V.4.1. Elementary Summer Air-Conditioning System

Figure V.33. shows the most elementary form of a summer-comfort air conditioning system: a cooling coil is the only processing device. This coil would be finned-tube type with the cooling medium being either chilled water or an evaporative refrigerant.

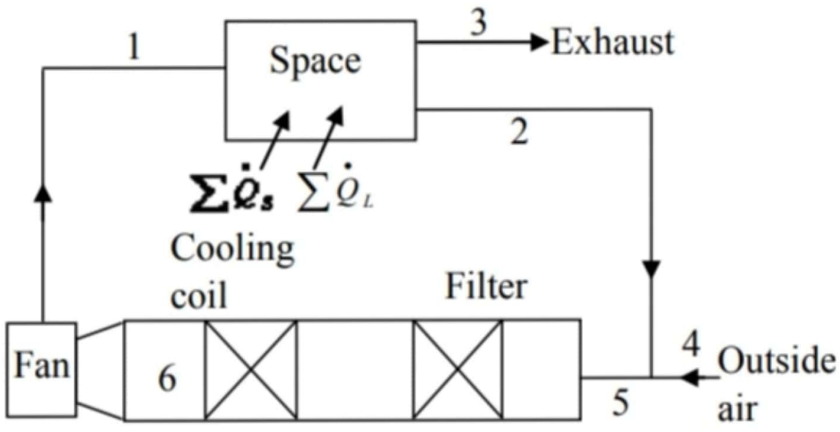


Figure V.33. Schematic representation for elementary summer air conditioning system (Kuehn, Ramsey and Threlkeld, 1998)

The steady- flow energy, entropy, exergy and material- balance equations are

Dry air mass balance

$$\dot{m}_{a1} = \dot{m}_{a2} + \dot{m}_{a3} \qquad \text{(V.51a.)}$$

$$\dot{m}_{a5} = \dot{m}_{a2} + \dot{m}_{a4} \qquad \text{(V.51b.)}$$

$$\dot{m}_{a1} = \dot{m}_{a5} = \dot{m}_{a6} = \dot{m}_{a7} \qquad \text{(V.51c.)}$$

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Energy balance

$$\dot{m}_{a5} h_5 = \dot{m}_{a7} h_7 + \dot{Q}_{out} \qquad \text{(V.52.)}$$

Entropy balance

$$\dot{m}_{a5} s_5 - \dot{m}_{a7} s_7 - \dot{Q}_{out} / T_6 + \dot{S}_{gen} = 0 \quad \text{(T is Kelvin)} \qquad \text{(V.53.)}$$

Exergy balance

$$\dot{m}_{a5} \psi_5 - \dot{m}_{a7} \psi_7 - \dot{Q}_{out} (1 - T_0 / T_6) - \dot{X}_{destroyed} = 0 \qquad \text{(V.54.)}$$

Exergy destroyed

$$\dot{X}_{destroyed} = T_0 \dot{S}_{gen} = T_0 \left(\dot{m}_{a7} s_7 + \dot{Q}_{out} / T_6 - \dot{m}_{a5} s_5 \right) \qquad \text{(V.55.)}$$

Exergy efficiency

$$\eta_{ex} = \frac{\dot{m}_{a7} \psi_7 + \dot{Q}_{out} (1 - T_0 / T_6)}{\dot{m}_{a5} \psi_5} = 1 - \frac{\dot{X}_{destroyed}}{\dot{m}_{a5} \psi_5} \qquad \text{(V.56.)}$$

Illustrative example: An elementary summer air conditioning system (Kuehn et. al., 1998) is considered using the values are:

$$T_{db2} = 26 [°C] \; ; \; \Phi_2 = 0{,}5 \; ; \; \dot{Q}_S = 10 \; [kW]; \; \dot{Q}_L = 2 \; [kW];$$
$$T_{db4} = 35 [°C] \; ; \; \Phi_4 = 0{,}6 \; ; \; T_{db6} = 10 [°C]; \; \Phi_6 = 1;$$
$$T_0 = 35 [°C] \; ; \; \Phi_0 = 0{,}6; \; P_o = 101{,}325 [kPa]; \; BF = 0{,}1667$$

T_{db2} , T_{db4} and T_{db6} are the dry bulb temperatures of state 2 , state 4 and state 6. Φ_2, Φ_4 and Φ_6 are the relative humdity of state 2, state 4 and state 6. $\dot{Q}_S$ is the sensible heat and $\dot{Q}_L$ is the latent heat. T_0 is the temperature and Φ_0 is the relative humidity of dead state. P_0 is the pressure of dead state.

Based on the balances (Eqs. V.51.-V.56.) and using EES with built-in thermodynamic functions we obtain following results:

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η_{ex}=0,08404; $SHR = 0,8$; $\dot{Q}_{out} = 18,14\ kj/s$; $\dot{X}_{dest}$=0,5882 kJ/s,
$\dot{S}_{gen}$=0,00191 kj/K; $T_5 = 28,25\ °C$; $\Phi_5 = 0,55$; $T_7 = 13,04\ °C$; $\Phi_7 = 0,9163$

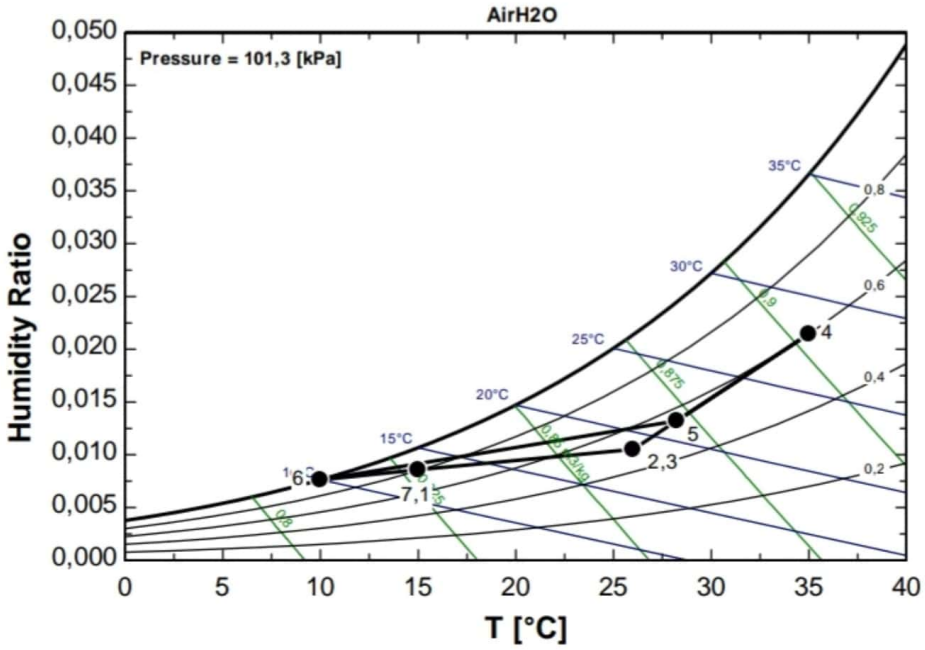


Figure V.34. Psychrometric process for elementary summer air conditioning process considered in the elementary summer air conditioning example

Figure V.34. shows that psychrometric process for elementary summer air conditioning process. The exergy efficiency of the process is calculated to be 8,404%, which is low. Figure V.35. shows that increasing the dry-bulb temperature of state 2 decreases rapidly exergy efficiency and increases linearly dry-bulb temperature of state 5.

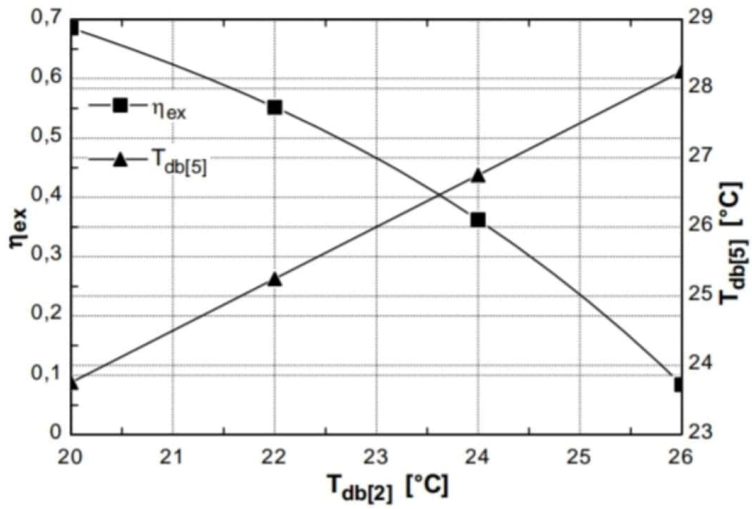


Figure V.35. Effect of temperature of space on exergy efficiency and temperature of mixing air for elementary summer air conditioning process considered in the elementary summer air conditioning example

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The sensible heat increases, both exergy efficiency and dry-bulb temperature of state 7 decreases rapidly and then slowly, as shown in Figure V.36.

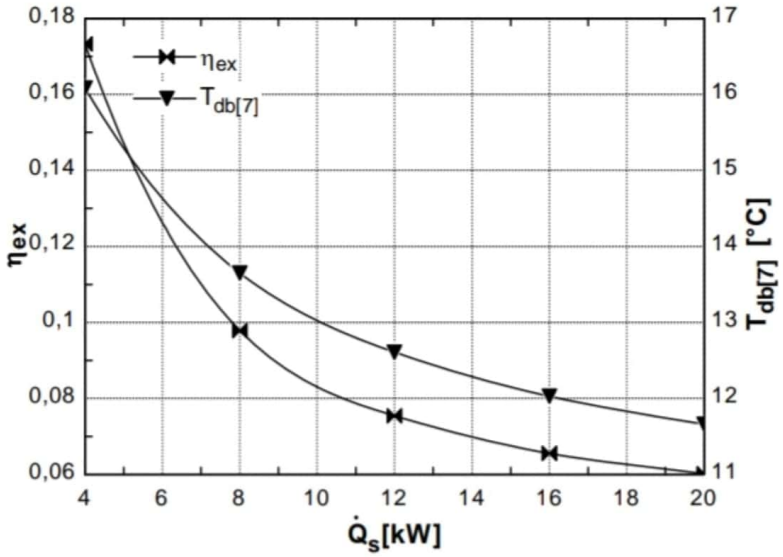


Figure V.36. Effect of sensible heat on exergy efficiency and temperature of cooling coil outlet for elementary summer air conditioning process considered in the elementary summer air conditioning example

The latent heat increases, exergy efficiency increases rapidly and sensible heat ratio decreases rapidly, as shown in Figure V.37.

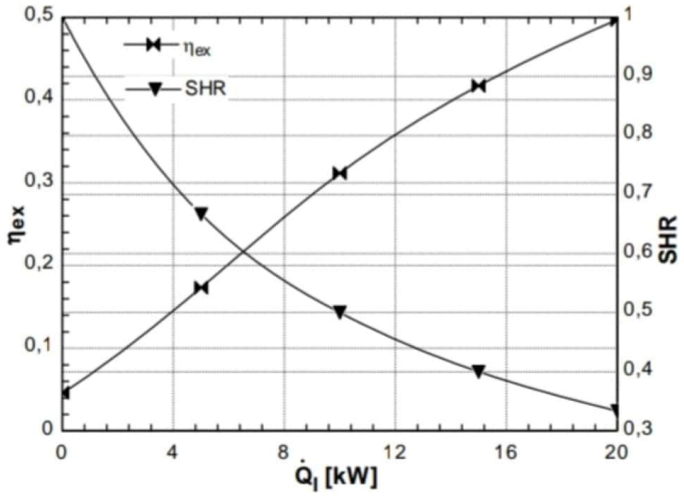


Figure V.37. Effect of latent heat on exergy efficiency and sensible heat ratio for elementary summer air conditioning process considered in the elementary summer air conditioning example

The dry-bulb temperature of state 4 increases, heat loss increases rapidly and dry-bulb temperature of state 5 increases linearly, as shown in Figure V.38.

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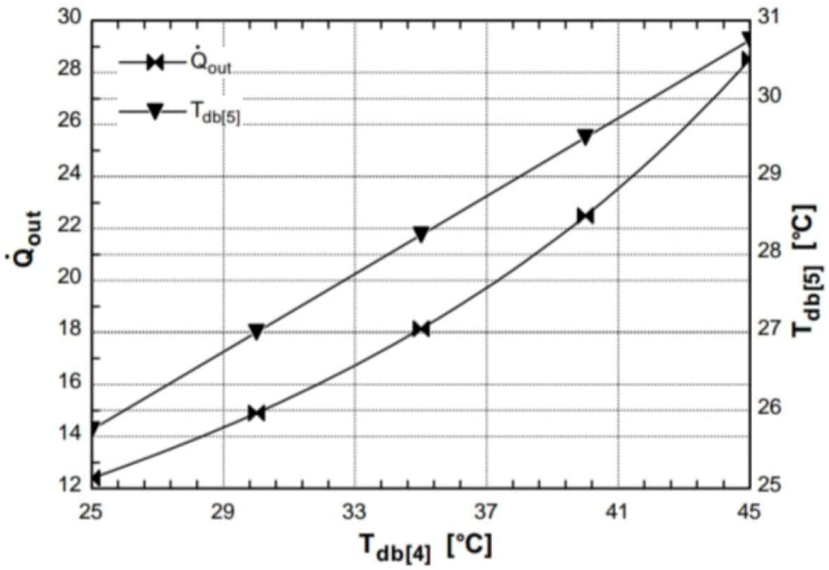


Figure V.38. Effect of temperature of outdoor air on exit heat and temperature of mixing air for elementary summer air conditioning process considered in the elementary summer air conditioning example

Figure V.39. shows that increasing the sensible heat decreases rapidly and then slowly exergy efficiency and mass flow rate of the system increases.

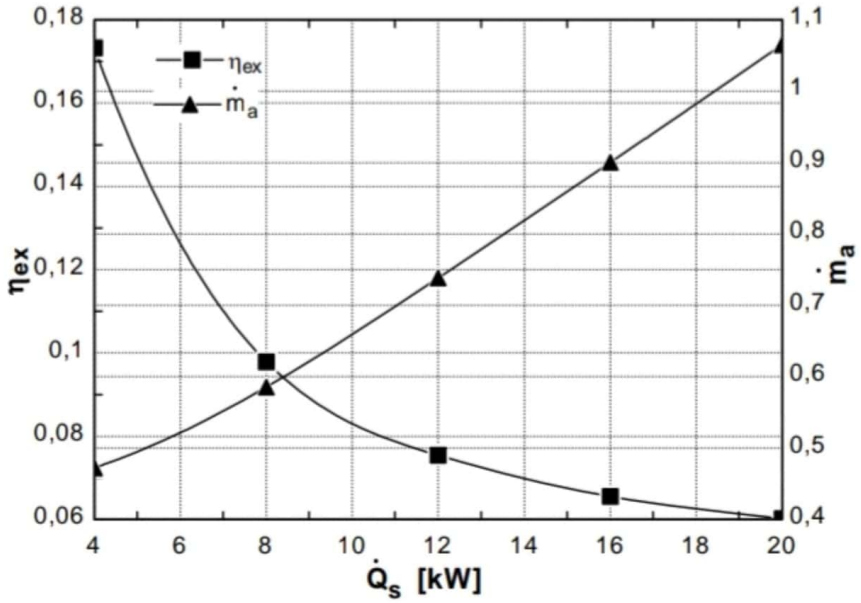


Figure V.39. Effect of sensible heat on exergy efficiency and mass flow rate of the system for elementary summer air conditioning process considered in the elementary summer air conditioning example

Figure V.40. shows that increasing the supply air temperature increases exergy efficiency and the bypass factor of cooling coil.

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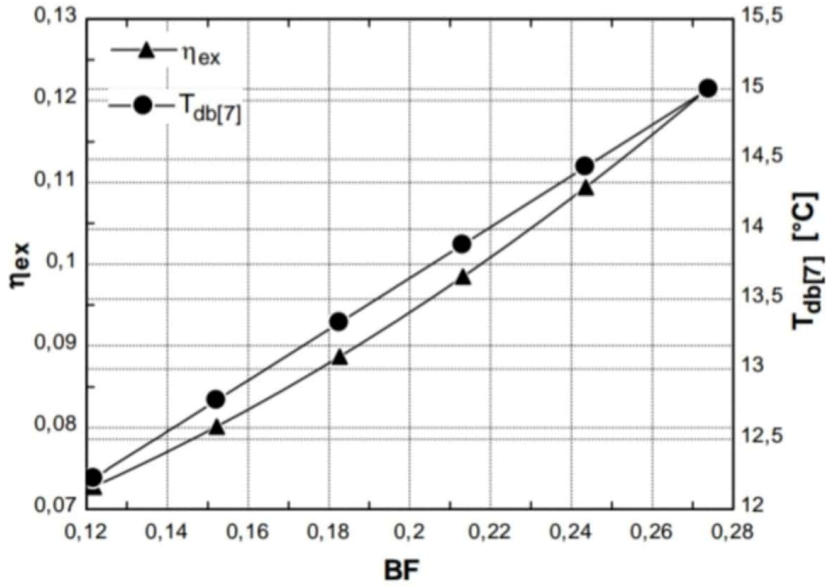


Figure V.40. Effect of bypass factor of the cooling coil on exergy efficiency and cooling coil outlet air temperature for elementary summer air conditioning process considered in the elementary summer air conditioning example

Figure V.41. shows that increasing the dead state temperature increases exergies of the state 1-state 2, state 5-state 6 and state 6-state 7.

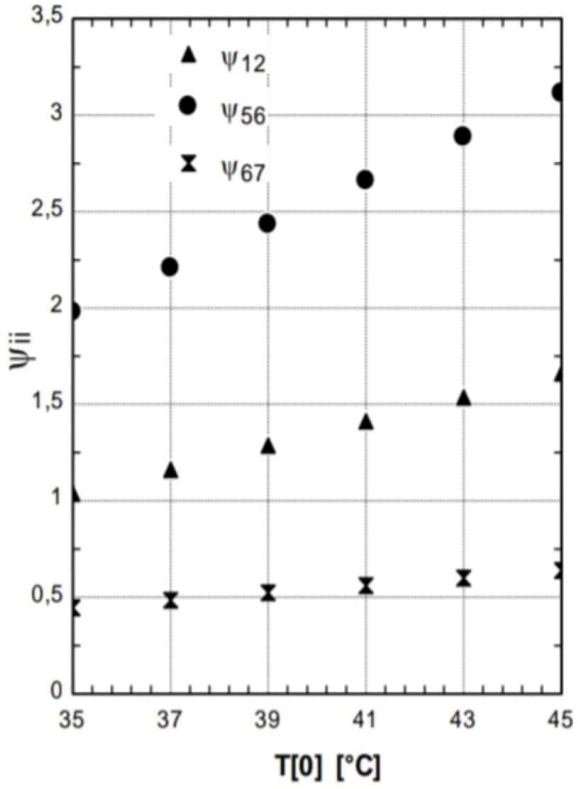


Figure V.41. Effect of dead state temperature on exergies of state 1-2, state 5-6 and state 6-7 for elementary summer air conditioning process considered in the elementary summer air conditioning example

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Figure V.42. shows that increasing the dead state temperature increases rapidly and then slowly exergy efficiency. As the relative humidity of the dead state increases sligthly with increasing dead state temperature while it does not change with dead state relative humidity.

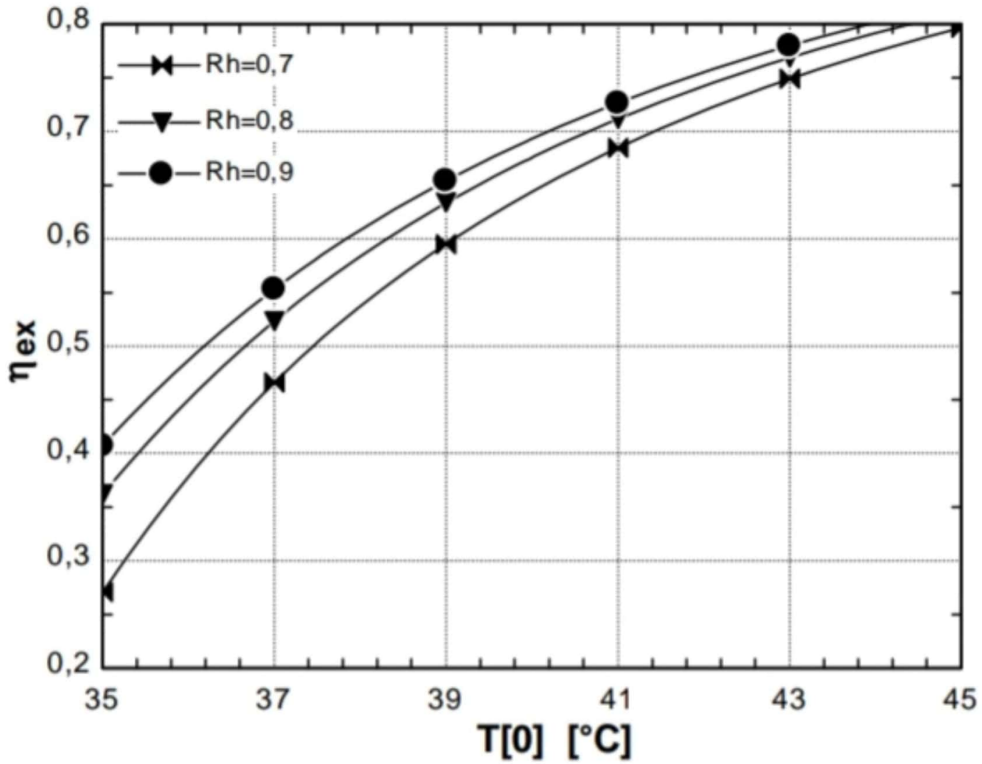


Figure V.42. Effect of dead state temperature and relative humidity on exergy efficiency for elementary summer air conditioning process considered in the elementary summer air conditioning example

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