MARLEY

thermal science

# Cooling Tower Performance vs. Relative Humidity

BASIC THEORY AND PRACTICE

## Total Heat Exchange

A mechanical draft cooling tower is a specialized heat exchanger in which two fluids (air and water) are in direct contact with each other to induce the transfer of heat.

Ignoring any negligible amount of sensible heat exchange that may occur through the walls (casing) of the cooling tower, the heat gained by the air must equal the heat lost by the water. This is an enthalpy driven process. Enthalpy is the internal energy plus the product of pressure and volume. When a process occurs at constant pressure (atmospheric for cooling towers), the heat absorbed in the air is directly correlated to the change in enthalpy. This is shown in Equation 1.

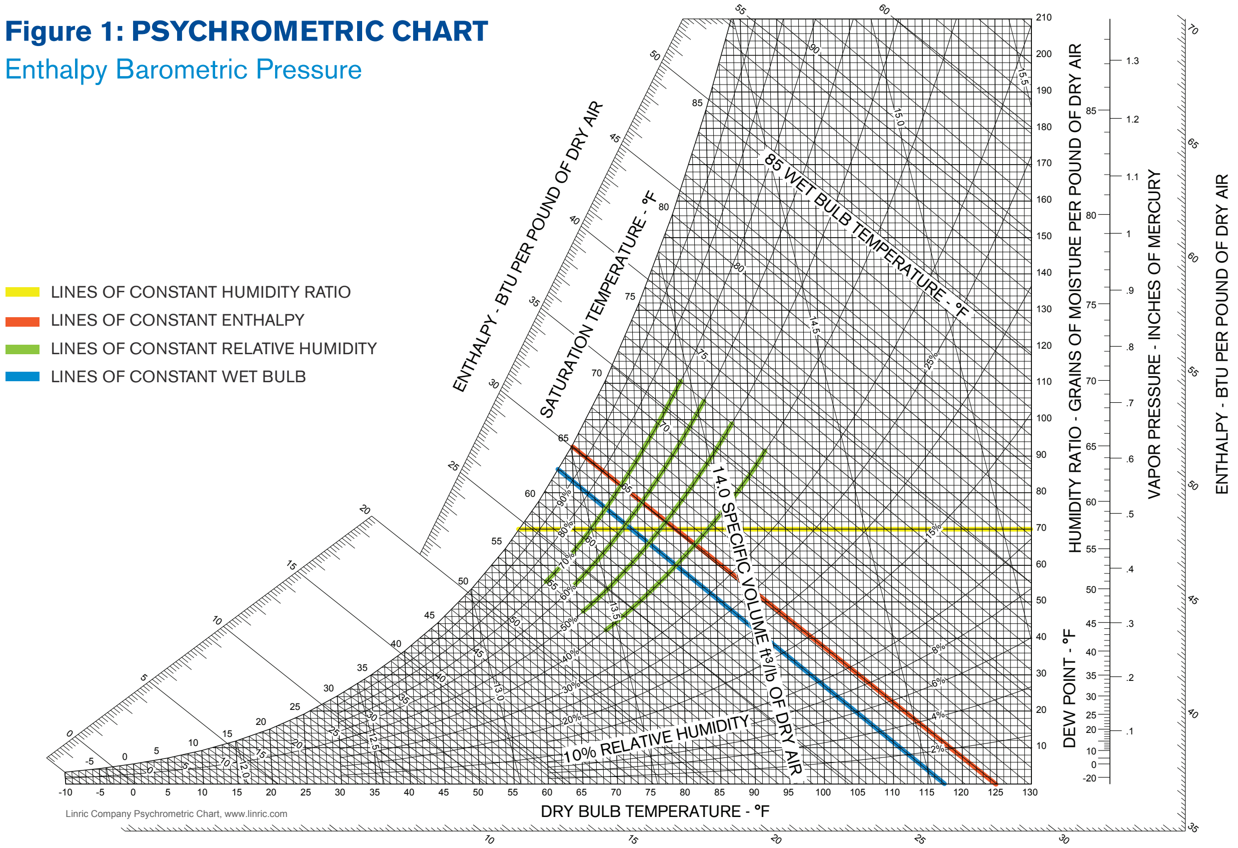
$$G (h_{out} - h_{in}) = L \times C_p (T_{HW} - 32°) - C_p (L - L_e)(T_{CW} - 32°) \qquad (1)$$

$G$ = mass rate of dry air [lb/min]
$L$ = mass rate of circulating water [lb/min]
$L_e$ = mass rate of evaporated water [lb/min]
$T_{HW}$ = temperature of hot water entering tower [°F]
$T_{CW}$ = temperature of cold water leaving tower [°F]
$h_{in}$ = enthalpy of air entering [Btu/lb/dry air]
$h_{out}$ = enthalpy of air leaving [Btu/lb/dry air]
$C_p$ = specific heat of water = 4.18 [Btu/lb-°F]
$W_{in}$ = humidity ratio of air entering [lb water/lb dry air]
$W_{out}$ = humidity ratio of air leaving [lb water/lb dry air]

In order to know how much heat the air flowing through a cooling tower can absorb, the enthalpy of the air entering the tower must be known. This is shown on the psychrometric chart **Figure 1.** The lines of constant enthalpy are close to parallel to the lines of constant wet bulb. This is why cooling towers are most often sized using the inlet wet bulb conditions.

**Figure 1: PSYCHROMETRIC CHART**

Enthalpy Barometric Pressure



## Effects of Relative Humidity – Thermal Performance

Cooling towers are rated most often using the inlet wet bulb temperature because these values are closely consistent with the enthalpy of the air. As the relative humidity changes along constant wet bulb lines, the enthalpy stays close to constant. This relationship is shown in **Figure 1.** Therefore, changes in humidity along a constant wet bulb temperature will result in almost no change to the tower's overall performance.

The inlet enthalpy of the air increases by only 0.5% when relative humidity increases by 60% at 68°F. Under standard conditions (78°F wet bulb, 95°F entering water temperature, and 85°F exiting water temperature), the overall nominal tonnage performance of an evaporative cooling tower model improves only a couple tenths of a percent when the inlet relative humidity is 90% compared to 10%.

## Evaporation

Unlike enthalpy, the relative humidity (RH) does affect the rate of evaporation within the cooling process. It is assumed that exiting air leaves the tower saturated (100% RH). The lower the RH of the ambient air entering the tower, the more water the air can absorb before becoming saturated over the same change in enthalpy (heat exchange). Therefore, the lower the entering RH, the higher the evaporation loss in the tower will be. Equation 2 shows the relationship between evaporation and humidity ratio.

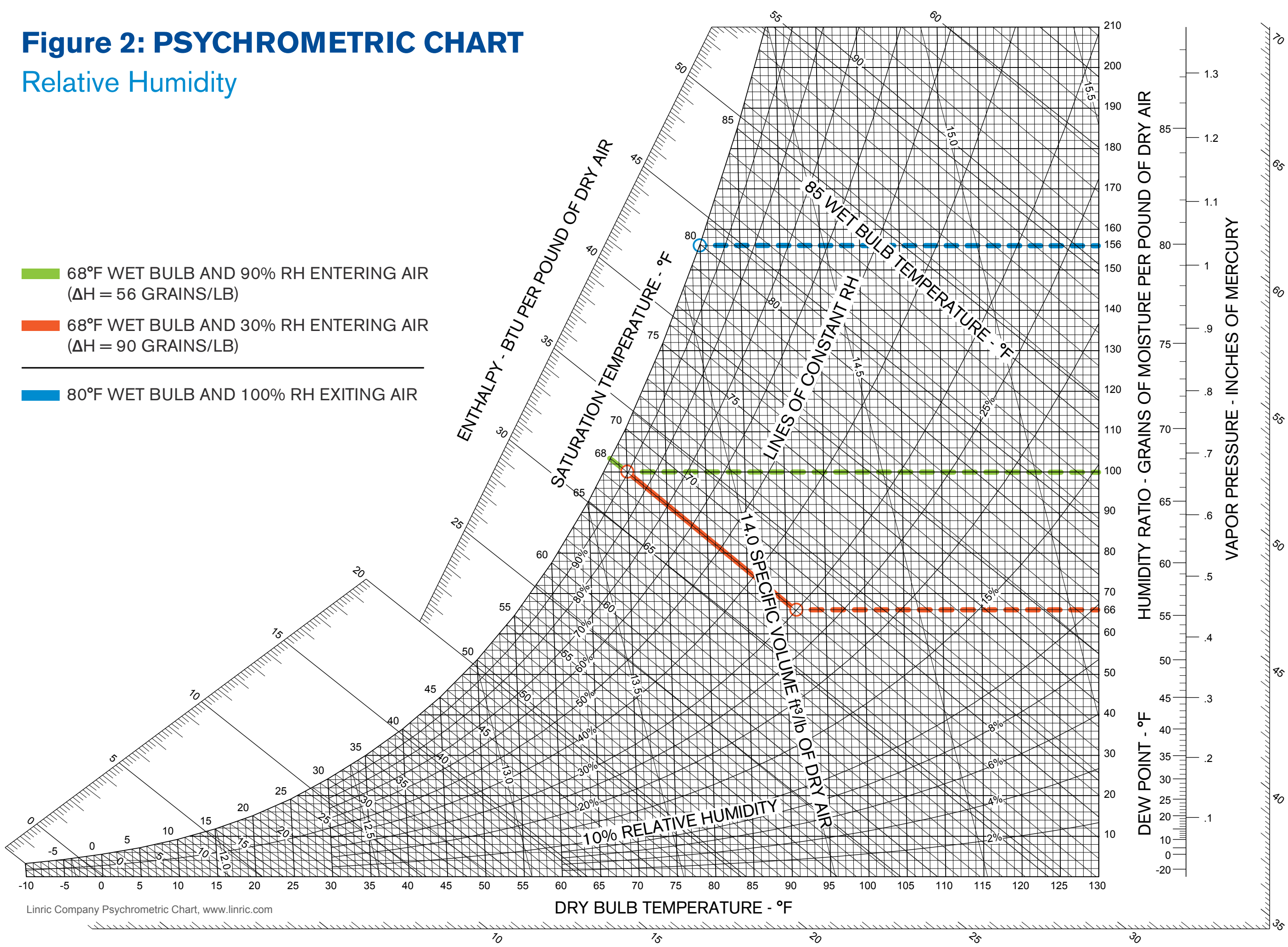
$$L_e = G\,(W_{out} - W_{in}) \qquad 2)$$

$G$ = mass rate of dry air [lb/min]
$L_e$ = mass rate of evaporated water [lb/min]
$W_{in}$ = humidity ratio of air entering [lb water/lb dry air]
$W_{out}$ = humidity ratio of air leaving [lb water/lb dry air]

**Figure 2** illustrates the changes in humidity ratio in the air entering and exiting an evaporative cooling tower, showing the relative percentage change in evaporation due to the change in the relative humidity of the entering air. The difference in evaporation between 30% RH and 90% RH entering air is approximately 62%. At standard conditions, this may be as much as 0.62% of the circulating water flow rate. This value is completely dependent on heat load and water load as well as the ambient conditions. A general rule to estimate evaporation (at 50% RH) is 1% of the recirculating water flow for every 12°F of range. This is shown in Equation 3.

### Figure 2: PSYCHROMETRIC CHART

Relative Humidity



$$L_e = L \times R \times 0.0008 \quad (3)$$

$L_e$ = evaporation rate (gpm)
L = tower water flow rate (gpm)
R = design range (°F)

## Conclusion

- Evaporative cooling is an enthalpy driven process.
- The lines of constant enthalpy on a psychrometric chart are close to parallel with lines of constant wet bulb temperature.
- Relative humidity does NOT affect the performance of an evaporative cooling tower.
- Relative humidity DOES affect the rate of evaporation from the tower. The relationship is inversely proportional.

Although RH does not have an effect on mechanical draft cooling towers (relative to the design wet bulb condition), dry bulb temperature and relative humidity are needed to determine the thermal performance for hyperbolic natural draft, fan-assisted natural draft, dry towers and plume-abated towers.

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