Applied Psychrometrics

APPLIED PSYCHROMETRICS

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To effectively trouble shoot an air conditioning system, you not only have to understand mechanical refrigeration & electricity, but one has to know properties of air & its behaviour thoroughly, as problem in any one of these three areas can cause poor system performance.

We will therefore try to understand properties of air first. Air is a mixture of many gases - mainly 78 % Nitrogen, 21 % Oxygen & 1 % Argon and other gases.

Moist air is a mixture of dry air & water vapour. The amount of moisture can very from zero to all that air can hold i.e. up to saturation point.

If dry air & water vapour were mixed together in a container, the pressure of this mixture is summation of pressure exerted by each component. This is Dalton's law.

The gas law, which dry air follows, states that if air were heated & maintained at constant pressure, the air would expand & weigh less per cubic foot volume. In other words the density of air decreases.

The air exerts pressure & the barometric pressure at sea level is 29.92 inches of mercury & the pressure is 14.696 lbs/sq.in.

a rise in barometric pressure indicates good weather ahead, whereas a decrease forecasts bad weather.

Dry air weighs more than wet air.

Psychrometrics is the representation of psychro means cold & metrics means measure of. It measures all properties of moist air.

Building Psychrometric chart

Since the behavior of temperature & humidity are predictable at atmospheric pressure, different characteristic values can be plotted on graph & used as standard reference.

Dry bulb temperature: Ordinary temperature scale known as dry bulb temperature is laid out horizontally & used as standard reference.

Wet Bulb temperature:- the temperature registered by the thermometer whose bulb is covered by a wetted wick and exposed to a current of rapidly moving air.

Specific Humidity Scale: 'Y' axis represents specific humidity i.e. amount of water vapour mixed with each pound of dry air. This scale is read in grains of water vapour per pound of dry air at standard atmosphere. It also has values of pounds of moisture per pound of dry air. However these values are rarely used.

Dew point & Saturation Line : When the air is cooled, at first, only temperature is reduced, no water vapour is removed until the air reaches its point of maximum humidity. Any further cooling will cause some water vapour to condense, as the ability of air to retain moisture decreases as the temperature is reduced. The temperature at which the moisture content or relative humidity has reached 100 % is called the dew point. A line which connects these & other 100 % saturation points is called as saturation line which is the same as 100 % relative humidity line. The dew point temperature of air depends upon the amount of water vapour present & is found on the chart by moving horizontally over to the saturation curve and reading temperature there.

The use of these values is made to take decisions as to what should be the maximum relative humidity inside premises, without moisture condensation on windows, during winter, or whether the duct running inside the air conditioned space needs insulation.

Relative Humidity Lines : These lines for partly saturated air look very much like saturation lines & are in increments of 10 % & indicate degree of saturation. Relative Humidity is defined as the amount of moisture in the air compared to the maximum amount that could be present at the same temperature. It is the ratio of actual water vapour pressure of the air to the saturated water vapour pressure of the air at the same temperature.

Wet Bulb Temperature : These lines are at 30 degree to dry bulb line. It means if we pass the air through series of water sprays that use the same water over & over again except for the small amount that may evaporate.

This device is called saturator. As the air goes through the water spray, the temperature of the air drops because heat is absorbed to evaporate the atomised water. If the sprays are well designed the air temperature drops down to almost water temperature and this temperature is known as wet bulb temperature.
A device called the sling psychrometer is used for convenience & gives quite accurate results. It consists of two thermometers mounted in a frame & attached to a handle by means of swivel, one thermometer and second wetted with cotton wick wrapped around its mercury bulb.

Latent Heat Process : This process occurs when water is evaporated or condensed & dry bulb temperature does not change. This shows up as a vertical line on the chart.

Sensible Heating & Cooling Process: This results in a change in temperature & is indicated by horizontal line on the chart.

Wet Bulb Process-Or Evaporative Cooling : This is shown as wet bulb line which runs diagonally at 30 degree to dry bulb line from lower up to saturation line.
Cooling & Dehumidification: If cooling is combined with dehumidification, The line is slopping downward from right to left. The amount of latent heat and sensible heat involved determines whether the line has gentle slope or a steep slope. The slope of this line is named as Sensible Heat Factor, which is equal to

$$= \frac{\text{Sensible Heat}}{\text{Sensible heat + Latent Heat}}$$

Mixing Air: Normally in air conditioning plants, outside air is mixed with recirculated air in a certain proportion. If these two points are plotted on chart then the mixture condition is in direct proportion to air quantities, the point being nearer to larger fraction i.e. recirculated air & can be determined by joining the two points in a straight line & dividing same in the proportion of air quantities.

Bypass Factor : when air is passed over the coil, some of the air hits the tubes and some of it goes through without hitting anything. The part that goes through freely is referred to as the bypass air, the reminder is contact air.

If conditions nearer to saturation are required, more rows of coils are needed.

The name used for the coils average surface temperature is **apparatus dew point.**

The overall bypass factor for the complete cooling coil can be determined from the entering air conditions, leaving air conditions and average surface temperature. The bypass factor for any coil depends upon coil construction, size of tube, size and type of fins, and tube and fin spacing.

When rows are increased the bypass factor reduces, however every row added has diminishing contribution. It means sixth row of tubes is not as valuable as second, third or even fifth row.

Another condition which affects the bypass factor is velocity of air through coil. If air quantity is reduced & velocity is reduced, bypass factor reduces. So for given air quantity (cfm) larger the coil, lower will be bypass factor. Lower the bypass factor, lower is the supply air temperature, which means to do same amount of job lower air quantity is required. This however would mean higher cost of cooling coil and lower air temp. may not be feasible if the room is small, without causing discomfort. Also lower temp. would mean more insulation of ducts which could be avoided if air at higher temp. is supplied with larger blowers. There are no hard and fast rules, however normally 3 to 4 row coils with 0.2 to 0.1 bypass factor are generally used for comfort air conditioning applications.

Specific Volume : Number of cubic ft. of air occupied by one pound of air at given temperature and pressure. One pound of air at 75 f dry bulb occupies 13.5 cft. At sea level. If air is heated it expands and occupies more volume which means density of air is reduced. If air is cooled, it occupies lesser volume. The specific volume lines slope at 70 degree to horizontal and slant to the left. This characteristic is used primarily for checking fan performance and determining fan motor sizes.

Enthalpy or Total Heat : Enthalpy is found by following along a wet bulb temperature line, past saturation line & out to the enthalpy scale. These values are used to determine total heat removed from a volume of air, by reading the scale between the two wet bulb lines.

Sensible Heat Factor Scale : The standard point located by a circle is 80 F dry bulb and 50 % R.H. If a line is drawn from point meeting the sensible heat factor scale and then a parallel line to this from room temp. meeting the saturation line, it would give us apparatus dew point. It thus tells us at what temp. the cooling coil must operate.

Following are some of the key formulas used

1) Sensible Heat = sp. ht. x sp. density x 60 min./hr x cfm xdelta T
= 0.24 x .075 x60 x cfm x delta T
= 1.08 x cfm x delta T

2) Total heat =Sp. Density x 60 min/hr x cfm x delta H
= .075 x 60 x cfm x delta H
= 4.5 x cfm x delta H

3) Latent Heat = 0.69 x grains/lb x cfm

Mastering psychrometric chart is not a difficult task, however the number of individuals who design air conditioning systems and select equipment for maintaining temp. & humidity without using psychrometric charts is really astounding. Most believe use of chart requires considerable engineering ability. Actually the solution of any air conditioning problem by means of psychrometric chart is the easiest way. Besides, one has much more assurance that the solution is correct, it being easier to visualise and check.

Some engineers are under misapprehension that use of psychrometric may result in more complicated system. Instead it is more likely to guide one to the simpler solution. Often engineers just ignore the real problem and specify package units which look likely to have enough total capacity. Such simple installations often become quite unprofitable when they fail to meet the requirements.

Only careful initial design will provide an installation which will give assurance of good performance and a definite knowledge of costs, so that the contractor can quote a price which will net an acceptable profit or avoid having the contract which will later result in a loss. Devoting time to master the psychrometric chart is definitely going to be a fruitful exercise.

1st November 98 Ramesh Paranjpey