ClimaCheck Calculation Summary

The ClimaCheck system monitors temperatures at various points in the refrigeration cycle, the high and low pressure, and the electrical power of the compressor and condenser fans. Calculated values include coefficient of performance (COP) in cooling and heating mode, cooling and heating capacity, refrigerant mass flow, and isentropic efficiency of compressors. In addition, the superheat and subcooling are derived using measured temperatures and pressures. By introducing ambient temperature and required temperature at load side of the condenser and evaporators, total system efficiency can be measured and used for benchmarking and detection of deterioration of performance.

The four steps of the basic vapor-compression cycle – compression, condensation, expansion, and evaporation – are illustrated on a pressure-enthalpy (p-h) diagram, shown in Figure 1. The first step in calculations is to determine the enthalpies at each point from tables or equations of thermodynamic properties for the particular refrigerant. Refer to Table 1, for description of the numbered points in Figure 1.

Pressure is measured at points 1 and 2 at the suction and discharge of the compressors, respectively. Temperature is measured at points 1, 2, 3, 5, 6, and 7. Note pressure from points 2 to 7 are approximately equal and the enthalpies at point 7 and 8 at the inlet and outlet of the expansion device are equal.

Figure 1. Pressure-enthalpy diagram for basic refrigeration cycle, neglecting pressure drops

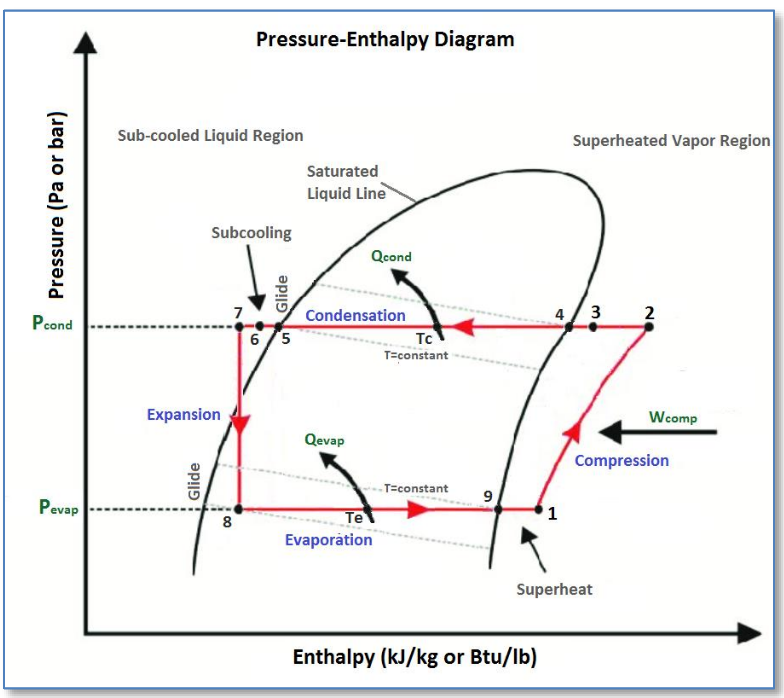

Table 1. Figure key to pressure-enthalpy (p-h) diagram

Point in p-h Diagram	Description
1	Compressor inlet
2	Compressor outlet
3	Condenser inlet (Difference between points 2 and 3 accounts for pressure drop and heat loss between compressor and condenser.)
4	Dew point at condenser pressure; condensation commences
5	Bubble point at condenser pressure; condensation complete
6	Condenser outlet
7	Expansion valve inlet
8	Evaporator inlet
9	Evaporator outlet (Point 9 and point 1 are same if heat pick up and pressure drop between evaporators and compressor is not considered.)
e	Evaporation midpoint $T_e = (T_8 + T_9)/2$ = average of temperature at evaporator inlet and dewpoint temperature at evaporation pressure
c	Condensation midpoint $T_c = (T_5 + T_4)/2$ = average of dewpoint temperature and bubble temperature at condensing pressure

ClimaCheck also uses a heat loss factor F_{HL} to account for heat loss from the shell of the compressor with no external cooling. This can vary depending on whether the compressor has liquid cooling, oil cooling, an external motor, or head fans, which blow air over the compressor head. The ClimaCheck default setting for the heat loss factor is 7%, which is based on research with manufacturers. Manufacturers report heat losses ranging from 6% to 10% with 7% being typical.

From these measurements and using equations of thermodynamic properties relating pressure, temperature, enthalpy, and entropy, the following is determined:

- Compressor power or work W_{comp} is measured and set equal to mass flow m times the enthalpy difference across the compressors: W_{comp}=m (h_2-h_1)
    - Refrigerant mass flow is calculated: $m = W_{comp}/(h_2-h_1)$
- The heating capacity of the system is the heat rejected in condensation: $Q_{cond} = m\ (h_3-h_6)$
- Enthalpies in and out of the expansion device are equal: $h_7=h_8$
- Cooling capacity is the heat absorbed in evaporation: $Q_{evap}=m\ (h_1-h_8)= m\ (h_1-h_7)$
- Cooling coefficient of performance is heat absorbed in evaporation divided by the compressor work: $COP_{cool} = Q_{evap}/W_{comp} = (h_1-h_7)/ (h_2-h_1)$
- Heating coefficient of performance is the heat rejected in condensation divided by the compressor work: $COP_{heat} = Q_{cond}/W_{comp} = (h_3-h_6) /(h_2-h_1)$
- Isentropic efficiency of the compressors is $E=(h_{2s}-h_1)/(h_2-h_1)\ (1- F_{HL})$where point 2s is at the condenser pressure (high pressure) and has the same entropy as point 1. F_{HL} is the percent heat loss from the shell of the compressor.

The condensation midpoint temperature T_c is the mean of the bubble point temperature (point 5) and the dew point at the condenser pressure (point 4). The evaporation midpoint temperature T_e is the mean between the dew point at the low pressure (point 9) and the evaporation inlet (point 8). T_c and T_e are determined from equations for saturation temperature at the high pressure and low pressure, respectively.

Subcooling is the difference between the bubble point temperature T_5 at the condensing pressure and temperature at the inlet of the expansion device T_7. Superheat is the difference between the dew point temperature at point 9 at the evaporator pressure and the temperature at the inlet of the compressor at point 1. Thus,

- Subcooling = T_5 - T_7
- Superheat = T_1 – T_9

Some systems have a desuperheater, which recovers heat from the superheated refrigerant gas leaving the compressors to heat water. To calculate desuperheater capacity, refrigerant temperature is measured at the combined discharge leaving the compressors (before desuperheater) and entering the condenser. Desuperheater capacity is the mass flow multiplied by the enthalpy difference between these two points.