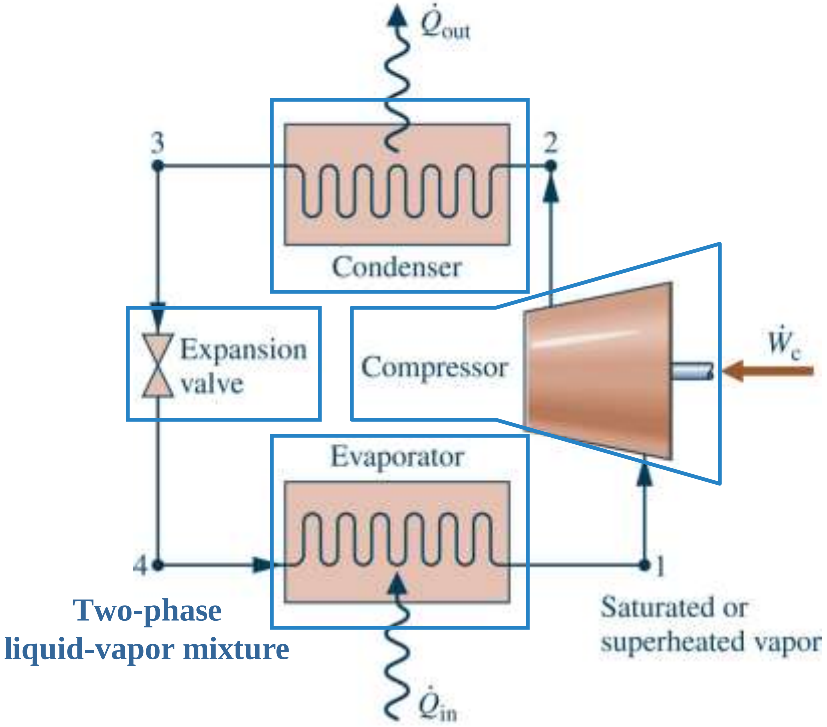
VAPOR COMPRESSION REFRIGERATION SYSTEM

VAPOR COMPRESSION REFRIGERATION CYCLE

Most common refrigeration cycle in use today

There are four principal control volumes involving these components:

- Evaporator
- Compressor
- Condenser
- Expansion valve

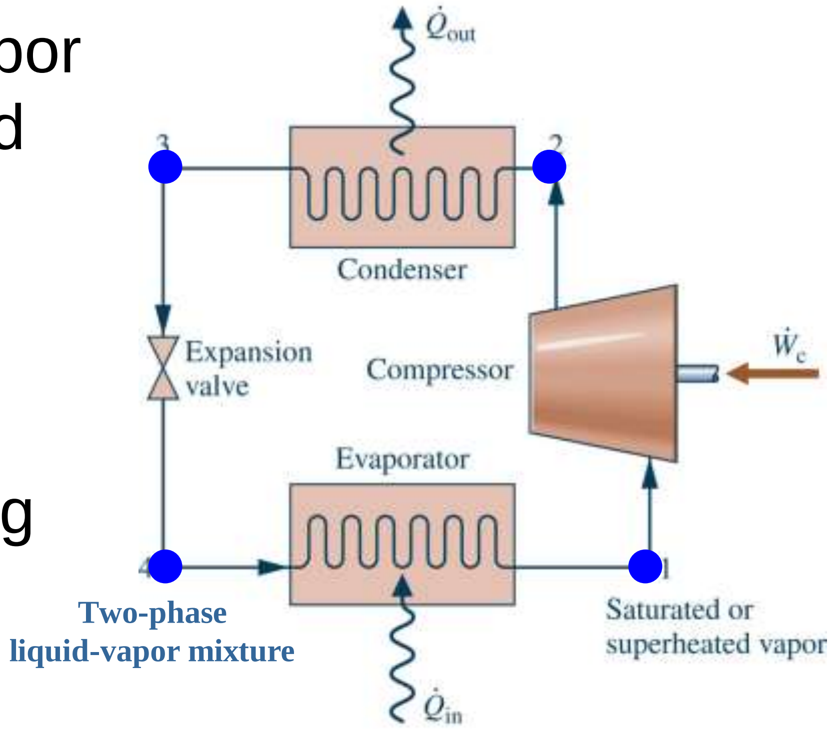


All energy transfers by work and heat are taken as positive in the directions of the arrows on the schematic and energy balances are written accordingly.

THE VAPOR-COMPRESSION REFRIGERATION CYCLE

- The processes of this cycle are

Process 4-1: two-phase liquid-vapor mixture of refrigerant is evaporated through heat transfer from the refrigerated space.
Process 1-2: vapor refrigerant is compressed to a relatively high temperature and pressure requiring work input.
Process 2-3: vapor refrigerant condenses to liquid through heat transfer to the cooler surroundings.
Process 3-4: liquid refrigerant expands to the evaporator pressure.



THE VAPOR-COMPRESSION REFRIGERATION CYCLE

Performance parameters

Coefficient of Performance (COP)

$$\text{C.O.P} = \frac{Q_{in}/\dot{m}}{\dot{W_c}/\dot{m}} = \frac{h_1 - h_4}{h_2 - h_1}$$

Carnot Coefficient of Performance

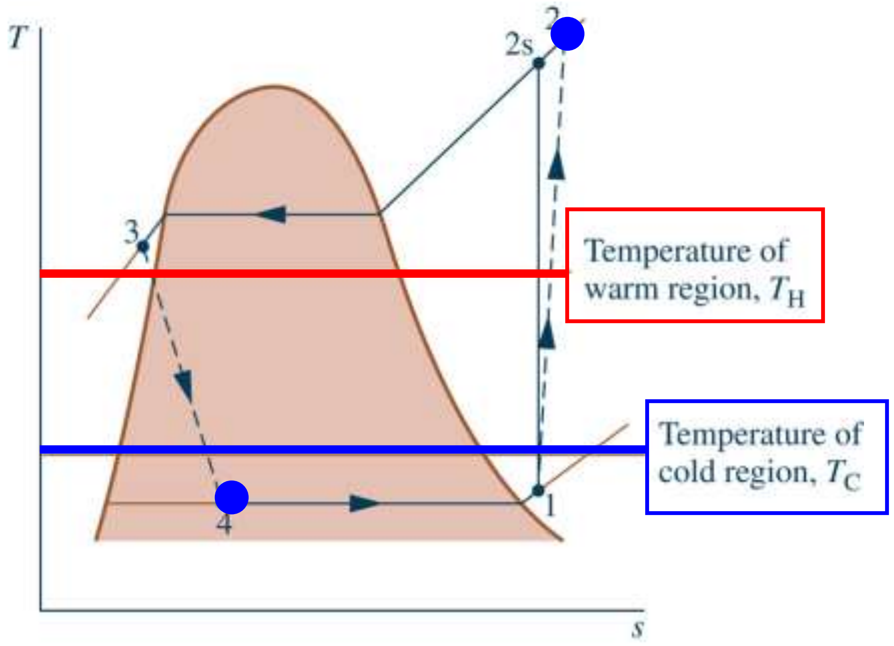
$$\text{C.O.P} = \frac{T_C}{T_H - T_C}$$

This equation represents the maximum theoretical coefficient of performance of any refrigeration cycle operating between cold and hot regions at $\boldsymbol{T_C}$ and $\boldsymbol{T_H}$, respectively.

FEATURES OF ACTUAL VAPOR-COMPRESSION CYCLE

Heat transfers between refrigerant and cold and warm regions are not reversible.

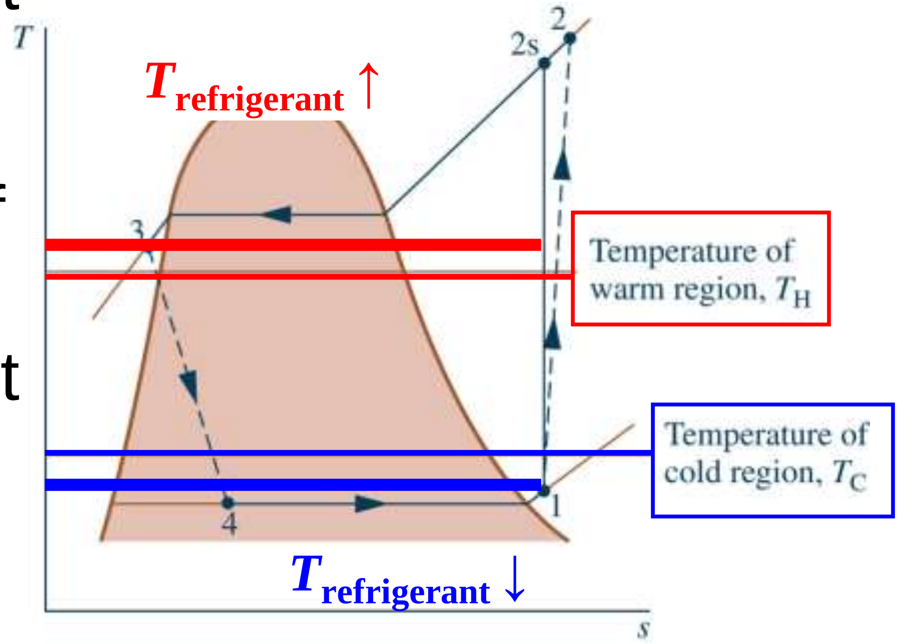
- Refrigerant temperature in evaporator is less than T_C.
- Refrigerant temperature in condenser is greater than T_H.
- Irreversible heat transfers have negative effect on performance.



FEATURES OF ACTUAL VAPOR-COMPRESSION CYCLE

The COP decreases – primarily due to increasing compressor work input – as the

- temperature of the refrigerant passing through the evaporator ***is reduced*** relative to the temperature of the cold region, T_C.
- temperature of the refrigerant passing

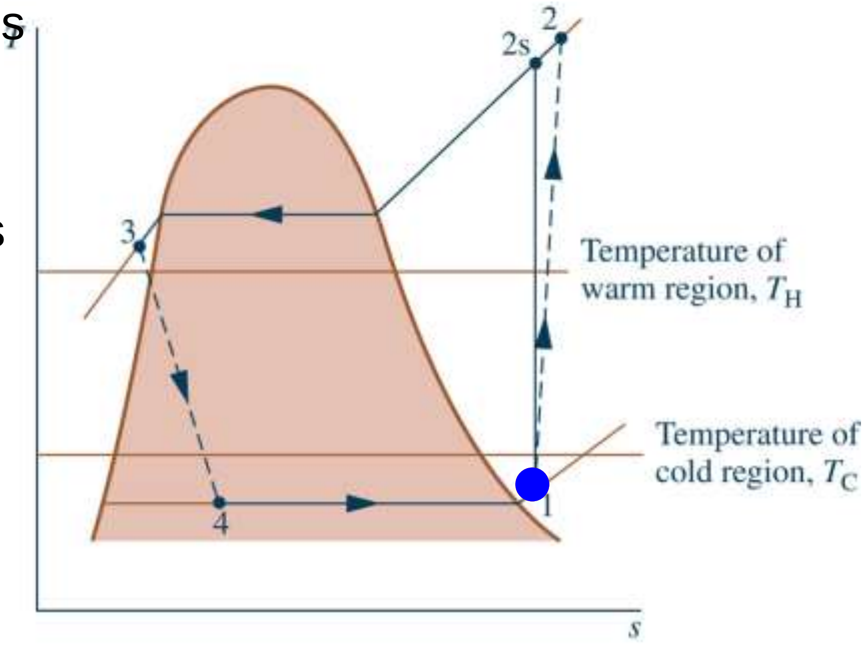


through the condenser ***is increased*** relative to the temperature of the warm region, T_H.

FEATURES OF ACTUAL VAPOR-COMPRESSION CYCLE

Irreversibilities during the compression process are suggested by dashed line from state **1** to state **2**.

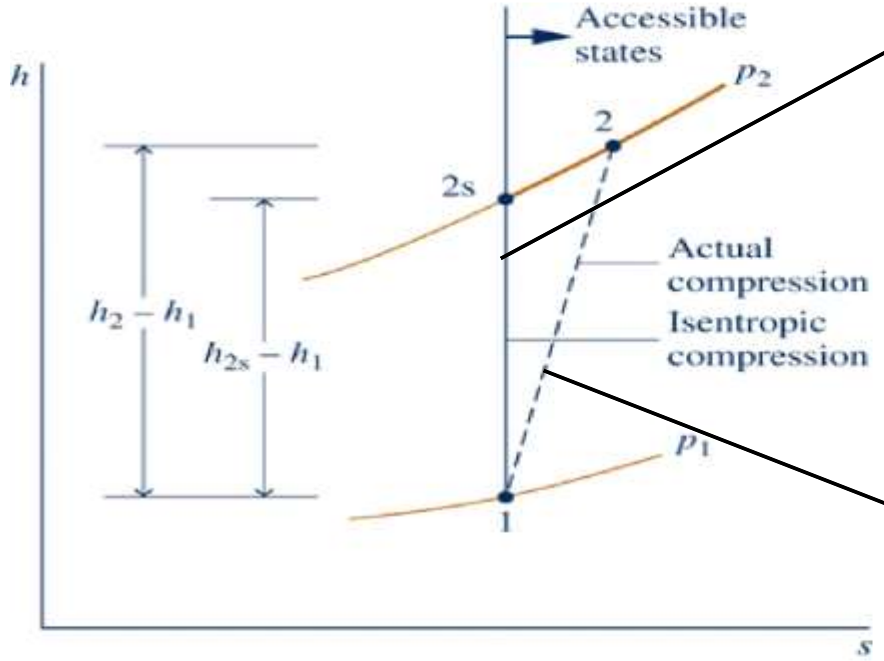
- An increase in specific entropy accompanies an adiabatic irreversible compression process. The work input for compression process **1-2** is greater than for the counterpart isentropic compression process **1-2s**.



- Since process **4-1**, and thus the refrigeration capacity, is the same for cycles **1-2-3-4-1** and **1-2s-3-4-1**, cycle **1-2-3-4-1** has the lower COP.

ISENTROPIC COMPRESSOR EFFICIENCY

The isentropic compressor efficiency is the ratio of the minimum theoretical work input to the actual work input, each per unit of mass flowing:



work required in an isentropic compression from compressor inlet state to the exit pressure

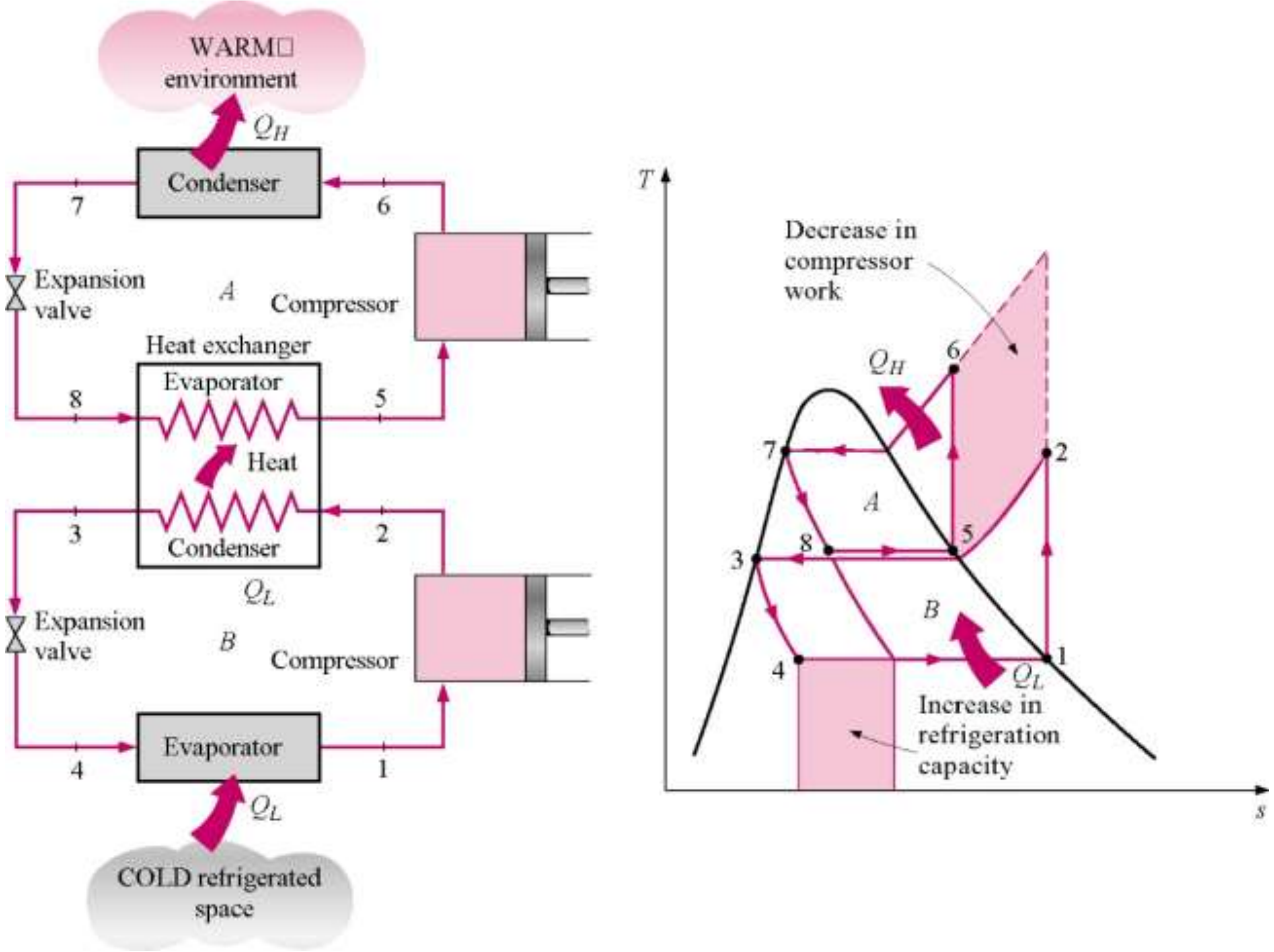
$$\eta_c = \frac{(-\dot{W}_{cv}/\dot{m})_s}{(-\dot{W}_{cv}/\dot{m})} = \frac{h_{2s} - h_1}{h_2 - h_1} \qquad \textbf{(Eq. 6.48)}$$

work required in an actual compression from compressor inlet state to exit pressure

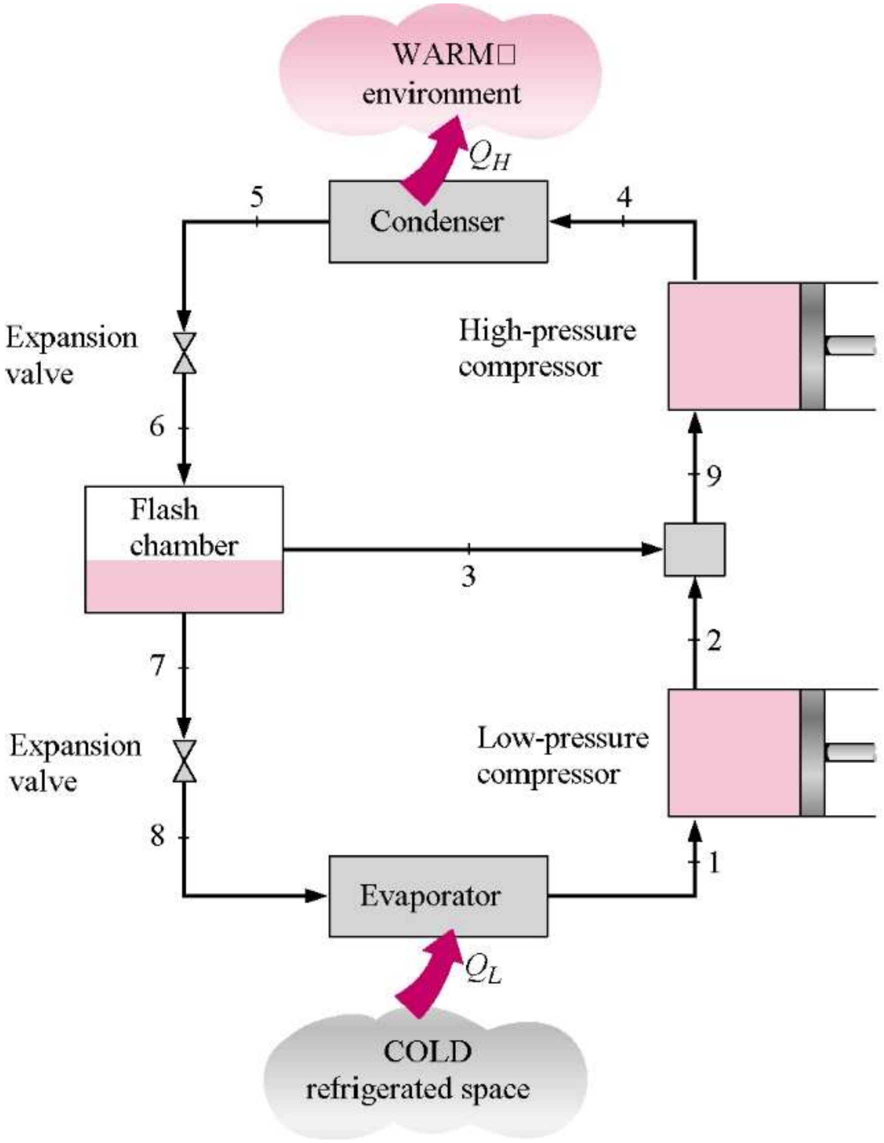
Other Refrigeration Cycles

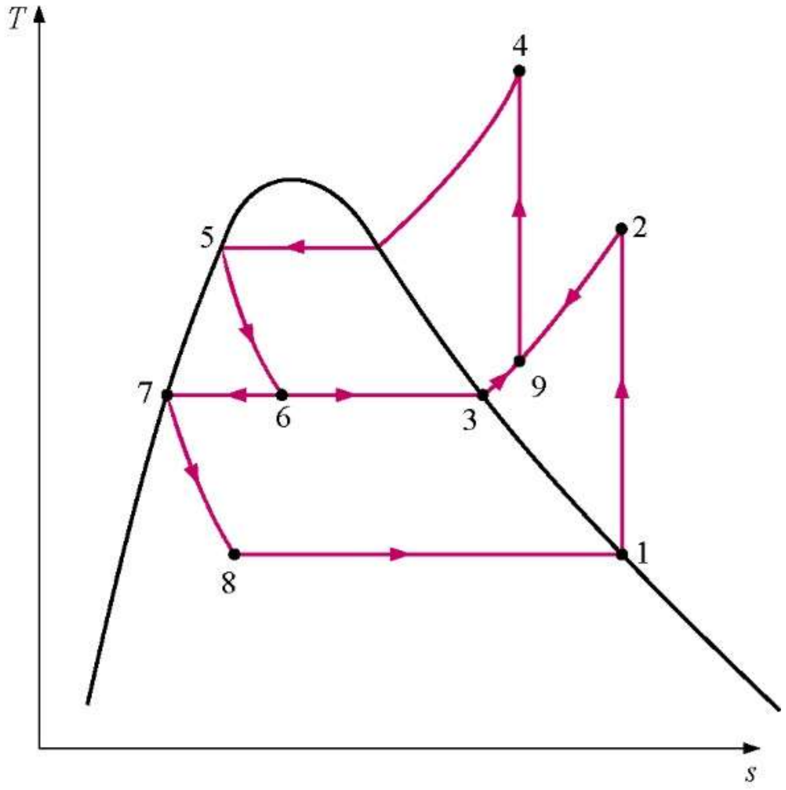
Cascade refrigeration systems

Very low temperatures can be achieved by operating two or more vapor-compression systems in series, called *cascading.* The COP of a refrigeration system also increases as a result of cascading.



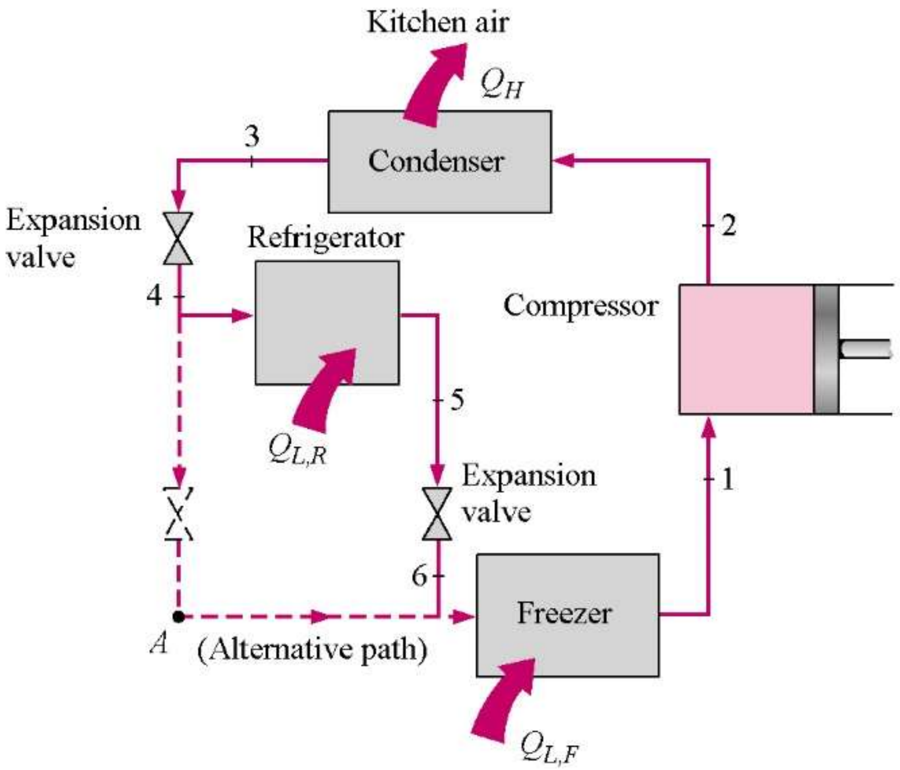
Multistage compression refrigeration systems

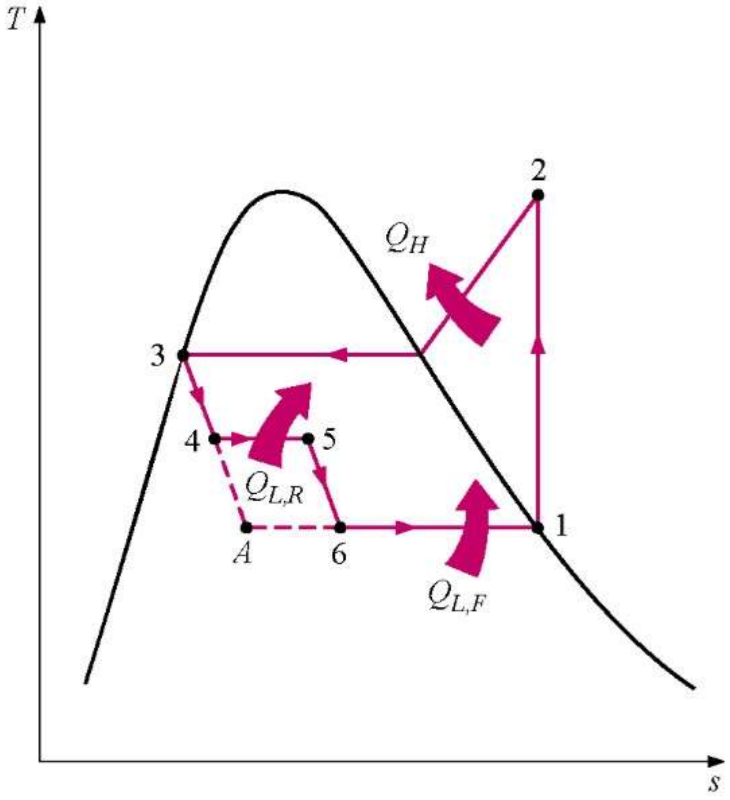




Multipurpose refrigeration systems

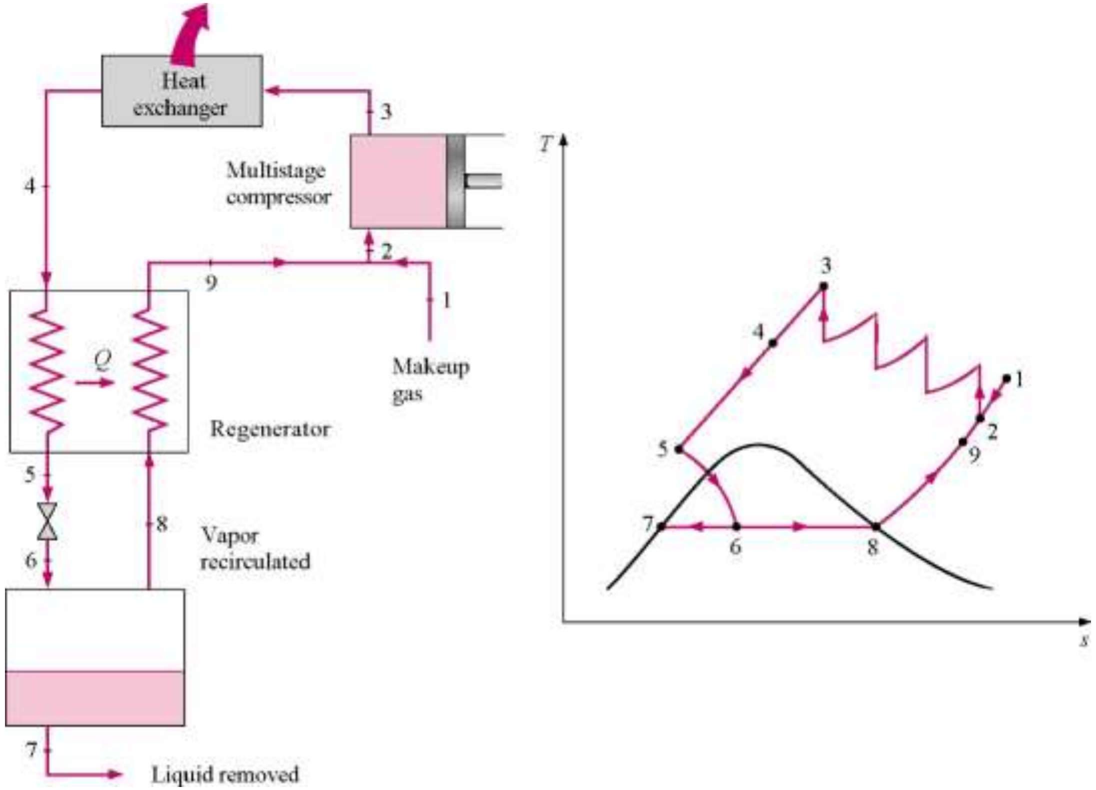
A refrigerator with a single compressor can provide refrigeration at several temperatures by throttling the refrigerant in stages.





Liquefaction of gases

Another way of improving the performance of a vapor-compression refrigeration system is by using *multistage compression with regenerative cooling.* The vapor-compression refrigeration cycle can also be used to liquefy gases after some modifications.



SELECTING REFRIGERANTS

- ►Refrigerant selection is based on several factors:
  - ►Performance: provides adequate cooling capacity cost-effectively.
  - ►Safety: avoids hazards (i.e., toxicity).
  - ►Environmental impact: minimizes harm to stratospheric ozone layer and reduces negative impact to global climate change.

REFRIGERANT TYPES AND CHARACTERISTICS

Refrigerant Data Including Global Warming Potential (GWP)

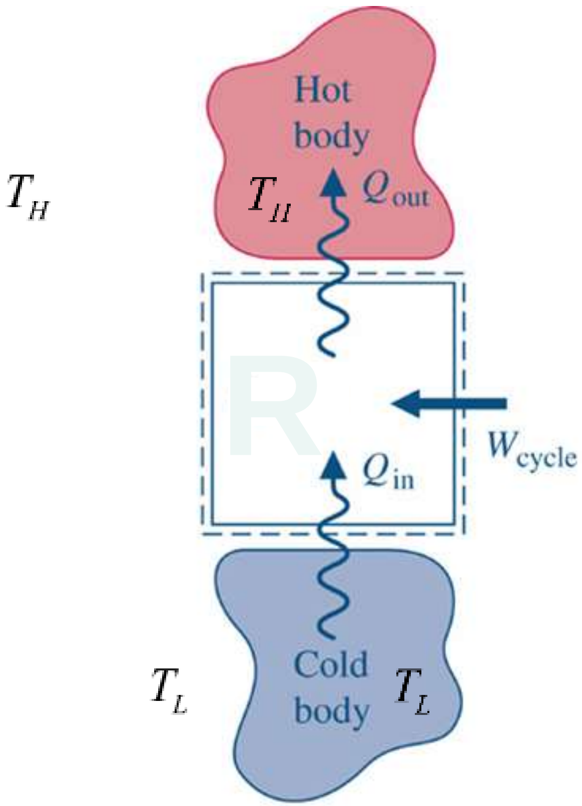
Refrigerant Number	Type	Chemical Formula	Approx. GWP
R-12	CFC	CCl_2F_2	10900
R-11	CFC	CCl_3F	4750
R-114	CFC	$CClF_2CClF_2$	10000
R-113	CFC	CCl_2FCClF_2	6130
R-22	HCFC	$CHClF_2$	1810
R-134a	HFC	CH_2FCF_3	1430
R-1234yf	HFC	$CF_3CF{=}CH_2$	4
R-410A	HFC blend	R-32, R-125 (50/50 Weight %)	1725
R-407C	HFC blend	R-32, R-125, R-134a (23/25/52 Weight %)	1526
R-744 (carbon dioxide)	Natural	CO_2	1
R-717 (ammonia)	Natural	NH_3	0
R-290 (propane)	Natural	C_3H_8	10
R-50 (methane)	Natural	CH_4	25
R-600 (butane)	Natural	C_4H_{10}	10

Global Warming Potential (GWP) is a simplified index that estimates the ***potential future influence on global warming*** associated with different gases when released to the atmosphere.

REFRIGERANT TYPES AND CHARACTERISTICS

- **Chlorofluorocarbons (CFCs) and Hydrochlorofluorocarbons (HCFCs)** are early synthetic refrigerants each containing chlorine. Because of the adverse effect of chlorine on Earth's stratospheric ozone layer, use of these refrigerants is regulated by international agreement.
- **Hydrofluorocarbons (HFCs) and HFC blends** are chlorine-free refrigerants. Blends combine two or more HFCs. While these chlorine-free refrigerants do not contribute to ozone depletion, with the exception of R-1234yf, they have high GWP levels.
- **Natural refrigerants** are nonsynthetic, naturally occurring substances which serve as refrigerants. These include carbon dioxide, ammonia, and hydrocarbons. These refrigerants feature low GWP values; still, concerns have been raised over the toxicity of NH_3 and the safety of the hydrocarbons.

VCR USED FOR COOLING



$$\eta_E = \frac{\text{energy sought}}{\text{energy that costs}} = \frac{Q_{in}}{W_{cycle}} = \mathrm{COP_C}$$

Observation: η_E may be $>1 \quad (\eta_E > 100\%)$

The concept of an efficiency being greater than 100% makes people uneasy. Therefore, the conversion efficiency for a refrigerator is called the **Cooling Coefficient of Performance (COP_C)**. A refrigeration system that is used for cooling is called a **refrigerator**.

ASSESMENT

In a refrigeration system, the expansion device is connected between the

(A) Compressor and condenser
(B) Condenser and receiver
(C) Receiver and evaporator
(D) Evaporator and compressor

ASSESMENT

The vapour compression refrigerator employs the following cycle

(A) Rankine
(B) Carnot
(C) Reversed Rankine
(D) Reversed Carnot