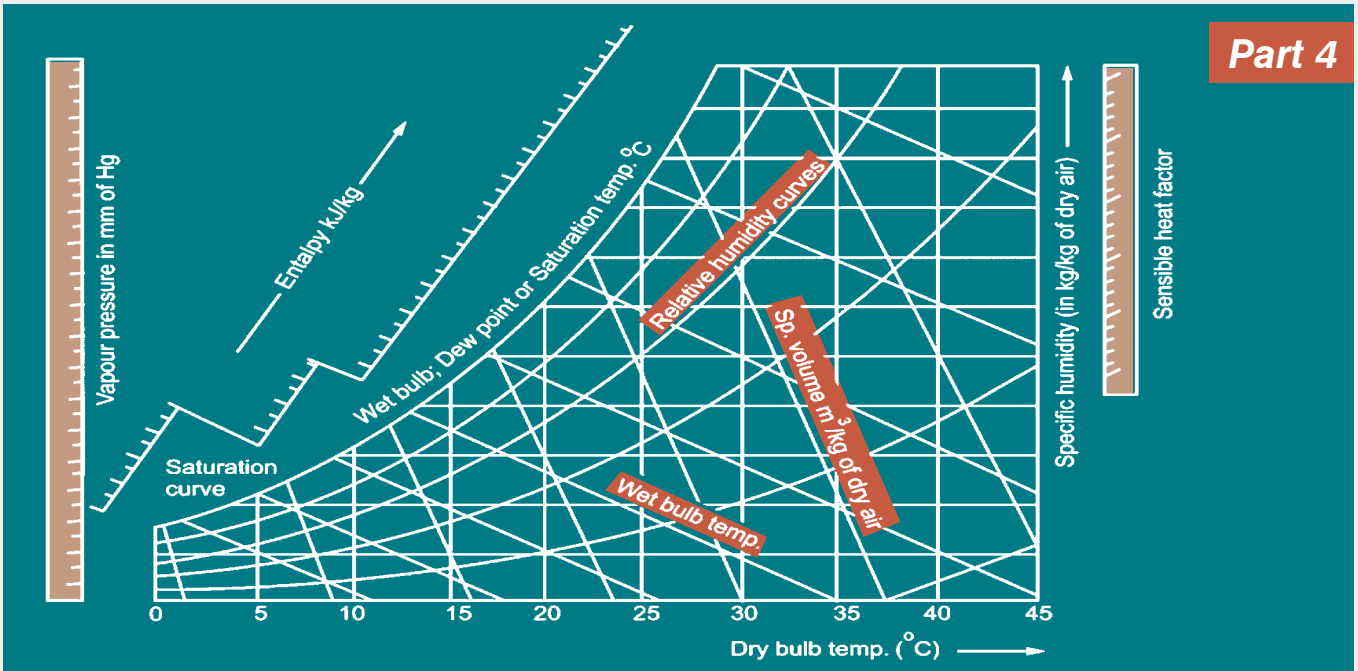

Understanding Psychrometrics

By Ramesh Paranjpey, *Distinguished 50-Year Member, ASHRAE*
Supported by Mukund Ranade, *AC Consultant*

Introduction

In this part, we shall discuss various psychrometric charts as well as the important property lines plotted on the chart. We shall begin with the basic pressure Vs temperature diagram for water.

A pressure-temperature (P-T) phase diagram for water illustrates the conditions under which water exists as a solid (ice), liquid, or gas (vapor). *Figure 1* features vapor region, saturated line, liquid region, liquid vapor equilibrium zone, solid ice region and triple point.

Psychrometric Charts

There are various types of psychrometric charts published by the companies like Carrier, Trane, Heatcraft and many more as well as ASHRAE. We shall produce below three important ones and use our observations based on the Carrier chart.

The credit of developing psychrometric chart goes to Dr Willis H carrier. In the year 1904, he developed a blue print version of psychrometric chart, which is very similar to even today's chart.

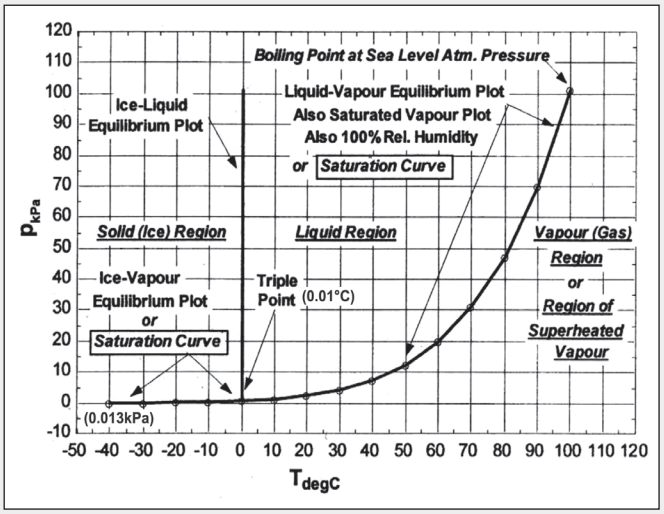

Figure 1: Pressure v/s temperature diagram for water (H_2O)

About the Authors

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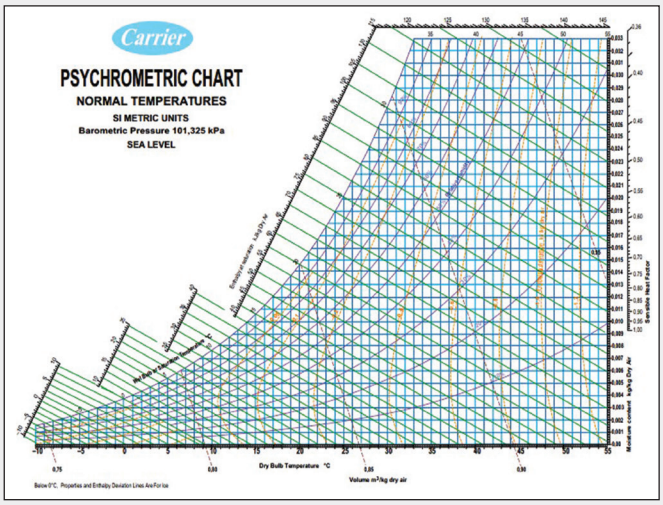

Figure 2: Carrier Psychrometric Chart is a graphical representation of various properties of air-vapor mixture

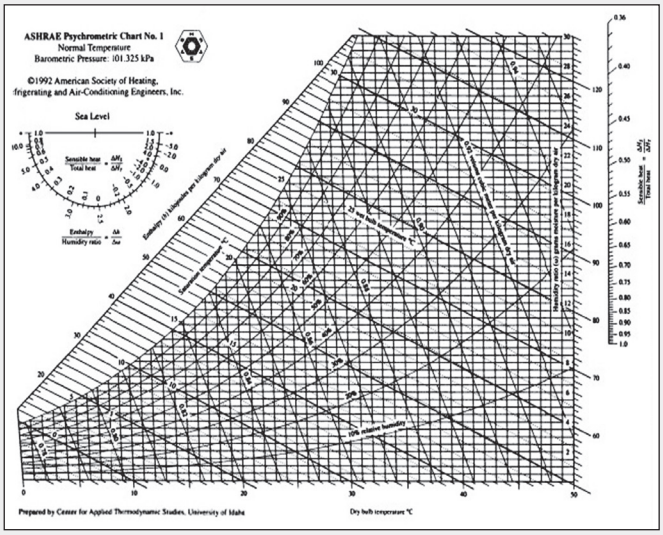

Figure 3: ASHRAE Psychrometric chart shows dry-bulb temperature on X axis and humidity ratio/moisture content on Y axis

Most commonly used charts are Carrier psychrometric chart and ASHRAE psychrometric chart at sea level with normal pressure of 101.325Kpa and normal temperature of 15°C.

The psychrometric chart conceived by Dr. Willis Carrier used dry-bulb temperature and water vapor density as rectangular plotting coordinates. With these coordinates, dry-bulb temperature isolines are all exactly vertical and evenly spaced. The X axis shows dry-bulb temperature and the Y axis shows humidity ratio as moisture content in $g/kg_{da.}$

In the ASHRAE chart, dry-bulb lines shown on the X axis are straight, but not precisely parallel to each other and inclined slightly from the vertical position. The Y axis also shows humidity ratio/moisture content in $g/kg_{da.}$

Wet-bulb temperature lines are oblique and in a slightly different direction from enthalpy lines. They are straight but are not precisely parallel to each other. Specific volume lines are straight

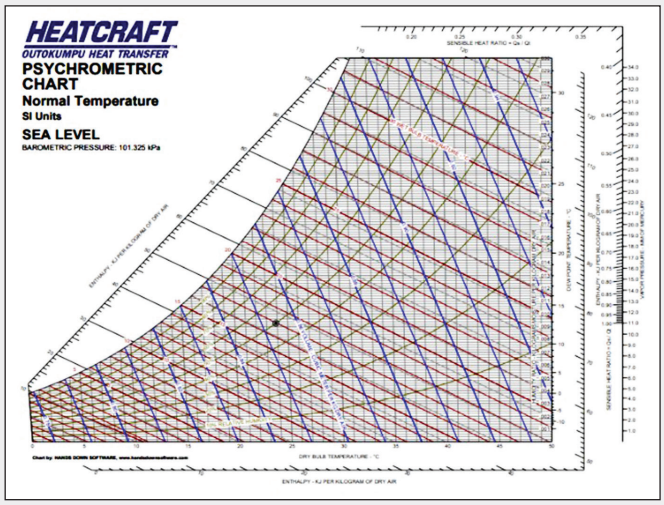

Figure 4: Psychrometric chart showing vapor pressure in mm of mercury on Y axis

but not precisely parallel to each other. A narrow rejoin above the saturation curve has been developed for fog conditions of moist air. The protractor to the left of the chart shows two scales: one for sensible/total heat ratio and one for the ratio of enthalpy difference to humidity ratio difference. The protractor is used to establish the direction of a condition line on the psychrometric chart.

The chart for sea level conditions can be used up to 500-meter level without much difference in calculations. As indicated earlier, Psychrometrics is not arithmetic and variation in calculations up to 3 to 5% are acceptable.

Carrier/ASHRAE has also charts for 750m, 1500m and 2250m altitude.

Carrier/ASHRAE charts are valid for normal ambient temperature up to 55°C/50°C.

Charts are also available for

- For low temperature 40°C to 10°C
- For high temperature 10°C to 120°C
- For very high temperatures 100°C to 200°C.

I am giving above one additional chart, which is slightly different from Carrier or ASHRAE charts as it shows vapor pressure in mm of mercury on Y Axis in addition to humidity ratio $g/kg_{da.}$ We know heat transfer takes place from higher temperature to lower temperature. Temperature is a measurable quantity and easy to understand.

The moisture present in the air is normally in superheated condition and is invisible. As the heat travels from higher temperature to lower temperature region, similarly moisture would also travel from higher vapor pressure to a lower vapor pressure.

The Carrier and ASHRAE charts indicate on Y axis only moisture content in g/kg_{da} of dry air. The heat craft chart in addition to this shows vapor pressure in mm of mercury and hence, it is reproduced *Figure 4*. Vapor pressure difference would indicate how moisture would travel and where the vapor barrier needs to be installed.

As indicated in *Figure 4* there are many psychrometric charts, for various temperatures, elevation levels of the place where we need to use the properties of air and we cannot carry so many charts with us every time.

The psychrometric software developed by many companies, including ASHRAE is, therefore, more convenient, faster way of using it for performing calculations. For making the use of software or excel spreadsheets, it is, however, essential that the person using software is fully aware of psychrometric fundamentals. The effort is, therefore, being made in these articles to understand the fundamental properties.

We shall now look at each individual line on psychrometric chart and its importance. For the sake of simplicity and understanding, we shall make use of Carrier psychrometric chart.

Dry Bulb Lines on Psychrometric Chart

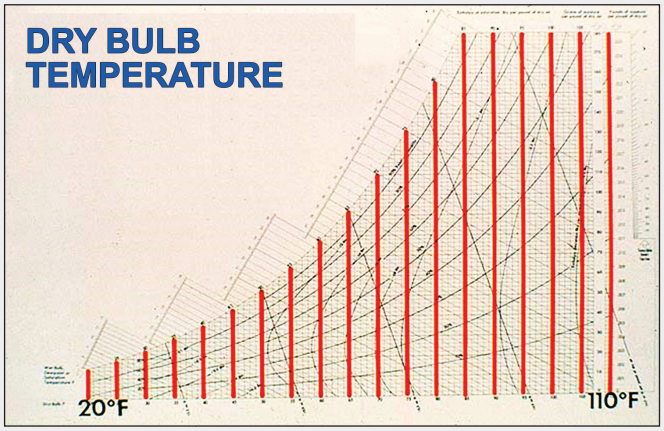

Figure 5: Dry bulb temperature on psychrometric chart

In dry bulb, lines on a psychrometric chart are vertical lines representing constant dry-bulb temperatures (DBT) in degrees Celsius (°C)/°F. These lines extend upward from the X axis where the DBT values are located and indicate the sensible heat or the actual air temperature, independent of its moisture content. The scale on Carrier chart for normal conditions is from -10°C to 55°C (20°F to 110°F).

Wet-Bulb Lines on Psychrometric Chart

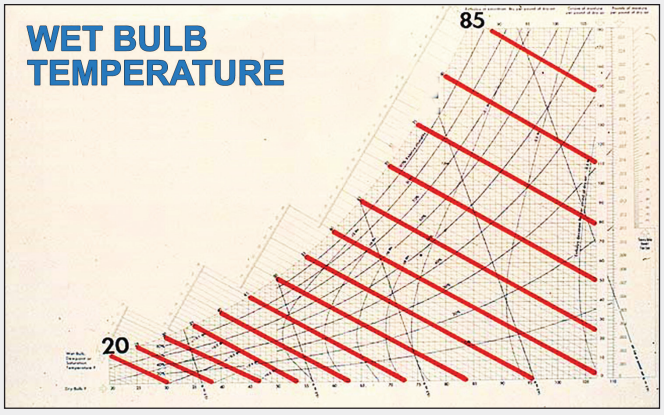

Figure 6: Wet-bulb temperature on psychrometric chart

The Wet-Bulb lines are straight lines that slope diagonally from the upper right to the lower left of the chart. Showing constant value of wet bulb temperature. The temperature scale is from 55°C to -10°C. the slope of lines is approximately 45 degrees to 'X' axis

On a psychrometric chart, you can read the wet-bulb temperature by following a line that slopes diagonally downward from the saturation curve (top of the chart) to the bottom-left.

Dew Point Temperature on Psychrometric Chart

It is the saturation temperature below which if you cool the air, the dew appears on the surface. The surface could be ducting, cold room walls, pipe lines, etc.

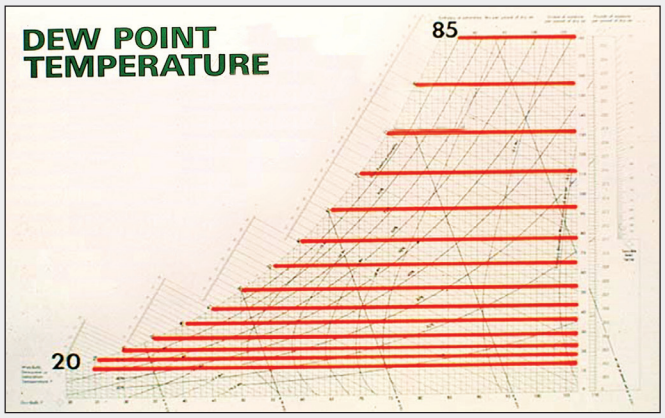

Figure 7: Dew point temperature on psychrometric chart

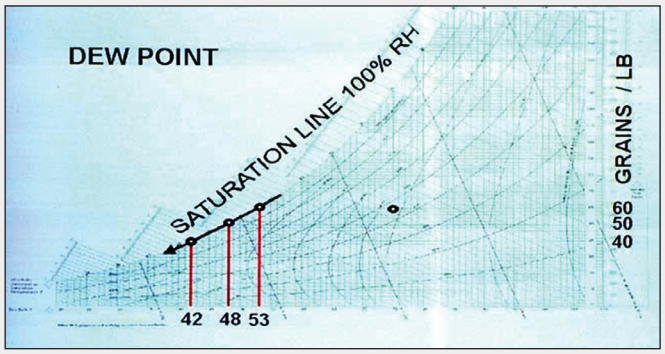

Figure 8: Saturation temperature below which if you cool the air, dew appears on the surface

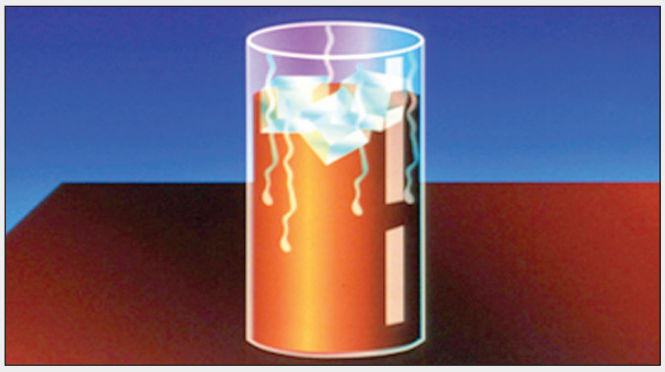

Figure 9: Dew formation on the glass surface

If you put thermometer in a glass and go on adding ice while stirring it, the moment dew appears on the surface is nearly a dew point temperature as registered on the thermometer.

Constant Enthalpy Lines on Psychrometric Chart

The wet-bulb lines are projected at a convenience distance beyond the saturation line. A stepped enthalpy scale is then laid out along the series of lines at right angle to the extended wet-bulb lines.

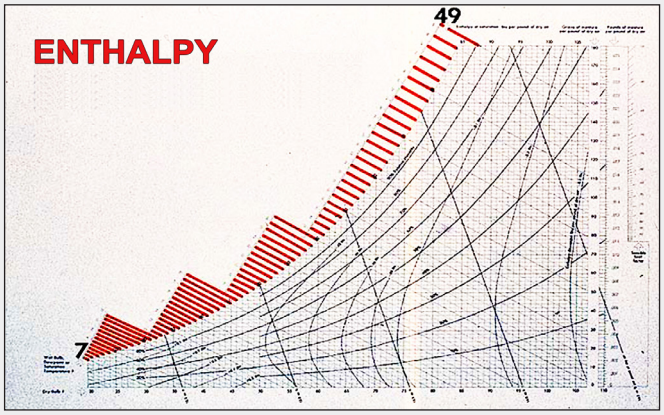

Figure 10: Enthalpy lines on psychrometric chart

The constant enthalpy (constant heat content) lines are same as wet-bulb temperature lines; however, the scale is different and for enthalpy, it is from 145kJ/kg(49Btu/lb.) to minus 10 kJ/kg(7Btu/lb.) of dry air. The scale is readable from the top right-hand corner to the bottom of the left-hand corner.

Specific Volume Lines on Psychrometric Chart

The specific volume is the volume of unit mass of dry air at a given temperature normally expressed as m^3/kg and is also shown in the psychrometric chart. Specific volume is the inverse of density (kg/m^3).

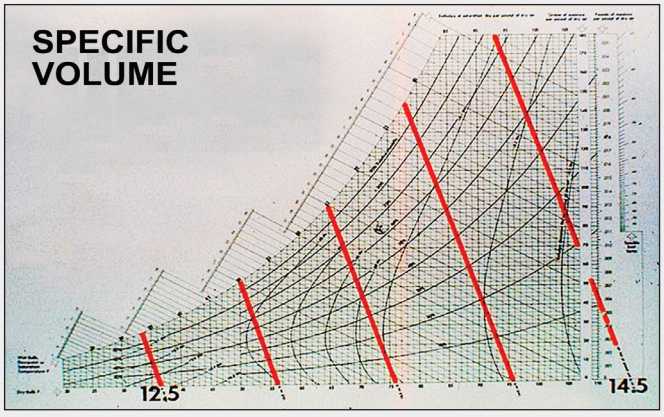

Figure 11: Specific volume lines on psychrometric chart

The constant specific volume lines are few. There are only five lines on Carrier chart and the value measures as m^3/kg of dry air. The scale from the right-hand corner is from $0.95m^3/kg_{da}$(14.5cu. $ft./lb_{da}$) to $o.75m^3/kg_{da}$(12. 5cu.ft/lb_{da}). The slope of these lines is at 90 degrees to the 'X' axis. The values are printed on the scale.

Relative Humidity Lines on Psychrometric Chart

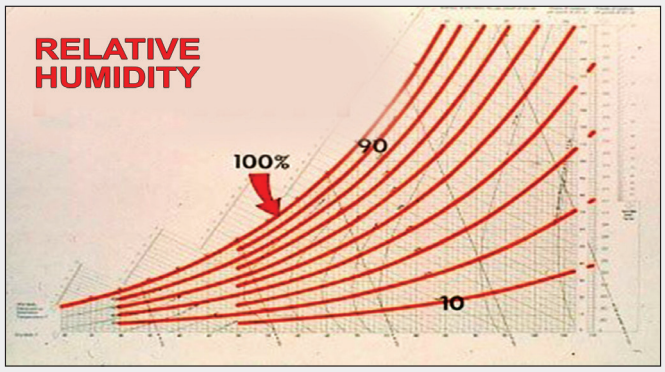

Figure 12: Relative humidity on psychrometric chart

Relative humidity lines are curved lines that start at the bottom left and extend to the top right, representing a constant percentage of the water vapor saturation in the air. These lines indicate the amount of moisture in the air relative to its maximum capacity at a given temperature with the highest line representing 100% relative humidity, also known as the saturation line or dew point line. The scale reads from the bottom right 10% to left as 100%. There are in all 9 lines and the 10^{th} line is saturation line with 100% relative humidity.

Sensible Heat Ratio (SHR) Indicator Scale Outside Y Axis

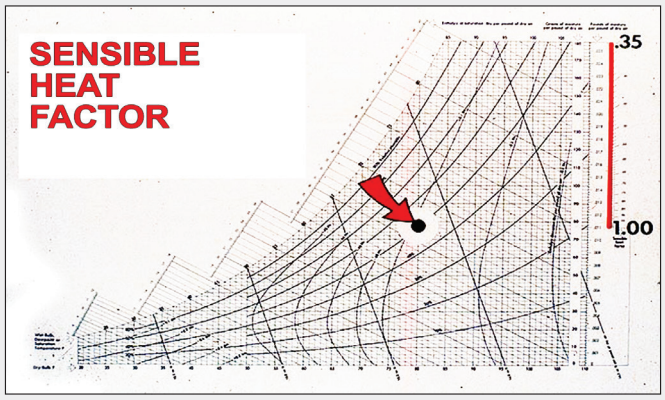

Figure 13: Sensible heat factor on psychrometric chart

It is a vertical scale on the right side radiating from the reference point. To use it, a line is drawn from the desired SHR value on the scale through the design indoor conditions, and this line represents the air conditioning process path with its slope indicating the SHR. This helps to determine the required supply air conditions for a given room heat load, balancing sensible (temperature) and latent (humidity) loads.

Alignment Circle on Psychrometric Chart

The alignment circle, also known as a reference or comfort point, is marked on a psychrometric chart at 25°C dry-bulb temperature and 50% relative humidity. This point serves as a specific condition for air quality and comfort, helping HVAC professionals analyze and design systems to achieve desired indoor conditions. RSHF line can

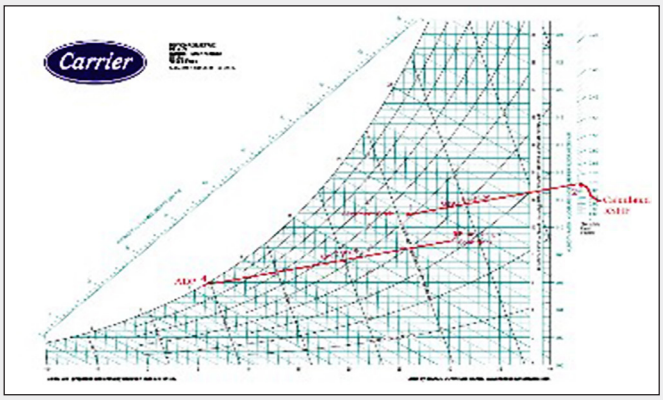

Figure 14: Reference or comfort point is marked on a psychrometric chart

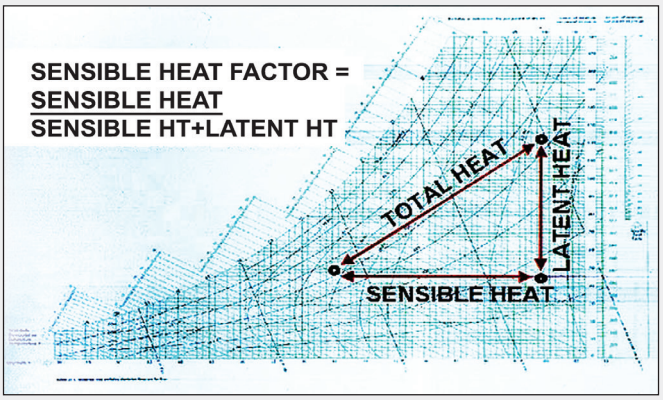

Figure 15: Sensible heat factor

also be drawn from the calculated value of RSHF without knowing the supply condition. On the Psychrometric chart, SHF scale is in the upper right-hand corner and also an alignment at 25°C DBT and 50% RH. *Figure 14* shows how to make use of RSHF, alignment circle and sloping line for use in cooling and dehumidification process**.**

Draw a base line through the alignment circle and the calculated value of RSHF is shown on the SHF scale in the upper right corner of the chart. This line is shown as 1-2. Draw the actual RSHF line through the room design condition parallel to the base line. This line is shown as 3-4. Thus, the supply condition of air falling on any point on the line 3-4 will offset the sensible heat and latent heat loads in the room provided adequate quantity of supply air is supplied. Thus, with proper quantity of air, heat generation will be equal to the heat removal and room design conditions will be maintained. The point 4 is known as Apparatus Dew Point (ADP), we shall discuss the use and importance of this point when we shall discuss actual air-conditioning process.

On the ASHRAE psychrometric chart, it is shown on the left-hand top with a semi-circle and performs similar function. On a typical psychrometric chart, the scale is represented by the slope of lines drawn between different air states. The slope of the process line connecting two points (representing different air states) corresponds to the ratio of sensible heat to total heat; a steeper slope means a higher sensible heat load, while a more horizontal slope indicates a higher latent heat load. The scale on the righthand side of the 'Y' axis is read from top to bottom as 0.36 at the top to 1.0 at the bottom.

Sensible Heat Factor on Psychrometric Chart

The Sensible Heat Factor (SHF) is the ratio of sensible heat to total heat, calculated using the formula: SHF = Sensible Heat (SH) / (Sensible Heat (SH) + Latent Heat (LH). In simpler terms, it tells you what proportion of the total heat added or removed in a process is used to change temperature (sensible heat) versus changing moisture content (latent heat).

Enthalpy Deviation Lines on the Carrier Psychrometric Chart

Since on the Carrier chart, the enthalpy line and the wet-bulb line are the same, which in reality is not true. The ASHRAE chart shows two independent lines, one for wet bulb and another for enthalpy and hence ASHRAE chart does not need enthalpy deviation lines.

Enthalpy deviation lines on a psychrometric chart are used to correct the enthalpy values read from the standard enthalpy lines, which are typically assumed to be coincident with wet-bulb temperature lines for saturated conditions. These charts are often a slight correction to account for the fact that enthalpy lines and wet-bulb temperature lines are not perfectly identical in non-saturated air, especially in situations where relative humidity is less than 100%. The deviation lines, which are almost vertical and convex to the left, show the small corrections (e.g., -0.05 to -1.5 kJ/kg DA) needed to find the accurate enthalpy value in a non-saturated air condition. There are in all eight lines on the chart.

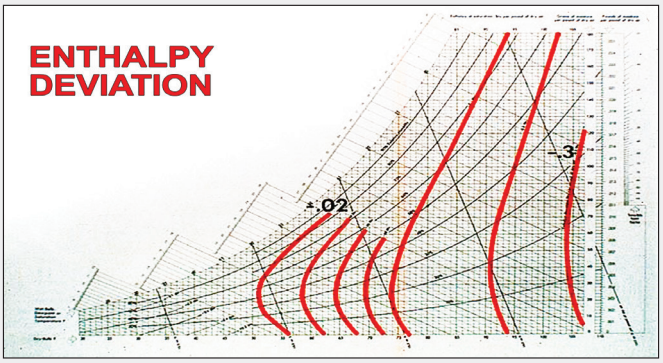

Figure 16: Enthalpy deviation lines

Determining Enthalpy Using a Psychrometric Chart

Locate your operating point on the psychrometric chart using other known any two properties like dry-bulb temperature, wet bulb or humidity ratio. Follow the diagonal line from your point to find the approximate enthalpy value on the enthalpy scale.

Apply the deviation**:** If you are dealing with a non-saturated condition, look for the nearest enthalpy deviation line.

Adjust the value**:** Use the deviation line's value to adjust your previously read enthalpy for greater accuracy.

Moving Ahead

In the next part, we shall use psychrometric chart to deal with basics psychrometric processes commonly used in day-to-day practice while working on air-conditioning system design.