# Chapter II Temperature transducers

# CHAPTER - II

## Temperature transducer

### 2.1 Introduction :

In this chapter survey of the different transducer used for the measurement of temperature is taken. The description of the actual transducer used and its temp. characteristics are presented. The details of the furnace constructed are given at the end.

### 2.2 Temperature sensor :

There are various types ot temperature sensors such as mechanical sensors, electrical sensors, optical sensors and distribution pyrometers (1).

The mechanical sensor include liquid in glass thermometers, liquid field thermometers, vapour pressure thermometers etc. The advantages of these sensors are

i) Simplicity and in expansive design.

ii) Rugged construction

iii) Self contained operation &

iv) Remote indications in special cases.

The drawbacks of mechanical temperature sensor are

i) Limited temperature coverage

ii) Large size

iii) Incompatibility with electrical systems and

iv) Poor dynamic response.

Electrical sensors :

These sensors include thermo-electric thermo-couple, Resistance thermometer and crystal transducer and semi-conductor Junction Voltage Variation.

Resistance type temperature sensor : (2)

These transducer derive the electrical resistance from the collision of the free electrons with ions of the crystal lattice. The mean free path length between the collisions decreases due to the increase in the amplitude of oscillation giving rise to increase in the electrical resistance.

The resistance thermometer are useful for the measurement of small as well as wide temperature differences. They suffer from the disadvantage of large size and requirement of sophisticated instrumentation.

The resistance material can be pure metal or alloy having either positive or negative temperature coefficient in the form of wire wound to have small size and improved thermal conductivity to decrease the response time. The metals used are Nickel, iron, copper, silver, gold, platinum etc.

Thermistors :

Thermistors are semi-conducting devices with (-ve) temperature coefficient of resistance. The sensors are made from oxides of iron, manganese, Nickel, cobalt and copper by sintering the mixture in the form of beads or disk. The variation of resistance with temperature is non-linear and the usable range is between 170 to 570°K. They are suitable for precision temperature measurement, temperature control, and temperature compensation because they offer large change in resistors with the temperature. They are used with Wheat-stone bridge Network.

Thermocouples :

The temperature sensing by thermocouple is a common practice. When the Junctions of the two dis-similar metals are kept at different temperatures a Thermo e.m.f. is generated and is proportional to temperature difference. The proporties of some standard thermo-couple are summarised in the table 2.

Solid state sensors :

It is established that the forward bias voltage of a P-n Junction varies linearly with temperature at constant forward current. For transistor the relation is

$$V_{BE} = \frac{KT}{q} \ln \left( \frac{I_E + I_{EO}}{I_{EO}} \right) \qquad - \qquad 1$$

Table 2 : Properties of Thermocouple

| Type (ISA standard) | Metal alloys used | Composition | Sensitivity UV/°C | Accuracy °C | Range °C | Remarks |
|---|---|---|---|---|---|---|
| Type E | Chromel (+)/ constantant (-) | 90% Ni,10% Cr/ 57% Cr,43% Ni | 40 to 55 | ± 1.8°<br>± 0.5% | - 18 to + 315<br>315 to 870 | High sensitivity |
| Type K | Chromel(+)/ alumel (-) | 90% Ni,10%Cr/ 94% Ni,3%Mn 2% Al, 1%Sr. | 40 to 55 | ± 2.2°<br>± 0.5% | + 18 to 276<br>276 to 1000 | Long life and low thermal conductivi ty popular for many applications. |
| Type J | Iron(+)/ constantan (-) | Fe/57% Cr 43% Ni | 45 to 57 | ± 2.2°<br>± 0.5% | - 18 to 276<br>276 to 1500 | Inexpensive,rapid deterioration above 560°C, mechanically strong. |
| Type S | Platinum(-)/ platinum(-) | pt/ 90% $P_t$ 10%Rh | 5 to 12 | ± 0.25% | 450 to 1500 | Low sensitivity, high stability,free from parasitic emf |
| Type T | Copper (+)/ constantan | Cu 157% Cu 43% Ni | 15 to 60 | ± 0.8° | -200 to + 93 | Especially suitable for measurement below 0°C; high reliability. |

Where $I_E$ = Emitter current.

$I_{EO}$ = Emitter reverse current.

$T$ = Absolute temp. of the Junction.

$q$ = Change on electron.

$K$ = Boltzmann's constant.

and $V_{BE}$ = Emitter base forward bias.

Ordinary P-n Junction diode or a zener diode can be used to detect the temperature. These sensors are kept in the environment whose temperature is to be measured. For a diode, the forward current is given by,

$$I = I_0 \exp\left(\frac{V}{nV_T}\right) - 1 \qquad -(2)$$

$$\text{Where } V_T = \frac{T}{11,600} = 26 \text{ mv at } 300^{\circ}K$$

The temperature dependence of reverse saturation current for silicon diode is given by (2)

$$I_o = KT^{3/2} \exp(-\Delta v/2V_T)$$

Where $\Delta V$ = Forbidden energy gap in volts.

This equation gives

$$\frac{dv}{dT} = \frac{V - (\Delta V + 3V_T)}{T}$$

with $V_T = 26$ mV at room temperature.

$$\frac{dv}{dT} = -\ 2.3\ mV/^{o}C$$

The optical sensors include spectral pyrometers, band radiation pyrometer, and total radiation pyrometer. These are indirect methods of measurement of high temperatures.

Experimental set-up to determine the temperature coefficient of Junction voltage is shown in fig.2.

Experimental Procedure :

In fig. 2 the experimental set up for determination of Junction temperature coefficient for a silicon P-n Junction diode is shown. Initially with a current of 10 mA the forward voltage across the diode is measured using a seperate power supply unit. The forward drop across the diode is balanced to give zero reading in the millivolt meter. The diode is now immersed in paraffin oil at 100$^{o}$C in a beaker. During the fall of temperature keeping the same current 10 mA the change in the forward voltage with respect to temperature is recorded after every 5$^{o}$C drop of temperature. This temperature variation of forward voltage is shown in graph fig. 2.1

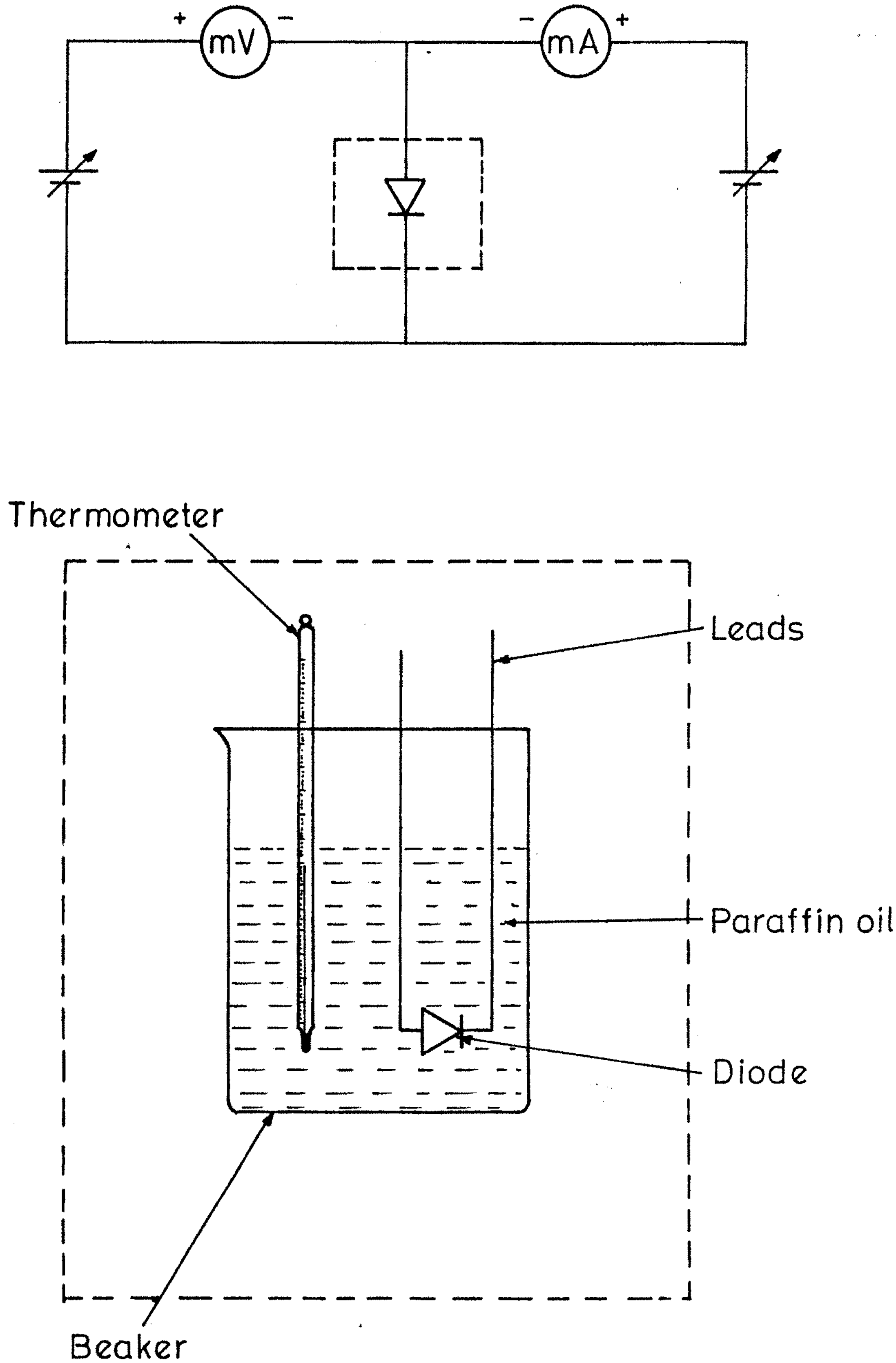
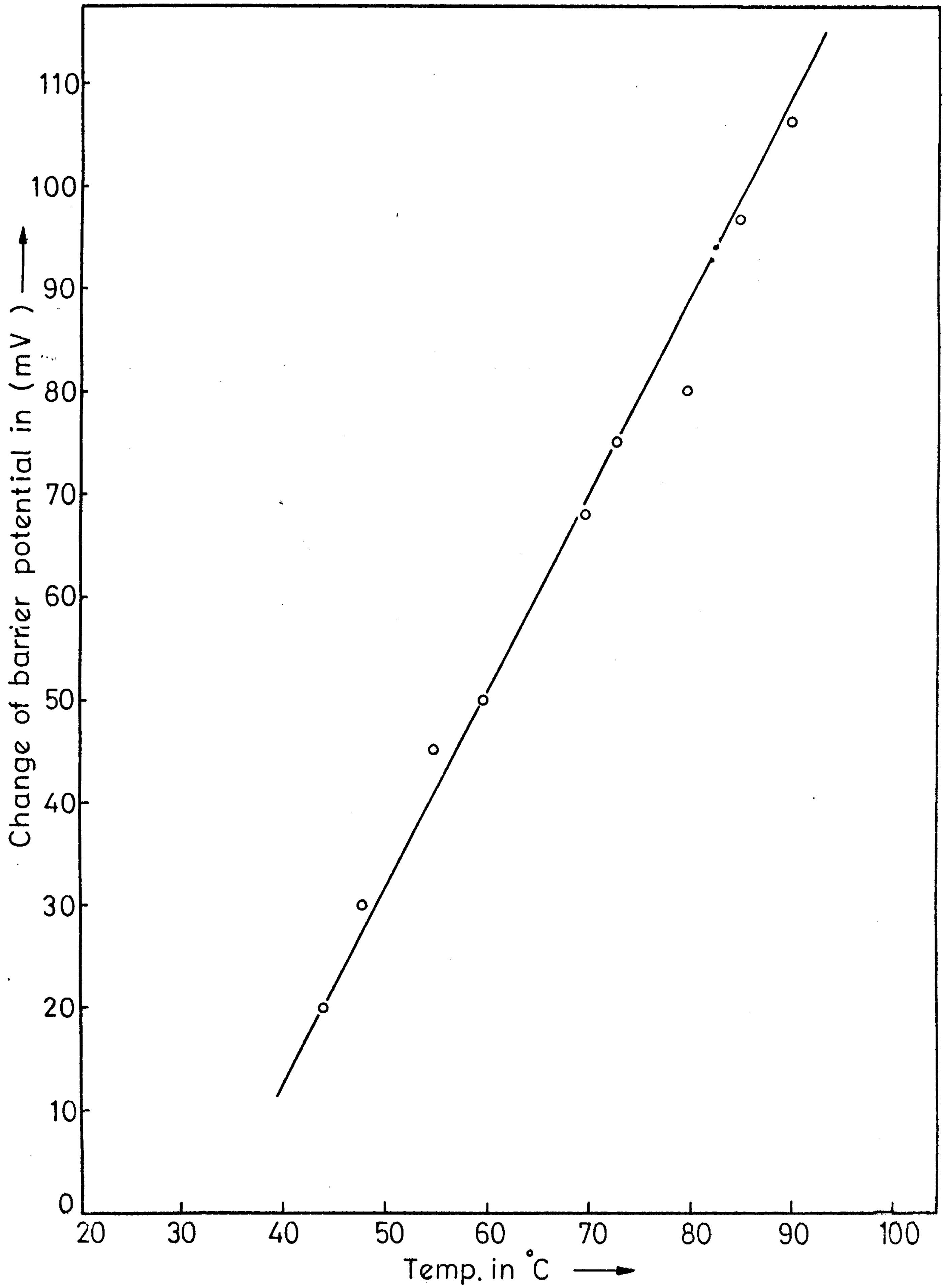



Fig. 2·0



Change of barrier potential in (mV)
110
100
90
80
70
60
50
40
30
20
10
0
20
30
40
50
60
70
80
90
100
Temp. in °C

Observation Table : (2.1)

| Sr.No. | Junction temp. in $^{o}C$ | Change of forward voltage in (mv) |
|---|---|---|
| 1 | $90^{o}$ | 106 |
| 2 | 85 | 96 |
| 3 | 80 | 80 |
| 4 | 73 | 75 |
| 5 | 70 | 68 |
| 6 | 60 | 50 |
| 7 | 55 | 45 |
| 8 | 48 | 30 |
| 9 | 44 | 20 |

I = Const.

= 10 mA.

BARR. BALASAHEB KHARDEKAR LIBRARY
SHIVAJI UNIVERSITY KOLHAPUR.

In the table (2.1) observations on temperature variation of diode forward voltage are given.

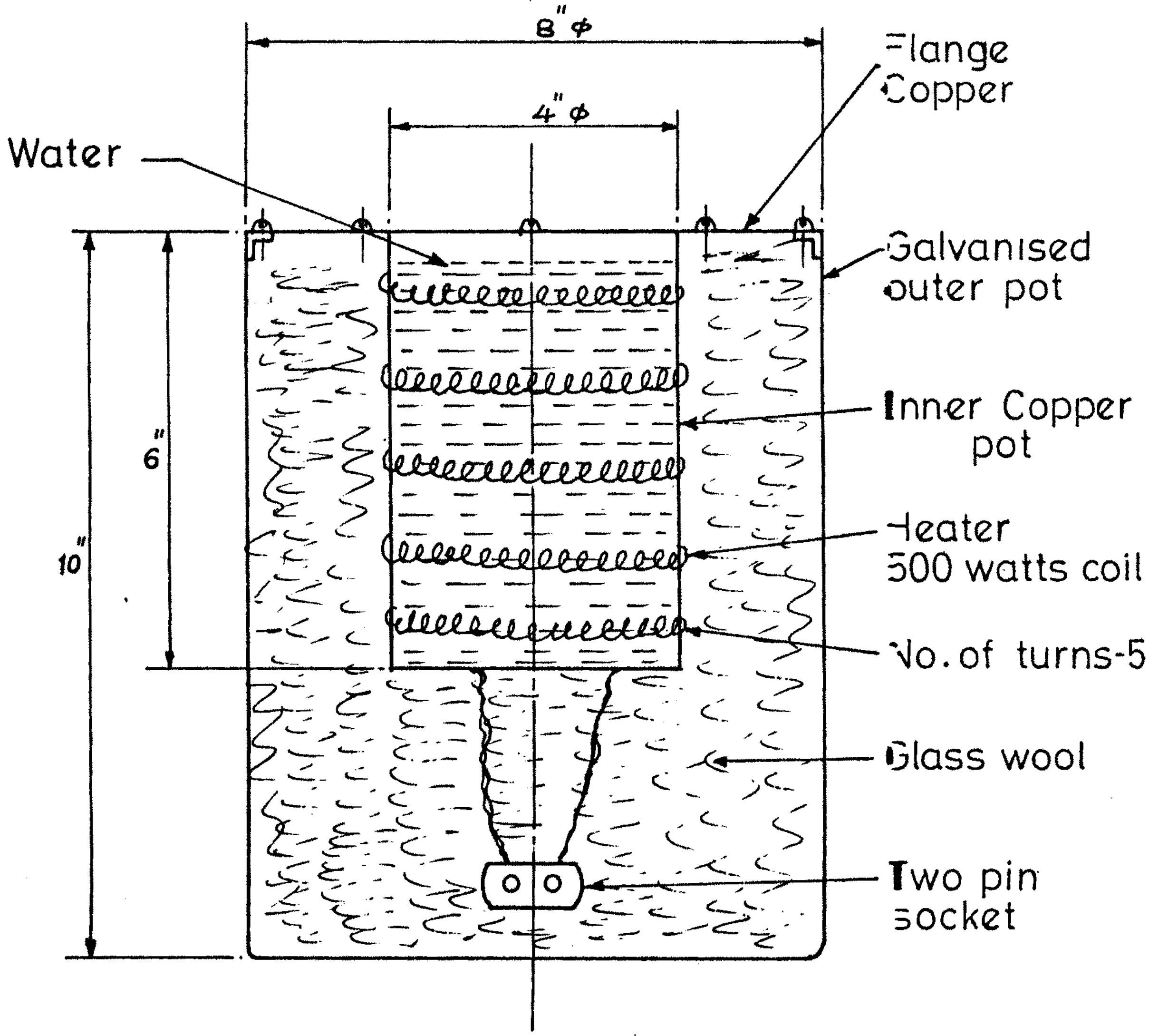
The slope of the graph comes out to be equal to -2 mV/°C. In order to make this change more detectible so as to reduce the error of measurement. We have used two diodes in series as temperature sensors. The temperature variation of diode forward characteristics exhibit perfect linearity which is an essential requirement of any transducer. The si-diode was used because its temperature range extends from - 60°C to 150°C (4).

I = const.

= 10 mA.

## 2.4 Furnace construction :

The furnace whose temperature is monitered and controlled is fabricated at USIC, Shivaji University, Kolhapur. The specifications for the design are supplied by US. A coiled coil with wattage of 500 is wound around an inner copper pot of diameter 4" and height 5'. Five turns of this colied coil are used. A galvanised outer pot of diameter 8" and height 10" surrounds the inner copper pot. Glass wool provides the insulation and copper flange the seperation between the inner pot and its outer pot. The details of the parts of the furnace are shown in fig. 2.




Furnace

Fig. 2·1

References :


1. C. S. Rangan, G. R. Sharma, V. S. Mani,
   Instrumentation Devices and systems
   TMH 1983 Pg- 191-219.

2. W. D. Cooper,
   Electronic Instrumentation and Measurement techniques.

3. K. R. Boatkar,
   Integrated circuits Khanna publishers, 1985
   Pg- 36-37.

4. V. S. Popov and S. A. Nikolayer,
   Basic Electricity and Electronics Mir publishers 1977
   Pg- 437.

## Chapter III  Architecture of 8085 and temperature control techniques.