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RESEARCH MEMORANDUM

PLANING CHARACTERISTICS OF THREE SURFACES REPRESENTATIVE OF HYDRO-SKI FORMS

By

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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

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PLANING CHARACTERISTICS OF THREE SURFACES REPRESENTATIVE OF HYDRO-SKI FORMS

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SUMMARY

The planing characteristics, as determined by tank tests, are presented for three surfaces representative of hydro-ski forms. One surface was of rectangular plan form with a flat bottom, the second surface had a rectangular plan form with transversely curved bottom and the third surface had a flat bottom but was triangular in plan form. The range of trims investigated was 4° to 20°. The data are presented in the form of plots of load, resistance, trimming moment, and draft against wetted area. Plots of wetted length, wetted area forward of the observed wetted length at the chine, and aerodynamic tare forces are included.

INTRODUCTION

The use of retractable planing surfaces, called hydro-skis, for supporting jet-propelled water-based airplanes during the high-speed part of their take-offs and landings, was proposed in reference 1. The results of some preliminary tests of models fitted with hydro-skis are presented in references 1 and 2.

Hydro-skis are intended to be parts of the airplane which can be extended for landing and take-off. Since the skis come from the fuselage which is generally rounded or the wing which is more or less flat, the skis also will generally have rounded or flat cross sections. Though some data are available on flat rectangular planing surfaces (see references 3 and 4), the range of trims is limited. Practically no data are available on the characteristics of planing surfaces with convex cross sections or plan forms other than rectangles.

Information as to the effects of plan form and cross-sectional curvature should therefore be an aid in designing hydro-skis and hydro-ski arrangements. Because of this, an investigation was initiated at Langley tank no. 2 to determine the characteristics of planing surfaces of several plan forms and transversely curved bottoms. This paper presents the results of some planing tests of three such surfaces. For convenience in locating the data presented, an index of figures is presented in table 1. Because of current interest of the Air Force and the Bureau of Aeronautics in obtaining data pertaining to hydro-skis, the data in this paper are presented without analysis or discussion to make it available as quickly as possible.

MODELS AND APPARATUS

The principal details of the models tested are given in figures 1 to 3. Model 250A had a flat bottom surface and a rectangular plan form. Model 250B had a rectangular plan form but the bottom was curved in cross section. Model 250D had a flat bottom and a triangular plan form; it was tested with the base of the triangle forward (leading edge). All models had the same plan-form area (0.347 sq ft) and were made of solid mahogany. The upper surface was arbitrarily faired by making all the longitudinal sections circular arcs with a height at the center of 5 percent of the chord which forms the bottom of the section.

The tests were made on the small model towing gear in Langley tank no. 2. The test setup is shown in figure 4.

Two lenticular struts supported the models from a trimming moment dynamometer which was fastened to the towing staff. A phosphor bronze strap in the dynamometer restrained the model in trim. Electrical strain gages fastened to this strap indicated the trimming moment encountered. The towing staff was free only in rise and the vertical load was varied by counterbalancing. Changes in draft were read by means of a disc and pointer arrangement which mechanically magnified changes in the vertical position of the staff. The guides for the staff were connected to the resistance dynamometer. This dynamometer consisted of a cantilever spring, the deflections of which were magnified by an optical system.

PROCEDURE

General

The tests consisted of towing the models at various speeds and loads, at fixed trims of 4°, 8°, 12°, 16°, and 20°. A sufficient number of loads were chosen at each trim to define the variations of resistance, trimming moment, and draft with wetted length. The maximum speed was determined by the measuring limits of the equipment and ranged from 30 to 35 feet per second. The minimum speed was set at 10 feet per second since indications were that below this speed satisfactory planing data could not be obtained with these models. Resistance, trimming moment, draft, and wetted length were read. Draft is the depth of the trailing edge of the model below the free-water surface. Trimming moment was measured about an arbitrary point above the model and from the measured results the trimming moment about the trailing edge at the center line of the model was calculated.

Wetted Length

The wetted length read was the distance from the trailing edge of the model to the intersection of the dynamic solid water boundary with the chine of the model. (See fig. 5.) Forward of this boundary there was a region of loose spray which seemed to fan out from the boundary. Because of the transverse curvature of model 250B some difficulty was encountered in visually reading wetted lengths particularly at the lower trims. A few underwater photographs (see fig. 5) showed that the visually read wetted lengths were satisfactory except at 4° trim. Therefore, additional underwater photographs were taken at 4° trim and the wetted lengths were obtained from these photographs.

Due to a forward curvature of the solid water boundary the wetted length at the center line of all models was greater than the observed wetted length. The manner in which this curvature varied with the models and their wetted length, trim, and speed was determined from underwater photographs.

The slight curvature of the solid water boundary on model 250A (rectangular plan form, flat bottom) gave only a small difference between the wetted length at the center line and the observed wetted length. This difference was within the experimental scatter of the test data obtained, and therefore was not considered.

Due to the transverse bottom curvature of model 250B, the difference in the two wetted lengths varied considerably with trim. However, the difference was less than that which would be indicated by the intersection of the water surface with the curved bottom surface of the model at rest as is shown in figure 5. Figure 6 indicates the difference in the wetted length at the center line and the observed wetted length at the chine.

For model 250D (triangular plan form, flat bottom) the dynamic water line was in the form of an arc having a ratio of mid-ordinate to chord (beam) equal to 0.10. Within the range of trims and speeds covered in these tests this ratio did not vary appreciably. Because of the triangular plan form of the model the chord of this arc and therefore the mid-ordinate, varied with wetted length or wetted area. Figure 7 shows the resulting difference in the wetted length at the center line and the observed wetted length at the chine.

Wetted Area

The wetted area is defined as the wetted plan-form area. This area was determined from the plan form of the models, the observed wetted length at the chine, and the additional wetted area forward of the observed wetted length. The additional wetted area forward of the observed wetted length was determined from the underwater photographs.

The wetted area forward of the observed wetted length varied in the same manner as the wetted length forward of the observed wetted length. The additional area involved was neglected for model 250A. The area involved for model 250B varied appreciably only with trim and is given in figure 8(a). The area involved for model 250D varied appreciably only with wetted length (or wetted area) and is given in figure 8(b) plotted against total wetted area.

Aerodynamic Tares

The aerodynamic tares for resistance, moment, and lift were determined for all trims. The aerodynamic drag and moment were determined with the model attached to the towing gear, with the model removed, and with the model and strut structure removed (towing staff alone). When the model was attached it was positioned approximately one-half inch above the water. When the model was removed the position of the staff and struts was the same as when the model was attached. With the strut structure also removed, the drag was measured at positions of the staff to cover the range for the drafts obtained in the tests. The aerodynamic moment tares were found to be negligible for all models.

The aerodynamic drag of the gear one-half inch above the zero draft position but with the model removed was the same for all models and did not vary appreciably with trim. This drag, plus the increments due to change in draft (as determined from the runs made with the staff alone) is given in figure 9.

The aerodynamic drag of the gear one-half inch above the zero draft position and with the model attached was found to be the same for models 250A and 250B. Its variation with trim was negligible for these models but not for model 250D. The difference in the drags with and without the model attached was considered to be the aerodynamic drag of the model alone. The aerodynamic drag correction for the model alone was assumed to be equal to the ratio of the unwetted plan-form area to the total plan-form area multiplied by the total aerodynamic drag of the model alone. This correction is given in figure 10 for models 250A and 250B and in figure 11 for model 250D. These values, in addition to those for the gear alone, were subtracted as tare corrections from all the resistance data before plotting.

The aerodynamic lift was determined by counterbalancing the model in the air at zero speed, then running at the desired speeds and trims and adding weight until the model moved downward, then removing the weights until the model moved upward. The average of these two weight limits was considered to be the lift. This lift, which varied appreciably with trim, was the same for models 250A and 250B but different for model 250D. The aerodynamic lift correction was also determined as a function of unwetted area in the same manner as for the aerodynamic drag; it is given in figure 12 for models 250A and 250B and in figure 13 for model 250D. The values given were subtracted as tare corrections from the values of load applied to the models.

RESULTS

The results are presented in the form of plots of the load on the water, resistance, trimming moment, and draft against total wetted area with speed and trim as parameters. Figures 14 to 17 give the results for the rectangular surface with a flat bottom (model 250A). Figures 18 to 21 are for the rectangular surface with curved bottom (model 250B) and figures 22 to 25 are for the triangular surface with a flat bottom (model 250D).

From the procedure described, the quantities in the figures are defined as follows:

(a) Resistance is the measured resistance less the aerodynamic drag of the towing gear less model (fig. 9) and the estimated aerodynamic drag of the unwetted portion of the model (figs. 10 and 11).

(b) Trimming moment is the measured trimming moment referred to the trailing edge of the model. The aerodynamic moment tare was negligible.

(c) The load on the water is the unbalanced weight of the model and gear less the estimated aerodynamic lift of the unwetted portion of the model (figs. 12 and 13). The aerodynamic lift tare on the gear alone was negligible.

(d) Draft is the depth of the trailing edge of the model below the free water surface.

(e) Wetted area is the wetted plan-form area computed from the plan form and the observed wetted length at the chine plus the wetted area forward of the observed wetted length (fig. 8). The latter was negligible for model 250A.

(f) Wetted length at the chine is the observed length from the trailing edge of the model to the intersection of the dynamic solid water boundary with the chine. The wetted length at the center line was appreciably greater for models 250B and 250D. (See figs. 6 and 7.)

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1. Dawson, John R., and Wadlin, Kenneth L.: Preliminary Tank Tests of NACA Hydro-Skis for High-Speed Airplanes. NACA RM No. L7I04, 1947.

2. Wadlin, Kenneth L., and Ramsen, John A.: Tank Spray Tests of a Jet-Powered Model Fitted with NACA Hydro-Skis. NACA RM No. L8B18, 1948.

3. Shoemaker, James M.: Tank Tests of Flat and V-Bottom Planing Surfaces. NACA TN No. 509, 1934.

4. Sottorf, W.: Analysis of Experimental Investigations of the Planing Process on the Surface of Water. NACA TM No. 1061, 1944.

TABLE 1.- INDEX OF FIGURES

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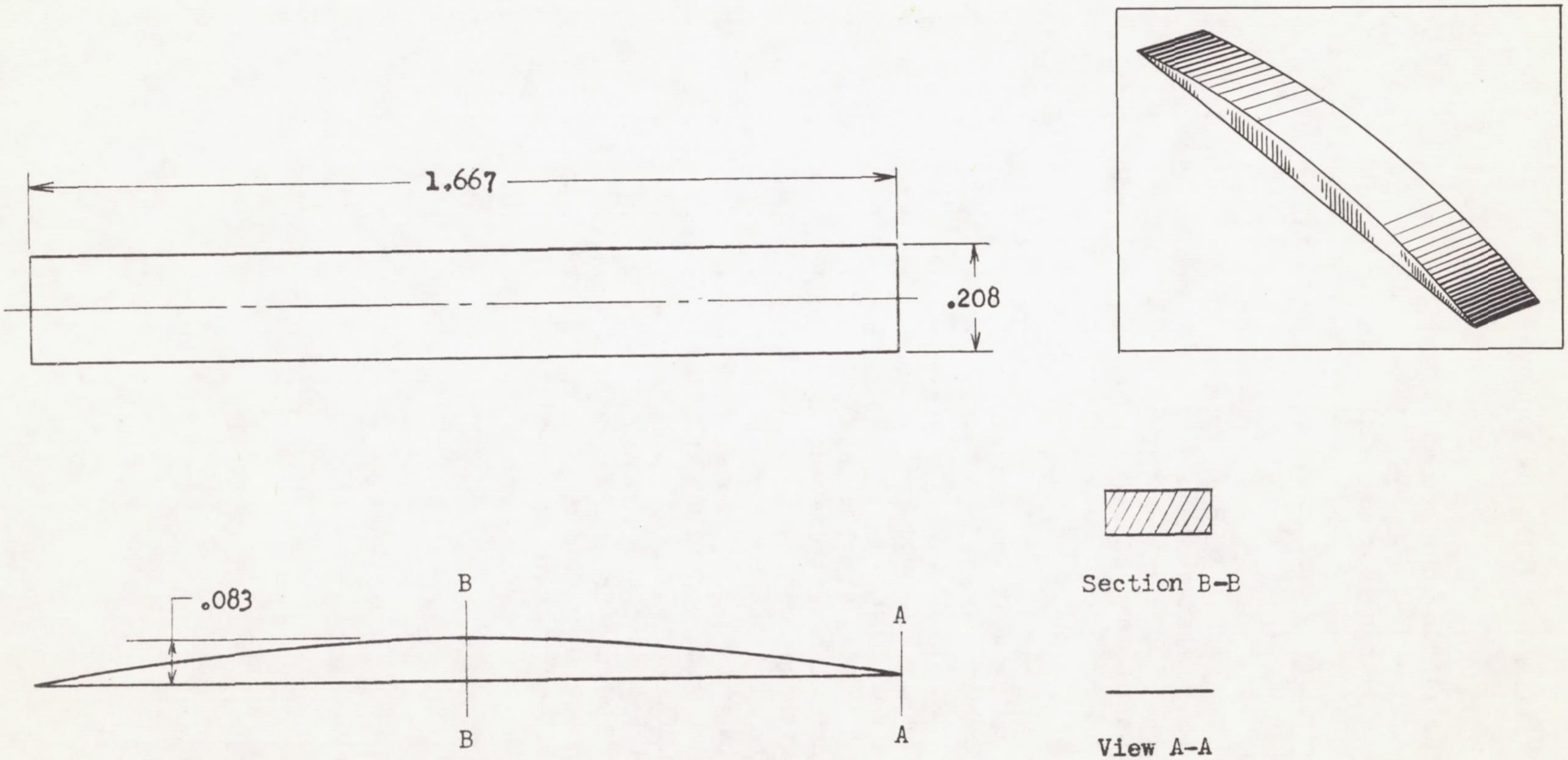


All longitudinal sections are circular arcs with a height at the center of 5 percent of the chord which forms the bottom of the section.

Figure 1.- Details of rectangular planing surface with flat bottom (model 250A). (All dimensions are in feet.)

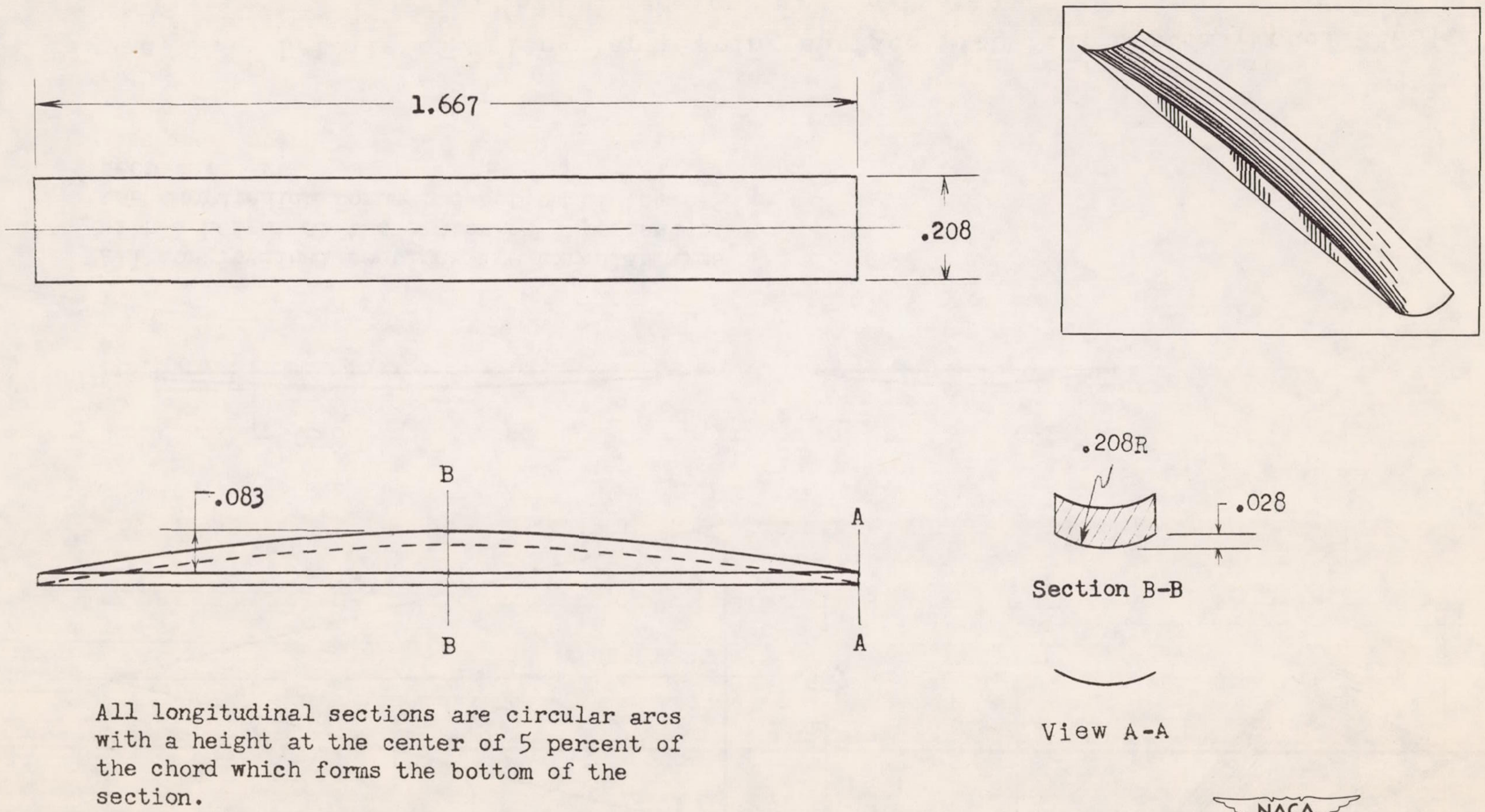
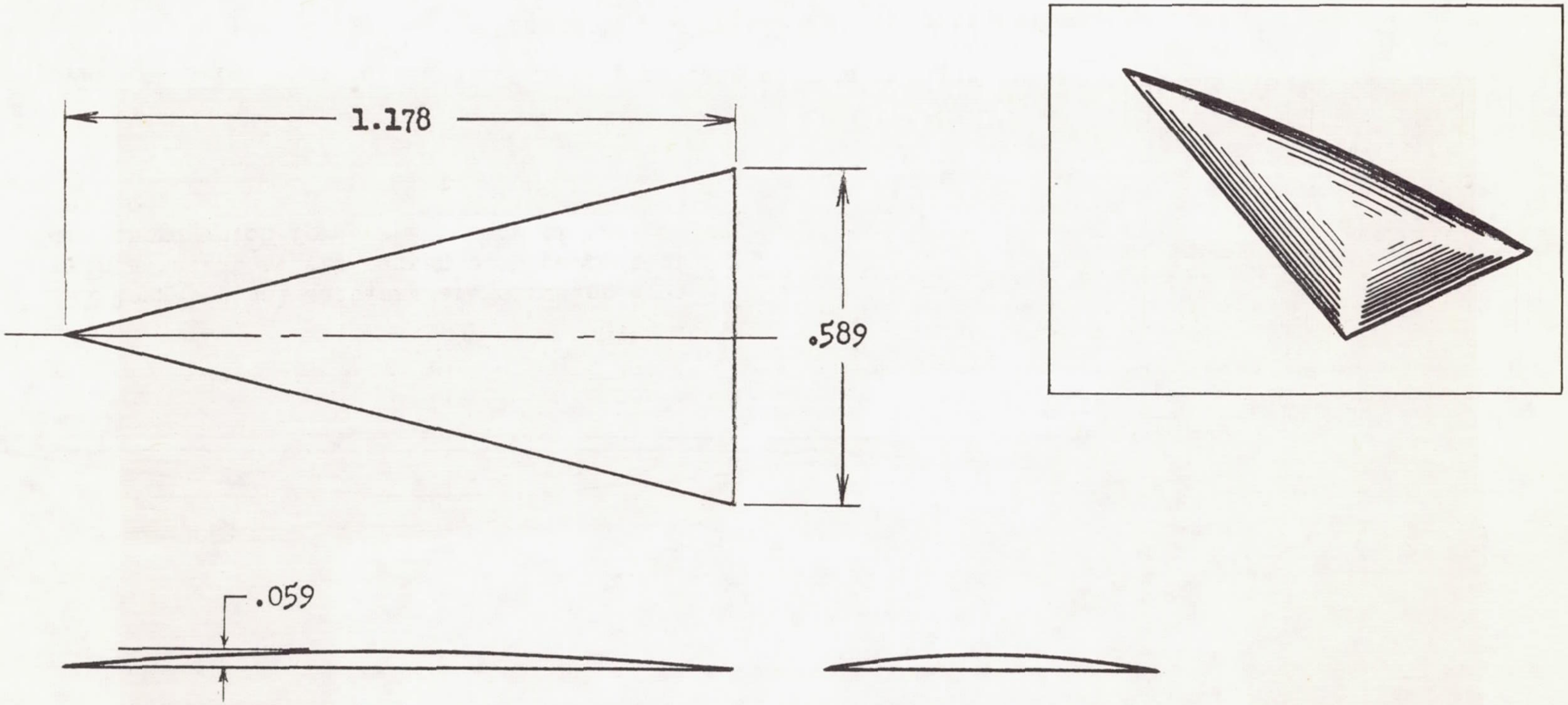


Figure 2. - Details of rectangular planing surface with transverse bottom curvature (model 250B).
(All dimensions are in feet.)



All longitudinal sections are circular arcs with a height at the center of 5 percent of the chord which forms the bottom of the section.

Figure 3. - Details of triangular planing surface with flat bottom (model 250D). (All dimensions are in feet.)

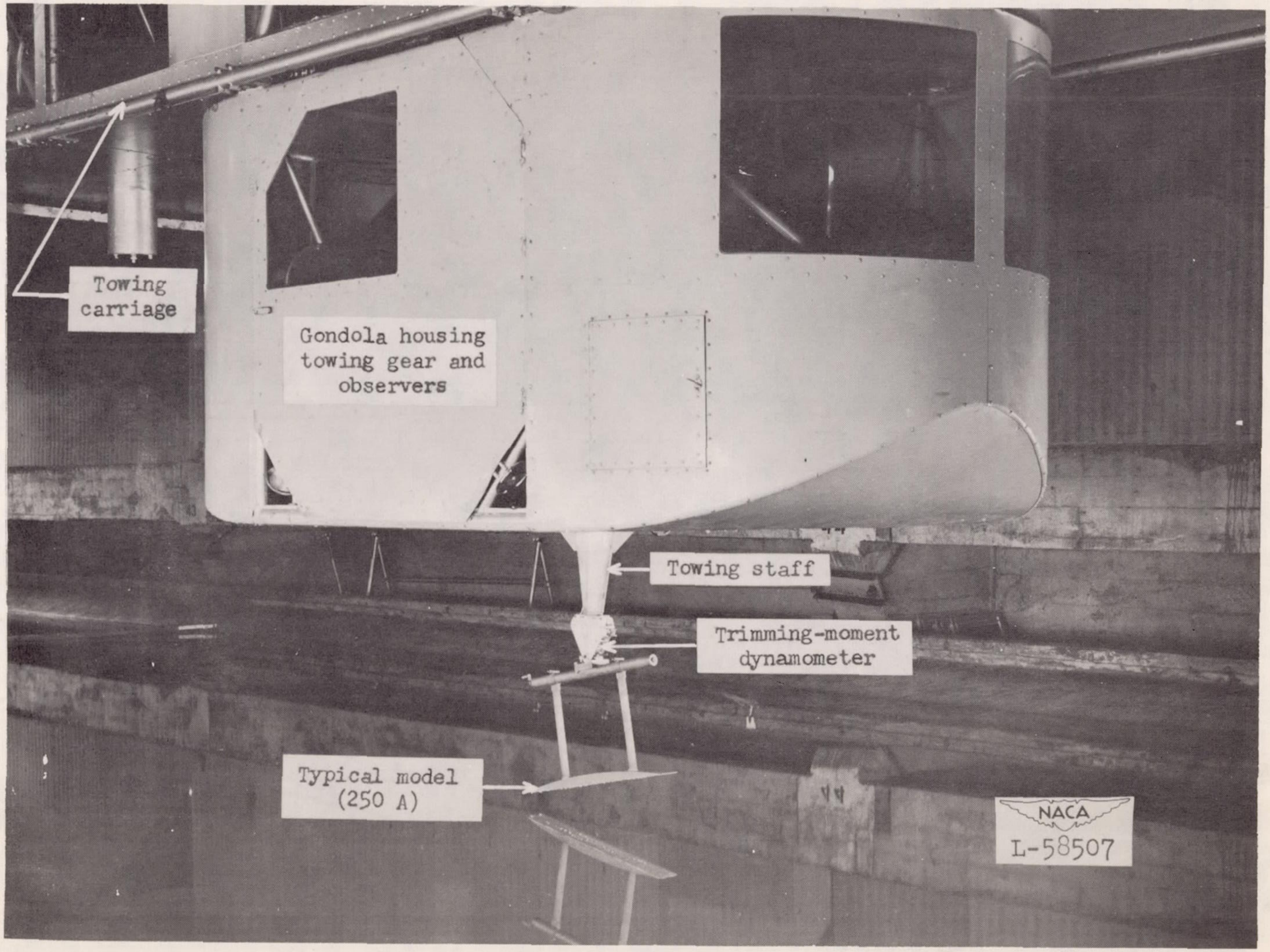
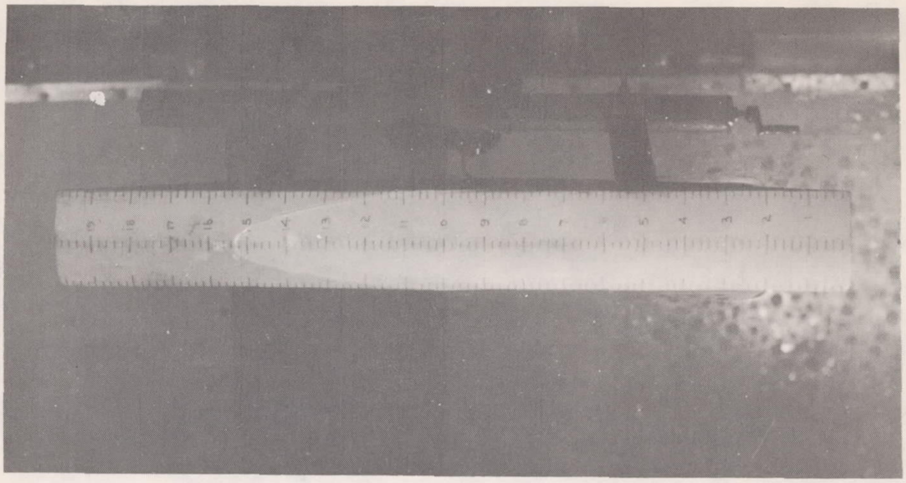
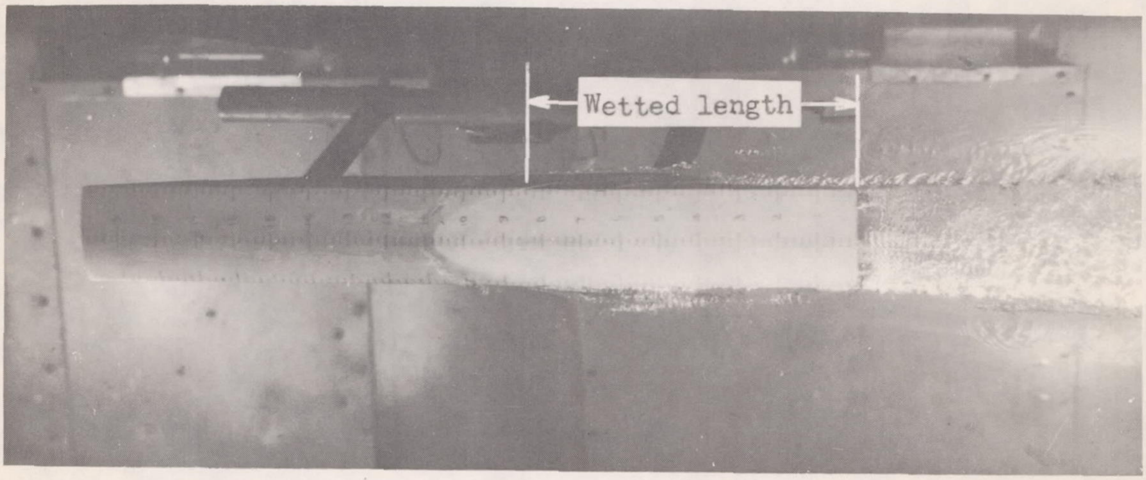


Figure 4. - Photograph of test set-up.

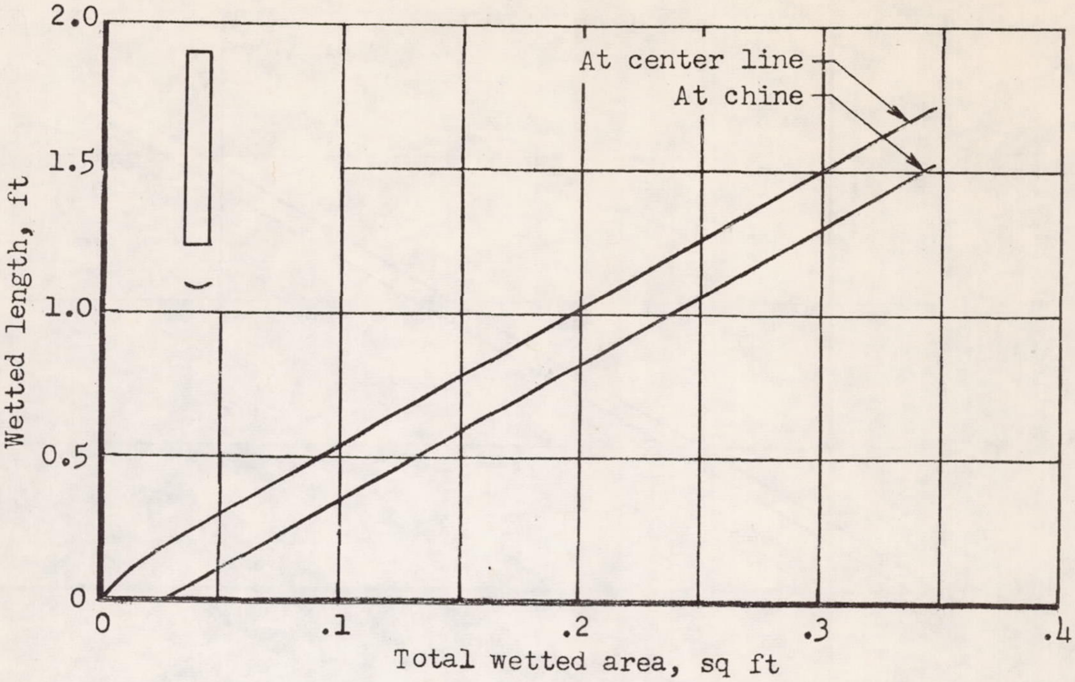


Typical static waterline.

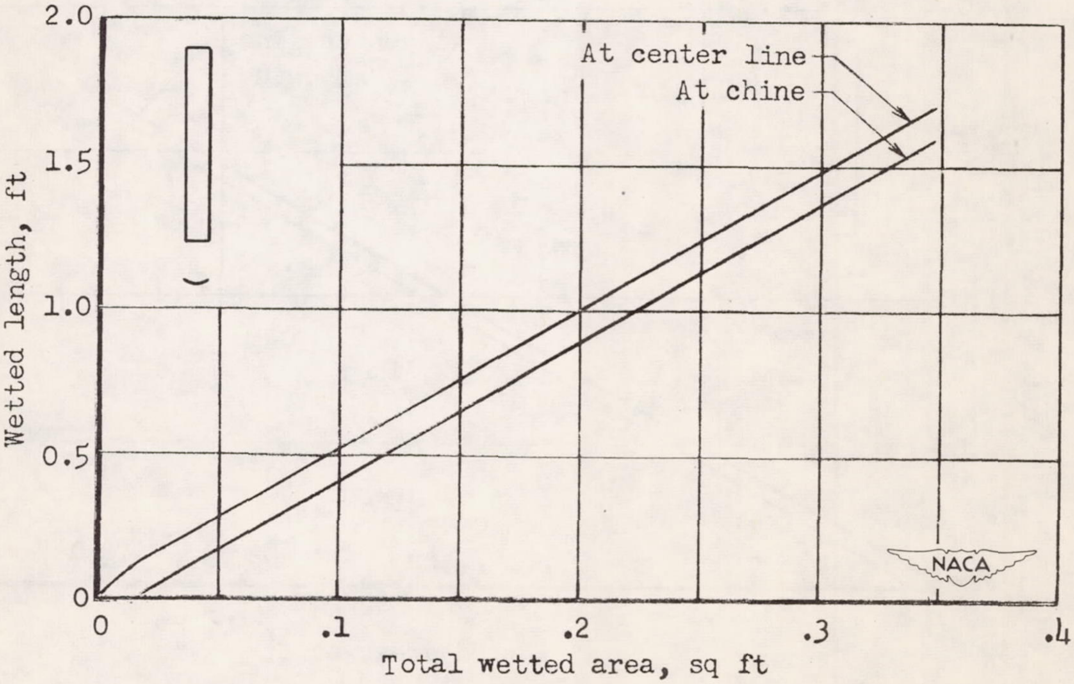


Typical dynamic waterline.

Figure 5. - Underwater photographs of model 250B at trim of 4°.

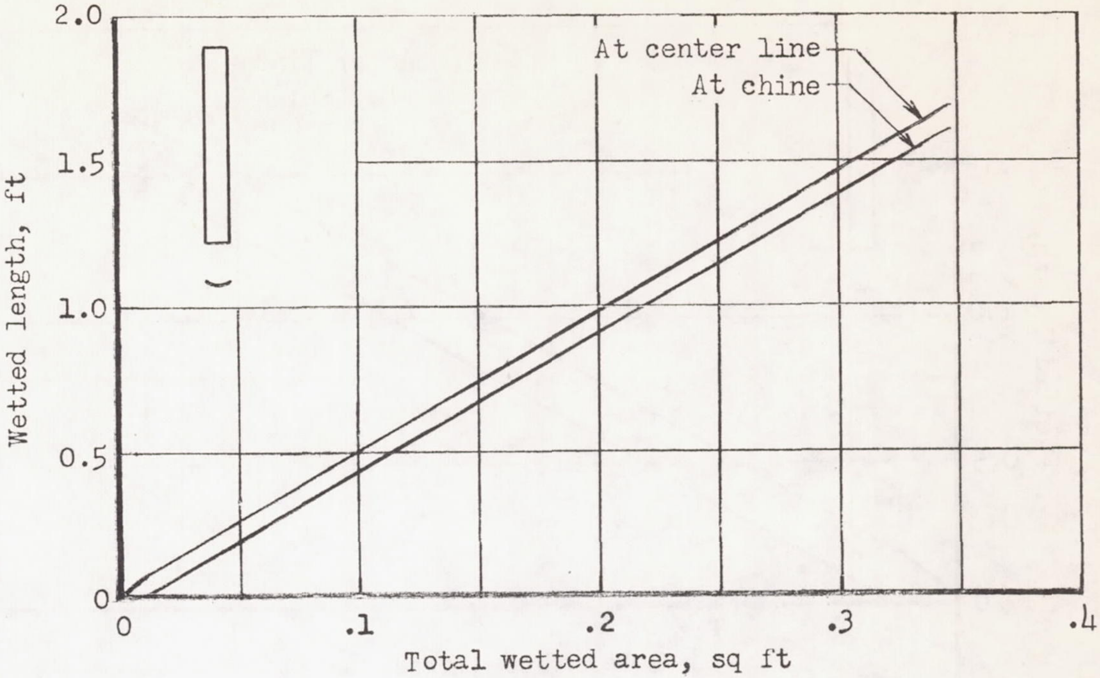


(a) $\tau = 4^{\circ}$.

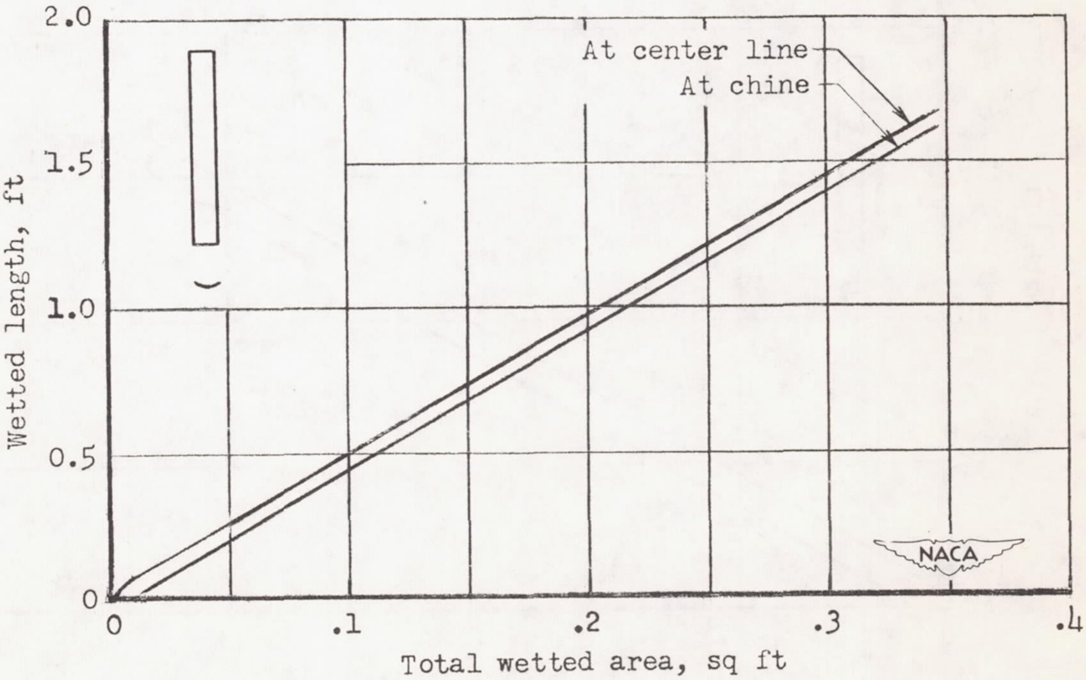


(b) $\tau = 8^{\circ}$.

Figure 6.- Variation of wetted lengths at chine and at model centerline with wetted area for model 250B.

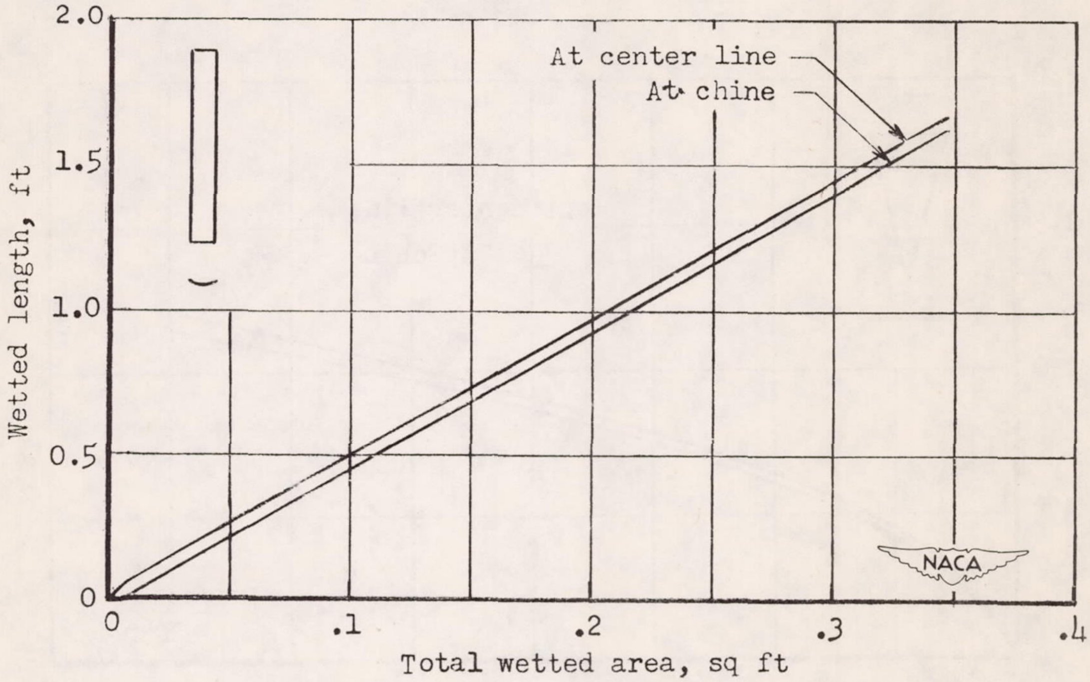


(c) τ = 12°.



(d) τ = 16°.

Figure 6 .- Continued.



(e) $\tau = 20^{\circ}$.

Figure 6 .- Concluded.

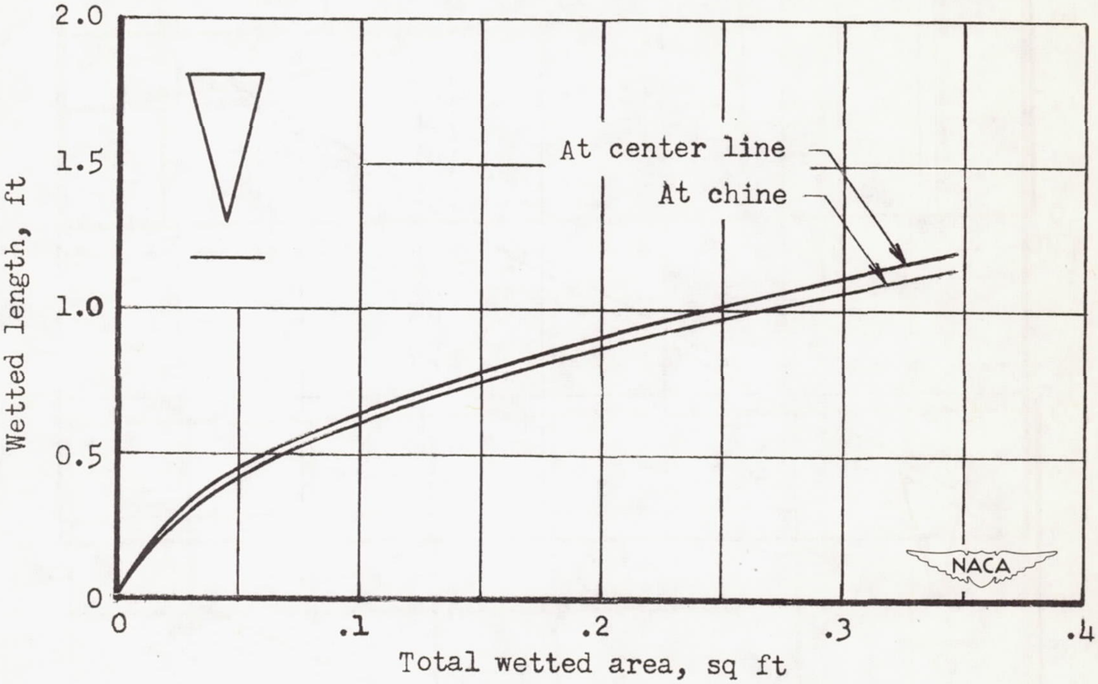
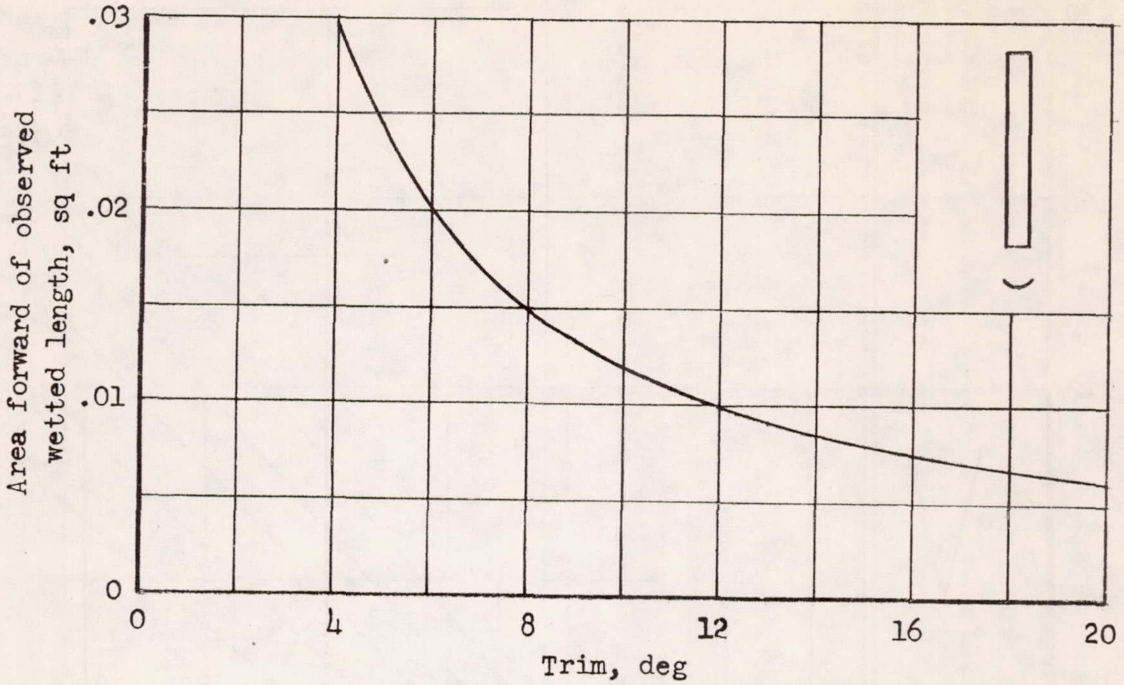
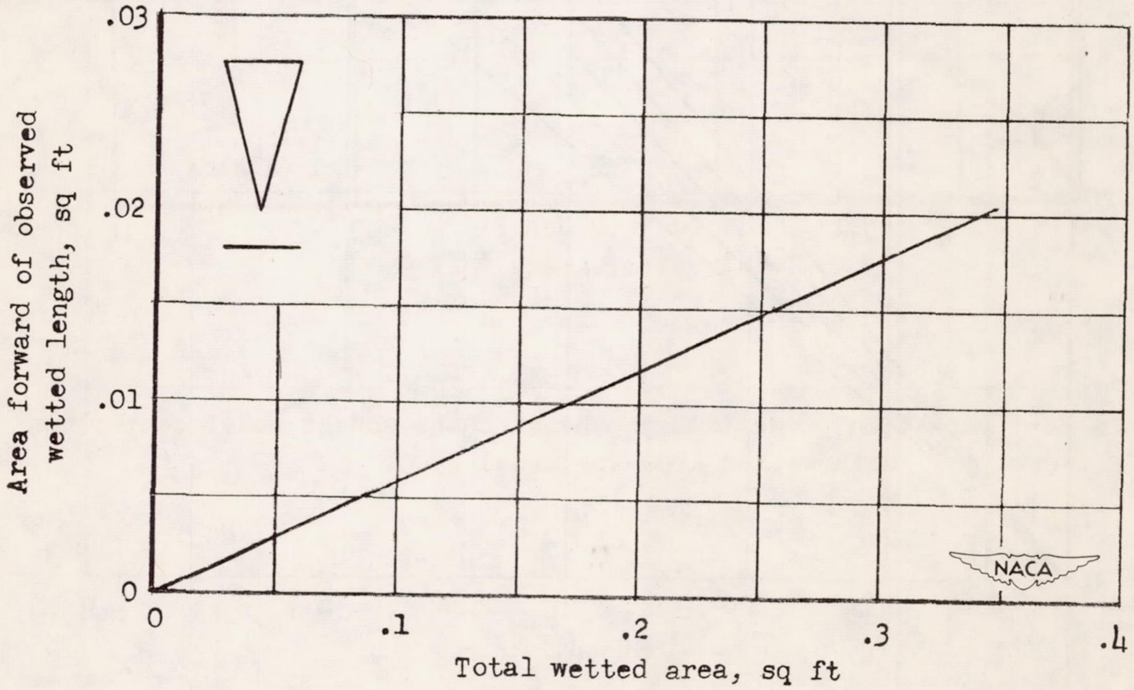


Figure 7.- Variation of wetted lengths at chine and at model centerline with wetted area for model 250D.



(a) Model 250B.



(b) Model 250D.

Figure 8.- Wetted area forward of the observed wetted length for models 250B and 250D.

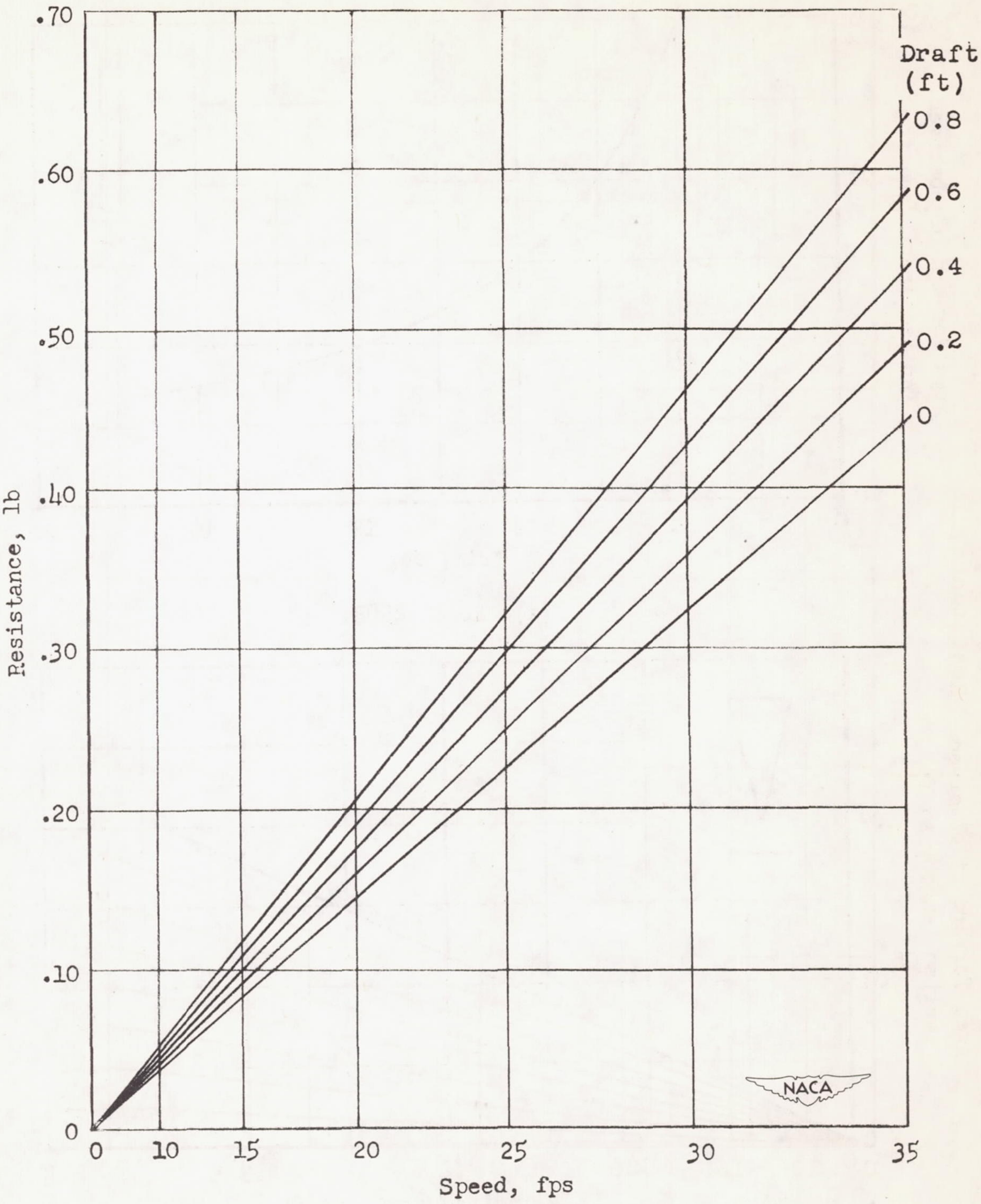


Figure 9.- Aerodynamic drag of towing gear less model.

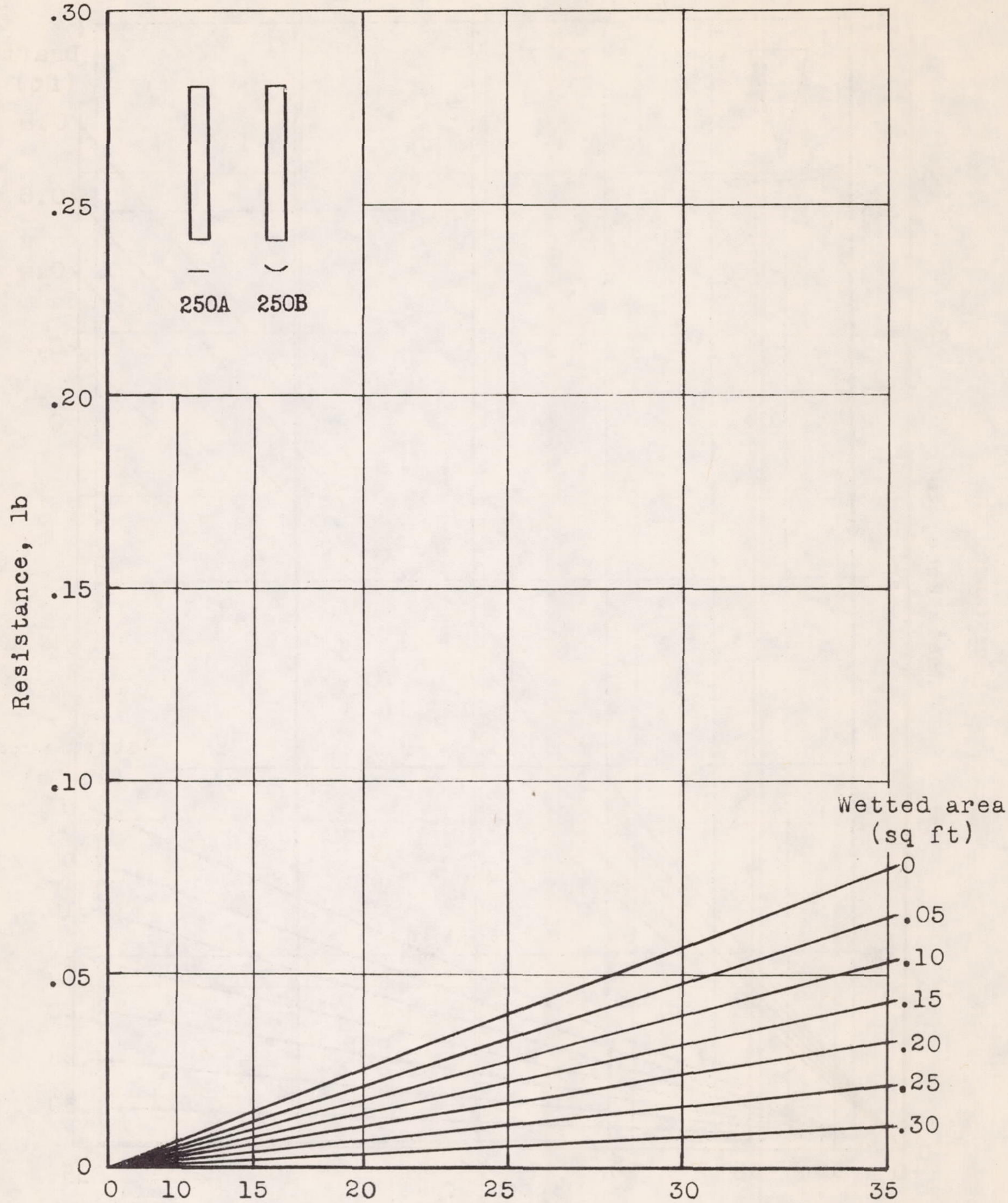
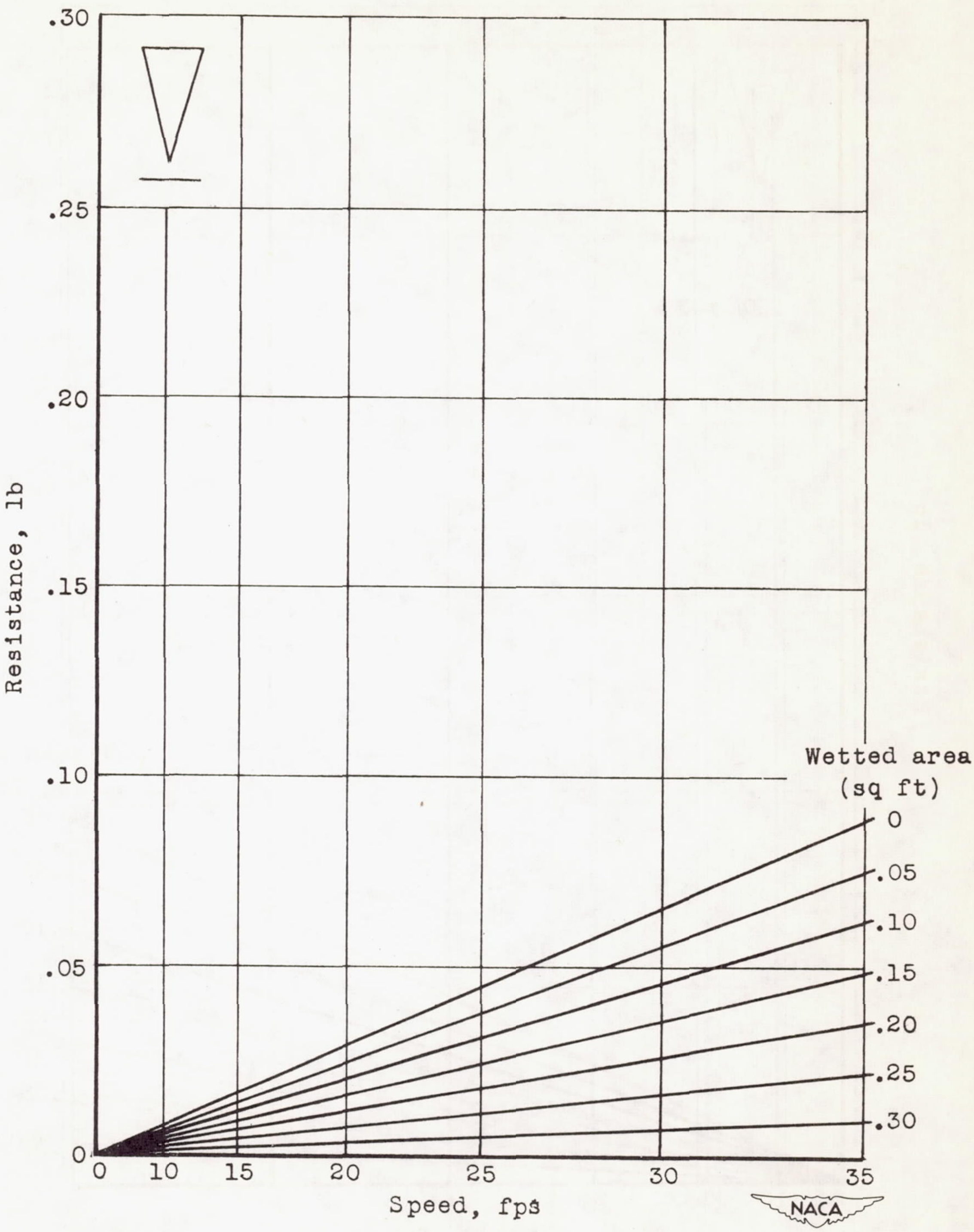
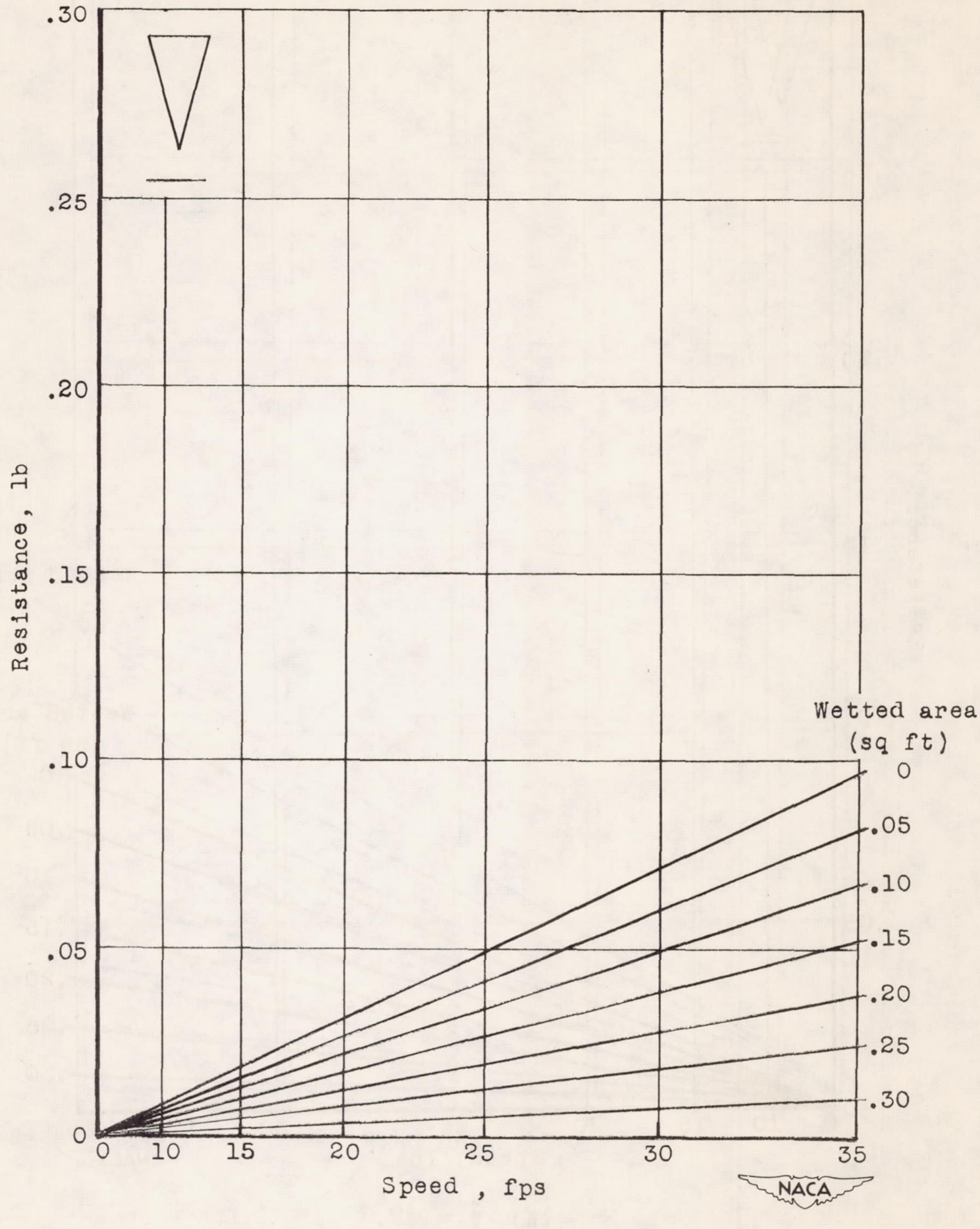


Figure 10.- Aerodynamic drag of models 250A and 250B.



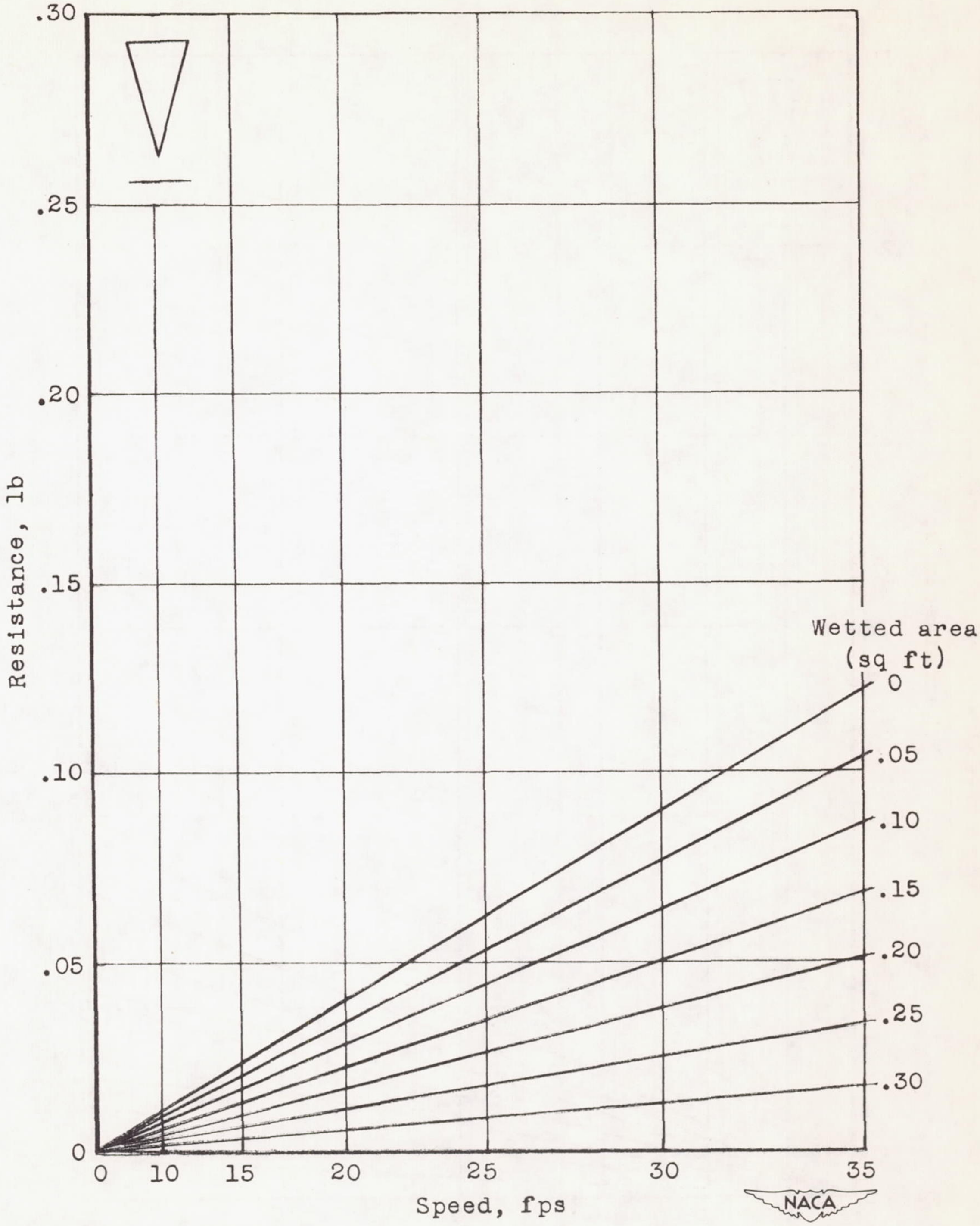
(a) $\tau = 4^{\circ}$.

Figure 11.- Aerodynamic drag of model 250D.



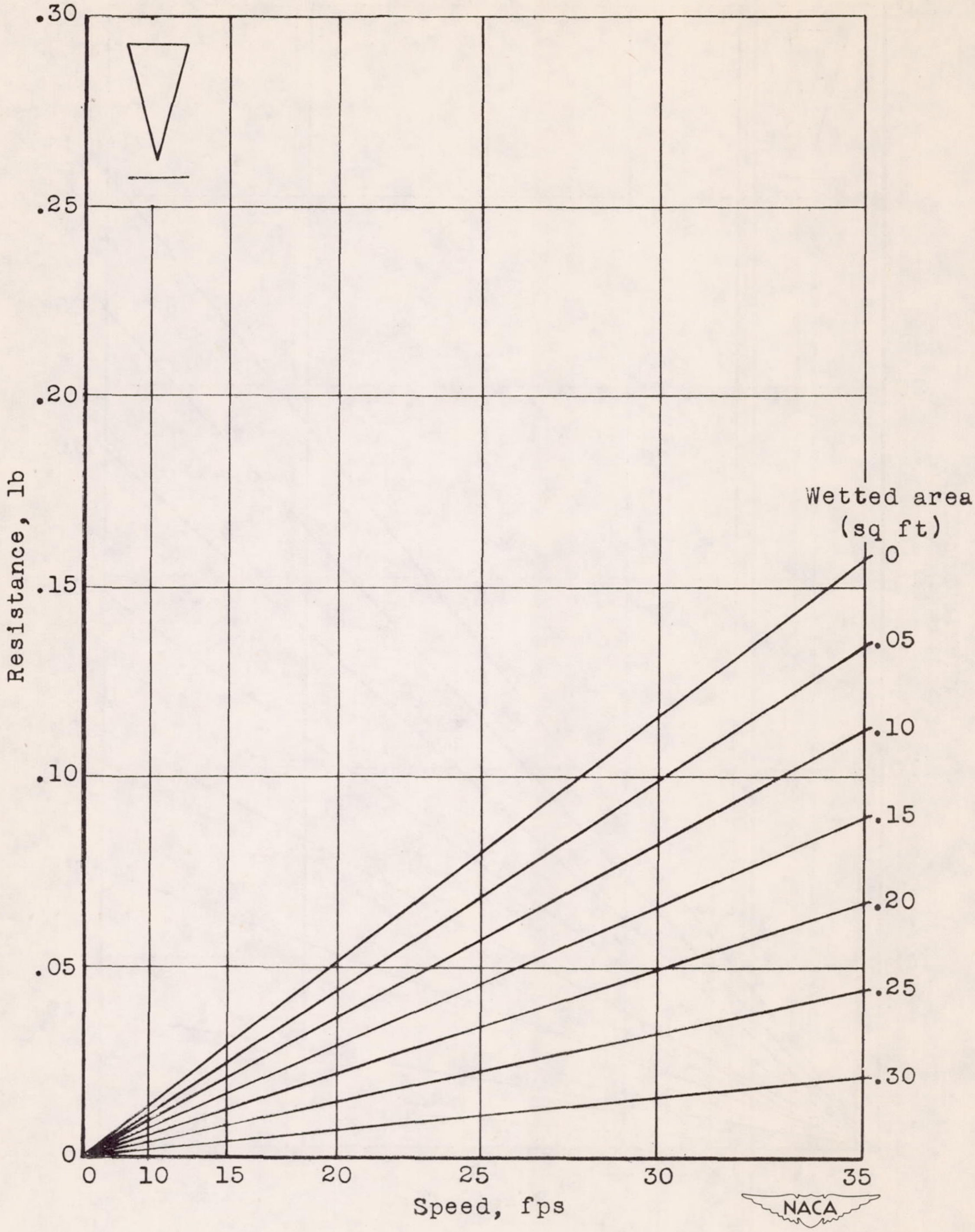
(b) $\tau = 8^{\circ}$.

Figure 11.- Continued.



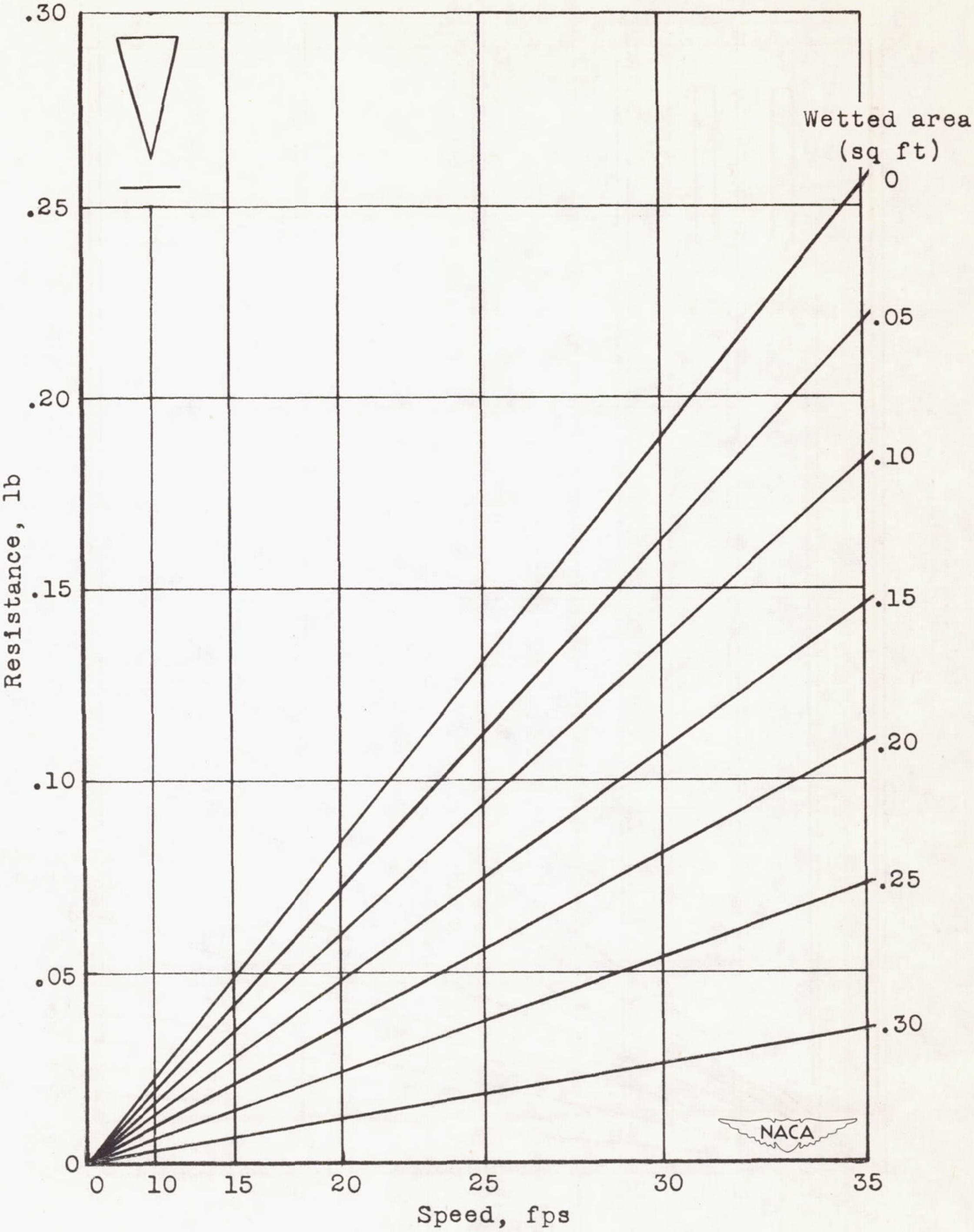
(c) $\tau = 12^{\circ}$.

Figure 11.- Continued.



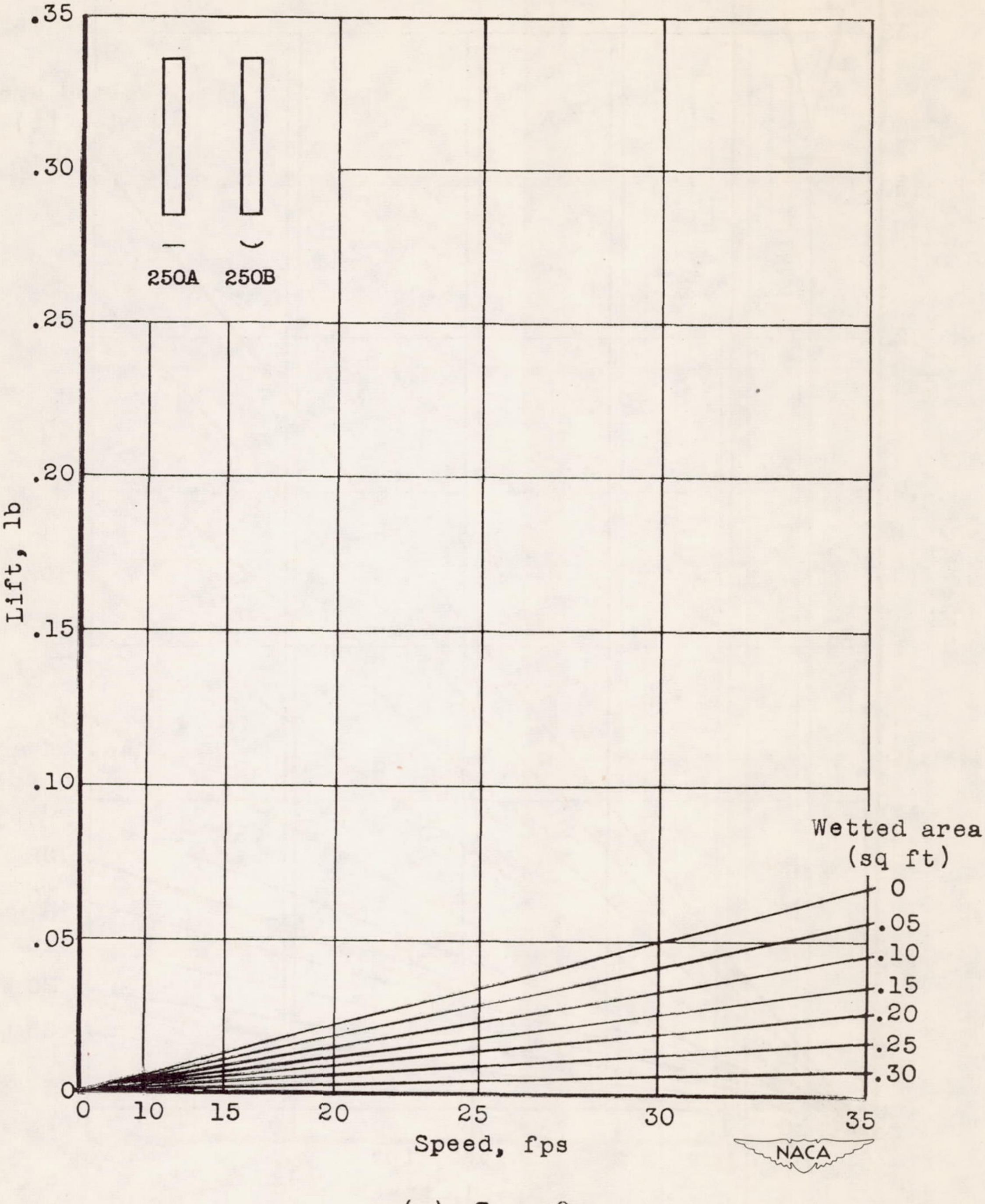
(d) $\tau = 16^{\circ}$.

Figure 11.- Continued.



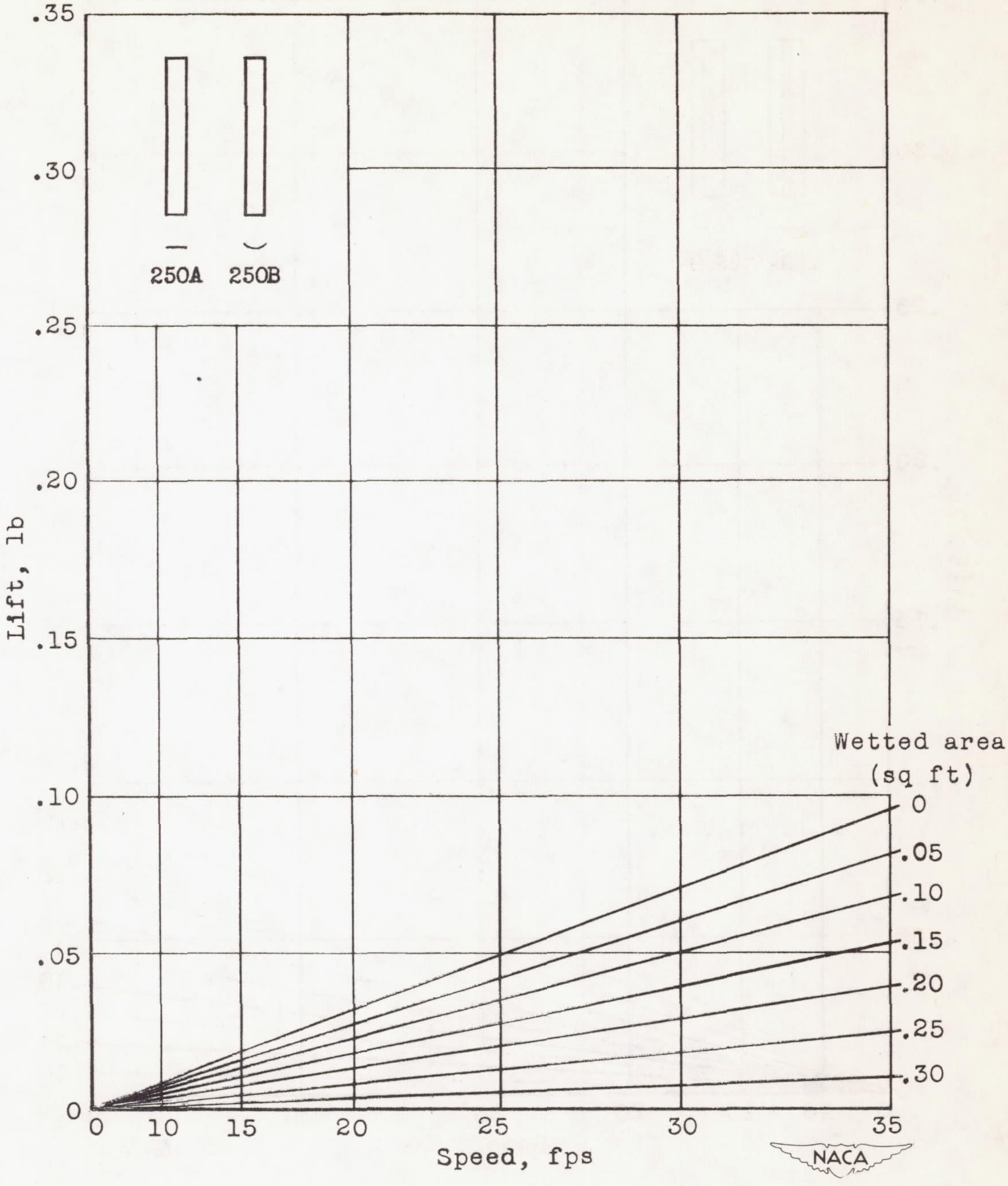
(e) $\tau = 20^{\circ}$.

Figure 11.- Concluded.



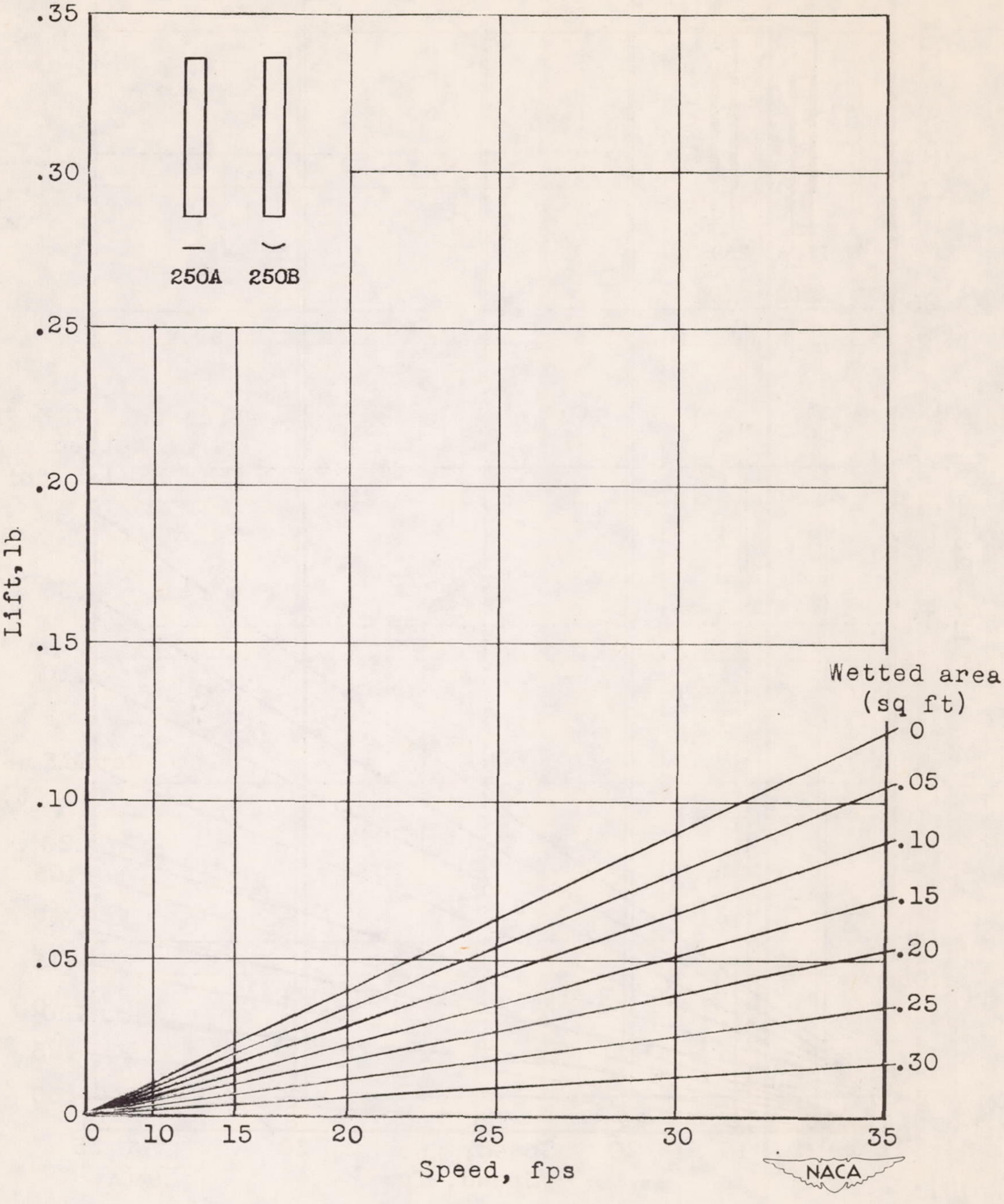
(a) $\tau = 8^{\circ}$.

Figure 12.- Aerodynamic lift of models 250A and 250B.



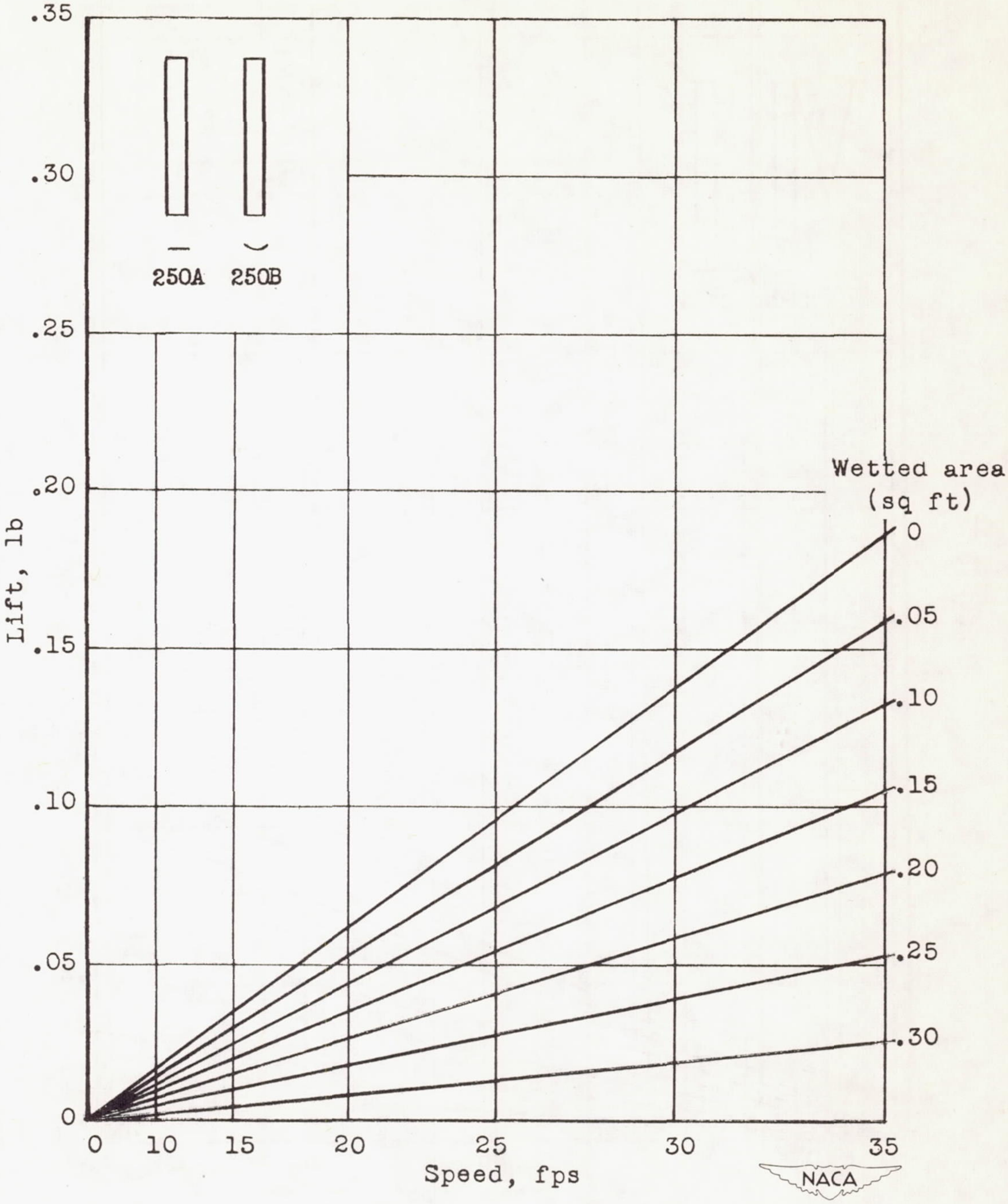
(b) $\tau = 12^{\circ}$.

Figure 12.- Continued.



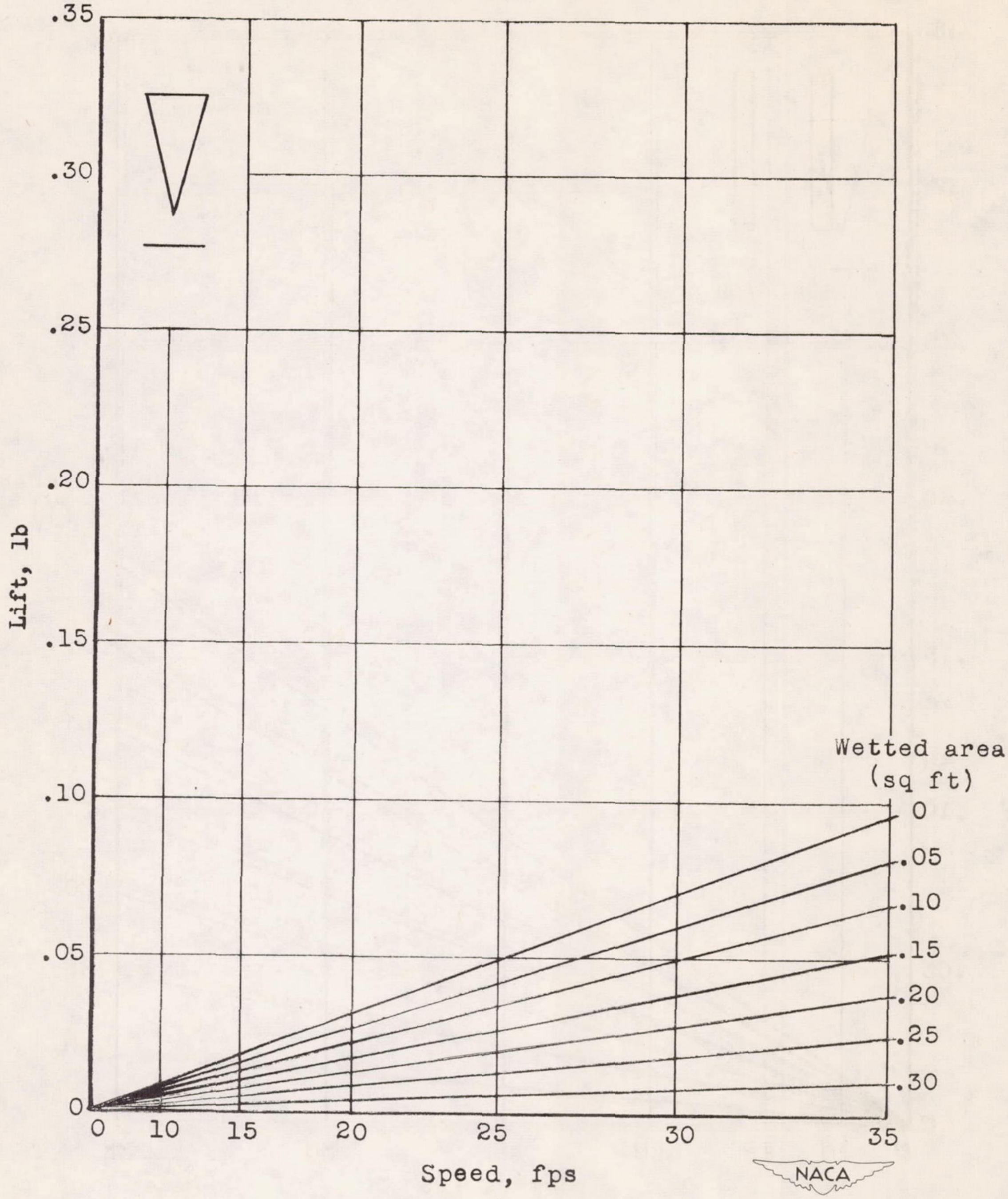
(c) $\tau = 16^{\circ}$.

Figure 12.- Continued.



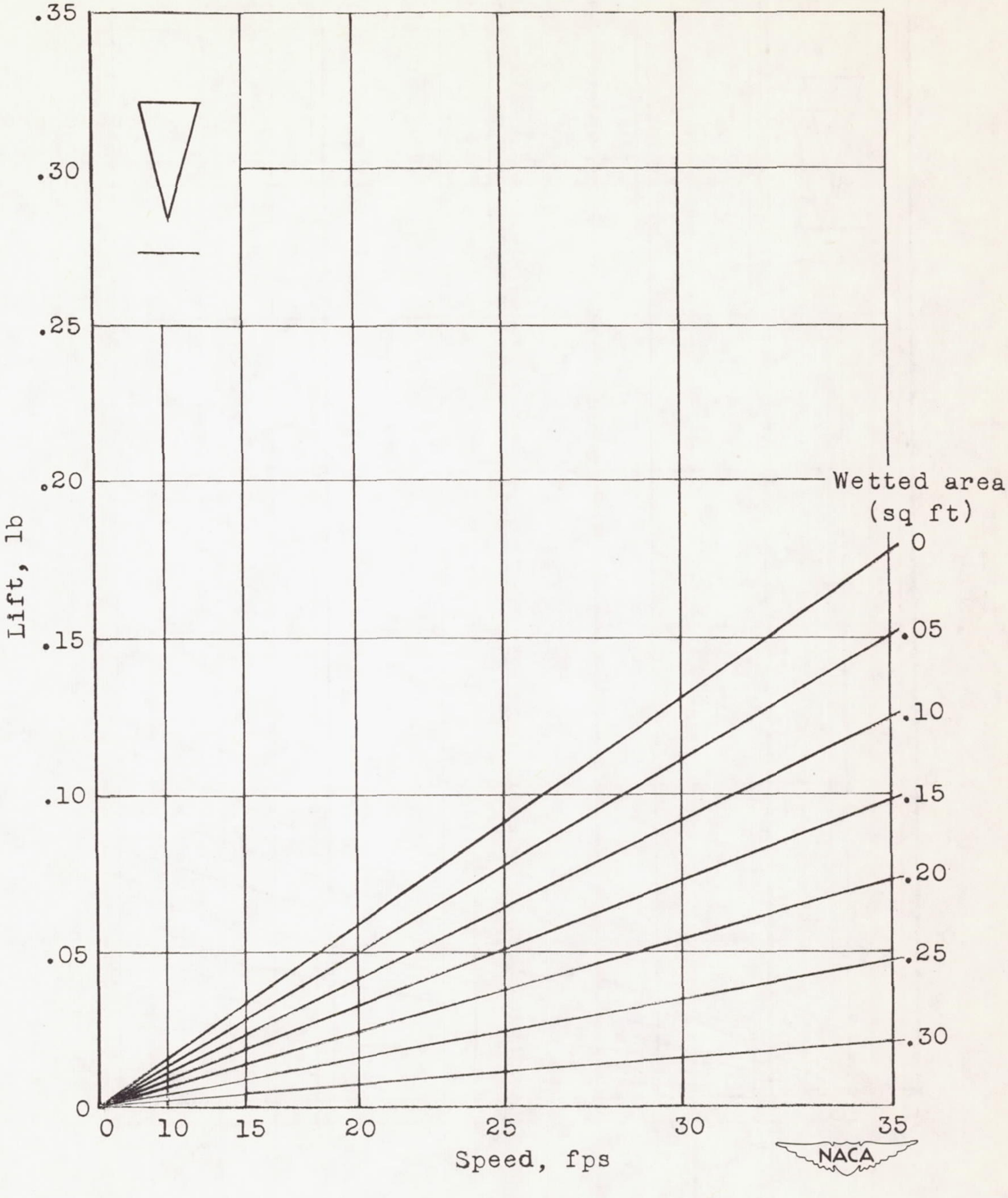
(d) $\tau = 20^{\circ}$.

Figure 12.- Concluded.



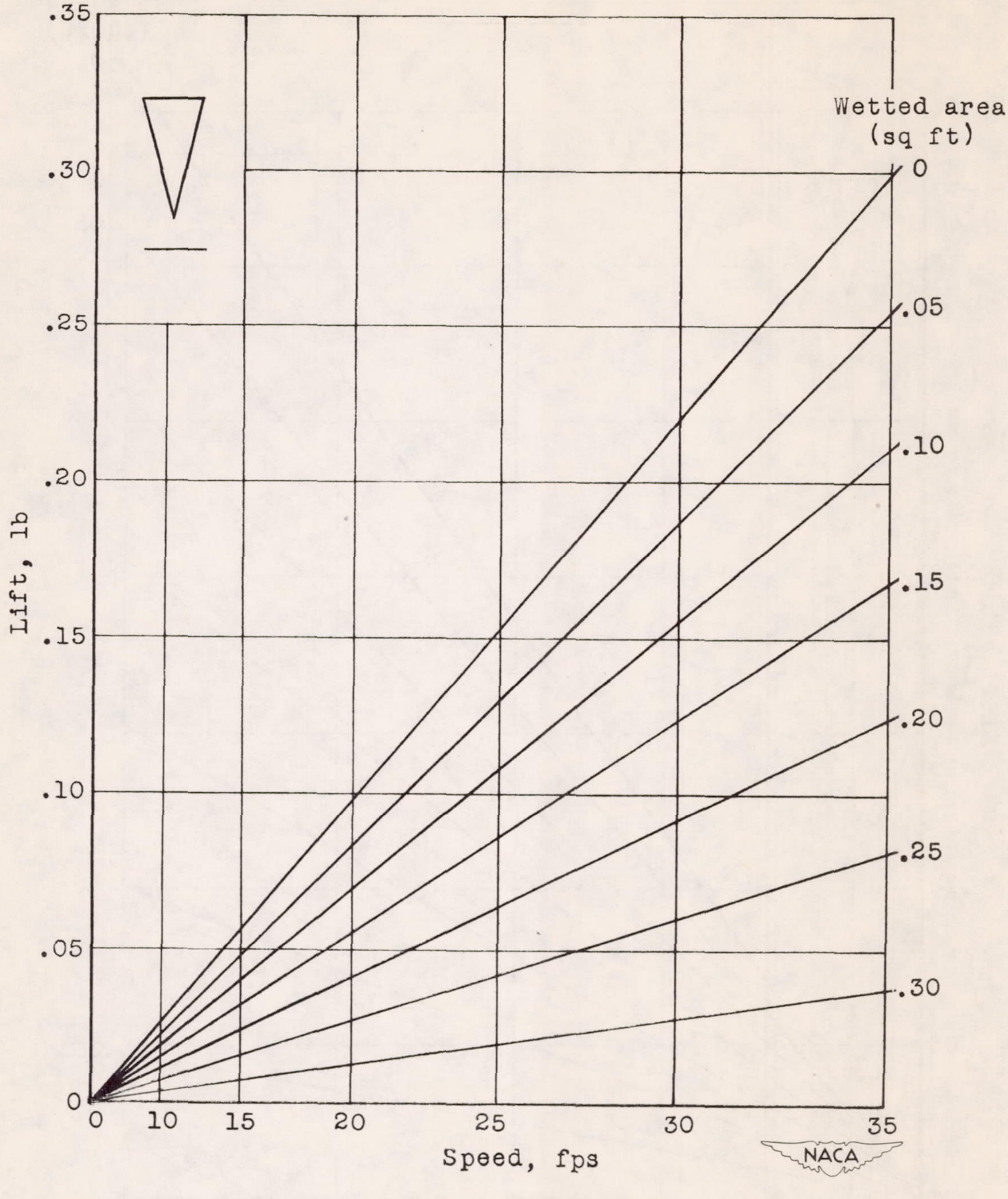
(a) $\tau = 8^{\circ}$.

Figure 13.- Aerodynamic lift of model 250D.



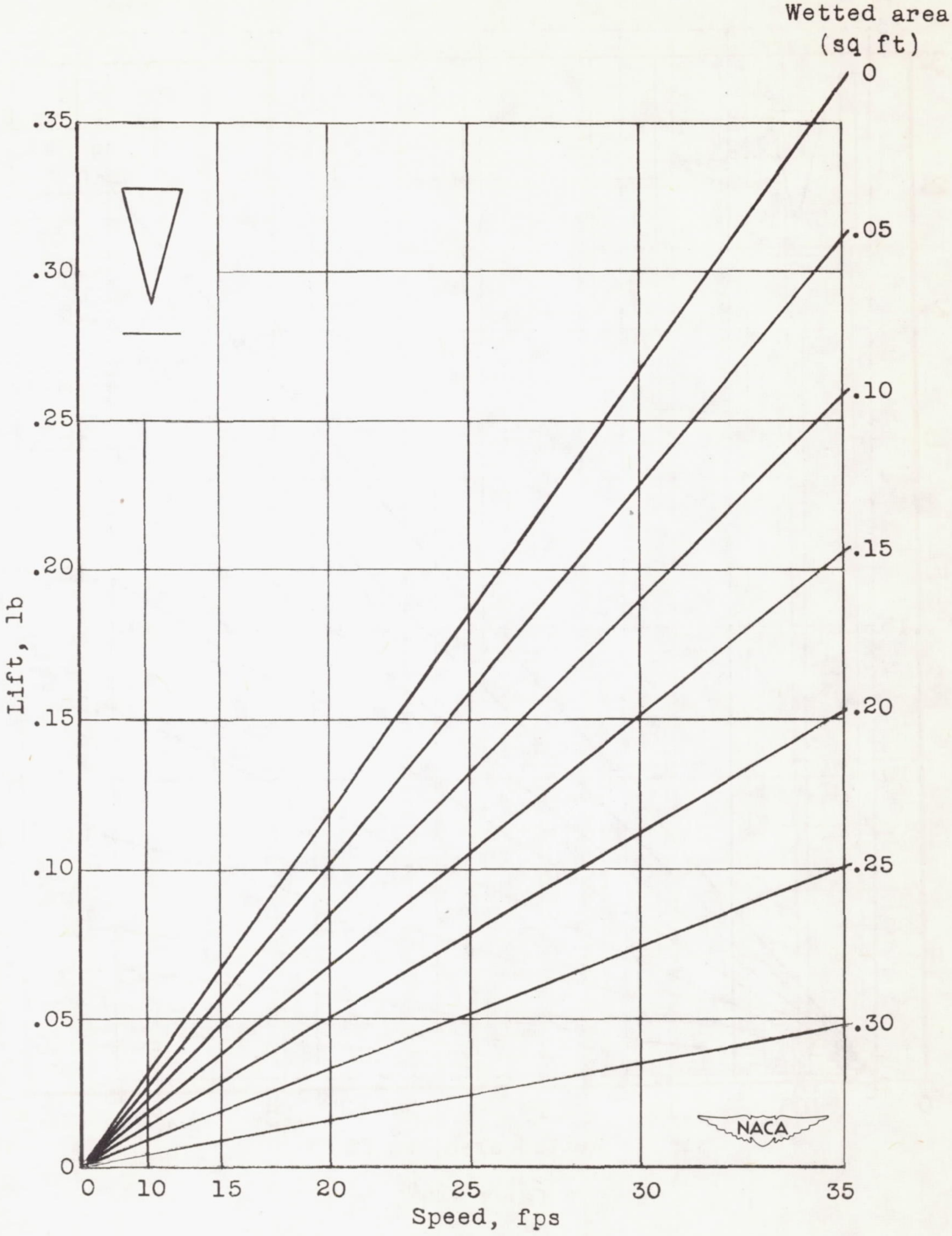
(b) $\tau = 12^\circ$.

Figure 13.- Continued.



(c) $\tau = 16^{\circ}$.

Figure 13.- Continued.



(d) $\tau = 20^{\circ}$.

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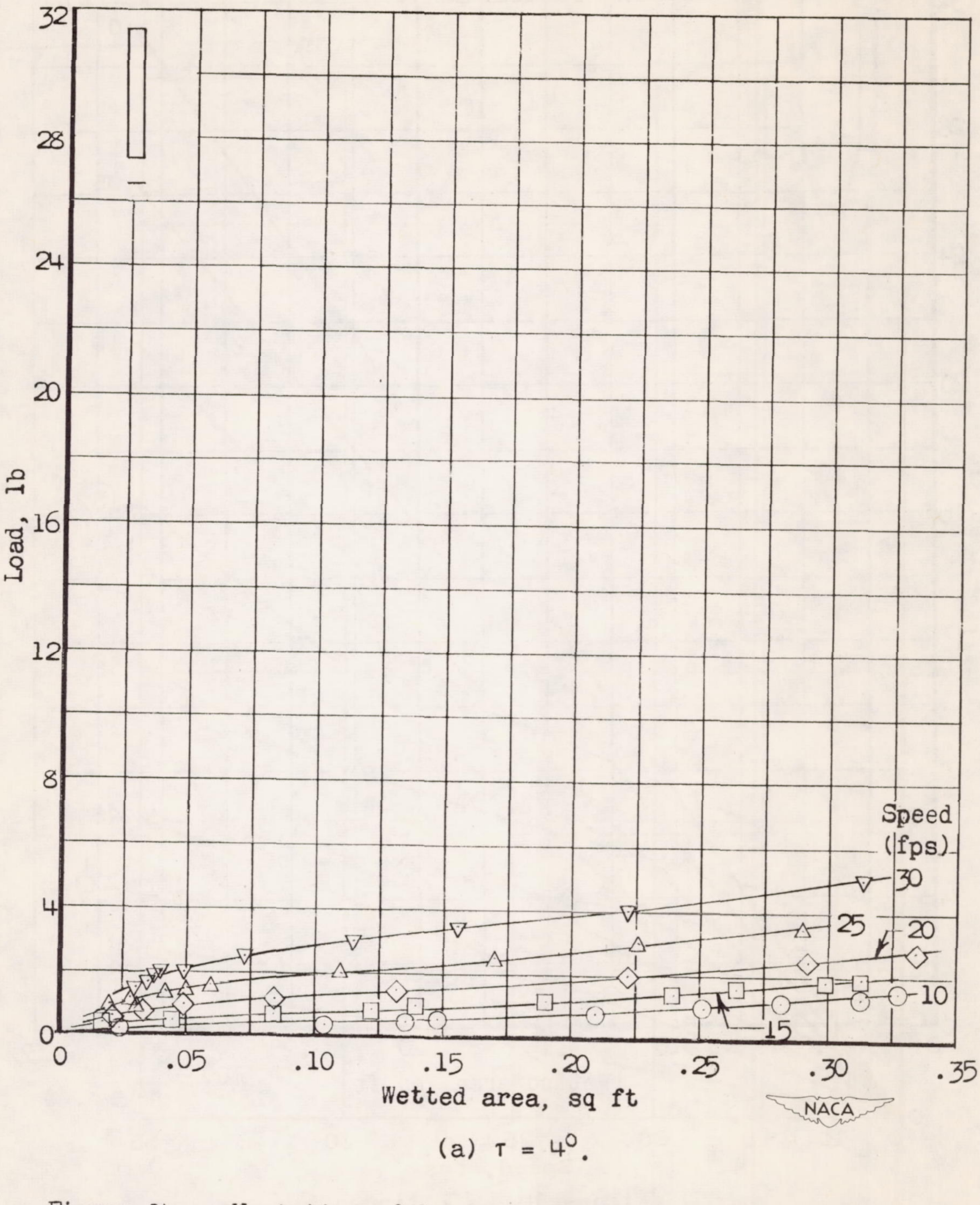
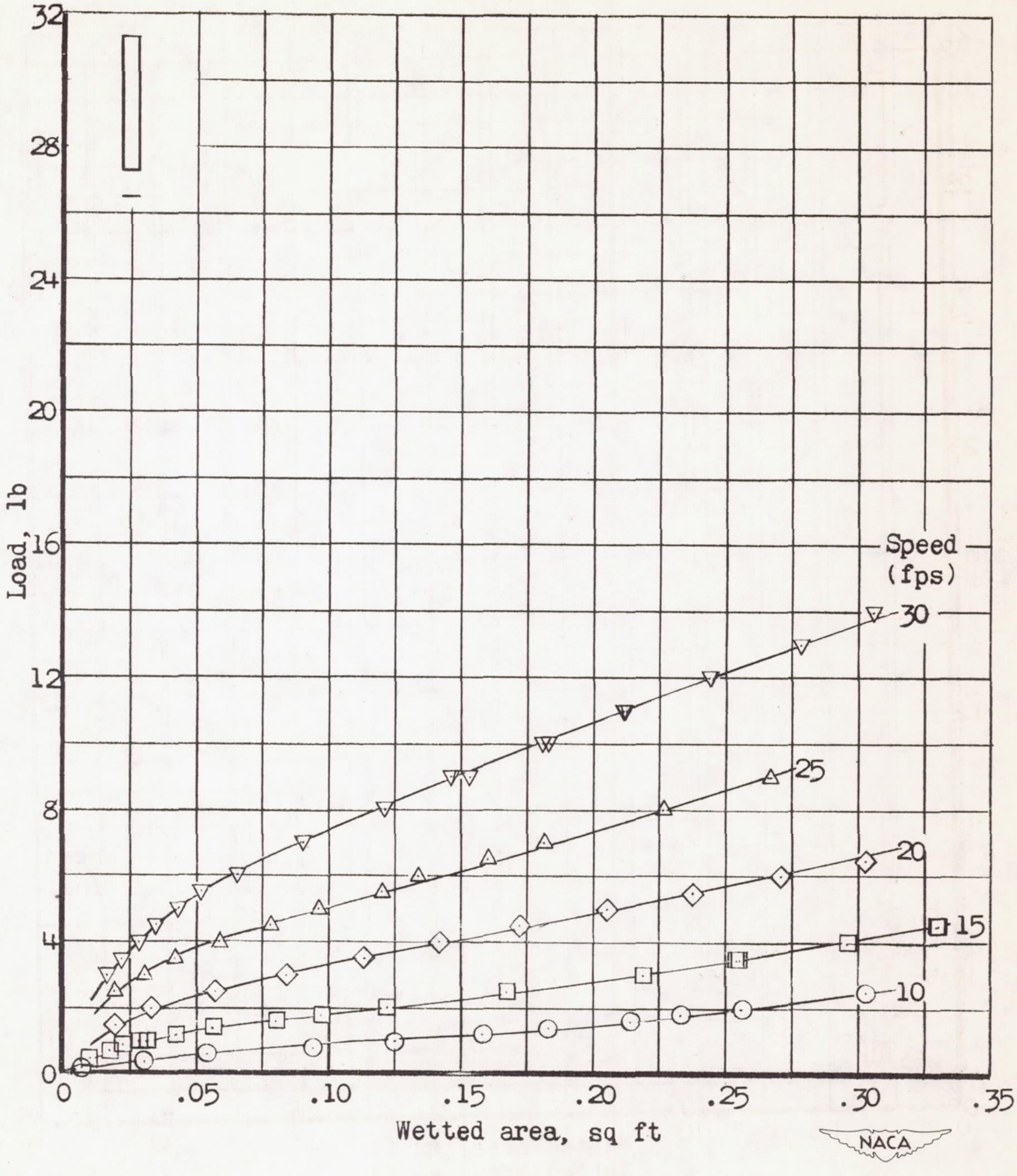


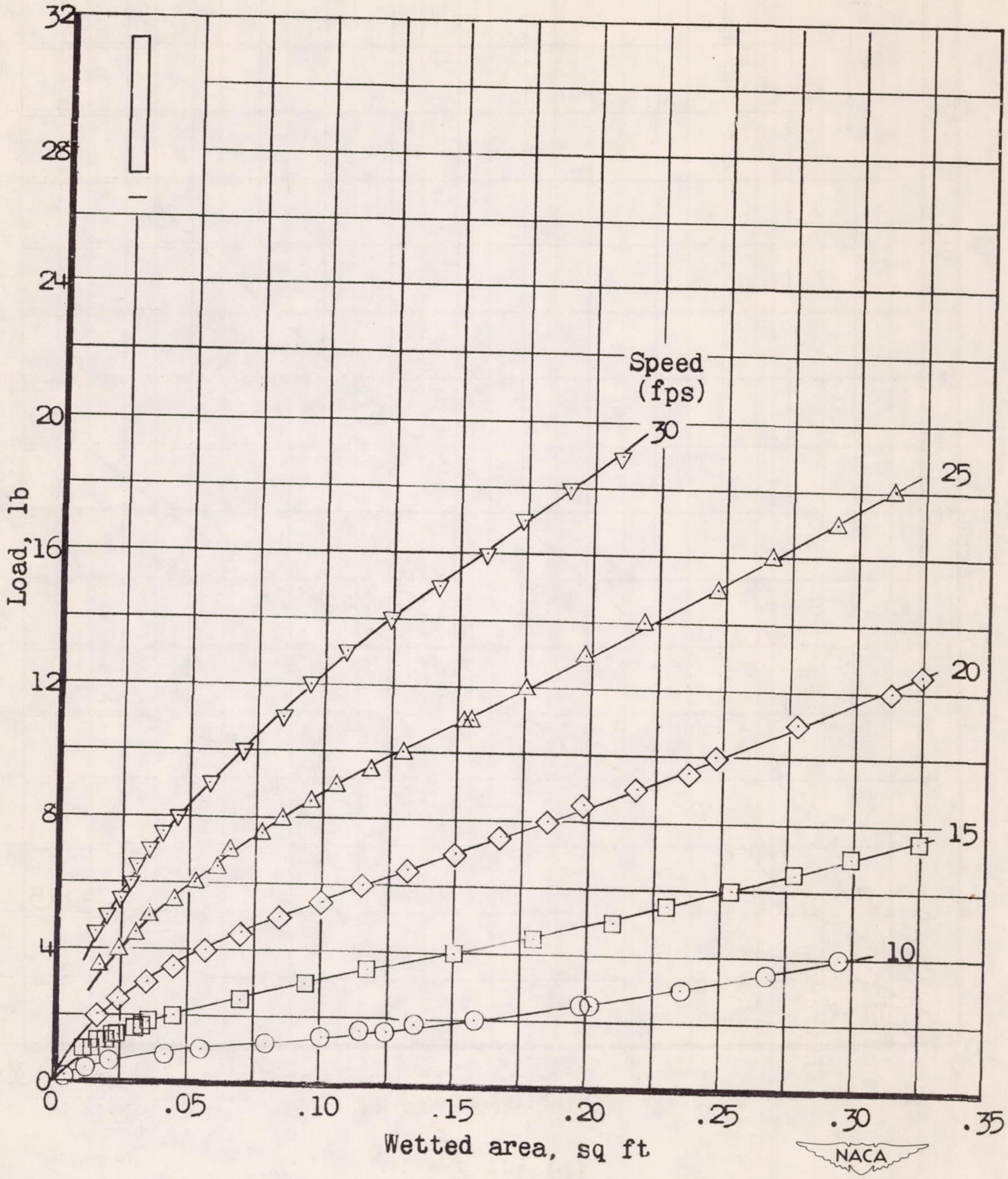
(a) $\tau = 4^{\circ}$.

Figure 14.- Variation of load with wetted area. Model 250A.



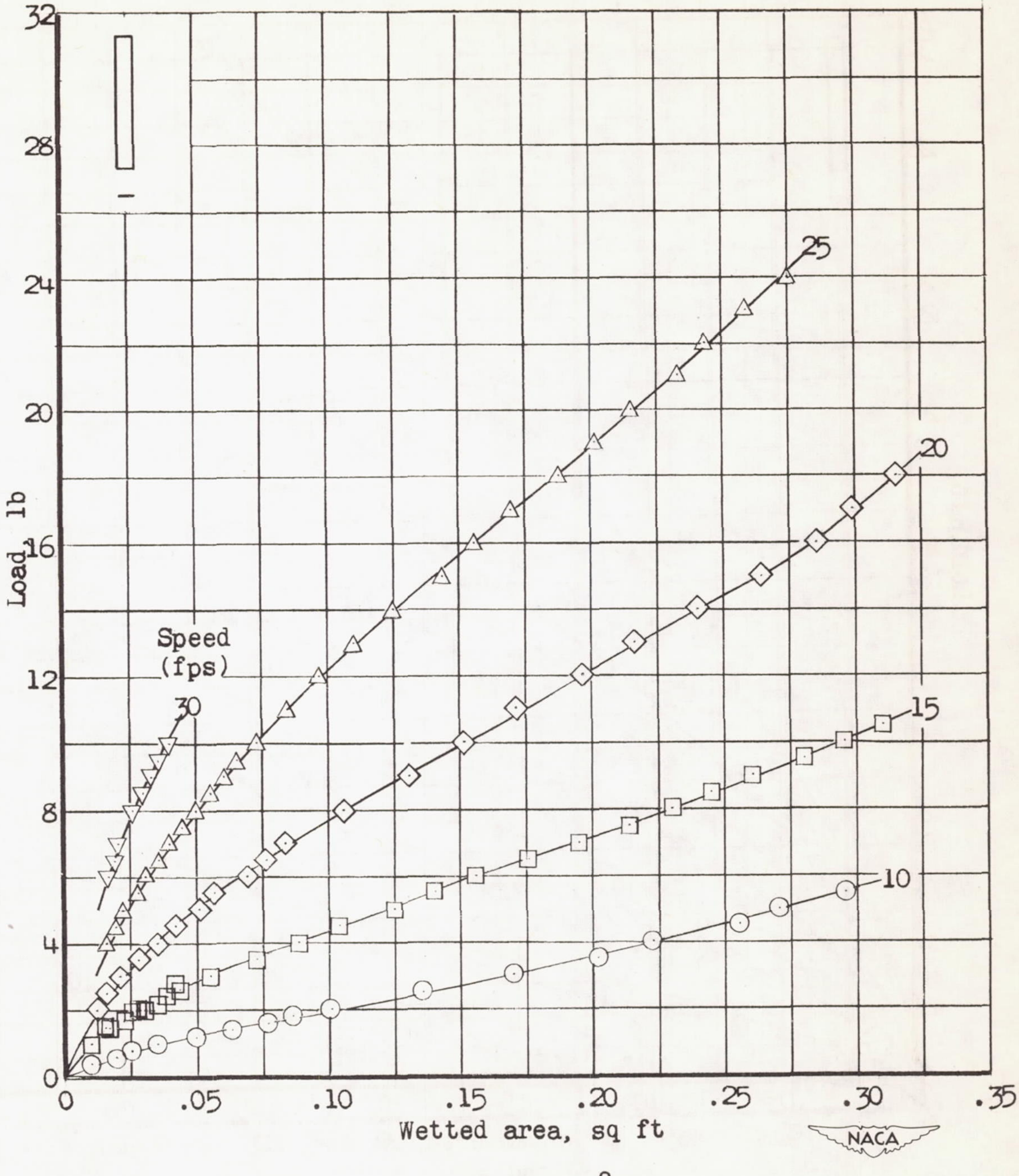
(b) $\tau = 8^{\circ}$.

Figure 14.- Continued.



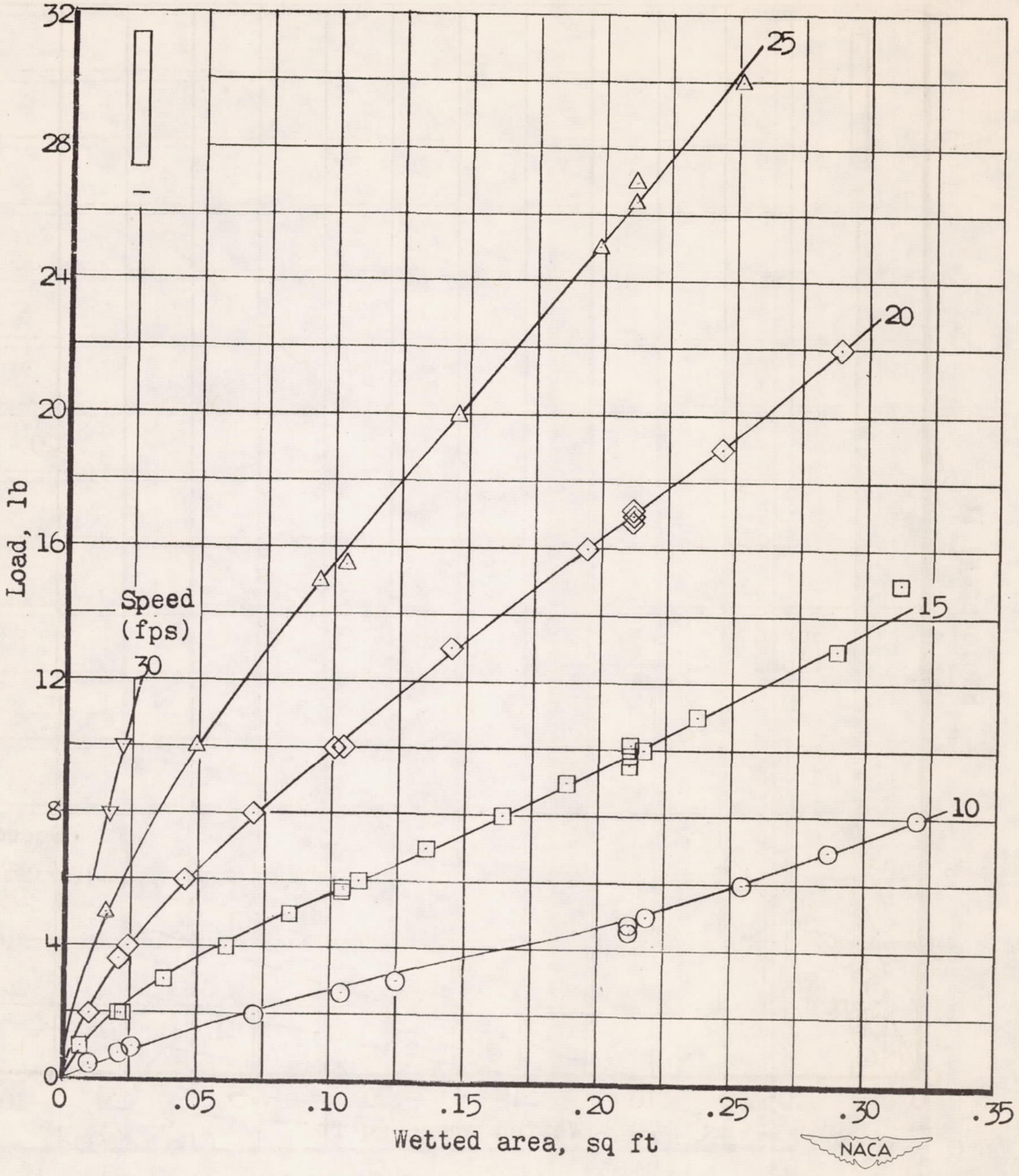
(c) $\tau = 12^{\circ}$.

Figure 14.- Continued.



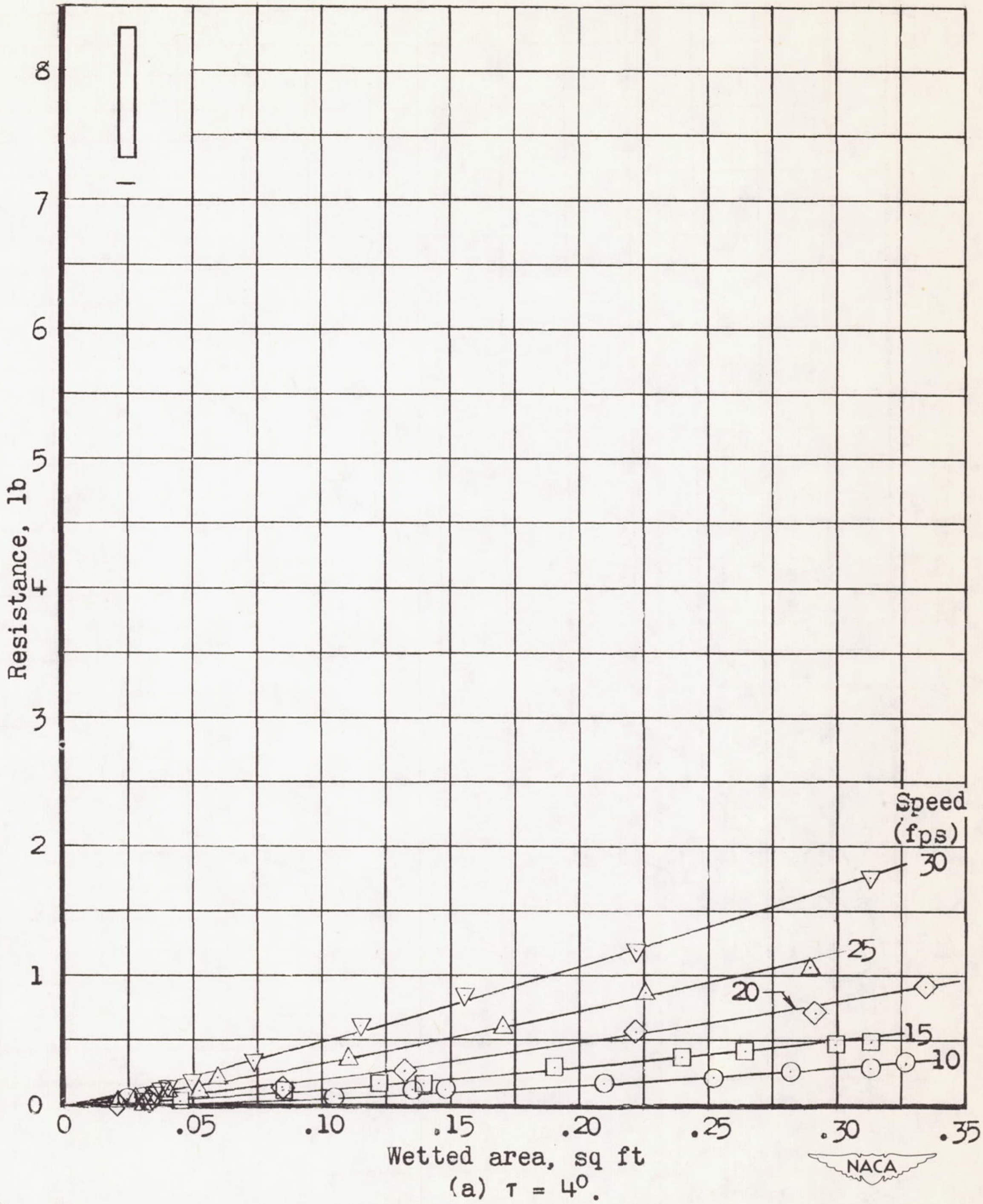
(d) $\tau = 16^{\circ}$.

Figure 14.- Continued.



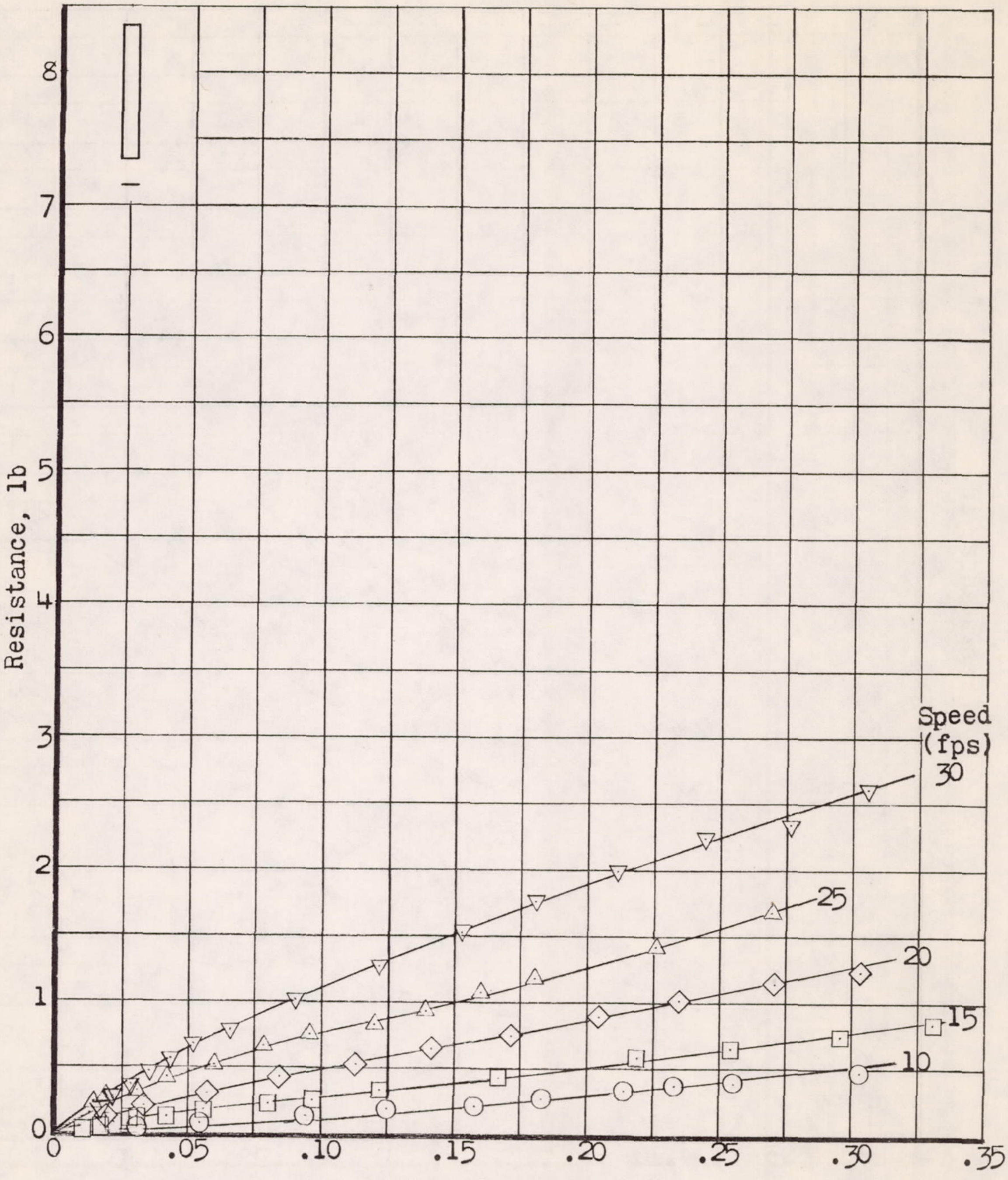
(e) $\tau = 20^{\circ}$.

Figure 14.- Concluded.



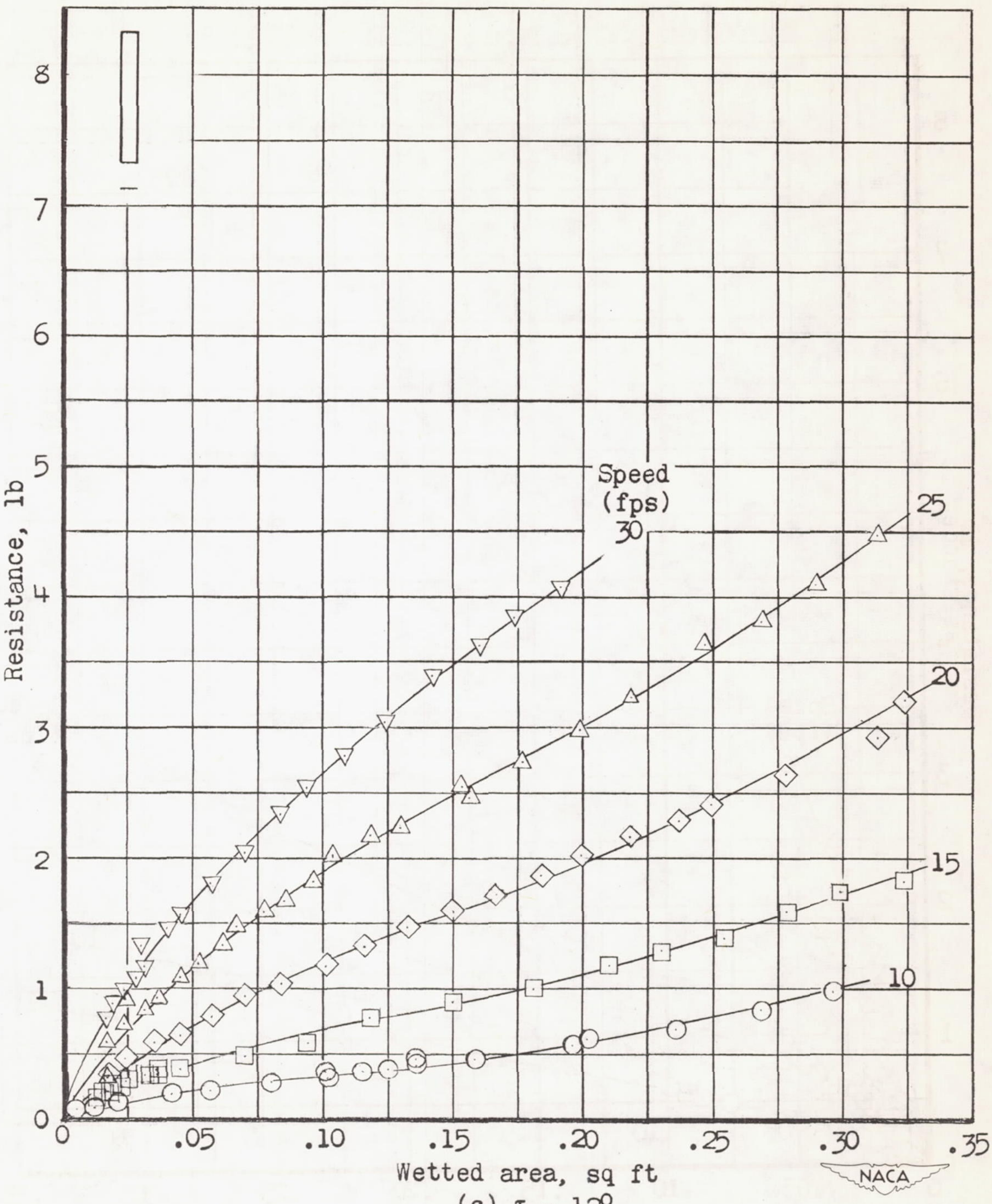
(a) $\tau = 4^{o}$.

Figure 15.- Variation of resistance with wetted area. Model 250A.



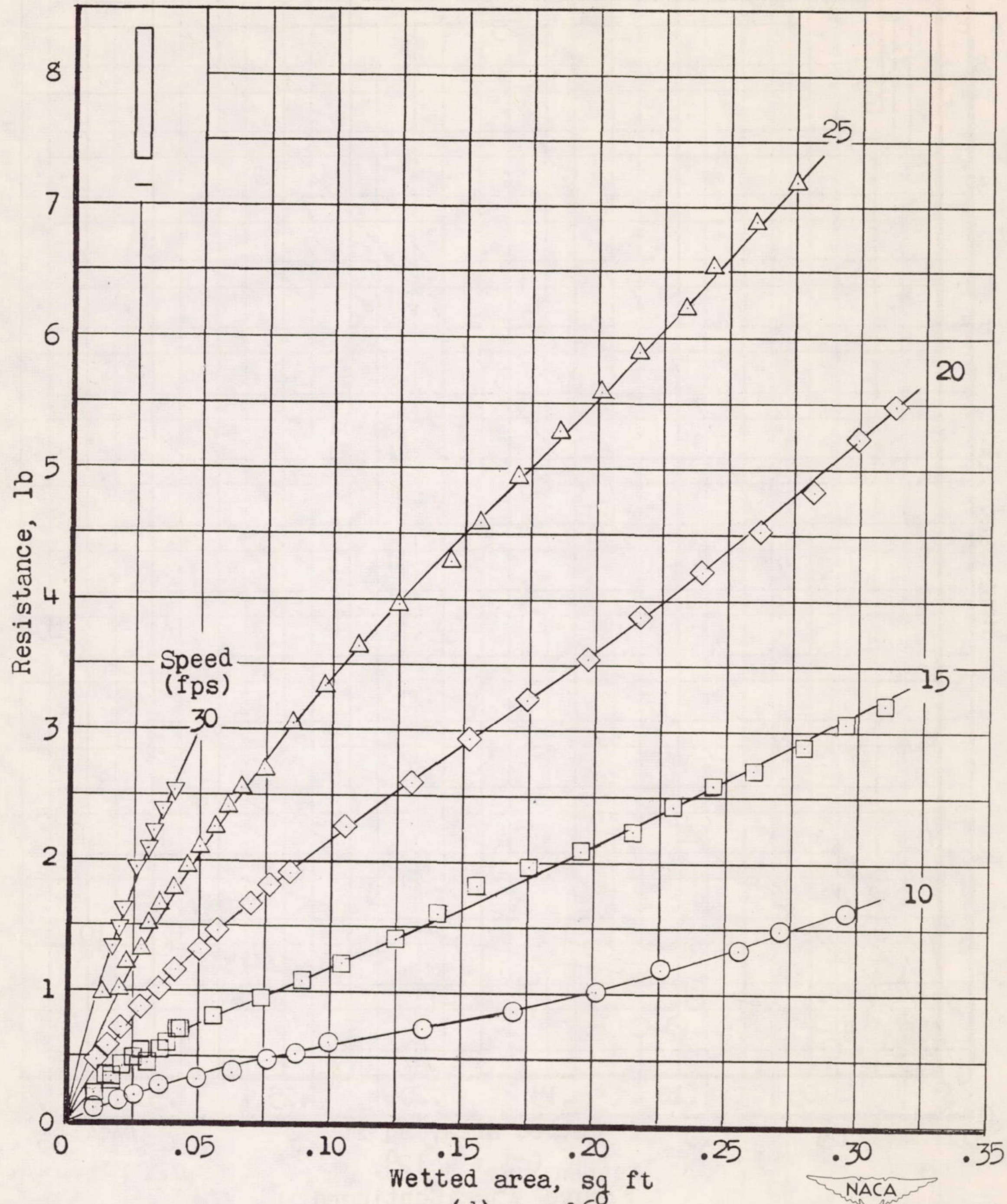
(b) $\tau = 8^{0}$.

Figure 15.- Continued.



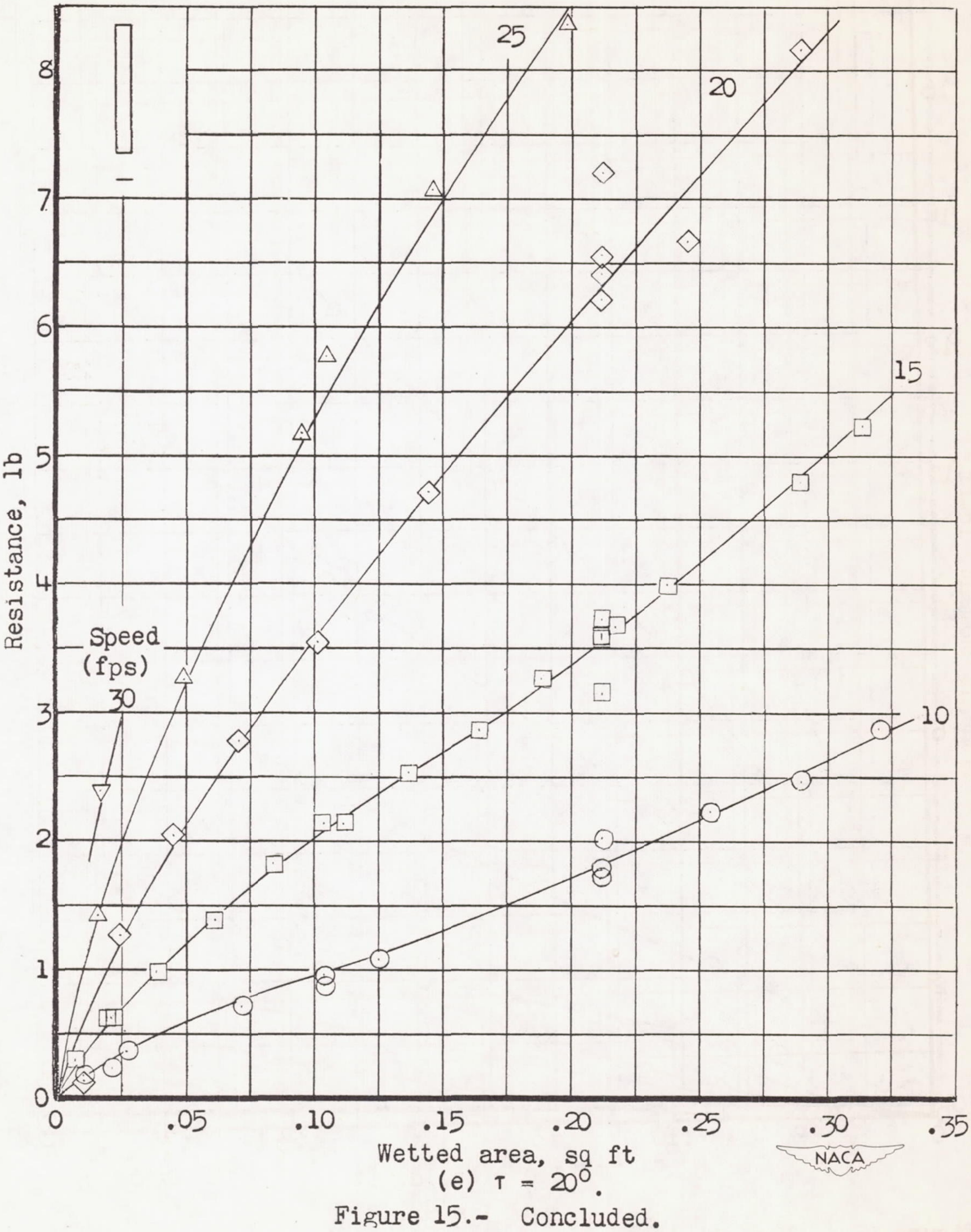
(c) $\tau = 12^{o}$.

Figure 15.- Continued.



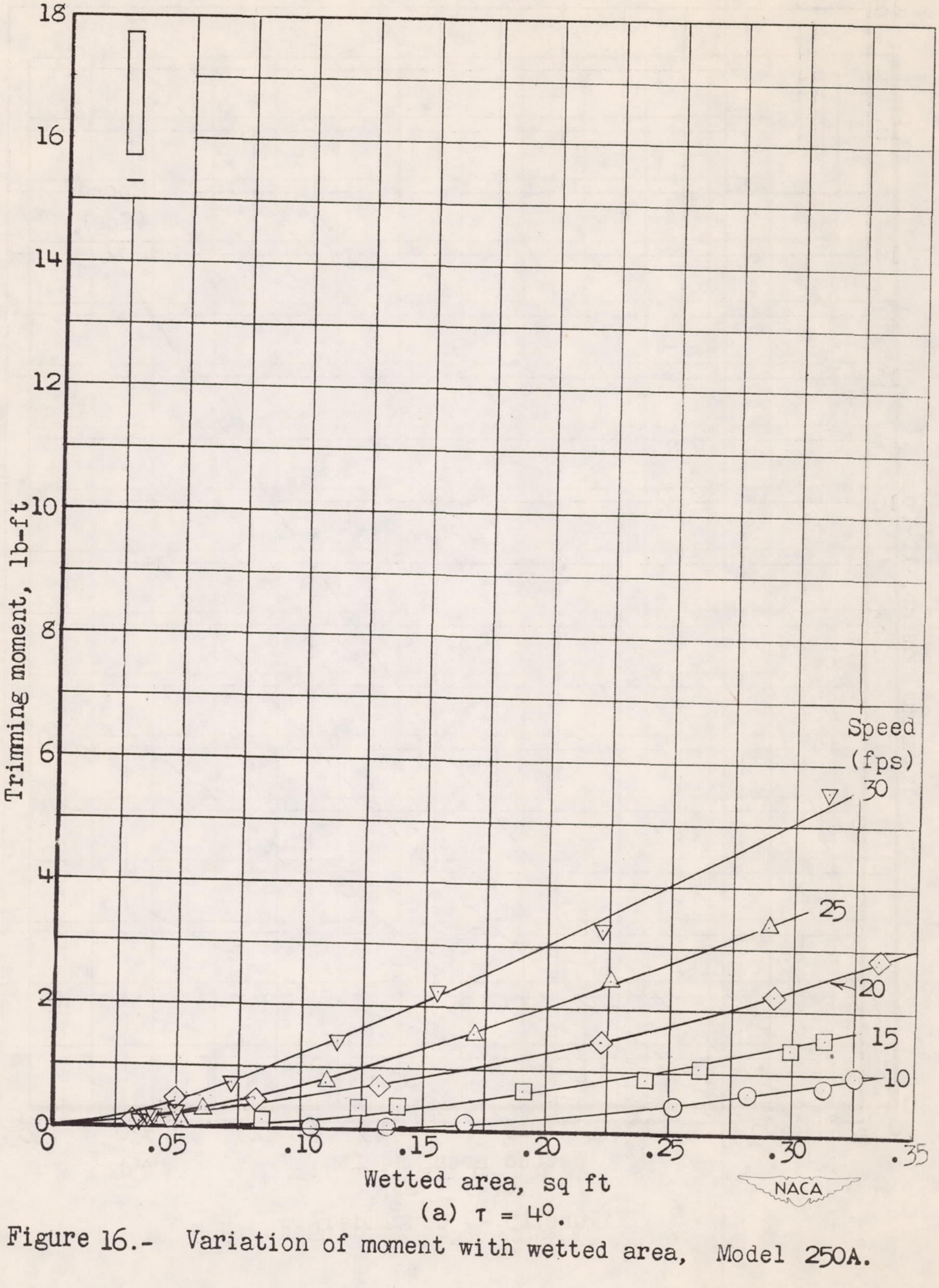
(d) $\tau = 16^{\circ}$.

Figure 15.- Continued.



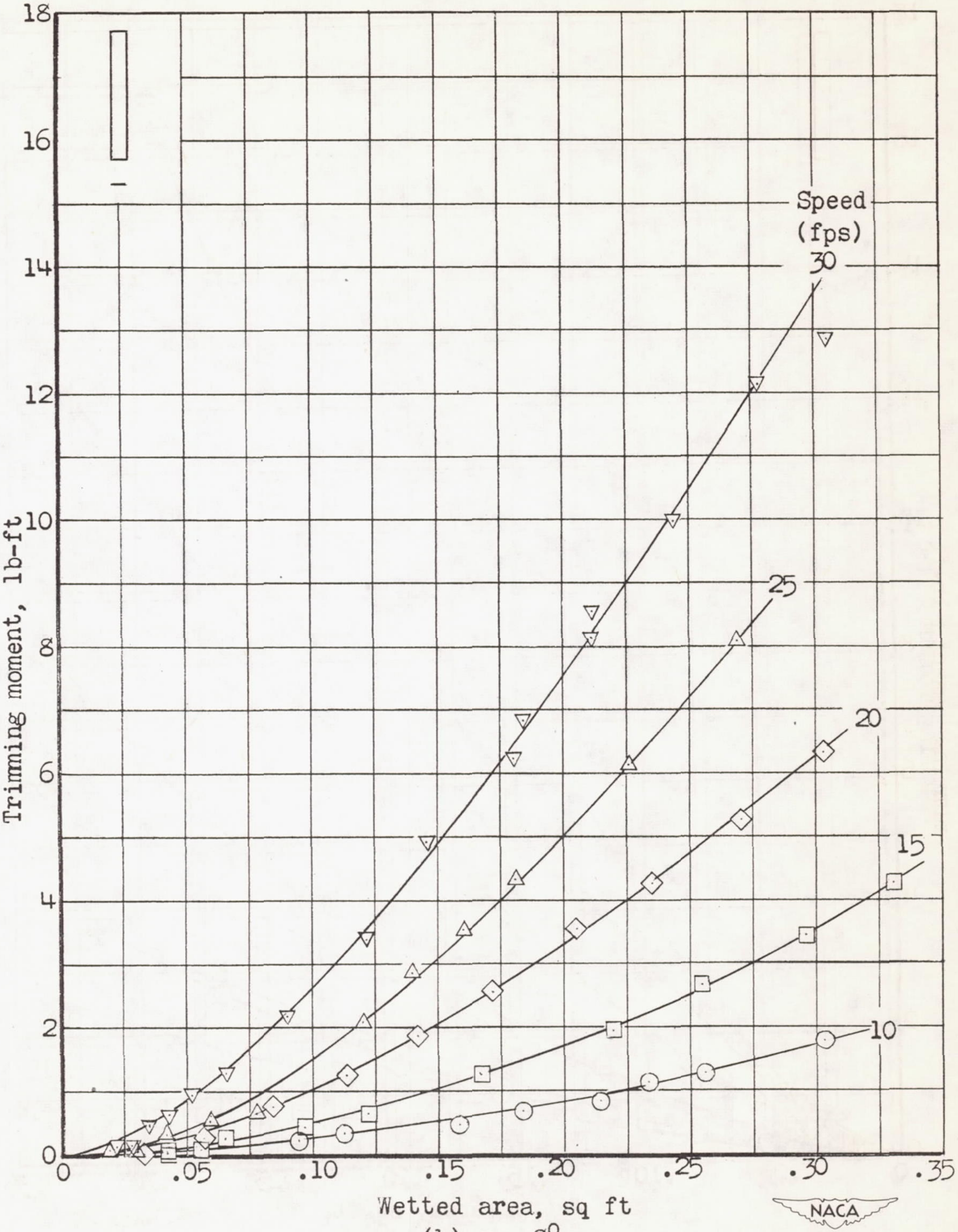
(e) $\tau = 20^{\circ}$.

Figure 15.- Concluded.



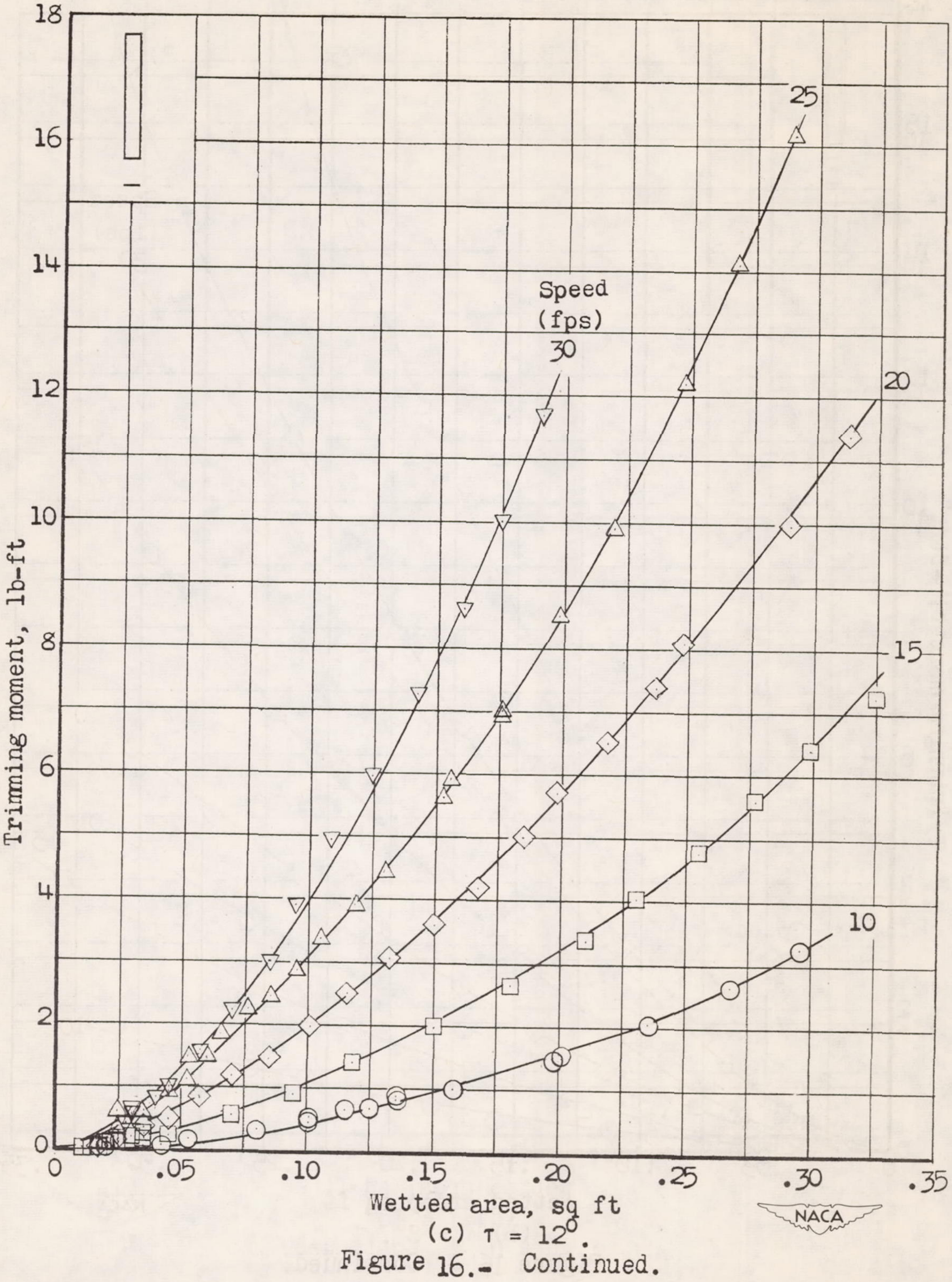
(a) $\tau = 4^{\circ}$.

Figure 16.- Variation of moment with wetted area, Model 250A.



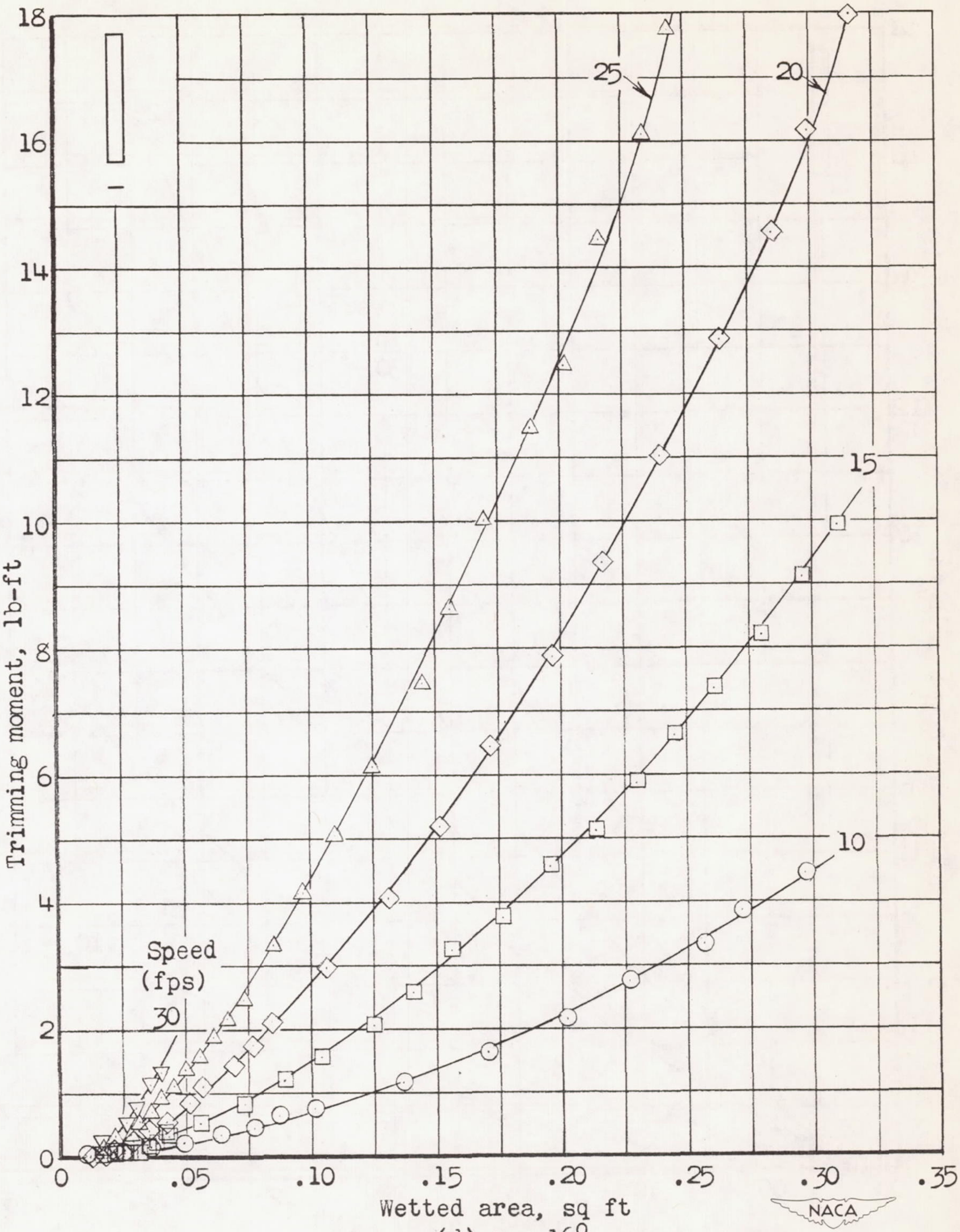
(b) $\tau = 8^{\circ}$.

Figure 16.- Continued.



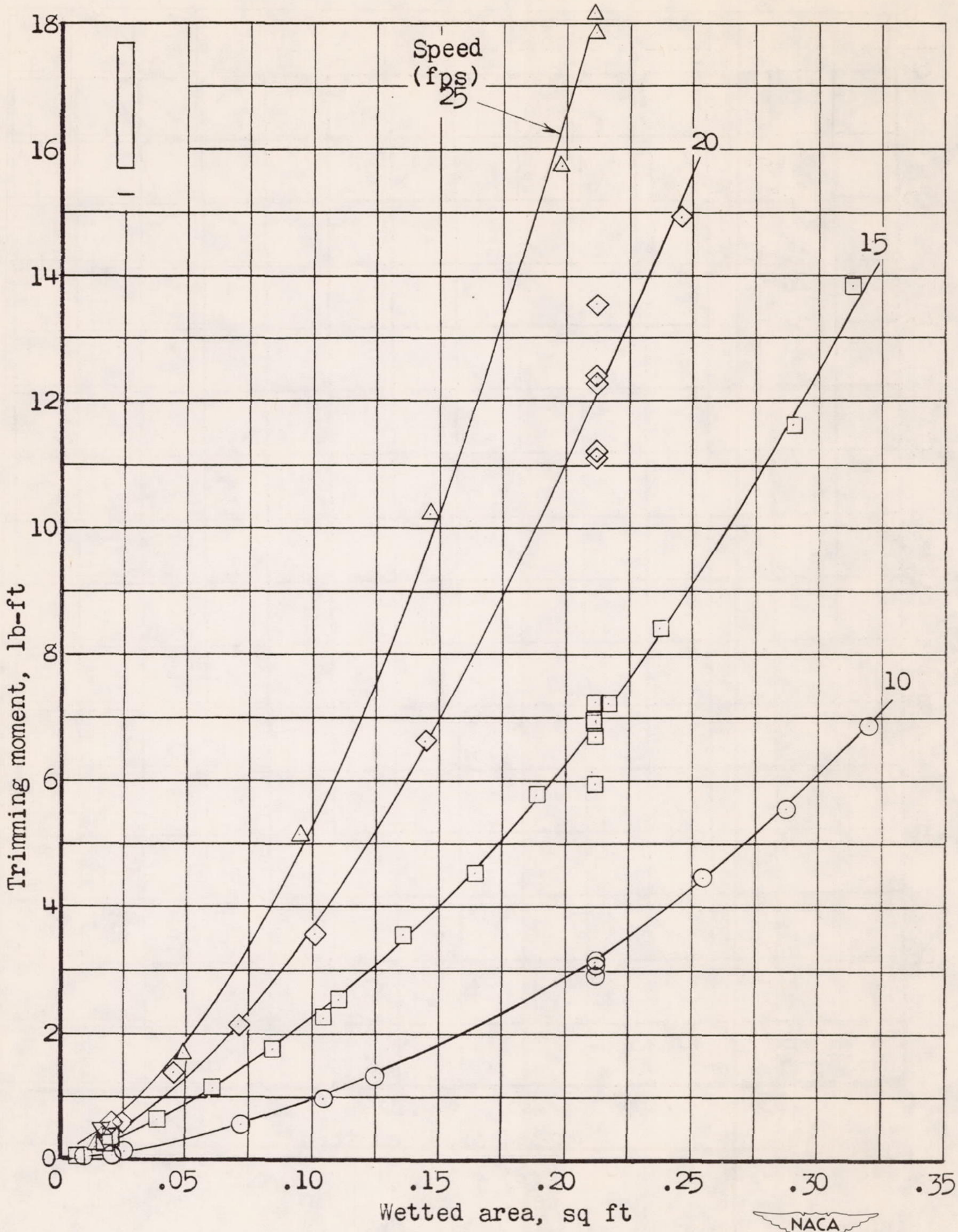
(c) $\tau = 12^{\circ}$.

Figure 16.- Continued.



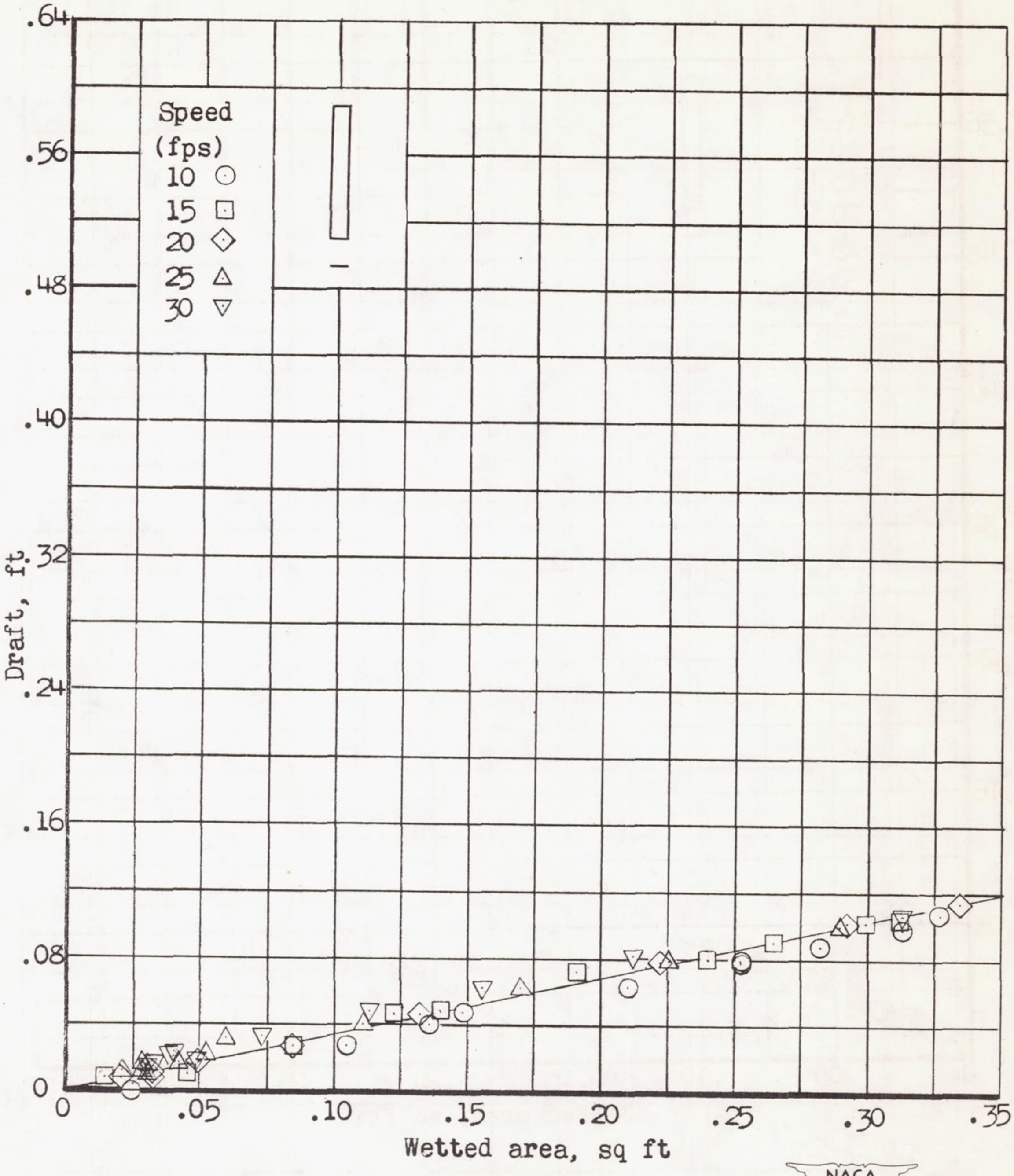
(d) $\tau = 16^{\circ}$.

Figure 16.- Continued.



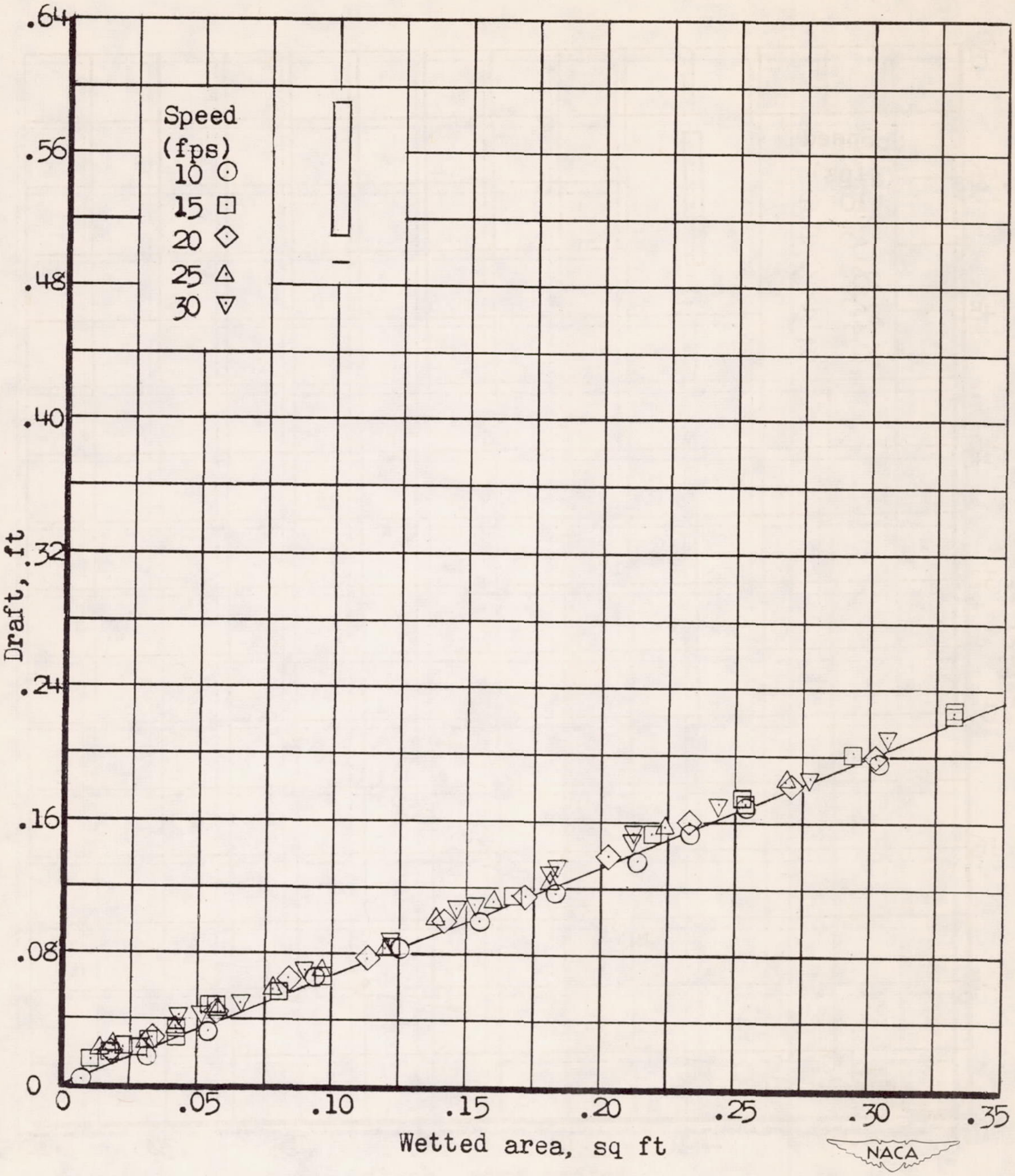
(e) $\tau = 20^{\circ}$.

Figure 16.- Concluded.



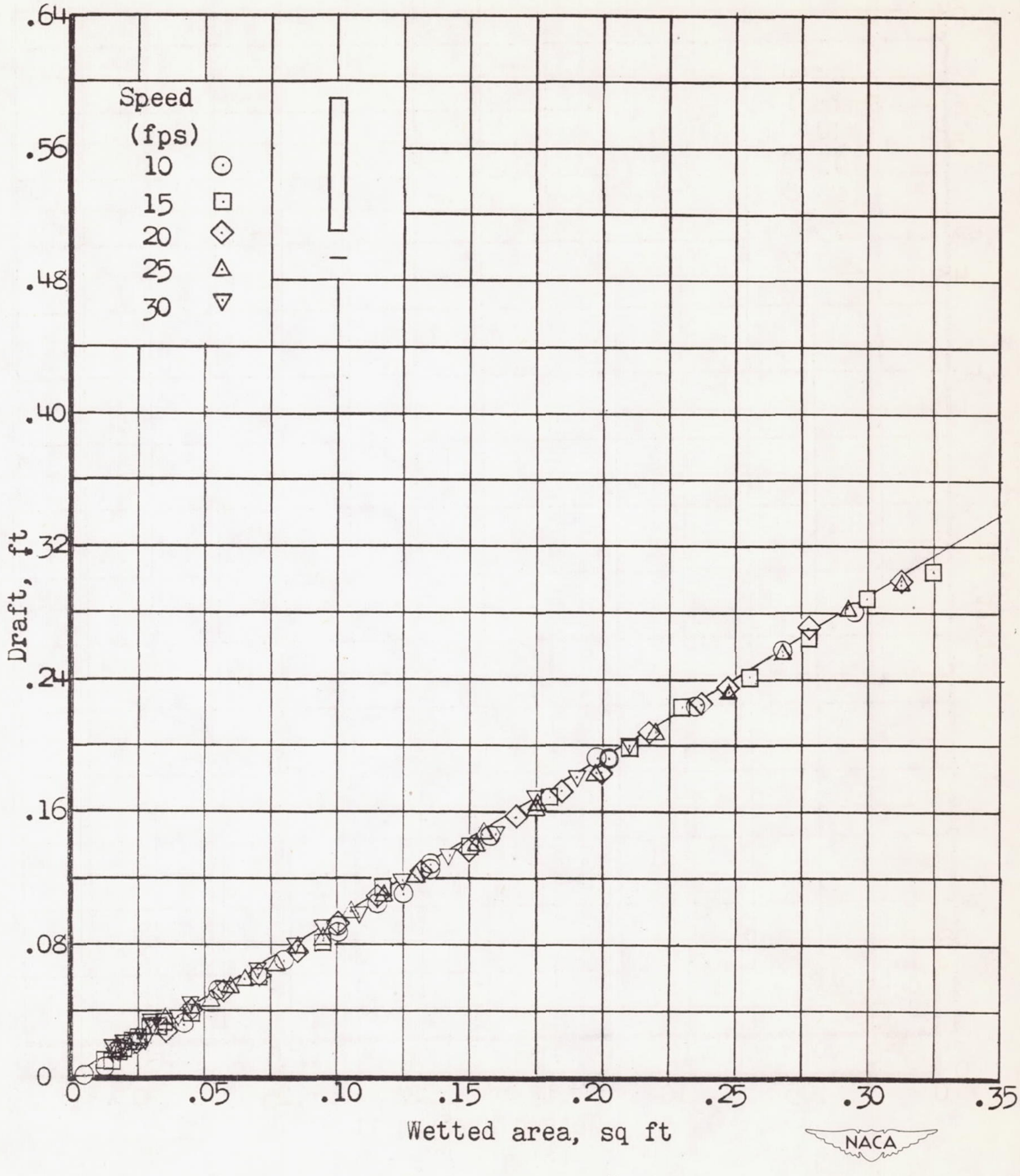
(a) τ = 4°.

Figure 17.- Variation of draft with wetted area. Model 250A.



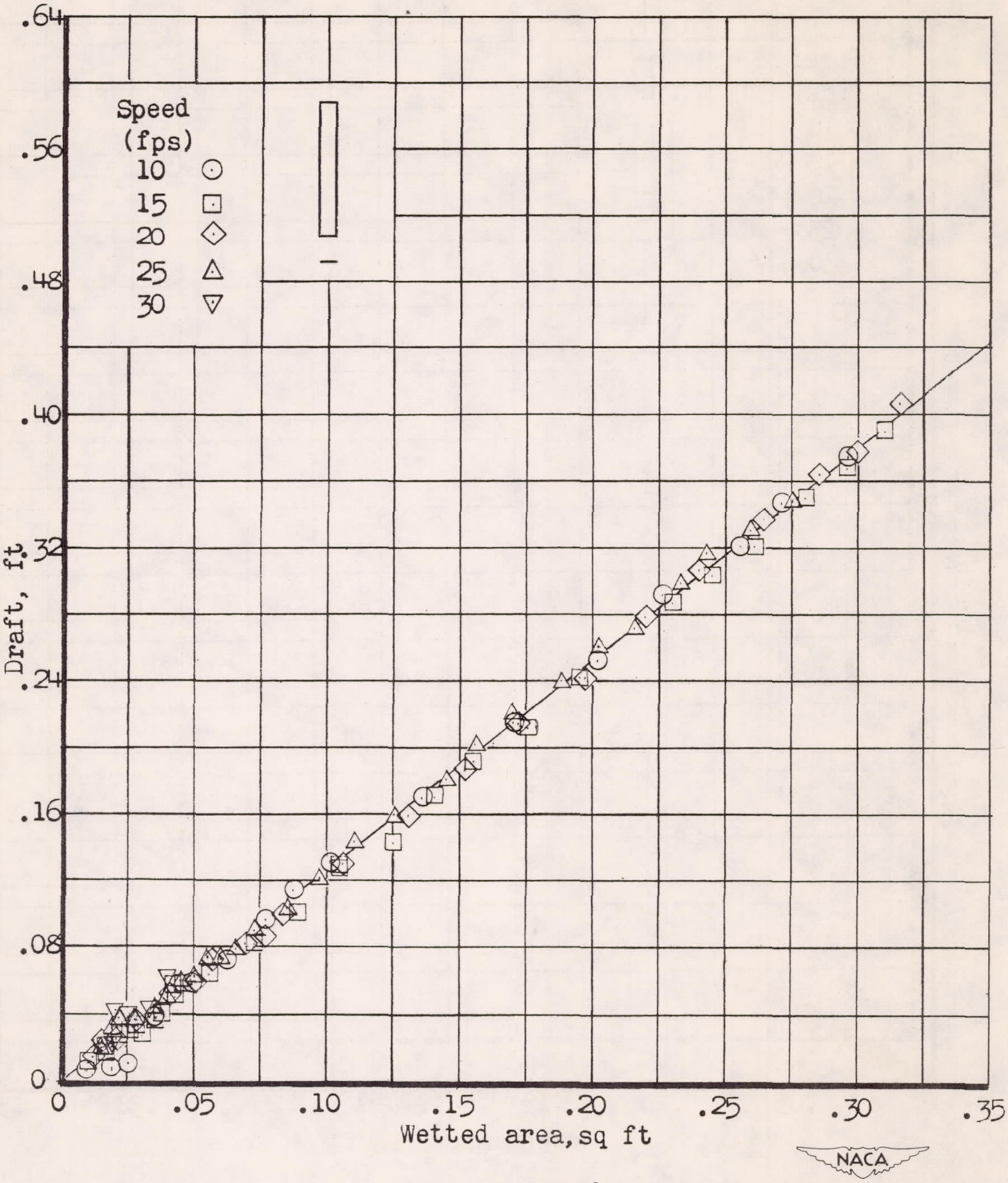
(b) $\tau = 8^{\circ}$.

Figure 17.- Continued.



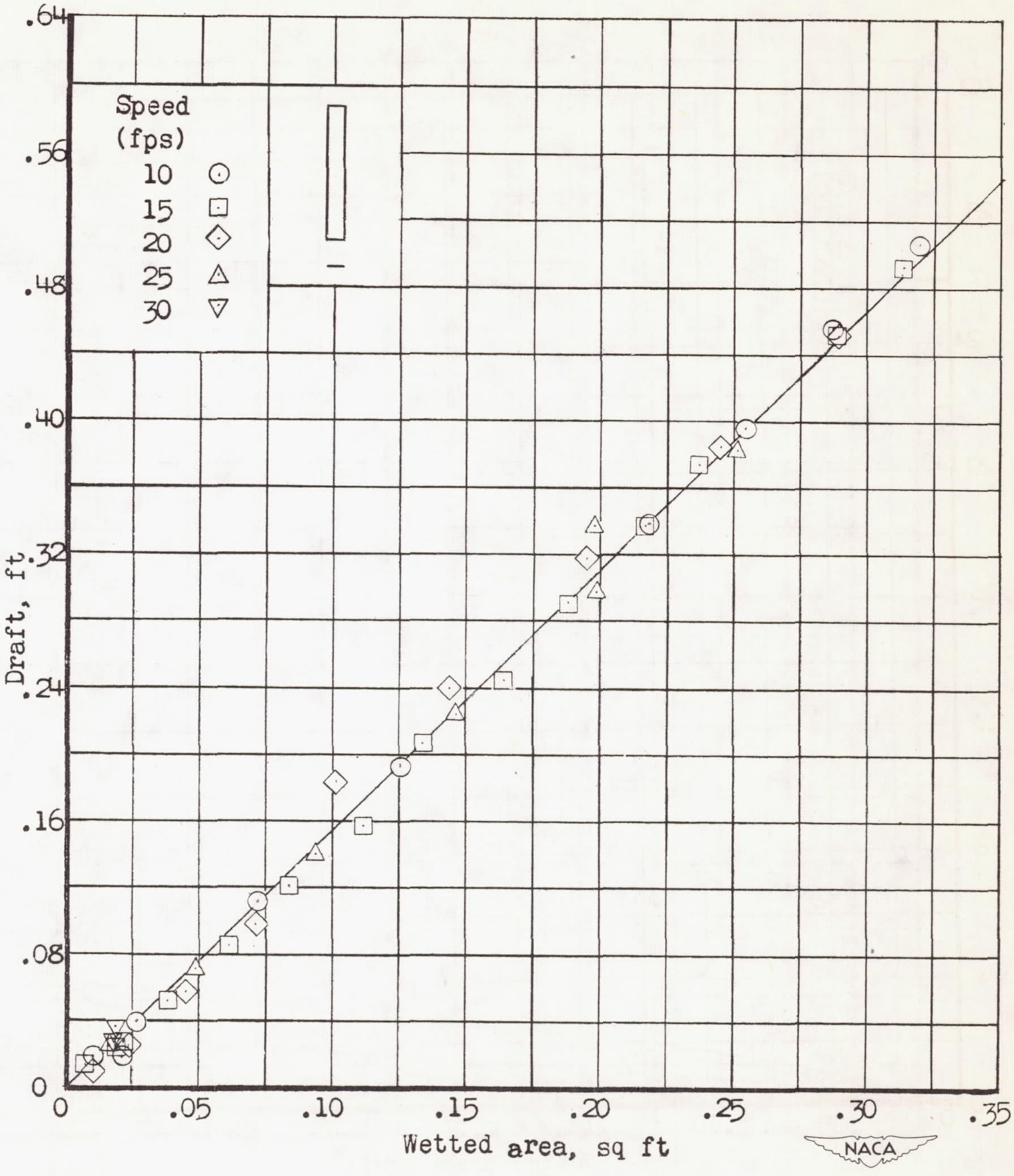
(c) $\tau = 12^{0}$.

Figure 17.- Continued.



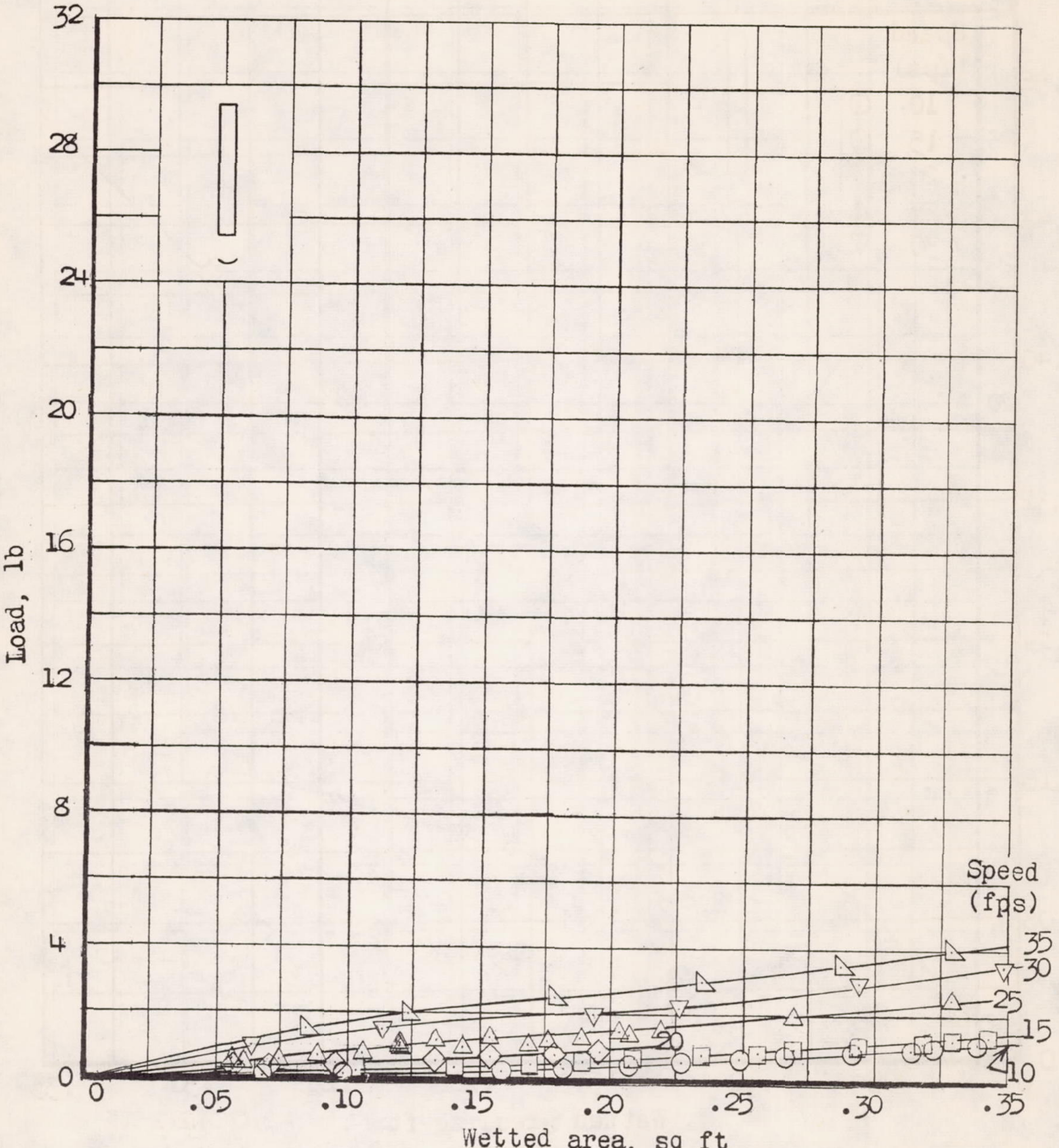
(d) $\tau = 16^{\circ}$.

Figure 17.- Continued.



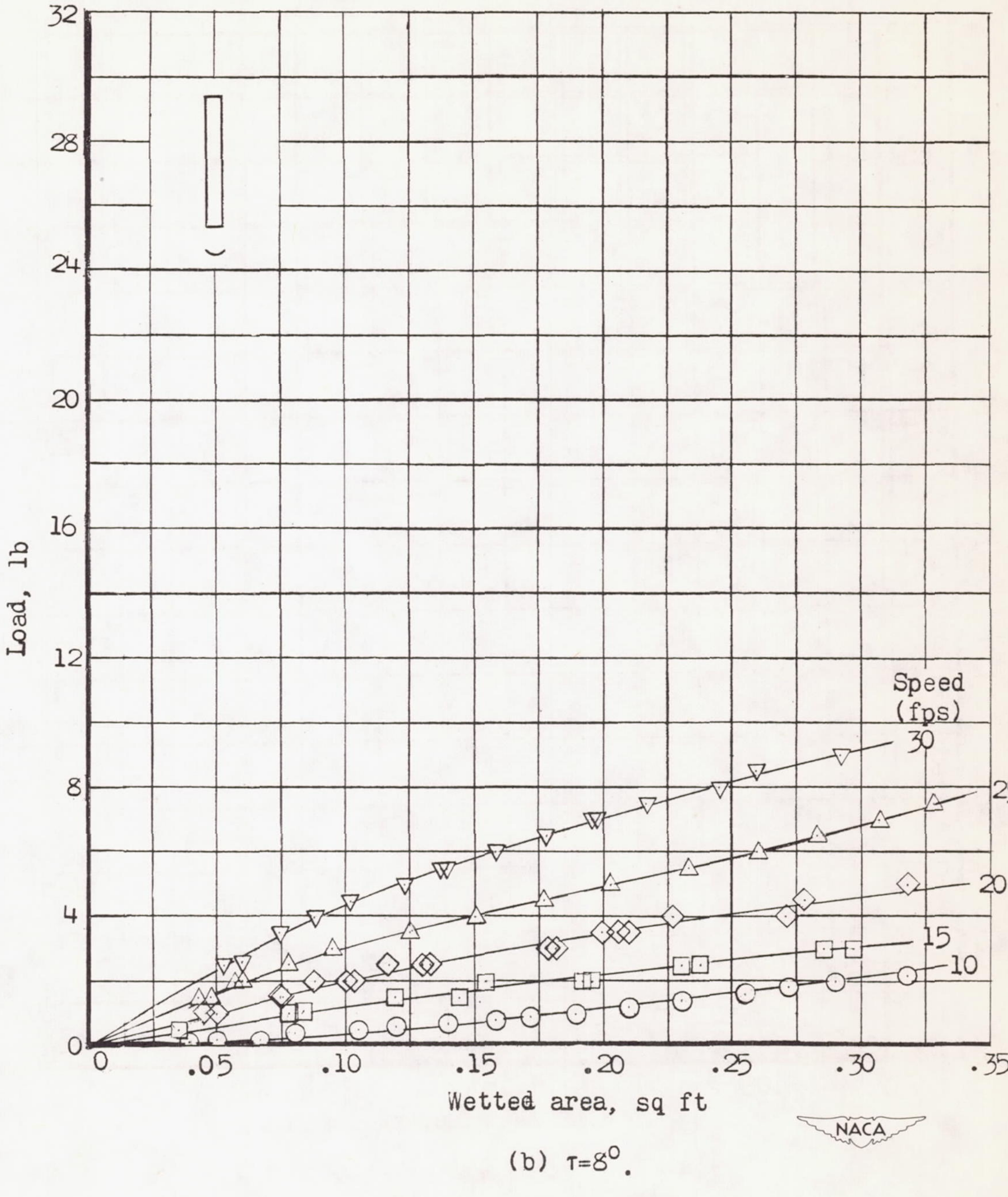
(e) $\tau = 20^{\circ}$.

Figure 17.- Concluded.



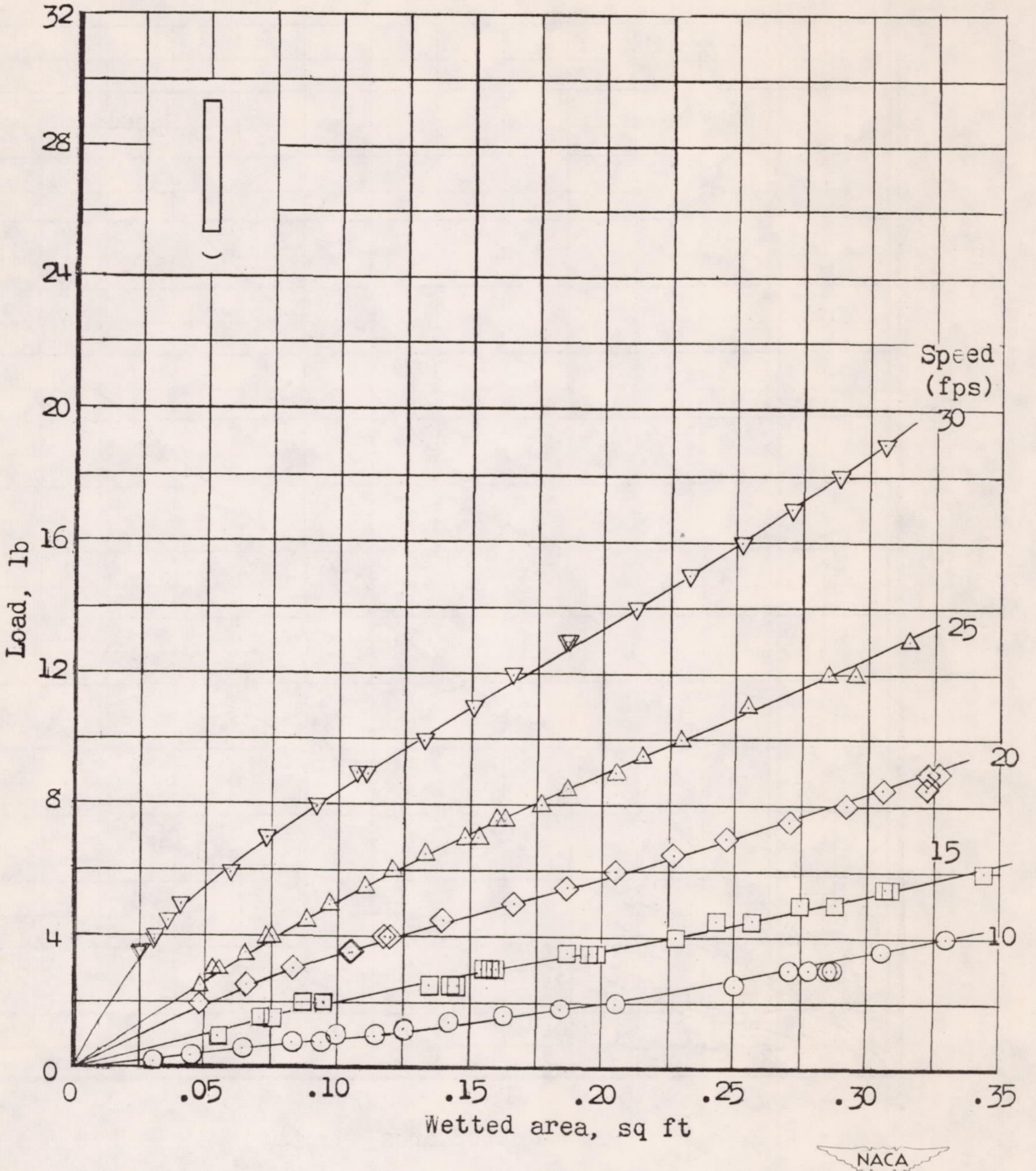
(a) $\tau = 4^{\circ}$.

Figure 18.- Variation of load with wetted area. Model 250B.



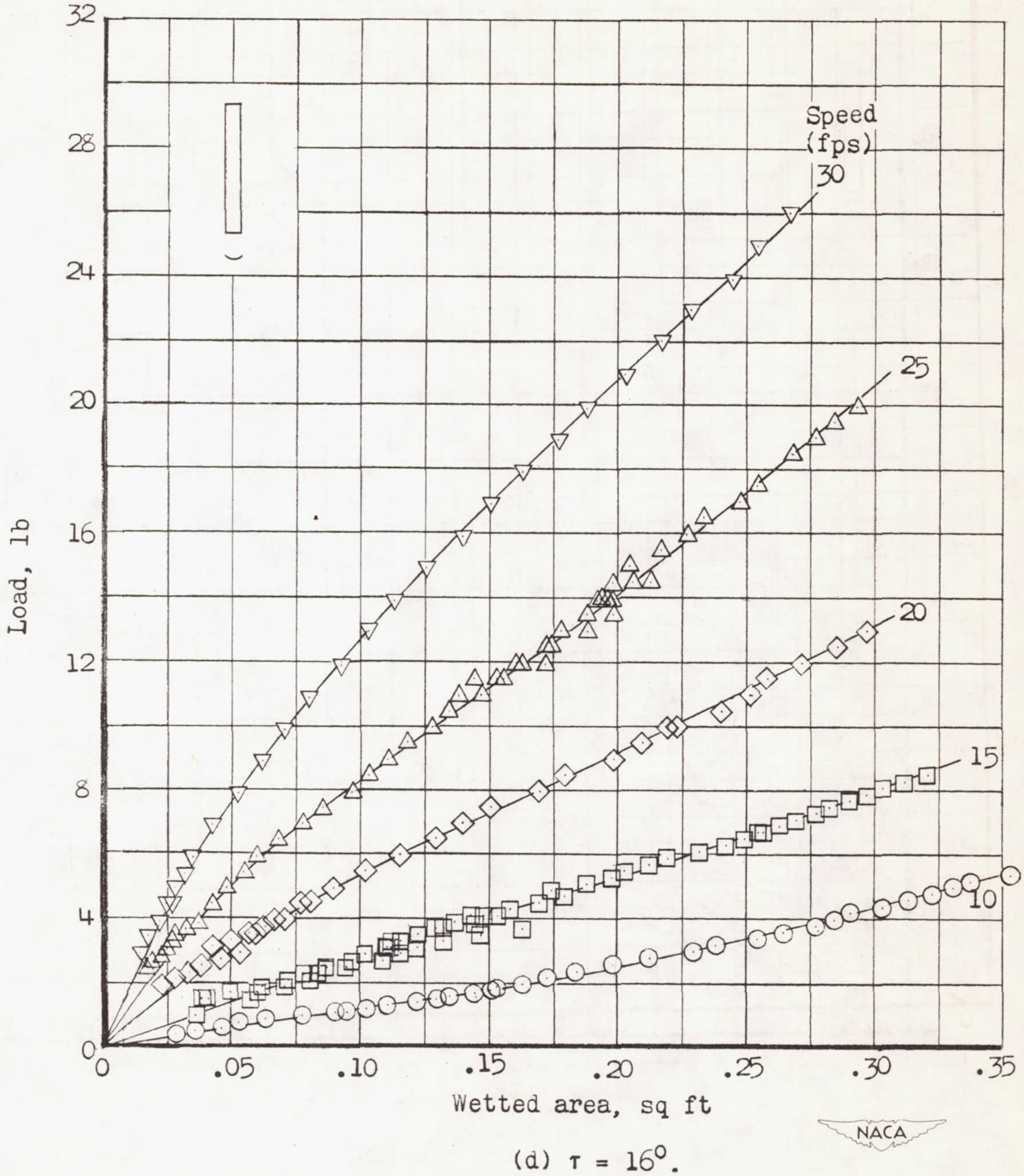
(b) $\tau = 8^{\circ}$.

Figure 18.- Continued.



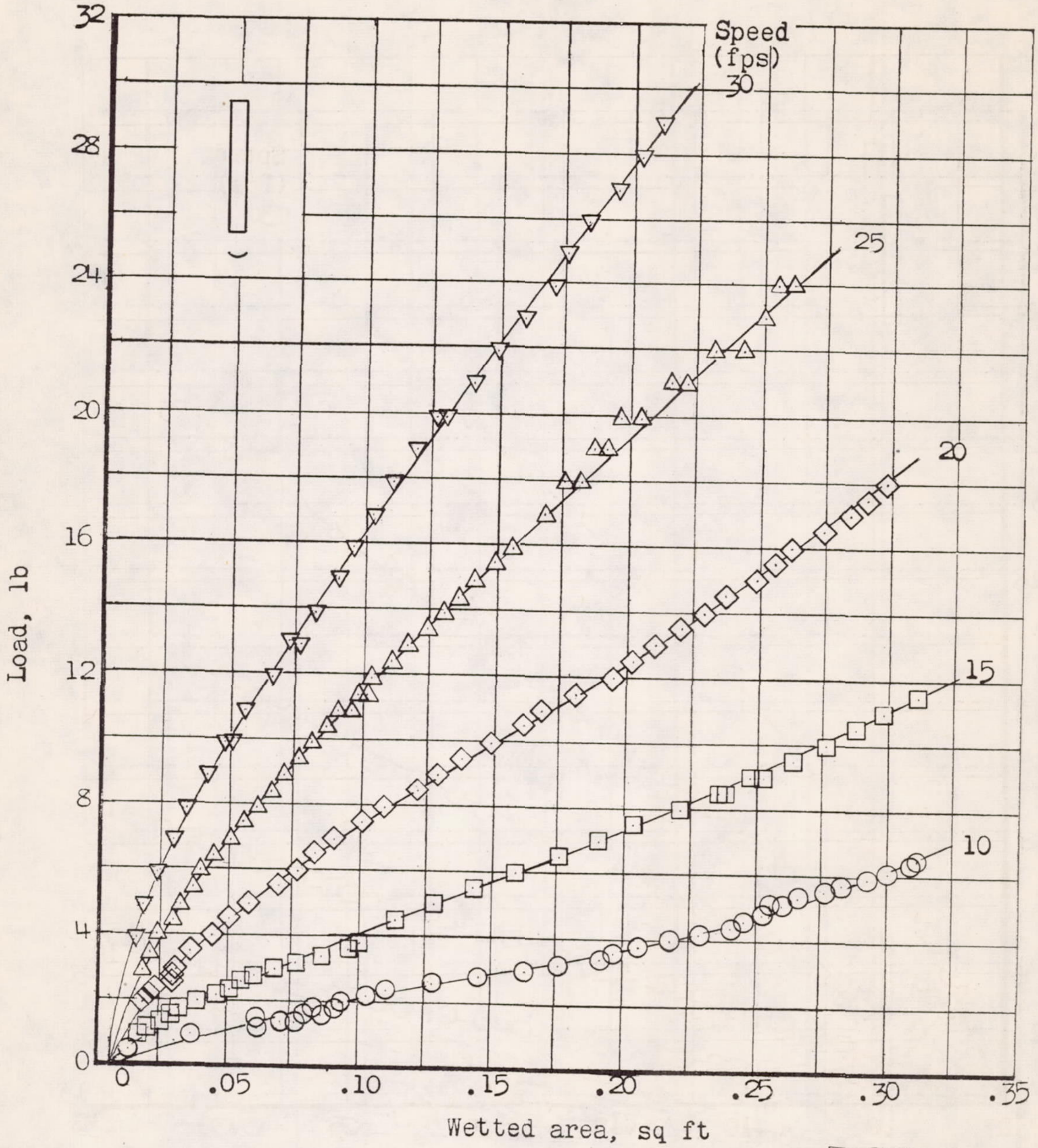
(c) $\tau = 12^{\circ}$.

Figure 18.- Continued.



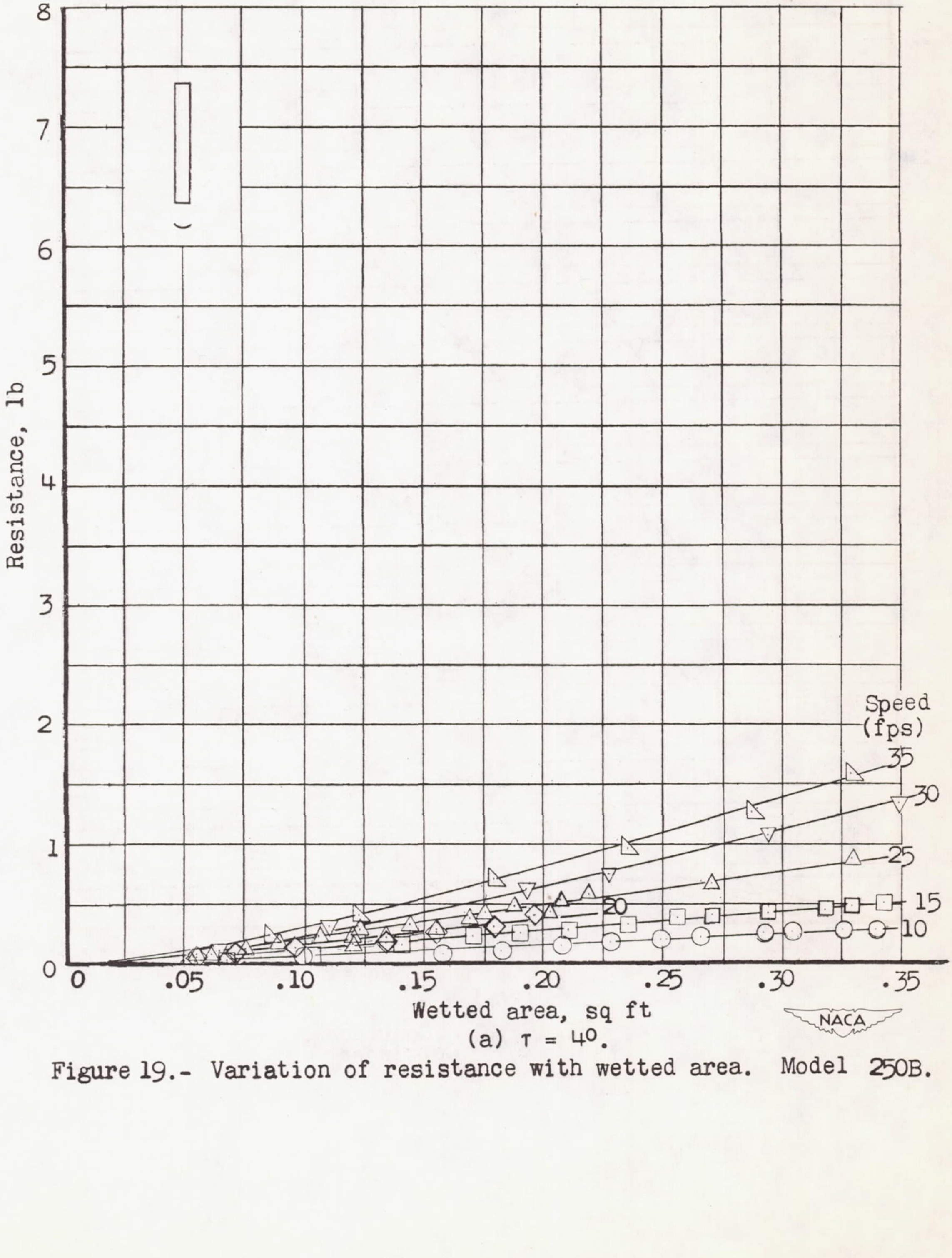
(d) $\tau = 16^{\circ}$.

Figure 18.- Continued.



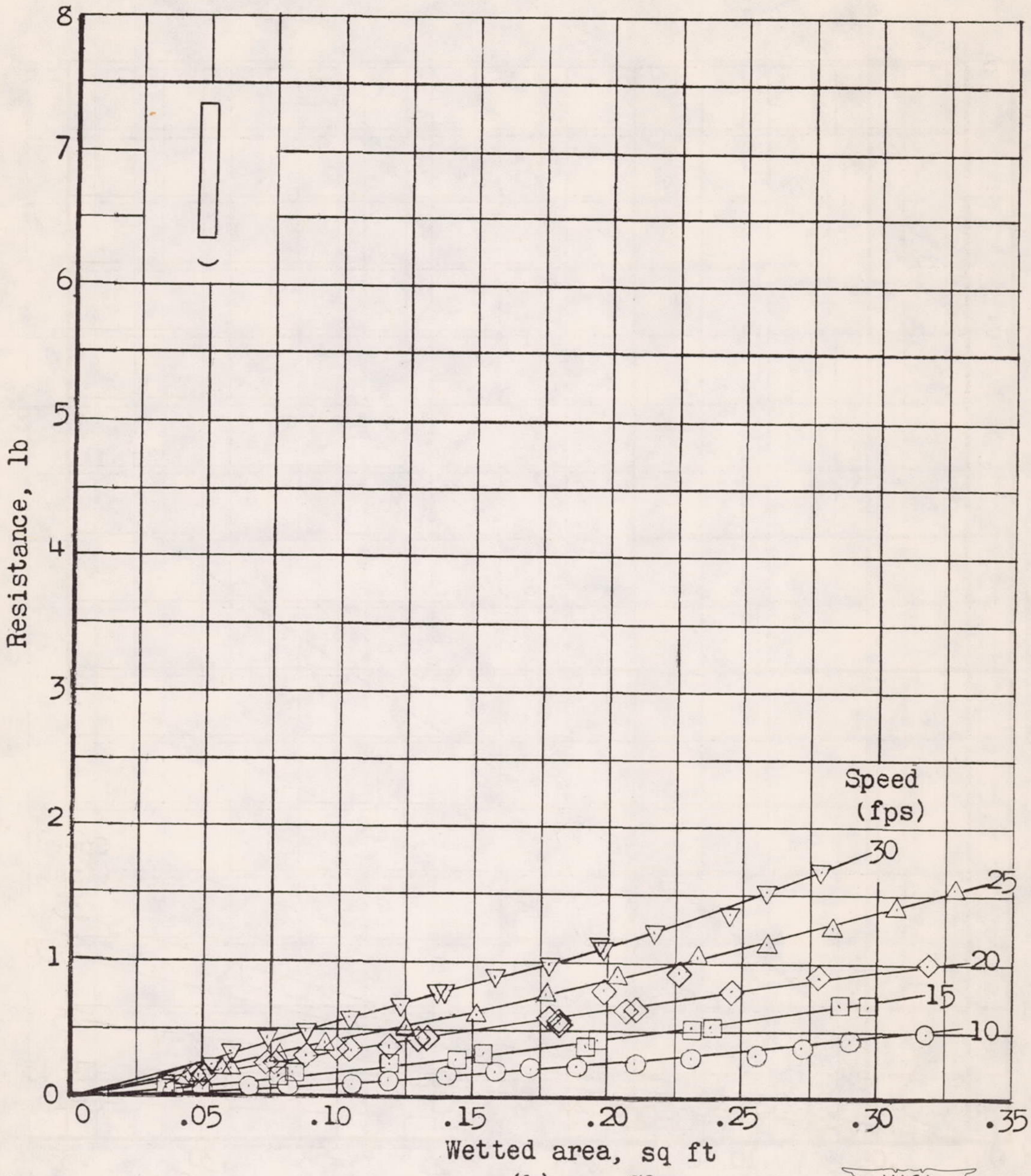
(e) $\tau = 20^{\circ}$.

Figure 18.- Concluded.



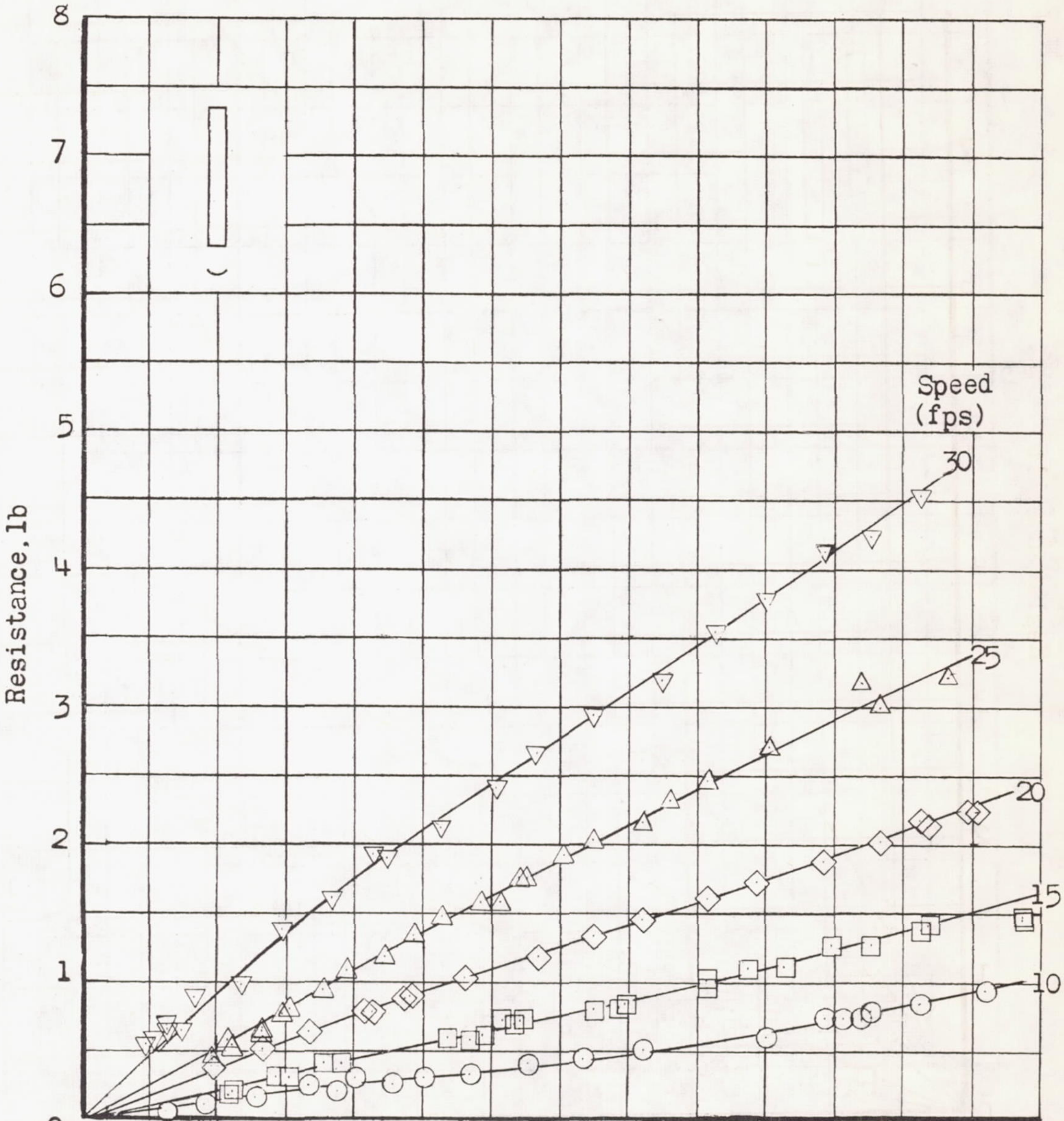
(a) $\tau = 4^{\circ}$.

Figure 19.- Variation of resistance with wetted area. Model 250B.



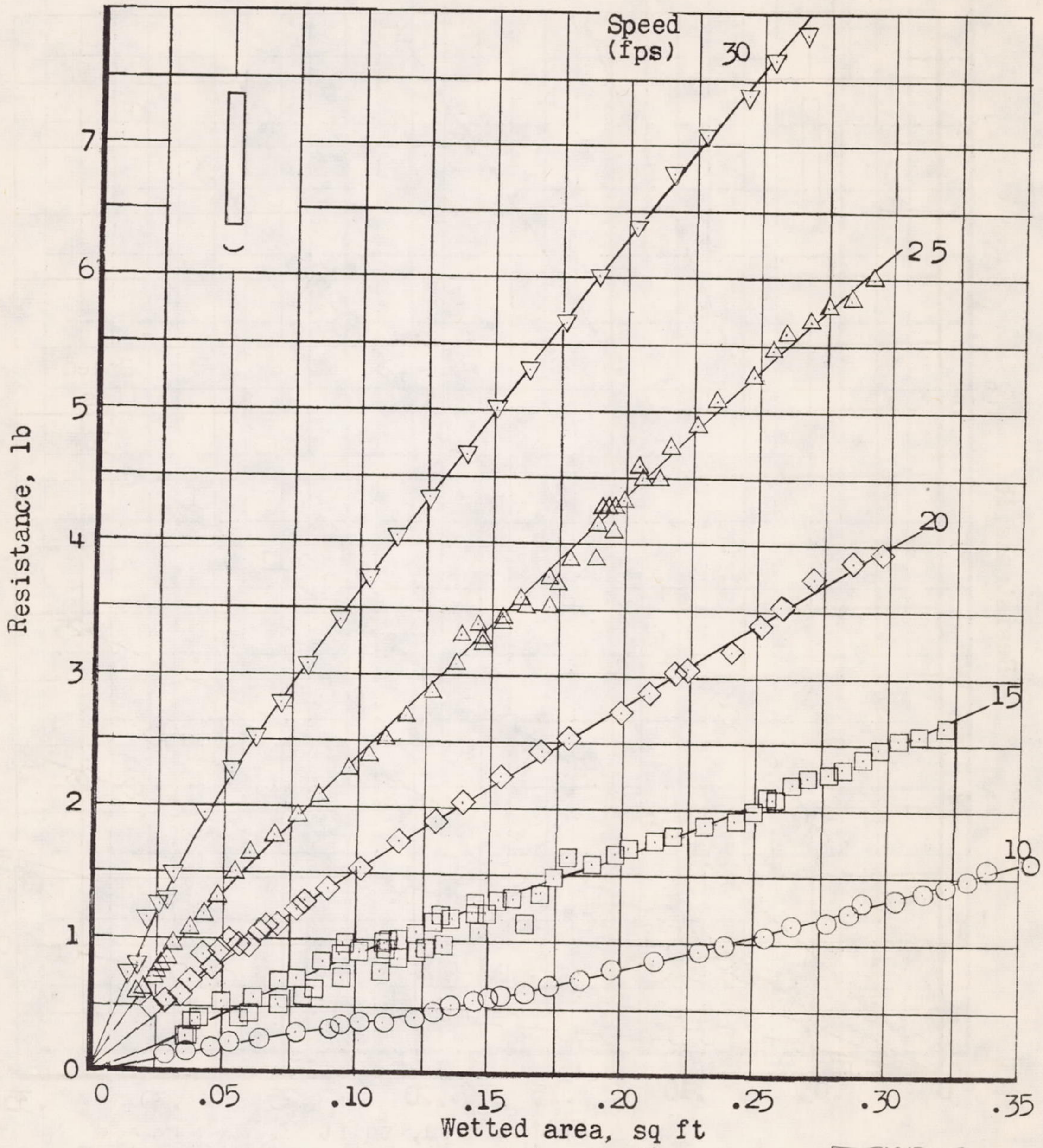
(b) τ = 8°.

Figure 19.- Continued.



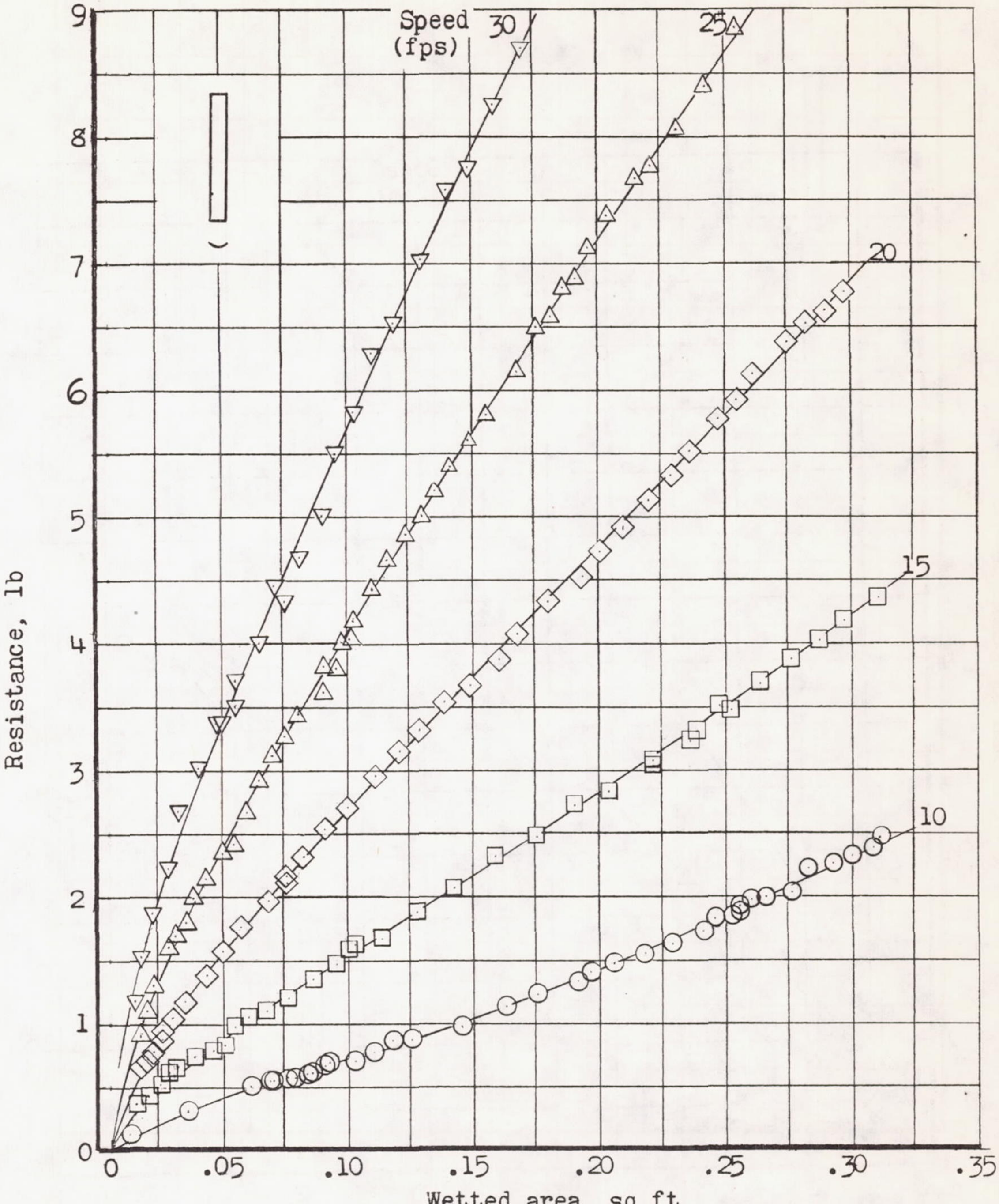
(c) $\tau = 12^{\circ}$.

Figure 19.- Continued.



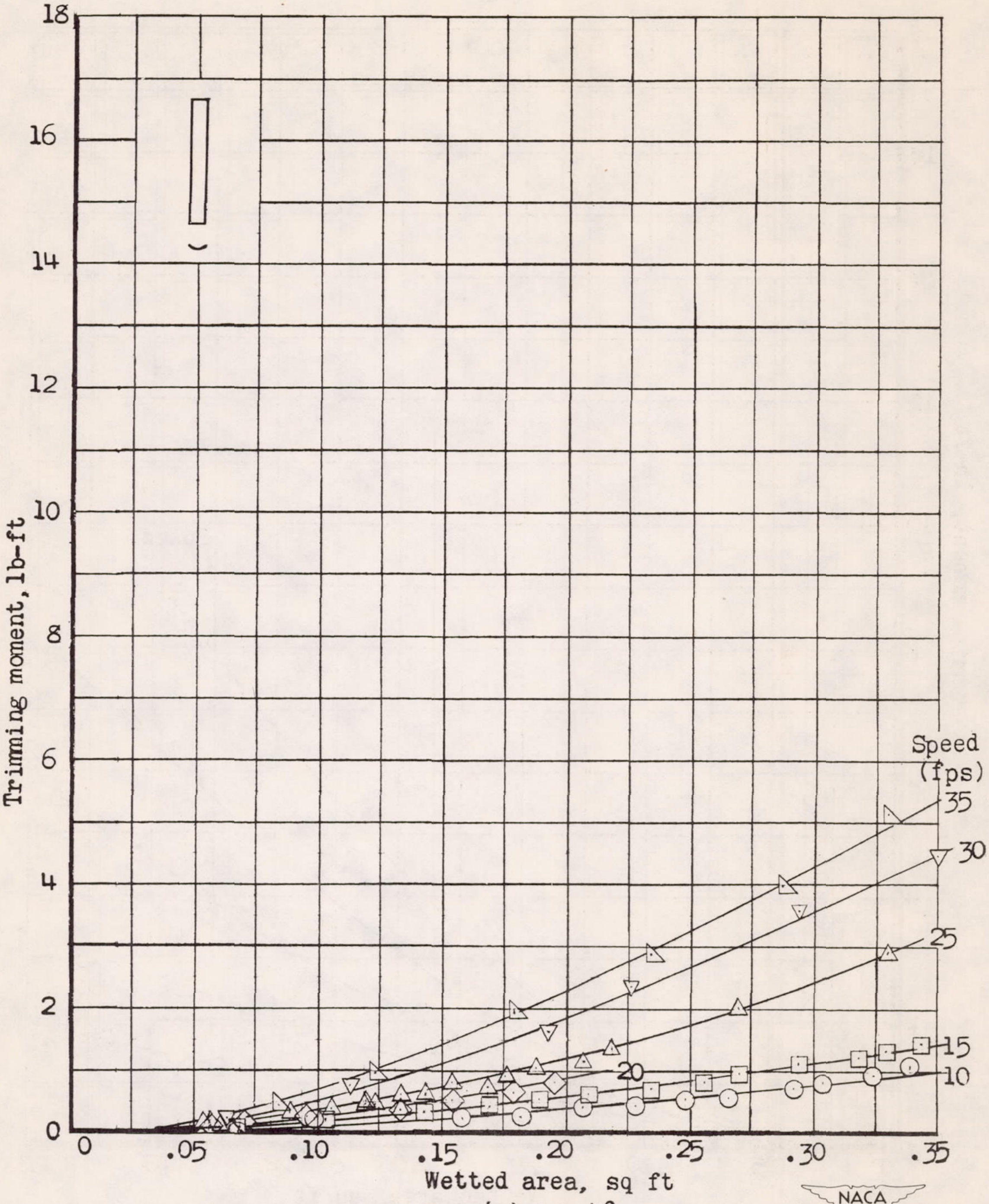
(d) $\tau = 16^{\circ}$.

Figure 19.- Continued.



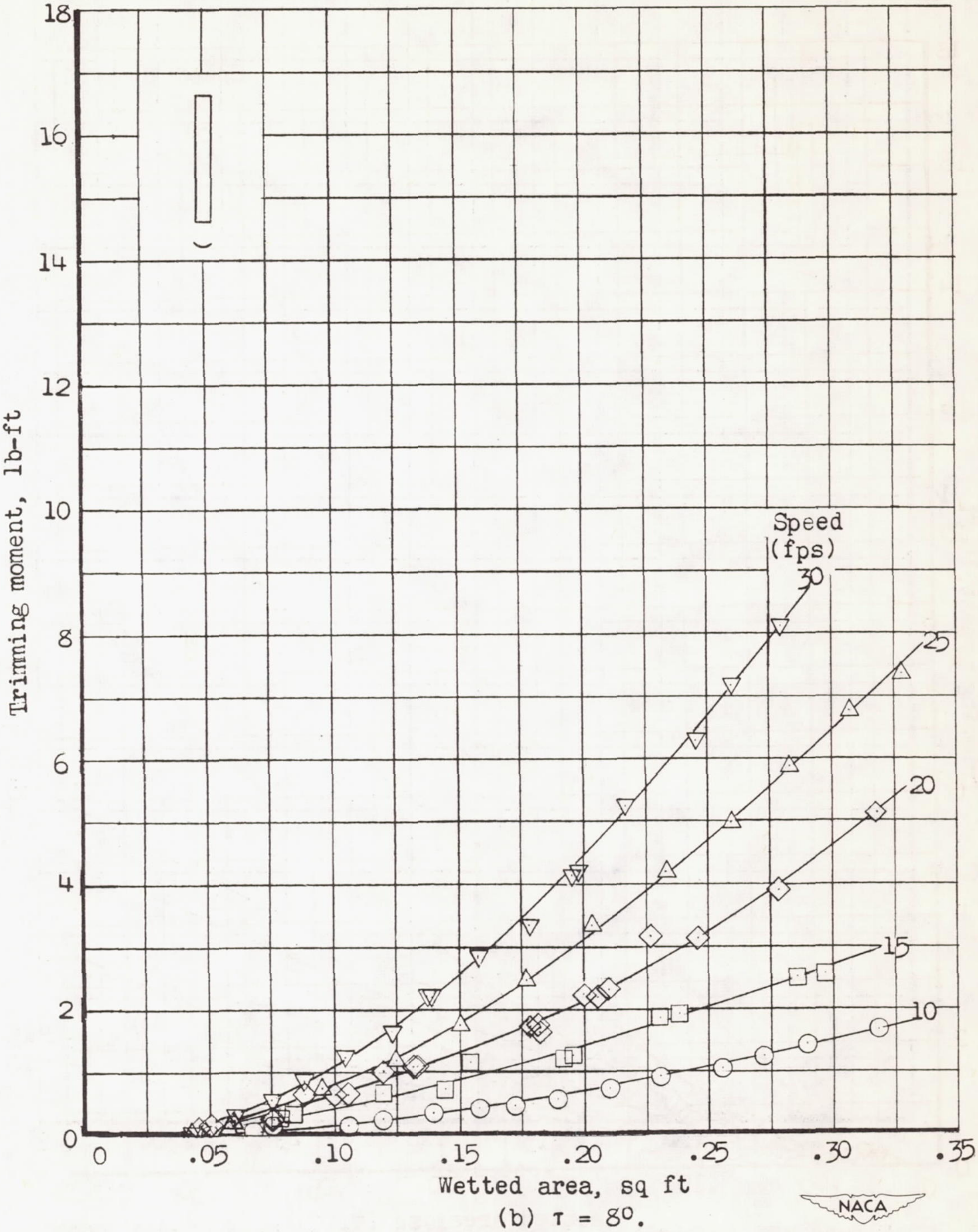
(e) $\tau = 20^{\circ}$.

Figure 19.- Concluded.



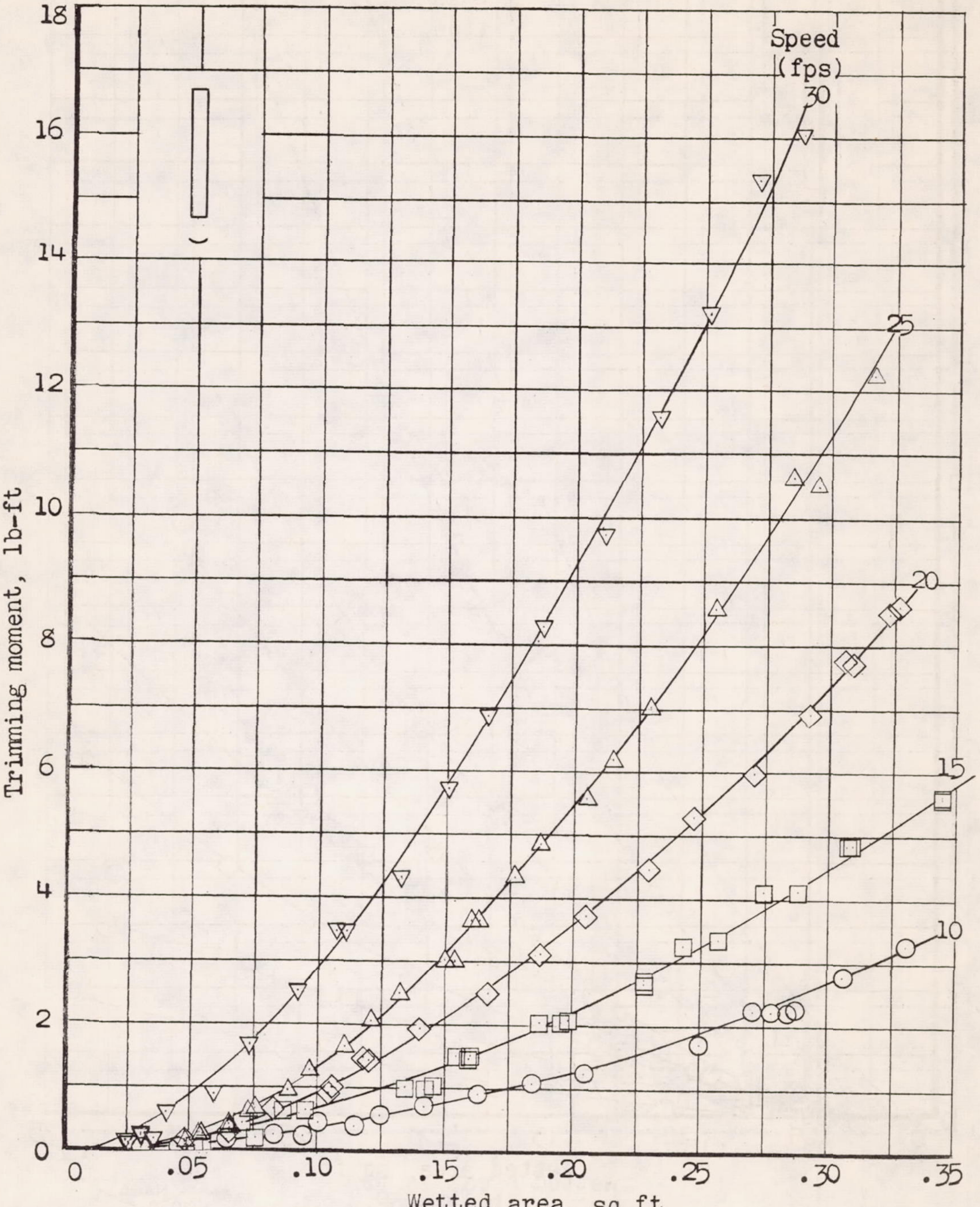
(a) $\tau = 4^{\circ}$.

Figure 20.- Variation of moment with wetted area, Model 250B.



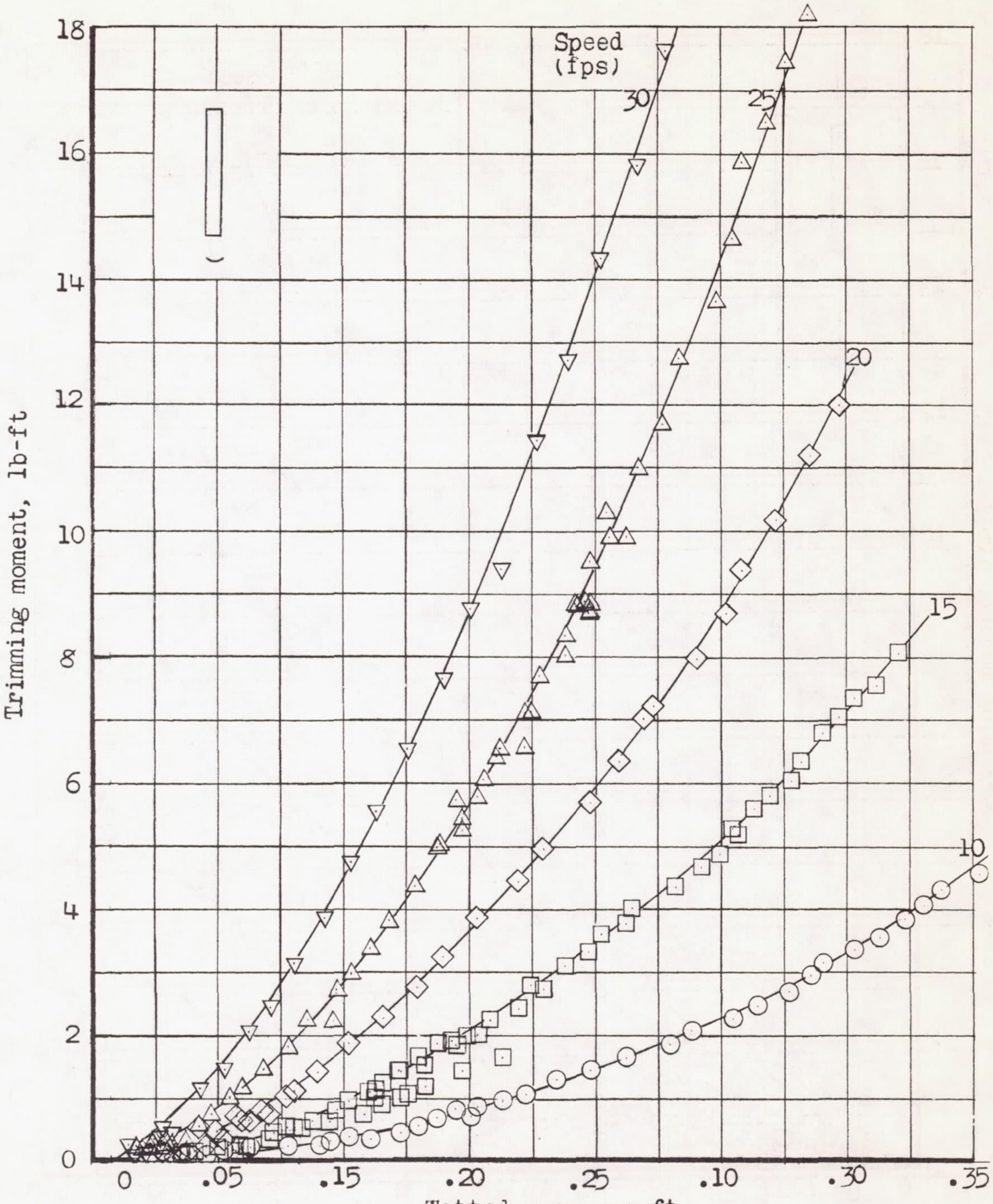
(b) $\tau = 8^{\circ}$.

Figure 20.- Continued.



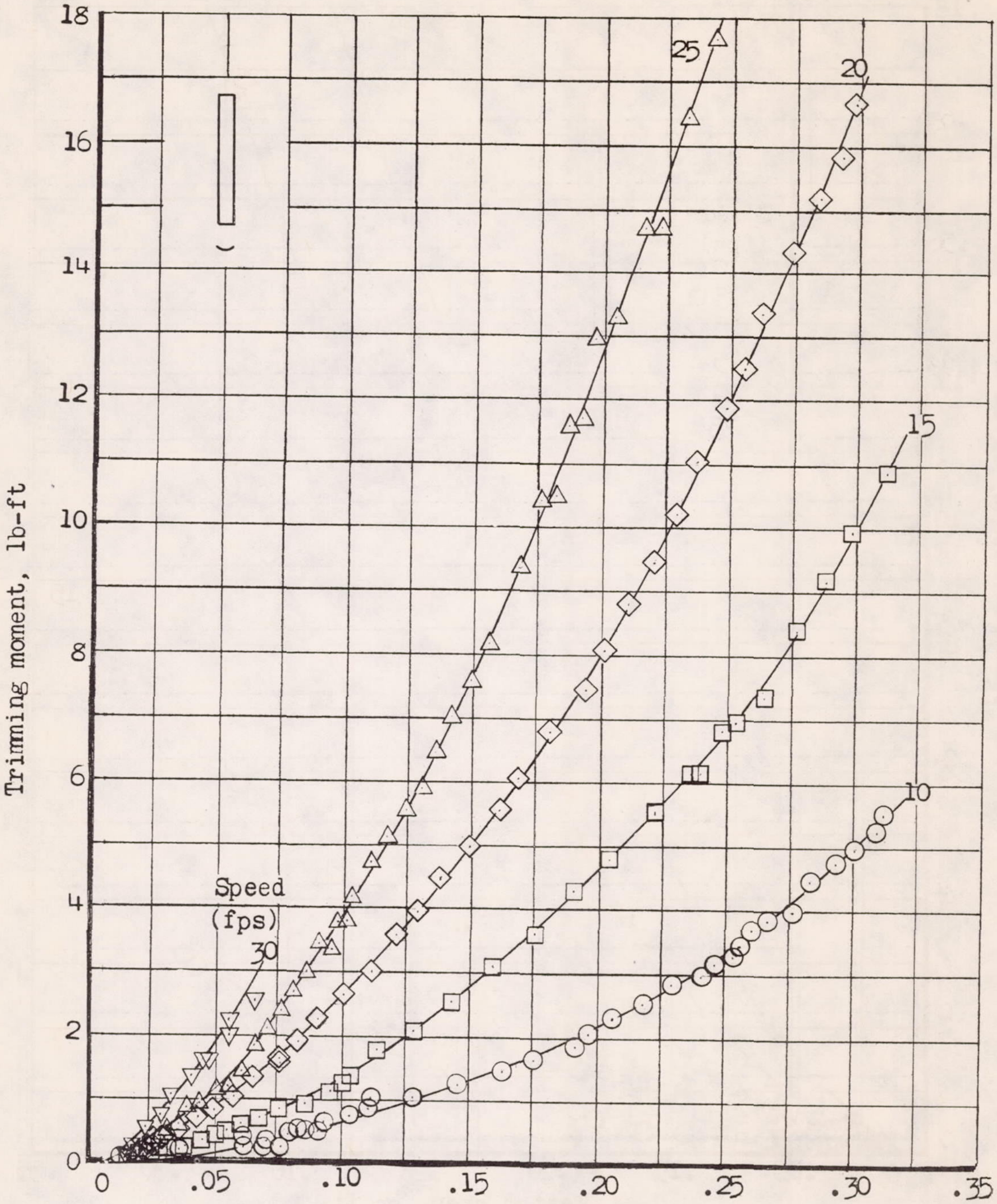
(c) $\tau = 12^{\circ}$.

Figure 20.- Continued.



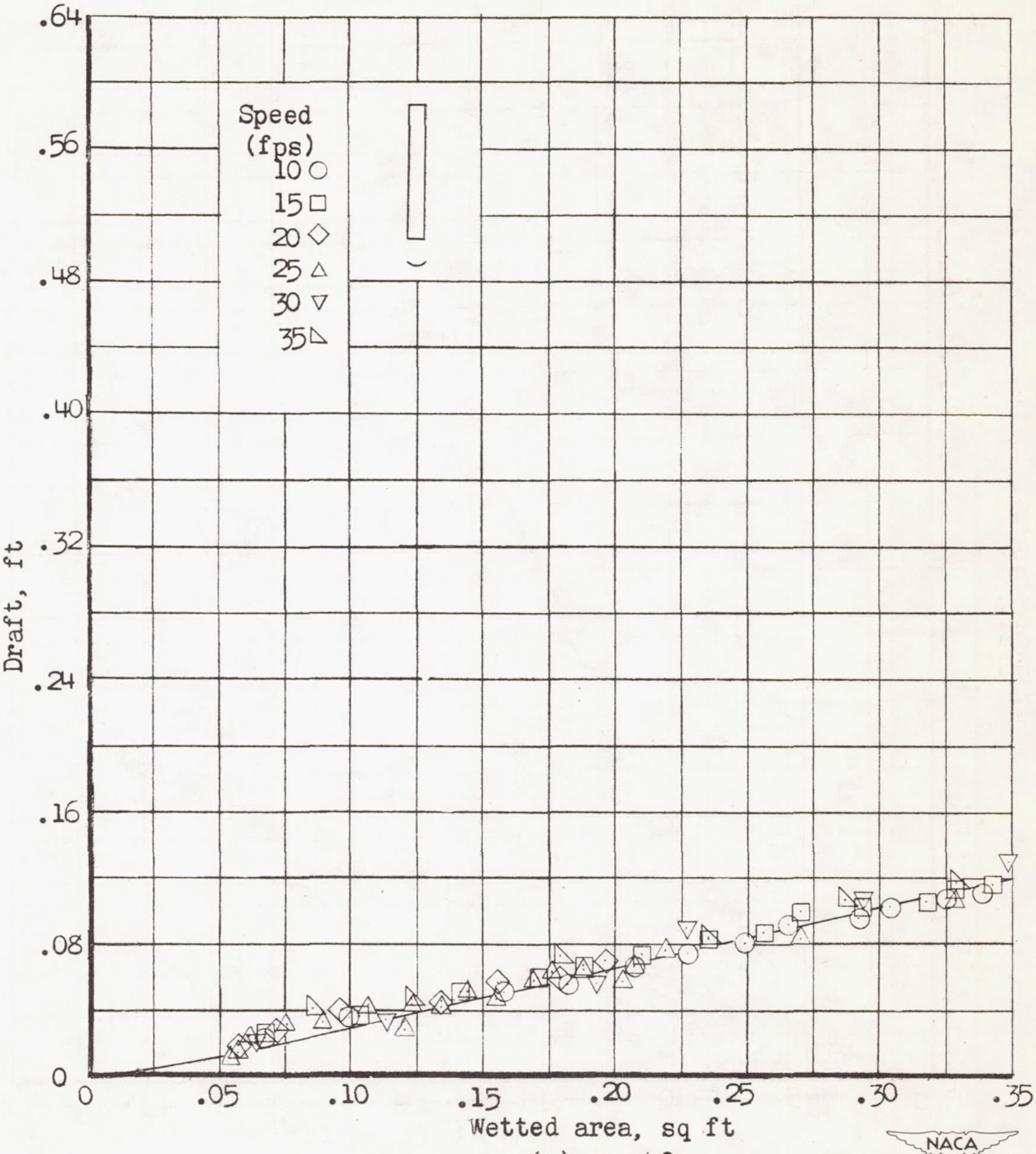
(d) τ = 16°.

Figure 20.- Continued.



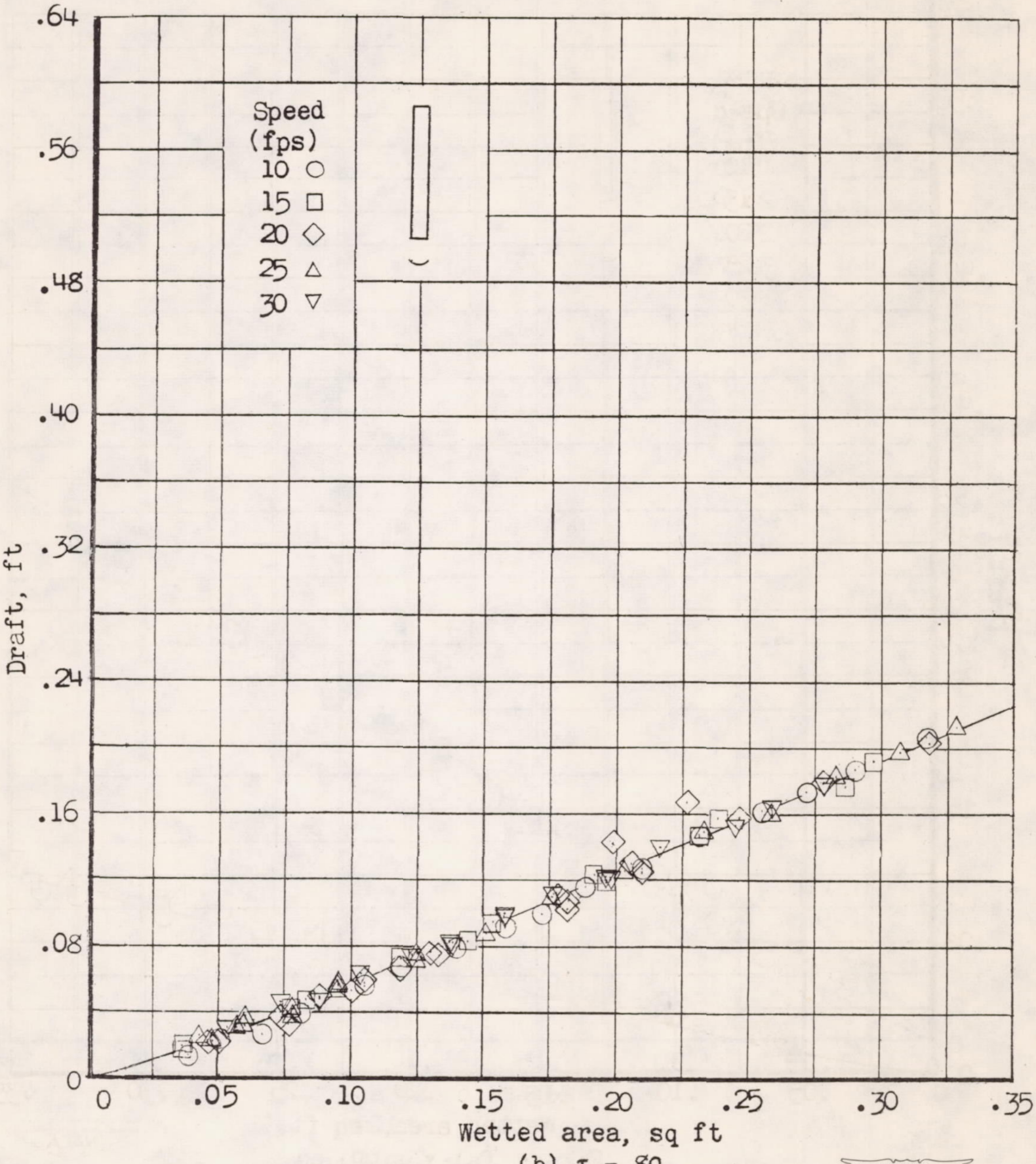
(e) $\tau = 20^{\circ}$.

Figure 20.- Concluded.



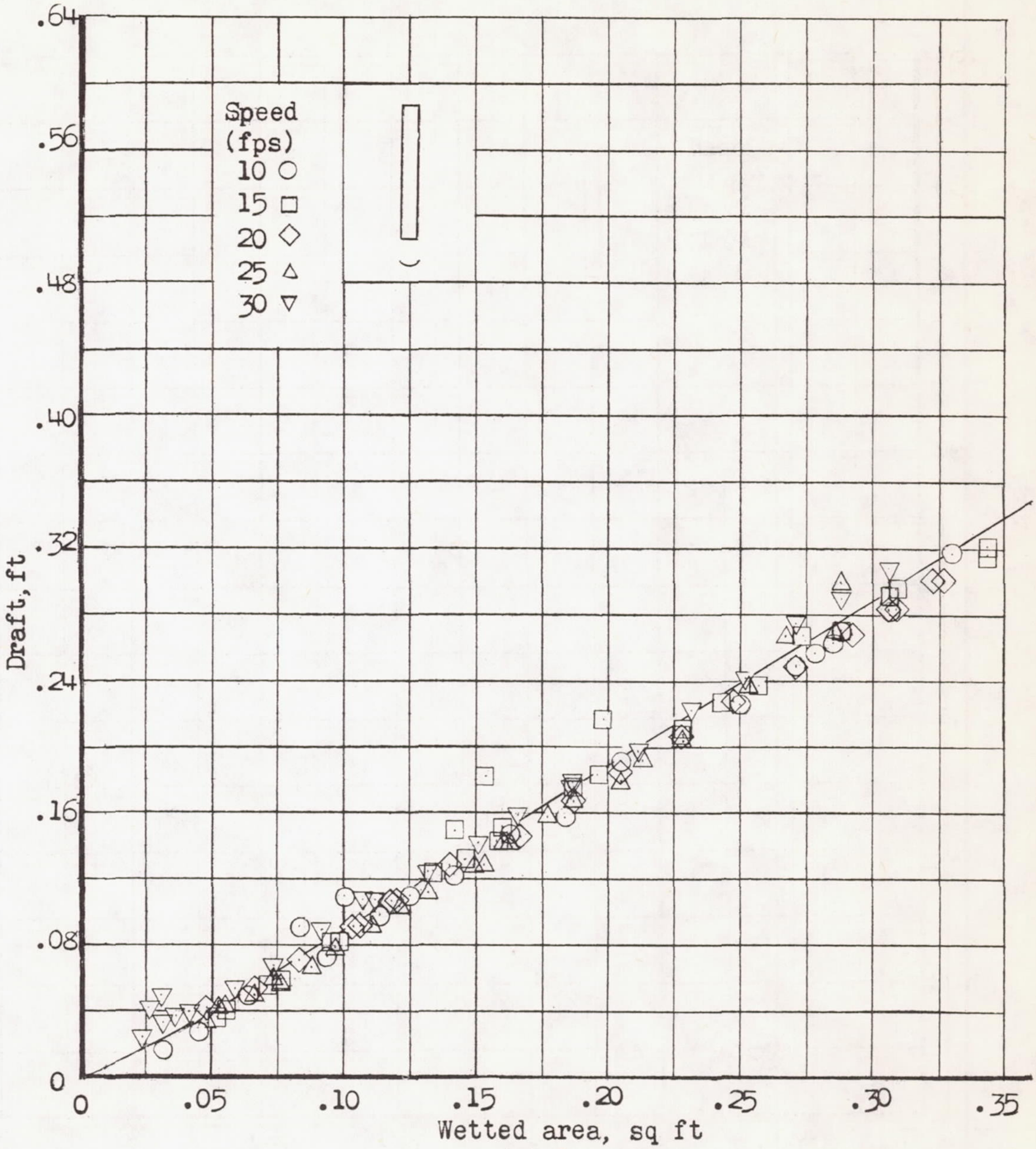
(a) $\tau = 4^{\circ}$.

Figure 21.- Variation of draft with wetted area. Model 250B.



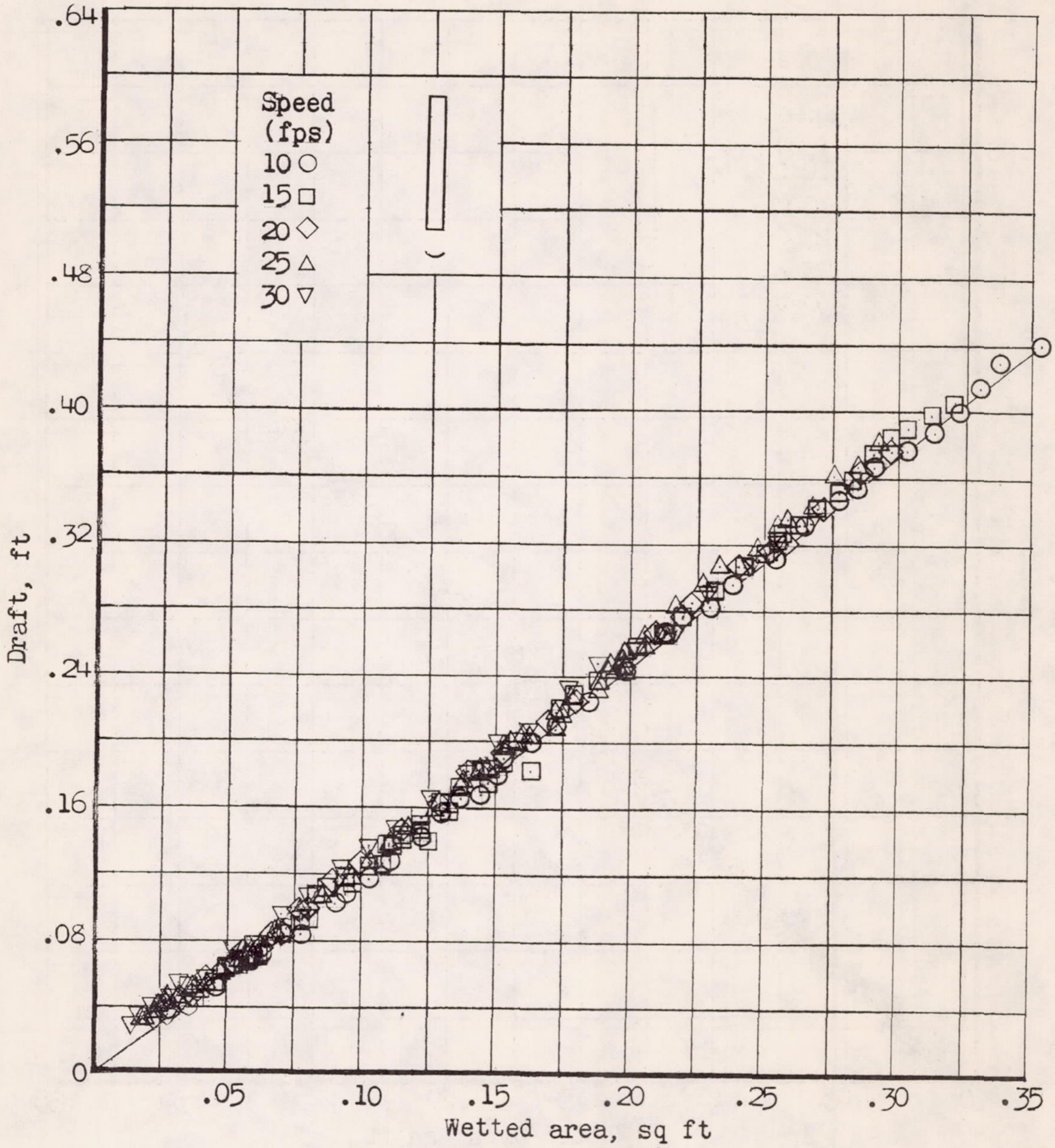
(b) τ = 8°.

Figure 21.- Continued.



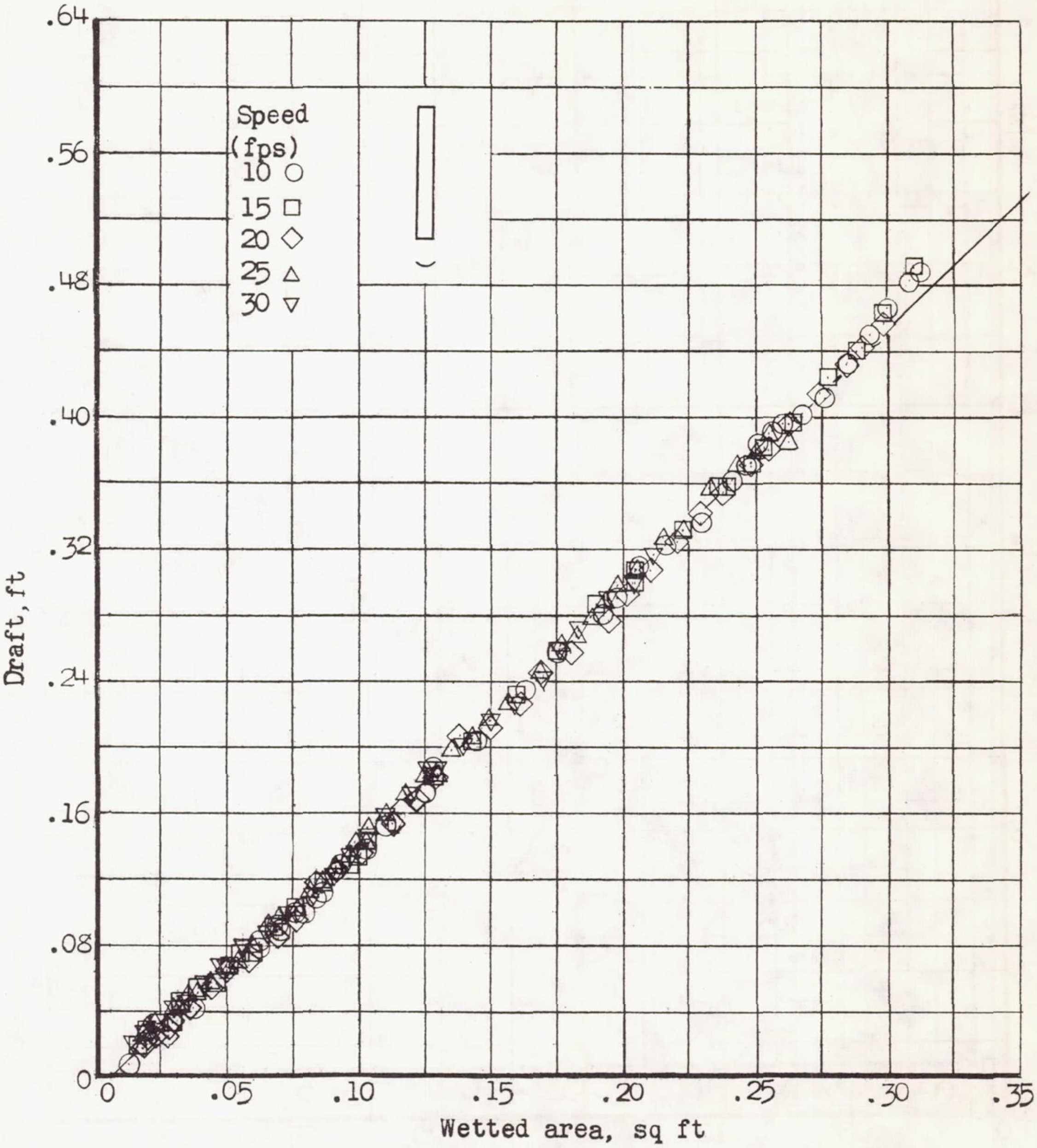
(c) $\tau = 12^{\circ}$.

Figure 21.- Continued.



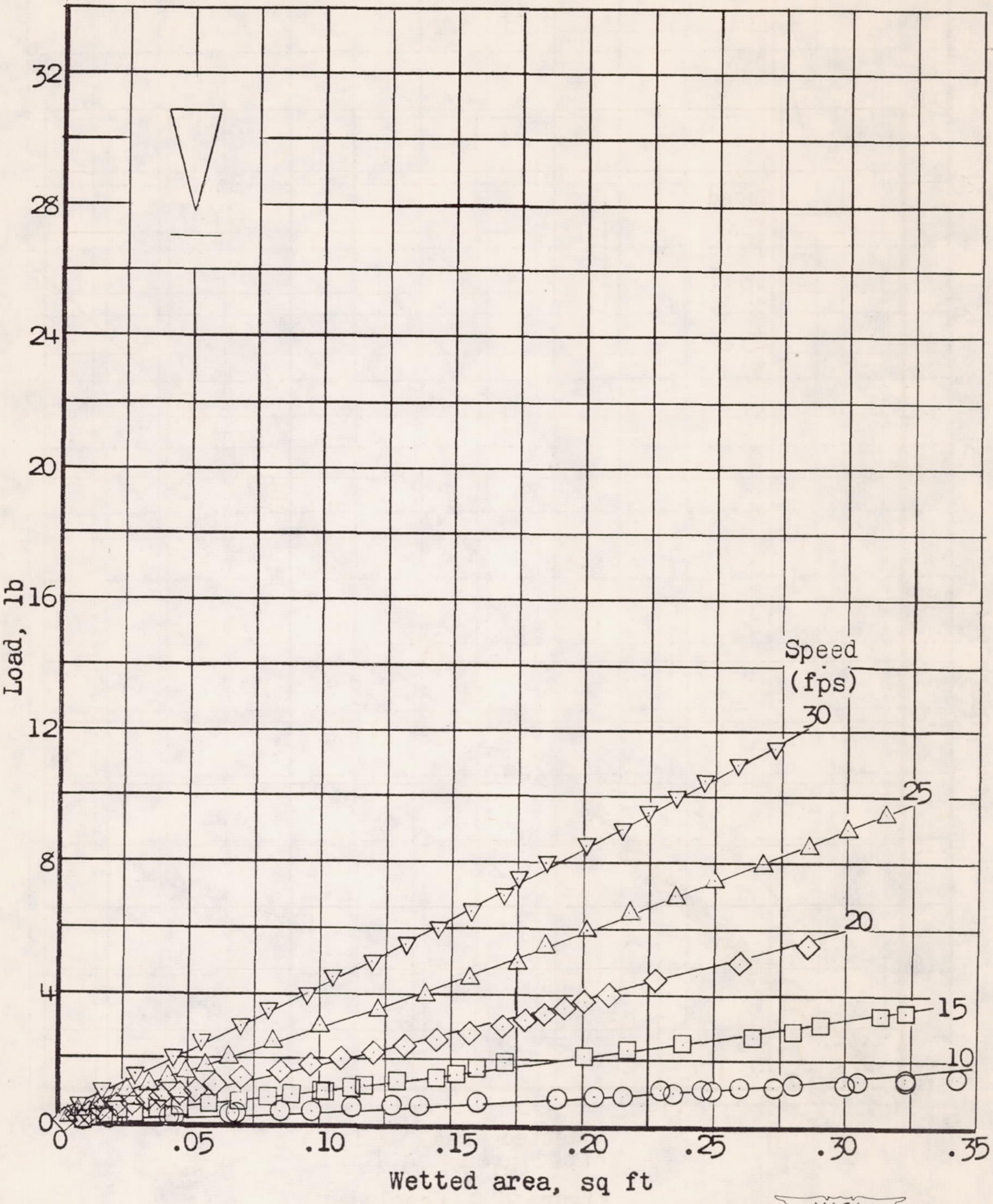
(d) $\tau = 16^{\circ}$.

Figure 21.- Continued.



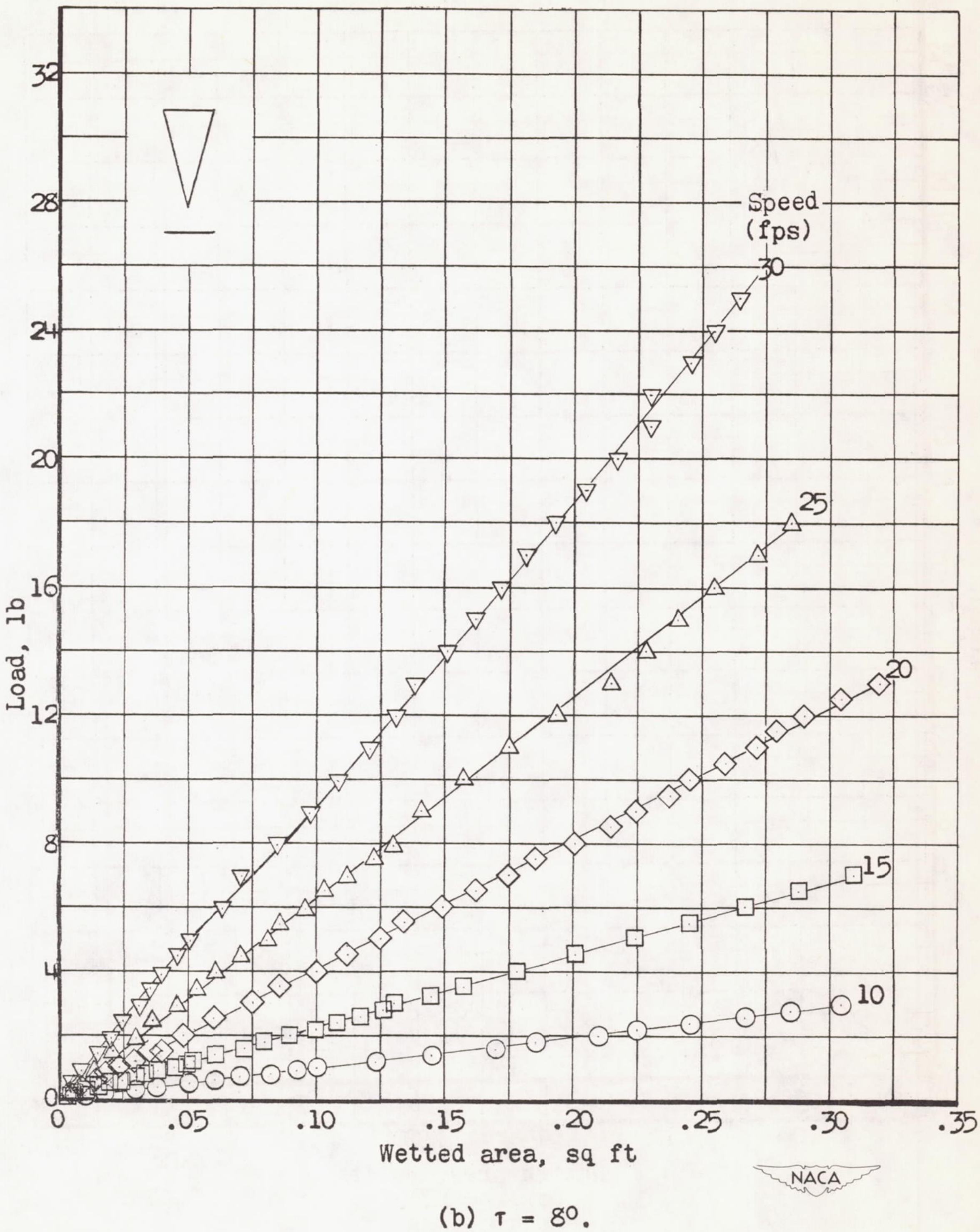
(e) $\tau = 20^{\circ}$.

Figure 21.- Concluded.



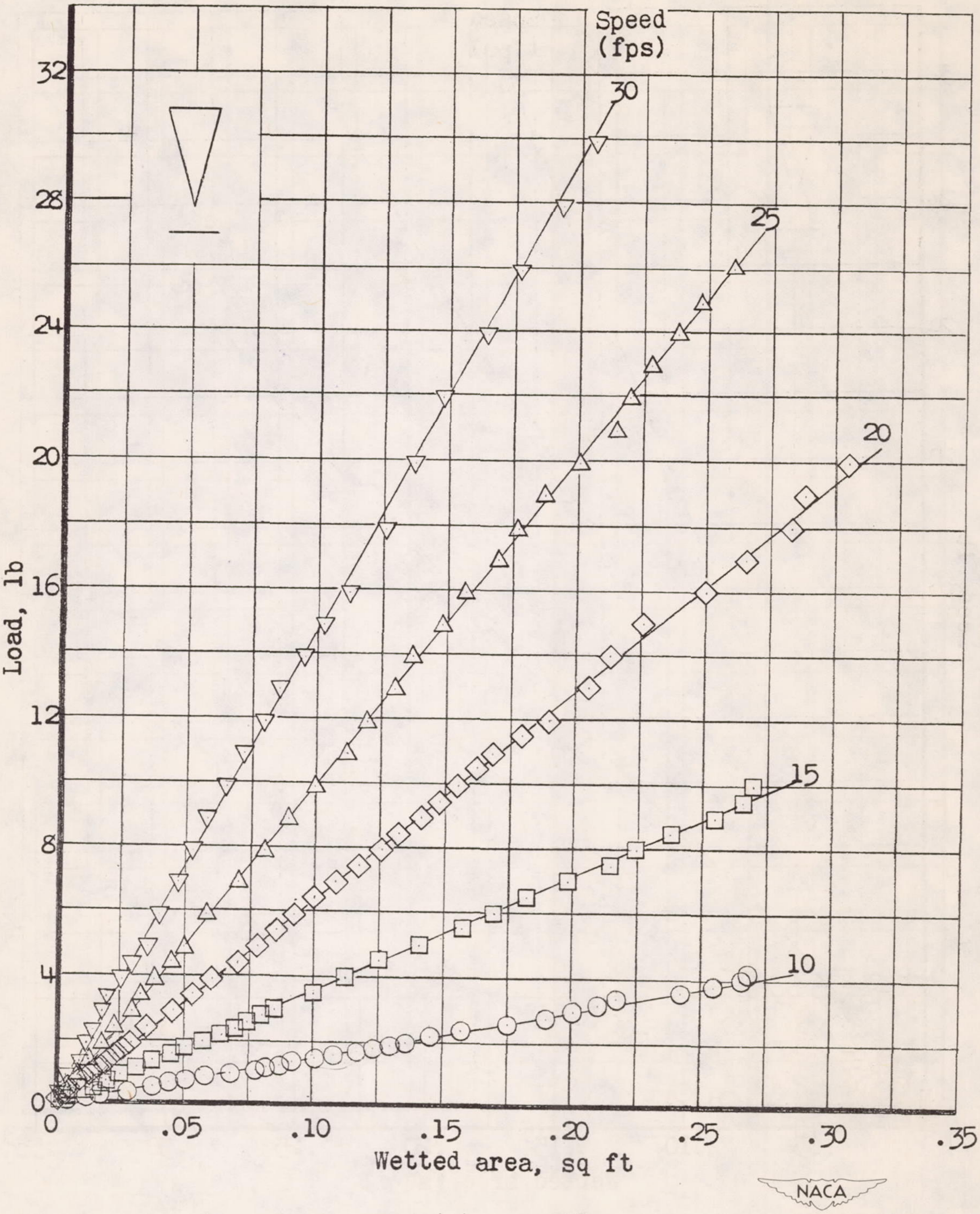
(a) $\tau = 4^{\circ}$.

Figure 22.- Variation of load with wetted area. Model 250D.



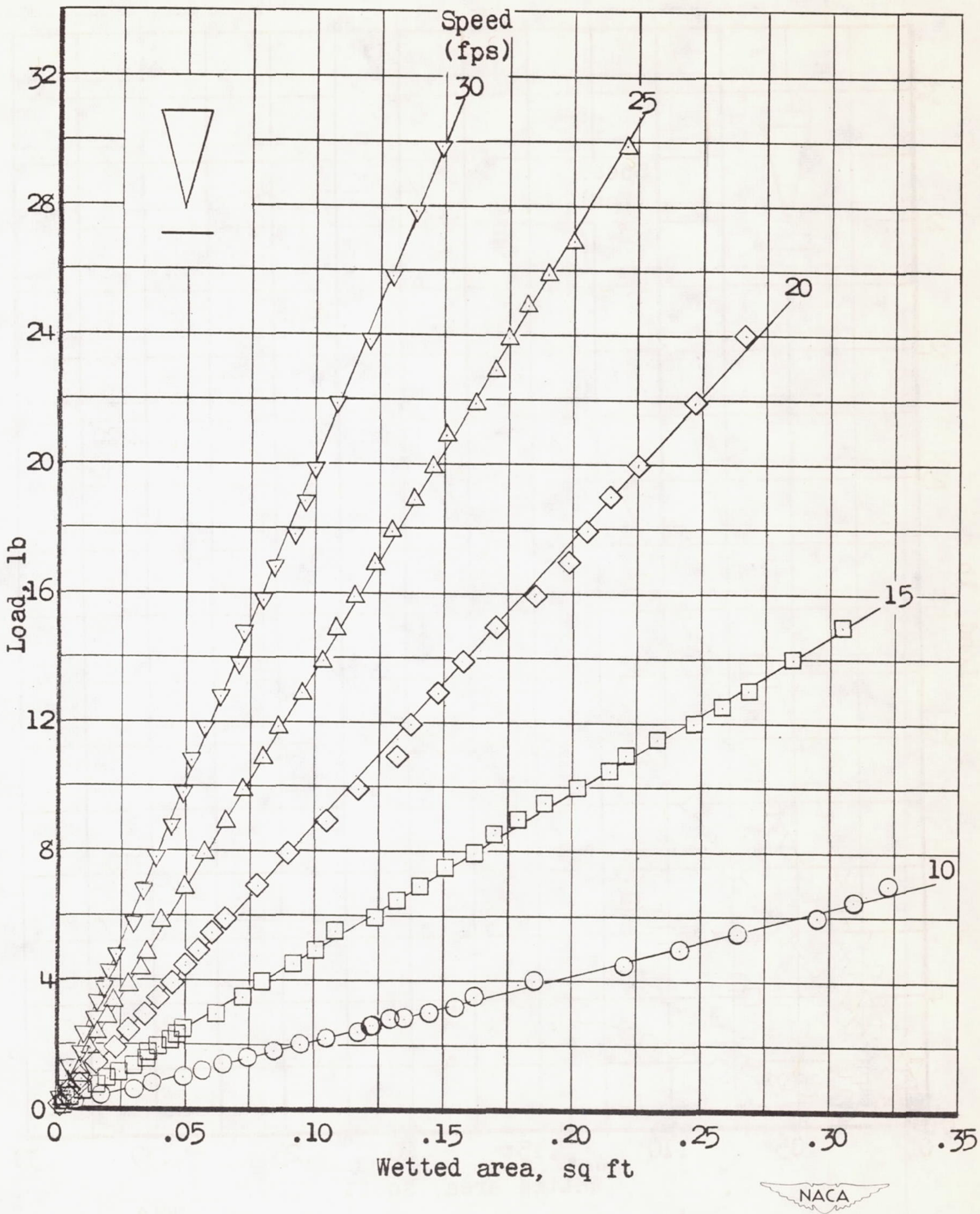
(b) $\tau = 8^{\circ}$.

Figure 22.- Continued.



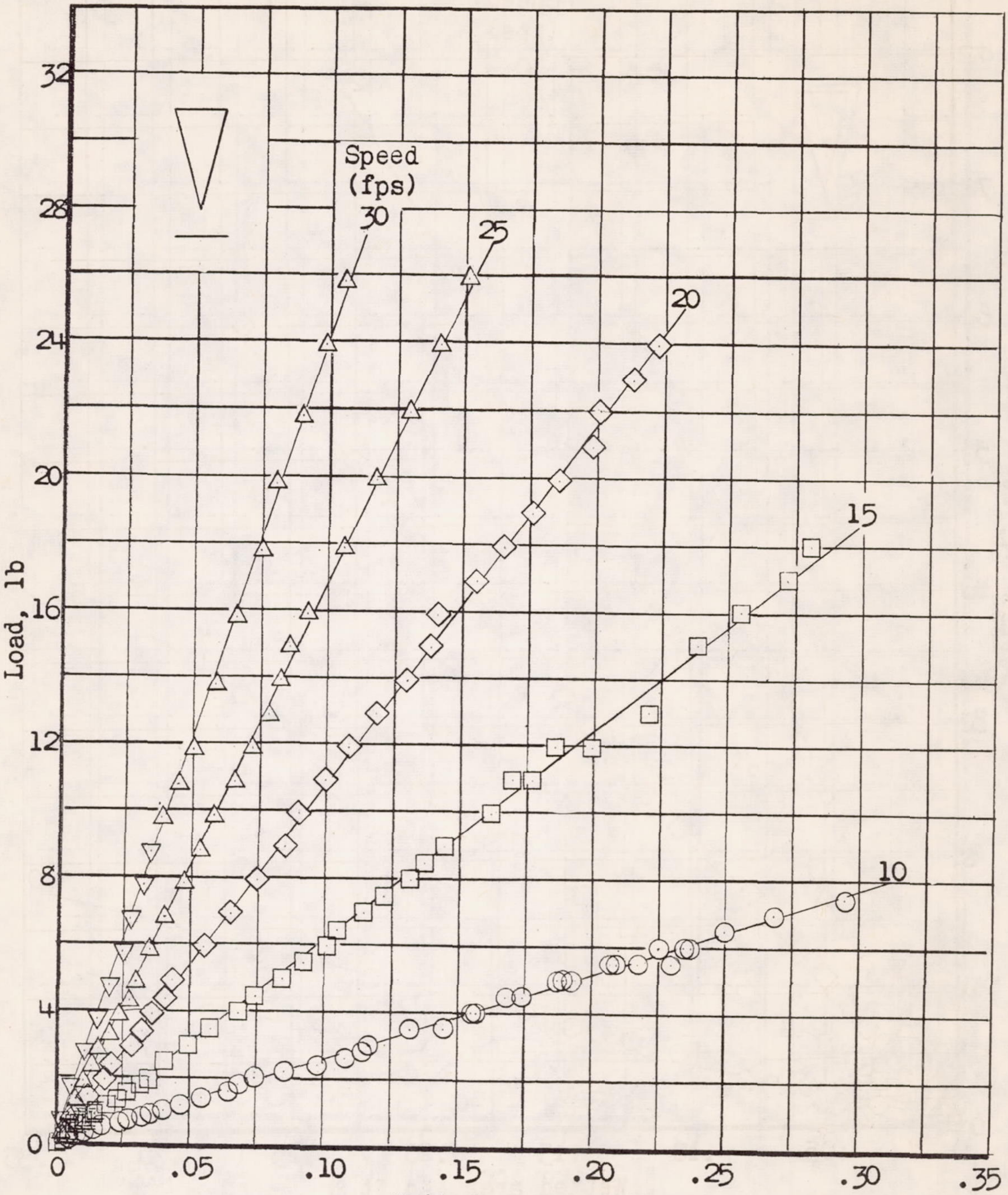
(c) $\tau = 12^{o}$.

Figure 22.- Continued.



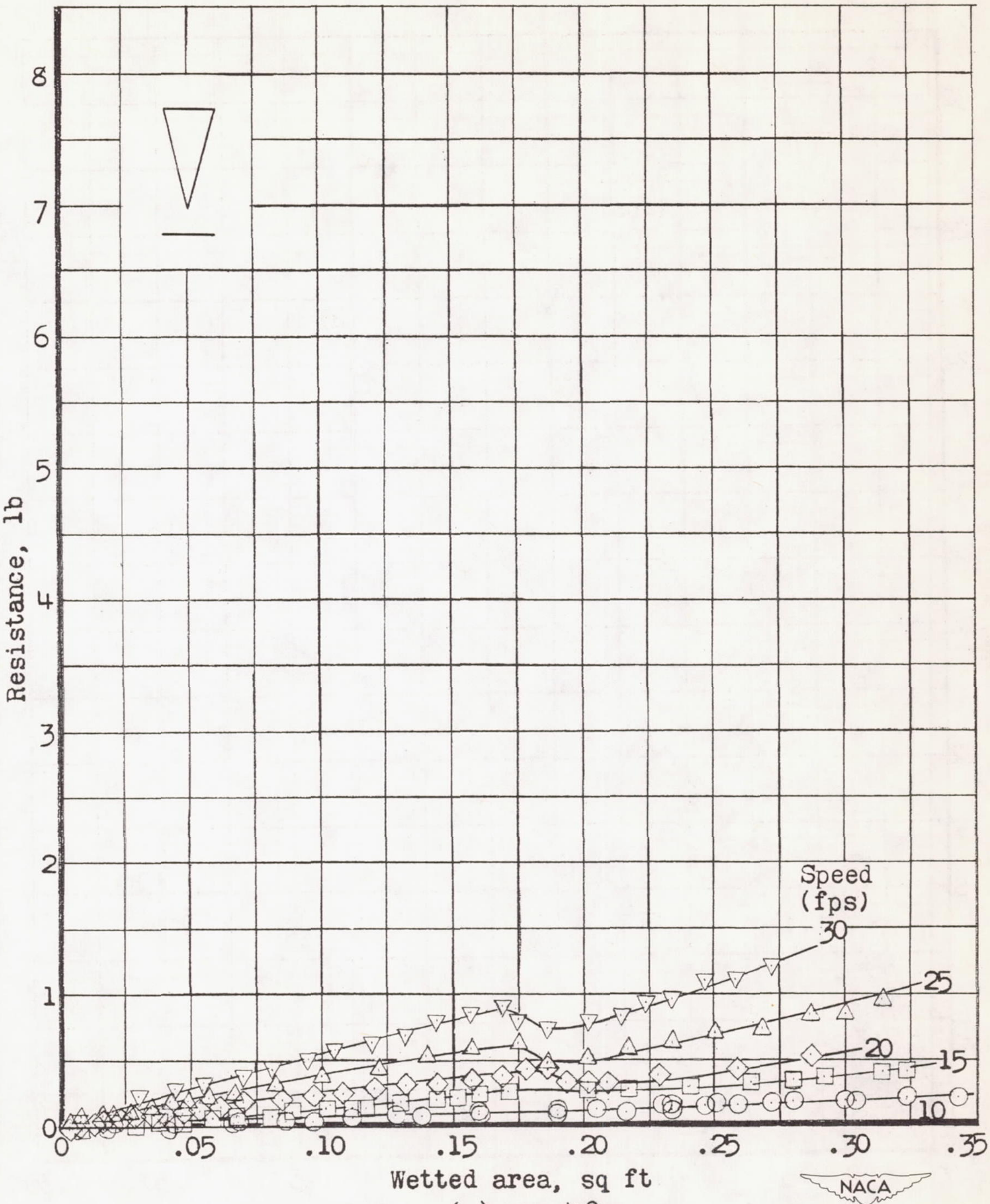
(d) $\tau = 16^{\circ}$.

Figure 22.- Continued.



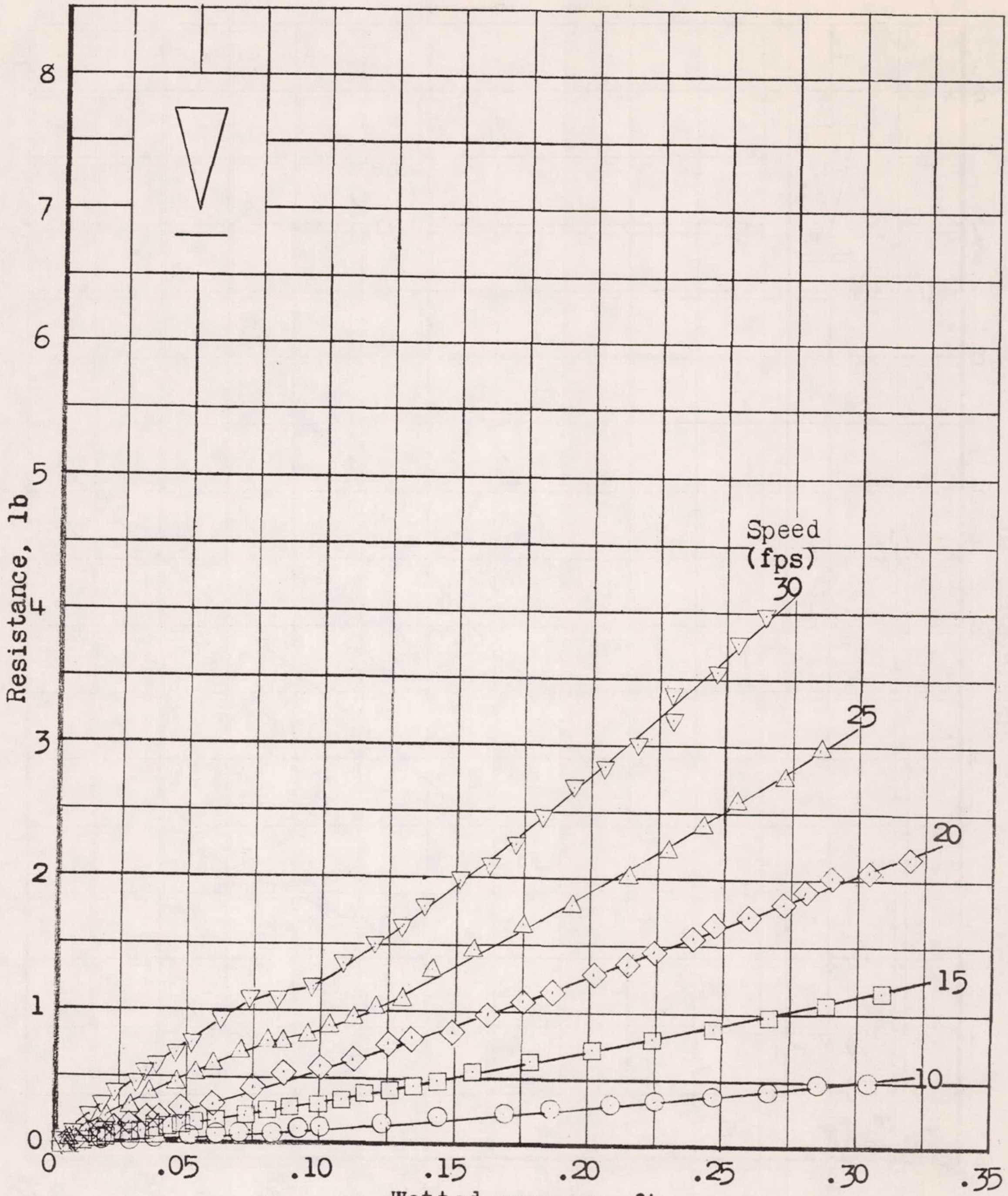
(e) $\tau = 20^{\circ}$.

Figure 22.- Concluded.



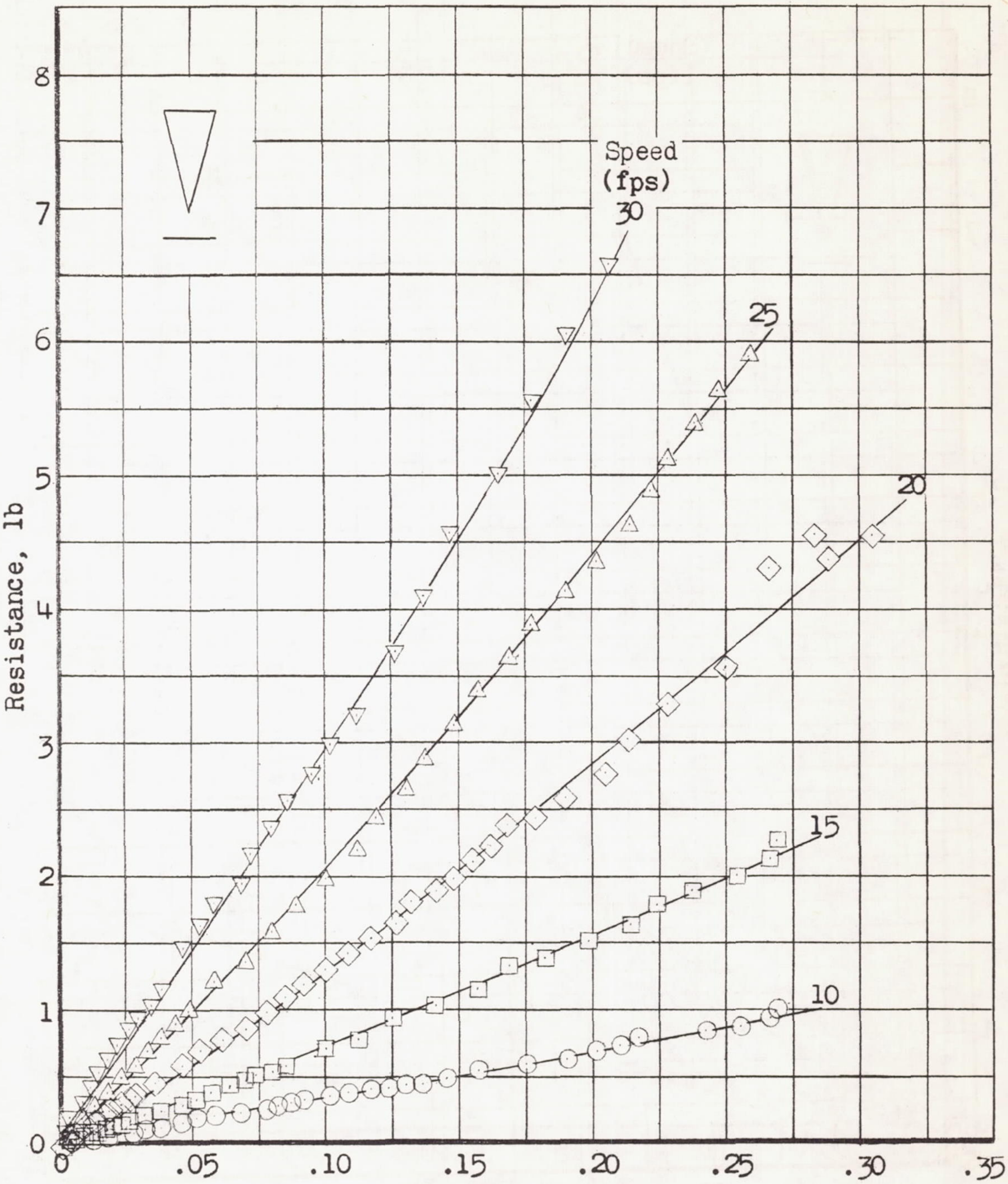
(a) $\tau = 4^{\circ}$.

Figure 23.- Variation of resistance with wetted area. Model 250D.



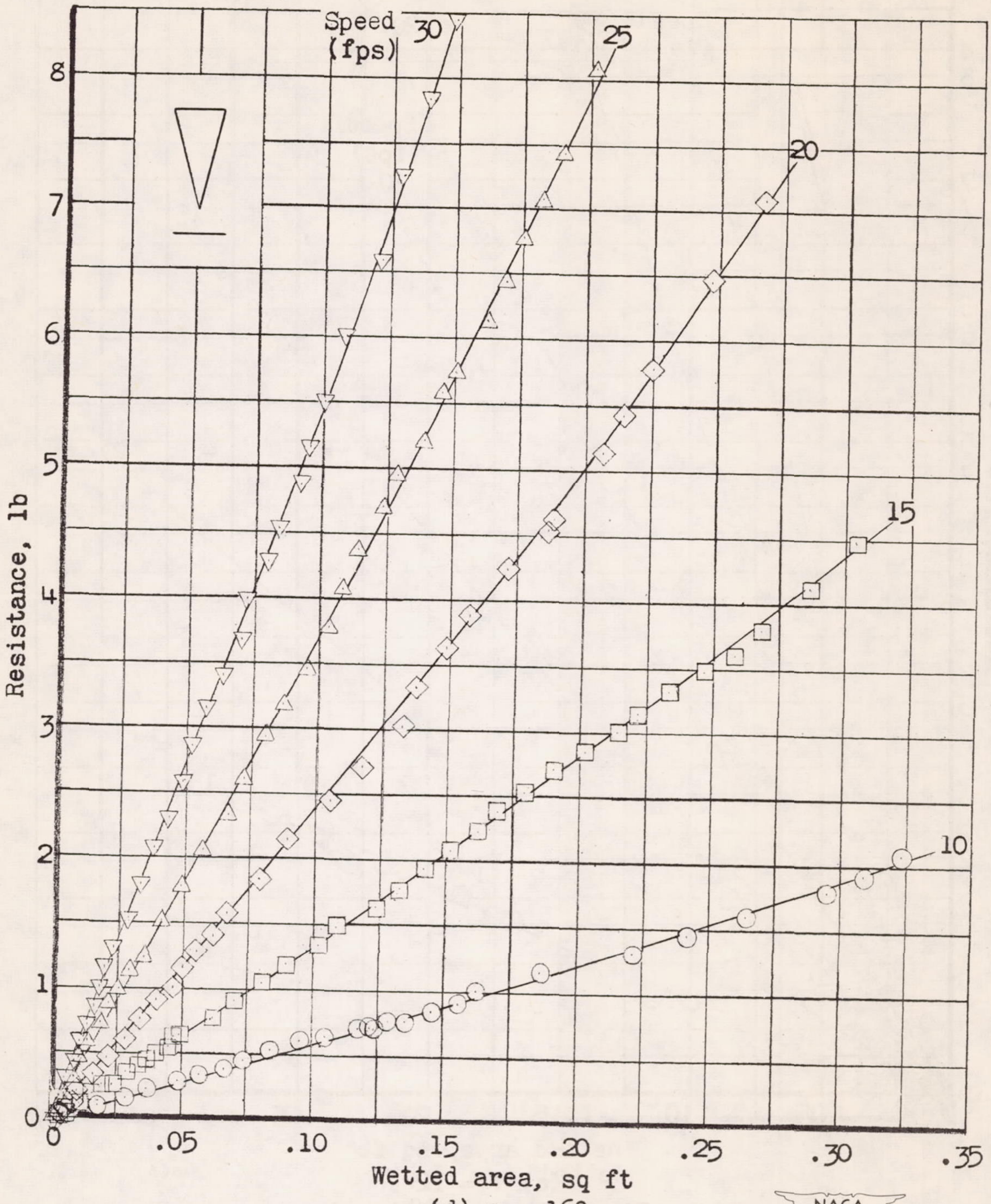
(b) $\tau = 8^{\circ}$.

Figure 23.- Continued.



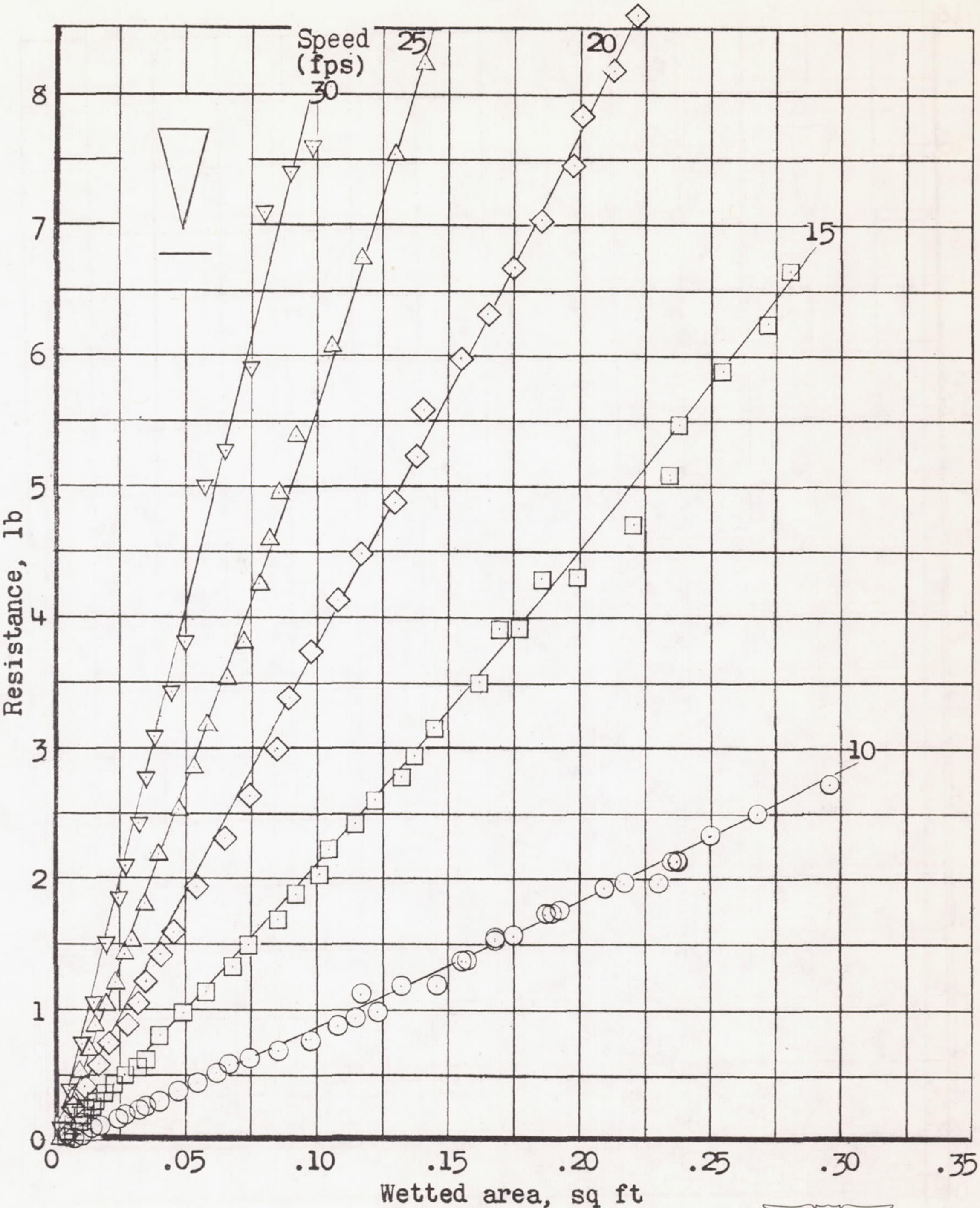
(c) τ = 12°.

Figure 23.-- Continued.



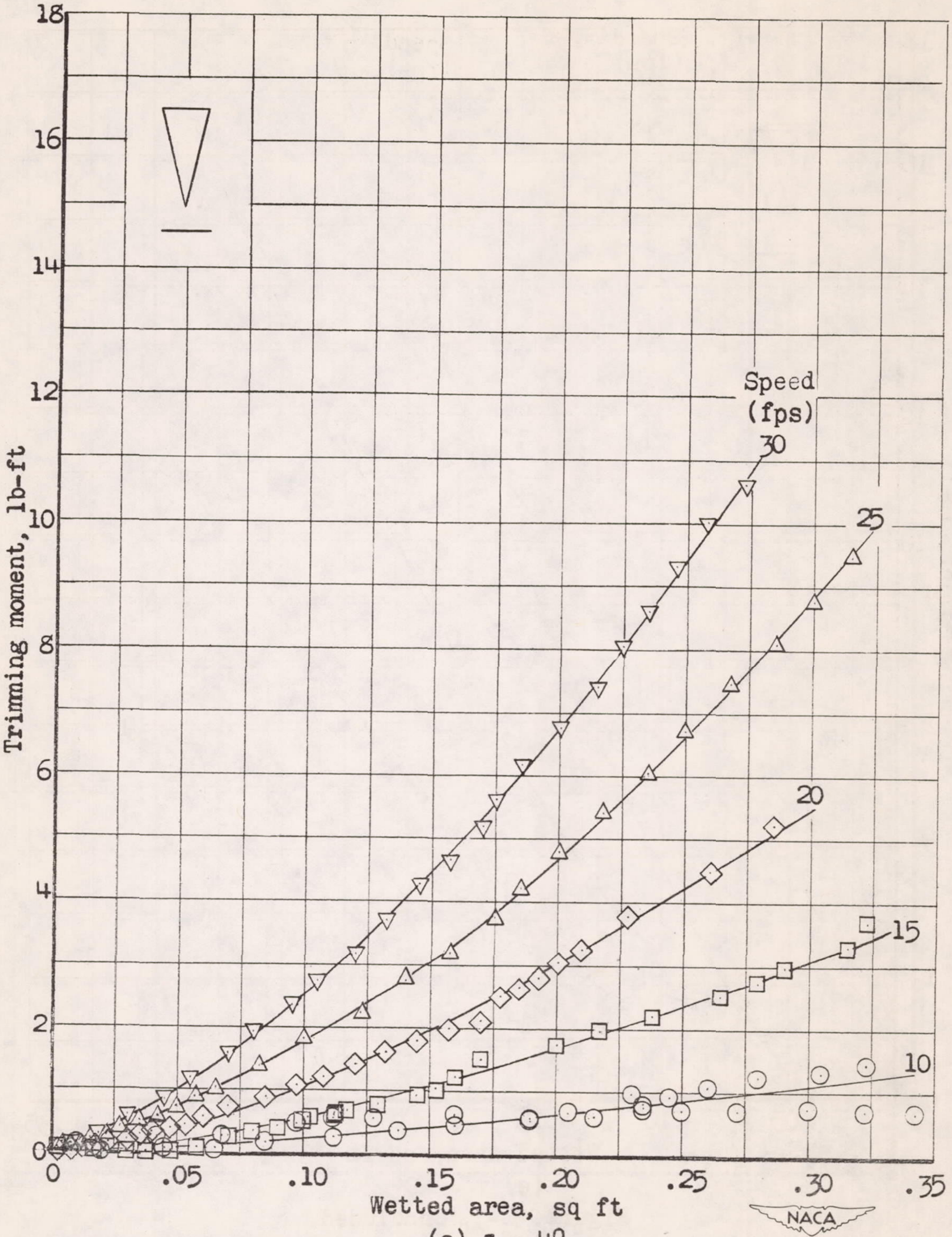
(d) $\tau = 16^{\circ}$.

Figure 23.- Continued.



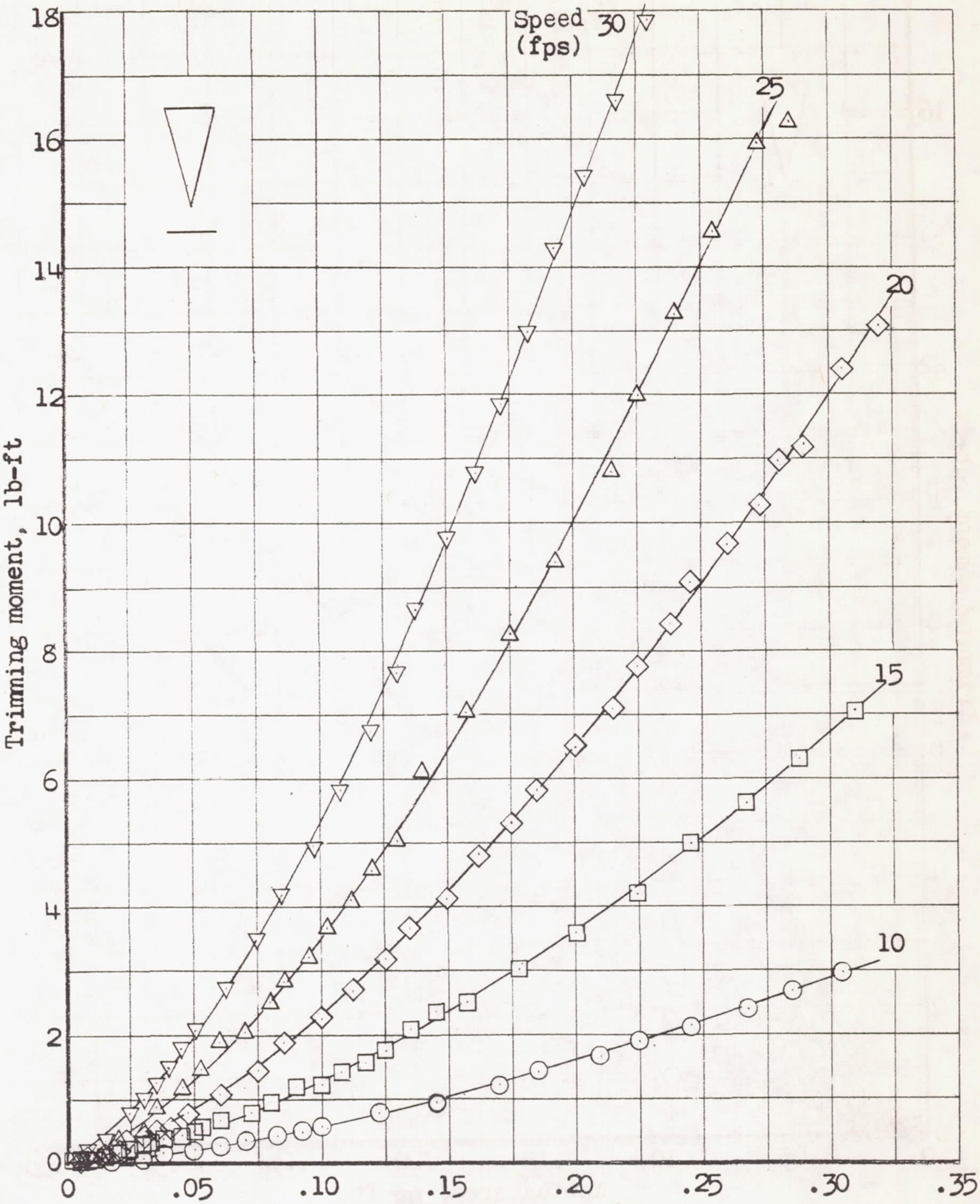
(e) $\tau = 20^{\circ}$.

Figure 23.- Concluded.



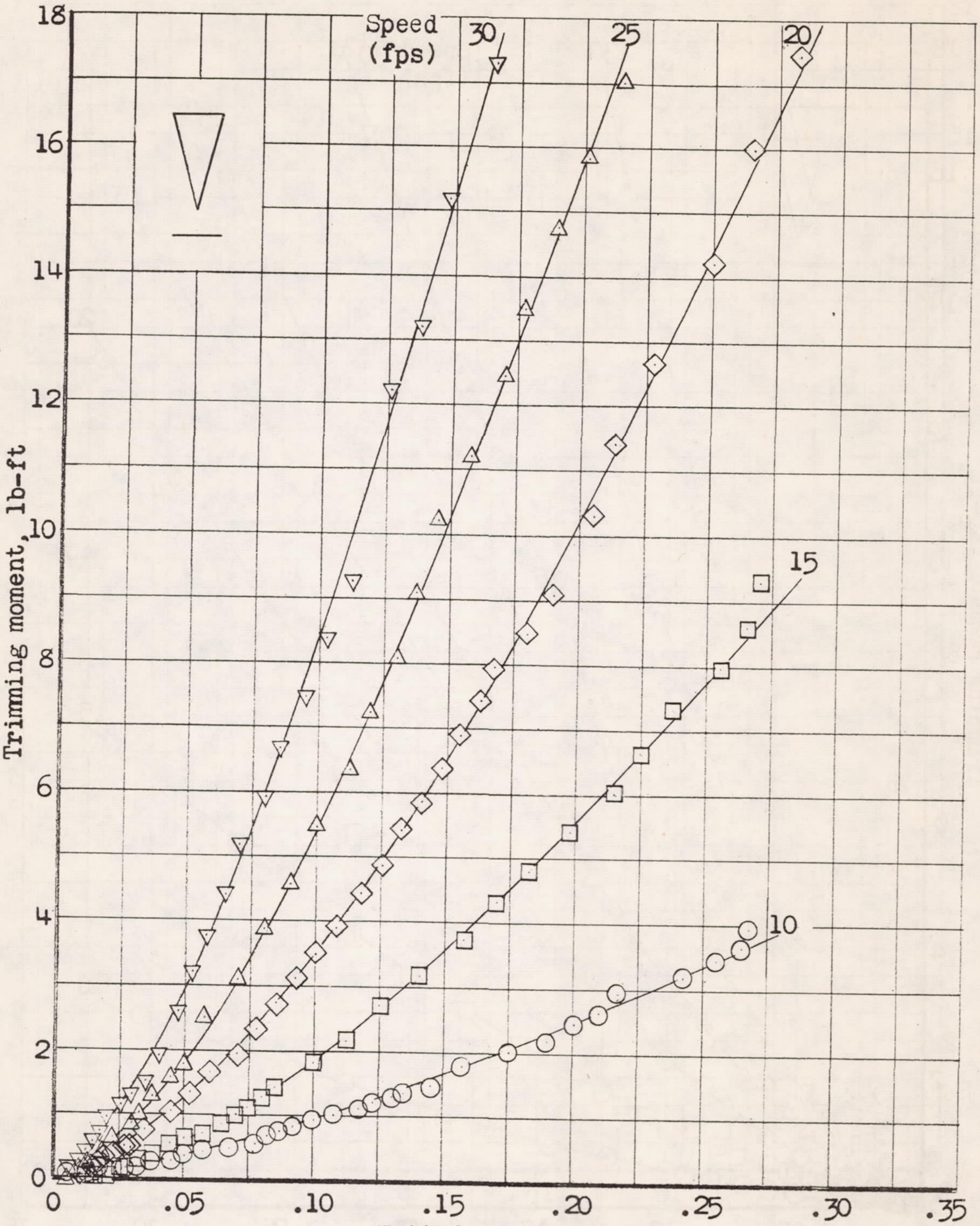
(a) $\tau = 4^{\circ}$.

Figure 24.- Variation of moment with wetted area. Model 250D.



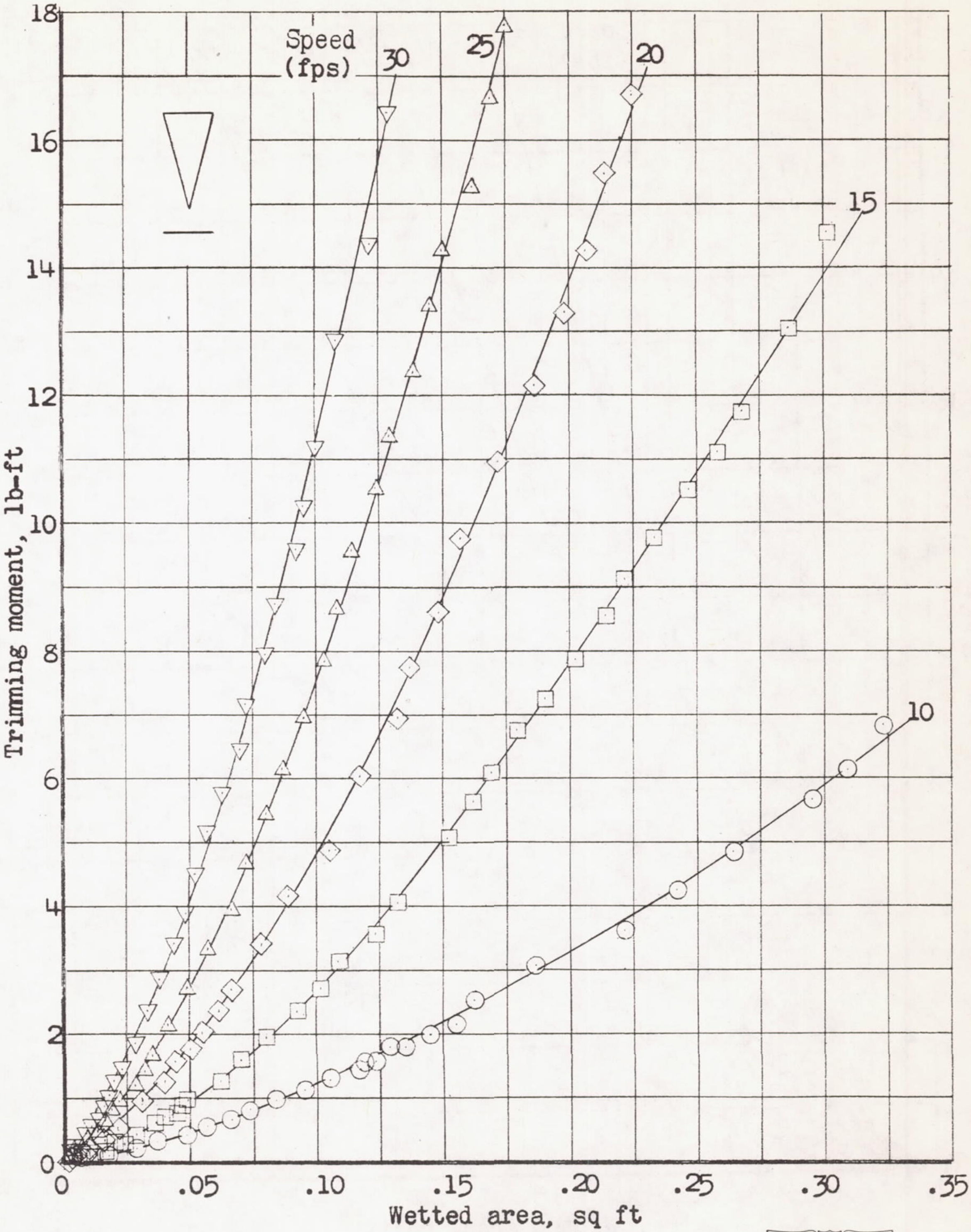
(b) $\tau = 8^{\circ}$.

Figure 24.-- Continued.



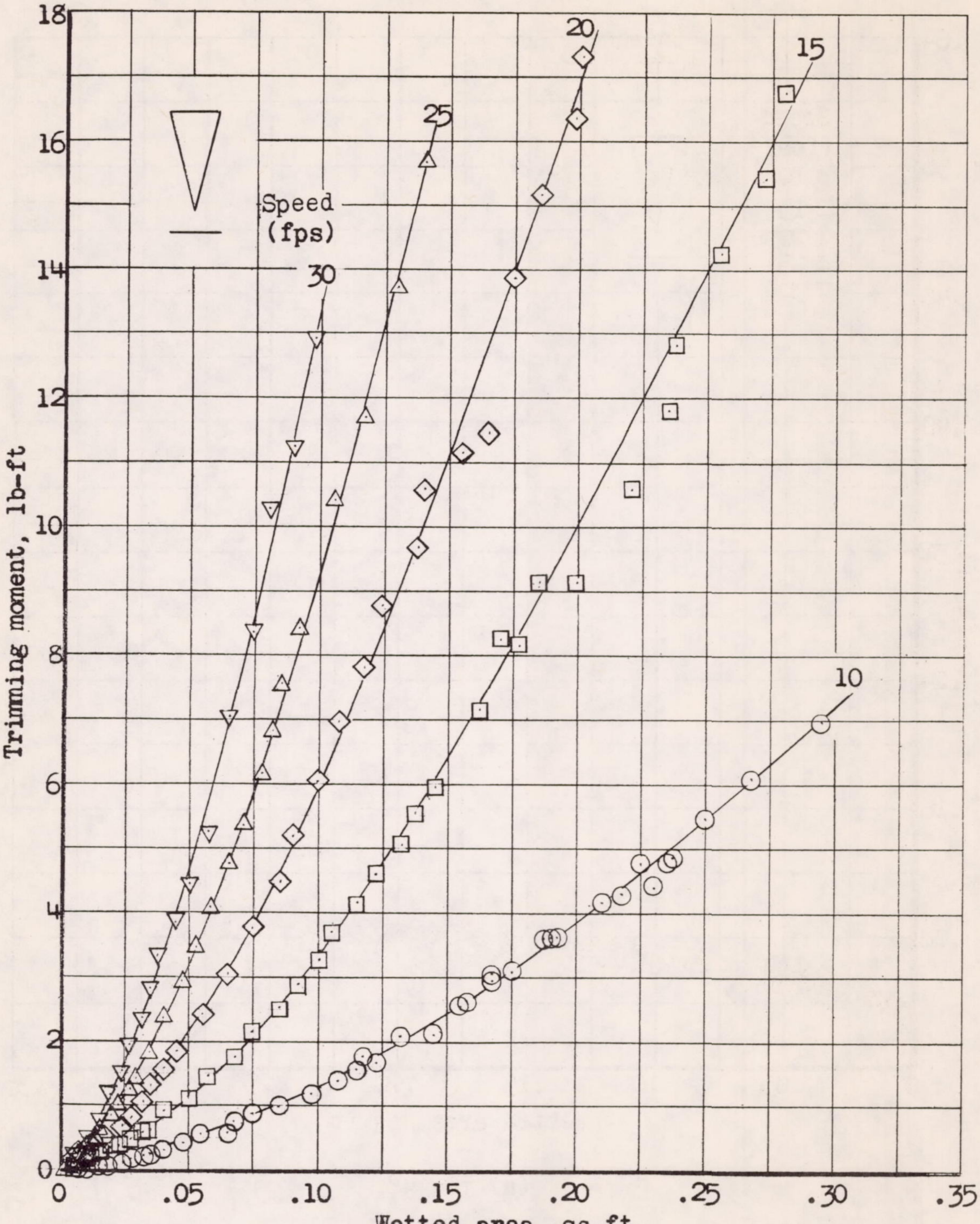
(c) $\tau = 12^{\circ}$.

Figure 24.- Continued.



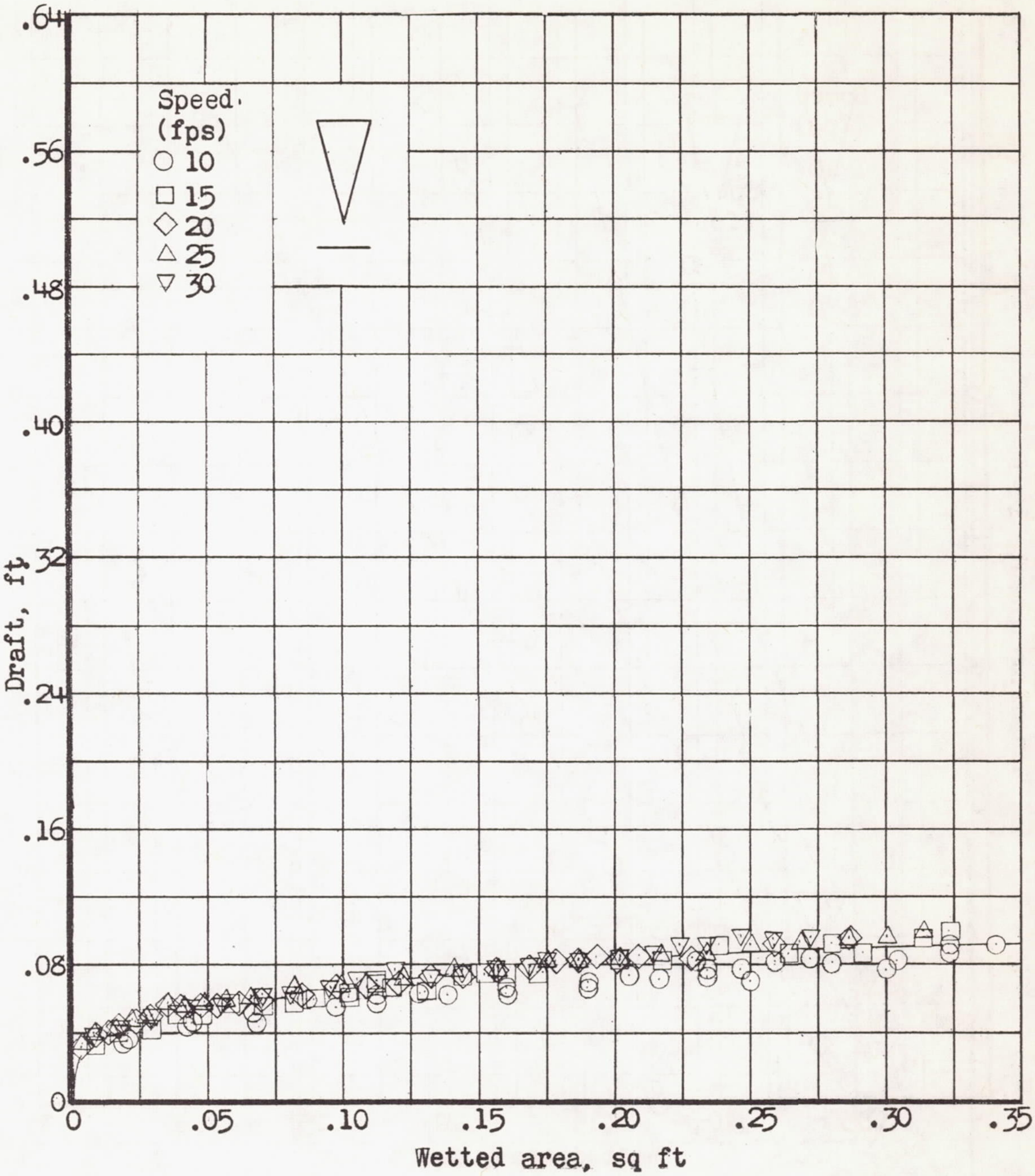
(d) $\tau = 16^{\circ}$.

Figure 24.- Continued.



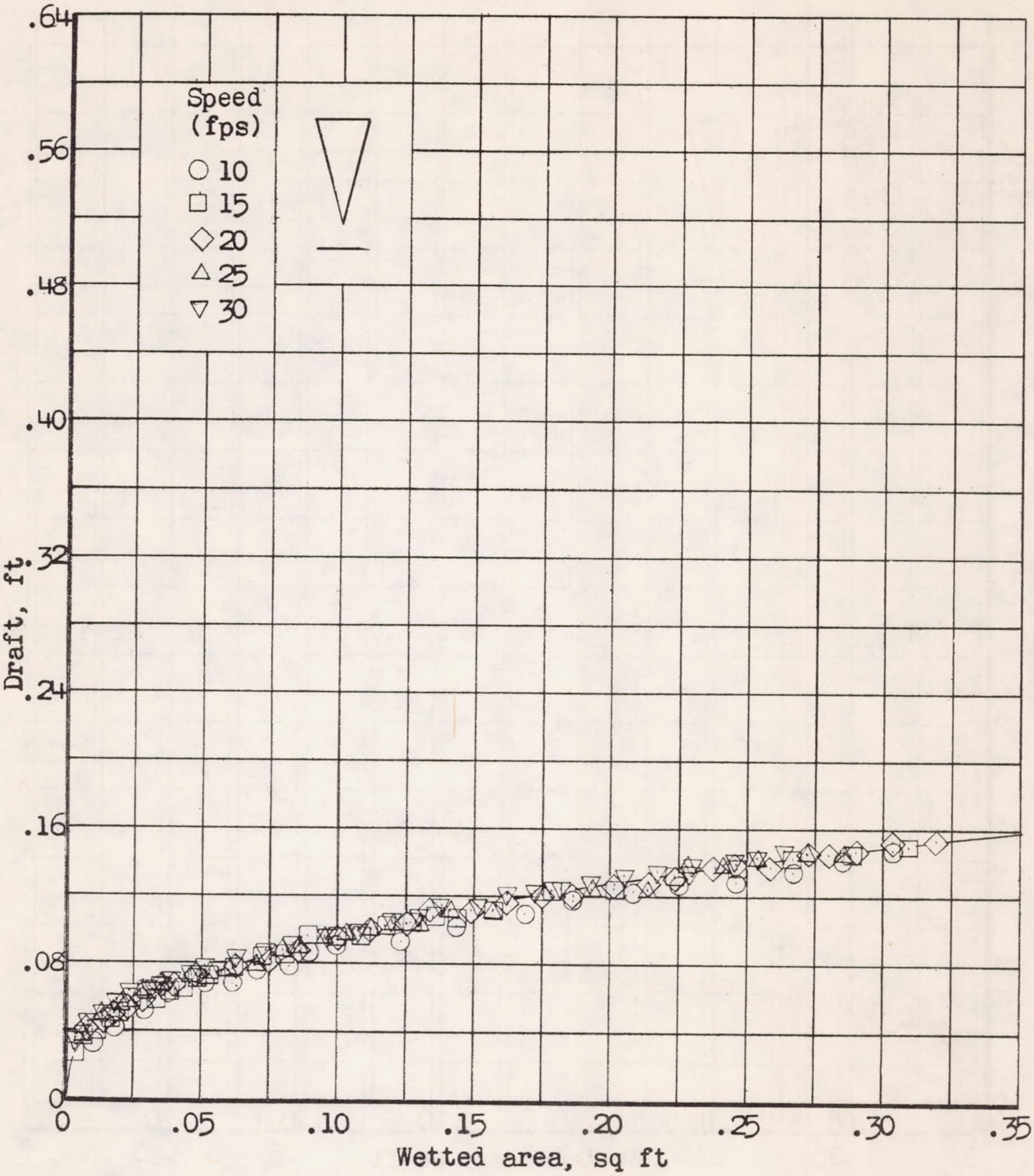
(e) $\tau = 20^{\circ}$.

Figure 24.- Concluded.



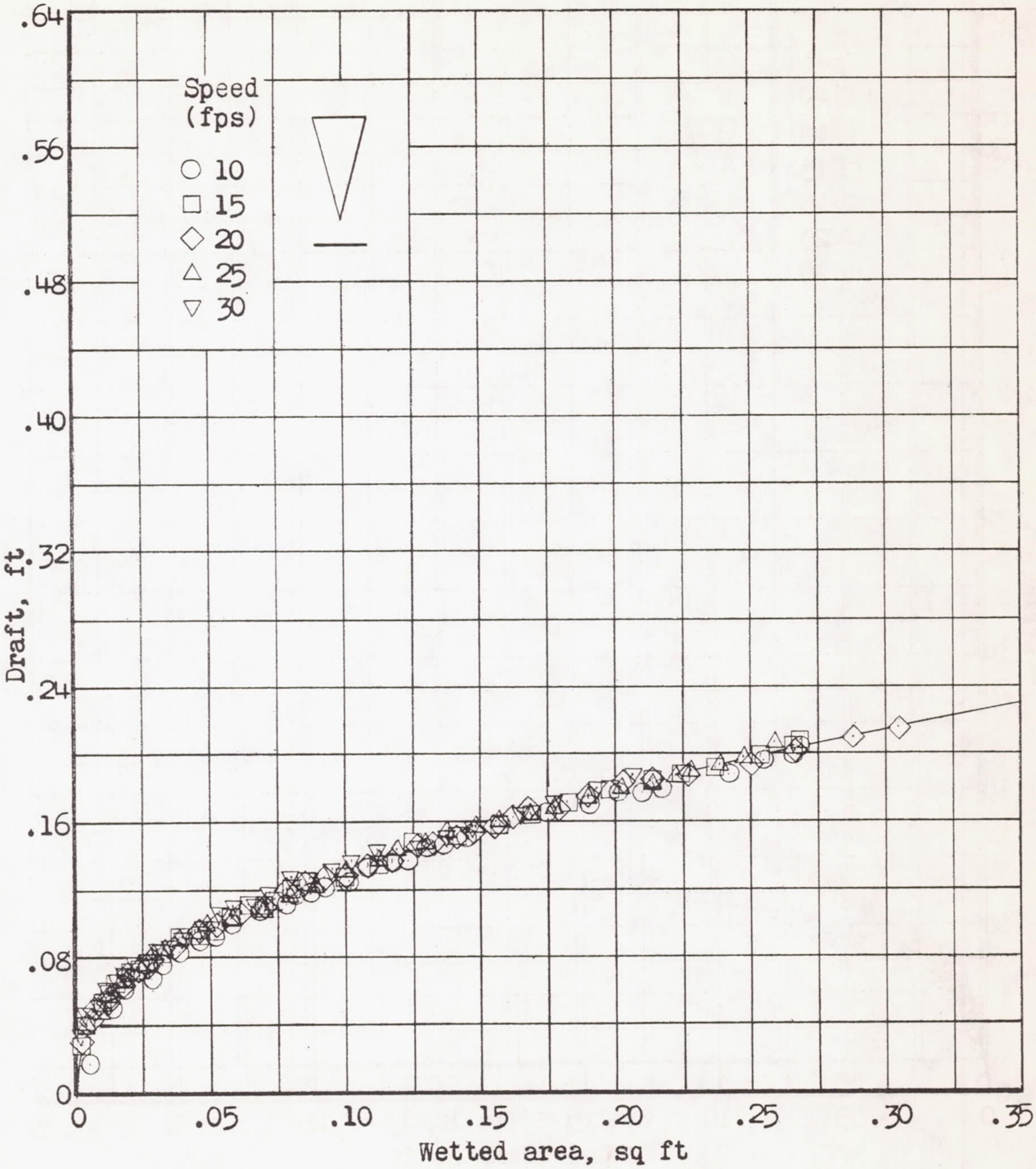
(a) $\tau = 4^{o}$.

Figure 25.- Variation of draft with wetted area. Model 250D.



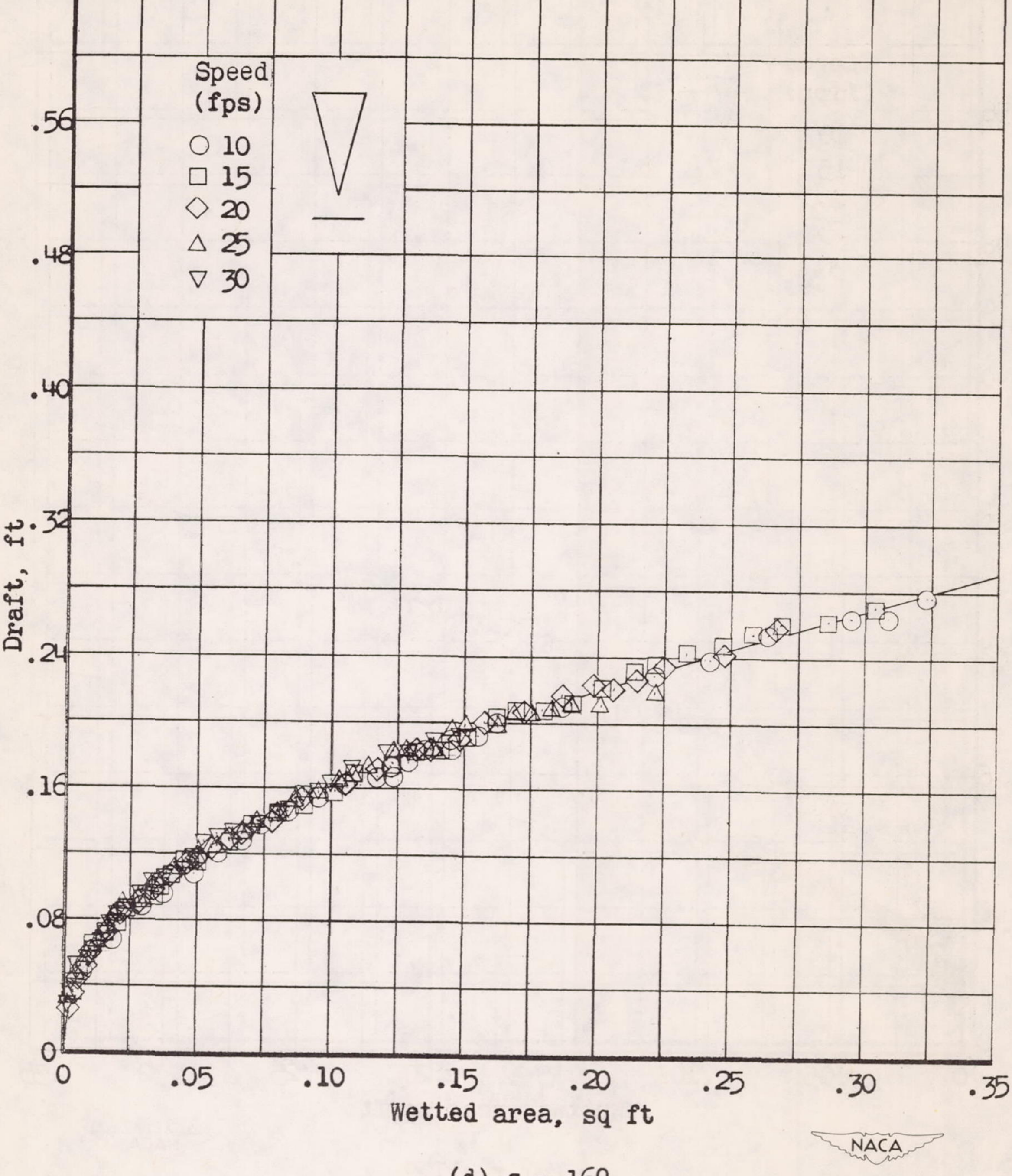
(b) $\tau = 8^{\circ}$.

Figure 25.- Continued.



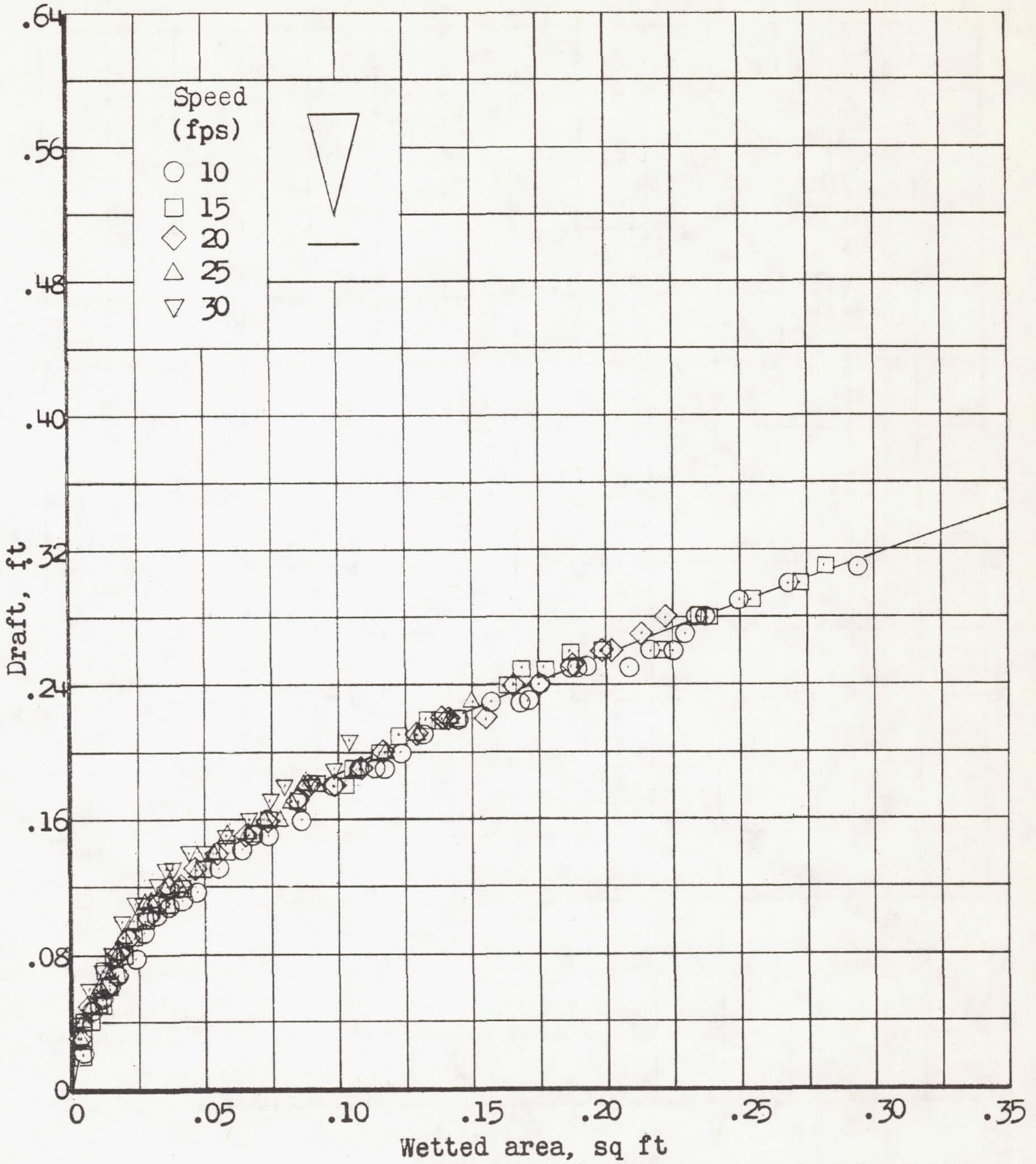
(c) $\tau = 12^{\circ}$.

Figure 25.- Continued.



(d) $\tau = 16^{\circ}$.

Figure 25.- Continued.



(e) $\tau = 20^{\circ}$.

Figure 25.- Concluded.