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PRELIMINARY WIND-TUNNEL INVESTIGATION OF THE EFFECT OF AREA SUCTION ON THE LAMINAR BOUNDARY LAYER OVER AN NACA 64A010 AIRFOIL

By

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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

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SUMMARY

A preliminary investigation was made in the Langley two-dimensional low-turbulence tunnel on an NACA 64A010 airfoil with permeable surfaces to obtain an indication of the stabilizing effect of area suction on the laminar boundary layer. Boundary-layer velocity profiles were measured at Reynolds numbers of 2.0×10^6, 4.0×10^6, and 6.0×10^6 and at various chordwise stations for values of the flow coefficient up to 0.012.

Although the surfaces of the airfoil model that was tested had many waves and irregularities of contour, the data corroborated qualitatively the theoretically predicted stabilizing effect of area suction on a smooth flat plate. The suction quantity required for the wavy airfoil tested, however, was much greater than the theoretical value for a smooth flat plate.

INTRODUCTION

The stability theory for the incompressible laminar boundary layer is based on theoretical analyses of the damping or amplification of mathematically small two-dimensional aerodynamically possible disturbances in the boundary layer (reference 1). A possible definition in the physical sense of a small disturbance is that a small disturbance does not produce transition from laminar to turbulent flow at its origin in contrast with a large disturbance, which does cause immediate transition. Small disturbances may either amplify, as they progress downstream and eventually grow large enough to cause turbulence, or they may be damped and cause no change in the downstream flow; if small disturbances of all frequencies tend to be damped rather than amplified, the laminar boundary layer is considered stable (reference 2).

Theoretical investigations have been made of the characteristics of flows past a flat plate through which there is a small normal velocity, and, in addition, the stability theory has been used to calculate the stability of the laminary boundary layer for this type of flow. Examples of some of this theoretical work can be found in references 3 to 7 and in British work (not generally available). The results of these analyses indicate that a small normal velocity into the surface at all points along the surface has a large stabilizing effect on the laminar layer. Inasmuch as there appear to be no data that show this effect experimentally, an investigation of the effect of area suction on the boundary-layer stability is being made in the Langley low-turbulence tunnels.

This paper presents the results of a few exploratory tests of a rather crude airfoil model made to show whether the laminar layer could be extended by means of area suction. The tests were made at Reynolds numbers of 2.0×10^6, 4.0×10^6, and 6.0×10^6.

SYMBOLS AND COEFFICIENTS

The symbols and coefficients used in the presentation of results are defined as follows:

α_o section angle of attack

c airfoil chord

b airfoil span

x distance along chord from leading edge of airfoil

y distance normal to surface of airfoil

ρ_o free-stream mass density

U_o free-stream velocity

q_o free-stream dynamic pressure $\left(\frac{1}{2}\rho_o U_o^2\right)$

U local velocity at outer edge of boundary layer

u local velocity inside boundary layer

Q total quantity flow through airfoil surfaces

C_Q flow coefficient $\left(\frac{Q}{bcU_o}\right)$

H_o free-stream total pressure

P local static pressure

S airfoil pressure coefficient $\left(\frac{H_0 - P}{q_0}\right)$

R free-stream Reynolds number based on airfoil chord

MODEL

A photograph of the 6-foot-chord by 3-foot-span model mounted in the Langley two-dimensional low-turbulence tunnel is presented as figure 1. A sketch of the model construction is shown in figure 2. The model was formed to the NACA 64A010 profile, ordinates for which are presented in reference 8, and consisted of a framework of plywood ribs and stiffeners spaced 3 inches apart. The frame was covered with a layer of coarse wire screen, which in turn was covered with two layers of 60-mesh screen. A continuous sheet of blotting paper was used as the porous airfoil surface. The porosity of the blotting paper was such that, with air at approximately standard density, an applied suction of 2 pounds per square inch induced a velocity of 1.0 foot per second through the paper. The flow quantity through the paper varied directly with the pressure drop, as is characteristic of dense filters.

The blotting paper was painted with lacquer at the model leading edge and bent to contour while wet in an attempt to prevent the creases that were expected to form at the leading edge. Large flat spots and creases, however, did occur, and examples of the resulting nose contour are shown in figure 3. The porosity of the blotting paper was substantially unaffected by the dried lacquer. In addition to the basic contour inaccuracies, the surface became slightly dimpled because of the sinking of the blotting paper and the fine screen into the mesh of the heavy screen by an amount which varied with the suction applied.

APPARATUS AND TESTS

The model was tested in the Langley two-dimensional low-turbulence tunnel and completely spanned the test section as shown in figure 1. A detailed description of this tunnel is given in reference 9. Flow measurements were made by means of an orifice plate in the suction duct. The suction flow was taken through one of the model end plates and was regulated by varying the blower speed and the orifice diameter.

A conventional multitube total-pressure "mouse" (reference 10) was used to obtain the boundary-layer measurements. The airfoil pressure distribution was obtained from a static-pressure tube on the boundary-layer mouse. At each station, the total- and static-pressure tubes were bent approximately to the airfoil contour. Boundary-layer measurements were made at Reynolds numbers of 2.0×10^6 and 4.0×10^6 for flow coefficients up to 0.012 and also at a Reynolds number of 6.0×10^6 for flow coefficients up to 0.008. The measurements were made at a spanwise station approximately 2 inches from the model center line. (See fig. 1.) All tests were made at 0° angle of attack.

RESULTS AND DISCUSSION

A typical variation of measured pressure coefficients with chordwise position is presented in figure 4 and clearly indicates the wavy nature of the airfoil surface. No significant changes in pressure coefficient were obtained with changes in the values of Reynolds number or flow coefficient. The boundary-layer velocity profiles, which are presented in figure 5, are shown plotted with $\frac{x}{c}\sqrt{R}$ as abscissa in order to present the laminar profiles in a form similar to previously reported laminar profiles. The boundary-layer profiles cannot be considered quantitative because the mouse tube heights changed with flexure of the blotting paper as the suction was varied.

Boundary-layer surveys for flow coefficients approaching zero (not presented) indicated that the transition from laminar to turbulent flow occurred forward of 6-percent chord for all Reynolds numbers tested. With a flow coefficient of 0.008, transition still occurred ahead of the 0.09c station at a Reynolds number of 6.0×10^6 as can be seen from figure 5(a) where the velocity profile appears to be turbulent in character. With a flow coefficient of 0.008, transition occurred between 0.09c and 0.12c at a Reynolds number of 4.0×10^6 as indicated by a comparison of figure 5(a) with 5(b) where the velocity profile appears to be laminar in character at 0.09c and turbulent at 0.12c; movement of the transition point slightly beyond 0.12c required a flow coefficient of 0.012 (fig. 5(b)). At a Reynolds number of 2.0×10^6 (fig. 5(c)), a flow coefficient of between 0.002 and 0.004 was sufficient to maintain laminar flow to 0.39c, which is about the normal transition position on a smooth and fair NACA 64A010 airfoil at the same Reynolds number. An increase in the value of C_Q to 0.008 moved the point of transition back to at least 0.48c at a Reynolds number of 2.0×10^6 as can be seen from figure 5(d).

The stability theory (reference 7) indicates that with constant area suction, a flow coefficient of 0.00024 is necessary to maintain stable laminar boundary layers on both sides of a flat plate. The flow coefficients required to maintain laminar flow over the blotting paper airfoil were much greater than the value indicated by the theory. It must be realized that the stability theory is based upon the assumption of small disturbances and a constant pressure along the surfaces. The numerous irregularities on the blotting paper airfoil cannot be considered small and the wavy pressure distribution is not similar to that used for the flat-plate calculations. Inasmuch as the present preliminary tests do indicate, however, that area suction has a stabilizing effect on the laminar boundary layer even in the presence of fairly large disturbances, it seems worth while to determine the degree to which area suction is stabilizing in the presence of varying degrees of disturbances and at large values of the Reynolds number.

CONCLUDING REMARKS

The results of preliminary tests of an NACA 64A010 airfoil with area suction of the boundary-layer air indicated that area suction has a stabilizing effect on the laminar boundary layer in the presence of surface waves and irregularities, at least for the lower range of Reynolds numbers investigated. The suction quantities required to maintain a laminar layer on this wavy surface were very much greater than the quantity predicted from the theory for small disturbances for a smooth flat plate. The results emphasize the necessity for obtaining quantitative measurements on a model of stiffer surface construction in order to determine the degree to which area suction is stabilizing in the presence of varying degrees of disturbances and at large values of the Reynolds number.

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REFERENCES

1. Lin, C. C.: On the Stability of Two-Dimensional Parallel Flows. Part I. Quarterly Appl. Math., vol. III, no. 2, July 1945, pp. 117-142; Part II, vol. III, no. 3, Oct. 1945, pp. 218-234; and Part III, vol III, no. 4, Jan. 1946, pp. 277-301.

2. Schubauer, G. B., and Skramstad, H. K.: Laminar-Boundary-Layer Oscillations and Transition on a Flat Plate. NACA ACR, April 1943.

3. Schlichting, H.: The Boundary Layer of the Flat Plate under Conditions of Suction and Air Injection. R.T.P. Translation No. 1753, British Ministry of Aircraft Production. (From Luftfahrtforschung, Bd. 19, Lfg. 9, Oct. 20, 1942, pp. 293-301.)

4. Iglisch, Rudolf: Exakte Berechnung der laminaren Grenzschicht an der längsangeströmten ebenen Platte mit honogener Absaugung. Schriften der Deutschen Akademie der Luftfahrtforschung, Bd. 8B, Heft 1, 1944.

5. Pretsch, J.: Die Leistungsersparnis durch Grenzschicht-beeinflussung beim Schleppen einer ebenen Platte. UM Nr. 3048, Deutsche Luftfahrtforschung (Berlin-Adlershof), 1943.

6. Schlichting, H.: Berechnung der laminaren Reibungsschicht mit Absaugung. Forschungsbericht Nr. 1480. Deutsche Luftfahrtforschung (Berlin-Adlershof), 1941.

7. Ulrich, A.: Theoretical Investigation of Drag Reduction in Maintaining the Laminar Boundary Layer by Suction. NACA TM No. 1121, 1947.

8. Loftin, Laurence K., Jr.: Theoretical and Experimental Data for a Number of NACA 6A-Series Airfoil Sections. NACA TN No. 1368, 1947.

9. von Doenhoff, Albert E., and Abbott, Frank T., Jr.: The Langley Two-Dimensional Low-Turbulence Pressure Tunnel. NACA TN No. 1283, 1947.

10. von Doenhoff, Albert E.: Investigation of the Boundary Layer about a Symmetrical Airfoil in a Wind Tunnel of Low Turbulence. NACA ACR, Aug. 1940.

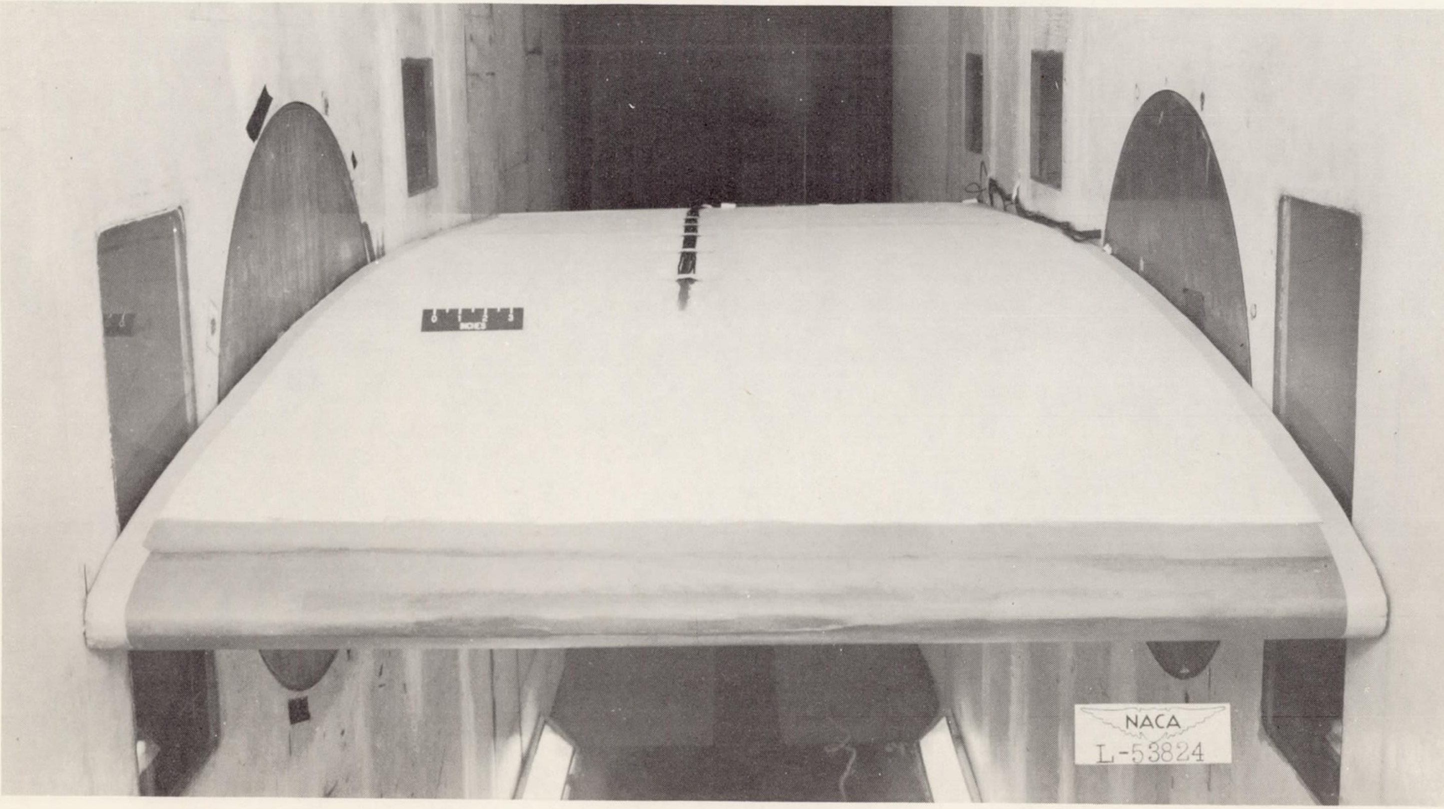


Figure 1.- Photograph showing boundary-layer mouse on the NACA 64A010 airfoil with permeable surfaces in the Langley two-dimensional low-turbulence tunnel.

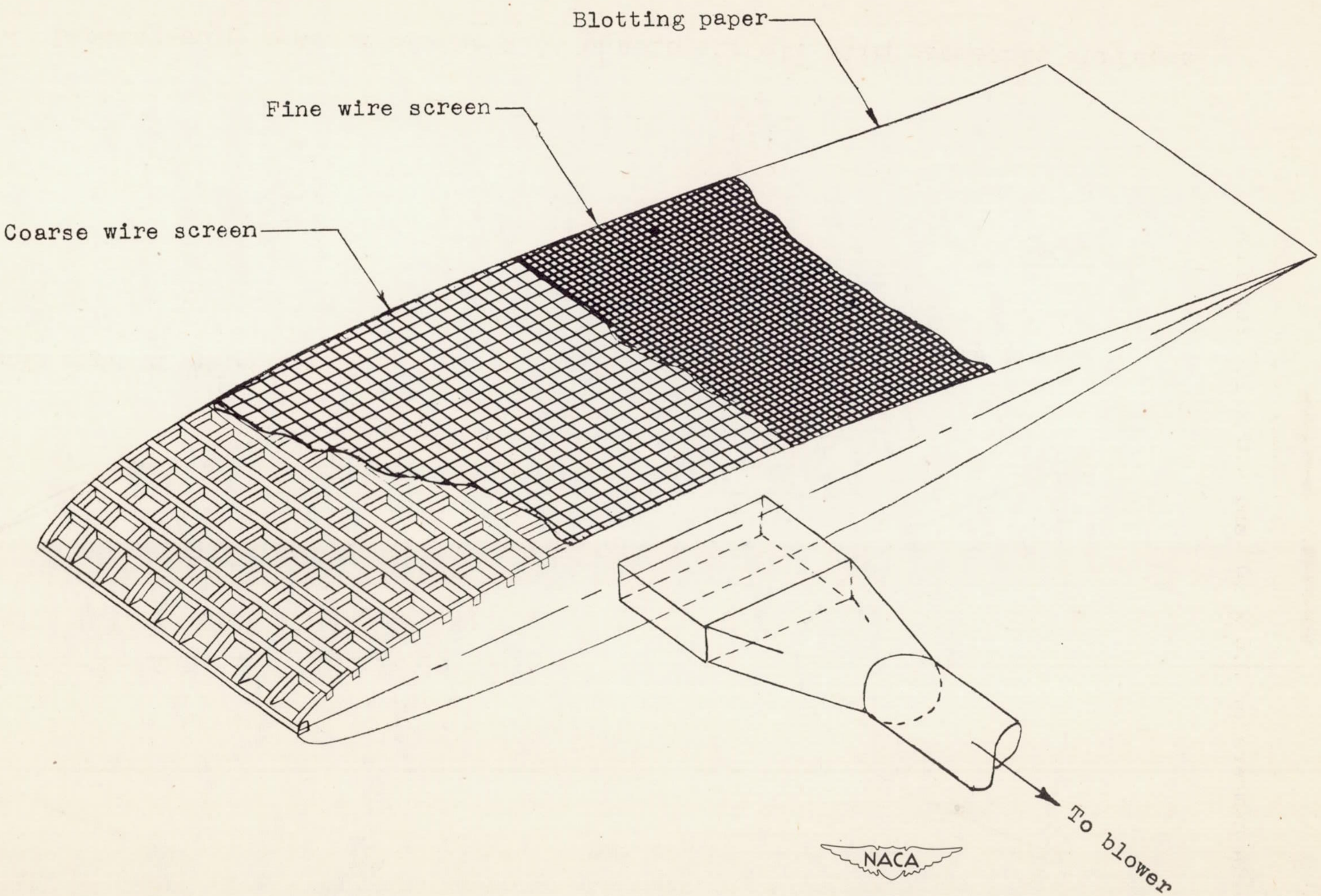


Figure 2.- Method used in construction of the NACA 64A010 airfoil with permeable surfaces.

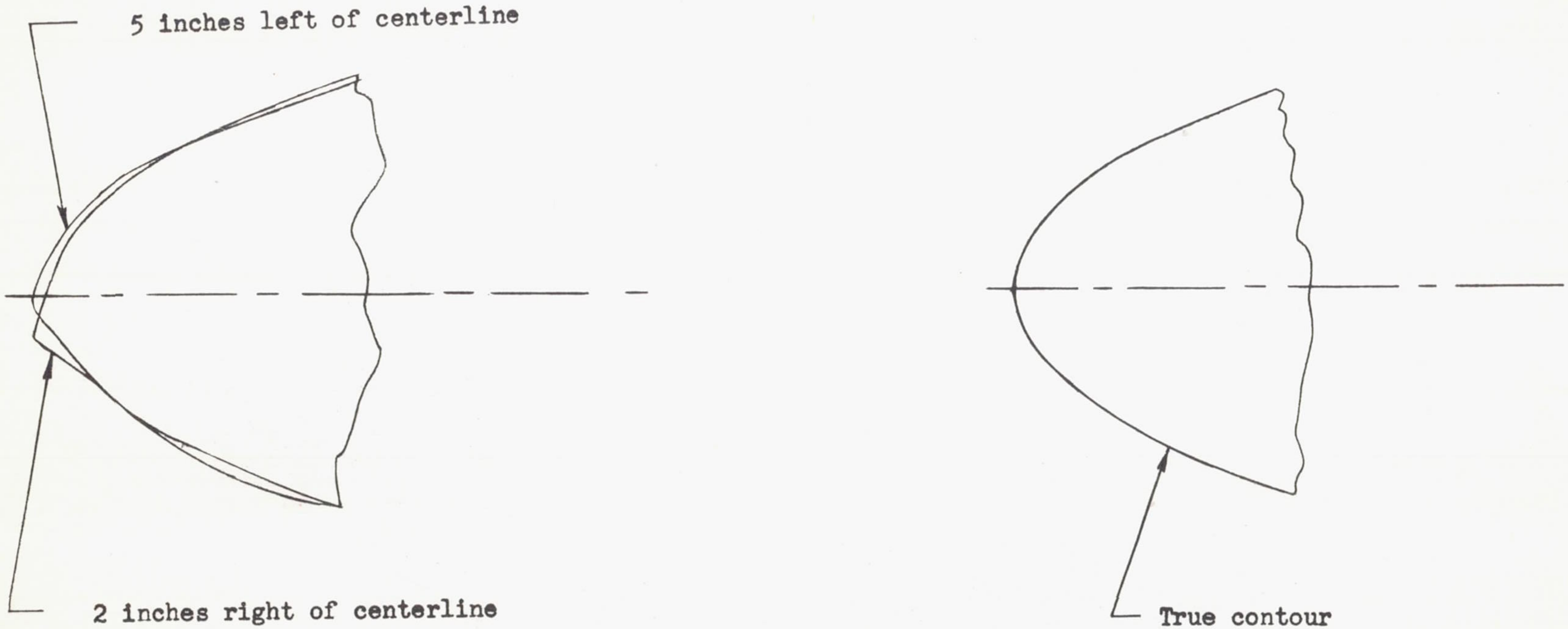


Figure 3.- Leading-edge contour of the NACA 64A010 airfoil with permeable surfaces.

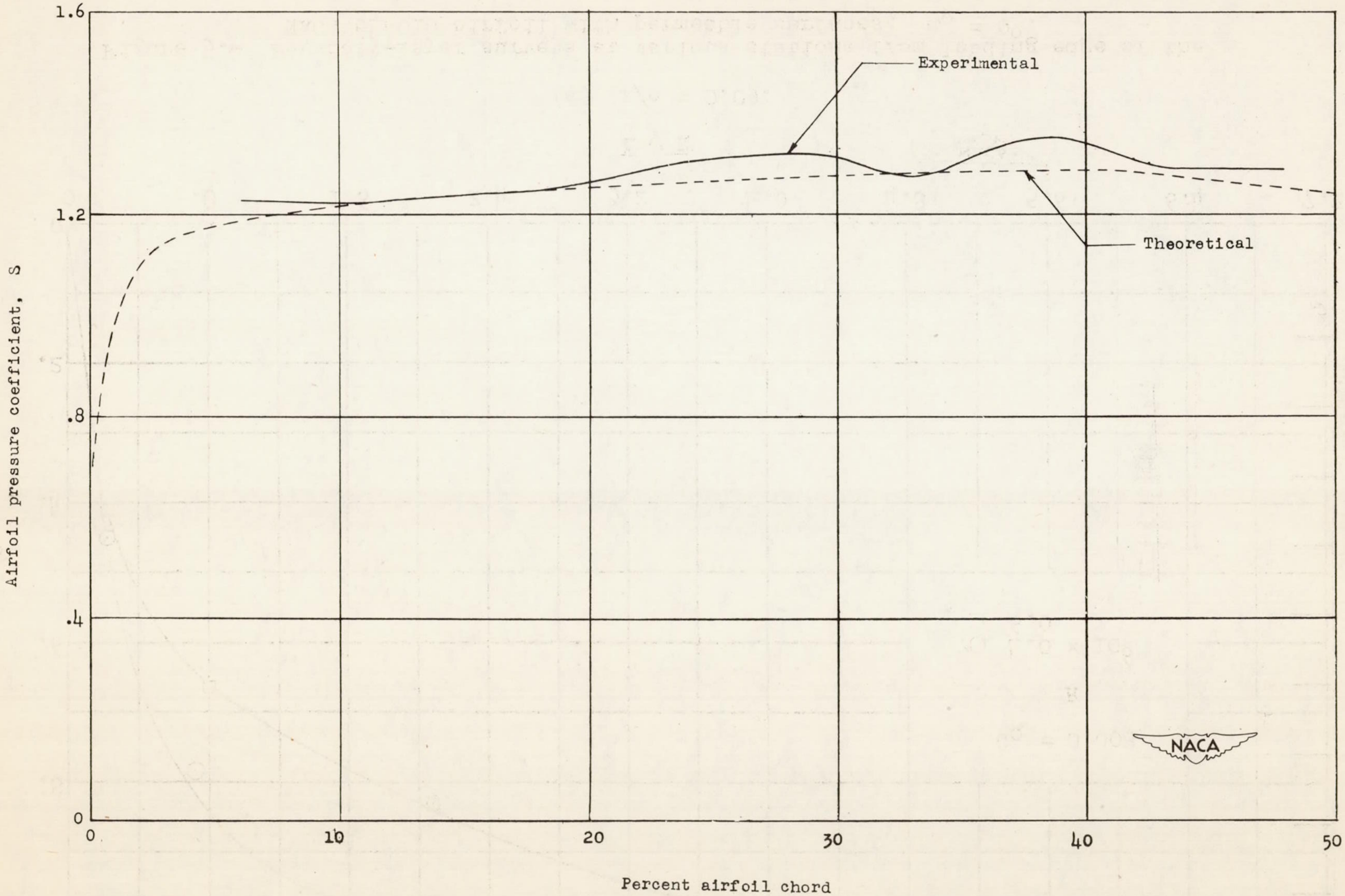
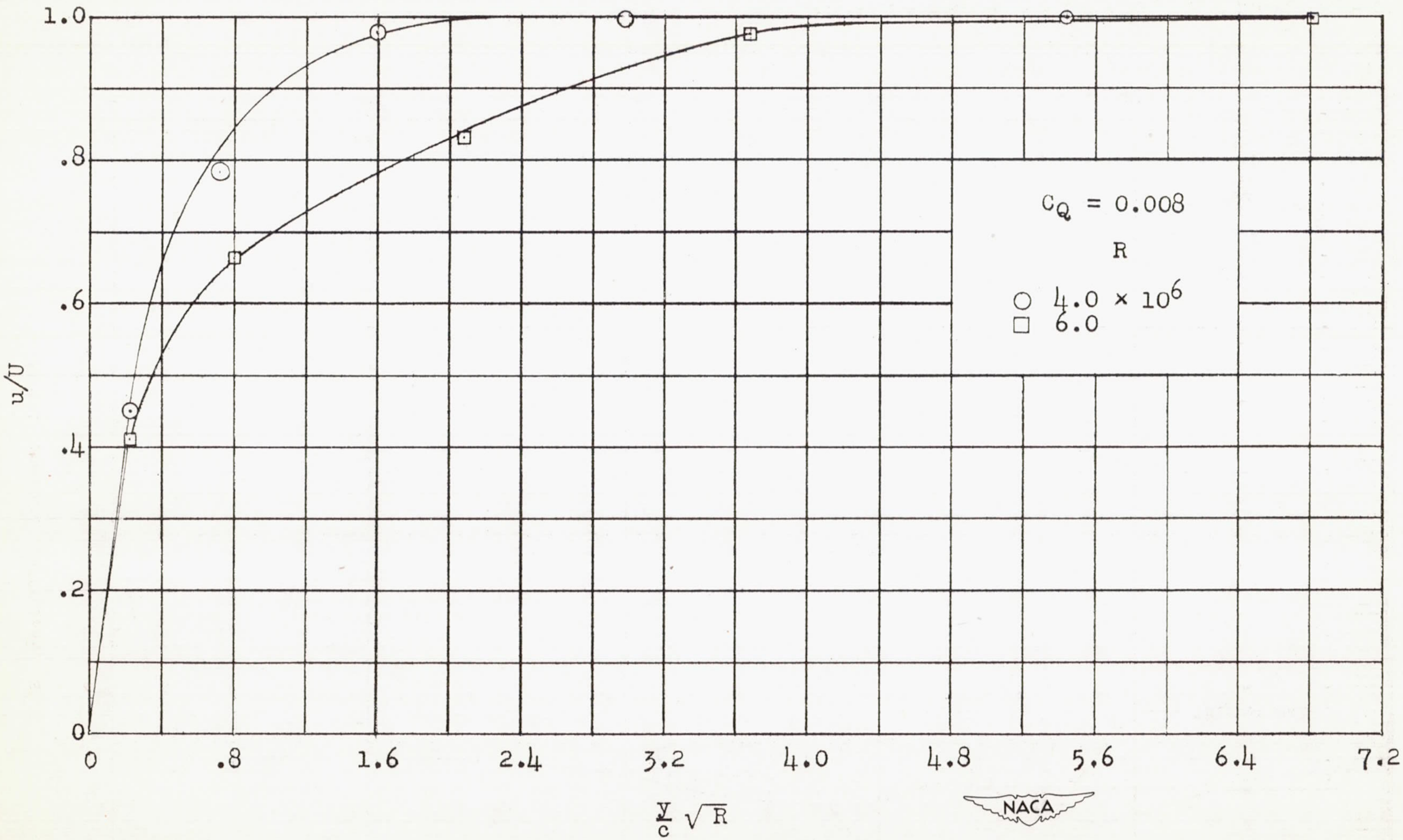
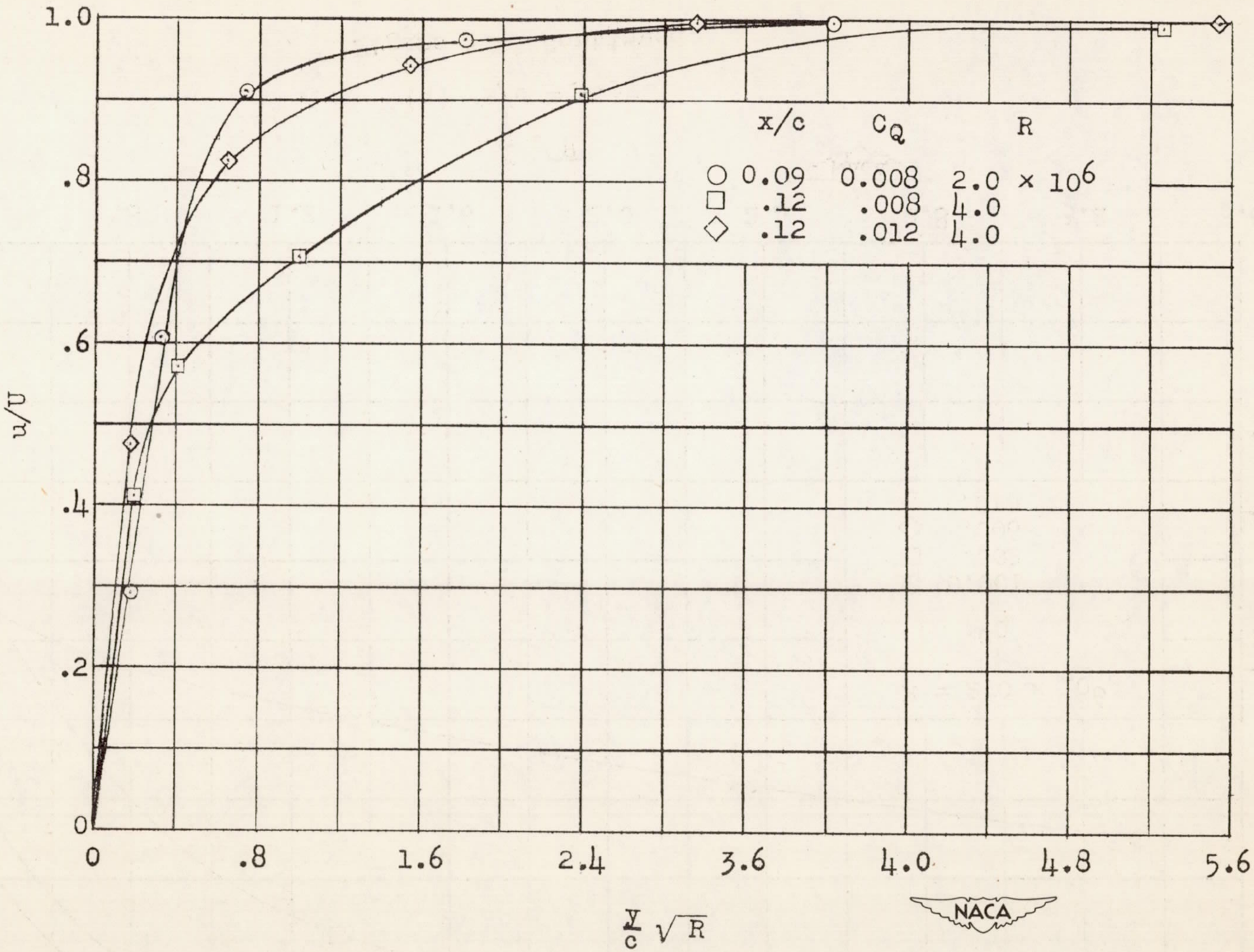


Figure 4.- Pressure distribution for the NACA 64A010 airfoil with permeable surfaces; $R = 2.0 \times 10^6$, $c_Q = 0.008$, $\alpha_o = 0^\circ$.



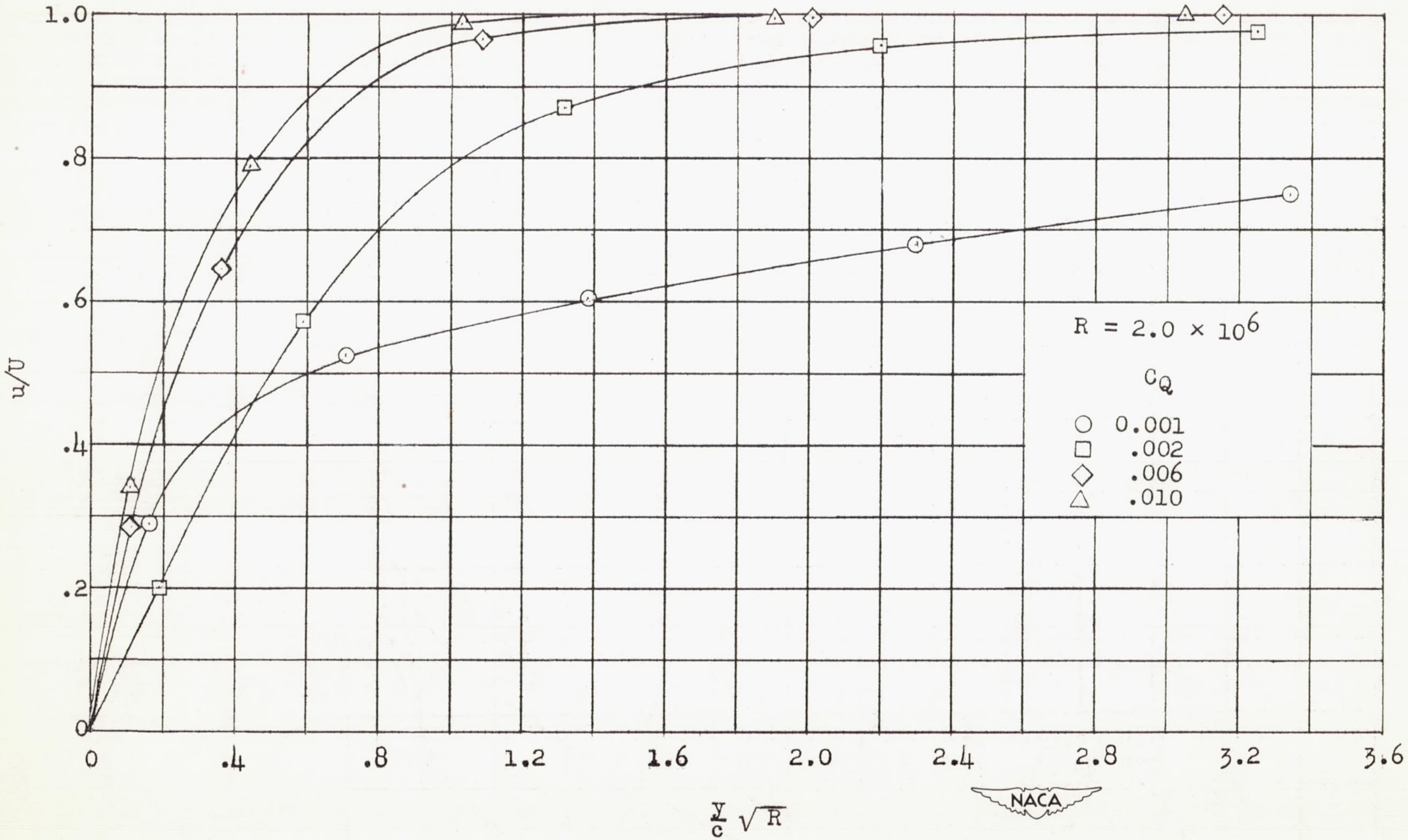
(a) x/c = 0.09.

Figure 5.- Boundary-layer surveys at various stations from leading edge of the NACA 64A010 airfoil with permeable surfaces; $\alpha_o = 0^o$.



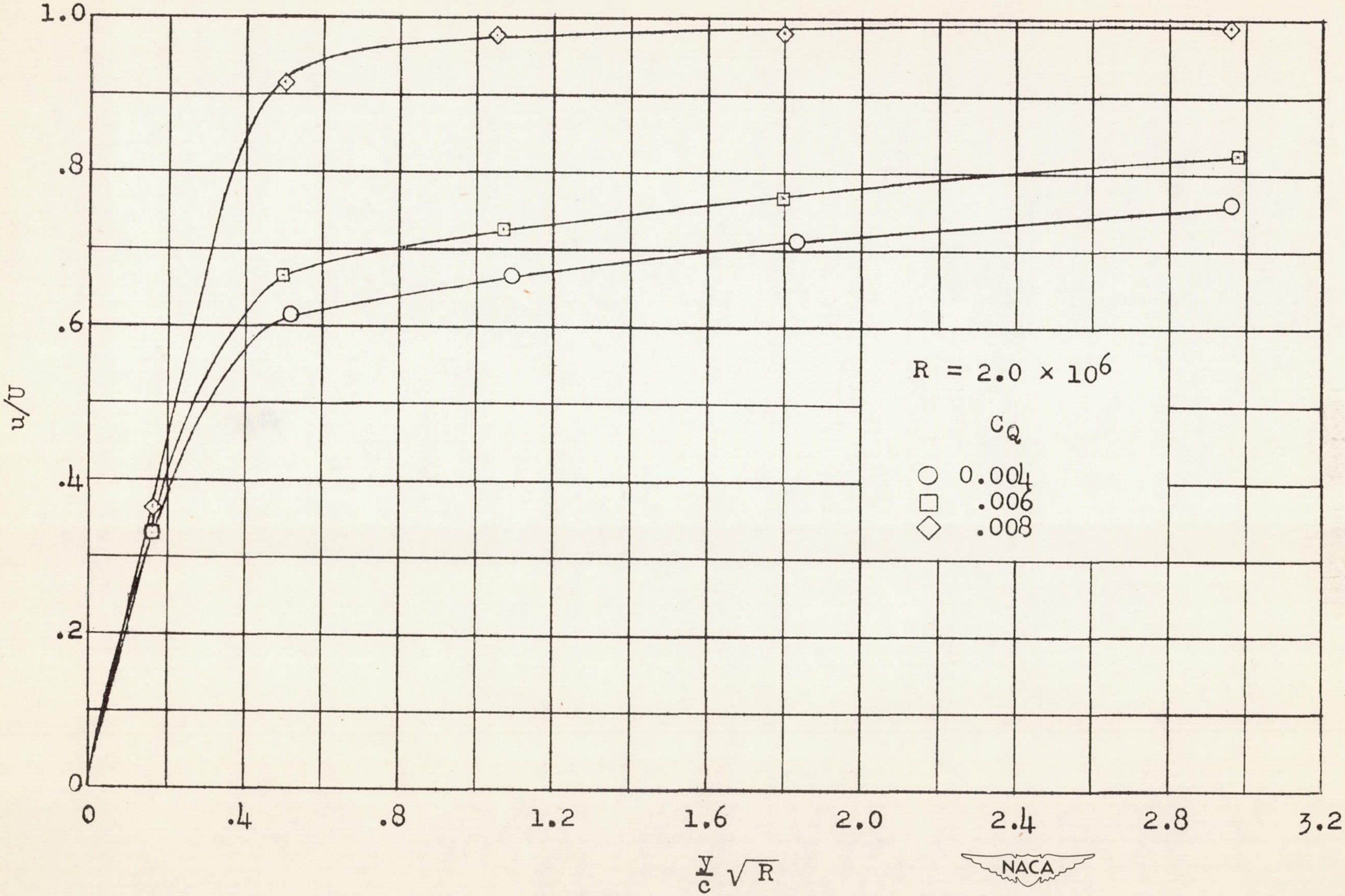
(b) x/c = 0.09 and 0.12.

Figure 5.- Continued.



(c) $x/c = 0.39$.

Figure 5.- Continued.



(d) $x/c = 0.48$.

Figure 5.- Concluded.