NAME OF THE EXPERIMENT:

CALIBRATION OF THERMOCOUPLES (J, K, and T TYPE) USING RESISTANCE TEMPERATURE DETECTOR OR PT-100.

- **Objectives:** To calibrate the given thermocouples using resistance temperature detector.

- **Apparatus:** Thermocouples of different type, Resistance Temperature Detector (RTD), Digital temperature indicator, Water baths with provision to heat the water.

- **Theory:**

(A) Thermocouple: The temperature is measured by using a thermocouple. When two different types of metal wires are joined at both ends, they form two junctions. One which senses the desired unknown temperature is called the hot or measuring junction, and the other junction maintained at a known fixed temperature is called the cold or reference junction. By knowing the temperature of one junction, the temperature of another junction may be easily calculated by using the thermo elastic properties of the material. The thermo elastic effects of the material are:

1. **Seebeck effect:** When two dissimilar metals are joined together, an electromotive force (emf) will exist between the two junctions, which is the primary function of the junction temperature. This phenomenon is called the “Seebeck effect”.
2. **Peltier effect:** If two metals are connected to an external circuit in such a way that a current is drawn, the emf may be altered slightly owing to the phenomenon called the “Peltier effect”.
3. **Thomson effect:** Further, if a temperature gradient exists along either of both the metals. The junction emf may undergo an additional slight alteration. This is called the “Thomson effect”.

Hence, there are three emfs present in a thermoelectric circuit: (i) Seebeck emf caused by dissimilar metals junction (ii) Peltier emf caused by the current flow in the circuit, and (iii) Thomson emf, resulting from a temperature gradient in the metals. Some of the materials are listed in the following table:

Sr. No.	Type	Metal	Temperature Range (°C)
1	J	Iron - Constantan* [40% Ni, 60% Cu]	-40 to +750
2	K	Chromel [90% Cr, 10% Ni] Alumel [95% Ni, 2% Al, 2% Mn, 1% Si]	-200 to +1350
3	T	Copper - Constantan	-200 to +350
4	E	Chromel - Constantan	-200 to +850
5	S	Platinum - Rhodium	0 to +1400
6	R	Rhodium - Iridium	0 to +2100

*Constantan is a copper-nickel alloy

Type J (iron–constantan) has a more restricted range (−40 °C to +750 °C) than type K but higher sensitivity of about 50 µV/°C. The Curie point of the iron (770 °C) causes a smooth change in the characteristic, which determines the upper temperature limit.

Type K (chromel–alumel) is the most common general-purpose thermocouple with a sensitivity of approximately 41 µV/°C. It is inexpensive, and a wide variety of probes are available in its −200 °C to +1350 °C (−330 °F to +2460 °F) range. Type K was specified at a time when metallurgy was less advanced than it is today, and consequently, characteristics may vary considerably between samples. One of the constituent metals, nickel, is magnetic; a characteristic of thermocouples made with magnetic material is that they undergo a deviation in output when the material reaches its Curie point, which occurs for type K thermocouples at around 185 °C.

Type T (copper–constantan) thermocouples are suitable for temperature measurements ranging from −200 to 350 °C. Since both conductors are non-magnetic, there is no Curie point and thus no abrupt change in characteristics.

Type-T thermocouples have a sensitivity of about 43 μV/°C. Note that copper has a much higher thermal conductivity than the alloys generally used in thermocouple construction and so it is necessary to exercise extra care when thermally anchoring type-T thermocouples.

(B) Resistance Temperature Detector (RTD) or PT-100: One of the most accurate methods of temperature measurement is the electrical resistance thermometer. It consists of some type of resistance element, which is exposed to the temperature to be measured. The resistance of an element depends on the temperature. The temperature is indicated through a measurement of the change in resistance of the element. Usually, platinum, nickel, and copper are the most commonly used materials. Although other materials like tungsten, silver, and iron can also be used. One of the most commonly used RTDs is the PT-100, where PT denotes that the sensor is made of Platinum (Pt) and 100 denotes that the sensor has a resistance of 100 ohms (at 0°C).

- **Experimental setup:**

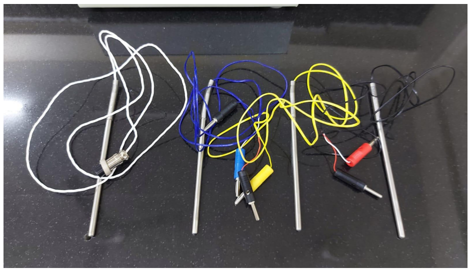

Fig. 1: Left: Photograph of the thermocouples showing probe (stainless steel sheath) and connection wire. **Right:** The Digital Temperature Indicator (DTI).

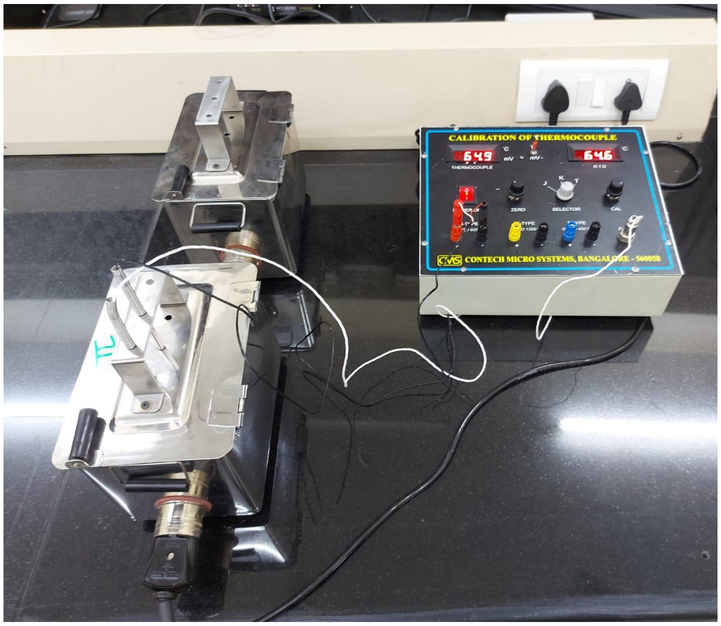

Fig. 2: Photograph of the experimental setup. **Right:** Digital Temperature Indicator. **Left:** Water bath with provision of water heater.

- **Experimental Measurements (Data table):**

    Use the following table to note down experimental observations for all three types of thermocouple provided.

Sr. No.	Temperature Readings (°C)		Error (Ta-Tm)	%Error (Ta-Tm)/Ta]x100
	RTD Temp. (Ta)	Thermocouple Temp. (Tm)		
1				
2				
3				
4				
5				
6				
..				

- **Procedure:**

    i) The experimental setup consists of one Digital Temperature Indicator (DTI) as shown in Figure 1 (Right), two sets of water baths with provision of a water heating coil, one Resistance Temperature Detector (RTD) coupled with white coloured wire, Three types of thermocouples, J-type (red coloured cable), K-type (yellow coloured cable), and T-Type (blue coloured cable).

    ii) Turn the type selector on DTI to the desired position according to the type of thermocouple you wish to calibrate (J-type or K-type or T-type).

    iii) Connect the RTD connector and the given thermocouple to the DTI (please follow the labeled connection points on the DTI).

    iv) To start the calibration procedure, first place the RTD and Thermocouple probes in a cold or room temperature water bath and power on the DTI. As the given thermocouple is not calibrated, one may notice the difference in the temperature reading (seen on a digital meter) for both the thermocouple and the RTD. Try to match the temperature reading of the given thermocouple to the RTD temperature using the ZERO(min.) knob on the DTI.

v) Now, take out both the thermocouple and RTD probes from the cold water and put them in another water bath with a heating coil. Turn on the water heater's power supply and heat the water to around 100 °C (monitor with an RTD digital meter at right). Once it reaches 100 °C, turn off the water heater, and try to match the thermocouple temperature reading with the RTD using the CAL (max.) knob.

vi) Repeat the above steps (iv & v) two more times. Now the given thermocouple is calibrated. In the next steps, we have to check how well the calibration is done.

vii) Begin heating the water and take readings every 5 °C until it reaches 100 °C. Note Down the RTD temperature (Ta) and thermocouple temperature (Tm) in the data table. Determine the error (Ta-Tm) as well as the percentage error [(Ta-Tm)/Ta] x 100. Plot the graph for Ta vs Tm for all three types of thermocouples and obtain the calibration factor by using linear regression.

viii) The graphs for all three thermocouples may appear the same. The difference can be seen above temperatures of 100 °C.

- **Result:** The given thermocouples are calibrated and the measurements are given in the data table. The calibration factors for the different thermocouples obtained from the graph using linear regression are:

(i) J- type = ----- (ii) K-type = ----- and (iii) T- type = ------.

- **Precautions:** The water bath with the heater gets really hot; do not touch it with your bare hand.

- **References:** Some of the text in this manual is taken from the user manual provided by Contech Micro Systems (the supplier of this instrument) and also from Wikipedia.