20 °C

Example 6.12: Heat Exchanger (2)
The steam in the previous example is cooled using water at 1 bar, ~~25~~ °C. The cooling water emerges at 40 °C at the exit of the heat exchanger. Determine the heat load and the entropy generation. Compare the result with the previous example.

Solution This example differs only in that the stream that absorbs the heat from the steam is now specified. We collect the properties of cold water from the steam tables approximating the enthalpy and entropy of the compressed liquid with those of the saturated liquid at the same temperature:

	T (°C)	P (bar)	H (kJ/kg)	S (kJ/kg K)
$1'$	20	1.0	83.92	0.2965
$2'$	40	1.0	167.54	0.5724

The heat load is the same as before:

$$Q = -297.9 \text{ kJ/kg}.$$

The entropy generation now involves a two streams and no bath:

$$\dot{S}_{\text{gen}} = \dot{m}\,(S_2 - S_1) + \dot{m}'(S'_2 - S'_1)$$

where $\dot{m}'$ is the mass flow rate of cold water. We obtain $\dot{m}'$ in terms of $\dot{m}$ through the energy balance. Noting that the sign of the heat must be reversed, the energy balance for the cold-water stream reads

$$-\dot{m}\,Q = \dot{m}'(H'_2 - H'_1) \quad \Rightarrow \quad \dot{m}' = \dot{m}\,\frac{-Q}{H'_2 - H'_1}$$

and by numerical substitution,

$$\dot{m}' = \dot{m}\,\frac{+297.9 \text{ kJ/kg}}{(167.54 - 83.92) \text{ kJ/kg}} = 3.56254\dot{m}\,.$$

Substitution into the entropy balance gives the entropy generation:

$$\begin{aligned} S_{\text{gen}} &= \dot{m}\,(7.6147 - 8.2171) \text{ kJ/kg K} + 3.56254\dot{m}\,(0.5724 - 0.2965) \text{ kJ/kg K} \\ &= \underline{0.381 \text{ kJ/kg K}}. \end{aligned}$$

Comments The entropy generation in this case is higher. This is because overall the temperature gradients between the steam and the cold water are higher compared to the bath, whose temperature is constant at 145 °C. The main point, however, is this: if the system that exchanges heat with the stream of interest is specified, the entropy generation is equal to the total change of entropy of all streams involved. If the system that exchanges heat with the system of interest is not specified, then one must make a suitable assumption as to the source or sink of that heat by invoking a heat bath.