PSYCHROMETERIC APPLICATIONS

Psychrometerics is the name given to the study of the interaction of air and water vapor. A knowledge of psychrometeric concepts are not only required for humidificaton and dehumidification but also for the selection of cooling coils.

The analysis of moist air processes using psychromteric principals relies on treating both the air and the water as if they were seperate components. By using properties of pure substances the ideal gas laws can be applied and combined to determine the net effect.

DEFINITIONS:

Realitive Humidity: (rh, ϕ),the ratio of the mole fraction of the water vapor in the mixture to the mole fraction of vapor in a saturated mixture at the same temperature and pressure.

$$\phi = \frac{p_v}{p_g}$$

Humidity Ratio: (ω), the ratio of the mass of water vapor to the mass of dry air.

$$\omega = \frac{m_v}{m_a}$$

Adabatic Saturation Temperature:

Dewpoint Temperature: the temperature at which water vapor begins to condense from air when cooled at a constant pressure and humidity ratio.

Dry Bulb Temperature: (DB), the air temperature of a room as measured with a standard thermometer.

Wet Bulb Temperature: (WB), the temperature measured by a thermometer cooled by the evaporation of water from a cloth sock placed over the thermometer.

Grains: (Gr), 7,000 Grains equals one pound of water.

Enthalpy: (h), amount of energy stored in a pound of air.

Vapor Pressure: (in Hg), the measure of the force resulting from the water molecules in the air. Vapor Pressure is measured in inches of mercury which is 13.6 times more dense than water.

Specific Volume: (V_c) the space occupied by a givin mass of a gas or mixture.

Saturation: the process by which water is removed from air and is deposited

PSYCHOMETERIC THEROY

Dry air is defined by the International Joint Committee on Psychrometeric Data as a mixture of gases in the folowing proportions:

	Molecular Weight	Volume Fraction	Partial Molecular Weight
Nitrogen	28.016	0.7809	21.8777
Oxygen	32.000	0.2095	6.7040
Argon	39.944	0.0093	0.3715
Carbon Dioxide	44.010	0.0003	0.0132
	Apparent Molecular Weight =		28.9650

The properties of dry air can be predicted using the Ideal Gas Laws for pressures up to three atmospheres. The Ideal Gas Law is used to model the relationship between the quantity of gas and the effects of temperature, volume and pressure.

The Ideal Gas Equation is expressed as follows:

$$p\,V = n \times \bar{R} \times T$$

Where:

p = Pressure of gas. (lbf/ft^2)
V = Volume of the gas. (ft^3)
n = Moles (Quantity) of gas.
R = Universal Gas Constant. (1545.32 ft x lbf/lbm x °R)
T = Absolute temperature of gas. (°R = °F + 460)

The actual mass of gas present can be determined by multiplying the number of moles by the molecular weight of the gas. Rearrainging the Ideal Gas Law results in the relation:

$$m_i = \frac{\bar{R} \times T}{V \times M_i}$$

The gas constant for dry air is determined by dividing the Universial Gas constant by the molecular weight of air.

$$R_a = \frac{\overline{R}}{M_a} = \frac{1545.32}{28.965} = 53.352\ \frac{ft\text{-}lbf}{lbm\text{-}R}$$

The Ideal Gas Law can also be used to describe the properties of water vapor. However, this assumption is only valid for psychometeric analysis were the error introduced by this assumption is negligible. The gas constant for water vapor can be determined givin that the molecular weight of water is 18.015.

$$R_v = \frac{\overline{R}}{M_v} = \frac{1545.32}{18.015} = 85.78\ \frac{ft\text{-}lbf}{lbm\text{-}R}$$

$$\omega = 0.625\ \frac{p_v}{p - p_v}$$

Applying the Gibbs Dalton law that the pressure of a mixture of gases is the summation of the partial pressure of the individual gases.

$$P = p_{N2} + p_{O2} + p_{CO2} + p_A + p_v$$

For moist air:

$$P = p_a + p_v$$

For perfect gases the mole fraction is equal to the partial pressure ratio of each constituent.

$$\omega = \frac{\dfrac{p_v}{R_v \times T}}{\dfrac{p_{sat}}{R_v \times T}}$$

$$h = h_a + \omega \times h_v$$

$$h_a = C_{pa}\ t$$

$$h_v = h_g + C_{pv}\ t$$

$$h = 0.240 \times t + \omega(1061.2 + 0.444\ t)$$

The Adiabatic Saturation Process:

Givin the pressure and temperature of an air and water vapor mixture one additional property such as phi, w or h is required to fix the state. However, the is no practical way to directly measure any of these parameters in real world conditions.

The Adiabatic Saturation Process indirectly allows for determination of specific humidity (w) of an air stream. The adiabatic saturation process consists of allowing an air stream to pass over a pan of water in an insulated duct and become saturated with out adding or removing heat. Once the air stream is saturated the absolute humidity humidity (W2) is known and the final temperature of the air stream can be measured. This temperature is refered to as the Adiabatic Saturation Temperature. By appling the first law of thermodynamics the Specific Humidity (W1) can be calculated. Once this is determined then the state of the air and water vapor mixture is fixed.

The Adiabatic Saturation Temperature is directly related to the amount of moisture in the air and by assuming that there is no heat transfer the values can be calculated. There is no practical aparatus for conduction this test.

Wet Bulb Temperature is a easily measured through the use of a simple devive known as a Psyhcrometer. However, the wet bulb temperature is a function of both heat and mass transfer rates.

Reasearch has shown that for air and vapor mixtures at atmospheric temperatures and pressures that the Wet Bulb temperature and the Adiabatic Saturation Temperature are roughly equal.

The Psychrometeric Chart was developed in the early part of this century by Richard Mollier a German engineer. The diagram is a graphic representation of the proporties of moist air. Givin just two conditions any of the other properties can be determined from the diagram.

The psychrometeric chart is more than just a source of physical properties it is also practical format for making air conditioning design calculations. The following examples show the common processes.

Moist Air Processes:

HEATING OR COOLING OF MOIST AIR

COOLING AND DEHUMIDIFYING OF MOIST AIR

HEATING AND HUMIDIFYING MOIST AIR

ADIABATIC MIXING OF TWO STREAMS OF MOIST AIR

ADIABATIC HUMIDIFICATION OF MOIST AIR