Refrigeration System Model with Refrigeration and Deep Freeze Stage

Energy conversion lab

Department of Mechanical Engineering IIT Kanpur

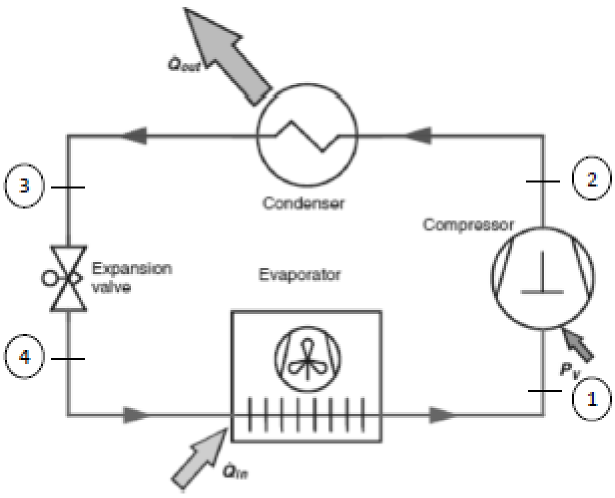
Title: Refrigeration System Model with Refrigeration and Deep Freeze Stage

Objective:

To learn the basics of refrigeration system.

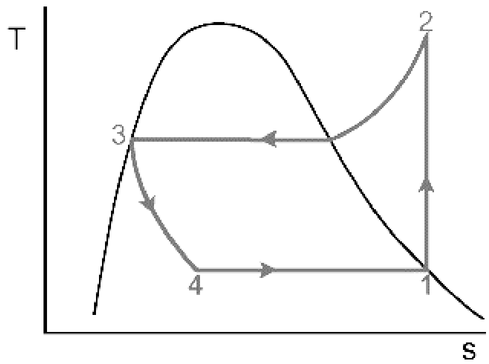
Theory

Major components of a refrigeration system are evaporator, condenser, compressor and expansion valve. Evaporator is the space that needs to be cooled by the refrigerant. Compressor compresses the refrigerant from the low pressure of the evaporator to the pressure at the condenser. Heat gained by the refrigerant is rejected at the condenser and the high pressure refrigerant is expanded into low pressure evaporator through an expansion valve.



Schematic representation of a simple vapour compression system

Fundamental operating principle of the refrigeration process



T-S diagram

The fundamental principle of refrigerating circuit is its dependency of the boiling temperature on pressure. Heat absorption occurs at a lower temperature while heat emission at a higher temperature. In a compression refrigeration system, this is achieved by evaporating the refrigerant at a low temperature to withdraw desired amount of heat from the cooling chamber. To allow this, pressure is reduced so that the evaporation temperature is below the desired cooling chamber temperature.Evaporation corresponds to the line 4-1(Isobaric evaporation). During evaporation in the evaporator, refrigerant absorbs heat flow from the environment. The heat energy absorbed is released back to the environment. This is done by raising the refrigerant to a higher pressure level, at which the boiling temperature is above the ambient temperature. The heat flow absorbed is discharged back to the environment by condensation of the refrigerant in the condenser. This corresponds to the line 2-3(Isobaric condensation). Pressure increase from 1-2(Isentropic compression) is achieved using a compressor. An expansion valve is used for throttling 3-4(Isenthalpic regulation).

Formulas:

1. Specific Refrigeration Capacity

$$q1 = (h1 - h4) \text{ kJ/kg}$$

2. Specific compression work

$$q2 = (h2 - h1) \text{ kJ/kg}$$

3. Coefficient of performance of Carnot Process

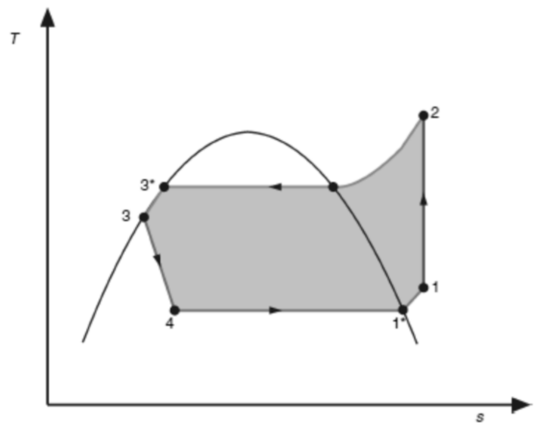
$$\varepsilon(c) = T1/(T2 - T1)$$

4. Coefficient of performance of refrigeration system

$$\varepsilon(k) = {}^{q1}/_{q2} = (h1 - h4)/(h2 - h1)$$

5. Performance factor of refrigeration system relative to Carnot Process

$$\eta = \varepsilon(k)/\varepsilon(c)$$



T-S diagram

The changes of state plotted above have the following meaning here:

1-2: Isentropic compression

2-3: Isobaric condensation

3-4: Isenthalpic regulation

4-1: Isobaric evaporation

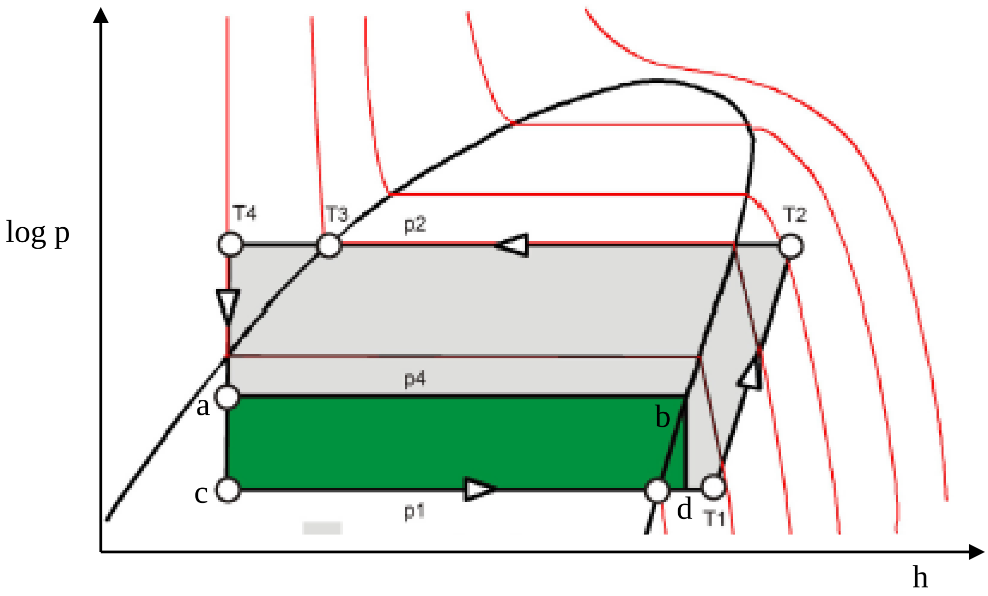
1*-1: Superheating

3*-3: Refrigerant supercooling

Superheating (1*-1) of the refrigerant: To prevent damage to a refrigeration system, it is necessary to superheat the refrigerant at the evaporator outlet. If the intake condition of the process were to lie directly on the condensation line, an incorrect evaporator load could cause "wet intake", which could cause damage to the compressor. Superheating at the evaporator outlet prevents this. The superheating should be around 5K - 8K.

Supercooling (3*-3): The expansion valve is intended to throttle the refrigerant to a lower pressure level after condensation. To guarantee optimum functioning of this valve, pure liquid must be present at the valve inlet, which is ensured by prior supercooling of the liquid. In addition, refrigerant supercooling can be used to achieve a better system performance.

Refrigeration process (evaporator in parallel)



log p-h diagram (evaporator in parallel)

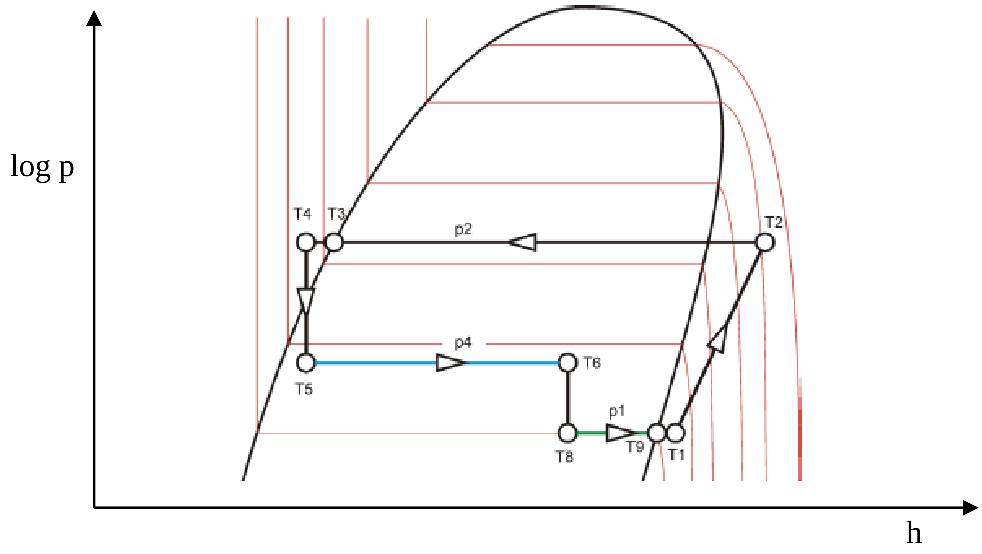
In case of refrigeration process in which two evaporators are used in parallel configuration specific refrigeration capacity is sum of individual capacity of refrigerator

$$q1 = q_{abd} + q_{cd} \text{ kJ/kg}$$

Coefficient of performance of refrigeration system

$$\varepsilon(k) = {}^{q1}/_{q2} = \frac{\frac{\dot{m}}{2}(h_d - h_c) + \frac{\dot{m}}{2}(h_1 - h_a)}{\dot{m}(h2 - h1)}$$

Refrigeration process (evaporator in series)



log p-h diagram (evaporator in series)

In case of refrigeration process in which two evaporators are used in series configuration specific refrigeration capacity is

$$q1= (h1-h4) \text{ kJ/kg}$$

Procedure

1. Turn on system supply
2. Run the computer programme.
3. Start system in following order without load-
   Nozzle => Chamber => Compressor
4. Record readings corresponding to an initial system set up.
5. Close system in following order-
   Compressor => Chamber => Nozzle
6. Repeat step 3-5 for:
   - System with load
   - Series without load
   - Series with load
   - Parallel without load
   - Parallel with load
7. Turn off system.

Observation and report

1. Record all relevant measurement values to create log p, h diagram.
2. Plot the cyclic process of a refrigeration system into a log p, h diagram.
3. Plot the process under cooling load and under no cooling load onto log p, h diagram. Also take into account the pressure loss by way of the evaporator.
4. Describe the effects of a cooling load on a cyclic process.

<u>Data Sheet</u>

Refrigeration System Model with Refrigeration and Deep Freeze Stage

Date of Experiment:

Name: Roll No.

Refrigeration system (Single evaporator): Observations								
With load								**Without load**
S.No	T (°C)	P (bar)	h (kJ/kg)		S.No	T (°C)	P (bar)	h (kJ/kg)
1					1			
2					2			
3					3			
4					4			
5					5			
6					6			
7					7			
8					8			
9					9			
10					10			
Refrigeration system (evaporator in series): Observations								
With load								**Without load**
S.No	T (°C)	P (bar)	h (kJ/kg)		S.No	T (°C)	P (bar)	h (kJ/kg)
1					1			
2					2			
3					3			
4					4			
5					5			
6					6			
7					7			
8					8			
9					9			
10					10			

Refrigeration system (evaporator in parallel): Observations								
With load								**Without load**
S.No	T (°C)	P (bar)	h (kJ/kg)		S.No	T (°C)	P (bar)	h (kJ/kg)
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								