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TECHNICAL NOTE

No. 1079

PRESSURE DISTRIBUTION OVER A PLUG-TYPE SPOILER-SLOT AILERON  
ON A TAPERED WING WITH FULL-SPAN SLOTTED FLAPS

By John G. Lowry and Thomas R. Turner

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Langley Field, Va.



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SUMMARY

A pressure-distribution investigation was made in the Langley 7- by 10-foot tunnel of a plug-type spoiler-slot aileron on a semispan tapered-wing model of a typical fighter airplane equipped with full-span slotted flaps. The results of the investigation indicate peak pressures on a plug-type spoiler-slot aileron that may result in a compressibility shock on the plug aileron at high speed. The maximum loads on the plug aileron occurred in the high-speed condition for maximum up aileron deflection.

INTRODUCTION

A pressure-distribution investigation was made in the Langley 7- by 10-foot tunnel of the plug-type spoiler-slot aileron on a tapered-wing model of a typical fighter airplane with full-span slotted flaps. A plug-type aileron is essentially a tapered plug that fits in through a slot in the wing to conform to the original external wing contour when in a neutral position. When the aileron is deflected, the plug projects through the upper surface of the wing as a spoiler and, at the same time, makes a slot through the wing behind the spoiler.

The purpose of this investigation was to obtain the air loads on the aileron designated as plug aileron 5 in reference 1. Tests were made at various angles of attack for both flap-retracted and flap-deflected conditions. In order to obtain more complete data, pressures were measured on a solid plug-type spoiler-slot aileron, designated as plug aileron 2 in reference 1, at two angles of attack with flap retracted.

In order to make the text and figures herein more concise, the term "plug aileron" is substituted for the previously used term "plug-type spoiler-slot aileron" and the term "plug" is used in the figures where reference is made to the component parts of the plug aileron.

## APPARATUS AND TESTS

A semispan wing model was mounted in the Langley 7- by 10-foot tunnel (reference 2) as shown schematically in figure 1. The wing model represents the cross-hatched part of the airplane shown in figure 2. The root chord of the model was adjacent to one of the vertical walls of the tunnel, the vertical wall thereby serving as a reflection plane. The flow over a semispan model in this setup is essentially the same as the flow would be over a complete model in a 7- by 20-foot tunnel. Provision was made for changing the angle of attack while the tunnel was in operation.

The semispan wing model used in these tests was built to the plan form shown in figure 3. The ordinates of the wing section are given in table I. The airfoil sections of the NACA 230 series tapered in thickness from approximately  $15\frac{1}{2}$  percent chord at the root to  $8\frac{1}{4}$  percent chord at the tip. The basic chord  $c_1$  of the model was arbitrarily increased  $3/10$  inch to reduce the trailing-edge thickness, and the last few stations were refaired to give a smooth contour. The full-span slotted flap, built to conform to the ordinates in table II, was pivoted about the flap pivot point given in table II.

The slot shape for the slotted flap is given in table II. The plug aileron was built of sheet metal to the dimensions given in figure 4 and was modified as shown in figure 5 and reference 1. The plug aileron was fitted with two rows of pressure orifices as given in table III. Row 1 was used for all force computations and row 2 was used only to find the effect of the holes on the local pressure.

All the tests except a few with flaps deflected were made at a dynamic pressure of 16.37 pounds per square foot. This pressure corresponds to a velocity of approximately 80 miles per hour and to a test Reynolds number of about

$2.05 \times 10^6$  based on the mean aerodynamic chord of the model, 33.66 inches. The turbulence factor for the Langley 7- by 10-foot tunnel is about 1.6.

With the model at a given angle of attack and aileron setting, time was allowed for the tunnel air velocity and for the manometer alcohol level to become stable before the pressures were photographically recorded.

## PRESENTATION OF DATA

### Coefficients

The pressure diagrams were mechanically integrated to obtain data from which section normal-force, chord-force, resultant-force, and hinge-moment coefficients were computed. The coefficients represent the values that would be obtained if section data were applied to the plug aileron at the spanwise position at which the pressures were measured. These coefficients apply only to geometrically similar sections. The coefficients, based on unit span, are defined as follows:

- $c_n$  normal-force coefficient ( $n/qc_p$ ), positive up
- $c_c$  chord-force coefficient ( $x/qc_p$ ), positive rearward
- $c_r$  resultant-force coefficient ( $\sqrt{c_n^2 + c_c^2}$ ), positive when directed rearward
- $c_h$  hinge-moment coefficient about aileron hinge axis ( $h/qM'$ )
- $P$  pressure coefficient  $\left(\frac{p - p_0}{q}\right)$

where

- $n$  normal force (normal to plug reference line)
- $x$  chord force (parallel to plug reference line)
- $h$  hinge moment about aileron hinge axis
- $p$  static pressure at a point on airfoil
- $p_0$  static pressure of free air stream

4

NACA TN No. 1079

- q dynamic pressure of free air stream ( $\frac{1}{2}\rho v^2$ )
- $\rho$  density
- V velocity
- $c_p$  chord of plug aileron, distance along plug-aileron reference line from hinge axis to trailing edge of plate 1
- $M'$  area moment of plate 1 about hinge axis of plug aileron
- and
- $\alpha$  angle of attack, corrected in accordance with the theory of trailing vortex images
- $\delta_a$  plug-aileron angle, positive when deflected down (angle between plug reference line and wing chord line)
- $\delta_f$  flap deflection relative to wing, positive when trailing edge is down

The various subscripts 1, 2, 3, 4, and 5 refer to the respective plates of plug aileron (fig. 6), and subscript p refers to the complete plug aileron. No corrections have been applied to the pressure data.

## Results

In order to facilitate correlation of data in the present report with the data given in reference 1, figure 7 (fig. 6 of reference 1) has been reproduced.

The various plates or faces of the plug aileron have been projected to the position shown in figure 6 to prevent overlapping of the pressure diagrams of the component parts of the plug aileron. In figures 8 to 33 the pressures over plates 1, 3, and 5 have been plotted normal to the respective plates and the pressures over plates 2 and 4 have been plotted parallel to the plug-aileron reference line. (See figs. 6 and 8.) The plug-aileron reference line is a line that passes through the hinge axis, is parallel to the wing chord line when the plug aileron is neutral, and revolves with the plug aileron. The pressures

from the orifices of row 1 only (see table III) have been plotted in figures 8 to 33.

The resultant forces for plates 1, 3, and 5 were assumed to be normal to the plates. No hinge moments were given for plates 2 and 4 since they are concentric about the hinge axis and, therefore, the resultant force passes through the hinge axis and gives no hinge moment.

Figures 34 to 38 give the section characteristics of the two modifications of the plug aileron.

## DISCUSSION

### Pressure Distribution

The pressure-distribution curves (figs. 8 to 33) show the distributions of pressure over plug aileron 5 and should be useful in plug-aileron design. These plots are for two angles of attack only. No curves are given for the pressure distribution over plug aileron 2 because they were very similar to those for plug aileron 5, except for slight changes in pressure gradient over plate 1 at small negative deflections and plate 3 for positive deflections. No curves are presented for the pressures of row 2 since the curves showed only slight variation from the pressures of row 1.

The peak pressure over the nose of plate 1 reached a maximum value of  $P$  equal to approximately -1 for the high-speed condition with the flap retracted (fig. 12) at a plug-aileron deflection of  $-10^\circ$ . This pressure corresponds to a critical speed of 460 miles per hour and may result in compressibility shock on the plug aileron. With the flap deflected  $40^\circ$  (fig. 28), the values of  $P$  increased to about -2.2 at a plug-aileron deflection of  $-2.5^\circ$  but this increase is not considered detrimental since the airplane speed is greatly reduced with flaps deflected. The exposed area of the plug aileron in the negative deflection range had a pressure difference across the plug aileron of about  $q$  acting upon it at low angles of attack. In most cases, the pressure difference decreased as the angle of attack increased. The decrease in pressure with angle of attack would be expected from consideration of the increase in boundary-layer thickness as the angle

of attack is increased. There were only small changes in the pressure difference over plates 3, 4, and 5 for negative plug-aileron deflections with flaps retracted. In the positive deflection range, the pressure difference over plates 3, 4, and 5 increased as the deflection was increased. The main effect of deflecting the full-span slotted flap was generally to increase the pressure difference on the various plates and cause a larger flow through the slot.

### Load Characteristics

The hinge-moment coefficients of plate 1 were much larger than those of plates 3 and 5 in the negative aileron-deflection range. (See figs. 34 and 35.) The hinge-moment and resultant-force coefficients increased on plates 1, 3, and 5 when the flaps were deflected  $40^\circ$ . The fact that plate 1 gave most of the hinge-moment coefficient explains why tilting of plate 1 was so effective in controlling the hinge-moment coefficients of the plug aileron as reported in reference 1. Most of the chord-force coefficient of the plug aileron for negative aileron angles was contributed by plate 2 for flap retracted. The maximum loads occurred at low angles of attack (high speed) and  $-50^\circ$  deflection. With the flap deflected  $40^\circ$ , plates 2 and 4 carried about the same loads except at high negative deflections where plate 2 carried the greater part of the load.

The chord- and normal-force coefficients for the complete plug aileron may be obtained by adding the appropriate values from figures 34 and 35. The data are presented for the component parts of the aileron since an aileron of this type would normally be built up and the loads on the individual parts were thought to be important.

The hinge-moment coefficients for the complete plug aileron plotted against the aileron deflections for the full-span slotted flap retracted and deflected  $40^\circ$  are given in figures 36 and 37. A comparison of these curves with the hinge-moment-coefficient curves for plate 1 of figures 34 and 35 shows that plate 1 not only gives most of the hinge-moment coefficient but also determines the irregularities in the curves. The curves of figures 36 and 37 agree qualitatively with the hinge-moment-coefficient curves for plug aileron 5 as reported in reference 1.

The characteristics for plug aileron 2 (solid plug) for two angles of attack with flap retracted are shown in figure 38. For most plug-aileron deflections the hinge-moment coefficients for the solid plug aileron are slightly lower than for plug aileron 5 for the same condition.

#### CONCLUSIONS

The peak pressures on the plug-type spoiler-slot aileron (plug aileron) may result in a compressibility shock in high-speed flight. The maximum loads on the plug aileron occurred in the high-speed condition for an up aileron deflection of  $50^{\circ}$ . The critical design condition is therefore for high speed with the maximum up aileron deflection.

Langley Memorial Aeronautical Laboratory  
National Advisory Committee for Aeronautics  
Langley Field, Va., Sept. 6, 1945

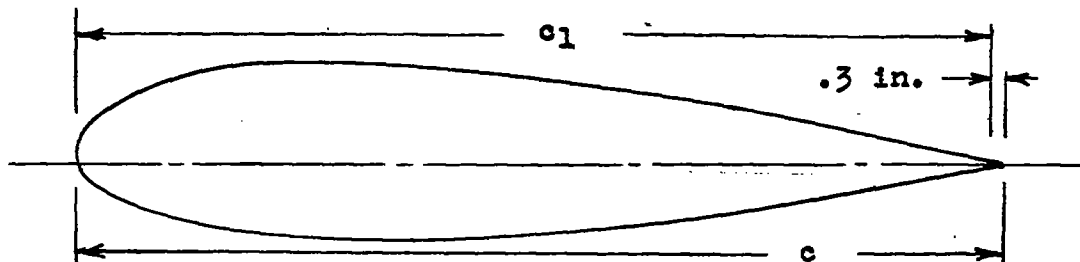
#### REFERENCES

1. Lowry, John G., and Liddell, Robert B.: Wind-Tunnel Investigation of a Tapered Wing with a Plug-Type Spoiler-Slot Aileron and Full-Span Slotted Flaps. NACA ARR, July 1942.
2. Wenzinger, Carl J., and Harris, Thomas A.: Wind-Tunnel Investigation of an N.A.C.A. 23012 Airfoil with Various Arrangements of Slotted Flaps. NACA Rep. No. 664, 1939.



**TABLE I**  
**ORDINATES FOR AIRFOIL**

[Spanwise stations in inches from root section. Chord stations and ordinates in percent of arbitrary wing chord  $c_1$ ]



Model wing station 0		
Station	Upper surface	Lower surface
0	0	0
1.25	3.48	-1.60
2.5	4.61	-2.36
5	6.10	-3.21
7.5	7.14	-3.82
10	7.89	-4.33
15	8.80	-5.12
20	9.22	-5.71
25	9.40	-6.10
30	9.37	-6.28
40	8.90	-6.23
50	8.02	-5.78
60	6.85	-5.05
70	5.44	-4.10
80	3.87	-2.97
90	2.12	-1.67
95	1.16	-.94
100	.18	-.16
100.73	.03	-.03

L.E. radius: 2.65. Slope of radius through end of chord: 0.305

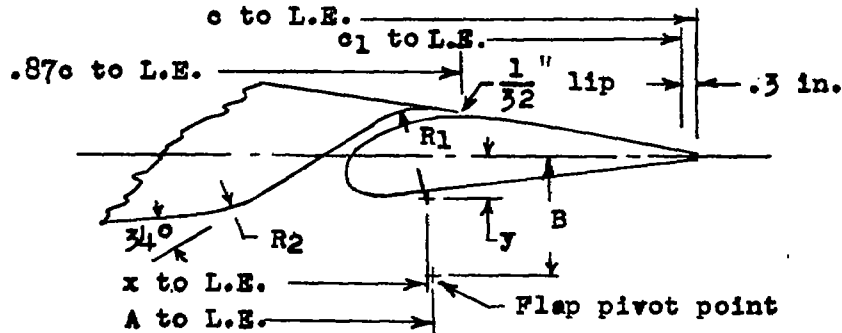
Model wing station 88.8		
Station	Upper surface	Lower surface
0	0	0
1.25	1.89	-.84
2.5	2.65	-1.07
5	3.70	-1.26
7.5	4.45	-1.40
10	4.98	-1.52
15	5.54	-1.86
20	5.73	-2.22
25	5.77	-2.46
30	5.71	-2.62
40	5.36	-2.70
50	4.78	-2.56
60	4.06	-2.27
70	3.21	-1.87
80	2.26	-1.36
90	1.22	-.78
95	.70	-.46
100	.18	-.14
101.2	.05	-.05

L.E. radius: 0.70. Slope of radius through end of chord: 0.305

TABLE II

ORDINATES FOR SLOTTED FLAP AND SLOT SHAPES

[Spanwise stations in inches from root section. Chord stations and ordinates in percent of arbitrary wing chord  $c_1$ ]



Flap stations

Model wing station 0		
Station	Upper surface	Lower surface
0	-1.29	-1.29
.52	-.08	-2.30
1.04	.48	-2.50
2.07	1.29	-2.60
4.15	2.17	-2.44
6.22	2.53	-2.18
8.29	2.40	-1.91
12.44	1.65	-1.32
16.58	.85	-.69
20.72	.03	-.03

L.E. radius: 1.19

Model wing station 88.8		
Station	Upper surface	Lower surface
0	-0.76	-0.76
.53	.01	-1.16
1.06	.36	-1.23
2.12	.80	-1.22
4.24	1.30	-1.10
6.36	1.42	-.99
8.48	1.35	-.87
12.72	.93	-.62
16.96	.51	-.32
21.20	.05	-.05

L.E. radius: 0.32

Slot Shape

	Station 0	Station 88.8
$R_1$	5.3	5.1
$R_2$	2.5	2
x	85	83.3
y	2.5	3.3

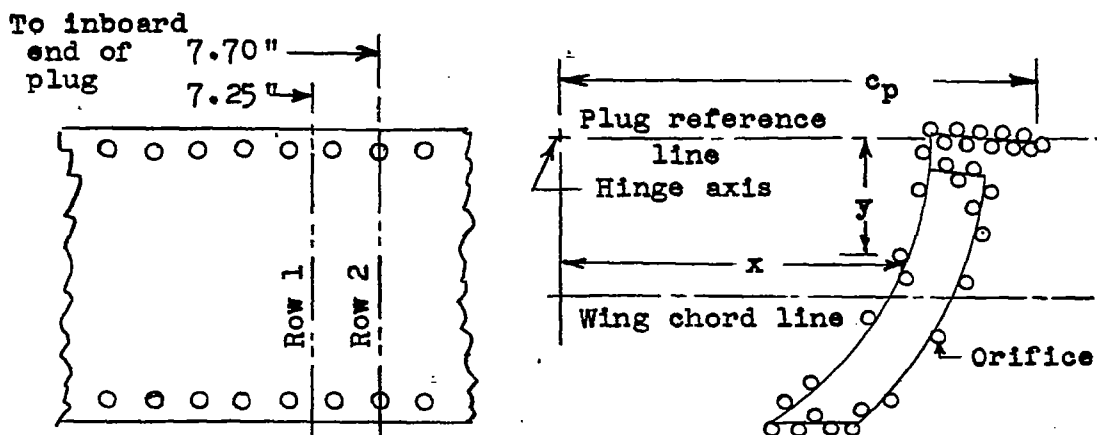
Flap pivot

	Station 0	Station 88.8
A	85.8	84
B	7.7	8

TABLE III

ORIFICE LOCATION ON PLUG AILERON

[Location of orifice from hinge axis in percent  
 aileron chord  $c_p$ ]



Row 1			Row 2			Row 2		
Orifice	x	y	Orifice	x	y	Orifice	x	y
1	79.52	1.18	a18	72.59	-31.83	34	80.60	0.99
2	83.66	.64	19	45.34	-66.39	35	84.71	.64
3	87.79	.32	20	49.76	-66.10	36	88.84	.06
4	91.92	-.22	21	55.29	-65.60	37	92.97	-.32
5	97.14	-.76	22	60.57	-65.18	38	94.91	-1.59
6	100.00	-1.59	a23	52.31	-65.82	39	90.72	-1.18
7	98.09	-1.91	24	67.73	-59.46	40	86.65	-.64
8	93.93	-1.59	25	78.22	-44.55	41	82.48	-.06
9	89.76	-.99	26	83.69	-32.88	42	78.22	-12.11
10	85.53	-.64	27	87.28	-21.18	43	54.05	-58.51
11	81.40	-.06	28	88.87	-13.20	44	45.34	-66.39
12	79.01	-3.24	a29	88.17	-17.21	45	49.76	-66.10
13	78.22	-12.11	a30	64.32	-63.56	46	87.28	-21.18
14	74.09	-27.98	31	86.39	-8.11	47	81.40	-7.63
15	66.45	-43.56	32	81.40	-7.63	-----	-----	-----
16	54.05	-58.51	a33	83.85	-7.86	-----	-----	-----
17	48.33	-63.40	-----	-----	-----	-----	-----	-----

<sup>a</sup>Inside plug.

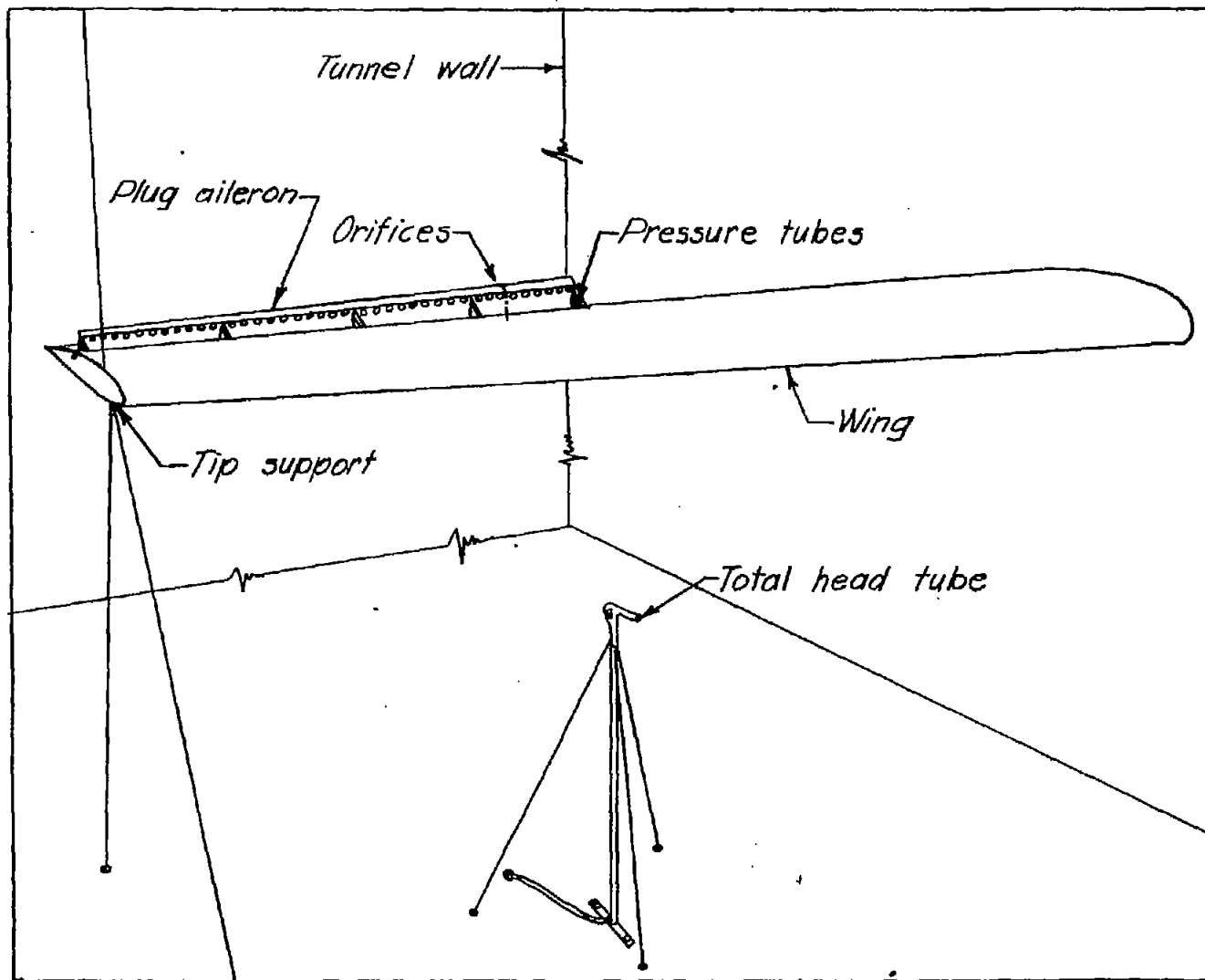
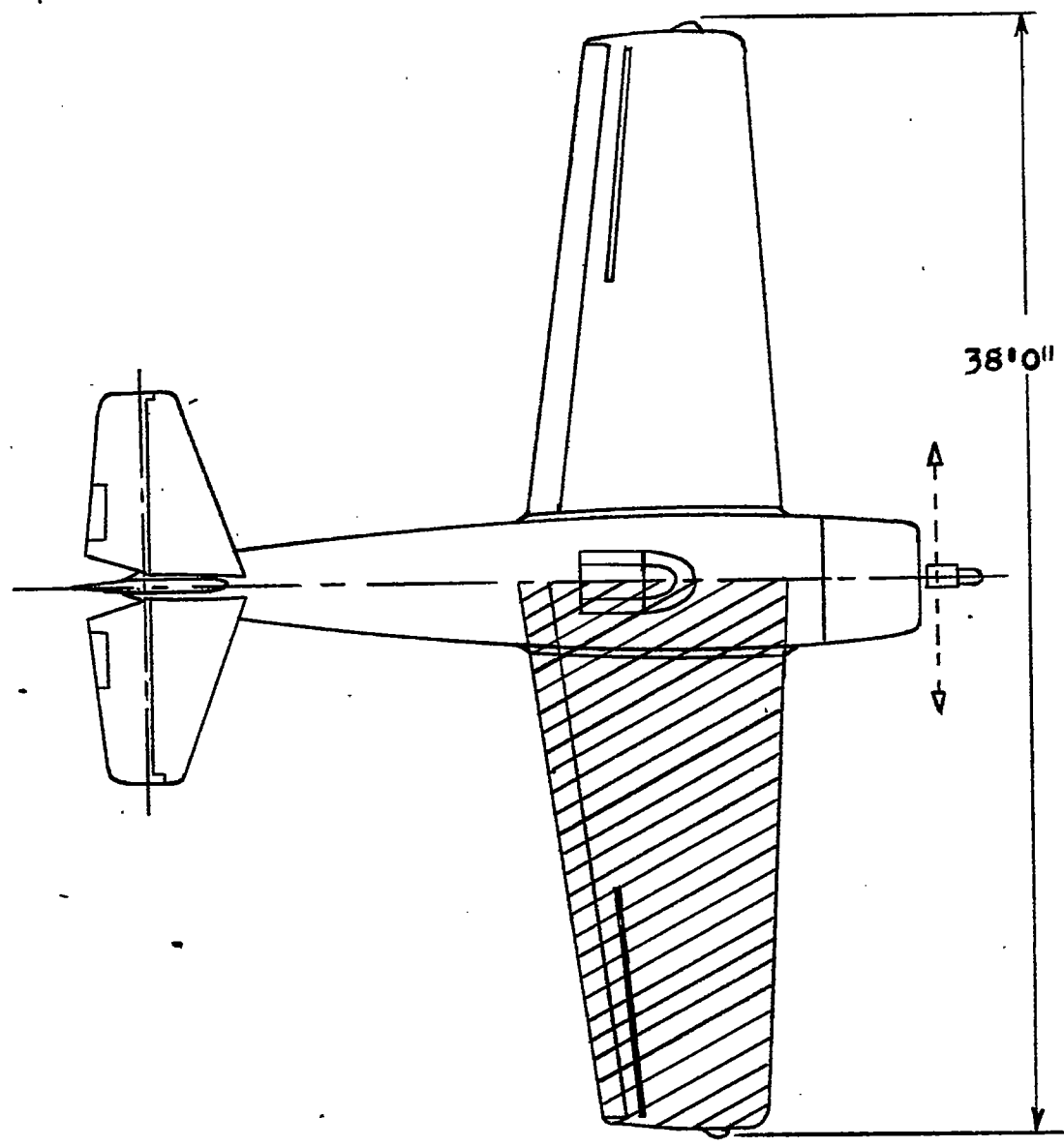


Fig. 1

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Figure 1.- Schematic diagram of test installation.

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Figure 2.- Part of airplane simulated.

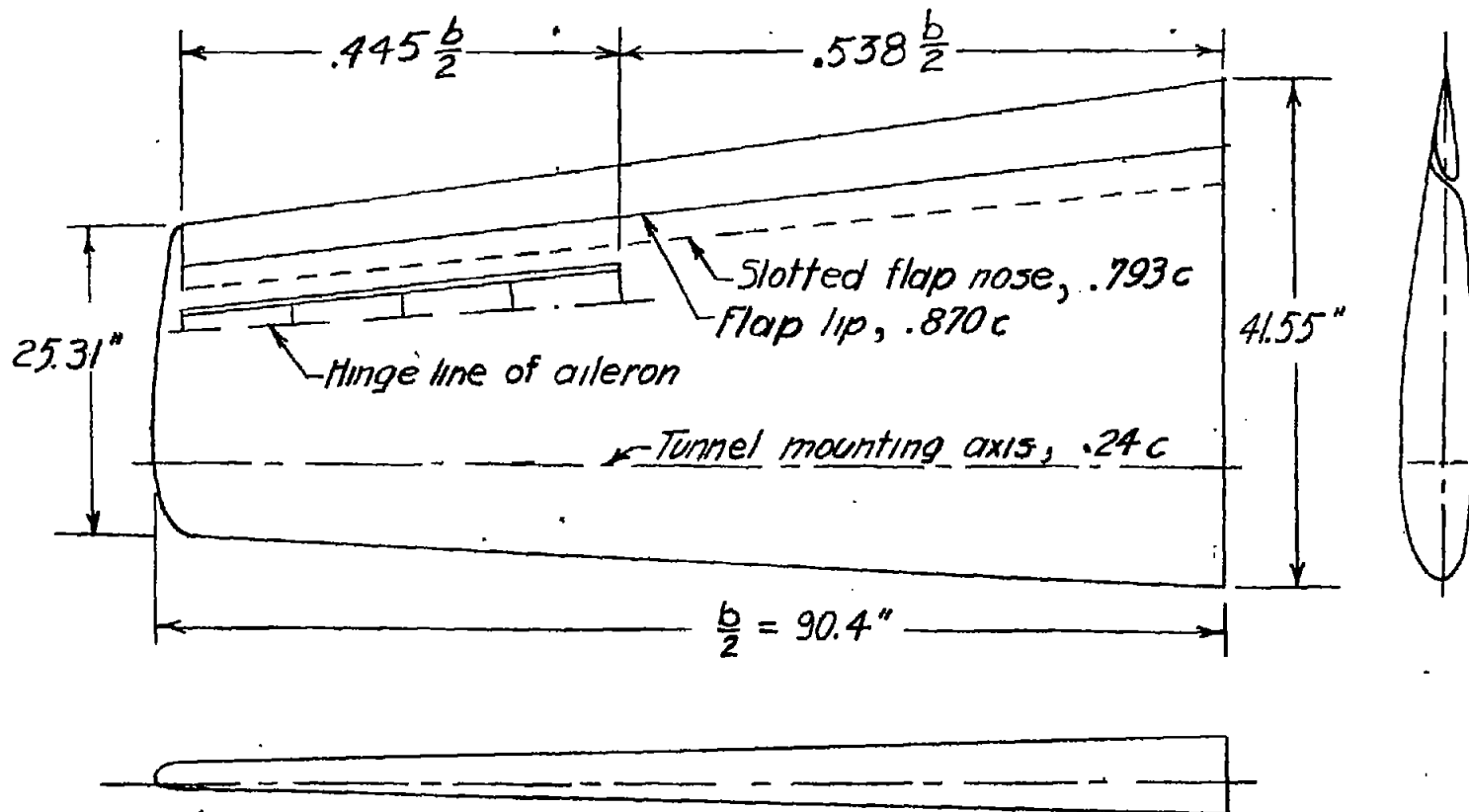
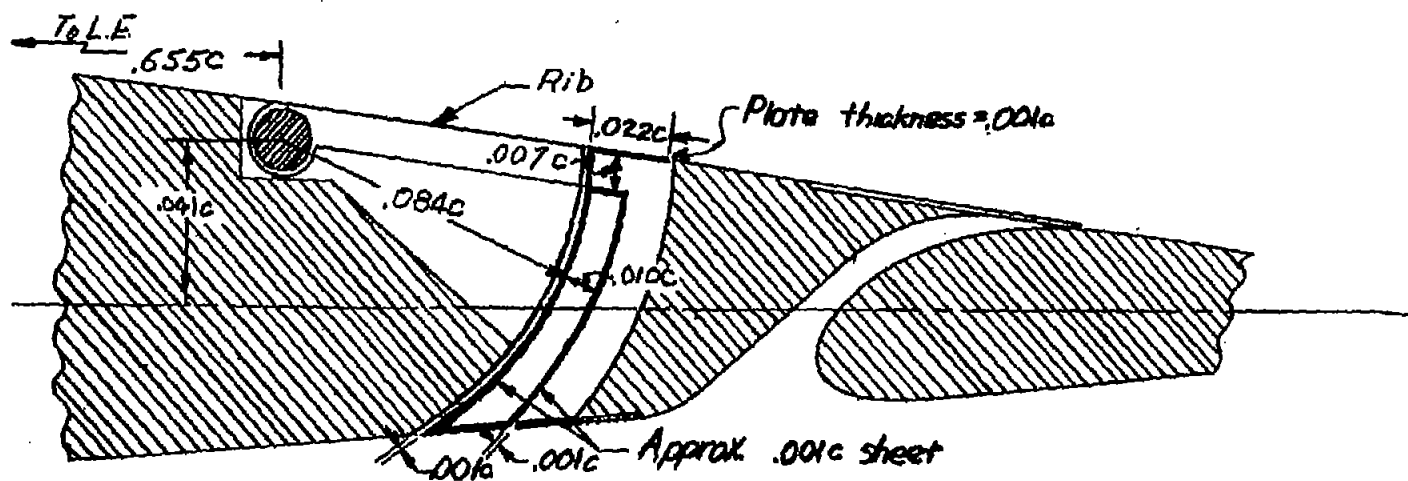
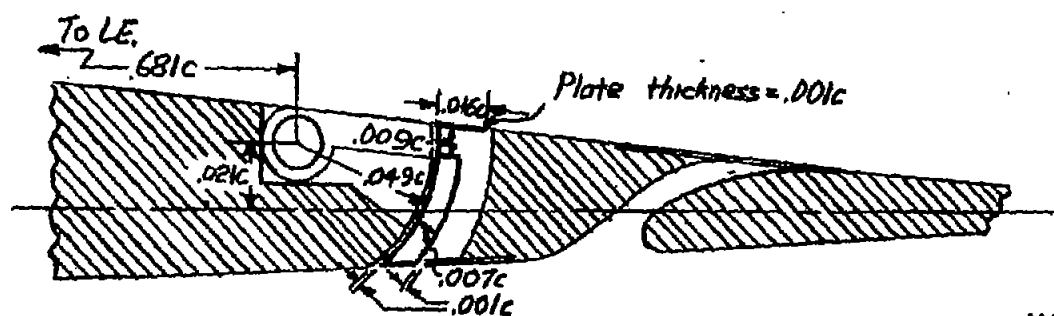


FIGURE 3.- Semispan model of tapered wing.

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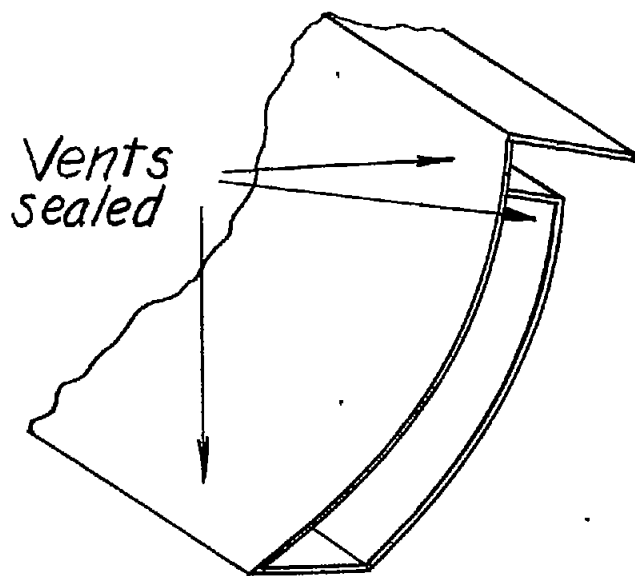
Inboard section



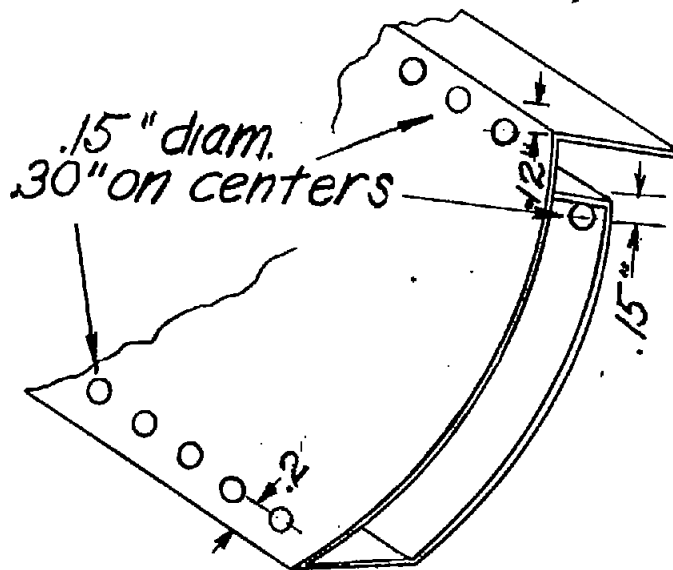
Outboard section

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Figure 4.- Details of the plug aileron on the tapered-wing model.



*Plug aileron 2*

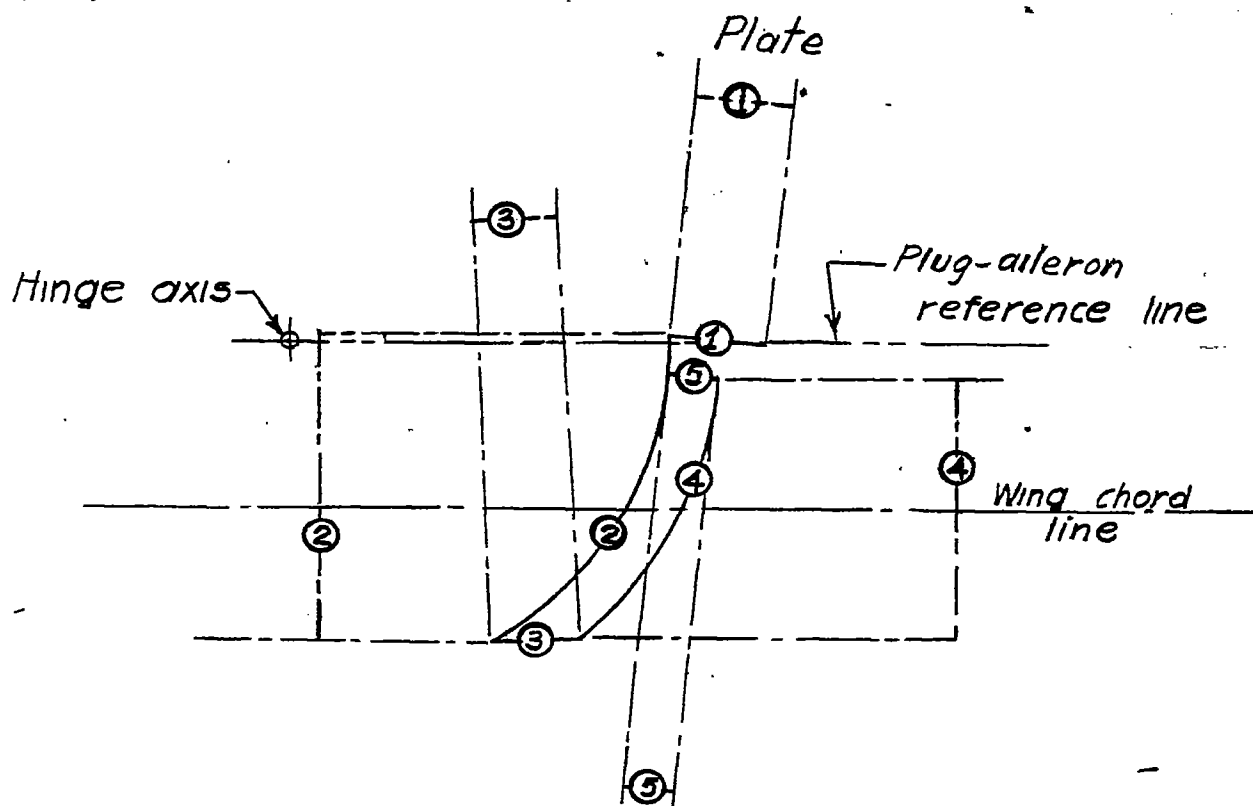


*Plug aileron 5*

*Figure 5.- Details of the modifications on the plug aileron.*

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Figure 6.- Plate designation and pressure axes layout of plug aileron.

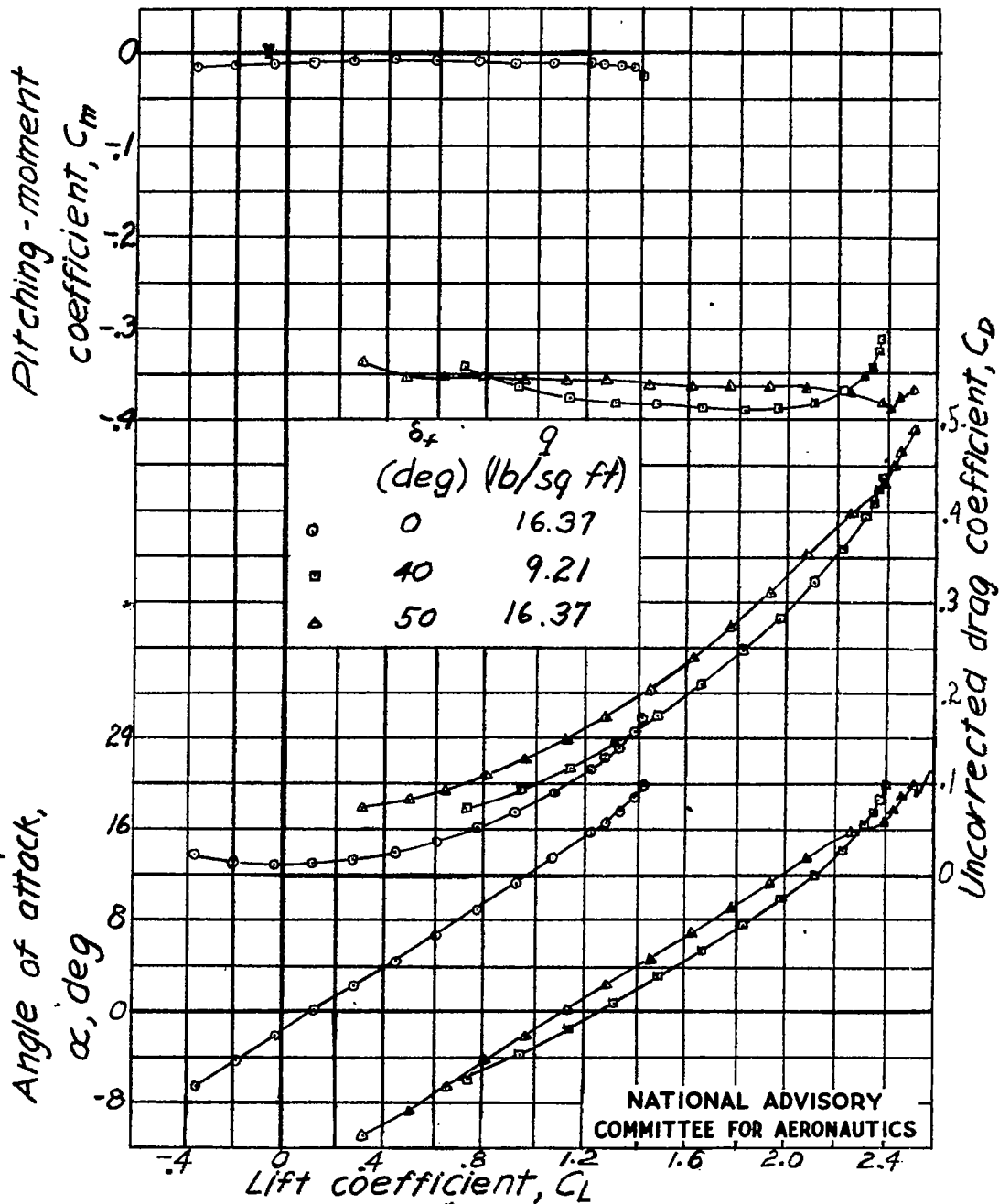


Figure 7.- Lift, drag, and pitching-moment coefficients of the tapered-wing model with full-span flap and plug aileron.  $\delta_a = 0^\circ$ .

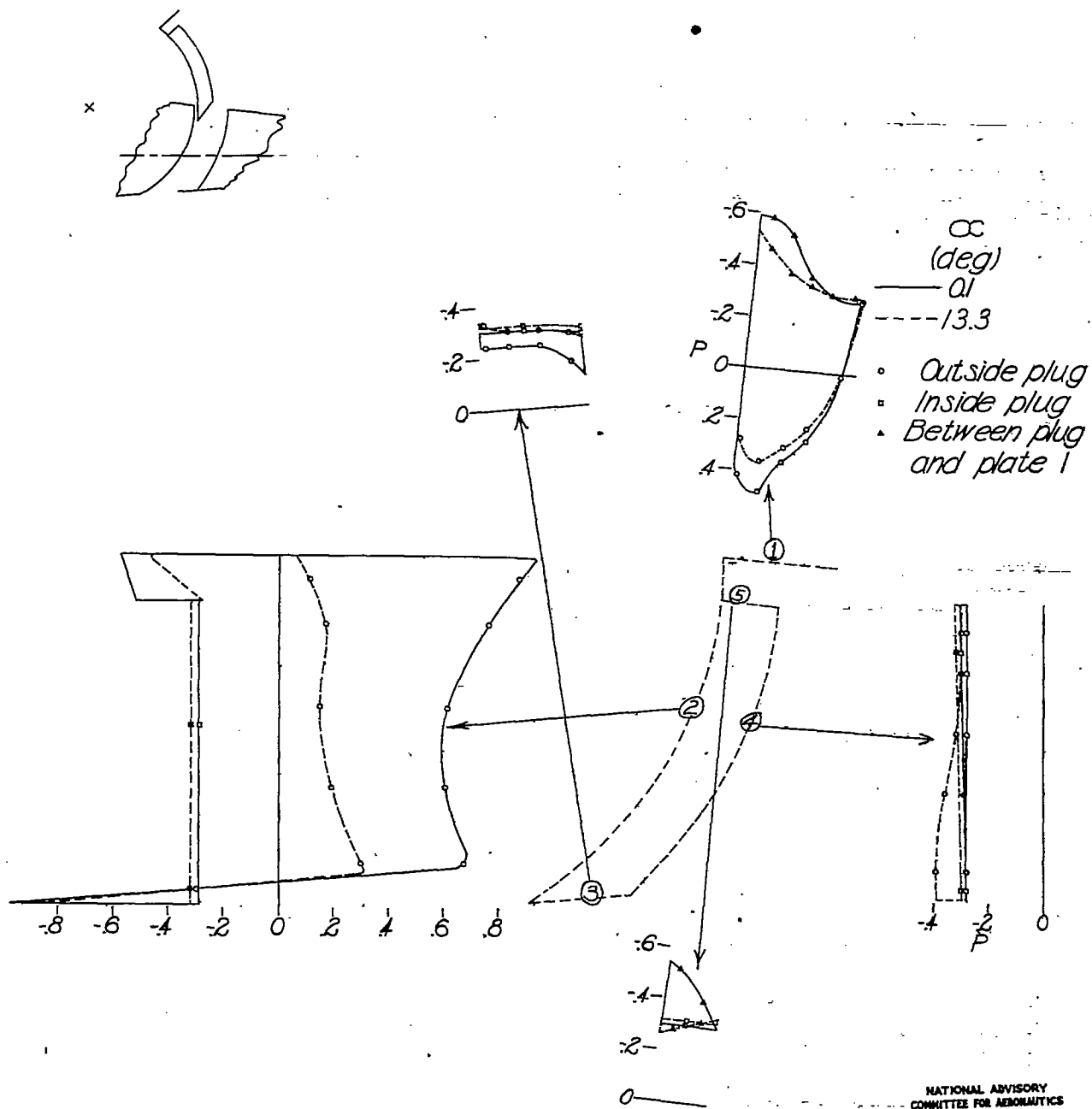
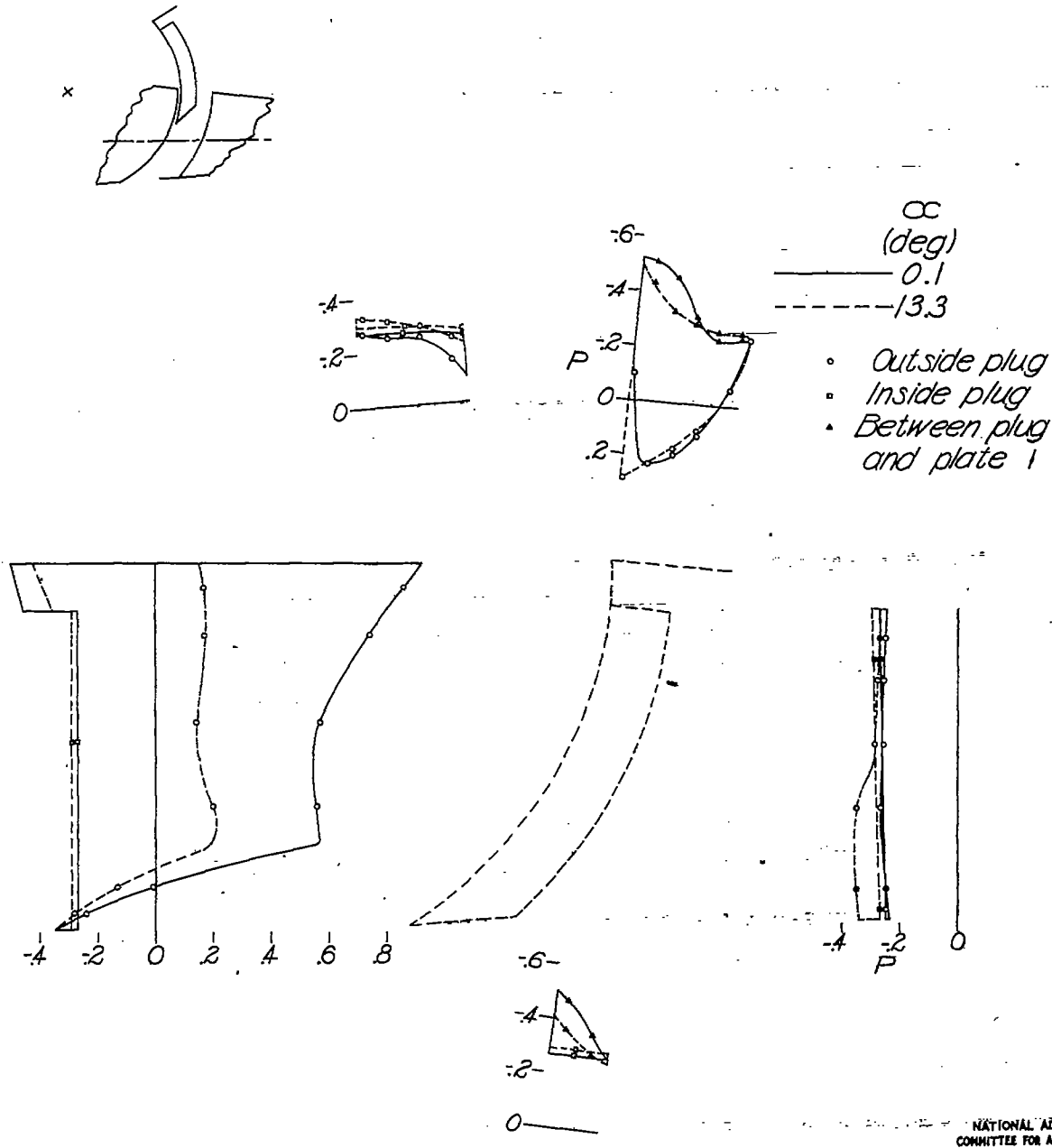


Figure 8.- Pressure distribution on plug aileron 5 on the tapered-wing model with full-span slotted flaps.  $\delta_f = 0^\circ$ ;  $\delta_a = -50^\circ$ .

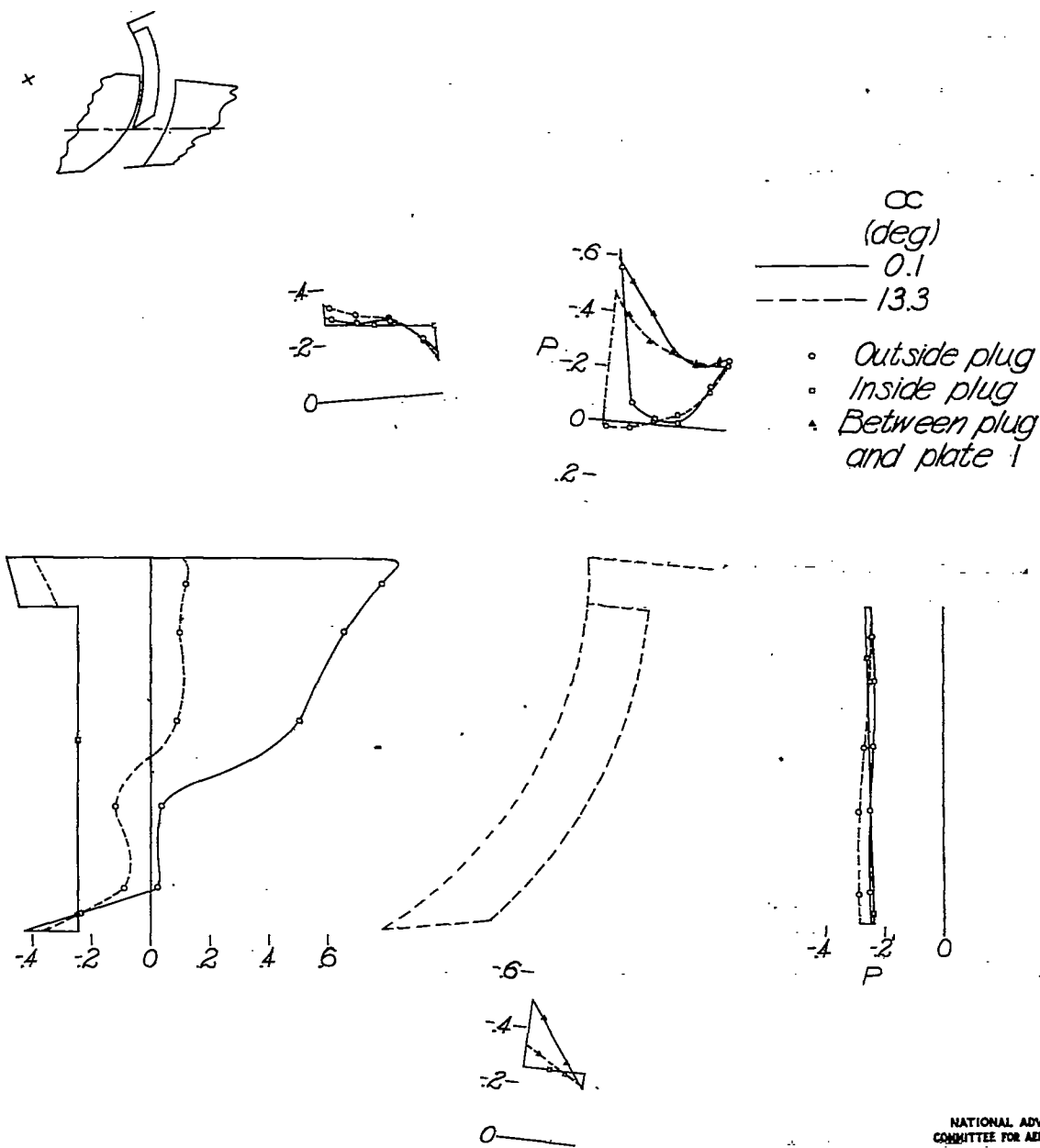
Fig. 9

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Figure 9.-Pressure distribution on plug aileron 5 on the tapered-wing model with full-span slotted flaps.  $\delta_f = 0^\circ$ ;  $\delta_a = -40^\circ$ .

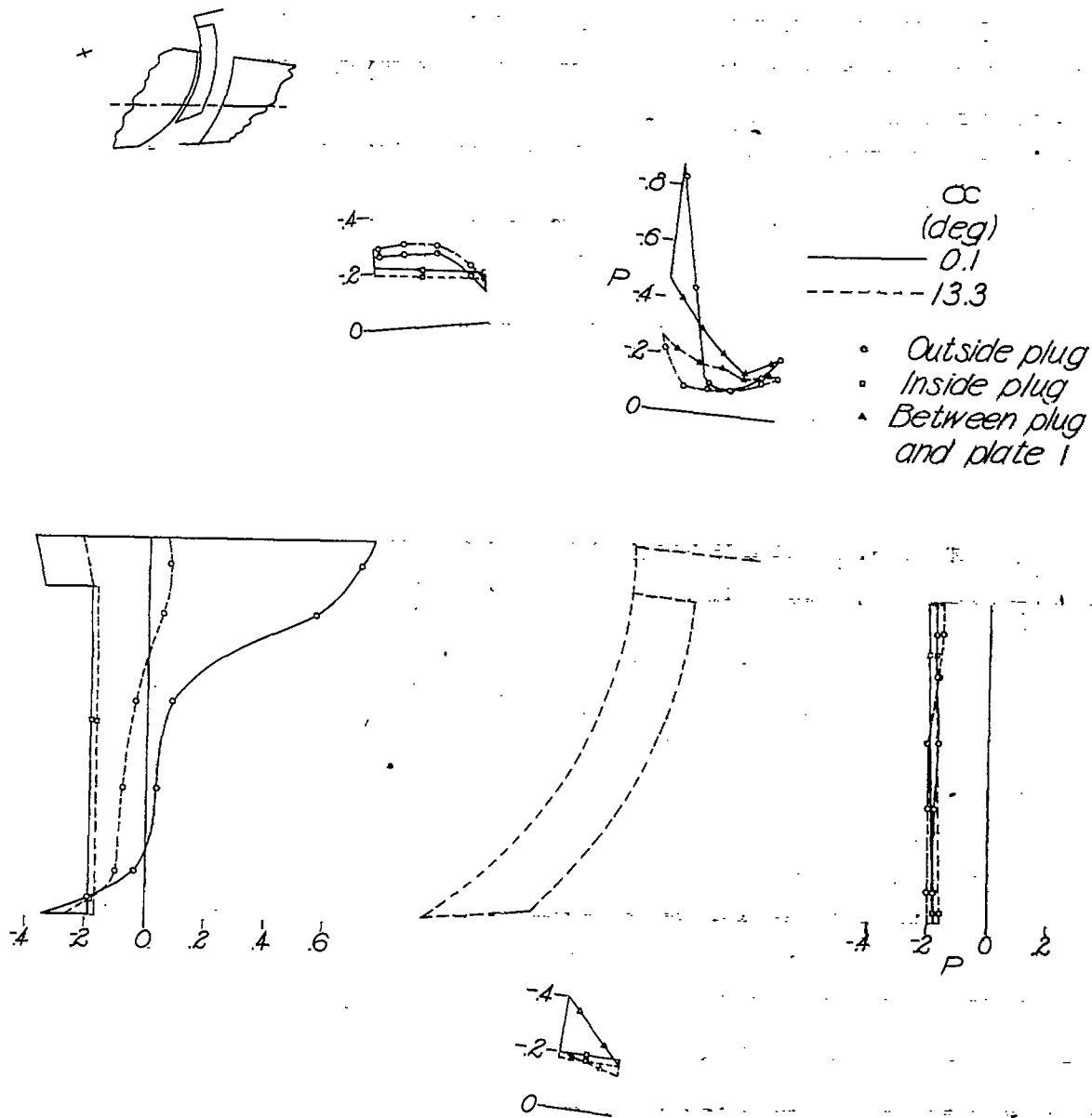


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Figure 10.-Pressure distribution on plug aileron 5 on the tapered-wing model with full-span slotted flaps.  $\delta_f = 0^\circ$ ;  $\delta_a = -30^\circ$ .

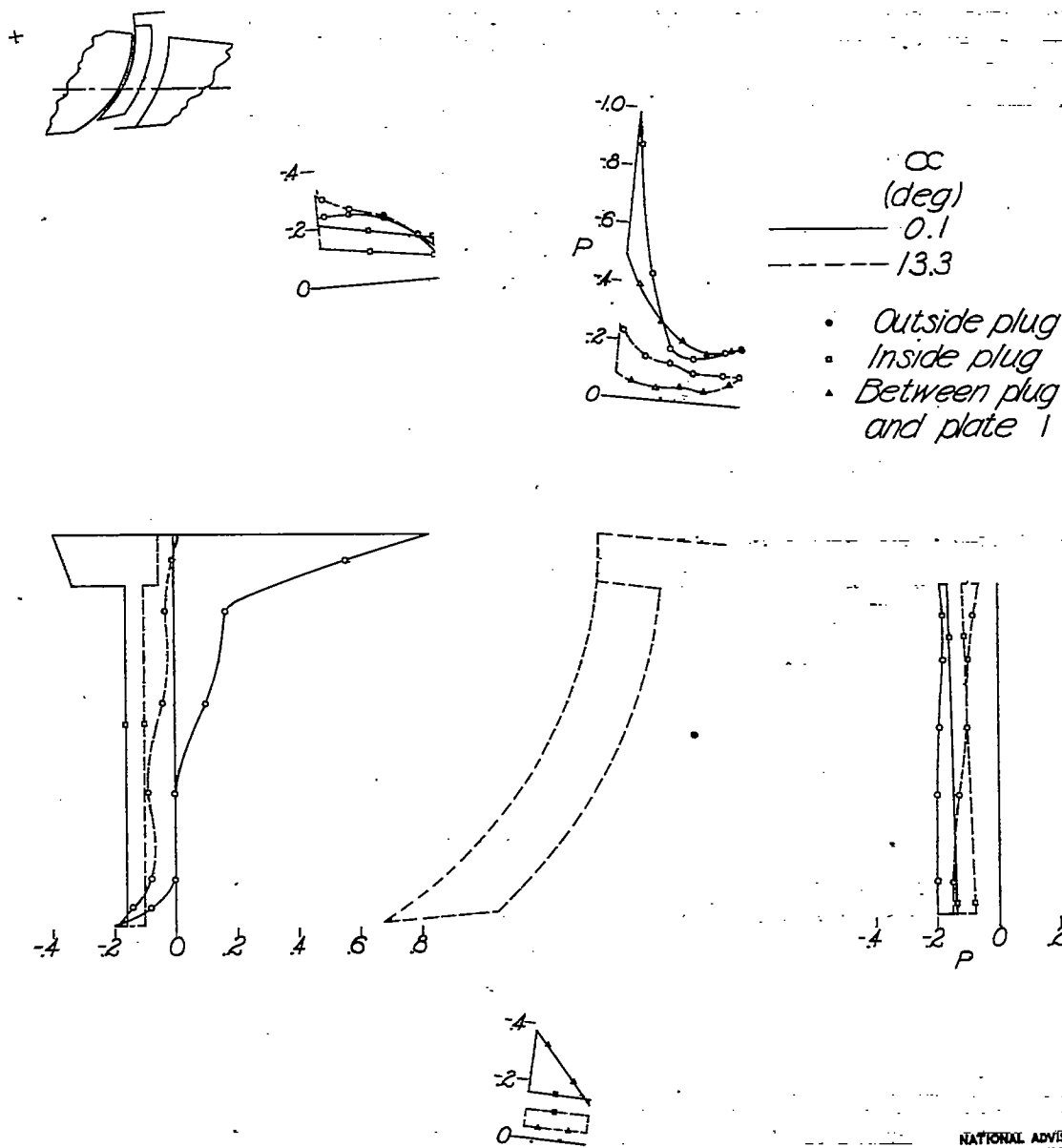
Fig. 11

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Figure 11.—Pressure distribution on plug aileron 5 on the tapered-wing model with full-span slotted flaps.  $\delta_f = 0^\circ$ ;  $\delta_a = -20^\circ$ .

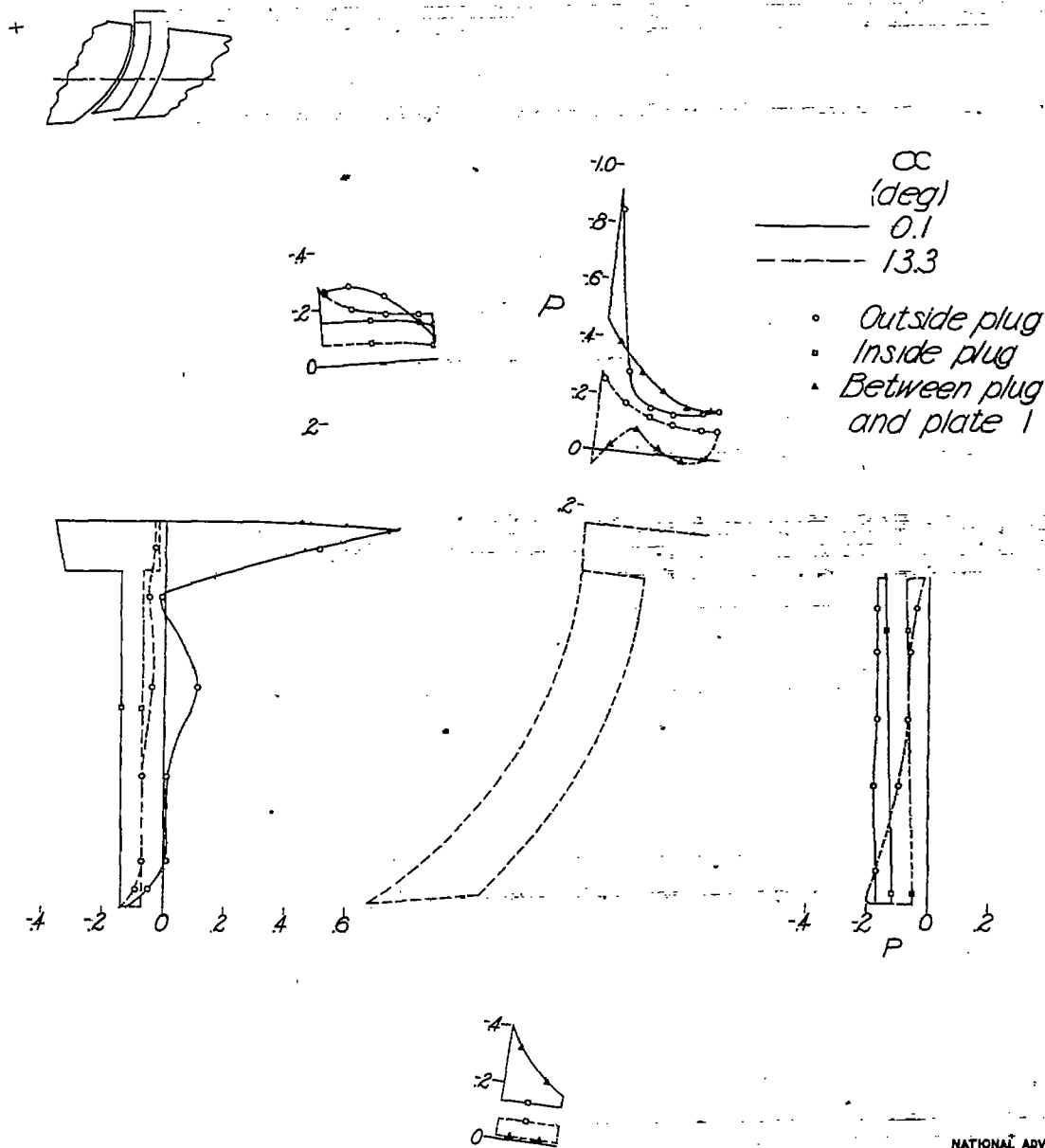


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Figure 12.-Pressure distribution on plug aileron 5 on the tapered-wing model with full-span slotted flaps.  $\delta_f = 0^\circ$ ;  $\delta_a = -10^\circ$ .

Fig. 13

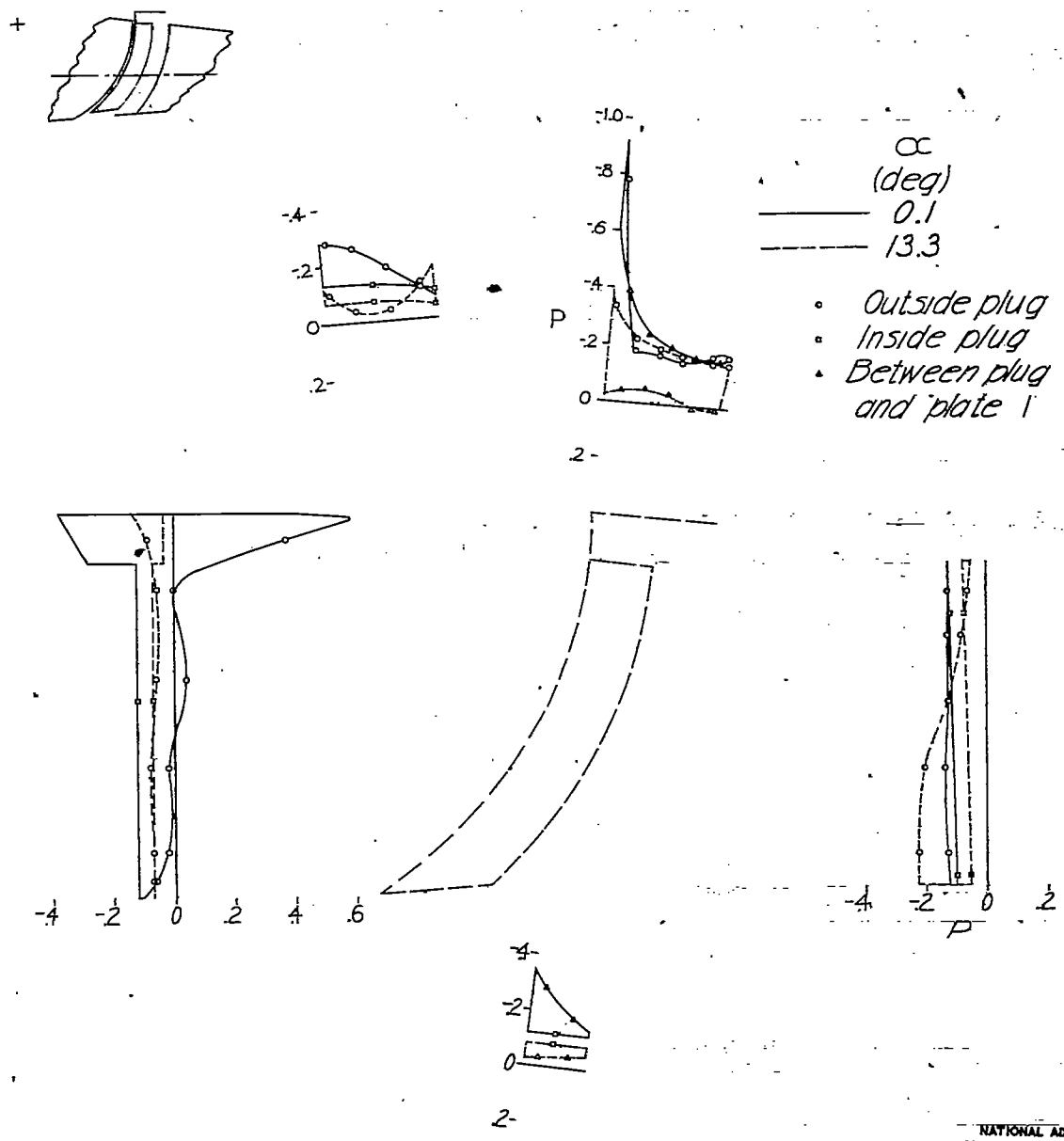
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Figure 13.-Pressure distribution on plug aileron 5 on the tapered-wing model with full-span slotted flaps.  $\delta_f = 0^\circ$ ;  $\delta_a = -7.5^\circ$ .



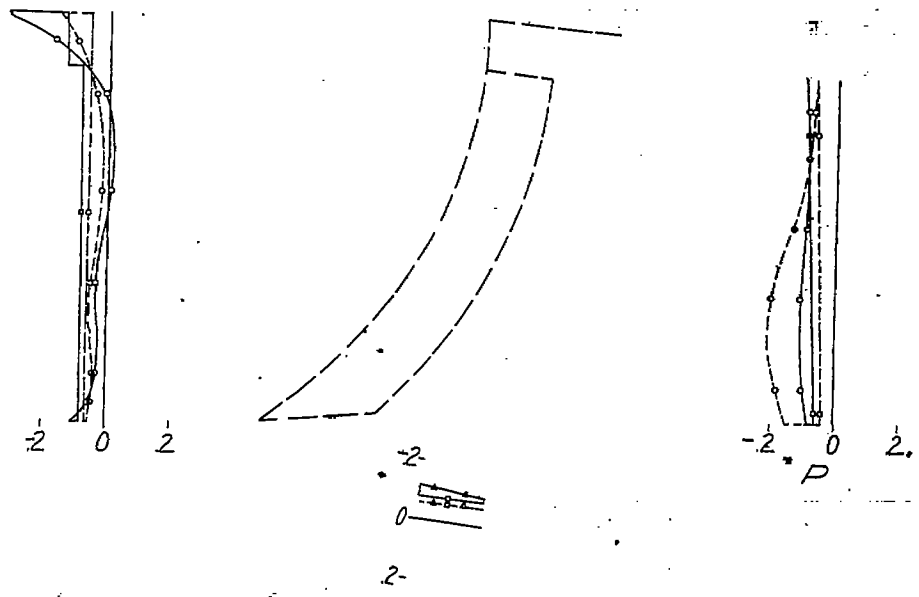
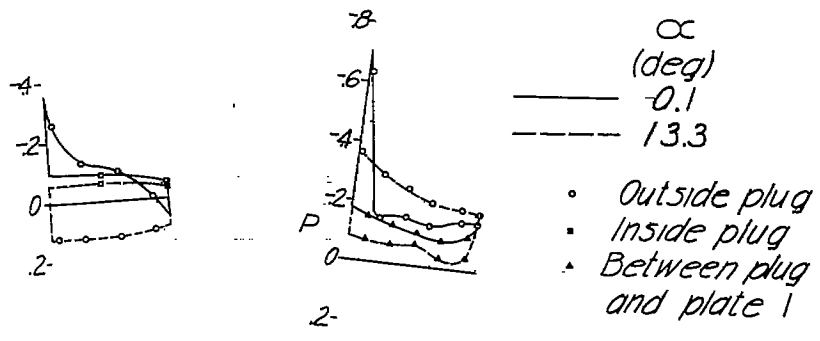
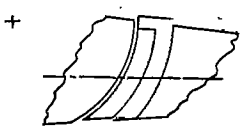


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Figure 14.-Pressure distribution on plug aileron 5 on the tapered-wing model with full-span slotted flaps.  $\delta_f = 0^\circ$ ;  $\delta_a = -5^\circ$ .

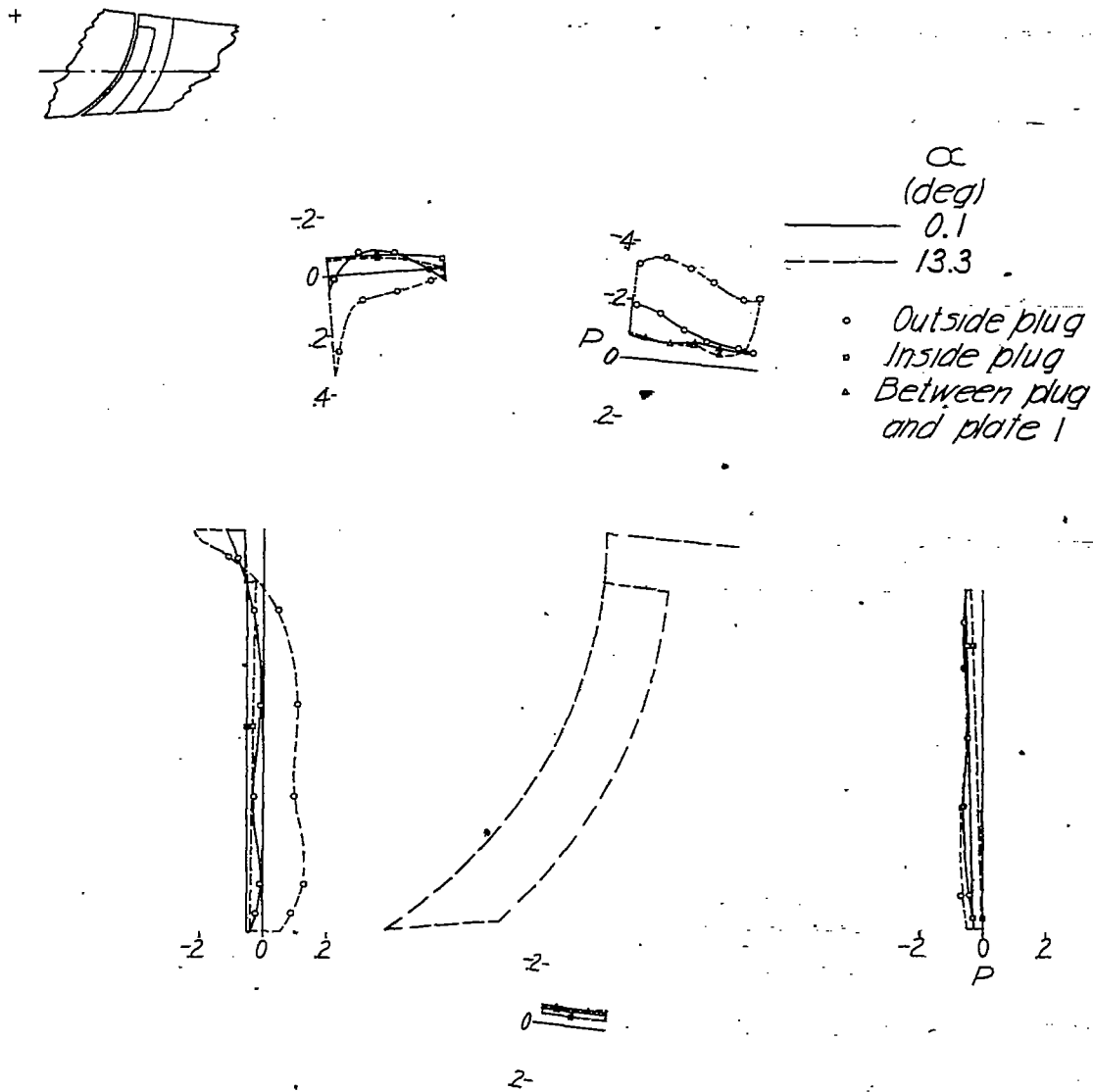
Fig. 15

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Figure 15.-Pressure distribution on plug aileron 5 on the tapered-wing model with full-span slotted flaps.  $\delta_f = 0^\circ$ ;  $\delta_a = -2.5^\circ$ .

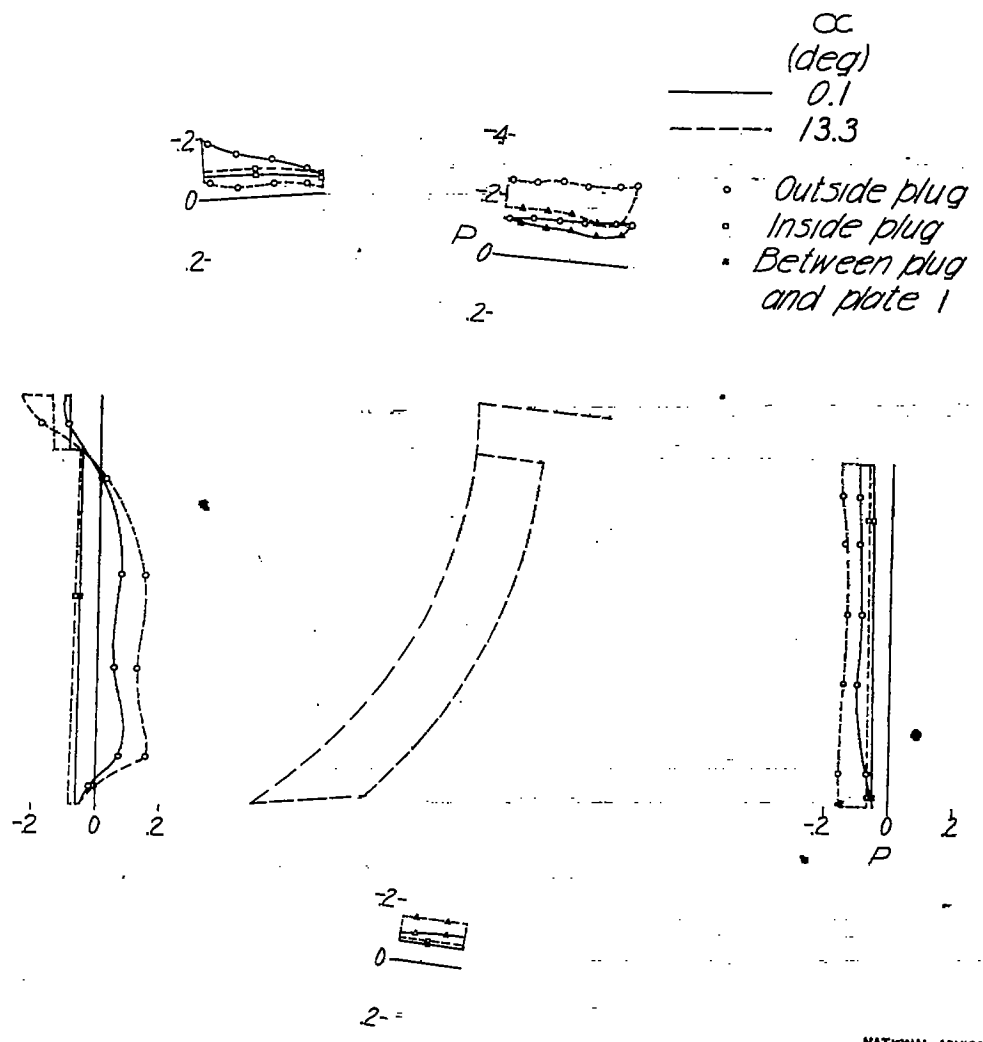
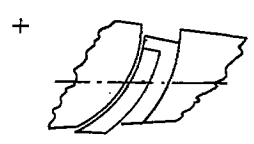


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Figure 16.-Pressure distribution on plug aileron 5 on the tapered-wing model with full-span slotted flaps.  $\delta_f = 0^\circ$ ;  $\delta_a = 0^\circ$ .

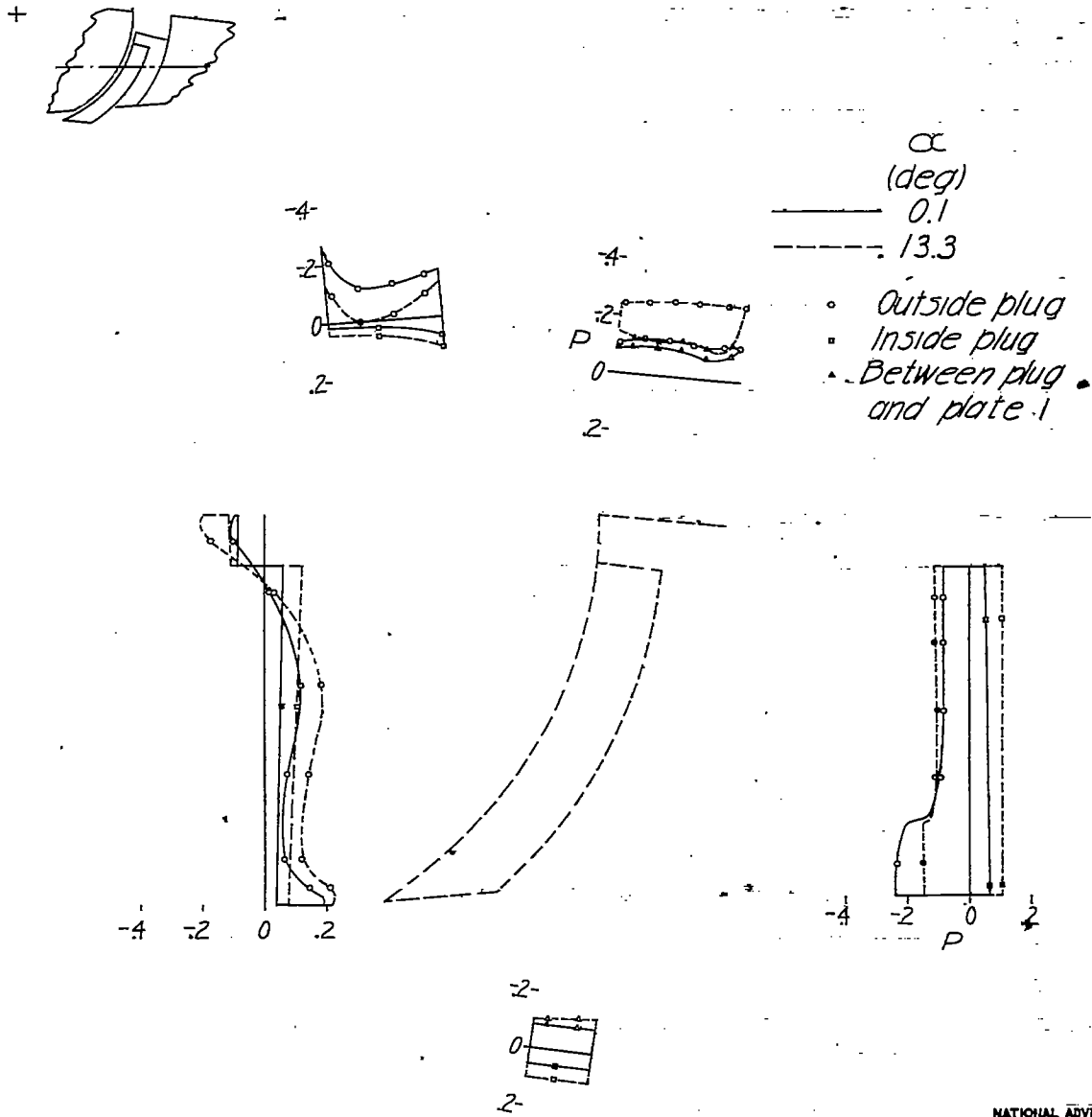
Fig. 17

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Figure 17.-Pressure distribution on plug aileron 5 on the tapered-wing model with full-span slotted flaps.  $\delta_f = 0^\circ$ ;  $\delta_a = 5^\circ$ .



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Figure 18.-Pressure distribution on plug aileron 5 on the tapered-wing model with full-span slotted flaps.  $\delta_f = 0^\circ$ ;  $\delta_a = 10^\circ$ .

Fig. 19

NACA TN No. 1079

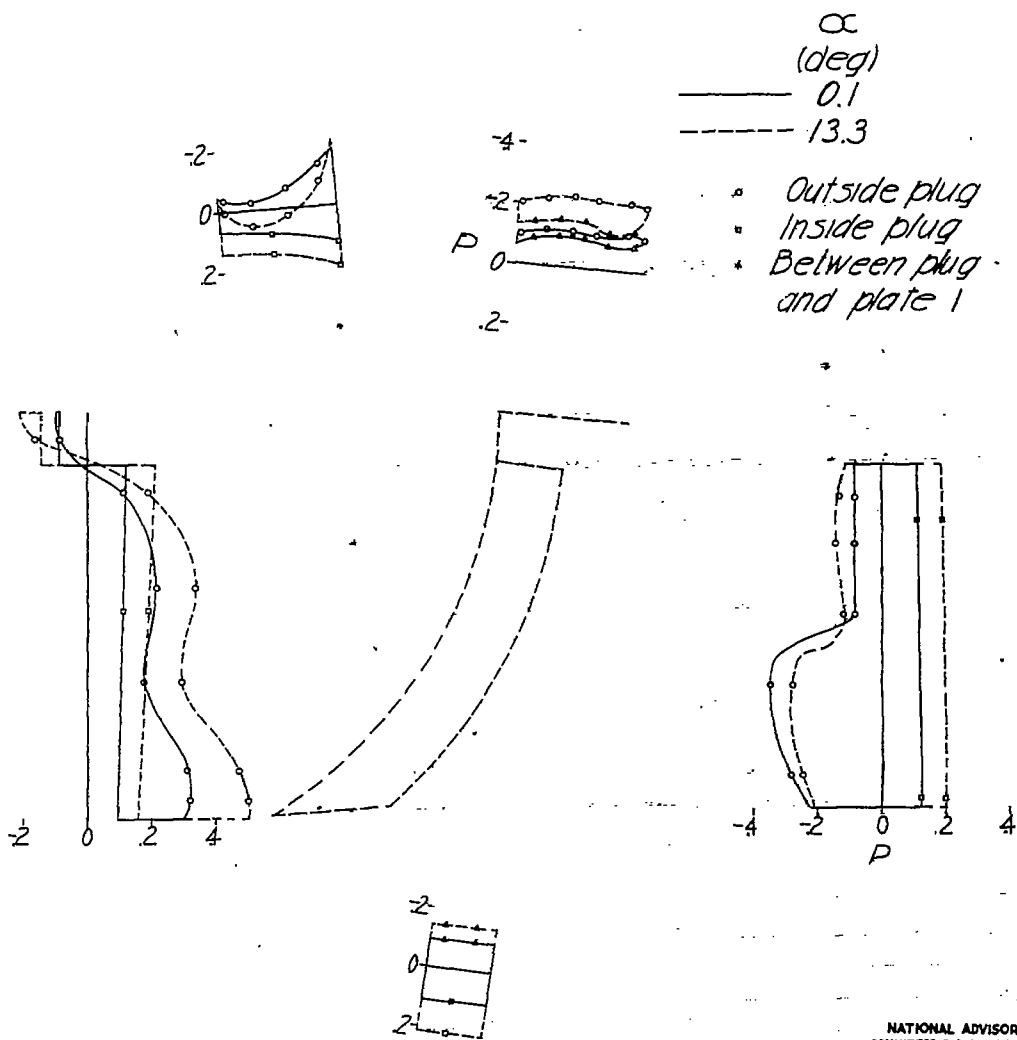
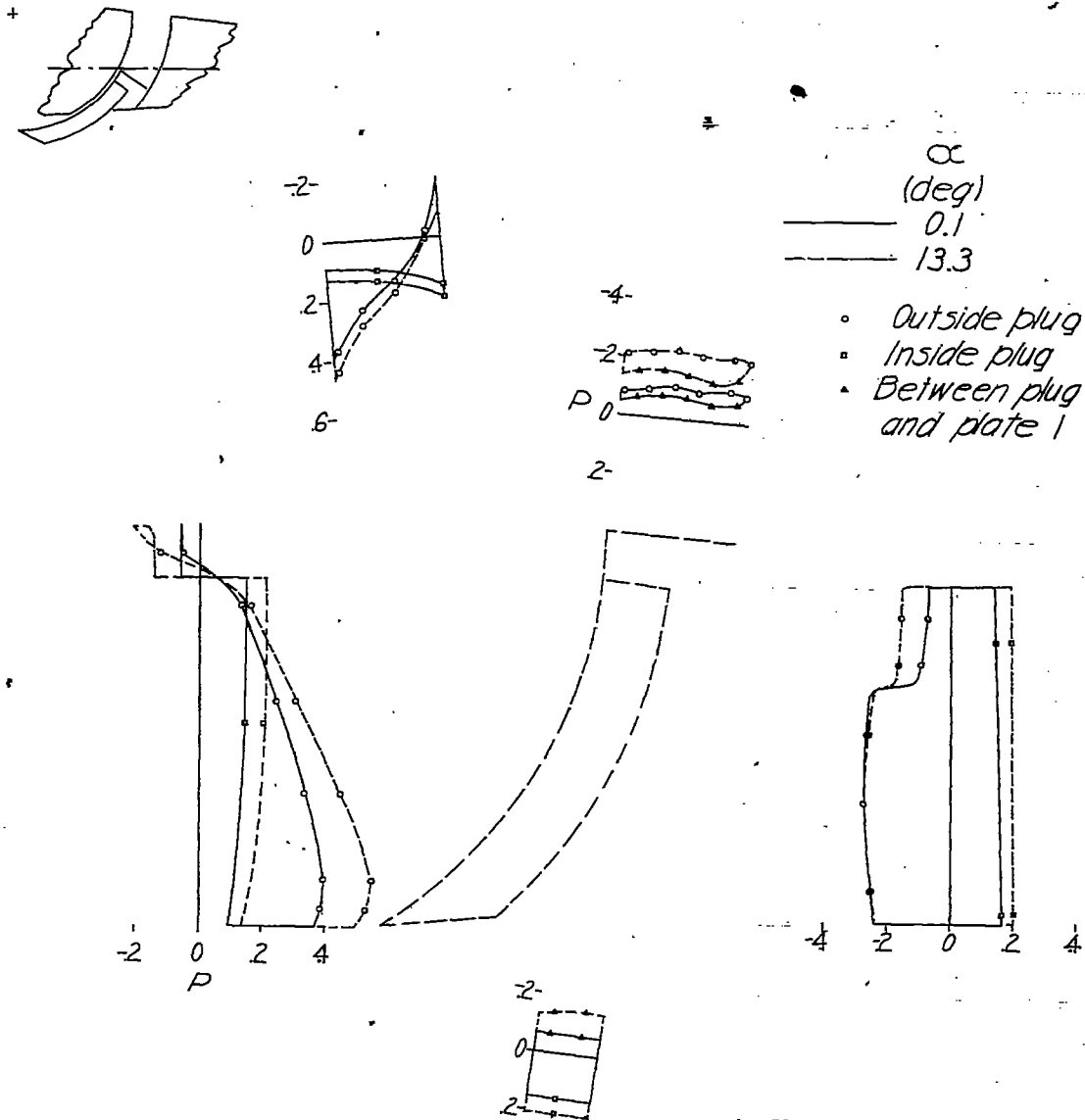


Figure 19.-Pressure distribution on plug aileron 5 on the tapered-wing model with full-span slotted flaps.  $\delta_f = 0^\circ$ ;  $\delta_a = 20^\circ$ .

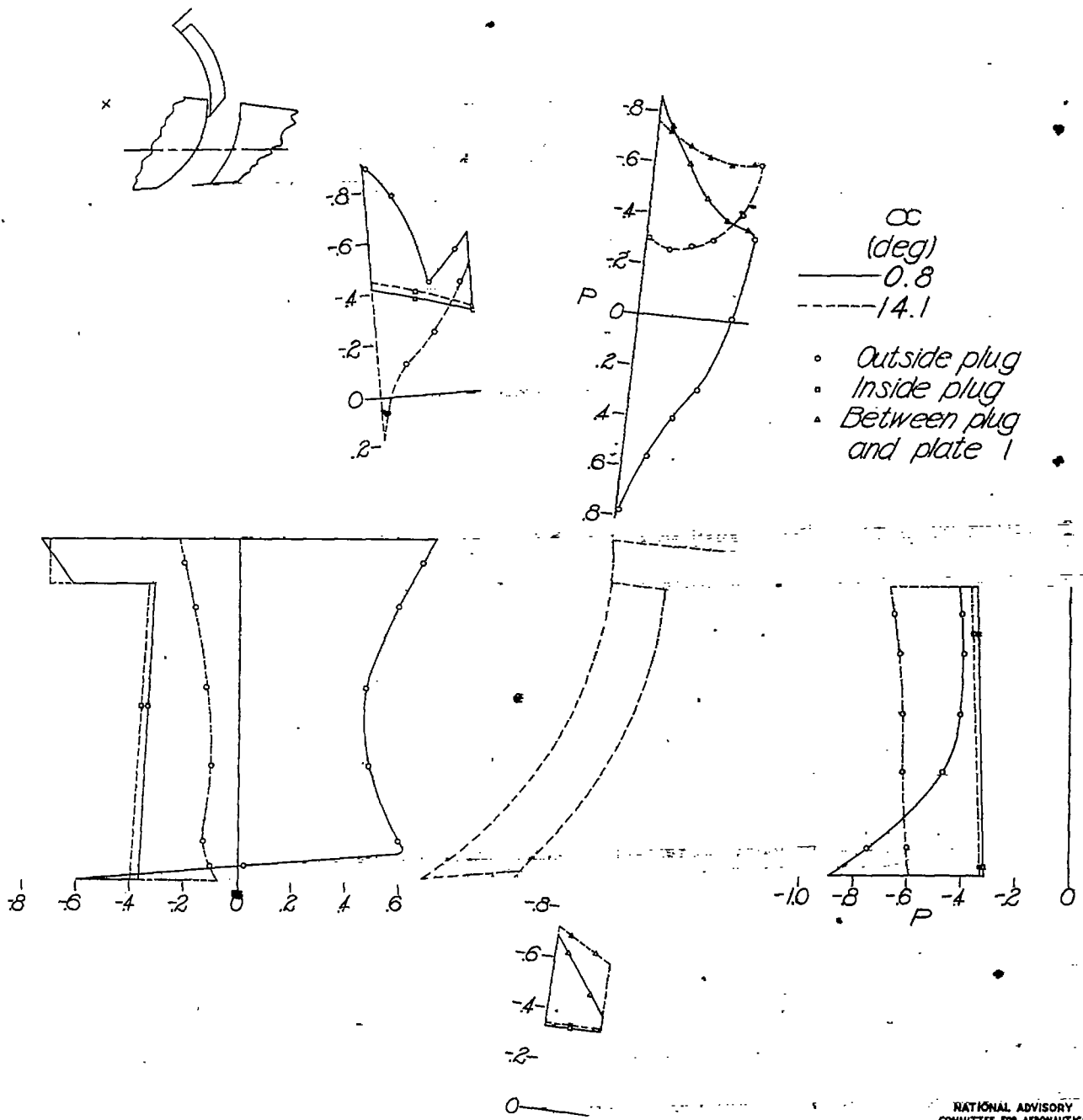


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Figure 20.-Pressure distribution on plug aileron 5 on the tapered-wing model with full-span slotted flaps.  $\delta_f = 0^\circ$ ;  $\delta_a = 30^\circ$ .

Fig. 21

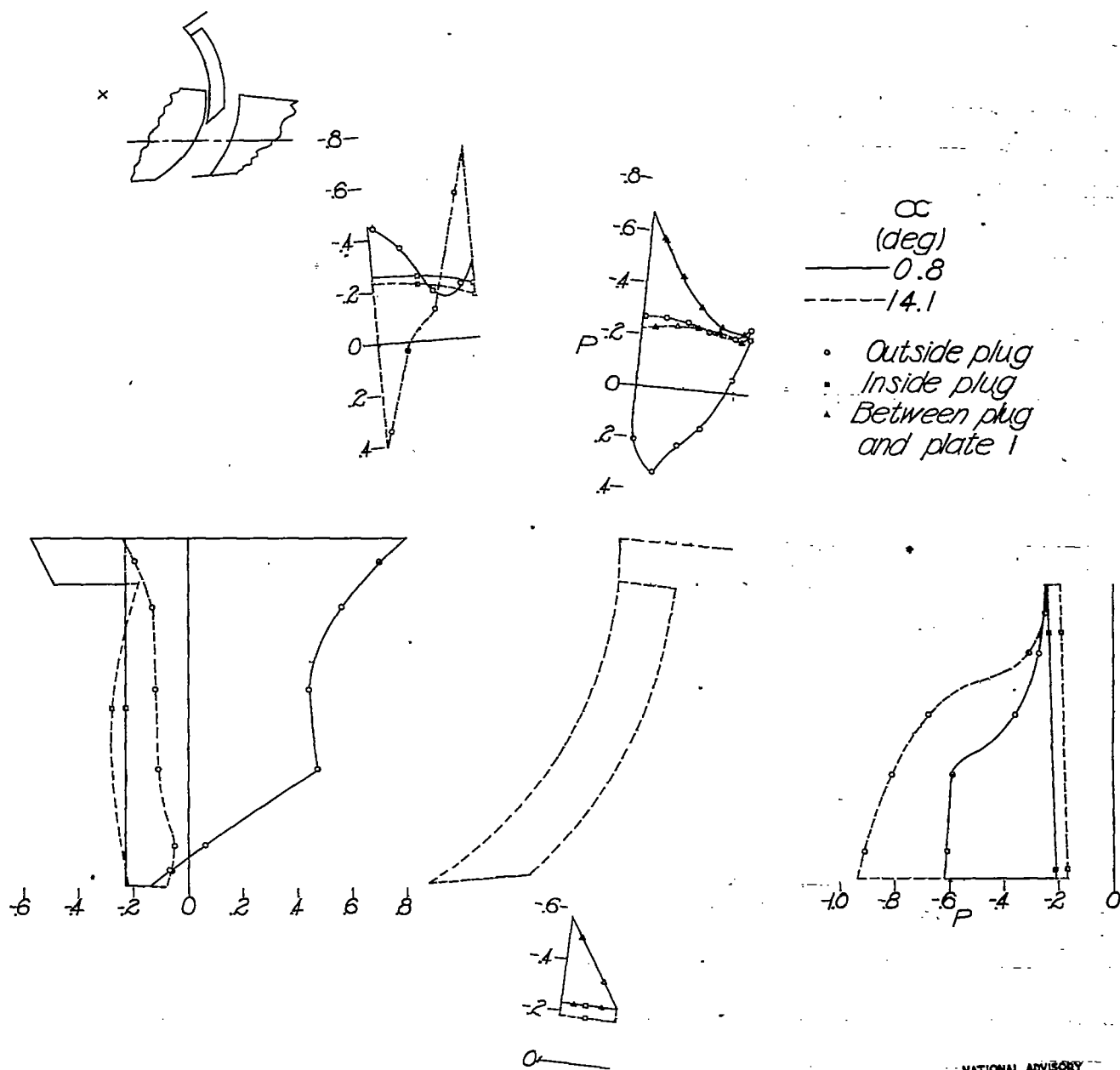
NACA TN No. 1079



NATIONAL ADVISORY  
 COMMITTEE FOR AERONAUTICS

Figure 21.- Pressure distribution on plug aileron 5 on the tapered-wing model with full-span slotted flaps.  $\delta_f = 40^\circ$ ;  $\delta_a = -50^\circ$ .



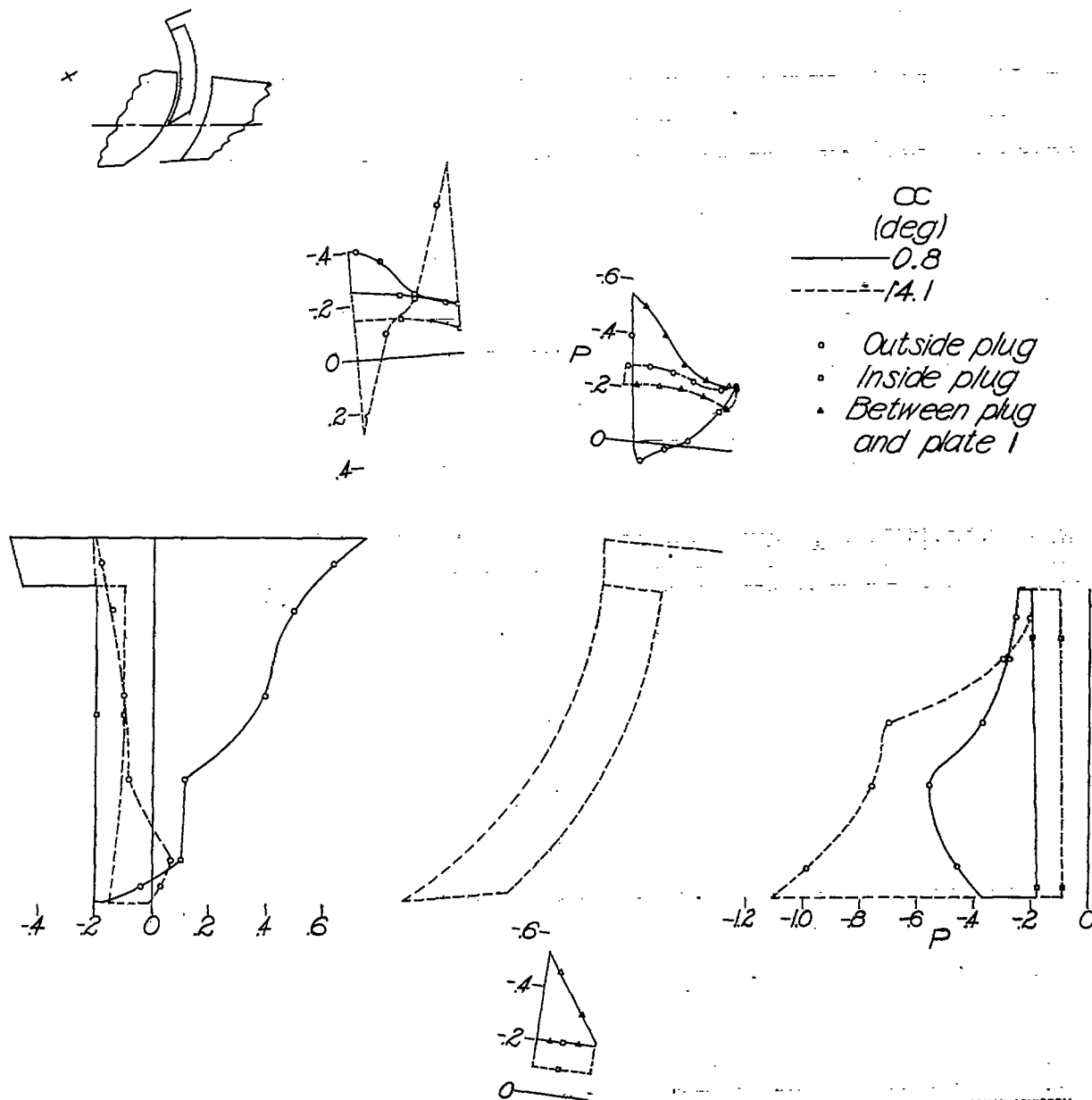


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Figure 22.—Pressure distribution on plug aileron 5 on the tapered-wing model with full-span slotted flaps.  $\delta_f = 40^\circ$ ;  $\delta_a = -40^\circ$ .

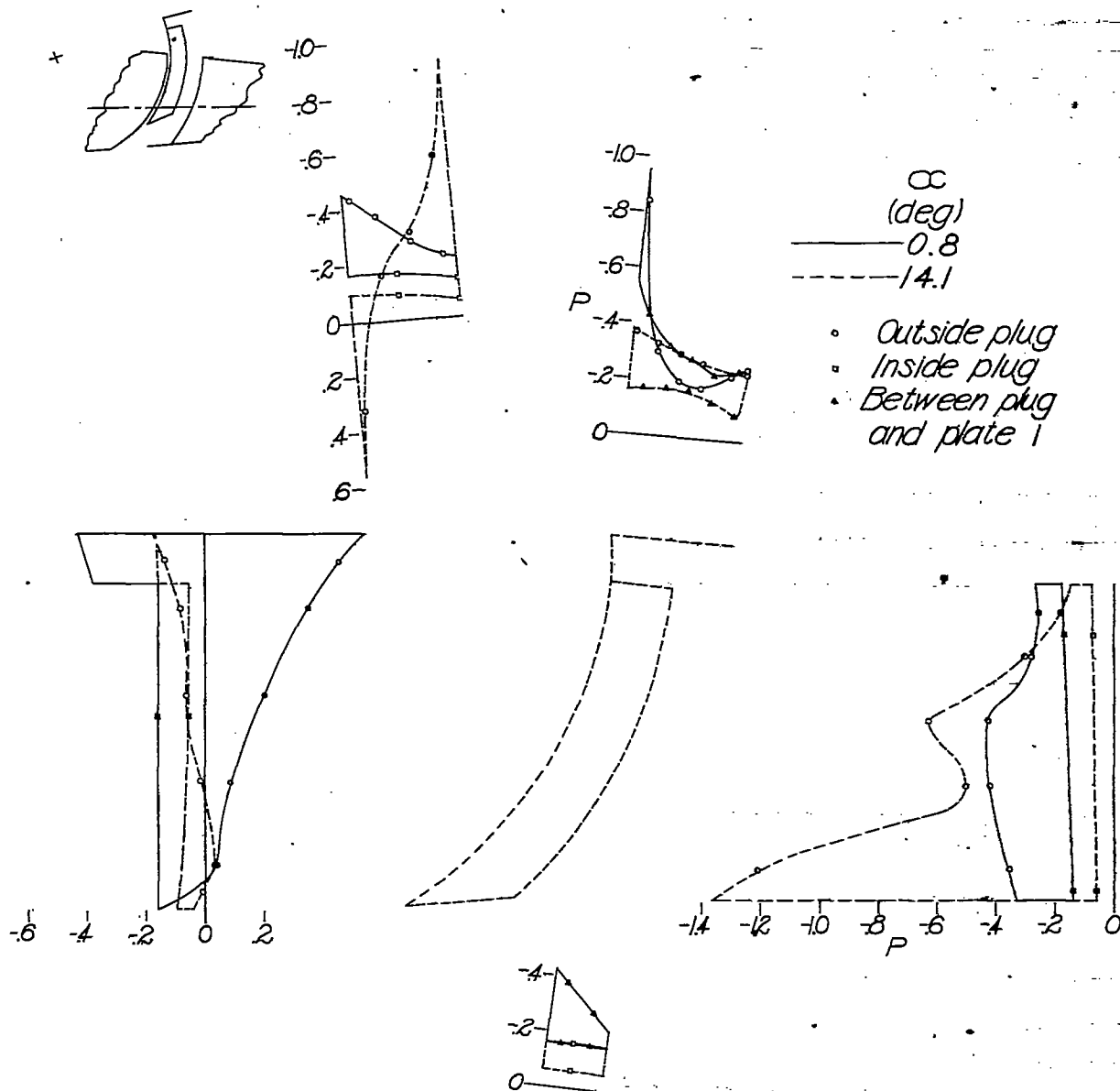
Fig. 23

NACA TN No. 1079



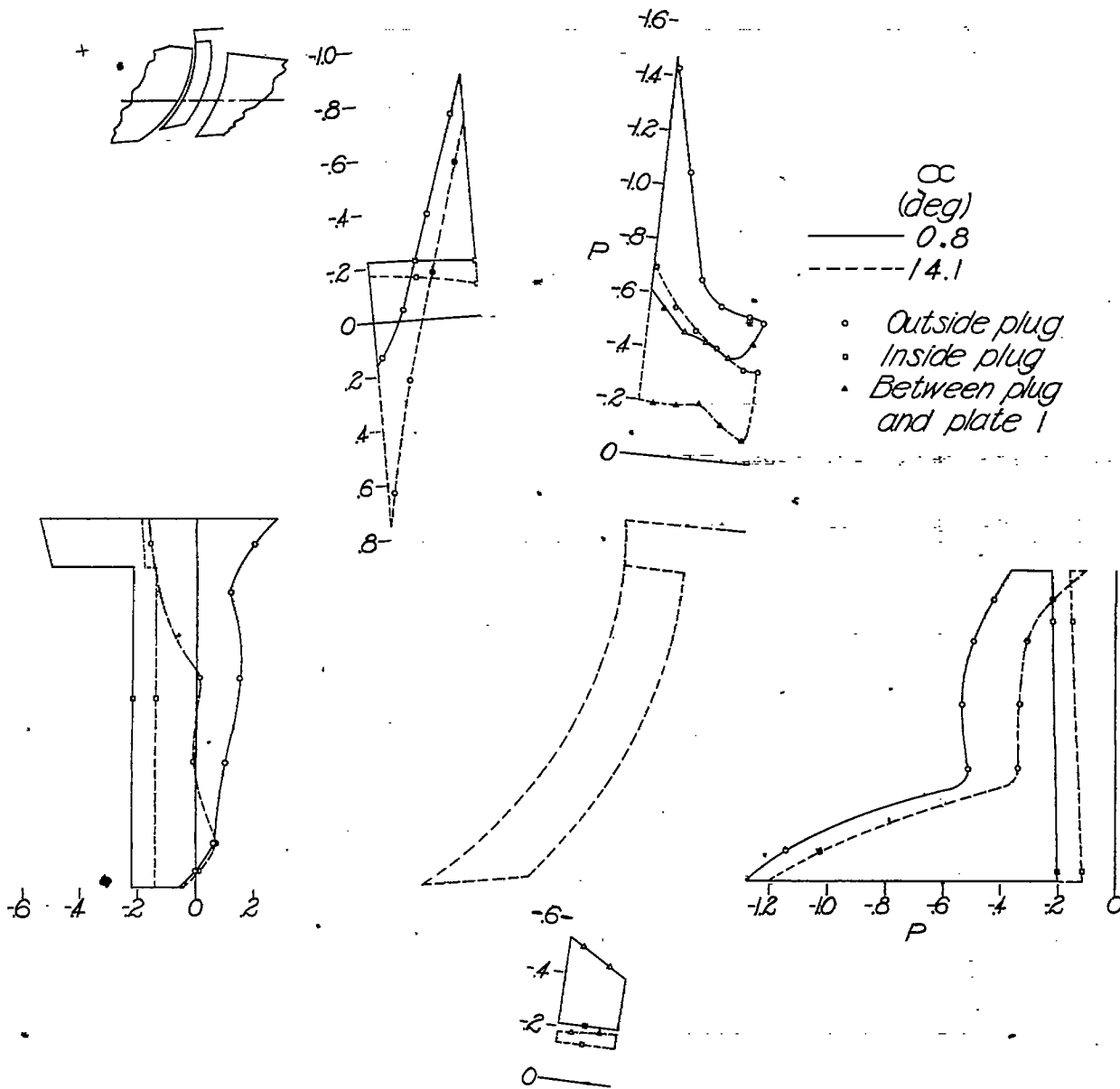
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Figure 23.-Pressure distribution on plug aileron 5 on the tapered-wing model with full-span slotted flaps.  $\delta_f = 40^\circ$ ;  $\delta_a = -30^\circ$ .



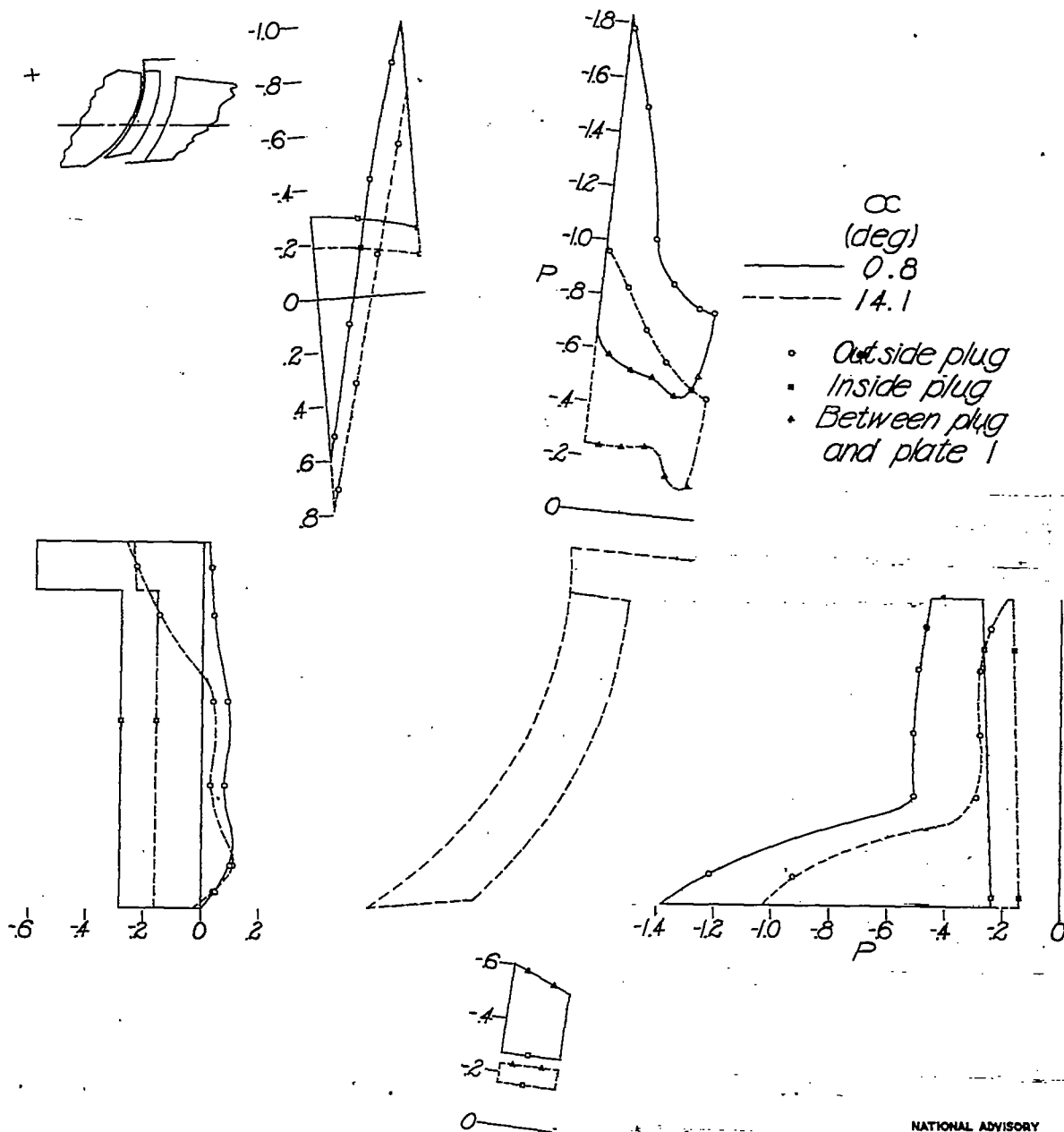
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Figure 24.-Pressure distribution on plug aileron 5 on the tapered-wing model with full-span slotted flaps.  $\delta_f = 40^\circ$ ;  $\delta_a = -20^\circ$ .



NATIONAL ADVISORY  
 COMMITTEE FOR AERONAUTICS

Figure 25.-Pressure distribution on plug aileron 5 on the tapered-wing model with full-span slotted flaps.  $\delta_f = 40^\circ$ ;  $\delta_a = -10^\circ$ .

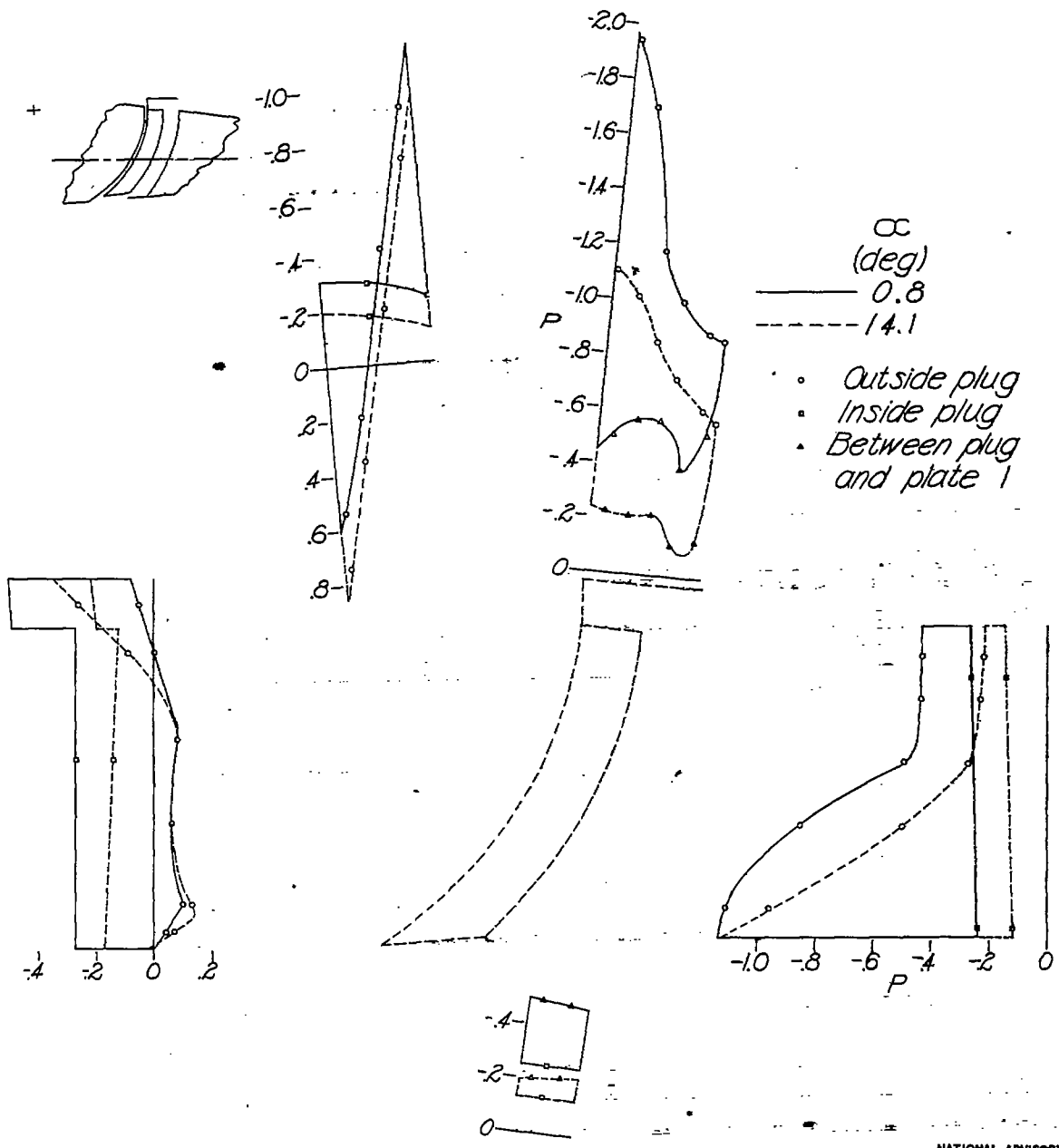


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Figure 26.—Pressure distribution on plug aileron 5 on the tapered-wing model with full-span slotted flaps.  $\delta_f = 40^\circ$ ;  $\delta_a = -7.5^\circ$ .

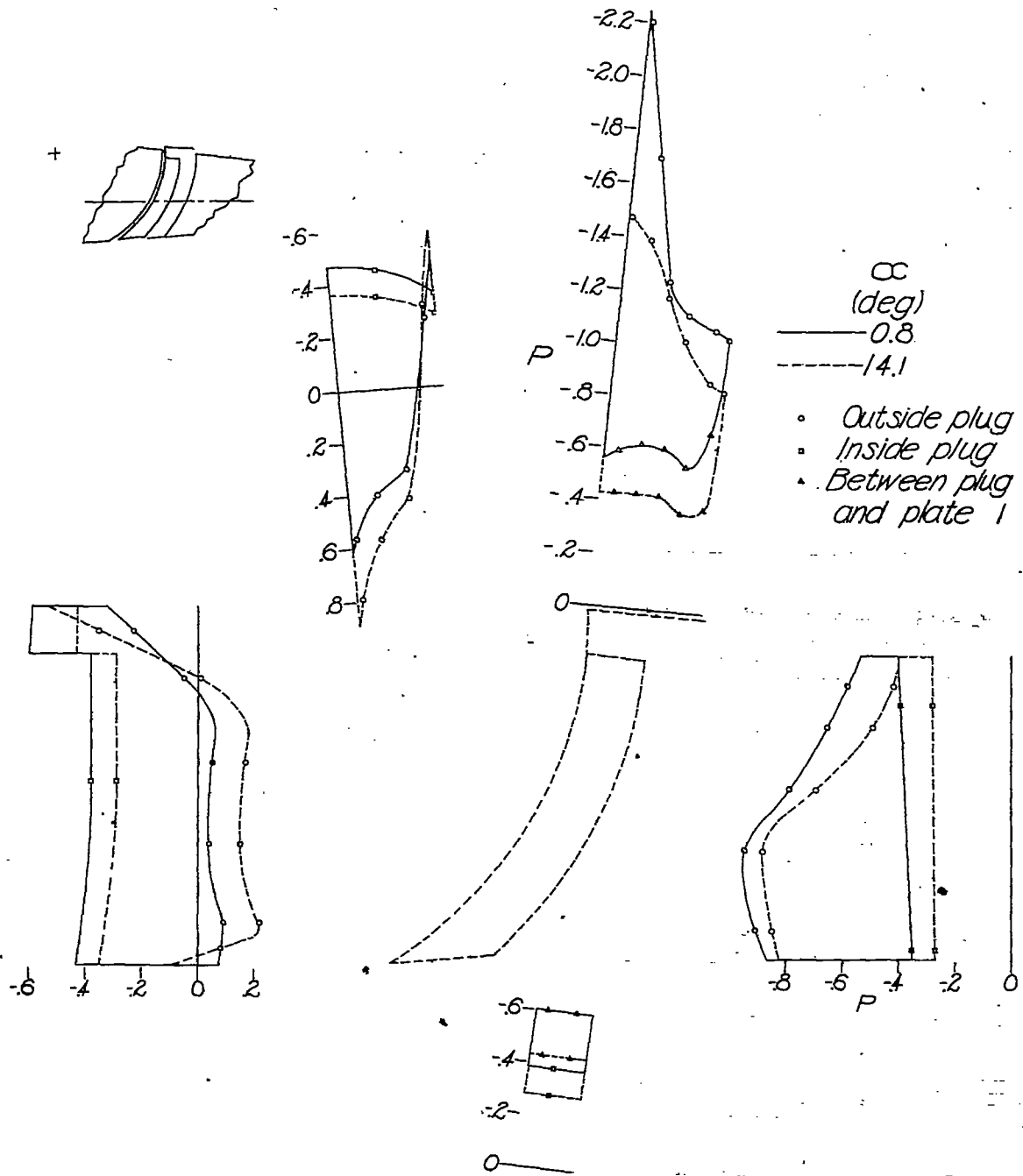
Fig. 27

NACA TN No. 1079



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Figure 27.-Pressure distribution on plug aileron 5 on the tapered-wing model with full-span slotted flaps.  $\delta_f = 40^\circ$ ;  $\delta_a = -5^\circ$ .

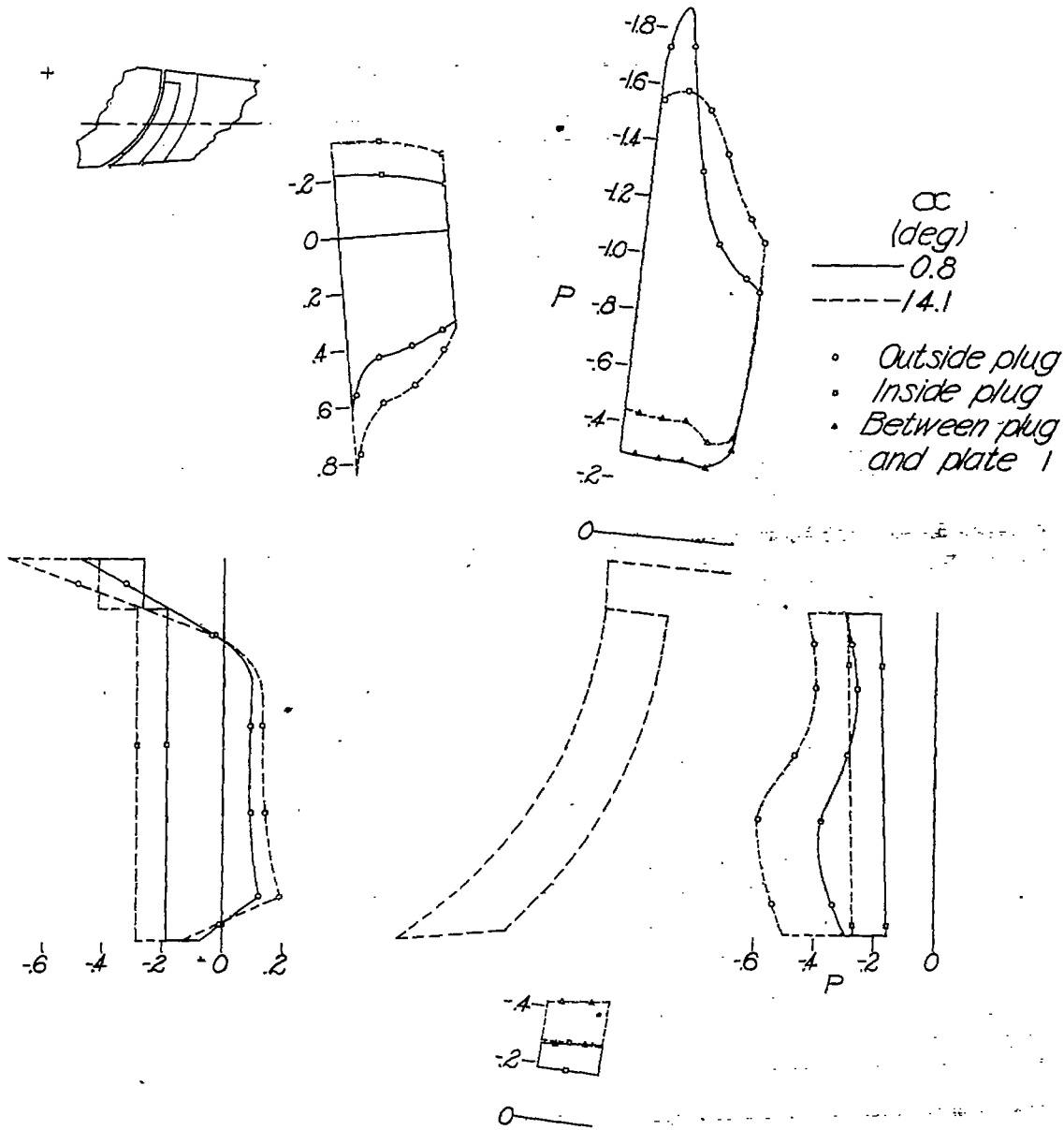


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Figure 28.-Pressure distribution on plug aileron 5 on the tapered-wing model with full-span slotted flaps.  $\delta_f = 40^\circ$ ;  $\delta_a = -2.5^\circ$ .

Fig. 29

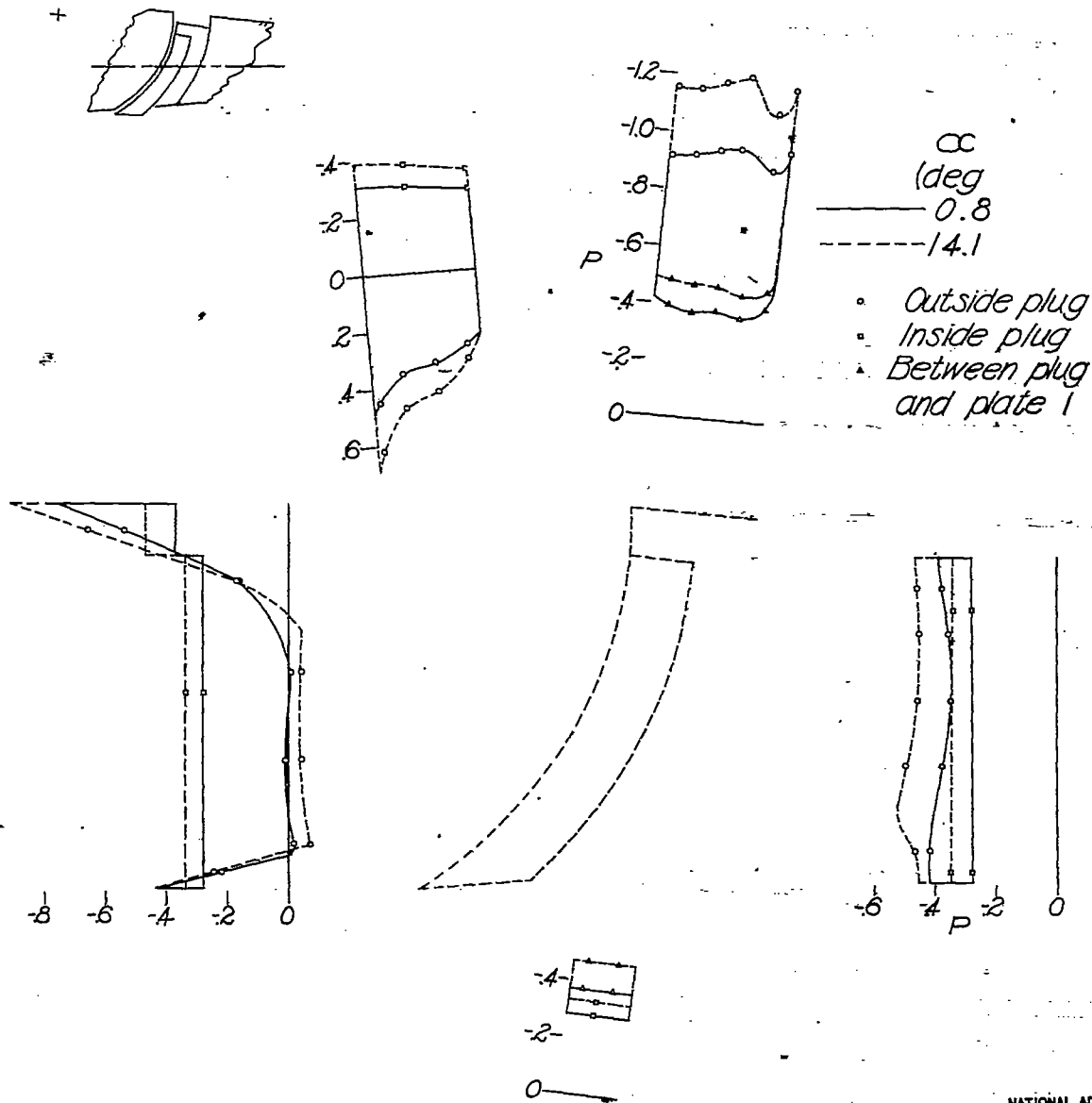
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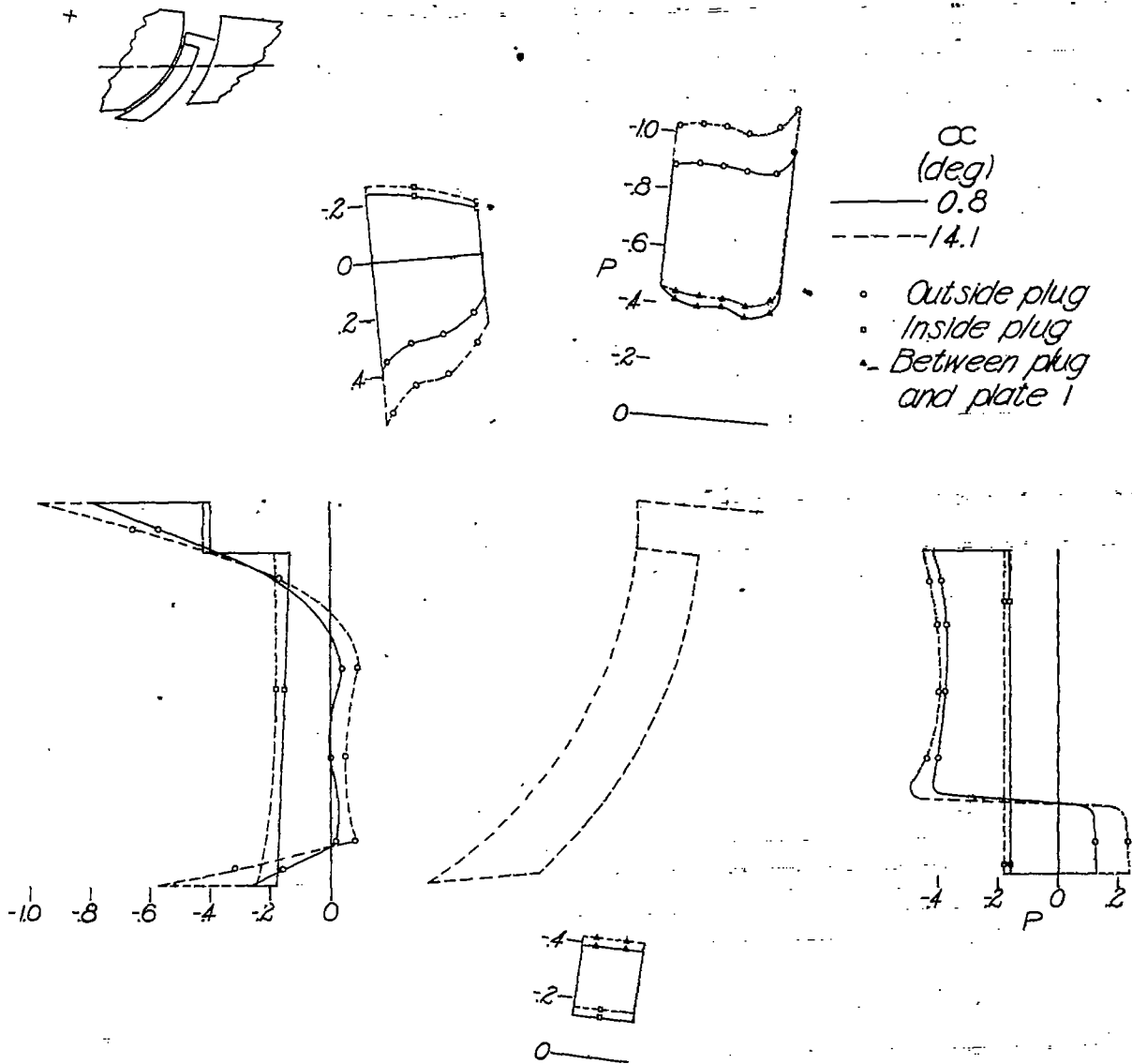
Figure 29.—Pressure distribution on plug aileron 5 on the tapered-wing model with full-span slotted flaps.  $\delta_f = 40^\circ$ ;  $\delta_a = 0^\circ$





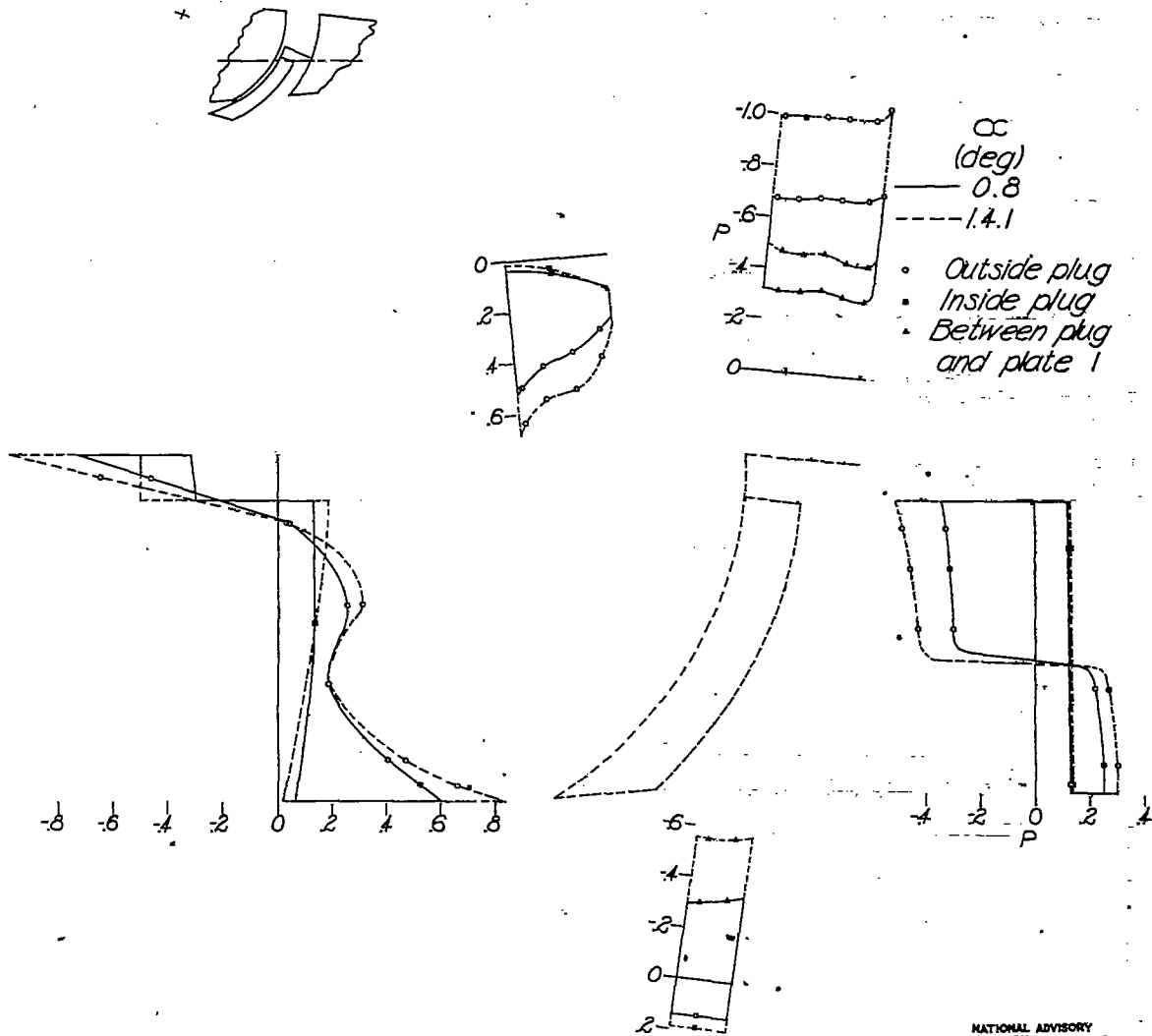
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Figure 30.—Pressure distribution on plug aileron 5 on the tapered-wing model with full-span slotted flaps.  $\delta_f = 40^\circ$ ;  $\delta_a = 5^\circ$ .



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 COMMITTEE FOR AERONAUTICS

Figure 31.—Pressure distribution on plug aileron 5 on the tapered-wing model with full-span slotted flaps.  $\delta_f = 40^\circ$ ;  $\delta_a = 10^\circ$ .

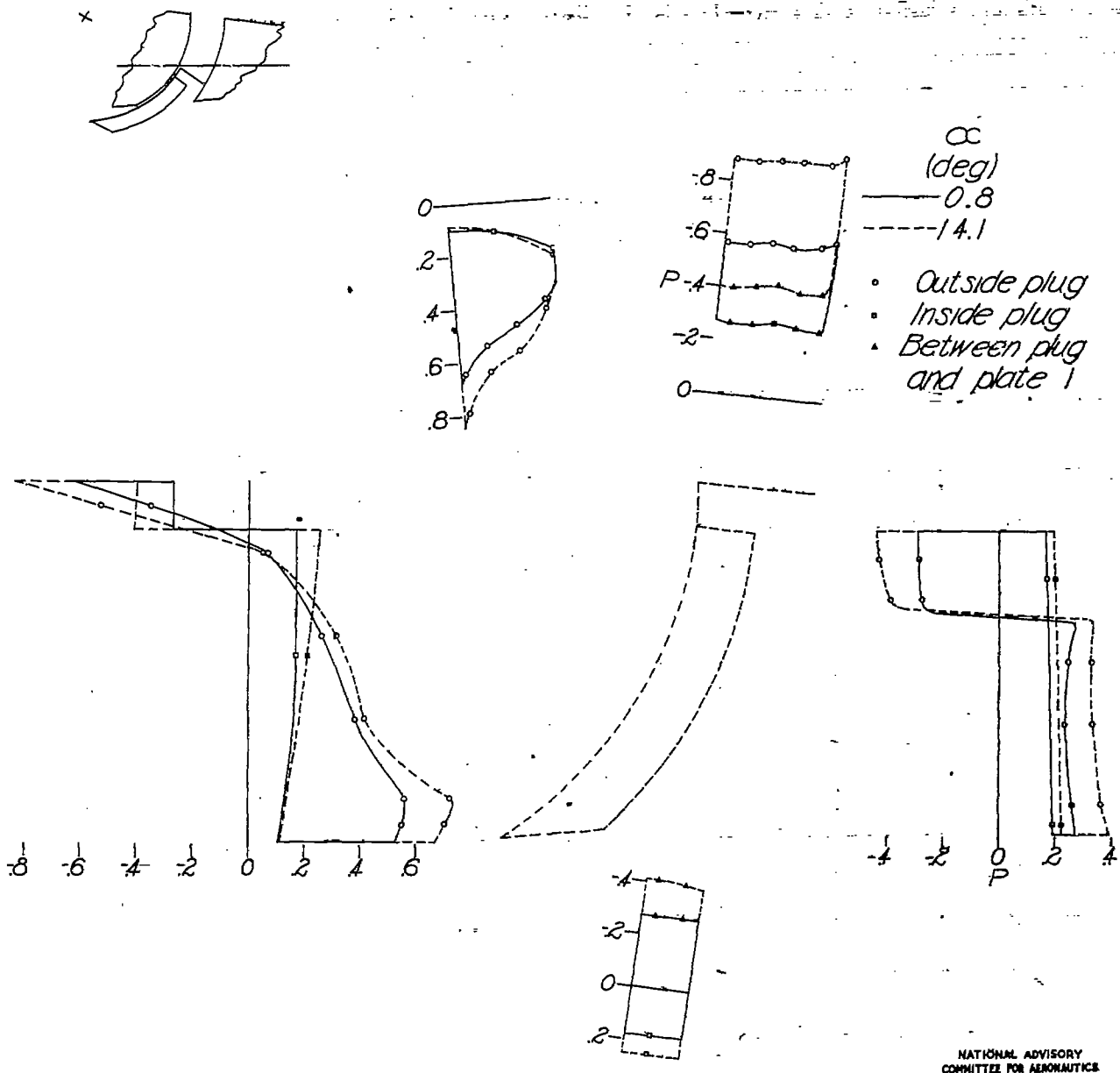


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Figure 32.—Pressure distribution on plug aileron 5 on the tapered-wing model with full-span slotted flaps.  $\delta_f = 40^\circ$ ;  $\delta_a = 20^\circ$ .

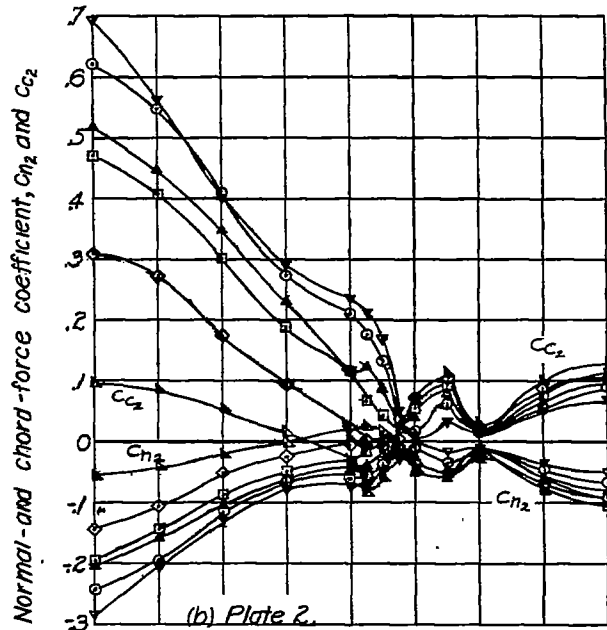
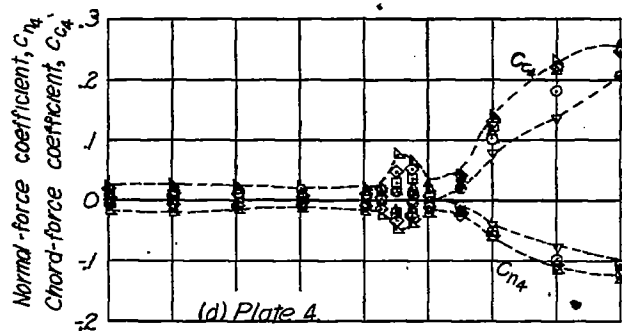
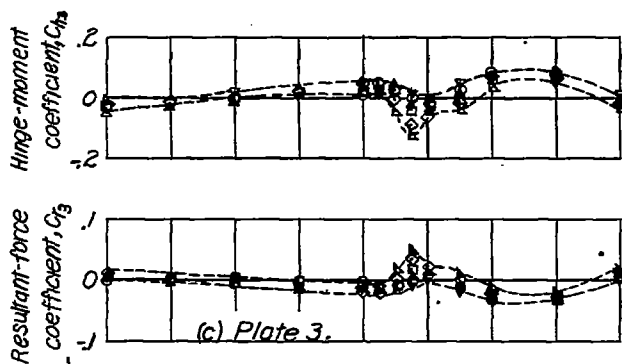
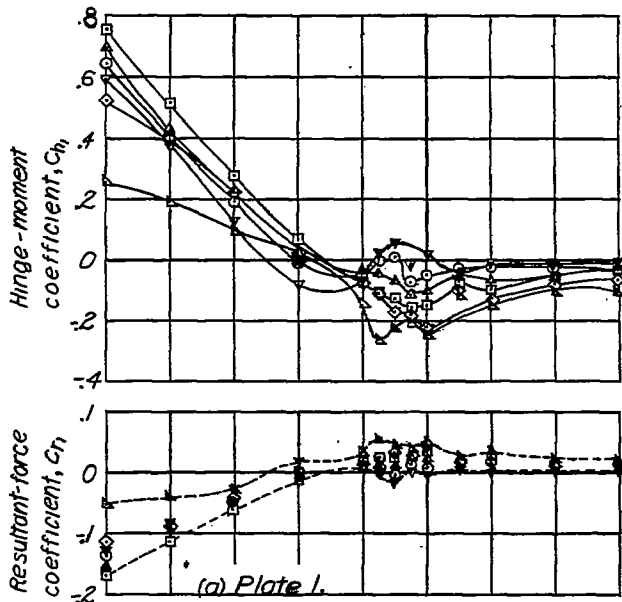
Fig. 33

NACA TN No. 1079



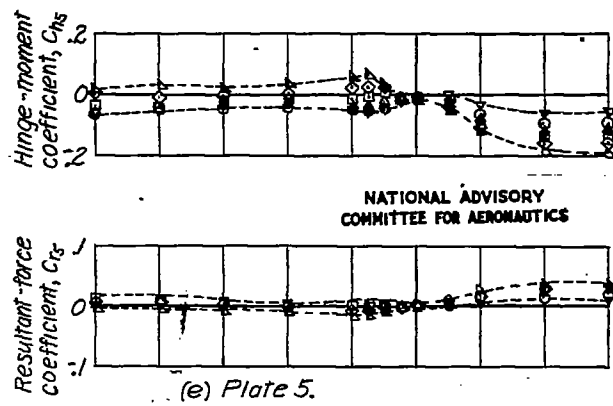
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Figure 33.-Pressure distribution on plug aileron 5 on the tapered-wing model with full-span slotted flaps.  $\delta_f = 40^\circ$ ;  $\delta_a = 30^\circ$ .



$\alpha$   
(deg)

- ▼ -4.3
- 1
- ▲ 4.5
- 8.9
- ◇ 13.3
- ▽ 17.6



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Figure 34.-Characteristics of plug aileron 5 on tapered-wing model with full-span slotted flaps.  $\delta_f = 0^\circ$ .

Fig. 35a-e

NACA TN No. 1079

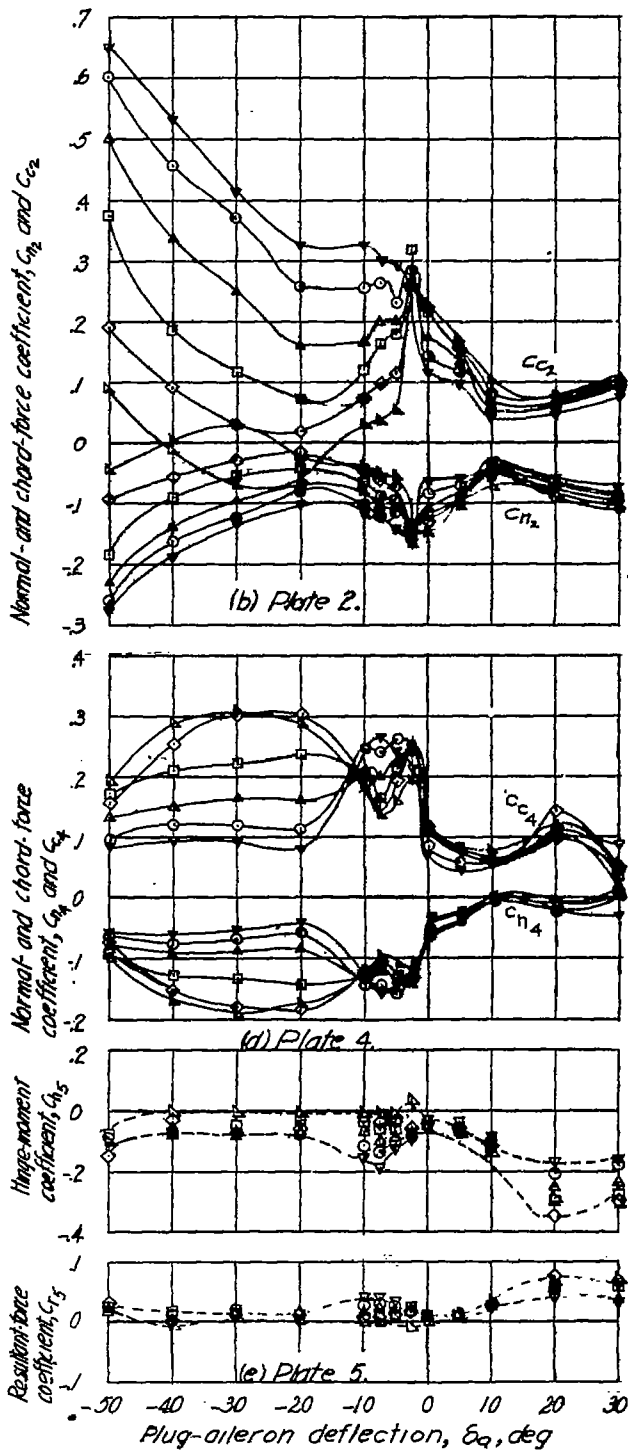
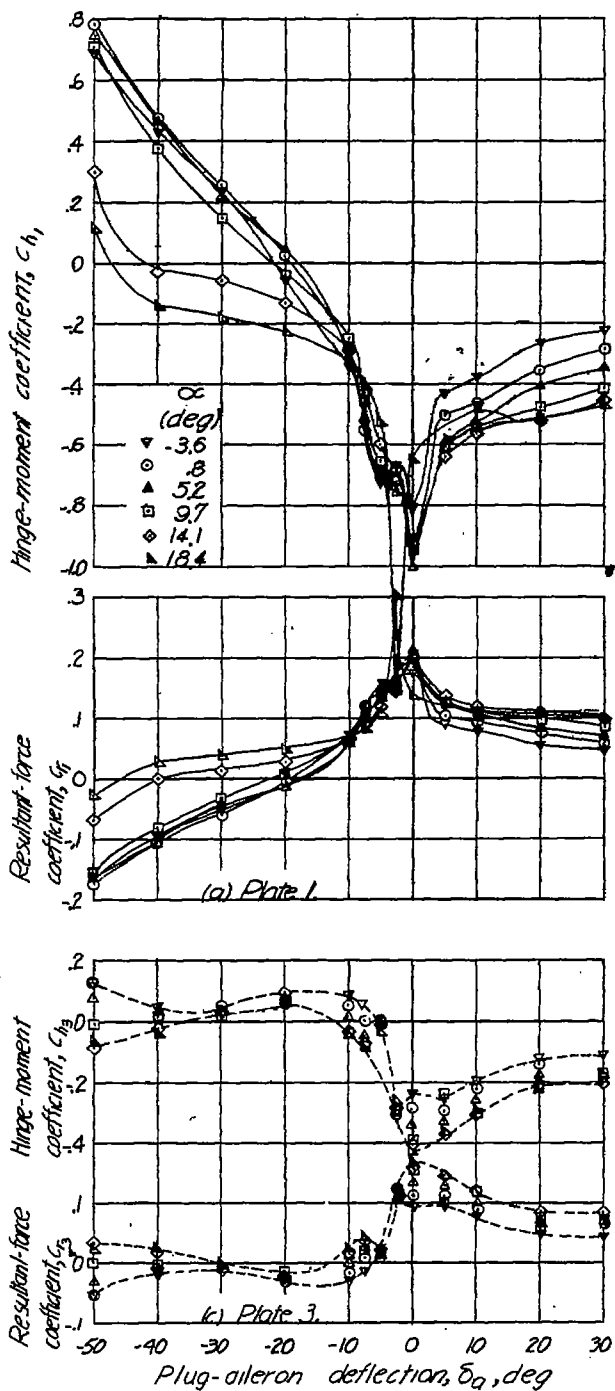


Figure 35. - Characteristics of plug aileron 5 on tapered-wing model with full-span slotted flaps.  $\delta_f = 40^\circ$ .

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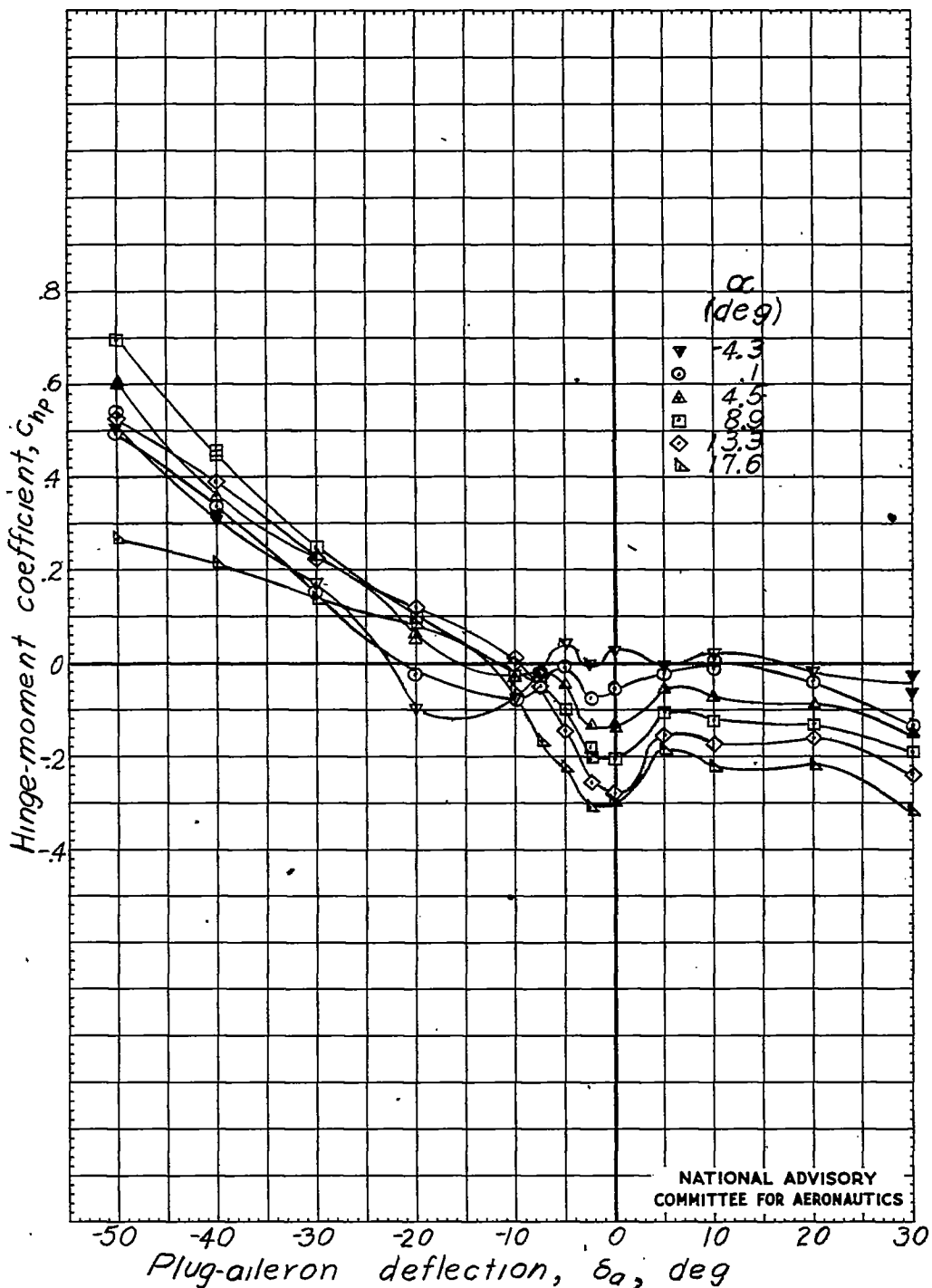
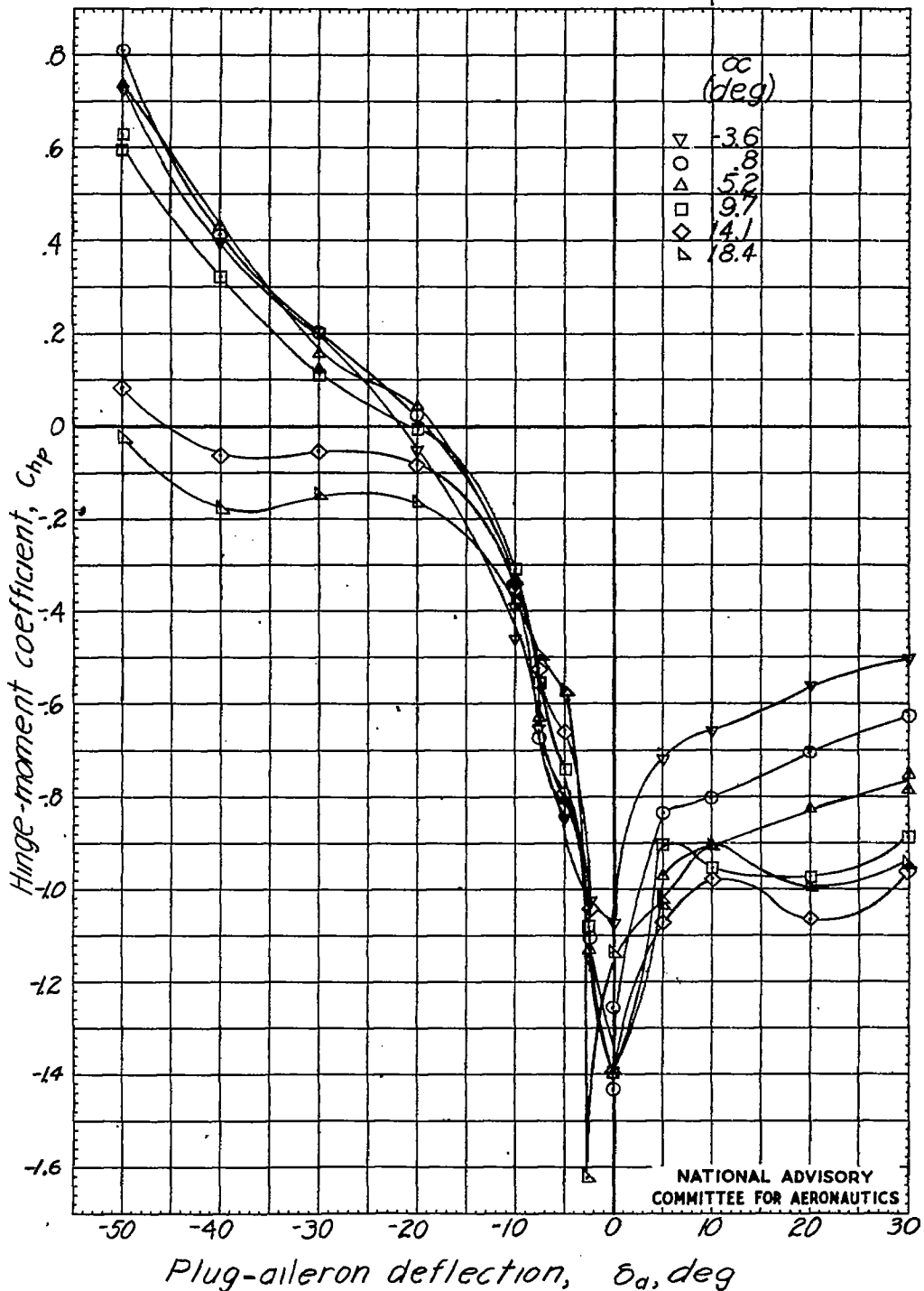


Figure 36.- Hinge-moment coefficients of plug aileron 5 on tapered-wing model with full-span slotted flaps.  $\delta_f = 0^\circ$ .

Fig. 37

NACA TN No. 1079



Plug-aileron deflection,  $\delta_a$ , deg  
 Figure 37.- Hinge-moment coefficients of plug aileron 5  
 on tapered-wing model with full-span slotted flaps.  
 $\delta_f = 40^\circ$ .



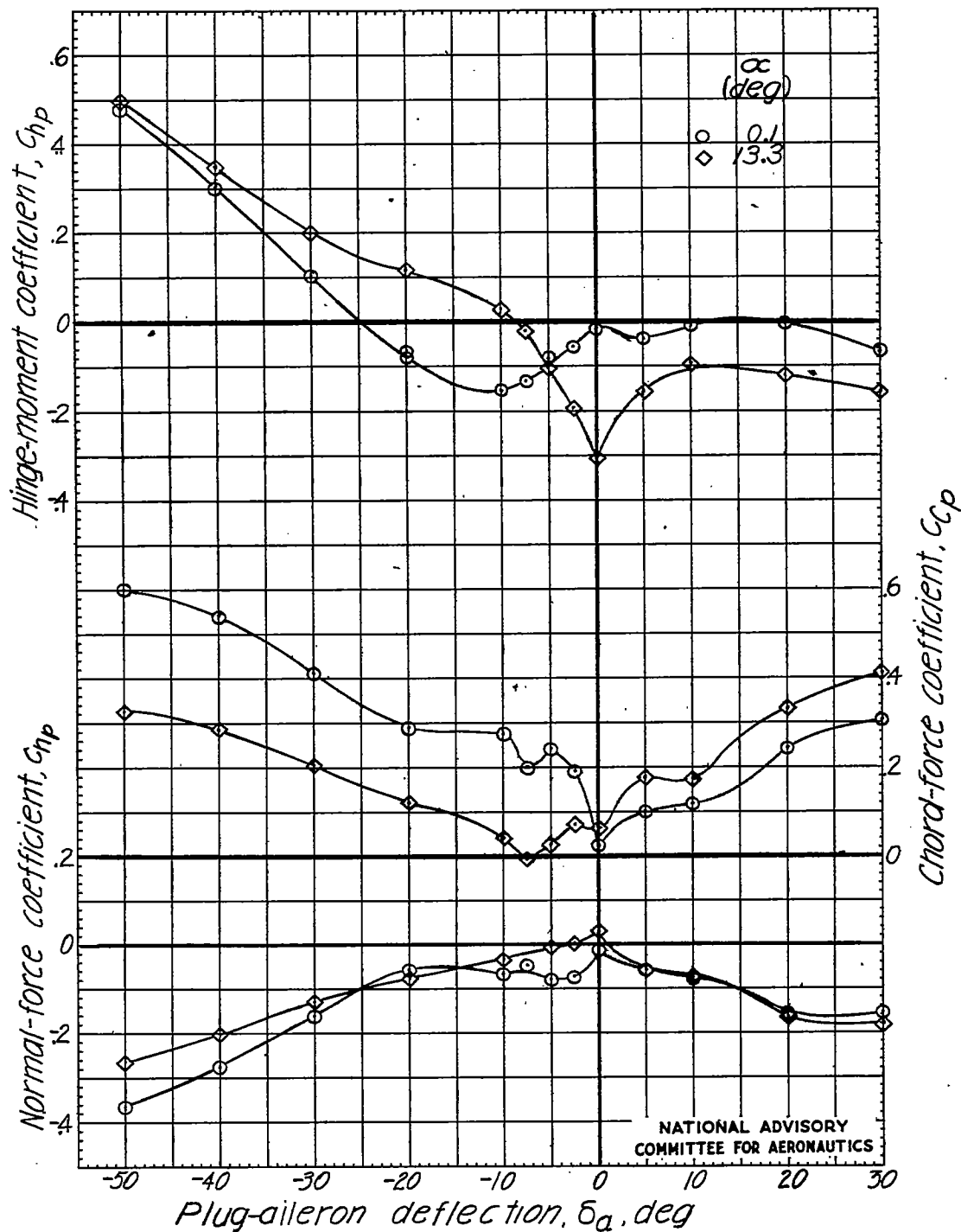


Figure 38.- Characteristics of plug aileron 2 on tapered wing model with full-span slotted flaps.  $\delta_f = 0^\circ$ .

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