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SPRAY CHARACTERISTICS OF A POWERED DYNAMIC MODEL OF A FLYING BOAT HAVING A HULL WITH A LENGTH-BEAM RATIO OF 9.0

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SUMMARY

An investigation of the spray characteristics of a $\frac{1}{10}$-size powered dynamic model of a twin-engine flying boat was made in Langley tank no. 1. The design was similar to that of the Boeing XPBB-1 flying boat, but the length-beam ratio of the hull was increased from 6.3 to 9.0 while constant length^2-beam product and height of hull were maintained. The hull frontal area was reduced approximately 23 percent and the volume was reduced approximately 11 percent by this increase in length-beam ratio.

At the same gross load, the spray characteristics of the model with a length-beam ratio of 9.0 compared favorably with those of the model of the XPBB-1 flying boat and no adverse effects on the spray characteristics were introduced by the higher length-beam ratio and smaller hull.

INTRODUCTION

In order to select the over-all proportions for a flying-boat hull, the designer should know the manner in which the hydrodynamic characteristics vary with the length-beam ratio and with the relationship of gross load to the absolute values of length and beam.

A few of the effects of length-beam ratio have been investigated in tests of series of hull models (references 1 to 4). The data given in references 1 and 4 are concerned principally with resistance and spray characteristics. Curves of yawing moment and trim limits of stability are included in reference 2 and the aerodynamic drag of hulls of several length-beam ratios is included in reference 3. An analysis of the results of resistance tests of several model investigations is reported in reference 4.

Analysis of the available data has shown that increasing the length-beam ratio of a hull to relatively high values results in favorable effects on resistance and spray characteristics when the length-beam product of the hull is held constant. It has also been shown (references 4 and 5) that the hydrodynamic resistance and spray characteristics are not changed appreciably by variations of length-beam ratio when length^2-beam product is held constant. When the length-beam ratio is increased while length^2-beam product is held constant, the plan-form area and volume of the hull decreases because of the resulting reduction of the length-beam product. The aerodynamic data of reference 3 indicate that a significant reduction in the air drag of a flying-boat hull may be gained by increasing length-beam ratio from about 6 to 9 while constant length^2-beam product is maintained. The favorable effects of high length-beam ratio, therefore, may be realized as a reduction in resistance and an improvement in spray characteristics with hulls of equal size or may be used as a means for reducing the size of the hull without detriment to these characteristics.

As a check on this analysis, an investigation has been undertaken in Langley tank no. 1 to determine the hydrodynamic performance of a powered dynamic model having a length-beam ratio of 9.0. The model represents a hypothetical flying boat similar to the Boeing XPBB-1 except that the length-beam ratio was increased from the original 6.3 to 9.0 with constant length^2-beam product and that somewhat different hull lines were used. In the design of the experimental model, the nacelles, wing, propellers, and tail surfaces were placed in the same relative locations and the height of the hull was unchanged.

The investigation of the spray characteristics of the experimental model over the practicable range of gross loads has been completed and the results are presented herein. Data from reference 6 and unpublished results obtained during the tests of reference 6 are included to give a comparison of these spray characteristics with those of the $\frac{1}{10}$-size model of the XPBB-1 flying boat.

SYMBOLS

C_{Δ_o} gross-load coefficient $\left(\frac{\Delta_o}{wb^3}\right)$

Δ_o gross load, pounds

V speed, feet per second

τ trim, degrees

w specific weight of water, pounds per cubic foot (63.5 for these tests)

b maximum beam, feet

L_f length of forebody from bow to step, feet

k nondimensional coefficient relating forebody proportions to spray characteristics

DESCRIPTION OF MODEL

The powered dynamic model (figs. 1 and 2), designated Langley tank model 203A, is a $\frac{1}{10}$-size model of a hypothetical flying boat essentially similar to the XPBB-1 flying boat except for the form and proportions of the hull. The nacelles, propellers, wing, and tail surfaces of the hypothetical flying boat were the same as those of the XPBB-1 and were placed in the same relative locations. The dimensions of the hull were derived by increasing the length-beam ratio from that of the parent design (6.3) to 9.0 while length^2-beam product was held constant. The ratio of length of forebody to length of afterbody was made the same as that of the parent design. The depth of the hull was made equal to that of the XPBB-1 flying boat.

The lines of the hull are shown in figure 1 and the general arrangement is compared with that of Langley tank model 174 (the $\frac{1}{10}$-size model of the XPB3-1) in figure 3. A further comparison of the dimensions of models 203A and 174 is given in table I. The forebody chine flare of both models was horizontal from the step to station 7. Forward of station 7 the chines of model 203A were turned down and reached a constant value of 10° at station 5. This value was maintained over the rest of the forebody. The depth of step was 9 percent beam. The angle between the forebody and afterbody keels was 5.4°. The increased length-beam ratio resulted in generally finer lines and less curvature than those of the XPB3-1. The lines above the chines were simplified in order to maintain vertical sides and thus facilitate modifications to the bottom.

The areas and volumes of the hulls of models 203A and 174 are compared in the following table:

Model	Maximum section area (sq in.)	Mean section area (sq in.)	Skin area (sq in.)	Total volume (cu in.)	Volume, nose to sternpost (cu in.)
203A	178	108	4570	12,570	12,110
174	231	133	4770	14,800	13,680

As compared with model 174, the maximum frontal area of model 203A was decreased approximately 23 percent, the volume (nose to sternpost) was reduced approximately 11 percent, and the skin area was reduced approximately 4 percent. These values would be expected to change slightly if the lines were adapted to an actual hull.

The model was of built-up construction similar to that described in reference 6. Two motors turned the three-blade metal propellers. Leading-edge slats were installed on the wing to delay the stall and make the stall occur at angles more nearly equal to those expected for the full-size airplane.

APPARATUS AND PROCEDURE

The tests were made in Langley tank no. 1, which is described in reference 7. The towing gear and some of the test procedures are described in reference 8.

The propellers of the model were adjusted to a blade angle of 14° and rotated at 4550 rpm to provide thrust for these tests. The effective thrust was measured with the model at 0° trim with flaps set at 0°. The effective thrust used in the tests of model 203A is shown in figure 4. This thrust is approximately the same as that used during tests of model 174 (fig. 4).

In order to provide data from which the approximate load on the water can be estimated, the aerodynamic lift and pitching moments were determined with full power and flaps at 20° by running the model in the air and measuring the change in tension in two supporting cables (one attached at the pivot that was located at 24 percent mean aerodynamic chord, 0.24 M.A.C., and one just forward of the vertical tail). Data obtained with an elevator deflection of -10° are shown in figure 5.

Spray photographs and observations were made with the model free to trim at constant and accelerated speeds over the practicable range of gross loads with the center of gravity of the model at 28 percent mean aerodynamic chord, the elevators at -10°, and the flaps at 20°. Speeds at which spray entered propellers or struck the flaps were noted for each load. The trim was the angle between the forebody keel and the base line.

RESULTS AND DISCUSSION

The range of speeds over which spray entered the propellers is plotted against gross load in figure 6. The most significant part of this spray range is that bounded by the solid lines. Within this range the bow "blister" entered the propeller disks and the greatest damage to the propellers would be expected.

Photographs showing the bow spray of model 203A are presented in figure 7. At a gross load of 65.0 pounds, light spray entered the propellers. At a gross load of 91.5 pounds, this spray was excessive. A gross load of 81.5 pounds appeared to be a practicable limit from considerations of spray in the propellers.

The range of speeds over which spray entered the propellers of model 174 is shown, together with comparable data for model 203A, in figure 8. This range was determined from a study of spray photographs (fig. 9) and motion pictures. The speeds at which the bow blister entered the propellers could not be distinguished from the speeds at which loose spray entered, but photographs and motion pictures indicate that these speeds are very nearly the same. The total speed range over which spray entered the propellers of model 174 was slightly less than that of model 203A and was shifted toward lower speeds. A study of the spray photographs (figs. 7 and 9) indicates that more spray was thrown over the top of the wing of model 174 than of model 203A. This fact is also shown clearly in the stern photographs (figs. 10 and 11). The down flare on the chines of model 203A forward of the propellers probably contributed to this difference.

The range of speeds over which spray struck the flaps of model 203A is shown in figure 12. Photographs showing the spray on the flaps of models 203A and 174 are presented in figures 10 and 11, respectively. The amount of spray striking the flaps with power appeared to be approximately the same for both models. The range of speeds over which the spray struck the flaps of model 174 was not accurately determined but the photographs and motion pictures indicate that this range is not greatly different from that of model 203A. The roach from under the afterbody of model 203A wetted the tail extension and the horizontal tail at the root (fig. 10). This spray was very heavy during runs without power.

At planing speeds the spray from under the forebody struck the tips of the horizontal tail of model 203A (fig. 10); without power, this spray was heavy. Similar spray characteristics were noted for model 174 (fig. 11) but the amount of spray striking the horizontal tail appeared to be less than for model 203A.

For conventional multiengine flying boats, the analysis of reference 5 indicates that the gross load and dimensions of the hull are related by the expression

$$C_{\Delta_0} = k\left(\frac{Lf}{b}\right)^2$$

where values of k are given for various spray conditions as follows:

Spray conditions	k
Light	0.0525
Satisfactory	.0675
Heavy but acceptable for overloads	.0825
Excessive	.0975

The values of k and the corresponding observed over-all spray characteristics of model 203A may be summarized as follows:

Gross-load coefficient, C_{Δ_o}	k	Spray evaluation
1.8	0.067	Light
2.3	.085	Practicable limit
2.6	.096	Excessive

This evaluation agrees essentially with what would be predicted from the values of the coefficient k derived from experience with conventional length-beam ratios. Hence, the possible reduction in hull size obtained by the increase in length-beam ratio investigated would not be expected to have any adverse effect on the spray characteristics of an airplane of the XPBB-1 type.

CONCLUDING REMARKS

The over-all spray characteristics of the model with a length-beam ratio of 9.0 were acceptable up to a gross-load coefficient of 2.3 and were excessive at a gross-load coefficient of 2.6. These characteristics were in agreement with those obtained with conventional length-beam ratios at the same values of the ratio of gross-load coefficient to the square of the forebody length-beam ratio.

A reduction in hull size is made possible by the high length-beam ratio without adverse effect on the spray characteristics of a multiengine flying boat. The use of high length-beam ratio therefore offers the possibility of reducing the over-all drag of such a flying boat in cases where the dimensions of the hull are primarily determined by spray and seaworthiness requirements.

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TABLE I

COMPARISON OF BASIC DIMENSIONS OF MODELS 203A AND 174

	Model 203A	Model 174
Hull:		
Beam maximum, in.	9.85	12.5
Length of forebody, in.	51.04	45.3
Length of afterbody, in.	37.64	33.4
Length of tail extension, in.	27.97	35.0
Length, over-all, in.	116.65	113.7
Length-beam ratio	9.0	6.3
Type of step	Transverse	Transverse
Depth of step at keel, in.	0.89	1.10
Angle of dead rise at step		
Excluding chine flare, deg	20	20
Including chine flare, deg	15.9	17.9
Angle of forebody keel, deg	0	0
Angle of afterbody keel, deg	5.4	5.4
Angle of sternpost to base line, deg	6.7	7.2
Angle of forebody chine flare at step, deg	0	0
Wing:		
Area, sq ft	18.26	18.26
Span, in.	167.65	167.65
Root chord, in.	19.20	19.20
Angle of incidence, deg	4	4
Mean aerodynamic chord (M.A.C.)		
Length, projected, in.	16.48	16.48
Leading edge aft of bow, in.	43.04	34.6
Leading edge forward of step, in.	8.0	8.3
Leading edge above base line, in.	18.34	18.35

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TABLE I - Concluded

COMPARISON OF BASIC DIMENSIONS OF MODELS 203A AND 174 - Concluded

	Model 203A	Model 174
Horizontal tail surface:		
Area, sq ft	3.33	3.33
Span, in.	51.6	51.6
Angle of stabilizer to wing chord, deg	-4	-4
Elevator root chord, in.	3.84	3.84
Elevator semispan, in.	20	20
Length from 25-percent M.A.C. of wing to hinge line of elevators, in.	59.4	59.4
Height above base line, in.	22.80	22.80
Propellers:		
Number of propellers	2	2
Number of blades	3	3
Diameter, in.	19.8	19.8
Angle of thrust line to base line, deg	2	2
Angle of blade at 0.75 radius, deg	14	14
Clearance above keel line, in.	9.9	9.9

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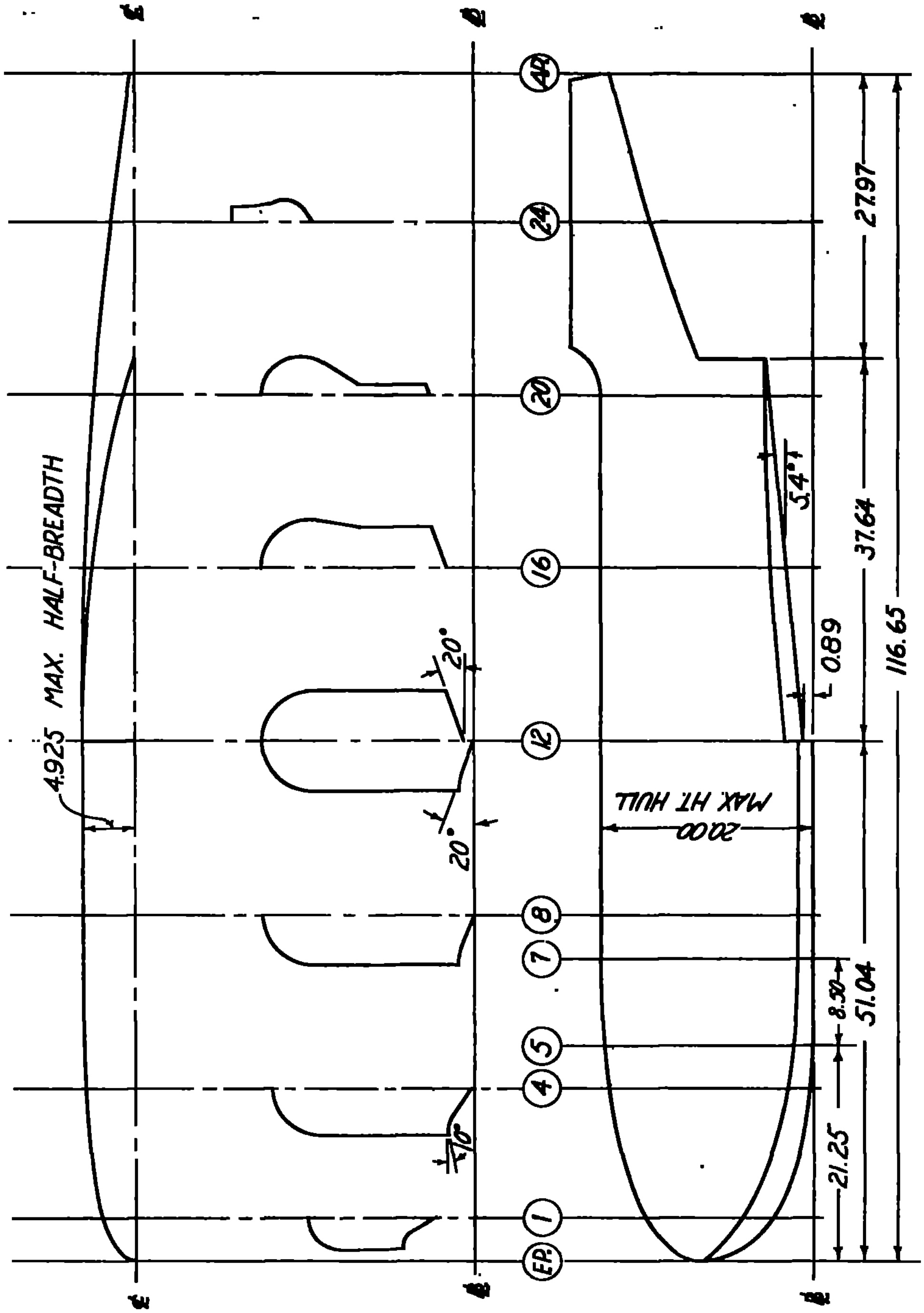

FIGURE 1.- MODEL 203A. LINES OF HULL. ALL DIMENSIONS IN INCHES.

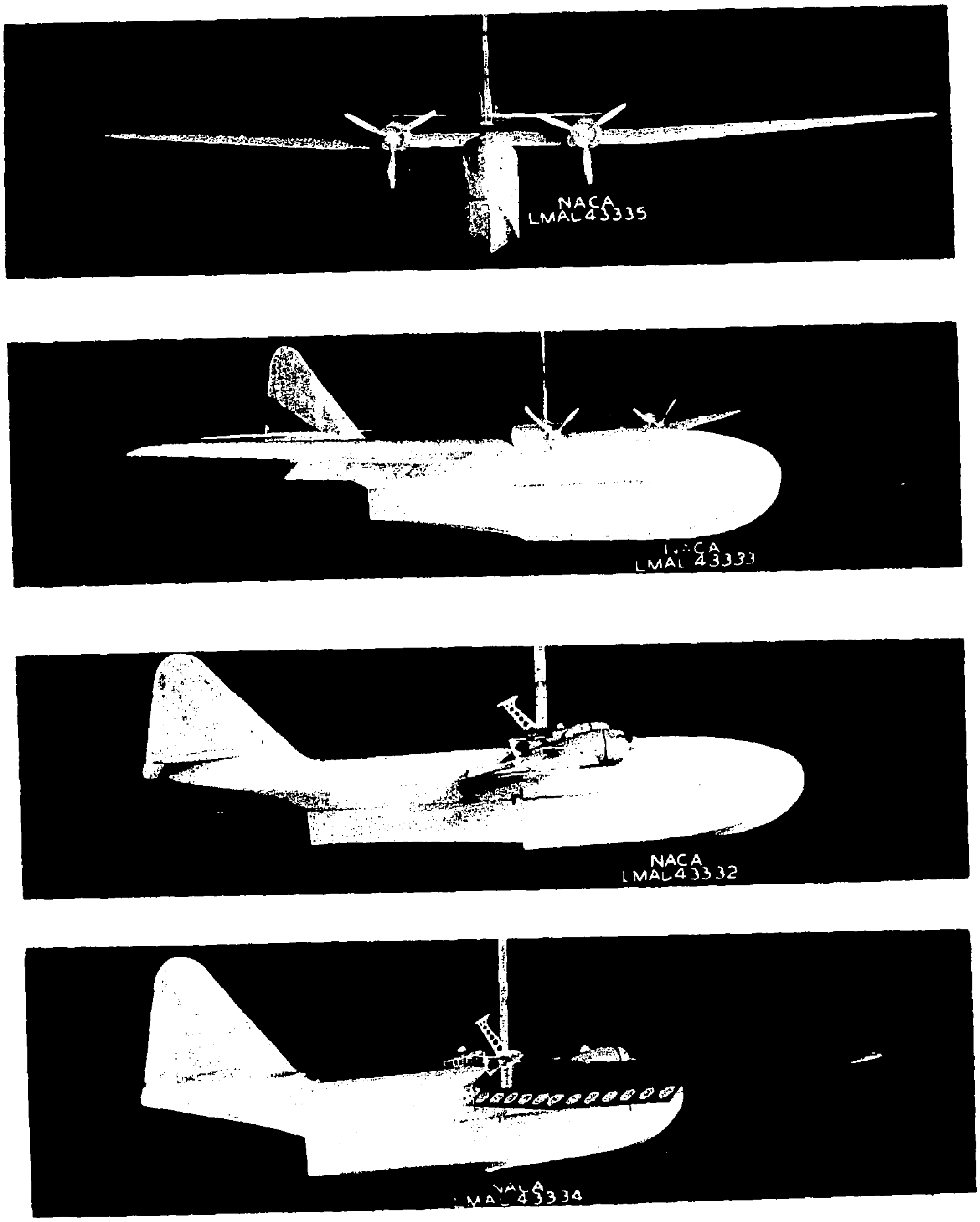

Figure 2.- Photographs of model 203A.

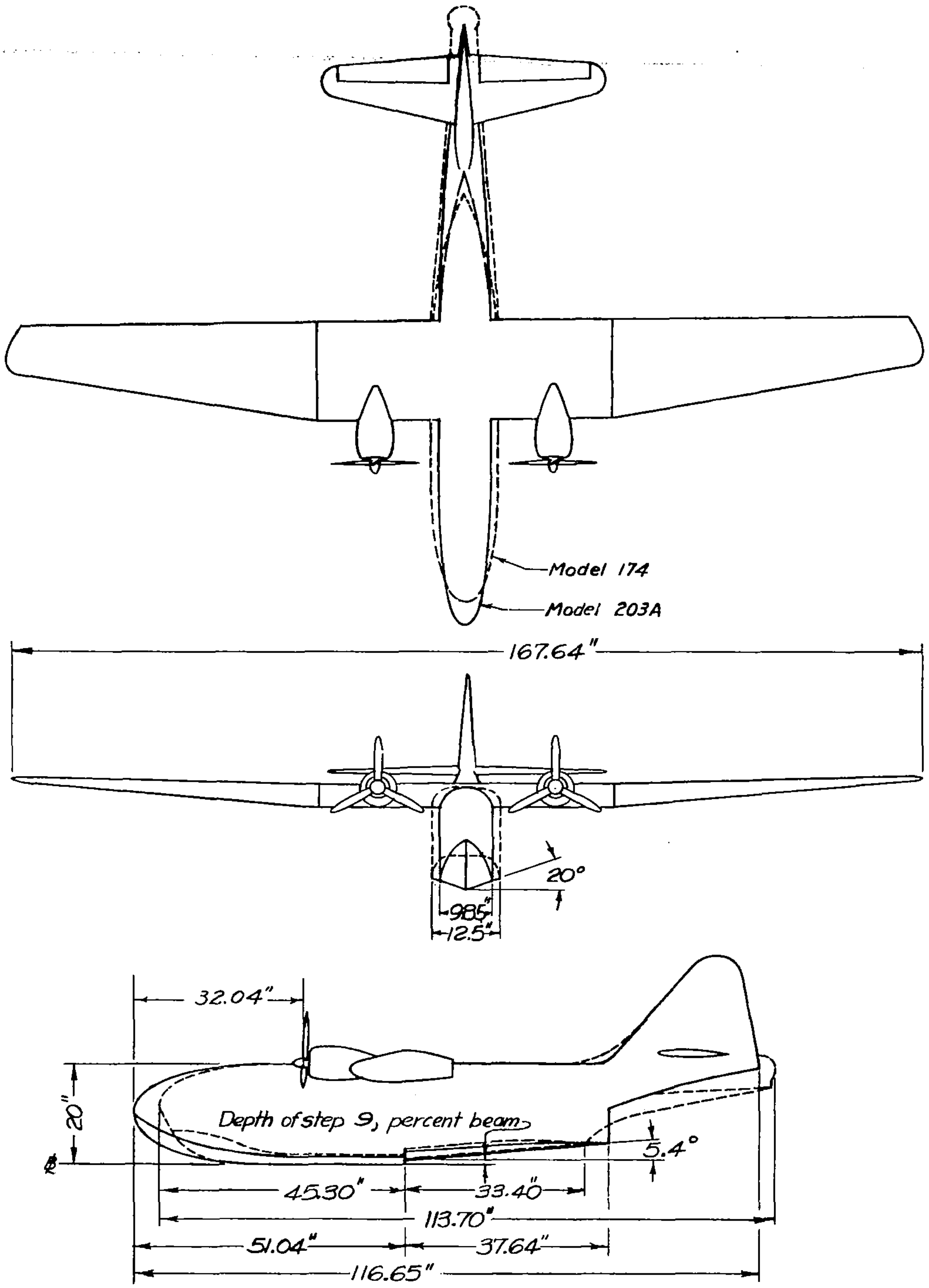

Figure 3 .– Comparison of model 203A with model 174 (XPBB-1).

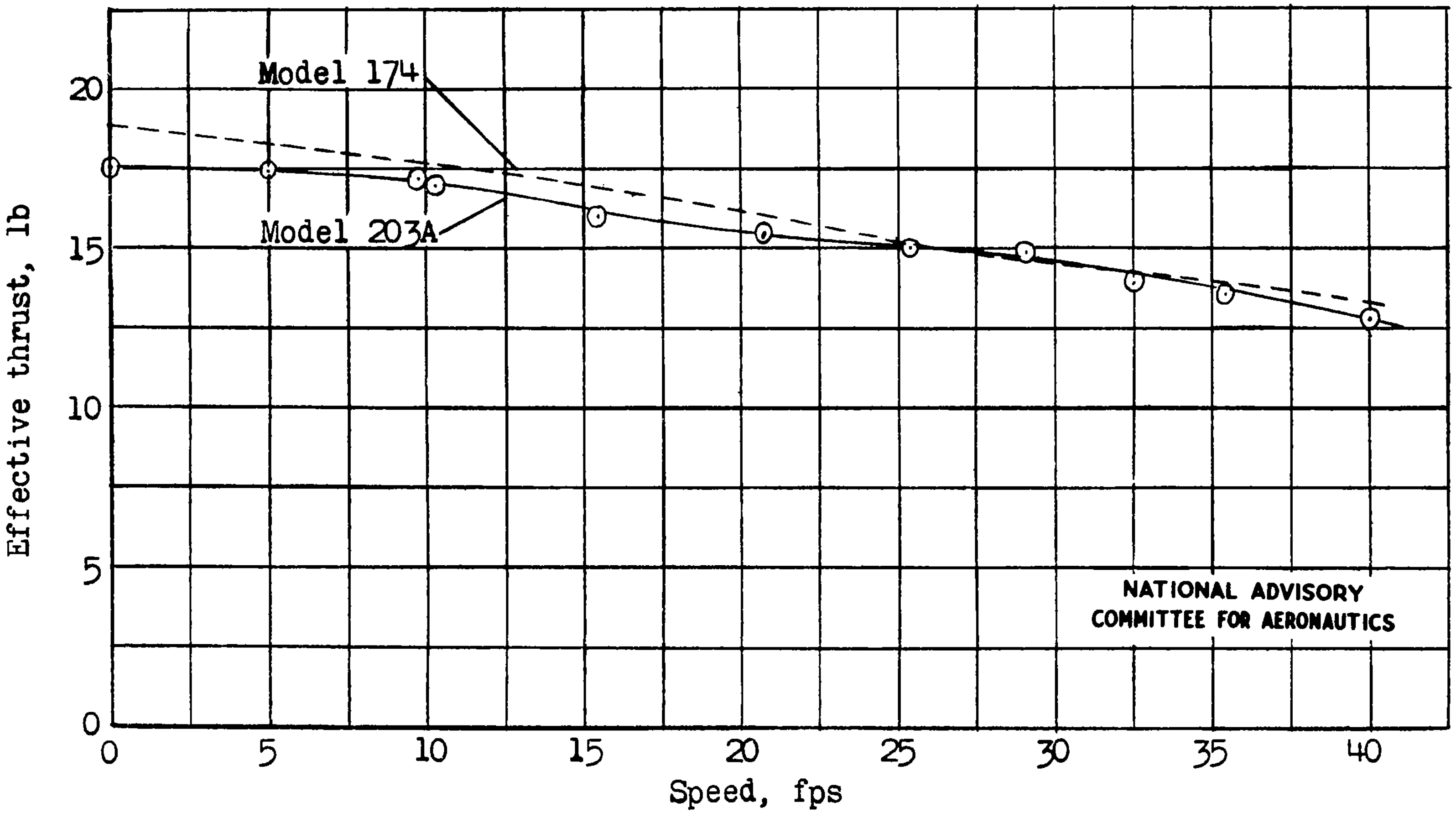

Figure 4 .- Model 203A. Variation of effective thrust with speed. Full power, 4,550 rpm; blade angle, 14°; flap deflection, 0°; trim, 0°.

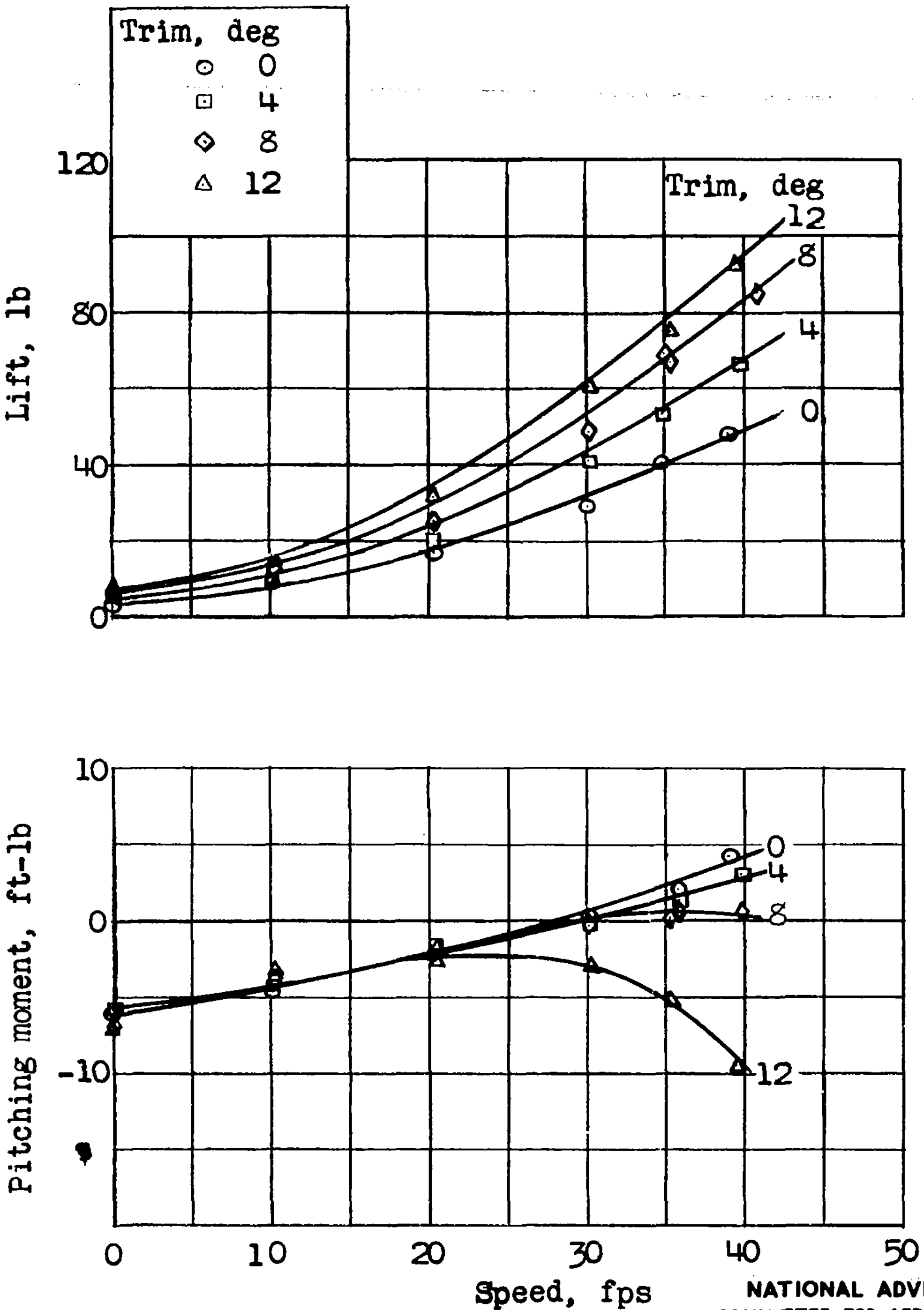

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Figure 5 .- Model 203A. Variation in aerodynamic lift and pitching moment with speed. Full power, 4,550 rpm; center of gravity, 24 percent M.A.C.; flap deflection, 20°; elevator deflection, -10°.

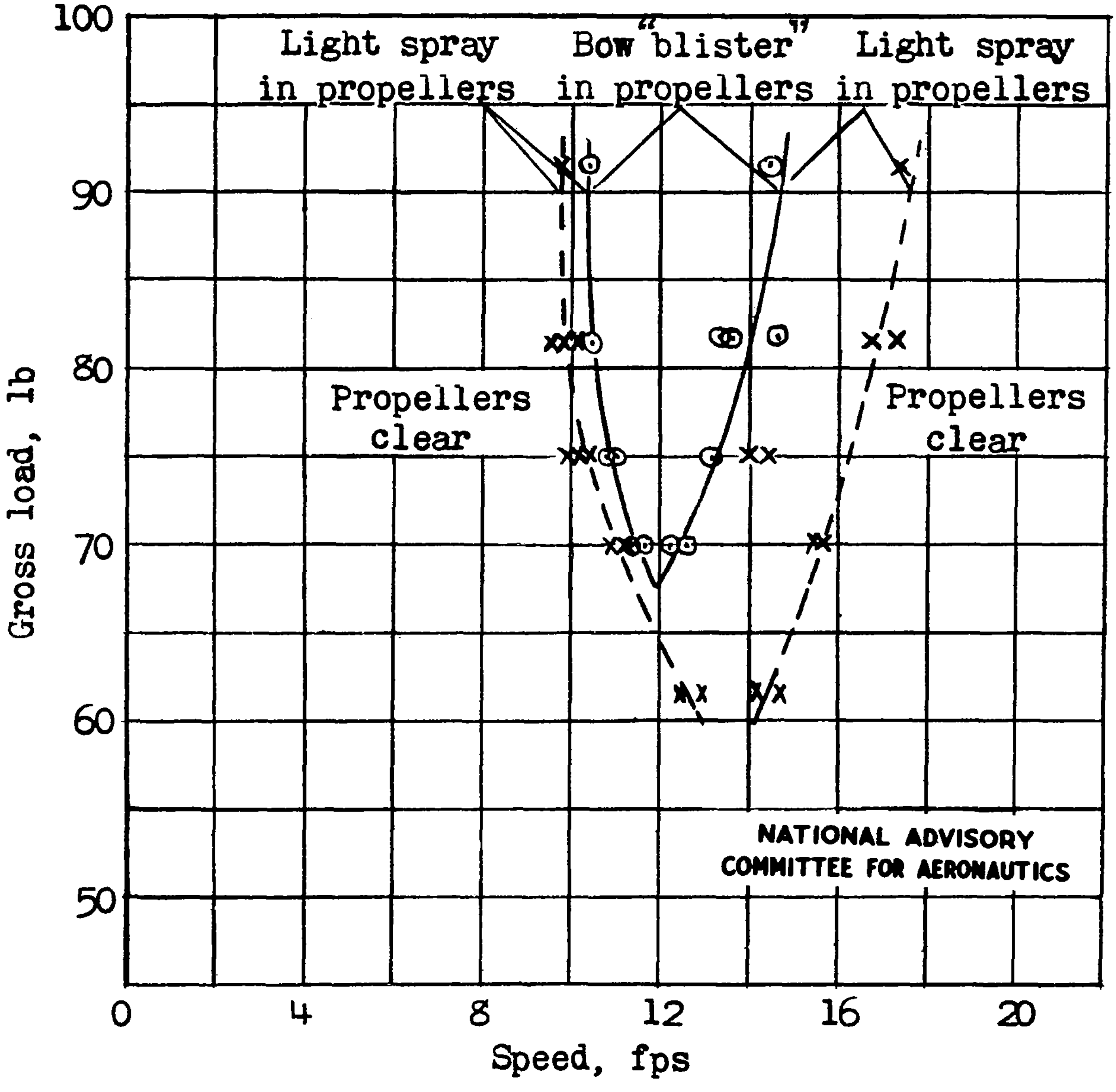

Figure 6 .- Model 203A. Speed range over which spray enters the propellers. Full power, 4,550 rpm; center of gravity, 28 percent M.A.C.; flap deflection, 20°; elevator deflection, -10°.

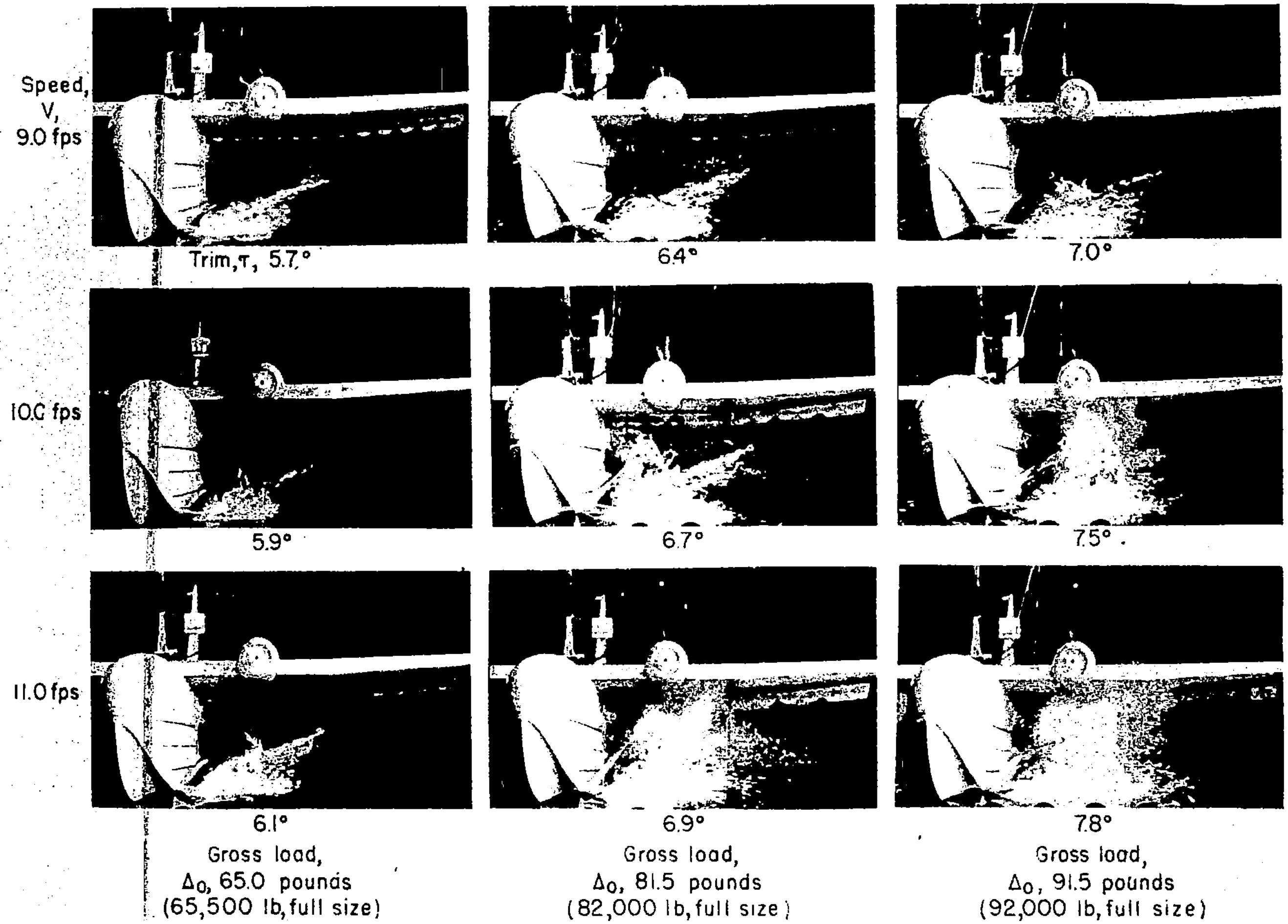

Figure 7.- Model 203A. Spray characteristics, bow. Full power, 4,550 rpm; center of gravity, 28 percent M.A.C.; flap deflection, 20°; elevator deflection, -10°.

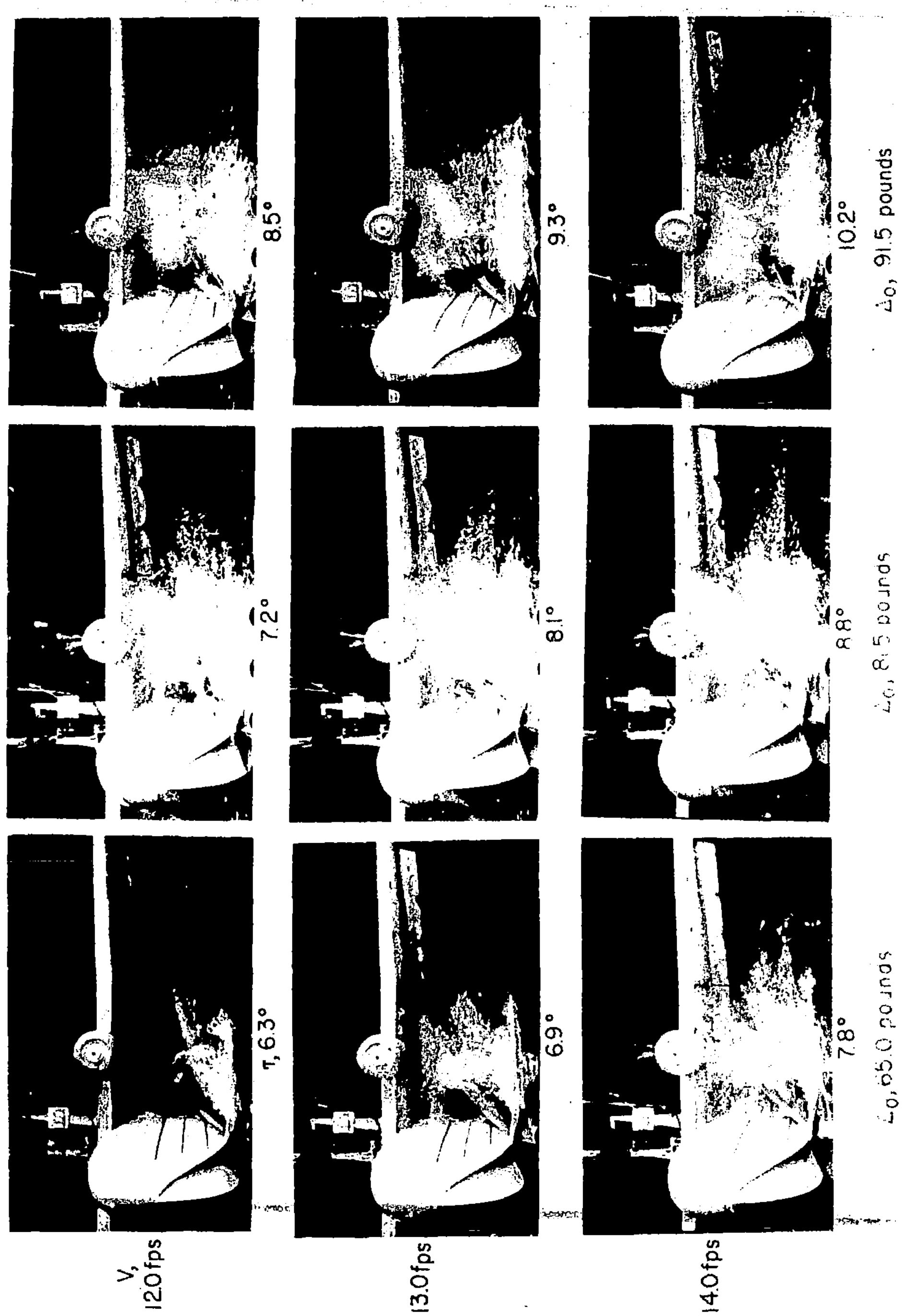

Figure 7.- Model 203A. Continued.

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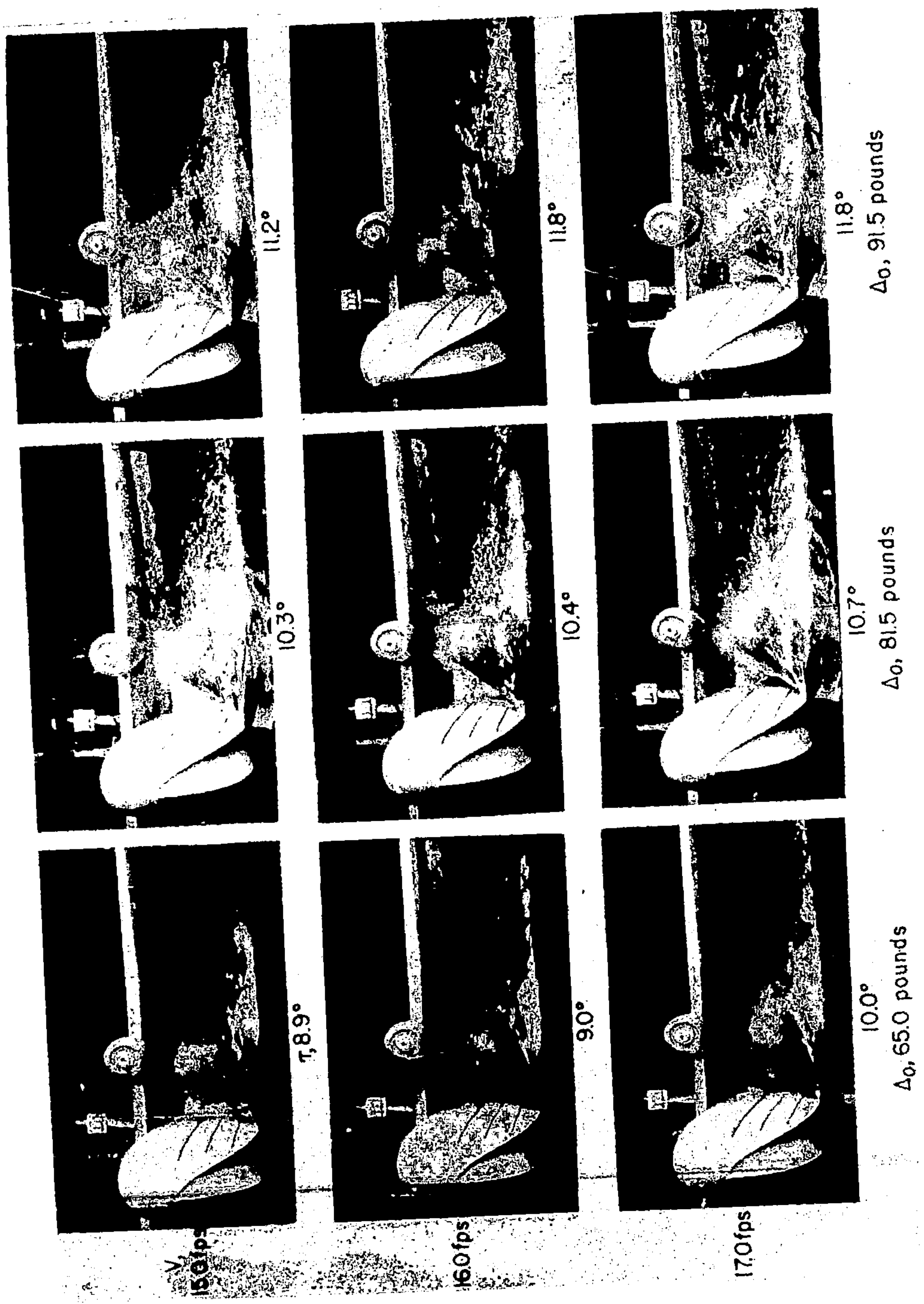

Figure 7.- Model 203A. Continued.

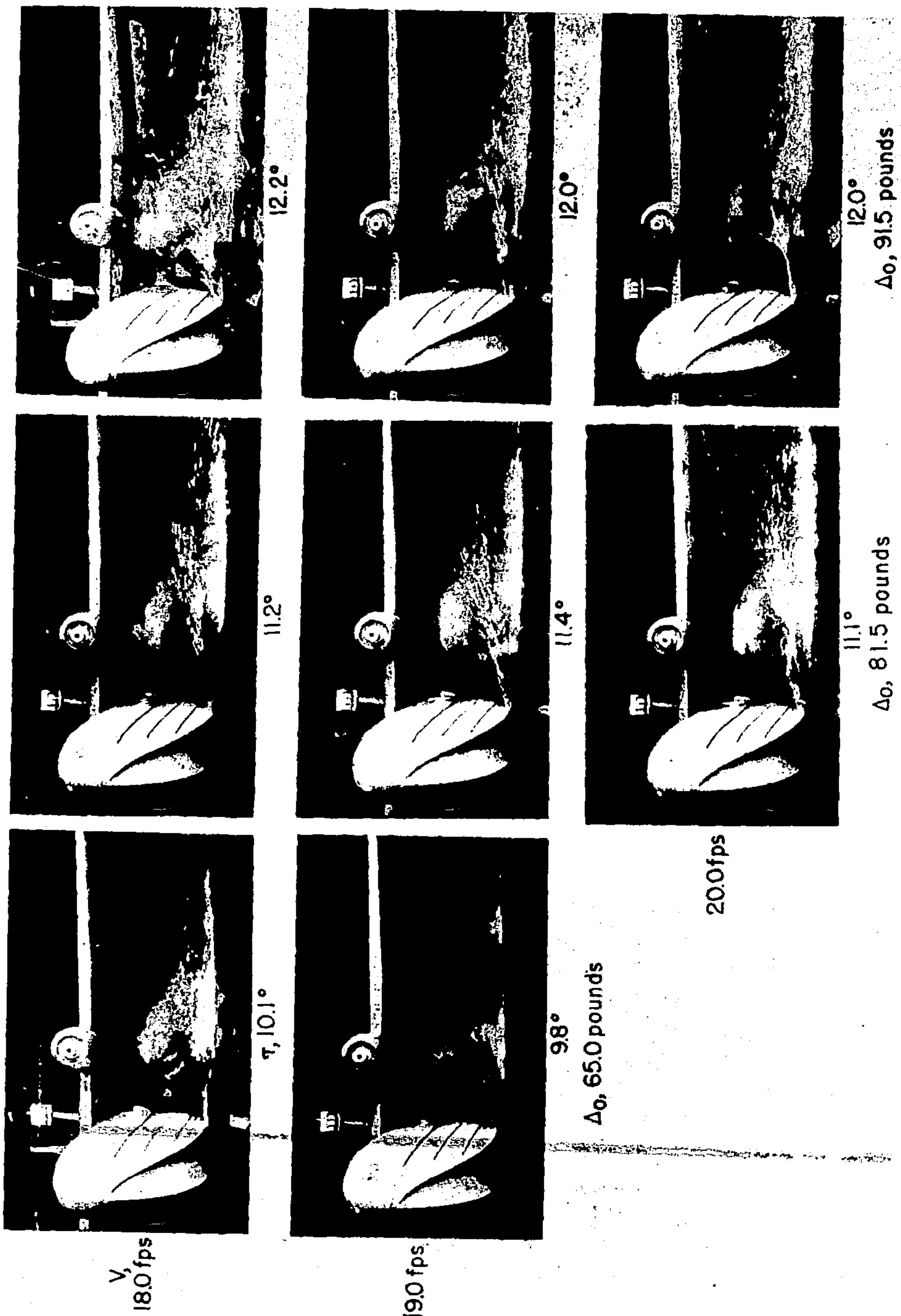

Figure 7.- Model 203A. Concluded.

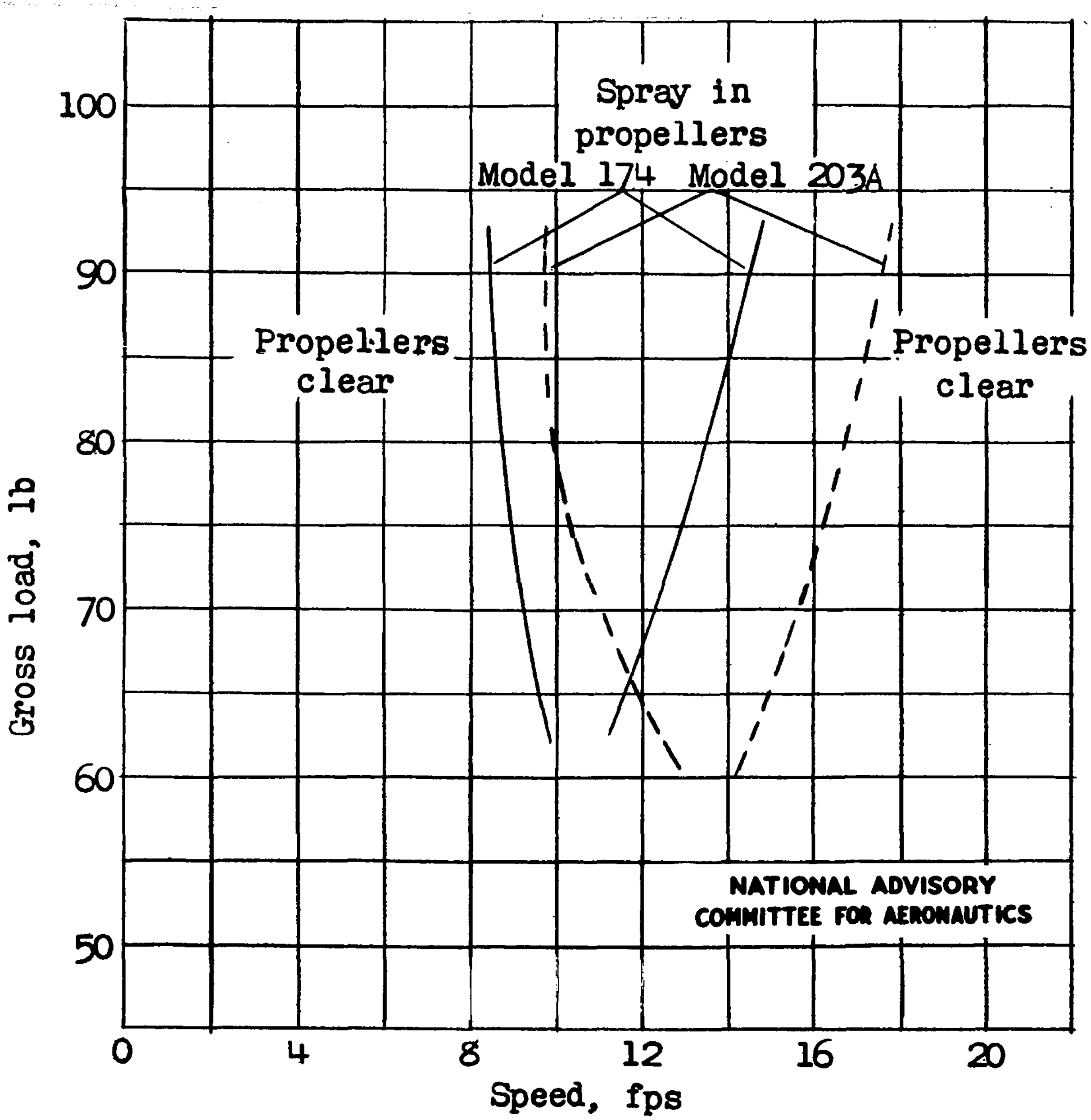

Figure 8 .- Model 174. Speed range over which spray enters propellers. Full power, 4,200 rpm; center of gravity, 28 percent M.A.C.; flap deflection, 20°; elevator deflection, -10°.

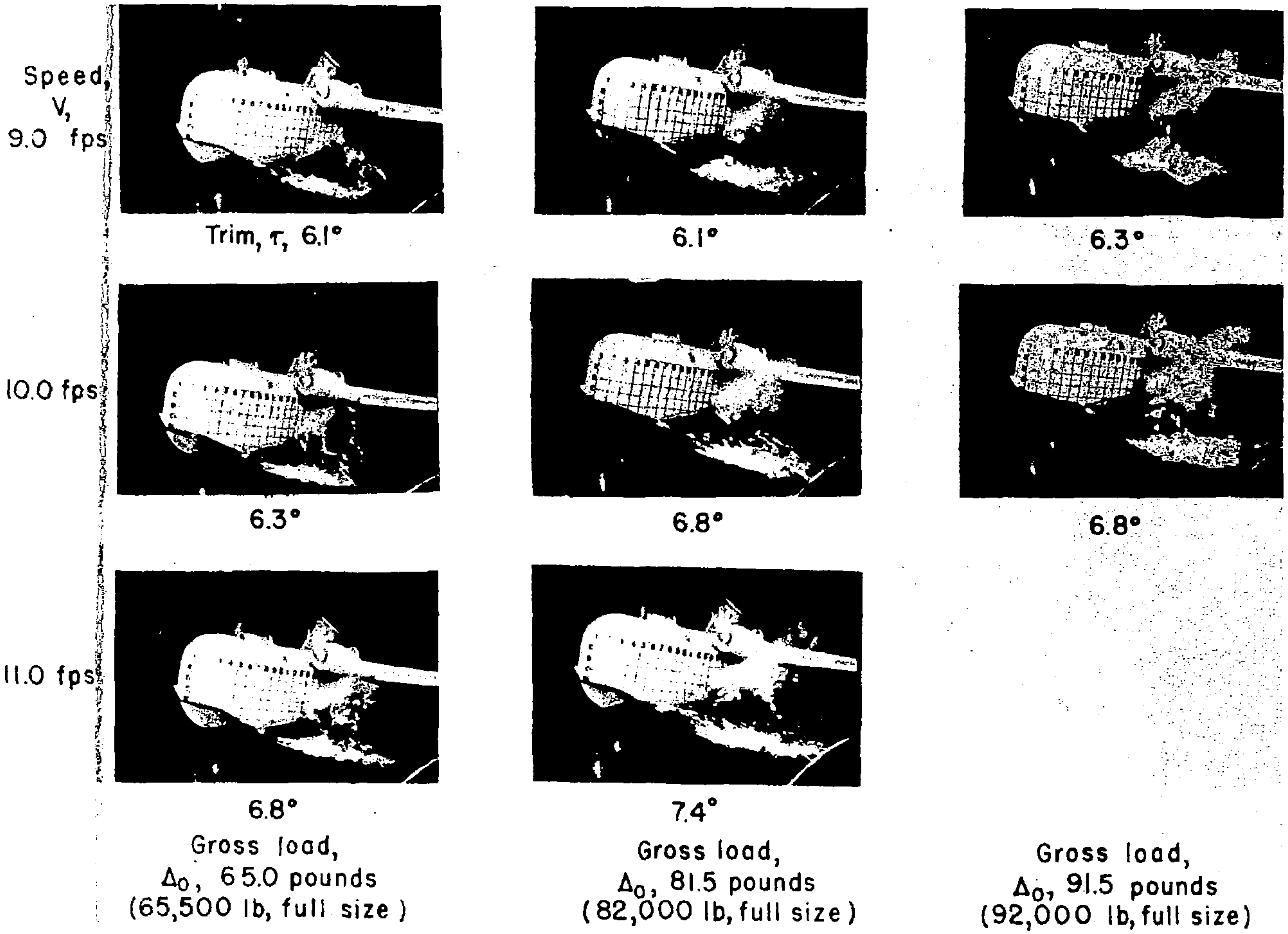

Figure 9.- Model 174. Spray characteristics, bow. Full power, 4,200 rpm; center of gravity, 28 percent M.A.C.; flap deflection, 20°; elevator deflection, -10°.

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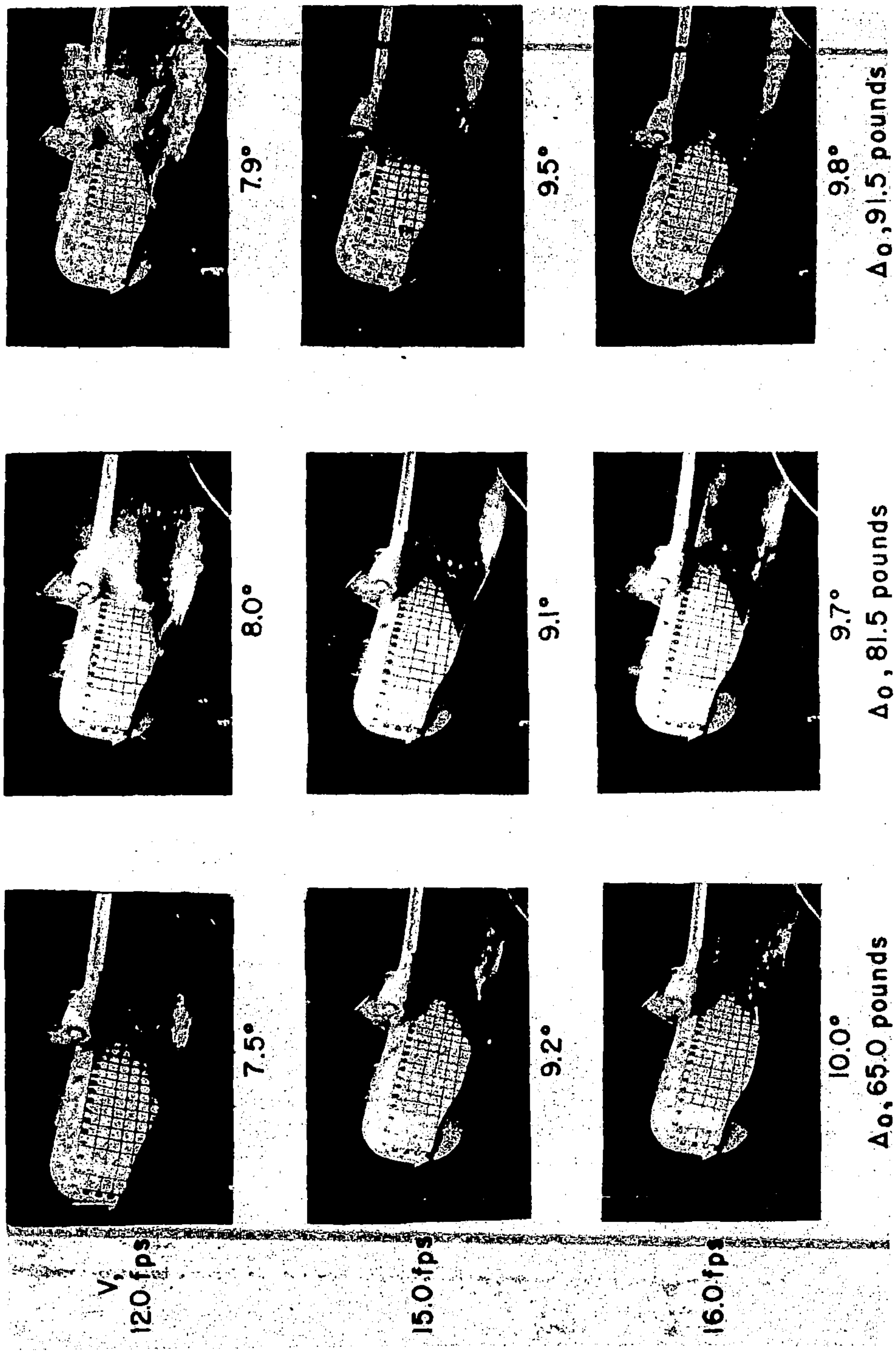
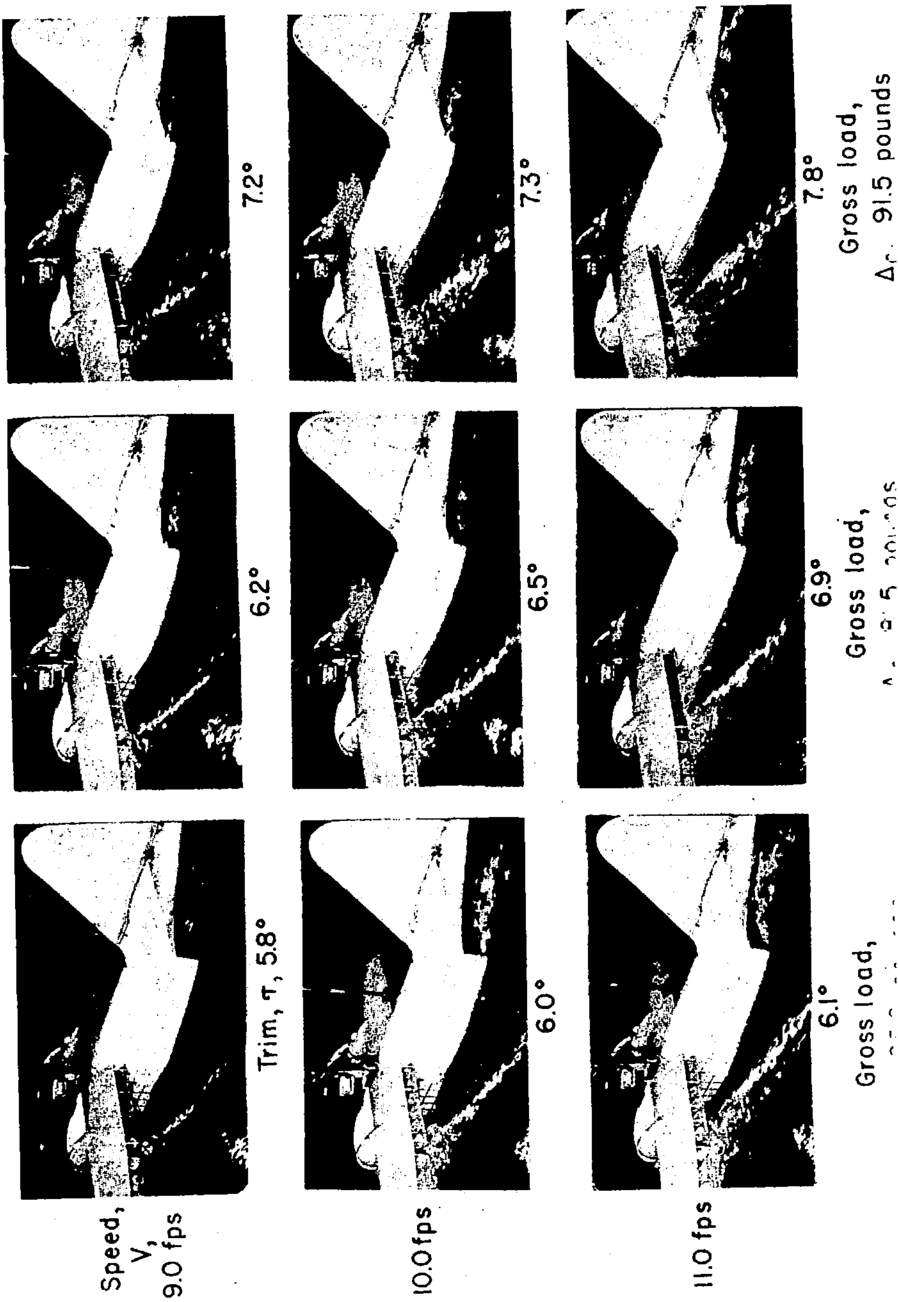


Figure 9.- Model 174. Concluded.


Speed, V, 9.0 fps
10.0 fps
11.0 fps
Trim, τ, 5.8°
6.2°
7.2°
6.0°
6.5°
7.3°
6.1°
6.9°
7.8°
Gross load,
Gross load,
Gross load,
91.5 pounds

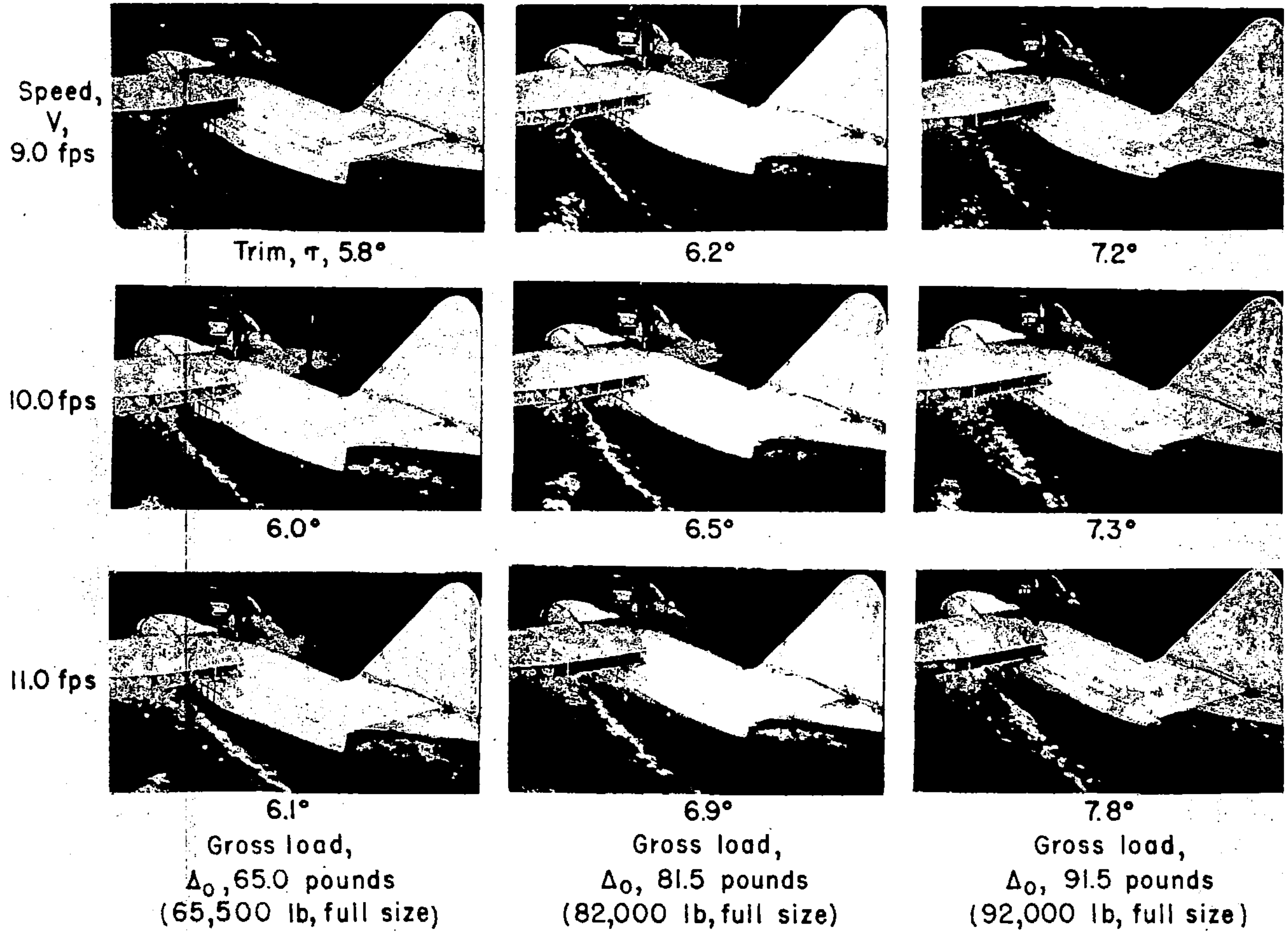


Figure 10.- Model 203A. Spray characteristics, flap and tail assembly. Full power, 4,550 rpm; center of gravity, 28 percent M.A.C.; flap deflection, 20°; elevator deflection, -10°.

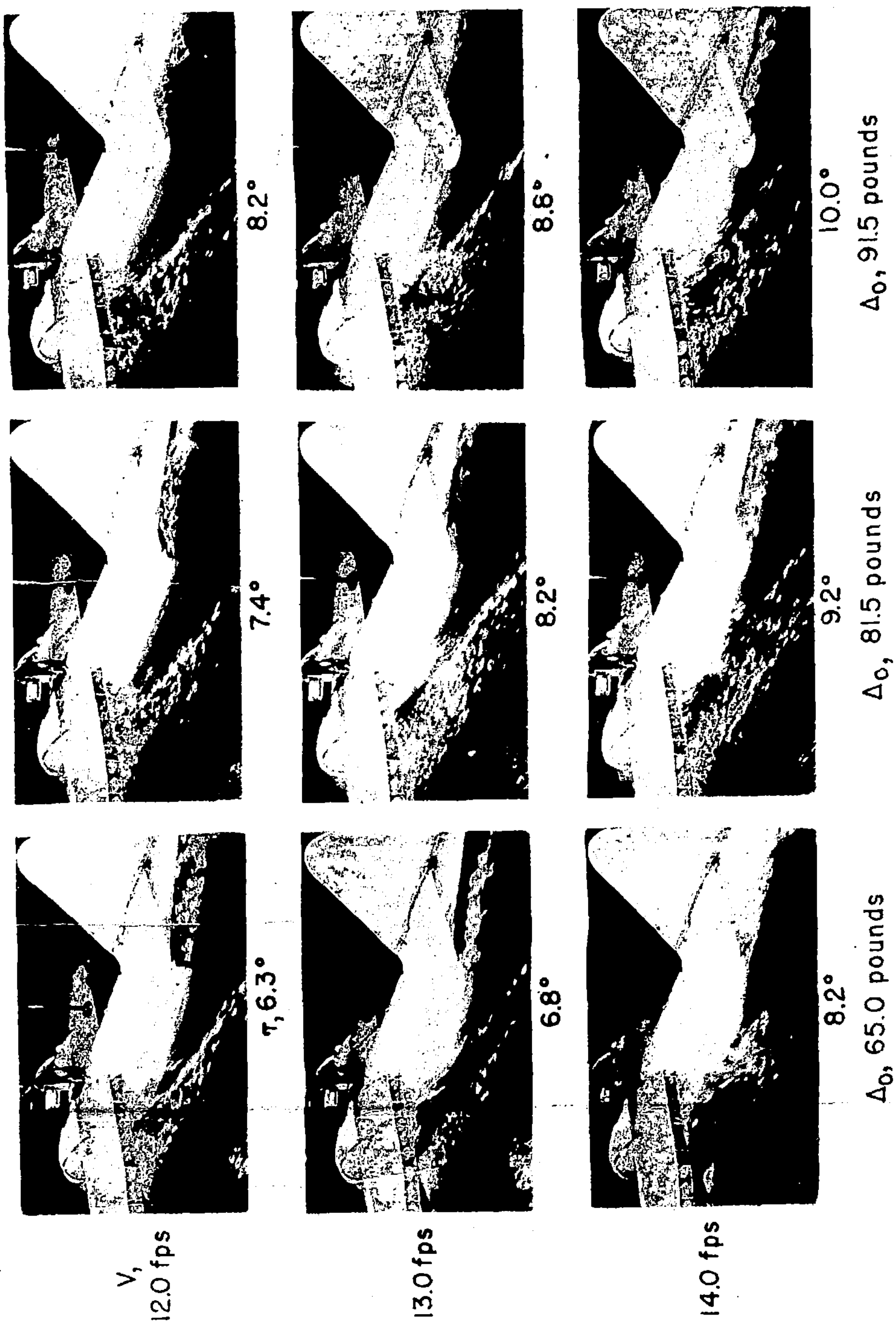


Figure 10.- Model 203A. Continued.

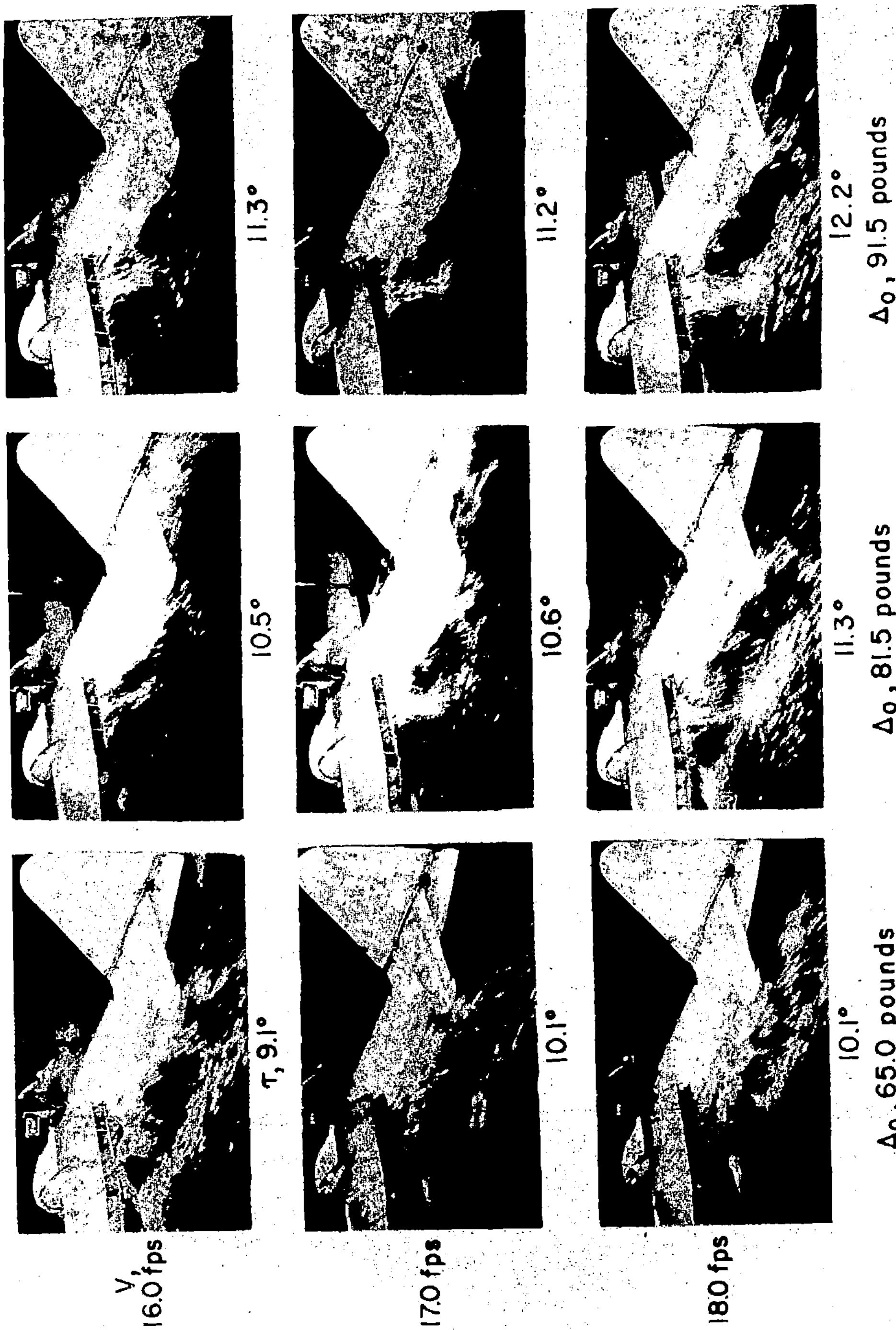


Figure 10.- Model 203A. Continued.

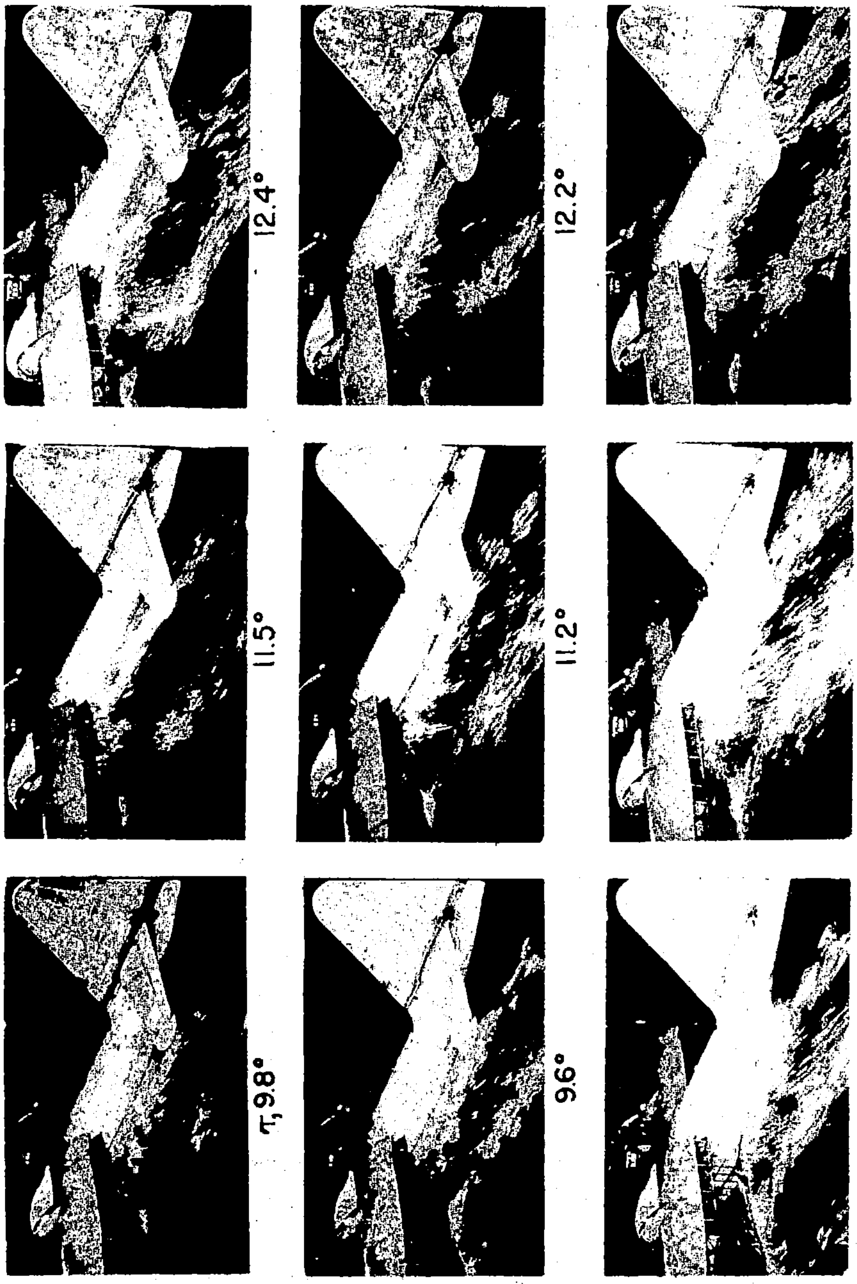


Figure 10.- Model 203A. Concluded.

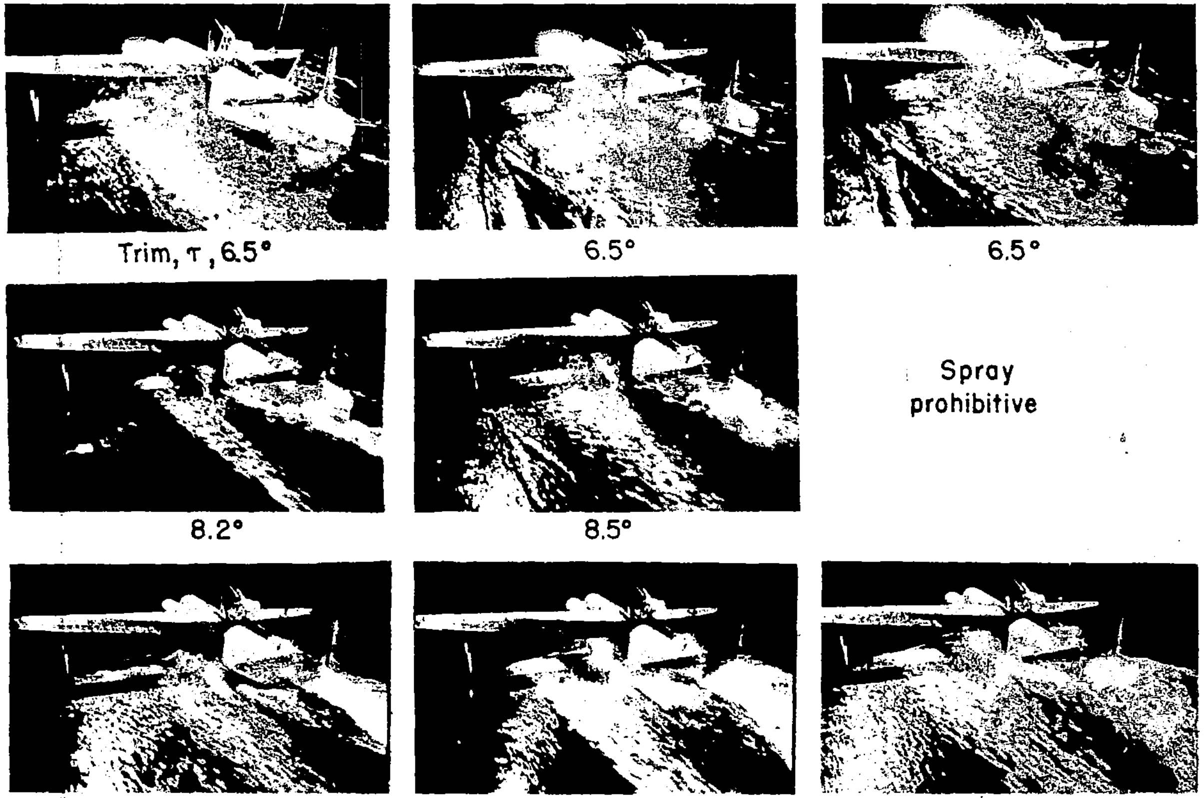


Figure 11.- Model 174. Spray characteristics, flap and tail assembly. Full power, 4,200 rpm; center of gravity, 28 percent M.A.C.; flap deflection, 20°; elevator deflection, -10°.

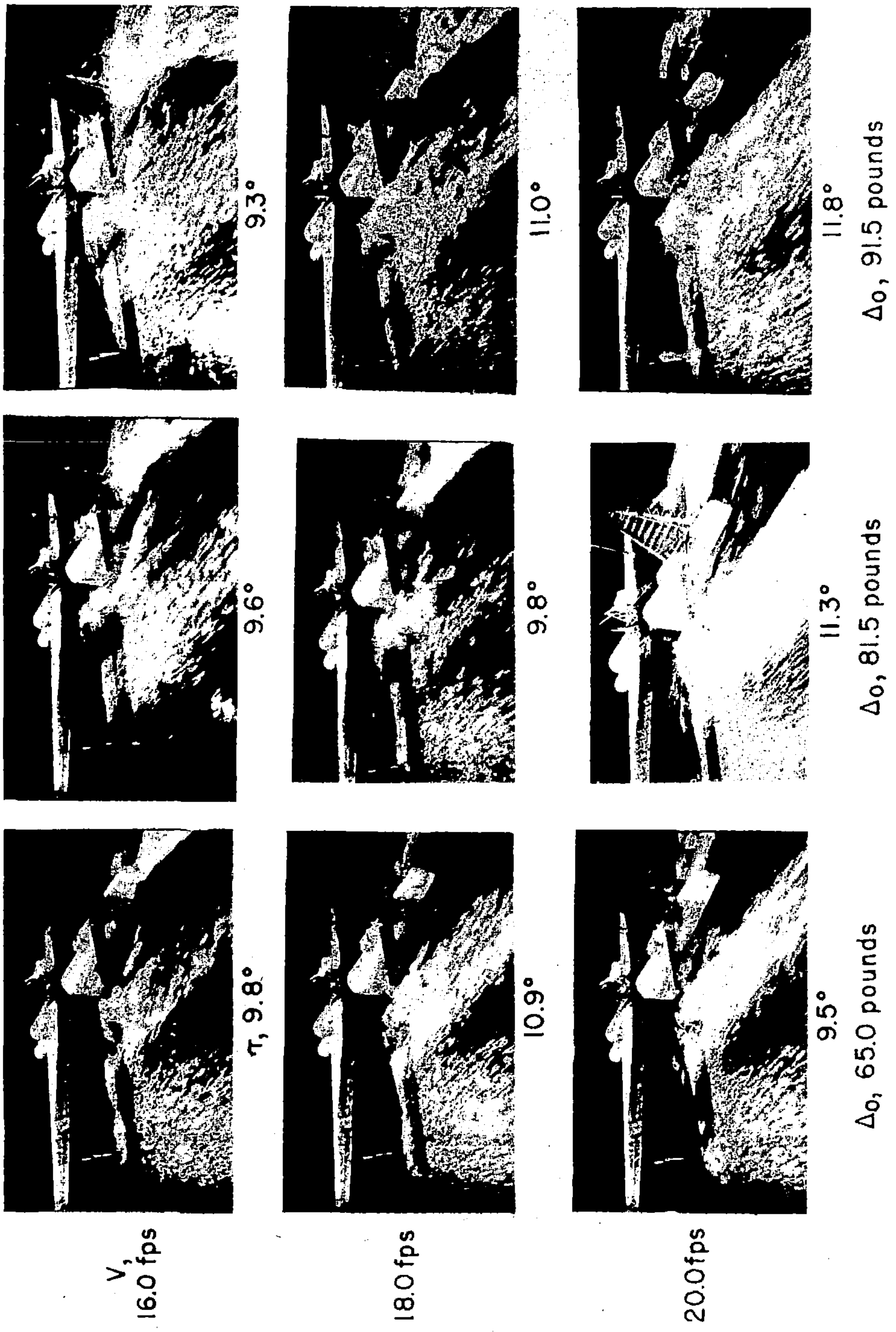


Figure 11.- Model 174. Concluded.

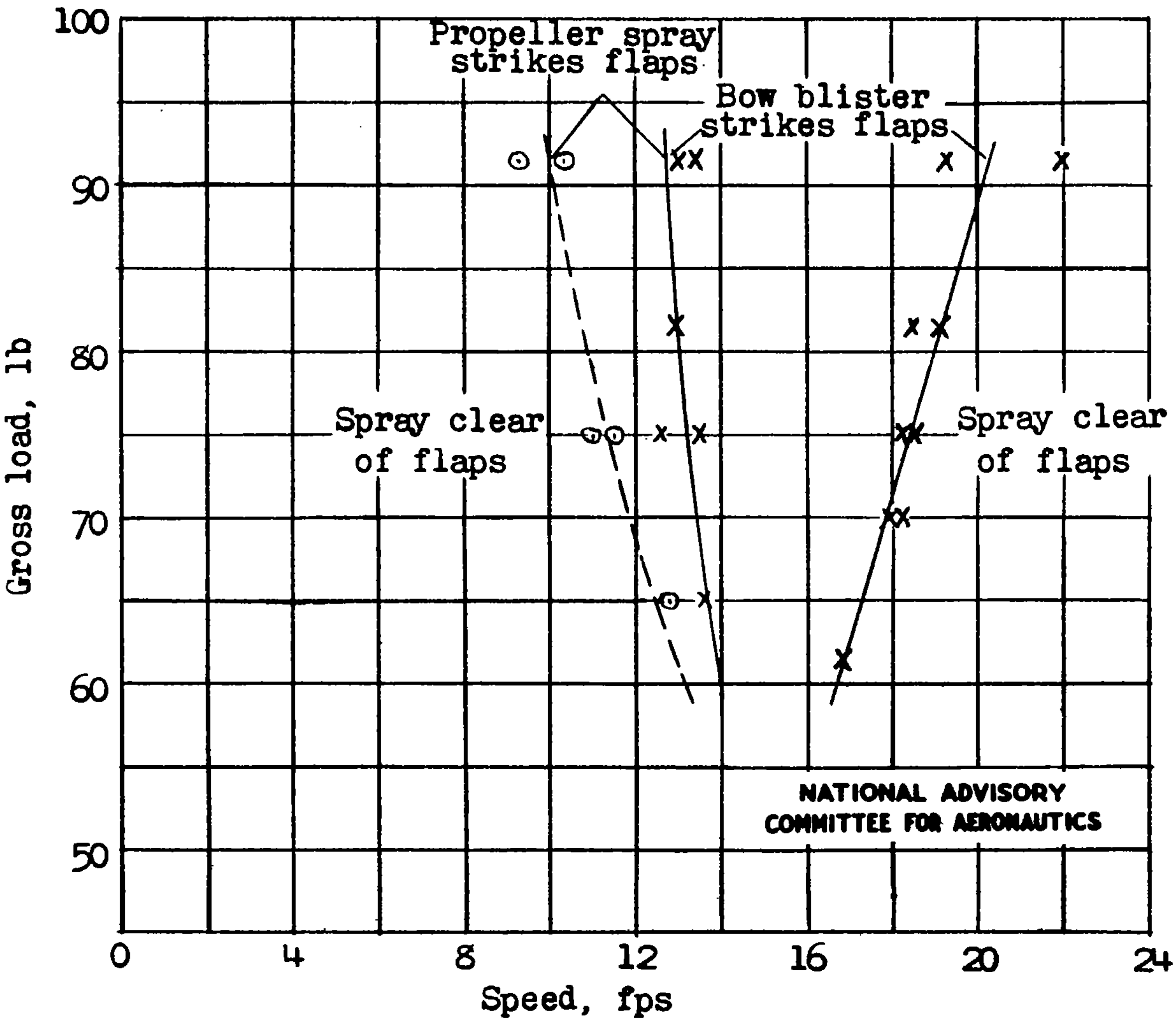


Figure 12.- Model 203A . Speed range over which spray strikes the flaps. Full power, 4,500 rpm; center of gravity, 28 percent M.A.C.; flap deflection, 20°; elevation deflection, -10°.