Refrigeration and Heat Pump Calculation

Project: ______________ Part/Position: ______________ Prepared by: ______________

Sample document - numeric values are only included in the purchased Pro export.

Overall assessment: OK - the second-law efficiency eta_G stays within the empirical range of – – – to – – – for real vapour-compression plants.

Inputs

Operating mode	– – –
Given refrigerating capacity Q_0	– – – kW
h_1 evaporator outlet	– – – kJ/kg
h_2 compressor outlet	– – – kJ/kg
h_3 liquid ahead of the expansion valve	– – – kJ/kg
v_1* specific volume at the compressor inlet	– – – m^3/kg
Evaporating temperature t_0	– – – °C
Condensing temperature t_c	– – – °C

Assessment

Criterion	Value	Limit	Status
Second-law efficiency eta_G (guideline)	– – –	– – –	● within guideline

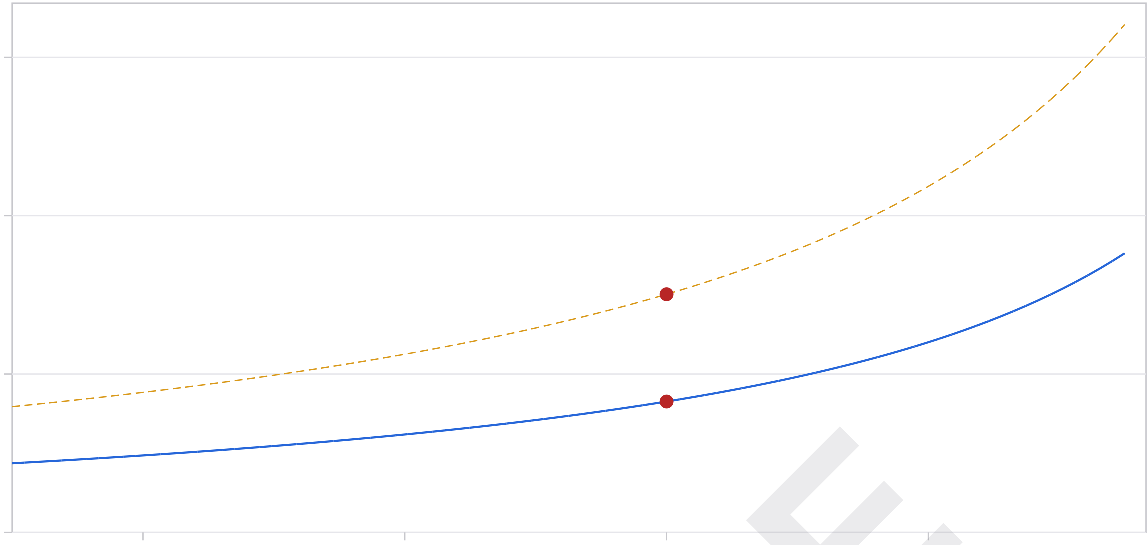
Duties and coefficients of performance

Refrigerating capacity Q_0	– – – kW
Compressor power P	– – – kW
COP refrigeration eps_K	– – –
COP heat pump eps_W	– – –

Characteristics

Carnot refrigeration eps_C,K	– – –
Carnot heat pump eps_C,W	– – –
Heating duty Q_c	– – – kW
Refrigerant flow m	– – – kg/s
Spec. refrigerating capacity q_0	– – – kJ/kg
Spec. compressor work w	– – – kJ/kg
Suction volume flow V	– – – m^3/h
Suction line heat flow Q_Saug	– – – kW

Coefficient of performance over the evaporating temperature



Calculation basis

The four states: the calculation covers the vapour-compression cycle built from four enthalpies read off the log p-h chart of the refrigerant - h_1 at the evaporator outlet, h_1^* at the compressor inlet, h_2 at the compressor outlet and h_3 for the liquid ahead of the expansion valve. The expansion is isenthalpic, so $h_4 = h_3$ is also the enthalpy at the evaporator inlet. Without a separate value for h_1^* the compressor draws exactly the evaporator outlet state.

Specific quantities: every component is balanced by the enthalpy difference across its own connections, $q_0 = h_1 - h_3$, $w = h_2 - h_1^*$ and $q_c = h_2 - h_3$. The refrigerating capacity thus arises in the evaporator alone, the compressor work only downstream of the suction line, and the condenser takes the hot gas back to the liquid enthalpy, covering desuperheating, condensation and subcooling.

Mass flow and duties: the specific refrigerating capacity q_0 links the plant size to the refrigerant flow, $m = Q_0/q_0$. From it follow $P = m \cdot w$, $Q_c = m \cdot q_c$ and, with the specific volume at the compressor inlet, the suction volume flow $V = m \cdot v_1^*$ that governs the compressor size.

Coefficients of performance and balance: the COP relates the benefit to the effort, $\varepsilon_K = Q_0/P$ for refrigeration and $\varepsilon_W = Q_c/P$ for the heat pump. If the suction gas picks up heat between evaporator outlet and compressor inlet, then $Q_{Saug} = m \cdot (h_1^* - h_1)$; this heat ends up in the condenser without loading the compressor. The balance then reads $Q_c = Q_0 + P + Q_{Saug}$ and ε_W exceeds ε_K by more than one. This is why ε_W is always formed from the actual duties and never abbreviated as $\varepsilon_K + 1$.

Carnot comparison and second-law efficiency: the Carnot cycle between the same temperature levels gives the upper bound, $\varepsilon_{C,K} = T_0/(T_c - T_0)$ and $\varepsilon_{C,W} = T_c/(T_c - T_0)$ with T in kelvin. The second-law efficiency $\eta_G = \varepsilon_K/\varepsilon_{C,K}$ classifies the COP achieved within that frame. The curve over the evaporating temperature follows from the Carnot curve with the second-law efficiency of the operating point assumed constant, $\varepsilon(t_0) = \eta_G \cdot \varepsilon_C(t_0)$; the enthalpies read off the chart are valid for exactly one pair of temperatures.

Validity: steady vapour-compression cycle from four enthalpies read off the chart, isenthalpic expansion, piping outside the suction line assumed free of heat pickup and pressure drop. The output is the internal compressor power, not the coupling or motor power; drive and fan power are not contained in the coefficients of performance. The classification of the second-law efficiency (empirical range – – – to – – –) is an empirical value for real vapour-compression plants and not a verification against a standard. Source of the relations and the worked figures: Langeheinecke/Jany/Thieleke, Thermodynamik für Ingenieure, 6th edition, worked example – – –, pp. 200 f.