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~~Special Report #171~~

CHARACTERISTICS OF NACA 4400R SERIES RECTANGULAR AND TAPERED AIRFOILS, INCLUDING THE EFFECT OF SPLIT FLAPS

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INTRODUCTION

At the request of the Bureau of Aeronautics, Navy Department, tests were made in the variable-density wind tunnel of a tapered wing of 3-10-18 plan form and based on the NACA 4400R series sections (reference 1). The wing was also tested with 0.2 chord split flaps, deflected 60°, in the center of the wing and having flap span to wing span ratios of 0.3, 0.5, 0.7, and 1.0, respectively. In order to get data from which to calculate the characteristics of the flapped wing, the investigation of reference 1 was extended to include tests of the four rectangular airfoils of the NACA 4400R series (4409R, 4412R, 4415R, and 4418R) with full-span 0.2 chord, trailing-edge split flaps deflected 60°.

MODELS AND TESTS

The numbers in the designation of the tapered wing (3-10-18) refer to taper ratio, aspect ratio, and root section percent thickness, respectively. The construction tip section was 9 percent thick. The wing was constructed using straight-line elements between corresponding points on the root (NACA 4418R) and tip (NACA 4409R) sections, and so that in front elevation the upper element was a straight line from tip to tip (fig. 1). All the models had a wing area of 150 square inches, were made of aluminum alloy, and had no geometric twist.

Measurements of lift, drag, and pitching moment were made in the variable-density wind tunnel according to standard procedure (reference 2) at a test Reynolds number of approximately 3,000,000, which corresponds to an effective Reynolds number R_e of approximately 8,000,000 (reference 3).

RESULTS

Standard plots showing the characteristics of the rectangular airfoils with 0.2 chord split flaps deflected 60° are shown in figures 2 to 5. The section characteristics after the stall are not shown. The principal characteristics are summarized in table I.

The characteristics of the tapered wing with the different flap arrangements are shown in figures 6 to 10. In figure 6, a calculated curve of C_{D_e}, determined by the method of reference 4, is given for comparison with the test results.

Values of angle of zero lift also were calculated by the method of reference 5 and show good agreement with measured values as shown in table II. The lift-curve slope was calculated (reference 4) for the plain wing but not for the wings with flaps because the slopes of the sections with flaps are far from constant. The moment about the aerodynamic center of the plain wing was calculated by the simpler method of reference 5 which assumes $c_{m_{a.c.}}$ is constant along the span. The moments for the wings with flaps deflected were obtained by the method of reference 5 using average values of the section moment coefficient for c_{m_0} and average values of Δc_m at a lift coefficient of 1.0 for the flapped portion of the span.

In the calculation of maximum lift by the method of reference 4, the span load distribution was obtained by the method of reference 6. Good agreement with experiment is shown for the plain wing but poor agreement for the wing with full-span flap. In fact, the measured maximum lift of the tapered flapped wing is higher than that of any of the flapped sections along the span. The discrepancy is attributed to the inadequacy of the assumptions involved in the calculation of maximum lift. These calculations were not made for the wings with partial-span flaps in view of the above and in view of the added uncertainty of the value of the section maximum lift developed near the flap end. In any case, the measured values of maximum lift coefficient of these tapered wings may not be attainable in flight due to the lateral instability associated with tip stalling before the angle corresponding to maximum lift can be reached (reference 7).

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Langley Field, Va.

REFERENCES

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6. Pearson, H. A.: Span Load Distribution for Tapered Wings with Partial-Span Flaps. Rep. No. 585, NACA, 1937.

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TABLE I

Characteristics of NACA 4400R Series Airfoils with

0.2c Split Flap Deflected 60°

Thickness (percent c)	$c_{l_{max}}$	α_{l_0}	$c_{m(a.c.)_0}$ at $C_L = 1$	$(a.c.)_0$ (percent c from c/4)		α_{l_0} (approx.) (1)	a_0 (approx.) (1)
				x	y		
9	2.10	-14.5	-0.231	0.3	5	-16.2	0.085
12	2.38	-15.3	-.248	.1	3	-16.3	.089
15	2.41	-15.4	-.270	.6	4	-16.8	.092
18	2.41	-16.4	-.272	.9	3	-17.4	.095

[1]These values apply to a linear lift curve approximating the experimental lift curve.

TABLE II

Characteristics of NACA 3-10-18 (NACA 4400R) Tapered Wing with 0.2c Split Flap Deflected 60°

Flap length (fraction span)	$\alpha_{L=o}$		a		$\frac{x_{a.c.}}{S/b}$		$C_{m(a.c.)_o}$ at $C_L = 1$		$C_{D_{o_{min}}}$		$C_{L_{max}}$	
	(exp.)	(calc.)	(exp.)	(calc.)	(exp.)	(calc.)	(exp.)	(calc.)	(exp.)	(calc.)	(exp.)	(calc.)
0	-2.4	-2.4	0.083	0.081	0.018	0.008	-0.038	-0.033	0.0077	0.0078	1.39	1.43
.3	-7.9	-7.6	.084	-	-	-	-.175	-.173	.076	-	1.89	-
.5	-11.1	-10.5	.086	-	-	-	-.240	-.226	.107	-	2.16	-
.7	-13.7	-13.0	.086	-	-	-	-.280	-.265	.125	-	2.38	-
1.0	-15.3	-15.5	[1].085	-	-	-	-.292	-.282	.144	-	2.61	2.25

[1]These values apply to a linear lift curve approximating the experimental lift curve.

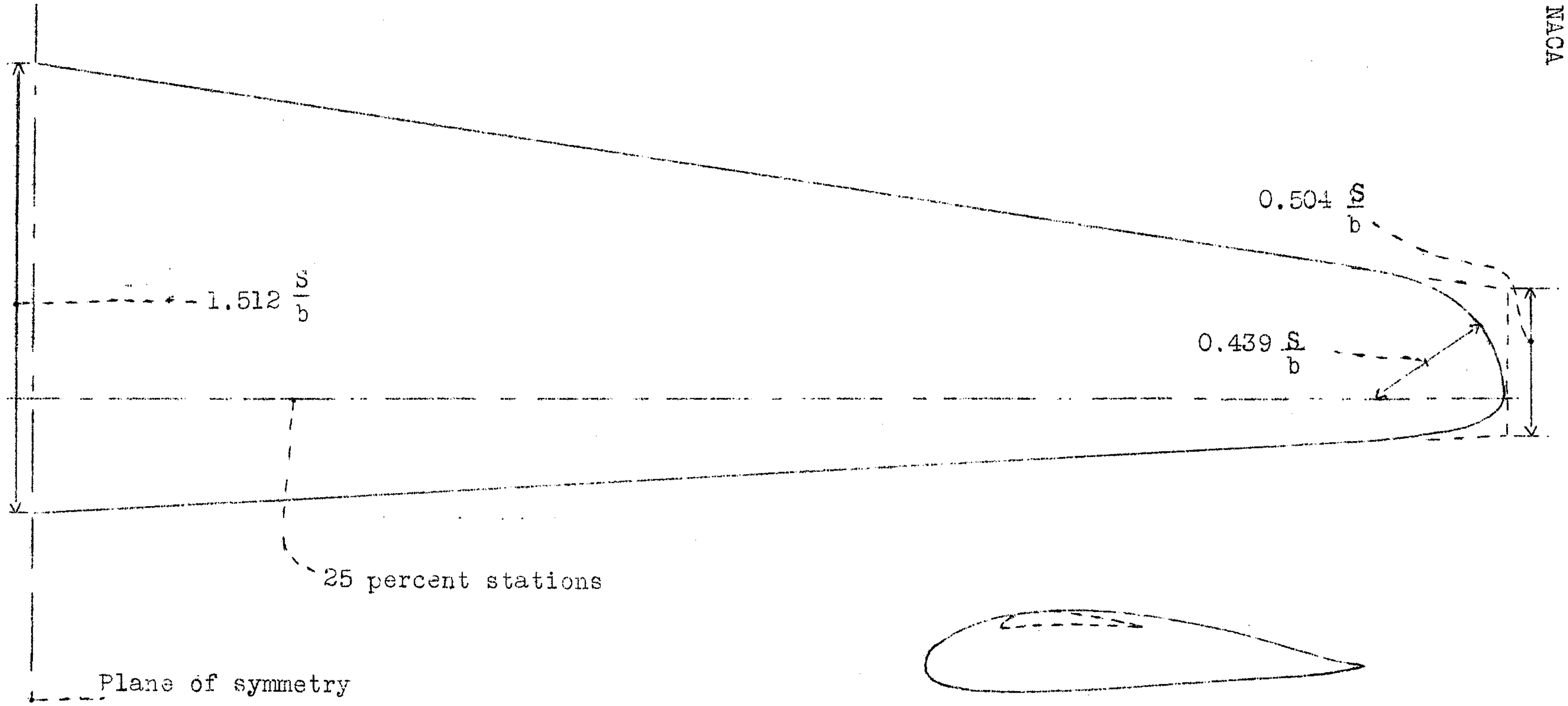
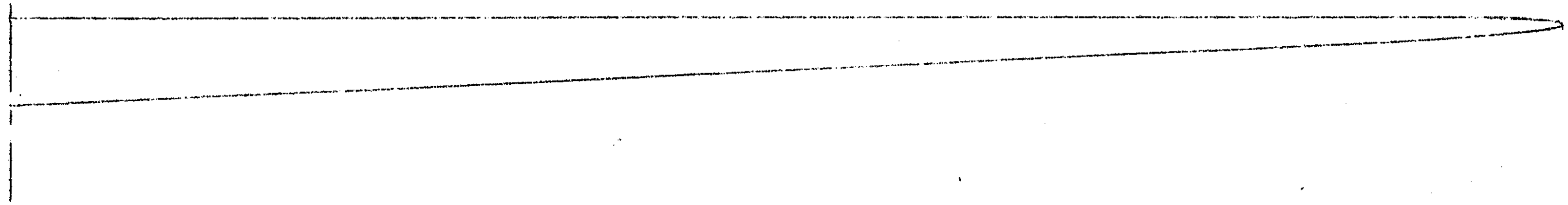


Figure 1.- NACA 3-10-18 tapered wing



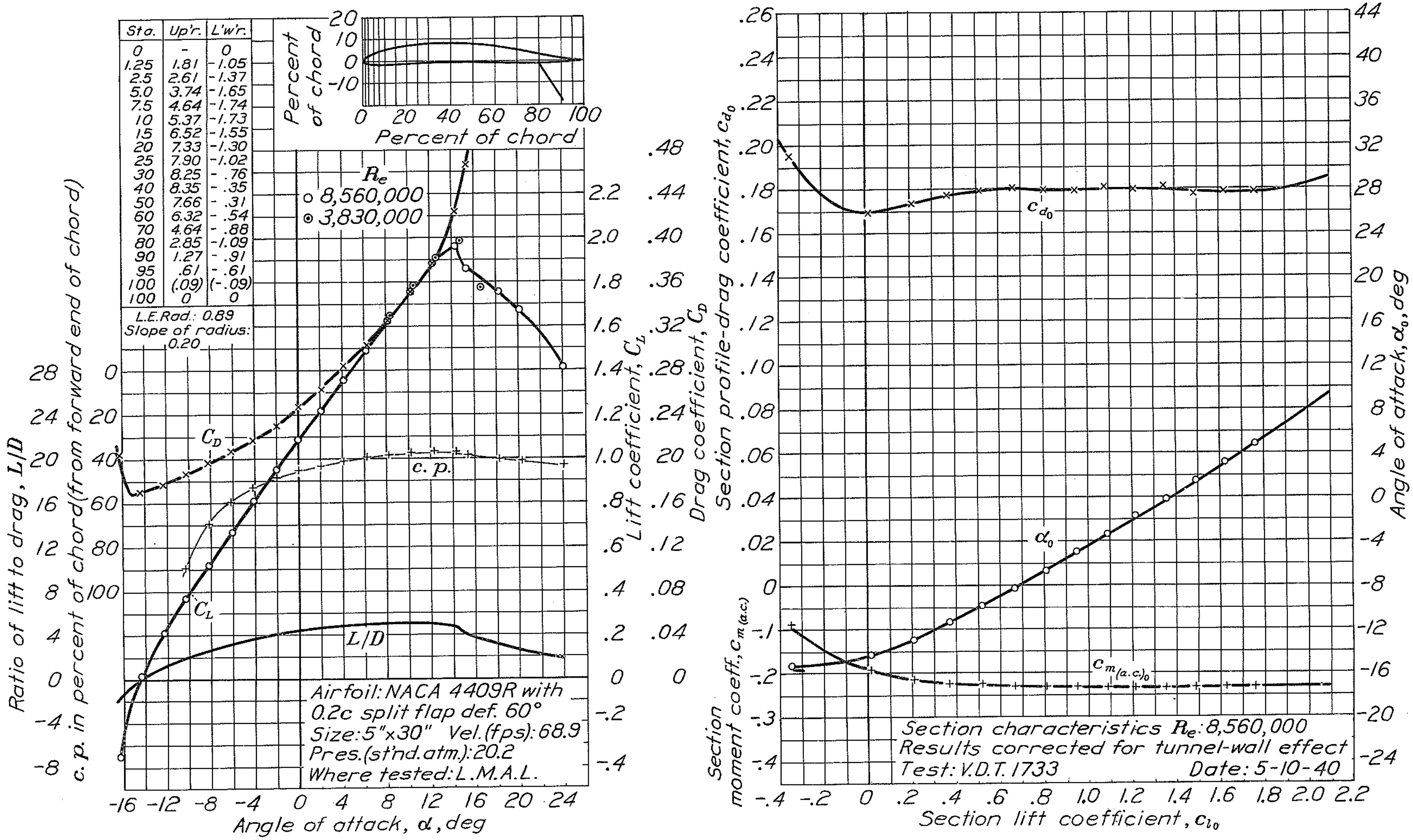
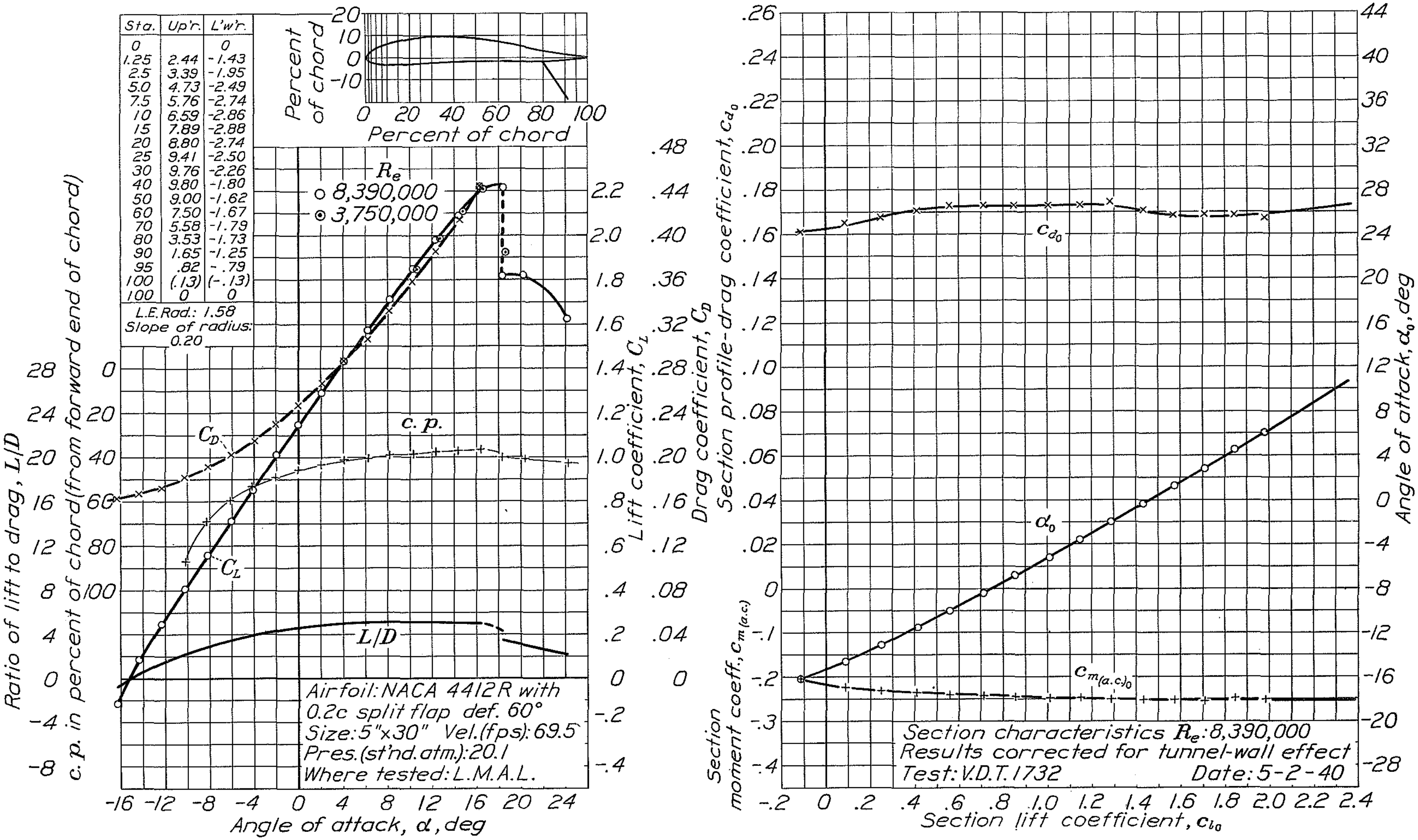


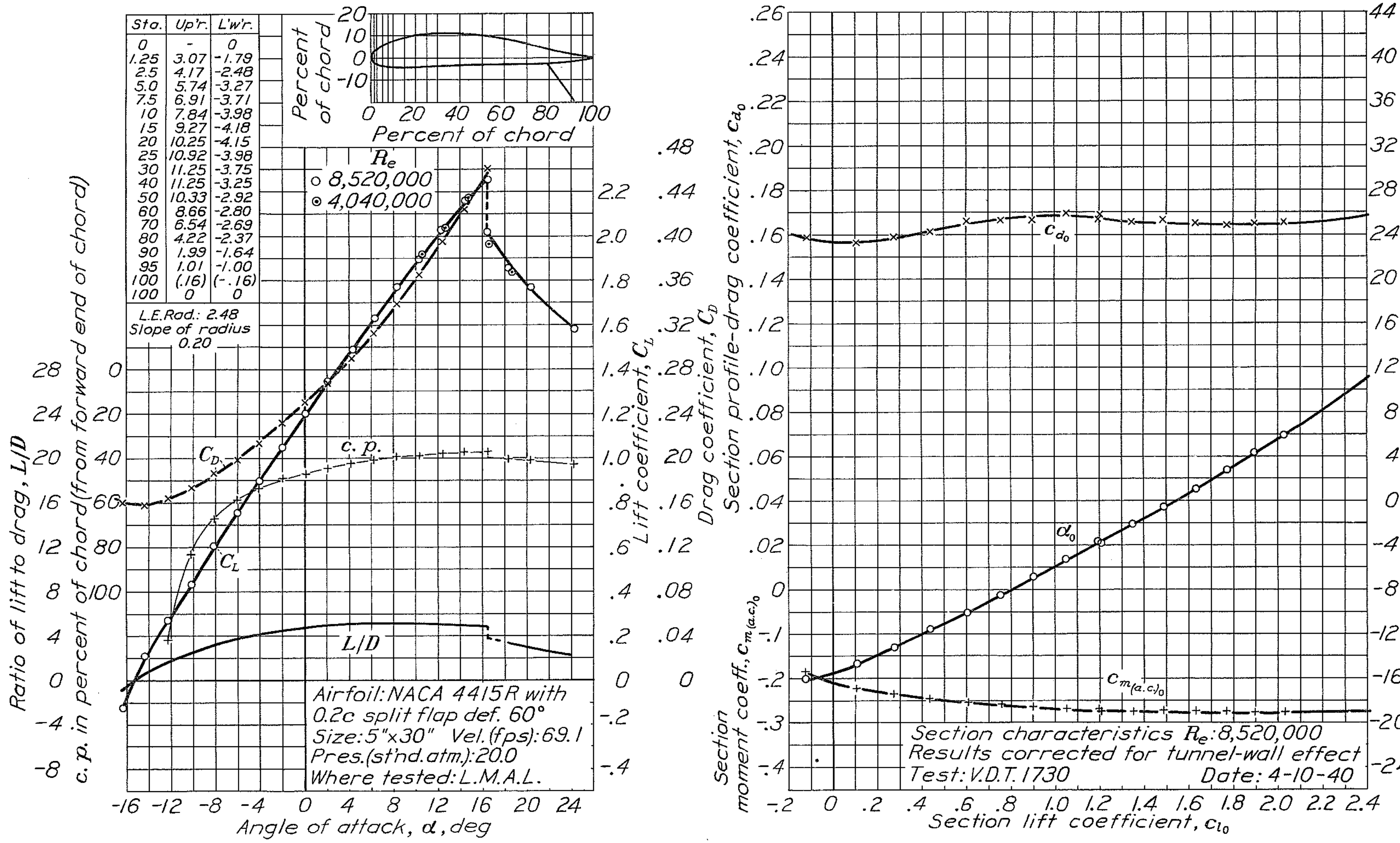
Figure 2.- NACA 4409R with 0.2c split flap deflected 60°.



Sta.	Up'r.	L'w'r.
0		0
1.25	2.44	-1.43
2.5	3.39	-1.95
5.0	4.73	-2.49
7.5	5.76	-2.74
10	6.59	-2.86
15	7.89	-2.88
20	8.80	-2.74
25	9.41	-2.50
30	9.76	-2.26
40	9.80	-1.80
50	9.00	-1.62
60	7.50	-1.67
70	5.58	-1.79
80	3.53	-1.73
90	1.65	-1.25
95	.82	-.79
100	(.13)	(-.13)
100	0	0

L.E. Rad.: 1.58
Slope of radius: 0.20

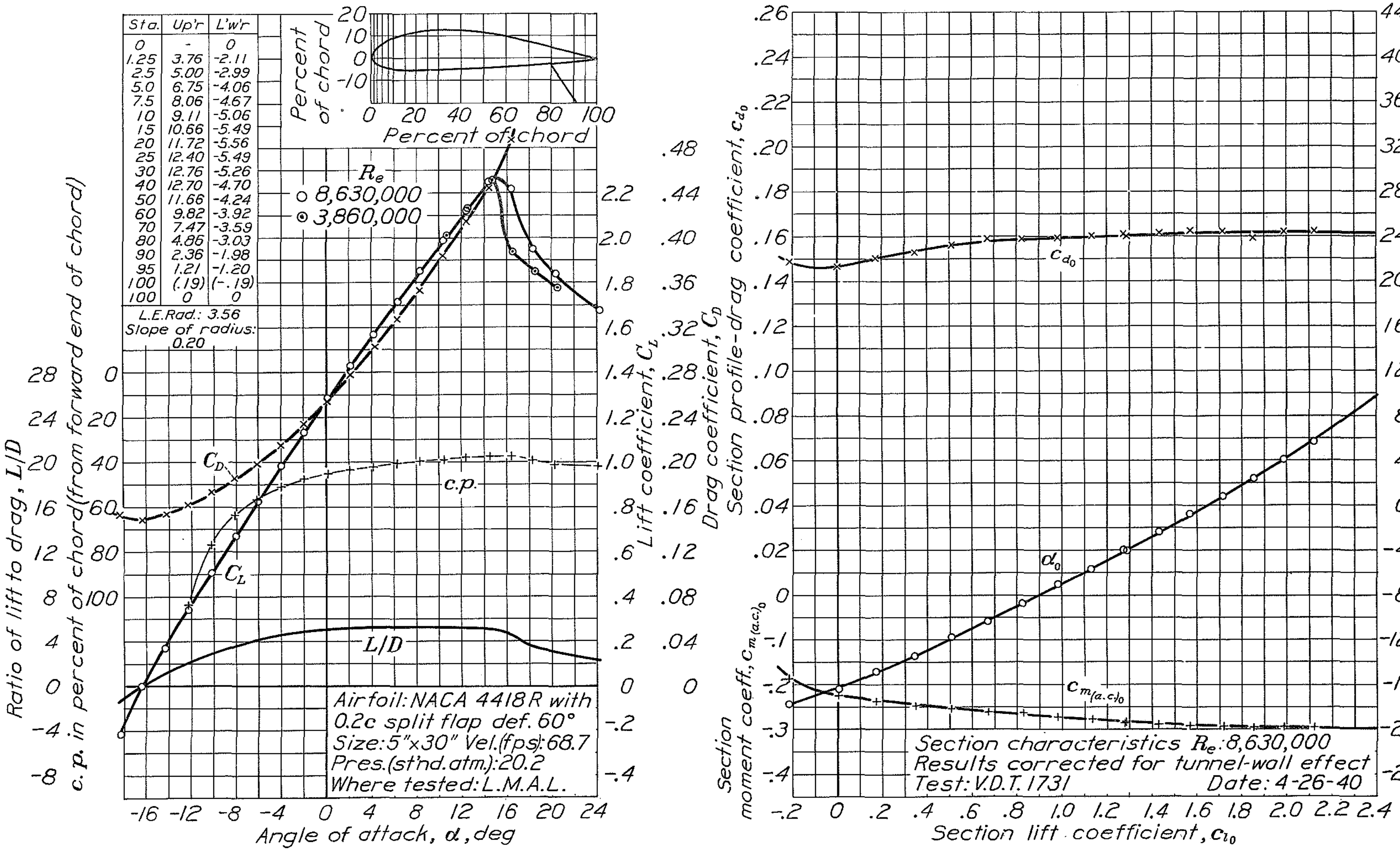
Figure 3.- NACA 4412R with 0.2c split flap deflected 60°.



Sta.	Up'r.	L'w'r.
0	-	0
1.25	3.07	-1.79
2.5	4.17	-2.48
5.0	5.74	-3.27
7.5	6.91	-3.71
10	7.84	-3.98
15	9.27	-4.18
20	10.25	-4.15
25	10.92	-3.98
30	11.25	-3.75
40	11.25	-3.25
50	10.33	-2.92
60	8.66	-2.80
70	6.54	-2.69
80	4.22	-2.37
90	1.99	-1.64
95	1.01	-1.00
100	(.16)	(-.16)
100	0	0

L.E. Rad.: 2.48
Slope of radius 0.20

Figure 4.- NACA 4415R with 0.2c split flap deflected 60°.



Sta.	Up'r	L'w'r
0	-	0
1.25	3.76	-2.11
2.5	5.00	-2.99
5.0	6.75	-4.06
7.5	8.06	-4.67
10	9.11	-5.06
15	10.66	-5.49
20	11.72	-5.56
25	12.40	-5.49
30	12.76	-5.26
40	12.70	-4.70
50	11.66	-4.24
60	9.82	-3.92
70	7.47	-3.59
80	4.86	-3.03
90	2.36	-1.98
95	1.21	-1.20
100	(.19)	(-.19)
100	0	0

Figure 5.- NACA 4418R with 0.2c split flap deflected 60°.

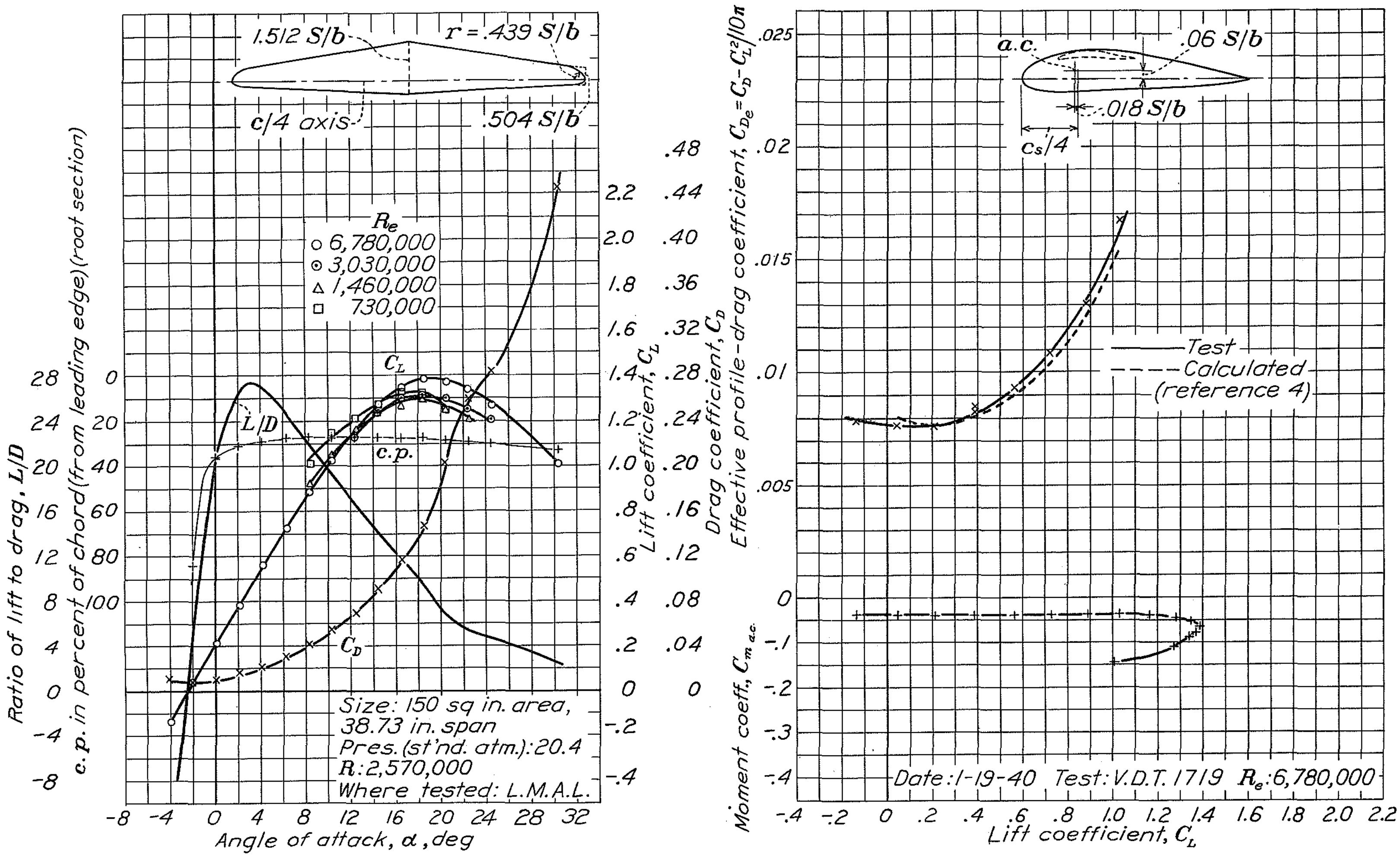


Figure 6.- The tapered NACA 3-10-18 (NACA 4400R) airfoil.

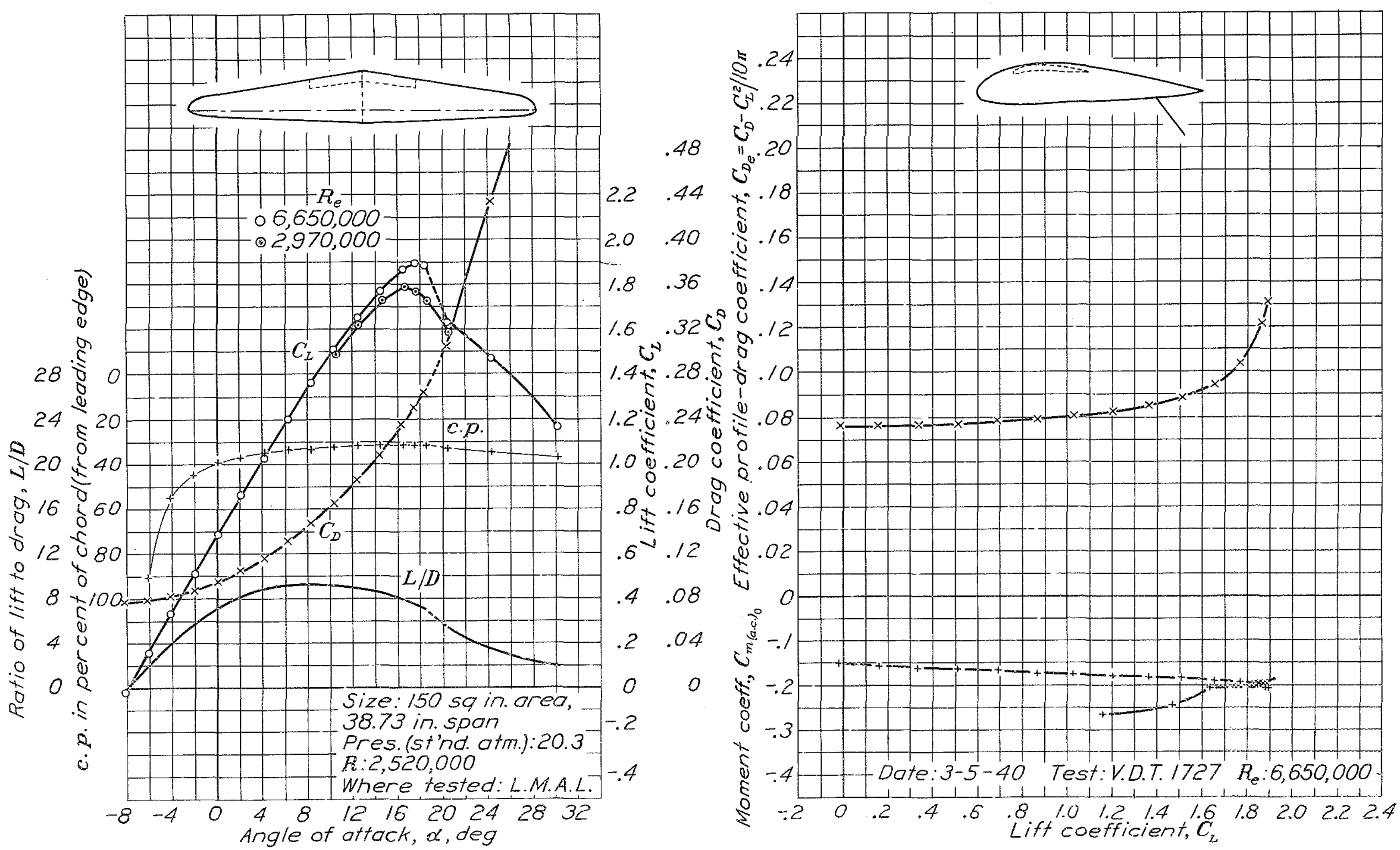


Figure 7.- The tapered NACA 3-10-18 (NACA 4400R) airfoil with 0.2 chord 0.3 span split flap deflected 60°.

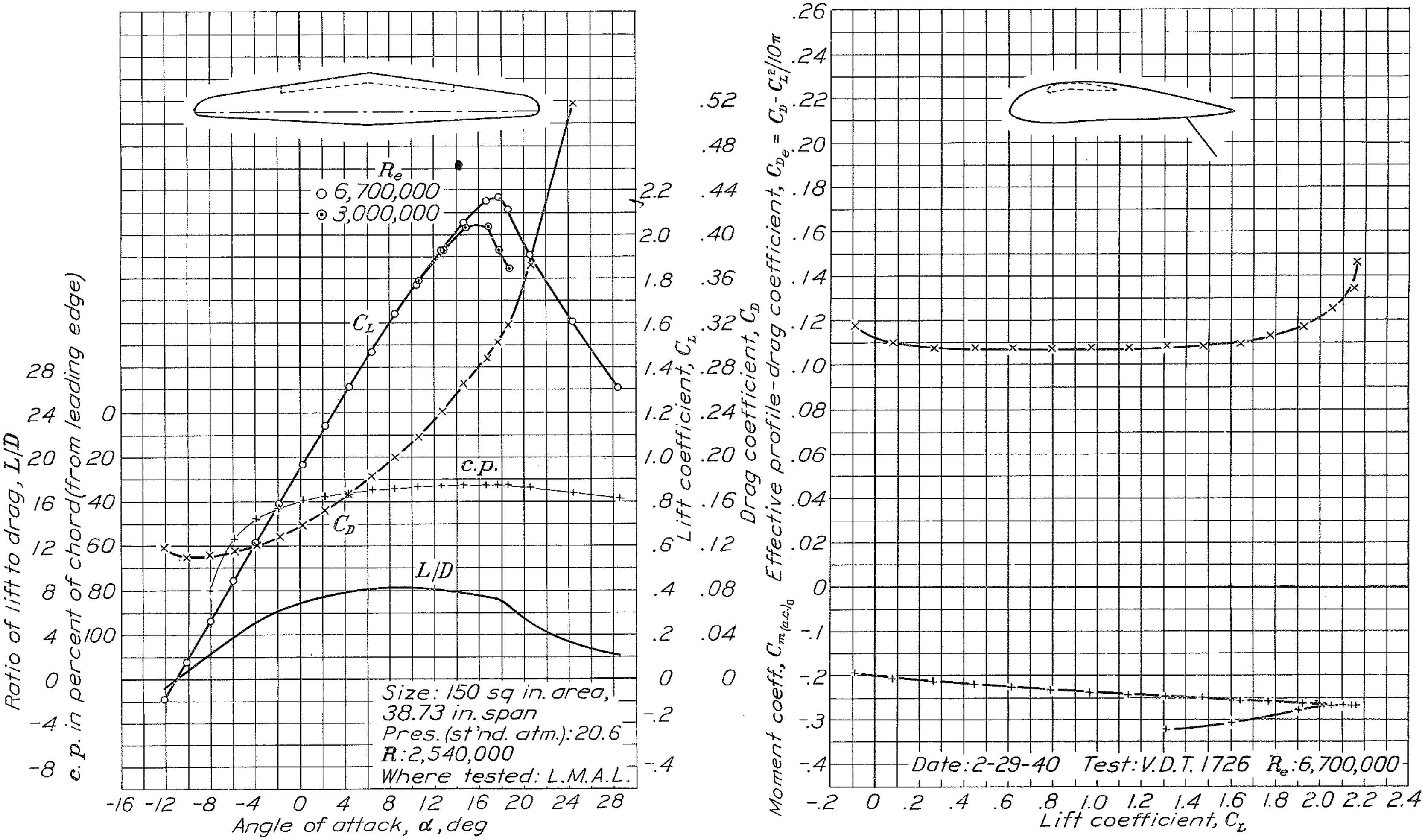


Figure 8.- The tapered NACA 3-10-18 (NACA 4400R) airfoil with 0.2 chord 0.5 span split flap deflected 60°.

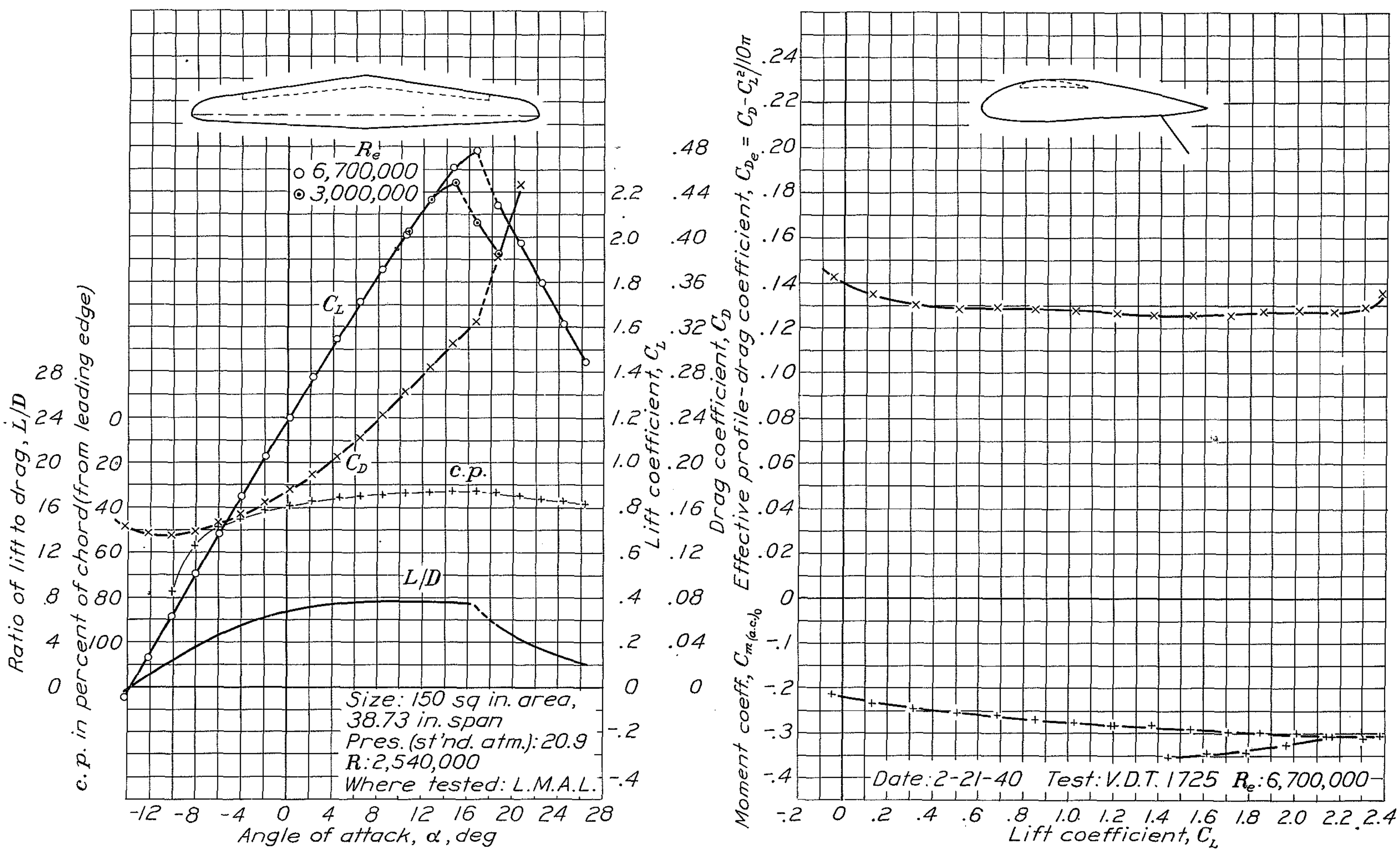


Figure 9.- The tapered NACA 3-10-18 (NACA 4400R) airfoil with 0.2 chord 0.7 span split flap deflected 60°.

NACA

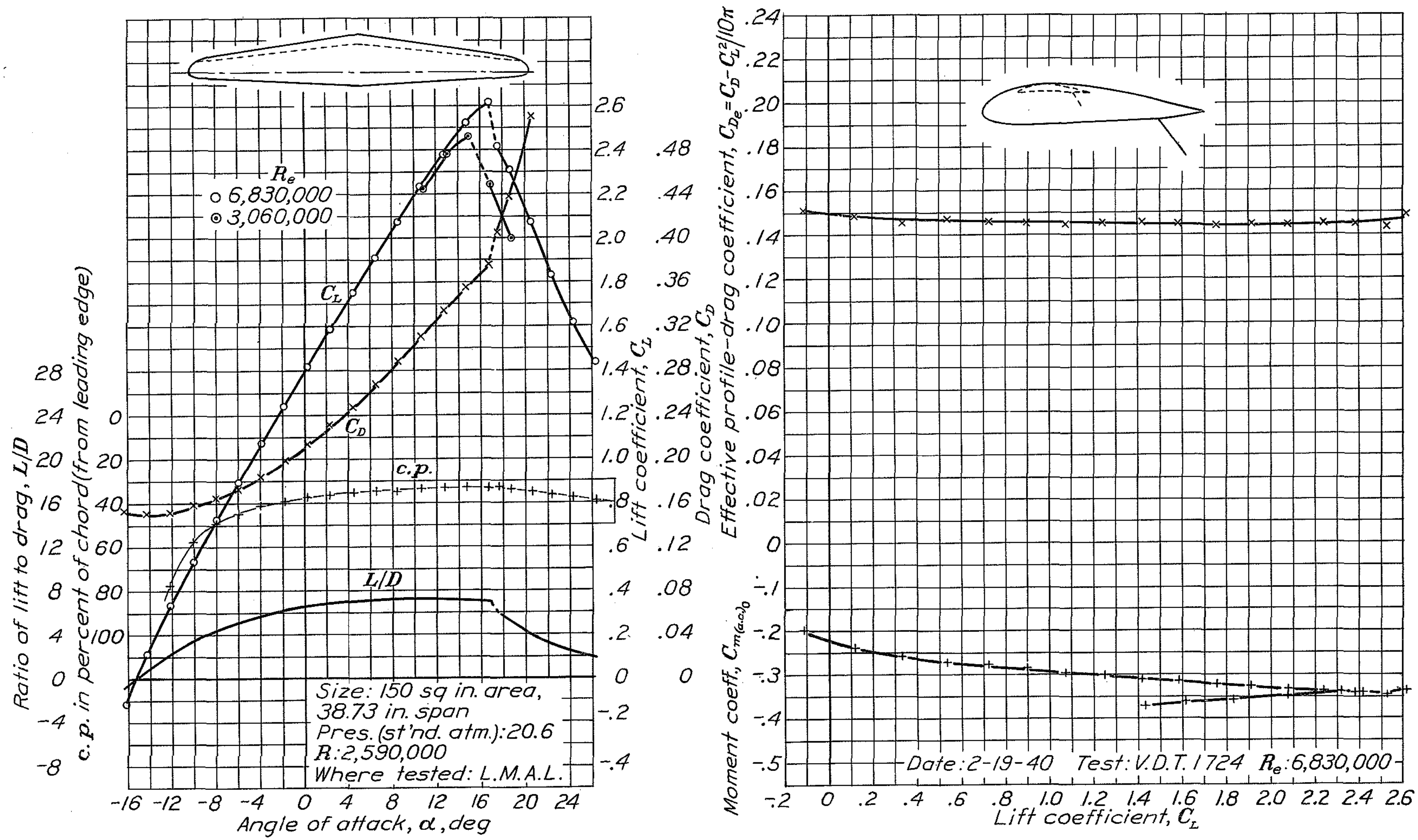


Figure 10.- The tapered NACA 3-10-18 (NACA 4400R) airfoil with 0.2 chord full-span split flap deflected 60°.

Fig. 10