STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS
DIVISION OF HIGHWAYS

A REPORT OF A SURVEY OF TRAFFIC VIBRATIONS AND THEIR PROBABLE EFFECTS ON THE CROCKER ART GALLERY

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State of California
Department of Public Works
Division of Highways
Materials and Research Department

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Mr. A. S. Hart
District Engineer
District III
Division of Highways
Marysville, California

Dear Sir:

Submitted for your consideration is:

A REPORT OF

A SURVEY OF TRAFFIC VIBRATIONS

AND THEIR PROBABLE EFFECTS

ON THE CROCKER ART GALLERY

Study made by . . . . . Structural Materials Section
Under general direction of . . . . . J. L. Beaton
Work supervised by . . . . . J. E. Barton
Report prepared by . . . . . J. E. Barton and W. Chow

F. N. Hveem
Materials and Research Engineer

JEB/WC:mw
cc: JCWomack
JWTrask
Dist. III (6)

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I. INTRODUCTION

This survey was initiated by Alan S. Hart, District Engineer, District III, to study the possible effect of vibrations from future heavy freeway traffic on the Crocker Art Gallery. The Director of the Crocker Art Gallery and Members of the Historic Landmarks Commission have expressed concern that the proposed freeway, Route 238, truck traffic vibrations might cause structural damage to this historic building.

A part of a resolution from The Landmarks Commission to the Sacramento City Council reads ..... ".....there may be great danger that the vibrations from heavy traffic on the freeway would soon damage and make unsafe the foundations and structure of the gallery.....".

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II. CONCLUSIONS

The vibrations caused by heavy traffic on a freeway at the presently assumed position of Route 238 could not affect the Crocker Art Gallery.

This opinion is based on traffic induced vibrations measured during this study and the following facts:

1. The nearest assumed roadway of Route 238 is approximately 600 feet from the Crocker Art Gallery.

2. The earth surrounding the Art Gallery absorbs all earth borne truck traffic induced vibrations within 115 feet.

   Even if the freeway were built within 115 feet of the Gallery, the magnitude of the truck traffic vibrations would be structurally insignificant.

It was noted during this study that while no traffic induced vibrations could be measured within the building, pedestrian traffic within the building did cause noticeable deflections and vibrations on the second floor.

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III. SURVEY

District III has assumed that south of P Street the proposed freeway will be on an elevated structure and north of P Street the proposed freeway could be constructed on either earth fill or a viaduct.

With the above considerations in mind, the Yolo Causeway (see Exhibit 1 in Appendix), which is an elevated structure, and a section of earth filled structure (see Exhibit 5) was selected as typically representative of the proposed type of construction for a vibration study. The locations were selected so that the soil condition would be somewhat similar to that found at the Crocker Art Gallery.

A survey of earth borne vibrations due to truck traffic was conducted at the above mentioned locations.

At the Yolo Causeway, an elevated structure supported on concrete piles, one vibration tester (accelerometer) was placed directly beneath the structure on the ground (Exhibit 2) and two vibration testers were placed in line and normal to the Causeway and 65-feet and 115-feet away from the first vibration tester respectively.

The vibration testers picked up earth borne vertical vibrations due to traffic and the vibrations were automatically recorded on an oscillograph.

Each time a truck traffic vibration record was made the truck causing the vibration was also logged. This gave us our correlation between vibrations and the cause of the vibrations.

Examination of Table I, Yolo Causeway Vibration Measurements at Stations 152 - 153, shows that the average peak to peak displacement directly beneath the causeway due to truck traffic was 0.0004 inches. The average displacement frequency was 20 cycles per second. The average drop off in peak to peak displacement 65 feet away was 50% or 0.0002 inches. The average displacement frequency was 18 cps. The drop off in peak to peak displacement at 115 feet away was to zero as measured by our vibration testers.

At stations 285 - 286, Yolo Causeway, the average peak to peak displacement directly beneath the causeway due to truck traffic was 0.00036 inches. The drop off at 65 feet and 115 feet was to zero as measured with our vibration testers. A typical vibration trace caused by a vehicle at this location is shown by Exhibit 3.

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A fill structure located on Highway 40, approximately 1 mile west of the Sacramento Tower Bridge, Station C 176+25 was selected as typically representing the type of fill that might be placed near the Gallery. This fill structure is approximately one mile long and 15 feet high.

A survey of truck traffic vibrations was conducted at this location. Two vibration testers were located in line and normal to the eastbound lanes of Highway 40. Location Map II (Exhibit 5) shows their exact location.

Examination of Table II (Exhibit 8) shows that the average ground peak to peak displacements due to truck traffic at Locations E was 0.00009 inches. The average displacement frequency was 23 cps. The drop off at 100 feet, except Run #11, was to zero.

A preliminary visual inspection was conducted both inside and outside of the Crocker Art Gallery in order to select the best locations for the truck traffic vibration survey. It was noted that the second floor gallery entrance into the main art exhibition room vibrated very noticeably with foot traffic.

An intensive vibration study was made at the Gallery Annex due to its close proximity to 3rd Street on which heavy truck traffic is now carried. (See Exhibits 9 through 16).

Vibration testers were set up to measure vertical, horizontal, and transverse vibrations in the basement window sills of windows 2 and 4, inside the Art Gallery, as shown on Map III (Exhibit 9). Results are shown in Table III (Exhibit 16), and indicate that no measurable vibrations were transmitted into the basement wall through earth borne vibrations.

The vibration testers were then moved outside of the Gallery basement and set up to measure vertical, horizontal, and transverse vibrations on window sill 3. The location is J and is shown on Map III. The results show that the peak to peak displacement due to truck traffic is very small. The average displacement frequency was 100 cps. The higher frequency of vibration indicates that the displacement is due to air borne sound vibration shaking the instruments. The instrument vibration in this case is not due to earth borne vibration.

To measure the amount of earth borne vibration transmitted to Locations K, L, and N, vibration instruments were set up at the above locations to measure vertical displacements. As shown in Table III the measured vibrations due to truck traffic were of insignificant amplitude at the building corners. At Location N, one foot into the street from the curb, the displacement average was 0.00008 inches. The average displacement frequency was 22 cps.

Representative vibration records are included in this report.

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IV. SUMMARY

The average peak to peak displacement on the ground directly beneath the Yolo Causeway due to truck traffic was 0.0004 inches. The average frequency was 20 cps. The drop off in displacement was 50% at 65 feet and not measurable within 115 feet with our vibration testers.

The average peak to peak displacement on the ground 25 feet away from the earth fill highway section was 0.0001 inches peak to peak, and not measurable at 100 feet with our vibration testers. The average frequency was 23 cps.

No measurable vibrations were recorded with our vibration testers on the inside basement wall of the Gallery Annex.

Measurable vibrations were recorded with our vibration testers on the outside basement wall of the Gallery Annex. These vibrations were due to air borne truck noises shaking the vibration testers. Displacements are small and in the order of 0.000004 to 0.00001 inches peak to peak. The average frequency was 100 cps.

No measurable vibrations were recorded with our vibration testers on the ground at the two building corners of the Gallery Annex.

Vibration measurements on 3rd Street show an average displacement of 0.00008 inches, peak to peak. The average frequency was 22 cps.

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APPENDIX

Exhibit

I. Map I Location of vibration testers at Yolo Causeway

II. Pictures of Yolo Causeway

III. Yolo Causeway vibration record

IV. Table I Yolo Causeway vibration data

V. Map II Location of vibration testers at Highway 40

VI. Picture of Highway 40 fill location

VII. Highway fill vibration record

VIII. Table II Highway fill vibration data

IX. Map III Location of vibration testers at the Crocker Art Gallery.

X - XII. Pictures of Crocker Art Gallery

XIII-XV. Gallery vibration records

XVI. Table III Gallery vibration data

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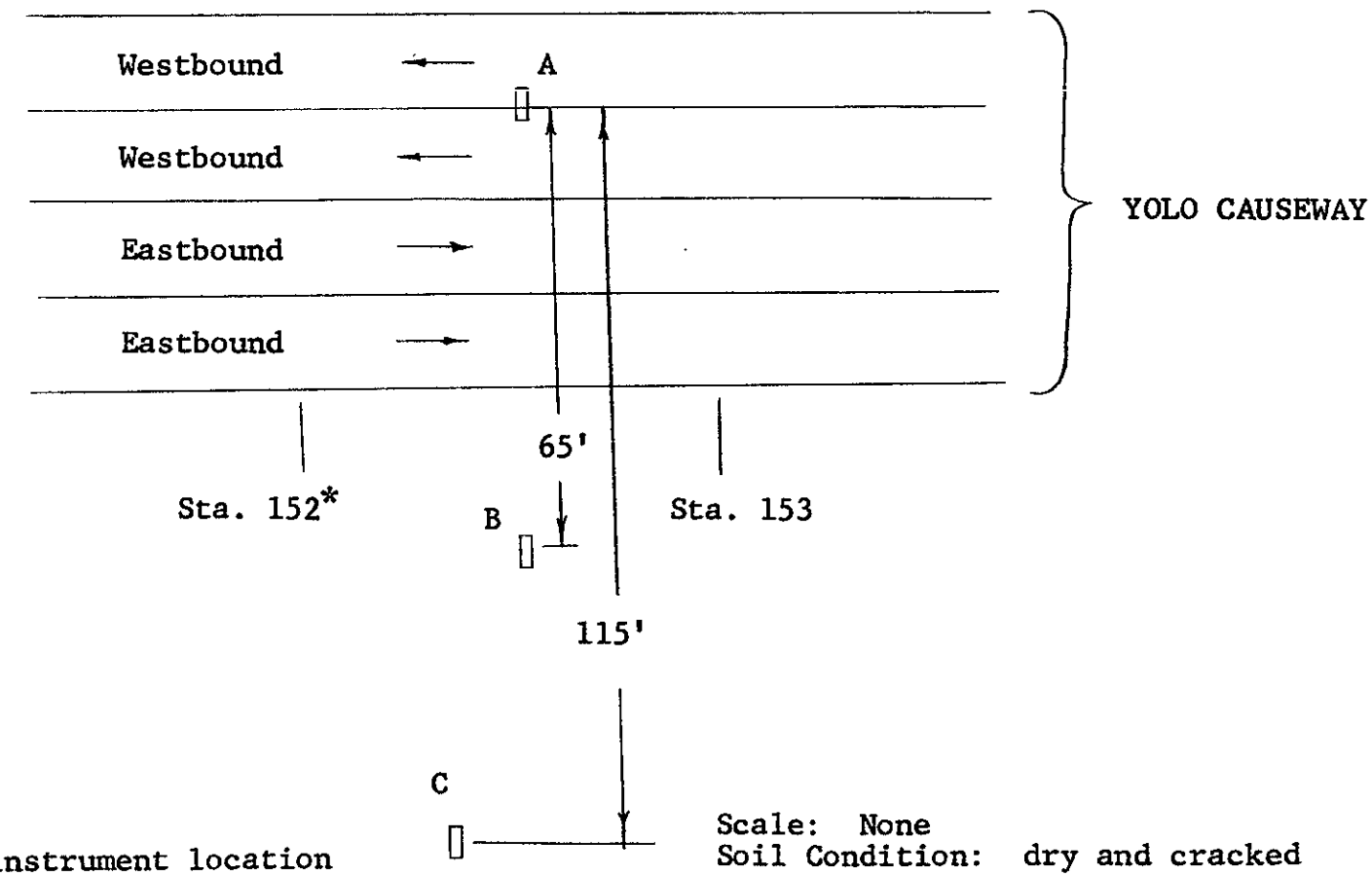
MAP I

VIBRATION MEASUREMENTS - YOLO CAUSEWAY

INSTRUMENT LOCATIONS A, B, & C



* Identical instrument location at Station 285-286

Scale: None
Soil Condition: dry and cracked

[] Vibration tester

Westbound lanes are supported on concrete piles, eastbound lanes on wood piles.

Exhibit 1

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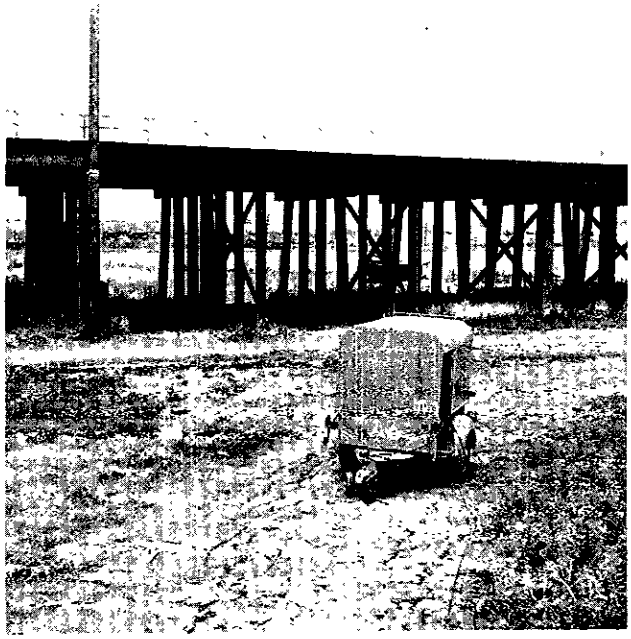
Exhibit 2

Location A: Yolo Causeway Vibration Tester in the foreground.



General view Yolo Causeway

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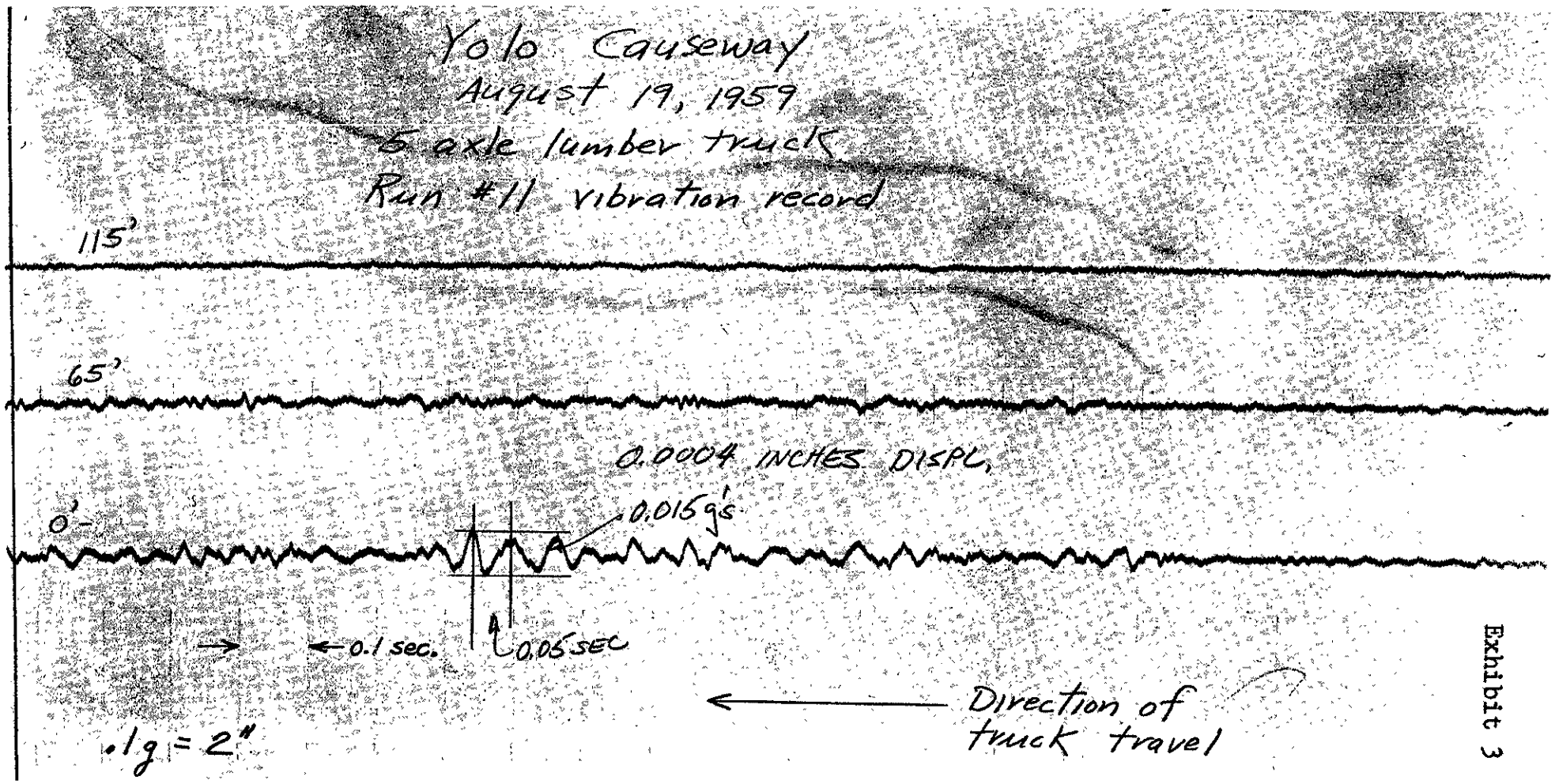

Exhibit 3

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TABLE I - THREE SIMULTANEOUS
VERTICAL VIBRATION MEASUREMENTS AT THE YOLO CAUSEWAY - AUGUST 19, 1959

Run No.	LOCATIONS						TRAFFIC	WEST BOUND	EAST BOUND
	A-0'		B-65'		C-115'				
	*D	*F	*D	*F	*D	*F			
1	-	-	-	-	-	-	Quiet period, no traffic		
2	.0002	25	-	-	-	-	5 axle truck	X	
3	.0001	25	.00008	25	-	-	3 axle van truck		X
4	.0003	25	.0002	20	-	-	5 axle lumber truck		X
5	.0002	25	-	-	-	-	5 axle truck	X	
6	.0005	17	.0006	12	-	-	5 axle trk. loaded w/D-9 Cat.		X
7	.0007	17	.0006	12	-	-	4 axle truck as above		X
8	.0008	17	.0005	14	-	-	2- 5 axle trucks		X
9	.0008	17	.0001	20	-	-	3 trucks	X	
10	.0002	25	.0002	20	-	-	Greyhound (WB) Trk. (EB)	X	X
11	.0004	20	-	-	-	-	5 axle lumber truck		X
12	.0002	20	-	-	-	-	5 axle oil truck	X	
13	-	-	-	-	-	-	Freight train		
14	.0003	20	.0004	14	-	-	5 axle truck		
15	.0007	17	.0003	17	-	-	5 axle cattle truck		X
16	.0002	25	.0001	25	-	-	5 axle truck		X
17	.0005	17	.00007	25	-	-	5 axle truck		X
18	-	-	-	-	-	-	Quiet period, no traffic		
	Runs #19 to #34 are set up at Stations #285 - #286								
19	-	-	-	-	-	-	Quiet period, no traffic		
20	.0005	14	-	-	-	-	5 axle oil tanker	X	
21	.0005	20	-	-	-	-	5 axle butane truck	X	
22	.0002	17	-	-	-	-	6 axle hay truck	X	
23	.0004	20	-	-	-	-	5 axle oil truck	X	
24	.0004	20	-	-	-	-	5 axle hay truck	X	
25	-	-	-	-	-	-	Quiet period, no traffic		
26	.0005	25	-	-	-	-	5 axle tomato truck	X	
27	.0001	20	-	-	-	-	5 axle truck		X
28	.0002	17	-	-	-	-	5 axle truck		X
29	-	-	-	-	-	-	Quiet period, no traffic		
30	.0005	17	-	-	-	-	5 axle truck		X
31	.0005	20	-	-	-	-	3 axle van		
32	.0003	25	-	-	-	-	Greyhound bus		
33			No good				Greyhound bus		
34	.0003	17	-	-	-	-	5 axle oil truck		

*D = Displacement in inches, peak to peak. *F = Frequency in cycles per second.
*- Insignificant data for displacement calculations.

Exhibit 4

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MAP II

VIBRATION MEASUREMENTS - LOCATIONS

Highway 40 Station C176+25, Fill Section

Approximately 1 mile west of Sacramento Tower Bridge

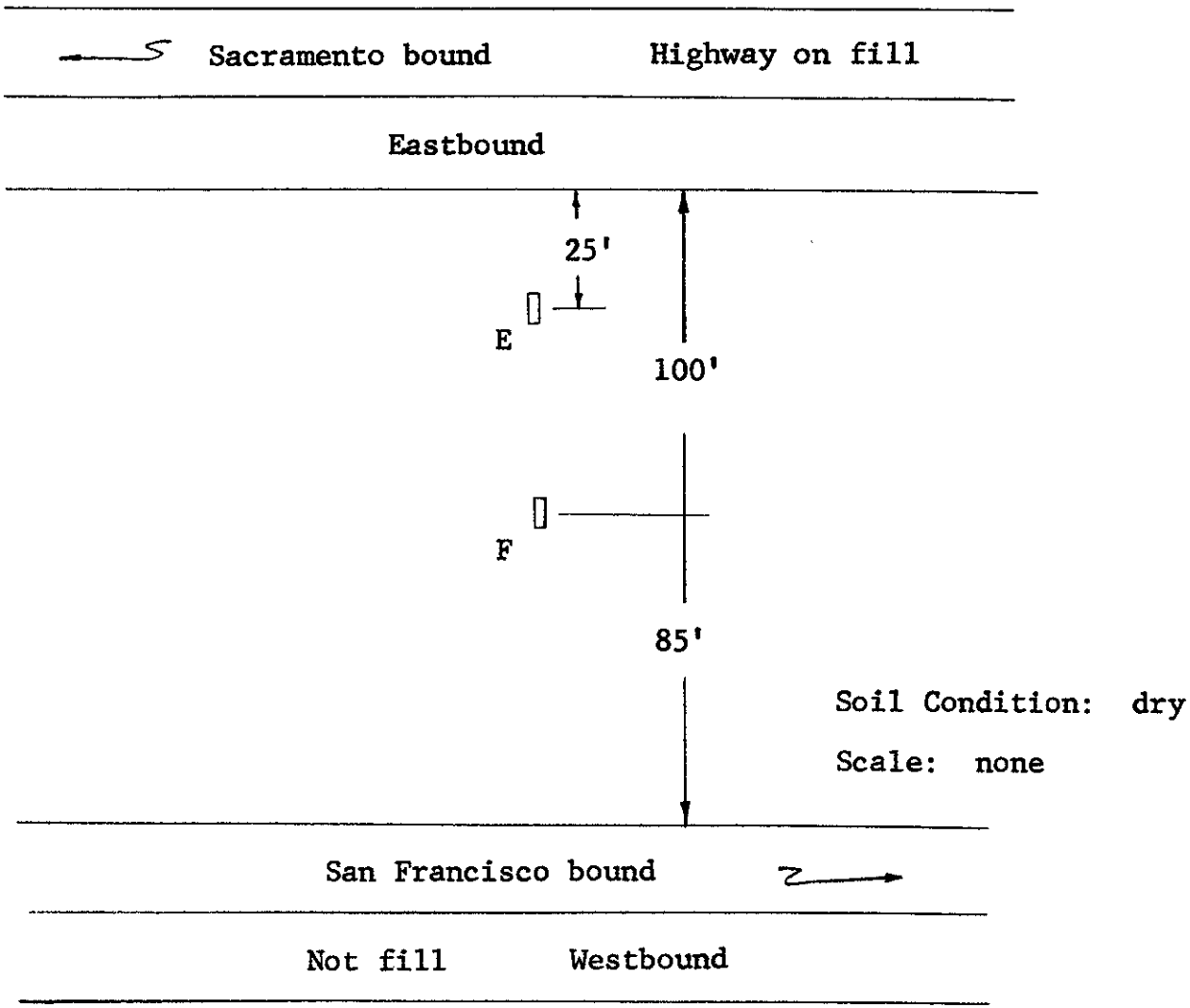

Exhibit 5

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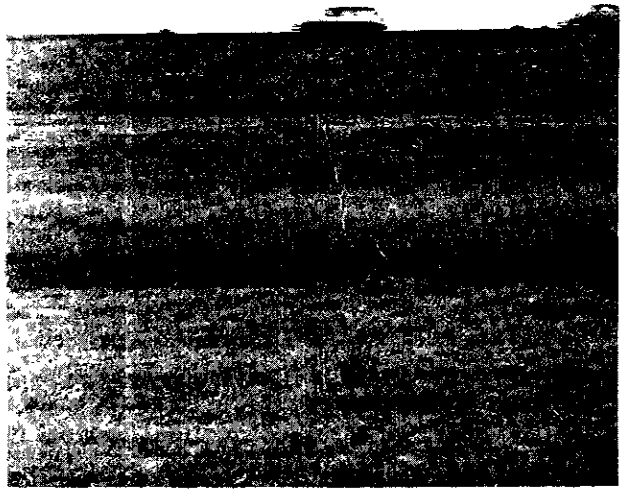
Exhibit 6



Fill Location on Highway 40
Station C 176+25

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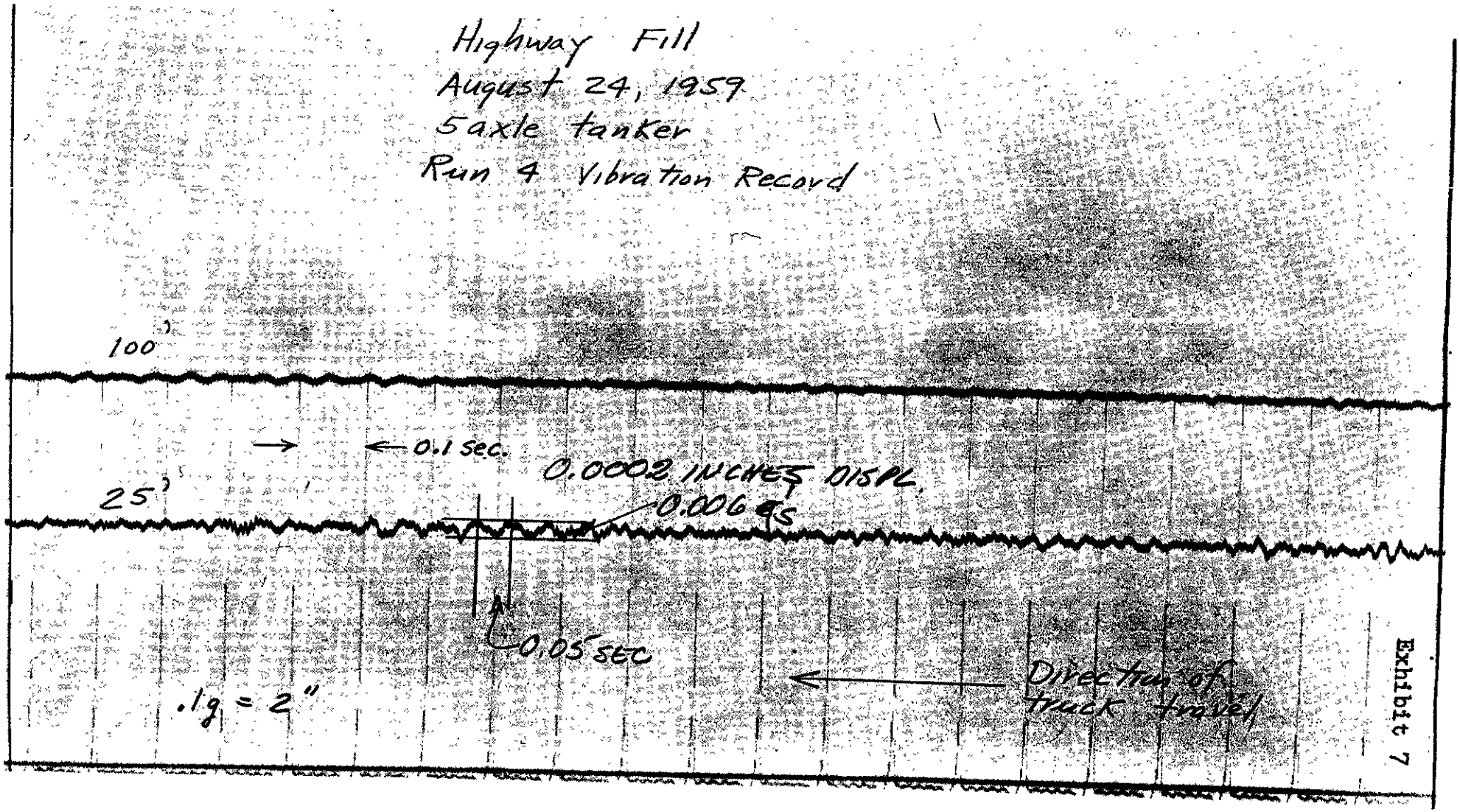

Exhibit 7

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TABLE II - TWO SIMULTANEOUS VERTICAL VIBRATION MEASUREMENTS AT A HIGHWAY FILL - AUGUST 24, 1959

Run No.	LOCATIONS				TRAFFIC	WEST BOUND	EAST BOUND
	E-25'		F-100'				
	*D	*F	*D	*F			
1	-	-	-	-	Quiet period, no traffic		
2	-	-	-	-	As above		
3	.0002	17	-	-	Egg truck		X
4	.0002	20	-	-	5 axle tanker		X
5	-	-	-	-	5 axle truck	X	
6	.00005	-	-	-	5 axle tanker		X
7	.00008	25	-	-	Greyhound bus		X
8	-	-	-	-	Quiet period, no traffic		
9	.0001	25	-	-	6 axle truck		X
10	.00004	-	-	-	5 axle poultry feed hopper		X
11	.0002	25	.0002	17	Lo-boy loaded w/army tank		X
12	-	-	-	-	4 axle cement hopper		X
13	.00008	25	-	-	5 axle tomato truck		X
14	.00008	25	-	-	5 axle tanker		X
15	.00005	-	-	-	5 axle tomato truck		X
16	.0001	25	-	-	5 axle truck		X

*D = Displacement in inches, peak to peak. *F = Frequency in cycles per second.

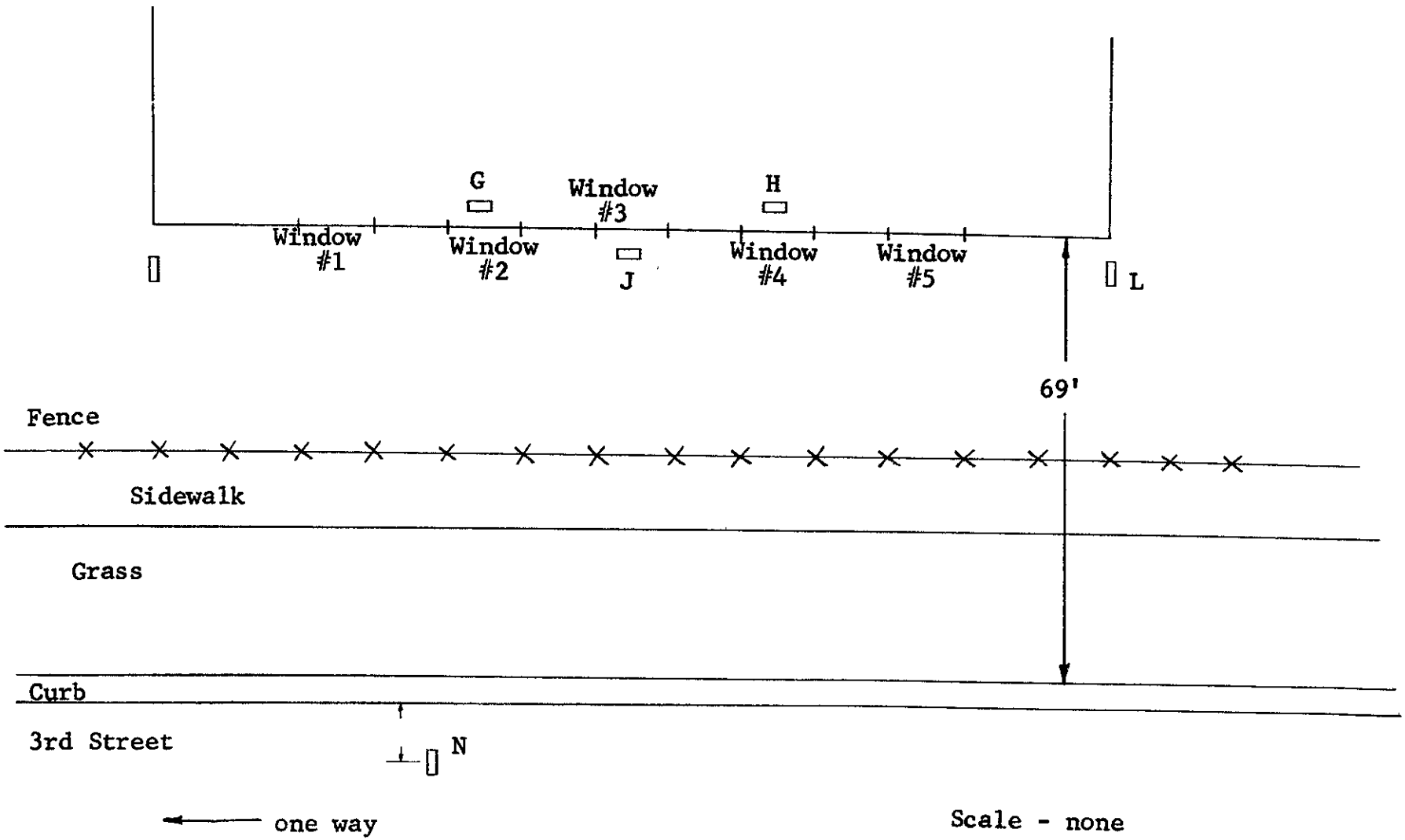
*- = Insignificant data for displacement calculations.

Exhibit 8

MAP III

VIBRATION MEASUREMENTS

CROCKER ART GALLERY - GALLERY ANNEX



Scale - none

Soil condition - damp

Exhibit 9

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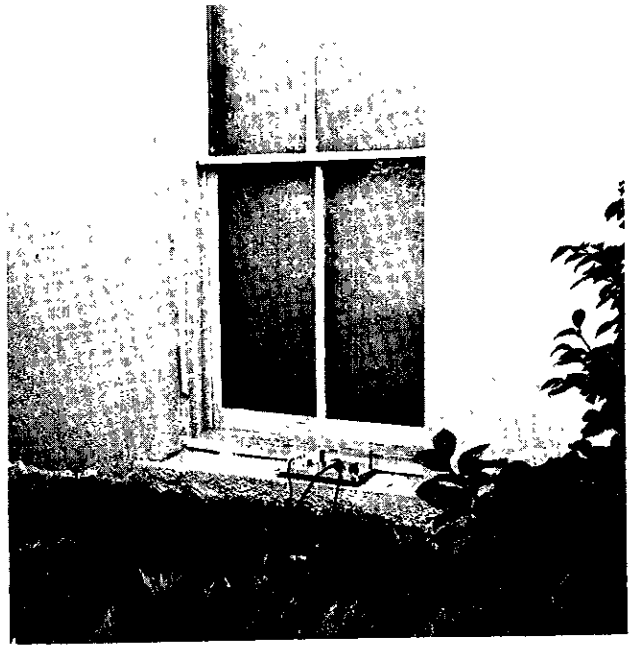
Exhibit 10

Crocker Art Gallery Annex



Location J Window Sill #3
Vibration tester on window sill #3

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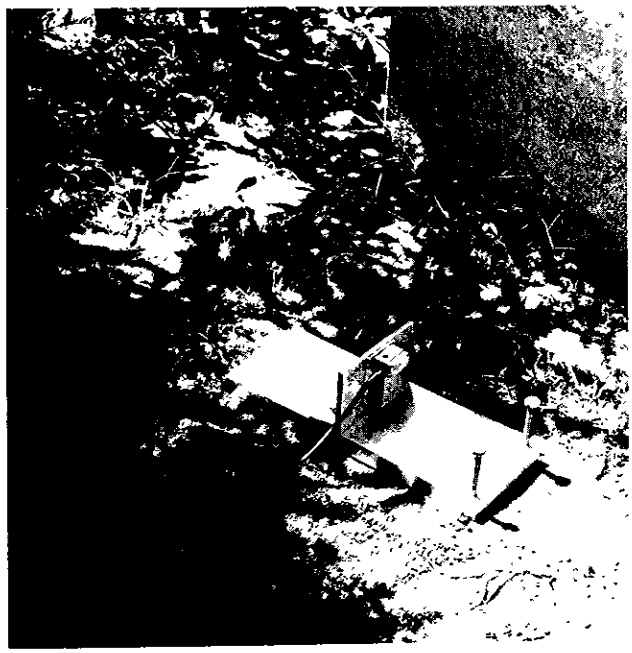
Location H: All three vibration testers placed inside the basement and on the brick sill of window #4



Location K: Vibration tester at corner of building.

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Location L: Vibration tester
at corner of building.

Location N: Vibration tester
on 3rd Street pavement.

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Crocker Art Gallery
August 31, 1959
Run 3 Vibration Record of Vibration Testers
inside basement on window sill
5 axle truck

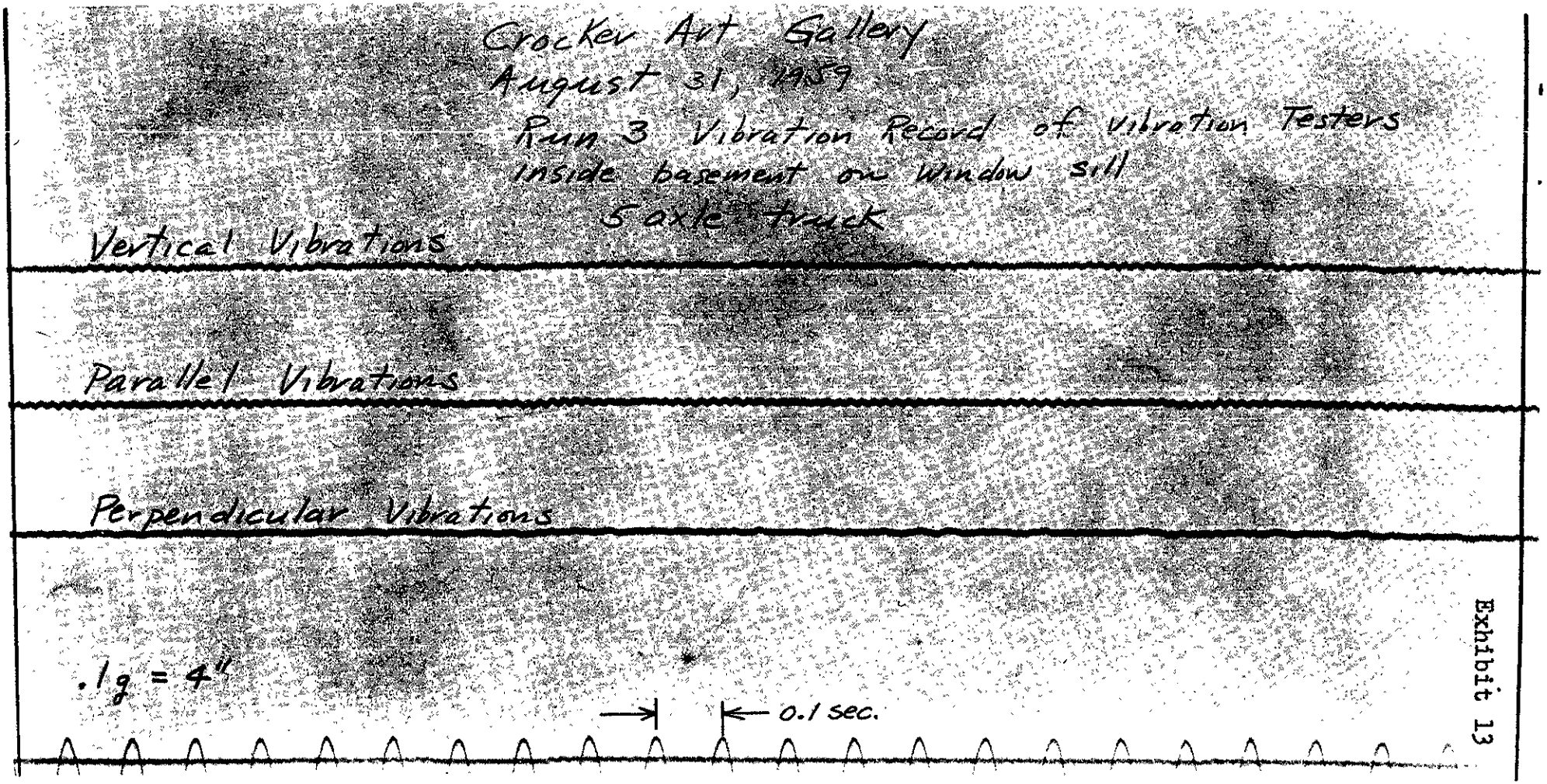

Exhibit 13

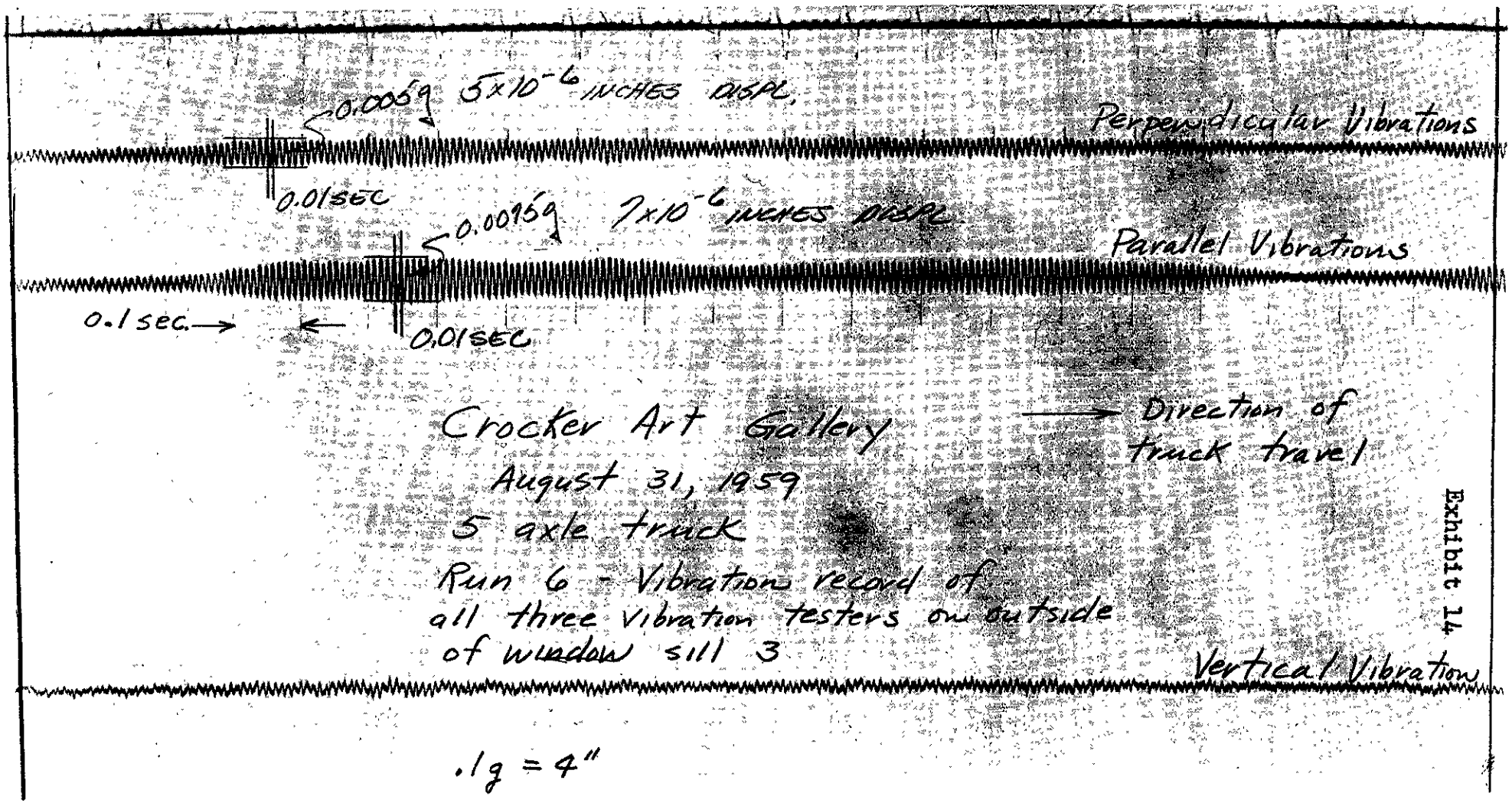

Exhibit 14

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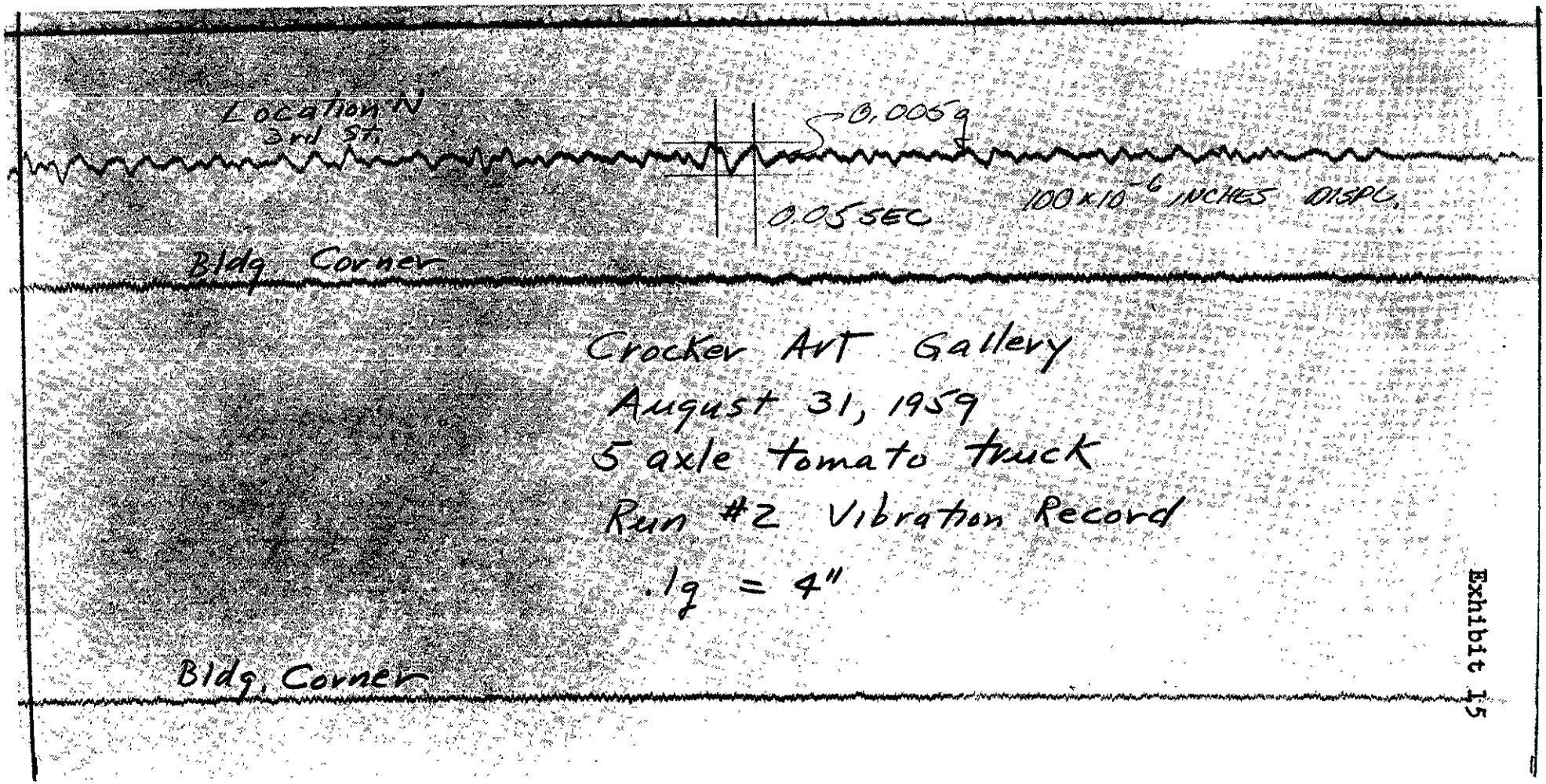

Exhibit 15

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TABLE III - THREE SIMULTANEOUS VIBRATION MEASUREMENTS AT THE CROCKER ART GALLERY - AUGUST 31, 1959

Run No.	LOCATION - G						TRAFFIC
	Channel 1		Channel 2		Channel 3		
	*D	*F	*D	*F	*D	*F	
1	-	-	-	-	-	-	5 axle truck
2	-	-	-	-	-	-	5 axle truck
3	-	-	-	-	-	-	5 axle truck
4	-	-	-	-	-	-	5 axle van
5	-	-	-	-	-	-	Quiet period, no traffic
6	-	-	-	-	-	-	City bus
7	-	-	-	-	-	-	Quiet period, no traffic
8	-	-	-	-	-	-	5 axle tomato truck
9	-	-	-	-	-	-	5 axle tomato truck
10	-	-	-	-	-	-	4 axle truck
11	-	-	-	-	-	-	5 axle truck
12	-	-	-	-	-	-	5 axle truck
			LOCATION H				
13	-	-	-	-	-	-	6 axle tomato truck
14	-	-	-	-	-	-	5 axle LASME truck
15	-	-	-	-	-	-	5 axle truck
16	-	-	-	-	-	-	5 and 6 axle tomato truck
17	-	-	-	-	-	-	Two trucks
18	-	-	-	-	-	-	Concrete mixer truck
19	-	-	-	-	-	-	Quiet period, no traffic
20	-	-	-	-	-	-	5 axle tomato truck
21	-	-	-	-	-	-	5 axle MT truck
22	-	-	-	-	-	-	Two trucks
23	-	-	-	-	-	-	Oil tanker and trailer
24	-	-	-	-	-	-	5 axle truck
25	-	-	-	-	-	-	5 axle truck
			LOCATION J				
1	-	-	-	-	-	-	5 axle truck, tomato
2	-	-	-	-	-	-	5 axle truck
3	-	-	-	-	-	-	5 axle truck
4	.000007	100	.00001	100	.000004	100	5 axle truck, tomato
5	-	-	-	-	-	-	Quiet period, no traffic
6	.000005	100	.000007	100	-	-	5 axle truck
7	-	-	-	-	-	-	4 axle truck
8	-	-	-	-	-	-	5 axle truck
9	-	-	-	-	-	-	3 axle truck

Exhibit 16

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TABLE III - THREE SIMULTANEOUS VIBRATION MEASUREMENTS AT THE CROCKER ART GALLERY - AUGUST 31, 1959

Run No.	LOCATION - J						TRAFFIC
	Channel 1		Channel 2		Channel 3		
	*D	*F	*D	*F	*D	*F	
10	-	-	-	-	-	-	Two trucks
11	-	-	-	-	-	-	5 axle cement truck
12	-	-	-	-	-	-	5 axle tomato truck
13	-	-	-	-	-	-	4 axle tomato truck
14	-	-	.000007	100	-	-	5 axle tomato truck
15	-	-	-	-	-	-	5 axle gas truck
16	-	-	-	-	-	-	Two 5 axle gas trucks
17	-	-	-	-	-	-	5 axle cement truck
18	-	-	-	-	-	-	5 axle gas truck
19	-	-	-	-	-	-	Quiet period, no traffic
20	-	-	-	-	-	-	5 axle truck
21	-	-	.000005	100	-	-	5 axle grain truck
22	-	-	.000008	100	-	-	5 axle truck (shifting gear)
23	-	-	-	-	-	-	6 axle truck
24	-	-	-	-	-	-	3 axle truck
25	-	-	-	-	-	-	5 axle tomato truck
	LOCATIONS						
	K		L		N		
1	-	-	-	-	.00007	23	5 axle tomato truck
2	-	-	-	-	.0001	20	5 axle tomato truck
3	-	-	-	-	.00008	20	5 axle truck
4	-	-	-	-	-	-	Quiet period, no traffic
5	-	-	-	-	.00007	25	5 axle truck
6	-	-	-	-	.00009	20	5 axle tomato truck
7	-	-	-	-	.00007	22	City bus
8	-	-	-	-	.0001	22	5 axle grain truck
9	-	-	-	-	.00008	24	4 axle truck
10	-	-	-	-	.00006	25	5 axle tomato truck

*D = Displacement in inches, peak to peak. *F ≐ Frequency in cycles per second.

*- = Insignificant data for displacement calculations.