GROUND VIBRATION INVESTIGATION AT HIGHWAY CONSTRUCTION SITES

FINAL REPORT

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TABLE OF CONTENTS

LIST OF FIGURES

INTRODUCTION

During the past few years, the Louisiana Department of Highways has become increasingly involved in litigations arising from vibrations around its highway construction sites. These vibrations were allegedly caused by pile driving operations and other construction practices, such as hauling large amounts of materials from one site to another. In the past the Department has usually been able to substantiate that the Department's construction practices were not to blame for the damages for which the suit was brought. However, this good fortune cannot continue forever, and the Legal Section of the Department feels that the Department will become subjected to all manner of suits due to the discovery of Bureau of Mines Report of Information #5968 quoted in part below:

> "On the average, only minor damage is observed for peak particle velocities of 5.4 inches (13.716 cm.) per second, and major damage is observed for peak particle velocities of 7.6 inches (19.304 cm.) per second. When the spread of the data is taken into consideration, the following statement can be made: Wave motions that have a peak particle velocity in excess of 2 inches (5.08 cm.) per second have a fair probability of producing some damage to structures, whereas wave motions that have a peak velocity less than 2 inches (5.08 cm.) per second have a very low probability of causing any damage."

The Legal Section felt that the inclusion of the last phrase, "whereas wave motions that have a peak velocity less than 2 inches (5.08 cm.) per second have a very low probability of causing any damage," would be the basis of enumerable suits once the plaintiffs' laywers discover the Bureau of Mines document.

PURPOSE

The purpose of this study was to measure vibration magnitudes on construction projects in terms of particle velocity rather than particle displacement or acceleration. Peak particle velocity was chosen as the best means of measurement after the U.S. Bureau of Mines made a statistical analysis of several reports on vibrations to residential structures and came to the conclusions that "a given degree of damage to a structure is most closely related to the magnitude of the particle velocity of the wave motion passing thru the earth at the structure location." The study was undertaken to determine the magnitude of the problem, if, in fact, one does exist; and if there is a problem, to supply the Legal Section with the information needed to protect the Department from unwarranted suits and to make just settlements.

SCOPE

This project's intention is to obtain a device capable of measuring vibration movements in terms of peak particle velocity rather than particle displacement or acceleration. With this device, trade name Shockorder SR-105, Research and Development Section personnel can collect data at highway construction sites. The data collected from pile driving sites would include: peak particle velocity, size and type of pile; hammer size; number of blows per foot penetration; and the distance from the pile to the measuring device. Haul road data would include: peak particle velocity; distance from haul roads; estimated weights of hauling vehicles and speeds traveled. As the data is assembled, a reassessment will be made to perhaps eliminate certain items or add other items deemed useful to the project.

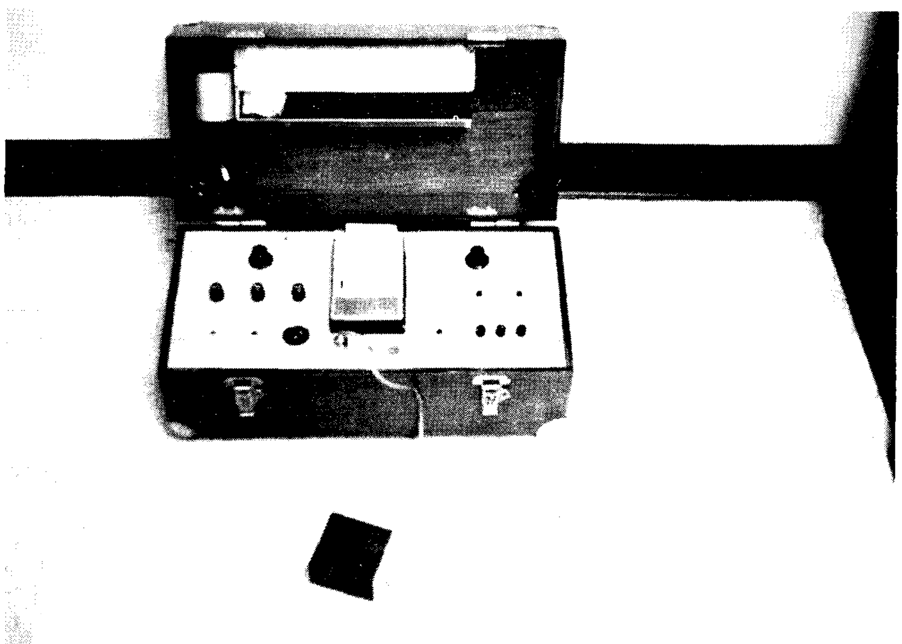
After the magnitude of the problem is found, the Research and Development Section could make recommendations to the Legal and Construction Sections as to what action should be taken. These recommendations could include:

1. Take no action toward measurement if vibration is so slight not to produce a potential hazard to adjacent structures, etc.
2. Make vibration measurement a part of the construction contract to be carried out by the contractor.
3. The Department could purchase several of these vibration measurement devices (one project, one per district, one or two for the Department, etc.) and keep track of the data for the Department's use.

particle velocity increases. If, at the next momemt, the particle's velocity further increases, the galvanometer pointer moves farther to the right. If, on the other hand, particle velocity lessens after the initial increase, the pointer remains in the same place, striking the paper every two seconds. It remains in this spot several seconds, provided no higher velocities are induced, at which time it slowly returns to the zero velocity position, making a bar graph record. In this way the peak velocity is recorded. The number of major divisions (0-12) on the paper that the galvanometer pointer moves to the right equals the peak particle velocity in inches per second. The velocity sensing transducer is located apart from the recording unit, and calibration signals are periodically applied to the transducer for manual system checking and calibration. See "Operating Instructions" in the Appendix.

Data Acquisition

During operation the Shockorder is placed at varying distances from the vibration source, usually near the structure under observation. The vibration source could be associated with blasting, pile driving operations, heavy traffic, or any other potentially damaging vibrations. The mounting stake is attached to the velocity transducer (Figure 2), and the stake is placed into the ground so a



[illegible] MOUNTING STAKE

good contact is made between the stake and the ground material. The velocity transducer lead is then connected to the Shockorder, and a simple calibration is made on the instrument. Due to the Shockorder's solid state circuitry, there is no need for a warm-up period. The power is turned on to the recorder, and the operator waits for the vibrations to appear on the visual indicating meter and on the paper. After the vibrations cease, the tape can be removed for examination.

Field Procedure

The Research and Development personnel spent considerable time learning how to operate and use the Model SR-105 Shockorder. After they became thoroughly familiar with the vibration instrument, they made measurements at construction sites throughout Louisiana in the different geologic areas set forth in the proposal. These geologic areas included: 1. loose alluvial and marshy materials from the New Orleans area; 2. firm alluvial materials of northwest Louisiana (Red River deposits); 3. firm terrace and loessial hill deposits from the Hammond, Lake Charles, and Baton Rouge areas. Measurements on the hard coastal plain upland deposits of North Central Louisiana were deleted due to the fact that no major construction was underway during this project's time span.

The actual data collection started with pile driving operations. Research and Development personnel who were to collect the vibration data first would contact the Assistant District Engineer in charge of construction in each district to see if any construction involving pile driving was underway. When suitable projects were located, Research and Development personnel would talk with the project engineer or inspector at the jobsite to get information about the pile driver itself (hammer size, stroke, etc.). Field book records were kept of the size and type of pile, pile number, blows per foot penetration, and the different distances the recording instrument was set up from the pile being driven. Records were also kept of the number of blows per last foot of penetration, date, location, highway number, project number and station numbers. Haul roads were measured after most of the pile driving measurements were taken. The actual calibration and recording procedure can be found in the Appendix.

DISCUSSION OF RESULTS

The total number of piles measured for vibrations associated with this construction practice was 210. Areas of investigation included Bossier City, Lake Charles, Hammond, Baton Rouge, Gonzales, LaPlace and the Greater New Orleans area. Figure 3 is an example of the type of results obtained. It is the strip chart record of a pile on bridge number 80 on I-12 near Hammond. This pile was a 24 inch x 24 inch x 50 foot (.6096 m x .6096 m x 15.24 m) concrete pile, and the 10,000 pound (4536 Kg) hammer with a 3.25 foot (1.0 m) stroke developed 32,500 ft. - lbs. (44,070 joules) of force. The Shockorder transducer was set 11 feet (3.35 m) from the pile. Technical data on most of the piles measured can be found in Table 1 in the Appendix. As can be seen, there was an 1.8 inch per second (4.572 cm/sec.) peak particle velocity in this example. Slightly more than half of the pile

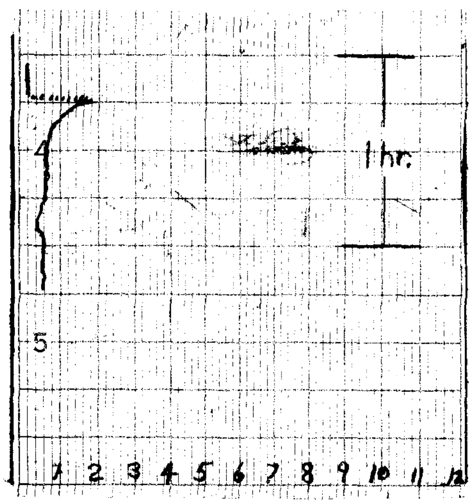


FIGURE 3

STRIP CHART RECORD OF A PILE ON I-12 NEAR HAMMOND

data came from the New Orleans sites. Figure 4 is another example of results obtained, but from the New Orleans area. This pile was from Golfer's Underpass on I-610 in New Orleans. An 18 inch x 18 inch x 75 foot (.4572 m x .4572 m x 22.86 m) concrete pile was measured. A 10,000 pound (4536 Kg.) ram with a three-foot (.91 m) stroke developed 30,000 ft. - lbs. (40,680 joules) and the recording instrument was 30 feet (9.144 m) from the pile. The maximum reading on this pile was 0.6 inch (1.524 cm.) per second. Many of the legal suits filed against the Department have been for alleged damages in the New Orleans area, where one-half inch (1.27 cm) per second of movement. The areas the most movement was registered was in the firm terrace and loessial hill deposits around Hammond and Baton Rouge. Several piles measured between one and two inches (2.54 cm. - 5.08 cm.) per second, although none measured in the low probability of damage zone. The maximum vibration measured was 1.8 inches (4.572 cm.) per second (see Figure 3) at a distance of 11 feet (3.35 m.) at a site near Hammond. Several other of the piles at this Hammond site required more than 100 blows per foot penetration with a 32,500 ft. - lb. (44.070 joule) hammer, even though the maximum vibration reached was only 1.6 in./sec. (4.064 cm./sec.) peak velocity. Perhaps something hard such as a buried log was encountered at this site. None of the 210 piles checked at nine different locations throughout the state produced vibrations which were in the damage range set by the Bureau of Mines. A subsequent publication of the Bureau of Mines, RI-6487, entitled "Design Requirements for Instrumentation to Record Vibrations Produced by Blasting", states the following:

> "A detailed study of vibration damage data for residential structures shows that particle velocity is a better criterion for structural damage than either displacement or acceleration. Minor damage, consisting of fine plaster cracks and opening of existing cracks, usually occurs at a velocity of 5.4 in/sec. (13.716 cm/sec.). Major damage, consisting of fall of plaster and serious cracking in plaster and mortar, usually occurs at a velocity of 7.6 in/sec. (19.304 cm/sec.). Thus, considering the average spread in the data, a criterion for a safe vibration level for residential structures has been set tentatively at a particle velocity of 2 in/sec. (5.08 cm/sec.). This is, this value of particle velocity should not be exceeded in the ground surrounding the structure if damage to the structure is to be prevented."

Haul roads were measured at several locations for vibrations made by loaded dump trucks, scrapers, and also regular heavy truck traffic was measured on a highway which traverses a marshy area near Houma, Louisiana. Speed ranges ran from about 8 m.p.h. (12.8 Km/hr.) up to 55 m.p.h. (88.495 (Km/hr.). In all cases the vibration measurements were below one inch (2.54 cm.) per second. It appears that haul road traffic would not be of concern as a damaging vibration source.

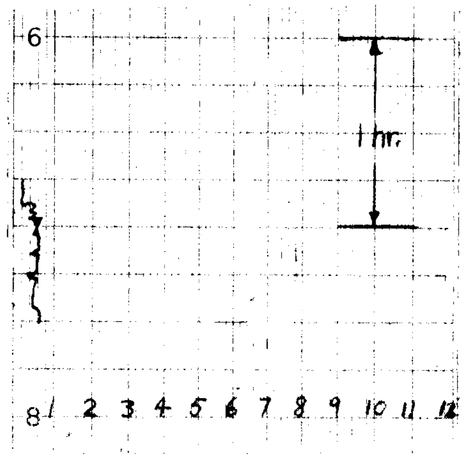


FIGURE 4

STRIP CHART RECORD OF A PILE ON I-610 IN NEW ORLEANS

the soil conditions consist of loose alluvial and marshy materials. The New Orleans area seemed to be where the greatest problems with construction - induced vibrations were occurring; therefore; a greater effort was devoted to this area.

When the collection of data began, the first area under observation was the firm alluvial deposits of northwest Louisiana (Red River deposits) near Bossier City. The recording instrument was set up near the pile being driven, and the readings were taken. It was gradually moved away from the piles being driven. This was done to give a record of the vibration magnitude versus distance from vibration source. From 0 feet (0 m.) to about 35 feet (10.668 m.) the recording instrument registered the vibrations received, although these vibrations diminished as distance increased. These vibrations were all under the peak particle velocity of 2 inches (5.08 cm.) per second, which is the limit set by the Bureau of Mines in its Report of Information, No. 5968, that states, "Wave motions that have a peak velocity less than 2 inches (5.08 cm.) per second have a very low probability of causing damage." Generally, with distances over 35 feet (10.668 m.) vibrations did not even register on the recording device. This vibration pick-up distance was even less than 35 feet (10.668 m.) in the loose alluvial or marshy materials in the state. In these "softer" areas the recording instrument was usually set up within 25 feet (7.62 m.) of the pile. In every case, the peak particle velocity was less than 2 inches (5.08 m.) per second. Most of the time, in these loose alluvial or marshy areas the recording pointer would not even reach

The authors wish to note that, even though the recording device indicated that the construction vibrations <u>were not</u> in the fair probability damage range set by the Bureau of Mines, they perceived the feeling of the vibrations themselves, the sight of vibration - produced effects (blades of grass shaking, boards around the construction site shaking, etc.), and the sound vibrations produced by the pile driver. The authors feel that humans relate these effects to causes other than the impacts which were being monitored. Figure 5 shows the levels of particle displacement established by the Bureau of Mines as well as others. This figure also shows the levels which are easily noticeable to persons and severe to persons, both of which are below the 2 inch-per-second lower limit fo Velocity Damage Critera. Perhaps a combination of the effects (feel, sight, and sound) produced by construction practices caused suits to be brought against the Department for the harassment caused by the construction. During this entire project, no data was gathered which indicated that any physical damage resulted from the construction practices that were monitored during the duration of this project.

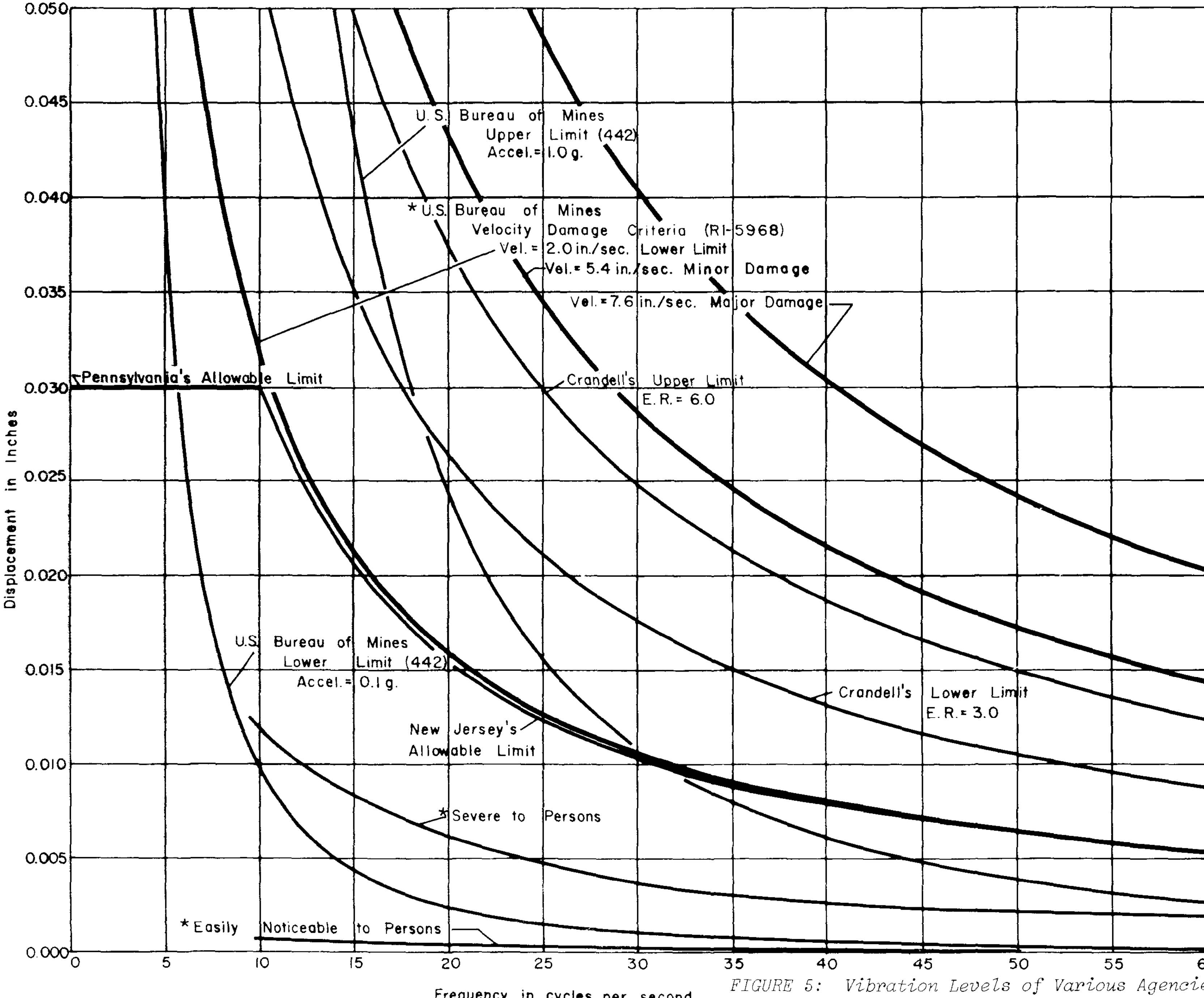


FIGURE 5: Vibration Levels of Various Agencies and their Allowable Limits

CONCLUSIONS

From the findings of this study the following conclusions can be reached:

1. Vibrations associated with the actual pile driving are not of enough magnitude to cause any physical damages to surrounding structures. No measurement exceeded the lower limit of 2 in./sec. (5.08 cm/sec.) set by the Bureau of Mines for having fair probability of producing some damage.
2. Construction traffic on haul roads does not appear to be a source of damage causing vibrations. Of the several haul road spots measured none of the vibrations received were in the damage range of 2 in./sec. (5.08 cm/sec.) and it is felt haul roads are not a problem area.
3. The authors feel that a combination of construction-produced effects (sounds, sight, and feeling) causes discomfort to persons near the construction zone; and this is the reason legal suits are brought.

It was not the purpose of this study to deal with the personal discomfort of the plaintiff, but rather to find evidence of potential physical damage to buildings, residents, etc., associated with vibrations.

REFERENCES

Damage Criteria Based on Particle Velocity. Technical Note 69-1 Prepared by HEC Industries, Inc., Dallas.

Duval, Wilbur Irving and David E. Fogelson. Review of Criteria for Estimating Damage to Residence from Blasting Vibrations. Report of Investigations, 5968, Bureau of Mines, United States Department of the Interior. Washington: Government Printing Office, 1962.

"Shockorder SR-105 Instruction Manual" Instruction Manual Prepared by HEC Industries, Inc., Dallas (Mimeographed.)

Thoenen, J. R. and S. L. Windes. Seismic Effect of Quarry Blasting. Bulletin 442, Bureau of Mines, United States Department of the Interior. Washington: Government Printing Office, 1941.

APPENDIX

OPERATING INSTRUCTIONS

OPERATION

The following procedures should be followed to make the unit read to continuously monitor vibrations:

1. Plug the transducer into the transducer socket marked "VER." Position the transducer properly. It is advisable to mount the transducer on the pointed stake which has been pushed into the soil.
2. Rotate the power switch to the "BATT TEST" position, "+12V", then "-12V." The recorder pointer should indicate "11" or above in each position.
3. Rotate the power switch to "ON."
4. Rotate the "TRANS CAL" "VER" control to the maximum counter-clockwise position.
5. Rotate the "TRANS CAL" switch to the "VER" position.
6. Depress and hold the "HOLD" button.
7. Depress the "CALIBRATE" button.
8. Rotate the "TRANS CAL" "VER" control clockwise until the recorder pointer indicates exactly "6."
9. Release the "HOLD" button.
10. Depress the "RESET" button.
11. Rotate the "TRANS CAL" switch to "OPERATE."
12. Turn the "RECORDER" switch on.
13. Depress and release the "RESET" button. The unit is now ready to monitor vibrations or shocks.
14. When the batteries need charging, a charging time of 12 hours is recommended.

TABLE 1
PILE DRIVING DATA

Date	Location	Size and Type Pile	Ram (lbs.) and Stroke (ft.)	Penetration (blows/last ft.)	Distance of Shockorder from Pile (Ft.)	Peak Part. Velocities in./sec.
5-11-72	I-220 Bossier City Proj. #451-02-13 Station 678 + 16	16"x16"x51' concrete	10,000 lb.x3.25'	44	50	0.4"
"	"	"	"	37	19	1.6"
"	"	"	"	44	23	1.6"
"	"	"	"	39	18	1.4"
"	"	"	"	39	23	1.6"
"	"	"	"	42	50	0.4"
"	"	"	"	35	50	0.4"
"	"	"	"	36	45	0.4"
5-12-72	"	"	"	41	45	0.4"
5-15-72	I-220 Bossier City Proj. #451-02-13 Station 690 + 37.45	16"x16"x39' concrete	"			
	Pile #5	"	"	70	32	0.2
	Pile #4	"	"	60	23	0.2
	Pile #3	"	"	57	18	0.4
	Pile #2	"	"	61	20	0.4
	Pile #6	"	"	38	15	0.6
	Pile #1	"	"	58	18	0.6
5-30-72	I-210 Lake Charles Proj. #450-30-02 Station 110 + 61.88 Pile #233	24"x24"x76' concrete	11,500 lbs.x3.25'	14	50	0.4

NOTE: 1 inch = 2.54 cm.
1 foot = 0.3048 meter
1 lb. = 0.4536 kilograms

TABLE 1 (CONTINUED)
PILE DRIVING DATA

Date	Location	Size and Type Pile	Ram (lbs.) and Stroke (ft.)	Penetration (blows/last ft.)	Distance of Shockorder from Pile (Ft.)	Peak Part. Velocities in./sec.
5-30-72	I-210 Lake Charles					
	Proj. #450-30-02					
	Station 110 + 61.83					
	Pile #232	24"x24"x76' concrete	11,500 lbs. x 3.25'	14	15	0.6
	Pile #231	"	"	12	5	1.6
	Pile #230	"	"	12	8	1.2
	Pile #229	"	"	16	11	0.8
	Pile #234	"	"	16	25	0.4
	Pile #228	"	"	17	10	0.6
6-15-72	I-10 Gonzales					
	Proj. #450-11-02					
	Station 49 + 39					
	Bent #2 Pile #183	14"x14"x60' concrete	5,000 lb. x 3.0'	34	18	0.4
	Pile #175	"	"	40	14	0.4
	Pile #174	"	"	44	6	0.4
6-19-72	I-12 Hammond					
	Proj. #454-03-05					
	Bent #3 east					
	Pile #58	24"x24"x50' concrete	10,000 lb. x 3.25'	111	13	1.6 *
6-20-72	Pile #57		"	77	13	1.0
	Pile #55	"	"	126	13	1.6
6-21-72	Bent #4 east					
	Pile #66	"	"	65	16	1.0

NOTE: 1 inch = 2.54 cm.
1 foot = 0.3048 meter
1 lb. = 0.4536 kilograms

*Some ft. over 500 blows per ft. of penetration Although only 1.6 in/sec. peak particle velocity was reached.

TABLE 1 (CONTINUED)
PILE DRIVING DATA

Date	Location	Size and Type Pile	Ram (lbs.) and Stroke (ft.)	Penetration (blows/last ft.)	Distance of Shockorder from Pile (Ft.)	Peak Part. Velocities in./sec.
6-21-72	Bent #4 east					
	Pile #65	24"x24"x50' concrete	10,000 lb.x3.25'	91	12	1.3
	Pile #64	"	"	72	11	1.8 *
6-22-72	Pile #62	"	"	73	8	1.4
	Pile #61	"	"	72	48	0.6
6-28-72	I-610 New Orleans					
	Proj. #450-34-05					
	Station 117 + 82.50					
	118 + 57.50					
	Bent #4 Pile #2	18"x18"x75' concrete	10,000 lb.x3.0'	19	25	0.6
	Pile #3	"	"	29	24	0.6
	Pile #4	"	"	20	24	0.6
	Pile #5	"	"	26	26	0.7
	Pile #6	"	"	27	30	0.7
	Pile #7	"	"	30	28	0.5
	Pile #8	"	"	28	28	0.8
6-29-72	Pile #9	"	"	25	30	0.6
	Pile #1	"	"	23	32	0.5
	Pile #2	"	"	24	32	0.9
9-13-72	I-55 LaPlace	54" round x 90'				
	Proj. #452-01-25	8" thick wall				
	Station 8.88 + 60	concrete	25,000 lb.x3.0'	90	50	0.2

NOTE: 1 inch = 2.54 cm.
1 foot = 0.3048 meter
1 lb. = 0.4536 kilograms

*Highest reading recorded

TABLE 1 (CONTINUED)
PILE DRIVING DATA

Date	Location	Size and Type Pile	Ram (lbs.) and Stroke (ft.)	Penetration (blows/last ft.)	Distance of Shockorder from Pile (Ft.)	Peak Part. Velocities in./sec.
9-13-72	I-55 LaPlace Proj. #452-01-25 Station 8.88 + 60	30" round x 90' concrete	24,000 lb.x3.0'	186	50	0.2
		24" round x 90'	25,000 lb.x2.3'	78	50	0.2
9-20-72	I-10 Reserve Reif Bridge Proj. #850-13-08 Station 21.55 + 78	54" round x 90' 8" thick wall concrete	40,000 lb.x2.0'	74	100	0.2*
		"	"	75	75	0.3
5-3-73 & 5-4-73	I-610 New Orleans Proj. #450-34-10 Bent 53-56	76' long corrugated pipe pile with metal driving core		6-9	25-30	0.1-0.4**
6-27-73	I-110 and Airline Highway - Baton Rouge Interchange Proj. #450-33-51	36' long timber piles	6500 lb.x3.0'	31	50	0.4
		"	"	27	50	0.4
		"	"	31	50	0.4
		"	"	33	50	0.6
		"	"	34	50	0.4
		"	"	29	50	0.4
		"	"	31	50	0.4
		"	"	30	50	0.4
		"	"	36	50	0.4
		"	"	32	50	0.4

NOTE: 1 inch = 2.54 cm.
1 foot = 0.3048 meter
1 lb. = 0.4536 kilograms

*On Spoil bank
**36 piles measured - All fell into these limits

TABLE 1 (CONTINUED)
PILE DRIVING DATA

Date	Location	Size and Type Pile	Ram (lbs.) and Stroke (ft.)	Penetration (blows/last ft.)	Distance of Shockorder from Pile (Ft.)	Peak Part. Velocities in./sec.
6-27-73	I-110 and Airline Highway - Baton Rouge Interchange Proj. #450-33-51	36' long timber pile	6500 lb.x3.0'	33	50	0.6
		"	"	29	50	0.4
		"	"	32	50	0.6
		"	"	31	50	0.4
		"	"	33	50	0.6
	new bent	"	"	34	50	0.4
		"	"	24	50	0.8
		"	"	28	50	0.6
		"	"	23	50	0.6
6-29-73	LDH #18	"	"	23	50	0.6
	LDH #13	"	"	26	45	0.6
	LDH #8	"	"	34	45	0.6
	LDH #3	"	"	30	48	0.4
	LDH #17	"	"	26	50	0.4
	LDH #12	"		30	47	0.6
	LDH #7	"		36	45	0.4
	LDH #2	"	"	[illegible]	46	0.4
	LDH #16	"	"	[illegible]	45	0.4
	LDH #11	"	"	30	48	0.6
	LDH #6	"	"	29	46	0.6
	LDH #1	"	"	26	48	0.4
				27	50	0.4

NOTE: 1 inch = 2.54 cm.
1 foot = 0.3048 meter
1 lb. = 0.4536 kilograms

TABLE 1 (CONTINUED)
PILE DRIVING DATA

Date	Location	Size and Type Pile	Ram (lbs.) and Stroke (ft.)	Penetration (blows/last ft.)	Distance of Shockorder from Pile (Ft.)	Peak Part. Velocities in./sec.
7-2-73	I-110 and Airline Highway - Baton Rouge - Proj. #450-33-51 - Ramp F	18"x18"x36'				
	Foot 3 - LDH #8	concrete	10000 lb.x3.25'	51	30	0.8
	LDH #4	"	"	70	30	0.4
	LDH #13	"	"	101	8	1.6
	LDH #3	"	"	68	20	0.8
	LDH #7	"	"	55	20	1.2
	LDH #12	"	"	82	12	1.4
	LDH #2	"	"	120	25	0.6
	LDH #6	"	"	70	15	1.0
7-3-73	LDH #1	"	"	53	20	0.8
	LDH #10	"	"	55	8	1.2
	Ramp F foot 4					
	LDH #5	"	"	60	27	0.8
	LDH #9	"	"	75	25	0.8
	LDH #14	"	"	67	28	0.6
	LDH #4	"	"	55	24	1.0
	LDH #8	"	"	70	23	1.2
	LDH #13	"	"	64	25	0.8
7-5-73	LDH #10	"	"	75	15	0.8

NOTE: 1 inch = 2.54 cm.
1 foot = 0.3048 meter
1 lb. = 0.4536 kilograms

TABLE 1 (CONTINUED)
PILE DRIVING DATA

Date	Location	Size and Type Pile	Ram (lbs.) and Stroke (ft.)	Penetration (blows/last ft.)	Distance of Shockorder from Pile (Ft.)	Peak Part. Velocities in./sec.
7-5-73	I-110 and Airline Highway - Baton Rouge					
	Proj. #450-33-51	18"x18"x36'				
	Foot E-15 LDH #11	concrete	10,000 x 3.25'	69	32	1.4
	LDH #7	"	"	85	28	1.2
	LDH #4	"	"	91	36	0.8
	LDH #10	"	"	70	24	1.2
10-2-73	I-610 New Orleans Proj. #450-34-06 London Avenue -					
	Franklin Avenue	88' long corr.				
	Bent 117W Foot c	pipe pile with				
	LDH #1	metal driving core	6500 lb. x 3.0'	26	25	0.2
	LDH #2	"	"	30	25	0.1
	Bent 117E Foot A					
	LDH #4	"	"	12	15	0.1
	LDH #5	"	"	17	15	0.1
	LDH #3	"	"	20	15	0.2
	LDH #1	"	"	30	15	0.1
	LDH #2	"	"	20	15	0.1
	Bent 117E Foot B					
	LDH #4	"	"	20	20	0.1
	LDH #5	"	"	26	20	0.2
	LDH #3	"	"	20	20	0.2
	LDH #1	"	"	19	20	0.2
	LDH #2	"	"	30	20	0.2

NOTE: 1 inch = 2.54 cm.
1 foot = 0.3048 meter
1 lb. = 0.4536 kilograms

TABLE 1 (CONTINUED)
PILE DRIVING DATA

Date	Location	Size and Type Pile	Ram (lbs.) and Stroke (ft.)	Penetration (blows/last ft.)	Distance of Shockorder from Pile (Ft.)	Peak Part. Velocities in./sec.
10-2-73	I-610 New Orleans					
	Bent 117E Foot C	88' long corr.				
	LDH #2	pipe pile	6500 lb. x 3.0'	18	15	0.1
	LDH #1	"	"	24	15	0.2
	LDH #3	"	"	30	17	0.2
	LDH #5	"	"	16	15	0.1
	LDH #4	"	"	28	15	0.2
	Bent 116E Foot C -					
	LDH #1	"	"	26	16	0.2
	LDH #2	"	"	22	16	0.2
	LDH #3	"	"	36	16	0.2
	LDH #4	"	"	36	16	0.2
	LDH #5	"	"	32	16	0.2
	Bent 116E Foot B -					
	LDH #5	"	"	32	17	0.2
	LDH #4	"	"	38	17	0.2
	LDH #3	"	"	36	17	0.2
	LDH #1	"	"	32	17	0.1
	LDH #2	"	"	40	17	0.2
	Bent 116E Foot A -					
	LDH #5	"	"	30	15	0.1
	LDH #4	"	"	34	15	0.2
	LDH #3	"	"	46	15	0.2
	LDH #2	"	"	37	15	0.2
	LDH #1	"	"	34	15	0.1

NOTE: 1 inch = 2.54 cm.
1 foot = 0.3048 meter
1 lb. = 0.4536 kilograms

TABLE 1 (CONTINUED)
PILE DRIVING DATA

Date	Location	Size and Type Pile	Ram (lbs.) and Stroke (ft.)	Penetration (blows/last ft.)	Distance of Shockorder from Pile (Ft.)	Peak Part. Velocities in./sec.
10-3-73	I-610 New Orleans					
	Bent 118W Foot C	88' long corr.				
	LDH #3	pipe pile	6500 lb. x 3.0'	20	16	0.1
	LDH #2	"	"	16	16	0.1
	LDH #1	"	"	16	16	0.1
	Bent 118W Foot B -					
	LDH #2	"	"	24	15	0.1
	LDH #1	"	"	24	15	0.1
	LDH #4	"	"	24	15	0.1
	LDH #3	"	"	30	16	0.1
	LDH #6	"	"	16	16	0.2
	LDH #5	"	"	28	15	0.2
	Bent 118W Foot A -					
	LDH #6	"	"	24	13	0.2
	LDH #5	"	"	28	13	0.2
	LDH #3	"	"	30	15	0.2
	LDH #4	"	"	28	15	0.1
	LDH #2	"	"	28	15	0.2
	LDH #1	"	"	28	15	0.2
	Bent 119W Foot A -					
	LDH #1	"	"	8	12	0.1
	LDH #2	"	"	7	12	0.1
	LDH #3	"	"	8	12	0.1
	LDH #4	"	"	10	12	0.1
	LDH #5	"	"	10	12	0.1
	LDH #6	"	"	8	12	0.1

NOTE: 1 inch = 2.54 cm.
1 foot = 0.3048 meter
1 lb. = 0.4536 kilograms

TABLE 1 (CONTINUED)
PILE DRIVING DATA

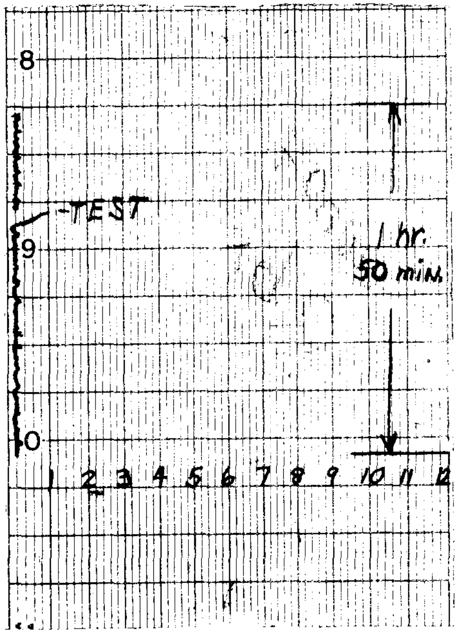
Date	Location	Size and Type Pile	Ram (lbs.) and Stroke (ft.)	Penetration (blows/last ft.)	Distance of Shockorder from Pile (Ft.)	Peak Part. Velocities in./sec.
10-3-73	I-610 New Orleans					
	Bent 119W Foot B	88' long corr.				
	LDH #1	pipe pile	6500 lb. x3.0'	7	15	0.1
	LDH #2	"	"	6	15	0.1
	LDH #4	"	"	6	15	0.1
	Bent #123E Foot A -					
	LDH #1	"	"	16	16	0.1
	LDH #2	"	"	24	16	0.2
	LDH #4	"	"	18	16	0.1
	LDH #3	"	"	22	17	0.1
	LDH #5	"	"	11	17	0.1
	LDH #6	"	"	15	17	0.1
	Bent 123E Foot B -					
	LDH #5	"	"	16	15	0.1
	LDH #6	"	"	18	15	0.2
	LDH #4	"	"	21	16	0.2
	LDH #3	"	"	20	16	0.1
	LDH #1	"	"	18	16	0.2
	LDH #2	"	"	24	17	0.2
	Bent 123E Foot C -					
	LDH #2	"	"	23	16	0.2
10-16-73	Bent L11 Foot A -					
	LDH #2	"	"	18	15	0.2
	LDH #1	"	"	19	15	0.2
	LDH #4	"	"	20	15	0.2
	LDH #3	"	"	18	15	0.2

NOTE: 1 inch = 2.54 cm.
1 foot = 0.3048 meter
1 lb. = 0.4536 kilograms

EXAMPLES OF HAUL ROAD MEASUREMENTS

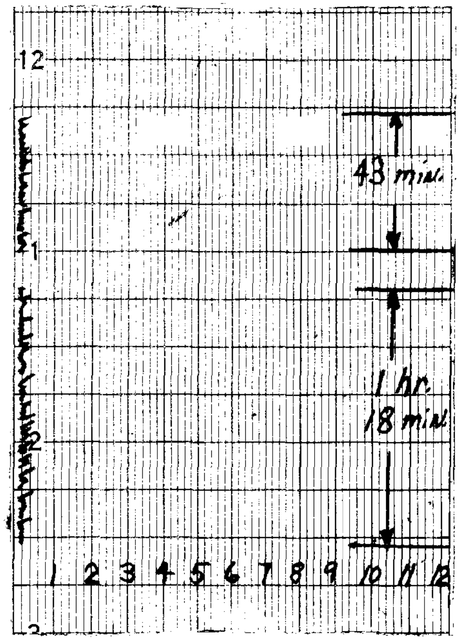
U.S. 90 NEAR HOUMA

local traffic over a
marshy area



HAUL ROAD NEAR RACELAND

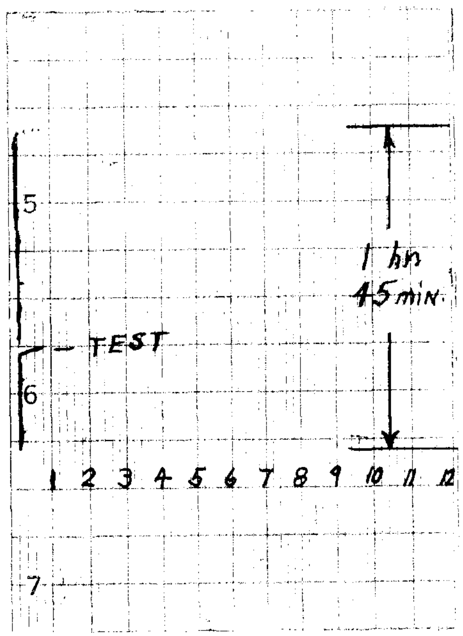
24 cu. yd. dump trucks hauling
sand for relocated U.S. 90 fill



EXAMPLES OF HAUL ROAD MEASUREMENTS

<u>I-12 NEAR COVINGTON</u>

24 cu. yd. dump trucks
and scrapers hauling
dirt for roadway from pit



<u>I-12 NEAR COVINGTON</u>

on roadway between dirt
pit and section of roadway
under construction