ZIROX Oxygen Measuring Technology

SGM5T

Oxygen monitor for inert and reactive gases

Manual

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Table of contents

1 General information

1.1 Introduction

This manual describes composition, mode of operation and use of the oxygen monitor SGM5T of the ZIROX Sensoren und Elektronik GmbH.

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The manufacturer guarantees that this manual was written in accordance with the functional and technical features of the delivered SGM5T.

This manual is not subject to the amendment service. If the manufacturer modifies the SGM5T with the aim of making technical improvements, the user is responsible for inserting the additional or updated pages supplied.

Proper operation of the SGM5T can only be ensured if the contents of this manual are known. Therefore, all chapters of this manual must be read carefully prior to operating the SGM5T.

The values on the device display in this manual are examples or preset parameters of the manufacturer. Process-specific parameters must be set by the user.

Pages, charts and figures are numbered consecutively.

1.2 Copyright

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1.3 Commonly used symbols

Symbol for imminent danger:

This symbol refers to imminent danger to persons' life and health.

⚠ danger

In case of disregard fatal injuries may result.

Symbol for indirect danger:

This symbol indicates indirect danger.

⚠ attention

The degree of the damage depends on the circumstances and the actions of the persons involved.

In case of disregard destruction or damage of the SGM5T, its single components or other material assets as well as minor injuries may result.

Symbol for proper handling:

This symbol appears where the manual refers to the adherence to rules, instructions and proper operation.

⚠ danger

In case of disregard damage or destruction of the SGM5T or its single components may result.

2 Application fields

The protective gas monitor SGM5T serves the continuous measuring of the oxygen concentration in industrial, laboratory and protective gases as well as in the process of mixing and producing of special forming gases in industry. The measuring of the free oxygen concentration in inert gases and also the measuring of bound oxygen in gas mixtures is possible.

The main application areas of the oxygen monitor are the following:

- food processing industry, in particular the production processes in breweries and food packing;
- processes of mixing and producing forming gases;
- production processes of welding and soldering, especially gas-shielded arc welding in steel and container production as well as plant construction
- production processes of electronic components under buffer gas.

ATTENTION

The introduction of explosive gas compounds, high concentrations of halogens and sulphuric gases (e.g. SO_2) into the SGM5T is not permitted.

The contact of the SGM5T with siliconic or phosphoric compounds is not permitted either.

Functions

The SGM5T

- measures and indicates the oxygen concentration in a measuring gas continuously;
- indicates any deviations of the oxygen concentration in the measuring gas from an adjustable set value;
- monitors the course of a particular production process under buffer gas;
- checks the purity of buffer gases and determines whether the requested protective effect of the buffer gas is reached.

The requirements and limit values provided in "Technical data" must be strictly observed.

Any other use is treated as non-authorized use.

3 Safety regulations

The following regulations for industrial safety provide basic information about potential danger during the operation of the buffer gas monitor SGM5T. Therefore, they must be observed and strictly followed by the responsible staff.

- A failure-free and functional operating of the SGM5T can only be guaranteed with knowledge of this manual. Therefore, all chapters of this manual must be read carefully before the installation and initiation of the SGM5T.
- The SGM5T is to be used for the functional operation only (see chapter 2).
- The SGM5T is to be installed, operated, and serviced by trained staff only.
- The SGM5T is to be connected to an isolated ground socket (Schuko-socket) with the supplied cable.

Explosive gas mixtures, halogens in high concentration, and sulphuric gases (e.g. SO_2) are not permitted to be measured by this SGM5T.

ATTENTION

Because of the high operation temperature of the sensor, the SGM5T produces a lot of heat. Make sure the device does not overheat because of covering.

ATTENTION

A vertical installation may cause heat accumulation and damage to the device.

Switch off and disconnect the device from the power supply before opening the housing cover.

DANGER

Special safety instructions for potential danger during certain working processes are provided in relevant text passages.

4 Functional description

4.1 Measuring principle

In industry and laboratories the measurement of the oxygen concentration in gases is often required. Mostly, it is measured in gases which have a considerable, temperature-independent oxygen concentration.

The NERNST equation is used as a basis for determining the oxygen concentration in gases with the oxygen monitor SGM5T.

NERNST equation

$$\boxed{U = \frac{RT}{4F} \ln \frac{p_{O2,\,air}}{p_{O2,\,meas.\,gas}}} \qquad \textbf{(I)}$$

U – cell voltage in V

R – molar gas constant, R = 8.314 J/ (mol · K)

T – measuring temperature in K

F – Faraday-constant, F = $9.648 \cdot 10^4$ C/mol

$p_{O2,air}$ – partial pressure of the oxygen at the reference electrode in dry air in Pa

$p_{O2,meas.gas}$ – partial pressure of the oxygen at the measuring electrode in the measuring gas in Pa.

The sensor of the SGM5T is based on the conductivity of oxide ions in a special ceramic substance (zirconium dioxide) with stabilizing additions. The conductivity of these oxide ions increases exponentially with the temperature and reaches a sufficiently high temperature above 600°C.

The gas to be measured passes through the ceramic oxide ion conductor which is a gas-tight tube. The ceramic tube is situated axially symmetrically in a thermally well-insulated heater. The electrodes of the galvanic sensor are made from platinum. The electrode on the outside of the tube, surrounded by dry air, is used as a reference electrode with a constant, known electrode potential (composition see chapter 6.1.2).

Equation for oxygen concentration

Based on the assumption that the total pressures of the gases are almost the same at both electrodes (in this case the volume concentrations may be used in the calculation instead of the partial pressures) and replacing the parameters by numbers in equation (**I**) the following equation applies:

$$\boxed{\varphi_{O_2} = 20.64 \cdot e^{\left(-46.42 \cdot \frac{U}{T}\right)}} \quad \textbf{(II)}$$

φ_{O2} – oxygen concentration in the measured gas in vol%

U – potential difference in mV

T – measuring temperature in K

20.64 – oxygen concentration in air with a relative humidity of 50% in vol%.

4.2 General recommendations

The oxygen may be in free or bound form inside the measuring gas[1]. (see chapter 10.1)

Thereby, the following dependencies are valid:

$U \sim T$ – for free oxygen

$U \sim \frac{1}{T}$ – for bound oxygen

The equation **(II)** for calculating the oxygen concentration is valid for measuring gases with free oxygen as well as for reducing gas mixtures in which oxygen only exists in bound form (e.g. in H_2/H_2O- or CO/CO_2-mixtures).

Reducing gas compounds

In reducing gas compounds, the oxygen partial pressure is inversely proportional to the temperature. For converting the measured value at the measuring temperature into other temperatures special thermodynamic equations are required.

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[1] Different conditions of oxygen in the measuring gas must be distinguished:

Free oxygen: Oxygen molecules in the gas are independent without a bond to other gas components (inert gases such as N_2 or Ar).

Bound oxygen: Free oxygen molecules do not exist in the gas, only in bound form e.g. as water vapor. Higher temperatures cause a dissociation and oxygen molecules are available. Since the dissociation degree increases with the temperature, the measurement result depends on the temperature.

Possibly, free oxygen can react with potential burnable gases at the hot platinum electrode. The result can be a reducing gas.

Air factor λ

When intentionally producing and monitoring reducing exhaust gases from the reaction of fuel with air, the air factor λ can be calculated and displayed if the chemical compounds and their concentration in the fuel are known.

For $\lambda < 1$ the calculation and indication of the CO-, CO_2-, H_2- and H_2O-concentrations is possible. For this, special counseling from the manufacturer is required.

4.3 Gas flow rate

NOTE

For exact measurements a flow rate between 5 and 10 l/h of the measuring gases must be ensured (see also chap. 8.1.2).

Contamination effects of the gas tubes (leaks, permeability, desorption) may cause falsified measuring result if the flow rate is too low.

ATTENTION

Asymmetric cooling of the sensor electrodes may cause falsified measuring results if the flow rate is too high. In extreme case (pressure surge or gas flow > 20 l/h), damage to the sensor is possible.

The gas flow rate is measured by a pressure difference sensor. The SGM5T displays an error message when the limit values are over- or underrun. However, the measuring will be continued.

If the device is operated with an internal pump, the gas flow will be regulated by the pump. An optimum gas flow of 8l/h is set.

4.4 Accuracy of the measurement

The manufacturer guarantees a measuring error of less than 3% (relative error) only with measurements of oxygen concentrations within a range of $2 \cdot 10^5$ ... 10 ppm. For measurements of oxygen concentrations of 10 ... 10^{-3} ppm the relative error is less than 5% if the gas inlet tube has no leaks or permeability.

For measurements of oxygen concentrations less than 10 ppm, the following aspects must be taken into account during evaluation:

- composition of the measuring gas (e.g. presence of burning gases)
- specific characteristics of the production process (e.g. material used)
- temperature of the measuring gas.

NOTE

To reduce the measuring error in low oxygen concentrations, the following conditions must be provided:

- The measuring gas must be extracted where a formation of layers can be avoided.
- The tube from the measuring point to the SGM5T must be as short as possible in order to avoid a change in the chemical balance in the tube.
- All gas inlet and outlet tubes must be free of leaks.
- For measurements of oxygen concentrations of less than 1000 ppm, the use of steel tubes is necessary.

- If the measuring gas contains reducing components (e.g. alcohol), the concentration of free oxygen cannot be determined correctly as chemical reactions occur at the electrode. In such cases the measuring gas should be filtered by an active carbon filter before entering the SGM5T (see chapter 10.1).

5 Technical data

5.1 Characteristics

Description	Oxygen monitor SGM5T
Application	Measuring of oxygen concentration in gases
Measuring range	$20.64 \cdot 10^{5} \ldots 10^{-25}$ ppm possible (see chapter 4.2)
	Measurements up to 100 Vol% on request
Accuracy at normal pressure	Relative error < 3% in the range of $2 \cdot 10^{5} \ldots$ 10 ppm Relative error < 5% in the range of 10 ... 10^{-3} ppm
Measuring gas flow rate	5 ... 10 l/h
Max. permitted pressure of the measuring gas	0.1 MPa (1 bar); > 1 kPa error correction required
Max. permitted temperature of the measuring gas	80°C at gas inlet
Pressure loss in the SGM5	Approx. 1 kPa (100 mm water column) at 10 l/h

5.2 Mechanical data / ambient conditions

Dimensions	320 × 240 × 90 (L × W × H in mm)
Weight	4 kg
Ambient temperature / humidity	10-40 °C, 80 % rH at 20 °C
Storage temperature / humidity	-20-60 ° C, 95 % rH at 20 °C
Relative humidity	Max. 80 %

5.3 Electrical data

Protection degree	IP 30
Current supply	
Voltage	110…230 V/50…60 Hz
Current consumption	30 VA
Heater measuring cell	24 V DC, approx. 15 W (internally controlled)

Keypad and display

Keypad	Membrane keypad with 6 keys
Text display	LCD dot-matrix

5.4 Interface data

Serial Interface RS-232

Transfer rate	Max. 19200 Baud, adjustable
Stop bits	1
Data bits	8
Parity	None
Handshake	None

Chart 1: *Serial interface protocol (CR = Carriage Return)*

Command	Response	Description
M2CR	M2x.xxExxCR	Output channel 1
M1CR	M1x.xxExxCR	Output channel 2
A1CR	A1xxxCR	Cell voltage in mV
A2CR	A2xxxCR	Temperature of cell electrode in °C

Chart 2: *Error indication*

Error code	Description
Error0	Transmission error
Error11	Measuring temperature too low
Error16	Thermocouple defective
Error20	System error

Pin assignment RS-232

Pin assignment of the RS-232 connector:
Connector SUB-D 9-pol. F

Pin-No.	Description
2	TxD
3	RxD
5	GNDA

Analog output

Current signal	0/4 ... 20 mA, range adjustable, alternatively 0 ⋯ 5 V or 0 ⋯ 10 V (on request)
Alarm indication	3 potential-free contacts

Charge	Resistive charge ($\cos\varphi = 1$)
Max. switching voltage	125 VAC, 60 VDC
Max. switching current	1A
Max. switching power	62.5 VA, 30 W
Min. permissible charge	1 mA at 5 VDC

Pin assignment for the analog output SUB-D 15-pol. F

Pin-No.	Name	Explanation	Conductor coloring (if 5pol.-cable is ordered)
1	Iout1+	Analog out 1	brown
2	Iout1-	Analog out 1	white
3	Iout2+	Analog out 2	
4	Iout2-	Analog out 2	
5			
6			
7	AL AK	Alarm relay Operating contact	
8	AL MK	Alarm relay	
9	AL RK	Alarm relay Break contact	
10	GW1 AK	Relay limit value 1	green
11	GW1 MK		yellow
12	GW1 RK		grey
13	GW2 AK	Relay limit value 2	
14	GW2 MK		
15	GW2 RK		

Optional:

Special analog output with automatic range control (on request)

The SGM5T changes automatically in the next higher or lower decade of the measurement if 99 % of the range are exceeded or 9 % are underrun.

The analog output delivers a current signal of 0 b 100 % of decade and additional three relays deliver a BCD- coded range signal.

Pin assignment digital IO

Digital IO		**Sub-D 15 pol. F**
1	BCD output 0	Relay for 2^0
2	BCD output 0	
3	BCD output 1	Relay for 2^1
4	BCD output 1	
5	BCD output 2	Relay for 2^2
6	BCD output 2	

Measurement ranges

BCD-switch output				Measurement range	Analog out
2^0	2^1	2^2	Range No.		
0	0	0	1	0.00 ··· 100.00VOL% (1000000 ppm)	4-20 mA
1	0	0	2	0.000 ··· 10.000VOL% (100000 ppm)	4-20 mA
0	1	0	3	0.0000 ··· 1.0000VOL% (10000 ppm)	4-20 mA
1	1	0	4	0.00 ··· 1000.0ppm	4-20 mA
0	0	1	5	0.00 ··· 100.00ppm	4-20 mA
1	0	1	6	0.000 ··· 10.000ppm	4-20 mA

Block X1

Clamp No.	Name	Remark
1	AGND	Analog ground
2	Vz	Cell voltage
3	Vt	Thermocouple voltage
4	Heater	
5	Heater	

Block X2

Clamp No.	Name	Remark
1	OUT1 +	Analog output 1
2	OUT1 -	Analog output 1
3	OUT2 +	Analog output 2
	OUT2 -	Analog output 2
5	RXD	RS232
6	TXD	RS232
7	GNDS	RS232
8	Vp +	External pump
9	Vp -	External pump
10	AL RK	Malfunction relay
11	AL MK	
12	AL AK	
13	GW1 RK	Limit value relay 1
14	GW1 MK	
15	GW1 AK	
16	GW2 RK	Limit value relay 2
17	GW2 MK	
18	GW2 AK	

Block X4

PE	PE	110…240 V AC, 50…60 Hz
N	N	
L1	L	

6 Composition of the oxygen monitor SGM5T

6.1 General composition

6.1.1 General overview

The general composition of the SGM5T is shown in Fig. 1.

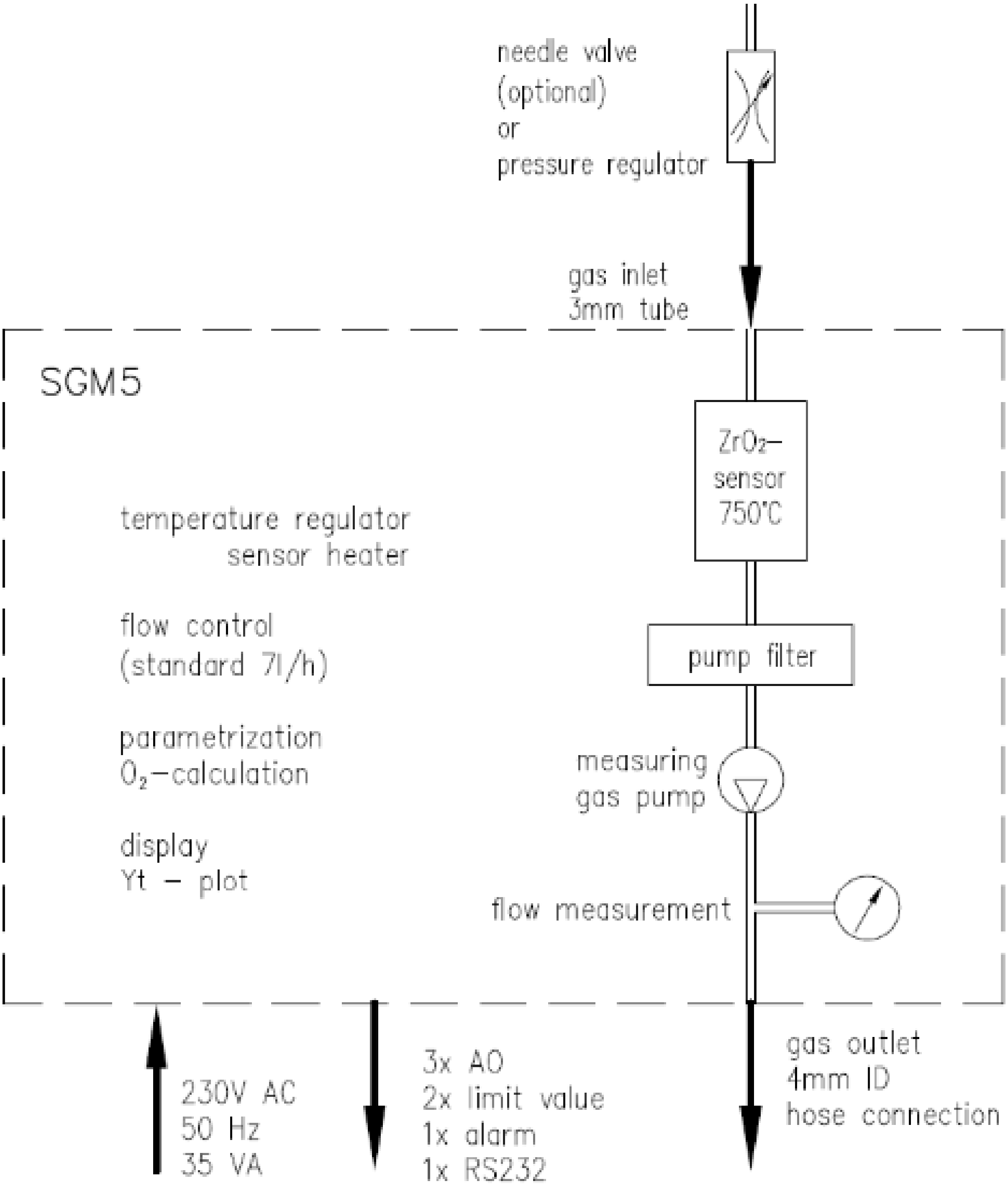


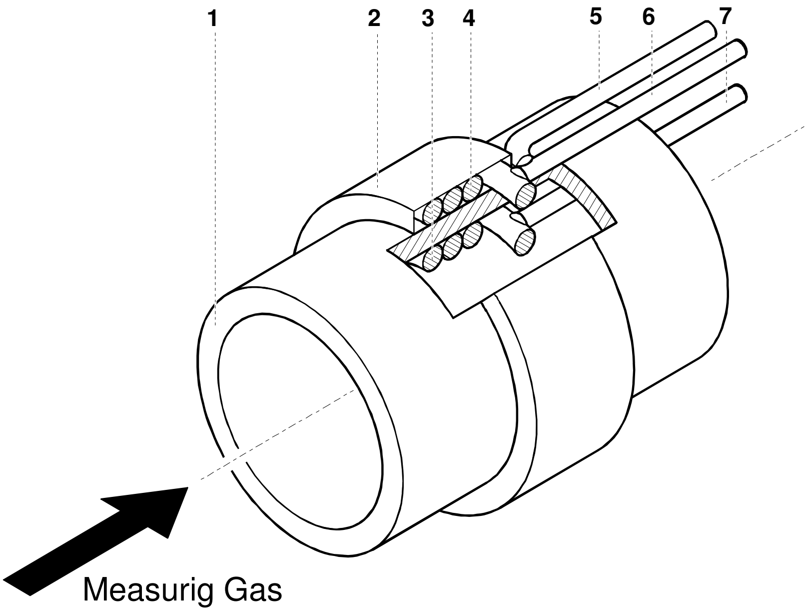
***Fig. 1:** General composition of the SGM5T*

The measuring gas gets into the sensor by means of little overpressure at the inlet or the optional pump ingests the measuring gas. In the first case, the optional pressure reducer or needle valve at the gas inlet can be used to control the gas flow. If the pump is installed, the gas flow is controlled by a flow control of the pump.

Asymmetric cooling of the sensor electrodes may cause falsified measuring results if the flow rate is too high. In extreme case (pressure surge or gas flow > 20 l/h), the sensor might be damaged.

ATTENTION

6.1.2 Construction principle of the solid electrolyte sensor



1 Ceramic tube
2 Ceramic cover of reference electrode
3 Measuring electrode
4 Reference electrode
5 Thermocouple
6 Connecting wire of reference electrode
7 Connecting wire of measuring electrode

Fig. 2: *Composition of the solid electrolyte sensor*

Measuring cell (sensor)

The measuring cell (sensor) consists of a tube made of zirconium dioxide (2/1) with two platinum electrodes. The measuring electrode is inside the tube (2/3). The reference electrode (2/4) is located on the outside of the tube and has a constant electrode potential. The electrodes and the ceramic tube form a galvanic solid-electrolyte measuring cell.

Sensor heater

In order to gain a higher oxide ion conductivity of the zirconium dioxide tube, the sensor is heated to 750°C. This also avoids interfering reactions with combustible components of the measuring gas at the electrode caused by chemical imbalances. A thermocouple (2/5) inside the measuring cell determines the actual electrode temperature. A regulator ensures a constant temperature.

The heated measuring cell produces thermal energy. Therefore, the SGM5T must not be covered.

ATTENTION

6.1.3 Electronic data processing

The following block diagram illustrates the data processing. *Electronics*

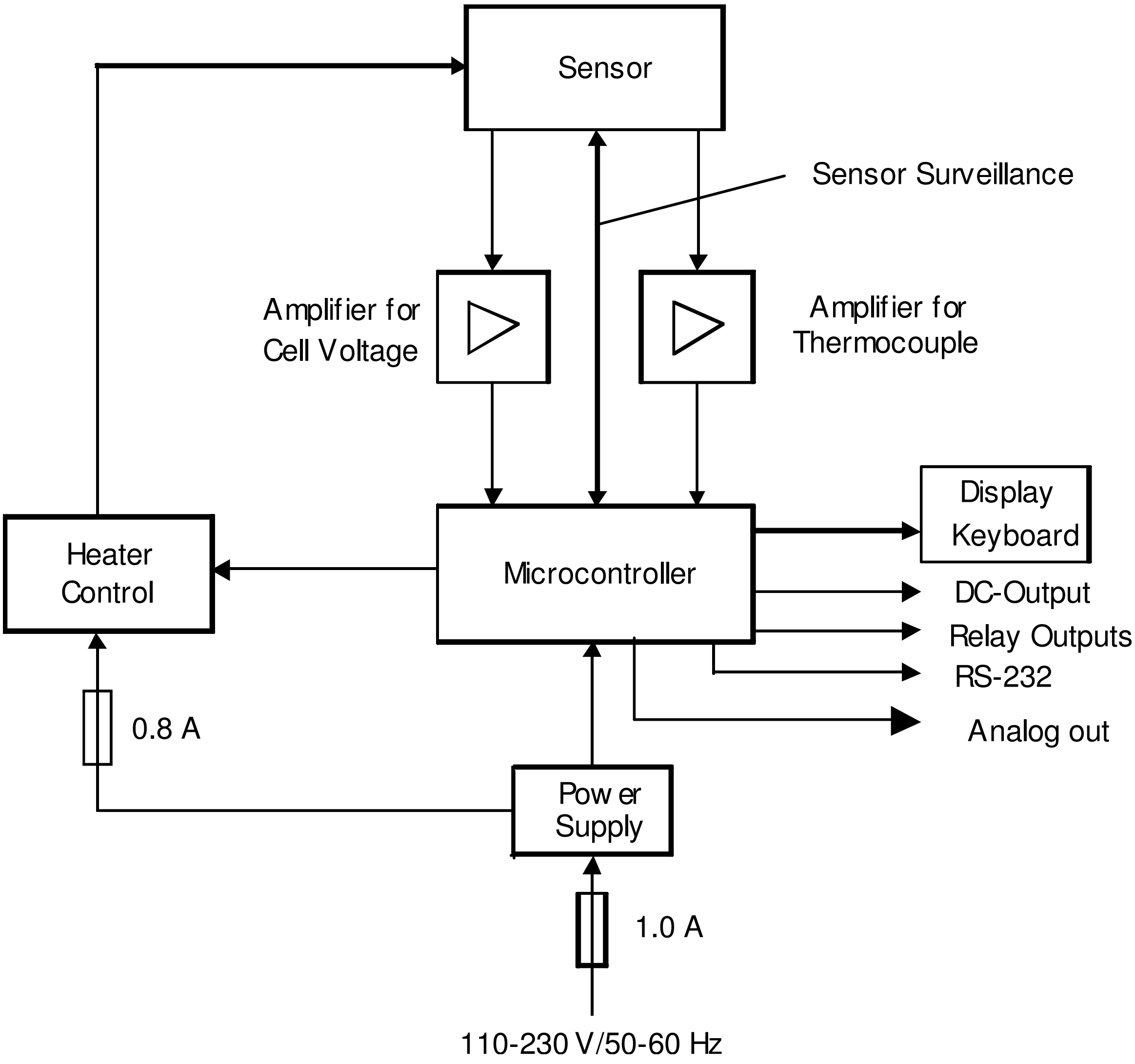


Fig. 3: *Block diagram of the SGM5T*

6.2 Composition of the oxygen monitor SGM5T

6.2.1 The mechanical composition

All components of the portable SGM5T are located in one housing.

6.2.2 Current supply

Fuse

The SGM5T is connected to the current supply with the supplied cord set.

The SGM5T has a connection module on the rear with a compartment for 2 fine fuses 1 A (T).

Five additional fuses are located on the electronics PCB. They are resettable.

Operating position and inclination adjustment

The SGM5T is designed as a desktop device. It is operated in horizontal position with a maximum angle of inclination of 30°. The angle of inclination of the SGM5T can be altered by pulling out the two attachment points of the carrying handle between 0° and 30°. When the attachment points are released, the carrying handle engages in the chosen position.

6.2.3 Front

The indicators and control elements are located on the front.

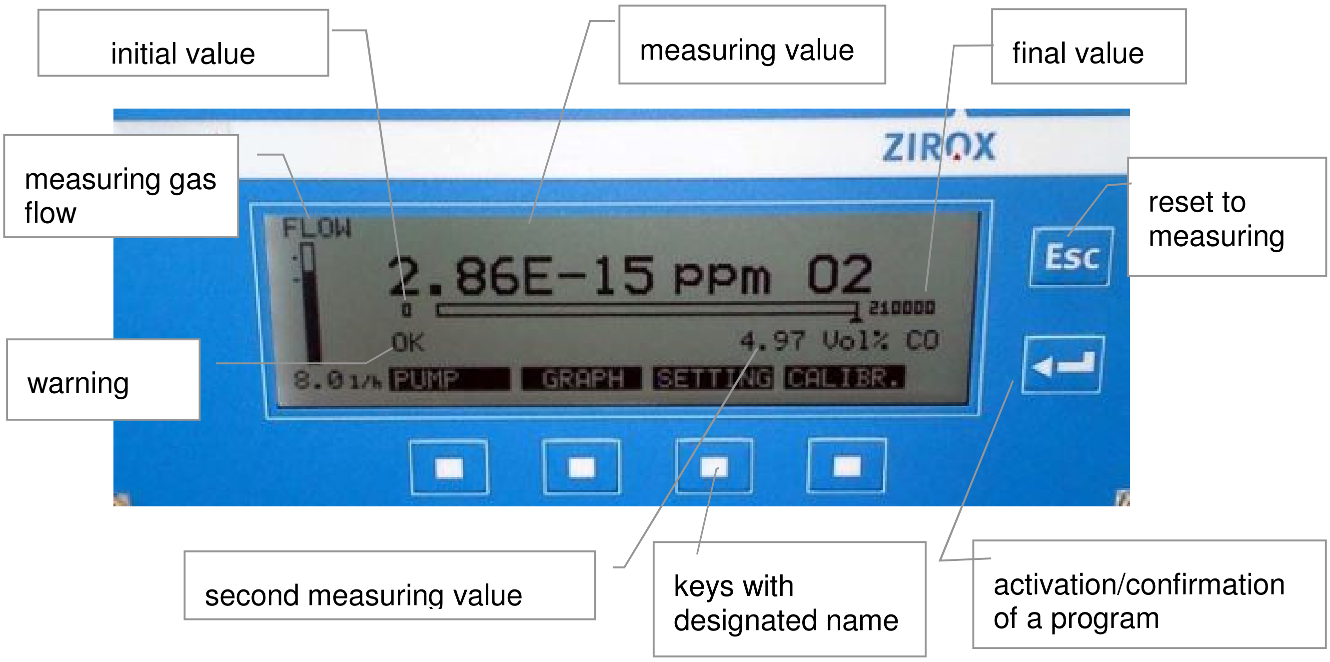


Fig. 4: *Front of the SGM5T*

6.2.4 Rear

All connections and the power switch are on the rear of the SGM5T.

Fig. 5: *Rear of the SGM5T*

Interface

Measuring values and status signals are transferred via serial interface RS 232 and analog current interface.

7 Installation and initiation

7.1 Installation conditions

- The protective gas monitor must be set up in a dry and mainly dust-free place.
- No heat sources or appliances which produce strong magnetic fields (e.g. electric motors, transformers) should be put in the proximity of the installation place.
- A vertical placement may cause damage by heat accumulation and is not permitted.

NOTE

7.2 Set-up of operating state

A temperature compensation is required after the transportation of the SGM5 from cold surroundings to a site with higher ambient temperature or humidity**.** **A waiting time of about 2 hours** before switching-on must be considered.

NOTE

1. Install the SGM5T in your favored place (see chapter 7.1).
2. Connect point of measurement and places of gas inlet and outlet of the SGM5T. Pay attention to leak-tightness. For a fast measuring result the dead volume of the gas lines must be kept low.
3. If a pressure limit is required, install a needle valve directly in front of the gas inlet (available from manufacturer of the SGM5T).
4. If the amount of water vapor in the measuring gas is likely to cause a condensation of water in a cold gas tube, a water trap must be installed in front of the gas inlet (The penetration of water into the hot measuring cell can destroy it and therefore must be absolutely prevented.).
5. If you want to install an external flow meter, you have to install it **behind** the gas outlet (where potential leaks do not have an influence on the measuring result).
6. Connect the SGM5T to the power supply.

Material of the connecting tubes

On long transport routes and at unfavorable temperatures the material of the connecting tubes must rule out any oxygen permeability. The manufacturer recommends the following materials in dependence on the measuring conditions:

Oxygen concentration of < 100 ppm .... Stainless steel tube

Silicone can cause measuring inaccuracies because of its oxygen permeability. Therefore, the manufacturer advises against use.

NOTE

The measuring gas can also flow through the SGM5 when it is off.

For using Swagelok®-fittings, please note the manufacturer's advice in the appendix of this manual!

8 Operation and parametrization

8.1 Operation

8.1.1 Switch-on and measurement indication

When the oxygen monitor is in operating state and all lines are connected according to chapter 7.2, the SGM5T can be switched on. The measuring cell reaches its operating temperature of 750 °C after approx. 10 minutes. The current measuring value is displayed but only reaches the indicated error limits after an hour when the thermal conditions in the measuring cell are even.

After switch-on the SGM5T is in display mode. On the display the programmed measuring value for output 1 is shown (normally the oxygen concentration) digitally according to the chosen dimension (vol% or ppm) or as an analog bar. In the second line of the display on the right side either the temperature of the measuring cell in °C or the cell voltage in mV is shown.

A warning or error message is possibly indicated on the left of the second line.

8.1.2 Gas flow

NOTE

The SGM5T (standard model) has an internal pump which realizes an optimum flow rate of 7 l/h. The pump can be switched on/off in the settings menu.

At excess pressure of the measuring gas the manufacturer recommends the installation of a high-quality needle valve. Appropriate needle valves can be delivered by the manufacturer of the SGM5T. For higher pressures of the measuring gas an **additional** pressure regulator is recommended which adjusts a pressure of approx. 100 kPa (1 bar) **excess pressure**.

⚠ ATTENTION

Asymmetric cooling of the sensor electrodes may cause falsified measuring results if the flow rate is too high. In extreme cases (pressure surge or gas flow > 20 l/h), damage to the sensor is possible.

8.1.3 Data monitoring

In the SGM5T, two limit values can be programmed which provide messages via relay exits. The relays are open in the active condition. This condition is displayed for active limit values on the left on the second line. The signaling is delayed. The response time can be adjusted for the data monitoring (limit value delay time) between 1 second and 99 seconds.

8.1.4 Status and error messages

Self-check of the SGM5T

During the measuring, the functions of the measuring cell are monitored. In case of faults and/or error, messages are displayed. The relay output is activated simultaneously.

The following status-/ error messages can appear:

Message	Condition	Remark
LIMIT 1	Limit 1 of measuring value (in vol%) exceeded or underrun	Limit value relay 1 activated
LIMIT 2	Limit 2 of measuring value (in vol%) exceeded or underrun	Limit value relay 2 activated
LIMIT 1/2	Limit 1 and 2 of measuring value (in vol%) exceeded or underrun	Limit value relays 1 and 2 activated
RANGE <<<	Range underrun	Alarm relay activated
RANGE >>>	Range exceeded	Alarm relay activated
FLOW <<	< 5 l/h	Alarm relay activated
FLOW >>	>10 l/h	Alarm relay activated
WARM UP	< 740° and <15 min	Alarm relay activated
LOW TEMPERATURE	< 740° and >15 min	Alarm relay activated
ERROR THERMOCOP.	No signal for internal temperature measuring	Alarm relay and limit value relay 1 and 2 activated
SELF TEST FAILED		Alarm relay activated

8.2 Parametrization

8.2.1 Adjustable parameters

***Chart* 3**: *Overview of the adjustable parameters*

Parameter	Range	Remark
Display (Setting via analog output 1 and 2)	Displayed: - Flow (vertical-bar chart) - Measuring value 1 in capital letters (horizontal bar chart) - Measuring value 2 in small letters - Menu item “pump”, “graph” , “settings” and “calibration”	In menu item “settings”-> “output 1” the measuring range for measuring value 1 (e.g. vol%., ppm O_2, $T_{z\ etc.)}$ and the analog output 0-20/4-20mV or for a device with a voltage output 0-5/0-10 V can be set Also selectable for output 2
Maximum measuring value	21.0 vol% or 210000 ppm Higher values on request	This value corresponds to the final value of the analog signal (e.g. 20 mA)
Response time t_{90}	1 ... 60 sec	Formed by arithmetical average of measured value
Limit value 1	21.0…0.0001 vol%	Selectable as lower or upper limit value with signs”>” or ”<”
Limit value 2	21.0⋯0.0001 vol%	See limit value 1
Delay time of the limit value	1 ... 30 sec	Time to alarm when limit value is exceeded
Transmission capacity of RS-232-interface	4800, 9600, 19200 Baud	
Measuring gas flow	Internal pump, switch on/off by keypad	Pumping power is regulated by internal flow measurement

8.2.2 Programming menus

The keys below the display refer to the following menus (the current meaning of the respective key is shown on the display). A definite parameter can be chosen, changed and finally confirmed with the ↵ -key.

8.2.2.1 Settings

SETTINGS

1 GENERAL
2 LIMITS
3 OUTPUT 1
4 OUTPUT 2

1 2 3 4

8.2.2.2 General settings

GENERAL SETTINGS

USER CODE:	0000	
NEW USER CODE:	0000	Max. 4 numeric characters
LANGUAGE:	ENGLISH	Alternatively German
BAUD RATE:	19200	Alternatively 4800, 9600

▼ ▲ SAVE RETURN

8.2.2.3 Limit values

LIMIT VALUES

LIMIT VALUE 1:	> 209000 ppm
LIMIT VALUE 2:	> 209000 ppm
DELAY TIME	1 – 30 sec

▼ ▲ SAVE RETURN

8.2.2.4 Output

OUTPUT 1		
VALUE:	O_2 ppm (< 1 ppm value switches automatically to exponential display)	Option: vol%O_2, O_2 log10, cell temperature, cell voltage
RANGE:	0/4-20mA	0-5 V
RANGE ZERO POINT:	0 ppm	Minimum: 1x10-15 ppm O_2
RANGE END MARK:	1000 ppm	Maximum: 1000000
AVARAGE FACTOR:	1 sec	
▼ ▲	SAVE RETURN	

The same applies to output 2.

8.2.2.5 Calibration

CALIBRATION	
ZERO GAS:	209000 ppm
CALIBR. ZERO POINT:	START
SPAN GAS:	100 ppm
CALIBR. SPAN GAS:	START
▼ ▲	SAVE RETURN

8.2.2.6 STRIP CHART

STRIP CHART		
TRACE:	O_2 linear	Alternat. Ucell, Utemp.
Yaxis-min:	0 ppm	Minimum: 1x10-15 ppm O_2
Yaxis-max:	100 ppm	Maximum: 1000000
Xaxis-max:	60 min	
▼ ▲	SAVE RETURN	

Keypad assignment main display:

PUMP	**XY-PLOT**	**SETTING**	**CALIBR.**
PUMP :	**ON**	**OFF**	**RETURN**

The measured values are moved about ¼ of the values to the left at the end.
The displayed results are not available in a memory.

8.3 Calibration

For measurements with high accuracy requirements a calibration is highly recommended (The high stability of the measuring cell requires one check-up per a year only!).

The device must be in operating state for a minimum of two hours before the calibration!

8.3.1 Zero calibration

The zero calibration serves the balance of the offset voltage of the ZrO_2-sensor. The offset is caused by the construction (when the electrode has a disadvantageous position in the heating field) and can occur because of aging of the sensor.

Before calibration, the sensor is flushed with ambient air. The gas flow is set by internal or external pump at the value which is used for measuring the measuring gas.

With the zero calibration, the working point in ambient air is calibrated with 20.64 vol.% O_2.

8.3.2 Span gas calibration

Certified test gas (oxygen concentration near future measuring conditions) must flow through the device.

The stability of the measuring value is checked during the calibration. The real calibration process starts as soon as the signal produced by the test gas is stable. Therefore, the duration of the calibration process can vary (variation smaller than 1 % in 4 seconds).

If the stability is not given, the calibration is stopped after 60 seconds.

Furthermore, the deviation of measuring value from set value is evaluated. At zero point calibration +/- 20 mV (cell voltage), at span gas calibration +/- 20 % of measuring value (cell voltage) are allowed.

For the adjustment, the following equation applies: Vcellkorr= (Vz+A)*B

With Vz=measured cell voltage, A=cell voltage at zero point, B=factor for final value adjustment.

Report of the calibration status:

OK (1.5)	Last calibration OK (calibration value)
WAIT ! 5	Calibration running
BREAK	Cancelled by pressing key
TIME OUT	Stability not reached within 60 sec
OUT OF RANGE	Range exceeded
FAILED	Device error

8.4 Fault clearance

***Chart 4**: Disturbances, causes and clearance*

Disturbance	Cause	Clearance
Display off	SGM5T off	Switch on SGM5T
	No current supply	Check current supply and cord line
	Equipment fuse tripped	Change equipment fuse
Warning: FLOW <<< (Flow too low)	Gas supply blocked, too long for chosen cross section or leaky	Check gas supply Remove blockages Establish tightness
	Pump defective	Replacement by manufacturer
Relatively high measuring value, although a low value for the oxygen concentration is expected	Gas flow too low	Increase flow rate
	Micro leaks in gas supply	Check fittings
Measurement is dependent on the flow rate (the smaller the flow, the higher the value or vice versa)	Leaks in the measuring gas supply	Check gas supply and fittings
Measuring value is significantly lower than expected	Components reacting with oxygen (at high temperatures) are in the measuring gas (e.g. hydrocarbons)	Use carbon filter or check existing filters for saturation
Warning: “WARM UP”	Measuring cell has not reached operating temperature yet	Wait 5 minutes Check temperature value on display Contact service if necessary
	Fuse for sensor heater tripped	Switch off Check again after switching on Consult service if necessary
	Heater or regulator defective	Consult service
Warning: ERROR THERMOCOP.	Thermocouple defective	Consult service
Warning: SELF TEST FAILED (system error)	Error program or data memory	Consult service

9 Maintenance, overhaul and storage

9.1 General notes

The electronics and the measuring cell are maintenance-free.

In case of defects in measuring cell or thermocouple, send the SGM5T to the manufacturer for an overhaul.

Storage

If not in use, the SGM5T has to be stored in the original packing (if possible) in a **dry, dust-free room**.

9.2 Replacement of the equipment fuse

⚠ danger

Turn off the SGM5T and separate it from the net supply before replacing the equipment fuse.

1. Open the cover plate in the input supply unit with a flat screwdriver or the like.
2. Remove fuse, examine and replace it by an identical type if necessary (1 A/T).
3. Put cover plate into place and engage it by pushing it slightly.

10 Appendix

10.1 Fundamentals of the use of potentiometric ZrO_2 solid electrolyte sensors for the optimal running of combustion processes

In various technological processes (e.g. production of glass or ceramics fibres, firing of porcelain, and generation of energy or crude gas from solid or liquid fuels etc.), the optimization and repeatable running of combustion processes ensure a consistently good product quality and exploitation of resources. Quality standards like ISO 9000 stipulate the collection and documentation of process-relevant data in order to guarantee the product quality. For the monitoring and controlling of such installations, measuring values are required as controlled quantity. These values are recorded in a wide range of gas compounds, preferably in real-time, and can be clearly assigned to completely established gas equilibrium.

Nowadays, those signals are generally obtained by using potentiometric ZrO_2 solid electrolyte sensors. The ZIROX company in Greifswald has developed both short and very long probes, which are equipped with sensors (either unheated or electrically heated), for operating in situ in various kinds of combustion installations, technical furnaces, and flames, producing the required signals. Apart from that, ZIROX produces devices with electrically heated sensors for the analysis of externally pre-mixed fuel-air compounds or of siphoned flue gases.

The chemical, thermodynamic, and electrochemical fundamentals, which the application of potentiometric solid electrolyte sensors (i.e. galvanic solid electrolyte cells) in the running of combustion processes is based on, are described in the following.

Oxygen concentration and air factor lambda

The best way to describe the conversion of gaseous, liquid or solid fuels with air is by using the air factor lambda. This quantity represents the ratio of the amount of air, which is fed to the combustion process, and the amount of air that is needed for a stoichiometric conversion of the supplied fuel. The amount of air can be indicated in volume, mass, or amount of substance (which are proportional to each other according to the ideal gas law; units like m^3, kg or mol shorten themselves when forming the ratio). If volume is the quantity used, lambda is given by the following equation:

λ = v (air volume fed) / v (air volume needed for stoichiometric combustion).

If too much air is fed to the process (excess air), then $\lambda > 1$. If too little air is fed to the process (air deficiency), then $\lambda < 1$. In case of exact stoichiometric combustion $\lambda = 1$.

(Only in automotive engineering, a different definition applies. In engine test benches the amount of consumed fuel is weighed, and the supplied air volume is converted into mass. When the air mass is divided by the fuel mass, e.g. for pure octane a value of 15.3 is obtained in an exact stoichiometric conversion.)

For the combustion of hydrocarbon (in motor fuel, natural gas, liquid gas) with the gross formula C_nH_m, the following reaction equation is obtained for λ in case of complete combustion in excess air:

$C_nH_m + \lambda \cdot (n + m/4)\ O_2 \rightarrow n\ CO_2 + m/2\ H_2 + (\lambda - 1) \cdot (n + m/4)\ O_2$.
In combustion processes with air deficiency, sufficiently high temperature and, if necessary, with catalysts for the establishment of complete gas equilibrium, a mixture of nitrogen, hydrogen, water vapor, carbon monoxide and carbon dioxide (the so-called “water gas” which can be produced from coal and water) develops from all organic substances. The reaction formula for air-deficient combustion cannot be described merely by the parameters λ, n and m. Rather, the following equation applies:

$C_nH_m + [(1\text{-}a/2) \cdot n + (1\text{-}b) \cdot m/4]\ O_2 \rightarrow (1\text{-}a) \cdot n\ CO_2 + a \cdot n\ CO + (1\text{-}b) \cdot m/2\ H_2O + b \cdot m/2\ H_2$,

where a and b are quantities determined by λ and the position of the temperature-dependent water gas equilibrium $CO + H_2O = CO_2 + H_2$.

Gas potentiometry with solid electrolyte cells only produces the oxygen concentration $\varphi(O_2)$ in the respective measuring gas. However, in many cases the determination of λ is desired. For the calculation of lambda, the following equations can be derived:

$$\lambda_1 = \frac{1 + \dfrac{\varphi(O_2)}{1+2V}}{1 - \dfrac{\varphi(O_2)}{\varphi(O_2)_{Luft}}} \qquad \lambda_r = 1 - \frac{1}{1+2V}\left[\frac{V}{1+\dfrac{\sqrt{\varphi(O_2)}}{K_C}} + \frac{1}{1+\dfrac{\sqrt{\varphi(O_2)}}{K_H}}\right]$$

These equations, valid for single hydrocarbons for $\lambda > 1$ (lean burn) and $\lambda < 1$ (rich burn), contain the carbon/hydrogen-ratio in the hydrocarbon $V = 2\ n/m$ and the thermodynamic equilibrium constants of the reactions

$CO_2 = CO + 1/2\ O_2$ $\qquad \lg K_C = 4.505 - 14700\ K / T$,

$H_2O = H_2 + 1/2\ O_2$ $\qquad \lg K_H = 2.947 - 13008\ K / T$.

In practice, however, usually compounds of different hydrocarbons are present. Fuel gases can also contain hydrogen, carbon monoxide, and nitrogen. Apart from that, the supplied air with its humidity and carbon-dioxide content also contributes to the gas equilibrium. In correspondingly modified equations, average values of V must be used. Thinning with nitrogen has some influence on λ in the lean burn range but not in the rich burn range because the equilibrium between the water gas components does not depend on pressure, and thus does not depend on the water gas concentration.

The change in the kind of equation that is needed for the calculation of λ, if the conditions change from excess of oxygen to lack of oxygen, constitutes a special problem. In that case for each measurement the concentrations of the water gas components have to be calculated. Depending on whether $\varphi(CO) + \varphi(H_2)$ is higher or lower than $2\ \varphi(O_2)$, one has to use either the one or the other equation (DE 43 23 879). The software developed for this purpose by the company *GO MESSTECHNIK Greifswald* produces the results virtually without time-delay.

Gas potentiometry using solid electrolyte sensors

Crystals of mixed oxides from ZrO_2 and CaO or Y_2O_3 have vacancies in the oxygen ion sublattices. Oxygen ions can migrate across them at high temperatures. Thus, they are solid electrolytes (i.e. solid ion conductors). At platinum layers on ceramic bodies of stabilized ZrO_2 (stabilized against breaking), electrode reactions with the oxygen ion vacancies V_O are possible:

$1/2\ O_2$ (gas) + 2 e^-(platinum) + V_O (solid electrolyte) = O^{2-}(solid electrolyte),

H_2O (gas) + 2 e^-(platinum) + V_O (solid electrolyte) = O^{2-}(solid electrolyte) + H_2 (gas).

Oxygen atoms separated off molecular oxygen or water vapor take up electrons on the surface of the platinum and move to oxygen vacancies of the solid electrolyte where they form oxide ions. This process, however, quickly comes to a standstill if the electrode is in an open circuit, and neither electrons nor oxygen ions can flow. In this state, the output of chemical work from the particle transfer equals the effort that has to be made in terms of electric work. An electrochemical equilibrium exists in this case, which is a dynamic equilibrium. The electrode reactions still occur but equally fast in both directions. The larger the so-called exchange current density, the less sensitive is the electrode to disturbances.

In electrochemical equilibrium, either the platinum has given off electrons and is positively charged, or it has taken up electrons and is negatively charged. The first is to be expected in oxygen, the second in hydrogen.

If two oxygen electrodes are exposed to different oxygen concentrations on opposite sides of a gastight sintered ZrO_2 solid electrolyte, the electrode exposed to the higher oxygen concentration will be charged more positively than the electrode exposed to the lower oxygen concentration in electrochemical equilibrium. A cell potential can be measured between the electrodes. The more the oxygen concentrations at the two electrodes differ, the higher is the cell potential.

In 1889, NERNST was the first to describe the quantitative connection between the cell potential and the particle concentrations at the electrodes with the so-called NERNST equation. In electrochemical thermodynamics this equation can be derived from the chemical potentials (consisting of energy and entropy components) of the particles participating in the cell reaction (i.e. sum of the electrode reactions). The chemical potential of the oxygen is given by

$$\mu\ (O_2) = (O_2)^{,} + R \cdot T \cdot \ln p\ (O_2).$$

For a solid electrolyte cell with two oxygen electrodes, the cell reaction is merely the transfer of oxygen from higher to lower partial pressure. The chemical work in cell reactions is described with the molar free reaction enthalpy (Gibbs free energy) $\Delta_R G$, which equals the difference in chemical potentials:

$$\Delta_R G = \mu\ (O_2)' - \mu\ (O_2)'' = R \cdot T \cdot \ln\ [p\ (O_2)'/p\ (O_2)''].$$

In isothermal cells, the standard potentials $\mu(O_2)^{,}$ on both sides are equally high, and thus drop out. $\Delta_R G$ equals the maximum work that can be won for an infinitely slow reaction, i.e. at extremely slow current flowing through the external circuit. It can be calculated using the equilibrium cell voltage U_{eq}, the molar charge F (Faraday's constant), and the amount of electrons that are exchanged in the cell reaction (4 electrons in case of O_2):

$W_{electric} = 4 \cdot F \cdot U_{eq}$.

From this, the NERNST equation for the equilibrium cell voltage follows:

$U_{eq} = (R \cdot T / 4 \cdot F) \cdot \ln [p (O_2)'/p (O_2)'']$.

In gas potentiometry, one of the electrodes is fed with a gas of known composition (reference electrode), and by measuring U_{eq} and T the gas at the measuring electrode is analyzed. Inserting the values for R and F into the equation above and converting it into the lg-form, the following equation is obtained for dry air under normal pressure at the reference electrode:

$U_{eq}/mV = 0.049606 \cdot T/K \cdot \lg [p (O_2) / (0.2093 \cdot 1013.25 \text{ mbar})]$.

In practice, the oxygen concentration $\varphi (O_2)$ in vol% is often used for calculations, which relates to the partial pressure as $p (O_2) = \varphi (O_2) \cdot p / 100$. If the total pressure does not vary much from the normal pressure (1013.25 mbar), the following equations are used for calculations:

$U_{eq}/mV = 0.049606\ T/K \cdot \lg [\varphi (O_2)/20.93 \text{ vol\%}]$,

$\varphi (O_2)/\text{vol\%} = 20.93 \cdot 10^{(U_{eq}/mV)/ (0.049606 \cdot T/K)}$.

If a gas is present at the measuring electrode that mainly consists of reducing components, the chemical standard potentials do not drop out when the cell voltage equation is derived. In this case, a NERNST equation is obtained for reaction cells with concentration-independent terms, e.g. cells with hydrogen and water vapor at one of the electrodes and air at the other electrode the equation, valid in the range 400...1000 °C,

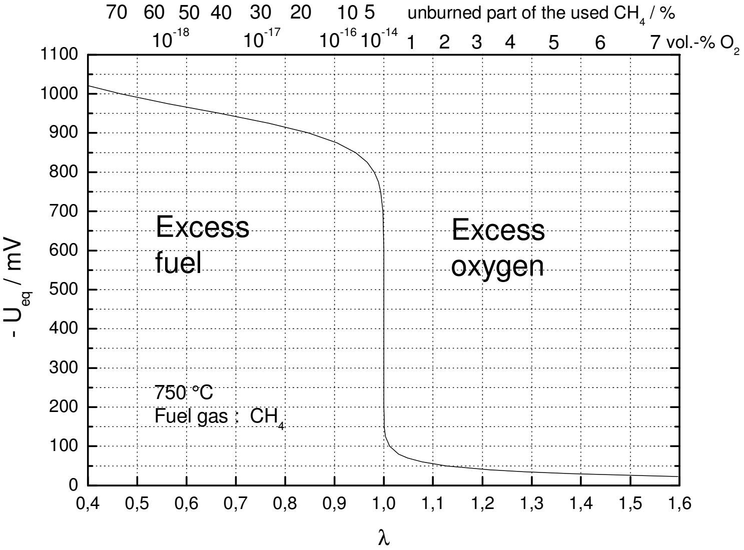
$U_{eq} (H_2, \text{H2O-air})/mV = -1280.6 + \{ 0.3165 + 0.0992 \cdot \lg [\varphi (H_2O)/\varphi (H_2)] \} \cdot T/K \ +/-1$.

In several technical processes the quotient $Q = \varphi (H_2O)/\varphi (H_2)$ has to be known. It can be calculated from this equation.

If the measuring electrode is the negative pole of the cell, the cell voltage is signed negatively.

In the diagram plotted below the dependence of the equilibrium cell voltage on λ, the oxygen concentration, and an excess CH_4 in methane combustion is shown.

The cell voltages calculated with the above-mentioned equations and presented in the diagram are only valid for isothermal cells with equal temperature at both electrodes. Such isothermal cells have been realized very carefully in the ZIROX products. Unlike these, the well-known lambda probes used in automobiles with catalysts in the exhaust tube are not isothermal. Their main purpose is indicating λ > or < 1, and they are less suitable for precise gas potentiometric analysis.


70 60 50 40 30 20 10 5 unburned part of the used CH4 / %
10-18 10-17 10-16 10-14 1 2 3 4 5 6 7 vol.-% O2
1100
1000
900
800
700
600
500
400
300
200
100
0
- Ueq / mV
Excess fuel
Excess oxygen
750 °C
Fuel gas : CH4
0,4 0,5 0,6 0,7 0,8 0,9 1,0 1,1 1,2 1,3 1,4 1,5 1,6
λ

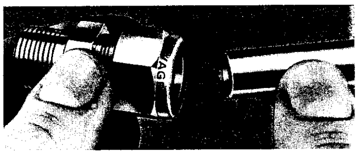
10.2 Mounting instructions for Swagelok®-fittings

Installation Instructions

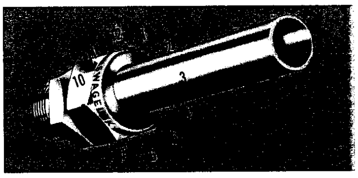
Swagelok tube fittings 1 in. or 25 mm and Under

Swagelok tube fittings come to you completely assembled, finger-tight and are ready for immediate use. Disassembly before use is unnecessary and can result in dirt or foreign material getting into fitting and causing leaks.

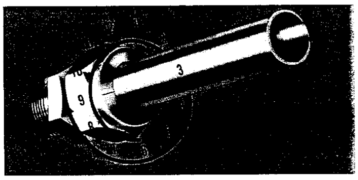
Swagelok tube fittings are installed in three (3) easy steps:



Step 1
Simply insert the tubing into the Swagelok tube fitting. ***Make sure that the tubing rests firmly on the shoulder of the fitting and that the nut is finger-tight.***



Step 2
Before tightening the Swagelok nut, scribe the nut at the 6 o'clock position.



Step 3
Hold the fitting body steady with a backup wrench and tighten the nut 1 1/4 turns.① Watch the scribe mark, make one complete revolution and continue to the 9 o'clock position.

By scribing the nut at the 6 o'clock position as it appears to you, there will be no doubt as to the starting position. When the nut is tightened 1 1/4 turns to the 9 o'clock position, you can easily see that the fitting has been properly tightened.

Use of the gap inspection gage (1 1/4 turns from finger-tight) ensures sufficient pull-up.

High Pressure Applications or High-Safety-Factor Systems

Due to variations in tubing diameters, a common starting point is desirable. Using a wrench, tighten the nut to SNUG position. Snug is determined by tightening the nut until the tubing will not rotate freely (by hand) in the fitting. (If tube rotation is not possible, tighten the nut approximately 1/8 turn from the finger-tight position.) At this point, scribe the nut at the 6 o'clock position and tighten the nut 1 1/4 turns.① The fitting will now hold pressures well above the rated working pressure of the tubing.

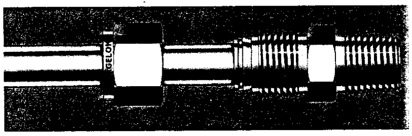
Note: A Swagelok Hydraulic Swaging Unit must be used for assembly of Swagelok tube fittings onto 1 1/4, 1 1/2, 2 in., 28, 30, 32, and 38 mm outside diameter steel and stainless steel tubing (see page 55).

①For 1/16, 1/8, 3/16 in., 2, 3, and 4 mm size tube fittings, only 3/4 turn from finger-tight is necessary.

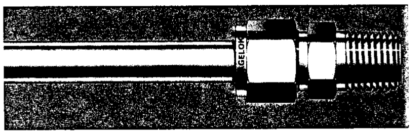
Retightening Instructions

Connections can be disconnected and retightened many times.
The same reliable leak-proof seal can be obtained every time the connection is remade.

1. Fitting shown in the disconnected position.

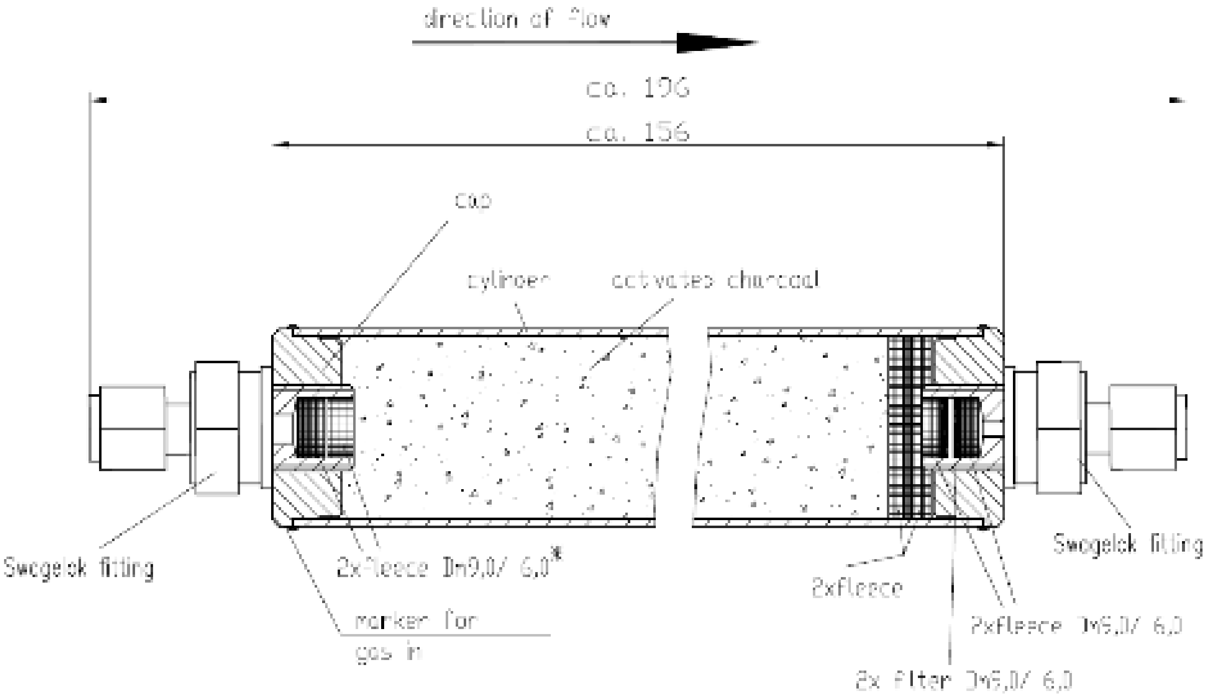


2. Insert tubing with preswaged ferrules into fitting body until front ferrule seats.



3. Tighten nut by hand. Rotate nut to the original position with a wrench. *An increase in resistance will be encountered at the original position.* Then tighten slightly with the wrench. Smaller tube sizes will take less tightening to reach the original position, while larger tube sizes will require more tightening. The wall thickness will also have an effect on tightening.

10.3 Activated carbon filter: description and application notes



10.3.1 Filter construction

The figure above shows the carbon filter. Two caps close a tube containing carbon. Both caps are welded into the tube. The Swagelok fittings have stoppers to keep the carbon inside. The gas way is protected against carbon particles with a pre-filter and a fine filter in the outlet of the carbon filter.

10.3.2 Application and operation of the filter

Organic components of the test gas (e.g. alcohols) are adsorbed by the carbon. After longer usage the cell voltage or the oxygen concentration can drop unexpectedly. This is a sign for saturation of the filter. The filter or the carbon filling must be changed.

10.3.3 Replacing

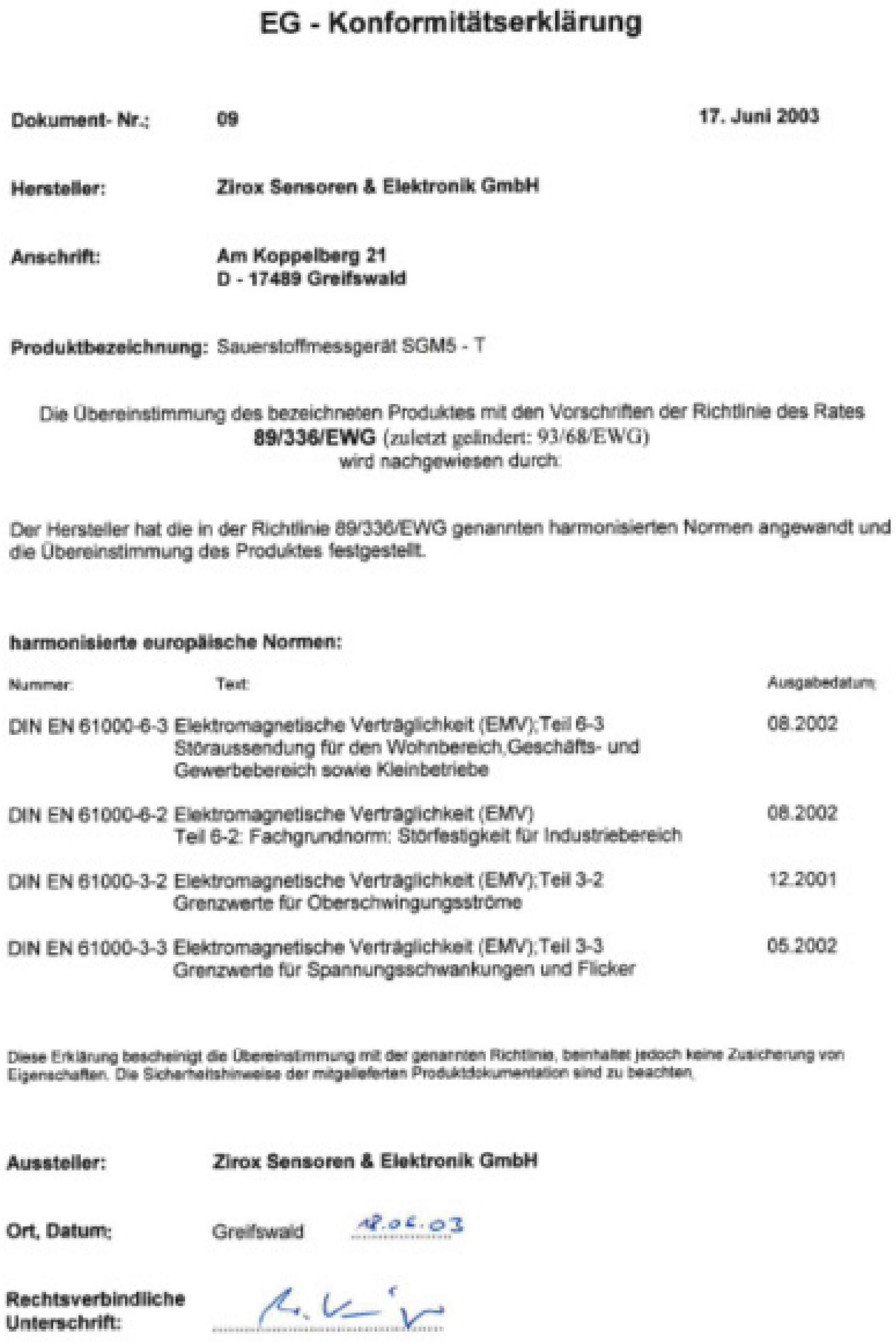
A saturated filter can be recycled by replacing the activated carbon filling only. For this purpose the carbon must be poured out after removing the Swagelok connection. Then new granulated carbon can be refilled into the container with a small funnel. The powder should be compressed by knocking a piece of wood against the filter housing. Finally, the removed Swagelok connection and the O-seal must be screwed onto the filter again.

Caution: Do not remove the closing stopper in the Swagelok fittings!

10.3.4 Technical data

Dimensions (diameter x length)	28 mm x 150 mm
Weight	Approx. 285 g
Volume	Approx. 100 ml
Duration of use	Depending on the components and the concentration of the adsorbed organic components e.g. approx. 1…3 months at raw gas from a fermenting tank (ZKG)
Carbon used	Granulated or pelletized, 1…3mm

10.4 Declaration of conformity



EG - Konformitätserklärung

Dokument- Nr.: 09 **17. Juni 2003**

Hersteller: **Zirox Sensoren & Elektronik GmbH**

Anschrift:
Am Koppelberg 21
D - 17489 Greifswald

Produktbezeichnung: Sauerstoffmessgerät SGM5 - T

Die Übereinstimmung des bezeichneten Produktes mit den Vorschriften der Richtlinie des Rates
89/336/EWG (zuletzt geändert: 93/68/EWG)
wird nachgewiesen durch:

Der Hersteller hat die in der Richtlinie 89/336/EWG genannten harmonisierten Normen angewandt und die Übereinstimmung des Produktes festgestellt.

harmonisierte europäische Normen:

Nummer:	Text:	Ausgabedatum:
DIN EN 61000-6-3	Elektromagnetische Verträglichkeit (EMV);Teil 6-3 Störaussendung für den Wohnbereich,Geschäfts- und Gewerbebereich sowie Kleinbetriebe	08.2002
DIN EN 61000-6-2	Elektromagnetische Verträglichkeit (EMV) Teil 6-2: Fachgrundnorm: Störfestigkeit für Industriebereich	08.2002
DIN EN 61000-3-2	Elektromagnetische Verträglichkeit (EMV);Teil 3-2 Grenzwerte für Oberschwingungsströme	12.2001
DIN EN 61000-3-3	Elektromagnetische Verträglichkeit (EMV);Teil 3-3 Grenzwerte für Spannungsschwankungen und Flicker	05.2002

Diese Erklärung bescheinigt die Übereinstimmung mit der genannten Richtlinie, beinhaltet jedoch keine Zusicherung von Eigenschaften. Die Sicherheitshinweise der mitgelieferten Produktdokumentation sind zu beachten.

Aussteller: **Zirox Sensoren & Elektronik GmbH**

Ort, Datum: Greifswald 18.06.03

Rechtsverbindliche Unterschrift:

10.5 Warranty conditions

ZIROX Sensoren & Elektronik GmbH warrants that the products manufactured and sold are free from manufacturing and material defects at the time of dispatch. In case of defects and faults within 12 months (probe) and 24 months (electronics assembly) respectively after dispatch, ZIROX will clear faults at its own option by repair or replacement. The purchaser must give prompt written notice to ZIROX. The purchaser is not entitled to claim other legal remedies based on this warranty.

For the ZIROX-Probes following warranty periods apply:

Working temperature up to 1200 °C: 12 month after
delivery Working temperature up to 1300 °C (high temperature probe): 6 month after
delivery

Working temperature up to 1400 °C (high temperature probe): 3 month after
delivery

ZIROX does not warrant supplied products which are subject to normal wear and tear (e.g. reference gas pump).

Corrosive gases and solid particles may cause damage and require repair or replacement due to normal wear and tear.

The contact of the products with explosive gas compounds, halogens in high concentrations and sulphuric gases (e.g. SO_2) is not permitted.

The contact of the products with siliconic or phosphoric compounds is not permitted either.

A connection of ZIROX and non-ZIROX products voids any warranty claims.

Warranty and warranty claims are only accepted if they are in accordance with the "General Sales and Delivery Conditions" of the manufacturer.

Warranty and liability claims for damage to persons and/or property are void if they are subject to the following:

- Normal wear and tear
- Improper use of the product
- Disregard of the manual's instructions
- Improper installation, initiation, operation and maintenance of the product
- Operation of the product without protective measures
- Unauthorized functional and technical modification of the product
- Dismantling of parts as well as installation of spare parts or additional units which are not delivered or permitted by the manufacturer
- Improper repairs or faulty operation
- External impact
- Acts of God

Attention: During installation of the equipment, the customer must ensure that all necessary supply lines are connected and the operating temperature of the probe is reached. Experience has shown that products installed but not in use may be damaged by the process or by external influence. ZIROX will not accept any responsibility for such damage.

11 Your own notes and remarks