3.9 Chemical Probes

3.9.1 pH and Redox Probes

3.9.1.1 pH Measurement

The pH value is a logarithmic measure for the concentration of the H ions in a hydrous solution and indicates by a numerical value whether it has an acid, neutral or alkaline reaction. The pH scale ranges from pH0 to pH14, pH7 is neutral. Below are a few examples for pH values of typical substances.

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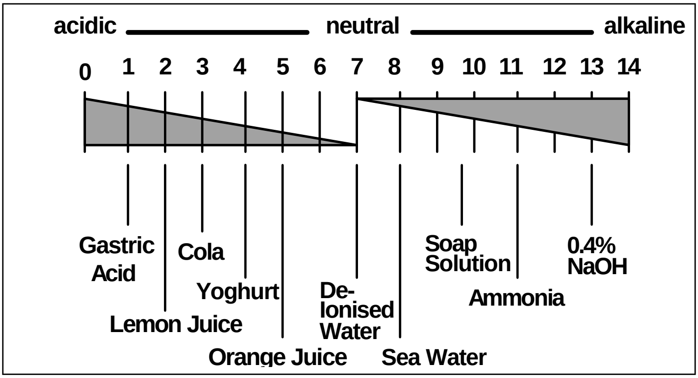
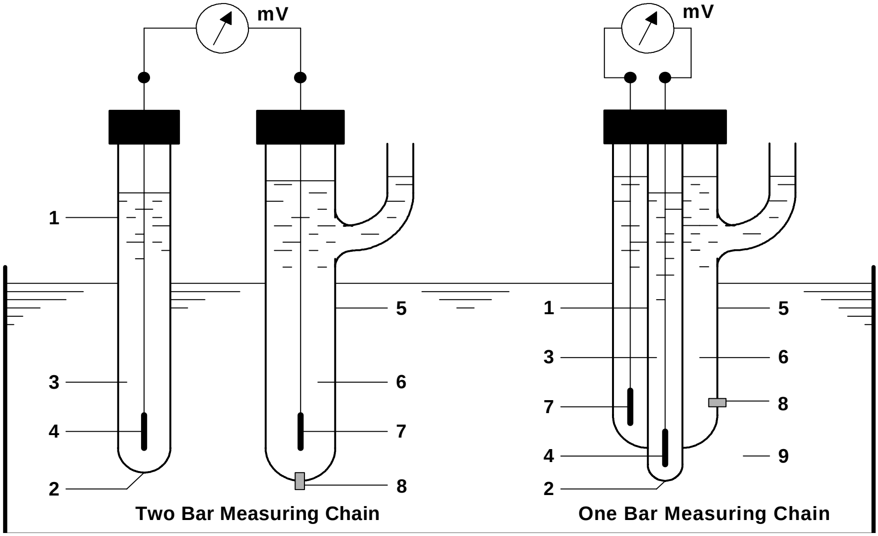


When measuring the pH value and the Redox potential the chain voltage between two electrodes is determined by potentiometric measurement.

pH Measuring Chains

A pH measuring chain for pH measurement always consists of a glass electrode (1) and a reference electrode (5) and is arranged either as a separated two-bar measuring chain (two single electrodes) or as a one-bar measuring chain with the latter being easier to handle.
The actual pH-sensitive sensor component is the glass membrane (2) of the glass electrode. A potential difference that occurs here corresponds to the difference in the pH value between the inner and outer side.
The glass electrode contains an inner electrolyte (3) that is buffered to pH7 and the inner conduction (4). The reference electrode consists of a reference electrolyte (6), the outer conduction (7) and a membrane (8), which provides the electrolytically conducting connection between the reference electrolyte (6) and the measuring solution (9).

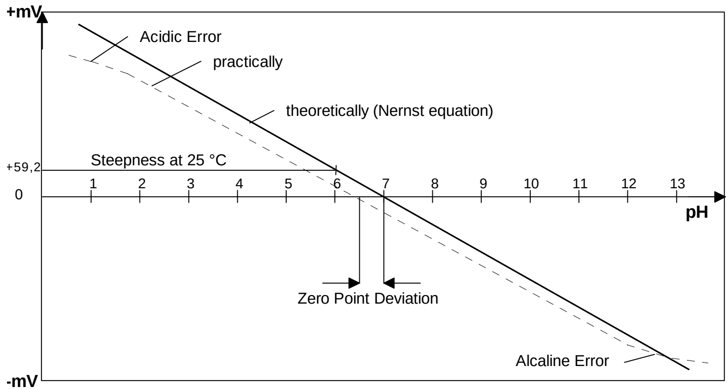


pH meas. chains:

1 glass electrode
2 glass membrane
3 inner electrolyte
4 inner conduction
5 reference electrode
6 reference electrolyte
7 outside conduction
8 membrane
9 measuring solution

Measuring Signal

The pH measuring signal of a pH measuring chain has its theoretical zero point at pH7 and changes at 25°C by 59.2mV if the pH of the measuring solution changes by one pH. The voltage is positive for acidic (pH0 to pH7) and negative for alkaline solutions (pH7 to pH14). The steepness increases by 0.2mV/K with rising temperatures. It decreases with decreasing temperatures.



In practice, the measuring signal of a pH measuring chain differs from the Nernst equation:

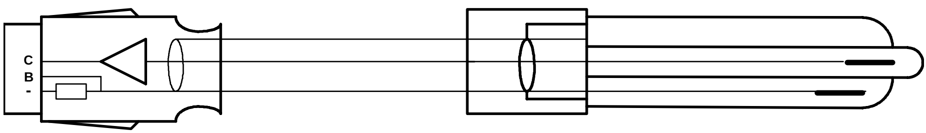
1. The real zero point slightly deviates from the theoretical pH7.
2. Due to ageing effects the steepness can be less than the theoretical value.
3. At very high pH values the steepness may decline. This is called the 'alkaline error' and depends on the glass type used for the membrane glass.
4. At very low pH values the 'acid error' may occur, i.e. the steepness may decline slightly.
5. Depending on the operating conditions, the measuring signal can be corrupted by many other influences, e.g. ageing, penetration of measuring solution into the reference electrode, depositions on the glass membrane.

☞ Because of manufacturing tolerances and various other influences, every measuring chain must be calibrated using special buffer solutions that have a defined pH value at the specified temperature.

ALMEMO® pH Measuring System

To avoid an invalidation of measuring signals caused by the measuring instrument, it is necessary to use measuring amplifiers with extremely high impedance (>500GΩ) for pH measuring chains. A special connecting cable (ZA 9610-AKY4), which has the required measuring amplifier integrated into the ALMEMO® connector, is available to connect all popular measuring chains with plug-on head type S7, SN6 to ALMEMO® measuring instruments. By impedance transformation and differential measurement it is also possible to acquire data from several probes that have different potentials and to transmit the data over longer distances free from disturbances.

The measurement is performed in the measuring range 2.6000V. For



Connecting Cable ZA 9610-AKY **Coaxial Connector** **Probe**

displaying the pH value with 2 digits it is necessary, according to the Nernst equation, to program the connector with the following parameters.

The connecting cables ZA 9610-AKY4 are, as standard, configured as follows:

Measuring range:	d2600	
Dimension:	PH	
Slope correction:	-0.1689	100 (1.00pH) : 592 (59.2mV)
Base value:	-7.00	
Exponent:	2	
Locking mode:	5	

Connection of the pH Probes

☞ As the system uses high-impedance signals, ensure that **NO** moisture can penetrate into the connector head or the transducer when screwing the pH probe to the connector head.

On connecting pH probes (dimension 'PH') to hand-held devices the following functions will be additionally activated under the function key F2:

- zero point correction
- slope correction
- temperature compensation.

By means of these functions the sensors can, by using buffer solutions, be individually calibrated in zero point and slope. If the temperature of the medium under test is different from the temperature of the buffer solution, a temperature compensation is possible. Similar to all other ALMEMO® sensors these parameters are also stored in the connector so that different pH probes with own connecting cables, can be interchanged without re-calibration.

Calibration

The system is operational after the ALMEMO® connector has been connected to the instrument. However, depending on the operating conditions, the probe should be re-calibrated at regular intervals. For calibrating pH probes three buffer solutions are available as accessories. The measuring accuracy is practically determined by the accuracy and purity of the buffer solution.

1. ZA 98PH-PL4: pH 4 (±0.05pH at 25°C) coloured red
2. ZA 98PH-PL7: pH 7 (±0.05pH at 25°C) coloured green
3. ZA 98PH-PL10: pH 10 (±0.05pH at 25°C) coloured blue

For sensors with the dimension ´PH´ or ´pH´ an automatic zero point correction and an automatic slope correction is available. For calibration purposes the locking mode for the correction values must not be set any higher than 3. On many devices, for manual operation, the functions “zero-point” and “gain” must also be activated.

Each device has a special key combination assigned for quickly and easily activating this adjustment mode and carrying out adjustment; (see device operating instructions, “Sensor adjustment”).

The zero point correction is always the first step, using the buffer solution pH7.

Zero Point Correction:

1. Hold pH probe in buffer solution pH7.
2. Allow for the measured value to stabilise.
3. Perform the zero point alignment (see device operating instructions).
   The zero point error is automatically stored in the connector.
   The device will display exactly " 7.00 PH".
4. Rinse the probe using distilled water, if possible.
5. Wipe the probe with a soft, 'fluff-free' paper cloth.

☞ Do NOT rub the probe! This could lead to electrostatical charging and, consequently, to measured values being invalidated.

Slope Correction:

1. Hold pH probe in buffer solution pH4 for acidic or in pH10 for alkaline measuring solutions.
2. Allow for measured value to stabilise.
3. In the event of deviation from the setpoint the procedure “zero-point adjustment” should be repeated. (see device operating instructions). The slope is re-calculated and stored and the probe is then accurately adjusted.
4. Rinse and wipe the probe (see above).

☞ If wrong buffer solutions or worn-out probes are used, the alignment might not provide accurate correction values anymore. In such cases the function 'Set measured value to zero' (see device operating instructions) can be used to re-establish the default values (slope correction -0.1689, base value -7.00).

Measurement

1. Immerse the probe into the measuring solution and slightly turn it.
   The electrode must be immersed far enough so the membrane is well covered with measuring solution.
2. Read out and record when a stable measured value has been achieved.
3. Rinse the probe and store it wet in KCl solution.

Temperature Compensation

pH values are calculated based on the electrode steepness at 25°C or, after a calibration, on the steepness of the buffer solution temperature. All ALMEMO® instruments allow for a temperature compensation when the temperature of the medium under test is largely varying from the nominal temperature.The adapter cable ZA 9640-AKY4, with an integrated Ntc temperature sensor is available for this purpose. This combined sensor is programmed with the temperature on the first channel and the pH value on the second channel. The instrument will recognise the dimension 'PH' on the second channel and the pH value will be compensated with respect to the measured temperature. The reference channel also allows for any other temperature sensor, with 0.01°C resolution, to be used for the compensation (see 6.3.4). However, for long-term measurements continuous updating of the measured temperature value must be ensured by a measuring point scan (cyclic or continuous).
On most devices the compensation temperature can also be entered manually; (see device operating instructions). The pH value is then compensated based on the temperature entered. The programming is described in the operating instructions of the corresponding device.

3.9.1.2 Redox Measurement

The level of the Redox potential (measured in mV) indicates the strength of an oxidizing or reducing reaction of a measuring solution. It allows for monitoring a variety of chemical processes (e.g. cyanide oxidation or chromate reduction). As the extermination of microorganisms (disinfection) is directly related to the strength of the oxidation (e.g. of chlorine) the Redox potential is successfully being used for monitoring disinfection processes.
The measurement is based on measuring the voltage potential of a precious metal electrode (platinum or gold) against a reference electrode. One-bar measuring chains are used as they are easier to handle than two-bar chains.

ALMEMO® Redox Measuring System

The connection cable ZA 9610-AKY5 can also be used as a transducer between Redox probes (e.g. FY96RXEK) and ALMEMO® measuring instruments. As voltages are only measured in the range ±1000mV the programming of the connectors is quite simple:

Measuring range:	D2600
Dimension:	mV
Exponent:	3
Locking mode:	5

Measurement
After connecting the probe to the instrument, the probe is immersed in a Redox buffer solution, e.g. 220mV (Order No.: ZB98RXPL2). The value of the buffer solution should be reached or exceeded within 30 seconds. The probe must be cleaned (see 3.8.1.3) if the value is not reached within this time or if it remains more than 20mV below the reference value. If false values are still displayed after cleaning the probe, it must be replaced.

3.9.1.3 Handling pH and Redox Probes

Storage of pH and Redox Probes

The pH and Redox one-bar electrodes must only be stored in humid conditions. To ensure humid storage, fill 3-molar KCl solution into the protection cap and put it back on the probe.

Life
The measuring probes are subject to natural ageing, even if they are handled properly. Depending on the application, the probe life can vary between six months and three years. Certain applications, especially when extreme operating conditions are involved, can reduce the probe life to a few days.

Cleaning and Service
Measuring probes should be visually inspected regularly (approx. once per month) and cleaned, if necessary. If contaminations on the glass membrane cannot be removed with a damp cloth, the cleaning agents listed below may be used.

Type of Contamination	**Detergent / Effective Time**
General deposits	NO domestic scouring powder
Lime or metal hydroxide	Aqueous hydrochloric acid (approx. 0.1%-3%) / 1 to 5 minutes
Oil, grease	Solvents such as alcohol or acetone
Biological coating	Solution of aqueous hydrochloric acid and pepsin / several hours

☞ In principle, the probes must be thoroughly rinsed after each cleaning process.

The metal surfaces of Redox probes can also be cleaned by grinding and polishing. If the ceramic membrane, mounted at the side of the reference electrode, is blocked due to deposits, it can be cleaned in the same way as the glass membrane. Furthermore, it can be cleaned by carefully scraping the membrane with a fingernail, razor blade or a fine file.

☞ The glass membrane must not be scratched during cleaning.

Product Overview	**Order No.**
Gel-filled, non-refillable pH electrode with shaft of synthetic material, glass fiber diaphragm, Typical applications: manual measurements e.g. swimming pools, drinking water	FY96PHEK
Polymer-filled, non-refillable pH electrode with glass shaft, PTFE ring diaphragm, screw connection thread PG13.5 Typical applications: Waste water, drinking water, industrial water	FY96PHER
KCl-refillable pH probe with glass shaft, refill stud, ceramik diaphragm Typical applications: manual measurements in the laboratory	FY96PHEN
KCl-refillable pH insertion electrode with glass shaft, ceramic diaphragm Typical applications: food, for example, meat, cheese	FY96PHEE
Non-refillable Redox electrode with shaft of synthetic material, glass fiber diaphragm Typical applications: manual measurements e.g. swimming pools, drinking water	FY96RXEK
KCl solution, 3-molar	ZB 98PH-NL
Buffer solution, pH 4.0, coloured red	ZB 98PH-PL4
Buffer solution, pH 7.0, coloured green	ZB 98PH-PL7
Buffer solution, pH 10.0, coloured blue	ZB 98PH-PL10
Redox buffer solution 220 mV against Pt-Ag/AgCl	ZB 98RX-PL2

ALMEMO® Connecting Cable with Transducer

for probes with plug-on heads S7, SN6	
programmed for pH	ZA 9610-AKY4
programmed for Redox	ZA 9610-AKY5
programmed for pH with NTC temperature sensor for temperature compensation	ZA 9640-AKY4

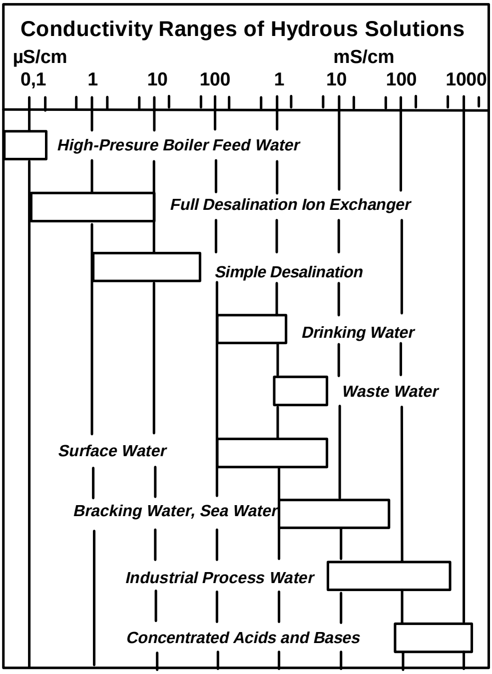
Technical Data of the Transducer

Input resistance:	> 1000GΩ
Amplification:	1
Potential of the reference electrode to GND:	< 2V
Current consumption:	< 1mA
Line length:	< 100m

3.9.2 Conductivity Probe

Basic Principles

The conductivity (unit S/m = Siemens/meter) is a measure for the ion concentration in a measuring solution. It is proportional to the salt, acid or base content in the measuring solution. High-purity waters have a conductivity of approx. 0.05µS/cm (at 25°C), natural waters approx. 100 to 1000µS/cm, some bases (e.g. potassium hydroxide solutions) up to slightly more than 1200mS/cm. The following illustration shows more examples of hydrous solutions relevant for measuring technique:



The measurement of the conductivity in electrolytes is performed by means of an electrochemical resistance measurement using a two-electrode measuring cell. A sinusoidal voltage, with a frequency of approximately 2kHz, is applied to the measuring electrodes. The current that flows through the measuring object is converted into a voltage. The voltage is rectified with phase synchronisation, smoothed and then indicated as conductance referred to 25°C.

ALMEMO® Conductivity Probes

For measuring the conductivity in electrolytes the ALMEMO® sensor range provides two conductivity sensors with integrated Ntc temperature sensor for two different measuring ranges 0 to 20.00mS (FY A641-LFP1), 0 to 200.0µS (FY A641-LFP2) or 0 to 200.0mS (FY A641-LFP3).

For each of the measuring variables, temperature and conductivity, two channels have been programmed in the connector:

Sensor	Ch.	Meas. Var.	Range	Resol.	Dim	Rng	Factor	Exp
FY A641-LFP1	1.	**temperature T**	-5...70 °C	0.01	°C	Ntc	-	0
	2.	**conductivity κ**	0.0...20.00 mS	0.01	mS	LF	0.1	1
	2.	**conductivity κ**	or	0.001	mS	LF	-	0
FY A641-LFP2	1.	**temperature T**	-5...70 °C	0.01	°C	Ntc	-	0
	2.	**conductivity κ**	0.0...200.0 µS	0.1	µS	LF	0.1	2
FY A641-LFP3	1.	**temperature T**	-5...70 °C	0.01	°C	Ntc	-	0
	2.	**conductivity κ**	0.0...200.0 mS	0.1	mS	LF	0.1	2

The sensor has already been adjusted before it is shipped. For a measurement it must be immersed to 30mm, at minimum, to allow the electrodes to be completely covered with liquid.

Temperature Compensation

As the conductivity is temperature-dependent the conductivity κ_{25}, at the reference temperature 25°C, is calculated and indicated by means of the continuous measured temperature T of the medium. For most diluted hydrous solutions and natural waters an approximate linear relationship between the conductivity and the temperature T is valid within the limited temperature range:

$$\kappa_T = \kappa_{25} (1 + \alpha_{25}/100 (T-25°C)$$

The conductivity κ_{25} is calculated as:

$$\kappa_{25} = \frac{\kappa_T}{1 + \alpha_{25}/100 (T - 25^oC)}$$

For the temperature coefficient α_{25} a setting of 1.9% is entered at the device.

☞ When using probe FY A641-LFP3 with its measuring range of 0 to 200.0 mS compensation is not performed because at high conductivity levels the temperature coefficient may vary very widely.

Maintenance and Service
Minor contaminations can be removed by using a soft brush. Intensive cleaning of heavily contaminated electrodes can lead to slight changes in the electrode spacing, which can influence the measuring result. The probe should then be re-adjusted.

Adjustment
The adjustment of the conductivity probe is performed at two points:

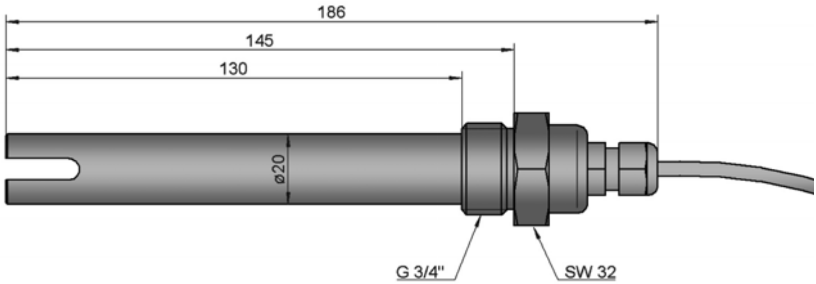
1. at 0mS/cm in dry state,
2. at 2.77mS/cm (0.02 M KCl reference solution at 25°C), or
   at 147µS/cm (0.001 M KCl reference solution at 25°C).

Sensor adjustment is performed in both points with the same “zero-point adjustment” procedure; (see device operating instructions, “Sensor adjustment” or manual chapt. 6.4.2).

Accessories

Reference solution 2.77 mS/cm at 25 °C, 250 ml 0.02 mol KCL	Order No. ZB 96LF-RL
Reference solution 147 µS/cm at 25 °C, 250 ml 0.001 mol KCL	Order No. ZB 96LF-RL2
Reference solution 111.8 mS/cm at 25 °C, 250 ml 0.001 mol KCL	Order No. ZB 96LF-RL3

Dimensions



Technical Data FYA641LFP1, FYA641LFP2

Probe:	**FYA641 LFP1**	**FYA641 LFP2**
Measuring range:	0.01 to 20 mS/cm	1 to 200 µS/cm
Temperature compensation:	0 to +70 °C, automatic	
Compensation coefficient:	1.9 linear	
Cell constant:	approx. 1 cm $^{-1}$	
Electrode material:	special carbon	
Accuracy:	0.01 to 5 mS/cm: ±1% of m.val. +0.05mS	±2% of m.val. +0.5µS
	5 to 20 mS/cm: ±2% of m.val. +0.05mS	
Nominal temperature:	25 °C ± 3 °C	
Operating temperature:	-5 to 70 °C	
Minimum immersion depth:	30 mm	
Shaft material:	PVC - C	
Dimensions:	130 mm long shaft, 20 mm ∅	
Fitting length / thread	145 mm / G3/4"	
Maximum pressure	16 bar at 25°C	
Cable length:	1.5 m	
Supply voltage:	8 to 12 V of measuring instrument	
Current consumption:	approx. 3mA	

Technical Data FY A641 LFP3

Probe:	**FY A641 LFP3**
Measuring range:	1 to 200mS/cm
Accuracy:	1 mS/cm +1.5% of meas. value
Operating electrodes:	4 electrodes, special coal
Temperature range:	0 to +70°C
Minimum immersion depth:	30mm
Output signal:	0.000 to 2.000VDC corresponds to 0.0 to 200.0mS/cm
Supply voltage:	8 to 12 V of measuring instrument
Current consumption:	approx. 15mA
Temperature sensor:	NTC type N 10k at 25°C
Shaft material:	PVC-C
Dimensions:	130mm long, 20mm ∅
Fitting length / thread	145 mm / G3/4"
Maximum pressure	16 bar at 25°C
Cable length:	1.5m

3.9.3 CO Probe for Gases

CO Measuring Technique
CO is produced from a partial combustion of carbon (combustible). It is very dangerous to people as it is highly toxic and is invisible and neutral in smell. Causes for the formation during combustion processes:
- lack of air
- too much excess air
- too early cool down of the flame

CO contained in the ambient air and its effects to the human system

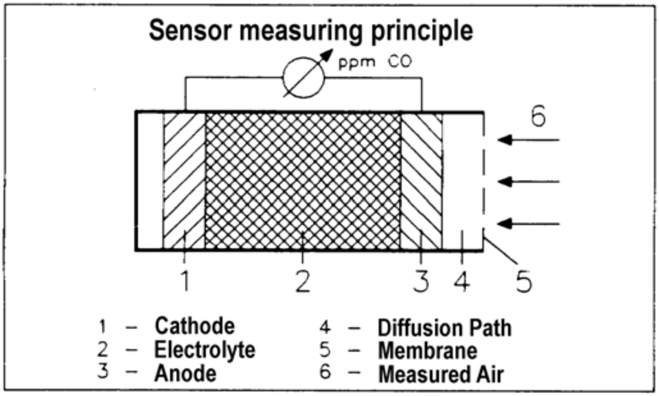
CO Concentration		Inhalation Time and Consequences
30 ppm	0.0003%	MAC value (the maximum permissible work place concentration, based on 8 hours working time) in Germany
200 ppm	0.02%	slight headaches within 2 to 3 hours
400 ppm	0.04%	headaches in the forehead area within 1 to 2 hours, spreading over the entire head
800 ppm	0.08%	dizziness, nausea and limb twitching within 45 minutes, unconsciousness within 2 hours
1600 ppm	0.16%	headaches, nausea, dizziness within 20 minutes, death within 2 hours
3200 ppm	0.32%	headaches, nausea, dizziness within 5 to 10 minutes, death within 30 minutes
6400 ppm	0.64%	headaches and dizziness within 1 to 2 minutes, death within 10 to 15 minutes
12800 ppm	1.28%	death within 1 to 3 minutes

Range of Applications

- For measurement, control and warnings in garages.
- For monitoring the air quality with respect to the maximum allowable concentration at working places (MAC value).
- For monitoring the outside air or protected air systems in house shelters or large shelter buildings.

Measuring Principle

The carbon monoxide gas sensor FY A600-CO contains a chemical measuring cell. The air to be analysed diffuses into the cell. At the electrode the released H^+ ions and electrons are used up in a cathode reaction. The current that is generated between the anode and cathode is directly proportional to the CO concentration in the measured air.



Reactions at the anode: $\mathbf{CO + H_2O \rightarrow CO_2 + 2H^+ + 2e^-}$

Reactions at the cathode: $\mathbf{{}^1/_2O_2 + 2H^+ + 2e \rightarrow H_2O}$

ALMEMO® Sensor

The carbon monoxide gas sensor FY A600 CO can be used for continuous measurement of the carbon monoxide concentration in air, in a range from 0-150 ppm to 0-5 percent by volume.
The sensor current is amplified and forwarded via 4-20mA interface to the ALMEMO® connector and the measured variable is further processed and indicated in ppm CO.

Technical Data

Gas:	CO
Measuring principle:	electrochemical reaction
Measuring range:	0-150ppm, 0-300 ppm, 0-5 %
Zero point error:	< 10 ppm CO
Gauge reading balance:	< 3 ppm CO
Accuracy:	±3% of full scale value
Zero point drift:	<2% (1 year)
Repeatibility:	<2% (1 year)
Linearity:	<2% of full scale value
Settling time, t90:	< 60s
Transverse sensitivity:	<2% by integrated filter
Output:	4 to 20 mA on ALMEMO® connector
Supply voltage:	from the ALMEMO® measuring instrument
Ambient temperature:	-10 to +40°C sensor temperature-compensated in range
Humidity:	0 to 90%, non-condensing
Life span of measuring cell:	approximately 2 years
Dimensions of measuring head:	diameter 80mm, height 80mm
Weight:	600g
Connecting Cable:	1.5m with ALMEMO® connector

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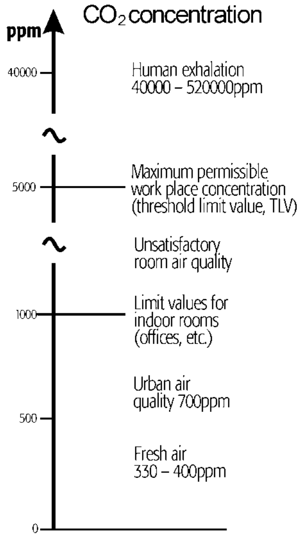
3.9.4 CO_2 Probe for Gases

General remarks on CO_2 measurement

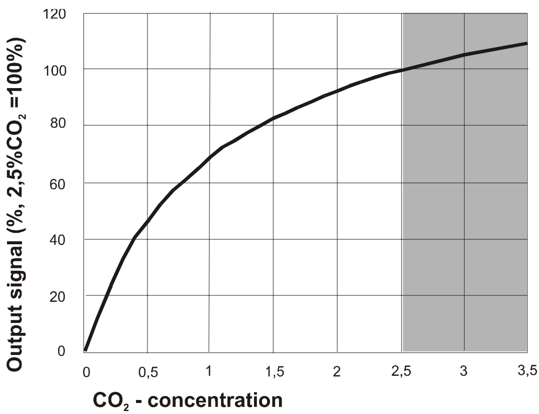
The CO_2 concentration is used as an indicator for the evaluation of the room air quality. A too high concentration of CO_2 in the room air (limit value 1000 ppm) is experienced as stale or stagnant air.



Measuring Principle

The operation of the carbon dioxide gas sensor module FY A600-CO2 is based on infrared optics. The sensor module utilises the light absorption of CO_2 in a narrow wave length range of the infrared spectrum.

The relation between the output signal of the module and the CO_2 concentration is substantially determined by the Lambert Beer absorption law. Due to further effects, the relation is not of a simple logarithmical character. The gas supply is realised, especially for air conditioning equipment via free convection. The sensor is not using any mechanically moving parts.



3.9.4.1 ALMEMO®-Carbon Dioxide Hand-Held Sensor

The sensor functions according to the 2-channel infrared absorption principle and is adapted to the ALMEMO® system via a digital interface.

Handling:
These instructions must be strictly followed before initial operation:

- Consider the operating range of the transducers! Overheating destroys the sensor!
- In case of a change of the ambient temperature (change of location indoor/outdoor) the measuring instrument requires a compensation period of a few minutes.
- The CO2 sensor contains sensitive optical components. Please treat the sensor like you would treat your photo camera. Intensive shocks alter the adjustment of the sensor. Test the measured values with fresh air 350 ...450 ppm (city air to 700 ppm).
- Avoid any dewing of the sensor as this affects the long-term stability.
- Improper handling invalidates the guarantee!

Initial Operation:

- Connect the sensor to the ALMEMO® measuring instrument. For a safe measurement it is recommended to operate the ALMEMO® measuring instrument with the mains power supply adapter (high power consumption of the sensor!)
- Switch the device on.
- After switch on a 30 second heating-up time of the sensor follows.
- After 30 seconds the measuring instrument is operational.
- The CO_2 concentration within the sensor requires approximately 60 seconds to adjust to the environment.
- Slightly waving the sensor reduces the time required for the adjustment.
- In case of a ´bedewed´ sensor higher measured values can occur.

To avoid any influences from the exhaled air the sensor should be kept as far away as possible from the body!

Operation with the device in SLEEP mode is not possible !
If more than one CO_2 probe is used with one ALMEMO® device an external power supply will be necessary for the CO_2 probes!

Depending on your specific measurement setup we provide different power supply solutions on request.

Technical Data

Sensor:	2-channel infrared absorption principle
Measuring range:	0 ...10 000 ppm (0...1 vol% CO_2)
Accuracy:	0...5000 ppm ±(50 ppm+ 2% of m.)
(at nominal conditions)	5000...10000 ppm ±(100 ppm +3% of m.)
Resolution:	1 ppm or 0.0001 vol %
Nominal conditions:	22°C ±2 °C / 50 % rF ± 10 % rF
Environmental temperature:	0...+50 °C
Storage temperature:	-20...+50 °C
Environmental humidity:	0... 90 % rF (non-condensing)
Temperature coefficient	0.4% of m. / °C
Connector programming:	range: DIGI V24 instruction: B55
Power supply:	6.5 to 12 VDC from ALMEMO® device. Operation with mains power supply adapter is recommended!
Current consumption:	effective approx. 40 mA, max. approx. 80 mA
Connecting cable:	1.5 m

3.9.4.2 ALMEMO® Sensor FYA600CO2

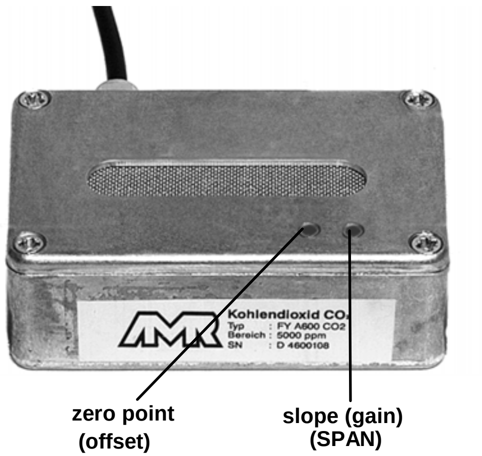
The sensor module FY A600-CO2 provides the output signal as a voltage between 0V (signal with absence of CO_2) and 2V (calibrated full scale value). The module is designed for a variable adjustment of the measurement range from 0,5% to 25% CO_2 and can, therefore, be used universally. As a standard, the present sensor version provides the output signal as a temperature-compensated signal.

Handling

Gas sensors are very delicate measuring devices.

☞ Make sure that gas sensors are not exposed to shocks or jolts. Mechanical stress may cause a misadjustment of the sensor.

A misadjustment of the sensor is usually related to the zero point (the curve character being maintained) In this case re-adjustment is necessary.



The response time is largely determined by the flow rate inside the sensor. COgas has a greater specific weight than air with the effect that it remains beneath air. The recommended position for installing the sensor is therefore upright (vertical).

Operation with the device in SLEEP mode is not possible !

If more than one CO_2 probe is used with <u>one</u> ALMEMO® device an <u>external</u> power supply will be necessary for the CO_2 probe!

Depending on your specific measurement setup we provide different power supply solutions on request.

Zero Point Verification in Ambient Air

The verification of the zero point can be performed with sufficient accuracy in ambient air conditions. The average CO_2 content of non-polluted ambient air is 330 to 370 ppm. (approx. 0.03%) This value may be exceeded locally e.g. in urban or industrial areas.

Calibration and correction

The CO_2 sensor module, when delivered, is already adjusted to the appropriate range and can be used immediately.

For subsequent re-adjustment the zero point (offset) and gain (SPAN) can be set on the CO_2 sensor module. To do so you will need synthetic air (CO_2-free!) and a test gas with a defined CO_2 concentration. A volume flow of at least 1 liter / minute must be set.

Technical Data

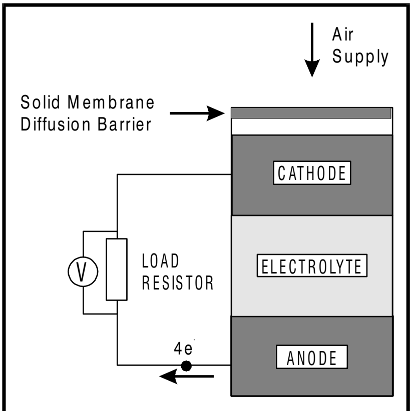
Gas:	CO_2
Measuring Principle:	IR optics
Meas. Ranges, nominal (% CO_2):	0...0,500%, 0...2.5%, 0...10%, 0...25%
Accuracy:	±2% of full scale value
Reproducibility:	±1% of full scale value
Resolution (dep. on meas. range):	50-100 ppm to 5000 ppm <200 ppm to 2.5%
Voltage Output:	0 to 2V for selected measurement range
Supply Voltage:	6.5 to 12V DC from the ALMEMO® measuring instrument, operation with mains power supply adapter is recommended
Current Consumption, effective:	50mA
Current Consumption, maximum:	70mA

Settling Time, t90:	<60s
Temperature Coefficient:	typically -0.4% signal/K
Temperature Range:	5 to +40°C
Relative Humidity:	0 to 95%
Dimensions:	90 x 30 x 36 mm (WxHxD)
Weight:	136g
Connecting Cable:	1.5m with ALMEMO® connector

3.9.5 O_2 Probe for Gases

Measuring Principle

The oxygen measuring cell contains a lead-oxygen cell, a lead anode and a gold cathode and uses a special acid electrolyte. The oxygen molecules of the gas mixture flow through a non-porous membrane into the electrochemical cell and are absorbed by the gold electrode.



Measuring principle

The chemical process can be described by the following equations of reactions:

O_2 reduction at the cathode: $O_2 + 2H_2O + 4e^- \rightarrow 4OH^-$

Oxidation at the lead anode: $2Pb + 4OH^- \rightarrow 2PbO + 2H_2O + 4e^-$

Reaction in the measuring cell: $2Pb + O_2 \rightarrow 2PbO$

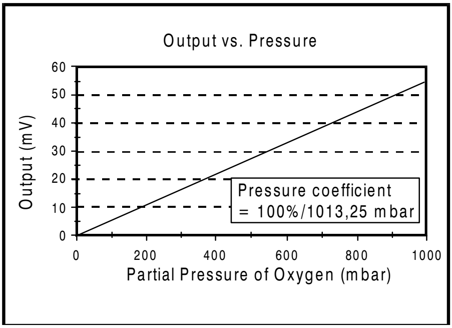
ALMEMO® Oxygen Sensor

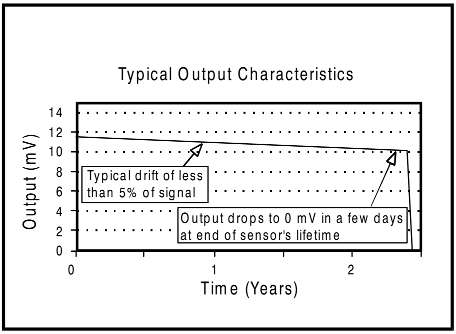
The oxygen sensor FY 9600-O2 can be used, for example, for measurements in air conditioning systems, air purifiers, oxygen rectifiers, greenhouses and oxygen incubators. The oxygen sensor is approved by PTB and is approved for exhaust gas measurements in the automotive industry.
The O_2 sensor contains a small circuit board, where measuring resistances and circuitry for the temperature compensation are located.
The response of the sensor is optimised by a compensating auxiliary probe. A correction value can be stored in the ALMEMO® connector plug to compensate for the natural ageing of the probes, so optimum output characteristics can be ensured for the whole operating life. For connecting the probe to ALMEMO® measuring instruments a standard jack connector (3.5mm) is used along with an adapter cable ZA 9600-AKO2.

3

Output Signal

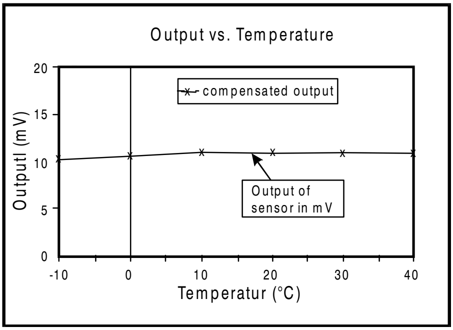
The current flow between the electrodes is proportional to the oxygen concentration in the gas mixture under test. For the temperature compensation the signals are measured as voltage drop over the resistance and the NTC. The change of the output voltage is proportional to the oxygen concentration, provided its penetration into the sensor is only limited by the diffusion. The sensor signal is determined by measuring the diffusion rate of the oxygen through the diffusion membrane. A plastic film is used as a diffusion membrane. At higher gas pressures the diffusion rate of the molecules increases. The output signal is, therefore, directly proportional to the oxygen partial pressure, which guarantees for a linear response at all concentrations.





Operating Life

The operating life of the sensor is dependent on the lead mass available for the oxygen reaction and of the oxidation rate. High oxygen partial pressures and high temperatures increase the output signal of the sensor and, therefore, shorten the life. At the end of the operating life the sensor signal quickly collapses to 0mV in air.



☞ By screwing on the protective cap when the system is not used, oxidation can be avoided and the operating life is increased.

Temperature Behaviour

The integrated temperature compensation (NTC near the sensor electrode) stabilises the output signal of the sensor and is effective in the range -10°C to 40°C.

Inspection and Adjustment

The probes are, due to the electrochemical processes, subject to natural ageing. Therefore, the nominal value should be inspected and corrected before each measurement or at regular intervals, if necessary. The sensor must indicate 20.9% O_2 in fresh air. The sensor must be re-adjusted by programming a correction value if the measured value deviates from this nominal value.

Most ALMEMO® display devices also permit automatic setpoint programming. As soon as the final setpoint is entered, the correction factor is automatically calculated and saved as “Factor” in the connector EEPROM.
For all new devices the adjustment procedure using keys is described in the operating instructions under "Entering the setpoint"; the adjustment procedure via the interface is described in the Manual, section 6.4.2. For this purpose the locking mode must be set to 4.

In so doing the following working sequence must always be observed :
1. Take the sensor outdoors into the fresh air.
2. Set connector to locking mode 4.
3. Enter and adjust the setpoint to 20.9 %.
   The correction factor is saved as FACTOR and the measured value is now displayed as 20.9 %.
4. Set connector to locking mode 5.

On devices without setpoint entry the factor (setpoint value / actual value) can be calculated and programmed by the user. (see 6.3.11)

3

Cross Sensitivity

In many applications it is important to obtain very accurate oxygen measurements. For this reason, our oxygen probes meet the requirements of OIML R99 and PTB. Only small cross sensitivities occur in typical gas mixtures:

Gas Mixture	**Output Signal**
16%CO_2 / N_2 balance	<0.01%O_2
5%H_2 / N_2 balance	<0.001%O_2
2000ppm n-Hexan / N_2 balance	<0.01%O_2
6%CO / N_2 balance	<0.002%O_2
3000ppm NO / N_2 balance	<0.002%O_2

Even if the sensor is used for longer periods in such gas mixtures, its output characteristics will not be affected:

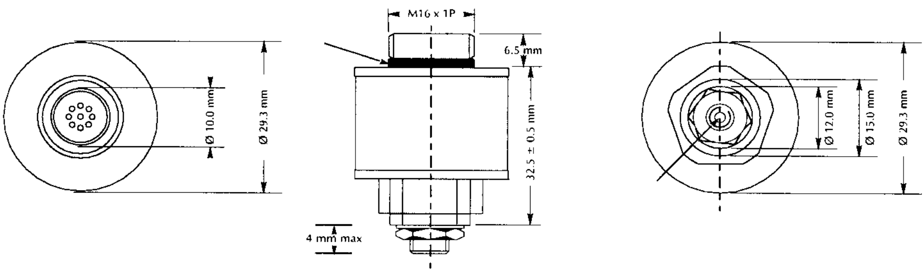
Gas Mixture	**Periods**
14.4%CO_2 / 3.6% CO / 2050ppm propane / N_2 balance	16 weeks
8%CO_2 / 10%O_2 / N_2 balance	72 hours
50%CO_2 / 10%O_2 / N_2 balance	18 hours

Although the measurement of the concentration is based on a capillary diffusion membrane, there is neither an increased CO_2 mass flow nor does a gas carrier effect occur. This means that the output signal of the oxygen sensor is only dependent on the oxygen partial pressure.

Technical Data

Gas:	O_2
Measuring principle:	electrochemical cell
Measuring range:	1...100% O_2, linear
Accuracy:	1% O_2
Resolution:	0.01% O_2
Response time:	< 40s
Signal drift:	< 2% signal/month (typically <5% over lifetime)
Offset voltage at 20°C:	< 20µV
Operating life:	2 years, at operation in 20.9% O_2
Nominal conditions:	20°C, 50%rH, 1013mbar
Temperature range:	-20 to +50°C
Temperature compensation:	effective in range -10 to +40°C
Pressure range:	atm. pressure ±10%
Relative humidity:	0 to 99 % non-condensing
Connecting cable:	adapter cable 1.5m long with jack connector on ALMEMO® connector plug (ZA 9600-AKO2)

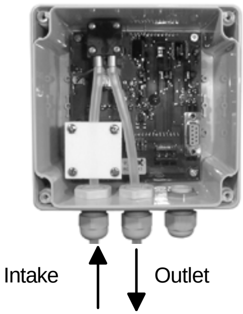
Dimensions:

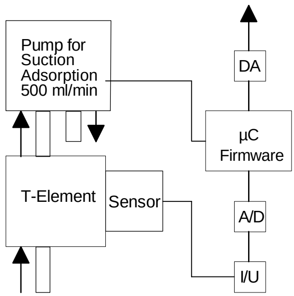


3.9.6 O_3 Probe for Gases

Measuring Principle

The ozone sensor FY 9600-O3 is based on an electrochemical three-electrode sensor. A membrane pump that is integrated in the sensor housing is used for taking air samples with a typical suction rate of 500 ml/min. For increasing the pump life the external air is sucked in using an interval operation and is measured during the second part of the suction phase.





ALMEMO® Ozone Sensor

The ozone sensor FY 9600-O3 can be used for many measuring tasks where ozone measurements have, so far, been too expensive. Each ozone sensor is supplied with a calibration certificate. As a result of the high long-term stability, only small maintenance costs are to be expected.

Calculation Formulae

The following formulae are used for converting the O_3 measured value from ppb to µg/m³, depending on the current atm. pressure and the temperature.

$$\text{Ozone } (\mu g/m^3) = \frac{0{,}57 \times \text{Atm. Press } [hPa]}{\text{Temperature } [K]} \times \text{Ozone (ppb)}$$

Example: 20°C and 1013 hPa = factor 2
Ozone (µg/m³) = 2 x Ozone (ppb)
This is the nominal value for conversion from ppb to µg/m³.

Measuring

Unlike temperature, ozone expands in clouds, i.e. there is a strong local and time-based distribution. The measurement is performed in interval operation. As a result, ozone values can vary up to 50% in short intervals.

☞ We generally do not recommend connecting a filter in series, as it will usually 'contaminate' quite quickly (e.g. pollen in the air) and will lead to an invalidation of the measuring results.

Applications

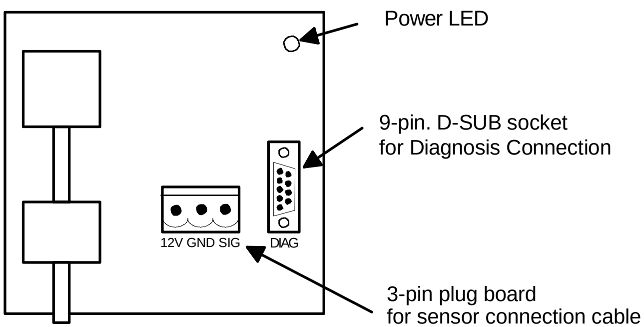
Ozone is a toxic trace gas that can cause major burns in human mucous membranes when breathed in high concentrations. Therefore, control measurements for the ozone content in air must be performed in many areas, for example:

- for leakage tests in industry
- for protection of health and safety standards at work
- for mobile air quality measurements
- for providing environmental data on advertising displays etc.

Notes for Installation

1. The maximum measuring accuracy can be achieved at a constant ambient temperature of approximately 20°C. We recommend the installation of the ozone sensor within a building, in a height of at least 3m, and with a suction hose (teflon hose) guided to the outdoor area.
2. The opening of the suction hose must be at a distance of at least 20cm from walls or other objects and must be directed downwards.
3. If an indoor installation is not possible, the ozone sensor must be mounted in a 24-hour shade position (North). However, in this case a lower measuring accuracy must be expected because of the larger temperature fluctuations. If mounted outdoors the ozone sensor should be protected from rainfall, e.g. it should be mounted on a balcony, under a canopy or a cover.
4. Mount the ozone sensor so it remains easily accessible for regular maintenance.
5. Install the ozone sensor at a location that has good ventilation so the ozone cannot disintegrate, due to a missing convection.

Connectors and LEDs



Maintenance

For measurements in outdoor environments the maintenance must be performed once per year in spring time, so the maximum measuring accuracy is available during the 'ozone season'. In case of season-independent measurements, we recommend maintenance at 24 month intervals.
Maintenance set ZB9600O3S: new electrochemical meas. cell, pump replacement, re-adjustment including calibration certificate

Exceptional weather conditions such as a hot and dry summer and high pollen, or even foreign substances, e.g. varnishes, lead to a premature deterioration of the sensor properties. A shorter maintenance interval may be necessary.

Technical Data

Gas :	ozone (O3)
Measuring principle :	electrochemical three-electrode sensor
Measuring range :	0 to 300 ppb
Accuracy :	typically 5% of final value under nominal conditions (for intermittent operation)
Long-term accuracy :	after 12 months under nominal conditions typically 5% of final value (for intermittent operation)
Exposure period :	until specification is reached, at least 2 hours (at 200 ppb); for a prolonged period the device was in an ozone-free environment
Measuring interval :	pump on : 5 minutes / pump off : 10 minutes Option : OY9600 O3 pump in continuous operation (factory setting)
Pump flow rate :	500 ml / minute
Signal output :	0 to 2 V Load resistance >100 kW
Voltage supply :	6 to 14 V, stable
Current consumption :	pump on : 50 mA, typical pump off : 25 mA, typical pump blocked : 180 mA, typical
Overload capacity :	1 ppm
Expected useful life :	Sensor, typically 24 months (at 20 °C) pump, typically 6000 hours
Nominal conditions :	20 °C, 30% RH, 1013 mbar, no contamination of contact surfaces
Operating range :	-20 to +40 °C / 30 to 80 % RH
Storage temperature :	0 to 20 °C at 30 to 80 % RH non-condensing
Dimensions	(LxWxH) 180 x 125 x 90 mm
Connecting cable :	1.5 meters long, with ALMEMO® connector programmed in ppb

3.9.7 O_2 Probe for O_2 Measurement in Liquids

Basic Principles of Oxygen Measurements in Water

Oxygen is not only a component of the air but it is also contained dissolved in water. It is very important for animals and organisms living in water and for the biological treatment of municipal and industrial waste water. The dissolved part increases with increasing atmospheric pressures and with decreasing temperatures.

An oxygen balance develops between the air and the water. The saturation state (air-saturated water) is reached when the partial pressure of the physically oxygen dissolved in water [**pO_2(Water)**] equals the partial pressure of the oxygen in the air [**pO_2(Air)**].

$$p\,O_2\,(\text{Water}) = p\,O_2\,(\text{Air})$$

As air does not only contain oxygen (20.9%) but also nitrogen (78.1%), rare gases (0.96%), carbon dioxide (0.03 %) and water vapour (humid air), the following equation is valid for the partial pressure of the oxygen in water-vapour-saturated air [**p´O2 (air)**]:

$$p'O_2\,(\text{Air}) = X\,O_2\,(p_L - p_W)$$

$X\,O_2$ = mole fraction of oxygen in air (0.2095)
p_L = atmospheric pressure
p_W = water vapour pressure

☞ The oxygen partial pressure in water-vapour-saturated air corresponds, at a balanced state, to the oxygen partial pressure in air-saturated water.

This is of a special practical importance when calibrating oxygen sensors.

For a valuation of the oxygen saturation state it is common to determine the oxygen saturation **O_2S** in % or the direct concentration specification **O_2C** in mg/l instead of the oxygen partial pressure. The value **O_2S** in % indicates how large the dissolved oxygen concentration **O_2C** is in water, in percent of the saturation value **O_2C_s**.

$$O_2S = \frac{O_2C}{O_2C_s} \bullet 100\%$$

Measuring Principle

For determining the dissolved oxygen, membrane-covered sensors that are based on current measurements according to the Clark principle, have proven to be suitable in laboratory and in process control. These sensors operate based on the principle of polarography. Simplified, a constant polarisation voltage is applied to two electrodes and the resulting current is measured, which is proportional to the concentration of the corresponding measuring ions. The selectivity of the corresponding reaction is dependent on the half-stage potential of the present competing reaction partners. On connecting a defined voltage different substances can be selectively measured.

In the case of determining the dissolved oxygen by means of the membrane-covered Clark cell, the cathode electrode is platinum and the counter or reference electrode is silver/silver chloride. Both electrodes are immersed into a chloride-containing electrolyte solution, which is separated from the measuring solution by an O_2 permeable teflon membrane. The thin teflon membrane allows the oxygen gas to flow through, but not any dissolved ions or other foreign substances.

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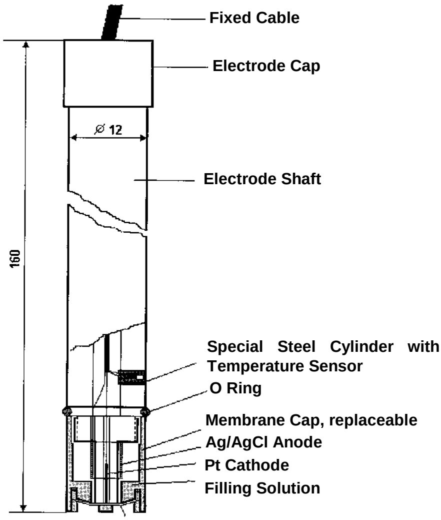

At this oxygen measuring method the oxygen that is dissolved in the water diffuses through the teflon membrane to the surface of a highly polished platinum electrode, which is acting as working electrode, and is electrochemically reduced to OH ions (base). An equivalent amount of electrons are absorbed by the silver counter electrode, which is the anode, and the resulting silver ions react with the chlorine ions of the filling electrolyte and form silver chloride that is separated on the silver electrode.

The individual reactions can be described with the following reaction equations:

Cathode: $O2 + 2\ H2O + 4\ electrons \rightarrow 4\ OH^-$
($U_{Ag/AgCl}$ = +611 mV)

Anode: $4\ Ag + 4\ Cl^- \rightarrow 4\ AgCl \downarrow + 4\ electrons$

These reactions are not spontaneous but must be forced by applying a polarisation voltage of a minimum of +611 mV to the platinum cathode and the silver anode. The resulting current is measured and represents a measure for the concentration of the discharged oxygen.
To avoid any other reactions the polarisation voltage must be kept relatively constant. A polarisation voltage of +650 mV is applied to the oxygen electrode.
'Difficult to dissolve' silver chloride and a base (OH ions) within the inner electrolyte are reaction products forming at the operating oxygen electrode. After long operating periods (several months) of the oxygen electrodes the silver salt must be removed by means of sodium thiosulphate, ammonia solution or removed mechanically, and the used electrolyte must be renewed.

ALMEMO® Oxygen Measurement

For O_2 measurement in liquids the ALMEMO® O_2 probe FY A640-O2 contains a Clark cell with a measuring amplifier and a Ntc temperature sensor. Three measuring channels allow for recalling the measuring variables, temperature, O_2 saturation and O_2 concentration:

Chan.	Meas. Variable	Meas. Range	Resol.	Dim	Range
1.	Temperature	-5 ... 50 °C	0.01	°C	Ntc
2.	O_2 saturation	0 ... 260 %	1	%	O2-S
3.	O_2 concentration	0.0 ... 40.0 mg/l	0.1	mg	O2-C

The oxygen saturation is influenced by the water temperature and the atmospheric pressure. Therefore, these two parameters must be considered when calculating the degree of saturation. The temperature sensor for temperature compensation has been integrated in the probe. Furthermore, an atmospheric pressure sensor can be connected. In case of constant conditions, the atmospheric pressure can also be entered. The reference value is 1013 mbar (normal pressure).
The oxygen concentration is calculated from the variables, saturation and temperature using the tables according to Wagner. The oxygen concentration is not dependent on the atmospheric pressure.

Calculation Formulae:

The following formulae are used by the measuring instrument to calculate the degree of saturation and the absolute amount of oxygen in mg/l by using the O_2 measured value and the temperature.

O_2 saturation, corrected:	$O_2S[\%]$	=	$O_2m \cdot SK \cdot Tk(Tm) \cdot Pn/Pm$
Measuring signal:	O_2m	=	O_2 saturation measured
Slope correction:	SK	=	$100 / (O_2c \cdot Tk(Tc) \cdot Pn/Pc)$
	O_2c	=	O_2 saturation during calibration
	Tc	=	temperature during calibration
	Pc	=	atm. pressure during calibration
Temp. compensation:	Tk(T)	=	exp(k1/(Tm+T0))/k0 (range 5 to 50°C) k0=4840, k1=2530, T0=273.15
	Tm	=	temperature measured
Atm. press. compensation:	Pn	=	normal atm. pressure 1013 mbar
	Pm	=	atm. pressure during measurement
O_2 concentration:	$O_2C[mg/l]$	=	$O_2m \cdot SK/100 \cdot Tk(Tm) \cdot O_2C_S(Tm)$
	O_2C_S	=	O_2 saturation concentr. acc. to Wagner

Atmospheric Pressure Compensation:

Three different methods can be used for atmospheric pressure compensation:

1. Manual entry in function 'mb'
2. Entry via interface using command: `g 0xxxx` [mbar] (see 6.2.6)
3. Measuring with additional atm. press. sensor FD A612 MA (see 6.7.2)

Calibration

The oxygen probe can be calibrated with regard to zero point and slope to achieve accurate measured values. The electrodes must be sufficiently polarised before starting the calibration. For this purpose, the electrode is connected to the measuring instrument that is being switched on. The polarisation time can take up to 30 minutes, especially when the electrode has not been in operation for a longer period. A sufficiently polarised electrode, which is in proper working order, provides a stable, non-drifting measured value.

Oxygen electrodes are calibrated at 0% oxygen saturation (calibration point 1) and 101% oxygen saturation (calibration point 2).

Preparation of Null Solution for Calibration Point 1:

Sodium sulphite salt solution ('null solution') is used as oxygen-free liquid (0% saturation). This solution can be prepared by dissolving sodium sulphite (Na_2SO_3) in water (accessory ZB 9640-NS). Either distilled (de-ionised) or tap water can be used. The required amount of sodium sulphite depends on the water that is used. Distilled or stale water usually contains less dissolved oxygen than fresh tap water. The required amount of sodium sulphite is therefore smaller. As a standard value, 1g sodium sulphite can be assumed for 100ml water.

When stored for a long period, the null solution absorbs oxygen from the air.

Therefore, the null solution should always be checked before the calibration is started.

Add, at first, a small amount of sodium sulphite to the null solution if your measuring instrument measures saturation values >0% in the null solution. The dissolved oxygen is chemically combined and the measured value for the oxygen saturation is reduced. A true 'null solution' is only achieved and allows for the calibration to be started when further salt additions do not lead to a further reduction of the saturation value (stable measured value).

Adjustment for Calibration Point 1:

1. Immerse the oxygen sensor deep enough in the null solution so that the integrated temperature sensor (special steel insert in shaft) is also immersed in the solution.
2. Allow for a settling time of approximately 2 to 3 min (display <50).
3. Select the function LOCKING MODE.
4. Unlock connectors
   (wherever possible only briefly and temporarily; see device instructions).
5. Select the function MEASURED VALUE.
6. Perform a zero point adjustment (see device instructions).
7. Thoroughly rinse the sensor afterwards with water to remove all residues of sodium sulphite.
8. Dab the membrane cap thoroughly to dry (e.g. with a cellulose cloth) before the calibration is started in water-vapour saturated air.

   Water droplets on the membrane can lead to an invalidation of the calibration.

Preparation for Calibration Point 2:
Water-vapour saturated air is used instead of air-saturated water. For this purpose, a moistened sponge is placed in a calibration vessel (accessory ZB 9640-AS). After 5 to 10 minutes the air contained in the vessel will be water-vapour saturated. Due to the properties of the membrane the calibration with water-vapour saturated air involves, even in the case of sufficient water-vapour saturation, minor differences (approximately 2%) compared to the sensors in air-saturated water. Despite the flow, an unaffected diffusion layer remains in the water, which leads to a reduction of the measured value. ALMEMO® measuring instruments are, therefore, set at calibration point 2 to the saturation value 101%, to obtain a correct measurement of the saturation value in water.

Adjustment for Calibration Point 2:
1. Place the thoroughly cleaned and dried sensor in the calibration vessel with water-vapour saturated air (101% O_2).
2. Add approximately 2ml water into the vessel and check the correct positioning of the receiving tube in the vessel (check the marking). The electrode must not rest on the water-soaked aerated plastics. A spacing of >1cm must be ensured.
3. Wait a few minutes until the balance is reached (stable reading).
   Select the function MEASURED VALUE.
4. Perform slope correction and zero point correction
5. Restore locking mode;
   (not necessary if unlocking was only brief and temporary).

Maintenance and Service

Storage:
The oxygen electrode should always be stored with the protective cap mounted to avoid evaporation of the electrolyte and to protect the membrane.

Cleaning the electrode:
For cleaning in daily use, simply rinse the electrode and dab it dry thoroughly, but avoid any damages to the membrane.

Renew the electrolyte filling:
If large air bubbles have been forming in the electrolyte area due to evaporation, or if this area is only filled to approximately 80%, the electrolyte filling must be renewed:

1. Position the electrode vertically.
2. Unscrew the membrane cap downwards.
3. Empty the membrane cap and fill it to the brim with electrolyte.
4. Re-screw the membrane cap to the vertically positioned electrode so that no air bubbles will be sealed in.

Replace the membrane cap:
The entire membrane cap must be replaced if the teflon membrane is damaged. Leakages of the membrane can be identified by formation of small water droplets on the membrane surface and by the measured values 'overflowing'. The cap replacement is handled in the same way as the electrolyte renewal.

Cleaning the electrode surfaces:
If the silver anode is coloured black after several months of measuring operation, the electrode surfaces should be cleaned.

1. Unscrew the cap with the gas-permeable membrane.
2. Immerse the sensor head approximately 2cm deep in sodium thiosulphate cleaning solution for approximately 30 minutes.
3. Rinse the sensor head thoroughly using distilled water.
4. Wipe the silver anode intensively with cellulose material or polishing linen.
5. Provide the electrode cap with a new solution filling and re-screw it on the oxygen electrode.
6. The electrode is operational again approximately 30 minutes after switching on (polarisation time).

Technical Data

Measuring ranges:	
Temperature range:	-5.0 to 50°C
O_2 saturation:	0 to 260% saturation
O_2 concentration:	0.0 to 40mg/l (5 to 40°C)
Measuring principle:	Clark
Working electrode (cathode):	Pt
Reference electrode (counter electrode):	Ag/AgCl
Membrane:	teflon
Settling time ($t_{90\%}$):	approx. 10 to 15s
Zero current at 0% saturation:	< 5nA
Measuring current at 100% saturation:	approx. 700nA
Accuracy oxygen measurement:	< ±1% of measured value
Flow velocity (incoming):	approx. 10cm/s
Storage temperature:	-10 to 50°C
Depth of immersion:	40mm
Filling volume (electrolyte):	0.6ml
Temperature sensor:	NTC type N (10k at 25°C)
Accuracy of temperature measurement (at nominal conditions):	-20 to 0°C: ±0.4°C, 0 to 70°C: ±0.1°C
Nominal conditions:	25°C ±3°C/1013 mbar
Shaft material:	PVC, black
Membrane cap:	replaceable (spare part)
Dimensions:	diameter 12mm, length 145mm
Connecting cable:	1.5m long with ALMEMO® connector
Polarisation voltage:	650mV
Service life (with one electrolyte filling):	several months
Overall service life (life):	several years

Accessories

Adjustment Set: 25g sodium sulphite in 20 ml PE bottle for preparation of the null solution; vessel for adjustment of the saturation level	Order No. ZB 9640 AS
25g sodium sulphite in 20 ml PE bottle	Order No. ZB 9640 NS
20ml filling solution in PE bottle for O_2 probe	Order No. ZB 9640 NL
Spare membrane cap with protection (2 pieces)	Order No. ZB 9640 EM