The University of Jordan

School of Engineering

Department of Chemical Engineering

Chemical Engineering Laboratory (4) (0905562)

Section no. (1)

Experiment no. (2)

Temperature measurements

Short Report

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Student Name	Registration #
Sedra Nibal Al-Burghili	0191293
Nour Ahmad Kharisat	0194083
Donia Majdi Khalil	0197045
Sura Mohammad Froukh	0197130
Lana Mamoon Abdelnabi	0198593

Instructor: Eng. Nariman Al-Dahleh

ABSTRACT

Temperature is one of the most important measurement parameters that is used for monitoring and control in various industries. For that reason, manufacturers have designed different temperature measurement devices with different measuring principles in order to suit variable applications. However, these devices vary in accuracy, speed of response and temperature working range.

In this experiment, the accuracy of vapor pressure, bi-metallic, thermistor, thermocouple and glass thermometer devices are studied along with their speed of response. In addition, Peltier thermo-electric effect and Seebeck thermo-electrical effect are studied. It was found that thermocouple is the most accurate device and has the fastest response to temperature changes.

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RESULTS

- **Part 1:**

Table 1: Comparison of accuracy for reading the boiling point between different devices.

Theoretical Saturated Pressure 101.7 KPa			
Tsat'd = 100.06 ˚C			
Thermometer	**Temperature Reading**	**Relative error (%)**	Accuracy
Glass Thermometer	96.80	3.26	Low accuracy, but it is better than vapor pressure
Vapor Pressure	90.00	10.05	The Least accurate
Bi-metallic	98.00	2.06	Accurate
Thermistor	98.20	1.86	Accurate
Thermocouple	98.30	1.76	The most Accurate

- **Part 2:**

Table 2: Plotting the temperature reading of each device versus time.

	Temperature Reading (˚C)			
Time(minutes)	**Glass Thermometer**	**Thermistor**	**Thermocouple**	**Voltage (mV)**
0.00	47.00	47.20	47.60	79.00
1.00	50.00	52.00	58.50	104.00
2.00	54.00	54.40	61.60	105.00
3.00	56.00	57.60	64.30	106.00
4.00	60.00	60.70	67.50	113.50
5.00	63.00	63.80	69.50	114.00
6.00	65.00	66.80	72.20	121.50
7.00	68.00	69.70	74.20	120.50
8.00	70.00	72.50	74.20	131.00
9.00	73.00	74.40	77.70	125.00
10.00	75.00	76.60	79.80	134.50
11.00	77.00	78.50	82.50	134.50
12.00	79.00	80.30	84.10	137.50
13.00	81.00	82.40	85.70	144.00
14.00	83.00	85.00	86.50	146.50
15.00	86.00	86.00	87.80	145.50
16.00	88.00	88.60	89.40	145.00
17.00	90.00	90.00	91.80	148.50
18.00	92.00	92.00	92.70	150.50

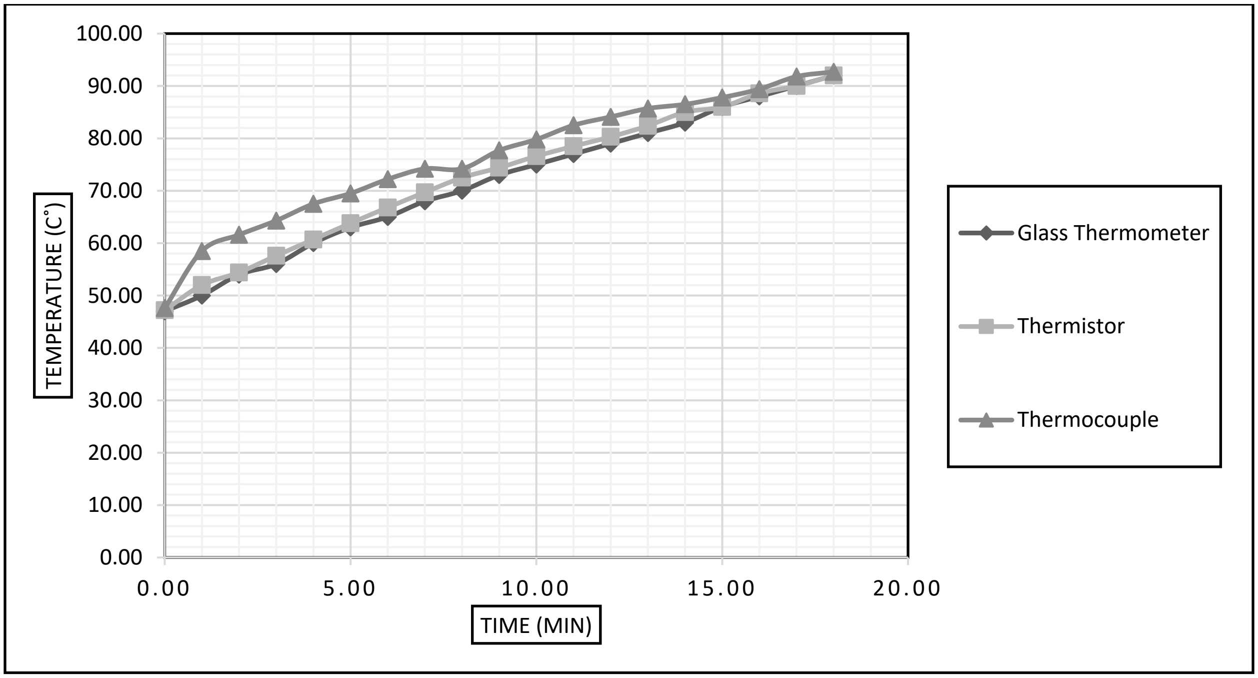

Figure 1: Temperature Reading for each device Vs. Time.

- **Part 3:**

A) Peltier thermo-electric

Table 3: Effect of glass thermometer temperature on the voltage readings compared to the ambient temperature.

Ambient Temperature = 25.00 ˚C	
Glass Thermometer temperature (˚C)	**Voltage (mV)**
18.00	-13.00
18.00	-12.00
19.00	-10.00
20.00	-9.00
22.00	-5.00
22.00	-3.00
24.00	0.00
25.00	5.00
26.00	8.00
27.00	15.00

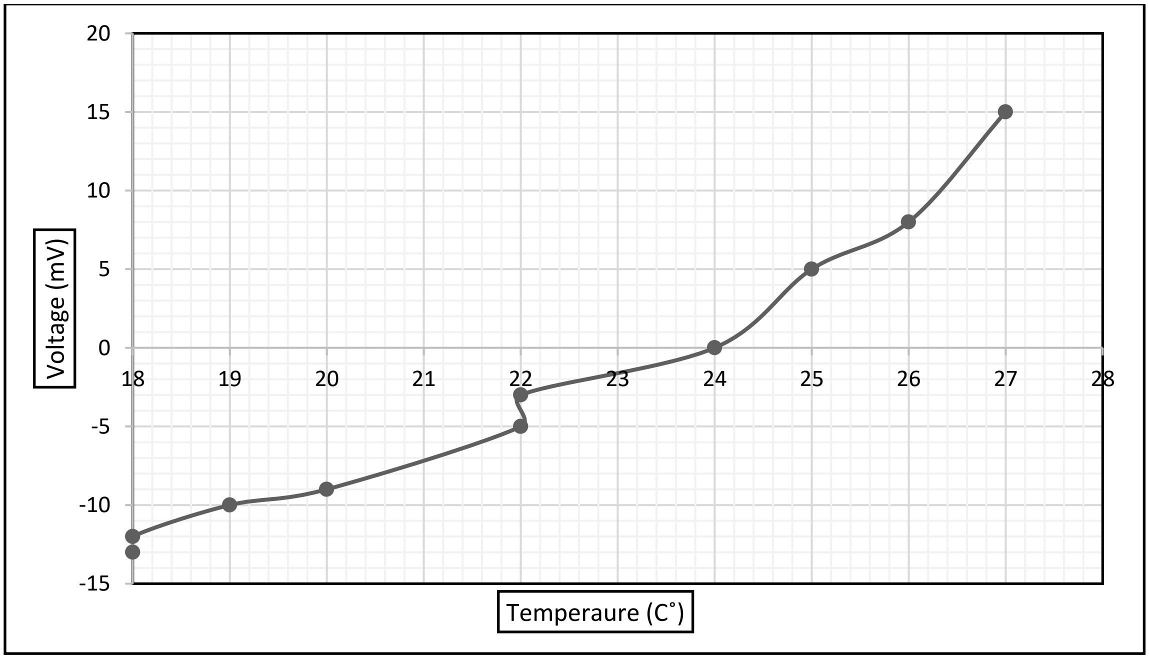

Figure 2: Voltage readings Vs. Glass thermometer temperature.

B) Seebeck Effect

Table 4: Seebeck Effect - Voltage Readings with Reference Temperature Selection

	Voltage (mV)
Both thermocouples in cold water	2.00
Both thermocouples in hot water	0.00
Thermocouple (1) in cold and (2) in hot water	180.00
Thermocouple (2) in cold and (1) in hot water	-180.00

DISCUSSION

Part 1: The utilization of liquid-in-glass thermometers, vapor pressure, and bi-metallic expansion devices for the measurement of a fixed scale point.

In the first part of the experiment, the objective was to determine the device's accuracy among the ones available. The water was brought to a boil, and the temperature measuring devices were arranged to identify the closest and most accurate one. It was acknowledged that there are many more temperature measuring devices beyond the ones mentioned in the experiment. The theoretical value, which represents the boiling point of water at 100 degrees Celsius and atmospheric pressure, was measured using the glass thermometer, vapor pressure, bi-metallic, thermistor, and thermocouple. Among these devices, the thermocouple (based on the principle discovered by Seebeck in 1821) demonstrated the highest precision and closest proximity to the theoretical value. The glass thermometer exhibited lower accuracy but was still acceptable. However, the vapor pressure value was deemed unacceptable, as the practical value deviated by approximately 10% from the theoretical value.When comparing temperature measurement equipment, the following static features were considered: range, error, accuracy, precision, repeatability, reproducibility, sensitivity, and hysteresis.

Part 2: Response of different temperature measuring devices as temperature changes with time.

In the second part of the experiment, a comparison was made between the glass thermometer and thermistor thermocouple. The temperature was recorded every 30 seconds until it reached the boiling point. Table (1) illustrates that the thermocouple consistently provided the highest temperature readings throughout the test period, indicating its accurate measurements. The thermistor readings were less accurate but still within an acceptable range. The glass thermometer, on the other hand, exhibited a lag and yielded the lowest temperature measurements among all devices.

Part 3: The Peltier thermo-electric effect and the Seebeck thermo-electric effect.

A) The Peltier thermo-electric effect:

When an electric current passes through the junction of different metals, heat is either absorbed or released. If the temperature is lower than the surrounding air temperature, the millivolt reading will be negative. The rate of heat transfer is proportional to the temperature difference, as indicated by the voltage measurement. In this experiment, the voltage reading started at -13 mV when the temperature was below the ambient temperature of 25 ºC and progressively increased as the temperature approached 0 mV at a reading of 24 ºC, which is close to the ambient temperature.

B) The Seebeck thermo-electric effect:

When two dissimilar metal junctions have different temperatures, an electrical current flows through the circuit. Notably, platinum-rhodium/Platinum and chrome/aluminum are frequently mentioned thermocouples. When two thermocouples are placed at the same location without a temperature gradient, the millivolt reading will be zero. To establish a driving force between a source and another environment of interest, the two thermocouples need to be situated in distinct environments. The Seebeck effect theory is confirmed when the thermocouples are swapped, as it results in identical voltage measurements with opposite signs.

CONCLUSION AND RECOMMENDATIONS

- Temperature measurement method based on the specific requirements of the application, accuracy needed, and environmental considerations.
- Certain reference temperatures are chosen for calibration.
- Liquid-in-glass thermometers are based on the principle that liquids expand or contract with changes in temperature such as mercury, which is directly proportional to temperature.
- In liquid-in-glass thermometers common fixed points include the freezing point and boiling point of water.
- In vapor pressure thermometers, as the temperature changes, the vapor pressure in the bulb changes, causing a corresponding change in the volume in a capillary tube.
- Bi-metallic strips consist of two different metals with different coefficients of thermal expansion bonded together, also, the bending in strips indicate temperature changes.
- Thermocouple consisting of two different metal wires joined at one end. When there is a temperature difference between the two ends.
- In the Seebeck effect, if the temperature at one end of the thermocouple is lower than the temperature at the other end, the generated millivolt reading will be negative.
- Thermocouples provide accurate readings while thermistor readings are less accurate.
- When measuring temperatures using a thermocouple, it's essential to consider the polarity of the voltage and understand whether a positive or negative millivolt reading corresponds to a higher or lower temperature at a particular end of the thermocouple.
- Calibration is recommended to ensure accurate temperature measurements.

REFERENCES

1) ÇengelY.A., Boles, M.A. and Mehmet Kanoğlu (2015). Thermodynamics: an engineering approach. New York: Mcgraw-Hill Education, Cop.
2) Chemical Engineering Laboratory (4) Manual Sheet. (2022). 1st ed. University of Jordan School of Engineering Department of Chemical Engineering.

APPENDICES

I. Sample Of Calculations

- For Part (1):

Boiling temperature for water at a pressure of 101.7 KPa: 100.06 ˚C
Measured temperature using glass thermometer: 96.80 ˚C

Glass Thermometer accuracy relative error:

$$RE\% = \left|\frac{T_{true} - T_{measured}}{T_{true}}\right| * 100\% = \left|\frac{100.06 - 96.8}{100.06}\right| * 100\% = 3.26\%$$

II. Date Sheet

Experiment (2)

Temperature Measurement Data Sheet

Part 1

Thermometer	Temperature (°C)
Glass thermometer	96.8
Vapor pressure	90
Bi-metallic	98
Platinum resistance	-
Thermistor	98.2
Thermocouple	98.3

Part 2

Time	Temperature (°C) Glass thermometer	Thermistor (°C)	Thermocouple (°C)	Voltage (mV)
0	47	47.2	47.6	79
1	50	52.0	58.5	104
2	54	54.7	61.6	105
3	56	57.6	64.3	106
4	60	60.7	67.5	113.5
5	63	63.8	69.5	114
6	65	66.8	72.2	121.5
7	68	69.7	74.2	120.5
8	70	72.5	77.7	131
9	73	74.4	79.8	125
10	75	76.6	82.5	134.5
11	77	78.5	84.1	134.5
12	79	80.3	85.7	137.5
13	81	82.4	86.5	144
14	83	85	87.8	146.5
15	86	86	89.4	145.5
16	88	88.6	90.5	145
17	90	90	91.8	148.5
18	92	92	92.7	150.5

Part 3

a- Peltier thermo-electric:

Ambient temperature: **25°C**

Temperature (°C) Glass thermometer	Voltage (mv)
18	-13
18	-12
19	-10
20	-9
22	-5
22	-3
24	0
25	5
26	8
27	15

b- Seebeck effect:

	Voltage
Both thermocouples in cold water	**2**
Both thermocouples in hot water	**0**
Thermocouple (1) in cold and (2) in hot	**180**
Thermocouple (2) in cold and (1) in hot	**-180**