NTC THERMISTORS FOR GAS FLOW MEASUREMENTS

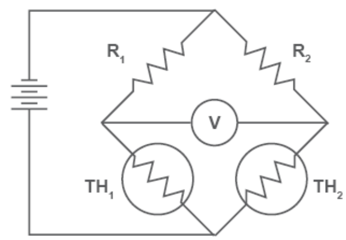
APPLICATION NOTE

NTC Thermistors are most often used in temperature measurements or control applications where the power is kept to a minimum to prevent self-heating error. However, a thermistor that is purposely self-heated significantly above ambient temperature can be used as a flow detector. The temperature of the self-heated thermistor will depend on how much power is dissipated into the surrounding medium. As the fluid flow velocity increases, the thermistor will dissipate heat better, it's temperature will drop, resulting in a higher resistance. The change in resistance is easily detected and correlated to fluid flow. This method can be applied to either liquid or gas flow.

A Wheatstone bridge circuit is very effective for constructing a simple flow meter. Figure 1 shows a thermistor (TH1) used as one element of a Wheatstone bridge. Under static conditions with no flow resistor the bridge is adjusted to null the volt meter. As the thermistor is cooled by the flowing gas the bridge will become unbalanced. The higher the velocity and cooling, the more the bridge is unbalanced. The change is read by the volt meter and can be calibrated in appropriate units such as liter per minute or meters per second.

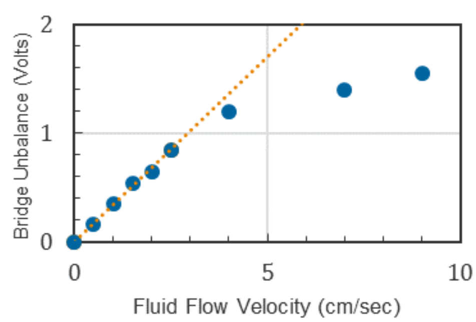
The thermistor will also be influenced by the actual gas temperature. A compensating thermistor (TH2 in Figure 1) is usually incorporated in the adjacent bridge leg for this purpose. The compensating thermistor is situated to see the same gas at the same temperature but in a stagnant gas area with no flow. The two thermistors will track each other, keeping the bridge in balance as the gas temperature changes. The compensating thermistor is also referred to as a reference thermistor.

FIGURE 1
Wheatstone Bridge Circuit



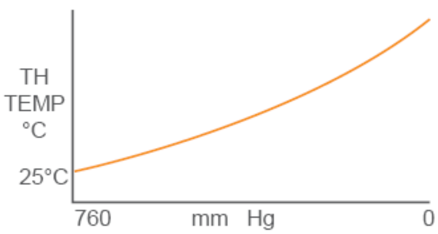
An example of bridge unbalance voltage vs. fluid flow velocity is shown in Figure 2. The bridge response is approximately linear at the lower flow rates. Measurement range is generally confined to flows in this linear portion.

FIGURE 2
Typical Thermistor Bridge Calibration Curve



A similar arrangement can be used for vacuum measurements. The sensing thermistor is placed in the vacuum chamber. The compensating thermistor remains outside at atmospheric pressure but shielded from stray gas flow. The bridge is balanced when both thermistors are at atmospheric pressure. As gas pressure is decreased in the chamber there will be fewer gas molecules surrounding the sensing thermistor to dissipate the heat and its temperature will rise as shown in Figure 3. The hotter thermistor will exhibit a lower resistance. The bridge will become unbalanced and the voltmeter will swing upscale. The meter can be calibrated in the required units such as inches or millimeters of mercury.

FIGURE 3
Thermistor Temperature as a Function of Gas Pressure



The same scheme is also employed for gas chromatography where different gases change the self-heated temperature of the thermistor by different amounts.

In order for the thermistor to provide the best sensitives while minimizing the effects of ambient temperature, the self-heat temperature rise needs to be quite high. The temperature is often raised by 100 to 200°C. If the thermistor is put directly across a fixed voltage supply, the thermistor will indeed heat up. Without safeguards in place the current will increase continually as the thermistor resistance drops, leading to thermal runaway and failure of the thermistor.

There are two common ways to prevent thermal runaway. A constant current source can be used instead of a fixed voltage supply. This will allow the thermistor to self-heat into a stable self-regulating state. In a bridge circuit as shown in Figure 1, R3 can be chosen with a significantly higher resistance than the thermistor, to create a near constant current through the sensing leg.

Examples

Assume the following:

Ambient Temp.	25°C
Gas	Air
Pressure	One Atmosphere
Thermistor	8K Bead, $Beta_{10/50}$ 2758
Diss. Constant	16mW /°C in Air
Self Heat	125°C Rise

BRIDGE CIRCUIT

1. Set R, and R_2 equal to the thermistor resistance at a temperature a little less than half the self-heat rise.

   ½ of 125°C = 62.5°C
   62.5°C + 25°C = 87.5°C
   80°C is chosen
   The resistance at 80°C = 1275 ohms
   A 1200 ohm resistor is chosen

2. Determine the actual self-heated temperature.

   25°C + 125°C rise = 150°C

3. Using the resistance temperature chart for B2758 look up the thermistor resistance at the self-heat temperature of 150°C: 234.6 ohms

4. Determine the power required to produce the required temperature rise of 125°C.

   16 mW /°C * 125°C = 20 milliwatts

5. Determine the supply voltage required to produce 20 milliwatts when the thermistor equals 234.6 ohms and series resistor equals 1200 ohms.

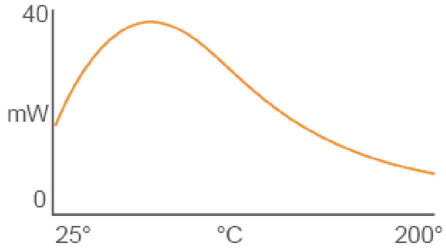
$$W = \frac{E^2}{R}$$

$$02 = \frac{\left\{Es\left(\frac{234.6}{1200 + 234.6}\right)\right\}^{2}}{234.6}$$

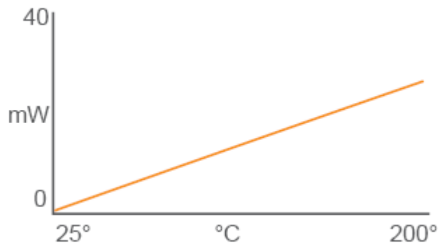
   E_s (supply voltage)= 13.25 volts

6. Determine power available to the thermistor as a function of the thermistor resistance from 25°C to 50°C beyond the self-heat temperature of 150°C which is then 200°C. It should be noted that the point of maximum power occurs where the thermistor resistance equals the series thermistor (1200). Above this point the power falls off as a function of temperature precluding thermal runaway of the thermistor.

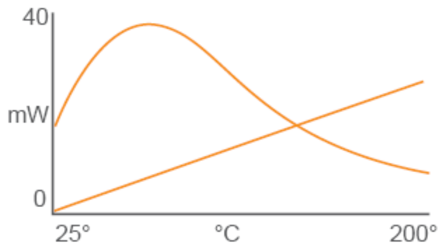
7. Plot the power available, not as a function of resistance, but rather as a function of the corresponding thermistor temperature.



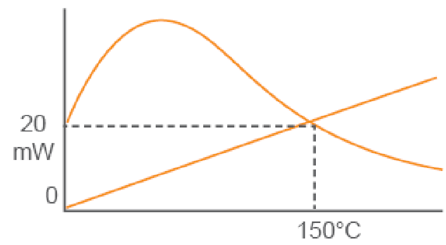
8. Plot power required to achieve self-heat temperature rise versus temperature. This is a straight line with its origin at 25°C and a slope equal to the dissipation constant of 16 mW / °C.



9. Superimpose the two graphs.



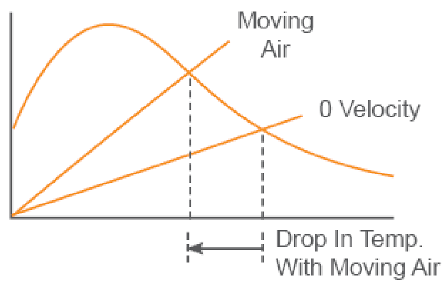
10. Note the point where the curves cross. This point is at 150°C and 20 milliwatts. Below this point (colder) there is more power available than required to attain that temperature and it will continue to rise. Above this point (hotter) not enough power is available and it will cool. Where the curves cross is the predicted stable point.



11.

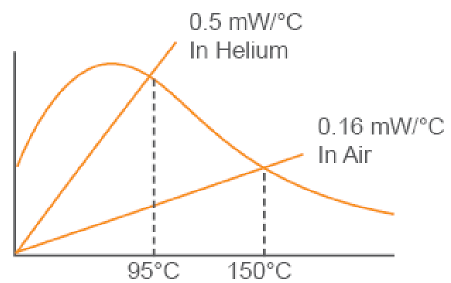
11a.

If the air velocity is now increased to some steady value, the self-heat thermistor temperature will drop. The increased air velocity has the effect of increasing the dissipation constant.



11b.
Lighter gases such as helium absorb and dissipate heat better than air. The same thermistor in helium has a dissipation constant of 5 milliwatts per °C. When this line is plotted on the same graph, the intersection indicates the new temperature. Note that this represents a drop-in temperature of 55°C. Each different molecular weight gas will produce a different dissipation constant and show up as different temperature.

This is one of the principles exploited in gas analysis.



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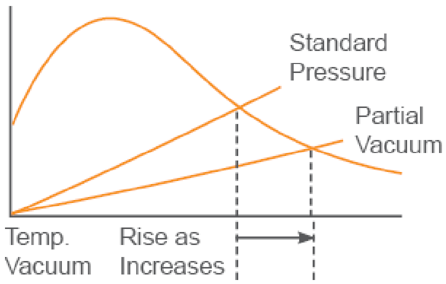
11c.
If the type of gas such as air is kept constant, but its pressure is reduced, the dissipation constant is also reduced. At lower pressures (higher vacuum) the same amount of power will produce a higher self-heat temperature. It is this change in thermistor temperature that is indicative of the state of the vacuum.



12. Sufficient data points for dissipation constant are generally not available over a wide range. However, if the dissipation constant is determined at the two extremes and in the center of the range of interest, then some very real predictions can be made relating to sensitivity and performance. It will be helpful to put these calculations on a spread sheet program with graphing capabilities as a means of providing a working mathematical model.

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