

Central Air Conditioning:

Bigger Isn't Better

BY CHRIS GREEN

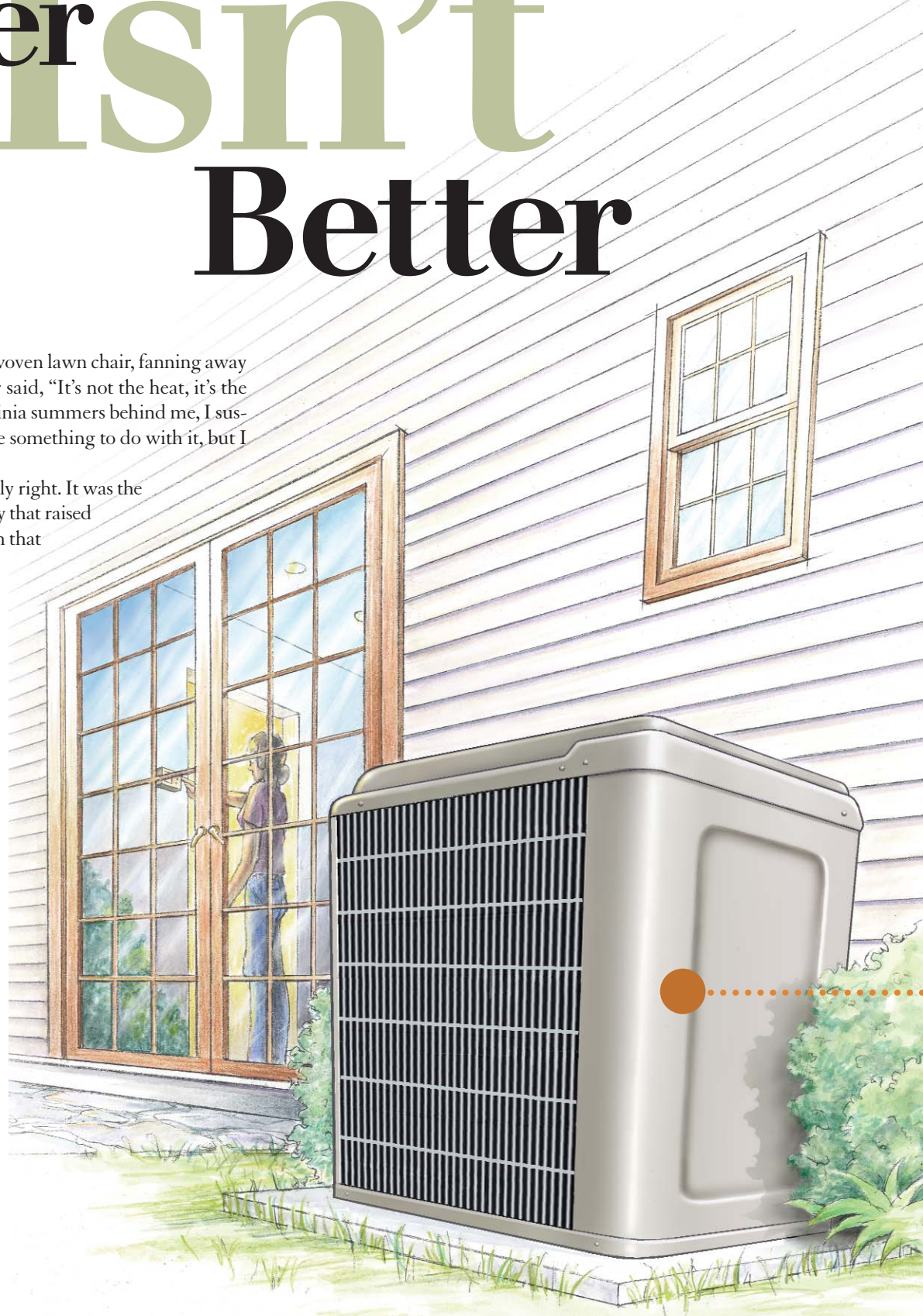
Sitting in a green-and-white woven lawn chair, fanning away the sweat, my grandmother said, "It's not the heat, it's the humidity." With seven Virginia summers behind me, I suspected that the heat did have something to do with it, but I kept this thought to myself.

It turns out that each of us had it partly right. It was the combination of high heat and humidity that raised us to our exalted level of discomfort on that oppressive summer day.

Seven years later, my parents finally built a house that included central air-conditioning. Although it was better than being without, the air-conditioning system wasn't ideal. The house had cold and hot spots, and my basement bedroom always felt cold and damp.

Unfortunately, these problems were not limited to my parents' house nor to the 1970s. Problematic air-conditioning systems abound nationwide. According to a recent study, 95% of new air-conditioning installations fail in regard to operating efficiency, with more than 70% of systems improperly sized or installed.

The top three reasons for poor air-conditioner performance are improper sizing (1.5 to 2 times too large is common); improper installation (incorrect refrigerant levels and air-flow); and poorly designed and installed duct systems. Because air-conditioning systems integrate refrig-



Considering your cooling needs



eration, air distribution, and electronics, there are lots of opportunities for mistakes.

Air conditioners move heat outside

Heat naturally moves from a higher energy level (warm) to a lower energy level (cool). You could say that heat, like water, flows downhill. Without help, heat that accumulates within a home will not leave on its own unless the heat sources (the sun, people, appliances, etc.) are removed. Help comes in the form of air-conditioning, which uses refrigeration combined with ventilation essentially to push heat uphill, or move it outside, where it's even warmer.

Residential air-conditioning systems are made up of an indoor and an outdoor unit connected by a pair of pipes that circulate refrigerant in a loop. By manipulating pressure and temperature, the indoor unit absorbs heat by blowing warm indoor air over a cold coil. The heat is released to the outdoor unit, which houses a compressor (compresses refrigerant and itself generates heat), and a condenser coil and fan

(dissipates the heat to the outside).

In addition to cooling, air conditioners serve another important function: They dehumidify the air. In the same way that moisture condenses on the side of a cold soda can sitting outside on a hot day, air conditioners wring moisture from warm, humid air as it is forced across the indoor unit's cold evaporator coil. Once past the evaporator, cool dehumidified air is delivered to the rest of the house—unless there's a problem.

Oversize units dehumidify poorly and waste money

Approximately two-thirds of all residential air conditioners are too large. According to Bruce Harley, an HVAC consultant with Conservation Services Group in Westboro, Mass., these oversize units “will

Air conditioners are responsible for about two-thirds of electricity use during peak summer periods, so you can save money by making energy-efficiency improvements before installing a new air-conditioning system.

- A **tight, well-insulated building** reduces cooling needs by keeping warm, humid air outside.

- **Buy high-performance low-e, argon-filled windows.** Up to 70% of the cooling load on the air-conditioning system is direct solar gain through windows, not from outdoor air temperatures.

- **Wide overhangs, trees, or vegetation** is helpful. East/west glass is more of a problem than south-facing glass in summer.

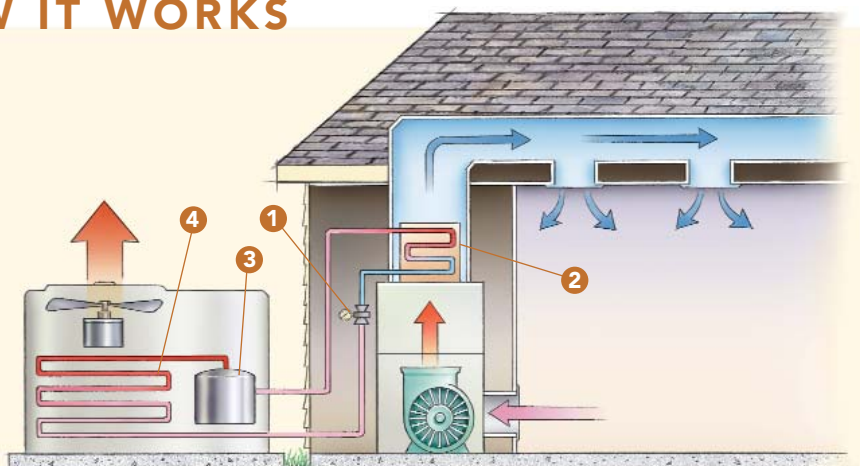
- Use **radiant barriers** on the underside of uninsulated roof rafters if the HVAC equipment is in the attic; otherwise, just insulate the attic. In addition, insulate the ductwork.

- Install **smart thermostats** that turn off the air-conditioning when it's not needed and then bring the house up to temperature before you arrive home.

Whether it's new or a replacement, a properly sized and installed system affords greater savings and comfort

CENTRAL AIR-CONDITIONING: HOW IT WORKS

Residential air conditioners are split systems—an indoor and an outdoor unit—that remove heat from the home and release it outdoors. A pair of pipes, which circulate refrigerant, form a loop and connect the units. Cold air is produced when compressed refrigerant is forced through a tiny valve or **metering device (1)** and expands into the **evaporator coil (2)**, similar to the cold spray an aerosol can produces as the compressed liquid passes through the valve. This causes the refrigerant's pressure and temperature to drop quickly, cooling the coil. As warm air passes over the evaporator, it is cooled and dehumidified. Moisture condenses on the evaporator's fins and drains away. After absorbing heat from the home's interior, the refrigerant is pumped to the outdoor unit, where it passes through the **compressor (3)** and is sent to the **condenser (4)** to lose some of its heat.



“Slightly undersized cooling equipment—

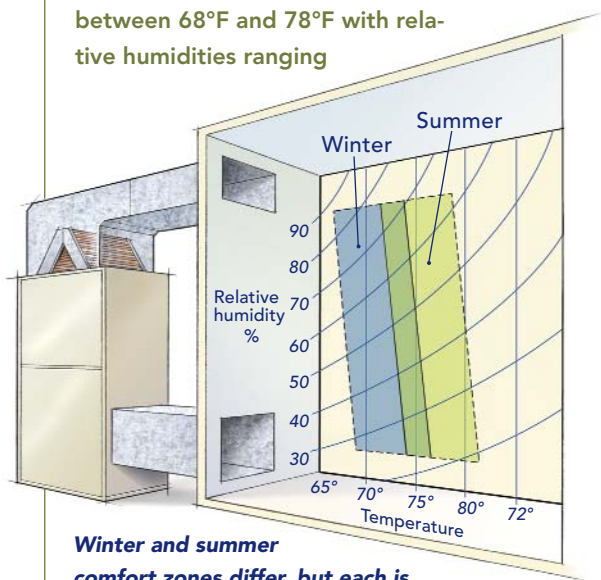
by a margin of 10% or less—may actually provide

You just want to be comfortable

Most of us don't want to worry about our air conditioners. They aren't high on our priority list. We expect our air conditioners simply to make our homes comfortable summer after summer. But what is comfortable?

Feeling comfortable isn't about temperature only. It's about a favorable blend of temperature and humidity. And of course, what's just right for one person may not be just right for another, so comfortable becomes a range.

That range or comfort zone is somewhere between 68°F and 78°F with relative humidities ranging



Winter and summer comfort zones differ, but each is a favorable blend of temperature and humidity.

from about 25% to 65%. To remain in the comfort zone as temperatures go up, relative humidity must go down (drawing above).

Even though most of us can sense changes in temperature of 1°F to 2°F, we are less sensitive to humidity. Levels between 25% and 65% feel about right. According to ASHRAE (American Society of Heating, Refrigerating, and Air-Conditioning Engineers), less than 25% relative humidity can lead to dry nose, throat, eyes, and skin. Greater than 70% can lead to mold, corrosion, and decay. High relative humidities in carpet and within fabric can lead to dust-mite infestation and mildew (mildew is mold growing on fabrics).

cool your house, but they're not necessarily designed to run efficiently." The first problem is that they dehumidify poorly. Oversize units satisfy the temperature at the thermostat so quickly that only a little moisture has time to condense on the evaporator coil. This phenomenon is known as short cycling, and it's more of a problem in humid climates. If cycles are very short, moisture on the coil can evaporate back into the house before it drains away.

Second, oversize units are least efficient when they start up. It takes up to 15 minutes for the unit to reach operating efficiency. So oversize units run more short cycles, and more of their time is spent running in the least efficient part of the cycle. As a result, they use more energy, and costs to operate them run 20% to 30% higher than for properly sized systems. Finally, at an installed cost of \$600 to \$800 per ton, oversize systems cost more. Why pay for 5 tons if 2½ will do the job?

How much cooling do you need?

Smaller systems use less energy and remove more moisture because they run long enough to reach peak efficiency. So what's the right size for an air-conditioning system? It depends.

The standard method for calculating the proper size for a residential central air-conditioning system is found in ACCA's (Air Conditioning Contractors of America) *Manual J—Residential Load Calculation* by Hank Rutkowski, P.E. It's a methodical approach to arrive at room-by-room cooling loads for sizing ducts and whole-house systems. The room-by-room totals are important because you can't design a duct system properly without this calculation.

Manual J takes into account and averages solar-heat gains, which don't peak in all rooms at the same time. It also includes the house's orientation to the sun and shading, which greatly affect the cooling load as well as the insulation values of walls, ceilings, and floors. Window types, locations, and specifications as well as internal-heat gains (people, lighting, and appliances) also are figured in.

The right-size system is not a rule-of-thumb amount derived from the square footage of a house. In her book *Air-Conditioning America* (Johns Hopkins University Press, 1998), Gail Cooper writes that air-conditioning engineers 100 years ago called sizing by the rule-of-thumb method "futile and foolish." According to the folks that I've talked to, that remains true in 2004.

Contractors sell large systems because they fear complaints

In defense of the people selling and installing large air-conditioning systems, they do so for a reason. Profit plays a part, sure: If you install a bigger system, you make more money. More important, though, contractors fear complaints about their systems' inability to maintain set temperatures in extremely hot conditions. So using a rule-of-thumb measurement or some other method, the contractor sizes the system larger. If 3 tons is good, 4 is better, right?

Besides, "maybe *Manual J* sizing isn't quite big enough," a contractor may say, or "Here, it gets hotter than that." But a recent study puts these fears to rest. Proctor Engineering Group (PEG), Electric Power Research Institute, Nevada Power, and Arizona Public Service tested a

more comfort at a lower cost.”

typical house with outdoor temperatures of up to 116°F (3°F above the mean extreme). The actual cooling required was less than *Manual J* predicted in all but three of the 1,316 hours that the house was monitored.

It's not necessary to oversize beyond *Manual J*, which has a built-in oversizing margin. On the first page of the introduction, *Manual J* states that “slightly undersized cooling equipment—by a margin of 10% or less—may actually provide more comfort at a lower cost.”

Most air-conditioning systems are installed improperly

Another major reason for poorly performing air-conditioning systems is faulty installation: incorrect refrigerant levels, low airflow, and poorly designed and installed duct systems. In one study of 55,000 air-conditioning systems by PEG, refrigerant levels were wrong 62% of the time; in another study, the figure was 68%.

Condenser units arrive from the factory with the proper amount of refrigerant for a given length of piping—usually 15 ft. or 25 ft.—to connect the indoor and outdoor units. Refrigerant levels often are wrong because line length in the field can vary, and technicians frequently don't make adjustments according to the manufacturer's recommendations.

What difference does it make if refrigerant levels are wrong? According to Armin Rudd of Building Science Corporation, if they are a little low, up to 20%, there's some loss of cooling. More than that, and there's an unacceptable loss of cooling along with frosting of the evaporator coil and, eventually, complete loss of cooling. If refrigerant levels are too high, the story is similar: again, loss of cooling with possible damage to the compressor.

The speed and the volume of air moving through air-conditioning systems were incorrect (usually too low) in about 72% of units tested in the PEG study. This was due partly to mismatched indoor and outdoor units, which occurs more often on retrofits than on new installations because only the exterior compressor/condenser unit typically is replaced. Also, airflow at the evaporator coil often is low because it usually isn't tested, so no one actually knows what it is.

Fan speeds at the evaporator coil should be around 400 cfm (cu. ft. per minute) per ton of cooling capacity. Slightly lower fan speeds improve dehumidification. In dry climates, fan speed should be increased.

Tied to airflow and directly affecting it are duct design and installation. Ducts are the least expensive part of the system and frequently are given short shrift. A properly designed duct system begins with determining the cooling load for each room (not based on the square footage), which can vary greatly. Duct runs need to be as short as possible; they need to be insulated; and when possible, they should be installed within conditioned space. Ducts also should be sealed. Leaky ducts waste energy, and in the right conditions may draw dust, spores, or combustion gas from a gas appliance back into the house.

Adequate return air also is important to minimize air-pressure imbalances within the space that affect cooling. The placement of registers in the room and the quality of the grilles greatly affect the duct system's ability to throw air across the room and mix the air properly. □

Chris Green is an assistant editor at *Fine Homebuilding*. Photo by John Curtis.

How do you find a good installer?

Because 70% of all central air-conditioning systems are installed improperly (according to a California new-home construction study), you could be paying anywhere from 25% to 50% too much in air-conditioning bills. Choose your air-conditioning installer carefully, or pay the difference in higher energy and maintenance costs.

One measure of a technician's expertise is whether he or she has completed a training program. All the major manufacturers offer training on installing their systems. In addition, several national certification programs are available through NATE (National Association of Training Excellence) and CheckMe! (through Proctor Engineering Group; www.proctoreng.com).

Although CheckMe! is not nationwide yet, it is available in California and soon will be in the Northeast. Technicians who complete their program perform diagnostic tests on each system tested, call in their results to a CheckMe! staff person, and receive immediate feedback on the health of the system. Afterward, PEG sends a certificate of completion to the homeowner.

Local electric utilities are another source for installer-certification pro-

grams similar to NATE or CheckMe! Rebates or incentives may be available for high-efficiency equipment.

In addition to asking about certified training, here are some other questions to ask installers:

- Do they use **Manual J** for sizing air-conditioning systems?
- Are they using **proper design temperatures** for your area?
- Will they verify that the indoor unit's **evaporator coil** and the outdoor unit's **condenser coil** match and that the system has the proper amount of refrigerant?
- Do they **seal the ducts** and test the system for leaks to a level of 10% or less?
- Do they **test airflow** at the evaporator coil?
- Can they **provide references**?

