# Fundamentals of Airside Systems


*A close look at the theory and mechanics of conditioning air*

DAIKIN LEARNING
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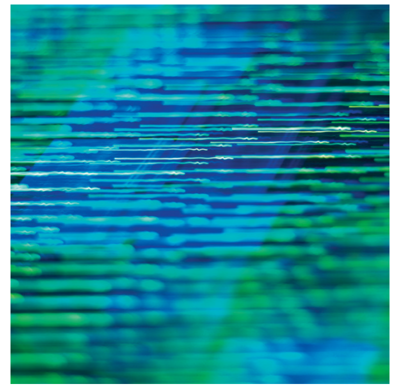
# 2 Psychrometry



## General

Psychrometrics is a subset of physics dealing with the properties and processes of a mixture of dry air and water vapor.

The word "psychrometrics" dates to 1825, when Ernest Ferdinand August of Germany named his wet-bulb thermometer a psychrometer using the Latin words ***psychro***, to make cold, and ***meter***, to measure.

A psychrometric chart is based on a specified barometric pressure or elevation with respect to sea level. The most common chart is based on 29.921 in. of Hg (101.325 kPa). This is the normal barometric pressure at sea level and 59° F (15° C).

In 1904, just two years out of Cornell University, Willis Carrier (1876-1950) developed a blueprint version of a psychrometric chart very similar to today's charts. Carrier was an employee of Buffalo Forge Company, and the 1906 issue of the company's catalog featured Carrier's chart.

Between 1926 and 1938, Claude A. Bulkeley (1875-1939), an American engineer of Wilmington, Delaware and associated with Niagara Blower, presented the Bulkeley psychrometric chart in ASHVE (a predecessor or ASHRAE) publications. His chart replaced the Carrier chart, previously in use at the time. Bukleley's chart used a logarithmic scale of water vapor pressure and a non-uniform dry-bulb temperature scale in order to present the water vapor saturation parameter as a straight line. His chart wasn't suitable for graphically presenting air-conditioning problems and so fell out of use, in favor of charts similar to the Carrier chart.

## Basics of the Psychrometric Chart

***Figure 2.1*** shows a simple temperature-pressure diagram for water. The diagram shows three regions of state for water – solid, liquid and gas. The curve represents the saturation of water vapor at various temperatures and pressures. This curve could be referred to as the dew-point curve. It also shows how water vapor can become a refrigerant if kept at a significant vacuum with respect to atmospheric pressure. Water can become a vapor at low temperatures, which would normally result in liquid or even solid phase at standard pressure.

While the phrase "the air is saturated with water vapor" is often heard, reality is that the air has nothing to do with saturation of water vapor. Saturation occurs when the volume of space contains the maximum possible number of water vapor molecules. The dry air that may occupy the same volume has no effect on the saturation of the water vapor.

A psychrometric (psych) chart also shows the various properties of air but does so at only one pressure. A typical psych chart is created at standard pressure of 29.921 in. of Hg ( 101.043kPa). Most psych charts won't show the solid water region but will show a saturation line, a two-phase or fog region and a superheated region. See ***Figure 2.2***.

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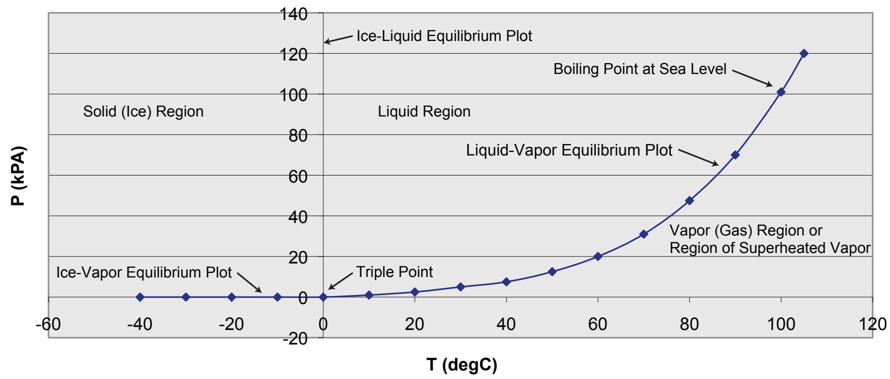


***Figure 2.1***
P-T Diagram for Water

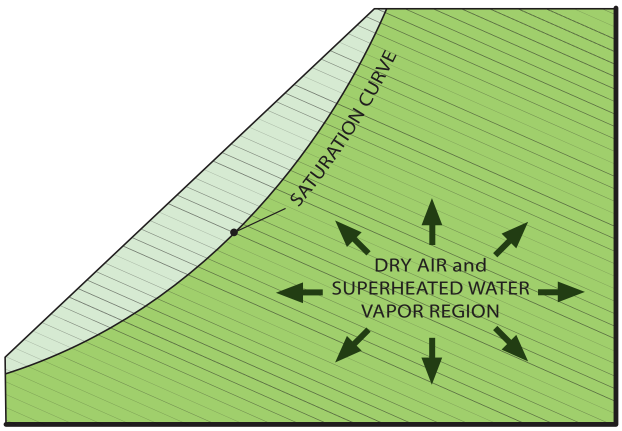


***Figure 2.2***
Basic Psychrometric Chart Zones

For the purposes of this discussion, all gases used in mixtures are assumed to be perfect gases.

## Gibbs-Dalton Law

The Gibbs-Dalton law states that in a mixture of ideal gases, the gas and vapor molecules share the same volume, and the pressure of the mixture is equal to the sum of the partial pressures of the individual component gases. The equation is in the form of:

$p_m = p_a + p_w$

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Where:

$p_m$ = total pressure

$p_a$, $p_w$ = partial pressures of the air and water vapor respectively

The mixture of dry air and water vapor is assumed to follow the perfect gas law:

pV = nRT

and the mixture becomes $(p_a+p_w)V = (n_a+n_w)RT$

Where:

P = vapor pressure, in. Hg (kPa)

V = volume, $ft^3$ ($m^3$)

n = number of moles of gas

R = gas constant, $ft\text{-}lb_f/lb_{mol}°R$ (kJ/K·kmol)

T = absolute temperature, °R (K)

## Dry-Bulb Temperature

Dry-bulb temperature is the true temperature of moist air at rest. Air at rest means no air is blowing across the thermometer, no evaporation or condensation is occurring and the quantity of water vapor is constant. The dry-bulb temperature is therefore the temperature of both the dry air and the water vapor occupying the same volume. Generally, when the term "temperature" is used in connection with air, it refers to the dry-bulb temperature.

On the psych chart, dry-bulb temperature is shown on the horizontal scale (the abscissa). Dry-bulb temperature lines on most charts are not perfectly vertical. A careful examination will show that the ASHRAE Psychrometric Chart No. 1 has dry-bulb lines that fan out or diverge as the humidity ratio increases. See ***Figure 2.3***.

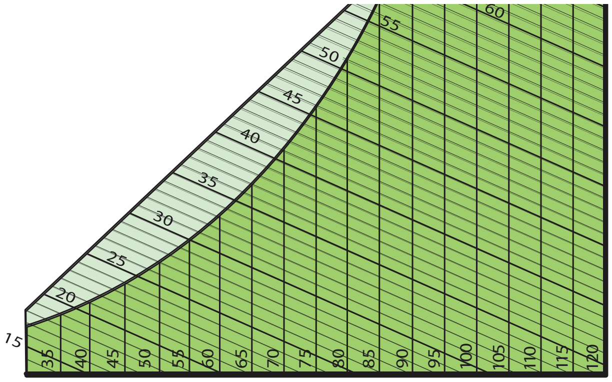


***Figure 2.3***
Dry-Bulb Temperature on Psychrometric Chart

The universal gas constant is agreed to be 1545.32 $ft\text{-}lb_f/(lb_{mol}\cdot°R)$ (8.314 kJ/K·kmol). Dry air mole weight is 28.9645 (carbon-12 scale). Water vapor mole weight is 18.01528. So, the respective gas constants are:

$R_{da}$ = 1545.32/28.9645 = 53.352 $ft\cdot lb_f/lb_m \times °R$

$R_w$ = 1545.32/18.01528 = 85.778 $ft\cdot lb_f/lb_m \times °R$