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TECHNICAL MEMORANDUMS

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No. 298

# RESULTS OF RECENT EXPERIMENTS WITH SLOTTED WINGS.

By G. Lachmann.

From "Zeitschrift für Flugtechnik und Motorluftschiffahrt,"
August 26, and September 26, 1924.

January, 1925.

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS.

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## TECHNICAL MEMORANDUM NO. 298.

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# RESULTS OF RECENT EXPERIMENTS WITH SLOTTED WINGS.*

By G. Lachmann.

In continuation of my article published in "Zeitschrift für Flugtechnik und Motorluftschiffahrt," May 26, 1924, I will now give the results of a more recent series of experiments performed on a wing designed for a cantilever monoplane. These experiments were conducted by the writer for the Udet Airplane Construction Co., Ltd., of Munich-Ramersdorf, the first firm in Germany to undertake the construction of airplanes with slotted wings.

Both wings were trapezial in their ground plan, with their tips rounded elliptically (Fig. 1). Their span was 1376.4 mm (54.19 in.) with a middle portion of uniform cross-section and a span of 122 mm (4.8 in.). To this middle portion were joined the two wings, whose thickness diminished toward their tips. Fig. 2 gives several cross-sections showing the relatively great thickness of the middle portion and the slight convexity on the pressure side. In designing the wing-section, the results of several years of experimentation were carefully considered. This wing section combines all known devices for increasing the lift, namely, the slot, the increased camber and angle of attack by means of an aileron running the whole length of the span and, lastly, an increase in the wing area by

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* From "Zeitschrift für Flugtechnik und Motorluftschiffahrt," August 26, and September 26, 1924.

means of an auxiliary wing adjusted by a sort of rectangular joint.

Special care was taken in designing the cross-section of the slot and of the auxiliary wing. In the position of horizontal flight, the auxiliary wing lies smoothly on the leading edge of the main wing, so that there is no increase in the wing-section drag. The construction of the auxiliary wing as a bent metal sheet has been abandoned on account of the unsatisfactory results obtained. The auxiliary wing is shifted forward not only to increase the lift, but also to prevent the backward shifting of the center of pressure, which occurs on opening the slot.

The full-sized aileron was actuated by the torsion of a rod running throughout the entire span. Hence it seemed advisable to compensate the moment of the aileron about its axis of rotation, especially near the wing tips, by running its axis of rotation as near as possible to its center of pressure.

A series of experiments was performed with this model at various aileron angles $\delta$ in the normal flight position and in the landing position. For both cases, all coefficients were applied to wings with the slot closed, $F = 2640 \text{ cm}^2$ (409.2 sq.in.). The angle of attack $\alpha$ was determined in all cases by the inclination of the tangents, which, with an aileron deflection of $\delta = 0^\circ$, can be drawn on the outline of the aileron and of the pressure side of the cross-section of the main wing.

The results obtained in both positions of the auxiliary wing are shown in Figs. 3-6. For horizontal flight with closed slot, an aileron angle $\delta = -5^\circ$ was found to be the best. The relatively large wing-section drag in the normal position is due, as shown by comparative experiments, almost exclusively to the somewhat too great relative thickness of the middle section of the wing and to the unfavorable shape of the leading edge of the wing-section. It is comparatively easy to reduce the relative thickness by lengthening the chord and increasing the taper toward the wing tips and thus obtain the wing-section drag of an ordinary thick wing.

The effect of the slot with an aileron deflection of $\delta = 0^\circ$ is very small. Only a small aileron deflection is required, however, to produce a great increase in the lift. On the average, the lift increase due to the auxiliary wing is about 40% above that produced by the aileron alone. On the basis of a maximum lift coefficient of about 1.5 for the unslotted wing-section, the lift increase resulting from the combined action of the slot and the aileron is about 95%. (On this basis, the angle of attack of the wing was $\alpha = 20.4^\circ$ for the case of maximum lift.) The corresponding reduction in the landing speed is about 30%. The moment curves are given in Figs. 5-6. Fig. 6 also gives the moment curve for the most favorable flight position ($\delta = -5^\circ$) for purposes of comparison. On drawing the line b, it is evident that the location of the center of pressure in the landing position coincides with its position when $C_L = 0.75$. If the center of pressure in the normal position for $C_L = 1.00$ is regarded then the intersection of the line a with the horizontal line through $C_L = 100$ gives the maximum retrogression of the center of pressure in shifting to the landing position with the same inclination of the airplane's axis. The distance between the center of pressure for the two positions of the auxiliary wing is only about 6% of the chord. The practical meaning of this result is that the airplane, in shifting from the normal position and an angle of attack of about 5° to the landing position, suffers no noteworthy change in trim, so that the adjustment of the damping surface, required in the first form of slotted wings with rotatable auxiliary wings, can be dispensed with.

Measurements of the thickness of the boundary layer of air on an unslotted wing and on a similar slotted wing.- The lift limit of a wing is determined by the so-called "separation" of the flow from the negative-pressure side of the wing section, when a certain critical angle of attack is exceeded. For unslotted wings, this angle lies between 15 and 18°. It is obvious that the phenomenon of separation is connected with the thickening of the boundary layer on the back of the wing section. By "boundary layer" is meant the conception, introduced by Prandtl, of a region in which the flow is retarded by friction.

The delay in the separation, for a slotted wing, can be explained by the flowing through the slot of an auxiliary air current which accelerates the boundary layer and delays the formation of dead air spaces. This knowledge suggests the possibility of replacing the action of the slotted wing by similar-acting mechanical devices, such as, for example, nozzles with a blast, suction channels connected with the engine, or a special suction pump for accelerating the boundary layer. In June, 1923, the following experiments were performed for the purpose of learning the behavior of the boundary layer on an unslotted and on a slotted wing section and of obtaining an idea of the order of magnitude of the thickness of the boundary layer.

*a) Experimental Conditions*.- The experiments were performed on wing section 0/100, both with and without slot. The wing had a chord of 60 cm (23.62 in.), a span of 150 cm (59.06 in.) and was arranged for obtaining a smooth flow between two parallel walls. A more detailed description of the model is given in my preceding article in "Zeitschrift für Flugtechnik und Motorluftschiffahrt," of May 26, 1924 (See Technical Memorandum No. 282, N.A.C.A.).

The pressure measurements were made with the help of the device shown in Fig. 7. Brass tubes (a), with inside threads in their lower ends, were soldered into the wing at the four test points. On the top of each tube there was a cover (b) with a slot. The following table gives the distance of the four test points from the leading edge of the auxiliary wing or of the ordinary wing in fractions of the chord c.

| Test point number | I | II | III | IV |
|---|---|---|---|---|
| Distance from leading edge | 0.303 c | 0.453 c | 0.603 c | 0.753c. |

The threaded adjusting tube (c') could be screwed into tube (a). The actual measuring tube (e) was introduced through tube (c'). It was held with the aid of the two prolongations (d), and the adjusting screw (c') and could be pushed above the top of the wing by turning this screw. These prolongations d, introduced into the slot of the cover (b), kept the 1 mm (0.039 in.) hole in the upper end of the measuring tube always perpendicular to the direction of the wind. This hole served to measure the static negative pressure and was closed with "plastilin" during the measurement of the pressures in the boundary layer.

At the bottom of the tube there was a removable nipple (f), for attaching the rubber tube leading to the pressure gage. The spring (g) kept the measuring tube from falling out of the wing, since the negative-pressure side (top) of the wing is downward during the experiment.

The writer is aware that this somewhat primitive arrangement is not perfect and that the results obtained with it are not scientifically accurate, like the experiments of Riabouchinsky* and Stanton** or the experiments of Burgers*** on polished glass plates with the aid of sensitive hot-wire instruments. The described method was intended simply to give an approximate idea of the order of magnitude of the thickness of the boundary layer as a guide in future experiments. Probably a uniform error was caused in the experimental results through the retardation of the flow by the tube. This error is automatically eliminated, however, in comparing the two wings. Moreover, the experiments had to be limited as much as possible, on account of their cost.

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* Riabouchinsky, "Etude experimentale sur le frottement de l'air." Bull. Inst. Aero. de Koutchino, 1914.

** T. E. Stanton, Proc. Roy. Soc., London, A 97, 1920.

*** J. M. Burgers and B. G. van der Hegge Zijnen, "Verhandlingen der Koninklijke Akademie van Wetenschappen te Amsterdam," 1924.

b) Execution and Results of Experiments.- The experiments on the unslotted wing were executed at angles of attack of 0, 5, 10 and 15°; on the slotted wing at angles of 5, 10, 15, 20 and 25°. The flow had already separated at an angle of attack of 30° and no further satisfactory experiments could be executed on account of the strong vibrations.

The mean velocity of the air was $v = 30$ m (98.4 ft.) per second. Its exact dynamic pressure was determined in every experiment.

In the experiments in the boundary layer, the pressure tube was first screwed into the wing until its upper end was just flush with the negative-pressure side of the wing. The vicinity of the opening was then made as smooth as possible with the aid of "plastilin." Then the small hole in the cover of the pressure tube was opened and the static pressure $p_o$ measured. Then the opening was again closed and the tube unscrewed from the wing. The distance of the center of the hole from the top of the wing is designated in the accompanying diagrams (Fig. 8) by $h$ and given in millimeters. At each test point the total pressure $p'$ of the flow was found for different distances $h$. The dynamic pressure $p$ was then found by subtracting the measured static pressure $p_o$ from the total pressure $p'$, i.e., $p = p' - p_o$. In this connection, it was assumed that the static pressure of the flow remained practically constant for the relatively short distance.

It seemed best not to introduce into the diagram the expression $p/q$, in which $q$ represents the temporary dynamic pressure of the undisturbed flow, but to convert the measured pressures p so as to correspond with a mean value of the dynamic pressure, $q = 58\ kg/m^2$ (11.88 lb./sq.ft.). These values are given in the accompanying tables and diagrams (Fig. 8).

Test point I, Section 0/100 without slot.

p for:

| Angle of attack | h=0 | h=1.4 .055 | h=2.6 .102 | h=4.6 .181 | h=6.6 .26 | h=8.6 .339 | h=10.6 mm .417 in. |
|---|---|---|---|---|---|---|---|
| $0^\circ$ | -25.5 | 60.3 | 77.7 | 80.6 | 77.1 | 74.8 | 73.1 |
| $5^\circ$ | -30.75 | 53.95 | 72.50 | 82.35 | 82.35 | 78.35 | 77.15 |
| $10^\circ$ | -35.95 | 44.07 | 67.25 | 84.05 | 87.55 | 83.55 | 81.75 |
| $15^\circ$ | -37.7 | 4.6 | 23.2 | 51.05 | 82.9 | 90.5 | 87.6 |

Test point II - p for:

| Angle of attack | h=0 | h=1.4 .055 | h=2.6 .102 | h=4.6 .181 | h=6.6 .26 | h=8.6 .339 | h=10.6 .417 | h=13.6 mm .535 in. |
|---|---|---|---|---|---|---|---|---|
| $0^\circ$ | -22.05 | 45.25 | 58.05 | 70.75 | 76.55 | 75.95 | 74.25 | 73.05 |
| $5^\circ$ | -29.6 | 46.4 | 58.6 | 72.5 | 80.6 | 82.9 | 81.2 | 81.2 |
| $10^\circ$ | -36.6 | 42.97 | 55.2 | 70.2 | 84.2 | 89.9 | 88.2 | 87.6 |
| $15^\circ$ | -40.6 | 20.9 | 26.7 | 41.18 | 62.65 | 76.0 | 92.8 | 93.9 |

Test point III - p for:

| Angle of attack | h:0 | 1.4 .055 | 2.6 .102 | 4.6 .181 | 6.6 .26 | 8.6 .339 | 10.6 .417 | 13.6 .535 | 18.1 mm .713 in. |
|---|---|---|---|---|---|---|---|---|---|
| $0^\circ$ | -19.7 | 37.7 | 52.8 | 59.7 | 69.0 | 73.6 | 73.6 | 72.5 | 71.9 |
| $5^\circ$ | -23.8 | 36.6 | 47.6 | 58.4 | 70.2 | 74.8 | 78.3 | 77.7 | 76.0 |
| $10^\circ$ | -27.8 | 34.18 | 42.3 | 53.3 | 67.2 | 74.2 | 81.2 | 80.6 | 79.4 |
| $15^\circ$ | -27.8 | 17.4 | 29.5 | 22.58 | 42.9 | 51.0 | 63.8 | 77.7 | 84.6 |

Test point IV - p for:

| Angle of attack | h:0 | 1.4<br>.055 | 2.6<br>.102 | 4.6<br>.181 | 6.6<br>.26 | 8.6<br>.339 | 10.6<br>.417 | 13.6<br>.535 | 16.9 mm<br>.665 in. |
|---|---|---|---|---|---|---|---|---|---|
| 0° | -23.8 | 26.12 | 30.2 | 31.35 | 31.92 | 36.6 | 25.12 | 29.02 | 25.54 |
| 5° | -21.3 | 27.1 | 30.6 | 31.2 | 31.7 | 34.6 | 27.1 | 30.0 | 25.36 |
| 10° | -21.3 | 34.6 | 32.3 | 32.3 | 32.9 | 35.2 | 30.6 | 31.2 | 27.1 |
| 15° | -16.8 | 31.9 | 29.0 | 29.6 | 30.1 | 31.3 | 27.2 | 28.4 | 24.92 |

Test point I, Section 0/100 with slot.

p for:

| Angle of attack | h=0 | h=1.6<br>.063 | h=4.6<br>.181 | h=7.6<br>.299 | h=10.6 mm<br>.417 in. |
|---|---|---|---|---|---|
| 5° | -54.5 | 64.95 | 92.3 | 87.5 | 80.6 |
| 10° | -69.5 | 75.88 | 121.7 | 115.9 | 109.5 |
| 15° | -81.75 | 89.29 | 133.95 | 125.85 | 120.55 |
| 20° | -88.2 | 87.04 | 140.4 | 131.7 | 125.9 |
| 25° | -97.4 | 85.7 | 150.8 | 140.3 | 134.5 |

Test point II - p for:

| Angle of attack | h=0 | h=1.5<br>.059 | h=2.6<br>.102 | h=4.6<br>.181 | h=6.6<br>.26 | h=8.6 mm<br>.339 in. |
|---|---|---|---|---|---|---|
| 5° | -30.2 | 33.14 | 45.3 | 51.9 | 56.9 | 62.2 |
| 10° | -38.8 | 37.96 | 52.5 | 66.7 | 87.0 | 92.8 |
| 15° | -45.8 | 42.43 | 62.05 | 82.1 | 98.0 | 99.8 |
| 20° | -50.5 | 42.24 | 67.0 | 85.0 | 102.7 | 104.5 |
| 25° | -52.7 | 38.2 | 58.1 | 80.0 | 102.6 | 107.2 |

Test point III - p for:

| Angle of attack | h=0 | h=1.7<br>.067 | h=4.6<br>.181 | h=7.6<br>.299 | h=10.6<br>.417 | h=13.6 mm<br>.535 in. |
|---|---|---|---|---|---|---|
| 5° | -22.6 | 23.1 | 42.3 | 46.4 | 50.4 | 54.55 |
| 10° | -28.4 | 24.93 | 52.0 | 70.8 | 81.8 | 80.0 |
| 15° | -30.2 | 26.14 | 55.8 | 77.2 | 84.2 | 80.7 |
| 20° | -31.4 | 25.6 | 55.2 | 77.8 | 85.4 | 81.3 |
| 25° | -31.9 | 22.05 | 49.3 | 72.5 | 85.3 | 81.8 |

Test point IV - p for:

| Angle of attack | h=0 | h=1.6 .063 | h=4.6 .181 | h=7.6 .299 | h=10.6 .417 | h=13.6 .535 | h=18.1 mm .713 in. |
|---|---|---|---|---|---|---|---|
| 5° | -14.85 | 16.59 | 28.10 | 34.55 | 40.95 | 44.45 | 25.36 |
| 10° | -17.4 | 20.3 | 36.0 | 46.4 | 56.2 | 63.2 | 22.5 |
| 15° | -17.4 | 20.3 | 36.0 | 46.4 | 56.8 | 64.9 | 24.95 |
| 20° | -16.8 | 19.7 | 34.8 | 45.7 | 53.4 | 60.4 | 25.5 |
| 25° | -15.7 | 13.96 | 25.56 | 32.5 | 41.3 | 51.1 | 24.4 |

The hatched areas indicate the variations in lift. For convenience of comparison, the pressure diagrams of both wings, for the same angle of attack, are given side by side, with the unslotted wing on the right.

The difference in the behavior of the boundary layer on the unslotted and on the slotted wing can be made still clearer by determining the velocity curves from the measured dynamic pressure curves and introducing them above the corresponding test points. This is done in Fig. 9. The different velocity curves are divided by horizontal lines at intervals of one millimeter (0.04 inch). The number on the temporarily lowest line gives the minimum distance of the bore of the pressure tube from the negative-pressure side of the wing in millimeters. The lowest part of the curves was completed in a logical manner. This left the velocity gradient $\frac{\partial v}{\partial y}$ (y=o), indefinite. Hence it was not possible to locate the separation point or to determine whether the back-flow had already set in. In this way, the transition from a smooth to a turbulent flow also remained undertain.

The boundary layer can be characterized by the value of h, for which the dynamic pressure or velocity curves attain their maximum and where the flow, delayed by the friction of the walls, is converted into a pure potential flow. The slight falling off of the curves, after passing their maximum, is, in harmony with the theory of circulation, due to the velocities in the potential flow, which decrease as the distance from the wing increases. The velocity of undisturbed flow, $v = v_0$, is attained at the distance $h = \infty$. With the slotted wing, the relatively great falling off of the curves at test point IV, after passing the maximum, is surprising. This phenomenon may be explained by the assumption that the pressure tube, after passing beyond a certain distance h, again enters a new boundary layer, namely, the one which has separated from the wing. It must be assumed that, with still further increase of h, this layer will be passed through and the dynamic pressure will rise again. In general, it may be seen, from the course of the curve at test point IV, especially for the unslotted wing, that the flow at this point has already separated, even for small angles of attack. Apparently a second and relatively thin boundary layer has been formed, over which the turbulent dead air flows with nearly uniform velocity.

Figs. 10 and 11 show, for comparison, the thickness h of the boundary layer throughout the length of the wing section at the different angles of attack. Since the curves in Fig. 8 show a very flat maximum, the distance from the upper surface, where the dynamic pressure attained 90% of the maximum value, was arbitrarily taken as the thickness of the boundary layer. From these diagrams it can be readily seen how the separation is produced by the gradual thickening of the boundary layer with increasing angle of attack. The boundary layer is probably produced in the following manner. The velocity at the leading edge of the wing increases rapidly with increasing angle of attack. The friction of the air produces a boundary layer. During the further course of the flow, the velocity diminishes toward the trailing edge. The boundary layer is delayed and collects on the upper side of the wing. It increases to a wedge shape at the trailing edge and finally separates the flow from the surface of the wing.

The effect of the flow through the slot on the thickness of the boundary layer can be seen by comparing the corresponding diagrams. It is very evident that the thickness of the boundary layer on a slotted wing, after reaching an angle of about 10°, is smaller than on an unslotted wing and that the velocity increases in the boundary layer. Both facts indicate that the flow is improved by the slot. The lift increase is due to this phenomenon, as shown by the increase in the hatched areas in Fig. 8. In the polar diagram also this phenomenon is expressed by the fact that the wing-section drag of the slotted wing, above the angle of attack $\alpha = 10^\circ$, is smaller than that of the normal wing.

A comparison of the static negative pressures shows that, at at test point I, they are much greater on the slotted wing than on the normal wing. According to the theory, however, the negative pressure on the main wing is diminished by the auxiliary wing. This apparent contradiction may be explained, however, as follows: Test point I lies in the first third of the chord. The main influence of the auxiliary wing extends to the negative pressure region immediately above the leading edge of the main wing, which is known, from previous, more complete pressure distribution experiments in this region, to run out into a sharp point.* The auxiliary wing cuts off this point and effects a more complete distribution of the negative-pressure region toward the trailing edge. This behavior of the negative-pressure region on a slotted wing may also explain why the center of pressure lies somewhat farther from the leading edge than on an unslotted wing.

On the basis of the above results, some idea can be formed as to the probable success of special mechanical devices for blowing or sucking away the boundary layer.

In order to determine the relation on a full-sized airplane wing from the model, we employ Karman's differential equation

$$\frac{7}{72}\,\frac{d\delta}{dx} = 0.0225\left(\frac{\nu}{v\delta}\right)^{1/4} \quad **$$

for the thickness $\delta$ of the turbulent boundary layer on a smooth surface. Its solution reads

$$\delta = \left(\frac{90}{7}\right)^{4/5} (0.0225)^{4/5} \left(\frac{\nu}{v}\right)^{1/5} x^{4/5}$$

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* Compare, e.g., pressure measurements on monoplane wings in Vol. II, pp. 43-47, of "Ergebnisse der Aerodynamischen Versuchsanstalt zu Göttingen."

**Von Karman, "Ueber laminare und turbulente Reibung," Zeitschrift fur Flugtechnik und Motorluftschiffahrt," Vol. I, 1921, pp. 233-298.

or $\delta$ for the length $l$

$$\delta_l = 0.37\, l \left(\frac{\nu}{v\, l}\right)^{1/5}$$

Hence the thickness of the boundary layer increases proportionally with $x^{4/5}$. On this assumption it follows, e.g., that for a wing with a chord of 1.8 m (5.9 ft.), with a landing speed of $v = 20$ m (65.6 ft.) per second and an angle of attack of $\alpha = 15^\circ$ in the position of test point I, a quantity of air of the order of magnitude 0.2 $m^3$ (7 cu.ft.) per second, for each meter of the span, flows within the boundary layer.*

The energy content of the layer of air flowing through such a slot is, under a like assumption, of about the order of magnitude of 260 m-kg per second (1880.6 ft.-lb.-sec.) for one meter of the span. To this there corresponds, regardless of the efficiency of the compressor, about 3.5 HP. for each meter of the span.

These numbers are naturally only approximations, but they indicate that such mechanical imitations of the slot effect require considerable power.

We could indeed conceive of the possibility of employing the whole power of the engine for generating a layer of air blowing over the wing, in order to utilize the impulsion of this mass of air for the forward thrust, instead of the propeller. The efficiency would surely be poor, however, since a relatively small mass

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* For the suction, a somewhat greater quantity naturally comes into play, since many suction points must be distributed along the wing, in order to prevent the renewing of the boundary layer.

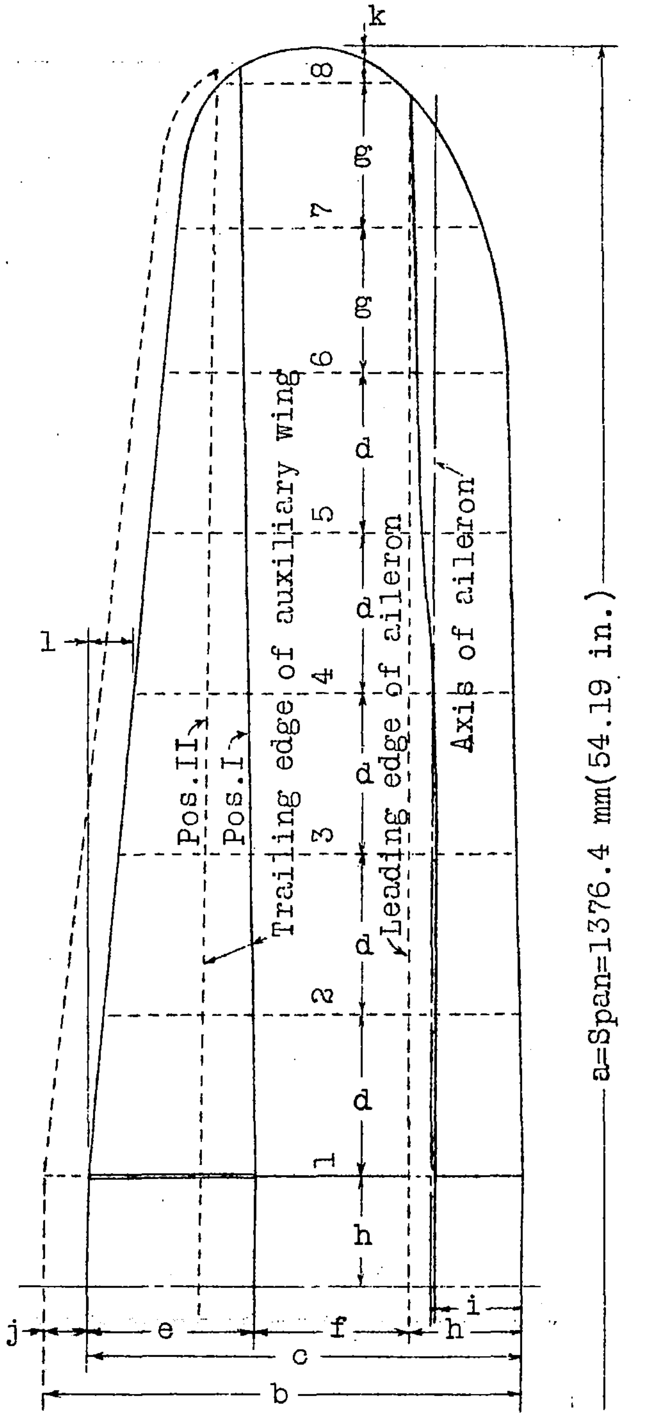
would be given a high velocity. If $\frac{P}{g} \times v'$ represents the force in the direction of flight, the delivered HP. is $N = \frac{P}{g} \times v' v$. The kinetic energy of the layer of air becomes $E = \frac{P}{g} \times \frac{v'^2}{2}$. The efficiency then becomes

$$\eta \leqq \frac{1}{1 + \frac{v'}{2\,v}}$$

If we assume, e.g., that $v' = 2v$, the efficiency is then $\eta \leqq 0.5$. Here, however, the energy recovered by increasing the pressure is disregarded. It still seems doubtful as to whether the decrease in the wing-section drag, obtained by blowing away the boundary layer, is proportionate to the decrease in efficiency and to the increase in weight in comparison with an ordinary airplane. Moreover, there is absolute dependence on the source of power, so that, in case of a forced landing due to engine trouble, the device for increasing the lift would fail.

Aside from these purely practical considerations, further thorough investigation of the phenomena within the boundary layer may finally discover the laws for the wing-section drag and of the separation, so that, after the problem of the induced drag has been solved, we will obtain a perfect picture of the phenomena of flow on an airfoil.

Translation by Dwight M. Miner,
National Advisory Committee
for Aeronautics.



a=1376.4 mm (54.19 in.)
b= 254.0 " (10.00 " )
c= 230.0 " ( 9.06 " )
d= 89.0 " ( 3.50 " )
e= 87.7 " ( 3.45 " )
f= 81.3 " ( 3.20 " )
g= 81.0 " ( 3.19 " )
h= 61.0 " ( 2.40 " )
i= 48.0 " ( 1.89 " )
j= 24.0 " ( .94 " )
k= 20.0 " ( .79 " )
l= 18.0 " ( .71 " )

Fig. 1

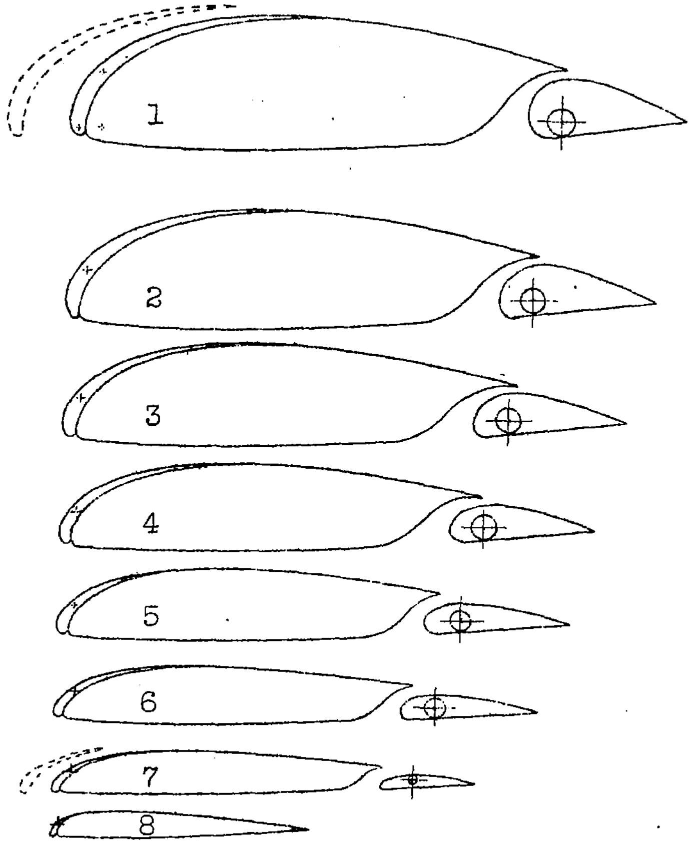


Fig. 2

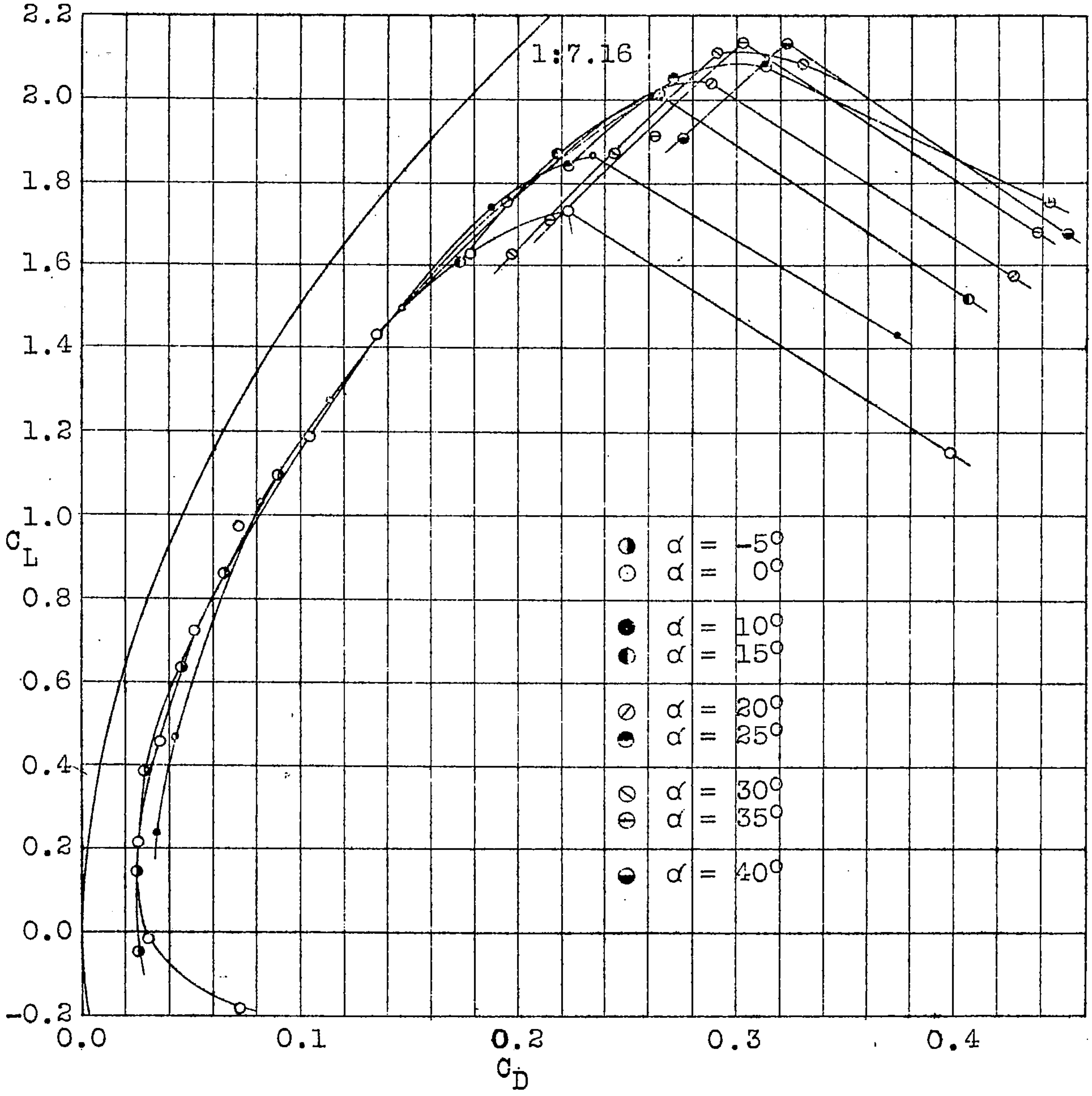


Fig. 3 Slot closed

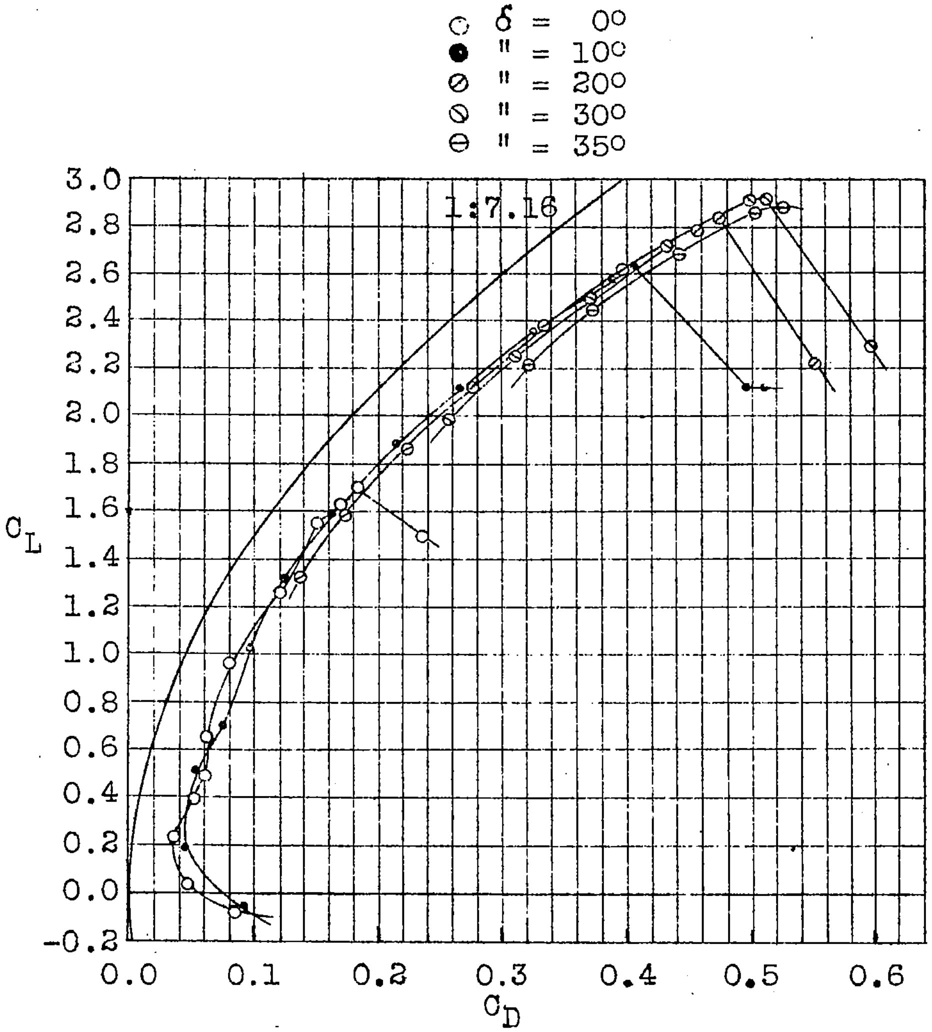


Fig. 4 Wing with aileron and slot

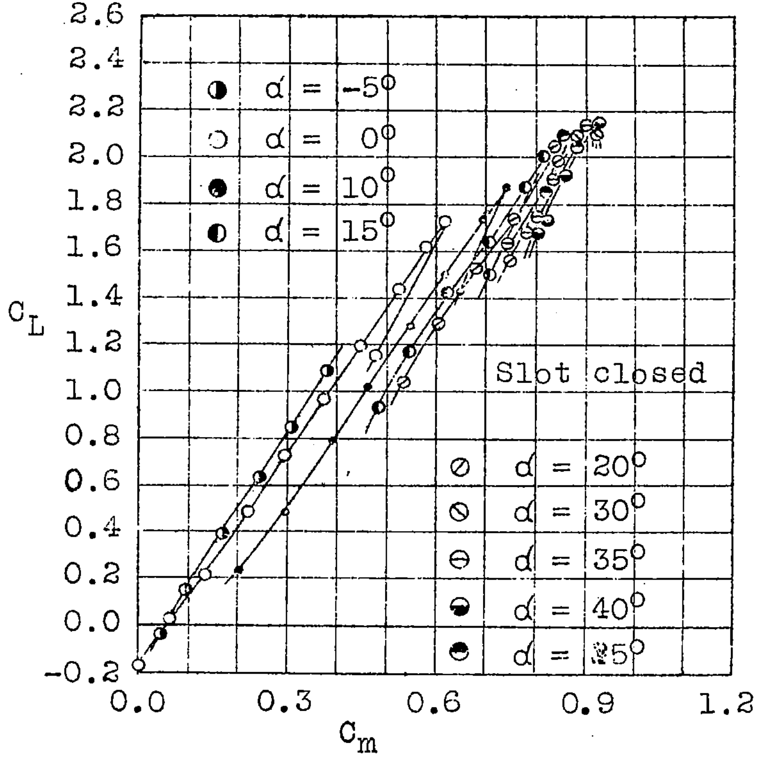


Fig. 5

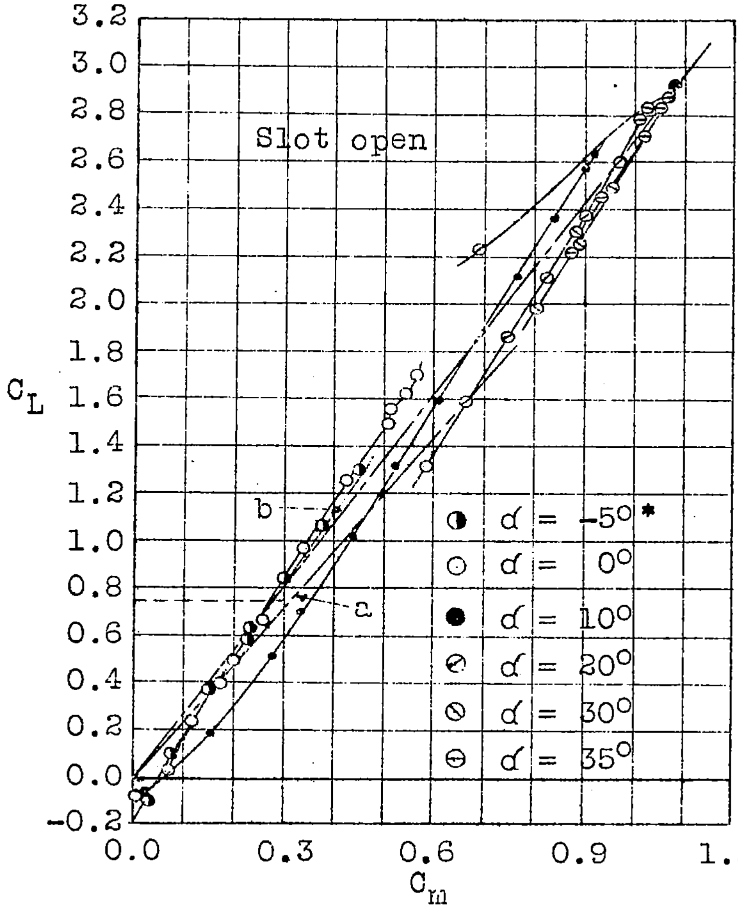
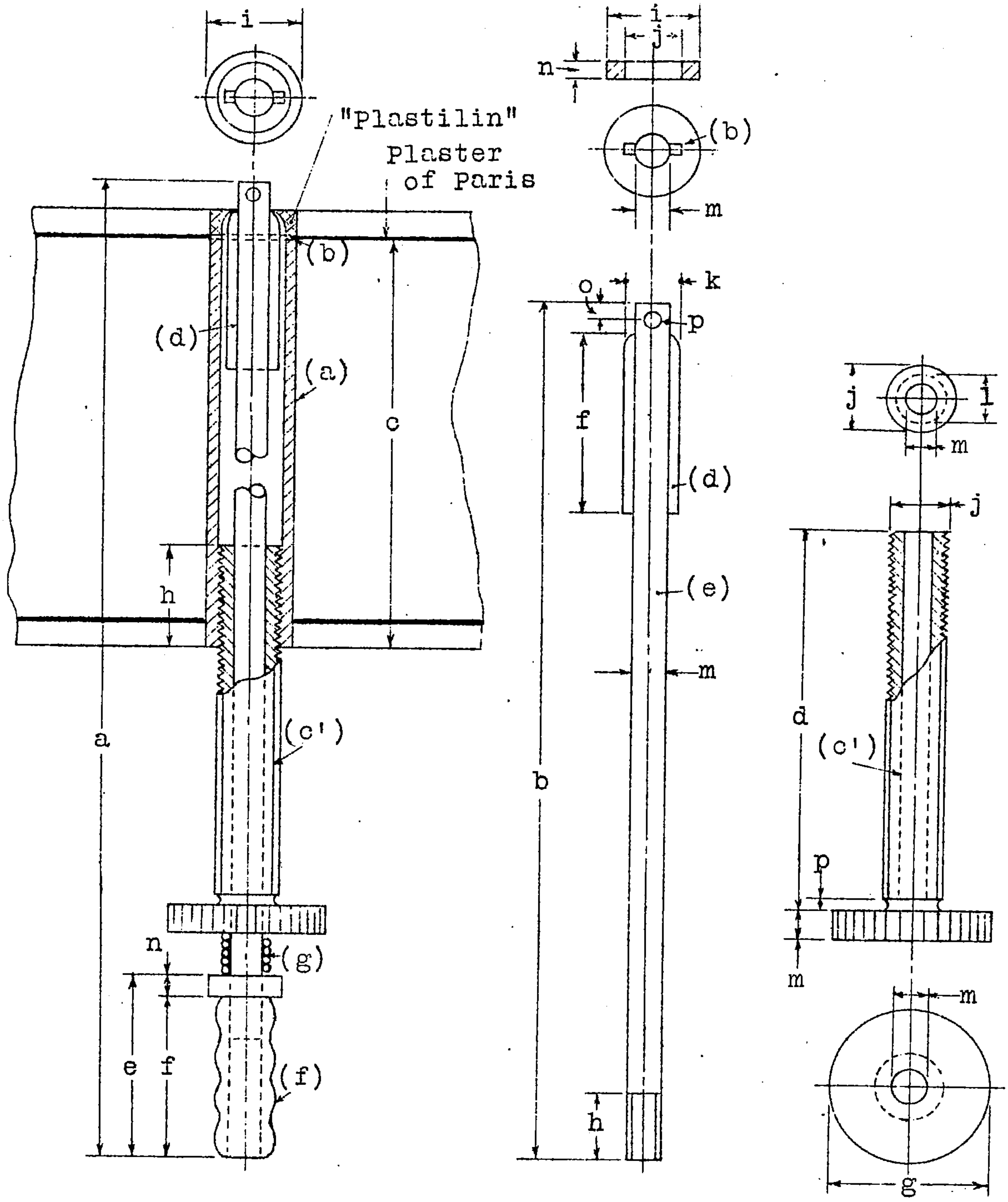


Fig. 6

*Slot closed



a=196 mm(7.72 in.)
b= 85 " (3.35 " )
c= 42 " (1.65 " )
d= 38 " (1.50 " )
e= 18 " ( .71 " )

f=16 mm( .63 in.)
g=15 " ( .59 " )
h=10 " ( .39 " )
i= 9 " ( .35 " )
j= 6 " ( .24 " )
k= 5 " ( .20 " )

l=4.5 mm( .18 in.)
m=3.0 " ( .12 " )
n=2.0 " ( .08 " )
o=1.5 " ( .06 " )
p=1.0 " ( .04 " )

Fig. 7

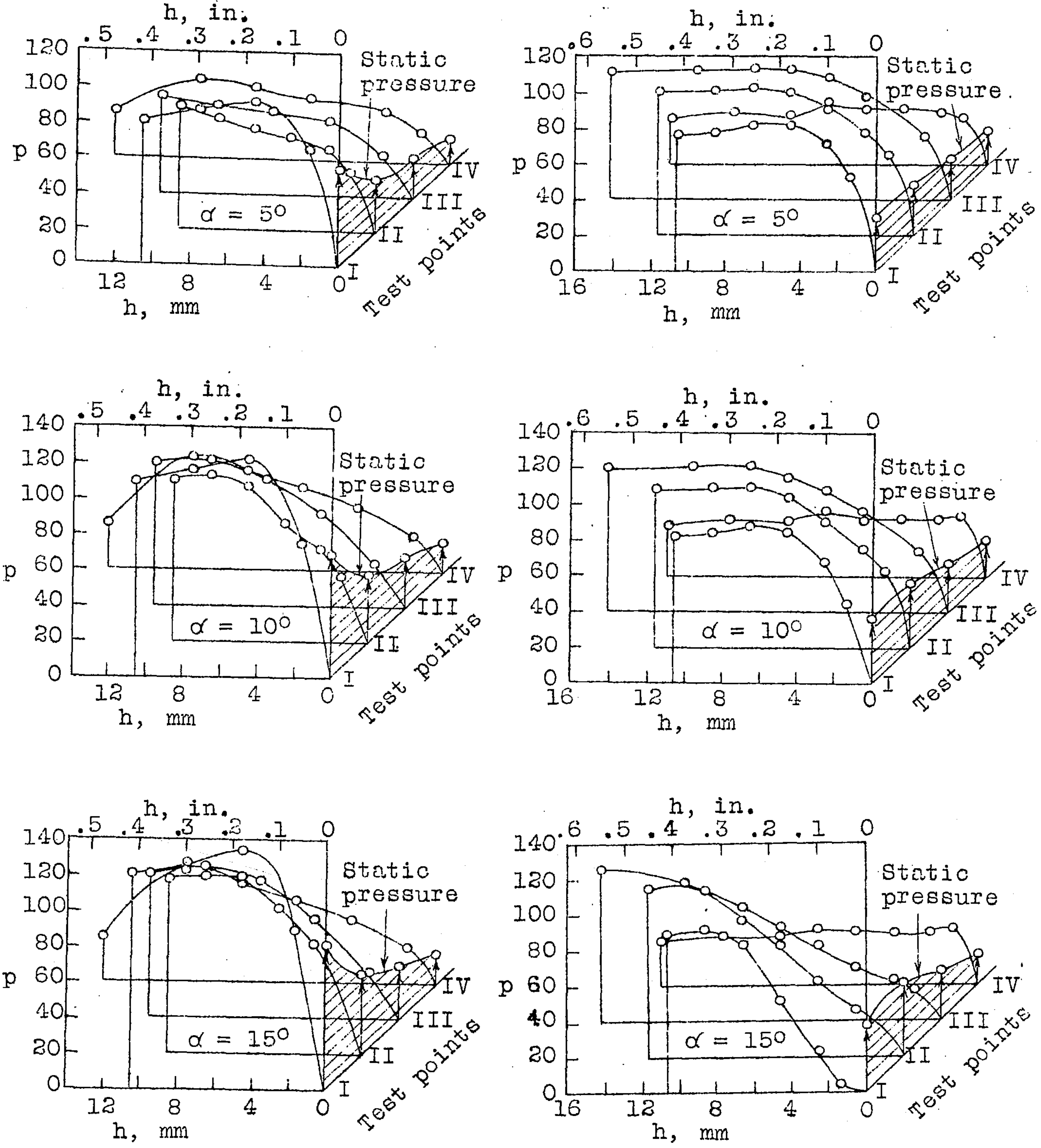
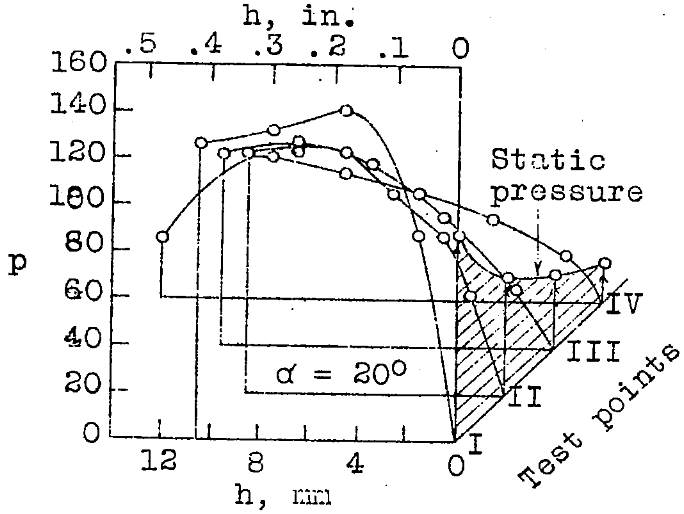


Fig. 8 (continued on next page)



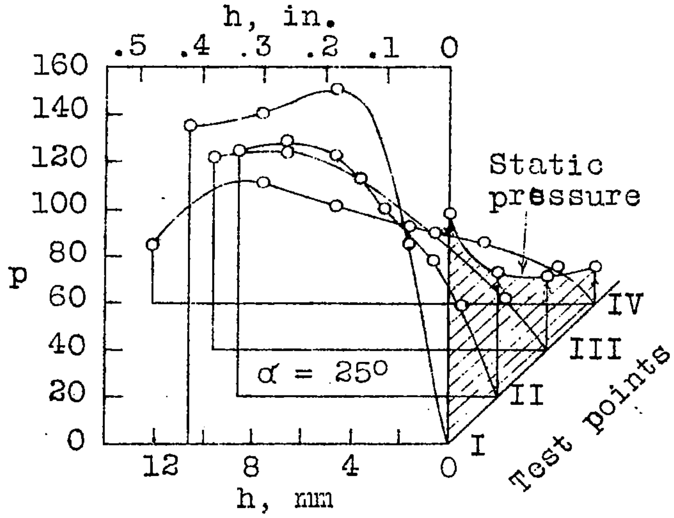
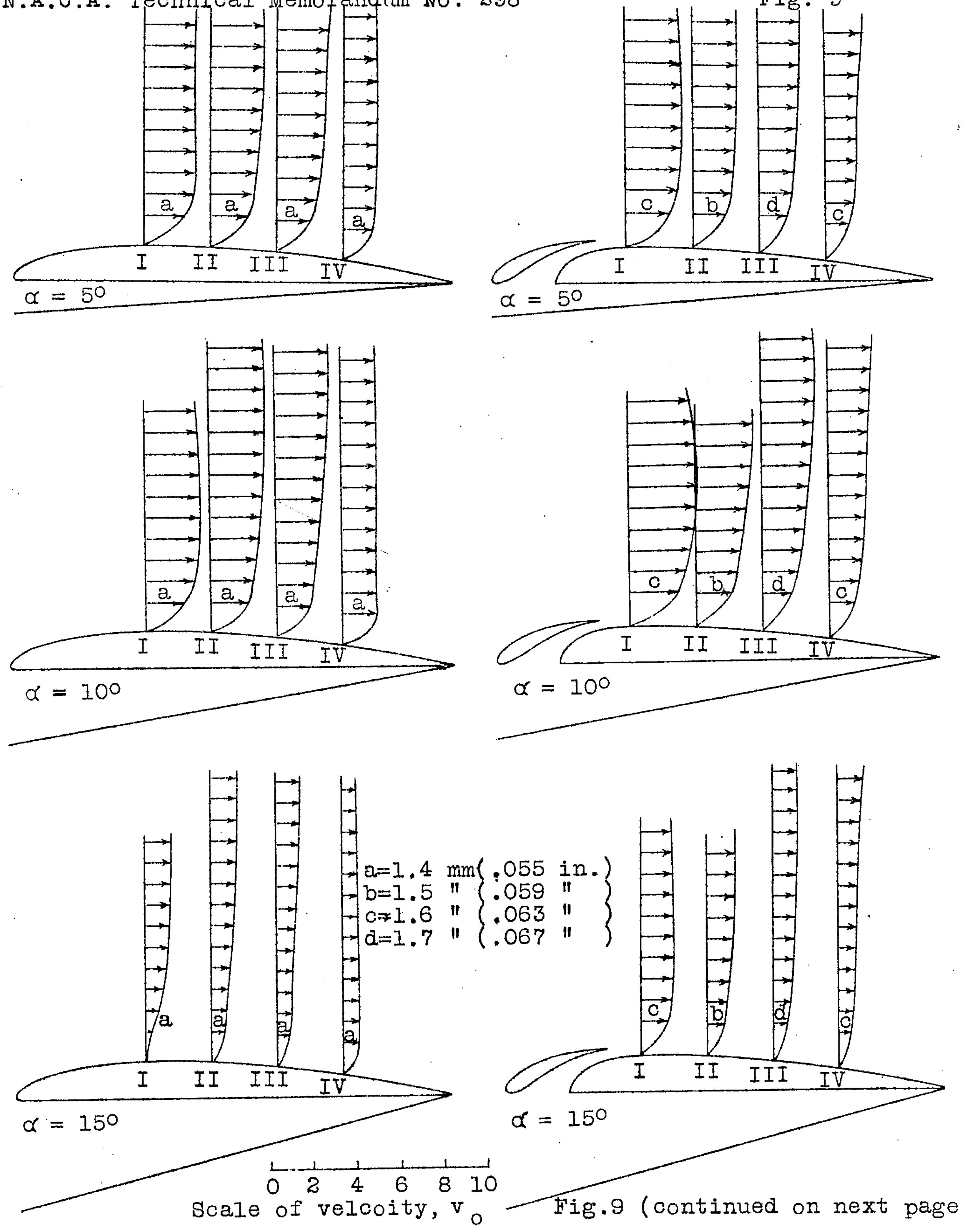


Fig. 8 (continued)



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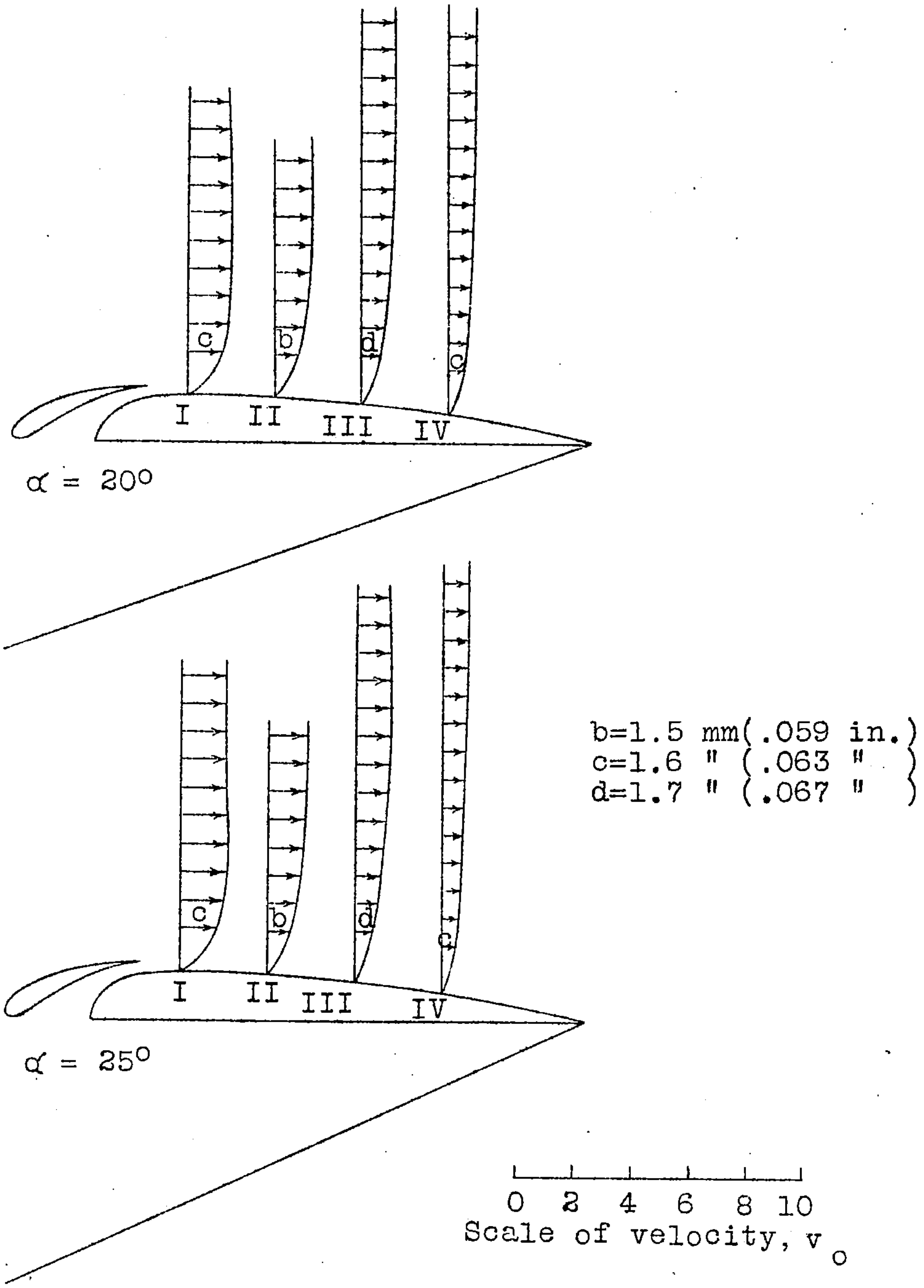

Fig. 9 (continued)

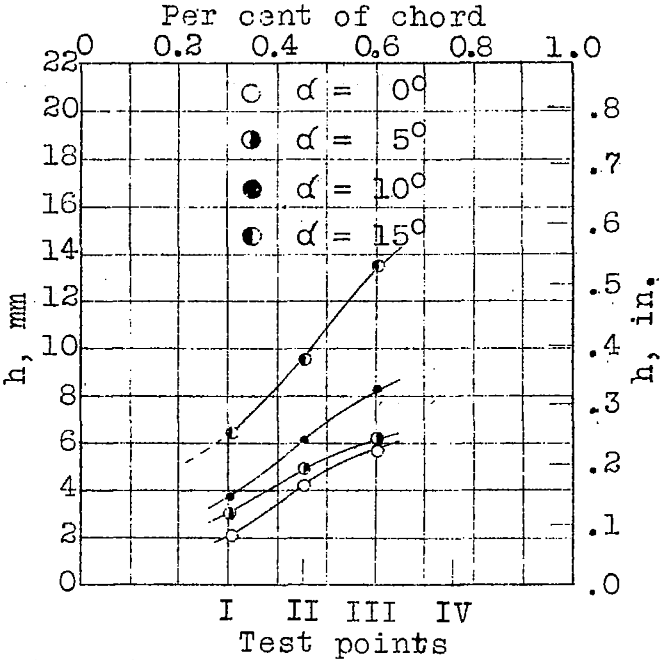

Fig. 10 Unslotted wing

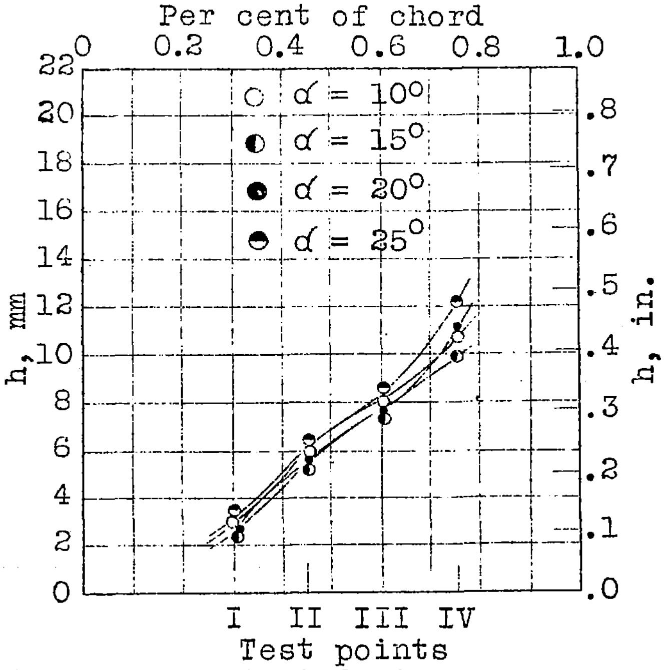

Fig. 11 Slotted wing