TECHNICAL NOTES.

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS.

No. 70.

THE EFFECT OF STAGGERING A BIPLANE.

By

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Summary. - This investigation was carried out by request of the United States Air Service at the Massachusetts Institute of Technology wind tunnel in 1918. As the data collected may be of general interest, they are published here by the National Advisory Committee for Aeronautics. The lift, drag, and center of pressure travel are determined for a biplane with a stagger varying from +100% to -100%. It is found that the efficiency and the maximum lift increase with positive stagger. With large positive staggers the center of pressure is far forward and has a very slight travel with changes in lift coefficient.

Introduction. - As staggered biplanes have certain advantages from the point of view of visibility, it was thought that a more complete investigation of the aerodynamic effects of stagger than had been done before would be of considerable value. Particular care was taken to examine the pitching moments of the various combinations, as they showed very interesting characteristics.

The references to work already done on stagger are given below:

Some Stable Biplane Combinations, J. C. Hunsaker;

British Advisory Committee R. & M. No. 196;

Nouvelles Recherches sur la Resistance de l'Air et l'Aviation, Eiffel.

Methods. - The wings used in this investigation were an aluminum U.S.A.15 section as an upper wing, and an R.A.F.15 section as the lower. Identical sections were not employed, as none were available, but the two sections used had very similar properties, and previous tests have shown that the individual properties of the wings have little influence on the biplane characteristics. When comparing the biplane with the monoplane the average of the two wings was taken as the monoplane value. The characteristics of these wings are shown in Fig. 1.

The wings (3" x 18") were supported at the lower end by a streamlined cross bar which was attached to the N.P.L. balance spindle. The upper ends of the wing were connected by a very light strut whose resistance was carefully determined for each case. The gap chord ratio was one in all cases. The speed of test was 13.4 m.p.s. (30 m.p.h.).

Precision. - The wings were lined up in each case to 0.05°. In every case three separate runs were made, resetting the wings each time. In nearly every case the reading checked within 1%, so that the average may be considered correct to better than this amount. It was necessary to obtain this rather high precision as the differences between different cases were generally small.

Results. - It was thought most convenient to plot C_L, C_D,* L/D and C.P. against stagger for each angle of attack (Figs. 2, 3, 4, 5). The effect of stagger is clearly shown by these curves and needs no discussion. For the use of the designer, correction fac-

* C_L= Lift, L; absolute coefficient $= \frac{L}{qS}$ $q = \frac{1}{2} \rho V^2$; S = area

C_D= Drag, D; " " $= \frac{D}{qS}$ V = True air speed

ρ = Density (Mass per unit volume)

tors to change monoplane values to those of a staggered biplane, are given in Table 1.

Table 1.

Corrections for Stagger.

(Monoplane values to be multiplied by these factors)

Gap/chord ratio is one.

Lift Corrections.

i	+100%	+75%	+50%	+25%	0	-25%	-50%	-75%	-100%	i
-2	1.75	1.25	1.00	.50	.25	-.25	-.50	-.88	-1.35	-2
0	1.07	1.00	.95	.91	.86	.81	.79	.76	.74	0
2	.93	.92	.90	.89	.88	.88	.87	.86	.85	2
4	.92	.91	.89	.87	.87	.86	.86	.86	.86	4
6	.93	.91	.89	.87	.85	.84	.85	.86	.87	6
8	.93	.91	.89	.87	.85	.84	.85	.85	.87	8
10	.93	.91	.89	.87	.85	.85	.85	.85	.86	10
12	.94	.92	.89	.87	.85	.84	.82	.81	.81	12
14	.99	.98	.96	.92	.88	.85	.82	.80	.79	14
16	1.13	1.11	1.09	1.05	1.01	.97	.93	.89	.86	16

L/D Corrections.

-2	-2.24	-1.57	-1.00	-0.57	-0.14	0.28	0.56	0.90	1.00	-2
0	0.98	0.94	0.90	0.85	0.80	0.75	0.73	0.72	0.71	0
2	0.85	0.84	0.83	0.81	0.80	0.80	0.80	0.81	0.82	2
4	0.85	0.83	0.82	0.81	0.80	0.80	0.80	0.81	0.82	4
6	0.84	0.83	0.82	0.81	0.81	0.82	0.82	0.82	0.83	6
8	0.84	0.84	0.83	0.82	0.82	0.82	0.82	0.82	0.83	8
10	0.84	0.84	0.84	0.84	0.83	0.83	0.83	0.83	0.83	10
12	0.86	0.86	0.86	0.85	0.84	0.83	0.70	0.66	0.65	12
14	0.89	1.00	1.05	1.07	0.88	0.80	0.75	0.72	0.70	14
16	1.57	1.60	1.78	1.57	1.53	1.65	1.54	1.50	1.42	16

Conclusions. - This test shows that it is advisable from the point of view of aerodynamic efficiency to use the highest possible degree of stagger. Moreover, a positive stagger greatly restricts the center of pressure travel, thus simplifying the problem of stability.

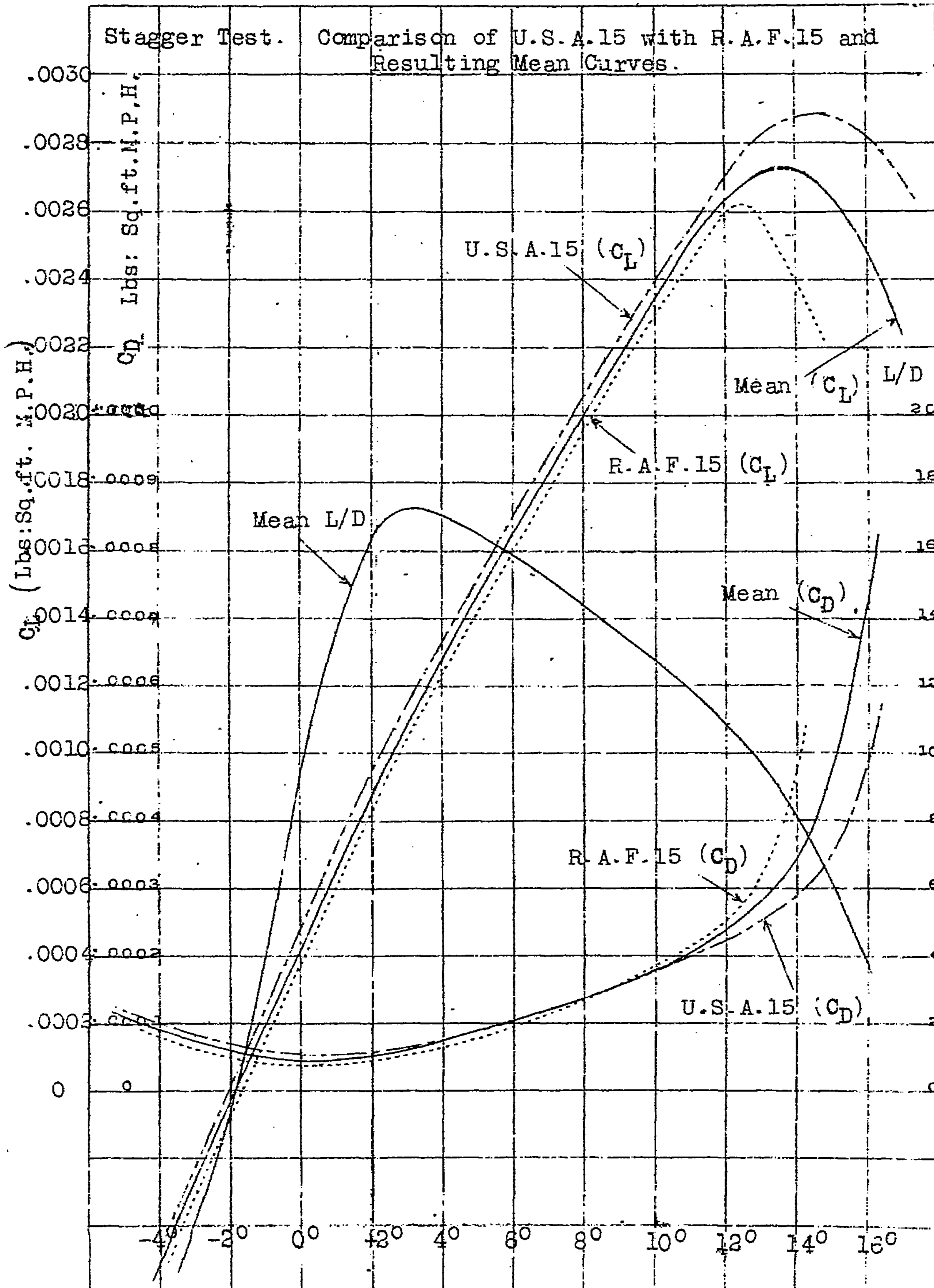


Fig. 1 Angle Wing Chord to Wind.

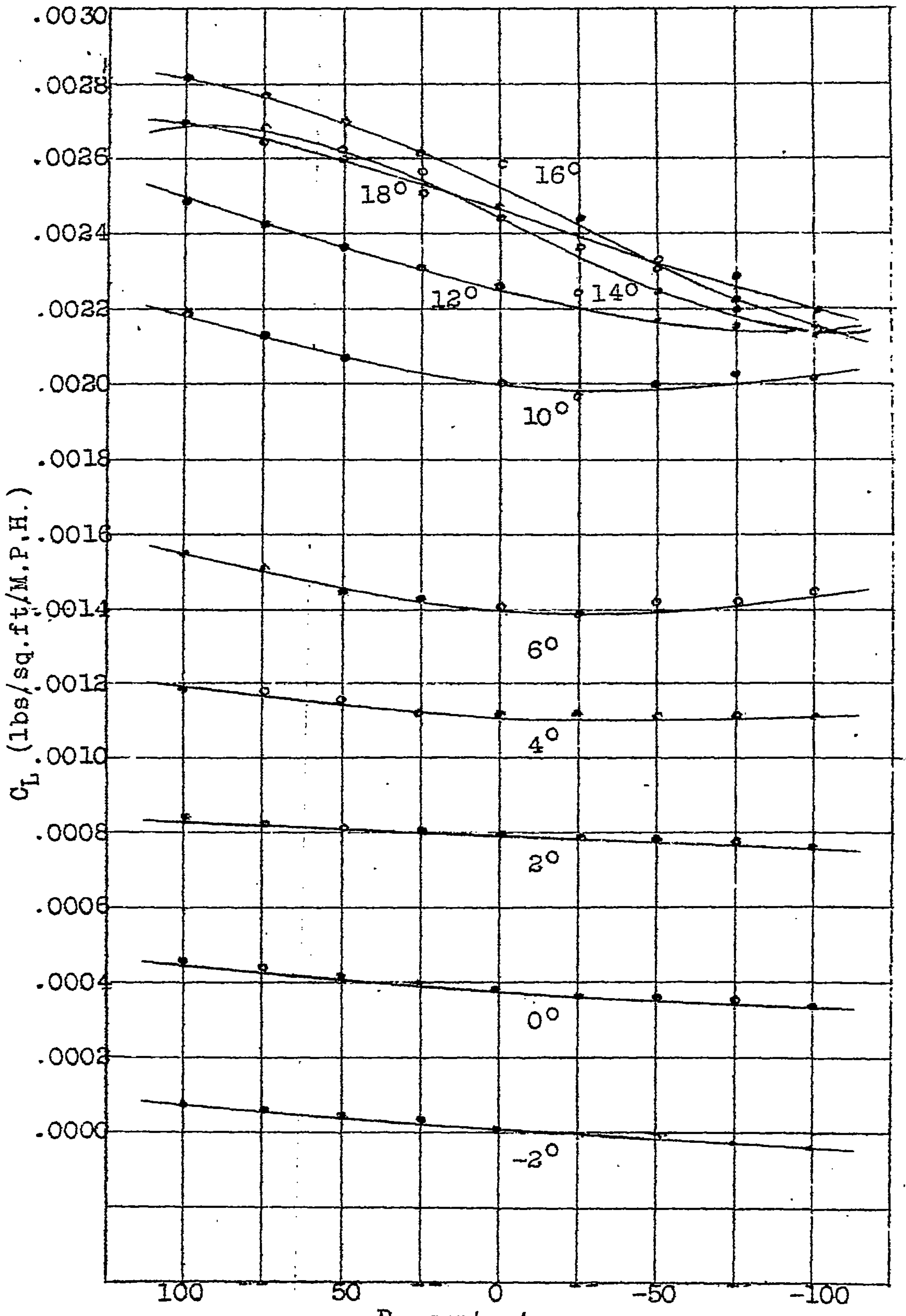


Fig. 2. Stagger test C_L vs. stagger.

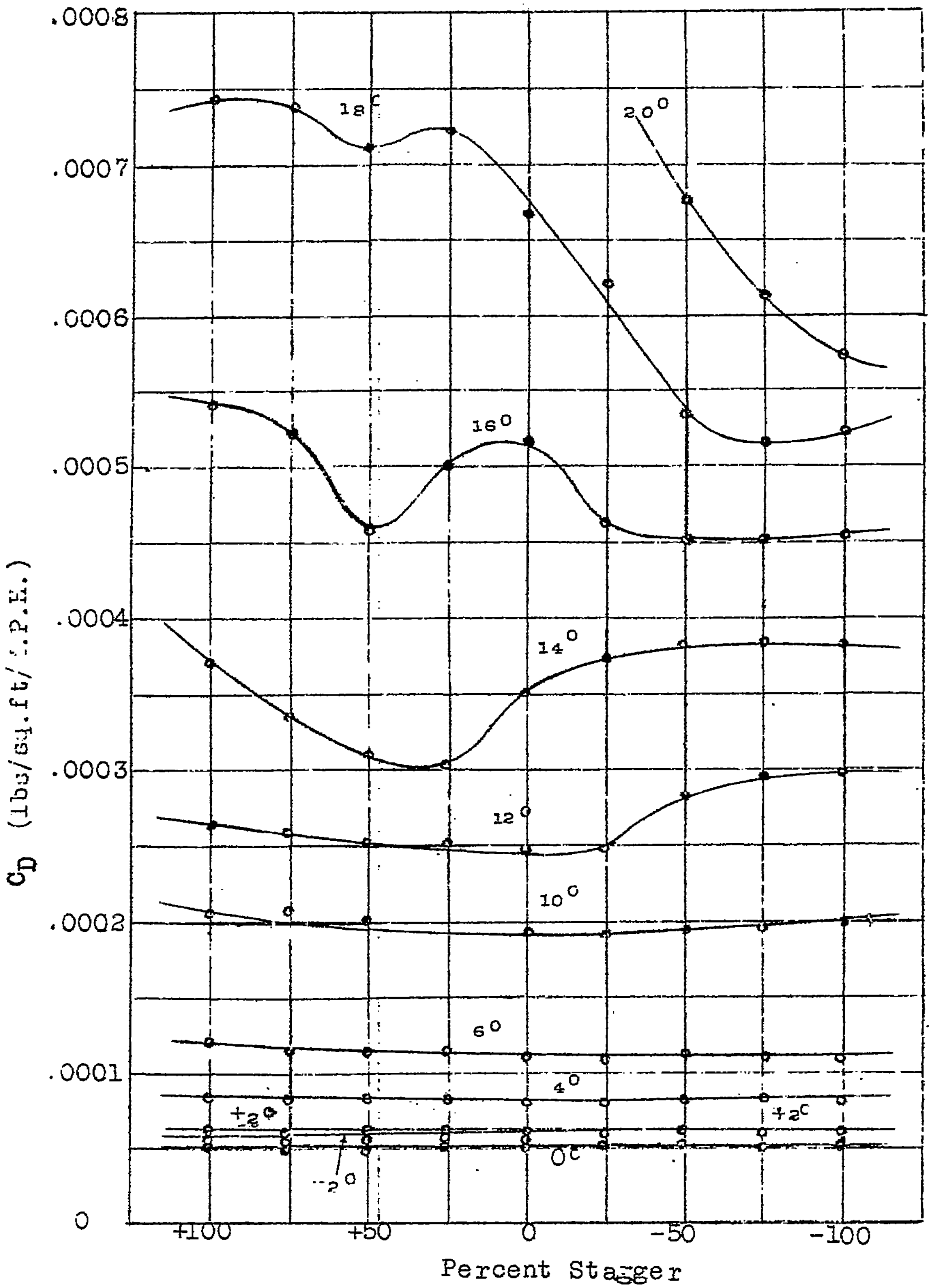


Fig. 3 Stagger Test C_D vs. Stagger.

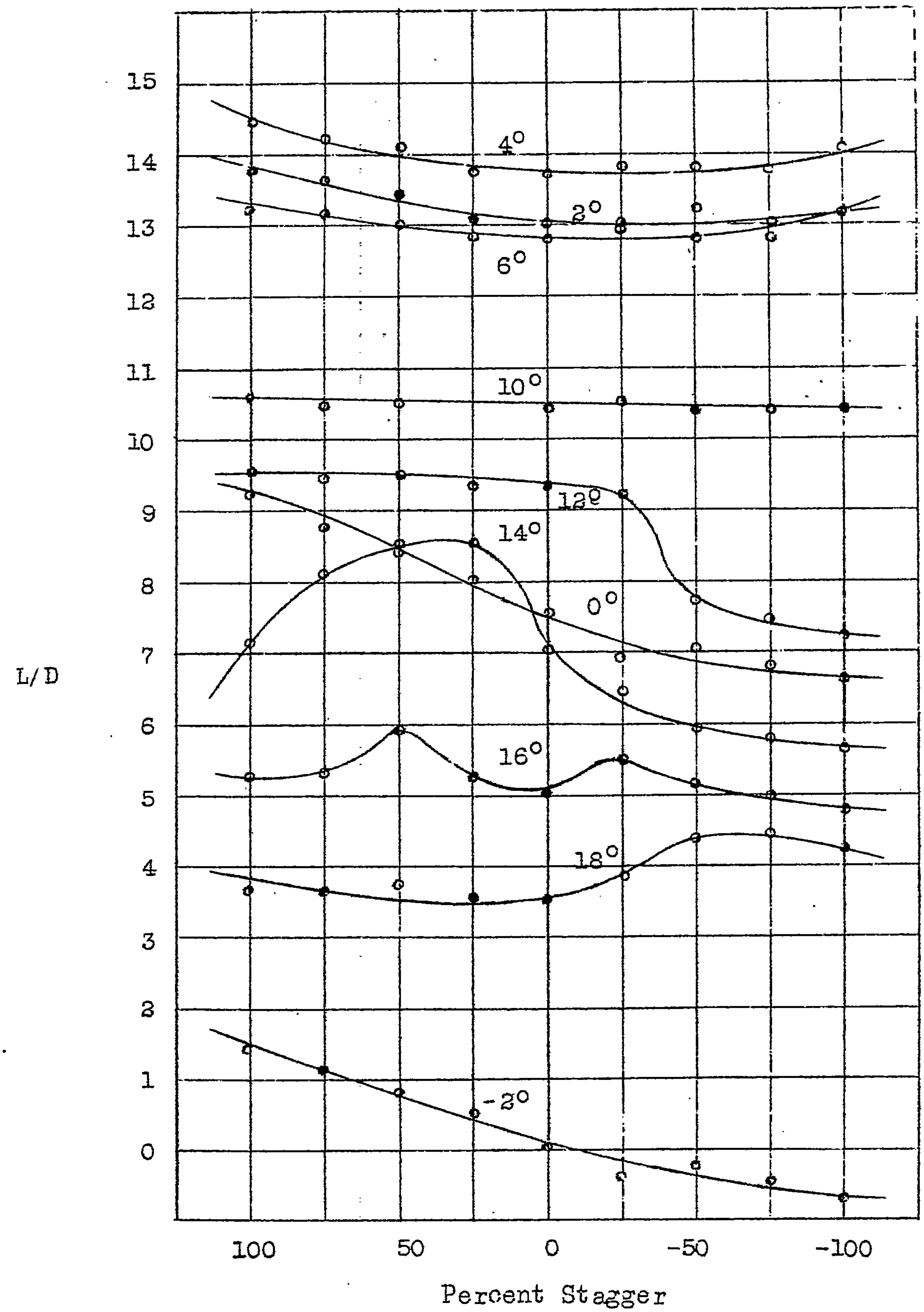
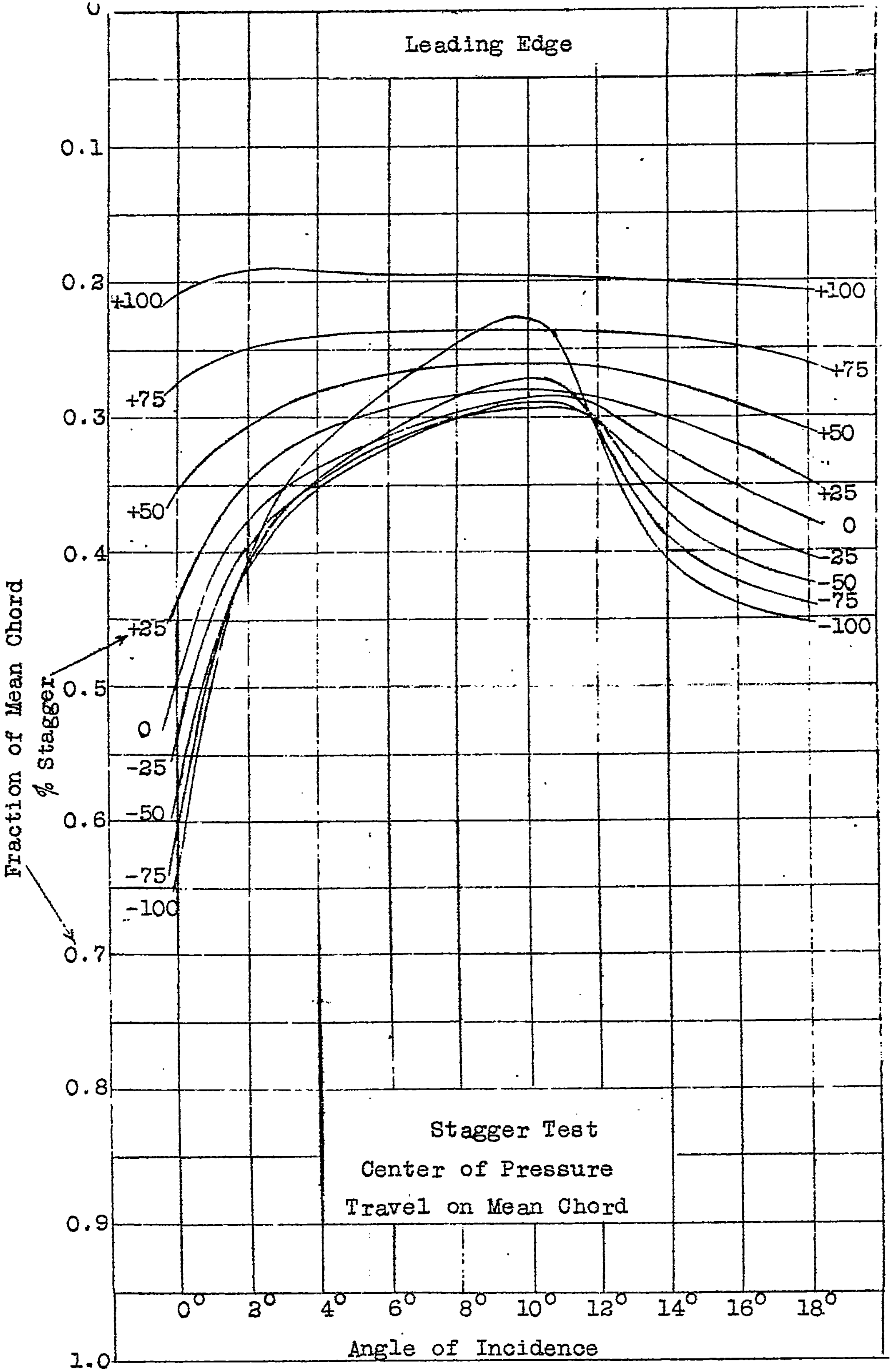


Fig. 4 Stagger Test L/D vs. Stagger.



Leading Edge
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Fraction of Mean Chord
% Stagger
+100
+75
+50
+25
0
-25
-50
-75
-100
0°
2°
4°
6°
8°
10°
12°
14°
16°
18°
Angle of Incidence
Stagger Test
Center of Pressure
Travel on Mean Chord

Fig. 5