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| **DEHRADUN INSTITUTE OF TECHNOLOGY** | | **LABORATORY MANUAL** |
| **PRACTICAL INSTRUCTION SHEET** | | |
| EXPERIMENT TITLE : **To study P, PI, and PID temperature controller for an oven and compare their performance** | | |
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**Objective**: To study P, PI, and PID temperature controller for an oven and compare their performance.

**Apparatus Used:**

| | Name of the apparatus | Range | Quantity |
|---|---|---|---|
| 1. | Temperature Controller System | | 1 |
| | PID | Kp (0-10) Kd(0-20) Ki(0-0.02) | |
| 2. | Oven | | 1 |

**Theory**

Temperature control is one of the most common industrial control systems that are in operation. This equipment is designed to expose the students to the intricacies of such a system in the friendly environment of a laboratory, free from disturbance and uncertainties of plant prevalent in an actual process. The plant to be controlled is a specially designed oven having a short heating as well as cooling time. The temperature time data may be obtained manually, thus avoiding expensive equipment like an X-Y recorder or a pen recorder. A solid state temperature sensor converts the absolute temperature information to a proportional electric signal. The reference and actual temperatures are indicated in degree Celsius on a switch selectable digital display.

The controller unit compares the reference and the measured signals to generate the error. Controller options available to the user consists of ON-OFF or relay with hysteresis settings and combination of proportional, derivative and integral blocks having independent coefficients settings. A block diagram of the complete system is shown in figure 1.

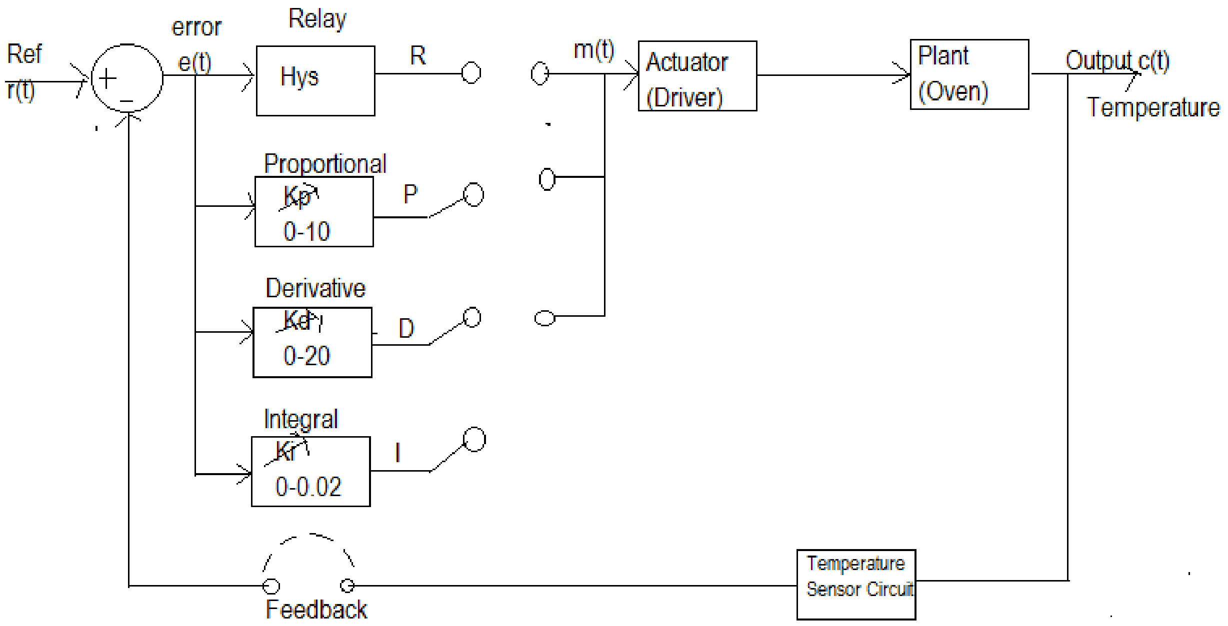

Fig1. Block Diagram of the Temperature Controller

**The Plant**

Oven: This is a thermal system which basically involves transfer of heat from one section to another.

There are three modes of heat transfer viz. conduction, convection and radiation. Heat transfer through radiation maybe neglected in the present case since the temperature involved is quite small. For conductive and convective heat transfer-

$$\theta = \alpha \Delta T$$

Where, $\theta$= rate of heat flow in Joules/sec

$\Delta T$= temperature difference in degree centigrade

$\alpha$= constant

Under assumption of linearity, the thermal resistance is defined as R= temperature difference/ rate of heat flow=$\Delta T/\theta$=1/ $\alpha$. This is analogous to electrical resistance defined by I=V/R. In a similar manner thermal capacitance of the mass is defined by

$$\theta = Cd(\Delta T)/dT$$

Which is analogous to the V-I relationship of a capacitor, namely I=C dV/dt. In the case of heat,

C= Rate of heat flow/ Rate of temperature change

The equation of an oven may be written by combining the above two equations, implying that a part of the heat input is used in increasing the temperature of the oven and the rest goes out as loss. Thus

$$\theta = \frac{CdT}{dt} + (1/R)xT$$

With initial condition T (t=0) = $T_{amb}$. Now, taking Laplace transform with zero initial condition

$$\frac{T(s)}{\theta(s)} = \frac{R}{1 + sCR}$$

An analogous electrical network is given by equation

I=C dV/dt+V/R

**Circuit Diagram**-

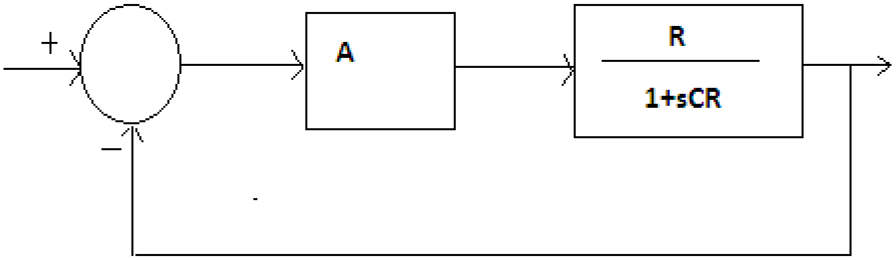

Fig 3. Closed Loop Temperature Control

**PROCEDURE:**

**Identification of Oven Parameters:** Plant identification is the first step before an attempt can be made to control it. In the present case, oven equations are obtained experimentally from its step response as outlined below.

In the open loop testing, the oven is driven through the P- amplifier set to a gain of 10. The input to this amplifier is adjusted through reference potentiometer. This input can be seen on digital display, so that when you set 5 $^0$C, the input to P amplifier is 50 mV.

- Keep switch $S_1$ to` WAIT`, $S_2$ to `SET` and open `FEEDBACK` terminals.
- Control P output to driver input and switch ON unit.
- Set P to 0.5 which gives $K_p$ =10. Adjust reference potentiometer to read 5.0 on the DVM. This provides an input of 0.5 V to the driver.
- Put switch $S_2$ to `MEUSRE` position and note down the room temperature.
- Put switch S1 to the RUN position and note temp reading every 15 sec.. till the temp becomes almost constant.
- Plot temp- time curve on a graph paper. Referencing to fig 3., calculate $T_1$ and $T_2$ and hence write the transfer function of the oven including its driver as
- $G(s)=K \exp(-sT_2)/(1+sT_1)$, with T in $^0$C

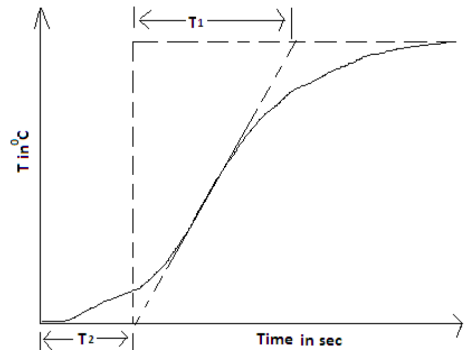

Fig3. Open loop Response of the Oven

**PID Controller Design:**

Ziegler-Nichols suggest the values of $K_P$, $K_D$ and $K_I$ for this controller as

$K_P= (1.2/K) x T1/T_2$; $T_1= (1/K_1) =2T_2$, giving $K_1= (1/2T_2)$

$K_D=T_D=0.5T_2$

- Starting with a cool oven, keep switch S1 to WAIT position and connect P, D and I outputs to driver input. Keep R output disconnected. Short feedback terminals.
- Set P, I and D potentiometer according to the above calculated values of $K_P$, $K_I$ and $K_D$ keeping in mind that the maximum values for theses are 20, 0.024 and 23.5 respectively.
- Select and set the desired temperature, say 60 0C.
- Switch S1 to RUN, and record temperature-time readings.
- Plot the response on a linear graph paper and observe the rise time, steady state error and percent overshoot. Fig 4.

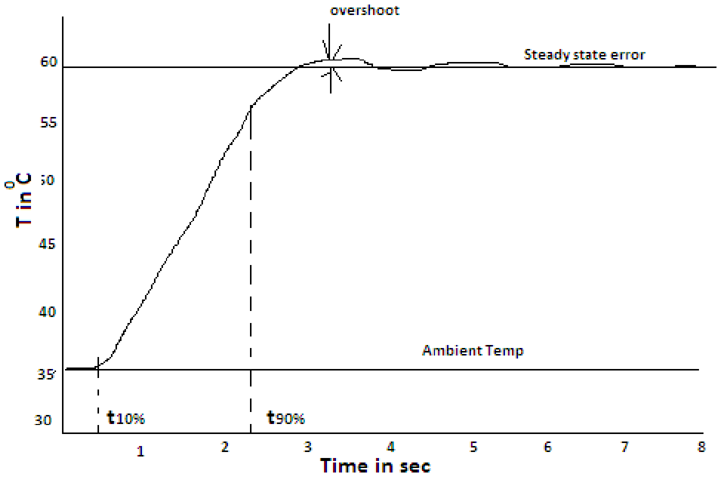

Fig4. Response with PID controller (Set temp=60 $^0$C)

## Observation Table:

## RESULT:

## Precaution: