NAVY DEPARTMENT

THE DAVID W. TAYLOR MODEL BASIN

WASHINGTON 7, D.C.

PRELIMINARY REPORT OF THE LIBERTY-SHIP SERIES FOR THE AMERICAN TOWING TANK CONFERENCE

by

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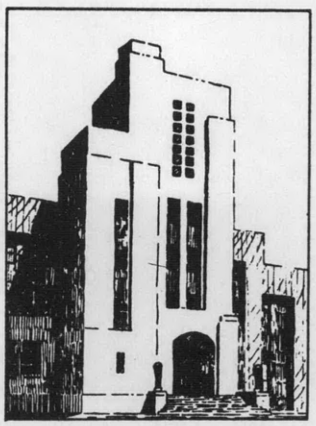

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Report 615

PRELIMINARY REPORT OF THE LIBERTY-SHIP SERIES FOR THE AMERICAN TOWING TANK CONFERENCE

INTRODUCTION

This is the first annual report of the work done on the Liberty Ship Series by the member laboratories of the American Towing Tank Conference.

The Liberty Ship Series is a series of six geometrically similar models of the Maritime Commission Liberty Ship design varying in nominal size from 5.5 to 30 feet in length. The characteristics of the ship and models composing this series are given in Table 1. The models were constructed at the David Taylor Model Basin and were to be tested, insofar as the size of model permitted, in the various towing tanks of the United States.

The minutes of the 1942 annual meeting of the ATTC directed that each member tank submit the towing test data of this series together with a complete description of the techniques employed, to the Taylor Model Basin. All models were to be towed without artificial turbulence-inducing devices as well as with such devices that may ordinarily be employed at each establishment.

The purpose of the series tests are:

1. To provide information for predicting the resistance of full-scale vessels from various sizes of geometrically similar models, and

2. To acquaint the members of the ATTC with the techniques employed by the various tanks for testing geometrically similar models with special reference to such problems as turbulence and scale effect.

A brief description of the tests completed to date and a discussion of the results obtained therefrom will be given in this report.

TEST SCHEDULE

Prior to the past year the 5.5-foot model was tested at the Hydraulic Laboratory of the Newport News Shipbuilding and Dry Dock Company and some preliminary tests were conducted in the large basin at the Taylor Model Basin. The tests at the Taylor Model Basin were rejected because the dynamometers on the large carriages are too heavy for tests of such small models, therefore, it is proposed to conduct any further tests of the 5.5- and 7-foot models in the smaller high speed basin and the 140-foot basin.

The original 5.5-foot model was either misplaced or inadvertently destroyed sometime this year, hence a new model has been recently constructed. It is proposed to test this new model at the Taylor Model Basin and then ship it to all other tanks for tests.

During the past year the 7-foot model was shipped to the Experimental Towing Tank at the Stevens Institute of Technology then to the Naval Tank at the University of Michigan, and then to the National Research Council at Ottawa, Canada.

Characteristics of Ship and Models

"Liberty Ship" Series of Geometrically Similar Models

cale Factor, λ	1	14.228	21.342	28.456	42.683	60.032	75.
ength B.P.	416.00	29.238	19.492	14.619	9.7463	6.9296	5.4
ength L.W.L.	427.30	30.032	20.022	15.016	10.011	7.1179	5.6
ength O.A.	441.50	31.030	20.687	15.515	10.344	7.3544	5.8
eam, Mld., ft.	56.896	3.999	2.666	1.999	1.333	0.9478	0.7
raft, E.K., ft.	27.000	1.898	1.265	0.9488	0.6326	0.4498	0.3
λ^2	1	202.44	455.48	809.74	1821.8	3603.8	572
λ^3	1	2880.5	9720.9	23042	77762	216350	433
$\lambda^{\frac{1}{2}}$	1	3.7720	4.6197	5.3344	6.5332	7.7480	8.6
ol. of Δ, ft.^{3}	481,880	167.29	49.572	20.913	6.1969	2.2273	1.1
, S.W. at 50°F tons	13,790	----	----	----	----	----	---
, F.W. at 68°F lbs.	30,026,000	10,424	3,088.9	1,303.1	386.14	138.79	69.
etted Surface,* ft.^{2}	37709	186.3	82.79	46.57	20.70	10.46	6.5
esigned Speed,** knots	11.00	2.916	2.381	2.062	1.684	1.420	1.2
esigned Speed, ft/min.	1115.	295.5	241.3	208.9	170.7	143.9	128.
esigned Speed, ft/sec.	18.58	4.925	4.021	3.483	2.844	2.398	2.1
anks Under-taking Tests	---	TMB EMB	TMB EMB NACA	TMB EMB NACA OTTAWA	TMB EMB NACA OTTAWA MICHIGAN	TMB EMB NACA OTTAWA MICHIGAN STEVENS	TM EM NAC OTT MIC STE NEW N

With rudder.
* On account of the low designed speed of the vessel, the tests should be arried to higher speed, preferably to the highest practicable speed in eac nstance.

ote: TMB will self-propel the 20- and 30-foot models.

TABLE 1

Tests were conducted at each of these laboratories and the model returned to the Taylor Model Basin. After tests at the Taylor Model Basin the 7-foot model will be shipped to the National Advisory Committee for Aeronautics, Langley Field, Virginia.

The 10-foot model has been in continuous use at TMB in connection with the Panama Canal project hence has not been available for the series work. It is expected that it will be shipped to Stevens Institute for tests in the near future.

The 15- and 20-foot models have been recently towed in the large basin at the Taylor Model Basin. It is proposed to ship the 15-foot model to Ottawa for additional tests.

It is planned to tow the 30-foot model in the large basin at TMB when opportunity permits.

DESCRIPTION OF TESTS

The tests of the 20-foot model at the Taylor Model Basin were conducted in the deep water basin which is 51 feet wide and 22 feet deep. The model was attached to the dynamometer floating girder with the regular heavy-duty towing bracket and stern-guide bracket. The movement of the girder was damped by a magnetic damper set for medium damping. Two 10-pound springs were used on the dynamometer. The model was carried up to the maximum speed at 0.4-knot increments with a 12-minute time interval between runs. The test was again conducted in the manner described except the speeds were chosen to fall between those previously run. Finally a few check spots were run at various

The test of the 20-foot model was conducted both with and without artificially stimulated turbulence. Turbulence was stimulated by a 1/8-inch cylindrical rod which was placed 6 inches forward of the stem at the load-water line. The rod was fixed to the carriage hence no tare correction for the resistance of the rod was made to the model resistance data.

The test on the 15-foot model was conducted in a similar manner. However, since the forces encountered were smaller, the model was towed with a light-duty towing bracket and the heavy stern-guide bracket was replaced by a stern-guide rod. Two 2-pound springs were used on the dynamometer and the damping employed was less than that for the 20-foot model. The same 1/8-inch cylindrical rod was used as the turbulence device.

Stevens Institute of Technology reports that the 7-foot model was towed in Tank 1. This tank is of semi-circular cross section with a radius of 4.5 feet. The wave damping boards were in place and turbulence was induced with a 1/8-inch strut towed 6 inches ahead of the model. No correction was made for the strut resistance as the strut was supported by the carriage independent of the model.

The University of Michigan reports that the 7-foot model was run with a tank water depth of 6 feet 8 inches and that the routine water spray for inducing turbulence was used.

PRESENTATION OF DATA

A preliminary analysis of the data obtained to date has been made by the Taylor Model Basin and is presented below.

The model test data furnished by the various tanks were, in general, tabulated as values of resistance in pounds against speed in knots, hence to convert the resistance values into dimensionless coefficient form, the tota-resistance coefficient, which is defined

$$C_t = \frac{R_t}{\rho/2 \; SV^2}$$

where C_t is the total-resistance coefficient

R_t is the total resistance

ρ is the mass density, and

V is speed

was calculated for each of the test spots. The frictional-resistance coefficient was then obtained from the Schoenherr formula

$$\frac{0.242}{\sqrt{C_f}} = \log_{10} \mathcal{R} \cdot C_f$$

where C_f is the frictional-resistance coefficient

$\mathcal{R}$ is the Reynolds number, equal to $\frac{VL}{\nu}$

V is the speed

L is the water line length, and

ν is the kinematic viscosity

The values for the frictional-resistance coefficients were subtracted from the values of the total-resistance coefficients or

$$C_t - C_f = C_r = \frac{R_r}{\rho/2 \; SV^2}$$

where C_r is the residual-resistance coefficient and R_r is the residual resistance. The residual-resistance coefficients for each test were plotted against speed-length ratio and are shown in Figures 1 to 4. A composite plot of all faired C_r curves is shown in Figure 5.

Since the residual-resistance coefficient is by definition the difference between the total-resistance coefficient and the frictional-resistance coefficient calculated from the Schoenherr formula, apparent differences in residual-resistance coefficients are not necessarily due to actual differences in residual resistance but more probably due to variances in frictional resistance.

DISCUSSION OF RESULTS

The curves in Figure 5 show that there is a large difference in the value of C_r at the lower speed-length ratios, but a fairly reasonable agreement at the higher speed-length ratios. To aid in making comparisons, values for the resistance coefficients at speed-length ratios of 0.400, 0.532 (about designed speed of 11 knots), and 0.700 are included in Table 5 for the model and in Table 6 for the ship.

The results of the tests with the 20-foot model at the Taylor Model Basin, for the conditions with and without induced turbulence, as shown in Table 2, indicate that at the designed speed-length ratio of 0.532 the increase in C_r due to induced turbulence is about 27 percent. However since the C_r is only about 14 percent of the total, the change in C_t for ship is about 6 percent.

TABLE 2

COMPARISON OF 20-FOOT MODEL WITHOUT INDUCED TURBULENCE WITH THE 20-FOOT MODEL WITH INDUCED TURBULENCE FOR TMB TESTS

$\frac{V}{\sqrt{L}}$	C_r* without Induced Turbulence	C_r with Induced Turbulence	Ratio $\frac{C_r}{C_r}$ with/without
0.400	260	550	2.12
0.532	510	650	1.27
0.700	1375	1435	1.04
$\frac{V}{\sqrt{L}}$	C_r without Induced Turbulence	C_t without Induced Turbulence	$\frac{C_r}{C_t}$
0.400	260	3465	0.075
0.532	510	3567	0.143
0.700	1375	4295	0.320
$\frac{V}{\sqrt{L}}$	C_t for Ship without Induced Turbulence	C_t for Ship with Induced Turbulence	$\frac{C_t}{C_t}$ with/without
0.400	1973	2263	1.15
0.532	2162	2302	1.06
0.700	2971	3031	1.02

*C coefficients are x 10^6

A comparison of the C_r for the 15-foot model for the conditions with and without induced turbulence, as shown in Table 3, indicates that the increase in C_r, at the designed speed-length ratio of 0.532 is about 15 percent. The resulting increase in C_t for ship is about 4 percent.

TABLE 3

COMPARISONS OF 15-FOOT MODEL WITHOUT INDUCED TURBULENCE WITH THE 15-FOOT MODEL WITH INDUCED TURBULENCE FOR TMB TESTS

$\frac{V}{\sqrt{L}}$	C_r* without Induced Turbulence	C_r with Induced Turbulence	$\frac{C_r \text{ with}}{C_r \text{ without}}$
0.400	345	540	1.57
0.532	567	651	1.15
0.700	1410	1445	1.02

$\frac{V}{\sqrt{L}}$	C_r without Induced Turbulence	C_t without Induced Turbulence	$\frac{C_r}{C_t}$
0.400	345	3885	0.089
0.532	567	3936	0.148
0.700	1410	4610	0.306

$\frac{V}{\sqrt{L}}$	C_t for ship without Induced Turbulence	C_t for Ship with Induced Turbulence	$\frac{C_t}{C_t}$
0.400	2058	2253	1.09
0.532	2219	2303	1.04
0.700	3006	3041	1.01

*C coefficients are x 10^6

In attempting to make a comparison of the data from the different tanks the results from the test of the 20-foot model with induced turbulence was arbitrarily chosen as a base. The results of these comparisons are shown in Table 4. At the designed speed-length ratio, the 20-foot and 15-foot models are in agreement but the 7-foot model at Stevens shows a 6 percent higher C_t for ship while the 7-foot model at Michigan shows about a 5 percent lower C_t.

TABLE 4

COMPARISONS OF 15-FOOT MODEL, AT TMB, AND 7-FOOT MODEL, AT STEVENS AND MICHIGAN, WITH THE 20-FOOT MODEL AT TMB. ALL WITH ARTIFICIALLY STIMULATED TURBULENCE

C_r for the models at the speed-length ratio of 0.400

Model	C_r*	$\frac{C_r}{C_r \text{ for 20-foot Model}}$
20-foot at TMB	550	1.000
15-foot at TMB	540	0.982
7-foot at Stevens	610	1.109
7-foot at Michigan	425	0.773

C_t for ship at the speed-length ratio of 0.400

Model	C_t	$\frac{C_t}{C_t \text{ from 20-foot Model}}$
20-foot at TMB	2263	1.000
15-foot at TMB	2253	0.995
7-foot at Stevens	2323	1.026
7-foot at Michigan	2138	0.945

C_r for models at the speed-length ratio of 0.532

Model	C_r	$\frac{C_r}{C_r \text{ for 20-foot Model}}$
20-foot at TMB	650	1.000
15-foot at TMB	651	1.002
7-foot at Stevens	796	1.225
7-foot at Michigan	542	0.834

C_t for ship at the speed-length ratio of 0.532

Model	C_t	$\frac{C_t}{C_t \text{ from 20-foot Model}}$
20-foot at TMB	2302	1.000
15-foot at TMB	2303	1.000
7-foot at Stevens	2448	1.063
7-foot at Michigan	2194	0.953

C_r for the models at the speed-length ratio of 0.700

Model	C_r	$\frac{C_r}{C_r \text{ for 20-foot Model}}$
20-foot at TMB	1435	1.000
15-foot at TMB	1445	1.007
7-foot at Stevens	1497	1.043
7-foot at Michigan	1420	0.989

C_t for ship at the speed-length ratio of 0.700

Model	C_t	$\frac{C_t}{C_t \text{ from 20-foot Model}}$
20-foot at TMB	3031	1.000
15-foot at TMB	3041	1.003
7-foot at Stevens	3093	1.020
7-foot at Michigan	3016	0.995

CONCLUSIONS AND RECOMMENDATIONS

Since the reported data from the Liberty Ship Series are rather limited at the present time, it is not possible to arrive at any definite conclusions. However it is apparent that the large variance between the residual-resistance coefficients obtained from different basins testing the same model emphasizes the need for a considerable amount of additional work on testing techniques. Special consideration should be given to the development of techniques for stimulating turbulence especially in the smaller models. The work on turbulence devices should be directed toward the adoption of standard devices since it is conceivable that turbulence can be overstimulated as well as understimulated.

Reliable full-scale data are needed in order to extend the correlation of the series from the smallest model through the larger models and up to full-scale.

The development of frictional-resistance formulations must necessarily go hand in hand with the series work in an effort to obtain better correlation of results of the various sizes of geometrically similar models. However, this work should be done independently of the series since it is evident that the discrepancies cannot, at the present time, be directly attributed to the frictional-resistance formulation used. Furthermore, if a frictional-resistance formula was arbitrarily chosen to successfully correlate the resistance of the various-sized models in this series, it would not necessarily follow that it would be satisfactory for hulls of other shapes.

TABLE 5

RESISTANCE COEFFICIENTS FOR MODEL FROM TESTS OF 20-FOOT, 15-FOOT, AND 7-FOOT MODEL OF LIBERTY SHIP SERIES

20-foot Model without Turbulence Device at TMB

$\frac{V}{\sqrt{L}}$	C_t*	C_f*	C_r*
0.400	3465	3205	260
**0.532	3567	3057	510
0.700	4295	2920	1375

20-foot Model with Turbulence Device at TMB

$\frac{V}{\sqrt{L}}$	C_t	C_f	C_r
0.400	3755	3205	550
0.532	3707	3057	650
0.700	4355	2920	1435

15-foot Model without Turbulence Device at TMB

$\frac{V}{\sqrt{L}}$	C_t	C_f	C_r
0.400	3885	3540	345
0.532	3936	3369	567
0.700	4610	3200	1410

15-foot Model with Turbulence Device at TMB

$\frac{V}{\sqrt{L}}$	C_t	C_f	C_r
0.400	4080	3540	540
0.532	4020	3369	651
0.700	4645	3200	1445

7-foot Model with Turbulence Device at Stevens

$\frac{V}{\sqrt{L}}$	C_t	C_f	C_r
0.400	4900	4290	610
0.532	4854	4058	796
0.700	5340	3843	1497

7-foot Model with Turbulence Device at Michigan

$\frac{V}{\sqrt{L}}$	C_t	C_f	C_r
0.400	4670	4245	425
0.532	4560	4018	542
0.700	5245	3825	1420

*C coefficients are x 10^6
**0.532 is designed speed-length ratio for 11 knots full scale.

TABLE 6

RESISTANCE COEFFICIENTS FOR FULL-SCALE SHIP FROM TESTS WITH 20-FOOT, 15-FOOT, AND 7-FOOT MODELS

20-foot Model without Induced Turbulence at TMB

$\frac{V}{\sqrt{L}}$	C_r*	C_f*	C_t*
0.400	260	1713	1973
**0.532	510	1652	2162
0.700	1375	1596	2971

20-foot Model with Induced Turbulence at TMB

$\frac{V}{\sqrt{L}}$	C_r	C_f	C_t
0.400	550	1713	2263
0.532	650	1652	2302
0.700	1435	1596	3031

15-foot Model without Induced Turbulence at TMB

$\frac{V}{\sqrt{L}}$	C_r	C_f	C_t
0.400	345	1713	2058
0.532	567	1652	2219
0.700	1410	1596	3006

15-foot Model with Induced Turbulence at TMB

$\frac{V}{\sqrt{L}}$	C_r	C_f	C_t
0.400	540	1713	2253
0.532	651	1652	2303
0.700	1445	1596	3041

7-foot Model with Induced Turbulence at Stevens

$\frac{V}{\sqrt{L}}$	C_r	C_f	C_t
0.400	610	1713	2323
0.532	796	1652	2448
0.700	1497	1596	3093

7-foot Model with Induced Turbulence at Michiga

$\frac{V}{\sqrt{L}}$	C_r	C_f	C_t
0.400	425	1713	2138
0.532	542	1652	2194
0.700	1420	1596	3016

*C coefficients are x 10^6
**0.532 is designed speed-length ratio for 11 knots full scale.
C_t for Ship does not include a roughness allowance.

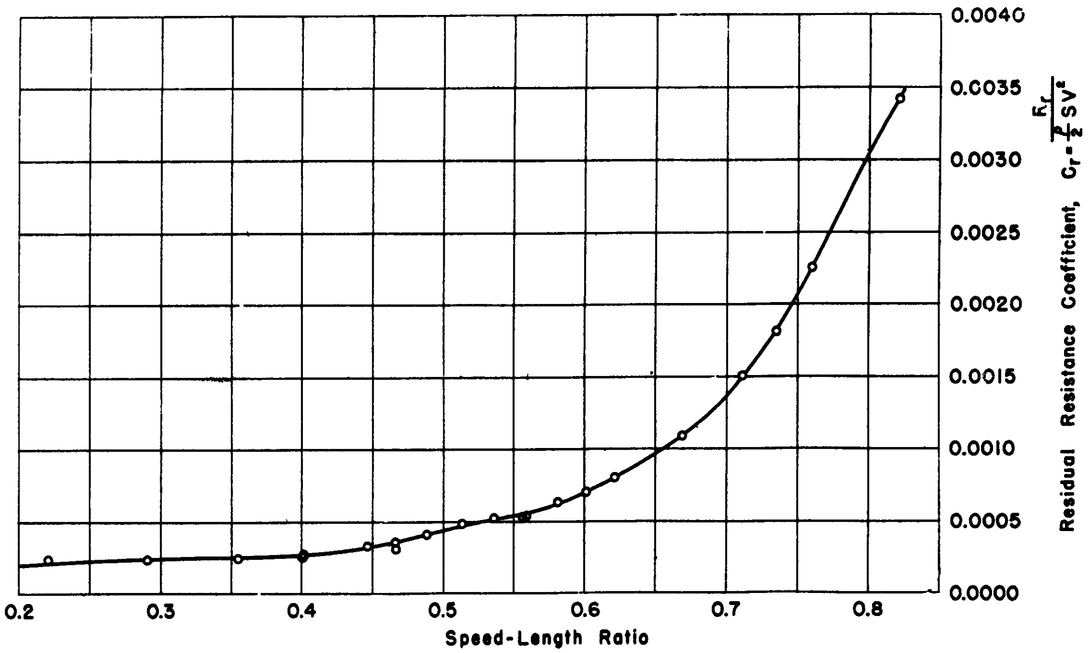

Figure 1a - Without Artificially Stimulated Turbulence

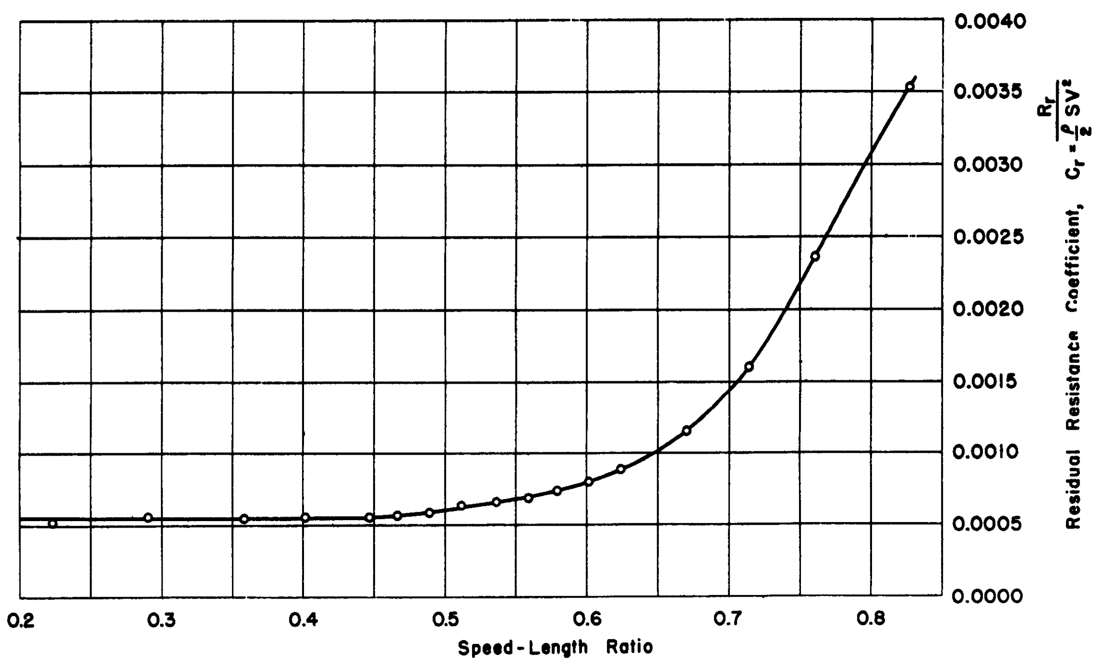

Figure 1b - With Artificially Stimulated Turbulence

Figure 1 - Residual Resistance Coefficients for the Liberty Ship Plotted Against Speed-Length Ratio

These coefficients were derived from data obtained from tests which were conducted at the Taylor Model Basin with the 20-foot model.

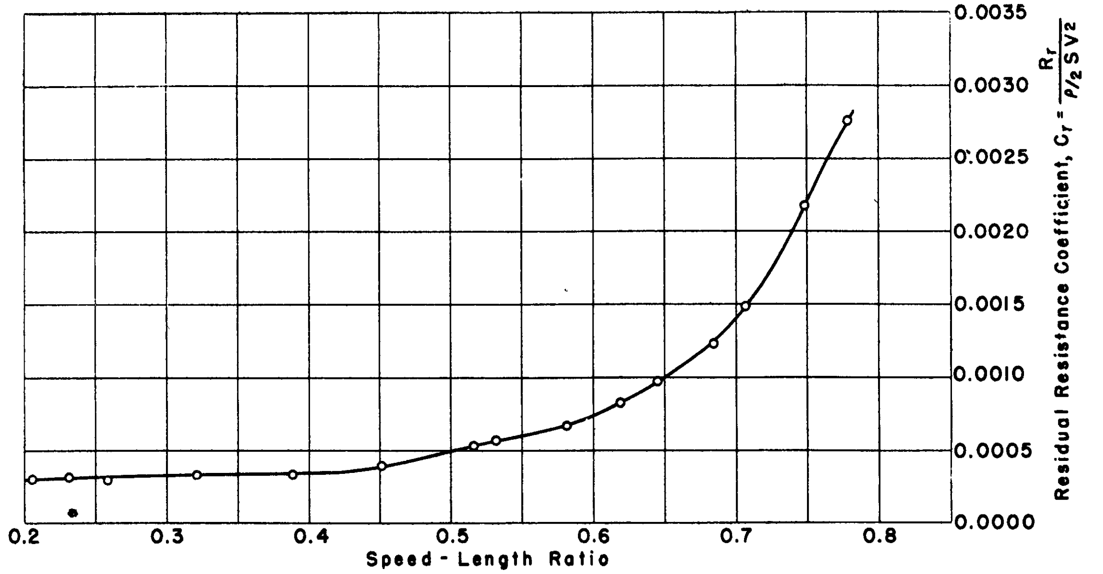

Figure 2a - Without Artificially Stimulated Turbulence

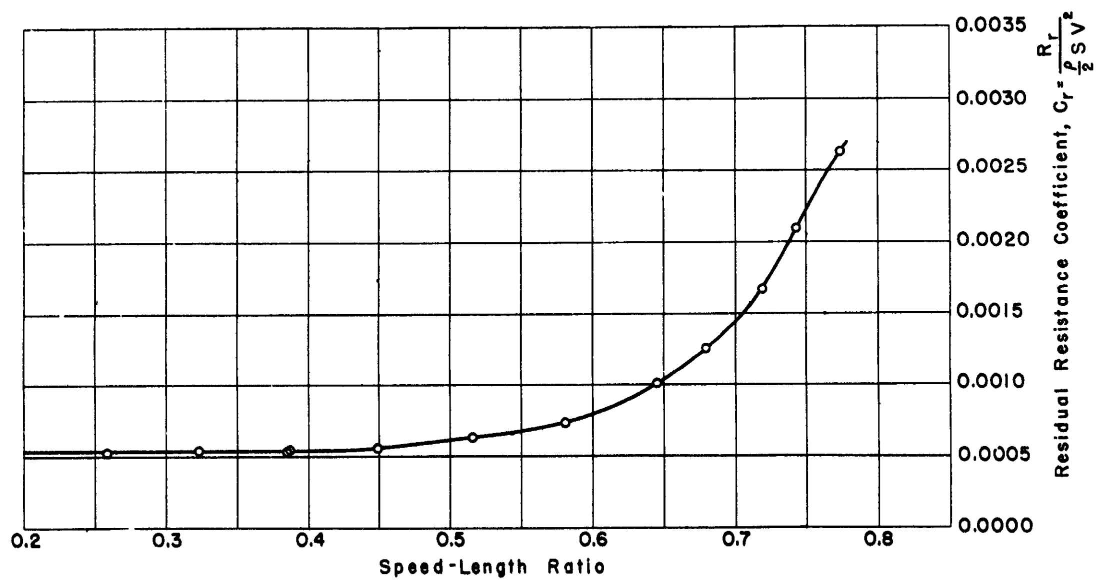

Figure 2b - With Artificially Stimulated Turbulence

Figure 2 - Residual Resistance Coefficients for the Liberty Ship Plotted against Speed-Length Ratio

These coefficients were derived from data obtained from tests which were conducted at the Taylor Model Basin with the 15-foot model.

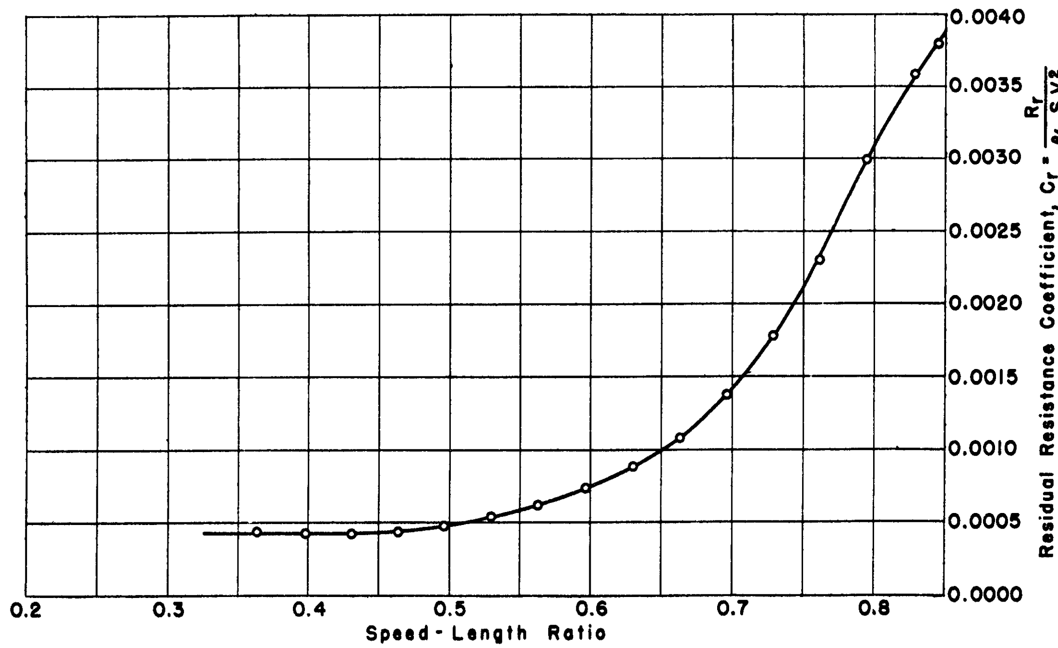

Figure 3 - Residual Resistance Coefficients for the Liberty Ship Plotted against Speed-Length Ratio

These coefficients were derived from data obtained from tests which were conducted at the University of Michigan Experimental Naval Tank with the 7-foot model. Turbulence was artificially stimulated.

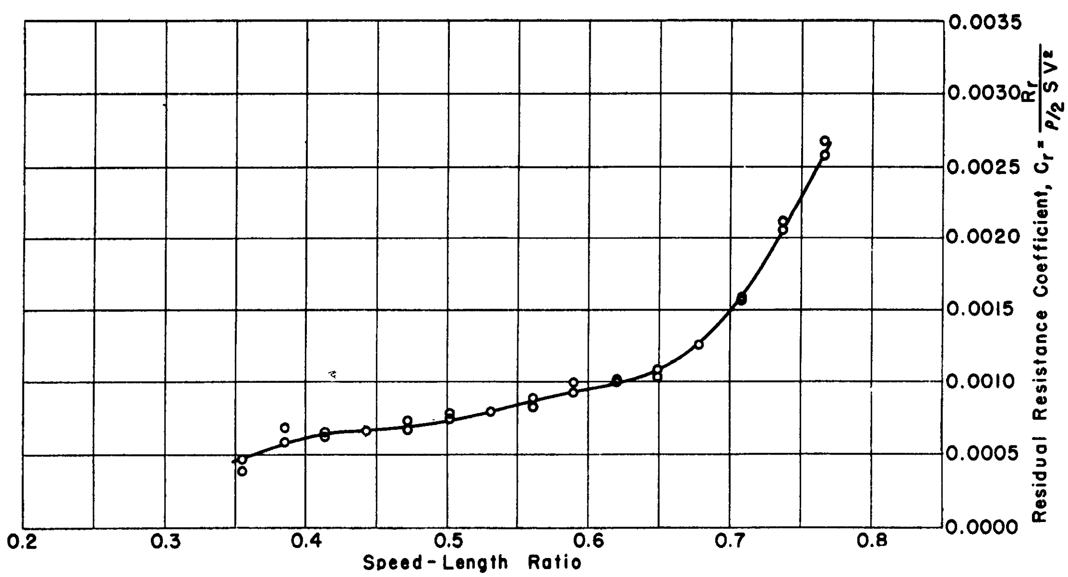

Figure 4 - Residual Resistance Coefficients for the Liberty Ship Plotted against Speed-Length Ratio

The coefficients were derived from data obtained from tests which were conducted at the Stevens Institute of Technology Experimental Towing Tank with the 7-foot model. Turbulence was artificially stimulated.

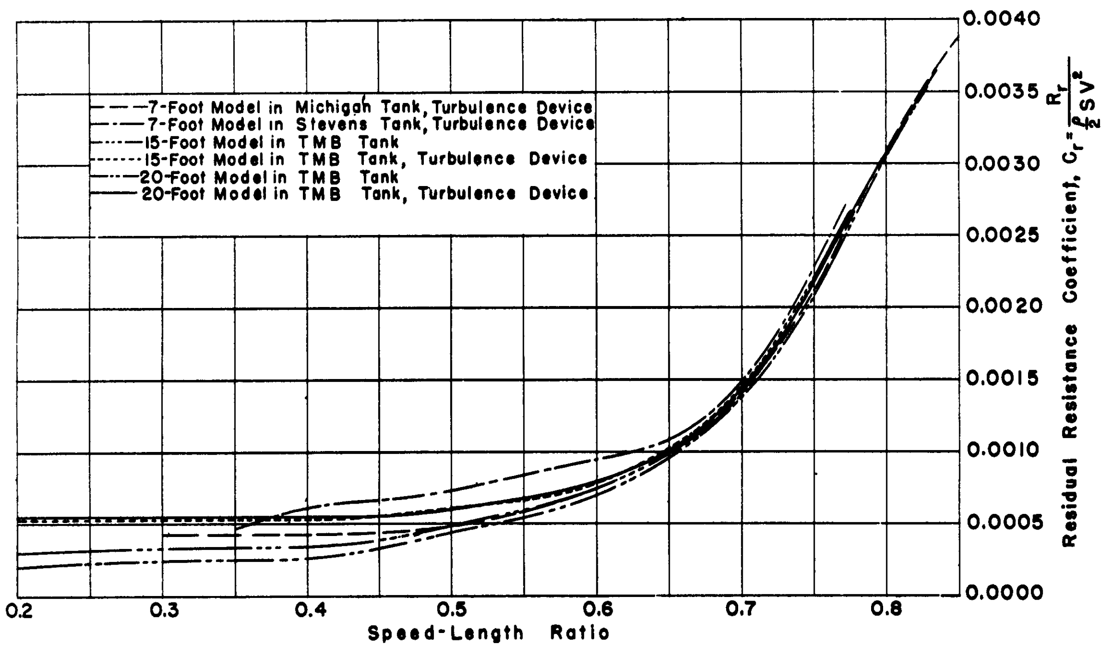

Figure 5 - Residual Resistance Coefficients for the Liberty Ship Plotted against Speed-Length Ratio

These coefficients are the results obtained for tests which were conducted at University of Michigan, Stevens Institute of Technology, and the David Taylor Model Basin with the 20-foot, 15-foot, and 7-foot models.

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