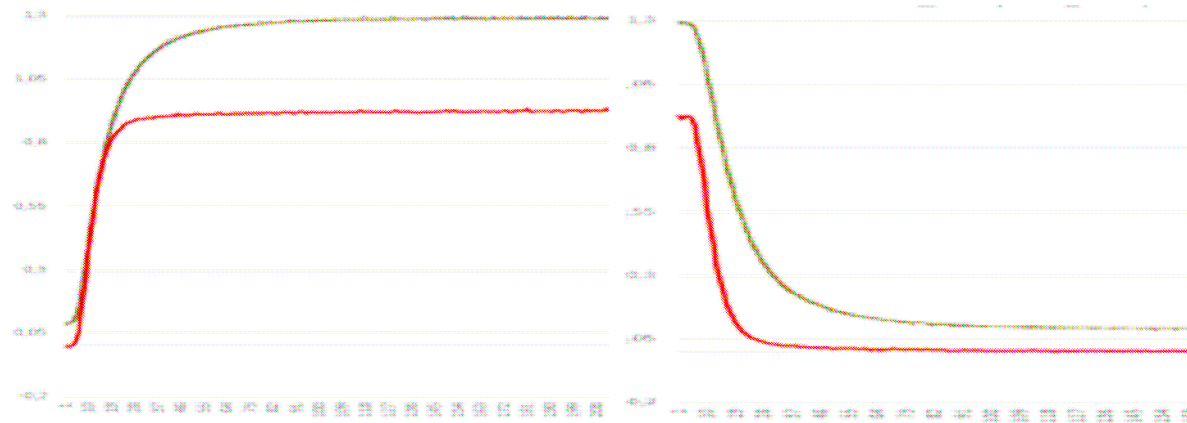


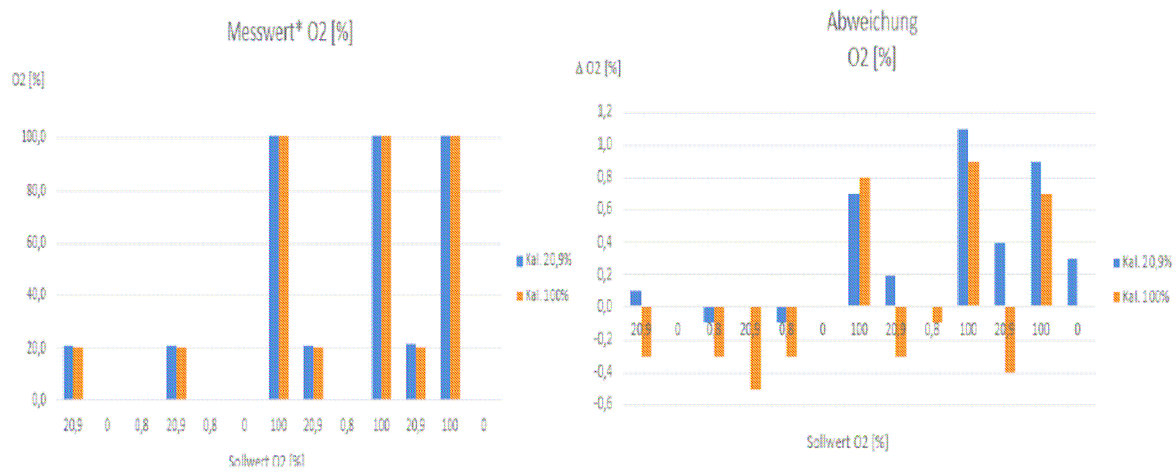
## Summary Test Results R-22VAN Oxygen Sensor (Vandagraph)above-mentioned

The sensor has undergone various tests to gain initial insights into the behavior of the sensor and to consider whether this sensor will be an alternative to the previously used sensor.

Step response: The time response of the sensor to gas changes ( $N_2 \leftarrow \rightarrow$  air) was investigated. The sensor (multicolored curve) shows a high degree of uniformity in the response to the jump signal. The reaction rate was slower by factor 1.9 (T90) or factor 1.4 (T99.5) compared to the previously used sensor (red curve).

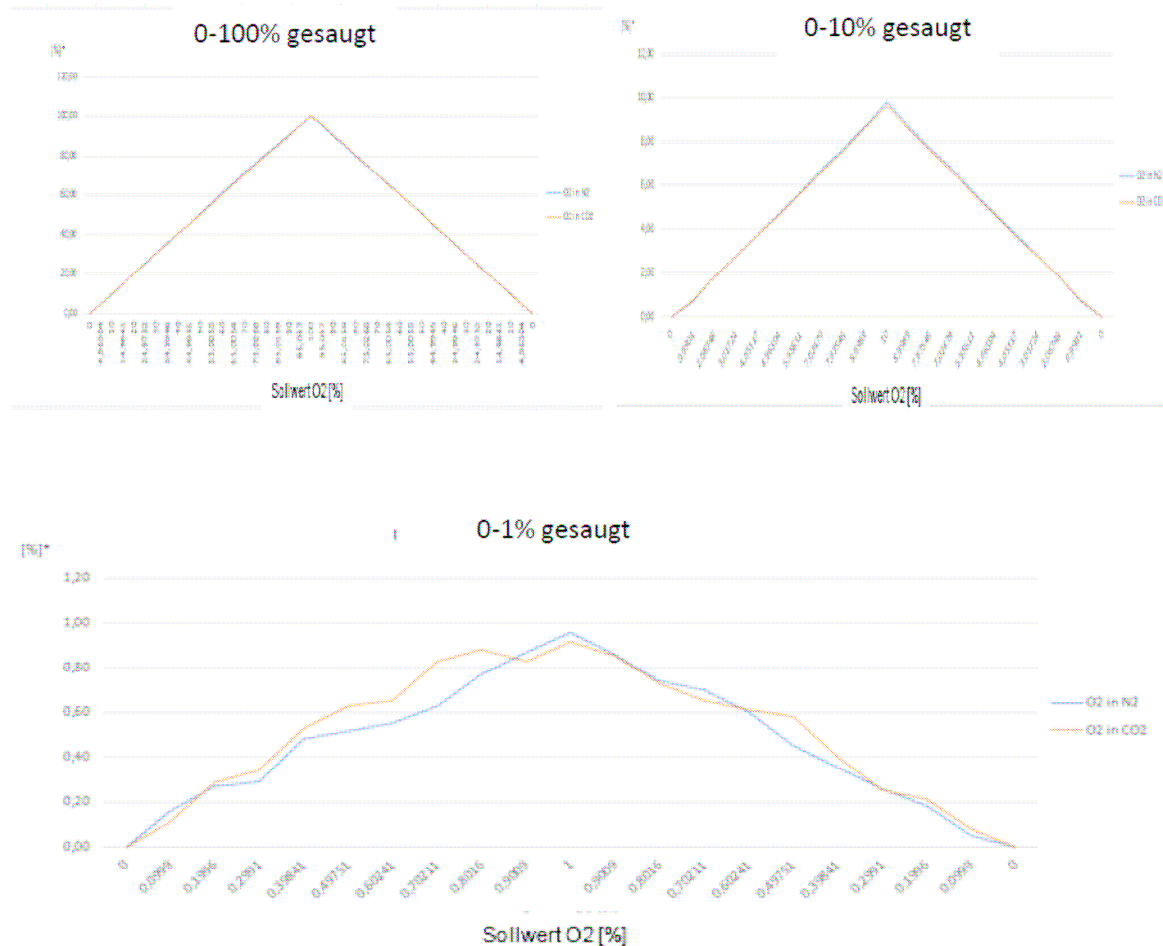


In this regard, another test was carried out: the sensor was installed in standard application in a standard analyzer and then detected with the device gases, with various changes between high, medium and low gas concentrations was driven off. Only the result of the first measurement was evaluated after each concentration change.



The maximum deviation from the setpoint here was 1.1%.

Linearity: The linearity of the test sensor was tested in two ways: 1. fumigated with slight overpressure; Here the pure (mV-) sensor signal was detected. 2. installed in the normal use case (gas analyzer), where the sensor is sucked by a pump; Here, the % signal of the analyzer was recorded, which was then compared with the setpoints and a deviation could be determined from these. It was measured with gas mixtures O<sub>2</sub> / N<sub>2</sub> (blue curve) and O<sub>2</sub> / CO<sub>2</sub> (orange curve).



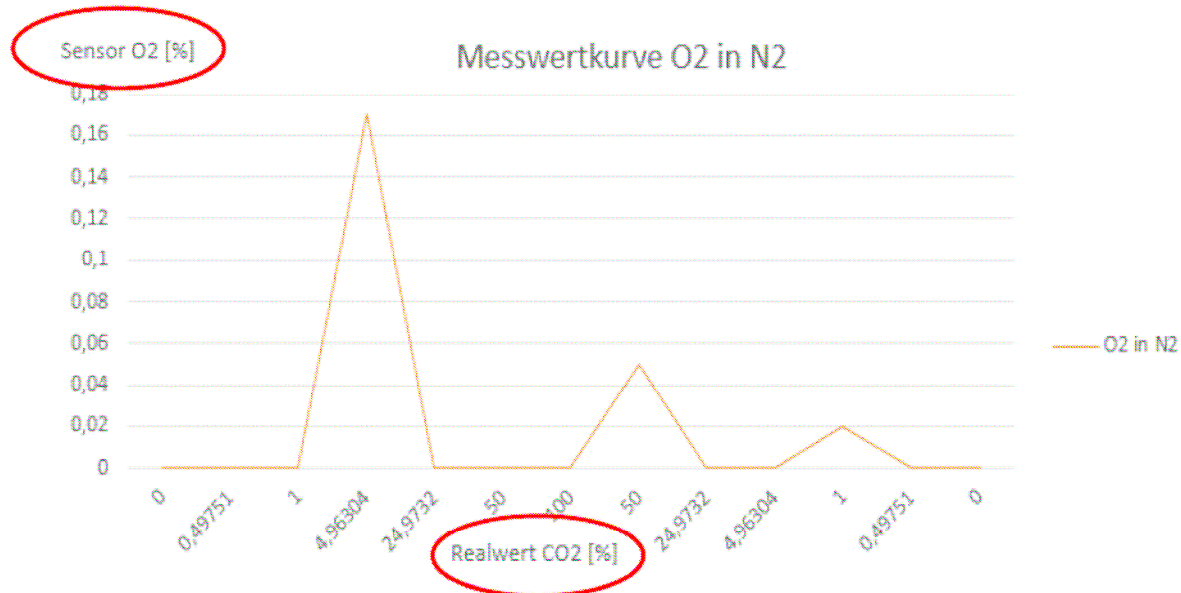
The measured value curves proved to be very linear in the measuring ranges 0-10% and 0-100%; the maximum observed deviations were 1.7% in the 0-100% range and -0.42% in the 0-10% range. In the area of greatest relevance, 0-1%, the measured value curve is initially not very linear, but this is due to the high diagram resolution in the area compared to the other areas. Good sensor behavior shows the maximum deviation of 0.13% from the setpoint in this measuring range.

0-100% aspirated

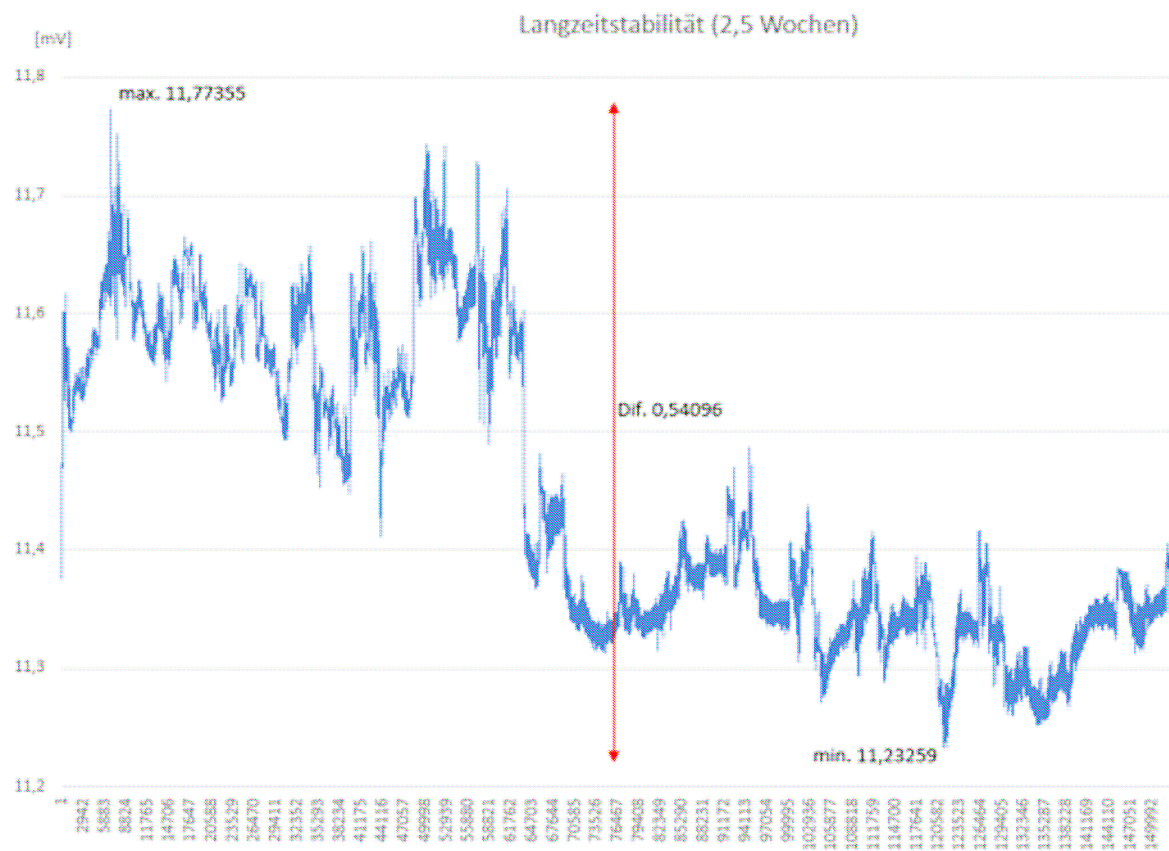
0-10% aspirated

0-1% aspirated

Cross-sensitivity: The sensor was fumigated with CO<sub>2</sub> in the analyzer, but the O<sub>2</sub> reading was read on the analyzer to determine if the sensor might also respond to CO<sub>2</sub> and thus would have a cross-sensitivity. Ideally, the readings should all be "0", which would not mean cross-sensitivity. As can be seen from the diagram, the sensor has a minimal, irregular cross-sensitivity to CO<sub>2</sub>. The maximum O<sub>2</sub> reading for CO<sub>2</sub> fumigation was 0.17%.

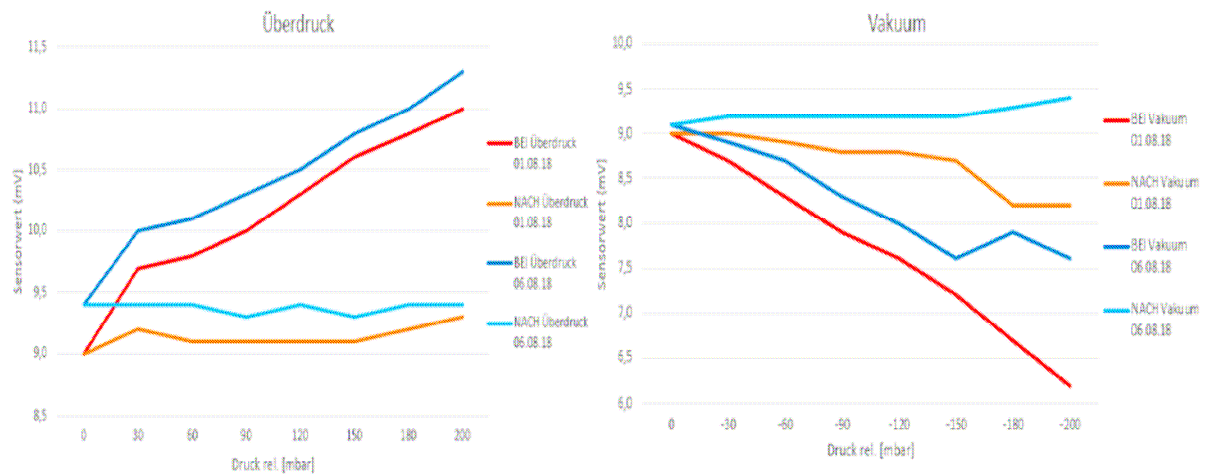


Long-term stability: The sensor was tested for long-term stability at constant gas concentration. The pure (mV) sensor signal was recorded for 18 days.



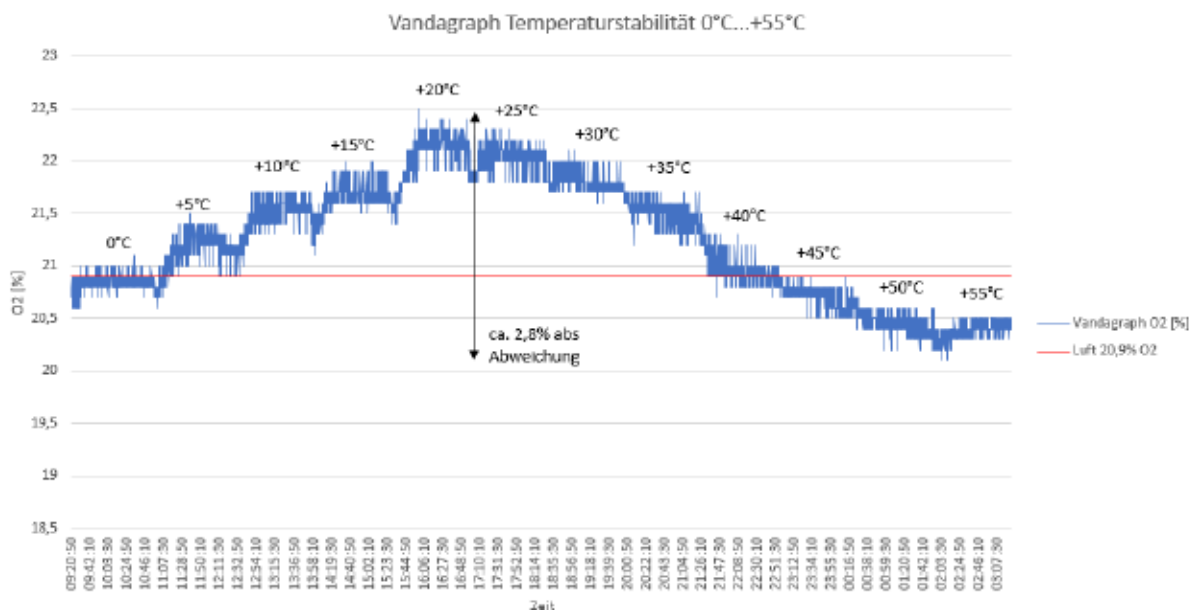
A maximum difference of the sensor signal of 0.54 mV was found. It can be seen from the diagram that the measured signal has dropped abruptly by approx. 0.2 mV after approx. Half of the test period (possibly external influences on the test setup), but has otherwise behaved rather stably.

**Pressure Drop Behavior:** It was examined how the sensor behaves when exposed to the pressure surges of the sample pump in the analyzer. There was a risk that a membrane deforming under pressure fluctuations (in part plastically) would affect the measurement result or, in the longer term, the calibration points in the analyzer. The sensor was operated with the pump in overpressure and also vacuum at different pressures, recorded the (mV) sensor signal.



During overpressure, the sensor signal deviated max. 2 mV from (red / dark blue curve), after discharge it settled with a maximum deviation of 0.3 mV (orange / light blue curve). During vacuum, the sensor signal deviated max. 2.8 mV from (red / dark blue curve), after discharge it settled with a maximum deviation of 0.8 mV (orange / light blue curve). It was noticeable that the measured signal curves did not run linearly in the range from -150 to -200 mbar (rel.).

**Temperature stability:** The sensor was tested for temperature stability with constant gas pairing and concentration (compressed air 20.9% O<sub>2</sub>) and constant pressure / flow. A temperature range of 0 °C to 55 °C has been used to provide a safe indication of the working range of the sensor from 0 °C to + 50 °C.



The maximum deviation detected by changing the temperature conditions is 2.8% (abs). The maximum deviation from the reference value (20.9% O<sub>2</sub>) is approximately 1.6%.

**There was physically only one sensor as a test object. In order to be able to make more reliable statements on the suitability of the sensor as an alternative, a further small amount of sensors should be procured for test purposes (optimally different production batches) from the manufacturer.**

Witten, 10.08.2018 S. Jaensch