Issue 9 vol 3 ISSN: 2321-8134

IJFEAT

INTERNATIONAL JOURNAL FOR ENGINEERING APPLICATIONS AND TECHNOLOGY

DESIGNING OF TEMPERATURE CONTROLLED WATER BATH

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Abstract

The proposed paper gives information about designing of temperature controlled water bath using thermostat. The paper focuses on understanding of the working principle of temperature sensor i.e. thermostat, interfacing with power supply and water heater and overall system characterization. The system requires following components: thermostat, water bath, heater coil, supply wire and indicator (light). The thermostat senses the temperature of water bath and make and breakits contact by setting the temperature setpoint. The contact of thermostat is used to switch on/off water heater to control temperature in waterbath. An indicator is used to indicate the water heaterson/off state and we should take precaution according to that. Experimentation is carried out for various temperature values between range of 30°C to 80°C and the system is characterized for temperature control. The system is calibrated by using thermometer as a standard temperature sensor. As per the characteristics of the system is concerned, it provides good linearity, acceptable error percentage and also less settling time subject to the substance that we are introducing in the water bath. The device is the basic model which can be extended for different water bath container like metal container and big size container. This device can be used in domestic; laboratory purpose as well as the expanded form of water bath can be used in industries. The introduced device is currently used in my college laboratory for experimentation and practical performance by undergraduate students.The detailed overview on components, construction, working, precautions, experimentation, characteristics and applications, are explained.

Keyword*: Thermostat, waterbath, temperature control, water heater, system characterization.*

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1. Introduction

Water bath is a temperature controlled equipment in which the liquid is heated and incubate at a constant temperature over a long period of time. All water baths have a digital or an analogue interface to allow users to set a desired temperature. Utilizations include warming of reagents, melting of substrates or incubation of cell cultures. It is also used to enable certain chemical reactions to occur at high temperature. Water bath is a preferred heat source for heating flammable chemicals instead of an open flame to prevent ignition.

A proposed system is a temperature controlled water bath using thermostat. It is an equipment made up of a container filled with normal liquid state sample, the temperature is sensed by using temperature sensor called thermostat and controlled by switch on/off of water heater. The system is used to incubate liquid samples at a constant temperature over a long period of time. The purposed system doesn't include any signal conditioning or any processing. System is build upon mechanical construction and interfacing of components with each other. It can be used up to 99.9 °C. When temperature is above 100°C, alternative methods are used.

2. Methodology

The equipment used in laboratory for incubating the liquid at constant temperature is costly, and also difficult to carry. Sowe design a system which controls the temperature in the water bath. It has analog user interface by which we can set a particular temperature between the ranges of the device and make the temperature constant inside the water bath at that particular set point. If the temperature falls below the set point the water heater will automatically switch on and heat the sample up to the set point. As the temperature increases more than the set point the heater will automatically switch off.

To build the proposed system we use following components:-

A. Water bath
B. Thermostat
C. Water heater
D. Indicator
E. Connecting wires

The brief information of components we used is given as.

A. Water bath

It is a simple container, of any shape (circular, square etc.) which is used for holding the liquid sample. Assembly is fixed on that container so it must be enough strong to bear load of all other components. And also resist in the temperature range and not rupture. Here we use a plastic jug which fulfills all the requirement.

B. Thermostat

We used a temperature sensor thermostat which is used any many appliances such as refrigerator, oven, iron etc. to sense the temperature. It works on AC and DC both power supplies.

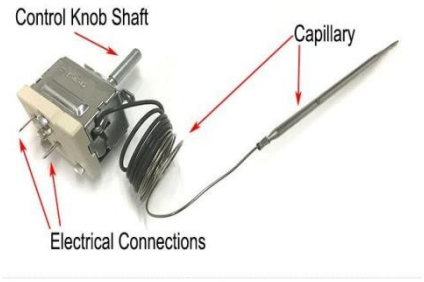

Fig- 1:- Thermostat

Thermostat is an unsophisticated simple electro mechanical switch, which consist of a capillary, control knob and having electrical connection coming outside from it as shown in fig-1.

1. Capillary is the sensing part of the device which is filled with a gas.
2. Control knob is used to adjust the required heating or cooling temperature
3. Electrical connections are the outputs of thermostat which are further used for various purposes like signal conditioning / processing etc.

C. Water-heater

We use a water heater to heat liquid placed into the water bath. Make sure that heater is dipped inside the liquid before switch on the supply.

D. Indicator

We use indicator which indicates the state of water heater. If heater is on the light will glow and if not then light will not glow.

E. Supply wire.

Normal copper wires are use for connection.

2.1Construction

In the proposed system we do mechanical construction, we use water jug as a water bath. Thermostat is fixed over the water bath such as control knob is facing out of the bath and the sensing part i.e. capillary tube is extended and dipped down into the liquid present in water bath. Water heater is placed inside the water bath, ensure that the heater coil is not making any contact with plastic jug and the capillary of the thermostat. The indicator is placed over a water bath to indicate heater is on/off. If heater is on indicating light glows and else not. Also we use proper insulating material to avoid shocks. The device is small and easily portable it can be just fitted into our luggage bag. The construction of the system is going to be clearer from fig-2.

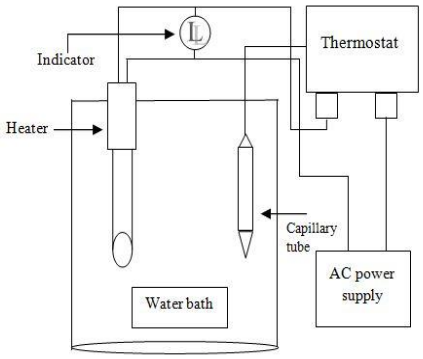

Fig-2:- Construction Diagram

2.2 Precautions

The whole system is working on AC power supply so we have to take some precaution while designing and handling this system.

- Make sure that each and every connections are properly insulated
- The heater is supported by insulated material and not making any contact with water bath as well as capillary.
- The capillary contains gas so tube will not get damage to avoid leakage of gas
- Do not touch the heater and water inside the water bath while power is on, switch off the system first

2.3 Developed System

Fig-3 :- Temperature Controlled Water Bath

2.4 Working

The propose system work on AC power supply. i.e. 230-250V, 50Hz AC power supply. Thermostat is a passive temperature sensor device. Thermostat is unsophisticated simple electro mechanical switch having make and break contact use to regulate the power supply. It has adjustable control knob, the set point can be set by using control knob.

Thermostat has a long capillary tube with a solid bulbous end. The capillary is dipped down into the Water bath to sense the temperature of liquid. Capillary is filled with gas which expands and contracts when temperature inside the bath changes. The gas moves the bellow these makes the two contacts open and close by some mechanical linkage. The contacts of the thermostat are normally close. The opening and closing of the contacts result in turn on and off of the water heater. We are also connecting an indicator for indicating the state of the heater.

In the experimentation of the system, we adjust the set point of the temperature by using control knob of the thermostat, if the sample liquid is at normal temperature it will be start heating up to the set point which will be indicated by the glowing of indicator and after that particular temperature reached the heater will automatically switch off and indicator also stops glowing. The contacts are normally close and as it crosses the set point due to mechanical linkage of bellows with the contacts they will open and breaks the path of the power supply.

3.Experimentation and Results

Experimentation of the proposed system is successfully carried out within range of 30^0c to 80^0c. But system can be applicable for the range of 100^0c. The proposed system is calibrated by using a thermometer as a standard temperature measurement sensor.The system is characterized for temperature control. Various static characteristics of temperature control system are defined by the characterization of the system

3.1 Static characteristics

We do the calibration using a thermometer for calculating the percentage error of the system also it tells us about the accuracy of the system. To calibrate the device we pour normal water into the bath, and thenwe set the different temperature set point on the thermostat and continuously monitor the temperature of the sample using thermometer and observe the results.

Error can be calculated by subtracting the temperature reading by thermometer after heating from the set point temperature.

$$\text{Error}(\%) = \left|\frac{\text{set point} - \text{thermometer temp.}}{set\ point}\right| \times 100$$

Set point	Thermometer Temperature (after heating)	Error (in %)
40^0	40^0	0%
60^0	61^0	1.6%
80^0	79^0	1.25%

Across all temperature range, linear relationship between actual temperature of waterbath and setpoint temperature is observed as shown in figure 4.

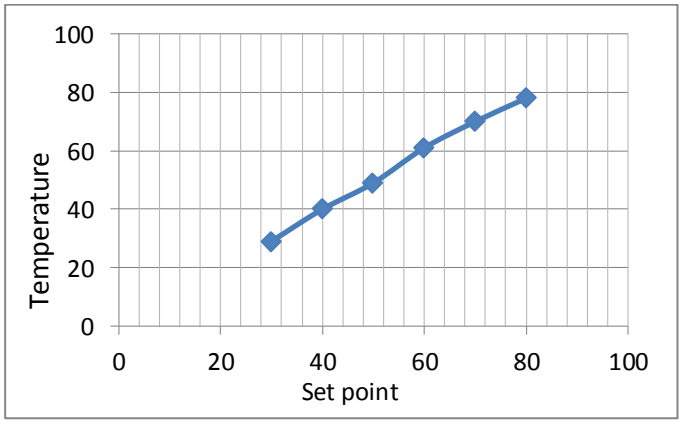

Fig-4:- Relation between actual temperature of water bath and set point temperature

The figure indicates mean error of 0.66 with maximum non-linearityof 4%.

3.2 Dynamic characteristics

3.2.1 Settling time

The time required by the system to reach up to its steady state condition is called the settling time of that system.The settling time of system is the time elapsed from the application of an ideal instantaneous step input to the time at which the system output has entered and remained within a specified error band.At the time of experimentation we measure the time required by the system to reach up to its set point temperature. We calculate the normalized temperature by using following formula.

$$\text{Normalized temperature:-}\ \frac{X-Xmin}{Xmax-Xmin}$$

Normalized settling time is calculated and recorded into the table 1.

Temperature (x)	Normalized temperature	Normalized settling time (in min)
50^0	0.4	5.85
70^0	0.8	6.25
80^0	1	6.00

Table-1:- Normalized settling time

3.2.2 Time constant

Time constant is the time for the system's step response to reach 63.2% of its final (asymptotic) value as shown in fig-4. The final value of experimentation is 80^0c so time constant is calculated at 50.56^0c. The time constant represents the elapsed time required for the system response to decay to zero.

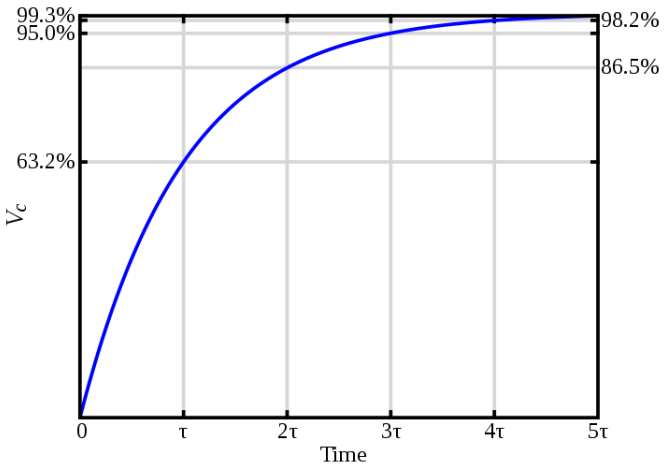

Fig- 4: – Time Constant

The time required to reach up to 50.56^0 c temperature is 2.34 min. which is the time constant of the system.

4. Applications

There is lots of application of temperature controlled system in daily life and in industries.

1. We can use the water bath for heating water upto particular degree temperature and make the water temperature constant at that particular temperature.
2. We can use it to boil water, milk, egg as an electrical cattle.
3. In home application we can use this system in oven , refrigerator , iron etc for making automatic control over that appliances
4. In industries to control boiler temperature we can use this system by making it more accurate and relevant
5. It is also used to enable certain chemical reactions to occur at constant temperature.

5. Conclusion

We successfully design a temperature controlled water bath usingthermostat. The system is giving acceptable error of only 0-3%. The proposed system has accuracy of 4% and mean error of 0.83. Normalized settling time is calculated and it observed that the system requires less settling time to reach the final steady state value.The proposed system is low cost, portable and easy to handle.

6. Acknowledgement

I specially thanks to my guide Mr. Pauroosh Kaushal for their valuable guidance and support in the successful implementation of this proposed work.

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