DEPARTMENT OF THE NAVY
DAVID TAYLOR MODEL BASIN

HYDROMECHANICS

○

AERODYNAMICS

○

STRUCTURAL MECHANICS

○

APPLIED MATHEMATICS

COMPARATIVE RESISTANCE TESTS WITH ATTC STANDARD MODEL

by

M. Gertler
and
C. H. Hancock
Newport News Shipbuilding and Dry Dock Company

Prepared by the Model Basin Correlation Subcommittee of the Friction Committee for Presentation at the Twelfth General Meeting of the

AMERICAN TOWING TANK CONFERENCE

to be held at
University of California, Berkeley, California
on 31 August to 2 September 1959

July 1959 Report 1357

PRNC-TMB-648a (Rev. 3-58)

COMPARATIVE RESISTANCE TESTS WITH ATTC STANDARD MODEL

by

M. Gertler
and
C. H. Hancock
Newport News Shipbuilding and Dry Dock Company

July 1959 Report 1357

TABLE OF CONTENTS

ABSTRACT

A program of comparative resistance tests involving the use of a standard model has been established by the Model Basin Correlation Subcommittee of the Friction Committee of the American Towing Tank Conference. This report presents the basic considerations underlying the program, a description of the ATTC Standard Model, and comparisons of the results of resistance tests made by three of the participating towing tanks. The test techniques, instrumentation, and facilities used for the program are described by the individual organizations in the appendixes.

INTRODUCTION

The American Towing Tank Conference has maintained an interest in comparative resistance tests among its member tanks since its inception in April 1938. At the outset, however, the primary concern was whether the same end results could be expected from tests of geometrically similar models of different sizes. With this in mind, geosim series, such as the San Francisco and LIBERTY SHIP series, were established and tested at various American tanks. In addition, comparative tests were carried out with numerous small-large model pairs. The results of the early tests of this type showed a wide variance in resistance, not only among comparable models of different sizes, but among tests of the same-size model conducted at different tanks.

The disparity among the early geosim tests was believed to be due to a variety of hydrodynamic causes such as transitional flow effects (lack of adequate turbulence), improper slope of the turbulent skin friction line which was used for extrapolation, transverse curvature effect, and variation of form resistance with Reynolds number. Although advances have been made in the development of turbulence stimulation devices and in the understanding of the foregoing hydrodynamic effects, the differences among the comparative resistance tests are still unexplained.

The variation in resistance test results experienced among the various towing tanks were discussed in a meeting of the Friction Committee of the ATTC which was held in Cambridge on 23 January 1953. It occurred to some of the members that the discrepancies might be explained, in large part, by differences inherent in the techniques, instrumentation and facilities rather than on the basis of hydrodynamic effects. It was further observed that the most troublesome of the test vehicles used in previous correlative programs were the full-form merchant ship types. With these "bad actors", it was difficult to separate the hydrodynamic troubles from those due to instrumentation and techniques. Accordingly, the Model Basin Correlation Subcommittee was established with Mr. C. H. Hancock of the Hydraulic Laboratory, Newport News Shipbuilding and Dry Dock Company as chairman and Mr. M. Gertler of the David Taylor Model Basin as a member.

The primary objective of the Subcommittee is to concentrate on techniques, instrumentation, and facilities used for model resistance tests and to avoid the issue of hydrodynamic effects. The specific mission of the Subcommittee is given by the following terms of reference:

"To organize and initiate comparative experiments on a standard model, in the various model basins, for the purpose of scrutinizing the resistance results obtained by the different towing techniques now is use and, if significant differences exist, to evaluate these techniques in an attempt to determine the causes of these differences".

To accomplish the aforementioned objectives, the Subcommittee undertook a study to select a suitable hull form and to determine a good material for construction of the standard model. The hull form considered first was the "Iris", a model of which has been used for many years by the Haslar tank to "standardize" their resistance measurements. It was decided later, however, to use a double-ended form due to W.C.S. Wigley.[1] The latter was chosen because it is mathematically derived, its wave resistance has been computed theoretically, and experimental data from tests with a 16-foot model are available. Furthermore, because of its fore and aft symmetry and smooth curvature, it was anticipated that laminar flow problems which are usually associated with tests of small models would be less acute and more amenable to turbulence stimulation devices.

The material considered first for the construction of the standard model was stainless steel. This was motivated by the desire to avoid changes in dimension and eliminate the need for refinishing once the model was built and the test program was underway. Plans were also made to pre-ballast the model, to provide portable turbulence stimulators which could be either applied or removed and yet retain identical surface conditions for comparable tests, and to take any other necessary precautions to avoid the human element in setting up initial conditions for testing. The idea of using stainless steel was discarded because of considerations of expense, machinability, and weight. Instead, fiberglas-reinforced plastic was selected as the material for construction of the standard model. It was found that all of the desirable features such as dimensional stability, retention of surface finish, and portability of stimulators could be retained with the fiberglas model. Furthermore, fiberglas construction had the added advantage of providing a mold which could be used to check the original model and to construct additional models for those participating tanks who wanted them.

Concurrent with the selection and construction of the standard model, a circular letter was prepared and sent to those member organizations of the ATTC who have towing tank facilities which can accommodate models approximately 5 feet long. The member tanks were urged

---

[1] References are list on page 48.

to cooperate in the program and to submit suggestions regarding model shapes, model sizes, turbulence stimulators, or any other methods or procedures that could be employed in the program. To date, the following organizations have agreed to participate in the program:

Newport News Shipbuilding and Dry Dock Company
Newport News, Virginia

David Taylor Model Basin
Washington, D. C.

National Research Council of Canada
Ottawa, Canada

Stevens Institute of Technology
Hoboken, New Jersey

University of California
Berkeley, California

Webb Institute of Naval Architecture
Glen Cove, New York

University of Michigan
Ann Arbor, Michigan

Instituto de Pesquisas Technologicas
Sao Paulo, Brazil

Massachusetts Institute of Technology
Cambridge, Massachusetts

So far, tests have been carried out with the Standard Model by Newport News Shipbuilding and Dry Dock Company, David Taylor Model Basin, and Stevens Institute of Technology. Tests will be made at Webb Institute of Naval Architecture in the Fall of 1959. The present plans of the Subcommittee are to examine the results of these three of four organizations to determine whether it will be fruitful to carry out the entire program involving all of the tanks.

The present report describes the ATTC Standard Model and compares the results obtained from those participating tanks who have had the opportunity to carry out their program of resistance tests. The portions of the report supplied by these organizations which deal with methodology and data presentation are reproduced in the Appendixes for purposes of primary reference and convenience.

DESCRIPTION OF STANDARD MODEL

The primary purpose of the ATTC Standard Model is to serve as a test vehicle to evaluate how closely the same resistance measurements can be obtained by various individuals employing different facilities, instrumentation and techniques. To adhere to this objective, strict attention was given to the selection of the hull form, the size, the method of fabrication, and other features intended to avoid the human element from entering into the preparation of the model itself. It is believed, therefore, that hydrodynamic problems such as those association with transitional flow and roughness, will not affect the interpretations of the results in terms of the main objective.

GEOMETRY

The hull form selected for the ATTC Standard Model is defined by lines given by W. C. S. Wigley for Model № 755 in his 1927 paper before the Institution of Naval Architects.[1] The form is symmetrical with respect to each of its mid-planes. The waterlines are sine curves and the sections are formed by two parabolic arcs which meet at the keel and have their vertices at the load waterline. The keel is horizontal and straight; the stem and stern endings are perpendicular to the keel. The freeboard is carried up vertically from the load waterline. The lines of the form are defined mathematically by the equation

$$y = \pm(1-z^2) \cos \frac{\pi x}{16}$$

where x, y, and z are the distances along the length, beam, and draft, respectively, with the origin taken at the center of the load waterplane. This results in a form having a length-to-beam ratio of 8.0.

Due to limitations in the sizes of the various participating towing tanks, the nominal length desired for the model was about 5 feet. In interest of simplicity for the particular proportions, however, the length of the Standard Model was established at 64 inches. The geometric characteristics of the model are given in Table 1 and its offsets are given in Table 2.

FABRICATION

The Standard Model was constructed by the Hydraulic Laboratory of the Newport News Shipbuilding and Dry Dock Company and donated by them to the ATTC for use in the Model Correlation Program. The model is made of Fiberglas reinforced plastic (Paraplex Resin) and the method of fabrication was as follows:

TABLE 1

Geometric Characteristics of ATTC Standard Model

DIMENSIONS

LENGTH, inches	64
BEAM, inches	8
DRAFT, inches	4
DISPLACEMENT, pounds	31.33
WETTED SURFACE, square inches	638.1

COEFFICIENTS

L/B_X	8.000	C_{PA}	0.6366
B_X/H	2.000	C_{WA}	0.6366
$\Delta/(0.010L)^3$	94.79	C_{PVA}	0.6666
$\nabla/(0.100L)^3$	3.316	C_{PR}	0.6366
$L/\nabla^{1/3}$	6.706	C_{WR}	0.6366
$S/\nabla^{2/3}$	7.006	C_{PVR}	0.6666
$S/\sqrt{\Delta L}$	16.00	A_X/A_M	1.000
C_B	0.4244	B_X/B_M	1.000
C_P	0.6366	H_X/H_M	1.000
C_X	0.6666	$\overline{BKW}/B_X$	0.000
C_{PF}	0.6366	$\overline{BR}/B_X$	-----
C_{WF}	0.6366	$\overline{DR}/B_X$	0.000
C_{PVF}	0.6666	$\overline{HS}/B_X$	0.000
C_{PE}	0.6366	$\overline{KB}/H$	0.6250
C_{WE}	0.6366	Max. $\overline{TMB}/B_X$	1.000
C_{PVE}	0.6666	Max. $\overline{WLB}/B_X$	1.000
C_W	0.6366	C_{IT}	0.4244
C_{PV}	0.6666	C_{IL}	0.3618

Notation is in accordance with SNAME Technical and Research Bulletin No. 1-13,"Explanatory Notes for Resistance and Propulsion Data Sheets, July 1953". All dimensions and coefficients are based on calculated values. The actual weight of the model is 31.39 pounds and, therefore, only the fourth significant figure of the above values are affected by this discrepancy.

TABLE 2

Offsets for the ATTC Standard Model

WATERLINE / STATION	0	1	2	3	4	5	6	7	8	9	10	14
0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1	0.000	0.1189	0.2252	0.3190	0.4004	0.4692	0.5256	0.5692	0.6004	0.6255	0.6256	0.6256
2	0.000	0.2348	0.4448	0.6304	0.7912	0.9272	1.038	1.125	1.186	1.235	1.236	1.236
3	0.000	0.3450	0.6536	0.9260	1.162	1.362	1.526	1.652	1.743	1.815	1.816	1.816
4	0.000	0.4468	0.8464	1.199	1.505	1.763	1.975	2.140	2.257	2.350	2.351	2.351
5	0.000	0.5372	1.018	1.442	1.810	2.121	2.376	2.574	2.715	2.827	2.828	2.828
6	0.000	0.6148	1.165	1.650	2.071	2.427	2.718	2.945	3.106	3.235	3.236	3.236
7	0.000	0.6772	1.283	1.818	2.281	2.673	2.994	3.243	3.422	3.563	3.564	3.564
8	0.000	0.7228	1.370	1.940	2.435	2.853	3.196	3.462	3.652	3.803	3.804	3.804
9	0.000	0.7508	1.422	2.015	2.528	2.963	3.319	3.595	3.793	3.950	3.951	3.951
10	0.000	0.7600	1.440	2.040	2.560	3.000	3.360	3.640	3.840	3.999	4.000	4.000

First, a wax pattern of the mold was constructed using template drawings which were prepared from the offsets in the preceding section. Then a fiberglas mold was formed from the pattern. As shown by Figure 1, the mold consists of two halves which can be joined together lengthwise down the center. Transverse stiffeners of plywood spaced about 7 inches apart were fastened to the outside of each half of the mold and enclosed to form a rectangular box or carrying case. Metal doweled joints were provided at both ends and along the bottom of the mold to assure perfect mating of the two halves.

The model itself is shown in Figure 2. It was formed by laying up fiberglas and plastic against the inside of the mold until a wall thickness of about 1/4 inch was obtained. Four transverse bulkheads made of fiberglas and plastic were fastened inside of the model at suitable intervals to provide stiffness and dimensional stability. The fine ends of the model were filleted with plastic. Special attention was given to surface smoothness throughout the entire process of fabrication. As a result, both the mold and model are about as smooth as glass, as can be seen from Figures 1 and 2. The mold and the model have been checked periodically against each other with the conclusion that the dimensions of both have remained true within close tolerance since they were originally constructed. The use of the mold as a carrying case has offered excellent protection to the model and only minor repairs have been necessary. The mold can be made available to those organizations who wish to construct standard models of their own.

TEST FEATURES

As mentioned earlier, the Standard Model incorporates a built-in ballast feature. This was accomplished by careful weighing and adding lead weights to ballast the model. To serve as a check on the ballasting, draft marks were scribed on the model. Most of the ballast weights were molded into the fiberglas to become an integral part of the model. However, a few small movable weights were retained to compensate for differences in weight or placement of towing apparatus. These weights were secured to the model with machine screws.

Four removable stimulating studs which were designed specifically for the Standard Form are provided with the model. The studs were machined from brass rod. The part of each stud that projects from the model (head) is a cylinder 0.21 inch in diameter and 0.03 inch in height. The stem of the stud is about 1/16 inch in diameter and is threaded. The model is drilled and tapped at predetermined locations to receive the studs. The arrangement of the studs with respect to one end of the model is shown in Figure 3. The studs are located along a vertical line $3\frac{13}{16}$ inch from the leading or trailing edge of the model. The first stud is $\frac{1}{2}$ inch below the waterline and the fourth stud is $\frac{1}{2}$ inch above the keel; the remaining studs are 1 inch apart.

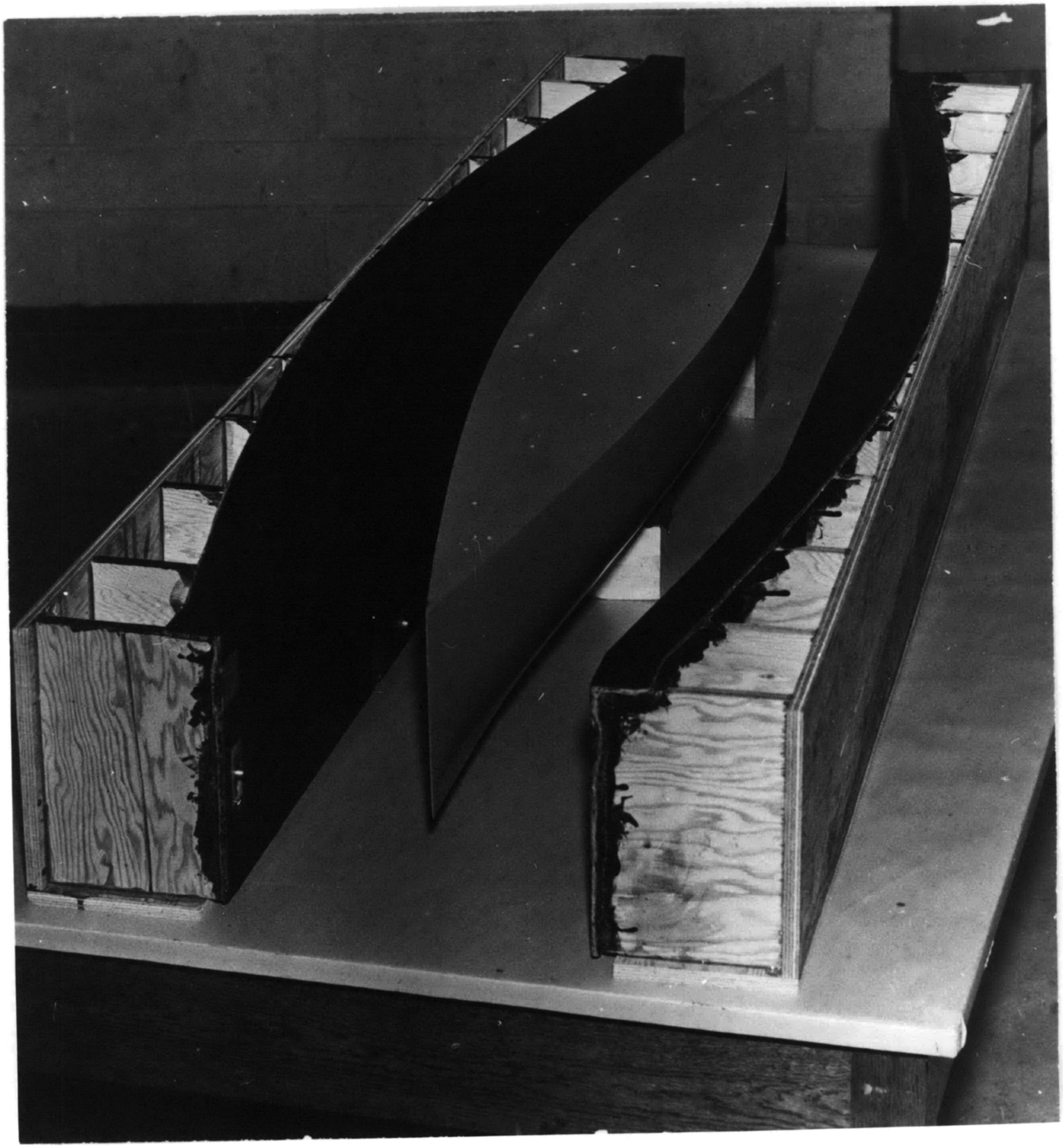


Figure 1 - Pattern and Mold for ATTC Standard Model

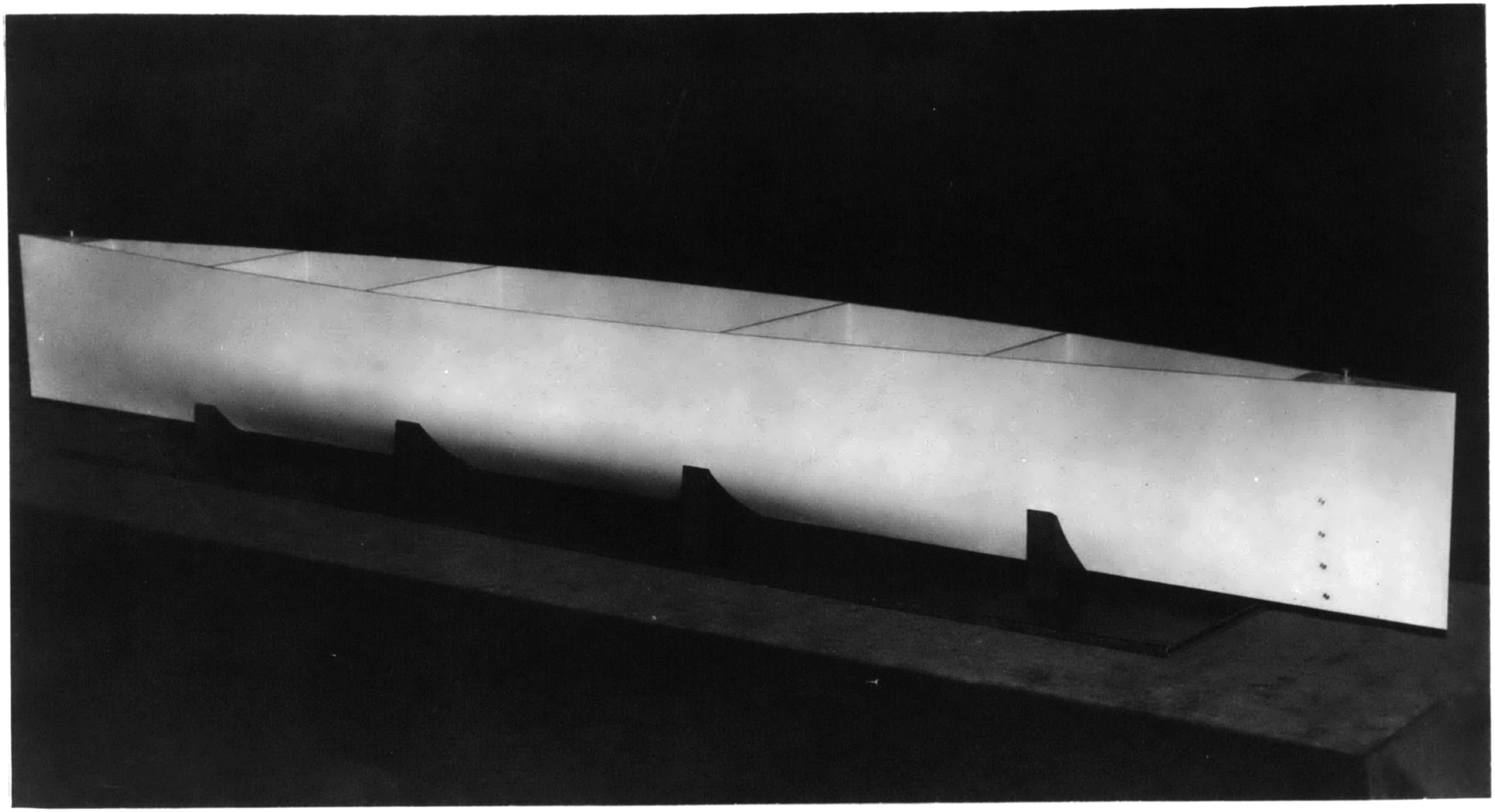


Figure 2 - ATTC Standard Model

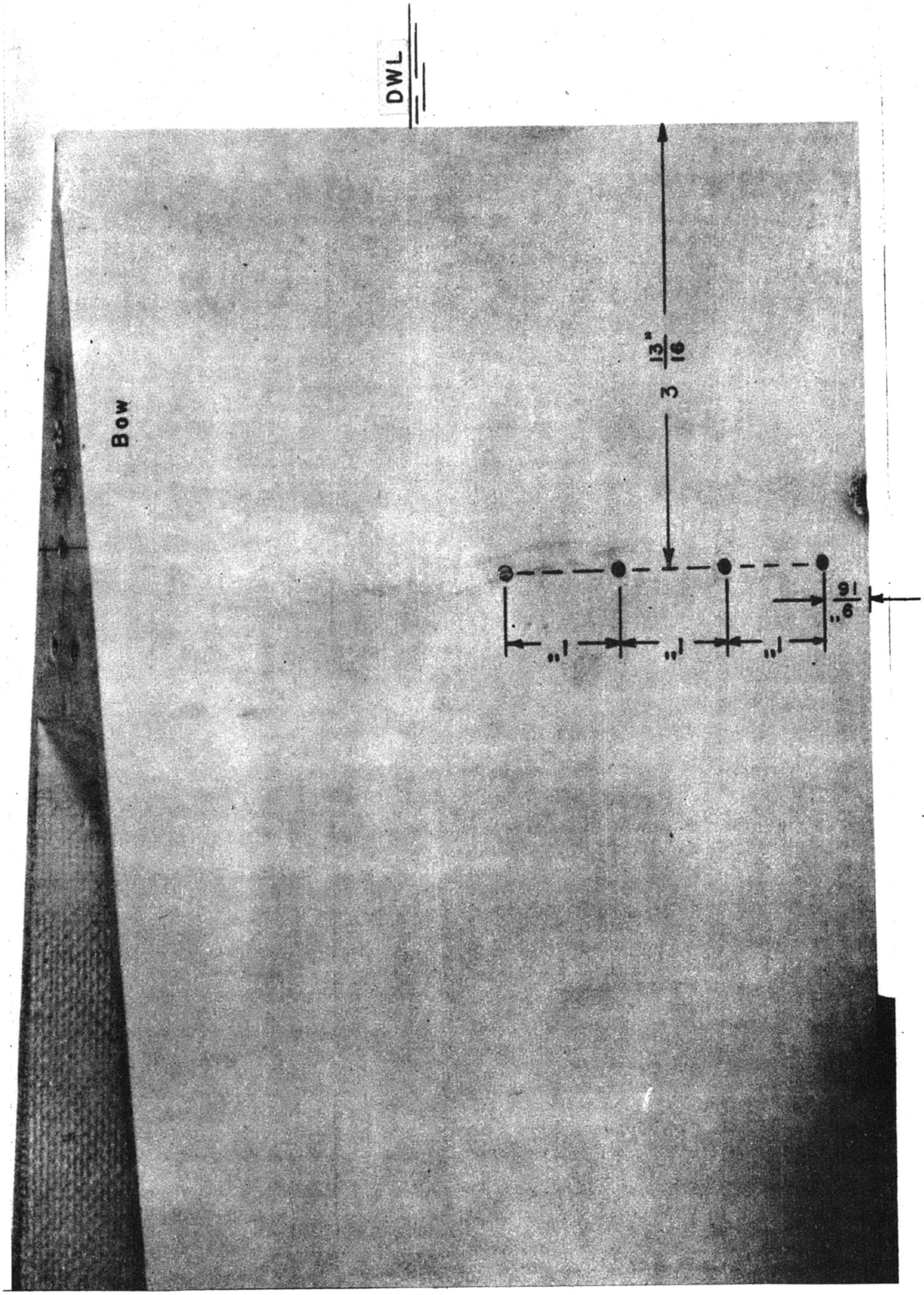


Figure 3 - Arrangement of Studs on ATTC Standard Model

A special pair of pliers which was drilled to obtain a split-clamping action about the head of the stud is provided with the model for attaching and removing the studs. In addition, brass plugs are provided which can be screwed into the stud openings when the studs are not in use. In this case, the plugs are screwed in flush with the skin of the model and the screw-driver slot is then filled with wax or plastilene to obtain a smooth surface.

When the model is transported from one organization to another, it is complete in every respect and carries all necessary parts including the studs, the plugs, compensating ballast weights, and all necessary tools. Individual instructions in the preparation and use of the model are given personally by a member of the Subcommittee.

COMPARISON OF TEST RESULTS OF PARTICIPATING TOWING TANKS

At the present time, resistance tests with the ATTC Standard Model have been carried out by Newport News Shipbuilding and Dry Dock Company, David Taylor Model Basin, and Stevens Institute of Technology. The facilities, instrumentation, and test procedures used by each organization and the test results obtained therefrom are described in the appendixes. The material in these appendixes has been reproduced directly from the reports of each organization.[2,3,4,5] The reports are not reproduced in entirety but those portions which deal with introductory material and model description have been omitted to avoid repetition. It should be understood that these reports contain first-hand information and, therefore, should be considered as the primary source of reference for the individual tests.

For purposes of comparison, the results of selected representative tests of each of the organizations are plotted in Figures 4 and 5 for the cases with and without the stimulating studs, respectively. To eliminate any differences between the results of the different tanks due to temperature of water, the comparisons are made on the basis of residual-resistance coefficient versus speed-length ratio. The residual-resistance coefficient was calculated by subtracting the frictional-resistance coefficients obtained from the ATTC Friction Line from the total-resistance coefficients computed from the experimental results. The results have been plotted on an expanded scale in a deliberate attempt to emphasize small differences.

It may be noted from Figures 4 and 5 that each of the facilities has the ability to repeat its own test results both closely and consistently. In general, the scatter in data spots about a mean faired line only amounts to a fraction of one percent of the total measurement in each case. Each towing tank also is able to repeat its own measurements very closely on separate tests. This fact is verified strongly in Appendix A which shows results of comparable tests made by Newport News about 1 year apart. The agreement is well within the small amount of scatter experienced on any one test.

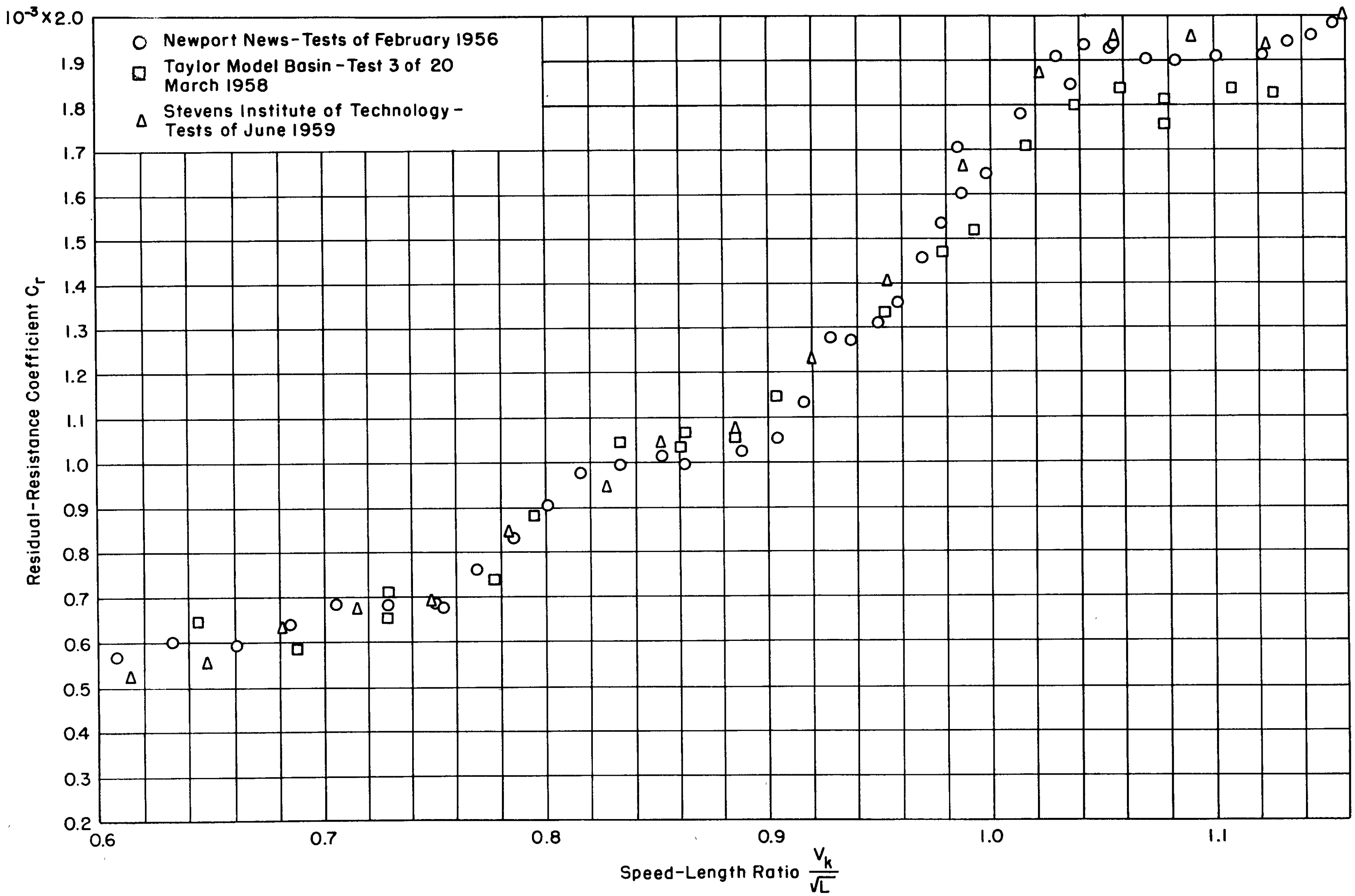


Figure 4 - Comparison of Resistance Test Results for the ATTC Standard Model with Stimulating Studs

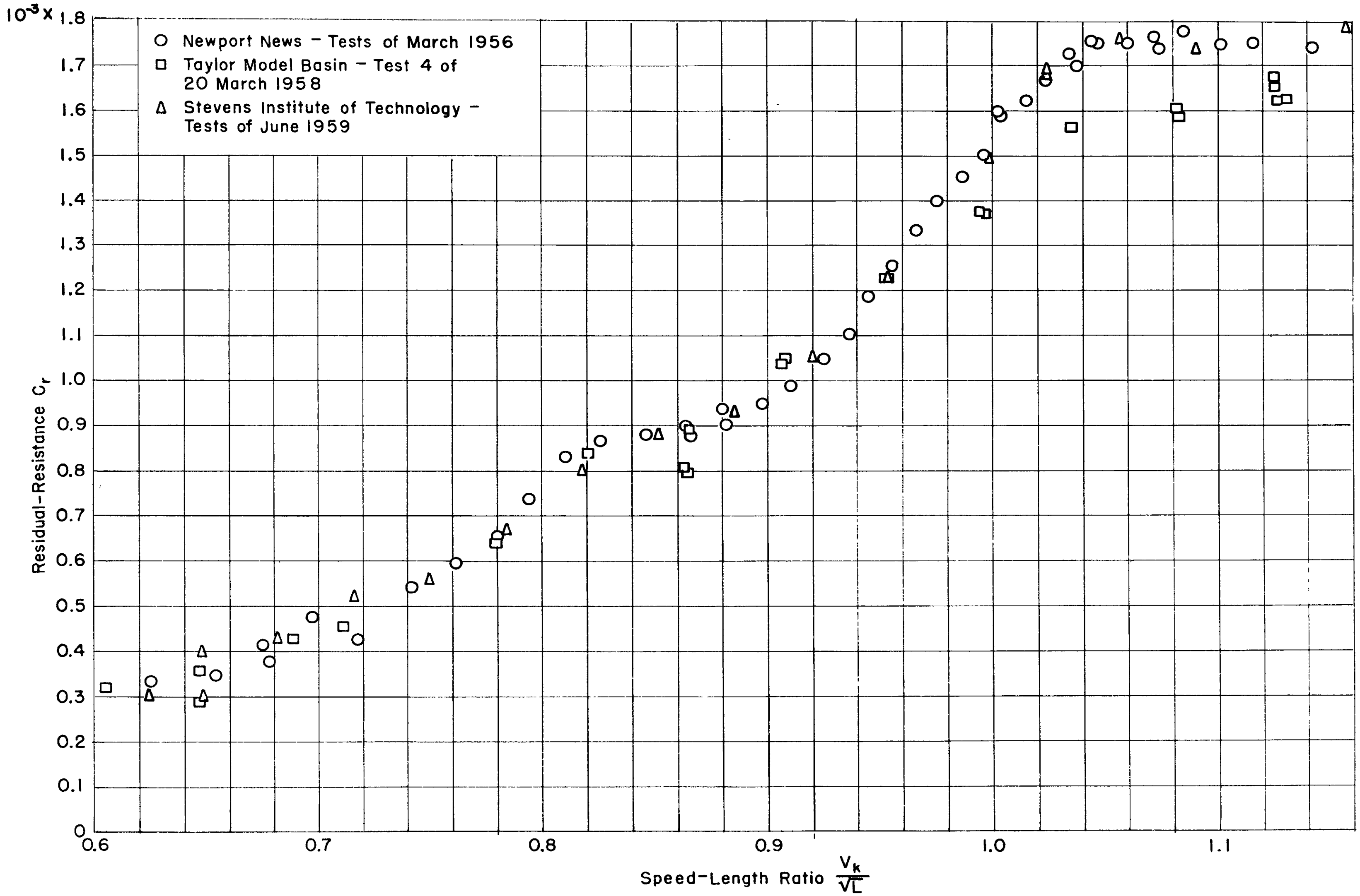


Figure 5 - Comparison of Resistance Test Results for the STTC Standard Model without Stimulating Studs

In addition to repeating their own data, two of the three tanks (Newport News and Stevens Institute) have results which coincide within a fraction of 1 percent over the entire speed range. The third (Taylor Model Basin) has results which closely repeat the other two up to a speed-length ratio of 1.0 but show some difference above this point, particularly in the wavemaking hump regime. The largest difference amounts to about 3 and 2 percent of the total model resistance at the given speed for the cases with bare hull and stimulator studs, respectively.

It is beyond the scope of this report and perhaps somewhat premature to explain the aforementioned differences in results. The variation is indeed small and is approximately within the range of what is usually considered to be test accuracy (± 1 percent). If, however, succeeding tests at other tanks add support to the fact that the differences are real and attributable to the facilities, the Subcommittee will explore the matter further to determine the reasons for the differences.

CONCLUSIONS AND RECOMMENDATIONS

On the basis of resistance tests with the ATTC Standard Model conducted at three different towing tank facilities, it is concluded that each of these facilities has the ability to repeat its own resistance test results both closely and consistently. Two of the three towing tanks are in very close agreement over the entire range of test speeds. The third towing tank agrees closely with the other two up to a speed-length ratio of 1.0 but at higher values the total resistance (corrected for differences in water temperatures) differs by as much as 2 to 3 percent. It is believed that although these differences are small they may be enough to warrant further investigation.

It is recommended, therefore, that the Model Basin Correlation Program be continued to include tests at two or more additional towing tank facilities to determine whether or not the differences which have been found so far are attributable to the use of particular facilities, instrumentation, or techniques. In view of the excellent repeatability extending over long periods of time, all member tanks of the ATTC are urged to build a standard model of their own to be used for checking purposes at their own establishments. The Subcommittee will be glad to furnish the mold and instructions for those desiring to build such a model.

ACKNOWLEDGMENT

The Model Correlation Subcommittee of the American Towing Tank Conference is very grateful to the participating organizations and the individuals concerned for their excellent cooperation and continued interest. Many valuable suggestions were received and some of these were incorporated into the formal program for the ATTC Standard Model.

APPENDIX A

TEST PROGRAM AT HYDRAULIC LABORATORY OF NEWPORT NEWS SHIPBUILDING AND DRY DOCK COMPANY

This appendix is composed of excerpts from Hydraulic Laboratory, Newport News Shipbuilding and Dry Dock Company Report of May 1957 entitled, "Resistance Test of ATTC Standard Friction Form for Model Basin Correlation Program", by W. F. Taylor, S. A. Naff, and J. S. Wiatt.

APPARATUS

The basin in which these tests were conducted is 56 feet long, 8 feet wide and 4-1/2 feet deep. The tank is equipped with a gravity dynamometer for towing and an "Events-Per-Unit-Time-Meter" for measuring speed. Figure 1a[1] shows the model at rest and Figure 1b shows the model running at 2.6 knots.

It has been suggested that speed is influenced by the acceleration of the model because the character of the boundary layer is changed by its rate of growth. Some experiments which were made with widely differing acceleration rates (Appendix B) did not indicate this to be so, at the range of towing weights and accelerations tested.

DESCRIPTION OF TESTS

In the Newport News Model Basin the speed is measured in the following manner : A clear plastic disk with 1860 fine, equally spaced lines engraved along radii close to the circumference is turned directly by the towing line. A slit light source on one side of the disk shines through the disk into a photocell on the other side. As the disk turns, this light beam is interrupted, since each engraved line is filled with black color, and a series of light pulses strike the photocell. This signal is amplified and fed into a Berkeley "Events-Per-Unit-Time" (EPUT) meter. This system is calibrated so that it reads the model speed directly in thousandths of a knot. The EPUT meter samples this speed for one second and holds the reading for one or two seconds. This gives from three to ten readings per run, depending on the model speed and the length of the accelerated travel.

In this towing tank, models are accelerated up to speed in a short distance by means of accelerating weights which fall for a short distance and then float off into cups of mercury. These weights remain constant for different towing speeds. The mercury cups are raised or lowered to allow these weights to act over varying distances for various model speeds. The towing weights maintain a constant model speed when the accelerating weights float off into the mercury cups. The EPUT meter is cut on by the falling of the accelerating weights into these cups, so that no readings are taken during the accelerating part of the run, and is cut off by an automatic switching device at the end of the run.

Ordinarily, as in test A, the accelerated travel distance is adjusted to give a model speed as nearly constant as possible for the length of the tank. A tolerance of plus or minus three thouandths of a knot is allowable if the resistance coefficient and the plus and minus curves plot satisfactorily. When this method is used, a plot is made of towing weight vs accelerated travel

---

[1] Figure numbers of original report are retained in this appendix.

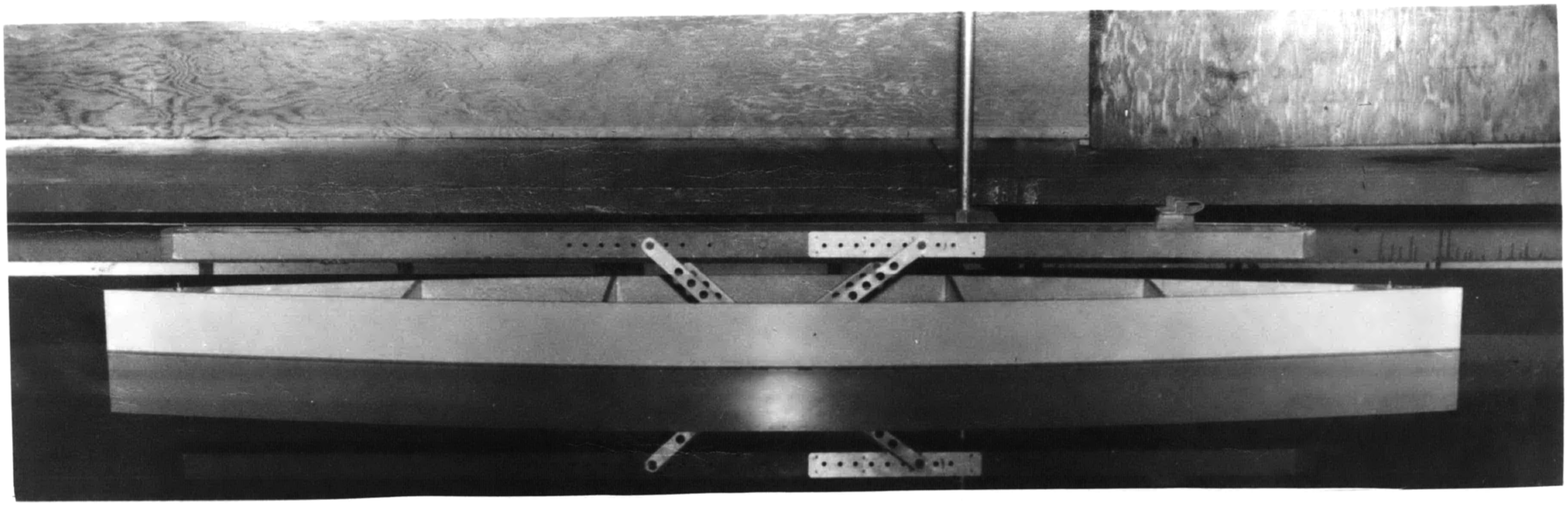


Figure 1a - Model at Rest

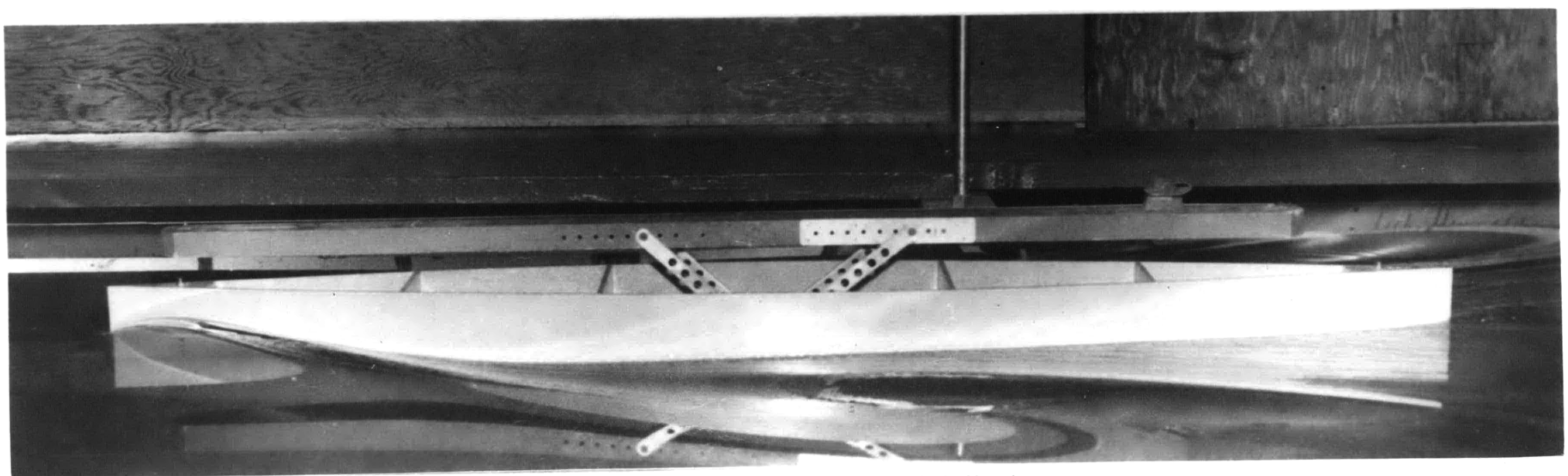


Figure 1b - Model Underway at 2.6 Knots

Figure 1 - Wave Profile of ATTC Standard Model

for any given towing weight is picked off this curve, Figure 2. For test B, covered by this report, however, the following method is used: For each towing weight three or four runs were made at different accelerated travel distances. A running plot was made of speed difference, i.e., final speed minus initial speed, versus final speed. By interpolating to zero difference in speed, the constant speed for any given towing weight was obtained, as seen in Figure 3. The internal resistance of the towing system, which was determined in the same manner as in an ordinary test, was subtracted from the towing weight to give the total resistance of the model at the speed measured by the EPUT meter.

Although the method used for these tests is longer than that ordinarily used, there are several advantages in the longer method. The most obvious of these is the fact that by obtaining several points an error due to one bad run is practically eliminated. One of the troublesome features of a short model basin is that an even speed is approached asymptotically with the model either accelerating or decelerating toward it. A short model basin, with a large difference between the initial and final speeds, produces a large error. Using the method of these tests, the model approaches a constant speed from both above and below so that this error is thereby eliminated. This method leads to the actual uniform speed for a given towing weight.

It is the usual practice at Newport News, first to obtain a resistance coefficient curve with the model fitted with sand strips and then to obtain a second curve for the bare hull condition. The bare hull curve is then subtracted, graphically, from the sand curve. The values so obtained are usually found to be constant although occasionally they will increase at the lower speed end of the curve, indicating that the bare hull may be entering a mixed flow condition. In such a case the constant value is subtracted from the sand curve to obtain the bare hull curve for turbulent flow.

In this report the mean tare resistance coefficients for the sand strips and the studs ($C_t \times 10^4 = 0.500$ and 0.150, respectively) were subtracted arithmetically, instead of graphically. It is also the Newport News practice to heat the basin water to around 80° F. The friction, the ATTC 1956 line, is computed for the 80° F. and a correction ($C_{con} \times 10^3 =$ T - 80° F.) is made to the model resistance coefficient for small changes in temperature.

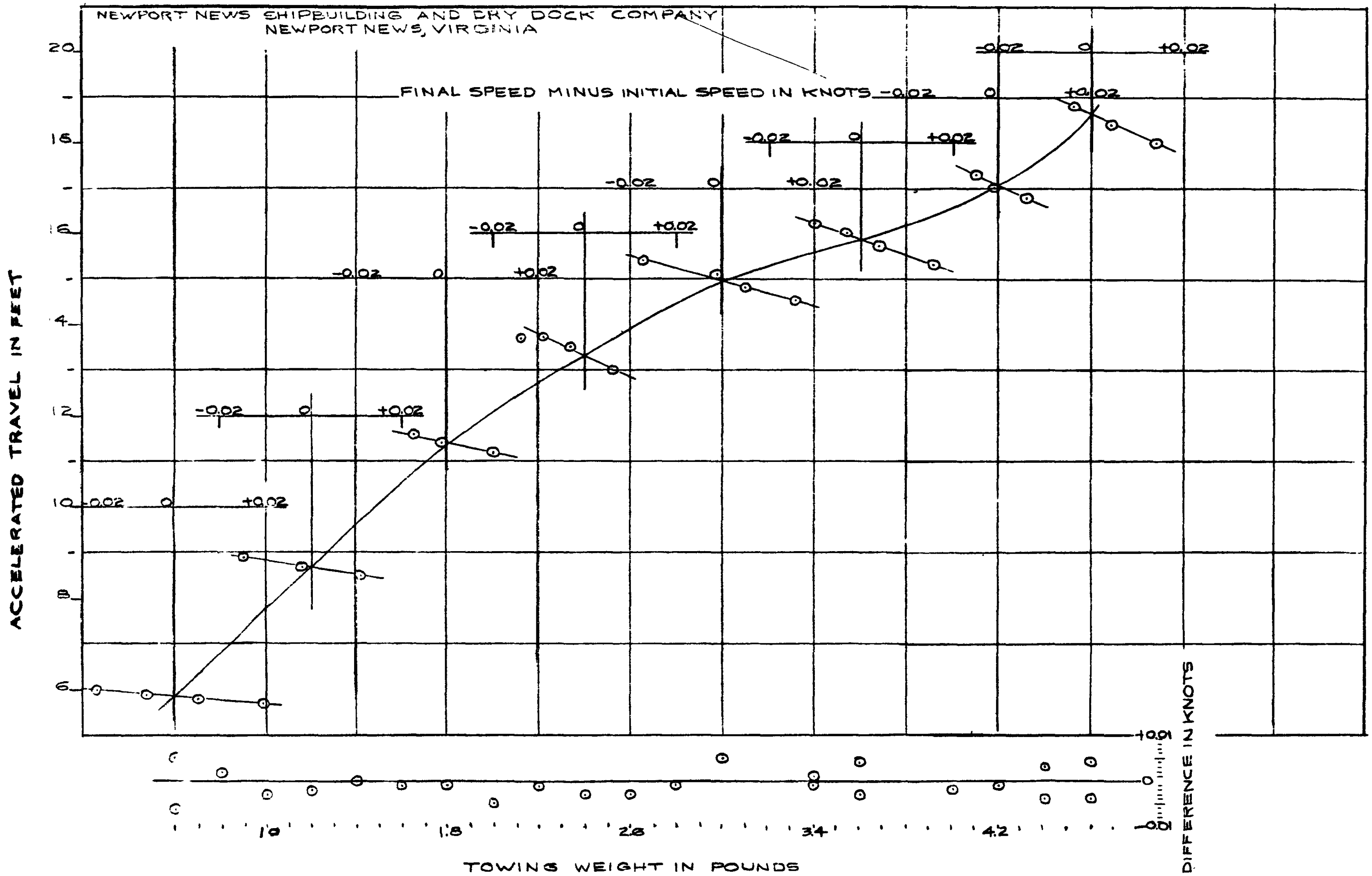


Figure 2 - Typical Plot of Towing Weight versus Accelerated Travel Used for Test A

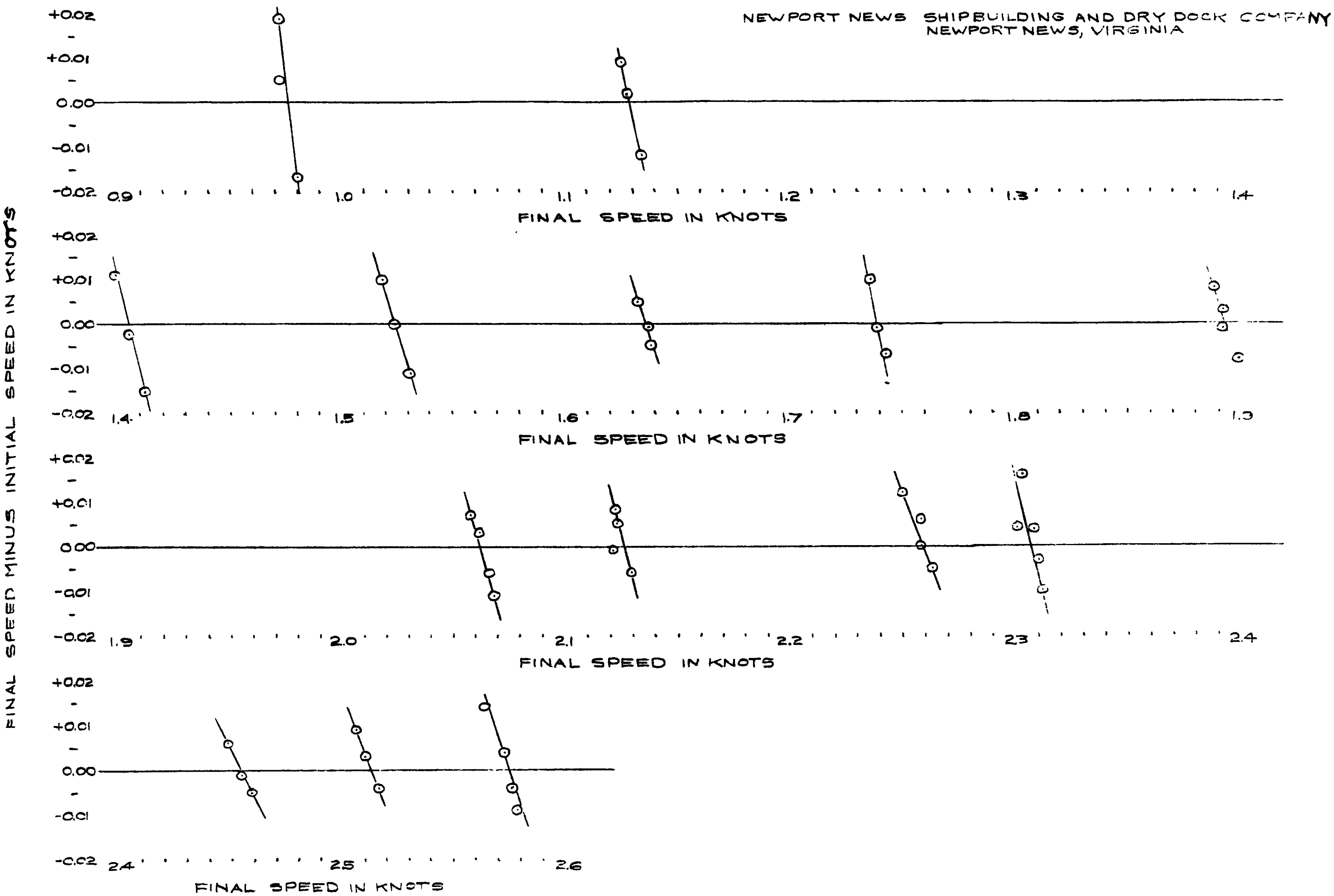


Figure 3 - Typical Plot of Final Speed Minus Initial Speed versus Final Speed Used for Test B

RESULTS

Four resistance curves are given in this report, as follows:

Test A (January-March 1956)

1. Net resistance coefficient with sand strips combined with the total resistance coefficient, bare hull.

2. Net resistance coefficient with studs.

Test B (May-June 1957)

3. Total resistance coefficient bare hull both ahead and astern.

4. Net resistance coefficient with studs going astern only.

Test A was reported in Reference 2. Test B was run at the recommendation of the Friction Committee at the 1956 ATTC.

The resistance curves for tests A and B are shown in Figures 4 and 5. The total resistance coefficients for the four curves are given in Table 1. The agreement between the model towed ahead and towed astern was good. Some differences were noted in the resistance for the studs and for the bare hull, hence two curves. The agreement between tests A and B for bare hull was good above 1.5 knots. The agreement between tests A and B for studs was good except at 2.1 knots.

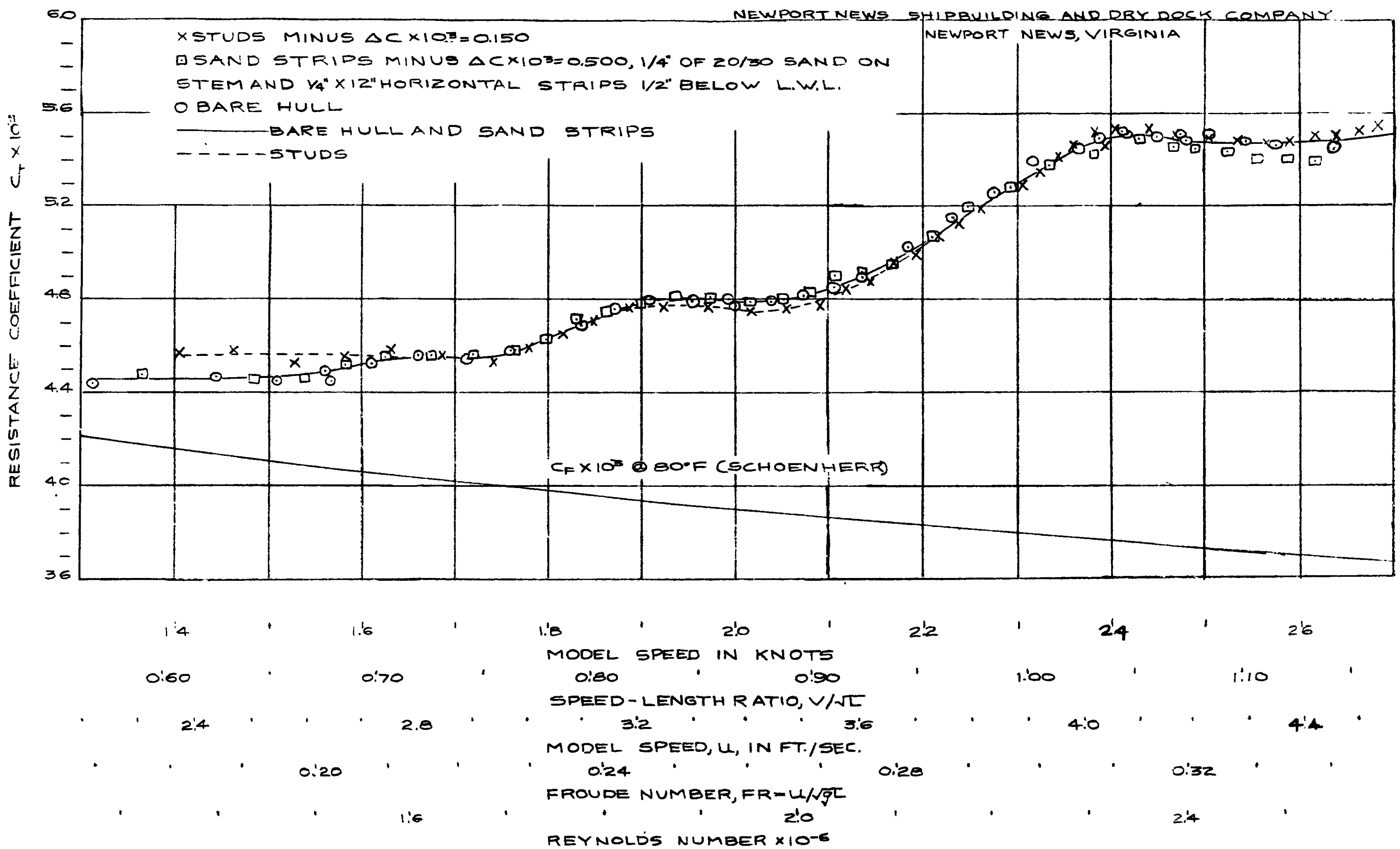


Figure 4 - Net Resistance Coefficients for Test A

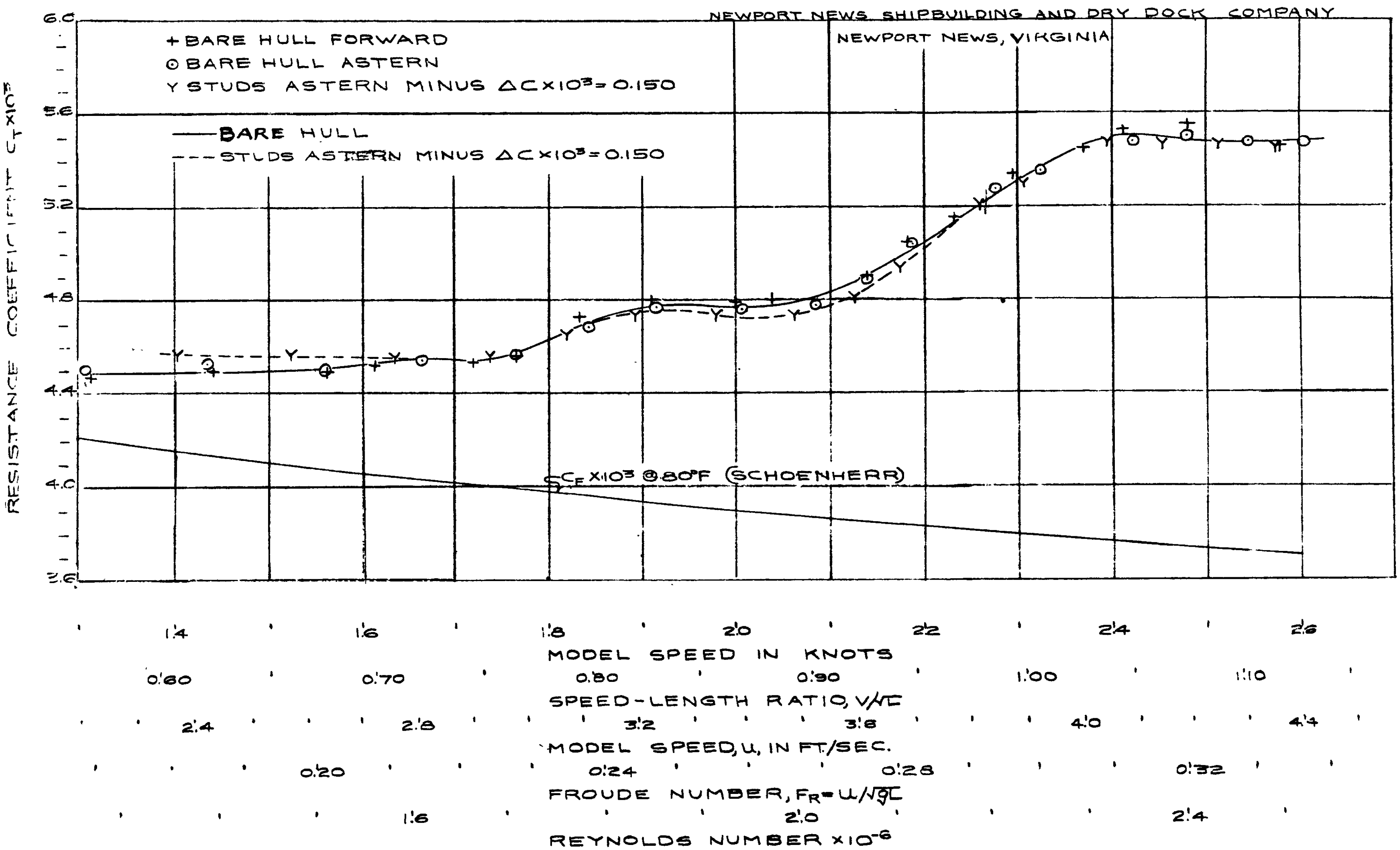


Figure 5 - Net Resistance Coefficients for Test B

TABLE 1

Total Resistance Coefficients for Tests A and B

Model Speed (knots)	C_t x 10 Bare Hull Ahead and Astern	C_n x 10 Studs Astern Only	C_t x 10 Bare Hull C_n x 10 Sand Ahead Only	C_n x 10 Studs Astern Only	C_f x 10 Schoen'r at 80 F.
1.3	4.495	4.580	4.460	4.570	4.220
1.4	4.495	4.575	4.460	4.560	4.160
1.5	4.500	4.560	4.465	4.555	4.105
1.6	4.525	4.550	4.520	4.540	4.060
1.7	4.540	4.540	4.550	4.550	4.020
1.8	4.625	4.625	4.630	4.630	3.980
1.9	4.760	4.740	4.780	4.765	3.935
2.0	4.760	4.715	4.790	4.750	3.890
2.1	4.830	4.770	4.845	4.815	3.860
2.2	5.040	5.010	5.040	5.020	3.825
2.3	5.305	5.305	5.295	5.295	3.795
2.4	5.495	5.495	5.495	5.495	3.765
2.5	5.475	5.475	5.475	5.475	3.730
2.6	5.480	5.480	5.475	5.475	3.700

APPENDIX A

Model Resistance Data Sheets

(a) Model Towed Astern (Bare Hull) - May 1957

Towline pull in pounds R x 10	Acceler. Travel in Feet	Final Speed in knots	Total Resist. Coefficient C_t x 10^3
1.937	12.1	1.843	4.669
2.935	15.1	2.187	5.026
3.932	16.6	2.423	5.476
0.942	7.9	1.307	4.509
2.336	13.5	2.006	4.755
3.334	15.5	2.276	5.272
4.331	18.2	2.545	5.474
1.340	9.7	1.561	4.501
1.738	11.5	1.765	4.562
0.743	6.8	1.164	4.486
0.545	6.0	1.018	4.309
1.539	10.6	1.664	4.542
3.533	15.7	2.324	5.352
4.132	17.3	2.480	5.497
2.735	14.7	2.141	4.881
1.141	8.7	1.435	4.532
2.137	12.6	1.915	4.765
4.531	18.8	2.604	5.471
2.535	14.2	2.084	4.774

(b) Model Towed Ahead (Bare Hull) - May 1957

Towline pull in pounds R x 10	Acceler. Travel in Feet	Final Speed in knots	Total Resist. Coefficient C_t x 10^3
1.938	11.9	1.833	4.721
2.935	14.9	2.183	5.038
0.942	7.9	1.313	4.472
3.933	16.3	2.413	5.525
2.436	13.8	2.038	4.803
4.431	19.0	2.579	5.455
1.639	11.1	1.721	4.530
2.137	12.5	1.910	4.794
1.141	8.8	1.442	4.490
3.134	15.2	2.232	5.150
0.743	6.9	1.170	4.440
2.735	14.7	2.139	4.896
0.545	6.1	1.022	4.268
3.434	15.5	2.295	5.334
1.439	10.1	1.614	4.521
4.132	17.3	2.480	5.500
1.340	9.7	1.562	4.491
0.843	7.4	1.248	4.433
2.336	13.4	1.999	4.785
3.733	16.1	2.370	5.444
1.738	11.4	1.766	4.558

(c) Model Towed Astern (with Studs) - June 1957

Towline pull in pounds R x 10	Acceler. Travel in Feet	Final Speed in knots	Total Resist. Coefficient C_t x 10^3	Net Resist. Coefficient C_n x 10^3
1.938	12.0	1.819	4.795	4.645
2.935	14.9	2.174	5.084	4.934
3.933	16.3	2.396	5.616	5.466
0.942	7.7	1.272	5.765	4.615
2.336	13.3	1.979	4.878	4.728
3.334	15.4	2.259	5.353	5.203
4.332	17.8	2.513	5.611	5.461
1.338	9.6	1.524	4.714	4.564
1.737	11.4	1.739	4.704	4.554
0.741	6.7	1.129	4.755	4.605
0.542	5.9	0.976	4.542	4.392
1.538	10.5	1.636	4.704	4.554
4.132	17.0	2.454	5.616	5.466
2.735	14.7	2.126	4.957	4.807
1.139	8.7	1.405	4.719	4.569
2.136	12.6	1.893	4.876	4.726
2.535	14.2	2.062	4.876	4.726
4.532	18.6	2.575	5.600	5.450
3.533	15.8	2.307	5.444	5.294

Note: All resistance measurements taken at 80°F. C x 10^3 studs = 0.150 (mean value taken from the plots)

APPENDIX A (cont.)

(d) Model Towed Ahead (with Studs) - January 1956

Towline pull in pounds R x 10	Acceler. Travel in Feet	Final Speed in knots	Total Resist. Coefficient C_t x 10^3	Net Resist. Coefficient C_n x 10^3
5.222	14.75	2.722	5.784[2]	5.634
5.721	15.3	2.795	6.002	5.802
5.422	15.1	2.752	5.864	5.714
5.621	15.3	2.783	5.951	5.801
5.122	14.6	2.706	5.743	5.593
5.522	15.2	2.766	5.922	5.772
6.121	15.6	2.843	6.200	6.050
5.921	15.5	2.819	6.113	5.963
6.321	15.7	2.869	6.296	6.146
6.221	15.7	2.856	6.255	6.105
6.021	15.5	2.833	6.149	5.999
5.821	15.3	2.808	6.058	5.908
5.022	14.4	2.687	5.708	5.558
4.523	12.6	2.563	5.633[1]	5.488
3.825	9.5	2.360	5.618	5.468

(e) Model Towed Ahead (with Studs) - February 1956

Towline pull in pounds R x 10	Acceler. Travel in Feet	Final Speed in knots	Total Resist. Coefficient C_t x 10^3	Net Resist. Coefficient C_n x 10^3
1.333	9.2	1.527	4.684[2]	4.534
1.930	11.6	1.816	4.795	4.645
1.731	11.1	1.743	4.673	4.523
1.532	10.1	1.630	4.732	4.582
1.134	8.3	1.403	4.724	4.574
0.935	7.4	1.271	4.754	4.604
2.130	12.1	1.885	4.915	4.765
2.727	14.3	2.117	4.992	4.842
2.329	12.9	1.970	4.918	4.768
2.927	14.5	2.167	5.110	4.960
2.528	13.8	2.054	4.907	4.757
3.127	14.8	2.215	5.221	5.071
0.737	6.35	1.125	4.795	4.645
0.538	5.6	0.986	4.540	4.390
3.526	15.35	2.304	5.440	5.290
3.925	15.9	2.393	5.611	5.461
3.326	15.1	2.259	5.343	5.193
3.725	15.6	2.342	5.563	5.413
3.226	15.0	2.239	5.273[1]	5.123
3.426	15.2	2.279	5.400	5.250
3.027	14.8	2.195	5.141	4.991
3.626	15.4	2.323	5.494	5.344
2.827	14.5	2.146	5.024	4.874
2.229	12.47	1.925	4.918	4.768
2.628	14.1	2.090	4.919	4.769

(f) Model Towed Ahead (with Studs) - February 1956

Towline pull in pounds R x 10	Acceler. Travel in Feet	Final Speed in knots	Total Resist. Coefficient C_t x 10^3	Net Resist. Coefficient C_n x 10^3
2.428	13.4	2.015	4.891[1]	4.741
1.831	11.35	1.778	4.740	4.590
1.432	9.7	1.579	4.702	4.552
1.035	7.8	1.336	4.742	4.592
1.631	10.6	1.685	4.703	4.553
1.233	8.7	1.461	4.727	4.577
0.637	6.0	1.058	4.653	4.503
0.836	6.9	1.199	4.756	4.606
0.687	6.175	1.094	4.700	4.550
2.030	11.9	1.850	4.855	4.705
1.731	11.1	1.739	4.683	4.533
4.125	10.4	2.437	5.687	5.537
4.324	11.5	2.502	5.642	5.492
4.723	13.3	2.616	5.650	5.500
4.424	12.0	2.534	5.638	5.488
4.224	11.0	2.470	5.664	5.514
4.623	12.9	2.591	5.628	5.478
4.823	13.7	2.641	5.658	5.508
4.922	14.0	2.664	5.679	5.529
4.125	10.4	2.435	5.685	5.535
4.025	10.0	2.406	5.699	5.549
3.925	9.6	2.379	5.679	5.529

Note: Superscript[1] denotes model tested at 80°F. Superscript[2] denotes model tested at 81°F and corrected to 80°F

C x 10^3 temperature = 0.009 (T-80°F)
C x 10^3 studs = 0.150 (mean value taken from plots)

APPENDIX A (cont.)

(g) Model Towed Ahead (with Sand Strips) - March 1956

Towline pull in pounds R x 10	Acceler. Travel in Feet	Final Speed in knots	Total Resist. Coefficient $C_t \times 10^3$	Net Resist. Coefficient $C_n \times 10^3$
0.935	7.2	1.245	4.947[2]	4.447
1.433	9.4	1.537	4.971	4.471
2.429	12.5	1.935	5.325	4.825
2.928	14.0	2.107	5.410	4.910
1.134	8.1	1.370	4.941[1]	4.441
1.732	10.4	1.673	5.062	4.562
1.333	9.0	1.484	4.961[2]	4.461
2.130	11.65	1.830	5.210	4.710
1.532	9.7	1.581	5.027	4.527
2.728	13.6	2.051	5.301[1]	4.801
2.330	12.2	1.899	5.285	4.785
2.030	11.4	1.797	5.140	4.640
2.529	12.8	1.974	5.316	4.816
2.828	13.8	2.081	5.340	4.840
2.230	11.9	1.863	5.259	4.759
2.628	13.2	2.014	5.298	4.798
1.931	11.2	1.762	5.090	4.590
1.632	10.0	1.625	5.067[2]	4.567
1.234	8.5	1.425	4.984	4.487
1.831	10.8	1.721	5.069	4.569
1.035	7.6	1.306	4.969[1]	4.469
0.737	6.2	1.098	5.003	4.503
0.538	5.32	0.939	4.993	4.493
0.836	6.75	1.171	4.989	4.489
0.638	5.75	1.019	5.028	4.528
3.127	14.6	2.167	5.452	4.952

(h) Model Towed Ahead (with Sand Strips) - March 1956

Towline pull in pounds R x 10	Acceler. Travel in Feet	Final Speed in knots	Total Resist. Coefficient C_t s 10	Net Resist. Coefficient C_n x 10
1.134	8.0	1.366	4.974[1]	4.474
3.925	15.4	2.335	5.886	5.386
3.327	14.7	2.210	5.577	5.077
3.726	15.1	2.292	5.798	5.298
3.027	14.3	2.136	5.245	4.745
3.227	14.5	2.183	5.527[3]	5.027
3.526	14.9	2.248	5.707	5.207
2.928	14.0	2.107	5.391	4.891
3.626	14.9	2.268	5.761	5.261
3.426	14.7	2.227	5.647	5.147
4.923	18.7	2.613	5.891	5.391
4.125	15.8	2.381	5.938	5.438
4.723	17.9	2.555	5.913	5.413
4.325	16.2	2.429	5.994	5.494
4.524	17.0	2.490	5.960	5.460
4.025	15.6	2.357	5.928	5.428
4.424	16.7	2.467	5.964[2]	5.464
4.823	18.4	2.588	5.910	5.410
4.225	16.0	2.408	5.972	5.472
4.624	17.5	2.526	5.946	5.446
3.826	15.2	2.314	5.851	5.351
3.127	14.5	2.163	5.458[1]	4.958

Note: Superscript[1] denotes model tested at 80°F. Superscript[2] denotes model tested at 81°F and corrected to 80°F. Superscript[3] denotes model tested at 79°F and corrected to 80°F.

$C \times 10^3 = 0.500$ (mean value taken from plot)

APPENDIX A (cont.)

(i) Model Towed Ahead (Bare Hull) - March 1956

Towline pull in pounds R x 10	Acceler. Travel in Feet	Final Speed in knots	Total Resist. Coefficient $C_t \times 10^3$
1.930	11.5	1.834	4.693[1]
2.927	14.4	2.183	5.019
0.935	7.5	1.313	4.440
3.925	15.9	2.411	5.522
1.432	9.75	1.609	4.528
3.426	15.2	2.300	5.299
2.428	13.3	2.032	4.820[2]
4.423	18.3	2.574	5.471
0.537	5.8	1.023	4.210
1.532	10.2	1.660	4.559
3.526	15.3	2.315	5.389
2.528	13.7	2.073	4.816
1.134	8.5	1.443	4.468
3.126	14.9	2.231	5.148
2.129	12.1	1.907	4.797
1.333	9.5	1.566	4.448[1]
3.326	15.0	2.275	5.258
2.329	13.0	1.999	4.770
1.731	11.0	1.759	4.579
2.727	14.2	2.136	4.895
3.725	15.6	2.365	5.445
0.736	6.7	1.180	4.324
1.034	8.1	1.382	4.430
3.027	14.7	2.209	5.078
2.030	11.8	1.870	4.770[2]
4.024	16.5	2.449	5.503
1.830	11.3	1.801	4.627

(j) Model Towed Ahead (Bare Hull) - March 1956

Towline pull in pounds R x 10	Acceler. Travel in Feet	Final Speed in knots	Total Resist. Coefficient $C_t \times 10$
2.827	14.4	2.163	4.947[2]
3.825	15.9	2.394	5.466
0.835	7.1	1.251	4.373
1.233	9.0	1.508	4.450
3.226	14.9	2.252	5.208
2.229	12.5	1.953	4.792
4.224	17.1	2.505	5.517
3.625	15.5	2.342	5.405[1]
2.628	14.0	2.104	4.853
4.124	16.9	2.481	5.483
0.637	6.25	1.103	4.281
4.324	17.7	2.542	5.475
3.925	16.0	2.415	5.511
4.623	19.4	2.637	5.447
3.526	15.3	2.318	5.374
4.124	16.9	2.475	5.513
3.825	15.9	2.387	5.499
1.631	10.6	1.714	4.549
1.333	9.4	1.559	4.491
2.329	13.0	1.992	4.801
2.428	13.5	2.038	4.786

Note: Superscript[1] denotes model tested at 80°F. Superscript[2] denotes model tested at 81°F and corrected to 80°F.

SAMPLE OF RAW SPEED DATA FROM E.P.U.T. METER FOR STUDS ASTERN

3.4 lbs. 15.4 ft.

2.258 K
56
2.258
diff. 0 K

3.4 15.2

2.252
55
2.258
6

3.4 15.6

2.268
63
2.263
-5

3.4 15.0

2.238
46
2.250
12

4.4 18.0

2.520
22
2.516
-4

4.4 17.6

2.507
11
2.510
3

4.4 lbs. 17.4 ft.

2.497 K
2.508
2.506
diff. 9 K

1.4 9.6

1.524
23
23
24
24
1.524
0

1.4 9.8

1.542
37
34
1.531
-11

1.4 9.4

1.508
06
11
15
16
1.518
10

18. 11.2

1.726
28
31
33
1.736
10

1.8 lbs. 11.6 ft.

1.750
48
47
46
1.743
diff. -7 K

0.8 6.7

1.126
24
21
24
26
27
1.128
2

0.8 6.9

1.146
41
39
36
37
35
34
33
1.134
-12

0.8 6.9

1.116
16
17
19
21
23
24
24
1.125
9

APPENDIX B

THE EFFECT OF ACCELERATION ON THE UNIFORM SPEED

It has been suggested that the character of the boundary layer, and thus the uniform speed of the model for a given towing force, is altered by the acceleration or the rate at which the boundary layer is built up.

Since the Newport News Basin is relatively short, relatively large acceleration weights are used to bring the model up to speed in a short length of run, so that a longer distance is available for measuring the uniformity of the speed.

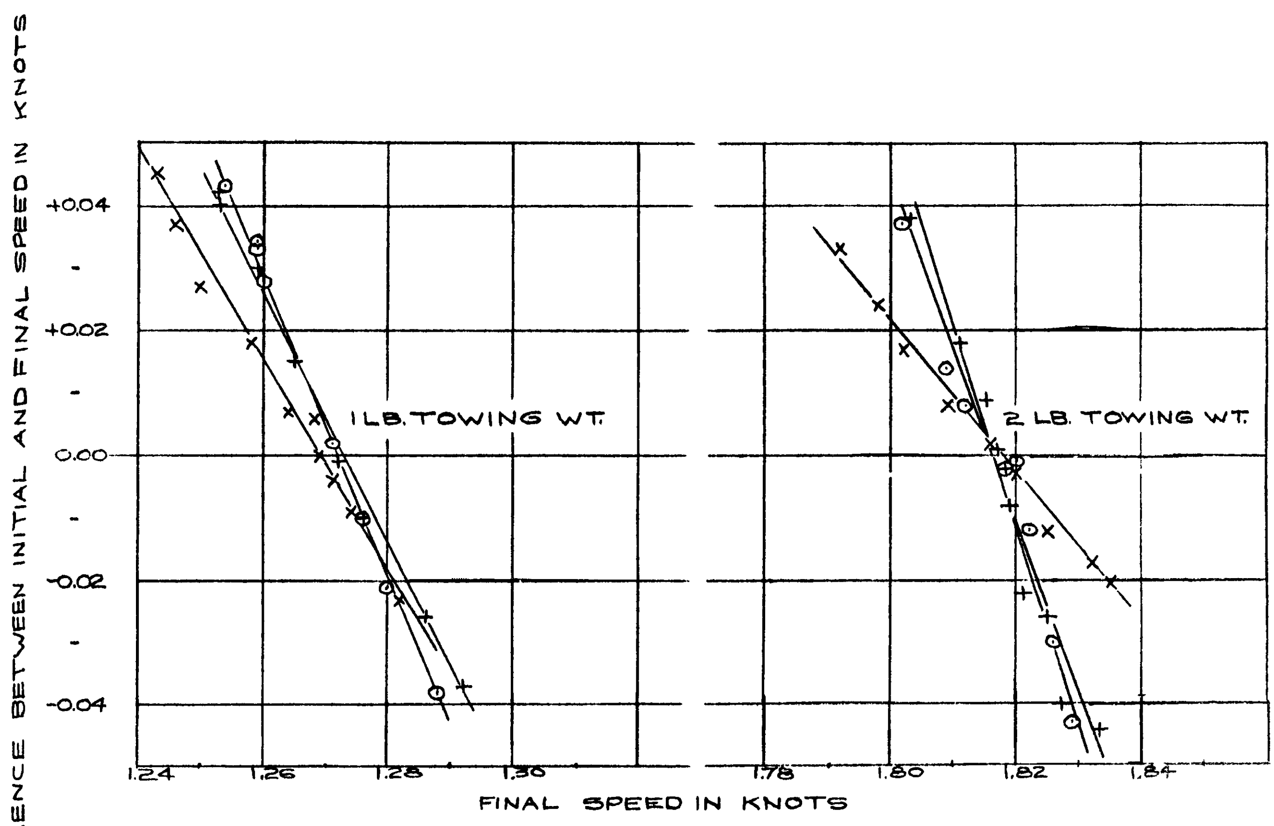
In order to determine if the rate of acceleration was affecting the terminal velocity, three acceleration weights were used, 2.09 pounds, 4.84 pounds, and 9.84 pounds.

Two Towing weights were used with the three acceleration weights. Accelerated travel was varied over a wide range. The difference between the initial and the final speed in knots was plotted against the final speed in knots. The uniform speed was determined by the intersection of a straight line through these points with the zero difference line (Figure 6).

There was a maximum difference of 0.003 and 0.002 knots for the 1 and 2 pound towing weights, respectively. This negligible difference indicates that the rate of acceleration has no appreciable effect on the terminal velocity within the range of accelerations and towing weights used.

Newport News Shipbuilding and Dry Dock Company
Newport News, Virginia

Towing wt in lbs	Accel. wt in lbs	Accel. Travel in ft	Extra wt Travel	Accel. in ft/sec^2	Final Speed in kts	Diff. x 10^3
1.0	2.09	12.1	--	0.220	1.269	- 3
"	4.84	7.4	--	0.489	1.272	--
"	9.84	3.3	3.7	0.766	1.271	- 1
2.0	2.09	20.0	--	0.451	1.816	- 1
"	4.84	11.6	--	0.825	1.817	--
"	9.84	5.0	6.6	1.067	1.818	+ 1



ACCEL. WT. IN LBS.	APPROX. ACCEL. IN FT/SEC^2 FOR 1 LB. TOWING WT.	APPROX. ACCEL. IN FT/SEC^2 FOR 2 LB. TOWING WT.
× 2.09	0.2	0.5
+ 4.84	0.5	0.8
⊙ 9.84	0.8	1.1

Figure 6 - The Effect of Acceleration on the Uniform Speed

APPENDIX B

TEST PROGRAM AT DAVID TAYLOR MODEL BASIN

This appendix is composed of excerpts from David Taylor Model Basin Report 1243 of August 1958 entitled, "The ATTC Model Basin Correlation Program Resistance Tests with the ATTC Standard Model (TMB Model 4695)", by W. B. Hinterthan and H. Y. Yeh.

TEST EQUIPMENT

The tests were carried out on Carriage 1 in a section of the deep-water basin, having dimensions of 963 feet by 51 feet by 22 feet. The Model Basin and the towing carriage have been described in detail by Captain Harold E. Saunders USN, in a series of papers presented before the Society of Naval Architects and Marine Engineers.[1] The carriage speed was kept as constant as possible within the measuring distance, the maximum variation being less than ±0.01 foot per second. The speed of the carriage was measured and digitally recorded on a revolution-speed-time recorder. This system of instruments electrically counted pulses at a rate of 100 pulses per foot. This count was obtained from an idler wheel of the towing carriage. The pulse count was taken over a 6-second time interval and digitally indicated and printed. The time base was accurate to 20 parts per million and the pulse count was accurate to within one count of the total count.

The model was attached to the floating girder of the carriage (Figure 7),[2] which in this special case was locked. Resistance was measured by a flexure-type drag dynamometer, called a "Dual Force Gage," (Figure 5) which used strain gages for measuring. The output of the drag gage was electrically connected to a control unit and thence to a strip chart recorder of a standard commercial type (Figure 6). This measuring system provides accuracy of 0.5 percent of full-scale drag force of 1 pound; i.e., the maximum error at 1-pound drag force was less than 0.005 pound.

The model was carefully aligned on the centerline of the carriage. An aluminum guide fork was fastened on the stern of the model. A rod centered and attached to the locked floating girder was fitted into this fork (Figure 9) and guided the model in the running direction. The clearance between the rod and the fork was 1/64 inch. The towpoint was at the model deck level.

TEST PROCEDURE

The surface of the model was cleaned with a cloth each time before being placed in the water. The weight of the model equipped with a free-trimming towing attachment and the guide forks, was 31.39 pounds. The displacement and draft mark checked very satisfactorily. The standard procedure at the Model Basin was to accelerate the model slowly up to the required speed. The rate of acceleration was not determined. Data were obtained only within a distance of 450 to 800 feet after the start of the trip. The return speed was kept constant at 2.5 feet per second. The time between starts of consecutive test trips was 12 minutes ±20 seconds. The maximum number of resistance spots obtained in one trip was 5 spots up to 4.0 feet per second and 4 spots between 4.0 and 4.4 feet per second. A dummy run at 3.4 feet per second was conducted before each test to stir up the basin water. The basin water temperature

---

[1] Saunders, H. E., "Tests on the Three Geometrically Similar Ship Models," SNAME, Vol. 40, pp. 75-148 (1931).

[2] Figure numbers of original report are retained in this appendix.

was 68 F. during the entire test period. The basin water was skimmed each morning to keep the water surface clean. Check spots were run in the opposite direction to make sure that no basin drift or current would affect the measurements. Test 4 was run 24 hours later than Test 1, to check repeatability of the tests.

TEST RESULTS

Four resistance tests were conducted

Test 1, 19 March 1958, bare hull, no stimulation (Table 2);

Test 2, 20 March 1958, bare hull, no stimulation (Table 3);

Test 3, 20 March 1958, bare hull, studs at bow (Table 4);

Test 4, 20 March 1958, bare hull, no stimulation (Table 5).

The conversion factor from feet per second to knots is 0.5925, as used at the Model Basin in accordance with current Navy Department Regulations. The values for mass density ρ and Kinematic viscosity ν used in C_T and Reynolds number calculations are those adopted by the American Towing Tank Conference in 1942.[1]

The total drag R_T in pounds, as measured without and with studs, plotted against model speed in feet per second, is shown in Figure 1. Figure 2 gives the calculated total resistance coefficient C_T against Reynolds numbers for the conditions with and without studs used as stimulating device. Scales in Figures indicated the change in C_T values when the resistance varies 0.01 pound. The bow and stern wave formations at a speed of 2.0 feet per second are shown in Figures 8 and 9.

COMMENTS

No difference in drag was obtained whether the model was towed in the normal ahead or in the opposite direction. The repeatability of these tests was satisfactory. The largest discrepancies in the resistance amounted to 0.01 pound (2.9 percent) at 4.2 feet per second.

[1] Gertler, M. "The Prediction of Effective Horsepower of Ships by Methods in Use at the David Taylor Model Basin," David Taylor Model Basin Report 576 pp. 17 and 18 (Dec 1947).

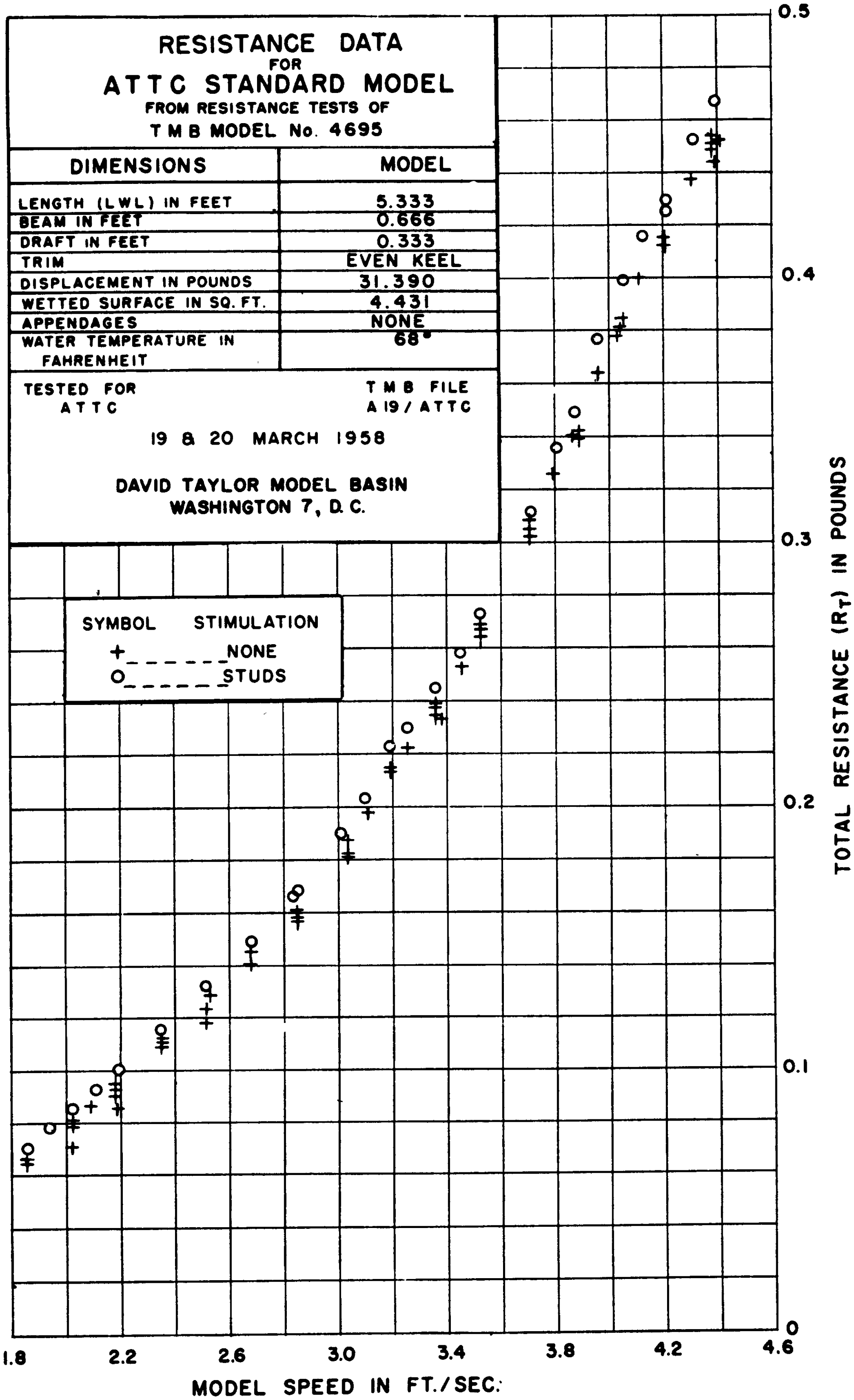

RESISTANCE DATA
FOR
ATTC STANDARD MODEL
FROM RESISTANCE TESTS OF
T M B MODEL No. 4695
DIMENSIONS
MODEL
LENGTH (LWL) IN FEET
5.333
BEAM IN FEET
0.666
DRAFT IN FEET
0.333
TRIM
EVEN KEEL
DISPLACEMENT IN POUNDS
31.390
WETTED SURFACE IN SQ. FT.
4.431
APPENDAGES
NONE
WATER TEMPERATURE IN FAHRENHEIT
68°
TESTED FOR ATTC
T M B FILE A19/ATTC
19 & 20 MARCH 1958
DAVID TAYLOR MODEL BASIN
WASHINGTON 7, D.C.
SYMBOL STIMULATION
+ NONE
O STUDS
MODEL SPEED IN FT./SEC.
TOTAL RESISTANCE (R_T) IN POUNDS
1.8
2.2
2.6
3.0
3.4
3.8
4.2
4.6
0
0.1
0.2
0.3
0.4
0.5

Figure 1

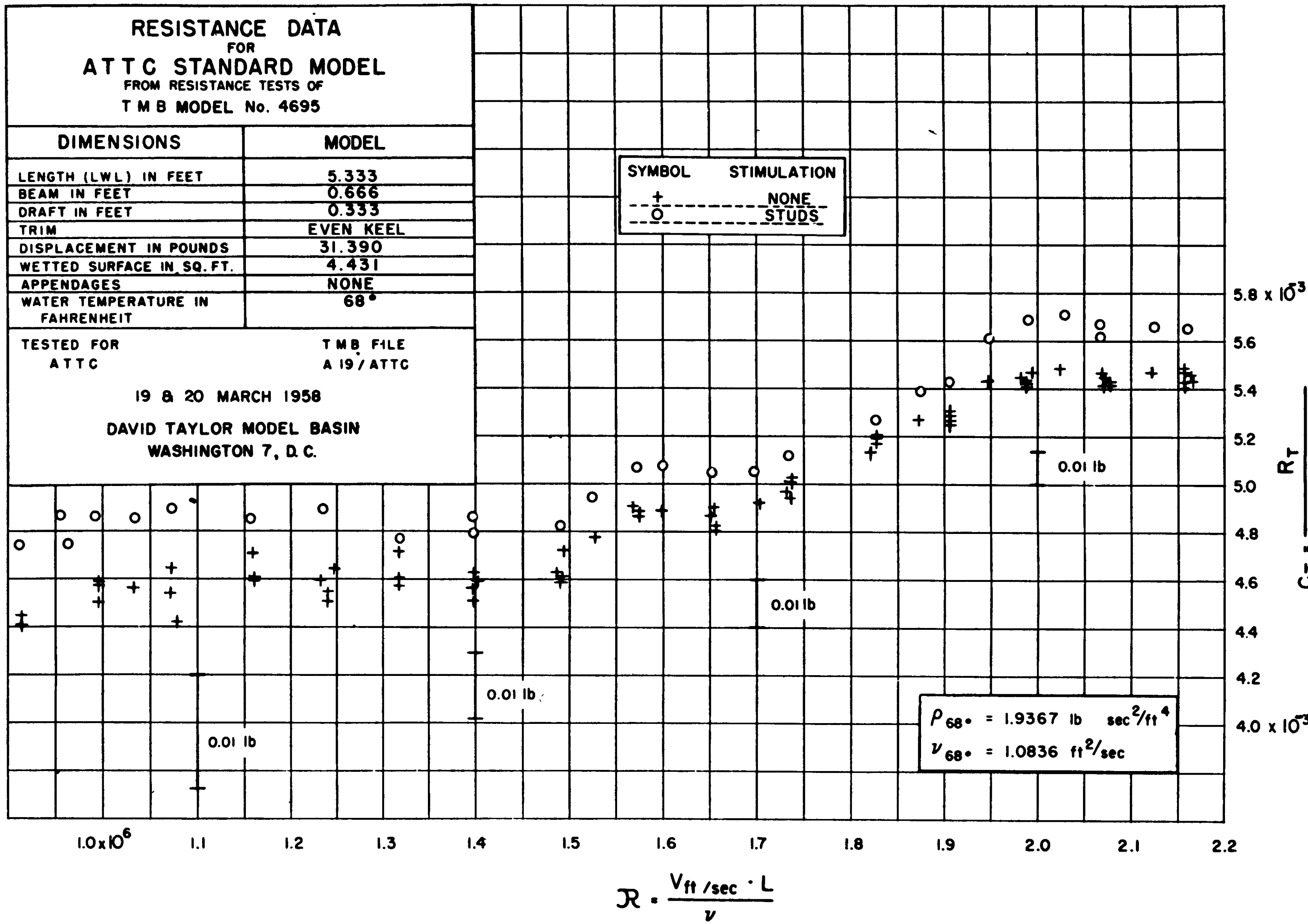

RESISTANCE DATA
FOR
ATTC STANDARD MODEL
FROM RESISTANCE TESTS OF
TMB MODEL No. 4695
DIMENSIONS
MODEL
LENGTH (LWL) IN FEET
5.333
BEAM IN FEET
0.666
DRAFT IN FEET
0.333
TRIM
EVEN KEEL
DISPLACEMENT IN POUNDS
31.390
WETTED SURFACE IN SQ. FT.
4.431
APPENDAGES
NONE
WATER TEMPERATURE IN FAHRENHEIT
68°
TESTED FOR ATTC
TMB FILE A 19/ATTC
19 & 20 MARCH 1958
DAVID TAYLOR MODEL BASIN
WASHINGTON 7, D.C.
SYMBOL
STIMULATION
+
NONE
O
STUDS
0.01 lb
0.01 lb
0.01 lb
0.01 lb
ρ68° = 1.9367 lb sec²/ft⁴
ν68° = 1.0836 ft²/sec
5.8 x 10⁻³
5.6
5.4
5.2
5.0
4.8
4.6
4.4
4.2
4.0 x 10⁻³
1.0x10⁶
1.1
1.2
1.3
1.4
1.5
1.6
1.7
1.8
1.9
2.0
2.1
2.2
CT = RT / (ρ/2 · (Vft/sec)²)
ℛ = Vft/sec · L / ν

Figure 2

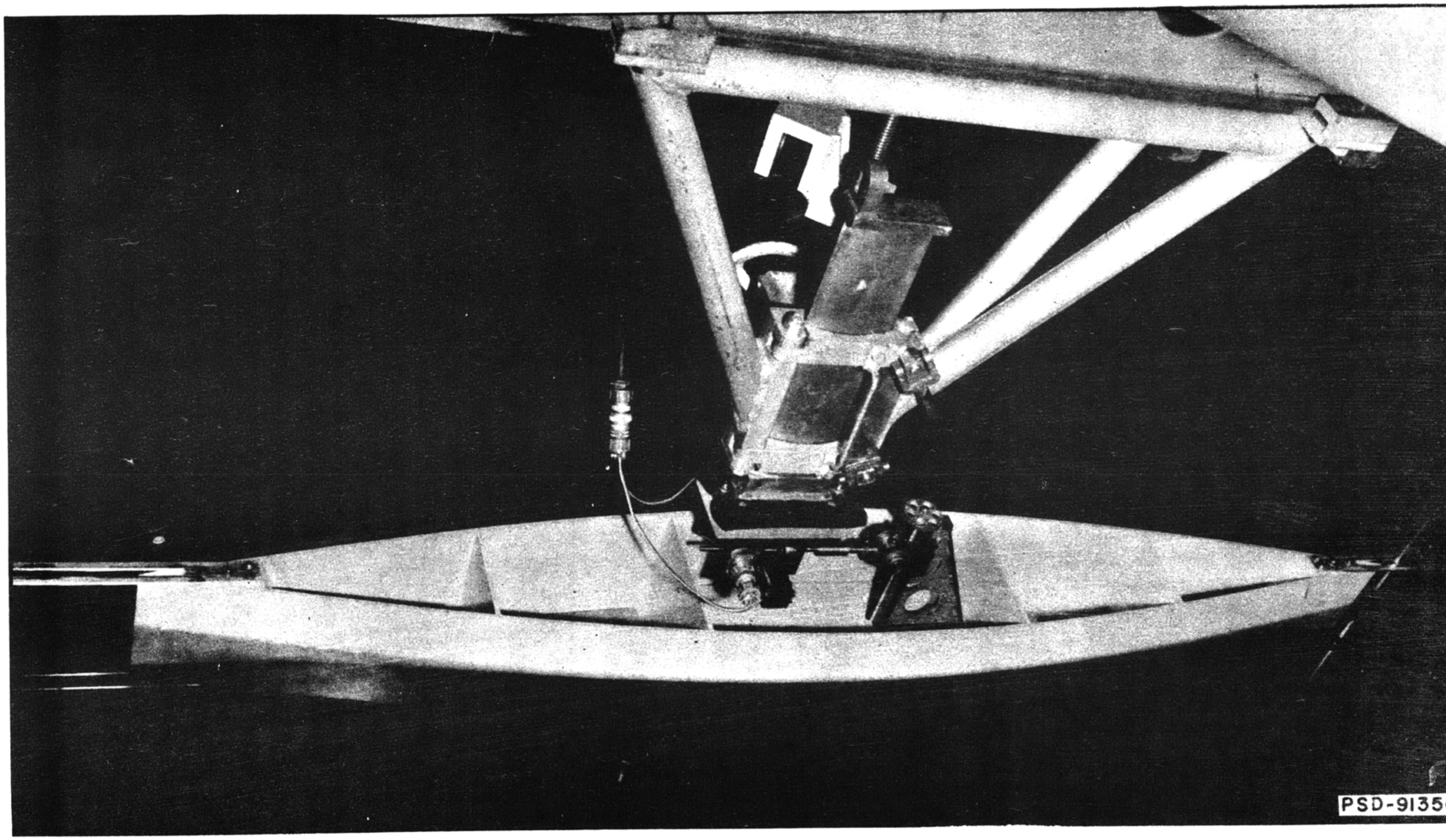


Figure 7 – Model Installation

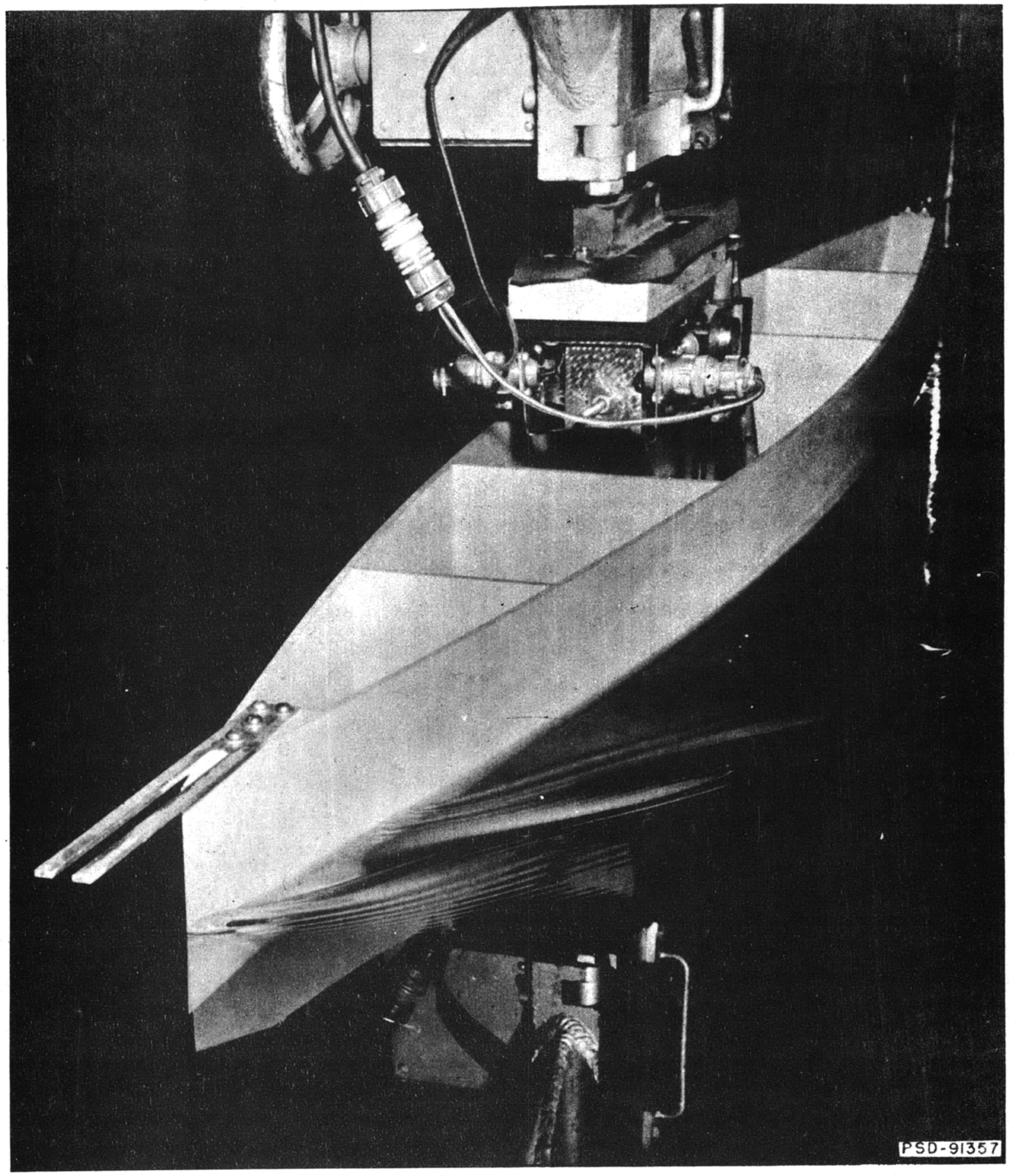


Figure 8 – Bow Wave System at a Speed of 2.0 Feet per Second

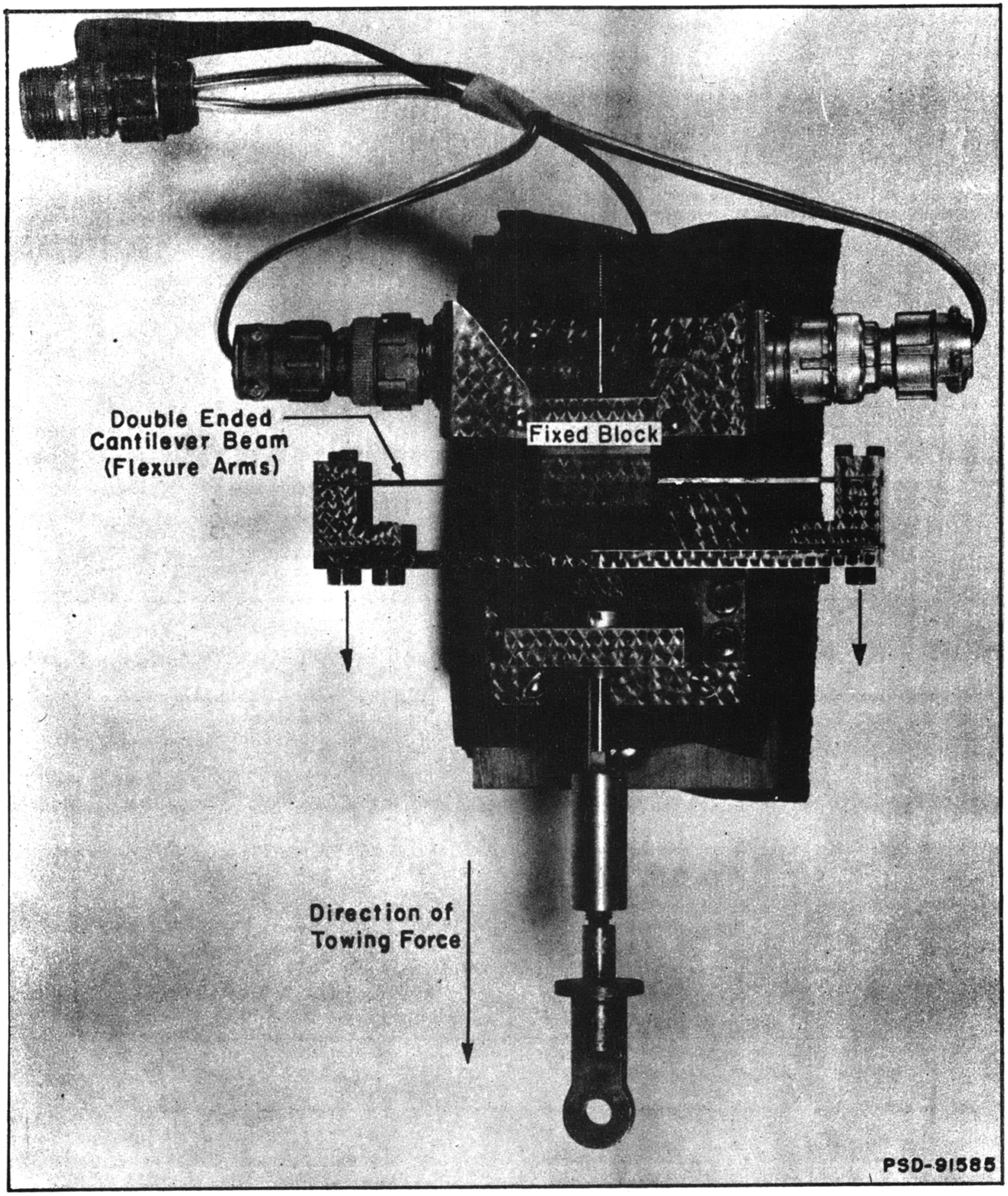


Figure 5 – Drag Dynamometer

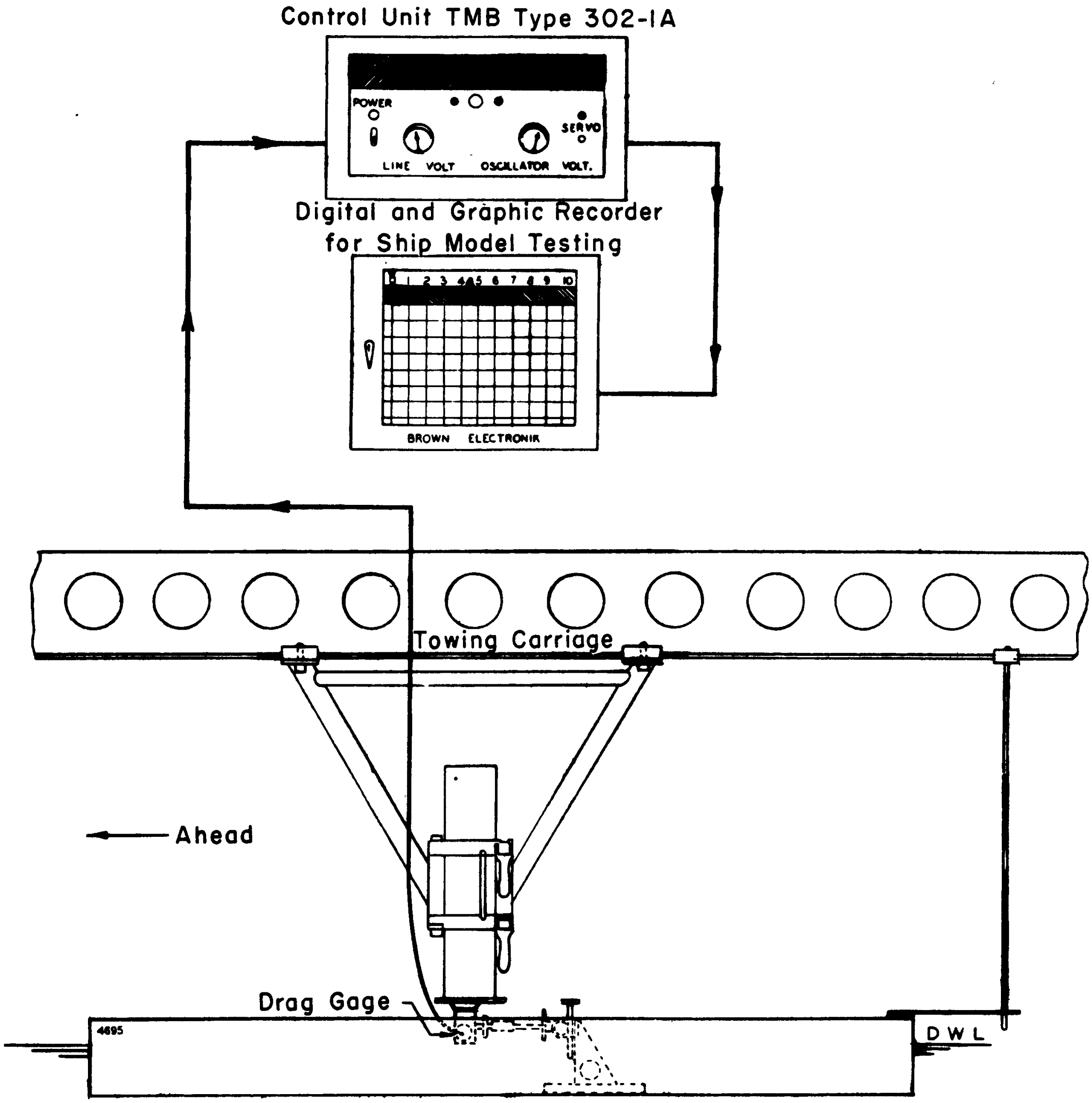


Figure 6 – Schematic of Drag Measuring System

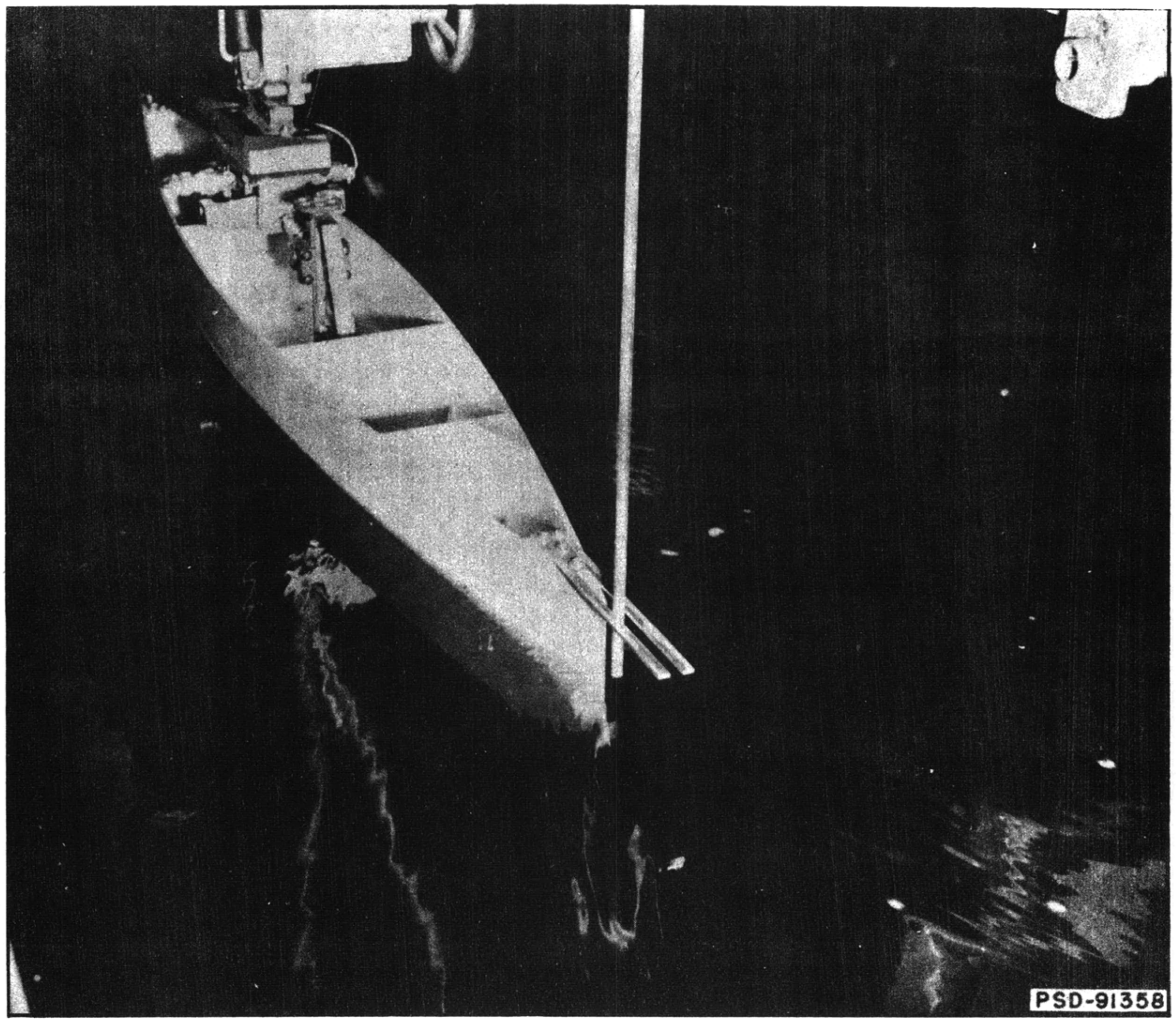


Figure 9 – Stern Wave System at a Speed of 2.0 Feet per Second

TABLE 1

Dimensions of ATTC Standard Model (TMB Model 4695)

Length	64.00 in.	5.333 ft
Beam	8.00 in.	0.666 ft
Draft	4.00 in.	0.333 ft
Wetted surface	639.1 sq in.	4.431 sq ft
Displacement	31.39 lb	
Trim	Even keel	
Water temperature	68° F.	
ρ (68 deg)	1.9367 lb × sec^2/ft^4	
ν (68 deg)	1.0836 ft^2/sec × 10^{-5}	
g	32.155 ft/sec^2	
γ (F.W.)	62.274 lb/cu ft	

TABLE 2

Resistance Data for ATTC Standard Model (TMB Model 4695)

Test 1, 19 Mar 1958. Bare hull. Stimulation, None.

Model condition is given in Table 1.

Model Speed		R_T	$C_T \times 10^3$	$R \times 10^{-6}$
ft/sec	knots	lb		
2.350	1.392	0.109	4.600	1.156
2.678	1.587	0.145	4.712	1.317
3.032	1.796	0.182	4.614	1.491
3.362	1.992	0.238	4.907	1.654
3.719	2.203	0.308	5.190	1.829
4.043	2.395	0.381	5.432	1.989
2.184	1.294	0.093	4.544	1.074
2.518	1.492	0.124	4.558	1.239
2.846	1.686	0.157	4.517	1.400
3.199	1.895	0.214	4.873	1.574
3.531	2.092	0.269	5.028	1.737
3.882	2.300	0.339	5.243	1.910
4.207	2.493	0.415	5.467	2.069
3.365	1.994	0.234	4.816	1.655
3.719	2.203	0.309	5.207	1.829
4.046	2.397	0.381	5.424	1.990
4.388	2.600	0.448	5.423	2.158
3.199	1.895	0.215	4.896	1.574
3.532	2.093	0.265	4.951	1.737
3.881	2.299	0.343	5.307	1.909
4.210	2.494	0.412	5.418	2.071
4.211	2.495	0.415	5.454	2.071
2.846	1.686	0.161	4.633	1.400

TABLE 3

Resistance Data for ATTC Standard Model (TMB Model 4695)

Test 2, 20 Mar 1958. Bare hull. Stimulation, None.

Model condition is given in Table 1.

Model Speed ft/sec	Model Speed knots	R_T lb	$C_T \times 10^3$	$R \times 10^{-6}$
2.022	1.198	0.079	4.503	0.995
2.353	1.394	0.112	4.715	1.157
2.679	1.587	0.141	4.578	1.318
3.032	1.796	0.181	4.589	1.491
3.366	1.994	0.235	4.834	1.656
3.716	2.202	0.306	5.170	1.828
4.049	2.399	0.385	5.474	1.992
4.396	2.604	0.452	5.451	2.162
3.025	1.792	0.182	4.635	1.488
3.358	1.990	0.235	4.864	1.652
3.709	2.198	0.303	5.136	1.824
4.035	2.391	0.378	5.411	1.985
4.381	2.596	0.445	5.404	2.155
1.852	1.097	0.065	4.417	0.911
2.180	1.292	0.095	4.659	1.072
2.508	1.486	0.124	4.595	1.234
2.838	1.681	0.158	4.571	1.396
3.190	1.890	0.214	4.901	1.569
3.524	2.088	0.265	4.973	1.733
3.874	2.298	0.339	5.264	1.906
4.204	2.491	0.415	5.475	2.068
2.023	1.199	0.080	4.578	0.995*
2.537	1.503	0.128	4.642	1.248*
3.250	1.926	0.222	4.898	1.600*
3.460	2.050	0.253	4.925	1.702*
3.798	2.250	0.326	5.267	1.872*
3.960	2.346	0.365	5.424	1.948*
4.117	2.439	0.400	5.498	2.025*
4.318	2.558	0.437	5.462	2.124*
3.107	1.841	0.198	4.778	1.528*

*Model tested in opposite direction.

TABLE 4

Resistance Data for ATTC Standard Model (TMB Model 4695)

Test 3, 20 Mar 1958. Bare hull. Stimulation, Studs.

Model condition is given in Table 1.

Model Speed		R_T	$C_T \times 10^3$	$R \times 10^{-6}$
ft/sec	knots	lb		
2.019	1.196	0.085	4.860	0.993
2.350	1.392	0.115	4.854	1.156
2.681	1.588	0.147	4.766	1.319
3.029	1.795	0.190	4.826	1.490
3.363	1.992	0.245	5.048	1.654
3.714	2.200	0.312	5.272	1.827
4.045	2.397	0.399	5.683	1.990
4.392	2.602	0.467	5.642	2.160
1.852	1.097	0.070	4.756	0.911
2.182	1.293	0.100	4.895	1.073
2.510	1.487	0.132	4.883	1.235
2.841	1.683	0.168	4.851	1.397
3.194	1.892	0.222	5.072	1.571
3.525	2.088	0.273	5.120	1.734
3.872	2.294	0.349	5.425	1.905
4.203	2.490	0.425	5.607	2.067
2.511	1.488	0.132	4.879	1.235
3.356	1.988	0.244	5.049	1.651
4.202	2.490	0.429	5.663	2.067
3.099	1.836	0.204	4.951	1.524
2.102	1.245	0.092	4.853	1.034
1.942	1.151	0.079	4.878	0.955
2.842	1.684	0.166	4.790	1.398
3.250	1.926	0.230	5.080	1.600
3.452	2.045	0.258	5.042	1.698
3.812	2.259	0.336	5.389	1.875
3.960	2.346	0.377	5.603	1.948
4.123	2.443	0.416	5.703	2.028
4.318	2.558	0.453	5.662	2.124

TABLE 5

Resistance Data for ATTC Standard Model (TMB Model 4695)

Test 4, 20 Mar 1958. Bare hull. Stimulation, None.

Model condition is given in Table 1.

Model Speed		R_T	$C_T \times 10^3$	$R \times 10^{-6}$
ft/sec	knots	lb		
4.387	2.599	0.454	5.495	2.158
4.387	2.599	0.452	5.474	2.158
2.095	1.241	0.086	4.561	1.031
1.858	1.101	0.066	4.456	0.914
4.401	2.608	0.452	5.439	2.165
4.218	2.499	0.415	5.436	2.075
4.032	2.389	0.380	5.448	1.983
3.887	2.303	0.342	5.276	1.912
3.724	2.206	0.308	5.163	1.832
3.535	2.094	0.269	5.017	1.739
4.391	2.602	0.450	5.439	2.160
4.212	2.496	0.415	5.452	2.072
3.879	2.298	0.341	5.282	1.908
3.532	2.093	0.268	5.012	1.737
3.196	1.894	0.214	4.882	1.572
2.849	1.688	0.160	4.594	1.401
2.518	1.492	0.124	4.591	1.239
2.189	1.297	0.091	4.426	1.077
3.371	1.997	0.239	4.902	1.658
3.038	1.800	0.187	4.723	1.494
2.680	1.588	0.142	4.605	1.318
2.359	1.398	0.110	4.607	1.160
2.028	1.202	0.081	4.590	0.998
2.520	1.493	0.123	4.514	1.240
3.368	1.995	0.234	4.808	1.657
3.365	1.994	0.234	4.816	1.655
2.520	1.493	0.123	4.514	1.240

APPENDIX C

TEST PROGRAM AT STEVENS INSTITUTE OF TECHNOLOGY

This appendix is a reproduction of original data received from the Davidson Laboratory by letter of 8 July 1959. A complete report describing the procedures, techniques, and instrumentation will be issued by the Davidson Laboratory at some future time.

7 July 1959

The tests were made in the Tank No. 1 of the Davidson Laboratory by the standard procedure of that laboratory.

TABLE 1

Results of Towing Tests of ATTC Standard Fiberglas Model

		(a) Bare Hull - 19 May 1959 Water Temp. 70.5°F			(b) Stud Test - 17 June 1959 Water Temp. 69°F		
Tank I Speed No.	Speed ft/sec	R_m, lb	$(Re)_m$ 10^6 x	C_{t_m} 10^{-3}	R_m, lb	$(Re)_m$ 10^6 x	C_{t_m} 10^{-3}
L - 20	3.453	0.2513	1.756	4.90	0.2590	1.721	5.05
12	2.394	.1122	1.218	4.55	.1179	1.193	4.78
21	3.586	.2756	1.824	4.99	.2863	1.787	5.18
13	2.526	.1260	1.285	4.60	.1307	1.259	4.77
22	3.719	.3056	1.891	5.14	.3166	1.853	5.33
14	2.658	.1394	1.352	4.59	.1460	1.325	4.81
23	3.850	.3432	1.958	5.39	.3544	1.919	5.56
15	2.792	.1553	1.420	4.64	.1610	1.391	4.81
24	3.984	.3791	2.026	5.56	.3922	1.985	5.75
16	2.924	.1710	1.487	4.66	.1763	1.457	4.80
25	4.116	.4076	2.093	5.60	.4232	2.052	5.81
17	3.056	.1897	1.554	4.73	.1969	1.523	4.91
26	4.250	.4316	2.161	5.56	.4491	2.118	5.78
18	3.188	.2110	1.621	4.83	.2176	1.589	4.98
27	4.382	.4544	2.229	5.51	.4738	2.184	5.74
19	3.321	.2310	1.689	4.87	.2391	1.655	5.05
28	4.514	.4866	2.296	5.56	.5069	2.250	5.79

(a):

$$(Re)_m = \frac{v\ell}{\nu} = \frac{v \times 5.33}{1.0485 \times 10^{-3}}$$

$$C_{t_m} = \frac{R}{\rho/2\, v^2 S}$$

(b):

$$(Re)_m = \frac{v\ell}{\nu} = \frac{v \times 5.33}{1.070 \times 10^{-5}}$$

$$\frac{R}{v^2} \; \frac{1}{4.298}$$

REFERENCES

1. Wigley, W. C. S., "Ship Wave Resistance - A Comparison of Mathematical Theory with Experimental Results, Part II," Transactions of Institute of Naval Architects, Vol. 69, pp 191-196, 1927

2. Taylor, W. F. and Bailey, J. P., "Preliminary Resistance Test of ATTC Standard Friction Form for Model Basin Correlation Program," Hydraulic Laboratory, Newport News Shipbuilding and Dry Dock Company (April 1956)

3. Taylor, W. F., Naff, S. A., and Wiatt, J. S., "Resistance Test of ATTC Standard Friction Form for Model Basin Correlation Program", Hydraulic Laboratory, Newport News Shipbuilding and Dry Dock Company (May 1957)

4. Hinterthan, W. B. and Yeh, H. Y., "The ATTC Model Basin Correlation Program Resistance Tests with the ATTC Standard Model (TMB Model 4695)," David Taylor Model Basin Report 1243 (August 1958)

5. Davidson Laboratory letter by Allan B. Murray of 8 July 1959 to Morton Gertler of Taylor Model Basin

INITIAL DISTRIBUTION

Copies	
3	CHBUSHIPS, Library (Code 312)
100	American Towing Tank Conference

David Taylor Model Basin. Report 1357.
COMPARATIVE RESISTANCE TESTS WITH ATTC STANDARD MODEL, by M. Gertler and C.H. Hancock; prepared by the Model Basin Correlation Subcommittee of the Friction Committee for Presentation at the Twelfth General Meeting of the American Towing Tank Conference to be held at University of California, Berkeley, California, 31 Aug–2 Sep 1959. July 1959. 49p. illus., tables, graphs, refs. UNCLASSIFIED

A program of comparative resistance tests involving the use of a standard model has been established by the Model Basin Correlation Subcommittee of the Friction Committee of the American Towing Tank Conference. This report presents the basic considerations underlying the program, a description of the ATTC Standard Model, and comparisons of the results of resistance tests made by three of the participating towing tanks. The test

1. Ship models – Model ATTC
2. Ship models – Model TMB 4695
3. Ship models – Resistance – Test methods
4. Resistance data
I. American Towing Tank Conference, 12th, Berkeley, Calif., 1959
II. Newport News Shipbuilding and Dry Dock Co. Hydraulics Laboratory
III. David Taylor Model Basin

David Taylor Model Basin. Report 1357.
COMPARATIVE RESISTANCE TESTS WITH ATTC STANDARD MODEL, by M. Gertler and C.H. Hancock; prepared by the Model Basin Correlation Subcommittee of the Friction Committee for Presentation at the Twelfth General Meeting of the American Towing Tank Conference to be held at University of California, Berkeley, California, 31 Aug–2 Sep 1959. July 1959. 49p. illus., tables, graphs, refs. UNCLASSIFIED

A program of comparative resistance tests involving the use of a standard model has been established by the Model Basin Correlation Subcommittee of the Friction Committee of the American Towing Tank Conference. This report presents the basic considerations underlying the program, a description of the ATTC Standard Model, and comparisons of the results of resistance tests made by three of the participating towing tanks. The test

1. Ship models – Model ATTC
2. Ship models – Model TMB 4695
3. Ship models – Resistance – Test methods
4. Resistance data
I. American Towing Tank Conference, 12th, Berkeley, Calif., 1959
II. Newport News Shipbuilding and Dry Dock Co. Hydraulics Laboratory
III. David Taylor Model Basin

David Taylor Model Basin. Report 1357.
COMPARATIVE RESISTANCE TESTS WITH ATTC STANDARD MODEL, by M. Gertler and C.H. Hancock; prepared by the Model Basin Correlation Subcommittee of the Friction Committee for Presentation at the Twelfth General Meeting of the American Towing Tank Conference to be held at University of California, Berkeley, California, 31 Aug–2 Sep 1959. July 1959. 49p. illus., tables, graphs, refs. UNCLASSIFIED

A program of comparative resistance tests involving the use of a standard model has been established by the Model Basin Correlation Subcommittee of the Friction Committee of the American Towing Tank Conference. This report presents the basic considerations underlying the program, a description of the ATTC Standard Model, and comparisons of the results of resistance tests made by three of the participating towing tanks. The test

1. Ship models – Model ATTC
2. Ship models – Model TMB 4695
3. Ship models – Resistance – Test methods
4. Resistance data
I. American Towing Tank Conference, 12th, Berkeley, Calif., 1959
II. Newport News Shipbuilding and Dry Dock Co. Hydraulics Laboratory
III. David Taylor Model Basin

David Taylor Model Basin. Report 1357.
COMPARATIVE RESISTANCE TESTS WITH ATTC STANDARD MODEL, by M. Gertler and C.H. Hancock; prepared by the Model Basin Correlation Subcommittee of the Friction Committee for Presentation at the Twelfth General Meeting of the American Towing Tank Conference to be held at University of California, Berkeley, California, 31 Aug–2 Sep 1959. July 1959. 49p. illus., tables, graphs, refs. UNCLASSIFIED

A program of comparative resistance tests involving the use of a standard model has been established by the Model Basin Correlation Subcommittee of the Friction Committee of the American Towing Tank Conference. This report presents the basic considerations underlying the program, a description of the ATTC Standard Model, and comparisons of the results of resistance tests made by three of the participating towing tanks. The test

1. Ship models – Model ATTC
2. Ship models – Model TMB 4695
3. Ship models – Resistance – Test methods
4. Resistance data
I. American Towing Tank Conference, 12th, Berkeley, Calif., 1959
II. Newport News Shipbuilding and Dry Dock Co. Hydraulics Laboratory
III. David Taylor Model Basin

techniques, instrumentation, and facilities used for the program are described by the individual organizations in the appendixes.

IV. Stevens Institute of Technology, Davidson Laboratory
V. Gertler, M.
VI. Hancock, C.H.

techniques, instrumentation, and facilities used for the program are described by the individual organizations in the appendixes.

IV. Stevens Institute of Technology, Davidson Laboratory
V. Gertler, M.
VI. Hancock, C.H.

techniques, instrumentation, and facilities used for the program are described by the individual organizations in the appendixes.

IV. Stevens Institute of Technology, Davidson Laboratory
V. Gertler, M.
VI. Hancock, C.H.

techniques, instrumentation, and facilities used for the program are described by the individual organizations in the appendixes.

IV. Stevens Institute of Technology, Davidson Laboratory
V. Gertler, M.
VI. Hancock, C.H.

David Taylor Model Basin. Report 1357.
COMPARATIVE RESISTANCE TESTS WITH ATTC STANDARD MODEL, by M. Gertler and C.H. Hancock; prepared by the Model Basin Correlation Subcommittee of the Friction Committee for Presentation at the Twelfth General Meeting of the American Towing Tank Conference to be held at University of California, Berkeley, California, 31 Aug–2 Sep 1959. July 1959. 49p. illus., tables, graphs, refs. UNCLASSIFIED

A program of comparative resistance tests involving the use of a standard model has been established by the Model Basin Correlation Subcommittee of the Friction Committee of the American Towing Tank Conference. This report presents the basic considerations underlying the program, a description of the ATTC Standard Model, and comparisons of the results of resistance tests made by three of the participating towing tanks. The test

1. Ship models – Model ATTC
2. Ship models – Model TMB 4695
3. Ship models – Resistance – Test methods
4. Resistance data
I. American Towing Tank Conference, 12th, Berkeley, Calif., 1959
II. Newport News Shipbuilding and Dry Dock Co. Hydraulics Laboratory
III. David Taylor Model Basin

David Taylor Model Basin. Report 1357.
COMPARATIVE RESISTANCE TESTS WITH ATTC STANDARD MODEL, by M. Gertler and C.H. Hancock; prepared by the Model Basin Correlation Subcommittee of the Friction Committee for Presentation at the Twelfth General Meeting of the American Towing Tank Conference to be held at University of California, Berkeley, California, 31 Aug–2 Sep 1959. July 1959. 49p. illus., tables, graphs, refs. UNCLASSIFIED

A program of comparative resistance tests involving the use of a standard model has been established by the Model Basin Correlation Subcommittee of the Friction Committee of the American Towing Tank Conference. This report presents the basic considerations underlying the program, a description of the ATTC Standard Model, and comparisons of the results of resistance tests made by three of the participating towing tanks. The test

1. Ship models – Model ATTC
2. Ship models – Model TMB 4695
3. Ship models – Resistance – Test methods
4. Resistance data
I. American Towing Tank Conference, 12th, Berkeley, Calif., 1959
II. Newport News Shipbuilding and Dry Dock Co. Hydraulics Laboratory
III. David Taylor Model Basin

David Taylor Model Basin. Report 1357.
COMPARATIVE RESISTANCE TESTS WITH ATTC STANDARD MODEL, by M. Gertler and C.H. Hancock; prepared by the Model Basin Correlation Subcommittee of the Friction Committee for Presentation at the Twelfth General Meeting of the American Towing Tank Conference to be held at University of California, Berkeley, California, 31 Aug–2 Sep 1959. July 1959. 49p. illus., tables, graphs, refs. UNCLASSIFIED

A program of comparative resistance tests involving the use of a standard model has been established by the Model Basin Correlation Subcommittee of the Friction Committee of the American Towing Tank Conference. This report presents the basic considerations underlying the program, a description of the ATTC Standard Model, and comparisons of the results of resistance tests made by three of the participating towing tanks. The test

1. Ship models – Model ATTC
2. Ship models – Model TMB 4695
3. Ship models – Resistance – Test methods
4. Resistance data
I. American Towing Tank Conference, 12th, Berkeley, Calif., 1959
II. Newport News Shipbuilding and Dry Dock Co. Hydraulics Laboratory
III. David Taylor Model Basin

David Taylor Model Basin. Report 1357.
COMPARATIVE RESISTANCE TESTS WITH ATTC STANDARD MODEL, by M. Gertler and C.H. Hancock; prepared by the Model Basin Correlation Subcommittee of the Friction Committee for Presentation at the Twelfth General Meeting of the American Towing Tank Conference to be held at University of California, Berkeley, California, 31 Aug–2 Sep 1959. July 1959. 49p. illus., tables, graphs, refs. UNCLASSIFIED

A program of comparative resistance tests involving the use of a standard model has been established by the Model Basin Correlation Subcommittee of the Friction Committee of the American Towing Tank Conference. This report presents the basic considerations underlying the program, a description of the ATTC Standard Model, and comparisons of the results of resistance tests made by three of the participating towing tanks. The test

1. Ship models – Model ATTC
2. Ship models – Model TMB 4695
3. Ship models – Resistance – Test methods
4. Resistance data
I. American Towing Tank Conference, 12th, Berkeley, Calif., 1959
II. Newport News Shipbuilding and Dry Dock Co. Hydraulics Laboratory
III. David Taylor Model Basin

techniques, instrumentation, and facilities used for the program are described by the individual organizations in the appendixes.

IV. Stevens Institute of Technology, Davidson Laboratory
V. Gertler, M.
VI. Hancock, C.H.

techniques, instrumentation, and facilities used for the program are described by the individual organizations in the appendixes.

IV. Stevens Institute of Technology, Davidson Laboratory
V. Gertler, M.
VI. Hancock, C.H.

techniques, instrumentation, and facilities used for the program are described by the individual organizations in the appendixes.

IV. Stevens Institute of Technology, Davidson Laboratory
V. Gertler, M.
VI. Hancock, C.H.

techniques, instrumentation, and facilities used for the program are described by the individual organizations in the appendixes.

IV. Stevens Institute of Technology, Davidson Laboratory
V. Gertler, M.
VI. Hancock, C.H.