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EFFECTS OF A SIMULATED ICE FORMATION ON THE AERODYNAMIC CHARACTERISTICS OF AN AIRFOIL

By Beverly G. Gulick

Langley Memorial Aeronautical Laboratory
Langley Field, Va.

NACA

WASHINGTON

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INTRODUCTION

In connection with the general study of icing problems an item of major interest is the effect of ice on the aerodynamic characteristics of a wing. Of particular interest is the effect of the ice which remains on a wing under some flight conditions in spite of the operation of rubber de-icers.

At the request of the N.A.C.A., a questionnaire seeking information as to the size and distribution of such ice particles on the wings was circulated to transport airplane operators by the Air Transport Association of America. The information received in response to this questionnaire shows that under certain conditions ice adheres to the wing in irregular ridges on both sides of the inflatable rubber tubes. One of the photographs received of icing conditions in flight is shown in figure 1.

Since it was not feasible to simulate all possible distributions of ice which might occur over the leading edge of a wing, a single distribution was arbitrarily chosen to represent a severe case of this type of icing. As a consequence of the limited test program the results are not general and only indicate the order and magnitude of the effects which may occur.

EQUIPMENT AND TESTS

As the 6- by 36-foot N.A.C.A. 0012 metal airfoil used for the investigation was primarily constructed to obtain section characteristics, particular care was taken to achieve a smooth surface. The entire surface was sprayed with several coats of paint primer which was smoothed with sandpaper between each application and finally polished with rubbing compound.

To simulate the ice formation, a mixture of tar and crushed slag was applied to a strip of cloth which was attached over the leading edge of the airfoil (fig. 2). The size of the crushed slag was limited to that which would pass through a 1/4-inch mesh sieve. Figure 3 shows the arrangement and size of the formations on the airfoil.

The tests were made in the full-scale wind tunnel (reference 1) at an air speed of approximately 60 miles per hour.

RESULTS AND DISCUSSION

The results showing the effects of the simulated ice formation on the aerodynamic characteristics of the airfoil are presented in figures 4 and 5. The data are fully corrected for all wind-tunnel effects.

The simulated ice formation reduces the slope of the lift curve over the entire useful angle-of-attack range although the greatest effect occurs near the angle for maximum lift. The maximum lift coefficient is reduced from 1.32 to 0.80 with no appreciable change in the angle of attack of maximum lift. The profile-drag coefficient at the high-speed lift coefficient is increased by 90 percent. Since the tests were made on an extremely smooth airfoil, this increase may be somewhat greater than should be expected for a service-type wing. The ratio of lift to drag is reduced throughout the angle-of-attack range, the maximum value being reduced from 23.7 to 14.5. The pitching-moment coefficients about the aerodynamic center are not greatly affected by the simulated ice formation.

Of the foregoing effects the reduction in the maximum lift coefficient is probably of greatest concern to airplane operators. This reduction in the maximum lift coefficient entails a corresponding increase in the airplane stalling speed which varies with the wing loading as shown in figure 5. Any increase in the stalling speed constitutes a potential source of danger. The danger lies, not so much in the higher stalling speed, but more in the possibility that the stall may occur without advance warning to the pilot. This is particularly true for a case in which reliance is placed chiefly on the air-speed meter to predict the stalling speed.

The increase in drag may be somewhat greater than should be expected on a service-type wing but, since the simulated formation does not necessarily represent the worst condition that may occur, the use of the foregoing

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results in making calculations of the probable effect of the ice on the range and rate of climb may not be too conservative.

Langley Memorial Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., March 5, 1938.

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REFERENCE

1. DeFrance, Smith J.: The N.A.C.A. Full-Scale Wind Tunnel. T.R. No. 459, N.A.C.A., 1933.

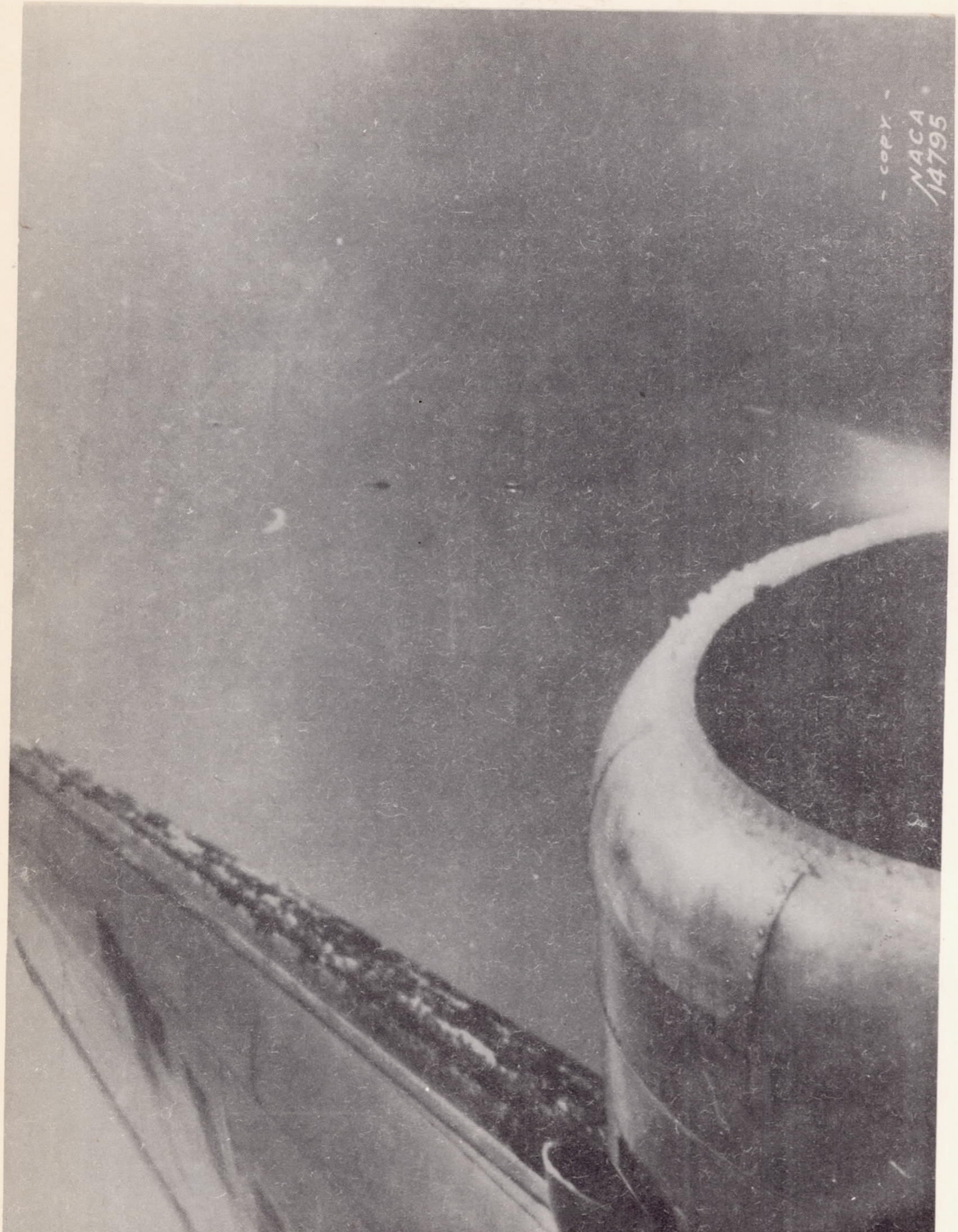

Figure 1.- Ice remaining on deicer and engine cowling.

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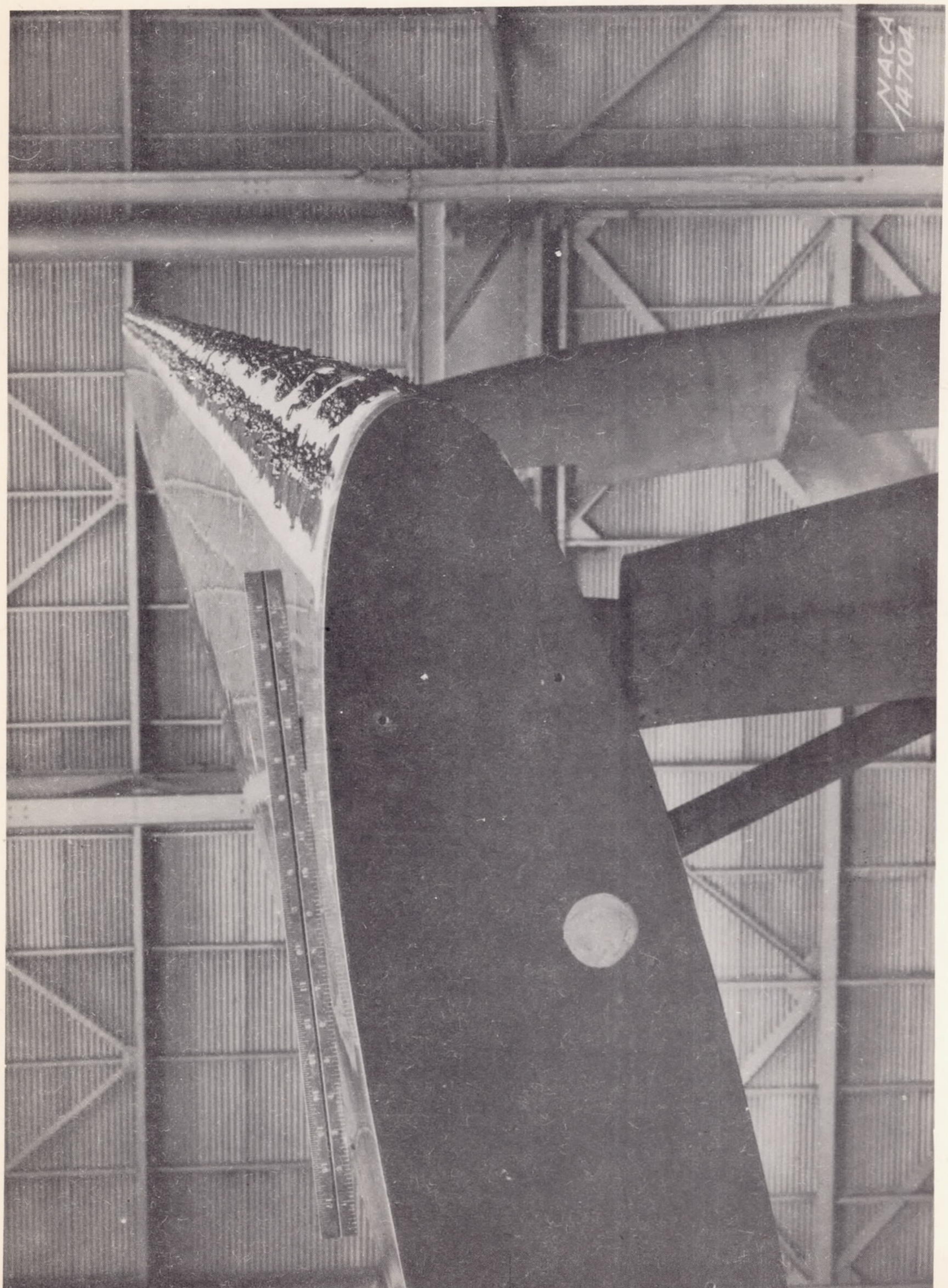

Figure 2.- The simulated ice formation on the N.A.C.A. 0012 airfoil.

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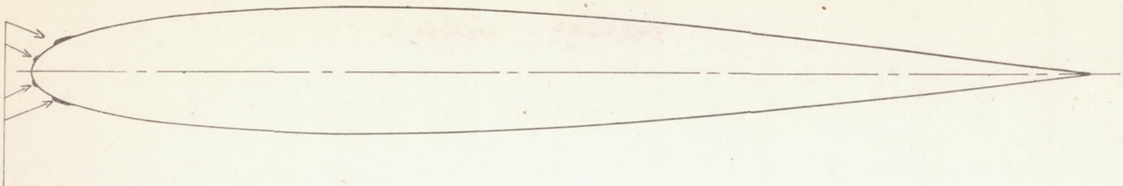
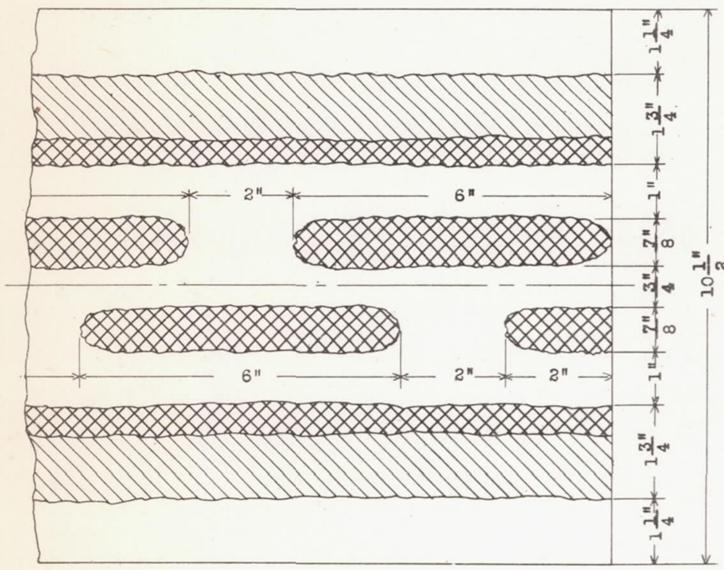
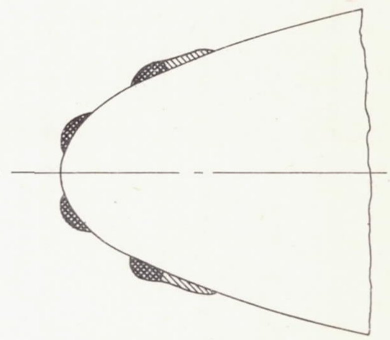


Formation on the N.A.C.A. 0012 airfoil.





The cloth strip with tar and slag applied to the nose of the airfoil.

Pattern of tar and slag on the cloth strip.

Tar and slag; maximum thickness 3/8"; average thickness 1/4"

Plain asphalt; " " 1/8"; " " 3/32"

Figure 3.- The size and arrangement of the simulated ice formations on the N.A.C.A. 0012 airfoil.

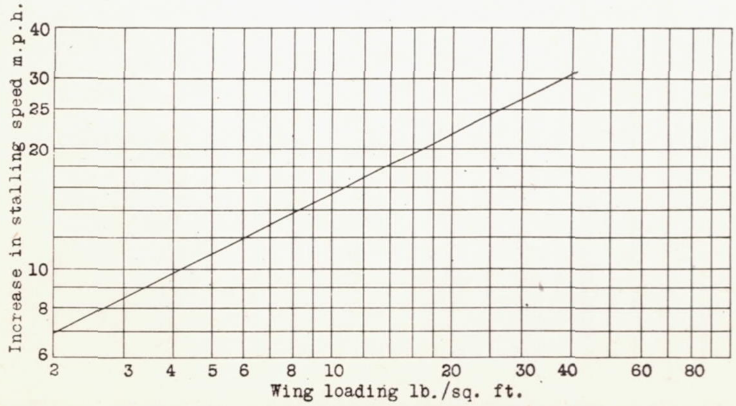


Figure 5 - The increase in stalling speed resulting from the simulated ice formation

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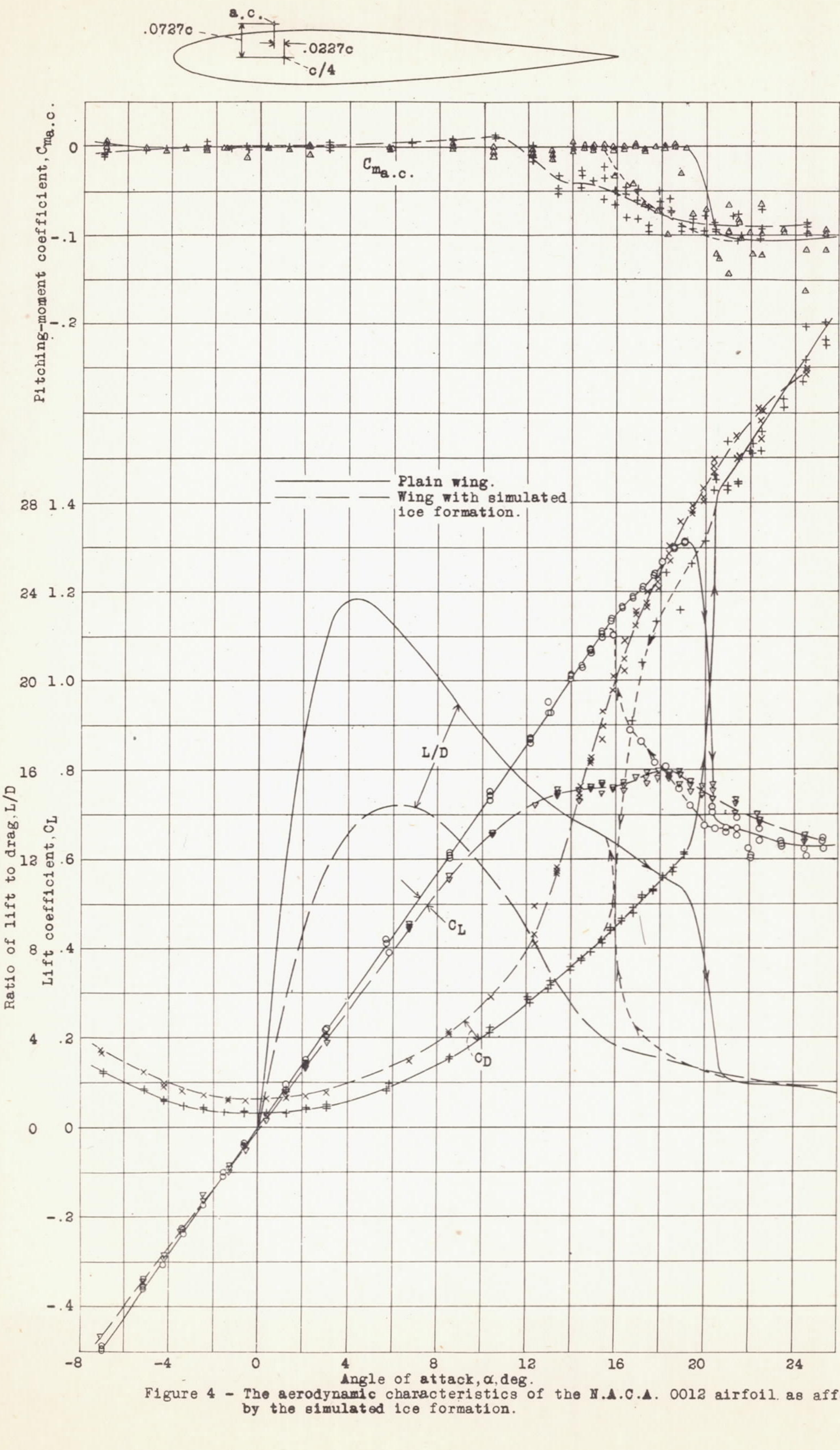

Figure 4 - The aerodynamic characteristics of the N.A.C.A. 0012 airfoil as affected by the simulated ice formation.