Product Characterisation Note

Contents

Document Purpose

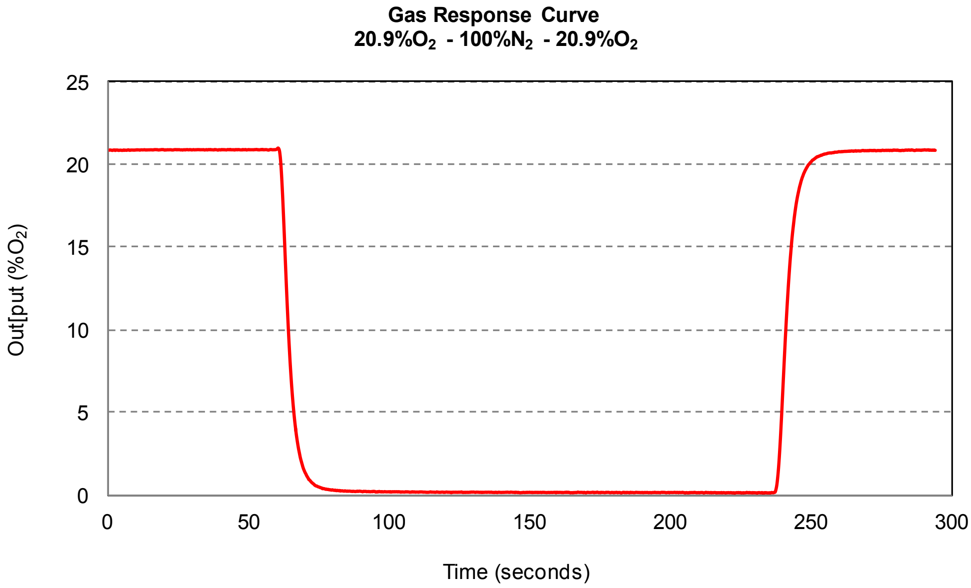
The purpose of this document is to provide indicative, technical performance data for the 4OxLL sensor to assist in the integration of the sensor into gas detection instrumentation. The sensor has been subjected to a rigorous testing programme as part of the development process. Within this document, detailed information on the results of this programme is presented. All data has been taken from equipment using a ±15 VDC power supply.

This document and the information contained within does not constitute a specification. The data is provided for informational purposes only and is not warranted by the manufacturer. It should be used in conjunction with the 4OxLL Product Datasheet, Operating Principles (OP19) and the Product Safety Datasheet (PSDS 5).

Product Characterisation Note

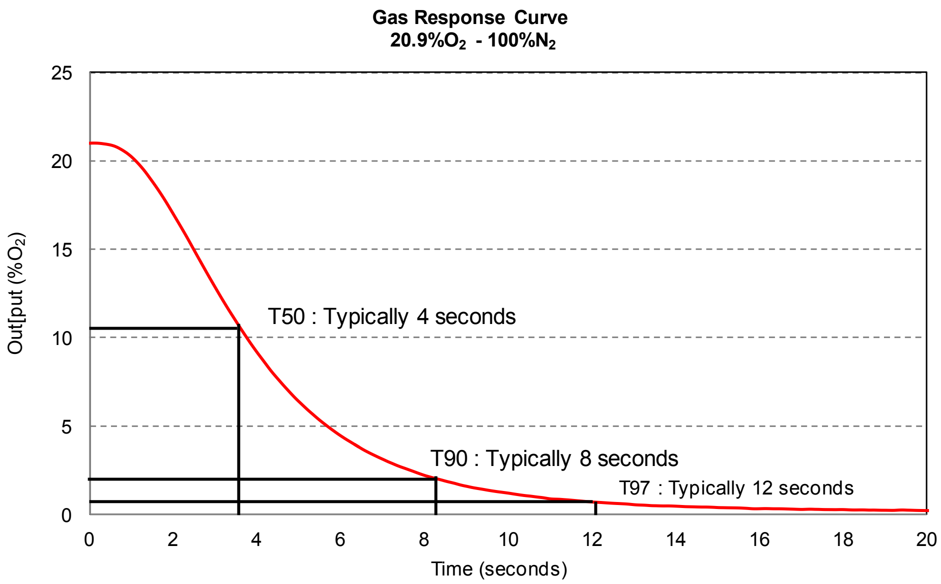
The Gas Response Curve

The data below shows the typical response curve for the 4OxLL. The presented results reflect the typical performance of a production batch.



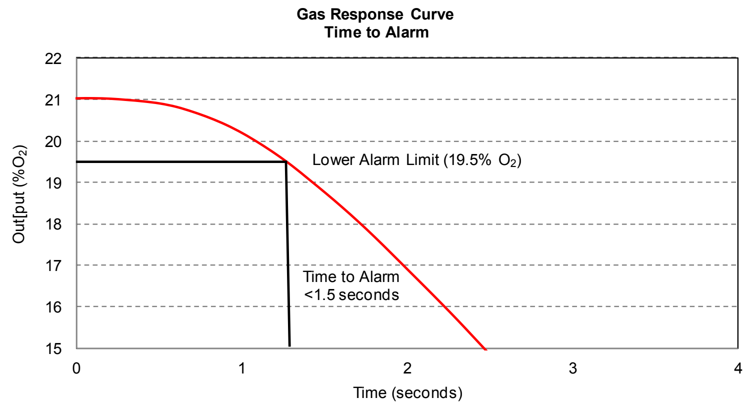
Typical T50, T90 and T97 Response Performance

The data below shows the typical response curve for the 4OxLL, indicating typical values for T50, T90 and T97 response times.



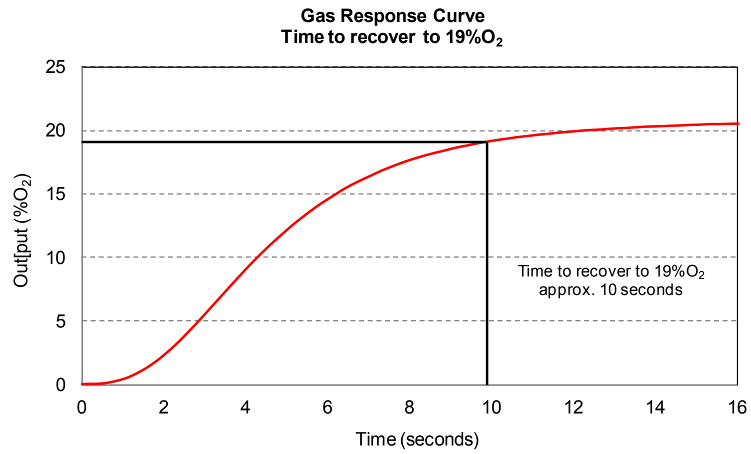
Typical Time to Reach Lower Alarm Level

The data below shows the time typically taken to reach the lower alarm level (19.5% O_2).



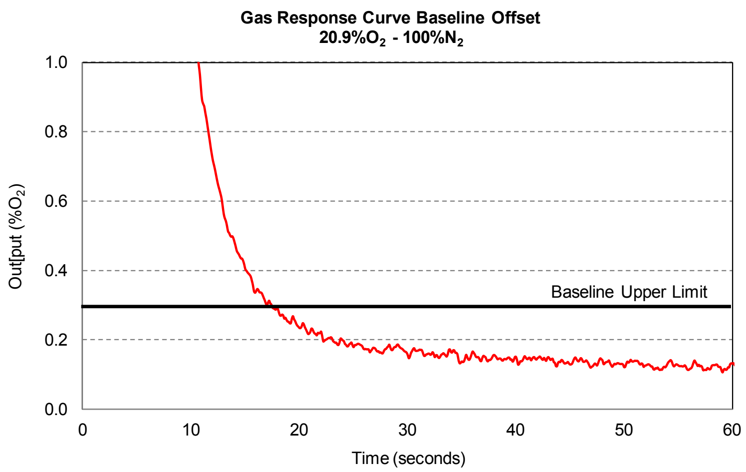
Typical Recovery Performance

The data below shows the typical recovery curve for the 4OxLL, indicating the typical recovery time to 19% O_2 following a 3 minute exposure to 100% nitrogen.



Typical Baseline Offset Performance

The data below shows the typical 4OxLL baseline offset falling to approximately 0.1% O_2 equivalent.

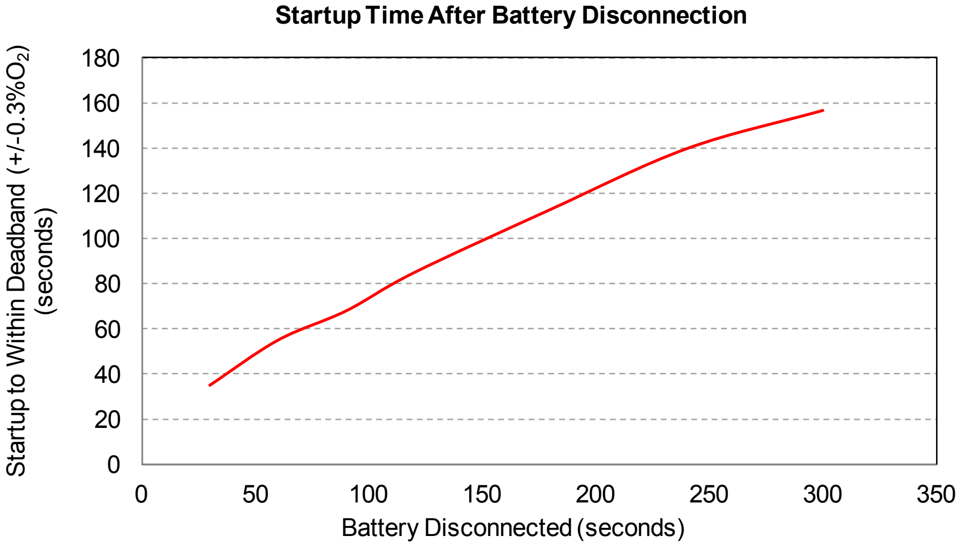


Startup Times

It is strongly recommended that a bias potential is maintained at all times, even when an instrument is switched off. Applying bias to a new CiTiceL, or to a CiTiceL which has been off bias, will produce a transient and rapidly decreasing offset - a period of stabilisation time will be required before meaningful measurements can be taken.

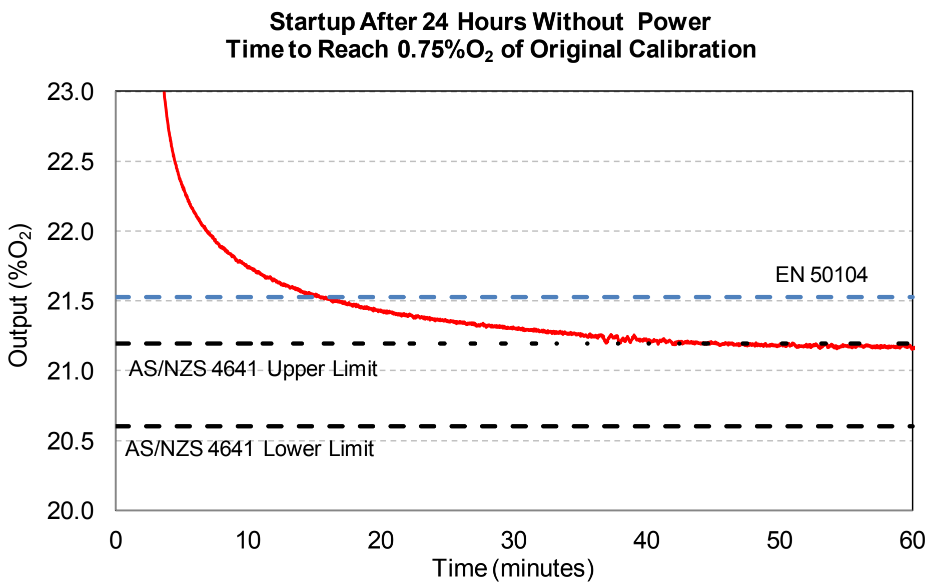
Startup Time (after battery disconnection)

The graph below shows the time typically required for the 4OxLL output to recover back to within the instrument deadband (± 0.3% O_2) after a battery disconnection or replacement. Typical environmental conditions during this test were 20°C and 27%rH.



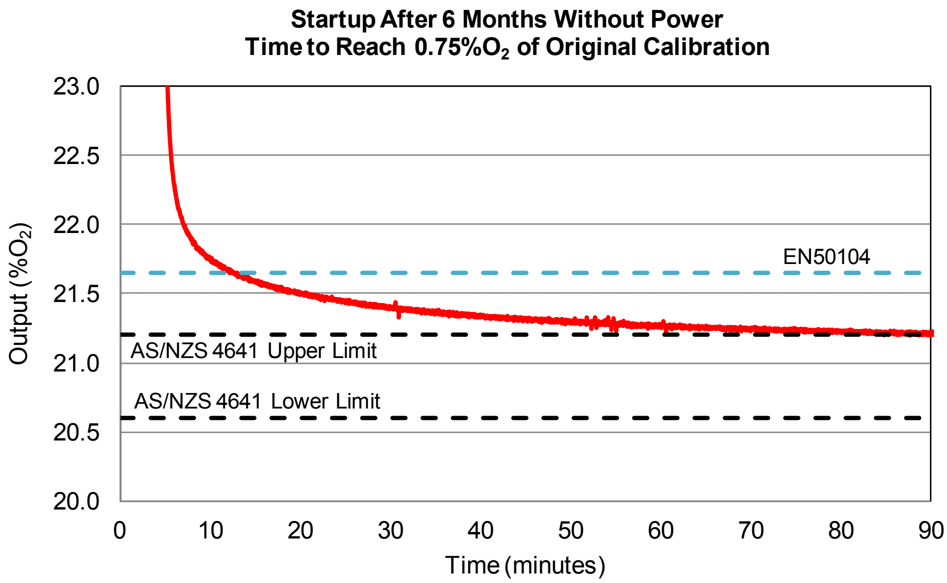
Startup Characteristics (after 24 hours un-powered)

The graph below shows typical 4OxLL startup characterisatics for a sensor which has been left un-powered for 24 hours. Typical environmental conditions during this test were 20°C and 27%rH.



Startup Characteristics (after 6 months un-powered)

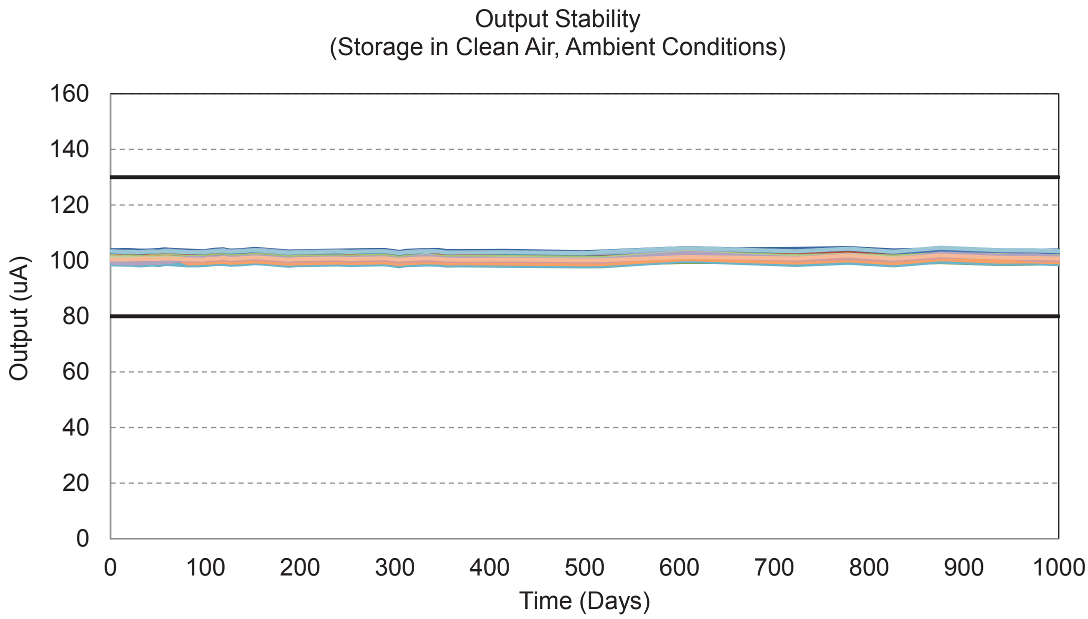
The graph below shows typical 4OxLL startup characterisatics for a sensor which has been left un-powered for 6 months. Typical environmental conditions during this test were 20°C and 27%rH.

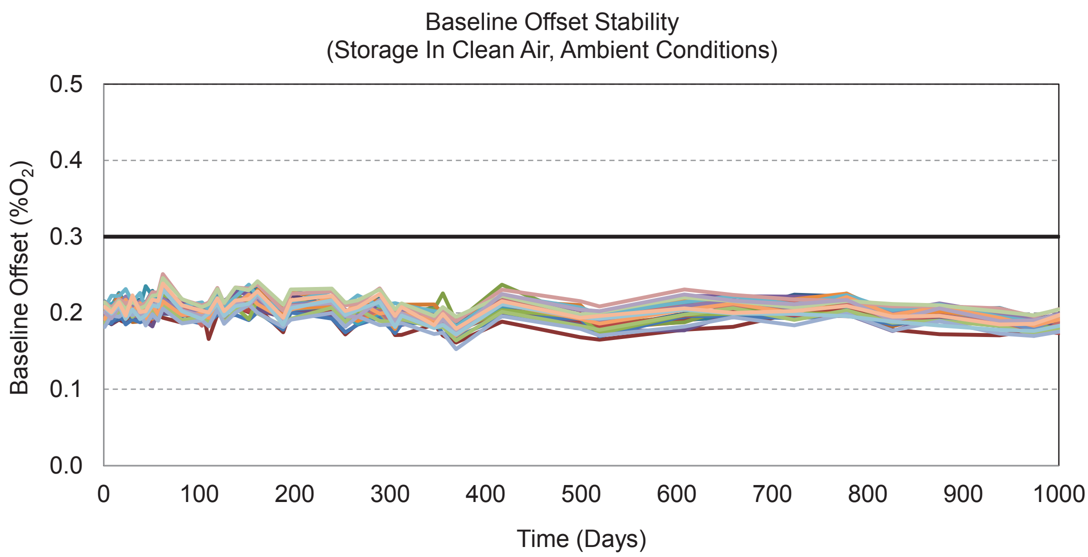


Performance Stability

The following data describes the stability of 4OxLL sensors over time, when stored in clean air. The presented results reflect the performance of a typical production batch.

Storage in Ambient Conditions





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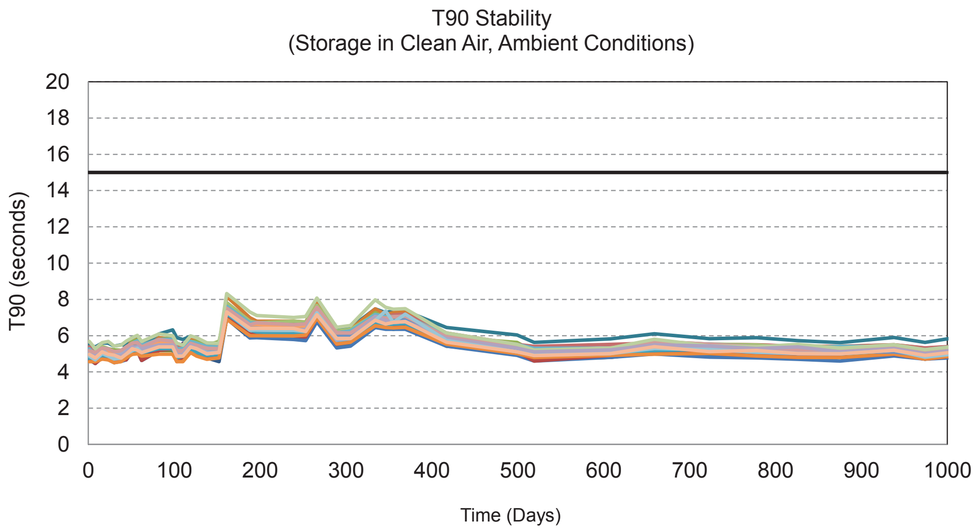
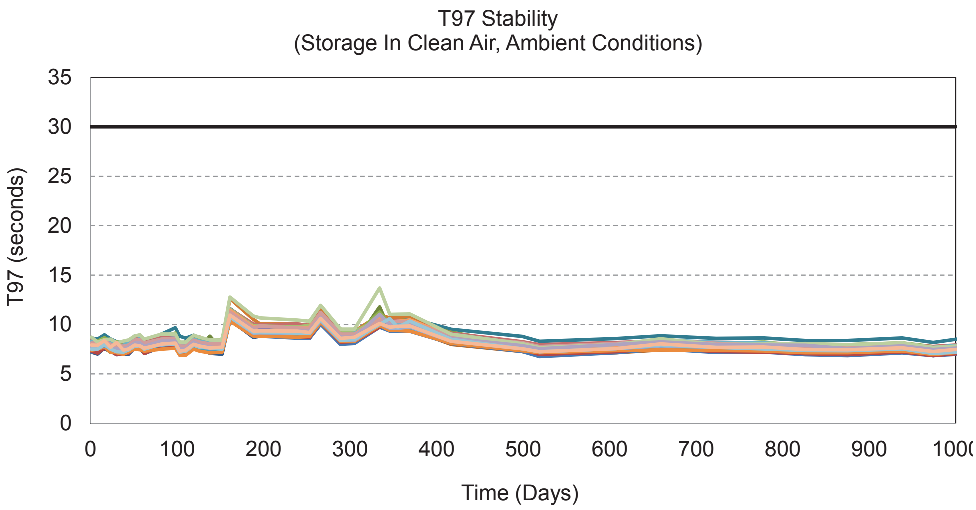
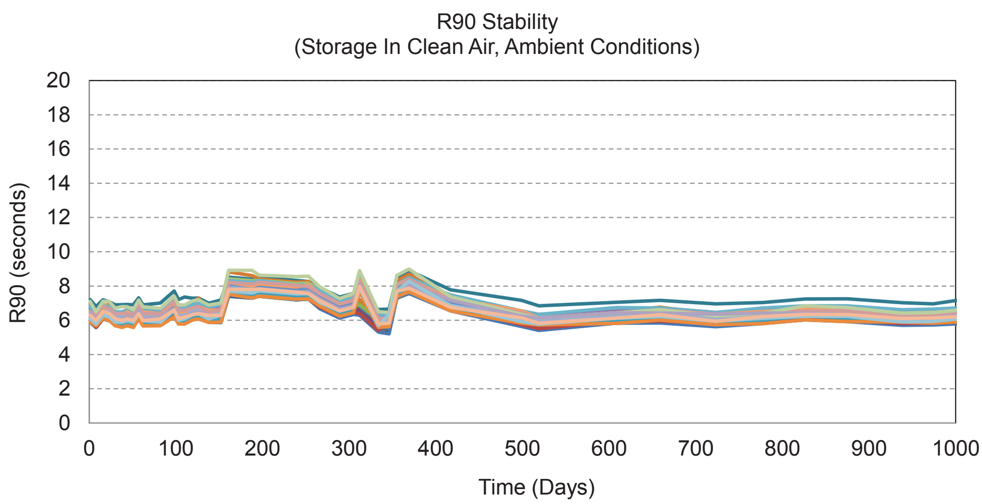
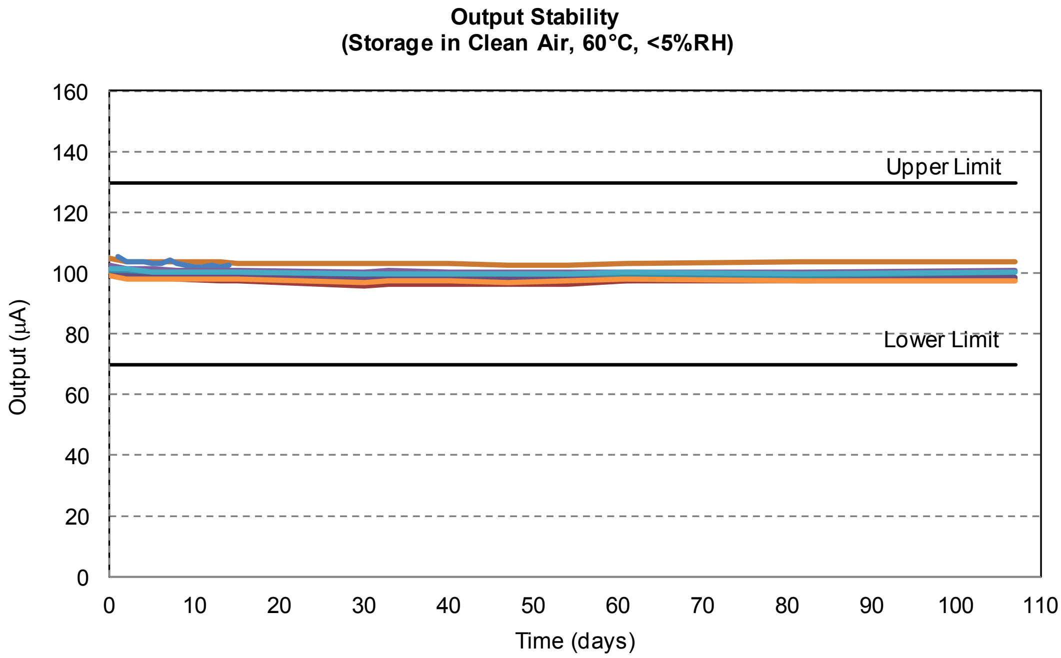
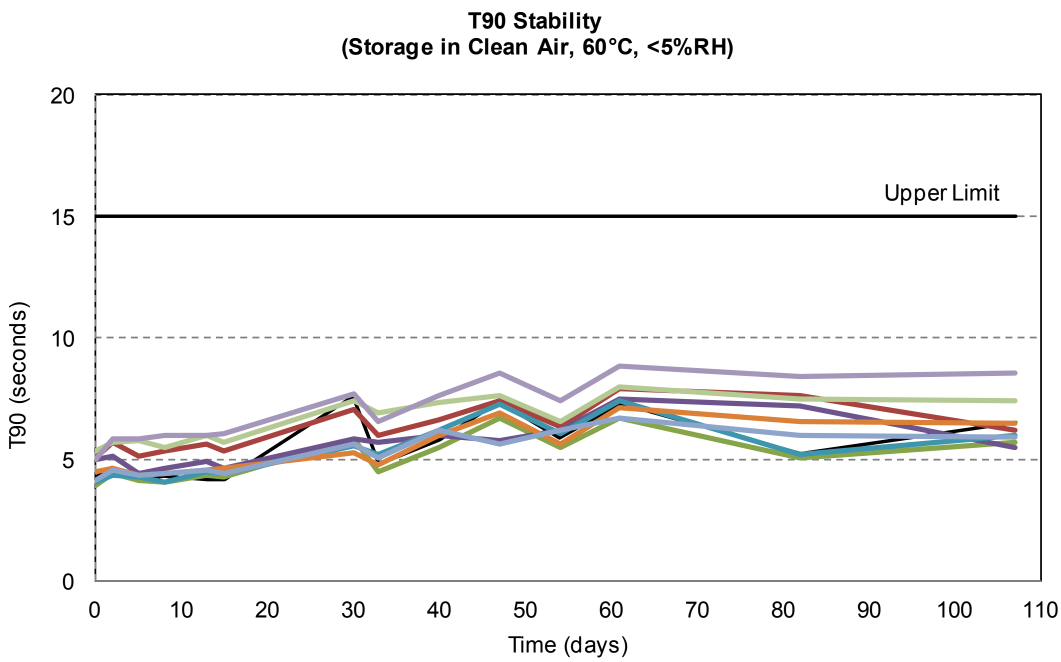






Storage in Hot, Dry Conditions (60°C, <5%RH)





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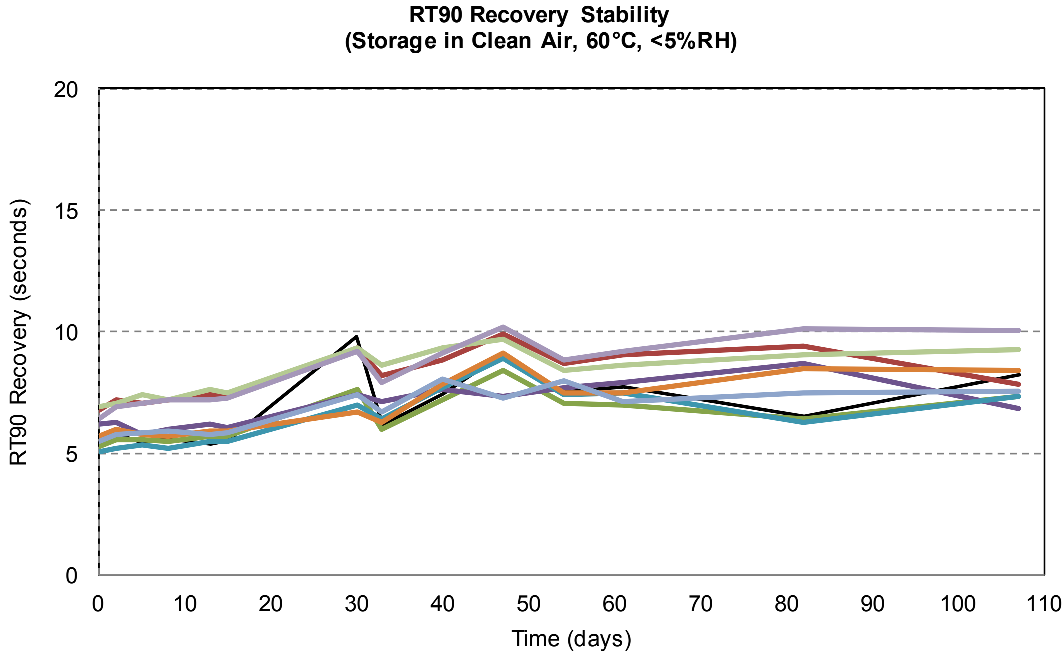

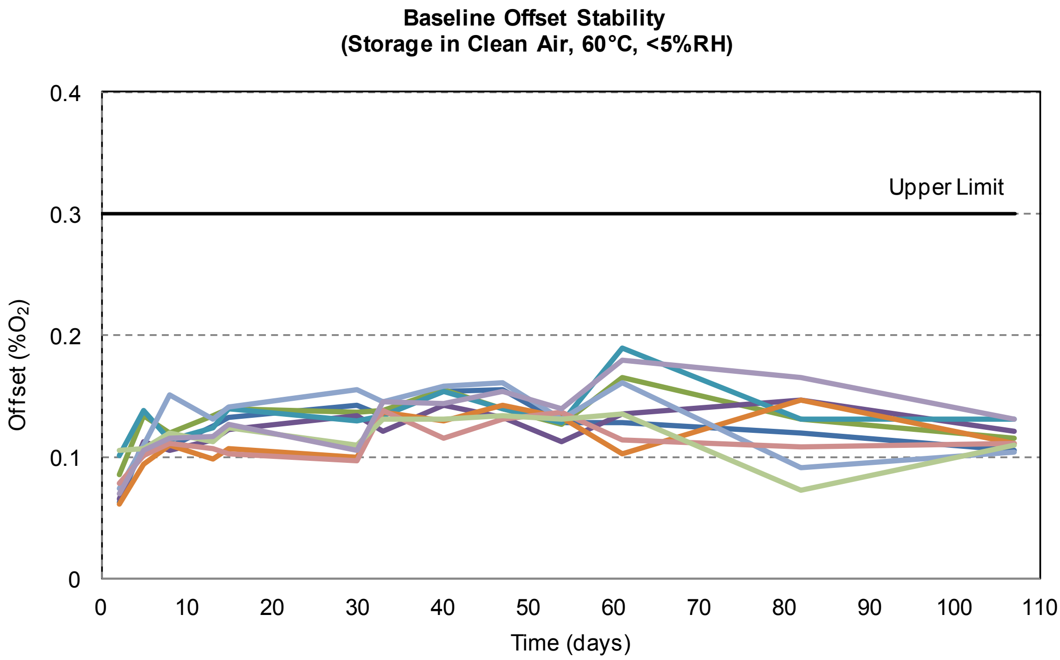

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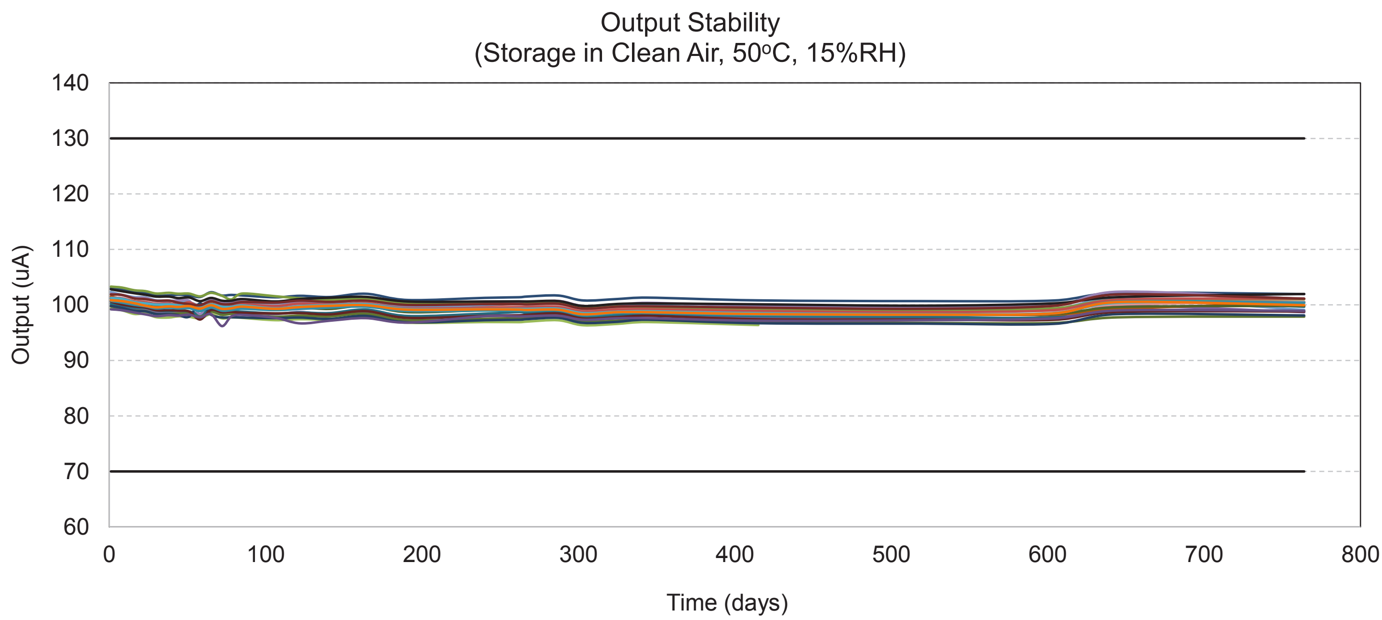
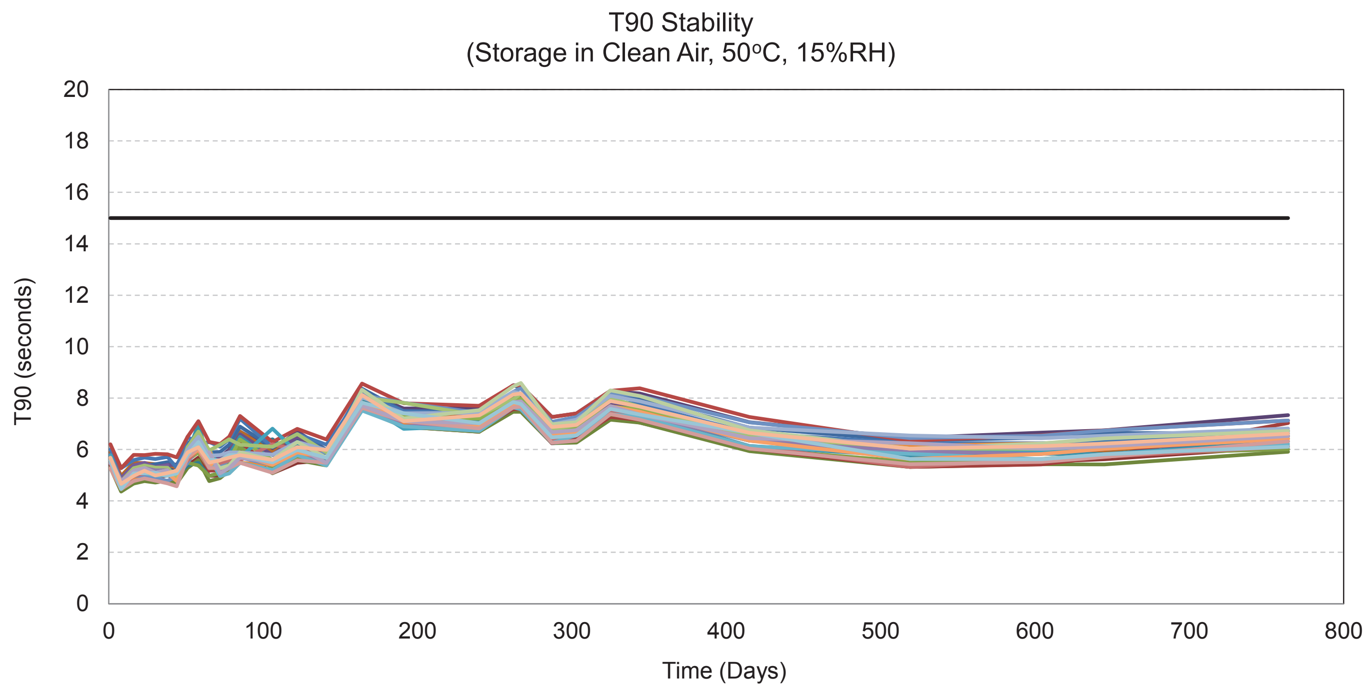
Storage in Hot, Dry Conditions (50°C, 15%RH)





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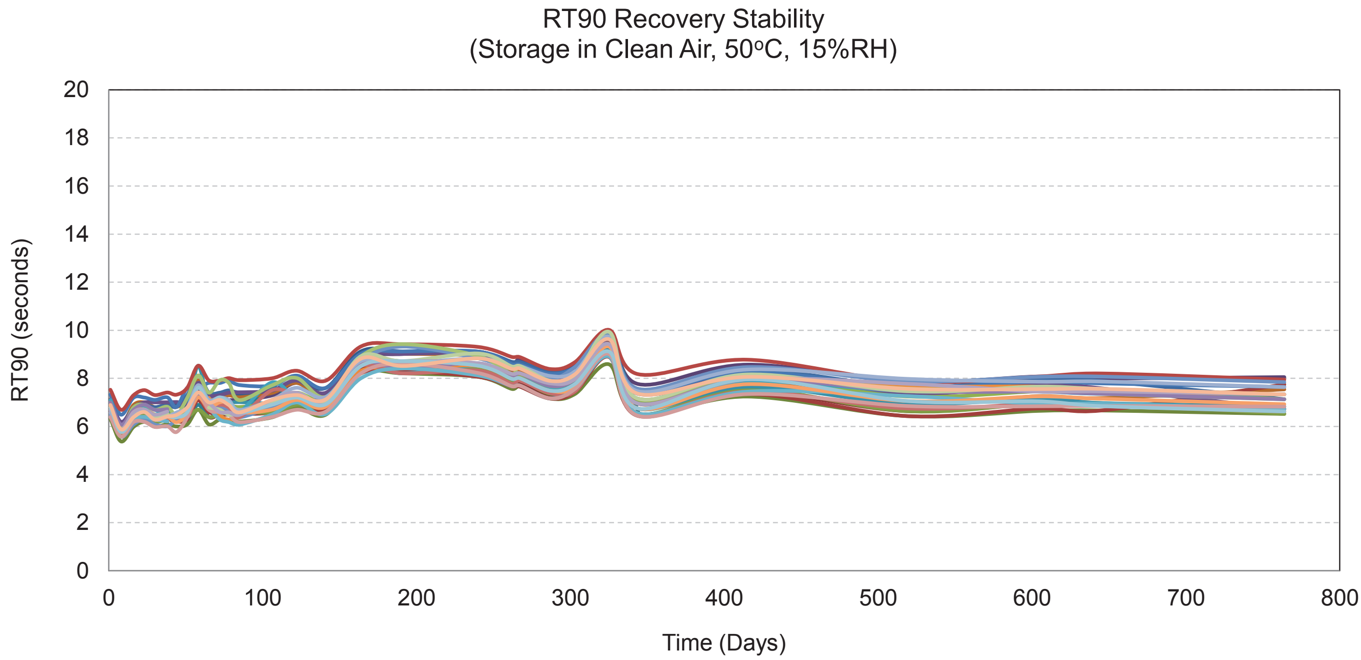

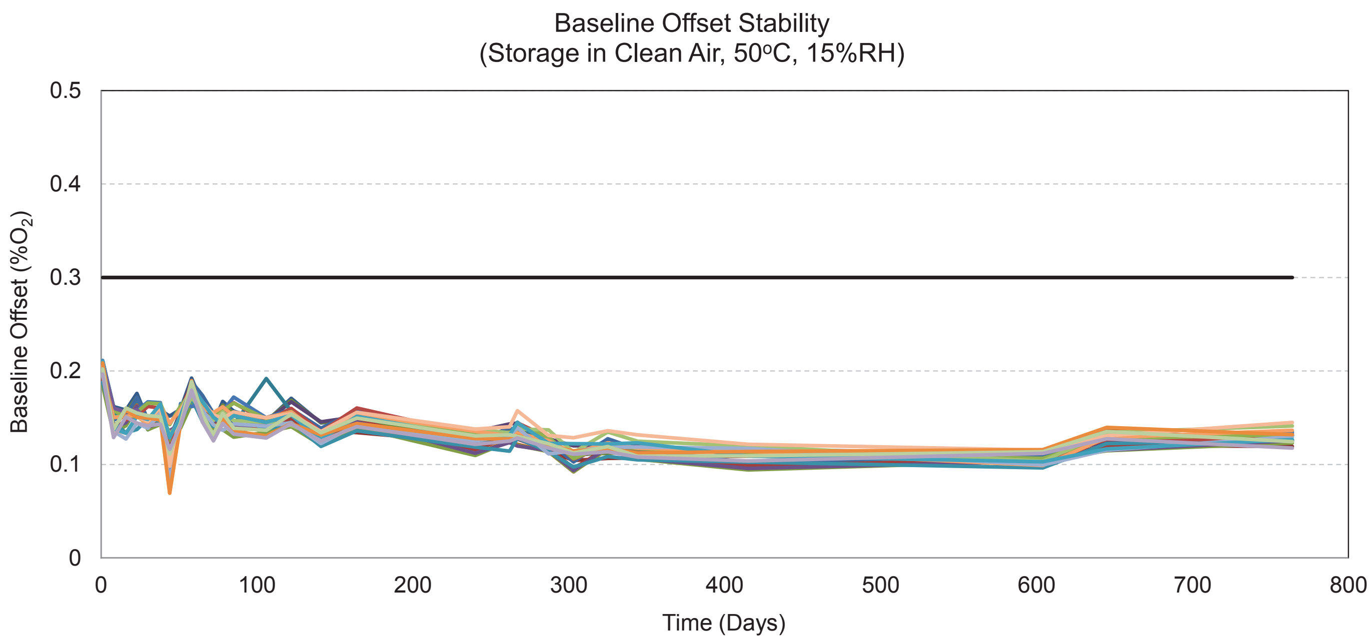

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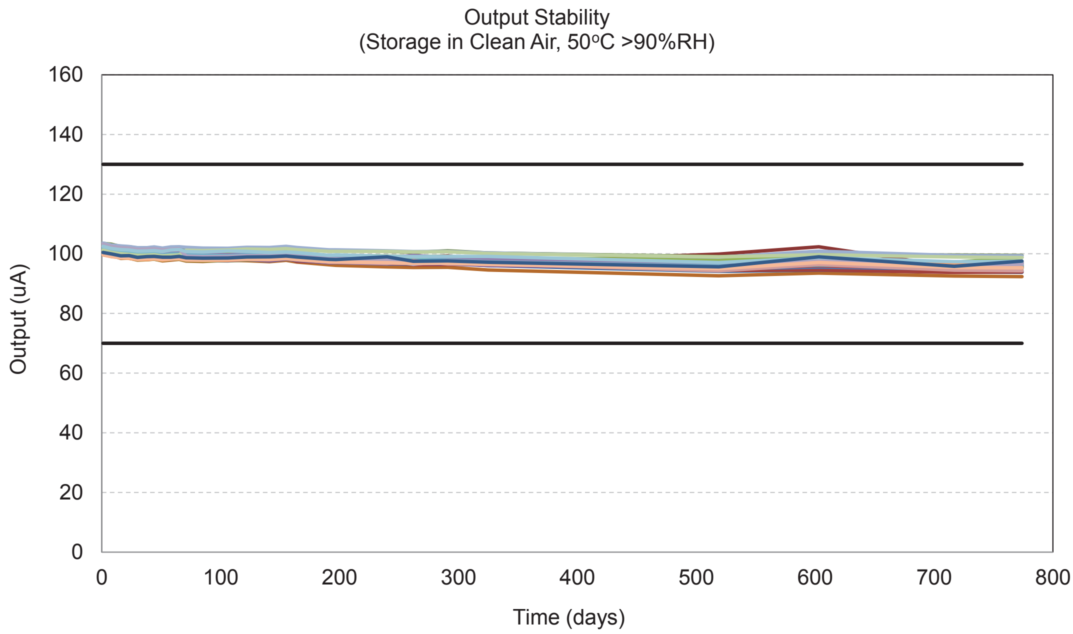
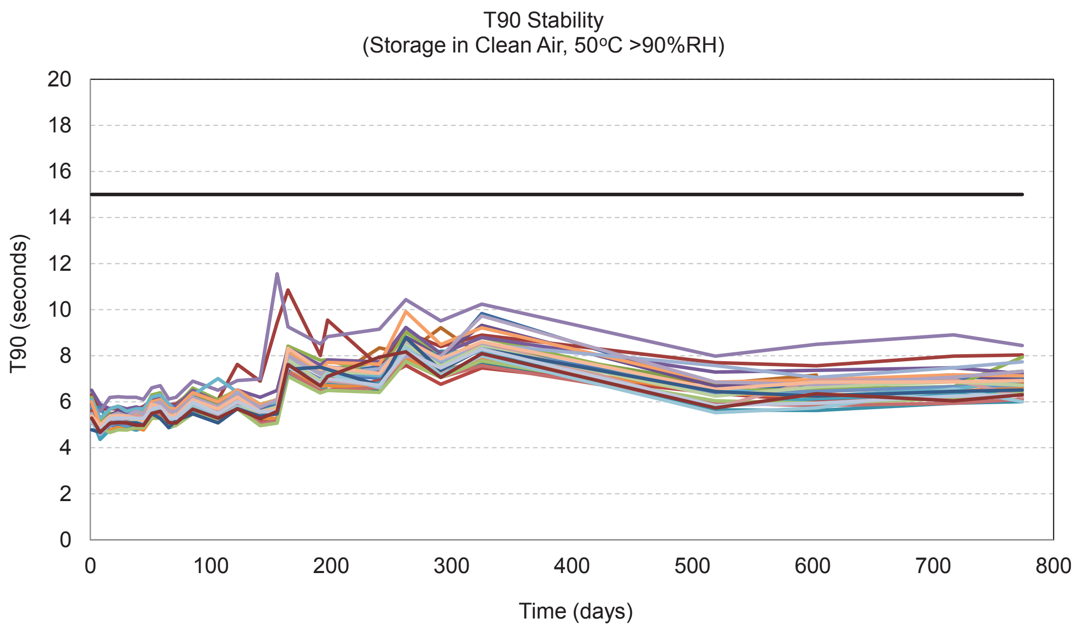
Storage in Hot, Wet Conditions (50°C, >90%RH)





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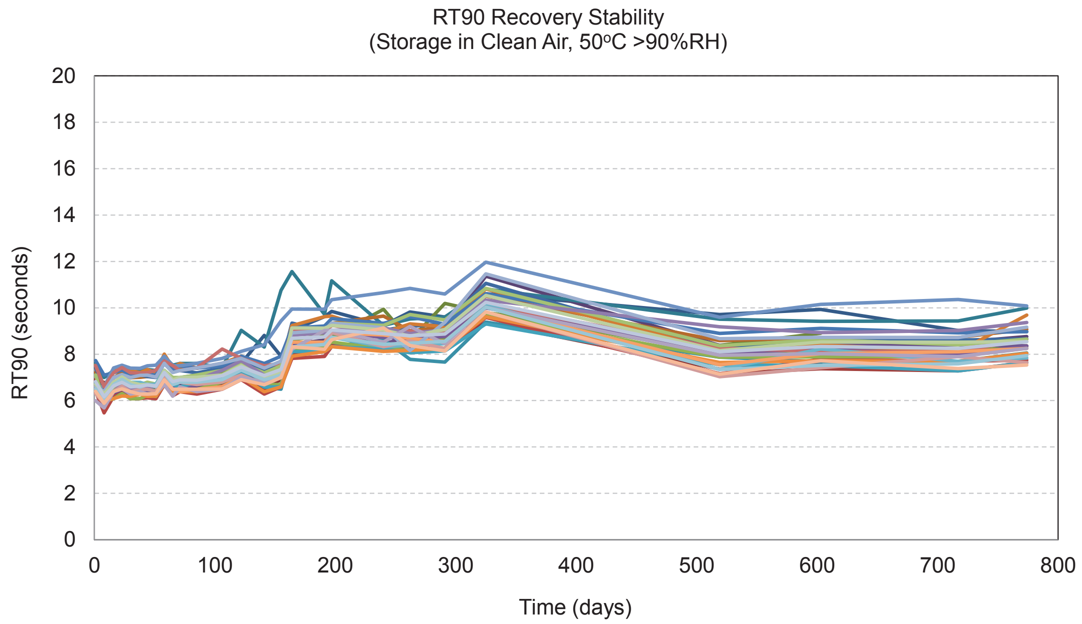
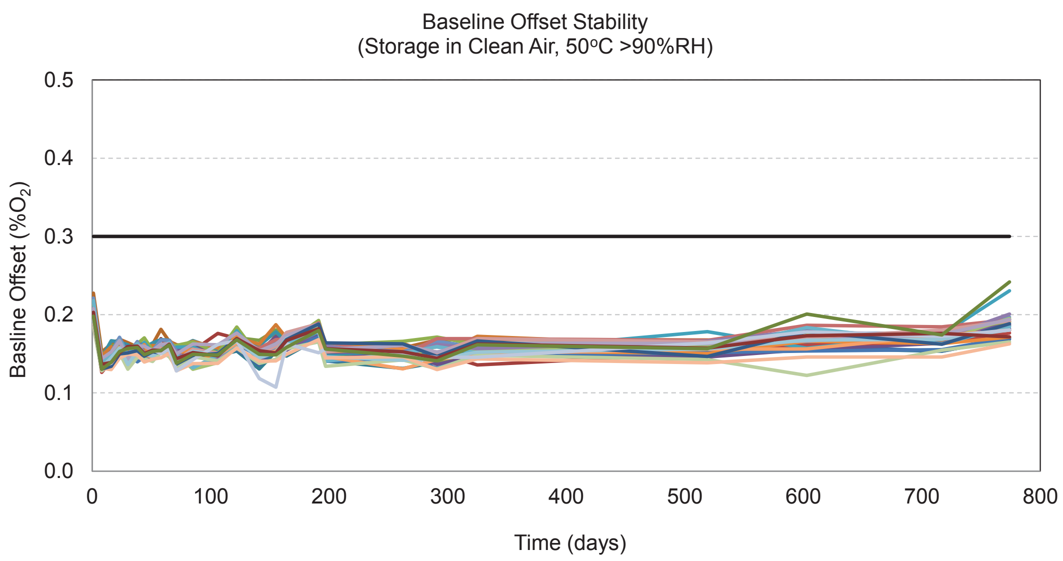
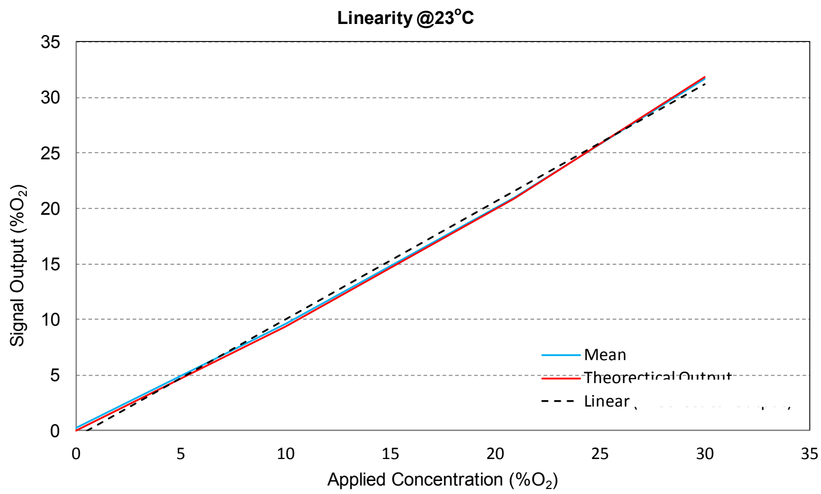




Linearity

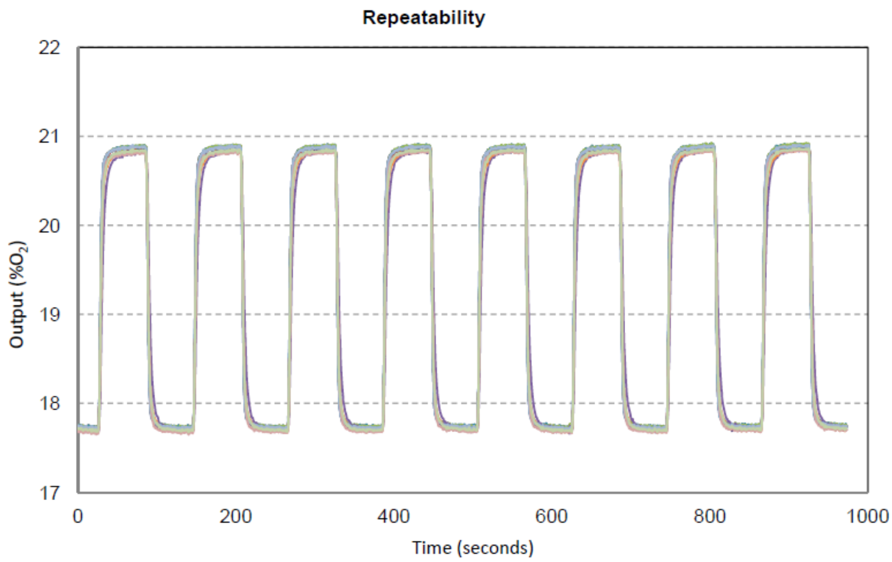
The data below shows the linearity performance of the 4OxLL when subjected to differing oxygen concentrations across the detection range. The presented results reflect the performance of a typical production batch. Across typical measurement ranges for industrial safety, the sensor can often be considered linear and no additional compensation should be required.



The data above shows that when calibrated at 20.9% O_2, the maximum error occurs at around 10% O_2 where the sensor output is approximately 0.5% lower than a linear response would indicate.

Repeatability

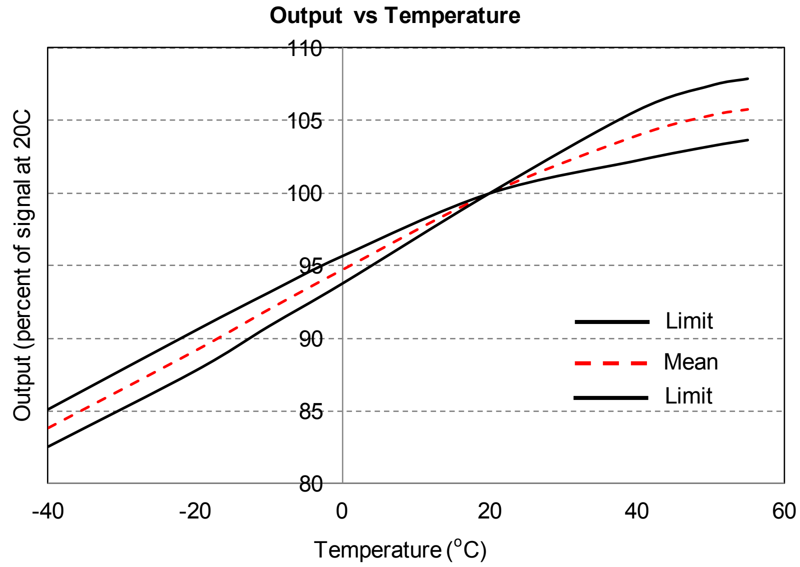
The data below shows the repeatability performance of the 4OxLL when exposed alternately to 20.9% O_2 and 18% O_2. The presented results reflect the performance of a typical production batch.



Application	1	2	3	4	5	6	7	8
Mean (20.9%)	20.864	20.864	20.876	20.869	20.877	20.863	20.866	20.866
Std Dev	0.029	0.027	0.029	0.027	0.027	0.028	0.030	0.026
Mean (18.0%)	17.716	17.713	17.722	17.723	17.724	17.717	17.718	17.728
Std Dev	0.024	0.021	0.025	0.021	0.024	0.020	0.017	0.022

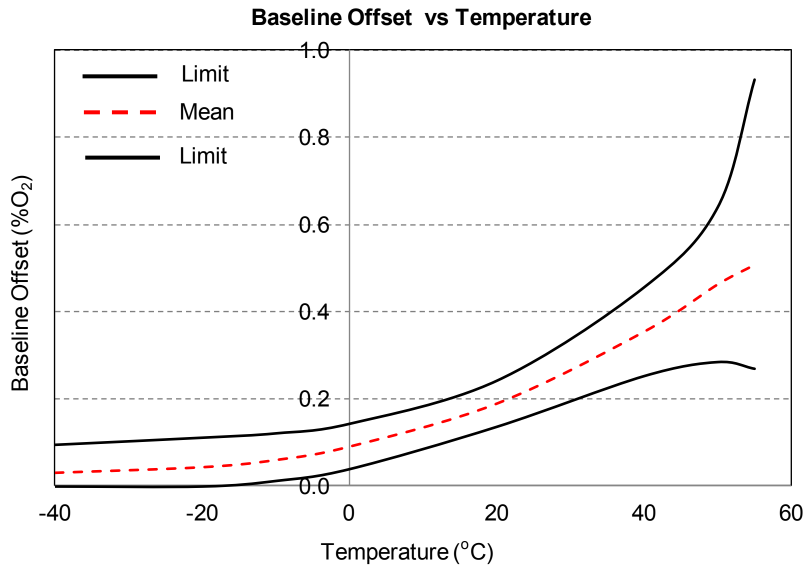
Output Variation with Temperature

The output of a 4OxLL CiTiceL® will vary as a function of ambient temperature. The data below shows the output performance across the operating temperature range and is presented normalised to the 20°C value. For instruments that are expected to function across a wide range of ambient temperatures, City Technology recommends that an electronic compensation algorithm is used to ensure maximum accuracy, The presented results reflect the performance of a typical production batch.



Baseline Offset Variation with Temperature

The electrical output in the absence of target gas (offset) of the 4OxLL will vary as a function of the ambient temperature. The data below shows the 4OxLL performance across the operating temperature range. Although the variation is relatively small, City Technology recommends the use of offset correction factors, particularly at higher temperatures, to minimise inaccuracies in the span measurement. The presented results



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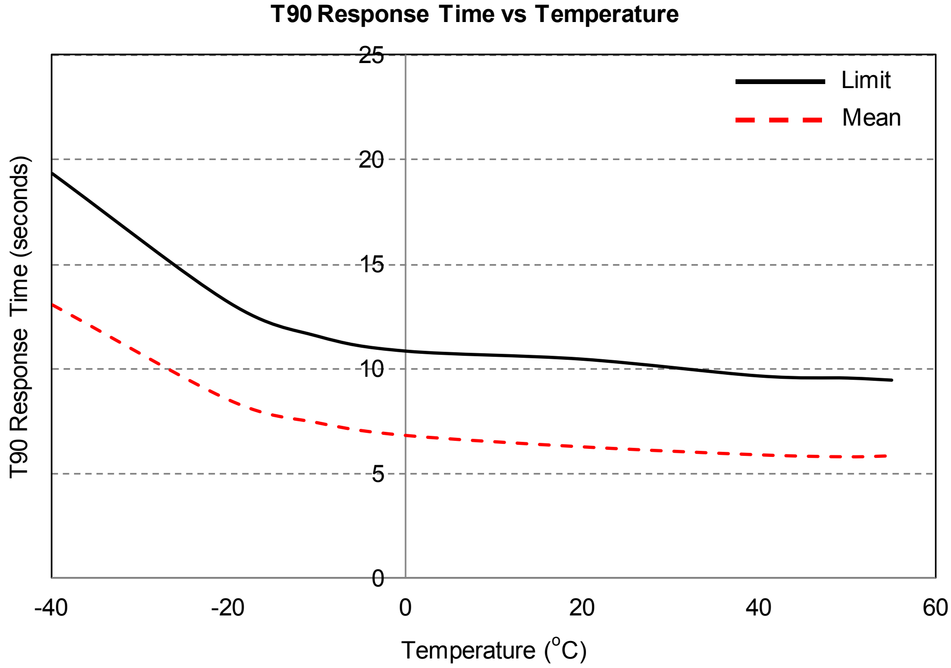
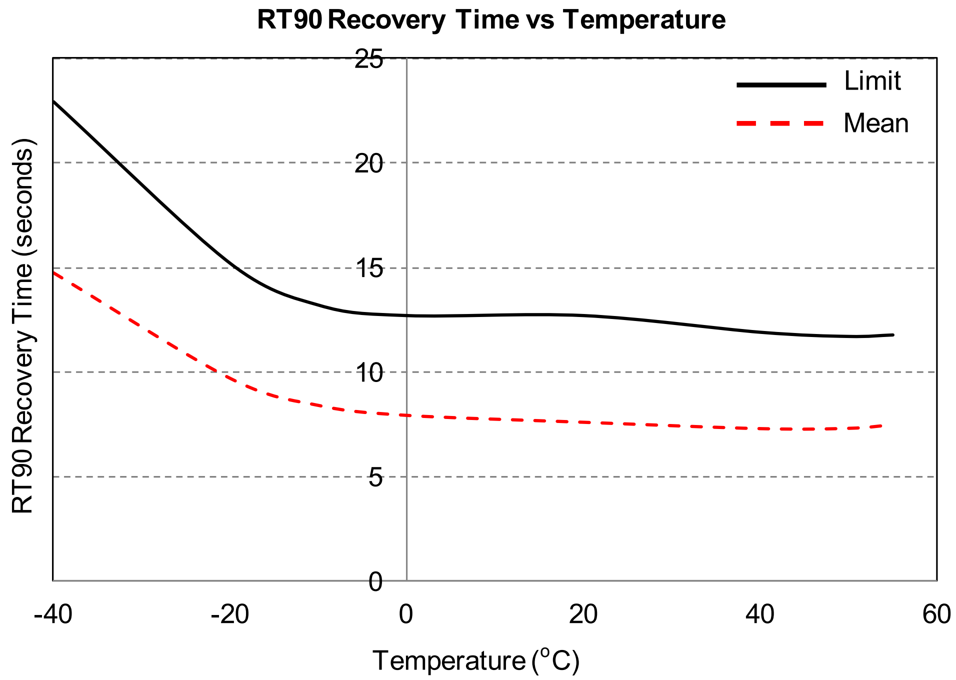
Response and Recovery Time Variation with Temperature

The response time of the 4OxLL will vary as a function of ambient temperature, becoming faster at higher temperatures and responding more slowly at lower temperatures. The data below shows typical T90 response times and RT90 recovery times of the 4OxLL across the operating temperature range. The presented results reflect the performance of a typical production batch.

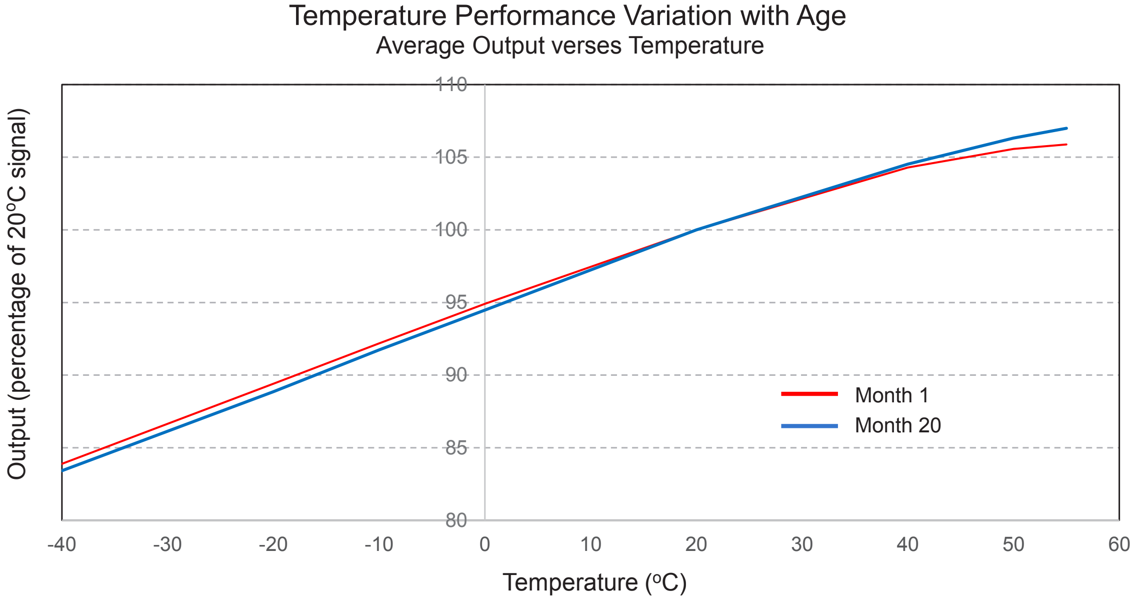


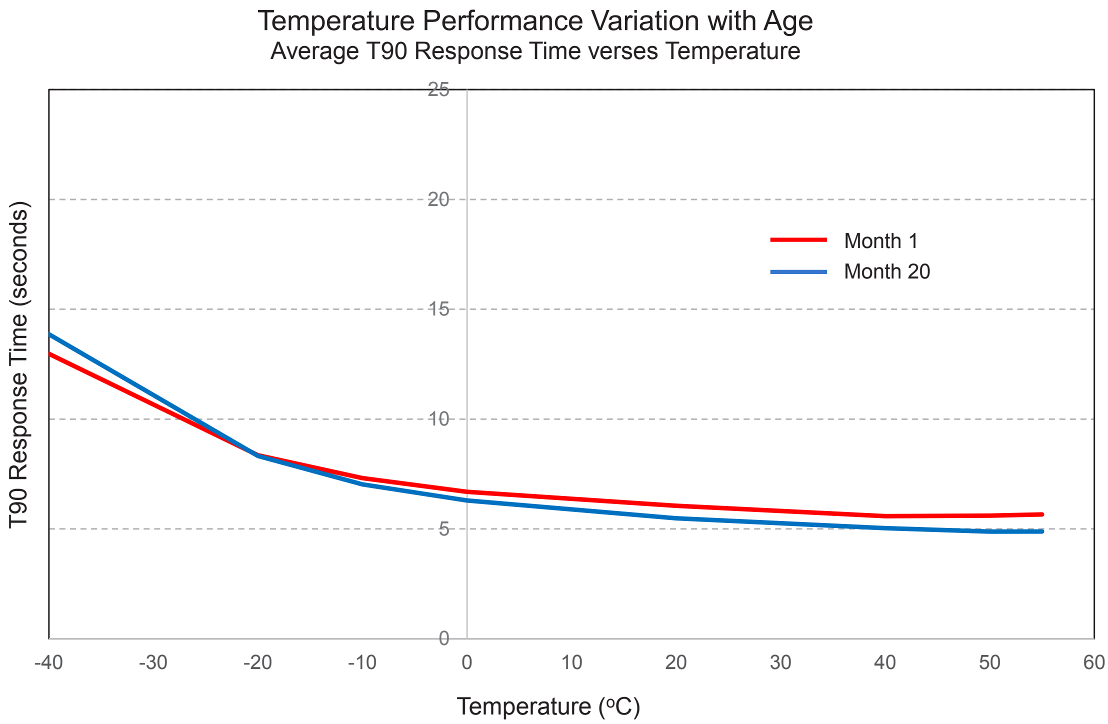


Product Characterisation Note

Effect of Ageing on Temperature Performance

The following data describes how the temperature performance of the sensor is effected by sensor age (based on a sample batch of 30 sensors). The presented results reflect the performance of a typical production batch.





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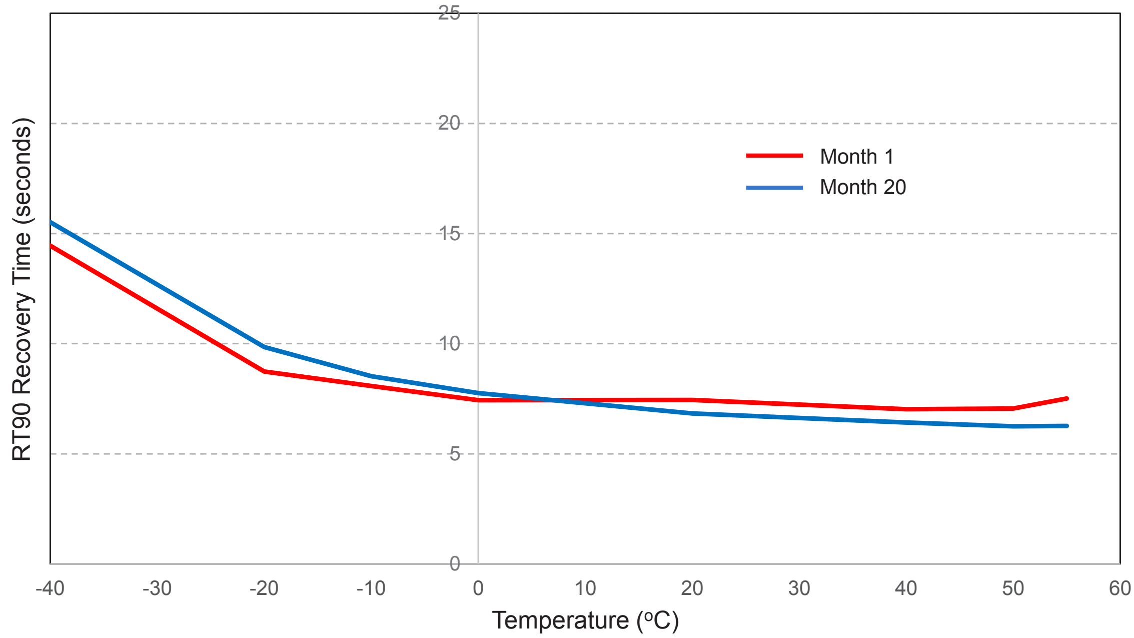
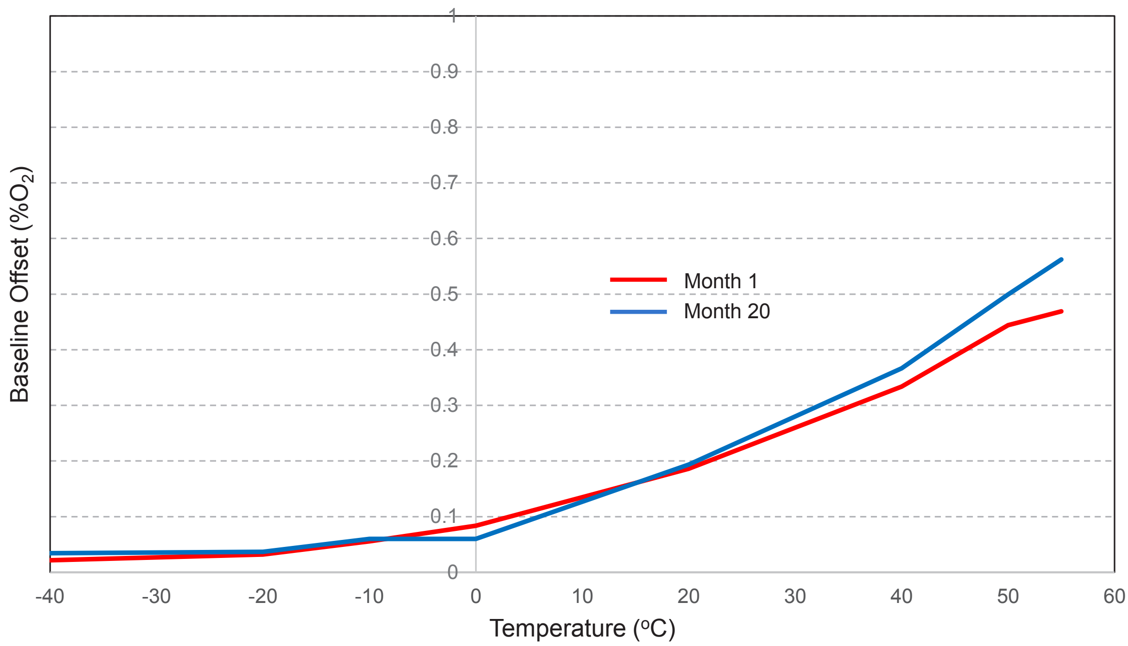
Temperature Performance Variation with Age
Average RT90 Recovery Time verses Temperature

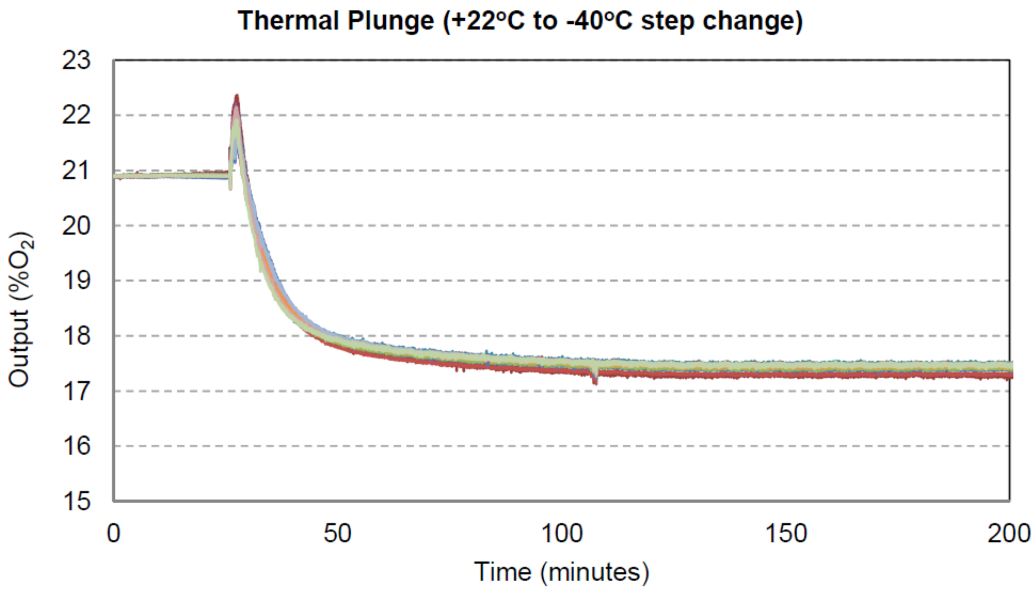


Temperature Performance Variation with Age
Average Baseline Offset verses Temperature



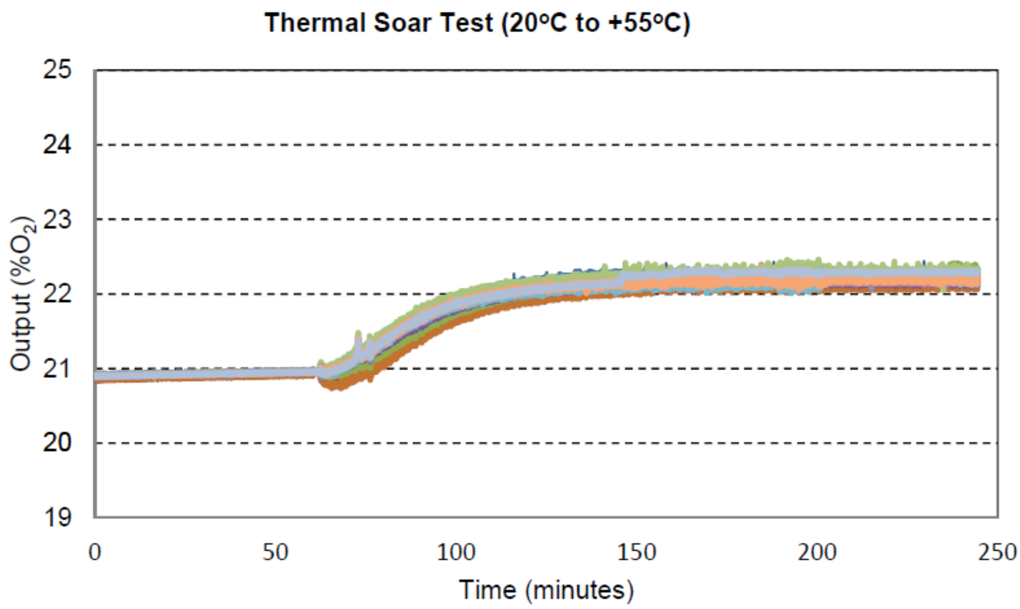
Thermal Plunge

The graph below describes the 4OxLL output when the sensor is exposed to a step-change thermal plunge from +22°C to -40°C.



Thermal Soar

The graph below describes the 4OxLL output when the sensor is exposed to a step-change thermal plunge from +20°C to +50°C.

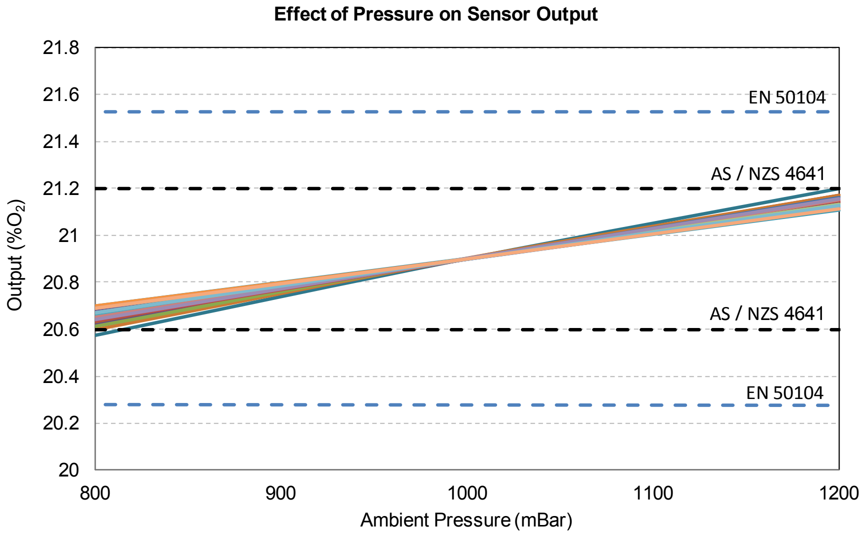


Pressure Performance

Steady State Performance

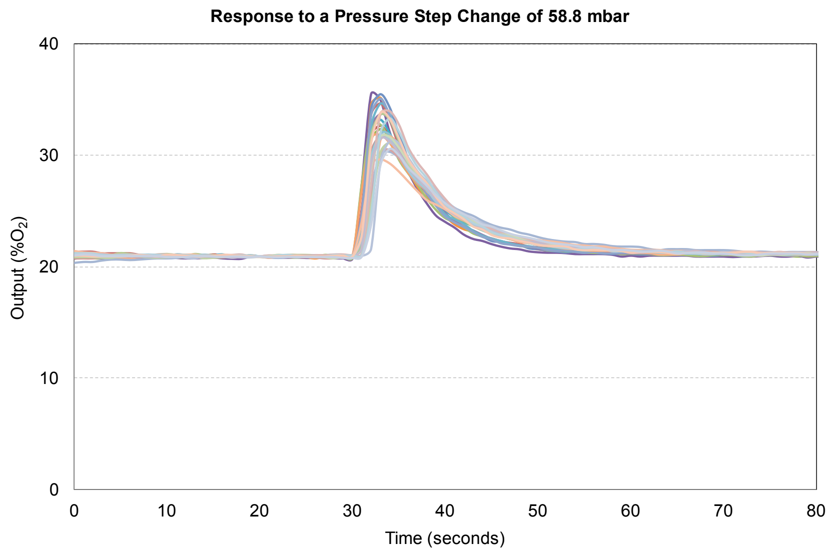
The 4OxLL CiTiceL output will vary slightly with gradual changes in ambient pressure - an increasing signal as pressure increases, and a decreasing signal as pressure decreases.

The graph below describes the 4OxLL pressure coefficients.



Transient Performance

The 4OxLL CiTiceL will give a transient response to a step change in pressure - an increase in signal for a positive pressure change and a decrease in signal for a negative pressure change. This transient usually fades away after a few seconds but may result in false alarms. The data below reflects the typical transient peak amplitudes from production batches.

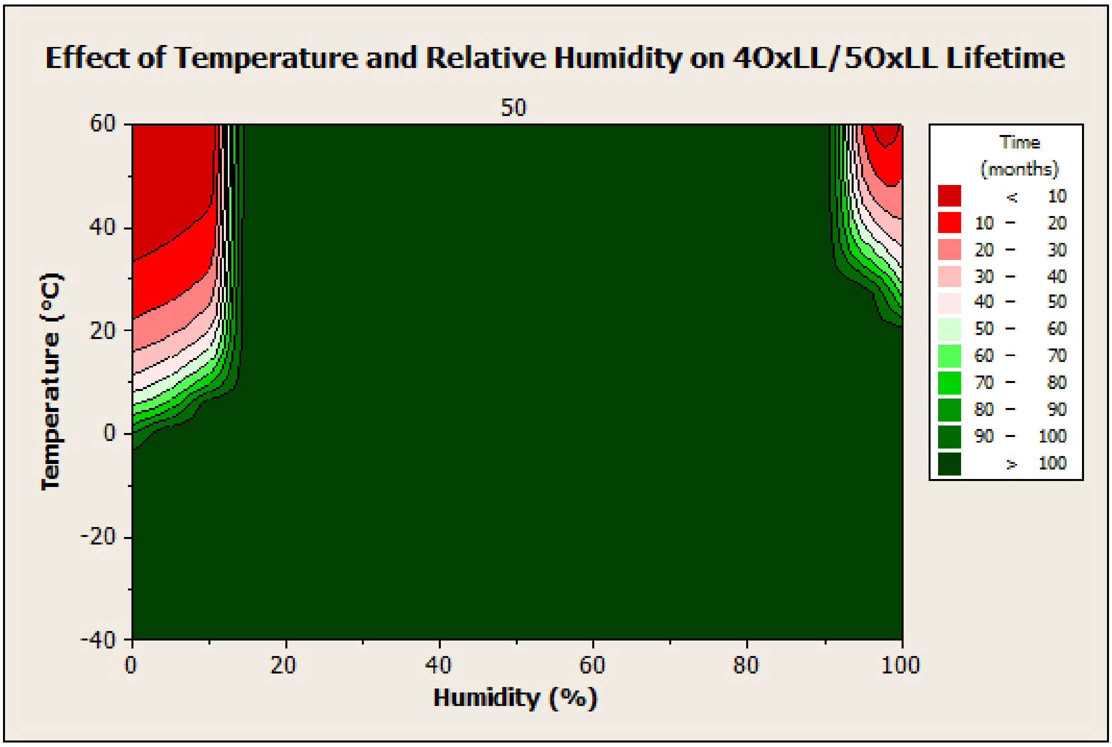


Effect of Temperature & Relative Humidity on Operational Life

The 4OxLL has been developed to demonstrate stable performance across a range of operating temperatures and relative humidities. The design of the sensor includes an aqueous electrolyte which tends to equilibriate towards the environment in which it is stored. At a fixed relative humidity of 64%, the sensor will neither lose nor gain water irrespective of the ambient temperature. However, if the sensor is subjected to an environment with an RH of less than 64%, it will gradually lose water. Equally, in an environment with an RH of greater than 64%, it will gradually absorb water from the atmosphere. The rate at which the sensor loses or gains water is determined by the ambient temperature -water transfer is faster at higher temperatures.

If the sensor is subjected to prolonged extremes of relative humidity at high temperatures for extended periods of time, there remains a risk that the performance of the sensor may be compromised, showing a loss in sensitivity, enhanced baseline or slower response time. It is therefore recommended that if the customer's intended use of the 4OxLL may subject it to prolonged exposures to extreme environments, they consult a member of the City Technology Technical Sales team for further advice as to the likely implications and how to overcome any issues seen.

The chart below is a theoretical model which provides an indication of the effect of continuous exposure of temperature and relative humidity on sensor lifetime.



Carbon Dioxide Performance

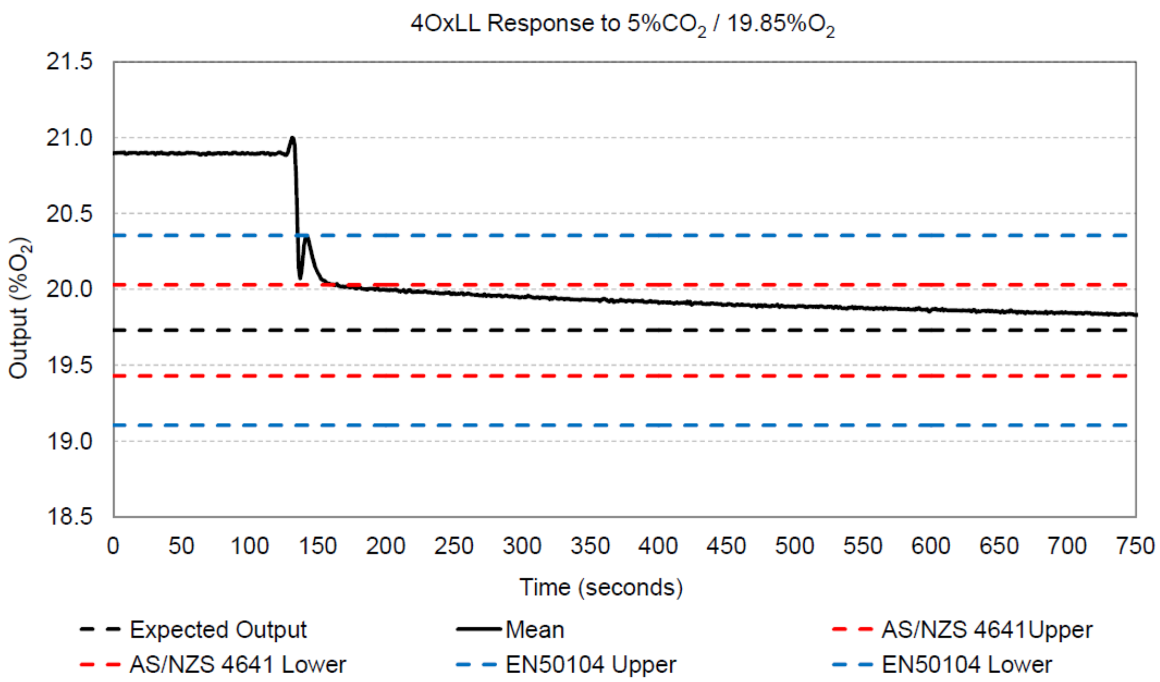
The 4OxLL will show an enhanced O_2 output when in the presence of CO_2. A signal increase of up to 0.015%O_2 per %CO_2 can be expected. This is anticipated to remain stable over life of the sensor.

The 4OxLL has been characterised in environments containing levels of CO_2 up to 20%. In general, the higher the level of CO2 present, the longer the exposure / purge times & recovery times will be required to meet accuracy standards.

The table below describes recommended exposure and recovery times for environments containing CO_2.

CO_2 Concentration	Exposure Time	Recovery Time
0 - 5%	2 - 5 minutes	2 - 5 minutes
5 - 10%	10 - 15 minutes	10 - 15 minutes

The graph below depicts thw behaviour of the 4OxLL sensor in an environment containing 5%CO_2 /19.85%O_2. The blue & red dotted lines depict accuracy limits taken from EN50104 and AS/NZS 4641 standards respectively, based around the theoretical oxygen sensor output (adjusted for non linearity).



In environments containing up to 5%CO_2, the sensor will reach accuracy standards within 30 seconds for EN50104 regulations and 2-3 minutes for the AS/NZS 4641 speciifcation.

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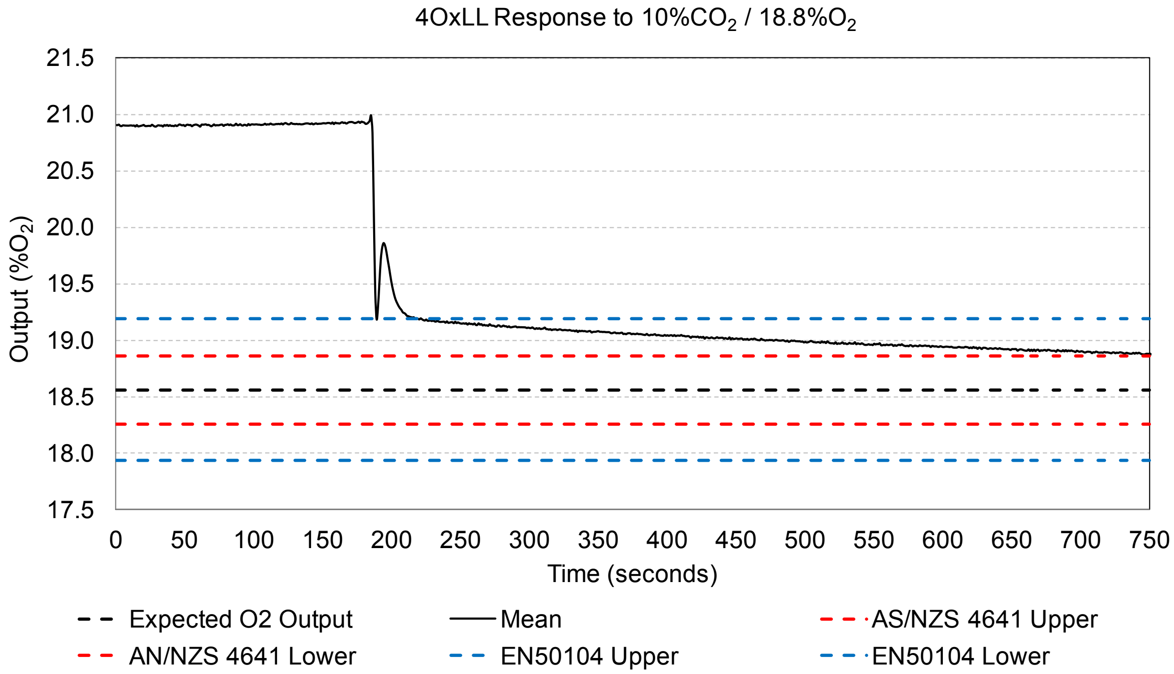
In environments containing between 5% and 10%CO_2, a longer exposure time is required for the sensor to stabilise and meet the AS/NZS 4641 accuracy requirements. The EN50104 accuracy requirement is achieved typically within 60 seconds and the AS/NZS 4641 requirements within 10-15 minutes.



Cross Sensitivity Data

The 4OxLL CiTiceL has been tested with a number of gases which may be present in applications to establish their level of cross interference. Although this table does provide a guide, it does not dictate the behaviour of any particular sensor or batch of sensors. This behaviour may vary depending upon the application and ambient conditions.

Gas	Concentration	Balance	%O_2 Equivalent
Ammonia, NH_3	37.5 ppm	21% O_2 / Balance N_2	<-0.2%O_2
Carbon Dioxide, CO_2	5%	21% O_2 / Balance N_2	0.015%O_2 / %CO_2 (see note)
Carbon Dioxide, CO_2	10%	21% O_2 / Balance N_2	0.015%O_2 / %CO_2 (see note)
Carbon Monoxide, CO	1000 ppm	21% O_2 / Balance N_2	<0.1%O_2
Chlorine, Cl_2	10 ppm	21% O_2 / Balance N_2	<0.15%O_2
Ethanol, C_2H_5OH	150 ppm	21% O_2 / Balance N_2	<0.1%O_2
Hydrogen, H_2	1000 ppm	21% O_2 / Balance N_2	<-0.2%O_2
Hydrogen Sulfide, H_2S	50 ppm	21% O_2 / Balance N_2	<0.1%O_2
Isobutylene, C_4H_8	75 ppm	21% O_2 / Balance N_2	<0.1%O_2
Methane, CH_4	3.75%	21% O_2 / Balance N_2	<-0.3%O_2
Nitrogen Dioxide, NO_2	10 ppm	21% O_2 / Balance N_2	<0.1%O_2
Nitric Oxide, NO	25 ppm	21% O_2 / Balance N_2	<0.1%O_2
Ozone, O_3	500 ppb	21% O_2 / Balance N_2	<0.1%O_2
Sulfur Dioxide, SO_2	25 ppm	21% O_2 / Balance N_2	<-0.1%O_2

NOTE : Adequate purge time must be allowed in order to meet the CO_2 accuracy. See previous section on CO2 cross sensitivity.