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TECHNICAL MEMORANDUMS
NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

No. 685

THE CONTROLS AT LOW HINGE MOMENTS

By M. Pris

Bulletin de la Chambre Syndicale des
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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

TECHNICAL MEMORANDUM NO. 685

THE CONTROLS AT LOW HINGE MOMENTS*

By M. Pris

At present the models sent to the Eiffel laboratory for study of a basic design, lend themselves to certain well-defined tests. The minimum amount of aerodynamic measurements stipulated by the S.T.Ae. include that of the polar curves for wing and airplane, and of the longitudinal and directional stability.

It is not a question of lateral stability nor of control hinge moments, studies disregarded there primarily for lack of practical measuring apparatus. However, the influence of these data on the conduction of the airplane is very vital, indeed, as borne out by the many deplorable accidents resulting from ignorance of these factors.

Stability and maneuverability.- A good airplane should be stable and at the same time, maneuverable.- stable, that is to say, capable of overlooking an error or a careless moment of the pilot. A very sensitive airplane may be acceptably piloted by a trained professional; one may even foresee that in bad weather or as a result of lack of visibility, the airplane may turn over on its back before the pilot has time to grasp the situation. It is said that every position of unstable equilibrium at low incidence has a corresponding stable flight angle at negative lifts. Admittedly, if the pilot has not left his seat and his flying height is sufficient, he can regain his normal flying attitude, but it is also well known how hazardous such matters may become, as in night flying, for instance. A stable airplane does not have this objectionable feature; it has a tendency to resume its angle of level flight at all times.

The stability curve given by the laboratory should thus have a positive slope at any incidence and, still, in spite of this expedient, piloting is far from being safe, as shown by M. Haus in his article on Stability and Maneuverability of Airplanes.

*"Les gouvernes a faibles moments de charniere." Bulletin de la Chambre Syndicale des Industries Aeronautiques, Vol. IX, No. 6, Nov.-Dec., 1931, pp. 1-30.

For a sufficiently low coefficient of stability, the reactions of the elevator may reverse themselves; in a dive the control stick pulls the hand, impressing a force which increases as the square of the airplane speed.

This fact is readily proved. C_M , the coefficient of stability of an airplane, is a function of airplane incidence i_a and of elevator setting β_e , thus

$$d C_M = \frac{d C_M}{d i_a} d i_a + \frac{d C_M}{d \beta_e} d \beta_e = \mu d i_a + \nu d \beta_e$$

$$\mu = \frac{d C_M}{d i_a} = \text{static stability factor}$$

$$\nu = \frac{d C_M}{d \beta_e} = \text{coefficient of sensitivity of elevator.}$$

The airplane is in balance when $d C_M = 0$ or

$$\frac{d \beta_e}{d i_a} = - \frac{\mu}{\nu}$$

On the other hand, the reactions of the stick are normal when the incidence diminishes with an elevator setting, the hinge moments pass from positive to negative (fig. 1), or, in other words, when $C_{M_c} = K' i_e + K'' \beta_e$

$$\frac{d C_M}{d i_a} < 0,$$

which, differentiated, yields

$$K' \frac{d i_e}{d i_a} + K'' \frac{d \beta_e}{d i_a} < 0$$

Replacing $\frac{d \beta_e}{d i_a}$ by its factor yields $\mu > \frac{d i_e}{d i_a} \frac{K'}{K''} \nu$

Haus takes the mean values:

$$\frac{K'}{K''} = 0.7 \quad \frac{d i_e}{d i_a} = 0.472 \quad \nu = 0.8;$$

then

$$\mu > 0.264.$$

The physical interpretation of this fact is as follows: At normal flight incidence, the elevator setting is neutral and the tail has a negative incidence, i.e., if the airplane is inferiorly stable, a slight displacement β produces an appreciable drop in incidence of airplane and tail surfaces in absolute value. In spite of the depression of the elevator, the negative couple of the hinge moment can increase in absolute value. The preliminary study on the model clarifies this question.

Now, what happens at high lift values? The stability of an airplane may be seriously impaired as the result of decrease in mean wing lift, and become the source of a spin or of a forced descent. It is general knowledge that the useful rolling moment which the ailerons set up diminishes and disappears at high incidence, whereas the fictitious yawing moment consistently increases. Then the movements of the pilot become altogether or almost ineffective, inducing spinning and sideslipping, whence the usefulness of preliminary model study.

Lastly, the necessity of positive stability in a dive entails at normal flight angles, greater efforts on the part of the pilot, particularly with large airplanes, where the designer is obliged to retain a large enough control surface to assure low landing speed, as a result of which the airplane is apt to be poorly maneuverable at cruising speed and very fatiguing to the pilot in rough weather. Wind-tunnel tests yield very valuable information on this subject. Conformable to current practice the designer with his experience, assures stability and maneuverability for average flight conditions, but in stunt flying or for new types, systematic study is a useful guide.

A very stable airplane remains very maneuverable when the hinge moments of the controls remain inferior to those obtained with the conventional forms and when the wing lift at high angles has been improved. From this point of view, elevators balanced by recoil of the hinge, and slotted wings present some interesting features.

THE PRIS HINGE MOMENT INDICATOR

A dial graduated from 0° to 90° (fig. 3), with its plane normal to the hinge and centered on the axis of rotation of the control surface, is rigidly mounted back of the wing or stabilizer.

Above the dial is a specially shaped, circular guide. The movable gear, consisting of a slider that can be locked above the guide, two springs with support and a pointer, is placed through the latter in the aileron or elevator.

For zero control setting chosen as starting point of the angles of setting ($\beta = 0$), the graduation indicated by the pointer is n_0 . After shifting the slider, before the test, this pointer faces graduation n_1 . During the test, under the influence of the deformation of the springs, the setting becomes modified and the pointer stops at n_2 . Under these conditions, the setting β° , measured from the original graduation, is $n_0 - n_2$, and the corresponding hinge moment is

$$\text{Moment} = C \times (n_2 - n_1)$$

The coefficient is obtained by a unique calibration of the springs whose tension is unaffected by n_1 . The strength of the springs employed, depends on the dimensions of the models.

The model is mounted on the spindle as for directional stability measurement, the different incidence readings are obtained by changing the position of the dial without stopping the airplane. Varying n_1 at 5° intervals results in a set of curves of the (CM_c) moments for the settings involved, as, for example, between -30° and $+30^\circ$ and for 0° , 10° , 15° , and 20° incidence.

ADVANTAGE OF METHOD

Rapidity of measurement and mounting. One should allow, on the average, from $1\frac{1}{2}$ to 2 minutes per point, inclusive of stops and mounting.

DISADVANTAGES

1) To insure accurate readings to within one-tenth of a degree, the operator must sit as close as possible to the open jet of the tunnel. The graduation should preferably be in degrees and half-degrees; the lighting and the shape of the pointer should be such as to make reading easy.

2) Vibrations occur when the flow on the model becomes bad and, especially, with slotted wings, for certain very limited zones of α and β . The model must be firmly attached, there must be no play or flexure in the support and the hinge, nor in the measuring device. However, in none of the tests made, did these vibrations prevent the tracing of clear curves. Lateral bracing is recommended. Lastly, covers should be fitted over the springs for protection against the wind.

MOUNTING OF SECTOR AND OF POINTER

Sector.— Figure 4 shows one method of mounting the sector. A sufficiently stiff strip, appropriately set in the wing or tail surface, is bolted on the sector, the holes for attachment ($\phi = 3$ mm) are 10° apart in a circle of 65 mm of the axis of the hinge. The plane of the sector is adjusted as needed with suitable wedges normal to the axis facing the wind.

For $\beta = 0^\circ$ the trailing edge of the control surface should ordinarily be between 40 and 45° on the dial.

Pointer.— A strip set in the flap (fig. 5) has two 3 mm holes corresponding to those on the pointer, their centers being on a line passing through the axis of the hinge and at around 40 to 50° of the dial.

The important dimensions thus are (fig. 6):

1. The 65 mm radius for the holes of the strip in the sector, and two or three 3 mm holes, 10° apart;

2. Two 3 mm holes, 58 mm and 75 mm from the axis in the strip in the pointer;

3. 18.5 mm spacing between the fronts of these strips.

With respect to the pilot, the strip holding the pointer is placed to the right of that holding the sector.

SPRINGS

Six double springs of the dimensions given in Figure 7, are necessary. For an elongation from 45 to 80 mm, or 35 mm at the highest, the springs should develop the listed values for tension:

Designation:	A	B	C	D	E	F
Traction (kg):	2.5,	1.5,	1.0,	0.5,	0.3,	0.1

Approximate areas of control surfaces (conventional form):

S (m ²):	0.08	0.005
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Stops have been provided to prevent the tension of one or the other of the springs from becoming zero. The weaker springs insure greater sensitivity, but the action due to the weight of the flap and the increase in vibrations form a stop in this direction.

Seemingly the best results are obtained when the maximum $n_1 - n_2$ does not exceed 10^0 .

CALIBRATION

Weight of flap.- The action due to this weight during the displacement $n_1 - n_2$ is negligible.

Pointer.- The aerodynamic moment of the pointer may attain to 3 or 4 per cent of that due to the flap. This value was obtained by mounting the pointer to the hinge axis after removing the flap (wing with aileron). The correction has shown it to be fairly independent of the wing incidence and a function of the setting only; for $n = n_0$ it becomes zero. This fact should be attributed to the importance of the wake in this zone.

The curve (fig. 8) gives $\frac{100 M}{hs}$ g/cm in function of

the setting, hs being the reading on the micromanometer for the Eiffel wind tunnel. ($V^2 = 3.8 \cdot hs$)

Springs.- Given the weights suspended back of the pointer at a known distance r from the axis yields a deflection Δn .

If Δn maximum = 10, the slider is shifted so as to measure the forces corresponding to $n_h + 2, n_h + 4, \text{etc.}, n_h + 10,$ n_h being the reading when the pointer is horizontal, so that r is now constant.

The calibration curve shows M (g/cm) versus Δn for the two springs.

TABULATION OF RESULTS.

$$n_0 = \frac{100 M}{hs} \text{ pointer} =$$

i°	hs	n_1	n_2	N_1	M_1	$\frac{100 M_1}{hs}$	$\frac{100 M_2}{hs}$	C_{M_c}	β°
0°									
5°									
10°									
15°									
20°									

$$\Delta n = n_2 - n_1.$$

M_1 = reading of moment on the calibration curve.

hs = micromanometer reading.

$\frac{100 M_2}{hs}$ = moment after correction due to pointer, taken constant for each series of setting.

$$C_{M_c} = \frac{100 M_c \text{ K g/m}}{\frac{\rho}{2} S_g c_g V^2} = \frac{100 M_2}{hs} \text{ g/cm} \times \frac{16}{\text{K S}_g c_g \times 100,000}$$

with $V^2 = K hs$ $\beta = n_0 - n_2$.

S_g = area of control surface.

c_g = mean chord of control surface.

Conformal to practice, β is figured positive when the aileron is deflected with respect to the wing and C_{M_c} positive when the flaps tend to rise.

MOUNTING OF MODEL

The axis of the hinge being without appreciable friction, the mounting is accordingly acceptable. The axis is formed by two pivots and, if necessary, an intermediate stop in form of a small fork, which prevents any flexure of the control surface normal to its plane. It also should be rigid enough in its plane to avoid flexure (notched out elevator). Suggested arrangements are shown in Figures 9, 10, and 11.

1) Figure 9. Ailerons separately.- Two pivots at the tips of the right aileron; intermediary attachment if necessary. Incidence sector (fig. 12) and usual axis for the left aileron. Before the test the left aileron should be given a setting similar to that which will be taken by the right aileron.

2) Figure 10. Elevator in two parts, joined with a flexible member. The pivots are placed at the right and left tips of the model, or distributed over the span. Ordinarily, one center stop will be needed.

3) Figure 11. Rigid one-piece elevators. The pivots are arranged as in case 2. Thin models may require an intermediate stop. The incidence sectors are equipped for obtaining polar curves.

Pivots.- The method of mounting shown in Figure 13 is that for the extremely difficult case of a thin wing. The pivot consists of a screw and lock nut provided with holes for adjustment with a pin; care should be exercised to have the point always free. (Fig. 14.) Small strips may be used, if necessary, to better close the openings made in the models.

Intermediate stop.- Figure 15. This consists of a fork with two arms, which ordinarily does not touch the control surface, because of its very small end play. The friction introduced is negligible, but centering of the axis passing through the fork is difficult to achieve.

Incidence sectors -- of which Figure 13 is an example -- maintain the settings while obtaining the polar curves.

Template. -- Figure 16. A wooden template for the top camber, 10 to 20 mm thick, yields the incidence and the position of the control surface for a neutral setting at one time.

TAIL GROUP STUDY

Conventional Tail Group

Fig 17

S.P.C.A. 90 Col. 3 (Société Provençale de Constructions Aéronautiques).

Span : 90 cm

Maximum chord : 30 cm

Thickness in center: 12.5 per cent

Area:

$S_e = 0.1919$ total

$C_e = 0.232$ mean

$S_g = 0.0801$

$C_g = 0.1065$ mean

The lift curves for 0° , -10° , and -20° setting, are normal, compared to the total area of S_e . Experience has shown that the action of the setting is felt, although very slightly, up to $50-60^\circ$.

The hinge moments are compared to the area and the mean chord of the elevator; the nondimensional coefficient C_{M_c} is given as function of the elevator movement for 0° , 5° , 10° , 15° , and 20° incidence of the stabilizer. It is seen that each of these curves consists of three straight segments separated by change in regime at about $\beta = 10^\circ$. This, undoubtedly, is due to the effect of the wake of the forward part to which the elevator is exposed at low incidence.

The evolution of the moments is quite regular up to about 15° incidence, whence it increases very rapidly.

limits
Application.— Such measurements are already used for evolving the mean load of the empennage. Here is an application to the research of the efforts of the pilot at different flight attitudes and different degrees of stability. The curves in Figure 17 give the coefficients of the longitudinal moment - elevator locked - with centering 30-33-35 per cent of the median chord of the wing of the airplane shown in the drawing. At 33 per cent the curve has a horizontal tangent toward zero lift. The three segments of the curve quoted above correspond to stability with elevator set at $+5.1$, those below for -4.1 setting. Lastly, the dash curve gives the stability at 30 per cent without tail surfaces. Of course a 35 per cent centering is beyond the ~~ambit~~ ^{limits} of the designer's use; the study is merely for the purpose of instruction.

It is assumed that different stabilizer settings correspond to these three centerings so as to maintain an identical normal flight incidence without forcing the pilot to appreciably modify the elevator setting.

The spacing of the coordinates between the curves with and without tail surfaces, yields the amount of tail-surface moment. The preceding tests yielded the position of the c.p. on the tail group; the lever arm up to the c.g. is readily measured for different flight conditions. The total stress or C_z as well as incidence i_e of the tail group is deduced as function of airplane incidence i_a . They are straights.

Settings β are obtained as function of i_a by interpolating the curves of the wind vane, by displacement parallel to the ordinates until their intersection with the axis of incidence occurs at the desired angle.

Given i_e and β_e , C_{M_c} is summarily obtained by reading the curves, whence the control stick reactions F , with a lever arm of 83 cm, assuming that there is no reduction ratio, that the wheel is weightless and the slipstream absent.

The gross weight of the airplane is nearly 5 metric tons. The $+$ sign denotes that the stick pushes in the hand; when F is negative, it pulls.

At 30 per cent the reactions are normal. In a dive the positive reaction grows rapidly, attaining 50 kg at $C_z = 10$ to 15. The vertical dive can also not be achieved (25° to 30° maximum for $V = 100$ m/s, approximately). At 33 per cent the forces are still in the same direction, although attenuated. At 35 per cent, there is a reversal as predicted by Haus. If such an airplane is to fly with this centering far behind that stipulated by the designer, the situation becomes dangerous, albeit not exactly catastrophic, and demanding the undivided attention of the pilot. With the weight of the wheel in mind, the forces F are about 4 kg less.

Summing up, such calculation attains to a more exact record of the behavior of the airplane than a simple examination of the stability curves. Of course, the effects due to the inertia of the airplane have not been taken into account.

S.P.C.A.: BALANCED TAIL SURFACES

Fig 19
The previously mentioned tail was modified by shifting the hinge 21.3 mm toward the trailing edge, the stabilizer shape being as in the graph. This placed the axis at 32 per cent of the chord with respect to the main chord of the elevator.

The hinge moments are reduced to 1/10 or 1/20 with respect to the former (dash-dot lines); their evolution is normal and the desired results are obtained. One objectionable feature of the lift should be pointed out: At between 20° and 30° settings the lift drops for positive incidence, as the result of the presence of a slot and especially because of the existence of a protuberance on the back formed by the leading edge of the elevator.

The incidence of the tail is always low and negative except at very high airplane lifts; nevertheless, it is desirable that the true magnitude of this phenomenon be palliated.

EIFFEL (25 per cent) BALANCED TAIL

Fig 20
A biconvex symmetrical profile, 800 mm span, 150 mm chord, e/l maximum 14/100 was used for stabilizer; the elevator 70 mm chord, had a similar profile. The axis

came to 17.5 mm of the leading edge of the elevator, or 25 per cent of the chord.

The curves for the hinge moments are a striking example of the utility of this particular measuring device. At 0° incidence the moments are zero between -20° and $+20^\circ$ settings; as the incidence is increased the moments become partially negative, there is an excess of compensation. The straight dot-dash line gives the values for an uncompensated elevator.

From the point of view of lift, the phenomenon is exactly identical to the one just described.

EFFEL COMPENSATED TAIL (18 per cent)

Fig 21

The axis of the hinge was shifted 5 mm forward, the compensation was more than 18 per cent. At 30° setting the lift is distinctly higher compared to the preceding case.

The evolution of the moments is more normal, the moments are consistently lower than those obtained with an uncompensated elevator. This evolution is readily explained: the protuberance created on the top camber is less.

BREGUET TAIL

In this empennage the trailing edge of the stabilizer is cut through and the thickness fashioned so that the leading edge of the elevator is tangent to the stabilizer, - 26 per cent compensation.

The moments are higher than for the identical Eiffel tail, but the lift continues to increase at 30° setting. This, undoubtedly, is due to the fact that the leading edge of the elevator no longer forms a protuberance on the top camber of the model. On the other hand, the fore part of the slot is in a zone of lower velocity set up by the rear portion of the stabilizer. The compensation is less effective.

The dash-dot line gives the moments for a compensated elevator.

S.P.C.A. TRAPEZOIDAL TAIL

The trailing edge of the stabilizer is rounded off and the tests were carried out for three different axes of the hinge placed at 0, 11.2, and 22.4 per cent of the mean chord of the elevator. The comparison was made with medium hinge setting, the trailing edge of the stabilizer rounded off and hollow. (See fig. 25.) Thus,

$$S_c = 0.2083 \text{ m}^2 \text{ (total area)}$$

$$S_g = 0.0502 \text{ m}^2 \left. \begin{array}{l} \\ \\ \end{array} \right\} \text{ (trailing edge hollow)}$$

$$C_g = 0.0557 \text{ m}^2$$

$$S_g = 0.0563 \text{ m}^2 \left. \begin{array}{l} \\ \\ \end{array} \right\} \text{ (trailing edge rounded off)}$$

$$C_g = 0.0625 \text{ m}^2$$

The evolution of the hinge moments is interesting to consider when studying what a slot of this shape would do. (Figs. 23 and 24.) The objectionable feature of the lift becomes more striking as the hinge is further withdrawn. The adoption of a hollow trailing edge for the stabilizer modifies this condition a little without affecting to any marked degree the magnitude of the hinge moment. It should be borne in mind that with this tail and for the front hinge, the slot still exists, although somewhat reduced.

FUTURE RESEARCH

There is still to be studied:

1. The effect of the height of the axis with respect to the stabilizer.
2. The shape of the profiles and of the slot.

AILERON STUDIES

Chantiers de la Loire Wing with Rear Slot

These measurements are given as examples with a small-size control.

Whereas the area of the S.P.C.A. elevator was 800 cm², that of the Loire aileron is 43 cm². If the hinge moments were defined with total area of wing and of chord as reference to assure uniformity with the longitudinal and directional stability data, the maximum of 60 attained to by C_{M_c} would become

$$\frac{260}{60} = 0.23.$$

This is much more exacting for these measurements. In Figure 25 the C_z maximum is plotted against the setting.

LeO (0.90 x 0.32) RECTANGULAR WING

Aileron chord = 8 cm. The shape of the slot is seen in Figure 27. The trailing edge of the wing forms a cylinder with the hinge forming the axis. The opening of this slot is very slight at neutral setting, then increases while turning the fluid that passes, in appropriate direction so as to render the aileron efficacious.

The hinge moments are notably lower, contrasted to those in a conventional aileron. Another fact to be kept in view is the high C_z , 195, for 20° incidence and 20° setting. At 25° incidence the maximum lift becomes 150, a noteworthy feature of the back slot.

LeO 30 TRAPEZOIDAL WING

The slot used here was built onto the model of that of the rectangular wing; a fictitious fuselage was added below the bottom camber and the moments of roll and of yaw were defined with respect to a c.g. located at 41 mm below the wing and at 55 mm aft of the median leading edge.

The ailerons were locked in opposite sense and the signs defined as follows: On the active aileron side, the wing moves back with $+C_n$ and moves up with $+C_r$, these factors being referred to the total wing area and to its mean chord. It is seen that for a low hinge moment the rolling moments remain sensibly unaffected by the incidence, even when near to the maximum lift.

The yawing moments decrease as the incidence increases and become zero or negative at maximum lift.

It seems as if the rolling moments were higher and the yawing moments lower than those obtained with the unslotted aileron.

Finally, the test on the rectangular wing, checked here for 10° setting, shows that a very high lift can be obtained.

This wing embodies notable improvements in stability as well as lift; slightly less effective than the wing with front slot, it more than balances this by being more simple in design and more reliable in action.

Action of wing with back slot.- The detrimental flow set up on the top camber of a wing is felt all the more as the incidence is increased and as the pertinent zone is nearer to the trailing edge. The Handley Page slot, as well as the Townend ring for streamline bodies, by constraining the fluid filaments into channels, forces them to hug the contours, thus increasing the lift generatrices of the effective rolling couple, decrease the drag generatrices of the yawing couple, and raising the efficiency of the ailerons by a fresh indraft of air in its place.

If the slotted wing does not improve the flow on the front portion, it prevents a worse flow (trailing edge zone) by replacing it by a small wing working in good conditions, as a result of the flow of smooth air from the bottom side through the slot and over the top side of the slot.

This result may be compared with an earlier test of Handley Page on a wing with 4 or 5 slots running parallel to the wing span. At a maximum lift of 500 or 600 (referred to the projected surface of the assembly), the rear aileron was almost normal in the flow at infinite distance; each one of them, working the air deflected by the one preceding, was at an incidence low enough to produce lift.

GÖTTINGEN WING

1.20 m span, 18 cm chord $A = 6.5$ fitted with aileron balanced 40 per cent.

The moments are given for 3° and 18° incidence, and compared to those of a symmetrical biconvex wing of the same size and unbalanced aileron. The results agree with those obtained previously.

The polar curves are extremely interesting; as for the LeO wing, the maximum C_z increases up to 190. Considering the enveloping curve of all these polars, we find a wing having a maximum lift of 190, a minimum C_x of 1.55, a maximum fineness of 18, and a C_{Mc} of 2.^x The incidence for maximum C_z with neutral setting is near 19° , with 52° setting it is 13.8° .

These are noteworthy features for landing, high lift and low incidence, and this is obtained with a slot with very low hinge moment.

N.A.C.A. WING (Reports Nos. 343 and 370)*

Conventional aileron tests, made on a 1.52 m by 0.254 m wing, comprising the measurements of hinge, rolling, and yawing moments about an axis located below the wing, as in the LeO trapezoidal wing test.

The figures are relative to an aileron, the reference lengths being the semispan for the roll and the distance from the c.g. to the tail, for the yaw.

The full lines represent the roll and the dot-dash lines, the yaw. It will be noted that practically the entire effective action is due to the aileron that moves up (right side of figure, β negative); it likewise is the one producing the minimum yawing moment.

Utilizing the sole action of the unset (or free) aileron instead of the conjugated ailerons would give the pilot, by a slightly greater surface, a very effective con-

*Heald, R. H., Strother, D. H., and Monish, B. H.: Effect of Variation of Chord and Span of Ailerons on Rolling and Yawing Moments at Several Angles of Pitch. T.R. No. 343, N.A.C.A., 1930.

Monish, B. H.: Effect of Variation of Chord and Span of Ailerons on Hinge Moments at Several Angles of Pitch. T.R. No. 370, N.A.C.A., 1930.

trol at any incidence. The hinge moments are equally propitious with the unset aileron; they remain low and may even become reversed.

This solution, resorted to in part, presents material advantages, although they are far below those which can be achieved by the use of a wing with back slot.

FUTURE EXPERIMENTS

1. Exploration of shape of slots giving minimum drag increase.
2. Effect of relative thickness of profile.
3. Research on maximum possible C_z (chord of slot, shape of slot, position of axis).

Translation by J. Vanier,
National Advisory Committee
for Aeronautics.

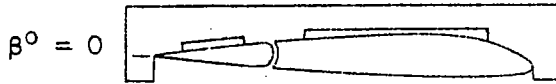


Fig. 16 Template for incidence and setting.

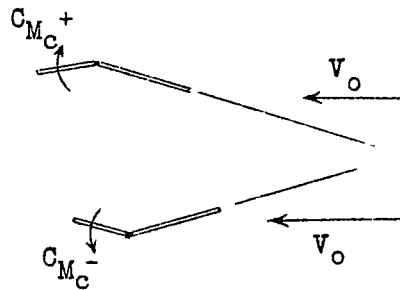


Fig. 1

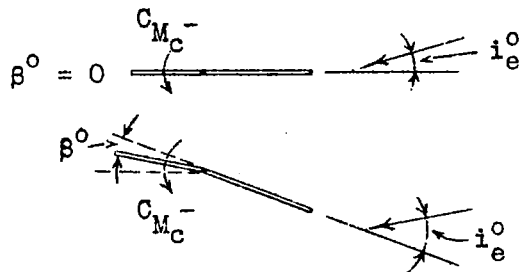


Fig. 2

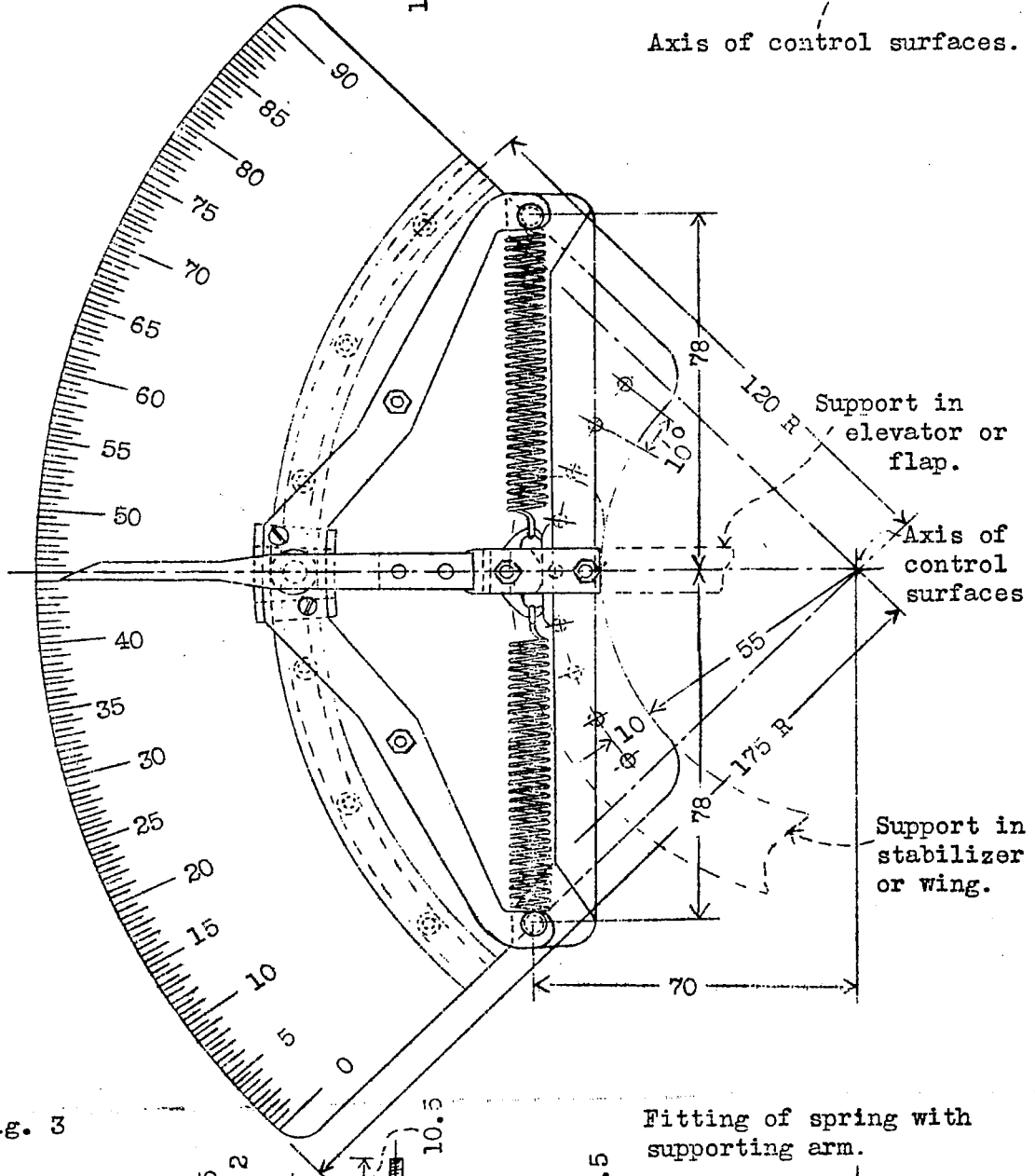
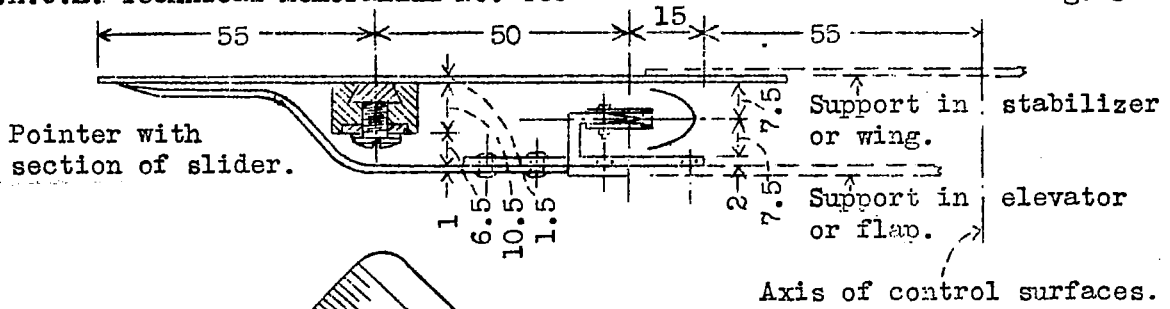
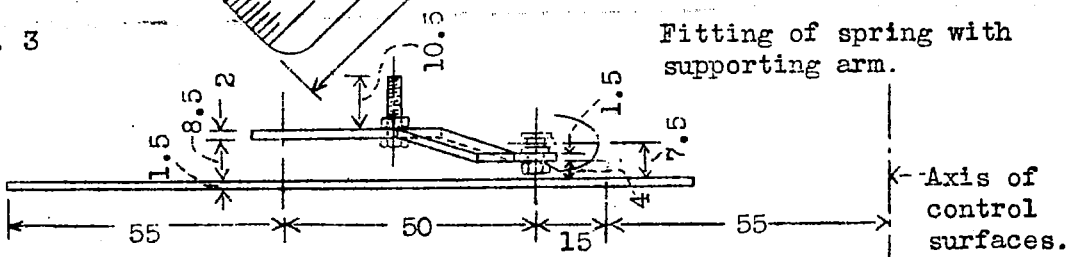


Fig. 3

Fitting of spring with supporting arm.



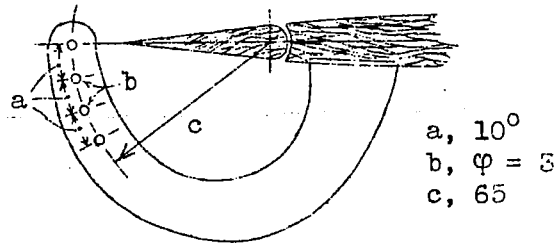


Fig. 4 Dial fitting

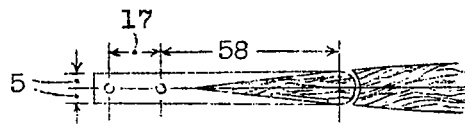


Fig. 5 Pointer fitting

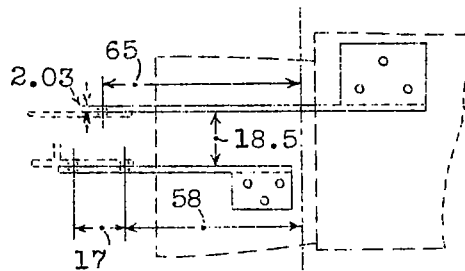


Fig. 6 Dimensions of mounting

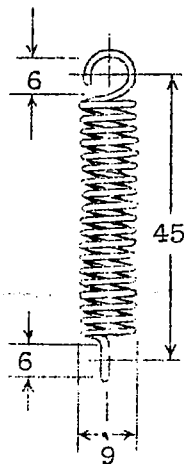


Fig. 7 Spring

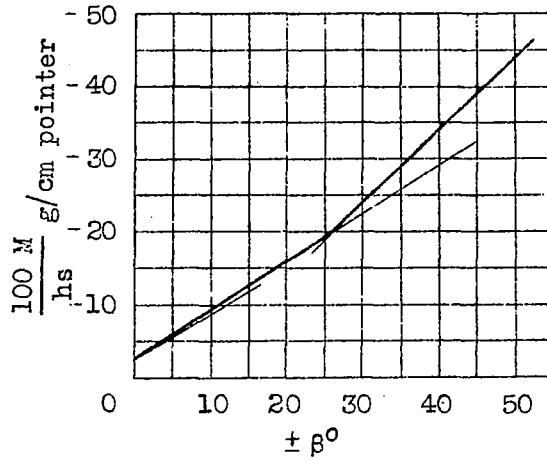


Fig. 8

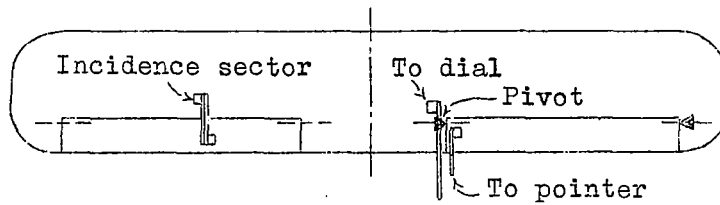


Fig. 9

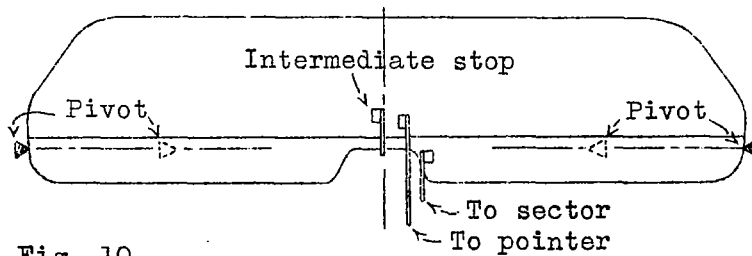


Fig. 10

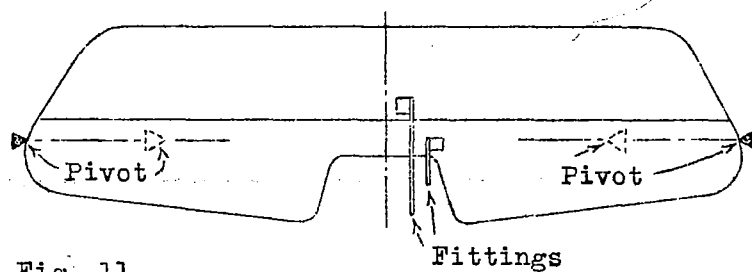


Fig. 11

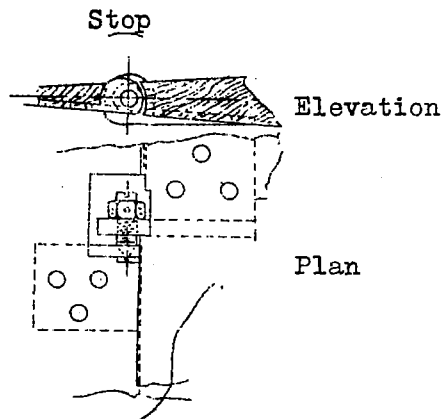


Fig. 13

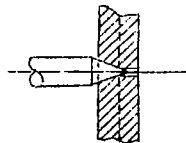


Fig. 14

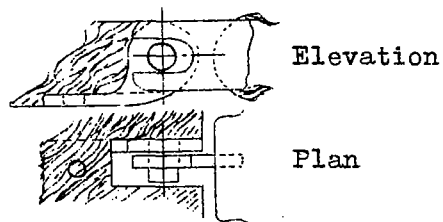


Fig. 15 Intermediate stop

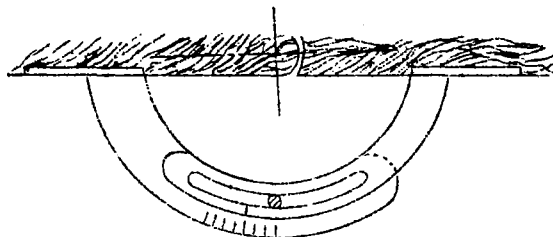


Fig. 12 Incidence sector

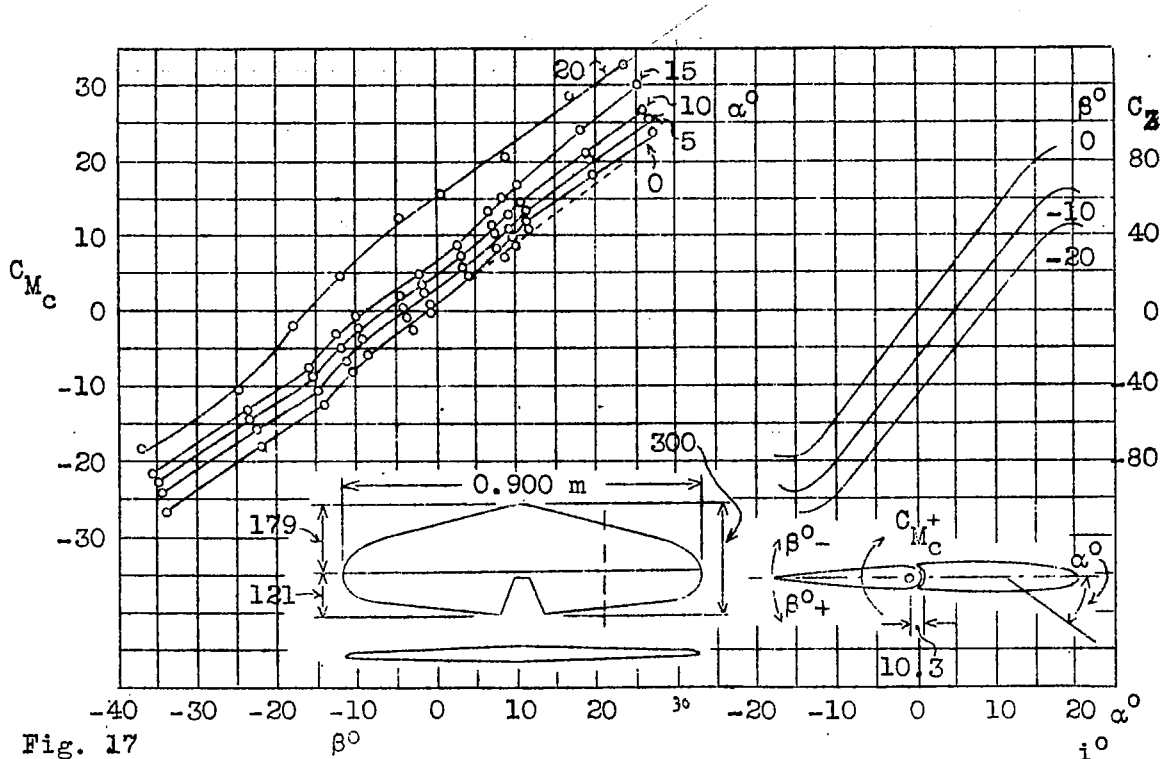


Fig. 17

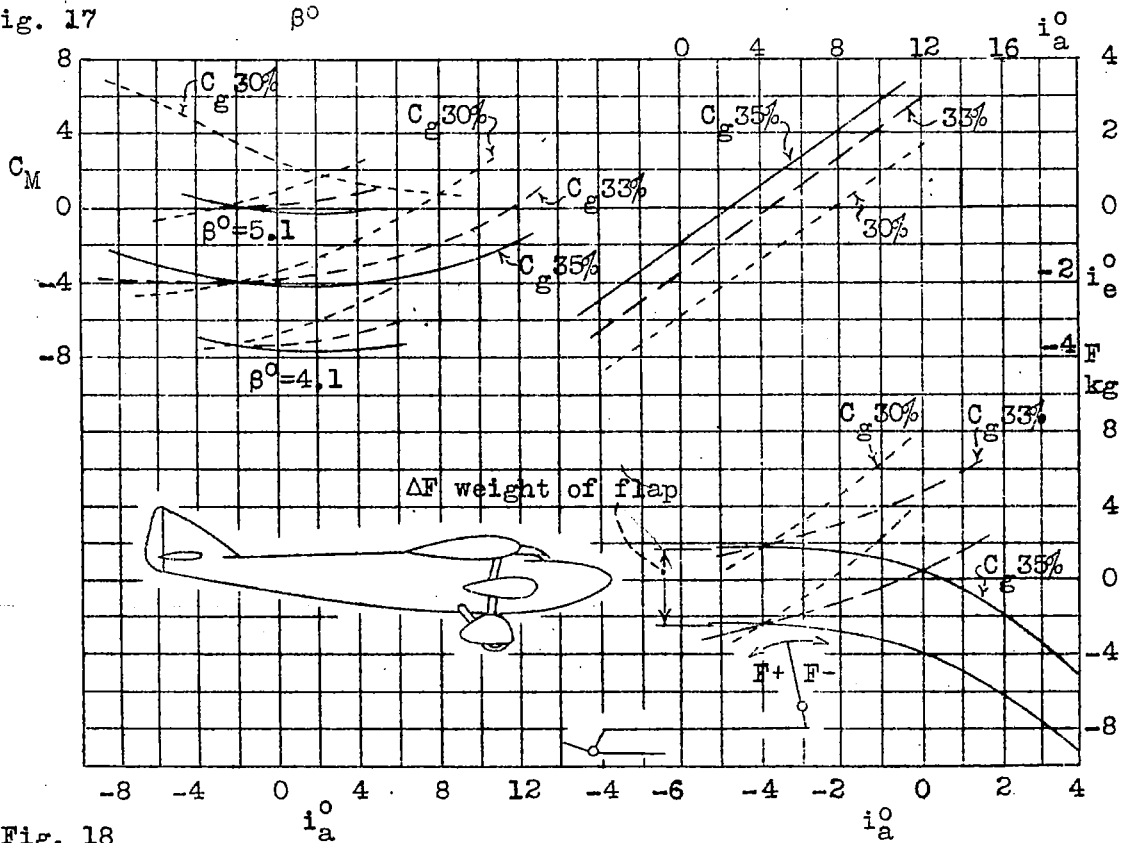


Fig. 18

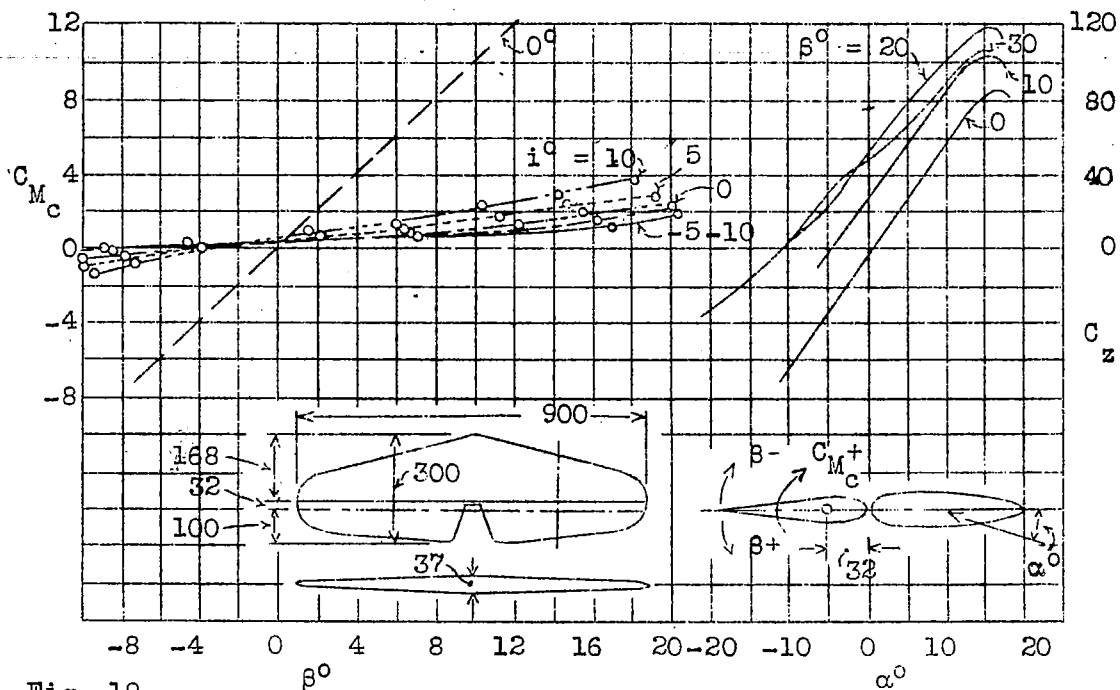


Fig. 19

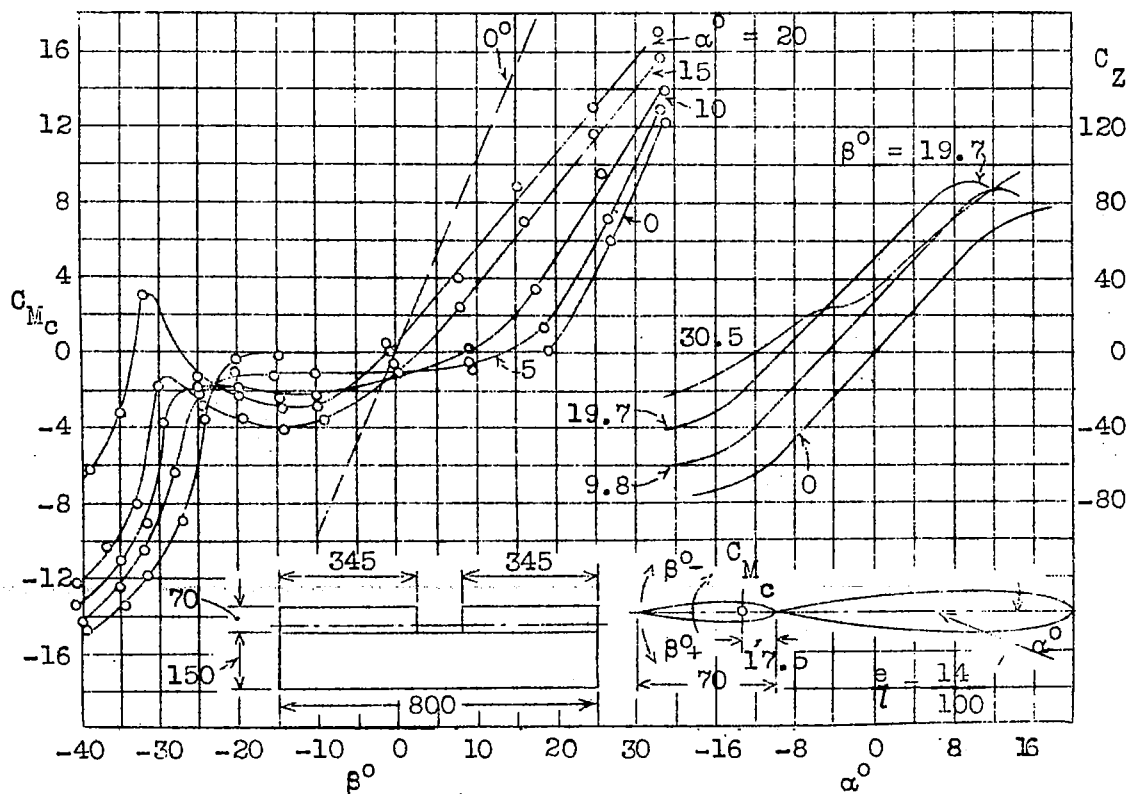


Fig. 20

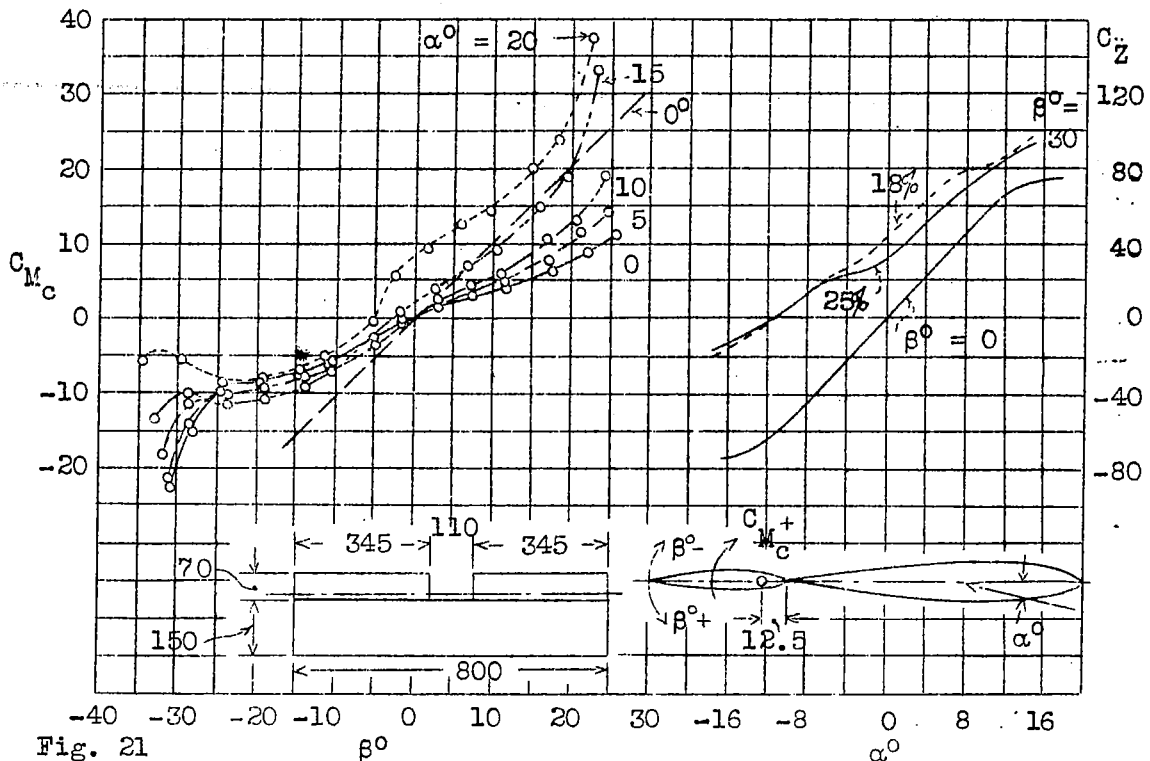


Fig. 21

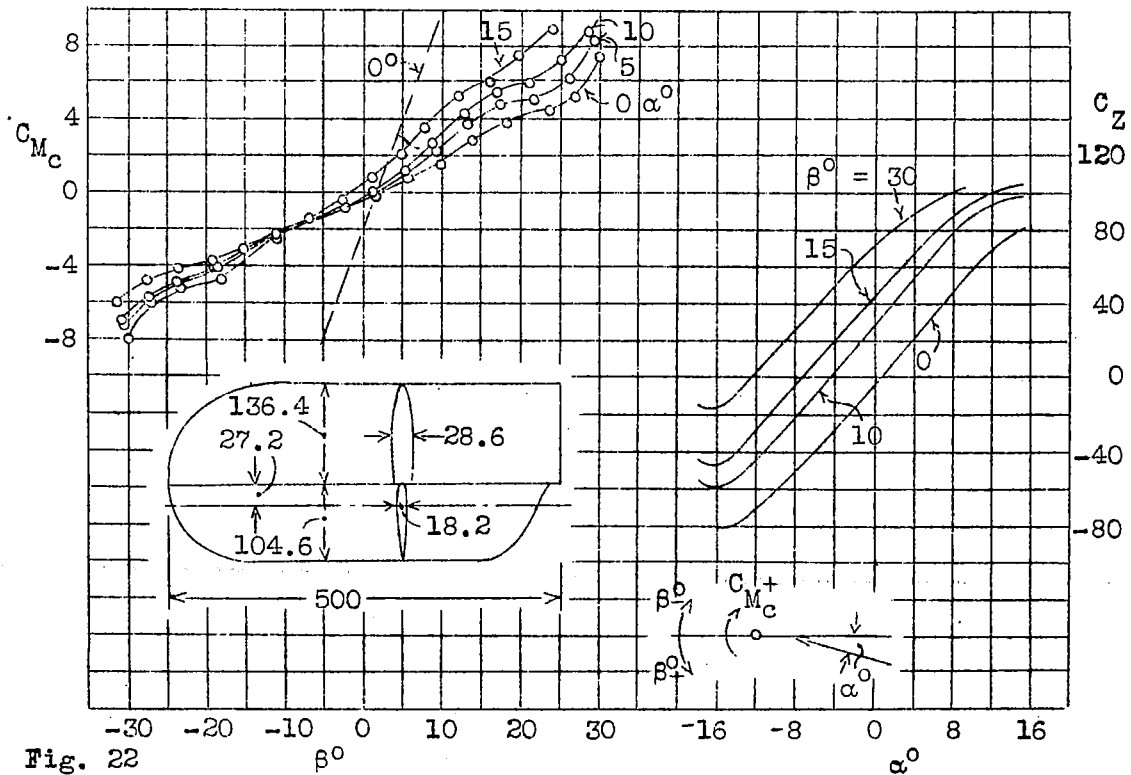


Fig. 22

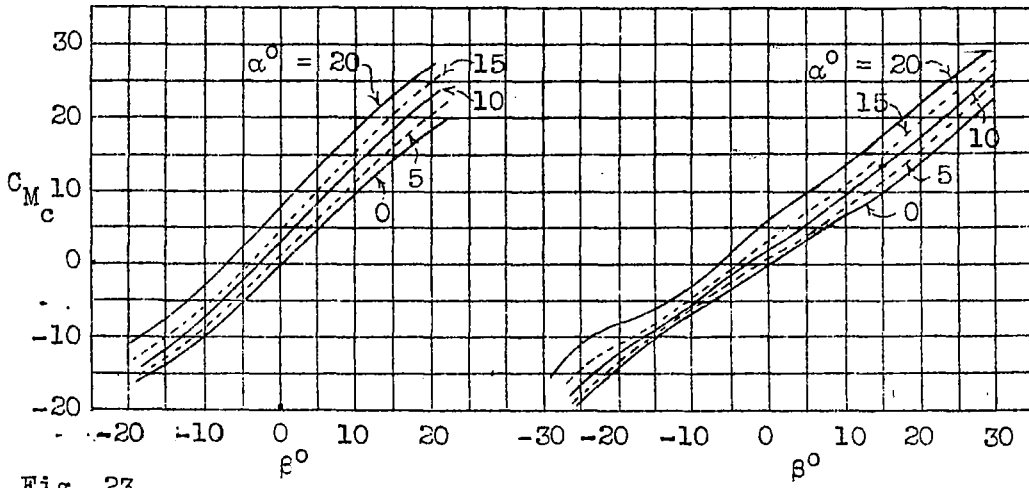
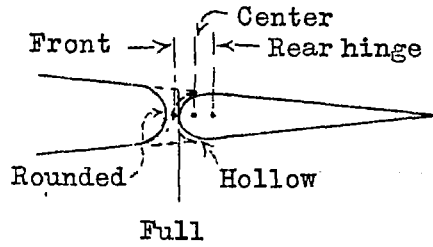


Fig. 23 Front hinge Center hinge
Rounded off

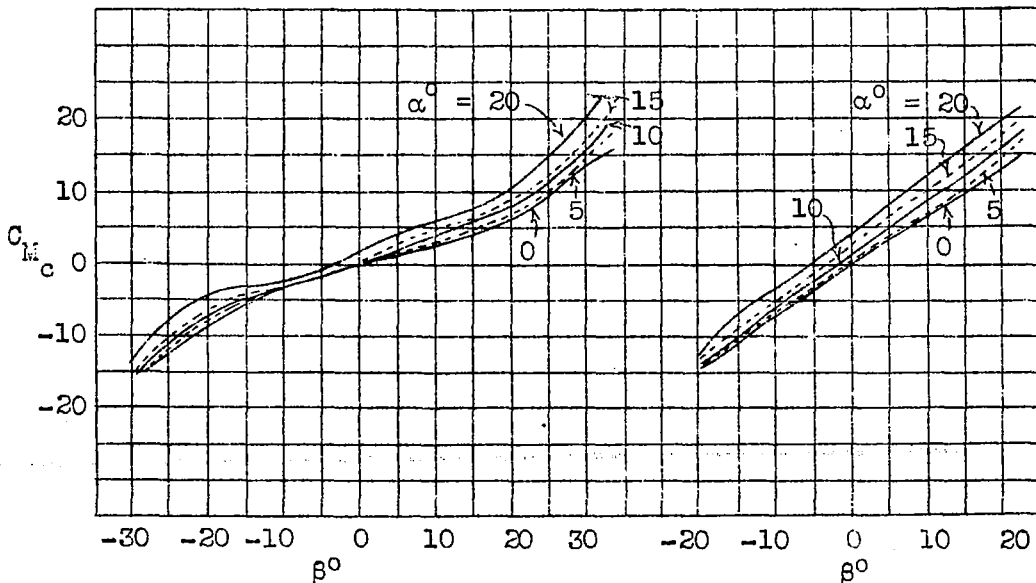


Fig. 24 Rounded off Rear hinge, R Hollow Center hinge, C

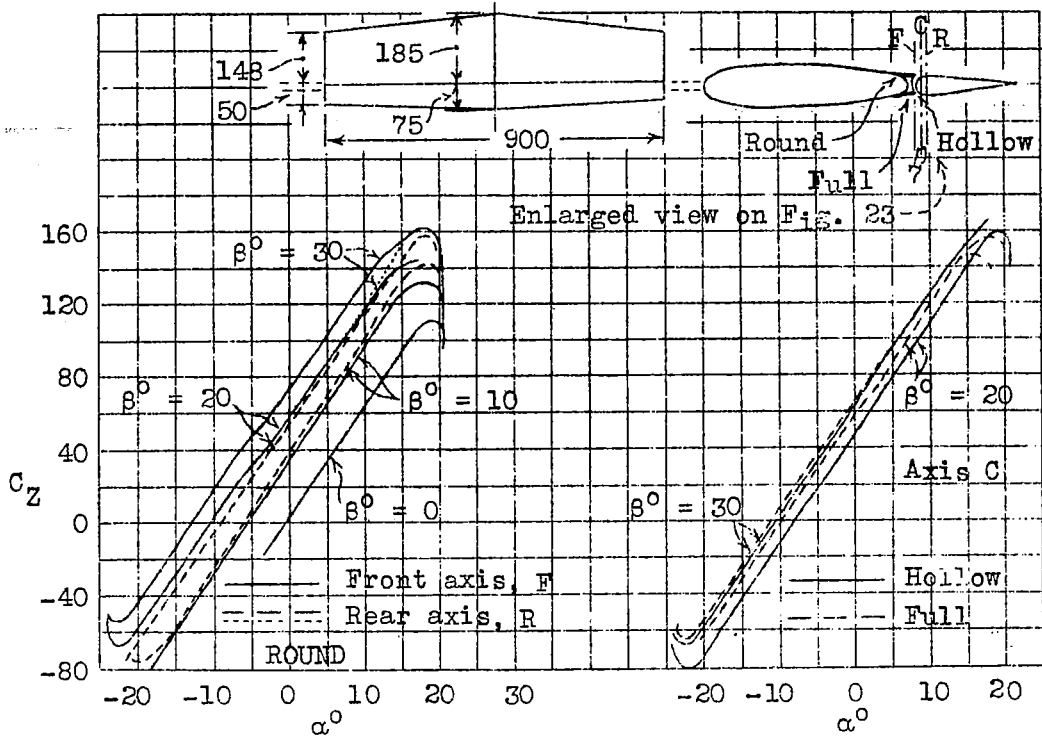


Fig. 25

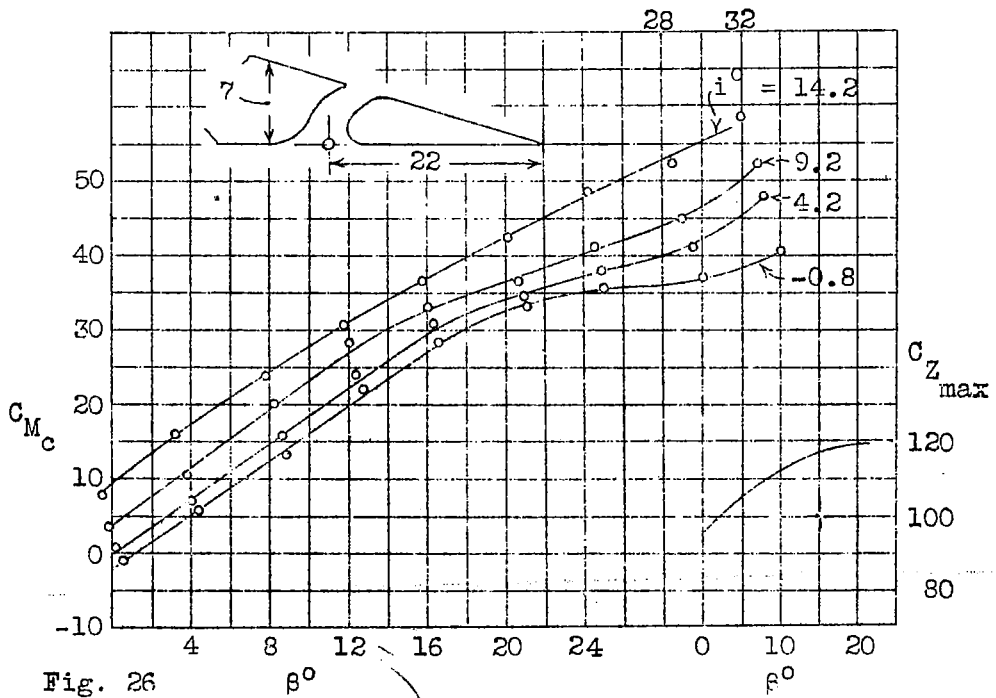


Fig. 26

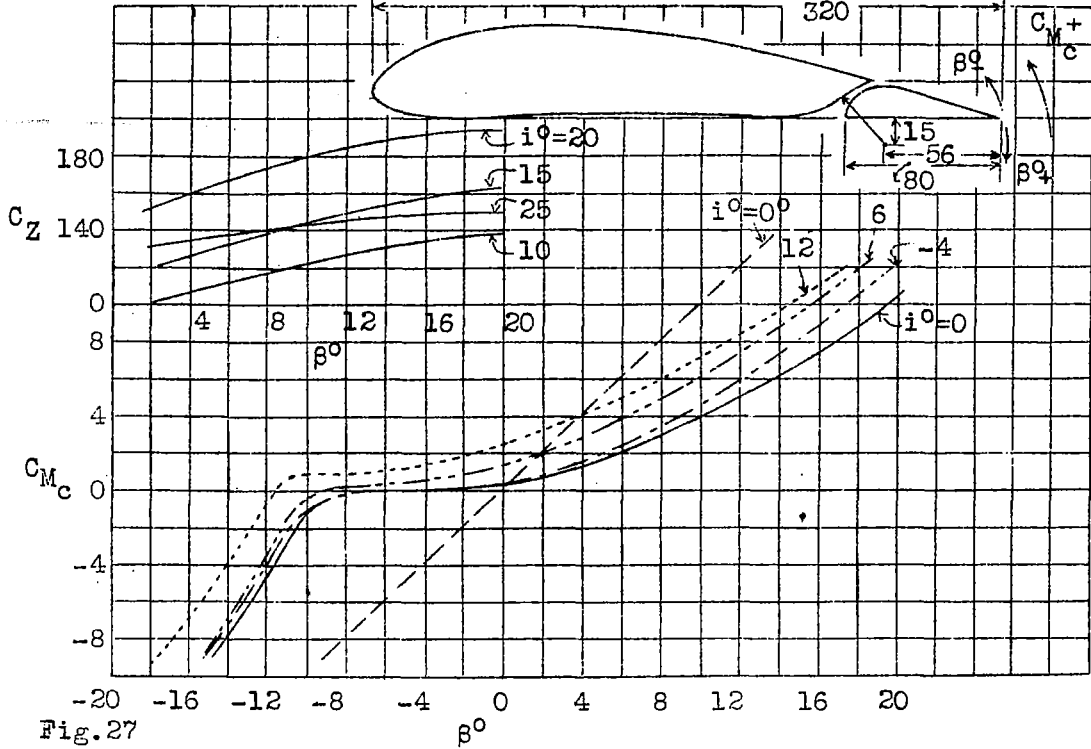


Fig.27

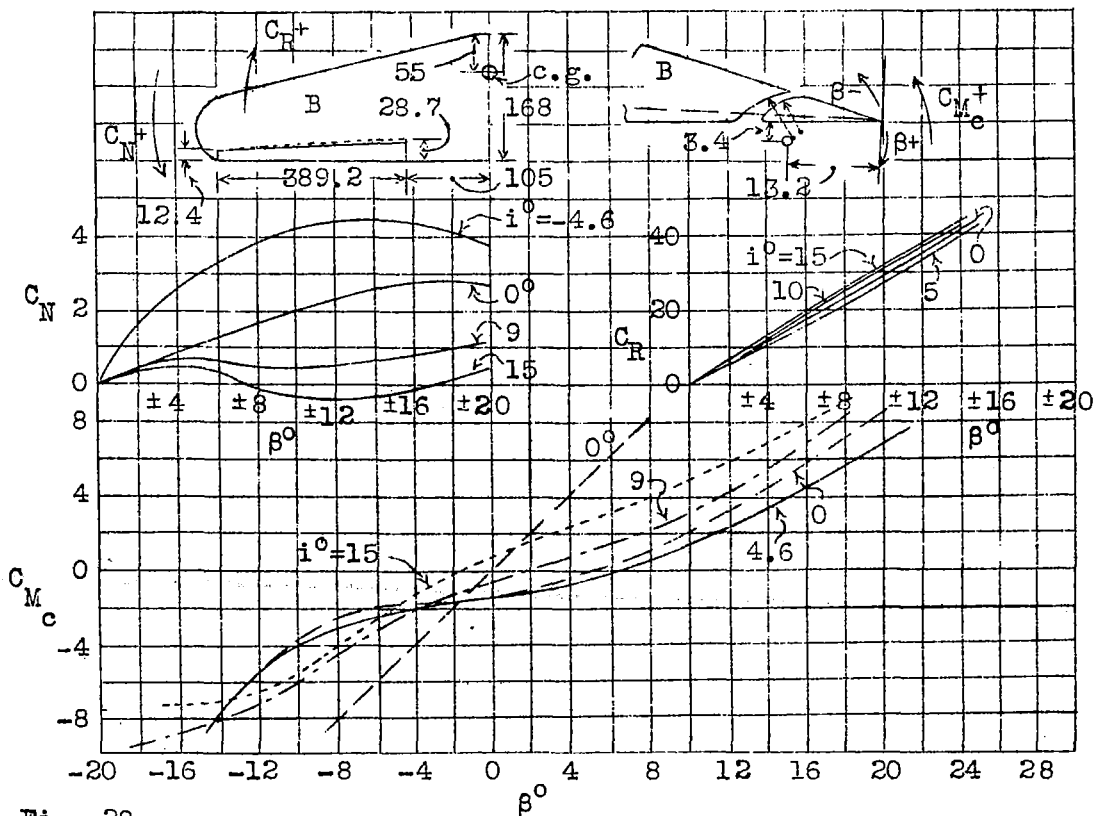


Fig. 28

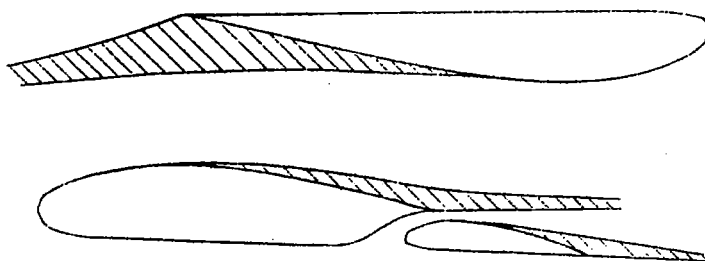


Fig. 29

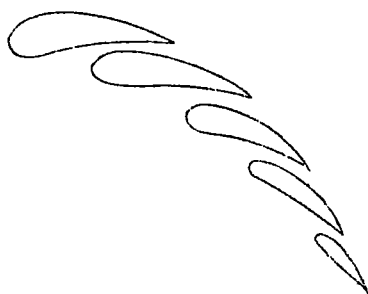


Fig. 30

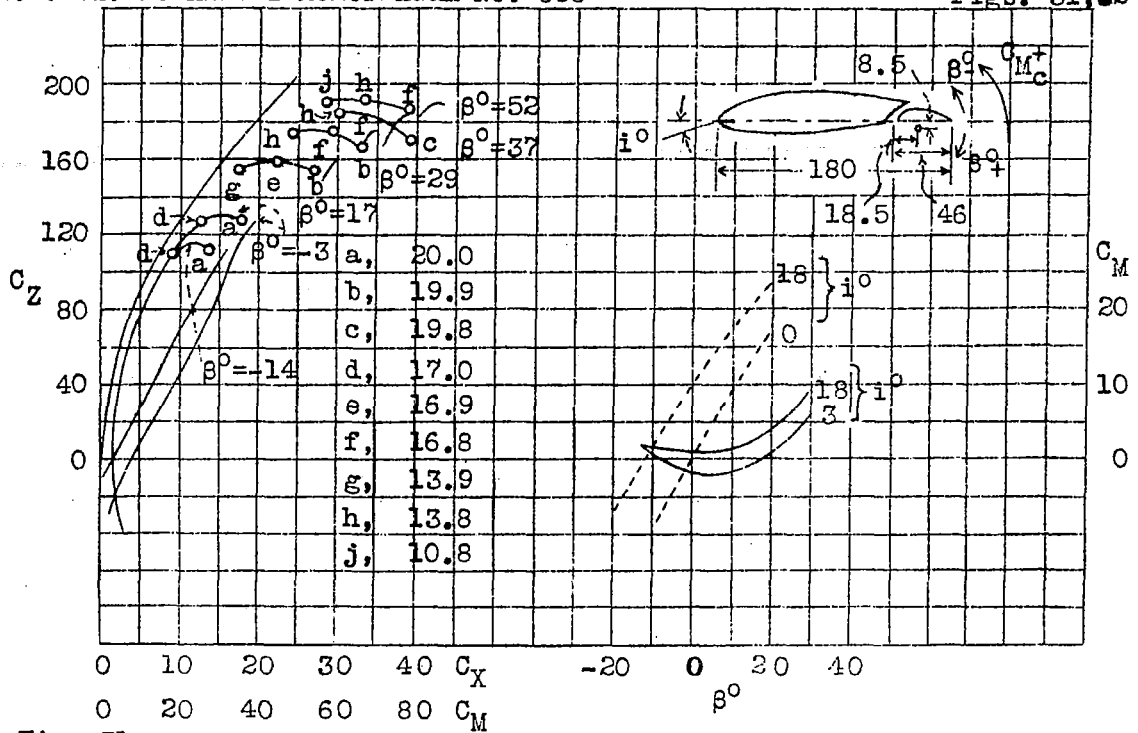


Fig. 31

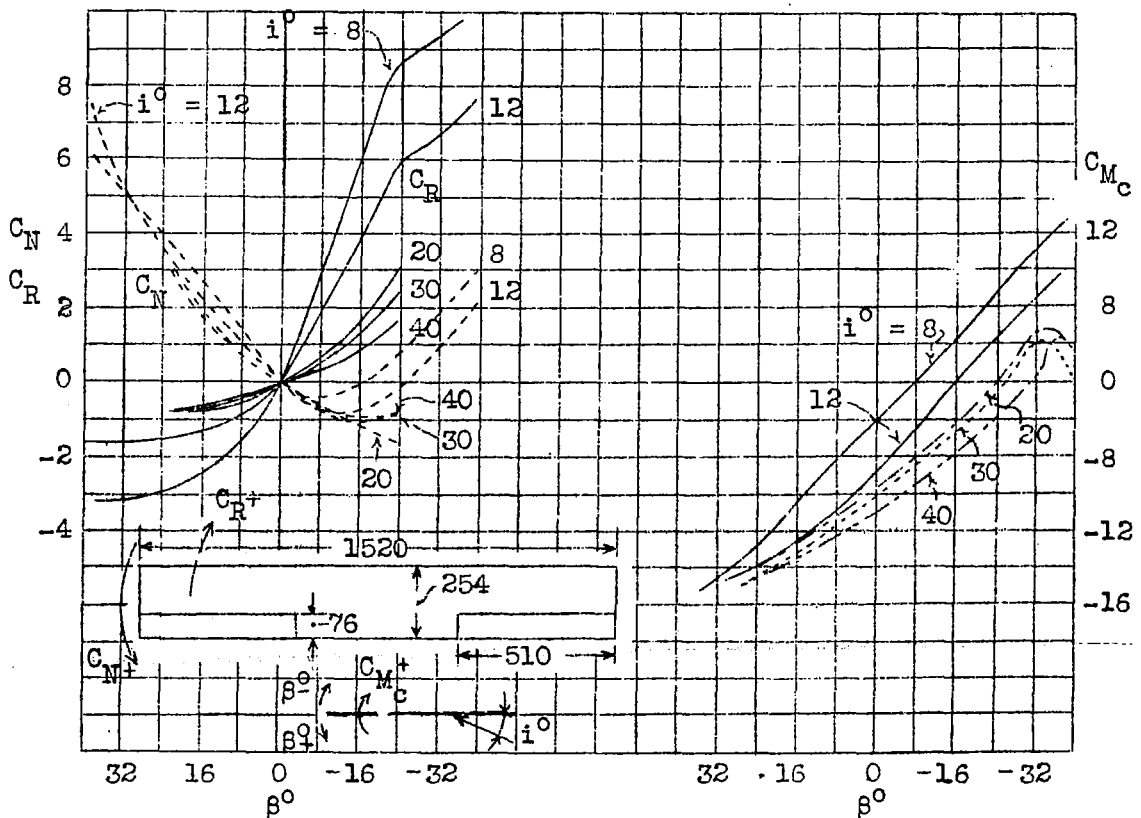


Fig. 32

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