CSMSS

Chh. Shahu College of Engineering, Aurangabad

Department of Mechanical Engineering

Heat Transfer Lab Manuals

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1. Mean Readings:

   $T_A = \frac{T1+T4}{2}$

   $T_B = \frac{T2+T5}{2}$

   $T_C = \frac{T3+T6}{2}$

2. Area (A)

   $A = \frac{\pi}{4} d^2$

3. Heat (Q) = K. A. $\frac{dt}{dx}$

   $= K.\ A.\ \frac{(TA-TC)}{b}$ $(b = b_1 + b_2 + b_3)$

Therefore, $K = \frac{Q*b}{A\ (TA-TC)}$

$Q = \frac{V*I}{2}$

Calculations:

Read the heat supplied Q = V*I

For calculating the thermal conductivity of composite wall, it is assumed that due to large diameter of the plates, heat flowing through central position is unidirectional i.e. axial flow, thus for calculations, central half diameter area where unidirectional flow is considered.

According to the thermocouples are fixed at close to centre of plates

$Q = \frac{V*I}{2}$

Now q = Heat Flux = $\frac{Q}{A}$

1. Total thermal resistance of composite slab $R_{total} = \frac{TA - TC}{q}$

2. Thermal Conductivity of composite slab, $K_{composite} = \frac{q*b}{(TA-TC)}$

3. b = Total Thickness of composite slab = $b_1 + b_2 + b_3$

Precautions:

1. Keep dimmer stat to zero before stat
2. Increase the voltage supply slowly
3. Keep all the assembly undisturbed
4. Remove airgap between the plates by moving hand press gently
5. While removing the plates do not disturb the thermocouples
6. Operate selector switch of temperature indicates gently

Results:

Thermal conductivity, thermal resistance of the composite wall are found to be:

$K_{composite}$ = and R_{th} =

Experiment No. 02

Thermal Conductivity of Metal Rod

Aim: To calculate the thermal conductivity of metal rod.

Objective: 1. To determine the thermal conductivity of the metal rod.

2. To Study of the variation in thermal conductivity with respect to temperature

Apparatus:

The apparatus consists of a metal bar one end of which is heated by an electric heater while the other projects inside a cooling water jacket. The middle portion of the bar is insulated with asbestos filled in a cylindrical shell concentric to the rod. The temperature of the bar is measured at 9 different sections, while radial temperature distribution is measured with 4 separate thermocouples. two thermocouples are also provided at the inlet & exit of the cooling water jacket.

The heater is provided with a dimmer-stat to control the heat input. Water under constant head is circulated through the jacket and its temperature rise & flow rate are measured.

Introduction:

Thermal Conductivity is the physical property of the material denoting the ease with the particular substance can accomplish the transmission of thermal energy by molecular motion.

Thermal Conductivity of a material is found to depend on the chemical composition of the substance of which it is composed. The phase (i.e. gas, liquid, solid) in which it exists. Its crystalline structure if a solid, the temperature and pressure to which it is subjected, and whether or not it is a homogeneous material.

Thermal conductivity of some materials:

Solid (Metals)	Thermal Conductivity	State (at temp.)
Pure Copper	330	20°C
Brass	95	20°C
Steel	46	20°C
Stainless Steel	14	20°C

Mechanism of Thermal Energy Conduction in Metals:

Thermal energy may be conducted in solids by two modes:

1. Lattice Vibrations and
2. Transport by free electrons.

In good electrical conductors a rather large no. of free electrons moves about in the lattice structure of the material. Just as these electrons may transport electric charge, they may also carry thermal energy from a high temperature region to a low temperature region. In fact, these electrons are frequently referred as the electron gas. Energy may also be transmitted as vibrational energy in the lattice structure of the material. In general, however this latter mode of energy transfer is not as large as the electron transport and it is for this reason that good electrical conductors are almost always good heat conductors viz. Copper, Aluminum and Silver. With increase in the temperature, however the increased lattice vibrations come in the way of transport by free electrons & for most of the pure metals the thermal conductivity decreases with increase in the temperature.

Procedure:

1. Keep the dimmer-stat at minimum voltage position. Switch ON the electric supply.
2. Adjust the dimmer-stat to supply a voltage of 80 to 120 volts to the heating coil. Maintain this constant throughout the experiment.
3. Start the cooling water supply and adjust it to about 350 cc.

4. Wait for steady state to be attained.
5. Note down the readings in the observation table as given below.
6. Note the mass flow rate of water in kg/s.

Observations:

1. Length of the metal bar = 457 mm
2. Size (diameter) of metal bar = 25 mm
3. Test length of the bar = 200 mm
4. No. of thermocouples mounted on bar = 5
5. No. of thermocouples in the insulation shell = 4
6. Heater coil (band type) = Ni-chrome
7. Water Jacket diameter = 55 mm
8. Water inlet temperature (T_{10}) =
9. Water outlet temperature (T_{11}) =
10. r_o = 55 mm
11. r_i = 35 mm
12. Specific heat of water (C_p) = 4.187×10^3 J/kg
13. Thermal Conductivity of water absorb plaster at 273 K = 0.52 W/mK
14. Mass flow rate of water (m) = 2PH = $\frac{2 x 10^{\wedge}-3}{3600} = 557\ x\ 10^{-3}$

Observation Table:

Time	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	T_{10}	T_{11}

Calculations:

1. Heat flowing at outlet of bar is given by:
   $Q_w = m.C_p\,(To - Tin)$

2. Heat conducted through the bar (Q)
   $Q = 2\pi Lk\,\frac{(T10-T11)}{ln(^{r0}/_{r1})}$

3. Total Heat = $Q_w + Q$
4. Thermal conductivity of bar (k)
   $Q = k.A\frac{dT}{dx}$ (where $\frac{dT}{dx}$ = slope from graph)

Result: Thermal Conductivity of Metal Rod = ____________ W/mK

Experiment No. 03

Aim: To determine thermal conductivity of insulating powder

Apparatus: This apparatus consist of two thin wall concentric copper sphere, the inner sphere houses the heating coil, the insulating powder (Asbestos powder lagging material) is packed between the two shells, the power supply to the heating coil is by using a dimmerstat and is measured by voltmeter and ammeter. Chromium aluminum thermocouples are used to measure the temperature. Thermocouple 1 to 4 are embedded on inner sphere temperature reading from 5 to 10 are to the outer surface temperature reading in turn enables to find out the thermal conductivity of the insulating powder as an isotropic material and the value of thermal conductivity can be determined.

Consider the transfer of a heat by conduction through the wall of hollow sphere formed by the insulating powder layered packed between thin copper sphere.

Let

r_i = inner radius of sphere in meters

r_o = outer radius of sphere in meters

T_i = Average temperature of inner sphere in °C

T_o = Average temperature of outer sphere in °C

Where $T_i = \frac{T1+T2+T3+T4}{4}$ And

$$T_o = \frac{T5+T6+T7+T8+T9+T10}{6}$$

Note that T_1 to T_{10}

Denote the temperatures of thermocouples 1 to 10 from the experimental value of q T_i & T_o in °C

The unknown thermal conductivity k can be determined by

$$K = \frac{q\,(ro-ri)}{4\pi ri.ro\,(Ti-To)}$$

Specifications:

1. Radius of inner copper sphere (r_i) = 50 mm
2. Radius of outer copper sphere (r_o) = 100 mm
3. Voltmeter range (0-100-200V)
4. Ammeter (0 – 2 Amps)
5. Temperature indicators 0 – 200°C calibration for chromel alumel
6. Dimmerstat 0-2A, 0-230V
7. Heater coil strip heating element sandwich between mild steel – 200 watts
8. Chromel alumel thermocouple no. 1 to 4 embedded on inner sphere to measures T_i
9. Chromel alumel thermocouples no. 5 to 10 embedded on outer sphere to measure T_o
10. Insulating powder – Asbestos magnesia comer, classify adjustable powder and powdered between the two spheres.

Observation Table:

1. Inner Surface:

Parameter	Voltage (V)	Current (I)	Q = V.I	T1	T2	T3	T4
Set 1							

2. Outer Surface:

Parameter	Voltage (V)	Current (I)	Q = V.I	T5	T6	T7	T8	T9	T10
Set 1									

Calculations:

For Set 1:

Q = V.I Watt

T_i = Inner surface temperature

T_o = Outer surface temperature

r_i = radius of inner copper sphere = 50 mm

r_o = radius of outer copper sphere = 100 mm

Using equations,

Q = V.I and q = Q/A

$$K = \frac{q\ (ro-ri)}{4\pi ri.ro\ (Ti-To)}$$

Result: The thermal conductivity of the insulating powder is found to be __________ W/m°C

Experiment No. 04

Aim: To Find emissivity of non-black surface (Test Plate)

Apparatus:

1. Two aluminum plates identical in all the dimensions, one coated with lamp black

2. Heater

3. Heating coils

4. Voltmeter

5. Thermocouples

6. Temperature indicators

Specification:

1. Test plate material aluminum = dia. 165 mm (actual)
2. Black plate material aluminum = dia. 165 mm (actual)
3. Heat from Ni-Chrome strip wound on mica sheet and sandwiched
4. Heater of capacity = 200 watts approx.
5. Dimmerstat for (1) – 0-2 Amp., 0-260 V
6. Dimmerstat for (2) – 0-2 Amp., 0-260 V
7. Voltmeter 0-100-200 V, Ammeter – 0 – 20 Amp.
8. Enclosure size 580 mm x 300 mm approximately with one side of perlox sheet
9. Thermocouple pt. 100 (3 Numbers)
10. Temperature indicator 0-200°C
11. MCB Switch

Experimental Procedure:

1. Gradually increase the input of the heater to black plates and adjust its same value 30 watts and adjust the heater input to test plate less than that of black plate
2. Check the temperature of the two plates with small times interval and adjust the input of test plate
3. This will require some time in order to reach steady state conditions
4. After obtaining steady state conditions record the temperature, voltmeter and ammeter reading for both the plates.
5. The same procedures is repeated for various surface temperature in increasing order.

Observation Table:

Sr. No.	Test Plate			Black Plate			Enclosure
	Vg	Ig	Tg	Vb	Ib	Tb	Ta temp.

Calculations:

1. $Q_g = V_g.I_g$
2. $Q_b = V_b.I_b$

d = 165 mm = 0.165 m

$A = 2\frac{\pi}{4}d^2 + \pi d t$

Tg = __________ K

Ta = __________ K

$Qb - Qg = (\varepsilon b - \varepsilon g)\sigma A(Tg^4 - Ta^4)$

Result: Emissivity of the test plate is ________

Experiment No. 05

Aim: To verify the Stefan Boltzmann Law

Objective: To measure the value of Stefan Boltzmann constant fairly close by an easy arrangement

Apparatus: The apparatus consists of an inverted hemispherical vessel which is blackened from the concave side and there is an arrangement for storing hot water at the convex side. The concave end is further sealed except for a small opening at the bottom. 4 thermocouples are fitted on the hemispherical shell. One is fixed on the blackened test plate (Copper). There is provision for heating water up and sending it for storage in the tank.

Theory: Radiation heat transfer is concerned with the exchange of thermal radiation energy between two or more bodies. Thermal radiation is defined as Electromagnetic radiation in the wavelength range of .1 to 100 microns (which encompasses the visible light regime.), and arises as a result of a temperature difference between two bodies. No medium need exists between two bodies for heat transfer to take place (as is need by conduction and convection.) Rather the intermediaries are photons which travel at the speed of light. The heat transferred into or out of an object by thermal radiation is a function of a several components. These include its surface reflectivity, emissivity, surface area, temperature and geometric orientation with respect to other thermally participating objects. In turn, an object's surface reflectivity and emissivity are a function of its surface conditions (roughness, finish etc.) and composition.

In conduction and convection energy is transferred through a material medium, but energy may also be transferred through regions where perfect vacuum exist. Radiation is an electromagnetic phenomenon of varying wavelengths closely allied to the transmission of light and radio. It proceeds in straight lines at the speed of light. A classic example of energy transmission by radiation is the Sun which transmits abundant energy to the earth by this means.

Radiation is independent of mass except for nuclear reactions. It is much a surface through a wide wavelength band. Electromagnetic radiation propagated as a result of temperature difference is termed as thermal radiation. An ideal thermal radiator is called a black body which will emit energy at a rate proportional to the fourth power of the absolute temperature of the body and directly proportional to the surface area.

Where the Stefan-Boltzmann constant & has a value of 5.67×10^{-8} W/m^2K^4 equation governs only the radiation emitted by a black body.

The net radiation exchange between two surfaces is proportional to diff. in absolute temperature to the fourth power

$$\frac{q}{A} \alpha \sigma (T_1^4 - T_2^4)$$

No object is perfectly black body. It cannot radiate all the heat given to it. To account for this Gray nature of surface, we introduce a factor called emissivity (ε). Again, radiation travels in a straight line so the radiation leaving one surface does not completely reach the other surface, but some of it is lost to the surrounding. So, we introduce another factor called view factor (F_{ij})

$$q = A \sigma (T_1^4 - T_2^4)$$

Experiment Procedure:

1. Heat up the water by the electric heater and after a certain temperature is attained, send it into the convex bottom tank.
2. Wait till thermocouples 1 to 4 show fairly similar readings.
3. Now insert the test disk into the slot provided and immediately start taking readings against time.
4. Plot the temperature-time graph and find out its slope at time = 0.

Observations:

1. Mass of the disc = 8 gm
2. Diameter of Test Disc (d) = 25 mm
3. Specific heat of copper (test disc) (C_p) = 385 kJ/kgK
4. Temperature of disc Td = Ts = 30 °C

Observation Table:

Thermocouple No.	T_1	T_2	T_3	T_4	T_{Avg}
Temperature in °C					

Temperature time response of the disc

Time in Sec.	0	5	10	15	20	25	30	35	40	45	50
Temp. in °C (T5)											

Calculations:

T_{Avg} = ___________ K

Area of Discharge (A): $= \frac{\pi}{4} d^2 = 0.0049 \text{ m}^2$

Slope $\left\{\frac{dT}{dt}\right\}$ from the graph

From the above relation we have $\sigma = \frac{m.Cp.\frac{dT}{dt}}{A\ ({T_{Avg}}^4 - {T_5}^4)}$

Result: The value of (dT/dt) at t=0 is obtained from the slope of the graph plotted temperature of disc vs time

Experimentally Stefan Boltzmann constant is found to be ___________ W/m^2K^4

Experiment No. 06

Aim: To determine the average surface heat transfer coefficient in natural convection and compare it with the value obtained by using appropriate correlation.

Apparatus:

The apparatus consists of a brass tube fitted in a rectangular duct in a vertical fashion. The duct is open at the top and bottom and forms an enclosure and serves the purpose of undisturbed surrounding. One side of the duct is made up of a transparent material for visualization. An electric heating element is kept in the vertical tube, which in turn heats the tube surface. The heat is lost from the tube to the surrounding air by natural convection. The temperature of the vertical tube is measured by seven thermocouples. The heat input to the heater is measured by an ammeter and a voltmeter and is varied by a dimmer-stat. The tube surface is polished to minimize the radiation losses.

Theory:

Convection is the heat transfer that occurs as a result of the movement of a fluid, and hence it is not possible in case of solids. It is well known that a hot metal plate will cool faster when placed in front of a fan than when exposed to still air. We say that heat is convected away and we call the process convective heat transfer. Heat will transfer by conduction through the walls of the fluid container. From the container walls, the heat will transfer by conduction and radiation into the fluid, causing convection currents to be set up in the fluid. Consider a heated plate. The temperature of the plate is Tp and the temperature of the fluid in which it is immersed is Tf. The velocity of flow increases from the wall of the plate to the surface of the fluid. At the wall, the velocity is zero. Therefore, heat transfer here is only by conduction. The change of temperature over the length (temperature gradient) is dependent on the rate at which the fluid carries the heat away. This process is described by the Newton's law of cooling.

$$Q = h.A_s(T_s - T_f)$$

The heat transfer rate is related to the overall temperature difference between the wall and the fluid and the surface area As. The quantity h is called the heat transfer coefficient and it can be calculated for simple systems, but has to be experimentally determined for complex systems. It includes the effects of conduction, radiation and convection at the considered surface. For instance, the convective heat transfer coefficient for free convection with water flowing on a hot vertical plate 1 ft high with a temperature difference of 30°C between the water and the plate is 4.5 W/m °C. The following figure shows the heat transfer from the surface of a plate. Factors affecting the heat transfer coefficient are:

- Shape and inclination of the surface over which convection takes place.
- Injection of new fluid Roughness of the surface
- Whether the flow is in an open or closed space
- Mode of convection (free/forced)
- Speed of flow and Reynold's number (laminar/turbulent flow)
- Presence of Electric and magnetic fields.

Heat transfer using movement of fluids is called convection. In natural convection, the flow is induced by the differences between fluid densities which result due to temperature changes.

The heat transfer rate for convection is given by the following equation:

$$Q = h.A_s(T_s - T_a)$$

h is the convection coefficient, As is the surface area and T_s and T_a are the surface and ambient temperatures, respectively. Density of fluid changes with temperature. In general, fluids expand as the temperature rises.

and thus the density decreases (density is the mass per unit volume). Warm fluids therefore are more buoyant than cooler fluids. A hot object will heat the surrounding fluid, which rises due to buoyancy force. The warm fluid is then replaced by cool fluid. Similarly, cool objects will draw heat away from the surrounding fluid which then falls due to increased density. The cool fluid is then replaced by warm fluid initiating convection currents.

For a hot horizontal plate surrounded by air, convection currents form when the air above the plate starts to rise. The air below the plate, however, cannot rise because the plate is blocking the flow. The heated fluid under the plate will eventually escape through the sides of the plate; however, the convective flow below the plate is very small compared to the flow on top. In general, natural convection is more pronounced (has a higher h) on the topside of a hot plate or the bottom side of a cold plate.

The convection coefficient is a measure of how effective a fluid is at carrying heat to and away from the surface. It is dependent on factors such as the fluid density, velocity, and viscosity. Generally, fluids with higher velocity and/or higher density have greater h. The convection coefficient for natural convection in gas is generally between 1 W/m^2 K and 20 W/m^2, typical values for liquid falls between 100 W/m^2K and 1000 W/m^2K

Procedure:

1. Switch on the electric supply and adjust the dimmer-stat to obtain the required heat input (say 40w, 60w).
2. Wait for steady state to be attained.
3. Note down the reading in the observation table as given below.
4. Repeat the experiment at different heat inputs. (Do not exceed 80 watts).

Observations:

1. Outer Diameter of Cylinder (d) = 32 mm
2. Length of Cylinder (L) = 540 mm

Observation Table:

Sr. No.	Voltage (V)	Current (I)	T1	T2	T3	T4	T5	T6	T7	T8
1										
2										
3										

Calculations:

1. Rate of heat transfer (Q) = V.I
2. Average temperature of surface (Ts) = $\frac{T1 + T2 + T3 + T4 + T5 + T6 + T7}{7}$
3. Ambient Temperature (Ta) = T8
4. Area of heat transfer (A_s) = πdL
5. $Q = h_{actual} \cdot A_s(T_s - T_a)$

Result: The actual value of heat transfer coefficient was found to be ____________ W/m^2K

Experiment No. 07

Aim: To determine the heat transfer coefficient in forced convection

Apparatus:

Standard Forced Convection set up.

The apparatus consists of a metal pipe provided with an electric heater. This assembly is covered with insulation so as to avoid any unaccounted heat losses. A blower is fitted to this pipe to provide a constant supply of high velocity air. Thermocouples are provided to measure necessary temperatures. The heater coil is fitted with voltmeter and ammeter. An orifice meter with a U-tube differential type manometer is fitted to measure the velocity of the air.

Theory: In many practical situation and equipment, we invariably deal with flow of fluid, e.g. Boiler, superheater, Automobile radiators, Air-heater, or cooler etc. Knowledge and evaluation of forced convection heat transfer coefficient of forced convection heat transfer coefficient for optimal design of all thermal systems, convection is transfer of heat within fluid by mixing of one portion of fluid with another.

Procedure:

1. Keep the dimmer stat at minimum voltage position. Switch ON the electric supply to the heater
2. Adjust the dimmer stat to supply constant voltage to the heating coil, Start the blower supply
3. Wait for steady state to be attained
4. Note down the reading in the observation table as given below

Observations:

Outer diameter of the pipe (d_o) = 38 mm

Inner diameter of the pipe (d_i) = 34 mm

Length of test section (L) = 300 mm

Orifice diameter = d = 19 mm

Sr. No.	Voltage (V)	Current (I)	T1	T2	T3	T4	T5	T6	Manometer Difference (h_w)

Calculations:

1. Air Inlet Temperature (T1) = _____ °C

2. Air Outlet Temperature (T2) = ______ °C

3. Density of Air (ρ_a) = 1. 03 Kg/m³

4. Discharge ($\bar{Q}$) = $C_d A_o \sqrt{2ghw\frac{\rho_w}{\rho_a}}$,   where ρ_w is density of water = 1000 kg/m³

C_d = Coefficient of Discharge = 0.68

A_o = Area of Orifice = $\frac{\pi}{4}d^2$

5. Mass flow rate (m_a) = $\bar{Q} \cdot \rho_a$

Velocity of air (v) = $\frac{\bar{Q}}{a_p}$ where, a_p – area of pipe in m^2

6. Heat gained by air (Q_{air}) = $m_a C_{pa} (T_6 - T_1)$ where C_{pa} – is specific heat of air = 1 kJ/kg.K

7. Average temperature of Inside Surface (T_s) = $\frac{T2+T3+T4+T5}{4}$

8. Bulk mean temperature (T_m) = $\frac{T1+T6}{2}$

9. Heat Transfer coefficient (h) = $\frac{Q_{air}}{A(T_s-T_m)}$, where $A = \pi d_i L$

Result: The heat transfer coefficient in forced convection is found to be __________ W/m^2K

Experiment No. 8

Aim: To Study Calibration of Pressure Gauge, Thermocouple and Flow Meter

Apparatus: Pressure Gauge, Thermocouple and Flow Meter

Theory:

1. **Pressure Gauge:** A bourdon- tube gauge, (fig. 1), measures the pressure by sensing the deflection of a coil tube. The pressure gauge is composed of a metal tube of copper with one end closed and formed as 3/4 of a circle and the other end connected to the pressure source. The applied pressure causes a little expansion in the circular shape of the tube, moving with it an attached pointer that is calibrated to indicate the pressure. When the applied pressure is more than the atmospheric pressure, the closed end will diverge causing an expansion in the circular shape of the tube. There is a connected mechanism of levers and gears to amplify the movement of the tube and transfer the action to pointer that indicates a definite pressure. When the pressure gauge is disconnected, the pointer must indicate zero pressure because in this case the pressure inside the tube is equal to the outside pressure which is the atmospheric pressure. The calibration of the pressure gauge is done according to this fact. The accuracy of the pressure -gauge is dependent on its calibration. The gauge must be calibrated from time to time especially after applying, high pressure.

2. **Thermocouple:** A thermocouple is **a sensor that measures temperature**. It consists of two different types of metals, joined together at one end. When the junction of the two metals is heated or cooled, a voltage is created that can be correlated back to the temperature. ... Thermocouples are commonly used in a wide range of applications.

3. **Flow meter:** A flow meter is a device used to measure the volume or mass of a gas or liquid. Flow meters are referred to by many names, such as flow gauge, flow indicator, liquid meter, flow rate sensor, etc. depending on the particular industry. However, they all measure flow. Open channels, like rivers or streams, may be measured with flow meters. Or more frequently, the most utility from a flow meter and the greatest variety of flow meters focus on measuring gasses and liquids in a pipe. Improving the precision, accuracy, and resolution of fluid measurement are the greatest benefits of the best flow meters.

Procedure for Calibration:

1. **Pressure Gauge Calibration:** The equipment required for the calibration of pressure gauge calibration are: 1. Pressure Comparator, and 2. Master Gauge

   Pressure Comparator operates in a similar manner as dead-weight tester for the generation of pressure, until the desired pressure is achieved.

   Master Gauge is a digital gauge used to calibrate measurement instrument, which offers a high accuracy against which the unit to be calibrated is compared.

   The procedure for calibration is as follows:

   1. First Identify the basic parameters on the unit to be calibrated (test gauge): such as least count, maximum range of pressure gauge, measuring unit etc.
   2. According to the basic parameters identified, now select a suitable master gauge for calibration of the unit.
   3. Release the pressure of pressure comparator before using it by the movable wheel.
   4. Place the Master Gauge on one side on the pressure comparator
   5. Select the unit/least count as per test gauge on Master Gauge with selection keys.
   6. Place the test unit (pressure gauges to be calibrated) to Right Hand Side, as shown in the figure.
   7. Use the handwheel to pump the liquid in the comparator for proceeding calibration steps until it reaches the desired range.

2. **Thermocouple calibration:**

A basic calibration process involves heating water to 30°C in a thermal bath. Next, each of two multimeter leads is attached to the free end (cold junction) of the thermocouple – at this point, the multimeter should register zero microvolts as both ends are at the same temperature. The hot junction of the thermocouple is then placed into the thermal bath. The voltage can be recorded once the multimeter reading becomes stable. The water temperature is increased to 35°C, and again the voltage is recorded. This process is repeated by increasing the temperature by five-degree increments and recording the voltage until 60°C is reached. Once all of the measurements have been taken, the voltage for the thermocouple type at the room's temperature is determined. (This figure can usually be looked up.) Then the given figure is added to each of the recorded voltage values gathered previously. Next, a curve-fitting method is used to fit a line to the recorded data – the slope of the line will be the voltage increase per each degree of temperature increase.

3. **Flowmeter Calibration:**

Liquid flow meter calibration can be done in several ways, but always involves comparison and adjustment of the flow meter under test to conform to a standard

some of the most widely-used flow meter calibration procedures are:

1. Master Meter Calibration
2. Gravimetric Calibration &
3. Piston Prover Calibration

Master Meter Calibration Procedure:

Master meter calibration compares the measurements of a flow meter under test to that of a calibrated flow meter or 'master' flow meter operating at the desired flow standard and adjusts its calibration accordingly. The master flow meter is usually a device whose calibration is set to a national or international standard.

Steps Involved:

1. Place the master meter in series with the flow meter under test.
2. Compare the readings of the master flow meter and flow meter using a measured volume of liquid.
3. Calibrate the flowmeter under test to conform with the master flow meter calibration.

Conclusion: Hence in this manner, the procedure for calibration of various measuring instruments like pressure gauge, thermocouple and flowmeter has been learned.