King Abdulaziz University
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Thermal Engineering & Desalination Technology Department

MEP 365 Thermal Measurements

RTD & Thermistor Calibration

Experiment No. 3

1-Objective

To calibrate a Resistance Temperature Detector (RTD) and a thermistor

2-Introduction

Among the methods use to measure the temperature is utilizing the fact that for some materials the electric resistance changes with the temperature. RTD stands for Resistance Temperature Detector in which the resistance of the RTD increases almost linearly with temperature. A good example material which use extensively is platinum. For other materials such as semi-conductor, the electric resistance inversely changes with the temperature. These materials are known as Thermistors.

The basic relation for the electric resistance variation with temperature for RTD is given by

$$R_{RTD} = R_o\left[1+\alpha(T-T_o)\right] \qquad (1)$$

where

R_{RTD} is the electric resistance of the RTD, [Ω]

R_o is the electric resistance of the RTD at the reference temperature T_o, [Ω]

T is the temperature, [°C]

T_o is the reference temperature, [°C]

α is the temperature coefficient of resistively, [1/°C]

Typical example of α for platinum is 0.00385 1/°C. Notice that the sensitivity coefficient for RTD is given by

$$K_{RTD} = R_o\alpha \qquad (2)$$

Again for typical platinum RTD, the sensitivity coefficient is bout 0.4 Ω/°C, which means that the sensitivity is very small i.e. for 1°C change, the resistance changes by 0.4Ω . For this reason, in order to measure the resistance R_{RTD} correctly, Wheatstone bridge is use. A typical Wheatstone bridge is shown on Figure 1 below.

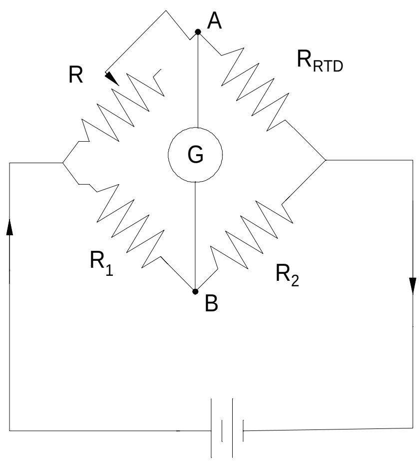

Figure 1 Wheatstone bridge used to measure the resistance for RTD

The bridge is balanced when the voltage between the point A and B in figure 1 is null. This can be achieved by changing the variable resistance R. When the bridge is balanced the four resistance are related together by the following equation [See your textbook for the derivation of this equation]

$$\frac{R}{R_{RTD}} = \frac{R_1}{R_2} \tag{3}$$

Notice that if R_1=R_2, then R_{RTD}=R.

It is to be noted that some RTD sensors come with three or four wire leads to reduce the effect of self heating when measuring the RTD resistance. For our experiment since we have short leads, the resistance RTD will be measured directly using a precise digital multi-meter.

The relationship on the other hand for the thermistor resistance with temperature is given by

$$R_T = R_o e^{\beta\left[\frac{1}{T}-\frac{1}{T_o}\right]} \tag{4}$$

where

R_T is the thermistor resistance at temperature T, [Ω]

R_o is the resistance at the reference temperature T_o, [Ω]

T is the temperature at which the resistance is R_T, [K]

T_o is the reference temperature, [K]

β is the material constant [1/K]

Unlike RTD there is no need to use Wheatstone bridge when measuring the resistance of the a thermistor R_T. Also to be noted that the variation of the thermistor resistance with temperature is not linear as can be seen from equation 4.

In this experiment, the values of α, and β will be determined, along-with fundamental equations similar to equations 1 and 4 above for RTD and the thermistor respectively.

3-Required parts

a-RTD sensor
b-Thermistor
c-Constant temperature bath
d-Precise thermometer
e-Digital multi-meters (2)

4-Procedure

The experiment setup is shown in Figure 2 below. The temperature of the constant temperature bath can be set to be any desire temperature as long as it is in the range of operation of the unit. [For laboratory experimental bath such the one we have in our laboratory the operational temperature range is between 10 and 80°C]. There is an indicator on the bath that shows the set point temperature and the actual fluid temperature. The procedural steps for the experiment are:

1-Insert the RTD sensor and the thermistor sensor inside the constant temperature bath

2-Take the RTD leads (only two will be used) to the Digital multi-meter to measure the RTD resistance, R_{RTD}. Do the same thing for the thermistor to measure the thermistor resistance R_T using another digital multi-meter.

3-Turn on the constant temperature bath on. Set the liquid temperature to 10 °C.

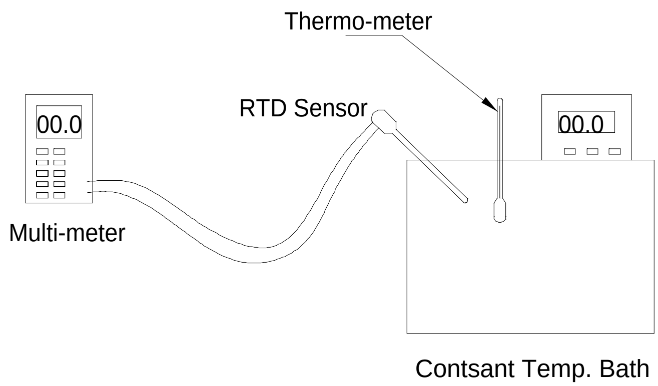

Figure 2 Setup for the RTD and thermistor calibration

4-When the liquid temperature reaches the set point temperature as indicated on the temperature display, measure R_{RTD}, and R_T. In case a precise thermometer is available, insert it in the proper hole on the top of the liquid bath and record also the thermometer reading when steady state condition is prevailed. Record the measured data in Table 1 below.

5-Change the setup fluid temperature to another temperature and repeat step 4. It is recommended to start with a temperature of 10°C, and increase T by 5°C each step for 7 to 8 readings.

Table 1 Measure data for RTD and thermistor calibration

No	T_{set} [° C]	T_{bath} [°C]	T_{therm} [C]	R_{RTD} [Ω]	R_T [kΩ]
1					
2					
3					
4					
5					
6					
7					
8					

5-Data Analysis

1-Plot the variation of R_{RTD}/R_o with $T-T_o$. Let T_o be the lowest temperature [in our case T_o=10° C]. For your information usually manufacturers take T_o=0°C at which $R=R_o$ [Typically for platinum R_o=100 Ω at 0 °C]

2-Use Trendline in Excel to curve fit the data, and find α (the temperature coefficient of resistivity).

3-Calculate the uncertainty of the curve fit equation for the RTD

4-For the thermistor plot $\ln(R_T/R_o)$ vs. $(1/T-1/T_o)$. Again take T_o to be the lowest temperature you have reached. Note that T and T_o must be in Kilven.

5-Use Tendline in Excel to find the curve fit equation for R_T/R_o

6-Calculate the uncertainty for the curve fit of the thermistor

7-From the developed equation what is the value of β for this thermistor?

6-Additional requirements

1-What is the sensitivity of the RTD

2-Calaulcte the sensitivity of the thermistor at T=40°C

3-Do an internet search and fill table 2 to show the characteristics of different temperature measuring sensors

Table (2) Comparison between different temperature sensors

Sensor	Cost	Time constant [Response time]	Temperature range	Uncertainty	Remarks
Thermometer					
Thermocouple					
RTD					
Thermistor					

Table 3 Grade distribution

No	Item	Grade	Remarks
1	Attend lab session and participate effectively in performing the experiment	10	
2	Submit the report on time with tables filled correctly	10	
3	Plot the variation of R_{RTD}/R_o vs. $T-T_o$	10	
4	Curve fit for R_{RTD} and uncertainty calculations	10	
5	Plot $\ln(R_T/R_o)$ vs. $[1/T-1/T_o]$	10	
6	Curve fit for R_T and uncertainty calculations	10	
7	Prepare the report according to the technical report (i.e. cover sheet, table of contents, objective, introduction)	10	
8	Prepare the report according to the technical report (i.e. Procedure, sketches, figures, discussions, conclusions, references)	10	
9	Use external sources for additional information (for example: library, internet, manual, etc)	10	
10	Overall impression about the report (organization, neatness, etc)	10	