Application Note AN-108

May 2016

SPEC Sensor^{TM} Performance in Extreme Environments

Scope

This application note discusses the effects of extreme RH and temperature on sensor performance and suggested approaches to mitigate these effects.

Relative humidity, both indoors and outdoors, typically fluctuates around an average value. This is typically observed as a daily cycle, superimposed on a longer, seasonal cycle. SPEC sensors will not typically be affected by the daily RH fluctuations. However, with prolonged operation at low RH, the sensor electrolyte composition may lose water, until it reaches equilibrium with the atmosphere. Over a period of a few weeks, this may be result in substantial change in sensitivity (nA/ppm).

Extended Operation at Extreme RH

SPEC Sensors is collecting long-term data on the effects of prolonged operation under different RH conditions. The following charts summarize operation of 5 groups of each sensor type (gas) over a six week period. During this time, the sensors are stored at room temperature in different chambers, at RH levels ranging from "0%" (<5 %RH) to > 97%, then removed from the RH chambers only long enough to test with the target gas.

Carbon Monoxide: Our CO sensor is virtually insensitive to long-term operation at RH extremes. The data shown below demonstrates ≤ ±5% change in sensitivity after 6 weeks in continuous operation in RH from 0 to >95 %RH.

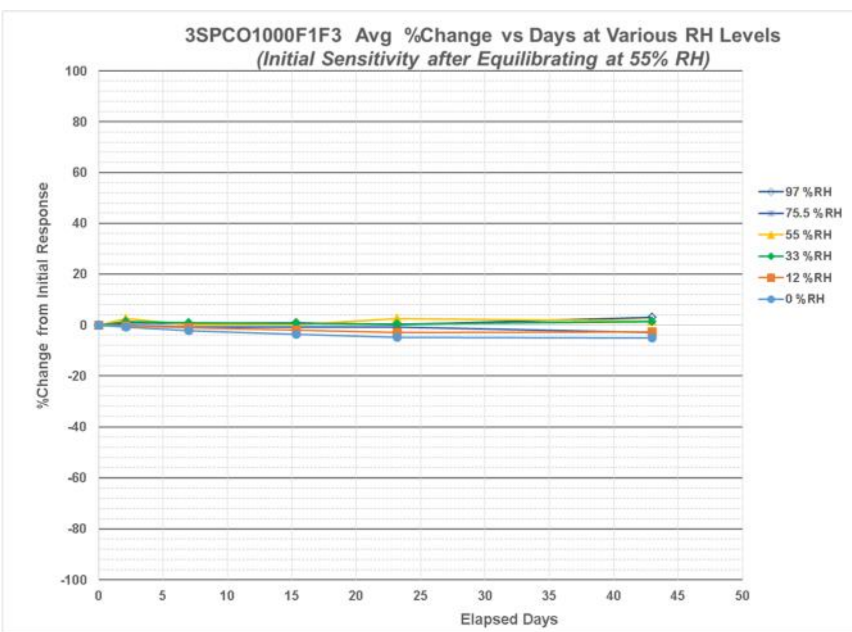


Figure 1: Average response of groups of CO sensors equilibrated at RH levels from 0 to >95 %RH, at room T.

Hydrogen Sulfide: The data presented for the 0 - 50 ppm H2S sensor demonstrates < ±15% change in sensitivity after 6 weeks in continuous operation in RH from 0 to >95 %RH.

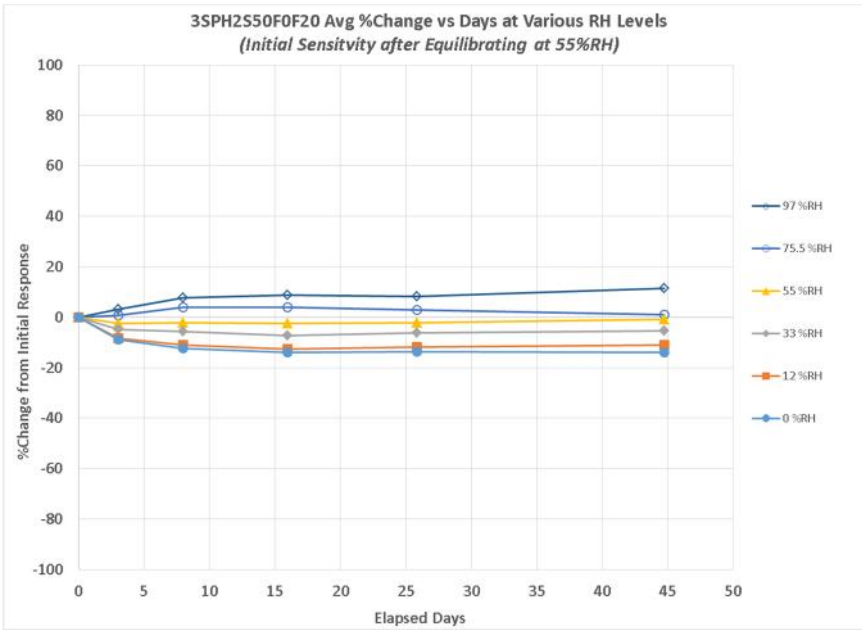


Figure 2: Average response of groups of H2S sensors equilibrated at RH levels from 0 to >95 %RH, at room T.

Ethanol: The data presented for the 0 – 1000 ppm ethanol sensor demonstrates < ±5% change in sensitivity after 6 weeks in continuous operation in RH from 0 to > 95 %RH.

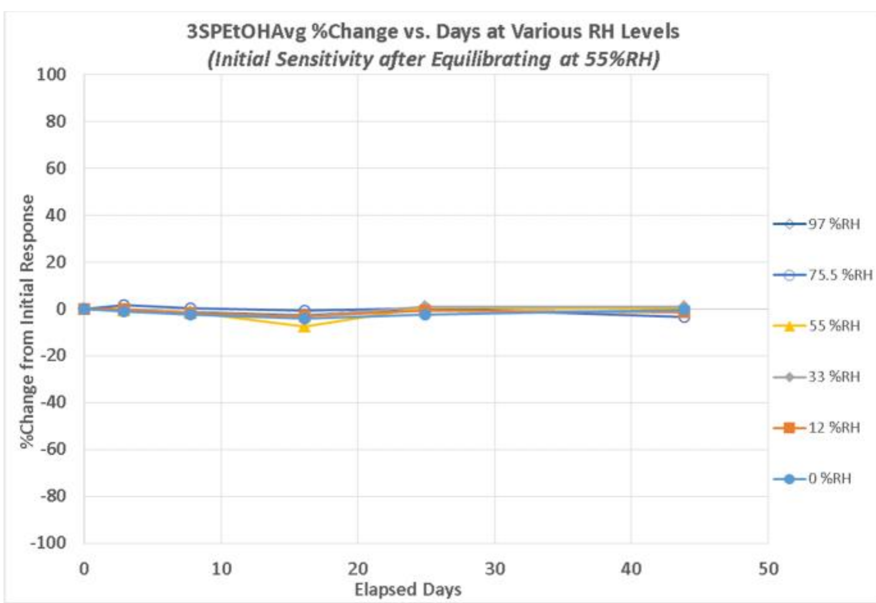


Figure 3: Average response of groups of ethanol sensors equilibrated at RH levels from 0 to > 95 %RH, at room T.

Nitrogen Dioxide: The data presented for the 0 - 20ppm NO2 sensor demonstrates < 5% in sensitivity change after 6 weeks in continuous operation in RH from 12 to > 95 %RH. With continuous exposure to 0% RH, the NO2 sensor will lose < 15% of its initial signal.

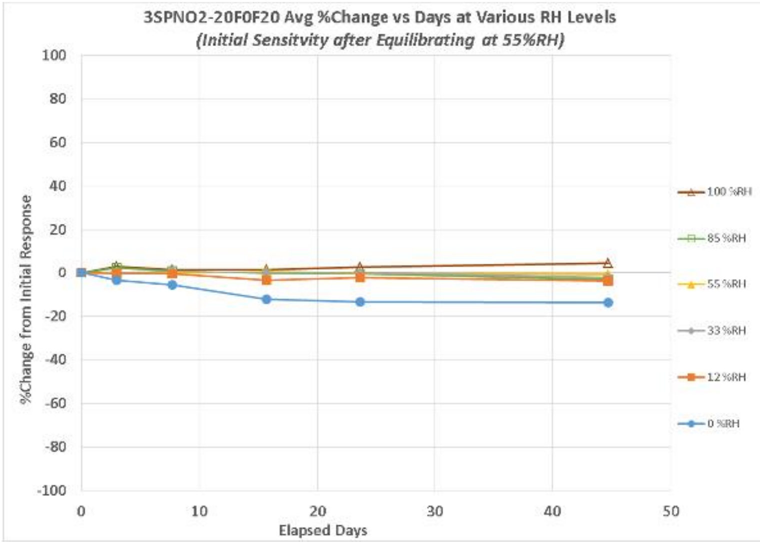


Figure 4: Average response of groups of NO2 sensors equilibrated at RH levels from 0 to > 95% RH, at room T.

Sulfur Dioxide: SO2 exhibits a greater sensitivity to RH extremes than do the other sensors. The data presented for the 0 – 20 ppm SO2 sensor demonstrates < ±20% change in sensitivity when the sensor is operated in conditions between 33 and 75 %RH. Sensors exhibit +30% increase in sensitivity after 6 weeks in continuous operation in RH > 95 %RH, and a loss of 67% when operated continuously at 0 %RH.

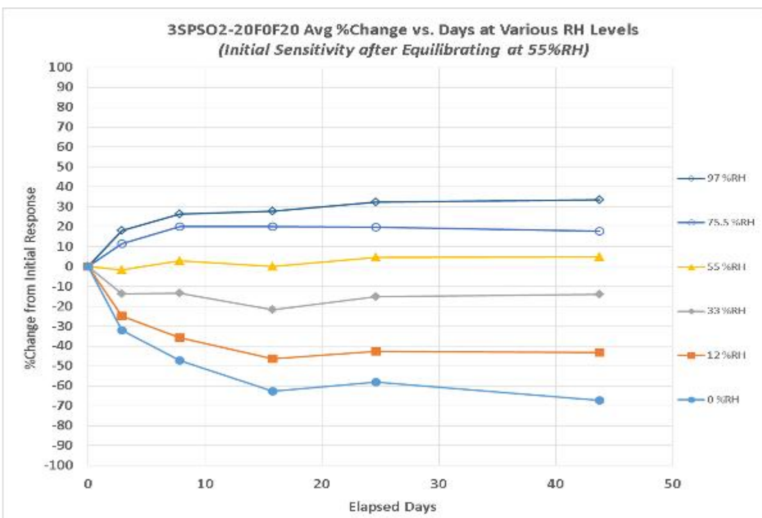
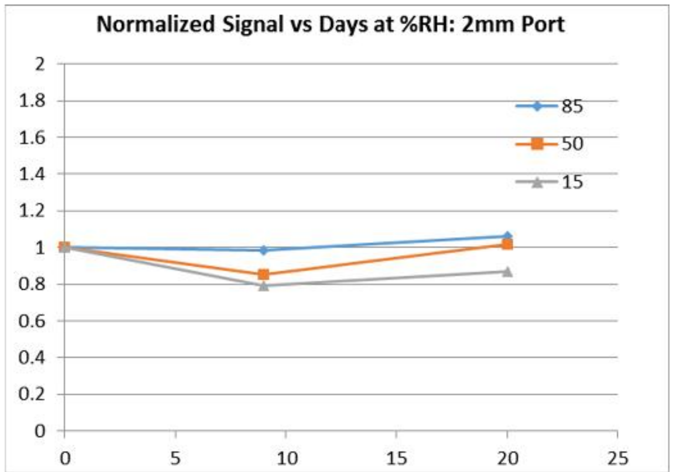


Figure 5: Average response of groups of SO2 sensors equilibrated at RH levels from 0 to > 95% RH, at room T.

Ozone: The data collected for the 0 – 20 ppm O3 sensor show no change in response when the sensors are equilibrated at 40 - 45% RH, and then moved to environments of 50 and 85 %RH. When moved from ambient RH to a dry environment (15 %RH), the sensors exhibit a drop in sensitivity of 10 - 20% after 3 weeks of continuous operation at this RH.

Figure 6: RH DATA FOR O3 – ADDITIONAL TESTING IN PROGRESS



Summary and Recommendations:

As can be seen from the above plots, change in response over the range 0 to 95 %RH is less than ±15% of that at 55 %RH, for all but SO2. For these sensors, RH correction is typically not necessary, as the sensor response typically takes 14 days to reach a stable signal following a large RH change. Ambient fluctuations in RH are typically on a shorter time scale.

For SO2, best stability is achieved when the ambient RH is maintained between 33% and 75 %RH. Over this range, sensitivity changes will typically be < ±20%.

NOTE: Where higher accuracy is required, consult SPEC engineers. SPEC has developed a unique RH Compensation Algorithm, based on a 7 - 14 day moving average RH. This requires on-board clock and T/RH sensor, or in outdoor applications, access to local time and weather conditions.

Operating Temperature

As discussed in ***SPEC AN-103***, SPEC sensors are specified for continuous use up to 40 °C, with intermittent operation up to 50 °C. The temperature behavior of the span, or sensitivity, is well-behaved up to 50 °C, and higher in some cases.

However, the zero current, or baseline, behavior of some sensors at temperatures above 40 °C is less well-behaved. **Figure 7** shows the average BL vs T for five of SPEC's sensors. There is virtually no T effect below 20 °C, a very repeatable BL between 20 and 35 – 40 °C, and in some cases (CO, SO2, NO) a large BL above 40 °C. NO2 and H2S exhibit a well-behaved BL even at 50 °C.

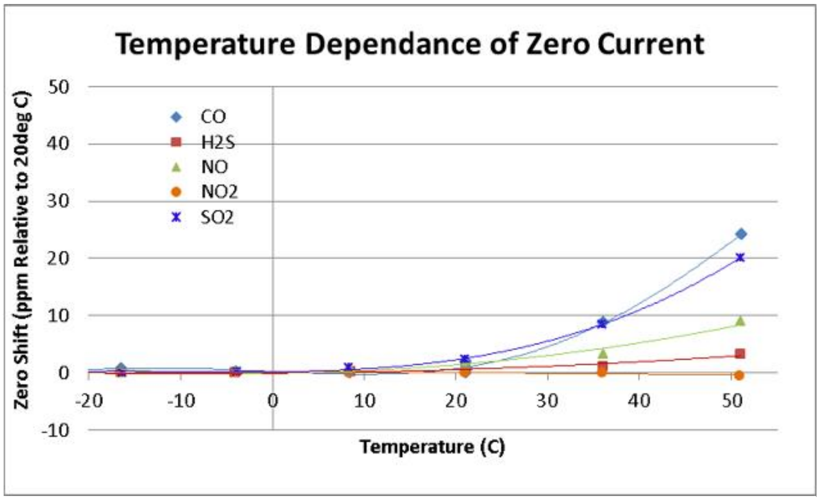


Figure 7: Average BL vs T for five of SPEC's sensors over the temperature range -30C to +50C.

Figure 8 illustrates the variability in the BL of CO sensors over -30 to +50 °C. These curves can be fit very well with a polynomial equation. Over the range -30 to +35 – +40 °C, a single point zero calibration with a common temperature correction can often be used. For applications where highest accuracy is desired, the sensor zero current must be measured at two temperatures, to determine the sensor specific coefficients.

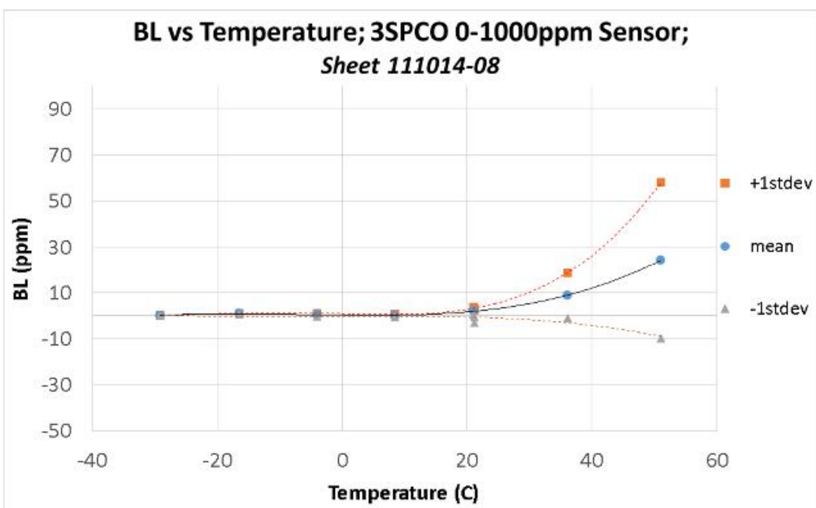


Figure 8: Variability of BL as a function of temperature for a set of 60 3SPCO1000F CO sensors.

Exposure to Extreme Temperature Conditions

While SPEC sensors are specified for -20 to +40 continuous, and -30 to +50 °C intermittent operation, the sensor package has been tested and shown to recover from temperatures as low as -40 °C for a period of 3 hours, and as high as 70 °C, for a period of 24 hours. These conditions may occur during shipping and storage, and should not damage the sensor. No warranty is implied as to performance of the sensor at these extreme temperatures, and the user should allow several hours to stabilize when returned to temperatures within the recommended range.

Aging of Sensor

As with all chemical sensors, the amperometric gas sensors may gradually lose sensitivity with time, or "aging". The phenomenon is due to a combination of factors including:

- Long-term operation in T and RH extremes, as discussed above.
- Accumulation of dust and oil vapors on the gas-permeable membrane.

If device is to be used in a dusty environment, or with potential spray or aerosols, a replaceable, non-woven, glass or polypropylene dust filter is recommended over the gas access opening in case.

In areas where condensation is possible, a hydrophobic, porous membrane (Zitex™, Porex™, or other PTFE membrane) is recommended over the gas access opening in case.

While the EC sensor electrodes are catalysts, and not normally consumed in the measurement, gradual contamination or oxidation of the electrode surface, or - in the case of chlorine and/or organohalides - a competing complexation reaction, may passivate or tie up active catalyst sites on the working electrode, reducing the sensitivity.

The user must confirm the stability of sensor signal for each specific application. In general, the stability is better if the sensor is operated with the working electrode at 0 mV or negative bias potentials. For applications such as NO_2, ozone, and SO_2, negative bias conditions will work quite satisfactorily. NO, Sulfides and mercaptans exhibit best sensitivity and response time at positive biases of 200 - 300 mV, and stability seems to be quite good.

NOTE: SPEC Sensors are calibrated under standard conditions (23 ±3 °C, 40 – 60 %RH, and sea level atmospheric pressure). For highest accuracy, it is always recommended to check performance of the sensors in the intended usage and environmental conditions, and calibrate under these conditions as needed.