

# **TC100 THERMAL CONDUCTIVITY SENSOR**

#### **TECHNICAL BULLETIN 043**

#### Percent range helium sensor For measurement of helium in air or oxygen

#### Introduction

The Neutronics thermal conductivity helium sensor is designed for gas composition measurement. Measurement of helium in air or oxygen is attractive due to the fact that the thermal conductivities of helium are so different from air, nitrogen, and oxygen. The TC100 is a thermal conductivity gauge made using silicon technology. The sensor chip consists of a silicon rim with a siliconenitride membrane. A heater in the center measures its temperature. The chip measures the thermal conductance between the ambient and the center of the membrane.

#### Description

The TC100 is a thin-film thermopile thermal conductivity sensor designed with a silicon-nitride closed-membrane structure for high sensitivity and resolution. The measurement principle is based on the decrease in effective thermal resistance between the sensitive area of the sensor and the ambient, caused by the thermal conductance of the surrounding gas.

### Sensor operation principle

The sensor measures the thermal resistance between the hot junctions of its thermopile in the center of the membrane and the cold junctions on the thick rim of the chip. This is achieved by heating the center of the membrane using the heater resistor  $R_{heat}$ . The resulting temperature increase of the center is measured by the thermopile. The actual temperature increase depends upon the effective thermal resistance between the membrane and ambient, influenced by factors such as thermal resistance of the membrane, the ambient gas, and any present gas flows.

The basic theory of operation is given by the following formula:

$$U_{\text{out}} = P_{\text{in}} \times S_{\text{tp}} / (G_{\text{mem}} + G_{\text{gas}})$$

where  $U_{out}$  is the output voltage of the sensor's thermopile in Volt.  $P_{in}$  is the input heating power in Watt, which is

#### Applications

Aerospace Chemical processing Diving Flat panel display manufacturing Gas generation / gas purity monitoring Helium production



#### **Features**

- Thin-film thermopile thermal conductivity sensor design for higher sensitivity, accuracy, and resolution (reliable performance)
- Rapid response time (T<sub>90</sub> < 1 second) and fast start-up performance (easy to use)
- Wide gas concentration measurement range of helium in air or oxygen (0 to 100%) (flexible)
- TC100 sensor is unaffected by position or motion (simple to install)
- Excellent repeatability and long-term stability (low cost of ownership)
- 316 Stainless Steel sensor housing assembly with Viton O-Ring (flexible)

#### Medical Metals manufacturing / welding Optical fibers Power / cooling systems Semiconductor and electronics manufacturing Superconductors

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given by:

#### $P_{\text{in}} = U_{\text{heat}} \times I_{\text{heat}} = U_{\text{heat}^2} / R_{\text{heat}} = I_{\text{heat}^2} \times R_{\text{heat}}$

with  $U_{heat}$  as the heating voltage over the heating resistance  $R_{heat}$  and  $I_{heat}$  as the heating current through the heating resistance  $R_{heat}$ . Note that the value of  $R_{heat}$  is temperature dependent, so that the power dissipated in  $P_{heat}$  is also temperature dependent, if the heating is performed from a pure voltage or current source. To eliminate this temperature dependence of  $P_{in}$ , the sensor is heated from a voltage (or current) source with an internal series resistance equal to  $R_{heat}$ .

The thermopile sensitivity  $S_{tp}$  is determined by the technology and thermoelectric characteristics of the sensor.

The thermal conductance  $G_{gas}$  is described below (based on standard design with a heat sink present above and below the membrane of the sensor). For very low pressures, the thermal conductance G between two parallel plates (in W/m2K) is given by:

 $G = G_{\circ}P$ 

Where  $G_0$  is the thermal conductivity in W/m<sup>2</sup>KPa, and *P* is the pressure in Pa.

For atmospheric pressures, *G* is given by:

$$G = K/d$$

where K is the thermal conductivity (in W/Km), and d is the distance between the plates. For the whole pressure range the formula becomes:

$$G = G_0 \left\{ (PP_t) / (P+P_t) \right\}$$

where  $P_t$  is the transition pressure and where the thermal conductance in the molecular regime equals that in the viscous regime.  $P_t$  depends upon the free mean path  $\lambda$  between collisions of the molecules and the plate distance *d*. Table 1 lists the transition pressure and free mean paths for helium along with several other gases for comparison.

The sensing element must be properly ventilated so that the measured gas can diffuse into the opening in the sensor cap. There are no restrictions regarding orientation, however, caution must be taken to prevent the condensation of water vapor on the sensor. Exposure to humidity and temperatures at the extreme ends of the range may lead to some drift of the sensor. For gas composition measurements, direct flow into the sensor or turbulence around it will influence the measurement.

|             | $\lambda$ at 1 Pa | P <sub>t</sub> at 0.3 mm | Go         | К        | G (1 bar, <i>d</i> 0.3 mm) |
|-------------|-------------------|--------------------------|------------|----------|----------------------------|
| Gas type    | in mm             | in Pa                    | in W/m²KPa | in mW/Km | in W/m <sup>2</sup> K      |
| argon       | 7.1               | 90                       | 0.66       | 18.0     | 60                         |
| helium      | 19.8              | 600                      | 0.84       | 151.0    | 500                        |
| nitrogen    | 6.7               | 90                       | 0.95       | 25.7     | 86                         |
| oxygen      | 7.3               | 90                       | 1          | 26.2     | 87                         |
| water vapor | 4.6               | 35                       | 1.9        | 19.9     | 66                         |

Table 1, thermal conductivity and free mean paths for helium and selected

## Technical specifications

| Sensor type           | TC100, thermal conductivity                        |  |  |
|-----------------------|--|--|--|
| Measurement range     | 0 to 100% helium concentration in air              |  |  |
| Display resolution    | 1 to 9.99% (X.XX); 10 to 99.9% (XX.X)              |  |  |
| Maximum offset drift  | 0.2% / year  |  |  |
| Response time         | T <sub>90</sub> < 1 second                         |  |  |
| Recovery time         | T <sub>10</sub> < 1 second                         |  |  |
| Data update rate      | 1 Hz   |  |  |
| Warm up time          | 1 second   |  |  |
| Expected service life | > 5 years  |  |  |
| Relative humidity     | 5 to 70%, non-condensing                           |  |  |
| Operating temperature | 32 to 104° F (0 to 40° C)                          |  |  |
| Pressure range        | 800 to 1200 mbar (11.6 to 17.4 psia) full accuracy |  |  |
| Storage temperature   | 10°C to +40°C (50°F to 104°F)                      |  |  |
| Part number           | 8-01-1001-38-X                                     |  |  |
|                       | www.apayzegas.co                                   |  |  |



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