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AERODYNAMIC CHARACTERISTICS OF THE NACA 747A315 AND 747A415 AIRFOILS FROM TESTS IN THE NACA TWO-DIMENSIONAL LOW-TURBULENCE PRESSURE TUNNEL

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WASHINGTON

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

CONFIDENTIAL BULLETIN

AERODYNAMIC CHARACTERISTICS OF THE NACA 747A315 AND 747A415 AIRFOILS FROM TESTS IN THE NACA TWO-DIMENSIONAL LOW-TURBULENCE PRESSURE TUNNEL

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SUMMARY

Two low-drag airfoils, the NACA 747A315 and the NACA 747A415, designed to have reduced pitching moments about the quarter-chord point and moderately high values of the design lift coefficient have been tested in the NACA two-dimensional low-turbulence pressure tunnel. Section lift, drag, and pitching-moment coefficients are presented for Reynolds numbers of 3×10^6, 6×10^6, and 9×10^6, together with section lift and section drag data for a Reynolds number of 6×10^6 for the same airfoils with roughened leading edges.

A comparison of the characteristics, at a Reynolds number of 9×10^6, of the NACA 747A315 and NACA 747A415 airfoils with characteristics of the NACA 65_2-415 airfoil is given in the following table:

NACA airfoil section	Minimum section drag coefficient	Range of section lift coefficient for low drag	Section pitching-moment coefficient about quarter chord at design section lift coefficient	Maximum section lift coefficient	Critical Mach number at design section lift coefficient
747A315	0.0038	0.22 to 0.62	-0.017	1.43	0.626
747A415	.0041	.32 to .72	-.036	1.50	.612
65_2-415	.0042	.08 to .58	-.071	1.62	.641

INTRODUCTION

The type of mean line usually used to camber the 6-series airfoils presented in reference 1 led to relatively high pitching-moment coefficients about the quarter-chord point for a given design lift coefficient. For example, the measured pitching-moment coefficients for airfoils having a mean line of type $a = 1.0$ cambered for a design lift coefficient of 0.4 were approximately -0.070. This moment coefficient is somewhat higher than is desirable for many applications.

The NACA 7-series airfoils were derived in an attempt to obtain moderately high values of the design lift coefficient and to retain the low-drag characteristics of the 6-series airfoils, but with reduced pitching moments. The NACA 7-series airfoils differ from the 6-series airfoils in that the 7-series airfoils have a slightly modified thickness distribution and are combined with mean lines in such a manner that more extensive regions of laminar flow are possible over the lower surface than over the upper surface. The chordwise load distribution is so chosen that the main portion of the lift is carried by the forward part of the airfoil and the pitching moments about the quarter-chord point are thus reduced.

The present report gives data for two airfoils of this type, designated the NACA 747A315 and the NACA 747A415 airfoils, from tests in the NACA two-dimensional low-turbulence pressure tunnel (TDT). Lift, drag, and pitching moments of these sections were measured for a range of Reynolds numbers from 3 to 9×10^6. The effect of roughness at the leading edge on the lift and drag characteristics of the sections was determined at a Reynolds number of 6×10^6.

SYMBOLS

x	distance from airfoil leading edge measured along chord line
α_0	section angle of attack
c	airfoil chord length

c_l	section lift coefficient
c_{l_i}	design lift coefficient for mean line
c_d	section drag coefficient
$c_{m_{c/4}}$	section pitching-moment coefficient about quarter-chord point
v	local velocity over airfoil surface
V	free-stream velocity
a	mean-line designation described in reference 1
R	Reynolds number
M_c	critical Mach number

DERIVATION OF AIRFOILS

In the derivation of the NACA 747A315 airfoil, an attempt was made to have uniform load from the leading edge to 0.4c back of the leading edge, to have this load decrease linearly to zero at 0.7c, and to have zero load from 0.7c to the trailing edge. This object was attained by combining a mean line of type $a = 0.4$ for a design lift coefficient of 0.763 with a mean line of type $a = 0.7$ for a design lift coefficient of -0.463. Ordinates and load distributions for these mean lines may be derived from data presented in reference 1.

In order to maintain a favorable pressure gradient to 0.7c along the lower surface of the NACA 747A315 airfoil, the resulting mean line was combined with a modification of the NACA 64,2-015 airfoil section. The 64,2-015 airfoil section was modified to reduce the slope of the pressure gradient from 0.4c to 0.7c. Figure 1 shows the pressure distribution over the modified symmetrical NACA 64,2-015 airfoil section, together with the pressure distribution of the NACA 747A315 airfoil at the design lift coefficient. Table I gives the ordinates of the modified 64,2-015 airfoil section. Table II gives the ordinates of the 747A315 airfoil section.

The NACA 747A415 airfoil was obtained by combining the modified 64,2-015 airfoil section with the following mean-line combination: $a = 0.4$, $c_{l_i} = 0.763$; $a = 0.7$, $c_{l_i} = -0.463$; and $a = 1.0$, $c_{l_i} = 0.100$. Figure 2 shows the theoretical pressure distribution of the NACA 747A415 airfoil at the design lift coefficient, together with that of the basic symmetrical section (the modified NACA 64,2-015 airfoil). Ordinates for the NACA 747A415 airfoil section are given in table III.

AIRFOIL DESIGNATION

The significance of the numbering system for these airfoils is explained by the following example: In the designation NACA 747A415, the first number "7" indicates the new series number; the second number "4" indicates the extent over the upper surface, in tenths of the chord from the leading edge, of the region of favorable pressure gradient at the design lift coefficient; the third number "7" indicates the extent over the lower surface, in tenths of the chord from the leading edge, of the region of favorable pressure gradient at the design lift coefficient. The significance of the last group of three numbers is the same as for the previous 6-series airfoils (reference 1); that is, the first number following the letter gives the design lift coefficient in tenths, and the last two numbers give the airfoil thickness in percent of the chord. The letter "A", which follows the first three numbers, is a serial letter to distinguish different airfoils having parameters that would correspond to the same numerical designation. For example, a second airfoil having the same extent of favorable pressure gradient over the upper and lower surfaces, the same design lift coefficient, and the same maximum thickness as the original airfoil but having a different mean-line combination and thickness distribution would have the serial letter "B."

TEST PROCEDURE

The models of the NACA 747A315 and 747A415 airfoil sections had a chord of 24 inches and a span of 35.5 inches. The methods of constructing and testing these models were the same as those described in reference 1. The normal corrections for wind-tunnel wall interference were made to the data obtained in the TDT according to the following formulas, in which the primed quantities refer to the values measured in the wind tunnel:

$$\alpha_o = 1.015\ \alpha_o'$$

$$c_d = 0.990\ c_d'$$

$$c_l = 0.975\ c_l'$$

$$c_{m_{c/4}} = 0.990\ c_{m_{c/4}}'$$

In addition to tests at Reynolds numbers of 3, 6, and 9×10^6 in the smooth condition, tests were made at a Reynolds number of 6×10^6 with the leading edges of the airfoils roughened. The roughness consisted of carborundum grains with a maximum diameter of about 0.010 to 0.015 inch. These grains were thinly sprinkled over the leading-edge portion of the wing section covering a region of $1\frac{7}{8}$ inches from the leading edge on the upper and lower surfaces across the span of the model. A thin coat of shellac was used to hold the grains on the surface.

Since the presentation of the data in reference 1, certain changes have been made in the method of computing lift coefficients from tunnel data. More accurate factors have been derived, which give the proportion of lift actually transferred to the floor and the ceiling of the tunnel in the finite length covered by the floor and ceiling orifices. The revised factors result in a decrease in the slope of the lift curve and a decrease in the values of the maximum lift coefficient of approximately 4 percent. In addition to the change in these factors, a correction for increased blocking effect at angles of attack in the neighborhood of maximum lift has been applied to the data presented herein. For the present data, this additional blocking correction derived from pressure measurements along the floor and ceiling of the tunnel resulted in a further reduction of the maximum lift coefficient by between 1 and 2 percent.

RESULTS AND DISCUSSION

Section lift, drag, and pitching-moment data obtained from the TDT tests are presented for the NACA 747A315 and 747A415 airfoils in figures 3 and 4, respectively. For each airfoil, the extent of the low-drag range is nearly as large as would be expected from the tests of a 15-percent thick 6-series airfoil. The center of the low-drag range for both airfoils, however, is about $0.1c_l$ higher than the design lift coefficient given from the combination of mean lines used for each airfoil. This difference is probably due to the approximations involved in the mean-line theory in which the increments in velocity over the upper and lower surfaces are assumed to be small compared with the free-stream velocity.

A comparison of the characteristics of the NACA 747A315 and the NACA 747A415 airfoils with those of the NACA 65_2-415 airfoil at a Reynolds number of 9×10^6 is given in the table that follows. The data for the NACA 65_2-415 airfoil given in the table were obtained from tests in the TDT and have been reduced in the same manner as for the 7-series airfoils. The values of critical Mach number M_c were obtained from the theoretical low-speed pressure distributions by using the chart presented on page 20 of the supplement to reference 1.

NACA airfoil section	$c_{d_{min}}$	Range of c_l for low drag	$c_{m_{c/4}}$ at design c_l	$c_{l_{max}}$	M_c at design c_l
747A315	0.0038	0.22 to 0.62	-0.017	1.43	0.626
747A415	.0041	.32 to .72	-.036	1.50	.612
65_2-415	.0042	.08 to .58	-.071	1.62	.641

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REFERENCE

1. Jacobs, Eastman N., Abbott, Ira H., and Davidson, Milton: Preliminary Low-Drag-Airfoil and Flap Data from Tests at Large Reynolds Numbers and Low Turbulence, and Supplement. NACA ACR, March 1942.

TABLE I.- MODIFIED NACA 64,2-015 AIRFOIL ORDINATES

[Stations and ordinates given in percent of airfoil chord]

Station	Ordinate
0	0
.5	1.199
.75	1.435
1.25	1.801
2.5	2.462
5.0	3.419
7.5	4.143
10	4.743
15	5.684
20	6.384
25	6.898
30	7.253
35	7.454
40	7.494
45	7.316
50	7.003
55	6.584
60	6.064
65	5.449
70	4.738
75	3.921
80	3.020
85	2.086
90	1.193
95	.443
100	0
L.E. radius: 1.544	

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TABLE II.- NACA 747A315 AIRFOIL ORDINATES

[Stations and ordinates given in percent of airfoil chord]

Upper surface		Lower surface	
Station	Ordinate	Station	Ordinate
0	0	0	0
.229	1.305	.771	-1.031
.449	1.599	1.051	-1.207
.911	2.065	1.589	-1.473
2.109	2.935	2.891	-1.927
4.564	4.264	5.436	-2.518
7.053	5.286	7.947	-2.952
9.558	6.140	10.442	-3.304
14.599	7.497	15.401	-3.843
19.668	8.503	20.332	-4.247
24.758	9.242	25.242	-4.546
29.867	9.731	30.133	-4.773
35.001	9.982	34.999	-4.926
40.200	9.962	39.800	-5.020
45.375	9.572	44.625	-5.040
50.447	8.964	49.553	-5.014
55.463	8.206	54.537	-4.930
60.435	7.324	59.565	-4.772
65.366	6.365	64.634	-4.509
70.241	5.354	69.759	-4.110
75.130	4.336	74.870	-3.502
80.073	3.295	79.927	-2.743
85.038	2.257	84.962	-1.915
90.016	1.289	89.984	-1.097
95.004	.481	94.996	-.405
100	0	100	0

L.E. radius: 1.544
Slope of radius through L.E.: 0.232

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TABLE III.- NACA 747A415 AIRFOIL ORDINATES

[Stations and ordinates given in percent of airfoil chord]

Upper surface		Lower surface	
Station	Ordinate	Station	Ordinate
0	0	0	0
.183	1.318	.817	-.994
.398	1.622	1.102	-1.160
.852	2.106	1.648	-1.406
2.041	3.016	2.959	-1.822
4.487	4.411	5.513	-2.349
6.972	5.488	8.028	-2.730
9.476	6.390	10.524	-3.038
14.521	7.827	15.479	-3.501
19.598	8.897	20.402	-3.845
24.698	9.687	25.302	-4.095
29.818	10.216	30.182	-4.286
34.964	10.497	35.036	-4.411
40.176	10.499	39.824	-4.485
45.364	10.121	44.636	-4.493
50.447	9.516	49.553	-4.462
55.474	8.753	54.526	-4.381
60.454	7.859	59.546	-4.235
65.393	6.878	64.607	-3.992
70.273	5.838	69.727	-3.622
75.164	4.783	74.836	-3.053
80.107	3.692	79.893	-2.344
85.066	2.592	84.934	-1.578
90.037	1.546	89.963	-.838
95.015	.639	94.985	-.247
100	0	100	0

L.E. radius: 1.544
Slope of radius through L.E.: 0.274

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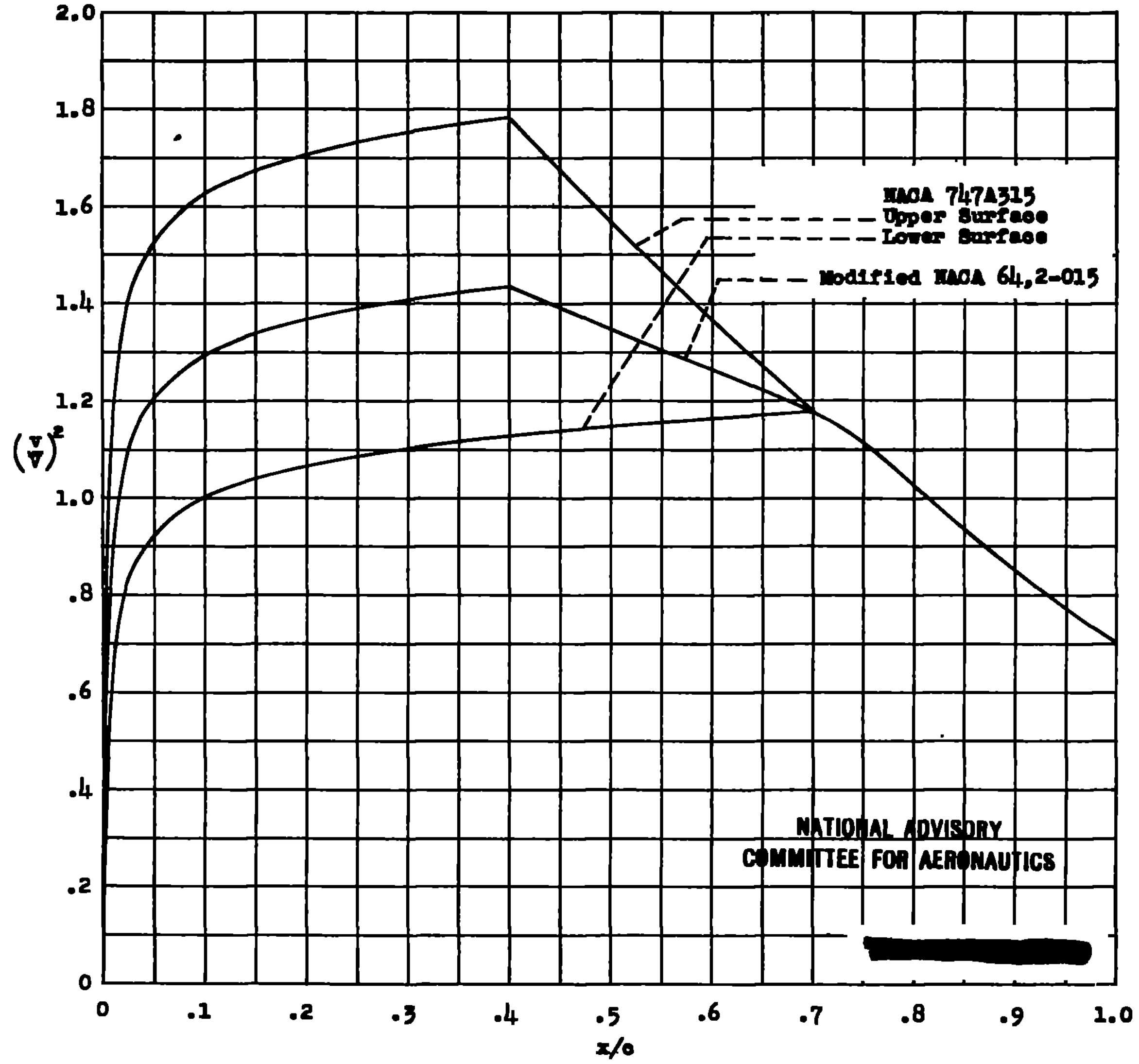

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Figure 1.- Theoretical pressure distribution for NACA 747A315 and modified NACA 64,2-015 airfoils.

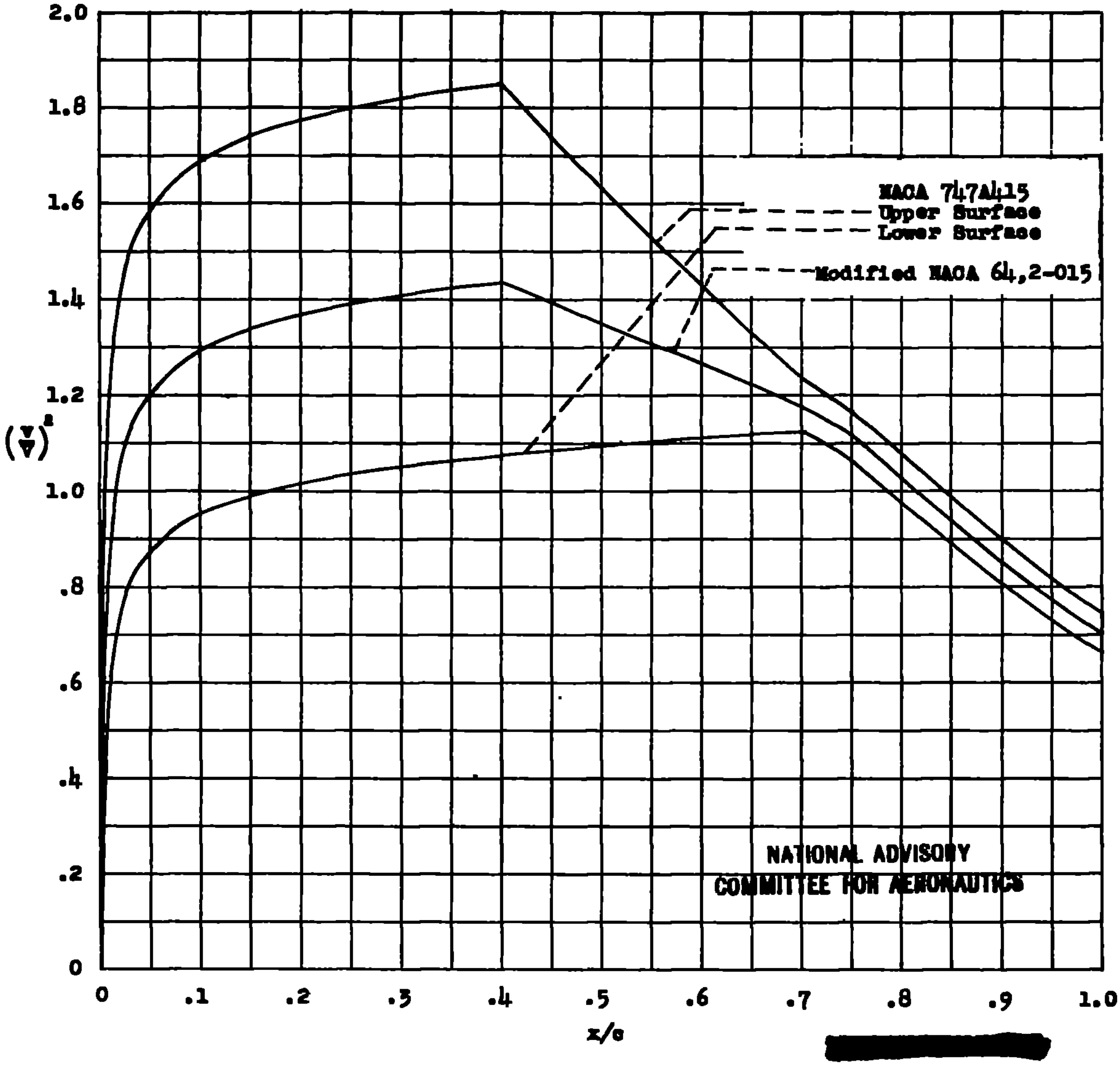

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Figure 2.- Theoretical pressure distribution for NACA 747A415 and modified NACA 64,2-015 airfoils.

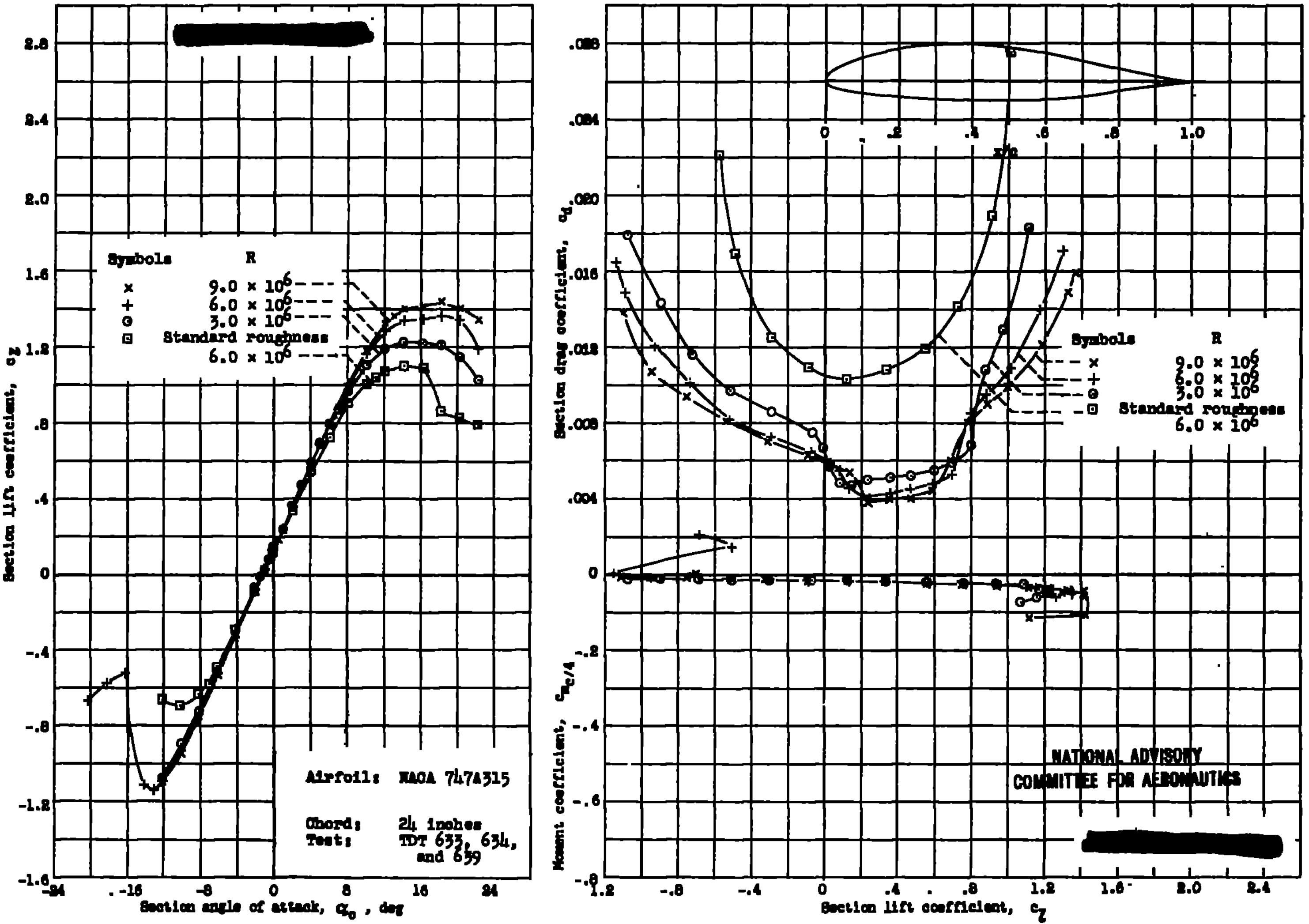

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Figure 3.- NACA 747A315 airfoil.

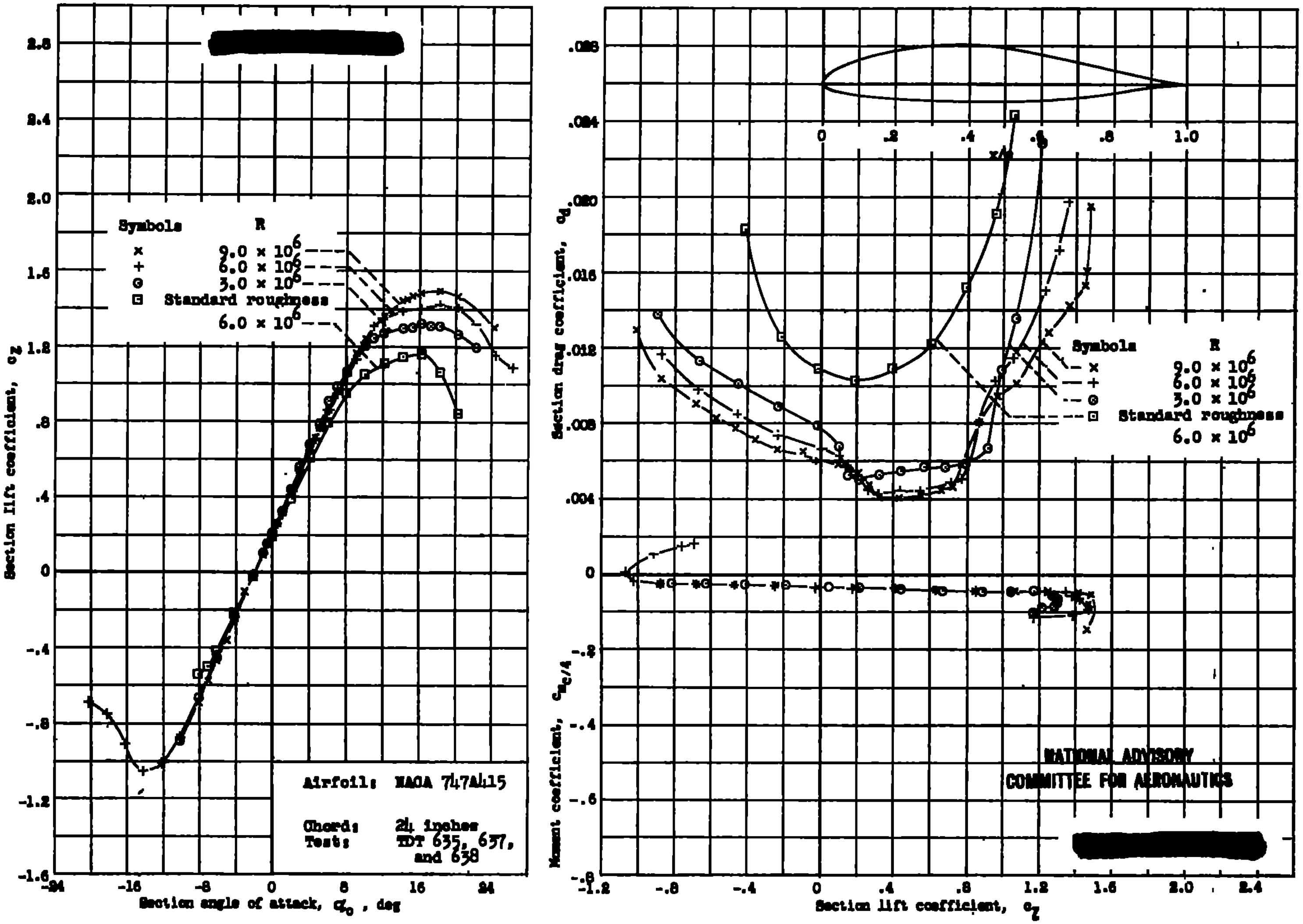
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Figure 4.- NACA 747A415 airfoil.