NAVY DEPARTMENT
DAVID TAYLOR MODEL BASIN
WASHINGTON, D.C.

EXPERIMENTS IN PHOTOGRAPHIC MEASUREMENT OF VELOCITY AND ACCELERATION WITH THE TYPE P AIRPLANE CATAPULT

by

Lieutenant D.C. Campbell, USNR

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PERSONNEL

B.F. von Bernewitz, C.H. Bradley, J. Muller, PhoM 1/c, USNR, and Lt. D.C. Campbell, USNR, of the Photographic Development Section obtained the photographs. The data were analyzed and the report was written by Lieutenant Campbell.

EXPERIMENTS IN PHOTOGRAPHIC MEASUREMENT OF VELOCITY AND ACCELERATION WITH THE TYPE P AIRPLANE CATAPULT

ABSTRACT

Photographic studies were made of the action of the Type P airplane catapult to determine the usefulness of photographic investigation in problems of this kind.

The photographic records from a high-speed camera and an ultra-high-speed camera showed vibrations during the first 10 seconds of the run which may produce accelerations as high as 30 g. However, the accelerations of long duration were low enough so that there was no danger of "blackout" of airplane personnel. Time-position and time-velocity curves were plotted from the photographic records.

The work described in this report indicates that photographic studies of catapult action can be made to give information of any kinematic characteristics desired.

INTRODUCTION

As the result of recent damage to airplane structures during catapult launching, the Bureau of Ordnance requested the David Taylor Model Basin (1)* to make photographic studies of the Type P catapult. To determine the usefulness of a photographic investigation of catapult action, a series of 6 tests were conducted using high-speed and ultra-high-speed motion-picture recording. The results of these tests are presented for the purpose of study in the Bureau of Ordnance and Bureau of Aeronautics to determine whether the results warrant further tests of this kind.

GENERAL FEATURES OF TESTS

The tests described in this report were conducted in the Washington Navy Yard on a Type P6-3 airplane catapult. A dead load of 6800 pounds, shown in Figure 1, was catapulted into the Anacostia River from equipment set up on the river bank. The dead load was designed to have its center of gravity approximately the same height above the tracks as that of the OS2U airplane and other planes which are launched from the catapult.

The catapult employed a 6-inch 47-caliber breech mechanism. Powder charges corresponding in granulation to 6-inch 47-caliber charges and 16-inch 45-caliber charges were used.

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* Numbers in parentheses indicate references on page 9 of this report.

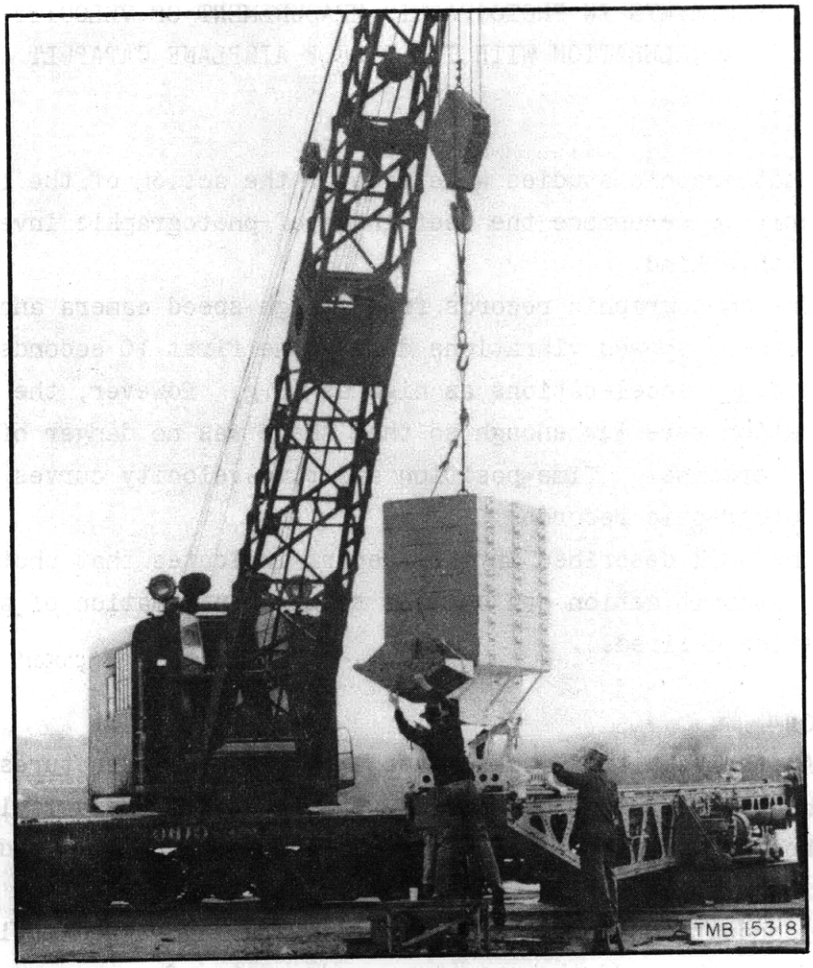

Figure 1 - Deadweight Load Being Lowered into Launching Position on the Catapult

The dead load weighed 6800 pounds and was designed to have its center of gravity correspond somewhat to that of the OS2U airplane. The catapult was set up so as to fire into the Anacostia River which can be seen in the background.

PHOTOGRAPHIC APPARATUS

Photographic records were made with a high-speed Mitchell motion-picture camera and an ultra-high-speed Eastman motion-picture camera. The cameras were located, as shown in Figure 2, approximately 170 feet from the side of the catapult.

The Mitchell camera ran at 120 frames per second and the Eastman camera ran at approximately 1350 frames per second. Timing of both records was obtained by placing a synchronous motor with a rotating disk in the field of view.

To provide a scale in the photographs, the horizontal frame supporting the catapult guide rails was painted white, with black lines at 6-inch

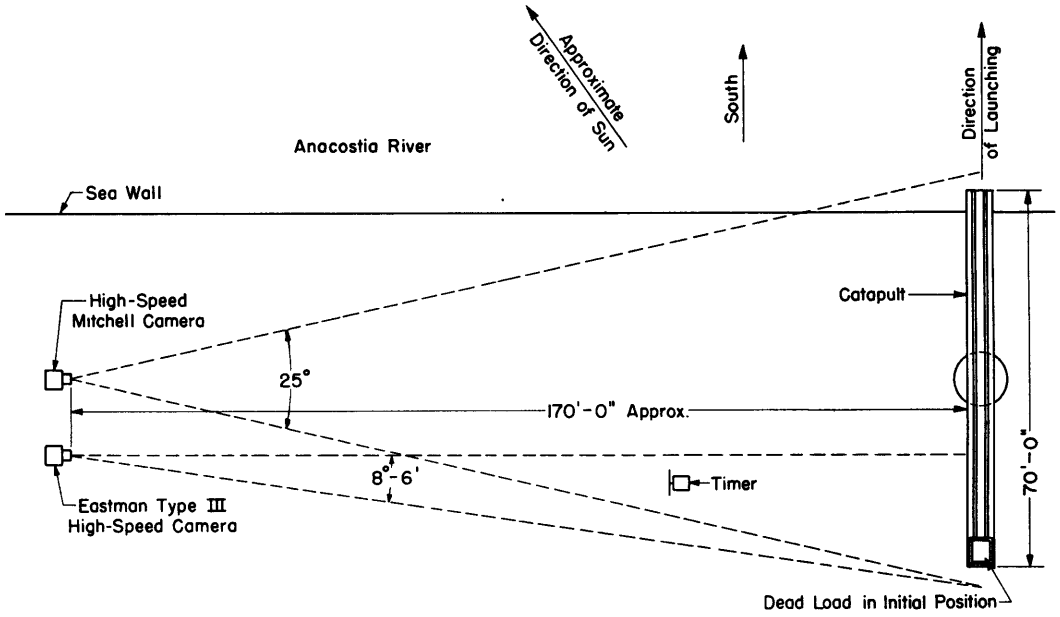

Figure 2 - Diagram Showing Location of Equipment for Catapult Launching Tests

The Mitchell camera used a 2-inch f/2.3 lens, the Eastman camera a 63mm f/2.7 lens. The coverage of both cameras is indicated by the broken lines.

intervals along the first 10 feet of its length and at 12-inch intervals over the rest of its length. A photograph showing the catapult and painted scale is shown in Figure 3.

TEST PROCEDURE

Short-wave radio communication was set up between the camera position and the catapult firing position. A verbal count was made by 1-second intervals from 10 down to 0. The Mitchell camera was started at 6 seconds, the Eastman camera started at 2 seconds, and the catapult was fired on the count of zero.

The Mitchell camera used 35mm Eastman Plus-X Panchromatic negative film. This was given normal development of 12 minutes in developer D-76. The Eastman camera employed Eastman Super-XX Panchromatic negative film and was given 50 per cent over-development, to a total of 15 minutes, in developer D-11.

TEST RESULTS

Good records were obtained from both cameras (2). The records and the analysis in this report were made from the Mitchell camera record. The greater speed of the Eastman record, approximately 10 times that of the

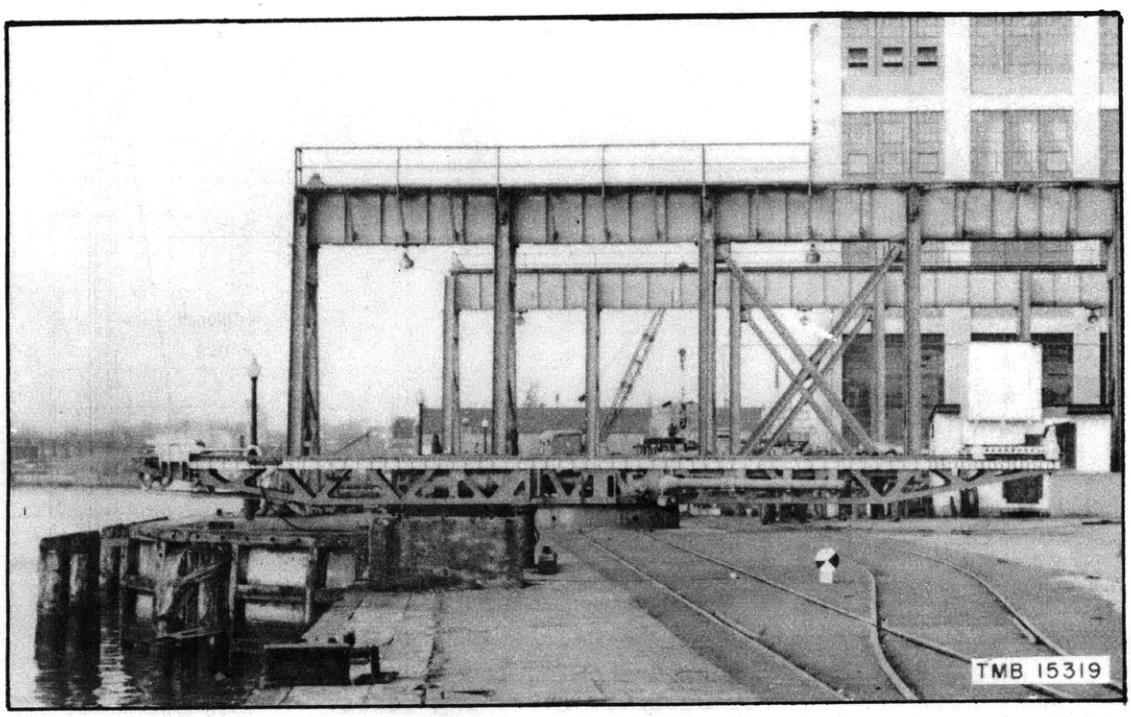

Figure 3 - Catapult on the Bank of the Anacostia River

The 6800-pound dead weight is at the head of the catapult to the right in the photograph. The side frame supporting the guide rails is painted with stripes at 6-inch intervals for the first 10 feet and at 12-inch intervals for the remaining 55 feet. The disk of the synchronous motor timer is seen in the right foreground.

Mitchell record, was found to be of no help since the higher-frequency motion which could be distinguished by higher-speed photography was of such magnitude as not to be resolved on the film. The Eastman record is interesting to view as a motion picture but was not used for analysis. Time-position and time-velocity curves for the six test runs are shown in Figures 4, 5, 6, 7, 8, and 9. The information derived from these experiments is presented in Table 1.

The catapult carriage starts its run with a jerky motion which lasts for approximately 1/10 second. Accelerations, perhaps as high as 30 g, are encountered during the 2 to 4 oscillations which take place. Camera resolution with the setup used in Figure 2 was not sufficiently clear to give complete information on the initial vibrations so that they are only approximated in the curves of Figures 4, 5, 6, 7, 8, and 9.

Measurement of accelerations of long duration gave a maximum of 2.82 g for Test 4 and a minimum of 1.16 g for Test 2. These accelerations are listed in Table 1.

Discussions with Dr. M.C. Shelesnyak at the Naval Medical Research Institute indicate that there is no danger of the accelerations found in these tests producing unconsciousness or "blackout" of airplane personnel. Blackout

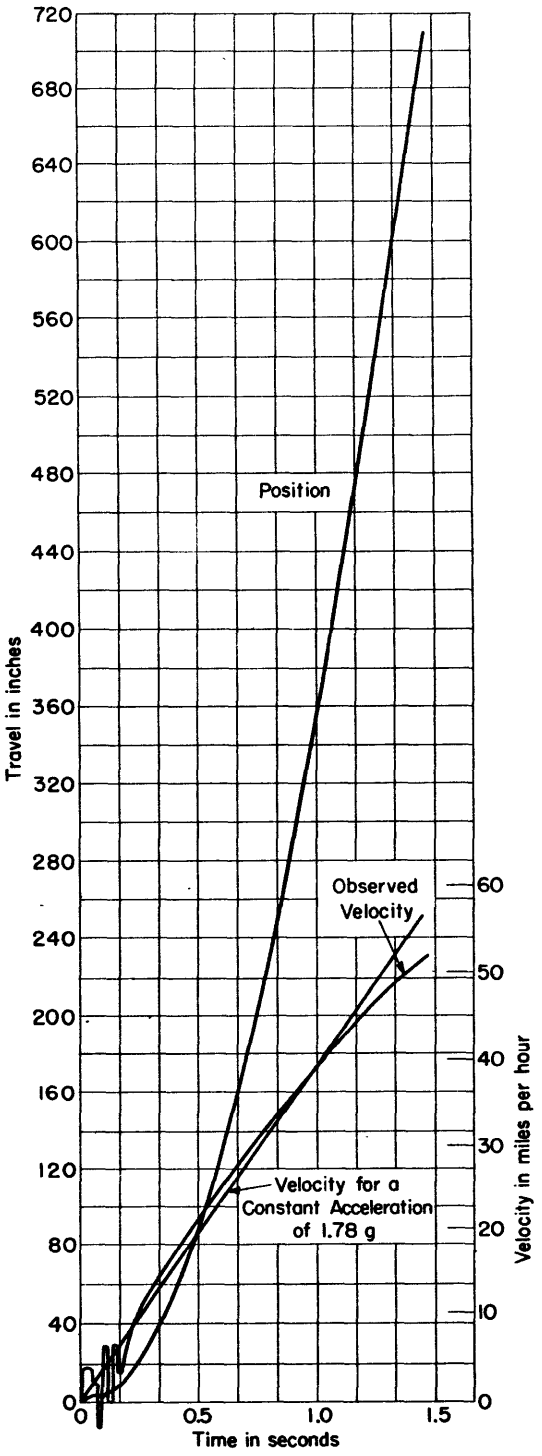

Figure 4 - Curves of Position and Velocity on Time for Test Run 1

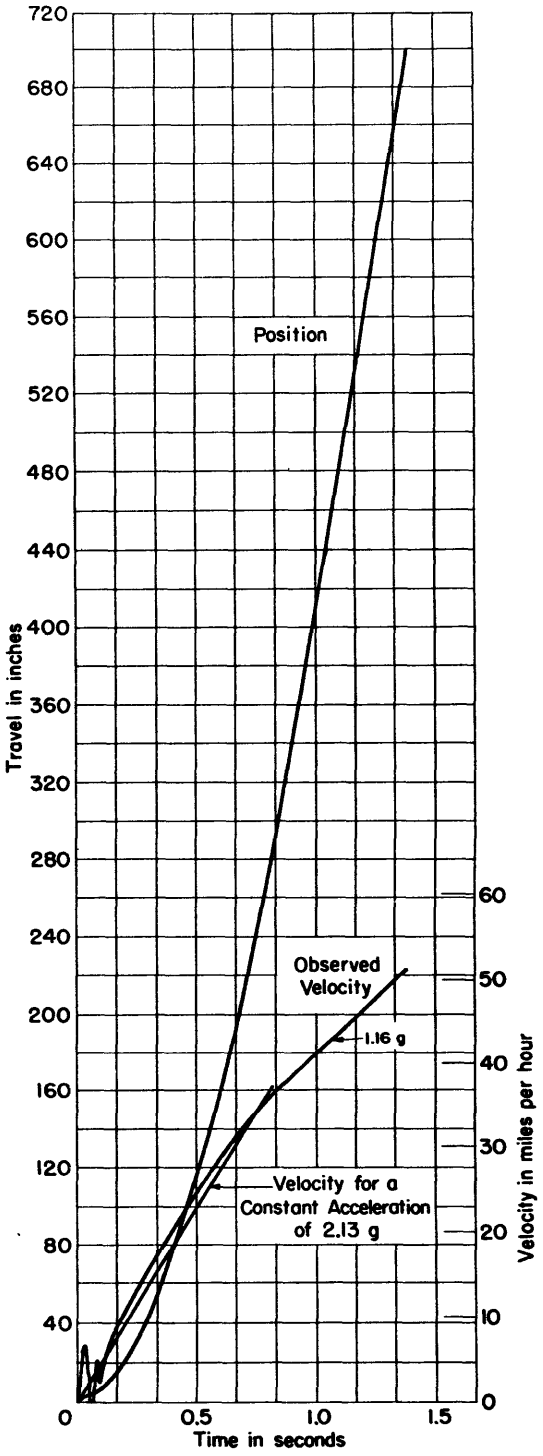

Figure 5 - Curves of Position and Velocity on Time for Test Run 2

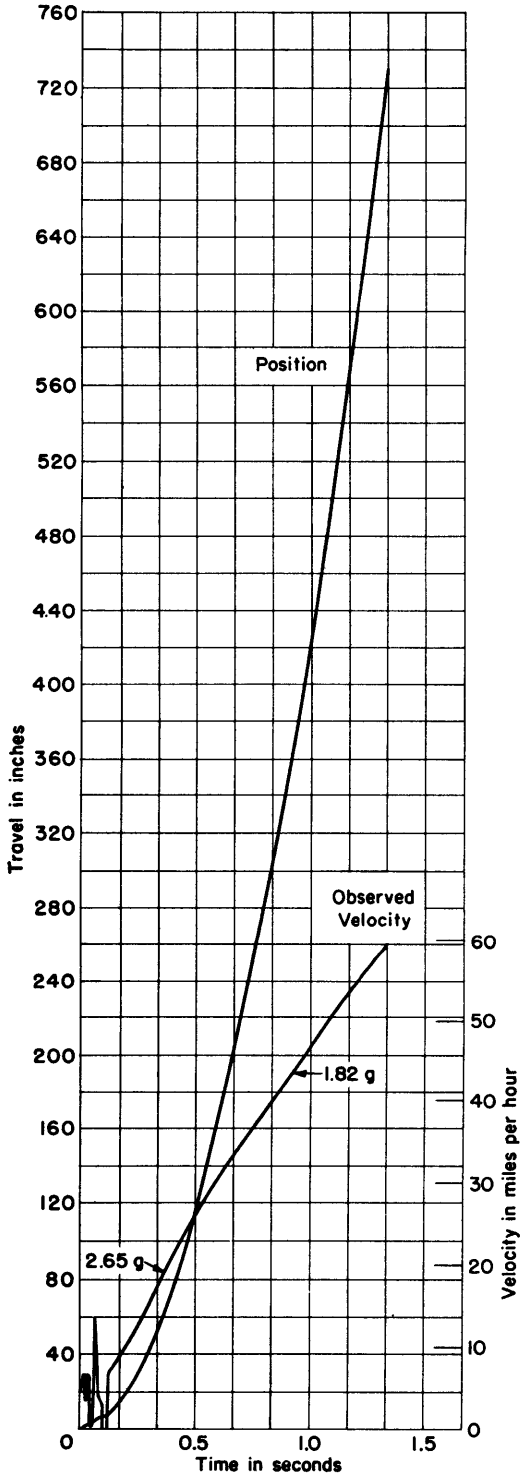

Figure 6 - Curves of Position and Velocity on Time for Test Run 3

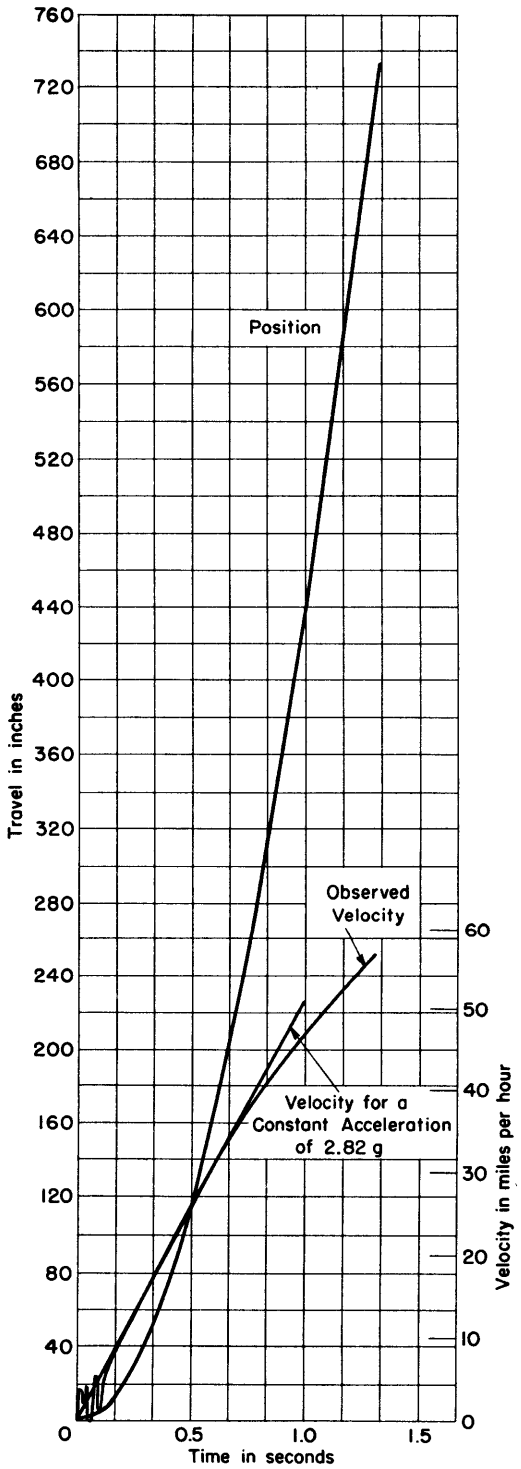

Figure 7 - Curves of Position and Velocity on Time for Test Run 4

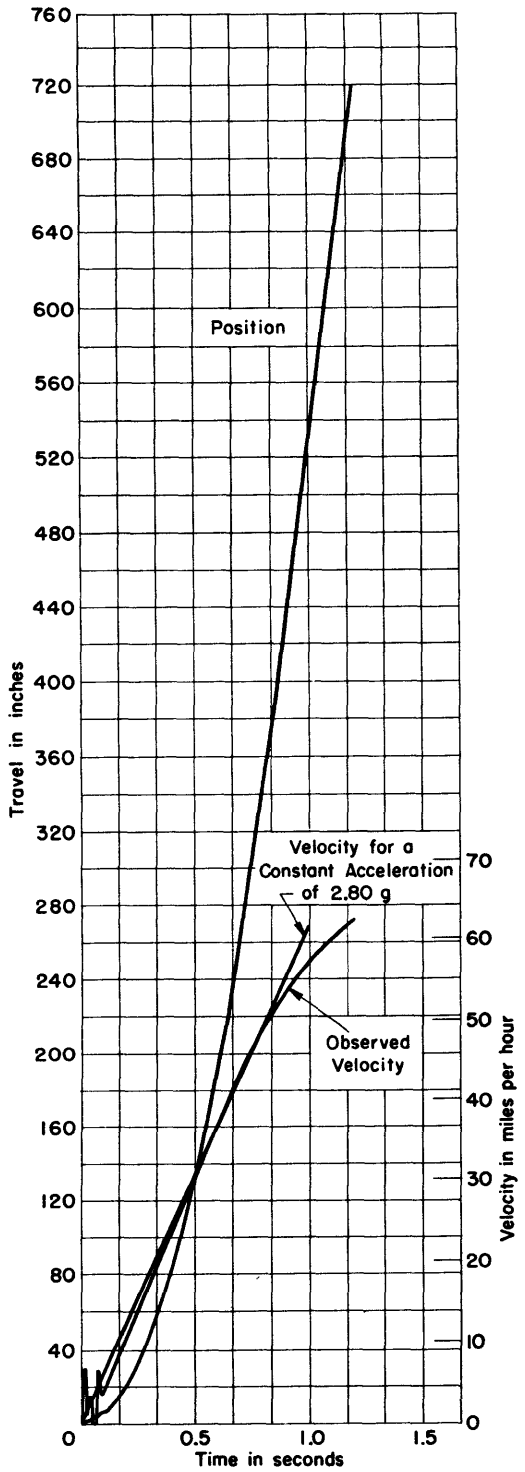

Figure 8 - Curves of Position and Velocity on Time for Test Run 5

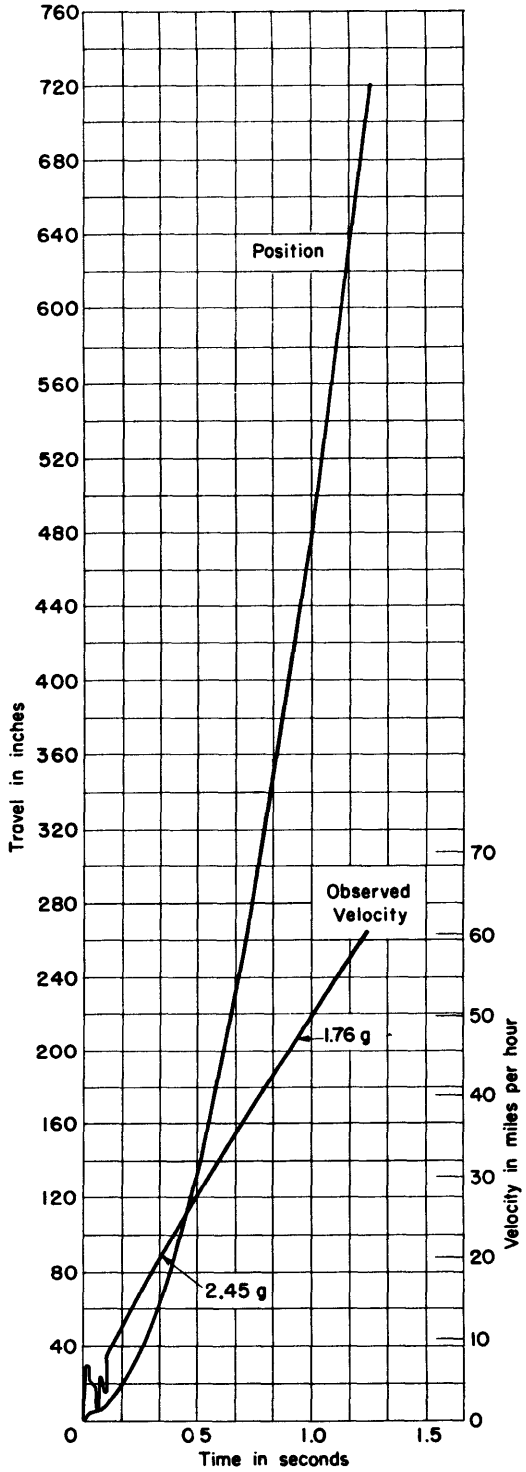

Figure 9 - Curves of Position and Velocity on Time for Test Run 6

TABLE 1

Data from Mitchell Camera Record

Test	Charge (Powder Granulation)			Flight Speed miles per hour		Accelerations of Long Duration g	Parabolic Constant $p = \frac{t^2}{2s}$ sec²/inch
	Diameter of Gun inches	Caliber	Weight pounds	Estimated	Observed		
1	16	45	19.75	52	52.0	1.78	0.00145
2	6	47	19.75	52	50.8	2.13 to 1.16	0.00121
3	16	45	20.75	54	59.1	2.65 to 1.82	
4	6	47	20.75	54	57.6	2.82	0.00110
5	16	45	24.75	60	61.0	2.80	0.00093
6	6	47	24.75	60	60.0	2.45 to 1.76	

is dependent on many things: The physical condition of the person involved, the position, tension of the muscles, relative height of heart and head, and period of time over which the acceleration is applied. A general rule indicates that an individual subjected to an acceleration of 4 g for 6 or 7 seconds will reach a condition of partial unconsciousness or "gray out".

The maximum velocities of the carriage taken after a travel of 52 feet were within a 2 1/2 per cent deviation of the final estimated velocities furnished by the Bureau of Ordnance. These velocities are given in Table 1.

The time-position curves of Records 1, 2, 4, and 5 were found to closely approach a parabola having the form

$$t^2 = 2ps \qquad [1]$$

When t is the time in seconds and s is the displacement in inches, p is found to range between 0.0009 sec²/inch and 0.0015 sec²/inch. These constants are presented in Table 1.

Differentiating Equation [1] $2t\,dt = 2p\,ds$, we can determine velocity

$$v = \frac{ds}{dt} = \frac{t}{p} \qquad [2]$$

For Records 1, 2, 4, and 5 the curve of velocity as a function of time is plotted from Equation [2]. These theoretical velocity curves are all in fair agreement with the observed velocity curves from times of 1/10 to 3/4 second.

Differentiating the velocity curve of Equation [2] the acceleration may be directly determined

$$a = \frac{dv}{dt} = \frac{d^2s}{dt^2} = \frac{1}{p}$$

CONCLUSIONS AND RECOMMENDATIONS

The work described in this report indicates that photographic studies of catapult action can be made to give information of any kinematic characteristics desired.

Vibrations producing high accelerations during the first 1/10 second are shown. Information as to the exact movements during this initial period can be obtained by close-range high-speed motion pictures.

It is recommended that further tests be run under conditions similar to those in Figure 2 with the Eastman high-speed camera placed 50 feet from the catapult so as to cover the action during the initial 10 feet of movement.

REFERENCES

(1) Bureau of Ordnance ltr. NP21(Re2a) of 8 January 1945 to TMB.

(2) Film on file at The Taylor Model Basin: 16mm Eastman, TMB Serial M-1136; 35mm Mitchell, TMB Serial M-1135.