SensOrLoc

Sensitivity, Orientation, and Location Checking Procedures at GSN and ANSS Stations

CRH

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The purpose of these procedures is to accurately check the sensitivity, orientation, and location of all seismic sensors at seismic stations **without disturbing the installed sensors at the stations**.

Outline of steps:

Step 1: Calibrate reference system (seismometer and Q330 data logger with baler) at ASL.
Step 2: Ship reference system and orientation-determining equipment to station.
Step 3: Determine and mark reference azimuth where reference seismometer will be installed.
Step 4: Set up reference system at station in a quiet environment.
Step 5: Record data on reference data logger overnight or during a quiet period while station system is recording data.
Step 6: Download data from baler onto laptop for safekeeping and transport back to ASL. ***Do not wipe the baler!***
Step 7: Check sensitivity of station data logger channels using voltage reference.
Step 8: Determine location of station GPS antenna and location of station seismometers relative to station GPS antenna (this step may be done at any time – order is not important).
Step 9: Ship reference system and orientation-determining equipment back to ASL or to next site to be checked.
Step 10: At ASL, **calibrate reference system** again.
Step 11: Archive data from reference system in Data Center.
Step 12: QC analysts will compare data from station and reference system to d**etermine sensitivity and orientation of station seismometer** relative to reference seismometer.

SensOrLoc Kits:

Each kit shall contain the following major items, with appropriate accessories added (such as interconnecting cables).

- STS-2 seismometer, standard gain, calibrated
- Seismometer orientation jig
- PVC tube, sand, installation accessories
- Q330 data logger, baler, GPS antenna with cable
  - Small battery may be included, or may be purchased at site
- Theodolite, if to be used to perform sun shot (preferred method??)
  - Add Sokkia gyro if orientation is far underground or sun shot not possible

    - No theodolite required if vertical rod/shadow method of sun shot is to be used. In this case, a level and vertical rod will be required.
    - Protractor, string, orientation accessories, chalk line, 36" straight edge, square, etc.
- Hand-held GPS
- Precision voltage reference source with input cable(s) appropriate for input to all channels of data logger at station.
- Hardigg shipping container for seismometer, Q330, baler, and accessories (plus small 12VDC battery, if necessary).

Reference System Naming Convention: The first Q330/baler is named AZI1. Subsequent systems will be named AZI2, AZI3, etc. Only BH? (40 sps) and LH? (1 sps) channels are saved on the baler. Channels are named as follows:

Input A (Q330 channels 1-3): 00/BHZ,N,E and 00/LHZ,N,E
Input B (Q330 channels 4-6): 10/BHZ,N,E and 10/LHZ,N,E

We will normally use only Input A. Input B may be used if any of channels 1-3 are not working properly.

Data Storage (Archive): Data will be stored in the DCC in a directory structure that will consist of the following directory levels:

Level 1: /xs0
Level 2: /ref_sys
Level 3: /AZIn_CODE, where n is 1, 2, 3 (etc) and CODE is the code of the station being tested (such as ECSD)
Level 4: /YEAR = year of data
Level 5: /DAY = day of data

Detailed Procedure:

Step 1: Calibrate reference seismometer (standard gain STS-2) and Q330 data logger (station code will be AZI1, AZI2, etc.) using Lennartz step calibration table, following the Lennartz Step Calibration Procedure (this has yet to be written with Leo's help). The Q330 and STS-2 shall be calibrated as a pair (producing counts/m/s) so that separate seismometer and data logger sensitivities need not be known. However, the Q330 reference data logger shall also be calibrated with a reference voltage during this step so that the sensitivity of the STS-2 can be backed out and compared to the factory value of 1500 V/m/s. This information will also be useful in case any STS-2/Q330 pair ever needs to be split up for any reason.

An alternative method for calibrating the reference seismometer/data logger pair is to set it up in the ASL tunnel and record data for comparison with one of the ASL reference instruments that are routinely recorded on either NHYX (STS-1s) or TST1 (a high gain STS-2). This method should be used only if the Lennartz step table is not working, not available, or there is not enough time to perform the calibration using the step table. The reference STS-2 in the ASL cross tunnel will be calibrated once per year using the Lennartz step calibration table to assure that its sensitivity is known.

Step 2: Ship reference system and orientation-determining equipment to station.

Step 3: First, determine where the reference seismometer will be installed. If the station uses borehole seismometers, the reference seismometer should be installed near the top of the borehole(s). It may be possible to install on the concrete pad around the boreholes (if one exists), pending results of testing this method at ANMO. However, it will probably be necessary to install the reference seismometer in a shallow hole. If the station seismometers are installed in a vault, the reference seismometer should be installed on the pier next to the station seismometers (or on the floor next to the pier if there is not enough space on the pier).

Case 1: Boreholes. Sun shot using theodolite or shadow method may be used.

Case 2: Vault with line-of-sight access from outside to reference seismometer installation spot. Sun shot using theodolite shall be used. Theodolite will be used to transfer accurate azimuth into vault, and will likely have to be used again in the vault to turn this (most likely non-north) azimuth to a cardinal direction for aligning the reference seismometer.

Case 3: Vault without line-of-sight access from outside to reference seismometer installation spot or sun not available. If a minimal number of angles need to be turned to transfer a sun-shot-derived azimuth from outside into the vault, then use a theodolite. However, if this is not practical, then the theodolite with gyro must be used to determine north directly in the vault.

Shadow method (assuming Case 1): Dig hole or set up reference seismometer on concrete pad or other hard surface, as appropriate. Set up vertical shadow rod at a distance and direction from the seismometer installation spot such that the sun will cast a shadow over the degree wheel on top of the seismometer orientation jig at the time when you expect the sun to be available. At the correct time, install and orient the seismometer using the azimuth of the sun's shadow as determined from a pre-printed table of sun azimuth for your latitude, longitude, and time. The reference seismometer should be installed to an accuracy of 1º or better.

Sun shot method (assuming Case 1): Dig hole or set up reference seismometer on concrete pad, as appropriate. Set up theodolite at a distance and direction from the seismometer installation spot that will allow you to transfer a line of known azimuth (preferably North or East) to the degree wheel on top of the seismometer orientation jig. At the correct time, install and orient the seismometer using the azimuth as determined by the sun shot (see **GSN SunShot Procedures Using Internet Solar Position Calculator** located at N:\PROJECTS\Goldbook\NEWSTUFF Pending Incorporation). The reference seismometer should be installed to an accuracy of 1º or better.

Sun shot method (assuming Case 2 or 3): Set up a theodolite at a distance and direction from the vault entrance that will allow you to transfer a line of known azimuth into the seismometer vault. Use standard surveying procedures to turn one or more angles and make an accurate East-West line on the pier or floor where the reference seismometer will be installed. Install the reference seismometer using the supplied alignment rod, which shall be pointed due East, parallel to the reference line you just made. The reference seismometer should be installed to an accuracy of 1º or better.

Gyro method (assuming Case 3): Set up a theodolite (with gyro) at a distance and direction from the reference seismometer installation spot that will allow you to mark an accurate East-West line on the floor or pier. If this is not possible, an accurate protractor may be used on the floor or pier surface to make an accurate East-West line from whatever line of known azimuth you are able to produce with the gyro/theodolite. Install the reference seismometer using the supplied alignment rod, which shall be pointed due East, parallel to the E-W reference line you just made. The reference seismometer should be installed to an accuracy of 1º or better.

Step 4: Install reference system in a quiet environment. It is quite important to install both the seismometer and the Q330/baler in a stable environment, to reduce the effects of temperature change and air movement. The most important element is the seismometer. In Cases 2 & 3 above (installation inside the existing seismometer vault), this will not be a problem as the reference seismometer simply needs to be covered with an air shield. In Case 1, the ideal situation is to bury the seismometer in a shallow hole. The standard method of doing this is to dig a hole big enough to allow complete burial of the seismometer and PVC tube to a depth of a few inches over the top. This will normally mean a hole about 2 feet deep and 2 feet in diameter. Use "standard" field system deployment techniques:

1. Put a flat bed of sand in the bottom of the hole with ceramic tile sitting level on top of the sand (rough side up).
2. Install, level, and accurately orient seismometer using one of the techniques in Step 3. Install 15" PVC tube around seismometer, fill space between seismometer and PVC tube either with insulating material or with a sand-filled cloth laundry bag **(sand is preferred over insulation)**.
3. Cover PVC tube with plastic bag (if needed to keep dry in wet environment) and then with dirt, to ground level.
4. Q330/baler may be installed close by inside an insulated Hardigg shipping container.

However, if it is not practical to dig a hole (due to frozen ground or rock, for example), it may be possible to install on a flat surface on the ground. In this case, install seismometer directly on hard, flat surface (or on tile on sand if surface is not hard and flat), put PVC tube over it with insulation or sand, and then cover PVC tube with an air shield (such as an upside down trash can with dirt shoveled around the edges to keep it from moving).

Step 5: Record data overnight. Record both BH data at 40 sps and LH data at 1 sps overnight on reference data logger. It is necessary to get several hours of quiet data, with the wind velocity at a minimum. If you experience wind or stormy conditions during the test, it may be necessary to record for another night during quieter conditions. This is most important if the reference seismometer is not installed in a seismic vault. Make sure that the station seismometers and data logger are collecting, storing (if appropriate), and transmitting data at the same time, because we need to have data from both the station system and the reference system in order to determine the sensitivity and orientation of the station seismometers.

Step 6: Download data from baler onto laptop computer for safekeeping and transport back to ASL. Also keep the data on the baler as a backup to the data stored on your laptop. **Do not wipe the baler!**

Step 7: Check sensitivity of all seismometer channels of station data logger. This is done by connecting a precision voltage reference source to each channel, one at a time, for at least 1 minute on each channel. Note the time (from the station GPS clock or other accurate UTC time source) that the voltage reference is connected to each channel. Again, make sure that the data logger is collecting, storing, and transmitting data during this test.

Step 8: Determine location of station GPS antenna and location of station seismometers relative to station GPS antenna (this step may be done at any time – order is not important).
1. Using handheld GPS, determine location of GPS antenna of station clock.
2. If feasible, use handheld GPS to determine location of station seismometers.
3. Use tape measure and compass to measure distance and direction from the station clock GPS antenna to the station seismometers.

Step 9: Ship reference system and orientation-determining equipment back to ASL or to next site to be checked.

Step 10: At ASL, calibrate reference system again (post-trip calibration).

Step 11: **A**rchive data from reference system in Data Center.

Step 12: QC analysts will compare data from station and reference system to determine sensitivity and orientation of station seismometer relative to reference seismometer. QC analysts will confer with ASL Scientist-in-Charge and DCC manager to determine whether or not the metadata for the tested station(s) should be updated with the newly determined sensitivities, orientations, and locations.

Add forms to be filled out:

- Form 1: Pre- and post-trip seismometer and data logger calibration.
- Form 2: Orientation form
- Form 3: Location form (combine with orientation form?)

Also needed: Procedure for checking orientation and sensitivity of strong motion sensor.

Note of 5 Feb 2008: There are two ways to check the sensitivity of an FBA-23 or Episensor: A. By exciting the cal coil with a known current or B. By tilting the accelerometer to exact 90 degree angles along the sensitive axes. Either of these methods will require disturbing the sensor. Since we don't want to disturb the sensor, we will only check the orientation (as installed) by comparing its alignment marks to a reference orientation mark in the vault, which must be brought in from outside using a theodolite. Sensitivity and an additional check on orientation may be derived at some other time by comparing signals from large earthquakes to signals from the BB seismometers at the site.

Operational check: First, make sure the accelerometer is bolted down securely. Then use "pinger" (spring loaded center punch with light tension and flat point) on the top, west, and south sides of accelerometer. This should produce triggers and identifiable signals that the QC folks can analyze. Carefully note the time of the pings!