NACA

RESEARCH MEMORANDUM

THE EFFECT OF A 4-PERCENT-HIGH SPOILER ON BUFFETING FORCES ON AN NACA $65_{(06)}$A004 TWO-DIMENSIONAL AIRFOIL AT SUBSONIC MACH NUMBERS

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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

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THE EFFECT OF A 4-PERCENT-HIGH SPOILER ON BUFFETING FORCES ON AN NACA $65_{(06)}$A004 TWO-DIMENSIONAL AIRFOIL AT SUBSONIC MACH NUMBERS

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SUMMARY

An NACA $65_{(06)}$A004 airfoil was tested to determine the effects of a solid-strip spoiler on buffeting forces. The spoiler was mounted at the 0.70-chord station of the airfoil and had a height equal to 4 percent of the airfoil chord. Data are presented for Mach numbers from 0.30 to 0.64 with a corresponding Reynolds number range from about 4.0 million to 7.0 million.

Fluctuations of both section normal-force coefficient and of section pitching-moment coefficient are presented as functions of angle of attack and of section normal-force coefficient.

Generally speaking, the spoiler decreased the fluctuating section normal-force and pitching-moment coefficients if comparison is made at constant angle of attack and increased these coefficients if comparison is made at constant section normal-force coefficient.

INTRODUCTION

The problem of buffeting is a serious one in the case of some aircraft and may limit the maximum speed and/or maneuverability. Therefore it is important for a designer contemplating the use of spoiler-type controls to know whether they would adversely affect the buffeting forces on the aircraft. Although considerable research has been done on spoiler-type ailerons, none of this effort is known to have been directed primarily toward determining the effect of spoilers on the buffeting forces on an airfoil.

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Reference 1 presents some material on a single spoiler projecting from the upper surface and a double spoiler projecting from both the upper and lower surfaces of a semispan wing. All spoilers were at the 0.75-chord station ahead of a conventional aileron. From the standpoint of buffeting forces (which were measured only qualitatively) the report suggests that the single spoiler produced no adverse effects while the spoilers protruding simultaneously from both the upper and the lower surface produced serious buffeting and reversal of aileron hinge moments.

The investigation reported in reference 2 was conducted to determine the effects of varying thickness and thickness distribution on the buffeting forces on several two-dimensional airfoils. The purpose of the present investigation is to extend the research reported in reference 2 to include the effects of a spoiler on the buffeting forces on one of the airfoils studied in that reference.

NOTATION

c_n section normal-force coefficient

Δc_n one-half the average of the three largest peak-to-peak fluctuations of the section normal-force coefficient

Δc_m one-half the average of the three largest peak-to-peak fluctuations of the section pitching-moment coefficient

M free-stream Mach number

α section angle of attack, deg

MODEL AND APPARATUS

The model used in the present investigation (fig. 1) had a 24-inch chord, approximately an 18-1/4-inch span, and had the NACA $65_{(06)}$A004 airfoil section. Construction was of aluminum. A solid-strip spoiler that extended perpendicular to the upper surface of the airfoil to a height equal to 0.04 of the airfoil chord was mounted at the 0.70-chord station.

The tests were conducted in the two-dimensional channel of the Ames 16-foot high-speed wind tunnel (fig. 2).

The model was instrumented with 30 flush-mounted pressure cells in matched pairs at 15 chordwise stations near the midspan on the upper and lower surfaces. The output of the cells was summed electrically to provide a record proportional to the instantaneous normal force. (See fig. 3.) The electrical responses from each pair of pressure cells and from the summing circuit were recorded on oscillographs. The galvanometer elements used in these oscillographs have an amplitude response which is flat to about 60 cycles per second. Previous tests have shown this to be adequate (ref. 2). The time duration for the average oscillograph record was 0.9 second. A more complete description of the apparatus and test procedures will be found in reference 2 as the same test equipment was used for both investigations. A description of pressure cells and basic electronic equipment similar to that used in the present investigation is presented in reference 3.

REDUCTION OF DATA

The intensity of the fluctuations of section normal-force coefficient was taken as one-half the average of the three largest oscillations of the instantaneous section normal-force coefficient over a 0.9-second record. The small amount of fluctuating normal force invariably present at low angles of attack is known to be caused in part by the residual noise level of the electronic instrumentation. No noise-level tares have been subtracted from the instantaneous section normal-force coefficient.

The fluctuations of instantaneous section pitching-moment coefficient were ascertained in the following manner: Each oscillograph record was visually examined and two vertical lines were drawn at each of five locations where it seemed that the variation of fluctuating pitching moment was largest. The variation of each individual trace between the lines was then measured. (Fig. 3 illustrates this method.) After each individual trace variation had been multiplied by its proper constant, a summation was made to obtain fluctuating pitching-moment coefficient. No noise-level tare has been subtracted from the fluctuating pitching-moment data.

The Mach numbers and angles of attack for the investigation are believed to be accurate within ±0.01 and ±0.2°, respectively. Data are presented over a Mach number range of 0.30 to 0.64, which corresponds to a Reynolds number range of about 4.0 million to 7.0 million. The test Mach number was corrected for constriction effects by the method of reference 4.

The static pressures on the upper and lower surfaces of the airfoil were measured by means of mercury-in-glass manometers which were connected to orifices on the model surface. Static pressures thus measured were used to compute the static normal-force coefficients.

RESULTS AND DISCUSSION

Values of Δc_n and Δc_m were measured at several Mach numbers for the model with the spoiler. To determine the effect of the spoiler on the above-mentioned coefficients, these data have been compared with those for the same airfoil without a spoiler on the bases of equal angle of attack and of equal normal-force coefficient. Static data for both the clean model and the model with the spoiler are presented in table I.

The effect of the spoiler on the static normal-force coefficient was similar to that discovered in previous investigations (ref. 5).

Effect of the Spoiler on the Fluctuation of Section Normal-Force Coefficient

The effect of the spoiler on the Δc_n at equal angle of attack is shown in figure 4(a). These data indicate that at equal angle of attack, the spoiler decreased Δc_n in nearly all cases for angles of attack from 6° to the limit of the data. It also appears that the angle of attack where a marked rise of buffeting intensity took place was delayed about 2° (to an angle of attack of about 6°) for the model with the spoiler. Comparison of the Δc_n values for the model without the spoiler with those for the model with the spoiler on the basis of equal c_n (fig. 4(b)) indicates that the spoiler tended to increase Δc_n except at Mach numbers of 0.30 and 0.64 at high normal-force coefficients.

Effect of the Spoiler on the Fluctuations of Section Pitching-Moment Coefficient

A limited number of data have been analyzed to determine values of Δc_m on the model with and without the spoiler for Mach numbers of approximately 0.4, 0.6, and 0.64 (fig. 5). Comparison of results on the basis of equal angle of attack (fig. 5(a)) indicates that on this basis the model with the spoiler generally had lower values of Δc_m than the model with no spoiler. This result is similar to the trends of the Δc_n data shown in figure 4(a). At equal c_n (fig. 5(b)), the effect of the spoiler on Δc_m was to reduce the fluctuations at the highest c_n values, while the model with the spoiler seems to have greater fluctuations than the plain model at the low values of c_n.

CONCLUDING REMARKS

Results are presented which show the effect of a spoiler on the buffeting forces on a two-dimensional airfoil over a Mach number range from 0.30 to 0.64 and a corresponding Reynolds number range from about 4.0 million to 7.0 million. The spoiler extended perpendicular to the upper surface of the airfoil a distance equal to 0.04 of the airfoil chord and was at the 0.70-chord station of a two-dimensional model having the NACA $65_{(06)}$A004 airfoil section. The data show that for constant angle of attack the spoiler decreased the fluctuating section normal-force coefficient except at the lower angles of attack where there was a slight increase. However, on the basis of constant c_n it appears that the spoiler generally tended to increase the fluctuating section normal-force coefficient. The trends of the fluctuating section pitching-moment coefficients were generally similar to those of the fluctuating section normal-force coefficients.

Ames Aeronautical Laboratory
National Advisory Committee for Aeronautics
Moffett Field, Calif., Dec. 22, 1954

REFERENCES

1. Laitone, Edmund V., and Summers, James L.: An Additional Investigation of the High-Speed Lateral-Control Characteristics of Spoilers. NACA ACR 5D28, 1945.

2. Coe, Charles F., and Mellenthin, Jack A.: Buffeting Forces on Two-Dimentional Airfoils as Affected by Thickness and Thickness Distribution. NACA RM A53K24, 1954.

3. Erickson, Albert L., and Robinson, Robert C.: Some Preliminary Results in the Determination of Aerodynamic Derivatives of Control Surfaces in the Transonic Speed Range by Means of a Flush-Type Electrical Pressure Cell. NACA RM A8H03, 1948.

4. Allen, H. Julian, and Vincenti, Walter G.: Wall Interference in a Two-Dimensional-Flow Tunnel, With Consideration of the Effect of Compressibility. NACA Rep. 782, 1944.

5. Lowry, John G.: Data on Spoiler-Type Ailerons. NACA RM L53I24a, 1954.

TABLE I.- STATIC DATA USED IN FIGURES 4 AND 5

(a) NACA $65_{(06)}$A004 model with 4-percent spoiler

M	α, deg	c_n	M	α, deg	c_n
0.30	0.4	[a]-0.250	0.40	0	-0.329
	2.0	[a]-.152		2	-.233
	4.1	.087		4.1	[a]-.045
	6.1	[a].273		6.0	.191
	8.0	.612		7.9	.512
	9.8	[a].793		9.8	[a].780
	11.8	.732		11.8	[a].710
.50	.1	(b)	.60	.2	-.433
	2.0	-.226		2.1	-.265
	4.2	[a].021		4.1	-.028
	6.0	.268		6.0	[a].200
	8.0	[a].637		8.0	[a].600
	9.8	.710		9.9	[c].700
	12.0	(b)		11.8	(b)
.64	2.0	-.270			
	4.1	-.020			
	4.9	.100			
	5.9	[c].268			
	7.9	.628			
	8.9	.771			
	9.9	.842			

[a]Static and fluctuating data not taken simultaneously. Normal-force coefficients have been adjusted slightly to compensate for angle-of-attack differences.

[b]Buffeting-force data presented, but static data not available.

[c]Normal-force coefficient has been estimated from curves of c_n vs. α.

TABLE I.- STATIC DATA USED IN FIGURES 4 AND 5 - CONCLUDED

(b) NACA $65_{(06)}$A004 plain model

M	α, deg	c_n	M	α, deg	c_n
0.30	0	-0.026	0.39	0.1	-0.029
	2.1	.198		2.2	.156
	4.1	.335		4.1	.364
	8.1	.698		6.0	.581
	9.8	.786		8.1	.733
	11.9	.765		9.9	.807
				11.8	.791
.49	1.0	.026			
	2.1	.136	.59	.2	.031
	4.2	.364		2.9	.285
	6.1	.595		3.9	.402
	8.1	.746		4.1	.378
	9.9	.782		5.0	.479
	10.9	.791		5.8	.605
				6.1	.637
.63	2.9	.258		7.1	.677
	5.0	.486		7.3	.740
	7.1	.698		7.9	.750
	8.9	.749		8.9	.800

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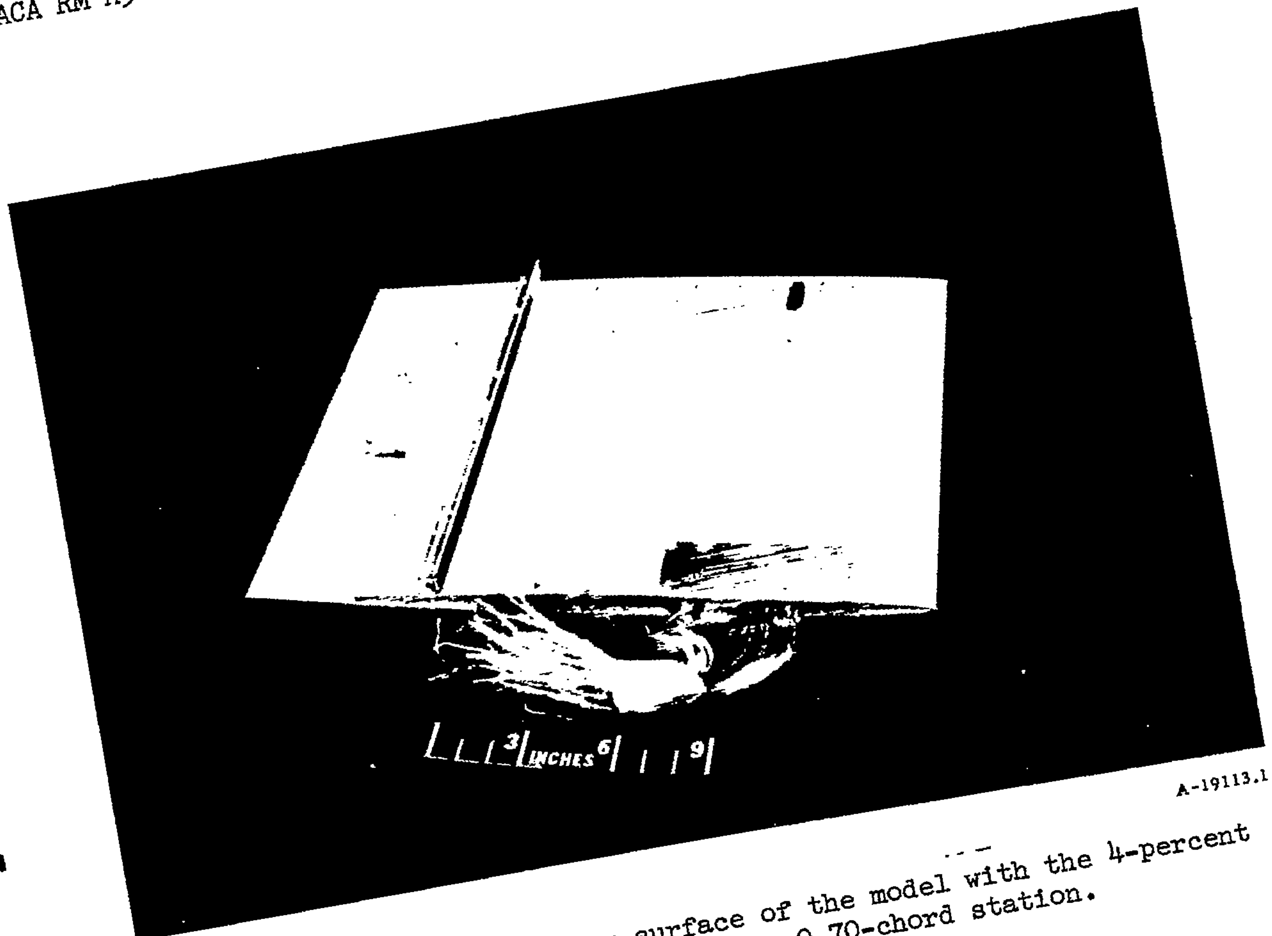

Figure 1.- View of the upper surface of the model with the 4-percent spoiler mounted at the 0.70-chord station.

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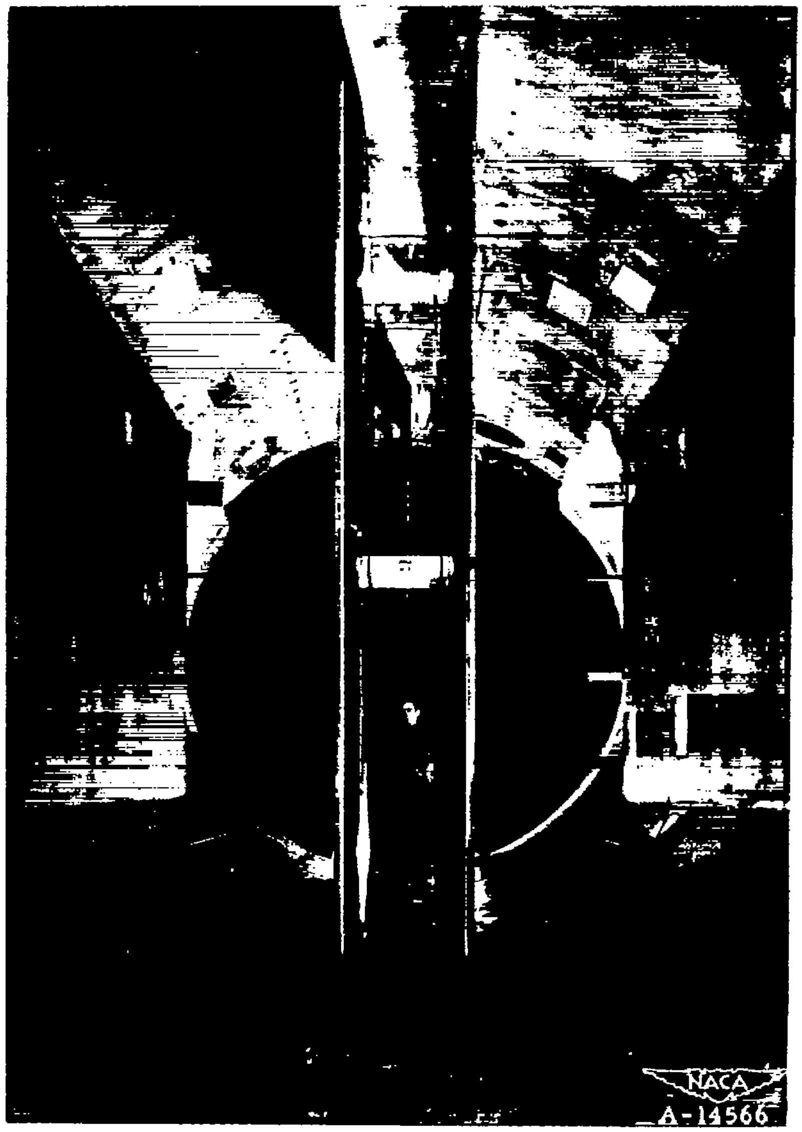


Figure 2.- View of the two-dimensional channel in the Ames 16-foot high-speed wind tunnel showing a model mounted between the walls.

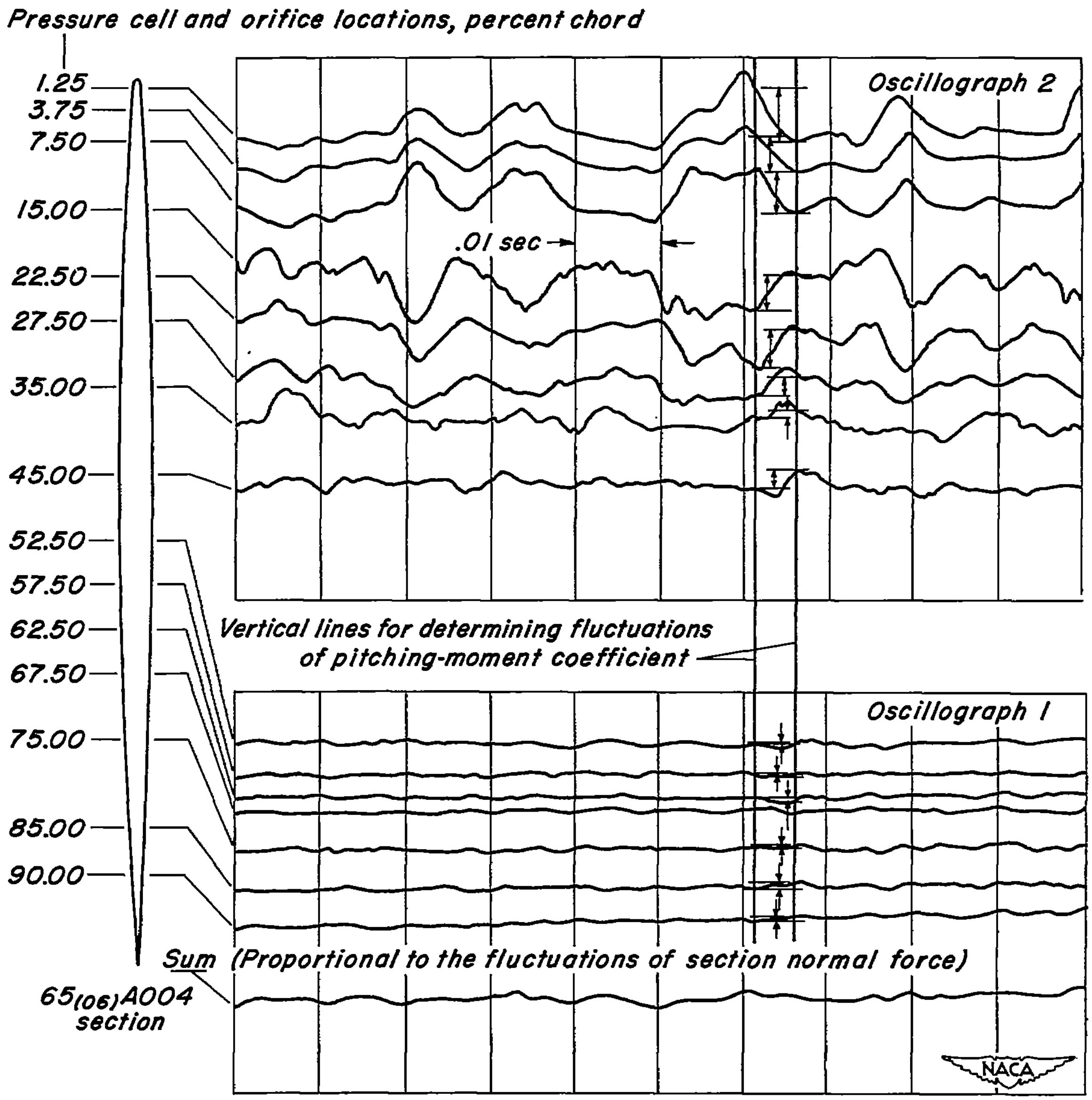
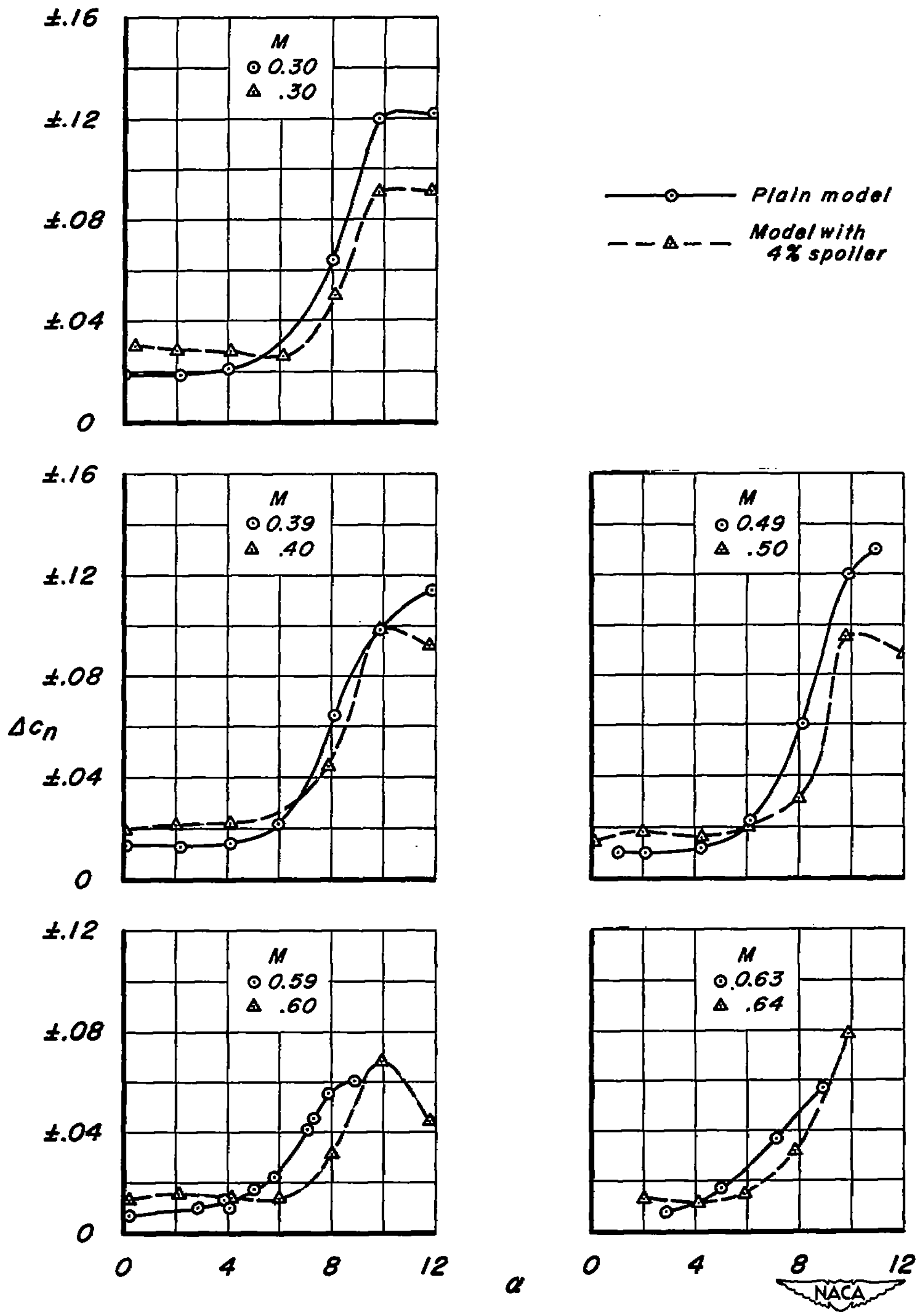
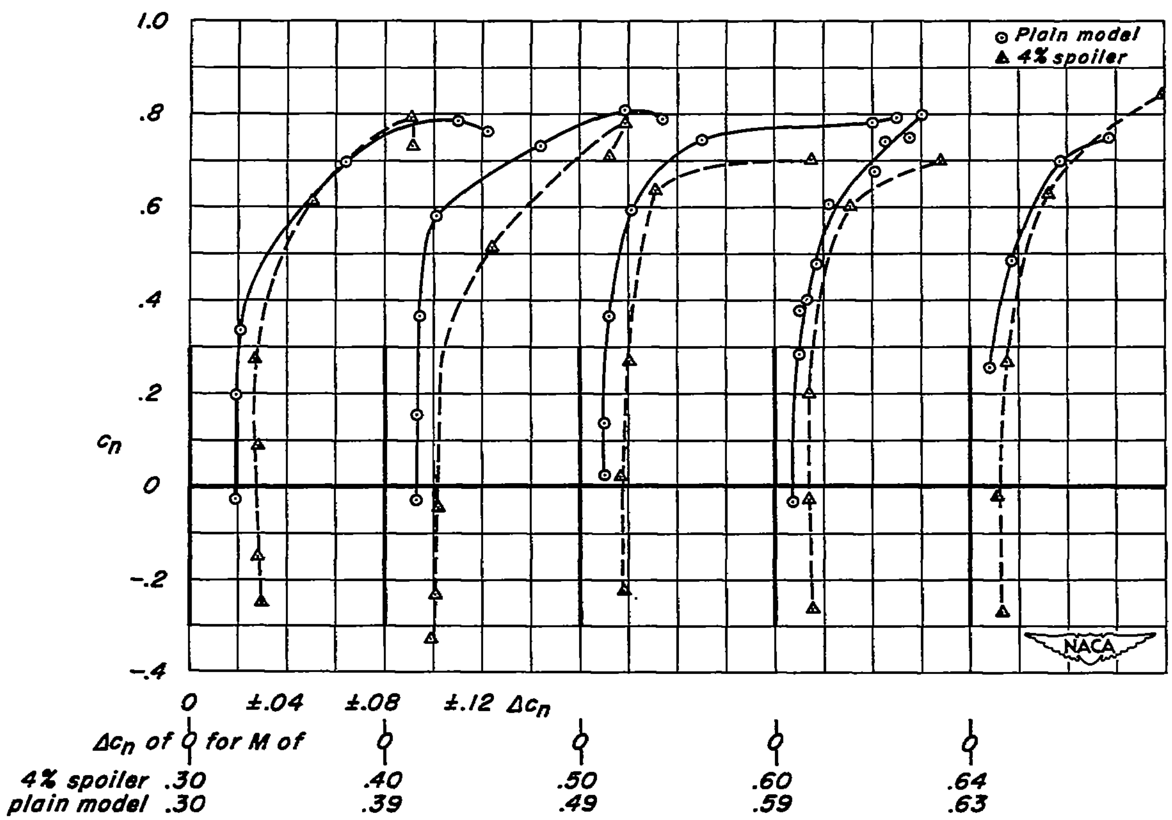


Figure 3.- Sample oscillograph record; NACA $65_{(06)}$A004 (no spoiler); $M = 0.59$; $c_n = 0.61$



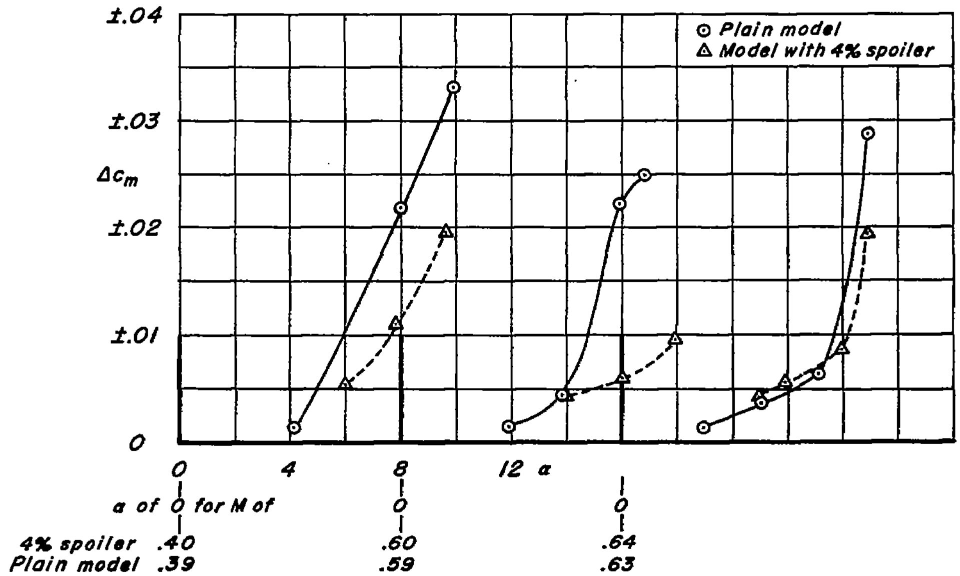
(a) Δc_n vs. α

Figure 4.- The effect of a 4-percent spoiler on the fluctuation of normal-force coefficient on the NACA $65_{(05)}$A004 airfoil.

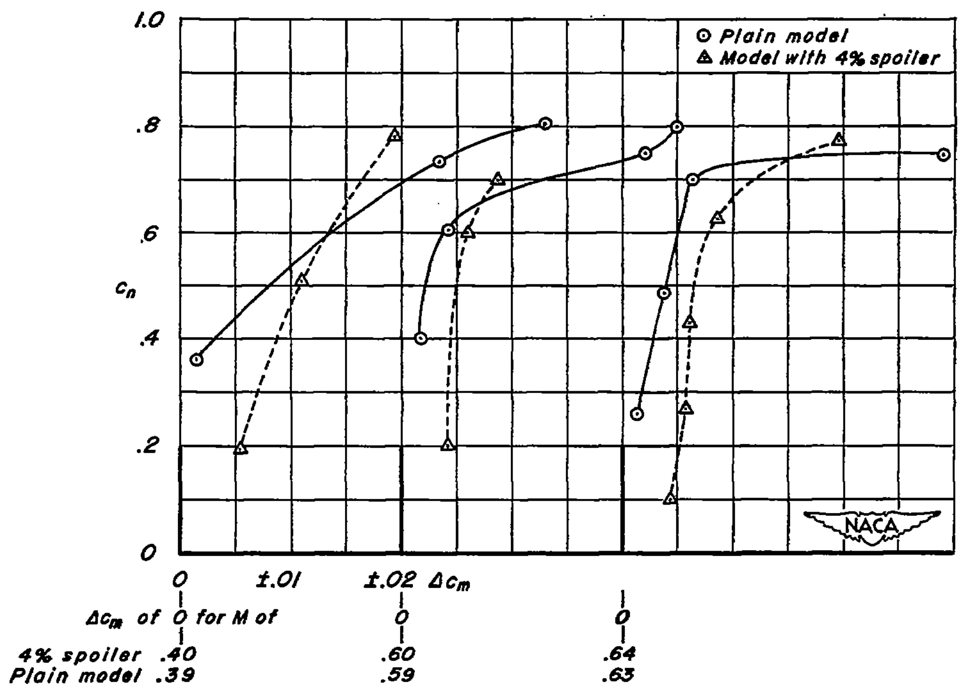


(b) c_n vs. Δc_n

Figure 4.- Concluded.



(a) Δc_m vs. α



(b) c_n vs. Δc_m

Figure 5.- The effect of a 4-percent spoiler on the fluctuation of pitching-moment coefficient on the NACA $65_{(06)}$A004 airfoil.

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