NTC THERMISTOR TESTING CONSIDERATIONS

APPLICATION NOTE

Thermistors are heat sensitive devices that are affected by all sources of heat energy. They are effected by ambient temperature, self-heat, conducted heat, thermal and solar radiation, etc. A proper test set up revolves around getting sufficient control of these effects, and quantifying or minimizing their influence. There are three basic areas of concern: The stability of the temperature controlled test bath, the accuracy of the independent temperature indicator, and the disturbing influence of the test itself on the thermistor.

GENERAL

The most basic question about a thermistor is “What is its resistance at a given temperature?” The thermistor is typically immersed in a liquid bath at an accuracy controlled temperature where its resistance is then measured. Air chambers are generally not used as they are extremely difficult to stabilize and control. How accurately should the bath temperature be controlled?

Assume the resistance is required on a 5% thermistor of curve at 25°C. The alpha is 4.4%/C. The 5% resistance tolerance is converted to an equivalent temperature tolerance.

5% divided by 4.4% / C° = 1.2 C°

As a rule of thumb, the bath error should be no greater than about a tenth of that approximately .1 C°. If a thermistor is specified with a temperature tolerance such as .02 C° then the bath must be capable of .02 C°.

It should be noted that a thermistor that is right on the limit of 5% may be misrepresented as 5.5% due to bath error. In the .2C° example, it may be misrepresented as .22 C°. Naturally the bath error may also at times make the thermistor look more favorable. If this is unacceptable, one of two things can be done. Either the bath must be controlled to a more acceptable accuracy or there must be a correction factor for the actual bath temperature at the time of measurement. To correct for temperature, the error is converted to equivalent resistance using the alpha and added to or subtracted as required from the original resistance reading.

Correcting for temperature can have its own pitfalls. The temperature in all controlled thermal systems tends to wander or cycle within a narrow range of temperatures called the system bandwidth. It may also be known as the “bath swing”. To minimize this influence, an operator may wait until the temperature jus hits the exact desired temperature and then quickly take the resistance reading. This can be a valid method provided the temperature is not swinging faster than a tenth of a degree in a minute or two.

However, there are two cautions. First that the independent temperature indicator and the thermistor under test have similar construction size, materials and thermal mass. If otherwise, the two devices will not follow or track each other. The larger or more massive device will lag behind in temperature. The second point is that the temperature swings tend to be somewhat sinusoidal with the average centered at the required test temperature. The result is that while the resistance reading is apparently taken at the exact required temperature it is also the point in the cycle with the fastest rate of change, for reference, if allowed to swing to its full range in one direction (to one of edge of the system bandwidth) then that would be the most stable point. In fact, for a few moments, the rate of change is practically zero, but it’s at a point furthest removed from the desired temperature.

LIQUID MEDIUM

If the thermistor under test and the independent temperature sensor are both in a protective housing then water can be used. If the thermistor is bare or has exposed leads then a non-electrically conductive liquid must be employed such as mineral spirits or oil.

In the high temperature realm, there are some cautions. Oils can produce smoke and fumes and should have a fume hood and power vent system. They can flash and burn and so should be used below the flash point or as the manufacture recommends. The large quality of hot oil can be a hazard to personnel and so splashes and spills must be precluded or minimized with fixtures or splash guards.

Silicone oils are also available as bath mediums but are usually avoided around electrical equipment. The oil seems to creep or carries as a vapor into places where it's not wanted such as switch and relay contacts. The minor arcing that normally occurs when contacts operate breaks down the oil leaving silica on the contact surfaces. This resulting white residue is non-conducting preventing contact closure and mysterious equipment malfunctions.

INDEPENDENT TEMPERATURE SENSOR

The temperature bath must incorporate an accurate temperature indicator. A thermistor, factory calibrated at the customers test point(s), is often the best sensor. Platinum resistance bulbs (RTD) can also be used but must also be calibrated. Thermistors, with their higher alphas and choice of more desirable higher resistance values, are easy to use. The higher resistance values available for their thermistors minimize lead errors. The higher alpha of the thermistor is also very important. A 1% reading error on the resistance of a thermistor equates to only a .05°C temperature error. Conversely, a .1% reading on a platinum resistance bulb translates to a 3° C temperature error. Thermocouples in general do not have the accuracy and stability as a reference.

SELF-HEAT

It is desirable to put a "high" test voltage on a thermistor under consideration on order to have the highest signal. The amount of voltage allowed depends on the dissipation constant and the resistance at the test temperature.

Example:
What will be the temperature rise due to self-heat on a 10K thermistor whose alpha is 4.4% / C° and dissipation constant is 1 milliwatt per degree when 2 volts is applied?

$W = E^2 / R$ or $mW = E^2 / K \text{ ohms}$

$mW = 2^2 / 10 = .4Mw$

Temp Rise = Power / Dissipation Constant
= .4 / 1 = .4 C° rise

This is too big an error for most purposes. Cutting back the voltage to 1 volt still produces a .1 C° error. A further reduction to .5 volts produces only a .025°C error which for most occasions will be acceptable. Note that as the voltage is reduced the corresponding temperature rise drops quickly.

The current supplied to the thermistor from common commercial digital multi meter (DMM) can be significant. Consult the DMM manufactures' specification for the intended meter range.

Example:
What will be the power dissipation and resulting temperature rise of 100 micro amps (100 uA) is passed through the same 10 K thermistor as above?

$W = 12 * R$
$W = (100 * 10^6)^2 * (10{,}000) = .1mW$

.1mW is equivalent to 1 C° rise. This is too much and an alternative must be sought. The DMM is too convenient and accurate an instrument to abandon quickly. On special order, some instrument manufactures have been able to set the current to a lower level. On larger thermistors or probe assemblies where the dissipation constant is an order of magnitude higher, the temperature rise due to the DMM current is likely to be negligible.

GLASS THERMOMETERS

Typical laboratory glass thermometers are not suitable for the precision usually required in thermistor test baths. A 0° C to 200° C thermometer with a 10-inch scale will have one degree marks every .050 inches, or less than a sixteenth of an inch. Half degree marks would be approximately a thirty-second of an inch with nothing smaller practical. Readability and accuracy cannot be better than half of that of .25 C°. Expanded scale thermometers improve the readability somewhat but still cannot provide the precision and accuracy required.

Common lab thermometers are usually three-inch immersion with the more precision types being total immersion (immersed at least up to the reading level). Now, to minimize the effects of temperature gradients in the bath, the thermistor under test and the thermometer bulb must be adjacent. This is at least inconvenient if the thermometer bulb is 10 inches or so below the bath surface. Glass thermometers also need periodic calibration checks as the glass can "cold flow" if exposed to its upper temperature limits especially for extended periods.

TEMPERATURE GRADIENTS

Temperature gradients and fluctuations must be minimized for best reading accuracy and repeatability. From here it is easier to point out what's wrong with a poor thermal system such as a large beaker on a hot plate. The hottest spot will be in the middle of the bottom surface, away from cooler sides. The coolest area will be the top surface near the rim. Here there is evaporative cooling, convection cooling, as well as some heat sinking from the beaker's rim above the liquid surface.

Adding a motor driven is a major improvement, but should be a propeller type and driven smartly to force the best mixing.

The next big improvement comes from insulating the sides and adding an insulation lid. This seems intuitive as it dramatically reduces the evaporative and convective cooling thus reducing cool spots. Less obvious is the benefit of requiring less make up heat. The heater is inherently the largest contributor of temperature gradients. It can only inject heat required if there is a large temperature difference between the heater and the bath liquid. A smaller heat demand results in a lower temperature difference between the heater and the liquid. This translates to a lower hot spot and lower gradients.

The placements of the temperature indicating sensors should be chosen carefully. Temperature profiles can run both in the vertical plane and horizontally to determine the most stable zone. This would not necessarily be in the geometric center. It is more likely to be quite far from the heater, somewhat down-stream of the impeller, away from the side walls and often three inches or so from the top surface. The thermistor under test would not just be in the same zone, but at the exact same depth as the indicating temperature sensor and as close as practical to it.

Where temperature gradients in the hundredths of a degree are sought, home grown designs are generally disappointing. There are too many subtle aspects in the bath geometry, heater geometry and placement, insulation, oil circulation, and temperature control, tec. Which are best left to specialty suppliers.

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