Sensor Certification

Introduction:

All equipment, especially sensors and cables, are cleaned and comprehensively tested when they arrive at the PIC, regardless of whether the equipment are newly delivered from the manufacturer or being returned from an experiment. PASSCAL makes every effort to ensure that all equipment are operating to the manufacturers specifications.

This article outlines the procedures undertaken and metrics employed by the PIC to verify that sensors operate within manufacturers specifications.

Procedures:

All sensors returning from a field experiment are subject to the following procedures:

- Unpacked and checked into the warehouse database system.
- Cleaned and visually scanned for damage.
- Undergo triage tests on the bench (e.g., power is applied, sensor is unlocked/locked if applicable, observe output voltage).
- All broadband and intermediate-period sensors are tested on a concrete pier in a vault for a week or more.
- All short-period sensors are tested on a concrete pier or bench for up to several days.
- All high-frequency sensors are subjected to a series of automated tests on the bench.

Bench Testing:

All incoming sensors (except high-frequency sensors), whether new or returning from a field campaign, are first cleaned and then tested on the bench. Bench testing includes, but is not limited to, the following:

- inspect physical condition (sensors have already been cleaned)
- check bubble level
- check feet operation
- functional check of locking and unlocking (motors or mechanical or none, depending on sensor)
- check mass positions for operation (i.e. do they center? if done by motors, or are they centered?)
- qualitative check of 'signal' on bench with oscilloscope
- current draw (during routine operation, and lock/unlock)
- tap test to check polarity

Details:

Broadband and Intermediate-Period Sensors:

Broadband and intermediate-period sensors are placed on one of PIC’s four dedicated concrete piers. Each pier is isolated from the rest of the building, and has sufficient numbers of DAS and GPS units to test simultaneously up to 10 sensors. Each pier has dedicated Q330 or RT130 DAS'. Pier testing also provides opportunities to test digitizer firmware. Pier tests usually extend for several days to weeks. Such long test periods allow broadband sensors to thermally equilibrate with their surroundings, and enable PIC staff to examine noise-levels, check amplitudes, sensor damping and period, run step and extended white-noise calibrations, and identify any spurious signals. Considerable effort is made to isolate the
sensor by means of thermal "hats" and levelling the sensors on optically-flat granite slabs. All data acquired from such tests are archived indefinitely, allowing PIC staff to identify changes brought about by component replacement or ageing. The pier tests also allow for testing of cables and break-out/host boxes. Sensors, cables and break-out/host boxes as returned from the field are tested as complete systems.

- the amplitudes are correct - within spec, i.e. they match or are within 3% of a reference sensor that is on the same pier.
- the long-period corner (period) is correct - within 3-4% spec, as determined with a step cal evaluated by our curve-fitting program called *bbcal*.
- the damping of the long-period corner is correct  within 3-4% (like the corner period - determined with a step cal evaluated by curve-fitting program *bbcal*).
- seismic signals recorded on a pier must match each other (and a reference sensor) in phase and amplitude (within 3%). Signals are mainly teleseisms and local trains. We also consider microseisms to be signals in this context.
- sensors cannot be too noisy. It is difficult to apply quantitative requirements.

Ideally a sensor's noise should be at least as low as a reference sensor's, but we do pass sensors with noise levels a little higher than the reference. Generally, we look for:

- vertical noise amplitude measurements (time & frequency domain) for sensors on a pier must match each other for frequencies higher than about 0.05Hz, i.e. the single-frequency microseism peak and higher.
- horizontal noise amplitude measurements for sensors should match each other over a greater bandwidth, because there is always a lot of horizontal ground motion on the piers. Typically horizontals match from about 0.0003 Hz all the way to Nyquist.
- additional criteria for data filtered in the bandwidth 0.002 - 0.03Hz include:
  - 'allowing' for a few pings per day (up to 8/day)
  - a few db of intermittent/spurious broadband noise, etc.

The problem with evaluating sensor noise in this bandwidth is that the sensors are responding to 'noises', such as microbarometric changes, that are not equal across the pier. Thus, it is difficult at times to separate what is sensor noise from what is another source of noise.

**Short-Period Sensors:**

If space and time permits, short-period sensors are also tested on the piers, albeit for much shorter durations. Similar tests as for broadband sensors are conducted.

**High-Frequency Sensors:**

High-frequency sensors are subjected to automated testing by quality-control systems specifically built for the seismic industry (e.g., oil exploration, structural monitoring, civil engineering, etc). The software runs on a laptop and can be configured to upload a test-sequence to a special-purpose DAS that is used to drive the sensor's mass. Among many calibration and operations parameters tested, the most important are:

- Resonant frequency (Hz)
- Damping constant
- Sensitivity (generator constant, v/m/s)
- First motion polarity

The results of the tests are compared against an acceptable range and are saved to a database.

**Accelerometers:**
Accelerometers are subject to a series of carefully-controlled and repeatable gymnast tests, as well as checking for noise levels and spurious signals.

**Repair:**

If any sensor falls outside of the manufacturers or PIC-determined specifications, the equipment are reported to the previous experiment PI and are generally slated for repair in-house. If repairs are difficult, equipment may be returned to the manufacturer.

**The Piers:**

![South Pier](image1)

Above: South Pier

![West and East Piers](image2)

Above: West and East Piers

**Further Reading:**

*Guidelines for Standardized Testing of Broadband Seismometers and Accelerometers, USGS Open File Report 2009-1285*

Related categories: Sensors