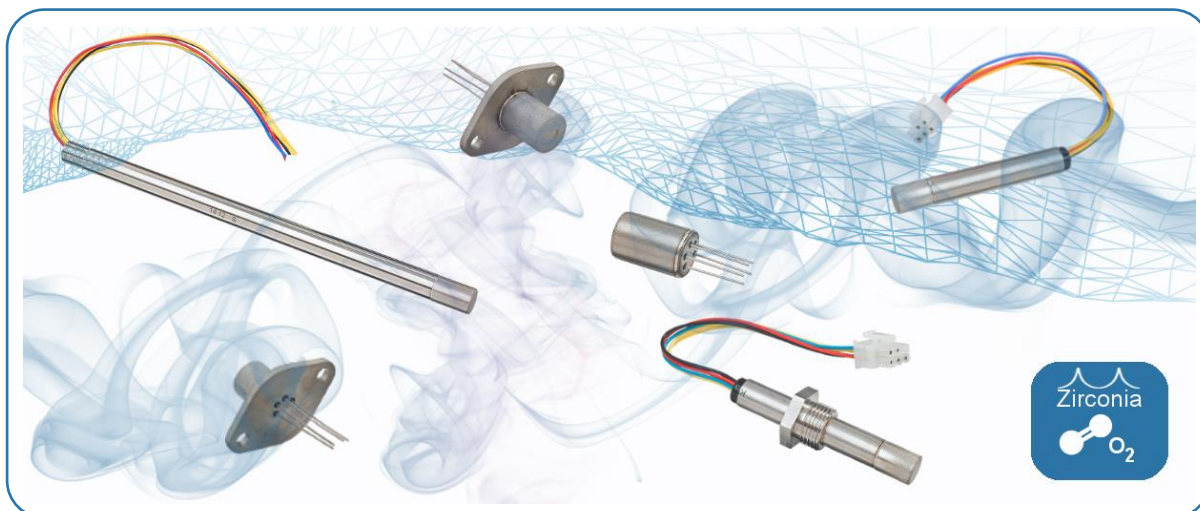


# O<sub>2</sub> SENSORS – Zirconium Dioxide (ZrO<sub>2</sub>)

## Oxygen Sensor Operating Principle Guide

This document describes the physics and concepts behind CO2Meter's range of dynamic and highly accurate oxygen sensors.



When reading this document, keep in mind the following key differentiators between CO2Meter's range of sensors and other zirconium dioxide oxygen sensors:

- CO2Meter's sensors measure partial pressure of oxygen in a gas or mixture of gases, NOT oxygen concentration %.  
CO2Meter's sensors do NOT require a reference gas.

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## 1 INTRODUCTION

The zirconium dioxide oxygen sensor does NOT measure oxygen concentration %, but rather it measures partial pressure of oxygen in a gas or mixture of gases.

The sensor employs a well proven, small zirconium dioxide based element at its heart and due to its innovative design does NOT require a reference gas. This removes limitations in the environments in which the sensor can be operated with high temperatures, humidity and oxygen pressures all possible. CO2Meter's range of oxygen sensors are therefore ideal for use in the following applications:

- Laboratory measurements
- Combustion control of systems using natural gas, oil, biomass, etc.
- Automotive emissions testing
- Oxygen generation in medical and aerospace markets
- Aerospace fuel tank inerting applications
- Agricultural applications including composting and cultivation
- Bakery ovens and heat treatment furnaces

Key to understanding the fundamentals of the sensor operation is the physics that govern it.

For information on the correct use and implementation which is key to getting the most from the sensor in a wide range of applications, refer to [AN-0050, Zirconia O<sub>2</sub> Sensor Operation and Compatibility Guide](#).

## 2 BACKGROUND PHYSICS

### 2.1 Partial pressure

#### 2.1.1 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.

#### 2.1.2 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.

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

From [Equation 1](#) it can be derived that the ratio of the number of particles ( $n_i$ ) of an individual gas component to the total number of particles ( $n_{total}$ ) of the gas mixture equals the ratio of the partial pressure ( $P_i$ ) of the individual gas component to the total pressure ( $P_{total}$ ) of the gas mixture.

$$\frac{n_i}{n_{total}} = \frac{P_i}{P_{total}} \quad (2)$$

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

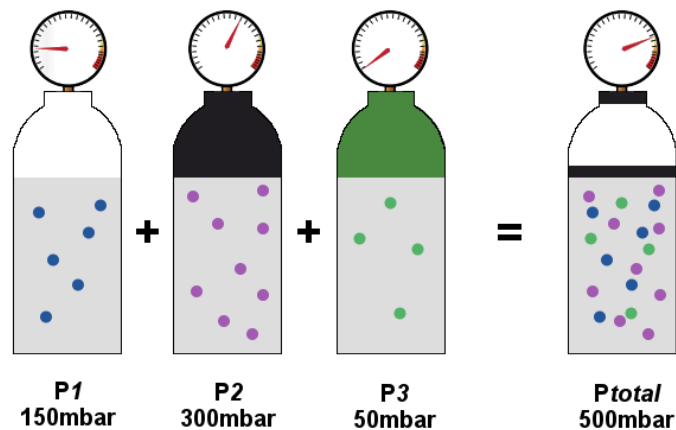


Figure 2-1  $P_{total} = P_1 + P_2 + P_3$  (Constant Volume & Temperature)

**Example 1:**

The atmospheric pressure at sea level (under standard atmospheric conditions) is 1013.25mbar. Here, the main components of **dry** air are nitrogen (78.08% Vol.), oxygen (20.95% Vol.), argon (0.93% Vol.) and carbon dioxide (0.040% Vol.). The volumetric content (%) can be equated to 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:

$$P_i = \frac{n_i}{n_{total}} \times P_{total} \quad (3)$$

The oxygen partial pressure then equates to:

$$P_i = \frac{20.95\%}{100\%} \times 1013.25\text{mbar} = 212.28\text{mbar}$$

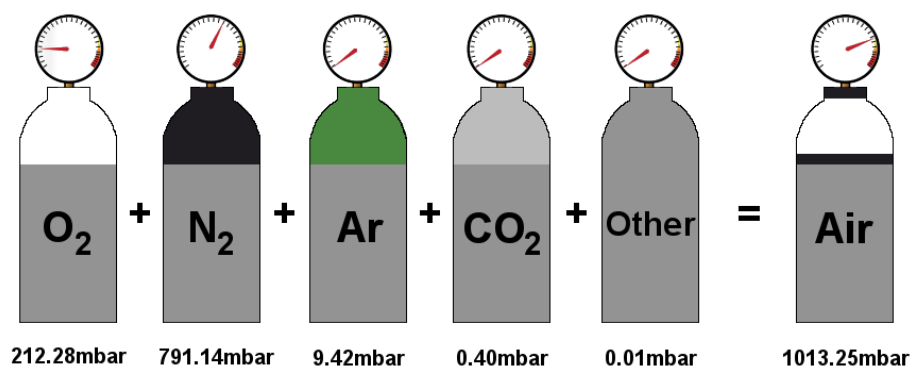


Figure 2-2 Partial Pressure at 0% Humidity

Of course, this value is only relevant when the atmosphere is dry (0% humidity). If moisture is present a proportion of the total pressure is taken up by water vapour pressure. Therefore, the partial oxygen pressure (ppO<sub>2</sub>) can be calculated more accurately when relative humidity and ambient temperature are measured along with the total barometric pressure.



Figure 2-3 Liquid Vapour Pressure

Firstly, water vapour pressure is calculated:

$$WVP = \left( \frac{H_{Rel}}{100} \right) \times WVP_{max} \quad (4)$$

- $WVP$  Water Vapour Pressure (mbar)
- $H_{Rel}$  Relative Humidity (%)
- $WVP_{max}$  Maximum Water Vapour Pressure (mbar)

For a known ambient temperature, maximum water vapour pressure ( $WVP_{max}$ ) can be determined from the lookup table in [APPENDIX A](#). The maximum water vapour pressure is also referred to as the dew point. Warmer air can hold more water vapour and so has a higher  $WVP_{max}$ .

Partial oxygen pressure then equates to:

$$ppO_2 = (BP - WVP) \times \left(\frac{20.95}{100}\right) \quad (5)$$

$ppO_2$	Partial Pressure O <sub>2</sub> (mbar)
$BP$	Barometric Pressure (mbar)
$WVP$	Water Vapour Pressure (mbar)

[Example 2 below](#) describes the effect of humidity reducing the partial oxygen pressure and therefore the volumetric content of oxygen.

**Example 2:**

On a typical day, the following information is recorded from a calibrated weather station:

Temperature:	22°C
Humidity:	32%
Barometric Pressure:	986mbar

Using the lookup table in [APPENDIX A](#),  $WVP_{MAX} = 26.43\text{mbar}$ .

$$WVP = \left(\frac{32}{100}\right) \times 26.43 = 8.458\text{mbar}$$

Partial oxygen pressure then equates to:

$$ppO_2 = (986 - 8.458) \times \left(\frac{20.95}{100}\right) = 204.795\text{mbar}$$

As we now know the oxygen partial pressure and the total barometric pressure we can work out the volumetric content of oxygen.

$$O_2\% = \left(\frac{204.8}{986}\right) \times 100 = 20.77\%$$

## 2.2 Zirconium Dioxide (ZrO<sub>2</sub>)

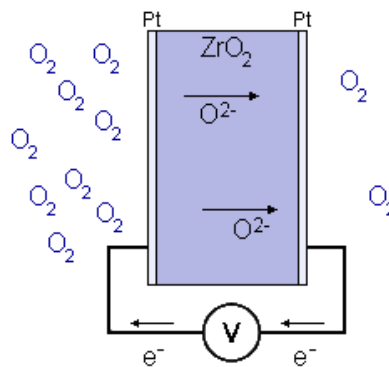
At high temperatures (> 650°C), stabilised zirconium dioxide (ZrO<sub>2</sub>) exhibits two mechanisms:

1. ZrO<sub>2</sub> partly dissociates producing mobile oxygen ions and therefore becomes a solid electrolyte for oxygen. A ZrO<sub>2</sub> disc coated with porous electrodes connected to a constant DC current source allows ambient oxygen ions to be transported through the material. This liberates an amount of oxygen at the anode proportional to the charge transported (electrochemical pumping) which according to Faraday's First Law of Electrolysis is:

$$N = \frac{it}{zF} \quad (6)$$

<i>N</i>	Number of Moles of Oxygen Transported
<i>i</i>	Constant Current
<i>t</i>	Time (seconds)
<i>z</i>	Ionic Valence of Oxygen
<i>F</i>	Faraday Constant = 96487 C/mol <sup>a</sup>

2. ZrO<sub>2</sub> behaves like an electrolyte. If two different oxygen pressures exist on either side of a piece of ZrO<sub>2</sub>, a voltage (Nernst voltage) is generated across it.



## 2.3 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. Electrolysis is:

$$\Delta V = \frac{k_B T}{e_0} \times \ln \left( \frac{c_1}{c_2} \right) \quad (7)$$

<i>k<sub>B</sub></i>	Boltzmann constant ( <i>k<sub>B</sub></i> = 1.38x10 <sup>-23</sup> J/K)
<i>T</i>	Temperature in K
<i>e<sub>0</sub></i>	Elementary charge ( <i>e<sub>0</sub></i> = 1.602x10 <sup>-19</sup> C)
<i>c<sub>i</sub></i>	Ion concentration in mol/kg

Either of these properties are used in many variants of oxygen sensors, however CO2Meter's oxygen sensors employ both principals simultaneously. This removes the need for a sealed reference gas making the sensor more versatile for use in a range different oxygen pressures.

<sup>a</sup> Where C is units of charge in coulombs, and mol is mole, a unit of substance.

### 3 SENSOR FUNCTION

#### 3.1 Sensor Cell Construction

At the core of the oxygen sensor is the sensing cell (Figure 3-1). The cell consists of two zirconium dioxide ( $ZrO_2$ ) squares coated with a thin porous layer of platinum which serve as electrodes. The platinum electrodes provide the necessary catalytic effect for the oxygen to dissociate, allowing the oxygen ions to be transported in and out of the  $ZrO_2$ .

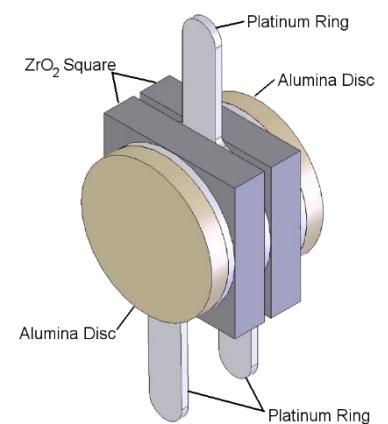


Figure 3-1 The Sensing Cell

The two  $ZrO_2$  squares are separated by a platinum ring which forms a hermetically sealed sensing chamber. At the outer surfaces, there are two further platinum rings which along with centre platinum ring provide the electrical connections to the cell.

Two outer alumina ( $Al_2O_3$ ) discs filter and prevent any ambient particulate matter from entering the sensor and also remove any unburnt gases. This prevents contamination of the cell which may lead to unstable measurement readings. Figure 3-2 shows a cross-section of the sensing cell with all the major components highlighted.

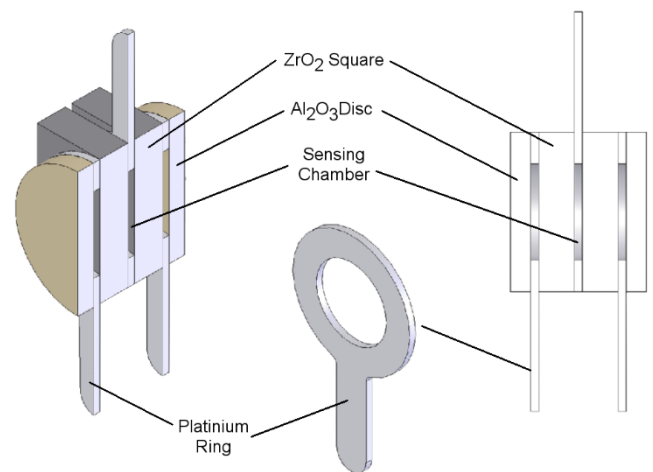


Figure 3-2 Cross-Section of the Sensing Cell

The cell assembly is surrounded by a heater coil which produces the necessary  $700^{\circ}C$  required for operation. The cell and heater are then housed within a porous stainless steel cap to filter larger particles and dust and also to protect the sensor from mechanical damage. Figure 3-3 shows the complete sensor assembly. Refer to *AN-0050, Zirconia  $O_2$  Sensor Operation and Compatibility Guide* for more information about other gases and chemicals with have an influence on the sensor operation and lifespan.

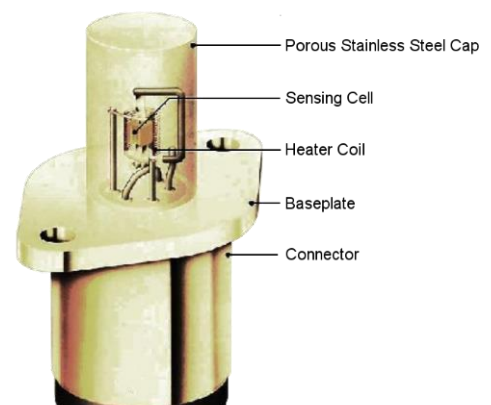


Figure 3-3 Complete Sensor Assembly



### 3.2 Pumping Plate

The first  $ZrO_2$  square works as an electrochemical oxygen pump, evacuating or re-pressurising the hermetically sealed chamber. Depending on the direction of the DC constant current source, the oxygen ions move through the plate from one electrode to the other, this in turn changes the oxygen concentration and therefore the oxygen pressure ( $P_2$ ) inside the chamber. The pumping is controlled so that the pressure inside the chamber is always less than the ambient oxygen pressure outside the chamber. Figure 3-4 shows the electrical connections to the cell.

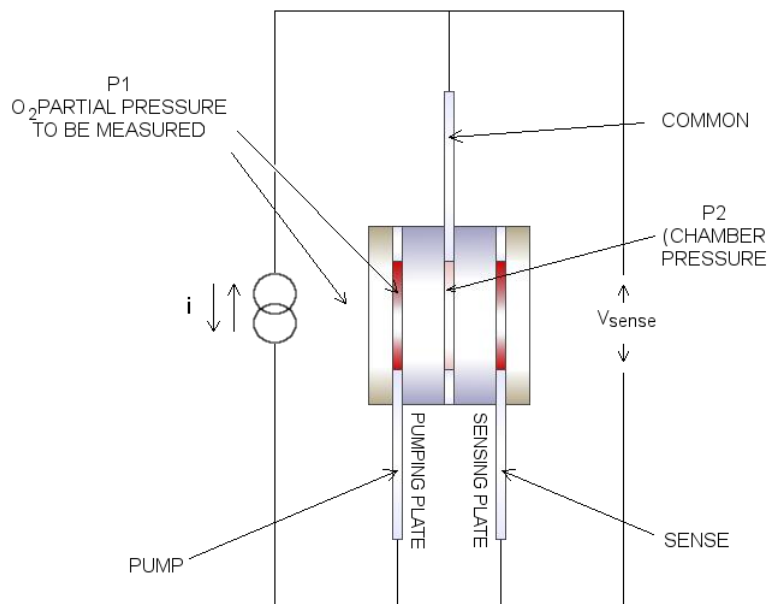


Figure 3-4 Electrical Connections to the Cell

### 3.3 Sensing Plate

A difference in oxygen pressure across the second  $ZrO_2$  square generates a Nernst voltage which is logarithmically proportional to the ratio of the oxygen ion concentrations (See 2.3 Nernst Voltage on page 2-4). As the oxygen pressure inside the chamber ( $P_2$ ) is always kept less than the oxygen pressure outside of the chamber ( $P_1$ ), the voltage at sense with respect to common is always positive.

This voltage is measured and compared with two reference voltages ( $V_1$  &  $V_5$ , Figure 4-1 on page 4-1) and every time either of these two references are reached the direction of the constant current source is reversed. When the  $ppO_2$  is high, it takes longer to reach the pump reversal voltages than it does in a low  $ppO_2$  atmosphere. This is because a greater number of oxygen ions are required to be pumped in order to create the same ratiometric pressure difference across the sensing disc.

#### Example 3:

$P_1$ , the  $O_2$  pressure we want to measure, is 10mbar and the set reference voltage is achieved when  $P_2$  is 5mbar. If  $P_1$  is then changed to 1bar,  $P_2$  would have to be 0.5bar in order to achieve the same reference voltage. This would involve evacuating far more oxygen ions and as the current source used to pump the ions is constant, would therefore take a lot longer.

Section 4 MEASUREMENT on page 4-1 explains the interpretation of the generated Nernst voltage and how this corresponds to oxygen pressure.

## 4 MEASUREMENT

CO2Meter's range of sensors have five connections:

**Two Heater Connections:** The heater requires a specific voltage to ensure the correct operating temperature at the cell.

**Three Cell Connections:** A reversible DC constant current source is applied between PUMP and COMMON in order to create the electrochemical pumping action. The resulting Nernst voltage is measured between SENSE and COMMON.

As previously explained, when the amplitude of the sense signal hits predetermined reference levels ( $V_1$  and  $V_5$ ) the direction of the constant current source is reversed. The duration of a complete pump cycle, that is, the time taken to once evacuate and refill the chamber, depends on the partial pressure of oxygen in the gas to be measured (see [Figure 4-1](#)); this time is equivalent to the cycle duration of the Nernst voltage ( $t_p$ ). The higher the ambient oxygen pressure is, the longer it takes for the oxygen pump at constant pump current to reach the same levels. Thus, the pumping cycle and therefore the cycle time of the Nernst voltage are linearly proportional to the oxygen partial pressure.

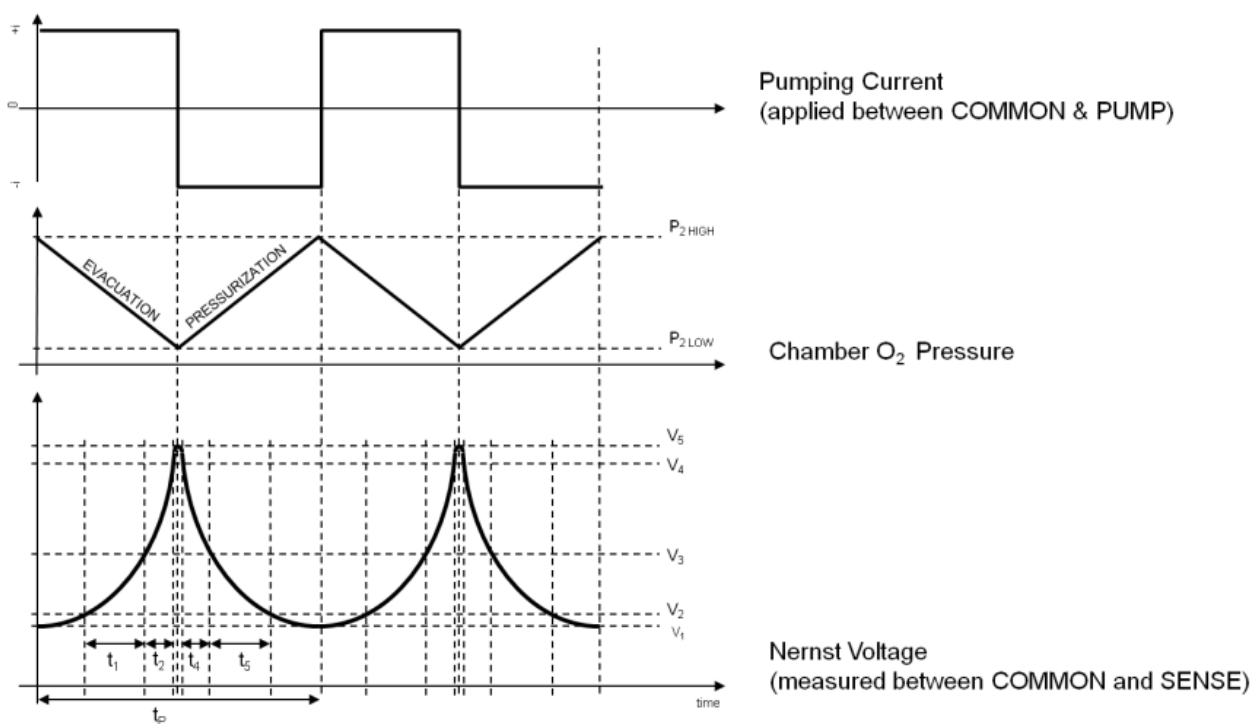


Figure 4-1 Pump Current and Generated Nernst Voltage

### Practical Considerations

In theory, any two values can be chosen for  $V_1$  and  $V_5$ ; in practice, they are chosen to:

1. Eliminate the effect of an electric double layer in the  $ZrO_2$  square formed by space charges.
2. Create the best response time for the application.
3. Reduce temperature dependence.

### Compensating for the Electric Double Layer

Not all of the charge supplied by the constant current source contributes to a pressure change in the chamber, some is absorbed by an electric double layer formed at the platinum/ZrO<sub>2</sub> interface as the current source is reversed. This effect is particularly noticeable at the pressure extremities and near the pump reversal voltages. As pressure increases the amount of charge required to change the chamber pressure also increases. To reduce this effect, the working chamber pressure should only vary 1 – 10% from the ambient pressure.

To overcome the influence of the double layer near the pump reversal points, Nernst voltages are chosen well away from V<sub>1</sub> and V<sub>5</sub>. (V<sub>2</sub>, V<sub>3</sub> and V<sub>4</sub> in Figure 4-1 illustrate this).

### Response Time

Due to the pump cycle time increasing as the oxygen pressure increases, at higher oxygen pressures V<sub>1</sub> and V<sub>5</sub> should be made close to each other in order to ensure a fast response.

### Compensating for Temperature Dependence

It can be seen that the Nernst voltage (Equation 7) is temperature dependant. However, the temperature dependence is such that under certain operating conditions, the combined temperature dependence of Nernst Law and the Gas Laws that govern oxygen can be vastly reduced. Again, much of this temperature dependence occurs around the pump reversal points so by choosing to measure Nernst voltages at V<sub>2</sub>, V<sub>3</sub> and V<sub>4</sub> we can make the temperature co-efficient (T<sub>c</sub>) virtually equal zero.

When operating in this T<sub>c</sub> = 0 mode the time taken to reach V<sub>2</sub>, V<sub>3</sub> and V<sub>4</sub> are measured. These are highlighted as t<sub>1</sub>, t<sub>2</sub>, t<sub>4</sub> and t<sub>5</sub> in Figure 4-1. The revised cycle time (t<sub>d</sub>) is then calculated as follows:

$$t_d = (t_1 - t_2) + (t_5 - t_4) \quad (8)$$

Not only does t<sub>d</sub> give a linear output proportional to the ambient oxygen pressure but unlike t<sub>p</sub>, it also passes through the origin. The graph in Figure 4-2 shows the output when calculating t<sub>d</sub> vs. t<sub>p</sub>.

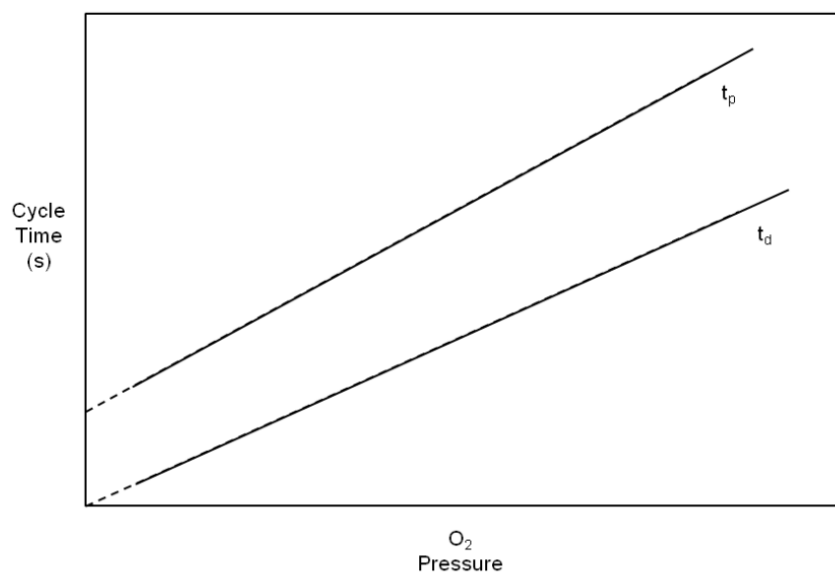


Figure 4-2 t<sub>d</sub> versus t<sub>p</sub>

One of the major benefits of having a linear response that passes through the origin is that sensor calibration (gain) can occur at one point anywhere on the slope. By measuring  $t_p$ , two-point calibration is required not only to set the gain but also to remove the zero offset.

It should also be noted that the response of both  $t_p$  and  $t_d$  are represented by a dotted line as they approach zero O<sub>2</sub> pressure (ppO<sub>2</sub>). This is because the sensor by definition requires at least some ambient ppO<sub>2</sub> in order to operate. If the ppO<sub>2</sub> is zero, the sensor, due to the applied constant current source, will try to pump the O<sub>2</sub> within the ZrO<sub>2</sub>. This will, in time, damage the ZrO<sub>2</sub> and degrade sensor performance. It is therefore imperative that the sensor is not used for prolonged periods in very low oxygen environments (less than 1 mbar ppO<sub>2</sub>), especially in reducing atmospheres (an atmosphere in which there is little free oxygen and oxygen is consumed).

**NOTE:** Calculating  $t_p$  is only recommended for very basic applications where high accuracy is not necessarily required; for this reason, CO2Meter recommends calculating  $t_d$  as per the following sections.

### Sensitivity/Slope

Sensitivity or Slope is defined as the Cycle Time ( $t_d$ ) in milliseconds divided by the ppO<sub>2</sub> in mbar of the known calibration atmosphere.

When calculating  $t_d$  (only one calibration point), sensitivity is defined as:

$$Sensitivity = \frac{t_d}{ppO_2} \quad (9)$$

Sensitivity/Slope for a nominal sensor, when calculating  $t_d$ , is typically 1.05ms/mbar. Though due to many factors that may influence the sensitivity (chamber volume, ZrO<sub>2</sub> thickness, etc.), there is a production tolerance of ±15%. This makes calibration a necessity to ensure good sensor to sensor repeatability.

## 4.1 Recommended Values for Use in Normal Atmospheric Pressures

When using the sensor to measure ppO<sub>2</sub> of approx. 1 – 1000mbar (0.1 – 100% of typical barometric pressure), the following values are recommended:

$t_d$  (T<sub>C</sub> = 0 mode)

Constant Current Source:	$i = 40\mu A$
Pump Reversal Voltages:	$V_1 = 40mV$ and $V_5 = 90mV$
Sense Voltages:	$V_2 = 45mV$ , $V_3 = 64mV$ and $V_4 = 85mV$

When using the sensor in higher O<sub>2</sub> pressures alternate values can be recommended on request.

**NOTE:** Due to the many benefits of operating the sensor in T<sub>C</sub> = 0 mode (calculating  $t_d$ ), this is the recommended mode of operation.

### Typical Measurement Procedure

1. Oxygen sensor heats up until the correct operating temperature is reached, minimum 60s from cold.
2. In order to begin the electrochemical pumping the cell is first evacuated by applying the constant current source between PUMP and COMMON.
3. The Nernst Voltage across SENSE and COMMON increases until V<sub>5</sub> is reached.

4. The pump current connections are reversed and the constant current now flows between COMMON and PUMP. The cell begins to re-pressurise.
5. The Nernst Voltage across SENSE and COMMON decreases until  $V_1$  is reached.
6. When  $V_1$  is reached one pumping cycle is complete and the process is repeated.
7. This cycling is repeated indefinitely and each time a complete waveform is captured,  $t_d$  is calculated.

## 4.2 Initial Sensor Drift and Active Burn-In

During the first 200hrs the sensor output can drift by up to  $\pm 3\%$ . This is due to a number of factors including:

1. Impurities in the zirconium dioxide migrating to the grain boundaries and to the surface of the platinum electrode bond.
2. Sintering of the porous platinum electrodes.
3. Heater coil ageing.
4. The internal stainless steel surface of the cap becoming less reflective due to thermal oxidation.

Regular calibration removes the effect of initial sensor drift as the sensor output is constantly re-referenced against the known calibration gas.

However, if regular calibration is not possible and the output is required to have stabilised prior to use in the application then it may be necessary to actively burn-in the sensor.

Active burn-in involves operating the sensor normally in a clean atmosphere typically for 200hrs. For most applications, this is a simple timed process and the sensor output is not monitored.

For demanding applications that require characterised sensor stability, active burn-in involves operating the sensor normally in a controlled atmosphere where the exact  $\text{ppO}_2$  is known. If this is fresh air, then all weather data must be recorded and the  $\text{ppO}_2$  calculated as previously described in [Example 2 on page 2-3](#).

With the  $\text{ppO}_2$  known, the sensor output ( $t_d$ ) can be normalised as described in [Equation 9](#). By calculating slope any variance in the sensor output can be considered to be drift and not due to environmental fluctuations.

The level of stability required will be dependent on the application specifications however in general the output can be considered stable when the slope value has varied by less than  $\pm 0.2\%$  of reading in the last 48hrs.

When CO2Meter perform active burn-in, measurements are taken at 12hr intervals and the environmental temperature is kept constant to negate any temperature dependence the sensor output may exhibit.

### 4.3 Calibration Processes – Converting $t_d$ to ppO<sub>2</sub> and O<sub>2</sub>%

The following procedures are relevant to  $t_d$  measurements made in  $T_c = 0$  mode as this is the recommended mode of operation.

In order to convert  $t_d$  to a ppO<sub>2</sub> measurement, sensitivity must first be calculated in a known ppO<sub>2</sub> atmosphere. The volumetric content can easily be calculated from Dalton's law if the total pressure of the gas mixture is known; refer to [Equation 2](#) on [page 2-1](#).

If a relative content (percent by volume) is to be determined without measuring the total pressure, Sensitivity must be calculated in the actual measurement environment with a known oxygen concentration. Future measurements will then be referenced to the total pressure at the time of this calculation. Typically, this would involve calibration in normal air to 20.7% (not 20.95%) to take into account average humidity levels. In order to maintain accuracy, calibration should occur regularly to remove variance caused by fluctuations in barometric/application pressure. As barometric pressure changes relatively slowly, daily calibrations are recommended. Regular calibration also removes any sensor drift which is typical in the first few hundred hours of operation as explained in [4.2 Initial Sensor Drift and Active Burn-In](#) on [page 4-4](#).

If regular calibration in fresh air is not possible it may be necessary to use a pressure sensor in conjunction with the sensor to automatically compensate the output for fluctuations in the barometric or application pressure. This is a relatively simple process as variations in the barometric pressure change the sensor output by the same proportion. So, if the barometric pressure changes by 1% the sensor output will also change by 1%.

Ideally the initial system calibration should be performed after the sensor has burned in for 200hrs. This will ensure any sensor drift, which may affect future accuracy, has occurred beforehand.

#### 4.3.1 ppO<sub>2</sub> Measurement Only

1. Place sensor in calibration gas with a known ppO<sub>2</sub>. If this is fresh air, then the weather data should be used to accurately calculate ppO<sub>2</sub> as described in [Example 2](#) on [page 2-3](#).
2. Oxygen sensor heats up until the correct operating temperature is reached, ~60s from cold.
3. Pumping cycles commence.
4. Leave sensor at the operating temperature for 5 – 10 mins to fully stabilise.
5. Calculate output  $t_d$ . Usually over at least ten cycles to average out any noise; the greater the averaging the better.
6. Calculate Sensitivity using [Equation 9](#) on [page 4-3](#).
7. Rearranging [Equation 9](#) allows ppO<sub>2</sub> to be calculated for all future  $t_d$  measurements (see [Equation 10](#) below):

$$ppO_2 = \frac{t_d}{Sensitivity} \quad (10)$$

#### 4.3.2 O<sub>2</sub>% Measurement Only – No Pressure Compensation

1. Place sensor in calibration gas, typically normal air (20.7% O<sub>2</sub>), though can be any gas of known concentration.
2. Oxygen sensor heats up until the correct operating temperature is reached, ~60s from cold.
3. Pumping cycles commence.
4. Leave sensor at the operating temperature for 5 – 10 mins to fully stabilise.
5. Calculate output  $t_d$ . Usually over at least ten cycles to average out any noise; the greater the averaging the better.
6. Calculate Sensitivity% using Equation 11 below:

$$\text{Sensitivity}\% = \frac{t_d}{O_2\%} \quad (11)$$

7. Rearranging Equation 11 allows O<sub>2</sub>% to be calculated for all future  $t_d$  measurements (see Equation 12 below).

**NOTE:** Any fluctuations in the barometric or application pressure will result in measurement errors proportional to the difference between the pressure at the time of measurement and the pressure when Sensitivity% was calculated.

$$O_2\% = \frac{t_d}{\text{Sensitivity}\%} \quad (12)$$

#### 4.3.3 ppO<sub>2</sub> and O<sub>2</sub>% Measurement – With Pressure Compensation

1. Place sensor in calibration gas, typically normal air (20.7% O<sub>2</sub>), though can be any gas of known concentration.
2. Calculate ppO<sub>2</sub> from the known oxygen concentration and the total pressure of the environment using Equation 13 below:

$$ppO_2 = \text{Total Pressure} \times \frac{O_2\% \text{ cal gas}}{100} \quad (13)$$

3. Oxygen sensor heats up until the correct operating temperature is reached, ~60s from cold.
4. Pumping cycles commence.
5. Leave sensor at the operating temperature for 5 – 10 mins to fully stabilise.
6. Calculate output  $t_d$ . Usually over at least ten cycles to average out any noise; the greater the averaging the better.
7. Calculate Sensitivity using Equation 9 on page 4-3.
8. Calculate all future  $t_d$  measurements using Equation 10 on page 4-5.
9. Rearranging Equation 13 allows O<sub>2</sub>% to be calculated from new ppO<sub>2</sub> measurements and the total pressure (see Equation 14 below).

$$O_2\% = \frac{ppO_2}{\text{Total Pressure}} \times 100 \quad (14)$$

## APPENDIX A – WATER VAPOUR PRESSURE LOOKUP TABLE

Lookup table for maximum water vapour pressure.

Temperature (°C)	Max water vapour pressure (mbar)	Temperature (°C)	Max water vapour pressure (mbar)
0	6.10	31	44.92
1	6.57	32	47.54
2	7.06	33	50.30
3	7.58	34	53.19
4	8.13	35	56.23
5	8.72	36	59.42
6	9.35	37	62.76
7	10.01	38	66.27
8	10.72	39	69.93
9	11.47	40	73.77
10	12.27	42.5	84.19
11	13.12	45	95.85
12	14.02	47.5	108.86
13	14.97	50	123.38
14	15.98	52.5	139.50
15	17.04	55	157.42
16	18.17	57.5	177.25
17	19.37	60	199.17
18	20.63	62.5	223.36
19	21.96	65	250.01
20	23.37	67.5	279.31
21	24.86	70	311.48
22	26.43	75	385.21
23	28.11	80	473.30
24	29.82	85	577.69
25	31.66	90	700.73
26	33.60	95	844.98
27	35.64	100	1013.17
28	37.78	110	1433.61
29	40.04	120	1988.84
30	42.42	130	2709.58



## APPENDIX B – SPECIAL NOTES AND APPLICATION HINTS

To ensure the best performance from your equipment it is important that the attached oxygen sensor is installed and maintained correctly.

Document *AN-0050, Zirconia O<sub>2</sub> – Sensor Operation and Compatibility Guide* provides some essential sensor operating tips and a complete list of gases and materials that **MUST** be avoided to ensure a long sensor life.

## APPENDIX C – DESIGNING INTERFACE ELECTRONICS

If you are not using one of CO2Meter's interface boards for sensor control and conditioning, refer to *AN-0113, Zirconia O<sub>2</sub> Sensor Software and Hardware Design Guide*.

## REFERENCE DOCUMENTS

Other documents in the Zirconium Dioxide product range are listed below; this list is not exhaustive, always refer to the [CO2Meter website](#) for the latest information.

Part Number	Title
AN-0050	O <sub>2</sub> Sensors – ZrO <sub>2</sub> Sensor Operation and Compatibility Guide
AN-0076	O <sub>2</sub> Sensors – ZrO <sub>2</sub> Sensor and Interface Selection Guide
AN-0113	O <sub>2</sub> Sensors – ZrO <sub>2</sub> Sensor Software and Hardware Design Guide
DS-0044	Zirconia O <sub>2</sub> Sensors Flange Mounted Series – Datasheet
DS-0051	Zirconia O <sub>2</sub> Sensors Miniature Series – Datasheet
DS-0052	Zirconia O <sub>2</sub> Sensors Probe Series - Short Housing – Datasheet
DS-0053	Zirconia O <sub>2</sub> Sensors Probe Series - Screw Fit Housing – Datasheet
DS-0055	Zirconia O <sub>2</sub> Sensors Oxygen Measurement System – Datasheet
DS-0058	OXY-LC Oxygen Sensor Interface Board – Datasheet
DS-0072	OXY-COMM Oxygen Sensor – Datasheet
DS-0073	Zirconia O <sub>2</sub> Sensors OXY-Flex Oxygen Analyser – Datasheet
DS-0074	O2I-Flex Oxygen Sensor Interface Board – Datasheet
DS-0122	Zirconia O <sub>2</sub> Sensors Probe Series - BM Screw Fit Housing – Datasheet
DS-0131	Zirconia O <sub>2</sub> Sensors Probe Series - Long Housing – Datasheet

### CAUTION

Do not exceed maximum ratings and ensure sensor(s) are operated in accordance with their requirements. Carefully follow all wiring instructions. Incorrect wiring can cause permanent damage to the device. Zirconium dioxide sensors are damaged by the presence of silicone. Vapours (organic silicone compounds) from RTV rubbers and sealants are known to poison oxygen sensors and MUST be avoided. Do NOT use chemical cleaning agents.

**Failure to comply with these instructions may result in product damage.**

### INFORMATION

As customer applications are outside of CO2Meter's control, the information provided is given without legal responsibility. Customers should test under their own conditions to ensure that the equipment is suitable for their intended application.

For technical assistance or advice, please email: [support@CO2Meter.com](mailto:support@CO2Meter.com)

**General Note:** CO2Meter reserves the right to make changes to product specifications without notice or liability. All information is subject to CO2Meter's own data and considered accurate at time of going to print.

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