## CORE

### Basic Refrigeration Circuit

1. Liquid refrigerant boils in the evaporator. Heat is absorbed. The heat energy absorbed converts refrigerant liquid into vapor.

2. Refrigerant vapor is drawn (sucked) from the evaporator into the compressor through the suction line.

3. The compressor changes low-pressure vapor to high-pressure vapor.

4. Heat in the compressed refrigerant vapor is rejected from the system in the condenser.

5. High-pressure refrigerant leaving the condenser is passed to the metering device.

6. In the metering device, refrigerant passes through a small orifice to lower refrigerant pressure before it is passed to the evaporator.

7. Metering devices can have a fixed-size orifice (capillary tube) or a variable-size orifice (expansion valve).

8. A manifold gauge set is used to check and set pressures in a refrigeration system.

9. The low-pressure gauge is usually on the left side and is blue. The high-pressure gauge is usually on the right side and is red.

10. The low-side gauge is a compound gauge that measures pressures above and below atmospheric pressure.

11. Pressure readings above atmospheric pressure are measured in psig (pounds per square inch gauge).

12. Pressure readings below atmospheric pressure are measured in inches of mercury (in. Hg) or millimeters of mercury (mm. Hg).

13. The low-side gauge typically measures up to 120 psig. The high-side gauge typically measures up to 500 psig.

14. The center port of the manifold is used for evacuation, charging and refrigerant recovery.

15. Liquid refrigerant can migrate to the coldest place in the system. If the compressor crankcase is the coldest location in the system, liquid refrigerant can accumulate there.

16. Never start a compressor if it is in deep vacuum or if the service valves are closed because the compressor's motor windings can be damaged.

17. Refrigerant lines can be contaminated with compressor oil. This contamination must be flushed out of the system.

18. Pure refrigerant should not be used to flush lines.

19. If a system has had a leak or component failure, an oil sample should be taken before the lines are flushed. The sample should be tested for acid using a paper test strip.

20. To conserve refrigerant supplies, find and repair leaks and recover and recycle refrigerants.

**Dehydration Techniques**

21. Dehydration is the process of removing water vapor (moisture).

22. A vacuum pump is used to evacuate (remove) moisture and non-condensable vapors from a system.

23. The system should be evacuated to the recommended vacuum. It is OK to go below the recommended level.

24. The vacuum gauge is more accurate if it is connected to the system far from the vacuum pump.

25. If a system is not completely evacuated, the compressor head pressure can rise. Also, the moisture, refrigerant and oil will combine at high temperature to form hydrofluoric acid (HF) and hydrochloric acid (HCl).

26. Evacuation will be faster if: (i) the refrigeration system is small; (ii) the ambient temperature is high; (iii) the recovery cylinder temperature is low; (iv) the suction line is large; (v) recovery hose diameter is large; (vi) recovery hose length is short; (vi) there is little moisture in the system; and (vii) a high-capacity vacuum pump is used.

27. The recovery hose diameter should be at least the size of the vacuum pump inlet.

28. After a system has been evacuated, the pressure reading should not rise when the vacuum pump is turned off. If the pressure does rise, there is a leak in the system.

## Chlorine, the Refrigerants and the Ozone Layer

29. Ozone is $O_3$, three atoms of oxygen bound together.

30. $O_3$ is in the stratosphere, a layer in the atmosphere above the earth.

31. Ozone protects the earth from dangerous ultraviolet radiation.

32. Chlorine (Cl), present in some refrigerants, destroys ozone. One Cl atom can destroy 100,000 molecules of $O_3$.

33. CFC's are chloro-fluoro-carbon refrigerants. They contain chlorine (Cl), fluorine (F) and carbon (C).

34. HCFC's are hydro-chloro-fluoro carbon refrigerants. They contain hydrogen (H), Cl, F and C.

35. HFC's are hydro-fluoro-carbon refrigerants. They contain H, F and C.

36. CFC's and HCFC's contain Cl, so they can damage the ozone layer. HFC's do not contain Cl; they do not damage the ozone layer.

37. The ability of a chemical to deplete (or damage) the $O_3$ layer is the Ozone Depletion Potential (ODP).

38. The ODP of CFC's is 20x (twenty times) the ODP of HCFC's. In other words, if the ODP of CFC's is 1, the ODP of HCFC's is 0.05.

39. The ODP of HFC's is zero.

40. Examples of CFC's are CFC-11, -12, -113 and -114. (Remember the sequence: 11, 12, 13, 14. Think of "1" as the ODP of CFC's.)

41. Examples of HCFC's are HCFC-22 and -123. (Remember the sequence 22, 23.)

42. An example of a HFC is HFC-134a.

43. Some refrigerants are mixtures of two or more refrigerant. These mixtures, called azeotropes, behave like a single refrigerant.

44. Examples of azeotropes are R-500 and -502. They contain CFC's and HCFC's.

## Health Effects and Evidence

45. The ozone layer blocks harmful ultraviolet (UV-B) radiation from the sun.

46. Ozone depletion allows more UV radiation to reach the earth's surface.

47. Ozone depletion and increased UV exposure can have these health effects: (i) skin cancer; (ii) cataracts; (iii) reduced immunity to disease.

48. Ozone depletion and increased UV exposure can have these environmental effects: (i) reduced timber (tree) growth; (ii) reduced crop yields; (iii) harm to marine food chains; (iv) increased $O_3$ at ground level.

**Federal Clean Air Act**

49. CFC production and importation stopped after December 31, 199**5**.

50. CFC supply is only from recovery and recycling.

51. State and local laws must comply with the Clean Air Act. They may be stricter.

**Prohibition Against Venting**

52. No venting of CFC's (Class I) or HCFC's (Class II) refrigerants allowed after July 1, 199**2**.

53. Illegal to vent CFC and HCFC substitutes after November 15, 199**5**.

54. HFC's cannot be vented.

55. It is illegal to falsify records or fail to keep required records.

56. It is illegal if required system evacuation levels are not reached.

57. It is illegal to vent CFC's, HCFC's and their substitutes.

58. Refrigerant must be recovered before a system is opened or tested for leaks.

**EPA Regulations – General**

59. An "appliance" (i) contains CFC or HCFC refrigerant and (ii) is for household (home) or commercial (business) uses.

60. Examples of appliances are air conditioners, refrigerators, chillers and freezers of any size.

61. Appliances must have a service port for adding and removing refrigerant.

62. Low-pressure appliances use low-pressure refrigerants such as CFC-11, -113 and HCFC-123.

63. High-pressure appliances use high-pressure refrigerants such as CFC-12, -114, -500, -502 and HCFC-22.

64. Refrigerant recovery devices can be self-contained or system-dependent.

65. A self-contained (or active) recovery system has its own compressor.

66. A system-dependent (or passive) recovery system uses the appliance's compressor to recover the refrigerant.

67. Recovery and recycling machines manufactured after November 15, 199**3** must be EPA certified.

68. EPA Section 60**9** is for motor vehicle refrigeration. (You are studying for certification under Section 60**8**.)

69. Only Section 60**9** technicians may buy CFC-12 in containers under 20 lb.

**EPA Regulations – Disposal of Equipment**

70. The final person in the disposal chain is responsible for recovery of refrigerant from an appliance before disposal.

**EPA Regulations – Penalties for Violations**

71. Fines up to $27,500 per day per violation.

72. Cash bounties up to $10,000 for reporting venting that results in a federal (U.S.) conviction.

73. The EPA can require technicians to demonstrate their ability to perform recovery and recycling procedures.

## EPA Regulations – Recovery, Recycling and Reclaiming

74. "Recovery" means removal of refrigerant from an appliance for external storage.

75. Recovered refrigerant can be in any condition.

76. Recovered refrigerant may or may not be tested or processed after recovery.

77. "Recycling" means cleaning refrigerant for re-use.

78. Recycling involves removing oil, non-condensable vapors, moisture, acidity and particulates.

79. "Reclaiming" means processing recovered refrigerant to be as pure as fresh refrigerant.

80. Purity levels for reclaimed refrigerant are given in ARI Standard 700.

81. Reclaimed refrigerant must be tested and meet ARI Standard 700.

## Leak Detection Techniques

82. Use a vacuum pump and gauge manifold to check a system for leaks.

83. Use a vacuum pump to evacuate (empty) a system. Operate the vacuum pump ("pull a vacuum" or "pull down the system") until the compound gauge reads about 29 in. Hg of vacuum. Then close the valve to the vacuum pump to isolate the system.

84. If the evacuated system has a leak, the system pressure will adjust to 0 psig.

85. You can test an empty system for leaks by pressurizing the system with dry nitrogen ($N_2$), an inert gas.

86. Find leaks with an electronic leak detector. Electronic types are preferred because they are more sensitive.

87. An ultrasonic leak detector is a kind of electronic detector.

**Recovery Overview**

88. All refrigerant recovery machines must be certified by the EPA. They must have a certification label.

89. Refrigerant recovery time:
    • larger system → longer time
    • lower ambient temperature (colder) → longer time.

90. Never mix different refrigerants. They can't be separated later.

91. If you send mixed refrigerants to a reclamation facility:
    • they may refuse it and charge you a fee ($) to return it
    • they may destroy it and charge you a large fee ($$)

92. Your customers may complain about the cost of refrigerant recovery. You may need to tell your customers:
    • recovery is required by law
    • recovery protects health and the environment
    • as a professional, your duty (responsibility) is to obey the law and protect the environment

93. If you are recovering liquid refrigerant, some liquid will be trapped between the service valves. It will not be recovered.

94. If you discover that a system contains a mixture of refrigerants, you should recover the refrigerant into a separate container. (Don't contaminate other refrigerants with this mixture.)

**Alternate Refrigerants**

95. There is <u>no</u> "drop-in" replacement for R-12. ("Drop-in" means you substitute the refrigerant only, not the oils and other lubricants).

96. The replacement for R-12 is R-134a. R-12 is a CFC. R-134a is a HFC.

97. When you replace R-12 in a system, the oils must be checked and changed too. (You can't just "drop-in" another refrigerant.)

98. "Ternary" means 3. A ternary blend contains 3 different refrigerants.

99. Ternary blends are not azeotropes. They do not behave like a single refrigerant.

100. An azeotrope has one pressure-temperature (P-T) curve.

101. A ternary blend has 3 P-T curves, one for each refrigerant in the blend.

102. The "family of curves" for a ternary blend is called the "temperature glide."

103. The individual refrigerants in a non-azeotropic blend all have different vapor pressures at different temperatures. This means they will leak from a system at different rates.

104. A blend should be charged into a system as a liquid, not as a vapor.

105. Charge blends by adding a measured (weighed) amount of liquid into the high side.

106. Leak test an R-134a system with pressurized nitrogen ($N_2$).

**Oils**

107. In general, do not mix different lubricants.

108. Use "ester" oils with R-134a.

109. Ester oils are hygroscopic. This means they absorb moisture.

110. Ternary blends use alkyl-benzene lubricants.

**Recovery Operations**

111. Recover refrigerant before lines are cut, soldered or brazed.

112. Wear butyl (rubber)-lined gloves and safety glasses when handling refrigerants.

113. Use dry nitrogen ($N_2$) to (i) test for leaks, and (ii) purge lines.

114. You must use a pressure regulator on the $N_2$ container.

115. Never use oxygen ($O_2$), high-pressure air or any flammable gas for leak testing or purging.

116. Never heat refrigerant tanks or lines with an open flame or live steam (steam under pressure).

117. $O_2$ + oil is explosive!

**Personal Safety**

118. Refrigerants are grouped by toxicity and flammability.

119. Toxicity groups are A → B. Flammability groups are 1 → 2 → 3.

120. Higher letter or number category means greater risk.

121. How to remember that flammability groups are numbers:
F**l**ammability = F**1**ammability

122. Many common refrigerants are in Group A1: low toxicity, not flammable.

123. R-123 is in Group B1: high toxicity, not flammable.

124. You can find safety information for any refrigerant on its MSDS (Material Safety Data Sheet).

125. Do not breathe (inhale) high concentrations of refrigerant vapor. They may cause heart problems or asphyxia (suffocation; inability to breathe).

126. Refrigerants displace oxygen from the air. Most deaths from refrigerants are due to lack of oxygen.

**Equipment Safety**

127. When pressure-testing a unit, do not exceed the unit's maximum pressure rating.

128. The maximum design pressure rating is on the unit's dataplate.

129. If separate ratings are given for the high and low sides, use the low side rating for pressure tests.

130. Sight glasses can be cleaned with an alcohol spray.

131. If a relief valve is damaged or corroded, it must be replaced.

132. Never test for leaks with oxygen or compressed air. Explosions may occur!

**Disposable Cylinders**

133. Never heat a refrigerant tank with an open flame or steam under pressure (called "live steam").

134. Heating a refrigerant tank with an open flame or live steam can cause (i) decomposition into a toxic material, (ii) venting of the refrigerant or (iii) tank explosion.

135. Never refill a disposable refrigerant container.

136. Disposable containers are only for fresh (virgin) refrigerant from the factory.

137. Recover leftover refrigerant from a disposable container before disposal. Container pressure should be 0 psig.

138. It is best to puncture a disposable refrigerant container after the refrigerant has been recovered.

139. Recycle the metal from empty disposable cylinders.

**Refillable Cylinders**

140. Refrigerant cylinders must always be (i) clean, (ii) undamaged, (iii) color coded and (iv) properly secured.

141. Refrigerant recovery cylinders must be approved by DOT (the U.S. Department of Transportation).

142. Recovery cylinders are gray with a yellow top.

143. Never use a recovery cylinder that has rust.

**Recovery Safety**

144. Never fill a refrigerant cylinder more that 80% of its capacity (by weight of refrigerant).

145. Overfilling a cylinder with refrigerant can cause the cylinder to explode.

146. Devices that prevent over-filling include (i) floats, (ii) thermistor sensors and (iii) weight scales.

147. Refrigerant cylinders must be pressure tested every 5 years.

**Shipping Cylinders**

148. Only use refillable cylinders for transport of recovered refrigerant.

149. Refillable cylinders must meet federal (U.S.) requirements (Title 49 of the Code of Federal Regulations).

150. Refillable cylinders must have a DOT (Department of Transportation) classification tag (label).

151. Cylinders must be stored upright (vertically).