Generic information about oxygen probes

Oxygen probes are used in the controlling of combustion processes. The most well-known use of oxygen probes is to control the combustion process of engines in automobiles, the so-called λ - control. Similar application is the use of the probes in the exhaust-flow of power plants. In the heat treatment industry, the oxygen probes are mostly used in carbonizing applications, where the amount of oxygen is transferred to the amount of carbon (so-called C-Pegel).

Theory of operation

All oxygen probes have a similar basic design and follow the principal according to the Nernst law.

The generic Nernst equation

The physical theory was described by Walther Nernst at the end of the 19th century and follows the equation:

$$E = E_0 + \frac{R \cdot T}{z_e \cdot F} \cdot \ln\left(\frac{c_1}{c_2}\right)$$

The used variables are:

- E – Electrode potential
- E_0 – cell potential at standard conditions
- R – is the universal gas constant
- T – Temperature of the cell in °K
- F – is the Faraday constant, the number of coulombs per mole of electrons
- C_1, c_2 – Concentration of the fluids
- z_e – is the number of electrons transferred in the cell reaction

This equation represents a generic galvanic cell. It is built by two fluids, which have a concentration gradient and are separated by a membrane. Due to the concentration gradient, a voltage is generated. Every battery is using this chemical reaction.

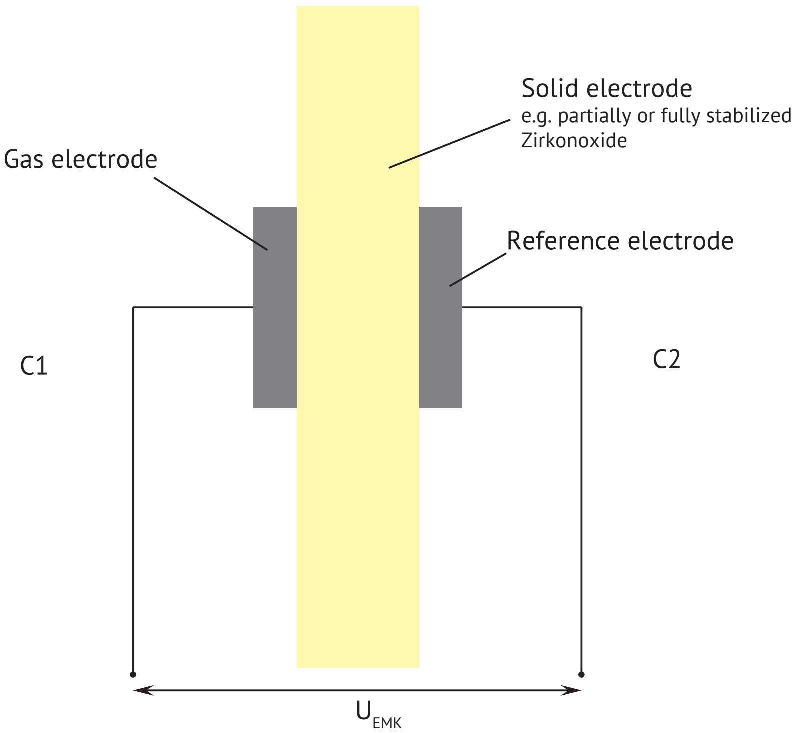
General design of an oxygen probe

The basic item of an oxygen probe is a solid-state electrolyte (SSE) which separates the gas (e.g. furnace) atmosphere from the reference one (usually the ambient air). Each side is electrically connected with electrodes respectively called gas- and reference electrode. The task of the SSE is to be the ion bridge for the electrochemical cell and is usually made from partial stabilized zirconium oxide (PSZ) or fully stabilized zirconium oxide (FSZ). The stabilization is achieved by doping of rare-earth metals such as Yttrium or Gallium as well a pure Al2O3.

To achieve a conductivity for ions, the temperature of the SSE needs to be above 500°C. Thus, the probe needs additional heating in applications with less heat such as exhaust of car engines or other bypass-systems. In other applications, such as the carbonizing heat treatment the temperatures are beyond 800°C, therefore a heating is not required.

Once a conductivity is reached, a movement of oxygen ions follows the gradient of the concentration from high to low. In terms of a heat treatment from the reference side towards the carbonizing atmosphere side. The movement happens along the defect in the zirconium grid. The ions take two electrons on the reference

Generical design of an oxygen probe



air side and recombine at the gas side. The exchange happens at the 3-phase border zirconium-gas-electrode.

This generated voltage can be measured and it represents the current oxygen concentration ratio in accordance to the Nernst law.

thermo-control Oxygen probe

The main field of use for oxygen probes made by thermo-control Körtvélyessy GmbH is the controlling of the carbonizing atmosphere in heat treatment furnaces. Following the high chemical and thermal demands thermo-control oxygen probes have specific design features to enhance their performance.

Ceramic protection tubes

Instead of the commonly used high temperature alloys such as Inconel©, thermo-control oxygen probes are built with ceramic components, e.g. the outer protection tube. This provides a high durability at higher temperatures due to the lack of deformation (The deformation of metallic tubes, resulting in damaging the inner zirconium tube, being the biggest reason for an exchange of the probe).

Since the ceramic tube is built into a dampening fitting it has also a high resistance against vibration or thermal shocks.

thermo-control Oxygen probe

Built-in Type S Thermocouple

All thermo-control Körtvélyessy GmbH oxygen probes are equipped with a type S thermocouple as a standard design. This thermocouple has the same benefits as all thermo-control Körtvélyessy made thermocouples: high precision measurement without a drift. This features enables a precise measurement of the oxygen probe cell for many years.

In many applications, the temperature of the cell is indirectly measured with the controlling thermocouple of the furnace (usually a type K or N thermocouple). Any kind of uneven temperature distribution along the furnace will result in a wrong calculation of the oxygen concentration, since the cell voltage is linear to its temperature. In addition, thermocouples of type K usually start to drift at temperatures beyond 900°C therefore this effect has to be taken into consideration as well.

Electrodes and wiring made from Platinum

This solution seems to be costly in the first view. However, it bears many advantages in the performance of the oxygen probe. One is that the two Platinum wires do not build a thermocouple, unlike the combination of different metallic tubes and wires do build a thermocouple with unknown voltage and behavior. Therefore, the two Platinum wires provide a stable and unchanged measurement of the oxygen probe cell.

Another advantage is the good bonding of the Platinum with the zirconium oxide tube ensuring a tight electrical contact through long years of service. This bonding mechanism is used already during the manufacturing process to enable a high performance from the start.