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RESEARCH MEMORANDUM

for the

Ballistic Research Laboratories,
Ordnance Department, U. S. Army

COMBUSTION IN THE WAKE AS A MEANS OF BODY-DRAG REDUCTION AS DETERMINED FROM FREE-FLIGHT TESTS OF 40-MILLIMETER SHELLS

By Clement J. Welsh

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NATIONAL ADVISORY COMMITTEE
FOR AERONAUTICS
WASHINGTON

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SUMMARY

The results of free-flight drag tests of 40-millimeter shells conducted by the National Advisory Committee for Aeronautics for the Ballistic Research Laboratories, Ordnance Department, U. S. Army, are presented.

A drag reduction at supersonic speeds of approximately 20 percent of the projectile's drag was obtained by combustion in the wake of the projectile in flight.

INTRODUCTION

The Ballistic Research Laboratories of the Ordnance Department, U. S. Army, requested the assistance of the NACA in making a free-flight drag investigation of a series of 40-millimeter shells. The purpose of this investigation was to furnish further information to the Ballistic Research Laboratories for use in their study of body-drag reduction by means of combustion in the wake of the body (ref. 1).

The tests in which the NACA assisted were measurements of the drag reduction on 40-millimeter shells in flight associated with the combustion of powder charges contained within some of the projectiles. The results are presented in this paper.

The free-flight tests were conducted at the Langley Pilotless Aircraft Research Station at Wallops Island, Va. The Mach number range was 0.875 to 2.075, and the corresponding Reynolds number range, based on projectile length, was 2.75×10^6 to 7.75×10^6.

MODELS AND TESTS

The general arrangement of the 40-millimeter shells used in this investigation is shown in figure 1, including a simplified sketch of the powder container for those rounds containing powder charges. (These rounds will be referred to in this paper as "hot rounds.") The external configuration of all the rounds was similar, and the weights of the individual rounds are listed in the following table. The even-numbered projectiles are the hot rounds, and the total configuration weights as listed include the powder weight (42.5 grams) in the hot rounds.

Round	Total configuration weight, lb
22	1.99
23	1.94
24	1.96
25	1.94
26	1.98
27	1.94
28	1.97
29	1.93
32	1.96
33	1.96

The shells were fired from a 40-millimeter gun at an elevation angle of 60°. Velocity was obtained from the CW Doppler velocimeter, and the trajectory and atmospheric data from an NACA modified SCR 584 radar tracking unit combined with radiosonde observations. Test data were reduced by methods described in reference 2 and include wind corrections.

In figure 2 the Reynolds number during flight, based on projectile length, is plotted against Mach number.

RESULTS

A summary plot of drag coefficients against Mach number for all the rounds tested is shown in figure 3. From these curves it appears that the powder charge in only one of the hot rounds (round 28) burned properly; movies of the tests substantiated this deduction. This particular round indicated a reduction in drag from that of the cold rounds of about 20 percent during the interval of powder burning. The other hot rounds had a slight reduction in drag at the upper end of the Mach number range; this reduction and the lower drag level of some of these rounds at lower Mach numbers may possibly be explained by powder burning at a slower rate.

As there was no definite knowledge of the amount of powder actually burned in individual hot rounds, the drag coefficients listed were calculated from initial projectile weights; however, the maximum possible error resulting would be approximately 5 percent. The discrepancies in the drag curves of the cold rounds are believed to be largely due to manufacturing tolerances in the construction of the shells.

The slant ranges of a typical cold round and of the hot round having the greatest reduction in drag are plotted against time in figure 4 in order that those interested in ballistic problems may have a better idea of the significance of a 20-percent reduction in drag on 40-millimeter shells.

A complete trajectory for a cold round is shown in figure 5 as tracked by the SCR 584 radar tracking unit. Although this trajectory is not corrected for wind, winds aloft are listed in table I in order that a more precise no-wind trajectory can be obtained if desired. The projection of the trajectory on the horizontal plane was 109° relative to north.

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REFERENCES

1. Scanland, T. S., and Hebrank, W. H.: Drag Reduction Through Heat Addition to the Wake of Supersonic Missiles. Memo. Rep. No. 596, Ballistic Res. Lab., Aberdeen Proving Ground, June 1952.

2. Welsh, Clement J.: Results of Flight Tests To Determine the Zero-Lift Drag Characteristics of a 60° Delta Wing With NACA 65-006 Airfoil Section and Various Double-Wedge Sections at Mach Numbers From 0.7 to 1.6. NACA RM L50F01, 1950.

TABLE I

MEASURED WINDS AT ALTITUDE

Altitude, ft	Velocity, ft/sec	α, deg (a)
0	27	0
1,000	58	21
2,000	57	35
3,000	51	45
4,000	49	54
5,000	53	62
6,000	62	68
7,000	63	71
8,000	55	68
9,000	45	62
10,000	42	59
11,000	44	62
12,000	47	63
13,000	47	57
14,000	48	56
15,000	49	58
16,000	51	65

[a]Direction wind is blowing toward, measured relative to north.

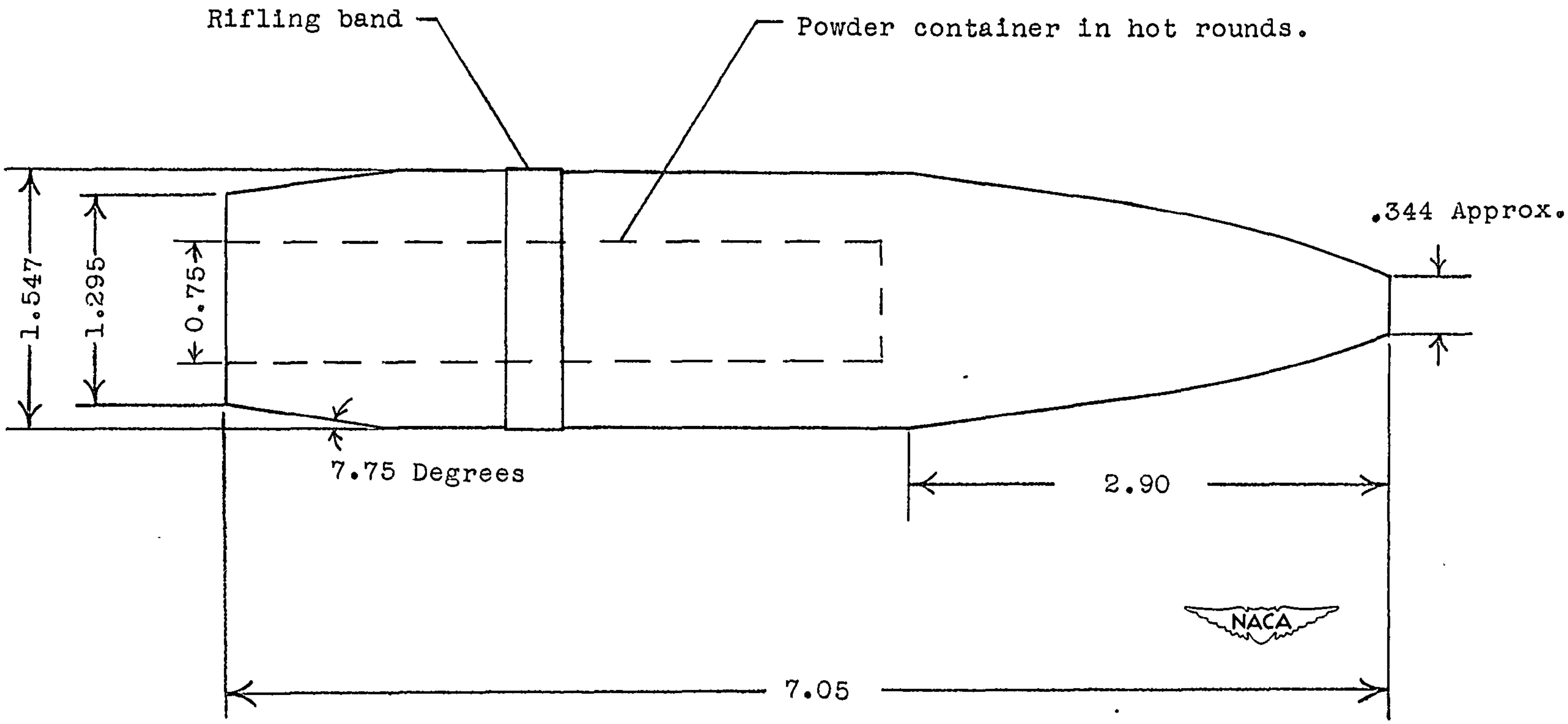

Figure 1.- General arrangement of the 40-millimeter shells tested.
All dimensions are in inches.

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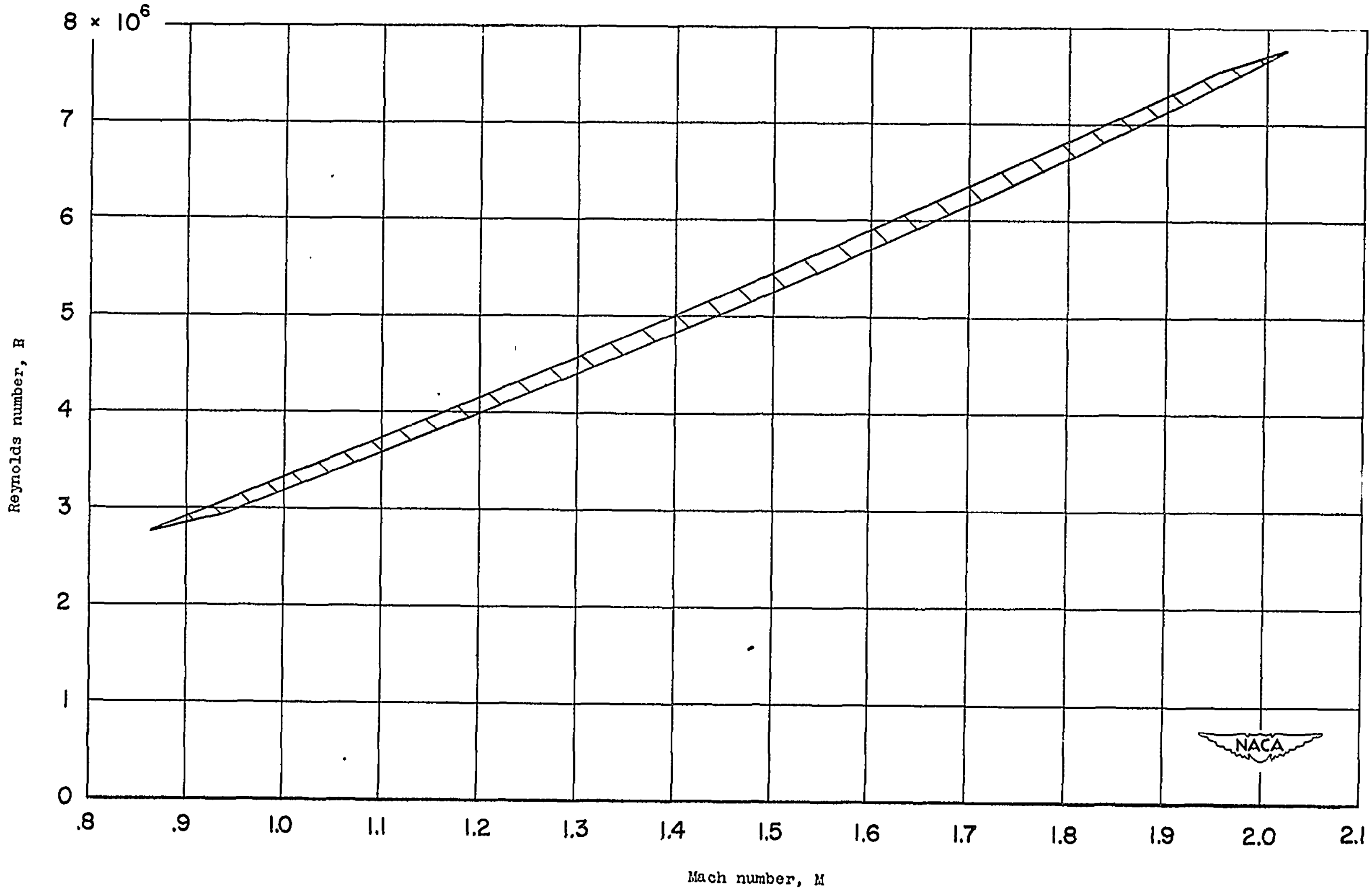

Figure 2.- Variation of the range of Reynolds number with Mach number for the present investigation.

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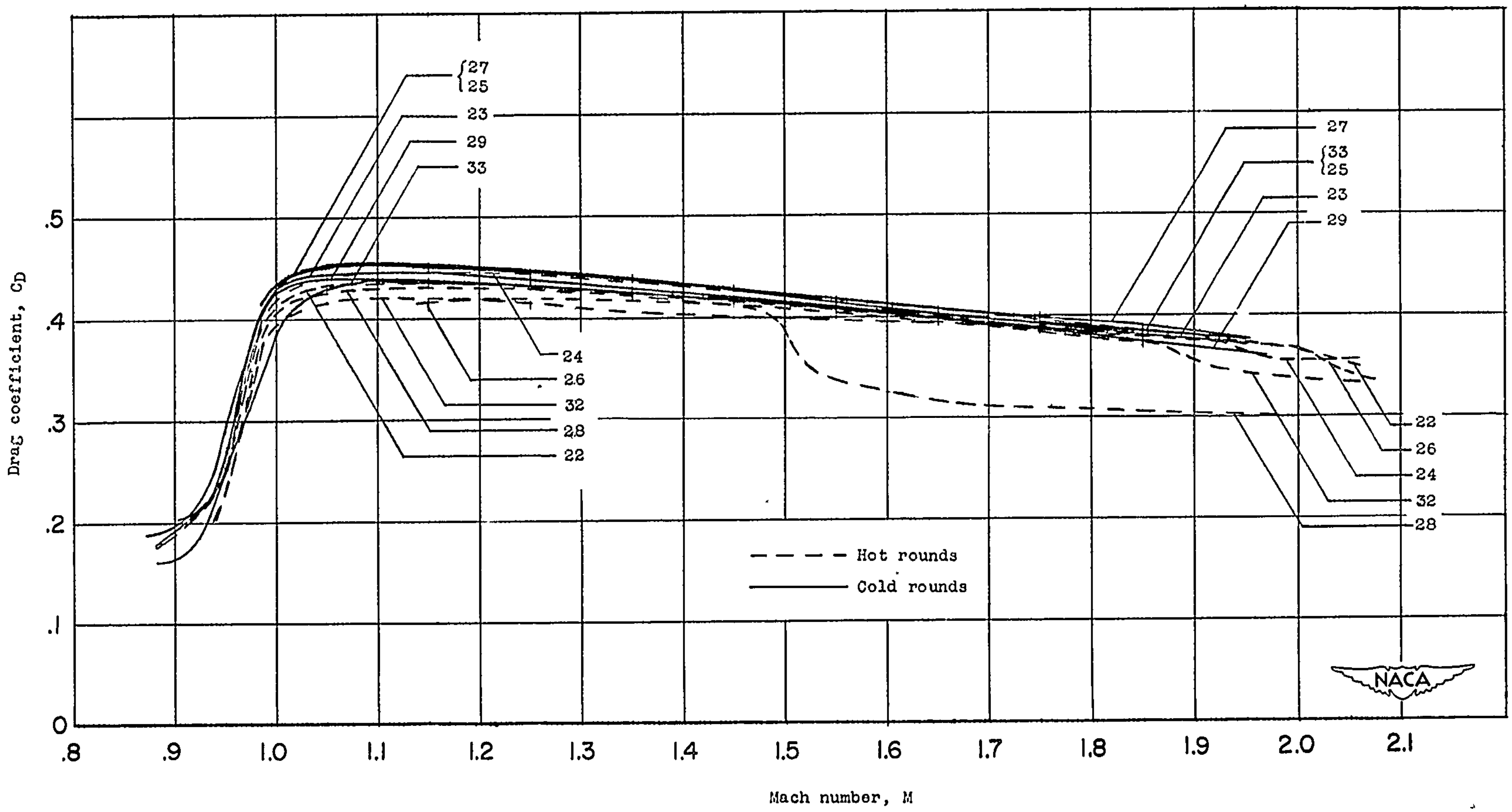

Figure 3.- Variation of drag coefficients of the various 40-millimeter shells tested. Rounds are identified by numbers.

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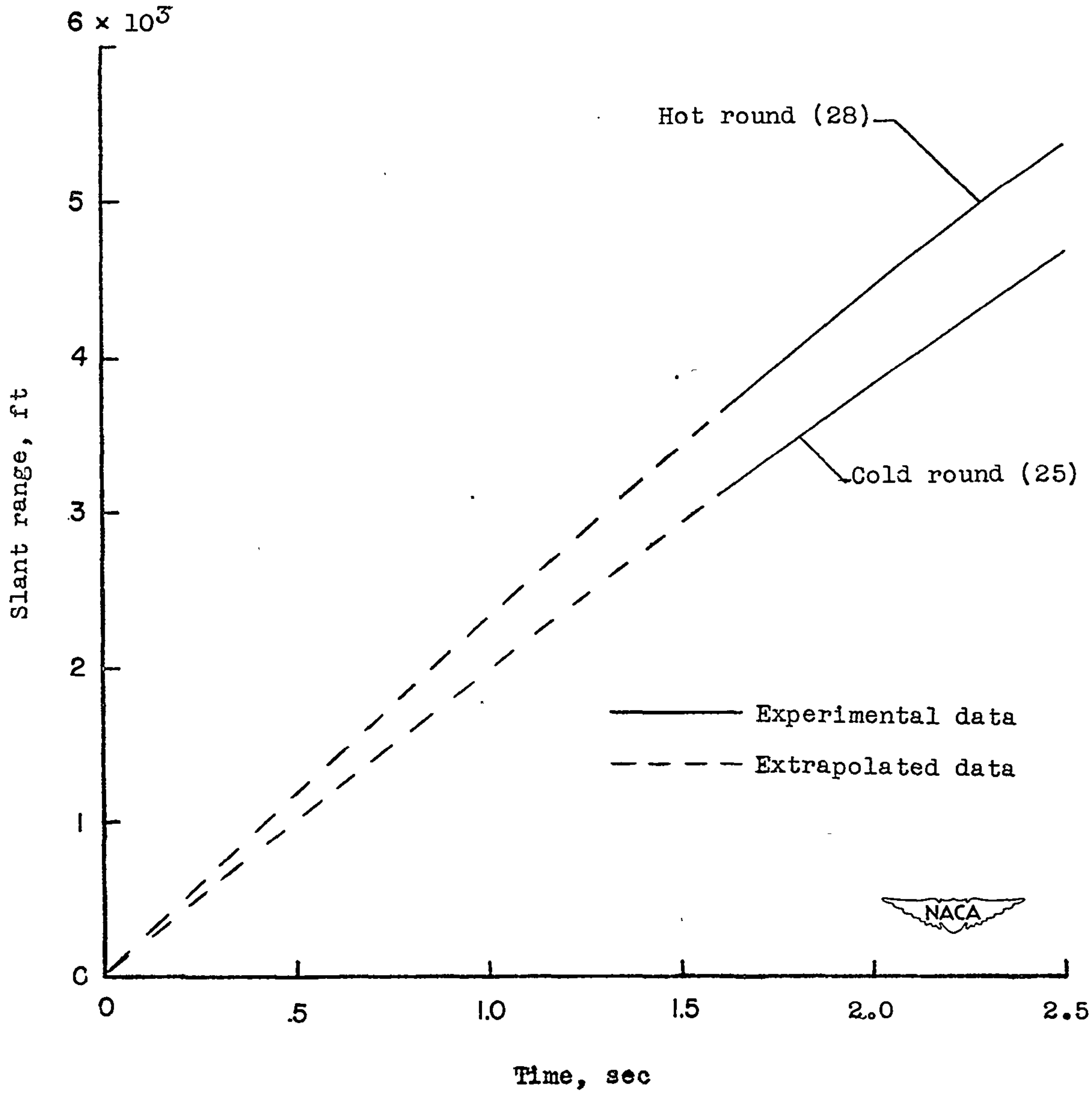

Figure 4.- Effect of heat release on the range of 40-millimeter shells of the present investigation.

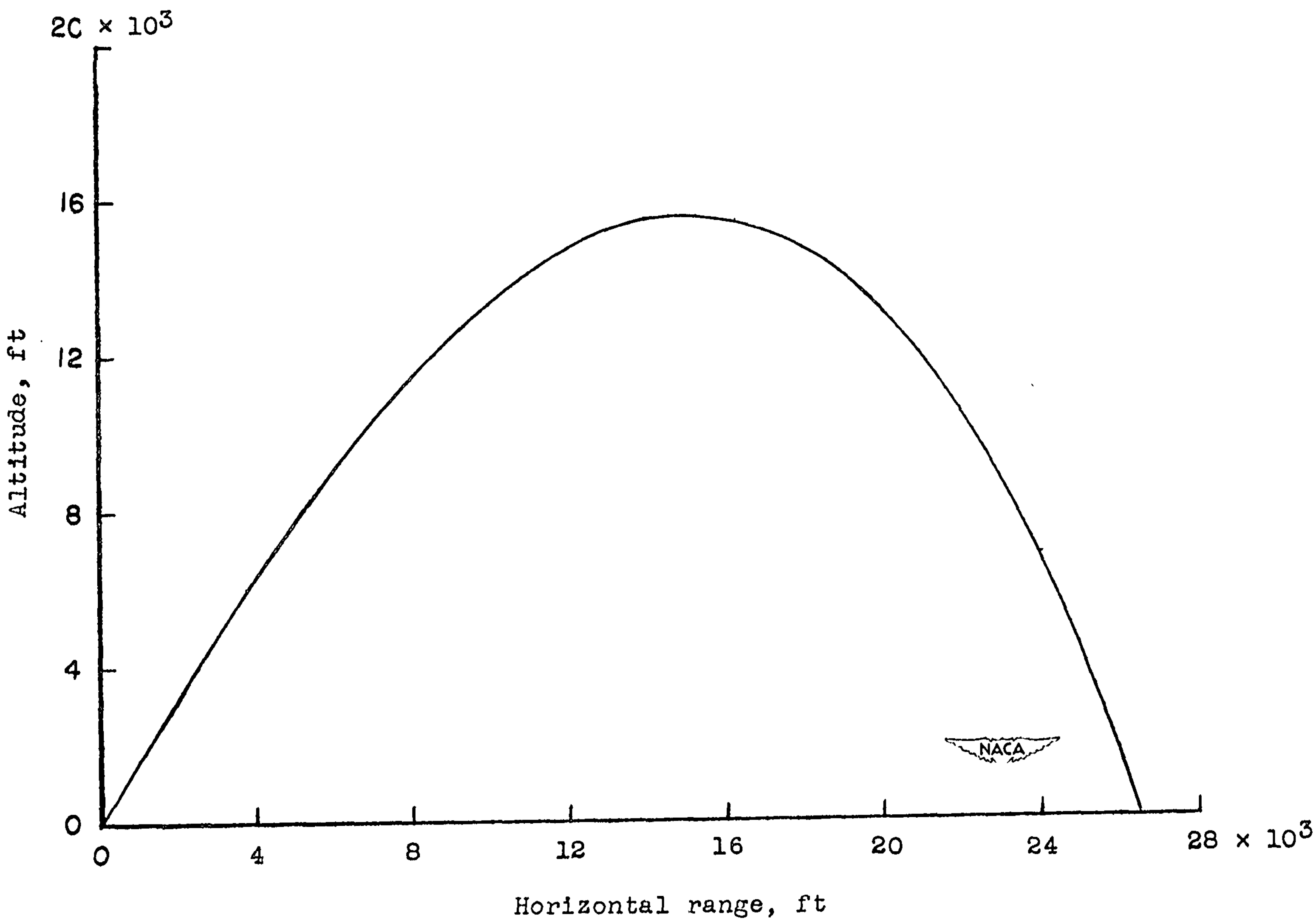

Figure 5.- Trajectory of a 40-millimeter shell. Round 25.

SECU[illegible] INFORMATION

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