# UNITED STATES

# EXPERIMENTAL MODEL BASIN

## NAVY YARD, WASHINGTON, D.C.

## RESISTANCE TESTS ON A 2-FOOT MODEL SUBMITTED BY PROF. K. DAVIDSON

BY J. G. THEWS



EXPERIMENTAL MODEL BASIN
ERECTED 1898
BUREAU OF
CONSTRUCTION AND REPAIR
NAVY DEPARTMENT

JULY 1932

REPORT NO. 333

# RESISTANCE TESTS on a 2-FOOT MODEL
# SUBMITTED by PROF. K. DAVIDSON

- By J.G. Thews -

U.S. EXPERIMENTAL MODEL BASIN
NAVY YARD, WASHINGTON, D. C.

July, 1932 Report No. 333

RESISTANCE TESTS on a 2-FOOT MODEL SUBMITTED by PROF. K. DAVIDSON

## Introduction

This test was conducted at the request of Prof. Kenneth Davidson of Stevens Institute of Technology, Hoboken, N.J., who has a small model basin. He desired to check some of his experimental results with those obtained at the U.S. Experimental Model Basin.

Prof. Davidson had a model which was intended to be an exact duplicate of the 24-inch U.S.E.M.B. model 2540 (one of the friction series) but due to an error on the part of his model builder it was made slightly finer, with reduced beam. Table 1 shows the main differences in the two models due to this error. In the following, Prof. Davidson's model will be referred to as model 2540-D and the prototype as model 2540.

TABLE 1

| | | Model 2540 | Model 2540-D |
|---|---|---|---|
| Length | L | 24.0 inches | 24.0 inches |
| Beam | B | 2.04 " | 1.96 " |
| Draft | H | 1.80 " | 1.99 " |
| Displ. | D | 1.750 lb. | 1.751 lb. |
| Wet. Sur. | A | 0.710 sq. ft. | 0.730 sq. ft. |
| B/H | | 1.133 | 0.985 |

Tests were made to determine the resistance curve for his model over the range of speeds from 0.2 knots to 1.7 knots (0.34 ft./sec. to 2.87 ft./sec.).

## Test Apparatus and Procedure

The experimental work was conducted in the 30-ft. model basin.

To insure clean water the basin was drained and refilled with hydrant water.

The temperature of the water was noted at the beginning and end of each test. The second test was performed one week after the first test.

In preparing the model for the tests the towing-bridle was attached to the top of the model, eight inches aft of the forward perpendicular. Before placing the model in the water it was carefully wiped to insure a clean surface.

The model towed well at all speeds during both tests. There was no apparent yawing or pitching.

After each test the dynamometer was calibrated for tare load. Table 2 gives the estimated accuracy of the dynamometer in measuring the resistance of the model at various speeds.

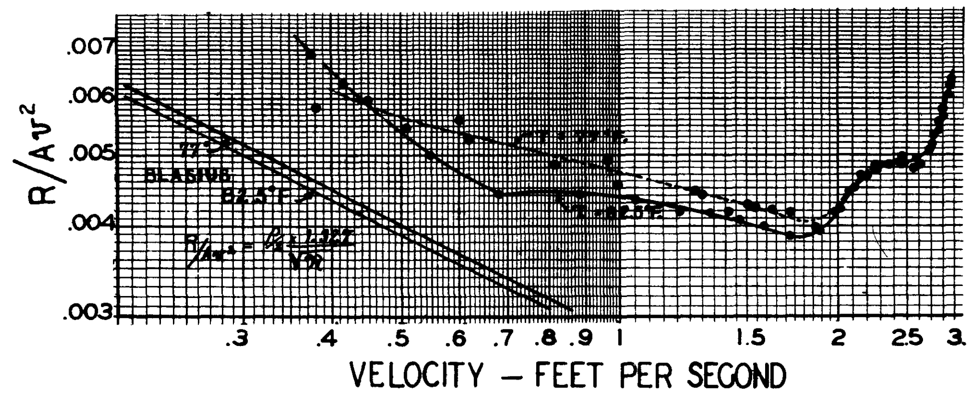


FIG. 1. MODEL 2540-D

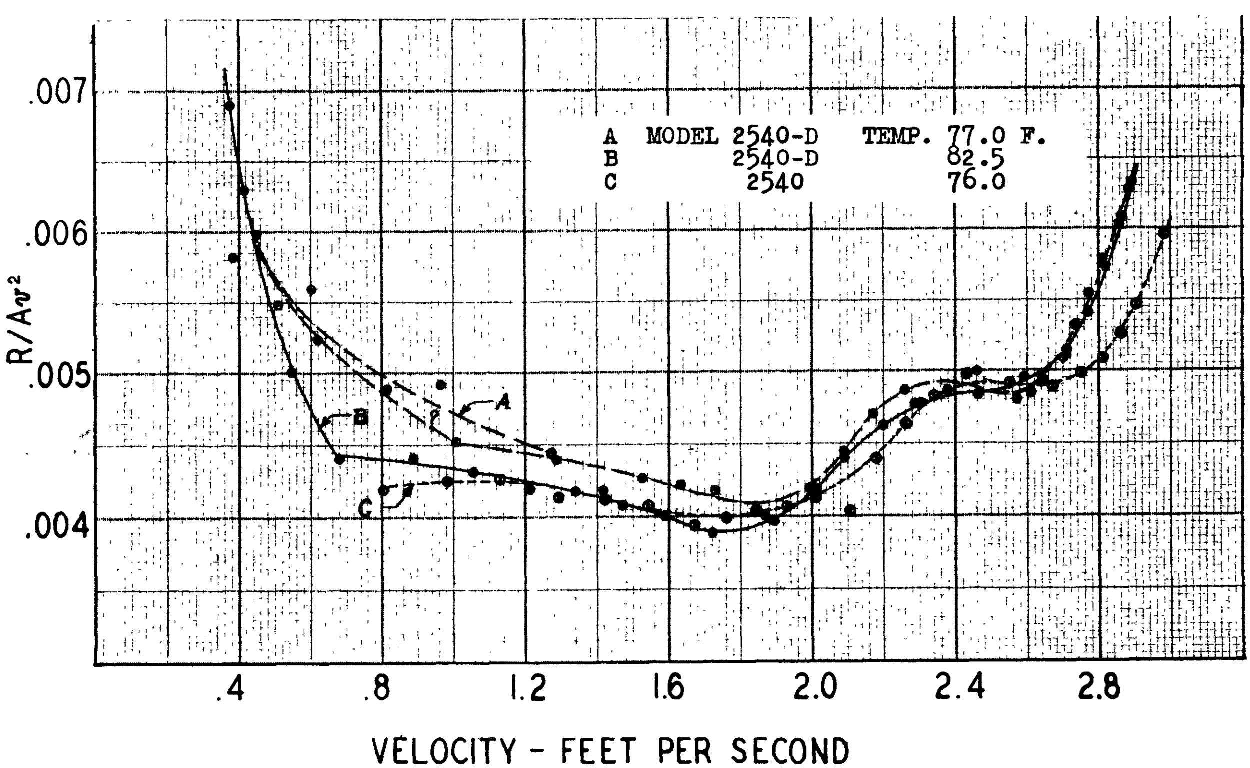


Fig. 2.

TABLE 2

| | | | | | | |
|---|---|---|---|---|---|---|
| Speed, ft./sec. | 0.3 | 0.4 | 0.6 | 1.0 | 1.5 | 2.0 |
| Max. Error*, per cent | 9.0 | 6.0 | 3.0 | 1.0 | 0.5 | 0.4 |

*Estimated accuracy of the dynamometer for the load-speeds of the two model considered.

## Test Results and Discussion

The numerical results of the two tests are given in Table 3. Figs. 1 and 2 show these data plotted on logarithmic and uniform scales. Table 4 gives data regarding model 2540.

The curves in Figs. 1 and 2 show clearly that the flow past the model 2540-D at speeds less than two feet per second is unstable. This is particularly true of the test run with the temperature at 77° F.

The plotted results of the second test with the temperature at 82.5° F. give a smooth curve throughout. The break at the velocity 0.68 ft. per sec. suggests rather definitely the change from laminar flow to mixed flow.

Other conditions being the same, turbulent flow develops greater frictional resistance than does laminar flow. From this it would appear that the test with the higher temperature should show a greater resistance than the one with the lower temperature. On the other hand, decreased temperature increases viscosity, density, and surface tension; and increases in each of these factors increase the resistance of the model. Apparently then at the lower speeds the increased resistance due to these latter factors more than outweighs that due to the former. Two other important factors in determining resistance at these low speeds are: (1) the degree of smoothness of the model surface and (2) the nature of the forward or entering edge of the model.

In view of the above and considering the general critical nature of this region of mixed flow no definite explanation can be offered for the lack of coincidence of the curves at the low speeds.

The humps of the two curves for the two different temperatures do not coincide. The flow in this region is naturally somewhat unstable, this even in the case of the 14 and 20-foot models. The difference of surface tension in the two cases is also partly responsible for this lack of coincidence. At speeds above this hump the curves coincide.

The corresponding resistances of the two models 2540-D and 2540 are of the same order of magnitude. The difference in the region of the hump is attributed to the different beam-draft ratios of the two models.

Model 2540 does not have the highly polished surface of 2540-D and this, in spite of the fact that it was run when the temperature was 76° F., is probably the reason that its plotted data show the same degree of mixed flow as do those for model 2540-D at the higher temperature.

The text of this report is not meant to be a complete analysis of the data. It is rather a brief description of the work done and of the results obtained; i.e., a few words of explanation to supplement the data as submitted to Prof. Davidson.

## Conclusion

The results show that ship models two feet or less in length have their useful range of speeds in a very critical region. To obtain consistent results particular attention must be given to the temperature of the water, surface tension as affected by the cleanness of the water's surface, the degree of smoothness of the model's surface, and the nature of the entering or leading edge of the model.

These factors are of such nature that their combined effects make ship models, of length two feet or less, impracticable for general test purposes. However, any careful study of this critical region is illuminating in regard to the transition from laminar to mixed flow and then to fully developed turbulent flow. For this reason and for the fact that scale effect is intimately tied up with the nature of the flow, work with these small models possesses real value.

Table 3

Data on Prof. K. Davidson's Model 2540-D

| Test No. 1 | | Temp. 77° F. | | Test No. 2 | | Temp. 82.5° F. | |
|---|---|---|---|---|---|---|---|
| No. | R, lb. | v,ft/sec | $R/Av^2$ | No. | R, lb. | v,ft/sec | $R/Av^2$ |
| 1 | 0.00062 | 0.382 | 0.00582 | 1 | 0.00037 | 0.168 | 0.01800 |
| 2 | 0.00080 | 0.417 | 0.00630 | 2 | 0.00072 | 0.378 | 0.00690 |
| 3 | 0.00088 | 0.449 | 0.00598 | 3 | 0.00110 | 0.549 | 0.00500 |
| 4 | 0.00104 | 0.510 | 0.00548 | 4 | 0.00150 | 0.682 | 0.00441 |
| 5 | 0.00148 | 0.601 | 0.00561 | 5 | 0.00254 | 0.888 | 0.00441 |
| 6 | 0.00147 | 0.620 | 0.00524 | 6 | 0.00352 | 1.056 | 0.00432 |
| 7 | 0.00238 | 0.817 | 0.00488 | 7 | 0.00450 | 1.213 | 0.00419 |
| 8 | 0.00335 | 0.966 | 0.00492 | 8 | 0.00547 | 1.340 | 0.00418 |
| 9 | 0.00334 | 1.006 | 0.00452 | 9 | 0.00644 | 1.470 | 0.00408 |
| 10 | 0.00529 | 1.276 | 0.00445 | 10 | 0.00742 | 1.594 | 0.00400 |
| 11 | 0.00529 | 1.284 | 0.00440 | 11 | 0.00840 | 1.721 | 0.00388 |
| 12 | 0.00626 | 1.420 | 0.00419 | 12 | 0.01036 | 1.895 | 0.00396 |
| 13 | 0.00724 | 1.524 | 0.00427 | 13 | 0.01235 | 2.010 | 0.00419 |
| 14 | 0.00724 | 1.526 | 0.00425 | 14 | 0.01433 | 2.10 | 0.00445 |
| 15 | 0.00822 | 1.636 | 0.00421 | 15 | 0.0163 | 2.20 | 0.00462 |
| 16 | 0.00920 | 1.736 | 0.00418 | 16 | 0.0183 | 2.29 | 0.00478 |
| 17 | 0.01018 | 1.870 | 0.00399 | 17 | 0.0183 | 2.30 | 0.00475 |
| 18 | 0.01217 | 1.995 | 0.00419 | 18 | 0.0213 | 2.46 | 0.00484 |
| 19 | 0.01416 | 2.088 | 0.00445 | 19 | 0.0242 | 2.59 | 0.00495 |
| 20 | 0.01615 | 2.170 | 0.00470 | 20 | 0.0272 | 2.71 | 0.00510 |
| 21 | 0.01813 | 2.260 | 0.00486 | 21 | 0.0302 | 2.77 | 0.00540 |
| 22 | 0.02011 | 2.380 | 0.00486 | 22 | 0.0332 | 2.82 | 0.00573 |
| 23 | 0.02210 | 2.462 | 0.00499 | 23 | 0.0362 | 2.86 | 0.00607 |
| 24 | 0.02309 | 2.570 | 0.00479 | 24 | 0.0382 | 2.88 | 0.00632 |
| 25 | 0.02408 | 2.610 | 0.00484 | | | | |
| 26 | 0.02508 | 2.640 | 0.00493 | | | | |
| 27 | 0.02707 | 2.700 | 0.00509 | | | | |
| 28 | 0.02907 | 2.735 | 0.00532 | | | | |
| 29 | 0.03106 | 2.770 | 0.00555 | | | | |
| 30 | 0.03306 | 2.810 | 0.00579 | | | | |
| 31 | 0.03605 | 2.860 | 0.00604 | | | | |
| 32 | 0.03804 | 2.880 | 0.00628 | | | | |

Where:

R is the tow-line resistance, lb.
v is the speed of model, ft./sec.
A is assumed wetted surface area (0.73 sq. ft.)

TABLE 4

Data on U.S.E.M.B. Model Number 2540

| No. | R, lb. | v, ft/sec | $R/Av^2$ |
|---|---|---|---|
| 1 | 0.0019 | 0.802 | 0.00418 |
| 2 | 0.0028 | 0.981 | 0.00425 |
| 3 | 0.0039 | 1.13 | 0.00428 |
| 4 | 0.0049 | 1.29 | 0.00414 |
| 5 | 0.0059 | 1.42 | 0.00411 |
| 6 | 0.0069 | 1.54 | 0.00407 |
| 7 | 0.0078 | 1.67 | 0.00393 |
| 8 | 0.0088 | 1.76 | 0.00400 |
| 9 | 0.0098 | 1.84 | 0.00404 |
| 10 | 0.0108 | 1.93 | 0.00407 |
| 11 | 0.0118 | 2.01 | 0.00411 |
| 12 | 0.0128 | 2.11 | 0.00404 |
| 13 | 0.0148 | 2.18 | 0.00439 |
| 14 | 0.0168 | 2.26 | 0.00463 |
| 15 | 0.0188 | 2.34 | 0.00484 |
| 16 | 0.0208 | 2.43 | 0.00498 |
| 17 | 0.0228 | 2.55 | 0.00491 |
| 18 | 0.0247 | 2.67 | 0.00488 |
| 19 | 0.0267 | 2.75 | 0.00498 |
| 20 | 0.0287 | 2.81 | 0.00509 |
| 21 | 0.0307 | 2.86 | 0.00526 |
| 22 | 0.0327 | 2.90 | 0.00547 |
| 23 | 0.0376 | 2.98 | 0.00596 |

Where:

R is the tow-line resistance, lb.

v is speed of model, ft./sec.

A is the wetted surface area (0.710 sq. ft.)

Temp. = 76 degrees F.