Drift Measurements in Pressure Sensors

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ABSTRACT

The use of bottom pressure recorders (BPR) to measure sea level change, ocean floor settling or geodetic processes requires extremely consistent and stable pressure readings. Proper long-term deployment of BPRs or other precision, unattended pressure measurement instrumentation therefore, relies on understanding the drift rate and response characteristics of the pressure sensors. Sea-Bird Electronics routinely screens sensors for pressure-temperature response characteristics, offset and slope. The drift performance of the frequency acquisition and storage electronics is verified to be ≤1.0 ppm/year; however, qualifying the pressure transducer is more challenging. Here we describe the testing protocols and present results in the characterization of the bulk drift of Digiquartz pressure sensors made by Paroscientific. This entails recording the output of the sensor relative to a reference sensor in a low thermal noise environment for 1.5 to 4 months. The data from one such test shows drift rates ranging from 0.75 PSIA per year to 3.0 PSIA per year. In the cadre of sensors under test, differences of as much as a factor of 10 were observed in drift performance.

METHOD

Sea-Bird employs a precision temperature chamber to measure the drift rate of 10k PSIA pressure sensors down to 0.25 PSIA/year.

- Each pressure sensor output is powered and recorded by a SBE 54 mounted outside the temperature chamber
- Pressure resolution of 0.028 PSIA
- Timebase drift of ±0.0028 PSIA/yr (±0.1ppm/yr at 0-20° C) for a 10k PSIA sensor
- Each measurement is a 60-second integration of pressure

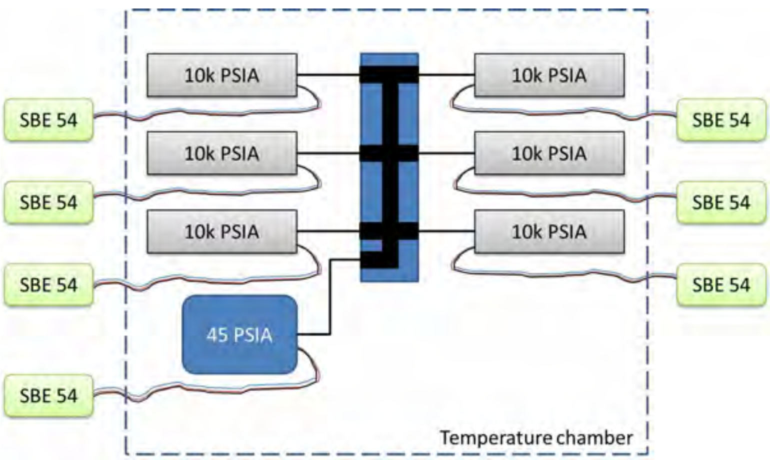

Figure 1. Temperature chamber schematic. Up to 6 high-range pressure sensors (typically Paroscientific 4000 series 10k PSIA full scale) are ganged via a manifold and attached to a 45 PSIA sensor (Paroscientific 245A-102). The assembly is placed into the chamber and isolated from the walls. A valve attached to the manifold (not shown) can be used to adjust the internal pressure. Plumbing is minimized to reduce the effect of temperature-based pressure changes in the manifold.

The low range reference sensor is necessary to eliminate pressure fluctuations due to remaining thermal noise. Although temperature is tightly controlled, the gas in the manifold changes pressure with temperature. These variations are much smaller than typical swings in atmospheric pressure, but large enough to dominate low drift sensors.

After the data from the SBE 54s is uploaded, the reference is subtracted from the sensor under test. The orientation offset is then removed and the pressure derivative is taken using linear curve fitting on successive 6-hour windows.

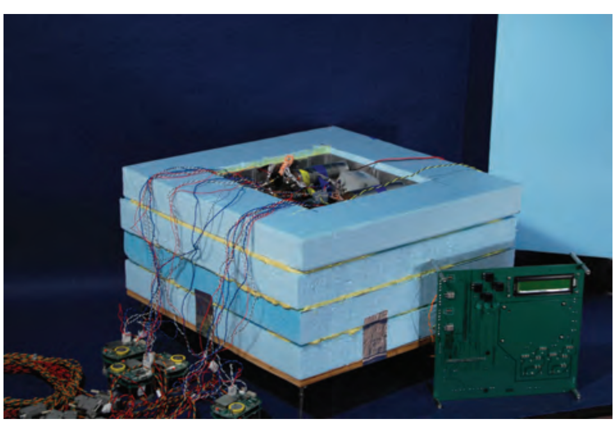

Figure 2. Custom temperature chamber. Air is temperature-controlled and actively circulated. The chamber has room for up to 6 sensors and a reference; interior is 10 x 10 x 3 inches. A 100W Peltier junction can vary the temperature between -5 and 55 °C. Thermal noise is approximately 1mC RMS at 20 °C.

RESULTS

Once the temperature effects of the sensors have stabilized, the high range sensors have been observed to drift at a constant rate relative to the reference. This can become the limiting drift as contributions from changes in temperature or pressure decay. For this data, changes in pressure are reduced and compensated for, while temperature effects are still visible. The greater drift rate in the first 10-15 days of data can be assigned to the constant drift plus the two styles of sensors coming into thermal equilibrium and the temperature chamber itself reducing thermal gradients.

Sensors, as shown in Figure 6, can drift up to ~5% full scale of the reference in a period of months. Comparing the reference to the Sea-Bird barometer indicates drift is in the high range sensor. Over time, these 10k PSIA sensors inexorably report a larger pressure value than the reference; the reverse has not been observed.

In experiments shown in Figures 3 and 4, the atmosphere inside the manifold was room air at ~15 PSIA. The sensors were attached to the manifold and the evacuation port was capped. Variations in atmospheric pressure do not affect interior pressure; however, changes in temperature from when it was sealed directly result in changes in pressure.

At day 50, the 10k PSIA sensors were disconnected from the SBE 54s, removing power for 48 hours. All of the sensors remained in the chamber, undisturbed, at constant temperature. When power was reapplied, the drift curves continued smoothly. It appears the sensors can be power cycled without a drift penalty, as long as the temperature remains constant.

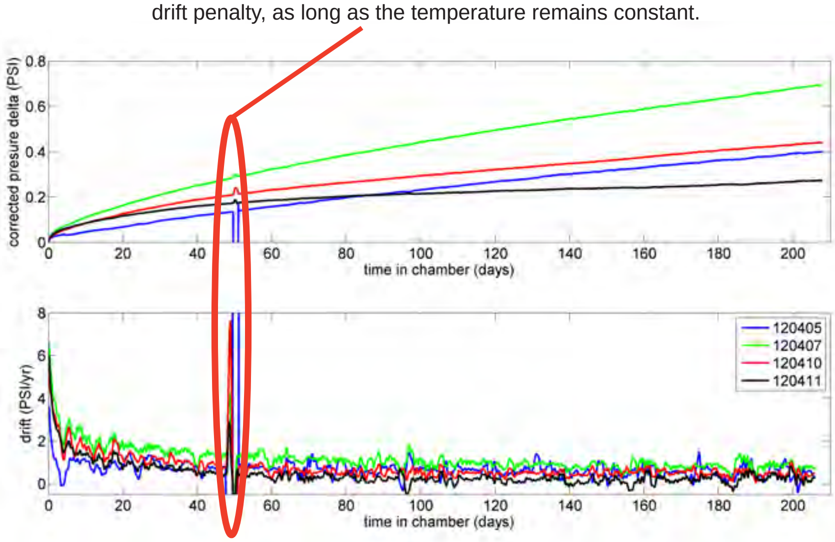

Figure 3. Long term test of 4 sensors at 20 °C. The upper graph is the pressure signals of the 10k sensors, with the reference subtracted. The pressure offset is removed for easier comparison. The lower graph is the pressure derivative scaled to PSIA/yr drift. Remaining noise is due to under-corrected changes in temperature. On close inspection, wiggles have a day periodicity that corresponds to the HVAC system.

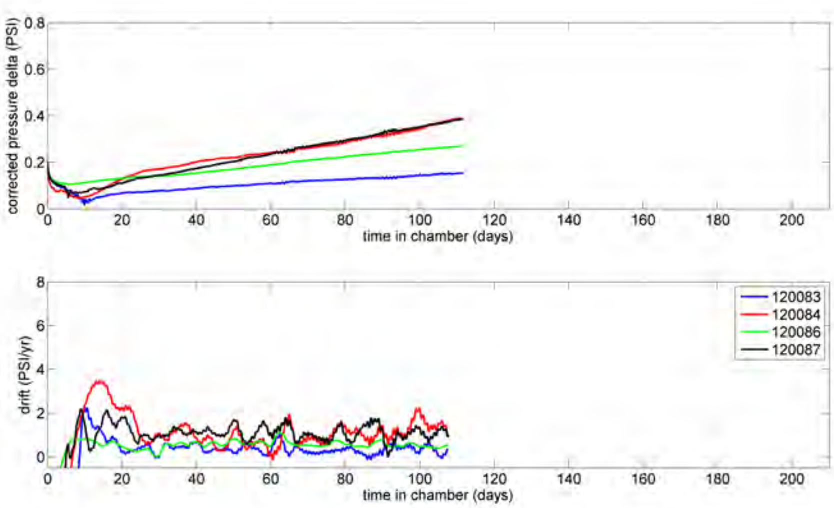

Figure 4. Four sensors under test. The dataset corresponds to a chamber temperature of 20 °C. Just prior, the chamber was set to 4 °C, which resulted in a brief undershoot of manifold pressure. Often sensors will have consistent pressure tracks, although their assigned serial numbers are quite distant. Sensors are evaluated at 40 days for settling, and are left in the chamber if the derivative is not obviously zero-slope.

Figure 5 shows a dataset where the manifold is evacuated to ~0.1 PSIA. Although the sensors still have their own calibrated temperature effects, this reduces the pressure noise from the gas inside the system expanding and contracting with changes in temperature. The challenge in this setup is keeping the system leak free.

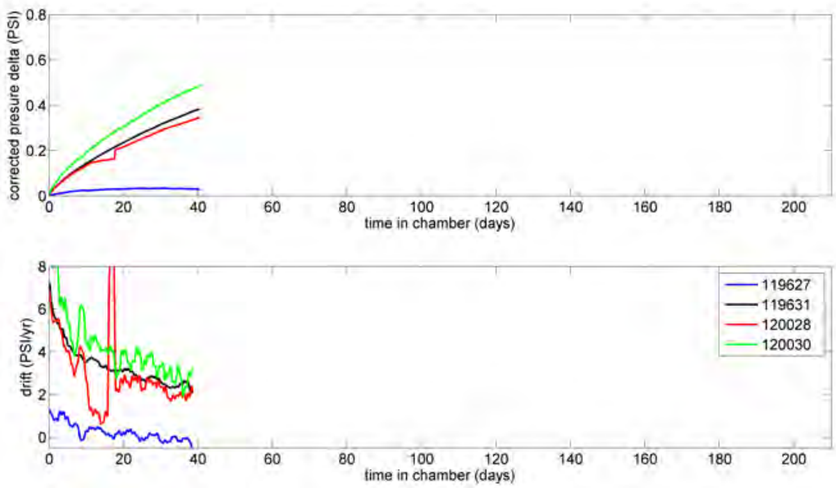

Figure 5. Four sensors under test, with manifold evacuated. This setup produces lowest noise datasets; however, maintaining gas-tight seals throughout the manifold is challenging. 40 days is typically enough time to assign a characteristic drift to a sensor.

CONCLUSIONS

Sea-Bird Electronics has developed a technique for determining the drift rate of quartz pressure sensors and has measured a succession of them over the past two years. The results are summarized in Figures 6 and 7. These are considered final drift rates, as a transition to a constant rate after a temperature transient is consistently observed. It is generally believed that drift rate reduces with increased sensor age and although this has not been observed at up to 240 days, there is customer data that points to increased stabilization. If drift rate slows in proportion to sensor age, the rate observed with these young sensors provides a pessimistic upper bound.

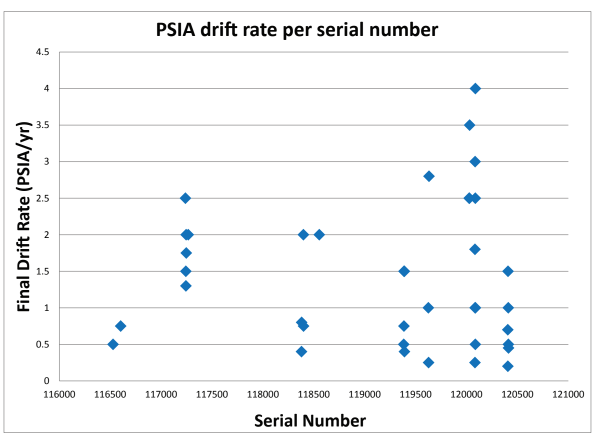

Figure 6. Final drift rate organized by serial number. Serial number range corresponds to a selection of sensors received by Sea-Bird from September 2009 to February 2011. Drift rate has not been observed to trend with serial number or manufacture date. All points were taken with techniques outlined in Method section.

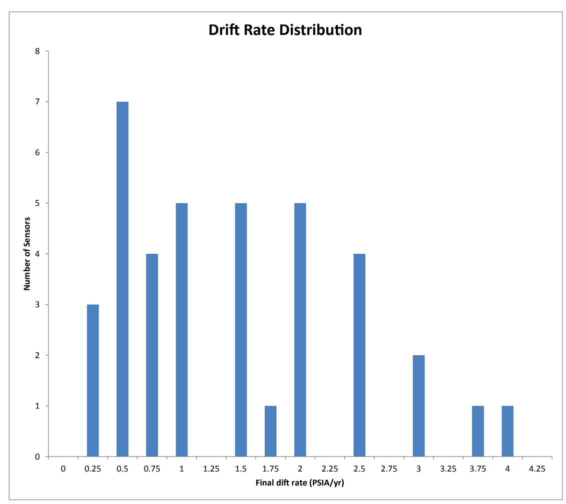

Figure 7. Distribution of final drift rates of examined sensors. A total of 38 sensors are measured over a period of 18 months. Throughput was decreased in 2011 due to trials lasting > 200 days. This is a restating of data in Figure 6.