What's Cool in Air Conditioning

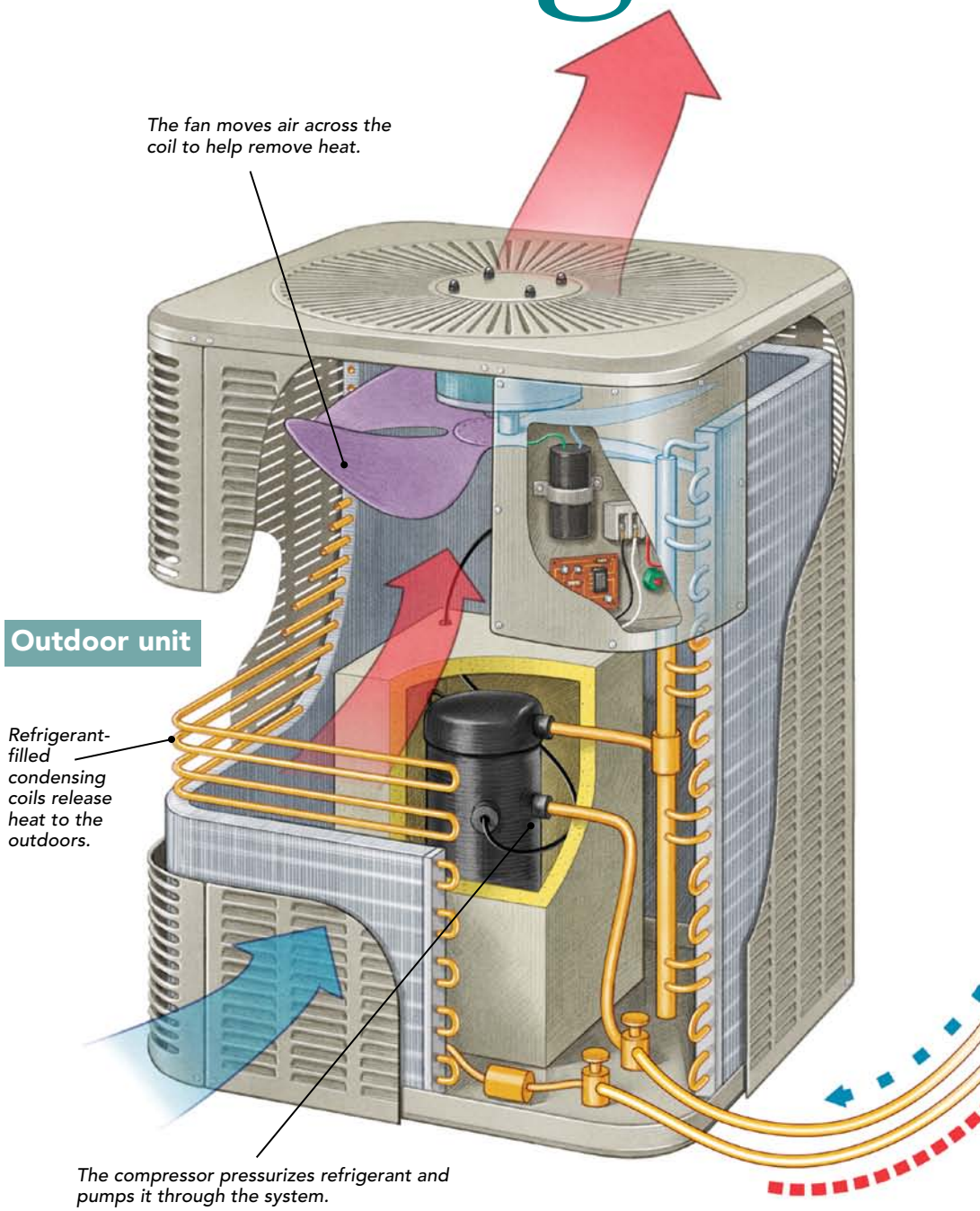
Understanding the technology behind today's systems improves your chances of installing the right one

BY SEAN GROOM

The invention of air-conditioning was an effort to deal with humidity, and cooling was a by-product of drying the air. Today, many people think of air-conditioning first and foremost as a cooling technology. In humid climates and in homes with tight building envelopes, though, humidity control is an important function not only for comfort but also for mold and mildew prevention.

As you shop for a central air conditioner, it's important to know that there's a relationship between cooling, humidity removal, and cost-efficient operation. It seems counterintuitive, but central air-conditioning systems that run long cycles and move relatively low volumes of air perform best, and they have the lowest electrical consumption. To achieve this level of performance, you need a system that has a variable-speed indoor fan, a compressor that is able to run at different cooling capacities, and a communication path between the two.

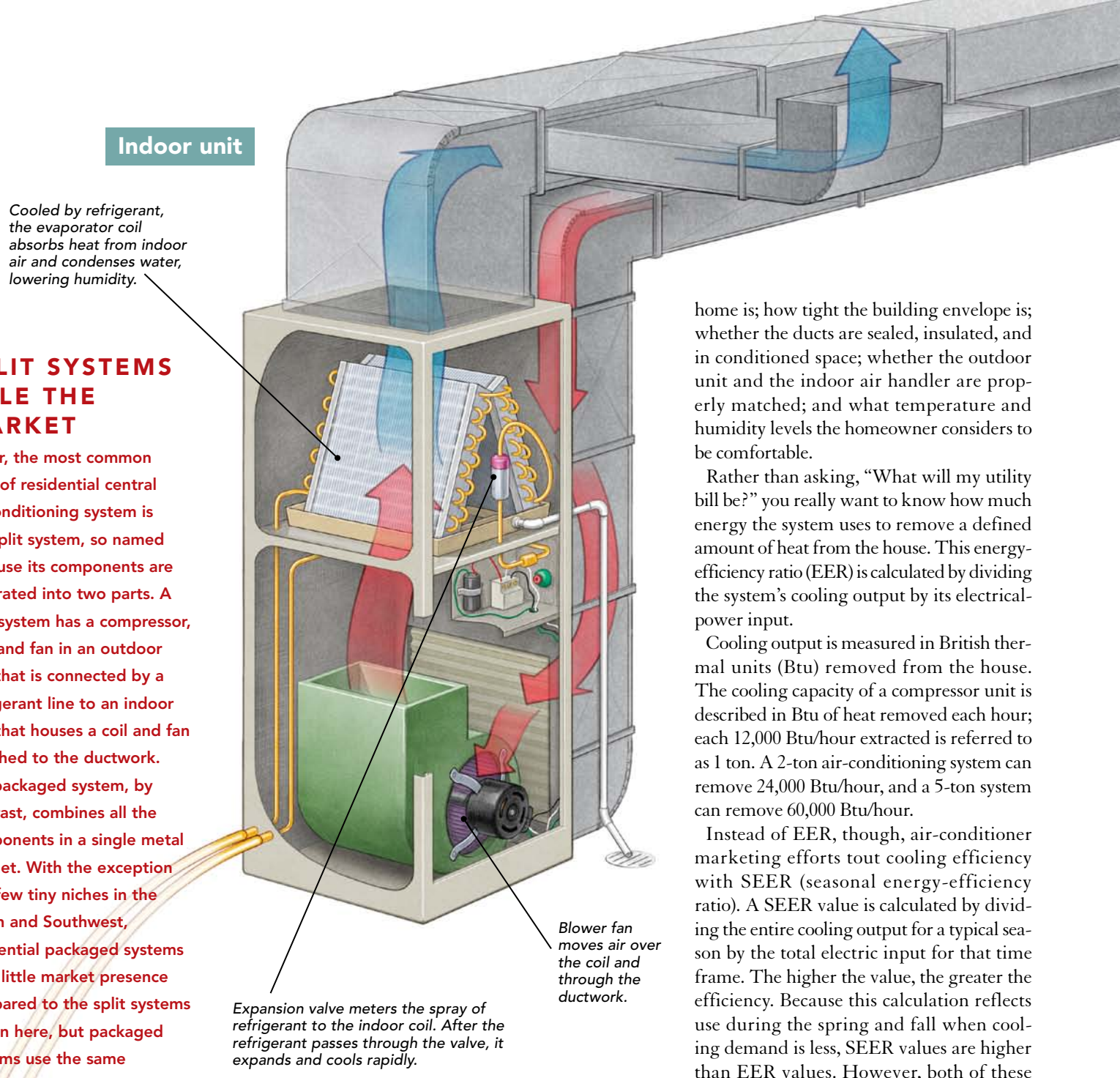
If you're installing a new central air-conditioning system, the purchasing decision is pretty simple: You buy the most efficient system you can afford. The decision isn't as straightforward when you're adding air-conditioning to a forced hot-air system or replacing a failed air-conditioning component. To ensure that you get the efficiency benefits you pay for in the new equipment in these cases, it's important to understand how indoor and outdoor components interact.



The truth about SEER ratings

The performance of a central air-conditioning system depends on how well insulated the

Technical drawings: John Hartman. Illustrations: Jacqueline Rogers.



SPLIT SYSTEMS RULE THE MARKET

By far, the most common type of residential central air-conditioning system is the split system, so named because its components are separated into two parts. A split system has a compressor, coil, and fan in an outdoor unit that is connected by a refrigerant line to an indoor unit that houses a coil and fan attached to the ductwork.

A packaged system, by contrast, combines all the components in a single metal cabinet. With the exception of a few tiny niches in the South and Southwest, residential packaged systems have little market presence compared to the split systems shown here, but packaged systems use the same technologies.

home is; how tight the building envelope is; whether the ducts are sealed, insulated, and in conditioned space; whether the outdoor unit and the indoor air handler are properly matched; and what temperature and humidity levels the homeowner considers to be comfortable.

Rather than asking, "What will my utility bill be?" you really want to know how much energy the system uses to remove a defined amount of heat from the house. This energy-efficiency ratio (EER) is calculated by dividing the system's cooling output by its electrical-power input.

Cooling output is measured in British thermal units (Btu) removed from the house. The cooling capacity of a compressor unit is described in Btu of heat removed each hour; each 12,000 Btu/hour extracted is referred to as 1 ton. A 2-ton air-conditioning system can remove 24,000 Btu/hour, and a 5-ton system can remove 60,000 Btu/hour.

Instead of EER, though, air-conditioner marketing efforts tout cooling efficiency with SEER (seasonal energy-efficiency ratio). A SEER value is calculated by dividing the entire cooling output for a typical season by the total electric input for that time frame. The higher the value, the greater the efficiency. Because this calculation reflects use during the spring and fall when cooling demand is less, SEER values are higher than EER values. However, both of these

Solving the efficiency equation

Cooling capacity The size of an air-conditioning system is described in tons, a relic of the day when ice was used for cooling. The amount of heat absorbed by melting 2000 lb. of ice over 24 hours is 288,000 Btu. That's 12,000 Btu/hour. Today, each "ton" of air-conditioning capacity transfers 12,000 Btu per hour. A 4-ton air conditioner can remove 48,000 Btu/hour, or about one-sixth the amount of heat needed to melt 2000 lb. of ice in a 24-hour period.

Btu The amount of energy required to raise the temperature of 1 lb. of water 1°F, or 1055 joules. (A joule is the amount of work required to produce 1 watt for 1 second.)

EER The energy-efficiency ratio (EER) states how much electricity the air conditioner needs to remove heat. The EER is calculated relative to the air conditioner's capacity and describes how much electricity is used to achieve the air conditioner's Btu/hour rating. A single-stage, 3-ton system with total system load of 2535w has a 14.2 EER:

- Capacity: 3 ton = 3 x 12,000 Btu/hour = 36,000 Btu/hour
- Efficiency: 36,000 Btu/hour ÷ 2535w = 14.2 EER

SEER The EER tells you how efficient an air conditioner can be; it doesn't represent the cost to run the system. Like MPG guidelines on a new car, the seasonal energy-efficiency ratio (SEER) approximates the cost of energy across the cooling season for comparison purposes by accounting for temperature and humidity variations. Some say that EER divided by 0.875 is a reasonable approximation of SEER, but that figure can be inaccurate. The math behind the SEER standard takes up 65 pages of the Federal Register, so there's no simple equation to show the calculations that factor time between running cycles and how much time a two-stage system runs at low capacity.

SHOPPING TIP

SEER ratings vary based on size

Advertised SEER ratings apply only to the smallest unit in a model line. While a manufacturer may list a unit as "up to 21 SEER," that number is for the 2-ton unit. The 5-ton unit in the same model line may be 16.5 SEER. As the amount of heat removed per hour increases, the efficiency of the unit decreases.

efficiency measures are theoretical performance scores that are arrived at by testing under prescribed indoor and outdoor temperature and humidity conditions and ideal installation circumstances. In addition, the scores apply only to the smallest unit in the manufacturer's model line. Consider Lennox's top-of-the-line XC21 series: It's advertised as "up to 21 SEER." That figure is for the company's 2-ton unit. Efficiency decreases as the capacity of the outdoor unit increases. Lennox's 5-ton XC21 uses more energy per hour to remove 60,000 Btu of heat than the 2-ton version does to remove 24,000 Btu. Consequently, the 5-ton unit scores only 16.5 SEER. This isn't unique to Lennox; all manufacturers list the SEER rating of the smallest (hence most efficient) unit in the series. An air-conditioning system's actual, real-world SEER (sometimes called the *applied* SEER) is influenced by the system's size. But that's only part of the "up to" qualification. The installer's skill and the quality of the building envelope are critical factors influencing operating efficiency.

The compressor unit is only half the system

Shoppers for a central air conditioner tend to fixate on the squat, louvered box that sits outside. Before the outdoor unit's condensing coil can release heat, though, the indoor, or evaporator, coil needs to capture the heat. An indoor coil is housed with the air handler, a fan that distributes cool air throughout the house. The air handler may be a stand-alone, dedicated air-conditioning component, or the furnace fan if the ductwork is also used for heating.

The indoor and outdoor components must be matched properly for the system to achieve its advertised SEER rating. The Air-Conditioning, Heating, and Refrigeration Institute (AHRI) maintains a database of compatible indoor and outdoor components and their verified SEER ratings. Unless you're purchasing a new, paired outdoor unit and air handler from the same manufacturer, your installer should check this resource.

If you're adding a new air-conditioning system or replacing an entire air-conditioning system that isn't tied to your heating system, you can start with a clean slate. Pick components designed to work together, and maximize the efficiency of the system as a whole. If your goal is to maximize efficiency, you'll be looking at a two-stage or variable-speed compressor with a SEER rating between 19 and 24.5. Compressor units with these advertised ratings, however, require an air handler with a variable-speed fan. Tim Storm, a product manager at Trane Ingersoll Rand, says that a variable-speed fan on the air handler contributes about 1 SEER to system performance.

A variable-speed fan has several advantages over a single-speed fan. The first is that it matches the airflow across the indoor coil to the rate of refrigerant flow through the coil. Not only does running the fan at reduced capacity use less electricity, but it also improves comfort. Slowing airflow across the coil provides time for more moisture to condense out of the air and cools the air to the target temperature with fewer cold and hot spots in the zone. It also reduces noise.

After the compressor shuts off, the system can continue to run the fan at a lower speed using 100w or less instead of the more than 400w used at full speed. This adds "free" dehumidification and cooling because even after the compressor stops, the coil is cold for a while. This continued air movement through the ducts helps to eliminate stratification of hot and cold air in rooms, which makes them more comfortable, and it continues filtering the air.

SHOPPING TIP

Consider a unit with a variable-speed fan

An air-conditioning compressor with a variable-speed fan reduces both electrical consumption and noise. Its slower airflow also provides more time for moisture to condense out of the air, and reduces cold and hot spots in the zone. If your existing air handler or furnace has a single-speed fan, however, you either have to stick with a single-stage compressor or replace the air handler, too.

Replace the system, not the components

Central-air systems generally work most efficiently when the indoor and outdoor components are installed as a pair. However, the split nature of the system can cloud decisions about replacing a failed component or adding central air to a forced hot-air system because of the up-front cost of replacing a functioning air handler. In the long run, however, energy savings wipe out added component costs.

If the existing air handler or the furnace has a single-speed blower fan, you're limited to a single-stage compressor unless you replace the air handler as well. If the replacement cost of the air handler or furnace is prohibitive, you're limited to the 14.5- to 17-SEER range for your most efficient option.

Another consideration is matching the sizes of the indoor and outdoor coils. Outdoor units generally last between 10 and 15 years. Because federal standards for air-conditioner efficiency have ratcheted upward over time, the indoor coil sized for a 12-year-old, 9-SEER compres-

SHOPPING TIP

Higher efficiency = fewer sizing choices

Single-stage air conditioners are manufactured in half-ton increments: 1.5 ton, 2 ton, 2.5 ton, etc., up to 5 ton. Because they vary their operating capacity, however, two-stage and inverter-driven systems (which are still uncommon in North America) are available only in whole-ton increments: 2 ton, 3 ton, 4 ton, and 5 ton.

Photo facing page: courtesy of Trane

SEER ratings: A wide range of efficiency

Federal rules dictate that new split-system central air-conditioning units must be rated at least 13 SEER, and anything above 14.5 SEER is labeled as an Energy Star model. This essentially lumps central air conditioners into two efficiency groups: economy and efficient. The highest-rated systems on the market top out at 24.5 SEER, up to 70% more efficient than other Energy Star products. That's an enormous performance difference, so it's best to look at central air conditioners in three efficiency groups—economy, efficient, and very efficient—based on the technological differences between each. It's worth noting that most air conditioners in the very-efficient category are alternating-current, two-stage systems rated up to 21 SEER. However, variable-speed air conditioners, including inverter-driven models using the same technology as minisplit systems, are the future of efficiency and can achieve 24.5 SEER. For a look at what makes an air conditioner more efficient, see "How It Works" on pp. 20-21.

$ ECONOMY
13 SEER

The minimum-standard, single-speed option

The mechanical components of a baseline 13-SEER air conditioner aren't that different from those in your refrigerator; the air conditioner is bigger, and instead of being self-contained, the air-conditioning system's parts are split between an outdoor unit and an indoor unit.

Economy systems have simple single-speed fans in the outdoor and indoor units, and basic controls and valves regulating air movement and refrigerant flow.

While these units are the least efficient on the market, they represent a 30% efficiency improvement over the units that met the previous minimum standard; many of those units are now reaching the end of their expected lifetime.

$$ EFFICIENT
14.5-17.0 SEER

Bigger coils, better motor and electronics

There are only two paths to improve efficiency in an air conditioner: Increase heat-transfer capacity and/or reduce electricity consumed.

The job of the coils is to transfer heat. The indoor coil (the evaporator coil) captures heat indoors, and the outdoor coil (the condensing coil) releases heat. Heat transfer and efficiency improve when the surface area of the coils is increased with longer lengths of pipe and/or fins.

Manufacturers also tinker with the electrical components to reduce the load by specifying more efficient compressors, fan motors, controls, and circuits. One common example is when manufacturers change the air-handler fan motor from the basic one-speed variety used in 13-SEER models to a constant-torque motor.

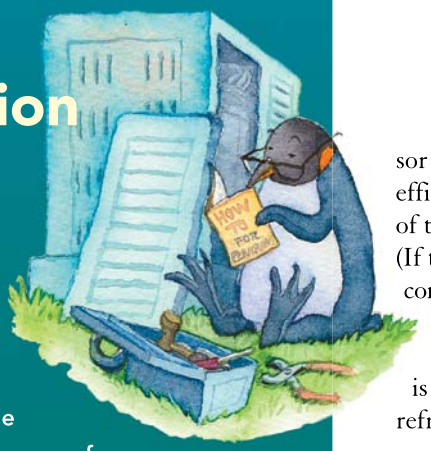
$$$ VERY EFFICIENT
18.0-24.5 SEER

Variable cooling capacity

Improving the efficiency of the motors and electrical components in the system will get you only so far. An air-conditioning system is sized to cool a house on the hottest day of the year, which makes it overkill almost all the time it's running. Traditional air conditioners are known as single-stage units, meaning they either run at 100% capacity or they're off.

A two-stage air conditioner allows the air-conditioning system to operate as two differently sized systems, adjusting the cooling output to match the need more precisely. It may help to remember the earlier observation that a 21-SEER-rated system is based on a 2-ton air conditioner. The same model in a 5-ton size is only 16.5 SEER, so running the system closer to 2-ton capacity whenever possible lowers operating costs.

Installation matters



Purchasing the compressor unit with the highest SEER rating doesn't guarantee the savings highlighted in the brochure; the performance of a system is only as good as its installer. Finding a good installer is critical, but most consumers don't know enough about air-conditioning systems to ask the right questions.

Here are some things to remember. For efficiency's sake, you want the smallest air conditioner you can get away with. A properly sized system will make you more comfortable. Don't settle for an installer who sizes a system by a rule of thumb or justifies the size of the system with "I used the same 4-ton unit on a house down the block." Correct sizing requires Manual J from the American Society of Heating, Refrigerating, and Air-conditioning Engineers (ASHRAE). Properly done, this method requires the installer to record house-specific insulation as well as heat-loss and heat-gain data that a software program combines with location-specific climate data to generate the house's heating and cooling load. Even if you're replacing an old unit, there's no guarantee that the original air conditioner was properly sized, and if you've replaced windows or added insulation, you may be able to get away with a smaller unit.

In addition to seeking technicians who perform good sizing calculations with Manual J, look for ones with a North American Technician Excellence (NATE) certification. NATE is an independent testing association for the HVAC industry. Certified technicians have passed two exams: one on core HVAC knowledge and a second in either an installation or service specialty such as air-conditioning or air distribution. To keep technicians current with technology, the certification requires renewal every five years. If you want to make sure that your new-system installation isn't the first time the technician has seen the product, make sure that he or she has been certified by the manufacturer.

sor is significantly smaller than the coil on today's even minimally efficient 13-SEER compressor. Mismatched coils lower the efficiency of the system, although they probably won't harm the compressor. (If the system is a heat pump, however, mismatched coils can cause compressor failure.) Furthermore, the 2010 ban on R-22 refrigerant in new compressors means that their metering devices are not compatible with the new R-410a refrigerant. (A metering device is the expansion valve on the indoor coil. It determines how much refrigerant is sprayed into the coil, at what rate, and when.)

Fine-tuned control

Although often an afterthought, a thermostat controls every system. For single-stage air conditioners with single-speed-fan air handlers, a programmable thermostat that lets the temperature drift higher than the normal target during the workday and then cools the house before you come home is best. That said, a basic, nonprogrammable thermostat won't prevent system features from working.

Air-conditioning systems with variable-speed air handlers and two-stage compressors need more robust controls. These more sophisticated interfaces can boost dehumidification by starting each cycle with a period of low airflow so that more moisture is taken out of the air before the temperature set point is reached. On many thermostats, such as Lennox's Comfort Sense 7000 and Carrier's Infinity Control, you can set separate temperature and humidity targets.

Serial communicating systems rely on the programmable thermostat, which typically must be the same brand as the indoor and outdoor units, to allow the components to communicate and to fine-tune performance continuously. The thermostat monitors and adjusts airflow rate over the evaporator coil while also logging performance data. This lowers maintenance costs and provides a measure of insurance. If the system senses operating conditions that could damage the compressor, it will shut down and lock out the compressor until a technician examines the unit. The technician can access fault messages indicating the source of the problem as well as a complete log of operational conditions.

Trane's communicating systems have an additional feature called Charge Assist that helps to ensure high efficiency by removing human error from the refrigerant-charging process. Rather than relying on calculation tables and metered supply hoses between the technician's supply tank and the outdoor unit, the technician simply hooks the tank to the outdoor unit. The system controls the recharge rate with an accuracy within 4 oz. of the ideal charge. □

Sean Groom is a contributing editor.

SHOPPING TIP

Refrigerant is not a selling point

When comparing air conditioners, don't be impressed by manufacturers' boasts about using non-ozone-depleting refrigerant. Although many existing systems use R-22—an HCFC (hydrochlorofluorocarbon) that both depletes the ozone layer and is a greenhouse gas—this refrigerant is available only for recharges and has been banned in new equipment since January 2010. Every air conditioner made today is charged with R-410a regardless of the product name the refrigerant is marketed under.