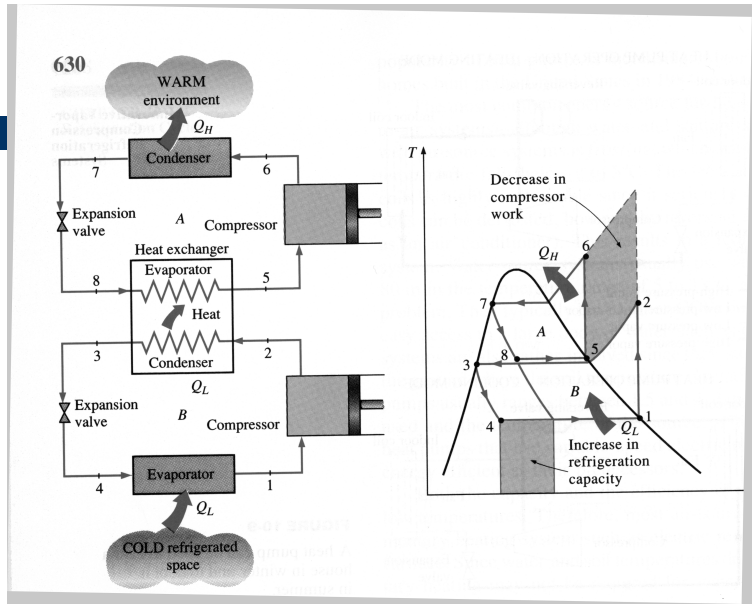
Multi-Pressure Refrigeration Systems

Figures from Refrigeration and Air Conditioning, 2.5 edition, by Stoecker and Jones and Thermodynamics:An Engineering Approach by Çengel and Boles

Cascade Refrigeration Systems

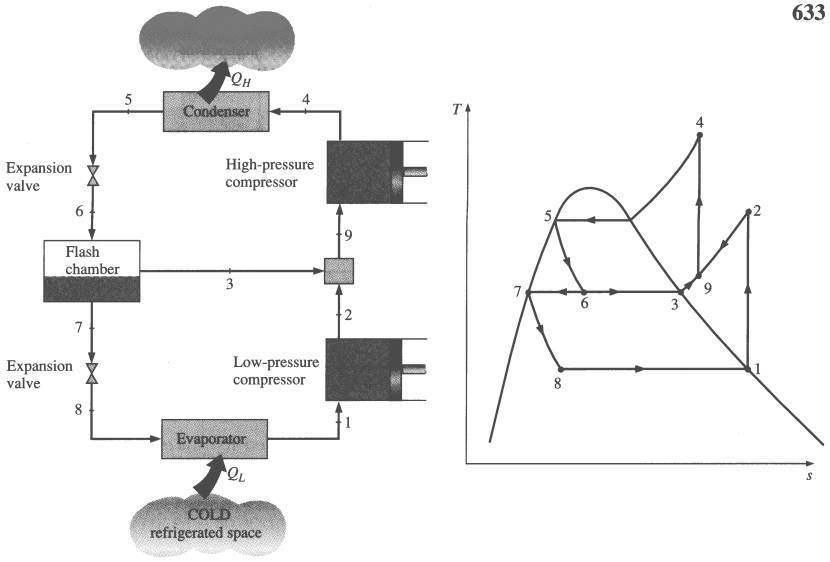
- Used in industrial applications where quite low temperatures are required
- The large temp difference requires a large pressure difference
- Compressors have low efficiencies for large pressure differences; this results in low system efficiency
- Refrigeration cycle is performed in stages
- The refrigerant in the two stages doesn't mix
- Higher efficiency results but also a higher first cost



From Cengel and Boles, Thermodynamics: An Engineering Approach

Multistage Compression Refrigeration

- Similar to a cascade system except the same fluid is used for both stages
- Compression is done in two stages with a mixing chamber in between.
- Expansion is also done in two stages. After the first expansion, a liquid/vapor mix is present.
- In the flash chamber, the saturated vapor is removed and sent to the mixing chamber while the liquid goes through the second expansion valve.
- Watch your mass flow rates! They're different in different parts of the cycle



From Cengel and Boles, Thermodynamics: An Engineering Approach

Benefits of Flash Gas Removal

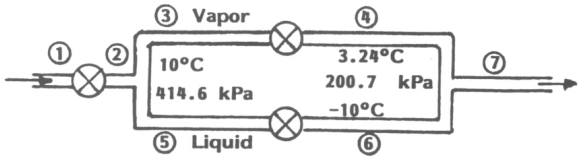


TABLE 17.2
Power required with and without flash gas removal at 2°C when the evaporating temperature is −20°C and the condensing temperature is 30°C for systems developing 100 kW of refrigeration.

Refrigerant	Compressor power, kW (no flash-gas removal)	Compressor power, kW (With flash-gas removal)			Percent saving
		Flash gas	Main	Total	
Ammonia	24.32	1.23	21.70	22.93	5.7
R-22	24.78	2.05	20.44	22.49	9.2
R-134a	25.20	2.50	19.85	22.35	11.3

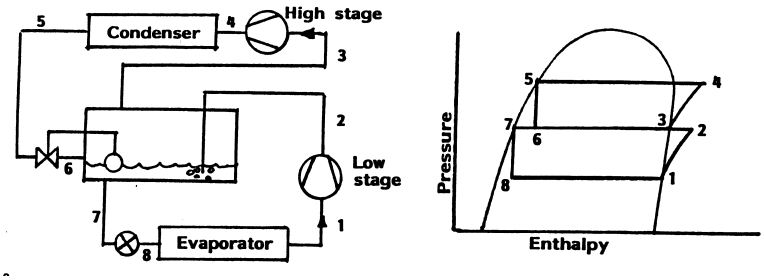
Here ammonia is best

Here R-134a is best

For re-compression of flash gas

From Stoecker and Jones, Refrigeration and Air Conditioning

Flash Gas Removal Plus Intercooling



From Stoecker and Jones, Refrigeration and Air Conditioning

•This is a similar process, but the vapor at 2 is also cooled to the saturation temperature by bubbling it through the liquid in the flash tank. Vapor velocity must be less than 1 m/s for this setup to work well.

Flash Gas Removal Plus Intercooling

- Intercooling alone usually doesn't result in a power reduction for R-134a, but it does for some refrigerants like ammonia (~4%).
- Intercooling may also be done with an external liquid such as water.
- When intercooling and flash gas removal are combined, the savings is similar for most refrigerants.
- A rough estimate of the optimum intermediate pressure can be found from $P_{intermediate} = \sqrt{P_{suction} P_{discharge}}$

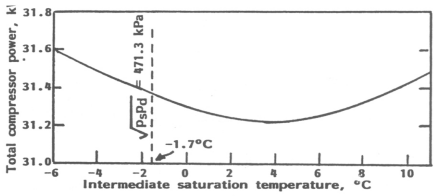


FIGURE 17.10
Total power required in a two-stage R-22 system with a refrigerating capacity of 100 kW as a function of the saturated intermediate temperature. The evaporating temperature is −30°C and the condensing temperature is 35°C.

From Stoecker and Jones, Refrigeration and Air Conditioning

One Compressor & 2 Levels of Evaporating Temp

- Often two evaporating temps are required – one for a freezer, and one for a refrigerator
- Why not use one evaporator with a really cold refrigerant temperature for both cases?
  - If you're using the evaporator to chill liquid, the liquid could freeze on the surface of the coils
  - In an air-cooling coil, excessive frost may form
  - If the air-cooling coil cools food, food near the coil could freeze
- Use of two compressors instead of one is more efficient but results in a greater first cost

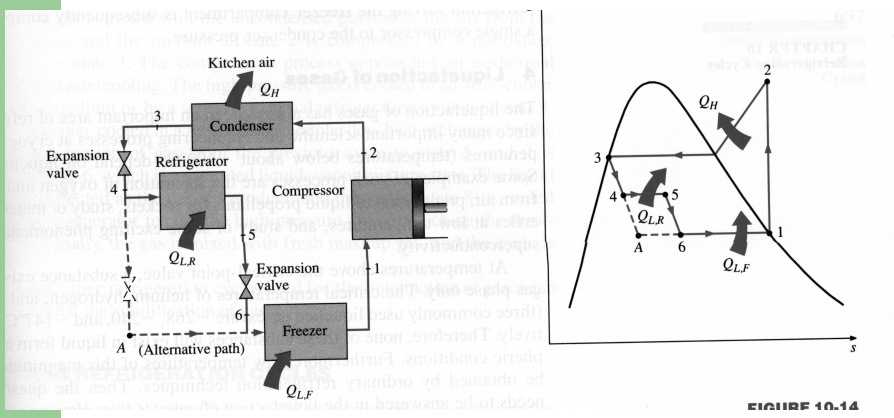
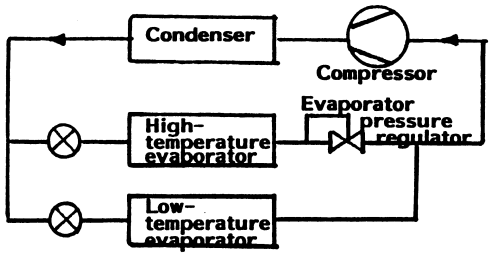


FIGURE 10-14

From Cengel and Boles, Thermodynamics: An Engineering Approach

A more common form of this system



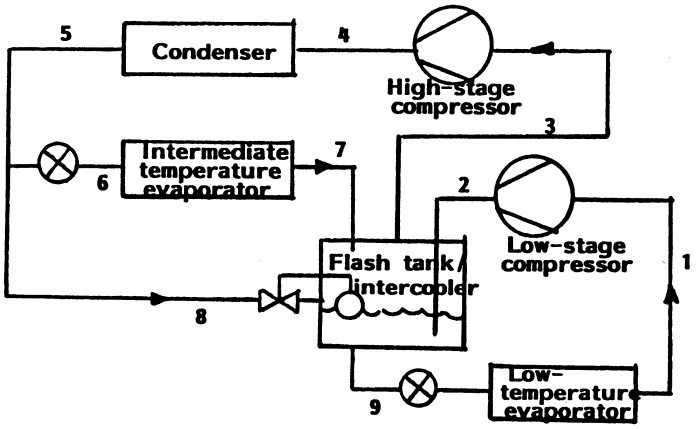
From Stoecker and Jones, Refrigeration and Air Conditioning

- Pressure regulator (sometimes called a back-pressure valve) maintains the higher evaporating temperature in the first evaporator.
- This results in a loss of efficiency but is easier to control than the previous configuration. The pressure regulator may be simply modeled as an expansion valve.

2 Compressors & 2 Evaporating Temps

- More efficient but greater first cost than using one compressor
- Used often in a plant storing both frozen & unfrozen foods where required refrigeration capacity is high (well over 100 kW)
- Approximation of optimum intermediate pressure:

$$P_{intermediate} = \sqrt{P_{suction} P_{discharge}}$$


5
Condenser
4
High-stage compressor
3
Intermediate temperature evaporator
6
7
2
Low-stage compressor
1
Flash tank/ intercooler
8
9
Low-temperature evaporator