TECHNICAL NOTES

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

No. 481

THE REDUCTION IN DRAG OF A FORWARD-SLOPING WINDSHIELD

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SUMMARY

This paper gives results of a short investigation of the drag of a forward-sloping closed-cabin windshield. The drag of the windshield in both the original and a final modified form was determined from tests in the variable-density wind tunnel. The final form of the windshield was arrived at by modifying the original as the result of flow observations in the N.A.C.A. smoke tunnel. The investigation was made primarily to study the utility of the N.A.C.A. smoke tunnel as applied to the problem of reducing the drag of objects for which the full dynamic scale could not be approached in the smoke tunnel, but designers should find the results of the flow observations and drag measurements of value because they show that most of the large drag added by the original windshield is eliminated by the modification of the windshield to the final form.

INTRODUCTION

The windshield of the modern high-speed transport airplane appears in many instances to be conspicuously lacking in aerodynamic refinement. A short investigation of such a windshield was therefore considered desirable. The investigation consisted of drag tests in the variable-density tunnel of a given type of windshield and of a modified form of the windshield arrived at as a result of air-flow observations made with model windshields in the N.A.C.A. smoke tunnel. Thus, the investigation also permitted a study of the utility of smoke-tunnel flow observations as applied to a practical engineering problem.

Various pieces of apparatus previously designed for air-flow observations have permitted tests to be made only at very low values of the Reynolds Number, most of the tunnels being of the order of 1 to 3 inches in diameter. The National Advisory Committee for Aeronautics, in order to allow the direct observation of air flows at larger values of the Reynolds Number and to permit greater ease of construction of the models, has designed and constructed a smoke-flow tunnel having a throat 2 feet in diameter. The dynamic scale attainable with this equipment is still rather low, the velocity being limited to about 10 feet per second. However, by using enlarged replicas, full-scale Reynolds Numbers may be reached for small objects such as round and streamline wires. For most of the flows in which the aeronautical engineer is interested, however, full-scale values of the Reynolds Number cannot be approached.

While the tests with which this report deals were made primarily to study the utility of the N.A.C.A. smoke tunnel as applied to the problem of reducing the drag of an object at a large value of the dynamic scale, the valuable results were obtained from the drag measurements made in the variable-density wind tunnel.

TESTS

The windshield over which the flow was studied in the N.A.C.A. smoke tunnel was formed of Plasticine on an existing model fuselage used in connection with some other tests made in the smoke tunnel. The form of the windshield was made to simulate roughly the forward-sloping V-type used on the Boeing 247 transport airplane. After the flow had been observed in the smoke tunnel, the windshield was altered in various ways and the flow observed after each alteration, investigating the effects of modifying the windshield slope, the shape of the roof over the windshield, the plan form, and the addition of guide vanes at the outer edges of the windshield. As a result of these observations a form of windshield was developed that will be referred to as the final form.

The tests with which this report is principally concerned were then made in the variable-density wind tunnel at a value of the Reynolds Number of approximately 3,000,000 (based on airfoil chord - see fig. 2) of a model with the original and final forms of windshield. The windshields were built of plaster of paris on an existing aluminum alloy airfoil and fuselage combination previously employed in connection with interference investigations.

DISCUSSION

The flow observed over the original windshield form is shown schematically in figure 1. Separation occurred on the top of the windshield as indicated, particularly at sections to either side of the center line. Three vortices were observed to form forward of the windshield as indicated. These vortices were continuous and streamed back along the windshield and, in plan view, left the fuselage surface at the outside edge of the windshield, producing a kind of separation.

The subsequent alterations of the windshield were made with a view to improving the flow conditions about it without departing too much from the practical form. It was particularly desired to retain the forward-sloping form as this form was considered very desirable with respect to vision. However, it was considered that the roof form behind the windshield could be modified. The sharp corners at the junctures of the forward windshield panels and roof portion were therefore eliminated by building up the roof portion sufficiently to permit the rounding off of these corners. This change might be accomplished in practice by means of a formed celluloid roof portion.

Several forms of guide vanes, or auxiliary airfoils, were introduced at the windshield edges where a break occurs in the plan view in an attempt to control the vortices that passed off at these points. Such devices, aside from the fact that they appeared rather ineffective with respect to their action on the vortices, were considered objectionable and in practice would have to be constructed of glass in order not to interfere with the field of view. Instead of using such devices, the final form was reached by altering the plan-form shape. Two additional flat windshield sections were introduced to reduce the abruptness of the break at the sides of the windshield. As a result of the modifications, the flow over the top was fairly satisfactory and the flow at the sides was definitely improved. The vortices forming in front of the windshield were, of course, still present.

The original and final windshield forms are indicated in figures 2 and 3 from photographs of models employed for the tests in the variable-density wind tunnel. The results of these tests at a Reynolds Number of approximately 3,000,000 are shown in figure 4. A study of the polar curves drawn on the figure will show that the unaltered windshield adds more drag to the combination than the entire fair fuselage, and also that most of the added drag is eliminated by the modification of the windshield to the final form. It appears therefore from these results that the N.A.C.A. smoke tunnel may, in some instances, be used as an aid in developing low-drag shapes, even though the full-scale Reynolds Number cannot be approached. The drag saving as a result of the modification may be represented as a drag coefficient of 0.0020 or a drag of the order of 8 percent of that of a clean airplane.

The differences between the aerodynamic characteristics of these windshields is so marked that an extensive investigation of the drag of windshields appears to be desirable.

Langley Memorial Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., November 15, 1933.

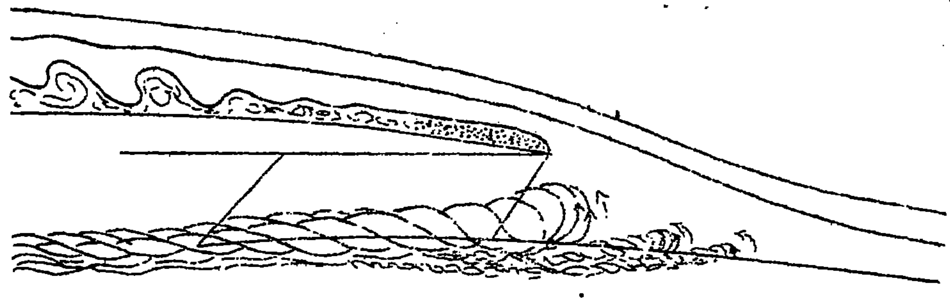

Figure 1.-Sketch of flow about original windshield.

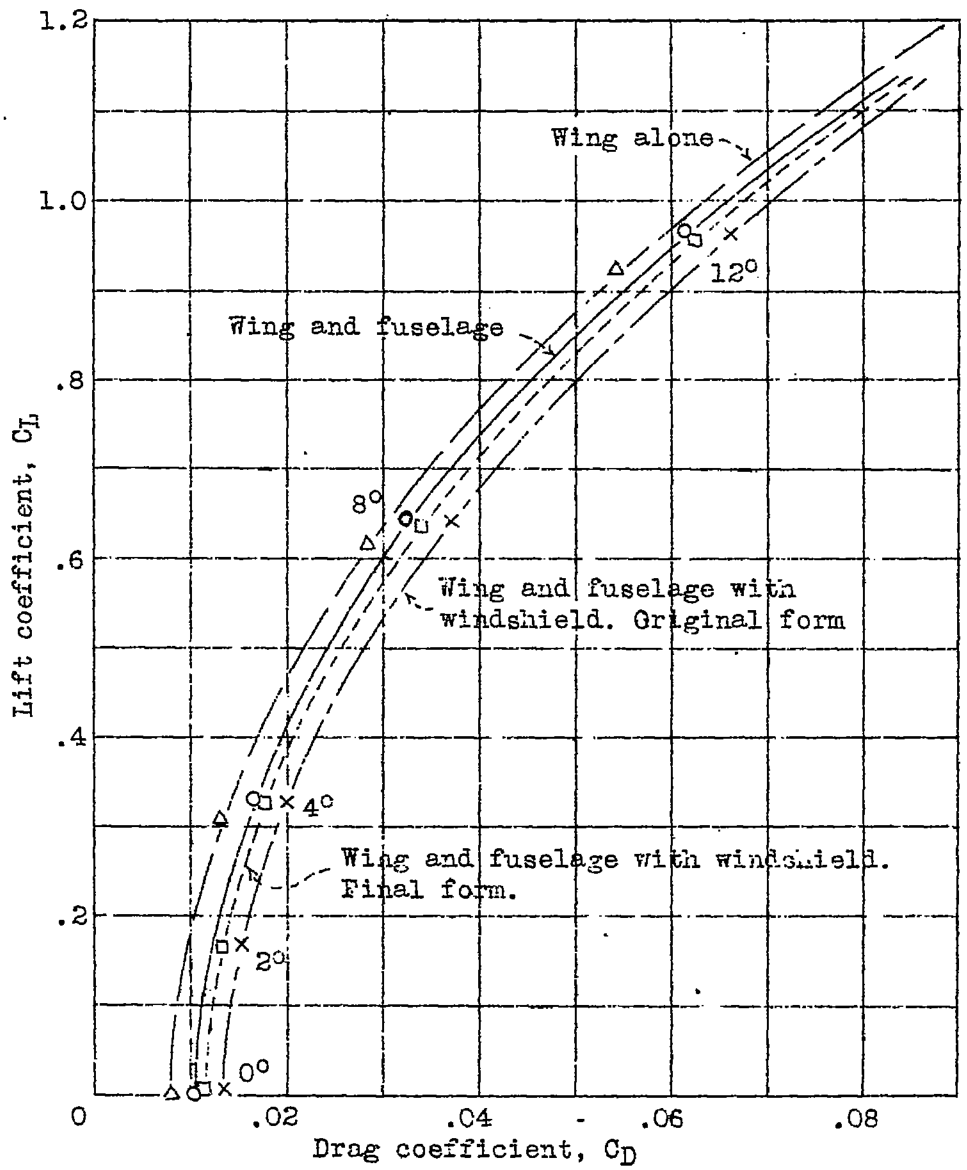

Figure 4.-Polar curves showing effects of windshields.

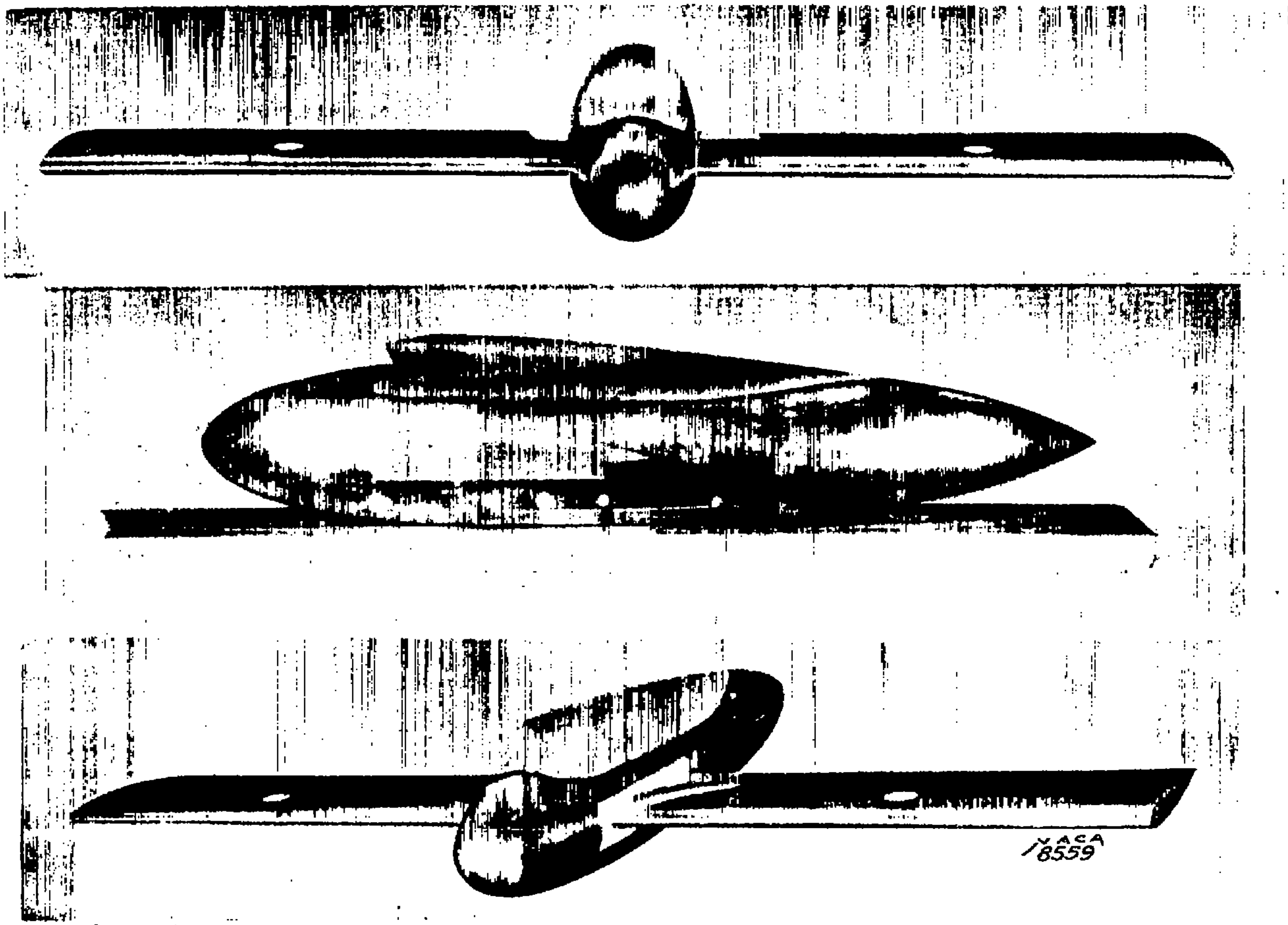

Figure 2.-Original windshield form.

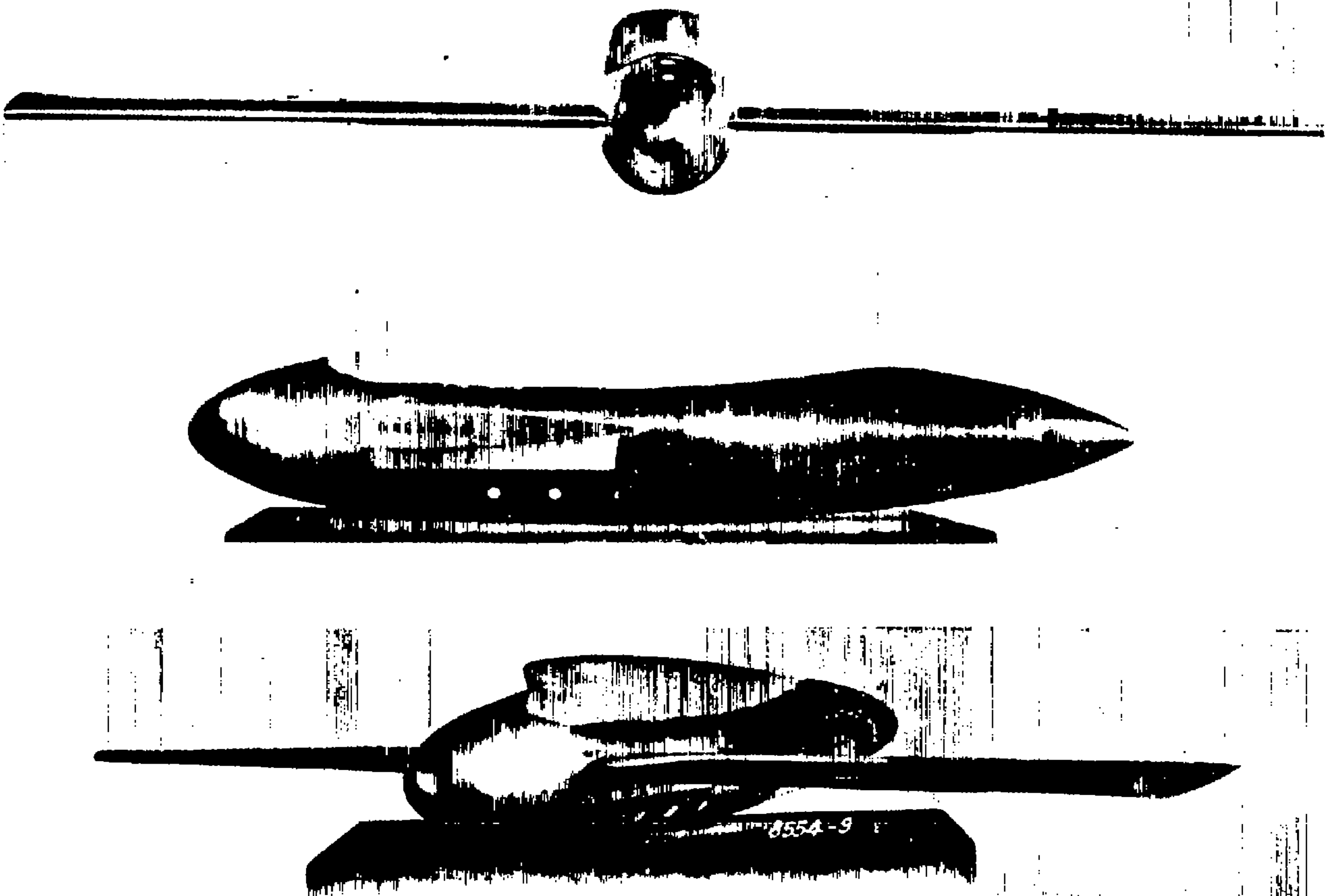

Figure 3.-Final windshield form.