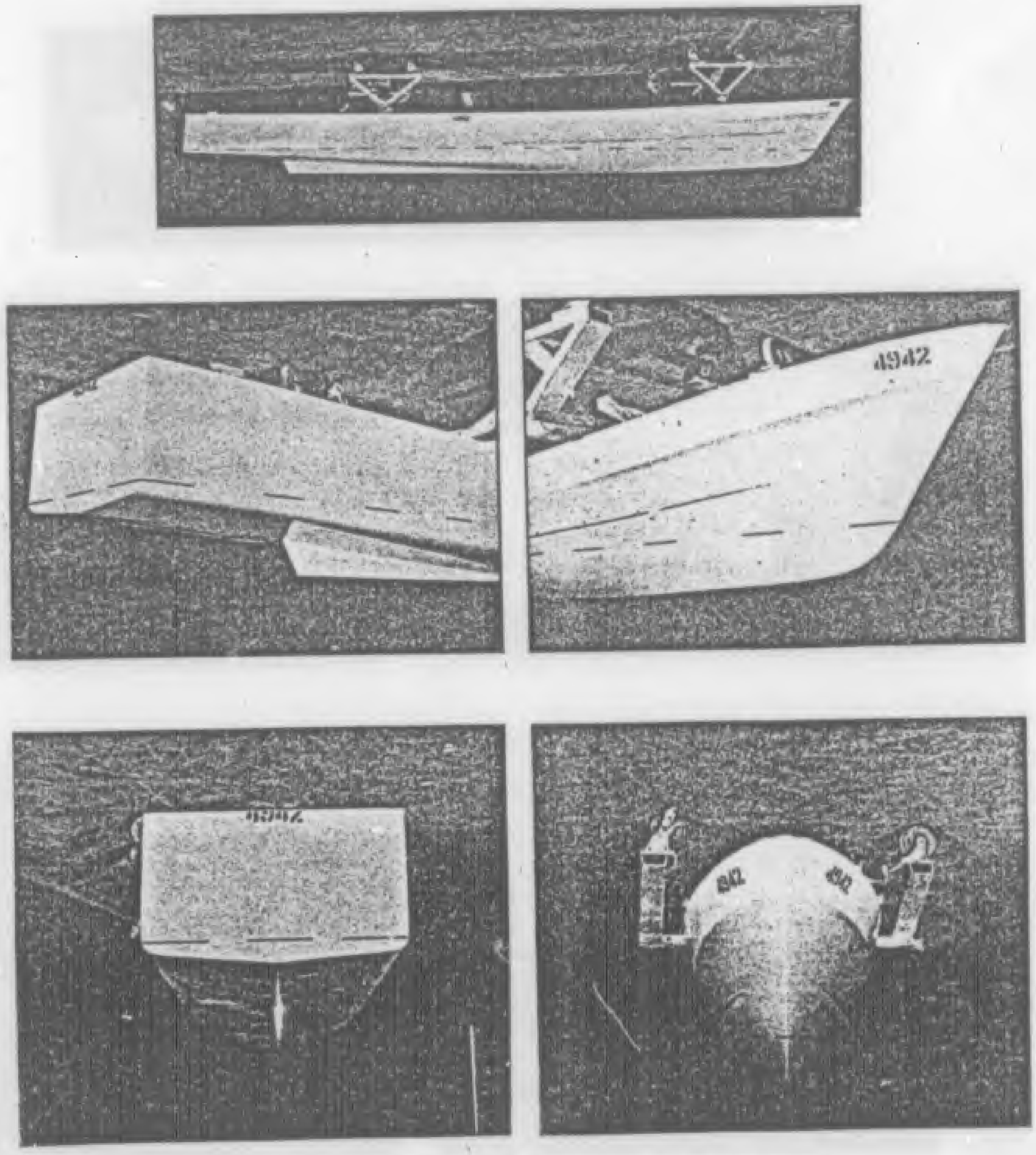


Figure 5 - Model 4942, Representing Hull Form B

[redacted]

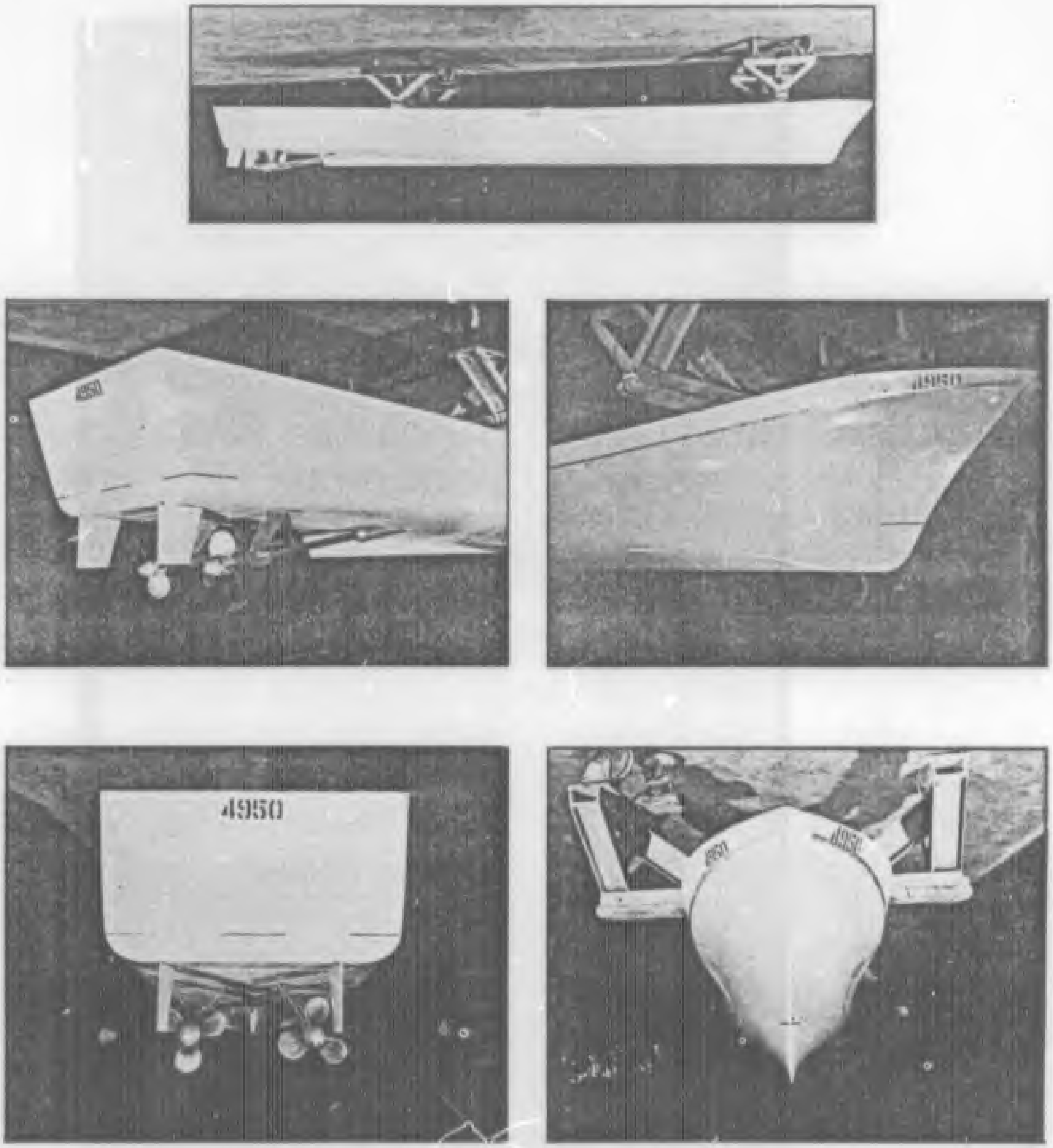


Figure 6 - Model 4950, Representing Hull Form C

[redacted]

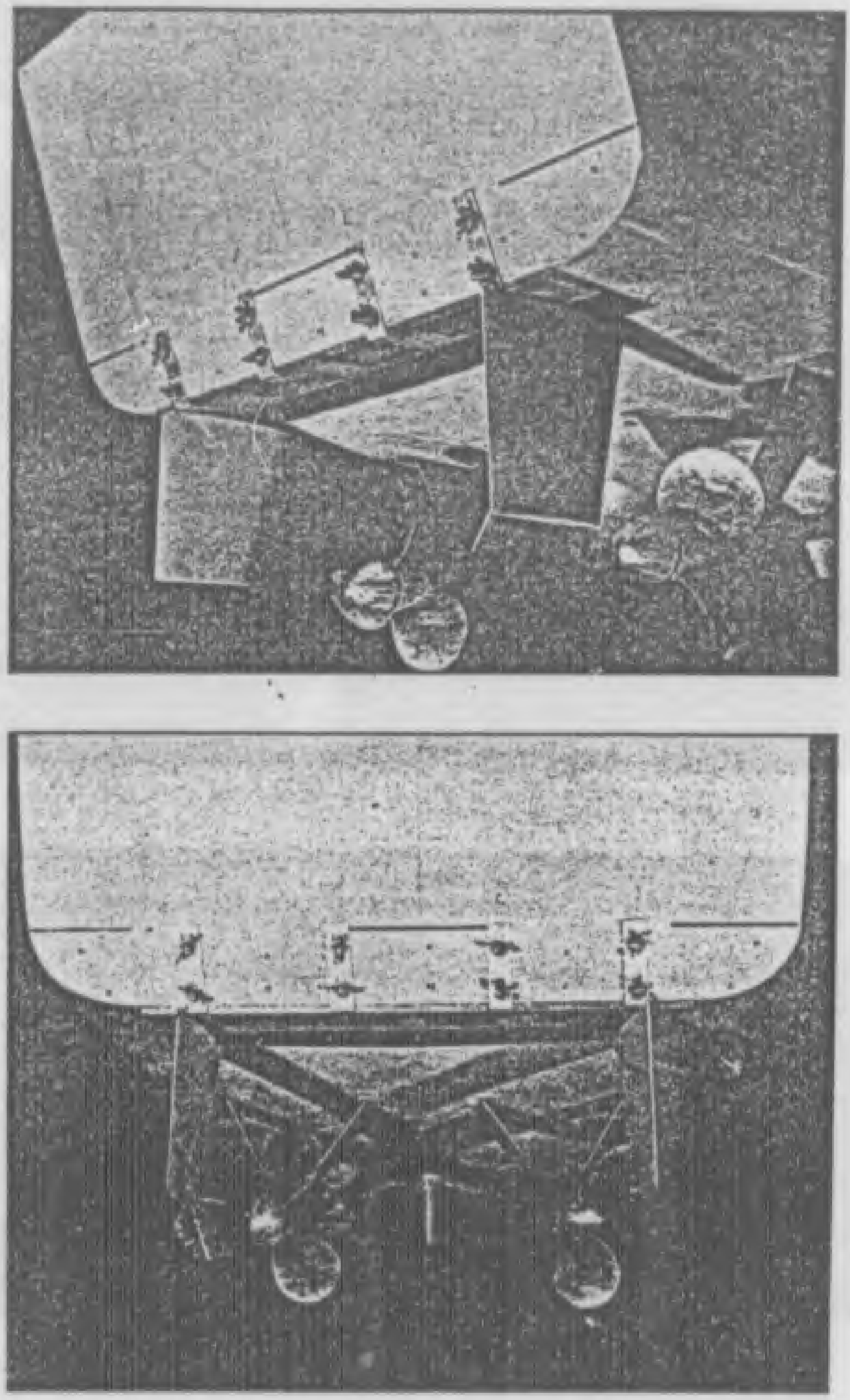


Figure 7 - Transom Wedges Fitted to Model 4950

[redacted]

[redacted]

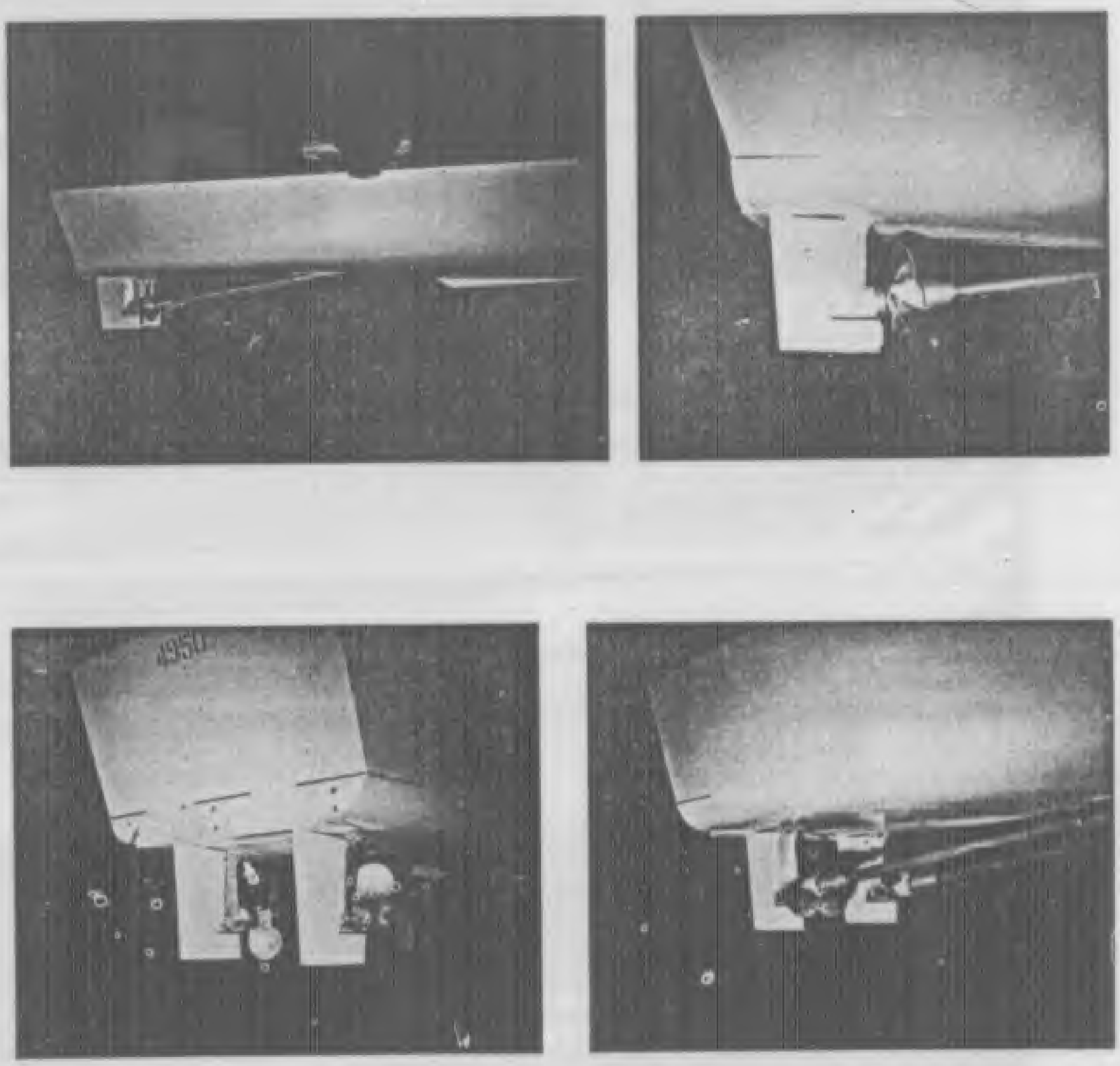
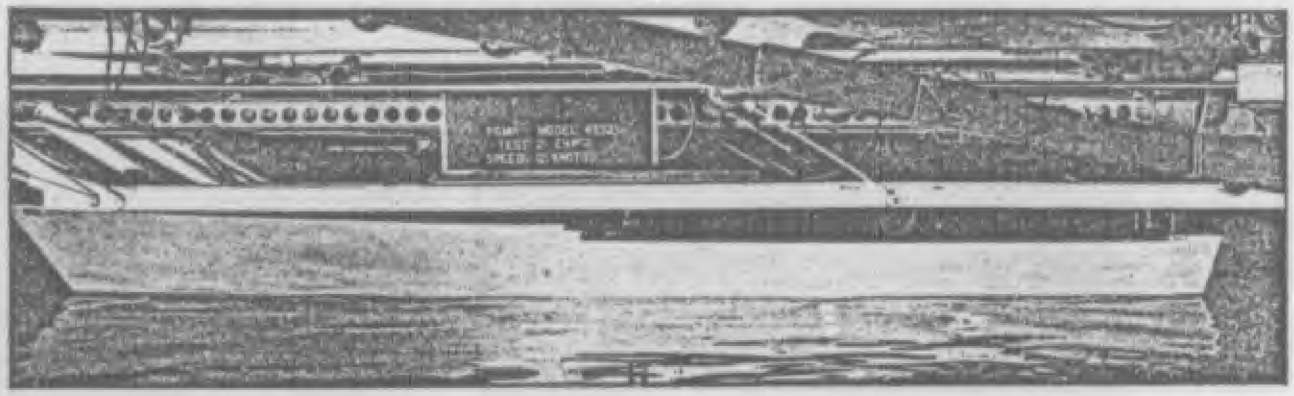


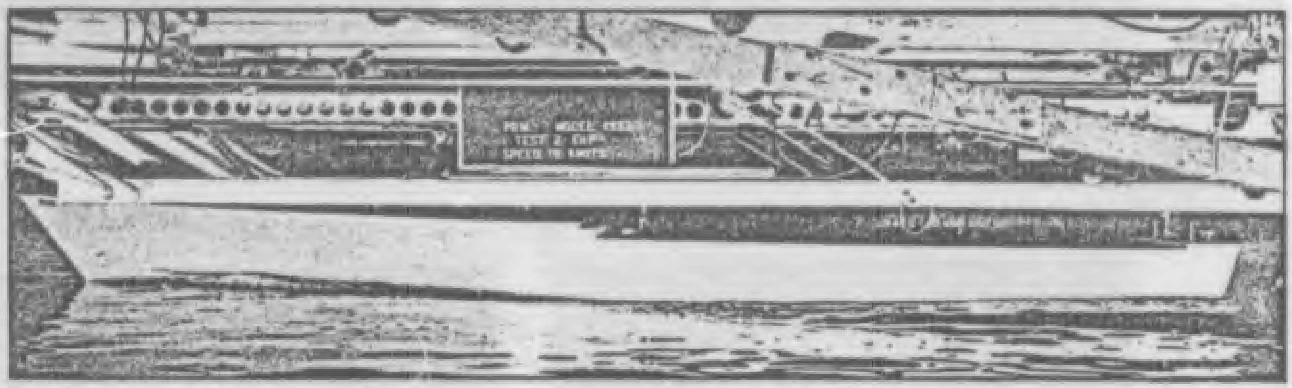
Figure 8 - TMB-Designed Appendages Fitted to Model 4950

[redacted]

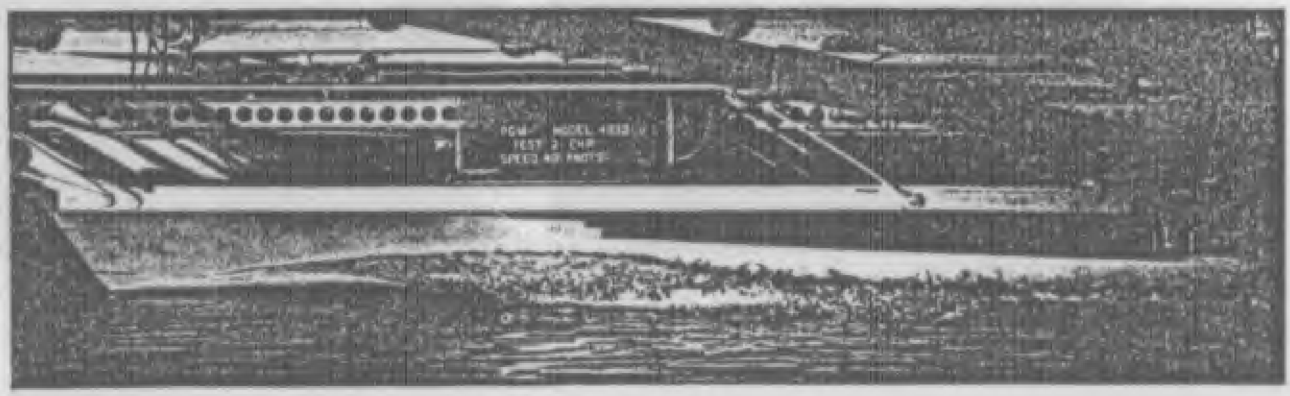
[redacted]



0 knots



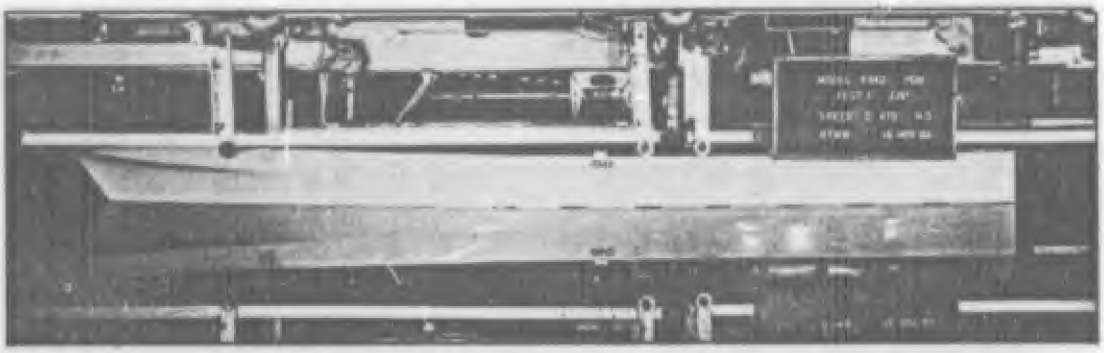
16 knots



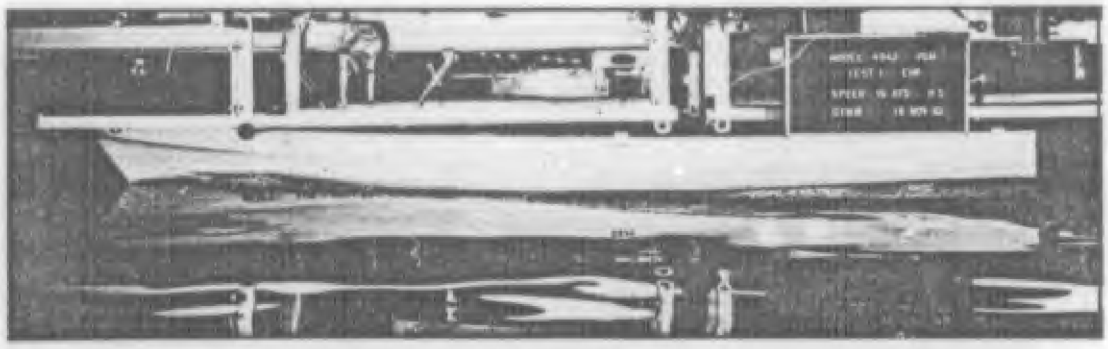
40 knots

Figure 9 - Hull Form A, Even Keel, 213.5 Tons Displacement

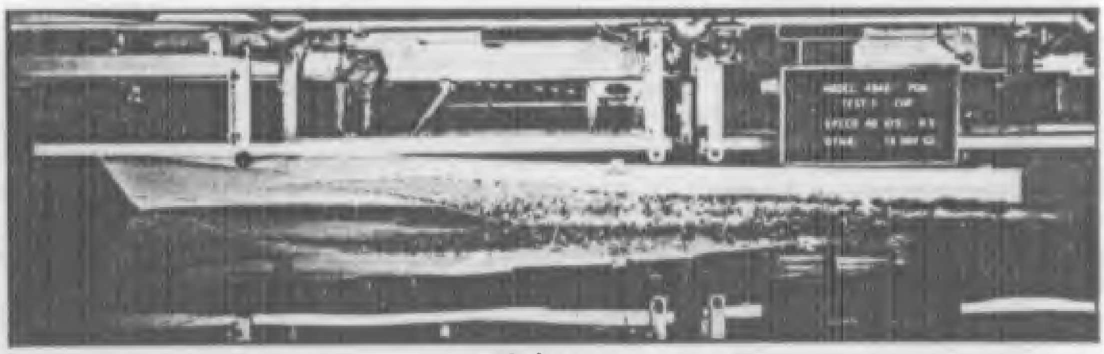
[redacted]



0 knots



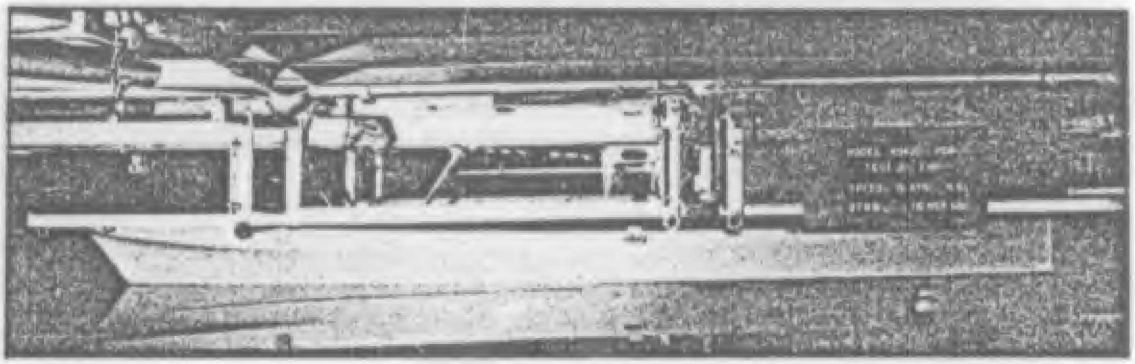
16 knots



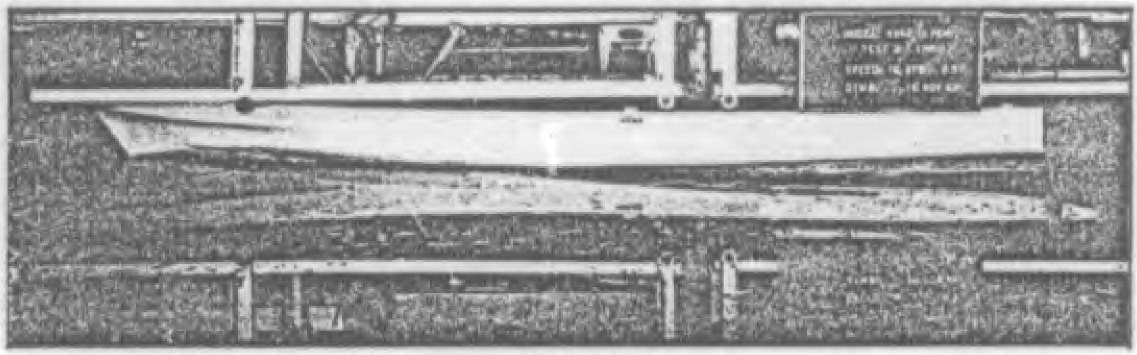
40 knots

Figure 10 - Hull Form B, Even Keel, 213.5 Tons Displacement without Spray Rail

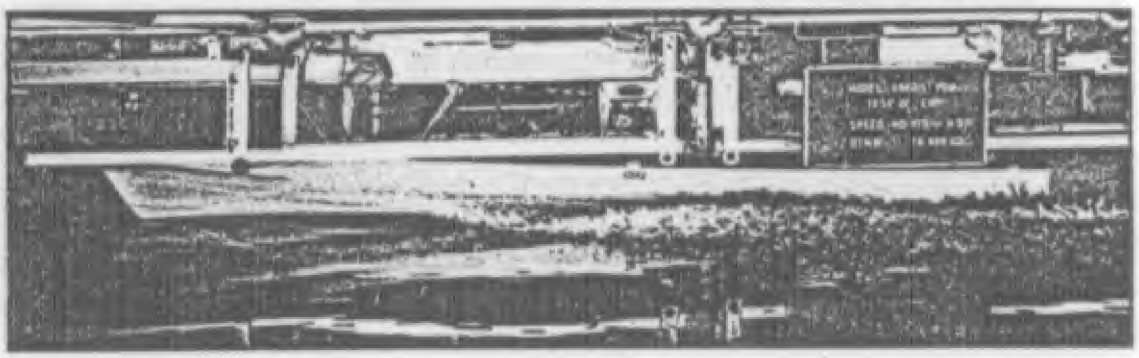
[redacted]



0 knots



16 knots



40 knots

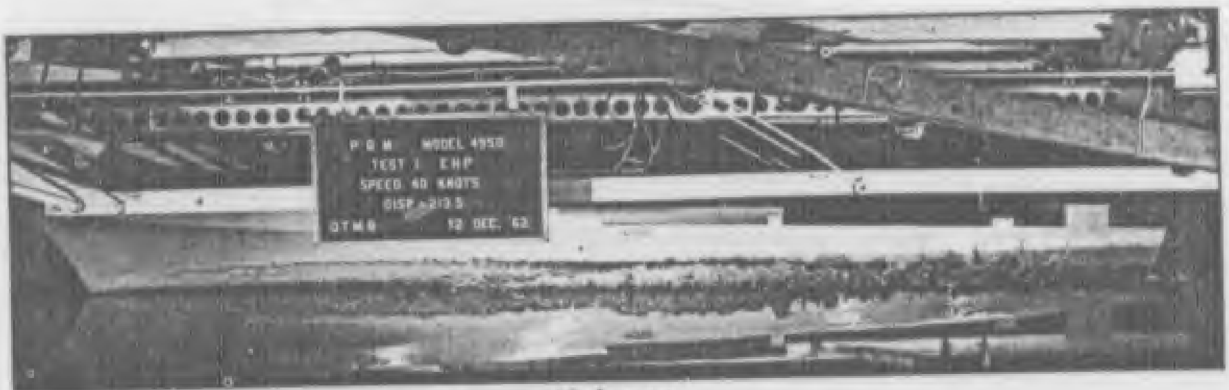
Figure 11 - Hull Form B, Even Keel, 213.5 Tons Displacement with Spray Rail

[redacted]

[redacted]

0 knots

16 knots



40 knots

Figure 12 - Hull Form C, Even Keel, 213.5 Tons Displacement

[redacted]

[redacted]

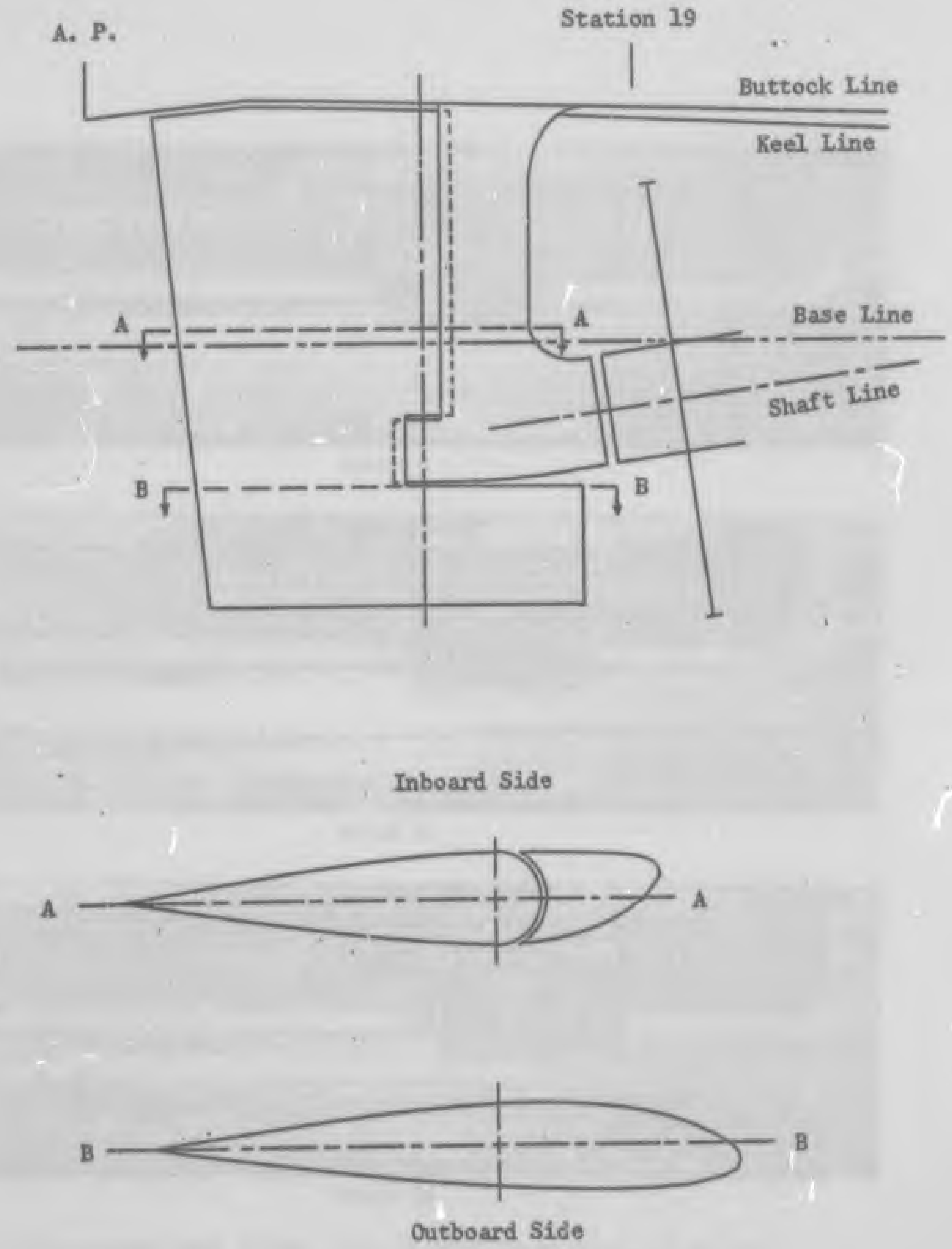


Figure 13 - TMB-Designed Appendages Fitted to Model 4950

[redacted]

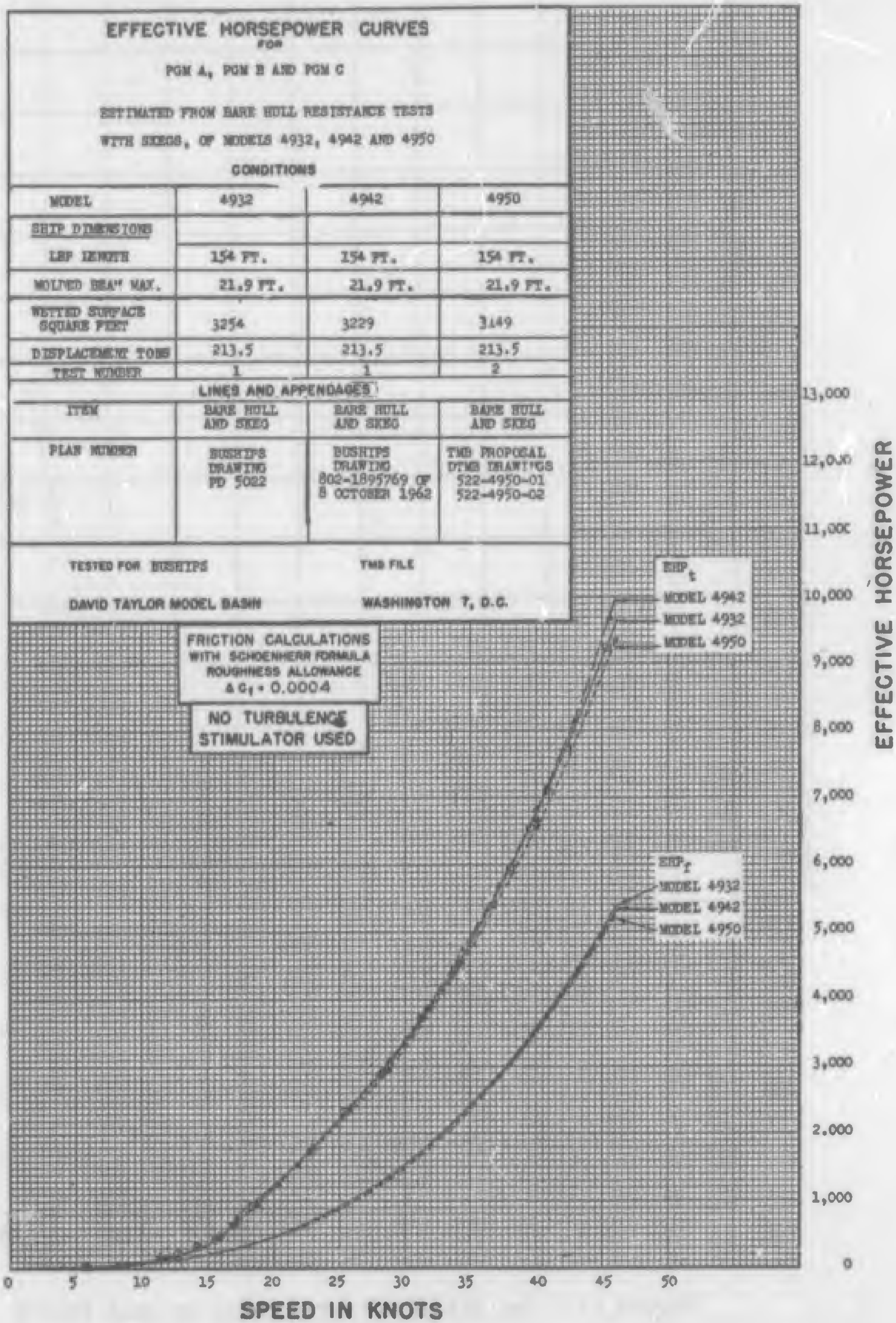

EFFECTIVE HORSEPOWER CURVES
FOR
PGM A, PGM B AND PGM C
ESTIMATED FROM BARE HULL RESISTANCE TESTS
WITH SKEGS, OF MODELS 4932, 4942 AND 4950
CONDITIONS
MODEL
4932
4942
4950
SHIP DIMENSIONS
LBP LENGTH
154 FT.
154 FT.
154 FT.
MOLDED BEAM MAX.
21.9 FT.
21.9 FT.
21.9 FT.
WETTED SURFACE SQUARE FEET
3254
3229
3149
DISPLACEMENT TONS
213.5
213.5
213.5
TEST NUMBER
1
1
2
LINES AND APPENDAGES
ITEM
BARE HULL AND SKEG
BARE HULL AND SKEG
BARE HULL AND SKEG
PLAN NUMBER
BUSHIPS DRAWING PD 5022
BUSHIPS DRAWING 802-1895769 OF 8 OCTOBER 1962
TMB PROPOSAL DTMB DRAWINGS 522-4950-01 522-4950-02
TESTED FOR BUSHIPS
TMB FILE
DAVID TAYLOR MODEL BASIN
WASHINGTON 7, D.C.
FRICTION CALCULATIONS WITH SCHOENHERR FORMULA ROUGHNESS ALLOWANCE ΔCf = 0.0004
NO TURBULENCE STIMULATOR USED
EHPt
MODEL 4942
MODEL 4932
MODEL 4950
EHPf
MODEL 4932
MODEL 4942
MODEL 4950
EFFECTIVE HORSEPOWER
SPEED IN KNOTS
0
5
10
15
20
25
30
35
40
45
50
1,000
2,000
3,000
4,000
5,000
6,000
7,000
8,000
9,000
10,000
11,000
12,000
13,000

Figure 14

[redacted]

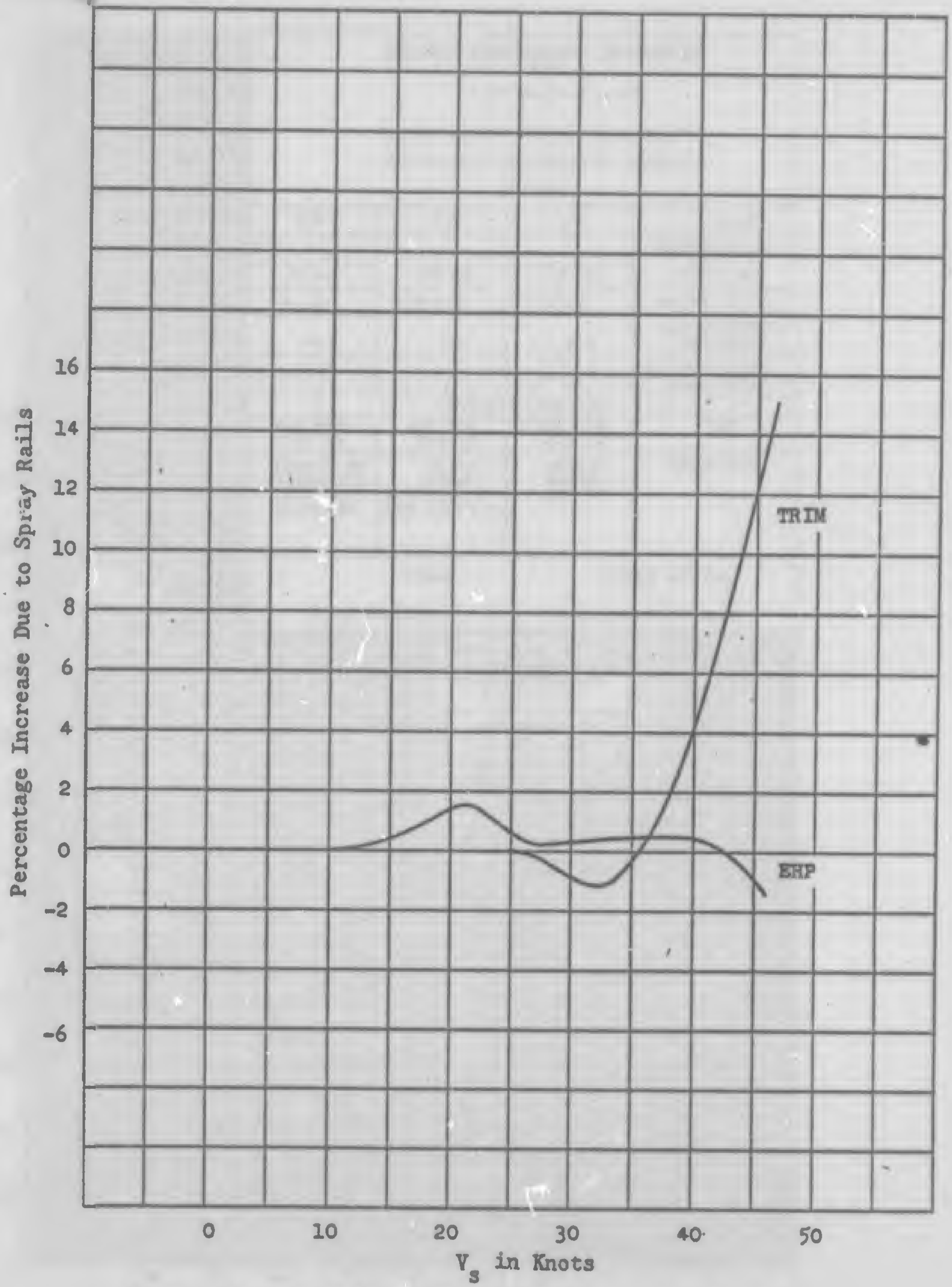


Figure 15 - The Effect of Spray Rails on Hull Form B from Test 2

[redacted]

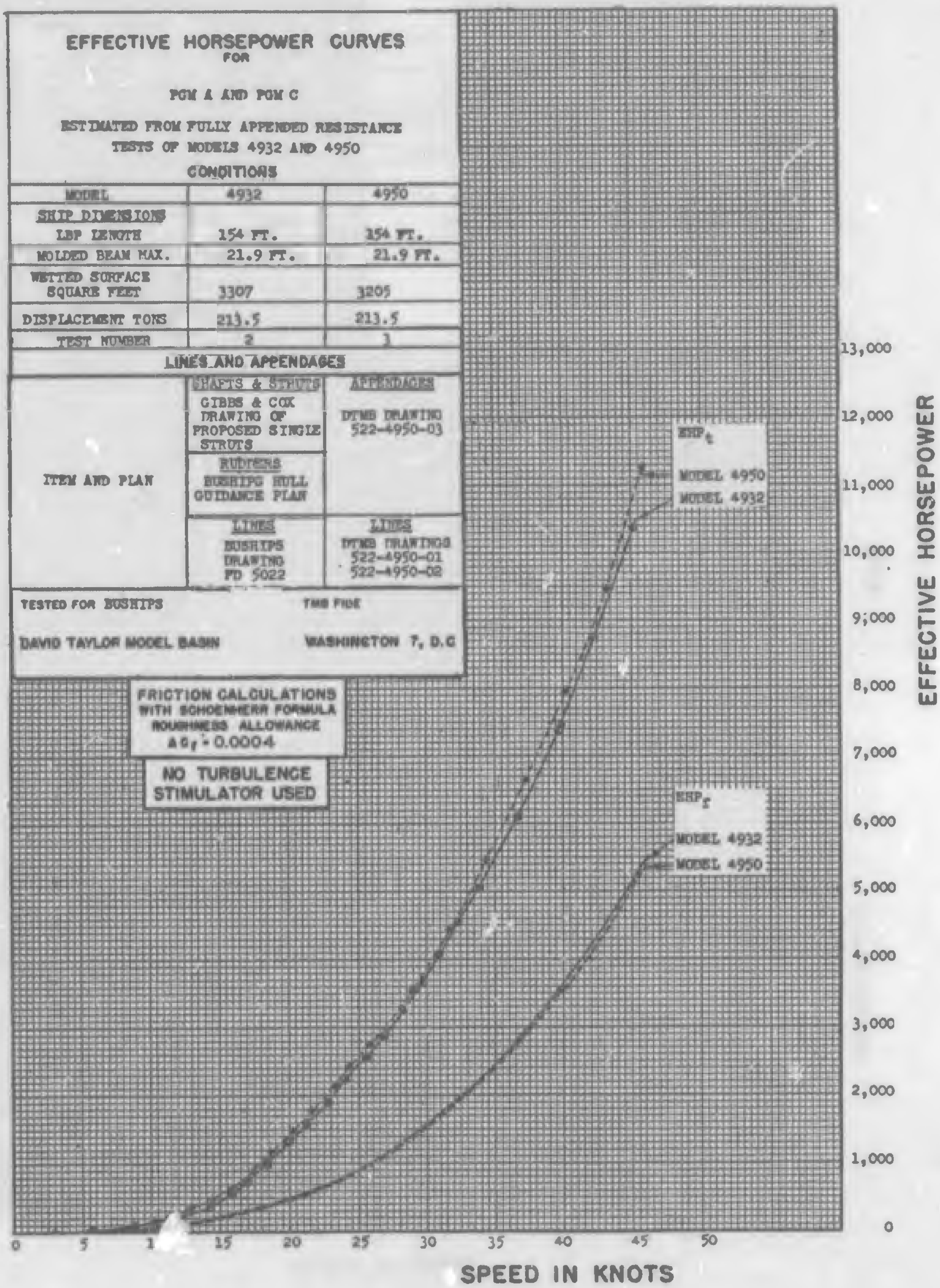

EFFECTIVE HORSEPOWER CURVES
FOR
PGM A AND PGM C
ESTIMATED FROM FULLY APPENDED RESISTANCE
TESTS OF MODELS 4932 AND 4950
CONDITIONS
MODEL 4932 4950
SHIP DIMENSIONS
LBP LENGTH 154 FT. 154 FT.
MOLDED BEAM MAX. 21.9 FT. 21.9 FT.
WETTED SURFACE SQUARE FEET 3307 3205
DISPLACEMENT TONS 213.5 213.5
TEST NUMBER 2 1
LINES AND APPENDAGES
ITEM AND PLAN
SHAFTS & STRUTS
GIBBS & COX DRAWING OF PROPOSED SINGLE STRUTS
RUDDERS
BUSHIPS HULL GUIDANCE PLAN
APPENDAGES
DTMB DRAWING 522-4950-03
LINES
BUSHIPS DRAWING PD 5022
LINES
DTMB DRAWINGS 522-4950-01 522-4950-02
TESTED FOR BUSHIPS
TMB FILE
DAVID TAYLOR MODEL BASIN
WASHINGTON 7, D.C
FRICTION CALCULATIONS
WITH SCHOENHERR FORMULA
ROUGHNESS ALLOWANCE
ΔC_f = 0.0004
NO TURBULENCE STIMULATOR USED
EHP_t
MODEL 4950
MODEL 4932
EHP_f
MODEL 4932
MODEL 4950
EFFECTIVE HORSEPOWER
13,000
12,000
11,000
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
0
5
15
20
25
30
35
40
45
50
SPEED IN KNOTS

Figure 16

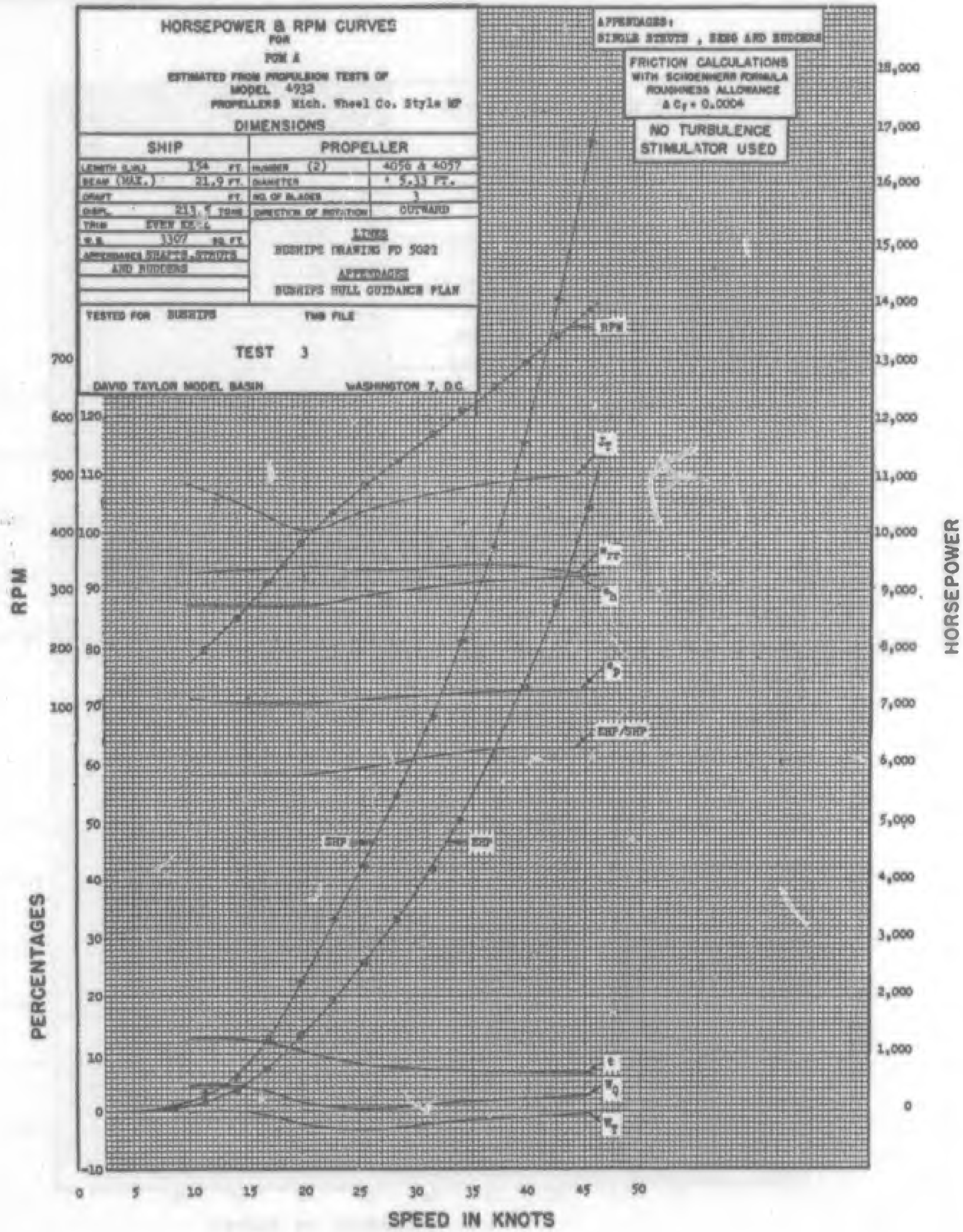

HORSEPOWER & RPM CURVES
FOR
ESTIMATED FROM PROPULSION TESTS OF
MODEL 4932
PROPELLERS Mich. Wheel Co. Style MP
DIMENSIONS
SHIP
PROPELLER
BEAM (MAX.) 21.9 FT.
DIAMETER 5.33 FT.
NO. OF BLADES 3
DIRECTION OF ROTATION OUTWARD
TRIM EVEN KEEL
W.S. 3307 SQ. FT.
APPENDAGES SHAFTS, STRUTS AND RUDDERS
LINES
BUSHIPS DRAWING PD 5021
APPENDAGES
BUSHIPS HULL GUIDANCE PLAN
TESTED FOR BUSHIPS
TMB FILE
TEST 3
DAVID TAYLOR MODEL BASIN
WASHINGTON 7, D.C.
APPENDAGES:
SINGLE STRUTS, SKEG AND RUDDERS
FRICTION CALCULATIONS
WITH SCHOENHERR FORMULA
ROUGHNESS ALLOWANCE
ΔCf = 0.0004
NO TURBULENCE
STIMULATOR USED
RPM
SHP/EHP
SHP
EHP
RPM
PERCENTAGES
HORSEPOWER
SPEED IN KNOTS

Figure 17

[redacted]

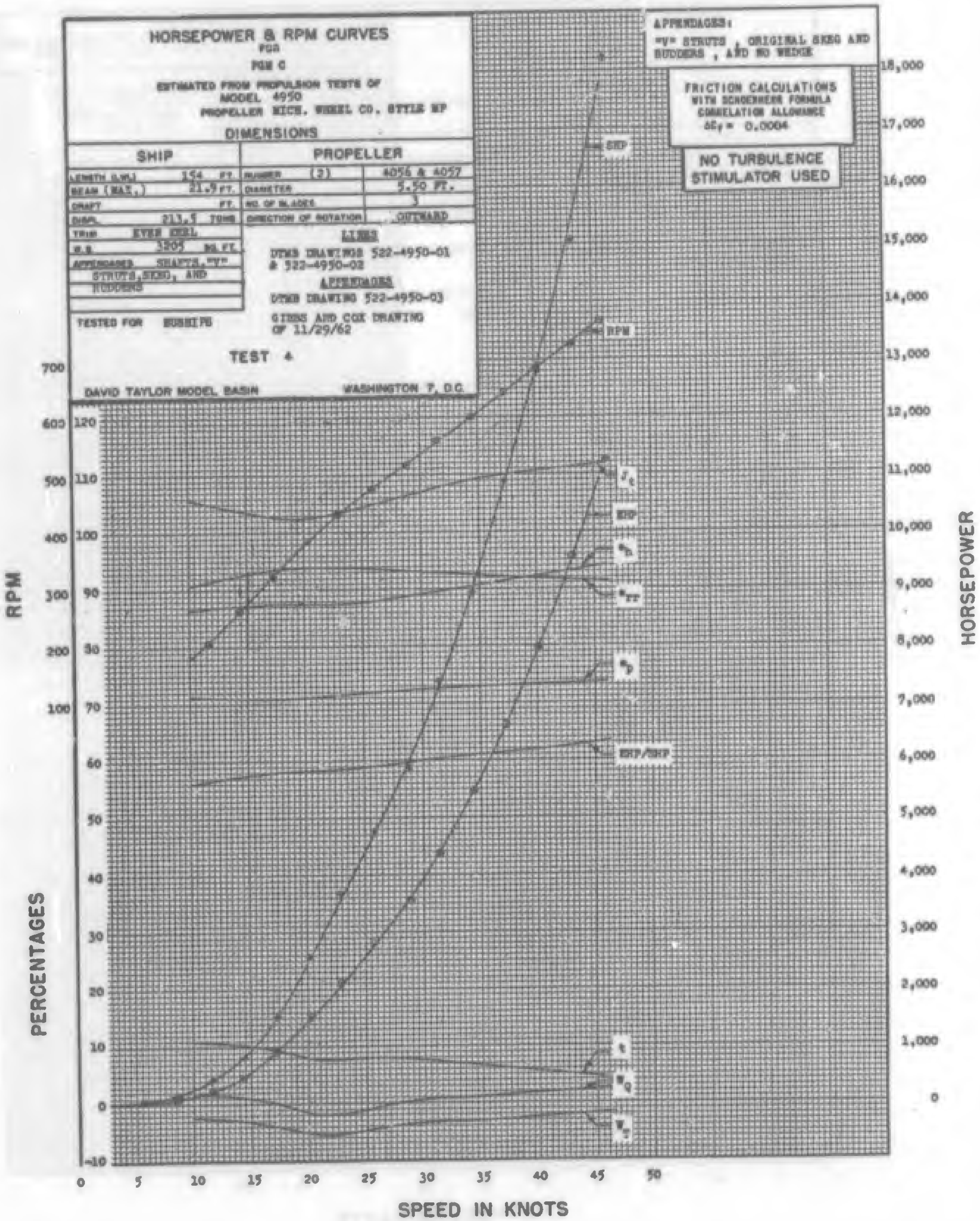


Figure 18

[redacted]

[redacted]

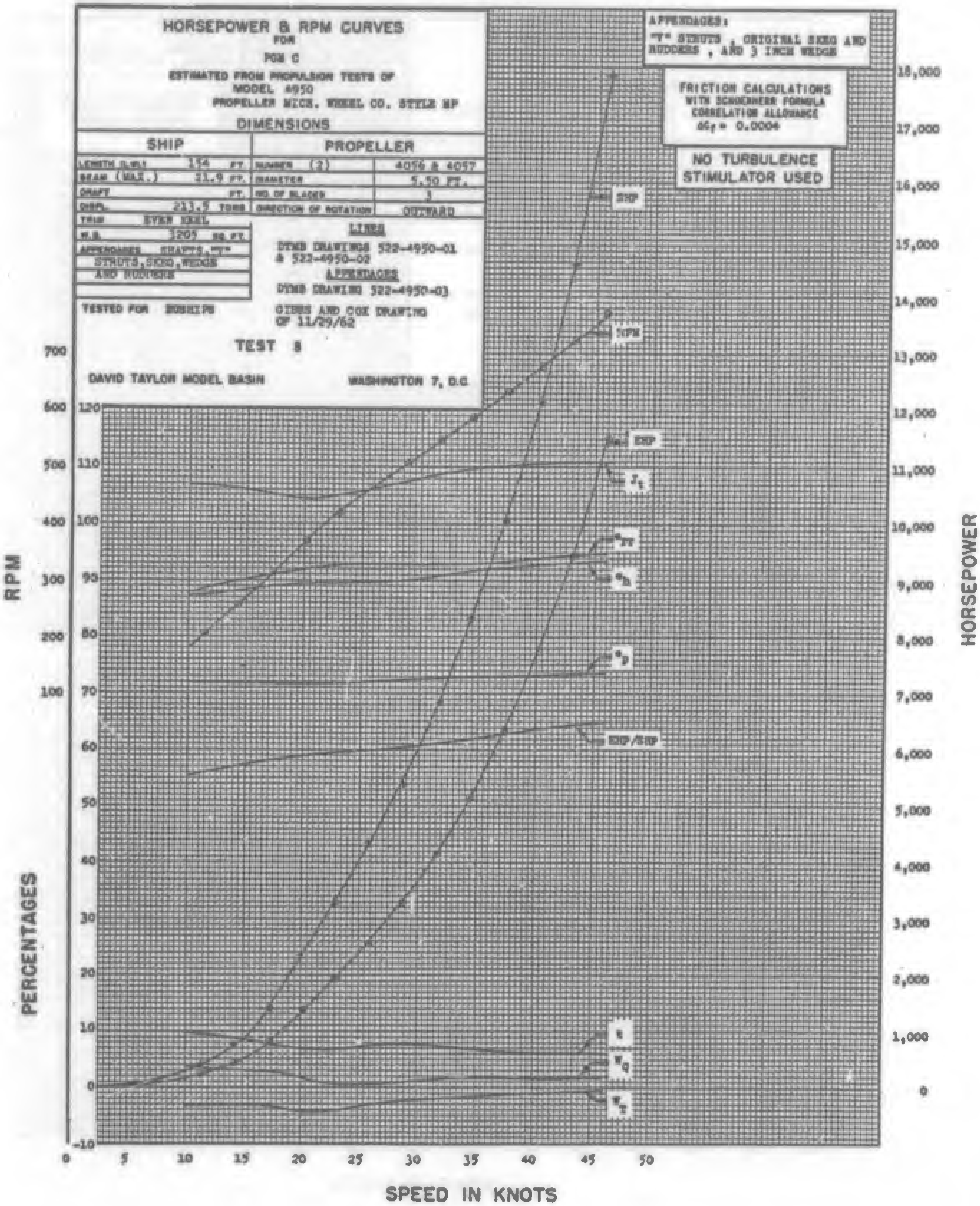


Figure 19

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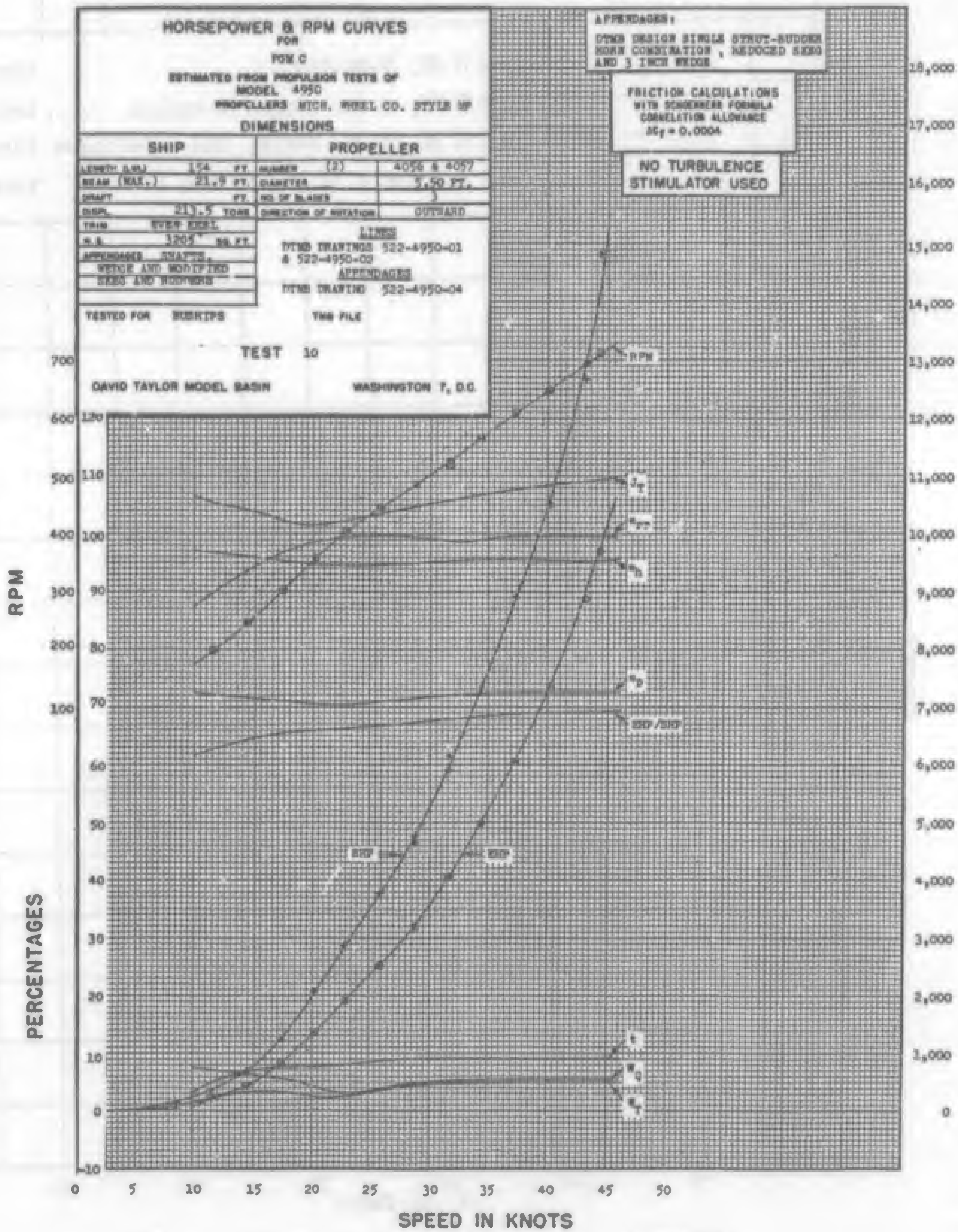

Figure 20

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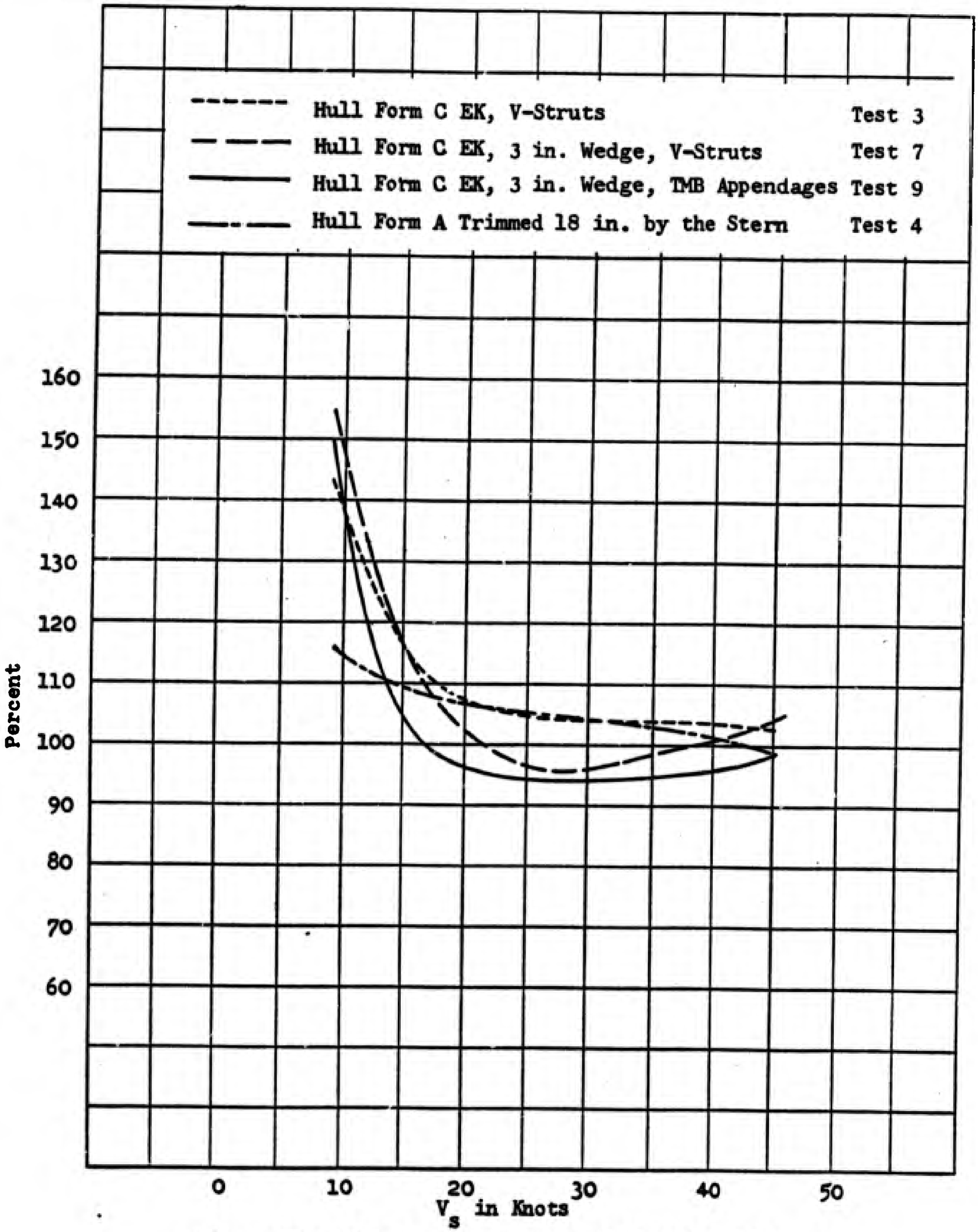

Figure 21 - EHP as a Percentage of that for Hull Form A from Test 2

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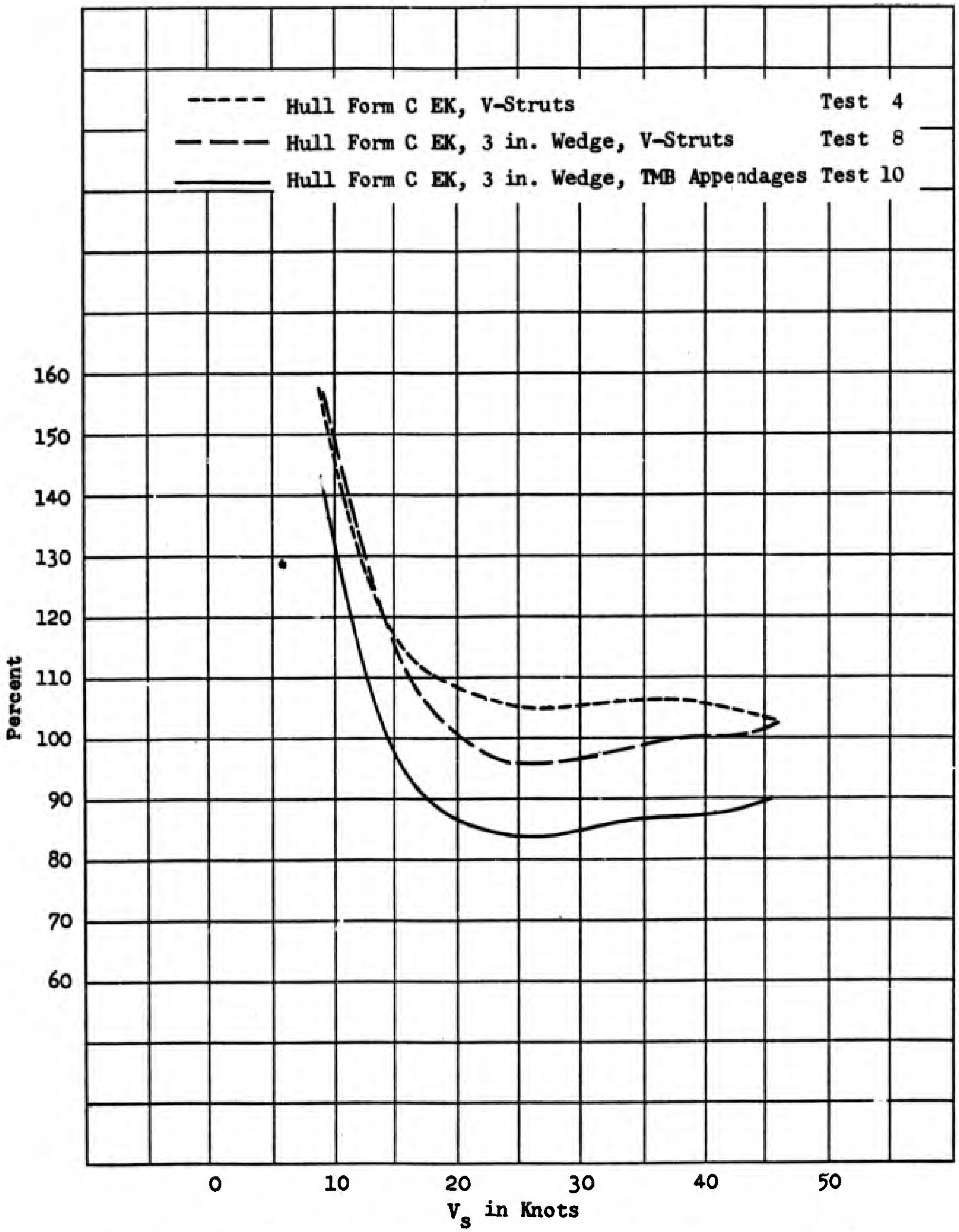

Figure 22 - SHP as a Percentage of that for Hull Form A from Test 3

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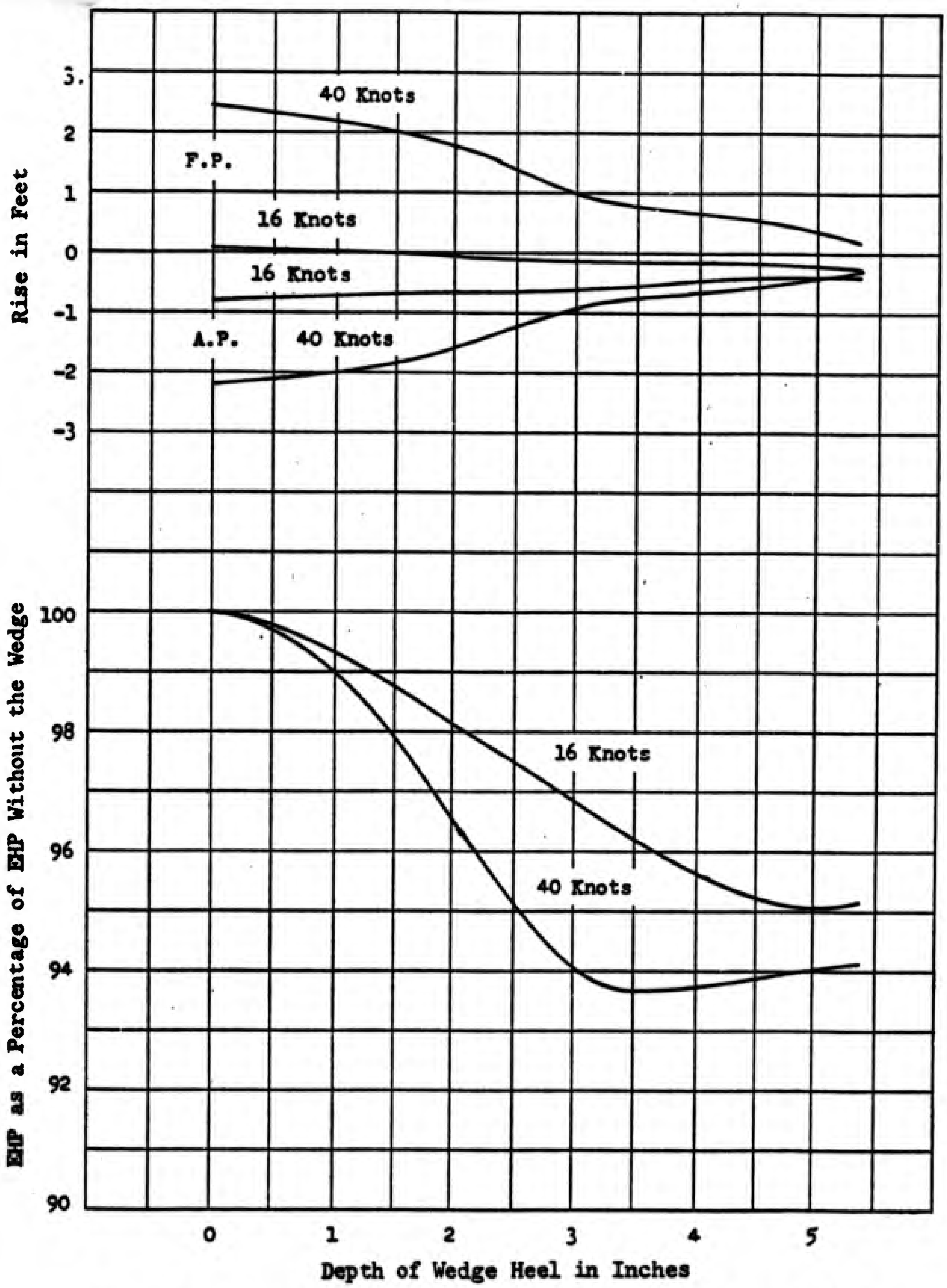

Figure 23 - The Effect of Transom Wedges on Hull Form C Test 6

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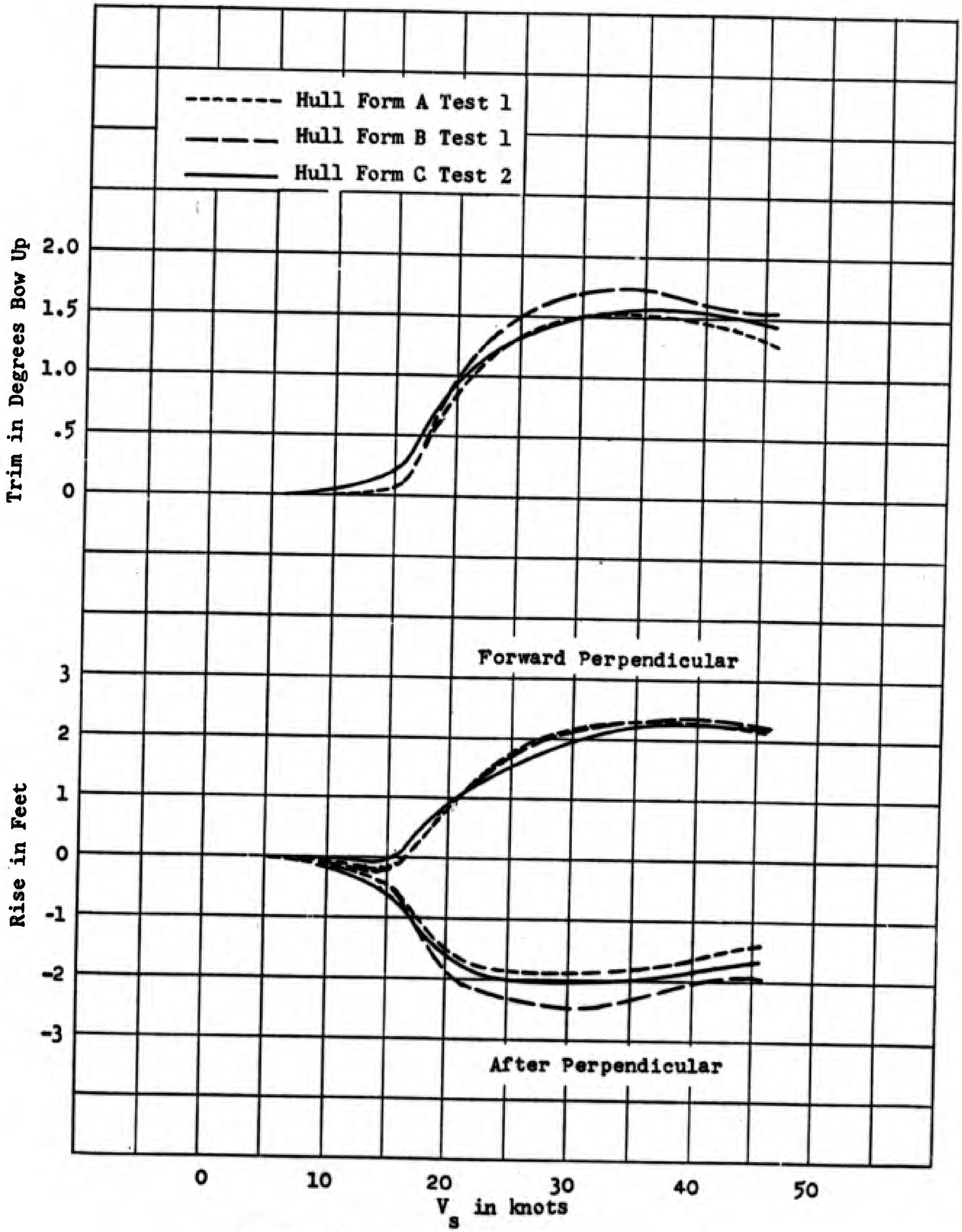

Figure 24 - Bare Hull Trim Comparisons

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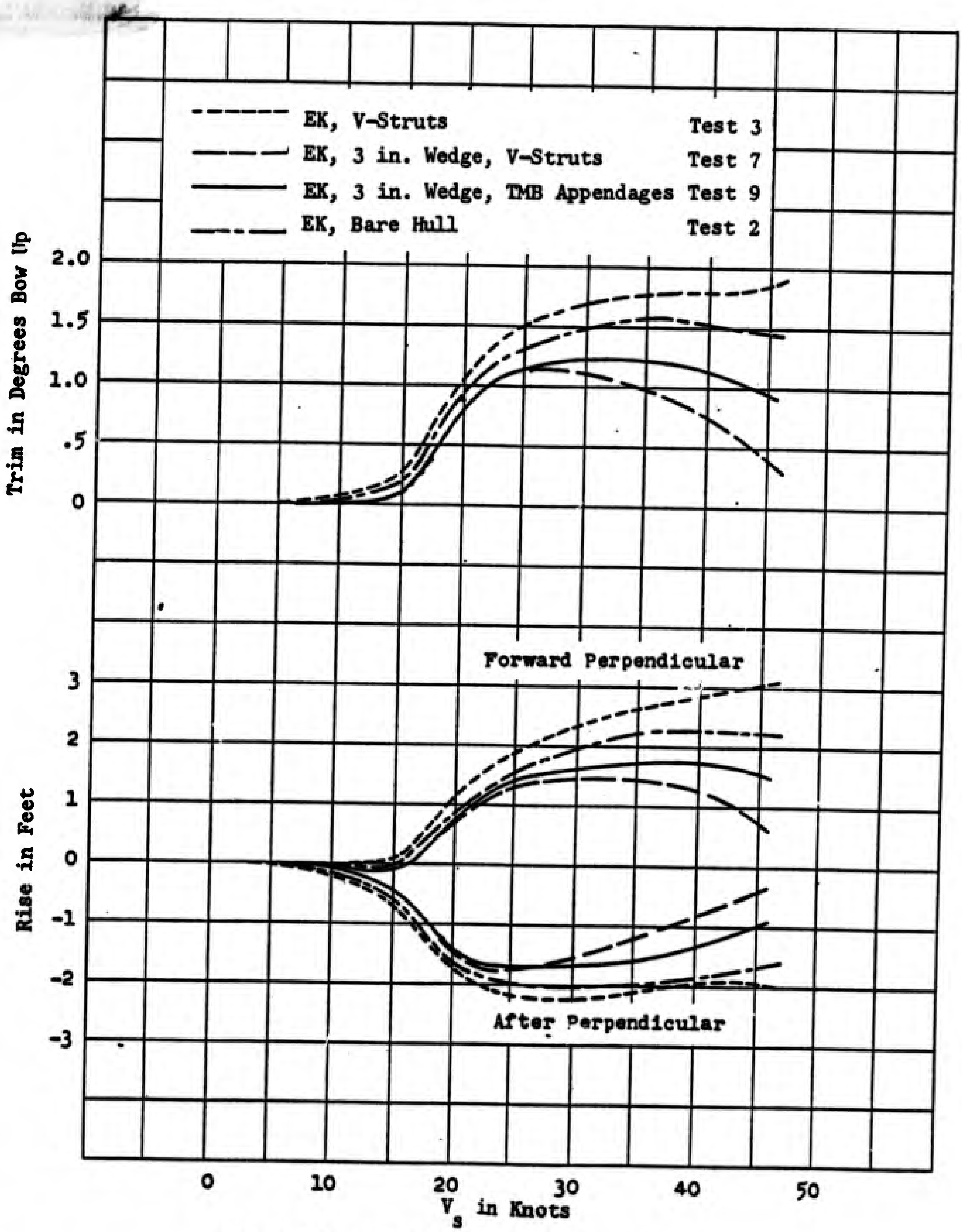

Figure 25 - Hull Form C Trim Comparisons

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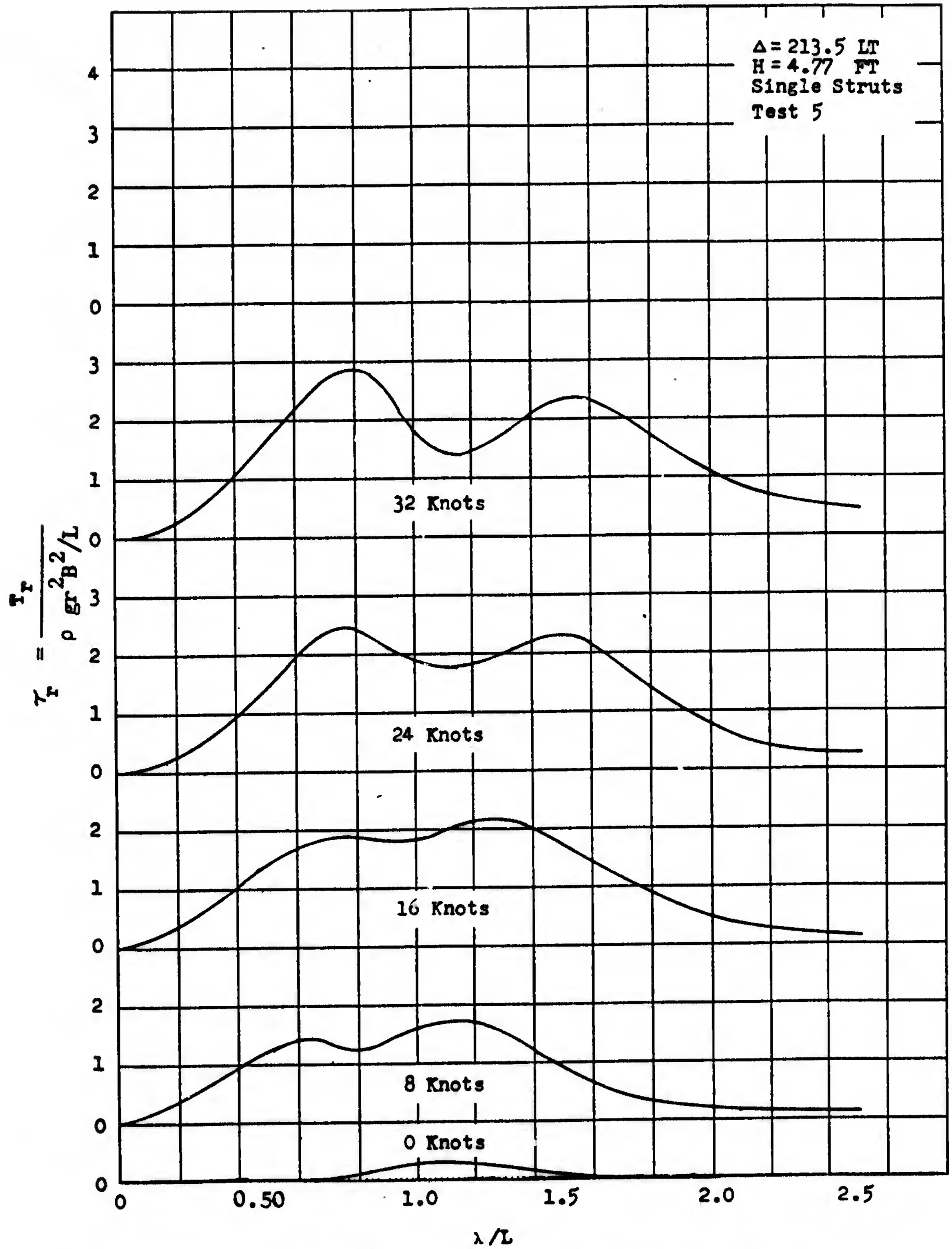

Figure 26 - Dimensionless Thrust Increase Due to Regular Waves from Model 4932 in Head Seas

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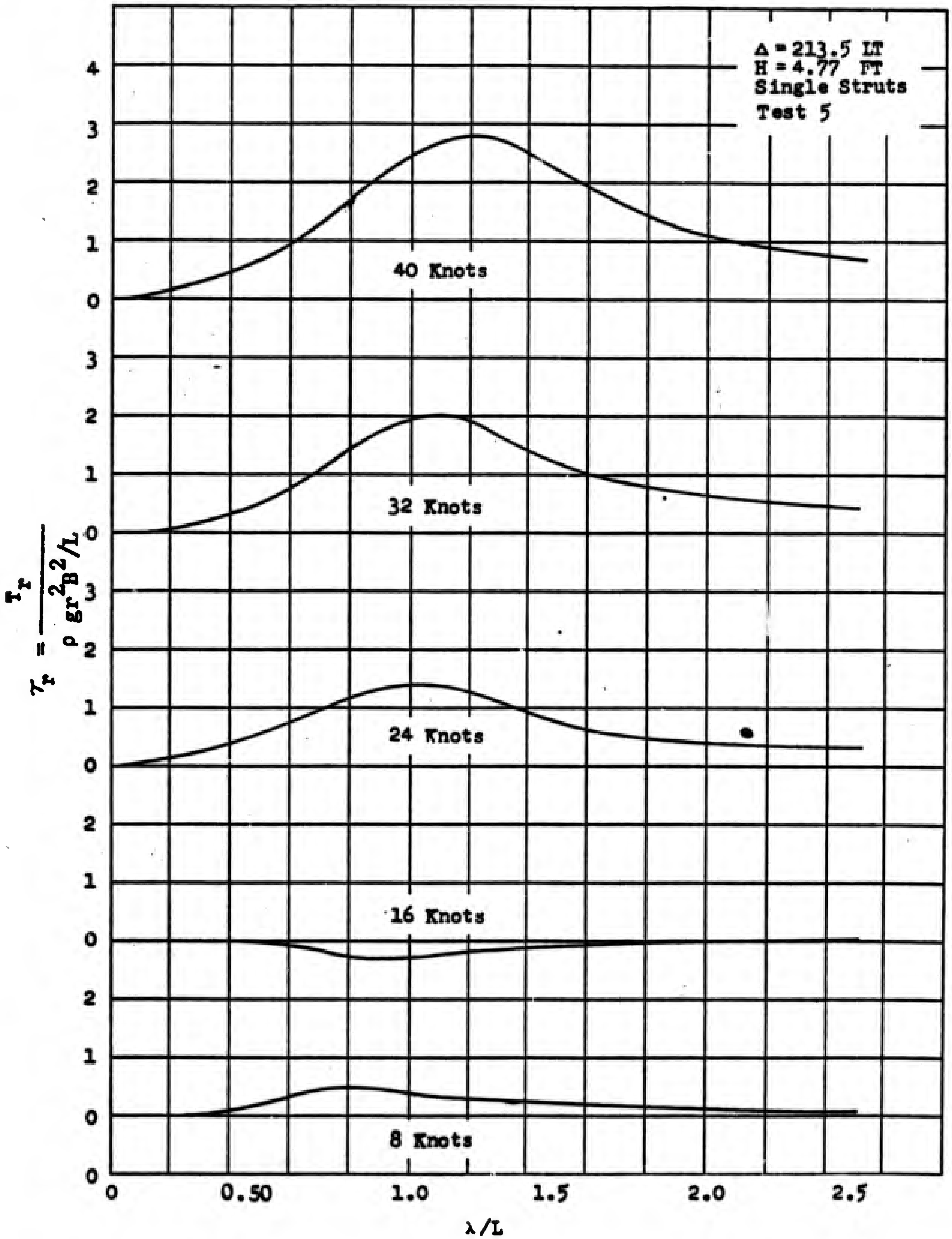

Figure 27 - Dimensionless Thrust Increase Due to Regular Waves from Model 4932 in Following Seas

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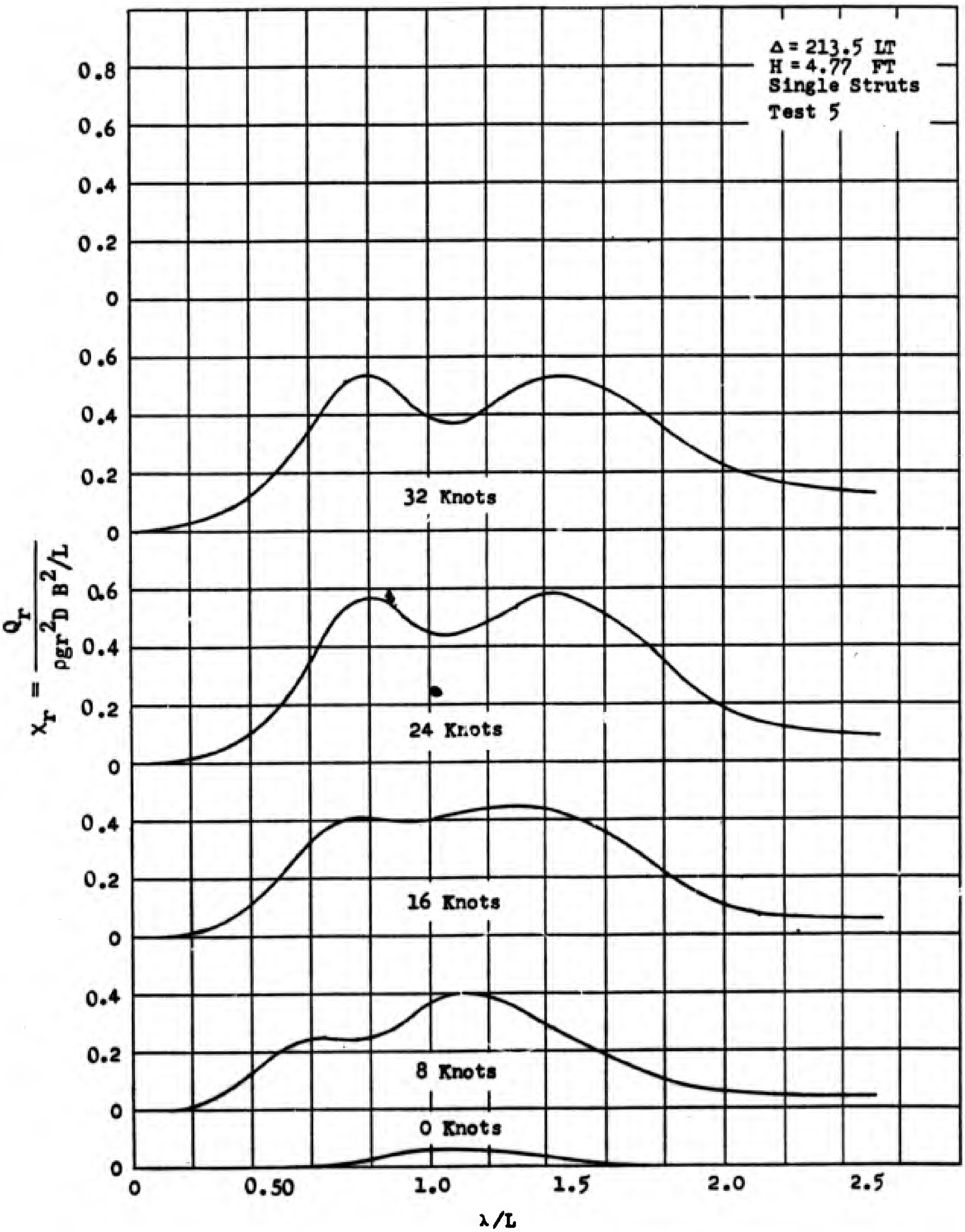

Figure 28 - Dimensionless Torque Increase Due to Regular Waves from Model 4932 in Head Seas

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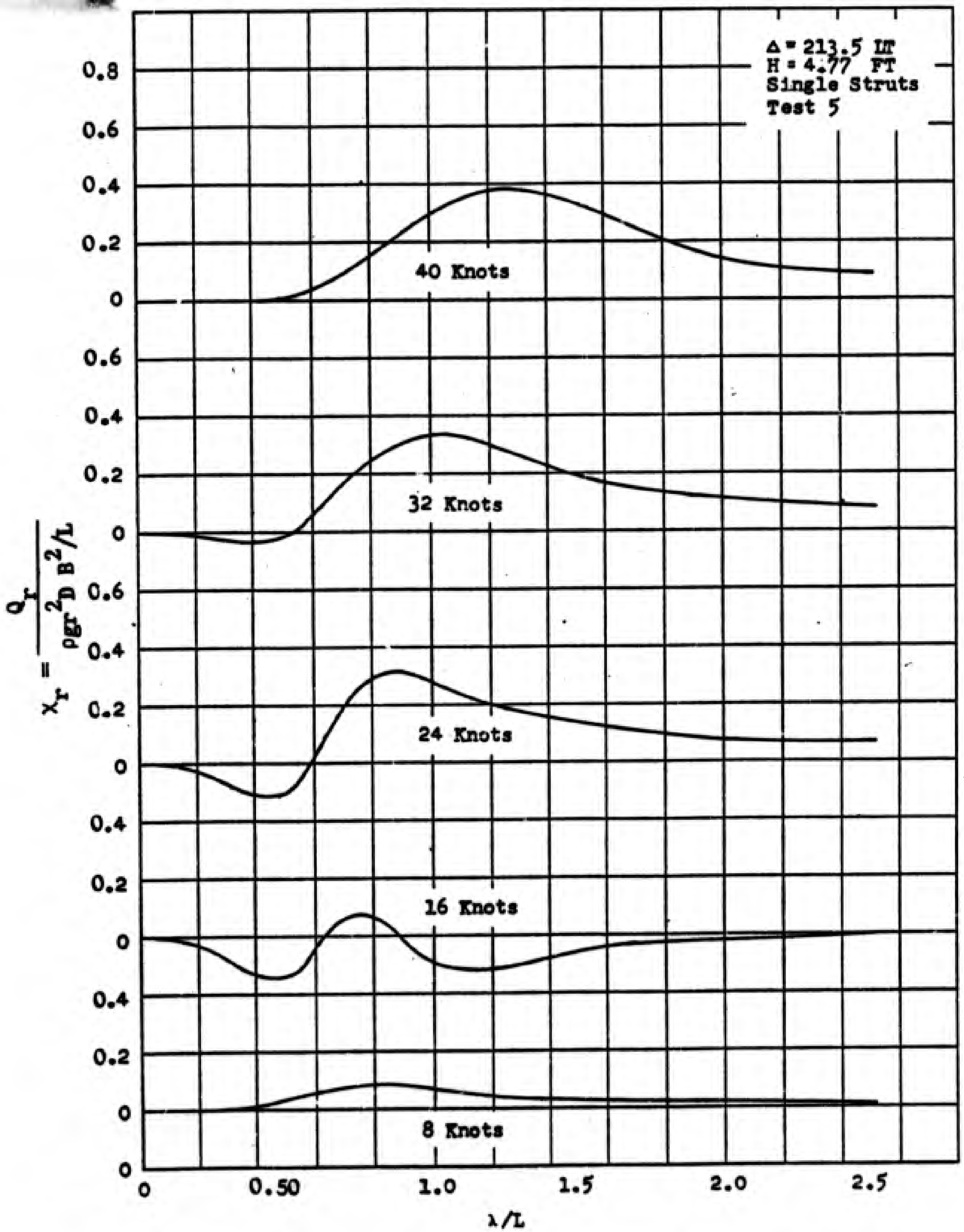

Figure 29 - Dimensionless Torque Increase Due to Regular Waves from Model 4932 in Following Seas

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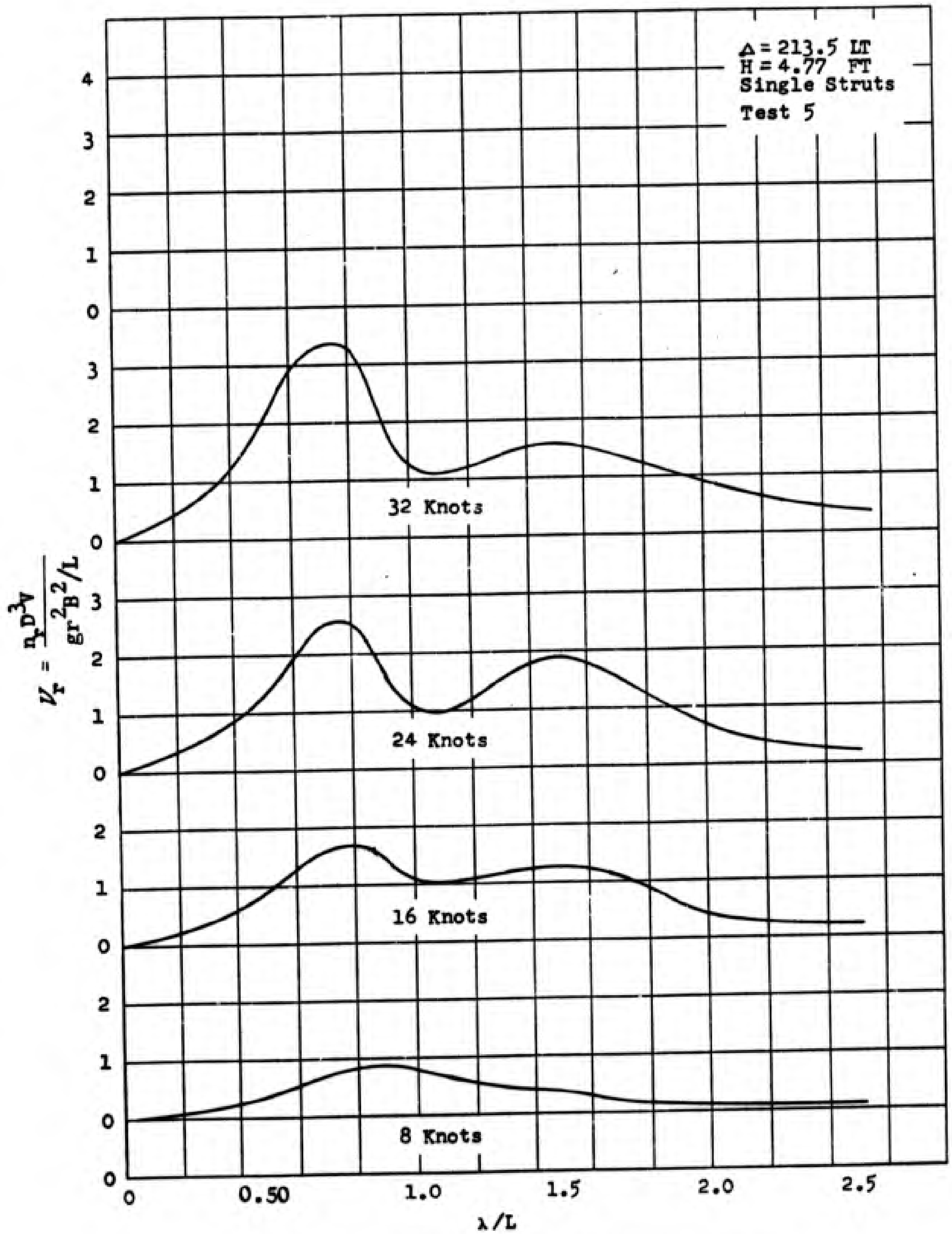

Figure 30 - Dimensionless RPM Increase Due to Regular Waves from Model 4932 in Head Seas

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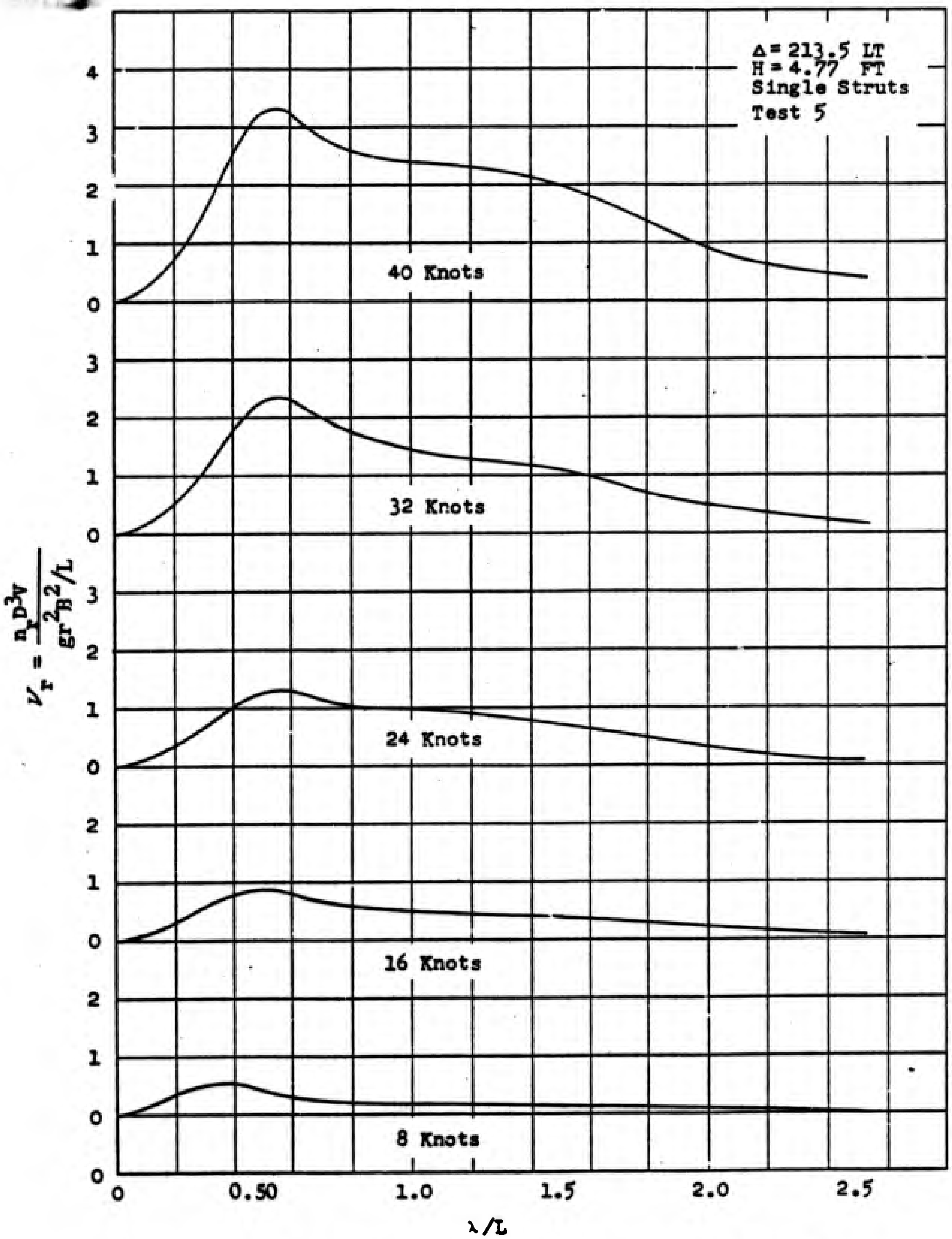

Figure 31 - Dimensionless RPM Increase Due to Regular Waves from Model 4932 in Following Seas

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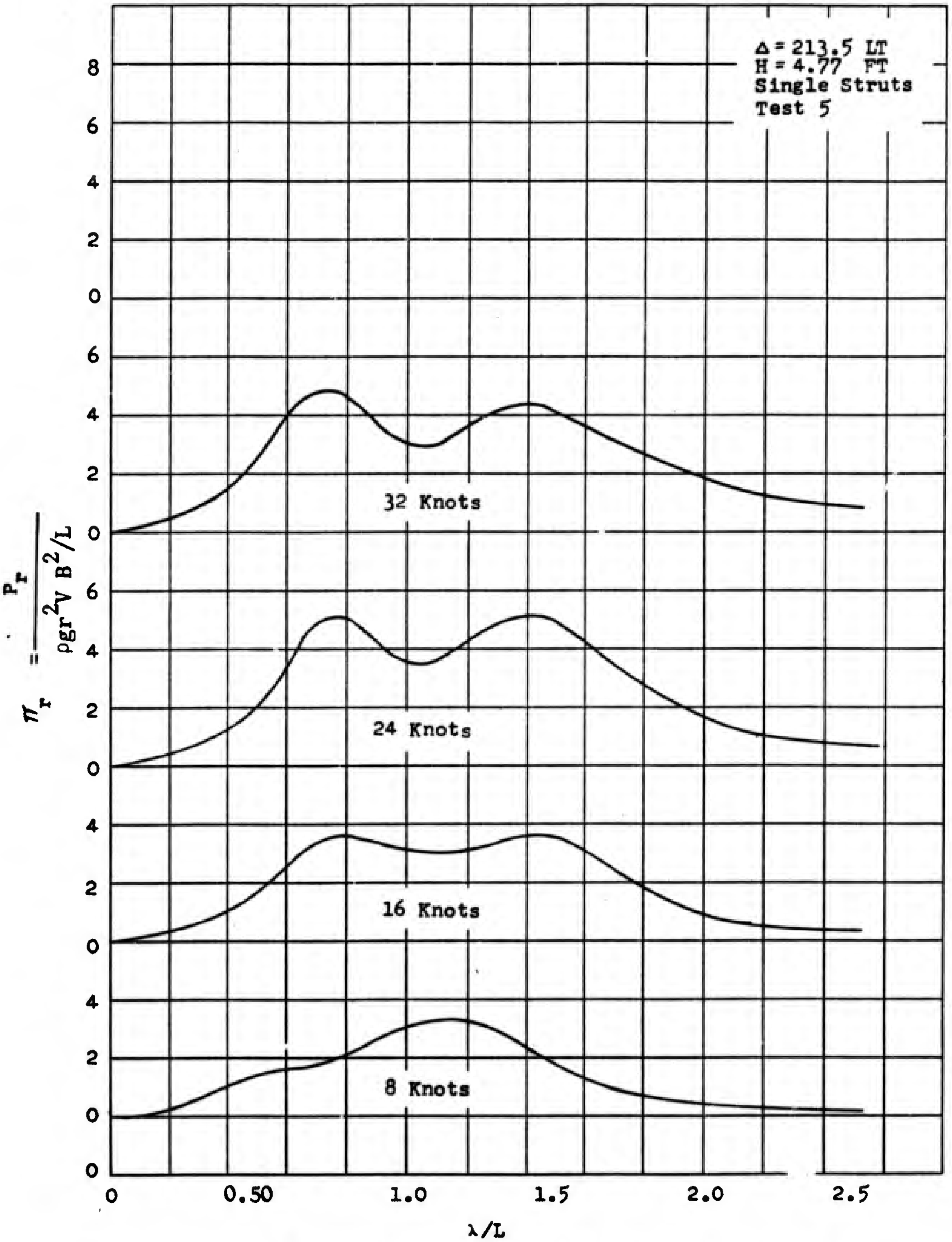

Figure 32 - Dimensionless Power Increase Due to Regular Waves from Model 4932 in Head Seas

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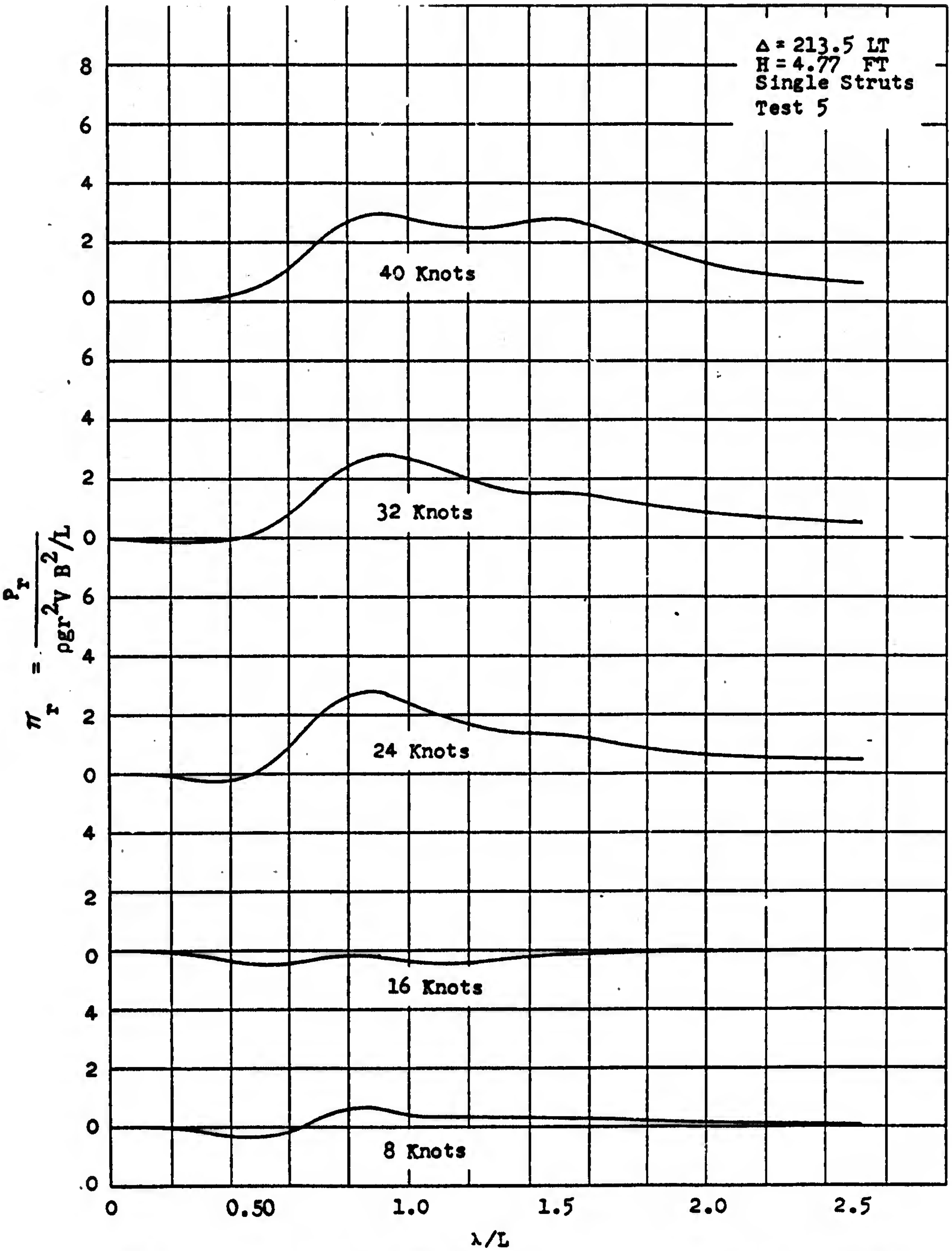

Figure 33 - Dimensionless Power Increase Due to Regular Waves from Model 4932 in Following Seas

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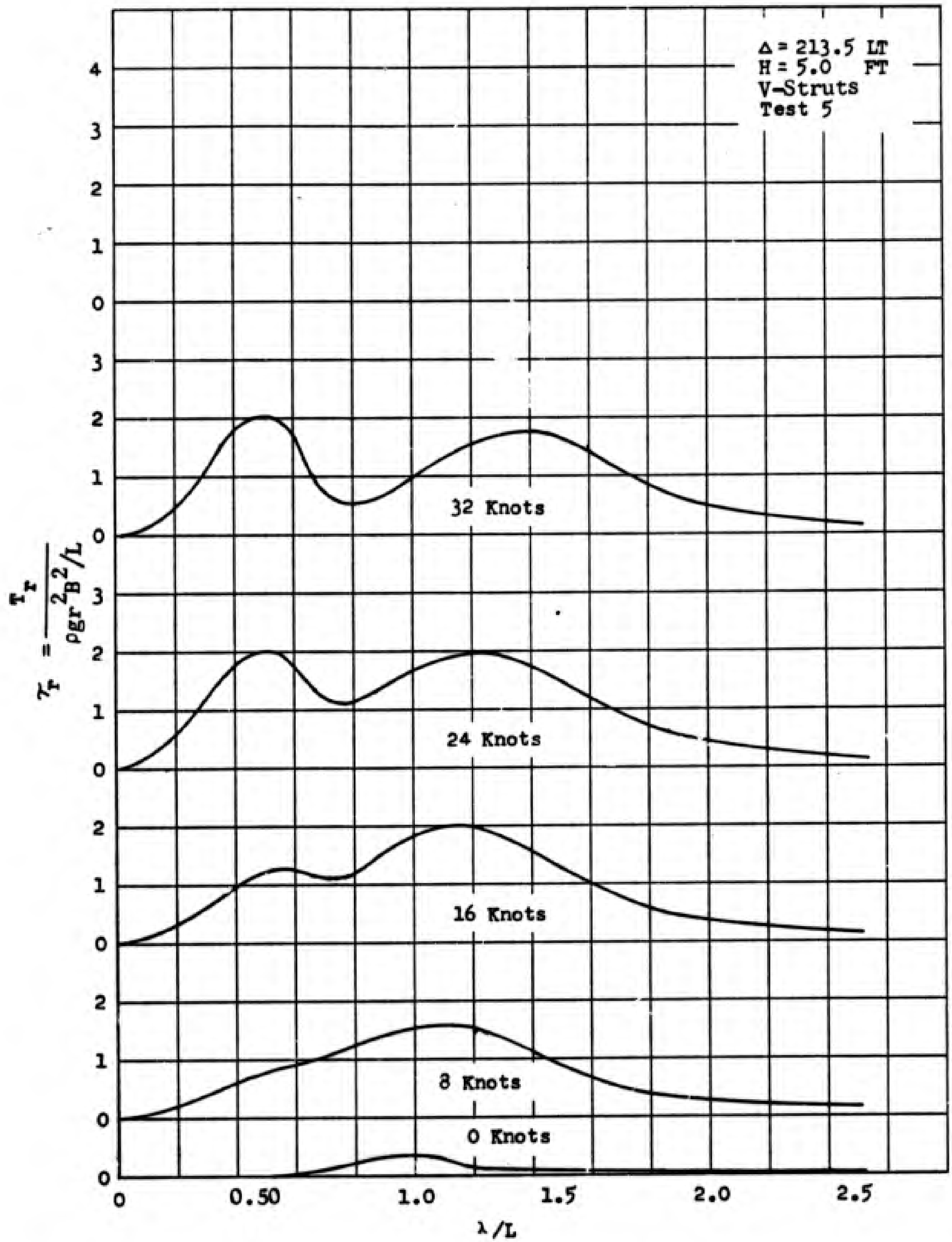

Figure 34 - Dimensionless Thrust Increase Due to Regular Waves from Model 4950 in Head Seas

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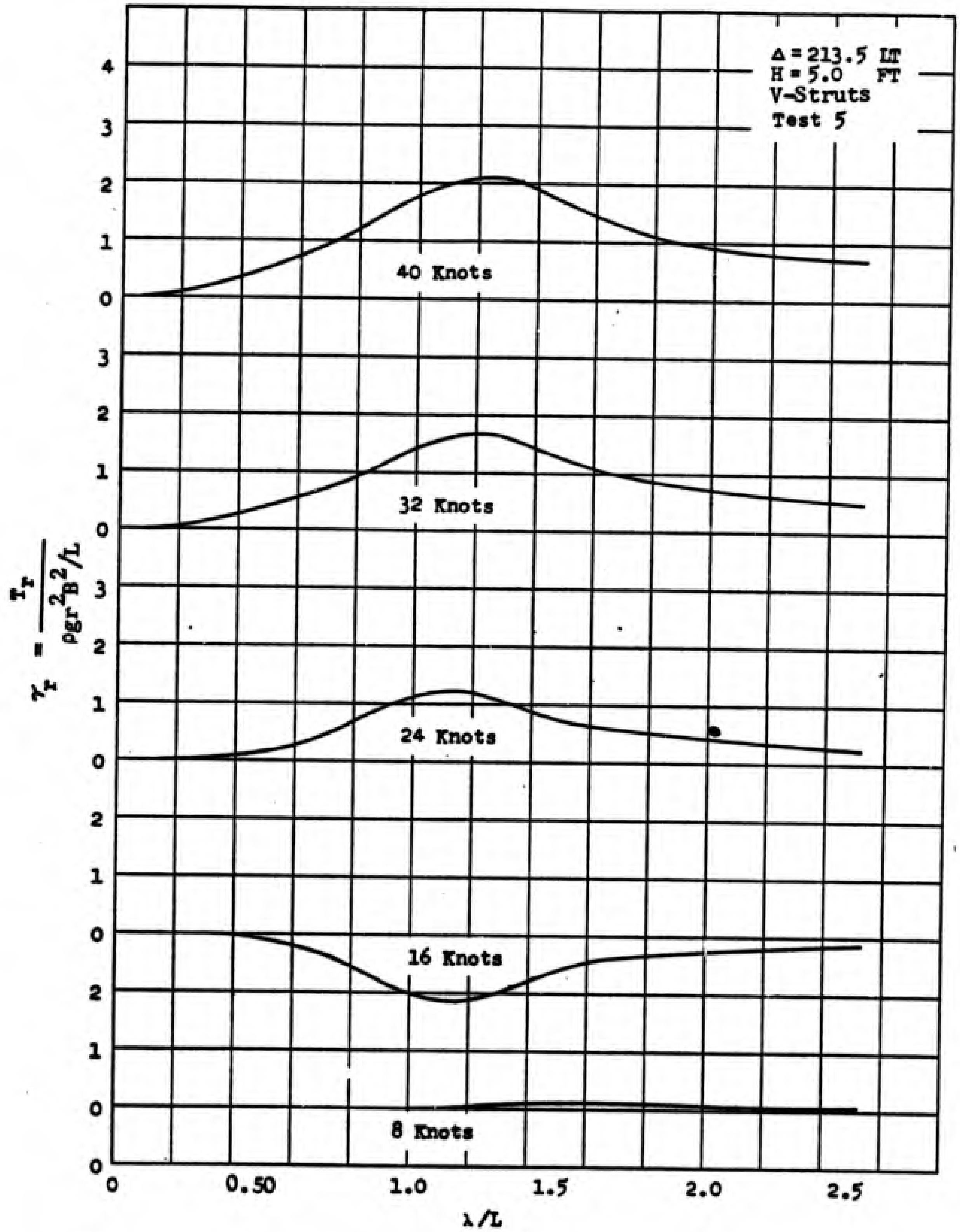

Figure 35 - Dimensionless Thrust Increase Due to Regular Waves from Model 4950 in Following Seas

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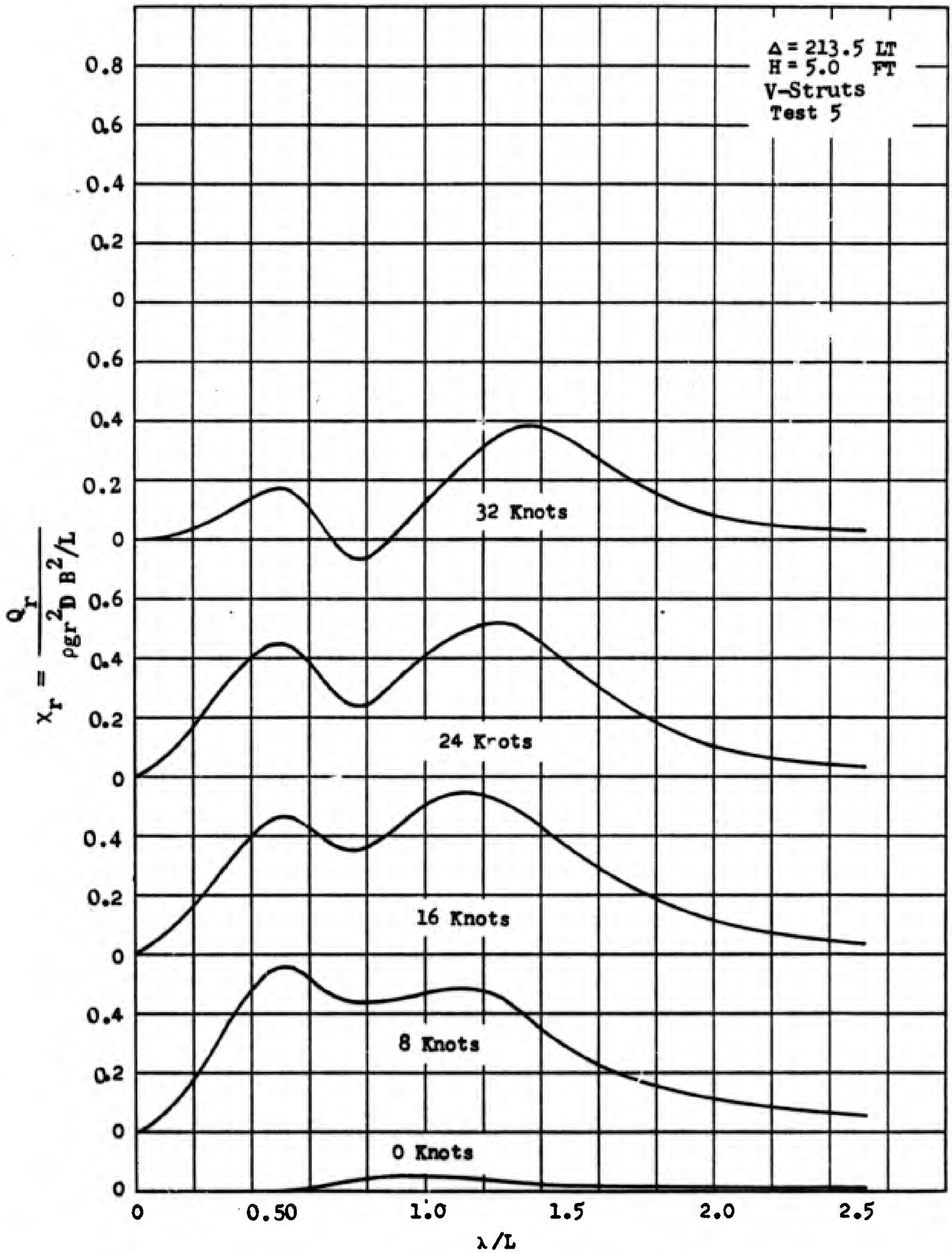

Figure 36 - Dimensionless Torque Increase Due to Regular Waves from Model 4950 in Head Seas

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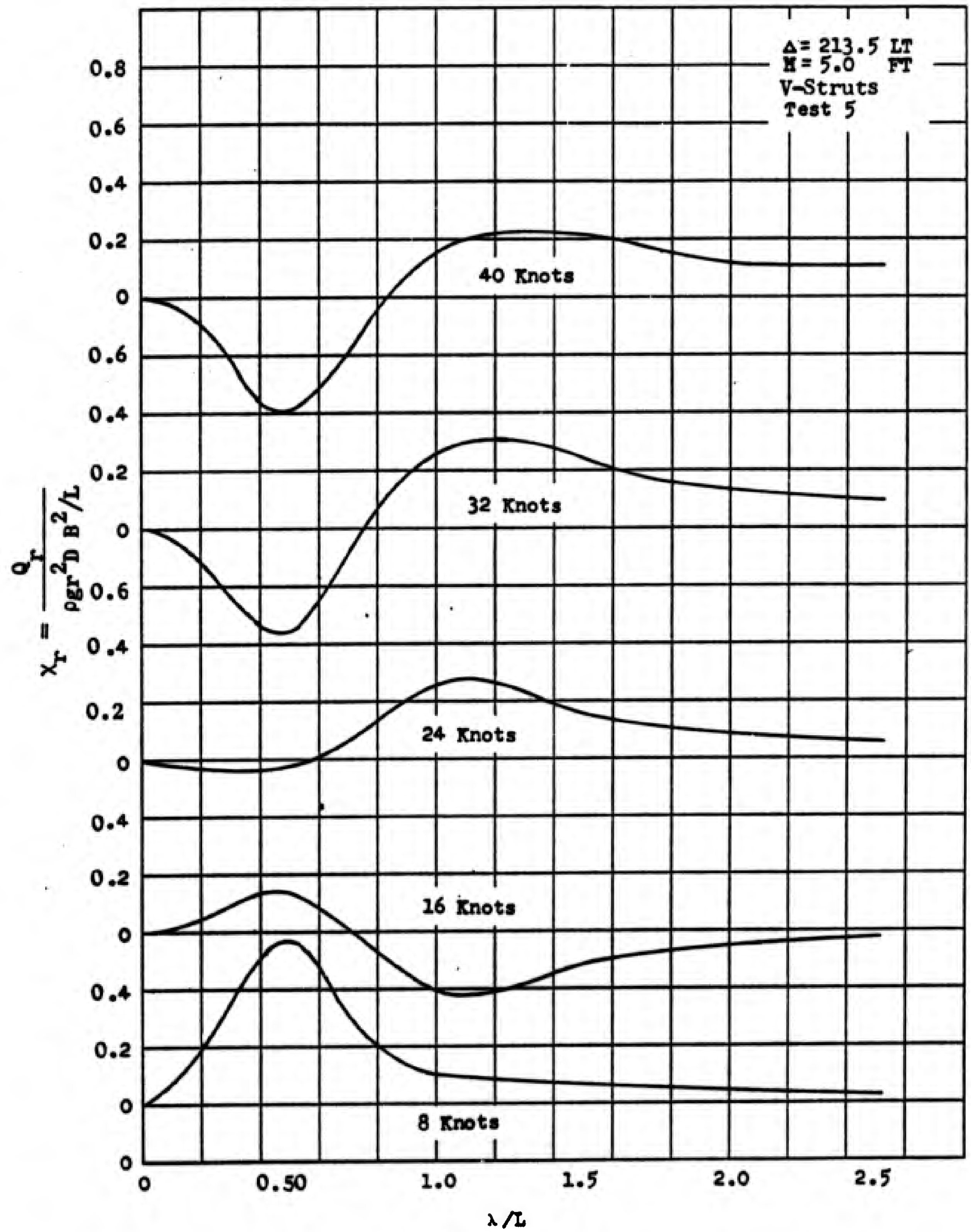

Figure 37 - Dimensionless Torque Increase Due to Regular Waves from Model 4950 in Following Seas

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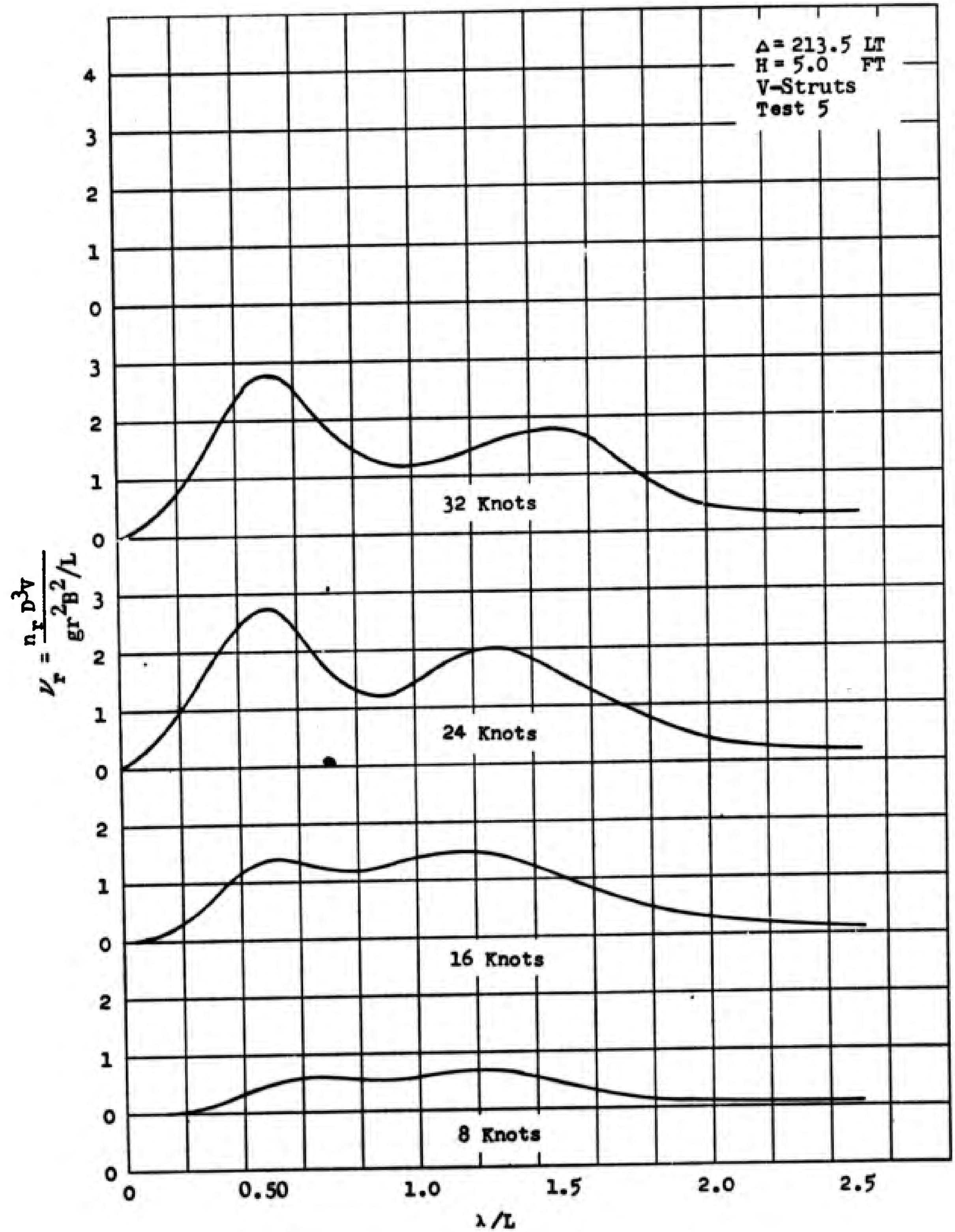

Figure 38 - Dimensionless RPM Increase Due to Regular Waves from Model 4950 in Head Seas

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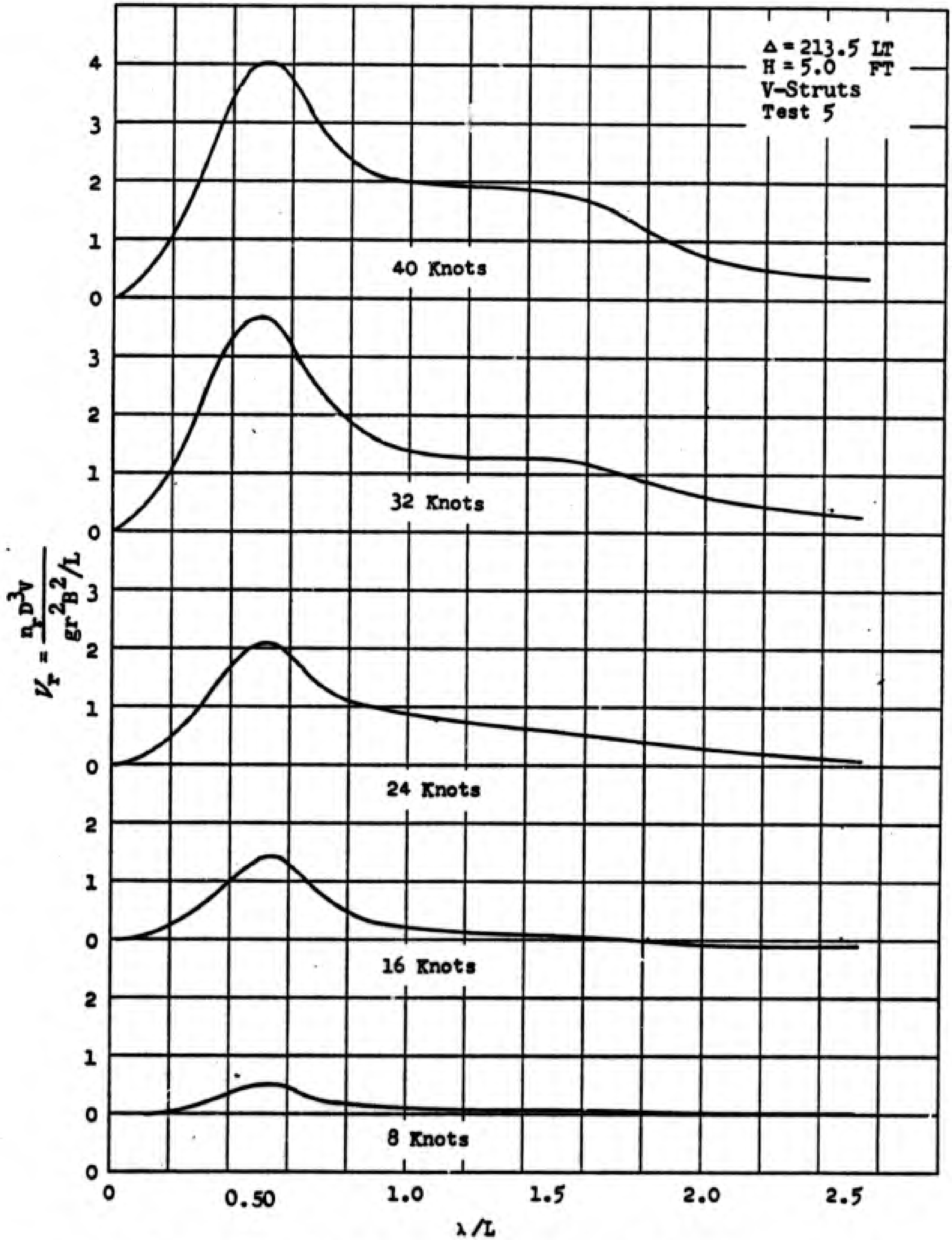

Figure 39 - Dimensionless RPM Increase Due to Regular Waves from Model 4950 in Following Seas

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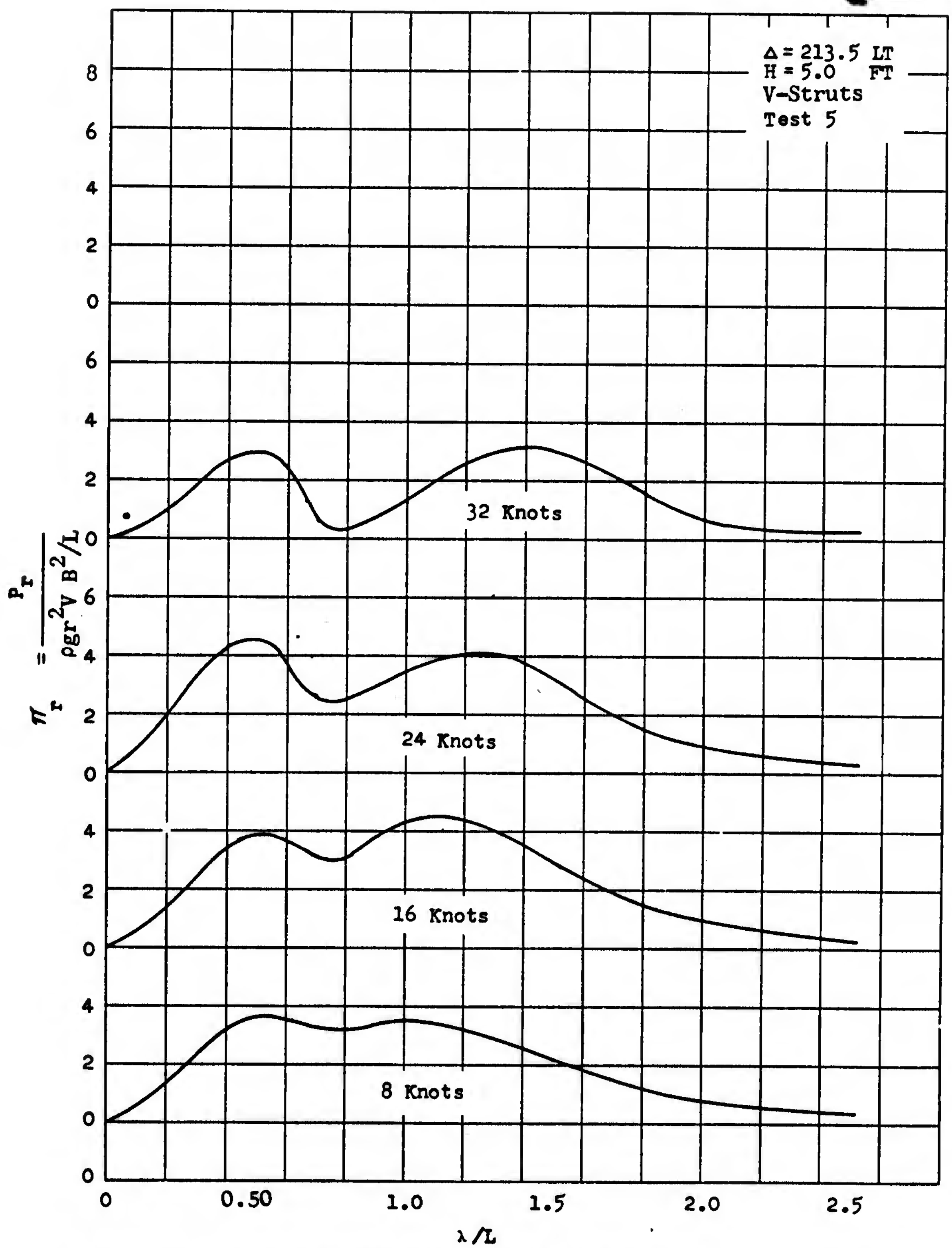

Figure 40 - Dimensionless Power Increase Due to Regular Waves from Model 4950 in Head Seas

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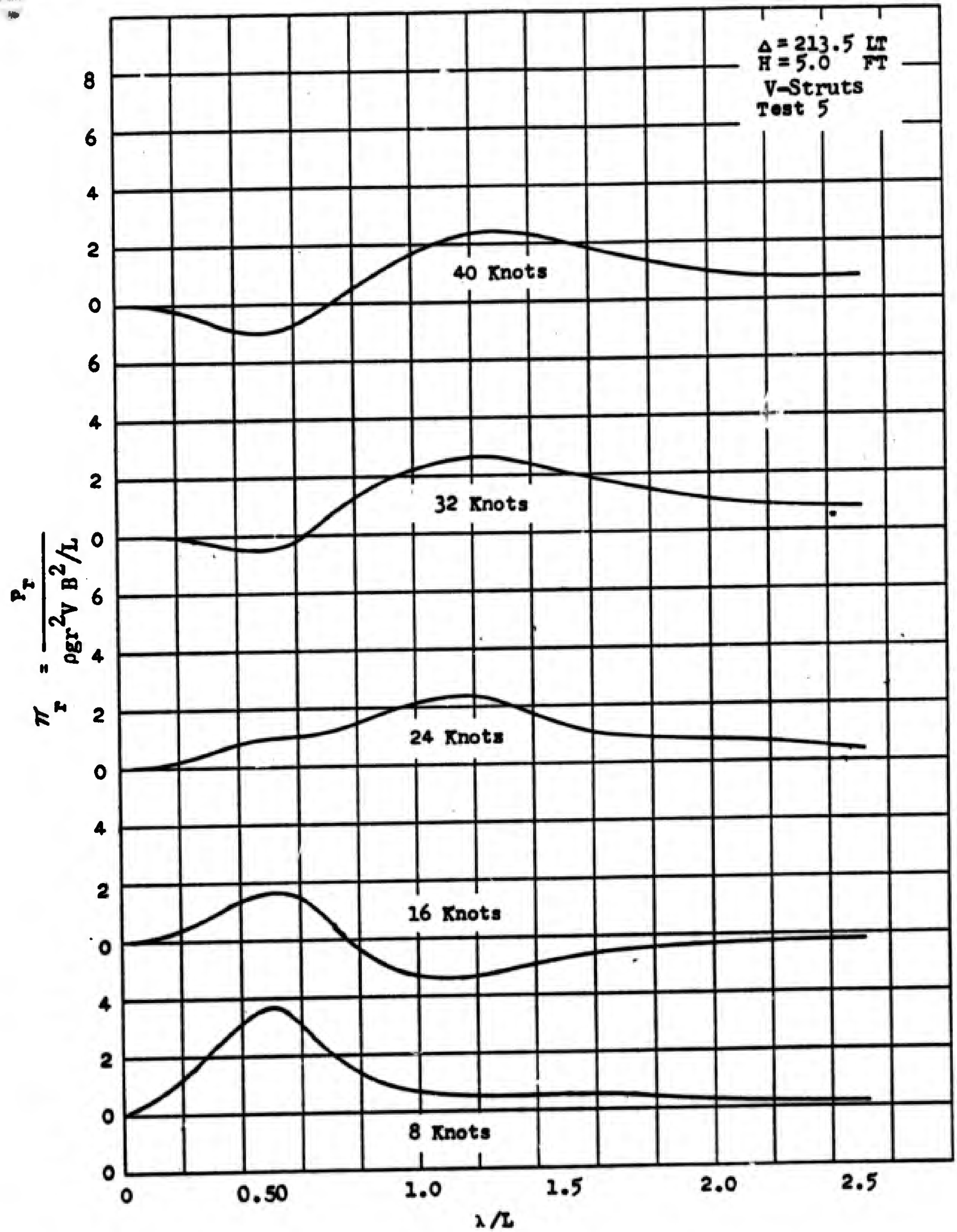

Figure 41 - Dimensionless Power Increase Due to Regular Waves from Model 4950 in Following Seas

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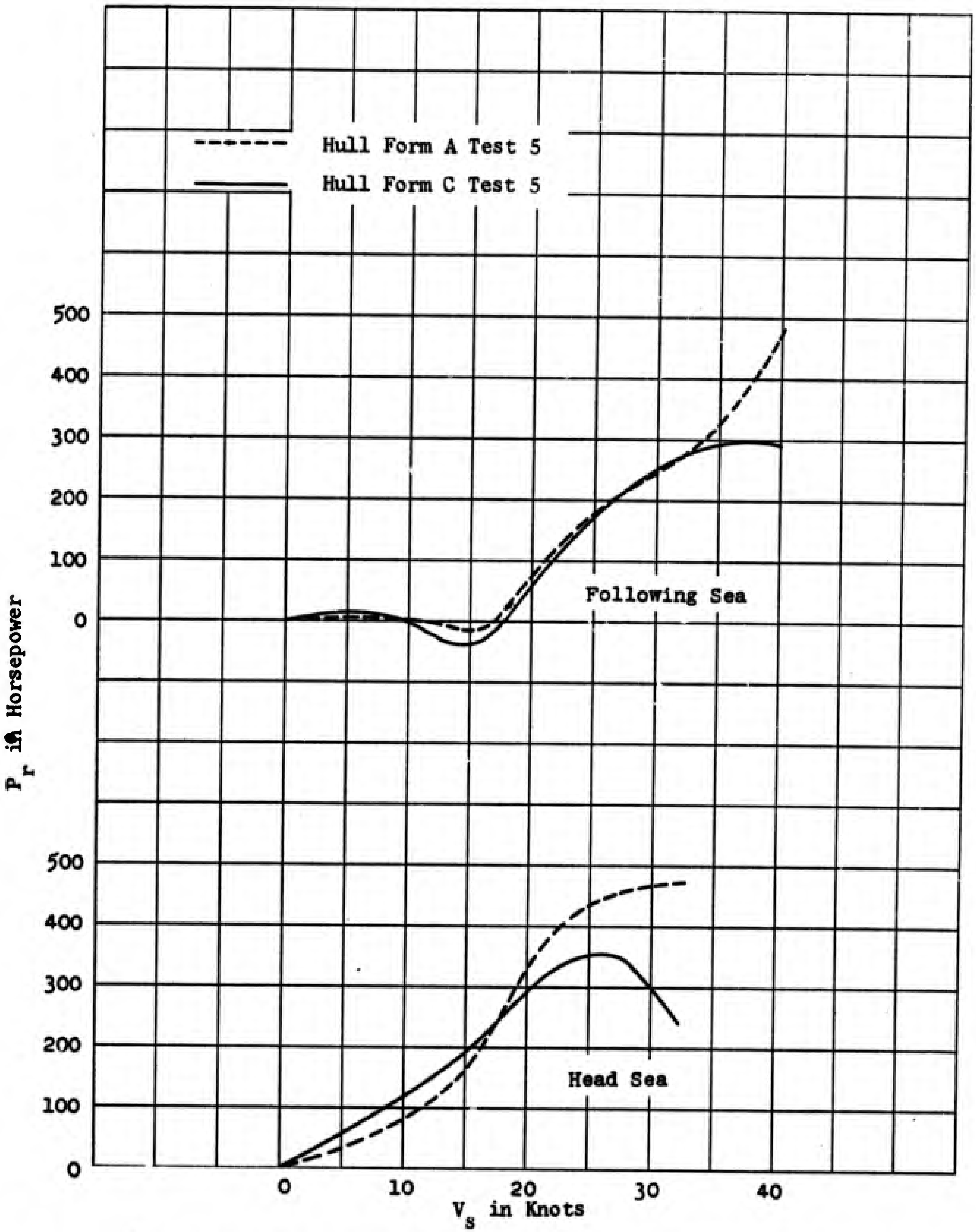

Figure 42 - Increase in SHP Due to a State 5 Neumann Spectrum Sea

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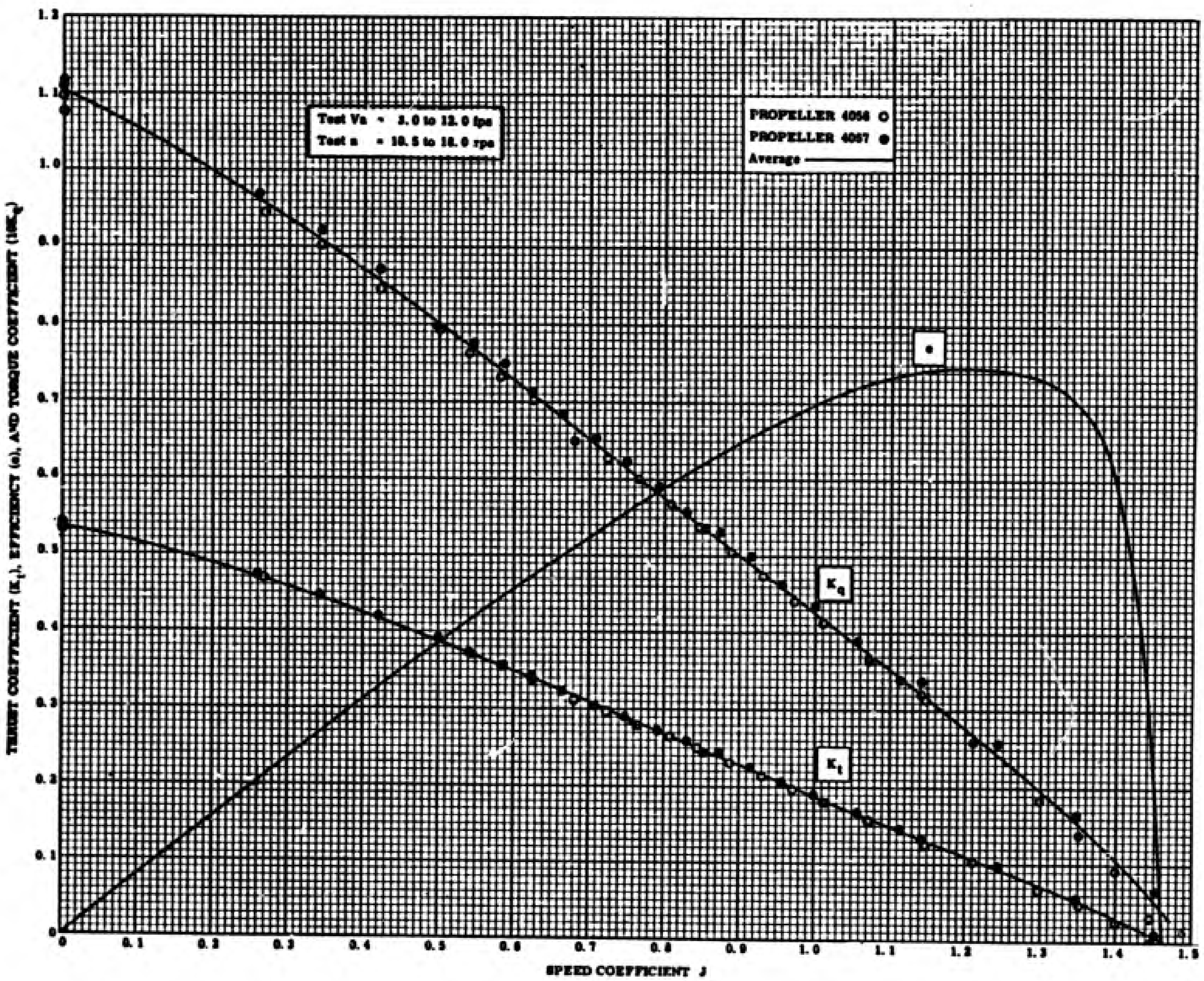

Figure 43 - Open Water Tests of Propellers 4056 and 4057

[redacted]

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11. Gerritsma, J., et al., "Propulsion in Regular and Irregular Waves," International Shipbuilding Progress, Vol. 8, No. 82, pp. 235-247 (Jun 1961).

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POWERING CHARACTERISTICS FOR A 154-FOOT HIGH SPEED PGM FROM TESTS OF MODELS 4932, 4942, and 4950 (U) by David R. Hoekzema. Apr 1964. iii, 51p. illus., graphs, tables, refs. [redacted]

Three models representing two Bureau of Ships designs and a David Taylor Model Basin design for a proposed 154-ft PGM were tested for resistance and propulsion characteristics. One of the BuShips designs was canceled from the test program after initial bare hull effective horsepower tests. Of the remaining two, the TMB design proved the better in both still water and waves. Significant improvements were made in the performance of the TMB design by the addition of transom wedges. Also of considerable value was the installation of TMB-designed

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3. Gunboats--Lines of flow--Model tests
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[redacted]

appendages incorporating a single contraflow strut behind the propeller supporting both the propeller shaft and the rudder.

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appendages incorporating a single contraflow strut behind the propeller supporting both the propeller shaft and the rudder.

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