THE PRINCIPLE FOR OPERATION OF ELECTRONIC THERMOMETERS IN TEMPERATURE MEASUREMENT AND TYPES

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Abstract. Recent days, in many industries, the production and development of electronic thermometers for temperature control and the measurement of a wide range of technological parameters is of great importance in the control of technological processes. In this regard, the work carried out in the measurement of temperature, the existing problems in the system and the science-based technologies for solving them are presented.

Keywords: Physicochemical properties, energy consumption, resistance thermometers, thermocouple, specific electrical resistance.

Electronic thermometers detect temperature changes using a thermoresistive device in which the electrical resistance changes in response to changes in temperature. This device may be a thermistor or a thermocouple and is incorporated into the tip of a probe. Thermistors are very small and therefore respond rapidly to changes in temperature. The current flow from a thermistor is translated into a temperature reading that is displayed on a digital readout. Electronic thermometers display either a predicted equilibrium temperature based on measurements taken over 15-30 seconds (in predictive mode) or an actual equilibrium temperature that is generally achieved in a minute or less (in continuous mode). The type of sensor used at the tip of the temperature measurement probe (or in dedicated hand-held thermometers) falls broadly to two types: thermocouple or thermistor. A third digital thermometer type, the resistance temperature detector, usually using platinum as the resistance metal (platinum resistance thermometer), is more often used in the laboratory for calibration of thermistors and thermocouples. Platinum resistance thermometers are stable over long periods, and are the most accurate sensors, especially in industrial applications. The disadvantage is in their cost. In the clinic it is not obvious, looking at a thermometer or bedside device, to know the type of measurement sensor without first checking the product information sheet, for temperature sensors may be engineered using a thermocouple or thermistor. Many physical properties change with temperature, such as the volume of a liquid, the length of a metal rod, the electrical resistance of a wire, the pressure of a gas kept at constant volume, and the volume of a gas kept at constant pressure. Filled-system thermometers use the phenomenon of thermal expansion of matter to measure temperature change. The filled thermal device consists of a primary element that takes the form of a reservoir or bulb, a flexible capillary tube, and a hollow Bourdon tube that actuates a signal-transmitting device and/or a local indicating temperature dial. A typical filled-system thermometer is shown in Figure-1. In this system, the filling fluid, either liquid or gas, expands as temperature increases. This causes the Bourdon tube to uncoil and indicate the temperature on a calibrated dial.

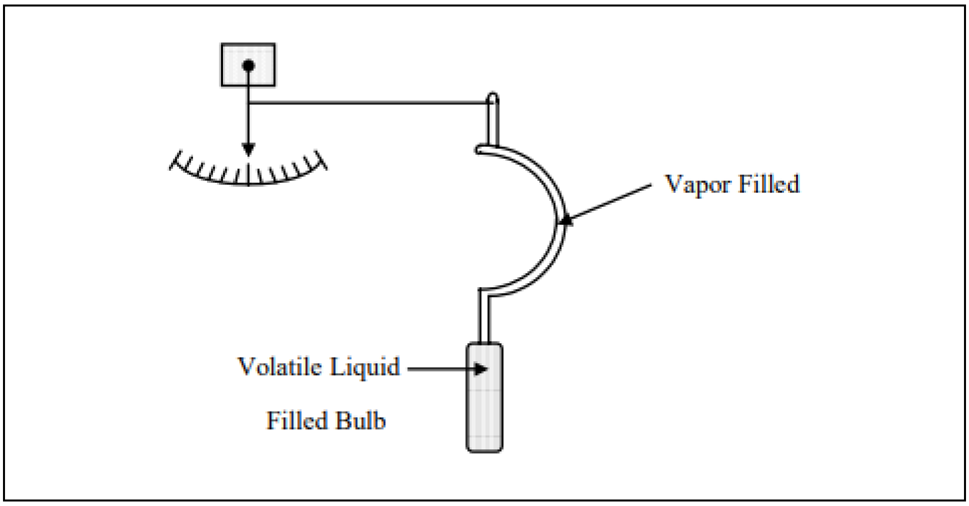

Figure -1. Filled bulb thermometer

A bimetallic strip curves or twists when exposed to a temperature change, as Bimetallic temperature sensors are based on the principle of that different metals experience thermal expansion with changes in temperature. To understand thermal expansion, consider a simple model of a solid, the atoms of which are held together in a regular array of forces that have an electrical origin. The forces between atoms can be compared to the forces that would be exerted by an array of springs connecting the atoms together. At any temperature above absolute zero (–273.15°C), the atoms of the solid vibrate. When the temperature is increased, the amplitude of the vibrations increases, and the average distance between atoms increases. This leads to an expansion of the whole body as the temperature is increased. The change in any linear dimension is L; the change in length that arises from a change in temperature (ΔT) can be designated by ΔL. Through experimentation, we find that the change in length ΔL is proportional to the change in temperature ΔT and the original length L. Thus,

$$\Delta L = kL\Delta T \quad (1)$$

a typical bimetallic dial thermometer using a spiral wound element. The spiral element provides a larger bimetallic element in a smaller area, and it can measure smaller changes in temperature. It is a low-cost instrument, but has the disadvantages of relative inaccuracy and a relatively slow response time. It is normally used in temperature measurement applications that do not require high accuracy

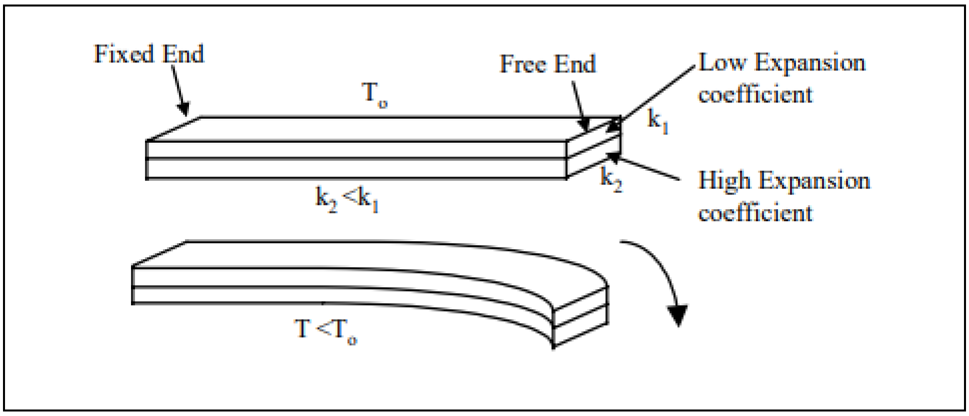

Figure -2.Thermoelectric Circuit.

When two wires composed of dissimilar metals are joined at both ends and one of the ends is heated, a continuous current flows in the “thermoelectric” circuit. All dissimilar metals exhibit this effect, and this configuration of two dissimilar metals joined together is called a thermocouple, which is abbreviated TC.

The logical question is, “If we already have a device that will measure absolute temperature (such as an RTD or thermistor), why do we even bother with a thermocouple that requires reference junction compensation?” The single most important answer to this question is that the thermistor, the RTD, and the integrated-circuit transducer are useful only over a limited temperature range. You can use thermocouples, on the other hand, over a wide range of temperatures. Moreover, they are much more rugged than thermistors (as evidenced by the fact that thermocouples are often welded to metal process equipment or clamped under a screw on the equipment).

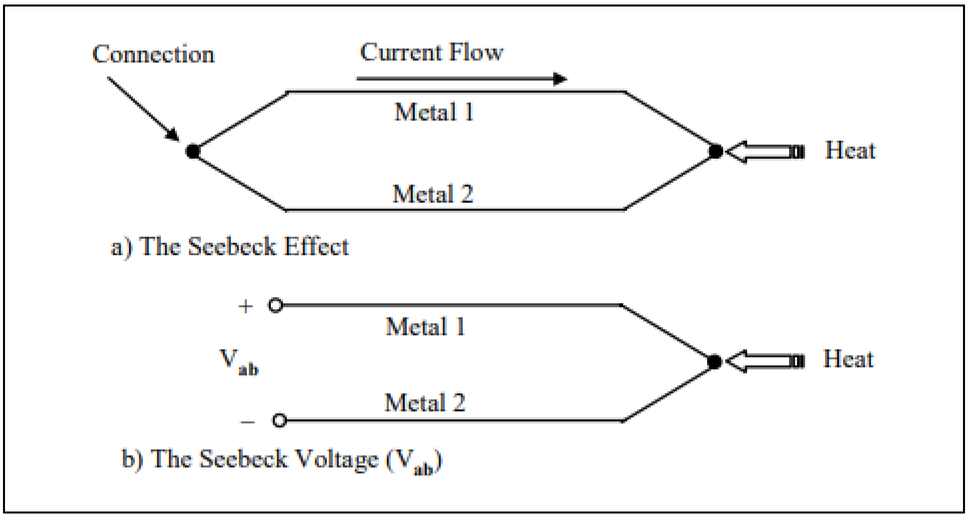

Figure -3. The thermoelectric circuit

They can be manufactured easily, either by soldering or welding. In short, thermocouples are the most versatile temperature transducers available. Furthermore, a computer-based temperature-monitoring system can perform the entire task of reference compensation and software voltage-to-temperature conversion. As a result, using a thermocouple in process control becomes as easy as connecting a pair of wires. The one disadvantage of the computer-based approach is that the computer requires a small amount of extra time to calculate the reference junction temperature, and this introduces a small dead time into a control loop. In principle, any material could be used to measure temperature if its electrical resistance changes in a significant and repeatable manner when the surrounding temperature changes. In practice, however, only certain metals and semiconductors are used in process control for temperature measurement. This general type of instrument is called a resistance temperature detector or RTD. RTDs are the second most widely used temperature measurement device because of their inherent simplicity, accuracy, and stability.

In a more rugged construction technique, the platinum wire is wound on a glass or ceramic bobbin. The winding reduces the effective enclosed area of the coil, which minimizes a magnetic pickup and its related noise. Once the wire is wound onto the bobbin, the assembly is then sealed with a coating of molten glass. The sealing process ensures that the RTD will maintain its integrity under extreme vibration, but it also limits the expansion of the platinum metal at high temperatures. Unless the coefficients of expansion of the platinum and the bobbin match perfectly, stress will be placed on the wire as the temperature changes. This will result in a strain-induced resistance change, which may cause permanent change in the resistance capacity of the wire.

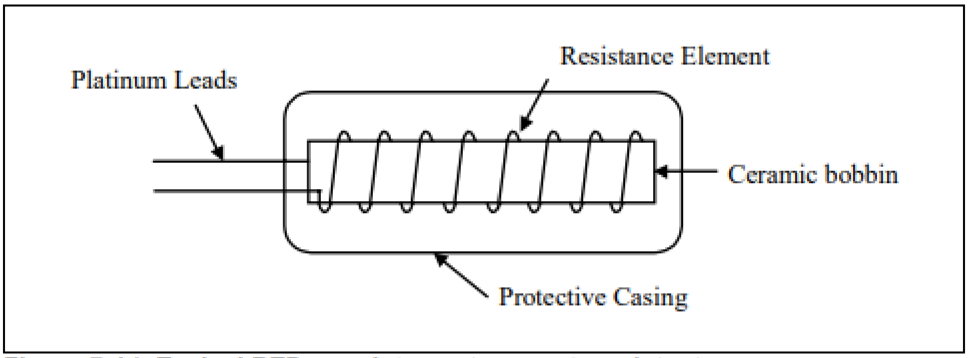

Figure -4. Typical RTD – resistance temperature detectors

The common values of resistance for platinum RTDs range from 10 Ω to several thousand ohms. The single most common value is 100 Ω at 0° C. The resistance only changes about 0.4 percent per one degree change in centigrade temperature. This change in resistance with temperature is called the temperature coefficient (α). The circuit uses a very stable excitation power source, three high-precision resistors that have a very low temperature coefficient, and a high-input impedance amplifier to measure the resistance change of the RTD with changes in temperature. The Wheatstone bridge method of measuring the resistance of an RTD has certain problems associated with it. These problems are solved by the technique of using a current source along with a remotely located DVM.

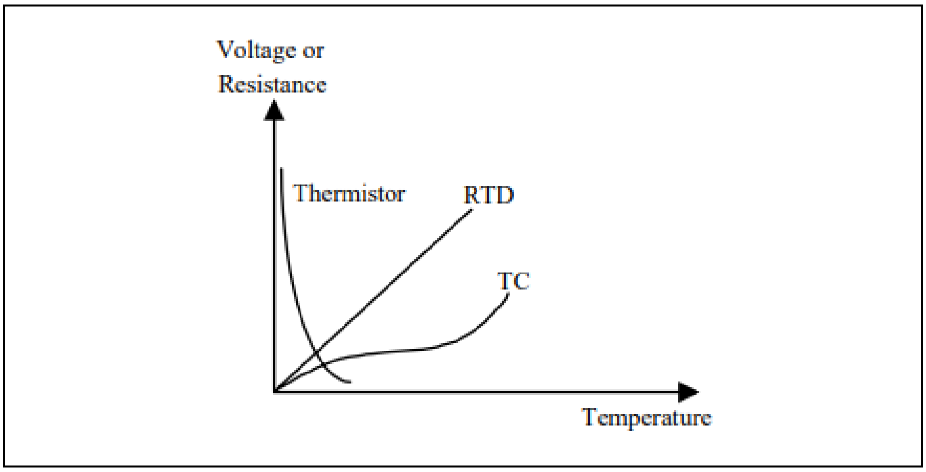

Figure -5. Comparison of TC, RTD, and thermistor

Conclusion. Thermistors can be manufactured very small, which means they will respond quickly to temperature changes. It also means that their small thermal mass makes them susceptible to self-heating errors. Thermistors are more fragile than RTDs or thermocouples, and you must mount them carefully to avoid crushing or bond separation. Except for the fact that these devices provide an output that is very linear with temperature, they share all the disadvantages of thermistors. They are semiconductor devices and thus have a limited temperature range. Integrated-circuit temperature sensors are normally only used in applications that have a limited temperature range. One typical application is in temperature data acquisition systems where they are used for thermocouple compensation.

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