Instrument Calibration – Lab 7:

Date Performed: 04/04/2023

Lab Instructor's name: Mark Vanpoppelen

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Name: (Printed)
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Signature:

Lab Report #7 – Temperature

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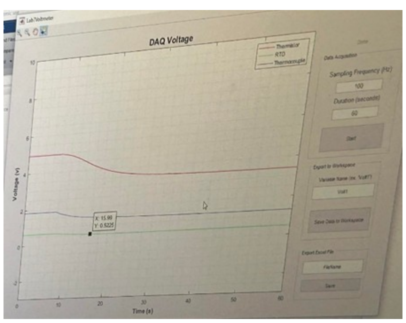
ABSTRACT

The temperature lab introduces students to the methods involved in measuring temperature from measured values. Utilizing the relationships between voltage and change in temperature, the student will utilize a Matlab code to collect voltages corresponding to temperature of a thermocouple within an oven. The different meters utilized in the experiments take advantage of thermal resistance in a wire due to temperature. Thermistors and RTD's fall into the category that utilizes electrical resistance while thermocouples operate off different electrothermal properties involving it's materials. The student, as always, walks through the errors associated in the attempt to calibrate the measurement devices and will ideally be able to support the experiment's real world applications with the associated mathematical theories.

I. Introduction



The first experiment seeks to calibrate each meter to read temperature from the measured voltage reading. The voltage readings will be read using a provided Matlab code and will be read each minute. The meters will be placed in an oven after an initial temperature reading of the room. The oven will progressively increase in temperature to 40 degrees C at which point the Matlab code will begin to collect the voltages. Experiment 2 requires the meters be left in the oven at 120 degrees Celsius before being plunged into an ice bath. The Matlab code should collect readings until steady state for each meter. What are the ideal temperature ranges for each meter and is there a response time associated?

A. Theory

The beauty in the verboseness of thermodynamics is that you have many tools to approach measuring the temperature and change in temperature of a given environment. The most obvious property to utilize would be the difference in the thermal expansion of two different substances, in many cases, that substance being two metals or a "thermocouple". The two metals, if "dissimilar" will create a small electro-magnetic field where they come into contact another highly utilized property is the change in electrical resistance due to heat. The thermocouple uses an ice bath to "calibrate" with the constant temperature of 0 degrees Celsius. Of the many methods of using electrical resistance is an "RTD" or "Resistance Temperature Detector" and in many applications utilizes a wheatstone bridge and more bridges can be added to reduce the error. A common downside to RTD's is their slow response times. This can be mitigated with smaller wires or other methods like a Thermistor, which is similar but has a greater resistance change. Thermistors do not require a wheatstone bridge and are made with ceramic-like semiconductors and therefore many of the specific properties for a given thermistor are dependent upon the materials it is composed and manufactures determine the properties.

Results and Discussion

Each method of measurement comes with it's own thermoelectric properties inherited from the thermodynamic principles utilized to make each method work. As a result, there are temporal elements to each method that impact the time constant of each meter's reading. For instance, the thermocouple had the largest time constant of 8.86 seconds. This is not a surprise, since the thermocouple operates on the temperature of two metals and depending on the materials and the size of the thermocouple, it will take longer to reach a "dissimilar" temperature than it would to otherwise heat or cool a relatively small wire or, even more so a ceramic-like semiconductor of a Thermistor. The benefit of using a Thermocouple, despite it's longer time constant, is that it is more suitable for high temperature applications like measuring the temperatures of machine parts in intense environments during the design phase. While Thermistors are highly sensitive at lower temperature ranges. Thermistors are suitable for lower temperature ranges while RTD's are ideal for measuring temperature in the negative Celsius range.

II. Conclusion

Temperature and temperature change are phenomena that must be carefully measured within real world engineering applications due to the potentially catastrophic issues that can be a result of poor thermal management. As a result, it is desirable to have a reliable method of measuring the temperature in a given area. It is the job of the practicing engineer to determine which method of measurement is not just accurate within the scope of the environment at hand, but time and therefore cost efficient. The importance of each of these measurement methods is that each one utilizes different thermodynamic material properties to measure the voltage with a temperature relationship. These methods are reliable and in use as industry standards for temperature measurement.

References

[1] M. Vanpoppelen, "MABE 345 Lab Report Required Sections.docx" U.S., Knoxville, TN, 2023.

[2] V. Aloi. (2023, February). ME/AE/BME 345 Instrumentation and Measurements class notes. [Online]. Available e-mail: valoi@utk.edu

[3] Omega "What Is A Thermistor And How Does It Work?" (Accessed 2023,April) Available online: https://www.omega.com/en-us/resources/thermistor

Appendix A: Equipment Information

1. DAQ
2. Thermristor
3. RTD
4. Thermocouple
5. Matlab
6. Ice bath
7. Oven

Appendix B: Handwritten Calculations

$$\frac{\log\left(\frac{R_{Th}}{R_{Th,0}}\right)}{\left(\frac{1}{T(K)} - \frac{1}{273.15}\right)} = \beta$$

$$\frac{\log\left(\frac{9137.87}{9665.5}\right)}{\left(\frac{1}{273} - \frac{1}{273.15}\right)} = 1.1096$$

Appendix C: Complete Data Sheet (data continued on hand written sheet)

Lab No. 7 Data Sheet

Name: Will Buziak Partner: Brenna Ellis

Partner: Toni Perkins Partner: ____________________

Experiment 1: Temperature Calibration

Temperature		RTD			Thermistor			Thermocouple	
T_{oven} (°C)	T_{oven} (K)	U_{RTD} (V)	R_{RTD} (Ω)	$\alpha \left(\frac{1}{°C}\right)$	U_{tm} (V)	R_{tm} (Ω)	$\beta\ (K)$	U_{tc} (V)	T_{tc} (°C)
0	273	3.428	467.13	N/A	.4688	9668.5	N/A	1.289	7.8
room	296	4.05	233.65	.0435	.4932	9137.87	296	1.348	19.6
40	313	4.45	121.57	.025	.5176	8659.96	313	1.426	35.2
60	333	4.722	58.87	.01667	.5518	8061	333	1.528	56.6
80	353	4.849	81.14	.0125	.5811	7604.3	353	1.631	76.2
100	373	4.912	17.91	.01	.6104	7313.93	373	1.733	96.6
120	393	4.946	10.91	.0083	.6348	6878.41	393	1.831	116.2

$\bar{\alpha} \left(\frac{1}{°C}\right)$	$\bar{\beta}\ (K)$
.01933	343.5

RTD: $R_{RTD} = 1000\left(\frac{5}{U_{RTD}(\text{V})} - 1\right)\ \Omega$, $\frac{R_{RTD}}{R_{RTD,0}} = 1 + \alpha T(°\text{C})$, where $R_{RTD,0}$ is the resistance of RTD at 0 (°C)

Thermistor: $R_{tm} = 1000\left(\frac{5}{U_{tm}(\text{V})} - 1\right)\ \Omega$, $\frac{R_{tm}}{R_{tm,0}} = e^{\beta\left(\frac{1}{T(K)} - \frac{1}{273.15\,\text{K}}\right)}$, $R_{tm,0}$ is the resistance of thermistor at 0 (°C)

Thermocouple: $T_{tc}(°\text{C}) = \frac{U_{tc}(\text{V}) - 1.25}{0.005}$

1

Experiment 2: Determination of Time Constant τ

Time Constants		
RTD	Thermistor	**Thermocouple**
$\tau_{RTD}\ (s)$	$\tau_{tm}\ (s)$	$\tau_{tc}\ (s)$
8.2	5.52	8.86

Time constant derivation:

$$\Gamma(t) = \frac{T(t) - T_\infty}{T_0 - T_\infty} = e^{-\frac{t}{\tau}} \qquad T(t) = T_\infty + (T_0 - T_\infty)e^{-\frac{t}{\tau}}$$

For $t = \tau$, and using $T_\infty = 0$ °C

$$\frac{T(\tau)}{T_0} = \frac{1}{e}$$

If $T_0 = 120$ °C

$$T(\tau) = \frac{120}{e} = 44.1 \text{ °C}$$

Lab Instructor's Signature: [signature] 4/5/23