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*Special Report #37*

THE RELATIVE HYDRODYNAMIC RESISTANCE OF VARIOUS  
TYPES OF RIVET HEADS FROM TESTS OF PLANING SURFACES

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*Special Report #37*

July 1935

# THE RELATIVE HYDRODYNAMIC RESISTANCE OF VARIOUS TYPES OF RIVET HEADS FROM TESTS OF PLANING SURFACES

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## AUTHORITY AND PURPOSE

The Committee was requested to investigate the effect of various types of rivet heads on hydrodynamic resistance by the Bureau of Aeronautics, Navy Department, in their letter of September 23, 1933. It was proposed by the N.A.C.A. to obtain the resistance of the various types by tests of planing surfaces on which the full-size rivets would be arranged in suitable patterns. The necessary surfaces, constructed as suggested by the Committee, were supplied for the tests by the Bureau.

## THE PLANING SURFACES

Details of the surfaces used in the tests are shown in figures 1, 2, 3, and 4. They take the form of aluminum boxes which fit over a common core of oak so that no attachment screws are necessary on the bottom surface. The core provides longitudinal stiffness and a means of attachment to the towing gear. It was found necessary to fit square-edged steel strips at the sides of the assembled surface as shown in figure 4, because the radius formed in breaking over the aluminum sheet allowed the water to flow around the original edges, making the wetted area indeterminate.

The rivet pattern, shown in figures 3 and 4, consists of a single longitudinal row on the center line at 2-inch spacing and transverse rows every 10 inches at 1-inch spacing. The arrangement is intended to simulate a typical panel on the planing bottom of a seaplane hull in way of a stringer. The surfaces were not perfectly flat and straight, but the departures from an ideal plane surface were probably no greater than those found in commercially flat sheet.

The rivet size was stated by the Bureau to be  $5/32$  inch in each case. The designation of the surfaces and the types of rivets corresponding to measurements of the heads are as follows:

<u>Model</u>	<u>Type of head</u>
56-A	Smooth surface (no rivets)
56-B	Sunken heads (mushroom heads with dimpled plating)
56-C	Brazier heads
56-D	Round heads

#### METHOD OF TESTING

Each surface was towed along the surface of the water in the N.A.C.A. tank as a planing surface, in the manner and using the equipment described in reference 1. The resistance of a planing surface includes both wave-making and frictional resistance but, as brought out in reference 2, the latter becomes an increasingly large part of the total as the angle that the planing surfaces makes with the water surface decreases. Accordingly the test runs were made at the lowest practicable angle of trim, which was found from preliminary runs to be  $1\frac{1}{2}^{\circ}$ . The constant speeds used for the test runs ranged from 30 to 60 feet per second, and at these speeds the surfaces were loaded in such a manner as to give wetted lengths ranging from 25 inches to 55 inches forward of the trailing edge.

The windage tare to be deducted from the gross resistance measured by the dynamometer was obtained by runs made with the smooth model at the angle of trim used in the tests but with the trailing edge one inch clear of the water. Thus the net resistance includes the interference at the intersections of the plate and the water but does not include the remaining air drag of the model or towing gear.

The wetted length was read visually at the side of the plates on a scale graduated in inches from the trailing edge. The tests on planing surfaces made by Sottorf (reference 3) show that this length is substantially constant across a flat planing surface.

## RESULTS

Faired curves of the values of net resistance and wetted length obtained from the tests of the surfaces are given in figures 5 to 12. The order of merit of the various arrangements may be found by comparisons among the resistance values given. Since the wetted length is extremely sensitive to change in trim, the difference in wetted length among the models is attributed primarily to small differences in the trim angle caused by very small errors in locking the gear controlling the angles for the different set-ups.

The properties of the water during the tests were as follows:

<u>Model</u>	<u>Test date</u>	<u>Water temp.</u> <u>°F.*</u>	<u>Specific weight</u> <u>lb./cu.ft.</u>	<u>Kinematic viscosity</u> <u>ft.<sup>2</sup>/sec.</u>
56-A	1-23-35	45.5	63.630	0.0000155
	1-29-35	43.0	63.645	.0000161
56-B	2- 4-35	41.0	63.651	.0000167
56-C	2- 6-35	41.0	63.651	.0000167
56-D	2- 8-35	41.0	63.651	.0000167

\*Measured one foot from surface.

## ANALYSIS

Figure 13, paralleling figure 11b of reference 2, shows the forces acting on a flat planing surface when the top and side edges are free of water and hence only under atmospheric pressure. From the diagram the friction component parallel to the plate may be found from the measured resistance and load.

Cross plots of resistance and wetted length against load for speeds of 30, 40, 50, and 60 feet per second were made for each model, enabling a further elimination of error in fairing the original data. The resistance and load

for wetted lengths of 25, 35, 45, and 55 inches were obtained from these cross plots and the friction component calculated for each condition. These forces were then converted to the nondimensional friction coefficient

$$C_f = \frac{F}{\frac{\rho}{2} V^2 A}$$

where  $F$  is friction force, lb.  
 $\rho$ , water density, lb. sec.<sup>2</sup>/ft.<sup>4</sup>  
 $V$ , speed, ft. per sec.  
 $A$ , wetted area, sq.ft.

In computing  $A$ , the width over the steel strips which were added was used.

Figure 14 shows the calculated values of  $C_f$ , for the surfaces with the various rivet heads, plotted against speed. Values of Prandtl's coefficient for a smooth flat plate having a turbulent boundary layer with laminar approach are plotted for comparison. These values are calculated from the relation

$$C_f = \frac{0.074}{R^{1/5}} - \frac{1700}{R}$$

where  $R$  is the Reynolds Number. This expression is taken from "Applied Hydro- and Aeromechanics," by Prandtl and Tietjens, published in 1934.

It will be seen that the coefficients obtained from the smooth planing surface tested in the tank are generally lower than those from Prandtl's formula. The fairly close agreements, however, particularly at the higher wetted lengths, establish the validity of the results from tests of planing surfaces for a comparative test of this nature.

Logarithmic plotting of the friction force against speed for wetted lengths of 45 and 55 inches (fig. 15) indicates that the force obtained varies approximately as  $v^{1.72}$  and that the relative merit shown will extend to the usual get-away speeds for seaplanes.

## CONCLUSIONS

From the standpoint of hydrodynamic resistance, the tests show that

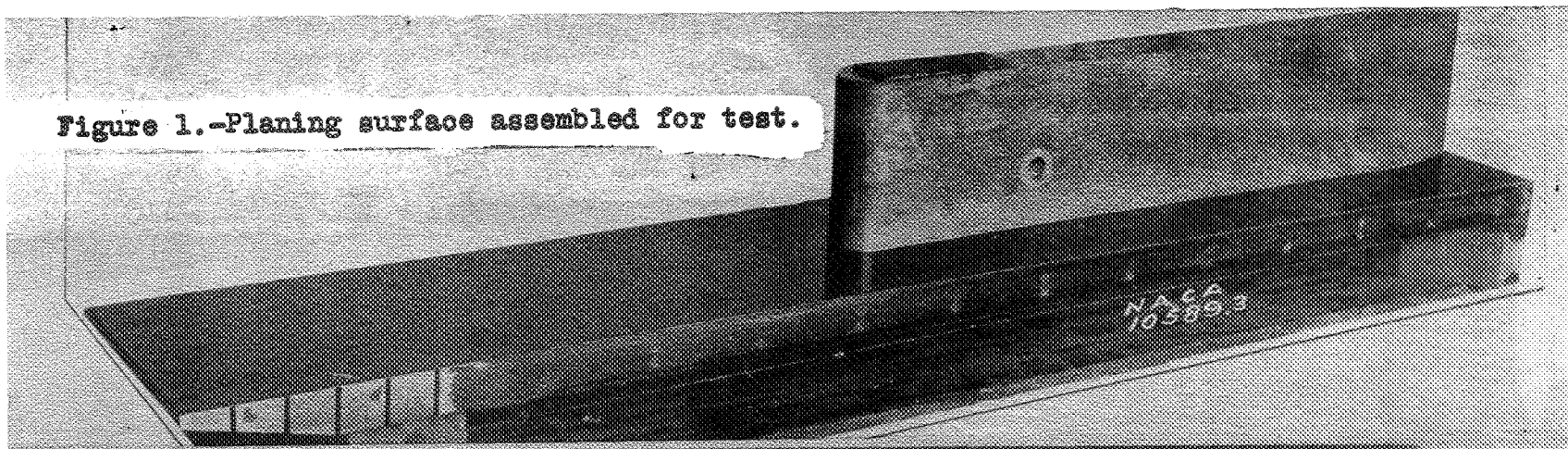
1. The sunken dimpled type of riveting is only slightly inferior to the flush type (smooth surface).
2. The brazier- and round-type heads have a larger adverse effect.
3. The brazier-type head is preferable to the round type.

Langley Memorial Aeronautical Laboratory,  
National Advisory Committee for Aeronautics,  
Langley Field, Va., April 5, 1935.

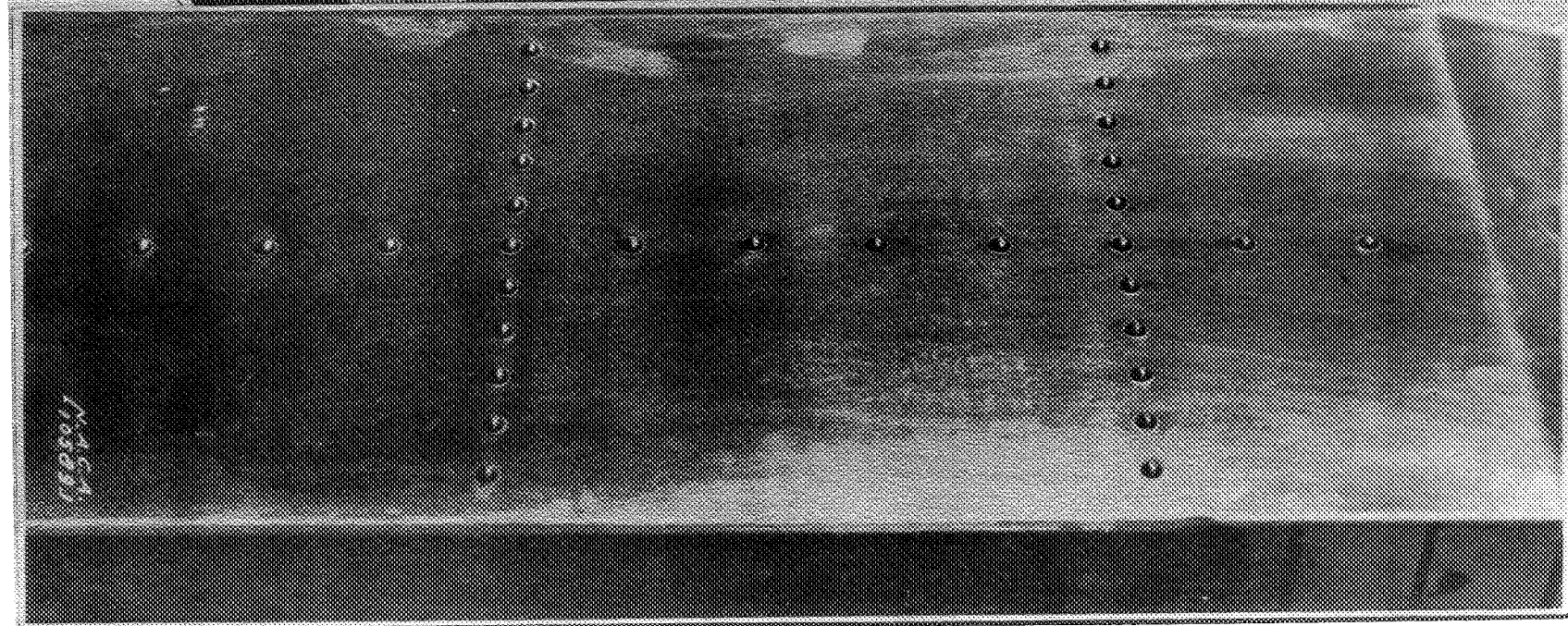
## REFERENCES

1. Shoemaker, James M.: Tank Tests of Flat and V-Bottom Planing Surfaces. T.M. No. 509, N.A.C.A., 1934.
2. Sottorf, W.: Experiments with Planing Surfaces. T.M. No. 739, N.A.C.A., 1934.
3. Sottorf, W.: Experiments with Planing Surfaces. T.M. No. 661, N.A.C.A., 1932.

Figure 1.-Planing surface assembled for test.



N.A.C.A.



FIGS. 1, 2

Figure 2.-Detail of model 56-D.

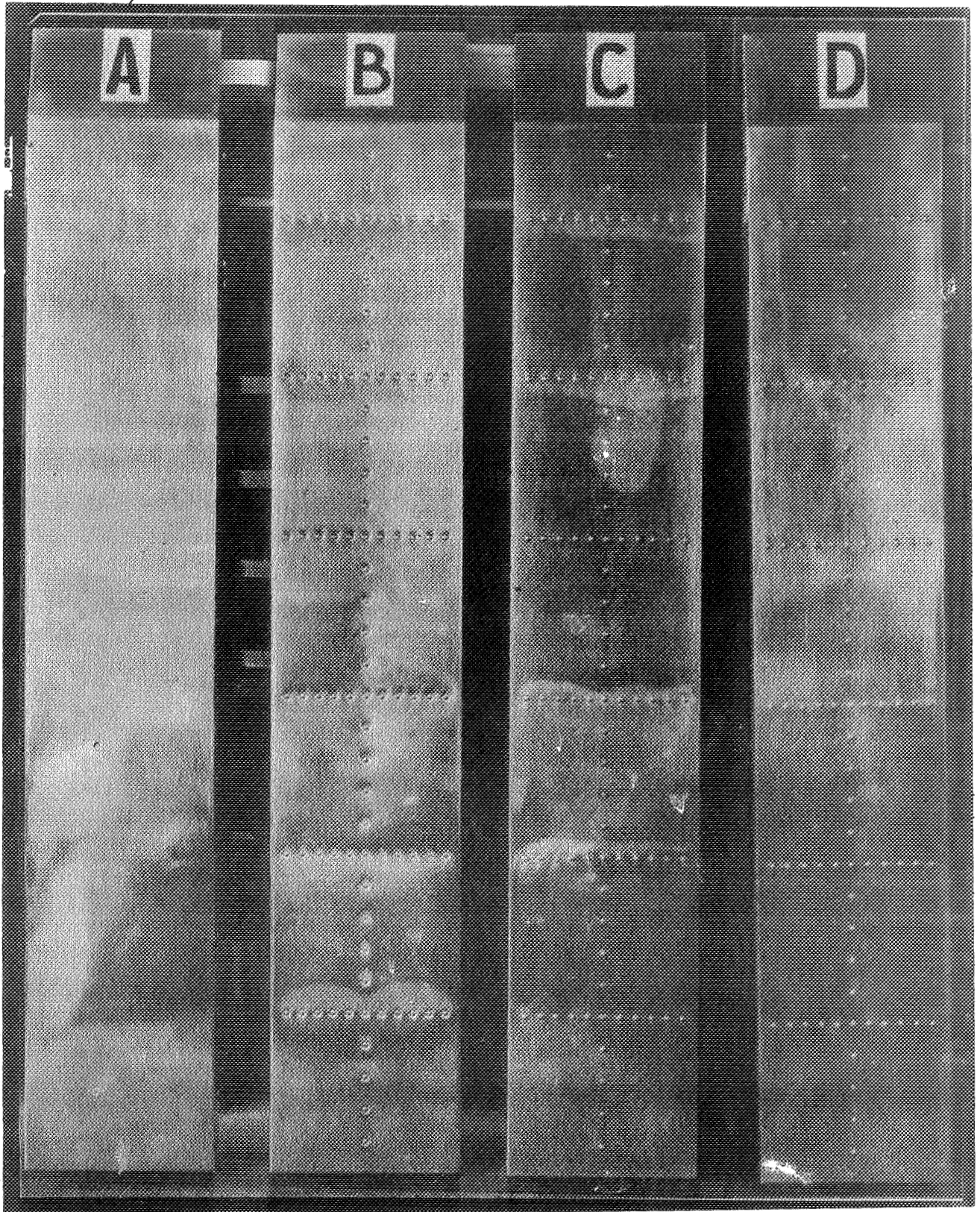


Figure 3.-Planing surfaces tested. D is assembled with strips and core.



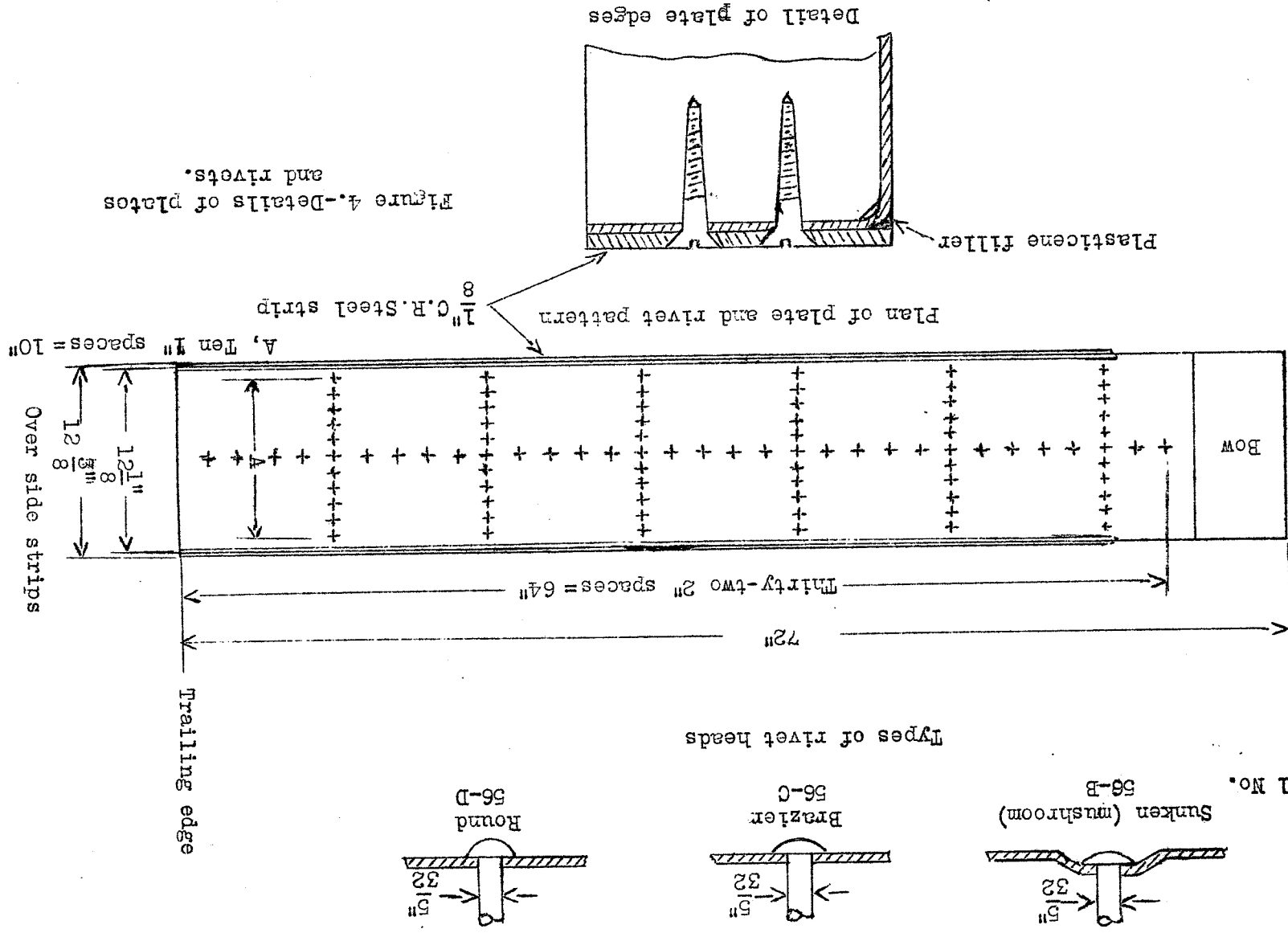


Figure 4.-Details of plates and rivets.

Type Model No.

Types of rivet heads

Bow

Plasticine filler

Detail of plate edges

Plan of plate and rivet pattern

1/8" C.R. Steel strip

A, Ten 1" spaces = 10"

Over side strips

Thirty-two 2" spaces = 64"

72"

Trailing edge

Round 56-D

Brazier 56-C

Sunken (mushroom) 56-B

5/16" 3/32"

5/16" 3/32"

5/16" 3/32"

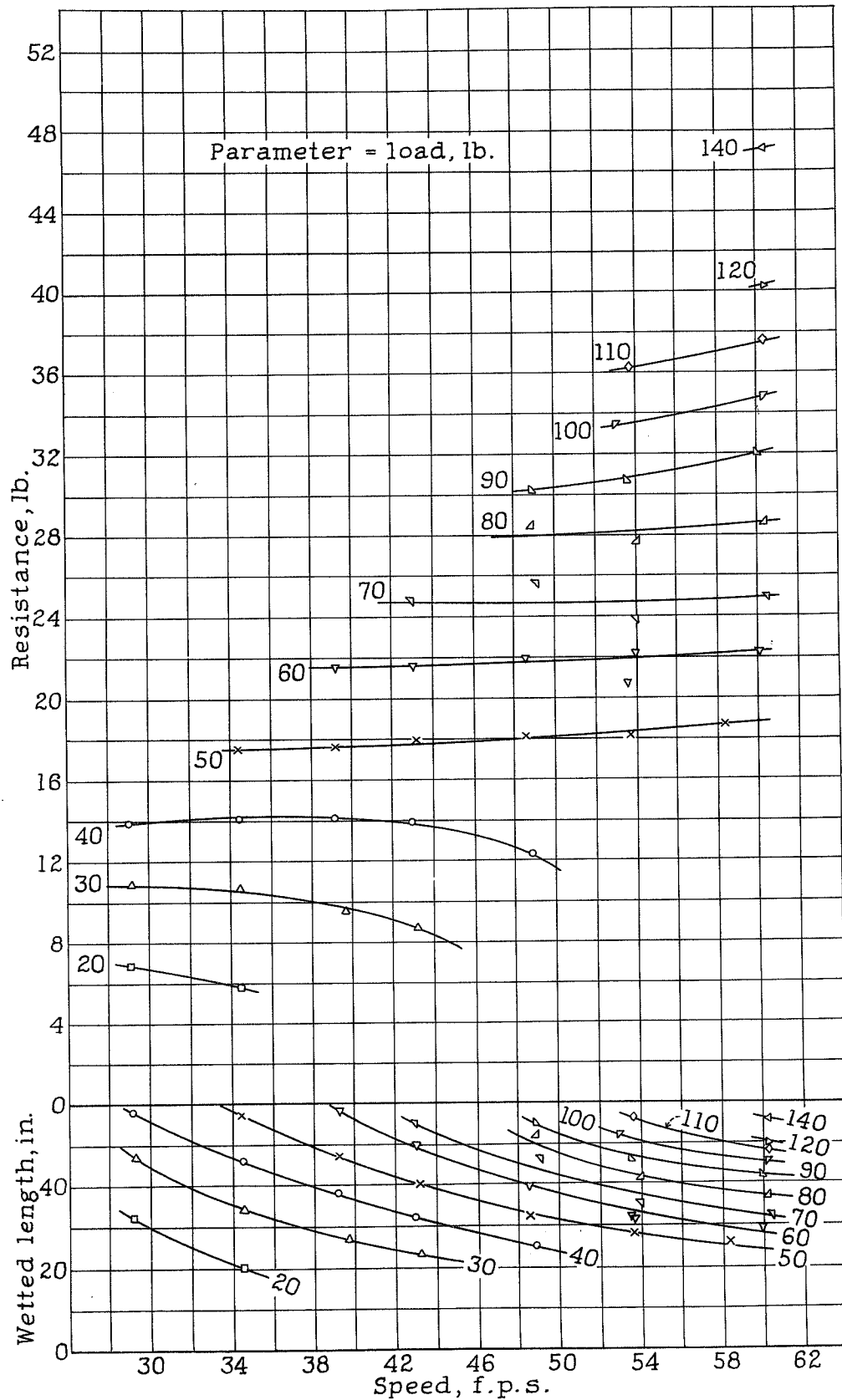


Fig. 5.-  
Model  
56-A.  
Variation  
of re-  
sist-  
ance  
with  
speed.  
 $\tau = 1.5^\circ$

Fig. 6.-  
Model  
56-A.  
Variation of  
wetted  
length  
with  
speed.  
 $\tau = 1.5^\circ$

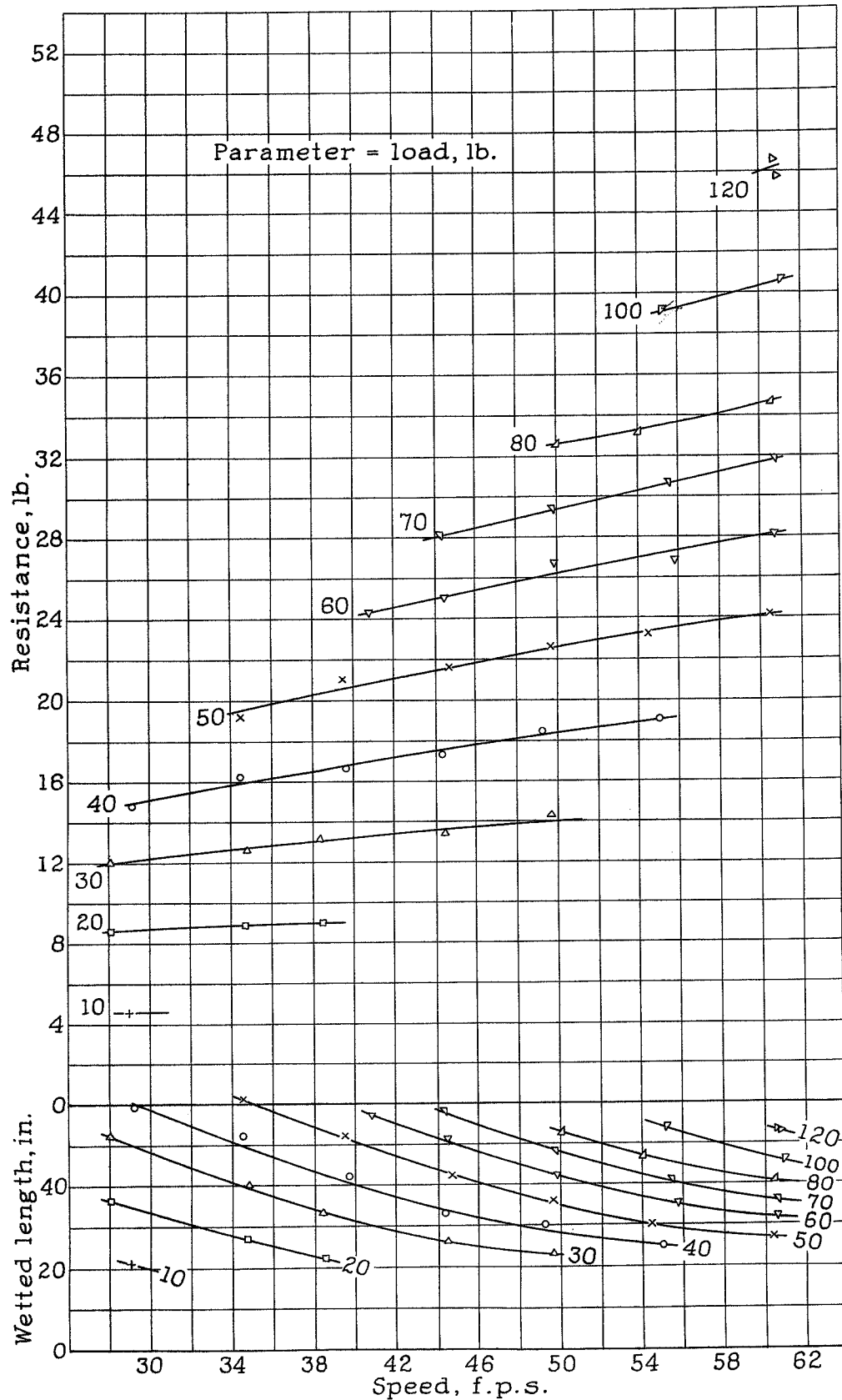


Fig. 7.-  
Model 56-B.  
Variation of resistance with speed.  
 $\tau = 1.5^\circ$

Fig. 8.-  
Model 56-B.  
Variation of wetted length with speed.  
 $\tau = 1.5^\circ$

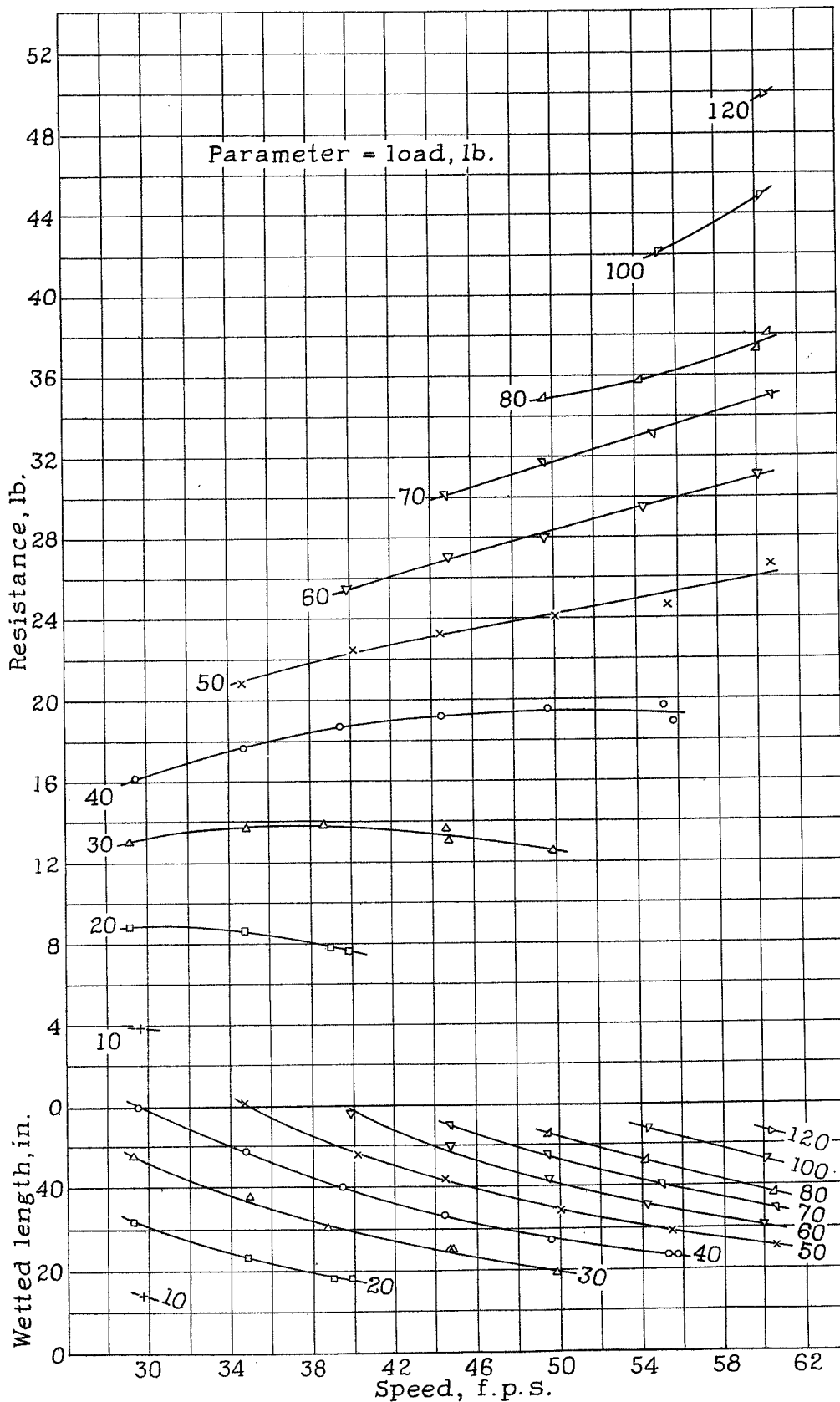


Fig. 9.-  
Model  
56-C.  
Variation  
of re-  
sist-  
ance  
with  
speed.  
 $\tau = 1.5^\circ$

Fig. 10.-  
Model  
56-C.  
Variation of  
wetted  
length  
with  
speed.  
 $\tau = 1.5^\circ$



N.A.C.A

Figs. 13,14,15

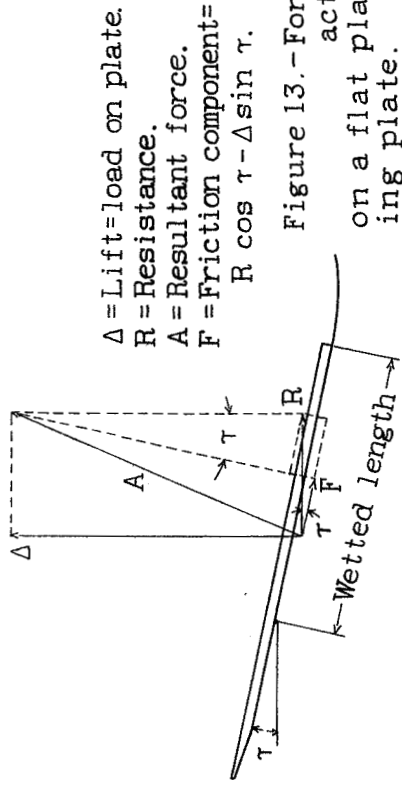


Figure 13. - Forces acting on a flat planing plate.

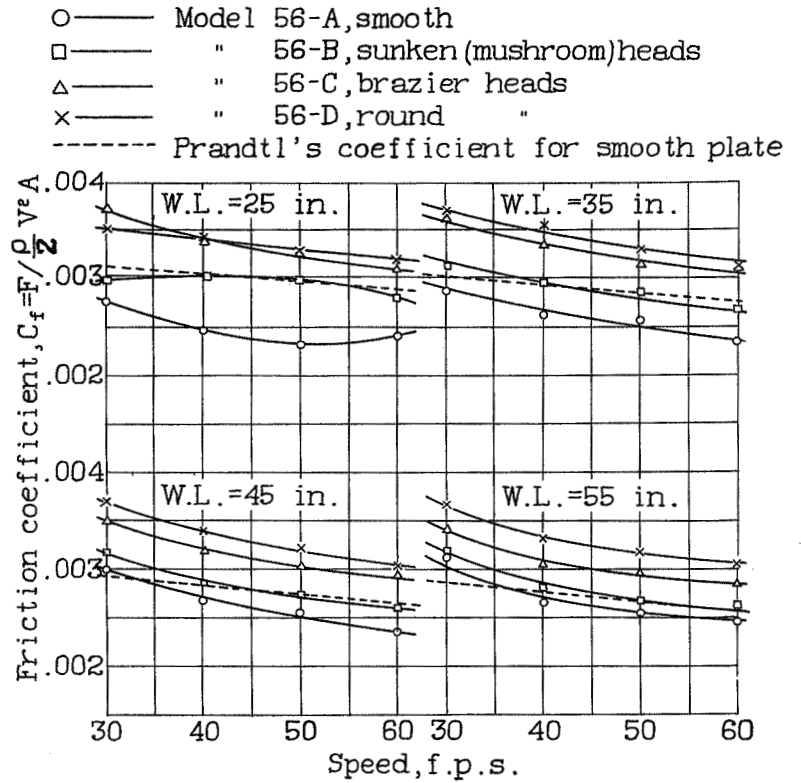


Figure 14. - Variation of friction coefficient with speed.

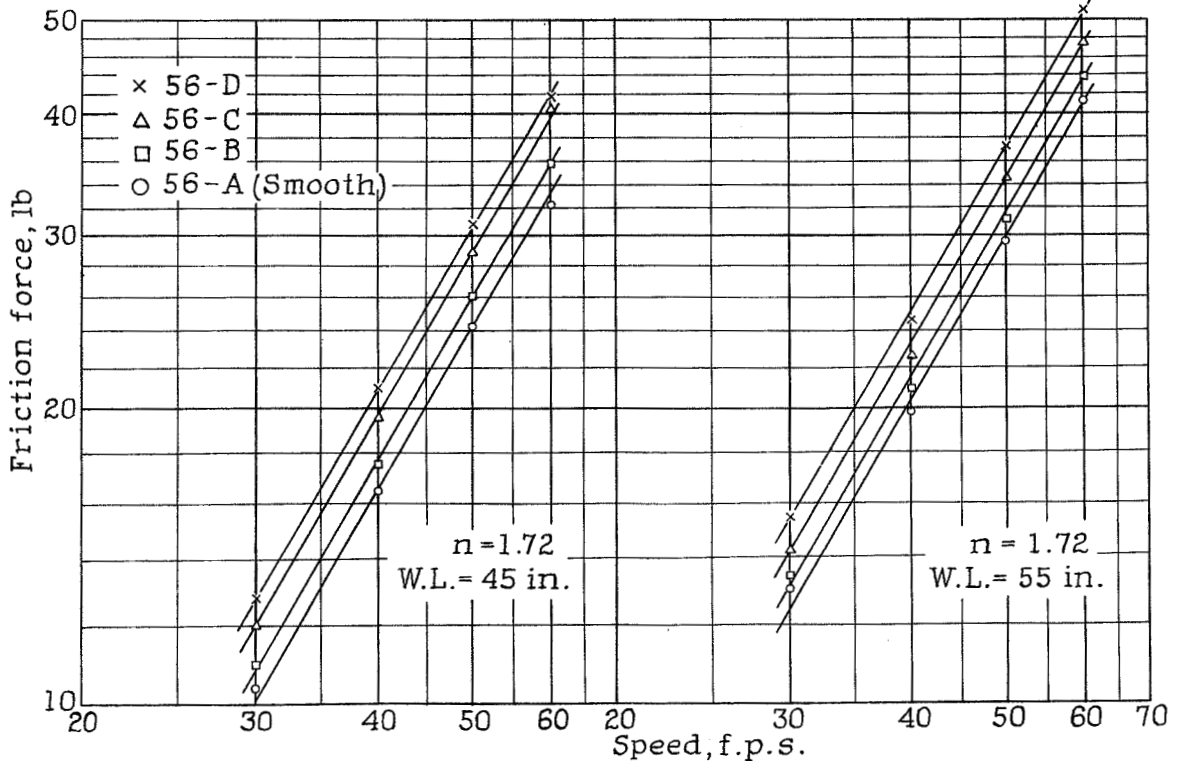


Figure 15. - Variation of friction force with speed