3/31/03

Discussion 4-03
Psychrometrics Review
(Part 2)

Construct Your Own Psychrometric Chart

A clear and thorough understanding of psychrometrics is so vital to any efforts to control the temperature and humidity of the air that *air conditioning could be thought of as the discipline of applied psychrometrics and control of air quality*.

The universal method employed to simplify analytical tasks in engineering, preceding the era of digital technology, was to use analog tools such as charts, graphs, tables and nomographs. Of course the most common of these devices, used in all fields of engineering, was the slide rule which served the engineering community well for many years in speeding the process of performing mathematical calculations. Mechanical engineers in the design of steam power systems relied heavily upon the Mollier (h-s) diagram for steam, and in the design and analysis of refrigeration systems, the (p-h) diagram for the refrigerants.

In the design and analysis of air conditioning systems, the fundamental relationships developed in last month's discussion are used to develop a chart which is a graph of the various characteristics defined in that discussion. The resulting graph, known as the "Psychrometric Chart"[1] has become so universally used in the field of air conditioning engineering that many practitioners think of psychrometrics and the Psychrometric Chart (abbreviated *Psych Chart*) as one in the same thing! This concept has become so wide spread that there are courses and textbooks purported to be on "Psychrometrics" which are actually on *How to use (or understand) the Psychrometric Chart.* (A case of the tail wagging the dog!)

However, to truly understand how to control the characteristics of air/water vapor mixtures requires an understanding of the principles presented in the previous *Discussion* while recognizing that the *Psych Chart* is a very useful analog representation of those principles.

Probably the most useful exercise one can perform to help understand the psych chart is to construct a chart from the fundamental principles previously discussed. The following exercise will require about a half-hour to an hour of the reader's time but should prove of significant value to both the engineering student and the experienced HVAC engineer who hasn't previously experienced it. All it will require is the relationships defined and developed in the previous *Discussion (3-03)*, a copy of the steam tables, a calculator, and a tablet of rectangular coordinate graph paper.

This exercise is to construct a psychrometric chart[2] for a barometric pressure of 29.92 inches Hg absolute (14.696 psia) and for a temperature range of 40° to 100° F. Assume (a) that air and water vapor behave as ideal gases, and (b) that the wet bulb and adiabatic saturation temperatures are identical. The chart will be developed as a rectilinear graph with the humidity ratio (**w**) scale on the ordinate and the dry bulb temperature scale on the abscissa. Proceed as follows.

1. Calculate the values of $\mathbf{w_s}$ (saturated humidity ratio) (in grains/lb) corresponding to dry bulb temperatures of 40° , 50° , 60° , 70° , 80° , 90° and 100° F. Plot those values against the dry bulb temperature. Connect the points with a smooth curve.

   This curve is known as the saturation curve. Since the saturated humidity ratio is the highest value that can exist at any given dry bulb temperature a stable condition cannot exist on the chart above or to the left of this curve. This means that all stable state points will be below and to the right of the curve. (For this reason, it is common to label the ordinate scale on the right margin of the chart.)

2. Calculate the values of **w**, (humidity ratio), corresponding to the following pairs of wet and dry bulb temperatures:

Wet bulb Temperature	Dry bulb Temperature
40	60
50	70
60	80
70	90
80	100
90	100

   Plot these values of **w** against the dry bulb temperature. Then, *assuming that the constant wet bulb temperature lines are straight*, draw the 40° , 50° , 60° , 70° , 80° and 90° F wet bulb temperature lines by connecting these points with the wet bulb temperature intercepts on the saturation curve (Note: More accurate curves can be drawn if values of **w** for each of these wet bulb temperatures and several dry bulb temperatures are calculated.)

   The value of the *chart* now starts to become evident, first, if the barometric pressure is 29.92 inches of mercury, reference to the chart can provide the humidity ratio at saturation, $\mathbf{w_s}$ for any dry bulb temperature within the range (40° to 100° F). Also, if the dry bulb temperature and the wet bulb temperature are known, the intersection point of these two characteristics will immediately provide the value of the humidity ratio of the superheated (non-saturated) mixture.

3. Calculate the values of **w** (humidity ratio) corresponding to relative humidities of 25%, 50%, and 75% at dry bulb temperatures of 40° , 50° , 60° , 70° , 80° , 90° and 100° F. Construct smooth curves through these points representing the constant RH lines of 25%, 50%

and 75%.

Commercially available copies of the psychrometric chart are available from ASHRAE publications and in both tablet and plastic laminate form from several manufacturers of HVAC equipment and machinery. On most of these charts:

- The humidity ratio is expressed in units of grains of moisture per pound of dry air as well as in pounds of moisture per pound of dry air.
- Constant relative humidity curves are plotted for each 10% between 10 and 90.
- An enthalpy scale is provided (BTU per pound of dry air). Since lines of constant enthalpy are very close to lines of constant wet bulb temperature, most charts do not provide the additional constant enthalpy lines. To accommodate the deviation, various techniques are used such as lines of constant corrections, scales at both sides requiring the use of straight edge, etc.
- Constant specific volume (cubic feet per pound of dry air) lines are often plotted.

Note on your *psych chart* that the point at which the dry bulb line intersects the saturation curve defines the wet bulb temperature that establishes the value of the corresponding constant wet bulb temperature line. For any statepoint off of the saturation curve the *dewpoint* temperature can be determined by following a constant humidity ratio line (horizontal line) to the left to the point at which it intersects the saturation curve. The corresponding value on the wet bulb (or dry bulb) temperature scale is the dewpoint temperature for that statepoint.

There are, of course certain limitations to the use of psychrometric charts. The most evident is, of course, the temperature range of the chart. Most publishers offer the charts in three temperature ranges "Normal", "Low" and "High", the specific ranges vary with publishers. Typical temperature ranges for published charts are:

Low	-20° to 50°
Normal	30° to 110°
High	60° to 250°

The other limitation is the barometric pressure. The 29.92 inches of mercury in the above exercise is, of course, standard (sea level) atmosphere. Some charts are available for other elevations, but the most common technique is to use a "standard" chart and for other elevations apply certain correction factors as multipliers.

The psychrometric chart has served the HVAC engineering community well for many years, and it will continue to serve as a valuable tool in teaching and in diagnostic analysis, following the principle of analog devices "a picture is worth a thousand words". However, in the age of digital technology it is destined to go the way of the slide rule in the daily practice of engineering.

Footnotes:

1. Originally published in 1906 by Willis H. Carrier in the Buffalo Forge Company Catalog.
2. This problem appeared in a similar form in "Engineering Thermodynamics" by Herman J. Stoever (John Wiley and Sons), 1951.