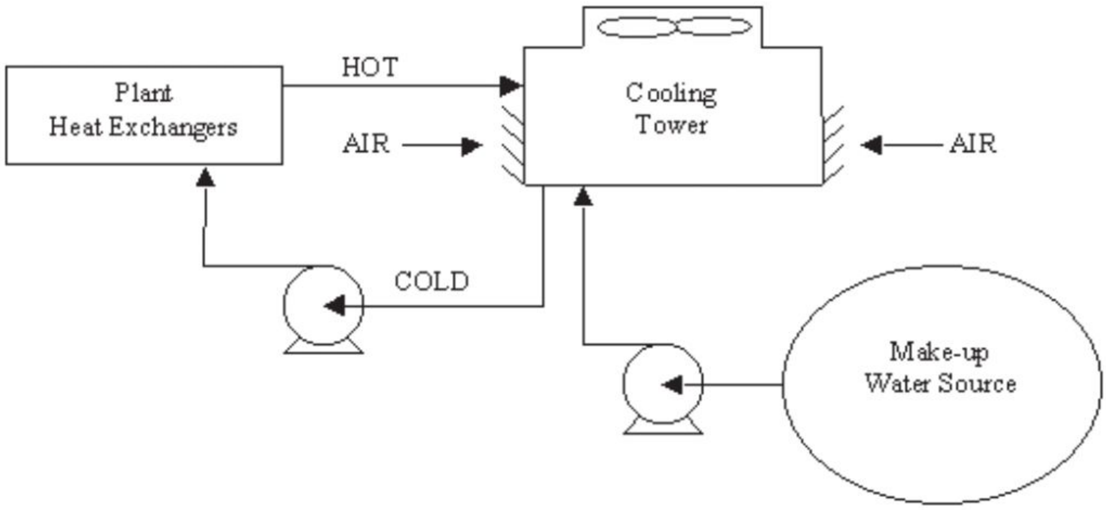
COOLING TOWER EXPERIMENT

1.Introduction :

Cooling towers are a very important part of many chemical plants. The primary task of a cooling tower is to reject heat into the atmosphere. They represent a relatively inexpensive and dependable means of removing low-grade heat from cooling water. The make-up water source is used to replenish water lost to evaporation. Hot water from heat exchangers is sent to the cooling tower. The water exits the cooling tower and is sent back to the exchangers or to other units for further cooling. Typical closed loop cooling tower system is shown in Figure (1).



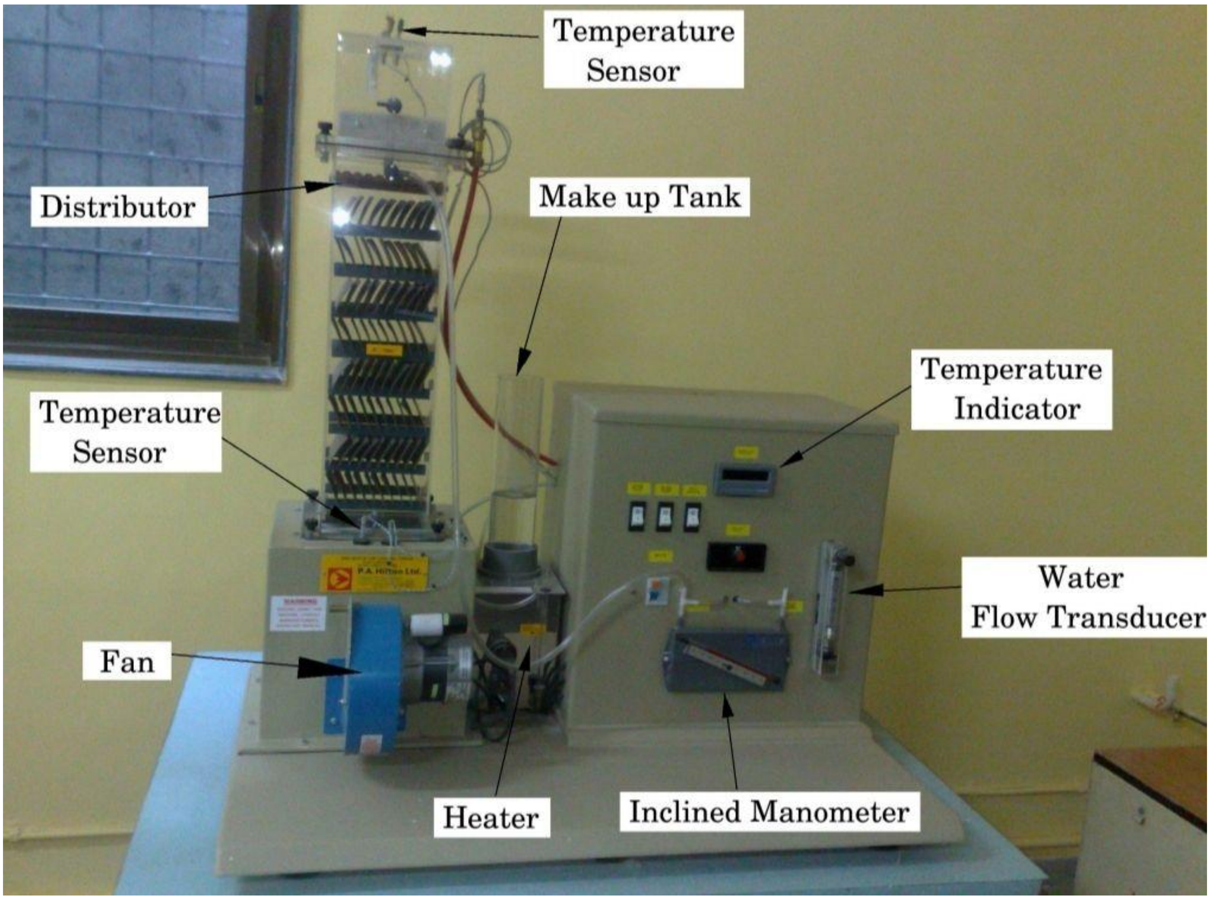
A cooling tower is a specialized heat exchanger in which air and water are brought into direct contact with each other in order to reduce the water's temperature. As this occurs, a small volume of water is evaporated, reducing the temperature of the water being circulated through the tower. Water, which has been heated by an industrial process or in an air-conditioning condenser, is pumped to the cooling tower through pipes. The water sprays through nozzles onto banks of material called "fill," which slows the flow of water through the cooling tower, and exposes as much water surface area as possible for maximum air-water contact. As the water flows through the cooling tower, it is exposed to air, which is being pulled through the tower by the electric motor-driven fan. In our experiment, we use the same principle but with a different design as be seen in Figure (2). The experimental apparatus consists from:

All components are mounted on a robust G.R.P. base plate with integral instrument panel. Components include:

- Air distribution chamber.
- A tank with heaters to simulate cooling loads of 0.5, 1.0 and 1.5kW.
- A make-up tank with gauge mark and float operated control valve. (iv) A centrifugal fan with intake damper to give 0.06kg s^{1}◌◌ max. air flow.
- A bronze and stainless steel glandless pump.
- A water collecting basin.
- An electrical control panel.

Packed Column : Four packed columns (A, B, C and D), each 150mm x 150mm x 600mm high, and fabricated from clear P.V.C., are available.Columns A, B and C have pressure tapping points and each contain eight decks of inclined, wettable, laminated plastic plates, retained by water distribution troughs.

- Column A has 7 plates per deck (giving 77m² per m³)
- Column B has 10 plates per deck (giving 110m² per m³)
- Column C has 18 plates per deck (giving 200m² per m³)
- Column D has no packings.



2. AIM: To simulate an industrial cooling tower and study its performance based on

- The cooling load
- Approach to wet bulb

3.Description :

The Bench Top Cooling Tower behaves in a similar manner and has similar components to a full size cooling tower and may be used to introduce students to their characteristics and construction. Water Circuit: Warm water is pumped from the load tank through the control valve and water flow meter to the column cap. After its' temperature is measured (t5), the water is uniformly distributed over the top packing deck and, as it spreads over the plates, a large thin film of water is exposed to the air stream. During its downward passage through the packing, the water is cooled, largely by the evaporation of a small portion of the total flow. The cooled water falls from the lowest packing deck into the basin, where its temperature (t6) is again measured and then passes into the load tank where it is re-heated before re-circulation. Due to evaporation, the level of the water in the load tank tends to fall. This causes the float operated needle valve to open and transfer water from the make-up tank into the load tank. Under steady conditions, the rate at which the water leaves the make-up tank is equal to the rate of evaporation plus any small airborne droplets in the air discharge. Air Circuit : Air from the atmosphere(with temperature t7), enters the fan at a rate which is controlled by the intake damper setting. The fan discharges into the distribution chamber and the air passes wet and dry bulb sensors (which measure the temperature t2 and t1 respectively) before entering the packed column. As the air flows through the packings, its' moisture content increases and the water is cooled. On leaving the top of the column the air passes through the droplet arrester, which traps most of the entrained droplets and returns them to the packings. The air is then discharged to the atmosphere via the air measuring orifice and further wet and dry bulb sensors (which measure the temperature t4 and t3 respectively). Droplets of water (resulting from splashing, etc.) may become entrained in the air stream and then lost from the system. This loss does not contribute to the cooling, but must be made good by "make-up" water. To minimize this loss, a "droplet arrester", or "eliminator" is fitted at the tower outlet. This component causes droplets to coalesce, forming drops which are too large to be entrained and these fall back into the packings. Under the action of the fan, air is driven upward through the wet packings. It will be seen that the change of dry bulb temperature is smaller than the change of wet bulb temperature, and that at air outlet there is little difference between wet and dry bulb temperatures. This indicates that the air leaving is almost saturated, i.e. Relative Humidity - 100%. This increase in the moisture content of the air is due to the conversion of water into steam and the "latent heat" for this accounts for most of the cooling effect. If the cooling load is now switched off and the unit allowed to stabilise, it will be found that the water will leave the basin close to the wet bulb temperature of the air entering. According to the local atmospheric conditions, this can be several degrees below the incoming air (dry bulb) temperature. With no load, the water would be cooled to the incoming wet bulb temperature, but this condition cannot be attained since the pump transfers about 100W to the water. Flow through the column may be observed through the transparent casing. Three sets of different packings, each in its own casing, are available. These may be interchanged quickly and without using tools. Water is heated using a 1kW and/or 0.5kW electric heater.

4.Procedure :

The Bench Top Cooling Tower should be prepared, started and allowed to stabilize under the following suggested conditions: Orifice differential 16 mm H2O Water flow rate 40 gm s ^{1} Cooling load 0 kW (Note: Stability is reached when there is no further appreciable change in temperature, or flow rate). At regular intervals over a measured period of say 10 minutes, all temperatures and flow rates should be noted and the mean values entered on the observation sheet. At the commencement of this period, fill the make-up tank to the gauge mark with distilled water. At the end of this period, refill the tank from a known quantity of distilled water in a measuring cylinder. By difference, determine the quantity of make up which has been supplied in the time interval. While keeping the water and air flows constant, the load should be increased to 0.5 kW, and when conditions have stabilised, the observations should be repeated. Similar tests should be made with cooling loads of 1.0 and 1.5 kW.

5. Calculations:

Using the wet and dry bulb temperatures, points A and B may be plotted on the psychrometric chart, and the following values read off:

h_A= /kg

h_B= /kg

ω_B= /kg

υ_{aB}= m 3 /kg of dry air

$$\dot{m}_a = 0.0137\sqrt{\frac{x}{(1+\omega_B)v_{aB}}}$$

m_E = m_E / y

Specific Enthalpy of make-up, (hf at room temp °C) h_E =

Applying the Steady Flow Equation to the system indicated by the Boundary

$$\dot{Q} - P = \Delta H + \Delta KE$$

$$\dot{Q} - P = 1.0 - (-0.01) \text{ kW}$$

$$= 1.1 \text{ kW}$$

(Pump power is approximately 100W, negative)

$$\Delta \dot{H} = \dot{H}_{Exit} - \dot{H}_{Entry}$$

$$= \dot{m}_a h_B - \dot{m}_a h_A - \dot{m}_E h_E$$

$$= \dot{m}_a (h_B - h_A) - \dot{m}_E h_E$$

- Mass Balance

$$\dot{m}_E = \dot{m}_{steamB} - \dot{m}_{steamA}$$

$$= \dot{m}_a (\omega_B - \omega_A)$$

Calculations for ‘Approach to Wet Bulb’ and ‘Cooling Range’

The pump transfers approximately 100W to the water, and this should be added to the load imposed in the load tank.

Total cooling load = Applied load + Pump input

= 1.0 + 0.1 kW

= 1.1 kW

Approach to Wet Bulb = t6 – t2

Cooling Range = t5 – t6

6. Discussion :

What are cooling tower do?

Where cooling tower used?

What are factors that affect the efficiency of acooling tower?