MEP 365 Thermal Measurements

Thermocouple Welding and Calibration

Experiment No. 2

1-Objectives

a) To practice thermocouple welding using the thermocouple welding machine
b) To calibrate a thermocouple
c) To apply the learned statistical analysis on reporting calibration test

2-Introduction

Temperature measurement is very important for a mechanical engineers and we practice it in our daily life. A medical doctor uses a liquid in glass thermometer or a like to measure the patient body temperature. Thermostat is used in occupied spaces to control the temperature. Weather condition is determined by many factors among them is the temperature. There are many ways in which temperature can be measured depending on the media, the temperature range and the applications. Among the methods used are liquid in glass thermometers, thermocouples, RTD, Thermistors and infra red thermometers. Each one of these devices measure certain effect of temperature from which the temperature is indicated. Thermocouple uses the fact that an Electro-Magnetic Force (emf) or voltage is generated in a dissimilar wire due temperature change.

3-Theory

A thermocouple is basically a two dissimilar materials joint at one end called a junction. The emf generated at the other two ends is due to temperature change. In order to use the T/C for temperature measurements, a reference junction is formed like J2 as shown in figure 1 below. Junction J1 is the place at which one needs to measure T_1, while junction J2 is kept at a reference temperature say T_2.

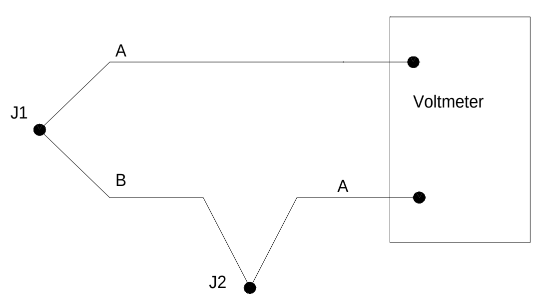

Figure 1 Basic idea of a thermocouple

The engineers' choice of a reference junction is ice point where a mixture of pure water and pieces of ice is kept at 0 °C. The voltmeter reading (i.e. emf) is proportional to the temperature difference between J1 and J2. There are many types of thermocouple wires. Each is characterized by a capital letter. Among the well known types are T, K, and J. Different applications require one type over the other. For engineering applications, the emf generated by a thermocouple with 0°C reference junction temperature can be written as

$$emf = a_0 + a_1 T + a_2 T^2 + a_3 T^3 + ... \quad (1)$$

4. Thermocouple Welding

A thermocouple can be made by simply tying the two ends of the thermocouple. For engineering application however, a welding machine is used to form the junction. Thermocouple welding machine is used to form the two junctions of a thermocouple wire. For perfect junction formation, the welding should be done in no-oxidizing environment (i.e. in Argon gas for example). This is done to ensure an ideal junction is formed.

For our welding machine in our lab, every student will experience the welding process, and at the present time no Argon gas is available, so welding will be done without the present of the inert gas such as Argon gas. The junction will not be perfect, but at least can demonstrate the welding, and calibration processes. The basic idea of welding process is to tie the two ends of the two materials wire and subject the tie to high temperature source so that the one or two materials melt on each others. To make sure that the junction is ok., one can inspect the junction visually may be using a magnifying lens.

4a. Required materials and devices

- Welding machine, See Figure 2
- Few thermocouple wires. Each of length say 50 cm. The welding machine can handle thermocouple with diameters up to 1 mm, therefore it is recommended to have a thermocouple wire with diameter say 0.5 mm [This means a AWG of 24 or AWG 30 wires]
- Wire stripper
- Glass goggle for eye protection
- Magnifying lens

4b. Experimental procedure

1-Bare a approximately 2 cm of the thermocouple wires from one end using the stripper

2-Twist the two bare ends together using pliers,. If you want you may cut the extra tips of the bare wires

3-Turn on the power of the welding machine. Put the selection dial on medium power

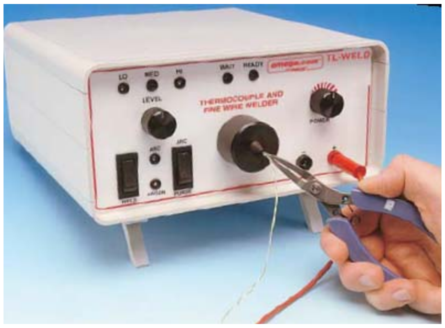

Figure 2 Welding machine

4-Put the glass goggle on to protect your eyes

5-Using the pliers hold the bare part of the wire and bring it in touch with the electrode on the welding machine, and then press the bottom of weld. You will see a spark if every thing is ok.

6-Take a look at the junction formed using the magnifying lens.

7-Do repeat the welding process if the resulted junction seems damaged
8-If necessary you may increase the (voltage) or power of the spark

It is required that every student in class to practice the welding of a thermocouple

5. Calibration of a thermocouple

5a Materials and devices needed

- Constant temperature bath (cold bath)
- Reference junction (usually a small container with ice and water mixture at 0°C)
- Precise liquid in glass thermometers (10-90°C)
- Digital multi-meter

5b. Experimental procedure

1-Using the welding machine and the above welding procedure to make a thermocouple with two junctions as shown in Figure 1. Make sure to identify the type of the thermocouple in order to use the proper calibration table.
2-Insert one junction of the thermocouple into the constant temperature bath and the other one into the reference temperature container which is kept at 0°C. Solid ice and pure water should always exist in the reference container to maintain the zero reference temperature
3-Connect the other two ends of the thermocouple into a multi-meter as shown in figure 3 to measure the generated emf

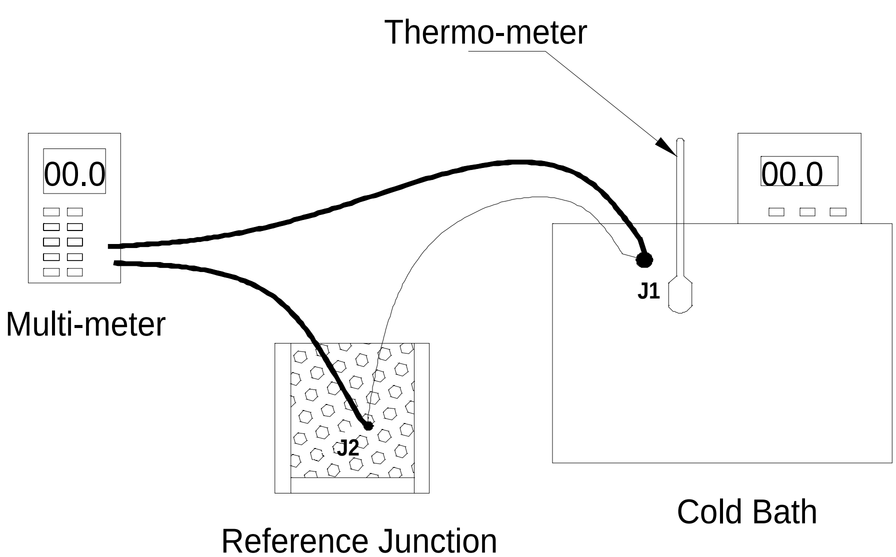

Figure 3 Set up for thermocouple calibration

4-Set the constant cold bath temperature at say 10° C. Wait till the constant bath temperature reaches this value by monitoring the temperature indicator on the bath.

5-Record the set point temperature of the bath T_b, and the precise thermometer temperature T_t (if available).
6- Record the emf generated from the thermocouple using the multi-meter i.e. mV_m.

7-Repeate the run for different constant bath temperatures. Every time increase the temperature by 10 °C
8-The measurements are summarized in table 1 below.
9-Use the appropriate thermocouple calibration table to find the emf generated for each set point temperature and record that in table 1. Your look for emf should be based on the precise thermometer reading T_t. In case there is no precise thermometer base you emf on the bath indicator temperature i.e. T_b.

Table (1) Measurements for thermocouple calibration experiment

Run	Bath temperature T_b [°C]	Thermometer reading T_t [°C]	multi-meter reading mV_m [mV]	Mill- volts from calibration tables mV_t [mV]
1				
2				
3				
4				
5				
6				
7				
8				
9				

6-Data analysis

a-Plot the variation of mill-volt measured and generated by the thermocouple mV_m, and the mill-volt as found from the thermocouple calibration tables mV_t against the bath set point temperature T_b. Search the internet to find the appropriate calibration table for the thermocouple used in the lab. You have to attach the tables, and you should also to mention the internet site.

b-Use Excel Trendline line to find the a third order equation that relates mv_m and T_b. The form of the equation is

$$mv = a_0 + a_1 T + \frac{1}{2} a_2 T^2 + \frac{1}{3} a_3 T^3$$

Write the expression of equation on graph, along with the R^2 value. Used what you have learned in class to find the uncertainty of the curve with probability 95%. Using this equation then the sensitivity is given by

$$K = \frac{\Delta mv}{\Delta T} = a_1 + a_2 T + a_3 T^2$$

Since the curve fit equation is not linear, then the K value is not fixed.
c- Plot T_b vs. mV_m and again use the Excel Trendline to find a correlation similar to

$$T = b_0 + b_1 * mv + b_2 * mv^2 + b_3 * mv^3$$

Also calculate the uncertainty of this equation with probability 95%.

d-Suppose we know that the temperature indicator on the constant bath temperature has a systematic error of ± 1 C, calculate the overall uncertainty of the thermocouple in question.

e- If this thermocouple is used in a situation, and the measured mill-volts was found to be 2.3 mv, what is the actual temperature, and the uncertainty.

f- You have to prepare your report according to the technical report format.

7-Report evaluation

#	Category	Marks	Your score
1	Attend the lab. session and participate in performing the experiment	10	
2	Complete Cover sheet, Table of contents, and Introduction	10	
3	Procedure	10	
4	Prepare clean understandable plot for mv_m and mv_t vs. temperature	10	
5	Find the curve fit relation between mv_m and T	10	
6	Prepare clean understandable plot for T vs. mv_m	10	
7	Find the curve fit relation between T and mv_m	10	
8	Report is neat and organized	10	
9	Discussion of the results	10	
10	Reference list & Conclusions	10	
Score			