ME 316 MECHANICAL ENGINEERING LABORATORY

TEMPERATURE MEASUREMENT

1. OBJECT

The purpose of the experiment is the calibration and correction of the temperature measuring devices, namely, thermocouples against high sensitivity mercury-in-glass thermometer.

2. THEORY

2.1 Introduction

Since the pressure, volume, electrical resistance, expansion coefficients, etc., are all related to temperature through the fundamental molecular structure, they change with temperature, Calibration may be achieved through comparison with established standard .The International Temperature Scale serves define temperature in terms of observable characteristics of materials.

Gas thermometers may be used at most in the approximate range of 1 K to 1000 K, the temperature scale is fixed by the use of paramagnetic properties of solids. Above 1000 K, the scale is fixed by thermal radiative properties of substances.

A truly sensitive measurement requires many corrections such as change in volume of the container, non-uniformity of temperature distribution in the sensitive volume. It must always be kept in mind that a thermometer measures its own temperatures. For this reason care must be taken to ensure that the thermometer in question is at thermal equilibrium with the system whose temperature is to be measured. This is one of the most frequent errors made in temperature measurement.

2.2 Expansion Thermometers

This type of thermometers makes use of the fact that all substances undergo some amount of expansion with increasing temperature.

The liquid-in-glass thermometer is one of the most common examples of expansion thermometers. Commonly, used liquids are mercury and alcohol. In operation the bulk of the liquid-in-glass thermometers is immersed up to calibration mark (for partial immersion thermometers) or totally (for total immersion thermometers) to the environment whose temperature is to be measured. Ethyl-alcohol thermometers may be used down to -155°°°C and mercury thermometers in the temperature range of -39 to 325°C. Range may be extended up to 525°C by filling the space above the liquid by pressurized gas.

It is important to note that the expansion registered by the thermometer is the difference between the expansion of the liquid and the expansion of the glass. The difference is a function not only of the heat transfer to the bulb from the environment, but also of the heat conducted into the bulb from the stem. High grade mercury-in-glass thermometers have the temperature scale markings graved on the glass along with a mark which designates the proper depth of immersion.

2.2 Thermocouples

The most commonly used method of measuring temperature after liquid-in-glass thermometers is by the use of thermocouples. An *emf* will exist across a junction of two different materials, which is primarily a function of the junction temperature. The phenomenon is called Seeback effect. There are two other effects which influence *emf* generated but main source of *emf* in temperature measurements is the Seeback effect.
The Peltier effect, converts a charge current into a heat current in a conductor, and its performance is described by the Peltier coefficient, which is defined as the ratio of the generated heat current to the applied charge current.

The output voltage of a simple thermocouple circuit is usually written in the form:

$$E = AT + \frac{1}{2}BT^2 + \frac{1}{3}CT^3$$

and the sensitivity

$$S = \frac{dE}{dT} = A + BT + CT^2$$

where A, B, C are the junction material dependent constants. The usual arrangement is to keep one junction at 0°C, the other one is used in temperature measurement. The most commonly used thermocouples are:

Copper-constantan (-200 to 350°C), Chromel-constantan (-200 to 950°C), Iron-constantan (200 to 650°C), Chromel-alumel (-200 to 1400°C), Platinum-platinum 10% rhodium (40 to 1700°C) the most sensitive one being chromel-constantan (7.3 mV for 100°C). Most commonly used thermocouple is Cu-constantan (called type T. 5.33 mV for 100°C).

Parallel arrangement of thermocouples may be used for average temperature measurements. For high sensitivity measurements a series combination (called thermopile) is used. In this case output of the thermopile shall be the sum of outputs of the single thermocouples.

Micro-volimeters are generally used to measure the output voltage. Direct-temperature reading arrangements are also possible and most commonly used in industrial applications. An amplifier should be utilized in order to use ordinary AVO-meters to measure temperatures since most sensitive scale of these devices are at most one volt.

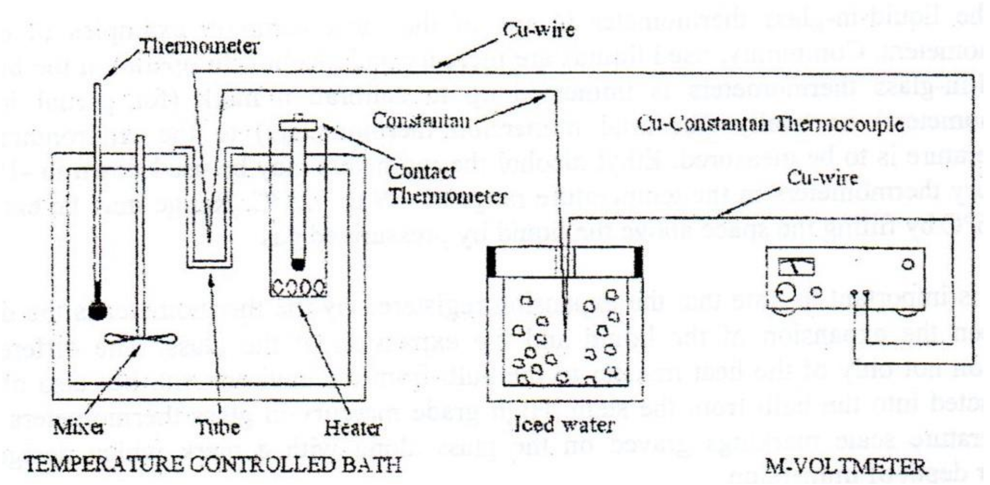

Fig. 1 Thermocouple System

3. LABORATORY EQUIPMENT

3.1 Thermocouple System

- Digital multimeter
- Thermos
-Pair of Cu-constantan thermocouple

Common to all is a mercury-in-glass thermometer and a temperature controlled bath. Temperature is controlled by contact thermometer on the bath set.

4. EXPERIMENTAL PROCEDURE

a) Fill the thermos with ice and add cold water to prepare ice water mixture at 0ºC,

b) Start temperature controlled bath circulation motor,

c) Make necessary electrical connections to start the experiment using Fig. 1.

d) Clean and place the probe and hot junction of the thermocouple into hot junction compartment of the temperature controlled bath. Place the cold junction of thermocouple into tube attached to the thermos cover. Close the cover loosely. Tube should be moved across the mixture back and forth during measurements to prevent continuous touching of ice cubes to the tube,

e) Set multimeter in proper range for measurements,

1) When steady state is reached take readings of bath temperature (no heating)

g) Adjust contact thermometer on the bath, 5°C above bath temperature turn on both of heaters. Red lights should count "ON". Wait until lights goes "OFF". Turn the heaters "OFF".

h) Watch closely changes in indications of the mercury thermometer and multimeters When all reach to the steady state (after about 2 to 5 mins.)

take the readings,

i) Repeat step (g) and (h) until 8 to 10 reading are taken.

j) Turn "OFF" the temperature controlled bath, multimeters and bridge power supply.

5. CALCULATIONS

5.1 Thermocouple Calibration Curve

Plot the voltage (mV) readings as abseissa and the temperature (°C) as ordinate. Find the thermocouple constant k (°C /mV) from the slope of the line:

$T = kV$

ME 316 TEMPERATURE MEASUREMENT EXPERIMENT

ITS-90 Table for Type J Thermocouple (Ref Junction 0°C) http://reotemp.com

°C	0	1	2	3	4	5	6	7	8	9	10
					Thermoelectric Voltage in mV						
0	0.000	0.050	0.101	0.151	0.202	0.253	0.303	0.354	0.405	0.456	0.507
10	0.507	0.558	0.609	0.660	0.711	0.762	0.814	0.865	0.916	0.968	1.019
20	1.019	1.071	1.122	1.174	1.226	1.277	1.329	1.381	1.433	1.485	1.537
30	1.537	1.589	1.641	1.693	1.745	1.797	1.849	1.902	1.954	2.006	2.059
40	2.059	2.111	2.164	2.216	2.269	2.322	2.374	2.427	2.480	2.532	2.585
50	2.585	2.638	2.691	2.744	2.797	2.850	2.903	2.956	3.009	3.062	3.116
60	3.116	3.169	3.222	3.275	3.329	3.382	3.436	3.489	3.543	3.596	3.650
70	3.650	3.703	3.757	3.810	3.864	3.918	3.971	4.025	4.079	4.133	4.187
80	4.187	4.240	4.294	4.348	4.402	4.456	4.510	4.564	4.618	4.672	4.726
90	4.726	4.781	4.835	4.889	4.943	4.997	5.052	5.106	5.160	5.215	5.269
100	5.269	5.323	5.378	5.432	5.487	5.541	5.595	5.650	5.705	5.759	5.814
110	5.814	5.868	5.923	5.977	6.032	6.087	6.141	6.196	6.251	6.306	6.360
120	6.360	6.415	6.470	6.525	6.579	6.634	6.689	6.744	6.799	6.854	6.909
130	6.909	6.964	7.019	7.074	7.129	7.184	7.239	7.294	7.349	7.404	7.459
140	7.459	7.514	7.569	7.624	7.679	7.734	7.789	7.844	7.900	7.955	8.010
°C	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**

#	Mercury-in-Glass Thermometer Reading, ^{0}C	Thermocouple Micro Voltmeter Reading, mV
1.		
2.		
3.		
4.		
5.		
6.		
7.		
8.		

6. REPORT

In your laboratory reports must have the followings:

a) Cover
b) Include a short introduction
c) Make all the necessary calculations by using data taken
d) Make a curve-fit using the method of Least-square and then draw it onto graphic paper
e) Discuss your results and add a conclusion end of the report

References:

1. Class notes
2. J.P.Holman. Experiment Methods for Engineers, McGraw-Hill
3. Uchida, K. I., Daimon, S., Iguchi, R., & Saitoh, E. (2018). Observation of anisotropic magneto-Peltier effect in nickel. *Nature*, *558*(7708), 95-99.