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INVESTIGATION OF SURFACE IRREGULARITIES ON AN NACA 63(420)-416, a = 1.0 AIRFOIL SECTION FOR THE GLENN L. MARTIN COMPANY DESIGN 195

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MEMORANDUM REPORT

for the

Army Air Forces, Materiel Command

INVESTIGATION OF SURFACE IRREGULARITIES ON AN NACA 63(420)-416, a = 1.0 AIRFOIL SECTION FOR THE GLENN L. MARTIN COMPANY DESIGN 195

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SUMMARY

The results of an investigation made in the NACA two-dimensional low-turbulence pressure tunnel of surface irregularities on a 60-inch-chord low-drag airfoil section are presented. Tests of riveted and piano-hinge-type skin joints at the front and rear spar locations (15-percent and 60-percent chord, respectively) in various combinations and modifications showed that either skin joint at the front spar, however treated, caused a substantial increase in drag, whereas irregularities at the rear spar caused no significant increase in drag so long as no leakage of air through the airfoil was present; leakage of air through the airfoil at either spar resulted in an additional increase of drag. An aileron slat installed on the lower surface of the airfoil caused no significant drag increment.

INTRODUCTION

The manufacture of airplane wings usually entails compromises between aerodynamic and structural characteristics in order to secure wings that are good not only with regard to the aerodynamics but also with regard to production and maintenance. In an effort to determine quantitatively the effects of riveted and piano-hinge-type skin joints and of an aileron slat on the drag characteristics of an NACA 63(420)-416, a = 1.0 airfoil section for application to the Glenn L. Martin Company Design 195, an investigation of a 60-inch-chord model of this section was made in the NACA two-dimensional low-turbulence pressure tunnel. Tests were made over a range of section lift coefficients from approximately -0.2 to 1.1 at Reynolds numbers of approximately 8,000,000 to 25,000,000 to determine the drag increases resulting from various modifications and combinations of skin joints at the front and rear spars and from addition of the aileron slat.

DESCRIPTION OF MODEL AND SURFACE CONDITIONS

The model of 60-inch chord was constructed solidly of wood by the Martin Company and had an NACA 63(420)-416, a = 1.0 airfoil section. Although there were no actual spars, provision was made on the model at the locations of the spars on the corresponding section of the Martin design 195 (located at 15-percent and 60-percent chord, respectively) for simulating the skin joints by means of spanwise metal strips which were submitted by the Martin Company unattached to the model and were then fastened to the airfoil with flat-head wood screws. The screws, countersunk in the metal strips, were prevented from contributing to the drag of the airfoil by glazing them with plaster and pyroxylin putty and sanding smooth. The metal strips were faired to the wood model with plaster and pyroxylin putty, but difficulties were experienced in maintaining a fair surface at this metal-wood joint when tunnel pressures were changed. These metal-wood joints were repeatedly refaired to prevent them from contributing to the drag of the airfoil. At the front and rear spar locations holes were drilled through the model to allow a flow of air from one surface to the other.

Photographs of the riveted and piano-hinge skin joints are presented in figures 1 and 2. The riveted skin joint was a butt joint with the skin flush-riveted to an internal metal plate. Some rivets protruded above the skin surface a few thousandths of an inch with very few protruding a maximum height of 0.010 inch; a very small number of rivets were recessed below the skin surface 0.002 to 0.003 inch. The spanwise skin gap was approximately 0.063 inch wide. The piano hinges were butt-jointed to the skin with flush rivets, some of which protruded above the skin surface up to a maximum height of 0.004 inch. The gaps between the hinges and the skin varied in width from about 0.034 to 0.042 inch.

The aileron slat (illustrated in photographs, figs. 3 and 4), which was 15 inches in span and $2\frac{5}{8}$ inches wide, extended approximately over the lower left half of the model, when viewed from the trailing edge, with the leading edge of the slat approximately 0.075 airfoil chord to the rear of the rear spar (fig. 5). A thin cardboard dam was fastened in a chordwise direction across the slat opening in the wing approximately 5.25 inches left of the tunnel center line to prevent spanwise flows of low energy air along the slot.

The model was tested with the following combinations:

(1) Both spars smooth. Plain metal inserts were screwed into the model at both spars, glazed, and sanded smooth.

(a) Without the aileron slat. The opening for the aileron slat in the lower surface of the model was filled with a wood block, glazed, and sanded smooth. This condition will be referred to in this report as the "smooth condition."

(b) With aileron slat in place.

(2) Smooth front spar and piano hinges at rear spar.

Piano hinges at rear spar:

(a) Unsealed.

(b) Externally sealed with fabric (figs. 3 and 4). The fabric strips were 2.25 inches wide with pinked edges and were applied to the skin joints with airplane dope.

(3) Piano hinges at rear spar externally sealed with fabric and piano hinges at front spar.

Piano hinges at front spar:

(a) Unsealed.

(b) Internally sealed with rubber dam.

(c) Sealed internally with rubber dam and externally with 2-inch-wide metallic tape furnished by the Martin Company (fig. 6).

(d) Externally sealed with fabric and faired with pyroxylin glazing putty. The metal hinge was painted with lacquer primer surfacer before applying the fabric strips to the hinge with airplane dope to provide a better surface than bare metal for adhesion of the dope. The edges of the fabric were then faired to the model with pyroxylin putty. The resulting surface was smooth but not fair, due to the thickness of the fabric tape.

(4) Piano hinges at rear spar externally sealed with fabric and riveted skin joints at front spar.

Riveted skin joints at front spar:

(a) As received from the Martin Company.

(b) Covered with 2.25-inch-wide fabric strips.

(c) As received except for a camouflage paint spraying over the entire model. The model was sprayed with synthetic enamel camouflage paint (Dupont Dark Earth 71-009) and lightly sanded with number 320 watercloth to remove protuberances and dust inclusions. The rivets were not sanded but were left untouched except for this paint spraying.

(d) Spanwise skin gap filled with plaster after spraying model with camouflage paint and lightly sanding as in the preceding condition (fig. 5).

TEST METHODS

The tests were made in the NACA two-dimensional low-turbulence pressure tunnel. The wake-survey method employing an integrating manometer was used to obtain the drag coefficients, and a manometer arrangement, which integrated the lift reaction of the model on the floor and ceiling of the tunnel test section, was used to obtain the lift coefficients. Details of test methods are given in reference 1.

RESULTS AND DISCUSSION

The drag data obtained are presented in figures 7 to 15. The effect of the aileron slat installed across the lower left side of the model can be seen clearly in figure 9 by the variation of drag coefficient along the span of the model. The small drag increment due to the slat diminishes with an increase in Reynolds number R up to 24,000,000, when the increment becomes zero (fig. 7). The drags above 24,000,000, as shown in figures 7 and 8, are slightly less than for the smooth condition, which is attributed to an accidentally smoother surface when the model was tested with the aileron slat. In general, no significant increase in drag resulted from the addition of the slat; all the drag coefficients of the succeeding tests, however, were measured at a spanwise station sufficiently removed from the slat.

Piano-hinge skin joints at the rear spar caused no measurable drag increase over the smooth condition when leakage of air through the airfoil was prevented by sealing the hinge externally (figs. 10 and 11). The externally sealed hinges were retained on the rear spar for the remainder of the tests, while various types of surface irregularities were investigated at the front spar.

Any type of surface irregularity at the front spar caused an appreciable increase in drag. The section drag coefficients obtained with unsealed piano hinges at the front spar were the highest for all conditions, increasing from 0.0056 to 0.0083 at a section lift coefficient of approximately 0.4 and a Reynolds number of 25,000,000 (figs. 12 and 13). Prevention of leakage of air through the airfoil by sealing the piano hinges internally reduced the drag appreciably and eliminated the rapid increase of section drag coefficient with section lift coefficient that occurred with the unsealed hinge above a section lift coefficient of 0.2 at a Reynolds number of 25,000,000 (figs. 12 and 13). When a 2-inch strip of metallic tape was externally applied to the piano hinges, a further small decrease in drag resulted (figs. 12 and 13) despite the fact that the outlines of the joint and the rivets were evident through the tape with little reduction of surface irregularity. When the tape was applied to the hinges, the irregularities of the skin joint were only slightly evident through the tape, but they became more pronounced during the test.

(Illustration, fig. 6 was photographed upon completion of the test.) Another test was made with the piano hinges externally sealed with metallic tape after removing the internal rubber dam. These results, however, are not presented because the air stream blew pieces of the tape off the upper surface during the test. Sealing the piano hinges externally with fabric tape and fairing the edges to the model with pyroxylin glazing putty reduced the section drag coefficients of the piano hinges at the front spar to their lowest values (figs. 12 and 13).

The plain riveted skin joints at the front spar, which increased the section drag coefficient from 0.0056 to 0.0072 at a section lift coefficient of approximately 0.4 and a Reynolds number of 25,000,000 (figs. 14 and 15), were improved at flight values of the Reynolds number by filling the skin gap (figs. 14 and 15). The model had been sprayed with camouflage paint when tested in this condition, but the effect of the paint, which will be discussed in the following paragraph, had been found previously to be negligible. Although these drags with the skin gap filled were the lowest obtained at the higher Reynolds numbers for either the riveted or piano-hinge skin joints at the front spar, they were only very slightly lower than the piano hinges with the faired fabric seal at the highest Reynolds number of 25,000,000. Before the skin gap had been filled, an attempt was made to reduce the irregularities of the riveted joints by covering the joints with fabric not faired to the surface. The resulting drags, however, were the highest for all conditions except the unsealed piano hinges at the front spar (figs. 14 and 15).

With riveted skin joints at the front spar, the model was sprayed with a synthetic enamel camouflage paint and lightly sanded; the rivets were left untouched except for the paint spraying. A comparison of the drags of the model with the riveted joints at the front spar before and after the spraying with camouflage paint shows that the camouflage paint caused a small increase in section drag coefficient at Reynolds numbers below 15,000,000 and a small decrease at the higher Reynolds numbers. This decrease in drag is probably due to an improvement of the surface fairness resulting from the addition of the camouflage paint. It appears that the camouflage paint lightly sanded produced no further increase in drag when surface irregularities in the form of the riveted skin joints were present at the front spar of the airfoil.

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CONCLUSIONS

The following conclusions may be drawn from the results in regard to the effects of the riveted and piano-hinge-type skin joints and aileron slat.

1. Any type of surface irregularities at the front spar, however treated, caused a substantial increase in drag.

2. Leakage of air through the airfoil from one surface to the other caused an additional increase in drag which may be prevented by sealing the skin joints.

3. Surface irregularities at the rear spar caused no significant increase in drag so long as no leakage of air through the airfoil was present.

4. The lowest drags at flight values of the Reynolds number for either the riveted or piano-hinge skin joints at the front spar were obtained with the riveted joints with the skin gaps filled. The lowest drags for the piano hinges at the front spar were obtained with the hinges sealed with fabric faired to the surface of the airfoil.

5. No significant increase in drag resulted from the addition of the aileron slat.

Langley Memorial Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., October 1, 1943.

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 A.C.R., March 1942.

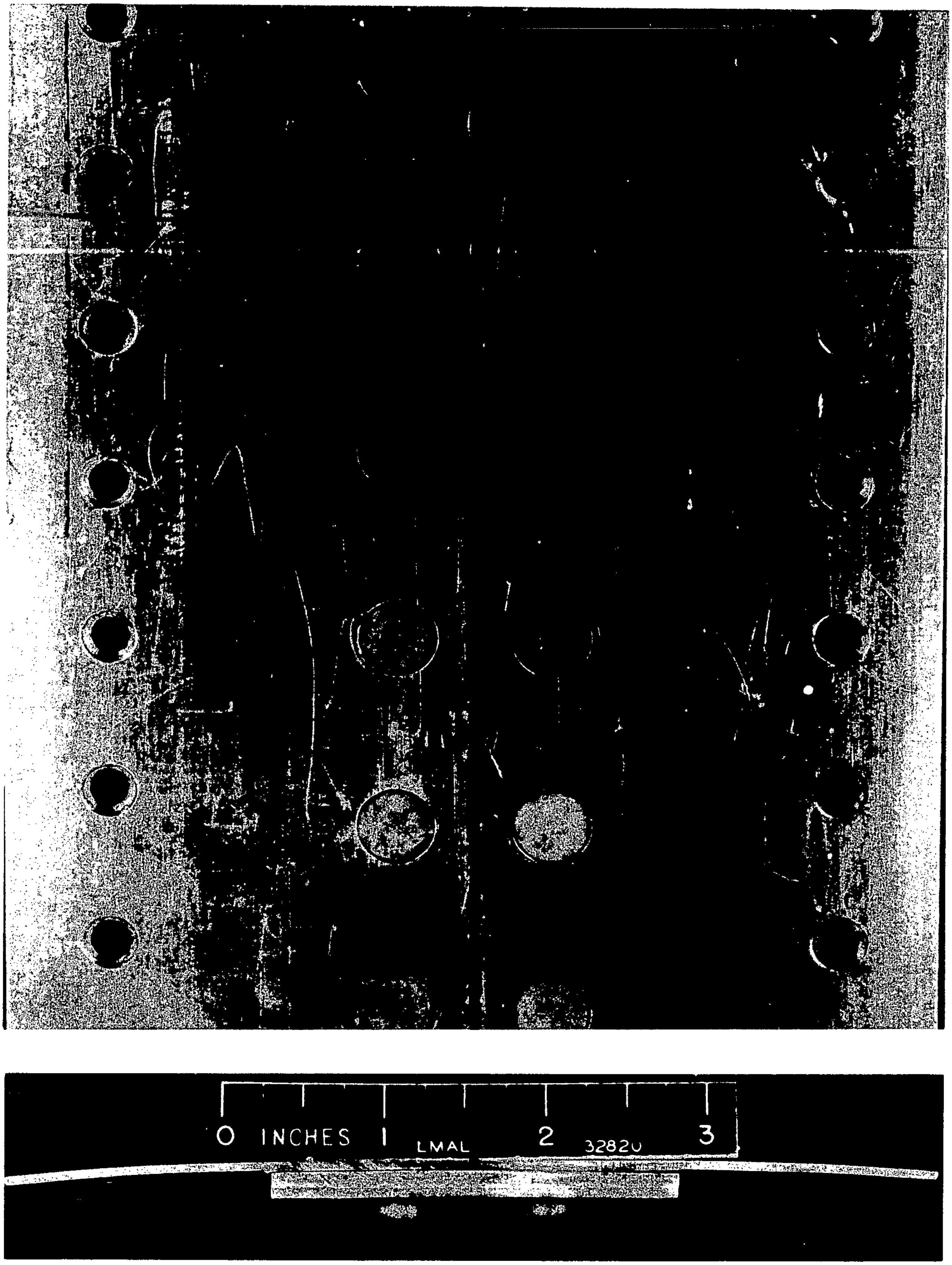

Figure 1.- Riveted skin joint used at front spar of 60-inch-chord, Martin design 195, roughness model, NACA 63(420)-416, a = 1.0 airfoil section.

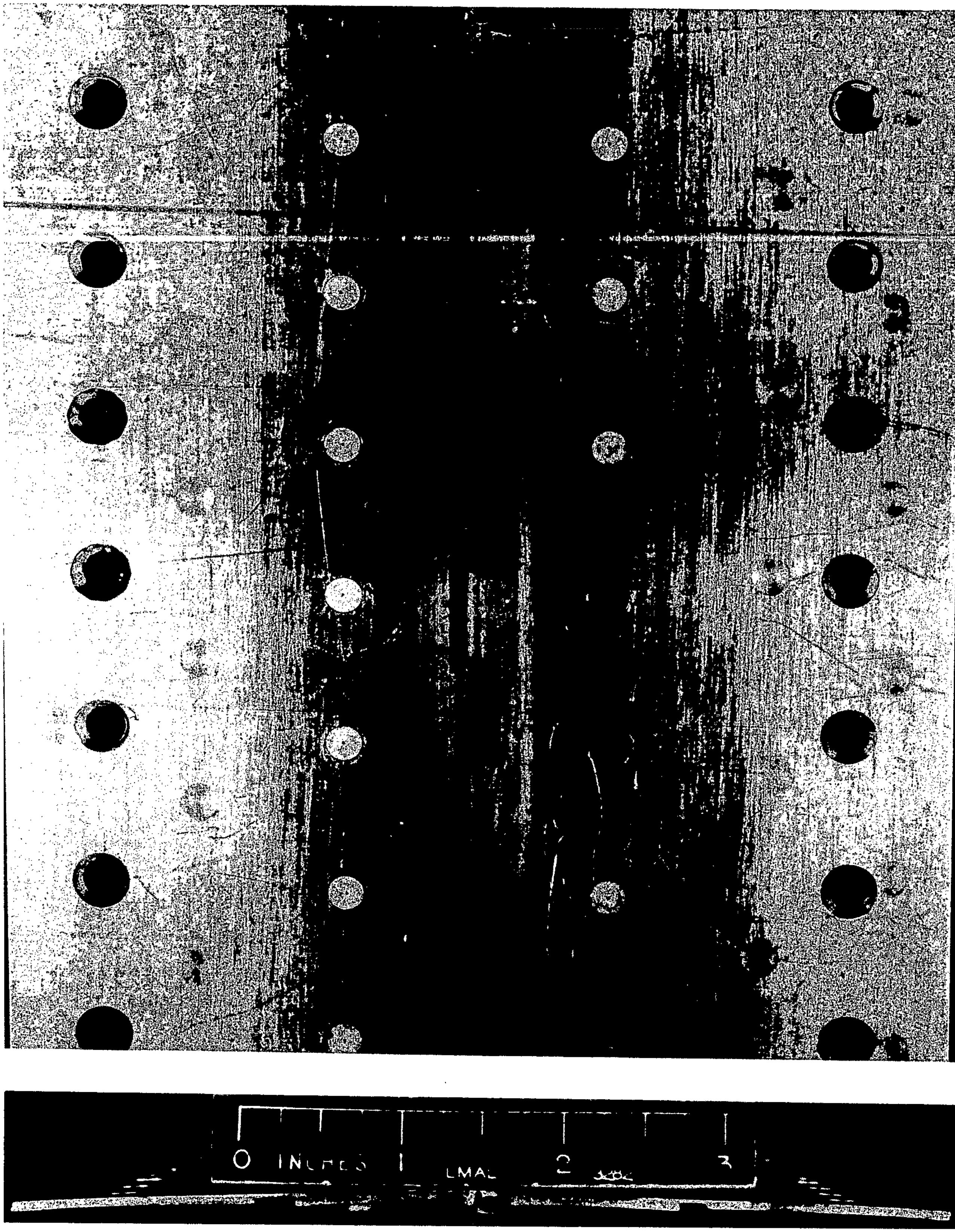

Figure 2.- Piano-hinge skin joint used at front and rear spars of 60-inch-chord, Martin design 195, roughness model, NACA 63(420)-416, a = 1.0 airfoil section.

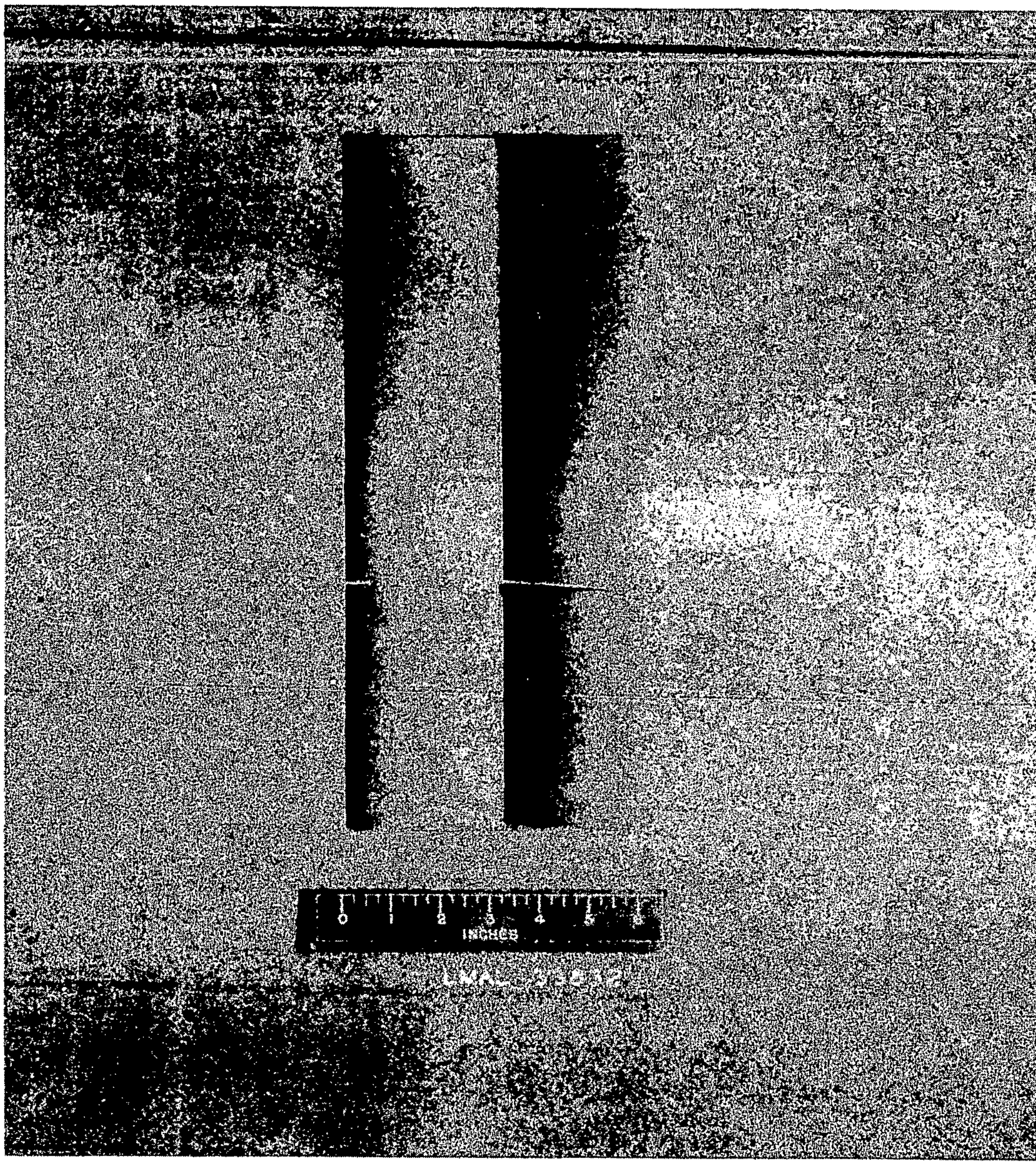

Figure 3.- Aileron slat and piano-hinge skin joint, externally sealed with fabric, at rear spar of 60-inch-chord, Martin design 195, roughness model, NACA 63(420)-416, a = 1.0 airfoil section, sprayed with camouflage paint.

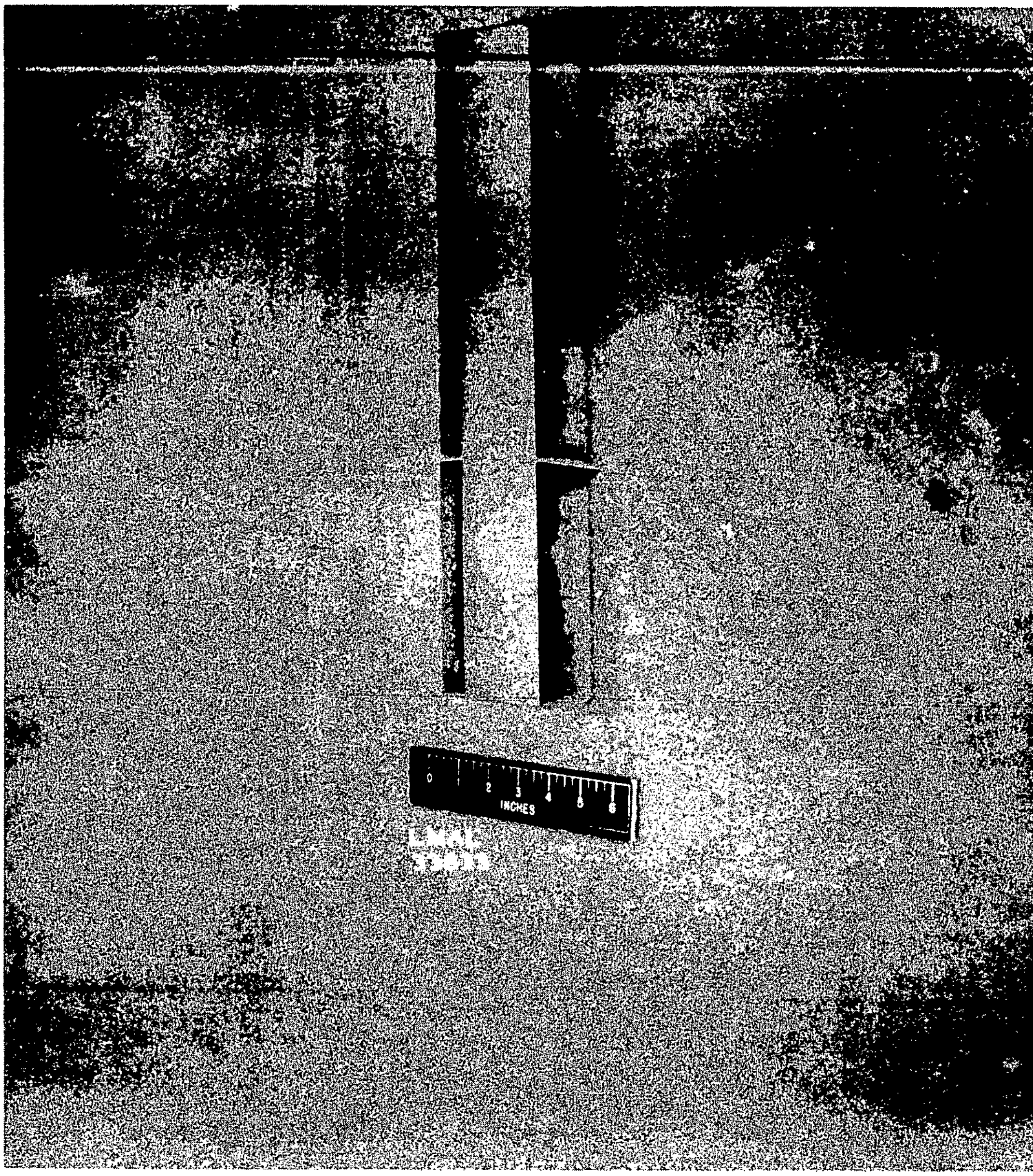

Figure 4.- Aileron slat and piano-hinge skin joint, externally sealed with fabric, at rear spar of 60-inch-chord, Martin design 195, roughness model, NACA 63(420)-416, a = 1.0 airfoil section, sprayed with camouflage paint.

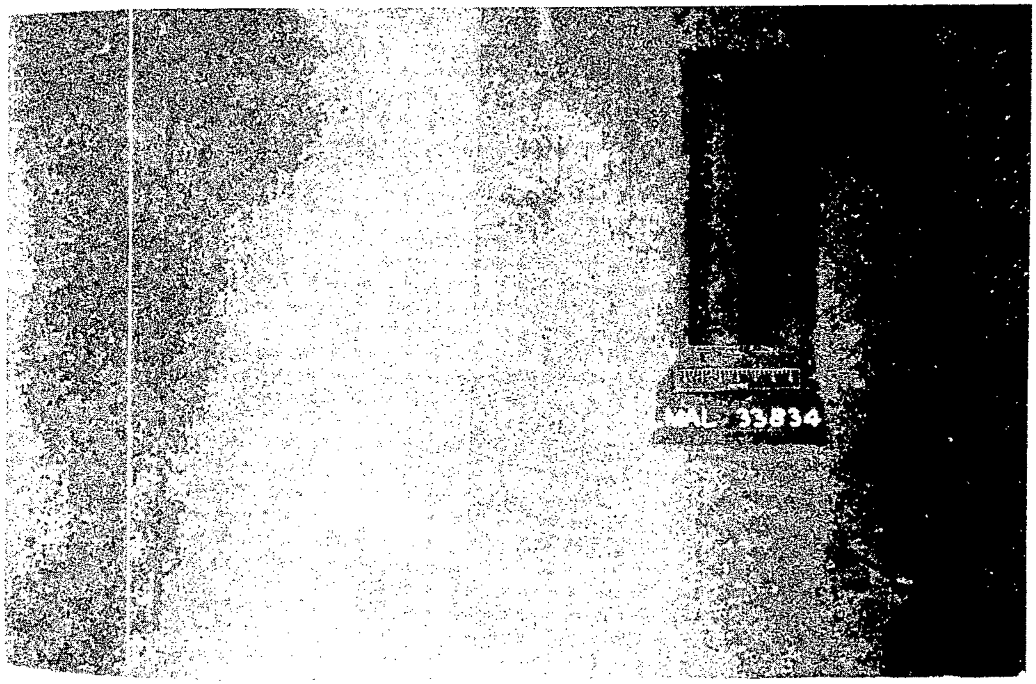

Figure 5.- Bottom view of 60-inch-chord, Martin design 195, roughness model, NACA 63(420)-416, a = 1.0 airfoil section showing riveted skin joint with skin gap filled at front spar, fabric-sealed piano-hinge skin joint at rear spar, and aileron slat; model sprayed with camouflage paint.

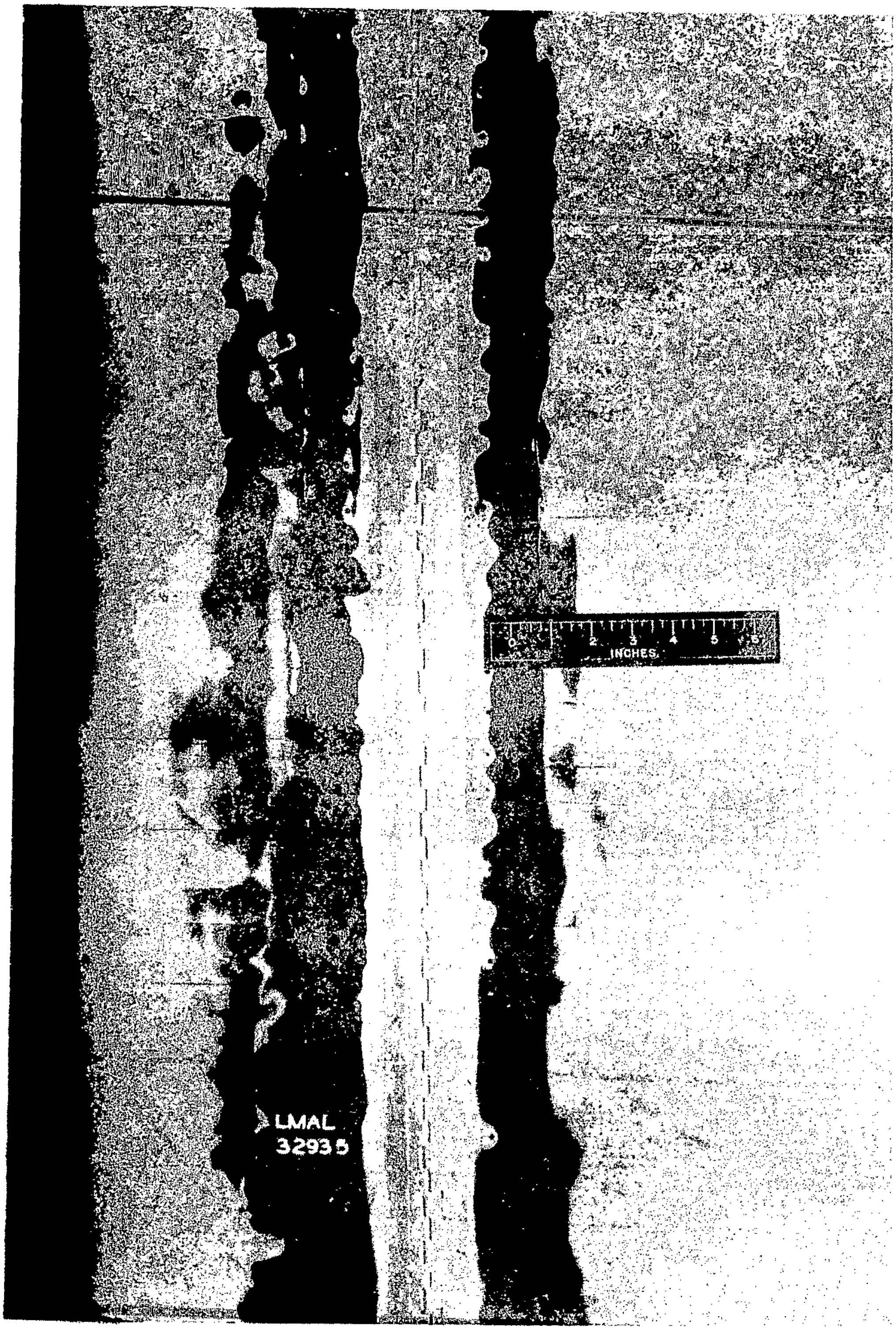

Figure 6.- Piano-hinge skin joint, externally sealed with metallic tape, at front spar of 60-inch-chord, Martin design 195, roughness model, NACA 63(420)-416, a = 1.0 airfoil section.

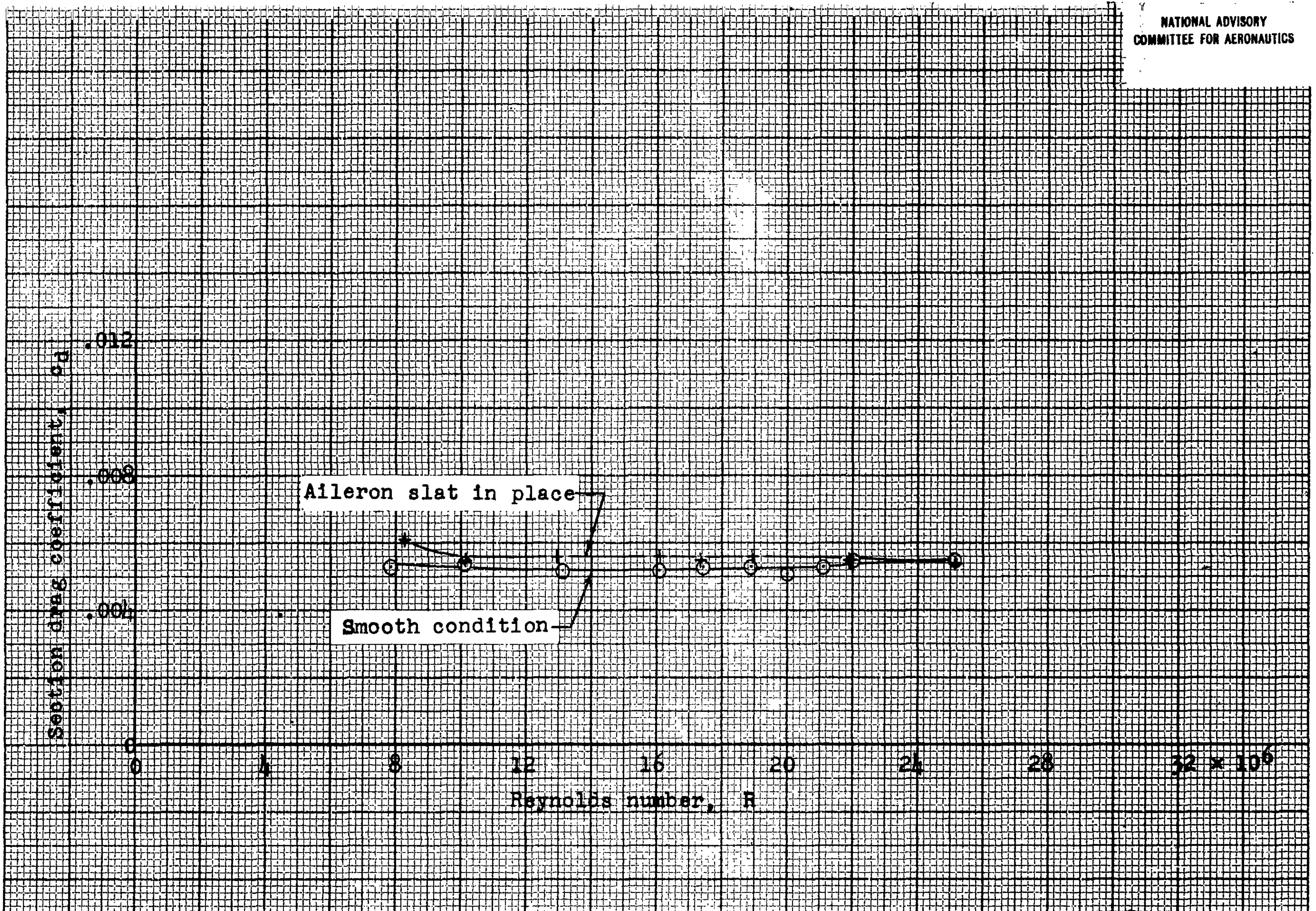

Figure 7 .- Variation of section drag coefficient with Reynolds number for 60-inch-chord, Martin design 195, roughness model. Airfoil section, NACA 63(420)-416, a = 1.0; c_l = 0.4 (approx.). Test, TDT 431.

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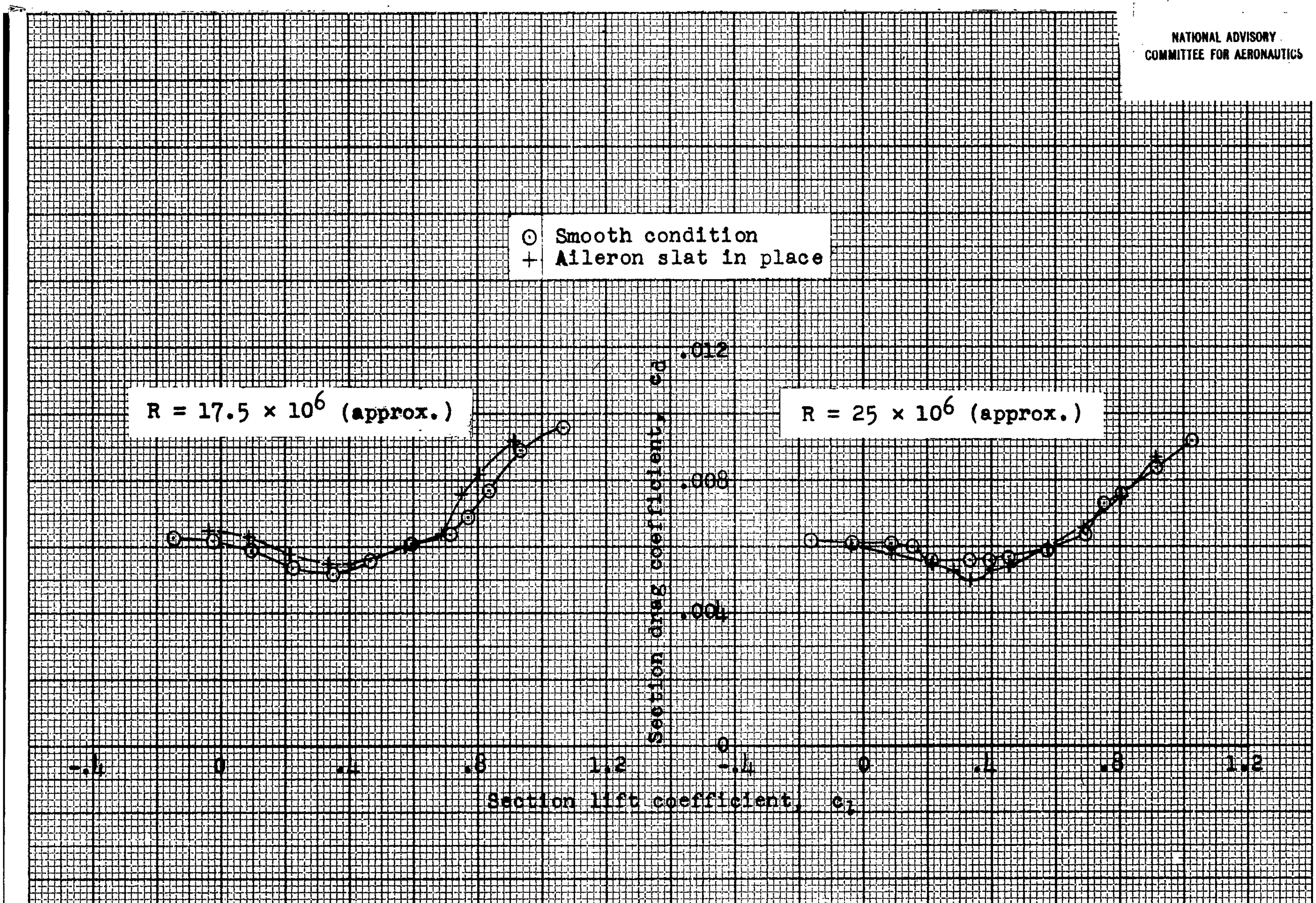

Figure 8.- Variation of section drag coefficient with section lift coefficient for 60-inch-chord, Martin design 195, roughness model. Airfoil section, NACA 63(420)-416, a = 1.0. Test, TDT 431.

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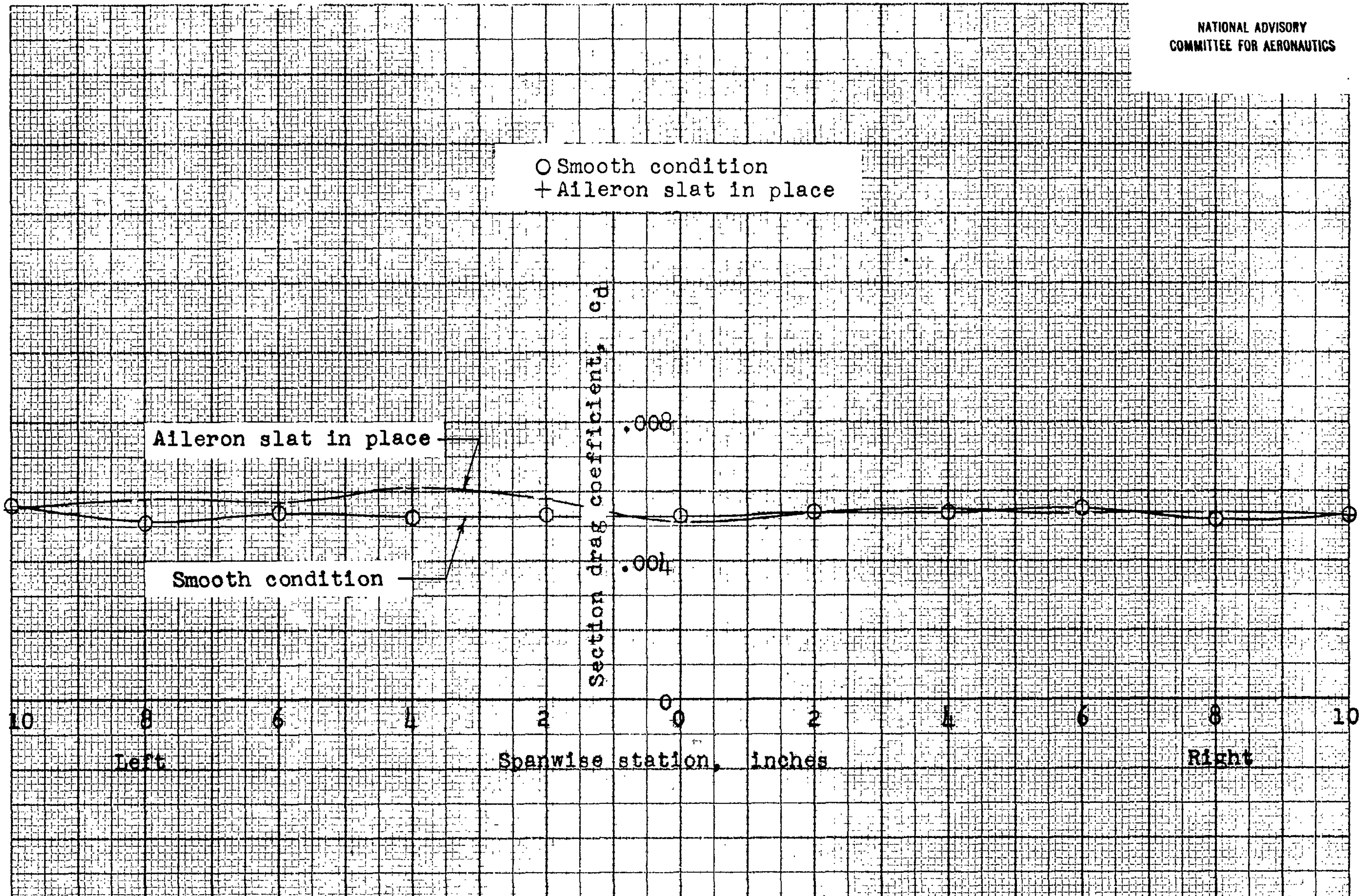

Figure 9 .- Spanwise variation of section drag coefficient for 60-inch-chord, Martin design 195, roughness model. Airfoil section, NACA 63(420)-416, a = 1.0; c_l = 0.4 (approx.); R = 10 × 10^6 (approx.). Test, TDT 431.

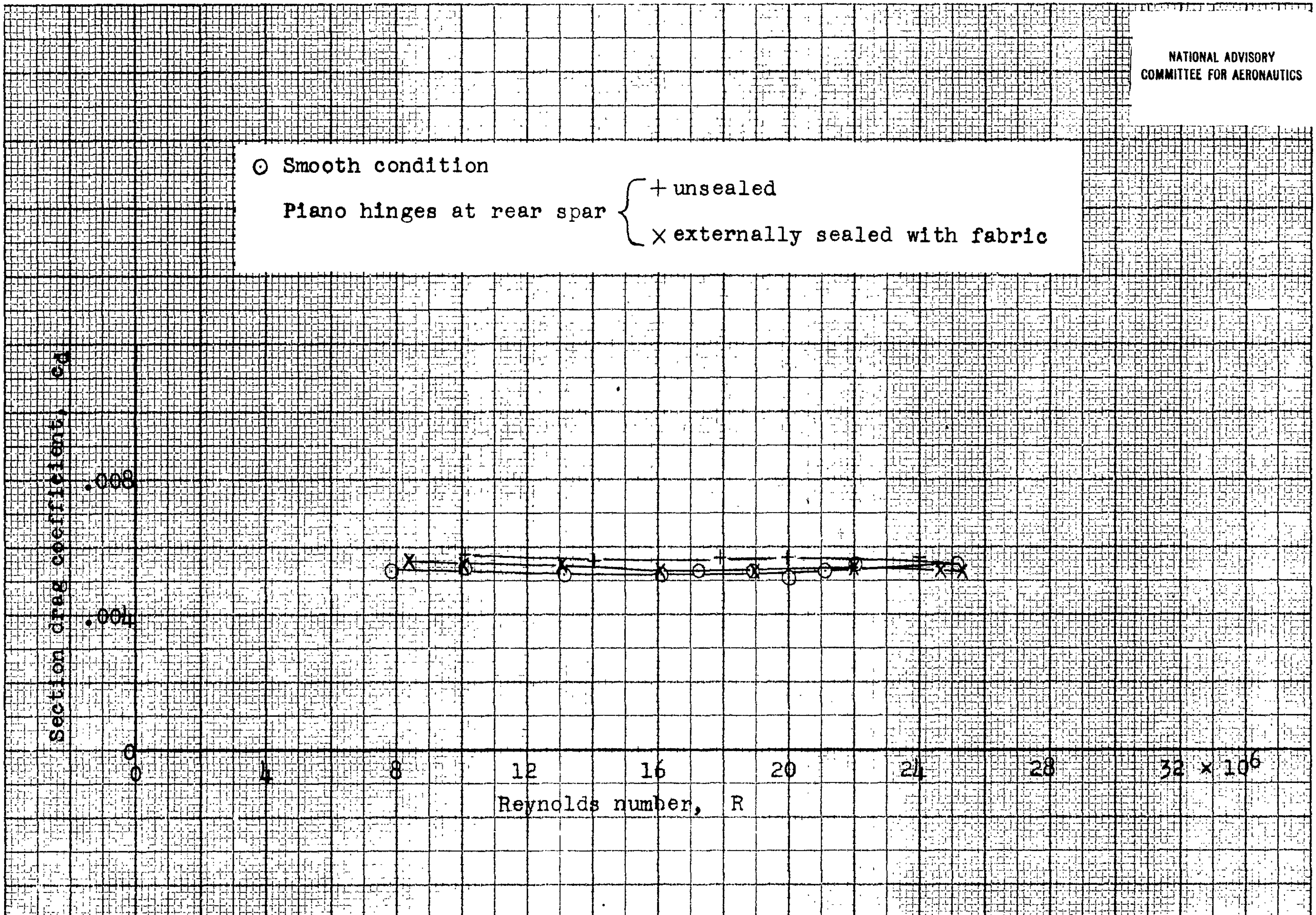

Figure 10.- Variation of section drag coefficient with Reynolds number for 60-inch-chord, Martin design 195, roughness model. Airfoil section, NACA 63(420)-416, a = 1.0; c_l = 0.4 (approx.). Front spar smooth. Test, TDT 431.

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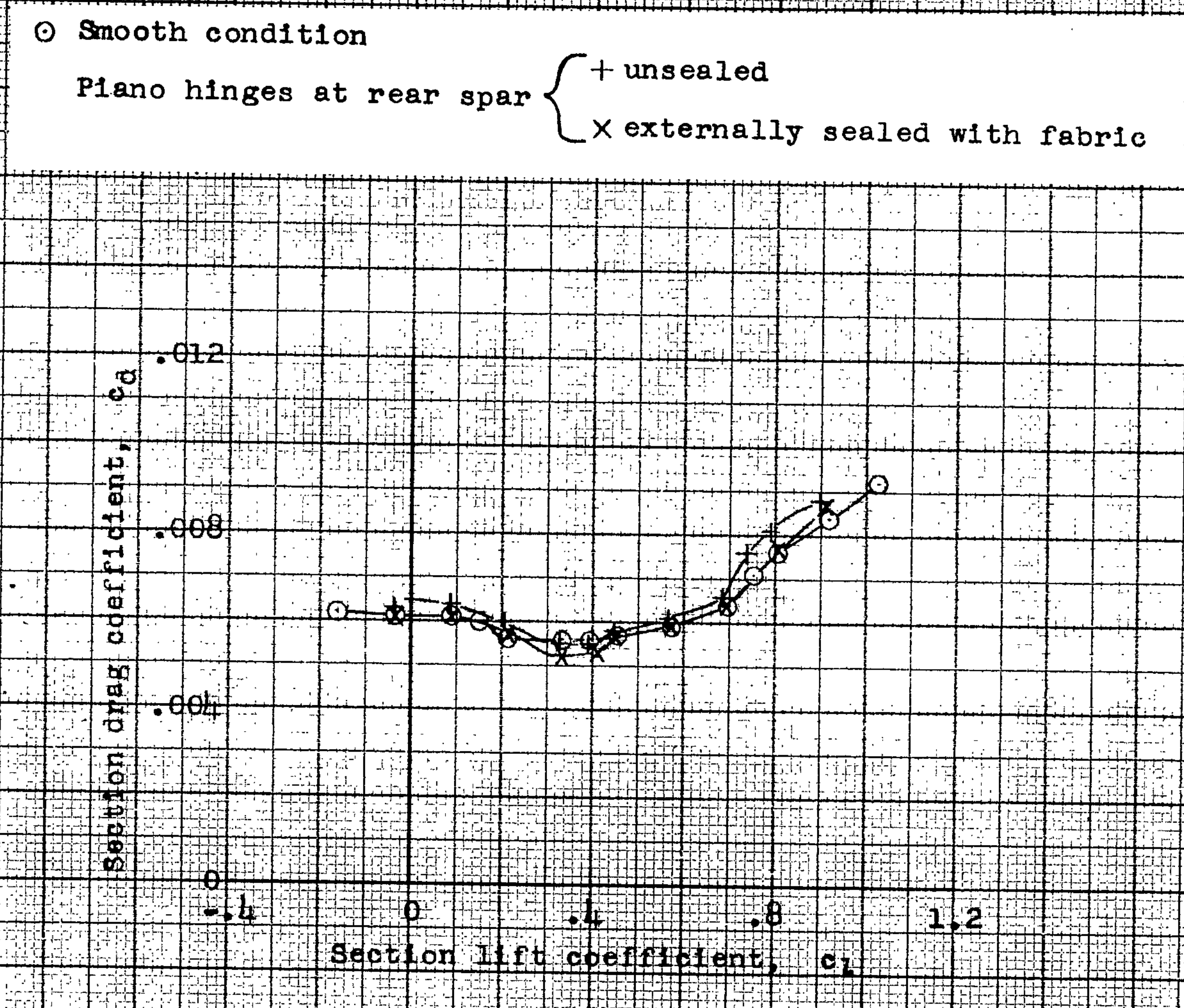

Figure 11.- Variation of section drag coefficient with section lift coefficient for 60-inch-chord, Martin design 195, roughness model. Airfoil section, NACA 63(420)-416, a = 1; $R = 25 \times 10^6$ (approx.). Front spar smooth. Test, TDT 431.

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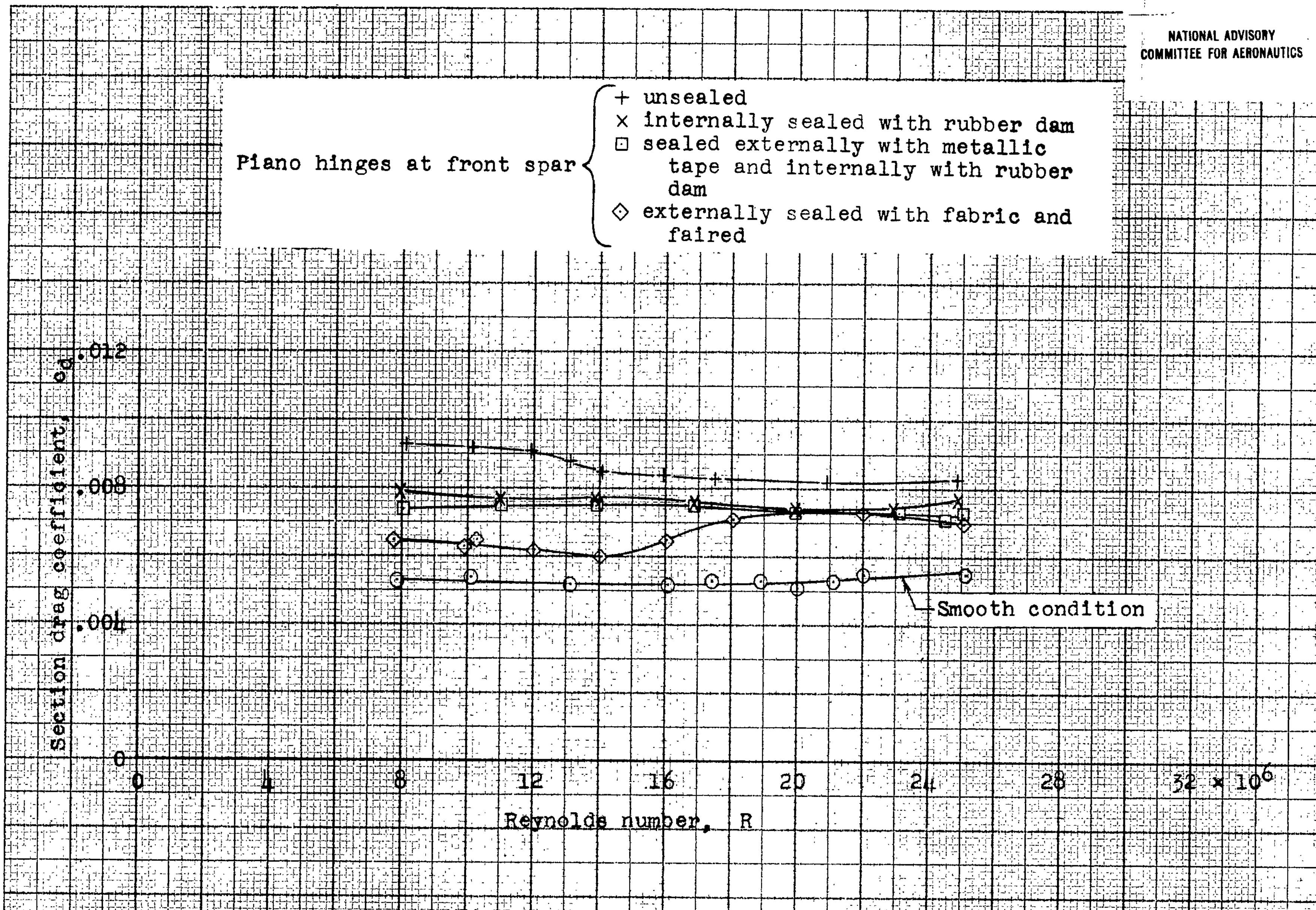

Figure 12.- Variation of section drag coefficient with Reynolds number for 60-inch-chord, Martin design 195, roughness model. Airfoil section, NACA 63(420)-416, a = 1.0; c_l = 0.4 (approx.). Piano hinges at rear spar, externally sealed with fabric. Tests, TDT 431, 436.

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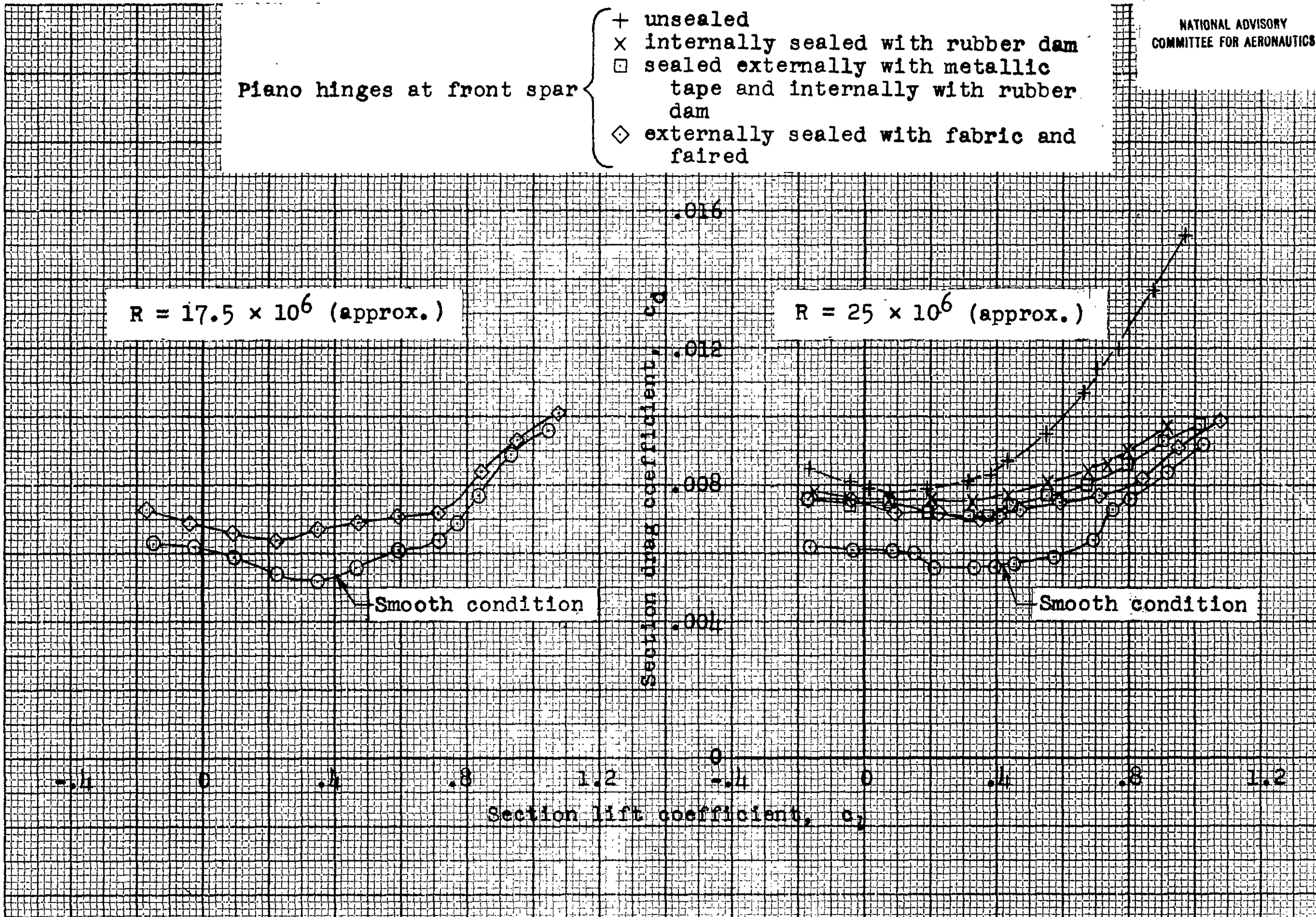

Figure 13.- Variation of section drag coefficient with section lift coefficient for 60-inch-chord, Martin design 195, roughness model. Airfoil section, NACA 63(420)-416, a = 1.0. Piano hinges at rear spar, externally sealed with fabric. Tests, TDT 431, 436.

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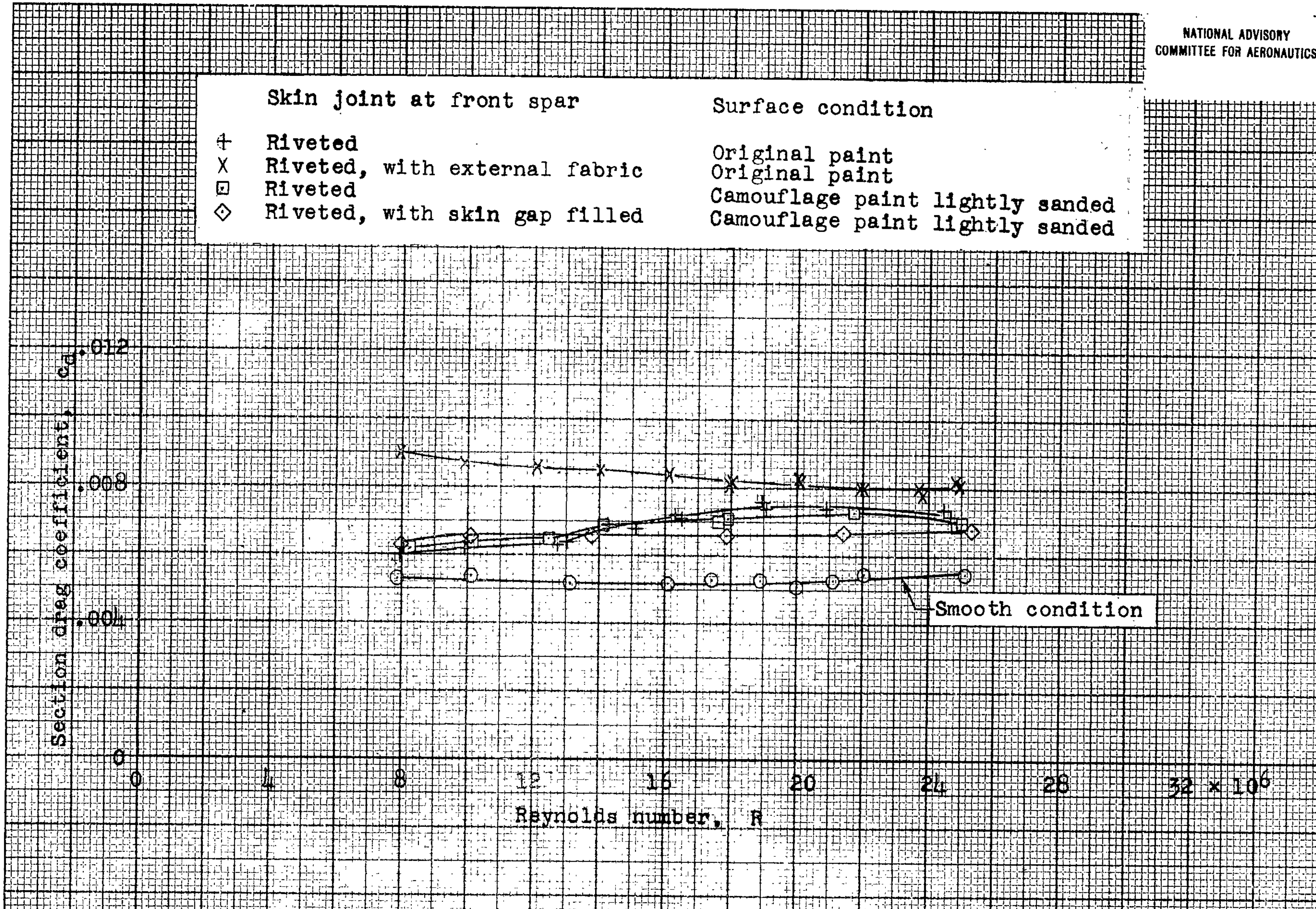

Figure 14.- Variation of section drag coefficient with Reynolds number for 60-inch-chord, Martin design 195, roughness model. Airfoil section, NACA 63(420)-416, a = 1.0; c_l = 0.4 (approx.). Piano hinges at rear spar, externally sealed with fabric. Tests, TDT 431, 439.

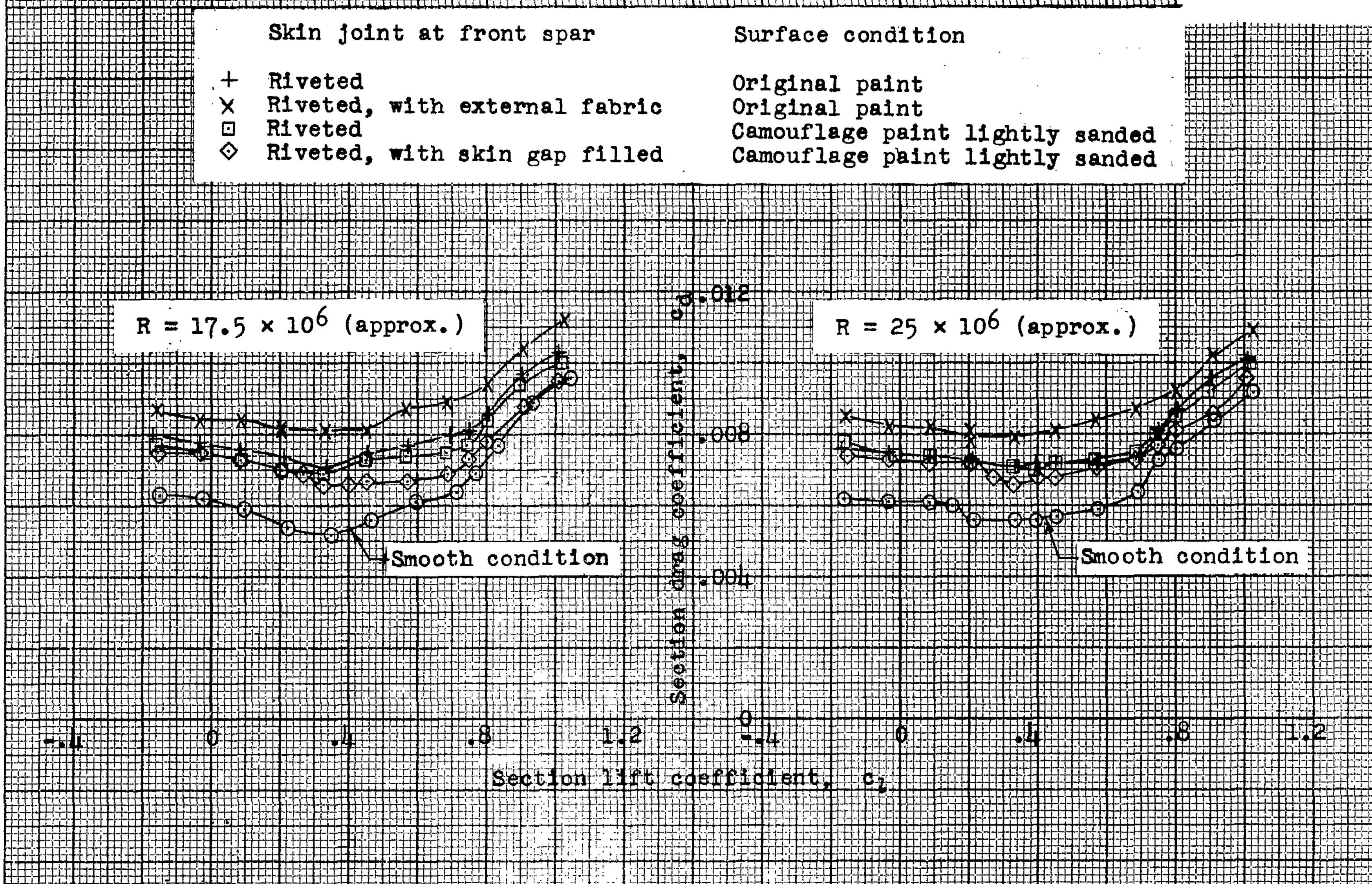

Figure 15.- Variation of section drag coefficient with section lift coefficient for 60-inch-chord, Martin design 195, roughness model. Airfoil section, NACA 63(420)-416, a = 1.0. Piano hinges at rear spar, externally sealed with fabric. Tests, TDT 431, 439.