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 silicone-nitride 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.

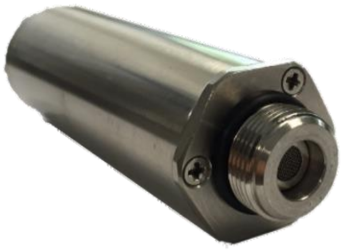
Sensor operation principle

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:

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

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



Features

- Thin-film thermopile thermal conductivity sensor design for higher sensitivity, accuracy, and resolution (reliable performance)
- Rapid response time (T_{90} < 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)

Applications

Aerospace	Medical
Chemical processing	Metals manufacturing / welding
Diving	Optical fibers
Flat panel display manufacturing	Power / cooling systems
Gas generation / gas purity monitoring	Semiconductor and electronics manufacturing
Helium production	Superconductors

given by:

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

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:

$$G = G_o P$$

Where G_o is the thermal conductivity in W/m^{2}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:

$$G = G_o \{(PP_t) / (P+P_t)\}$$

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 λ 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.

Gas type	λ at 1 Pa in mm	P_t at 0.3 mm in Pa	G_o in W/m^{2}KPa	K in mW/Km	G (1 bar, d 0.3 mm) in W/m^{2}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_{90} < 1 second
Recovery time	T_{10} < 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

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