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# RESEARCH MEMORANDUM

for the

Bureau of Ordnance, Department of the Navy

FLIGHT TESTS OF TWO SMOKE-PRODUCING DEVICES  
HAVING DEACON ROCKET BOOSTERS

By Wade E. Lanford

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SUMMARY

Two smoke-producing models having Deacon rocket boosters were flown at the Pilotless Aircraft Research Station at Wallops Island, Va. to test the functioning of the models and to obtain trajectory and drag data. The maximum drag coefficient for the first model was 1.19. Modifications of the launching lugs were made on the second model in order to obtain lower drag, and a maximum drag coefficient of 1.00 was obtained for this model. The length of the smoke trail obtained was about 43,000 feet for the first model and about 44,000 feet for the second model.

INTRODUCTION

The Naval Ordnance Laboratory has been studying blast waves from large explosions by determining photographically the apparent displacement of smoke trails due to refraction of light passing through the blast wave. Each background grid of smoke trails was produced by simultaneously launching a number of 5-inch spin-stabilized rockets which centrifugally expelled "FS," a solution of sulfur trioxide in chlorosulfonic acid, along the flight path. However, tumbling which causes the smoke-producing rocket to produce an erratic smoke trail and follow an unpredictable flight path was experienced with the spin-stabilized smoke-producing rockets.

For tests that were to be conducted in the Pacific Ocean, a new type of smoke-producing device was needed to produce a grid consisting of individual smoke trails that would extend up to the top of the trajectory which would possibly be required to be as high as 35,000 feet.



The Langley Pilotless Aircraft Research Division has successfully employed stagnation pressure to discharge FS and, because of the past experience of the Naval Ordnance Laboratory of the tumbling of spin-stabilized rockets, it was decided that a device employing stagnation pressure to discharge FS would be used on the smoke-producing device needed. Preliminary estimates by the Naval Ordnance Laboratory indicated that a Deacon rocket booster equipped with a tank carrying between 35 and 50 pounds of FS would fulfill this need. It was then requested by the Naval Ordnance Laboratory that two devices having Deacon rocket boosters be launched at two different elevation angles at the Pilotless Aircraft Research Station at Wallops Island, Va. to test the functioning of the smoke generator and to obtain drag and trajectory data that would be needed to employ this type of device to produce the smoke-trail grid required. The results obtained from the flights of these two devices are presented.

## SYMBOLS

$C_D$	drag coefficient, $\frac{\text{Drag}}{qS}$
$r$	radius, in.
$S$	cross-sectional area, sq ft
$V$	flight velocity, ft/sec
$W$	weight, lb
$a$	acceleration, ft/sec <sup>2</sup>
$g$	acceleration due to gravity, ft/sec <sup>2</sup>
$q$	dynamic pressure $\left(\frac{1}{2} \rho V^2\right)$ , lb/ft <sup>2</sup>
$\gamma$	flight-path angle, deg
$\rho$	air mass density, slugs/ft <sup>3</sup>

## DESCRIPTION OF MODELS

Each model consisted of a Deacon rocket booster with a body from which FS would discharge fitted to the front. A four-fin tail assembly

fitted to the rear stabilized the models aerodynamically. Shown in figure 1 are Model 1 on the launching stand, model 2 being filled with FS while on the launching stand, the launching lugs, and the general configuration of the models.

The manner in which stagnation pressure is utilized to discharge approximately 34 pounds of FS from each model is illustrated in figure 2. When the model is accelerating, the smoke-producing liquid is in the position shown in figure 2(a). Air flows into the impact tube, bubbles through the liquid, and then flows out the discharge tube. When the deceleration of the model is greater than  $g \sin \gamma$ , the smoke-producing liquid is in the position shown in figure 2(b) and stagnation pressure forces the liquid out the discharge tube as long as the level of FS is behind the most forward part of the discharge tube.

#### TEST TECHNIQUES

Prior to launching, each model was filled with FS in the manner shown in figure 1(b). The first model was launched at an elevation angle of  $70^\circ$ , and the second model was launched at an elevation angle of  $54^\circ 12'$ . Rapid-sequence pictures were taken of each model flight from a location about 13 miles southwest of the launching site, and the entire trajectory of each model is shown from the launching until the model dropped into the ocean.

Tracking the models with an SCR-584 radar set provided azimuth, elevation, and slant range as functions of time which could be used to compute altitude and azimuth as functions of horizontal range. A CW Doppler velocimeter was used to obtain time histories. Rawinsonde equipment was released at the approximate time of firing of each model in order to obtain air density, air temperature, and wind velocity as functions of altitude. A stop watch was used to measure the times during which smoke trails were produced.

#### DATA REDUCTION

The drag coefficient  $C_D$  was computed from flight data obtained after burnout of the rocket booster by using the following equation:

$$C_D = \frac{-W}{qS} \left( \frac{a}{g} + \sin \gamma \right)$$

During the part of the flight when FS was being expelled from the model, the model weight decreased from approximately 125 pounds to approximately 91 pounds. Since there was no way for determining the weight variation with time during the part of the flight when FS was being expelled, an average weight of 108 pounds was used for computing drag coefficients.

## RESULTS AND DISCUSSION

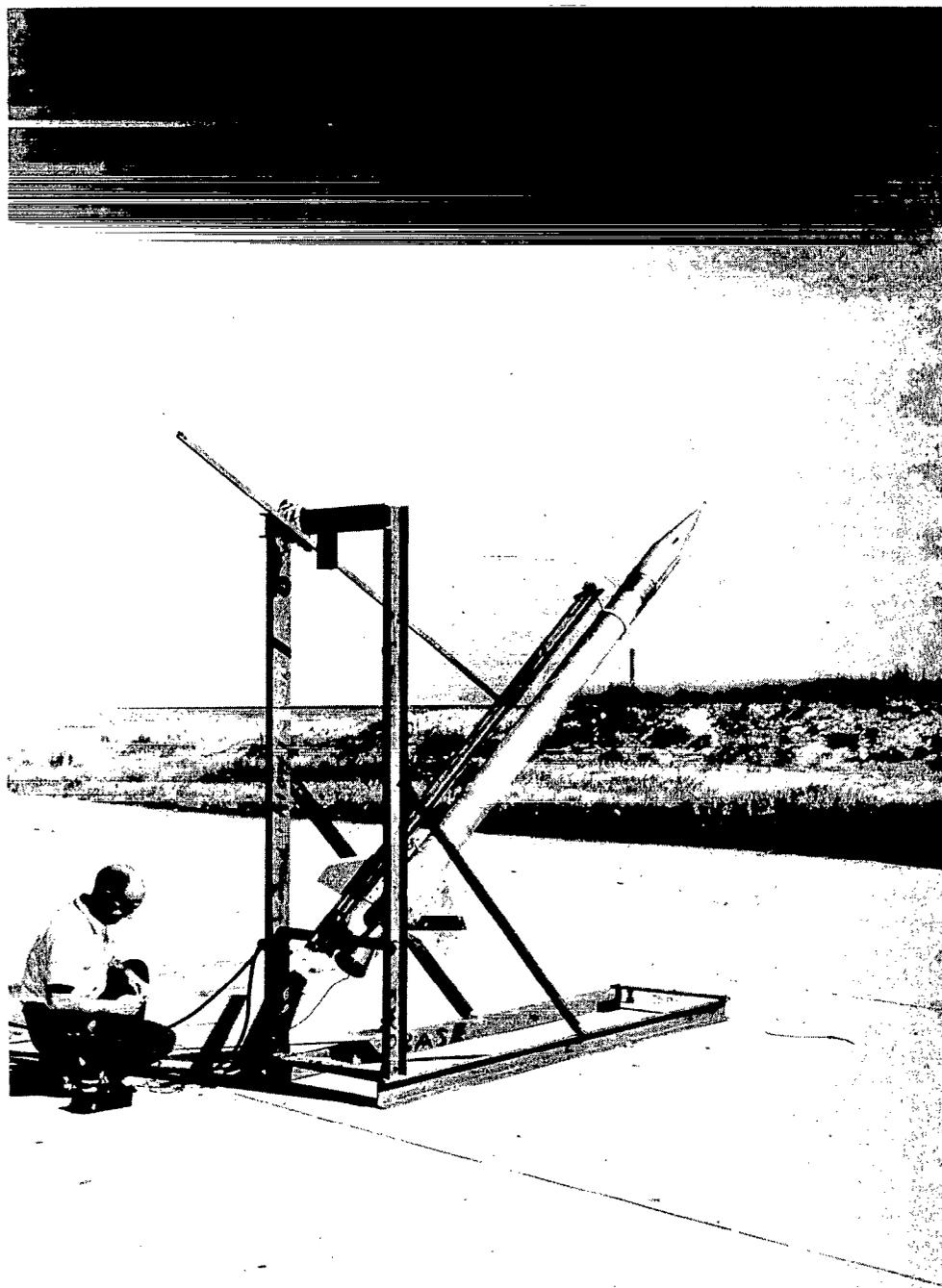
Model 1 produced a smoke trail for 67 seconds after the Deacon rocket booster had burned out. The length of the smoke trail was approximately 43,000 feet. It was determined from photographs taken by the Naval Ordnance Laboratory that the width of the smoke trail for this model and also for model 2 was about 10 feet. A photograph taken of the smoke trail of model 1 in flight is shown in figure 3. Model 1 reached an altitude of 27,000 feet (see fig. 4), although an altitude of 35,000 feet was desired. This fact indicated that the drag for model 1 was higher than had been anticipated. Model 1 was fitted with launching lugs as shown in figure 1(c). Aerodynamic calculations indicated that a considerable reduction of drag could be obtained by changing the design of the launching lugs. Accordingly, model 2 was fitted with launching lugs (also shown in fig. 1(c)) which were shorter and thinner than those used for model 1. It can be seen from figure 5 that the velocity of model 2 was greater at any particular time after the launching than the velocity of model 1 at the corresponding time. Figure 6 indicates that there was a reduction of drag coefficient of approximately 17 percent over the whole Mach number range between model 1 and model 2. Maximum drag coefficient was 1.19 for model 1 and 1.00 for model 2. The length of the smoke trail for model 2 was about 44,000 feet and was produced during a period of 54 seconds. Model 2 reached an altitude of 25,000 feet. Calculations indicate that if model 1 had been fitted with launching lugs identical to those used for model 2, at least a 20 percent increase in altitude would have been obtained which would have allowed model 1 to reach an altitude of 32,400 feet. Figure 4 indicates that each model produced a smoke trail for a considerable distance beyond the top of the trajectory, which was all that was needed. If the amount of FS used in each smoke-producing device were reduced to that needed to produce a smoke trail to the top of the trajectory and if the launching angle were increased to an angle greater than the  $70^\circ$  angle which was used for model 1, an altitude even greater than 32,400 feet and probably as much as the desired altitude of 35,000 feet would be reached.

## SUMMARY OF RESULTS

Flight tests of two smoke-producing devices having Deacon rocket boosters indicated the following results:

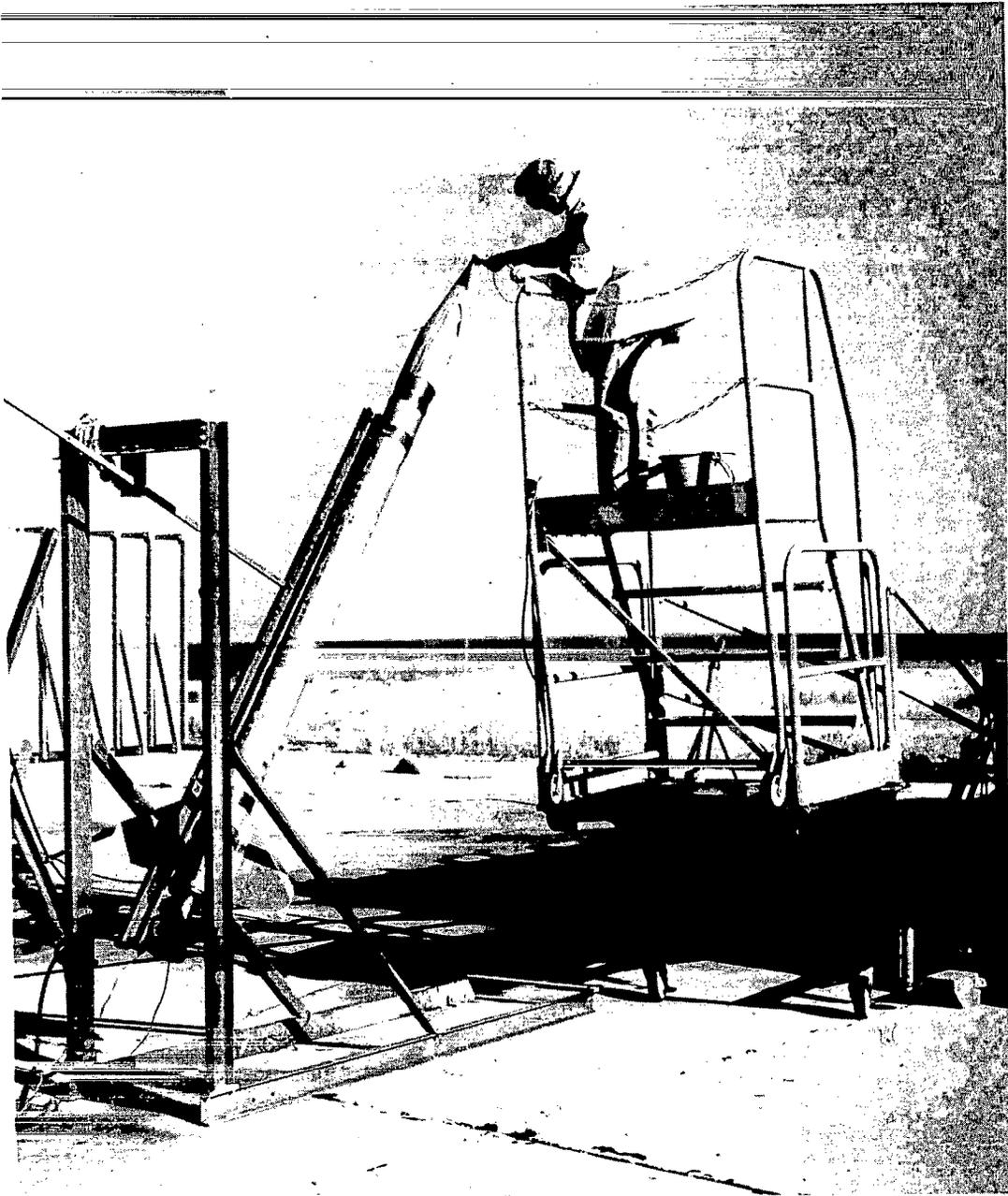
1. Smoke generators on both models produced smoke trails up to maximum altitude.
2. The maximum drag coefficient was 1.19 for the first model and 1.00 for the second model.
3. The reduction of drag coefficient obtained by changing the type of launching lugs was approximately 17 percent over the entire range of Mach numbers.
4. The length of the smoke trail obtained was about 43,000 feet for the first model and about 44,000 feet for the second model.

Langley Aeronautical Laboratory,  
National Advisory Committee for Aeronautics,  
Langley Field, Va., May 13, 1958.



(a) Photograph of model 1 on launching stand. L-91331

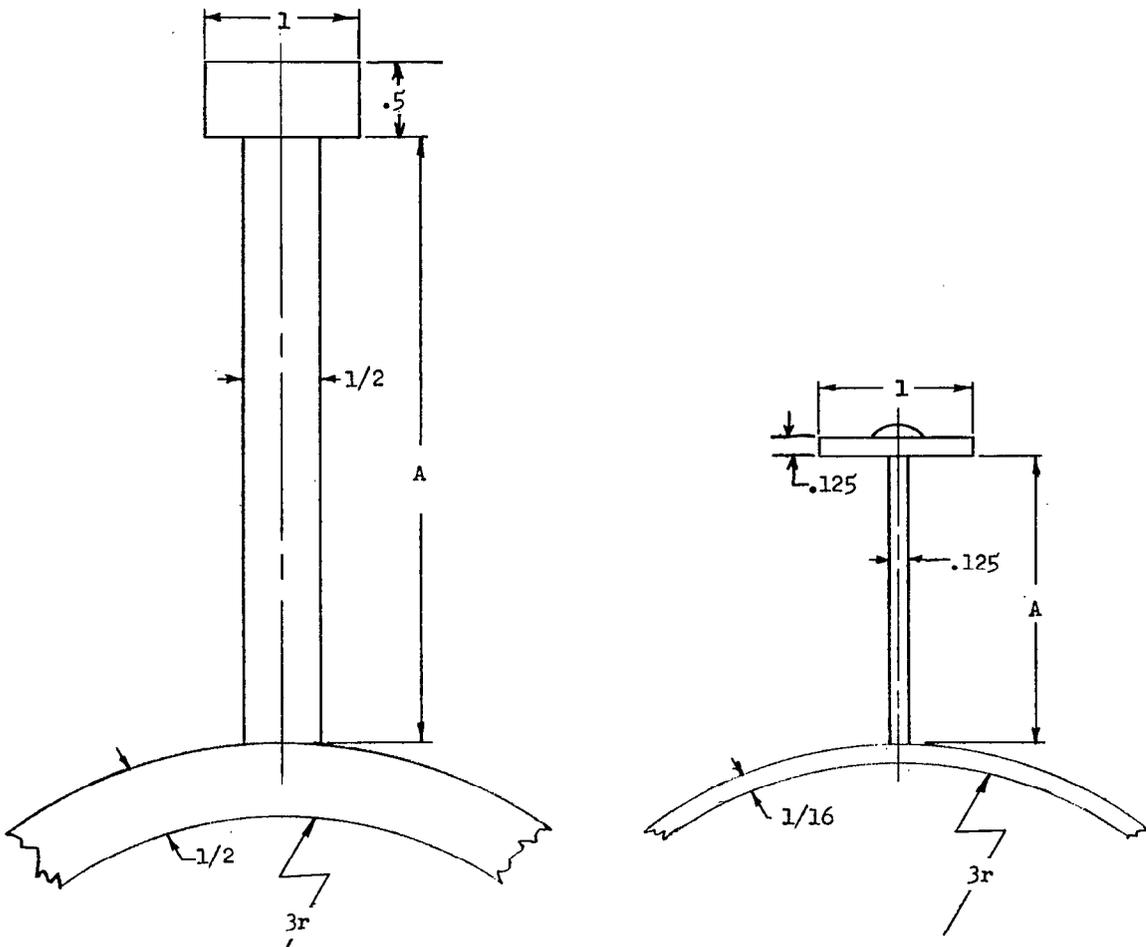
Figure 1.- Test configuration.



L-91334

(b) Photograph of model 2 on launching stand being filled with FS.

Figure 1.- Continued.



Model 1

Model 2

Dimension A		
	Front Lug	Rear Lug
Model 1	4	2
Model 2	3	1

(c) Launching lugs. All dimensions are in inches.

Figure 1.- Continued.

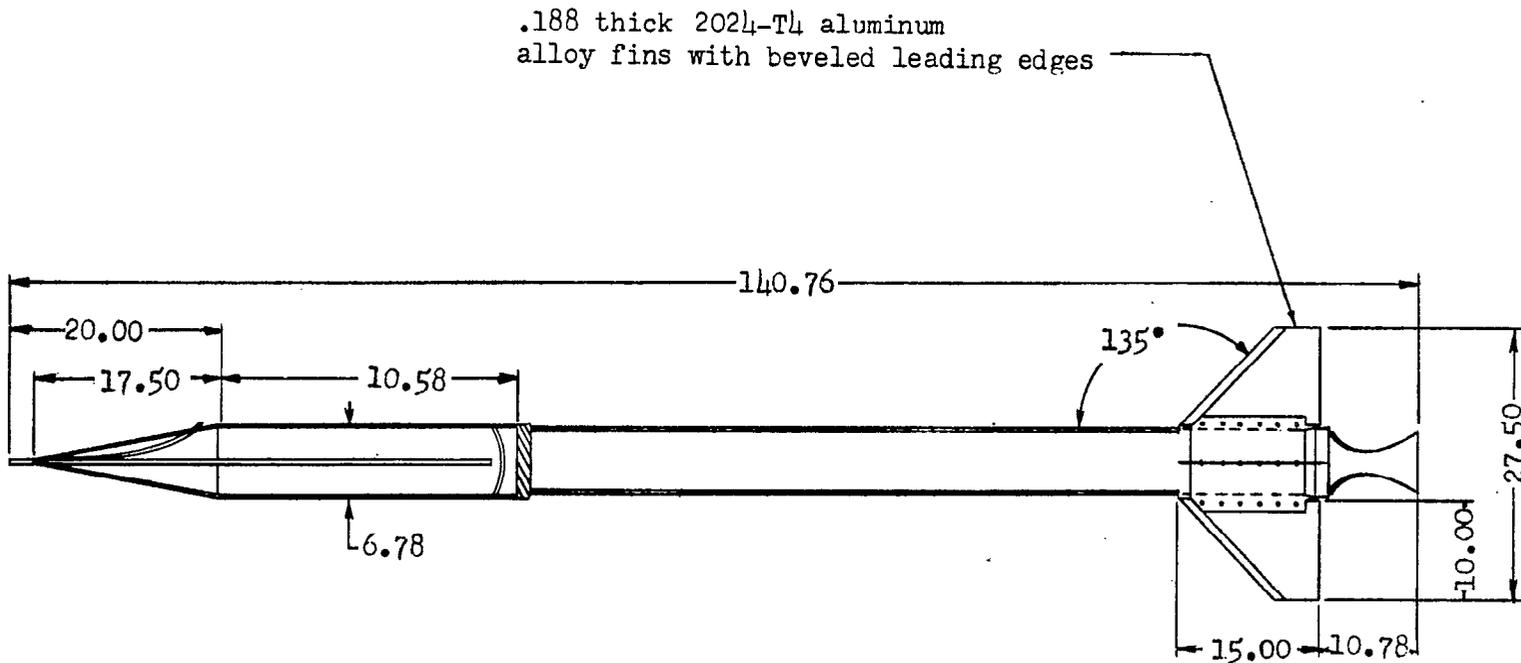
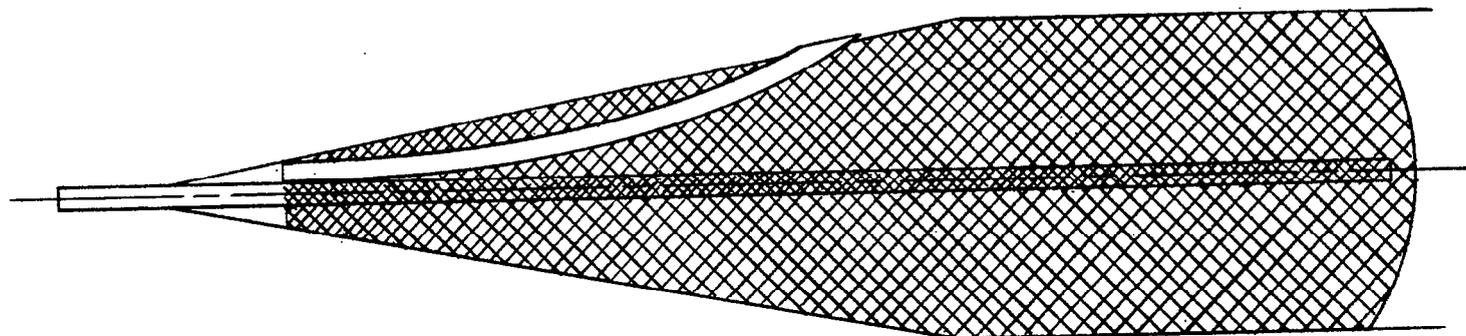
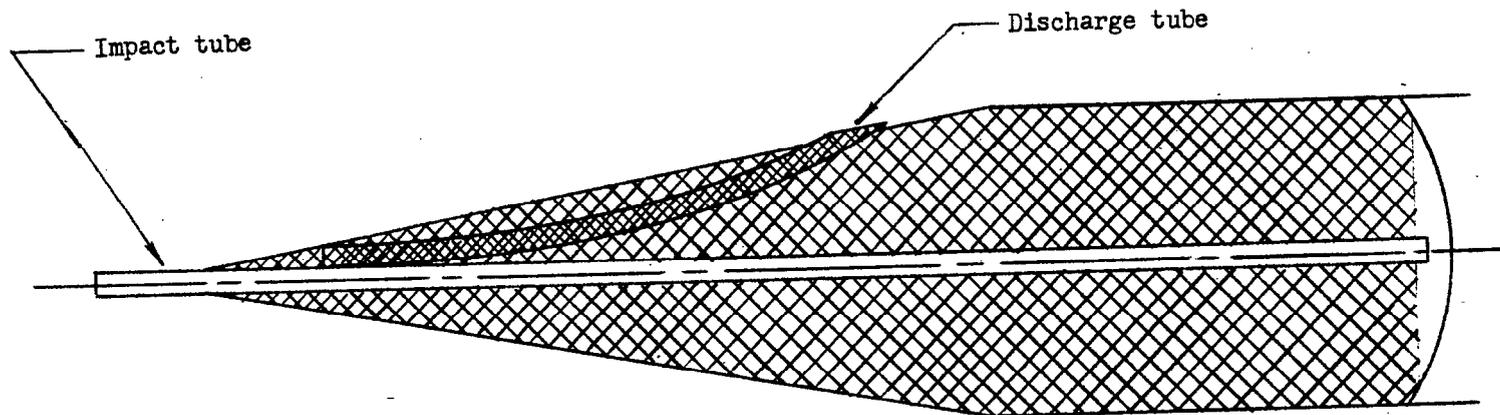


Figure 1.- Concluded.



(a) Model accelerating. FS not being discharged.



(b) Model decelerating. FS being discharged.

Figure 2.- Illustration of operation of FS discharge device.

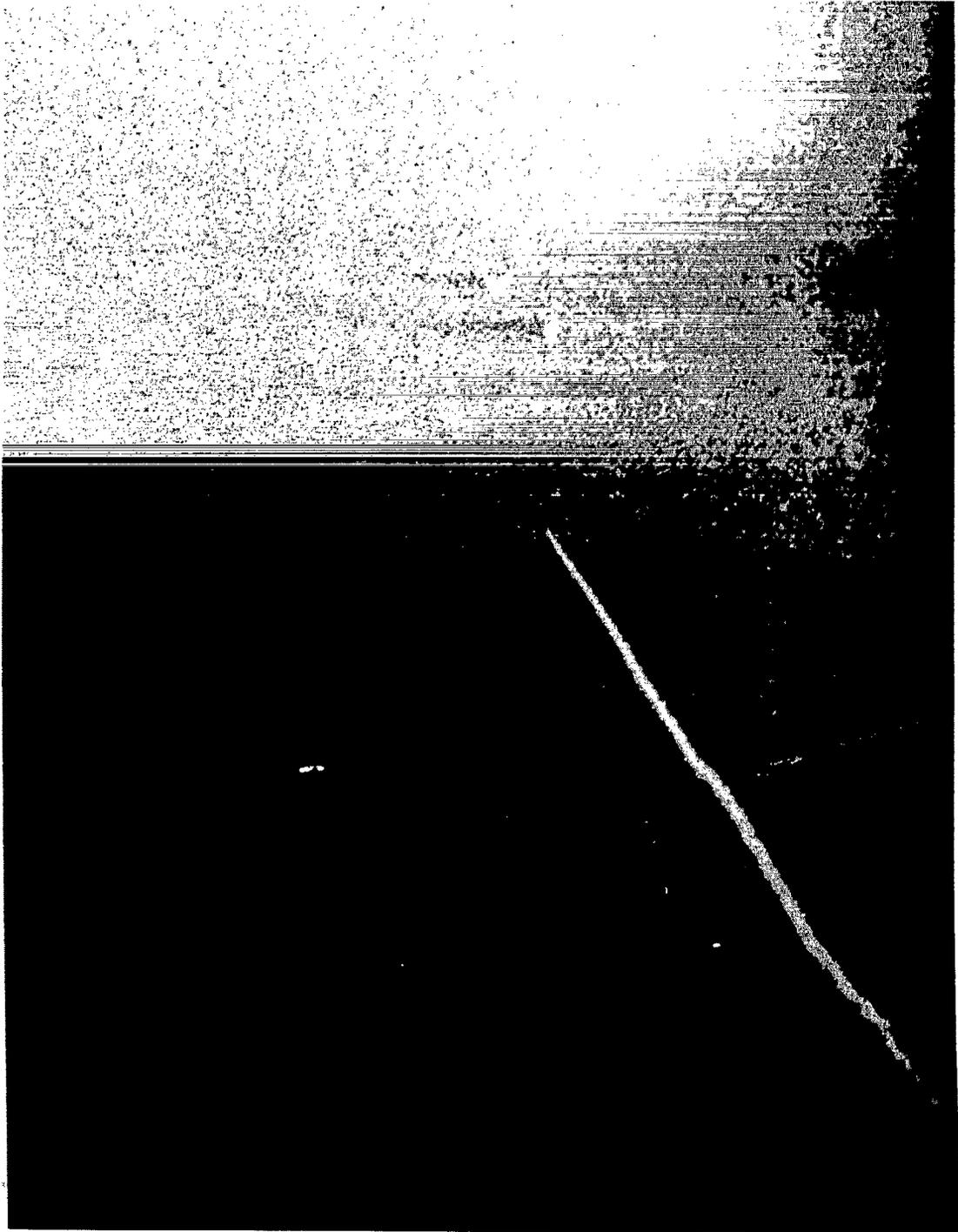


Figure 3.- Photograph of FS trail of model 1. L-58-1677

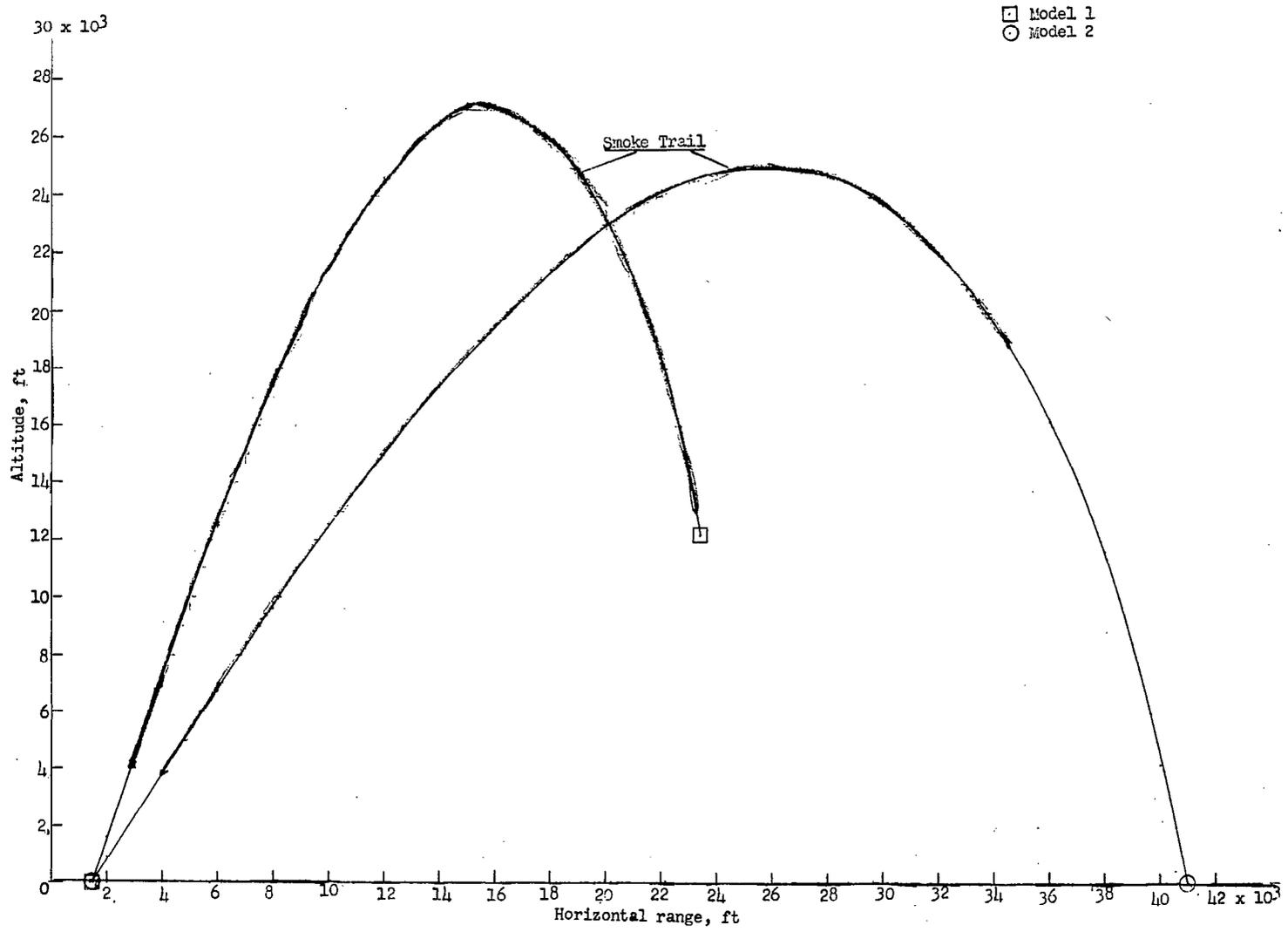


Figure 4.- Altitude as a function of horizontal range.

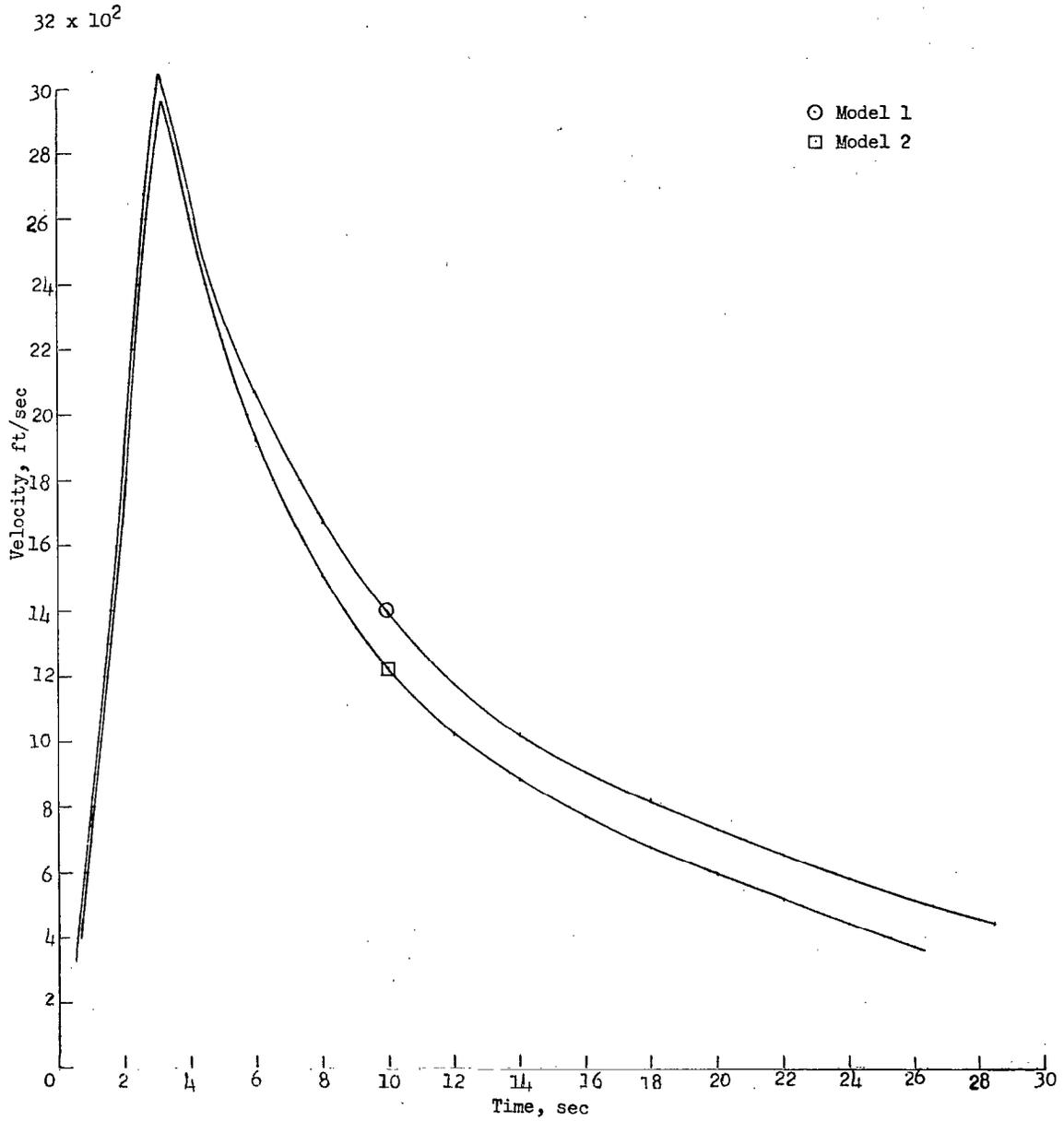


Figure 5.- Velocity as a function of time.

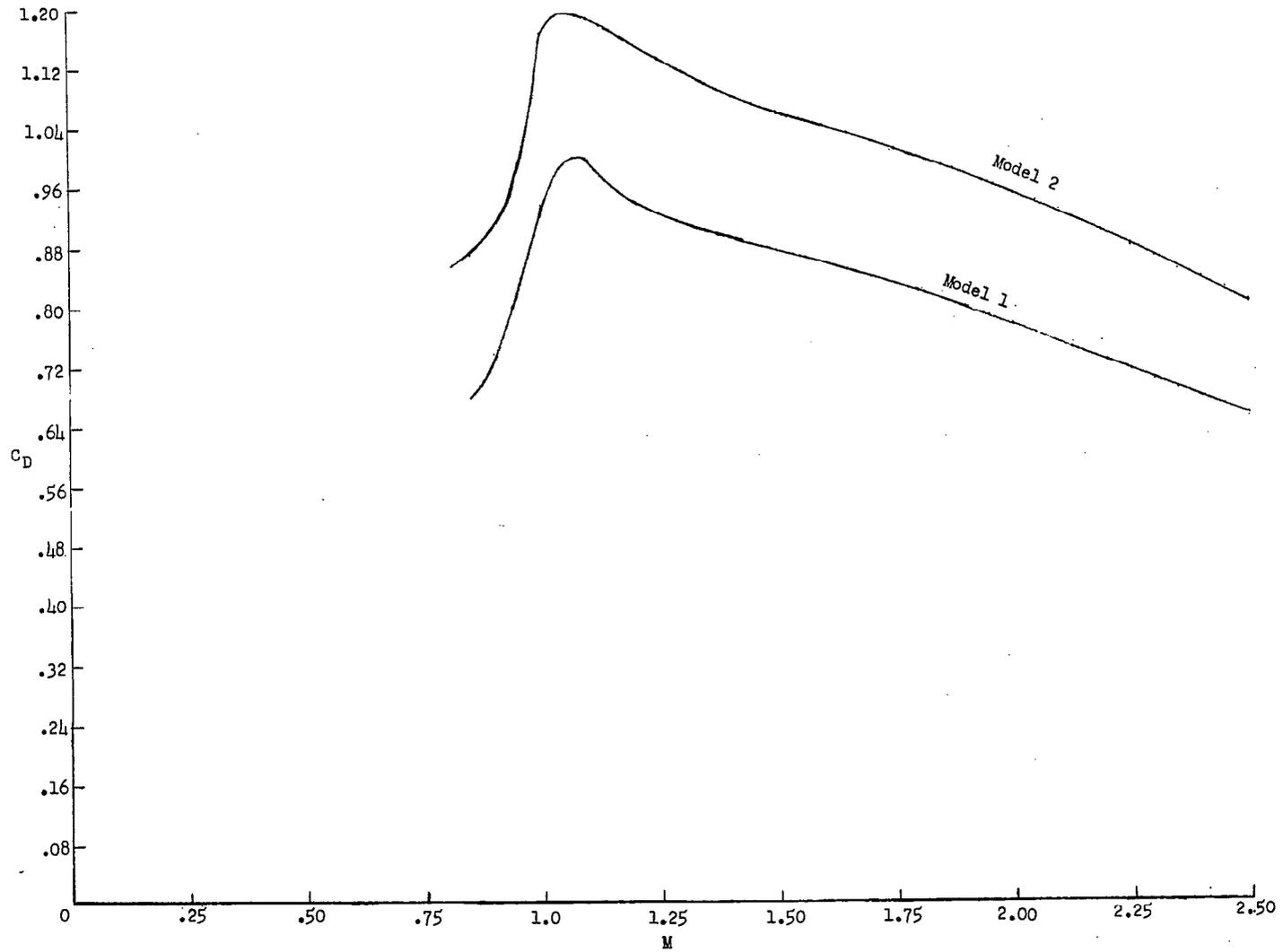


Figure 6.- Drag coefficient as a function of Mach number.

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ABSTRACT

The tests were made at the Pilotless Aircraft Research Station at Wallops Island, Va. The functioning of the smoke generator was tested, and trajectory and drag data was obtained.

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