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Report No. 8

THE EFFECT OF BULBOUS BOW RETROFITS ON THE RESISTANCE AND SEAKEEPING OF A 50 METER FRESHFISH STERN TRAWLER

by
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and
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30 April 1985

Prepared for the Canadian Department of Fisheries and Oceans
Halifax, Nova Scotia

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Introduction:

This report describes the research conducted at MIT on bulbous bow retrofits applied to a Canadian trawler 50 meters in length. This is the third vessel in a series of three trawler hulls included in a larger study. The results from the other trawlers are presented in a recent Master's Thesis by Heliotis(1).

The most significant part of the thesis and this report is the ship model towing tank results. Experimental data and analyses are supplemented by results from the MIT 5-D Ship Motions Program(2) and results from a resistance regression model by Holtrop(3) as implemented on computer by Sedat(4).

The lines drawing of the 50 meter trawler(5) was provided by the Canadian Department of Fisheries and Oceans together with information on the propulsion and operation of the vessel in its present fishery. A 4.5' model of the hull was constructed and a series of 12 bulbous bow retrofits were prepared.

Calm water model resistance tests were conducted on the bare hull and then with each retrofitted bulb. All tests were done at constant draft, i.e., the bulb configurations were of heavier displacement than the original hull. The calm water results were compared and a "best" bulb was selected for seakeeping tests. The bare and bulbous models were tested in regular waves over a range of wave lengths at both steaming and trawling speedsw Pitch, heave, bow accelerations, and resistance were measured. These results are compared with the 5-D program predictions.

All bulbs were fitted to the maximum limits of the forward draft and a regression model was used to explore the effects of varying the vertical bulb location. Propeller calculations were then used to predict the effect on BHP requirements based on the performance of the best bulb.

Model Construction:

The available lines drawing included only the water lines and buttock lines. From these a section drawing was prepared as shown in Figure 1.

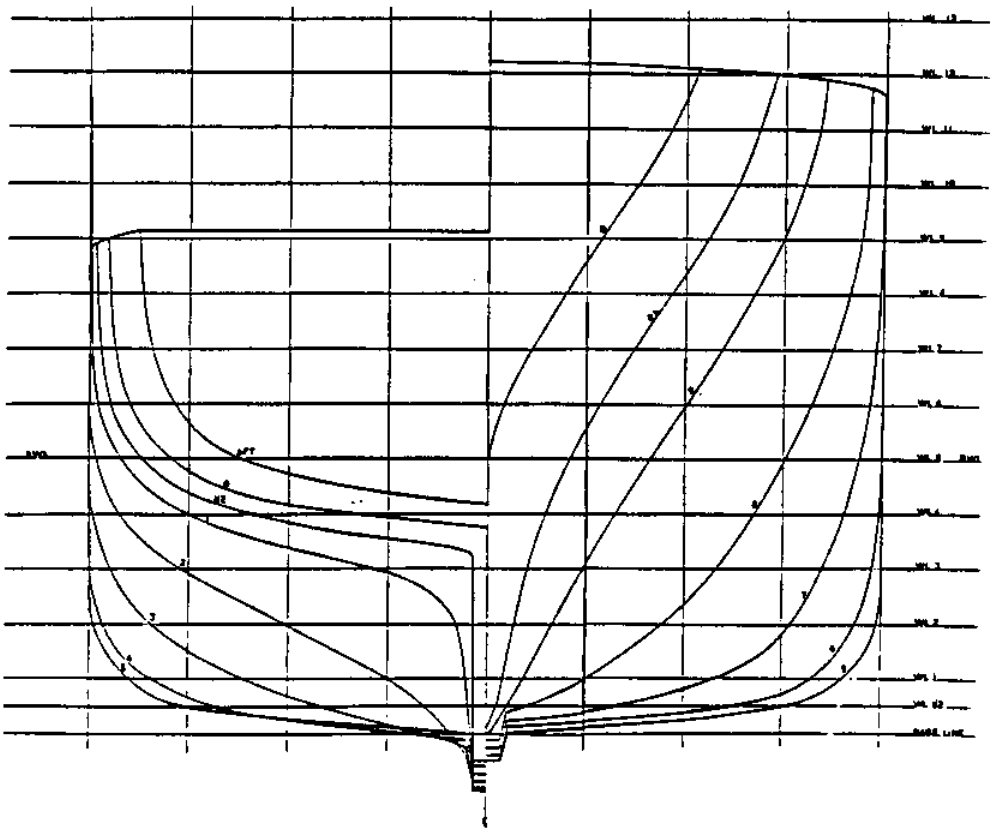

Figure 1. Section drawing of the 50m freshfish stern trawler

These drawings were photographically reduced to yield an image of 4.5' overall length. Sea Tech Inc., of Hingham, Massachusetts was contracted to construct the model from clear pine using these reduced drawings. The hull was laminated from planks planed to the thickness of the waterline spacing. To allow for ballasting, the hull is hollow but with a minimum wall thickness of 1.0 inches. A strip of 0.030" walnut veneer was rabbeted-in along the design waterline. After sanding to specified tolerances and fairness, the hull was finished with multiple coats of marine varnish. The scale ratio of the model was 35.62 to 1.

The bulb retrofits studied were cylindrical with hemispherical caps. This geometry was selected due to its potential economy of full-size fabrication and reports of some success with this type of bulb on the U.S. West Coast(6). The parameters varied were diameter and length. All bulbs were positioned with their lower edge even with the intersection of the forward perpendicular and an extension of the bottom of the keel.

Three bulb diameters were used to cover a range of possible sizes from 10 to 30 percent of the midship section area. The same bulb retrofits used during the earlier trawler experiments were used on this model. These were 2", 3.5", and 4.5" in diameter and for this hull the actual bulb percentages were 9, 18.5, and 30.3, respectively. In most cases throughout this report, they are referred to simply as 10, 20, and 30 percent bulbs.

The hemispherical caps were machined on a numerically controlled lathe from PVC round bar. Transition pieces were constructed from PVC tubing to attach the caps to the hull. Lengthening rings of 0.5, 1.0, and 1.5 diameters were prepared to allow for variation of bulb length. Each retrofit component was designed to be a press-fit with its neighbor. The transition pieces were accurately fitted to the hull and a thin application of silicone caulk at each joint was all that was needed to keep the bulbs in place and watertight. A description of each bulb is presented in Table 1. Figures 2 through 5 are photos of the retrofitted model during the testing.

Bulb Description	Percent of A	Diameter (feet)	Length Fwd. of Stem(ft)	Submergence (feet)
10%	9.1	5.94	4.8	-7.0
10% - 0.5D	9.1	5.94	7.8	-7.0
10% - 1.0D	9.1	5.94	10.7	-7.0
10% - 1.5D	9.1	5.94	13.7	-7.0
20%	18.5	10.40	5.9	-2.5
20% - 0.5D	18.5	10.40	11.1	-2.5
20% - 1.0D	18.5	10.40	16.3	-2.5
20% - 1.5D	18.5	10.40	21.5	-2.5
30%	30.5	13.37	6.7	+0.4
30% - 0.5D	30.5	13.37	13.4	+0.4
30% - 1.0D	30.5	13.37	20.1	+0.4
30% - 1.5D	30.5	13.37	26.7	+0.4

Table 1. Specifications of bulbs tested.

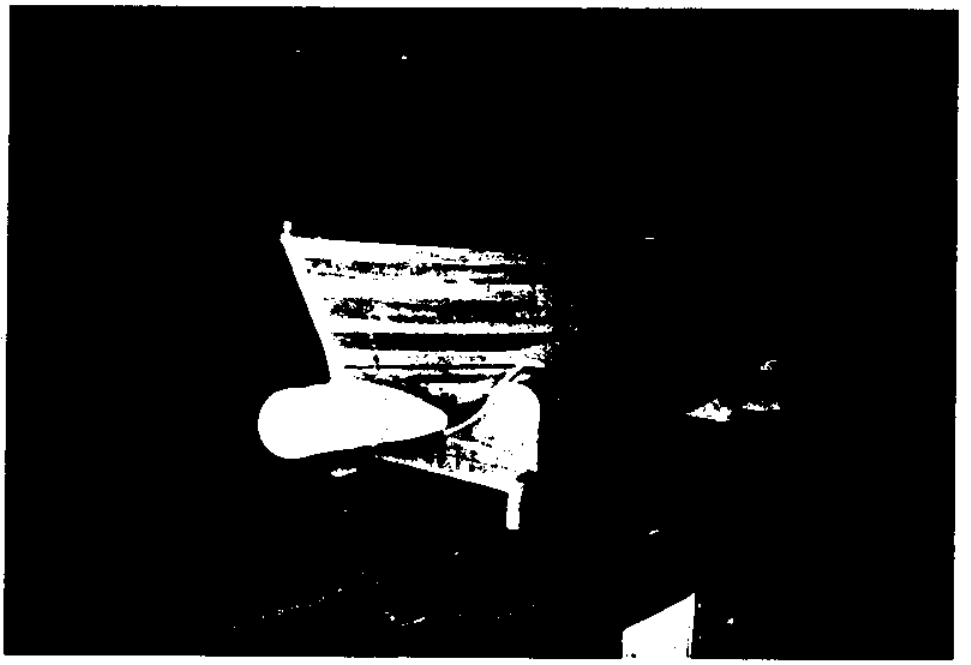

Figure 2. The 20% bulb with 0.5D ring.

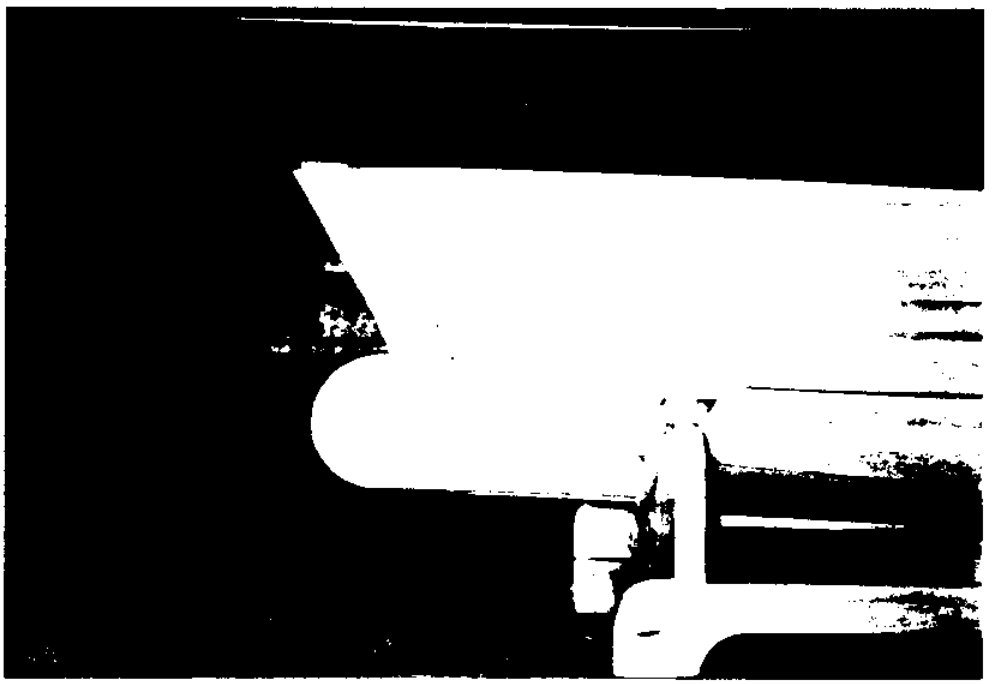

Figure 3. The 30% bulb with no rings.

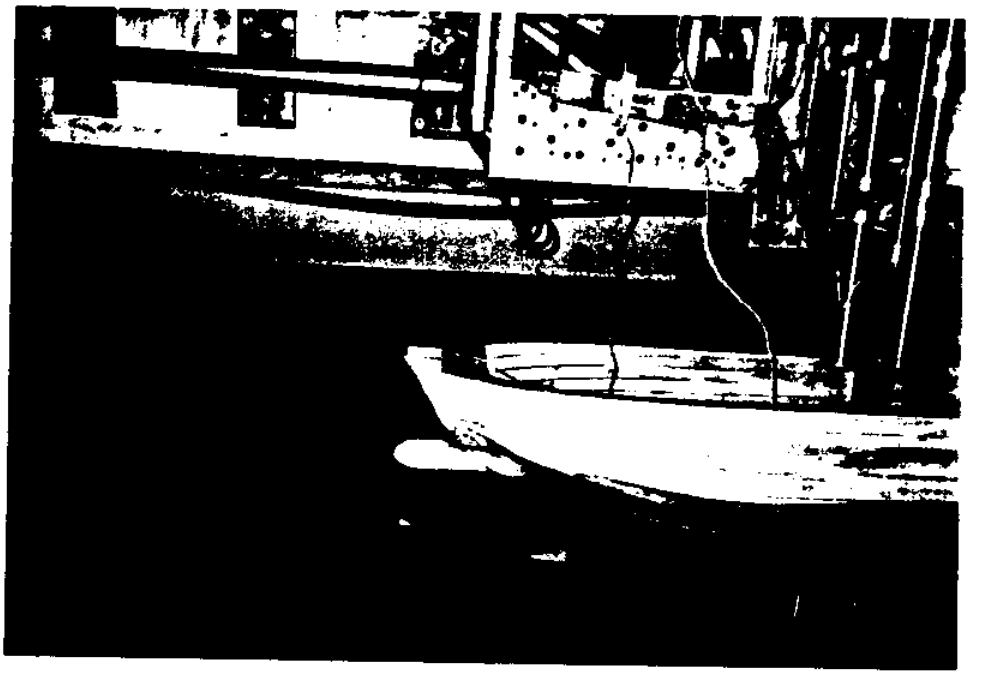

Figure 2. The 20% - 0.5D bulb during calm water tests.

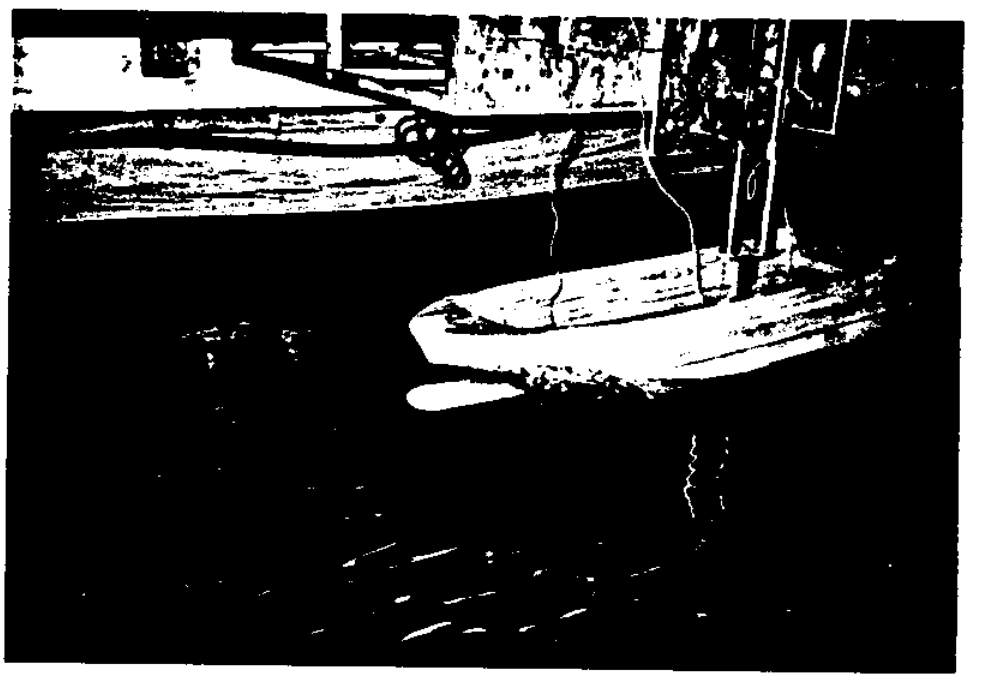

Figure 5. The 20% - 0.5D bulb during seakeeping tests.

Test Facility:

The MIT Ship Model Towing Tank is 108' long, 8' 7" wide, with a normal water depth of 4' (7). The towing carriage is instrumented for resistance and motions measurements. One end of the tank is fitted with a wave generator while the other end has a wave absorbing "beach". Regular waves and various sea spectra can be developed.

Test Procedure:

To insure a proper transition from laminar to turbulent flow, a row of turbulence stimulators was attached to the hull 4% of the LWL behind the stem. These were comprised of 0.125" diameter by 0.062" long studs spaced 0.25" apart. When the bulbs were attached, the row of studs were continued in a vertical line around the transition piece.

The base hull was floated in the tow tank and ballasted to its design water line. Lead billets were used and fixed in place with clay. The correct displacement was then verified by weighing the ballasted model.

The towing carriage force block was attached to the inside of the hull at the center of floatation, on the centerline, and in a vertical position such that the force applied to the model would be approximately in line with the location of the propeller shaft. The force block is designed to pivot about the pitch axis and is attached to air-bearing heave rods to allow for vertical motions. The model is restrained from roll, sway, yaw, and surge relative to the carriage.

The model was towed over a range of ship speeds from 3 to 15 knots. The order of speed selection was randomized and five minutes elapsed before commencing the next run or until all waves from the previous run dissipated. The actual speeds of each run are tabularized in Appendix A.

The procedure was repeated for each bulb retrofit. Ballast was added to the bow to counteract the buoyancy of the bulb. In some cases, the overall ballast arrangement had to be adjusted due to the forward location of the bulbs.

As noted in Table 1, the top surface of the 30% bulb was above the still waterline due to its size relative to the forward draft. At all towing speeds this bulb became submerged.

The seakeeping tests were done in a similar manner except that the placement of the ballast in the model was done to yield a longitudinal radius of gyration of 0.25 of the model length. Runs were made at ship speeds of 11.5 knots and 5.0 knots to represent reported steaming and trawling conditions. Wave lengths from 0.7 to 3.0 times LWL were generated. Wave heights were maintained at a constant 5% of the LWL.

Since the pitch and heave response of a trawler is clearly affected by the presence of the trawl gear during trawling, this effect was simulated during the tank tests. A parachute-type drogue with appropriate drag characteristics was towed from a point on the transom centerline at the main deck. This was kept submerged by a weight at the junction of the tow wire and the drogue. The weight was equivalent to the weight of two appropriately sized trawl doors and produced a vertical warp angle of approximatety 20 degrees. The set-up is diagrammed in reference 1.

Pitch motions, heave motions, bow accelerations, and wave height were recorded during each run. The accelerometer was located on the 01 deck at station 10 1/2.

Calm Water Results:

The model drag at each calm-water speed is presented in the tables of Appendix 1 together with the nondimensionalized values and the scaled-up results. These results are presented graphically in Appendix 2 where comparisons among the various bulb lengths are included.

Figure 6 shows the effect of bulb size on EHP for speeds of 10, 11.5, and 13 knots. Attempts to interpolate between the discrete bulb sizes should be discouraged, however the advantage of larger bulbs at higher speeds is evident.

To demonstrate more clearly the importance of operating speed on optimum bulb selection, the EHP changes for the three bulb diameters are presented versus speed in Figure 7. This reveals that the 20% bulb offers an advantage over the range of speeds above 4 knots. The 10% bulb is superior to the 20% bulb at the lower speeds, however above 10 knots its effect is diminished, becoming a detriment above 11.5 knots. The 30% bulb is a clear detriment at lower speeds due to its large wetted surface but offers an advantage above 11.5 knots. Above 13 knots and beyond the range of the graph, the 30% bulb is most beneficial.

In Figures 6 and 7, the best length bulb for each diameter is used in the comparisons. It can be seen in Appendix 2 that the effect of length variations is more important with the 20 and 30 percent bulbs. We should recall however that the length increments are based on diameter and the actual length variations of these larger bulbs were quite extreme (see Table 1).

To better visualize the effects of length, the results of the four 20% bulbs are shown in Figure 8 in terms of EHP changes relative to the bare hull. From this it can be seen that the 0.5 D. ring presents the greatest potential over the speeds of interest. Only the shortest version offers no benefits over the speed range covered.

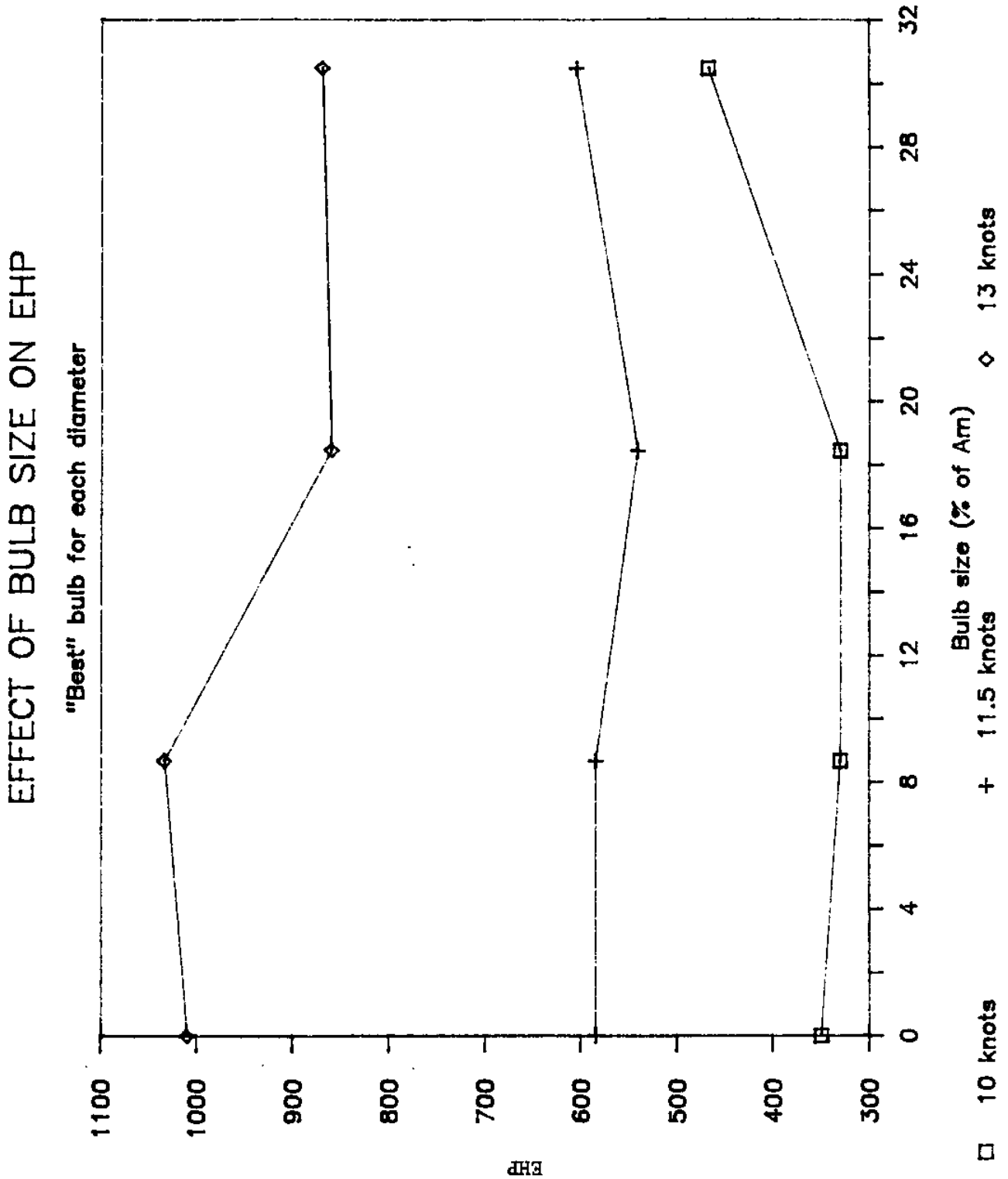
EFFECT OF BULB SIZE ON EHP
"Best" bulb for each diameter
EHP
1100
1000
900
800
700
600
500
400
300
0
4
8
12
16
20
24
28
32
Bulb size (% of Am)
10 knots
11.5 knots
13 knots

Figure 6

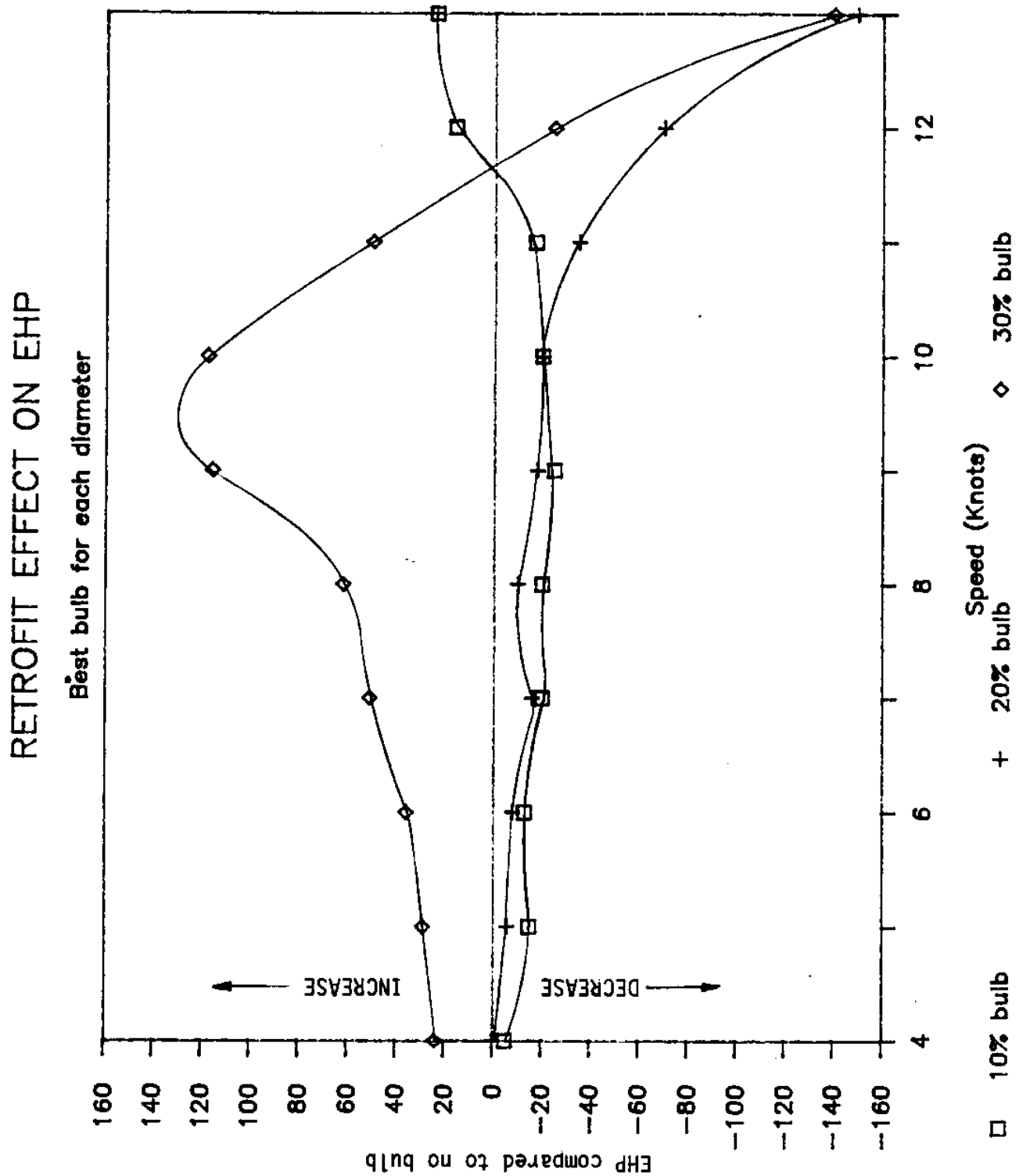
RETROFIT EFFECT ON EHP
Best bulb for each diameter
INCREASE
DECREASE
EHP compared to no bulb
160
140
120
100
80
60
40
20
0
-20
-40
-60
-80
-100
-120
-140
-160
4
6
8
10
12
Speed (Knots)
10% bulb
20% bulb
30% bulb

Figure 7

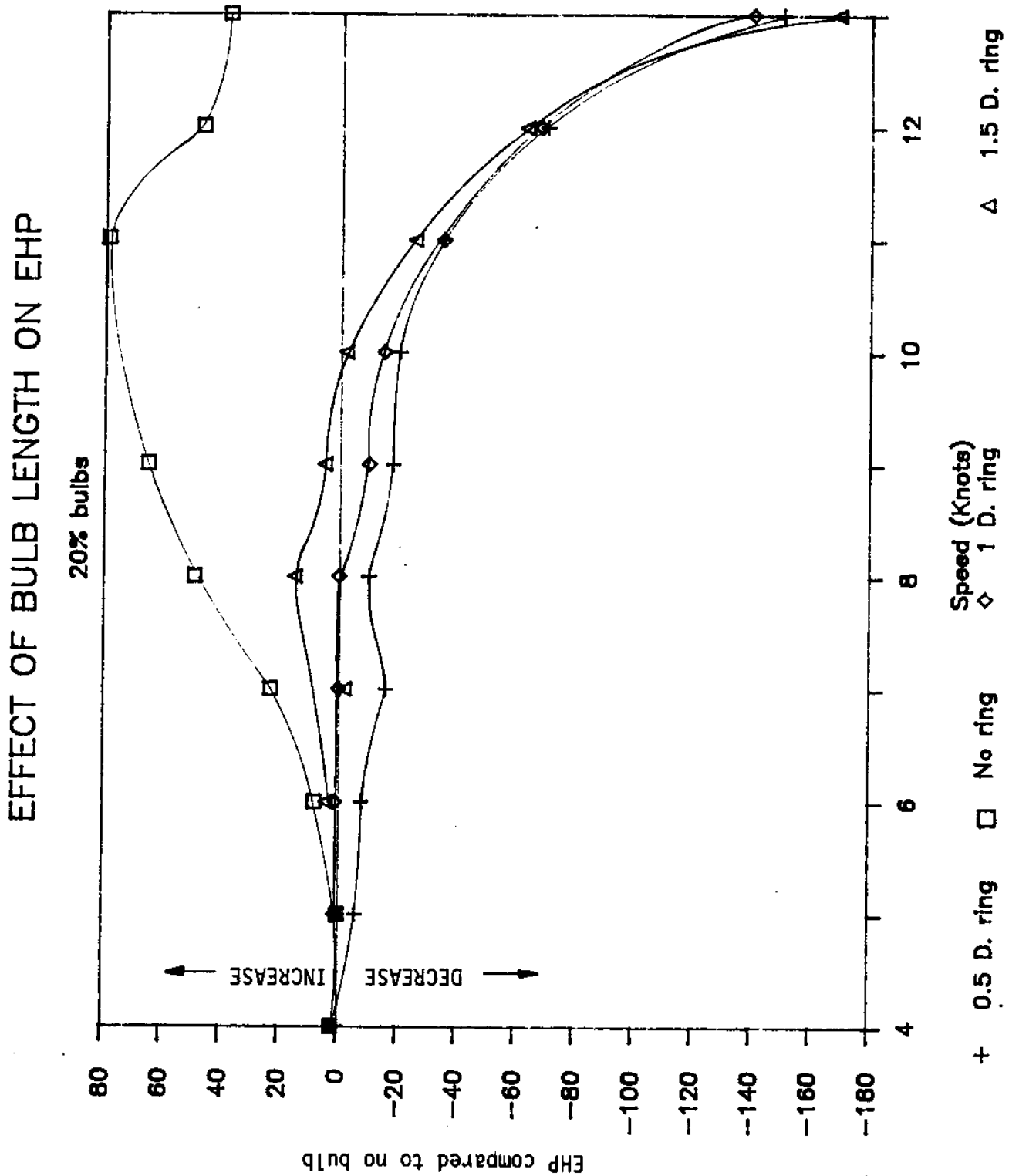
EFFECT OF BULB LENGTH ON EHP
20% bulbs
INCREASE
DECREASE
EHP compared to no bulb
80
60
40
20
0
-20
-40
-60
-80
-100
-120
-140
-160
-180
4
6
8
10
12
Speed (Knots)
+ 0.5 D. ring
□ No ring
◇ 1 D. ring
△ 1.5 D. ring

Figure 8

Regular wave Results:

From the recorded data the average pitch and acceleration responses were determined for each regular wave length. For the cruising speed, the non-dimensionalized pitch results are shown in Figure 9. Comparing the 20% bulb with the bare hull we can see the bulb's apparent effectiveness in reducing pitch at wave lengths less than two ship lengths. Above this point the bulb seems to be a disadvantage.

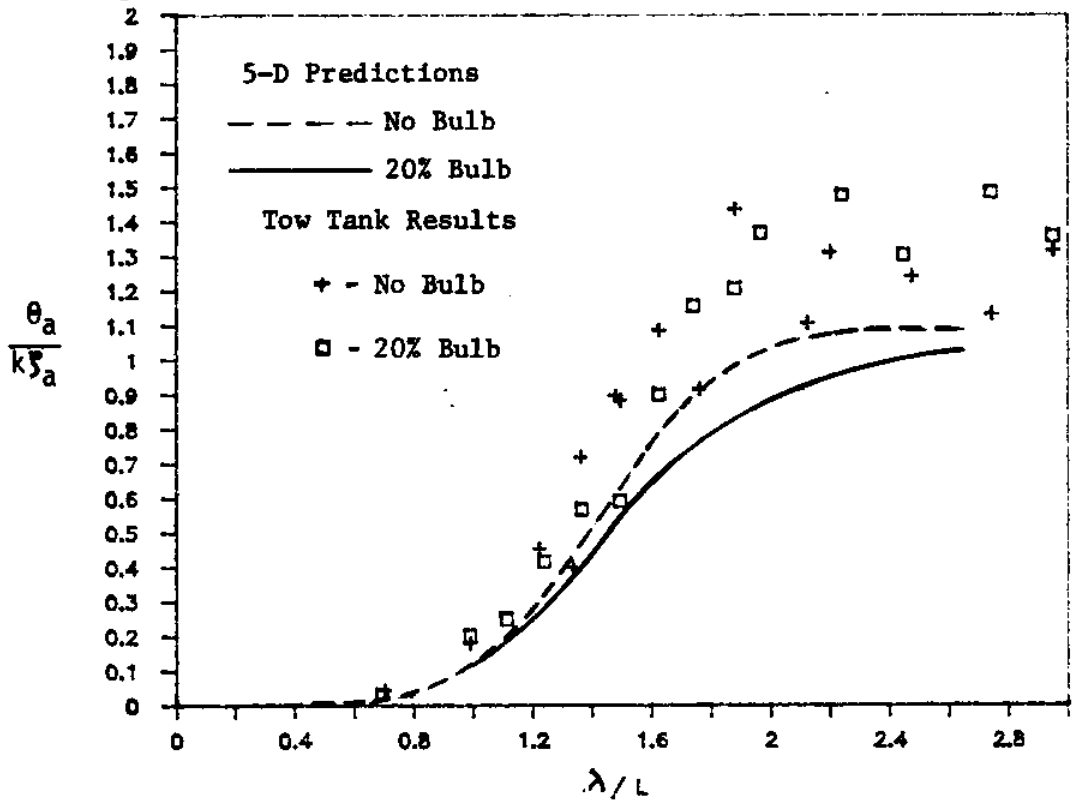

Figure 9. Pitch response at a cruising speed of 11.5 knots.

Figure 10 is a similar presentation of bow accelerations. The significance of the bulb is more evident since the higher frequencies associated with the shorter wave lengths are important with respect to accelerations and crew comfort.

As would be expected, the pitch response levels-off at the longer wave lengths as the vessel begins to simply follow the slope of the wave surface. The lower frequencies in this region cause the accelerations to diminish and little difference is found with the bulb.

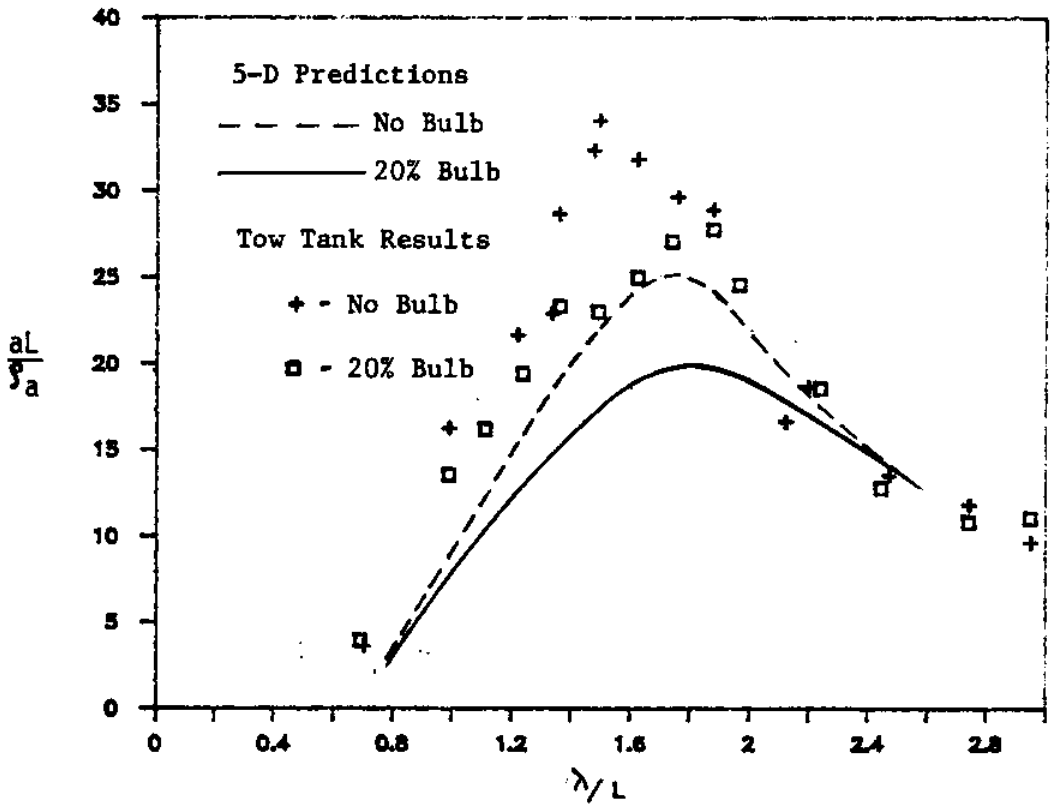

Figure 10. Vertical bow accelerations at 11.5 knots.

The results at a trawling speed of 3.0 knots are presented in Figures 11 and 12. Here the effect of the bulb, if any, is not evident. The presence of the trawl-simulating drogue causes the motions to become more complicated than would occur with the trawler alone. The frequent coincidence of bare and bulb data suggests an unusual system response which is not effected by minor changes in the hull form.

We are unaware of any previous experiments of this type other than those reported in the thesis by Heliotis(1). Trawl interaction with vessel motion is an area where research is obviously needed.

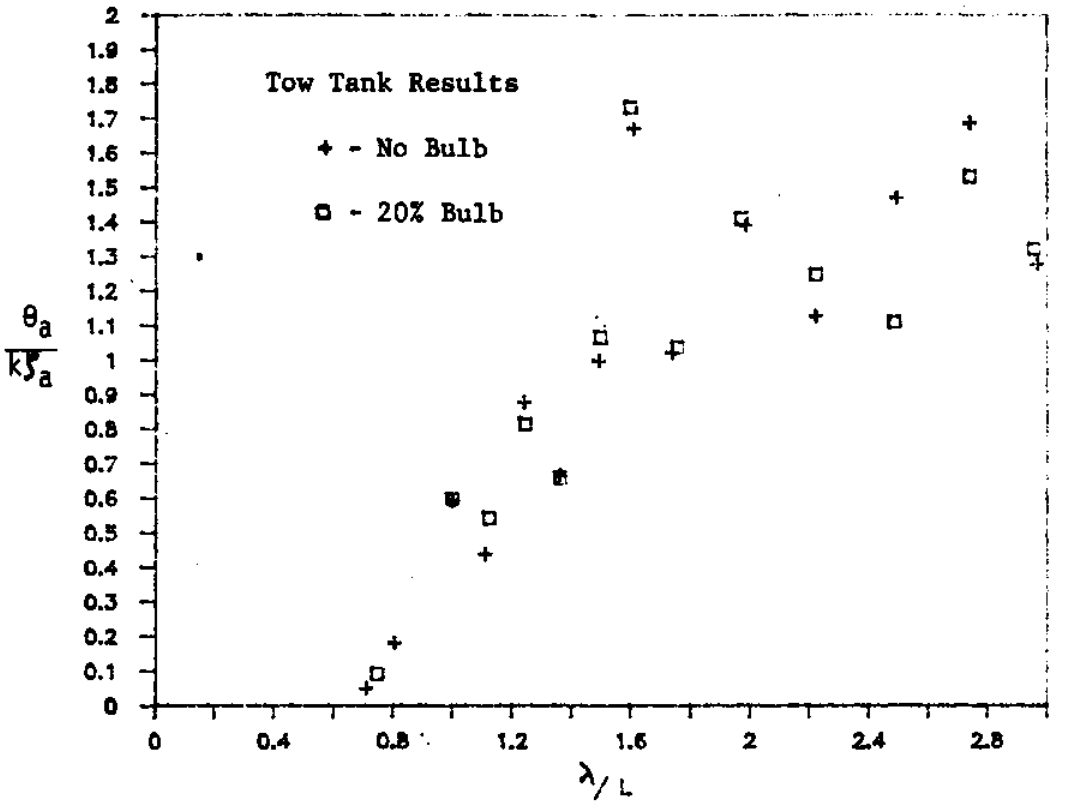

Figure 7. Pitch response at 3.0 knots with drogue.

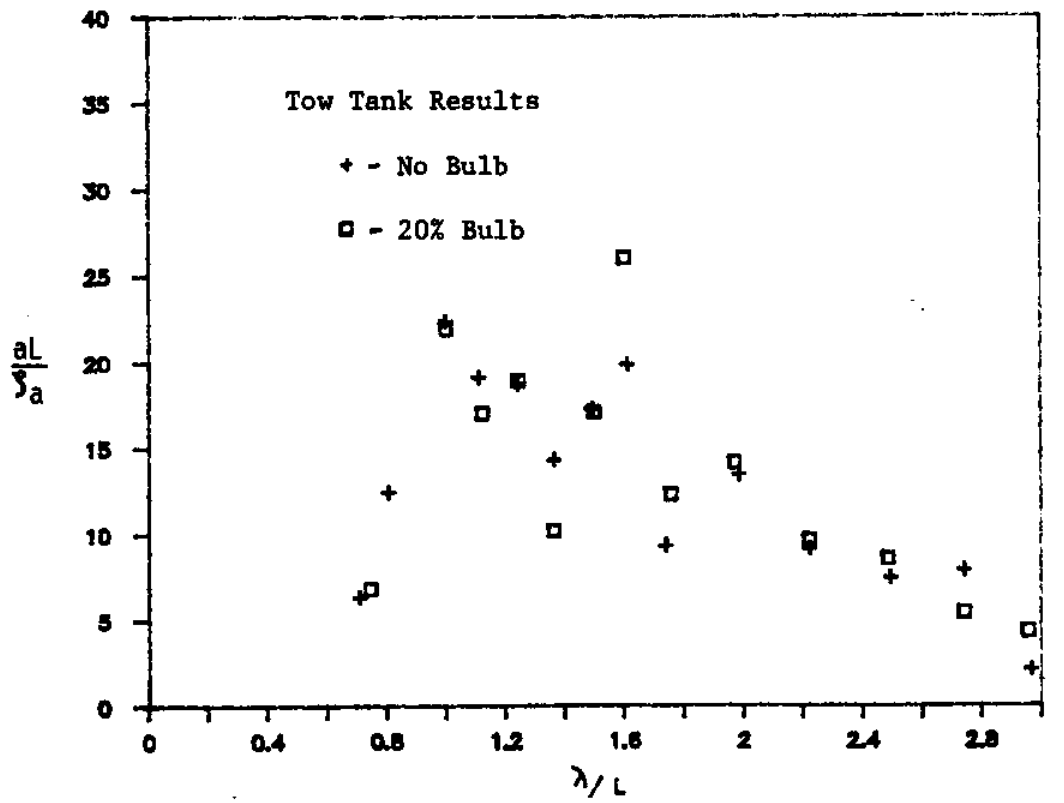

Figure 8. Vertical bow accelerations at 3.0 knots with drogue.

Added Resistance Results:

Vessel motions affect powering requirements therefore resistance measurements were taken during the seakeeping tests. The results are presented in Figures 13 and 14 in terms of non-dimensionalized added resistance σ_ω, defined by:

$$\sigma_\omega = \frac{R - R_{calm}}{\rho g B^2 / L \, \zeta_a}$$

Figure 13 shows that in a seaway, the 20% bulb experiences more added resistance than the bare hull counterpart. However, since the results are based on the difference between the measured resistance and the corresponding calm-water resistance, the net effect is less important since the 20% bulb has less resistance to begin with.

At the trawling speed the results are uninterpretable due to the complex response caused by the drogue/vessel system. In this case, the resistance found while towing the drogue in calm water is used in the comparison.

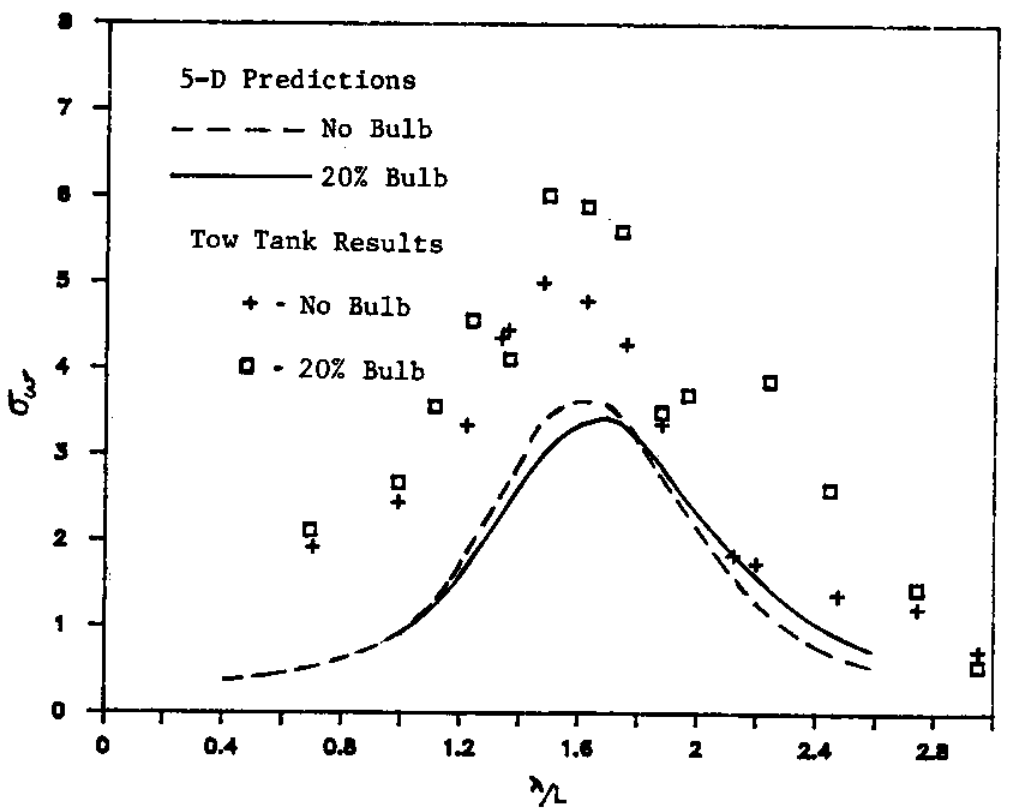

Figure 13. Added resistance at a cruising speed of 11.5 knots.

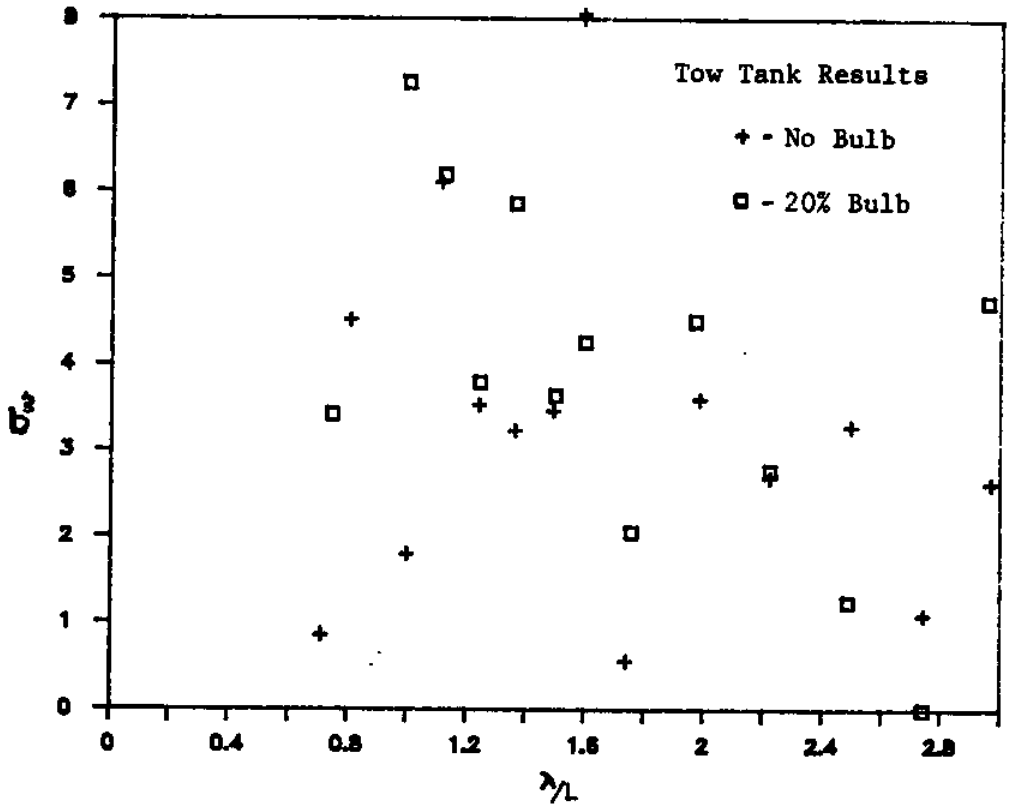

Figure 14. Added resistance at 3.0 knots with drogue.

5-D Motions Program Results:

The MIT 5-D Ship Motions Prediction Program(2) was run on the bare hull and the 20%-0.5D bulb over a range of regular waves comparable to the tow tank experiments. These runs were for the cruising speed only since the program is unable to include the effects of a towed object.

The results are plotted in Figures 9, 10, and 13 for comparison with the experimental data. The program results clearly show the pitch damping effects of the bulb retrofit. Reasonable agreement with the tow tank results are found, especially in the shorter wave lengths for pitch and the longer wave lengths for accelerations. There is some disagreement in results for added resistance in the vicinity of the peak.

The similar trends between the experimental and computer results are encouraging. The differences in actual response values could be due to the fact that the 5-D program is best suited for more slender ships than the one under consideration.

Effect of Bulb Height:

Exploring experimentally the effect of bulb height was beyond the scope of this research. To gain some insight into the possible advantage of vertical locations other than those tested, a regression model was used. The model is based on a compilation of test results from the Netherlands Ship Model Basin(3) and an implementation in PC BASIC was obtained from Webb Institute. The model includes bulb area and centroid height above the baseline as parameters. It is doubtful however, that it was intended for use on trawler-type hulls.

The results of a series of runs with and without bulbs are presented in Appendix 3. Most noticable is the underestimation of the 50m trawler's resistance based on the hull description.

Comparing the bare hull with the 10% predictions at 11.5 knots, the relative benefits of the bulb forms are in remarkable agreement with our experimental results. Further, we might interpret that a slight improvement could be gained by moving this small bulb closer to the surface by two or three feet.

The predictions for the 20% bulb show little change from the bare hull values at 11 and 12 knots. At higher speeds the bulb is beneficial. Similarly, the 30% bulb is of little use except at these high speeds. Using 15 knot results as a guide, it seems that the 5.0' height used in the experiments is suitable. The 30% values suggest that our forward draft limitation was restrictive and dropping the bulb by two or three feet might be helpful.

Power Requirement Calculations:

The calm water reduction in EHP requirements with the 20% -.05D bulb at 11.5 knots is 52 horsepower as shown in Figure 3. From Appendix 2, the bare hull EHP at that speed is 600 horsepower. The net effect on shaft horsepower (SHP) is dependent on a variety of efficiencies and conditions which can be calculated or estimated. They are summarized in Table 2.

The SHP reduction of the retrofit bulb depends upon the operating regime of the engine. If the propeller turns are maintained at full RPM the propeller efficiency changes very little and the reduction remains at 10%. If a more moderate RPM is allowed the reduced resistance allows an improved propulsion efficiency and the net reduction in SHP of 13.3%.

Parameter	Bare Hull		With 20% - 0.5D Bulb	
EHP	600		548	
V_S	19.42 ft/sec		19.42 ft/sec	
w (8)	.245		.245	
t = 0.95w	.233		.233	
$\eta_h = \frac{1-t}{1-w}$	1.016		1.016	
η_s	0.98		0.98	
η_r	1.02		1.02	
$V_A = (1-w)V_S$	14.665 ft/sec		14.665 ft/sec	
D	9.022 ft		9.022 ft	
R	16,990 lbf		15,520 lbf	
T = R/(1-t)	22,150 lbf		20,230 lbf	
ρ	1.993 slugs/ft		1.993 slugs/ft	
Kt/J^2	0.635		0.580	
RPM	200	150	200	150
J	0.488	0.652	0.488	0.652
P/D	0.760	1.140	0.740	1.090
η_p (9)	0.550	0.560	0.553	0.580
SHP	1074	1054	975	930

Table 2. Power Calculations.

Conclusions:

Our results indicate significant reductions in SHP requirements for the simple bulb designs we tested. It is also evident that if this vessel was operated at a speed/length ratio more typical of trawlers, the benefits would be much greater. For example, Figure 8 predicts EHP reductions of over 165 horsepower (17%) at 13 knots.

The simple shaped bulbs included in this study are crude compared to the carefully formed bulb commonly seen on merchant ships and naval vessels. We feel that the complication of fabricating the latter type is inconsistent with the construction practices used for most fishing vessels.

The calculations of SHP summarized in Table 2 are based on the information available. The wake fraction and thrust deduction were estimated from data related to ship hulls. In addition, the propeller efficiencies are based on B-Series data since the specifications of the nozzle were unavailable. Propeller B 4-85 was assumed.

In general, the reduced propeller thrust required for the retrofitted vessel at steaming speed should result in improved propulsive efficiency.

Since the resistance and SHP requirements are based on constant draft rather than constant displacement, the results presented here may be conservative. Increased payload due to the bulb's volume may be possible. Conversely, if stability conditions allow, the buoyancy of the bulb could be used to decrease the forward draft and allow further resistance reductions.

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Appendix 1

Tabulated Towing Tank Results.

FULL SCALE CALM WATER RESISTANCE FOR THE 50m TRAWLER
No Bulb

T=80°F ρf=1.9336 lbs*sec²/ft⁴ νf=0.92608E-5 ft²/sec (Lwl)m=4.24 ft Sm=3.87 ft²
Δm=58.66 1 ρs=1.9905 lbs*sec²/ft⁴ νs=1.27908E-5 ft²/sec (Lwl)s=151.2 ft Ss=4910.2 ft²

No	Vm (Knots)	Rt,m (lbs)	Ct,m (*1000)	Rn,m (*10E-6)	Cf,m (*1000)	Cr (*1000)	Vs (Knots)	Vs (ft/sec)	Rn,s (*10E-6)	Cf,s (*1000)	Ct,s (*1000)	Rt,s (lbs)	EHP
1	1.993	0.535	12.634	1.540	4.277	8.357	11.895	20.078	237.345	1.845	10.202	20099.7	733.76
2	1.202	0.166	10.777	0.929	4.763	6.014	7.174	12.109	143.146	1.979	7.993	5727.8	126.11
3	1.495	0.247	10.366	1.155	4.544	5.822	8.923	15.061	178.039	1.920	7.742	8582.4	235.02
4	2.283	0.854	15.369	1.764	4.159	11.210	13.626	23.000	271.881	1.812	13.022	33663.3	1,407.73
5	0.61	0.058	14.621	0.471	5.558	9.063	3.641	6.145	72.645	2.183	11.246	2075.5	23.19
6	1.798	0.407	11.809	1.390	4.370	7.440	10.731	18.114	214.123	1.871	9.311	14929.3	491.69
7	1.495	0.243	10.198	1.155	4.544	5.655	8.923	15.061	178.039	1.920	7.574	8396.3	229.93
8	2.557	1.248	17.904	1.976	4.064	13.840	15.261	25.760	304.512	1.784	15.624	50668.2	2,373.14
9	0.84	0.068	9.040	0.649	5.160	3.880	5.013	8.463	100.035	2.083	5.963	2086.8	32.11
10	2.169	0.641	12.780	1.676	4.203	8.578	12.945	21.851	258.305	1.824	10.402	24271.5	964.30
11	0.507	0.032	11.677	0.392	5.809	5.868	3.026	5.108	60.378	2.244	8.112	1034.3	9.60
12	2.325	0.858	14.888	1.797	4.143	10.745	13.876	23.423	276.883	1.807	12.552	33653.6	1,433.21
13	2.492	1.229	18.564	1.926	4.085	14.478	14.873	25.105	296.771	1.790	16.269	50109.0	2.287.29

FULL SCALE CALM WATER RESISTANCE FOR THE 50m TRAWLER
10% Bulb with no ring

T=80°F ρf=1.9336 lbs*sec²/ft⁴ νf=0.92608E-5 ft²/sec (Lwl)m=4.24 ft Sm=3.938 ft²
Δm=59.345 ρs=1.9905 lbs*sec²/ft⁴ νs=1.27908E-5 ft²/sec (Lwl)s=151.2 ft Ss=4996.47 ft²

No	Vm (Knots)	Rt,m (lbs)	Ct,m (*1000)	Rn,m (*10E-6)	Cf,m (*1000)	Cr (*1000)	Vs (Knots)	Vs (ft/sec)	Rn,s (*10E-6)	Cf,s (*1000)	Ct,s (*1000)	Rt,s (lbs)	EHP
1	2.016	0.573	12.128	1.558	4.267	7.861	12.032	20.310	240.084	1.842	9.703	19903.8	734.99
2	1.804	0.404	10.679	1.394	4.367	6.312	10.767	18.174	214.837	1.871	8.182	13439.7	444.10
3	1.008	0.122	10.329	0.779	4.952	5.376	6.016	10.155	120.042	2.029	7.406	3797.7	70.12
4	2.563	1.356	17.757	1.981	4.062	13.695	15.297	25.821	305.226	1.784	15.478	51316.3	2,409.13
5	1.987	0.543	11.831	1.536	4.280	7.551	11.859	20.018	236.631	1.846	9.397	18725.0	681.52
6	1.402	0.21	9.190	1.084	4.607	4.583	8.367	14.124	166.963	1.937	6.520	6468.4	166.11
7	0.553	0.038	10.689	0.427	5.689	5.000	3.300	5.571	65.856	2.215	7.215	1113.6	11.28
8	2.236	0.776	13.351	1.728	4.177	9.175	13.345	22.526	266.284	1.817	10.991	27734.9	1,135.94
9	3.119	3.938	34.822	2.410	3.906	30.916	18.615	31.422	371.440	1.738	32.654	160323.5	9,159.45
10	1.629	0.318	10.308	1.259	4.462	5.847	9.722	16.411	193.997	1.897	7.744	10371.2	309.46
11	2.502	1.212	16.655	1.934	4.082	12.573	14.933	25.206	297.962	1.789	14.362	45375.3	2,079.52

FULL SCALE CALM WATER RESISTANCE FOR THE 50m TRAWLER
10% Bulb with 0.5 diam. ring

T=80°F ρf=1.9336 lbs*sec²/ft⁴ νf=0.92608E-5 ft²/sec (Lwl)m=4.24 ft Sm=3.995 ft²
Δm=59.435 ρs=1.9905 lbs*sec²/ft⁴ νs=1.27908E-5 ft²/sec (Lwl)s=151.2 ft Ss=5068.79 ft²

No	Vm (Knots)	Rt,m (lbs)	Ct,m (*1000)	Rn,m (*10E-6)	Cf,m (*1000)	Cr (*1000)	Vs (Knots)	Vs (ft/sec)	Rn,s (*10E-6)	Cf,s (*1000)	Ct,s (*1000)	Rt,s (lbs)	EHP
1	1.544	0.318	11.322	1.193	4.513	6.809	9.215	15.555	183.874	1.911	8.720	10643.7	301.02
2	1.543	0.284	10.124	1.192	4.513	5.611	9.209	15.545	183.755	1.911	7.522	9169.7	259.17
3	2.016	0.609	12.718	1.558	4.267	8.451	12.032	20.310	240.084	1.842	10.293	21420.0	790.98
4	2.568	1.445	18.598	1.985	4.061	14.537	15.326	25.871	305.822	1.783	16.320	55104.6	2,592.03
5	1.202	0.161	9.458	0.929	4.763	4.695	7.174	12.109	143.146	1.979	6.674	4936.9	108.70
6	1.986	0.567	12.201	1.535	4.280	7.921	11.853	20.008	236.512	1.846	9.767	19724.6	717.54
7	2.235	0.842	14.307	1.727	4.177	10.130	13.339	22.516	266.165	1.817	11.946	30553.7	1,250.83
8	0.506	0.031	10.276	0.391	5.812	4.464	3.020	5.098	60.259	2.245	6.709	879.5	8.15
9	1.804	0.435	11.345	1.394	4.367	6.978	10.767	18.174	214.837	1.871	8.849	14744.2	487.21
10	0.814	0.084	10.760	0.629	5.197	5.563	4.858	8.201	96.939	2.093	7.655	2597.1	38.72
11	2.369	0.972	14.700	1.831	4.128	10.572	14.139	23.866	282.123	1.803	12.375	35558.6	1,543.00

FULL SCALE CALM WATER RESISTANCE FOR THE 50m TRAWLER
10% Bulb with 1 diam. ring

T=80°F ρf=1.9336 lbs*sec²/ft⁴ νf=0.92608E-5 ft²/sec (Lwl)m=4.24 ft Sm=4.052 ft²
Δm=59.525 ρs=1.9905 lbs*sec²/ft⁴ νs=1.27908E-5 ft²/sec (Lwl)s=151.2 ft Ss=5141.11 ft²

No	Vm (Knots)	Rt,m (lbs)	Ct,m (*1000)	Rn,m (*10E-6)	Cf,m (*1000)	Cr (*1000)	Vs (Knots)	Vs (ft/sec)	Rn,s (*10E-6)	Cf,s (*1000)	Ct,s (*1000)	Rt,s (lbs)	EHP
1	1.401	0.239	10.199	1.083	4.608	5.591	8.362	14.114	166.844	1.937	7.528	7673.7	196.92
2	2.016	0.583	12.015	1.558	4.267	7.748	12.032	20.310	240.084	1.842	9.590	20241.6	747.47
3	1.008	0.11	9.068	0.779	4.952	4.115	6.016	10.155	120.042	2.029	6.145	3242.3	59.86
4	1.988	0.542	11.487	1.536	4.279	7.208	11.865	20.028	236.750	1.846	9.053	18581.2	676.62
5	0.507	0.028	9.124	0.392	5.809	3.314	3.026	5.108	60.378	2.244	5.559	742.0	6.89
6	2.566	1.37	17.428	1.983	4.061	13.366	15.315	25.851	305.584	1.783	15.150	51801.5	2,434.76
7	1.804	0.423	10.887	1.394	4.367	6.520	10.767	18.174	214.837	1.871	8.391	14180.5	468.58
8	2.235	0.812	13.615	1.727	4.177	9.438	13.339	22.516	266.165	1.817	11.255	29196.6	1,195.27
9	0.748	0.064	9.581	0.578	5.299	4.282	4.464	7.536	89.079	2.119	6.400	1859.6	25.48
10	2.439	1.19	16.755	1.885	4.103	12.652	14.557	24.571	290.459	1.795	14.448	44632.0	1,993.95

FULL SCALE CALM WATER RESISTANCE FOR THE 50m TRAWLER
10% Bulb with 1.5 diam. ring

T=80°F ρf=1.9336 lbs*sec²/ft⁴ νf=0.92608E-5 ft²/sec (Lwl)m=4.24 ft Sm=4.109 ft²
Δm=59.615 ρs=1.9905 lbs*sec²/ft⁴ νs=1.27908E-5 ft²/sec (Lwl)s=151.2 ft Ss=5213.4 ft²

No	Vm (Knots)	Rt,m (lbs)	Ct,m (*1000)	Rn,m (*10E-6)	Cf,m (*1000)	Cr (*1000)	Vs (Knots)	Vs (ft/sec)	Rn,s (*10E-6)	Cf,s (*1000)	Ct,s (*1000)	Rt,s (lbs)	EHP
1	2.081	0.615	11.738	1.608	4.239	7.499	12.420	20.965	247.825	1.834	9.333	21285.1	811.34
2	1.401	0.256	10.780	1.083	4.608	6.172	8.362	14.114	166.844	1.937	8.110	8382.3	215.11
3	2.563	1.435	18.056	1.981	4.062	13.993	15.297	25.821	305.226	1.784	15.777	54577.2	2,562.22
4	1.203	0.188	10.737	0.930	4.763	5.974	7.180	12.120	143.265	1.979	7.953	6061.5	133.57
5	2.236	0.726	12.002	1.728	4.177	7.825	13.345	22.526	266.284	1.817	9.642	25386.1	1,039.74
6	0.61	0.04	8.885	0.471	5.558	3.327	3.641	6.145	72.645	2.183	5.510	1079.7	12.06
7	1.986	0.553	11.588	1.535	4.260	7.308	11.853	20.008	236.512	1.846	9.154	19014.4	691.70
8	2.5	1.376	18.197	1.932	4.083	14.114	14.921	25.186	297.724	1.790	15.904	52344.0	2,396.98
9	1.804	0.406	10.311	1.394	4.367	5.944	10.767	18.174	214.837	1.871	7.815	13393.5	442.58
10	2.441	1.148	15.924	1.887	4.103	11.822	14.568	24.592	290.697	1.795	13.617	42728.0	1,910.45
11	2.558	1.4	17.684	1.977	4.064	13.620	15.267	25.770	304.631	1.784	15.404	53080.6	2,487.10
12	2.331	0.926	14.086	1.801	4.141	9.945	13.912	23.483	277.598	1.806	11.751	33624.2	1,435.66

FULL SCALE CALM WATER RESISTANCE FOR THE 50m TRAWLER
20% Bulb with no ring

T=80°F ρf=1.9336 lbs*sec²/ft⁴ νf=0.92608E-5 ft²/sec (Lwl)m=4.24 ft Sm=4.198 ft²
Δm=60.1 lb ρs=1.9905 lbs*sec²/ft⁴ νs=1.27908E-5 ft²/sec (Lwl)s=151.2 ft Ss=5326.35 ft²

No	Vm (Knots)	Rt,m (lbs)	Ct,m (*1000)	Rn,m (*10E-6)	Cf,m (*1000)	Cr (*1000)	Vs (Knots)	Vs (ft/sec)	Rn,s (*10E-6)	Cf,s (*1000)	Ct,s (*1000)	Rt,s (lbs)	EHP
1	2.015	0.608	11.858	1.557	4.267	7.591	12.026	20.300	239.965	1.842	9.434	20607.9	760.61
2	1.404	0.307	12.333	1.085	4.605	7.728	8.379	14.144	167.202	1.937	9.664	10249.6	263.59
3	1.008	0.126	9.820	0.779	4.952	4.868	6.016	10.155	120.042	2.029	6.897	3770.5	69.62
4	1.987	0.556	11.152	1.536	4.280	6.872	11.859	20.018	236.631	1.846	8.718	18519.6	674.04
5	2.557	1.347	16.315	1.976	4.064	12.251	15.261	25.760	304.512	1.784	14.035	49370.3	2,312.35
6	1.699	0.449	12.318	1.313	4.422	7.896	10.140	17.116	202.333	1.886	9.782	15191.6	472.77
7	0.507	0.027	8.318	0.392	5.809	2.509	3.026	5.108	60.378	2.244	4.753	657.3	6.10
8	2.236	0.766	12.133	1.728	4.177	7.956	13.345	22.526	266.284	1.817	9.773	26288.1	1,076.68
9	2.498	1.148	14.569	1.931	4.083	10.486	14.909	25.166	297.486	1.790	12.275	41211.7	1,885.69

FULL SCALE CALM WATER RESISTANCE FOR THE 50m TRAWLER
20% Bulb with 0.5 diam. ring

T=79°F ρf=1.9339 lbs*sec²/ft⁴ νf=0.93751E-5 ft²/sec (Lwl)m=4.24 ft Sm=4.331 ft²
Δm=60.41 t ρs=1.9905 lbs*sec²/ft⁴ νs=1.27908E-5 ft²/sec (Lwl)s=151.2 ft Ss=5495.10 ft²

No	Vm (Knots)	Rt,m (lbs)	Ct,m (*1000)	Rn,m (*10E-6)	Cf,m (*1000)	Cr (*1000)	Vs (Knots)	Vs (ft/sec)	Rn,s (*10E-6)	Cf,s (*1000)	Ct,s (*1000)	Rt,s (lbs)	EHP
1	2.016	0.549	10.392	1.539	4.278	6.114	12.032	20.310	240.084	1.842	7.956	17932.8	662.21
2	1.405	0.266	10.366	1.073	4.617	5.749	8.385	14.155	167.321	1.936	7.686	8413.7	216.53
3	1.987	0.507	9.879	1.517	4.291	5.588	11.859	20.018	236.631	1.846	7.434	16277.5	592.44
4	2.236	0.745	11.463	1.707	4.187	7.276	13.345	22.526	266.284	1.817	9.093	25210.7	1,032.56
5	0.507	0.035	10.475	0.387	5.827	4.648	3.026	5.108	60.378	2.244	6.892	982.5	9.12
6	2.565	1.319	15.423	1.958	4.072	11.351	15.309	25.841	305.465	1.783	13.135	47922.6	2,251.56
7	1.203	0.176	9.356	0.918	4.775	4.580	7.180	12.120	143.265	1.979	6.559	5264.3	116.00
8	1.707	0.362	9.557	1.303	4.429	5.128	10.188	17.197	203.286	1.885	7.013	11332.3	354.33
9	0.814	0.082	9.520	0.621	5.212	4.308	4.858	8.201	96.939	2.093	6.401	2352.1	35.07
10	2.506	1.074	13.156	1.913	4.091	9.065	14.956	25.246	298.438	1.789	10.854	37802.4	1,735.23

FULL SCALE CALM WATER RESISTANCE FOR THE 50m TRAWLER
20% Bulb with 1 diam. ring

T=79°F ρf=1.9339 lbs*sec²/ft⁴ νf=0.93751E-5 ft²/sec (Lwl)m=4.24 ft Sm=4.46 ft²
Δm=60.59 t ρs=1.9905 lbs*sec²/ft⁴ νs=1.27908E-5 ft²/sec (Lwl)s=151.2 ft Ss=5656.24 ft²

No	Vm (Knots)	Rt,m (lbs)	Ct,m (*1000)	Rn,m (*10E-6)	Cf,m (*1000)	Cr (*1000)	Vs (Knots)	Vs (ft/sec)	Rn,s (*10E-6)	Cf,s (*1000)	Ct,s (*1000)	Rt,s (lbs)	EHP
1	2.236	0.741	11.087	1.707	4.187	6.900	13.345	22.526	266.284	1.817	8.716	24898.4	1,019.76
2	1.401	0.247	9.413	1.070	4.620	4.794	8.362	14.114	166.844	1.937	6.731	7548.2	193.70
3	1.987	0.532	10.080	1.517	4.291	5.789	11.859	20.018	236.631	1.846	7.635	17223.1	626.85
4	0.61	0.048	9.650	0.466	5.574	4.075	3.641	6.145	72.645	2.183	6.259	1330.6	14.87
5	2.561	1.348	15.375	1.955	4.073	11.302	15.285	25.801	304.988	1.784	13.085	49034.5	2,300.21
6	1.543	0.288	9.049	1.178	4.525	4.524	9.209	15.545	183.755	1.911	6.435	8753.4	247.40
7	1.008	0.136	10.013	0.770	4.966	5.047	6.016	10.155	120.042	2.029	7.076	4107.8	75.84
8	2.504	1.099	13.112	1.912	4.092	9.020	14.944	25.226	298.200	1.789	10.809	38722.6	1,776.05
9	1.804	0.413	9.493	1.377	4.378	5.115	10.767	18.174	214.837	1.871	6.986	12989.1	429.21
10	2.325	0.754	10.434	1.775	4.154	6.280	13.876	23.423	276.883	1.807	8.087	24977.7	1,063.73
11	2.469	1.065	13.069	1.885	4.103	8.966	14.736	24.874	294.032	1.793	10.758	37469.4	1,694.55

FULL SCALE CALM WATER RESISTANCE FOR THE 50m TRAWLER
20% Bulb with 1.5 diam. ring

T=79°F ρf=1.9339 lbs*sec²/ft⁴ νf=0.93751E-5 ft²/sec (Lwl)m=4.24 ft Sm=4.597 ft²
Δm=60.9 lb ρs=1.9905 lbs*sec²/ft⁴ νs=1.27908E-5 ft²/sec (Lwl)s=151.2 ft Ss=5832.60 ft²

No	Vm (Knots)	Rt,m (lbs)	Ct,m (*1000)	Rn,m (*10E-6)	Cf,m (*1000)	Cr (*1000)	Vs (Knots)	Vs (ft/sec)	Rn,s (*10E-6)	Cf,s (*1000)	Ct,s (*1000)	Rt,s (lbs)	EHP
1	2.016	0.552	9.889	1.539	4.278	5.611	12.032	20.310	240.084	1.842	7.454	17847.4	659.06
2	1.407	0.291	10.703	1.074	4.616	6.087	8.397	14.175	167.559	1.936	8.023	9357.5	241.16
3	2.502	1.007	11.712	1.910	4.092	7.620	14.933	25.206	297.962	1.789	9.409	34703.1	1,590.42
4	0.814	0.08	8.791	0.621	5.212	3.579	4.858	8.201	96.939	2.093	5.671	2214.0	33.01
5	1.987	0.56	10.327	1.517	4.291	6.037	11.859	20.018	236.631	1.846	7.883	18335.7	667.35
6	0.507	0.04	11.330	0.387	5.827	5.503	3.026	5.108	60.378	2.244	7.748	1173.3	10.90
7	2.574	1.299	14.275	1.965	4.069	10.206	15.362	25.932	306.536	1.783	11.989	46798.0	2,206.44
8	1.703	0.363	9.113	1.300	4.431	4.682	10.164	17.157	202.809	1.885	6.567	11221.1	350.03
9	2.236	0.694	10.107	1.707	4.187	5.919	13.345	22.526	266.284	1.817	7.736	22787.3	933.30
10	1.203	0.191	9.609	0.918	4.775	4.834	7.180	12.120	143.265	1.979	6.813	5808.9	128.00

FULL SCALE CALM WATER RESISTANCE FOR THE 50m TRAWLER
30% Bulb with no ring

T=79.5° ρf=1.93375 lbs*sec²/ft⁴ νf=0.93179E-5 ft²/sec (Lwl)m=4.37 ft Sm=4.528 ft²
Δm=60.78 1 ρs=1.9905 lbs*sec²/ft⁴ νs=1.27908E-5 ft²/sec (Lwl)s=155.5 ft Ss=5745.05 ft²

No	Vm (Knots)	Rt,m (lbs)	Ct,m (*1000)	Rn,m (*10E-6)	Cf,m (*1000)	Cr (*1000)	Vs (Knots)	Vs (ft/sec)	Rn,s (*10E-6)	Cf,s (*1000)	Ct,s (*1000)	Rt,s (lbs)	EHP
1	2.016	0.568	10.330	1.596	4.246	6.084	12.032	20.310	246.912	1.835	7.919	18678.1	689.73
2	1.402	0.293	11.018	1.044	4.644	6.373	8.367	14.124	171.712	1.929	8.303	9470.8	243.22
3	1.989	0.548	10.238	1.481	4.312	5.926	11.871	20.038	243.605	1.839	7.765	17826.8	649.48
4	0.506	0.05	14.434	0.377	5.865	8.569	3.020	5.098	61.973	2.235	10.805	1605.4	14.88
5	2.235	0.751	11.112	1.664	4.209	6.903	13.339	22.516	273.735	1.810	8.713	25257.1	1,033.99
6	1.008	0.143	10.402	0.751	4.994	5.408	6.016	10.155	123.456	2.021	7.430	4380.8	80.89
7	1.804	0.493	11.197	1.343	4.401	6.796	10.767	18.174	220.947	1.863	8.659	16353.3	540.38
8	2.552	1.18	13.392	1.900	4.097	9.295	15.231	25.710	312.560	1.778	11.073	41849.7	1,956.28
9	1.628	0.388	10.820	1.212	4.498	6.323	9.716	16.401	199.391	1.890	8.212	12631.2	376.67
10	2.485	1.032	12.352	1.850	4.119	8.233	14.831	25.035	304.354	1.784	10.018	35898.9	1,634.04
11	1.203	0.226	11.542	0.896	4.802	6.741	7.180	12.120	147.339	1.971	8.712	7316.5	161.22

FULL SCALE CALM WATER RESISTANCE FOR THE 50m TRAWLER
30% Bulb with 0.5 diam. ring

T=79.5° ρf=1.93375 lbs*sec²/ft⁴ νf=0.93179E-5 ft²/sec (Lwl)m=4.55 ft Sm=4.734 ft²
Δm=61.19 l ρs=1.9905 lbs*sec²/ft⁴ νs=1.27908E-5 ft²/sec (Lwl)s=162.2 ft Ss=6006.43 ft²

No	Vm (Knots)	Rt,m (lbs)	Ct,m (*1000)	Rn,m (*10E-6)	Cf,m (*1000)	Cr (*1000)	Vs (Knots)	Vs (ft/sec)	Rn,s (*10E-6)	Cf,s (*1000)	Ct,s (*1000)	Rt,s (lbs)	EHP
1	2.011	0.583	10.246	1.658	4.213	6.034	12.002	20.260	256.912	1.825	7.859	19283.5	710.32
2	1.007	0.184	12.897	0.830	4.883	8.014	6.010	10.145	128.648	2.009	10.023	6166.6	113.74
3	1.54	0.405	12.138	1.269	4.454	7.684	9.191	15.515	196.740	1.893	9.577	13780.4	388.72
4	1.986	0.535	9.641	1.637	4.223	5.417	11.853	20.008	253.718	1.829	7.246	17339.8	630.78
5	0.506	0.057	15.823	0.417	5.723	10.101	3.020	5.098	64.643	2.221	12.322	1914.1	17.74
6	2.565	1.217	13.147	2.114	4.009	9.138	15.309	25.841	327.688	1.767	10.905	43529.0	2,045.14
7	2.235	0.692	9.846	1.842	4.122	5.724	13.339	22.516	285.529	1.800	7.523	22801.2	933.45
8	1.202	0.24	11.807	0.991	4.697	7.110	7.174	12.109	153.560	1.960	9.069	7950.1	175.04
9	1.804	0.482	10.527	1.487	4.308	6.218	10.767	18.174	230.467	1.853	8.071	15936.3	526.60
10	1.4	0.327	11.858	1.154	4.545	7.313	8.356	14.104	178.855	1.918	9.231	10977.7	281.51
11	2.323	0.804	10.590	1.915	4.090	6.499	13.864	23.403	296.771	1.790	8.290	27140.7	1,154.85
12	2.509	1.062	11.991	2.068	4.027	7.964	14.974	25.277	320.533	1.772	9.736	37183.4	1,708.86
13	1.993	0.526	9.412	1.643	4.220	5.192	11.895	20.078	254.613	1.828	7.020	16916.5	617.55

FULL SCALE CALM WATER RESISTANCE FOR THE 50m TRAWLER
30% Bulb with 1 diam. ring

T=79.5° ρf=1.93375 lbs*sec²/ft⁴ νf=0.93179E-5 ft²/sec (Lwl)m=4.74 ft Sm=4.94 ft²
Δm=61.685 ρs=1.9905 lbs*sec²/ft⁴ νs=1.27908E-5 ft²/sec (Lwl)s=168.9 ft Ss=6267.79 ft²

No	Vm (Knots)	Rt,m (lbs)	Ct,m (*1000)	Rn,m (*10E-6)	Cf,m (*1000)	Cr (*1000)	Vs (Knots)	Vs (ft/sec)	Rn,s (*10E-6)	Cf,s (*1000)	Ct,s (*1000)	Rt,s (lbs)	EHP
1	2.016	0.638	10.746	1.731	4.175	6.571	12.032	20.310	268.190	1.815	8.386	21578.1	796.82
2	1.402	0.343	11.946	1.204	4.504	7.441	8.367	14.124	186.509	1.907	9.349	11634.2	298.77
3	1.804	0.584	12.284	1.549	4.272	8.012	10.767	18.174	239.987	1.842	9.855	20305.4	670.97
4	0.506	0.055	14.705	0.434	5.667	9.038	3.020	5.098	67.313	2.208	11.247	1823.1	16.90
5	1.987	0.62	10.750	1.706	4.188	6.562	11.859	20.018	264.332	1.818	8.381	20949.3	762.47
6	1.629	0.482	12.434	1.399	4.364	8.070	9.722	16.411	216.707	1.868	9.939	16697.9	498.24
7	1.008	0.176	11.858	0.866	4.838	7.020	6.016	10.155	134.095	1.998	9.017	5800.8	107.10
8	2.537	0.966	10.274	2.178	3.985	6.289	15.141	25.559	337.498	1.760	8.049	32798.8	1,524.18
9	1.202	0.266	12.603	1.032	4.655	7.948	7.174	12.109	159.903	1.949	9.897	9052.7	199.31
10	2.235	0.668	9.154	1.919	4.088	5.066	13.339	22.516	297.323	1.790	6.856	21682.7	887.66
11	2.47	0.937	10.514	2.121	4.007	6.507	14.742	24.884	328.585	1.766	8.273	31956.0	1,445.79
12	2.289	0.642	8.388	1.966	4.069	4.319	13.661	23.060	304.507	1.784	6.104	20246.8	848.91
13	2.279	0.66	8.699	1.957	4.072	4.627	13.602	22.960	303.177	1.785	6.412	21084.6	880.17

FULL SCALE CALM WATER RESISTANCE FOR THE 50m TRAWLER
30% Bulb with 1.5 diam. ring

T=79.5° ρf=1.93375 lbs*sec²/ft⁴ νf=0.93179E-5 ft²/sec (Lwl)m=4.93 ft Sm=5.146 ft²
65.94 t ρs=1.9905 lbs*sec²/ft⁴ νs=1.27908E-5 ft²/sec (Lwl)s=175.58 ft Ss=6529.16 ft²

No	Vm (Knots)	Rt,m (lbs)	Ct,m (*1000)	Rn,m (*10E-6)	Cf,m (*1000)	Cr (*1000)	Vs (Knots)	Vs (ft/sec)	Rn,s (*10E-6)	Cf,s (*1000)	Ct,s (*1000)	Rt,s (lbs)	EHP
1	1.804	0.645	13.085	1.611	4.237	8.847	10.767	18.174	249.479	1.833	10.680	22923.1	757.47
2	2.016	0.738	11.988	1.800	4.142	7.846	12.032	20.310	278.796	1.805	9.652	25871.0	955.35
3	1.018	0.199	12.930	0.900	4.796	8.134	6.016	10.155	139.398	1.987	10.120	6781.9	125.22
4	1.987	0.717	11.989	1.775	4.154	7.835	11.859	20.018	274.786	1.809	9.644	25112.7	914.00
5	2.553	1.065	10.787	2.280	3.949	6.838	15.237	25.720	353.059	1.749	8.588	36915.3	1,726.29
6	0.552	0.059	12.783	0.493	5.500	7.284	3.294	5.561	76.337	2.167	9.451	1899.2	19.20
7	2.235	0.778	10.282	1.996	4.056	6.227	13.339	22.516	309.082	1.781	8.007	26379.1	1,079.93
8	1.628	0.505	12.579	1.454	4.329	8.251	9.716	16.401	225.139	1.859	10.109	17670.8	526.95
9	2.491	0.934	9.937	2.225	3.969	5.969	14.867	25.095	344.485	1.755	7.724	31609.1	1,442.25
10	1.804	0.614	12.456	1.611	4.237	8.218	10.767	18.174	249.479	1.833	10.051	21573.3	712.87
11	2.235	0.77	10.177	1.996	4.056	6.121	13.339	22.516	309.082	1.781	7.901	26030.8	1,065.67
12	1.203	0.283	12.910	1.074	4.615	8.295	7.180	12.120	166.365	1.938	10.233	9766.7	215.21
13	1.399	0.365	12.312	1.249	4.469	7.843	8.350	14.094	193.470	1.898	9.741	12573.8	322.21
14	1.987	0.717	11.989	1.775	4.154	7.835	11.859	20.018	274.786	1.809	9.644	25112.7	914.00

FULL SCALE CALM WATER RESISTANCE FOR THE 50m TRAWLER
No Bulb

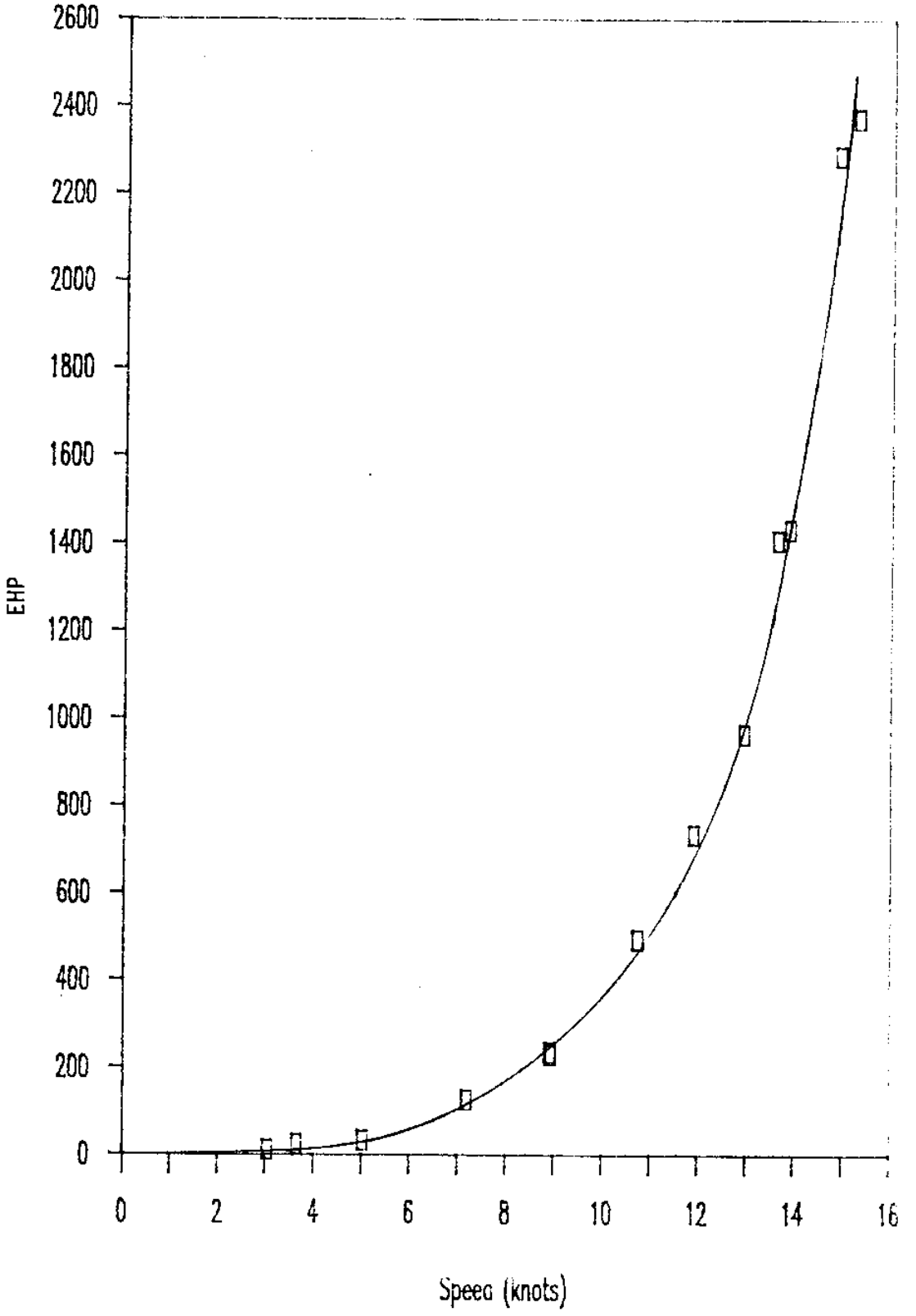
T=80°F ρf=1.9336 lbs*sec²/ft⁴ νf=0.92608E-5 ft²/sec (Lwl)m=4.24 ft Sm=3.87 ft²
Δm=58.66 t ρs=1.9905 lbs*sec²/ft⁴ νs=1.27908E-5 ft²/sec (Lwl)s=151.2 ft Ss=4910.2 ft²

No	Vm (Knots)	Rt,m (lbs)	Ct,m (*1000)	Rn,m (*10E-6)	Cf,m (*1000)	Cr (*1000)	Vs (Knots)	Vs (ft/sec)	Rn,s (*10E-6)	Cf,s (*1000)	Ct,s (*1000)	Rt,s (lbs)	EHP
1	1.993	0.535	12.634	1.540	4.277	8.357	11.895	20.078	237.345	1.845	10.202	20099.7	733.76
2	1.202	0.166	10.777	0.929	4.763	6.014	7.174	12.109	143.146	1.979	7.993	5727.8	126.11
3	1.495	0.247	10.366	1.155	4.544	5.822	8.923	15.061	178.039	1.920	7.742	8582.4	235.02
4	2.283	0.854	15.369	1.764	4.159	11.210	13.626	23.000	271.881	1.812	13.022	33663.3	1,407.73
5	0.61	0.058	14.621	0.471	5.558	9.063	3.641	6.145	72.645	2.183	11.246	2075.5	23.19
6	1.798	0.407	11.809	1.390	4.370	7.440	10.731	18.114	214.123	1.871	9.311	14929.3	491.69
7	1.495	0.243	10.198	1.155	4.544	5.655	8.923	15.061	178.039	1.920	7.574	8396.3	229.93
8	2.557	1.248	17.904	1.976	4.064	13.840	15.261	25.760	304.512	1.784	15.624	50668.2	2,373.14
9	0.84	0.068	9.040	0.649	5.160	3.880	5.013	8.463	100.035	2.083	5.963	2086.8	32.11
10	2.169	0.641	12.780	1.676	4.203	8.578	12.945	21.851	258.305	1.824	10.402	24271.5	964.30
11	0.507	0.032	11.677	0.392	5.809	5.868	3.026	5.108	60.378	2.244	8.112	1034.3	9.60
12	2.325	0.858	14.888	1.797	4.143	10.745	13.876	23.423	276.883	1.807	12.552	33653.6	1,433.21
13	2.492	1.229	18.564	1.926	4.085	14.478	14.873	25.105	296.771	1.790	16.269	50109.0	2,287.29

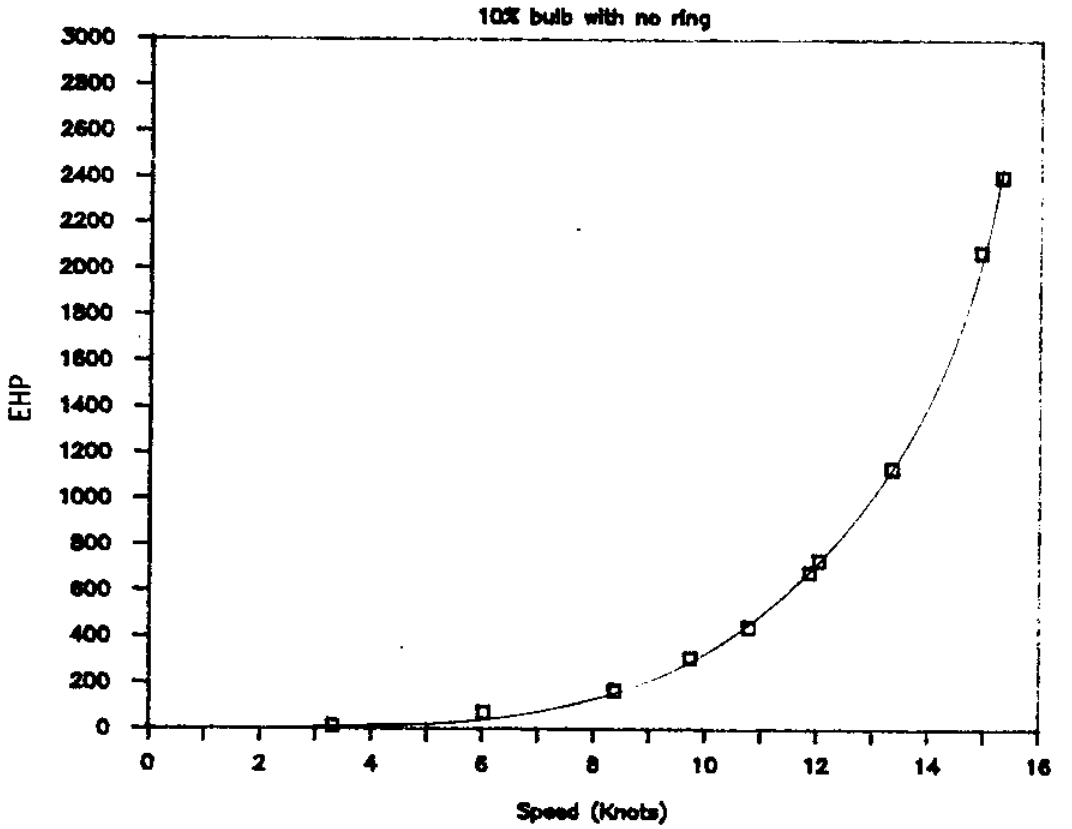
Appendix 2

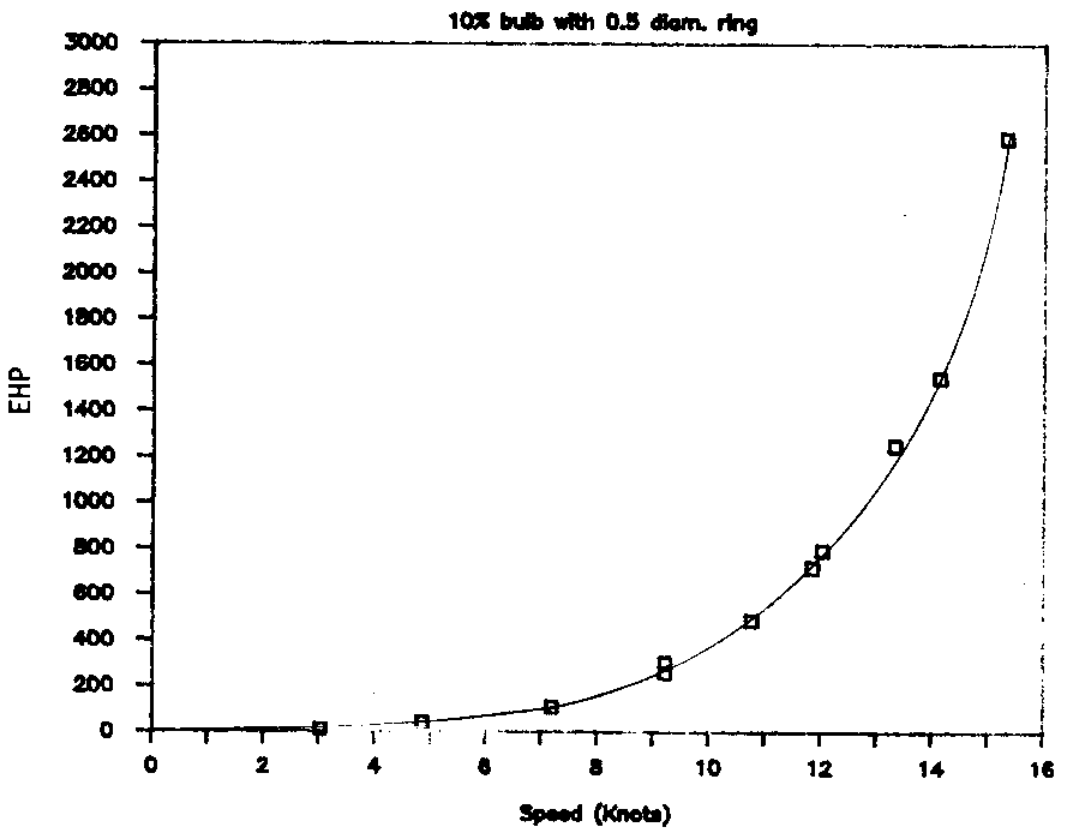
Graphs of EHP verses Speed.

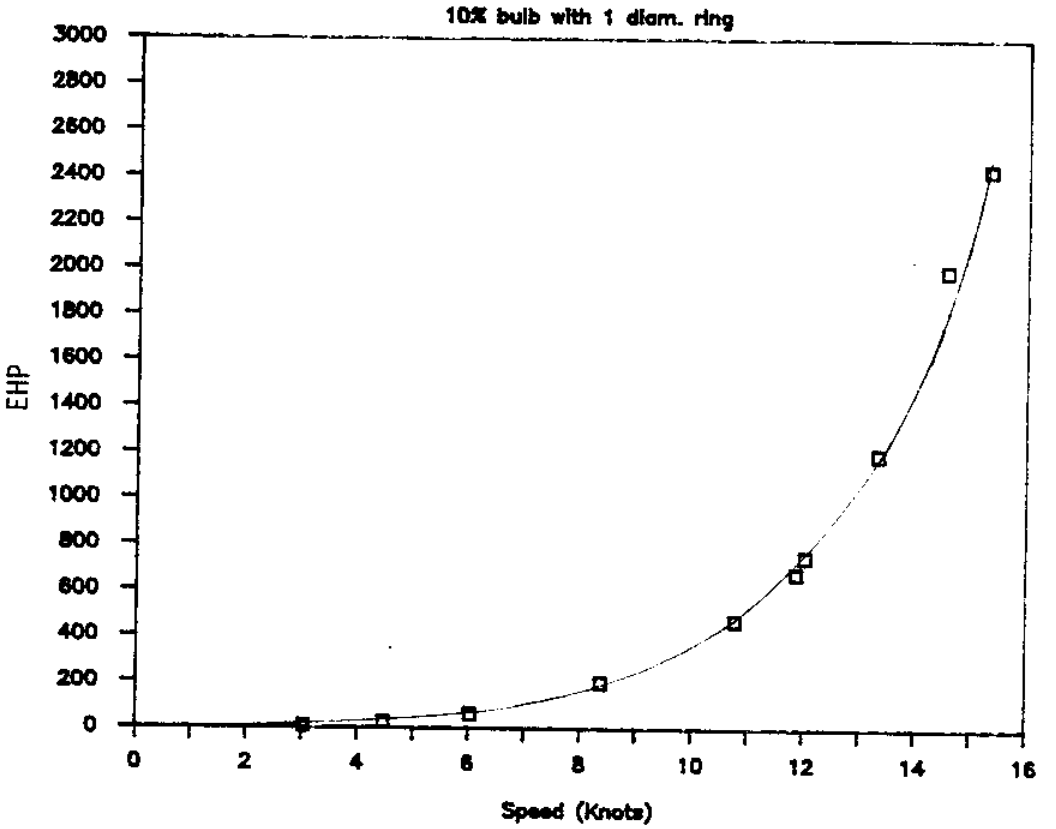
50 m TRAWLER WITH NO BULB

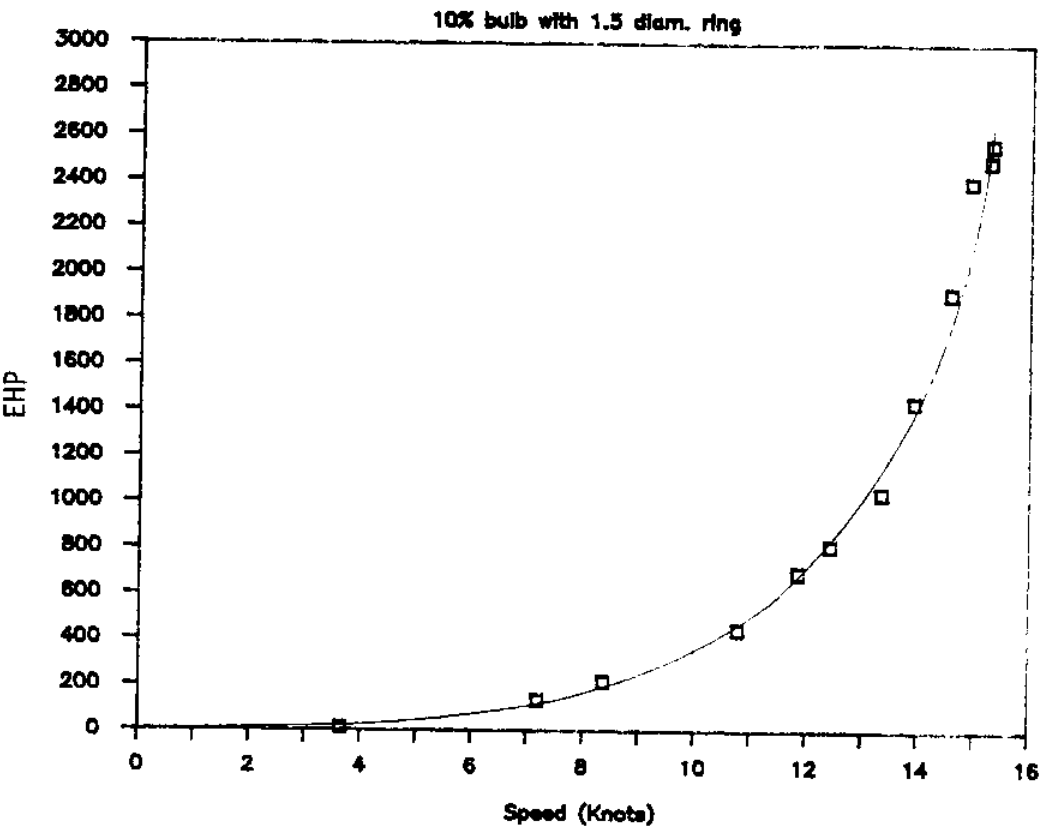


50 m TRAWLER WITH 10% BULBS

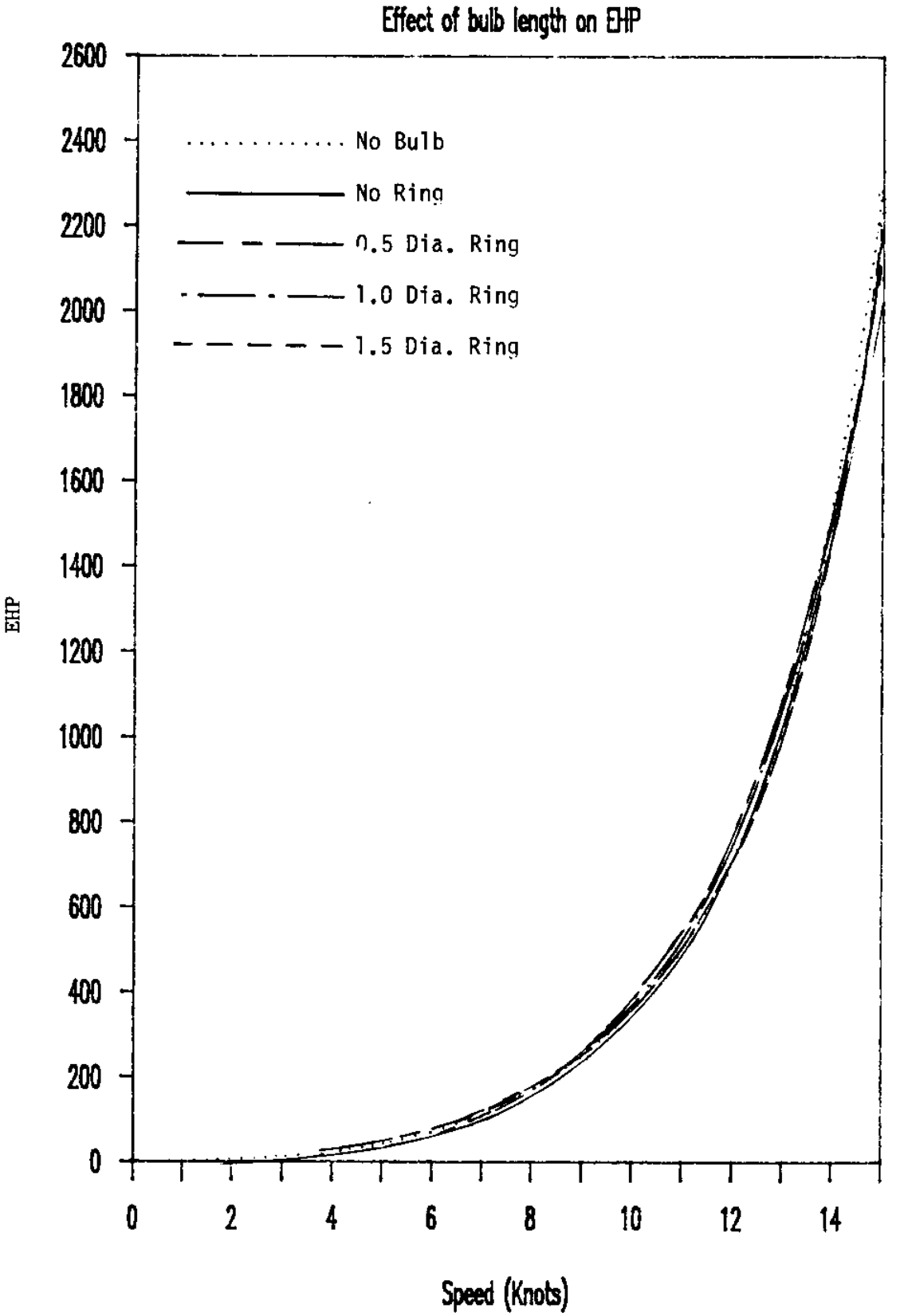




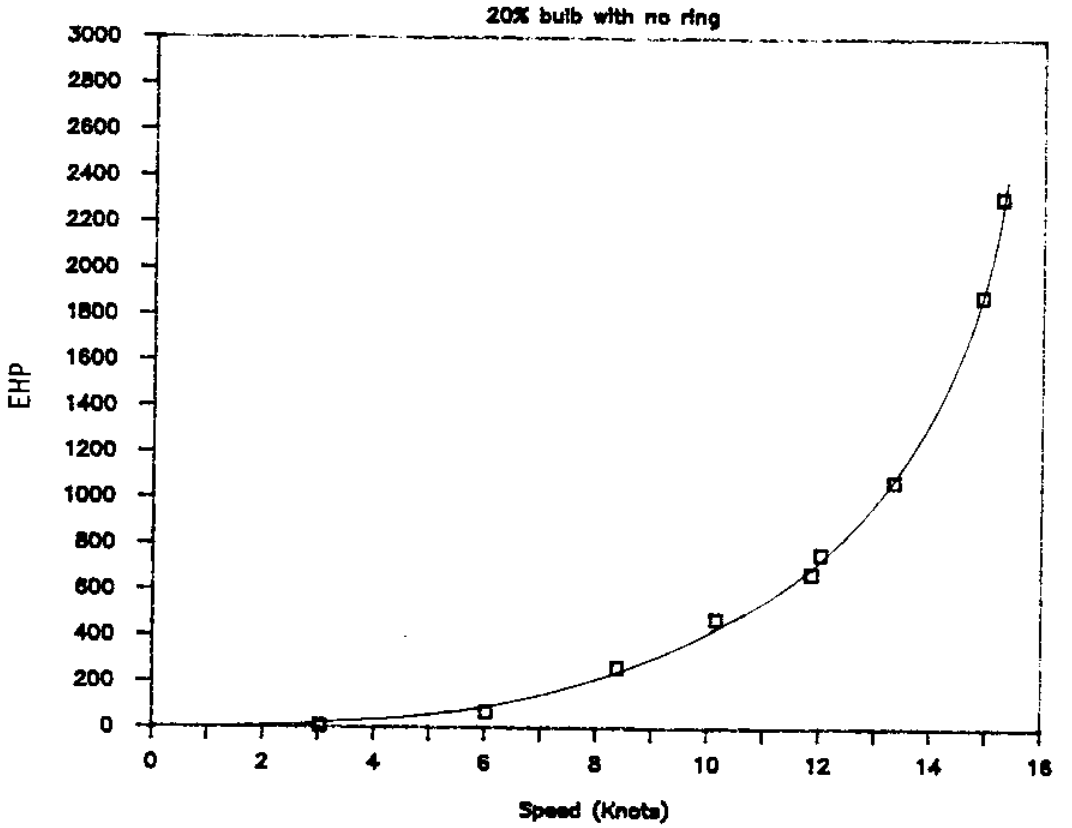

10% bulb with 1 diam. ring
EHP
Speed (Knots)
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
2400
2600
2800
3000
0
2
4
6
8
10
12
14
16

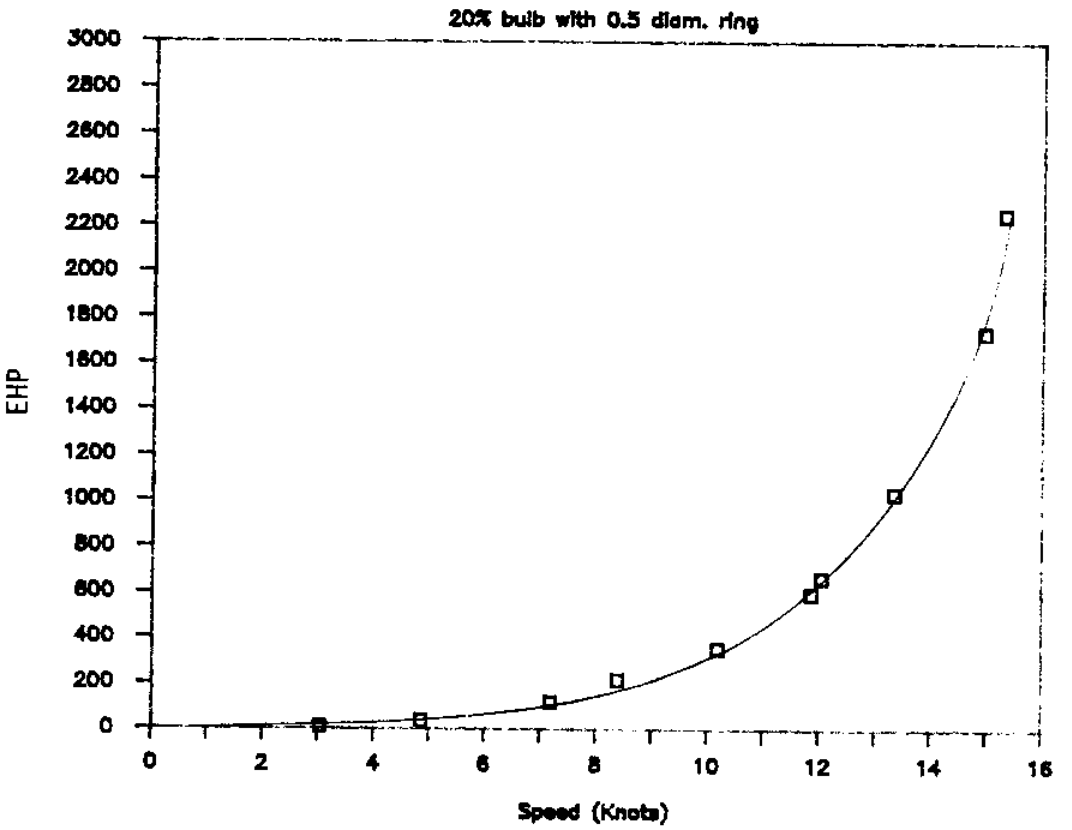

10% bulb with 1.5 diam. ring
EHP
Speed (Knots)
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
2400
2600
2800
3000
0
2
4
6
8
10
12
14
16

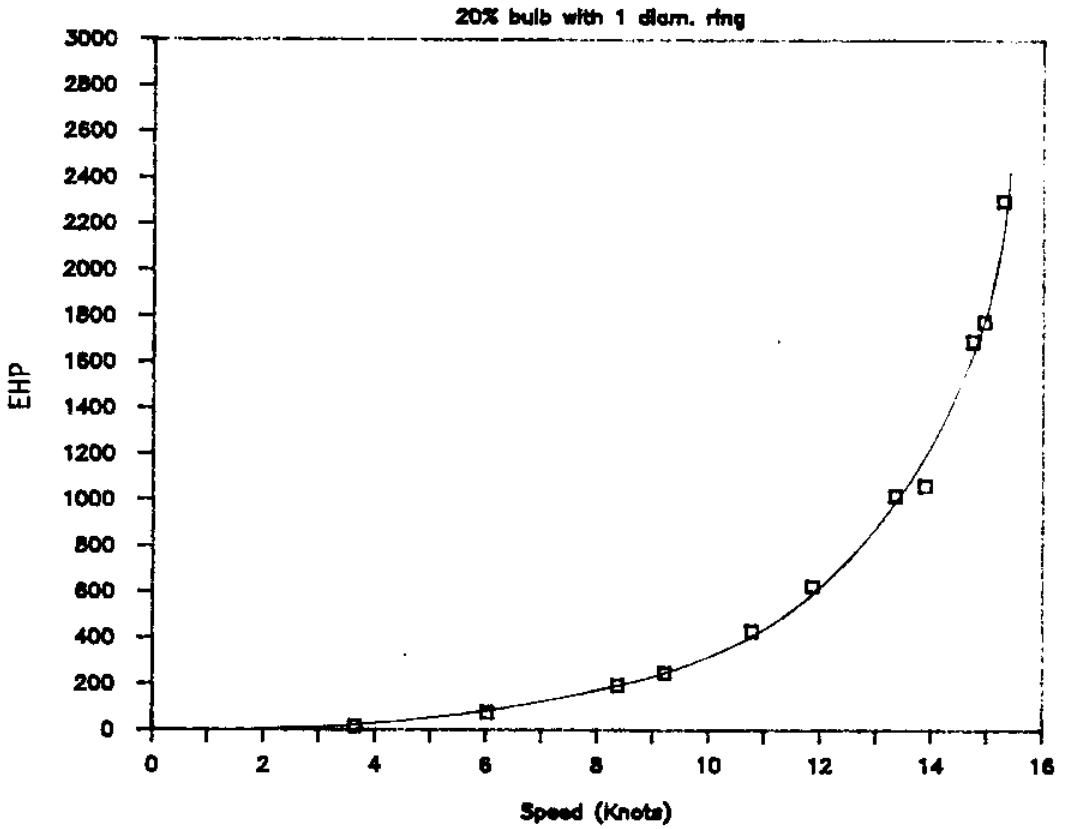
10% BULBS

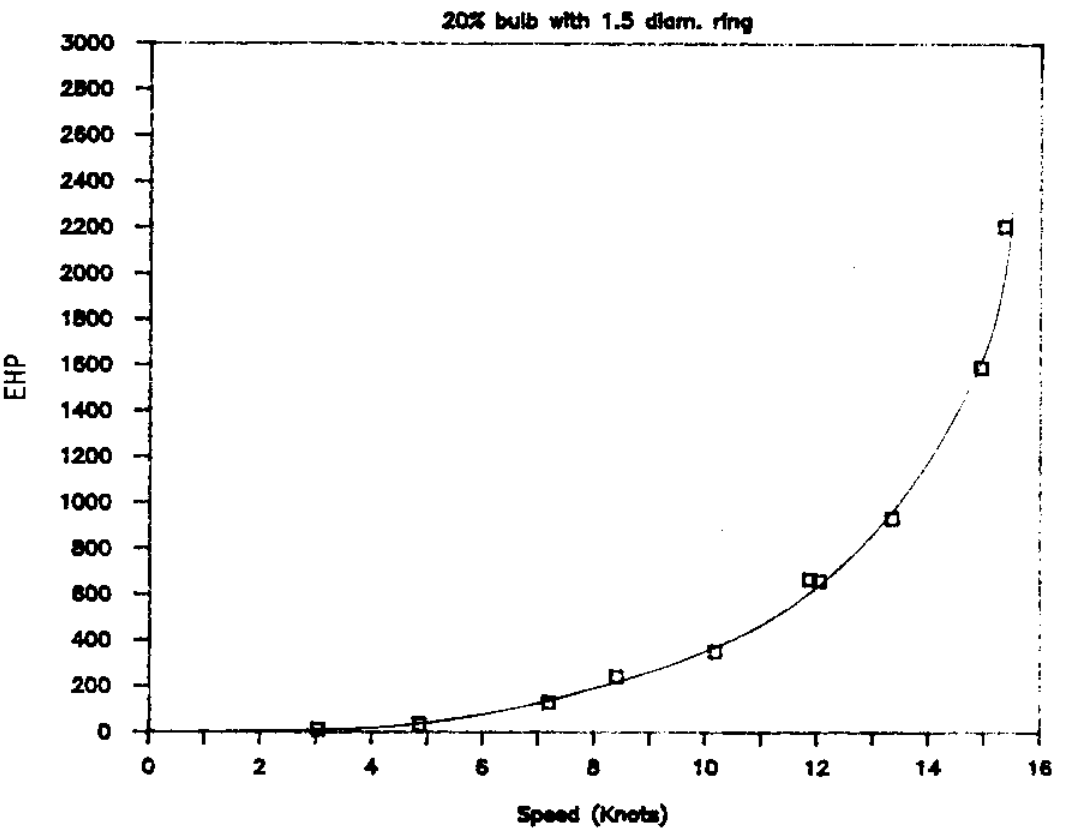

Effect of bulb length on EHP
No Bulb
No Ring
0.5 Dia. Ring
1.0 Dia. Ring
1.5 Dia. Ring
EHP
2600
2400
2200
2000
1800
1600
1400
1200
1000
800
600
400
200
0
0
2
4
6
8
10
12
14
Speed (Knots)

50m TRAWLER WITH 20% BULBS

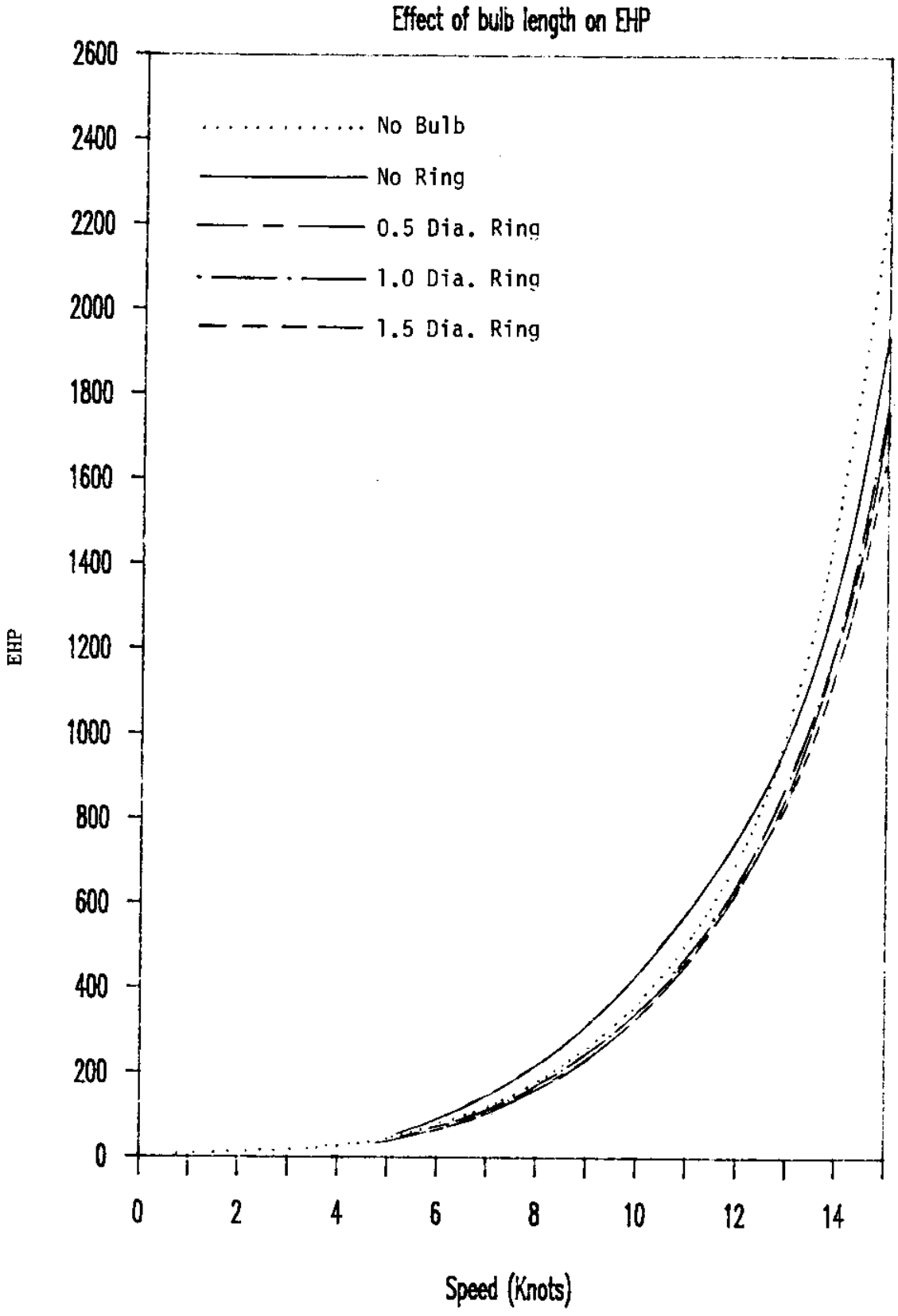




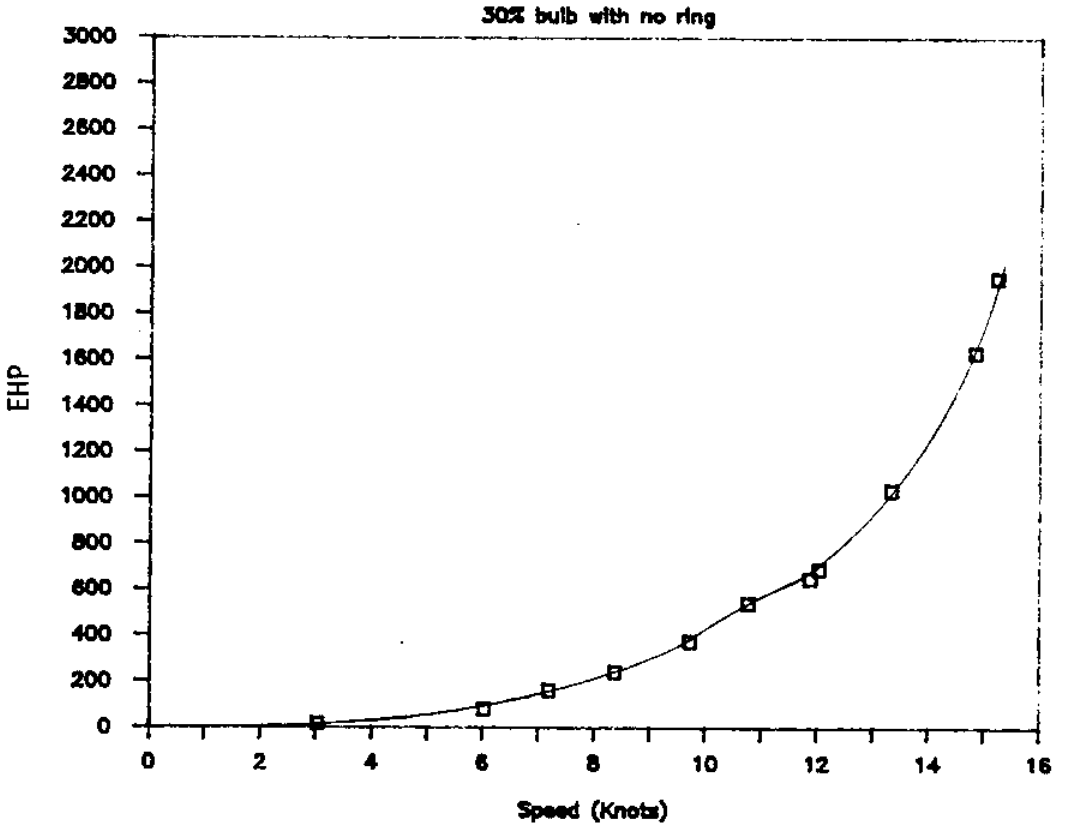

20% bulb with 1 diam. ring
EHP
Speed (Knots)
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
2400
2600
2800
3000
0
2
4
6
8
10
12
14
16

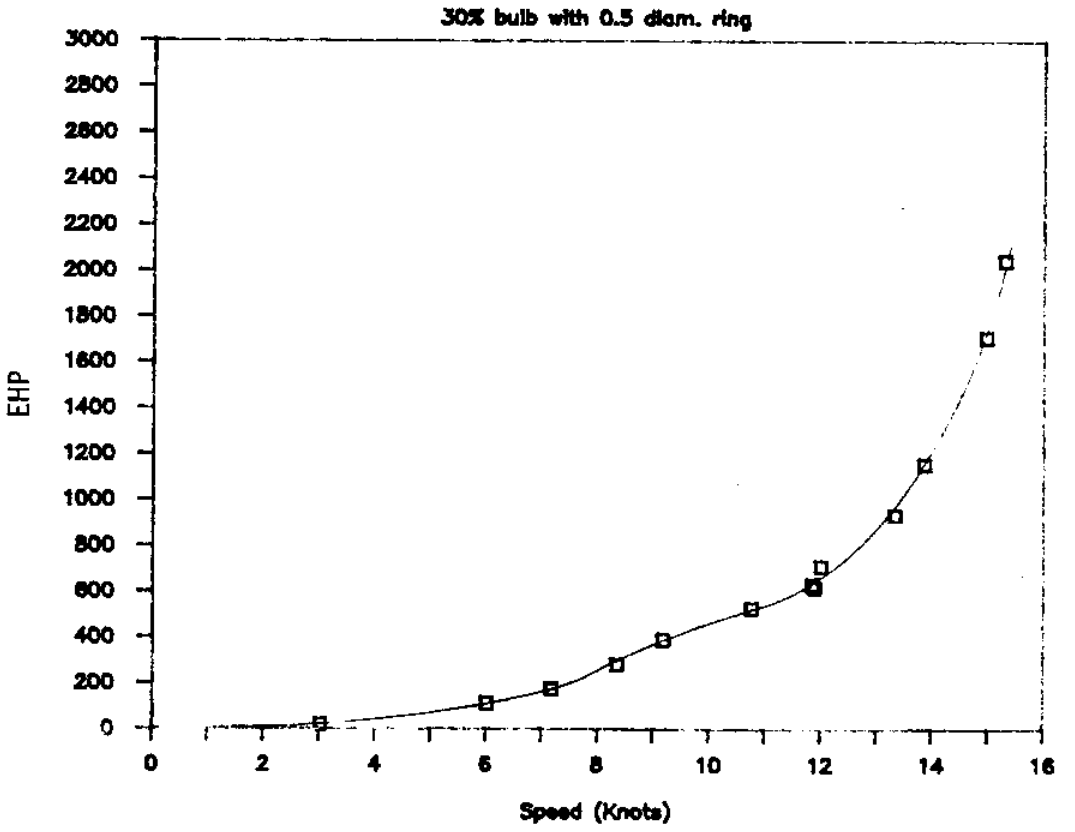

20% bulb with 1.5 diam. ring
EHP
Speed (Knots)
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
2400
2600
2800
3000
0
2
4
6
8
10
12
14
16

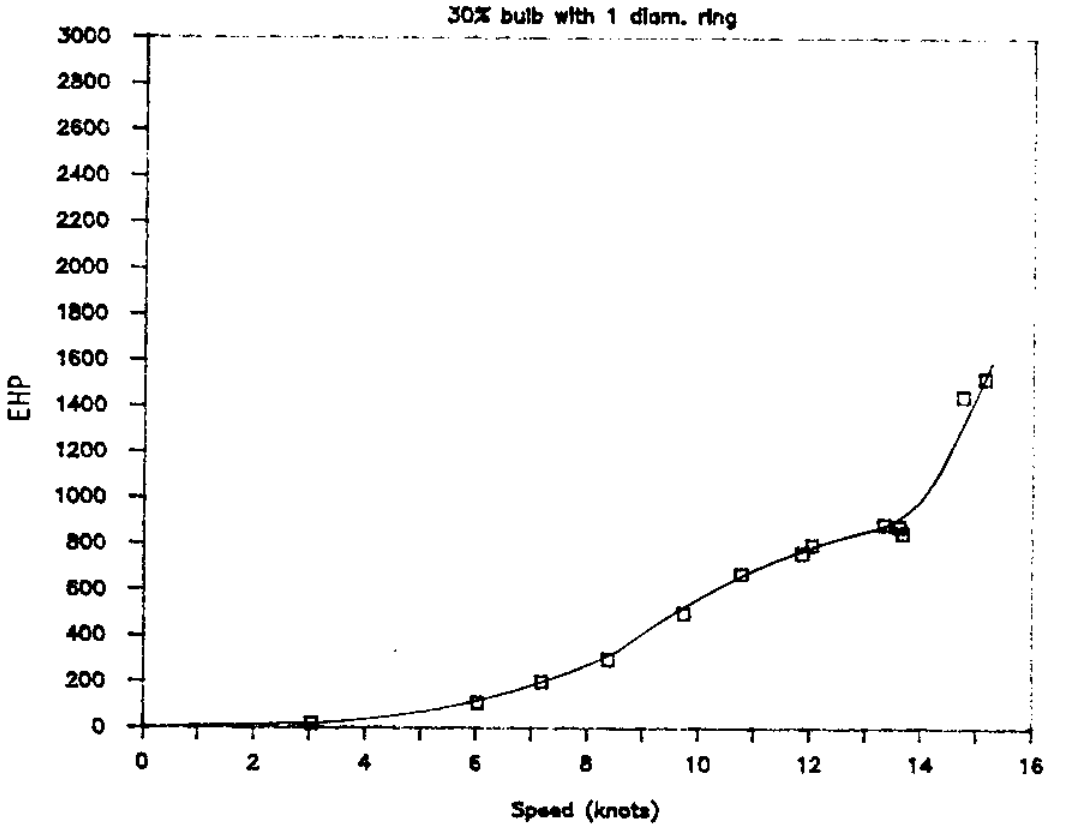
20% BULBS

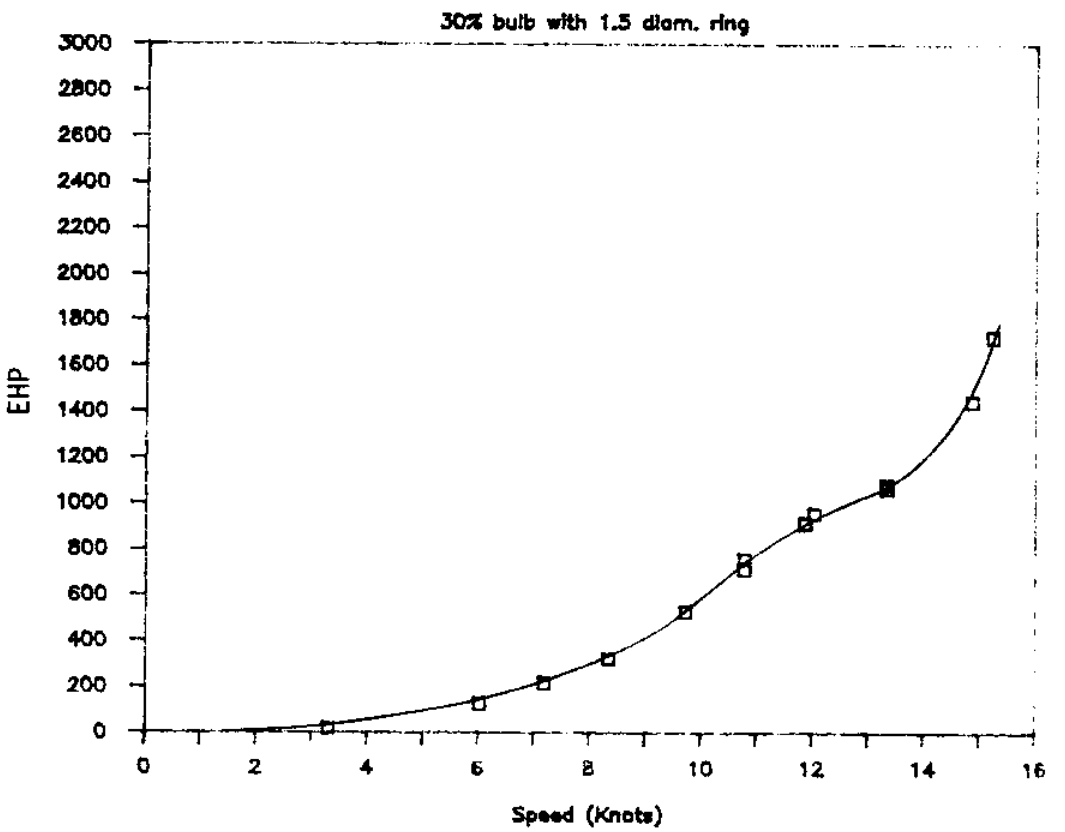

Effect of bulb length on EHP
No Bulb
No Ring
0.5 Dia. Ring
1.0 Dia. Ring
1.5 Dia. Ring
EHP
2600
2400
2200
2000
1800
1600
1400
1200
1000
800
600
400
200
0
0
2
4
6
8
10
12
14
Speed (Knots)

50m TRAWLER WITH 30% BULBS

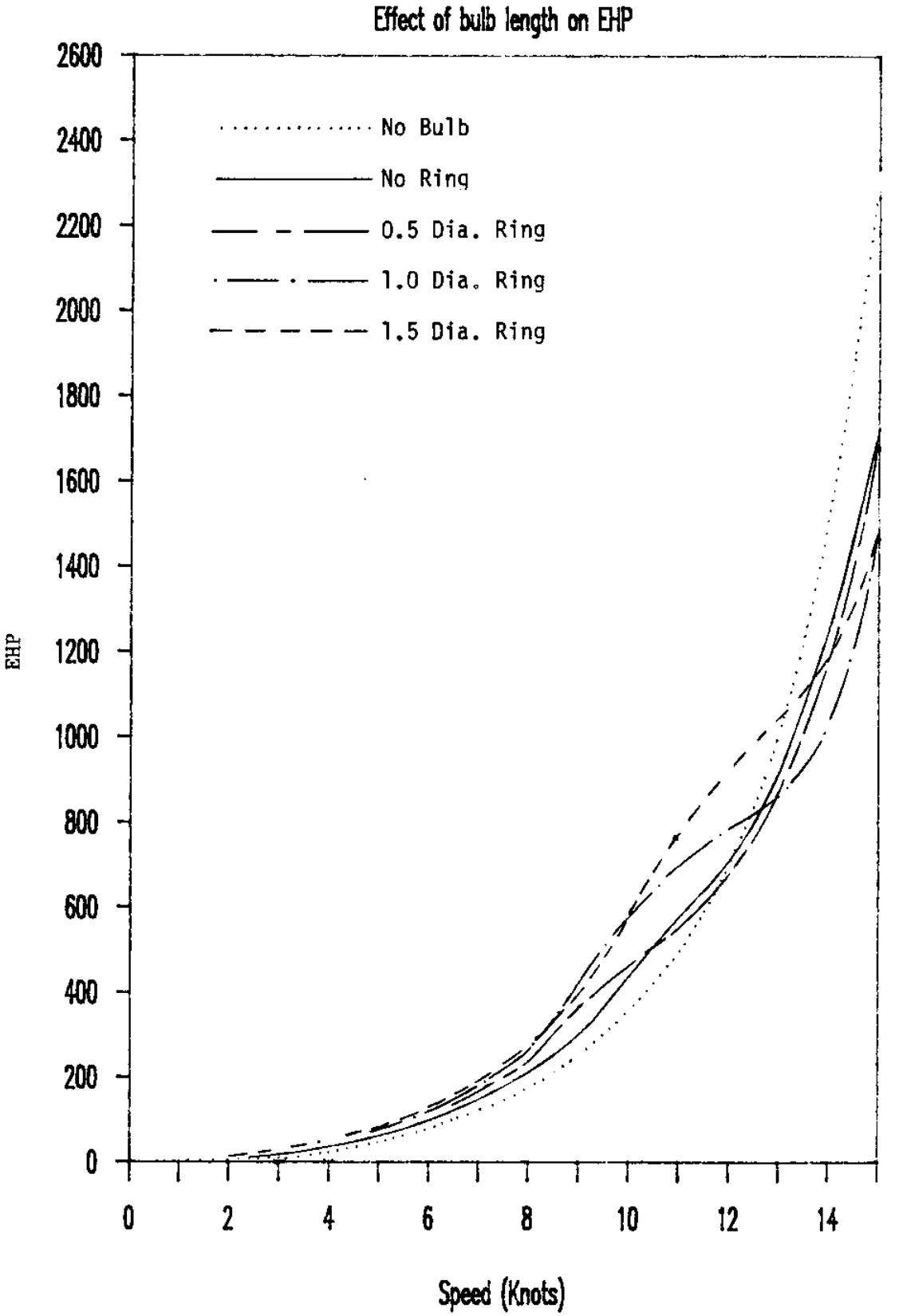





30% bulb with 1 diam. ring
EHP
3000
2800
2600
2400
2200
2000
1800
1600
1400
1200
1000
800
600
400
200
0
0
2
4
6
8
10
12
14
16
Speed (knots)


30% bulb with 1.5 diam. ring
EHP
3000
2800
2600
2400
2200
2000
1800
1600
1400
1200
1000
800
600
400
200
0
0
2
4
6
8
10
12
14
16
Speed (Knots)

30% BULBS


Effect of bulb length on EHP
No Bulb
No Ring
0.5 Dia. Ring
1.0 Dia. Ring
1.5 Dia. Ring
EHP
2600
2400
2200
2000
1800
1600
1400
1200
1000
800
600
400
200
0
0
2
4
6
8
10
12
14
Speed (Knots)

Appendix 3

Results of Resistance Regression Model.

164' Hull, No Bulb

INPUT DATA:

LWL	Ta	Tf	VOLUME	B	Cm	Cwp	LCB%	P/D est.
150	16.0	13.1	40506	38.5	.91	.83	-2.40	0.65

DIA	Hb	Ab	K2+1	Sapp	Cstern	At	Nprops	BAR est.
10.0	0.0	0.0	1.50	154.0	+0	34.0	1	.65

Vkts	Wt	Rf	Rw	Rapp	Rb	Rtr	Ra	Rtotal	EHP
1.0	.22	65	0	2	+0	+18	+13	98	0.3
2.0	.22	234	0	6	+0	+68	+51	359	2.2
3.0	.22	496	0	13	+0	+142	+114	765	7.0
4.0	.22	844	0	23	+0	+234	+202	1303	16.0
5.0	.22	1277	0	34	+0	+336	+316	1963	30.1
6.0	.22	1791	2	48	+0	+442	+455	2738	50.5
7.0	.22	2385	20	64	+0	+545	+619	3633	78.1
8.0	.22	3057	102	82	+0	+636	+809	4686	115.1
9.0	.21	3805	355	102	+0	+711	+1023	5997	165.7
10.0	.21	4630	1033	124	+0	+760	+1263	7811	239.9
11.0	.21	5529	2710	148	+0	+778	+1529	10695	361.3
12.0	.21	6503	4819	174	+0	+758	+1819	14074	518.6
13.0	.21	7549	7759	202	+0	+692	+2135	18337	732.1
14.0	.21	8668	13380	232	+0	+573	+2476	25329	1089.0
15.0	.21	9859	23922	264	+0	+394	+2843	37282	1717.3

164' Hull, 10% Bulb, 3.9' Above BL

INPUT DATA:

LWL	Ta	Tf	VOLUME	B	Cm	Cwp	LCB%	P/D est.
150	16.0	13.1	41446	38.5	.91	.83	-1.48	0.65

DIA	Hb	Ab	K2+1	Sapp	Cstern	At	Nprops	BAR est.
10.0	3.9	33.8	1.50	154.0	+0	34.0	1	.65

Vkts	Wt	Rf	Rw	Rapp	Rb	Rtr	Ra	Rtotal	EHP
1.0	.22	67	0	2	+0	+18	+13	100	0.3
2.0	.22	241	0	6	+0	+68	+52	368	2.3
3.0	.22	510	0	13	+0	+142	+117	783	7.2
4.0	.22	869	0	23	+0	+234	+208	1334	16.4
5.0	.22	1315	0	34	+0	+336	+326	2011	30.9
6.0	.22	1844	2	48	+0	+442	+469	2806	51.7
7.0	.21	2456	17	64	+0	+545	+638	3720	80.0
8.0	.21	3148	84	82	+0	+636	+834	4784	117.5
9.0	.21	3919	300	102	+0	+711	+1055	6087	168.2
10.0	.21	4769	831	124	+0	+760	+1303	7787	239.1
11.0	.21	5695	2262	148	+0	+778	+1576	10460	353.3
12.0	.21	6697	4090	174	+0	+758	+1876	13596	501.0
13.0	.21	7775	6391	202	+0	+692	+2201	17262	689.1
14.0	.21	8928	10712	232	+0	+573	+2553	22998	988.7
15.0	.21	10154	19006	264	+0	+394	+2931	32749	1508.6

164' Hull. 10% Bulb, 5.0' Above BL

INPUT DATA:

LWL	Ta	Tf	VOLUME	B	Cm	Cwp	LCB%	P/D est.
150	16.0	13.1	41446	38.5	.91	.83	-1.48	0.65

DIA	Hb	Ab	K2+1	Sapp	Cstern	At	Nprops	BAR est.
10.0	5.0	33.8	1.50	154.0	+0	34.0	1	.65

Vkts	Wt	Rf	Rw	Rapp	Rb	Rtr	Ra	Rtotal	EHP
1.0	.22	67	0	2	+0	+18	+13	100	0.3
2.0	.22	241	0	6	+0	+68	+52	368	2.3
3.0	.22	510	0	13	+0	+142	+117	783	7.2
4.0	.22	869	0	23	+0	+234	+208	1335	16.4
5.0	.22	1315	0	34	+0	+336	+326	2011	30.9
6.0	.22	1844	2	48	+0	+442	+469	2806	51.7
7.0	.21	2456	17	64	+0	+545	+638	3720	80.0
8.0	.21	3148	83	82	+0	+636	+834	4783	117.5
9.0	.21	3919	296	102	+0	+711	+1055	6083	168.1
10.0	.21	4769	819	124	+0	+760	+1303	7775	238.8
11.0	.21	5695	2231	148	+0	+778	+1576	10429	352.3
12.0	.21	6697	4035	174	+0	+758	+1876	13540	499.0
13.0	.21	7775	6305	202	+0	+692	+2201	17175	685.7
14.0	.21	8928	10567	232	+0	+573	+2553	22853	982.5
15.0	.21	10154	18749	264	+0	+394	+2931	32492	1496.7

164' Hull, 10% Bulb, 6.0' Above BL

INPUT DATA:

LWL	Ta	Tf	VOLUME	B	Cm	Cwp	LCB%	P/D est.
150	16.0	13.1	41446	38.5	.91	.83	-1.48	0.65

DIA	Hb	Ab	K2+1	Sapp	Cstern	At	Nprops	BAR est.
10.0	6.0	33.8	1.50	154.0	+0	34.0	1	.65

Vkts	Wt	Rf	Rw	Rapp	Rb	Rtr	Ra	Rtotal	EHP
1.0	.22	67	0	2	+0	+18	+13	100	0.3
2.0	.22	241	0	6	+0	+68	+52	368	2.3
3.0	.22	510	0	13	+0	+142	+117	784	7.2
4.0	.22	869	0	23	+1	+234	+208	1335	16.4
5.0	.22	1315	0	34	+2	+336	+326	2013	30.9
6.0	.22	1844	2	48	+2	+442	+469	2808	51.7
7.0	.21	2456	16	64	+3	+545	+638	3723	80.0
8.0	.21	3148	81	82	+4	+636	+834	4786	117.6
9.0	.21	3919	291	102	+5	+711	+1055	6084	168.2
10.0	.21	4769	808	124	+6	+760	+1303	7770	238.6
11.0	.21	5695	2199	148	+7	+778	+1576	10404	351.5
12.0	.21	6697	3976	174	+8	+758	+1876	13490	497.1
13.0	.21	7775	6213	202	+9	+692	+2201	17093	682.4
14.0	.21	8928	10414	232	+10	+573	+2553	22710	976.4
15.0	.21	10154	18478	264	+11	+394	+2931	32232	1484.7

164' Hull, 10% Bulb, 7.0' Above BL

INPUT DATA:

LWL	Ta	Tf	VOLUME	B	Cm	Cwp	LCB%	P/D est.
150	16.0	13.1	41446	38.5	.91	.83	-1.48	0.65

DIA	Hb	Ab	K2+1	Sapp	Cstern	At	Nprops	BAR est.
10.0	7.0	33.8	1.50	154.0	+0	34.0	1	.65

Vkts	Wt	Rf	Rw	Rapp	Rb	Rtr	Ra	Rtotal	EHP
1.0	.22	67	0	2	+0	+18	+13	101	0.3
2.0	.22	241	0	6	+3	+68	+52	370	2.3
3.0	.22	510	0	13	+9	+142	+117	792	7.3
4.0	.22	869	0	23	+18	+234	+208	1353	16.6
5.0	.22	1315	0	34	+32	+336	+326	2043	31.4
6.0	.22	1844	2	48	+48	+442	+469	2853	52.6
7.0	.21	2456	16	64	+66	+545	+638	3785	81.4
8.0	.21	3148	80	82	+85	+636	+834	4865	119.5
9.0	.21	3919	286	102	+104	+711	+1055	6178	170.8
10.0	.21	4769	794	124	+124	+760	+1303	7873	241.8
11.0	.21	5695	2161	148	+143	+778	+1576	10502	354.8
12.0	.21	6697	3908	174	+161	+758	+1876	13575	500.2
13.0	.21	7775	6107	202	+178	+692	+2201	17156	684.9
14.0	.21	8928	10236	232	+195	+573	+2553	22717	976.7
15.0	.21	10154	18162	264	+211	+394	+2931	32116	1479.4

164' Hull, 20% Bulb, 3.0' Above BL

INPUT DATA:

LWL	Ta	Tf	VOLUME	B	Cm	Cwp	LCB%	P/D est.
150	16.0	13.1	43265	38.5	.91	.83	-1.34	0.65

DIA	Hb	Ab	K2+1	Sapp	Cstern	At	Nprops	BAR est.
10.0	3.0	81.8	1.50	154.0	+0	34.0	1	.65

Vkts	Wt	Rf	Rw	Rapp	Rb	Rtr	Ra	Rtotal	EHP
1.0	.23	71	0	2	+0	+18	+14	105	0.3
2.0	.23	255	0	6	+0	+68	+54	383	2.4
3.0	.22	538	0	13	+0	+142	+122	816	7.5
4.0	.22	917	0	23	+0	+234	+218	1391	17.1
5.0	.22	1387	0	34	+0	+336	+340	2098	32.2
6.0	.22	1946	2	48	+0	+442	+490	2928	53.9
7.0	.22	2591	16	64	+0	+545	+666	3882	83.4
8.0	.22	3321	77	82	+0	+636	+870	4986	122.5
9.0	.22	4135	292	102	+0	+711	+1101	6341	175.3
10.0	.22	5031	732	124	+0	+760	+1360	8007	245.9
11.0	.22	6008	2092	148	+0	+778	+1645	10672	360.5
12.0	.22	7065	4018	174	+0	+758	+1958	13973	514.9
13.0	.22	8202	5986	202	+1	+692	+2298	17381	693.9
14.0	.22	9418	9399	232	+1	+573	+2665	22288	958.2
15.0	.22	10711	16230	264	+1	+394	+3059	30660	1412.3

164' Hull, 20% Bulb, 4.0' Above BL

INPUT DATA:

LWL	Ta	Tf	VOLUME	B	Cm	Cwp	LCB%	P/D est.
150	16.0	13.1	43265	38.5	.91	.83	-1.34	0.65

DIA	Hb	Ab	K2+1	Sapp	Cstern	At	Nprops	BAR est.
10.0	4.0	81.8	1.50	154.0	+0	34.0	1	.65

Vkts	Wt	Rf	Rw	Rapp	Rb	Rtr	Ra	Rtotal	EHP
1.0	.23	71	0	2	+0	+18	+14	105	0.3
2.0	.23	255	0	6	+0	+68	+54	383	2.4
3.0	.22	538	0	13	+0	+142	+122	817	7.5
4.0	.22	917	0	23	+1	+234	+218	1392	17.1
5.0	.22	1387	0	34	+1	+336	+340	2099	32.2
6.0	.22	1946	2	48	+2	+442	+490	2929	54.0
7.0	.22	2591	15	64	+3	+545	+666	3884	83.5
8.0	.22	3321	75	82	+4	+636	+870	4989	122.6
9.0	.22	4135	287	102	+5	+711	+1101	6341	175.2
10.0	.22	5031	719	124	+6	+760	+1360	8000	245.7
11.0	.22	6008	2053	148	+7	+778	+1645	10640	359.4
12.0	.22	7065	3943	174	+8	+758	+1958	13907	512.5
13.0	.22	8202	5876	202	+10	+692	+2298	17280	689.8
14.0	.22	9418	9226	232	+11	+573	+2665	22124	951.2
15.0	.22	10711	15931	264	+12	+394	+3059	30371	1399.0

164' Hull, 20% Bulb, 5.0' Above BL

INPUT DATA:

LWL	Ta	Tf	VOLUME	B	Cm	Cwp	LCB%	P/D est.
150	16.0	13.1	43265	38.5	.91	.83	-1.34	0.65

DIA	Hb	Ab	K2+1	Sapp	Cstern	At	Nprops	BAR est.
10.0	5.0	81.8	1.50	154.0	+0	34.0	1	.65

Vkts	Wt	Rf	Rw	Rapp	Rb	Rtr	Ra	Rtotal	EHP
1.0	.23	71	0	2	+0	+18	+14	105	0.3
2.0	.23	255	0	6	+1	+68	+54	384	2.4
3.0	.22	538	0	13	+4	+142	+122	820	7.6
4.0	.22	917	0	23	+8	+234	+218	1400	17.2
5.0	.22	1387	0	34	+15	+336	+340	2112	32.4
6.0	.22	1946	2	48	+23	+442	+490	2950	54.4
7.0	.22	2591	15	64	+32	+545	+666	3913	84.1
8.0	.22	3321	74	82	+42	+636	+870	5026	123.5
9.0	.22	4135	281	102	+53	+711	+1101	6383	176.4
10.0	.22	5031	704	124	+64	+760	+1360	8043	247.0
11.0	.22	6008	2010	148	+75	+778	+1645	10665	360.3
12.0	.22	7065	3861	174	+86	+758	+1958	13902	512.3
13.0	.22	8202	5753	202	+97	+692	+2298	17244	688.4
14.0	.22	9418	9033	232	+107	+573	+2665	22028	947.0
15.0	.22	10711	15598	264	+117	+394	+3059	30143	1388.5

164' Hull. 20% Bulb, 6.0' Above BL

INPUT DATA:

LWL	Ta	Tf	VOLUME	B	Cm	Cwp	LCB%	P/D est.
150	16.0	13.1	43265	38.5	.91	.83	-1.34	0.65

DIA	Hb	Ab	K2+1	Sapp	Cstern	At	Nprops	BAR est.
10.0	6.0	81.8	1.50	154.0	+0	34.0	1	.65

Vkts	Wt	Rf	Rw	Rapp	Rb	Rtr	Ra	Rtotal	EHP
1.0	.23	71	0	2	+1	+18	+14	106	0.3
2.0	.23	255	0	6	+8	+68	+54	391	2.4
3.0	.22	538	0	13	+25	+142	+122	842	7.8
4.0	.22	917	0	23	+54	+234	+218	1446	17.8
5.0	.22	1387	0	34	+95	+336	+340	2193	33.7
6.0	.22	1946	2	48	+146	+442	+490	3073	56.6
7.0	.22	2591	15	64	+203	+545	+666	4083	87.8
8.0	.22	3321	72	82	+265	+636	+870	5246	128.9
9.0	.22	4135	274	102	+329	+711	+1101	6652	183.9
10.0	.22	5031	687	124	+394	+760	+1360	8356	256.6
11.0	.22	6008	1962	148	+458	+778	+1645	11000	371.6
12.0	.22	7065	3768	174	+521	+758	+1958	14245	524.9
13.0	.22	8202	5615	202	+582	+692	+2298	17591	702.3
14.0	.22	9418	8817	232	+639	+573	+2665	22344	960.6
15.0	.22	10711	15224	264	+694	+394	+3059	30347	1397.9

164' Hull, 20% Bulb, 7.0' Above BL

INPUT DATA:

LWL	Ta	Tf	VOLUME	B	Cm	Cwp	LCB%	P/D est.
150	16.0	13.1	43265	38.5	.91	.83	-1.34	0.65

DIA	Hb	Ab	K2+1	Sapp	Cstern	At	Nprops	BAR est.
10.0	7.0	81.8	1.50	154.0	+0	34.0	1	.65

Vkts	Wt	Rf	Rw	Rapp	Rb	Rtr	Ra	Rtotal	EHP
1.0	.23	71	0	2	+4	+18	+14	109	0.3
2.0	.23	255	0	6	+33	+68	+54	416	2.6
3.0	.22	538	0	13	+101	+142	+122	918	8.5
4.0	.22	917	0	23	+216	+234	+218	1607	19.7
5.0	.22	1387	0	34	+372	+336	+340	2470	37.9
6.0	.22	1946	2	48	+560	+442	+490	3488	64.3
7.0	.22	2591	14	64	+771	+545	+666	4651	100.0
8.0	.22	3321	70	82	+994	+636	+870	5973	146.7
9.0	.22	4135	266	102	+1221	+711	+1101	7537	208.3
10.0	.22	5031	668	124	+1447	+760	+1360	9390	288.3
11.0	.22	6008	1908	148	+1668	+778	+1645	12155	410.6
12.0	.22	7065	3664	174	+1880	+758	+1958	15499	571.2
13.0	.22	8202	5459	202	+2083	+692	+2298	18936	756.0
14.0	.22	9418	8571	232	+2275	+573	+2665	23734	1020.4
15.0	.22	10711	14800	264	+2455	+394	+3059	31684	1459.5

164' Hull, 20% Bulb, 2.0' Above BL

INPUT DATA:

LWL	Ta	Tf	VOLUME	B	Cm	Cwp	LCB%	P/D est.
150	16.0	13.1	43265	38.5	.91	.83	-1.34	0.65

DIA	Hb	Ab	K2+1	Sapp	Cstern	At	Nprops	BAR est.
10.0	2.0	81.8	1.50	154.0	+0	34.0	1	.65

Vkts	Wt	Rf	Rw	Rapp	Rb	Rtr	Ra	Rtotal	EHP
1.0	.23	71	0	2	+0	+18	+14	105	0.3
2.0	.23	255	0	6	+0	+68	+54	383	2.4
3.0	.22	538	0	13	+0	+142	+122	816	7.5
4.0	.22	917	0	23	+0	+234	+218	1391	17.1
5.0	.22	1387	0	34	+0	+336	+340	2098	32.2
6.0	.22	1946	2	48	+0	+442	+490	2927	53.9
7.0	.22	2591	16	64	+0	+545	+666	3882	83.4
8.0	.22	3321	78	82	+0	+636	+870	4987	122.5
9.0	.22	4135	297	102	+0	+711	+1101	6346	175.4
10.0	.22	5031	744	124	+0	+760	+1360	8019	246.3
11.0	.22	6008	2127	148	+0	+778	+1645	10707	361.7
12.0	.22	7065	4085	174	+0	+758	+1958	14040	517.4
13.0	.22	8202	6087	202	+0	+692	+2298	17481	697.9
14.0	.22	9418	9557	232	+0	+573	+2665	22444	964.9
15.0	.22	10711	16501	264	+0	+394	+3059	30930	1424.8

164' Hull, 30% Bulb, 2.0' Above BL

INPUT DATA:

LWL	Ta	Tf	VOLUME	B	Cm	Cwp	LCB%	P/D est.
150	16.0	13.1	43784	38.5	.91	.83	-0.81	0.65

DIA	Hb	Ab	K2+1	Sapp	Cstern	At	Nprops	BAR est.
10.0	2.0	135.3	1.50	154.0	+0	34.0	1	.65

Vkts	Wt	Rf	Rw	Rapp	Rb	Rtr	Ra	Rtotal	EHP
1.0	.23	74	0	2	+0	+18	+14	108	0.3
2.0	.23	264	0	6	+0	+68	+56	394	2.4
3.0	.22	558	0	13	+0	+142	+127	841	7.7
4.0	.22	951	0	23	+0	+234	+225	1433	17.6
5.0	.22	1438	0	34	+1	+336	+352	2161	33.2
6.0	.22	2017	2	48	+1	+442	+507	3017	55.6
7.0	.22	2685	14	64	+1	+545	+691	4000	86.0
8.0	.22	3442	68	82	+2	+636	+902	5132	126.1
9.0	.22	4285	261	102	+2	+711	+1141	6503	179.7
10.0	.22	5214	638	124	+3	+760	+1409	8149	250.2
11.0	.22	6227	1833	148	+4	+778	+1705	10695	361.3
12.0	.22	7323	3604	174	+4	+758	+2029	13893	512.0
13.0	.22	8501	5319	202	+5	+692	+2382	17100	682.7
14.0	.22	9761	8181	232	+5	+573	+2762	21515	925.0
15.0	.22	11102	13973	264	+6	+394	+3171	28910	1331.7

164' Hull, 30% Bulb, 3.0' Above BL

INPUT DATA:

LWL	Ta	Tf	VOLUME	B	Cm	Cwp	LCB%	P/D est.
150	16.0	13.1	43784	38.5	.91	.83	-0.81	0.65

DIA	Hb	Ab	K2+1	Sapp	Cstern	At	Nprops	BAR est.
10.0	3.0	135.3	1.50	154.0	+0	34.0	1	.65

Vkts	Wt	Rf	Rw	Rapp	Rb	Rtr	Ra	Rtotal	EHP
1.0	.23	74	0	2	+0	+18	+14	108	0.3
2.0	.23	264	0	6	+0	+68	+56	395	2.4
3.0	.22	558	0	13	+1	+142	+127	842	7.8
4.0	.22	951	0	23	+3	+234	+225	1436	17.6
5.0	.22	1438	0	34	+5	+336	+352	2166	33.3
6.0	.22	2017	2	48	+8	+442	+507	3024	55.7
7.0	.22	2685	14	64	+11	+545	+691	4009	86.2
8.0	.22	3442	66	82	+15	+636	+902	5144	126.4
9.0	.22	4285	256	102	+19	+711	+1141	6514	180.0
10.0	.22	5214	624	124	+23	+760	+1409	8156	250.5
11.0	.22	6227	1793	148	+28	+778	+1705	10680	360.8
12.0	.22	7323	3525	174	+32	+758	+2029	13842	510.1
13.0	.22	8501	5202	202	+37	+692	+2382	17016	679.3
14.0	.22	9761	8002	232	+41	+573	+2762	21371	918.8
15.0	.22	11102	13667	264	+45	+394	+3171	28643	1319.4

164' Hull, 30% Bulb, 4.0' Above BL

INPUT DATA:

LWL	Ta	Tf	VOLUME	B	Cm	Cwp	LCB%	P/D est.
150	16.0	13.1	43784	38.5	.91	.83	-0.81	0.65

DIA	Hb	Ab	K2+1	Sapp	Cstern	At	Nprops	BAR est.
10.0	4.0	135.3	1.50	154.0	+0	34.0	1	.65

Vkts	Wt	Rf	Rw	Rapp	Rb	Rtr	Ra	Rtotal	EHP
1.0	.23	74	0	2	+0	+18	+14	108	0.3
2.0	.23	264	0	6	+2	+68	+56	397	2.4
3.0	.22	558	0	13	+8	+142	+127	848	7.8
4.0	.22	951	0	23	+17	+234	+225	1450	17.8
5.0	.22	1438	0	34	+30	+336	+352	2191	33.6
6.0	.22	2017	2	48	+47	+442	+507	3063	56.4
7.0	.22	2685	13	64	+67	+545	+691	4065	87.4
8.0	.22	3442	64	82	+89	+636	+902	5216	128.1
9.0	.22	4285	249	102	+113	+711	+1141	6602	182.5
10.0	.22	5214	609	124	+137	+760	+1409	8254	253.5
11.0	.22	6227	1749	148	+162	+778	+1705	10770	363.8
12.0	.22	7323	3439	174	+186	+758	+2029	13910	512.6
13.0	.22	8501	5075	202	+210	+692	+2382	17062	681.2
14.0	.22	9761	7806	232	+234	+573	+2762	21369	918.7
15.0	.22	11102	[illegible]	264	+257	+394	+3171	28521	1313.8

164' Hull, 30% Bulb. 5.0' Above BL

INPUT DATA:

LWL	Ta	Tf	VOLUME	B	Cm	Cwp	LCB%	P/D est.
150	16.0	13.1	43784	38.5	.91	.83	-0.81	0.65

DIA	Hb	Ab	K2+1	Sapp	Cstern	At	Nprops	BAR est.
10.0	5.0	135.3	1.50	154.0	+0	34.0	1	.65

Vkts	Wt	Rf	Rw	Rapp	Rb	Rtr	Ra	Rtotal	EHP
1.0	.23	74	0	2	+1	+18	+14	109	0.3
2.0	.23	264	0	6	+11	+68	+56	405	2.5
3.0	.22	558	0	13	+35	+142	+127	875	8.1
4.0	.22	951	0	23	+76	+234	+225	1509	18.5
5.0	.22	1438	0	34	+135	+336	+352	2296	35.2
6.0	.22	2017	2	48	+208	+442	+507	3224	59.4
7.0	.22	2685	13	64	+294	+545	+691	4291	92.2
8.0	.22	3442	63	82	+387	+636	+902	5512	135.4
9.0	.22	4285	243	102	+485	+711	+1141	6967	192.6
10.0	.22	5214	592	124	+586	+760	+1409	8686	266.7
11.0	.22	6227	1701	148	+686	+778	+1705	11246	379.9
12.0	.22	7323	3345	174	+785	+758	+2029	14415	531.2
13.0	.22	8501	4936	202	+882	+692	+2382	17595	702.4
14.0	.22	9761	7592	232	+975	+573	+2762	21896	941.4
15.0	.22	11102	12967	264	+1065	+394	+3171	28963	1334.1

164' Hull, 30% Bulb, 6.0' Above BL

INPUT DATA:

LWL	Ta	Tf	VOLUME	B	Cm	Cwp	LCB%	P/D est.
150	16.0	13.1	43784	38.5	.91	.83	-0.81	0.65

DIA	Hb	Ab	K2+1	Sapp	Cstern	At	Nprops	BAR est.
10.0	6.0	135.3	1.50	154.0	+0	34.0	1	.65

Vkts	Wt	Rf	Rw	Rapp	Rb	Rtr	Ra	Rtotal	EHP
1.0	.23	74	0	2	+5	+18	+14	113	0.3
2.0	.23	264	0	6	+38	+68	+56	432	2.7
3.0	.22	558	0	13	+118	+142	+127	959	8.8
4.0	.22	951	0	23	+255	+234	+225	1688	20.7
5.0	.22	1438	0	34	+446	+336	+352	2607	40.0
6.0	.22	2017	2	48	+681	+442	+507	3697	68.1
7.0	.22	2685	12	64	+949	+545	+691	4946	106.3
8.0	.22	3442	61	82	+1237	+636	+902	6361	156.3
9.0	.22	4285	235	102	+1537	+711	+1141	8011	221.4
10.0	.22	5214	574	124	+1838	+760	+1409	9920	304.6
11.0	.22	6227	1648	148	+2137	+778	+1705	12644	427.1
12.0	.22	7323	3241	174	+2428	+758	+2029	15953	587.9
13.0	.22	8501	4782	202	+2708	+692	+2382	19267	769.2
14.0	.22	9761	7356	232	+2977	+573	+2762	23661	1017.2
15.0	.22	11102	12563	264	+3232	+394	+3171	30726	1415.4

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