Chapter 15
Cooling and Freezing

Review Questions

Which of the following statements are true and which are false?

1. Ammonia (R 717) as a refrigerant in industrial refrigeration systems has a wide range of evaporating and condensing temperatures, but its vapors are toxic and form flammable mixtures with air.
2. Tubing in ammonia refrigeration units is made of copper.
3. A disadvantage of ammonia as a refrigerant is its low value of latent heat of vaporization.
4. The higher the value of the latent heat of vaporization of a refrigerant the lower the required refrigerant flow rate for a given refrigeration load.
5. Refrigerants containing chlorine may reach the upper atmosphere, react with ozone, and deplete the ozone layer.
6. Hydrofluorocarbons (HFCs) are replacing chlorofluorocarbons (CFCs) as refrigerants.
7. HFC-134a is used in refrigeration systems with moderately low temperatures.
8. Refrigerant 404a is used in refrigeration systems with low temperature applications.
9. Compressor, evaporator, condenser, and expansion valve are the main components of a mechanical refrigeration system.
10. Expansion of the refrigerant in the expansion valve of a Carnot cycle takes place at constant entropy.
11. Compression of the refrigerant in the compressor takes place at constant enthalpy.
12. Evaporation of the refrigerant in the evaporator takes place at constant pressure.
13. The condenser is at the low pressure side of a mechanical refrigeration system.
14. The latent heat of vaporization of the refrigerant is absorbed from the surroundings of the evaporator.
15. Refrigerant vapors leaving the evaporator may be superheated.
16. Liquid refrigerant leaving the condenser may be subcooled.

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17. The coefficient of performance (COP) is equal to the ratio of the refrigeration effect to the net work input.
18. COP is always less than one.
19. The higher the temperature difference between condenser and evaporator, the higher the COP.
20. Refrigeration load includes heat transferred into the refrigeration space by conduction through the walls and by air entering into the space, heat removed from the product, heat generated by the product, heat generated by lights, motors, and people.
21. Water evaporation from the surface of the product can result in considerable weight loss in blast air freezers.
22. Individually quick frozen (IQF) products can be produced in belt freezers and fluidized bed freezers.
23. Cryogenic freezing results in frozen products with large ice crystals.
24. The rate of freezing in plate freezers is high.
25. Water activity of a frozen product is only a function of temperature.
26. Bound water does not freeze.
27. Bound water affects water activity of a frozen product.
28. As water in a solution changes to ice, solute concentration increases and freezing point decreases.
29. Heat capacity and thermal conductivity below the freezing point change significantly with temperature.
30. Thawing is slower than freezing because the thermal conductivity of ice is lower than that of water.

Examples

Example 15.1

Lettuce was vacuum-cooled and then loaded into a refrigerated car for shipment to a market. The trip will last 48 h. Calculate the total amount of heat removed and the peak refrigeration load (maximum heat removal rate) if: the amount of lettuce loaded is 3000 kg, the temperature in the truck is 2°C, the temperature of lettuce when loaded is 5°C and will drop to 2°C in 2 h, the heat capacity of lettuce is 4.02 kJ/kg °C, the area of the walls of the truck is 80 m², the overall heat transfer coefficient for the walls is 0.3 W/m2 °C, the outside air temperature is 20°C, and the heat of respiration of lettuce in the temperature range of 2 to 5°C is 35x10⁻³ W/kg.

Solution

Step 1
State your assumptions:

- The truck is initially at 2°C.
- The truck is tightly closed so that air leakages are negligible.
- The cooling requirements of the packaging material are neglected.