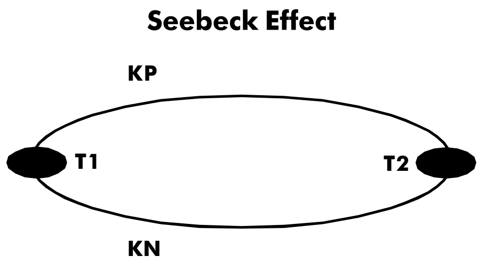
Temperature Sensor Theory

There are many different types of temperature sensors. We will deal with the two most common types, thermocouples and RTDs. Not because they are the most common, but because these two are the only two types Smart Sensors makes. (So if you are curious about other sensors, you will have to go elsewhere to find out how they work).

Thermocouples - How do they work?

In 1821 Thomas Seebeck, while making a pot of tea, discovered that when two dissimilar metals are joined together, a current flows, as long as the temperature at one of the junctions is at a higher temperature than the other junction. Little did he know, as he finished his tea, that he would be famous for discovering the current that flowed in this circuit and the EMF (Electro Motive Force) that produced this current would be forever called the Seebeck Effect.

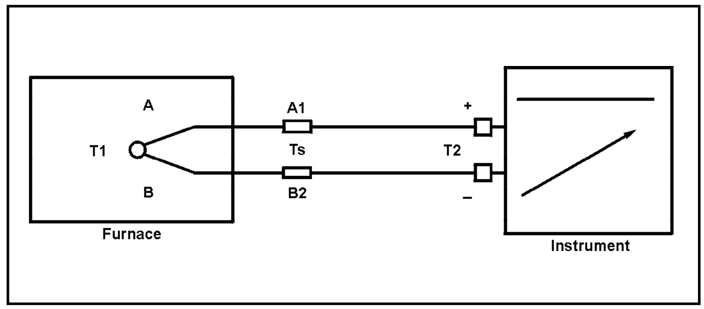


Seebeck circuit showing the positive (kp) and negative (kn) of a Chromel Alumel thermocouple. If the temperatures (T1 and T2) are different at the two junctions a current will flow in the circuit.

Seebeck was responsible for developing the most rugged and simplistic yet cost effective way of measuring temperature over a broad range. Copper Constantan, Chromel Alumel, Iron Constantan and Chromel Constantan, the standard thermocouple calibrations that are in use today, were derived from this research. They work the same way the scientist's theory said they would work. When you apply heat to T1 and T2 is at a different temperature the two dissimilar metals will produce a EMF. The EMF is different for different metals and unfortunately it is not linear, but it is accurate enough to handle most process applications. Accuracy improvements have been made primarily by closer control of the chemical composition; today thermocouples have accuracy as low as 1/2 degree Fahrenheit. There have been other calibrations introduced since then and many improvements to the way thermocouples are used; but the credit for developing thermocouples as we use them today goes to Thomas Seebeck.

A few years later, Jean Peltier made the second most important contribution to thermocouple theory. In essence he discovered that when heat flows across a thermoelectric junction, heat is either absorbed or liberated. The direction of the current flow dictates whether the heat is absorbed or liberated. If the current produced by the Seebeck Effect is at the hotter of the two junctions, heat is absorbed, while heat is liberated at the cooler or cold junction. He discovered this phenomena without drinking a single cup of tea.

These two guys really developed the rules for the proper use of thermocouples. First, and most important, is that the EMF developed by the joining (hot junction) of two dissimilar metals will report the temperature at that junction regardless of the temperature along the length of the wires. Second, and my personal favorite, is that the introduction of a third metal in the circuit can cause unwanted variances in the EMF unless the same temperature is maintained along the entire length where the third metal is introduced. This means that all you thermocouple users can not use cheap baling wire to make your connections to the instrument. Third, quite simply stated this rule allows the EMF signal to be brought back to a standard reference junction, usually 32°F, without maintaining intermediate reference junctions at a constant temperature.



The diagram above has three junctions. The hot or measuring junction T1 reports the furnace temperature. A and B are the primary positive and negative thermocouple elements. A secondary junction Ts is used to transition to thermocouple extension wire. This is done to reduce the cost of the thermocouple circuit. The cost of MI cable is several times more expensive than thermocouple extension wire. Certain applications require the flexibility that only thermocouple extension wire can bring. Finally T2 as the reference junction connects the thermocouple to the instrument. Seebeck and Peltier discovered that if T1 and T2 are at the same temperature there will be no current flow in the circuit.

Basic and Advanced Thermocouples

When it comes right down to it there are only two basic types of thermocouple constructions. One is the kind our old friends Peltier and Seebeck used: Two dissimilar wires with a junction and insulated from one another. This is the most rudimentary construction and it can work given the simplicity of the application. Second and let's get modern here; the mineral insulated cable design that SSi uses.

This type uses a high purity magnesium oxide (MgO) to insulate the thermocouple wires from each other and the sheath. This insulation possesses high insulation resistance and upper temperature limits that far exceed the usable range of standard grade thermocouples. It is densely packed within a metallic sheath to insure concentric positioning of the conductors and improved mechanical strength, even when exposed to mechanical pressures such as bending, twisting or flattening.