The Mystery and Magic of Refrigeration

So, what's the problem? It's hot outside and we want to keep it cool inside. Solving the winter heating problem is relatively simple. We take the energy stored in a fossil fuel, convert it to heat, and deliver the heat energy to the living space. But summer cooling is more complex. Cold doesn't exist. Cold is the absence of heat. So, in order to cool, we must remove heat.

That's simple. Just open a window and turn on a fan. The heat in the room is blown out through the window. Right? Mmm… not quite. In order for us to move air with a fan, we must have an air source. In a modern tightly sealed home, with only one window open, very little air is actually going to move through the window. Yes, the fan may actually make the house more comfortable, but only because it creates turbulence, causing the air to move over the occupant's skin. If we open another window to create an air source, we bring air in through one window and out through another. If our objective is to move air, then yes, we have accomplished, but the net change in temperature is going to be impacted by the outdoor air temperature. If it's hot outside, then we're actually going to be bringing warm air in, which is contrary to our objective of lowering indoor air temperature. Yes, if indoor air temperatures are equal to outdoor air temperatures, we have made the house more comfortable. And if outdoor air temperatures are actually lower than indoors, the net temperature drop in the house may, in fact, be positive. This may have been good enough for our grandparents, but most home purchasers expect something more sophisticated. In most parts of North America, central air conditioning is the answer.

Refrigeration Theory

Let's start with two coils – one inside the house and one outside. We'll use these coils to transfer heat between a fluid inside each coil and the air surrounding that coil. Let's use the indoor coil to absorb heat energy from the indoor atmosphere, and the outdoor coil to release heat energy to the outdoor air. Now, put a fan by each coil and use these fans to blow air across the coil. The indoor fan blows indoor air across the indoor coil where heat energy is absorbed by the fluid inside the coil. The outdoor fan blows outdoor air across the outdoor coil where heat is released to the outdoor air. So, the fluid is warmed indoors by moving indoor air across the indoor coil, and then cooled by moving outdoor air over the outdoor coil.

Obviously, we're going to need some mechanism to move the fluid between the two coils. So let's connect them by two tubes – one taking the warmed fluid from the indoor coil to the outdoor coil; and the other bringing the cooled fluid back in after it has released it's heat energy to the outdoor atmosphere.

Believe it or not, this is how central air conditioning works. The system we've described so far though, will actually be counter-productive. If we can find a fluid that will absorb and release heat readily, and we come up with some mechanism for moving the fluid through the system, from one coil to the other and back again, we still have the same problem as the fan with two open windows. If it's warmer outdoors than it is indoors, we're going to be moving heat into the house, not removing heat as we had intended. Have we solved the problem? Not yet. So let's take a closer look.

BTU is an acronym that stands for **B**ritish **T**hermal **U**nit. A British thermal unit is a measure of heat energy equal to that required to raise the temperature of one pound of water one degree Fahrenheit. Assuming atmospheric pressure at sea level, the freezing point of water is 32 degrees. Boiling point is 212. Therefore, 180 (212 - 32) BTUs of heat energy are required to raise the temperature of one pound of water one degree Fahrenheit. If we put a pound (16 ounces) of 32-degree water in a container and introduce heat, we will need 180 BTUs to raise the temperature of the water to 212 degrees. Scientists call this *sensible* heat because we can sense the temperature change. The water is warmer after we heated it than it was before. What happens though, if we continue to provide heat to the water after it reaches the boiling point (212 degrees F)? It begins to boil. And as it boils, the temperature remains a constant 212 degrees, but begins to change states – it converts to steam. It takes 970 BTUs of heat energy to convert one pound of 212 degree water into 212-degree steam. We call this energy the *latent* heat of vaporization.

The scientists who design air conditioning systems formulate very specific fluid materials that have very unique properties regarding their boiling points under various pressures. For our purposes, let's call these fluids generically *refrigerants*. Let's also name the coils. We'll call the indoor coil, the evaporator coil, and the outdoor coil, the condenser. That's right – the refrigerant is going to flow through this system, back and forth between the indoor evaporator coil and the outdoor condenser coil. It's going to condense into a liquid in the condenser coil and boil off into a vapor indoors in the evaporator. As discussed above, we can store an extraordinary amount of heat in a vapor. So, as the refrigerant is vaporized in the evaporator, it absorbs the latent heat of vaporization and as it is liquefied in the condenser it releases that latent heat.

So what do we have so far? Two coils – the evaporator located indoors, and the condenser outdoors. One fan blows indoor air across the evaporator and another fan blows outdoor air over the condenser coil. Refrigerant flows through the evaporator coil where it captures the latent heat as it boils off into a vapor. The refrigerant then, containing the heat energy, passes through a tube that takes it outdoors to the condenser coil. In the condenser coil, the refrigerant condenses back into a liquid and in so doing, releases the heat energy to the outdoor atmosphere. The cooled refrigerant is then conducted back through a second tube and returned to the evaporator. The cycle repeats.

You'll notice though, a few holes in our theory. First is that we haven't yet described a mechanism for moving the refrigerant through the system. Why not use a pump? If our only purpose in providing the pump were to simply move the refrigerant, then we could put the pump anywhere in the system that was convenient. However there is still one more dynamic that we haven't addressed yet. What causes the refrigerant to change states? Herein lies the mystery. We're warming the refrigerant by moving cool indoor air over it. Then we're cooling it by blowing warm outdoor air over it. Hmmm….

Somehow this just doesn't sound right. If it's seventy-five degrees in the house and ninety-five degree outside, we have to warm the refrigerant to its boiling point by moving *seventy-five* degree air over it; and then cool it to the dew point by moving *ninety-five* degree air over it.

The answer to this apparent dilemma is found in the answer to the question, "What is the purpose of the compressor?" Let's back up and first ask ourselves, "What is a compressor?" A compressor is a pump that pumps into a container. The more of a fluid we can force into a container, the higher the pressure. For our purpose, this container is the condenser coil located outdoors. So yes, the refrigerant is at a higher pressure in the condenser than it is in the evaporator. As we raise the pressure in the evaporator, we impact two other dynamics – boiling point (and its inverse - dew point) and temperature. There is a direct correlation between pressure and boiling point. As pressure rises, so also the boiling point rises. As goes the boiling point, so goes the dew point. So, if we can deliver the refrigerant to the evaporator at low pressure, we can boil it off at a low temperature. If we can deliver the same refrigerant to the condenser at higher pressure, we can condense it at a higher temperature. But have we answered the question yet? *What is the purpose of the compressor?* Sure, the compressor is the pump that propels the refrigerant through the system. And, the compressor raises the pressure in the condenser, and in so doing raises the dew point. Remember though, we said that *two* things change in the condenser as a function of the increased pressure. The dew point is one. What is the other?

Or let's ask the same question another way. *How are we going to warm the refrigerant in the evaporator by moving seventy-five degree indoor air over it and then cool the refrigerant in the condenser by moving ninety-five degree outdoor over it?* The answer has to include some kind of mechanism for raising the temperature without introducing additional heat. The answer is in the third but primary purpose of the compressor – to raise the temperature. That's right - an important property of gases is that their temperatures rise with increased pressure. Diesel engines take advantage of the rise in temperature of compressed air to ignite the fuel without the use of a conventional spark plug. With increased pressure we not only get higher boiling point, but also higher temperature.

Remember we're trying to cool the same air that we heated by moving seventy-five degree air over it indoors by moving ninety-five degree air over it outdoors. For that to work, we need the refrigerant to be cooler than seventy-five degrees as it passes through the evaporator and warmer than ninety-five degrees in the condenser. How do we accomplish this without introducing additional heat? We compress it. We put the same number of molecules of refrigerant, containing the same number of BTUs of heat energy into a smaller space. What do we get? Higher temperature!

So let's look at it, and let's remember to use the terminology to help us understand the system.

Why don't we start indoors where the refrigerant has just been warmed in the evaporator? It's just been through the evaporator, so it's a vapor. It hasn't been through the compressor yet, so it's low pressure, and because it's low pressure, it's also low temperature. Because remember, the primary purpose of the compressor is to raise the temperature.

The refrigerant, drawn by the compressor, passes through a tube that conducts it outdoors to the condenser. It passes through the compressor, becoming high pressure. It's high-pressure, therefore it's high-temperature. It hasn't yet been through the condenser, so it's still a vapor.

Next, the refrigerant is conducted through the condenser as warm outdoor air blows across the coil. Because it's high temperature (higher than the outdoor air) it is cooled to the dew point inside the condenser. So as it passes through the condenser, it cools and condenses, releasing the latent heat of vaporization to the outdoor atmosphere.

As it leaves the condenser, the refrigerant remains under pressure. It's high pressure, so it's still high temperature - not as hot as it was when it entered the condenser, but still much hotter than it will be after it is taken back indoors and the pressure released. Now that it's been cooled in the condenser, it's a liquid - a high pressure, high temperature, liquid.

Conducted back inside through a second tube, the refrigerant passes through an expansion device of some type where the pressure is released. With the drop in pressure comes a drop in temperature, preparing it to be heated again by blowing indoor air over the evaporator coil. Heat is extracted from the indoor air, cooling the air and warming the refrigerant. As the refrigerant passes through the evaporator coil, being warmed by the heat it absorbs from the indoor air, it boils off into a vapor, absorbing the latent heat of vaporization. Now we have a low pressure, low temperature, vapor. The cycle repeats.

In summary then, we warm the refrigerant in the evaporator coil inside the house by moving indoor air over it. We raise the temperature without adding heat by compressing it. Then we cool it in the condenser coil outside by moving outdoor air over it.

As it boils off into a vapor in the evaporator, it absorbs the latent heat of vaporization. It releases the latent heat as it condenses in the condenser.

The refrigerant changes from a low-pressure low-temperature vapor to a high-pressure high-temperature vapor when it is compressed by the compressor. Then it condenses into a high-pressure high-temperature liquid in the condenser. We release the pressure at the expansion device, converting it to a low-pressure low-temperature liquid. Finally, it boils off in the evaporator changing back into a low-pressure low-temperature vapor.

There are still a few important components that we do well not to overlook. We touched briefly on the two tubes that carry the refrigerant back and forth between the coils. One of them is large, insulated, and cold to the touch. The other is smaller, is not insulated, and is warm to the touch. It's the cold insulated line that carries the warmed vaporized refrigerant from the evaporator to the compressor. It's the smaller warm one that carries the cooled liquid back to the evaporator. The larger insulated pipe is called the suction line because the refrigerant is being drawn (or sucked) by the compressor at that point. The small warm pipe is called the liquid line, because it carries the cooled high-pressure high-temperature liquid back to the evaporator. The purpose of the insulation on the suction line is to keep humid air from contacting the cold pipe thereby inhibiting condensation on the pipe.

If all that's clear, let's move on. If not, go back to the top of page one and read through it again.

Typical Configurations

The system described above is commonly referred to as a split system, air-to-air, central air conditioner. The term s*plit system* refers to its configuration with one coil, the evaporator, located indoors and the other, the condenser, outdoors. *Air-to-air* implies that it is designed to extract heat from the indoor air and release it to the outdoor air. An air conditioning system is considered *central* when conditioned air is distributed through the entire house. In a central system conditioned air is conducted through the house by ducts. The typical window unit or through-wall air conditioner, which works on the same principle, while still air-to-air, is neither split nor central. The unit located outdoors, which includes the compressor and the condenser, is properly named the *compressor condenser*, but is often referred to as either the *compressor* or the *condenser*. However, it is sometimes inappropriately called the heat pump. We'll talk about heat pumps in a moment. The unit located indoors, which includes the blower fan and the evaporator coil, is often called the *air handler*.

Designs of central air conditioning air handlers are dependant on a number of factors. The simplest design is a stand-alone version with return air entering a return plenum at the bottom and conditioned air exiting the unit from a supply plenum at the top. Immediately above the return plenum is the filter, followed by the evaporator coil, with the blower fan located above the coil but below the supply plenum. Stand-alone systems are found in homes without central forced-air heat. It is sometimes convenient, though, to integrate the cooling system with a central heating system, sharing the ductwork. This is accomplished by two different methods. The first, commonly found in moderate climates, is in effect the stand-alone unit just described with an optional *heat pack* - electric resistance heating elements located above the fan. It is not uncommon in some more northern climates to piggyback an evaporator coil onto a forced-air heating system – usually a fossil fuel burning furnace, but sometimes an electric furnace. In these configurations the air conditioner shares the ductwork, the blower fan, and the filter with the heating system. Configuration here is critical.

Remember, air conditioning serves two purposes. It cools the air, but it also dehumidifies. The moisture that is extracted from the indoor air condenses on the cold evaporator coil and is collected in a pan below the coil. There is potential for the pan to fail, allowing condensate water to drip down onto whatever is located below. If what is below is an electric furnace, potential for condensate water to drip onto the heating elements can be a significant safety hazard. Shorting out those 240-volt elements could result in significant damage, even fire. Therefore it is usually considered inappropriate to install a central air conditioning evaporator above an electric furnace.

If, on the other hand, the evaporator is located above the heat exchanger of a fossil fuel-burning furnace, there is potential for rusting of the heat exchanger. However, this risk involves a failure – leaking from the drip pan. The more significant risk in this case, involves an installation in which the evaporator coil is located upstream of the heat exchanger. Here, even under normal conditions, potential exists for condensate water moved by the blower fan to splatter over the outside of the heat exchanger promoting rust of the heat exchanger. So, an appropriate installation of central air conditioning piggybacked onto a fossil fuel burning furnace has the evaporator downstream of the heat exchanger, while it is inappropriate to install the evaporator above an electric furnace.

Inspection Procedures and Testing Protocol

Properly setup and operating, the typical split-system air-to-air central air conditioning system that we just explored should provide about a fifteen to twenty degree temperature drop across the evaporator coil. This means that the air coming off the coil should be about fifteen to twenty degrees colder than the air entering the system. In other words, the difference between return air and supply air should be between fifteen and twenty degrees.

Testing protocol then is pretty simple. Turn the thermostat down. Wait about ten or fifteen minutes. Place a thermometer as close to the evaporator coil as practical and take a reading. Move the thermometer to a location as close as practical to the supply side of the coil and take another reading. Because we’re cooling, supply air is going to be lower temperature than return air. Subtract one reading from the other, and look for a difference of about fifteen to twenty degrees Fahrenheit. If room temperature is seventy degrees, return air is going to be the same – seventy degrees. Supply air then should be between fifty and fifty-five degrees – fifteen to twenty degrees below return air. Oh, okay – forty-nine to fifty six (14 – 21 degrees). Remember we’re home inspectors, not HVAC technicians.

The filter cover often provides easy access to return air close to the coil, but the closest return grill will do. The vibration damper can be a convenient place to get a temperature on the supply side of the coil. The problem is that you’ll have to pierce the fabric of the damper. This is easily done with the sharp end of the thermometer probe. Some very particular type of homeowner may be offended that you have ‘damaged’ his duct by poking a hole in it. This is a common procedure, but use your judgment. Another home inspector or HVAC technician, who tested the system previously, may have already pierced the damper for you. If so, you'll want to use the same hole. If not, the nearest return grill and the nearest supply register or diffuser are typically considered to be adequately near the coil.

If supply air temperatures are too high (you're not getting adequate temperature drop) problems might be compressor related. Or there may be inadequate airflow over the condenser coil. If, on the other hand, supply temperatures are too low (the temperature drop is greater than 20 degrees) the system may be super-cooling. This could be caused by an inadequate refrigerant charge or possibly by inadequate airflow over the evaporator coil. Something as simple as deferred filter maintenance can cause an air conditioner to super-cool.

Because a clogged filter restricts airflow, there may be inadequate heat to warm the refrigerant as it flows through the evaporator. The refrigerant is then conducted out to the condenser were it is cooled and then brought back inside where it isn't warmed before being sent back out to the condenser to be cooled again. With each repetition of the cycle, refrigerant temperatures drop, eventually causing humidity in the indoor air to manifest as frost on the outside of the evaporator coil. This frost then, further restricts airflow over the coil, exacerbating the precipitous decline in refrigerant temperature. Eventually, the frost build-up on the coil is capable of completely blocking airflow over the evaporator coil. Any evidence of frost anywhere on the system, either on the evaporator coil or the suction line, would be reason to call for further evaluation.

When practical, remove the access cover to expose the evaporator coil. Look for any blockage, either frost or dirt, on the coil. Look for dust on the blower fan blades, and anything else that doesn't appear normal. It's usually difficult to see the coil from the upstream side, but that's where the dirt is going to build up – especially when filter maintenance has been neglected.

Remove the filter cover and demonstrate filter replacement. You may want to refrain from pulling the filter all the way out of the unit. They are sometimes difficult to replace. Inspect the filter itself. Dirt on the filter suggests deferred maintenance. A clean filter is meaningless information. It may have been replaced yesterday for the first time in years - for your benefit. Don't be surprised to find that a filter that has not been serviced recently has been sucked up out of its track and against the evaporator coil.

Talk to people about maintenance. Educate them about the filter. Most home inspectors recommend a thirty to sixty day maintenance cycle for disposable or washable filters. A short conversation suggesting that your client maintain a contract with a local HVAC contractor is usually well received.

Don't hesitate to recommend a routine professional cleaning and service. The heating and cooling system is the one most complicated and expensive component of the house that requires routine maintenance and has a revolving replacement cycle. Besides possibly roofing, HVAC systems are probably the area of greatest concern for most homebuyers.

Look at the compressor condenser. It should be approximately level. Check for airflow. Properly installed, the unit should be installed at least one foot away from the building and have twenty-four inches of clearance on three sides and above. Condenser fins are delicate and easily damaged by lawnmowers, weed eaters, and dogs.

Touch both refrigeration lines. The larger insulated line, the suction line, should be cold to the touch. Expect to find condensate on any section of the suction line that is not covered by insulation. The liquid line, the smaller pipe without insulation, should be warm to the touch.

Listen to the compressor. Be sure to have the system running when you walk the outside. It's best to hear it at startup. Learn to recognize the sound of a smoothly running compressor. Report on anything unusual.

Determining Age & Capacity

Remember, we find age information in serial numbers and capacity information in model numbers. Each manufacturer has its own method of encoding this information. Learn to recognize the common ones.

You'll recall that BTU is an acronym that stands for British thermal unit. A British thermal unit is a measure of heat energy equal to that required to raise the temperature of one pound of water one degree Fahrenheit. It takes 180 BTUs to raise the temperature of one pound of water from 32 degrees F. to 212 degrees. And it takes 970 BTUs to turn that one pound of 212-degree water into 212-degree steam.

There is a similar calculation that we can apply at the other end of the scale. It takes 12,000 BTUs to convert one ton of ice to water. This information is important to home inspectors because air conditioners are rated in tons. A 12,000 BTU air conditioner is referred to as a one-ton unit. Because air conditioners are sized in half-ton increments, look for a number within the model number that is divisible by 6 and then divide that number by 12. So, a compressor condenser unit with the model number XXX42XXX is a 3-1/2-ton unit. 42 is divisible by 6. And 42 divided by 12 is 3.5.

Like we said though, different manufacturers encode capacity information in model numbers in different ways. Lennox, for instance, has a simple code for each size – simple that is if you know the code.

Heat Pumps

Earlier in this chapter, we discussed the method used to cool indoor living space - refrigeration. We absorb heat from the cool indoor air and release heat to the warm outdoor air. If we can do this for summer cooling, why can't we reverse that process for winter heating - absorb heat from the cold outdoor air and release it to the warm indoor air? We can. That's what a heat pump does. In essence, a heat pump is simply an air conditioner running in reverse. In fact, most residential air-to-air heat pump systems are identical to what we discussed above with a few added features. In the summer it's a cooling system. In winter it's a heating system.

The significant component that makes an air-to-air air conditioner a heat pump is a reversing valve. The reversing valve is usually found outdoors in the compressor condenser unit and is often visible, to the experienced eye, without dismantling the unit. Going back to our discussion of refrigeration theory you'll recall that the refrigerant is compressed into the condenser coil. If we're going to move heat in rather than out, we'll want to have the condenser located indoors rather than outdoors. Rather than relocate the coils though, we redirect the refrigerant. It's the reversing valve that accomplishes this. With the system in its cooling mode, the compressor pumps the refrigerant into the condenser coil located outdoors. With the system in its heating mode, the reversing valve redirects the refrigerant to the coil located indoors. Now the coil that we have been referring to as the evaporator, the one located indoors, functions as the condenser and the coil located outdoors becomes the evaporator. So now we're absorbing heat from the outdoor atmosphere as we boil the refrigerant in the outdoor coil and we're releasing that heat to the indoor atmosphere as we condense it in the indoor coil. In fact, with heat pumps we no longer refer to the evaporator coil inside the house and the compressor condenser unit outdoors. We simply call them the inside unit and the outside unit.

This seems simple so far, but we do have a few engineering problems to work through. So let's go back to our original premise. It's cold in the winter and it's hot in the summer. We size heating systems to run full-time on the coldest night of the winter and still keep the house comfortable. Inversely, we size cooling systems to run full-time on the hottest summer day. A heat pump, being both a heating system and a cooling system, faces us with the question, "Do we size it for the summer cooling load, or for the winter heating load?" Let's consider the options.

There is some optimal temperature range that people find desirable year round. For most of us that temperature is somewhere around seventy degrees Fahrenheit. In North American climates extreme winter temperatures are in the neighborhood of zero degrees. Extreme summer temperatures are around one hundred. Sure, it gets even more extreme in some locations, but let's keep it simple. In summer we're faced with only about a thirty-degree difference between the extreme outdoor air temperature and the desirable indoor temperature (100 – 70). The seventy-degree difference we're faced with in the winter though (70 – 0), is a significantly greater challenge. So how do we size the system? If we calculate a capacity that compensates for the seventy-degree winter heating load, we'll be over-sized for the thirty-degree summer cooling load. If however, we size the system for the summer cooling load, we'll be undersized for the winter heating load. It sounds like a no-brainer. Size it for the winter heating load and allow it to get plenty of rest in the summer. That's a good idea except for one complication.

Air conditioning serves two purposes. It cools the air. But it also dehumidifies. As humid indoor air contacts the cold fins and tubes of the evaporator coil, moisture condenses, drips down, and is collected in a pan below the coil. This condensate water then is conducted away through a condensate drainpipe to some external location for disposal - typically a floor drain, a laundry tub, or just the ground outdoors. Dehumidification in a humid summer climate is desirable. In fact, the engineers who design these systems usually undersize a cooling system in order to get it to run a little bit longer than it otherwise would in order to accomplish dehumidification. So, if we size a heat pump for the winter heating load, it will be oversized for the summer cooling load, allowing it to satisfy the thermostat and shut down before it draws enough humidity from the air.

It is for this reason that heat pumps are usually sized to meet the demands of the summer cooling load, and work well in the spring and fall when heating needs are moderate. When temperatures drop below forty degrees Fahrenheit though, heat pumps struggle to keep up. So the refrigeration is supplemented in some way – commonly by an electric resistance heat pack built into the indoor unit. These electric heating elements are similar to those used in electric furnaces.

Learn to recognize a heat pump. The most obvious indicator is usually the thermostat. The typical heat pump thermostat is similar to a furnace with central air thermostat, with a few additional features. Either thermostat will have a thermometer for reading room temperature and a mechanism for controlling the temperature setting. Either one will have the fan switch with its two settings – on and auto. And they'll both have a mode control. However, heat pump thermostats often have a blue (sometimes green) light labeled *auxiliary heat.*

With the mode setting on cool and the temperature setting below the room temperature the heat pump should operate in its cooling mode until the temperature drops to the setting temperature. In the heat mode, with the setting temperature one or two degrees above room temperature, the heat pump should operate in its heating mode and run until it satisfies the thermostat. However, there are actually two heating modes. When the heat pump fails to meet the demands of the thermostat and room temperature drops more than two degrees below the setting temperature, the electric resistance auxiliary heat kicks in.

In its normal heating mode, most air-to-air heat pumps deliver conditioned air at about fifteen to twenty degrees above room temperature. If room temperature is seventy degrees, air at the register is likely to be about eighty-five to ninety degrees – sometimes ninety-five degrees depending on the efficiency of the system. Human skin temperature is somewhere around ninety–five degrees. Therefore, heat delivered at the register is likely to feel cool to a person holding her hand to the register. This dynamic is the source of many misconceptions about heat pumps. People accustomed to fossil fuel burning or electric furnaces may be used to sensing one hundred twenty or one hundred thirty degree air at the registers. To them, even ninety-five degree air can seem cool. It's common for the new occupant of a home with a heat pump to be confused by this apparent cool air delivered by a system in its heat mode.

We're trying to heat the house to seventy, or maybe seventy-two degrees. Ninety-degree air will do that. But someone who is unfamiliar, feeling that *cool air*, may be inclined to manipulate the thermostat, and in so doing, trigger the auxiliary heat. It is common practice for people to conserve energy by turning the heat down in the morning before they leave for work, turning it back up again when they arrive home. This strategy is effective with fossil fuel burning or electric furnaces, but is a false economy with a heat pump. You see, two things change when the auxiliary heat kicks in – not only the temperature of the air, but efficiency as well. All the heat that was lost during the day is recovered with the much more expensive electric resistance auxiliary heat.

> I performed a home inspection one spring afternoon a few years ago. The owners had already moved out in late summer and left the house in the care of a family with two teenage children. The house sitters, as well as the owners, had apparently taken very good care of the home. Things were clean, well maintained, and in good order. I found the thermostat set on heat and forty degrees. It was about forty degrees outside. I had already tested the heat pump in the heat mode and found it to be in normal working order, when the teenage daughter arrived home from school. I watched her walk in the front door, directly to the thermostat, and then to her room where she started her homework. Sensing the sudden rise in temperature, I glanced at the thermostat and noticed that she had set it to seventy-two degrees. 'A pretty normal setting,' I thought. 'These people probably think they're saving energy by turning the heat down while they're away.' The heat pump continued to operate in the auxiliary heat mode delivering hundred and thirty degree air as room temperature rose quickly.
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> Only minutes later, the teenage son arrived, went upstairs, and started his homework. After about five minutes, he skipped briskly down the stairs, grabbed an apple from the kitchen, and paused briefly in the dining room to adjust the thermostat on his way back up. By now I had finished the first floor and was headed outside, but snuck a quick look at the thermostat on my out. It was back down around fifty.
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> I inspected the exterior and grounds and walked the roof before coming back inside. As I entered through the front door, the son left the thermostat and headed back upstairs. I checked again and found the thermostat set at seventy-six.
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> About the time I came down from the attic, Dad showed up. He stopped calmly in the foyer, placed his hand on the stair rail and shouted, "Has anyone turned the heat on yet?" Two quick responses assured him that everything was normal, "Yeah Dad. No problem. We got it."
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> In the next fifteen minutes, while I finished writing the report, delivered my summary, collected the check, and thanked my client and the agent for their business, I noticed the Dad turn the heat down twice, and the brother and sister each turn it up once.

> Dad happened to walk out to get the mail just as I was leaving. I don't usually have much conversation with owners, but tenants are sometimes a good source of information. Finding my curiosity difficult to contain, I casually inquired into his perception of the condition and function of the heating system. "How does the heat work?" I asked. "Okay," was his tentative response. "The furnace works just fine. But the thermostat must be out of calibration."

Inspection procedure and testing protocol for a heat pump in its cooling mode is identical to any electric compressor central air conditioner. The outside unit should be level and have access to plenty of free flowing air. The suction line should be cold and wet and the liquid line warm. Look for the same design tolerance of fifteen to twenty degree temperature-drop across the coil. Check the filter. Remove the inside unit access panel and observe the blower fan and the evaporator coil. Now go one step further and observe the electric auxiliary heat element compartment. Evidence of electric arcing or excess heat in here is a significant find.

Testing the heat is a little bit more involved. It helps to remove the thermostat cover of a conventional thermostat. You'll find two mercury switches in there. With the mode switch in the heat position, slowly slide the setting control up until one mercury bubble falls into the on position. This should put the system in its heat pump mode. Give it a few minutes and take a supply air temperature reading. Look for about a fifteen to twenty degree temperature rise across the coil. If the house is at a comfortable seventy degrees, that reading will be about eighty-five to ninety degrees F. Some newer more efficient systems may give you as much as ninety-five degrees (twenty-five degree rise). Now slide the setting control up until the second mercury switch activates. Give it a few moments and check your thermometer again. Expect to find temperatures between one hundred ten and one hundred thirty degrees.

Remember though, we don't test air conditioners when outdoor ambient temperature is below sixty-five degrees. That includes heat pumps in the cooling mode. And we don't test heat pumps in the heating mode when it's above sixty. There is that small convenient window in the spring and fall when it's appropriate to test heat pumps in both modes. But most of the time, you'll test them in one mode or the other. Explain this limitation to your client.