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DRAG MEASUREMENTS AT HIGH REYNOLDS NUMBERS OF A 100-INCH-CHORD NACA 23016 PRACTICAL CONSTRUCTION WING SECTION SUBMITTED BY CHANCE VOUGHT AIRCRAFT COMPANY

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WASHINGTON

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MEMORANDUM REPORT

for the

Bureau of Aeronautics, Navy Department

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INTRODUCTION

Calculation of the high-speed performance of some airplanes involves the estimation of airfoil drag coefficients at Reynolds numbers of the order of 65 to 75 million. Very little data on airfoil drag coefficients at such high Reynolds numbers are available. At the request of the Bureau of Aeronautics, Navy Department, therefore, drag measurements were made in the Langley Memorial Aeronautical Laboratory two-dimensional low-turbulence pressure tunnel of an available 100-inch-chord model of the NACA 23016 wing section. The model was constructed by the Chance Vought Aircraft Company according to practical construction methods. In the present series of tests, section drag coefficients were measured over a range of Reynolds numbers from approximately 4 to 68 million at lift coefficients from about -0.05 to 0.275 with three types of surface conditions.

DESCRIPTION OF MODEL AND TEST METHODS

The 100-inch-chord NACA 23016 wing section used for these tests had a single spar located at the 30-percent-chord station. Both the upper and lower surfaces were unfair at this point. In addition, a flat spot located at approximately the 0.095c station on the lower surface and extending halfway across the model span was detected by rocking a straight edge over the forward portion of the airfoil in a chordwise direction. The skin forward of the spar was approximately 0.050 inch thick and was riveted to both chordwise and spanwise stiffeners. A thinner skin (approximately 0.015-inch thick) aft of the spar was riveted to chordwise stiffeners spaced 9 inches apart.

The tests were made with the model surfaces in three conditions:

(1) As received.- As received, the model was painted with zinc chromate primer. A few rivets behind the spar had been glazed. Three minor scratches located on the upper surface near the leading edge, which were apparently the result of handling and shipping, were filled and sanded smooth.

(2) Painted.- All local surface defects forward of the spar, such as rivets, were faired and the surfaces were sprayed with gray primer surfacer which was sanded smooth. The surfaces behind the spar were also painted and sanded, but no attempt was made to correct local surface defects in this region.

(3) Camouflaged.- A double coat of neutral gray camouflage paint (Navy specification no. 14105) was sprayed over the gray primer surfacer (condition 2). No particular effort was made to spray the camouflage paint on smoothly because, for this condition, it was desired to simulate the spraying abilities of an inexperienced person. Door joints were simulated by shellacking a length of string 0.012-inch in diameter at the 0.25c station across the span on both the upper and lower surfaces. Photographs of the model showing the simulated door joints are given in figure 1(a) and (b). A rear bottom view of the model is presented in figure 1(c) to show the rivet spacing and surface irregularities.

Lift and drag coefficients were obtained by the methods described in reference 1. The data have been corrected for tunnel-wall constriction by the following formulas:

$$c_d = 0.896\ c_d'$$

$$c_l = 0.7285\ c_l'$$

where the primed quantities represent the values of the coefficients measured in the tunnel.

RESULTS AND DISCUSSION

Curves of section drag coefficient plotted against Reynolds number for various surface conditions and lift coefficients are given in figure 2. A comparison of the results presented in figure 2(c) with the skin friction of smooth flat plates is presented in figure 3.

It is seen from figure 2 that the variation of drag coefficient with lift coefficient, particularly at high Reynolds numbers, was relatively small. Above a Reynolds number of 25 million, the changes in surface condition of the model had more effect on the drag coefficient than changes in the Reynolds number. As would be expected, the lowest drag coefficients were obtained with the smoothest surfaces (condition 2).

The variation of the profile drag of this airfoil with Reynolds number was similar to that of the turbulent skin friction of smooth flat plates up to a Reynolds number of approximately 15 million. Above this Reynolds number, the scale effect on drag was small. These results appear to be similar to those for rough pipes given on page 146 of reference 2, where the skin friction of pipes with relatively small surface roughness at first follows the same curve as for smooth pipes. At some higher Reynolds number, depending upon the grain size of the roughness, the skin friction approaches a constant value and shows little further change even up to extremely high Reynolds numbers. As in the case of the rough pipes, the value of the drag coefficient, for the present tests, at high Reynolds numbers was primarily a function of the model surface condition.

Although extrapolation formulas based on the skin friction drag of smooth flat plates may be reliable for airfoils having aerodynamically smooth surfaces, the data presented herein indicate that, at least for models having surface conditions similar to those of the present tests, such formulas would tend to give too low values of the drag coefficient at high Reynolds numbers.

CONCLUSIONS

As a result of tests of an NACA 23016 practical construction section over a range of Reynolds numbers from approximately 4 to 68 million, the following conclusions may be drawn:

1. Above a Reynolds number of about 25 million, the changes in surface condition of the model had more effect on the drag coefficient than changes in the Reynolds number.

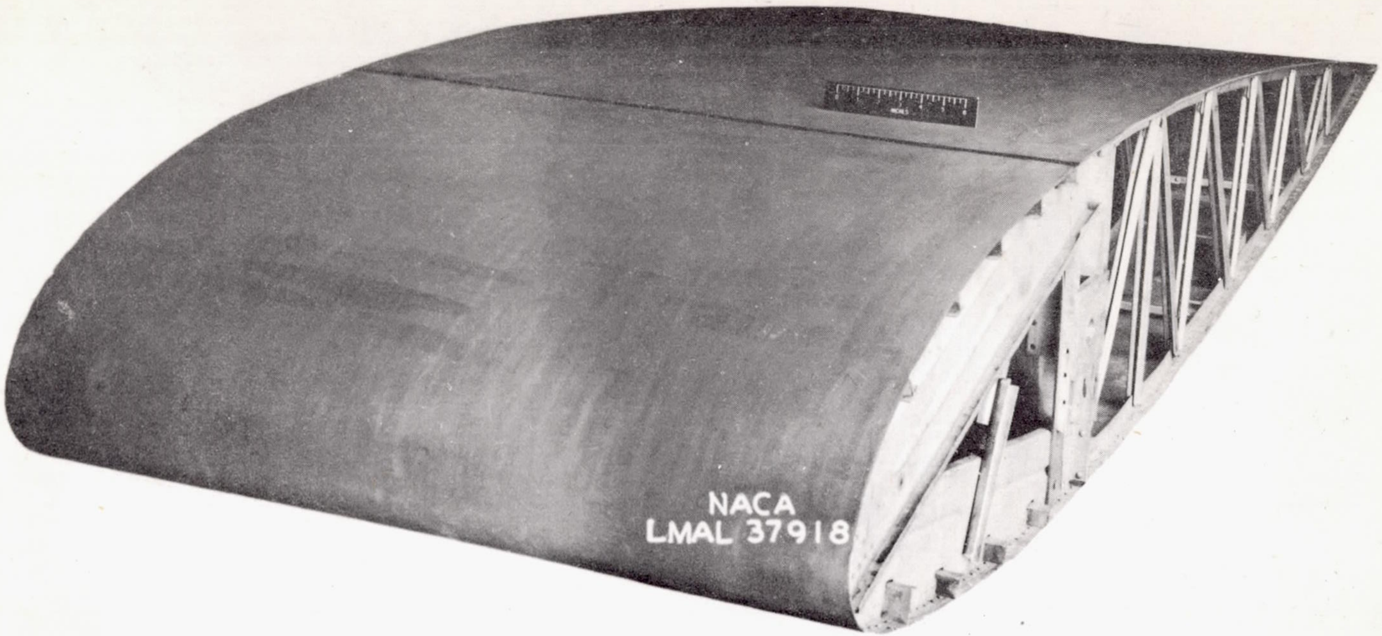
2. Extrapolation formulas based on the turbulent skin friction drag of smooth flat plates tend to give too low values of the drag coefficient at high Reynolds numbers when applied to airfoils having surfaces comparable to those of the model investigated in the present tests.

Langley Memorial Aeronautical Laboratory
National Advisory Committee for Aeronautics
Langley Field, Va., June 30, 1944

REFERENCES

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.

2. Prandtl, L.: The Mechanics of Viscous Fluids. Vol. III, div. G, sec. 23 of Aerodynamic Theory, W. F. Durand, ed., Julius Springer (Berlin), 1935, p. 146.

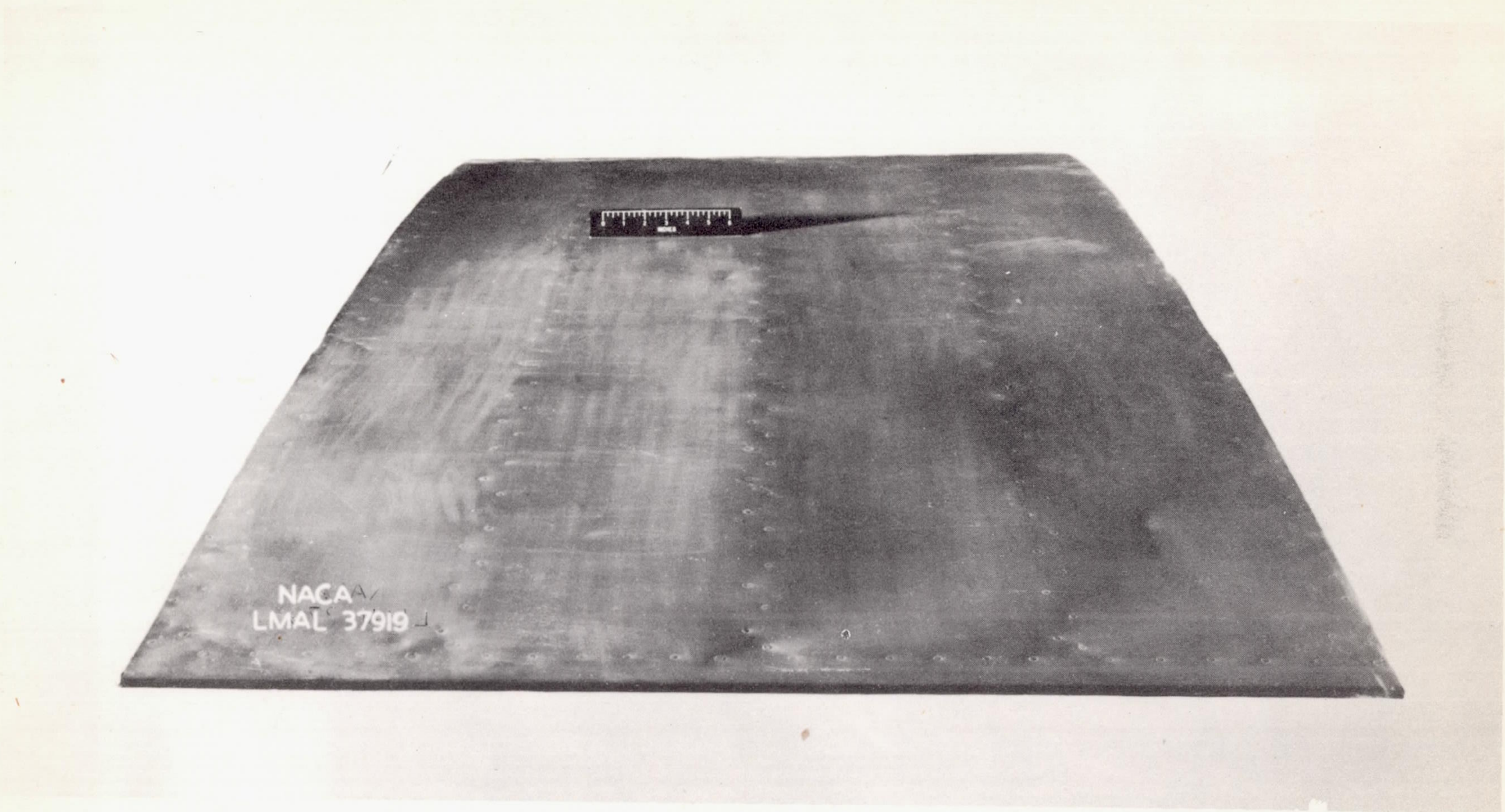


(a) Front top view showing simulated door joint.

Figure 1.- Practical construction wing model of NACA 23016 section submitted by Chance Vought Aircraft, camouflage painted.

(b) Front bottom view showing simulated door joint.

Figure 1.- Continued.



(c) Rear bottom view showing rivet spacing and surface irregularities.

Figure 1.- Concluded.

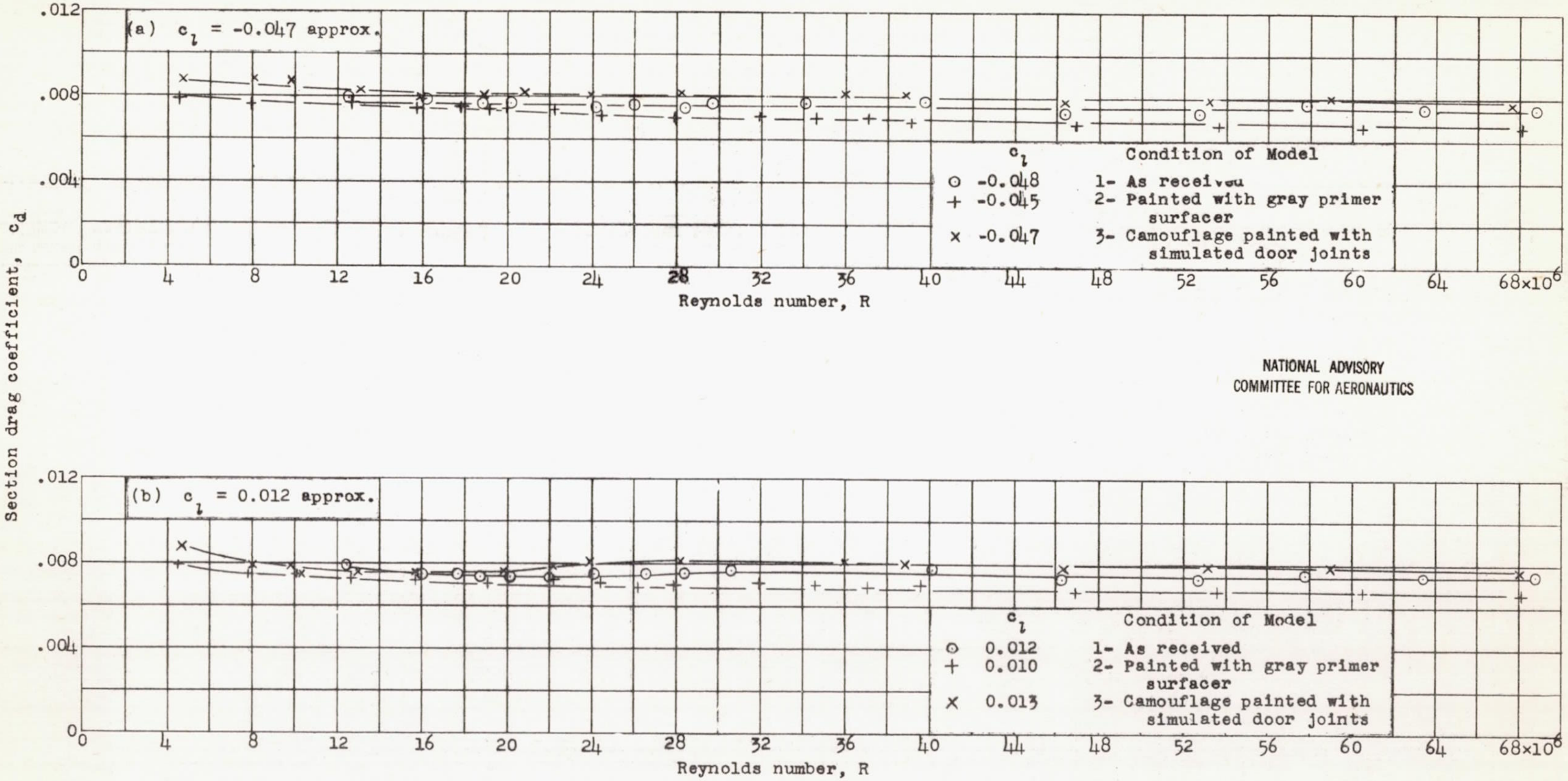


Figure 2 .- Drag scale effect of a 100-inch-chord NACA 23016 practical construction wing section submitted by Chance Vought Aircraft. Tests, TDT 430, 432, and 443.

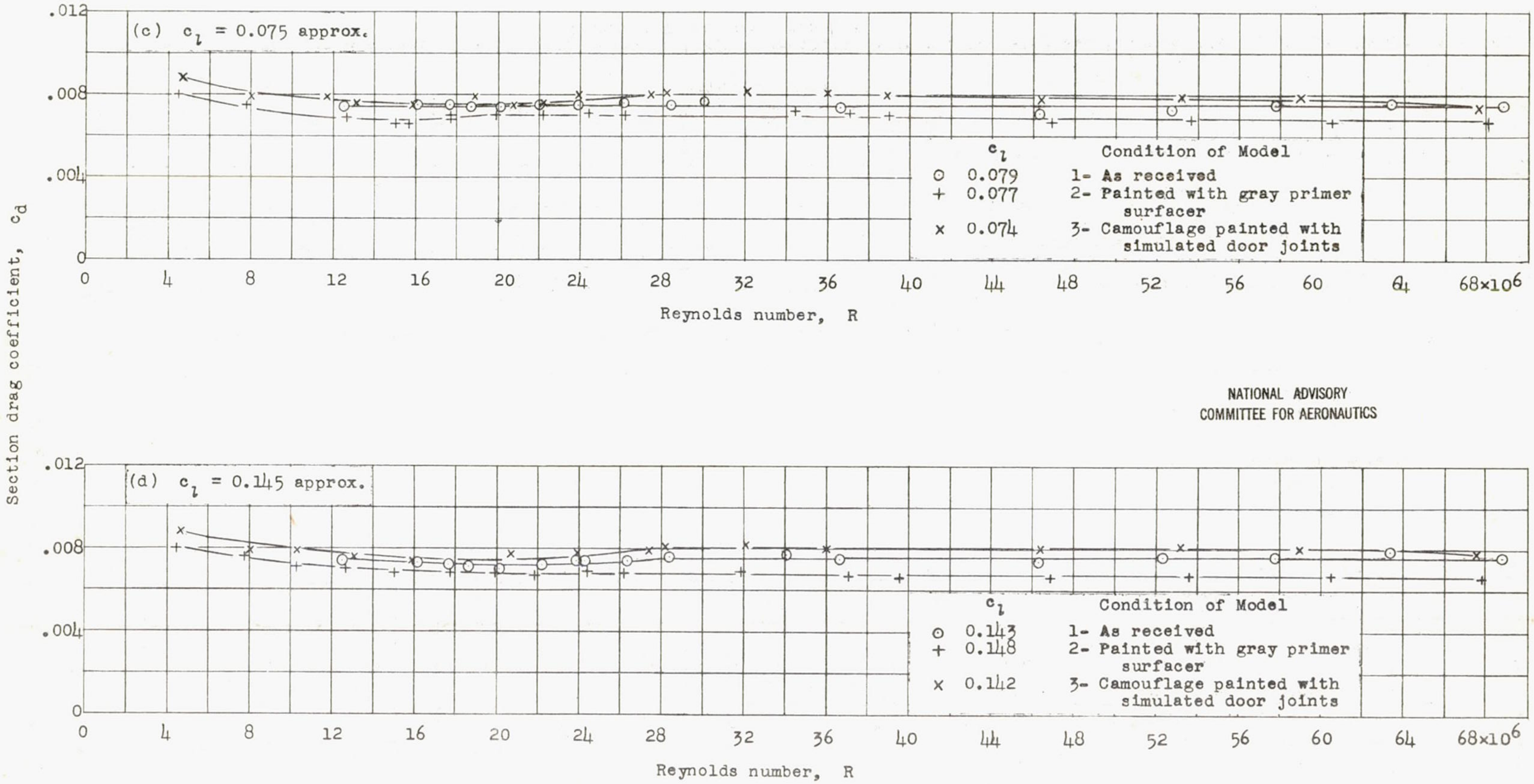


Figure 2.- Continued.

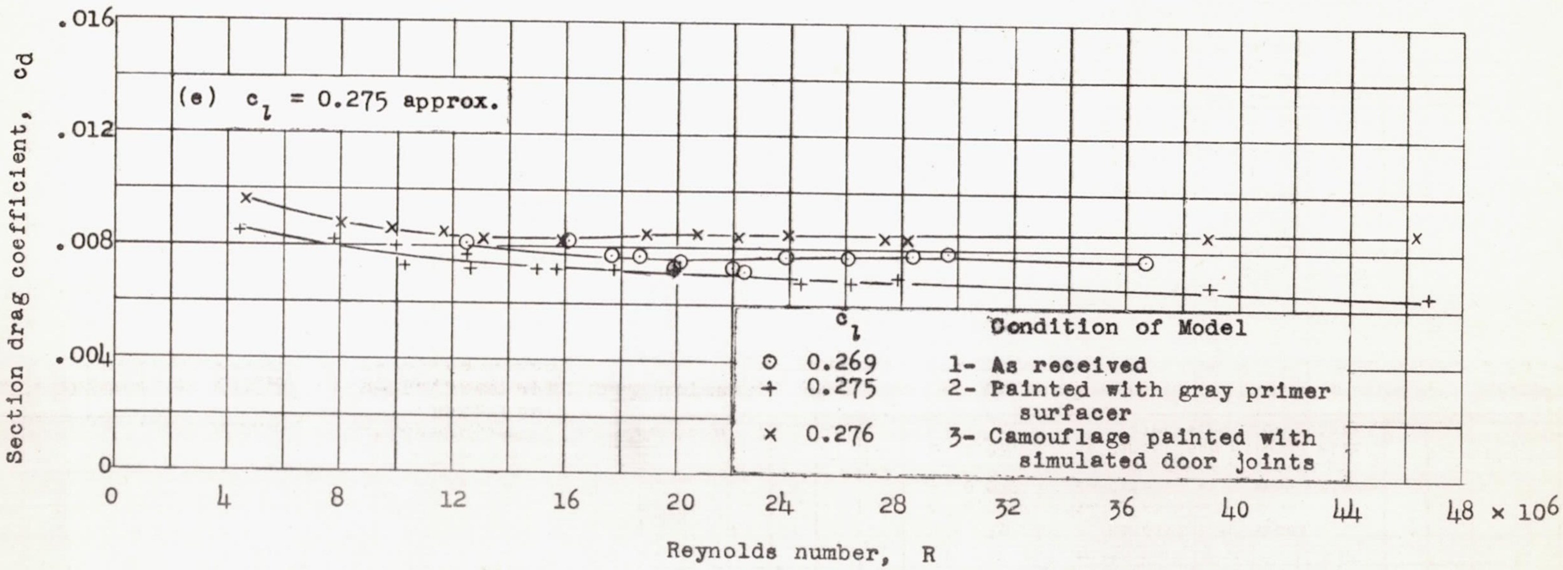


Figure 2.- Concluded.

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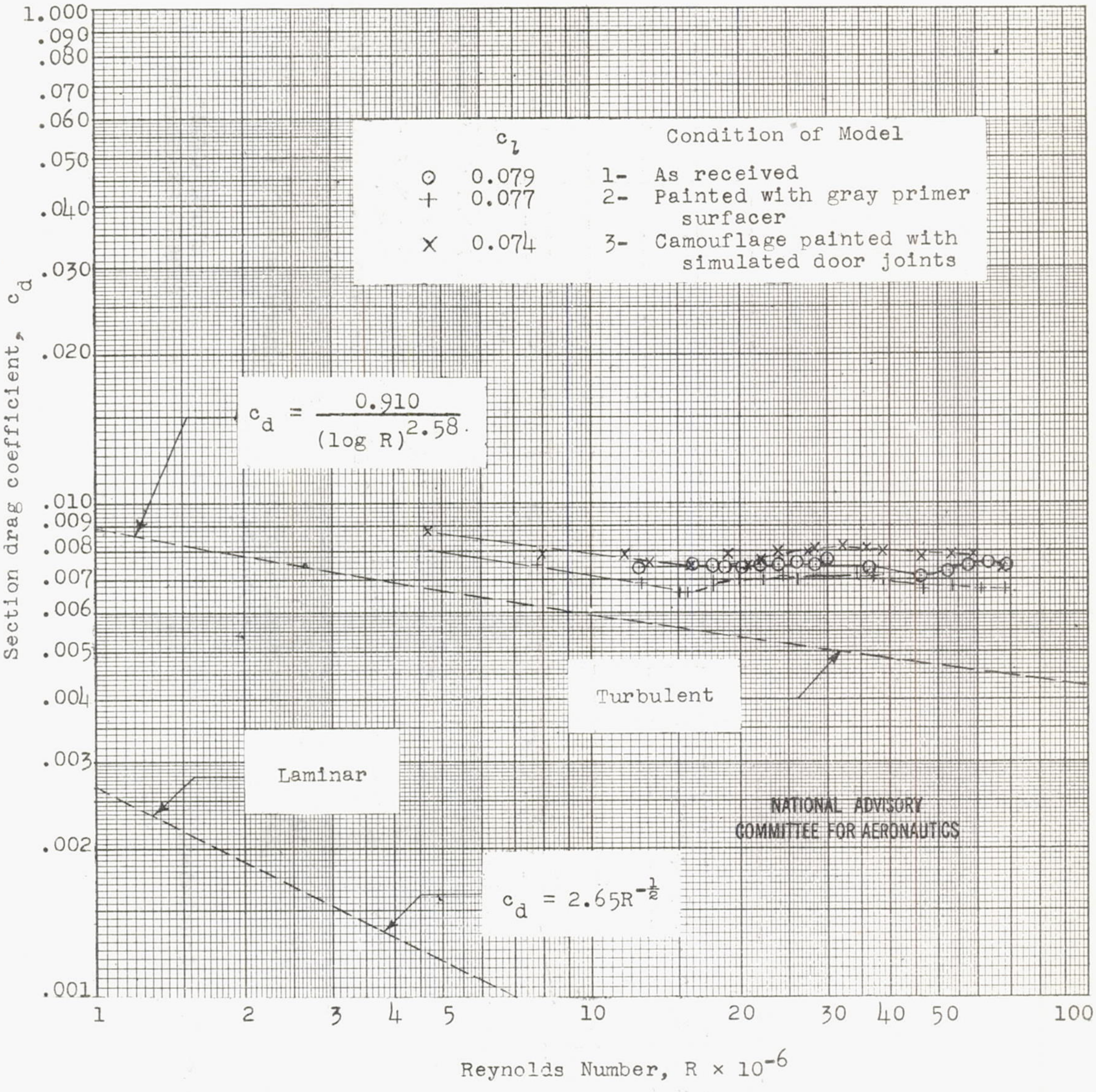

Figure 3.- Comparison of the drag coefficient of the NACA 23016 airfoil section with the skin friction of smooth flat plates.