PDHonline Course E298 (3 PDH)

Heat Pump Systems

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Heat Pump Systems

Lee Layton, P.E

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Introduction

For climates with moderate heating and cooling needs, heat pumps offer an energy-efficient alternative to furnaces and air conditioners. Like a refrigerator, heat pumps use electricity to move heat from a cool space into a warm space, making the cool space cooler and the warm space warmer. During the heating season, heat pumps move heat from the cool outdoors into a warm house; during the cooling season, heat pumps move heat from a cool house into the warm outdoors. Because they move heat rather than generate heat, heat pumps can provide up to four times the amount of energy they consume.

Heat Pumps can provide up to four times the amount of energy they consume.

A heat pump is a device that moves heat from one location to another location using mechanical work. Most heat pump technology moves heat from a low temperature heat *'source'* to a higher temperature heat *'sink'*. A heat pump for heating and cooling a building is known as a reversible cycle heat pump. Other examples of heat pumps are food refrigerators, freezers, and air conditioners. These systems can also operate in reverse, producing heat.

Heat pumps can be thought of as a heat engine which is operating in reverse. Heat flows naturally from a higher to a lower temperature. Heat pumps, however, can force the heat flow in the other direction, using a relatively small amount of drive energy such as electricity. Thus, heat pumps can transfer heat from natural heat sources in the surroundings, such as the air, ground or water, or from man-made heat sources such as industrial or domestic waste, to a building or an industrial application. Heat pumps can also be used for cooling. Heat is then transferred in the opposite direction, from the application that is cooled, to surroundings at a higher temperature. Sometimes the excess heat from cooling is used to meet a simultaneous heat demand.

In order to transport heat from a heat source to a heat sink, external energy is needed to drive the heat pump. Theoretically, the total heat delivered by the heat pump is equal to the heat extracted from the heat source, plus the amount of drive energy supplied.

The most common type of heat pump is the air-source heat pump, which transfers heat between the house and the outside air. It works by exploiting the physical properties of an evaporating and condensing fluid known as a refrigerant. In heating, ventilation, and cooling (HVAC) applications, a heat pump normally refers to a vapor-compression refrigeration device that includes a reversing valve and optimized heat exchangers so that the direction of heat flow may be reversed. When heating with electricity, a heat pump can reduce the amount of electricity used for heating by as much as 30%–40%. High-efficiency heat pumps also dehumidify better than standard central air conditioners, resulting in less energy usage and more cooling comfort in summer months. However, the efficiency of most air-source heat pumps as a heat source drops dramatically at low temperatures, generally making them unsuitable for cold climates, although there are systems that can overcome that problem.

Higher efficiencies are achieved with geothermal (ground-source or water-source) heat pumps, which transfer heat between the residence and the ground or a nearby water source. Although they cost more to install, geothermal heat pumps have low operating costs because they take advantage of relatively constant ground or water temperatures. Ground-source or water-source heat pumps can be used in more extreme climatic conditions than air-source heat pumps, and customer satisfaction with the systems is very high.

Another type of heat pump for residential systems is the absorption heat pump, also called a gas-fired heat pump. Absorption heat pumps use heat as their energy source and can be driven with a wide variety of heat sources.

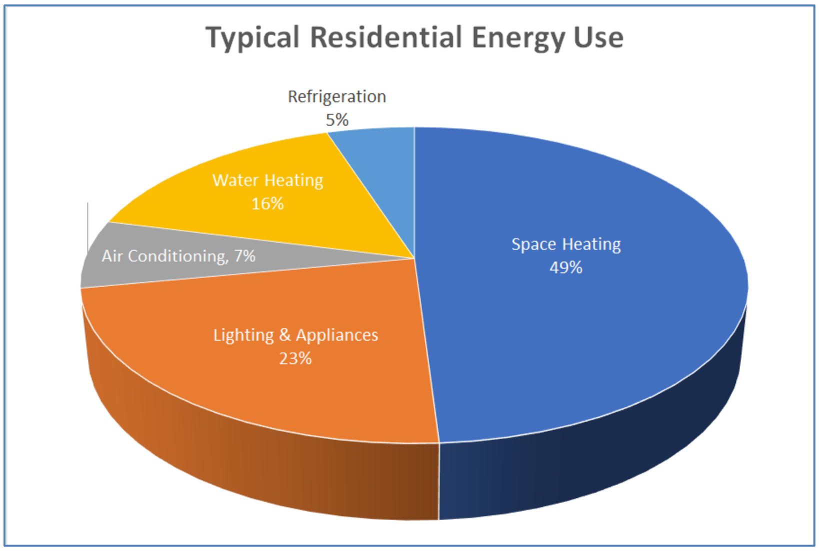


Figure 1

Heating and cooling are the major energy consumers in a residential dwelling. The adjacent chart, Figure 1 shows the typical energy use for a residential building. As you can see space heating is the largest consumer of energy at 49% of the total usage in a home, followed by lighting and appliances, which is 23% of the total. Water heating is the third largest consumer of energy at 16% of the total. These values vary based on the area of the country with air conditioning making up a larger percentage in the South and Southwest parts of the United States. Small commercial buildings will have similar usage patterns except that the water heating will be less, and the air conditioning and lighting will be a larger percentage.

As previously mentioned well over half the energy consumption in residential and small commercial buildings is for the heating, ventilation, and air-conditioning system. The next two pie charts show the types of heating and cooling systems in use today. Looking at Figure 2. For cooling needs, packaged systems make up 54% of the systems in use. Chillers are the next largest segment with a total of 31% of the market spread among the different types of chillers. The remaining systems are divided between individual units such as window units and through-the-wall systems. Of the chiller systems, centrifugal units are the predominate system and only 2% of the systems are absorption systems. Unfortunately, packaged systems, which represent the largest share of the market, generally have efficiencies that are much lower than chiller type systems.

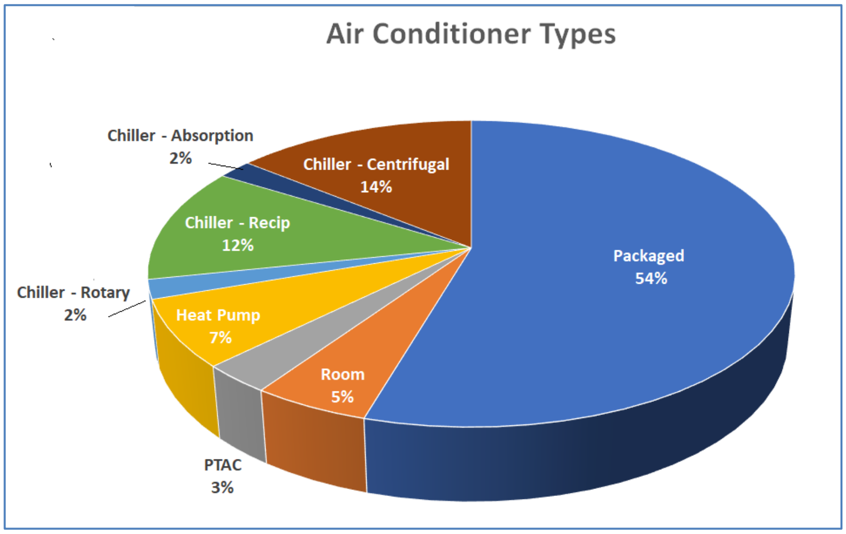


Figure 2

For heating systems, the types of systems are more evenly divided among the different types of systems.

Like the cooling systems, packaged heating systems have the largest percentage share of the market, but the share is only 25% of the total. Next are boiler systems at 21% followed closely by furnaces and unit systems.

In the commercial markets, retail space is the major heating consumer with public buildings and office space being the next largest users. This type of floor space tends to have packaged and boiler systems.

Figure 3 shows the energy consumption impact of various heating systems. Because heat pumps consume less primary energy than conventional heating systems, they are an important technology for reducing gas emissions that harm the environment, such as carbon dioxide (CO_2), sulphur dioxide (SO_2) and nitrogen oxides (NOx). However, the overall environmental impact of electric heat pumps depends very much on how the electricity is produced. Heat pumps driven by electricity from, for instance, hydropower or

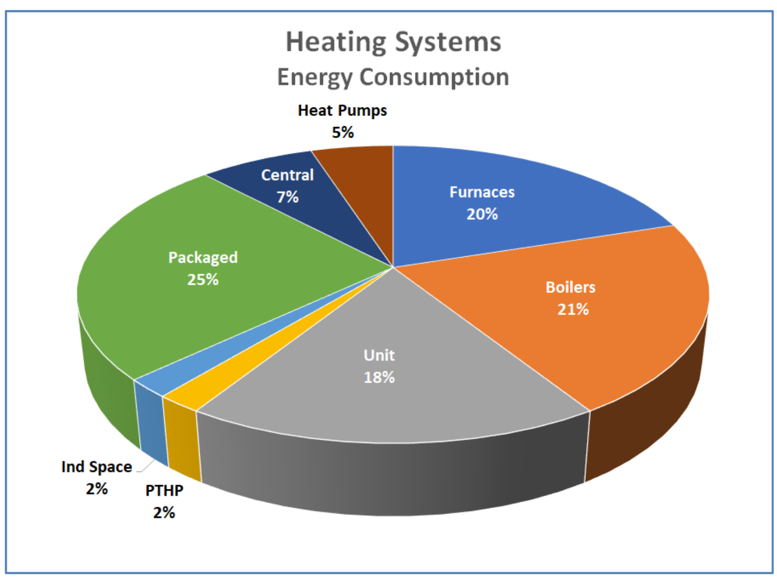


Figure 3

renewable energy reduce emissions more significantly than if the electricity is generated by coal, oil or gas-fired power plants.

In this course, we will review the basic operation of a heat pump, the components that make up a heat pump, operating cycles, and discuss a few of the advantages and disadvantages of the most common types of heat pumps in use today.

Chapter 1
Heat Pump Components

To move heat from a colder location to a warmer area requires thermodynamic work. Heat pumps differ in how they apply this work to move heat, but they can essentially be thought of as heat engines operating in reverse. A heat engine allows energy to flow from a hot *source* to a cold heat *sink*, extracting a fraction of it as work in the process. Conversely, a heat pump requires work to move thermal energy from a cold source to a warmer heat sink.

Since the heat pump uses a certain amount of work to move the heat, the amount of energy deposited at the hot side is greater than the energy taken from the cold side by an amount equal to the work required. Conversely, for a heat engine, the amount of energy taken from the hot side is greater than the amount of energy deposited in the cold heat sink since some of the heat has been converted to work.

A typical heat pump's refrigeration system consists of a compressor and two coils made of copper tubing - one indoors and one outside - which are surrounded by aluminum fins to aid heat transfer. In the heating mode, liquid refrigerant in the outside coils extracts heat from the air and evaporates into a gas. The indoor coils release heat from the refrigerant as it condenses back into a liquid. A reversing valve, near the compressor, can change the direction of the refrigerant flow for cooling as well as for defrosting the outdoor coils in winter.

In HVAC applications, a heat pump normally refers to a vapor-compression refrigeration device that includes a reversing valve and optimized heat exchangers so that the direction of heat flow may be reversed. The reversing valve switches the direction of refrigerant through the cycle and therefore the heat pump may deliver either heating or cooling to a building. In the cooler climates the default setting of the reversing valve is heating. The default setting in warmer climates is cooling. Because the two heat exchangers, the condenser and evaporator, must swap functions, they are optimized to perform adequately in both modes. As such, the efficiency of a reversible heat pump is typically slightly less than two separately optimized machines.

Traditionally when outdoor temperatures fell below around 32F, an alternate source of heating was required. Today, modern heat pumps can operate at much lower temperatures – some even down to minus 15F. When auxiliary heating is required it is often low-efficient, electric resistance coils. Some units now have gas-fired backup furnaces instead of electric resistance coils, allowing them to operate more efficiently. Because of the need for auxiliary heat, air-source heat pumps aren't always the most efficient heating source in extremely cold weather areas of the country.

Most central heat pumps are split-systems—that is, they each have one coil indoors and one outdoors. Supply and return ducts connect to a central fan, which is located indoors. Some heat pumps are packaged systems. These usually have both coils and the fan outdoors. Heated or cooled air is delivered to the interior from ductwork that protrudes through a wall or roof.

A heat pump delivers more heat output than the equivalent of the electric input it uses. It is not uncommon for a heat pump to deliver 250% to 400% more heat than you would obtain from an equivalent electric resistance heating system.

The efficiency and performance of today's air-source heat pumps is one-and-a-half to two times greater than those available 30 years ago. This improvement in efficiency has resulted from technical advances and options such as these:

- Thermostatic expansion valves for more precise control of the refrigerant flow to the indoor coil.
- Variable speed blowers, which are more efficient and can compensate for some of the adverse effects of restricted ducts, dirty filters, and dirty coils.
- Improved coil design.
- Improved electric motor and two-speed compressor designs.
- Copper tubing grooved inside to increase surface area.

The most common heat pumps use electrically driven compressors. However, in addition to electrically driven compressors, natural gas-driven heat pumps are commercially available. In one example, the gas-fired heat pump uses the absorption cycle, where the energy for refrigerant compression is provided by a gas burner. Another approach is to use a natural gas fired engine to drive the heat pump. In this case, a natural gas engine is used to drive the compressor. During operation, heat is recovered from the engine jacket cooling water and engine exhaust. Gas heat pumps are less common than electric heat pumps and performance compared to electric heat pumps is lower, with lower Coefficient's of Performance (COP) for both absorption and engine-driven units than for conventional electric heat pumps. The inherent variable-speed capability of an engine offers part-load efficiency advantages compared to single speed electric compressor drives. They promise to reduce global warming through more efficient conversion of natural gas and reduced emissions from electric power plants as they do not use electricity to drive the heat pump.

This chapter is a look at the various components of a heat pump system. Chapter two discusses the actual operation of the heat pump cycles.

A heat pump system consists of the compressor, heat exchange coils, reversing valve, expansion device, defrost controls, accumulator, crankcase heater, refrigerant, and thermostat. We will look at each of these briefly.

Compressor

The primary component in a heat pump is the compressor. A compressor pumps refrigerant around the refrigerant circuit and increases the pressure of the refrigerant vapor. This increase in pressure allows the refrigerant to condense at a higher temperature. Refrigerant vapor always flows through the compressor in the same direction – it enters the suction pipe at low pressure and is discharged at a higher pressure. Most heat pump compressors are positive displacement units, which includes reciprocating, rotary and scroll compressors.

Many manufacturers have switched to scroll rotary compressors that are more efficient and reliable for heat pump applications. A few manufacturers use variable-speed or two-step compressors because they can vary the capacity of the compressor to match the heating or cooling load precisely. Other manufacturers use multiple-speed compressors that have discreet speed steps and therefore perform better in both heating and cooling functions.

Heat Exchanger Coils

Heat exchanger coils include the evaporator and condenser coils. The coils absorb or reject heat between two mediums of different temperatures. Because a heat pump can reverse its function from heating to cooling and vice versa, each heat exchanger coil can be either an *evaporator coil* or a *condenser coil*. In the heating mode, the outdoor coil (evaporator) in an air-source heat pump absorbs while the condenser in the indoor air stream rejects heat. In cooling mode, the coil in the indoor air stream absorbs heat while the outdoor coil rejects the excess heat. See Table 1.

Table 1
Heat Pump Coils

Coil	Heating Mode	Cooling Mode
Outdoor Coil	Evaporator	Condenser
Indoor Coil	Condenser	Evaporator

Fans

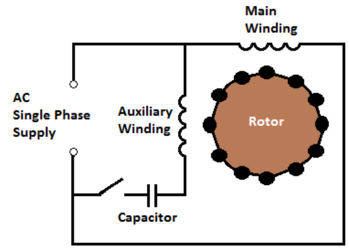


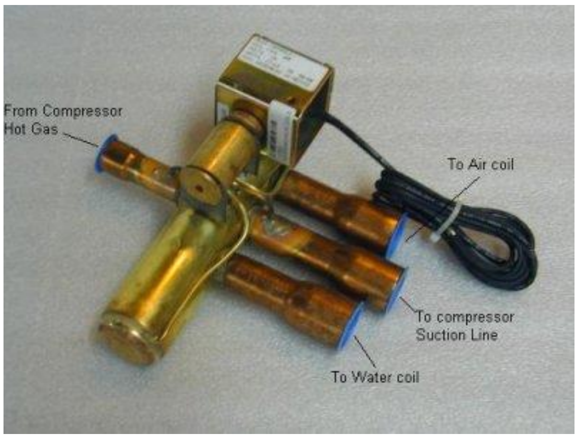
Figure 4

The most common heat pump types use standard permanent split-capacitor blower motors as shown in Figure 4 on the right. These motors are economical and usually only operate at one speed. Because of the capacitor they require maintenance than newer type motors.

The current standard for fan motors is an *electronically commutated motors* (ECMs). ECMs are brushless DC motors and are more efficient than conventional motors. ECMs operate over a wider range of speeds with the same efficiency as conventional motors.

These motors are often associated with top-of-the-line two-stage or multi-stage heat pumps of all types. In fact, an ECM indoor blower drive may be required to achieve SEER 16 or greater ratings in air-source heat pumps. When a dual capacity heat pump operates at low capacity, the ECM indoor blower uses about 30% of the power needed by the blower at high capacity. Air temperature at outlets is typically warmer with ECM blower equipped dual capacity heat pumps operating in high capacity mode. When operating in the circulation mode only (i.e., no heating or cooling) power draw can be 100 watts or lower with an ECM blower motor compared to 300 to 400 watts with a conventional blower motor. ECM motors cost approximately 50% more than a comparable split-capacitor motor.

Reversing Valve



A *reversing valve* automatically controls the direction of refrigerant through the system for heating and cooling in all heat pumps and in defrost mode in air-source heat pumps. Its position is controlled by a heating/cooling thermostat in the home or the defrost control in an air-source heat pump during the defrost cycle. A reversing valve has a connection on one side of the unit and three connections on the other side. The sole connection is from the compressor output. The center connection on the other side of the reversing valve leads to the suction side of the compressor. The remaining two connections lead to the condenser and evaporator coils.

Expansion Device

Heat pumps have an *expansion device* that meters or regulates the flow of liquid refrigerant to the evaporator. It reduces pressure of the liquid refrigerant to enable vaporization, and therefore heat absorption, to take place in the evaporator coil.

There are two types of expansion devices used today,

1. Fixed flow area type.
2. Thermostatic expansion (TEX) valve.

Thermostatic expansion valves are used where there is a varying load on the evaporator. They are recommended over fixed flow types. TEX valves have efficiencies of 5-10% better than fixed flow valves.

Defrost Sensor and Control

Below about 40F frost may accumulate on the outdoor coil of an air-source heat pump. Notice the frost build up on the heat pump in the adjacent photo. Frost impedes heat transfer between air and refrigerant and reduces capacity and must be reduced. Heat pumps generally defrost by one of two methods,

1. Time/temperature – Defrosting occurs after a pre-set compressor runtime if the coil temperature is below a pre-set value.
2. Demand defrost – Defrosting is initiated by either the presence of frost which increases pressure drop across the outdoor coil or by the temperature difference between the refrigerant and air.

With either method the outdoor coil is defrosted by re-directing compressor heat to the outdoor coil to melt frost. Demand defrost can reduce the energy required for defrosting by 5–10%.

Accumulator

An *accumulator* is a storage vessel that prevents excess liquid refrigerant from passing into the compressor, which could cause damage. This is especially important during the heating cycle when all refrigerant may not evaporate after passing through the evaporator coil. See Figure 5 for a description of accumulator operation.

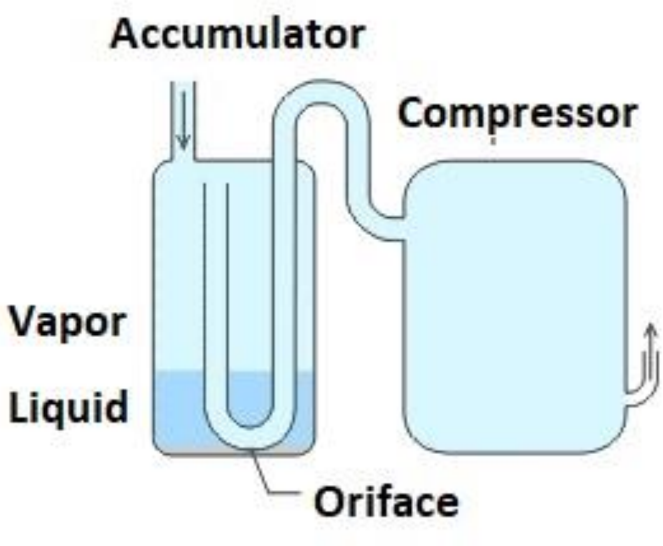


Figure 5

The accumulator has an inverted trap, much like a P-trap in a plumbing system, for the vapor to pass through on the way to the compressor. The trap can also have the undesirable characteristic of trapping compressor oil, so there is a small orifice in the bottom of the trap to pull back into the vapor flow.

Scroll compressors, as compared to reciprocating, have a relatively high tolerance to liquid when slugging occurs.

Crankcase Heater

A crankcase heater used to raise the oil temperature in the compressor. Higher oil temperature causes refrigerant to vaporize and this prevents it from mixing with the crankcase oil. Diluting the oil strains compressor due to the larger volume of liquid in the crankcase. There are two primary types of crankcase heaters: band heater, and an insertion heater. A band heater is shown in the photo on the right.

Refrigerant

The refrigerant for heat pumps is a liquid that has a low boiling point. For years the standard heat pump refrigerant was R22 Freon. R22 performs well over the range of temperatures commonly found in the operation of heat pumps. R22 is known as a hydro-chlorofluorocarbon

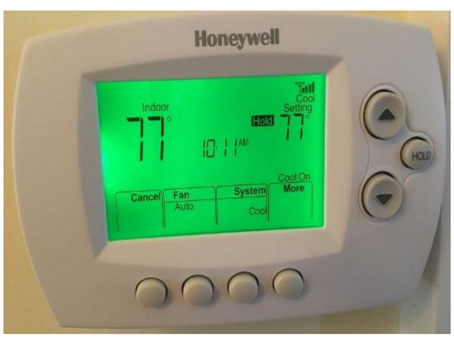
(HCFC) refrigerant and is considered by many to be harmful to the environment. It has an ozone depletion (ODP) factor of 0.05.

Because of the environmental concerns with R22, many heat pumps today use R-407C or R-410A (also known as "Puron"), which are hydro-fluorocarbons (HFC). Both R-407C and R-410A have zero ozone depletion potential (ODP). Performance (heating capacity and efficiency) is about the same with R-407C and about 4% better with R410A compared to R-22.

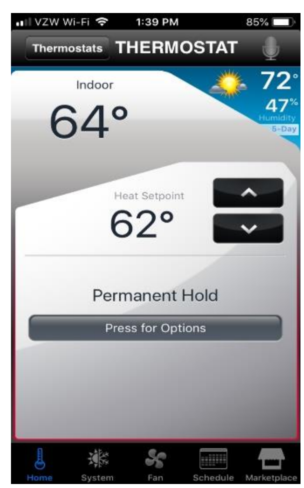
Thermostats

Modern thermostats offer precise control of the heat pump and will allow the system to operate within a narrow range of temperature settings. The Department of Energy recommends that in the cooling mode the thermostat be set at 78F and in the heating mode the thermostat be set to 68F. In the cooling mode, for each one degree the thermostat is raised above 78F, energy savings of be about 1% is possible. The same factor holds true in the heating mode, for each one degree the thermostat is lowered below 68F, the energy savings may be about 1%.

Today, programmable thermostats are prevalent and relatively cheap at less than $100.00 for most systems. For air-conditioning and gas furnaces programmable thermostats are cheap and offer a quick pay-back. Heat pumps are more complicated than gas furnaces and require more sophisticated programmable thermostats. For heat pumps, the thermostat must have special algorithms to prevent expensive auxiliary heating sources from operating unnecessarily.



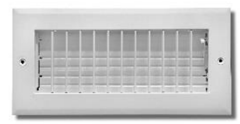
Programmable thermostats usually have provisions to set different schedules for weekdays and weekends. Some offer schedules for each day of the week. Most have several setback periods for each day. A "5+2" programmable thermostat has two schedules, a weekday and a weekend schedule. A "5+1+1" programmable thermostat has a weekday schedule and separate schedules for Saturday and Sunday. The photo shown on the left is an example of a "5+1+1" programmable thermostat.



Today, wifi enabled thermostats are the norm as well as "smart thermostats" that can learn the use patterns in a home a develop a programming schedule that coincidences with the homeowner's lifestyle.

Wifi enable thermostats enable homeowners to remotely control their thermostats using their smartphone or tablet. This includes the ability to adjust schedules, raise and lower the temperature, place the thermostat schedule on hold, and turn the fan on and off. A screen shot of a smartphone wifi thermostat is shown above.

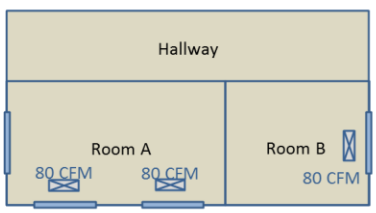
Diffusers



Diffusers – also known as Registers – return air to the room after it has been conditioned. The objectives of a diffuser is to quietly mix the incoming air with the existing room air without causing a draft. In system design *terminal velocity* is the point where air mixing ceases in the room. In residential applications the design velocity is typically 50 fpm or less in the occupied zone. Another design term related to diffusers is *throw*, which is the distance at which the air velocity is reduced to a specified level (e.g., 50 fpm). The throw of a diffuser changes as airflow changes.

Air Flow Ducts

lot of effort goes into designing a ducting system to distribute air in a building. Poorly designed and leaking duct systems are the cause of many HVAC complaints. Duct design must balance the initial cost of the duct system with potential operating costs and comfort levels. For a given space, large ducts have lower velocities, pressure drop, and less fan energy. In contrast, smaller ducts reduce initial costs and save building space, but with increased fan energy, pressure drop, and higher velocities.



Air Handling Units

Air Handling Units (AHUs) are where the air exchange between the compressor and the inside are occurs. An AHU consists of a coil that either absorbs (evaporator) or rejects (condenser) heat, a large squirrel cage fan, auxiliary heating elements, and perhaps a source of make-up air.
The purpose of the AHU is to exchange the heat from the compressor with the inside air. It delivers air to the diffusers and air from the building is returned through the return duct system to the AHU. The air flow is based on the static pressure of the system.

Air Filters

Air filters are inserted, either at the air handler, or in the return ducts to the air handler. The purpose of air filters is to remove some about particles, fibers, and spores from the air circulating in the building. The are three generally accepted rating processes for air filters. These include Minimum Efficiency Reporting Value (MERV), Micro-particle Performance Rating (MPR), and High Efficiency Particulate Arresting (HEPA) filters. List below are a few facts about these filter ratings:

- **MERV**
    - Developed by the ASHRAE
    - Higher numbered filters = finer filtration
    - Scale is 1-20
- **MPR**
    - Developed by 3M
    - Rates ability to capture airborne particles smaller than one micron
    - Scale 300 – 2800
- **HEPA**
    - Reduces the amount of dust blown through a system
    - Helpful for asthma or other chronic lung diseases

Table 2 list the characteristics of some common MERV filters.

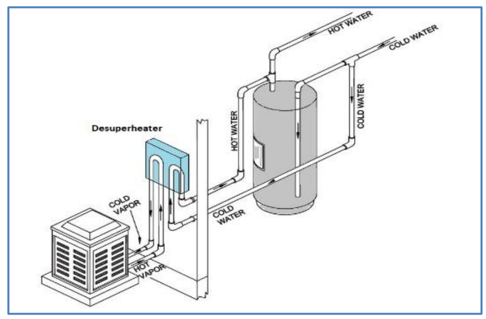
Table 2
Typical MERV Rating Filter Applications

MERV Rating	Dust Spot Efficiency	Arrestance	Typical Controlled Containment	Typical Applications
1	< 20%	< 65%	Textile Fibers Carpet Fibers	Window A/C Units
4	< 20%	75%-80%	> 10.0 pm Particle Size Pollen	Minimal Residential
7	25% - 30%	> 90%	Mold Spores Hair Spray	Better Residential

12	70% - 75%	> 95%	1.0 - 3.0 pm Particle Size Legionella	Superior Residential
13	89% - 90%	> 98%	Sneeze	Superior Commercial
16	N/A	N/A	0.3-1.0 pm Particle Size	General Surgery
20	N/A	N/A	< 0.30 pm particle size	Clean rooms

Domestic Water Heating

While not a required component of a heat pump, some heat pumps are equipped with a device called a *desuperheater* and is used to heat domestic water. The desuperheater is a heat exchanger located between the compressor and the condenser heat exchanger. Domestic water is circulated from a domestic hot water storage tank through the desuperheater when the heat pump is operating in either heating or cooling mode. The hot refrigerant gas leaving the compressor gives up heat to the domestic water in the desuperheater.



A desuperheater can supply typically 25% and more of the water heating required in a residential application. Some heat pumps can produce hot water on demand even if there is no space heating or cooling demand. Operating savings can be higher with these systems because more water heating can be done than with desuperheater-only systems. Desuperheaters in heating dominated climates take away about 10-15% of the heating capacity of the heat pump that would otherwise be used for space heating. Desuperheaters increase the load on the ground heat exchanger in heating dominated climates.

Chapter 2
Operating Cycles

The following is a more detailed look at the various cycles in a heat pump system.

As you look at these cycles, remember that all heat pumps operate in a similar manner in terms of the refrigerant boiling and condensing, pressure increasing and decreasing and the flow of refrigerant through the system.

> **Gas Laws**
> With either a liquids or gas:
> 1. As pressure increases, boiling point and condensing temperature increases.
> 2. As pressure decreases, boiling point decreases and condensing temperature decreases.

For the purposes of the following discussion it is convenient to refer to the coils as the "inside coil" and the "outside coil" versus the condenser coil and the evaporator coil since the roles change from the heating to the cooling cycle. A volatile liquid, known as the working fluid or refrigerant, circulates through system.

Heating Cycle

Figure 6 shows a typical split-system heat pump in the heating mode.

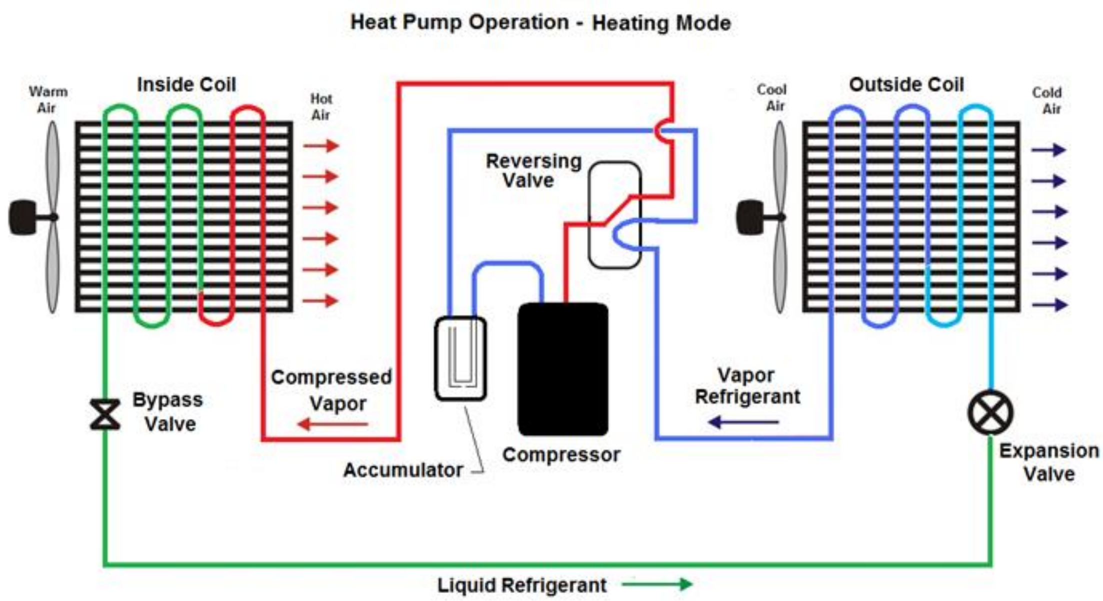


Figure 6

Looking at Figure 6 and beginning at the outside coil (right side of the drawing) we see that the heat is at the outside coil (evaporator) from the heat in the outside air and the refrigerant changes from a low-pressure liquid to a low-pressure gas. Since the temperature of the liquid working fluid is kept lower than the temperature of the heat source, the heat flows from the heat source to the liquid, and the working fluid evaporates. Next, the low-pressure gas is compressed into a high-pressure gas by a compressor. Leaving the compressor, heat is released in the inside coil (condenser) and delivered to the home. The vapor condenses to a high-pressure liquid as it gives up heat. As the liquid leaves the inside unit, it passes through an expansion valve. The high-pressure liquid is expanded through the expansion valve to become a low-pressure liquid and the cycle is repeated.

Cooling Cycle

Figure 7 shows a typical split-system heat pump in the cooling mode.

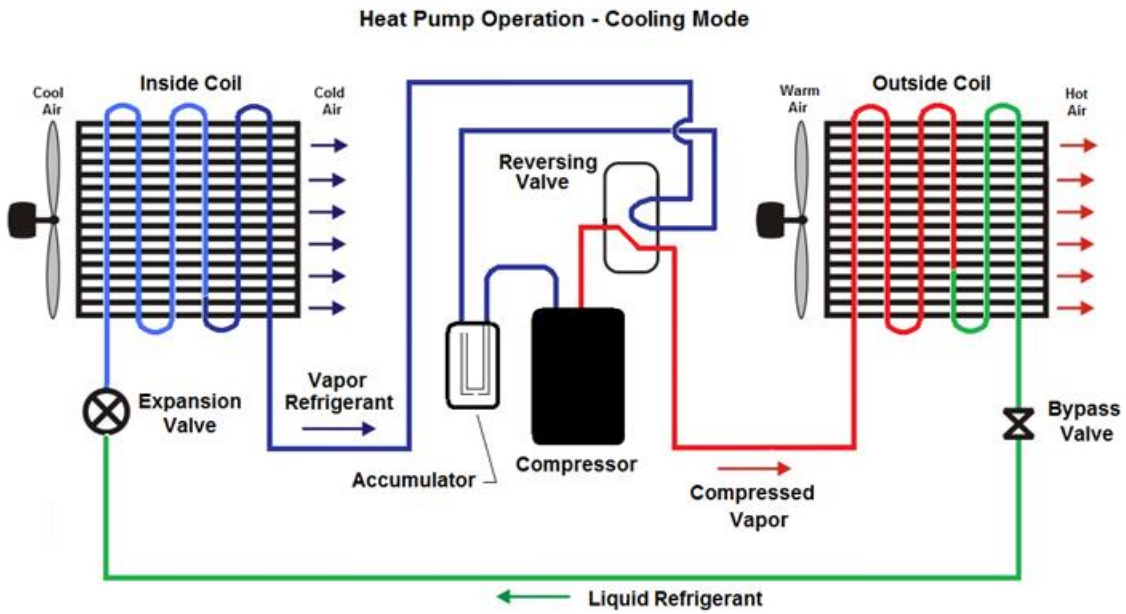


Figure 7

The cooling cycle is simply the reverse of the heating cycle. In the cooling mode, the reversing valve is energized, causing the refrigerant flow to change direction. In this mode, heat is absorbed by the inside coil (evaporator) as warm air passes over it. The outside coil rejects heat into the atmosphere. The refrigerant cycle is the same for both the heating and cooling modes; only the role of the heat exchanger coils change.

Let's follow the cooling cycle through a series four steps.

Step 1. The first step in the process is to remove heat from the building.

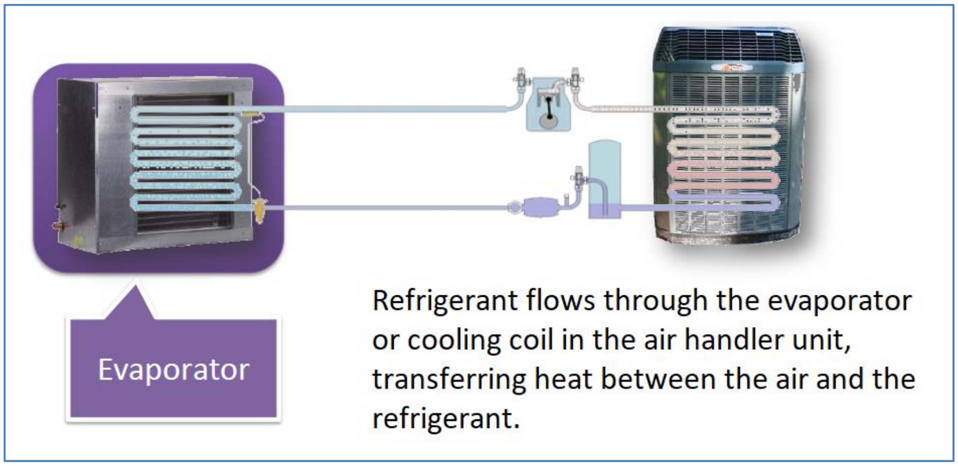


Figure 8

Step 2. The refrigerant - in a vapor state - enters the compressor where it is compressed which raises its temperature.

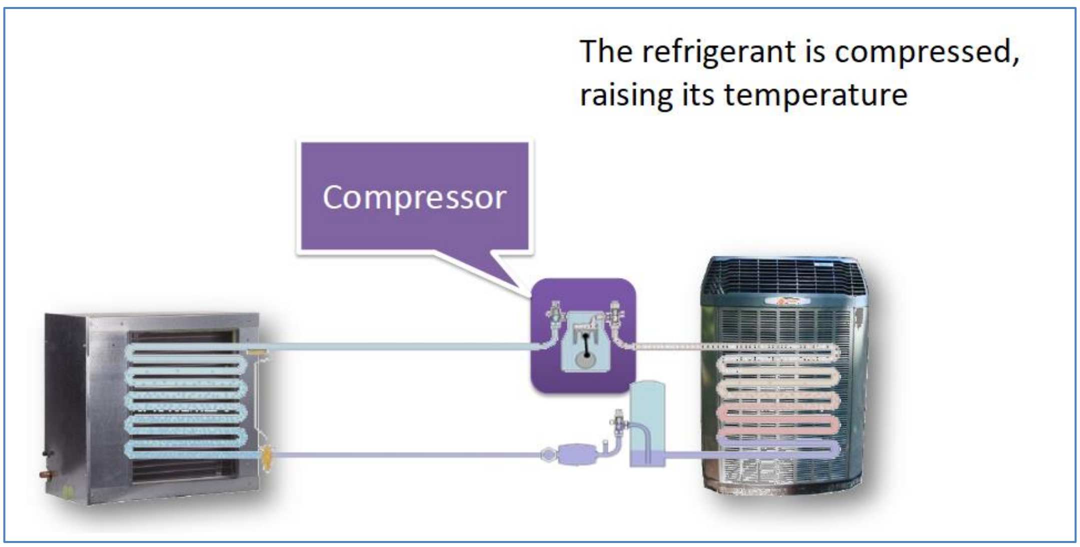


Figure 9

Step 3. After being compressed the refrigerant enters the condenser (outside coil) where air blowing across the coils removes heat from the refrigerant and causes the refrigerant to condense back into its liquid form.

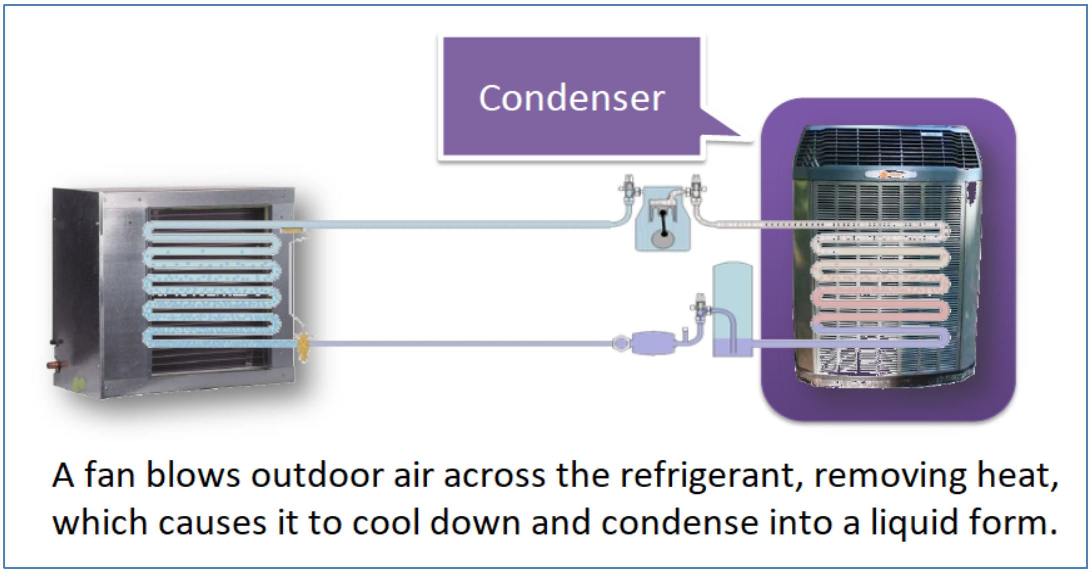


Figure 10

Step 4. The liquid refrigerant is metered to ensure the correct volume of liquid refrigerant enters the evaporator and the process begins again.

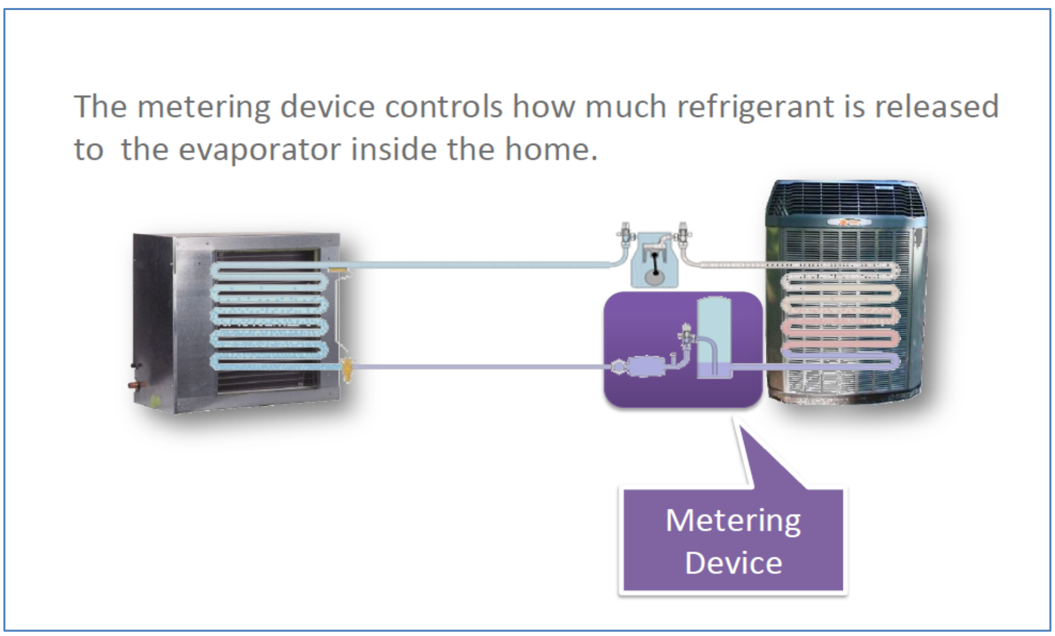


Figure 11

Defrost Cycle

Air source heat pumps require a defrost cycle. In heating mode, the outdoor evaporator coil often operates below 32F and moisture in the air causes frost to build up on the coil. This leads to reduced heat transfer, insufficient airflow and an overall reduction in efficiency.

To remove frost build-up, the system is reversed (put in cooling mode) for a short time. The outdoor coil becomes a condenser and rejects heat that melts the frost. The cooling effect is not felt indoors during a defrost cycle because backup heat maintains the indoor temperature.

Defrost control is automatic and performs well under most conditions. However, if the control malfunctions then the outdoor coil could become caked with ice or cause the defrost cycle to operate longer than necessary causing energy waste.

Absorption Heat Pump Heating Cycle

In absorption systems, compression of a working fluid is achieved thermally in a solution circuit which consists of an absorber, a solution pump, a generator and an expansion valve.

Absorption systems require a fluid pair. The most common working pairs for absorption systems are water (working fluid) and lithium bromide (absorbent); and ammonia (working fluid) and water (absorbent). Water is used as the absorbent and ammonia is the refrigerant. The refrigerant vaporizes in the evaporator and is absorbed by the absorbent in the absorber.

Absorption heat pumps are thermally driven, which means that heat rather than mechanical energy is supplied to drive the cycle. Absorption heat pumps for space conditioning are often gas-fired. Absorption systems utilize the ability of liquids to absorb the vapor of the working fluid.

A gas burner provides heat input to boil the solution, causing the release of refrigerant vapor. The refrigerant vapor condenses, releasing its heat to the house and returns to the evaporator where the cycle is repeated.

Heat is extracted from the heat source in the evaporator. Useful heat is given off at medium temperature in the condenser and in the absorber. In the generator high-temperature heat is supplied to run the process. A small amount of electricity may be needed to operate the solution pump.

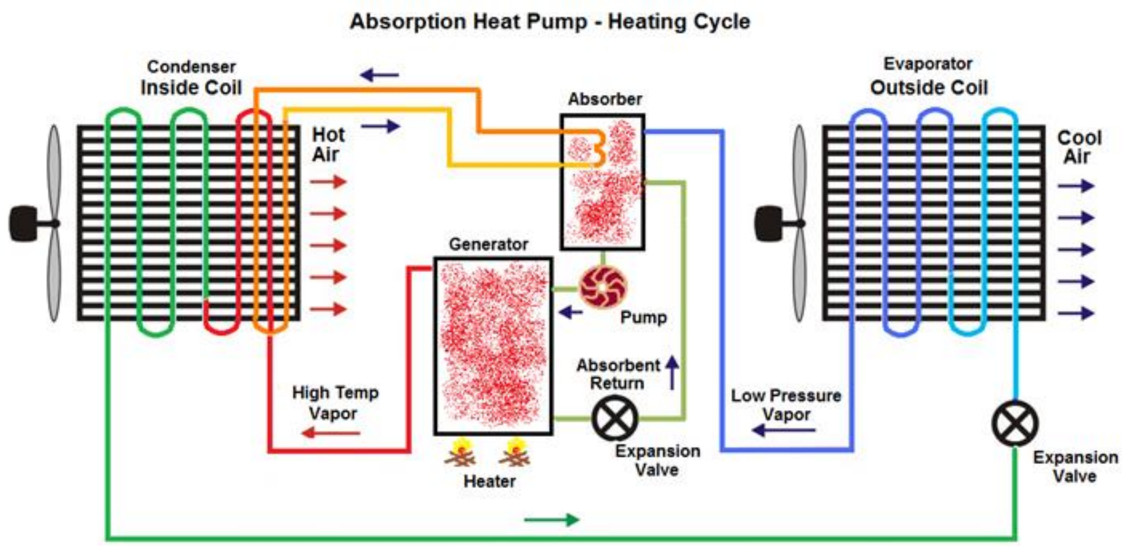


Figure 12

Starting at the outside coil on the right side of Figure 12, low-pressure vapor from the evaporator is absorbed in the absorbent. This process generates heat. The solution is pumped to high pressure and then enters the generator, where the working fluid (ammonia) is boiled off with an external gas heat supply at a high temperature. The working fluid, which is now in a gas state (vapor) is condensed in the condenser while the absorbent is returned to the absorber via the expansion valve.

Chapter 3
Heat Pump Types

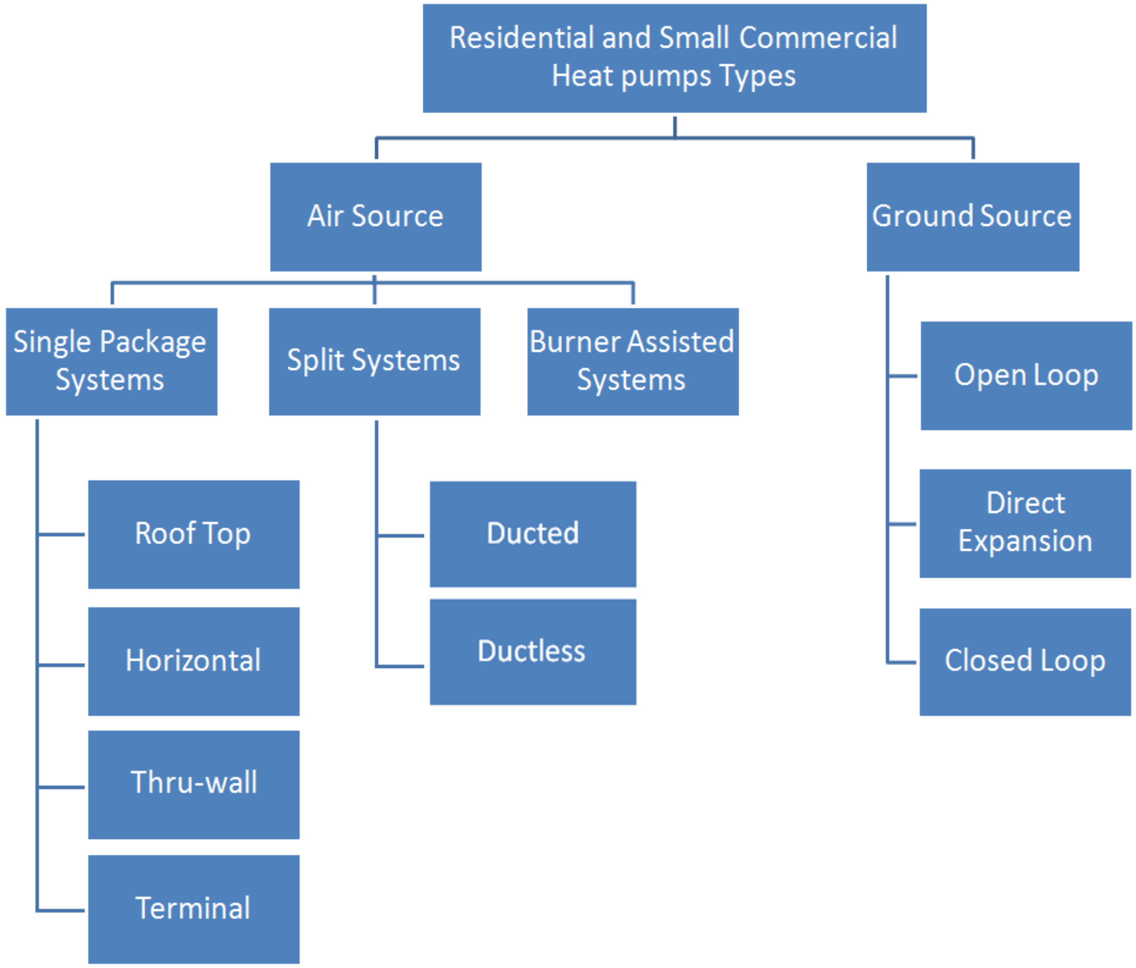
Almost all heat pumps currently in operation are either based on a vapor compression, or on an absorption cycle. Compression heat pumps always operate on mechanical energy (through electricity), while absorption heat pumps may also run on heat as an energy source (through electricity or burnable fuels).

Air source heat pumps are relatively easy to install and have therefore historically been the most widely used heat pump type. However, they suffer limitations due to their use of the outside air as a heat source or sink. The higher temperature differential during periods of extreme cold or heat leads to a lower efficiency. In mild weather, the COP may be around 3.5, while at temperatures below around 23F an air-source heat pump's COP will drop below 2, which is still considerably better than the COP of a conventional heating system.

Ground source heat pumps typically have higher efficiencies than air-source heat pumps. This is because they draw heat from the ground or groundwater which is at a relatively constant temperature all year round below. This means that the temperature differential is lower, leading to higher efficiency. Ground-source heat pumps typically have COPs of 3.5 to 4.0 at the beginning of the heating season, with lower COPs as heat is drawn from the ground. The tradeoff for this improved performance is that a ground-source heat pump is more expensive to install due to the need for the digging of wells or trenches in which to place the pipes that carry the heat exchange fluid. When compared versus each other, groundwater heat pumps are generally more efficient than heat pumps using heat from the soil.

Except for the broad categories of air-source versus ground-source systems, there are some problems in trying to group heat pumps into categories because of the commonality and minute differences between some systems. Air-source heat pumps are classified by the type of equipment used, layout of the equipment and the method of distributing conditioned air. There are also differences based on the type of back up heat supplied (electric or gas). Ground-source systems are categorized by the layout of the loops (vertical or horizontal etc.) Regardless of the difficulties, the following is an attempt to categorize heat pump systems.

Air-source systems are divided into three categories: Single packaged systems, split-systems, and burner assisted systems. Singe-packaged systems can be further divided into roof-top systems, horizontal systems, thru-the-wall units, and packaged terminal units. Split systems are generally divided into ducted and ductless systems. The following figure shows the heat pump categories graphically.



The following describes the characteristics of a few of the common types of heat pumps.

Single-package systems - Rooftop

With a single-package rooftop system, all of the components of the heat pump are packaged into one unit. Several units can be staged together to suit larger customer demands. Units can serve different zones with appropriate controls.

For systems less than 5-tons, the HSPF is in the range of 7.7 to 8.5. SEERs of 13 to 16 are possible. Above 5 tons, the COP is 3.2 to 3.4 and the EER is 9.7 to 12. These systems are used in small commercial office buildings, shopping malls and plazas, hospitals, schools and other institutions.

Advantages:

1. Conditioned area is quiet because unit is located outside
2. Can be installed quickly.
3. Servicing is confined to a single area
4. Units are similar to other heating/cooling rooftop units.

Disadvantages:

1. Need lifting equipment for installation.
2. Entire system is inoperative if any malfunction occurs.
3. Requires defrost cycle and back-up heat.

Single-package systems - Through-the-wall or Packaged Terminal

As the name implies, this unit sits in a wall with no ductwork. They are similar in appearance to window air conditioners. Typically used for localized heating and cooling such as heating one room. They require backup heating for cold winter operation, which is supplied by built-in resistant heating elements or a water coil supplied by a boiler augmented heat pump. Most units switch to back-up heat below the balance point. Through-the-wall units are available in horizontal and vertical configurations.

These systems have a COP of 2.9 to 3.5 and an EER of 10 to 12. They are available is sizes from ½ ton to two tons. Typical applications include hotels, motels, small office buildings, hospitals rooms, nursing homes, and apartments.

Advantages:

1. Can be used in new or replacement markets.
2. They are quiet.
3. Does not require a refrigeration specialist to install.
4. Can be replaced quickly by removing complete chassis of unit.

Disadvantages

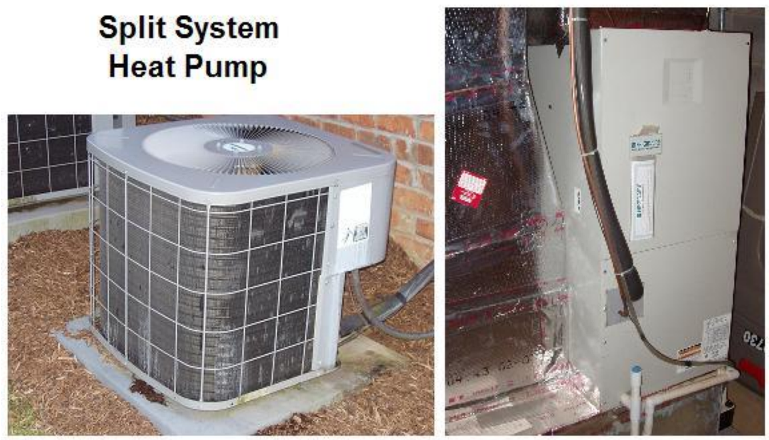
1. Limited to use in buildings where each room or zone has an outside wall.
2. Small cabinet size and poor airflow impact performance.
3. Defrost cycle and need for back-up heater.

Split systems - Ducted

A ducted split system is the most common heat pump configuration for a residential application. These systems consist of an indoor and an outdoor unit each containing a heat exchanger coil.

They can be used with vertical up-flow, down-flow or horizontal furnace or fan-coil indoors. Refrigerant piping connects outdoor and indoor units.

Ducted split systems typically have an HSPF of 7.7 to 10.5 and a SEER of 13 to 19. They can be found in sizes ranging from ¾ ton to six tons. The most common application is residential and small commercial buildings.



Advantages:
1. Easy to install with new or existing warm-air furnaces.
2. Reliable.
3. Noise levels are usually low.

Disadvantages
1. Requires refrigeration specialist to install.
2. Unit outdoors exposed to elements.
3. Defrost needed and requires back-up heat.

Split systems - Ductless

The outdoor unit consists of compressor, controls and coil. The indoor unit consists of a coil connected to outdoor unit by refrigerant piping. Multizone heat pumps can have up to five indoor units connected to one outdoor unit. Indoor units are typically wall or ceiling mounted. All indoor units must be on the same mode (heating or cooling) at any one time.

Ductless split systems have an HSPF of between 7 and 10 and a SEER of between 10 and 13. Units are available is sizes of one to four tons. These systems are frequently used in small commercial buildings and special applications such as computer rooms or conference rooms.

Advantages:
1. Allows people to select individual temperatures for each room or area.
2. Only uses the capacity of the system that is required.

3. Very quiet.
4. Good for retrofitting older buildings where installation of ductwork may be prohibitively expensive.

Disadvantages:
1. Higher initial costs than other systems.
2. Lower efficiency due to cabinet size constraints and refrigerant line loss.
3. Unit outdoors and requires defrost cycle.

The photo below shows an excellent example of a min-split ductless system. This small 9,000 BTU system from LG is called the "Art Cool" system.

Burner-assisted systems (dual fuel)

A burner assisted heat pump is a conventional heat pump with a gas burner under the outdoor coil acting as a condensing gas furnace and is sometimes referred to as *dual fuel systems*. The fuel supply can be propane or natural gas. The gas burner supplies auxiliary heat to building interior and can also supply air conditioning during the summer. The gas burner comes into operation when temperatures go below a set temperature, such as 28F.

The COP of burner assisted systems range from 2.4 to 2.7 with EERs of between 8 and 9. System sizes range from two to 15 tons. There are many applications for burner assisted systems including homes, small commercial buildings, offices, and retail stores.

Advantages:
1. Very efficient because of combination of air-to-air heat pump with a high efficiency condensing gas furnace.

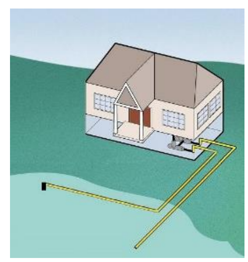
2. Since gas is used during the coldest weather, this unit lowers demand on the electrical system during peak usage.
3. Reversal of system during defrost is not required since gas flame is used for both auxiliary heat and defrosting of coil.

Disadvantages:
1. In the event of a very rare compressor failure, the entire system is inoperative.
2. Unit is located outdoors.
3. Only one supplier.
4. Requires two energy sources (gas and electricity.)

Ground Source Heat Pumps

The two primary types of ground source heats (GSHPs) are open loop systems and closed loop systems. A third from of GSHPs is a direct expansion system. Each of these are explained below.

Open Loop Systems



Ground source heat pumps are a unique form of heat pump that uses groundwater or surface water as a heat source versus using air for the heat source. During heat pump operation the water is disposed of through a re-injection well. Heat can also be rejected to the incoming domestic water supply for the hot water tank to reduce energy costs. The required water flow through the system depends on the size of heat pump but is in the range of two gallons per minute /ton.

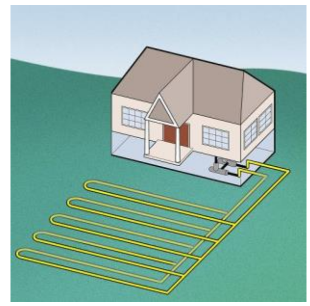
Some heat pumps have economizer cycles that allow cool water to circulate through a water-to-air exchanger in the ductwork, which provides cooling without using the compressor, if the ground-water temperature is low enough. Another form of open loop system is a standing column well where one very deep well is used for both supply and return.

Ground source open-loop systems have COPs of 3.0 to 5.0 and EERs of 16 to 30. The application for open loop systems is primarily residential and small commercial buildings.

Advantages:
1. Very economical to operate.
2. No defrosting required.
3. Better performance than air-source and other ground source heat pumps.

Disadvantages:
1. Higher initial costs than air-source heat pumps.
2. Some energy used for pumping water.
3. Investigation needed before well development.
4. Well production not known until well developed.
5. Reliability depends on groundwater quality that can change over time.

Closed Loop Systems



Ground source closed-loop heat exchangers are generally a parallel configuration of multiple pipe systems and can be installed either vertically or horizontally. The total length of pipe installed depends on the required amount of heating and cooling, local climate, soil conductivity and lot size available. For example, 250 feet of trench per ton of capacity for 2-pipe horizontal heat exchangers and 140-300 feet of borehole per ton for vertical heat exchangers are typical.

Horizontal heat exchangers can be coiled in a body of water or buried in the ground. Several pipes can be buried in one trench with heat exchangers at an average depth of four to six feet, depending on location. The closed heat exchanger system reduces the need for large quantities of water. Rejected heat can be used for domestic water heating. Piping is usually high-density polyethylene plastic, although materials such as copper have been used in the past.

The COP of ground source closed loop systems is in the range of 3.0 to 5.0 and they can have EERs of 13 to 25. Applications include residential, small commercial, and school systems. Applications that have a continuous need for cooling or heating may not be good applications for closed loop systems since the loop may not have enough time to recover from the heat insertion or rejection.

Advantages:
1. No defrosting required.
2. Very efficient.
3. No outdoor equipment required.
4. Auxiliary heat is not necessary.

Disadvantages:
1. Higher initial costs than other systems.
2. Some energy used to pump fluid through heat exchangers.
3. More complex than typical heating system.
4. Limited number of qualified contractors.

5. Design is complex compared to air source heat pumps.
6. Indoor unit with compressor connected to ductwork can be noisy.

Direct Expansion systems

A more recent development has been the direct expansion (DX) ground source heat pump that works in a similar fashion to conventional GSHPs, except that a secondary fluid is not required. Copper pipes buried in the ground connect with the heat pump's refrigerant circuit and refrigerant is circulated directly. This development claims to reduce costs as the ground loop is now more efficient so less loop length is required for any given application.

Direct Expansion (DX) ground-source heat pumps are similar in operation to the conventional, closed-loop GSHPs that use a secondary fluid (antifreeze solution) in the loop to transfer the heat. DX systems do not have a secondary fluid circulating pump. Copper pipe is buried in the ground that is connected directly into the refrigerant circuit of the heat pump. Refrigerant circulating directly through the copper ground heat exchanger transfers the heat.

Direct expansion systems have a COPs of greater than four and EERs of 12 to 16. Direct expansion systems are typically found in residential and small commercial applications.

Advantages:

1. No defrosting required.
2. Very efficient.
3. Unit indoors.
4. Lower initial cost than conventional GSHPs.

Disadvantages:

1. Large quantities of refrigerant can be expensive.
2. Qualified refrigeration mechanic must make final loop connections.
3. If loop becomes damaged, it could be costly to repair.

Advanced Heat Pump Designs

Other heat pump technologies that are commercially available include Reverse Cycle Chillers, Cold Climate Heat Pumps, and All-Climate Heat Pumps. The following is a brief description of these technologies.

Reverse Cycle Chillers

One of the more notable innovations in air-source heat pumps is called a *Reverse Cycle Chiller* (RCC). It offers the advantages of allowing the homeowner to choose from a wide variety of heating and cooling distribution systems, from radiant floor systems to forced air systems with multiple zones. It also offers the potential for lower winter electric bills and hotter air out of the supply vents for greater comfort.

An RCC is especially economical for all-electric homes or in areas where natural gas is not available. Depending on other fuel rates, it may even be the least expensive heating option over all the remaining heating fuel choices.

The system consists of a standard, single speed, air-source heat pump, sized to the heating load rather than the usual smaller summer cooling load. The heat pump is connected to a large, heavily insulated tank of water that the heat pump heats or cools, depending on the season of the year. Most systems will use a fan coil with ducts, employing the stored water to heat or cool the air and distribute it to the house. During the heating season, the hot water can be distributed through a radiant floor system.

The RCC eliminates one of the biggest complaints about air source heat pumps, which is the periodic blowing of cool air during their defrost cycle and during the initial start of the heating cycle as the distribution ducts warm up. The RCC system solves these problems by using the stored heat in the water tank to defrost the cooling coils, rather than the room air.

The RCC system also allows the heat pump to operate at peak efficiency even at low temperatures. This provides greater comfort and economy without the need for electric resistance auxiliary heating coils.

Another significant energy saving benefit is that the RCC can be equipped with a refrigeration heat reclaimer (RHR). This is similar to the common desuperheater coil found on the high-end heat pumps and air conditioners. The main difference is that the RHR not only makes hot water during the cooling season, but also does it during the heating season by using the excess capacity of the outdoor unit during the milder winter weather to make essentially free domestic hot water. In the summer it makes free hot water by reclaiming the waste heat from the house as long as the system is also cooling the building.

The combined RCC and RHR system costs about 25% more than a standard heat pump of similar size. The simple payback on the additional cost in areas where natural gas is not available is in about two to three years.

<u>Cold Climate Heat Pump</u>
A Cold Climate Heat Pump features a two-speed, two-cylinder compressor for efficient operation; a back-up booster compressor that allows the system to operate efficiently down to

15F; and a plate heat exchanger called an "economizer" that further extends the performance of the heat pump to well below 0F.

All-Climate Heat Pump

An All Climate Heat Pump can operate in the coldest days of winter without supplemental heat, maintaining comfortable indoor temperatures even when the temperature outdoors falls below zero. The heat pump could reduce heating and cooling costs 25%–60%.

While the design of most heat pumps puts the focus on cooling, the All Climate Heat Pump is designed with heating as the primary focus. Although initial costs for the All Climate Heat Pump are high the energy savings over the life of the system makes up the up-front cost.

Chapter 4
Performance Characteristics

Understanding the efficiency rating of commercial HVAC equipment can be daunting. There are myriad acronyms used, such as Tons, COP, EER, SEER, HSPF, and FLV. Some efficiency ratings are only at full load, while others attempt to accommodate part-load conditions. The following is a discussion of these efficiency ratings and how they compare.

Tonnage

Heating and cooling systems are measured ins of capacity. To simplify the numbers, the term "Ton" is used to describe BTU's of capacity in 12,000 BTU increments. Therefore, a 3-ton air-conditioner doesn't weigh three tons – instead it has 36,000 BTU's of capacity and a 5-ton system has 60,000 BTU's of capacity.

Full Load Value (FLV)

Heat pump efficiency can be measured by kilowatts of energy required to generate one ton of cooling, known as the Full Load Value (FLV). This is the basic measure of energy efficiency of heating and cooling systems. It is the electrical demand required per ton of heating or cooling, which is expressed in kilowatts per ton (kW/Ton.) The lower the kW/Ton, the more efficient the system, therefore a lower FLV number indicates a more efficient system. A very efficient electric centrifugal chiller might have an FLV in the range of 0.6 kW/ton. FLV is related to Coefficient of Performance (COP) by the following formula,

$$\mathbf{FLV = 3.516 / COP}$$

Where,
FLV = Full Load Value, kW/ton.
COP = Coefficient of Performance.

If a heat pump has a COP of 5.9, what is the FLV?

FLV = 3.516 / 5.9

FLV = 0.6 kW/ton.

Coefficient of Performance (COP)

For full-load rating conditions, heat pumps have efficiencies sometimes expressed as Coefficient of Performance (COP) ratings. COP is usually reserved for heating efficiency but can also be defined as the ratio of the cooling effect produced divided by the energy input expressed on the same basis. A bigger COP number represent a more efficient heat pump system.

The heat delivered by a heat pump is theoretically the sum of the heat extracted from the heat source and the energy needed to drive the cycle. The steady-state performance of an electric compression heat pump at a given set of temperature conditions is referred to as the *coefficient of performance* (COP). It is defined as the ratio of heat delivered by the heat pump and the electricity supplied to the compressor.

The COP of a heat pump is closely related to the temperature lift, i.e. the difference between the temperature of the heat source and the output temperature of the heat pump. The COP of an ideal heat pump is determined solely by the condensation temperature and the temperature lift.

The COP is based on a single temperature point and doesn't necessary reflect how well a system performs on a day-to-day basis. In fact, COP values have no standard testing requirements so COP values can only be used to compare different models if the manufacturers used the same test method. For heating, the COP measurement point is usually 47F. It is a measure of how much heat, in BTU's, is provided at 47F compared to the amount of power, in BTU's of energy required to generate the heating BTU's. Since there are 3.413 BTU's per hour per watt of electrical energy, the formula for COP is,

$$\textbf{COP = Heating BTU's / } (\mathbf{P_{in}} \textbf{ * 3.413)}$$

Where,
COP = Coefficient of Performance.
Heating BTU's = Heating BTU's at 47F.
P_{in} = Electrical Power consumed, watts.

If a unit has 40,000 of heating BTU's and the input power to the unit is 3,348 watts, what is the heating COP of the heat pump?

COP = 40,000 / (3,348 * 3.413)

COP = 3.5.

Energy Efficiency Rating (EER)

Heat pump efficiency is commonly measured by the number of BTUs of cooling provided per watt of electricity consumed. This is known as the Energy Efficiency Ratio (EER). A bigger EER number represents a more efficient system. Both FLV and COP can be converted to EER.

The Energy Efficiency Ratio, or EER, is a measure of how efficiently a cooling system operates at a specific outdoor temperature. A 95F outdoor temperature is usually selected for the EER rating. A higher EER rating means the system is more efficient than a system with a lower EER rating. The EER rating relates energy consumed to generate a given level of BTU cooling capacity. The energy consumption of different units can be compared by dividing the BTU cooling capacity of the systems by their EER ratings. The formula is,

$$\mathbf{EER = BTU's / P_{in}}$$

Where,
EER = Energy Efficiency Ratio.
P_{in} = Power input, watts.
BTU's = Cooling Capacity, BTU's.

For example, assume we are comparing two different cooling systems, both of which provide 36,000 BTU's of cooling capacity. One unit has a power requirement of 3,600 watts and the other has a power requirement of 3,000 watts. What are the EER's for these two units and their relative efficiency?

For the first unit,

EER = 36,000 / 3,600

EER = 10.

For the second unit,

EER = 36,000 / 3,000

EER = 12.

The first unit has an EER of 10 and the second unit has an EER of 12. Since both units have the same cooling capacity (in BTU's), the relative power consumption is simply the difference in the power consumption of the two units. In this case, the second unit uses 600 watts less power than the first unit, which means that it is 20% more efficient (600 / 3,600 *100 = 20%.) Different size units can be compared by comparing their EER's. The relative efficiency is found by dividing one EER by another EER. In our example, the relative efficiency is found as

Relative efficiency = 12 / 10 = 1.20.

This says that the second unit is 20% more efficient than the first.

The EER can be converted to kW/ton by dividing the EER *into* 12.

Table 3 below compares FLV, COP, and EER for different FLV efficiencies.

Table 3
Comparison of FLV, COP and EER

FLV	COP	EER
0.6	5.9	20
0.75	4.7	16
1.0	3.5	12
1.5	2.3	8

As you can see in the table, an FLV of 0.6 kW/ton is roughly equivalent to an EER of 20. And an EER of 20 is roughly equivalent to a COP of 5.9, because there are 3,413 BTUs per kW.

Seasonal Energy Efficiency Ratio (SEER)

A deficiency in the Energy Efficiency Rating is that it only measures the efficiency at one temperature point. The Seasonal Energy Efficiency Ratio (SEER) was developed as a means of measuring efficiency at various temperatures over a full heating or cooling season. The Seasonal Energy Efficiency Ratio, or SEER, is the total amount of cooling the unit will provide for an entire cooling season divided by the total energy used during the cooling season. The SEER allows a consumer to compare the cost of operating different systems over the entire cooling season. Instead of just measuring power consumed like the EER, the SEER measures energy consumed in kilowatt-hours. The formula is,

SEER == Seasonal BTU's / E_{in} / 1,000

Where,
SEER = Seasonal Energy Efficiency Ratio.
E_{in} = Energy consumed for the cooling season, kWh's.
Seasonal BTU's = The BTU's of cooling capacity provided for the entire season.

Consider two units that have a seasonal BTU rating of 200,000,000, but one of the units has a SEER of 14 and the other has a SEER of 16. What is the expected energy consumption of the two units?

Because the SEER's are known, and we want to know the expected energy consumption we need to rearrange the formula to find the energy consumption.

For the first unit,

E_{in} = 200,000,000 / 14 / 1,000

E_{in} = 14,286 kWh's.

And for the second unit,

E_{in} = 200,000,000 / 16 / 1,000

E_{in} = 12,500 kWh's.

As you can see from this example, the SEER allows us to directly evaluate the expected energy consumption of various cooling systems. In this case, the difference is 1,786 kWh per year. The 16 SEER unit is 14% more efficient than the 14 SEER unit (16/14 = 1.14.)

Heating Seasonal Performance Factor (HSPF)

The HSPF is the heating equivalent of SEER. The HSPF is a measure of efficiency over an entire heating season. This considers the energy losses from cycling, frost build-up, and the supplemental resistant heating used during defrost. The relationship between the HSPF and energy consumption is,

HSPF = Heating BTU's / E_{in} / 1,000

Where,
HSPF = Heating Seasonal Performance Factor.
E_{in} = Energy consumed for the heating season, kWh's.
Heating BTU's = The BTU's of heating capacity provided for the entire season.

Building heat requirements and the prevalent weather conditions influence HSPF ratings. Higher ratings indicate more efficient heat pumps during heating season.

Chapter 5
Commissioning

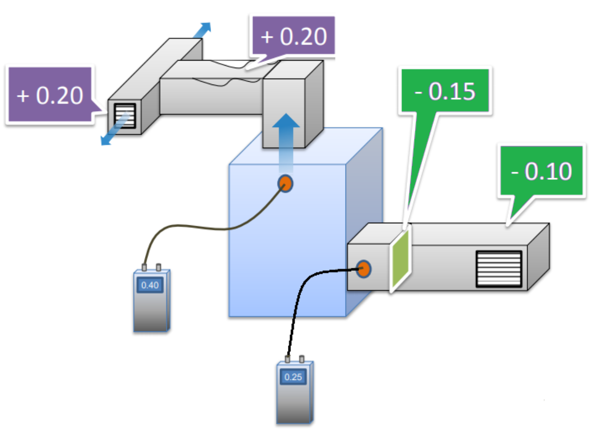
This chapter covers some of the basics of commissioning a new HVAC system. This is a broad overview and by no means an exhaustive commissioning plan. The three major issues when commissioning an HVAC system include:

1. Measuring air handler airflow
2. Checking refrigerant charge
3. Measuring airflow at the registers

Measuring air handler airflow

HVAC fans are designed to move a specified amount of air across the heating or cooling coils and then through the ducts to the rooms. However, during installation there are many things that can go wrong. Flexible ducts may have sharp bends and ductwork may be damaged during construction, including crushed ducts and duct leaks. These issues can increase the static pressure of the system.

The airflow of the fan can be determined by measuring the total external static pressure. A digital manometer is used to check the external static pressure on both the supply and return sides of the air handler and the airflow is measured in *inches of water column* (IWC). A manufacturer blower table can then be used to look up this pressure and read the corresponding airflow. This ensures that the system is operating as designed, so that the equipment can heat and cool the home as efficiently as possible. For example, look at Figure 13. In this figure the external static pressure on the supply side is 0.40. The external static pressure on the return side is 0.25, therefore the total external static pressure TESP) is 0.65.



Total Static Pressure
0.20
0.20
0.15
0.10
0.065 IWC

The pressures measured in this test should then be compared to the manufacturers table for the specific air handler to

Figure 13

verify that the actual airflow compiles with the design requirement. The actual airflow is considered acceptable if it is within 15% of the airflow design requirement. Figure 14 shows a typical air handler air flow chart. Assuming the fan is on speed tap #3 and interpolating from the chart an TESP of 0.65 would result in air flow of approximately 685 fpm.

Model	Speed Tap	Static Pressure (in w.c)								
		0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
ASPT 25B14AB	1	640	585	580	545	510	490	410	340	280
	2	800	765	725	700	670	645	595	565	490
	3	840	805	800	760	740	700	670	625	580
	4	985	950	920	885	850	815	800	760	725
	5	1,475	1,440	1,400	1,375	1,335	1,305	1,270	1,240	1,150
ASPT 29B14AB	1	595	590	565	530	505	455	380	305	260
	2	790	775	745	705	665	625	585	515	445
	3	865	820	790	770	735	695	645	595	530
	4	1,015	980	955	925	880	840	795	770	720
	5	1,505	1,465	1,430	1,410	1,385	1,350	1,315	1,285	1,220
ASPT 33C14BA	1	865	685	615	540	480	410	335	270	215
	2	935	875	820	785	720	655	600	550	490
	3	1110	1050	1000	955	905	855	795	760	710
	4	1355	1310	1260	1220	1180	1135	1095	1055	1005
	5	1560	1515	1475	1430	1395	1370	1330	1295	1260

Figure 14

Checking refrigerant charge

The amount of refrigerant in a HVAC unit is necessary to keep temperatures within target ranges and to keep liquid refrigerant out of the gas side of the unit. Improper charging results in inefficient operation may cause premature compressor failures.

There are two tests to ensure the proper amount of refrigerant:

- Subcooling Test
- Superheat Test

The *sub-cooling test* is to ensure the refrigerant is in liquid form after it leaves the condenser. The compressor sub-cooling parameter is generally found on the compressor nameplate. Sub-cooling is the temperature of the refrigerant below its boiling point (liquid saturation temperature). See Figure 15.

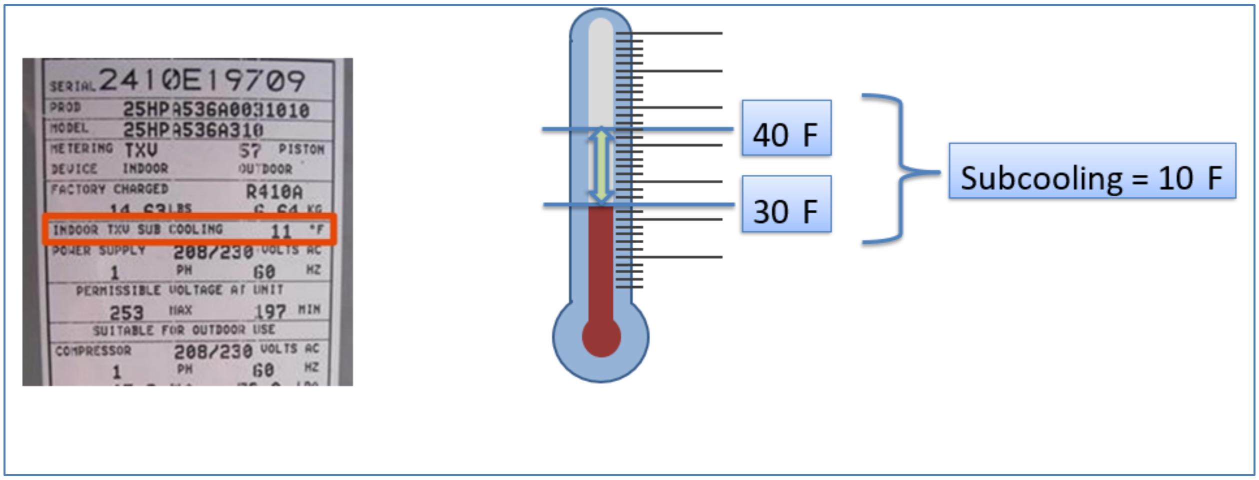


Figure 15

The *superheat test* ensures the refrigerant is in gas form before it arrives at the compressor. Superheat test checks that the temperature of the refrigerant above its boiling point (liquid saturation temperature). See Figure 16.

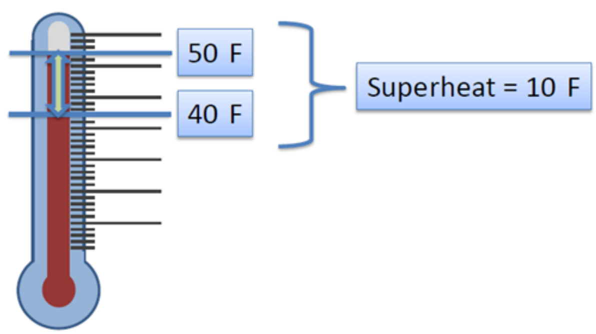


Figure 16

Testing the refrigerant charge through sub-cooling and superheat ensure the refrigerant is in the correct state (either gas or liquid) at the correct time.

Measuring airflow at the registers

The airflow needed by each room is directly related to its heating and cooling load. Proper airflow is needed to deliver, or remove, the proper amount of heat from each room. Construction issues or poor maintenance are frequent issues in HVAC operational issues. See the photo below of a typical ductwork failures.

Figure 17

The airflow can be measured with an anemometer as well as other specialized tools. The airflow in each register must be within +/-20% of the design airflow for each room.

Summary

A heat pump is an energy-efficient alternative to furnaces and air conditioners. Because they move heat rather than generate heat, heat pumps can provide up to four times the amount of energy they consume. Heat pumps can force the heat flow in the other direction, using a relatively small amount of drive energy. Thus, heat pumps can transfer heat from natural heat sources in the surroundings, such as the air, ground or water, or from man-made heat sources such as industrial or domestic waste, to a building. Heat pumps can also be used for cooling. Heat is then transferred in the opposite direction, from the application that is cooled, to surroundings at a higher temperature.

In this course, we have looked at the basic operation of heat pumps for heating and cooling residential and small commercial buildings. The components of a heat pump system, the basic operating cycles and the various performance measurements were reviewed.

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