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WIND-TUNNEL INVESTIGATION OF CONTROL-SURFACE CHARACTERISTICS

XI - VARIOUS LARGE OVERHANG AND INTERNAL-TYPE AERODYNAMIC BALANCES FOR A STRAIGHT-CONTOUR FLAP ON THE NACA 0015 AIRFOIL

By Richard I. Sears and H. Page Hoggard, Jr.

Langley Memorial Aeronautical Laboratory
Langley Field, Va.

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ADVANCE RESTRICTED REPORT

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WIND-TUNNEL INVESTIGATION OF CONTROL-SURFACE CHARACTERISTICS

XI - VARIOUS LARGE OVERHANG AND INTERNAL-TYPE AERODYNAMIC BALANCES FOR A STRAIGHT-CONTOUR FLAP ON THE NACA 0015 AIRFOIL

By Richard I. Sears and H. Page Hoggard, Jr.

SUMMARY

Force-test measurements in two-dimensional flow have been made in the NACA 4- by 6-foot vertical tunnel to determine the characteristics of several different shaped overhang-type aerodynamic balances applied to a straight-contour flap mounted on an NACA 0015 airfoil. The chord of the flap was 30 percent of the airfoil chord and the chord of the overhang was 50 percent of the flap chord. Cover plates of several widths were used to cover partly the break in airfoil contour caused by the sharp-nose overhang.

The flap with blunt-nose overhang was overbalanced throughout certain ranges of flap deflection. The hinge-moment characteristics were improved at the expense of increased drag by sharply tapering the nose profile of the overhang. The hinge-moment characteristics of a flap with a long sharp-nose overhang can be nearly reproduced by using a somewhat shorter blunt-nose overhang.

The addition of cover plates over the nose of the flap having a long overhang of sharp profile materially reduced the drag of the airfoil with uncovered flap overhang. Unless the gap at the flap nose was sealed, the addition of cover plates caused the lift available for control to be less than for the same flap without cover plates. The addition of cover plates adversely affected the hinge-moment characteristics of the flap with sharp-nose overhang unless the air leak through the gap at the flap nose was sealed. This fact is particularly evident for the widest cover plates.

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INTRODUCTION

The NACA has instituted an extensive investigation of the section aerodynamic characteristics of various flap arrangements in an effort to determine the types best suited for control surfaces and to supply experimental data for design purposes. The results of this investigation that relate to the present report are given in the references.

This paper presents the aerodynamic characteristics of an NACA 0015 airfoil with a straight-contour flap having a chord 30 percent of the airfoil chord (0.30c) and an overhang of various nose shapes that is 50 percent of the flap chord ($0.50c_f$). Cover plates of three widths and gaps of four sizes at the flap nose were tested with the sharp-nose balance.

A blunt-nose balance was first investigated and gave values of flap hinge-moment coefficient that showed overbalance at negative angles of attack. Several balances of more tapered profile were then tested and found to have improved flap hinge-moment characteristics. The increased drag, due to the break in the airfoil contour caused by the tapered-profile balance, was, however, excessive and led to the use of cover plates in an effort to reduce the drag by partially covering the break in the airfoil contour. Cover plates of several widths and gaps of several sizes at the flap nose were tested to determine the aerodynamic characteristics of these airfoil-flap combinations.

APPARATUS AND MODEL

The tests were made in the NACA 4- by 6-foot vertical tunnel (reference 1). The test section of this tunnel has been converted from the original open, circular, 5-foot-diameter jet to a closed, rectangular, 4- by 6-foot throat for force tests of models in two-dimensional flow. A three-component balance system has been installed in the tunnel to measure lift, drag, and pitching moments. The hinge moments of the flap were measured with a special torque-rod balance built into the model.

The 2-foot-chord by 4-foot-span model was made of laminated mahogany to a modified NACA 0015 contour. (See table I.) The modified airfoil was of NACA 0015 contour

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forward of the 0.70c station and had a straight contour from the 0.70c station to the trailing edge, which has the same thickness as the unmodified NACA 0015 airfoil.

The various balance-nose shapes (fig. 1) were made as interchangeable blocks and were fastened to the flap with screws. The model was cut at the 0.50c station and the space from this cut to the flap nose was filled with interchangeable tail blocks. In this way it was possible to vary the gap at the balance nose by using tail blocks of varying chordwise length.

The 1/16-inch steel cover plates were rolled to approximate the airfoil contour and were made in three widths. The narrow plates covered one-half the distance from the rear outer edge of the tail block to the flap hinge axis measured along the chord line (fig. 1). The medium plates covered three-fourths the distance; the wide plates, seven-eighths the distance. The distance from the trailing edge of these plates to the flap hinge axis was 0.072c, 0.036c, and 0.018c for the narrow, the medium, and the wide cover plates, respectively.

Because of the shape of the sharp-nose balance, the distance from the trailing edge of the cover plate normal to the sharp-nose balance varies with flap deflection (fig. 2). This distance is referred to in this paper as the "vent width." When the flap is not deflected, the vent width is 0.0052c with the wide cover plates in place, 0.0130c with the medium cover plates, and 0.0260c with the narrow cover plates. The vent width varies inversely with the width of the cover plates. With flap neutral, the ratio of the gap at the flap nose to the width of the vent for the various arrangements tested is given in table II.

For tests with the gap at the flap nose sealed, a rubber-sheet seal was attached to the nose and the ends of the sharp-nose balance and to the tail block and the end plates of the airfoil. Care was taken to keep the rubber sheet slack enough to prevent interference with the readings of flap hinge moment at all flap deflections.

The model, when mounted in the tunnel, completely spanned the test section. With this type of installation, two-dimensional flow is approximated and the section characteristics of the airfoil and flap may be determined. The model was attached to the balance frame by torque tubes that extended through the sides of the tunnel. The angle of attack was set

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from outside the tunnel by rotating the torque tubes with an electric drive. Flap deflections were set inside the tunnel by templets and were held by a friction clamp on the torque rod that was used in measuring the hinge moments.

TESTS

The NACA 0015 airfoil model with a 0.30c straight-contour flap was tested with a $0.50c_f$ blunt-nose balance on the flap. Several modifications of the blunt-nose balance (fig. 1) were tested to determine the effect of sharper nose shapes on the flap hinge-moment characteristics.

Only the flap hinge moment was read when the flap was tested with the blunt- and the modified-nose balances. The values of lift, drag, pitching moment, and flap hinge moment were read when the sharp-nose balance was tested both with and without cover plates.

The tests were made at a dynamic pressure of 15 pounds per square foot, which corresponds to an air velocity of about 76 miles per hour at standard sea-level conditions. The effective Reynolds number of the tests was approximately 2,760,000. (Effective Reynolds number = test Reynolds number × turbulence factor. The turbulence factor for the 4- by 6-foot vertical tunnel is 1.93.)

The blunt-nose flap was set at deflections from 0° to 30° in 5° increments. The modified- and sharp-nose shapes were set at deflections of 0°, 2°, 5°, 10°, 15°, and 20°. With the narrow cover plates in place, the deflections were the same but, with the medium and the wide cover plates, it was not possible to reach 20° before the rear portion of the flap-nose balance touched the trailing edge of the cover plate. The maximum deflections were thus limited to 15° for the tests with the medium and the wide cover plates.

The blunt-, modified-, and sharp-nose flaps were tested with a 0.005c gap throughout the deflection range. For each flap deflection, force tests were made throughout the angle-of-attack range at 2° increments from negative stall to positive stall. When either stall position was approached, the increment was reduced to 1° angle of attack.

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RESULTS

Symbols

The coefficients and symbols used in this paper are defined as follows:

c_l	airfoil section lift coefficient (l/qc)
c_{d_o}	airfoil section profile-drag coefficient (d_o/qc)
c_m	airfoil section pitching-moment coefficient (m/qc^2)
c_{h_f}	flap section hinge-moment coefficient $(h_f/qc_f{}^2)$

where

l	airfoil section lift
d_o	airfoil section profile drag
m	airfoil section pitching moment about quarter-chord point of airfoil
h_f	flap section hinge moment
c	chord of basic airfoil with flap neutral
c_f	flap chord
q	dynamic pressure

and

α_o	angle of attack for airfoil of infinite aspect ratio
δ_f	flap deflection with respect to airfoil

also

$$c_{l_\alpha} = \left(\frac{\partial c_l}{\partial \alpha_o}\right)_{\delta_f}$$

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$$c_{l_{\alpha(\mathrm{free})}} = \left(\frac{\partial c_l}{\partial \alpha_0}\right)_{ch_f=0}$$

$$ch_{f_\alpha} = \left(\frac{\partial ch_f}{\partial \alpha_0}\right)_{\delta_f}$$

$$ch_{f_{\delta_f}} = \left(\frac{\partial ch_f}{\partial \delta_f}\right)_{\alpha_0}$$

$$\alpha_{\delta_f} = \left(\frac{\partial \alpha_0}{\partial \delta_f}\right)_{c_l}$$

The subscripts outside the parentheses indicate the factors held constant during the measurement of the parameters.

Precision

The accuracy of the data is indicated by the deviation from zero of lift and moment coefficients at an angle of attack of 0°. The maximum error in effective angle of attack at zero lift appears to be about ±0.2°. Flap deflections were set within ±0.2°. Tunnel corrections, experimentally determined in the 4- by 6-foot vertical tunnel, were applied only to lift. The hinge moments are probably slightly higher than would be obtained in free air and, consequently, the values presented are considered conservative. Relative values of drag should be reasonably independent of tunnel effect, although the absolute value is subject to an unknown correction.

Presentation of Data

Flap section hinge-moment coefficients as a function of angle of attack for a 0.30c straight-contour flap on the NACA 0015 airfoil having $0.50c_f$ blunt- and modified-nose balances are presented in figures 3 to 6. Section aerodynamic characteristics of the same airfoil and the same flap with a $0.50c_f$ sharp-nose overhang without cover plates are given in figure 7 and with cover plates of various sizes in figures 8

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to 19. Some of the data in figures 8 to 19 are replotted in figure 20 to show the effects of vent width and gap size on the variation of c_{h_f} with c_l throughout the range of flap deflections for three angles of attack. Aerodynamic parameters for the various combination of balance-nose shapes, gaps, and vent widths are presented in table III. The values of $c_{h_{f_{\delta_f}}}$ and $c_{h_{f_\alpha}}$ from table III are presented in figure 21 as a function of cover-plate width and gap size. Increments of minimum airfoil section profile-drag coefficient over that of the sealed plain flap on the same airfoil are given as a function of gap size and nose shape in figure 22 for the various cover-plate widths.

SECTION AERODYNAMIC CHARACTERISTICS

Lift

The slope of the lift curve (table III) for most of the control surfaces with cover plates (figs. 8 to 19), regardless of nose-gap condition, was greater than that of the control surface without cover plates (fig. 7) and with a 0.005c nose gap. The slope c_{l_α} tended to increase slightly as the cover plates were made wider and as the gap at the flap nose was reduced. In consideration of airplane stability with fixed control it appears, therefore, that wide cover plates over a long sharp-nose balance are desirable if the gap at the nose of the balance cannot be sealed. Previous data (references 2 and 3) indicate, however, that if the gap can be sealed c_{l_α} should be nearly the same with or without cover plates.

From the consideration of obtaining lift for control, the flaps with cover plates and sealed gap at the nose gave just about the same lift characteristics as the flap without cover plates and with a large nose gap. Of all the arrangements tested, the flap with shortest cover plate and sealed gap (fig. 8) gave the greatest shift in angle of zero lift for large flap deflections and the greatest lift at zero angle of attack. The lift effectiveness of the flap at small deflections α_{δ_f} showed a tendency to decrease as the nose gap was made larger (table III). These tests indicate, therefore, that unless the gap at the flap nose is sealed, the addition of cover plates over the nose of a flap with a long sharp overhang causes the lift available for control to be less than that of the same flap without cover plates. It

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is to be expected that decreasing the nose gap would improve the lift characteristics of the flap without cover plates.

It should be noted that the maximum deflection of the flap, which largely determines the maximum shift in angle of zero lift, is limited to 20° by the cover plates. If the design of the flap-nose shape were altered, the flaps with medium and with wide cover plates could be deflected 20°. Previous data for a thinner airfoil (references 3 and 4) indicate that, without cover plates, a flap with a long sharp-nose overhang is effective when deflected 5° or 10° beyond the unporting angle (20° in this case) if the flap deflection and the angle of attack are of opposite sign. The use of cover plates may, therefore, impose undesirable restrictions on the maximum lift that can be obtained by the elevator for landing or by the rudder for causing sideslip.

The slopes of the lift curve with flap free have been computed from other slopes measured from the data presented and are given in table III. In every case the addition of cover plates over the sharp-nose overhang caused this slope to be less than the slope for the same flap without cover plates because the flap with cover plates had a large value of $c_{h_{f_\alpha}}$ or a small value of $c_{h_{f_{\delta_f}}}$. These results indicate, therefore, that the control-free stability of the airplane should be less for the control surface equipped with cover plates of the type tested than for the same flap without cover plates.

Flap Hinge Moments

The hinge-moment parameters $c_{h_{f_\alpha}}$ and $c_{h_{f_{\delta_f}}}$ for all the control-surface arrangements tested are shown in table III. The tabulated values were measured at 0° angle of attack and 0° flap deflection and are, therefore, applicable over only the small range in which the curves are linear. The parameters are, however, indicative of the relative merits of the various balance arrangements.

The flap-nose overhang without cover plates (figs. 3 to 7) developed its greatest balancing moments when the flap deflection and the angle of attack were of opposite sign. This effect is typical of the flap-nose-overhang type of aerodynamic balance. The shape of the flap nose had a marked

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effect on the magnitude of the balancing moment. For positive flap deflection, the blunt-nose shape gave pronounced overbalance at negative angles of attack but gave relatively little balance at positive angles of attack. As the flap-nose shape was tapered, the flap became less overbalanced at negative angles of attack but, at positive angles of attack, the hinge-moment characteristics remained nearly the same. The nose shapes for the $0.50c_f$ overhang, which gave reasonably acceptable hinge-moment curves (figs. 6 and 7), gave hinge-moment characteristics substantially the same as those for the $0.35c_f$ blunt-nose overhang (reference 5). Hence these results tend to indicate that hinge-moment characteristics of a large flap-nose overhang of tapered profile can be nearly reproduced by a smaller nose overhang of blunt profile. A rudder with a long sharp-nose overhang should have slightly less tendency toward rudder lock in a forced sideslip and should require slightly less pedal force to hold zero sideslip under unsymmetrical power conditions than a rudder with a shorter blunt-nose overhang.

In an effort to decrease the drag of the sharp-nose overhang, cover plates of various widths were fitted over the nose of the balance. This arrangement caused the aerodynamic balance to resemble an internal balance both in form and in hinge-moment characteristics (figs. 8 to 19). The extent to which this resemblance occurred varied directly with the width of the cover plates. The widest plates gave characteristics most nearly like those of an internal balance; whereas the narrowest cover plates gave characteristics more nearly like those of the uncovered sharp-nose balance.

With a sealed gap at the nose of the balance, the pressure on that part of the balance nose under the cover plates is expected to be the same as that existing on the airfoil surface at the rearward edge of the cover plate. The distribution of resultant pressure over the surface of an airfoil in two-dimensional flow is discussed in reference 6. From the experimental data presented in this reference, it can be seen that the rate of change of resultant pressure with angle of attack increases toward the nose of the airfoil and that the rate of change of resultant pressure with flap deflection increases toward the flap hinge axis. As was expected with a sealed gap at the nose of the balance, the balance with the widest cover plates, which was effectively vented nearest the hinge axis, thus gave the smallest value of $c_{h_{f_{\delta_f}}}$ and the largest value of $c_{h_{f_\alpha}}$ (table III). The balance with

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the narrowest cover plates, which was effectively vented nearest the airfoil nose, gave the largest value of $c_{h_{f_{\delta_f}}}$ and the smallest value of $c_{h_{f_\alpha}}$.

The effect of increasing the gap or leak at the nose of the balance was to decrease the effectiveness of the balance (fig. 21). For the balance with wide cover plates, both $c_{h_{f_\alpha}}$ and $c_{h_{f_{\delta_f}}}$ were considerably increased; but, for the narrowest cover plates, the effect of nose gap was much smaller, this arrangement being more nearly like an overhang without cover plates. Figure 20 illustrates the effects of a leak through the nose gap on both the lift and the hinge moments of the flap with cover plates of various sizes.

The hinge-moment characteristics of the various sealed internal balances were computed from the pressure-distribution data presented in reference 6. These data were arbitrarily corrected for change in airfoil thickness by the ratio of the hinge-moment slopes for a plain flap on the NACA 0015 and on the NACA 0009 airfoils. The calculated hinge-moment characteristics were in fair agreement with the test results for the cover plates of various widths when the pressure acting on the balance was assumed to be that at the rearward edge of the cover plate.

The test results tend to indicate that the addition of cover plates over a long sharp-nose overhang to form an internal balance adversely affects the hinge-moment characteristics of the control surface unless the air leak through the nose gap is sealed. This fact was particularly evident for wide cover plates. The shortest cover plates with the smallest nose gap gave hinge-moment characteristics nearly the same as those of the sharp overhang without cover plates. Subsequent tests indicate that the exact position of the cover plates, that is, whether they lie exactly on the airfoil contour or are bent slightly in or out, has a critical effect on the hinge-moment characteristics.

Pitching Moment

The slopes of the curves of pitching moment as a function of lift at constant angle of attack and at constant flap deflection are given in table III. The aerodynamic center of the lift due to angle of attack was at approximately the 0.23c station for the airfoil having a sharp-nose flap both with and without cover plates. The aerodynamic center of the lift due

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to flap deflection was at about the 0.41c station for the airfoil with cover plates and a sealed gap at the flap nose. With an unsealed gap or without cover plates, the aerodynamic center shifted slightly farther rearward. The position of the aerodynamic center of the lift caused by changing the effective camber of an airfoil is a function of aspect ratio (reference 7) and moves toward the trailing edge as the aspect ratio is decreased.

Drag

Because of the unknown tunnel correction, the values of drag coefficients cannot be considered absolute; the relative values should, however, be independent of tunnel effect. No drag measurements were made on the blunt- or modified-nose balances but their minimum profile-drag coefficient values will probably be between the value (reference 2) of 0.0135 for the $0.50c_f$ blunt-nose balance and the value of 0.0162 for the sharp-nose balance without cover plates.

The addition of the cover plates reduced the minimum profile-drag coefficient as was expected (fig. 22). The profile-drag coefficient decreased as the cover plates were made wider, presumably because the break in the airfoil contour between the cover-plate edge and flap hinge axis became smaller. The airfoil with the straight-contour plain flap had a minimum profile-drag coefficient of 0.0131 with gap sealed or unsealed (reference 8). From these results it is apparent that the addition of cover plates over a long sharp-nose overhang does decrease the minimum drag of the uncovered balance. The short cover plates reduce the drag of the sharp-nose balance to a value which is nearly the same as that of a blunt-nose balance of the same size. Wide cover plates give a still greater reduction in drag.

CONCLUSIONS

The results of tests of an NACA 0015 airfoil with a straight-contour flap having a chord 30 percent of the airfoil chord and several flap-nose overhangs 50 percent of the flap chord indicate the following general conclusions:

1. The addition of cover plates over the nose of a flap having a long overhang of sharp profile materially

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reduced the drag as compared with that of the uncovered overhang; the reduction in drag was greatest for the widest cover plates.

2. When the gap at the nose of a long sharp overhang was not sealed, the addition of wide cover plates increased the slope of the lift curve. With the gap sealed, however, the slope should be nearly the same with or without cover plates.

3. All arrangements of cover plates tested materially decreased the slope of the lift curve with controls free as compared with that for the sharp-nose flap without cover plates. The addition of cover plates should, therefore, decrease the control-free stability of an airplane with control surfaces having a long sharp-nose overhang.

4. Unless the gap at the flap nose was sealed, the addition of cover plates over the nose of a flap with a long sharp overhang caused the lift available for control to be less than for the same flap without cover plates and with a large nose gap. The addition of cover plates also restricted the maximum flap deflection.

5. The addition of cover plates over the nose of a flap with a long sharp-nose overhang adversely affected the hinge-moment characteristics unless the air leak through the gap at the flap nose was sealed.

6. The hinge moments of the flap with a large blunt-nose overhang were overbalanced throughout certain ranges of flap deflections. These characteristics were improved at the expense of increased drag by sharply tapering the nose profile of the overhang.

7. The hinge-moment characteristics of a flap having a long sharp-nose overhang can be nearly reproduced with a somewhat shorter nose overhang of blunt profile and at the same time the minimum drag can be appreciably decreased. A rudder with a long sharp-nose overhang should have slightly less tendency toward rudder lock in a forced sideslip and should require slightly less pedal force to hold zero sideslip under unsymmetrical power conditions than a rudder with a shorter blunt-nose overhang.

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TABLE I

ORDINATES FOR A MODIFIED NACA 0015 AIRFOIL WITH A 0.30c STRAIGHT-CONTOUR FLAP

[Stations and ordinates in percent of airfoil chord]

Station	Upper surface	Lower surface
0	0	0
1.25	2.37	-2.37
2.5	3.27	-3.27
5	4.44	-4.44
7.5	5.25	-5.25
10	5.85	-5.85
15	6.68	-6.68
20	7.17	-7.17
25	7.43	-7.43
30	7.50	-7.50
40	7.25	-7.25
50	6.62	-6.62
60	5.70	-5.70
70	4.58	-4.58
80	3.10	-3.10
90	1.63	-1.63
95	.90	-.90
100	(.16)	(-.16)
100	0	0

L. E. radius: 3.48

TABLE II

RATIO OF GAP TO VENT WIDTH AT ZERO FLAP DEFLECTION FOR NARROW, MEDIUM, AND WIDE COVER PLATES

Flap-nose gap	Gap/Vent width		
	Narrow cover plate	Medium cover plate	Wide cover plate
Sealed	0.00	0.00	0.00
0.0011c	.04	.08	.21
.0023c	.09	.18	.44
.0050c	.19	.38	.96

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TABLE III

PARAMETER VALUES FOR VARIOUS COMBINATIONS OF BALANCE-NOSE SHAPES, GAPS, AND COVER PLATES ON A 0.30c STRAIGHT-CONTOUR FLAP WITH A 0.50c_f BALANCE ON AN NACA 0015 AIRFOIL

Data from figure	Balance-nose shape	Gap	Cover plates	Parameters						
				$\left(\frac{\partial c_l}{\partial \alpha_0}\right)_{\delta_f}$	$\left(\frac{\partial \alpha_0}{\partial \delta_f}\right)_{c_l}$	$\left(\frac{\partial c_{h_f}}{\partial \alpha_0}\right)_{\delta_f}$	$\left(\frac{\partial c_{h_f}}{\partial \delta_f}\right)_{\alpha_0}$	$\left(\frac{\partial c_m}{\partial c_l}\right)_{\delta_f}$	$\left(\frac{\partial c_m}{\partial c_l}\right)_{\alpha_0}$	$\left(\frac{\partial c_l}{\partial \alpha_0}\right)_{free}$
2	Blunt	0.0050c	None	--------	--------	0.0028	0.0018	--------	--------	--------
3	Mod. 1	.0050c	None	--------	--------	.0005	.0000	--------	--------	--------
4	Mod. 2	.0050c	None	--------	--------	.0005	-.0010	--------	--------	--------
5	Mod. 3	.0050c	None	--------	--------	.0003	-.0029	--------	--------	--------
6	Sharp	.0050c	None	0.088	-0.49	-.0003	-.0052	0.017	-0.178	0.086
7	Sharp	Sealed	Narrow	.095	-.54	-.0012	-.0036	.015	-.160	.078
8	Sharp	0.0011c	Narrow	.093	-.50	-.0013	-.0032	.016	-.169	.074
9	Sharp	.0023c	Narrow	.089	-.46	-.0015	-.0039	.022	-.170	.073
10	Sharp	.0050c	Narrow	.087	-.43	-.0017	-.0042	.025	-.185	.072
11	Sharp	Sealed	Medium	.095	-.52	-.0013	-.0032	.018	-.155	.075
12	Sharp	0.0011c	Medium	.093	-.46	-.0026	-.0040	.022	-.170	.065
13	Sharp	.0023c	Medium	.093	-.46	-.0027	-.0040	.020	-.165	.064
14	Sharp	.0050c	Medium	.090	-.43	-.0021	-.0052	.023	-.173	.074
15	Sharp	Sealed	Wide	.097	-.53	-.0017	-.0030	.016	-.160	.068
16	Sharp	0.0011c	Wide	.093	-.48	-.0029	-.0045	.019	-.172	.066
17	Sharp	.0023c	Wide	.093	-.47	-.0034	-.0054	.020	-.162	.066
18	Sharp	.0050c	Wide	.093	-.46	-.0033	-.0056	.020	-.162	.068

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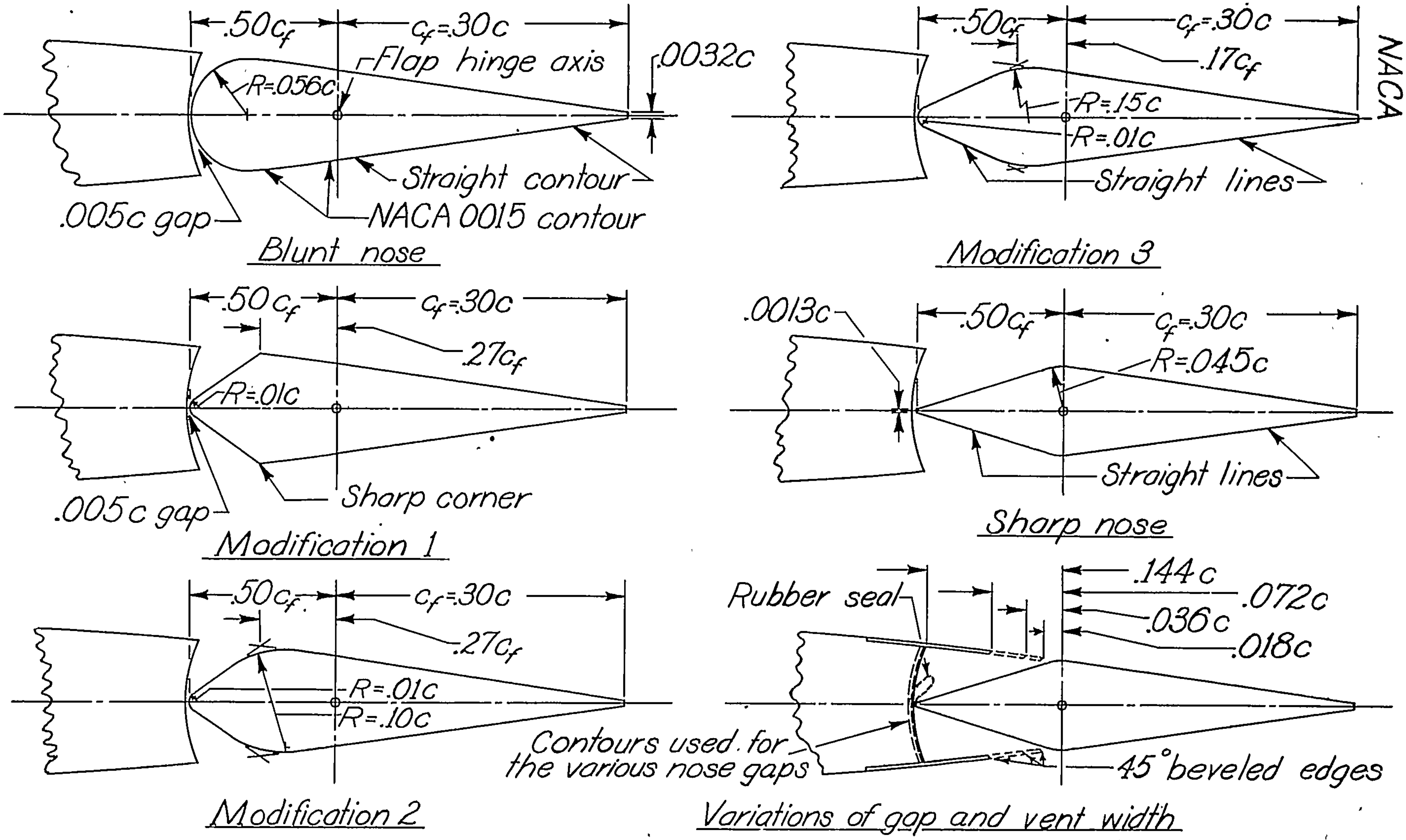

Blunt nose

Modification 3

Modification 1

Sharp nose

Modification 2

Variations of gap and vent width

Figure 1.- Details of several 0.50c_f balances tested on the 0.30c straight-contour flap of an NACA 0015 airfoil.

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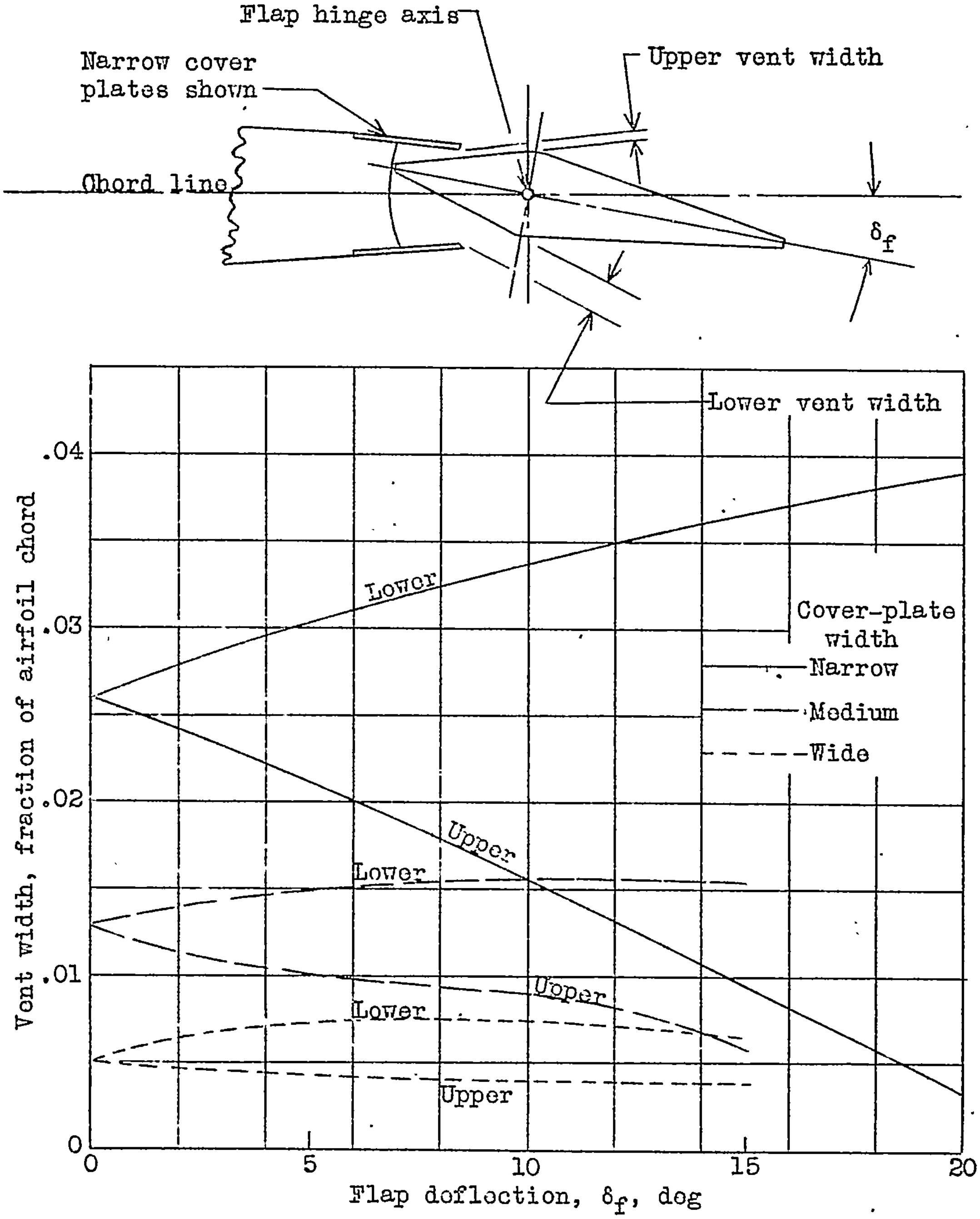

Figure 2.- Variation of upper and lower vent widths with flap deflection for the 0.30c flap with $0.50c_f$ sharp-nose balance on the NACA 0015 airfoil.

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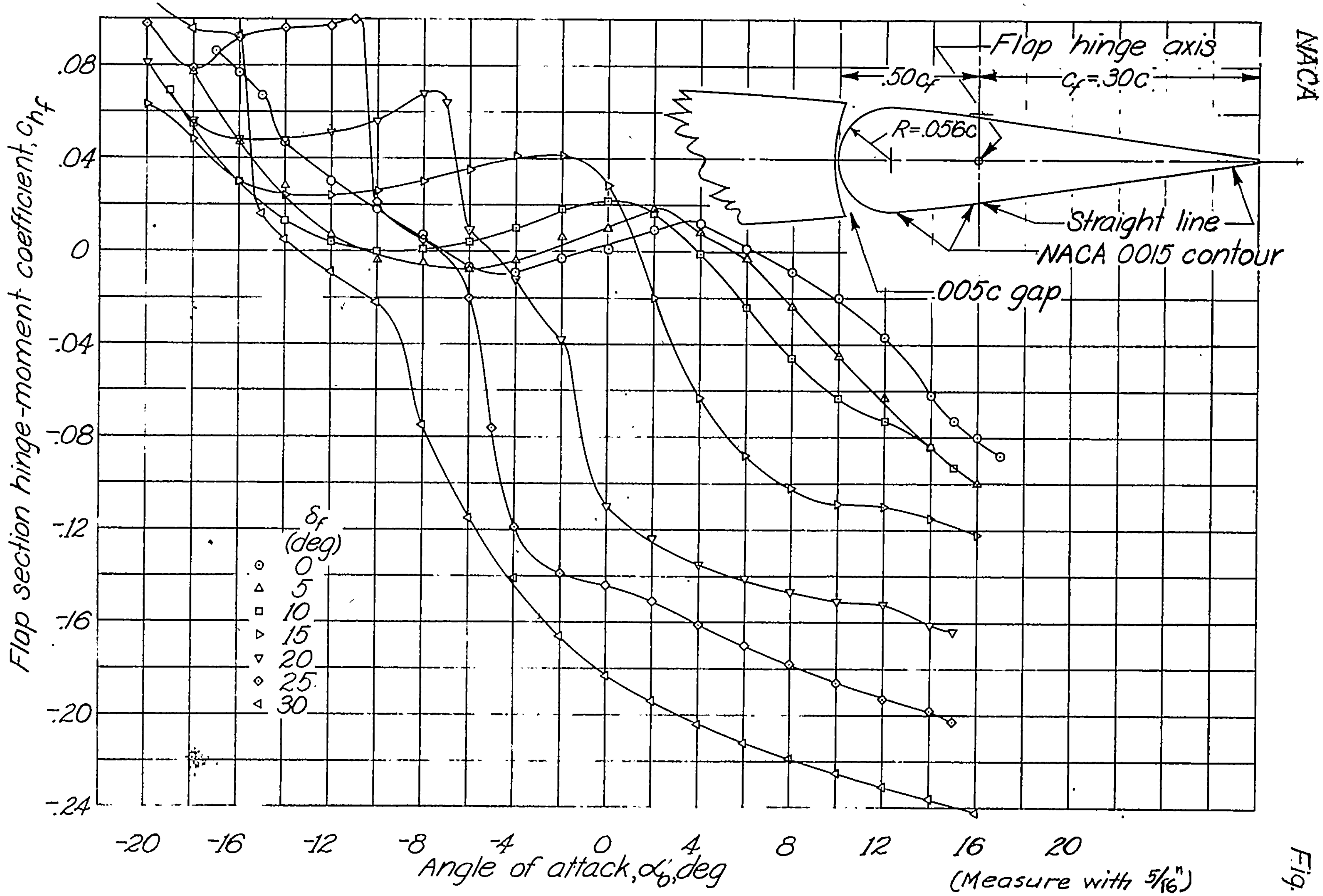

Figure 3 .- Flap section hinge-moment characteristics of an NACA 0015 airfoil with a 0.30c straight-contour flap having a 0.50c_f balance with blunt nose shape. 0.005c gap.

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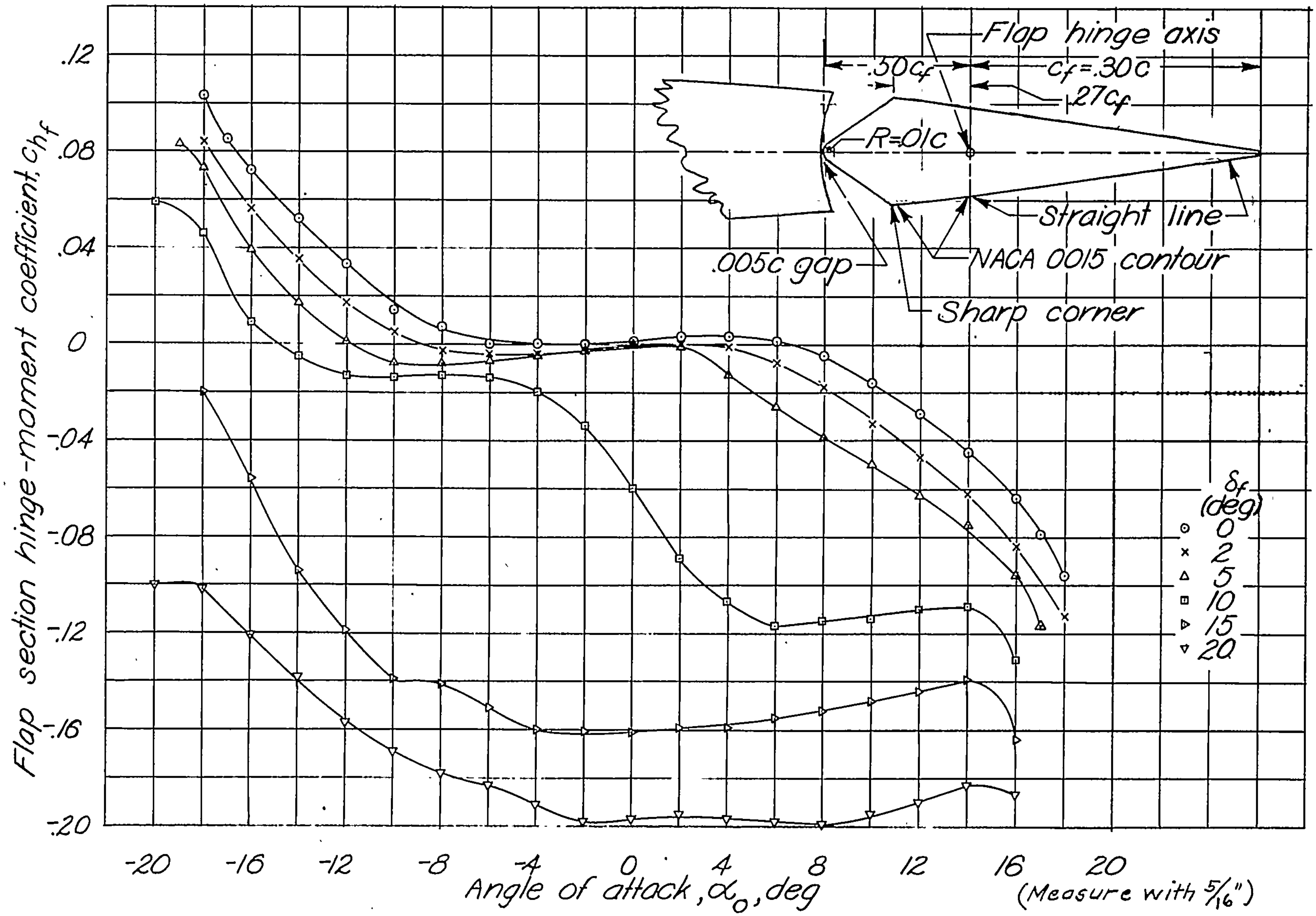

Fig. 4

Figure 4.-Flap section hinge-moment characteristics of an NACA 0015 airfoil with a 0.30c straight-contour flap having a 0.50c_f balance with modified blunt nose. Modification 1; 0.005c gap.

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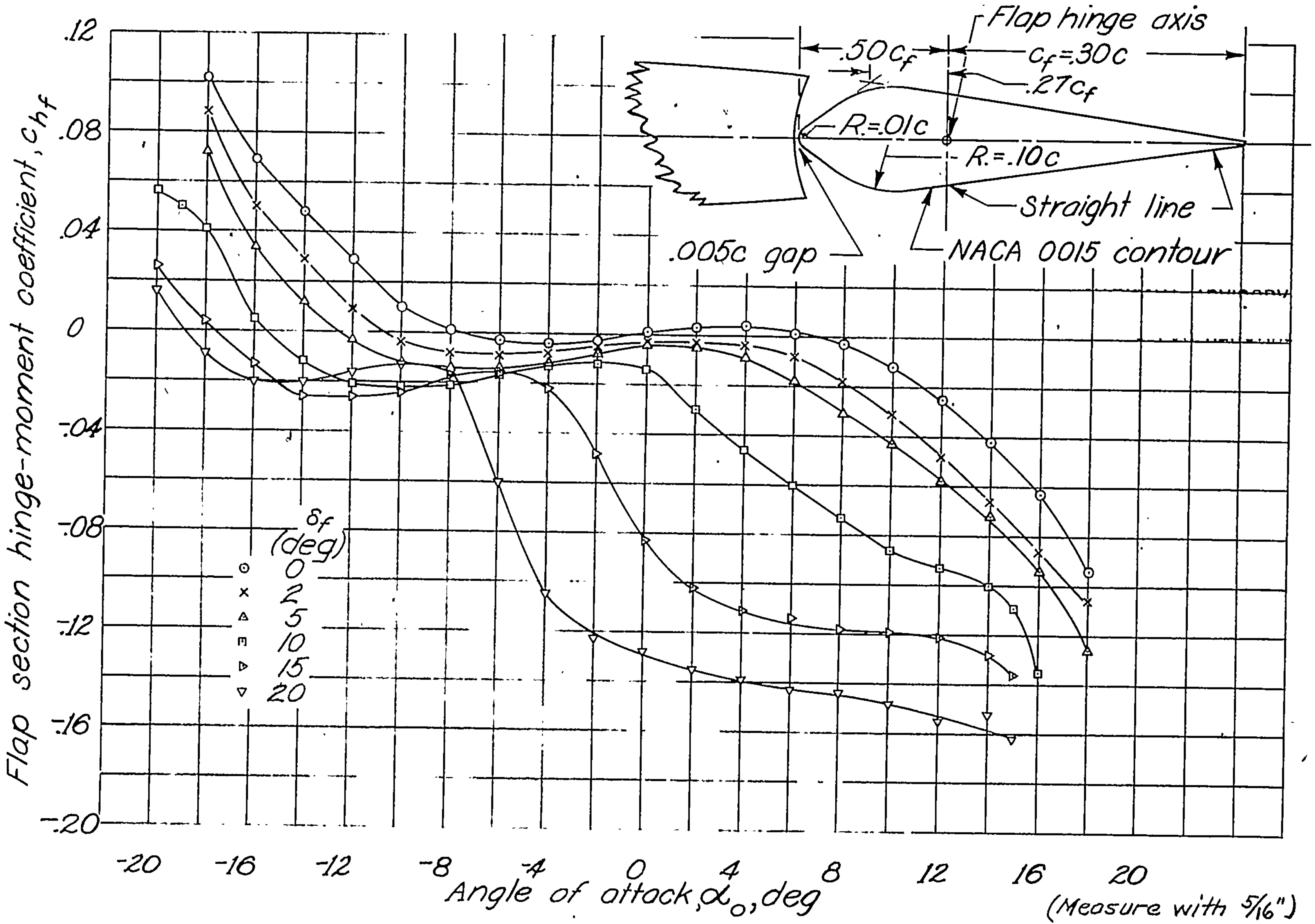

(Measure with 5/16")

Figure 5.- Flap section hinge-moment characteristics of an NACA 0015 airfoil with a 0.30c straight-contour flap having a 0.50c_f balance with modified blunt nose. Modification 2; 0.005c gap.

Fig. 5

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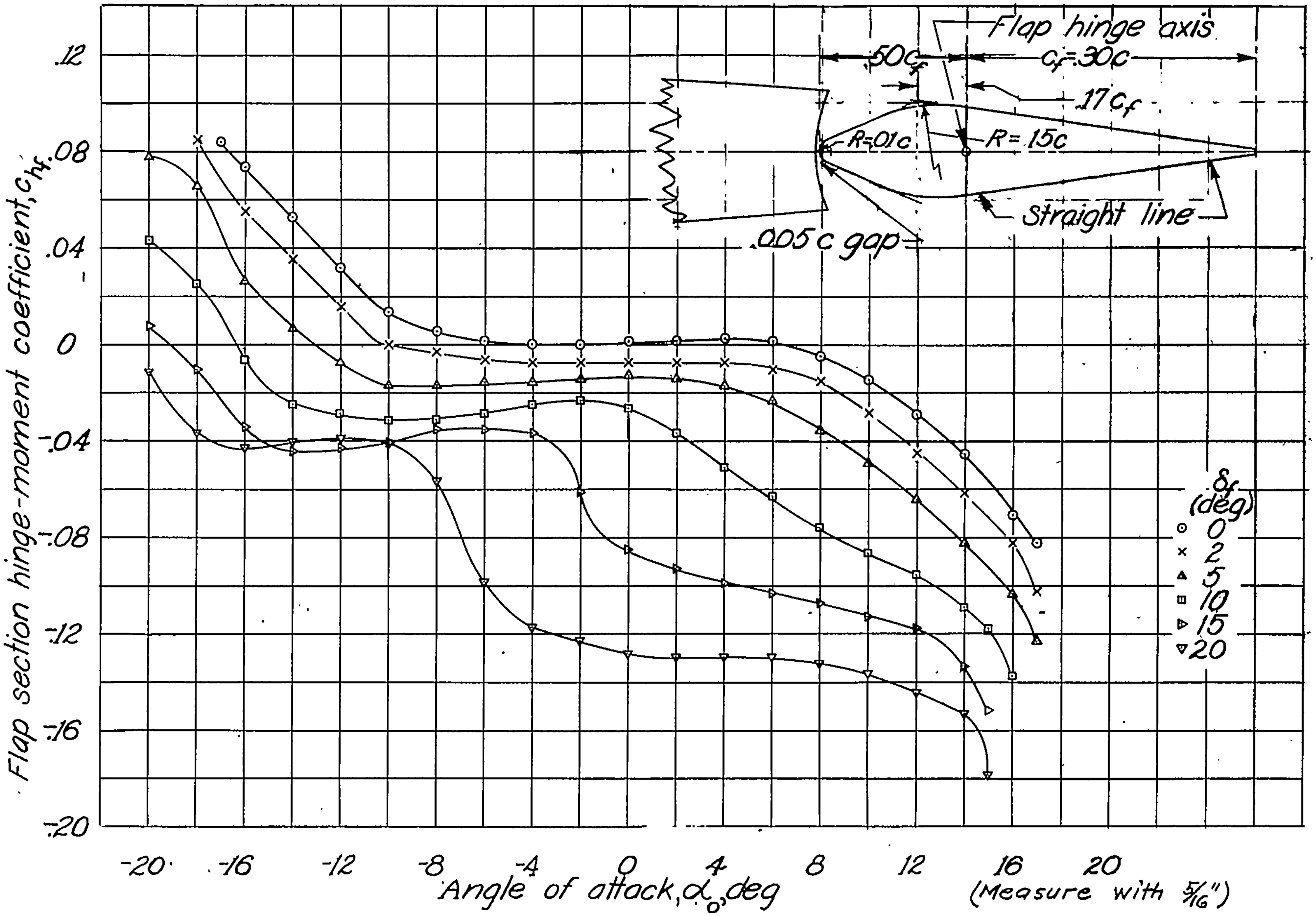

Figure 6.- Flap section hinge-moment characteristics of an NACA 0015 airfoil with a 0.30c straight-contour flap having a 0.50c_f balance with modified blunt nose. Modification 3; 0.005c gap.

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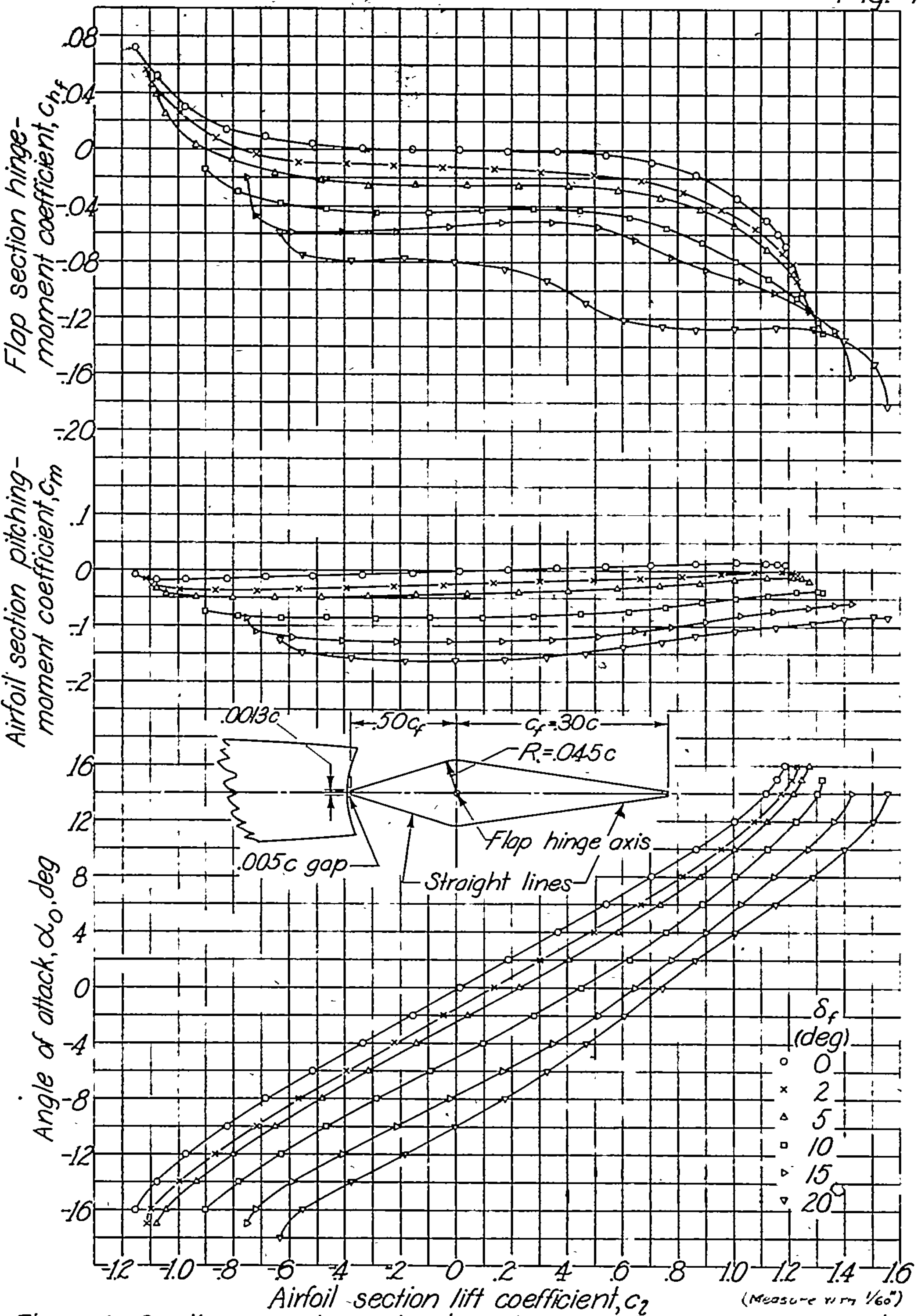

(Measure with 1/60")

Figure 7.-Section aerodynamic characteristics of an NACA 0015 airfoil with a 0.30c straight-contour flap having a 0.50c_f balance with sharp nose shape. 0.005c gap.

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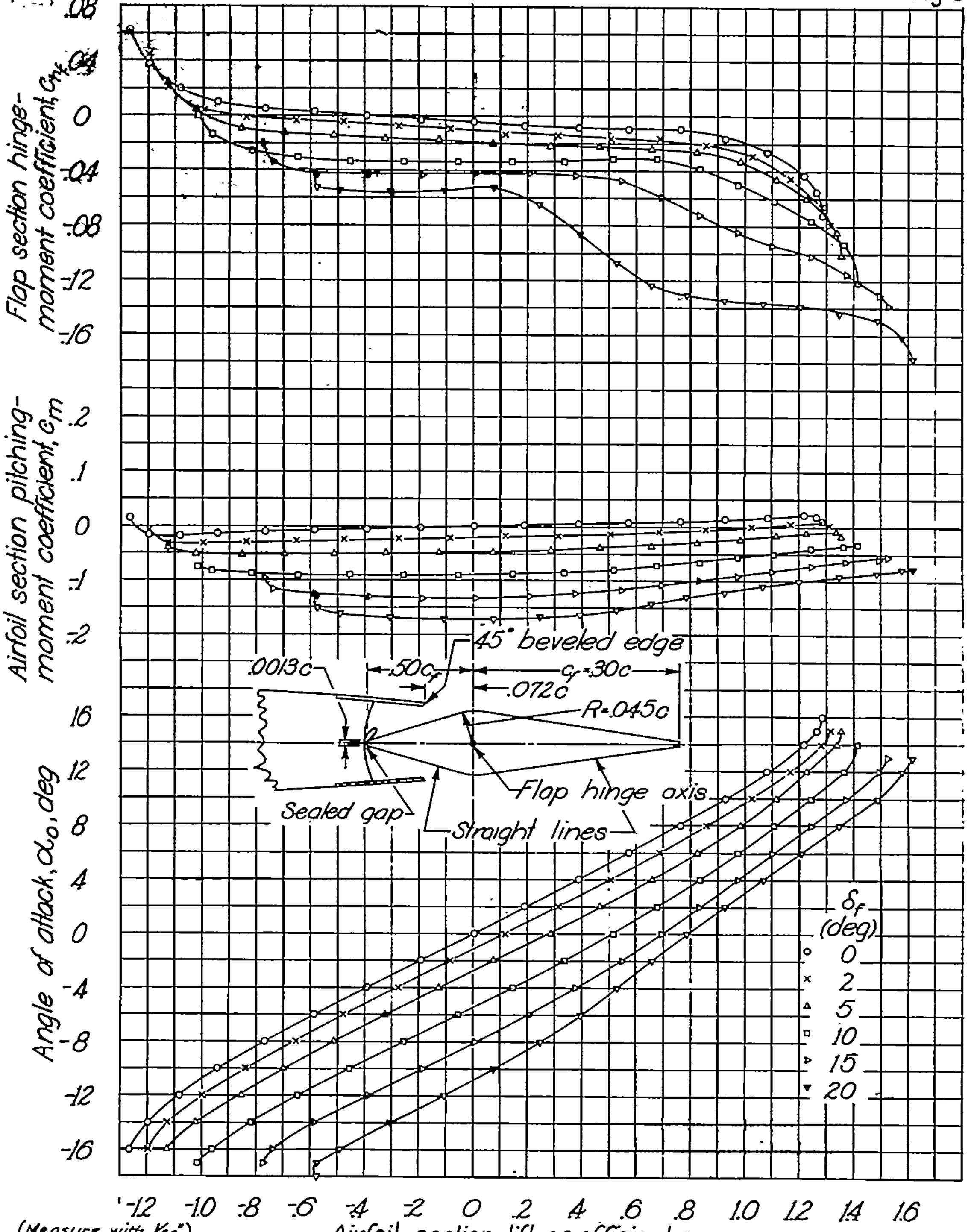

(Measure with 1/60")

Figure 8.- Section aerodynamic characteristics of an NACA 0015 airfoil with a 0.30c straight-contour flap having a 0.50c_f balance with sharp nose shape. Narrow cover plates; sealed gap.

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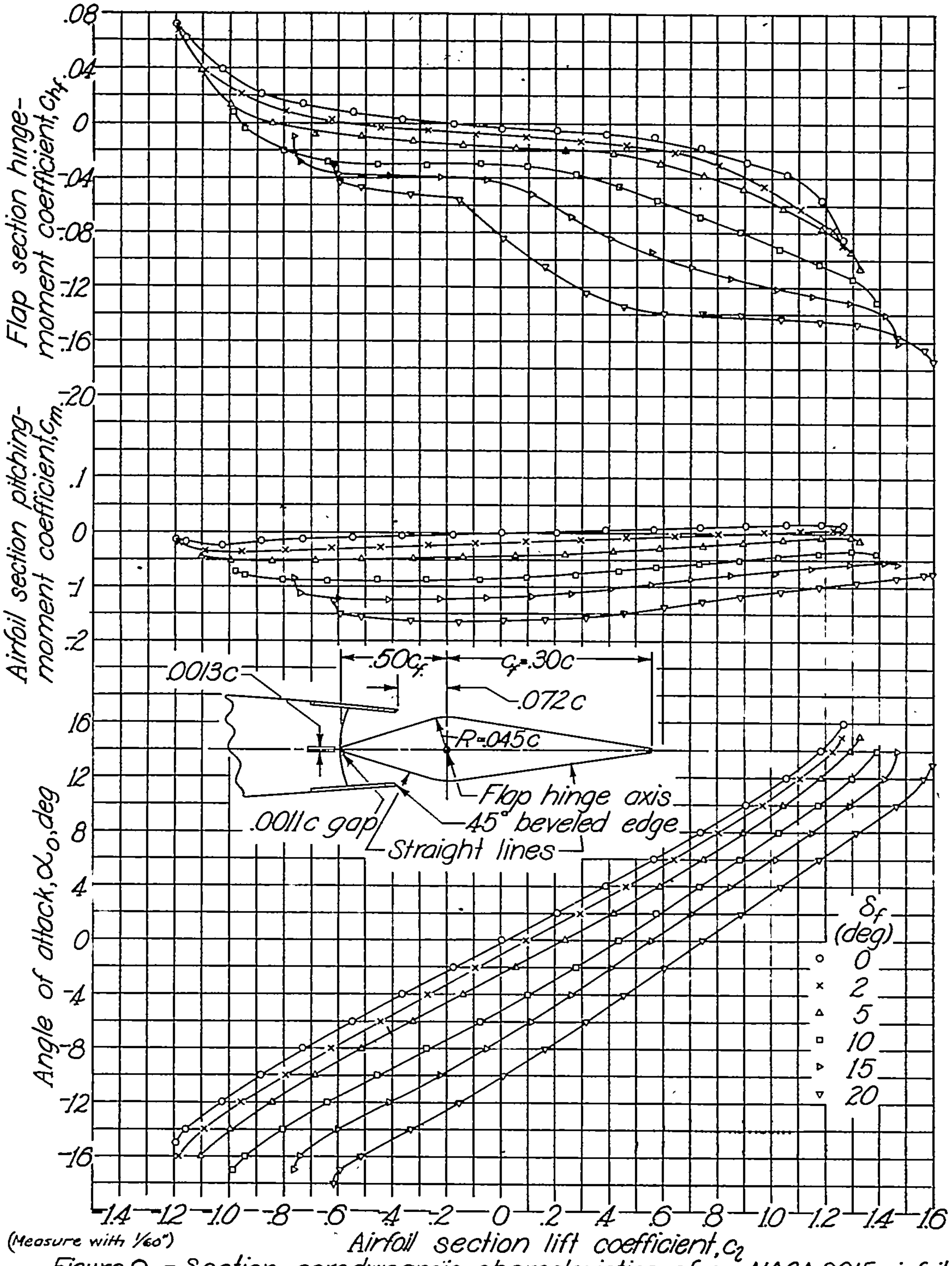

(Measure with 1/60")

Figure 9.- Section aerodynamic characteristics of an NACA 0015 airfoil with a 0.30c straight-contour flap having a 0.50 c_f balance with sharp nose shape. Narrow cover plates; 0.0011c gap.

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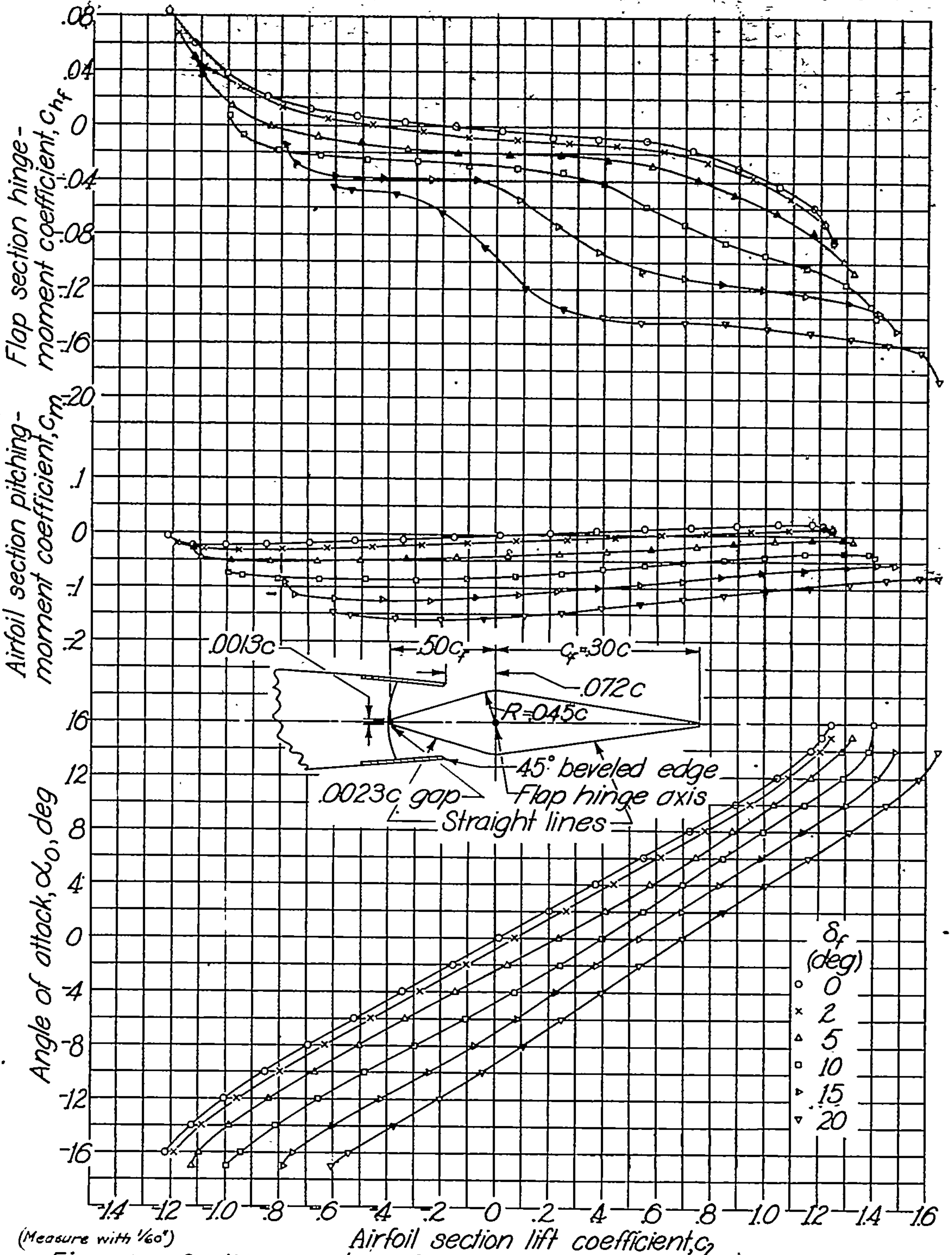

(Measure with 1/60")

Figure 10.- Section aerodynamic characteristics of an NACA 0015 airfoil with a 0.30c straight-contour flap having a 0.50c_f balance with sharp nose shape. Narrow cover plates; 0.0023c gap.

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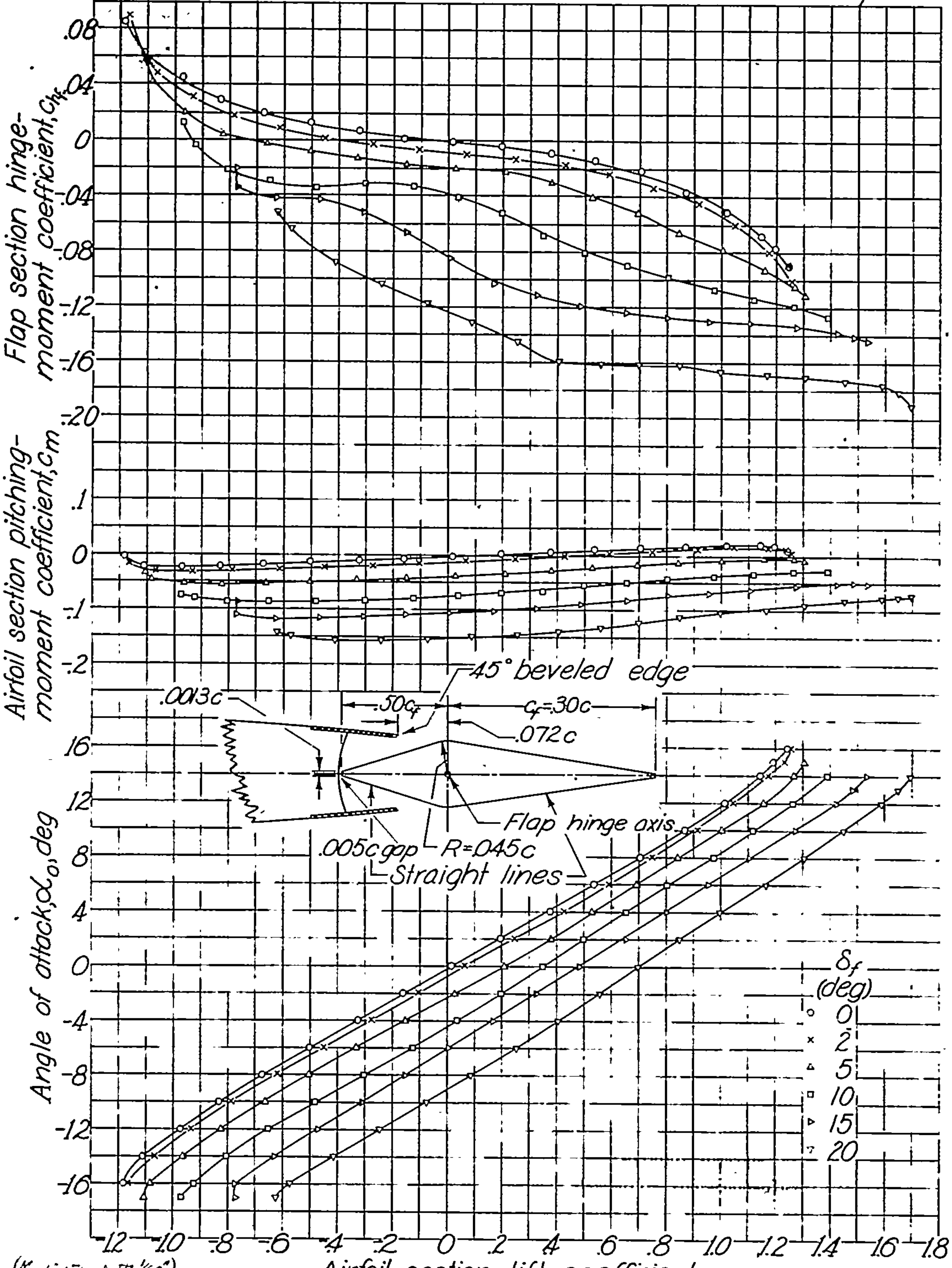

Figure 11.-Section aerodynamic characteristics of an NACA 0015 airfoil with a 0.30c straight-contour flap having a 0.50c_f balance with sharp nose shape. Narrow cover plates; 0.005c gap.

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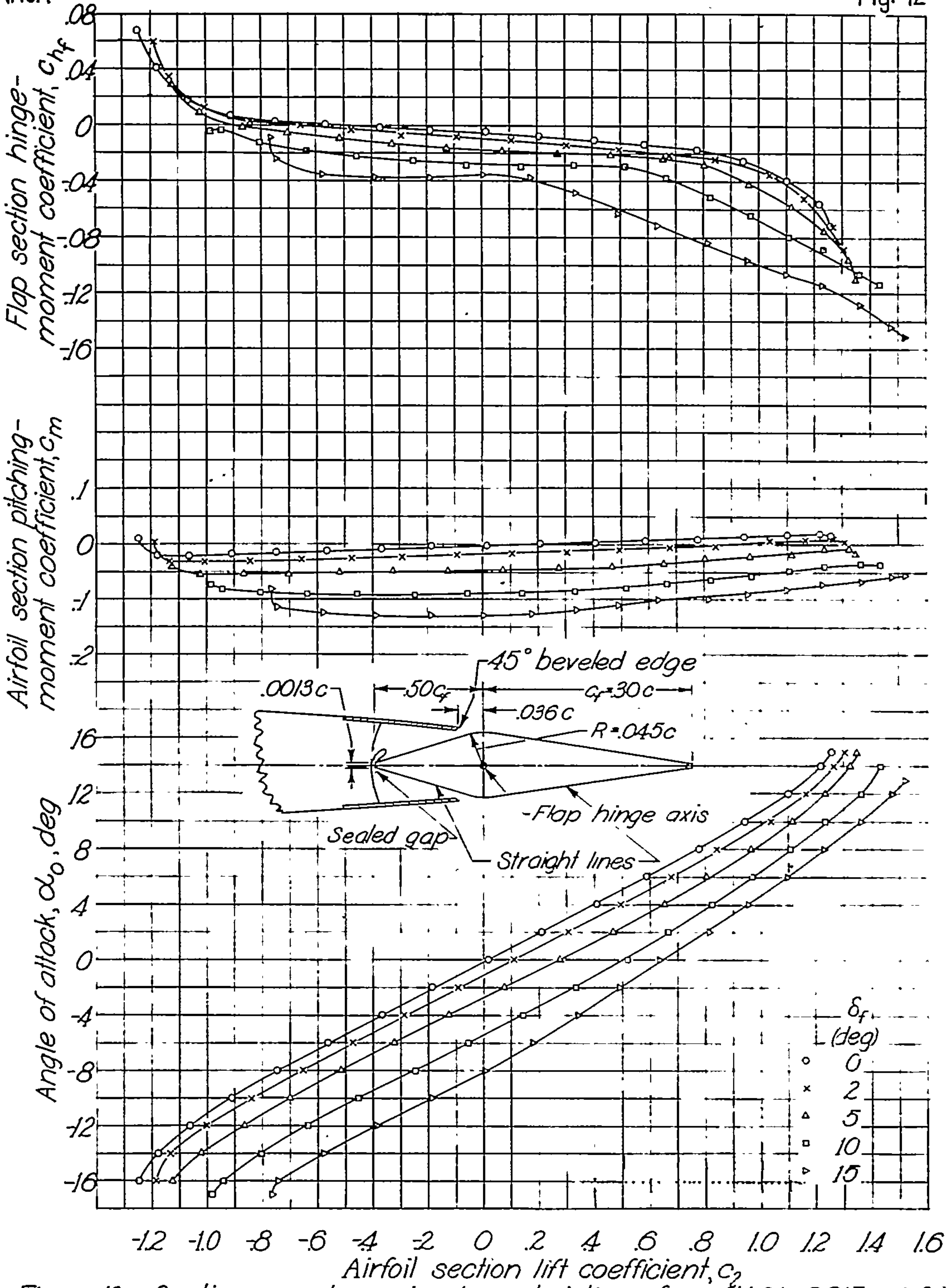

Figure 12.- Section aerodynamic characteristics of an NACA 0015 airfoil with a 0.30c straight-contour flap having a 0.50c_f balance with sharp nose shape. Medium cover plates; sealed gap

(Measured with 1/32")

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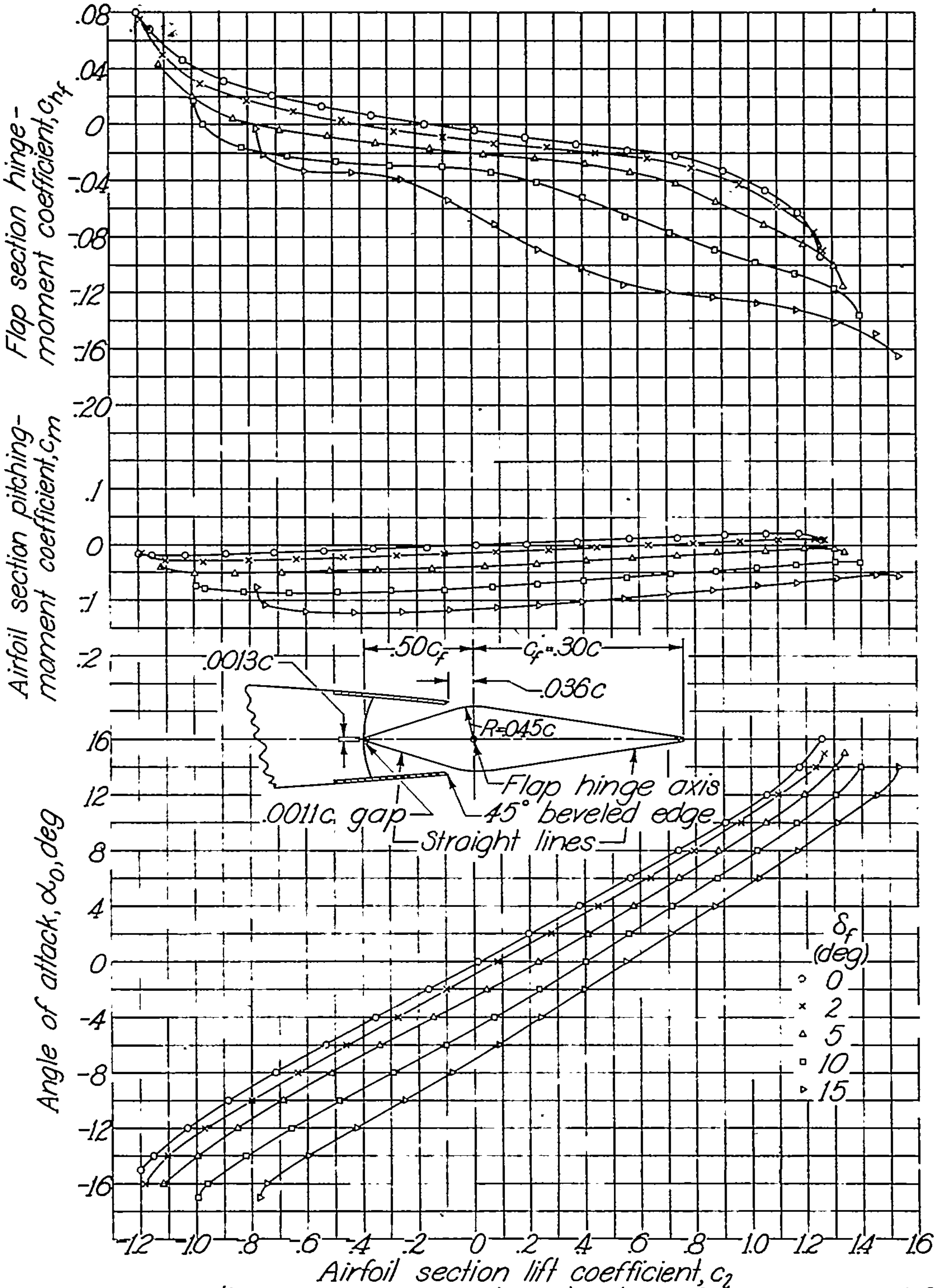

Figure 13.- Section aerodynamic characteristics of an NACA 0015 airfoil with a 0.30c straight-contour flap having a 0.50c_f balance with sharp nose shape. Medium cover plates; 0.0011c gap.

(Measure with 1/60")

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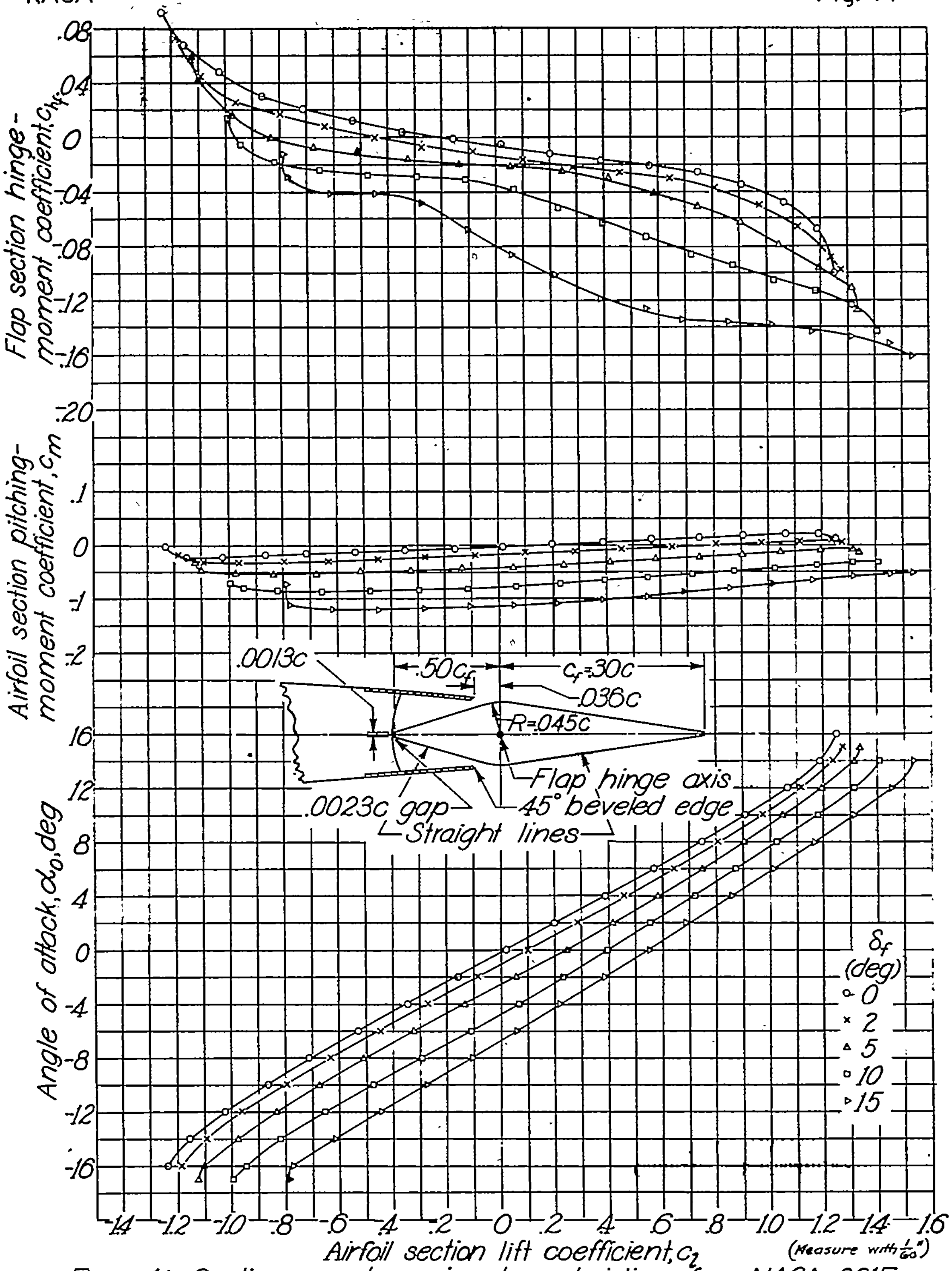

Figure 14.-Section aerodynamic characteristics of an NACA 0015 airfoil with a 0.30c straight-contour flap having a 0.50c_f balance with sharp nose shape. Medium cover plates; 0.0023c gap.

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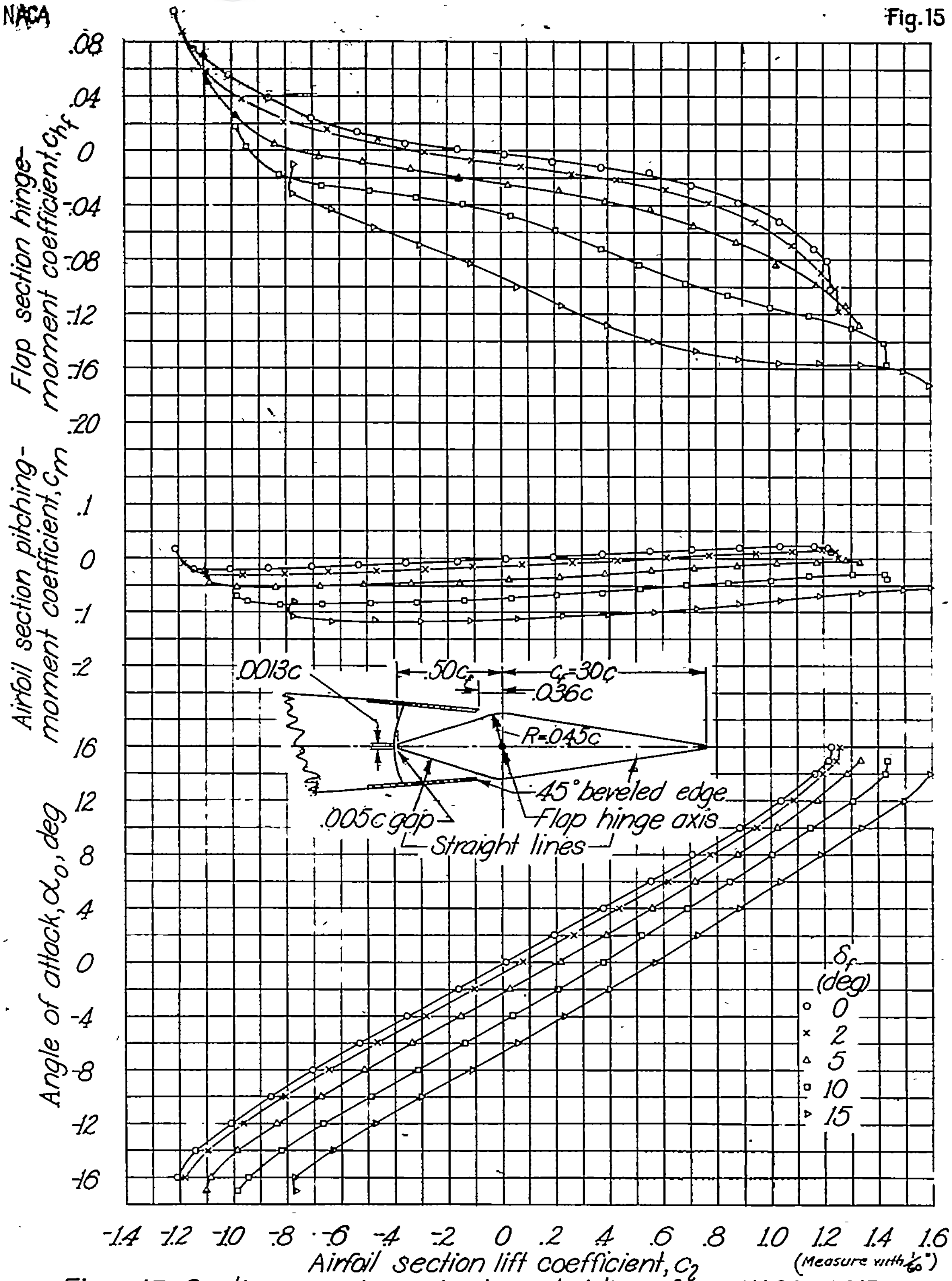

Figure 15.- Section aerodynamic characteristics of an NACA 0015 airfoil with a 0.30c straight-contour flap having a 0.50c_f balance with sharp nose shape. Medium cover plates; 0.005c gap.

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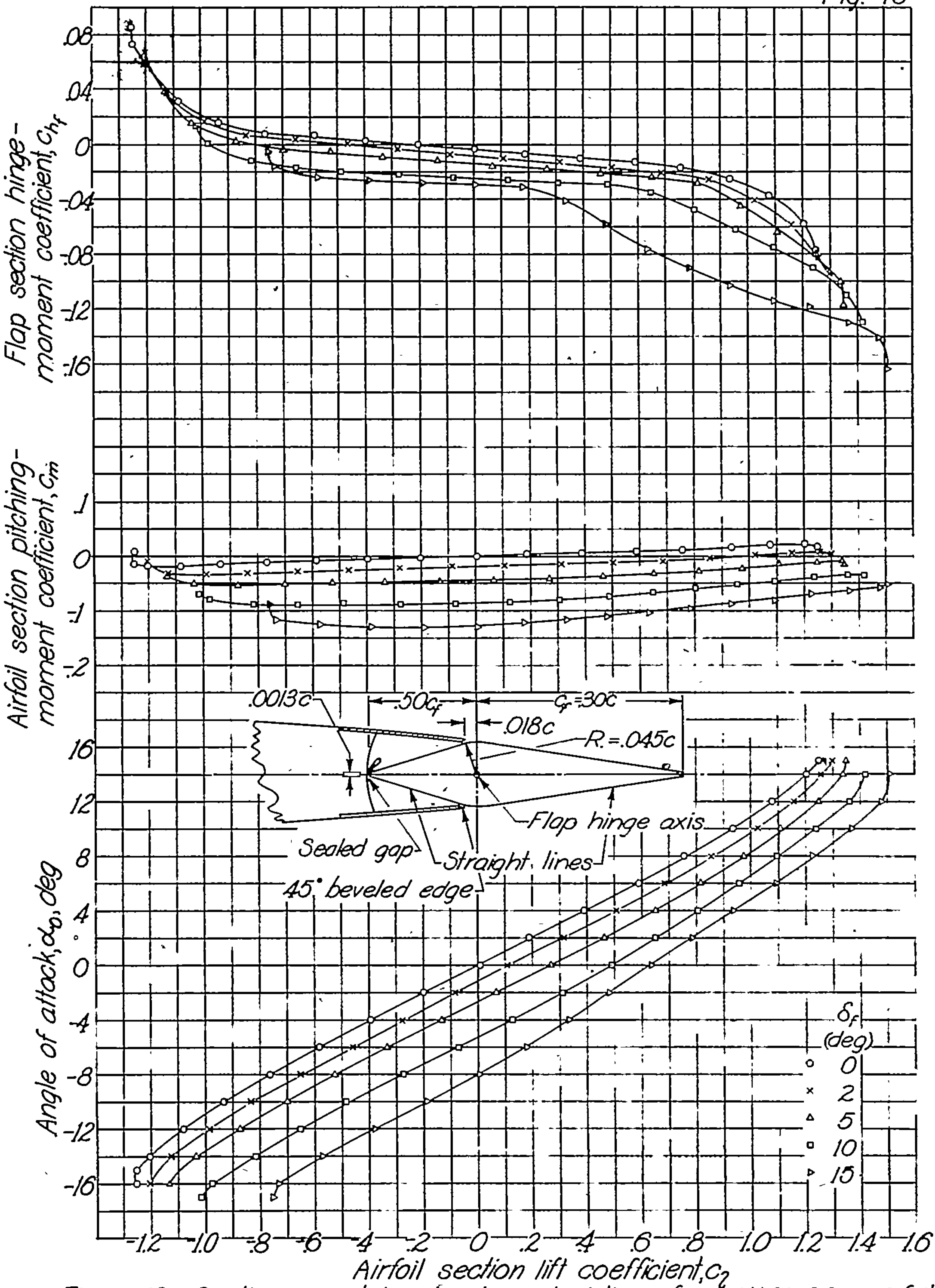

Figure 16.- Section aerodynamic characteristics of an NACA 0015 airfoil with a 0.30c straight-contour flap having a 0.50c_f balance with sharp nose shape. Wide cover plates; sealed gap.

(Measure with 1/60")

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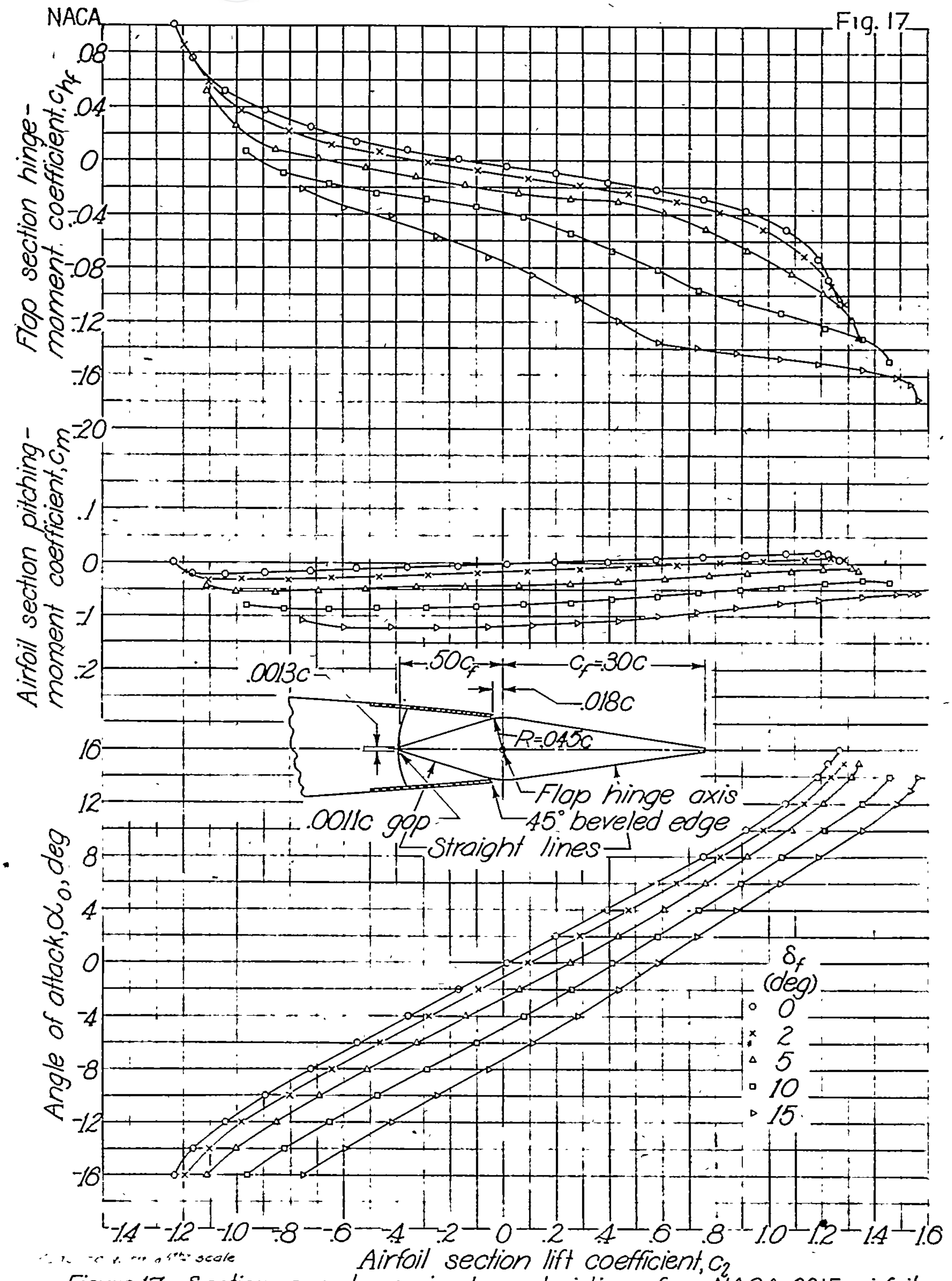

Figure 17.- Section aerodynamic characteristics of an NACA 0015 airfoil with a 0.30c straight-contour flap having a 0.50c_f balance with sharp nose shape. Wide cover plates; 0.0011c gap.

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Fig. 18

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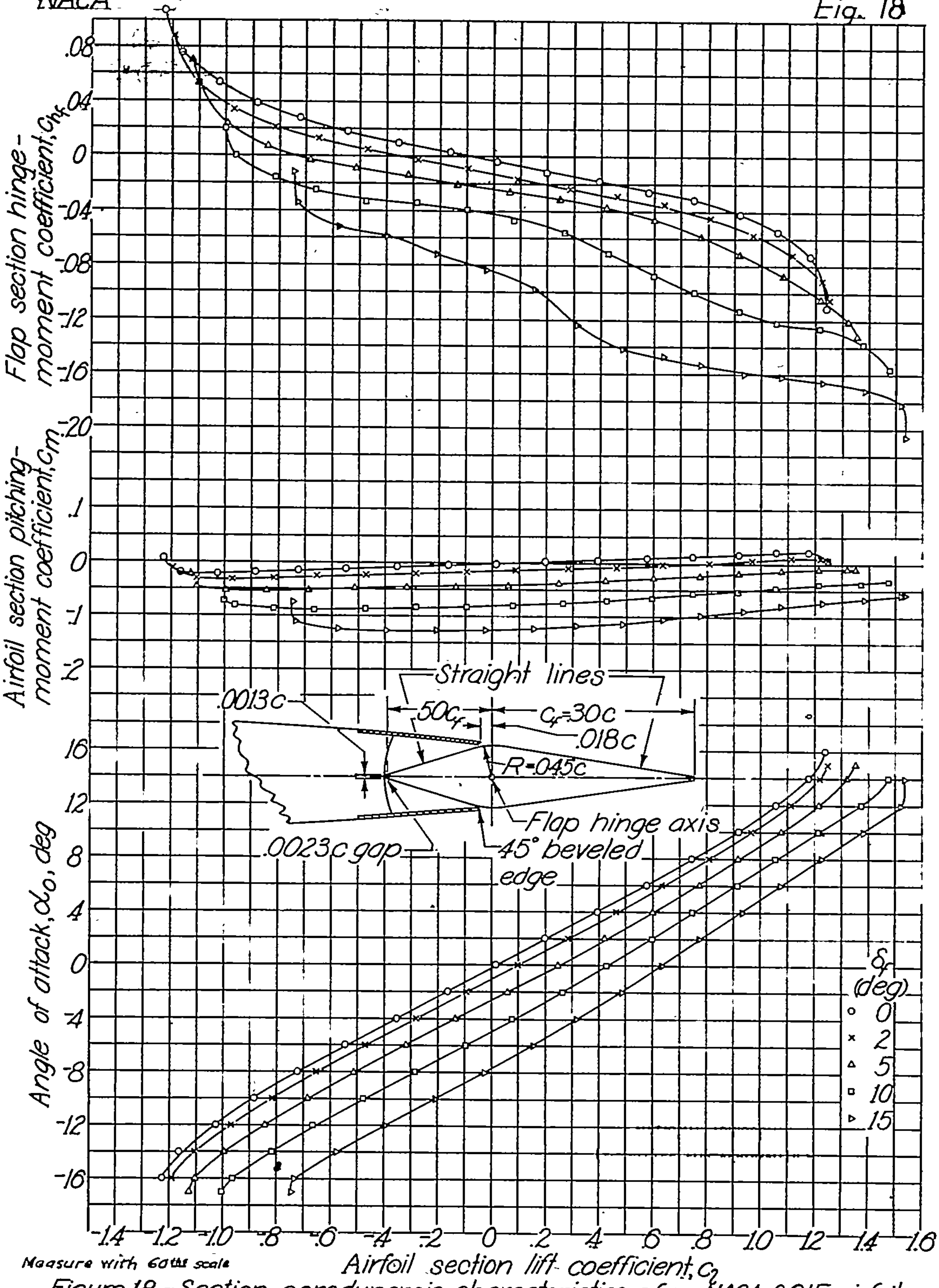

Measure with 60ths scale

Figure 18.- Section aerodynamic characteristics of an NACA 0015 airfoil with a 0.30c straight-contour flap having a 0.50c_f balance with sharp nose shape. Wide cover plates; 0.0023c gap.

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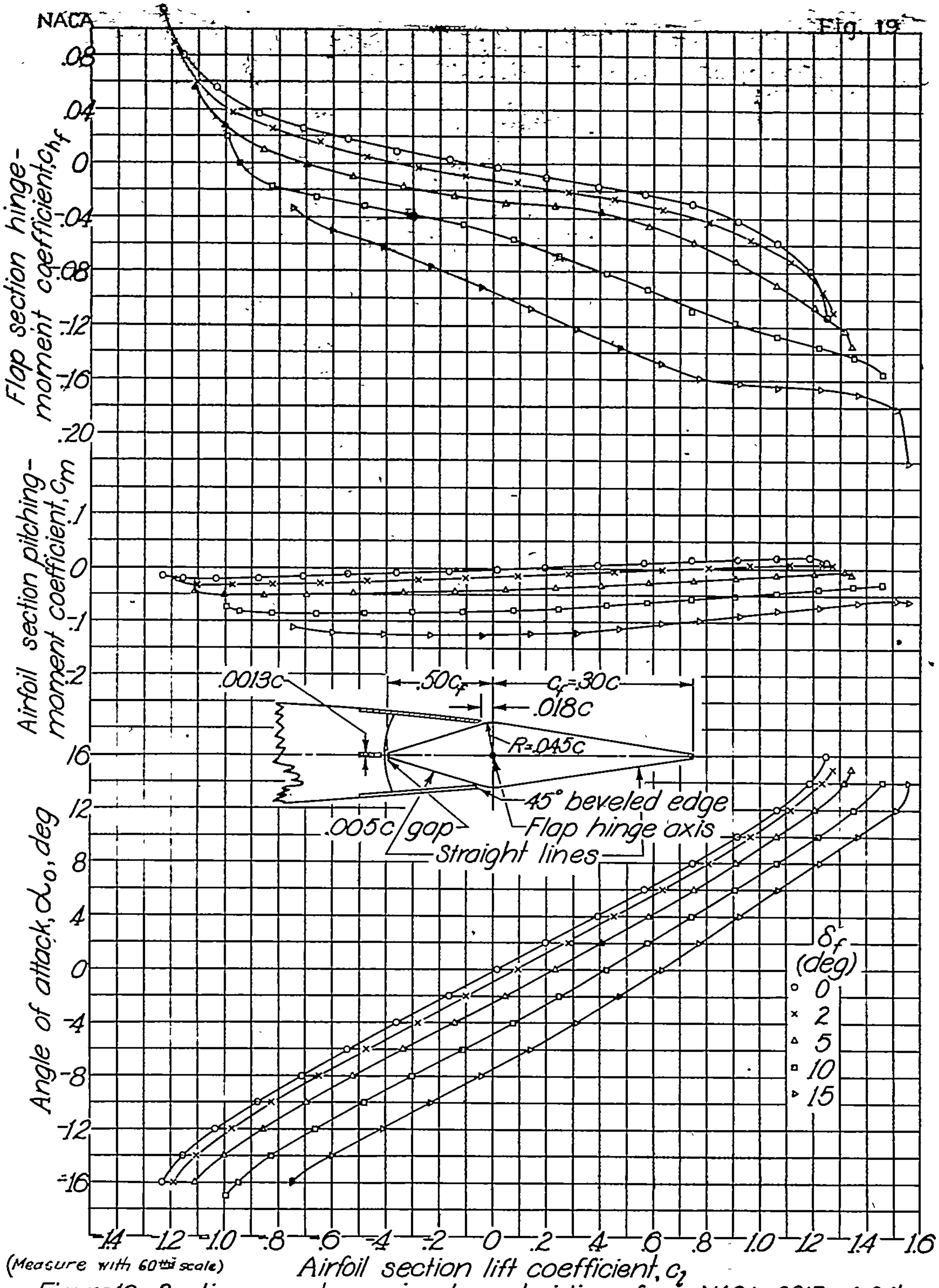

Figure 19.-Section aerodynamic characteristics of an NACA 0015 airfoil with a 0.30c straight-contour flap having a 0.50c_f balance with sharp nose shape. Wide cover plates; 0.005c gap.

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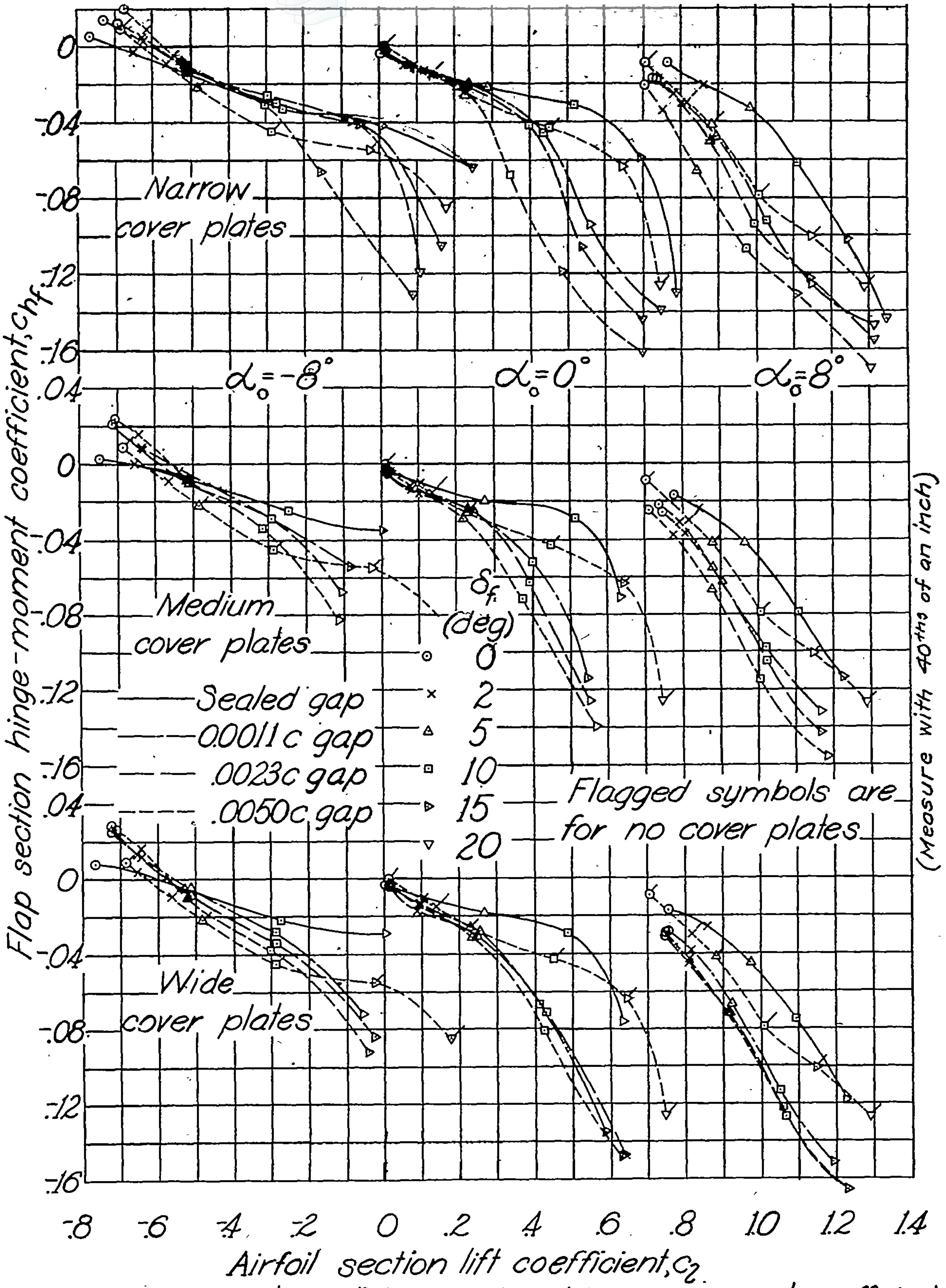

Figure 20.- Variation of flap section hinge-moment coefficient with airfoil section lift coefficient at several angles of attack and flap deflections for sharp-nose balance with three cover-plate widths and several gap sizes.

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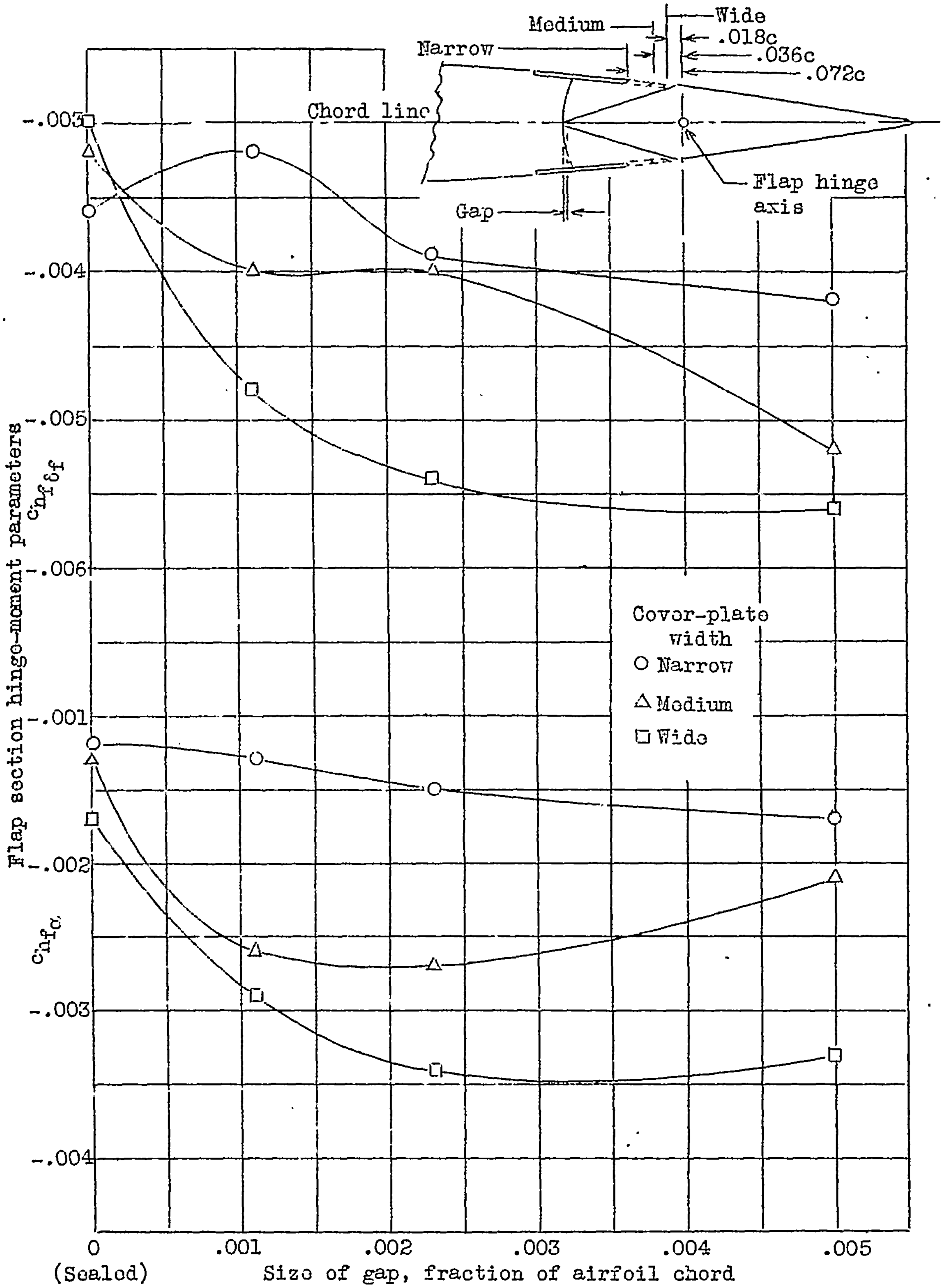

Figure 21.- Variation of flap section hinge-moment-coefficient parameters with gap size for three cover-plate widths.

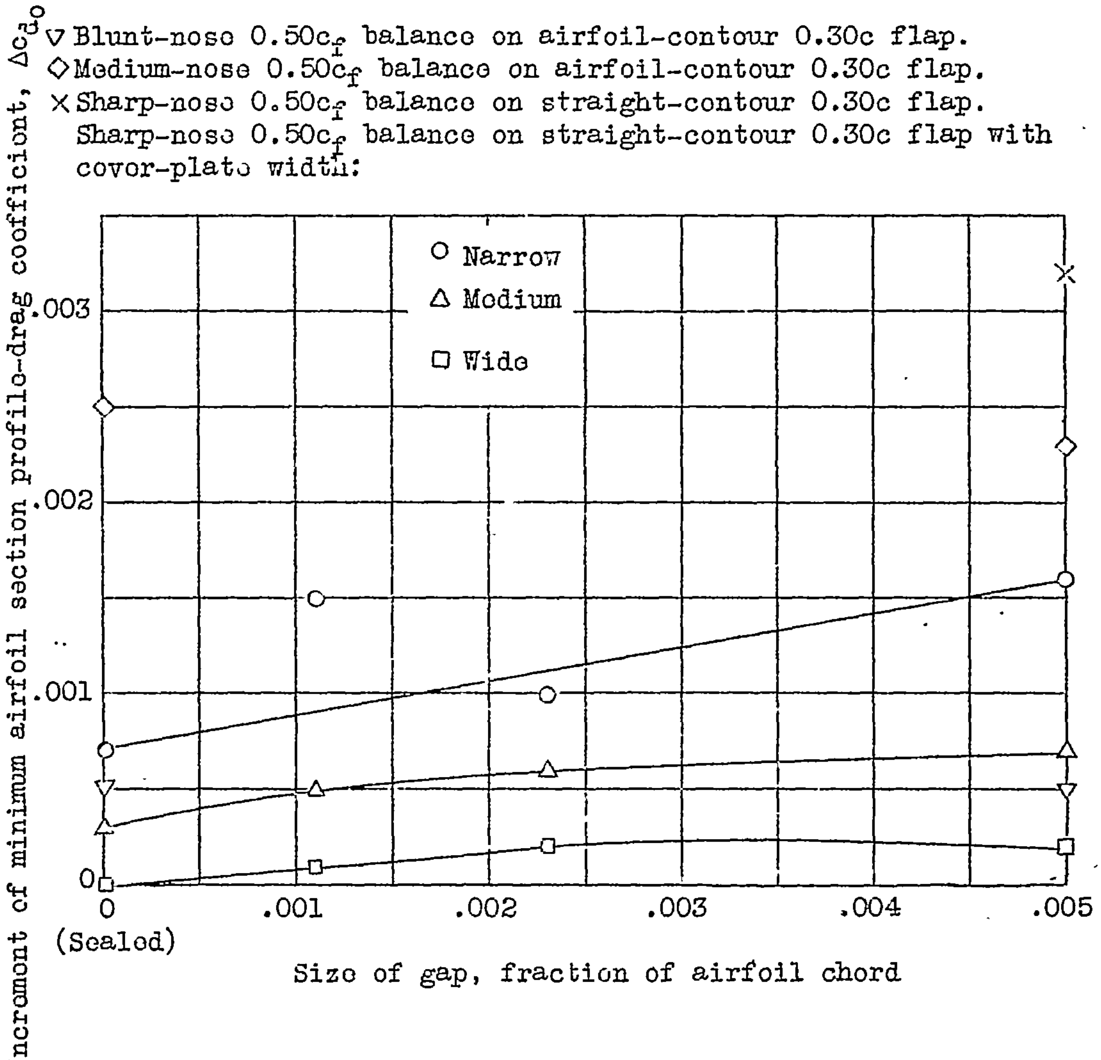

Figure 22.- Variation of the increment of minimum profile-drag coefficient with gap size for various 0.30c flaps on an NACA 0015 airfoil. (Data for airfoil-contour flap taken from reference 2.)