Copy No. 16

RB No. 3L13

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

RESTRICTED BULLETIN

WIND-TUNNEL TESTS OF AN NACA 44R-SERIES TAPERED WING WITH A STRAIGHT TRAILING EDGE AND A CONSTANT-CHORD CENTER SECTION

By Robert H. Neely

Langley Memorial Aeronautical Laboratory
Langley Field, Va.

December 1943

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

RESTRICTED BULLETIN

WIND-TUNNEL TESTS OF AN NACA 44R-SERIES TAPERED WING WITH A STRAIGHT TRAILING EDGE AND A CONSTANT-CHORD CENTER SECTION

By Robert H. Neely

SUMMARY

As part of a general investigation in the NACA 19-foot pressure tunnel to determine stall characteristics and effectiveness of high-lift devices on wings of various sections, tests were made of a tapered wing having NACA 44R-series airfoil sections. Lift, drag, pitching-moment, and stall characteristics were determined at a Reynolds number of 4,850,000 for the plain wing and for the wing with partial- and with full-span split flaps.

The stall progressed slowly over the plain wing; a gradual loss of lift for angles of attack up to and beyond that for the maximum lift coefficient resulted. As compared with the stall of the plain wing, the initial stall of the wing with either partial-span or full-span flaps deflected occurred at a higher angle of attack and the stall progressed much more rapidly. The maximum lift coefficients at a Reynolds number of 4,850,000 were 1.35 for the plain wing, 2.25 for the wing with partial-span flaps at 60°, and 2.67 for the wing with full-span flaps at 60°. The positions of the aerodynamic center, in terms of mean chords back of the leading edge of the root section, were approximately 0.458 with no flaps, 0.483 with partial-span flaps at 60°, and 0.498 with full-span flaps at 60°.

INTRODUCTION

As part of a general investigation in the NACA 19-foot pressure tunnel to determine stall characteristics and effectiveness of high-lift devices on wings, tests have been made of a tapered wing having NACA 44R-series airfoil sections. The lift curves for the NACA 44R-series airfoil sections (reference 1) have rounded peaks, which is desirable from considerations of stall characteristics; however, the airfoils have a relatively low compressibility limit. The NACA 44R-series airfoils are a modification of the NACA 44-series airfoils with the trailing edge reflexed to reduce the pitching moment. The plan form of the test wing is the same as that of the NACA 230-series wing designated wing III in reference 2 and that of the NACA low-drag wing in reference 3. Lift, drag, pitching-moment, and stall characteristics were determined for the plain wing and for the wing with partial- and with full-span split flaps.

APPARATUS AND TESTS

Model

The wing model, provided by the Bureau of Aeronautics, Navy Department, was constructed according to NACA specifications. The wing was made of laminated mahogany and finished with lacquer. A smooth surface was obtained by rubbing the wing with No. 400 carborundum paper.

A sketch of the model is given in figure 1. The wing has a straight trailing edge and a square center section; the outer panels are tapered 2:1. The span is 15 feet; the area, 32.14 square feet; and the aspect ratio, 7.0. The wing was constructed to the NACA 4416R airfoil section at the root and to the NACA 4409R section at the theoretical tip sections. The maximum thickness of the root sections is 16.5 percent of the chord. Straight-line fairings were used between corresponding percentage stations of the root and the theoretical tip chords. The wing has a geometric washout of 3° between the root and the theoretical tip sections.

The model was tested with simple split flaps having a chord 20 percent of the wing chord. The spans of the partial-span and the full-span flaps are 53 percent and 90 percent of the over-all wing span, respectively.

Tests

The method of mounting the model in the test section of the tunnel is shown in figure 2. All tests were made with the air in the tunnel compressed to an absolute pressure of 35 pounds per square inch.

Lift, drag, and pitching moment were measured over an angle-of-attack range from -4° to 24° for the wing with no flaps; for the wing with the partial-span flaps at 15°, 30°, 45°, and 60°; and for the wing with the full-span flaps at 60°. These tests were made at a Reynolds number of approximately 4,850,000 and a Mach number of 0.12. In addition, tests were made for a small range of angle of attack to measure maximum lift at Reynolds numbers of 2,700,000 and 3,800,000.

Stalling characteristics were determined by observing the behavior of wool tufts attached to the upper surface of the wing at the 20-, 30-, 40-, 50-, 60-, 70-, 80-, and 90-percent-chord points in parallel rows spaced approximately 7 inches along the span. The progression of the stall was recorded by sketching the stalled portions of the wing at various angles of attack. The stall characteristics were determined at a Reynolds number of approximately 4,800,000 for the plain wing, for the wing with partial-span flaps at 60°, and for the wing with full-span flaps at 60°.

RESULTS AND DISCUSSION

Coefficients

The data presented herein are given in standard NACA nondimensional-coefficient form corrected for the effects of model support tares and interference, airflow misalinement, and jet-boundary interference.

The coefficients and symbols used herein are defined as follows:

C_L lift coefficient (L/qS)

$C_{L_{max}}$ maximum lift coefficient

C_D drag coefficient (D/qS)

C_m pitching-moment coefficient about quarter-chord point of root section $(M/qS\bar{c})$

where

L	lift
D	drag
M	pitching moment
q	free-stream dynamic pressure $\left(\frac{1}{2}\rho V^2\right)$
S	wing area (32.14 sq ft)
$\bar{c}$	mean wing chord (S/b, 2.14 ft)
ρ	mass density of air (slugs/cu ft)
V	free-stream velocity

and

c	wing-section chord
b	wing span (15 ft)
α	angle of attack of root chord
δ_f	flap deflection measured between lower surface of wing and flap
R	Reynolds number $(\rho V\bar{c}/\mu)$
M	Mach number (V/a)
μ	coefficient of viscosity
a	velocity of sound in air

Lift and Stalling Characteristics

The aerodynamic characteristics of the wing for a Reynolds number of 4,850,000 are presented in figure 3. The peak of the lift curve of the plain wing is well rounded, which indicates a gradual loss of lift in the vicinity of $C_{L_{max}}$. The addition of flaps results in a sharper peak of the lift curve. The maximum lift coefficients at a Reynolds number of 4,850,000 are 1.35 for the plain wing, 2.25 with partial-span flaps at 60°, and 2.67 with full-span flaps at 60°. The maximum lift coefficient obtained with the plain wing is about 0.25 less than that obtained with an NACA 230-series wing of similar plan form but with no twist (wing III of reference 2); however, the maximum lifts obtained with comparable flaps deflected 60° are approximately the same for both wings.

The variations of maximum lift coefficient with Reynolds number, as presented in figure 4, show that $C_{L_{max}}$ increases with Reynolds number and that the increment of $C_{L_{max}}$ due to a particular flap deflection is little affected by change in Reynolds number.

Diagrams showing the progression of the stall over the wing are given in figures 5 to 7. Lift characteristics obtained during the tuft tests are presented in these figures for correlation with the diagrams. For the plain wing (fig. 5), flow separation was first indicated at the trailing edge at an angle of attack of 14.2°. The stall progressed slowly, with gradual loss of lift. With flaps deflected (figs. 6 and 7), flow separation was first indicated near the angle of $C_{L_{max}}$, which was greater than the initial stall angle of the plain wing. The progression of the stall was much more rapid and the loss of lift beyond the angle of $C_{L_{max}}$ was considerably greater than that for the plain wing. The stall alternated from the left wing to the right wing slightly after the angle of $C_{L_{max}}$ was reached. For higher angles of attack, this oscillation disappeared.

Drag Characteristics

The drag coefficient of the plain wing near zero lift is approximately 0.0090, which is about 0.0010 greater than that obtained with the NACA 230-series wing, wing III of reference 2.

Pitching-Moment Characteristics

The slopes of the pitching-moment curves dC_m/dC_L are -0.140 for the plain wing, -0.165 with partial-span flaps at 60°, and -0.180 with full-span flaps at 60°.

If it is assumed that dC_m/dC_L gives the distance of the aerodynamic center from the 0.25c point of the root section, the corresponding positions of the aerodynamic center are $0.458\bar{c}$, $0.483\bar{c}$, and $0.498\bar{c}$ back of the leading edge of the root chord. The pitching-moment coefficient of the plain wing at zero lift is -0.03.

CONCLUDING REMARKS

The main results of the investigation of an NACA 44R-series tapered wing with a straight trailing edge and a constant-chord center section, with partial-span and with full-span split flaps, are summarized as follows:

1. The stall progressed slowly over the plain wing, which resulted in a gradual loss of lift up to and beyond the angle of maximum lift coefficient. As compared with the plain wing, flow separation for the wing with partial-span or full-span flaps deflected occurred initially at a higher angle of attack and the stall progressed much more rapidly. With flaps deflected, the stall alternated from the left wing to the right wing slightly after the angle of maximum lift coefficient was reached.

2. The maximum lift coefficients at a Reynolds number of 4,850,000 were 1.35 for the plain wing, 2.25 for the wing with partial-span flaps at 60°, and 2.67 for the wing with full-span flaps at 60°. The maximum lift coefficient obtained with the plain wing is about 0.25 less than that obtained with an NACA 230-series wing of similar plan form but with no twist; however, the maximum lifts obtained with comparable flaps deflected 60° are approximately the same for both wings.

3. The drag coefficient of the plain wing at zero lift was 0.0090, which was about 0.0010 greater than that of a comparable NACA 230-series wing.

4. The positions of the aerodynamic center, in terms of mean chords back of the leading edge of the root section, were approximately 0.458 with no flaps, 0.483 with partial-span flaps at 60°, and 0.498 with full-span flaps at 60°.

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

REFERENCES

1. Sherman, Albert: Preliminary Report on the Characteristics of the N.A.C.A. 4400R Series Airfoils. NACA A.C.R., March 1939.

2. Neely, Robert H.: Wind-Tunnel Tests of Two Tapered Wings with Straight Trailing Edges and with Constant-Chord Center Sections of Different Spans. NACA A.R.R., March 1943.

3. Muse, Thomas C., and Neely, Robert H.: Wind-Tunnel Investigation of an NACA Low-Drag Tapered Wing with Straight Trailing Edge and Simple Split Flaps. NACA A.C.R., Dec. 1941.

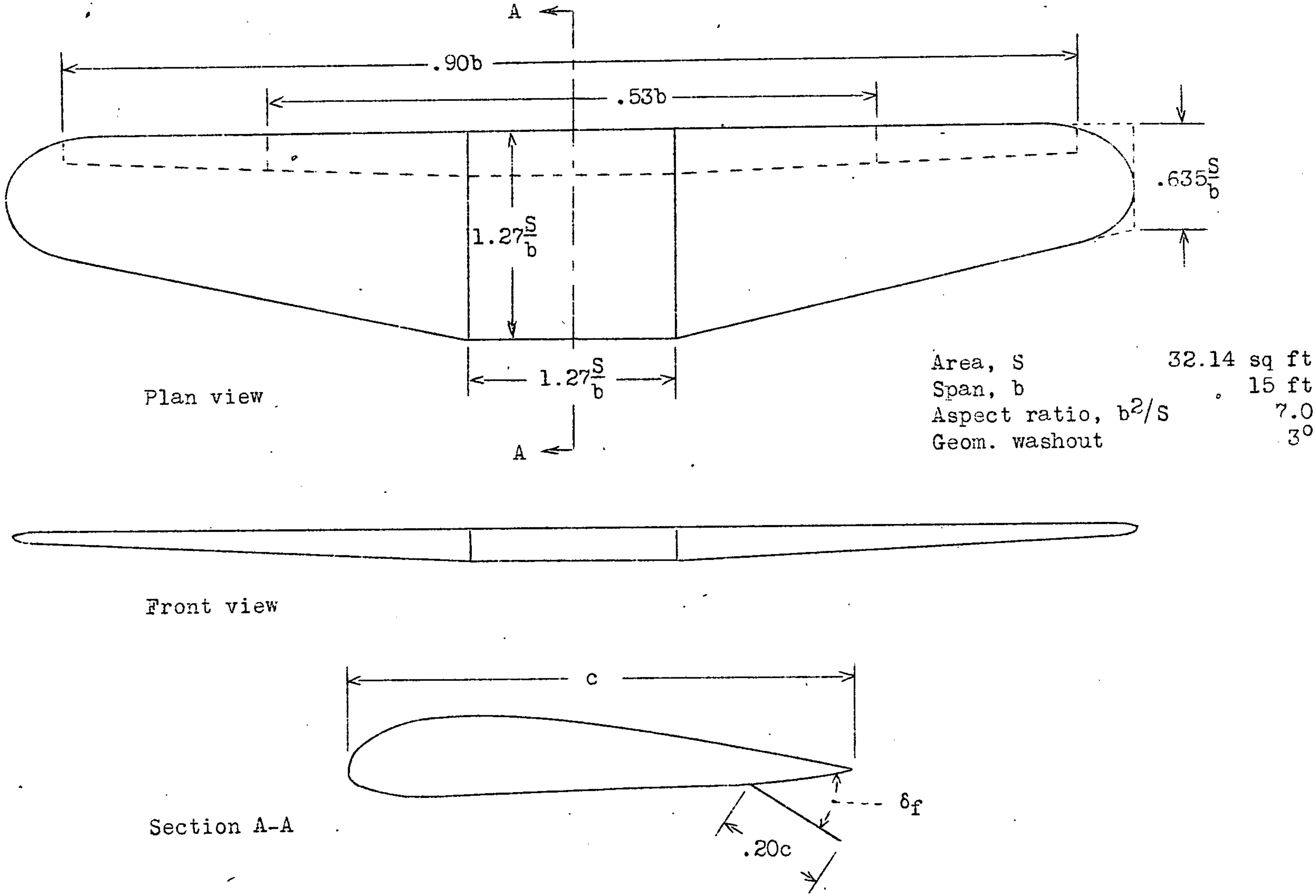

Figure 1.- NACA 44R-series tapered wing.

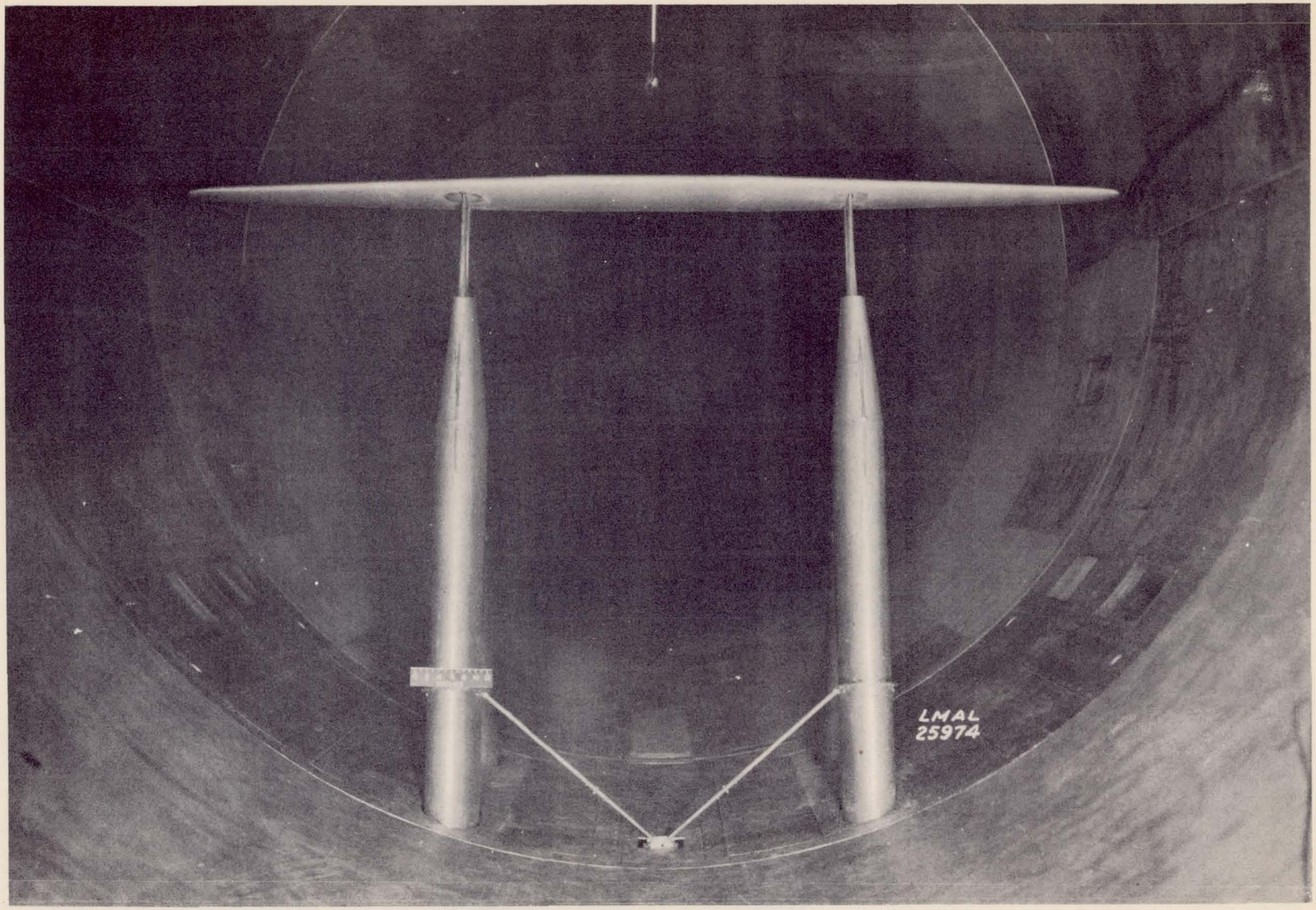

Figure 2.- Method of mounting wing in test section of NACA 19-foot pressure tunnel.

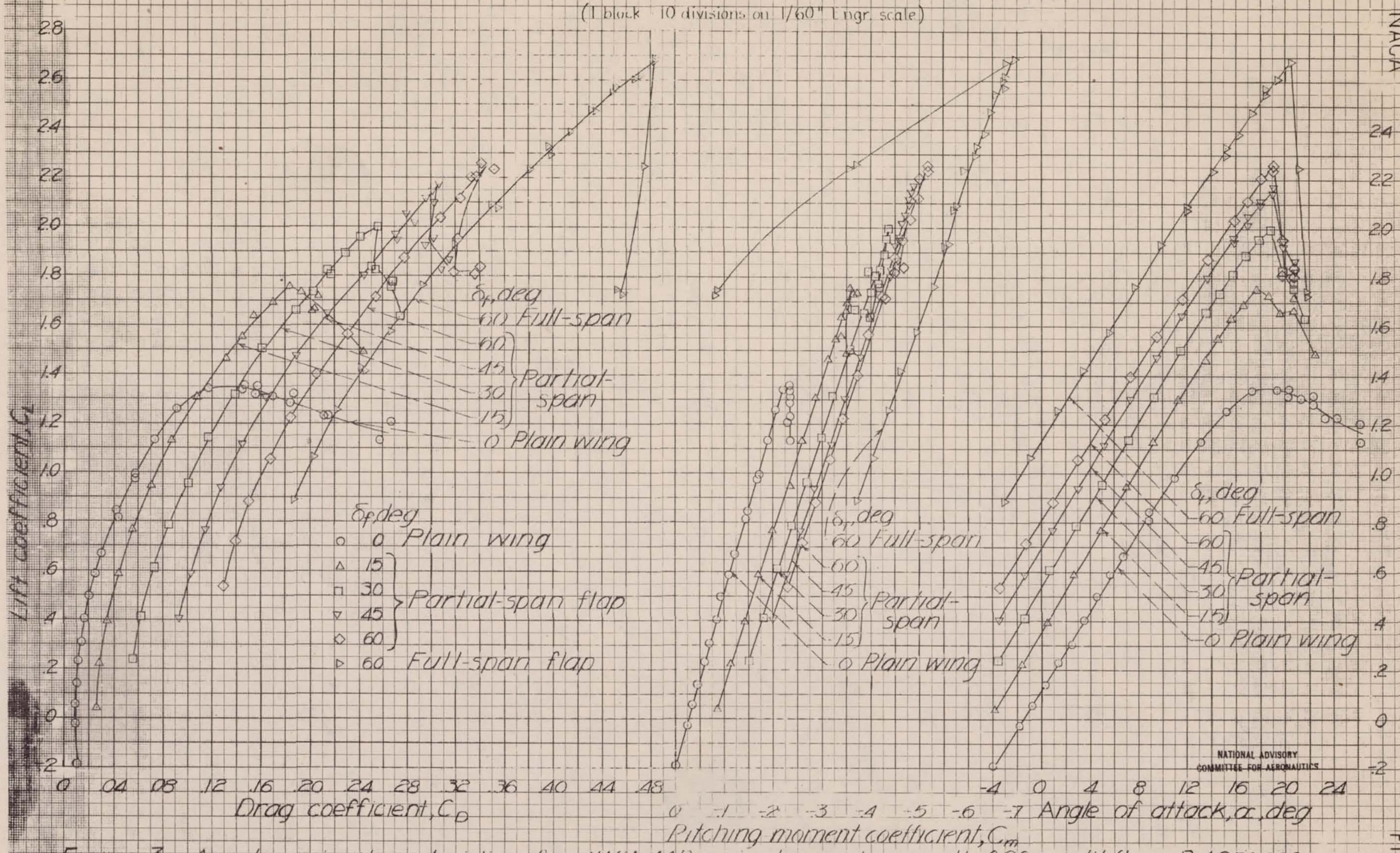

Figure 3.—Aerodynamic characteristics of an NACA 44R-series tapered wing with 0.20c split flaps. R=4,850,000; M 0.12.

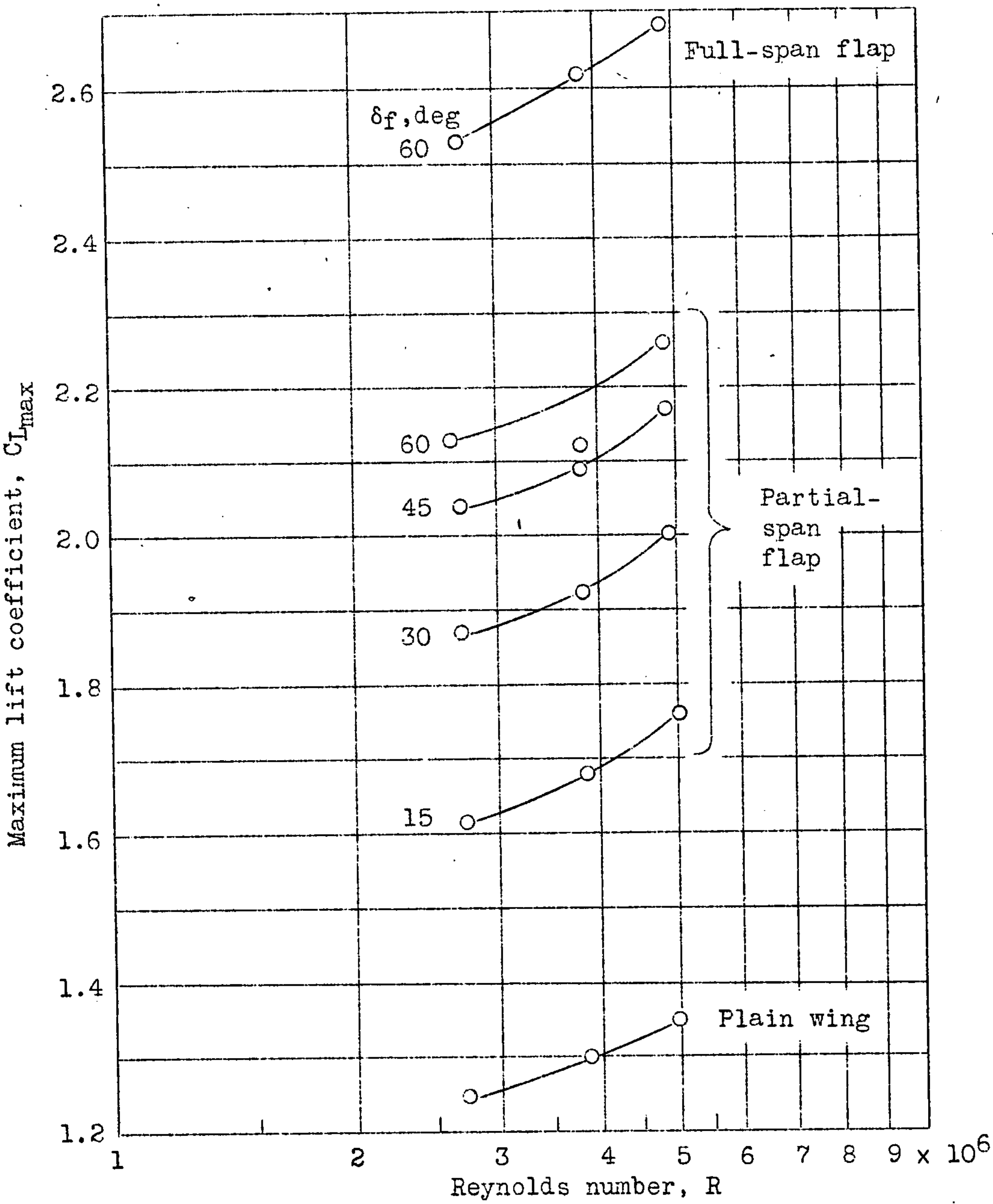

Figure 4.- Variation of maximum lift coefficient with Reynolds number of an NACA 44R-series tapered wing with 0.20c split flaps.

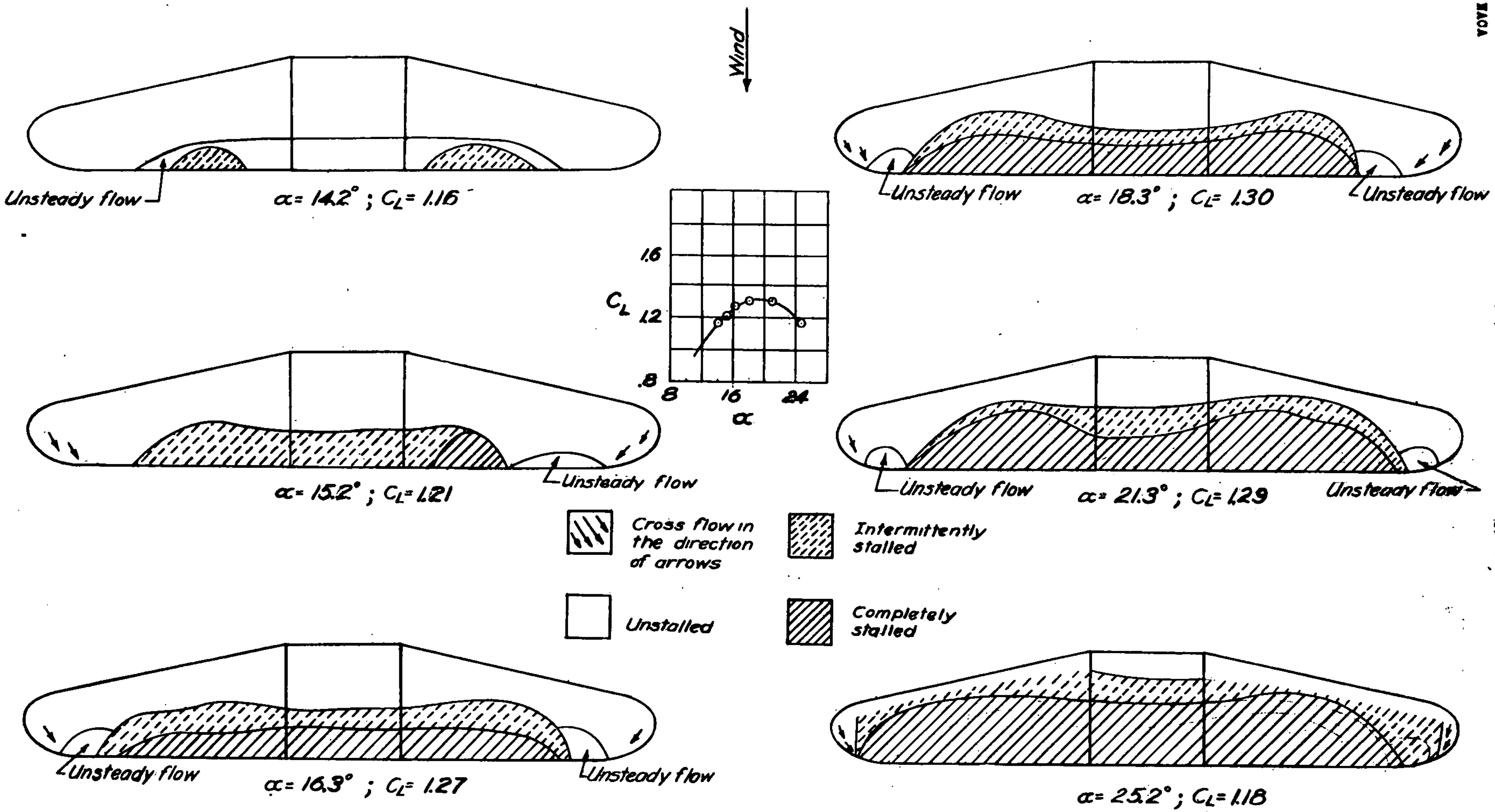

Figure 5 .- Stall diagrams of an NACA 44R-series tapered wing. Plain wing; R=4,800,000; M=0.12.

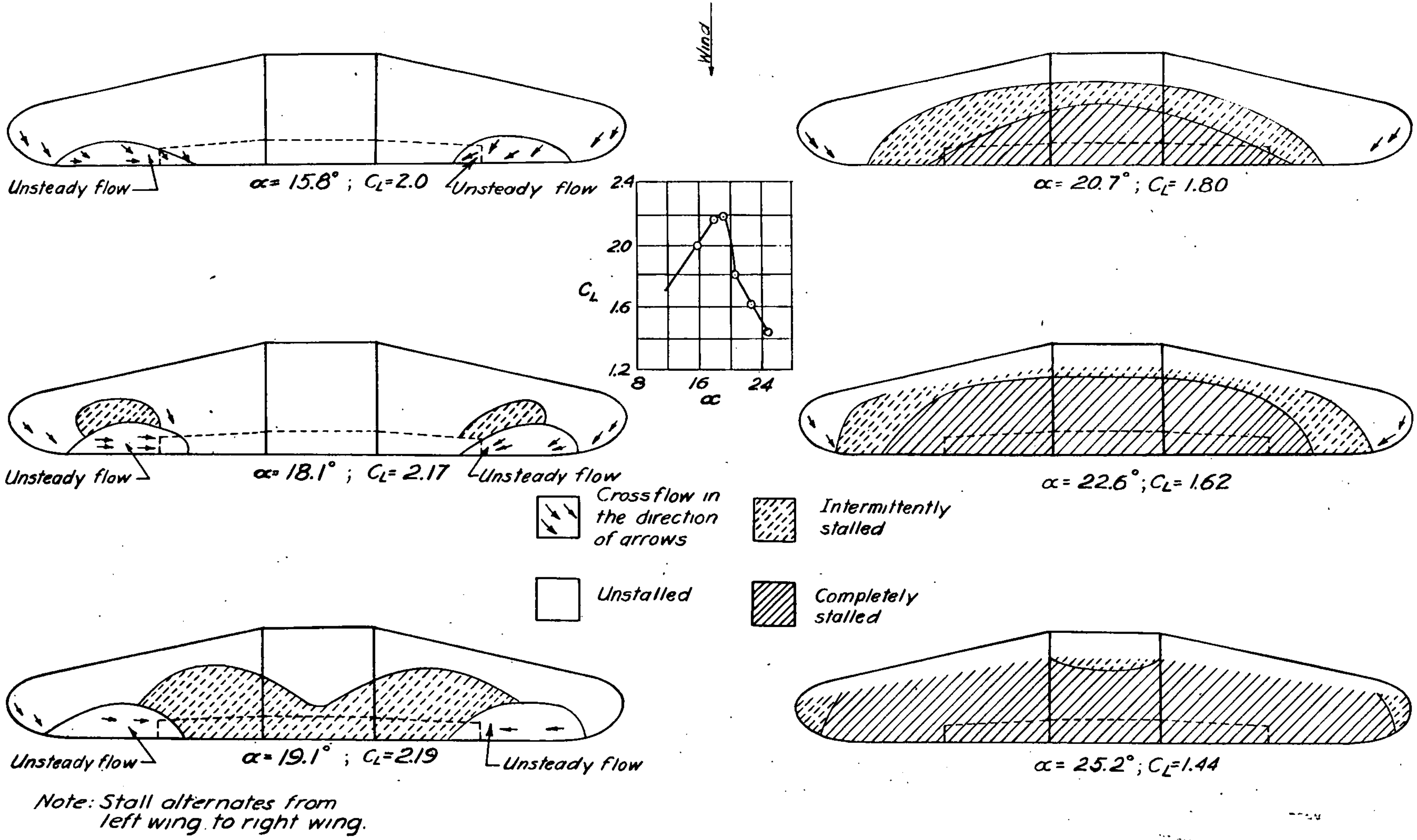

Figure 6 .- Stall diagrams of an NACA 44R-series tapered wing with partial-span split flaps. $\delta_f = 60°$; $R = 4,750,000$; $M = 0.12$.

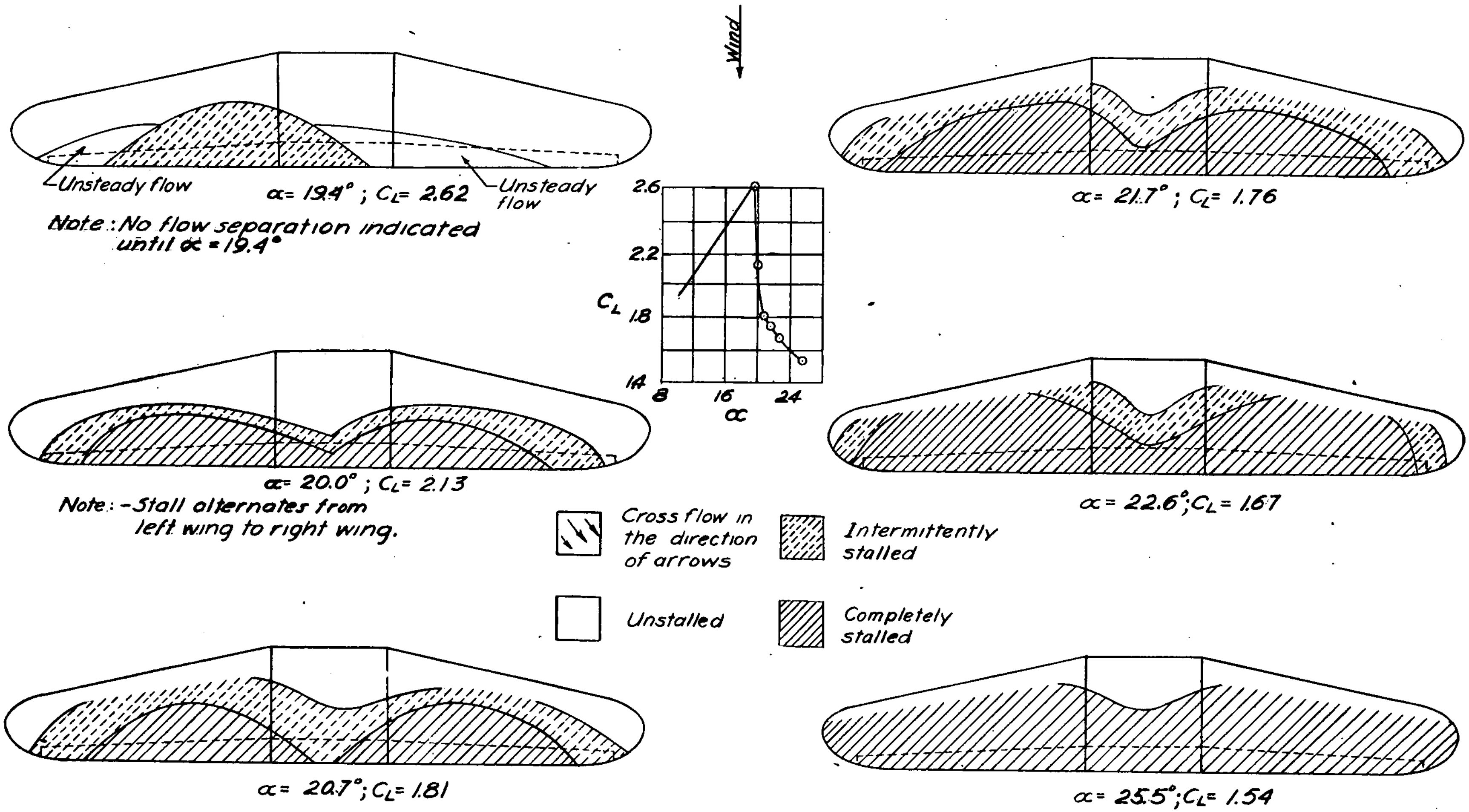

Figure 7.- Stall diagrams of an NACA 44R-series tapered wing with full-span split flaps. $\delta_f = 60°$; $R = 4,750,000$; $M = 0.12$.