NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

TECHNICAL NOTE

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AN INVESTIGATION OF EFFECTS OF REVERSED-TYPE LONGITUDINAL STEPS ON RESISTANCE AND SPRAY CHARACTERISTICS OF A FLYING-BOAT HULL

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Washington

July 1947

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SUMMARY

An investigation has been made of a flying-boat-hull model to determine the effects on the resistance and spray characteristics of reversed-type longitudinal steps designed so that the surfaces of the steps normal to the hull bottom face inboard, or toward the keel of the hull.

Results of the tests were compared with results of tests of a conventional flying-boat-hull model. At speeds near the hump speed, the reversed-type longitudinal steps effected no appreciable improvement in the resistance and spray characteristics of the hull, whereas at higher planing speeds they effected a small improvement in the resistance and an appreciable reduction in the height of the spray by decreasing the lateral flow of the spray and directing it aft. This reduction in spray would be advantageous if wetting of the tail extension and horizontal tail at high speeds were objectionable. In any practical application, the improvements in resistance and spray characteristics could be obtained with reversed-type longitudinal steps extending about one beam forward of the transverse step.

INTRODUCTION

Numerous forms and arrangements of longitudinal steps have been tested in the past (references 1 to 3) with the object of improving the resistance and spray characteristics of flying-boat hulls and seaplane floats. In several cases, longitudinal steps have been successfully applied to full-scale flying-boat hulls (references 4 and 5). In all instances mentioned the form of the longitudinal steps was such that the surfaces of the steps normal to the bottom of the hull faced outboard, or away from the keel of the hull.

Longitudinal steps of the reversed type so constructed that the surfaces of the steps normal to the bottom of the hull face inboard, or toward the keel of the hull, are the subject of the present investigation. Longitudinal steps of this reversed form have been applied with some success to the bottoms of lap-strake high-speed motorboats. This application indicated that there might be advantages in applying them to seaplane and flying-boat hulls. The dimensions and locations of the reversed-type longitudinal steps used in this investigation were supplied by Mr. William J. Snadecki and were based on the results of his experience with lap-strake speed boats of the Pigeon-Snadecki design.

In order to determine the effects of the reversed-type longitudinal steps on the resistance and spray of flying boats, the steps were applied to the forebody of a model of the hull of a conventional flying boat. Tests were made of the model with the conventional bottom and with the modified bottom incorporating the longitudinal steps, and a comparison is made of the resistance and spray characteristics of the two configurations.

SYMBOLS

C_Δ	load coefficient $\left(\frac{\Delta}{wb^3}\right)$
C_R	resistance coefficient $\left(\frac{R}{wb^3}\right)$
C_V	speed coefficient $\left(\frac{V}{\sqrt{gb}}\right)$
C_M	trimming-moment coefficient $\left(\frac{M}{wb^4}\right)$
Δ	load on water, pounds
w	specific weight of water, pounds per cubic foot (63.4 for these tests, usually taken as 64 for sea water)
b	beam of hull, feet
R	resistance, pounds
V	speed, feet per second
g	acceleration of gravity, 32.2 feet per second per second

M trimming moment, pound-feet (tail-heavy moments are considered positive)

τ trim; angle between forebody keel at step and horizontal

MODELS

The parent form selected for these tests was Langley tank model 120-R, which is a $\frac{1}{8}$-size model of the hull of a conventional flying boat. The principal dimensions of the hull and the location of the center of moments used in these tests are given in table I. The modified model, which was designated Langley tank model 204, is shown in the photographs of figure 1. Model 204 was constructed by cutting the reversed-type longitudinal steps into the forebody of model 120-R. The form and arrangement of the longitudinal steps are shown in figure 2. The faces of the steps were cut normal to the bottom of the parent form to a constant depth of 5/32 inch (1 percent beam). The steps were decreased in depth at the forward ends in order to fair them into the keel. The distance between the steps was 1.4 inches (approximately 10 percent beam) at the transverse step and was continuously decreased forward of the transverse step.

APPARATUS AND PROCEDURE

The models were tested in Langley tank no. 1, which is described in reference 6. The water in the tank was at the 12-foot level during the tests.

The tests were made by the general method described in reference 6. The models were tested in both the fixed-trim and free-to-trim conditions. For the free-to-trim tests the models were pivoted about the center of gravity, which was located 14.50 inches above the keel and 6.93 inches forward of the transverse step. A wide enough range of fixed trims was tested to determine the minimum resistance characteristics of model 204. The air drag of the towing gear was subtracted from the measured resistance. The air drag of the models is included in the resistance values presented.

Spray photographs of the models were taken at low speeds with the models free to trim and at high speeds with the models fixed in trim. The direction of the flow of water over the bottom of the forebody was also determined. For these tests the bottom of the forebody was coated with a thin film of linseed oil, and spots of a mixture of lampblack and linseed oil were applied in a regular pattern. The model was then lowered into the water at predetermined conditions of speed, load, and trim, for the length of time necessary to streak the lampblack. The flow pattern as determined by the lampblack streaks was photographed.

RESULTS AND DISCUSSION

The free-to-trim characteristics of the model with longitudinal steps (model 204) are presented in figure 3. The trim and resistance at the hump speed with model 204 free to trim was approximately the same as that obtained for the model without the longitudinal steps (model 120-R). The load-resistance ratio Δ/R at the hump was approximately 4.0, which is an average value for conventional flying boats.

For the model with longitudinal steps, best trim, resistance at best trim, and trimming-moment at best trim are plotted against speed in figure 4. The trim for minimum resistance occurred at the hump speed at approximately 9° and at high speed at approximately 5°. These values of trim are approximately the same as those obtained for the model without the longitudinal steps.

A comparison of the resistance for the model with and without longitudinal steps is given in figures 5(a) and 5(b) for fixed trims of 9° at hump speed and 5° at high speed. At speeds near the hump the longitudinal steps had no appreciable effect on the resistance. At high speeds, however, the resistance was decreased when longitudinal steps were used.

Spray photographs of the models, taken at points approximately along the unloading curve of a flying boat having a gross load coefficient of 0.94 and a speed coefficient at get-away of 7.5, are presented in figures 6 and 7. The photographs of figure 6 were taken with the models free to trim and the photographs of figure 7 with the models at 7° fixed trim. It can be seen from figures 6(a) and 6(b) that at low speeds the only effect of the longitudinal steps was to break up slightly the forward part of the bow blister. The height of the main spray blister in the region of the propellers, however, was not appreciably changed. From figures 6(c) and 6(d), it can be seen that for speeds in the region of the hump the light loose water at the forward boundary of the spray from the model without longitudinal steps was eliminated by the longitudinal steps. The photographs of figure 7 show that at high speeds an appreciable reduction in the height of the spray around the tail extension was effected by the application of the longitudinal steps. This reduction in spray would be advantageous if wetting of the tail extension and horizontal tail was objectionable.

The manner in which the longitudinal steps reduced the high-speed spray is illustrated by the drawings of figure 8, which represent the flow patterns obtained for the two models for a typical high-speed condition. At high speeds the longitudinal steps reduced the lateral flow of the spray and directed it aft. The forebody area wetted by the spray was thereby reduced. If would appear, then, that the reversed-type longitudinal steps effected a reduction in resistance and spray only at the higher planing speeds. These improvements in resistance and spray characteristics, therefore, could be obtained with the application of reversed-type longitudinal steps extending about one beam forward of the transverse step.

CONCLUDING REMARKS

Application of reversed-type longitudinal steps to the forebody of a model of a conventional flying-boat hull effected no appreciable improvement in the resistance or spray characteristics near the hump speed. At the higher planing speeds, the reversed-type longitudinal steps effected a small improvement in the resistance of the hull and an appreciable reduction in the height of the spray by decreasing the lateral flow of the spray and directing it aft. This reduction in spray would be advantageous if wetting of the tail extension and horizontal tail was objectionable. Since favorable results were obtained only at high speeds, in any practical application the extent of the reversed-type longitudinal steps need be only about one beam forward of the transverse step.

Langley Memorial Aeronautical Laboratory
National Advisory Committee for Aeronautics
Langley Field, Va., May 19, 1947

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3. Allison, John M., and Ward, Kenneth E.: Tank Tests of Models of Flying Boat Hulls Having Longitudinal Steps. NACA TN No. 574, 1936.

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5. King, H. F.: The Dornier Flying Boats. Flight, vol. XXXVI, no. 1611, Nov. 9, 1939, pp. 372a-372d.

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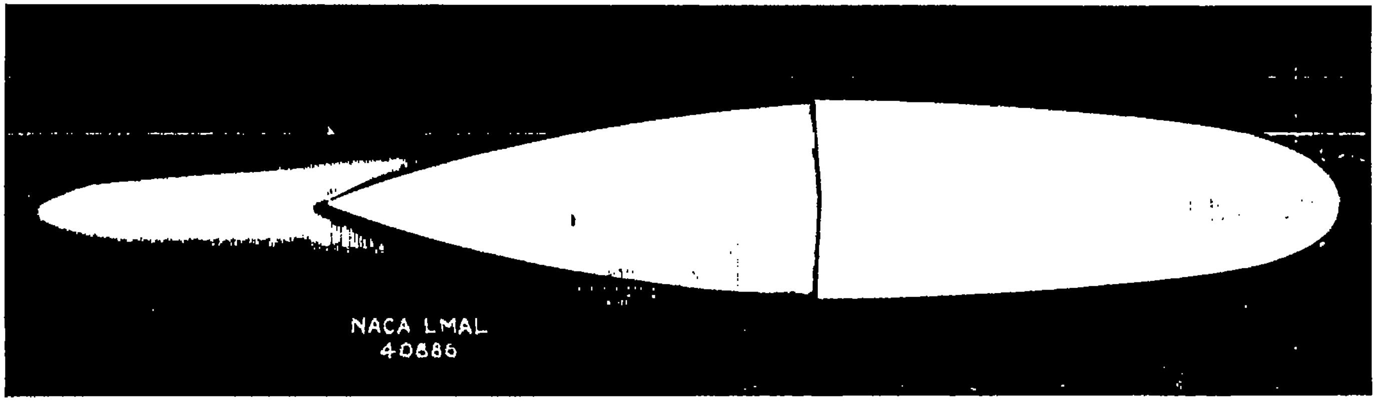
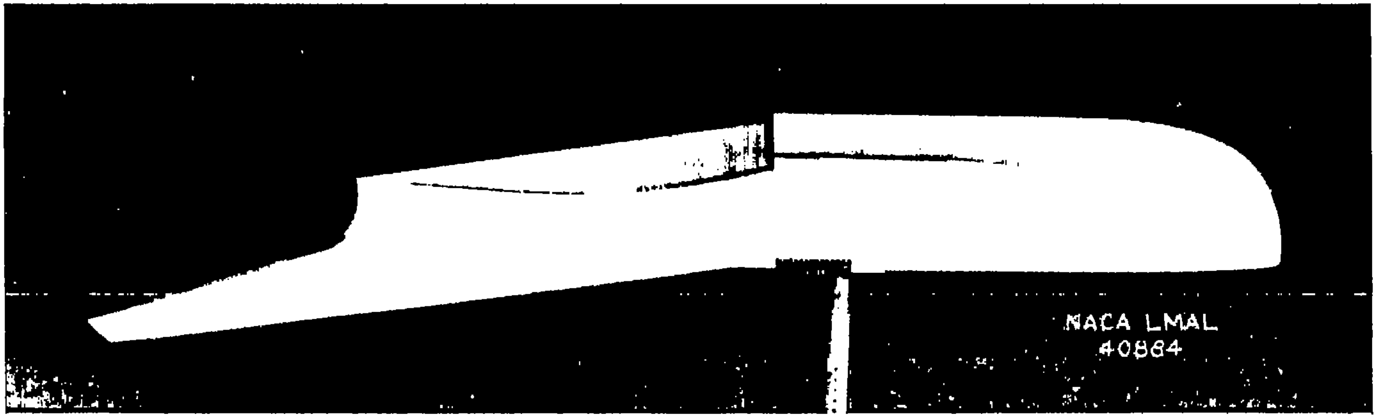
TABLE I

PRINCIPAL DIMENSIONS OF LANGLEY TANK MODELS 120-R AND 204

Dimension	Model 120-R	Model 204
Distance center of moments forward of step, in.	6.93	6.93
Distance center of moments above keel, in.	14.50	14.50
Length over all, in.	120.04	120.04
Beam, in.	15.00	15.00
Depth of step, in.	.73	.73
Length of forebody, in.	50.31	50.31
Length of afterbody, in.	41.10	41.10
Length of tail extension, in.	28.63	28.63
Angle of dead rise (measured to chine), deg	17	17
Depth of longitudinal steps, in.	-----------	5/32
Distance between longitudinal steps at transverse step, in.	-----------	1.4



(a) Plan form.



(b) Profile.

Figure 1.- Plan-form and profile views of model 204.

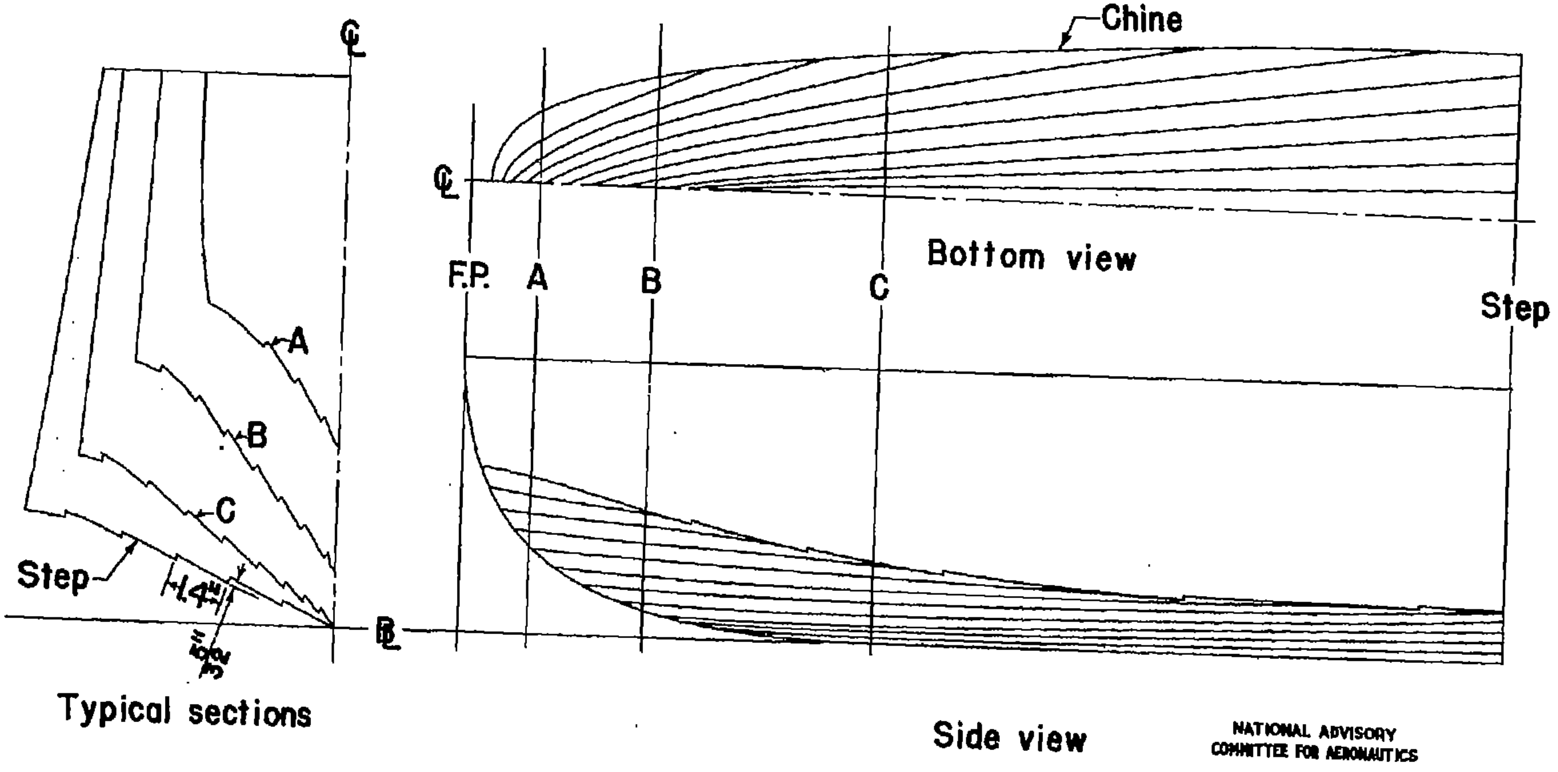


Figure 2.- Longitudinal steps on forebody of model 204.

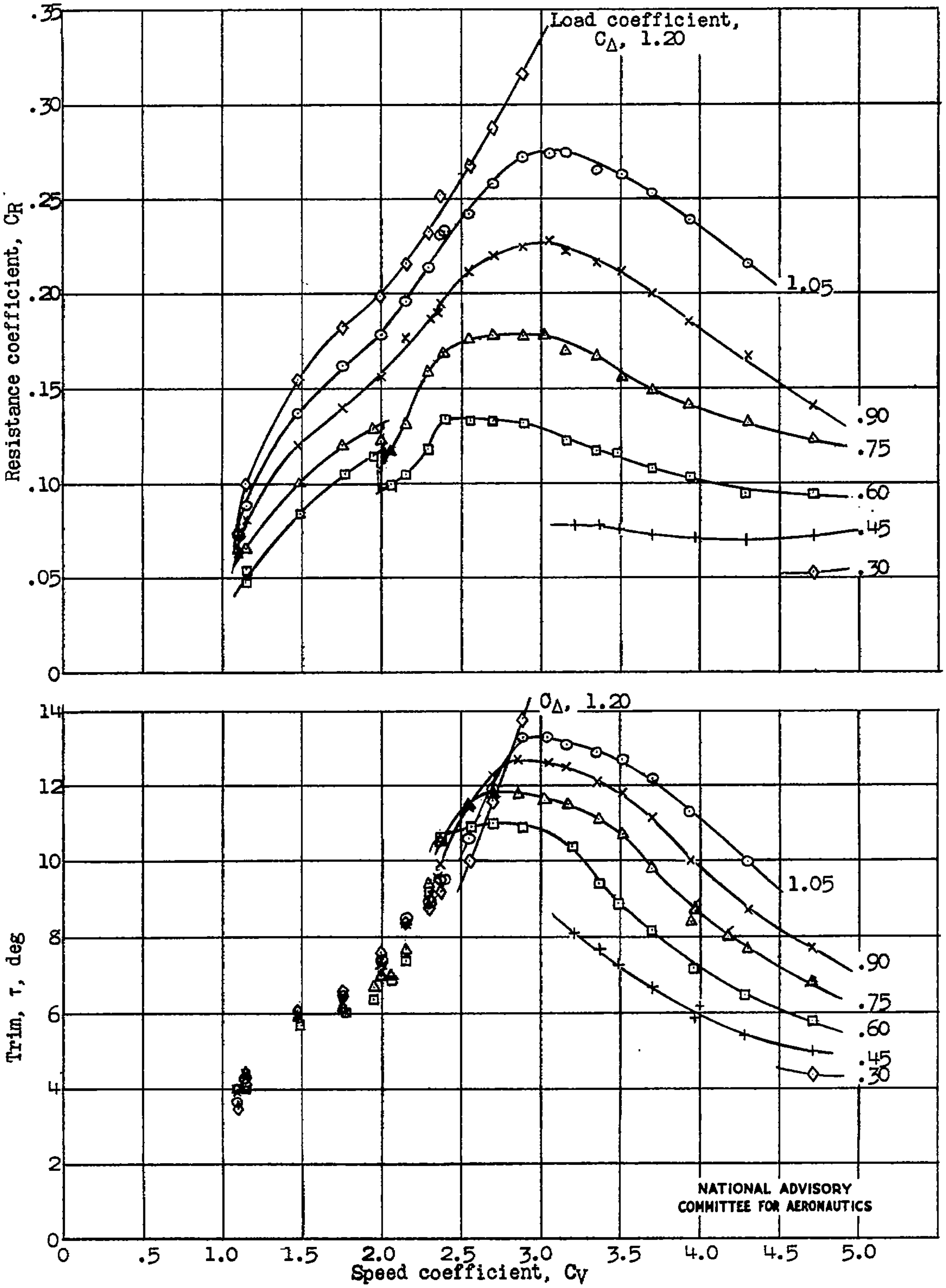


Figure 3.- Model 204. Variation of resistance and trim with speed, free to trim.

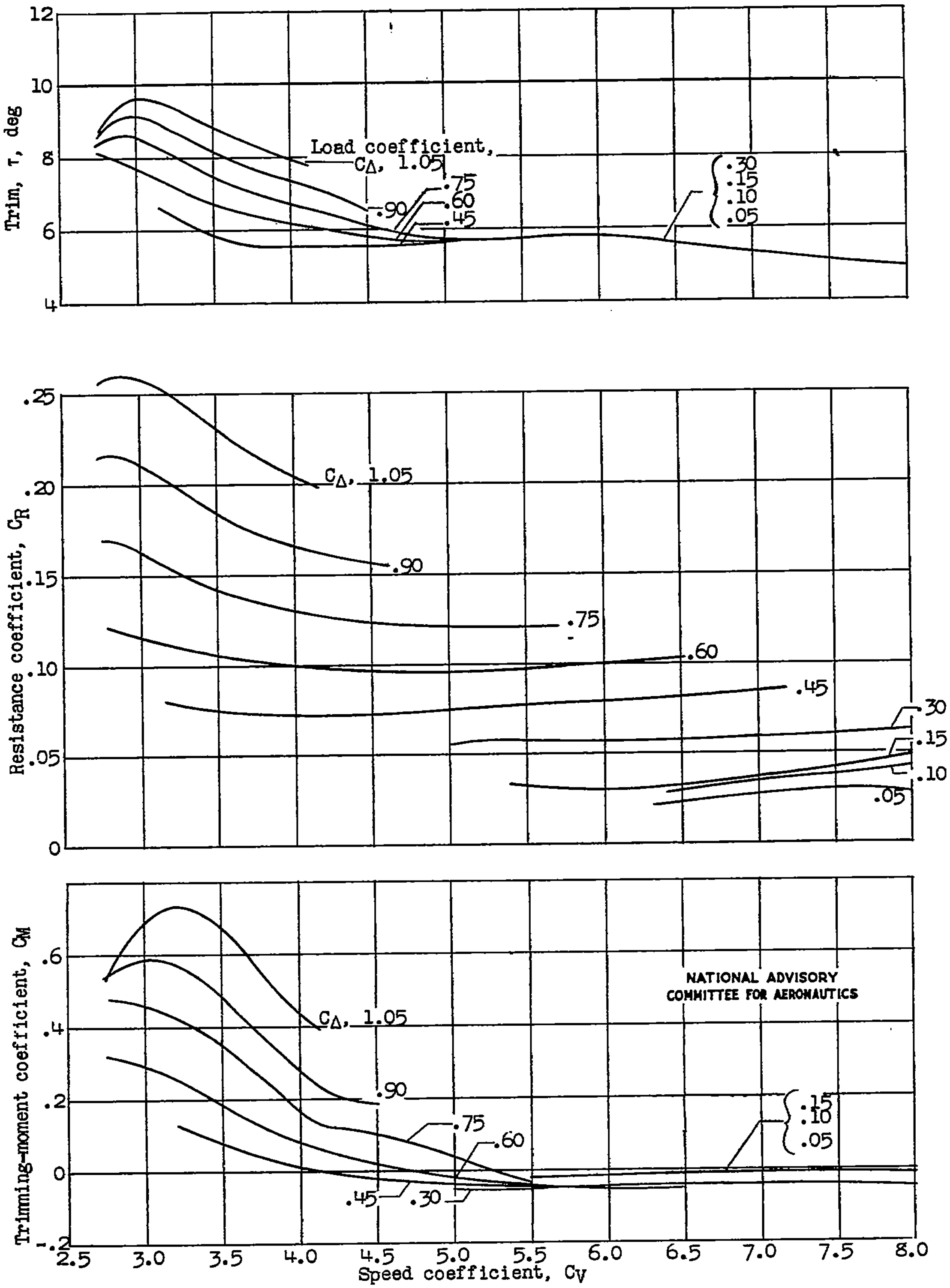
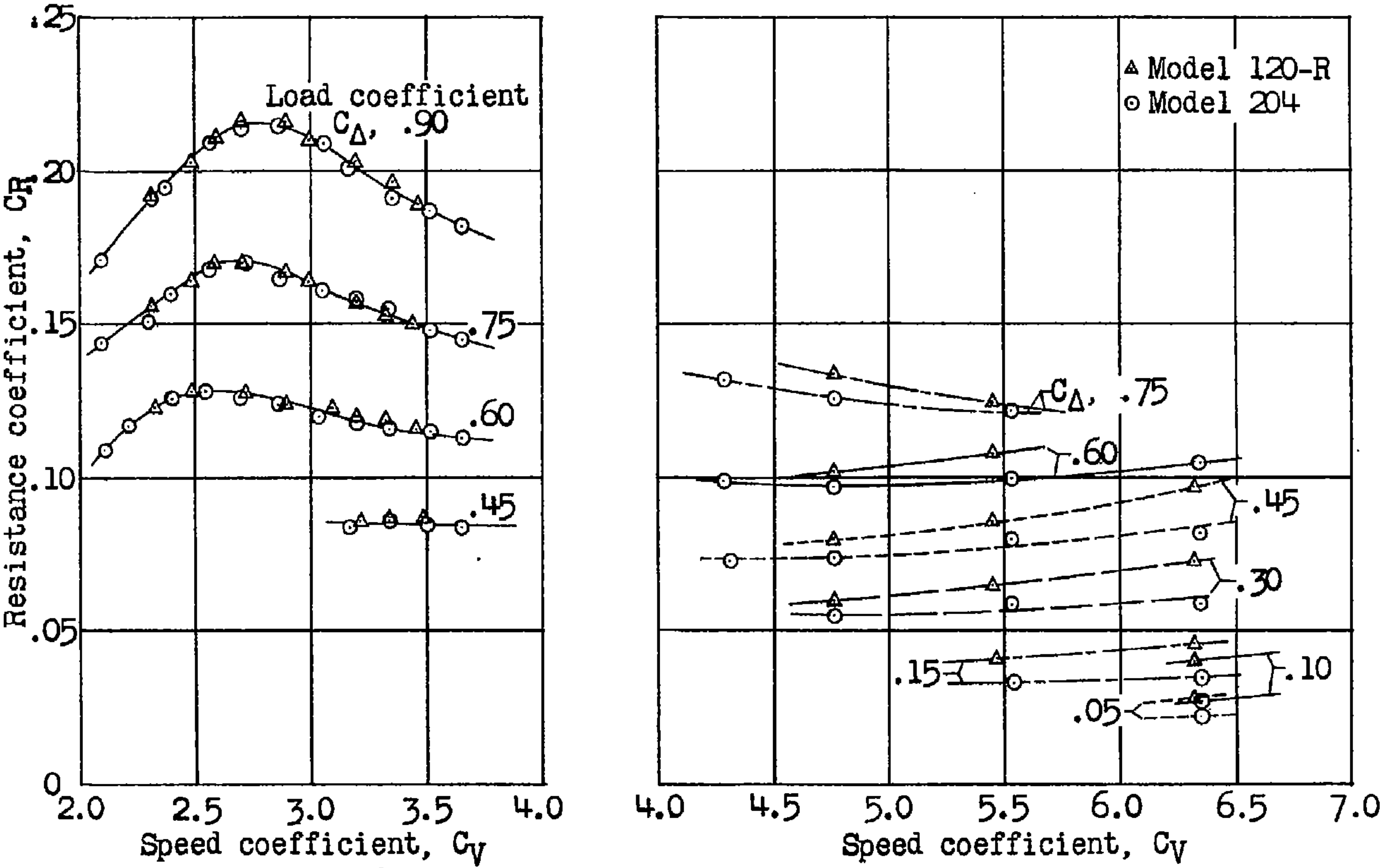


Figure 4.- Model 204. Variation of best trim, resistance at best trim, and trimming moment at best trim with speed.



(a) τ, 9°.

(b) τ, 5°.

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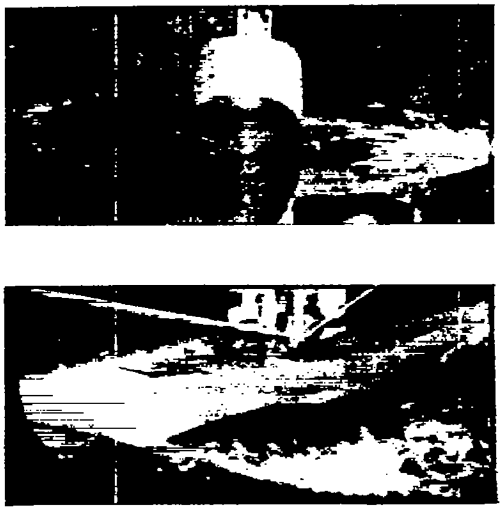
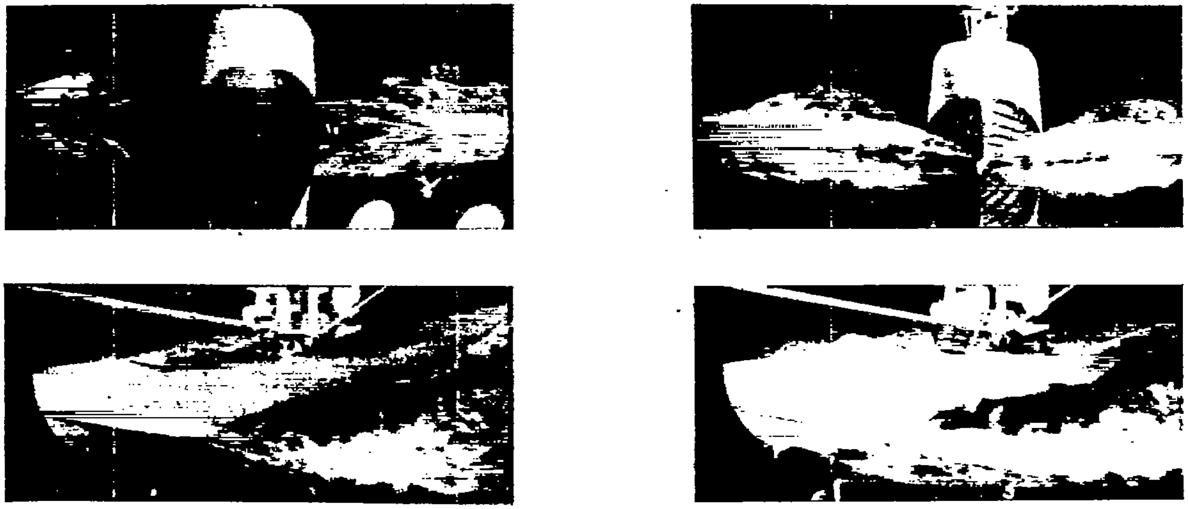
Figure 5.- Models 120-R and 204. Comparison of variation of resistance with speed.



Model 120-R; τ, 6.3° Model 204; τ, 6.1°

(a) C_V, 1.58; C_Δ, 0.90.



Model 120-R; τ, 7.5° Model 204; τ, 7.2°

(b) C_V, 1.97; C_Δ, 0.90.

Figure 6.- Models 120-R and 204. Spray photographs, free to trim.

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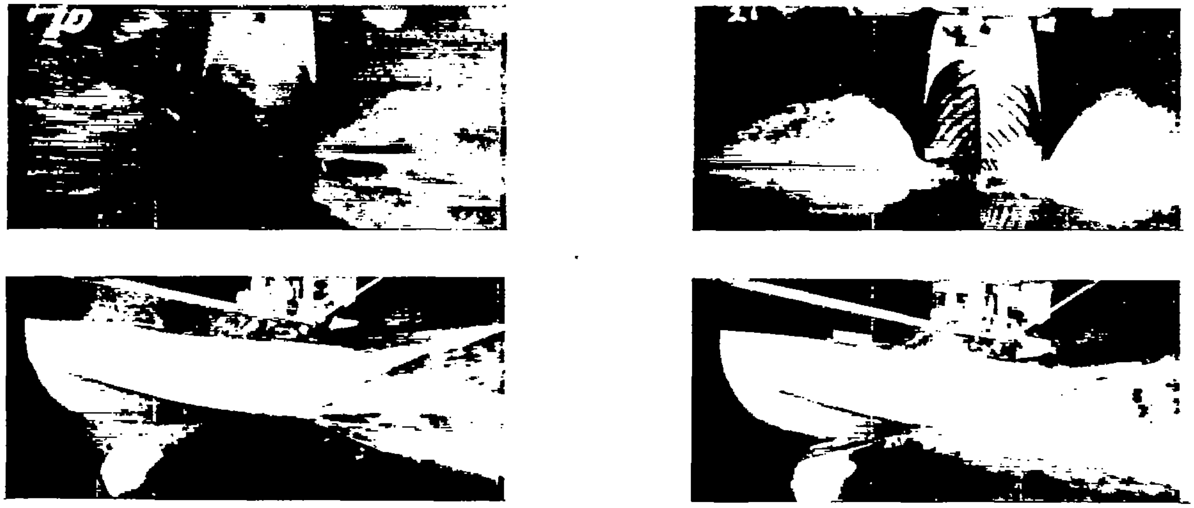
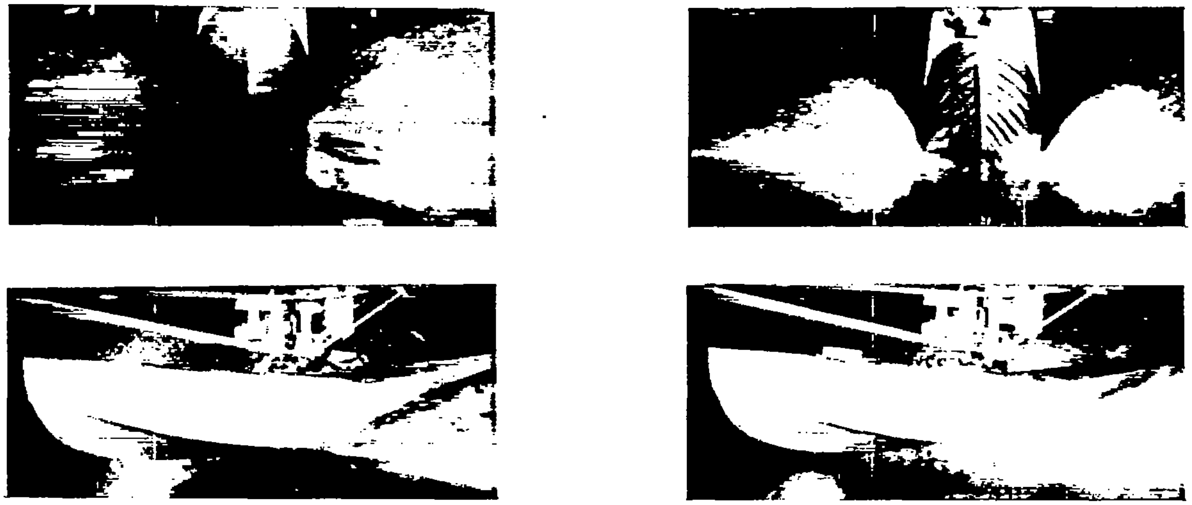


Model 120-R; τ, 11.9° Model 204; τ, 11.9°

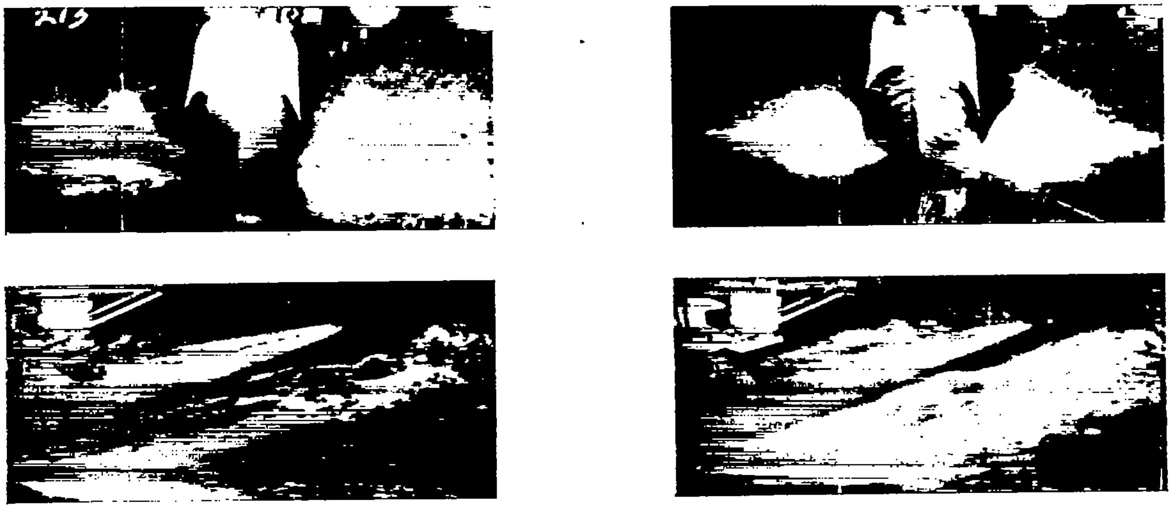
(c) C_V, 2.75; C_Δ, 0.75.



Model 120-R; τ, 11.7° Model 204; τ, 11.5°

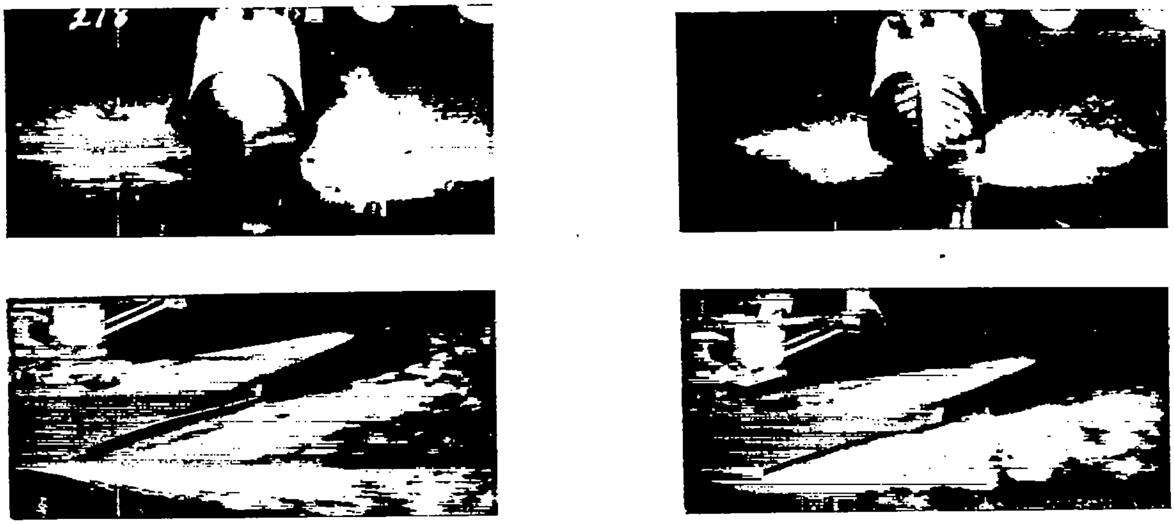
(d) C_V, 3.18; C_Δ, 0.75.

Figure 6.- Concluded.



Model 120-R Model 204

(a) C_V, 3.95; C_Δ, 0.75.



Model 120-R Model 204

(b) C_V, 4.74; C_Δ, 0.60.

Figure 7.- Models 120-R and 204. Spray photographs, 7° fixed trim.

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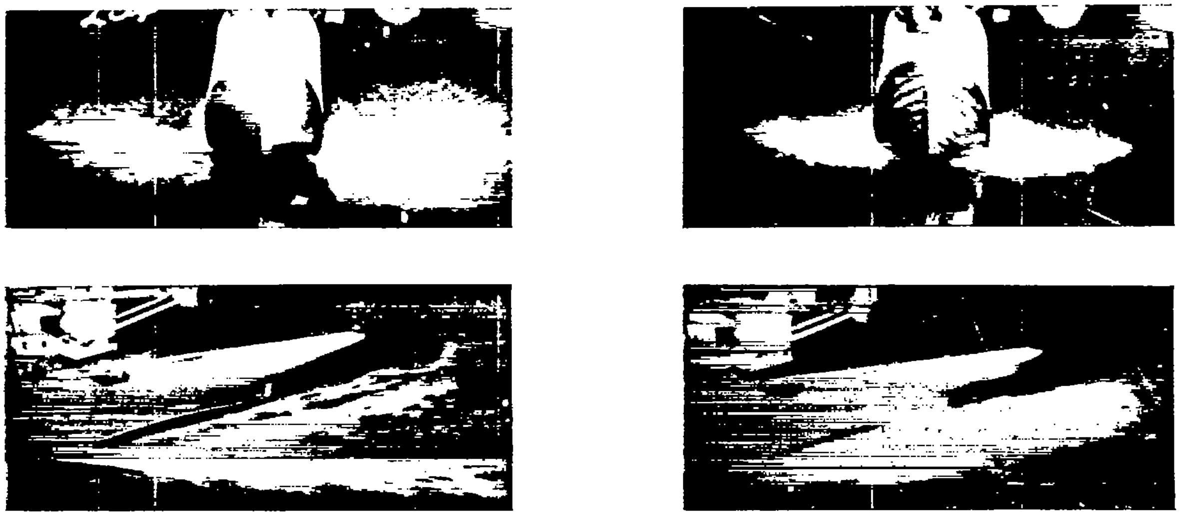
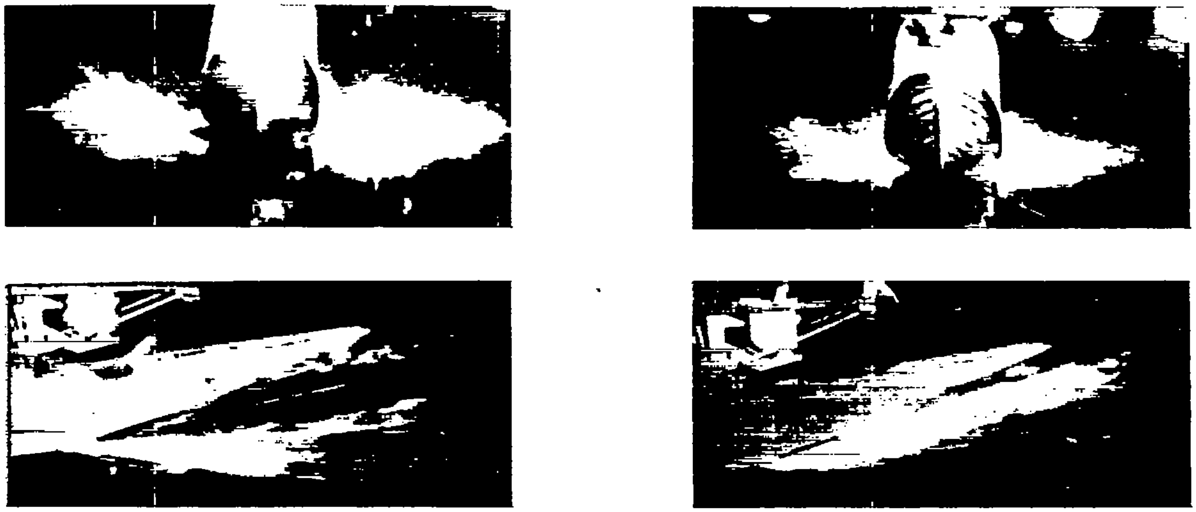


Model 120-R Model 204

(c) C_V, 5.53; C_Δ, 0.45.



Model 120-R Model 204

(d) C_V, 6.32; C_Δ, 0.30.

Figure 7.- Concluded.

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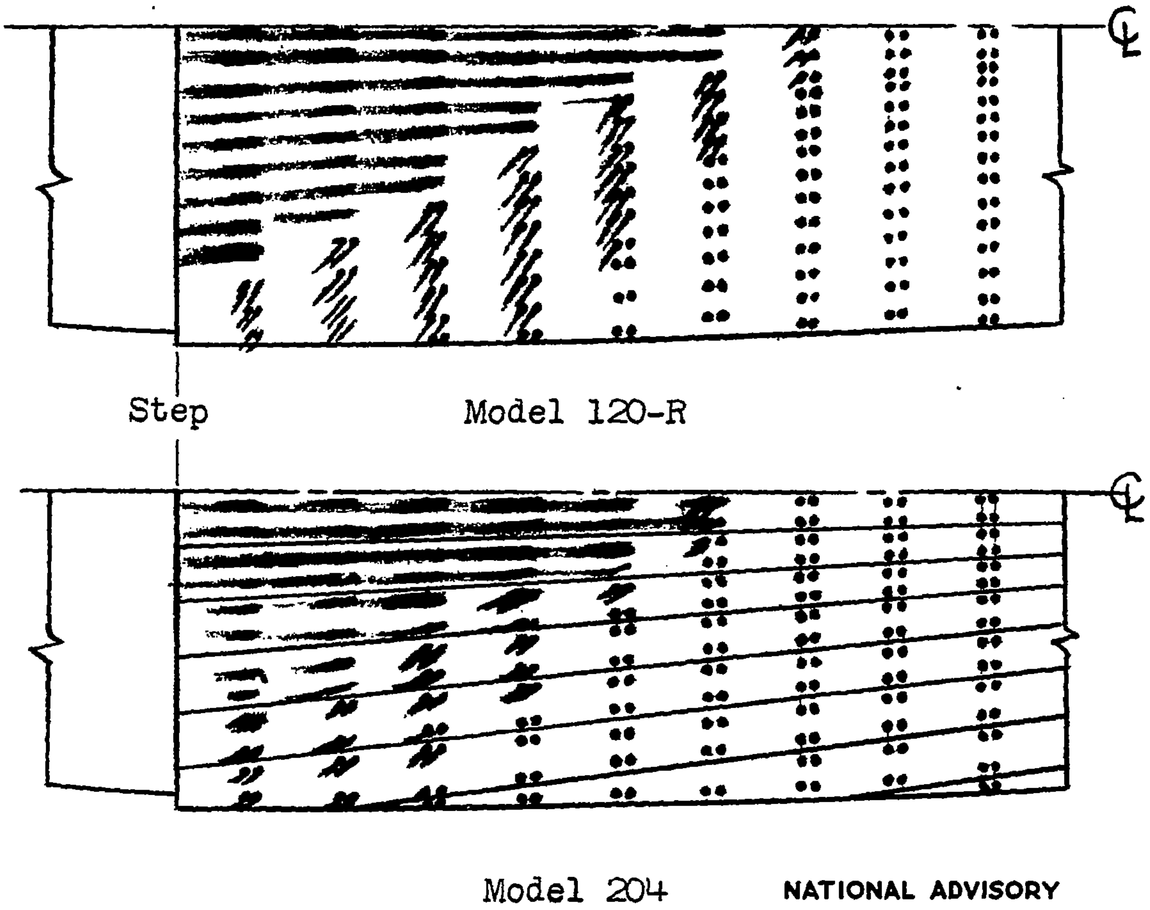

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Figure 8.- Models 120-R and 204. Flow patterns on forebody bottoms. C_V, 4.75; C_Δ, 0.35; τ, 6.0°.