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NACA

RESEARCH MEMORANDUM

FLIGHT TESTS TO DETERMINE THE EFFECT OF LENGTH OF A CONICAL WINDSHIELD ON THE DRAG OF A BLUFF BODY AT SUPERSONIC SPEEDS

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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

WASHINGTON

January 29, 1947

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SUMMARY

Flight tests have been conducted to determine the effect of length of a conical windshield on the drag of a bluff body moving at supersonic speeds. A comparison is made between results thus obtained (for a 3-inch windshield) and the results of previous drag tests of body-windshield combinations (for windshields of 0, 1-inch, and 10-inch length). The test results showed that the effect of increasing the length of a conical windshield mounted ahead of a bluff body moving at supersonic speeds is to decrease the drag; that the effect is greatest for short windshields; and that the effect increases with Mach number. Results also showed that a conical windshield of relatively small dimensions can appreciably increase the effective fineness ratio of a bluff body at supersonic speeds.

INTRODUCTION

In view of practical considerations, such as provision of adequate visibility for a pilot or an automatic target-seeking device, the Langley Pilotless Aircraft Research Division is conducting an investigation to determine means whereby the drag of a blunt-nose body at supersonic speeds may be reduced to a value comparable with that of a pointed-nose body.

Theoretical considerations indicate that, if a conical windshield is placed ahead of a blunt-nose body at supersonic speeds, the low-velocity wake behind the conical windshield will expand and thus cause the external flow to follow the contour formed by the extension of the surface of the conical windshield. Thus, a small conical point might produce substantially the same effect as a long pointed nose but have the advantages of improved visibility and reduced structural weight.

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In order to determine the magnitude of the effects of a conical windshield, the supersonic flight investigation of reference 1 was continued and the results are presented herein. Reference 1 determined the reduction in drag effected by a 1-inch conical windshield of 22° 22' included nose angle placed 8.04 inches ahead of the almost hemispherical nose of a fin-stabilized body of 5-inch diameter. The effect of increasing the length of the windshield to 3 inches is given in the present paper. As in reference 1, the drag of the 3-inch windshield is compared with that of a pointed nose of fineness ratio 3.5 formed by fairing a median curve between a cone and a circular arc tangent to the 5-inch-diameter body.

BODIES AND TESTS

<u>Bodies</u>.- A photograph of the blunt-nose test body equipped with the conical windshield 3 inches long is given as figure 1. This body was obtained by modifying the body of the dimensions given in figure 2(b). The sharp nose was replaced by a spherical surface which faired tangentially into the rear part of the sharp nose as shown in figure 2(c). The 3-inch conical windshield was mounted on a boom as shown in figure 3(b) so that the apex of the windshield coincided with the position of the apex of the original sharp nose. The included angle of the windshield, 22° 20', was approximately equal to the included angle of the original sharp nose.

The 1-inch-windshield body of reference 1 was derived in the same manner as the 3-inch-windshield body, and differed only in length of the windshield and in diameter of the supporting boom. The 1-inch windshield is shown in figure 2(a) and in greater detail in figure 3(a). The comparable sharp-nose and blunt-nose bodies of reference 1 are the shapes shown in figures 2(b) and 2(c), respectively.

All the test bodies were propelled by 3.25-inch-diameter Mk. 7 aircraft rocket motors enclosed within the bodies. At a preignition temperature of 69° F, the rocket motors provided approximately 2200 pounds of thrust for approximately 0.87 second.

<u>Tests</u>.- The body with the 3-inch conical windshield as well as the bodies in reference 1, were launched at an elevation angle of 75° to the horizontal. Because of the large elevation angle and the short duration of burning of the rocket motor, the trajectory of the bodies during their supersonic coasting flight (after the propellant was expended) was approximately a straight line. The flight velocity was measured during this coasting period by means of a CW Doppler radar set (AN/TPS-5) located at the point of launching.

RESULTS AND DISCUSSION

The variation of velocity with time for the test body with the 3-inch conical windshield, as measured with the radar unit, is presented in figure 4. The amount of scatter of the experimental points, although greater than usual, still permits satisfactory reduction of the data. The maximum velocity reached by the test body was 1672 feet per second, which corresponds to a Mach number of 1.49. The part of the velocity curve during which coasting flight was attained (after the end of burning) was graphically differentiated to obtain the deceleration. The product of the deceleration and the known mass of the test body gave the forward-acting inertia force. This product was equated to the sum of the drag and the known weight of the body. The values of the drag thus obtained are presented in figure 5 as a function of the flight velocity. Although the scatter of the velocity-time curve has been greatly magnified by its differentiation, the drag curve is satisfactorily determined. An almost linear variation of drag with velocity is evidenced between the limits of 1100 and 1500 feet per second.

From the faired curve of drag against velocity given in figure 5, the drag coefficient of the test body with a 3-inch windshield has been computed and is presented in figure 6 as a function of the Mach number. For comparison, the drag-coefficient curves for the body with a 1-inch windshield and the blunt-nose and sharp-nose bodies of reference 1 are included. The drag coefficients were based on body frontal area exclusive of the fins (0.1364 sq ft) and include the drag of the fins. The figure shows that the drag-coefficient curve for the test body with the 3-inch windshield intersects the curve for the blunt-nose body of reference 1 at a Mach number of 1.05 and is 96, 89, and 85 percent of the blunt-nose drag coefficient at Mach numbers of 1.1, 1.2, and 1.4, respectively.

As an indication of the consistency of the drag-coefficient curves obtained by the testing technique employed, the variation of drag coefficient with Mach number, evaluated for five identical sharp-nose test bodies, is presented in figure 7. The scatter of the points is approximately ±3 percent relative to the mean faired curve, which varies approximately 2 percent from that presented in reference 1. Of the five test bodies (fig. 7), test bodies A and B were fired at identical atmospheric conditions and test bodies C and D were fired at identical atmospheric conditions. The scatter can be attributed to slight inaccuracies in model fabrication, test method, and reduction of the experimental data.

Figure 8, a cross plot of figure 6, shows curves of percentage drag decrement against windshield length. The percentage drag decrement is the precentage reduction of the drag of the blunt-nose body effected by the use of a conical windshield. The sharp-nose test body of reference 1 has been assumed to be the result of increasing the length of the windshield to 10 inches since it is evident that an increase in length of the conical windshield to the point at which it becomes tangent to the blunt nose would result in decreasing the drag to approximately the value obtained with the actual sharp nose tested. Although the sharp nose is not of conical shape, actually having been derived by taking the mean curve between a conical and circular-arc profile, little discrepancy in aerodynamic characteristics should result from the difference as is indicated in reference 2, and the resulting values are believed to be of the proper order of magnitude. Consequently, the points at 3 inches and 10 inches have been connected by dashed lines. For the Mach number of 1.1, the 0, 1-inch and 3-inch points have also been connected by a dashed line to indicate that the decrements are small enough to fall within the precision of the tests. The curves show that the short-length windshields (3 in. and less) are most effective per unit length in decreasing the drag of the blunt-nose as is indicated by the curve for the 3-inch windshield, which is 61 percent as effective as the 10-inch windshield at a Mach number of 1.4. Also, the effectiveness of the windshield increases with Mach number, the effectiveness being approximately 11 percent greater at a Mach number of 1.4 than at a Mach number of 1.1. For a given windshield length, the decrement in drag coefficient resulting from an increase in Mach number decreases as the Mach number increases.

CONCLUSIONS

Flight tests of the effectiveness of conical windshields of various length with a 22° 20' included angle in reducing the drag of a 5-inch-diameter, blunt-nose body at Mach numbers of 1.1 to 1.4, when the apex of the windshields is located 8.04 inches ahead of the body, lead to the following conclusions:

1. A conical windshield is effective in reducing the drag of a blunt body.

2. The decrease in drag coefficient effected by the windshields becomes greater, and the decrement per inch of windshield length becomes less, with increasing length of windshield.

3. For an increase in Mach number the reduction in drag coefficient resulting from the use of a conical windshield increases; the increase is greatest at the low Mach numbers.

4. The magnitude of the decreases in drag coefficient of a blunt body at Mach numbers of 1.1, 1.2, and 1.4, respectively, effected by a 1-inch conical windshield were about 0, 4, and 6 percent; by a 3-inch conical windshield, about 4, 11, and 15 percent; and by a 10-inch conical windshield, the limiting condition which made the windshield continuous with the body proper, about 14, 23, and 27 percent.

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REFERENCES

1. Alexander, Sidney R.: Results of Tests to Determine the Effect of a Conical Windshield on the Drag of a Bluff Body at Supersonic Speeds. NACA RM No. L6E08a, 1946.

2. Ferri, Antonio: Supersonic-Tunnel Tests of Projectiles in Germany and Italy. NACA ACR No. L5H08, 1945.

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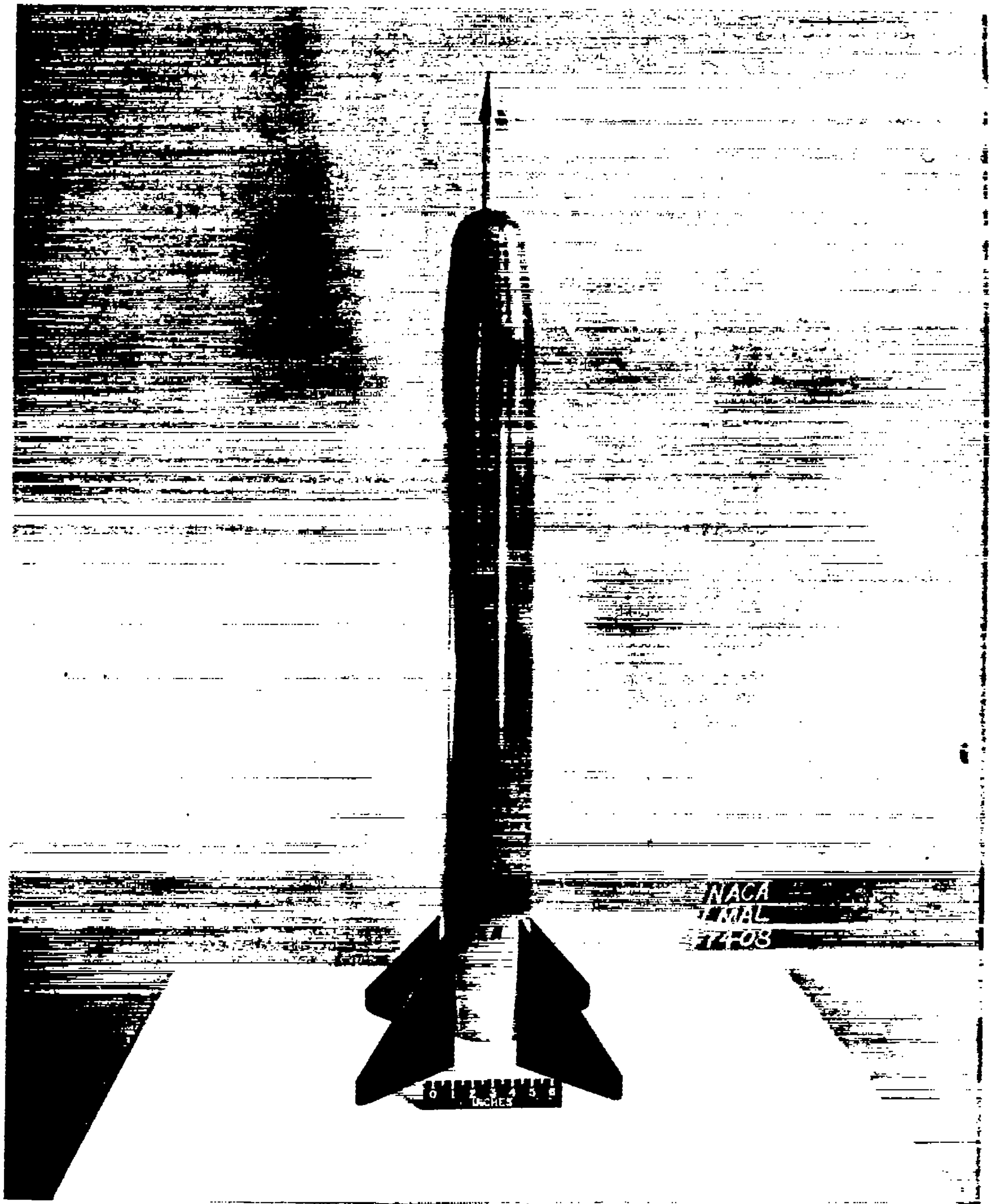

Figure 1.- General view of test body.

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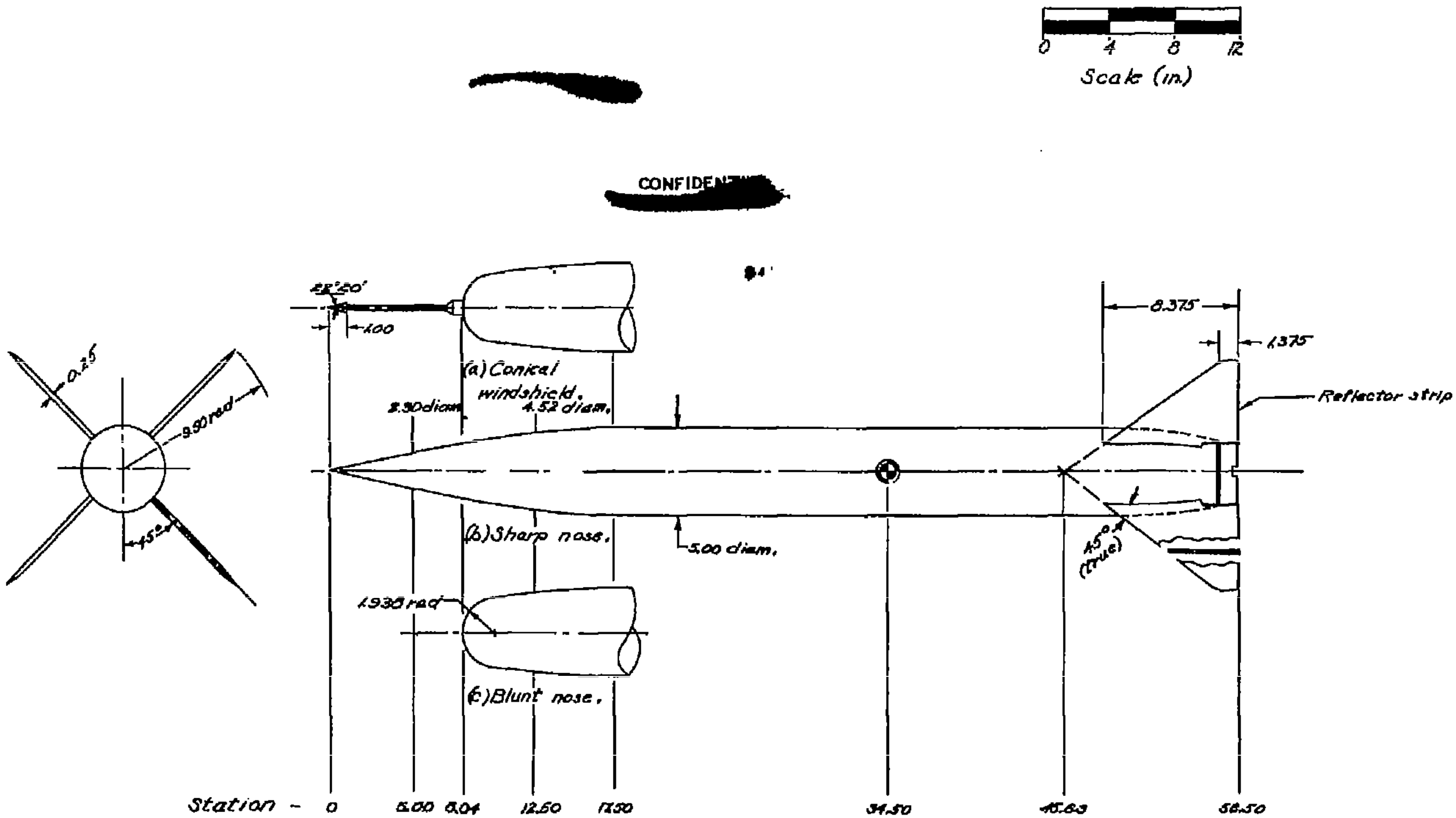

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Figure 2. – General arrangement of test body showing nose shapes investigated in reference 1. Fin area (exposed) = 136.5 square inches; design weight (burnt out) = 28.8 pounds.

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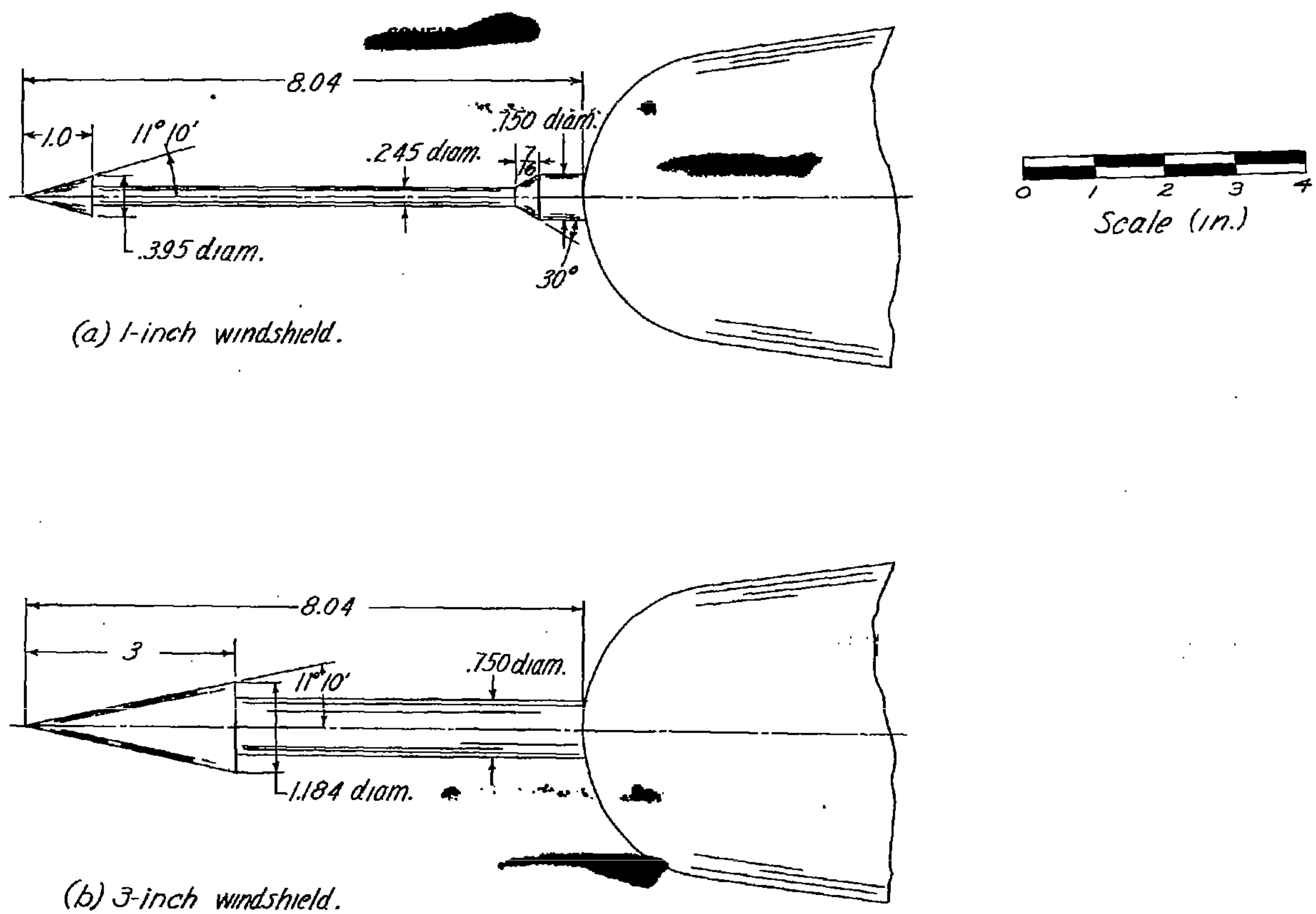

(a) 1-inch windshield.

(b) 3-inch windshield.

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Figure 3.- Comparison of conical windshields tested.

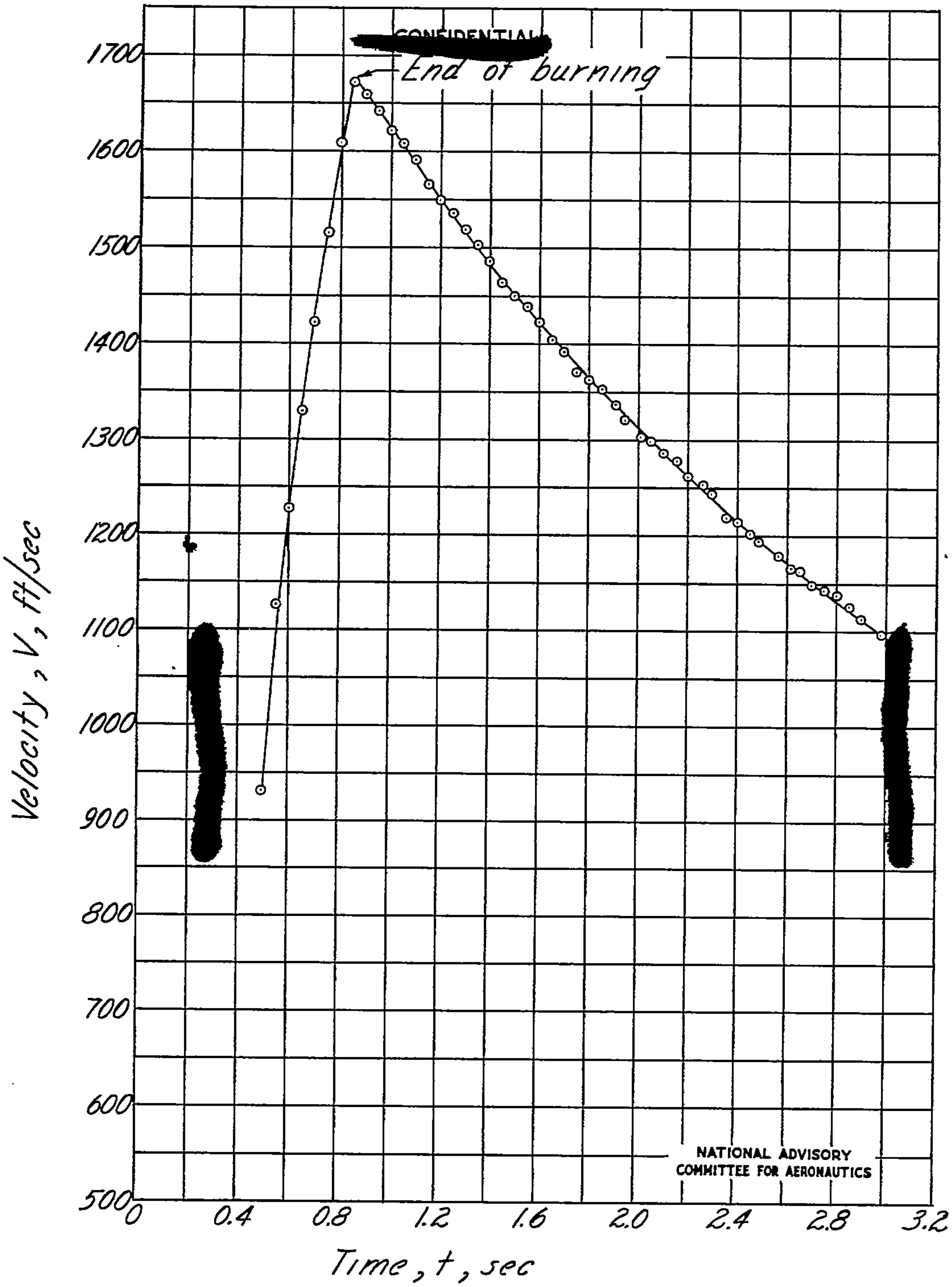

Figure 4.- Velocity-time curve for test body with 3-inch conical windshield.

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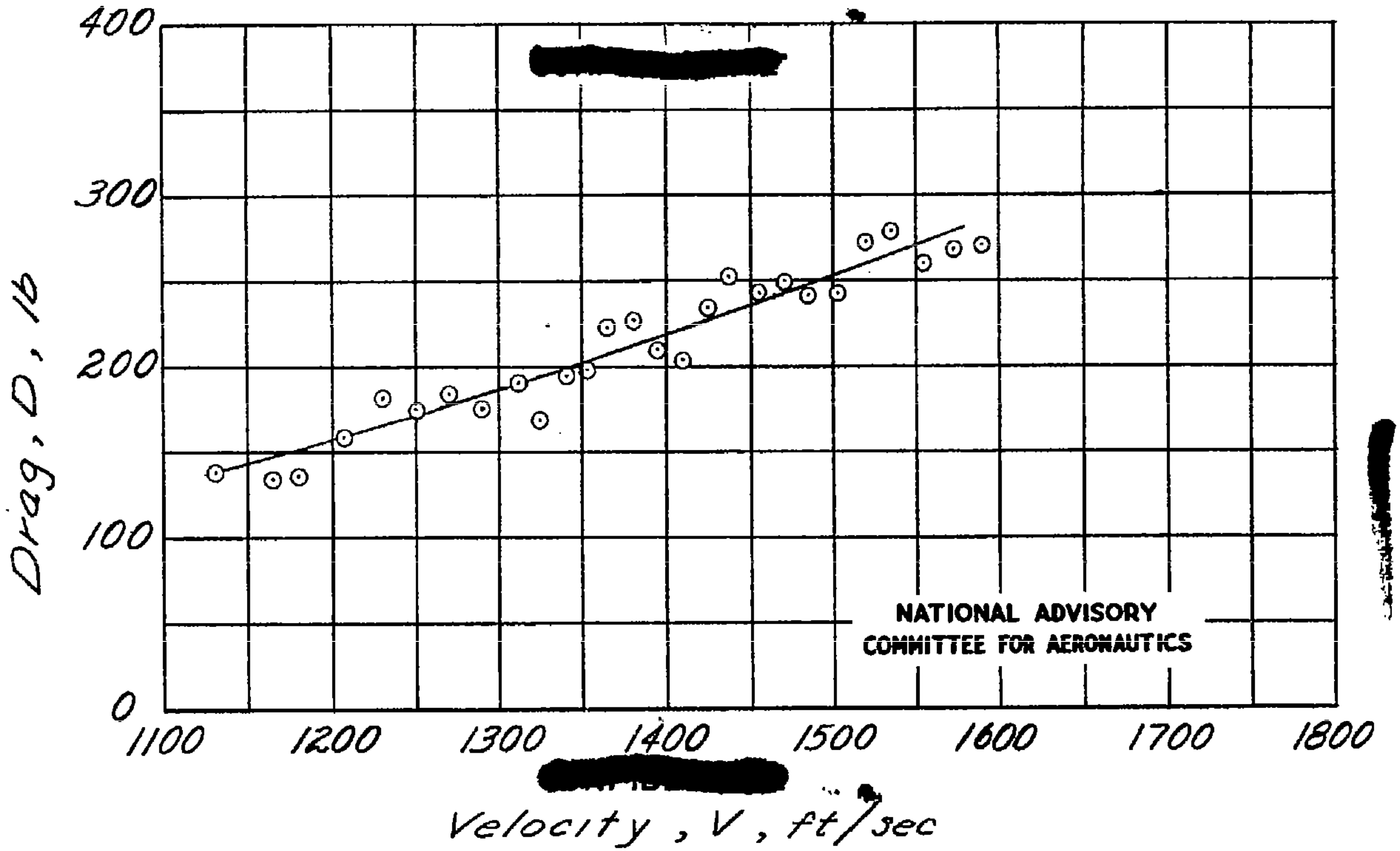

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Figure 5.- Drag against velocity for test body with 3-inch conical windshield.

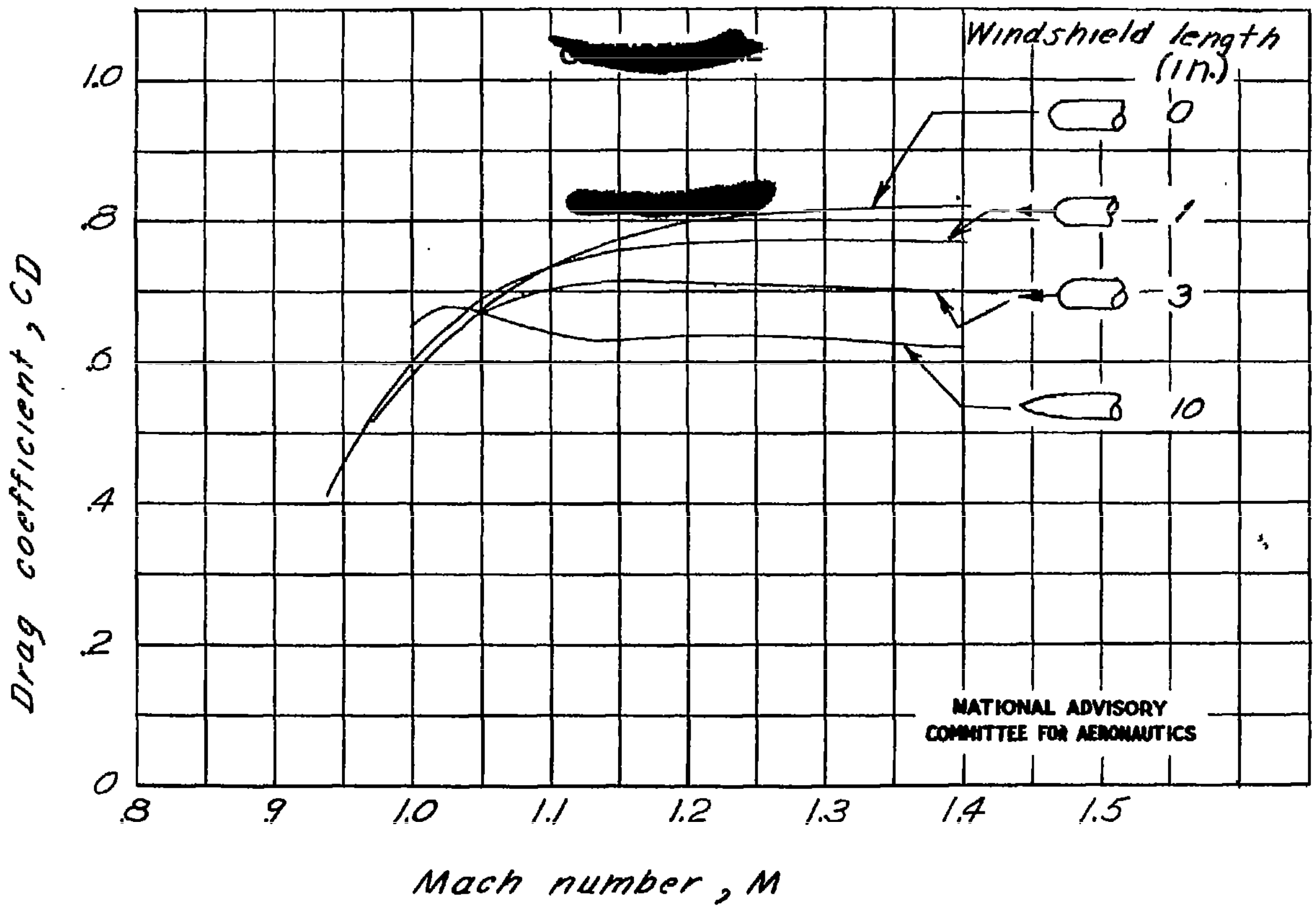

Figure 6.- Variation of d[redacted]cient with Mach number for varying windshield lengths.

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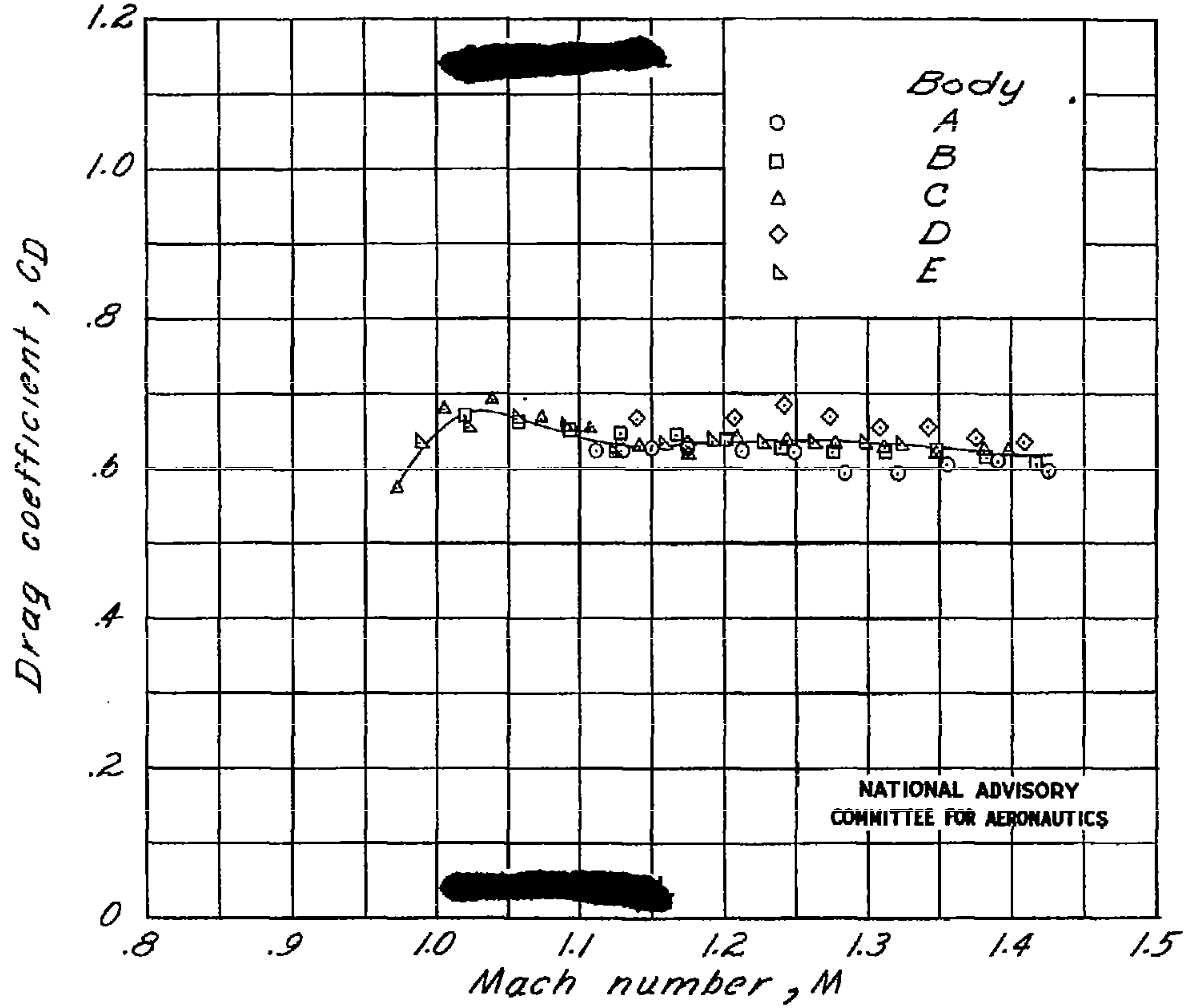

Figure 7.- Exper[redacted]atter as determined from firings of five identical sharp-nose bodies.

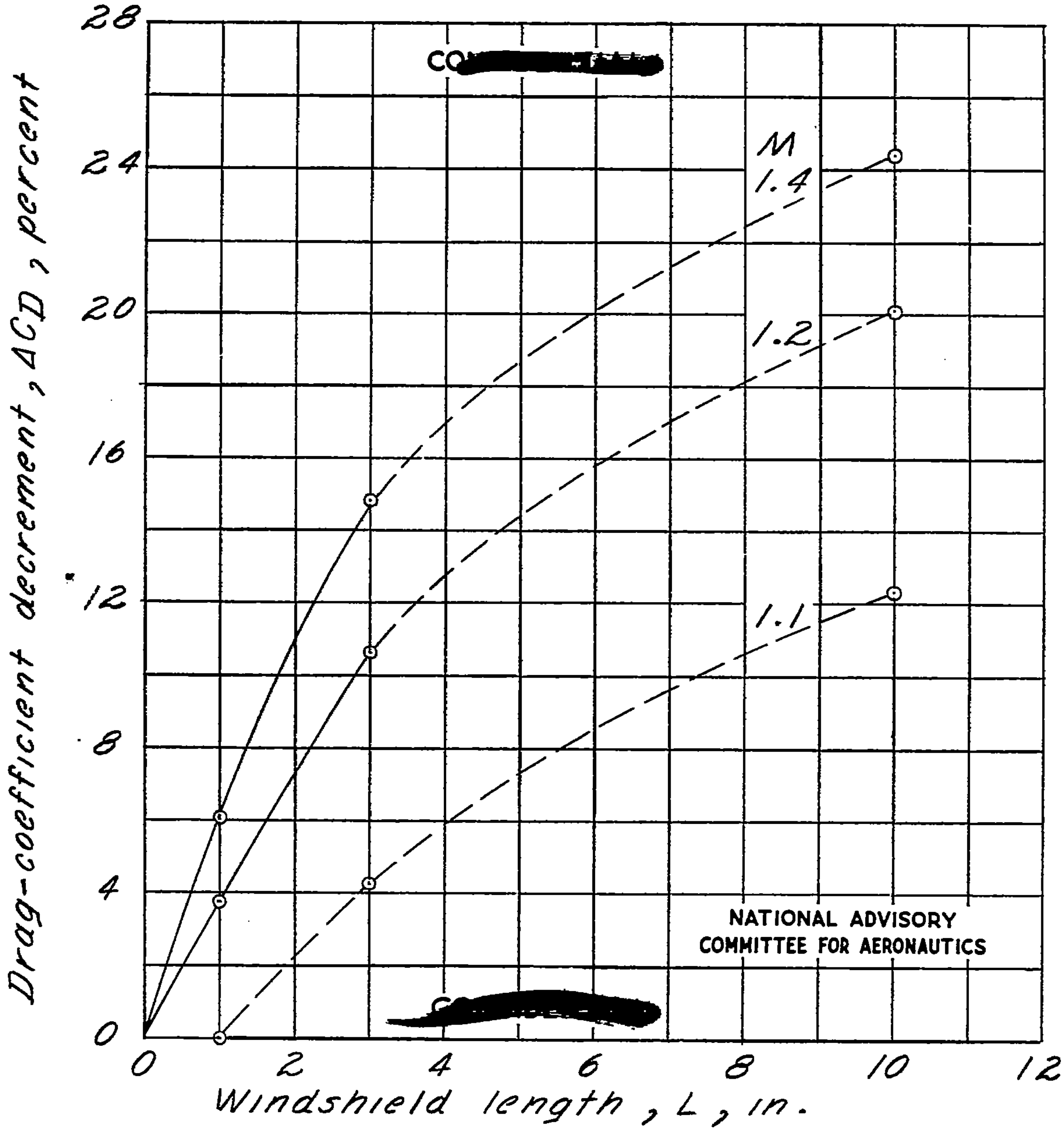

Figure 8.--Variation of drag-coefficient decrement with windshield length for three values of Mach number.