UNIT – V: Psychrometric Property and Processes

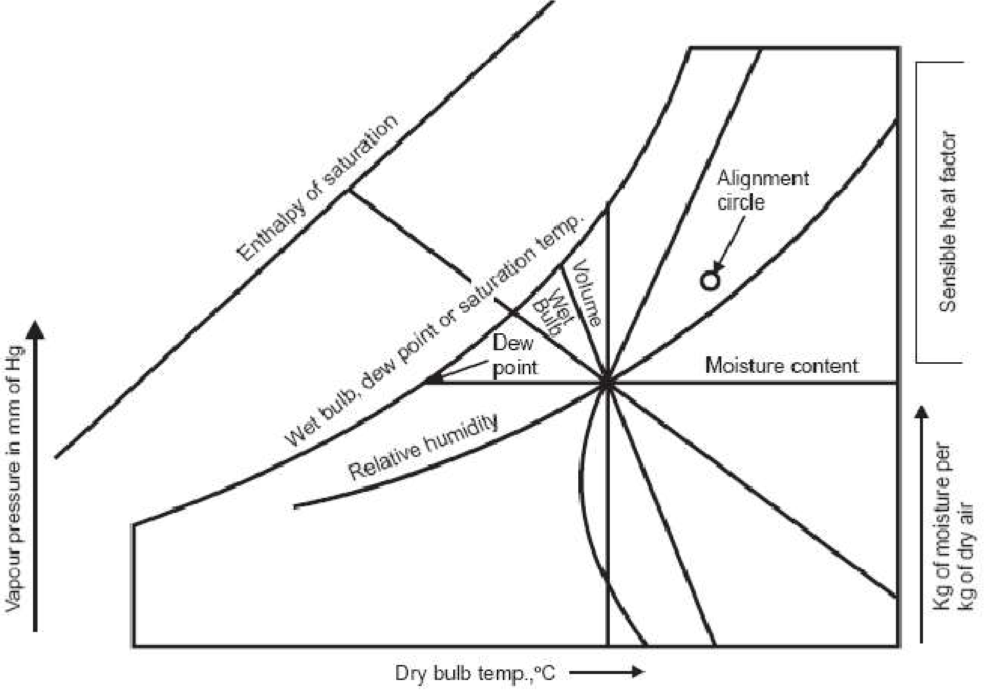
Introduction to Air Conditioning :

PSYCHROMETRIC CHARTS

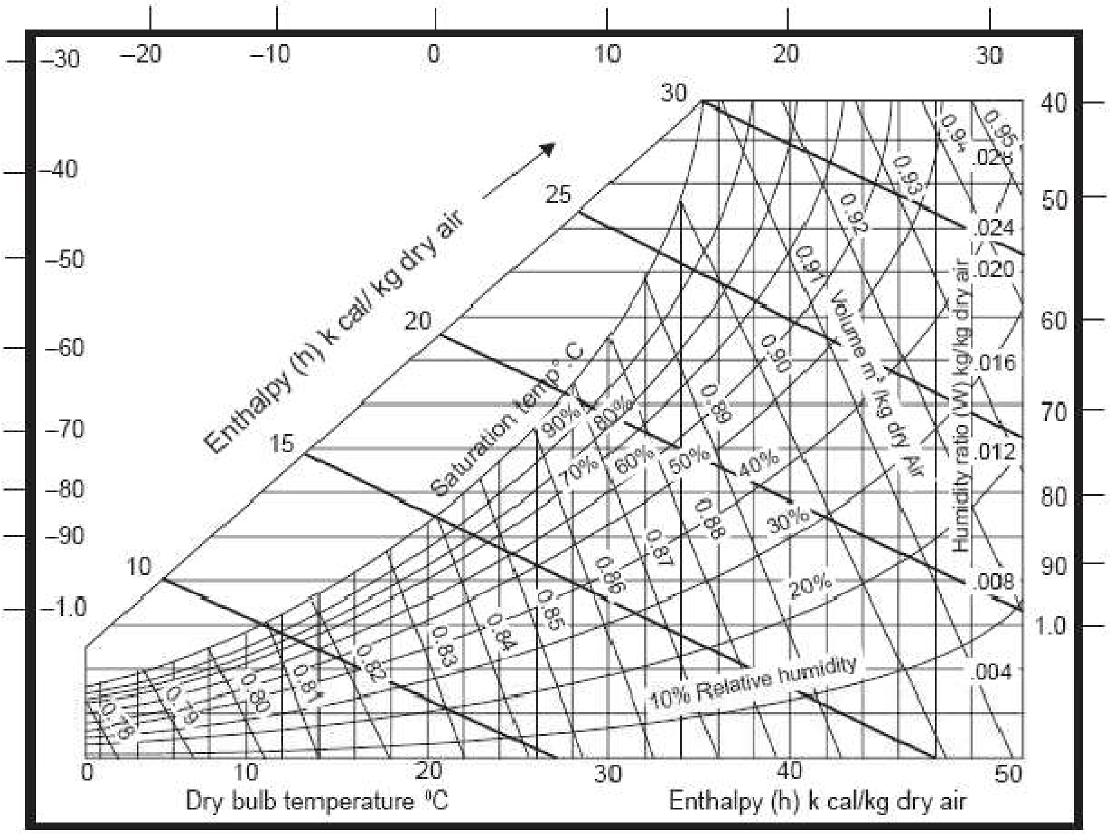
The psychrometric charts are prepared to represent graphically all the necessary moist air properties used for air conditioning calculations. The values are based on actual measurements verified for thermodynamic consistency.

For psychrometric charts the most convenient co-ordinates are dry bulb temperature of air vapour mixture as the abscissa and moisture content (kg/kg of dry air) or water vapour pressure as the ordinate. Depending upon whether the humidity contents is abscissa or ordinate with temperature co-ordinate, the charts are generally classified as Mollier chart and Carrier chart. Carrier chart having t_{db} as the abscissa and W as the ordinate finds a wide application. The chart is constructed as under :

1. **The dry bulb temperature (°C)** of unit mass of dry air for different humidity contents or humidity ratios are indicated by vertical lines drawn parallel to the ordinate.
2. **The mass of water vapour in kg** (or grams) per kg of dry air is drawn parallel to the abcissa for different values of dry bulb temperature. It is the major vertical scale of the chart.
3. **Pressure of water vapour** in mm of mercury is shown in the scale at left and is the absolute pressure of steam.
4. **Dew point temperatures** are temperatures corresponding to the boiling points of water at low pressures of water vapour and are shown in the scale on the upper curved line. The dew points for different low pressures are read on diagonal co-ordinates



5. **Constant relative humidity lines** in per cent are indicated by marking off vertical distances between the saturation line or the upper curved line and the base of the chart. The relative humidity curve depicts quantity (kg) of moisture actually present in the air as a percentage of the total amount possible at various dry bulb temperatures and masses of vapour.
6. **Enthalpy or total heat** at saturation temperature in kJ/kg of dry air is shown by a diagonal system of co-ordinates. The scale on the diagonal line is separate from the body of the chart and is indicated above the saturation line.
7. **Wet bulb temperatures** are shown on the diagonal co-ordinates coinciding with heat coordinates. The scale of wet bulb temperatures is shown on the saturation curve. The diagonals run downwards to the right at an angle of 30° to the horizontal.



8. The volume of air vapour mixture per kg of dry air **(specific volume)** is also indicated by a set of diagonal co-ordinates but at an angle of 60º with the horizontal. The other properties of air vapour mixtures can be determined by using formulae (already discussed). In relation to the psychrometric chart, these terms can quickly indicate many things about the condition of air, for example :

If dry bulb and wet bulb temperatures are known, the relative humidity can be read from the chart. If the dry bulb and relative humidity are known, the wet bulb temperature can be determined. If wet bulb temperature and relative humidity are known, the dry bulb temperature can be found.

PSYCHROMETRIC PROCESSES

In order to condition air to the conditions of human comfort or of the optimum control of an industrial process required, certain processes are to be carried out on the outside air available. The processes affecting the psychrometric properties of air are called **psychrometric processes.**

These processes involve mixing of air streams, heating, cooling, humidifying, dehumidifying, adiabatic saturation and mostly the combinations of these.

The important psychrometric processes are enumerated and explained in the following text :

1. Sensible heating
2. Sensible cooling
3. Cooling and dehumidification
4. Cooling and humidification
5. Heating and dehumidification
6. Heating and humidification.
7. Mixing of air streams

Sensible Heating

When air passes over a dry surface which is at a temperature greater than its (air) dry bulb temperature, it undergoes sensible heating. Thus the heating can be achieved by passing the air over heating coil like electric resistance heating coils or steam coils. During such a process, the specific humidity remains constant but the dry bulb temperature rises and approaches that of the surface.

The extent to which it approaches the mean effective surface temperature of the coil is conveniently expressed in terms of the equivalent **by-pass factor.**

The by-pass factor (BF) for the process is defined as the ratio of the difference between the mean surface temperature of the coil and leaving air temperature to the difference between the mean surface temperature and the entering air temperature. Thus on Fig. 10.8, air at temperature t_{db1}, passes over a heating coil with an average surface temperature t_{db3} and leaves at temperature t_{db2} .

The by-pass factor is expressed as follows : $BF = \frac{t_{d3}-t_{d2}}{t_{d3}-t_{d1}}$

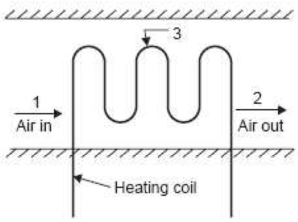


Fig. 10.8. Sensible heating.

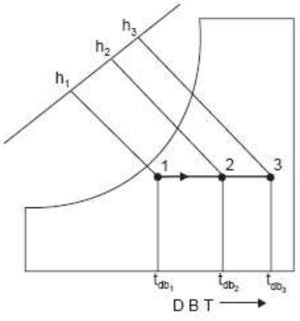


Fig. 10.9

Or in terms of lengths on the chart (Fig. 10.9) it is $\frac{length\ 2-3}{length 1-3}$

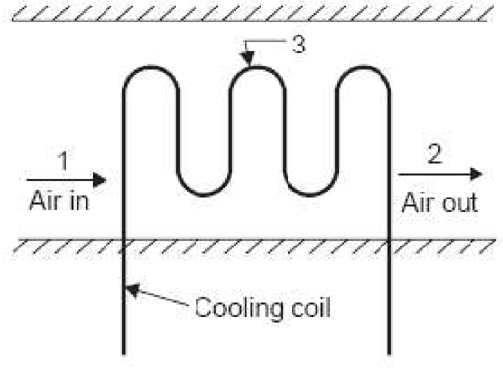
The value of the by-pass factor is a function of coil design and velocity. The heat added to the air can be obtained directly from the entering and leaving enthalpies ($h_2 - h_1$) or it can be obtained from the humid specific heat multiplied by the temperature difference ($t_{db2} - t_{db1}$).

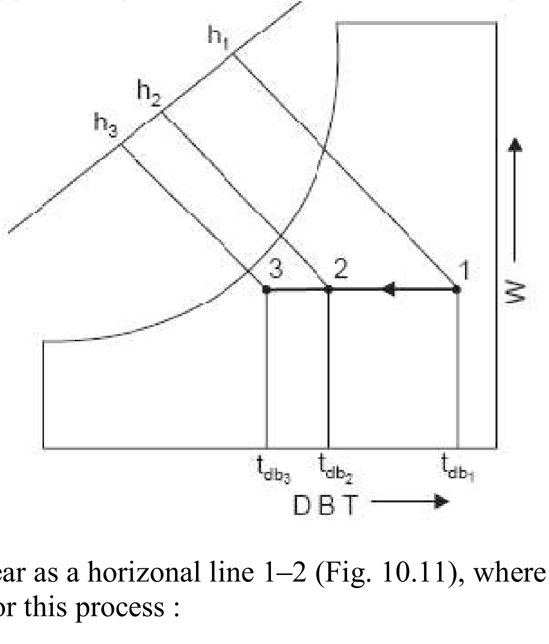
In a complete air conditioning system the preheating and reheating of air are among the familiar examples of sensible heating.

'By-pass factor' can be considered to represent the fraction of air which does not come into contact with coil surface.

Sensible Cooling

Refer Fig. Air undergoes sensible cooling whenever it passes over a surface that is at a temperature less than the dry bulb temperature of the air but greater than the dew point temperature. Thus sensible cooling can be achieved by passing the air over cooling coil like evaporating coil of the refrigeration cycle or secondary brine coil. During the process, the specific humidity remains constant and dry bulb temperature decreases, approaching the mean effective surface temperature.





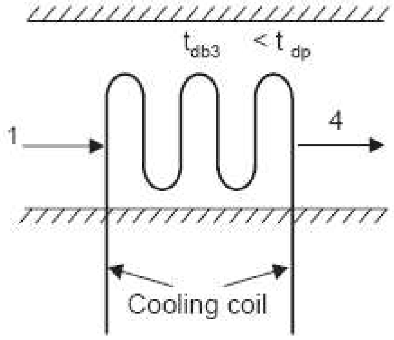
On a psychrometric chart the process will appear as a horizonal line 1–2 (Fig. 10.11), where point 3 represents the effective surface temperature. For this process :

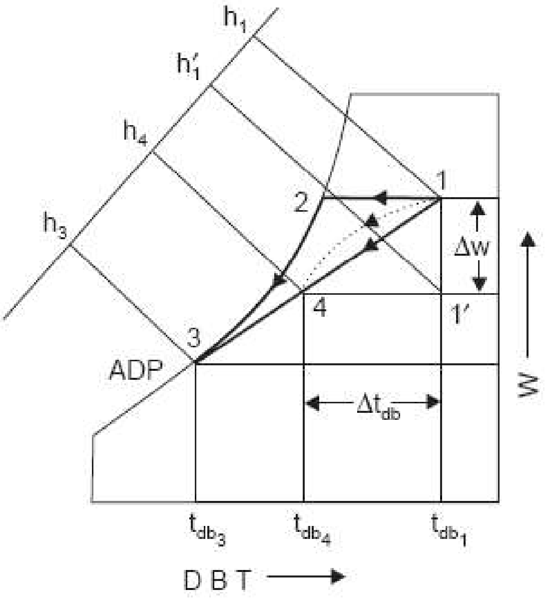
By-pass factor BF $= \frac{t_{d2}-t_{d3}}{t_{d1}-t_{d3}}$

The heat removed from air can be obtained from the enthalpy difference ($h1 - h2$) or from humid specific heat multiplied by the temperature difference (t_{d1} -- t_{d2}) .

Cooling and Dehumidification

Refer Figure Whenever air is made to pass over a surface or through a spray of water that is at a temperature less than the dew point temperature of the air, condensation of some of the water vapour in air will occur simultaneously with the sensible cooling process. Any air that Cooling and dehumidification.





comes into sufficient contact with the cooling surface will be reduced in temperature to the mean surface temperature along a path such as 1-2-3 in Fig. 10.12, with condensation and therefore dehumidification occurring between points 2 and 3. The air that does not contact the surface will be finally cooled by mixing with the portion that did, and the final state point will somewhere on the straight line connecting points 1 and 3. The actual path of air during the path will not be straight line shown but will be something similarly to the curved dashed line 1–4. It from a continuous mixing of air which is connecting a particular part of the coil and air which is by passing it. It is convenient, however to analyse the problem with the straight line shown, and to assume that the final air state results from the mixing of air that has completely by passed the coil with air that has been cooled to the mean effective surface temperature. If there is enough contact between air and surface for all the air to come to the mean surface temperature, the process is one of zero by pass. In any practical system, complete saturation is not obtained and final state will be a point such as 4 in Figure with an equivalent by pass factor equal to is $\frac{length\ 2-3}{length 1-3}$

For processes
involving condensation, the effective surface temperature, *e.g.* *tdb*3 in Figure is called '**apparatus dew point**' (ADP). The final state point of air passing through a cooling and dehumidifying apparatus is in effect a mixture condition that results from mixing the fraction of the air, which is equal to the equivalent by-pass factor (BF) and is at initial state point and the remaining fraction which is equal to one minus by pass factor (1–BF) and is saturated at the apparatus dew point (ADP).

Total heat removed from the air is given by Qt $= h_1 - h_4$

$= (h_1 - h_{1'}) + (h_{1'} - h_4)$

$= Q_L + Q_S$

where, Q_L = Latent heat removed $(h1 - h1')$, and

Q_S = Sensible heat removed $(h1' - h4)$

The ratio Q_L/Q_S is called sensible heat factor (SHF) Orsensible heat ratio (SHR)

$\therefore$ SHF $= \frac{Q_S}{Q_S + Q_L}$

The ratio fixes the slope of the line 1—4 on the psychrometric chart. Sensible heat factor slope lines are given on the psychrometric chart. If the initial condition and SHF are known for the given process, then the process line can be drawn through the given initial condition at a slope given by SHF on the psychrometric chart.

The capacity of the cooling coil in *tonnes* of refrigeration is given by,

$$\text{Capacity in TR} = \frac{m_a(h_2 - h_1) \times 60}{14000},$$

where m_a = mass of air, kg/min and h = enthalpy in kJ/kg of air.

Heating and Dehumidification

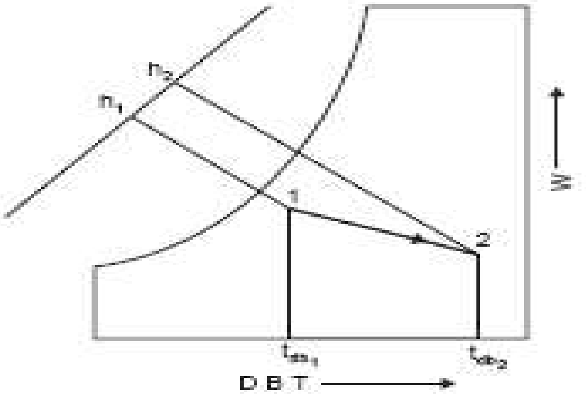


Fig. 10.14. Heating and dehumidification.

If air is passed over a solid absorbent surface or through a liquid absorbent spray simultaneous heating and dehumidification is accompanied. In either case the dehumidification results from adsorbent or absorbent having a lower water vapour pressure than air. Moisture is condensed out of the air, and consequently the latent heat of condensation is liberated, causing sensible heating of air. If these were the only energies involved, the process would be the inverse of the adiabatic saturation process. There is, however, an additional energy absorbed or liberated by the active material, termed the heat of adsorption or absorption.

For the solid adsorbents used commercially, such as silica gel or activated alumina, and for the more common liquid absorbents, such as solutions of organic salts or inorganic compounds like ethylene, glycol, heat is involved and results in additional sensible heating. Thus the path lies above a constant wet bulb line on the psychrometric chart such as path 1-2 in Fig.

Heating and Humidification

If air is passed through a humidifier which has heated water sprays instead of simply re-circulated spray, the air is humidified and may be heated, cooled or unchanged in temperature. In such a process the air increases in specific humidity and the enthalpy, and the dry bulb temperature will increase or decrease according to the initial temperature of the air and that of the spray. If sufficient water is supplied relative to the mass flow of air, the air will approach saturation at water temperature. Examples of such processes are shown on Fig.

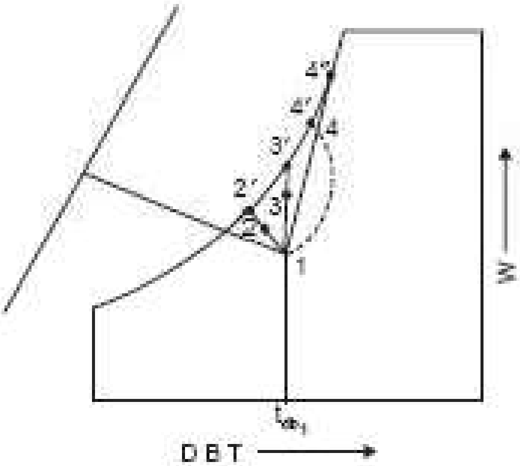


Fig. 10.15. Heating and humidification.

Process 1-2 : It denotes the cases in which the temperature of the heated spray water is less than the air DBT.

Process 1-3 : It denotes the cases in which the temperature is equal to the air DBT.

Process 1-4 : It denotes the cases in which a spray temperature is greater than air DBT.

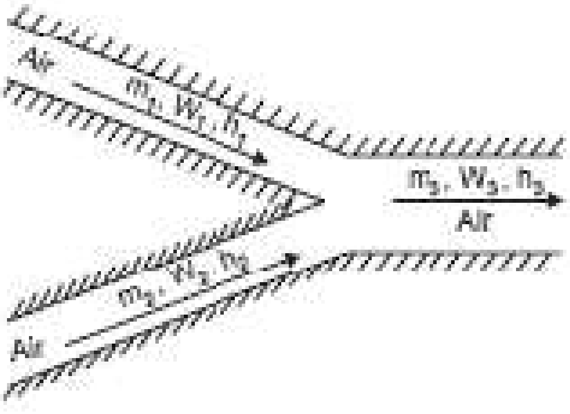
As in the case of adiabatic saturation, the degree to which the process approaches saturation can be expressed in terms of the by-pass factor or a saturating efficiency.

If the water rate relative to the air quantity is smaller, the water temperature will drop significantly during the process. The resultant process will be a curved line such as the dashed 1-4 where 4 represents the leaving water temperature.

Note. It is possible to accomplish heating and humidification by evaporation from an open pan of heated water, or by direct injection of heated water or steam. The latter is more common. The process line for it is of little value because the process is essentially an instantaneous mixing of steam and the air. The final state point of the air can be found, however by making a humidity and enthalpy balance for the process. The solution of such a problem usually involves cut-and-try procedure.

Mixing of Air Streams

Refer Figs. 10.6 and 10.7. Mixing of several air streams is the process which is very frequently used in air conditioning. This mixing normally takes place without the addition or rejection of Air either heat or moisture, i.e., adiabatically and at constant total moisture content. Thus we can write the following equations :

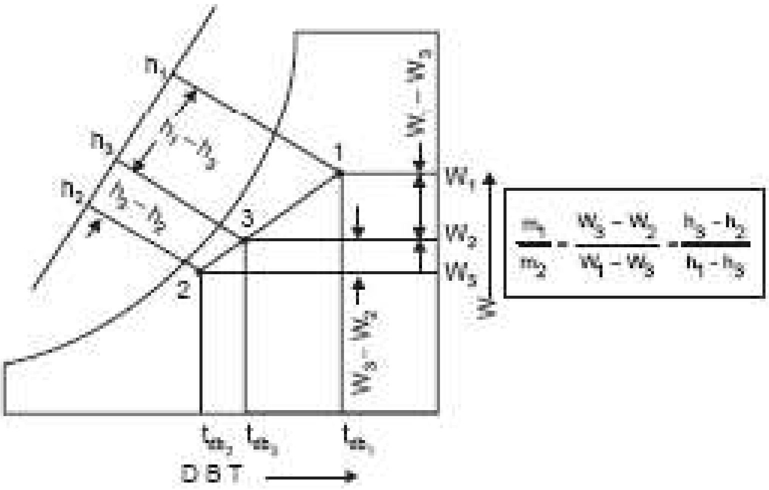


. Mixing of air streams.

$m_1 + m_2 = m_3$

$m_1W_1 + m_2W_2 = m_3W_3$

$m_1h_1 + m_2h_2 = m_3h_3$



Rearranging of last two equations gives the following :

$m_1(W_1 – W_3) = m_2(W_3 – W_2)$

$m_1(h_1 – h_3) = m_2(h_3 – h_2)$

$$\frac{m_1}{m_2} = \frac{W_3-W_2}{W_1-W_2} = \frac{h_3-h_2}{h_1-h_3}$$

Where m = mass of the dry air at particular state points
W = specific humidity
h = specific enthalpy

On the psychrometric chart, the specific humidity and enthalpy scales are linear, ignoring enthalpy deviations. Therefore, the final state 3 lies on a straight line connecting the initial states of the two streams before mixing, and the final state 3 divides this line into two parts that are in the same ratio as were the two masses of air before mixing.

If the air quantities are known in volume instead of mass units, it is generally sufficiently accurate to units of m3 or m3/min. in the mixing equations. The inaccuracy introduced is due to the difference in specific volume at two initial states. This difference in densities is small for most of the comfort air conditioning problems.