White Paper:
Residential HVAC Split System Basics

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INTRODUCTION

In the process of conducting assessments on dwellings, particularly if the issues at hand are related to the building envelope or to the interior environment, it is important to have a basic understanding of the ***HVAC*** (heating, ventilation and air conditioning) system. This tutorial is geared primarily toward “typical” or split system air conditioning systems found in residential dwellings or light commercial buildings such as stand-alone houses, town houses, condominiums, apartments and light commercial buildings.

Florida is located in the ***Cooling Climate Zone*** meaning that it is concerned primarily with the cooling and dehumidifying aspects of HVAC. However, it is worth noting that while Florida is in the Cooling Climate Zone, only heating of structures is required by Florida’s *Building Code*. Therefore, within Florida the HVAC system is usually used to accomplish both heating and cooling. The heating is accomplished with a heat pump and/or an electric heat strip within the air handler and the cooling is accomplished within the air conditioning portion of the unit. These aspects will be discussed within this tutorial.

HVAC SYSTEM - Types

The ***split system*** is the most common for homes where a minimum of one system is utilized. However, ***package units*** can be used on smaller structures and ***multiple systems*** can be used on larger more complex structures. Package units are most often found in smaller structures such as mobile homes and modular units. The package unit is a self-contained, all-inclusive unit which is usually configured as a thru-wall unit attached to an exterior wall. Larger homes and building may utilize more than one system depending on the square footage and other design criteria including the method of construction, windows, ceiling height, solar exposure, etc.

HVAC SYSTEM - Components

Typical HVAC systems or ‘split’ systems, also known as *central air conditioning* are comprised of three primary components: the outside unit or the ***compressor / condenser***, the inside unit or the ***air handling unit*** (AHU), and the air distribution system ***the ducts***. Aside from the two copper lines (hot side and cold side) that transport refrigerant between the compressor / condenser and the air handling unit, the inside and outside units in a split system are physically separated.

Additional components include the ***refrigerant lines***, the drain line or ***condensate line,*** the ***filtration system,*** and the controls or ***thermostat / humidistat***. Oftentimes the condensate line will exit the house with or adjacent to the refrigerant lines. Normally these lines/pipes will be clumped together and will either go below grade before entering the house via the slab or will go up and through the attic space.

Compressor / Condenser

The outside unit of a split system consists primarily of a fabricated steel housing, the refrigerant compressor, a condensing coil, and a cooling fan. **The compressor / condenser within the housing is designed to recompress warm refrigerant gas (pulled from the indoor air handler cooling coil) back to a liquid refrigerant that can be returned to the indoor cooling coil once again. When the room thermostat calls for cooling, both the indoor blower or air handler and the outdoor compressor/condenser begin to work. The cooling fan on top of the housing** moves outdoor air across the condensing coil to cool it and assist in condensing the high pressure, high temperature refrigerant gas back into a liquid. The outside unit is typically found secured to a pad along the side or rear of the house. It should be noted that Florida’s Building Code has both prescriptive and performance requirements on the placement and attachment of outside units based on wind loads and flood plains.

Air Handling Units

The indoor unit or the air handler unit is another steel housing comprised usually of a ‘squirrel-cage’ fan or blower driven by an electric motor, the evaporator coil, an electric heat strip, and a filter. The cooled refrigerant circulated to and from the outside compressor/condenser unit flows through the many feet of copper making up the evaporator coil, while the fan blows air returning to the unit across the coil to be delivered through the supply ducts to the living spaces. If equipped with an electric heat strip, the heat strip will be activated during heating time periods. AHU's are typically located either within the garage, in a utility closet, or in the attic and are often configured such that return air is drawn through a filter before reaching the evaporator coil.

Ducts

The duct system should be a closed 'loop' system whereby ambient air within the dwelling is returned to the AHU (through a filter) and is blown across the evaporator coil such that conditioned air is delivered to the living spaces via ceiling diffusers connected to tributary ducts within the attic space. In smaller dwellings, particularly condos, and prior to building codes changes, the return air was often accomplished via a single return grill ducted directly to the AHU, or to a return air box under the AHU, or to the closet which houses the AHU. Building codes now stipulate that dedicated return air ducts be routed to individual living spaces, bedrooms, etc. It is important to understand the configuration of the system with respect to the return air configuration. Remember, conditioned air circulation is only as good as the balance of the system as a whole, if air from a space or room cannot get to the AHU (closed door, etc.), that space will not benefit from the conditioned air circulation. The existence of mold within room corners, along wall to ceilings, and along the apex of vaulted ceilings is often indicative of ineffective conditioned air circulation.

In older homes (50's, 60's, and 70's) the ducts were often comprised of sheet metal (both circular and rectangular in cross section) wrapped with paper-covered insulation. Newer ducts typically consist of foil covered fiberglass duct board panels configured in rectangular cross sections, as well as flexible circular ducts made from coiled wire and plastic sheeting covered with fiberglass insulation and foil. Generally the duct board sections will be constructed as the return or supply plenums or the primary trunks which are connected directly to the AHU, the 'flex' ducts then serve as the tributary ducts where diameters are 'stepped' down (supply side)

based on flow requirements. Even in systems with individual air returns, the supply ducts/diffusers will nearly always outnumber the return ducts/grilles because supply air will be routed to closets and bathrooms as opposed to the return air which is accomplished in a hallway, bedroom, or a primary living space. Thus the return air ducts will usually be larger in diameter as will the size of the grille attached to the wall or ceiling.

Refrigerant Lines

As stated previously the refrigerant lines which consist of copper tubing extend between the exterior compressor/condenser and the interior air handler unit. The smaller diameter copper or the cold copper line (when in the cooling mode) delivers the recently compressed (thereby liquefied and under pressure) Freon (R-22) or Puron (410A) from the outside unit to the air handler. At the air handler it first passes through a metering device or expansion valve which lowers the pressure of the refrigerant. The refrigerant is then circulated through the evaporator coil where the return air is blown across it. At this point the heat is drawn out of the air and absorbed by the refrigerant within the coil thereby causing the refrigerant to heat up and return to a gaseous state. The larger diameter copper line or the hot line in turn delivers the now heated gas, low in pressure, back to the compressor where the cycle is repeated until the thermostat signals the system to stop. Because of the moving mechanical parts within the system, particularly the compressor piston(s), lubricating oil is necessary. This oil is entrained within the refrigerant so as to circulate with the refrigerant throughout the cycle.

The refrigerant utilized within a typical split system will either be Freon (R-22) or Puron (R-410A). Until recently Freon was used in most air conditioning and heat pump units, however under the Clean Air Act of 1990, no air conditioners can use Freon as of 2010 and by 2020 production will be totally banned. Puron has become the refrigerant of choice and is considered to be the answer for preventing ozone damage from air conditioners.

Condensate Line

The condensate water or water removed from the air by the air handling units is collected within the housing and routed to a drainage system. The drainage system normally consists of a drain line or condensate line, a drainage pan with float switch. The condensate line, usually a PVC pipe, is to extend to the exterior of the house, often to a location adjacent the outside unit.

A secondary means of condensate water collection is employed by a drainage pan which is placed beneath the AHU. This pan is usually equipped with a float switch which shuts the system down if the water level within the pan rises to a level causing the float to switch the unit off. Water in the secondary drainage pan usually indicates that the condensate line is plugged (a common occurrence), excessive condensation build-up is occurring and/or the system is in need of service.

It is important to understand the layout or the routing of condensate drain lines because they have been known to leak within wall cavities. It is also important to realize that condensate drain lines can condensate if not properly insulated. This 'byproduct' can also result in minor staining to ceilings and walls where drain lines pass through.

Thermostat / Humidistat

The thermostat setting within the air conditioned space ultimately determines what the temperature will be assuming the system can operate to reach the desired temperature. During cooling the thermostat would be set to the temperature that is comfortable to the occupants (usually the highest comfortable temperature, likely somewhere between 74 and 80 degrees). Attempting to control humidity by maintaining a lower temperature may be counter-productive, in fact relative humidity will likely rise as building materials cool and approach the dew point, thereby resulting in condensation in unwanted locations such as wall cavities or behind wall paper.

In some cases where the relative humidity must be controlled more definitively, a humidistat may be used in conjunction with the thermostat. If a dehumidifier is used in lieu of the air conditioner or as a supplement to it, it will in itself control the humidity based upon its ‘dialed-in’ setting. However in some cases a humidistat will be used in conjunction with the air conditioner thermostat, particularly in dwellings left vacant for extended periods. In this case the humidistat may be the ‘driver’ or the trigger for cycling of the air conditioner in order that the relative humidity as selected is maintained. Or both the relative humidity (via the humidistat) and the temperature setting (thermostat) control the operation of the system. In either case, inspect the wall-mounted panel (either digital or analogue) and determine if a humidistat is part of the system and the setting being utilized. It is important to note that the 2010 Residential Energy Efficiency Code section 403.1.3 states: *Where a humidistat is used for comfort dehumidification, it shall be capable of being set to prevent the use of fossil fuel or electricity to reduce humidity levels below 60 percent.*

Filtration System

System filtration is most often accomplished on the return air side with a single or central air filter. The filter will usually be a ‘slide-out’ filter which nearly matches the cross section size of the AHU and fits within a slot on the return side. With multiple return air ducts, the filters will usually be in the ceiling or wall grilles. Look at the condition of the filters, if it looks like air can’t pass very well or if the filter tends to get sucked into the duct, they are heavily soiled, need to be replaced, and conditioned air circulation may be marginalized. Remember conditioned air circulation throughout is only as good as the flow of the return air.

SYSTEM DESIGN – A/C

Obviously the main duty of the A/C system is to cool the air within the living spaces, however just as importantly the A/C must control humidity. The level of humidity is just as critical to maintaining the ‘feels-good’ temperature in the interior as is the cooling function of the A/C system. The lower the relative humidity is, the cooler it will feel. It is important to understand that not only is humidity brought in from the exterior, but moisture vapor is created within the interior via showers, cooking, laundry, etc. This humidity must be controlled or the ‘feels-like’ temperature will be raised along with the humidity level. Generally speaking, the interior relative humidity level should be maintained between 40% and 60%.

As the return air moves across the evaporator coil within the air handling unit the humidity is reduced as the relatively cold evaporator coil condenses the water vapor from the air. This condensate water is then collected within the housing and routed to the condensate drain system. This process whereby the moisture vapor is condensed and collected serves to reduce relative humidity within the living spaces.

The adage ***‘bigger is not always better’*** applies in this case, because if the system is oversized it may not run long enough during the hot humid periods to reduce the interior humidity level. In other words if the unit is too robust it will blow cool air until the thermostat ‘signals’ that the set temperature has been achieved while not allowing the air mass to cycle through the unit enough to draw out the moisture. At the other end of the spectrum, if the system is undersized, the air mass will not be moved enough to cool or draw out the moisture. Therefore, HVAC systems MUST be properly sized and the air flow properly designed. As discussed specific control of relative humidity may be accomplished with a separate dehumidifier or a humidistat function included with the air conditioning system.

Houses either ***blow*** or ***suck***. In cooling climates we tend to want the house to blow a little or create some positive internal pressure such that the moisture laden exterior air is pushed away or held at bay. Depending upon the construction of the house, particularly construction whereby the house is tighter and does not breathe, negative pressure within the house can be created. Negative pressure can result from interior exhaust fans, gas fired appliances and/or leaking ducts located outside of the conditioned envelope. Nevertheless be mindful of the potential for negative interior pressures or system imbalance creating an inward vapor drive. Excessive negative interior pressure developed by the HVAC system can result in an inward vapor drive. Remember that there will be natural convective or diffusive moisture vapor migration from areas of higher pressure/temperature (hot exterior) to areas of lower pressure/temperature (cooled interior).

Minimum Efficiencies for Cooling Equipment. According to the Florida Building Code 2010 Energy Conservation: 403.6.2.2 *Cooling equipment installed in residential units shall meet the minimum efficiencies of the 503.2.3 tables in chapter 5 of this code for the type of equipment installed. Equipment used to provide water heating functions as part of a combination system shall satisfy all stated requirements for the appropriate space heating or cooling category.* (Remember, this pertains to residential applications, the specific energy code for commercial applications should be referenced as required.)

It is important to note that some air conditioning systems are capable of providing heated water as a 'by-product' of the system. This can be accomplished by a heat exchanger which captures the heat given off by the hot/low-pressure copper line of a 'split system'. This is often used to preheat water thereby reducing the amount of energy required to heat the residence's hot water supply. This is accomplished by running the incoming water through a heat exchanger.

SYSTEM DESIGN – Heat

Within Florida the HVAC system is usually used to accomplish both heating and cooling. The heating is accomplished with a ***heat pump*** and/or an ***electric heat strip*** within the air handler unit. A heat pump system is a variant of the typical compressor/condenser unit whereby the systems refrigerant is forced to flow in the opposite direction. Thus the AHU fan blows across a heated coil instead of a cooled coil and heated air is delivered into the dwelling. Heat pump systems are more common in cooling climates where heating requirements are relatively limited. During cooling periods the outside **compressor/condenser fan will be blowing hot air and during heating periods the air blown from the outside unit should be cooler. If and when interior heating requirements are such that the heat pump cannot maintain the desired temperature an electric heat strip located within the air handler will be activated and the air drawn into the air handler will be blown across it such that the supply air is heated. The odor that is experienced in the living space the first time the**

heat strip is activated during the heating season is a result of the heat strip burning off the dust and debris that collects on it.

Minimum Efficiencies for Heating Equipment. According to the Florida Building Code 2010 Energy Conservation: 403.6.2.3 *Heating equipment installed in* <u>*residential*</u> *units shall meet the minimum efficiencies of the 503.2.3 tables in chapter 5 of this code for the type of equipment installed.* <u>*Exception:*</u> *Existing mechanical systems undergoing alteration need not meet the minimum equipment efficiencies of this section except to preserve the original approval or listing of the equipment.* (Remember, this pertains to residential applications, the specific energy code for commercial applications should be referenced as required.)

TROUBLESHOOTING

Be sure to look for and consider the following:

- **If the filters are completely soiled the air flow will suffer.**
- **If there is a single air return in the entire dwelling unit and the dwelling is vacant, dark, and interior doors remain closed the air flow will suffer.**
- **If the AHU is in a closet with a single air return thru the closet door and the top of the closet has openings into the attic or a ceiling cavity, unwanted air sources are drawn into the system.**
- **The AHU is in a closet in the hall outside where the closet door is not sealed thereby drawing in unwanted air.**
- **The AHU is in a closet and the condensate drains into an open drain in the floor of the closet.**
- **The AHU condensate drain is leaking in a wall or floor cavity.**
- **The ducts in the attic have loose tape joints or have been damaged by rats allowing ambient attic air to intrude.**
- **The supply diffuser is right next to a return grille. The code does stipulate what the separation should be; therefore it is incumbent upon the A/C contractor to configure properly.**

- **The AHU in the attic is situated immediately below the hot roof deck. Remember the AHU is trying to create 77 degree air, what is the net effect of a 145 degree roof deck next to it.**
- **Ducts have been added to supply a Florida room or the garage, but the system capacity was not designed for it.**
- **Ducts in the attic bend tightly over truss members such that they are pinched.**
- **The supply plenum in the attic had a hole cut into it to cool the A/C guy while he was working and the hole was not properly sealed.**
- **The supply diffusers on the ceilings are dripping condensation and are corroded due to excessive moisture in the system.**
- **There is no filtration and the evaporation coil (sometimes visible when looking into the return side of the AHU) is completely covered with mold, dust and debris.**

- **Condensation is dripping from the attic ducts at taped joints or rat holes and staining the ceilings.**
- **The refrigerant lines traversed under the slab through a large diameter PVC pipe which has filled with ground water causing eventual deterioration of the copper.**
- **The sheet metal chase housing the refrigerant lines and which is attached to the exterior wall of the house is not sealed, particularly at the top, thereby letting water flow directly into the wall cavity.**

About Bracken Engineering:

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