Report 1055

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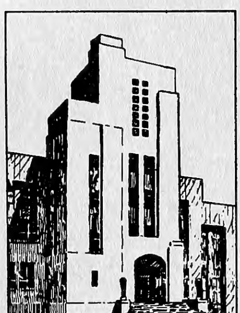
BEHAVIOR OF A PROPOSED OCEANOGRAPHIC RESEARCH VESSEL IN WAVES

by

F.V. Reed



RESEARCH AND DEVELOPMENT REPORT

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NOTATION

B	Maximum beam
C_B	Block coefficient
C_P	Longitudinal prismatic coefficient
C_X	Coefficient of maximum sectional area
H	Draft
h	Waveheight
L	Length of ship
r_m	Amplitude of wave
V_R	Ship speed producing resonant period of encounter
z_m	Amplitude of heave
ϑ_m	Maximum slope of wave
λ	Wavelength
ψ_m	Amplitude of pitch

ABSTRACT

A 5-foot model of a proposed oceanographic research vessel was tested for seaworthiness. Measurements of speed, pitch, and heave were made in a variety of wave conditions with the model heading into the waves, and qualitative observations were made in several wave conditions with the model in following seas.

INTRODUCTION

BACKGROUND

The broad definition of oceanography as "the science which is done at sea"[1] may be taken to epitomize the notion that it is the science which results when the naval architect, the hydrodynamicist, the meteorologist, the seismologist, the biologist, and the chemist turn their attention to the study of the sea.

The diversified character of the studies means that a ship designed to conduct such research must meet, specifically or by compromise, needs which may be common to or conflicting among the various branches. To list but a few of the items of equipment and facilities which must be available at one time or another, there are echo-sounding gear, explosives for seismological work, trawls of various kinds, snappers, dredges and corers for bottom-sampling, means of taking water samples and temperature, and laboratories and stowage facilities for samples and specimens.

THE PROBLEM

The problem of designing a ship specifically for oceanographic research is far from simple. Should she be large like the Russian hydrographic ship WITJAS, purportedly of 5500 tons displacement,[2] or small like the 380-ton ATLANTIS, should she be a 12 or a 16 knot ship, and should it be attemped to provide for all types of acoustical work – these are only a few of the difficult questions that must be answered.

The per-diem cost of an oceanographic expedition is quite high and is one of the more important factors which put an upper limit on the size of the research ship. The ship must be large enough to carry sufficient personnel and equipment to make an expedition scientifically profitable, and yet her requirements as to crew, rations, and fuel–not to mention maintenance cost between cruises–must be modest.

Seaworthiness is of course a basic requirement of any vessel intended for long periods of blue-water sailing, but more is desired of the research ship than mere ability to survive heavy weather. It is desirable to reduce the sea-excited motion of the ship as much as possible. Excessive motion not only means misery and consequent inefficiency for personnel but adds

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[1]References are listed on page 9.

to the difficulty of handling gear and, most important of all, hampers the conduct of even the most routine scientific work. In addition it might be mentioned that for certain types of work it would be a great advantage to be able to control the heading of the ship at speeds below steerageway and even while lying to.

Precise criteria for satisfactory performance do not exist, but there is obvious benefit in a vessel which will permit operations which have previously been prevented by a state 5 sea.

PROPOSED HULL DESIGN

A hull which has been proposed to meet the many and diverse requirements of oceanographic research was designed by CDR R.T. Miller, USN. The lines and outboard profile are shown in Figure 1 and several views of a 5-foot model of this vessel are shown on Figure 2. Pertinent design particulars are listed in Table 1.

TABLE 1

Design Characteristics of the Oceanographic Research Vessel

Length, overall, feet	181
Length, waterline, feet	170
Length between perpendiculars, feet	163
Draft (design waterline), feet	14.75
Displacement (design waterline), tons	1000 (salt water)
Design speed (still water), knots	12
Longitudinal prismatic coefficient C_P	0.53
Coefficient of maximum sectional area C_X	0.80
Block coefficient C_B	0.423
Ratio of ship length to maximum beam L/B	5.2
Ratio of maximum beam to draft B/H	2.2

The values of C_X, C_B, L/B, and B/H are typical of tugs and trawlers of the same approximate size as the proposed ship; the same is true of the deadrise.

The level of the forecastle deck terminates farther forward on the starboard side than on the port side; see Figures 2a and 2b. This affords 100 feet of clear working space on the starboard side for streaming equipment. The rubrail on the starboard side is faired into the hull down to the waterline, starting at the after end of the deck house and extending forward some 14 feet. This arrangement preserves the function of the rubrail without offering an obstruction to gear being worked overside.

The model was ballasted to the design waterline to give a radius of gyration of $0.22\,L$, resulting in a pitching period (determined experimentally) of 0.738 seconds or 4.3 seconds full scale. The figure $0.22\,L$ for the radius of gyration is somewhat smaller than that usually

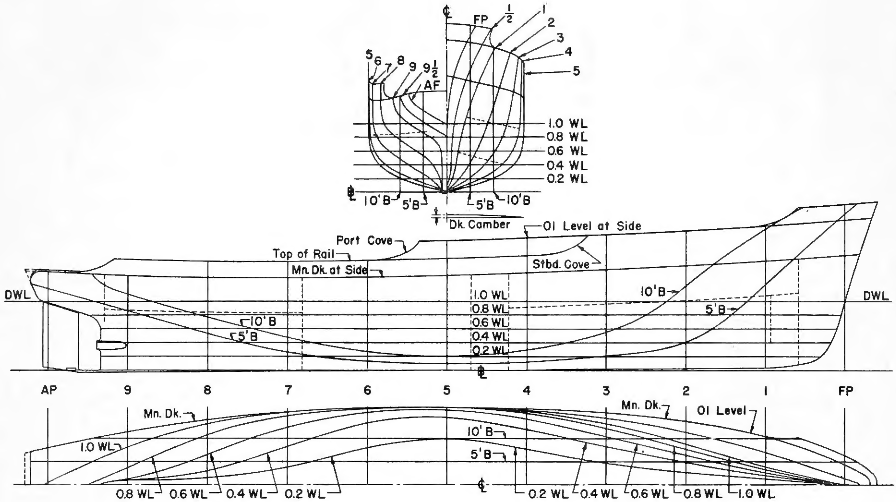

Figure 1a - Preliminary Lines

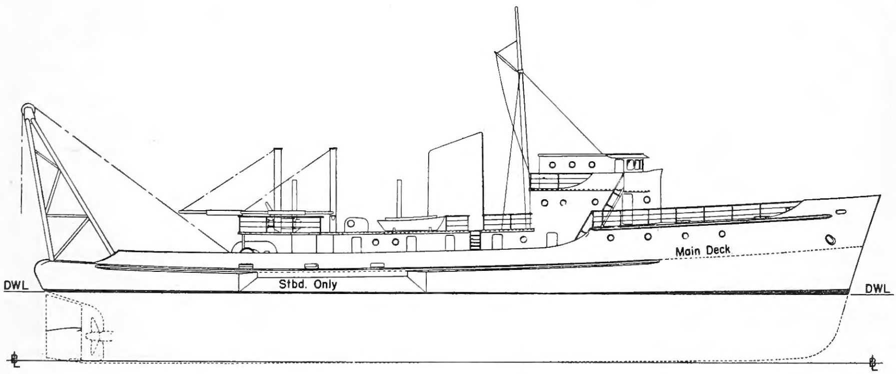

Figure 1b - Outboard Profile (Rev. 2)

Figure 1 - Oceanographic Research Vessel

Figure 2a - Starboard Side

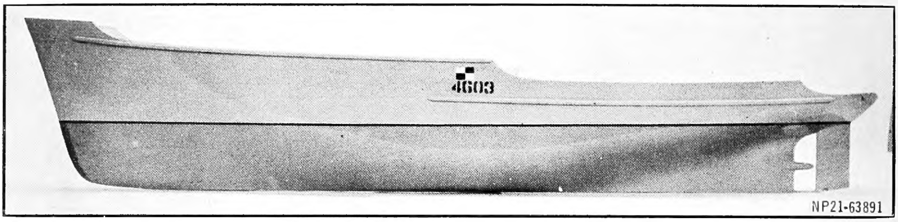

Figure 2b - Port Side

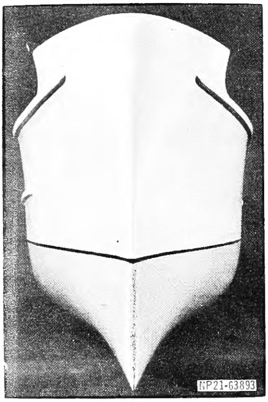

Figure 2c - Bow View

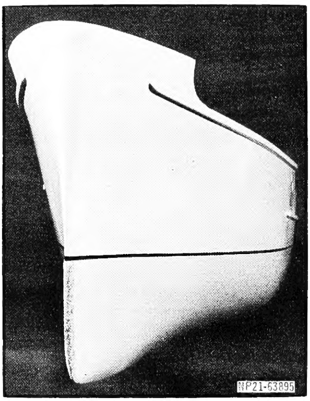

Figure 2d - Quarter View

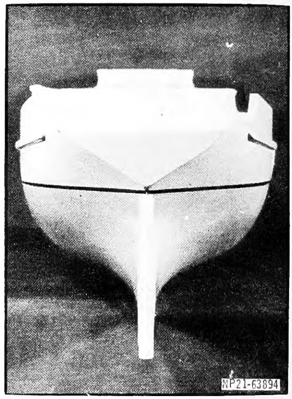

Figure 2e - Stern View

Figure 2 - Model of Oceanographic Research Vessel

assumed in the absence of specific data for such tests at the Taylor Model Basin. The smaller value was chosen in view of the intended location of most of the massive items of equipment—the winch and stowage reel for deep-sea cable and the main propulsion plant. These, with most of the fuel, will be located in the middle half-length of the ship.

MODEL TESTS

The tests were conducted in the 140-foot basin, using a pneumatic wavemaker and a gravity-type dynamometer.

Wavelengths corresponding to 127.5, 170, 204, and 340 feet ($\lambda/L = 0.75, 1.0, 1.2, 2.0$) were used, each with λ/h values of 20, 30, and 40. The model was tested in head seas using tow forces corresponding to still-water speeds of 6 and 12 knots. Pitch, heave, and speed were measured for these conditions.

The model was also run in several sea conditions with her stern to the sea, viz., $\lambda = 0.75L$, $1.0L$, $1.2L$, and $2.0L$, all at $\lambda/h = 20$. These tests were for qualitative results, no measurements of pitch and heave being taken.

The measurements of total resistance in still water were obtained incidentally in order to determine the data necessary to carry out the tests. It is considered that scaling of resistance data from a 5-foot model to full scale is of doubtful validity. The resistance curve is given , Figure 5, page 9, merely to indicate the reproducibility of the data.

RESULTS AND DISCUSSION

The results of the tests are presented in Figures 3 and 4 and Table 2. Figure 3 shows the reduction of speed in waves; the tow force and the λ/h ratio are constant for each curve; speed is plotted against wavelength. The magnitude of pitch and heave are shown in Figures 4a through 4d; each figure involves a single wavelength and each curve represents amplitude of motion plotted against speed for a constant ratio of λ/h. The speed V_R which would produce resonance in pitch—the most violent motion for a given wavelength should be expected at this speed—is shown for each wavelength.

As the curves show, reduction of speed in waves is in some cases quite drastic. However, in heavy weather, ship speed is more likely to be determined by the master, in the interest of safety and comfort, rather than by lack of power. High speed is useful mainly in traveling to and from station, so that a ship which can make 7 or 8 knots in a state 4 sea would probably be quite satisfactory from the standpoint of speed.

As to the observed pitching and heaving, they, too, are quite drastic on occasion, and are considerable throughout most of the conditions investigated. Unfortunately this behavior is characteristic of small ships in large waves. Table 2 shows that the pitch amplitude referred to the maximum slope of the exciting wave (column ψ_m/ϑ_m) is never larger than 1.12, and the nondimensional heave z_m/r_m does not exceed 1.3. In view of the fact that values of

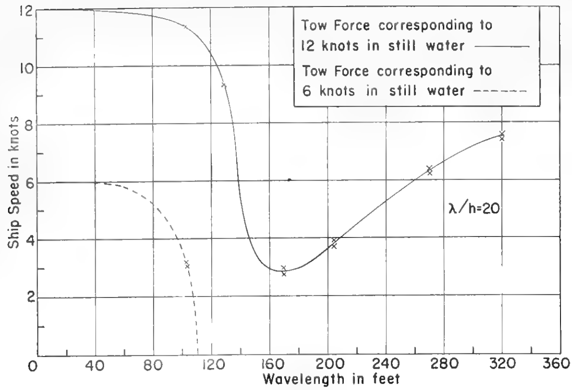

Figure 3a - $\lambda/h = 20$

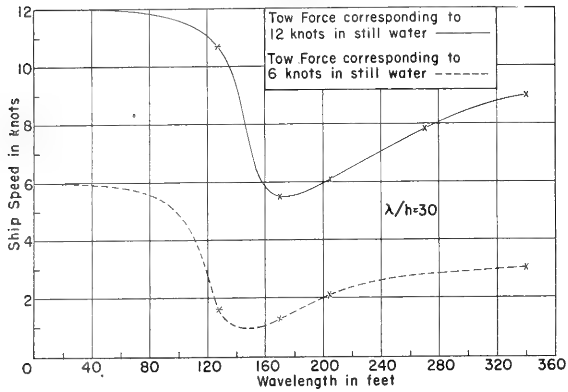

Figure 3b - $\lambda/h = 30$

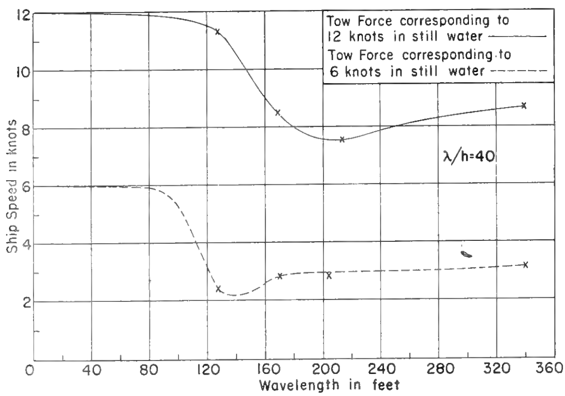

Figure 3c - $\lambda/h = 40$

Figure 3 - Reduction of Speed with Constant Tow Force and Wavelength/Waveheight Ratio

Length of ship equal to 170 feet.

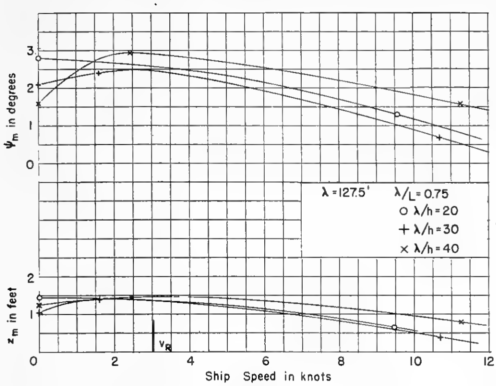

Figure 4a - Wavelength 127.5 Feet

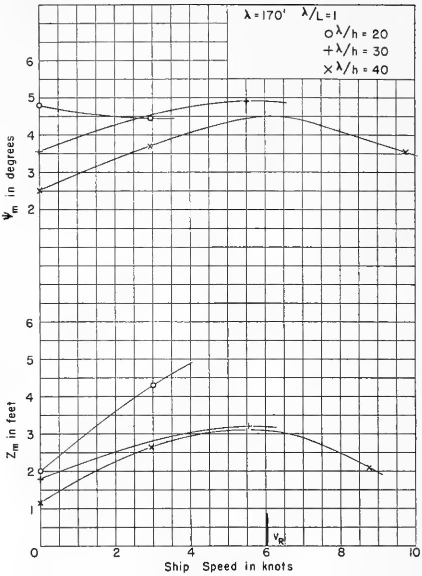

Figure 4b - Wavelength 170 Feet

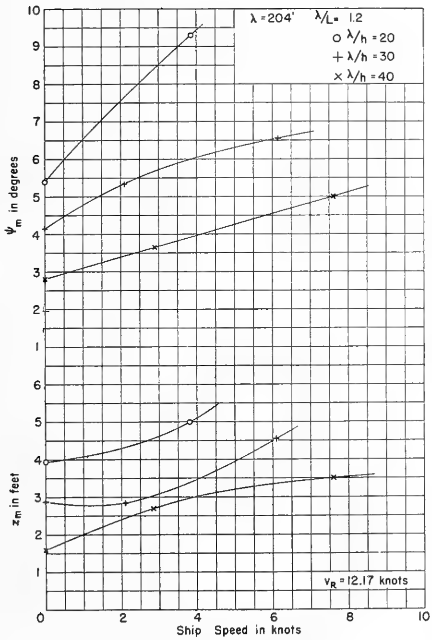

Figure 4c - Wavelength 204 Feet

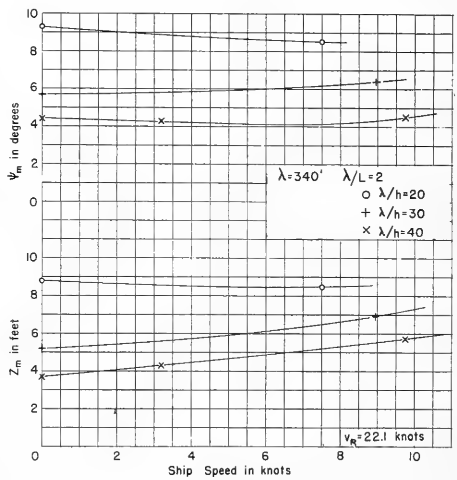

Figure 4d - Wavelength 340 Feet

Figure 4 - Plots of Pitch and Heave versus Speed for Constant Wavelength

1.6 and 2 for ψ_m/ϑ_m and z_m/r_m are not unusual for other vessels, it appears that the values recorded here are by no means excessive.

Throughout the tests in head seas, the bow was dry except for an occasional bit of splashing; the stern shipped water only in the steepest waves–i.e., $\lambda/h = 20$–of lengths $\lambda = 0.75L$, $1.0L$ and $1.2L$.

The model rode easily and was dry in following seas at speeds of 6 and 12 knots. When lying to, she took water at the stern in seas of $\lambda = 0.75L$, $\lambda/h = 20$, and also $\lambda = 1.0L$, $\lambda/h = 25$ and steeper, and was dry otherwise.

TABLE 2

Tabulation of Test Results

λ ft	h ft	λ/h	ψ_m deg	z_m ft	Speed knots	z_m/r_m	ψ_m/ϑ_m	Tow Force
127.5	6.30	20.24	2.85	1.45	0	0.284	0.321	Zero
127.5	4.31	29.22	2.07	1.04	0	0.339	0.336	
127.5	3.25	39.20	1.55	1.28	0	0.316	0.337	
127.5	4.30	29.60	2.40	1.40	1.59	0.598	0.395	6 knots Stillwater
127.5	3.17	40.20	2.95	1.48	2.45	0.915	0.658	
127.5	6.52	19.60	1.33	0.67	9.52	0.310	0.145	12 knots Stillwater
127.5	4.36	29.20	0.73	0.37	10.70	0.417	0.119	
127.5	3.19	40.00	1.55	0.78	11.25	0.420	0.344	
170	8.36	20.6	4.80	2.01	0	0.482	0.549	Zero
170	5.46	30.1	3.55	1.78	0	0.574	0.594	
170	4.02	42.2	2.50	1.14	0	0.568	0.586	
170	4.19	40.5	3.67	2.69	2.92	1.280	0.826	6 knots Stillwater
170	8.66	19.6	4.45	4.34	2.97	1.000	0.485	12 knots Stillwater
170	5.78	29.4	4.90	3.21	5.54	1.183	0.800	
170	4.26	39.9	3.02	2.07	8.74	0.972	0.670	
204	10.20	20.00	5.40	3.95	0	0.772	0.600	Zero
204	6.97	29.30	4.15	2.87	0	0.824	0.676	
204	5.36	38.90	2.80	1.59	0	0.595	0.605	
204	6.86	29.75	5.35	2.85	2.075	0.833	0.884	6 knots Stillwater
204	5.13	39.80	3.67	2.69	2.860	1.050	0.812	
204	10.30	19.78	9.30	4.99	3.830	0.969	1.020	12 knots Stillwater
204	6.77	30.10	6.55	4.54	6.120	1.195	1.095	
204	5.10	40.20	5.00	3.00	7.580	1.177	1.117	
340	16.90	20.05	9.35	8.78	0	1.040	1.065	Zero
340	11.24	30.20	5.70	5.25	0	0.934	0.956	
340	8.50	40.00	4.42	3.70	0	0.871	0.982	
340	8.59	39.94	4.30	4.56	3.17	1.063	0.954	6 knots Stillwater
340	17.30	19.67	8.50	8.59	7.49	0.925	0.928	12 knots Stillwater
340	11.33	30.00	6.49	5.56	8.96	0.982	1.083	
340	8.75	38.90	4.55	5.70	9.74	1.290	0.983	

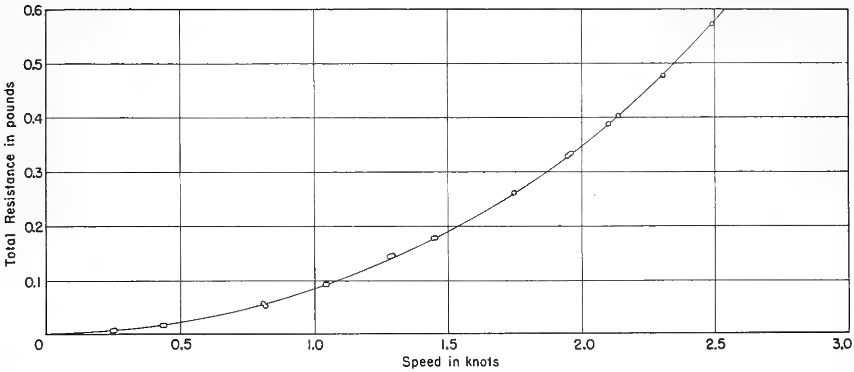

Figure 5 - Total Resistance of Model in Still Water

CONCLUSION

Within the limitations of the tests conducted, the model of the proposed oceanographic research vessel rode easily, was reasonably dry and showed motions which were on the average somewhat less than those observed on models of other types of vessels.

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David W. Taylor Model Basin. Rept. 1055.
BEHAVIOR OF A PROPOSED OCEANOGRAPHIC RESEARCH VESSEL IN WAVES, by F.V. Reed. Aug 1956 iv, 11 p. incl. figs., tables, refs. (Research and development report)
UNCLASSIFIED

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