

# Temperature Detectors: Choosing The Correct Device To Fit Application



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When we mention temperature detectors for motors we usually think of winding temperature detectors. However, temperature detectors can also be used to monitor bearings and airflow. In this article we will describe the more common types of temperature detectors and how they can be applied to windings, bearings and to check ventilation (airflow).

We will begin by describing the different types of temperature detectors most commonly used in motors and generators. For simplicity we will use the term “motors” to mean both motors and generators. Although our focus is on temperature detectors for motors and generators, the detectors may also be found in transformers and other equipment. These are resistance temperature detectors (RTDs), thermocouples, thermostats, and thermistors.

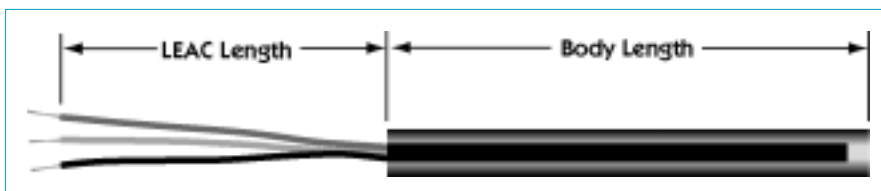


Figure 1. Common RTD type.

## Common RTD Types

RTDs (Figure 1) consist of a wire coil or deposited film of pure metal for which the change in resistance is a known function of temperature. The common RTD types by metal, and their characteristic resistance and base temperature are: copper ( $10.0\Omega$  @  $25^\circ\text{C}$ ), platinum ( $100\Omega$  @  $0^\circ\text{C}$ ), and nickel ( $120\Omega$  @  $0^\circ\text{C}$ ). Instrumentation measures the resistance of the RTDs and converts the readings to temperature. If the temperature exceeds a set point, an alarm or shutdown can be activated. A distinct advantage of an RTD is that the resistance change with respect to temperature is linear. That permits the user to know the winding temperature at all times.

Thermocouples are two-lead devices made up of a welded junction of two dissimilar metals that generate a distinct minute voltage in proportion to temperature. The junction metals and type codes for thermocouples are: chromel-constantan (E), iron-constantan (J), chromel-alumel (K) and copper-constantan (T). The generated voltage is sensed by instrumentation and converted to temperature. As with RTDs, if the temperature exceeds a set point, an alarm or shutdown can be activated.

## Four Types Of Detectors

Thermostats used in motors are two-lead devices that utilize the unequal expansion of two different metals to open or close an integral switch at a prescribed temperature. To describe them another way,

thermostats in motors are bi-metallic normally open (NO) or normally closed (NC) switches that activate at a specific temperature for the purpose of protecting a winding or bearings. Unlike the other temperature detector types, the thermostat cannot be used to indicate temperature values. Of the four types of temperature detectors, thermostats are the only devices intended to have control system voltage, or in some cases line voltage, applied to them. **Note:** The manufacturer’s part number of some thermostats, and some thermistors, includes the temperature setting.

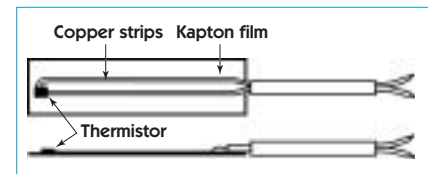


Figure 2. Thermistor temperature detector.

The fourth type of temperature detector is the thermistor (Figure 2). Thermistors are resistive two-lead devices that are composed of metal oxides formed into beads (or thin flat shapes) and encapsulated in epoxy or glass. There are two types of thermistors: positive temperature coefficient (PTC) and negative temperature coefficient (NTC). The resistance of a PTC type increases dramatically and non-linearly near the temperature set point; conversely, the NTC resistance drops dramatically and non-linearly near the temperature set point. Alarms or shutdown can be activated when instrumentation senses the dramatic change in thermistor resistance. The NTC type is more common than the PTC type.

## Unknown Type Of Detector

If the type of temperature detector is unknown, how can it be determined?

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Begin by testing lead to lead with a digital multimeter (DMM). It is easier to accurately read the display of a DMM compared to an analog multimeter, thus the suggestion to use a DMM for this test. If the detector has three leads, two white and one red, it is probably an RTD. Most 2-lead RTDs have a red and a white lead. Therefore, if the detector leads are a combination of red and white, that is an indicator (but not assurance) that the detector is an RTD. The lead to lead resistance values, from a red to any white lead will be about 10, 100 or 120 ohms for an RTD. The resistance from a white to white lead of a 3-lead RTD will be nearly zero. The white leads join together within the RTD, so the white lead to white lead resistance is only the resistance of the two leads. If the detector is a thermistor, the lead to lead resistance of the two leads will typically be in the many hundreds or thousands of ohms. For example, one common type of NTC thermistor has a rated resistance of 2252 ohms at 25° C. Testing of thermistors is described later in the article.

## Thermocouple Or Thermostat

The DMM may display a resistance much lower than the 10 ohm (at 25° C) value of the lowest resistive device, the copper RTD. In that case, test for DC voltage lead to lead, using a millivoltmeter, or DMM on the millivolt scale. A voltage between 0 and 3 millivolts at room temperature indicates the detector is a thermocouple. If there is no voltage from the detector, and the resistance is nearly zero ohms, it is probably a thermostat. Conversely, if the resistance reading is “infinity,” it could be a normally open (NO) thermostat, or a detector that has failed in the “open” condition. Testing of thermostats, described later, can be used to determine if an

open circuit is a NO thermostat or an open detector.

A thermocouple temperature sensing instrument with the ability to select the E, J, K or T type thermocouples can be used to determine the type. (This instrument is similar in size and cost to a multi-meter.) Use a piece of metal, such as a short length of 1” (25mm) keystick, to check for the thermocouple type. With the keystick initially at an accurately known “room temperature,” measure its temperature with the instrument set to each type, i.e., E, J, K and then T. Next, heat the keystick to about 100° C, and measure the temperature with each type thermocouple instrument. Make certain that the temperature of the keystick remains at very nearly 100° C ( $\pm 2^\circ$  C). Compare the indicated temperature values for each thermocouple to the actual temperatures. The most accurate temperature reading will indicate the type of thermocouple.

## Precise Comparisons Needed

The K and T type thermocouples will produce nearly the same temperature results, thus requiring very precise comparisons. Manufacturers of thermocouples produce tables of millivolts versus temperature for each type thermocouple. If the millivolt versus temperature table is available, a millivolt meter capable of reading to at least four-digit accuracy can be used to determine the type of thermocouple. To illustrate the need for this level of accuracy, at 50° C the output of a type K is 2.022 millivolts and the output of a type T is 2.035 millivolts.

Thermostats are usually, but not always, normally closed (NC). When the temperature set point is reached, the NC thermostat contacts open. Typically the contacts are in series with a relay coil, such as the holding coil for a motor starter. When the thermostat opens, the current to the control coil is

interrupted and the coil opens its contacts, taking the motor or generator offline or setting off an alarm. On very small motors, a NC thermostat might be used to open the wye (or the start and run windings of a single-phase motor) directly. That may be hazardous, because the motor can restart without warning when the temperature decreases and allows the device to close.

A simple test for a thermostat is to heat the detector, or the winding area if the detector is embedded, with a heat gun. First, connect an ohmmeter to the two leads of the detector. If the detector is NC, the initial resistance will be “zero” ohms; and if the thermostat is NO, the initial resistance will be “infinity” ohms. When the detector reaches its set point temperature it will change mode, i.e., if NC it will become open (infinity ohms) and if NO it will close (zero ohms). If the thermostat does not change mode and its test temperature is known to exceed 200° C, the detector is defective. This is because the operating temperature and insulation class of most electric motor windings requires that a thermal device operate somewhere between 120° C and 185° C.

## A Challenge For Testing

Thermistors present a challenge for testing. Some thermistors are so sensitive that the current flow from an ohmmeter can exceed the thermistor’s capability and cause the thermistor to fail, i.e., become an open circuit. A digital multimeter (DMM) uses a lower test current than an analog meter; therefore, do not use an analog meter to test thermistors. If possible, determine from the thermistor manufacturer if the thermistor to be tested can withstand the current from an ohmmeter. If it can, the resistance can be measured at a known temperature, and the thermistor heated to

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another known temperature. The heat gun method mentioned above can be used for this purpose. The resistance values at the two temperatures should be different, and can be compared to the thermistor manufacturer's tables of resistance versus temperature, if they are available. If the thermistor type is not known, the change in resistance with temperature will reveal if the thermistor is the NTC or PTC type. The NTC type will have a lower resistance at a higher temperature, and the PTC type will have a higher resistance at a higher temperature.

## Devices for Windings, Bearings

What types of temperature detectors are used in windings and bearings?

Resistance temperature detectors (RTDs) are used in windings and in bearings. The RTD is the most common detector used in form coil windings. The RTD element is embedded in an insulated wedge-shaped material, having an appearance of a slot wedge. It is normally placed between the bottom and top coils, with the sensing tip near the axial center of the core because that is usually the hottest spot. There is at least one RTD per phase, and often there are two, with one set of three acting as spares in the event an RTD fails. An RTD failure is almost always to an open circuit. RTDs can also be attached to the endturns of a winding; however, that is not the hottest winding location, and airflow variations can affect temperatures at the RTDs. Therefore, it is best to locate RTDs in the center of the core, between coils.

RTDs can be used in random windings; however, the physical size of such RTDs must be small, to allow the RTD to be embedded in the round wires of the winding. It is not common to find RTDs in random windings. Copper and platinum are

more common than nickel RTDs for detecting temperatures in motors and generators.

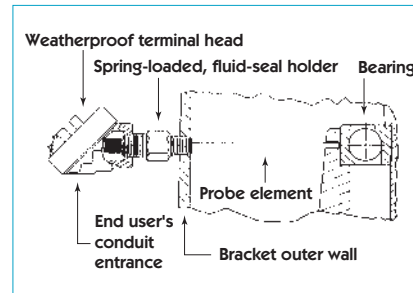


Figure 3. Bearing temperature detection installation.

## Used To Detect Bearing Temperature

The RTD can also be used to detect bearing temperature (Figure 3). Tip sensitive RTDs at the end of a metal rod, usually spring loaded to assure good physical contact with the bearing, are inserted through holes in the bearing housing. The tips contact either the outer race of a rolling bearing (ball or roller) or the bearing shell near the babbitt lining of a sleeve bearing. The RTD tip should be in direct contact with the bearing shell, as close as possible to the load zone of the babbitt. If the winding has RTDs, the bearing RTDs are usually the same type, e.g., copper, platinum or nickel. That allows the same instrumentation to be used to sense both winding and bearing temperatures.

Thermocouples are also used for both bearing and winding temperature detection. The J and K types are the most common. The relatively small shape and physical ruggedness of the thermocouple make them useful for temperature detection of random windings. Thermocouples are also used in form coil windings but are not nearly as common as RTDs. The thermocouple, which is point sensitive at the bi-metal junction, should have that point embedded in the slot

between coils at the center of the core. That is the same location as for RTDs, the reason again being maximum sensitivity to the typical hottest spot in the winding. Thermocouples are also commonly used to detect bearing temperatures, with the location and insertion process being the same as for RTDs described above. In addition to their use in winding and bearing temperature detection, thermocouples are the most common type to be used to check airflow. Typically they are embedded in a rod that protrudes into the airstream to measure temperature.

## Thermostats Common For Random Windings

The physical size of thermostats makes them impractical for use with form coils. Thermostats are the most common type of temperature protection for random windings. They are either embedded in the endturns or attached to the endturns. The embedded detectors provide a more accurate indication of winding temperature as they are not affected by airflow over the endturns. It may help to keep in mind that the hottest area of a TEFC motor winding is the outer circumference of the winding extension, while the inner circumference is much cooler due to the airflow inside the motor. Thermostats may be used on bearing housings, but due to their physical size are not practical for directly sensing bearing temperatures. The housing location being remote from the bearing also reduces the accuracy of the sensed temperatures; therefore, thermostats are not often used to detect bearing temperatures.

Thermistors are not physically as large as thermostats but are bulky enough to be impractical for form coil windings. Thermistors are typically embedded in the endturns of random

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windings. Though not as common as thermocouples for random winding temperature detections, thermistors are very often used in hermetic refrigeration stators. Thermistors are not normally used for bearing temperature detection.

## Conclusion

Selection of the appropriate temperature device requires much

more than what we have considered here. One of the primary selection factors is determining the temperature setting. See the prior articles in *CURRENTS* that address overtemperature (“What Does It Mean When A Rewound Motor Runs ‘Hot’?”, *CURRENTS*, January 2000) and temperature limits (“Understanding Motor Temperature Rise Limits,”

*CURRENTS*, November 2003). Further, while discussing the addition of auxiliary equipment with your customer, be sure to factor in existing devices. A customer whose motors are all fitted with one device may be better off with the same device, rather than another device requiring different procedures and instrumentation.