# APL103 Lab

## Experiment 7:Temperature Measurement Devices

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## OBJECTIVES:

To study various temperature measuring instruments and to estimate their response time.

1. Mercury-in-glass thermometer
2. Electrical resistance thermometer
3. Thermocouple
4. Vapor-pressure thermometer.
5. Mercury-in steel
6. Bi-metallic strip

## THEORETICAL BACKGROUND:

***1. Mercury-in-glass thermometer:*** This is the most common thermometer used to measure body temperature, room temperature etc.

***2. Thermocouple*****:** This relies on the Seebeck effect — when two junctions are formed with two dissimilar metals and the junctions are kept at different temperatures, then an e.m.f. is developed between them which is proportional to the difference in temperature. If fine wires are used to form the junctions, then the time constant can be quite small (ms). Here we will assume that the time constant for the thermocouple is effectively zero and estimate the time constants for the other devices.

***3. Electrical resistance thermometer*****:** Also called a resistance temperature device (RTD). It has a resistance wire (usually a platinum coil) as the sensing element. After calibration, the temperature may be determined by simply measuring the resistance.

***4. Bi-metallic strip:*** Here two metals with different coefficients of thermal expansion are bonded together. When the temperature changes, the composite strip will bend due to the different rates of expansion. Usually, the strip is arranged in the shape of a helix, within the sensing element, so that it twists with changes in temperature. This twist is shown on the readout.

***5. Mercury-in-Steel thermometer:*** Here a steel bulb and the connecting tube is filled with Mercury. If the total volume is kept nearly constant, then the pressure of the Mercury will vary with temperature due to its tendency to expand and contract. The changes in pressure can be measured (e.g., using a Bourdon gauge) and the temperature may be determined.

***6. Vapour-pressure thermometer:*** Here we have a bulb filled with liquid that has a significant variation in vapour pressure in the temperature range to be measured. At each temperature there is a unique pressure at which the liquid and gas are in equilibrium and hence this pressure can be used to measure the temperature.

## APPARATUS:

Steel bath with stirrer, heater, stopwatch, and the temperature measuring devices

## OBSERVATIONS:

1. Least Count of Stopwatch: 1 sec
2. Least Count of the instruments:
    a. Mercury-in-glass thermometer = 1°
    b. Thermocouple = 0.00001 V
    c. Electrical resistance thermometer = 0.00001 V
    d. Bi-metallic strip = 1°
    e. Mercury-in steel = 1°
    f. Vapour-pressure thermometer = 1°

### Heating Cycle:

| Sr No | Time (in s) | Mercury-in-glass(in °C) | RTD (in V) | THC-K (in V) | VPT (in °C) | Mercury-in-steel(in °C) | Bi-Metallic (in °C) |
|---|---|---|---|---|---|---|---|
| 1 | 0 | 18 | 1.08534 | -0.01573 | 58 | 14 | 21 |
| 2 | 313.53 | 23 | 1.10829 | 0.00314 | 60 | 19 | 23 |
| 3 | 447.98 | 28 | 1.1348 | 0.02138 | 62 | 24 | 27 |
| 4 | 578.78 | 33 | 1.15678 | 0.04413 | 65 | 29 | 31 |
| 5 | 689.61 | 38 | 1.17861 | 0.06398 | 68 | 34 | 34 |
| 6 | 815.41 | 43 | 1.20288 | 0.08688 | 71 | 40 | 37 |
| 7 | 924.52 | 48 | 1.22532 | 0.10719 | 74 | 44 | 42 |
| 8 | 1057.17 | 53 | 1.24379 | 0.12866 | 78 | 50 | 46 |
| 9 | 1183.16 | 58 | 1.26547 | 0.14902 | 81 | 55 | 50 |
| 10 | 1319.92 | 63 | 1.28638 | 0.16994 | 85 | 60 | 56 |
| 11 | 1465.58 | 68 | 1.30561 | 0.18968 | 90 | 65 | 60 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 12 | 1629.95 | 73 | 1.32317 | 0.20979 | 93 | 70 | 66 |
| 13 | 1812.2 | 78 | 1.34042 | 0.22827 | 97 | 73 | 70 |
| 14 | 2037.47 | 83 | 1.35767 | 0.24567 | 101 | 78 | 75 |
| 15 | 2462.43 | 88 | 1.3766 | 0.26277 | 105 | 82 | 80 |
| 16 | 3881.85 | 93 | 1.38774 | 0.27209 | 108 | 83 | 80 |

**Stable Temperature-No Change even after boling for about 3 min**

| Mercury-in-glass(in °C) | RTD (in V) | THC-K (in V) | VPT (in °C) | Mercury-in-steel(in °C) | Bi-Metallic (in °C) |
|---|---|---|---|---|---|
| 91 | 1.38774 | 0.27209 | 108 | 83 | 80 |

## Cooling Cycle:

| Sr No | Time (in s) | Mercury-in-glass(in °C) | RTD (in V) | THC-K (in V) | VPT (in °C) | Mercury-in-steel(in °C) | Bi-Metallic (in °C) |
|---|---|---|---|---|---|---|---|
| 1 | 0 | 91 | 1.3853 | 0.26757 | 106 | 82 | 80 |
| 2 | 119.13 | 88 | 1.37263 | 0.25468 | 103 | 79 | 75 |
| 3 | 239.55 | 83 | 1.35843 | 0.23972 | 100 | 76 | 73 |
| 4 | 359.17 | 80 | 1.34698 | 0.22628 | 98 | 74 | 70 |
| 5 | 479.14 | 77 | 1.33462 | 0.21346 | 95 | 71 | 68 |
| 6 | 599.54 | 74 | 1.32363 | 0.20185 | 93 | 69 | 64 |
| 7 | 719.7 | 71 | 1.31355 | 0.19147 | 91 | 66 | 63 |
| 8 | 840.05 | 69 | 1.30332 | 0.18048 | 89 | 63 | 61 |
| 9 | 960 | 66 | 1.29462 | 0.17116 | 87 | 61 | 59 |
| 10 | 1080.14 | 64 | 1.28638 | 0.16246 | 86 | 59 | 57 |
| 11 | 1200.08 | 62 | 1.27829 | 0.15452 | 85 | 57 | 56 |
| 12 | 1319.98 | 60 | 1.2705 | 0.14719 | 83 | 56 | 54 |

## Analysis:

Calibration in MIG Thermometer:

| Corrected Temp | Indicated Temp |
|---|---|
| 0 | 0 |
| 100 | 93 |

**Corrected temperature = a + b (Indicated Temperature)**

1. At 0°C it shows 0 degree (given)
2. At 100°C it shows 93°C

Using the relation stated above we can see that,

0 = a + 0

100 = a + b(93)

a = 0

b = 1.075268817

Hence, after calibration, we get the corrected ambient temperature for all the devices as follows:

| | | Mercury-in-glass (in °C) | RTD (in V) | THC-K (in V) | VPT (in °C) | Mercury-in-steel (in °C) | Bi-Metallic (in °C) |
|---|---|---|---|---|---|---|---|
| AT | Indicated | 18 | 1.08534 | -0.01573 | 58 | 14 | 21 |
| AT | Corrected | 19.35484 | 19.35449 | 19.35484 | 19.35487 | 19.35483 | 19.35484 |
| | | | | | | | |
| BT | Indicated | 93 | 1.38774 | 0.27209 | 108 | 83 | 80 |
| BT | Corrected | 100 | 99.99964 | 99.99999 | 100 | 99.99996 | 99.99999 |
| | | | | | | | |
| | a | 0 | -270.088 | 23.76228 | -74<br>-74.1935 | 2.992052 | 1.366867 |
| | b | 1.075269 | 266.6837 | 280.193 | 1.612903 | 1.16877 | -9.34937 |

### Heating Cycle Readings After correction:

| Sr No | Time(in s) | Mercury-In-glass (in °C) | RTD(in V) | THC-K (in V) | VPT(in °C) | Mercury-In-steel (in °C) | Bi-Metallic (in °C) |
|---|---|---|---|---|---|---|---|
| 1 | 0 | 19.35484 | 19.35449 | 19.35484 | 19.35487 | 19.35483 | 19.35484 |
| 2 | 153.53 | 24.73119 | 25.47488 | 24.64209 | 22.58068 | 25.19868 | 22.08857 |
| 3 | 287.98 | 30.10753 | 32.54466 | 29.75281 | 25.80649 | 31.04253 | 27.55604 |
| 4 | 418.78 | 35.48388 | 38.40637 | 36.1272 | 30.6452 | 36.88638 | 33.02351 |
| 5 | 529.61 | 40.86022 | 44.22808 | 41.68903 | 35.4839 | 42.73023 | 37.12411 |
| 6 | 655.41 | 46.23657 | 50.70049 | 48.10545 | 40.32261 | 49.74285 | 41.22471 |
| 7 | 764.52 | 51.61291 | 56.68487 | 53.79617 | 45.16132 | 54.41793 | 48.05904 |
| 8 | 897.17 | 56.98926 | 61.61052 | 59.81191 | 51.61293 | 61.43055 | 53.52651 |
| 9 | 1023.16 | 62.3656 | 67.39222 | 65.51664 | 56.45164 | 67.2744 | 58.99398 |
| 10 | 1159.92 | 67.74195 | 72.96858 | 71.37828 | 62.90326 | 73.11825 | 67.19518 |
| 11 | 1305.58 | 73.11829 | 78.09691 | 76.90929 | 70.96777 | 78.9621 | 72.66265 |
| 12 | 1469.95 | 78.49464 | 82.77987 | 82.54397 | 75.80648 | 84.80595 | 80.86385 |
| 13 | 1652.2 | 83.87098 | 87.38017 | 87.72194 | 82.25809 | 88.31226 | 86.33132 |
| 14 | 1877.47 | 89.24733 | 91.98046 | 92.59729 | 88.7097 | 94.15611 | 93.16566 |
| 15 | 2302.43 | 94.62367 | 97.02878 | 97.38859 | 95.16132 | 98.83119 | 99.99999 |
| 16 | 3721.85 | 100 | 99.99964 | 99.99999 | 100 | 99.99996 | 99.99999 |

### Cooling Cycle Readings After correction:

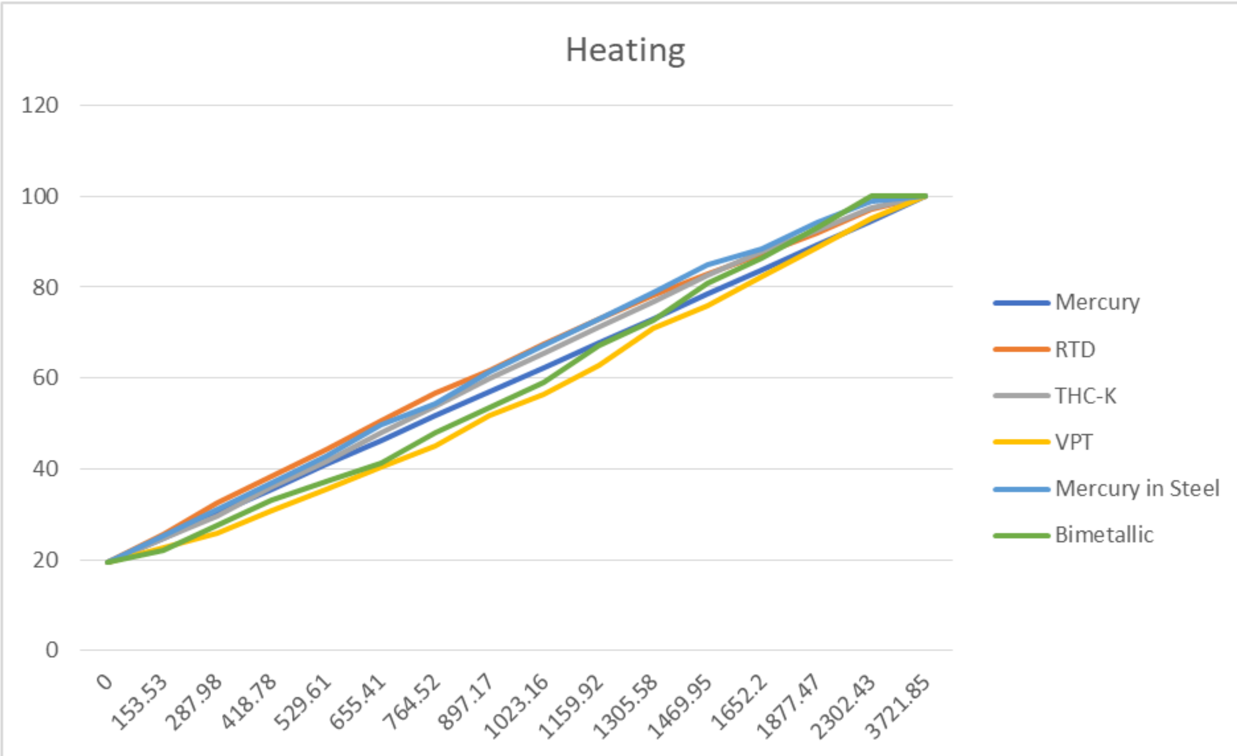
| Sr No | Time(in s) | Mercury-in-glass(in °C) | RTD(in V) | THC-K(in V) | VPT(in °C) | Mercury-in-steel(in °C) | Bi-Metallic(in °C) |
|---|---|---|---|---|---|---|---|
| 1 | 0 | 97.8494623 | 99.3489296 | 98.6940410 | 96.774218 | 98.831192 | 99.99999 |
| 2 | 119.13 | 94.6236559 | 95.9700471 | 95.0823532 | 91.935509 | 95.324882 | 93.16566 |
| 3 | 239.55 | 89.2473118 | 92.1831385 | 90.8906659 | 87.0968 | 91.818572 | 90.43192 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 4 | 359.17 | 86.0215053 | 89.1296102 | 87.1248720 | 83.870994 | 89.481032 | 86.33132 |
| 5 | 479.14 | 82.7956989 | 85.8333996 | 83.5327977 | 79.032285 | 85.974722 | 83.59759 |
| 6 | 599.54 | 79.5698924 | 82.9025458 | 80.2797570 | 75.806479 | 83.637182 | 78.13012 |
| 7 | 719.7 | 76.3440860 | 80.2143741 | 77.3713537 | 72.580673 | 80.130872 | 76.76325 |
| 8 | 840.05 | 74.1935483 | 77.4861998 | 74.2920326 | 69.354867 | 76.624562 | 74.02952 |
| 9 | 960 | 70.9677419 | 75.1660516 | 71.6806338 | 66.129061 | 74.287022 | 71.29578 |
| 10 | 1080.14 | 68.8172043 | 72.9685780 | 69.2429547 | 64.516158 | 71.949482 | 68.56205 |
| 11 | 1200.08 | 66.6666666 | 70.8111068 | 67.0182223 | 62.903255 | 69.611942 | 67.19518 |
| 12 | 1319.98 | 64.5161293 | 68.7336408 | 64.9644076 | 59.677449 | 68.443172 | 64.46145 |

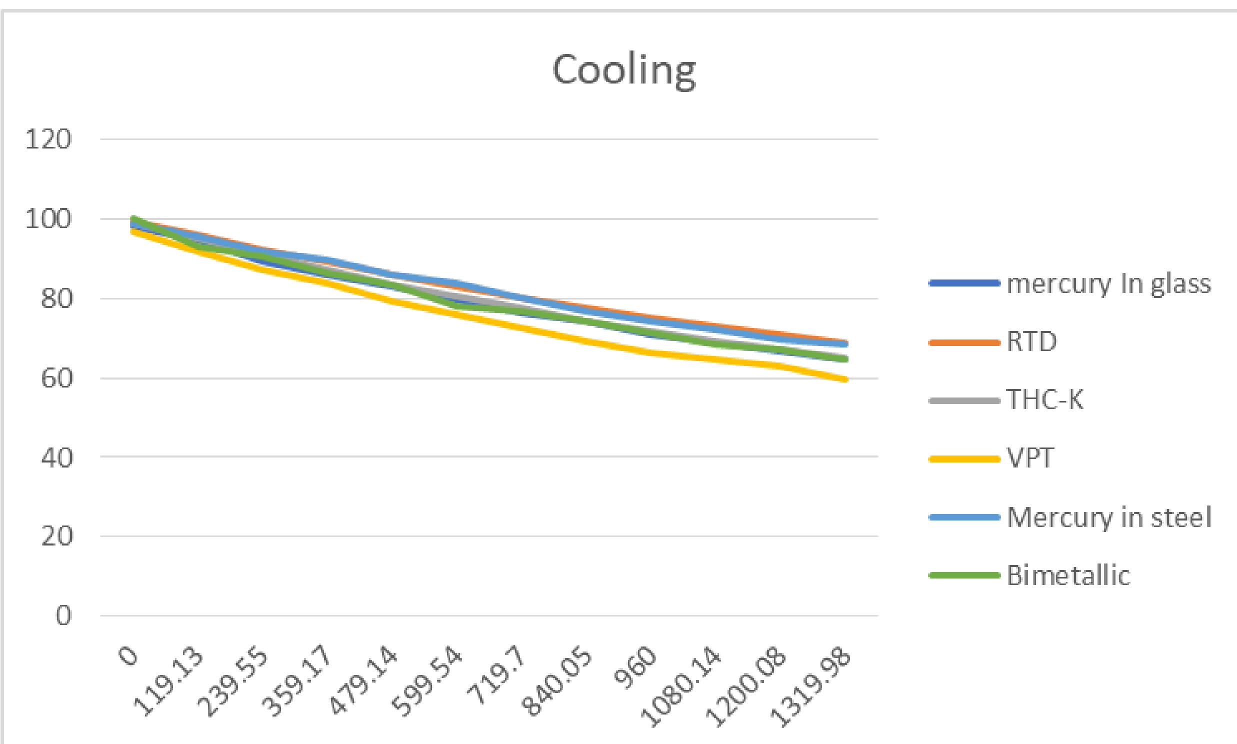
For each of the devices, the slope of the linear part of the curve from the graph for increasing temperatures is the time constant of that particular temperature device.

| Time (in s) | Mercury-in -glass (in °C) | RTD (in V) | THC-K (in V) | VPT (in °C) | Mercury-in -steel (in °C) | Bi-Metallic (in °C) |
|---|---|---|---|---|---|---|
| 2302.43 | 94.62367 | 97.02878 | 97.38859 | 95.16132 | 98.83119 | 99.99999 |
| 3721.85 | 100 | 99.99964 | 99.99999 | 100 | 99.99996 | 99.99999 |
| **Slope** | 0.003787694 | 0.002093009 | 0.001839765 | 0.003408913 | 0.000823413 | 0 |

## Graphs for Heating Cycle:




## Graphs for cooling cycle:



## DISCUSSION:

1. **Compare all the devices based on the following: ruggedness, ease of use, linearity, accuracy, and time of response.**

   a. *Ruggedness:* MiS > THC-K > RTD > VPT > Bi-M > MiG
   b. *Ease of Use:* THC-K > RTD = Bi-M = MiS > VPT > MiG
   c. *Linearity:* THC-K > RTD > VPT > MiG > MiS > Bi-M
   d. *Accuracy:* RTD > THC-K
   e. *Time of Response*: RTD > THC-K > VPT

2. **Suggest ways to improve the experiment.**

   1) At higher temperatures, it becomes very difficult to take readings through a naked eye, as the glass starts to become hazy due to the boiling vapours. Maybe a digital thermometer would have been a better option, in which direct readings can be observed.
   2) There are rapid fluctuations in the readings of THC-K and RTD, especially at higher temperatures. Maybe, if a temporary memory is allocated to it, so that it can store the value when we press a button or some other mechanism. This way, extracting readings from the device becomes much easier.
   3) While performing experiment, we found it pretty difficult to place the stirrer in the middle of the beaker’s base, because of which uniformity in the temperature of the entire water in the beaker cannot be ensured.
   4) The water in the beaker was quite dirty, which must be accounting for higher boiling points than usual. So, a beaker with clean water should be used for the experiment.
   5) Lastly, there were 6 devices working simultaneously, and even if there were 5 people to take the readings, one person or the other was not in a perfect position to take the readings, which must be resulting in parallax error.