Heat Balance

AHRI 550/590-2011 SECTION 6.4.1

To verify the validity of a water-cooled chiller performance test, AHRI 550/590-2011 requires the Heat Balance to be calculated at each load point proving energy in the system equals energy out of the system within allowable tolerance.

HEAT BALANCE EQUATIONS AND SAMPLE CALCULATIONS

Omitting the effect of small heat losses and gains, the general heat balance equation is:

$$q'_{ev} + (w_{input}) \times 3412.14 = q'_{cd} + q'_{hrc} \qquad \text{(equation C15)}$$

Percent Heat Balance, which is calculated during the water-cooled chiller performance test and documented in the test data, is defined as:

$$HB = \frac{[q'_{ev} + (w_{input}) \times 3412.14] - (q'_{cd} + q'_{hrc})}{q'_{cd} + q'_{hrc}} \times 100\% \qquad \text{(equation C17)}$$

Where q'_{ev} = gross refrigerating capacity of the evaporator, Btu/h
q'_{cd} = gross heating capacity of the condenser, Btu/h
q'_{hrc} = gross heating capacity of the heat reclaim condenser, Btu/h
w_{input} = power input, kW

The gross refrigerating capacity and gross heating capacity are obtained by using the following equations:

$$q'_{ev} = m_w \left[c_p \times (t_e - t_l) + \frac{K_3 \times \Delta p}{\rho}\right] \qquad \text{(equation C18)}$$

$$q'_{cd} \text{ and } q'_{hrc} = m_w \left[c_p \times (t_l - t_e) - \frac{K_3 \times \Delta p}{\rho}\right] \qquad \text{(equation C19a and C19b)}$$

Where m_w = mass flow rate of the heat exchanger, lbm/h
c_p = specific heat at the average of entering & leaving water temperatures of the heat exchanger, Btu/lbm • °F
t_e = entering water temperature of the heat exchanger, °F
t_l = leaving water temperature of the heat exchanger, °F
K_3 = constant = 0.18505
Δp = water side pressure drop of the heat exchanger, psid
ρ = water density at the average of entering and leaving water temperatures of the heat exchanger, lbm/ft^3

The power input, W_{input}, for the Heat Balance equation is calculated using the kW measured at the starter, and the efficiency of the motor for air-cooled motors.

Hermetic Motors: $W_{input} = kW_{measured}$

Air-Cooled Motors: $W_{input} = kW_{measured} \times$ % motor efficiency

HEAT BALANCE EQUATIONS AND SAMPLE CALCULATIONS *(continued)*

Using a typical chiller arrangement with one evaporator, one compressor, one condenser and no heat reclaim condenser, the Heat Balance percent equation is as follows:

$$\textbf{Percent Heat Balance = HB =} \frac{[q'_{ev} + (w_{input}) \times 3412.14] - q'_{cd}}{q'_{cd}} \times 100\%$$

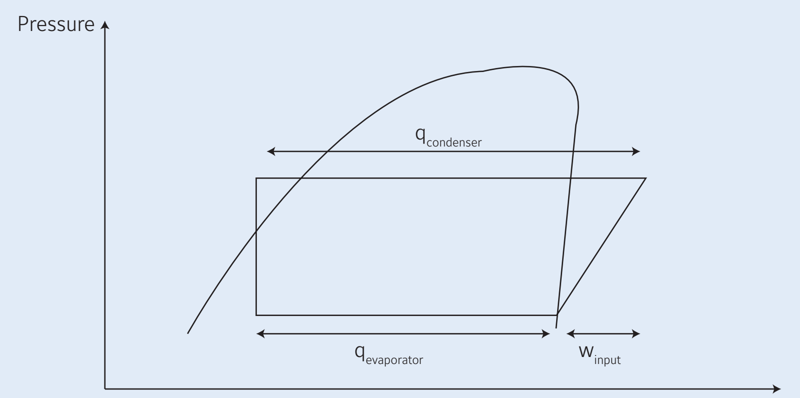
The pressure enthalpy diagram to the right shows the concept of heat balance in a vapor compression cycle

$q_{condenser}$ = heat rejected

$q_{evaporator}$ = cooling load

w_{input} = power input, compressor

The work done by the evaporator to handle the cooling load plus the work done by the compressor is balanced by the work done by the condenser rejecting the cooling load and compressor heat.



Pressure Enthalpy Diagram

evaporator	**condenser**
t_e = 54°F	t_e = 85°F
t_l = 44°F	t_l = 95°F
flow = 1196 GPM	flow = 1380 GPM
Ðp = 16 ftH_2O = 6.93 psid	Ðp = 9.5 ftH_2O = 4.11 psid
K_3 = constant = 0.18505	k_3 = constant = 0.18505
ρ = 62.42817097 (equation 20)	ρ = 62.12998818 (equation 20)
c_p = 1.001758319 (equation 21)	c_p = 0.997902713 (equation 21)

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

m_w = 598,866 lbm/h	**m_w = 687,698 lbm/h**
$q'_{ev} = m_w \left[c_p \times (t_e - t_l) + \frac{K_3 \times \Delta p}{\rho}\right]$	$q'_{cd} = m_w \left[c_p \times (t_l - t_e) - \frac{K_3 \times \Delta p}{\rho}\right]$
q'_{ev} = 6,011,492 Btu/h	**q'_{cd} = 6,854,139 Btu/h**

$kW_{measured}$ = 281 kW % motor efficiency = 98%

W_{input} = 281 kW x 98% = 275 kW

$$\textbf{Percent Heat Balance = HB =} \frac{[6{,}011{,}492 + (275) \times 3412.14] - 6{,}854{,}139}{6{,}854{,}139} \times 100\% = 1.40\%$$

PUBL-7282 (0214) Supersedes: Nothing