Bigger is Not Better

Sizing Air Conditioners Properly—How They Size Air Conditioning Systems in Florida
Sizing Air Conditioners: Recommendations for Contractors

It is generally accepted that "the right way" to specify an air conditioning system is to calculate the loads and select a piece of equipment that will provide comfort to the customer in a wide variety of conditions. Unfortunately, this is rarely practiced. A colleague of ours (we will call him Bill) approached us at a conference seeking advice on selecting an air conditioner for his renovated home. Our recommendations included, "Be sure that the cooling load is calculated and that the air conditioner is sized to that load." When Bill attempted to follow these instructions, only one of the four contractors would submit a sizing calculation (two others just wanted to know how many square feet there were in the house).

Bill hired the contractor who did the calculation and installed a high-efficiency four-ton unit. Is this a success story? Not really. The contractor calculated a total cooling load of 37,580 BTUs per hour at 105 degrees F outside and 70 degrees F inside. While the cooling load he calculated could have been met by a three-and-a-half-ton air conditioner, the contractor convinced Bill to buy a four-ton unit "because then you will always have plenty of cooling." Bill's air conditioner short-cycles (runs for shorter periods of time than it should) even during the hottest weather and removes very little moisture from the air. What went wrong? Four things:

The design temperature for the area is 97 degrees F. The contractor increased the outside design temperature by 8 degrees F.
The recommended design indoor temperature is 75 degrees F. The indoor temperature was lowered by 5 degrees F. The temperature "fudges" increased the inside to outside differential by 59%.
The contractor increased the calculated load by 20% as a safety factor.
The equipment selected was a half-ton larger than the next highest available size to meet the load he calculated.

A two-and-a-half-ton air conditioner would have been perfect for Bill's house. Instead, he paid more for an extra one-and-a-half tons of cooling. In addition to costing more to buy, Bill's air conditioner will use more energy than a properly sized system, raising his utility bills. It won't dehumidify the air as well as a smaller system would, and chances are that Bill will be less comfortable. The utility, which gave Bill a rebate for his purchase, will also lose, since the oversized unit aggravates summer peak-load requirements.

Selecting the Right Air Conditioner for the Job

Before one can design an efficient and effective air conditioning system, the load must first be calculated using established techniques. The Air Conditioning Contractors of America (ACCA) conducted an industry study of residential cooling load calculations and developed Manual J to estimate these loads. Manual J was adopted by ACCA and the Air-Conditioning and Refrigeration Institute (ARI), and is the standard method of sizing loads for residences.

ACCA has also produced Manual S for selecting equipment and Manual D for duct design (revised in January 1995). Manual S provides a method to select air conditioners based on the estimated sensible and latent load calculated for the particular house in the local climate.

If mistakes are made in the load calculations or the sizing method is flawed or incorrect inputs are used, the equipment will be incorrectly sized and will not perform as it should. Field studies have shown that most equipment is substantially oversized compared to Manual J specifications. Studies found that 53% of the air conditioners checked were a ton (12,000 Btu/h) or more oversized and a found a third of the air conditioners to be a ton or more oversized.

What is "Proper" AC Sizing?

A properly sized air conditioner should provide maximum value to the customer as well as a reasonable profit and further customer referrals for the contractor. If an air conditioner is cycling even at four in the afternoon on the hottest days, it is a sure sign it is oversized.

Incidentally, if the air conditioner is running continuously on hot days, it doesn't necessarily mean that it is the right size. It is more likely that the system is oversized and has one of three big problems: leaky ducts, improper charge, or low air flow across the coil.

Oversizing: Causes and Effects

Customers depend on the expertise of contractors in selecting air conditioners. Yet contractors generally size air conditioners at least a half-ton larger than necessary and often oversize by a ton or more. Even the most conscientious contractor is driven to avoid call-backs (or even lawsuits). An oversized air conditioner can mask problems from duct leaks, improper flow across the coils, and improper charge.

Unfortunately, many customers think that "bigger is better," so in a competitive situation, the contractor proposing the proper size unit may lose the bid. Contractors are hesitant to adopt an unfamiliar method of sizing when the methods they have developed over the years have served them well: "I've done it this way for 30 years and I've never had a complaint."

It is no surprise then that air conditioners are oversized; however, the advantages of a properly sized air conditioner are so large that these barriers need to be overcome. Customers pay a price for oversized air conditioners, and in many climates, lose comfort as well.

A properly sized air conditioner costs the customer less (see Figure 1). Bill's air conditioner cost him more money because it was too big. The contractor had the opportunity to discuss the value of the air conditioner based on the delivered efficiency and offer Bill equipment at a lower cost. He missed the opportunity.

Short Cycles

Air conditioners are very inefficient when they first start operation. It is far better for the air conditioner to run longer cycles than shorter ones. The efficiency of the typical air conditioner increases the longer it runs. Most of the cooling season the cooling loads are well below the capacity of properly sized air conditioners, and for oversized units the short cycling is a substantial problem. Because of the short cycles, Bill's high-efficiency air conditioner is less efficient.

Moisture Buildup

The ability of the air conditioner to remove moisture (latent capacity) is lowest at the beginning of the air conditioner cycle. The moisture removed from the indoor air is dependent upon the indoor coil temperature being below the dew-point temperature of the air. The moisture then wets the indoor coil and, should the unit run long enough, will begin to flow off the coil and be removed out of the condensate drain. For short cycles, the coil does not have time to operate at the low temperature and when the unit stops, the moisture on the coil evaporates back into the indoor air. Thus, in humid climates, a properly sized air conditioner will do a far better job of removing moisture from the air than oversized units. Bill's oversized air conditioner could not remove enough moisture from the air, so his house was cold and clammy.

Noisy Operation

The speed of the air blowing through the supply registers and the air being drawn into the return grille affects an air conditioner's performance. If the air speed is too high, it will be noisy and uncomfortable, and the return grille filter effectiveness will be reduced. The speed through the grilles depends on the size of the air conditioner (a larger unit has more air flow and higher air speed) and the area of the grille (a smaller grille causes higher air speed).

With a properly sized air conditioner, it is easier to have sufficient supply and return grille area to keep the air speed low and the noise at a minimum. Common complaints about oversized air conditioners are that they blast frigid air and that they are noisy. A properly sized air conditioner, with proper ductwork and grilles, will provide longer cycles, more consistent temperatures, and better mixing of the house air. ACCA Manual D

specifies a maximum return grille velocity of less than 500 ft per minute and a maximum supply outlet of less than 700 ft per minute.

Example: A standard 24" x 24" return grille, the 500 ft per minute requirement is exceeded with all units over 2 and one-half tons, with the resulting increase in noise.

Most Contractors Oversize

Contractors submitted methods that they sincerely believed would properly size air conditioners. Some of the methods, however, were based on information from as long ago as 40 years. These methods did not take into account the latest efficiency developments in building insulation, windows, and air tightness.

The methods were often handed down from the person who taught them the business. "I learned this from my father and it has always worked." Since the contractors had received few or no complaints of inadequate cooling, they considered their methods sufficient. Unfortunately, they were significantly oversizing units; particularly on newer more energy-efficient homes. In an effort to properly determine cooling load, some contractors had spent good money on computer programs, had developed their own methods from books in the library, or borrowed from other contractors in the area.

Manual J will vary with the climate because of the way latent loads are treated. Of the approved computer methods, Right-J from Wrightsoft was the most user friendly. Right-J from Wrightsoft faithfully followed ACCA Manual J.

Many assumed that the latent load was 30% of the sensible load. The actual latent load is highly dependent on the air tightness of the home, the local climate, and the interior moisture sources (such as people). For hot, dry climates, the latent load will be far less than 30%, particularly if the house has a large amount of air leakage from the attic. For humid climates, the latent load can be higher than 30% of the sensible load if the house has a significant amount of air leakage. In all cases, infiltration loads (air leakage) were not specifically addressed or were calculated by an oversimplified procedure. Contractors often assumed that infiltration rates were the same in all buildings or only depended on floor area. With the widespread use of blower door testing, we now know that homes vary significantly in their leakage rate.

Don't Duck the Duct Factor

The effect of duct leakage has only recently been investigated to any significant extent. As a result, cooling loads due to duct leakage are not included in any of the methods. Duct leakage has three effects on design cooling load. First, a supply leak is a direct loss in capacity. Second, a return leak will often bring in superheated attic air. Third, the difference between supply leakage and return leakage will cause increased infiltration. While it is tempting to treat duct leakage as additional infiltration, the effect is actually more complex.

Sizing by the Square Foot

The "square-foot-per-ton" sizing method avoids calculating the cooling load of the building and proceeds directly from the square footage of the building to the size of the air conditioner. No contractor submitted such a method for approval, but a number of contractors reported that they often used this method or knew others who did. In a study by the Florida Solar Energy Center, 25% of the contractors reported that they size by floor area.

While this approach is rapid and simple, it does not account for orientation of the walls and windows, the difference in surface area between a one-story and a two-story home of the same floor area, the differences in insulation and air leakage between different buildings, the number of occupants, and many other factors. In some cases contractors attempt to cover these variables by categorizing the home as low (a new home in a moderate climate), average, or high (an old home in a hot climate) but this method also falls short of properly sizing air conditioners.

Selecting Equipment with Manual S

Manual J (or other methods) gives a contractor both the sensible and latent design loads for the house. A common, but wrong, practice is to divide the total cooling load by 12,000 Btu/h per ton and choose an air conditioner with that nominal tonnage. Nominal tonnage does not indicate capacity under differing design conditions.

Manual S provides a process for selecting equipment that will meet the sensible and latent loads at Manual J design conditions. Its primary strength is that it guides the user to select an air conditioner that has a total BTUH capacity between 100% and 115% of the calculated total load. This is a major improvement over a number of other methods. In dry climates the infiltrating air carries less moisture into the house, the indoor relative humidity is lower, and the latent load is lower. With less moisture in the house air, the air conditioner runs at a higher sensible capacity.

Problems with Manufacturer's Data

Air conditioners selected based on standard indoor conditions of 80 degrees F with 50% relative humidity (which is the standard ARI capacity rating condition) will be incorrectly sized for 75 degrees F. Unfortunately, many of the major manufacturers provide information only at 80 degrees F. It would be a great improvement if the manufacturers provided tables that presented the sensible and latent capacities at 75 degrees F for a variety of indoor humidity’s.