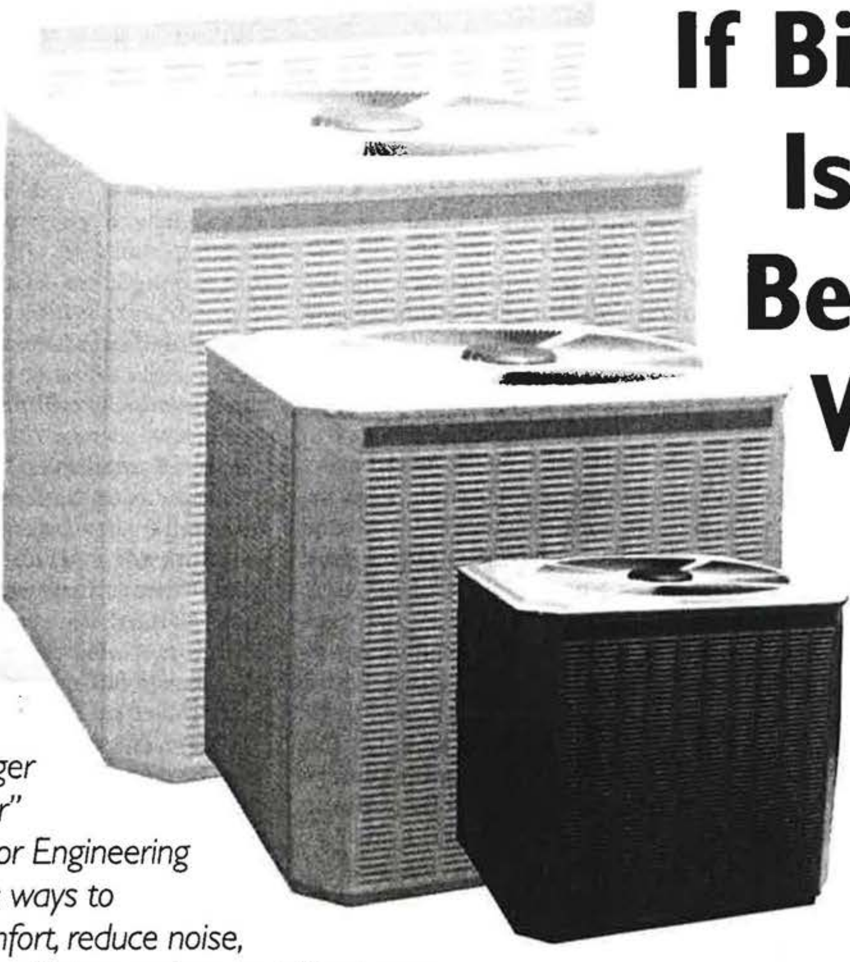
# Sizing Air Conditioners:

## If Bigger Is Not Better, What Is?



*In this follow-up to the original "Bigger Is Not Better" article, Proctor Engineering Group offers ways to improve comfort, reduce noise, and increase efficiency when installing home air conditioners.*

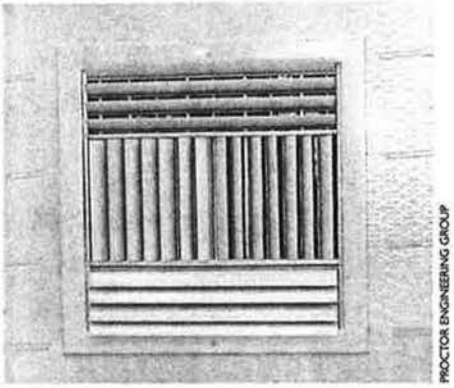
by John Proctor and Peggy Albright

Since the publication of "Bigger Is Not Better—Sizing Air Conditioners Properly" (*HE* May/June '95, p. 19), homeowners, builders, and contractors have questioned us about sizing and performance issues raised in that article. The purpose of this sequel is to answer frequently asked questions, explain the characteristics of a good air conditioning system, and describe how to get the most comfort and efficiency from a residential system.

### Bigger Still Is Not Better

Let's review why bigger is not better. Since optimum efficiency is achieved when systems run continuously, it is important that an air conditioner be sized to achieve the longest run times possible. Standard sizing calculations are based on a design temperature that is exceeded only 73 hours in a normal cooling season. An air conditioner sized to run continuously at design conditions will cost less initially and will have a lower operating cost.

Air Conditioning Contractors of America (ACCA) has published design manuals (*Manuals J, S, D,* and *T*) that produce far better results than the rough-and-tumble rules of thumb used by the vast majority of HVAC contractors. A contractor will achieve (and the customer will enjoy) a much higher-quality job if these manuals are followed




Equipment sizing is not the only key to comfort—small details in register placement and design can have a great impact on air flow and overall comfort. For example, the louvers of this air-conditioning register are designed to spread air in four directions.

in the design and installation of central air conditioning systems. A recent investigation of new houses has shown that an air conditioner delivering a capacity equal to *Manual J* would be adequate even during extraordinarily hot summers (see "How Big Is Big Enough?").

The main problems typically found in the field are improperly sized air conditioners, improperly designed duct systems, poor grille selection, and poor installation of all three components. These problems are most easily avoided in new construction, but retrofit contractors can and should follow the recommendations in this article whenever feasible.

### *The Disadvantages of Oversizing*

In recent years Proctor Engineering Group has investigated air conditioner comfort, efficiency, and economy in a range of locations. One interview, with a homeowner in Palm Springs, California, brought out several issues that we have found repeatedly. This house was a moderate sized older home with beautiful overhangs shading the east and west windows. I was invited to sit at the kitchen table to talk with the owner, a man in his early 60s. He complained that his cooling bills were high and he was never comfortable during the cooling season (which extends over most of the year in Palm Springs).

As we talked the air conditioner came on and a strong stream of cold air moved by my shoulder. The owner went over to the supply register and closed the damper. He came back to the table explaining that with the register open he was blasted with cold air that made him uncomfortable. The noise coming from the closed register made it hard to have a conversation at the table. He stated that the system was always noisy. When I suggested that we move to another room for our conversation, he said, "That wouldn't make any difference, there are only hot places and cold places; no place is right in this house. We are looking for a new house."

The situation we found in this house exists, in various degrees, in millions of homes across the United States. The heating and cooling distribution system was not matched to the cooling loads of the individual rooms or to the needs of the occupants. On top of that, the air conditioner was not matched to the distribution system. Discomfort and expense are the inevitable results.

## Bigger Is Not Better—Comfort Is Better

In 1923, in an effort to pinpoint the indoor environment conditions that make people comfortable, F.C. Houghten and C.P. Yaglou conducted studies to determine how people feel under varying temperature and humidity conditions. The result of this research was the identification of a "comfort zone" based on temperature and humidity. The modern version of this comfort zone is shown in Table 1. Tolerance to heat is affected by the amount of humidity in the air—at higher temperatures, the humidity level must be held lower to ensure comfort.

**Table 1. Summer Comfort Zone.**

| Relative Humidity | Maximum Comfortable Temperature | Minimum Comfortable Temperature |
|---|---|---|
| 60% | 78.5°F | 72.5°F |
| 50% | 79°F | 73°F |
| 40% | 79.5°F | 73.5°F |
| 30% | 80°F | 74°F |

The comfort zone was found to be acceptable to 90% of test subjects drawn from a range of age groups and genders, with work and life-styles involving varying levels of activity and clothing. An air conditioning system that establishes and maintains indoor conditions within this zone will provide thermal comfort. It will produce a neutral sensation—occupants will feel neither too hot nor too cold.

An air conditioner can easily bring the temperature inside a house into the comfort range. In fact, bigger air conditioners virtually ensure that the temperature at the thermostat can be as cold as we set it. Unfortunately, cold alone is not comfortable. In fact, it is distinctly uncomfortable. To maintain a general level of comfort, the moisture level must also be controlled. This is best achieved by smaller, not larger, air conditioners.

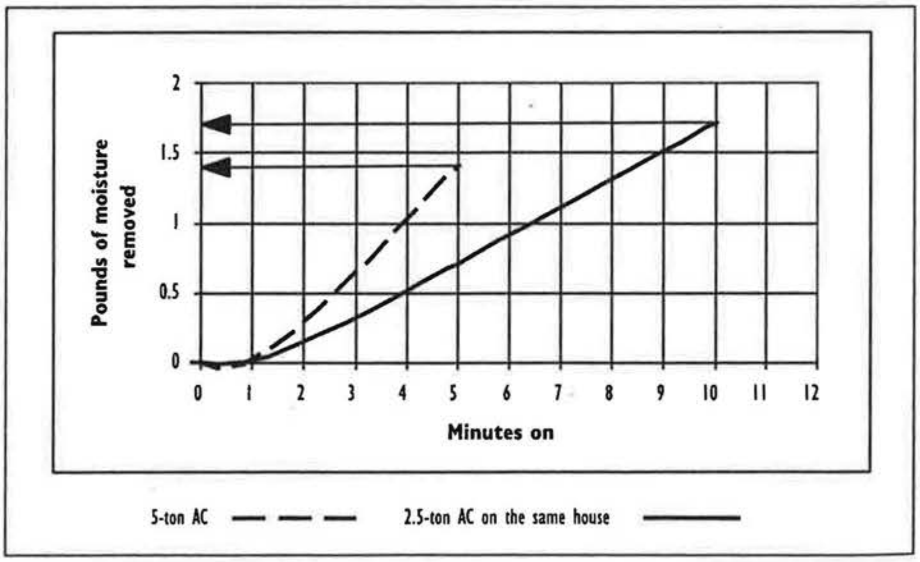



Figure 1. Smaller air conditioners remove more moisture from a house. In this example, a 5-ton unit running for five minutes removes 1.4 pounds of water. A 2.5-ton air conditioner in the same house, running for ten minutes, removes 1.7 pounds of moisture—an increase in moisture removal of 21%.

### *Smaller Units Remove More Moisture*

An air conditioner's ability to remove moisture increases when the equipment runs for longer periods of time. At the beginning of every cycle in hot moist climates, the air conditioner actually puts moisture into the house as water evaporates off the inside coil. Once it's been running a while, it begins to remove moisture. Since a smaller air conditioner runs longer to keep the house at the temperature setpoint, it removes more moisture than a larger unit would be able to (see Figure 1).

PROCTOR ENGINEERING GROUP

We're not sure what manual the installer of this creative air conditioning system was working with, but we don't recommend it!

The amount of moisture removed is a function not only of how long the air conditioner runs, but also of its Sensible Heat Ratio (SHR)—the percentage of the total capacity delivered as lower house temperature. A low SHR will result in more moisture removal. For hot, wet climates, air flow across the coil should be reduced slightly to decrease the SHR, and the air conditioner condensing unit and indoor coil combination should be chosen to have a low SHR. Typical matched units from major manufacturers have SHRs in the 68%–80% range when it is 95°F outside and 75°F with 50% relative humidity inside. Note that if you don't use a matching indoor coil and outdoor unit from the same manufacturer, you shouldn't expect to get their published SHR.

### *Even Temperatures Are Necessary for Comfort*

Our homeowner in Palm Springs didn't have a problem with moisture, but he did have a problem with uneven temperatures. When the air conditioner was on, portions of his home and even different parts of individual rooms were at significantly different temperatures. Stagnation of air in one part of a room (for example, in one corner or at head level) makes people uncomfortable. Proper mixing of the air and proper distribution to individual rooms prevents this problem.

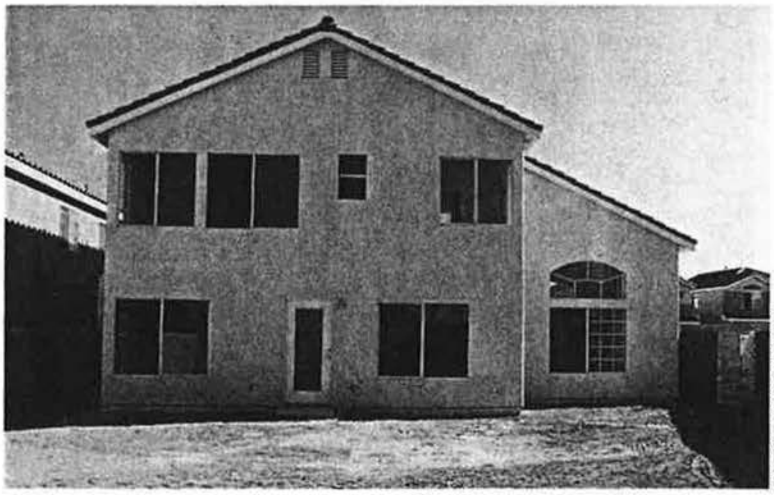
Uneven temperatures have become more common due to the modern practice of severely reducing overhangs above the windows. Without overhangs, rooms with west-facing windows will overheat in the afternoon, since their need for cooling can easily double.

An inefficient method of attempting to get proper distribution and mixing of the air is to use a large air handler fan to circulate air all or most of the time. This is sometimes effective in mixing the air, but at a high price. There is an old rule of thumb that between four and six house volumes of air must pass through the air handler in an hour. At six air changes per hour (ACH), a 1,400 ft$^2$ home would need a continuously running fan that delivers 1,120 cubic feet per minute (CFM)—equivalent to almost 3 tons—regardless of the cooling load of the house. The common practice is to install an air conditioner (inside and outside unit) with the capacity to meet those flow requirements. There are many disadvantages to this practice. They include:

- The need for a larger and more expensive duct system to handle the increased flow.
- Increased duct conduction due to constant circulation and the larger surface area of the duct system.
- Reduced moisture removal due to short compressor cycles, caused by the oversized outdoor unit.
- Reduced moisture removal due to the constant air circulation, because water re-evaporates from the coil while the compressor is off, and is distributed back around the house.
- Increased cooling load due to duct leakage and fan energy delivered as heat.

A better solution is first to design and install a delivery system that properly distributes the cooling to each room, then to select and place supply grilles that "throw" the delivered air into the right places in the room to promote mixing.

ACCA's *Manual D: Duct Design* and *Manual T: Terminal Design* can lead the installing contractor through the process of selecting the proper-size duct and type of register, based on the location of the register, the size of the room, the restriction of the duct run, and the dimensions and heat gain of the room. Unfortunately, only the best contractors and builders ever pay attention to these critical details.



PROCTOR ENGINEERING GROUP

A place in the sun may be a good thing, but too much sun can make a house's cooling load soar. The lack of overhangs and sun protection on this new house will concentrate heat gains in certain rooms, making it difficult to properly balance cooling distribution.

The problems of stagnation and overheating can be reduced by

### *Proper Charge Helps Make an Efficient System*

A new split system air conditioner comes from the factory with the proper amount of factory-installed charge for a standard length of refrigerant lines. When the unit is installed, the contractor needs to evacuate the lines and indoor coil and weigh in any additional charge needed if the installed lines are longer. Evacuation also allows the installer to check for leaks. Most of the time, evacuation is not done. As a result, air and moisture are captured in the line set and coil, the unit ends up undercharged, and leaks are not detected. In many cases the amount of undercharge is severe.

In the summer of 1995, Proctor Engineering Group and Arizona Public Service Company monitored a group of 22 newly constructed homes. Nearly all of those homes had undercharged air conditioners. One of the worst units had 62% of the correct charge (and 79% of proper flow). The homeowner complained to the builder that the air conditioner was not working right. She was told that the wrong amount of insulation had been installed in her attic, and an insulation contractor was called in to apply additional insulation. Shortly thereafter, the true problem showed itself when the air conditioner compressor failed.

PROCTOR ENGINEERING GROUP

These cardboard frames are specifically designed for insulating over ducts. The walls of the boxes allow weatherizers to build up a deeper layer of insulation around long duct runs.

### *Eliminating Duct Leaks Helps Make an Efficient System*

The evidence against leaky and underinsulated ducts continues to mount. Leaky ducts are a large contributor to system inefficiency that gets worse when it's hotter outside. The Arizona Public Service Company test found that sealing a 13% supply leak saved 22% of the cooling energy consumption when outdoor temperatures were between 100°F and 105°F.

To ensure a tight duct system, the installing contractor must test duct integrity using specialized tools (see *HE* Sept/Oct '93 for more information on duct testing).

### *A Smaller Air Conditioner Helps Make an Efficient System*

Air conditioners are very inefficient when they first start operation. It is far better for the air conditioner to run long cycles than short ones, because efficiency increases the longer it runs. For example, increasing the run time from five minutes to nine minutes resulted in an energy savings of 10% for the unit described in "Bigger Is Not Better" (*HE* May/June '95).

Because of the inefficiencies associated with the start-up of the air conditioner, a smaller unit will produce the same amount of cooling with lower energy consumption, under most conditions.

It is not uncommon for poor cooling performance to be attributed to insufficient equipment size, when in fact there is more than enough cooling capacity. We know designers who determine the system air flow based on floor area (this oversizes the air conditioner in energy-efficient homes), and then try to squeeze down the size of the duct system so that it can be installed in the house. They explain that they can't use a higher insulation level on the ducts because there is no room, and, when faced with poor performance, increase the size of the air conditioner.

Most household air conditioning problems will be eliminated when the capacity of the air conditioner is reduced to ACCA *Manual J* and *Manual S* standards; an appropriately designed, insulated, and leakproof distribution system is used; and the system is installed to meet the manufacturer's standards.

### *Resources*

F.C. Houghten and C.P. Yaglou: ASHVE Research Report No. 673, "Determination of the Comfort Zone," ASHVE *Transactions,* Vol. 29, 1923, p. 361.

*Manual J, D, S,* and *T.* Available from Air Conditioning Contractors of America, 1712 New Hampshire Ave., NW, Washington, DC 20009. Tel: (202)483-9370.

*John Proctor is the managing partner of Proctor Engineering Group in San Rafael, California. Peggy Albright is an independent writing consultant for researchers in the electric utility industry.*