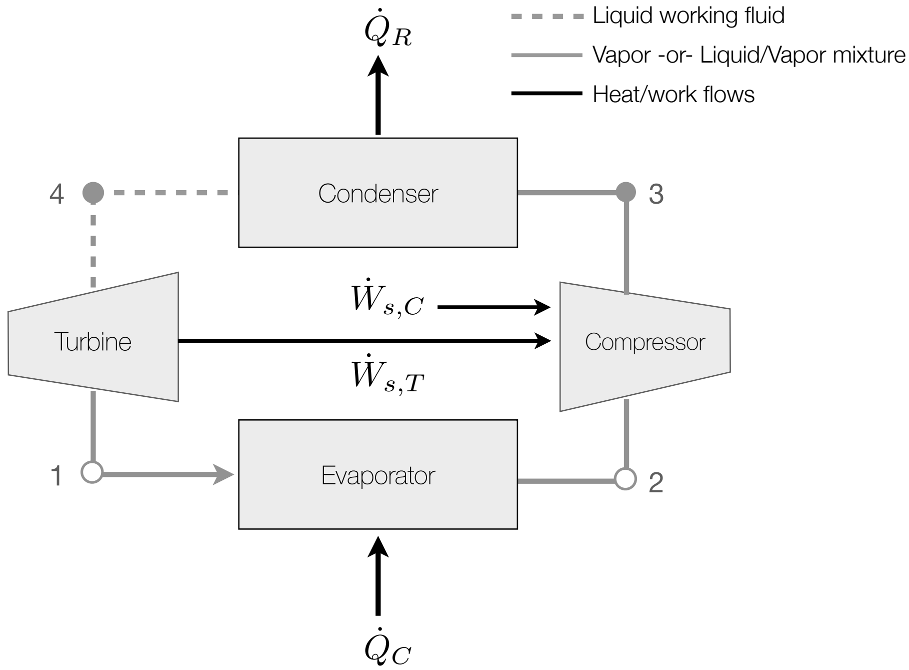

Figure 1: Schematic of a modified vapor compression refrigeration cycle (VCRC) where the throttle valve has been replaced by a turbine. The term $\dot{Q}_C$ (kW) denotes the cooling rate, while $\dot{Q}_R$ denotes the rate that is removed from the condenser.

1. (XX pt) The vapor compression refrigeration cycle (VCRC) is a four step *open* process to cool systems. The teaching team proposed a modification to the original cycle in which the throttle valve is replaced by a turbine which can supply work to the compression step (Fig. 1). In the modified cycle, $\mathcal{P}_{ij}$ connects operating point $\mathcal{O}_i$ to $\mathcal{O}_j$:

   $\mathcal{P}_{12}$ $(1 \rightarrow 2)$: *isobaric* heating in an evaporator from $\mathcal{O}_1$ to $\mathcal{O}_2$

   $\mathcal{P}_{23}$ $(2 \rightarrow 3)$: *adiabatic compression* in a compressor from $\mathcal{O}_2$ to $\mathcal{O}_3$

   $\mathcal{P}_{34}$ $(3 \rightarrow 4)$: *isobaric* cooling in a condenser from $\mathcal{O}_3$ to $\mathcal{O}_4$

   $\mathcal{P}_{41}$ $(4 \rightarrow 1)$: *adiabatic expansion* in a turbine from $\mathcal{O}_4$ to $\mathcal{O}_1$

   Assume: (i) the cycle operates at steady-state; (ii) the working fluid R134A has a mass flow rate of $\dot{m}$ = 0.167 kg s^{-1}; (iii) the turbine efficiency is η_T = 75%; (iv) compressor efficiency is η_C = 81%; (v) neglect changes in the kinetic and potential energy in the system and streams.

   a) (XX pt) Compute the missing state values in Table 1.
   b) (XX pt) Compute the missing heat and work rate values in Table 2.

c) (XX pt) Compute the reversible (ideal) coefficient of performance $\omega = \dot{Q}_C/\dot{W}_{s,C}$ using the values in Table 1.

d) (XX pt) Would you expect the ideal coefficient of performance to increase, decrease or stay the same if we did not recycle $\dot{W}_{s,T}$? (explain your answer).

Table 1: State table for the Vapor Compression Refrigeration Cycle (VCRC) problem using R134A as the working fluid. The quantity θ denotes the vapor quality (fraction of vapor).

$\mathcal{O}$	T (°C)	P (MPa/kPa)	H (kJ/kg)	S (kJ/kg-K)	θ
$\mathcal{O}_1$					
$\mathcal{O}_2$	-60	15.89 kPa		1.8024	1.0
$\mathcal{O}_3$					1.0
$\mathcal{O}_4$	70		304.8		0.0

Table 2: Path table for the modified refrigeration problem using R134A as the working fluid.

Path	$\dot{Q}_s$ (kW)	$\dot{W}_{s,T}$ (kW)	$\dot{W}_{s,C}$ (kW)	$\dot{W}^*_{s,T}$ (kW)	$\dot{W}^*_{s,C}$ (kW)
$\mathcal{P}_{12}$		0.0	0.0	0.0	0.0
$\mathcal{P}_{23}$	0.0				
$\mathcal{P}_{34}$		0.0	0.0	0.0	0.0
$\mathcal{P}_{41}$	0.0		0.0		
Cycle				N/A	N/A