Demystifying HVAC

Test Your HVAC Knowledge

By Ron Prager

How much do you know about HVAC? Try testing yourself with the following questions and then take a look at the answers on the following page.

1) One ton of air conditioning is equal to:
   a) 12,000 BTUH
   b) Approximately 1 horsepower of compressor capacity
   c) The amount of heat required to melt 2000 lbs (one ton) of ice into water over a 24 hour period.
   d) All of the above.
   e) None of the above

2) A packaged rooftop air conditioner with gas fired heat:
   a) Heats by releasing the energy contained in natural gas and cools by releasing the energy in electricity.
   b) Heats by electrically charging natural gas and cools by vaporizing natural gas.
   c) Heats by releasing the energy contained in natural gas and cools by moving heat from the indoor air to the air outdoors.
   d) Heats by releasing the energy contained in natural gas and cools by removing humidity from the air.
   e) All of the above.

3) The compressor in a packaged HVAC unit:
   a) Pumps refrigerant throughout the system.
   b) Converts liquid refrigerant to gaseous refrigerant.
   c) Converts gaseous refrigerant to liquid refrigerant.
   d) Removes heat from the refrigerant.
   e) All of the above.

4) The condenser in a packaged HVAC unit:
   a) Transfers heat to the refrigerant from the indoor air.
   b) Transfers heat from the refrigerant to the outdoor air.
   c) Converts liquid refrigerant to gaseous refrigerant.
   d) Converts oil vapor to liquid oil.
   e) All of the above.

5) The evaporator in a packaged HVAC unit:
   a) Transfers heat to the refrigerant from the indoor air.
   b) Transfers heat from the refrigerant to the outdoor air.
   c) Converts liquid refrigerant to gaseous refrigerant.
   d) Converts oil vapor to liquid oil.
   e) All of the above.

6) The drier in a packaged HVAC unit:
   a) Helps the condenser fan motor to start.
   b) Removes humidity from the air.
   c) Removes moisture and debris from the refrigerant.
   d) Removes moisture from the flue gas.
   e) Removes moisture from the condensate pan.

7) In a packaged HVAC unit, the blower:
   a) Is a centrifugal fan.
   b) Moves air from the space through the indoor coil, the heat exchanger, and the air distribution system.
   c) Is usually belt driven.
   d) Draws in outdoor air during economizer operation.
   e) All of the above.

8) Which of the following can cause the indoor coil of a packaged HVAC unit to ice over?
   a) The unit is low on refrigerant charge.
   b) The blower belt is broken.
   c) The outdoor ambient temperature is extremely low.
   d) The thermostat is set below 68°F.
   e) All of the above.

9) Which of the following can cause a packaged HVAC unit to run high head pressure?
   a) The unit is low on refrigerant charge.
   b) The blower belt is broken.
   c) The outdoor ambient temperature is extremely low.
   d) The condenser coil is dirty.
   e) All of the above.

10) Condenser coil fins are often damaged by:
   a) Hail storms.
   b) Frequent pressure washing.
   c) Salt spray.
   d) Insufficient rinsing after cleaning coils with strong acids and bases.
   e) All of the above.

11) Water cooled air conditioning systems:
   a) Use building furnished water at a temperature of approximately 45°F to cool the air.
   b) Use condensate water circulating through chilled water coils.
   c) Use building furnished water at a temperature of approximately 80°F to transfer heat from water cooled condensers in individual packaged units.
   d) Use building furnished water at a temperature of 80°F to transfer heat from coils in air handlers.
   e) Are also known as swamp coolers or evaporative coolers.

12) On a packaged HVAC unit with gas heat, the draft inducer:
   a) Cools the compressor.
   b) Is piped into the gas line and increases gas pressure.
   c) Operates with the economizer to exhaust building air.
   d) Pulls the burning flue gases through the heat exchanger.
   e) Blows air over the condenser coil.

13) On a packaged HVAC unit, the economizer:
   a) Allows cooling to be accomplished by introducing outdoor air in lieu of operating compressors.
   b) Allows compressor so operate more efficiently.
   c) Allows outdoor air to cool the condenser coil.
   d) Allows outdoor air to circulate without the use of a blower motor.
   e) All of the above.

14) A packaged HVAC unit with gas heat is found to have a rotted heat exchanger. The unit must be shut down because.
   a) It might overheat and start a fire.
   b) It might draw in outdoor air through the rotted heat exchanger.
   c) Continued operation might destroy the draft inducer.

d) The unit might produce carbon monoxide and this poisonous gas might enter the conditioned space.
e) All of the above.

15) HVAC units that utilize hot water, chilled water, or steam coils must be equipped with a freeze-stat:
a) To prevent a condensate leak caused by icing over of the cooling coil.
b) To prevent the water in these coils from freezing causing the coils to burst.
c) To prevent the temperature of the air being discharged to the space from going too low.
d) To limit the amount of cold outdoor air being brought into the space.
e) All of the above.

16) If a technician diagnoses a badly burned out compressor, you would expect him to install:
a) A new compressor and liquid line filter drier.
b) A new compressor, liquid line drier, and suction filter drier.
c) A new compressor, liquid line drier, and contactor.
d) A new compressor, liquid line drier, contactor and expansion valve.
e) A new compressor, liquid line drier, suction filter drier, and contactor.

17) A heat pump is:
a) A device that circulates steam.
b) A device that pumps condensate back to a boiler.
c) A type of compressor.
d) An air conditioner with a valve that allows the refrigerant flow to be reversed so that the condenser becomes the evaporator and vice a versa.
e) All of the above.

18) A technician recommends pressure washing condenser coils on a packaged rooftop unit. You check the service history and determine that the coils were cleaned 3 months ago. You then ask for:
a) Pictures of the coil.
b) Pressure measurements, sub-cooling measurement, and temperature rise of air through condenser coil.
c) Geographic location of site.
d) If coil is made up of two coils wrapped around one another.
e) All of the above.

19) On a packaged HVAC unit operating in cooling mode:
a) The discharge air temperature should be approximately 55°F and the difference in temperature between the air supplied to the space and returned from the space should be 10°F.
b) The discharge air temperature should be approximately 55°F and the difference in temperature between the air supplied to the space and returned from the space should be 20°F.
c) The discharge air temperature should be approximately 65°F and the difference in temperature between the air supplied to the space and returned from the space should be 10°F.
d) the discharge air temperature should be approximately 65°F and the difference in temperature between the air supplied to the space and returned from the space should be 20°F.
e) the discharge air temperature should be approximately 45°F and the difference in temperature between the air supplied to the space and returned from the space should be 30°F.

20) Which of the following is not a possible cause of a condensate leak:
a) Clogged drainage piping.
b) Unit not installed level.
c) No P trap installed.
d) Unit operating at lower than normal pressures.
e) Unit operating at higher than normal pressures.

Answers to HVAC Quiz:

1. **The correct answer is (d)** ***All of the above.***

   One ton of air conditioning capacity is defined as the amount of refrigeration effect produced by 2000 lbs (or one ton of ice) melting over a 24 hour period. If we divide 2000 by 24 we get the effect of melting 83.3 lbs of ice equaling one ton of refrigeration effect. This also equals 12,000 BTU's (British thermal units) per hour. The definition of a BTU is the amount of heat required to raise the temperature of 1 lb of water 1°F. Nominally, it requires a 1 horsepower compressor to circulate enough refrigerant to produce a refrigeration effect of 12,000 BTUH. (British thermal units per hour.)

2. **The correct answer is (c)** ***Heats by releasing the energy contained in natural gas and cools by moving heat from the indoor air to the outdoor air.***

   When we burn a fossil fuel like natural gas, the process is called combustion. We are actually releasing energy by causing the carbon in the fuel to combine with oxygen. The result is generation of heat, water vapor, and Carbon dioxide.

   We cannot absorb energy in a chemical reaction within an air conditioning unit in order to accomplish cooling. We can however, move heat from one place to another. We know that heat naturally tends to travel from a substance at a higher temperature to a substance that is at a lower temperature. Put a cold spoon in a glass of hot tea and the heat leaves the tea and increases the temperature of the spoon. What if we wanted to remove heat from the spoon and add it to the tea even though the spoon is cooler than the tea? We would be attempting to move heat from a cooler body to a warmer body. This is opposite the direction of the natural flow of heat. In order to accomplish this we would need to create conditions that cause heat to move opposite the natural direction of flow. We could accomplish this by transferring heat from the spoon to a substance that is at a lower temperature than the spoon, then create conditions that allow this substance to rise to a temperature that is greater than the temperature of the tea, and allow the substance to transfer its heat to the tea. This is how an air conditioner cools. It removes heat from 75°F indoor air and transfers it to outdoor air that may be as hot as 105°F by adding energy and using a substance known as a refrigerant. As the air conditioner removes heat from the indoor air, the temperature of the indoor air drops. Usually, we design the air conditioning system so that the temperature of the air exiting the air conditioning apparatus drops to around 55°F.

   As the temperature of the indoor air decreases, it hits the dew point of the indoor air. This is the temperature at which moisture in the air will condense into liquid water. This is how an air conditioner dehumidifies. Let's look at a glass of ice tea on a humid day. Notice the water vapor from the air condensing on the glass. This cold glass is actually dehumidifying the air around it. Now substitute a cold aluminum finned copper coil for the glass and you understand how an air conditioner dehumidifies.

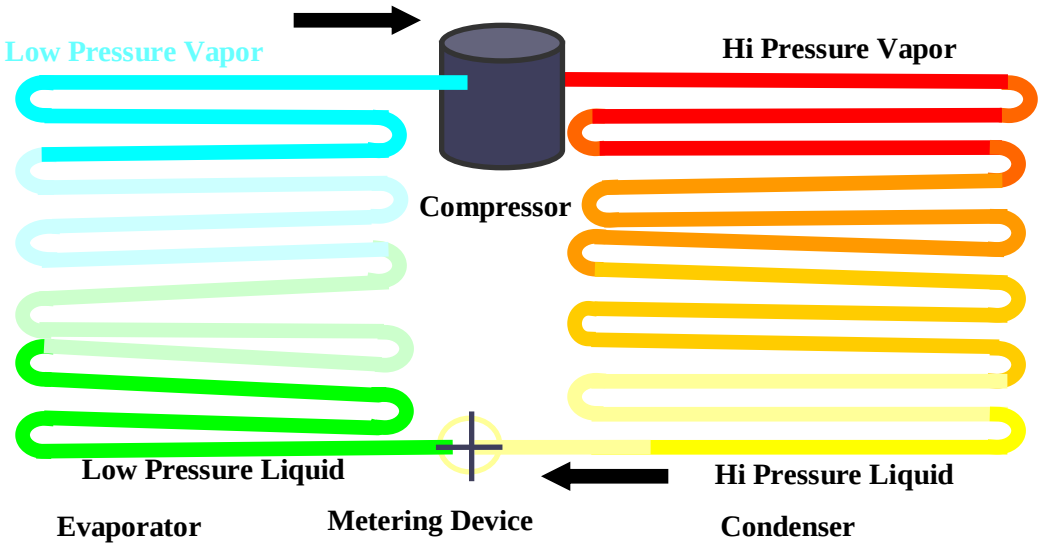
3. **The correct answer is (a).** ***Pumps refrigerant throughout the system.***

   A compressor is a pump that is designed to pump a gas. So, the compressor is used to pump refrigerant gas through the air conditioning system. Like any pump, the pressure of the gas is greater at the outlet of the compressor than it is at the inlet. It is this pressure difference that causes the refrigerant to move through the system. We are using energy in the form of electricity and converting it to mechanical energy with a motorized compressor in order to pump the refrigerant. In the answer to question #2, we noted that an air conditioner moves heat from cooler air and transfers it to warmer air. We also noted that this is opposite the direction that heat normally flows. It is the electrical energy, converted to mechanical energy, that we are adding to the refrigerant, that allows us to force heat to flow from a cool mass to a warm mass.

4. **The correct answer is (b).** ***Transfers heat from the refrigerant to the outdoor air.***
In order to understand the purpose of a condenser and how it works, we must first understand the refrigeration cycle used in packaged air conditioners. In the answer to question #1, we said that one BTU is defined as the amount of heat required to raise one lb of water 1°F. Now, I will tell you that it would take 760 BTU's to change 1lb of water at 212°F to 1 lb of steam at 212°F. This means that there is a huge quantity of heat required to change the state of a fluid when compared with the amount of heat required to change the temperature of that fluid. It is this process and the heat required to drive it, that allow an air conditioner to operate effectively.

Heat is transferred from the indoor air to a liquid refrigerant running through the evaporator coil. Note that this heat flows naturally because the indoor air is warmer than the evaporator coil. This increase in heat causes the liquid refrigerant to vaporize or evaporate into the refrigerant's gaseous state. As the refrigerant changes state it absorbs a large amount of heat per pound of refrigerant vaporized. By picking a refrigerant with a low boiling point, and controlling the pressure that the refrigerant is boiling at, we can determine what temperature the refrigerant is evaporating at. Typically, the refrigerant in the evaporator coil is evaporating at a temperature of 35°F to 40°F. If we chose to discard the refrigerant after it becomes a gas, this would be the end of our cycle. However, since refrigerant costs money, and it damages the atmosphere, we need to continue the cycle and use it over and over again.

So, after the refrigerant vapor leaves the evaporator coil, we draw it into the compressor described in question #3. The compressor pumps the vapor into the condenser. The compressor raises the pressure of the refrigerant gas so that the boiling point is raised. The boiling point is also the condensing point. So while in the evaporator, we were dealing with refrigerant evaporating at 40°F, after the compressor raises the pressure, the refrigerant will condense (change back to its liquid state) at a temperature of 140°F inside the condenser. This works out really well, because if we blow 105°F outdoor air over the condenser, we can remove lots of heat from the 140°F refrigerant gas and convert it back to a liquid. We can now send this liquid back to the evaporator to be boiled off again and absorb heat in the process. In order to maintain a low pressure and corresponding boiling point in the evaporator and a high pressure and boiling point in the condenser, we separate the two with a metering device. This device controls the flow of refrigerant and maintains the pressure difference. A chart of the refrigeration cycle is shown below.



5. **The correct answer is (a) and (C).** ***Transfers heat to the refrigerant from the indoor air and converts liquid refrigerant to gaseous refrigerant.***
As described in the answer to question #4.

6. **The correct answer is (c).** ***Removes moisture and debris from the refrigerant.***
A liquid line filter drier is a steel shell, around 3" in diameter, filled with a desiccant and fitted with a strainer. This shell is normally installed just ahead of the metering device in the refrigerant circuit. Silica gel is normally the desiccant that fills the drier. This is the same stuff that fills the little cotton bags that come packed with electronic equipment. The purpose in both cases is to absorb moisture. The strainer filters out any particles of dirt and debris. Sometimes, when a burned out compressor is replaced, a technician will install a larger version of this device, ahead of the compressor, called a suction line filter drier. These are installed to protect the new compressor from any residue left in the system from the burned out compressor.

7. **The correct answer is (e).** ***All of the above.***
The blower is the fan that moves air from the store through the HVAC unit and through the air distribution system. It is normally a centrifugal type fan that looks like something you would see a hamster running in. A motor drives this fan via two pulleys, also called sheaves. A drive belt runs between the pulleys, transferring power from the motor to the blower wheel. When the unit calls for economizer operation, the outdoor air damper opens, the return air damper closes, and the blower pulls air from outdoors and discharges it through the unit and into the air distribution system.

8. **The correct answer is (e).** ***All of the above.***
Evaporator coils (indoor coils) ice over when the temperature of the coil is below 32°F. This can occur if there is not enough heat load on the coil, or if the pressure of the refrigerant within the coil drops too low. Causes of low heat load are a broken drive belt, or setting the thermostat too low. A broken belt results in no airflow over the coil and therefore very little heat is transferred to the coil. A low thermostat temperature

setting allows the temperature of the air in the conditioned space to be lowered to the point that it cannot provide enough heat load to keep the coil above 32°F.

Insufficient refrigerant charge and low outdoor temperatures cause the unit to operate at pressures that are lower than normal. Due to the relationship between boiling point and pressure, this causes the temperature within the coil to drop below 32°F and the coil ices over.

9. The correct answer is (d). *The condenser coil is dirty.*

When the finned surfaces on a coil age dirty and the dirt plugs the spaces between the fins, the amount of air flowing over the coil is reduced and the coil's ability to transfer heat is reduced severely. Because of the relation ship between pressure and temperature, the heat builds up in the coil, the temperature of the refrigerant rises and so does the pressure in the condenser coil.

10. The correct answer is (e). *All of the above.*

Hail storms damage condensers when hail stones bend the thin aluminum fins. Coils can actually be completely destroyed by hail. Similarly, fins can be easily damaged by pressure washing. Air containing salt spray corrodes the thin aluminum fins and breaks the bond between the fins and the copper tubes. Chemicals used to clean the coils must be thoroughly rinsed off during the cleaning process. If left in place, these chemicals work their way into the connection between the aluminum fins and the copper tubes and cause corrosion, breaking the metal to metal connection.

11. The correct answer is (c). *Use building furnished water at a temperature of approximately 80°F to transfer heat from water cooled condensers in individual packaged units.*

There are three basic types of HVAC systems that utilize water in the cooling process. The first type are water cooled systems. These transfer heat from the refrigerant to water in a water cooled condenser rather than transferring heat to outdoor air via an air cooled condenser. The condenser water is normally furnished by the building. Typically, water enters the condensers at 80°F and leaves the condensers at 90°F. The water then goes to a cooling tower where a portion of the water is evaporated. This cools the balance of the water down to 80°F and it is sent back to cool the condensers once again.

The second type of system is a chilled water system. In this type of system, water is cooled to 45°F by chillers in a central plant. This water is circulated throughout a building and runs through water coils in air handling units, leaving the coils at an approximate temperature of 55°F. Room air is drawn into the air handlers and is blown over the chilled water coils where it exits at a temperature of approximately 52°F.

The third type of system is known as an evaporative cooler or a swamp cooler. It is normally only found in very dry climates and is used to cool make-up air in kitchens, and stock rooms. Air is drawn into the cooler by a blower and passes over an absorbent pad. The pad is continuously soaked with water. As the hot dry air passes over the wet absorbent pad, some of the water is evaporated. This cools the wet pad the same way moisture evaporating from your skin cools your body. The air leaves the cooler at a reduced temperature. This temperature is dependent on the relative humidity of the air being drawn into the cooler.

12. The correct answer is (d). *Pulls burning flue gases through the heat exchanger.*

A draft inducer is a blower that draws a mixture of air and burning natural gas through the combustion chamber and heat exchanger of a furnace. Unlike a fireplace, which depends on a chimney to provide natural draft, an induced draft furnace requires no chimney and is not affected by downdrafts or obstructions nearby.

13. **The correct answer is (a).** ***Allows cooling to be accomplished by introducing outdoor air in lieu of operating compressors.***

This answer is pretty much self explanatory, except for the fact that controls within the air conditioning unit determine when outdoor air conditions are suitable to allow economizer operation to take place. You would not want to attempt to cool a space by bringing in outdoor air at 90°F or at 90% relative humidity. Economizers have the potential to save significant amounts of compressor run time. This translates into a significant savings in energy and dollars. Obviously economizers are most effective in cooler climates.

14. **The correct answer is (d).** ***The unit might produce carbon monoxide and this poisonous gas might enter the conditioned space.***

The heat exchanger in a gas furnace is a tubular steel device that separates the burning gases from the air being delivered to the conditioned space. The burning gasses are flowing inside the tubes and the conditioned air is passing over the outside of the tubes. If these tubes are holed or cracked, the products of combustion can enter the conditioned air. Under certain conditions, due to incomplete combustion these products of combustion can contain significant quantities of carbon monoxide. This is a poisonous odorless gas that can make people extremely ill and in high concentrations over an extended period of time will cause death.

15. **The correct answer is (b).** ***To prevent water in these coils from freezing, causing the coils to burst.***

A freezestat is a control that automatically shuts down an HVAC unit and closes the outdoor air dampers if it senses a temperature below 35°F. Any coil containing unheated water can freeze and will burst if the coil is exposed to temperatures below 32°F. This situation can be caused by a heating issue, an evaporator coil near the water coil icing over, or by infiltration of cold outdoor air. The freezestat is installed to prevent temperatures within the coil from falling low enough to cause damage.

16. **The correct answer is (e).** ***A new compressor, liquid line drier, suction filter drier, and contactor.***

When a compressor burns, the interior of the piping and coils within the air conditioning unit are filled with soot, burned oil, and acid. This is residue from the varnish on the windings and the lubricating oil within the compressor overheating. The interior of the system is actually supposed to be maintained in close to sterile conditions for proper operation. If the system is not cleaned up properly, the new compressor can fail due to damage from the residue. Whenever a refrigerant circuit is opened to the atmosphere, the liquid line drier should always be replaced. The suction filter drier is required to help clean the system from the residue of the burned compressor. Replacing the contactor is a good idea whenever a compressor burns because the contactor may have been subjected to extremely high current during the burnout and because a defective contactor may actually have been the cause of the burnout.

17. **The correct answer is (d).** ***An air conditioner with a valve that allows the refrigerant flow to be reversed so that the condenser becomes the evaporator and vice a versa.***

Picture taking a window air conditioner and reversing it in the window. It would blow cool air outdoors and blow hot air indoors. Essentially, the reversing valve in a heat pump unit accomplishes the same function. Heat pumps are available in many types. There are water source heat pumps that operate like water cooled air conditioners, split system heat pumps that operate like split system air conditioners, and packaged rooftop heat pumps. The disadvantage of a heat pump is that as the outdoor temperature drops so does the capacity of the heat pump. When water source heat pumps are used to heat a building, heat must be added to the water loop during heating season by a boiler

and heat must be transferred from the water loop by a cooling tower during the cooling season.

18. The correct answer is (e). All of the above.

Pictures of the coil may show visible debris, pollen or a coil that is physically damaged. Pressure measurements and sub-cooling measurements will tell you if the coil is operating inefficiently and is usually a good barometer of the cleanliness of the coil as well as a measure of refrigerant charge. Certain geographic locations, and units that are physically located on dirty city streets may require multiple coil cleanings each season due to debris and soot being sucked into the coil. You may have heard about coils needing to be split in order to be cleaned properly. Some manufacturers have built HVAC units with one single row condenser coil placed in front of a second coil to form a two or three row coil. Debris gets trapped between the two coils and forms a blanket. The only way to clean this type of coil properly is to separate the two coils and wash each individually.

19. The correct answer is (b). The discharge air temperature should be approximately 55°F and the difference in temperature between the air supplied to the space and returned from the space should be 20°F.

Some times you will hear a technician say that the "Split ," on a unit is 18°F. He is referring to the difference in temperature between the air entering the evaporator coil and the air leaving the coil. It is also referred to as delta "T." Optimally, we would like to see this temperature be approximately 20°F. If it is significantly higher than 20°F you probably are not moving enough air through the cooling coil. If it is significantly lower, there are any number of possible causes. If we assume a normal return air temperature of 75°F, we would expect to see a discharge air temperature of 55°F.

20. **The correct answer is (e).** ***Unit operating at higher than normal pressures.***

Answers a through d are all common causes of condensate leaks. Clogged drain lines are the most common cause of leaks. Debris in the unit drain pan clogs the drainage piping and the condensate backs up into the pan until the pan overflows. Similarly, if the unit is not installed level, condensate can overflow the pan before it reaches the drainage outlet on the pan.

A "P" trap prevents air from being sucked into the unit through the drainage piping. If air is constantly being sucked in through the drainage piping, water cannot flow out through the piping and it overflows the pan.

If a unit operates at lower than normal pressures, the temperature in the evaporator coil may be low enough for the coil to ice over. When the pressure reaches the threshold of the low pressure safety control, the unit shuts down, the ice melts, and chunks of ice fall outside the pan and melt, or the ice blocks the drainage piping. In either case, water falling outside the drain pan spills into the conditioned space and ruins the ceiling tiles and merchandise.