Consulting, Resource, Education, Training, and Support Services for Home Inspectors
"A candle loses no light when it lights another candle."

OPERATION AND EVALUATION OF HEAT PUMPS IN THE HEATING MODE

OPERATION IS DEPENDENT ON THE OUTSIDE AIR TEMPERATURE

Here is an explanation regarding why air source heat pumps shouldn't be operated in the heating mode when the outside temperature is above 65° F.

We will begin by reviewing how an air source heat pump works when it is operating in the heating mode. The compressor sends a high temperature/high pressure gas (the refrigerant) through the reversing valve (four-way valve) which directs the flow of the refrigerant into the insulated suction line (the larger line) and toward the inside coil (the finned-tube coil located in the supply plenum of the air handler/plenum assembly).

As this high temperature/high pressure gas moves through the inside coil, the blower in the air handler blows cool inside air (cooler than the refrigerant) over the coil and the gas moving through the coil cools by **giving up heat** to the air being blown across the coil. In this process, the gas cools down enough to change state from a high temperature/high pressure gas to a high temperature/high pressure liquid **and the air coming off of the coil and being delivered to the living space is warmed.**

This now high temperature/high pressure liquid refrigerant exits the inside coil, passes through a one-way check valve (a valve that only permits liquid refrigerant flowing toward the outside coil and compressor to pass through it, bypassing the expansion device that is utilized in the air-conditioning mode), and moves back down the uninsulated liquid line (the small line) toward the exterior unit where the outside coil, outside fan, and the compressor are housed.

As the high temperature/high pressure liquid refrigerant approaches the outside coil it encounters another on- way check valve (this valve only permits liquid refrigerant to flow from the outside coil toward the inside coil and prevents the flow of liquid refrigerant toward the outside coil and compressor). This check valve diverts the refrigerant through an expansion device. The high temperature/high pressure liquid exits the expansion device as a low temperature/low pressure atomized liquid (very fine, tiny droplets – a mist) and enters the outside coil.

As this low temperature/low pressure atomized liquid moves through the outside finned-tube coil, the outside fan blows warm outside air (warmer than the temperature of the atomized liquid refrigerant) over the coil. In the process, the atomized liquid moving through the outside coil heats up and changes state from a low temperature/low pressure liquid back to a low temperature/low pressure gas. The air coming off of the outside coil is cold because it has given up some of its heat to the refrigerant in the coil.

This low temperature (cool)/low pressure refrigerant gas now passes through an accumulator (to remove any remaining liquid refrigerant before it enters the compressor where it could cause "liquid slugging" and damage the compressor) and returns to the compressor where it once again becomes a high temperature/high pressure gas through the process of being compressed and is sent back toward the inside coil to repeat the whole process.

Now, to the issue of operating an air source heat pump in the heating mode, as just described, when the outside temperature is above 65° F. We have to remember that in a closed system such as the refrigerant circulating system of a heat pump, as pressure increases, temperature also increases. So, on a day when the air being blown across the outside coil above a certain temperature, 65° F, the temperature of the refrigerant gas exiting the outside coil will be higher and so will the pressure of the gas within the system.

This means that the gas entering the compressor will be at a higher temperature and, therefore, higher pressure than it would if the outside temperature were lower. The result is that the pressure of the gas being discharged from the compressor will also be higher. This increased "discharge pressure" can be high enough to damage components in the system which aren't designed or intended to be subjected to this pressure. To avoid being held accountable for damage to the heat pump system due to operating it when the outside temperature may result in excessive refrigerant pressure, inspectors should refrain from operating them in the heating mode when the outside temperature is above 65° F.

Some manufactures equip their heat pumps with a mild weather switch to reduce the potential for system operation in the heating mode at times during the heating season when the outside temperature may reach or exceed a predetermined limit. This switch is installed in the suction line (also called the vapor line) between the inside coil and the reversing valve. It is designed to sense the discharge pressure of the compressor in the heating mode and to shut off the electrical power to the outside fan when the discharge pressure reaches a preset limit (when the outside temperature is above 70° F which typically results in an increase in the discharge pressure).

With the outside fan off, the air flow over the outside coil decreases and the atomized liquid refrigerant moving through the outside coil picks up less heat, thus, decreasing in pressure as well.

Since an inspector typically will not know if a particular unit is equipped with a mild weather switch, the rule of thumb that says, "Don't operate heat pumps in the heating mode when it's above 65° F outside," still applies. Make sure you have a thermometer so you can determine the outside ambient temperature in the area of the compressor/condenser unit on marginal days. Also, always remember to document the outside temperature in the written report and, if it is above 65° F, state that the heat pump was not operated in the heating mode due the potential for damaging the unit when the outside temperature is above 65° F.

EVALUATION WHEN CONDITIONS PERMIT OPERATION IN THE HEATING MODE

While comparing the temperature between air being discharged at supply registers and air returning at return grilles provides one means of assessing the cooling operation of a central air conditioning system, it does not follow that the same is true for heat pumps operating in the heating mode. The temperature differential across the indoor coil of a heat pump operating in the heating mode will vary depending on the outside temperature and the air density. The less dense the air, the less "heat" it will contain.

The temperature differential between the return air and the supply air (when any backup heating components are not operating) is one potential indicator of performance for a heat pump when it is operating in the heating mode. However, unless inspectors are performing calculations based on the size of the unit in tons, the elevation of the unit in feet above sea level, and a number of other factors, the temperature differential won't be particularly useful in evaluating system performance.

The rate of refrigerant flow in a heat pump operating in the heating mode is lower than when it's operating in the cooling mode. Therefore, it takes longer for the refrigerant in the system to reach equilibrium after the unit starts. Equilibrium is simply the normal state of the refrigerant in the system when the system is in operation. This means that the system must operate longer in the heating mode before a meaningful temperature differential or “delta t” (Δ t) can be measured. The actual period of time it takes for the refrigerant in a heat pump to reach equilibrium depends on the load conditions under which the system is operating. In short, the colder the outside ambient temperature, the longer it will take for the refrigerant to reach equilibrium.

One method that can be used to determine when the system has reached equilibrium is to monitor the Δ t periodically starting at the beginning of the cycle. When the Δ t stabilizes, the system has reached equilibrium. At this point, Δ t measurements should be taken immediately upstream and immediately downstream of the indoor coil rather than only at a return grille and at a supply register. This is because a Δ t obtained by measuring temperatures at a return and at a supply includes ductwork heat losses and can distort the evaluation of the system’s performance.

The temperature differential across the indoor coil of a heat pump operating in the heating mode will vary depending on the tonnage of the unit, the outside temperature, the air density (air is less dense in Denver at 5280 feet than in Kansas City at a lower elevation and the less dense the air, the less "heat" it will contain), the cleanliness of the coils, and airflow within the system air distribution ductwork.

Unlike the Δ t taken in the cooling mode, there can be significant variations in an “acceptable” Δ t for heat pumps operating in the heating mode. For example, assuming a three ton unit with clean coils, properly sized ductwork, and a properly sized air handler fan, operating near sea level, when the outside temperature is around 52°F and the indoor temperature is 70°F, the Δ t will be about 29°F measured as close to both sides of the indoor coil as possible. If the outdoor temperature is 37°F and the indoor temperature is 70°F, the Δ t will be about 22°F. These numbers also assume that any back up or emergency heating elements or burners are not energized.

Better information may be obtained by comparing the outside temperature to the supply register temperature. If the back up heat is on, the temperature differential between a supply and a return can be dramatically different than when the back up heat is off.

In this next example, we will assume a two ton unit operating near sea level with an indoor temperature of 68°F. When the outside temperature is around 50°F, the temperature at a supply register near the supply plenum will be about 98°F - a 48°F difference between outside temperature and indoor supply temperature. Again, assume the same two ton unit and an indoor ambient temperature of 68°F. If the outside temperature is 40°F, the temperature at a supply register near the supply plenum will be about 95°F - a 55°F difference between outside temperature and indoor supply temperature. These numbers also assume that any back up or emergency heating elements or burners are not energized.

Keep in mind that the average human body temperature is around 98.6°F - warmer often than the air coming out of a supply register of a heat pump system operating in the heating mode. However, if the air at a supply register is 85°F, it is still warming the room and the people in it.

It should be clear that evaluation of a heat pump's normally intended function or operation in the heating mode is a little more problematic than the evaluation of the same system in the cooling mode. It may be better for home inspectors to simply comment on whether the unit produced “warm” air at the supplies (both with and without back up heat on where a back up heat source is present and part of the system).