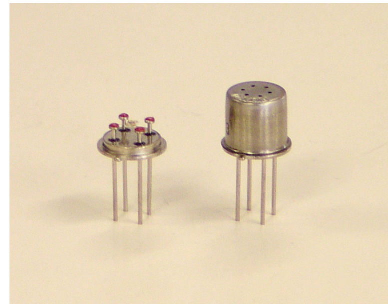
Technical Information for Air Quality Control Sensors

FIGARO

an ISO9001 company

The Figaro 2600 series is a new type thick film metal oxide semiconductor, screen printed gas sensor which offers miniaturization and lower power consumption. The TGS2600 displays high selectivity and sensitivity to low concentrations of various air contaminants such as those found in cigarette smoke.



See also Technical Brochure 'Technical Information on Usage of TGS Sensors for Toxic and Explosive Gas Leak Detectors'.

IMPORTANT NOTE: OPERATING CONDITIONS IN WHICH FIGARO SENSORS ARE USED WILL VARY WITH EACH CUSTOMER'S SPECIFIC APPLICATIONS. FIGARO STRONGLY RECOMMENDS CONSULTING OUR TECHNICAL STAFF BEFORE DEPLOYING FIGARO SENSORS IN YOUR APPLICATION AND, IN PARTICULAR, WHEN CUSTOMER'S TARGET GASES ARE NOT LISTED HEREIN. FIGARO CANNOT ASSUME ANY RESPONSIBILITY FOR ANY USE OF ITS SENSORS IN A PRODUCT OR APPLICATION FOR WHICH SENSOR HAS NOT BEEN SPECIFICALLY TESTED BY FIGARO.

1. Specifications

1-1 *Features*

* High selectivity to low gas concentrations
* Low power consumption
* Small size
* Long life

1-2 *Applications*

* Air cleaners for indoor air cleaners
* Air cleaners for vehicles
* Air quality monitors

1-3 *Structure*

Figure 1 shows the structure of TGS2600. Using thick film techniques, the sensor material is printed on electrodes (noble metal) which have been printed onto an alumina substrate. The main sensing material of the sensor element is tin dioxide (SnO_2). One electrode is connected to pin No.2 and the other is connected to pin No.3. An RuO_2 heater printed onto the reverse side of the substrate and connected to pins No.1 and No.4 heats the sensing material.

Lead wires are Pt-W and connected to sensor pins which are made of Ni-plated Ni-Fe 50%.

The sensor base is made of Ni-plated steel. The sensor cap is made of stainless steel and contains 6 pin holes on the sensor's top.

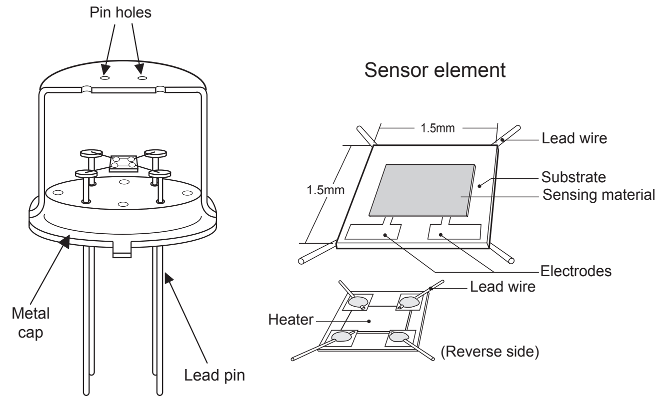


Fig. 1 - Sensor structure

1-4 *Basic measuring circuit*

Figure 2 shows the basic measuring circuit. Circuit voltage (Vc) is applied across the sensor element which has a resistance (Rs) between the sensor's two electrodes and the load resistor (RL) connected in series. DC voltage is always required for the circuit voltage, and the polarity shown in Fig. 2 **must** be maintained. The sensor signal (VRL) is measured indirectly as a change in voltage across the RL. The Rs is obtained from the formula shown at the right.

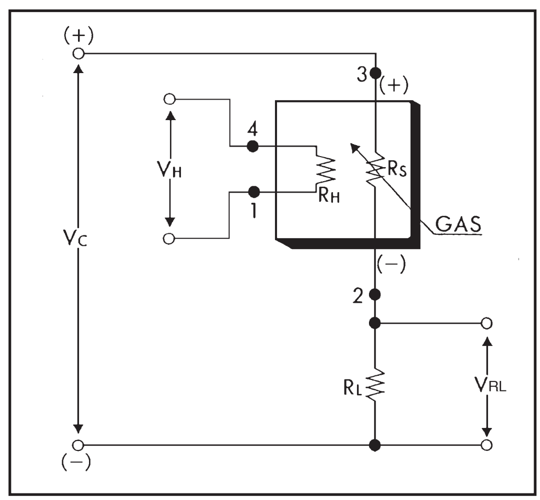


Fig. 2 - Basic measuring circuit

NOTE: In the case of VH, there is no polarity, so pins 1 and 4 can be considered interchangeable. However, in the case of VC, when used with DC power, pins 2 and 3 must be used as shown in the Figure above.

$$Rs = \frac{Vc - V_{out}}{V_{out}} \times R_L$$

Formula to determine Rs

1-5 *Circuit & operating conditions*

The ratings shown below should be maintained at all times to insure stable sensor performance:

Item	Specification
Circuit voltage (V_C)	5.0V ± 0.2V DC
Heater voltage (V_H)	5.0V ± 0.2V DC/AC
Heater resistance (room temp)	83Ω (typical)
Load resistance (R_L)	variable (0.45kΩ min.)
Sensor power dissipation (P_S)	≤15mW
Operating & storage temperature	-10˚C ~ +50˚C
Optimal detection concentration	1 ~ 30ppm

1-6 *Specifications* NOTE 1

Item	Specification
Sensor resistance (air)	10kΩ ~ 90kΩ
Sensor resistance gradient (β)	0.3 ~ 0.6
β = Rs(10ppm hydrogen)/Rs(air)	
Heater current (R_H)	42 ± 4mA
Heater power consumption (P_H)	210mW (typical)

NOTE 1: Sensitivity characteristics are obtained under the following standard test conditions:

(Standard test conditions)
Temperature and humidity: 20 ± 2˚C, 65 ± 5% RH
Circuit conditions: V_c = 5.0±0.05V DC
V_H = 5.0±0.05V DC
R_L = 10.0kΩ ± 1%
Preheating period: 7 days or more under standard circuit conditions.

All sensor characteristics shown in this brochure represent typical characteristics. Actual characteristics vary from sensor to sensor and from production lot to production lot. The only characteristics warranted are those shown in the Specification table above.

1-7 *Dimensions*

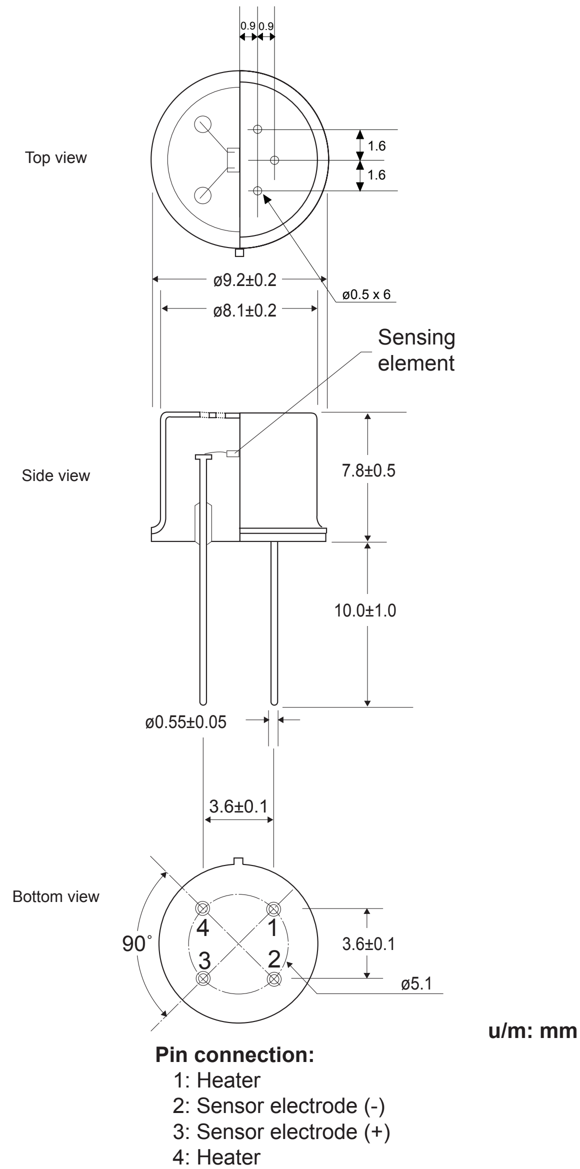


Fig. 3 - Sensor dimensions

Mechanical Strength:

The sensor shall have no abnormal findings in its structure and shall satisfy the above electrical specifications after the following performance tests:

Withdrawal Force - withstand force of 5kg in each direction
Vibration - frequency-1000c/min., total amplitude-4mm, duration-one hour, direction-vertical
Shock - acceleration-100G, repeated 5 times

2. Basic Sensitivity Characteristics

2-1 *Sensitivity to various gases*

Figure 4 shows the relative sensitivity of TGS2600 to various gases. The Y-axis shows the ratio of the sensor resistance in various gases (Rs) to the sensor resistance in clean air (Ro) taken at standard test conditions of 20°C/65%RH.

Figure 5 shows the relative sensitivity of TGS2600 to various gases in cigarette smoke. The Y-axis shows the ratio of the sensor resistance in cigarette smoke (Rs) to the sensor resistance in clean air (Ro) taken at standard test conditions of 20°C/65%RH. This data was taken in a 20m^3 room with cigarettes placed on a flat surface. The burning time for one cigarette was approximately 8 minutes. (*Note: Generally, the activation point for an air cleaner would be around Rs/Ro=0.85, while the Rs/Ro for just one cigarette is as low as 0.65, making this sensor ideal for air cleaner application*).

This data shows that TGS2600 has good sensitivity to low concentrations of air contaminants, including those found in cigarette smoke.

<u>**NOTE**</u>:
All sensor characteristics in this technical brochure represent typical sensor characteristics.

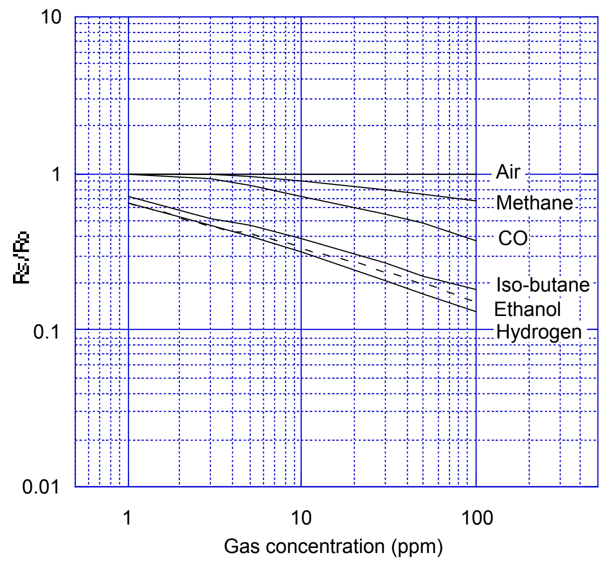


Fig. 4 - Sensitivity to various gases (Rs/Ro)

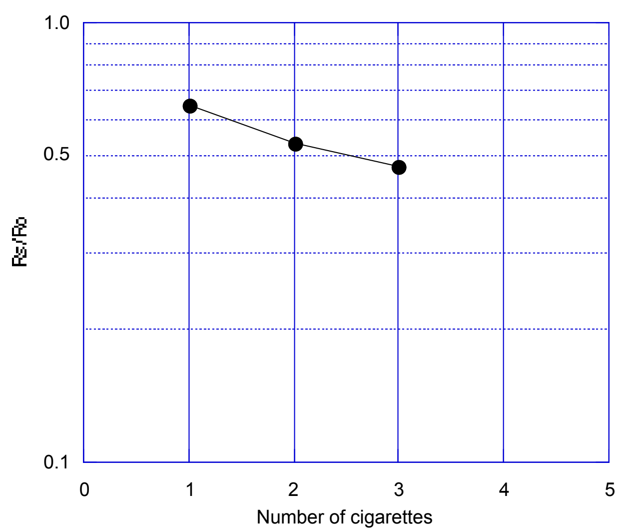


Fig. 5 - Sensitivity to cigarette smoke (Rs/Ro)

2-2 *Temperature and humidity dependency*

Figure 6 shows the temperature and humidity dependency of TGS2600 in clean air. The Y-axis shows the ratio of sensor resistance in clean air under various atmospheric conditions (Rs) to the sensor resistance in clean air at 20˚C/65%RH (Ro).

RH / (˚C)	40%RH	65%RH	85%RH	100%RH
-10				2.35
0				1.60
10	1.61	1.42	1.25	
20	1.30	1.00	0.93	
30	0.99	0.80	0.70	
40	0.78	0.61	0.54	
50	0.63	0.48	0.43	

Table 1 - Temperature and humidity dependency
(typical values of Rs/Ro for Fig. 6)

Table 1 shows a table of values of the sensor's resistance ratio (Rs/Ro) under the same conditions as those used to generate Figure 6.

Figure 7 shows the temperature and humidity dependency of TGS2600 in hydrogen. The Y-axis shows the ratio of sensor resistance in 10ppm of hydrogen under various atmospheric conditions (Rs) to the sensor resistance in clean air under the same atmospheric conditions (Ro).

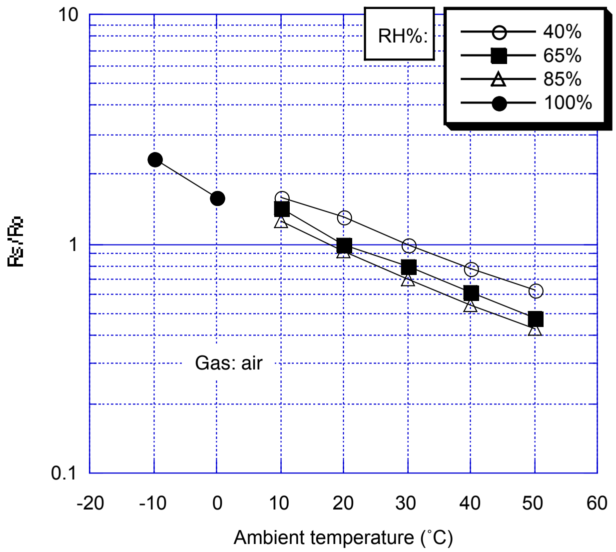


Fig. 6 - Temperature and humidity dependency (Rs/Ro)
in clean air

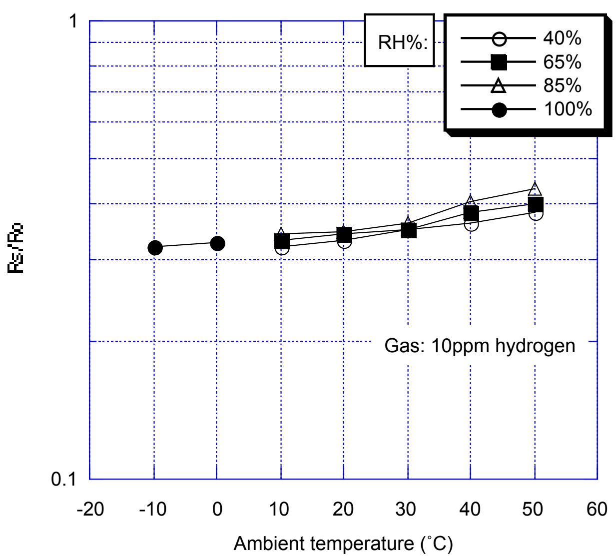


Fig. 7 - Temperature and humidity dependency (Rs/Ro)
in 10ppm of hydrogen

Figure 8 shows the temperature and humidity dependency of TGS2600 in ethanol (used as a representative gas for VOCs to which the sensor is likely to respond). The Y-axis shows the ratio of sensor resistance in 30ppm of ethanol under various atmospheric conditions (Rs) to the sensor resistance in clean air under the same atmospheric conditions (Ro).

This section demonstrates that, when used in the range of 10˚C~50˚C, sensitivity in air (Fig. 6) shows temperature dependency, but sensitivity in gas (Figs. 7 & 8) is relatively unaffected by temperature. As a result, temperature compensation for the sensor is not required, although is a greater accuracy is desired, temperature compensation for air values can be done.

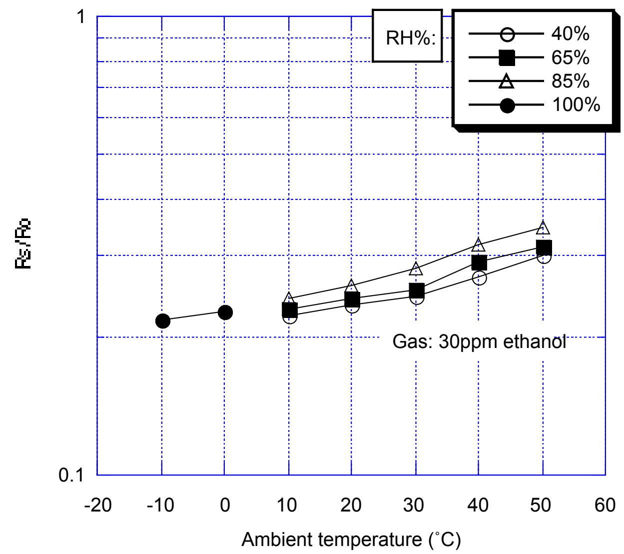


Fig. 8 - Temperature and humidity dependency (Rs/Ro) in 300ppm of ethanol

2-3 *Heater voltage dependency*

Figure 9 shows the change of the sensor resistance ratio in clean air according to variations in the heater voltage (VH). The Y-axis shows the ratio of sensor resistance in clean air at various heater voltages (Rs) compared to sensor resistance in clean air at VH=5.0V (Ro).

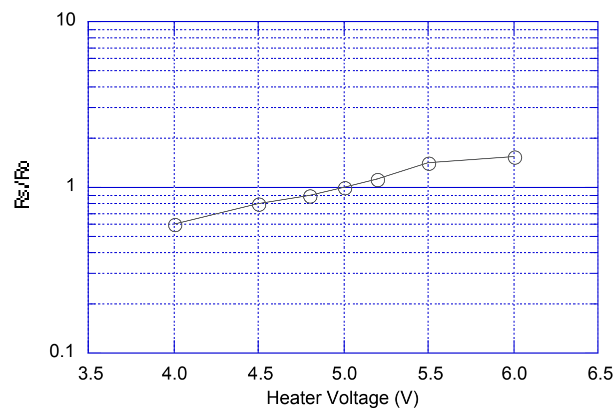


Fig. 9 - Heater voltage dependency in clean air

Figure 10 shows the change of the sensor resistance ratio in hydrogen and ethanol according to variations in the heater voltage (VH). The Y-axis shows the ratio of sensor resistance in gases at various heater voltages (Rs) compared to sensor resistance in clean air at the same heater voltage (Ro).

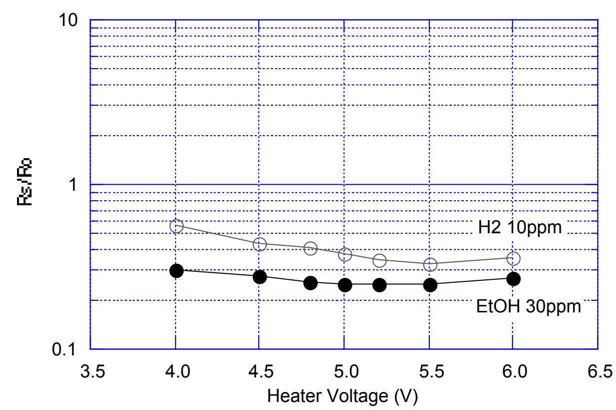


Fig. 10 - Heater voltage dependency in various gases

Note that 5.0V as a heater voltage must be maintained because variance in applied heater voltage will cause the sensor's characteristics to be changed from the typical characteristics shown in this brochure.

2-4 *Gas response*

Figure 11 shows the response pattern of the sensor when inserted into and later removed from 10ppm of hydrogen after a 3 minute period. The Y-axis shows the ratio of sensor resistance over time (Rs) compared with sensor resistance in clean air just prior to insertion into hydrogen (Ro).

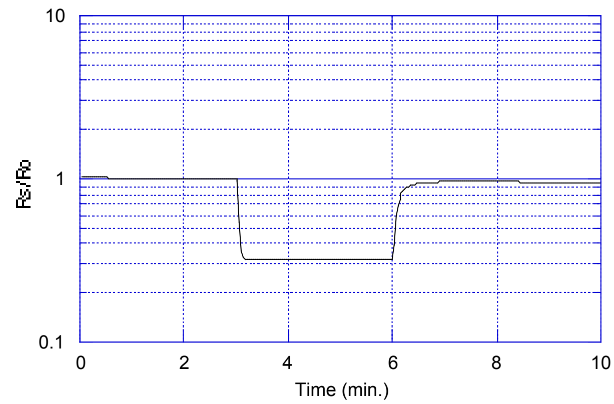


Fig. 11 - Gas response to hydrogen

Figure 12 shows the response pattern of the sensor when inserted into and later removed from 30ppm of ethanol after a 3 minute period. The Y-axis shows the ratio of sensor resistance over time (Rs) compared with sensor resistance in clean air just prior to insertion into ethanol (Ro).

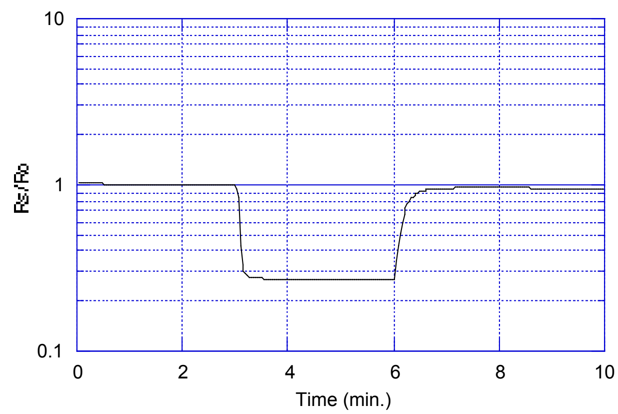


Fig. 12 - Gas response to ethanol

As these charts display, the sensor's response speed to the presence of gas is extremely quick, and when removed from gas, the sensor will recover back to its original value in a short period of time.

Figure 13 shows the response pattern of the sensor to the various gases found in cigarette smoke. The Y-axis shows the ratio of sensor resistance over time (Rs) compared with sensor resistance after 1 minute in clean air (Ro). This data was taken in a 20m^3 room with cigarettes placed on a flat surface. The burning time for one cigarette was approximately 8 minutes.

This test consisted of the following sequence:

0- 1 min.: clean air (20°C/65%RH)
1- 9 min.: first cigarette burning
9-14 min.: no ventilation
14-22 min.: second cigarette burning
22-27 min.: no ventilation
27-35 min.: third cigarette burning

(*Note: Generally, the activation point for an air cleaner would be around Rs/Ro=0.85, while the Rs/Ro for just one cigarette is as low as 0.65*).

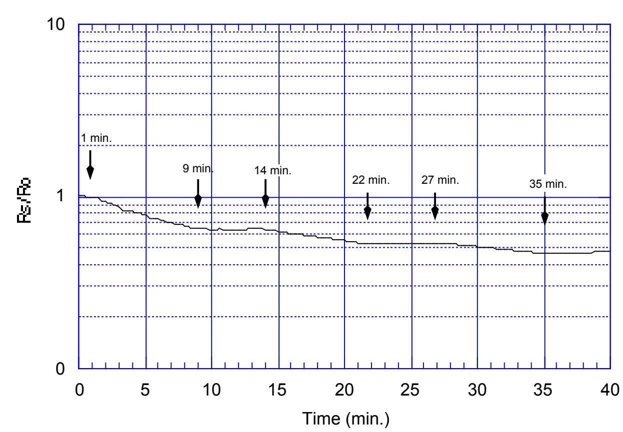


Fig. 13 - Response to cigarette smoke

This data demonstrates that TGS2600 is ideal for usage in air cleaners designed to ventilate when cigarette smoke and other air contaminants are present.

2-5 *Initial action*

Figure 14 shows the initial action of the sensor resistance (Rs) for a sensor which is stored unenergized in normal air for 30 days and then energized in clean air. The Y-axis represents sensor resistance in clean air at various times after energizing (Rs) compared with sensor resistance 20 min. after energizing (Ro).

The Rs drops sharply for the first seconds after energizing, regardless of the presence of gases, and then reaches a stable level according to the ambient atmosphere. Such behavior during the warm-up process is called "Initial Action".

Since this 'initial action' may cause an air cleaner to activate unnecessarily during the initial moments after powering on, it is recommended that an initial delay circuit be incorporated into the device's design (*refer to ...*).

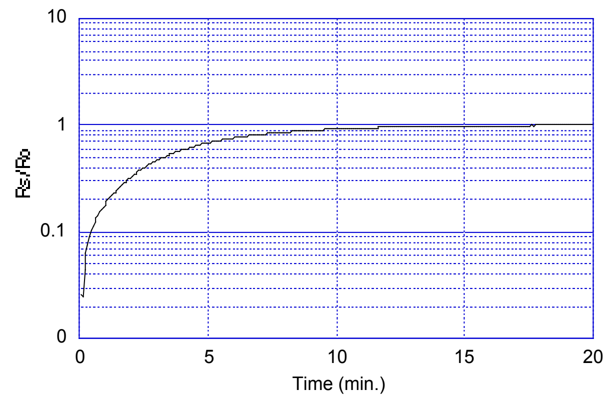


Fig. 14 - Initial action

2-6 *Long-term characteristics*

Figures 15 - 18 show the long-term stability of TGS2600 as measured for more than 400 days. In Figures 15 & 16, the sensor is first energized in normal air. Measurement for confirming sensor characteristics is conducted under standard test conditions. Figure 15 depicts sensor resistance in clean air over the test period, while in Figure 16 the Y-axis shows the ratio of sensor resistance in gases (Rs) compared with sensor resistance in fresh air on the same day (Ro). In Figures 17 & 18, the sensor is left unenergized in

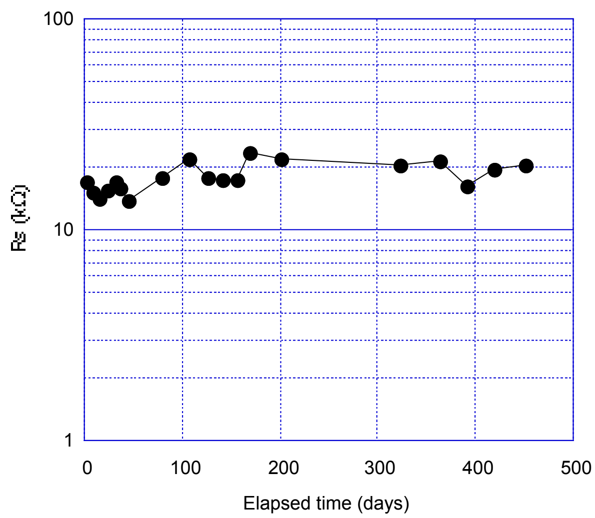


Fig. 15 - Long-term stability (continuous energizing)

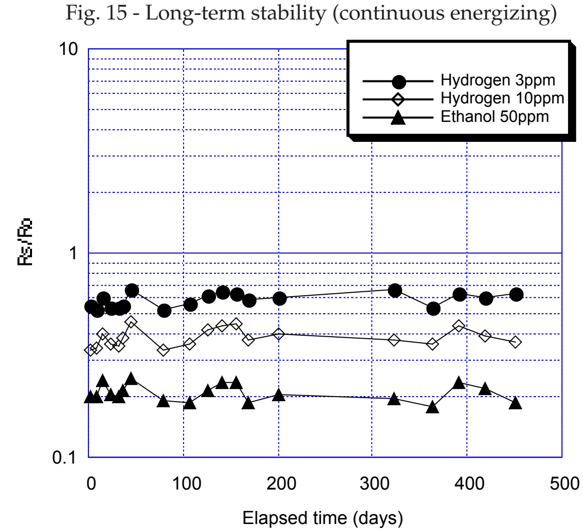


Fig. 16 - Long term stability (continuous energizing) in various gases

normal air for the entire test period except for the measurement period. Measurement for confirming sensor characteristics is conducted under standard test conditions. Figure 17 depicts sensor resistance in clean air over the test period, while in Figure 18 the Y-axis shows the ratio of sensor resistance in gases (Rs) compared with sensor resistance in fresh air on the same day (Ro).

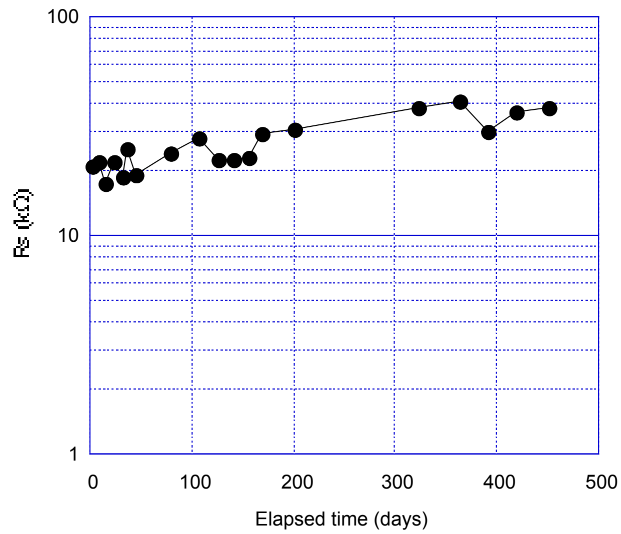


Fig. 17 - Long term stability (unenergized) in clean air

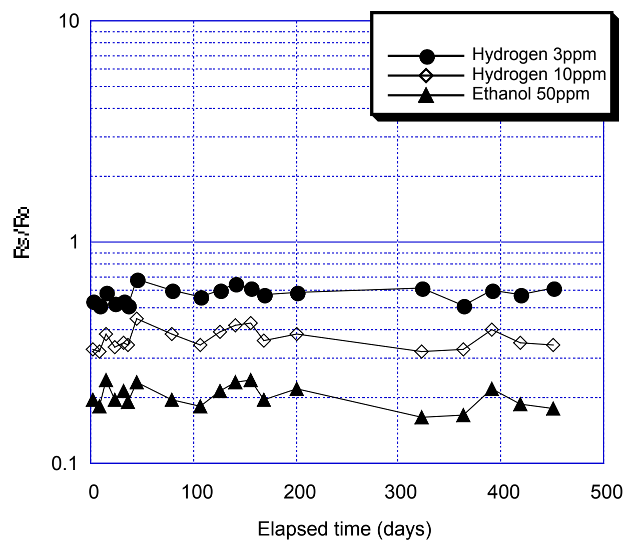


Fig. 18 - Long term stability (unenergized) in various gases

3 Cautions on Usage of Figaro Gas Sensors

3-1 *Situations which must be avoided*

1) Exposure to silicone vapors
If silicone vapors adsorb onto the sensor's surface, the sensing material will be coated, irreversibly inhibiting sensitivity. Avoid exposure where silicone adhesives, hair grooming materials, or silicone rubber/putty may be present.

2) Highly corrosive environment
High density exposure to corrosive materials such as H_2S, SOx, Cl_2, HCl, etc. for extended periods may cause corrosion or breakage of the lead wires or heater material.

3) Contamination by alkaline metals
Sensor drift may occur when the sensor is contaminated by alkaline metals, especially salt water spray.

4) Contact with water
Sensor drift may occur due to soaking or splashing the sensor with water.

5) Freezing
If water freezes on the sensing surface, the sensing material would crack, altering characteristics.

6) Application of excessive voltage
If higher than specified voltage is applied to the sensor or the heater, lead wires and/or the heater may be damaged or sensor characteristics may drift, even if no physical damage or breakage occurs.

7) Operation in zero/low oxygen environment
TGS sensors require the presence of around 21% (ambient) oxygen in their operating environment in order to function properly and to exhibit characteristics described in Figaro's product literature. TGS sensors cannot properly operate in a zero or low oxygen content atmosphere.

8) Polarization
These sensors have polarity. Incorrect Vc connection may cause significant deterioration of long term stability. Please connect Vc according to specifications.

3-2 *Situations to be avoided whenever possible*
1) Water condensation
Light condensation under conditions of indoor usage should not pose a problem for sensor performance. However, if water condenses on the sensor's surface and remains for an extended period, sensor characteristics may drift.

2) Usage in high density of gas
Sensor performance may be affected if exposed to a high density of gas for a long period of time, regardless of the powering condition.

3) Storage for extended periods
When stored without powering for a long period, the sensor may show a reversible drift in resistance according to the environment in which it was stored. The sensor should be stored in a sealed bag containing clean air; do <u>not</u> use silica gel. *Note that as unpowered storage becomes longer, a longer preheating period is required to stabilize the sensor before usage.*

4) Long term exposure in adverse environment
Regardless of powering condition, if the sensor is exposed in extreme conditions such as very high humidity, extreme temperatures, or high contamination levels for a long period of time, sensor performance will be adversely affected.

5) Vibration
Excessive vibration may cause the sensor or lead wires to resonate and break. Usage of compressed air drivers/ultrasonic welders on assembly lines may generate such vibration, so please check this matter.

6) Shock
Breakage of lead wires may occur if the sensor is subjected to a strong shock.

7) Soldering
Ideally, sensors should be soldered manually. However, wave soldering can be done under the following conditions:

a) Suggested flux: rosin flux with minimal chlorine
b) Speed: 1-2 meters/min.
c) Preheating temperature: 100±20°C
d) Solder temperature: 250±10°C
e) Up to two passes through wave soldering machine allowed

Results of wave soldering cannot be guaranteed if conducted outside the above guidelines since some flux vapors may cause drift in sensor performance similar to the effects of silicone vapors.

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