Evaporators, Condensers, and Controls

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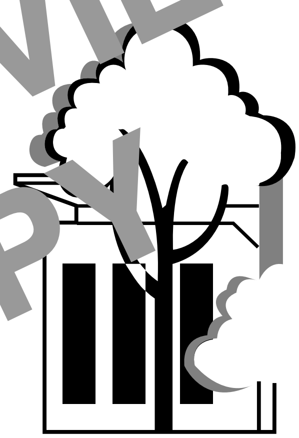
EVAPORATORS, CONDENSERS, AND CONTROLS

Lesson One

Liquid Ammonia Evaporator Supply Methods



TPC Training Systems

46301

Lesson

1 Liquid Ammonia Evaporator Supply Methods

TOPICS

Gravity Feed Systems
Liquid Overfeed (Recirculation) Systems
Pumped Overfeed System
Dump Trap System
Controlled Pressure Receiver (CPR) System
Direct Expansion (DX) Systems
Flooded Liquid Chiller Systems

OBJECTIVES

After studying this Lesson, you should be able to…

- Explain how refrigerant flows in a thermosiphon system and describe the requirements for a surge drum in a gravity feed system.
- List the benefits of a machine room liquid recirculation unit and benefits compared to direct expansion systems.
- Describe the various level controls used in a recirculation unit and explain how the liquid refrigerant is pumped from the recirculation unit through the evaporator coils.
- Describe how a dump trap functions and how it differs from a pumped overfeed system.
- Discuss the operation of a CPR system.
- Explain how a thermostatic expansion valve works and why a DX coil must have more heat transfer surface than an overfeed coil.
- Describe the liquid feed and operation of flooded ammonia shell-and-tube fluid coolers.

KEY TECHNICAL TERMS

Thermosiphon 1.01 gravity feed system that works by means of heat transfer causing a difference in weights in the supply and return lines

Cavitation 1.13 the rapid formation and collapse of vapor bubbles

Dump trap 1.22 a vessel connected below the recirculation supply vessel and vented to both the vapor above the liquid level and to a high-pressure refrigerant vapor source

Previous Units in this Course presented the basics of industrial ammonia refrigeration systems and information about the compressors commonly used in these systems. This Unit deals with other major components—the evaporators, condensers, and controls without which the system could not work.

This Lesson explains the functions and equipment of the various methods by which liquid ammonia is supplied to the evaporators. You will read about and compare gravity feed and liquid overfeed (recirculation) systems, including pumped overfeed methods. This Lesson also explains how dump trap systems, direct expansion (DX) systems, and flooded liquid chiller systems work.

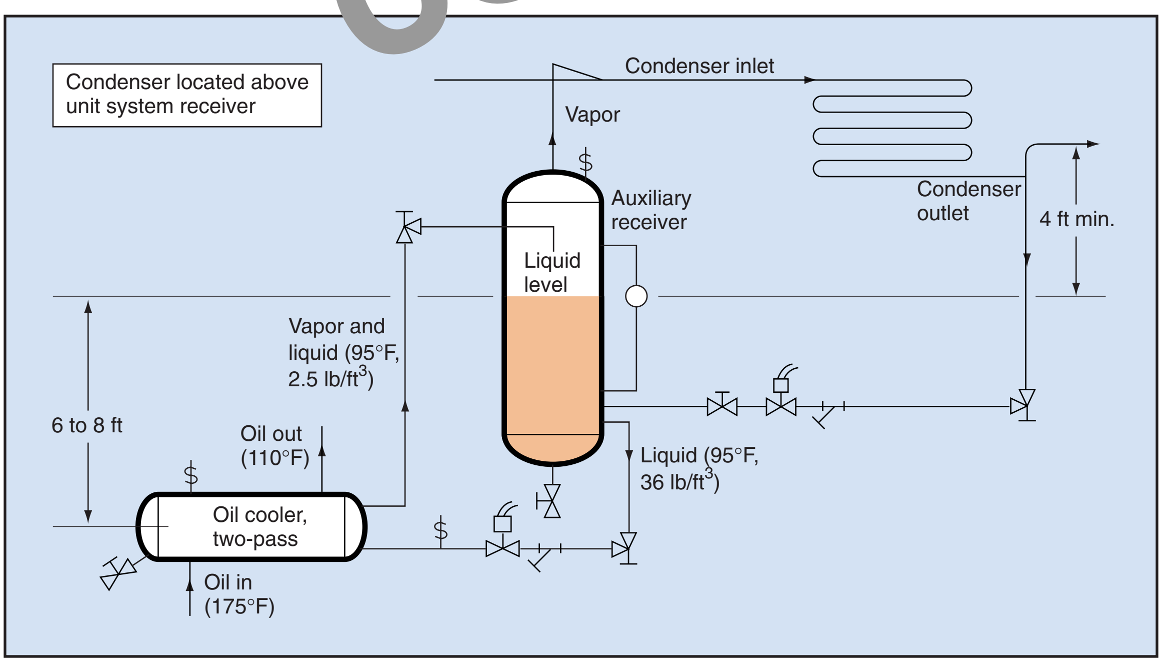
Gravity Feed Systems

1.01 Gravity feed systems, also known as *thermosiphon* systems, work by means of a liquid refrigerant storage vessel located above the evaporator with the liquid in the storage vessel at the evaporating temperature and pressure. The flow of refrigerant through the evaporator in a gravity feed system depends on heat from the product being cooled.

1.02 Heat is transferred to the refrigerant in the evaporator, causing the refrigerant to boil. This, in turn, causes the return line to contain bubbles of vapor, and the refrigerant in the return line becomes a mixture of liquid and vapor. The weight of the mixture in the return line is significantly lighter than the liquid refrigerant in the supply line, which contains no vapor. The difference in weights in the supply and return lines causes the refrigerant flow.

1.03 Figure 1-1 illustrates thermosiphon operation in an oil cooler system on a screw compressor. The thermosiphon oil cooler is essentially a gravity feed 80 to 95°F shell-and-tube evaporator, with the refrigerant liquid at the system condensing pressure. The liquid refrigerant flows through the cooler in response to the high temperature of the oil being cooled. The liquid and the vapor generated in the cooler return to the supply vessel, and the vapor then continues on to the condenser inlet. Because of the high evaporating temperature in the oil cooler and the fact that the vapor is at high pressure and returned to the condenser, the thermosiphon becomes a special kind of evaporator.

Fig. 1-1. Typical thermosiphon oil cooler system



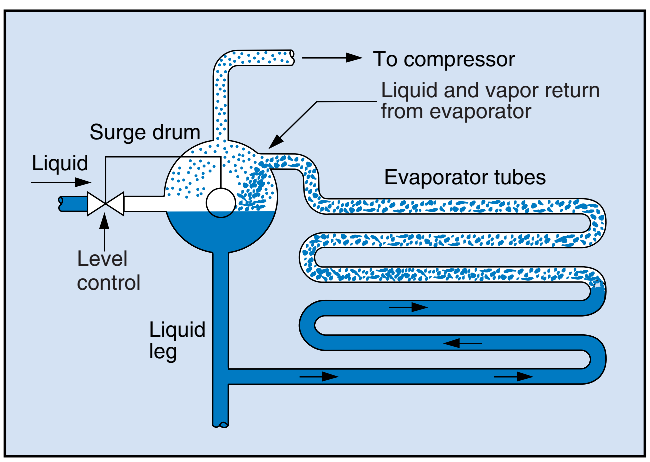
1.04 A gravity feed system used for refrigeration is known as a *flooded surge drum system*. The refrigerant flows to and through the evaporator in the same manner as through the thermosiphon oil cooler. The difference is that the liquid is maintained within a surge drum located just above the evaporator. The pressure and temperature within the surge drum are at the evaporating condition. Figure 1-2 shows a typical gravity feed flooded surge drum evaporator.

1.05 Notice that the liquid level in the surge drum is maintained near the midpoint of the vessel. The space above the liquid receives the return liquid and vapor from the evaporator. This space must be of adequate size to slow down the velocity of the vapor enough to ensure separation of the liquid refrigerant from the vapor returning to the compressor suction.

1.06 For gravity feed, the return line must be connected above this liquid level so that the flow of refrigerant through the evaporator can be established. If both connections were below the liquid level, refrigerant flow probably would not start through the evaporator.

1.07 A common application for gravity feed systems is on small evaporator coils used to cool liquids or emulsions—for example, mayonnaise, margarine, or ice cream. Gravity feed coils may also be used as air cooling coils. When used as air cooling coils below freezing, connections to the surge drum system also include the hot gas used in the coil defrost process.

Fig. 1-2. Gravity feed surge drum system



Liquid Overfeed (Recirculation) Systems

1.08 The most common method of feeding liquid refrigerant to the evaporators in industrial ammonia plants is by means of liquid overfeed systems, also known as recirculation systems. The recirculation system requires a relatively large vessel containing liquid refrigerant at the evaporating pressure and temperature. The vessel is equipped in one of two ways—with liquid refrigerant pumps or with a pressure transfer dump system—to pump the cold refrigerant throughout the plant to the many evaporators wherever they are located. With large loads, the vessel is often located close to the load.

1.09 It is convenient to have this vessel located in the machine room for maintenance purposes. A particular benefit is that a single oil pot is sufficient to collect and provide for removal of oil carryover from the entire system. Without this arrangement, oil would be transferred to all of the evaporator coils. Oil removal at each coil would be difficult and extremely time- consuming.

1.10 The refrigerant is pumped through the evaporator coils at a 3:1 to 4:1 overfeed rate. This means that the evaporator coil surface is totally wetted throughout its entire length and therefore has a higher rate of heat transfer than DX (direct expansion) coils using thermostatic expansion valves. This arrangement results in the use of coils that are smaller and lighter in weight and therefore are also less expensive.

1.11 The overfeed return contains both the vapor generated in the system's many evaporator coils and also the liquid that did not vaporize. The refrigerant returns to the recirculation vessel, where the vapor must be separated from the liquid so that the liquid can be recirculated to be vaporized. In order to provide for this separation, the recirculation vessel must be large enough so that the vapor velocity is low, allowing the liquid time to drop into the liquid pool in the vessel.

1.12 Figure 1-3 shows a horizontal recirculation system. Refer to Unit 461, Lesson Five, for a more complete discussion of recirculation units. The recirculation vessel or unit accomplishes four main functions, as described in the following paragraphs.

1.13 One function of the recirculation vessel or unit is to maintain a supply of liquid refrigerant at an adequate height above the pumps to ensure that cavitation is prevented. *Cavitation* is the rapid formation and collapse of vapor bubbles in a fluid flowing at low pressure. This operating level is controlled to within 1 to 2 in. of the setpoint. Most systems today use an electronic level control system, which is adjustable and has provisions for various setpoints.

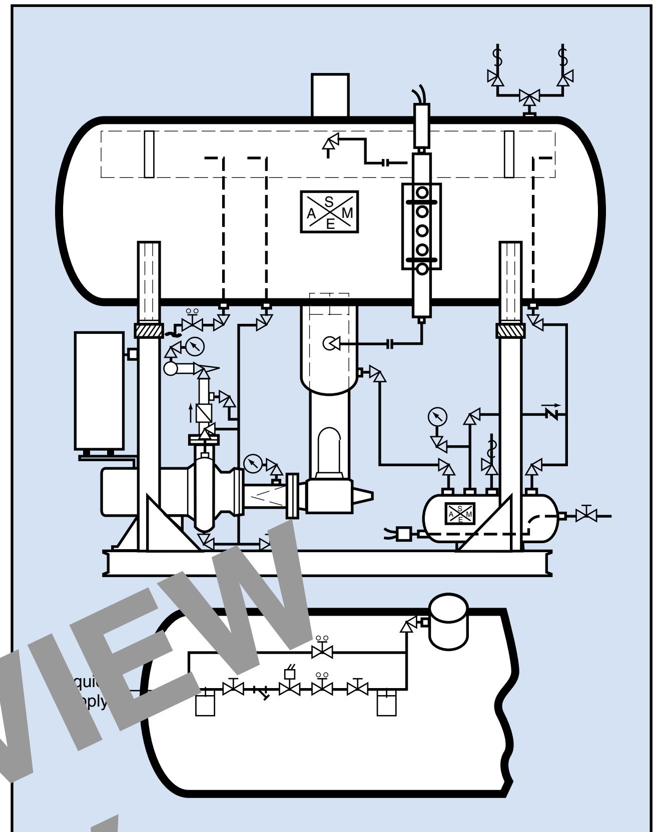
1.14 A second function of the recirculation vessel or unit is to maintain a sufficient surge volume within the vessel. This feature ensures that additional return of refrigerant during defrost and shutdown cannot cause the liquid level to rise to a level at which liquid refrigerant can return to the compressors.

1.15 A third function of the recirculation vessel or unit is to provide for the adequate separation of liquid refrigerant from the vapor. This ensures that the vapor returning to the compressors is free of any liquid refrigerant carryover. The recirculation unit is the primary suction accumulator for most industrial ammonia systems.

1.16 The fourth function of the recirculation vessel or unit is to provide a control system. The control system accomplishes the following:

- controls the liquid refrigerant make-up maintaining the liquid supply
- provides a low-level pump cutout to stop the pump if the refrigerant level falls too low
- provides a high-level alarm and compressor cutout if the liquid level rises to the dangerous point of possibly carrying liquid to the compressors.

Fig. 1-3. Horizontal recirculation system



Pumped Overfeed System

1.17 A pumped overfeed system uses liquid refrigerant pumps in connection with the recirculation unit. The pumps normally take the refrigerant at its saturated temperature and pressure condition and increase the pressure to approximately 30 psi above the saturated pressure. This process essentially subcools the refrigerant to prevent the formation of vapor in the feed to the evaporators.

1.18 The pressure of 30 psi is not critical. However, the pressure must be high enough to raise the refrigerant to whatever height the piping runs and to deliver it throughout the entire system. The refrigerant pressure should be about 5 psi above the evaporating pressure when it reaches the evaporators.

1.19 Each evaporator is fitted with a hand expansion balance valve at the liquid inlet. The valve at each evaporator is adjusted to provide the pressure drop required to ensure equal feed to all evaporators. This adjustment is discussed in Lesson Five.

1.20 Once adjusted, the hand balance valve need not be readjusted. The coil solenoid valve is located upstream from the hand balance valve. The purpose of the solenoid valve is to control the flow of refrigerant—on or off—depending on the temperature requirements at the coil and whether the coil is in the defrost mode.

Dump Trap System

1.21 An alternate way to feed the liquid refrigerant using a recirculation unit is by means of dump traps, also called pumper drums. The dump trap system was originally used many years ago before liquid refrigerant pumps were common. The system is still in use today and is available from several manufacturers.

1.22 A *dump trap* or pumper drum is a vessel that is connected below the recirculation supply vessel and vented to both the vapor above the liquid level and also to a high-pressure refrigerant vapor source. The connection uses a three-way solenoid valve either to vent the dump trap vessel to the recirculation vessel or to block the recirculation line and introduce high-pressure vapor to the dump trap.

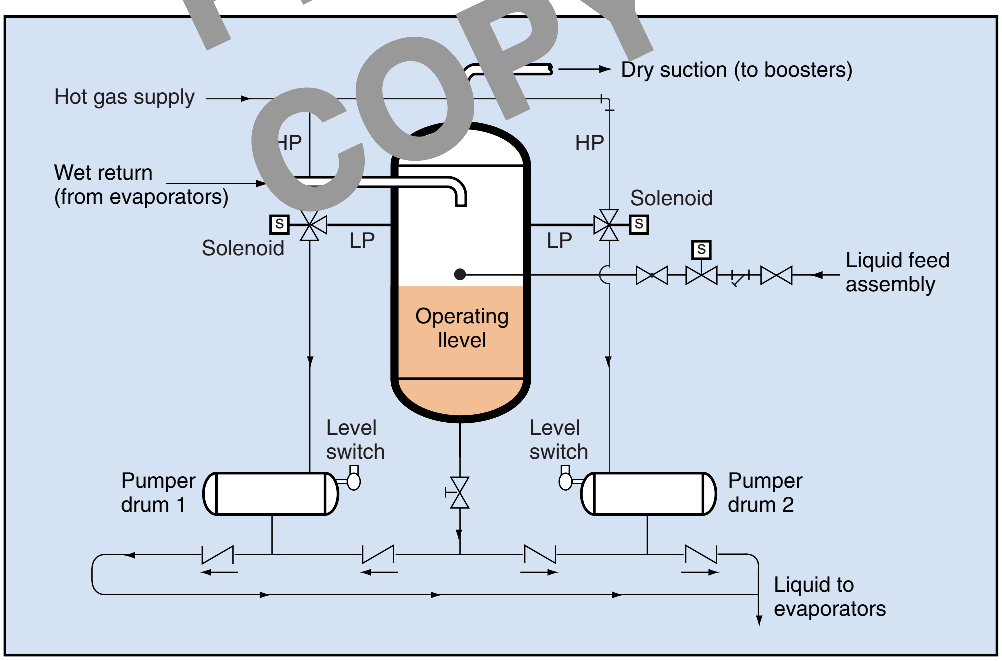
1.23 When the dump trap is vented to the recirculation vessel, the liquid refrigerant fills the dump trap vessel. When the dump trap vessel is sufficiently full, a level control switch reverses the solenoid, which now permits high-pressure vapor into the dump trap. The high pressure forces the liquid refrigerant out of the dump trap and into the evaporator coils throughout the system.

1.24 There are normally two dump traps on the recirculation unit so that while one trap is filling, the other feeds liquid refrigerant to the evaporators. As soon as a dump trap is full, it switches and takes over the refrigerant feed from the other dump trap, which starts to fill. Figure 1-4 shows a typical dump trap recirculation system.

1.25 An offshoot of the dump trap system is the use of a single dump trap vessel in the machine room. This vessel can be connected temporarily to any of the vessels in the machine room to facilitate the removal or transfer of liquid refrigerant from one location to another. Facilities with this arrangement find that use of the dump trap greatly simplifies the handling of refrigerant during times of inadvertent shutdown or system malfunction.

The Programmed Exercises on the next page will tell you how well you understand the material you have just read. Before starting the exercises, remove the Reveal Key from the back of your book. Read the instructions printed on the Reveal Key. Follow these instructions as you work through the Programmed Exercises.

Fig. 1-4. Dump trap (pumper drum) system



1-1. Liquid refrigerant in a gravity storage vessel is at the ________ temperature and pressure.	1-1. EVAPORATING Ref: 1.01
1-2. Thermosiphon refrigerant supply systems used for refrigeration applications are known as ________ systems.	1-2. FLOODED SURGE DRUM Ref: 1.04
1-3. Most industrial ammonia refrigeration plants supply refrigerant by means of ________, also known as a(n) ________ system.	1-3. LIQUID OVERFEED; RECIRCULATION Ref: 1.08
1-4. For convenience, a recirculation vessel should be located in the ________.	1-4. MACHINE ROOM Ref: 1.09
1-5. Refrigerant in a liquid overfeed system is pumped at an overfeed rate of ________ to ________.	1-5. 3:1; 4:1 Ref: 1.10
1-6. A liquid supply recirculation vessel must be installed high enough above the pumps to prevent ________, the rapid formation and collapse of vapor bubbles.	1-6. CAVITATION Ref: 1.13
1-7. In a pumped overfeed system, a ________ valve is installed at each evaporator to equalize liquid overfeed.	1-7. BALANCE Ref: 1.19
1-8. Two dump traps are used so that one can ________ while the other ________ the evaporators.	1-8. FILL; FEEDS Ref: 1.24

Controlled Pressure Receiver (CPR) System

1.26 The controlled pressure receiver (CPR) system is another method used to supply liquid refrigerant to the numerous evaporators throughout a refrigeration plant. CPR systems consist of a controlled high-pressure liquid receiver that is controlled at some intermediate pressure below the normal variation of summer/winter condensing conditions. This pressure is maintained by means of a pressure regulator that is vented to the system low side. Figure 1-5 shows a typical CPR system.

1.27 The liquid feed to the CPR is generally through a pilot-operated high-side float that is used to drain the condenser to the CPR vessel. As mentioned, the pressure in the CPR is maintained by the pressure regulator, shown connected to the system suction accumulator in Fig. 1-5. The temperature of the refrigerant in the CPR is the saturated temperature equivalent to the setpoint pressure.

1.28 The liquid from the CPR is directed to the evaporators by the pressure differential existing between the vessel and the evaporators. The feed to the evaporators is an overfeed similar to that provided by a recirculation unit. Each evaporator has a hand expansion balance valve to ensure equal liquid distribution to all evaporators.

1.29 Return from the evaporators, which is both liquid and vapor, is to the suction accumulator. The accumulator is used to separate the liquid from the vapor, and the vapor is directed to the compressor suction. In the accumulator, the liquid level gradually rises because there is no direct outlet for the refrigerant. The liquid refrigerant is removed and transferred back to the CPR by means of a dump trap vessel. This vessel periodically fills and is pressurized when it becomes full, in this way returning the refrigerant to the CPR.

Direct Expansion (DX) Systems

1.30 Direct expansion (DX) systems are very important in halocarbon air conditioning and commercial refrigeration. They are also used to a much lesser degree with ammonia refrigeration. DX sys-

Fig. 1-5. Controlled pressure receiver (CPR) system

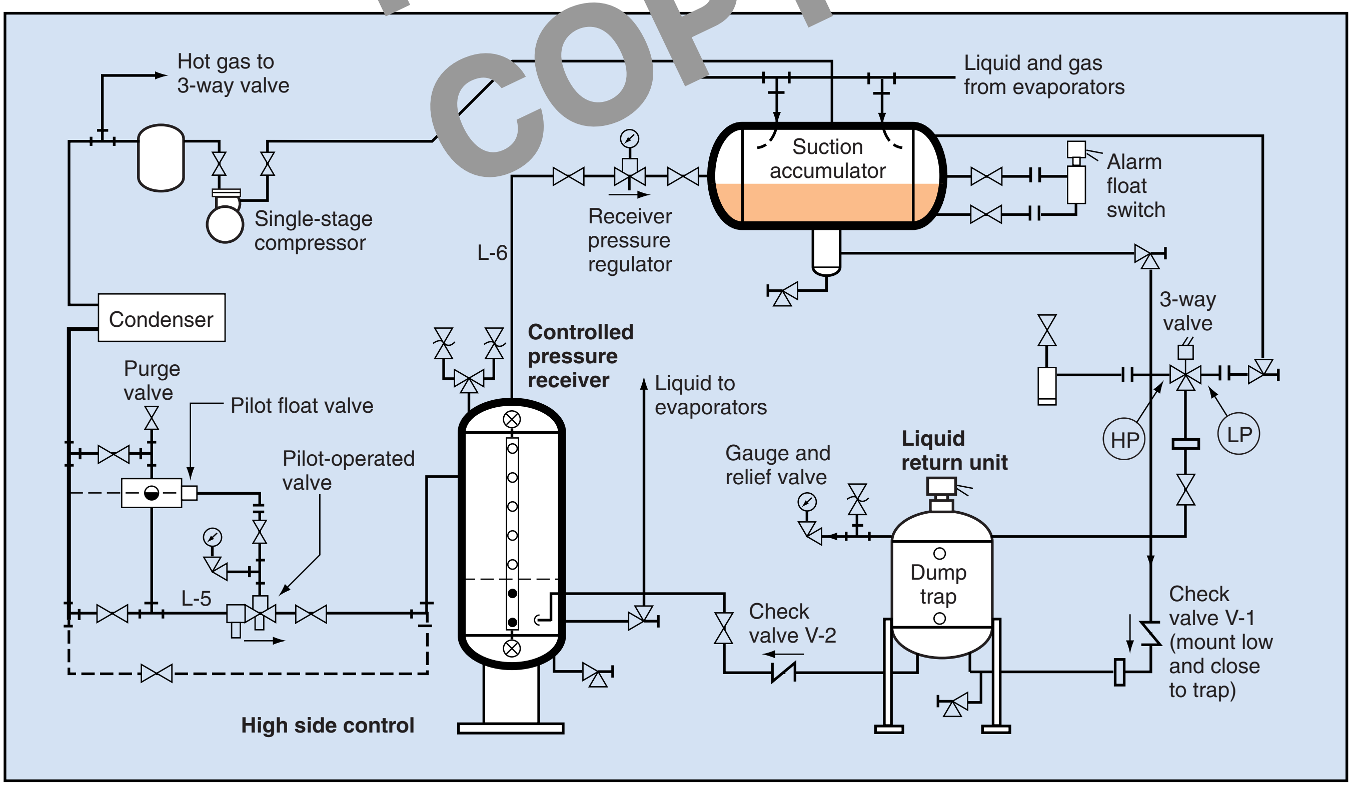
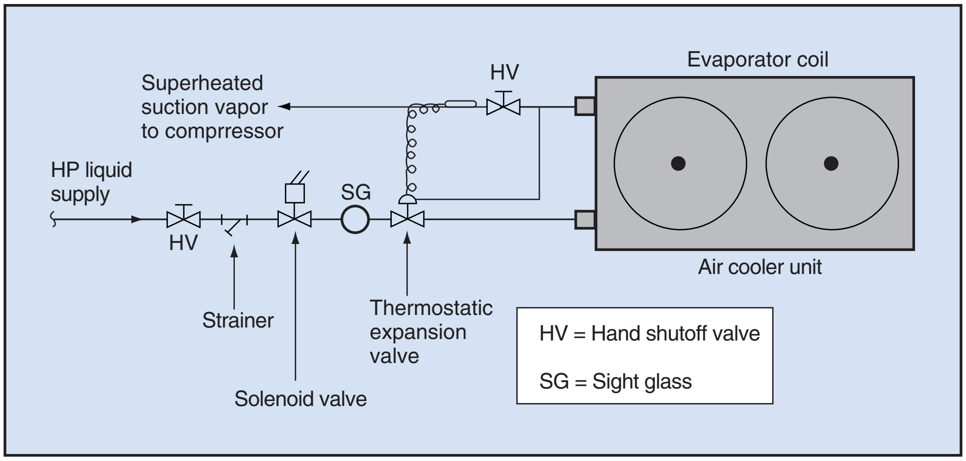


Fig. 1-6. Direct expansion (DX) system with thermostatic expansion valve



tems feed refrigerant from the high-pressure system through a thermostatic expansion valve into the coils of the evaporator.

1.31 The control scheme by which the thermostatic expansion valve functions requires that there be some superheat at the end of the evaporator coil. This superheat, or temperature above the saturated temperature in the evaporator, provides the control mechanism for the thermostatic expansion valve. The bulb of the expansion valve is strapped to, or inserted into, the outlet of the evaporator. The superheat warms the bulb, which contains a fluid with properties similar to the refrigerant in the system. The higher the temperature at the bulb, the higher the pressure within the bulb.

1.32 This pressure is carried through a capillary tube back to the power element of the thermostatic expansion valve, where it exerts a force on the diaphragm of the power element. The diaphragm deflects and is counterbalanced by an adjusting spring. Movement of the diaphragm causes a movement of a needle valve, which normally modulates to maintain a constant flow of the required refrigerant to the evaporator.

1.33 Increasing pressure at the power element causes the valve to open and feed additional refrigerant to the coil. The additional refrigerant reduces the superheat temperature to the control range desired. Too low a superheat causes the valve to close, reducing the refrigerant feed and increasing the superheat. The operation is the same whether the refrigerant is ammonia or one of the halocarbons. Figure 1-6 shows a DX coil and thermostatic expansion valve system.

1.34 In general, the amount of superheat is 7 to 10°F. In normal operation, there is a slight deviation in superheat from the desired setpoint, and the valve opens and closes (modulates) to maintain the setpoint. Any change in the refrigeration load on the coil causes a change in the required refrigerant flow.

1.35 An increase in superheat tells the system that not enough liquid is being fed to the evaporator. The pressure in the bulb increases, forcing the thermostatic expansion valve to open a bit more, allowing more refrigerant into the evaporator. The increase in refrigerant flow to the evaporator causes a decrease in superheat. This process repeats over and over, with the valve constantly adjusting itself to maintain the superheat setpoint determined by the adjusting spring tension adjustment.

1.36 Ammonia thermostatic expansion valves are available in sizes ranging from 2 to 100 tons capacity. Valves for capacities less than 2 tons are not practical because the required valve orifice size is so small (less than 0.030 in.) that clogging with dirt becomes a problem. Also, ammonia evaporators that small are rare.

1.37 DX coils are at a disadvantage compared with overfeed evaporators, because the superheat requirement makes it necessary to use a longer coil. In fact, the coil must be long enough so that all of the refrigerant supplied to the coil is boiled off before the end of the coil, with an additional length of coil after vaporization in which the vapor can be superheated. This makes the coil longer, heavier, and therefore more expensive, and also reduces the overall heat transfer rate. The system is less efficient because of the superheated vapor returned to the system.

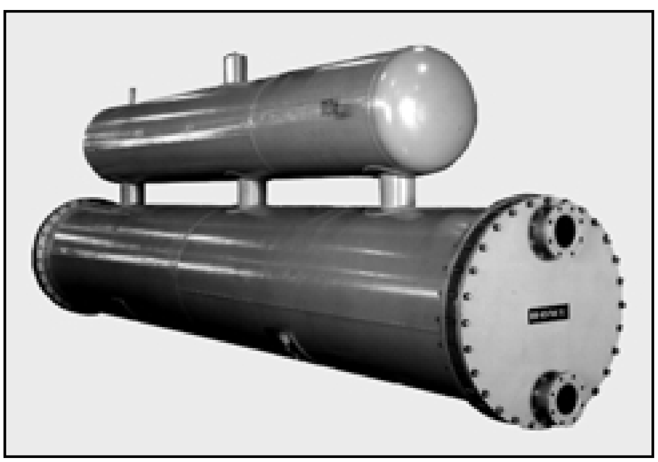
1.38 In ammonia systems, DX coils are generally used on smaller, more specialized refrigeration equipment and quite often on dock loads and other higher-temperature unit coolers. The DX system is also used on shell-and-tube liquid refrigerant subcooler (economizer) applications with screw compressor units. Another common usage for expansion valves on ammonia systems is with the control of liquid injection oil cooling. In this case, the thermostatic expansion valve is modified from the standard with a special fluid in the power assembly bulb.

Flooded Liquid Chiller Systems

1.39 A flooded liquid chiller is a shell-and-tube evaporator designed to cool liquids—for example, water, brines, and process fluids. The fluid to be cooled flows through the tubes, and the refrigerant is in the shell of the vessel. The level of the liquid in the vessel is controlled to some specific setpoint determined by test, by experience, or by some control scheme measuring the compressor discharge temperature. In the latter case, a reduced discharge temperature indicates liquid carryover.

1.40 In industrial ammonia applications, the flooded chillers include, as an integral part of the chiller, a suction accumulator vessel designed to separate any liquid carryover from the vapor going to the compressor. This accumulator is typically a horizontal vessel mounted directly over the chiller and is quite often about the same size as the chiller itself. Figure 1-7 shows a shell-and-tube flooded ammonia chiller.

Fig. 1-7. Shell-and-tube flooded ammonia chiller



1.41 The liquid feed to the flooded chiller enters at the bottom. Depending on the diameter and length of the vessel, the feed may be located at several points along the bottom or at a distribution header located inside. The goal is to provide relatively equal distribution of the entering liquid along the length of the vessel to obtain optimum heat transfer.

1.42 A number of baffle plates are installed to support the tubes inside the vessel. The baffle plates are of relatively thin metal ($^{1}/_{16}$ to $^{3}/_{16}$ in.) and include holes just slightly larger than the tubes. The tubes are installed through the holes, thus keeping the tubes properly separated from one another and supporting them from sagging. It is important to make certain that the liquid distribution is provided between the baffles, because it is difficult for the refrigerant to get between them once it starts to rise.

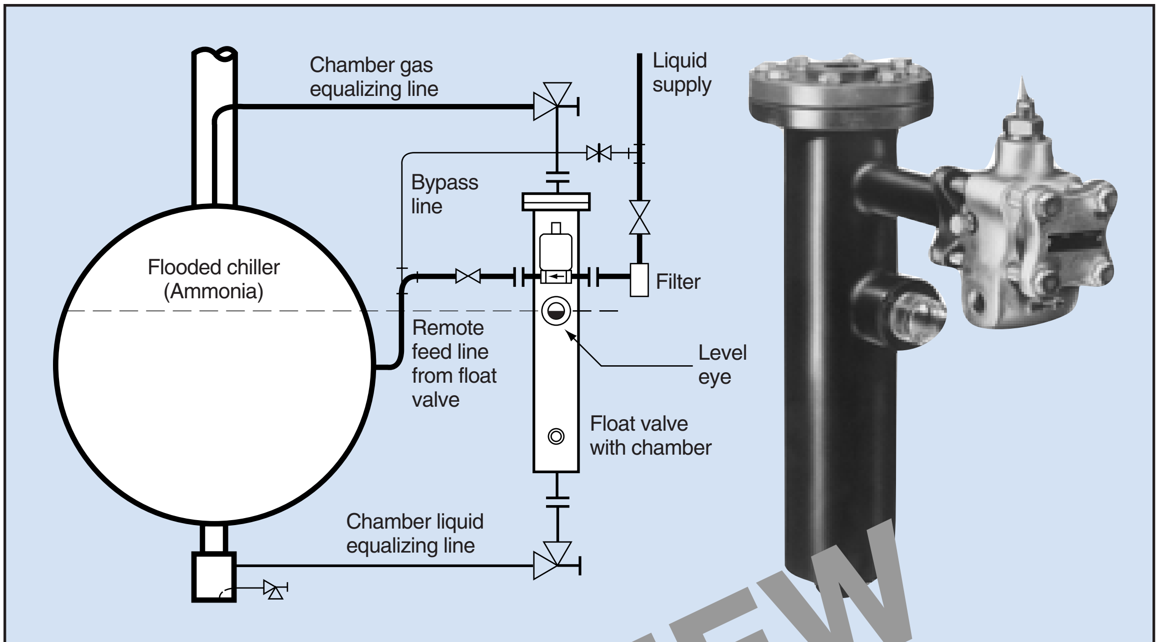
1.43 Sometimes the liquid distribution and baffle arrangement is improperly designed, in which case there is little you can do. However, if a new chiller is being ordered or purchased, it is wise to review the drawings before manufacture to be certain that the internal liquid feed is evenly distributed throughout the length of the vessel and between the baffles.

1.44 The liquid supply to the chillers may be through any of the following devices:

- a low-side float mounted at the desired level
- a hand expansion valve and solenoid valve set controlled by a level switch
- a motorized control valve operating in conjunction with an electronic level controller and compressor discharge temperature control.

These methods are discussed in the paragraphs that follow.

Fig. 1-8. Low-side float valve



1.45 Figure 1-8 shows a low-side float controlling the liquid supply to a flooded chiller. The level of the liquid in the float chamber must be located at the desired liquid level in the chiller. The low-side float is piped so that the pressure in the float chamber is at the same pressure as the chiller. Sometimes this is accomplished by equalizing the float chamber to the chiller above the liquid level. High-pressure liquid from the receiver is brought to the float and passes directly through the float to the chiller. On larger systems, the float is used as a pilot to actuate the liquid feed to the chiller, as shown in Fig. 1-8.

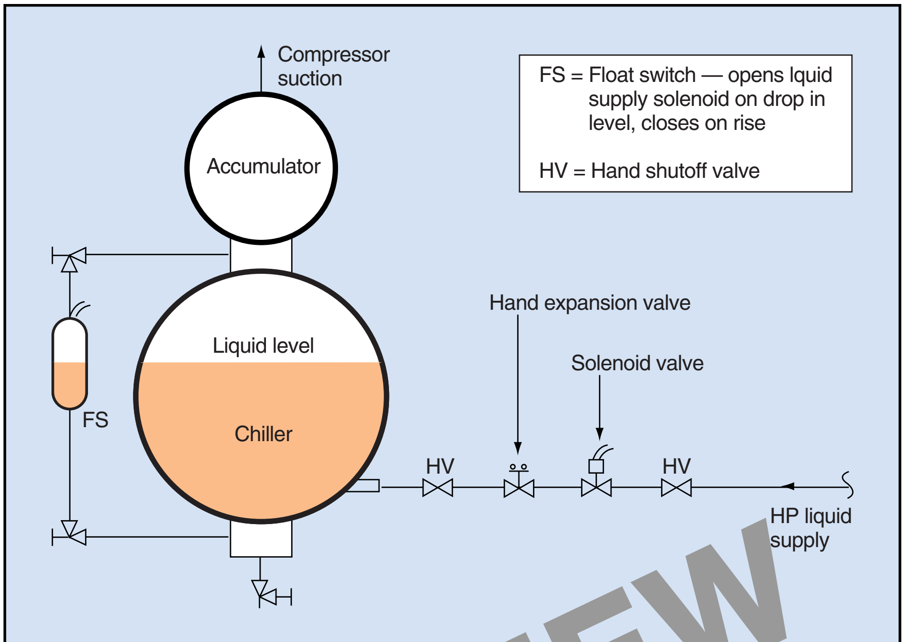
1.46 Another common method of chiller liquid supply works by means of a hand expansion valve and solenoid, as shown in Fig. 1-9 on the following page. In this method, the flow rate is controlled by the adjustment of the hand expansion valve, and the actual refrigerant flow is controlled by the periodic opening and closing of the solenoid valve. The solenoid valve, in turn, is controlled by a level switch that senses the liquid level in the chiller. The level switch opens and closes the solenoid to maintain a relatively constant liquid level within the chiller.

1.47 Both the low-side float and the hand expansion/solenoid valve/level switch arrangement are typically hard-piped into the chiller and are not easily relocated should their initial position be incorrect. A better arrangement enables you to control the liquid level setpoint to optimize chiller capacity at various conditions.

1.48 A motorized control valve operating in response to an electronic level controller provides this desirable feature of variable level control. The electronic level controller provides an adjustable setpoint to maintain a predetermined discharge temperature superheat at the compressor. This control method optimizes chiller capacity at various load conditions. Typically, the valve used is a sliding gate valve with a number of small openings in the gate. These holes mate with the same series of holes in the valve body for the full open position and need to move only the diameter of the holes to the fully closed position.

1.49 Many liquid chillers use an internal spray system in addition to partial flooding. The spray system is a variation on the flooded chiller in which the liquid refrigerant supply is reversed from the bottom of the chiller to the top side of the coils. The refrigerant is still on the shell side of the chiller, but is sprayed (under pressure) in an overfeed manner onto the coils. The chiller contains considerably less refrigerant than non-spray chillers, permitting a reduction in the over-

Fig. 1-9. Chiller supply through hand expansion valve/solenoid valve



all quantity of refrigerant required in the system. Figure 1-10 illustrates a typical spray chiller.

1.50 The liquid overfeed drains to the center drop leg, where it is pumped to the spray header over the coils. The vapor generated is drawn to the compressor through the suction trap mounted above the chiller. Liquid refrigerant make-up is into the bottom of the chiller. The spraying arrangement ensures wetting all coil surfaces and enhances heat transfer.

1.51 The tubes in an ammonia flooded chiller are typically steel or aluminum tubing. The tubing is externally enhanced with low fins (19 to 40 fins per inch). Internally the tubes may be plain or, more common in newer equipment, spirally enhanced with multiple ridges to increase the transfer capability. The external fins can increase the surface contacting the refrigerant by three to four times more than without the fins. The internal spiral ridge induces swirling action, which provides additional turbulence to the more viscous fluid being cooled. Both of these features increase heat transfer characteristics. The next Lesson discusses tube design in greater detail.

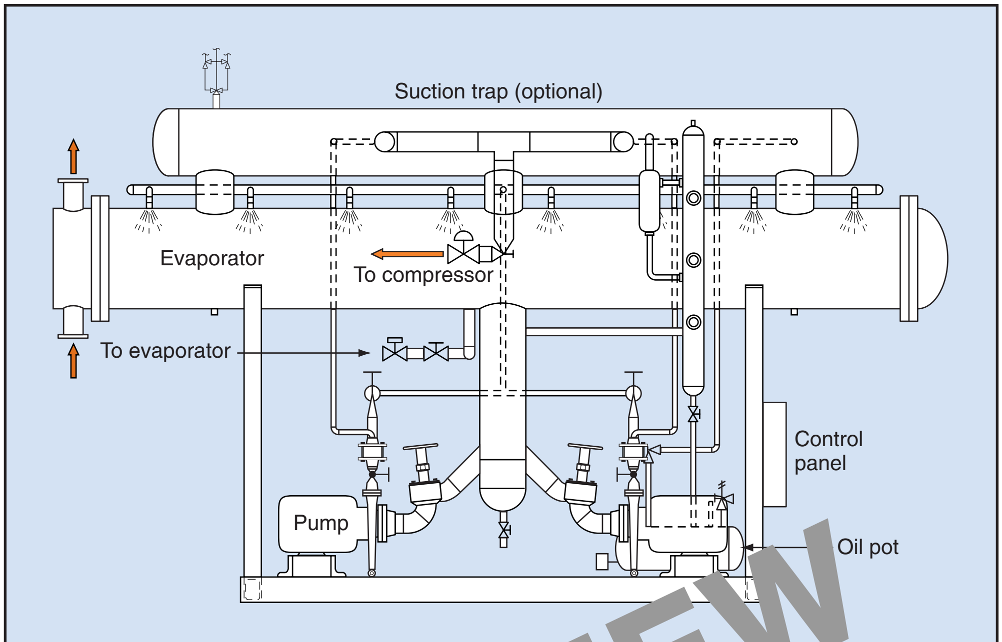
1.52 An important item on any flooded ammonia chiller is either a drop leg or an oil pot to trap any oil that may accumulate in the chiller. Oil accumulates in the chiller because the refrigerant that is vaporized to cool the process fluid essentially distills the oil, which then concentrates within the chiller. Because the oil is heavier than the ammonia, the oil fortunately is located at the bottom where it can be periodically drained.

1.53 For comparison, flooded halocarbon chillers are treated in a different manner because the oil is either miscible or partially miscible with the refrigerant. Any oil that forms a two-phase separation floats on top of the heavier liquid refrigerant. To remove oil from the halocarbon chillers, two methods are used. The first is to bleed a small trace of refrigerant from the chiller into the compressor suction vapor line. The refrigerant vaporizes and the oil returns to the compressor.

1.54 The second method is to add an oil-distilling vessel beneath the chiller and connect it to the chiller so that liquid refrigerant can be drawn into the vessel. A heater distills the oil from the refrigerant, and the process is repeated until the vessel becomes almost full of oil. At this time, the oil is either manually or automatically returned to the compressor lubrication system.

1.55 The vapor that is generated during operation of the chiller rises into the accumulator vessel mounted on top of the chiller. This vessel is essentially empty and provides the necessary space and low vapor velocity

Fig. 1-10. Ammonia spray chiller



required to permit any liquid droplets or mist to separate and return through the risers back into the chiller. The vapor is then drawn off the top of the accumulator to the compressor suction. The vapor entering an ammonia chiller suction is free of liquid refrigerant but essentially at a saturated temperature condition.

1.56 Certain system conditions are critical to the proper operation of an ammonia chiller system. Important, but often overlooked, monitoring equipment for chillers includes the following:

- thermometers indicating the process fluid entering and leaving temperatures
- pressure gauges indicating the process fluid inlet and outlet pressures
- a flowmeter indicating the flow rate of the process fluid in gallons per minute.

1.57 These measurements are required to monitor conditions in the chiller. The temperature difference, along with the fluid flow rate, is a measure of the capacity of the chiller. The pressure difference between the inlet and outlet connections is a measure of the condition of the tubes. Increase in pressure drop from the normal warns of a fouling of the tubes and a condition that requires corrective action. Tube fouling also reduces the flow rate of the fluid and lowers capacity.

1.58 Also helpful are sight glasses mounted on the upper side of the chiller, permitting you to look inside to evaluate the liquid level and refrigerant or tube surface condition within the chiller. It is best to use a pair of sight glasses, one on each side of the chiller, so that a light can be placed to shine through from one side while you look through the sight glass on the opposite side.

1-9. The liquid feed to the evaporators from a CPR is moved by the ________ between the vessel and the evaporators.	1-9. PRESSURE DIFFERENTIAL Ref: 1.28
1-10. Refrigerant return from the evaporators in a CPR system is to the ________.	1-10. SUCTION ACCUMULATOR Ref: 1.29
1-11. Systems that feed the liquid refrigerant through ________ are known as DX systems.	1-11. THERMOSTATIC EXPANSION VALVES Ref: 1.30
1-12. A DX coil must be ________ than a corresponding overfeed coil to generate superheat.	1-12. LONGER Ref: 1.37
1-13. A flooded chiller is a shell-and-tube evaporator with the liquid refrigerant on the ________ side and the fluid being cooled on the ________ side.	1-13. SHELL; TUBE Ref: 1.39
1-14. A reduced discharge temperature in a flooded liquid chiller indicates ________.	1-14. LIQUID CARRYOVER Ref: 1.39
1-15. Ammonia flooded chillers always require either a(n) ________ or a(n) ________ to catch oil.	1-15. DROP LEG; OIL POT Ref: 1.52
1-16. Liquid/vapor separation in a flooded chiller takes place mainly in the ________ mounted on the chiller.	1-16. ACCUMULATOR Ref: 1.55

Answer the following questions by marking an "X" in the box next to the best answer.

1-1. Refrigerant flows in a thermosiphon system because the refrigerant in the return line ________ than the refrigerant in the supply line.

- ☐ a. is at a lower pressure
- ☐ b. is at a lower temperature
- ☐ c. moves at a greater velocity
- ☐ d. weighs less

1-2. Refrigerant in a gravity feed surge drum is at

- ☐ a. condensing temperature and evaporating temperature
- ☐ b. condensing temperature and pressure
- ☐ c. evaporating temperature and condensing pressure
- ☐ d. evaporating temperature and pressure

1-3. Compared to direct expansion systems, recirculation systems

- ☐ a. are more common on smaller, specialized equipment
- ☐ b. provide better heat transfer
- ☐ c. require a longer coil
- ☐ d. wet less of the coil surface

1-4. Which of the following is a recirculation vessel device designed to stop the compressor in case of possible liquid carryover?

- ☐ a. High-level control
- ☐ b. Low-level control
- ☐ c. Pressure regulator
- ☐ d. Refrigerant makeup control

1-5. In a pumped overfeed system, refrigerant pressure entering the evaporators should be

- ☐ a. about 5 psi above evaporating pressure
- ☐ b. equal to the evaporating pressure
- ☐ c. sufficient to provide 7 to 10°F of superheat
- ☐ d. 30 psi for all systems

1-6. Dump traps switch between filling and feeding refrigerant by means of a ________ control switch and a ________ valve.

- ☐ a. level; hand expansion
- ☐ b. level; solenoid
- ☐ c. pressure; thermostatic expansion
- ☐ d. temperature; pressure regulator

1-7. The liquid in a CPR is at the

- ☐ a. compressor suction temperature
- ☐ b. condensing temperature
- ☐ c. CPR setpoint temperature
- ☐ d. evaporating temperature

1-8. The control mechanism for thermostatic expansion valves in DX systems is

- ☐ a. a pressure differential
- ☐ b. a temperature differential
- ☐ c. subcooling
- ☐ d. superheat

1-9. Which of the following contaminants will gradually increase because of distillation in a flooded ammonia chiller if the chiller is not serviced periodically?

- ☐ a. Nitrogen
- ☐ b. Noncondensables
- ☐ c. Oil
- ☐ d. Rust

1-10. The most direct indication of tube fouling in a flooded chiller is increased

- ☐ a. flow rate
- ☐ b. outlet temperature
- ☐ c. pressure drop
- ☐ d. temperature drop

SUMMARY

Gravity feed systems work according to thermosiphon principles. A flooded surge drum system is a gravity feed system for a refrigeration plant. The surge drum holds the liquid refrigerant above the evaporator at the evaporator pressure and temperature. Gravity feed systems are used on smaller plants.

Most industrial ammonia plants use liquid overfeed (recirculation) systems instead of gravity feed. A liquid overfeed system uses either liquid refrigerant pumps or dump traps. The pumped overfeed system raises the refrigerant pressure about 5 psi above evaporating pressure and feeds refrigerant by means of a solenoid/hand expansion balance valve arrangement. The dump trap system uses a three-way solenoid valve. Most systems use two traps so that one can fill while the other feeds refrigerant to the evaporators. Locating the recirculation vessel in the machine room simplifies oil removal.

The controlled pressure receiver (CPR) system consists of a high-pressure receiver controlled by a pressure regulator. Liquid feed is through a float connected to drain from the condenser. Direct expansion (DX) systems are used less often with ammonia than with halocarbon refrigerants. These systems work by means of a thermostatic expansion valve and about 7 to 10°F of superheat at the end of the evaporator coil. These systems are less efficient than other systems and require larger coils.

Flooded chiller systems are shell-and-tube evaporators with liquid refrigerant in the shell and the liquid to be cooled in the tubes. Chiller units include a suction accumulator for liquid/vapor separation. Liquid distribution should be provided between the internal baffles. Liquid is supplied by means of a low-side float, a hand expansion valve/solenoid valve arrangement controlled by a level switch, or a motorized valve operated by an electronic level controller and compressor discharge temperature control. Only the electronic controller provides variable level control. Monitoring equipment for ammonia flooded chillers includes inlet/outlet thermometers and pressure gauges, a flowmeter, and sight glasses for checking conditions in the chiller.

Answers to Self-Check Quiz

1-1. d. Weighs less. Ref: 1.02

1-2. d. Evaporating temperature and pressure. Ref: 1.04

1-3. b. Provide better heat transfer. Ref: 1.10

1-4. a. High-level control. Ref: 1.16

1-5. a. About 5 psi above evaporating pressure. Ref: 1.18

1-6. b. Level; solenoid. Ref: 1.23

1-7. c. CPR setpoint temperature. Ref: 1.27

1-8. d. Superheat. Ref: 1.31

1-9. c. Oil. Ref: 1.52

1-10. c. Pressure drop. Ref: 1.57

Contributions from the following sources are appreciated:

Figure 1-5. H.A. Phillips and Co.
Figure 1-7. Howe Corporation
Figure 1-8. H.A. Phillips and Co.
Figure 1-10. ThermoFluid International, Inc.