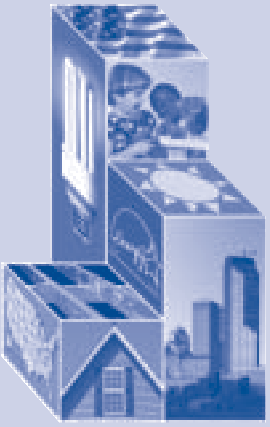
RIGHT-SIZE HEATING AND COOLING EQUIPMENT

The correct size improves comfort and reduces costs, maintenance, and energy use



Buildings for the 21st Century

Buildings that are more energy efficient, comfortable, and affordable…that's the goal of DOE's Office of Building Technology, State and Community Programs (BTS). To accelerate the development and wide application of energy efficiency measures, BTS:

- Conducts R&D on technologies and concepts for energy efficiency, working closely with the building industry and with manufacturers of materials, equipment, and appliances
- Promotes energy/money saving opportunities to both builders and buyers of homes and commercial buildings
- Works with state and local regulatory groups to improve building codes, appliance standards, and guidelines for efficient energy use
- Provides support and grants to states and communities for deployment of energy-efficient technologies and practices

BIGGER IS NOT ALWAYS BETTER WITH HVAC SYSTEMS

Determining the correct size of residential heating and cooling equipment is key to achieving comfortable interior conditions — temperature and humidity — and saving on initial and operating costs. Size of cooling systems is particularly critical for optimal energy efficiency and comfort. When equipment is oversized, initial costs are higher, efficiency is reduced, energy costs increase, and comfort may be compromised. One Florida study showed a typical 9 percent increase in annual space cooling electricity usage for units that were oversized by 50 percent or more.

Correctly sized equipment is especially important in humid climates, where short-cycling of air conditioning equipment can lead to poor humidity control. Similar to an automobile in stop-and-go traffic, the overall efficiency of an air conditioner, furnace, or heat pump is reduced by excessive cycling. More starts and stops accelerate wear and tear on the equipment, which can lead to premature failure.

Oversized systems also use more fan power for the blower and often exhibit more duct leakage due to higher operating duct pressures. Finally, oversized air conditioners and heat pumps greatly aggravate the summer utility peak demand on hot days. In the Florida study cited above, a 13 percent higher summer peak electrical demand was correlated to oversized units.

USE THE BEST GUIDE

Beware of casual sizing estimates based on home floor area or contractor "experience." The residential equipment sizing procedures recommended for use in the United States are found in Manual J and Manual S, produced by the Air Conditioning Contractor's Association of America (ACCA). Good computer programs are available to simplify the load calculations specified in Manual J. Once the heating and cooling loads are known, Manual S can be used to select compatible equipment.

Unfortunately, ACCA-approved sizing methods are often not used and over-sizing is very common. In one large-scale survey, nearly 40 percent of contractors indicated that they purposefully over-sized equipment, citing reasons such as "to reduce call backs," "to allow for future expansion, " or "customers demanded it." Those who claimed to size in accordance with Manuals J and S were heavily outnumbered by the "bigger is better" school.

SIZING AND EFFICIENCY GO HAND IN HAND

Manual J procedures determine the design heating and cooling loads based on the amount of wall, ceiling, window, and floor area, their insulation value, and building envelope and duct air leakage. Building orientation, roof surface color, and occupancy can also make a difference. The sizing calculations for new construction should take into account the various efficiency measures incorporated in the home. As a home's efficiency is improved, the recommended size of the HVAC system should drop.

HOW TO DETERMINE "JUST THE RIGHT SIZE"

- Insist that documented sizing calculations be performed on your home using the ACCA Manual J procedure. Manual S should be used to select equipment. ACCA methods have sufficient built-in safety factors to accommodate most conditioning needs. Therefore, it is important to follow all instructions in Manuals J and S, using precise area measurements and other specific data.
- The most recent version of Manual J should be used, since it incorporates large impacts on efficiency, such as duct leakage and duct heat gains and losses.
- Insect screening can have a significant impact on peak cooling heat gain and should be considered with the new procedures in the latest version of Manual J.
- If drapery or blind positions are not known, they should be assumed to be in place. Otherwise sensible loads will often be overestimated.
- Infiltration assumptions should be approached with caution. In lieu of other information, an infiltration rate of 0.35 ACH is recommended.
- Don't alter the suggested design temperatures for your location. Using the annual extreme temperatures will lead to over-sizing. For Manual J, the $97^1/_2$ percent design temperatures should be used for cooling and the $2^1/_2$ percent design temperature should be used for heating.
- Be aware that exaggerating temperatures for indoor heating and cooling set points can have large impacts on required equipment size. Generally, Manual J recommends 75°F for cooling and 70°F for heating. Use judgment based on homeowner comfort preferences before altering these recommendations.

COMPARE THE DIFFERENCE

Consider HVAC sizing factors for a hypothetical 2,000-square-foot home in Raleigh, North Carolina

	Conventional Construction	**With Energy Efficiency Upgrades**
Wall insulation level	R-11	R-19
Ceiling insulation level	R-19	R-38
Window glass	single pane	double-glazed, low-e solar
Window overhangs	one foot	two foot
Duct leakage	average, with ducts in unconditioned attic	none, with ducts inside the conditioned space
House air leakage*	8 air changes per hour at 50 pascals pressure	6 air changes per hour at 50 pascals pressure
Manual J design heating load	46,100 Btu/hr	21,300 Btu/hr
Manual J design cooling load	52,100 Btu/hr	23,300 Btu/hr
Electric heat pump size	4.0 to 4.5 ton (48 to 54,000 Btu/hr)	2 ton (24,000 Btu/hr)
Annual heat energy usage	12,641 kWh	4,677 kWh **Savings $717****
Annual cooling energy usage	3,808 kWh	1,790 kWh **Savings $182****

* *Measured by blower door test*

** *Savings at $0.09/kWh*

An hourly computer simulation shows that efficiency improvements along with re-sizing would cut heating energy use by 63 percent and cooling energy use by 53 percent. Without re-sizing, the efficiency measures would save 54 percent for heating and 47 percent for cooling. In this case, right-sizing reduces costs for the air conditioner, heat pump, furnace, and ductwork, and these savings partly offset the cost of the efficiency improvements. Better yet, right-sizing provides a 10 percent bonus energy savings otherwise not available.

- Select a programmable thermostat so that your home can be conditioned before you arrive, thus avoiding the temptation to over-size equipment for rapid cool-downs or warm-ups. This will improve sizing-related performance and potentially save energy associated with more reliable thermostat set-back and set-ups.
- Select variable speed air handlers to gain important advantages for both hot humid and hot dry climates. In hot dry climates, the air handlers can be set to provide high air flow rates (for instance 450 to 500 cfm/ton) so that the air conditioner provides the sensible air cooling that is needed. For humid climates, many variable speed systems “ramp up” blowers slowly, providing energy savings and improved dehumidification.
- Selecting variable speed air handlers also allows for proper adjustment of air conditioner and heat pump air flow. Maintaining proper air flow is essential for heat pumps, which use supplemental strip heat if the achieved heating capacity is deficient. Inadequate air flow can rob systems of 5 percent or more of their potential performance.

A NOTE ABOUT HEAT PUMPS

For climates without extended periods of sub-freezing temperatures, heat pumps are an excellent energy-efficient alternative to furnaces and air conditioners. Similar to a refrigerator, a heat pump uses electricity (or natural gas) to move heat from a cool space into warm space. During the heating season, heat pumps move heat from the cool outdoors into your warm house; during the cooling season, heat pumps move heat from your cool house into the warmer outdoors.

Because they move heat rather than generate heat, heat pumps can provide up to four times the amount of energy they consume. If you heat with electricity, a heat pump can trim usage by as much as 30 to 40 percent. High efficiency heat pumps with variable speed air handlers can also dehumidify better than standard single capacity units, resulting in less energy usage and more cooling comfort in summer.

- Heat pumps require a ductwork system, generally with larger duct sizes than other central heating systems. For proper heat pump operation, air flow should be 50 to 60 liters per second per kilowatt-hour (kWh), or 400 to 500 cubic feet per minute per ton of cooling capacity.
- Heat pumps also require the proper thermostat type to function correctly. When choosing a set-back thermostat for a heat pump, choose a model that locks out resistance heating during temperature ramp-up.
- Size the electric resistance heat (heat strips) normally installed on heat pumps using procedures outlined in Manual S. Often, when the system is turned on or the thermostat setting is changed, the heat strips are activated. Since they are much less efficient, they cause a large increase in energy use (and an even bigger spike in the utility’s peak demand). With excess strip heat capacity on a cold morning, costly resistance heat will do most of the duty while the more efficient heat pump does less than its share. In sunbelt climates such as southern California and Florida, where there are less than 2,000 heating degree days, consider installing the smallest amount of electric resistance heat (4-5 kW). In any climate, consider installing an outdoor thermostat set at 35°F or 40°F, which prevents the heat strips from activating unless outdoor temperatures fall lower.
- Manual S advises that, in colder climates, electric heat pumps be sized up to 25 percent larger than the required cooling size to reduce the use of supplemental resistance heat. Units that adjust the indoor blower speed according to humidity level can help ensure good indoor cooling comfort in these cases. There are also two-capacity heat pumps that can be installed to run only at the lower capacity when cooling and at low or high capacity when heating. These heat pump units can provide good indoor comfort while minimizing energy use and peak electric demand in both operating modes.

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For more information, contact:

Energy Efficiency and Renewable Energy Clearinghouse (EREC)
1-800-DOE-3732
www.eren.doe.gov

Or visit the BTS Web site at:
www.eren.doe.gov/buildings

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DON'T FORGET THE DUCTS

Air leakage and heat losses from ducts can rob your space conditioning system of its capacity under peak conditions. In many residential air conditioning systems, the duct system passes through unconditioned zones, which may have thermally disadvantageous consequences. The insulation level of ducted systems tends to be between R-4 and R-6, with very high temperature differences across the insulation in many cases.

The latest edition of Manual J shows how important certain variables can be. For instance, in the Sunbelt states where slab-on-grade construction dominates, the ducts are often in the unconditioned attic. This space can reach 135°F under peak summer conditions, while the air in the ducts may be 55°F to 60°F. Simulation studies show that cooling systems can easily lose 30 percent of their peak sensible capacity from this heat gain alone. If a radiant barrier or colored tile roof is present, peak attic temperatures might drop to 115°F. Furthermore, a white tile or white metal roof might drop the peak temperature to 100°F. Very different conditions affect duct systems located in crawlspaces or basements.

Duct leakage can produce even larger impacts. Supply leaks can lose highly conditioned air and depressurize your home, adding more infiltration. Return leaks can add to the air conditioner or furnace loads and draw air from unintended locations.

All these issues add up to a strong case for having the duct system properly sealed and placed within the conditioned space. Once these decisions are made:

- Make sure that duct sealing and testing are part of your plan for sizing and installing a new air conditioning system. Sealed ducts are particularly critical for systems with variable speed air handlers, which may operate with higher air flows and duct pressures.
- In new construction, seriously consider installing the duct system inside the insulated building envelope. This will both reduce space conditioning energy use and improve comfort by reducing the time it takes the indoor temperature to reach the thermostat set-point.

EFFICIENT OPERATION

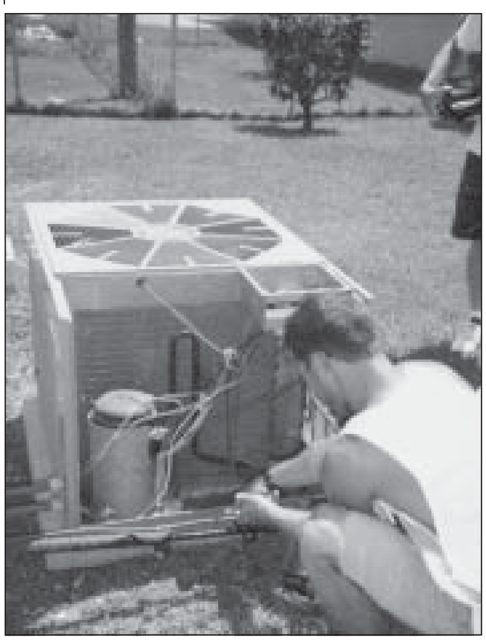

Photo credit: Florida Solar Energy Center

To ensure efficient operation, an air conditioning technician examines the refrigerant charge during installation of a two-ton air conditioner.

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