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INVESTIGATION OF THE DIVING CHARACTERISTICS OF THE APOLLO COMMAND MODULE DURING WATER LANDINGS

MANNED SPACECRAFT CENTER
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SUMMARY

Tests were conducted to investigate the diving characteristics of the Apollo command module during water landings using a 1/7-scale model. For all landings investigated, the model was released into calm water. Vertical and horizontal velocities were varied to simulate two- and three-parachute landings, and wind drift, respectively. Roll and pitch attitude were also varied to represent the launch-abort conditions and parachute oscillation. The test results indicate that the Apollo command module may be expected to penetrate water to depths of at least 8 to 12 feet, with an occasional plunge to depths of 14 to 17 feet under worst-case conditions. In all tests, the underwater velocity decreased rapidly to 5 to 10 ft/sec prior to the command module reaching a depth of 8 feet.

INTRODUCTION

This paper presents the results of two test programs conducted in the water test-tank facility located in building 260 at the Manned Spacecraft Center. The primary purpose of the tests was to determine the underwater velocity profile and maximum dive depths that an Apollo command module would exhibit during a landing after a launch abort. The maximum dive depth data were required to analyze the launch site landing area at Kennedy Space Center to determine locations of shallow-water areas in which possible command module damage due to bottom contact might occur. A landing in such an area could result in incapacitation of members of the flightcrew as well as rupture of the pressure vessel. The latter condition could cause the spacecraft to assume an attitude dangerous to the crew or one from which it would be impossible for the crew to escape. The purpose of this paper is to provide data for recovery planners that can be used in conjunction with other information such as results of spacecraft structural tests, information on underwater bottom characteristics in the launch site area, and launch abort trajectory analyses.

APPARATUS AND PROCEDURE

A 1/7-scale model of the Apollo command module was used to conduct the tests. The model consisted of a hollow body of revolution with an outside shell constructed of fiber glass. A removable upper deck with simulated equipment was bolted to the vehicle. A three-axis balance system with lead weights inside the model was used to achieve the proper center of gravity and moments of inertia. The bifilar-pendulum method was used to determine the scaled moments of inertia. Scale relationships are given in table I.

The water-landing penetration investigation was conducted by launching the model as a free body using a pendulum apparatus (fig. 1). A predetermined free-fall height was used to obtain the desired vertical velocity component. The horizontal velocity was achieved by pulling the pendulum up to a predetermined height as shown in figure 1. The model was released electrically from the pendulum while at the vertical position of the swing using a solenoid and cam-operated switch. Each drop was recorded on film at 120 frames per second with a motion picture camera located at the waterline. The film was analyzed using a single-frame film viewer which provided accurate measurement of time and displacement with reference to the surface of the water.

RESULTS AND DISCUSSION

A summary of the test conditions is given in table II. These conditions represent the variables associated with a landing after a launch abort. Both the two-parachute and the nominal three-parachute landing modes were investigated.

All tests results are presented in figures 2, 3, and 4. These plots show the effect of the various test variables on the depth of dive for the Apollo command module. Shown in figure 4 are plots of dive depth versus velocity. These curves represent typical underwater velocities of the lowest point on the spacecraft. They were generated by plotting the underwater position of the model with respect to time and differentiating the resulting curve.

The majority of the test results indicate that the Apollo command module will penetrate the water at least 8 to 12 feet, and occasionally 14 to 17 feet. The deepest water penetration appears to result from a high-pitch, 180-degree roll, with a moderate-wind condition. From observations made of the impact behavior of the model during the test drops, it appears that higher wind velocities will result in less water penetration since the model tends to dish out, or tumble, rather than dive.

The tumbling of the model results in a greater possibility of its assuming a Stable II flotation attitude (apex-down). (Test drops resulting in a Stable II attitude are labeled "II" on the plotted data.) A side effect of underwater tumbling is the possibility of the upper deck striking bottom. This condition was observed on several drops. Figure 5 shows two typical drops that were recorded by the camera.

CONCLUSIONS

For analysis purposes, a penetration depth of at least 17 feet must be considered as a possibility for bottom contact with a two-parachute landing configuration. Also to be considered is that almost any underwater attitude may result from various combinations of wind, oscillation, roll, and pitch.

Using the probable dive depths of the Apollo command module and the corresponding velocity profiles, hydrostatic and dynamic pressures may be calculated. Also, underwater impact velocities for use in structural failure analyses and launch-area abort recovery planning may be predicted.

TABLE I.- SCALE RELATIONSHIPS

[S = Scale of model]

Quantity	Full size	Scale factor	Model
Length	L	S	SL
Area	A	S^2	S^2A
Weight	W	S^3	S^3W
Moment of inertia	I	S^5	S^5I
Time	T	$\sqrt{S}$	$\sqrt{S}\ T$
Speed	V	$\sqrt{S}$	$\sqrt{S}\ V$
Linear acceleration	a	1	a
Angular acceleration	α	S^{-1}	$S^{-1}\alpha$

TABLE II.- TEST PARAMETERS AND SPACECRAFT DATA

[Full-scale]

Test 1		Test 2	
Weight, lb	10 000	Weight, lb	11 344
Center of gravity, in.	X = 35.7	Center of gravity, in.	X = 37.7
	Y = 0.7		Y = 0
	Z = 4.4		Z = 4.3
Two-parachute landing			
Vertical velocity, ft/sec	33	Vertical velocity, ft/sec	37
Oscillation, deg	±8	Oscillation, deg	±8
Wind, ft/sec	0, 15, 30	Wind, ft/sec	20, 30
Roll, deg	0, 90, 180	Roll, deg	90, 135, 180
Three-parachute landing			
Vertical velocity, ft/sec	27	Vertical velocity, ft/sec	29
Oscillation, deg	±6	Oscillation, deg	±4
Wind, ft/sec	0, 15, 30	Wind, ft/sec	20, 30
Roll, deg	0, 90, 180	Roll, deg	90, 135, 180

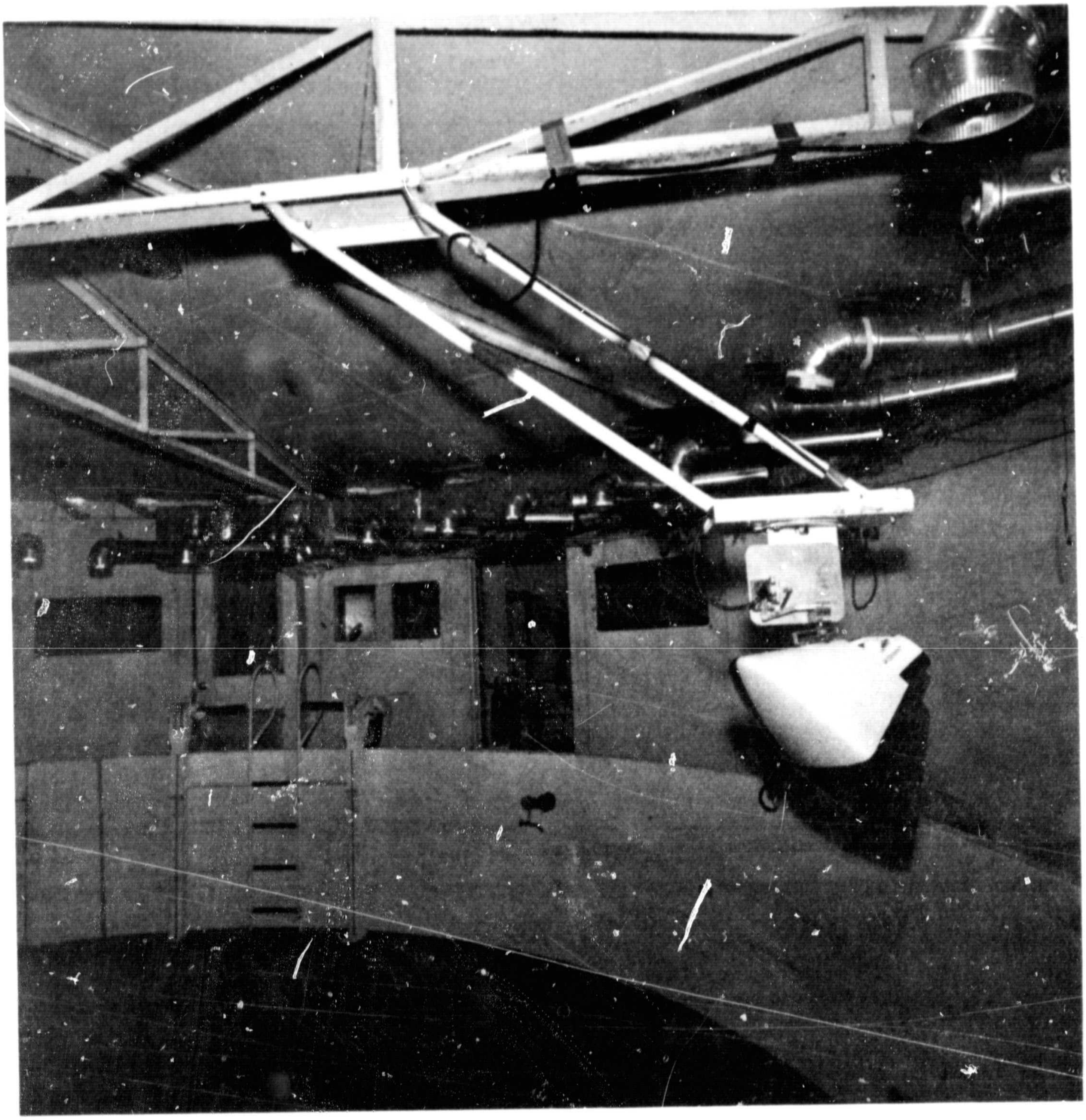
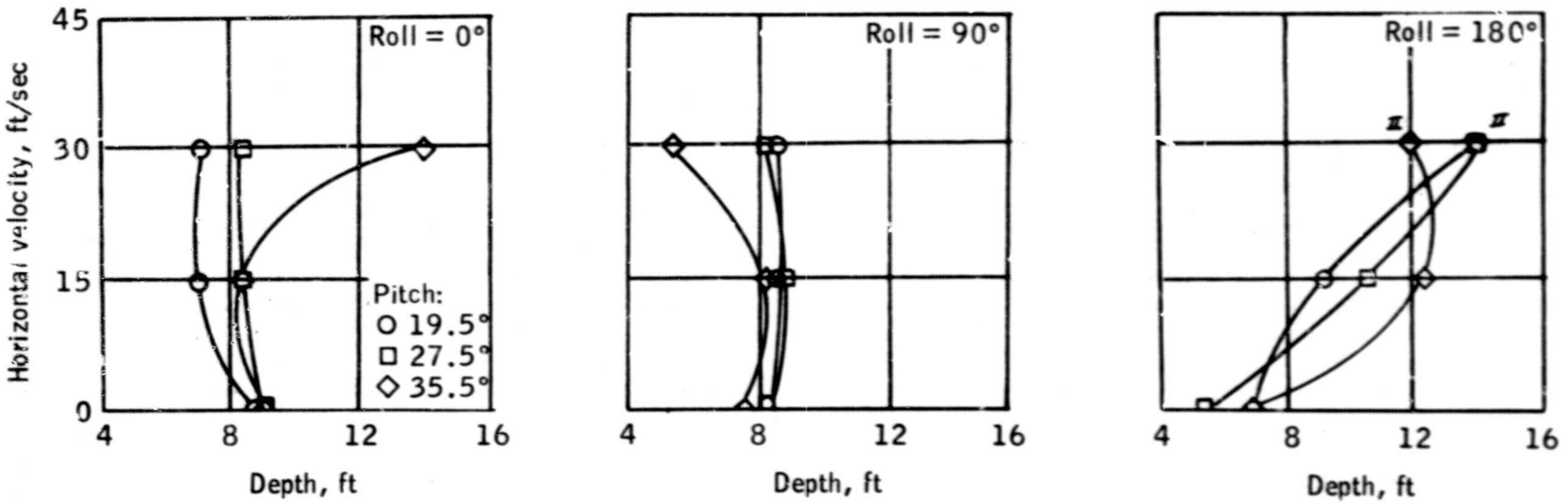
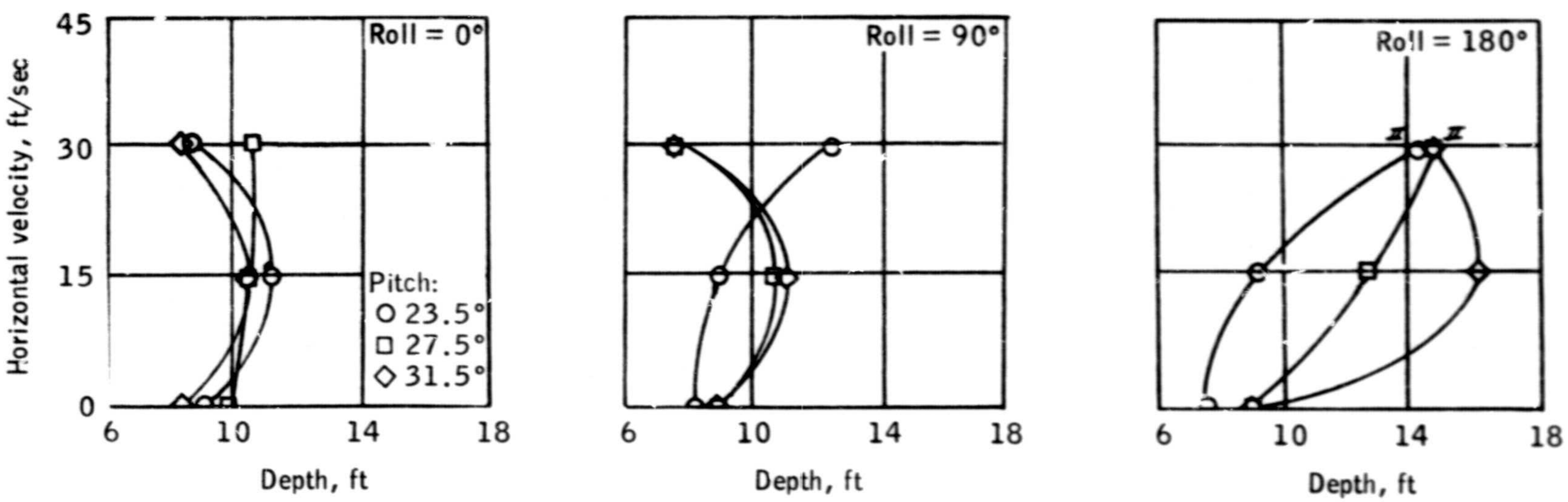


Figure 1.- Pendulum apparatus, model, and test tank.

Symbol II indicates an apex down flotation attitude



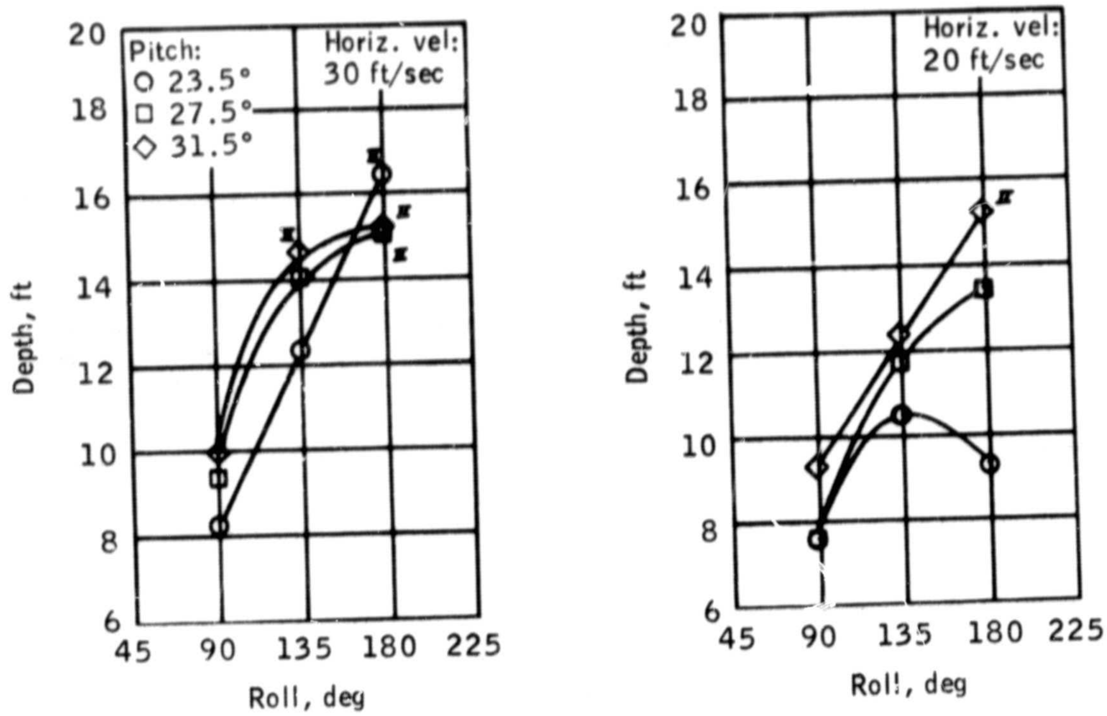
(a) Vertical velocity = 27 ft/sec.



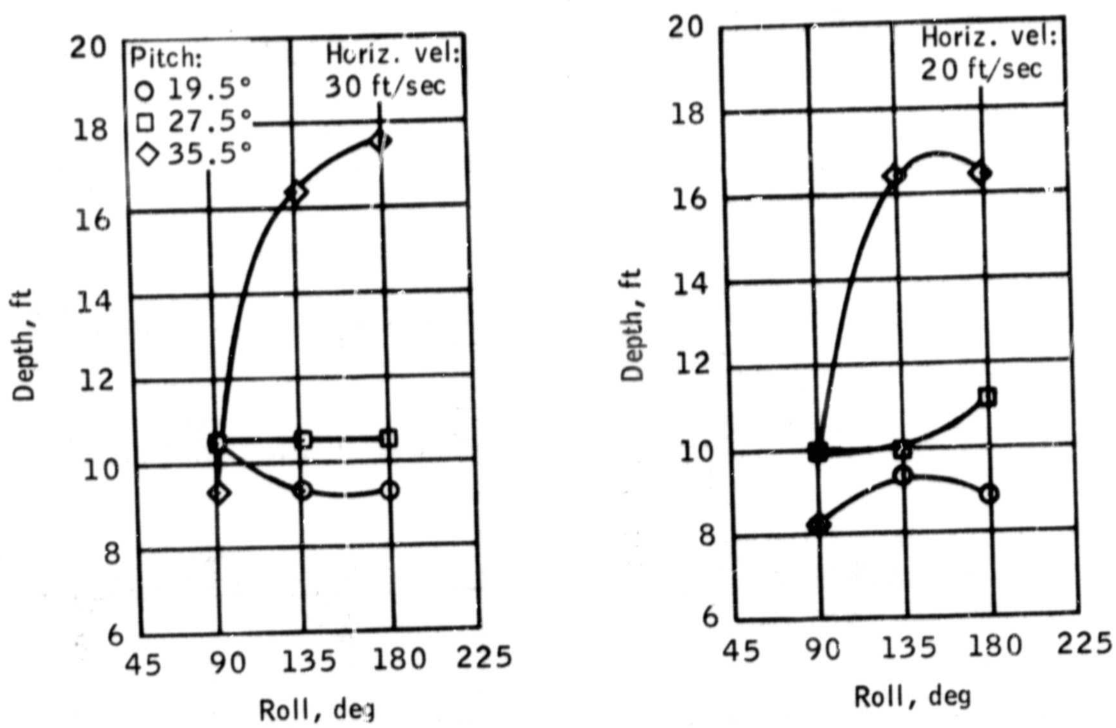
(b) Vertical velocity = 33 ft/sec.

Figure 2.- Apollo CM (1/7-scale) water penetration test series 1 data.

Symbol II indicates an apex down flotation attitude

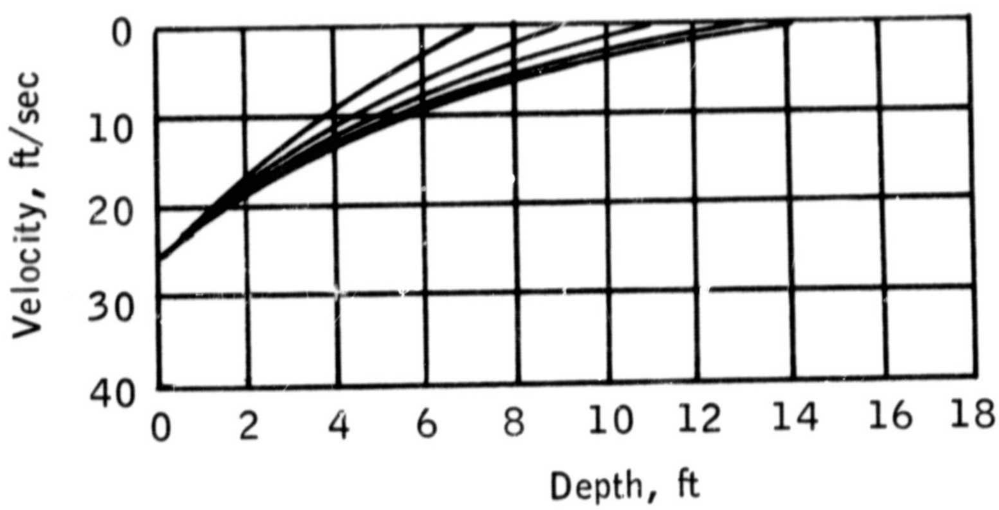


(a) Vertical velocity = 29 ft/sec.

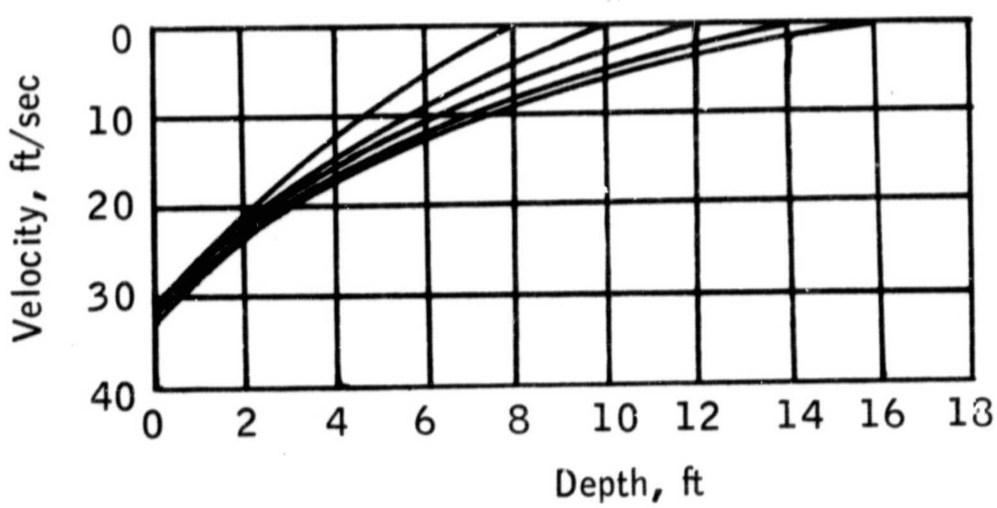


(b) Vertical velocity = 37 ft/sec.

Figure 3.- Apollo CM (1/7-scale) water penetration test series 2 data.



(a) Vertical velocity = 27 ft/sec.



(b) Vertical velocity = 33 ft/sec.

Figure 4.- Typical velocity curves — test series 1.

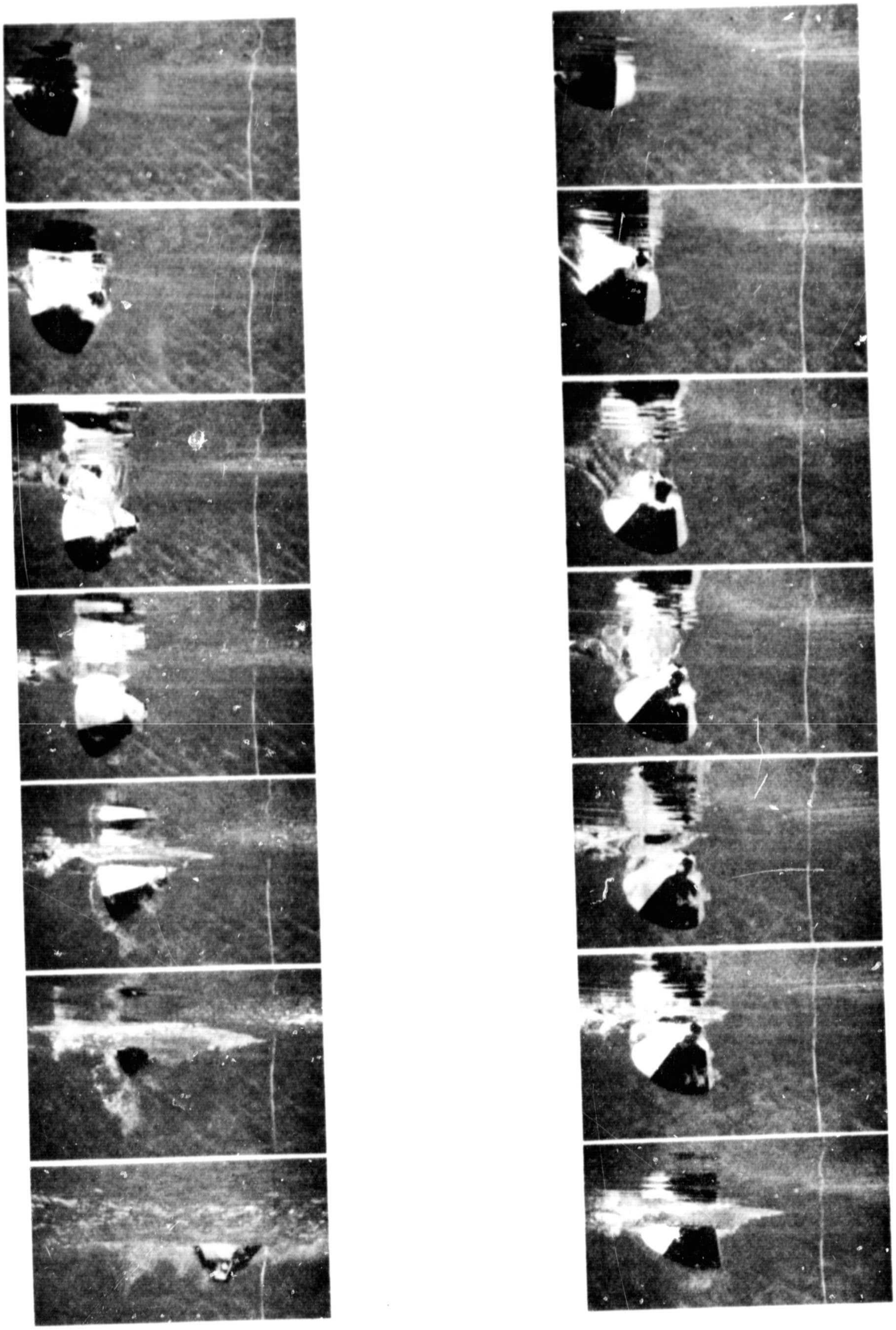


Figure 5.- Typical sequences.

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