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# OPERATION PLUMBBOB

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Project 26.4f

PHOTOGRAPHIC ANALYSIS OF EARTH MOTION,  
SHOT RAINIER

Issuance Date: July 7, 1958

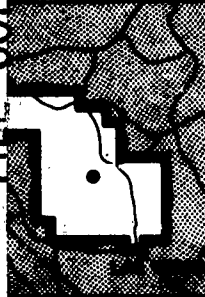
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~~Report to the Test Director~~

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**PHOTOGRAPHIC ANALYSIS OF EARTH  
MOTION, SHOT RAINIER.**

~~By~~

Staff of Edgerton, Garmeshausen & Grier, Inc.

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(5)

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~~Boston, Massachusetts and Las Vegas, Nevada~~  
May 1958

**ABSTRACT**

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The purpose of Project 26.4f was to record photographically earth motions resulting from the underground detonation of the Rainier device. A reference light on a tower near Surface Zero was observed to rise nine inches at 390 msec after zero. This result is in agreement with results obtained by other projects under Program 26.

↑

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**OPERATION PLUMBBOB - PHOTOGRAPHIC ANALYSIS OF EARTH  
MOTION - SHOT RAINIER PROJECT 26.4f**

**1. OBJECTIVE**

Project 26.4f was required to provide photographic coverage of the area in the neighborhood of Surface Zero on the underground shot, Rainier. This coverage was intended as back-up for other projects under Program 26. The project was required to provide analysis of the film records only in the event that corroboration of other results was desired.

**2. INSTRUMENTATION**

The major points of interest were the tunnel portal and a point halfway up the east slope of the mesa, at which point the device was closest to the surface. Additional points were located along two lines up to 800 ft distant from Surface Zero. To accomplish the photography of these areas, three photostations were selected, as shown in Fig. 1. Station Les, on a ridge east of the tunnel portal, was intended to record action at the portal and the weak spot halfway up the slope. Station Doe, located on top of the mesa about 9000 ft northwest of Surface Zero, was placed so as to obtain maximum record time before the ground shock disturbed the camera truck. Cameras at this station photographed an 800-ft line of targets running west from Surface Zero. The third station, Station Kump, was located about 4000 ft south of Surface Zero. This station photographed a 400-ft line of targets running south from Surface Zero. It also recorded a side view of the action on the slope and at the tunnel portal. Table 1 lists the cameras and their primary objectives for the three photostations.

To cover the possibilities of ground excursion from a few inches to several feet over time intervals (during which the motion took place) from less than a second to several seconds, it was necessary to provide frame rates and lenses for a wide range of action. In general, cameras with long focal length lenses were set to record short, rapid motions, while cameras with shorter focal length lenses were employed to record gross motions.

Since the shot was to be fired at about 1000 PDT, cameras at Station Doe would be facing directly into the sun. To overcome the effects of the resultant back-lighting and reduced contrast, it was

Table 1 - CAMERA SUMMARY FOR PROJECT 26.4f

Station	Camera	Lens		View
		Focal Length (mm)	Speed (frames/sec)	
Les	Eastman	25	1000	Weak spot
	Eastman	25	1000	Portal
	Mitchell	50	100	Portal, weak spot, 12-300
	Mitchell	35	24	Portal, weak spot, 12-300
Doe	Mitchell	305	100	SZ towers
	Mitchell	305	100	SZ towers
Kump	Eastman	63	1000	SZ
	Eastman	63	1000	Weak spot
	Mitchell	75	100	SZ general
	Mitchell	152	100	Weak spot
	Mitchell	305	100	SZ towers
	Bell & Howell	50	24	SZ, weak spot

decided to use three 300-watt lamps on top of each of the towers being photographed. Two of the lamps were aimed toward the station primarily photographing that line, and the third was aimed toward the station photographing the other line. The towers themselves were 17 ft high, to insure that the targets would be visible over the 12 ft of scrub vegetation on the slope. Since there was a possibility of failure of the lights, the towers were draped with salvage white parachute nylon and the tower legs were painted white for better visibility.

Because no light from the device itself was expected, an alternate means of recording the time of the detonation on film was required. A board was placed near Surface Zero with flash bulbs facing Stations Kump and Doe. The bulbs, fired on the zero signal, gave a visible light flash which was recorded on the film.

Each photostation consisted of one 6 x 6 truck in which the cameras were mounted. A generator at each station provided 120 v dc to the cameras. Timing signals to start and stop the cameras were automatic. The high-speed cameras used 200-cycle markers to record camera speed; the low-speed cameras used similar 12.5-cycle markers.

### 3. RESULTS

Only one of the film records, EG&G Film No. 43773, was suitable for earth motion analysis. This film, exposed at Kump Station, was obtained by a Mitchell camera equipped with a 305-mm focal length lens and running at 100 fr/sec. A combination of factors prevented usable information from being recorded by the other cameras. The shorter focal length lenses used on the other cameras at Kump Station and on all the cameras at Les Station, coupled with the low magnitude of the motion itself, caused these records to show only a slight movement of the reference light. The motion was so slight that no accurate



measurements were possible. At the third station, Doe, these factors were complicated by the additional distance of this station from Surface Zero.

Analysis of the one suitable record indicates that the maximum change in level of the reference light was a rise of 9 in., occurring at 390 msec. The raw data show considerable scatter, undoubtedly attributable to fluctuations in the position of the film at the gate and to consequent movement of the reference edge of the frame. To enable a best fit curve to be constructed through the measured points, the data were smoothed by an increment method defined in the Appendix. Figures 2, 3, and 4 show the displacement of the light vs time. Figure 2 shows the raw data points; Fig. 3 shows the same points plotted together with the smoothed data points; and Fig. 4 shows only the smoothed data points. The curve of displacement vs time is the same for all three plots.

Deflections were measured from the edge of the frame, and the film measurement was related to actual motion of the reference light by the photogrammetric formula

$$d = \frac{R_{oa}}{f} (x - x_0) \quad (1)$$

where  $d$  = displacement of the light from the pre-shock arrival position (in.)

$x$  = measured position of the light with respect to the frame edge ( $10^{-3}$  in.)

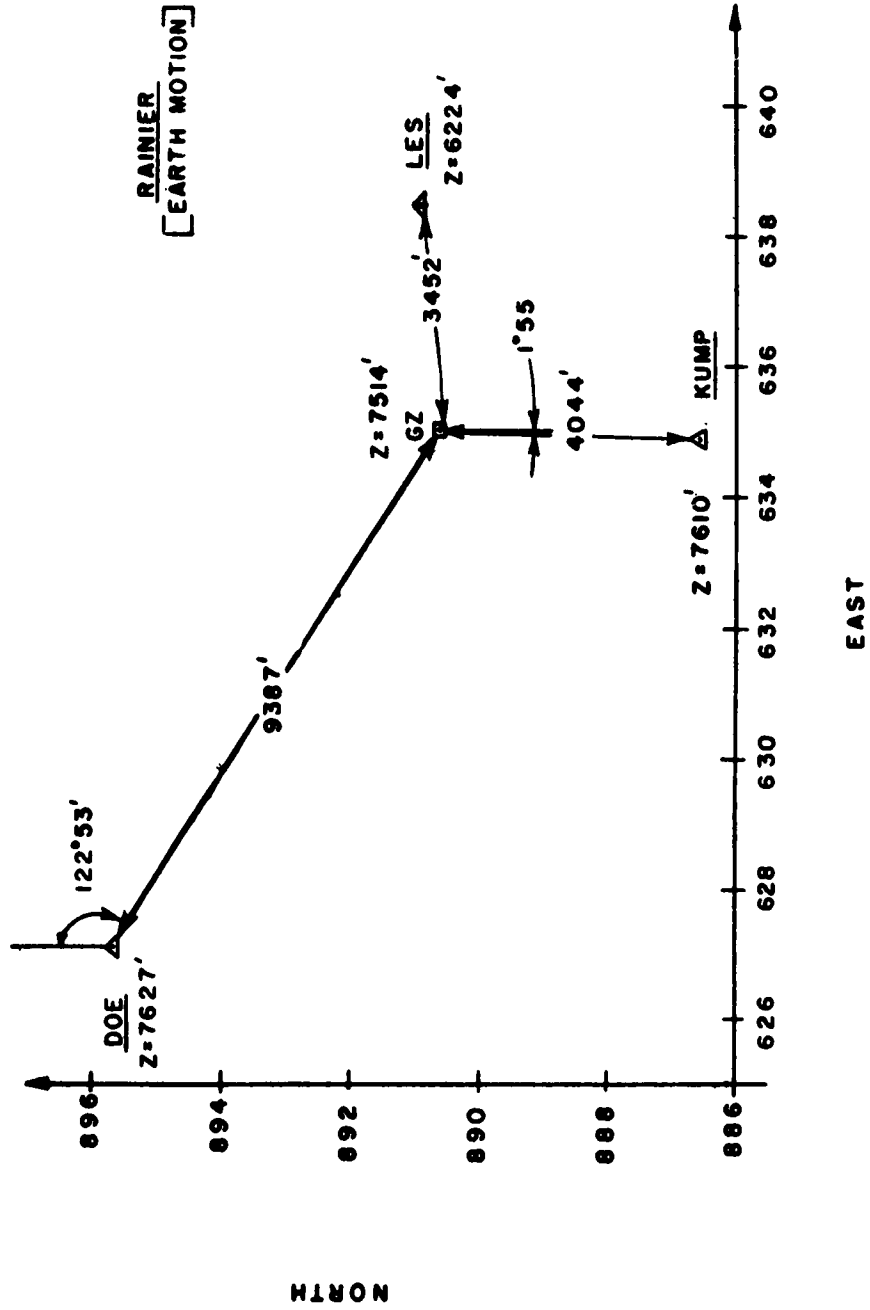
$x_0$  = stable position of the light with respect to the frame edge ( $10^{-3}$  in.)

$R_{oa}$  = range along the optical axis (m)

$f$  = lens focal length (mm)

Although expansion of the shock wave along the surface of the ground was apparent both in the original negative and in projection prints when these were inspected at normal speeds, it could not be resolved in a frame-to-frame analysis; therefore, no measurements of shock wave propagation could be made.

KUMP  
6 X 6 #1      LES  
6 X 6 #2      DOE  
6 X 6 #3



Coordinates in thousands of feet, NTS grid system.

Fig. 1 - Station layout for Project 26.4f.

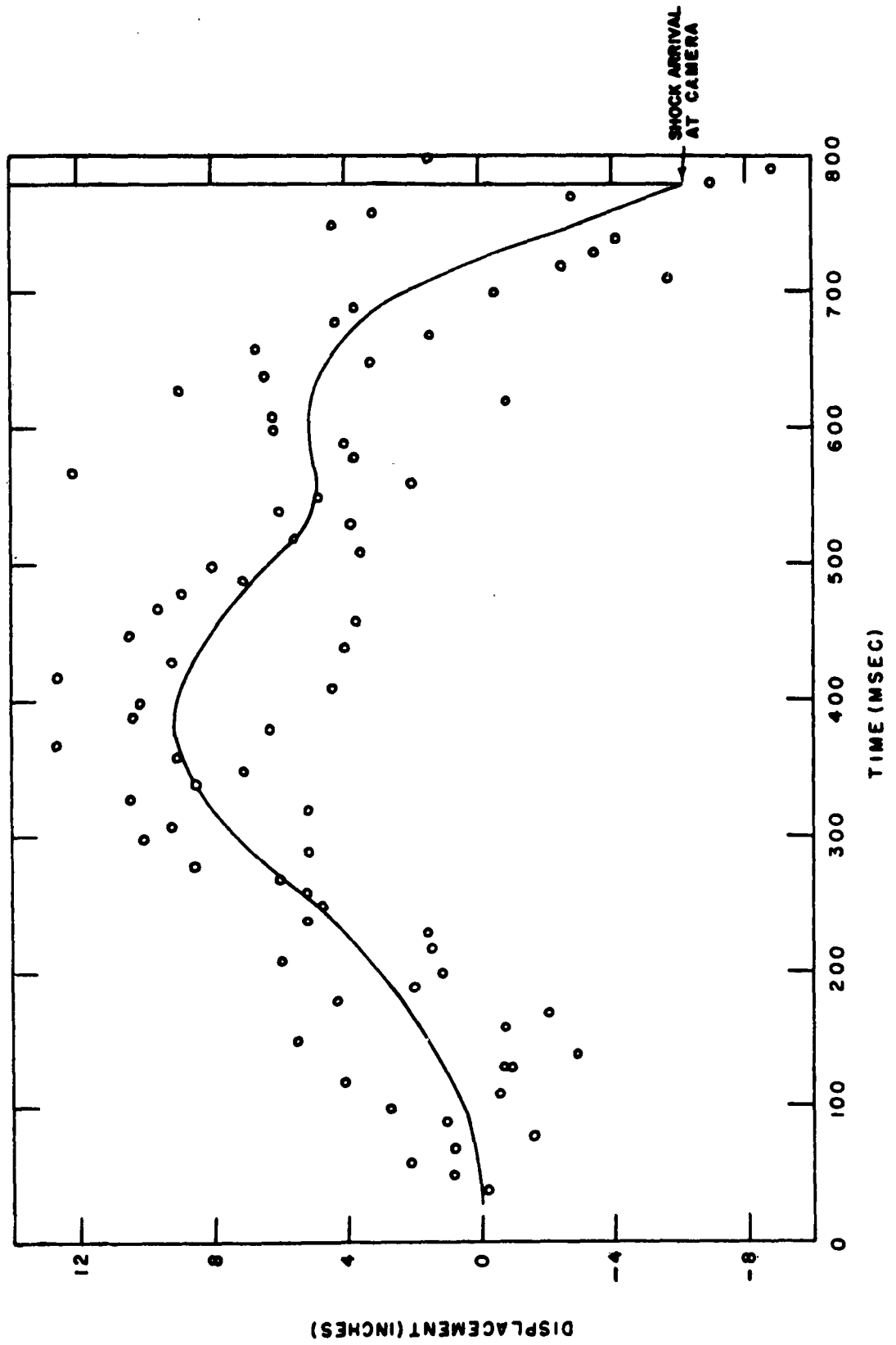


Fig. 2 - Displacement of reference light vs time (raw data points).

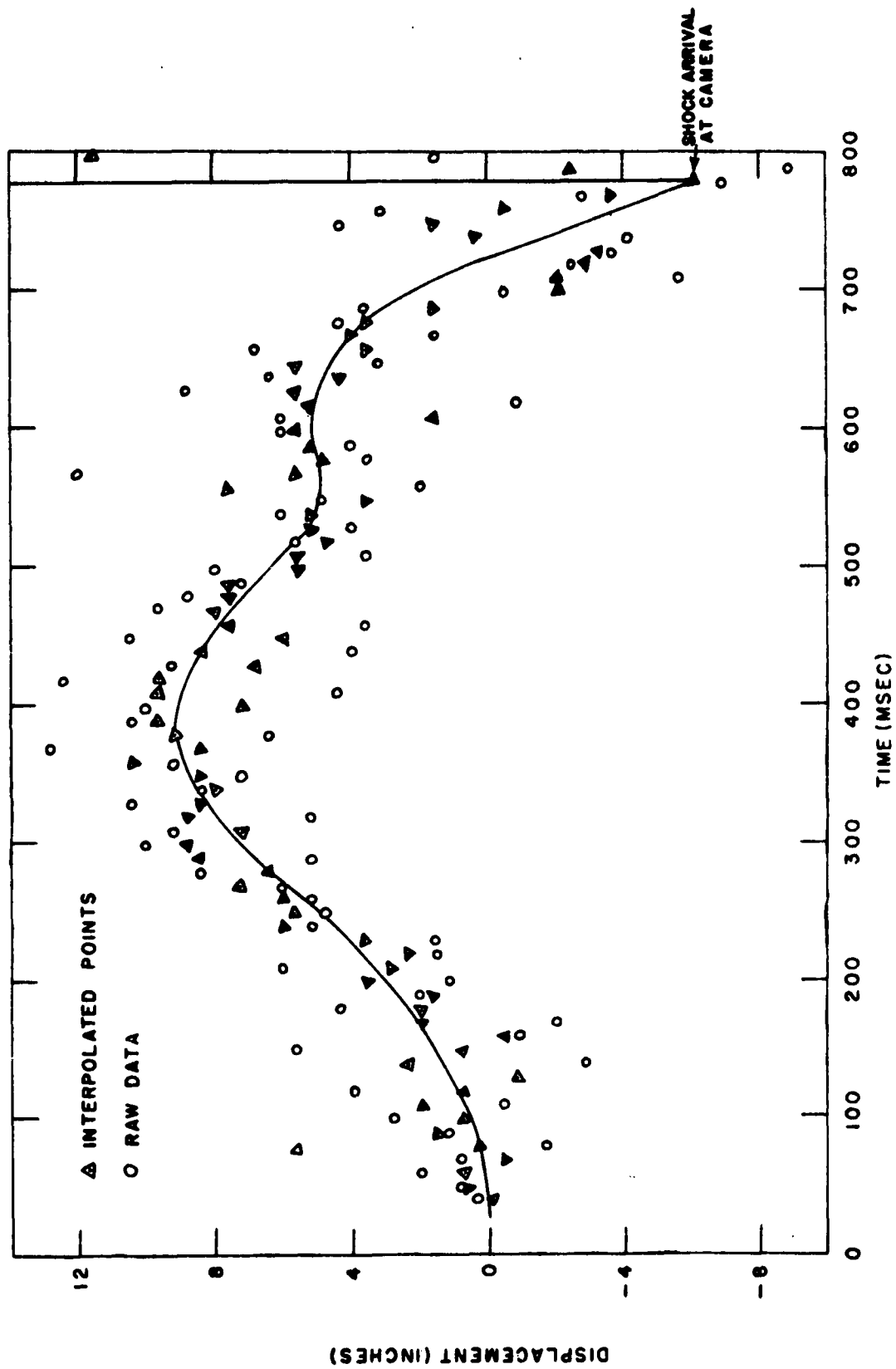


Fig. 3 - Displacement of reference light vs time (raw data points and interpolated points).

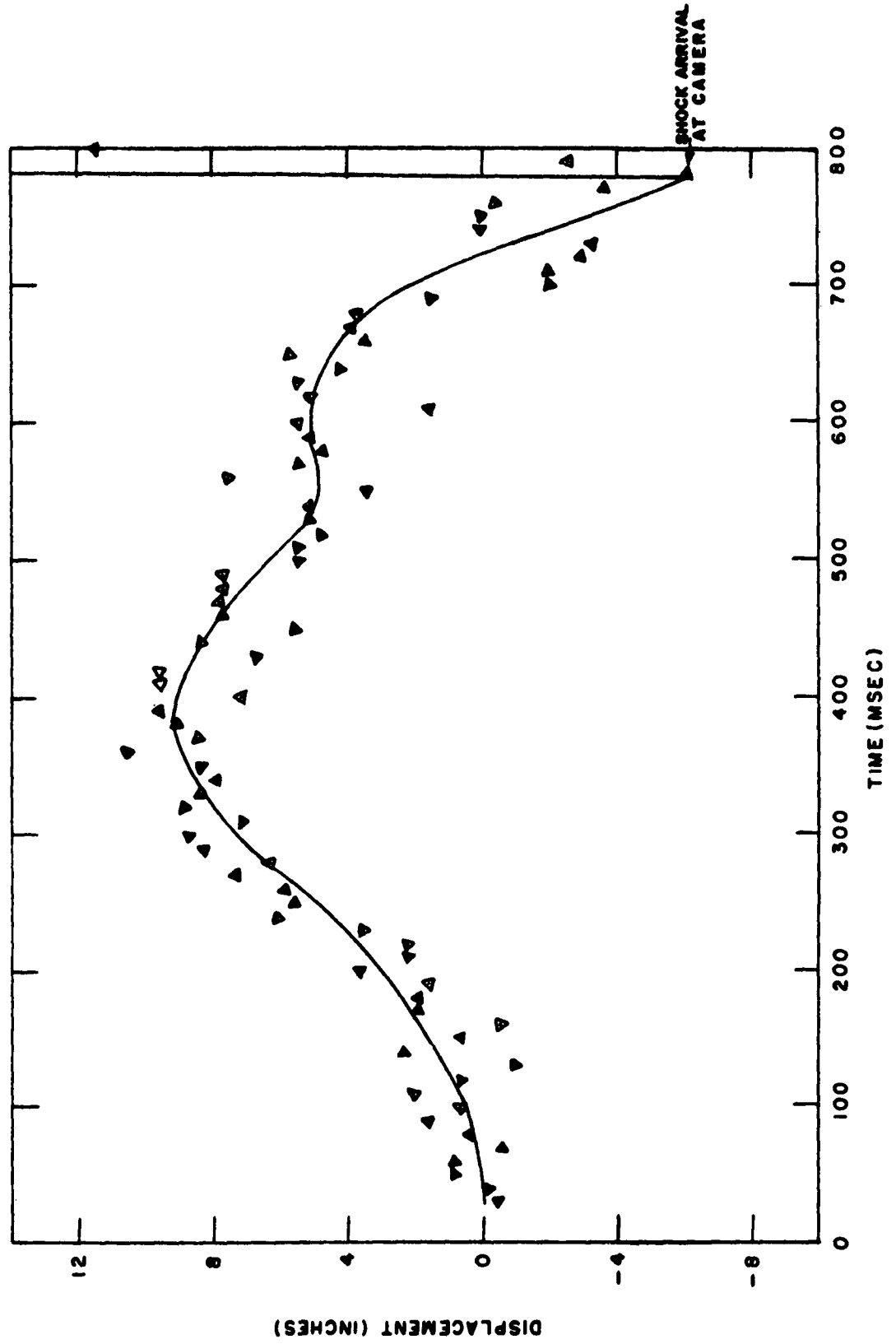
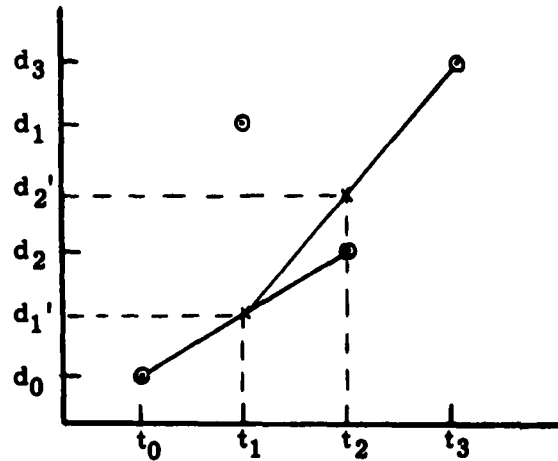


Fig. 4 - Displacement of reference light vs time (interpolated points).

## APPENDIX

### CURVE SMOOTHING WITH UNEQUAL INCREMENTS OF $t$



$d_0, d_1, d_2 \dots d_n$  denote raw data points.  $d_1', d_2' \dots d_n'$  denote data points obtained by smoothing function at times  $t_1, t_2 \dots t_n$ .

Since  $d_0, d_1'$  and  $d_2$  lie on a straight line, it follows that:

$$\frac{d_1' - d_0}{t_1 - t_0} = \frac{d_2 - d_1'}{t_2 - t_1}$$

hence

$$d_1' = \frac{d_2 (t_1 - t_0) + d_0 (t_2 - t_1)}{t_2 - t_0}$$

and

$$d_2' = \frac{d_3 (t_2 - t_1) + d_1' (t_3 - t_2)}{t_3 - t_1}$$

$$d_n' = \frac{d_{(n+1)} (t_n - t_{(n-1)}) + d'_{(n-1)} (t_{(n+1)} - t_n)}{t_{(n+1)} - t_{(n-1)}}$$

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