NACA

RESEARCH MEMORANDUM

for

U. S. Army Ordnance

A WIND-TUNNEL INVESTIGATION TO DETERMINE THE EFFECT OF VARIOUS HEAD DESIGNS ON THE AERODYNAMIC CHARACTERISTICS IN PITCH OF THE ARMY ORDNANCE CORPS T205 3.5-INCH HEAT ROCKET

By William D. Morrison, Jr., and Richard E. Kuhn

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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

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A WIND-TUNNEL INVESTIGATION TO DETERMINE THE EFFECT OF VARIOUS HEAD DESIGNS ON THE AERODYNAMIC CHARACTERISTICS IN PITCH OF THE ARMY ORDNANCE CORPS T205 3.5-INCH HEAT ROCKET

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SUMMARY

The aerodynamic characteristics in pitch of the Army Ordnance Corps T205 3.5-inch HEAT rocket with various head designs and one fin modification have been determined at velocities of 500, 700, and 900 feet per second in the Langley high-speed 7- by 10-foot tunnel. The results presented are those of the full-scale model.

Comparison of results obtained at 500 feet per second shows, in general, that for changes on the forward portion of the head the missile configurations having the greatest stability - most rearward center-of-loads location - were those having the highest drag. However, very limited comparisons indicate that the shape of the rear position of the head may be an important factor in reducing the drag and increasing the restoring moments.

Generally, large increases in drag were noted for the various head designs with an increase in Mach number from 0.62 to 0.82. Pitching-moment-curve slopes increased with Mach number on all models except those having reasonably well-faired forward sections. These models showed a decrease in stability with increases in Mach number.

INTRODUCTION

As a result of a request made by the Picatinny Arsenal, Army Ordnance Corps, an investigation was conducted in the Langley high-speed

7- by 10-foot tunnel to determine the aerodynamic characteristics in pitch of the Army Ordnance Corps T205 3.5-inch HEAT rocket with various head designs.

The data presented in this paper were obtained on the full-scale model at 500, 700, and 900 feet per second through an angle-of-attack range from -6° to 20°

COEFFICIENTS AND SYMBOLS

All forces and moments are presented relative to a system of wind axes which has its origin at the calculated center of gravity of the model. A sketch of this axis system, showing the positive directions of the forces, moments, and angles, is shown in figure 1. The calculated center of gravity is located at the balance pitch center line for all head designs except the M28A2. For this design it was necessary to transfer the moment data 3.58 percent of the model length to the calculated center of gravity.

C_L lift coefficient, Lift/qS

C_D drag coefficient, Drag/qS

C_m pitching-moment coefficient, Pitching moment/qSl

C_N normal-force coefficient, Normal force/qS

C_c chord-force coefficient, Chord force/qS

C.P. center-of-pressure location, $\frac{\text{Pitching moment} \times 100}{\text{Normal force} \times l}$, percent of model length; positive where center of pressure is rearward of center of gravity

C.G. center-of-gravity location; 11.53 in. from rear of model for all configurations except M28A2, 12.38 in. from rear of model for M28A2

q free-stream dynamic pressure $\frac{1}{2}\rho V^2$, pounds per square foot

ρ mass density of air, slugs per cubic foot

V free-stream velocity, feet per second

R	Reynolds number (based on l)
M	Mach number
l	over-all length of model, 1.963 ft
S	frontal area of model, 0.0668 sq ft
α	angle of attack, degs

MODELS AND TESTS

Detailed drawings of the various rocket-head designs and the complete model are presented as figure 2. Photographs of the test configurations are presented as figure 3.

A modified production rocket was used as the model for this investigation. The portion of the missile forward of the fins and propulsive-charge chamber was replaced with a cylindrical section and internally adapted to house the strain-gage balance and sting support.

The missile heads (figs. 2 and 3) were turned from solid blocks of mahogany or maple. These heads were then bored so as to provide a slip fit over the cylindrical section of the missile.

Forces and moments were determined by means of an electrical strain-gage balance located inside the model. (See fig. 2.) A photograph of the model in the test section of the tunnel is presented as figure 4.

The model was located on the sting support in such a manner that the angle-of-attack plane or pitching plane bisected the angle between two of the fins.

Corrections were applied to the angle of attack to account for deflections of the sting and balance under air loads.

The following tabulation covers the velocity, Mach number, and Reynolds number range of this investigation; Reynolds numbers are based on the model length:

Velocity, ft/sec	M	R
500	0.44	5,100,000
700	.62	6,600,000
900	.82	7,750,000

RESULTS AND DISCUSSION

The data were originally obtained about the body axes (providing normal force and chord force) and were transferred to the system of wind axes by the following equations:

$$C_L = C_N \cos \alpha - C_c \sin \alpha$$

$$C_D = C_N \sin \alpha + C_c \cos \alpha$$

The basic data for all configurations at 500, 700, and 900 feet per second are presented as figures 5 to 16. Summary plots at a representative velocity of 500 feet per second, to show the effects of systematic changes in various geometric parameters, are presented as figures 17 to 22.

It can be noted (figs. 17 to 19) that the missile configurations having the greatest stability or restoring moment generally obtain this stability at the expense of higher drag. Changes in the forward slope of the head (from designs 3 to 8, for instance) result in a decrease in the aerodynamic lift on the head and consequently an increase in stability. This forward slope change probably increases the tendency to flow separation and consequently increases the drag. This effect is quite noticeable when comparing the aerodynamic characteristics of head designs 7 and 8, which have identical shapes rearward of the intersection of the forward slope and maximum diameter.

Although there are very limited data to corroborate any effects of slope changes on the rear of the heads, it is interesting to note the difference in the aerodynamic characteristics between head designs 7 and 11 (fig. 18), where the major difference in design is the slope change on the rear of the head. Head design 11, which has the more blunt rear portion, has higher drag but an appreciably smaller restoring moment than head design 7. From this observation it may be surmised that the drag and stability of these rockets also are dependent on the rearward slope of these heads.

Figures 20 and 21 show how critical the stability of the rocket is to a small change in radius provided where the forward contour of the missile head blends into the maximum diameter. Head design numbers 7 and 11, as supplied by the Picatinny Arsenal, did not have the 0.15-inch radius specified on the drawings. These head designs were investigated with (designs 7 and 11) and without (designs 7A and 11A) this radius. If this intersection of slopes remains abrupt, the separation resulting from the rather sharp edge markedly increases the drag while reducing the lift and consequently increasing the stability.

In hope of increasing the stability of these rocket configurations without large penalties in drag, the fins were extended forward some 3 inches (fig. 22). Although there was a large increase in the lift with some increase in drag, the restoring moments were not improved, probably because the resulting lift occurred at a more forward location on the missile body.

The effects of Mach number on stability are not too consistent, but, in general, it can be noted that those head designs with reasonably well-faired forward shapes (M28A2, 3, 3A) showed a decrease in stability with increased Mach number while those with abrupt changes in contour (which would tend to induce shocks and reduce the lift on the head) show increases in stability with increasing Mach number. It also will be noted that those designs with the most abrupt changes in contour (7, 7A, 8) also exhibit the largest drag increases. All designs exhibited some increase in drag with Mach number.

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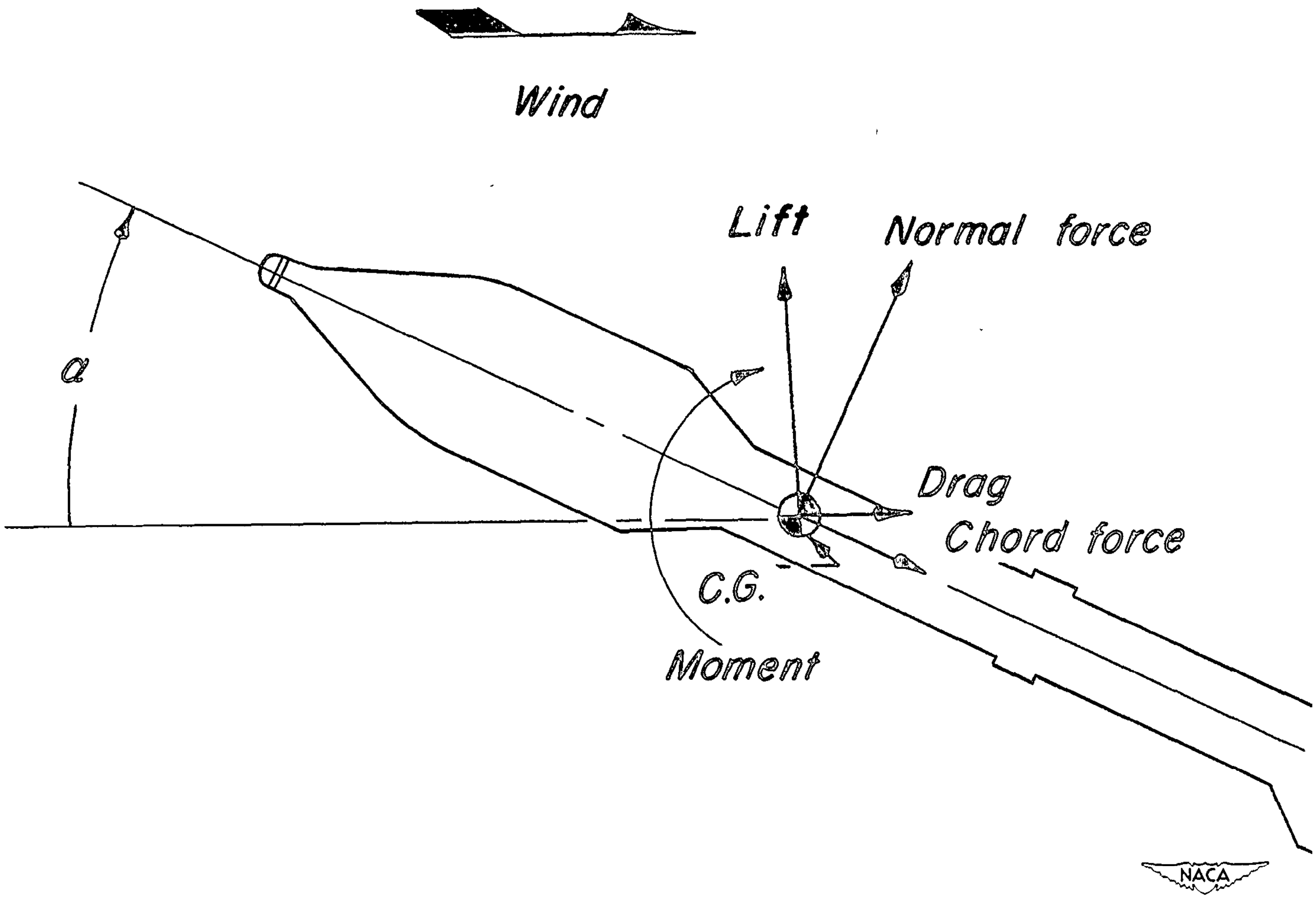
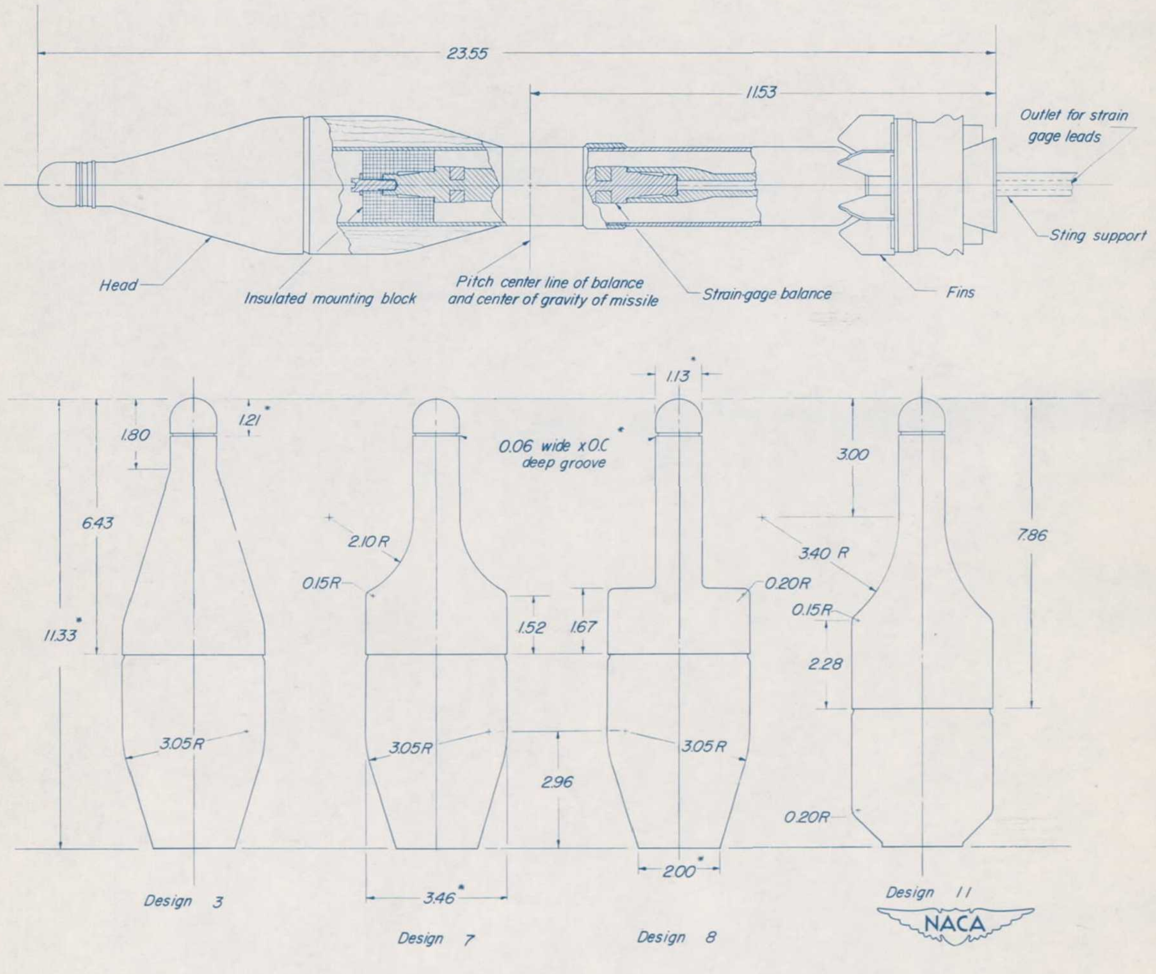
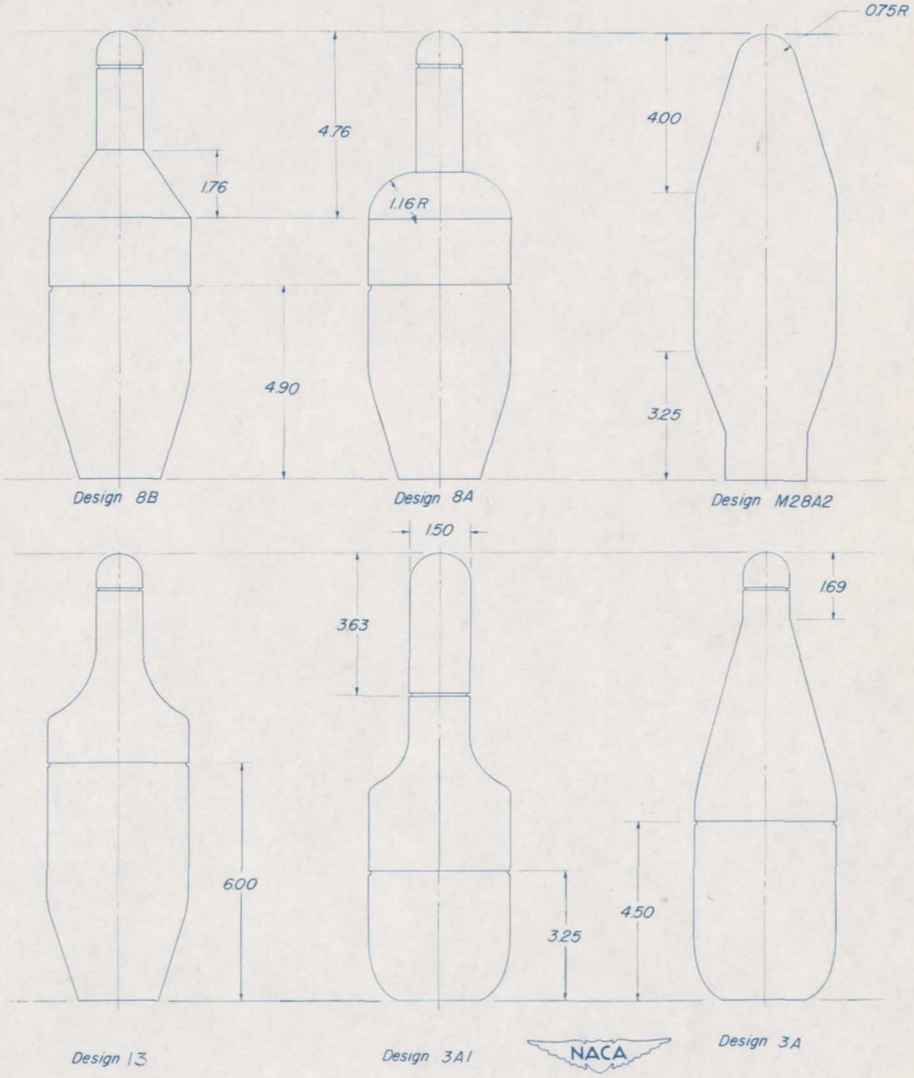


Figure 1.- Sketch of model showing system of axes and positive direction of forces, moments, and angles.



(a) Head designs 3, 7, 8, and 11 and sectioned view of model showing strain-gage installation.

Figure 2.- Details of models. All dimensions are in inches. Dimensions marked with an asterisk are common to all designs except where indicated.



(b) Head designs 8B, 8A, M28A2, 13, 3A1, and 3A.

Figure 2.- Concluded.

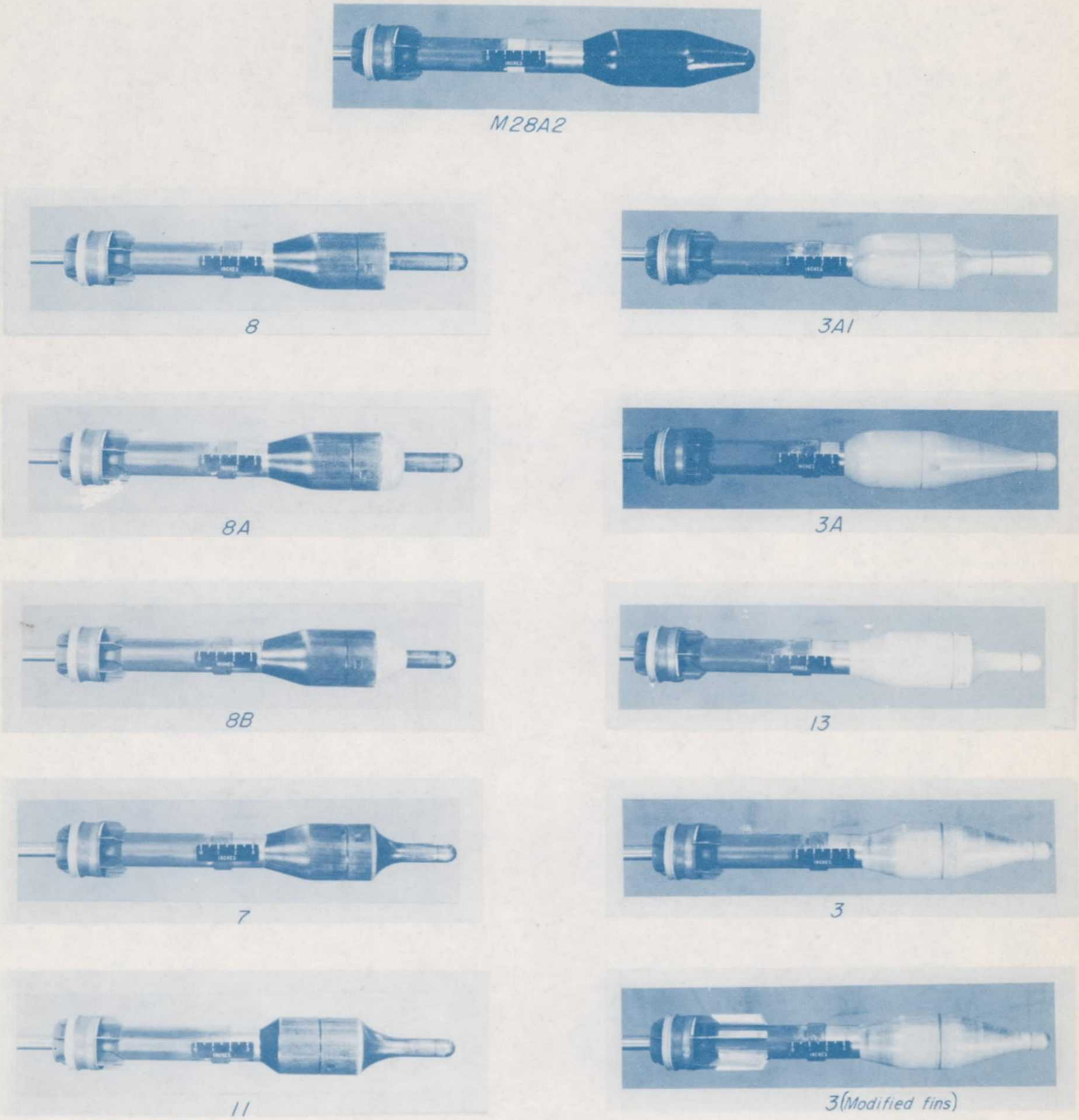


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Figure 3.- Photograph of the model with the various head designs and model with extended fins.

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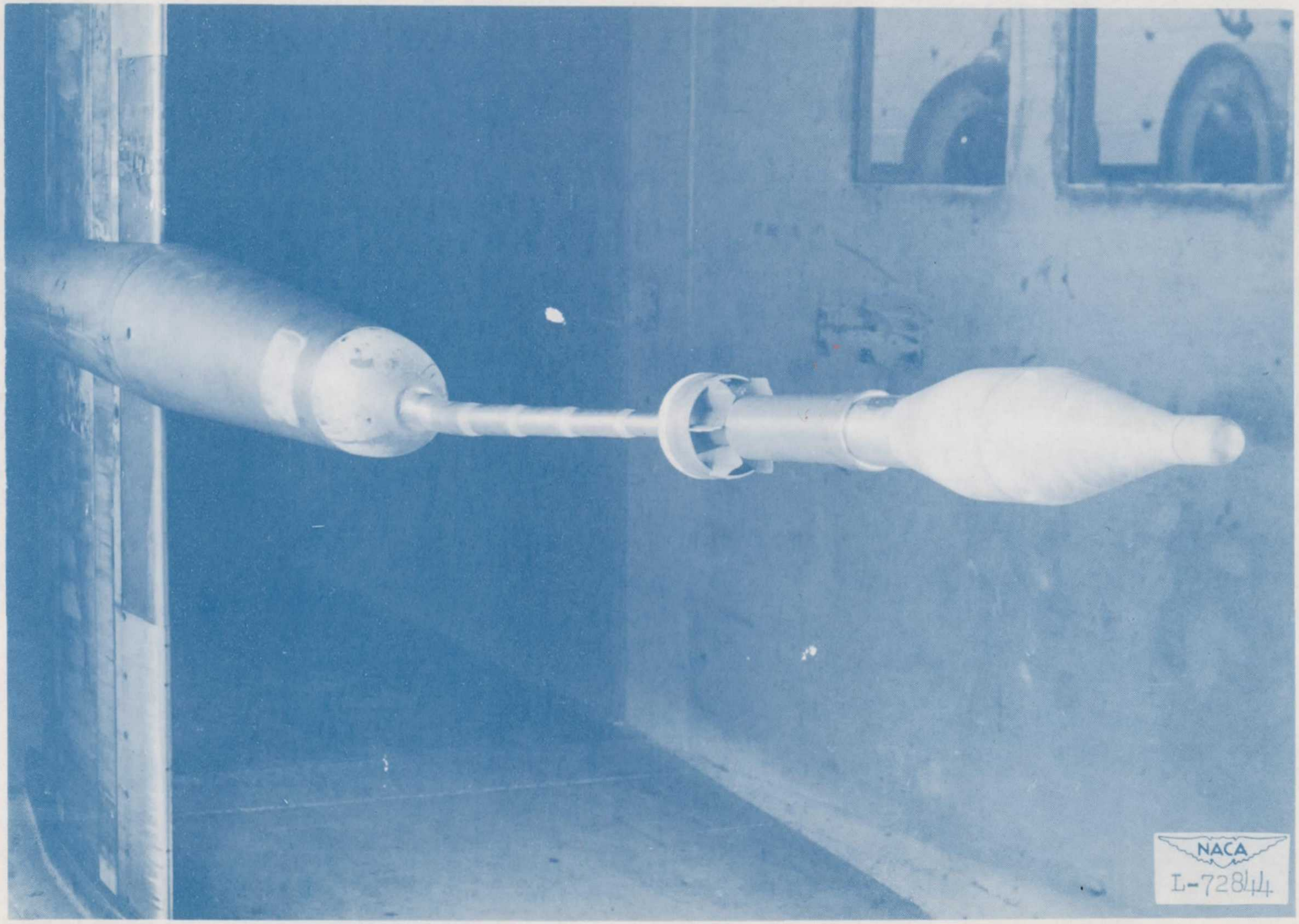

Figure 4.- Photograph of model in the test section of the Langley high-speed 7- by 10-foot tunnel. (Design head 3.)

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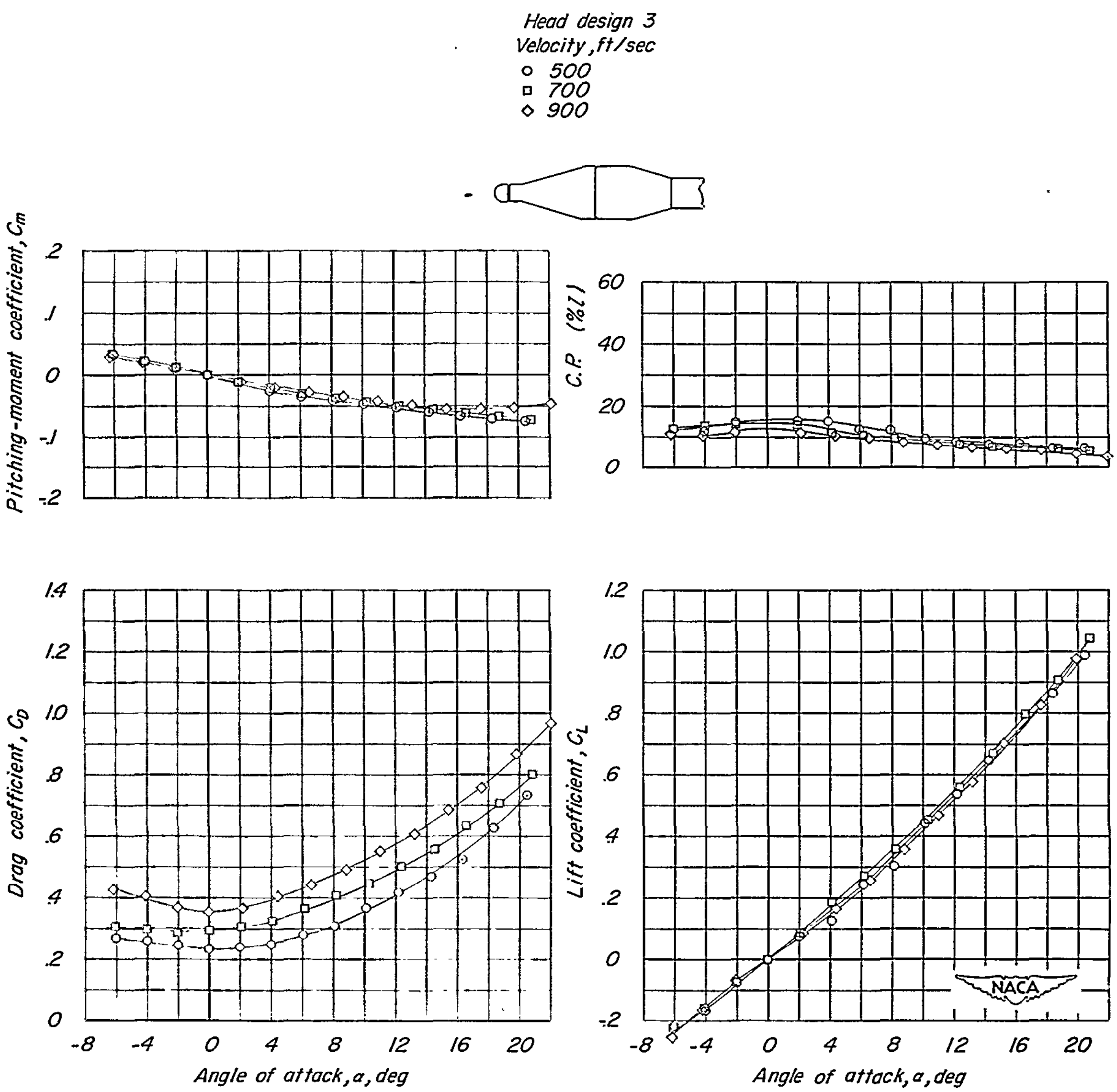

Figure 5.- Aerodynamic characteristics at velocities of 500, 700, and 900 feet per second of Army Ordnance Corps T205 HEAT rocket with head design 3.

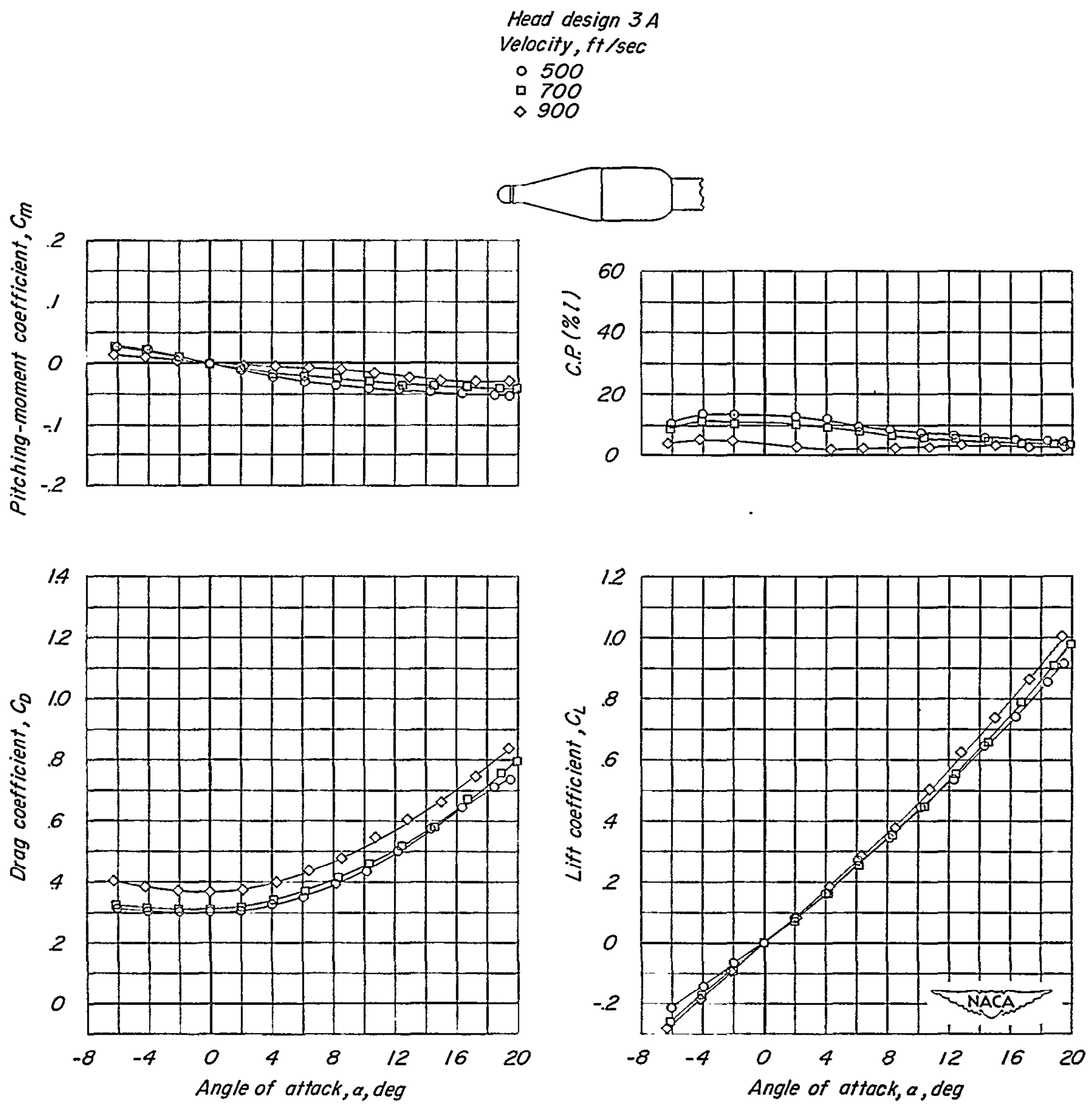

Figure 6.- Aerodynamic characteristics at velocities of 500, 700, and 900 feet per second of Army Ordnance Corps T205 HEAT rocket with head design 3A.

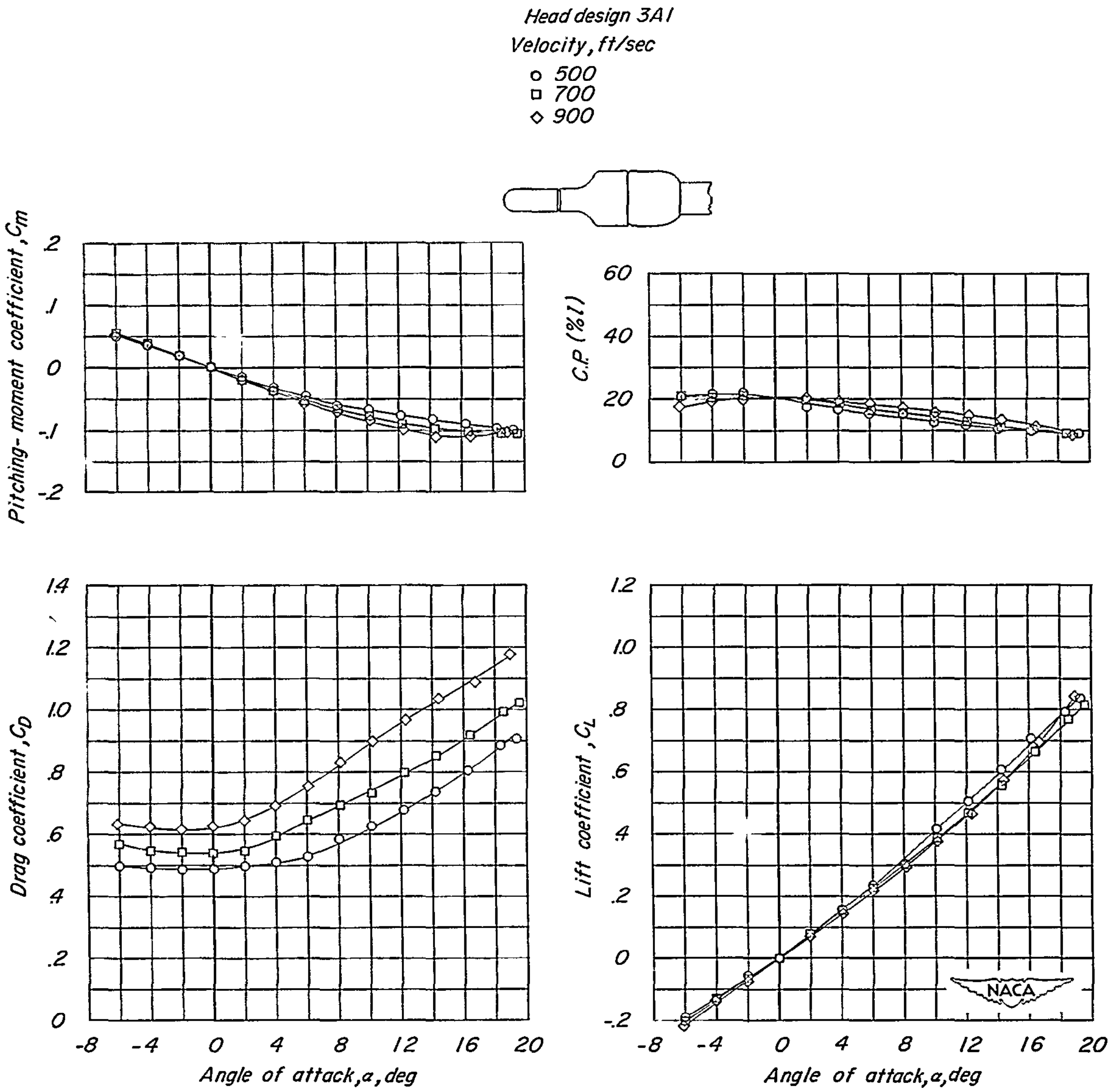

Figure 7.- Aerodynamic characteristics at velocities of 500, 700, and 900 feet per second of Army Ordnance Corps T205 HEAT rocket with head design 3A1.

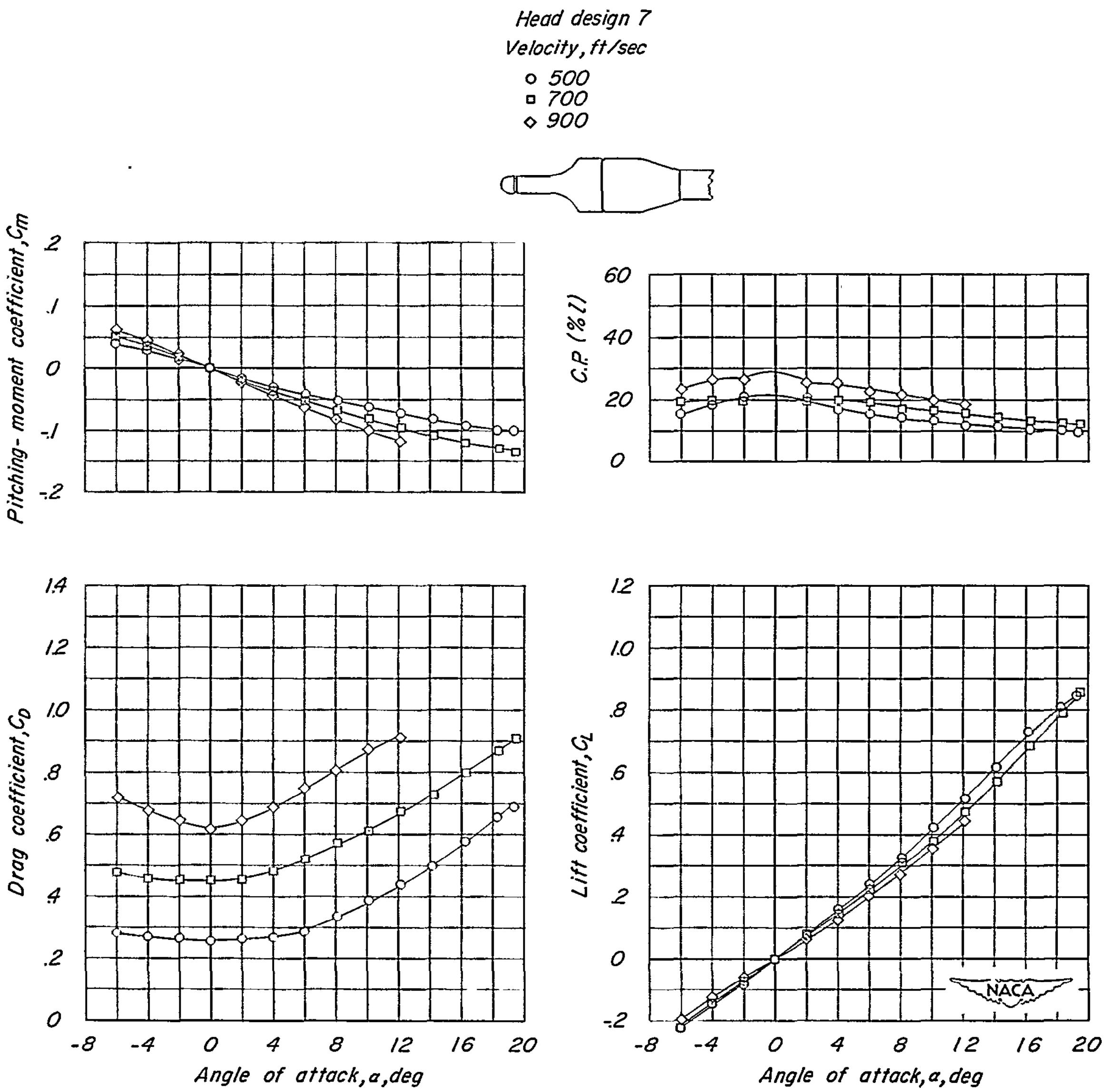

Figure 8.- Aerodynamic characteristics at velocities of 500, 700, and 900 feet per second of Army Ordnance Corps T205 HEAT rocket with head design 7.

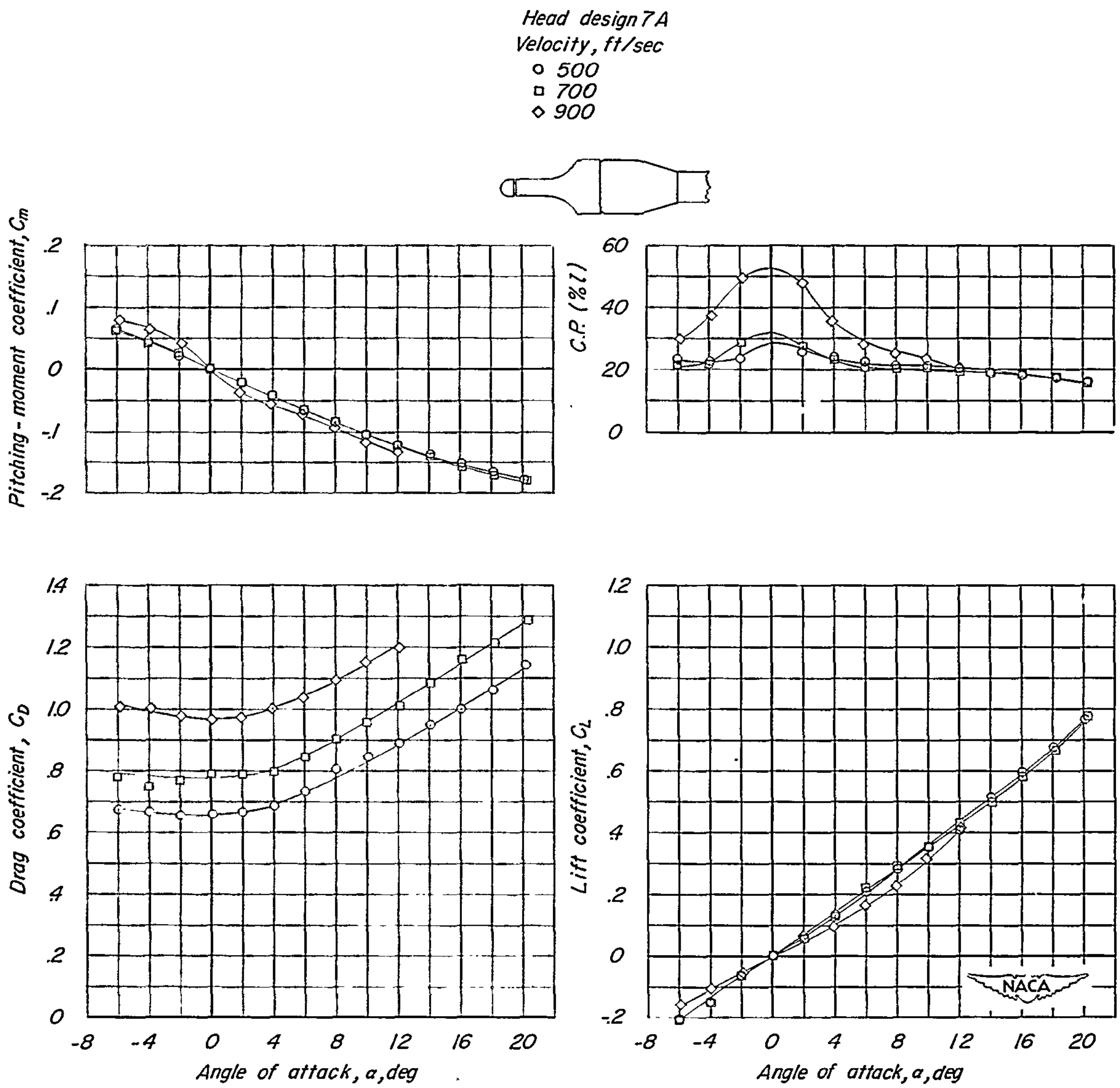

Figure 9.- Aerodynamic characteristics at velocities of 500, 700, and 900 feet per second of Army Ordnance Corps T205 HEAT rocket with head design 7A.

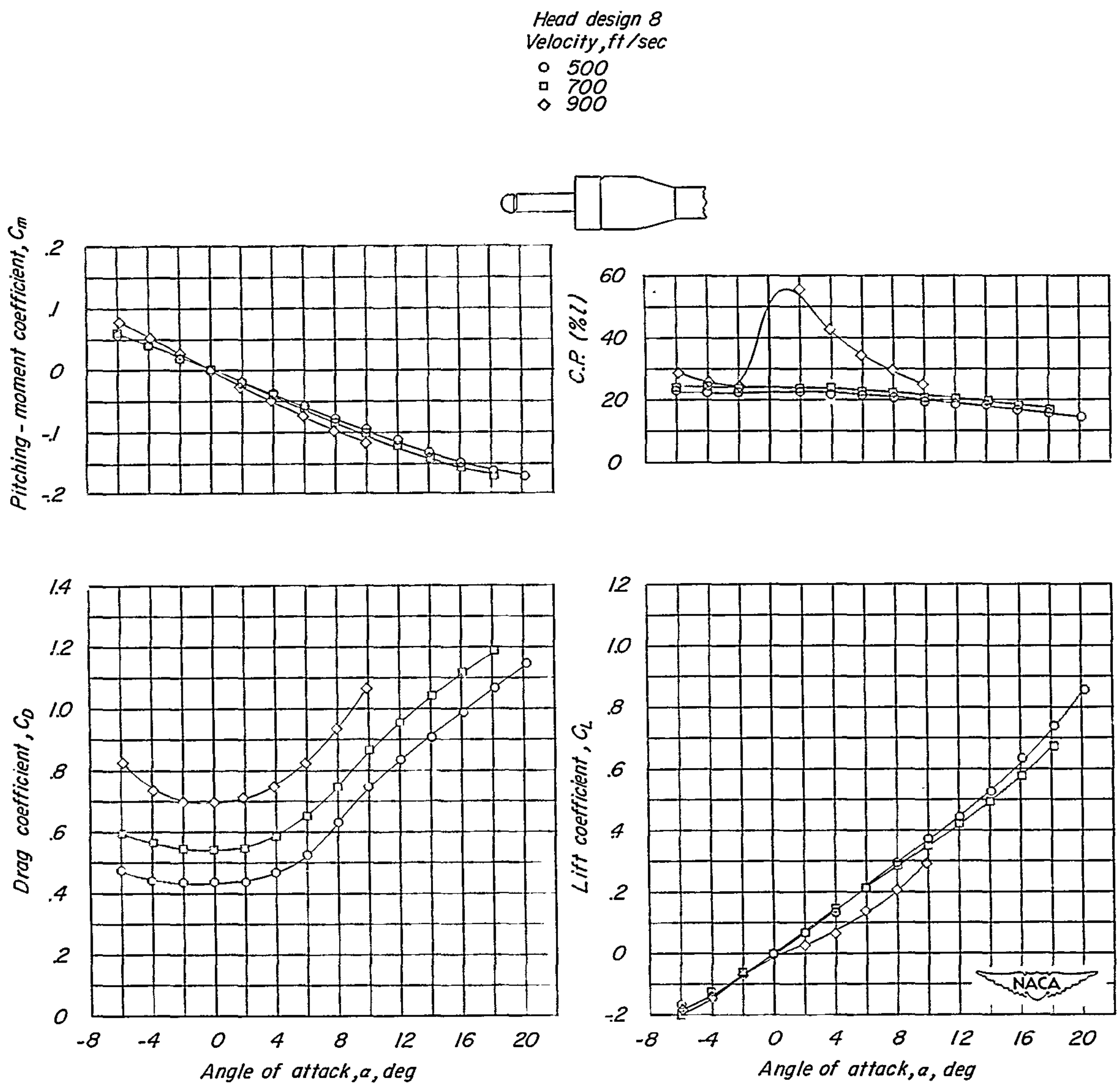

Figure 10.- Aerodynamic characteristics at velocities of 500, 700, and 900 feet per second of Army Ordnance Corps T205 HEAT rocket with head design 8.

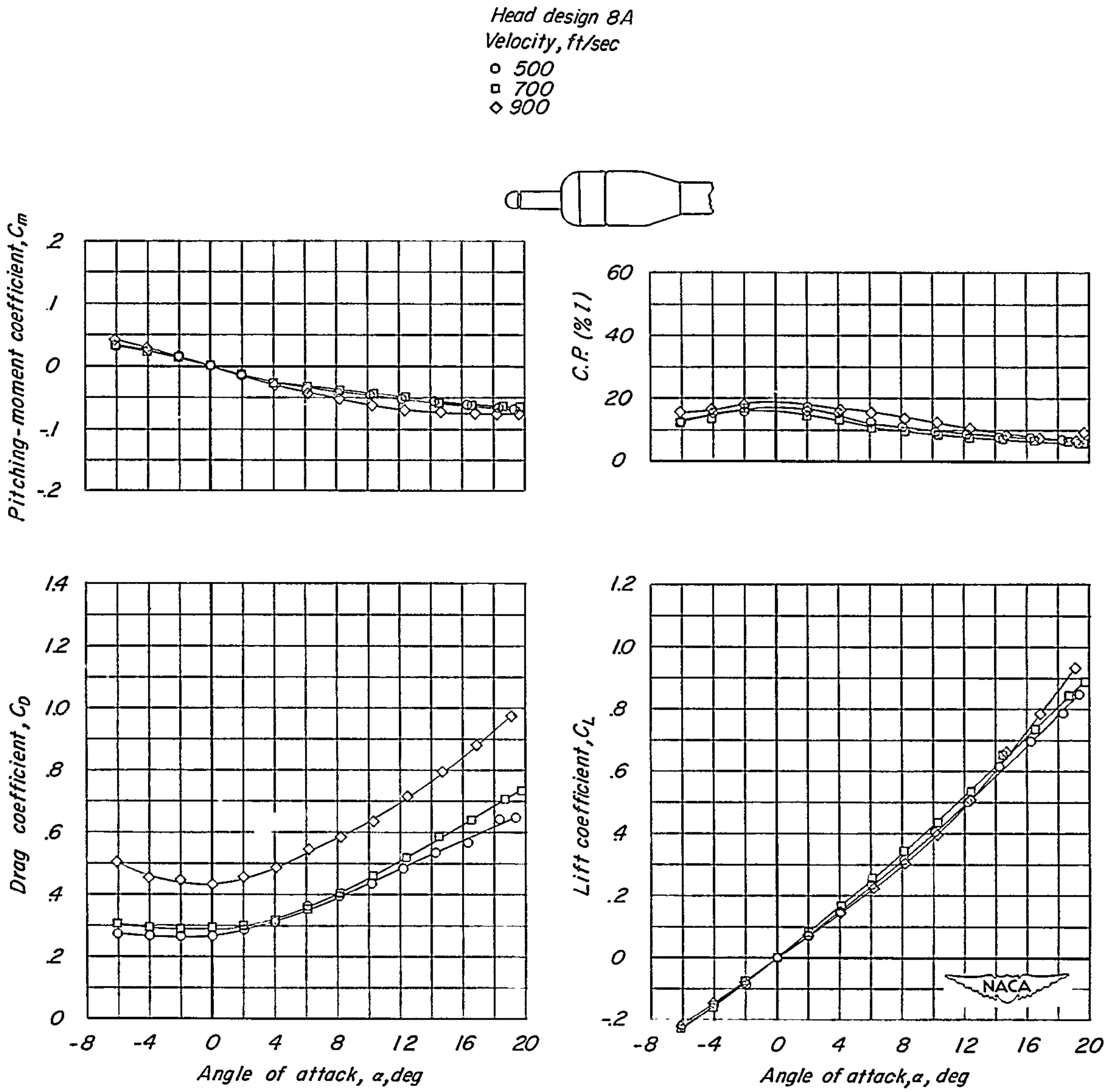

Figure 11.- Aerodynamic characteristics at velocities of 500, 700, and 900 feet per second of Army Ordnance Corps T205 HEAT rocket with head design 8A.

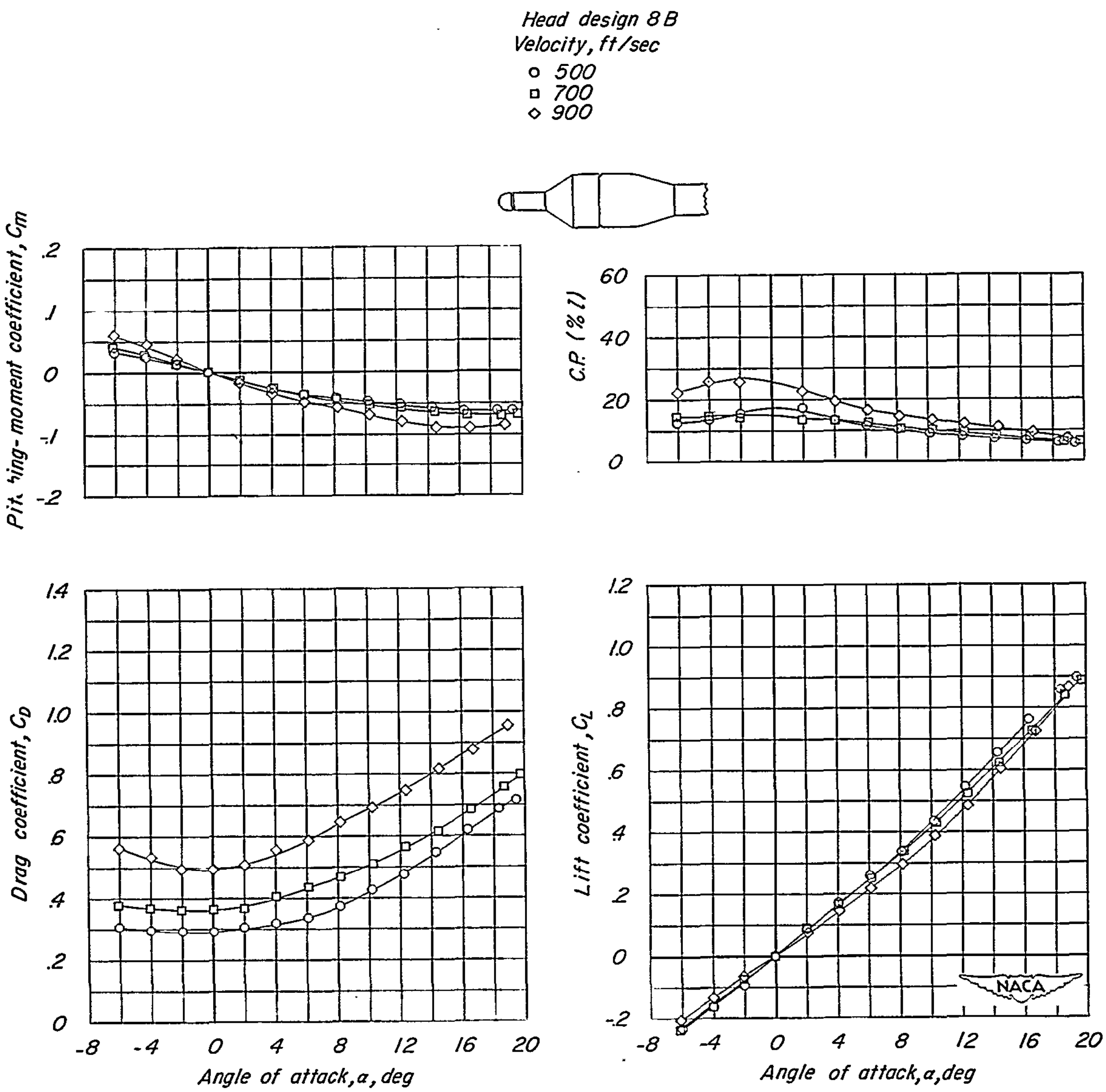

Figure 12.- Aerodynamic characteristics at velocities of 500, 700, and 900 feet per second of Army Ordnance Corps T205 HEAT rocket with head design 8B.

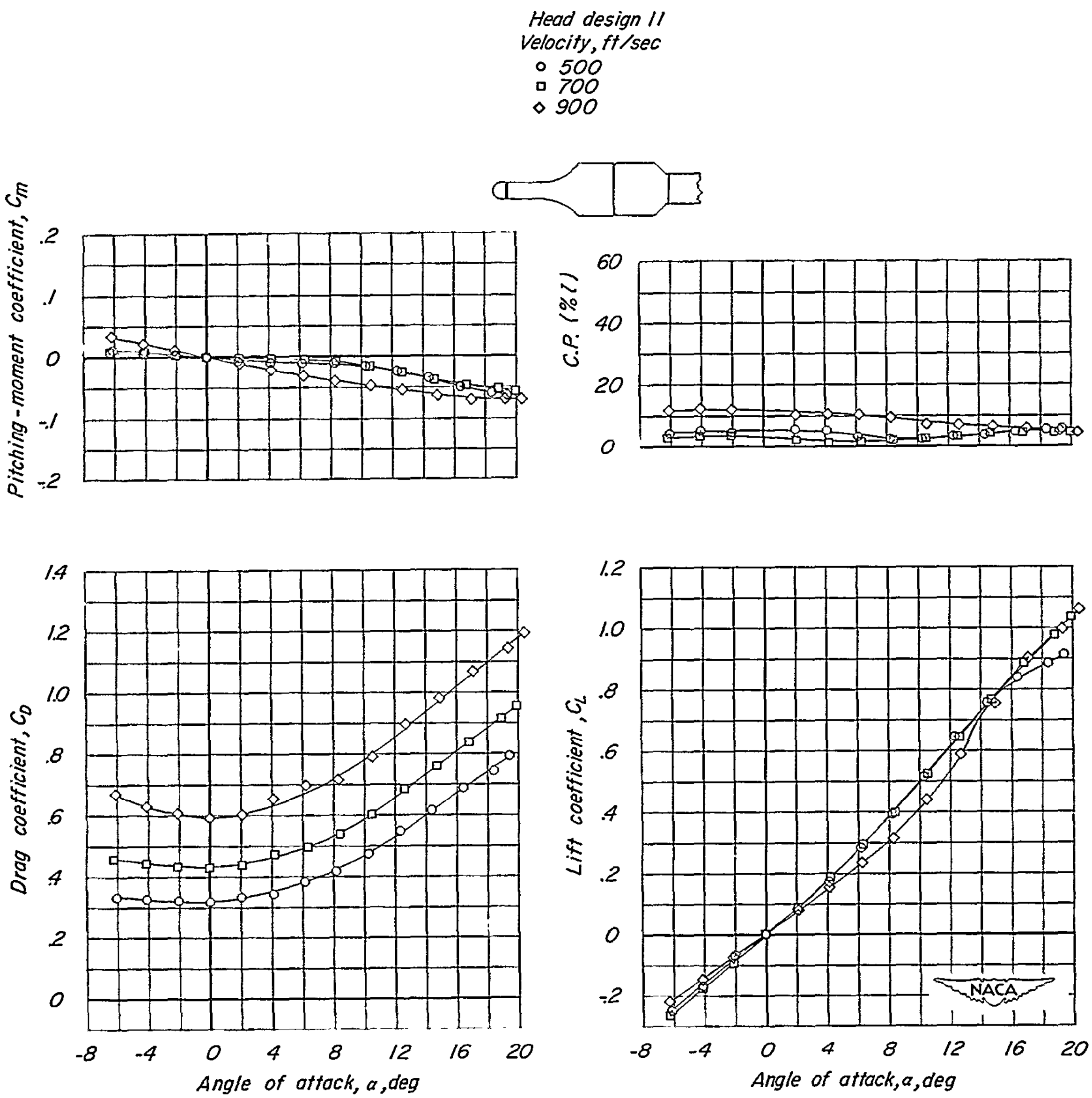

Figure 13.- Aerodynamic characteristics at velocities of 500, 700, and 900 feet per second of Army Ordnance Corps T205 HEAT rocket with head design 11.

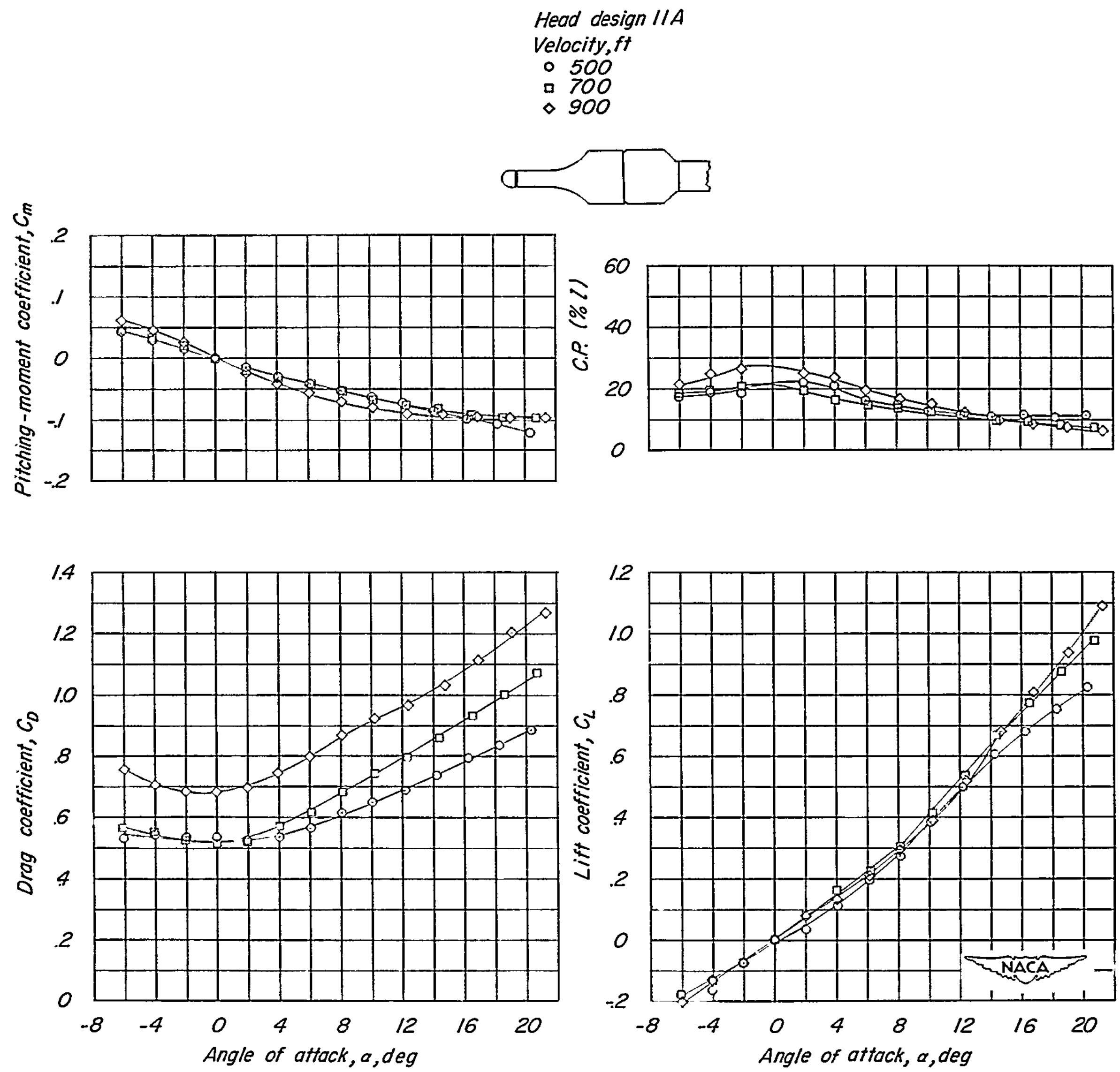

Figure 14.- Aerodynamic characteristics at velocities of 500, 700, and 900 feet per second of Army Ordnance Corps T205 HEAT rocket with head design 11A.

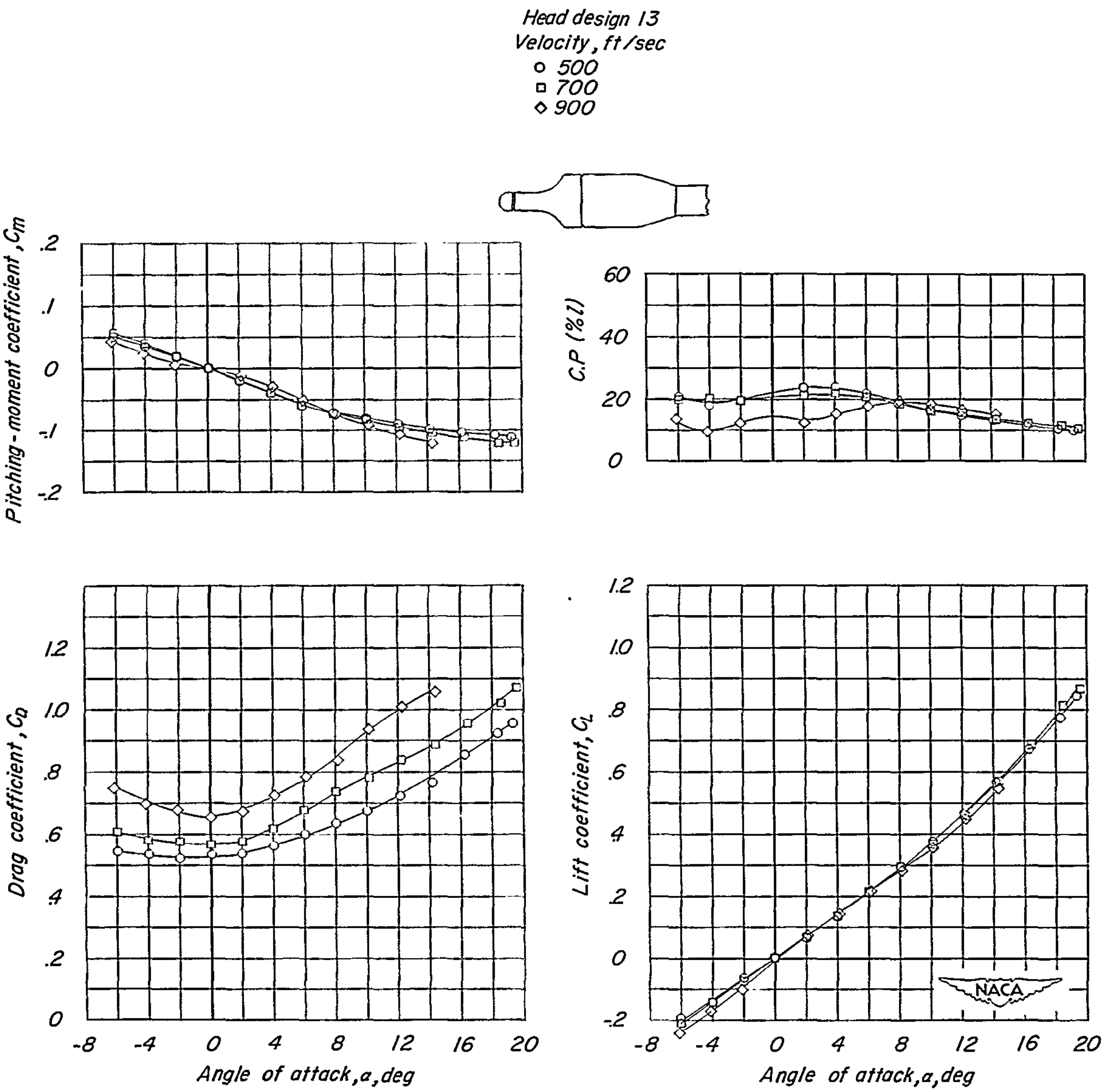

Figure 15.- Aerodynamic characteristics at velocities of 500, 700, and 900 feet per second of Army Ordnance Corps T205 HEAT rocket with head design 13.

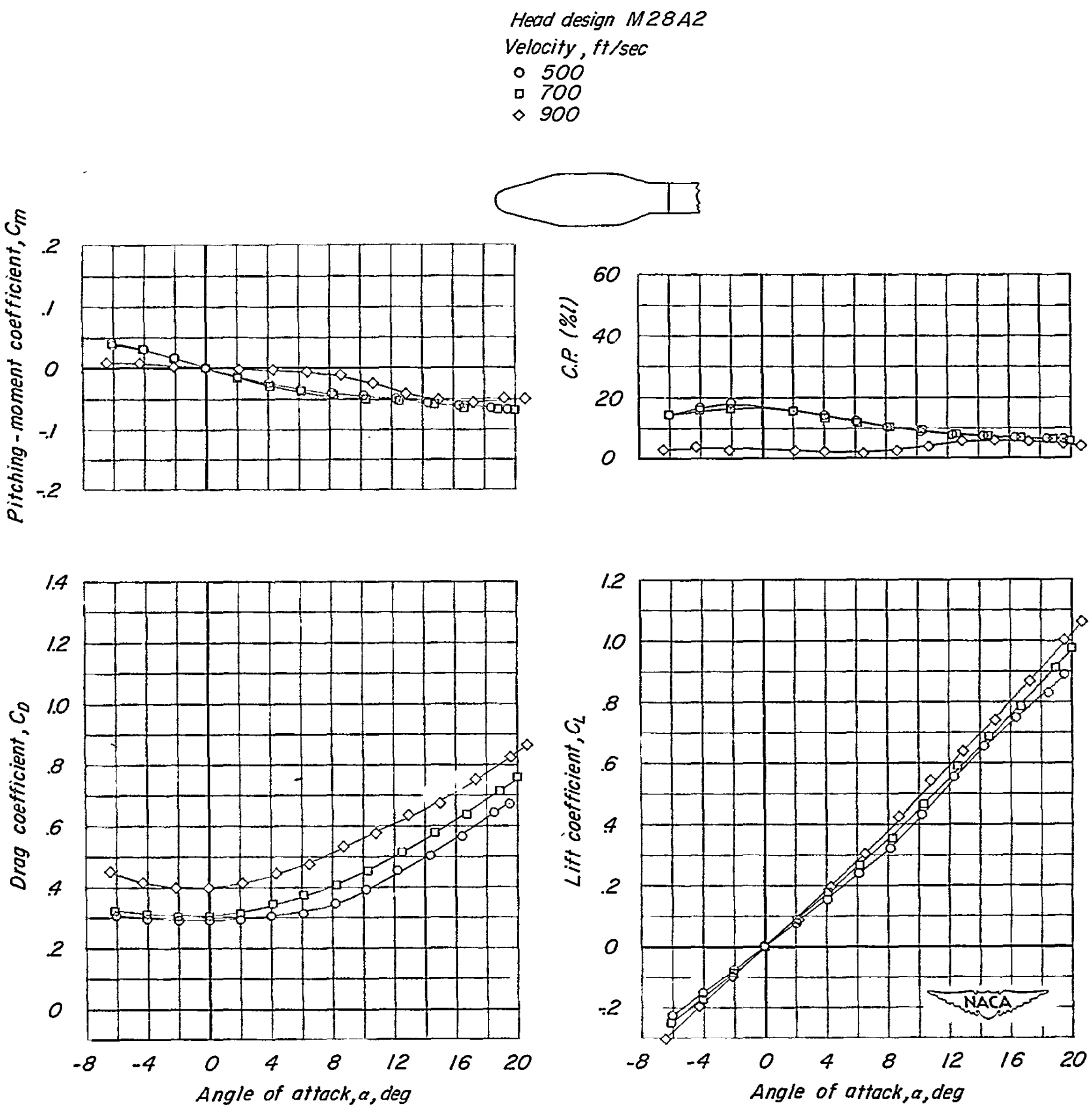

Figure 16.- Aerodynamic characteristics at velocities of 500, 700, and 900 feet per second of Army Ordnance Corps T205 HEAT rocket with head design M28A2.

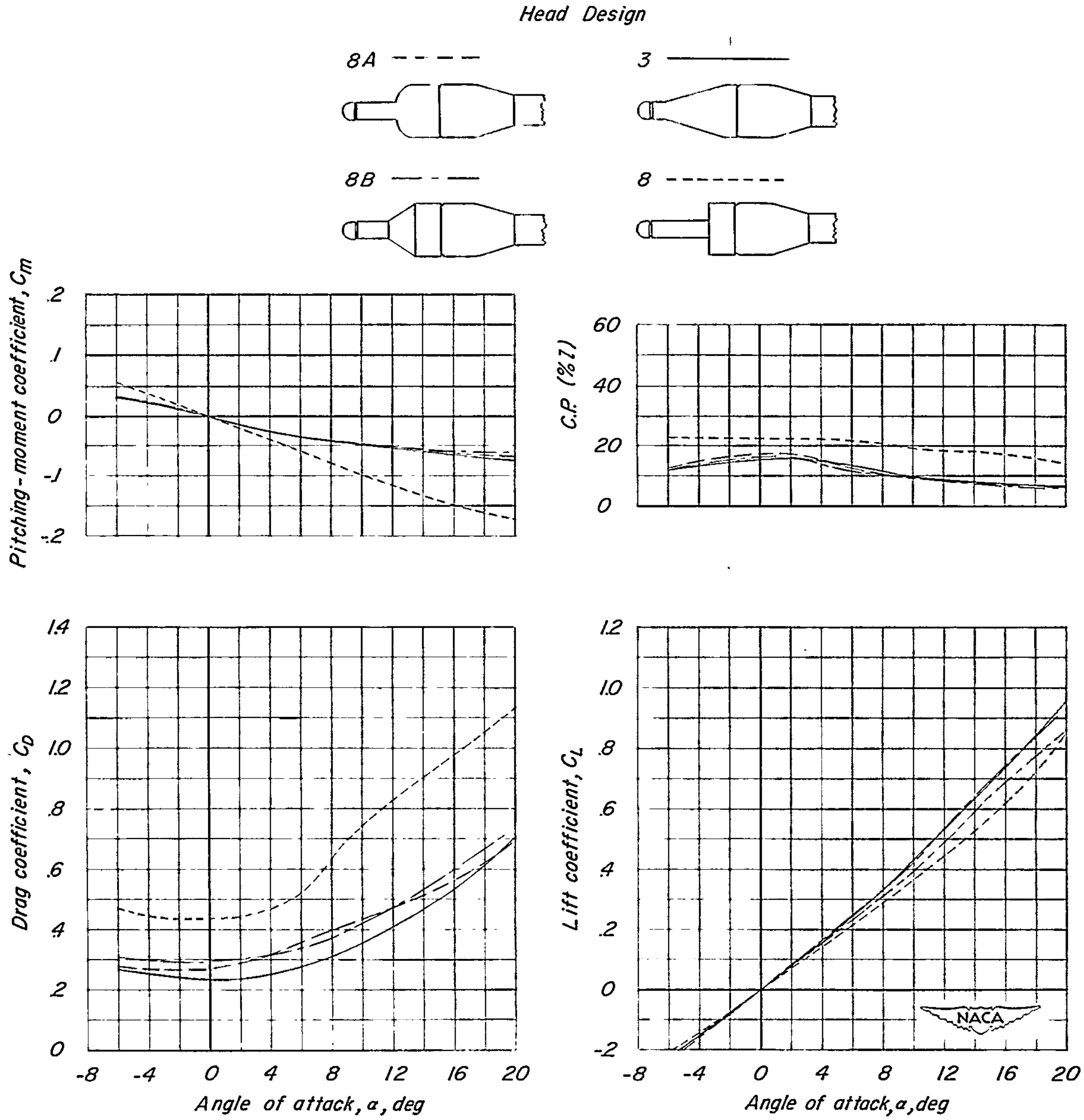

Figure 17.- Comparisons of the aerodynamic characteristics at 500 feet per second of the Army Ordnance Corps T205 HEAT rocket with head designs 3, 8, 8A, and 8B.

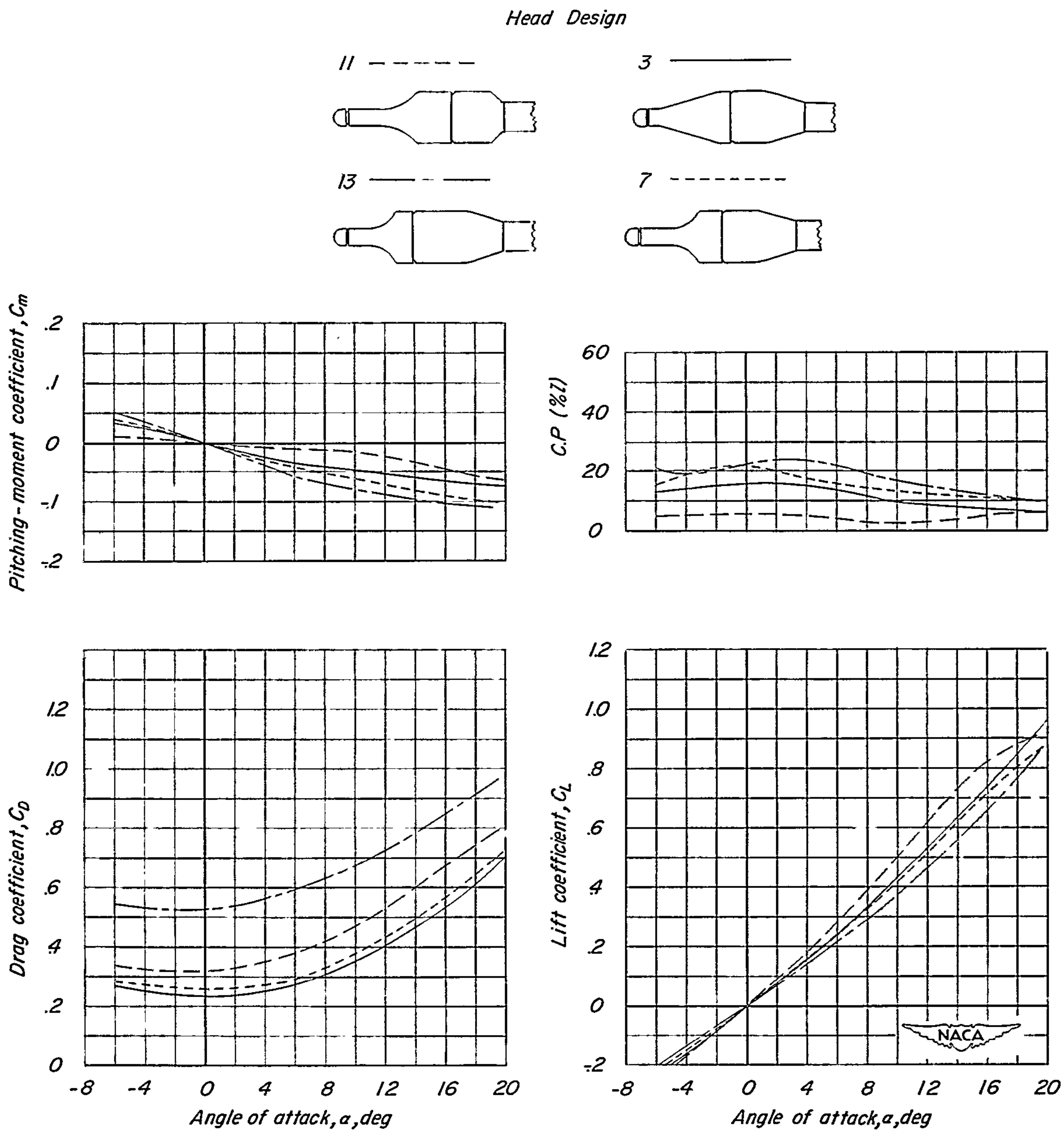

Figure 18.- Comparisons of the aerodynamic characteristics at 500 feet per second of Army Ordnance Corps T205 HEAT rocket with head designs 3, 13, 7, and 11.

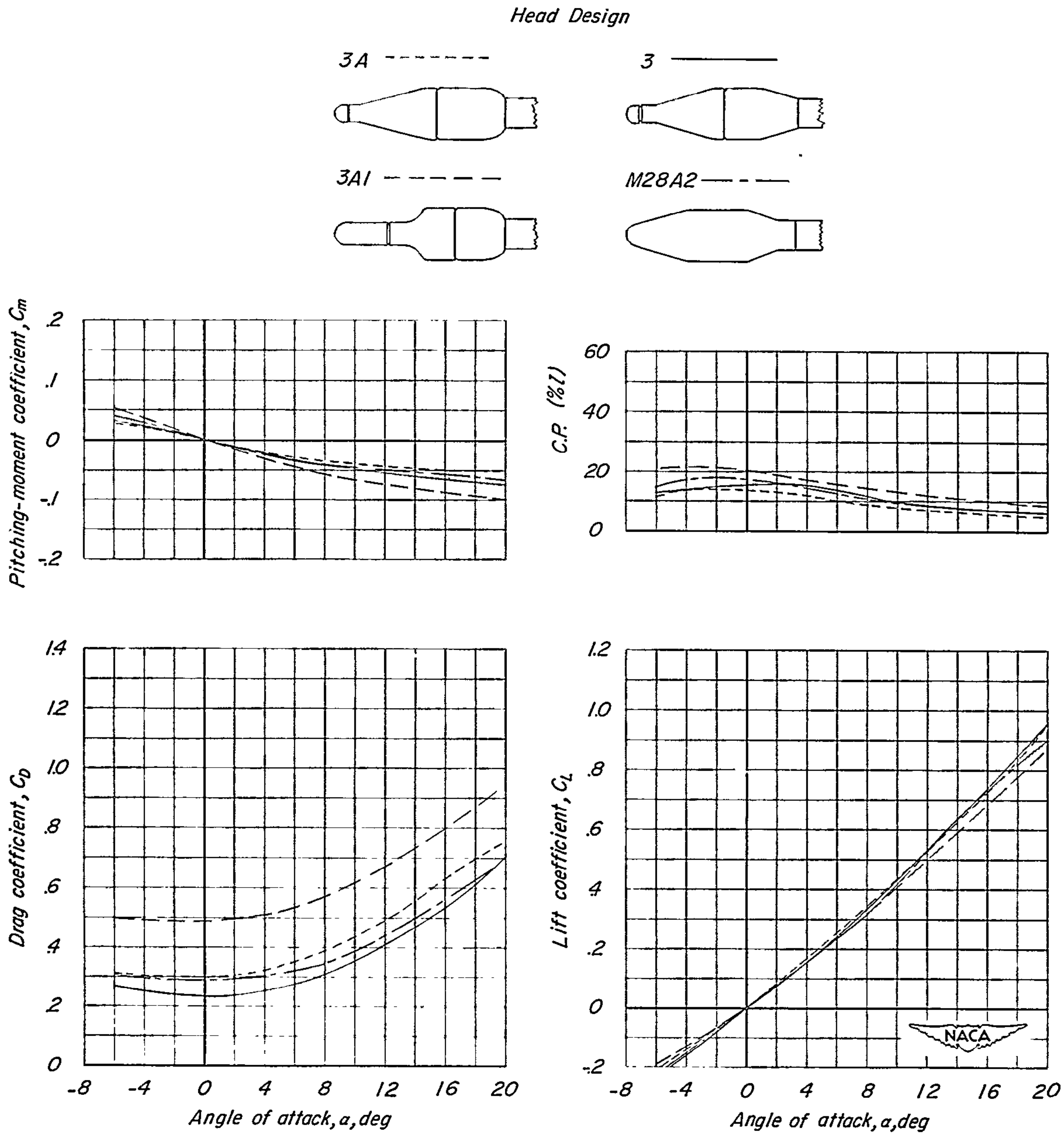

Figure 19.- Comparisons of the aerodynamic characteristics at 500 feet per second of Army Ordnance Corps T205 HEAT rocket with head designs 3, 3A, 3A1, and M28A2.

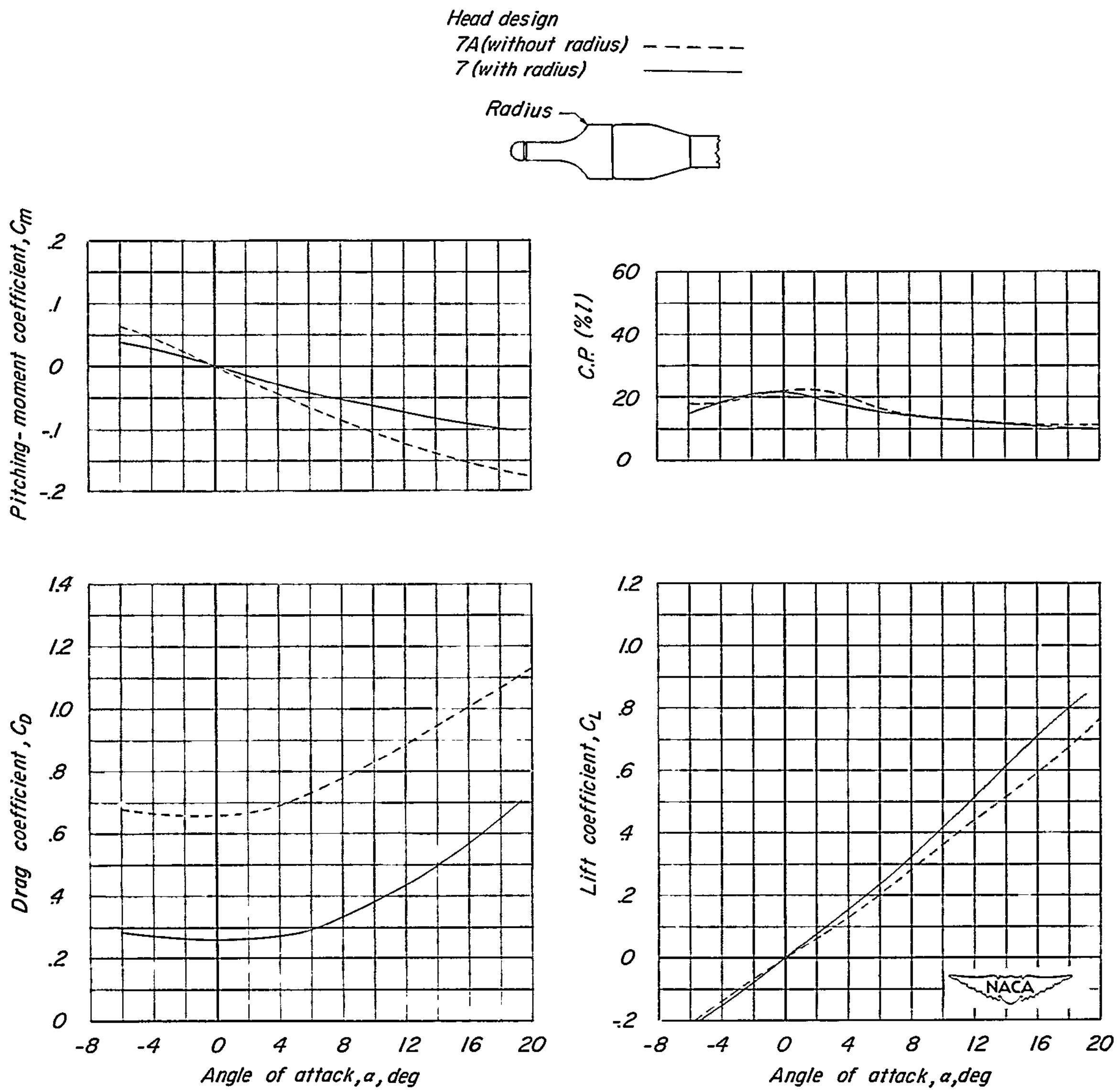

Figure 20.- Comparisons of the aerodynamic characteristics at 500 feet per second of Army Ordnance Corps T205 HEAT rocket with head design 7 with and without radius at intersection of forward slope and maximum diameter.

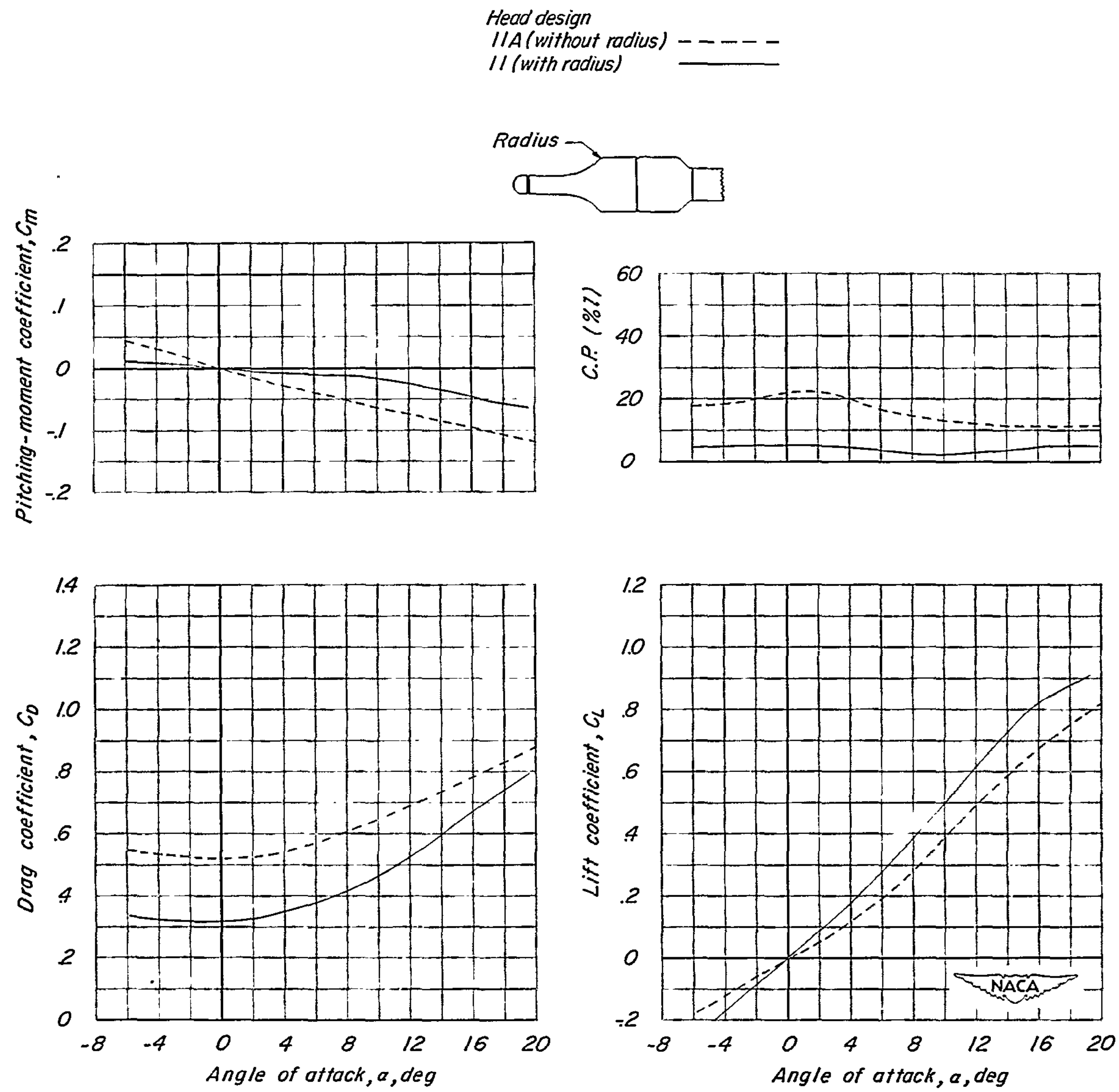

Figure 21.- Comparisons of the aerodynamic characteristics at 500 feet per second of Army Ordnance Corps T205 HEAT rocket with head design 11 with and without radius at intersection of forward slope and maximum diameter.

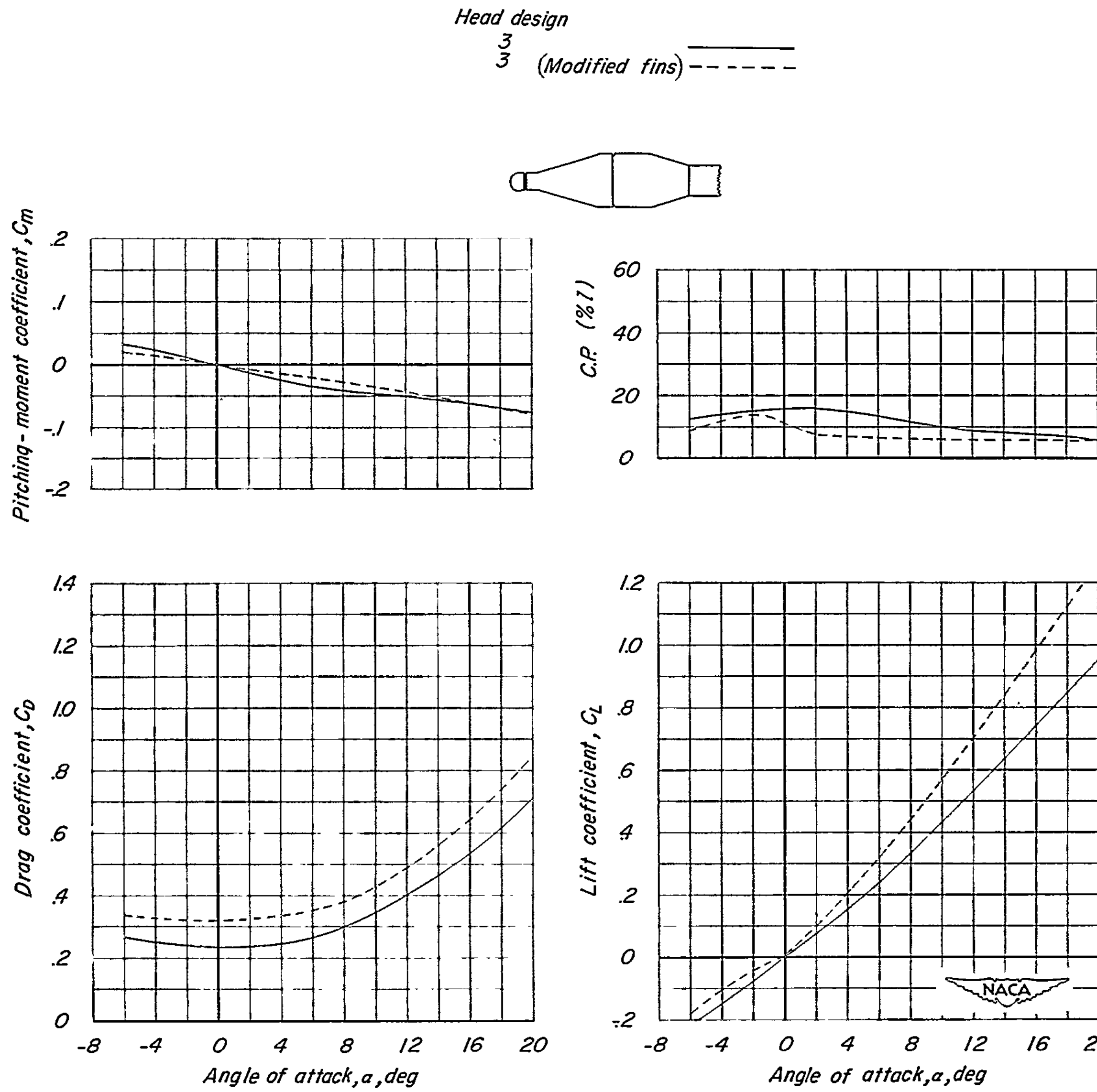

Figure 22.- Aerodynamic characteristics at 500 feet per second of Army Ordnance Corps T205 HEAT rocket with extended fins and head design 3.

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