# Air Conditioning FOR Humid Climates

PHOTOS BY CHRIS FLORIO

**by Dwayne Akers**

A two-stage compressor, a variable-speed air handler, and advanced controls provide effective dehumidification and efficient cooling with a single system

No matter where you work, air conditioning for comfort has always been challenging: Comfort is a subjective quality, and the expectations vary from one person to the next. But in hot, humid areas like the southern coastal states, heating and cooling design can pose particularly tough problems. As a custom heating and air conditioning contractor in North Carolina, I know how hard it can be to keep a home comfortable during humid weather. In this part of the world, both the outdoor temperatures and the atmospheric humidity levels can vary through a wide range, and not necessarily together. Con-trolling both temperature and humidity with the same comfort system, 365 days a year, calls for a lot of technical savvy.

I work mainly in the custom home market, and my customers have high expectations. Even so, I have to compete against typical fly-by-night contractors who are willing to undercut my prices by 50%. Those lowball contractors will cut all kinds of corners to make a buck. Rarely, if ever, do they take the time to properly estimate even the total cooling load for a new system; you'll surely never see them correctly evaluate the split between dehumidification requirements ("latent cooling load") and simple cooling requirements ("sensible cooling load"). And they don't have the knowledge, skill, or training to design and install a system that properly deals with both kinds of loads and does it efficiently. Yet that's the key to comfort in my climate. Temperature is the only factor a thermometer shows you, but humidity is often the more important factor in the comfort equation, and on many days humidity is the bigger energy load for the air conditioning system. Handle humidity well, and you're on your way to licking the problem. Fail to handle it, and the problem will lick you.

## Sensible vs. Latent Heat

Any discussion of air conditioning needs to recognize the two kinds of heat load that affect our indoor comfort level: sensible heat and latent heat. *Sensible heat* is simply heat that can be "sensed" by the body, and is easily measured with a thermometer. *Latent heat* is heat that is added to or subtracted from a substance without changing its temperature. You can boil a gallon of water into room air or pull a gallon of water out of the air with a dehumidifier and not change the room air temperature. But evaporating water into the air nevertheless adds the water's "latent heat of evaporation" to the total heat in the air, and pulling that water back out removes that same amount of latent heat.

Warm air will hold more water vapor than cool air will. That's why we speak of "relative humidity" (RH), not just "humidity." At 100% relative humidity, air is saturated and can't hold any more moisture. At 50% RH, the air contains only half the amount of moisture it could hold.

Cool air won't hold the moisture that hot air will hold, so cooling air without removing moisture at the same time increases the air's relative humidity. Take a roomful of air at 95°F and 50% RH, for example. If we cool that air down to 75°F but don't remove any moisture, it will end up at 95% RH. That air is very near its dew point, so you'll see moisture condensing on any cold surface (such as a pitcher of ice water).

***Humidity and comfort.*** When it comes to human comfort, there is a direct relationship between temperature and humidity levels. Scientific studies back up the personal experience of most people: When the air is dry, occupants feel comfortable at a slightly warmer temperature than when the atmosphere is moist. So properly addressing the latent cooling loads allows comfort to be achieved at higher thermostat set points.

During humid conditions, the air conditioner or heat pump has to remove the latent heat load from the space, not just cool the air. That's why you expect to see condensate draining from the air handler or evaporator coil whenever the comfort system is operating.

For every pound of condensed vapor that drains away, 970 Btus of heat are removed from the space. In fact, the dehumidification part of air conditioning accounts for a big part of the system's workload. Evaporation takes a lot of energy, and adds a lot of heat, compared with a simple temperature increase. To raise the temperature of one pound of water from 32°F to the boiling point of 212°F, for example, requires the addition of 180 Btus of heat (a Btu, or British thermal unit, is the amount of heat required to raise a pound of water by one degree Fahrenheit). Converting that same pound of water from 212°F liquid to 212°F vapor (that is, steam) takes 970 Btus — about five times the energy.

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Reversing the process takes the equivalent amount of work. For example, to cool the air in a room by 20 degrees, from 95°F to 75°F, we have to remove 5 Btus of sensible heat per pound of air (a pound of air is equivalent to about 12.3 cu. ft.). But pulling enough moisture out of that air to get it back down to 50% RH requires the removal of 8 Btus of latent heat per pound of air. So on a hot, humid day in a house with a properly sized 5-ton cooling system, 3 tons of that capacity might be working to dehumidify the air, while only 2 tons are working to actually cool it.

The balance between the latent load and the sensible load varies from place to place and from season to season (see

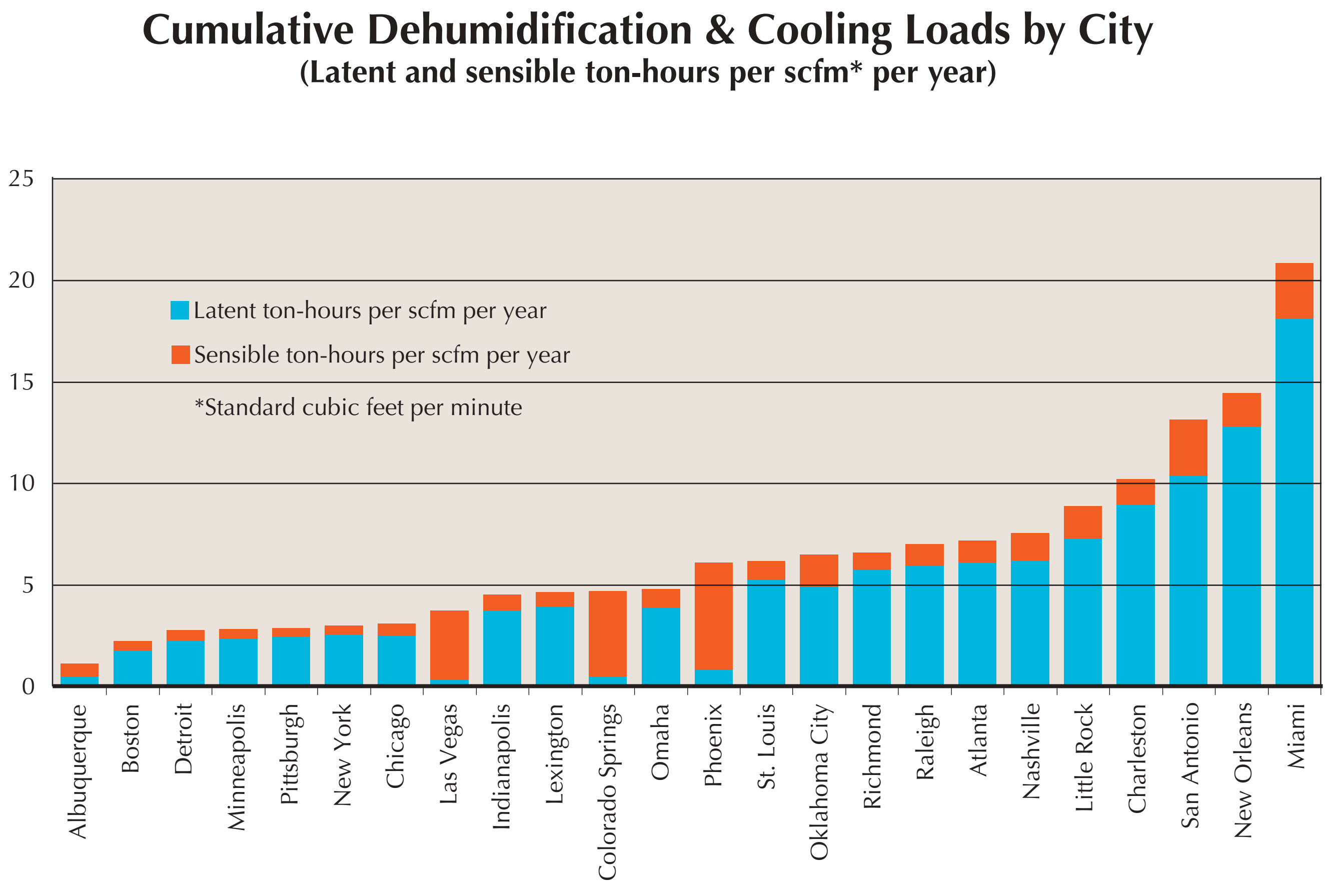



**Figure 1.** From region to region and season to season, air conditioning systems are asked to handle wide variations in load conditions. This chart compares the balance between sensible and latent loads in a sampling of locations within the United States, on an annual basis. Systems have to meet local needs: Dehumidification requirements are a negligible part of the load in some areas, but are the dominant factor in other locations.

Figure 1). In Arizona, you may be able to design a system based on peak outdoor temperatures, with no worries about humidity. But in my climate, a system needs to be sized to dehumidify as well as to cool — or better yet, to switch between dehumidification and sensible cooling as needed.

## Efficiency vs. Dehumidification

Since the early 1990s, manufacturers have redesigned heating and cooling equipment in order to meet tougher energy-efficiency standards. Seasonal Energy Efficiency Ratio (SEER) ratings have increased as a result of these changes. A system manufactured in the early ’90s typically had SEER ratings around 8. Today, the minimum rating allowed by law is 10; in 2006, this will increase to a minimum of 13. Already, some manufacturers have exceeded that requirement, earning ratings upward of 18-SEER on their top-performing units.

To achieve these gains, engineers have modified the condensing units (the outdoor coils and compressors, which transfer heat to the outside air when the house is being cooled). Condensers have been redesigned to decrease the head pressure, which reduces the power needed to operate the system. This is accomplished by increasing the condenser coil size, which increases the heat transfer area. Thinner refrigerant tubing that is “rifled” increases refrigerant surface contact and speeds heat transfer. This causes a lower refrigerant saturation temperature, allows for additional “subcooling” of the refrigerant, and increases the refrigerant’s ability to do work.

The indoor evaporator coil, which cools air in the house, has also been modified. Evaporator coils in SEER-10 and SEER-12 units operate at higher saturation temperatures than do the older SEER-8 system coils, resulting in a warmer coil surface contacting the airstream. But a warmer coil reduces the latent capacity of the system, since the coil cannot condense moisture out of the airstream as quickly. This means that longer cycle times are needed to remove the latent load. Air needs to flow over the coil for more minutes per hour, to allow time for the moisture to condense on the coil and drain away.

This becomes a critical problem whenever the system has more than the required capacity: Oversized systems will cool the structure and satisfy the thermostat before the latent load can be reduced, resulting in high humidity levels in the structure. Homeowners end up setting the thermostat to a colder temperature to get the same comfort level that could be obtained at a higher indoor temperature if humidity were lower. And a house that is continuously cool but remains damp is at risk for mold and mildew, causing unpleasant odors, allergic symptoms, and respiratory discomfort for the occupants.

If the system is oversized for peak load conditions, it will fail to dehumidify properly even on the very hottest days. But even systems that are properly sized for the peak load conditions may not dehumidify well on days when temperatures are more moderate but atmospheric humidity remains high. If the system can't adapt to the seasonally changing balance between cooling needs and dehumidification needs, the thermostat will be satisfied long before the air is sufficiently dry: You'll see a lot of short-cycling, with rapid cooling but poor moisture control. That's the particular problem we face in North Carolina for many months of the year.


**Figure 2.** Bryant's top-of-the-line Evolution heat pump has a two-speed compressor controlled by a dedicated circuit board. The compressor experiences fewer on/off cycles than one-speed models, operating at low speed for most of its service hours, and achieves 15-SEER cooling performance with effective dehumidification. Other manufacturers have comparable systems that adjust to low-load or part-load situations.

## Practical New-Tech Solutions

Faced with the combined challenges of efficiency and load balancing, several companies have developed new systems that adjust throughout the day to changing conditions. This new generation of air conditioners is designed to solve the humidity problem while maintaining high operating efficiencies.

Every contractor has his own favorite brand of equipment. I don't have time to baby-sit the systems after installation, so I want to install a product I'm familiar with and whose performance I can predict and rely on. I have developed a preference for Bryant's solution. I know how the Bryant systems perform, how they last, and what they do. Those are the systems I install on a daily basis, and the ones I'm going to discuss for the rest of this article.

**Figure 3.** Inside the house, the author installs a variable-speed air handler that is matched to the outdoor condensor. Controlled by advanced electronic circuitry, the air handler's motor can continually adjust to changing loads, ramp up and down gradually as needed, and even sense and adjust to changes in static pressure in the duct system.

These systems have four main elements:

- ✓ a two-stage compressor with its own control board in the condenser unit
- ✓ a variable-speed air handling unit
- ✓ electronically controlled zone dampers
- ✓ a high-tech circuit-board control module

The control unit manages every aspect of the system: Indoor and outdoor sensors continually monitor air temperature and humidity, and the microprocessors adjust the compressor, fan, and dampers as needed to maintain the desired conditions that are programmed into the control center. When the house needs moderate cooling and a lot of moisture removal, the system can provide that; when there's a need for rapid cooling without extra dehumidification, the system can accomplish that as well.

## Two-Speed Condensing Units

It's standard practice to size cooling and heating equipment using the ACCA Manual J method, or with a computer program that implements the Manual J technique. Using climate data appropriate to the geographic location, and a description of the building to be cooled, Manual J totals up room by room the maximum heat gains and heat losses the building will experience. The system is then sized so its maximum capacity matches the load predicted during the peak 5% of the total cooling hours.

But during the remaining 95% of the cooling season, the system's full capacity isn't needed. So manufacturers have developed systems that ramp down to lower speeds to match low-load conditions. Two-speed condensing units for air conditioners and heat pumps are now available in a range of sizes, suited to meeting most of the load conditions likely to be encountered. Some units, like the Bryant 698B Evolution model (Figure 2, previous page), use a single compressor that can run at either high or low speed, while others couple two compressors together in the same refrigerant circuit, using one at a time for low-load conditions and both together to handle maximum-load conditions.

On low speed, a two-speed system operates at 50% of rated capacity, but with longer run times than if it were operating at maximum capacity. Given the seasonal and weather conditions typical in my climate, a two-speed system operates on low speed nearly 80% of the time.

This has many benefits. The longer run times allow better humidity control and improve comfort by eliminating frequent sharp temperature swings. Operating for more minutes per hour also promotes a continual mixing of the air in the home, which results in more even, consistent temperatures throughout the home's living space. Long, slow running of the compressor also lowers the system's energy consumption and reduces start-and-stop stress on the motors and bearings.

***Variable-speed air handlers.*** Inside the building, most of my systems use the Bryant FV4 air handler (Figure 3), which is designed to partner with the outdoor units I install. Like some other advanced air handlers, the FV4's fan is driven by an electronically commutated motor (ECM), which can precisely adjust the fan speed. Airflows can be custom tailored for each job, and with the sophisticated control system Bryant supplies, motor speeds can change continuously to suit the needs of the moment. ECM motors operate quietly and are highly efficient, typically using 60% to 75% less energy than older low-tech models use. The new motors add to the system's installed price, but lower operating costs pay that back in just a few years.

ECM motors can correct for slight resistance in the duct system and for dirty air filters by adjusting the motor speed to maintain optimum operation. The motor's instruments can estimate the static pressure of the duct system on shut down by monitoring the number of revolutions it takes for the motor to come to a complete stop. The program in the motor determines the static pressure of the duct system, then adjusts the motor speed on the next start-up cycle.

During operation, ECM motors can change speed 60 times per second, at the peak of each electrical hertz cycle. They can adjust to lower the airflow and increase latent capacities or to increase the airflow and increase sensible capacities: At slower speeds, the air has longer "dwell time" on the coil and more humidity will condense; at faster speeds, the moving air will give up less moisture but more total heat to the coil. The motors can also be instructed to run continuously at low speed between cooling and heating cycles, to promote air mixing and to maximize the effect of air cleaners and filters in the duct system. This broad flexibility in fan settings gives the hvac contractor the ability to customize each home's conditions to satisfy different comfort preferences.

**Figure 4.** The author likes to zone heat pump or air conditioner setups using zone dampers within the ductwork, controlled by the same master circuit board that manages other aspects of the system. If one zone requires more or less cooling or dehumidification, the master controller can address that zone's needs independently of other zones.

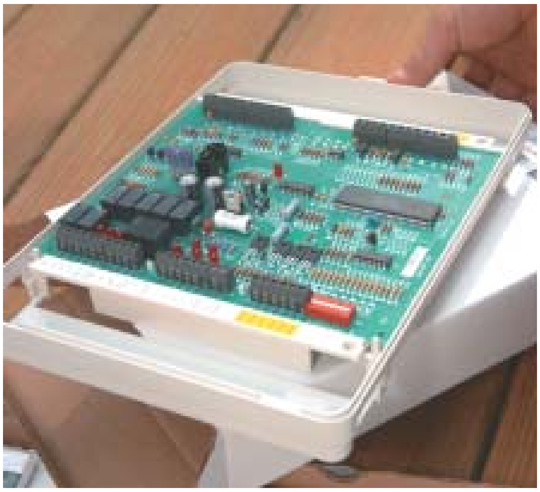
Taking advantage of the motor's capabilities, the Bryant system can be set to precondition the cooling coil at initial start-up, and to give the fan a two- or three-minute soft "ramp up" to full speed at the start of the cycle and a soft "ramp down" at the end. That way, the system provides a slow, quiet inflow of air at a comfortable temperature, instead of coming on each time with a sudden blast of unconditioned air that has been sitting in the ducts.

***Zone dampers.*** I do a lot of zoning with my systems. Zoning is something of an art, and ten different contractors could tell you ten different ways to do it. Sometimes different parts of the house need their own independent systems, each with its own condenser, air handler, and controls. But in typical cases, I prefer to install a single air handler and duct system and divide up the zones using controllable dampers in my ductwork (Figure 4). For the house shown in these pictures, I used zone dampers to create two zones, one for upstairs and one for downstairs. The dampers are controlled by the same electronic module that controls the condenser and the air handler. The system can provide different humidity levels and temperatures in each zone, and it can dehumidify, cool, or heat one zone at a time if need be.

## Advanced Controls

A device called the "user interface" (Figure 5, next page) is the brain center of the zone system: It continually sense temperatures in the home, checks the outdoor temperatures, and tells the control boards in the air handler and the condenser unit what to do. It will also talk to the zone dampers, opening and closing them as needed to condi-

**Figure 5.** The “user interface” circuit board is the brain of the comfort system; it continually adjusts the air handler, outdoor heat pump, and zone dampers based on sensor input and its programmed instructions. The board shown, a Bryant Evolution control, is capable of managing a wide variety of mechanical systems and can serve as many as eight independent zones.



tion each of the home’s various zones.

The Bryant board I use can handle any combination of residential heating and cooling. It can control heat pumps, gas furnaces coupled with central air conditioning, or gas furnaces with piggyback heat pumps. It can run variable-speed systems or two-speed systems and is capable of independently managing as many as eight zones.

The Bryant controller will work with any brand of equipment, from any manufacturer. I use it with virtually every system I install. I am qualified to sell other brands of control unit, but this is the most flexible and capable zone-control product I have ever used.

The thermostat for this device has a seven-day independent control program. You can program it for four different periods per day, per zone. When I install a system, I program the boards on the equipment, I talk to the homeowners about what conditions they want in the home, and I program the user interface for the customer. Once everything is set up, no one has to touch it again.

This component is one of the keys to the Bryant system's effective humidity control. A typical thermostat senses room temperature and initiates a call for cooling when the temperature rises. But the Bryant Thermidistat, matched with an air handler equipped with a variable-speed blower, offers an option for those times when it is cool in the home but the humidity is high, causing that "sticky" feeling.

This control can be set to maintain humidity levels in the cooling mode as low as 50% RH. If the humidity level rises in the home, the control initiates a call for cooling. During the dehumidification mode, the indoor blower speed is reduced approximately 40%. This allows the evaporator coil to become much colder than normal; meanwhile, lower airflow velocity allows the air to maintain contact with the coil longer, allowing the cold coil to wring the humidity from the air. This drastically increases the latent capacity of the comfort system without overcooling the structure.

**Figure 6.** Careful installation work is key to any system's success. Here, the author makes a brazed joint in a copper refrigerant line as he installs a refrigerant dryer that will protect the system against moisture and corrosion.

## A Case Study

To monitor how the system works, I installed data-logging devices in one home where conditions were particularly severe. This house was built on totally saturated soil, downhill from a pond. To provide accessibility, the floors had been set level with the outdoor grade. During construction, the excavation had to be continuously pumped in order to stay dry enough for the foundation stemwalls to be built and for concrete to be placed for a crawlspace slab.

Unfortunately, no vapor barrier was installed under the crawlspace slab for this house, and the concrete constantly wicks moisture into the house from the saturated soil beneath it. My system was designed according to Manual J standards, with no allowance made for this extreme and unusual moisture source. But the data I collected show that the system I installed, which is much like the one I've described in this story, has been able to maintain the exact design conditions I set it up for: 75°F temperature and 50% RH, with variation of no more than one degree or 5% RH.

I was hoping that the data I collected would also verify the energy performance of this system. But the energy used to pull all that excess humidity out of this home threw those numbers out of whack. The electrical bills for running the system were not outrageous, but they were somewhat higher than I would expect if the house didn't have that particular moisture problem. In houses that have mainly atmospheric humidity to contend with, my systems are typically very economical to operate.

**Figure 7.** Before filling the system with refrigerant, the author purges the loops with nitrogen to eliminate moisture and oxygen that could corrode refrigerant lines and mechanical components.

## Workmanship Crucial to Performance

Installation is the critical part of any comfort system. You can go out and buy the best system on the market, but if it's not properly installed, you've got a piece of junk. I can't cover every aspect of workmanship in one short article, but let's take a look at a few important details.

In Figure 6, previous page, I'm brazing a joint in a refrigerant line as I attach a refrigerant dryer to the line. The dryer's purpose is to clear oxidation and moisture out of the refrigerant. These systems use a lubricant that is particularly vulnerable to moisture; if the line isn't kept dry, there's likely to be corrosion and excessive wear.

The refrigerant dryer is a mandated standard item that has to be installed on every new system. Any time the line is opened for repair or modification, the dryer should also be replaced. What's not standard, however, is the solder I'm using to braze the tubing joints. I like to use a 15% silver formula, because it is the most compatible formula with the copper in the lines. Less expensive phosphorus-based formulas are more commonly used, but they don't provide the strength and durability of the 15% silver joints. It's not critical in this particular case, but when we place copper lines underground, as I do for some of my geothermal installations, it's very important.

When I braze a joint, I clamp a set of tubing cutters onto the line to hold the plastic insulation back from the area where I'm applying heat. That keeps the insulation from melting. I've also wrapped the valve in a wet rag, to keep it cool while I apply my torch to the joint and melt the brazing compound. When the joint has cooled, I'll take the cutter and the rag off, and put the insulation back in place.

Figure 7 shows us flowing nitrogen through our refrigerant loops to clear out any oxygen or water vapor before we load the system with refrigerant. Not all contractors do this, but it's a good idea — it eliminates the moisture and oxidation that can cause corrosion, the same contaminants that the refrigerant dryer is supposed to help protect against.

## Ductwork

Proper duct installation is key. We use only metal ductwork — no fiberglass duct board or flexible duct. We

**Figure 8.** Thorough sealing of all duct joints is a critical quality-control step. Leaks in the ductwork allow moisture into the airstream, which will decrease system efficiency and may lead to condensation and mold growth inside the ducts. Applying sealant mastic with brushes or gloved hands is the preferred method for achieving airtight ductwork.

also seal every duct joint with mastic (Figure 8). When ducts are leaky, the losses don't occur just when the system is running. Air never stops moving — you have leaks when the system is on and leaks when it's off. It's a continuous loss, not a momentary one. Air and moisture getting into the duct system cost money, stress the system, and contribute to all kinds of problems. Careful duct-sealing is well worth the trouble.

Duct sizing and layout are also critical to system performance, but that topic deserves its own article. Here are a few key points:

✓ ducts should be well supported
✓ runs should be kept as straight as possible
✓ sweeping curves are better than sharp bends
✓ ducts should be insulated to R-6 or more

All of these quality details help the system perform effectively and reliably. But providing first-rate comfort along with high efficiency is about more than workmanship — it starts with good design. If your hvac contractor makes a careful, room-by-room estimate of the sensible and latent loads for the particular house, and if he chooses equipment of the right capacity that can adjust to a changing balance between those loads, you're well on your way to meeting the homeowner's needs.

***Dwayne Akers*** *owns and operates Akers Custom Comfort, Inc. (www.acchvac.com), a second-generation residential and commercial hvac installation and service contractor based in Stokesdale, N.C. Akers Custom Comfort specializes in state-of-the-art energy equipment, including direct-exchange geothermal heat pump systems.*