

# Capacity—Tons of Refrigeration

## AHRI 550/590-2011 SECTION 5.1.3

AHRI 550/590-2011 defines capacity as a measurable physical quantity that characterizes the water-side heat flow rate in Btu/hr or Tons of Refrigeration, tons<sub>R</sub>. Net refrigerating capacity of a chiller is the capacity of the evaporator available for cooling of an external load. The net refrigerating capacity for the evaporator shall use the water temperatures, water flow rate and water properties at the evaporator entering and leaving conditions and be calculated as follows:

### CAPACITY EQUATIONS AND SAMPLE CALCULATIONS

$$q_{ev} = (m_w) (c_p) (t_e - t_l) \quad \text{(equation 6)}$$

Where  $m_w$  = mass flow rate, lbm/h

$c_p$  = specific heat at the average of entering & leaving water temperatures, Btu/lbm • °F

$t_e$  = entering water temperature, °F

$t_l$  = leaving water temperature, °F

This calculation utilizes two values that are not directly measured in the test facility

(1)  $m_w$  = mass flow rate of water

(2)  $c_p$  = specific heat of water

Mass flow rate =

$m_w$  = measured GPM x 0.13368 ft<sup>3</sup>/gal x density of water lbm/ft<sup>3</sup> x 60 min/hr

Density of water =

$$\rho = (-7.4704 \times 10^{-10} \times t^4) + (5.2643 \times 10^{-7} \times t^3) - (1.8846 \times 10^{-4} \times t^2) + (1.2164 \times 10^{-2} \times t) + 62.227 \quad \text{(equation 20)}$$

Specific heat of water =

$$c_p = (-4.0739 \times 10^{-13} \times t^5) + (3.1031 \times 10^{-10} \times t^4) - (9.2501 \times 10^{-8} \times t^3) + (1.4071 \times 10^{-5} \times t^2) - (1.0677 \times 10^{-3} \times t) + 1.0295 \quad \text{(equation 21)}$$

(t = water temperature, °F)

Using the measured volumetric evaporator flow rate in gallons per minute (GPM) and measured evaporator entering and leaving water temperatures in °F, we then calculate the density of water,  $\rho$ , the mass flow rate of water,  $m_w$ , and the specific heat of water,  $c_p$ . These values are used to calculate net refrigerating capacity,  $q_{ev}$ , in Btu/h.

1 ton of refrigeration is equal to 12,000 Btu/h, so the net refrigerating capacity,  $q_{ev}$ , is divided by 12,000 Btu/h to calculate tons of refrigeration, tons<sub>R</sub>.

## CAPACITY EQUATIONS AND SAMPLE CALCULATIONS (*continued*)

### EXAMPLE CALCULATION:

Entering Evaporator Water Temperature, $t_e$	$t_e = 54^\circ\text{F}$
Leaving Evaporator Water Temperature, $t_l$	$t_l = 44^\circ\text{F}$
Volumetric Flow Rate in Gallons Per Minute	flow = 1196 GPM

Calculate density of water,  $\rho$ , at location of flow meter, (entering temperature,  $t_e$ )

$$\rho = (-7.4704 \times 10^{-10} \times 54^4) + (5.2643 \times 10^{-7} \times 54^3) - (1.8846 \times 10^{-4} \times 54^2) + (1.2164 \times 10^{-2} \times 54) + 62.227$$

$$\rho = 62.41084829 \text{ lbm/ft}^3$$

Calculate mass flow rate,  $m_w$

$$m_w = 1196 \text{ gal/min} \times 0.13368 \text{ ft}^3/\text{gal} \times 62.41084829 \text{ lbm/ft}^3 \times 60 \text{ min/h}$$

$$m_w = 598,700 \text{ lbm/h}$$

Calculate specific heat,  $c_p$ , at the average of entering & leaving water temperatures

$$\frac{t_e + t_l}{2} = \frac{54^\circ\text{F} + 44^\circ\text{F}}{2} = 49^\circ\text{F} = \text{average water temperature}$$

$$c_p = (-4.0739 \times 10^{-13} \times 49^5) + (3.1031 \times 10^{-10} \times 49^4) - (9.2501 \times 10^{-8} \times 49^3) + (1.4071 \times 10^{-5} \times 49^2) - (1.0677 \times 10^{-3} \times 49) + 1.0295$$

$$c_p = 1.002 \text{ Btu/lbm} \cdot ^\circ\text{F}$$

Calculate net refrigerating capacity

$$q_{ev} = (598,700) \times (1.002) \times (54 - 44) = 5,998,974 \text{ Btu/hr}$$

Calculate tons of refrigeration

$$\text{tons}_R = \frac{5,998,974}{12,000} = 500 \text{ Tons of Refrigeration}$$