Department of Energy
Office of Civilian Radioactive Waste Management
Yucca Mountain Site Characterization Office
P.O. Box 98608
Las Vegas, NV 89193-8608

SEP 25 1996

L. D. Foust
Technical Project Officer
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Bank of America Center, Suite P-110
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Las Vegas, NV 89109

VERIFICATION OF CORRECTIVE ACTION AND CLOSURE OF DEFICIENCY REPORT (DR) YM-96-D-010, REVISION 1, RESULTING FROM YUCCA MOUNTAIN QUALITY ASSURANCE DIVISION'S (YMQAD) AUDIT YM-ARP-96-01 OF THE UNIVERSITY OF NEVADA AT RENO/SEISMOLOGICAL LABORATORY

The YMQAD staff has verified the corrective action to DR YM-96-D-010, Revision 1, and determined the results to be satisfactory. As a result, the DR is considered closed.

If you have any questions, please contact either Robert B. Constable at (702) 794-5580 or Donald J. Harris at (702) 794-1467.

Robert B Constable for

Richard E. Spence, Director
Yucca Mountain Quality Assurance Division

YMQAD:RBC-2692

Enclosure:
DR YM-96-D-010, Revision 1

cc w/encl:
T. A. Wood, DOE/HQ (RW-14) FORS
J. G. Spraul, NRC, Washington, DC
S. W. Zimmerman, NWPO, Carson City, NV
R. L. Strickler, M&O, Vienna, VA
B. R. Justice, M&O, Las Vegas, NV
R. P. Ruth, M&O, Las Vegas, NV
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D. G. Horton, DOE/OQA, Las Vegas, NV

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recip: NMSS/HLUR

OFFICE OF CIVILIAN RADIOACTIVE WASTE MANAGEMENT
U.S. DEPARTMENT OF ENERGY
WASHINGTON, D.C.

8 ☐ Performance Report
☑ Deficiency Report

NO. YMQAD-96-D010, R1

QA: L

PERFORMANCE/DEFICIENCY REPORT

1 Controlling Document:
QARD, DOE/RW-0333P, Rev. 4

2 Related Report No.
YM-ARP-96-01

3 Responsible Organization:
M&O/UNRSL

4 Discussed With:
W. Rodman (USGS)/W. Nicks (UNRSL)

5 Requirement/Measurement Criteria:
QARD, Paragraph 4.2.1C.1, "Procurement documents shall include a requirement for the supplier to have a documented QA Program that implements applicable QARD requirements prior to the initiation of work." Paragraph 7.2.2A, "Supplier selection shall be based on an evaluation, performed before the contract is awarded, of the suppliers' capability to provide items or services in accordance with the procurement document requirements".

6 Description of Condition:
Contrary to the above requirements, Teledyne Geotech model 18300, Drawing 990-18300-9600 seismometers were procured from an unqualified supplier whose QA program was not evaluated. The seismometers were provided with Calibration Certifications which contained the Coil Motor Constant reading which was subsequently used by UNRSL as calibration input without verifying the actual Coil Motor Constant prior to their calibration of the seismometer, Drawing 990-18300-9600, Model 18300, S/N 3183.

7 Initiator Donald J Harris
Donald J. Harris Date 1/10/96

9 QA Review Donald J Harris
QAR Donald J. Harris Date 1/10/96

10 Response Due Date
20 working days from issuance

11 QA Issuance Approval [signature] for
QAR (PR)/AQQAM (DR) Date 1-16-96

12 Remedial Actions:

Investigate the procedure used by the seismometer manufacturer to determine coil motor constants. Determine if the procedure meets the requirements of the QARD. If the procedure meets the QARD requirements, qualify the coil motor constants in accordance with OCRWM approved procedure. If the procedure to determine the coil motor constant does not meet QARD requirements, evaluate the benefit of qualified magnitudes versus the cost of verifying all seismometer coil motor constants. Evaluate whether increased magnitude uncertainties are acceptable to meet project needs.
Responsible Individual: David von Seggren. Due Date: July 31, 1996

13 Remedial Action Response By: R. C. Quitt
RICHARD C. QUITTMEYER Date 2/14/96

14 Remedial Action Due Date JULY 31, 1996
Date

15 Remedial Action Response Acceptance
QAR D Harris Date 3/13/96

16 PR Verification/Closure
QAR N/A Date

Exhibit AP-16.1Q.1 Enclosure Rev. 07/03/9

8
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QA: L

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DEFICIENCY REPORT

17 Recommended Actions:

Either qualify the supplier to provide calibration services or verify the Coil Motor Constant Reading prior to use by UNRSL in their calibration.

18 Investigative Actions:

Of the 18 sets of Teledyne Geotech 3-component seismometers installed as part of the Southern Great Basin Seismic Monitoring Network, all were procured by the USGS in 1990 from an unqualified supplier. Thus none of the coil motor constants used as calibration input were qualified.

Future procurements for the seismic monitoring effort will be carried out by the M&O rather than the USGS. The subcontract for UNR and implementation of quality assurance requirements for this scope of work was transitioned from the USGS to the M&O at the beginning of FY 1996. Thus root cause determination with respect to USGS procurements is not appropriate.

19 Root Cause Determination:

N/A

20 Action to Preclude Recurrence:

N/A

21 Response by: R.C. Quitt [signature] RICHARD C. QUITTMEYER Date 2/14/96	22 Corrective Action Completion Due Date:
23 Response Accepted QAR [signature] Date 3/13/96	24 Response Accepted AOQAM [signature] for Date 3.20.96
25 Amended Response Accepted QAR Date	26 Amended Response Accepted AOQAM Date
27 Corrective Actions Verified QAR [signature] Date 9/13/96	28 Closure Approved by: AOQAM [signature] for Date 9.24.96

ORIGINAL
THIS IS A RED STAMP

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U.S. DEPARTMENT OF ENERGY
WASHINGTON, D.C.

8 ☐ Performance Report
☑ Deficiency Report

NO. YMQAD-96-D010

QA: L

PERFORMANCE/DEFICIENCY REPORT

1 Controlling Document:	2 Related Report No.
QARD, DOE/RW-0333P, Revision 4	YM-ARP-96-01

3 Responsible Organization:	4 Discussed With:
USGS/UNRSL	W. Rodman (USGS)/W. Nicks (UNRSL)

5 Requirement/Measurement Criteria:

QARD, Paragraph 4.2.1C.1, Procurement documents shall include a requirement for the supplier to have a documented QA program that implements applicable QARD requirements prior to the initiation of work. Paragraph 7.2.2A,Supplier selection shall be based on an evaluation, performed before the contract is awarded, of the suppliers' capability to provide items or services in accordance with the procurement document requirements.

6 Description of Condition:

Contrary to the above requirements, Teledyne Geotech model 18300, Drawing 990-18300-9600 seismometers were procured from an unqualified supplier whose QA program was not evaluated. The seismometers were provided with Calibration Certifications which contained the Coil Motor Constant reading which was subsequently used by UNRSL as calibration input without verifiying the actual Coil Motor Constant prior to their calibration of the seismometer, Drawing 990-18300-9600, Model 18300, S/N3183.

7 Initiator	9 QA Review
Donald J. Harris (signature) Donald J. Harris Date 10/25/95	QAR Donald J. Harris (signature) Date 11/1/95
10 Response Due Date 20 working days from issuance	**11 QA Issuance Approval** QAR (PR)/AQQAM (DR) (signature) Date 11/7/95

12 Remedial Actions:

13 Remedial Action Response By:	14 Remedial Action Due Date
Date	Date
15 Remedial Action Response Acceptance QAR Date	**16 PR Verification/Closure** QAR Date

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U.S. DEPARTMENT OF ENERGY
WASHINGTON, D.C.

DEFICIENCY REPORT

17 Recommended Actions:

Either qualify the supplier to provide calibration services or verify the Coil Motor Constant Reading prior to use by UNRSL in their calibrations.

18 Investigative Actions:

19 Root Cause Determination:

20 Action to Preclude Recurrence:

21 Response by: Date	22 Corrective Action Completion Due Date:
23 Response Accepted QAR Date	24 Response Accepted AOQAMM Date
25 Amended Response Accepted QAR Date	26 Amended Response Accepted AOQAMM Date
27 Corrective Actions Verified N/A QAR [signature] Date 1/11/96	28 Closure Approved by: AOQAMM [signature] Date 1.16.96

Report on Seismometer Calibration for the Southern Great Basin Digital Seismic Network

David von Seggern

University of Nevada, Reno, Seismological Laboratory

August 28, 1996

Background

In Deficiency Report YMQAD-96-D010, R1, it was noted that the seismometers of the Southern Great Basin Digital Seismic Network (SGBDSN) were purchased from an unqualified vendor (Teledyne-Brown Engineering). The output of the seismometers (volts) relative to input (meters/sec) is given by a factor which is essential for determination of true ground motion from recorded seismic data. This factor is given in the specification sheet delivered with each seismometer by Teledyne-Brown Engineering. In order to get an accurate, qualified determination of this factor, the seismometers would need to be removed from the field sites and sent to a qualified laboratory where this factor could be measured in a qualified manner. As an alternative to this expensive, disruptive approach, we have undertaken analysis of real recorded data as presented in this report. We believe that these results, although not as accurate as laboratory determinations, are sufficiently accurate relative to the unknown effects on recorded amplitudes from seismometers. These effects are due to variable wave attenuation in the earth and variable site effects dependent on local geology, among others; these effects can together cause amplitude variations several times the uncertainty of the seismometer scale factor. Documentation of the procedure used in this analysis is contained in Scientific Notebook #0090, "Development of the Central Hardware and Software Facilities for the SGBDSN."

Current Calibration Procedure

The calibration procedure in use for the SGBDSN seismometers is given in detail in NWI-UNR-001 (draft) and will not be repeated here. In essence, this indirectly determines the volts/(meter/sec) for each instrument by application of a DC current through a calibration coil and subsequent analysis of the recorded response pulse. The mathematical expressions imply that the product

Gg*Gc

is directly determined where Gg is the constant of the seismometer output coil [volts/(meter/sec)] and Gc is the constant of the seismometer calibration coil (newtons/ampere). Gg can only be confirmed with the calibration procedure if Gc is known for certain. In this case, neither is known in a "qualified" sense although both constants are given by the manufacturer on their specification sheet. We have run the calibration procedure for several months now, and the results indicate that Gg, as given by the manufacturer, is correct if the stated value of Gc is assumed to be correct.

The problem is to determine that Gg is correct independent of the assumption that Gc is correct. We need to eliminate the possibility that errors in Gg and Gc offset one another, such that the product Gg*Gc is unchanged. This elimination can be done by looking at actual seismic waves because only Gg affects the actual observed amplitudes. The calibration coil constant Gc does not affect the output of the seismometer during normal recording, only during the brief calibration windows.

Use of Surface Wave Measurements

High-frequency (about 1 Hz and higher) signals from earthquakes are highly variable in their amplitude over even a small network with the 100-km aperture of the SGBDSN. However, teleseismic surface waves at longer periods are known to have stable amplitudes with small variance over such dimensions. Only by sampling such a relatively constant wavefield can the relative values of Gg be shown to be nearly identical. By inference, the values of Gc would be shown to be nearly identical. This does not, however, confirm the absolute value of either Gg or Gc, which both may still be in error in a consistent manner across all seismometers, but offsetting one another. In order to verify Gg, we will also measure the surface waves on another set of independent CMG-4 seismometers manufactured by Guralp Systems. Four (4) of the current SGBDSN stations have such seismometers while eighteen (18) have the S-13 seismometers. A major difference between the two instruments is the natural frequency, 1 Hz for the S-13 and .0333 Hz for the CMG-4. If both sets of measurements, from the S-13 and from the CMG-4 seismometers, when reduced to true ground motion with the manufacturer's stated Gg constants, show nearly the same values, this would be strong evidence for the correctness of Gg in both cases.

Method of Measurement and Data Reduction

Of the many teleseismic events recorded by the SGBDSN during 1995 and 1996, only a few were judged suitable for surface-wave measurements. Most events fail to be suitable simply because the S-13 systems are tuned to high-frequency recording, with a seismometer natural frequency of 1 Hz. We chose 5 events as follows:

#	year	day	time (UTC)	latitude longitude	geographic location
1	1995	337	18:10:52	44.66N 149.38E	Kuril Islands
2	1996	001	08:22:40	0.66N 119.92E	Minahassa Pen., Sulawesi
3	1996	120	14:52:38	6.52S 154.80E	Solomon Islands
4	1996	163	18:35:00	12.71N 125.00E	Samar, Philippine Islands

5	1996	218	02:19:21	15.21S 173.37W	Tonga Islands

Peak-to-trough amplitudes were measured on the vertical-component waveforms at a period of approximately 20 sec in each case. Relative arrival times across the SGBDSN for 20-sec period Rayleigh waves were computed based on back azimuth to the earthquake source, and these were used to guide the picking of the correct waveform peaks across the network. The amplitudes were measured in counts. Correct conversion from counts to volts depends on knowing the DAS A/D conversion scale (counts per volt). For purposes of this report, we assume that this is known correctly. (We and many other independent seismologists have done numerous tests to verify the DAS A/D scaling). Those amplitudes taken from the CMG-4 seismometers were converted to S-13 equivalent amplitudes. This is an important step and requires that we use the ratio of the two manufacturers' Gg constants and the ratio of the normalized responses at a period of 20 sec. Thus the equivalent S-13 amplitude is

$$A' = A\,[Gg\,(S\text{-}13)/Gg\,(CMG\text{-}4)]*[R\,(S\text{-}13)/R\,(CMG\text{-}4)]$$

where

A is the measured CMG-4 amplitude

Gg are the respective generator constants

R are the respective normalized responses at 20-sec period

The values for R are read from the response curves at f = 0.05 Hz when the high-frequency portions (>1 Hz) are overlain, and the values used for Gg are nominal values taken as averages of the actual values given on the manufacturer's specification sheets. The correction factor to be applied to A was thus calculated to be approximately 0.231. Values of equivalent S-13 amplitude A' were then tabulated for the four CMG-4 stations.

Results

Figure 1 shows the measured amplitudes for each event on a log scale. There are several missing observations, and these are mostly due to the fact that certain stations were not yet installed at the time of the event. Four outlier values were identified in a preliminary plotting of data and were eliminated from the analysis. A few remaining missing values are explained by station downtime or lack of recordings for some reason.

Figure 1 shows several important facts. Firstly, for each event, the measured amplitudes are remarkably consistent, with a range of only about 0.1 log units. (We note that station magnitudes for local events typically have a range of 1.0 or more log units and a standard deviation of several tenths.) Thus, the amplitudes indicate strongly that the constants Gg for the instruments are within a range as small as or smaller than 0.1 log units. Again, the constant Gc of the calibration coil has no effect here. Secondly, the CMG-4 amplitudes, after appropriate correction to an S-13 amplitude, are very close to the amplitudes for the actual S-13 stations. Thirdly, the amplitudes for a given station tend to be consistently biased relative to the average level for each event, indicating small, but consistent, site effects or instrument effects.

An appropriate statistical model for the observed amplitudes is given by

$$\log_{10}A = a + s_i + r_j + e_{ij}$$

where

a = constant

s_i = effect of ith source (mean amplitude of the surface waves)

r_j = effect of jth station (bias due to site geology, coupling, or seismometer itself)

e_{ij} = random, normally distributed error term

Log amplitudes are used to partially compress the source effect and also because it is well known that log amplitudes, not amplitudes, have a normal distribution in seismological observations. The above regression, termed a "two-way layout", can be solved with missing observations, as in this case, with only slightly more programming effort. Only the r_j results of the regression are of interest here; the antilogs of these are plotted in Figure 2 versus the Gg stated on the manufacturer's specification sheet for the S-13 seismometers only. There is one outlier point, for the SYM station: and we believe that the Gg value is indeed in error for this instrument. This merely reinforces our trust in the actual calibrations discussed above: for those calibration results also revealed that the Gg value for this instrument was probably measured or recorded in error. Figure 2 shows an apparent weak correlation between the computed receiver effect and the stated S-13 Gg values. We would expect this result; the scatter which makes this a poor correlation is undoubtedly due to site and propagation effects on the amplitudes. The important result of Figure 2 though is the small range of computed receiver effects. This result indicates that the seismometers across the SGBDSN are outputting nearly identical amplitudes, to within ±5%. This is important evidence in confirming that we "know" the Gg values to within that range also.

Results for Horizontal Seismometers

The measurements were done on the vertical-component seismometers because the vertical component of the Rayleigh waves is not influenced by the direction of wave propagation and is generally of higher S/N ratio than the corresponding horizontal components of motion. In order to make some check on the horizontal seismometers, we measured amplitudes for event 5 only, and only on the S-13 recordings. The amplitudes, identified as "NS" from the north-south component and "EW" from the east-west component are plotted in Figure 3. There is much larger scatter, as expected, than for the vertical-component results in Figure 2, which represent an "averaging" over

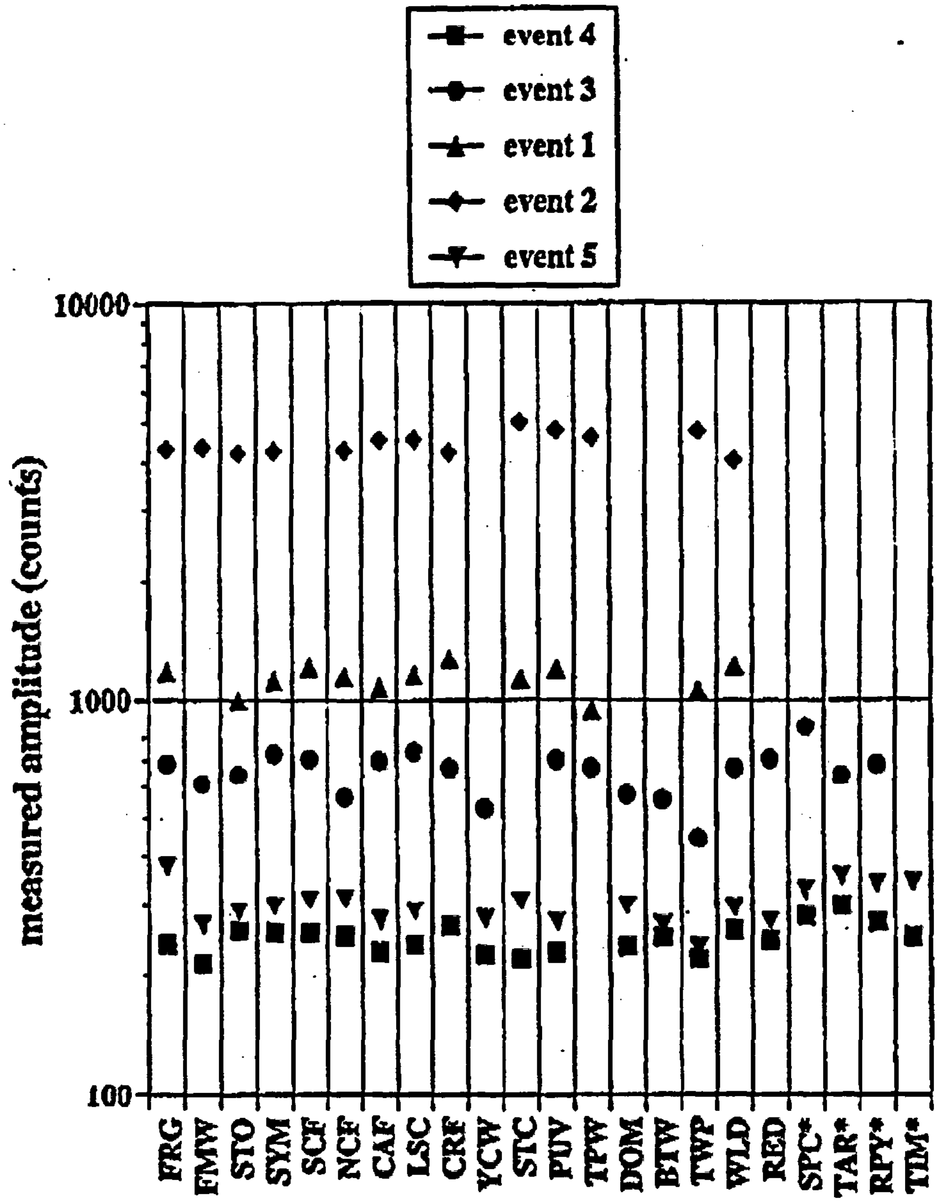
5 events. It would probably require measurements on tens of events to reduce the horizontal-component scatter to a level attained for the vertical components, but this one event shows that there are no gross variations in the seismometer constants Gg for horizontal components.

Conclusion

We have satisfactorily investigated the correctness of scaling constants for S-13 model seismometers manufactured by Teledyne-Brown Engineering. By utilizing wavefields that are relatively constant over the 100-km aperture of the SGBDSN (Rayleigh waves at 20-sec period) from 5 teleseismic events, we have shown from carefully measured amplitudes that the Gg values of the S-13 vertical-component seismometers must have a fairly narrow range of values (±5%) and, with one exception, are consistent with the manufacturer's values provided at the time of instrument delivery. This consistency agrees with our routine calibration results for these instruments over the past year.

The amplitudes were also measured on the recordings of independent CMG-4 instruments (Guralp Systems); and, when these amplitudes were corrected to equivalent S-13 ones by using the information from both manufacturers, the two sets of amplitudes agreed very closely, to within roughly ±5%. This provides strong corroboration of the correctness of the S-13 Gg values. This agreement could occur also if both manufacturers made errors of similar size and in the same direction when measuring or reporting instrument constants, but this is a very unlikely hypothesis.

A set of measurements from one event on the horizontal components of the S-13 instruments showed that these instruments were consistent across the network also, although the scatter was much greater than the vertical-component results which were averaged over five events. A set of several tens of events would probably be necessary to attain a result for the two horizontal components comparable to that for the vertical component.



* CMG-4 stations SPC, TAR, RPY, TIM scaled to S-13 equivalent)

Figure 1

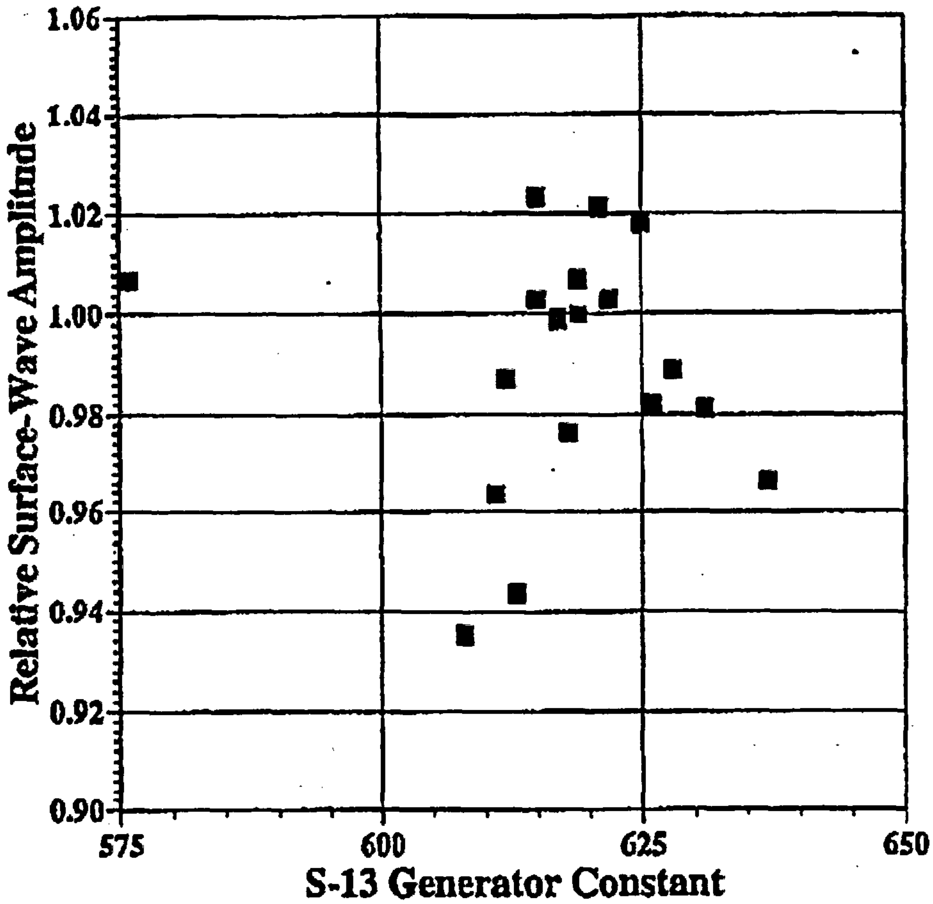

1.06
1.04
1.02
1.00
0.98
0.96
0.94
0.92
0.90
Relative Surface-Wave Amplitude
575
600
625
650
S-13 Generator Constant

Figure 2

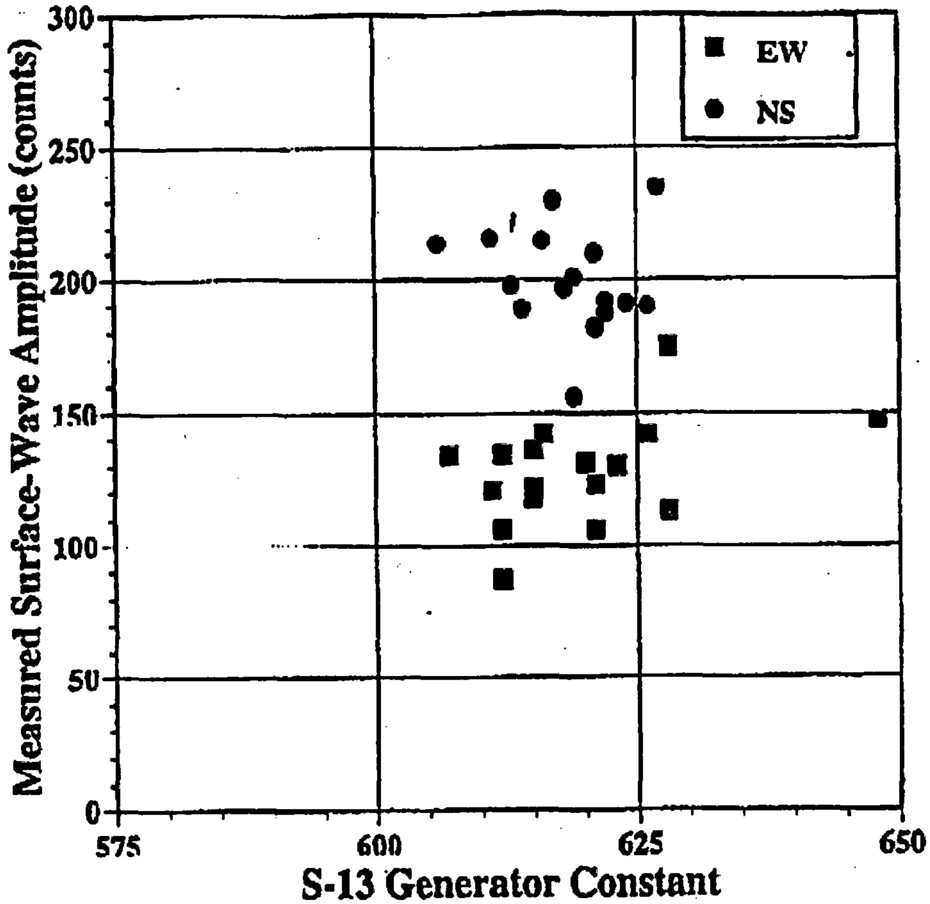

EW
NS
Measured Surface-Wave Amplitude (counts)
300
250
200
150
100
50
0
575
600
625
650
S-13 Generator Constant

Figure 3

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QA: L

PR/DR CONTINUATION PAGE

VERIFICATION OF CORRECTIVE ACTION FOR DR YM-96-D-010, REVISION 1

Block 27 - Corrective Action Verified -

Verified by review of the University of Nevada at Reno, Seismological Laboratory, "Report on seismometer calibration for the Southern Great Basin Digital Seismic Network", dated August 28, 1996, author David Von Seggern.

The Report's conclusion is the S-13 seismometer instruments procured from Teledyne - Brown Model 18300, coil motor constant readings used by UNRSL as calibration input were suitable and within an acceptable tolerance for calibration, based on the above report results. The Report provided an acceptable methodology and confirmed the seismometer is within an acceptable tolerance of calibration accuracy for their intended application.

Donald J. Harris
Donald J. Harris, QAR

September 13, 1996
Date