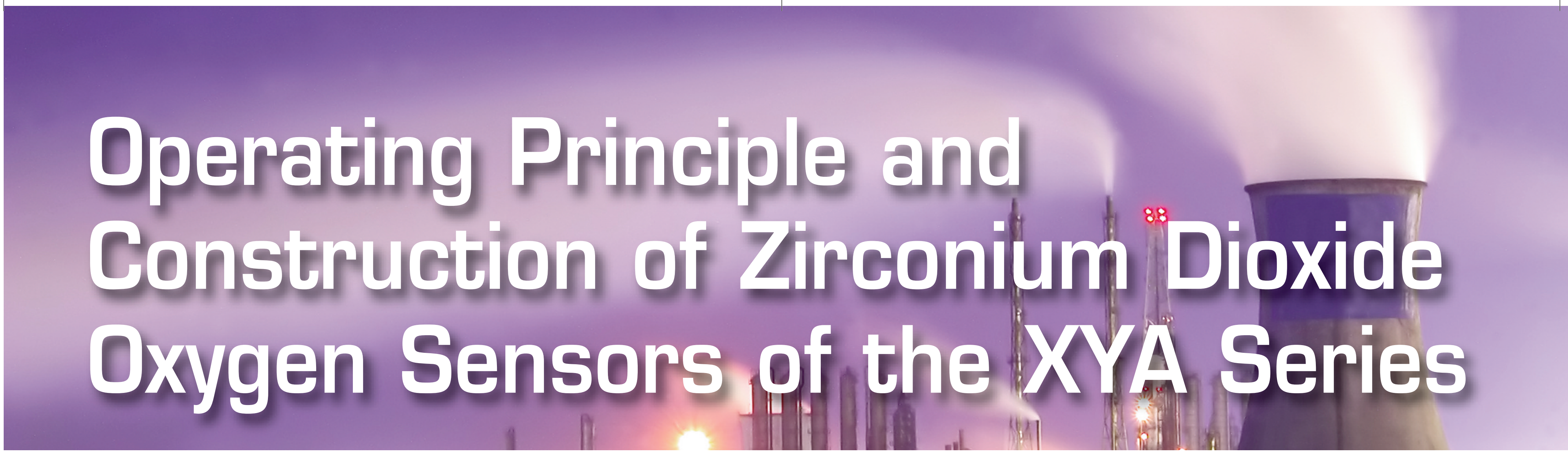

Operating Principle and Construction of Zirconium Dioxide Oxygen Sensors of the XYA Series

Partial Pressure

Definition:
The partial pressure is defined as the pressure of a single gas component in a mixture of gases. It corresponds to the total pressure which the single gas component would exert if it alone occupied the whole volume.

In biology and medicine above all the partial pressures of oxygen and carbon dioxide are of importance. Here, the term partial pressure is also used for the concentration of gases dissolved in liquids, e.g. in blood or water. Thereby the partial pressure of a gas dissolved in a liquid is the partial pressure of that gas which would be generated in a gas phase in equilibrium with the liquid at the same temperature.

Dalton's law: The total pressure p_{total} of a mixture of ideal gases is equal to the sum of the partial pressures p_i of the individual gases in that mixture.

$$P_{total} = \sum_{i=1}^{k} P_i \qquad (1)$$

From equation (1) it can be derived that the ratio of the number of particles (amount of substance) n_i of an individual gas component to the total number of particles in a gas mixture equals the ratio of the partial pressure p_i of a gas component i to the total pressure p_{total} of the gas mixture.

$$\frac{n_i}{n_{total}} = \frac{p_i}{p_{total}} \qquad (2)$$

n_i : Number of particles in gas i
n_{total} : Total number of particles
p_i : Partial pressure of gas i
p_{total} : Total pressure

Example:
The atmospheric pressure at sea level (standard condition) is 1013.25 hPa. Here the main components of dry air are nitrogen (78.09 % Vol.), oxygen (20.95 % Vol.), argon (0.927% Vol.) and carbon dioxide (0.033% Vol.). The volumetric content can be equated with the number of particles n since the above gases can be approximated as ideal gases.

Equation (2) can be solved for the partial pressure of an individual gas i to get:

$$p_i = \frac{n_i}{n_{total}} \cdot p_{total} \qquad (3)$$

Then the oxygen partial pressure calculates to:

$$p_i = \frac{20.95\%}{100\%} \cdot 1013.25\ \text{hPa} = \underline{\underline{212.275\ \text{hPa}}}$$

Nernst voltage

Two different ion concentrations on either side of an electrolyte generate an electrical potential known as the Nernst voltage. This voltage is proportional to the natural logarithm of the ratio of the two different ion concentrations.

$$\Delta U = \frac{k_B T}{e_0} \cdot \ln\left(\frac{c_1}{c_2}\right) \qquad (4)$$

k_B: Boltzmann constant (k_B=1.38•10-23 J/K)
T: Temperature in K
e_0: Elementary charge (e_0=1.602•10-19 C)
c_i: Ion concentration in mol/kg

Zirconium dioxide (ZrO_2)

At high temperatures >650°C zirconium dioxide (ZrO_2) exhibits two mechanisms:
1. ZrO_2 partly dissociates to produce oxygen ions which can be transported through the material when a voltage is applied.
2. ZrO_2 behaves like an electrolyte. If two different oxygen pressures exist on either side of an ZrO_2 element a voltage (Nernst voltage) can be measured across that element (see 1.2 Nernst voltage).

Sensor Function

Sensor construction

Sensortechnics' oxygen sensors of the XYA series consist of two zirconium dioxide (ZrO_2) discs coated with thin porous layers of platinum which serve as electrodes (see *Fig. 1*). The two discs are attached to a platinum ring, forming a hermetically sealed chamber.

At the outer surfaces of the ZrO_2 discs there are two further platinum rings to provide for the sensors electrical contacts. The first disc is connected to a reversible current source, at the second disc a voltage (Nernst voltage) can be measured.

Two outer alumina (Al_2O_3) elements prevent any ambient particulate matter from entering the sensor. In addition, these filters remove unburnt gases and oxidise sulphur dioxide to sulphur trioxide to prevent unstable measurement readings. The complete assembly is surrounded by a heating coil which provides for the necessary operating temperature of the sensor (not shown in *Fig. 1*). Additionally, Sensortechnics' XYA series is housed in stainless steel caps to protect the sensors against dirty environments and mechanical destruction.

Pumping disc

The first ZrO_2 disc (pumping disc) works as an electrochemical oxygen pump, evacuating or pressurising the sealed chamber. Depending on the direction of the connected reversible current source the oxygen ions move through the disc from one electrode to the other thus changing the oxygen concentration in the chamber. The chamber is successively evacuated or filled until the sensing voltage V_S reaches a preset voltage level. The higher the ambient oxygen pressure is, the longer the XYA sensors need to reach these voltage levels.

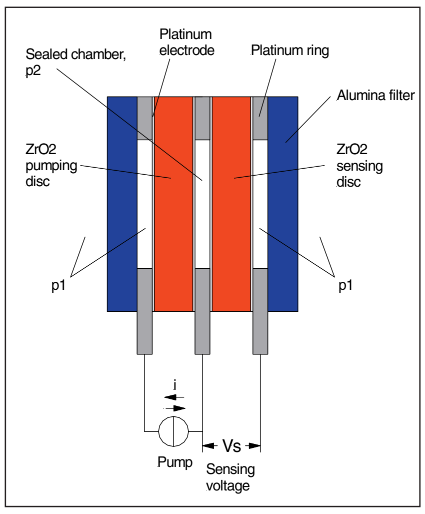

Fig. 1: Sensor construction

Sensing disc

A difference in oxygen pressure across the second ZrO_2 disc (sensing disc) generates a Nernst voltage which is logarithmically proportional to the amount of the oxygen concentration difference.

This voltage is sensed and compared with two reference voltages V1 and V2 (see *Fig. 2*). Each time either of these two references is reached the pump current of the oxygen pump is reversed and the Nernst voltage approaches its other reference value. Thereby V1 is the sensing voltage for the highest and V2 the sensing voltage for the lowest oxygen pressure achieved in the chamber.

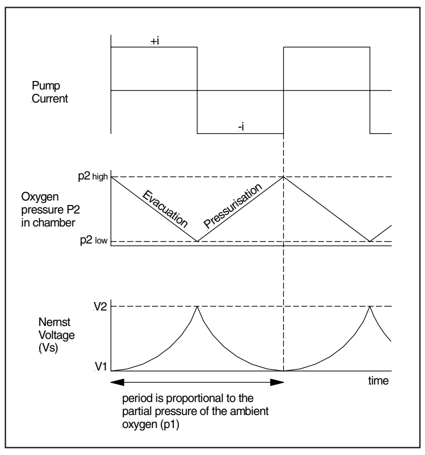

Fig 2: Sensing voltage (Nernst voltage) as a function of the oxygen pressure p2 in the chamber

Measurement

Sensortechnics' XYA zirconium dioxide oxygen sensors do not directly measure the concentration (volumetric proportion) of the ambient oxygen but the partial oxygen pressure. However, the volumetric proportion can easily be calculated from

Dalton's law (see equation (2)) if the total pressure of the gas mixture is known.

If a relative content (percent by volume) should be determined, the XYA sensors have to be calibrated in the actual measurement environment with a known oxygen concentration. If the measurement environment is ambient dry atmosphere its known oxygen concentration of 20.95 % Vol. can be used for calibration. Sensortechnics' ZBXYA control circuit boards offer oxygen measuring ranges of 0...25 % Vol. and 0...100 % Vol.

The duration of a pump cycle, i.e. the time taken to once evacuate and refill the chamber, depends on the partial pressure of the ambient oxygen (see *Fig. 3*). This time is equivalent to the cycle duration of the Nernst voltage. The higher the ambient oxygen pressure is, the longer it takes for the oxygen pump at constant pump current to establish the same oxygen pressure values on both sides of the pumping disc and to evacuate the chamber respectively. Thus, the pumping cycle and therefore the cycle time of the Nernst voltage is a measure of the ambient oxygen partial pressure.

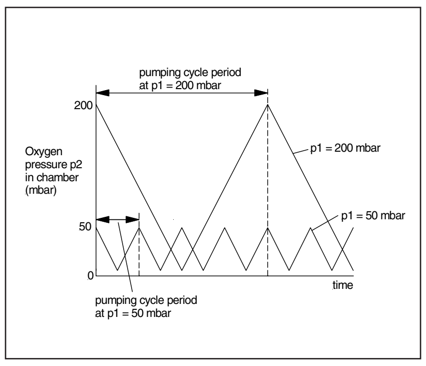

Fig. 3: Pumping cycle period depending on the ambient oxygen partial pressure p2

Example of a measurement procedure:
1. XYA sensor heats up until operating temperature is reached
2. Assumption: oxygen pressure in the chamber is high.
The Nernst voltage V1 (lower reference voltage) can be tapped off the electrodes of the sensing disc (see *Fig. 2*)
3. With that, the pump current is reversed
4. The oxygen pump starts to evacuate the chamber
5. The Nernst voltage increases until the upper reference voltage V2 is reached
6. The pump current reverses again
7. The chamber fills up until V1 is reached
8. The pumping cycle starts from the beginning
9. The cycle time of the Nernst voltage is determined by the ZBXYA control circuit board and translated to a volumetric oxygen concentration (percent by volume) reading.

Please visit **www.sensortechnics.com/oxy** for more information

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New Infrared Flammable & CO_2 Gas Sensor Detects Hazards Where Conventional Sensors Fail

Xgard IR from **Crowcon** (UK) is a new, low cost infrared (IR) flammable gas and carbon dioxide (CO_2) sensor designed for use in fixed point detection systems where conventional detectors can prove unreliable or suffer from interference and damage.

Conventional flammable gas detectors based on catalytic pellistors are susceptible to poisoning or temporary inhibition when exposed to gases such as hydrogen sulphide. This can make their readings unreliable and even destroy the sensor altogether. The new Xgard IR is totally immune to poisoning and will reliably warn of gas hazards in environments that are unsuitable for other types of sensor. Infrared sensing has other benefits too. Unlike catalytic pellistors, IR sensors will fail to safety, detect flammable gas in inert backgrounds and are not damaged by high gas concentrations.

Typical environments requiring flammable gas monitoring include water and sewage treatment facilities. Continuous CO_2 monitoring is common in laboratories.

This new IR sensor can be specified with two types of enclosure: polyester-coated aluminium or 316 stainless steel for maximum corrosion resistance in extreme environments. The sensor, which has a life expectancy of over 5 years, is a simple plug-in module that makes replacement quick and easy. ATEX* approved for use in hazardous areas, the Xgard IR is Exd flameproof rated.

The standard junction box is designed for both wall and ceiling mounting, and four cable gland options ensure compatibility on any site. The detector takes a range of accessories for harsh or wet conditions and for remote sampling.

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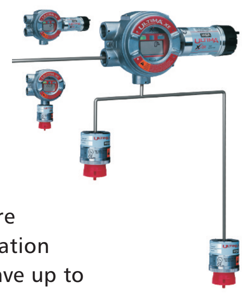
NEW: ULTIMA X³ Technology Up to 3 Sensors per Monitor and Digital Data Transfer



MSA's state-of-the-art ULTIMA X series gas monitors now feature innovative X³ technology. In addition to all the benefits of the ULTIMA X series, X³ gas monitors feature digital communication capabilities and can have up to three sensors connected to each monitor. Sensor combinations of electrochemical, catalytic and infrared type sensor are available.

A maximum of 31 monitors can be connected to the same data communication line via industry standard ModBUS RTU or connected to a PLC or DCS control system. When using ModBUS digital communication the ULTIMA X³ monitor operates as a slave device on the network. Since ULTIMA X³ units can each be equipped with up to 3 sensors, 93 sensors can share a single data line. The modular design also allows the use of remote sensors up to 30 metres apart, each sensor up to 15 metres from the monitor.

The ULTIMA X³ gas monitor includes all the following features, interchangeable smart catalytic and electrochemical sensors that can be changed under power even in a hazardous area, large clear LCD display and optional status LED's and alarm relays. New smart sensors are automatically recognised, including gas type, range and alarm set points. Sensor calibration and parameter changes are made using a non-invasive infrared hand-held controller.

The ULTIMA X³ gas monitors large easy to read LCD "scrolling display" conveniently alternates between sensor reading and gas type together with sensor flag 1, 2 or 3 and scrolling diagnostic text messages. Internal relays can be configured for 3 common alarms or one individual alarm for each sensor and the digital communication allows for remote diagnostics.

The new ULTIMA X³ multi-sensor gas monitor with digital communication is a perfect match for all applications and industries.

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