Application Note AN-104

May 2016

Short-Term Environment Effects on Performance

Scope

This application note describes the typical effects of environmental conditions on the operation and performance of SPEC Sensor's electrochemical gas sensors. (See Application Note AN 108 for information on long term sensor performance changes from use in low humidity and high temperature.)

The following sections discuss the effects of various environmental parameters, and how to minimize or compensate for Temperature Dependency, Relative Humidity Effects, Air Flow variation, Pressure changes.

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 calibrate the sensors in the intended usage and environmental conditions.*

Temperature Dependency

Electrochemical gas sensors are sensitive to ambient temperature. The temperature of the sample will affect the sensitivity/span, as well as, the zero reading (baseline) of the sensor. These effects are due to different chemical mechanisms, and should be corrected for separately. From our experience, temperature compensation using the average temperature dependence resolves more than 90% of the problem.

Temperature Dependence of Sensitivity

The sensitivity (expressed as nA/ ppm) changes by typically +0.1 to +0.6%/C at temperatures below 20 °C, and 0 to 0.3%/deg from 20 – 40 °C. The data in **Figure 1** is typical of five of the SPEC gas sensors. These curves are provided in each individual datasheet.

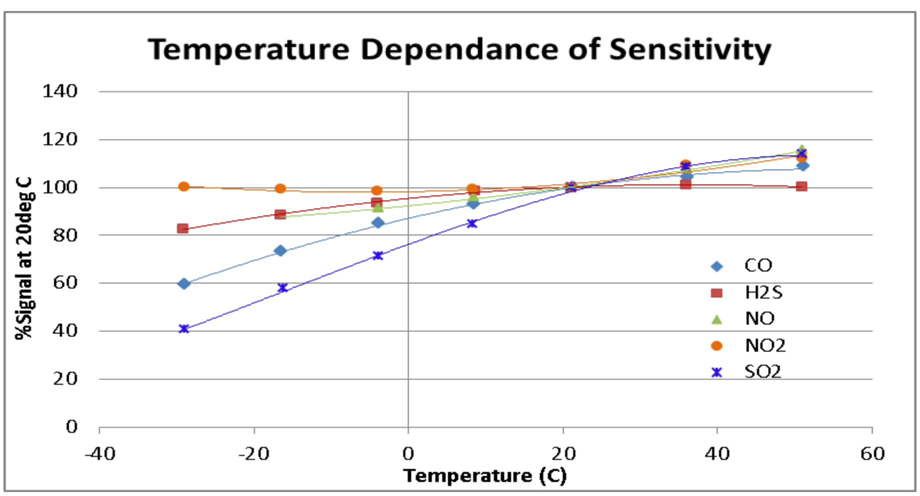


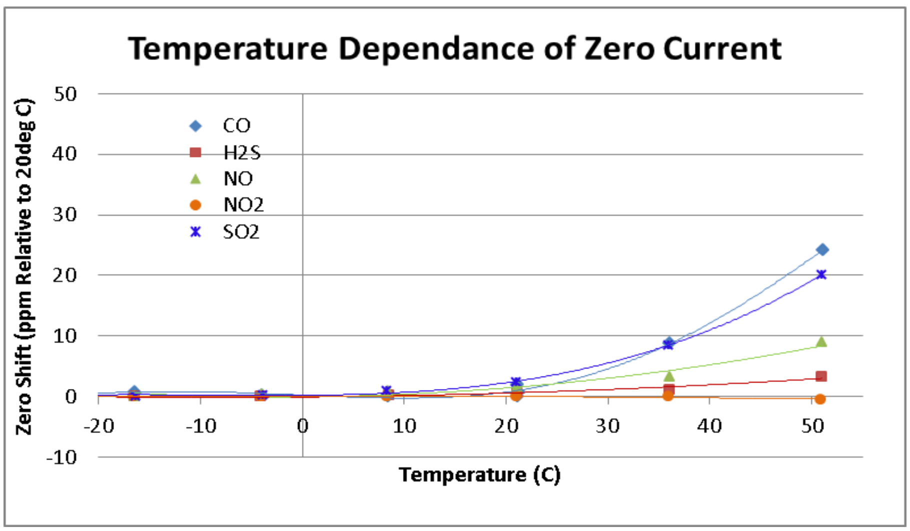
Figure 1: Typical temperature dependence of 5 different SPEC gas sensors

CAUTION: Avoid prolonged exposure to temperatures outside the recommended operating and storage range – as this may cause irreversible damage and loss of sensitivity. Although testing has shown the UL-recognized CO sensors can withstand short excursions (<24hrs) to temperatures up to 70 °C, this does not imply all sensors can withstand exposure to such high temperatures.

NOTE: *Because the instrument electronics and other design factors can influence the temperature dependency, the user is encouraged to collect data with the final package to validate the specific temperature compensation equation for their product.*

Temperature Dependence of Zero/Baseline

The zero current is typically very low and constant at temperatures below 20 °C. The recommended operating range for temperature is -20 to +40 °C for most sensors, although maximum sensitivity is achieved at temperatures of +20 to +40 °C. Figure 2 presents the average temperature effect on zero current for five of the SPEC gas sensors.



Electronic Temperature Compensation

Electronic compensation for sensitivity may be accomplished using a thermistor with an equal but inverted temperature coefficient (“Tempco”) in the gain portion of the circuit.

Software Temperature Compensation

Software compensation typically uses a sequential algorithm shown in the following example, which assumes a linear effect on zero and span

a. Subtract the temp-corrected baseline/zero on the raw signal (mV or nA)

$$nA_z(T_m) = nA_z(T_0) + \left[\left({nA}/{^\circ C}\right) * (T_m - T_0)\right]$$

$$nA_c(T_m) = nA_u(T_m) - nA_z(T_m)$$

Where

$T_0 =$ *Calibration or reference temperature, a constant* $[=]\ ^\circ C$

$T_m =$ *Temperature at which measurement is made* $[=]\ ^\circ C$

$nA_c(T_m) =$ *Zero corrected net current at measurement temperature*

$nA_u(T_m) =$ *Uncorrected signal current at* T_m

$nA_z(T_m) =$ *Zero concentration current at* T_m

$nA_z(T_0) =$ *Zero concentration current at* T_0*, a constant*

${nA}/{^\circ C} =$ *Baseline response to temperature*

b. Correct the net span.

$$ppm = \frac{1}{CF} * nA_c(T_m) * \left[1 - \frac{\%}{^\circ C} * (T_m - T_0)\right]$$

Where

$CF =$ *Calibration factor* $\frac{nA}{ppm}$ *at temperature* T_0

${\%}/{^\circ C} =$ *Span temperature correction factor*

More Considerations on Managing Software Temperature Dependence

For most accurate software compensation, it is recommended that the reference thermistor is mounted in direct contact with the sensor surface. If the gas sensor and thermistor have different heating and cooling rates, there will be either over- or under-compensation in the signal during periods of changing temperature.

For maximum accuracy at low concentrations (less than 0.1 ppm), buffering the sensor from transient T changes will also reduce “noise” in compensated output.

If it is anticipated that the environment may even occasionally be outside the recommended intermittent minimum and maximum temperatures, the temperature of the sensor and gas stream should be controlled.

Relative Humidity (RH) Effects

The effects of humidity on the sensor response are more subtle and complex: there may be transient spikes in the sensor zero with rapid changes in humidity, as well as gradual changes in sensitivity with prolonged exposure at different RH levels. This discussion describes the immediate, short-term effects of RH changes; see AN-108 for details on long-term operation under extreme environmental conditions (RH and temperature)

RH Effect on Baseline (zero current)

Typically, a rapid change in the relative humidity of a sample causes a spike in the baseline, sometimes equal to several hundred ppb's, which rapidly stabilizes to a level within 10's of ppb of the original baseline. The direction of the spike is typically in the "positive" direction (with respect to response to target gas) with humidity increase, and "negative" with humidity decrease. This is shown in Figure 3, an example of the response of the sensor BL to rapid RH changes. [NOTE: this figure is for illustrative purposes, the precise magnitude and width of the spike will vary by sensor and conditions.]

The user may determine for specific applications whether this transient BL disturbance affects desired performance. In these cases, contact SPEC Sensors for additional information regarding reduction of this effect, or compensation of the BL for rapid RH changes.

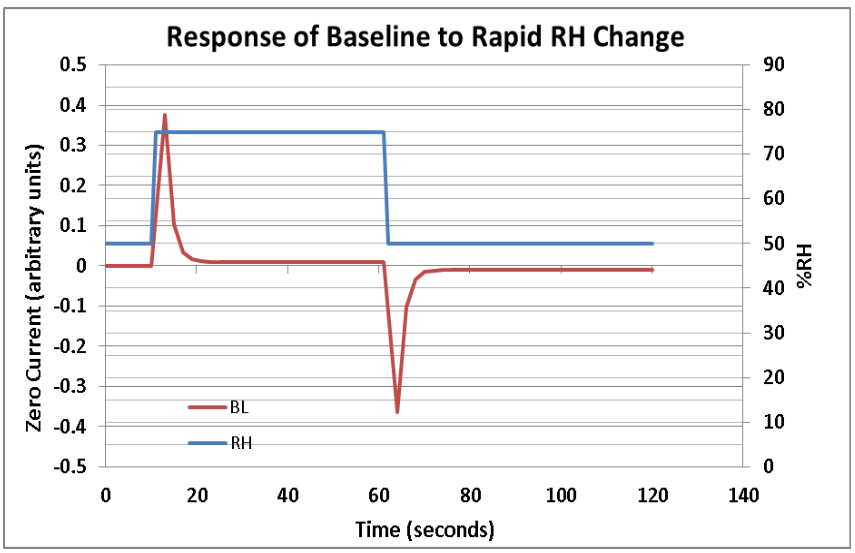


Figure 3: an example of the response of the sensor BL to rapid RH changes.

Span/Sensitivity

Short-term effects of RH changes on response of the sensor are typically negligible. See ***AN-108*** for details on seasonal humidity variations and effects of extended operation under extreme environmental conditions (RH and temperature).

Flow Rate

To some extent, the sensitivity and response time of the sensor is affected by the velocity of the air stream past the face of the sensor. This is particularly true at low flow rates. For very accurate measurements, it is recommended that the user draw a sample with a pump, and have a controlled flow rate across the sensor, with minimum internal volumes (to minimize lag and mixing). Our sensitivity and response time data is collected in a fixture in which the velocity of the gas stream is 0.1 - 0.2 m/sec, approximating ambient air flow in a room.

NOTE: *If the application involves potential of large and fluctuating air currents, it is recommended to position a baffle or inert porous membrane in front of the sensor to avoid air flow directly on the face of the sensor. Using a porous PTFE membrane will also protect the sensor from condensation and accumulating dust and oil vapors.*

Pressure

SPEC toxic sensors are designed for use at ambient pressures, with minimal pressure or vacuum on the sensor face. Sensors are calibrated under standard conditions (23 ± 3 °C, 40 – 60 %RH, and sea level atmospheric pressure). While sensors perform predictably when operated under ambient conditions other than 1 atmosphere, the output will vary approximately linearly with the pressure. For highest accuracy, SPEC Sensors recommend calibrating the sensors at the intended usage pressure. While it is possible in principle to attempt to automatically compensate for this pressure effect, SPEC Sensors has no data and can provide no guidance in this.

NOTE: **Avoid sampling designs which subject the sensor to rapid pressure changes.** When exposed to a rapid pressure change, SPEC sensors may show a baseline current spike, then settle to a constant output. Pulsation from a diaphragm pump must be dampened (e.g. – with flow restrictor orifice and pulse dampening chamber) to eliminate the baseline “oscillation” arising from the constant pos./neg. pressure spikes.

Revision History

Rev Date	Description of Rev	Approved by:
2015-03-24	Working Draft	M. Findlay
2015-04-17	Rev 0.01 with Title change and Brian K comments	M Findlay
2016-05-16	Rev 0.02 correct temperature	L Ploense
2016-05-18	R.03 Added Caution concerning exposure to high temperatures	M Findlay
2016-05-23	R.03b Corrected y-axis label on Fig 2	M.Findlay
2016-05-26	R.03c Restate and reformat T comp Eqns	L. Ploense