1. Specifications

1.1 *Shape and Dimensions*

The accompanying technical drawing (No. 88MD-109C--*see attachment*) illustrates the fundamental design of the oxygen sensor.

1.2 *Characteristics*

During normal operating mode, the sensor's output voltage will range from 11.0 to 15.0mV under the following standard conditions:

a) standard atmospheric pressure
b) temperature at 25˚C ± 1˚C
c) relative humidity at 60% ± 5%

1.3 *Characteristic Data (typical values--see attachment)*

Fig. 1: Oxygen concentration versus output voltage characteristics
Fig. 2: Temperature versus output voltage characteristics
Fig. 3: Linearity of output voltage under accel. life test
Fig. 4: Long term stability of output voltage at room temperature

1.4 *Life Span*

The life span of the sensor is defined as the elapsed time period until the output voltage of the sensor falls to 70% or less than the initial output voltage of the sensor. These specifications apply under the following conditions:

a) standard atmospheric pressure
b) temperature of 25˚C ± 1˚C
c) relative humidity of 60% ± 5%

The life span of the sensor can be expressed by the following equation:

Life span = oxygen concentration level (%) x operational hours (h)
(at constant temperature of 20˚ ± 1˚C)

1.5 *Storage and Operating Temperature*

Storage temperature should be between -20˚C and +60˚C.

Operating temperature should be between 5˚C and 40˚C. This corresponds to the effective range of the internal temperature compensation circuit.

2. Handling Instructions

1) Do not expose the sensor to a temperature outside the range between -20˚C and +60˚C.

2) Whether in use or in storage, keep the sensor either horizontal or in a vertical position with the tip of the sensor (where the hexagonal nut is locked into place) pointing downwards only. This will prevent output signal fluctuations which could be caused if the cathode were to dry out.

3) Prevent condensation on the sensing element.

4) Do not subject the sensor to excessive shock or vibration.

5) The sensor must be connected to equipment which has an input impedance of 1000K ohms or higher.

6) The equipment to which the sensor is connected should not generate a counter-electromotive force, i.e. it must NOT charge the sensor.

7) Do not attempt to disassemble or repair the sensor.

3. Testing Procedures Prior to Shipment

KE-25 sensors are tested and passed by using the test procedures as shown in the attached Table 89T-027B.

4. Warranty

Figaro warrants that KE sensors, when used under normal conditions, will be free from defects in material and workmanship for a period of one (1) year from date of shipment. At its discretion, Figaro will repair or replace any sensor which is found to be defective in materials or workmanship while subjected to normal use and service during this warranty period. The company shall not be obliged to repair or replace any units found to be defective due to damage, unreasonable use, or which have been opened or otherwise physically altered. Sensors shall be warranted to meet the following conditions for a period of one year after the date of purchase from Figaro:

1) Va Test : 7.7mV ~ 15.0mV (KE-25)
2) Accuracy Test : $(V_a - V_0) / (V_{100} - V_0) = 0.21 \pm 0.02$
3) Vibration Test (directional alignment) : the sensor is rotated 270˚ once per second for 10 seconds, during which time Vair is recorded. From the original value, output voltage observed in this test should within be ±0.5mV for KE-25.

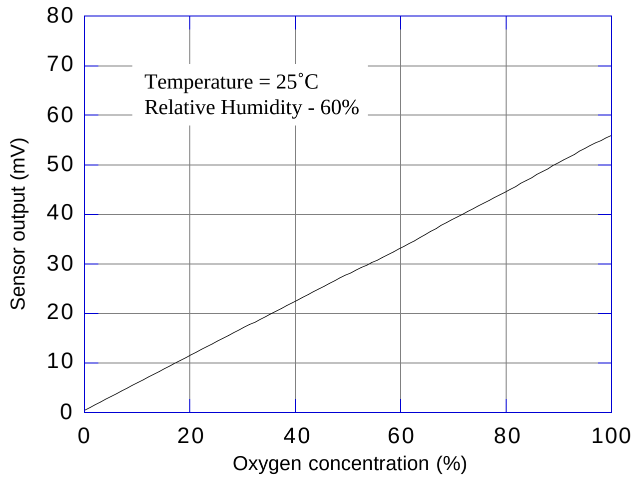

Fig. 1 - Oxygen concentration vs. output voltage characteristics of KE-25 (typical values)

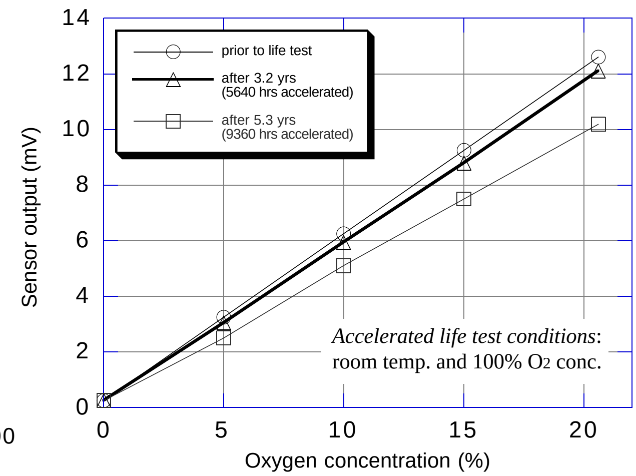

Fig. 3 - Linearity of KE-25 output voltage under accelerated life test (typical values)

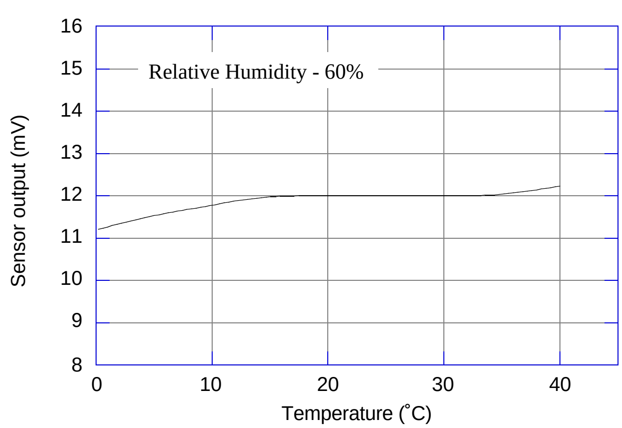

Fig. 2 - Temperature vs. output voltage characteristics of KE-25 (typical values)

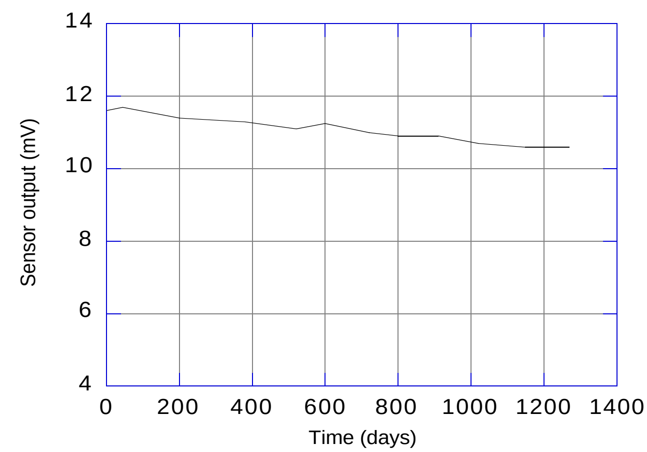

Fig. 4 - Long term stability of KE-25 output voltage at room temperature (typical values)

Table 89T-027B
Testing procedure for KE-25

Test Items	Test Method	Acceptance Std
Output voltage	Output voltage (V_a) in normal air measured by voltmeter	V_a = 11.0~15.0mV at 25˚C/60%RH
Linearity	Output voltage in 0% O_2 (V_0) and in 100% O_2 (V_{100}) as measured by voltmeter	$V_0 \leq 0.5$mV V_{100} = 50.0~75.0mV
Temperature characteristics	Output voltage at 40˚C (V_H) and at 5˚C (V_L) measured by voltmeter	V_H/V_a = 0.91 ~ 1.09 V_L/V_a = 0.91 ~ 1.09
Accuracy	Calc. by V_0, V_{100}, and V_a	$(V_a-V_0)/(V_{100}-V_0)$ = 0.21±0.02
Casings	Visual inspection	Casing damage free
Dimensions	Outer dimensions measured by side calipers & scales	Dimensions meet spec. in drawing 88MD-109C

FIGARO

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Technical Information for GS Oxygen Sensor KE-Series

The GS Oxygen Sensor KE-Series is a unique galvanic cell type oxygen sensor which provides a linear output voltage signal relative to percent oxygen present in a particular atmosphere. The sensor features long life expectancy and excellent chemical durability, making it ideal for oxygen monitoring.

1. Introduction

The GS Oxygen Sensor KE series (KE-25 and KE-50) is a unique galvanic cell type oxygen sensor which was developed in Japan in 1985. Its most notable features are a long life expectancy and excellent chemical durability. The KE series oxygen sensor is ideal to meet the ever-increasing demand for oxygen monitoring in various fields such as combustion gas monitoring, the biochemical field, medical applications, domestic combustion appliances, etc.

2. Basic Technical Information

The KE series sensor is a lead-oxygen battery which incorporates a lead anode, an oxygen cathode made of gold, and a weak acid electrolyte. Oxygen molecules enter the electrochemical cell through a non-porous fluor carbonide membrane, diffuse in the acid electrolyte, and are reduced at the gold electrode. The current which flows between the electrodes is proportional to the oxygen concentration in the gas mixture being measured. The terminal voltages across the thermistor (for temperature compensation) and resistor are read as a signal, with the change in output voltages representing the change in oxygen concentration.

Both the KE-25 and the KE-50 sensors are based on identical design and performance principles. The basic difference between these two models is in the thickness of the fluor carbonide membrane. This affects the diffusion speed of oxygen molecules and, as a result, the response speed and life of the sensor. Each model shows basically the same performance in the various conditions described in the technical data, e.g. influence by other gases, pressure dependency, etc.

NOTES:

* A small volume air bubble is contained in the sensor body in order to compensate for internal influence from pressure changes.
* A sponge disc is placed at the end of the sensor body to keep the gold electrode wet.
* A gold film (cathode) and a fluor carbonide membrane are held by the o-ring and plastic disc under sufficient pressure as provided by tightening the plastic top.
* The electrolyte is primarily composed of 'acetic acid' with a pH of approximately 6.

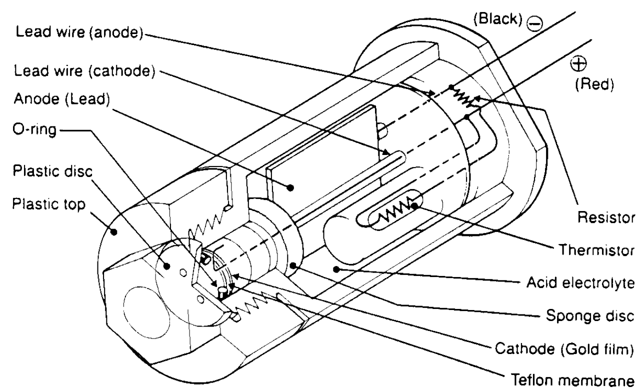

Fig. 1 - Structure of KE-25/KE-50

3. Specifications of the KE Series

3.1 Manufacturing code number

The manufacturing code number shown on the side of the sensor body indicates the manufacturing Year/Month/Lot No. (since September 1990).

Example:	95	09	01
	⇑	⇑	⇑
	Year	Month	Lot No.
	1995	*Sept.*	*01*

3.2 *Sensitivity characteristics (see Figs. 2-1 & 2-2)*

1) Output signal in air (Va) is specified at certain ranges for each model.

2) The coefficient of output voltage changes from 0% to 100% oxygen has been tested and confirmed. The range of this value $(Va-V_0)/(V_{100}-V_0)$ is 0.21 ± 0.02.

NOTE: V_0 = output voltage at 0% of O_2
V_{100} = output voltage at 100% of O_2

3) The accuracy (in full scale) of the KE-25 is ± 1% and for KE-50 is ± 2%. When calibrated at both 100% and at 0% of O_2, the measured values at 21% of O_2 shall be within 21% ± 1% for KE-25 and at 21% ± 2% for KE-50.

3.3 *Distribution of offset voltage* (*V_0 = output voltage at 0% O_2*)

Theoretically, GS oxygen sensors have a small current at 0% of O_2 which is referred to as offset voltage. This

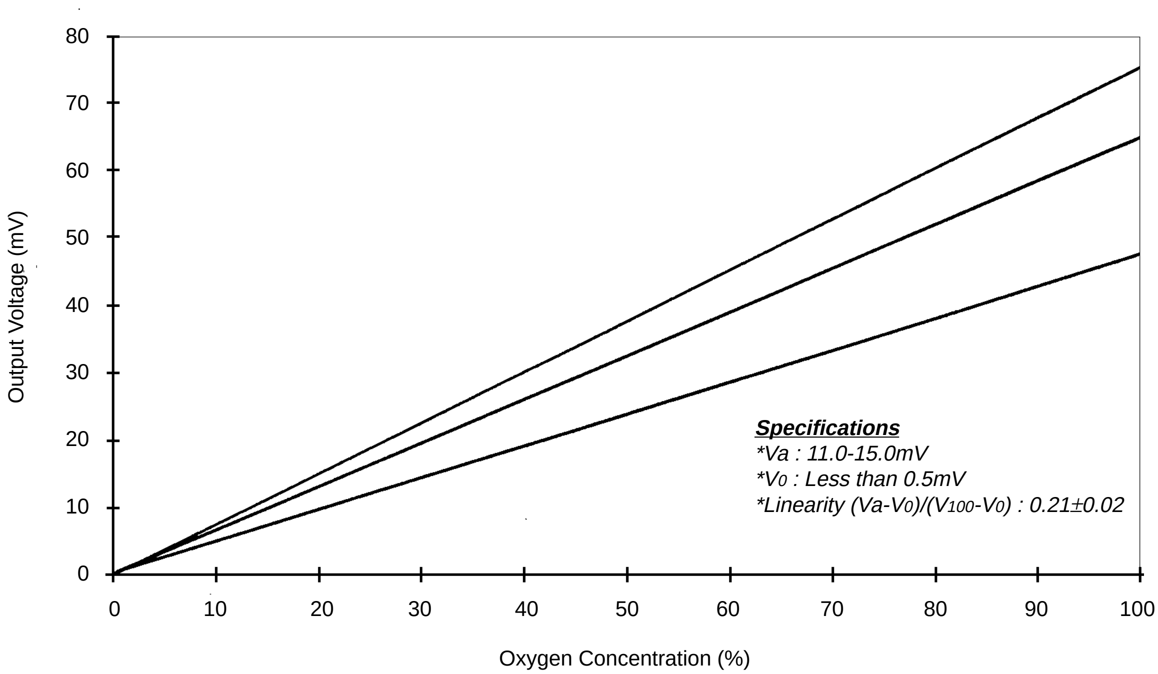

Fig. 2-1 - KE-25 sensitivity characteristics and distribution of offset voltage

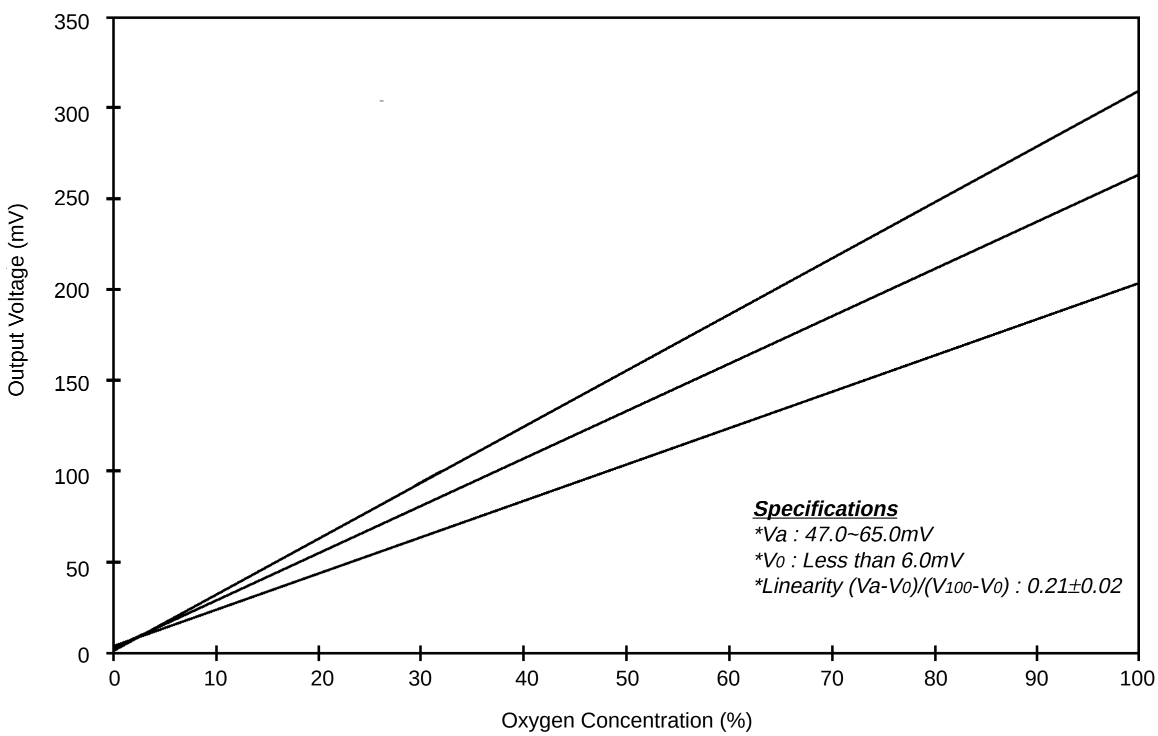

Fig. 2-2 - KE-50 sensitivity characteristics and distribution of offset voltage is due to the dissolved oxygen in the electrolyte reacting with the electrode, producing a current. As long as the sensors are used in normal air conditions, this current is produced and remains stable.

3.4 *Life expectancy and long term characteristics*

1) Life expectancy
The life expectancy of the KE oxygen sensor is expressed in %-hours as follows:

[Oxygen Concentration (%)] x [Exposure Time (hours)]

Accordingly, the life of KE-50 is approximately 1,800,000 %-hours, and the KE-25 is 900,000 %-hours. *The end of life for KE sensors is specified as the point at which output voltage is reduced to 70% from the initial output voltage of the sensor.* These facts indicate that the expected life time in ambient conditions (21% O_2 at 20˚C) is 10 years for KE-50 and 5 years for KE-25.

2) Relationship between expected life time and storage temperature
A correlation exists between the sensor's life time and its storage temperature—the life time becomes longer as the storage temperature becomes lower. The discharging current changes two times per 20˚C, so the life expectancy becomes two times longer (shorter) as the storage temperature is reduced (increased) by 20˚C.

3) Long term stability and warranty
The KE-25 and KE-50 are warranted for one year after the date of shipment. When these sensors are used in normal air without any incidence of improper use, both KE-25 and KE-50 show good performance in long term characteristics as illustrated in Figs. 3-1 and 3-2. (Refer to Sections 1.2 and 1.3 of *Specifications for Oxygen Sensor KE-25/KE-50* dated 12/19/89 for details of what is considered "improper usage".)

Please note that there are various factors which may influence the life time of KE oxygen sensors in actual use and that their life span can be variable.

3.5 *Storage temperature*

1) The absolute minimum storage temperature for the sensor is -20˚C. Below this temperature, the electrolyte will freeze. KE sensors are not damaged by the freezing of the electrolyte, and they can be used again after the electrolyte melts.

2) The specified maximum storage temperature is 60˚C. This is a result of the temperature limitation of ABS resin, the material which is used to make the sensor's body. Storage at 70˚C would be acceptable as long as it is not continuous.

3) It is not required that the sensor be stored in low temperatures (i.e., in refrigerators, etc.) because the sensor's life is long. However, storing the sensor at lower temperatures is advantageous for extending the life of the sensor for the reason explained in Section 3.4 above.

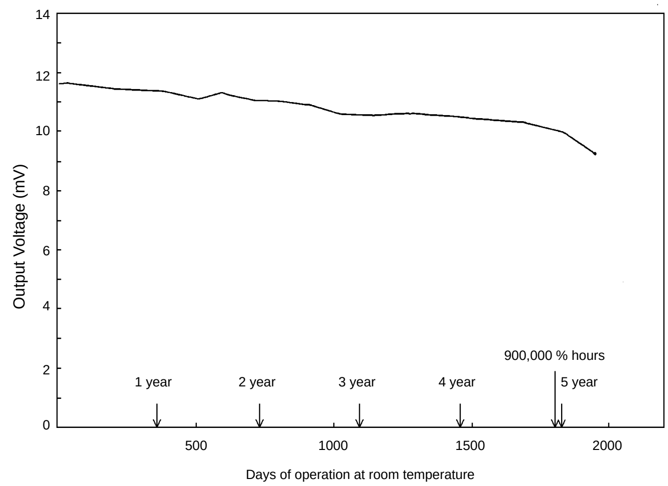

Fig. 3-1 - KE-25 long term stability

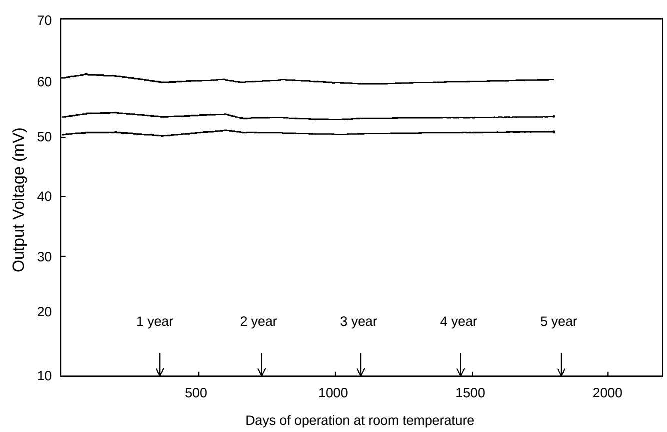

Fig. 3-2 - KE-50 long term stability

4. **Technical Information**

4.1 *Influence from various gases*

An excellent advantage of KE oxygen sensors is that the sensor is unaffected by CO, H_2, and various acidic gases such as CO_2, H_2S, NOx, SOx, etc.

Influence Level	Gas Type
Unaffected	CO_2,CO,H_2S,SO_2,H_2, cigarette smoke (a) Cl_2,CFC's CH_4 (b) Negative ions (Cl^-,etc.), N_2, argon, etc.
Influence at high concentrations	NH_3 (c)
Influenced	Ozone (d)

NOTES:

a) See *Technical Data: Evaluation Test Data of KE-50*.
b) KE oxygen sensors can be used in the presence of a 50% level of CH_4 in the air.
c) KE oxygen sensors are not affected by the presence of low concentrations of ammonia in a range from several ppm to several ten ppm. However, the life span of the sensor may be shortened if it is exposed to a higher concentration of ammonia.
d) The sensitivity of the KE oxygen sensor can be affected by ozone. In addition, materials used in the sensor such as the o-ring and plastics may be damaged by ozone.

4.2 *Humidity dependency*

Figure 4 shows an example of humidity dependency for KE-25 with Va = 12mV. The y-axis on the left shows output voltage changes and the y-axis on the right shows the changes in O_2 readings when the sensor is calibrated at 21% of O_2 with 0% RH. The sensor itself is not influenced by humidity, but its output voltage may show some variation to the extent that O_2 is displaced by humidity.

4.3 *Effects of pressure change*

1) Pressure dependency

KE series sensors have a proportional dependency to ambient pressure changes. The equation to express this relationship is as follows:

$$V\ out = V\ out\ (standard) \times \frac{P}{1013}$$

V out = Output Voltage
V out (std) = Output Voltage at 1013 mb
P = Atmospheric Pressure (mb)

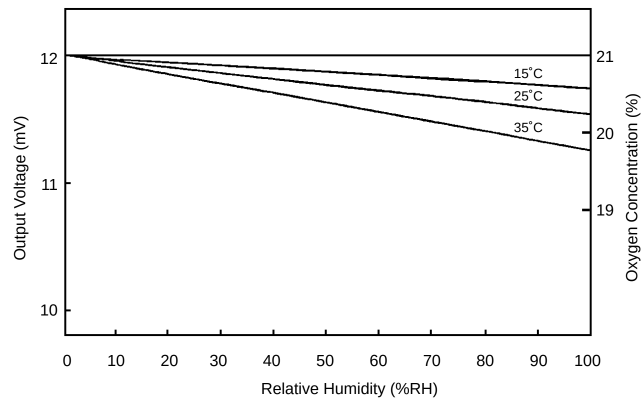

Fig. 4 - KE-25 effect of humidity on output voltage

2) Operating pressure ranges

KE oxygen sensors are usable in a range from 500 hPa to 1520 hPa (approximately 0.5 atm to 1.5 atm) continuously, and at 2 atm for a short period of time. Performance of the sensor under continuous exposure to 2 atm has not been confirmed.

3) Response to atmospheric pressure changes

Figure 5 shows the response to an alternating atmospheric pressure change between 1 atm and 1.5 atm (3 minute periods at each pressure). As shown in this figure, output voltage of the KE sensor responds to pressure changes quickly, and output voltage has not been changed over a span of 3650 cycles.

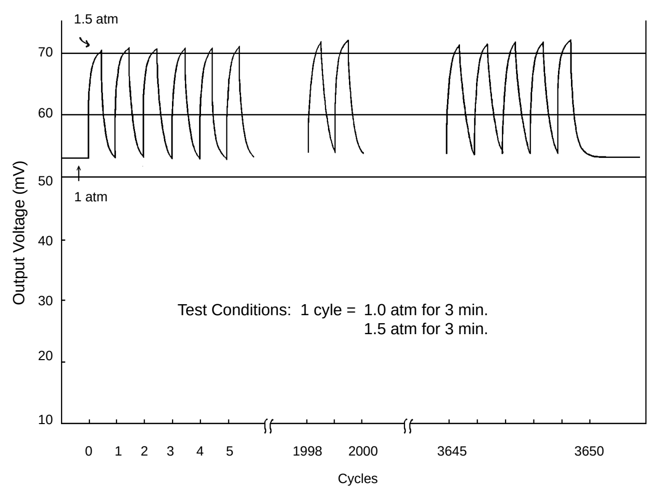

Fig. 5 - KE-50 response of output voltage to ambient pressure changes

4.4 *Temperature dependency*

1) *Standard sensors with built-in temperature compensation circuit*

The standard KE sensor has a built-in temperature compensation circuit which uses a thermistor that is mounted inside the sensor's body (*see Fig. 1*). The temperature dependency of the KE series with this built-in compensation circuit is shown in Figs. 6-1 and 6-2.

If users require a smaller temperature dependency in this range, or if the operating temperature range for an application is wider than this range, some additional compensation method is necessary.

2) *External Temperature Compensation Circuit*

The KE sensor may show some transient characteristics if the ambient temperature changes very widely and quickly. This is caused by the difference in response speed to temperature changes between the sensor current and the resistance of the thermistor. For applications that require a quicker response to temperature changes, a sensor with an external thermistor is also available (please inquire). The connection diagram is shown in Fig. 7.

4.5 *Consumption of oxygen by the sensor*

KE sensors consume a small amount of oxygen during detection. It is recommended that these sensors be used under conditions where air exchange is greater than 2~3 ml/minute.

5. General Notices

5.1 *General handling instructions*

1) General handling instructions are described in the specifications of KE-25 and KE-50.

2) Disassembling or repair of the sensor will result in a change of sensitivity characteristics and therefore should be avoided. The reason for such a change is related to the sensor's structure. The most important factor in determining sensitivity is the condition of the cathode which is determined by affixing the F.E.P. membrane with a suitable pressure via tightening the plastic top. Loosening of the plastic top will change the internal pressure and change the sensor's sensitivity.

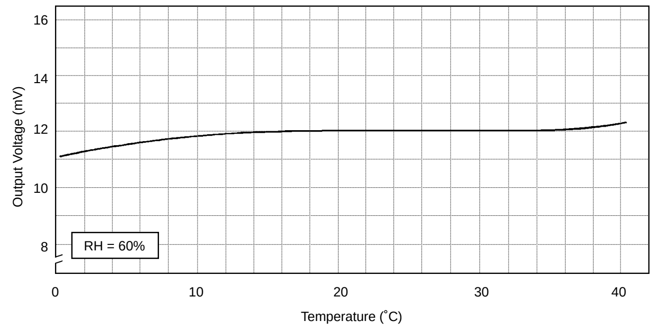

Fig. 6-1 - KE-25 temperature dependency of output voltage

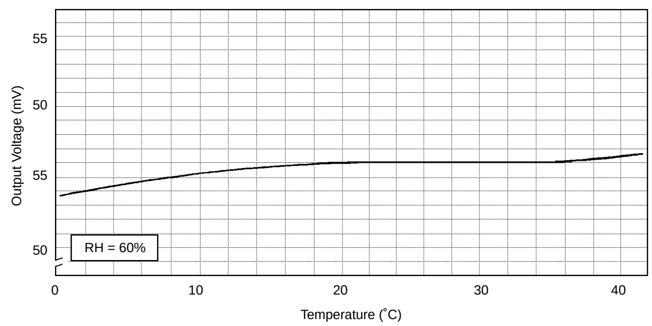

Fig. 6-2 - KE-50 temperature dependency of output voltage

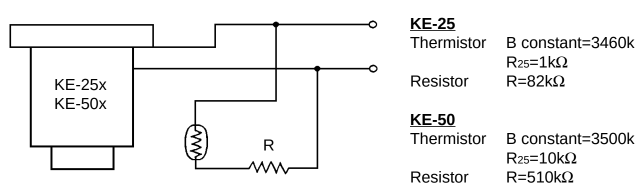

Fig. 7 - External temperature compensation circuit

5.2 *Shock and vibration*

1) The KE sensor is resistant to 2.7 G of shock.

2) Vibration is a possible factor which may influence the sensitivity characteristics of the sensor, and as such should be avoided in actual use. Vibration may cause a change in the condition of the membrane as described above in *Section 5.1*.

5.3 *Direction of the sensor*

Using the sensor in the normal position (plastic top located down) is recommended in order to avoid any potential for output signal changes caused by the position of the sensor. This situation may occur for the following reasons:

* KE sensors have a small air bubble inside their body, used to counter the effects of ambient pressure changes. A sponge disc is positioned so as to keep the cathode wet at all times, even if the sensor is used in an 'upside down' position.
* The probability of output voltage changing is very small, though theoretically possible, since the cathode would dry up only if the position of the sponge disc is not suitable and if the sensor is kept in the 'upside down' position for an extended period of time.

There is no special temperature dependency related to direction of the sensor.

6. Special Requirements

6.1 *Sensor design*

1) *Sensor without flange at the bottom*
KE oxygen sensors without the bottom flange are available (please inquire).

2) *Sensor with round-shaped top with o-ring*
This type of sensor is suitable for insertion into a pipe which has an inside diameter of 16mm (please inquire). Refer to the attached drawing No. 89MD-1311.

3) *Modification of sensor design*
Please note that the price of modified sensors will be higher than that of standard products. The amount of price increase will depend on the nature of the required design and the quantity to be ordered.

6.2 *Specifications*

Please inquire to Figaro regarding any special requirements concerning the specifications for KE sensors. Figaro will make every effort to find the most suitable ways to meet your requirements.

7. Warranty

Figaro warrants that KE oxygen sensors, when used under normal conditions, will be free from defects in material and workmanship for a period of one (1) year from the date of shipment. At its discretion, Figaro will repair or replace any sensor which is found to be defective in materials or workmanship while subjected to normal use and service during this warranty period. The company shall not be obliged to repair or replace any units which are found to be defective due to damage, unreasonable use, or which have been opened or otherwise physically altered. Sensors shall be warranted to meet the following conditions for a period of one year after the date of purchase from Figaro:

1) Va Test - 7.7mV ~ 15.0mV (KE-25)
32.9mV ~ 65.0mV (KE-50)
2) Linearity Test - $(Va - V_0) / (V_{100} - V_0) = 0.21 \pm 0.02$
3) Vibration Test (directional alignment) - the sensor is rotated 270˚ once per second for 10 seconds, during which time Vair is recorded. From the original value, output voltage observed in this test should within be ±0.5mV for KE-25 and ±2.0mV for KE-50.

Guidelines for GS Oxygen Sensors

Characteristics	KE-25	KE-50	Related Pages
1. Detection Range	O_2 : 0-100%	O_2 : 0-100%	Page 2
2. Accuracy	± 1%	± 2%	Page 2
3. Response Time (90%)	approx. 12 sec.	approx 60 sec.	
4. Life (in air at 20˚C)	900,000 %-hours (approx. 5 years)	1,800,000 %-hours (approx. 10 years)	Page 4
	Life will be variable depending on exposed oxygen concentration, operation/storage temperatures, etc.		
5. Principle	Acid electrolyte (acetic acid: pH = approx. 6) Use of F.E.P. (fluor carbonide) membrane for O_2 diffusion Built-in temperature compensation circuit		Page 2
6. Specifications	Output voltage in air Linearity (tested and selected at 0% and 100% of O_2), etc.		Page 3
7. Operating Temperature	Standard: 5˚C to 40˚C (effective range of internal temperature compensation circuit) * Application of an external thermistor is possible		Page 6
8. Storage Temperature	Standard: -20˚C to +60˚C * For a short period, sensor can be stored at +70˚C		Page 4
9. Influence from Other Gases	Virtually no inluence from CO_2, SO_2, H_2S, H_2, CO, NO_x, etc. Possible influence from high concentrations of amnmonia Possible influence by ozone		Page 5
10. Effects of Air Pressure	Continuous use in pressure range from 0.5 atm to 1.5 atm (for a short period of time, at 2.0 atm) Output voltage changes in proportion to ambient pressure changes Good repeatability during cyclical pressure changes		Page 5
11. Shock and Vibration	Resistant to 2.7G Strong vibration should be avoided		Page 6
12. Required Volume of Sample Gas	minimum 2-3ml/min. (approx.)		Page 6