Graham Sensor Technologies Inc.

Custom Thermocouples, RTD's, Thermistors, Thermowells, & Bi-Metal Thermometers

Poor Boy's Verification of RTD's

or

How To Field Check RTD's With Limited Equipment

There comes a time in every sensor project where you would like to verify the sensor's accuracy but you do not want to send the sensor out for calibration. The following is some simple guidelines to help you in testing RTD's in the field. This is not a replacement for having a true calibration certificate but is solely meant to give you peace of mind that the RTD's are working well, with care you will get to with in ½ a deg or better.

NOTE: THIS METHOD IS ONLY TO SEE IF THE RTD'S ARE FUNCTIONING PROPERLY.

At the end of this paper is a Glossary of Terms and some notes on temperature that may help explain why we have to do things a certain way to get the best accuracy from our simple tests.

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Let's Get Started

There are two points that can be reproduced in the field fairly easily:

1. Ice Point – the melting (and freezing) point of ice, 0°C. The ice point is frequently used as a calibration check point on resistance temperature detectors and as the reference junction for thermocouples.
2. Boiling Point – the equilibrium temperature between a liquid and its vapour. It is commonly associated with water at 100°C, and 1 standard atmosphere. This is harder to do in the field as elevation and barometric pressure come into play. If you have a glass thermometer you can get a better reading, unless you are below sea level most error will be on the low side of 100°C. The nice thing about using water is it will not go over that temperature no matter what heat source you use.

Ice Point

Apparatus

1. Use the best DVM in the shop, 4 ½ digits or better.
2. A Dewar flask or insulated container with 6" minimum height (note 18" would be better, tall and thin, the more ice the longer it will last).

You need to place the probe 10 times its diameter in to the ice. For Example, ¼" diameter probe would need to go at least 2 ½" into the ice, but 4" would be better. Make sure that you are not touching the bottom of the Dewar.

Ideally measurements should be made on an apparatus suitable for the characteristic of the component to be measured as follows; ice point temperature resistance measurements may be taken using a digital multimeter with an accuracy of ±0.01%.

Ice Point Temperature Resistance

In a Dewar flask or suitable container, place distilled or bottled water, and shaved or crushed clear ice (<2mm pieces can be made by wrapping the ice in a clean cloth and hitting it with a hammer) made from distilled of bottled water. The bath should have enough water to provide good thermal contact with the RTD, but not enough to float the ice. The spaces between ice particles must be filled with water (no air pockets) and the ice must extend all the way to the bottom of the Dewar flask. Left to itself, a cavity may form as the conducted heat melts the ice, hence stirring is required every few minutes. The tool used for stirring should not be removed from the Dewar flask during the test, to avoid introducing heat sources.

Thoroughly clean the Test Instrument with distilled or bottled water and insert it into the bat, leaving a minimum of 1" of ice at the bottom of the Dewar Flask. Oil and dirt can affect the temperature.

In general, when you push down on the ice pack, the water should rise only ¼" above the ice pack. The ice point bath is the most widely used and simplest fixed point. The ice bath may be realized with an error of less than 0.01°C. Contamination of any surfaces and or touching the ice with your hands may be jeopardizing the accuracy of the ice point. Wipe down the Dewar flask and ice crusher with distilled of bottled water prior to performing this test. Immersion Error may occur if the thermometers are not immersed at least 2 to 3 inches into the bath. Allow the temperatures to stabilize for at least ½ hour, stirring the ice frequently, and draining off excess water. Add ice as necessary. Sensor accuracy is a function of production tolerance and any additional calibration which the sensor may get. Calibration can improve the accuracy of an RTD by 10 times over production tolerance.

Let's Take Some Readings

Measure the Ice Point resistance of the sensor. At this point you have left the sensor in the Dewar flask for a reasonable length of time and you have stirred the bath.

When measuring a 3 wire RTD you must do this in two stages.

There is no standard colour coding for RTD's, some will come with 2 white and 1 red wire, others will have 2 red and 1 white, and some may have a white, a red, and a black. Our standard is 1 red & 2 white wires, the 2 white wires are connected together at the RTD bulb so you can tell what lead wire resistance is and what the bulb's resistance is.

1. Set You DVM to the lowest resistance range. At 00C the RTD will read between 99.90 & 100.10 after you have removed the lead wire resistance.
2. Connect one red wire and one white wire to the meter and log the resistance value, depending how long the leads are the resistance value will be above 100Ω. You can tell if the RTD has reached equilibrium by looking at the readings and noting if the value keeps dropping.
3. Connect one white wire and the other white wire to the meter. Log this value. Depending on how long the sensor is an how long the wire is this value can be anywhere from 0.01Ω to 20 or 30Ω for really long runs of wire.
4. Subtract the second reading from the first this will give you the RTD resistance value at said temperature, look at the table below:

Below 0°C										
Temp. (°C)	-0	-0.1	-0.2	-0.3	-0.4	-0.5	-0.6	-0.7	-0.8	-0.9
-2	99.2181	99.1790	99.1399	99.1008	99.0617	99.0226	98.9835	98.9443	98.9052	98.8661
-1	99.6091	99.5700	99.5309	99.4918	99.4527	99.4136	99.3745	99.3354	99.2963	99.2572
-0	100.000	99.9609	99.9218	99.8827	99.8437	99.8046	99.7655	99.7264	99.6873	99.6482
Temp. (°C)	+0	+0.1	+0.2	+0.3	+0.4	+0.5	+0.6	+0.7	+0.8	+0.9
+0	100.000	100.039	100.078	100.117	100.156	100.195	100.234	100.274	100.313	100.352
+1	100.391	100.430	100.469	100.508	100.547	100.586	100.625	100.664	100.703	100.742
+2	100.781	100.820	100.860	100.899	100.938	100.977	101.016	101.055	101.094	101.133

Above 0°C

Boiling Point

Apparatus

1. Use the best DVM in the shop, 4 ½ digits or better.
2. A Dewar flask or insulated container with 6" minimum height (note 18" would be better, tall and thin, the more ice the longer it will last).

You need to place the probe 10 times its diameter in to the ice. For Example, ¼" diameter probe would need to go at least 2 ½" into the ice, but 4" would be better. Make sure that you are not touching the bottom of the Dewar.

Let's Take Some Readings

When measuring a 3 wire RTD you must do this in two stages.

There is no standard colour coding for RTD's, some will come with 2 white and 1 red wire, others will have 2 red and 1 white, and some may have a white, a red, and a black. Our standard is 1 red & 2 white wires, the 2 white wires are connected together at the RTD bulb so you can tell what lead wire resistance is and what the bulb's resistance is.

1. Set You DVM to the lowest resistance range.
2. Connect one red wire and one white wire to the meter and log the resistance value, depending how long the leads are the resistance value will be above 100Ω. You can tell if the RTD has reached equilibrium by looking at the readings and noting if the value keeps rising.
3. Connect one white wire and the other white wire to the meter. Log this value. Depending on how long the sensor is an how long the wire is this value can be anywhere from 0.01Ω to 20 or 30Ω for really long runs of wire.
4. Subtract the second reading from the first this will give you the RTD resistance value at said temperature, look at the table below:

Below 100°C										
Temp. (°C)	+0	+0.1	+0.2	+0.3	+0.4	+0.5	+0.6	+0.7	+0.8	+0.9
96	136.987	137.025	137.063	137.101	137.139	137.177	137.215	137.253	137.291	137.329
97	137.367	137.405	137.443	137.481	137.519	137.557	137.595	137.633	137.671	137.709
98	137.747	137.785	137.823	137.861	137.899	137.936	137.974	138.012	138.050	138.088
99	138.126	138.164	138.202	138.240	138.278	138.316	138.354	138.392	138.430	138.468
100	138.505	138.543	138.581	138.619	138.657	138.695	138.733	138.771	138.809	138.847
101	138.885	138.923	138.961	138.998	139.036	139.074	139.112	139.150	139.188	139.226
102	139.264	139.302	139.340	139.378	139.415	139.453	139.491	139.529	139.567	139.605
Above 100°C										

Glossary of Terms

Accuracy	A statement that is used to define the largest allowable error in a device or system. It is an indication of how close measured values are to true values. It can be expressed in both measured units and in percentages.
Alpha (-)	The temperature coefficient of resistance of a material, derived from measurements at 0°C and at 100°C: {R sub {100} – R sub {0}} over {100 times R sub {0}}. It indicates the basic change in resistance temperature detectors (RTD's).
ANSI	An abbreviation for American National Standards Institute.
ASTM	An abbreviation for American Society for Testing and Materials.
AWG	An abbreviation for American Wire Gauge.
Atmospheric Pressure	See Atmospheric Pressure in Notes.
Boiling Point	See Boiling Point in Notes.
Compensating Loop	Utilized in RTD's, a compensating loop is an extra pair of lead wires that have the same resistance as the actual lead wires, but which are nor connected to the RTD element. Its purpose is to correct for lead wire resistance errors when making temperature measurements.
Callendar – Van Dusen Equation	An interpolation equation which provides resistance values as a function of temperature for RTD's.
Dielectric Strength	A measure of the voltage that an insulating material can withstand before an electrical breakdown occurs. It is sometimes referred to as breakdown potential.
DIN 43760	German Institute for Standards document that covers nickel and platinum resistance elements. This is the most popular specification for 100Ω platinum RTD's with a resistance vs. temperature curve specified by 0.00385 ohms/ohm/C.
Fahrenheit Temperature Scale	A temperature scale with the ice point at 32 and the boiling point of water at 212. The formula for conversion to the Celsius scale is: − .
Fixed Point	A very reproducible temperature at the equilibrium point between phase changes in a material. The triple point of water (0.01°C) is an example of a fixed point.
Freezing Point	The fixed temperature point of a material that occurs during the transition from a liquid to a solid state. This is also known as the melting point for pure materials.
Ice Point	The melting (and freezing) point of ice, 0°C. The ice point is frequently used as a calibration check point on resistance temperature detectors and as the reference junction for thermocouples.
Insulation Resistance	A ratio of the applied voltage to the total current flow between two conductors separated by insulation or any conductor and the sheath.
Interchange Ability	A statement that describes how closely a sensor adheres to its defining equation, and the maximum variation that would exist in the readings of identical sensors mounted side-by-side under identical conditions.
Primary Standard	A term that applies to an instrument that meets conditions required for establishing the International Practical Temperature Scale.
Repeatability	The ability of a sensor or system to indicate the same reading under repeated identical conditions.
Resistance	A property of conductors that determines the current produced by a given

	difference of potential. Dimensions, material and temperature all influence resistance.
Response Time	The time required for a sensor to reach 63.2% of the step change in temperature for a particular set of test conditions.
RTD	An abbreviation for resistance temperature detector. It is a circuit element whose resistance increases with increasing temperature in a predictable manner. Platinum is the most popular material used in RTD's.
Secondary Standard	A measurement device that has been referenced to a primary standard.
Triple Point of Water	A thermodynamic state (of water) in which the gas, liquid, and solid phases all occur in equilibrium. For water, the triple point is 0.01°C.
Temperature Calibration Point	A temperature at which the output of a sensor is compared or determined by comparison against a standard.
Thermal Gradient	The distribution of differential temperatures in and across an object.
Temperature	See Temperature in Notes.
Working Standard	A measurement device that has been referenced to a secondary standard.

Notes

Atmospheric Pressure

The surface of the earth is at the bottom of an atmospheric sea. The standard atmospheric pressure is measured in various units:

The fundamental SI unit of pressure is the Pascal (Pa), but it is a small unit so kPa is the most common direct pressure unit for atmospheric pressure. Since the static fluid pressure is dependent only upon density and depth, choosing a liquid of standard density like mercury or water allows you to express the pressure in units of height or depth, e.g. mmHg or inches of water. The mercury barometer is the standard instrument for atmospheric pressure measurement in weather reporting. The decrease in atmospheric pressure with height can be predicted from the barometric formula.

The unit mmHg is often called torr, particularly in vacuum applications: 760 mmHg = 760 torr.

For weather applications, the standard atmospheric pressure is often called 1 bar or 1000 millibars. This has been found to be convenient for recording the relatively small deviations from standard atmospheric pressure with normal weather patterns.

Boiling Point

The boiling point is the equilibrium temperature between a liquid and its vapor. It is commonly associated with water at 100°C, and 1 standard atmosphere.

The boiling point is defined as the temperature at which the saturated vapor pressure of a liquid is equal to the surrounding atmospheric pressure. For water, the vapor pressure reaches the standard sea level atmospheric pressure of 760 mmHg at 100°C. Since the vapor pressure increases with temperature, it follows that for pressure greater than 760 mmHg (e.g. in a pressure cooker), the boiling point is above 100°C and for pressure less than 760 mmHg (e.g. at altitudes above sea level), the boiling point will be lower than 100°C. As long as a vessel of water is boiling at 760 mmHg, it will remain 10 100°C until the phase change is complete. Rapidly boiling water is not at a higher temperature than slowly boiling water. The stability of the boiling point makes it a convenient calibration temperature for temperature scales.

Temperature

A convenient operational definition of temperature is that it is a measure of the average translational kinetic energy associated with the disordered microscopic motion of atoms and molecules. The flow of heat is from a high temperature region toward a lower temperature region. The details of the relationship to molecular motion are described in kinetic theory. The temperature defined from kinetic theory is called the kinetic temperature. Temperature is not directly proportional to internal energy since temperature measures only the kinetic energy part of the internal energy, so two objects with the same temperatures do not general have the same internal energy (see water – metal example). Temperatures are measured in one of three standards temperature scales, Celsius, Kelvin, or Fahrenheit.