FIGARO
FIGARO ENGINEERING INC.

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FIGARO GAS SENSOR TGS 822

Feature

- High sensitivity to organic vapours such as alcohol.

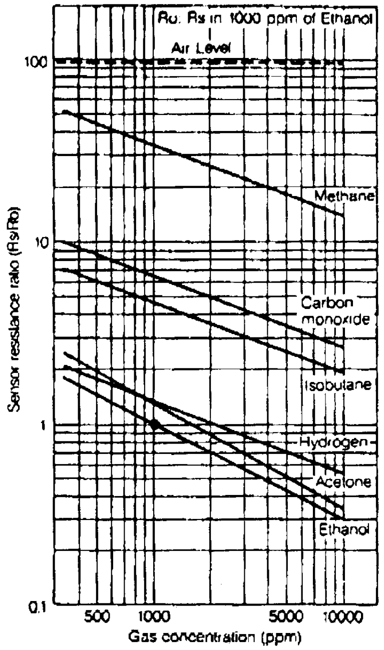
Applications

- Breath alcohol detectors, organic vapour monitors and industrial gas detectors.

Specifications

Model	TGS 822
Structure	Same as TGS813
Circuit conditions	Circuit voltage (V_C): 24V max. A.C. or D.C. Heater voltage (V_H): 5V A.C. or D.C. Heater power consumption (P_H): Approx. 650mW
Detectable gases and the detection range	Ethanol 50 ~ 10,000 ppm n-Pentane 50 ~ 5,000 ppm n-Hexane 50 ~ 5,000 ppm Benzene 50 ~ 5,000 ppm Acetone 50 ~ 5,000 ppm Methanol 50 ~ 5,000 ppm Methyl ethyl ketone 50 ~ 5,000 ppm

*Please contact Figaro for other detectable gases.



TGS 822 Sensitivity Characteristics
(Typical data)

Test Circuit and Sensor Performance

TYPE NO.	TGS 822
TEST CONDITION (A) Circuit Voltage (V_C) (B) Heater Voltage (V_H) Heater Power Dissipation (P_H) (C) Load Resistance (R_L)	 10V(A.C. or D.C.) 5V (A.C. or D.C.) Approx. 650mW. 4KΩ
WARM-UP TIME	Approx. 2 min.
HEATER RESISTANCE (R_H)	38Ω ± 3Ω
*SENSOR RESISTANCE(R_S)	1 ∿ 10KΩ in Ethanol 300ppm/air
*RATIO OF RESISTANCE	$\frac{\text{Rs in Ethanol 300ppm/air}}{\text{Rs in Ethanol 50ppm/air}} = 0.42 \pm 0.05$

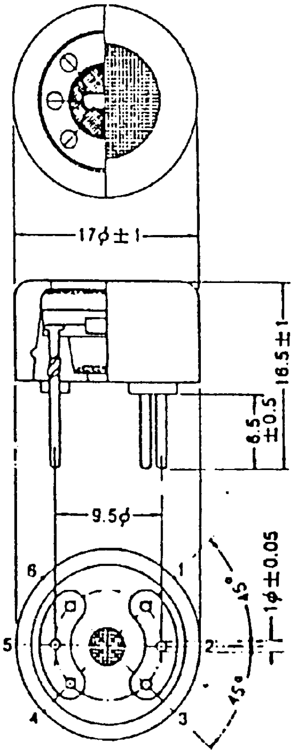


Table II Electric and sensitivity characteristics

Items	Conditions	Ratings
1) Sensor resistance (R_S)	R_S in 300 ppm ethanol/air	1 KΩ ~ 10K Ω*
2) Change ratio of resistance	R_S in 300 ppm ethanol/air R_S in 50 ppm ethanol/air	0.4 ± 0.1*
3) Heater resistance (R_H)	at room temperature	38Ω ± 3Ω
4) Heater power consumption	V_H = 5V	660mW ± 55mW

* These are obtained under the conditions shown in Table III.

Table III Standard test conditions

Atmospheric conditions	Clean air Temperature: 20 ± 2 ℃ Relative humidity: 65 ± 5 %
Circuit conditions	V_C = 10 ± 0.1 V (AC or DC) V_H = 5 ± 0.05 V (AC or DC) R_L = 3.9 KΩ ± 1 %
Conditioning	7 day energizing or more

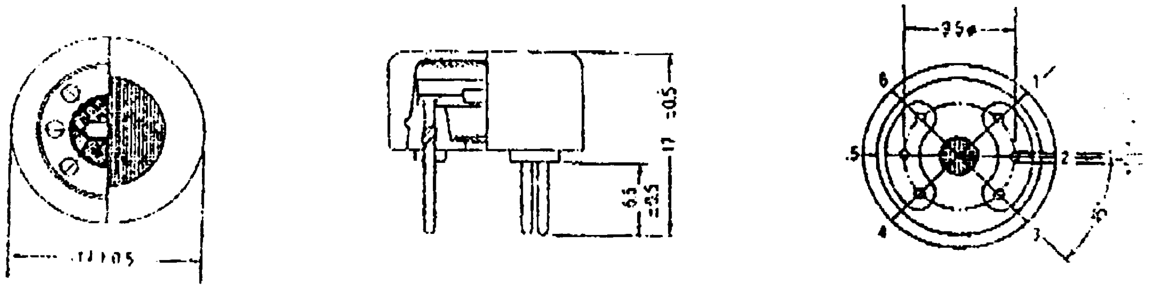
Table IV Mechanical durability

Items	Test conditions	Criterion
1) Vibration test	Frequency: 1000 cpm Vertical amplitude: 4 mm Duration: 1 hr.	Should maintain the characteristics shown in Table II.
2) Shock proof test	Acceleration: 100 G Number of impacts: 5	

Table V Material

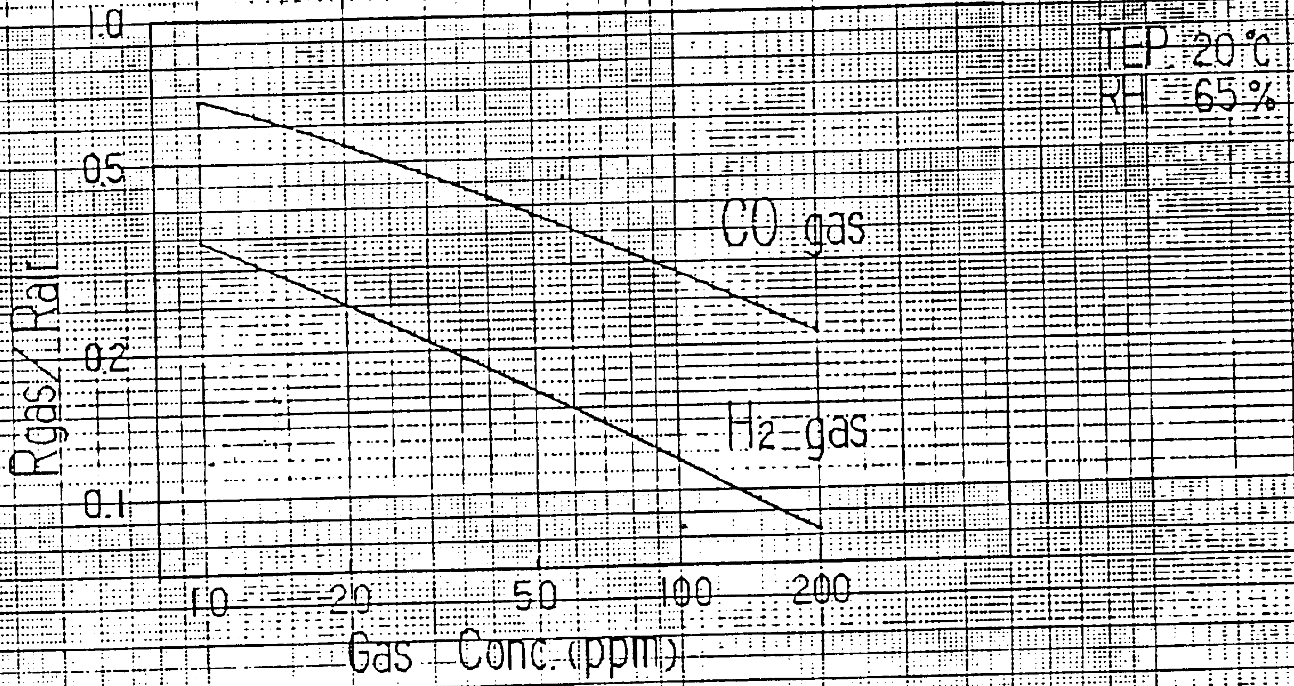
Sensing element	Tin dioxide(SnO_2) ceramic
Heater coil	Chrome alloy (Diameter: 60 μm)
Lead wire	Gold alloy (Diameter: 80 μm)
Housing	Nylon 66 (UL 94HB)
Pin	Nickel
Flame arrestor	Double 100-mesh stainless steel gauze (SUS316)
Weight	ca. 2.6 g

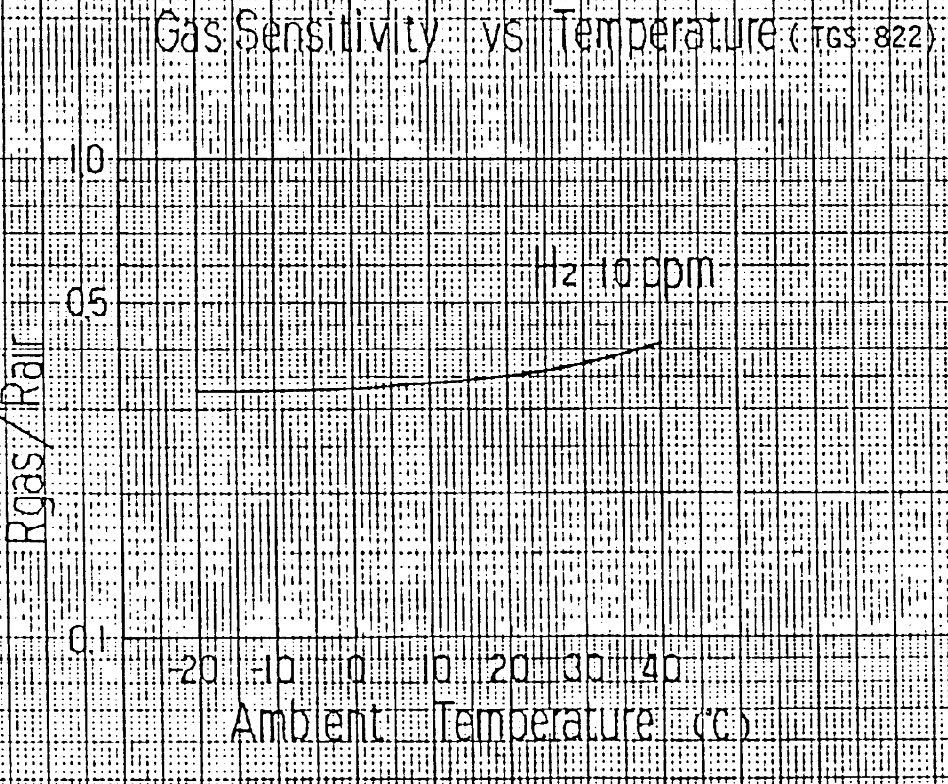
Fig.3 Dimensions



Dimensions in millimeter

Gas Sensitivity (TGS822)




Gas Sensitivity vs Temperature (TGS 822)
1.0
0.5
0.1
Rgas / Rair
H2 10 ppm
-20
-10
0
10
20
30
40
Ambient Temperature (°C)

1. Principle of TGS Sensor

The adsorption of a gas molecule on the surface of a semiconductor generally results in the transfer of electrons due to the differing energy levels of the gas molecule and the semiconductor surface.

Oxygen, which can accept electrons, is adsorbed on the surface of n-type semiconductors. The transfer of electrons from the donor level of the semiconductor to the layer of adsorbed gas results in decreased conductivity of the semiconductor material.

The TGS is a bulk semiconductor formed by sintering powdered tin dioxide. Hence a very large number of grain boundaries exist between individual crystals. The adsorption of oxygen forms potential barriers at these grain boundaries accompanied by a large reduction of semiconductor conductivity.

Fig. 1 illustrates the relationship between Oxygen pressure in the atmosphere (P_{O_2}) and TGS conductivity. Reduced oxygen pressure increases the sensor conductivity.

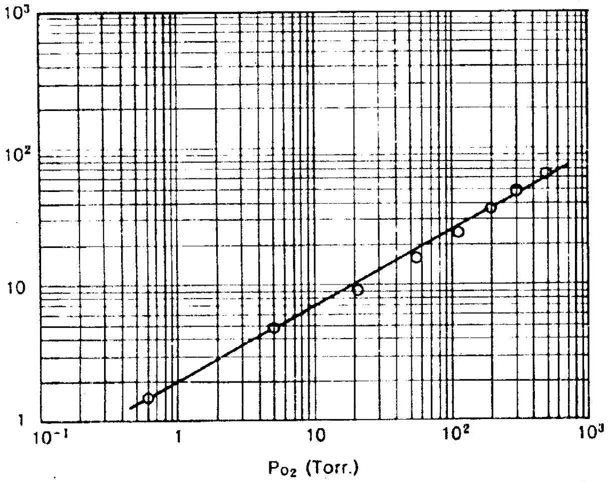


FIG. 1. RELATIONSHIP BETWEEN THE RESISTANCE OF TGS (Rs) AND THE PRESSURE OF OXYGEN (P_{O_2}).

◆**Sample:** #812

◆**Test condition:** V_C 10V D.C. / V_H 5V D.C. / R_L 4KΩ

Because the partial pressure of oxygen in air is virtually constant, the rate and amount of oxygen adsorption by a TGS sensor is related to the temperature of the sensor. Hence the conductivity of a TGS sensor maintained at a fixed temperature in air will remain constant.

When a TGS sensor which has already adsorbed oxygen in this manner comes into contact with reduction or combustible gases such as Carbon Monoxide, Hydrocarbons etc., the molecules of these gases are adsorbed such that the transfer of electrons is in the opposite direction to the oxygen reaction, resulting in an increased density of electrons in the semiconductor space charge layer and decreased potential barriers at the grain boundaries.

The increased conductivity (decreased resistance) of the TGS sensor corresponding to gas concentration is illustrated in Fig.2. The adsorption of gases on the sensor surface is reversible i.e. desorption can also occur. Fast response times are achieved by heating the sensor surface within the range 200°C to 400°C.

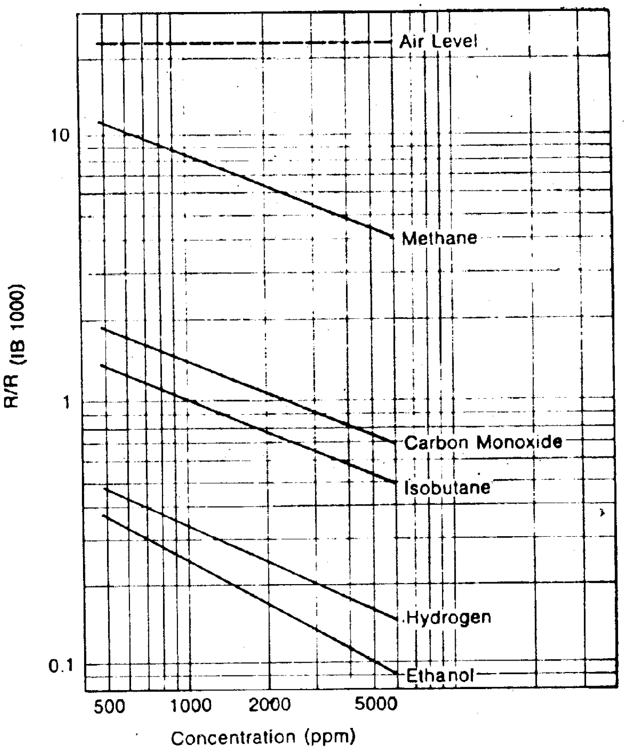


FIG. 2. RELATIONSHIP BETWEEN THE RESISTANCE OF TGS (Rs) AND THE CONCENTRATION OF GASES.

◆**Sample:** #812

◆**Test condition:** V_C 10V D.C. / V_H 5V D.C. / R_L 4KΩ

A sensor placed in a gas concentration ranging from 2 ~ 30% vol. will maintain a fixed resistance over a long period and irreversible deoxidation of the sensor is not discernible. When the combustible gas is removed and replaced by fresh air the sensor resistance returns to its original value.

Fig. 3 shows the response of the TGS sensor to Isobutane gas.

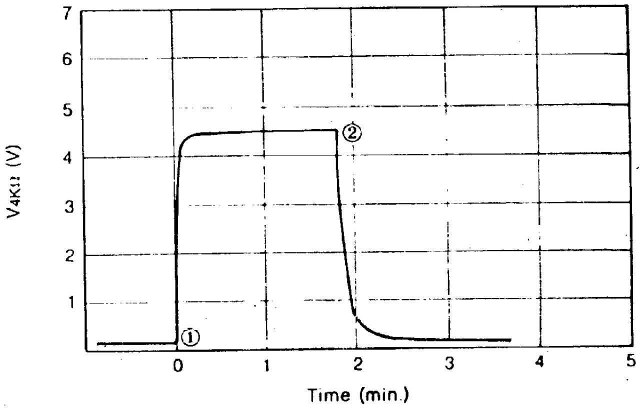


FIG. 3. RESPONSE CURVE AGAINST ISOBUTANE.

◆**Sample:** #812

◆**Test condition:** V_C 10V A.C. / V_H 5V A.C. / R_L 4KΩ

◆**Measuring procedure:**

① Put the TGS into a hermetic-sealed test box containing 1000 ppm of isobutane.

② Take it out suddenly in a few minutes.

2. Main Features of the TGS Sensor

1. Long life and good reliability. In normal use recalibration or replacement will not be necessary for 5 years or more.
2. The TGS is not permanently poisoned by toxic gases.
3. Several toxic gases e.g. Carbon Monoxide, Ammonia etc. can be detected at low levels before dangerous concentrations occur.
4. No loss of sensitivity even at gas concentrations so high that oxygen (air) is displaced.
5. The sensor is resistant to vibration and mechanical shock.
6. Sensor output is sufficiently large to allow gas detectors to be designed using a minimum number of components. Consequently reliable low cost detectors can be produced.

3. TGS Applications

There are many suitable applications for the TGS in the field of gas detection, but each application requires careful analysis in relation to both the gas and gas level to be detected.

For example, when detection of potentially explosive concentrations of flammable gases is required, the alarm level is a function of the LEL (Lower Explosive Limit) of the gases involved. For non toxic flammable gases an alarm level of 10% LEL is generally recommended. Due to the non specific response of the TGS it is possible for false alarms to be caused by exhaust fumes, smoke, alcohol etc if the alarm point chosen is too low.

Where toxic gases are to be detected, reference must be made to the TLV (Threshold Level Values) published by Health and Safety Authorities. Refer to Table III.

Because the TGS sensor is used to protect lives and property it is essential that its characteristics are fully understood ensuring that alarm levels are correctly calculated and precisely calibrated.

Gas Leak Alarm This type of detector is normally required to detect dangerous concentrations of Town Gas, LPG (Liquified Petroleum Gases), Natural Gas (Methane) etc. These gases have different LEL and density values which must be reflected in the calibration and location of detectors. Refer to table III.

Automatic Ventilation By responding to the presence of gas, smoke or fumes in cooking areas, car parks, laboratories, etc. TGS detectors can be used to control ventilation fans. Fixed or variable sensitivity controls may be fitted.

Fire Alarms The TGS will respond to Carbon Monoxide which is one of the principal gases given off at the early stages of fire. Accordingly, fire protection additional to that provided by conventional ionization, photo electric and thermal detectors can be achieved by installing TGS detectors calibrated on Carbon Monoxide, typically within the range 200 to 1000 ppm. Suitable applications include fire detection in computor areas, TV sets, and electrical equipment by detecting smouldering cables etc.

Battery Powered Portable Units Designed to detect the presence of gas leaks or pockets of gas, can also be based on the TGS.

Carbon Monoxide Detection CO is a highly toxic gas and a frequent cause of fatal accidents. A low level alarm point is desirable but this may not be possible where tobacco or other smoke and fumes are normally present. The alarm level should never exceed 1,000 ppm. Refer to Table I for detailed CO data.

Industrial Gas Detectors In industrial applications the TGS can be used to detect CO, ammonia, solvent vapours, hydrocarbon gases etc. Where indication of the gas concentration present is required e.g. a meter or recorder, the sensor should be powered for 2 ~ 3 weeks before calibration to ensure stability.

4. General Instructions for Using the TGS Sensors

1. The recommended circuits shown in the data sheets relating to each type of sensor should always be used. Other circuits may result in sensor characteristics differing from those published by Figaro. Where necessary, voltage stabilization should be provided.
2. Temperature and humidity changes have some effect on the sensitivity of the TGS sensor. The inclusion of temperature compensation e.g. thermistor, in the circuit will improve detection accuracy. Since absolute air humidity is related to temperature this compensation will also tend to reduce the effects of humidity changes.
3. Response to gas. Variations in sensitivity to gas exist between individual sensors and so it is necessary to calibrate each detector in a gas concentration corresponding to the required alarm level.
4. Calibration. Calibration must be carried out in controlled temperature/humidity conditions using clean air and pure gas. Air contaminants such as traces of smoke, alcohol, solvents, paint, paint thinners, adhesives, trichloro cleaners etc. must be removed or avoided. Recommended conditions are 20°C ± 2° C, R.H. 65% ±5%.
5. TGS sensors which have been in stock must be conditioned before alarm calibration is carried out. Conditioning is best performed by connecting assembled detector boards to a power supply for 3 ~ 4 days in a controlled environment prior to calibration.
6. Stocks of TGS sensors and completed detectors should be protected from moisture by silica gel or similar desiccant. Please ensure that they are not exposed to fumes or gases produced by adhesives, packing materials etc.

MEASURING THE CHARACTERISTICS OF TGS SENSORS

Full scale production of TGS detectors requires specially built test and calibration facilities. However, the following equipment and test procedures will enable preliminary evaluation and measurements to be carried out.

Fig. 1. shows the standard basic measurement circuits used with the different sensor types. Sensitivity data published by Figaro is based on measurements made using these circuits in controlled atmosphere, temperature 20°C ±2°C, R.H. 65% ± 5%.

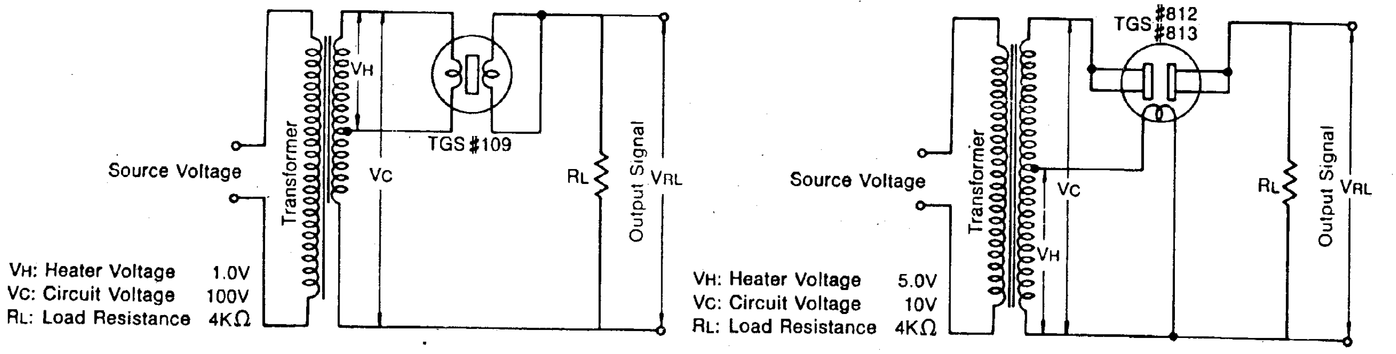


FIG. 1. BASIC MEASURING CIRCUIT.

As shown in Fig. 2, the test apparatus consists of power supply, test box and signal detector. The basic characteristic of the TGS sensor i.e. its conductivity in different gas concentrations when VC, VH and RL are varied can be measured as a voltage across RL connected in series with the sensor.

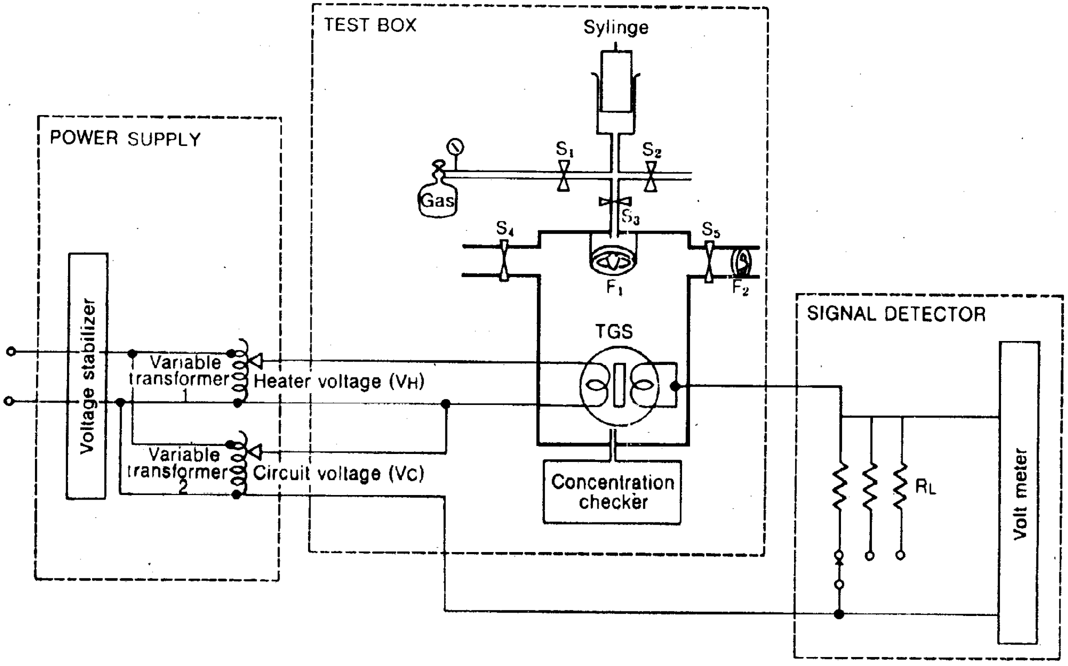


FIG. 2. STANDARD MEASURING SYSTEM.
Sensor TGS #109 in use

1. Specification for test apparatus

Power supply: Stability of V_C and $V_H = \pm 1\%$
Voltage range of V_C and $V_H = \pm 20\%$ of standard values.
When using type #109 sensor, ensure that the components in the heater circuit are adequately rated for the relatively large current taken by the 2Ω heater coil and that V_H is measured at the sensor pins.

Test box: General construction Acrylic plastic
Test box includes;

1. Access door with airtight seal.
2. TGS socket connected to V_C, V_H and R_L.
3. Gas inlet port.
4. Mixing fan.
5. Air supply/exhaust piping complete with valves and fan.
6. Syringe for injecting required volume of gas.
7. Instrument to measure accurately the gas concentration.
   It can be of the optical or hot wire type etc.

Signal detector: This contains a number of load resistors e.g. 2, 3, 4, 5 and 10 KΩ. If desired an automatic scanner can be constructed to allow a large number of sensors to be tested at the same time.

2. Test procedure

1. Conditioning the sensor prior to testing

While in stock the sensor is unenergised and requires to be powered for some days before reaching its normal operating resistance. Usually one to five days conditioning is necessary. The first reading in air is taken after 24 hours and thereafter at daily intervals to determine that the sensor resistance has stabilized.

2-1. Procedure for conditioning

The temperature of the sensor is one of the most important factors effecting its performance. During conditioning V_C, V_H and R_L must be kept constant. The temperature of sensor type #109 depends not only on the heater current but also on the added heat supplied by the circuit current. Under certain circumstances the heat resulting from the circuit current flowing through sensor type #109 can exceed the heat supplied by the heater.

2-2. Importance of conditioning in clean air

The TGS is not selective i.e. it will react with a wide range of gases. Hence it is very important that no gases are present during conditioning so that a true "base reading" in air is obtained. If the sensor comes into contact with solvent vapour such as trichloroethylene during the conditioning period then the period of conditioning must be extended until the effects of the solvent have worn off. Similarily if any changes in circuit values or test atmosphere are introduced, the sensor will require several hours to adapt to the changed conditions.

3. Measurement of sensor output

The output of the sensor is measured indirectly by reading the voltage appearing across the load resistor R_L.

Test Procedure

① First condition the sensor by switching on the circuit with sensor installed for 48 hours.
② Allow 1 hour for the sensor to adapt to test conditions. Data showing the base reading in air is measured at temperature 20°C ± 2°C and R.H. 65% ± 5%. Changes in temperature and humidity will result in changes in sensor output.
③ Replace contents of test box with clean fresh air by opening valves S_4 & S_5 and switching on fans F_1 & F_2 (Fig. 2.). After 3 minutes close S_4 & S_5, shut off F_1 & F_2.
④ Wait 60 seconds before taking measurement of output voltage in fresh air.
⑤ With S_2 & S_3 closed open S_1 and allow syringe to fill to required level. Open S_2 and close S_1. Pressure in syringe now becomes equal to that of the atmosphere.
Open S_3, close S_2 and inject syringe contents into test box.
⑥ Operate mixing fan for 30 seconds.
⑦ Wait further 90 seconds and take measurement of output in gas.

4. Checking the effects of temperature and humidity

① The TGS is effected by changes in temperature and humidity so these values should be kept constant throughout testing.
② If temperature and/or humidity are changed, time must be allowed for the sensor to adapt to the new conditions. This can be checked by reference to the output voltage across R_L. When this voltage reaches a steady value further testing may proceed.
③ When using the volume method to calculate gas concentration ensure that the gas injected is at the same temperature as the air in the test box. Note: 1cc Gas/litre = 1,000 ppm
④ When making high temperature measurements do not use any materials in the test box which may give out gases or vapours.

REFERENCE DATA

I. Effect of Carbon Monoxide on the Human Body

Toxic symtoms developed by a stationary person exposed to Carbon Monoxide

Concentration of CO in air	Inhalation time and toxic symtoms developed.
0.02% (200ppm)	Slight headache within 2~3 hours.
0.04% (400ppm)	Frontal headache within 1~2 hours, becoming widespread in 2.5 to 3.5 hours.
0.08% (800ppm)	Dizziness, nausea and convulsions within 45 minutes. Insensible within 2 hours.
0.16% (1,600ppm)	Headache, dizziness and nausea within 20 minutes. Death within 2 hours.
0.32% (3,200ppm)	Headache, dizziness and nausea within 5~10 minutes. Death within 30 minutes.
0.64% (6,400ppm)	Headache, dizziness in 1~2 minutes. Death in 10~15 minutes.
1.28% (12,800ppm)	Death in 1~3 minutes.

II. Toxic Effects of Various Gases and Vapours

Based on research by K.B. Lehmann and U. Henderson-Haggard

*	Effect Toxic Gas	Fatal concentration if inhaled for 5~10 minutes.		Acute poisoning if inhaled for 30~60 minutes		Temporary discomfort if inhaled for 30~60 minutes.	
		mg/ℓ	ppm or cc/m^3	mg/ℓ	ppm or cc/m^3	mg/ℓ	ppm or cc/m^3
×	CHLORINE	0.7	500	0.07	50	0.007	5.0
△	HYDROGEN CHLORIDE	4.5	3,000	1.5	1,000	0.15	100
△	HYDROGEN SULFIDE	1.2	800	0.6	400	0.3	200
△	SULFUROUS ACID	8.0	3,000	1.2	400	0.3	100
○	AMMONIA	3.0	5,000	1.5	2,500	0.15	250
△	HYDROGEN PHOSPHIDE	1.4	1,000	0.6	400	0.15	100
△	HYDROGEN ARSENIDE	1.0	300	0.2	60	0.06	20
○	CARBON MONOXIDE	6.0	5,000	2.4	2,000	1.2	1,000
×	CARBON DIOXIDE	165	90,000	90	30,000	55	30,000
×	PHOSGENE	0.2	50	0.1	25	0.004	1.0
○	BENZENE	65	20,000	25	7,500	10	3,000
△	CHLOROFORM	125	25,000	75	15,000	25	5,000
△	CARBON TETRACHLORIDE	350	50,000	175	25,000	70	10,000
△	CARBON DISULFIDE	6.0	2,000	3.0	1,000	1.5	500
△	HYDROGEN CYANIDE	0.2	200	0.1	100	0.05	50
○	BENZINE	120	30,000	80	20,000	60	15,000
○	ACETYLENE	550	500,000	275	250,000	110	100,000
○	ETHYLENE	110.0	950,000	920	800,000	575	500,000

* Classification by Figaro Engineering Inc.
- ○ can be detected by TGS
- △ may react with TGS in certain circumstance/not confirmed by measurement.
- × cannot be detected by TGS

		Molecular Formula	Explosive limits in air (vol %)	TLV (ppm)	Density (air=1)
ALCOHOLS	METHANOL	CH_4O	5.5~37.0	200	1.1
	ETHANOL	C_2H_6O	3.3~19.0	1,000	1.6
	n-PROPANOL	C_3H_8O	2.0~14.0	200	2.1
	iso-PROPANOL	C_3H_8O	2.0~12.0	400	2.1
	n-BUTANOL	$C_4H_{10}O$	1.4~12.0	100	2.6
	iso-BUTANOL	$C_4H_{10}O$	1.7~11.0	100	2.6
THERS	METHYL ETHER	C_2H_6O	3.4~18.0		1.6
	ETHYL ETHER	$C_4H_{10}O$	1.7~48.0		2.6
KETONES	ACETONE	C_3H_6O	2.1~13.0	1,000	2.0
	METHYL ETHYL KETONE	C_4H_8O	1.8~11.5	200	2.4
ESTERS	METHYL ACETATE	$C_3H_6O_2$	3.1~16.0	200	2.6
	ETHYL ACETATE	$C_4H_8O_2$	2.1~11.5	400	3.0
	n-PROPYL ACETATE	$C_5H_{10}O_2$	1.7~ 8.0	200	3.5
	iso-PROPYL ACETATE	$C_5H_{10}O_2$	1.7~ 8.0	250	3.5
	n-BUTYL ACETATE	$C_6H_{12}O_2$	1.2~15.0	150	4.0
	iso-BUTYL ACETATE	$C_6H_{12}O_2$	2.4~10.5	150	4.0
NITROGEN COMPOUNDS	NITRO METHANE	CH_3NO_2	7.3~		2.1
	MONO METHYL AMINE	CH_5N	4.2~20.7	10	1.1
	DIMETHYLAMINE	C_2H_7N	2.8~14.4	10	1.6
	TRIMETHYL AMINE	C_3H_9N	2.0~12.0		2.0
	MONO ETHYL AMINE	C_2H_7N	3.5~14.0	10	1.6
	DIETHYL AMINE	$C_4H_{11}N$	1.7~10.1	25	2.5
INORGANIC GASES	AMMONIA	NH_3	16.0~25.0	50	0.6
	CARBON MONOXIDE	CO	12.5~74.0	50	1.0
	HYDROGEN	H_2	4.0~75.0		0.07
	HYDROGEN CYANIDE	HCN	6.0~41.0	10	1.0

TLV values shown are as published by ACGIH (AMERICAN CONFERENCE OF GOVERNMENTAL INDUSTRIAL HYGIENISTS) 1966.