TECHNICAL NOTES

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

TN No. 428

CHARACTERISTICS OF AN AIRFOIL AS AFFECTED BY FABRIC SAG

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SUMMARY

This report presents the results of tests made at a high value of the Reynolds Number in the N.A.C.A. variable-density wind tunnel to determine the aerodynamic characteristics of an airfoil as affected by fabric sag. Tests were made of two Göttingen 387 airfoils, one having the usual smooth surface and the other having a surface modified to simulate two types of fabric sag.

The results of these tests indicate that the usual sagging of the wing covering between ribs has a very small effect on the aerodynamic characteristics of an airfoil.

INTRODUCTION

Prior to the present investigation, but few tests have been made to determine the aerodynamic effects of fabric sag in airplane wings. In connection with a study of the lift coefficients of the wings of a full-sized airplane and of a model, the British Advisory Committee, in 1916, investigated the characteristics of the model airfoil as affected by fabric sag. (Reference 1.) From the results of these tests they concluded that the effect of the sag was not very great. In a later investigation, Kumbruch in Germany (reference 2) arrived at the same conclusion and his tests at two values of the Reynolds Number indicated that the differences were even smaller at the higher value of the Reynolds Number. These early tests, however, were both made at comparatively low values of the Reynolds Number, and the effect of fabric sag on the characteristics of actual wings was therefore not definitely established. Rizzo (reference 3), in studying the precision of wing sections, concluded that the slight decrease in average thickness caused by the fabric sag would have very little effect on the wing characteristics.

The practice of some designers of providing a wing structure that reduces the usual fabric sag but entails an increase in weight led to a request by the Bureau of Aeronautics, Navy Department, for information on the effect of sag at a high value of the Reynolds Number to determine if the greater weight resulting from this type of structure is justified. The present investigation was made to supply this information.

For the purpose of obtaining a representative form of sagged surface, measurements were taken of a number of wings on airplanes in service. The normal rib profile and the transverse profile of the sag between two adjacent ribs at several positions back from the leading edge were obtained for each wing. The majority of wings measured had a sharp discontinuity of the surface at the end of the reinforced nose. As this discontinuity was believed to have a greater effect than the normal sag alone, it was decided to incorporate this type in the present investigation. For the most severe condition noted, the angle between tangents of the reinforced and sagged surfaces at the point of discontinuity was approximately 7°.

The wing of the Committee's Fairchild FC-2W2 airplane of Göttingen 387 section, which represents a badly sagged surface, was chosen as a basis for the models. Tests were made of an airfoil of uniform section and of one modified to represent wings having fabric sag with and without nose reinforcement. The tests were made in the variable-density wind tunnel of the National Advisory Committee for Aeronautics during May, 1932.

APPARATUS AND METHODS

Models.- Two 5 by 30 inch duralumin airfoils of the Göttingen 387 section were constructed as described in reference 4. One model was maintained with the usual smooth surfaces, and tests of this model were used as a basis for comparison with tests of the other model, the upper surface of which was hand-finished to represent the two types of fabric sag investigated. The profile of the smooth-surface model was carefully checked with the rib profile of the sagged model by measurement. With the nose points and the chord lines coinciding on plots of these profiles, the maximum separation of the contours was 0.05 per cent of the chord.

The first type of sag constructed on the sagged model represented that found on fabric-covered wings having nose reinforcement, and was patterned after the worst condition observed. A photograph of this model is shown in Figure 1. Diagrammatic sections are given in Figure 2 of the rib and sag center profiles along the chord and the transverse profiles of the sag between two adjacent ribs. The discontinuity representing the end of a reinforced nose at the front spar position was unfortunately rounded somewhat from the desired sharp edge during the process of polishing the modified surface. As the amount of sag on the lower surface of the wing was negligible, it was unnecessary to modify the lower surface of the model

The second type of sag, representing that found on wings without nose reinforcement, was constructed by fairing out the surface discontinuity on the nose of the sagged airfoil. The resulting sections are shown in Figure 2 by dotted lines.

Tests.- The models were tested in the variable-density wind tunnel at an average Reynolds Number of 3,160,000. Descriptions of the tunnel and method of testing may be found in reference 4. The airfoil having smooth surfaces was tested first and was followed by the airfoil having the first type of sag. This latter airfoil was then modified to represent the second type of sag and tested. A repeat test was then made of the first airfoil to establish the accuracy of the test results.

RESULTS

The results are presented graphically in Figures 3a and 3b. In the first figure the lift coefficient C_L, drag coefficient C_D, L/D ratio, and center-of-pressure position are plotted against the angle of attack α for the three types of surface. These data have been corrected for tunnel-wall effect by the method given in reference 4. The profile and specified ordinates of the Göttingen 387 section are included in this figure.

The profile-drag coefficient C_{D_0}, angle of attack for infinite aspect ratio α_0, and the pitching-moment coefficient about a point one-quarter of the chord behind the leading edge $C_{m_{c/4}}$, are plotted against the lift coefficient in Figure 3b. These infinite aspect ratio characteristics have been derived from the observed data by the method given in reference 4.

The precision of these results may be estimated from the results of the two tests of the airfoil of uniform section. The two tests were made one before and one after the tests of the sagged airfoils and the displacement of the test points in Figures 3a and 3b indicates the precision to be expected for all four tests.

DISCUSSION

The results of these tests indicate that the effect of sag on the aerodynamic characteristics of an airfoil is very small. The lift curves are almost identical until the region of maximum lift is reached. The airfoils with sagged surfaces have somewhat higher values of the maximum lift than the airfoil with uniform section. This result may be due to the thinner average section resulting from the sag, as recent tests in the variable-density tunnel have indicated an increase in maximum lift with a decrease in thickness for thick airfoils. The differences, however, are only slightly larger than the experimental error.

The drag curves are nearly the same throughout the normal flying range. The values of the minimum drag of the sagged airfoils are slightly higher than the average value for the airfoil of uniform section, but are probably within the experimental error. The other characteristics, as may be noted by referring to the figures, are negligibly affected by the sag.

The effect of the discontinuity as reproduced on the model representing a sagged wing with nose reinforcement is unimportant. This discontinuity, however, may have adverse effects where it occurs on other airfoil sections or where a reinforced nose of a wing causes an abrupt break in the surface more sharply defined or nearer the leading edge.

CONCLUSIONS

These results indicate that the usual sagging of the wing covering between ribs has a very small effect on the aerodynamic characteristics of an airfoil.

Langley Memorial Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., July 28, 1932.

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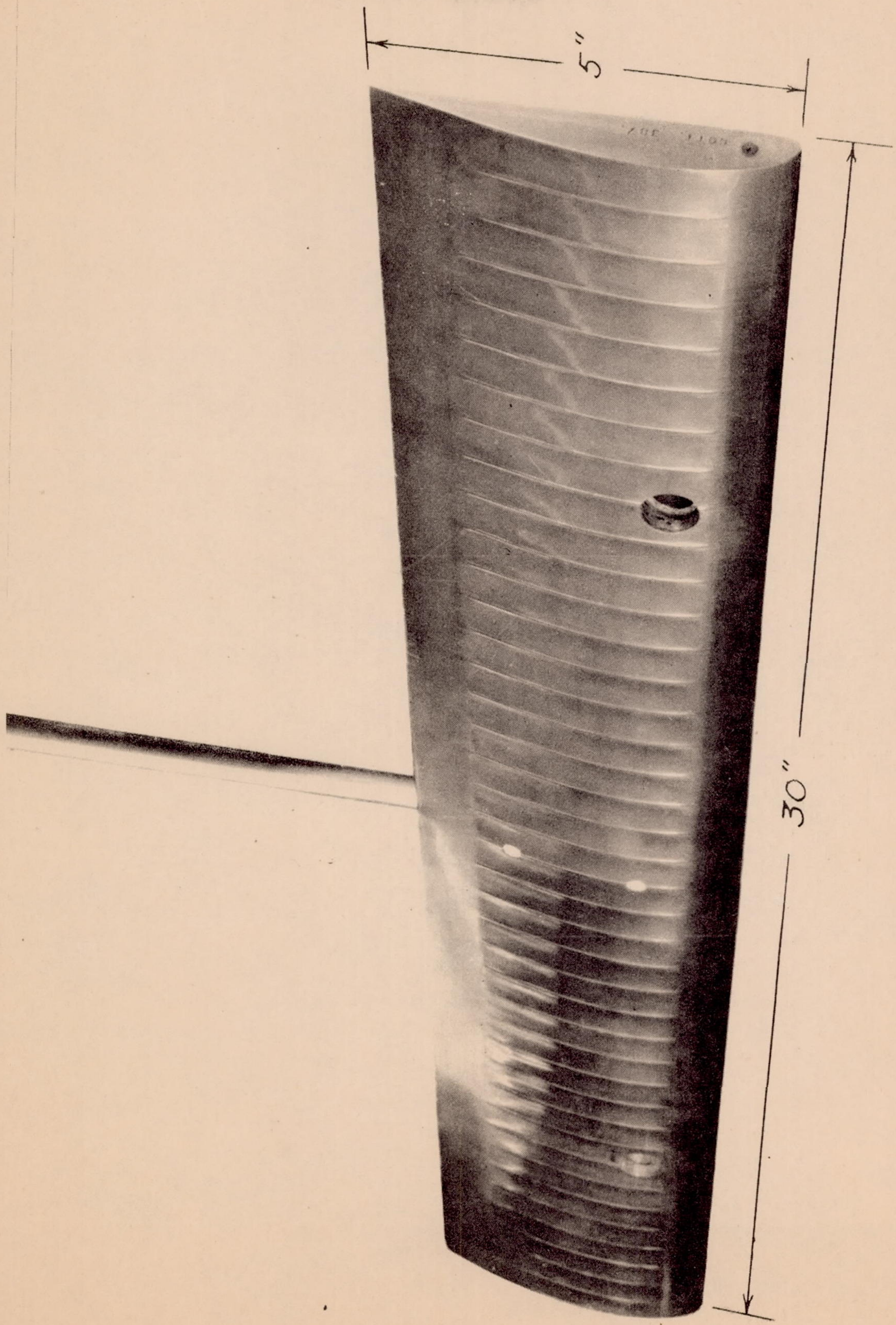


Fig. 1 Airfoil simulating wing having fabric sag.

Station along chord	$2\frac{1}{2}$	5	$7\frac{1}{2}$	10	15	20	25	30	40	50	60	80
Depth of sag, d(reinforced nose)	–	–	–	–	0.00	0.40	0.48	0.40	0.36	0.32	0.28	0.00
" " ", d(unreinforced nose)	0.00	0.10	0.20	0.32	0.40	0.48	0.48	0.40	0.36	0.32	0.28	0.00

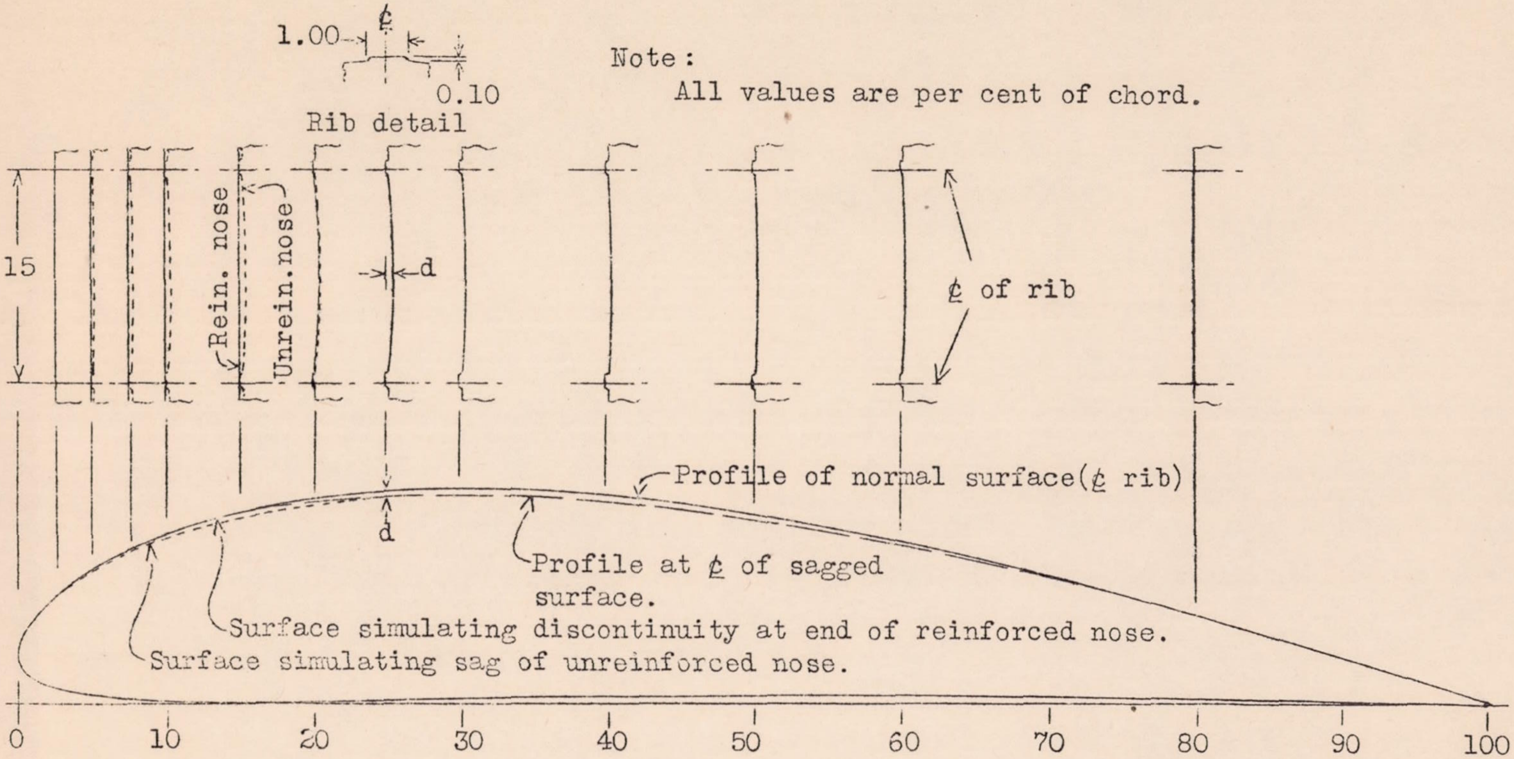
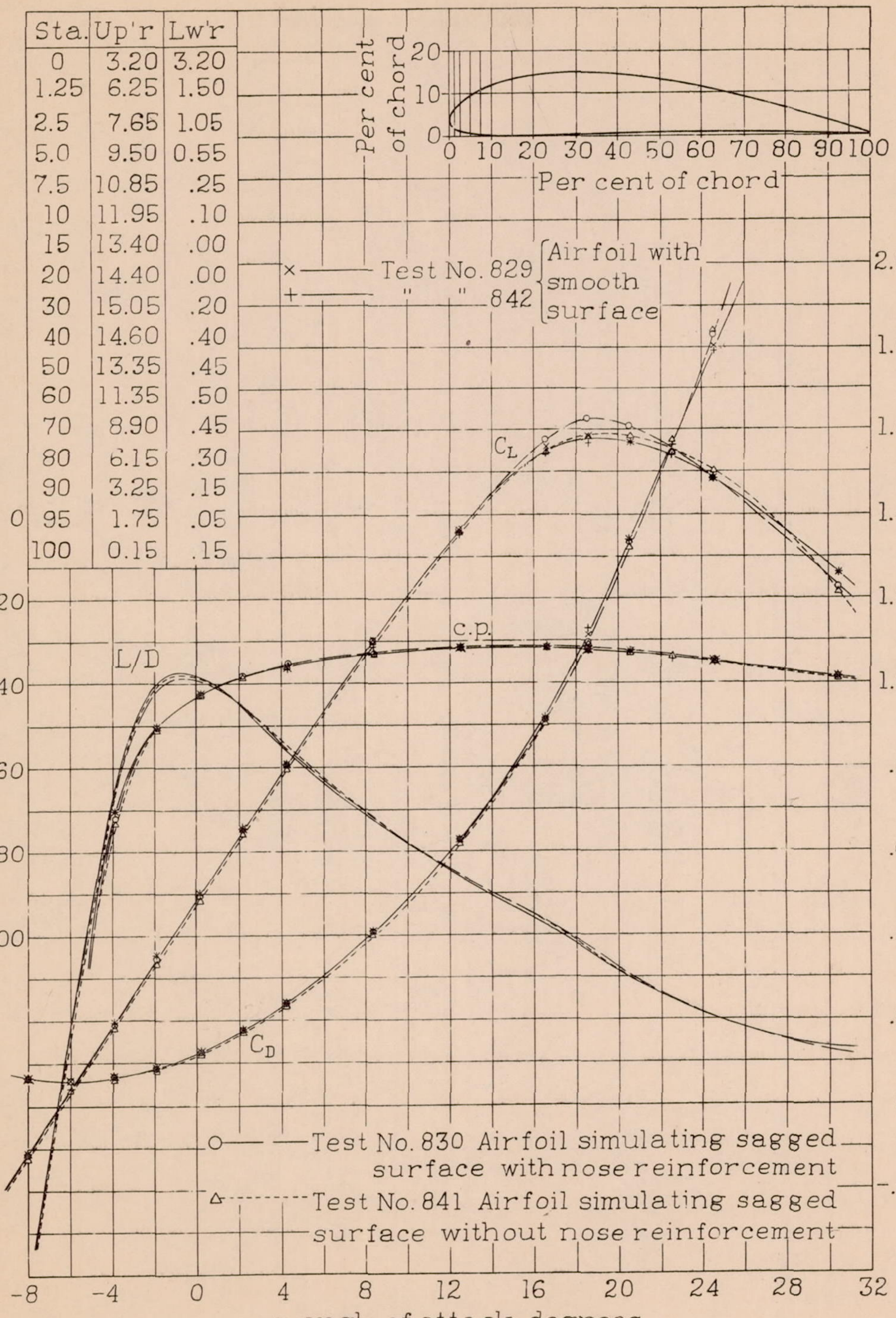


Fig.2 Detail of sagged surfaces.

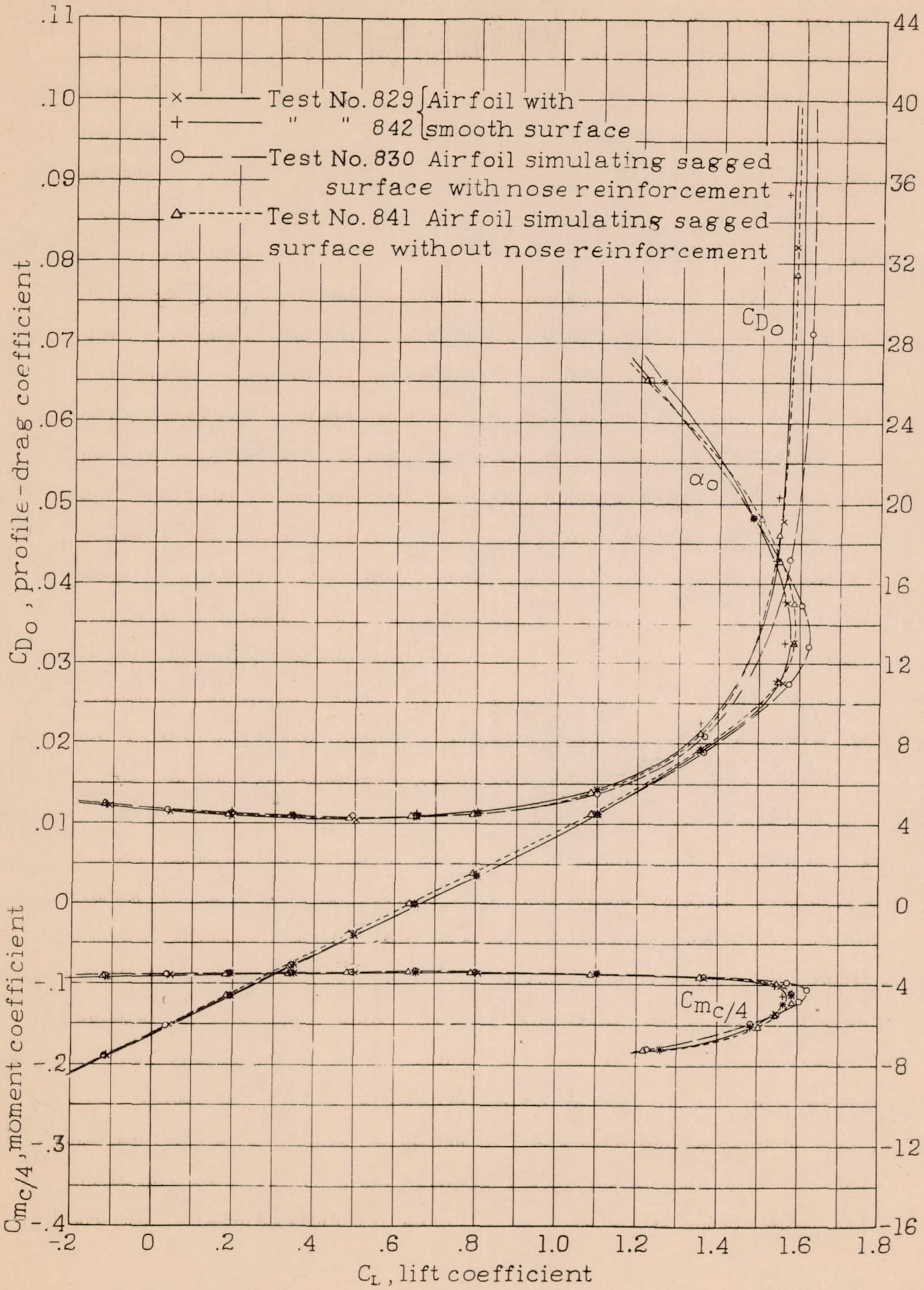


Sta.	Up'r	Lw'r
0	3.20	3.20
1.25	6.25	1.50
2.5	7.65	1.05
5.0	9.50	0.55
7.5	10.85	.25
10	11.95	.10
15	13.40	.00
20	14.40	.00
30	15.05	.20
40	14.60	.40
50	13.35	.45
60	11.35	.50
70	8.90	.45
80	6.15	.30
90	3.25	.15
95	1.75	.05
100	0.15	.15

Airfoil: Gött. 387
Size: 5" by 30"
Press. (st'n'd. atm.): 20.8
Where tested: L.M.A.L.
Results corrected for tunnel-wall effect

R.N.: 3,160,000
Vel. (ft./sec.): 69
Date: May 1932
Test: V.D.T. 829, 830, 841, 842

Fig. 3a Comparison of airfoils having smooth and sagged surfaces.



Airfoil: Gött. 387
Date: May 1932

R.N.: 3,160,000
Test: V.D.T. 829, 830, 841, 842

Results corrected to infinite aspect ratio

Fig. 3b Comparison of airfoils having smooth and sagged surfaces.