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DRAG MEASUREMENTS OF A PROTRUDING 0.50-CALIBER MACHINE GUN

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SUMMARY

Drag and cross-wind force measurements of a Browning 0.50-caliber M2 machine gun at air speeds from 90 to more than 400 miles per hour were made in the NACA 8-foot high-speed wind tunnel. The machine gun protruded through the top of the tunnel wall into the air stream and tests at several fore-and-aft angles were made by pivoting the gun in a plane parallel to the air flow. Sufficient data were taken to permit the calculations of the power required to turn the gun against the aerodynamic forces and to determine the horsepower absorbed in air drag by the protruding gun for different speeds up to 400 miles per hour.

For the speed range covered in the tests, the drag and the cross-wind force coefficients for the machine gun were only slightly affected by Reynolds number and Mach number. The drag for equal fore-and-aft angles was nearly the same, the drag being slightly less when the gun pointed downstream. As an indication of the magnitude of the drag forces to be expected at high speeds, calculations based on data obtained show that a protruding machine gun when mounted vertical to the air flow on an airplane flying 350 miles per hour at sea-level conditions, for example, would have a drag of 83 pounds and would absorb 78 horsepower.

Additional tests were made to study the effects of the slots in the cooling jacket of the machine gun. The data obtained indicate that in actual installations of machine guns on airplanes some gain (that is, less drag) due to closing the jacket slots is to be expected at low altitudes and for speeds up to about 360 miles per hour, but at high altitudes no gain can be expected.

INTRODUCTION

For accurate design the power required by the various component parts of an airplane must be known; even the parts that need not be considered at low speeds require appreciable power to propel them at high speeds, particularly when compressibility effects are considered. Because of its poor aerodynamic shape, the drag of a machine gun and the power required to propel it through air will be very high. The need for such weapons makes it necessary to consider the aerodynamic effects in the design of gun installations.

The purpose of the present investigation was (1) to determine the drag of a protruding Browning 0.50-caliber M2 machine gun and the power absorbed in air drag at different speeds; and (2) to obtain the basic data necessary to permit the calculation of the power to drive such protruding guns when used in power-operated turrets. These basic data are, of course, the forces and the center-of-pressure location along the gun barrel. Additional tests were also made to study the effects of the slots in the gun-barrel jacket.

The tests were made in the NACA 8-foot high-speed wind tunnel following a request of the Matériel Division Liaison Office.

APPARATUS AND METHODS

The tests were made in the NACA 8-foot high-speed wind tunnel, which is a single-return, circular-section, closed-throat tunnel having an air speed continuously controllable from approximately 75 to more than 500 miles per hour.

A Browning 0.50-caliber M2 machine gun, which had a slotted jacket of 1.875 inches outside diameter, was used in the tests. As shown in figure 1, the gun protruded through the top of the wind tunnel into the air stream so that actual conditions, as regards boundary layer on the body from which the actual gun might protrude, were simulated by the boundary layer along the tunnel wall. Drag, cross-wind, and pitching force measurements were made at several velocities from 90 to more than 400 miles per hour. Angle changes were made by pivoting the gun in a plane parallel to the air flow. Data were obtained at angles of 0° (perpendicular to the air flow), 15°, 30°, 45°, and 60° fore and 15° and 45° aft. Lateral angles were not included because the same lengths of protruding gun and attitudes are represented by the fore and the aft movement.

The effects of the slots in the barrel jacket were determined by tests of a solid replica of the jacket (fig. 2), this being mounted and tested in the same way as the actual gun.

PRECISION

The possible error in the drag and the cross-wind force coefficients is indicated by the scatter of the test points. The accuracy of the center-of-pressure coefficient was relatively poor at low speeds, because of the small forces, but it improved with speed. At a Mach number of 0.390 the possible error in C_p was determined to be ± 0.01 for the machine gun when perpendicular to the air stream and ± 0.02 for the smooth-jacketed replica of the machine gun.

RESULTS AND DISCUSSION

The following symbols are used in this paper. (See fig. 2.)

α angle made by the barrel of the machine gun with the perpendicular to the air flow. The angle of the gun is positive when the gun muzzle points into the air stream.

L length of gun protruding into air stream, measured along gun axis

D outside diameter (1.875 in.) of barrel jacket

A axial cross-section area of gun in air stream. This area is equal to $L \times D$ plus area of small protruding part of gun barrel outside the outer end of the jacket (this small area amounted to $1\frac{1}{3}$ percent of total area for case when $\alpha = 0^{\circ}$).

C_D drag coefficient based on area A

C_C cross-wind force coefficient based on area A. (See fig. 2 for definition of positive direction.)

l projection of length L on plane perpendicular to air flow ($l = L \cos \alpha$)

d distance from top of tunnel wall to center of pressure of resultant air force on gun axis, measured parallel to l

C_p center of pressure coefficient (d/l)

V velocity

ρ air density

a speed of sound

M Mach number (V_o/a)

μ coefficient of viscosity

R Reynolds number $(V_o \rho_o D/\mu_o)$

The subscript zero indicates values in the undisturbed stream.

As figure 3 indicates, the drag and the cross-wind force coefficients for the 0.50-caliber machine gun were only slightly affected by Reynolds number and Mach number. Evidently, the flow of air through the jacket slots produced a relieving effect that delayed the formation of the compressibility burble. The drag for equal positive and negative values of angle was nearly the same, the drag being slightly less when the gun pointed downstream. When the gun was vertical to the air flow, the cross-wind force coefficient was not zero, as might be expected. This result was probably due to the existence of a difference in static pressure between the muzzle end of the gun in the air stream and the breech end that remained outside the air stream; hence, the resulting axial force.

The values of center-of-pressure coefficient, C_p, for the machine gun were but slightly affected by Mach number changes. (See fig. 3.) The test points for angles of 45° and 60° at Mach numbers below 0.3 are not shown because small changes equal to the possible variation in the cross-wind force and drag values, which were in the order of 1.5 pounds for the lowest Mach number, caused large variations in C_p determination. The forces at the higher Mach numbers, however, were sufficiently large to give good C_p values. For positive angles the center-of-pressure location was practically independent of angle. As the angle was made negative, however, the C_p value decreased and became a minimum when α was approximately -15°; for negative angles greater than -15° the center-of-pressure coefficient increased.

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The drag-coefficient curves for the 0.50-caliber machine-gun replica, which had an unslotted barrel jacket, are shown in figure 4. It is apparent that critical Reynolds number and compressibility phenomena strikingly materialize when a barrel jacket with no slots is used. From the drag curves it is seen that when the unslotted gun replica is perpendicular to the air flow, the critical region in which the drag coefficient decreases begins at a Reynolds number of about 100,000. The minimum drag coefficient occurs when R is 340,000, and compressibility effects become pronounced at a Mach number of 0.45. For comparison purposes the two-dimensional-drag curve for a smooth 2-inch-diameter circular cylinder perpendicular to the air flow (test points from unpublished 8-foot high-speed tunnel data) is included in figure 4. The two main points of difference in the drag-coefficient curves of the 2-inch cylinder and the $1\,^7/_8$ - inch jacket cylinder of the gun replica consist in the greater drag coefficient and the absence of marked drag-coefficient decrease in the critical Reynolds number region for the 2-inch cylinder. The higher drag coefficient for the 2-inch cylinder is probably due to the fact that the 2-inch cylinder data are two-dimensional, whereas the gun replica data are three-dimensional. In the case of the gun replica the leakage of air around the gun muzzle into the negative-pressure dead-water region back of the gun favorably alters the pressure distribution in this region so that a decrease in pressure drag results.

As the angle of the gun increases, the drag coefficient decreases and Reynolds number and Mach number effects diminish, so that at 60° inclination the drag coefficient is essentially independent of R and M for the speeds tested. This behavior is to be expected because elliptical cross sections are exposed to the air flow when the axis of the gun makes an angle with the plane perpendicular to the flow.

The comments that applied to the cross-wind force coefficient behavior of the machine gun at $\alpha = 0°$ also apply to the unslotted replica of the machine gun at 0°. Figure 4 illustrates the fact that the cross-wind force coefficient of the gun replica was strongly influenced by critical Reynolds number and compressibility effects. The curves of cross-wind force coefficient tended to follow the drag-coefficient curves in that the magnitude of the cross-wind force coefficient decreased in the critical Reynolds number region and increased at higher speeds owing to compressibility effects.

In figure 4 it is to be noted that the values of center-of-pressure coefficient for the machine gun with unslotted jacket show more scatter and irregularity than the values for the actual machine gun. This result, no doubt, was largely due to the fact that the flow about the replica gun was more disturbed by Reynolds number and compressibility effects than was the flow about the machine gun, and to the fact that the forces on the smooth-jacketed gun replica were less than on the actual gun. As was the case with the actual machine gun, the minimum value of C_p occurs when α is about -15°. Some of the test points at the lowest Mach numbers for -15° and -45° are not shown because the low values of the forces resulted in poor accuracy in C_p determination.

Figure 5 gives a comparison of the drag of the machine gun and the smooth-jacketed replica at several altitudes from sea level to 20,000 feet, the angle α being 0° in all cases. The altitude curves were obtained by use of the drag data given in figures 3 and 4. Owing to the increase in kinematic viscosity with altitude the Reynolds number at a given speed tends to decrease with altitude or, conversely, the speed corresponding to a given Reynolds number will increase with altitude. Thus, changes in the forces that are related to Reynolds number effects will occur at velocities that increase with altitude. Likewise, since the velocity of sound decreases with altitude, the velocity at which some particular compressibility phenomenon takes place is less at altitude than at sea level. Cylinder tests in the 8-foot high-speed wind tunnel indicate that the drag coefficient of the smooth-jacketed machine gun replica would probably behave as shown in figure 5 by the full-line curves at 15,000 and 20,000 feet; compressibility effects would apparently prevent the full development of the marked drag decrease in the critical Reynolds number region. In actual installations of machine guns on airplanes, some gain due to closing the jacket slots is to be expected at low altitudes for speeds up to about 360 miles per hour, but, at high altitudes, no gain can be expected. For over-all operation it appears that, excluding the possibility of enclosed guns, the most effective means of lowering the forces would be to eliminate the jacket.

The horsepower required to propel the actual machine gun and the smooth-jacketed replica at $\alpha = 0^\circ$ for several speeds and at altitudes varying from sea level to 20,000 feet is illustrated in figure 6. It is seen that

78 horsepower would be absorbed in air drag by an actual machine gun when mounted vertical to the air flow on an airplane flying 350 miles per hour under sea-level conditions.

CONCLUSIONS

For the speeds tested, the drag and the cross-wind force coefficients for the 0.50-caliber machine gun were only slightly affected by Reynolds number and Mach number.

The drag for equal fore-and-aft angles was nearly the same, the drag being slightly less when the gun pointed downstream.

A single protruding 0.50-caliber machine gun when mounted vertical to the air flow on an airplane flying 350 miles per hour at sea-level conditions, for example, could be expected to have a drag of 83 pounds and to absorb 78 horsepower. This high drag indicates that serious consideration should be given to enclosing guns.

In actual installations of machine guns on airplanes, some gain due to closing the jacket slots is to be expected at low altitudes and for speeds up to about 360 miles per hour, but at high altitudes no gain can be expected.

With a protruding gun it appears that a considerable drag reduction for over-all operation could be effected if the jacket can be eliminated.

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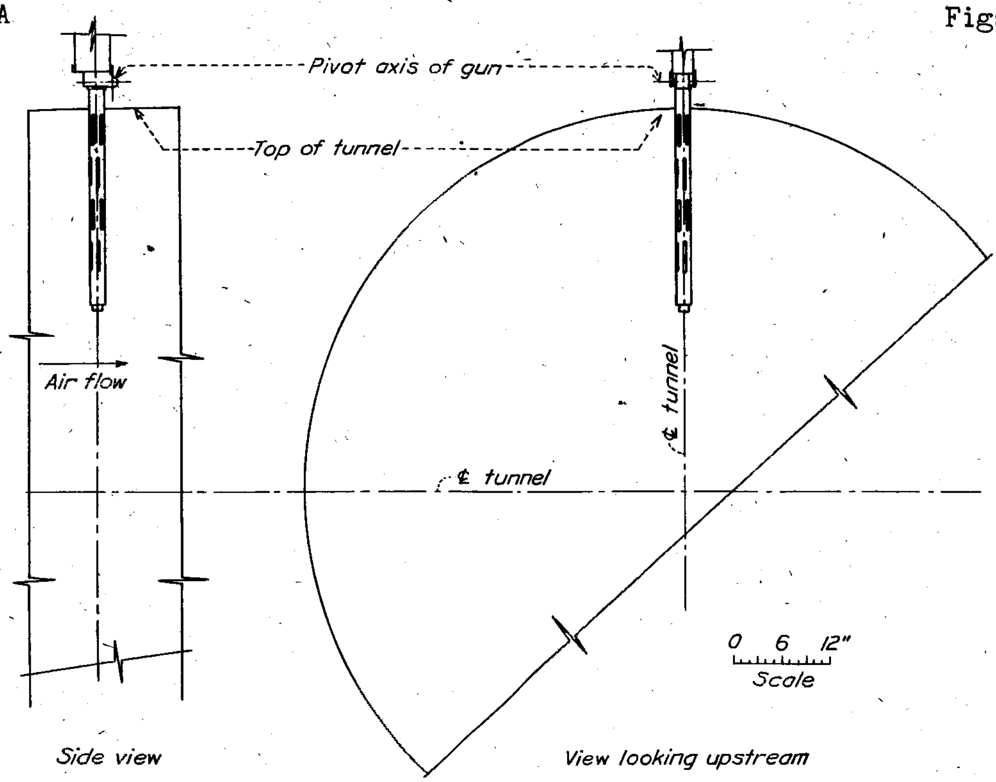
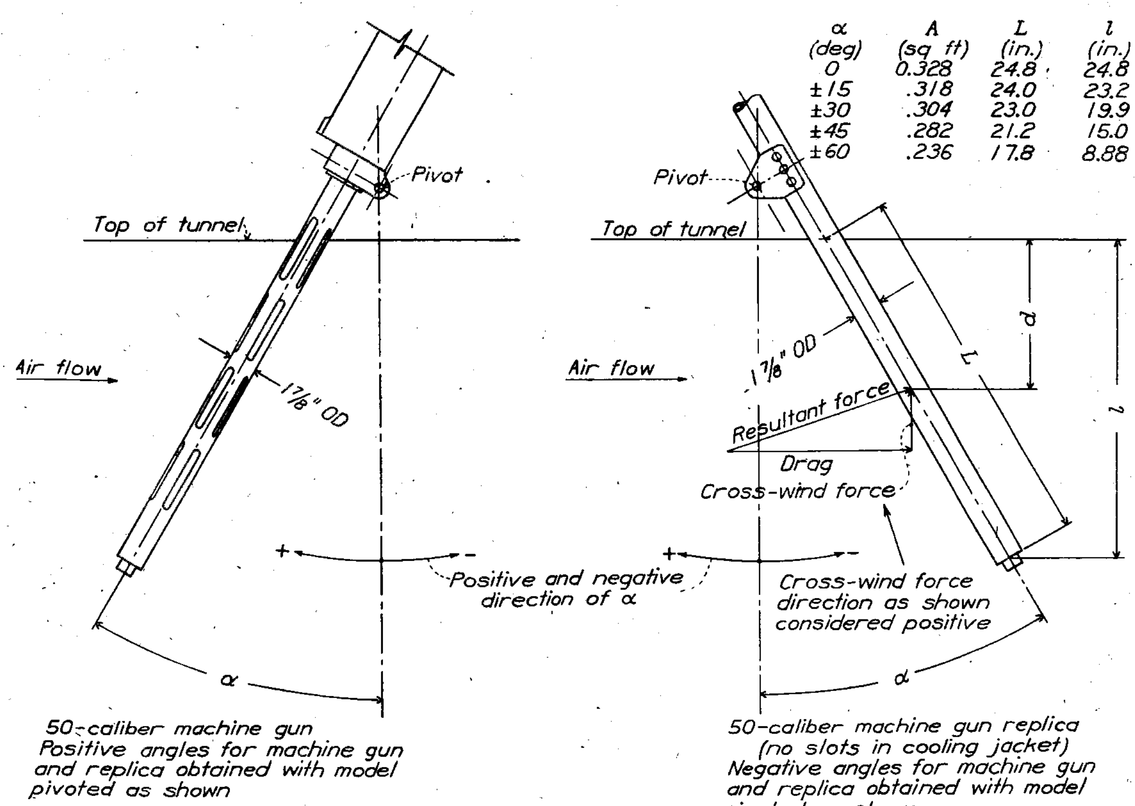


Figure 1. Sketch showing mounting of 0.50-caliber machine gun in 8-foot high speed wind tunnel.



α (deg)	A (sq ft)	L (in.)	l (in.)
0	0.328	24.8	24.8
±15	.318	24.0	23.2
±30	.304	23.0	19.9
±45	.282	21.2	15.0
±60	.236	17.8	8.88

Figure 2.- Dimensions of 0.50-caliber machine gun.

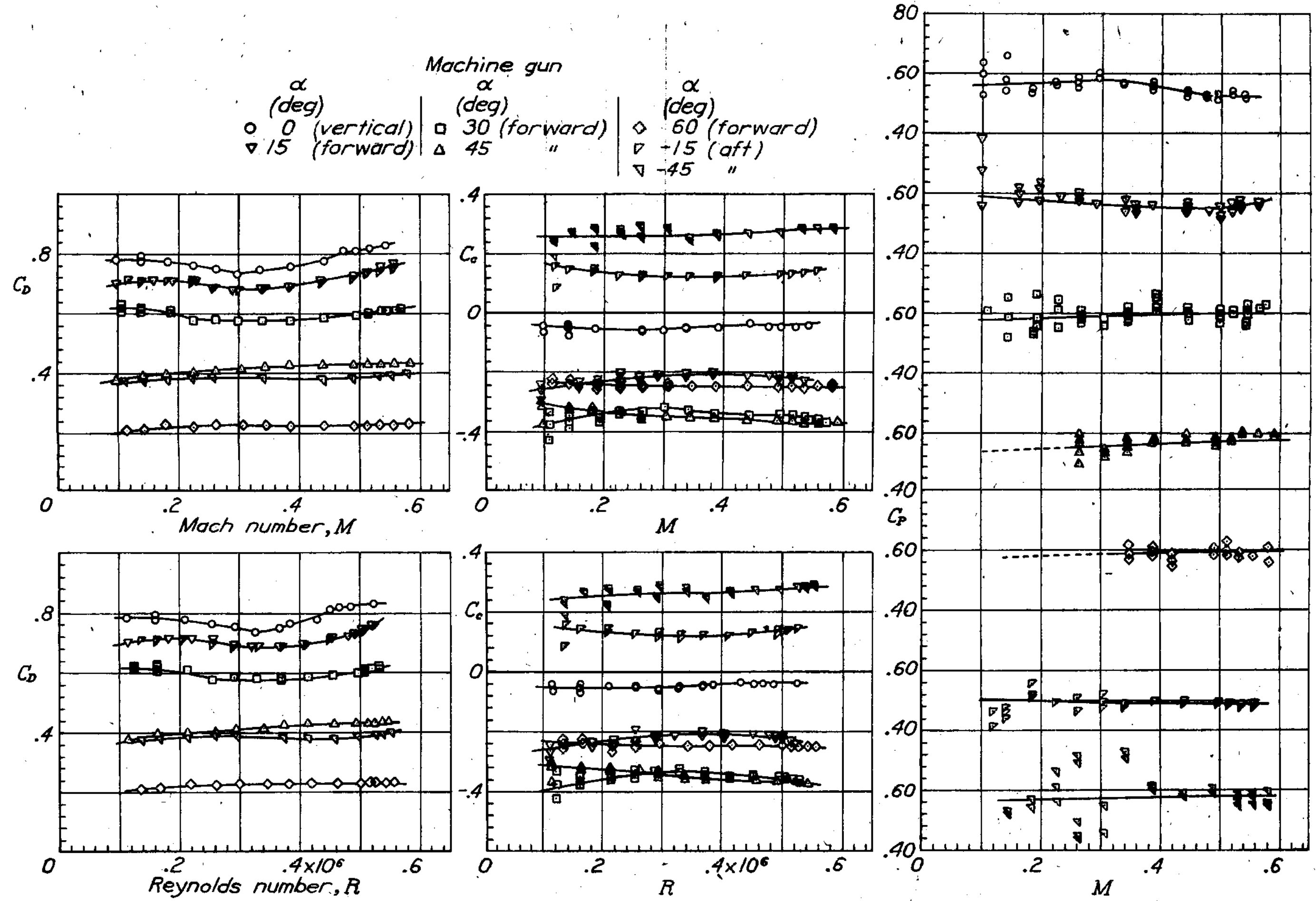


Figure 3.- Variation of C_D, C_c, and C_p with Mach number and Reynolds number for the 0.50-caliber machine gun in different positions.

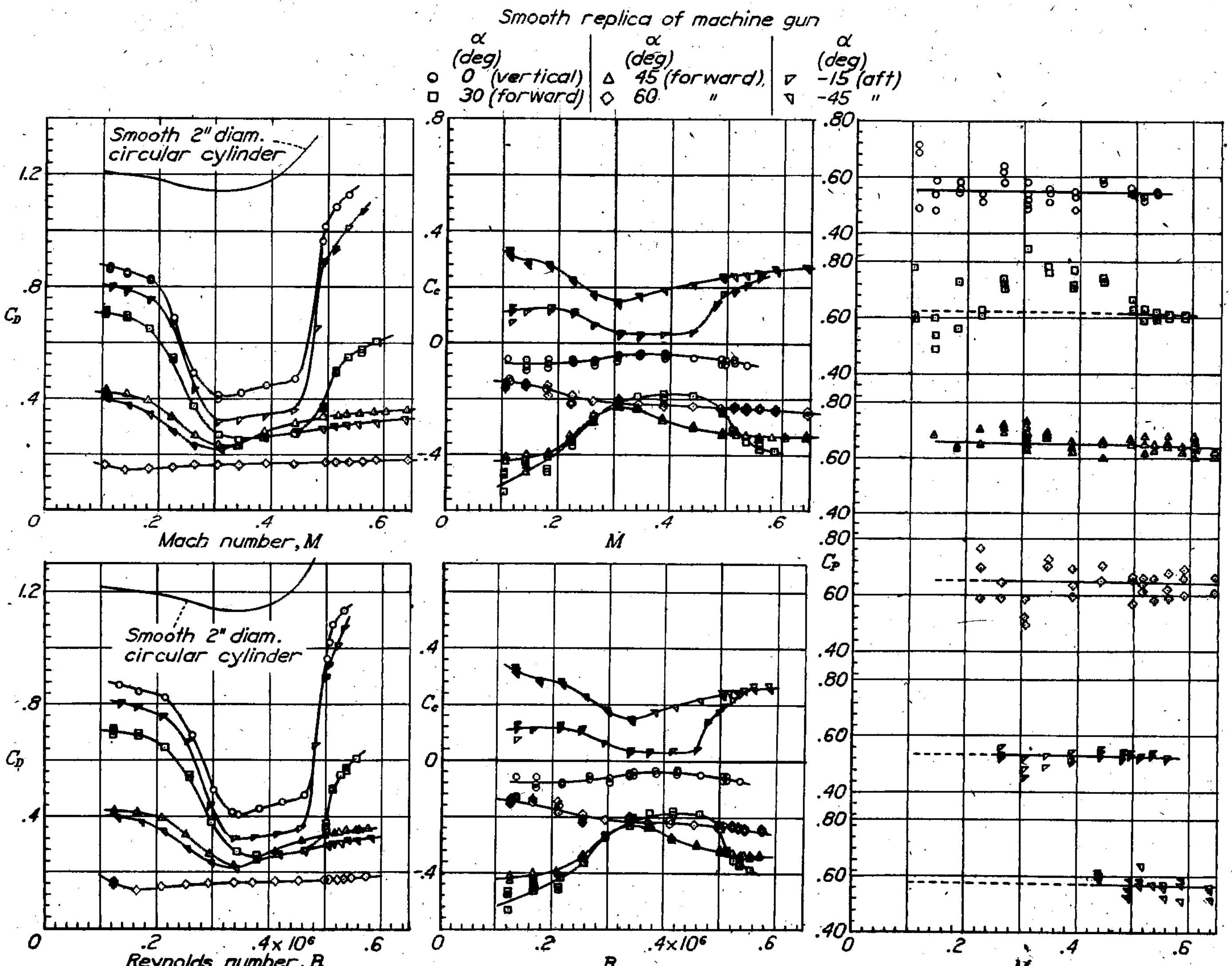


Figure 4.- Variation of C_D, C_C, and C_p with Mach number and Reynolds number for the machine-gun replica in different positions.

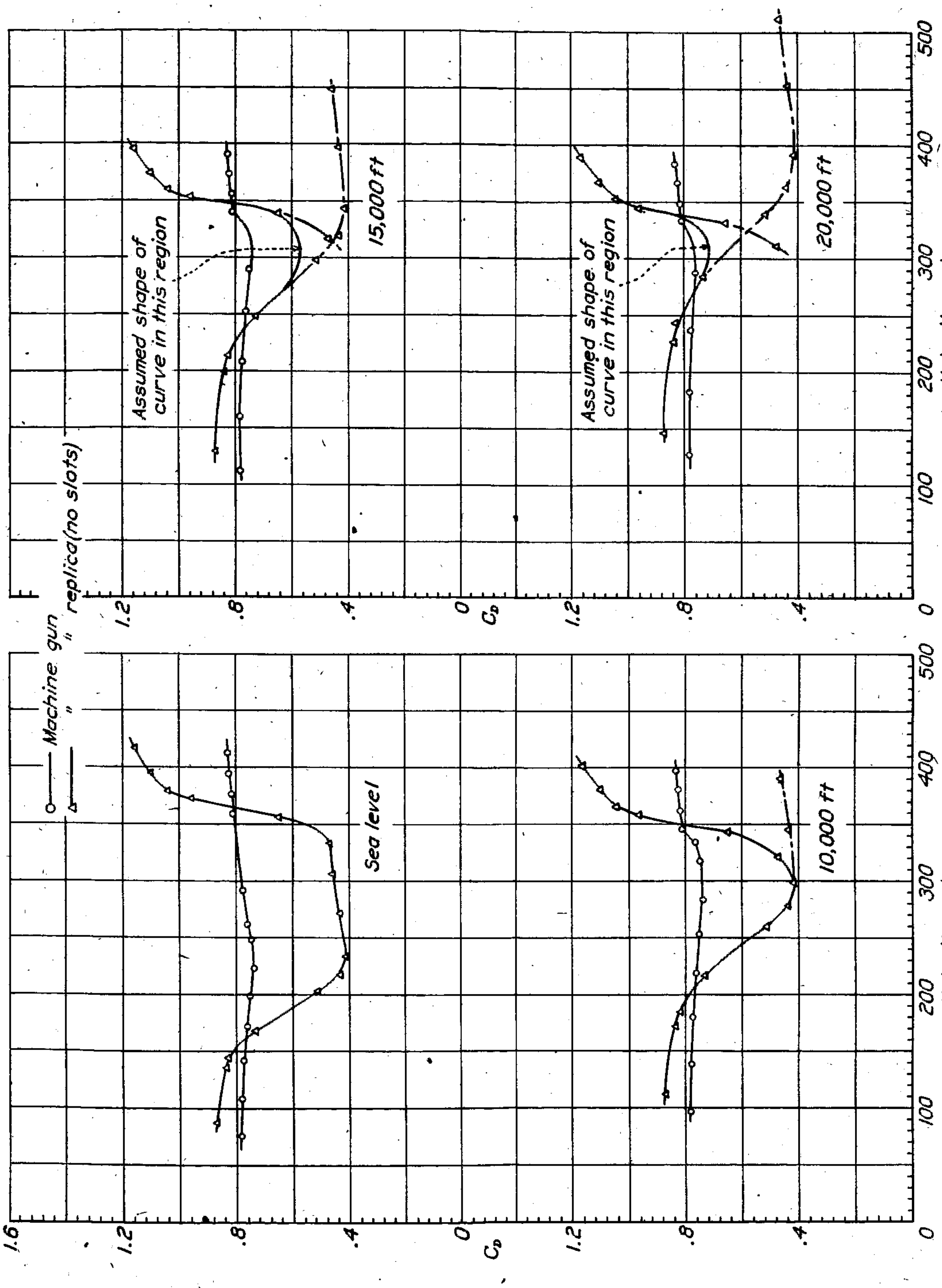


Figure 5.- Drag comparison of machine gun and replica at several altitudes. $\alpha = 0^{\circ}$.

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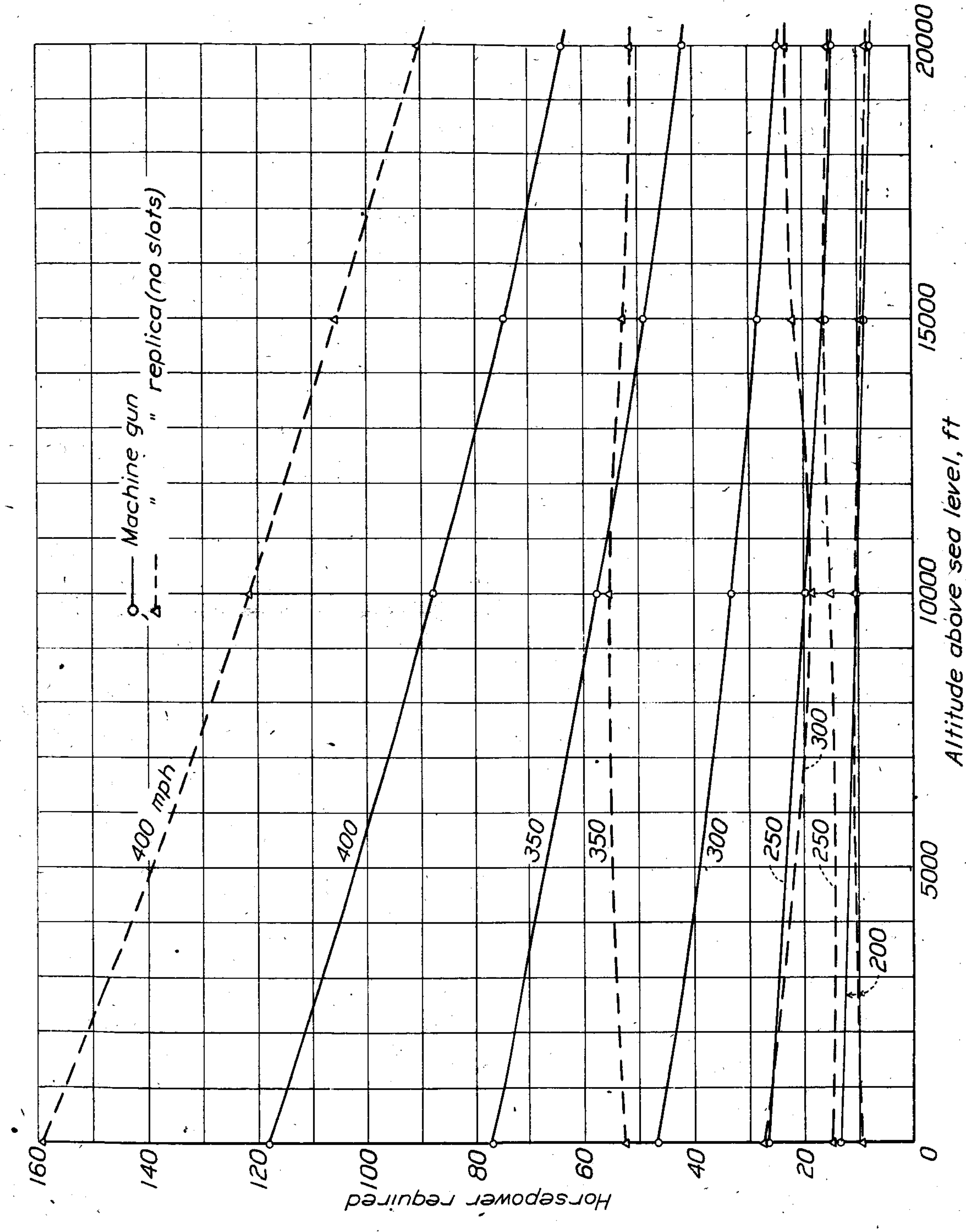

Figure 6.- Horsepower required by machine gun and replica at several altitudes. $\alpha = 0°$.