
Home Energy Magazine Online May/June 1995

Bigger is Not Better:

Sizing Air Conditioners Properly

by John Proctor · Zinoviy Katsnelson · Brad Wilson

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°F outside and 70°F inside. Whil cooling load he calculated could have been met by a three-and-a-half ton air conditioner, the contractor conv Bill to buy a four-ton unit "because then you will always have plenty of cooling."

Bill's air conditioner short-cycles (cycles on and off more often and for shorter periods of time than it should) 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°F. The contractor increased the outside design temperature
- The recommended design indoor temperature is 75°F. The indoor temperature was lowered by 5°F. Th 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 three-and-a-half ton air conditioner would have been perfect for Bill's house. Instead he paid more for an e half-ton of cooling. In addition to costing more to buy, Bill's air conditioner will use more energy than a prop sized system, raising his utility bills. It won't dehumidify the air as well as a smaller system would, and chanc 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.

Key Cooling Terms

Sensible Cooling Load - The heat gain of the home due to conduction, solar radiation, infiltration, appliances, people, and pets. Burning a light bulb, for example, adds only sensible load to the house. This sensible load raises the dry-bulb temperature.

Dry-bulb Temperature - The temperature measured by a standard thermometer.

Latent Cooling Load - The net amount of moisture added to the inside air by plants, people, cooking, infiltration, and any other moisture source. The amount of moisture in the air can be calculated from a combination of dry-bulb and wet-bulb temperature measurements.

Wet-bulb Temperature - When a wet wick is placed over a standard thermometer and air is blown across the surface, the water evaporates and cools the thermometer below the dry-bulb temperature. This cooler temperature (called the wet-bulb temperature) depends on how much moisture is in the air.

Design Conditions - Cooling loads vary with inside and outside conditions. A set of conditions specific to the local climate are necessary to calculate the expected cooling load for a home. Inside conditions of 75°F and 50% relative humidity are usually recommended as a guideline. Outside conditions are selected for the 2.5% design point.

2.5% Design - Outside summer temperatures and coincident air moisture content that will be exceeded only 2.5% of the hours from June to September. In other words, 2.5% design conditions are outdoor temperatures historically exceeded 73 out of the 2,928 hours in these summer months.

Capacity - The capacity of an air conditioner is measured by the amount of cooling it can do when running continuously. The total capacity is the sum of the latent capacity (ability to remove moisture from the air) and sensible capacity (ability to reduce the dry-bulb temperature). Each of these capacities is rated in Btus per hour (Btu/h). The capacity depends on the outside and inside conditions. As it gets hotter outside (or cooler inside) the capacity drops. The capacity at a standard set of conditions is often referred to as "tons of cooling."

Tons of Cooling - Air conditioner capacity is rated at 95°F outside with an inside temperature of 80°F and 50% relative humidity. Each ton of air conditioning is nominally 12,000 Btu/h (this comes from the fact that it takes 12,000 Btu to melt a ton of ice). While an air conditioner may be called a three ton unit, it may not produce 36,000 Btu/h in cooling. There is a wide variety of actual capacities that are called "three tons."

EER - The Energy Efficiency Ratio is the efficiency of the air conditioner. It is capacity in Btu per hour divided by the electrical input in watts. EER changes with the inside and outside conditions, falling as the temperature difference between inside and outside gets larger. EER should not be confused with SEER.

SEER - The Seasonal Energy Efficiency Ratio is a standard method of rating air conditioners based on three tests. All three tests are run at 80°F inside and 82°F outside. The first test is run with humid indoor conditions, the second with dry indoor conditions, and the third with dry conditions cycling the air conditioner on for 6 minutes and off for 24 minutes. The published SEER may not represent the actual seasonal energy efficiency of an air conditioner in your climate.

Manual J - Manual J is a widely accepted method of calculating the sensible and latent cooling (and heating) loads under design conditions. It was jointly developed by the Air Conditioning Contractors of America (ACCA) and the Air-Conditioning and Refrigeration Institute (ARI).

Manual S - Manual S is the ACCA method of selecting air conditioning equipment to meet the design loads. It ensures that both the sensible capacity and the latent capacity of the selected equipment will be adequate to meet the cooling load.

Manual D - Manual D is the ACCA method for designing duct systems. Contractors often find it a laborious process and most duct systems are just installed, not designed. The amount of time necessary to design a duct system is certainly warranted in tract construction where the design is used repeatedly and for custom homes where the total cost of the home warrants a proper design. In short, designing a duct system is essential for proper equipment performance and customer comfort.

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 usin 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 (see "Calculating Loads Manual J," p.22). Manual J was adopted by ACCA and the Air-Conditioning and Refrigeration Institute (ARI 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 Manual S provides a method to select air conditioners based on the estimated sensible and latent load calcula 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 equ is substantially oversized compared to Manual J specifications. In the Model Energy Communities Project, Pa Gas and Electric Company (PG&E) found that 53% of the air conditioners checked were a ton (12,000 Btu/h) more oversized and a study by Pacific Northwest Laboratories found a third of the air conditioners to be a ton more oversized.

Because of the efficiency penalty of oversized air conditioners and because oversized air conditioners contrib substantially to utility demand peaks, in 1994, PG&E commissioned a study by Proctor Engineering Group to compare common load calculations and sizing methodologies to Manual J calculated values.

What is "Proper" AC Sizing?

Since optimum efficiency is achieved at continuous running, it is important that the air conditioner be sized t achieve the longest run times possible. Manual J specifies use of the 2.5% design temperature as developed b American Society of Heating, Refrigeration, and Air-Conditioning Engineers (ASHRAE). A theoretical perfec air conditioner will run continuously for the 73 hours during the year when the outdoor temperature is greate the 2.5% design point. For instance, a 2.5% summer design temperature of 100°F for Fresno, California, mea the temperature generally only exceeds 100°F for 73 hours in the season (0.025 x 2,928 hours in the months through September). During the rest of the time the air conditioner will cycle and operate at less than its pote efficiency.

A properly sized air conditioner should provide maximum value to the customer as well as a reasonable profi further customer referrals for the contractor. If your air conditioner is cycling even at four in the afternoon oı hottest days, it is a sure sign it is oversized. Incidentally, if the AC is running continuously on hot days, it doe necessarily mean that it is undersized. It is possible that the duct system is leaky, the air conditioner is impro charged, or the air flow across the inside coil is too low (see "An Ounce of Prevention; Residential Cooling Re HE May/June '91 p. 23).

Why Are Air Conditioners Oversized?

Customers depend on the expertise of contractors in selecting an air conditioner. Yet contractors generally si: 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). If the air conditioning system isn't w properly (duct leaks, improper flow across the coils, improper charge) then the oversized air conditioner can the problem. 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 m sizing when the methods they have developed over the years have served them well: "I've done it this way for 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. Customer 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 mı because it was too big. The contractor had the opportunity to discuss the value of the air conditioner based oı delivered efficiency and offer Bill equipment at a lower cost. He missed the opportunity.

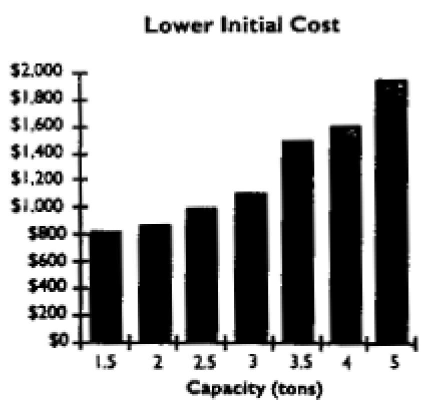


Figure 1. Initial air conditioner cost (quoted wholesale).

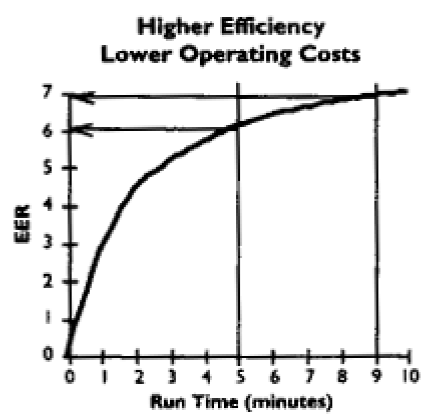


Figure 2. Air conditioner efficiency versus run time.

Air conditioners are very inefficient when they first start operation. It is far better for the air conditioner to rı longer cycles than shorter ones. The efficiency of the typical air conditioner increases the longer it runs (see F

2). If the on-time of the air conditioner is only 5 minutes (a fairly typical run time) the efficiency (EER) is 6.2 the other hand, a properly sized air conditioner were used (one 50% smaller), the same amount of cooling wo place in less than 10 minutes, and the efficiency would rise to 6.9. This represents a savings of 10% for the cu: Most of the cooling season the cooling loads are well below the capacity of properly sized air conditioners, an oversized units the short cycling is a substantial problem. Because of the short cycles, Bill's high-efficiency ai conditioner is less efficient.

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

In addition, the speed of the air blowing through the supply registers and the air being drawn into the return affects an air conditioner's performance. If the air speed is too high, it will be noisy and uncomfortable, and t 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 ca higher air speed). With a properly sized air conditioner, it is easier to have sufficient supply and return grille keep the air speed low and the noise at a minimum. Common complaints about oversized air conditioners are they blast frigid air and that they are noisy. A properly sized air conditioner, with proper ductwork and grilles 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 su outlet of less than 700 ft per minute. Figure 3 shows that for a standard 2' x 2' return grille, the 500 ft per mi requirement is exceeded with all units over 21/2 tons, with the resulting increase in noise.

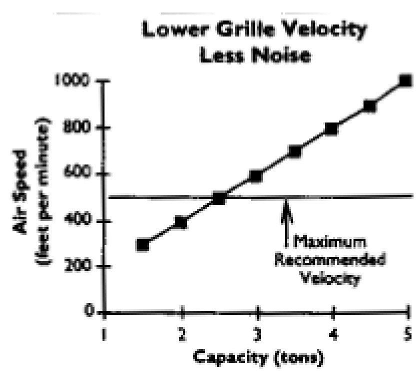


Figure 3. Air speed for a standard 2 ft x 2 ft return grille.

Calculating Cooling Loads with Manual J

Manual J is a method of calculating the cooling and heating loads for a single family residence. It calculates room by room loads for duct design purposes, and whole house loads for equipment selection purposes. It was jointly developed by the Air-Conditioning Contractors of America (ACCA) and the Air-Conditioning and Refrigeration Institute (ARI) after ACCA conducted an industry study of residential load calculations. Manual J procedures are based on a number of sources including the ASHRAE Handbook of Fundamentals. The basic structure of Manual J is:

Heat Gain (Btu/h) = HTM x Area

where HTM is a Heat Transfer Multiplier (in Btu/h/ft2). Area is the area of the building component (such as a wall).

The HTMs take into account orientation, shading, temperature difference, solar gain, thermal storage, diurnal temperature swing, construction, R-Values, and roof color.

Manual J is a simplified adaptation of more complex modeling, yet it does not make many of the gross assumptions that some other load calculation methods use. It estimates both the latent and sensible cooling loads (both are necessary to properly size a system).

It is the result of a process that involved a large part of the HVAC industry and is widely accepted. It is in fact the basis for many of the other methods that are used, including many of the computer programs. For the contractor it is "safe." Because contractors helped develop it, any compromises that were made were not in the direction of undersizing units.

Manual J bases the infiltration rate on floor area and Best, Average, or Poor construction, but far better models of infiltration exist based on blower door testing. Manual J also does not have a method of considering duct leakage (although the new Manual D discusses duct leakage at some length and recommends that duct leakage be eliminated, not calculated). The existing duct leakage in homes consumes some (but usually not all) of the safety margin built into Manual J. If duct leakage were brought under control, units could be sized smaller than Manual J.

While Manual J is simplified, it is still not simple. Because of the many values and tables, it is easy to make an error when using it. In most cases, either a set of tables specific to the contractor's service area, or a computer program should be used to reduce the likelihood of errors. The Florida Solar Energy Center is developing a more simplified sizing methodology for Florida that compares favorably with Manual J results. While individuals who have used Manual J extensively are convinced that it has a substantial oversizing margin, there are no field studies that have determined the size of that margin.

Sizing Up the Sizing Calculations

To qualify for PG&E's air conditioner rebates in 1994, contractors were required to submit their load calculat methods, and they had to submit the actual calcuations, for approval for each job. We compared over 40 diffe load calculation methods submitted by manufacturers, distributors, and contractors to Manual J. Manual J w as a baseline because it is the most widely accepted load calculation methodology and is generally recognized providing a safe estimate of cooling load. (Some experts believe Manual J consistently overestimates the load about 20%, as a built-in "safety" factor.)

In the second part of the study, Proctor Engineering Group compared four different equipment selection met determine how close the selected equipment capacity came to the calculated load. The capacity of an air cond is dependent not only on the outdoor conditions, but also on the actual indoor conditions (temperature and humidity). Proctor Engineering Group developed a procedure for estimating the expected indoor humidity at conditions. By knowing both indoor and outdoor conditions, the capacity of the selected air conditioner was determined.

For both parts of the study, loads were calculated for buildings of different age and construction in two differ climate zones.

Most Contractors Oversize

The submitted calculations were all over the place (see Figure 4). In the extreme, the calculated load was thre the Manual J calculated load.

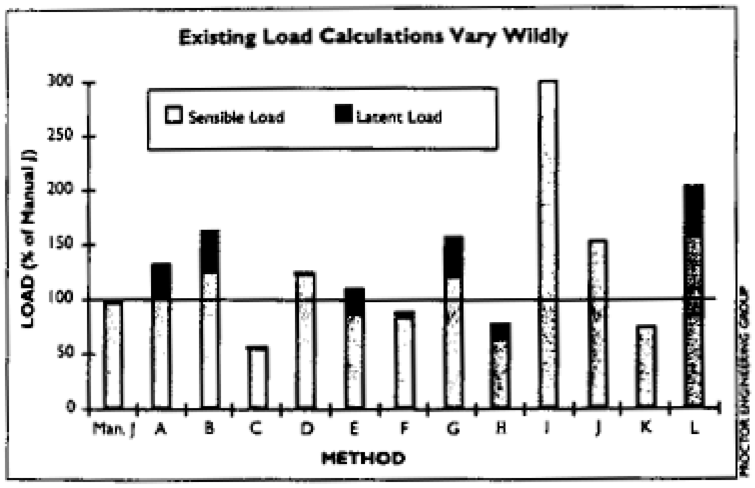


Figure 4. Examples of submitted load calculation results.

Of the 40 load calculations that were submitted, we approved those that yielded building loads within 20% of J as received. This group included four worksheets, one calculator method, and five computer programs. The approval process was interactive and led to many stimulating conversations. David, a contractor for over 20 y shared some of the "seat of the pants" methods he had observed through the years. One method was to "buy t distributor's overstock," another was to "install the rejected unit from a previous job," and still another was to the unit sitting in the truck or at the shop." David referred to these methods as "sizing by cost."

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 the latest efficiency developments in building insulation, windows, and air tightness. The methods were often down from the person who taught them the business. "I learned this from my father and it has always worked the contractors had received few or no complaints of inadequate cooling, they considered their methods suffi 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 progra developed their own methods from books in the library, or borrowed from other contractors in the area. Proc Engineering and PG&E worked with these contractors to find ways to bring their methods within 20% of Ma With changes, an additional ten methods were approved. This second group included seven worksheets, one calculator method, and two computer programs. Altogether, 50% of the submitted methods were approved fo PG&E's service territory. Methods that will calculate loads within 20% of Manual J will vary with the climate of the way latent loads are treated. Of the approved computer methods, RHVAC from Elite Software was the user friendly. Right-J from Wright Associates faithfully followed ACCA Manual J.

A number of the methods did not calculate the latent load of the home. Many assumed that the latent load wa of the sensible load. The actual latent load is highly dependent on the air tightness of the home, the local clim 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 c 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 oversimpl procedure. Contractors often assumed that infiltration rates were the same in all buildings or only depended area. With the widespread use of blower door testing, we now know that homes vary significantly in their leal rate.

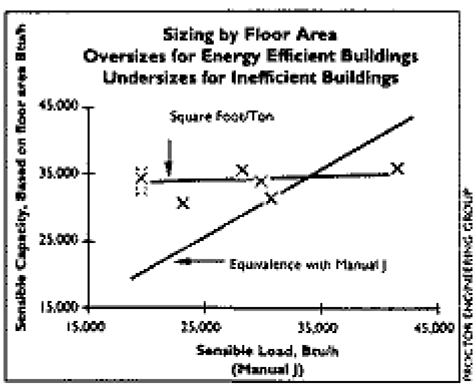
With the amount of data required to do an accurate load calculation, the possibility of errors is increased. Eve computerized methods of load calculation were seriously lacking in error checking procedures that could cato operator errors. For example, window areas can exceed wall areas, or wall areas facing north can be one squa with a south wall of 300 ft2 and east and west walls of 200 ft2. Many of the methods also oversimplified the ı and gave insufficient options for climate, building assemblies (windows, doors, walls, etc.), and shading.

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

How should the loss due to duct leakage be taken into consideration when an air conditioner is sized? The an course is simple. Don't take duct leakage into account--fix the leaks!

Sizing by the Square Foot

The "square-foot-per-ton" sizing method avoids calculating the cooling load of the building and proceeds dire from the square footage of the building to the size of the air conditioner. No contractor submitted such a met approval but a number of contractors reported that they often used this method, or knew others who did. In a by the Florida Solar Energy Center 25% of the contractors reported that they size by floor area (see "How The Air Conditioning Systems in Florida,"). While this approach is rapid and simple, it does not account for orie of the walls and windows, the difference in surface area between a one-story and a two-story home of the sam area, the differences in insulation and air leakage between different buildings, the number of occupants, and other factors. In some cases contractors attempt to cover these variables by categorizing the home as low (a n home in a moderate climate), average, or high (an old home in a hot climate) but this method also falls short properly sizing air conditioners. Figure 5 was produced with those types of categorizations.



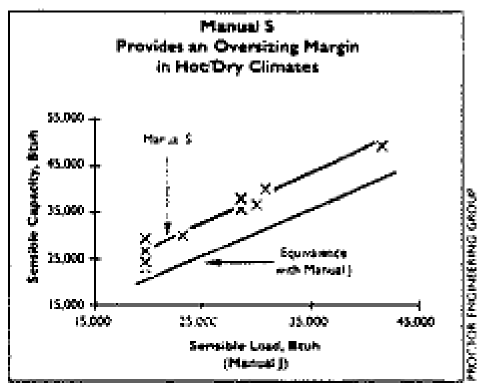


Figure 5. Sizing by house floor area. Figure 6. Manual S selection from Manual J loads.

Selecting Equipment with Manual S

Manual J (or other methods) gives a contractor both the sensible and latent design loads for the house. A con but wrong, practice is to then divide the total cooling load by 12,000 Btu/h per ton and choose an air conditic with that nominal tonnage. Nominal tonnage, however, does not indicate capacity under differing design con Manual S provides a process for selecting equipment that will meet the sensible and latent load at Manual J c conditions. It guides the user to select an air conditioner that has a sensible capacity between 100% and 115% calculated sensible load. It further specifies that the latent capacity must exceed the calculated latent load. Fc example if the calculated design load was 20,530 Btu/h sensible and 1,380 Btu/h latent, an air conditioner w capacities of 22,100 Btu/h sensible and 9,300 Btu/h latent might be chosen (108% of sensible load and 674% latent load).

The result of this method will be an oversized air conditioner. Design indoor conditions for Manual S are 75°I 50% relative humidity. The actual indoor relative humidity at design in much of the western United States (in California, Nevada, Arizona, New Mexico, and parts of Texas) is closer to 35%.

Air conditioner sensible capacity increases with drier indoor air. Under design outdoor conditions in Las Veg actual capacity of our example air conditioner is 26,860 Btu/h sensible and 1,805 Btu/h latent (131% of load) example, Manual S results in an air conditioner that is 31% oversized. Both Manual J and Manual S are safe r If these two methods are applied there is no reason to add additional "safety factors" when selecting air cond equipment.

Problems with Manufacturer's Data

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

How They Size Air Conditioning Systems In Florida

To determine actual practices used by contractors to size air conditioners, researchers with the Florida Solar Energy Center recently surveyed the 450 members of the Florida Air Conditioning Contractors Association and sent surveys to a general list of 5,559 HVAC contractors.* The overall response rate was a respectable 9%. An analysis of the survey results found that the following typifies residential sizing practices in that state.

- Sizing is accomplished using Manual J by 33% of the respondents, software is used by 34% of the respondents, square footage is used by 24%, and "other" procedures are used by 8%. Generally, respondents who are not members of ACCA were much more likely to use square footage or "other" procedures.
- Of the respondents reporting "other" methods, 29% use a utility's short form, 26% use their own calculations, 19% use load sheets or manuals, 11% hire others, and 14% use personal experience or other methods.
- Of 127 contractors indicating the square feet they estimate per ton for AC sizing, the most common response (36.2%) was 500 ft2. The range was from 350 to 700 ft2 per ton and the average was 502 ft2 per ton.
- Fifty-two percent of respondents use a room-by-room method of sizing, 41% use whole house, and 6% use other methods.
- Air-flow calculations for each room are done with square footage estimation by 30%, with software by 22%, with Manual D by 20%, with CFM-per-ton by 18%, and with other methods by 10%.
- Of the 79 contractors providing a CFM per ft2 estimate, 42 of them (53%) use 1.0 CFM per ft2--but with a great deal of variability. A value of .8 CFM per ft2 was the second most common response (10%) and a value of 1.5 CFM per ft2 was the next most popular response.
- Construction drawings are used for obtaining take-off measurements by 62% of the respondents with 23% making their own measurements at the site, and 10% not using take-offs.

Inaccurate Sizing Methods?

When asked about contractor experiences with inaccurate sizing methods, some responses were humorous. One contractor said "listening to the builder" was the most unreliable method, while another indicated that "listening to the homeowner" was equally problematic.

The survey indicated that sizing is fairly evenly split between Manual J calculations, computer software, and estimation by floor area. Not surprisingly, each camp had strong opinions of the other methods. Many using Manual J or computerized methods regarded square footage as an inaccurate means of sizing.

Some of those using square footage mentioned that not accounting for vaulted ceilings or large expanses of glass could lead to low estimates. However, the square footage camp strongly derided Manual J and computerized methods for undersizing units. The most common reported reason for the perceived failure of Manual J or computerized methods was that customers desire lower temperatures than Manual J assumes.

Nearly 40% of the respondents indicated that they have at times purposely oversized units. Almost none purposefully undersized units. Many indicated that they round up predicted sizing by half a ton to allow for future expansion or to "reduce callbacks." Of those who explained why they oversize, over 30% indicated a customer request--often a demand--for low temperatures. By far the most commonly expressed reasons for oversizing were either to "provide more cooling" or to lower temperatures. "I oversize by 50%," indicated one contractor, "so customers will not complain."

The survey also shows that some contractors use sizing estimation values half again larger than others for sizing units, and twice as large for determining room air flow. The few respondents who did emphasize the need to size units small, were completely outnumbered by the "bigger-is-better" school.

** See "How Contractors Really Size Air Conditioning Systems," by Robin K. Vieira, Danny S. Parker, Jon F. Klongerbo, Jeffrey K. Sonne, and Jo Ellen Cummings, Florida Solar Energy Center, 300 State Road 401, Cape Canaveral, FL 32920. Tel:(407)783-0300.*

Recommendations for Consumers

There are contractors out there who would like to do the job right. "I love to do houses but only if we can do t properly. I try to work inexpensively, but not cheaply.... No flex or triangles, thank you." (One contractor's re in the FSEC Survey.) Consumers purchasing air conditioning equipment should:

- Give the contractor the "Recommendations for Contractors" that follows and insist that the list be obs
- If the contractor wants to size by square footage, find another one. (There are no certification organiza that meet our criteria, however the Florida Solar Energy Center found that members of ACCA were ha likely to use floor area to size an air conditioner as other respondents.)
- Insist on a copy of the calculations (or computer inputs and outputs)--even if you don't understand th
- Be willing to pay for the time the contractor must spend to do the job right. Don't take the lowest bid.

Recommendations for Contractors

- Check all numbers for consistency. For example, in typical construction, total area of exterior walls fac north or east (including a wall to garage) is usually equal to the total area of the opposite south or wes ceiling area is usually equal to the building footprint area; window area is usually from 10% to 25% of area; gross wall area is bigger than the window area.
- Use design outdoor conditions and daily temperature range exactly for your location per Manual J or ASHRAE Handbook of Fundamentals. Otherwise, use the data for the closest location with a similar cl
- Use standard 75°F design indoor temperature.
- Consider both location and level of insulation of ducts.
- When selecting cooling factors for roofs, floors, and walls consider their R-value and type; for example wall or masonry wall. Partitions and knee walls that separate a conditioned space from an unconditior space like an attic or garage should be treated separately from the exterior sunlit surfaces.
- Pay great attention to window type, material, and interior shading. An error in this area can throw off window heat gain by as much as 100%.
- Always account for the effect of the overhang shading. This is one of the most efficient load reduction measures. When calculating this effect, consider window height, overhang length and distance to the t the window as shown on page 30 of Manual J.
- Calculate infiltration rate depending on air tightness of the building based on blower door measureme While you are at it, measure the duct leakage and suggest that it be fixed before the air conditioner is i

- Calculate the latent load based on the number of people and the outdoor air humidity ratio. Do not us "typical" multiplier of 1.3 or any other to calculate the total load from the sensible load. This implies th building has a latent load that is exactly equal to 30% of its sensible load and that the quality of constr and location are not important. It also means that if a new source of the cooling load is added, for exar another window, the moisture gains will also increase. This simply is not accurate.
- Consider ventilation load if appropriate.
- Select equipment based on the detailed manufacturer's performance data. Do not rely on the nominal since different units may have more than 10% capacity difference.
- Choose equipment based on the ACCA Manual S without using any safety factors. This method selects that has the sensible capacity at least equal to but no more than 15% greater than the building sensible and the latent capacity equal to or greater than the latent load at standard indoor conditions of 75°F d and 50% relative humidity. For dry climates, Manual S alone, oversizes by approximately 20% compar Manual J load.
- Properly evacuate the coil and refrigerant lines before releasing the refrigerant charge from the outsid into the system (use a micron gauge).
- After installation, check the air flow across the coil and the refrigerant charge using the manufacturer' suggested methods. Correct any deficiencies.

John Proctor is president of Proctor Engineering Group in San Rafael, California. Zinoviy Katsnelson is a senior research engineer with Proctor Engineering Group. Brad Wilson is a senior program development manager at Pacific Gas and Electric Company in San Francisco, California.

This article is apart of a series of energy-efficient remodeling, which is being funded by the Environmental Protection Agency and the Department of Energy.