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No. 594

TANK TESTS OF TWO MODELS OF FLYING-BOAT HULLS TO DETERMINE THE EFFECT OF VENTILATING THE STEP

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SUMMARY

The results of tests made in the N.A.C.A. tank on two models of flying-boat hulls to determine the effect of ventilating the step are given graphically. The step of N.A.C.A. model 11-C was ventilated in several different ways and it was found that the resistance of the normal form is not appreciably affected by aftificial ventilation in any of the forms tried. Further tests made with the depth of the step of model 11-C reduced likewise show no appreciable effect on the resistance from ventilation of the step. Tests were made on a model of the hull of the Navy P3M-1 flying-boat hull both with and without ventilation of the step. It was found that the discontinuity which is obtained in the resistance curves of this model is eliminated by ventilating the step.

INTRODUCTION

The designers of early flying-boat hulls were often forced to provide means for "ventilating" the step in order to obtain reasonable performance on the water. With improvements in the design of hulls, however, this practice became unnecessary and has been practically abandoned. The construction is still revived occasionally, however, and designs incorporating ventilation of the step have been presented at the tank quite recently. The forced ventilation of the step is usually proposed by some one who has been in touch with small motorboat practice, where special means for ventilating the step are often provided.

The frequent citing of successful applications of artificial ventilation to motor boat hulls led the Bureau of Aeronautics of the Navy Department to request an investigation of the possibilities of improving the take-off performance of present flying-boat hulls by providing artificial means of ventilating the step. Because of the higher priority of other projects the tests were made as feasible between tests of other models and were scattered over a period of about two years.

THE MODEL

The first model chosen for these experiments was N.A.C.A. model 11-C. This model is not a scale model of any particular flying-boat hull but it is generally similar to many hulls in use in America. The lines of this model are given in reference 1, in which the results of a general tank test on it are reported.

The tests made with model 11-C showed that ventilation of the step had little effect on the resistance of the model. At the suggestion of the Bureau of Aeronautics, further tests were made on a model for which it had been found that under some conditions of loading a discontinuity would be obtained in the resistance curve at a speed slightly lower than the hump speed. The model chosen for these tests (N.A.C.A. model 18) is a 1/6-size model of the Navy P3M-1 flying-boat hull. The lines of this model are given in reference 2, in which the results of several specific tests on it are reported.

The several methods used for providing ventilation for the step in these tests are shown in figure 1. The following variations of N.A.C.A. models 11-C and 18 were tested.

Model 11-C-14: step ventilated by two tubes opening at the deck of the model.

Model 11-C-14 with scoops: the same as model 11-C-14 but with air scoops added on the deck to increase the amount of air flowing to the step.

Model 11-C-15: blower forcing air through a 1/16-inch slot in the full-depth step.

Model 11-C-16: the same as 11-C-15 but with a 1/4-inch slot in step.

Model 11-C-17: the same as 11-C-15 but with a 1/2-inch slot in step.

Model 11-C-18: normal depth of step ventilated from holes placed in bow of model (as requested by Bureau of Aeronautics).

Model 11-C-19: ventilated as 11-C-14 but depth of step reduced to 1/8 inch.

Model 11-C-20: ventilated as 11-C-18 but depth of step reduced to 1/8 inch.

Model 18: model 18 without ventilation.

Model 18-V: model 18 ventilated by two tubes opening at the deck of the model.

APPARATUS AND PROCEDURE

The N.A.C.A. tank and its carriage are described in reference 3. The towing gear used in the present tests was similar to the one described in reference 4.

The tests on the variations of model 11-C were made at constant speed, fixed trim, and constant load. Several loads were tested and most of the tests were made for a number of trims. All the tests were made over a sufficient speed range to determine the hump resistance. The possibility that the ventilation of the step might reduce the high-speed resistance was investigated by a few tests at high speeds.

The tests on model 18-V were made at constant speed and constant load but free to trim. This method was chosen because tests of this nature had just been made on model 18 in connection with another research problem, and the results showed marked discontinuities in the resistance curves. As the tests on model 18 had been made with load parameters corresponding to even load coefficients instead of even pounds, the data for models 18 and 18-V are presented nondimensionally. The nondimensional coefficients used are:

Resistance coefficient, $C_R = \frac{R}{wb^3}$

Load coefficient, $C_\Delta = \frac{\Delta}{wb^3}$

Speed coefficient, $C_V = \frac{V}{\sqrt{gb}}$

where V is speed

g, acceleration of gravity

b, maximum beam of hull

Δ, load on water

w, specific weight of water (w = 63.5 pounds per cubic foot for the water in the N.A.C.A. tank during these tests)

R, water resistance

RESULTS AND DISCUSSION

The results from the tests on model 11-C with the various types of ventilation are shown and are compared with the results obtained without ventilation of the step in figures 2 to 4. In these figures resistance is plotted against speed and the actual points obtained in the tests are shown.

The resistance of model 11-C is compared with that of models 11-C-18, 11-C-14, and 11-C-14 with scoops in figure 2. Although there are some sizable differences obtained at the heaviest loads for the 3° and 5° trims, no consistent differences due to ventilation are indicated.

The first results from the high-speed tests of these models seemed to show that ventilating the step produced a reduction in the resistance at high speed. It was later shown, as a result of tests made with the ventilating holes closed, that the reduction in resistance had been produced by other causes. The final results of the tests at high speeds showed that the resistance at high speeds was not reduced by ventilating the step. Because of the inconsistency between the data from the two sets of tests, the data for the high-speed resistance of this model are omitted.

The results obtained from forced ventilation of the step by means of a small blower are shown in figure 3.

These results are given for one trim angle only but a few points taken at several other trim angles show similar results. There appears to be no change in the hump resistance due to the air being forced out through the step.

The effect of ventilating a very shallow step (1/8-inch depth) is shown in figure 4. The results compared with those obtained with model 11-C-11 (reference 5), which is the same model without ventilation, show no change in resistance due to ventilation.

In connection with the present tests some measurements of the pressures obtained just aft of the step of model 11-C without ventilation were made by means of a U-tube manometer. It was found that at very low speeds negative pressures amounting to several inches of water are obtained but as soon as the chines "clean up" the negative pressures are reduced to the order of 1/2 inch of water and the pressures are reduced only slightly with further increase in speed.

The results obtained from the tests on model 18 are shown in figure 5. The curves from figure 5 are repeated in figure 6 without the test points. The test points on this figure were obtained from model 18-V and their departures from the curves show the effect of ventilation of the step.

Figure 6a clearly shows that ventilating the step has eliminated the discontinuous peak which occurs in the resistance curves of model 18 at a speed slightly lower than the hump speed. It will be noted that the curve for $C_\Delta = 0.2$ has no perceptible discontinuity and the ventilation did not affect this curve. Figure 6b shows that the trim is practically unaffected by the ventilation.

The discontinuity in the resistance curve referred to above has been encountered frequently in tests made at the N.A.C.A. tank. It occurs when the chines "clean up", i.e., the spray begins to break cleanly from the chines without wetting the sides of the model, and air begins to flow down the bottom just behind the step, thus bringing the pressure at the rear of the step nearly to atmospheric pressure. At speeds slightly less than the speed at which the discontinuity occurs there undoubtedly exist very appreciable negative pressures aft of the step. The magnitude of the discontinuity and the speed at which it occurs are functions of the loading condition and the form of the hull in the region of the step. If the form of the hull is such that with a given loading condition the chines can clean up at a comparatively low speed, i.e., the release of the negative pressures at the step is not delayed, the discontinuity usually does not appear or is of negligible magnitude.

It has been known for some time that this discontinuity in the resistance curve could be eliminated by ventilation. Tests made by the Navy Department in the Experimental Model Basin at Washington show results similar to those obtained in the present tests and the subject is given some discussion in reference 6. However, unless the peak of the discontinuity in the resistance curve approaches the value of the hump resistance very closely, its effect on the take-off performance will be very small.

Resistance curves in which the discontinuity peak equaled the hump resistance have been obtained at the N.A.C.A. tank in only a few cases. Model 18, under some loading conditions, has this characteristic, but even in this case it is questionable if it would have more than a very slight effect on the take-off characteristics because of the extremely short duration of the peak of the discontinuity and because of the additional thrust available at the lower speed as compared with the hump speed.

These considerations, along with the tendency of the hump resistance to become less and less important in recent designs, indicate that this discontinuity in the resistance curves may generally be ignored. In cases where it is found by tank tests that the discontinuity may cause trouble in taking off, it can be eliminated by any suitable method of providing relief for the negative pressure at the step. In a case of this nature it will probably be found that a slight alteration in the lines of the hull can achieve the desired result with less effect on the interior than would accompany the methods of ventilation used in these tests.

This discussion is based entirely on smooth water tests in the tank and the effect of rough water on the discontinuity is problematical.

It should be noted that the high peaks occurring in the resistance curves of hulls of the pointed-step type (as developed at the N.A.C.A. tank) are not analogous to the discontinuities discussed above.

CONCLUSIONS

The following conclusions are based upon the results of tests of two hulls and are strictly valid only for those hulls. It is believed, however, that the conclusions will hold quite generally.

1. If the resistance curve rises to a maximum before the true hump and, when the chines clean up, shows a sudden drop in the form of a discontinuity, the resistance at speeds below this maximum may be reduced and the discontinuity eliminated by providing ventilation of the step.

2. Unless the magnitude of the resistance just before the discontinuity equals or exceeds the resistance at the true hump the improvement in performance that may be obtained from eliminating the discontinuity by ventilating the step is relatively small.

3. When the peak of the discontinuity is greater than the true hump, ventilation may help, but slight alterations in the form of the hull will probably prove as successful in reducing the effect of the discontinuity to insignificance.

Langley Memorial Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., February 13, 1937.

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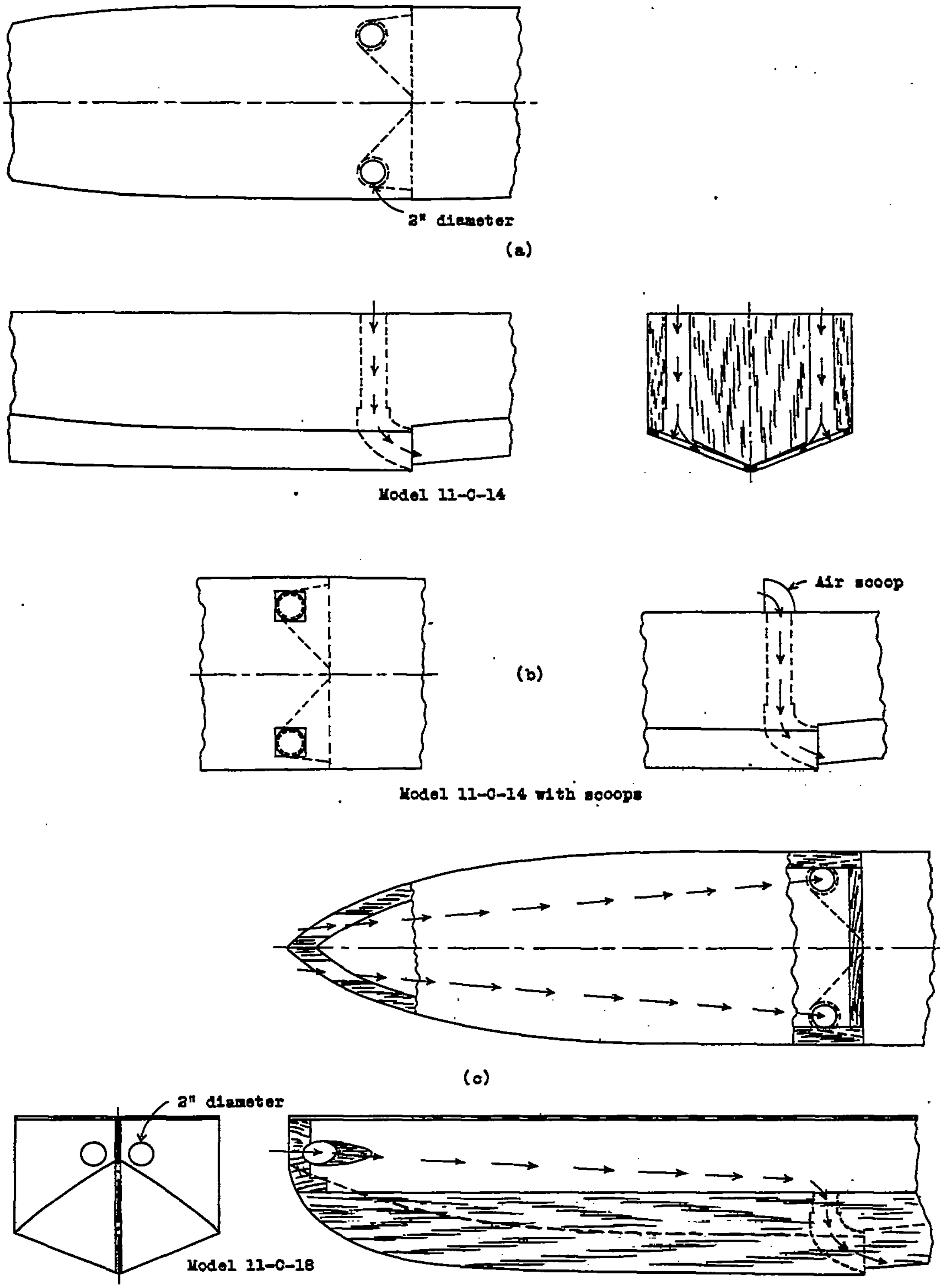
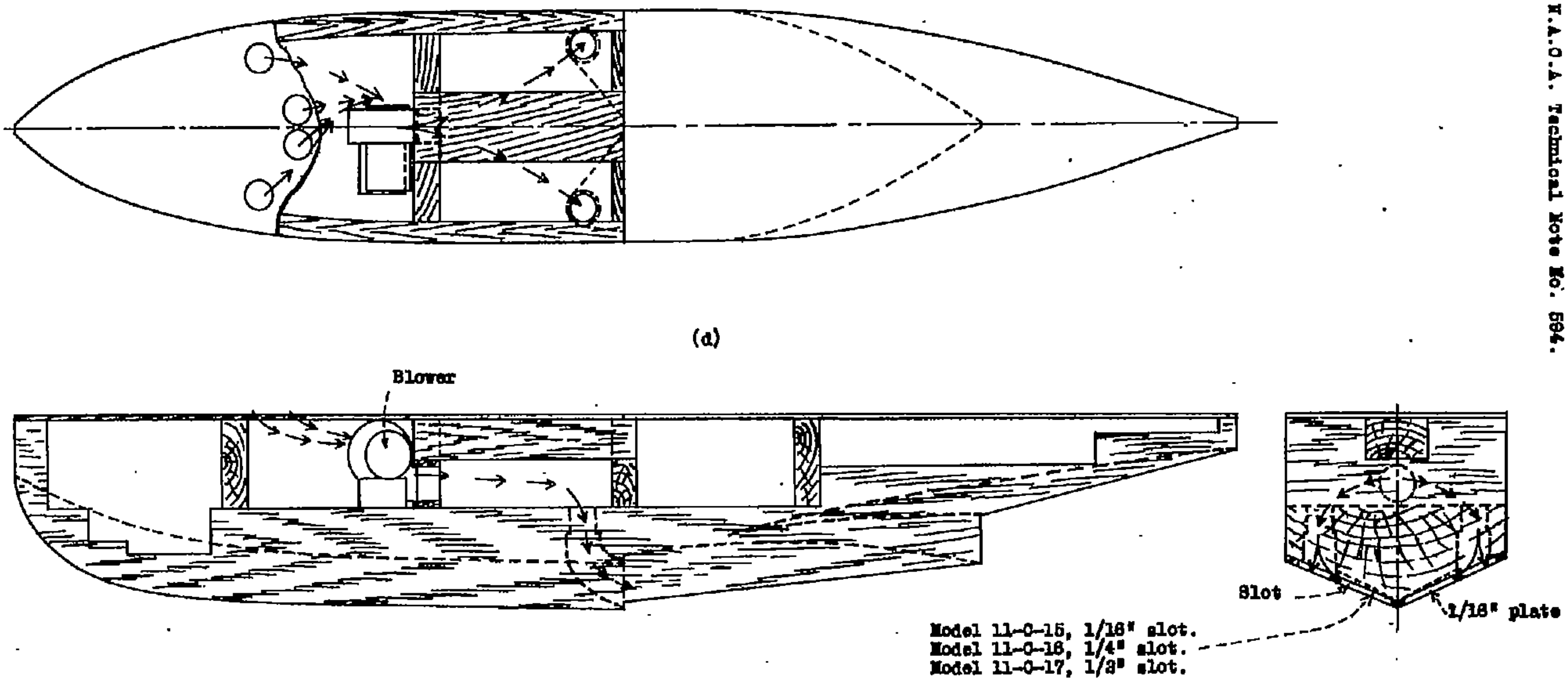
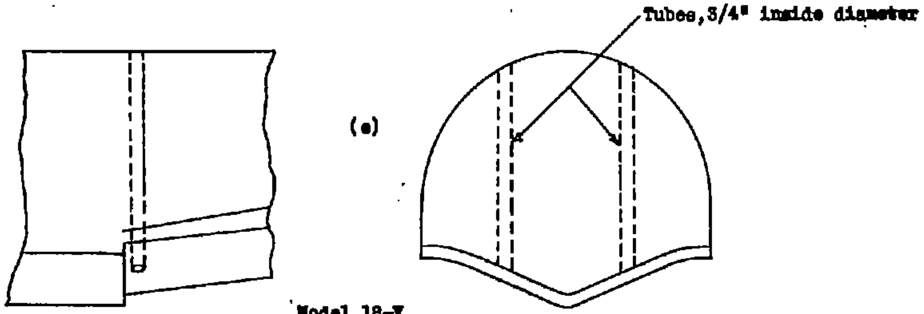


Figure 1.- Methods used in ventilating step.(Continued on following page)



(d)



(e)

Model 18-V
(Continuation of figure 1.)

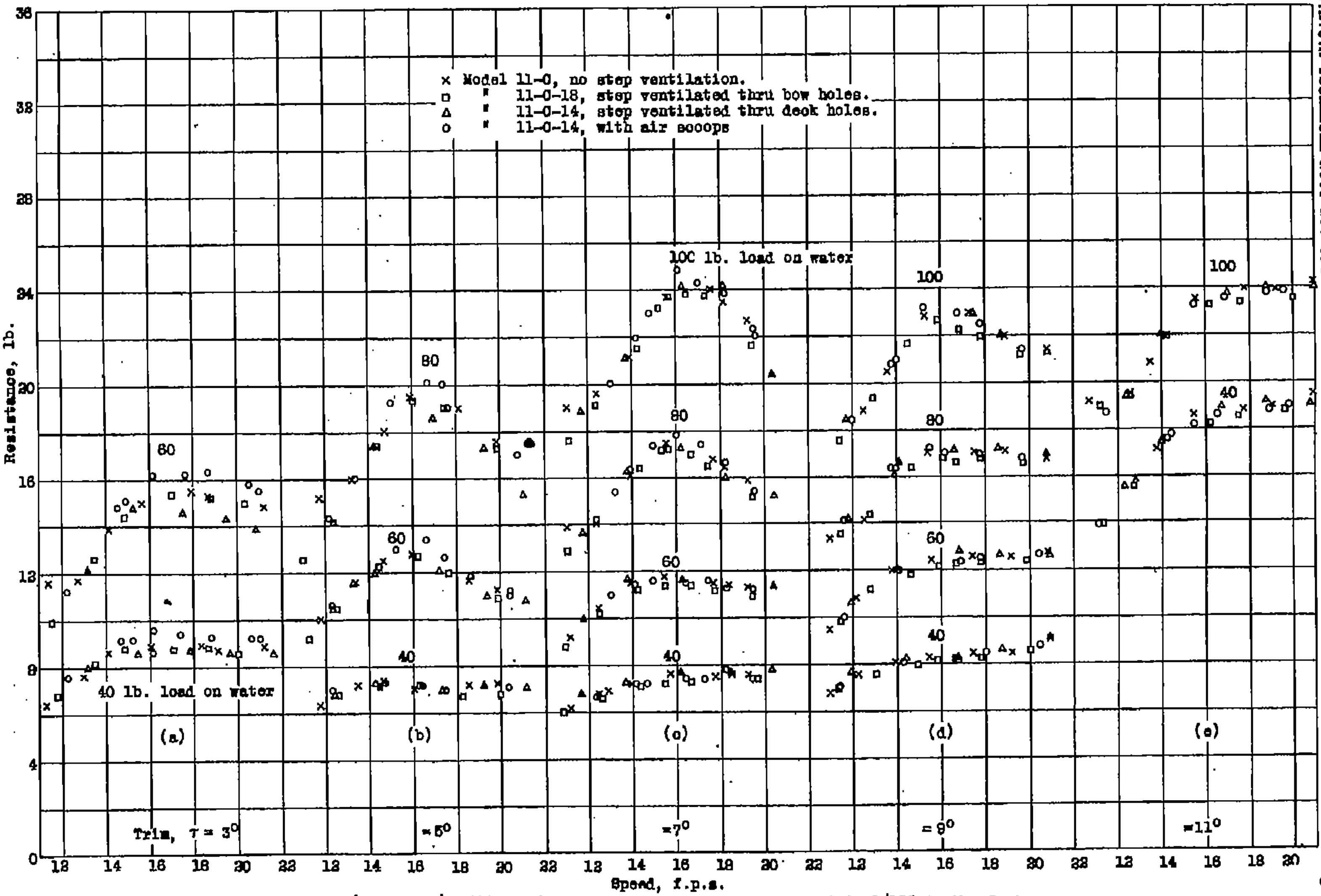


Figure 2 (a,b,c,d,e).-Effect of ventilating the step of model 11-0, 9/16" depth of step.

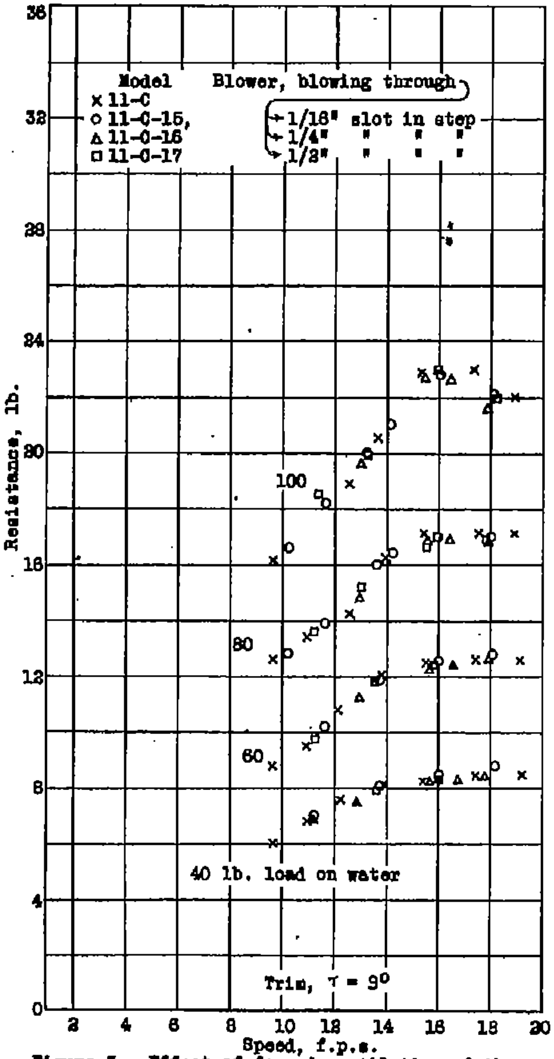


Figure 3.- Effect of forced ventilation of the step of model 11-C.

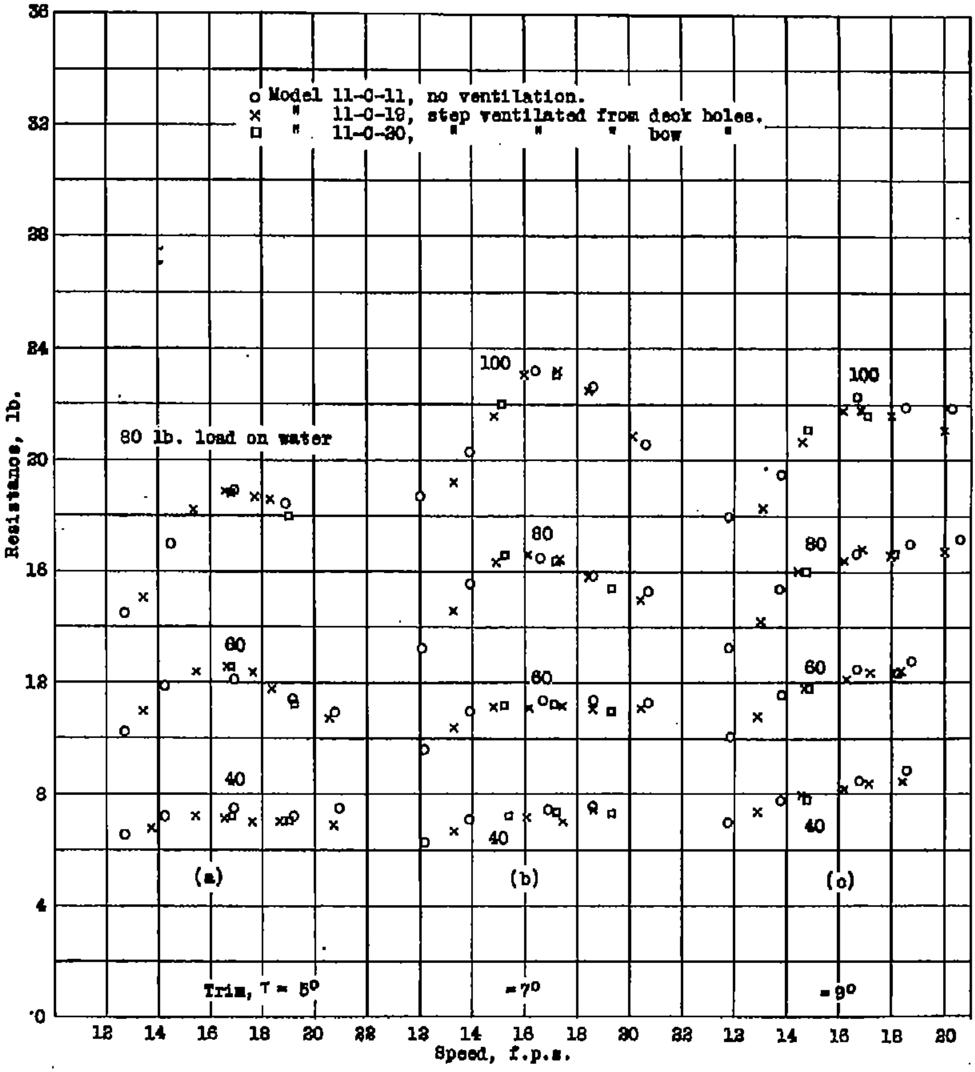


Figure 4.- Effect of ventilating the step of model 11-C-11, 1/8" depth of step.

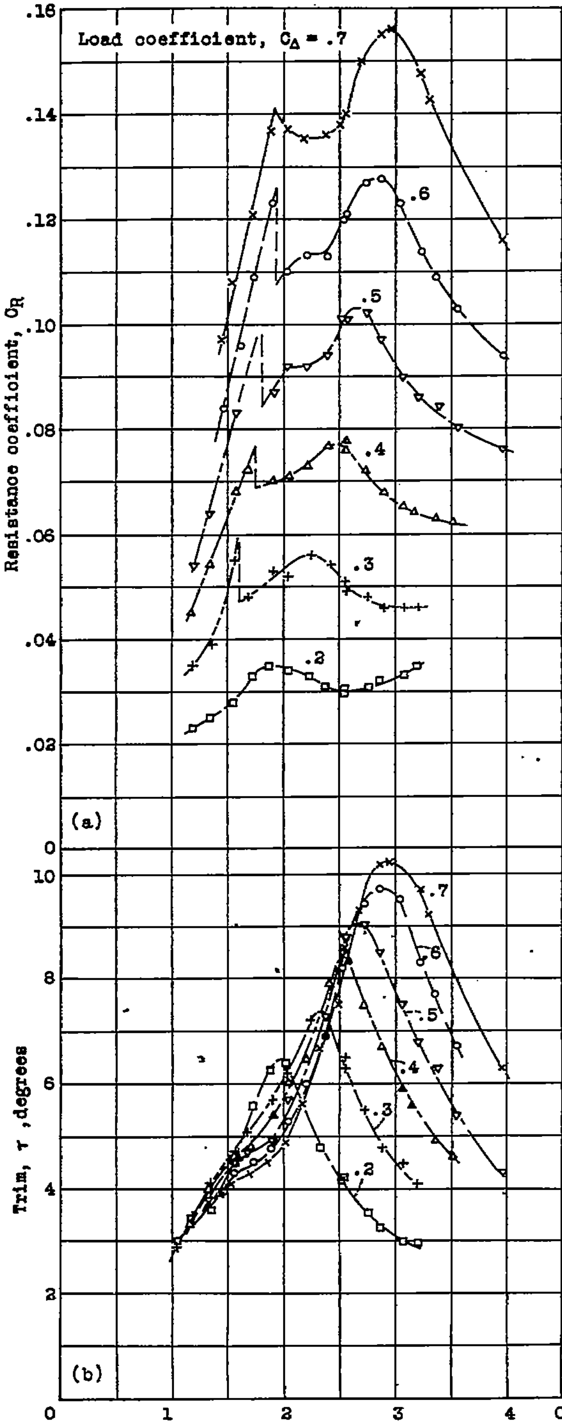


Figure 5.- Model 18. Resistance and trim, free to trim.

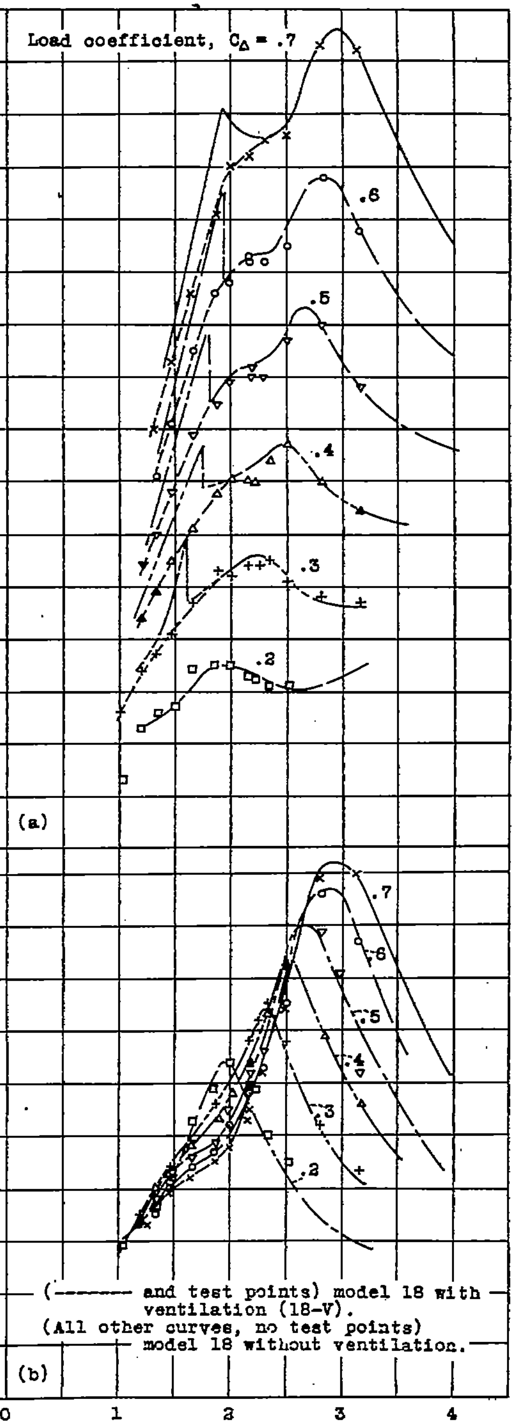


Figure 6.- Comparison of resistance and trim for models 18 and 18-V, free to trim.