APPENDIX F

Seismic Velocity Logging Report by GeoVision

GEOVision

geophysical services
a division of Blackhawk Geometrics

STANFORD LINEAR ACCELERATOR

BORINGS LCLS-3 AND LCLS-5

SUSPENSION P & S VELOCITIES

July 30, 2004

STANFORD LINEAR ACCELERATOR
BORINGS LCLS-3 AND LCLS-5
SUSPENSION P & S VELOCITIES

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INTRODUCTION

OYO suspension velocity measurements were performed in two land borings adjacent to the Stanford Linear Accelerator. Suspension logging data acquisition was performed on July 18 and 19, 2004 by Tony Martin of GEOVision. The work was performed under subcontract with Rutherford and Chekene, with Gyimah Kasali as the field liaison for Rutherford.

This report describes the field measurements, data analysis, and results of this work.

SCOPE OF WORK

This report presents the results of suspension velocity measurements collected on July 18 and 19, 2004, in the uncased borings designated LCLS-3 and LCLS-5, as detailed below. The purpose of these studies was to supplement stratigraphic information obtained during R&C's soil sampling program and to acquire shear wave velocities and compressional wave velocities as a function of depth, which, in turn, can be used to characterize ground response to earthquake motion.

BORING DESIGNATION	DATE LOGGED	GENERAL LOCATION	COORDINATES	
LCLS-3	7/19/04		NA	NA
LCLS-5	7/18/04		NA	NA

Table 1. Boring locations and logging dates

The OYO Model 170 Suspension Logging Recorder and Suspension Logging Probe were used to obtain in-situ horizontal shear and compressional wave velocity measurements at 1.64 ft intervals. The acquired data was analyzed and a profile of velocity versus depth was produced for both compressional and horizontally polarized shear waves.

A detailed reference for the velocity measurement techniques used in this study is:

> Guidelines for Determining Design Basis Ground Motions, Report TR-102293, Electric Power Research Institute, Palo Alto, California, November 1993, Sections 7 and 8.

SUSPENSION INSTRUMENTATION

Suspension rock velocity measurements were performed using the Model 170 Suspension Logging system, manufactured by OYO Corporation. This system directly determines the average velocity of a 3.28 ft high segment of the soil column surrounding the boring of interest by measuring the elapsed time between arrivals of a wave propagating upward through the soil column. The receivers that detect the wave, and the source that generates the wave, are moved as a unit in the boring producing relatively constant amplitude signals at all depths.

The suspension system probe consists of a combined reversible polarity solenoid horizontal shear-wave source (S_H) and compressional-wave source (P), joined to two biaxial receivers by a flexible isolation cylinder, as shown in Figure 1. The separation of the two receivers is 3.28 ft, allowing average wave velocity in the region between the receivers to be determined by inversion of the wave travel time between the two receivers. The total length of the probe as used in this survey is 19 ft, with the center point of the receiver pair 12.1 ft above the bottom end of the probe. The probe receives control signals from, and sends the amplified receiver signals to, instrumentation on the surface via an armored 7 conductor cable. The cable is wound onto the drum of a winch and is used to support the probe. Cable travel is measured to provide probe depth data.

The entire probe is suspended by the cable and centered in the boring by nylon "whiskers", therefore, source motion is not coupled directly to the boring walls; rather, the source motion creates a horizontally propagating impulsive pressure wave in the fluid filling the boring and surrounding the source. This pressure wave is converted to P and S_H-waves in the surrounding soil and rock as it impinges upon the boring wall. These waves propagate through the soil and rock surrounding the boring, in turn causing a pressure wave to be generated in the fluid surrounding the receivers as the soil waves pass their location. Separation of the P and S_H-waves at the receivers is performed using the following steps:

1. Orientation of the horizontal receivers is maintained parallel to the axis of the source, maximizing the amplitude of the recorded S_H -wave signals.
2. At each depth, S_H-wave signals are recorded with the source actuated in opposite directions, producing S_H-wave signals of opposite polarity, providing a characteristic S_H-wave signature distinct from the P-wave signal.
3. The 7.02 ft separation of source and receiver 1 permits the P-wave signal to pass and damp significantly before the slower S_H-wave signal arrives at the receiver. In faster soils or rock, the isolation cylinder is extended to allow greater separation of the P- and S_H-wave signals.
4. In saturated soils, the received P-wave signal is typically of much higher frequency than the received S_H-wave signal, permitting additional separation of the two signals by low pass filtering.
5. Direct arrival of the original pressure pulse in the fluid is not detected at the receivers because the wavelength of the pressure pulse in fluid is significantly greater than the dimension of the fluid annulus surrounding the probe (meter versus centimeter scale), preventing significant energy transmission through the fluid medium.

In operation, a distinct, repeatable pattern of impulses is generated at each depth as follows:

1. The source is fired in one direction producing dominantly horizontal shear with some vertical compression, and the signals from the horizontal receivers situated parallel to the axis of motion of the source are recorded.
2. The source is fired again in the opposite direction and the horizontal receiver signals are recorded.
3. The source is fired again and the vertical receiver signals are recorded. The repeated source pattern facilitates the picking of the P and S_H-wave arrivals; reversal of the source changes the polarity of the S_H-wave pattern but not the P-wave pattern.

The data from each receiver during each source activation is recorded as a different channel on the recording system. The Model 170 has six channels (two simultaneous recording channels), each with a 12 bit 1024 sample record. The recorded data is displayed on a CRT display and on paper tape output as six channels with a common time scale. Data is stored on 3.5 inch floppy diskettes for further processing. Up to 8 sampling sequences can be summed to improve the signal to noise ratio of the signals.

Review of the displayed data on the CRT or paper tape allows the operator to set the gains, filters, delay time, pulse length (energy), sample rate, and summing number to optimize the quality of the data before recording. Verification of the calibration of the Model 170 digital recorder is performed every twelve months using a NIST traceable frequency source and counter, as outlined in Appendix B.

SUSPENSION MEASUREMENT PROCEDURES

Both borings were logged uncased, filled with bentonite based drilling fluid. The boring probe was positioned with the mid-point of the receiver spacing at grade, and the mechanical and electronic depth counters were set to zero. The probe was lowered to the bottom of the boring, then returned to the surface, stopping at 1.64 ft intervals to collect data, as summarized below.

At each measurement depth the measurement sequence of two opposite horizontal records and one vertical record was performed, and the gains were adjusted as required. The data from each depth was printed on paper tape, checked, and recorded on diskette before moving to the next depth.

Upon completion of the measurements, the probe zero depth indication at grade was verified prior to removal from the Boring.

BORING NUMBER	RUN NUMBER	DEPTH RANGE (FEET)	DEPTH AS DRILLED (FEET)	LOST TO SLOUGH/COLLAPSE (FEET)	SAMPLE INTERVAL (FEET)	DATE LOGGED
LCLS-3	1	4.9 – 45.9	67	0.0	1.64	7/19/04
LCLS-5	1	9.8 – 121.4	134	0.5	1.64	7/18/04

Table 2. Logging dates and depth ranges

SUSPENSION DATA ANALYSIS

The recorded digital records were analyzed to locate the first minima on the vertical axis records, indicating the arrival of P-wave energy. The difference in travel time between receiver 1 and receiver 2 (R1-R2) arrivals was used to calculate the P-wave velocity for that 3.28 ft segment of the soil column. When observable, P-wave arrivals on the horizontal axis records were used to verify the velocities determined from the vertical axis data.

The P-wave velocity calculated from the travel time over the 7.02 ft interval from source to receiver 1 (S-R1) was calculated and plotted for quality assurance of the velocity derived from the travel time between receivers. In this analysis, the depth values as recorded were increased by 5.15 ft to correspond to the mid-point of the 7.02 ft S-R1 interval, as illustrated in Figure 1. Travel times were obtained by picking the first break of the P-wave signal at receiver 1 and subtracting 2.7 milliseconds, the calculated and experimentally verified delay from source trigger pulse (beginning of record) to source impact. This delay corresponds to the duration of acceleration of the solenoid before impact.

The recorded digital records were studied to establish the presence of clear S_H-wave pulses, as indicated by the presence of opposite polarity pulses on each pair of horizontal records. Ideally, the S_H-wave signals from the 'normal' and 'reverse' source pulses are very nearly inverted images of each other. Digital FFT - IFFT lowpass filtering was used to remove the higher frequency P-wave signal from the S_H-wave signal. Different filter cutoffs were used to separate P- and S_H-waves at different depths, ranging from 700 Hz in the slowest zones to 2000 Hz in the regions of highest velocity. At each depth, the filter frequency was selected to be at least twice the fundamental frequency of the S_H-wave signal being filtered.

Generally, the first maxima was picked for the 'normal' signals and the first minima for the 'reverse' signals, although other points on the waveform were used if the first pulse was distorted. The absolute arrival time of the 'normal' and 'reverse' signals may vary by +/- 0.2 milliseconds, due to differences in the actuation time of the solenoid source caused by constant mechanical bias in the source or by boring inclination. This variation does not affect the R1-R2 velocity determinations, as the differential time is measured between arrivals of waves created by the same source actuation. The final velocity value is the average of the values obtained from the 'normal' and 'reverse' source actuations.

As with the P-wave data, S_H-wave velocity calculated from the travel time over the 7.02 ft interval from source to receiver 1 was calculated and plotted for verification of the velocity derived from the travel time between receivers. In this analysis, the depth values were increased by 5.15 ft to correspond to the mid-point of the 7.02 ft S-R1 interval. Travel times were obtained by picking the first break of the S_H-wave signal at the near receiver and subtracting 2.7 milliseconds, the calculated and experimentally verified delay from the beginning of the record at the source trigger pulse to source impact.

Figure 2 shows an example of R1 - R2 measurements on a sample filtered suspension record. In Figure 2, the time difference over the 3.28 ft interval of 1.88 milliseconds for the horizontal signals is equivalent to an S_H-wave velocity of 1745 ft/sec. Whenever possible, time differences were determined from several phase points on the S_H-waveform records to verify the data obtained from the first arrival of the S_H-wave pulse. Figure 3 displays the same record before filtering of the S_H-waveform record with an 1400 Hz FFT - IFFT digital lowpass filter, illustrating the presence of higher frequency P-wave energy at the beginning of the record, and distortion of the lower frequency S_H-wave by residual P-wave signal.

SUSPENSION RESULTS

Suspension R1-R2 P- and S_H-wave velocities are plotted in Figures 4 and 5. Partial equipment failure during data collection in LCLS-5 prevented collection of R1-R2 data, other than a single data point at 37.0 meters, so S-R1 data analysis was employed to obtain a smoothed velocity profile for this boring. This data is presented for LCLS-5 in Figures 5 and A-2. The R1 – R2 suspension velocity data presented in these figures are presented in Tables 3 and 4. P- and S_H-wave velocity data from R1-R2 analysis and quality assurance analysis of S-R1 data are plotted together in Figures A1 and A2 to aid in visual comparison. It must be noted that R1-R2 data is an average velocity over a 3.28 ft segment of the soil column; S-R1 data is an average over 7.02 ft, creating a significant smoothing relative to the R1-R2 plots. S-R1 data are presented in Tables A1 and A2. Good correspondence between the shape of the P- and S_H-wave velocity curves is observed for both these data sets. The velocities derived from S-R1 and R1-R2 data are in excellent agreement, providing verification of the higher resolution R1-R2 data.

Calibration procedures and records for the suspension measurement system are presented in Appendix B.

SUMMARY

Discussion of Suspension Results

Both P- and S_H-wave velocities were measured using the OYO Suspension Method in two uncased land borings at depths up to 121.4 ft below grade adjacent to the Stanford Linear Accelerator, near Palo Alto, California. Both borings were located near a freeway in heavy use, however, no significant signal contamination from cultural vibration was observed.

Both borings exhibit similar velocity profiles. Saturated earth material, as indicated by a sustained Vp above 5400 ft/sec, is not seen in either boring.

Quality Assurance

These velocity measurements were performed using industry-standard or better methods for both measurements and analyses. All work was performed under GEOVision quality assurance procedures, which include:

- Use of NIST-traceable calibrations, where applicable, for field and laboratory instrumentation
- Use of standard field data logs
- Use of independent verification of data by comparison of receiver-to-receiver and source-to-receiver velocities
- Independent review of calculations and results by a registered professional engineer, geologist, or geophysicist.

Data Reliability

P- and S_H-wave velocity measurement using the Suspension Method gives average velocities over a 3.28 ft interval of depth. This high resolution results in the scatter of values shown in the graphs. Individual measurements are very reliable with estimated precision of +/- 5%. Standardized field procedures and quality assurance checks add to the reliability of these data.

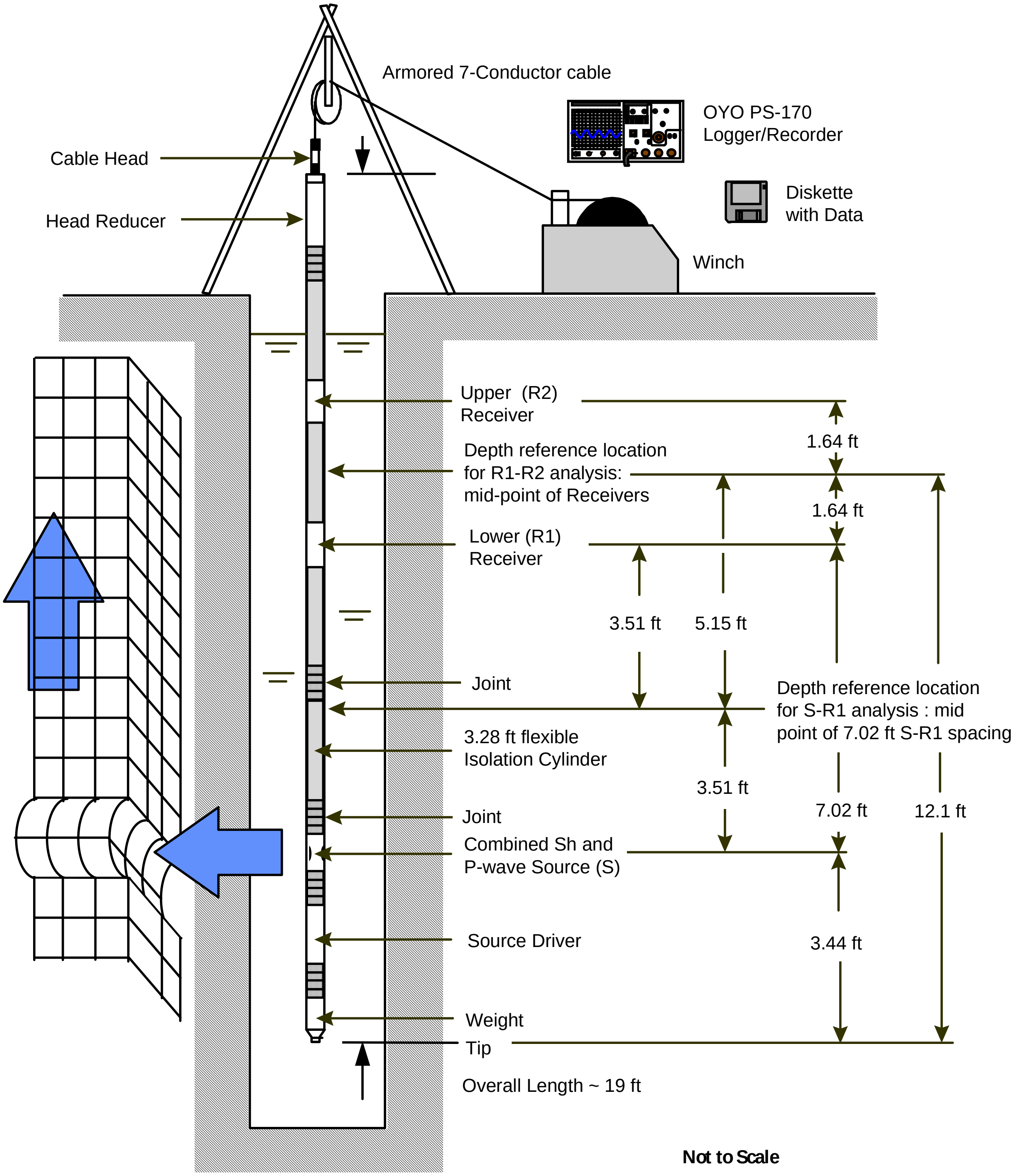

Figure 1. Concept illustration of P-S logging system

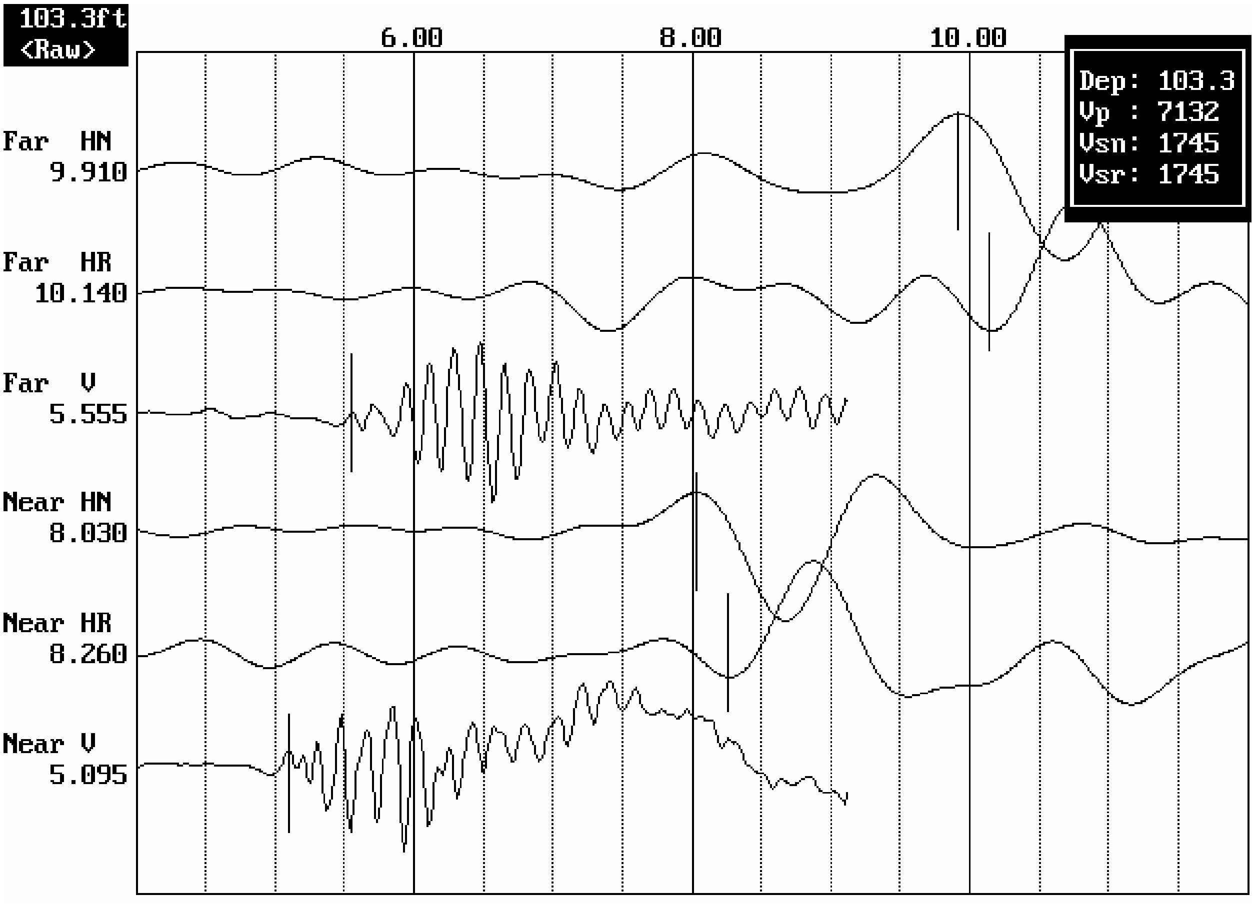

Figure 2. Example of filtered (1400 Hz lowpass) record

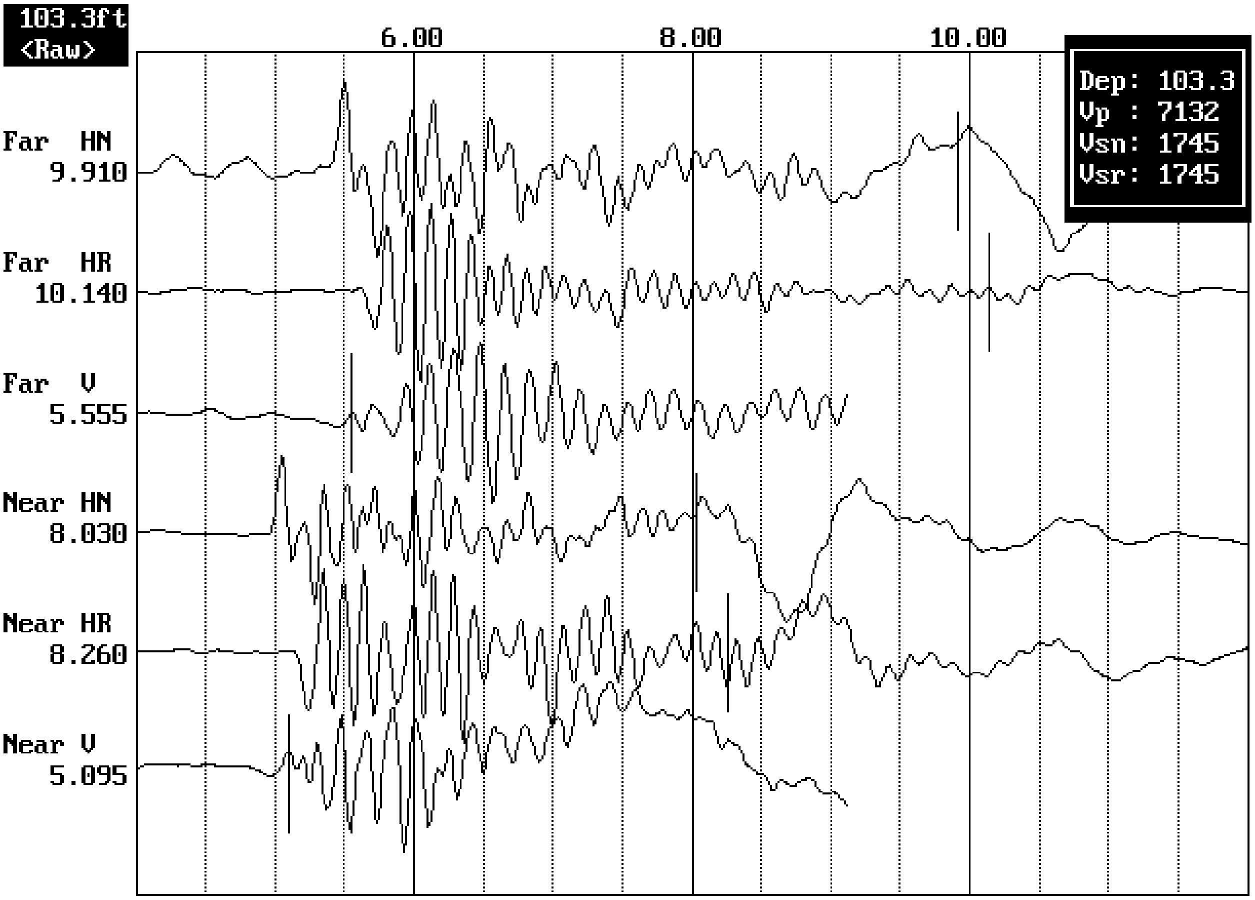

Figure 3. Example of unfiltered record

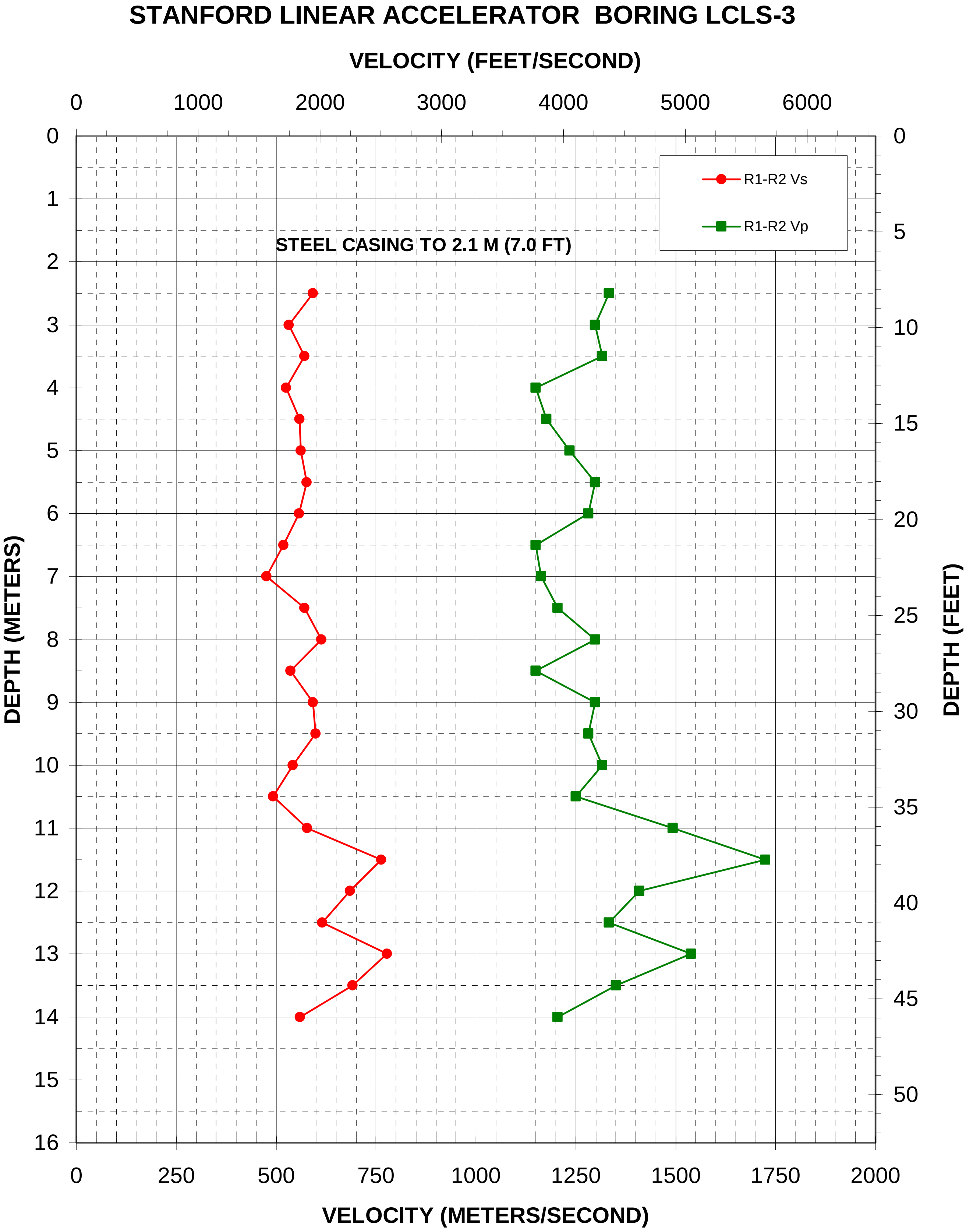

Figure 4. Boring LCLS-3, Suspension P- and S_H-wave velocities

Depth		Pick Times						Velocity			
(m)	(feet)	Far-Hn (millisec)	Far-Hr (millisec)	Far-V (millisec)	Near-Hn (millisec)	Near-Hr (millisec)	Near-V (millisec)	V-S_H (m/sec)	V-P (m/sec)	V-S_H (ft/sec)	V-P (ft/sec)
1.5	4.9				7.30	7.56					
2.0	6.6				6.04	6.50	5.00				
2.5	8.2	7.92	8.70	5.29	6.06	7.18	4.54	592	1333	1941	4374
3.0	9.8	8.14	9.34	5.62	6.30	7.42	4.85	532	1299	1745	4261
3.5	11.5	7.78	7.76	5.62	6.04	6.00	4.86	571	1316	1875	4317
4.0	13.1	7.97	7.97	5.53	6.01	6.12	4.66	525	1149	1722	3771
4.5	14.8	7.95	8.10	5.78	6.17	6.30	4.93	559	1176	1833	3860
5.0	16.4	8.06	8.24	5.38	6.29	6.45	4.57	562	1235	1843	4050
5.5	18.0	7.88	8.88	5.17	6.27	7.02	4.40	576	1299	1891	4261
6.0	19.7	8.67	8.55	5.16	7.04	6.59	4.38	557	1282	1828	4206
6.5	21.3	8.59	8.92	5.39	6.63	7.02	4.52	518	1149	1700	3771
7.0	23.0	8.55	8.69	5.21	6.63	6.41	4.35	476	1163	1562	3815
7.5	24.6	8.37	8.41	5.30	6.48	6.80	4.47	571	1205	1875	3953
8.0	26.2	7.54	7.63	5.32	5.91	6.00	4.55	613	1299	2013	4261
8.5	27.9	7.56	7.63	5.35	5.60	5.86	4.48	536	1149	1759	3771
9.0	29.5	7.40	7.47	5.12	5.62	5.87	4.35	592	1299	1941	4261
9.5	31.2	7.47	8.31	4.94	5.80	6.64	4.16	599	1282	1965	4206
10.0	32.8	7.59	7.92	4.78	5.80	6.02	4.02	542	1316	1778	4317
10.5	34.4	7.42	7.70	4.95	5.42	5.64	4.15	493	1250	1616	4101
11.0	36.1	7.19	7.34	4.89	5.41	5.66	4.22	578	1493	1896	4897
11.5	37.7	7.04	7.92	4.82	5.72	6.62	4.24	763	1724	2504	5657
12.0	39.4	7.38	7.56	5.57	5.85	6.17	4.86	685	1408	2247	4621
12.5	41.0	7.63	7.78	5.69	6.03	6.13	4.94	615	1333	2019	4374
13.0	42.7	7.66	7.85	5.55	6.36	6.58	4.90	778	1538	2553	5047
13.5	44.3	7.44	7.54	5.77	6.05	6.04	5.03	692	1351	2270	4434
14.0	45.9	7.94	7.98	5.77	6.14	6.21	4.94	560	1205	1838	3953

Table 3. Boring LCLS-3, Suspension R1-R2 depth, pick times, and velocities

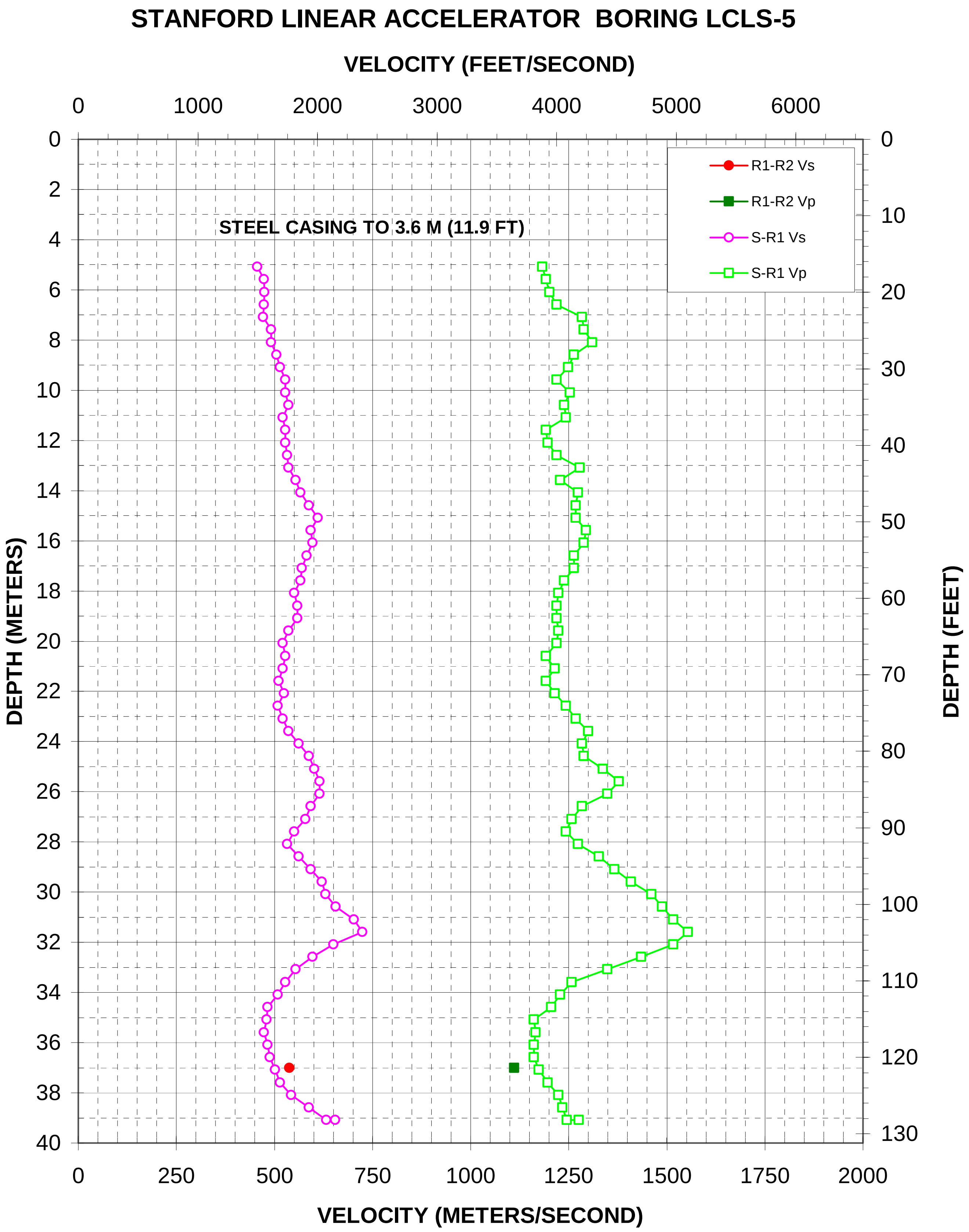

Figure 5. Boring LCLS-5, R1 - R2 high resolution analysis and S-R1 quality assurance analysis

Depth		Pick Times						Velocity			
(m)	(feet)	Far-Hn (millisec)	Far-Hr (millisec)	Far-V (millisec)	Near-Hn (millisec)	Near-Hr (millisec)	Near-V (millisec)	V-S_H (m/sec)	V-P (m/sec)	V-S_H (ft/sec)	V-P (ft/sec)
37.0	121.4	7.54	7.70	5.38	5.69	5.83	4.48	538	1111	1764	3645

Table 4. Boring LCLS-5, Suspension R1-R2 depth, pick times, and velocities

APPENDIX A

SUSPENSION VELOCITY MEASUREMENT QUALITY ASSURANCE SUSPENSION SOURCE TO RECEIVER ANALYSIS RESULTS

STANFORD LINEAR ACCELERATOR BORING LCLS-3

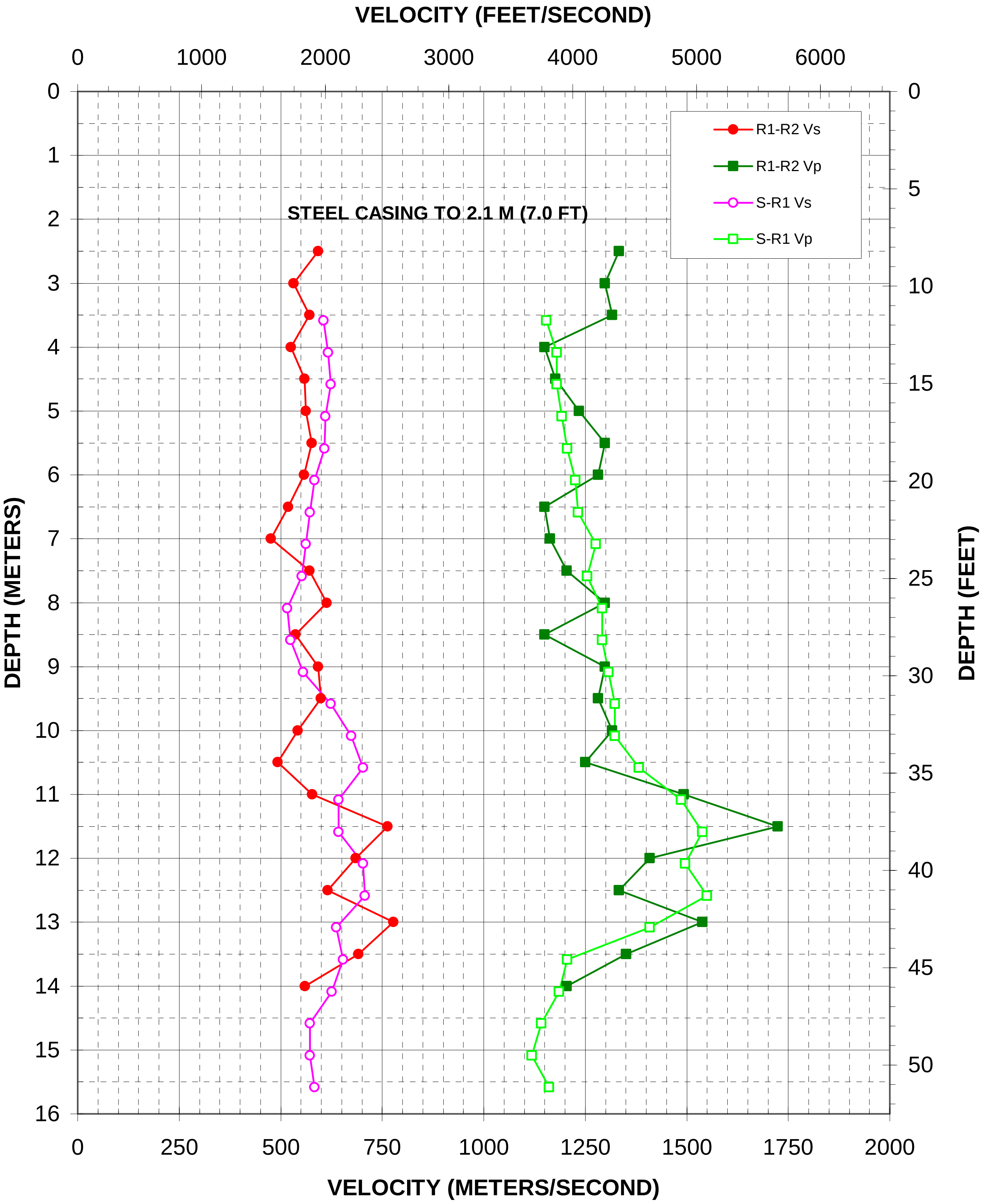

Figure A-1. Boring LCLS-3, R1 - R2 high resolution analysis and S-R1 quality assurance analysis P- and S_H-wave data

Depth (meters)	Velocity		Depth (feet)	Velocity	
	V-S_H (m/sec)	V-p (m/sec)		V- S_H (ft/sec)	V-p (ft/sec)
3.1			10.1		
3.6	606	1154	11.8	1989	3787
4.1	616	1179	13.4	2023	3869
4.6	624	1179	15.0	2046	3869
5.1	610	1192	16.7	2000	3912
5.6	608	1206	18.3	1994	3955
6.1	583	1226	20.0	1914	4022
6.6	573	1233	21.6	1878	4045
7.1	562	1276	23.2	1844	4188
7.6	552	1254	24.9	1812	4115
8.1	517	1292	26.5	1695	4238
8.6	524	1292	28.2	1720	4238
9.1	555	1307	29.8	1821	4289
9.6	624	1323	31.4	2046	4341
10.1	674	1323	33.1	2211	4341
10.6	702	1382	34.7	2304	4535
11.1	642	1486	36.4	2106	4876
11.6	642	1539	38.0	2106	5049
12.1	702	1497	39.6	2304	4910
12.6	707	1550	41.3	2319	5085
13.1	636	1409	42.9	2088	4623
13.6	654	1206	44.6	2144	3955
14.1	625	1186	46.2	2052	3890
14.6	573	1142	47.9	1878	3747
15.1	573	1119	49.5	1878	3670
15.6	583	1160	51.1	1914	3807

Table A-1. Boring LCLS-3, S - R1 quality assurance analysis P- and S_H-wave data

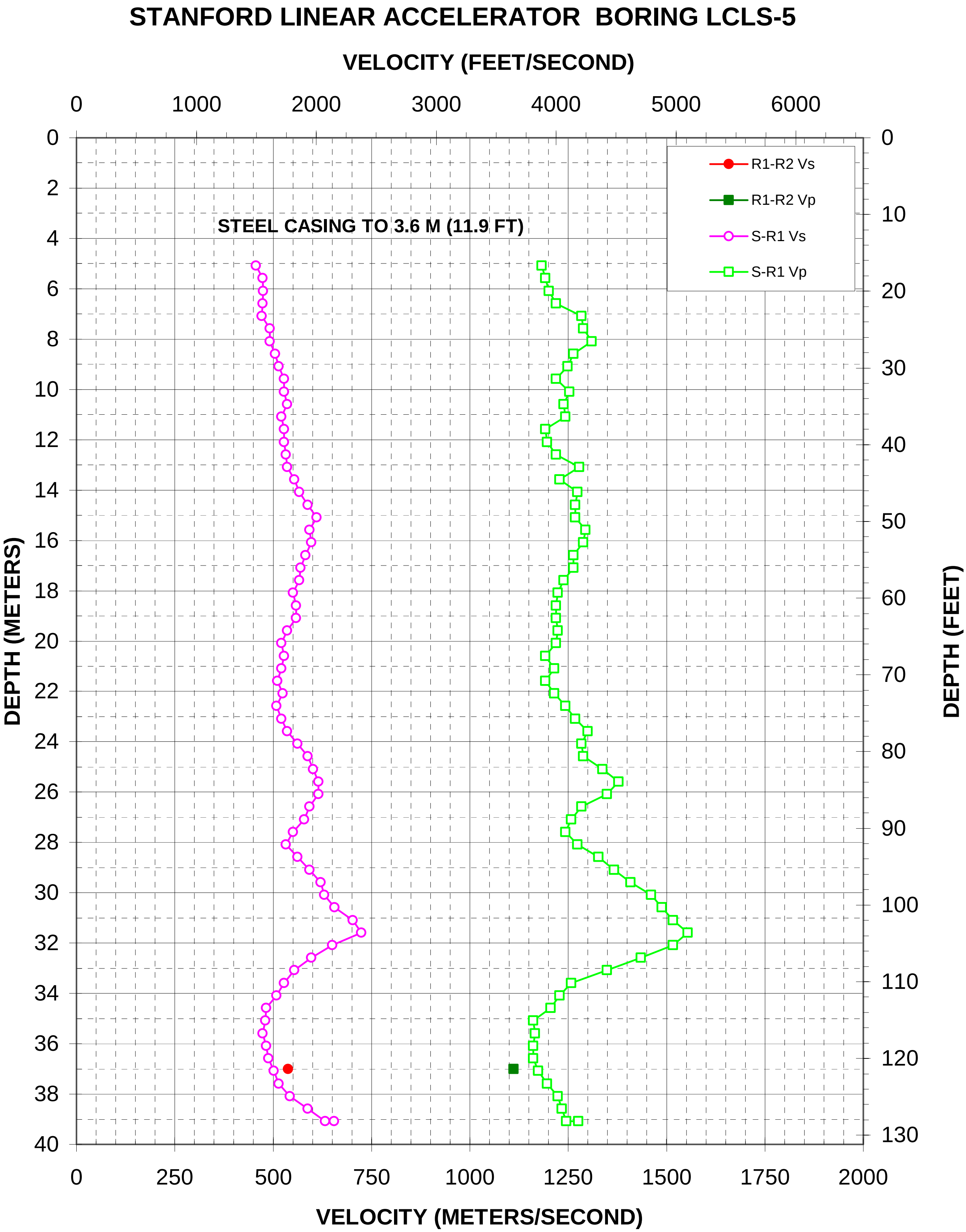

Figure A-2. Boring LCLS-5, R1 - R2 high resolution analysis and S-R1 quality assurance analysis

Depth (meters)	Velocity		Depth (feet)	Velocity	
	V-S_H (m/sec)	V-p (m/sec)		V- S_H (ft/sec)	V-p (ft/sec)
5.1	457	1183	16.7	1499	3881
5.6	474	1192	18.3	1555	3910
6.1	475	1201	20.0	1557	3939
6.6	474	1219	21.6	1555	4000
7.1	471	1283	23.2	1545	4211
7.6	491	1289	24.9	1612	4228
8.1	491	1310	26.5	1612	4298
8.6	505	1263	28.2	1656	4144
9.1	515	1248	29.8	1688	4095
9.6	528	1219	31.4	1733	4000
10.1	528	1253	33.1	1733	4111
10.6	535	1238	34.7	1757	4063
11.1	521	1243	36.4	1711	4079
11.6	528	1192	38.0	1733	3910
12.1	528	1196	39.6	1733	3925
12.6	532	1219	41.3	1745	4000
13.1	535	1278	42.9	1757	4194
13.6	554	1229	44.6	1818	4031
14.1	566	1273	46.2	1857	4177
14.6	588	1268	47.9	1930	4160
15.1	611	1268	49.5	2004	4160
15.6	593	1294	51.1	1944	4245
16.1	597	1289	52.8	1959	4228
16.6	583	1263	54.4	1912	4144
17.1	570	1263	56.1	1871	4144
17.6	566	1238	57.7	1857	4063
18.1	550	1224	59.3	1806	4016
18.6	558	1219	61.0	1831	4000
19.1	558	1219	62.6	1831	4000
19.6	535	1224	64.3	1757	4016
20.1	521	1219	65.9	1711	4000
20.6	528	1192	67.5	1733	3910
21.1	521	1215	69.2	1711	3985
21.6	511	1192	70.8	1677	3910
22.1	525	1215	72.5	1722	3985
22.6	508	1243	74.1	1667	4079
23.1	521	1268	75.7	1711	4160
23.6	535	1299	77.4	1757	4262
24.1	562	1283	79.0	1844	4211
24.6	588	1289	80.7	1930	4228
25.1	602	1338	82.3	1973	4388
25.6	616	1378	83.9	2019	4522
26.1	616	1349	85.6	2019	4426
26.6	593	1283	87.2	1944	4211
27.1	578	1258	88.9	1898	4127
27.6	550	1243	90.5	1806	4079
28.1	532	1273	92.1	1745	4177
28.6	562	1326	93.8	1844	4352
29.1	593	1366	95.4	1944	4483
29.6	620	1409	97.1	2035	4622
30.1	630	1461	98.7	2068	4793
30.6	656	1488	100.3	2153	4883
31.1	703	1517	102.0	2306	4976
31.6	724	1554	103.6	2374	5098
32.1	651	1517	105.3	2136	4976
32.6	597	1434	106.9	1959	4706
33.1	554	1349	108.5	1818	4426
33.6	528	1258	110.2	1733	4127
34.1	508	1229	111.8	1667	4031
34.6	482	1205	113.5	1583	3954
35.1	480	1161	115.1	1573	3810
35.6	474	1165	116.7	1555	3824
36.1	482	1161	118.4	1583	3810
36.6	488	1161	120.0	1603	3810
37.1	502	1174	121.7	1646	3852
37.6	515	1196	123.3	1688	3925
38.1	543	1224	125.0	1781	4016
38.6	588	1233	126.6	1930	4047
39.1	633	1246	128.2	2076	4087
39.1	655	1276	128.2	2149	4185

Table A-2. Boring LCLS-5, S - R1 quality assurance analysis P- and S_H-wave data

APPENDIX B

OYO 170 VELOCITY LOGGING SYSTEM
NIST TRACEABLE
CALIBRATION PROCEDURE

TABLE B1

GEOVISION VELOCITY LOGGING EQUIPMENT DESCRIPTION AND CALIBRATION PROCEDURES

EQUIPMENT	FUNCTION	CALIBRATION REQUIREMENTS	MAINTENANCE REQUIREMENTS
OYO Model 170 Suspension Logging Data Logger	Records data from probe and sends control signals to probe	Every twelve months, calibrate sample clock using an NTIS-traceable external signal counter and signal generator per attached procedure. (see Attachment B2)	Diagnose and repair by manufacturer's authorized representative if sample clock is out of specification or instrument fails.
OYO Model 170 Suspension Logging Probe	Suspended in borehole to provide both seismic source and sense wave arrivals at two locations 1 meter apart	No sensor calibration is necessary, as amplitude is not important to the velocity measurement.	Repair as needed by manufacturer-trained personnel.
Winch System (several interchangeable models available)	The winch and cable suspend the probe in the borehole and connect it to the data logger	No calibration required	Repair as needed. Lubricate moving parts frequently, and keep cable clean.

ATTACHMENT B2

CALIBRATION PROCEDURE FOR GEOVISION'S VELOCITY LOGGING SYSTEM

1.0 OYO Model 170 Data Logger Unit

1.1 Purpose

The purpose of this calibration procedure is to verify that the sample clock of the OYO Model 170 is accurate to within 1%.

1.2 Calibration Frequency

The calibration described in this procedure shall be performed every twelve months minimum.

1.3 Test Equipment

- Function Generator, Krohn Hite 5400B or equivalent
- Frequency Counter, HP 5315A or equivalent, current NIST traceable calibration
- Test cable, function generator to OYO 170 Data Logger input channels

1.4 Procedure

- Connect function generator to OYO Model 170 data logger using test cable
- Set up function generator to produce a 100.0 Hz, 0.250 volt peak square wave
- Record a data record with 100 microsecond sample period
- Measure the square wave frequency in the digital data using the data logger's screen display or utility software

1.5 Calibration Criteria

The measured square wave frequency in the digital data must fall between 99.0 and 101.0 Hz to be deemed acceptable. If outside this range, the data logger must be repaired and retested.

MICRO PRECISION
CALIBRATION INC.

11562 Knott Avenue. Suite 3, Garden Grove, CA 92841
Ph. (714) 901-5659 Fax (714) 901-5649

Calibration Report

Customer: **GEOVISION Corona CA 92882**

Account: **15214**

Instrument: **BB9414 Digital Universal Test Center**

Mfg: **Tenma**	Model: **72-5085**	Serial #: **MB00006378**
Size:	Resltn:	Location:

Cust Ctrl:	Dept:	P.O.:
Job Number: **L19625**	Report Number: **146108**	Report Date: **081903**

Work Performed: **Inspected, cleaned, and calibrated.** Page **1** of **1**

Parts Replaced: **None**

Received Condition: **In tolerance** Returned Condition: **In tolerance**

Function Tested	
Multimeter	Function Generator cont'
AC/DC Volts & Current	Amplitude
Resistance & Capacitance	Sine wave distortion& flatness
Power Supply	Square wave symmetry, rise & fall time
Voltage	Triangle wave linearity
Current	TTL rise & fall time, output level
Ripple	
Frequency Counter	
Frequency range & Accuracy	
Input Sensitivity	
Function Generator	
Frequency	

Ctrl #	Manufacture, Model #, & Description of standards used for calibration	Due Date	Traceability
T1300	Hewlett Packard 33120A Arbitary Waveform Ge	011704	83836
J8300	Hewlett Packard 8657A Signal Generator	052704	137792
P5300	Tektronix THS710 Oscilloscope w/DMM	030504	133387
L1600	Hewlett Packard 34401A Multimeter	121803	97906

Services provided conform to ANSI/NCSL Z540-1-1994, ISO 10012-1:1992 or ISO/IEC 17025 as applicable.
All work performed complies with MPC Quality System QM 540-94, Rev 1e.

Environmental: 73 Deg F / 45% Rh

Uncertainty: Accuracy Ratio > 4:1

Cal Procedure: Manufacture Man

Technician: HOMERO E. CARDONA

Test Date: 081903

Cycle: 12

Due Date: 081904

Quality Approval: QC 3

Form Cert 2-25-02

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a division of Blackhawk GeoServices

SEISMOGRAPH CALIBRATION DATA SHEET REV 7/11/02

INSTRUMENT DATA

SYSTEM MFR:	OYO	MODEL NO.:	3331
SERIAL NO.:	12004	CALIBRATION DATE:	8/21/03
BY:	R. STELLER	DUE DATE:	8/21/04
COUNTER MFR:	TENMA	MODEL NO.:	72-5085
SERIAL NO.:	MB00006378	CALIBRATION DATE:	8/19/03
BY:	MICROPRECISION CAL	DUE DATE:	8/19/04
FCTN GEN MFR:	TENMA	MODEL NO.:	72-5085
SERIAL NO.:	MB00006378	CALIBRATION DATE:	8/19/03
BY:	MICROPRECISION CAL	DUE DATE:	8/19/04

SYSTEM SETTINGS:

GAIN: 10
FILTER: 20 KHZ
RANGE: 100 mSEC
DELAY: 0
STACK: 1 (STD) 1
PULSE: 1.6 mSEC
DISPLAY: VARIABLE
SYSTEM: DATE = CORRECT DATE & TIME 8/21/03 4:29 Pm

PROCEDURE:

SET FREQUENCY TO 100.0HZ SQUAREWAVE WITH AMPLITUDE APPROXIMATELY 0.25 VOLT PEAK. RECORD BOTH ON DISKETTE AND PAPER TAPE. ANALYZE AND PRINT WAVEFORMS FROM ANALYSIS UTILITY. ATTACH PAPER COPIES OF PRINTOUT AND PAPER TAPES TO THIS FORM. AVERAGE FREQUENCY MUST BE BETWEEN 99.0 AND 101.0 HZ.

AS FOUND 100.0 AS LEFT 100.0

WAVEFORM	FILE NO	FREQUENCY	TIME FOR 9 CYCLES Hn	TIME FOR 9 CYCLES Hr	TIME FOR 9 CYCLES V	AVERAGE FREQ.
SQUARE	001	100.0	90.0	90.0	90.0	100.0
SQUARE	002	100.0	90.0	90.0	90.0	100.0
SINE	003	100.0	90.0	90.0	90.0	100.0
SINE	004	100.0	90.0	90.0	90.0	100.0

CALIBRATED BY: ROBERT STELLER 8/21/03
NAME DATE SIGNATURE

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SEISMOGRAPH CALIBRATION DATA SHEET REV 7/11/02

INSTRUMENT DATA

SYSTEM MFR:	OYO	MODEL NO.:	3331
SERIAL NO.:	15014	CALIBRATION DATE:	8/21/03
BY:	R. STELLER	DUE DATE:	8/21/04
COUNTER MFR:	TENMA	MODEL NO.:	72 - 5085
SERIAL NO.:	MB 00006378	CALIBRATION DATE:	8/19/03
BY:	MICROPRECISION CAL	DUE DATE:	8/19/04
FCTN GEN MFR:	TENMA	MODEL NO.:	72 - 5085
SERIAL NO.:	MB 00006378	CALIBRATION DATE:	8/19/03
BY:	MICROPRECISION CAL	DUE DATE:	8/19/04

SYSTEM SETTINGS:

GAIN: 10
FILTER: 20 KHz
RANGE: 100 mSEC
DELAY: 0
STACK: 1 (STD) 1
PULSE: 1.6 mSEC
DISPLAY: VARIABLE
SYSTEM DATE = CORRECT DATE & TIME 8/21/04 4:13 pm

PROCEDURE:

SET FREQUENCY TO 100.0HZ SQUAREWAVE WITH AMPLITUDE APPROXIMATELY 0.25 VOLT PEAK. RECORD BOTH ON DISKETTE AND PAPER TAPE. ANALYZE AND PRINT WAVEFORMS FROM ANALYSIS UTILITY. ATTACH PAPER COPIES OF PRINTOUT AND PAPER TAPES TO THIS FORM. AVERAGE FREQUENCY MUST BE BETWEEN 99.0 AND 101.0 HZ.

AS FOUND 100.0

AS LEFT 100.0

WAVEFORM	FILE NO	FREQUENCY	TIME FOR 9 CYCLES Hn	TIME FOR 9 CYCLES Hr	TIME FOR 9 CYCLES V	AVERAGE FREQ.
SQUARE	101	100.0	90.0	90.0	90.0	100.0
SQUARE	102	100.0	90.0	90.0	90.0	100.0
SINE	103	100.0	90.1	90.0	90.0	100.0
SINE	104	100.0	90.0	90.0	89.9	100.0

CALIBRATED BY: ROBERT STELLER 8/21/03
NAME DATE SIGNATURE

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SEISMOGRAPH CALIBRATION DATA SHEET REV 7/11/02

INSTRUMENT DATA

SYSTEM MFR: O40
MODEL NO.: 3331
SERIAL NO.: 19029
CALIBRATION DATE: 8/21/03
BY: R. STELLER
DUE DATE: 8/21/04

COUNTER MFR: TENMA
MODEL NO.: 72-5085
SERIAL NO.: MB00006378
CALIBRATION DATE: 8/19/03
BY: MICROPRECISION CAL
DUE DATE: 8/19/04

FCTN GEN MFR: TENMA
MODEL NO.: 72-5085
SERIAL NO.: MB00006378
CALIBRATION DATE: 8/19/03
BY: MICROPRECISION CAL
DUE DATE: 8/19/04

SYSTEM SETTINGS:

GAIN: 10
FILTER: 20 KHZ
RANGE: 100 MSEC
DELAY: 0
STACK: 1 (STD) 1
PULSE: 1.6 MSEC
DISPLAY: VARIABLE
SYSTEM DATE = CORRECT DATE & TIME 8/21/03 4:39 pm

PROCEDURE:

SET FREQUENCY TO 100.0HZ SQUAREWAVE WITH AMPLITUDE APPROXIMATELY 0.25 VOLT PEAK. RECORD BOTH ON DISKETTE AND PAPER TAPE. ANALYZE AND PRINT WAVEFORMS FROM ANALYSIS UTILITY. ATTACH PAPER COPIES OF PRINTOUT AND PAPER TAPES TO THIS FORM. AVERAGE FREQUENCY MUST BE BETWEEN 99.0 AND 101.0 HZ.

AS FOUND 100.0
AS LEFT 100.0

WAVEFORM	FILE NO	FREQUENCY	TIME FOR 9 CYCLES Hn	TIME FOR 9 CYCLES Hr	TIME FOR 9 CYCLES V	AVERAGE FREQ.
SQUARE	201	100.0	90.0	90.0	90.0	100.0
SQUARE	202	100.0	90.0	90.0	90.0	100.0
SINE	203	100.0	90.1	90.0	90.0	100.0
SINE	204	100.0	90.0	90.0	90.1	100.0

CALIBRATED BY: ROBERT STELLER (NAME) 8/21/03 (DATE) (SIGNATURE)